REDACTED

FEASIBILITY STUDY

REVISION 1

Barite Hill / Nevada Goldfields Site Operable Unit 1

McCormick County, South Carolina

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Acronyms and Abbreviations

%	percent
ACL	alternate concentration limit
amsl	above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirements
Black & Veatch	Black & Veatch Special Project Corp.
BERA	Baseline Ecological Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMZ	Contaminated Media Zone
COC	chemical of concern
CSM	conceptual site model
CWR	capped waste rock
cy	cubic yards
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FS	Feasibility Study
ft	feet/foot
gpm	gallons per minute
GRA	general response actions
HH&E	human health and the environment
HHRA	Human Health Risk Assessment
HI	hazard index
IC	institutional control
kg	kilogram
kg/day	kilograms per day
kg/m^3	kilograms per cubic meter
lb	pound
L/min	liters per minute
m^3	cubic meters
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mEq	milliequivalents
mg	milligrams
mg/L	milligrams per liter
Mgal	million gallons
NaOH	sodium hydroxide
NCP	National Oil and Hazardous Substance Pollution Contingency Plan

NPW	net present worth
O&M	operations and maintenance
OLC	Open Limestone Channel
OTIE	Oneida Total Integrated Enterprises
OU	Operable Unit
pH	hydrogen ion concentration
lbs	pounds
RAO	remedial action objectives
RG	Remedial Goal
RI	Remedial Investigation
ROD	Record of Decision
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SCLRC	South Carolina Land Resources Commission
SCR	South Carolina Regulation
SDWA	Safe Drinking Water Act
Site	Barite Hill/Nevada Goldfields Site
TBC	to be considered
TDS	total dissolved solids
Tetra Tech	Tetra Tech, Inc.
T/M/V	toxicity, mobility and volume
TOC	total organic carbon
USGS	U.S. Geological Survey
Willowstick®	Willowstick® Technologies, LLC
XRD	X-ray diffraction

1.0 Introduction

The Barite Hill / Nevada Goldfields Site (Site; Comprehensive Environmental Response, Compensation, and Liability Information System [CERCLIS] ID: SCN000407714) is located approximately three miles southwest of the town of McCormick in McCormick County, South Carolina. The 795-acre site is located west of U.S. Route 221 and north of State Road S-33-30 (Figure 1-1). Coordinates for the Site are: 33°52'25'N, 82°17'41"W (U.S. Environmental Protection Agency [EPA], 2012). Approximately 135 acres of the property has been disturbed by historic and modern mining. The remaining property serves as an undisturbed buffer zone in a natural state. Gold and Silver mining operations occurred between 1991 and 1995. The Site is surrounded by forested and agricultural land and rural residential areas. No buildings, homes or commercial facilities are located within a 0.5 mile radius of the Site.

EPA Region 4 divided the Site into five operable units (OUs):

- OU1 – Barite Hill Main Pit Lake System
- OU2 – Overburden and Bedrock Groundwater
- OU3 – North Tributary to Hawe Creek
- OU4 – Southwest Tributary and Hawe Creek
- OU5 – General Barite Hill Mine Site

Previous investigations of the site revealed extensive surface water and sediment contamination in the North Tributary. Consequently, the EPA conducted a Remedial Investigation (RI) for OU3 (Black & Veatch Special Project Corp. [Black & Veatch], 2015) to evaluate contaminant migration pathways and nature and extent. Since it was determined that contaminated Pit Lake water and OU1 groundwater migrates to the North Tributary via fractures and seeps or over the lake spillway, the top priority is to develop remedial alternatives that will prevent or control source contaminant migration to OU3. It is expected that a selected remedy for OU1 will reduce toxicity, mobility and volume (T/M/V) of contaminants in OU3 and that after source controls in OU1 have been implemented, water and sediment quality in OU3 will subsequently improve. This sequential approach provides the means to monitor the seeps and tributary as a result of actions in OU1.

If monitoring results indicate that residual contaminant inputs remain, then this adaptive management approach would allow for more cost-effective and design-specific alternatives to treat or control any remaining threats to human health and the environment (HH&E) in OU3. In addition, the five year review requirement under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121 will be used to evaluate the implementation and performance of the phased remedy to determine if it is or will be protective of HH&E.

Consequently, development of technologies and alternatives for OU3 is deferred to a second phase that will be dependent on monitoring results in the North Tributary.

This Feasibility Study (FS) addresses OU1 which includes surface water in the lake, runoff into the lake, groundwater gaining to and discharging from the Pit Lake, sediment contained within the lake, and source materials potentially contributing contamination to the Pit Lake including waste rock on the south shore and pit highwalls enclosing the lake (Figure 1-2).

Building on information presented in the OU1 and OU3 RI reports (Black & Veatch, 2017, 2015) and the human health and ecological risk assessments, this FS relies on analyses of surface water hydrology, hydrogeology, sediment, ecological and other conditions within OUs 1 and 3 to support the evaluation of potential remedial measures.

Consistent with EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (1988), this report accomplishes the following:

- Identifies remedial action objectives (RAOs);
- Considers the range of available remediation technologies;
- Evaluates technologies considered relevant to remediation of OU1 with the ultimate goal of protecting the North Tributary;
- Compares remediation alternatives against both CERCLA and National Oil and Hazardous Substance Pollution Contingency Plan (NCP) criteria to evaluate remedy effectiveness; and
- Provides the EPA with the information needed to select a preferred remedy.

1.1 SCOPE AND OBJECTIVES

The work embodied in the FS is based on the following two primary objectives:

- Identify and screen a range of remediation technologies that address the occurrence of elevated concentrations of chemicals of concern (COCs) in OU1 and migration pathways to OU3, and
- Evaluate viable remedial alternatives against the RAOs and the NCP criteria.

This FS focuses on remedial alternatives that manage the potential risks associated with the presence of contaminants in OU1 surface water and groundwater in a cost-effective manner. Screening and evaluation are conducted to ensure protection of HH&E.

1.2 SITE INFORMATION AND HISTORICAL SITE OPERATIONS

Detailed discussions of the project background including site description, site history, and the associated environmental impacts are provided in the RI reports for OU1 and OU3 (Black & Veatch, 2018 and 2015).

1.2.1 Operational History

The operational history of the Site is summarized in Table 1-1. Features of Nevada Goldfields' operation are shown in Figure 1-2. Approximately 135 acres of the 795-acre Site were disturbed by mining operations (South Carolina Department of Health and Environmental Control [SCDHEC], 2006).

The Barite Hill Mine lies within the Lincolnton-McCormick Mining District. Gold was discovered in the district in 1852 and several small mines began operating shortly thereafter (Pardee and Park, 1948; Clark, et al., 1999a). Early mines consisting of at least two shafts and small underground workings were constructed at Barite Hill at an unknown time (Clark, et al., 1999b). Following intermittent exploration activities in the 1960s to early 1980s, the property was purchased by Gwalia (USA) Ltd. in 1988. Shortly after mining began in 1991, the mine operation was turned over to Nevada Goldfields, Inc. (Clark, et al., 1999a).

Nevada Goldfields, Inc. operated the Site as an open-pit, cyanide heap leach operation from 1991 to 1994. During that time, they recovered an estimated 64,700 ounces of gold and 119,500 ounces of silver from oxide and sulfide ore (Clark, et al., 1999a).

When mining activities ceased in 1994, Nevada Goldfields began site reclamation activities and they reclaimed large portions of the disturbed area (SCDHEC, 1998). Nevada Goldfields abandoned the Site in June 1999 and the State assumed control of the Site in July 1999. The Site has been inactive since that time.

The Main Pit is located at the former Barite Hill which was a small topographic high with a pre-mining elevation of about 510 feet (ft) above mean sea level (amsl; EPA, 2012a). Prior to mining, topsoil was stripped and stockpiled on-site. Ore was loosened using standard drill-and-blast techniques, excavated and loaded onto haul trucks, then carried either to the ore processing facility, sub-ore stockpile, or waste rock dump. Benches cut along the mine pit walls were used as haul roads and to increase the stability of highwalls. The pit was excavated to a depth of about 340 ft amsl (Nevada Goldfields, 1993a); the present maximum depth is about 368 ft amsl, approximately 55 ft below the present water elevation at full pool.

Mined ore was trucked to the processing area located in the central part of the Barite Hill Site (Figure 1-2) which hosted a crusher, agglomerator, and conveyor system. The agglomerated ore was conveyed to an asphalt-lined reusable leach pad for cyanide leaching or to a permanent heap leach facility in the area between the reusable leach pad and waste area C (Figure 1-2). Various process ponds were used to collect the leachate, recycle the cyanide solution and for other water management operations. Detailed descriptions of ore beneficiation (including from the Rainsford Pit), processing, water management and other operations in the other OUs are presented in RI report for OU3 (Black & Veatch, 2015).

Wastes generated by the mining operation included waste rock (sub-ore-grade), spent ore, and process waste water. Two large stockpiles of pyritic waste rock covering approximately 10 acres combined were left on the south and southwest sides of the Main Pit when the Site was abandoned (Gobla, 2007). The rock comprising these piles contains a large percentage of pyrite and is strongly acid generating. In part, this material may represent sulfide ore that could not be leached due to its high sulfur content. This waste was used to partly backfill the Main Pit during the final stages of mining (Nevada Goldfields, 1993a) and likely accounts for the present elevation of the pit floor (i.e., sulfide waste rock was backfilled to raise the pit floor from the mined elevation of 340 ft to the present 368 ft amsl). The remaining portion was capped as part of EPA's 2008 Removal Action described in Section 2.1.3. Runoff and seepage from the piles drained to the Main Pit.

1.2.2 Post-Mining Reclamation

Nevada Goldfields initiated post-mining reclamation of various disturbed areas of the Site in November 1994 (SCDHEC, 1998). Sulfide-bearing waste rock dumps on the south and southwest margins of the Main Pit were not reclaimed. Nevada Goldfields covered an unknown proportion of these waste rock piles with gunite prior to departing the Site (Gobla, 2007). The Main Pit was partly backfilled with rock from the stockpiles along its southern margin. In January 1995, a controlled discharge of 2.8 million gallons (Mgal) of process water and 0.5 Mgal of water from the treatment pond was routed to the pit following a period of high rainfall that increased solution inventories to unacceptably high levels (Nevada Goldfields, 1995). The alkaline discharge mixed with acidic water already held by the pit neutralizing both (Nevada Goldfields, 1995). Prior to abandoning the Site, Nevada Goldfields neutralized the Pit Lake, which was smaller than the present lake, with lime to a hydrogen ion concentration (pH) of 11 (SCDHEC, 2006). No other reclamation work was completed at the pit. By November 2003, water in the pit had a measured

pH of 2.0 to 2.2 (SCDHEC, 2006). This water was entering seeps and fractures in the pit walls where it negatively impacted groundwater.

1.2.3 EPA Removal Actions

When Nevada Goldfields abandoned the Site in June 1999, the Barite Hill Main Pit (hereafter called the Pit Lake) began to fill with water, eventually forming a lake; hereafter referred to as the Pit Lake. By 2007, the lake contained approximately 60 Mgal of water (Harrington et al., 2009) with a pH between 2.0 and 2.2 and a high content of dissolved metals; previous measurements by State personnel showed that lake pH decreased to values less than zero with depth (SCDHEC, 2007). The potential for overflow or a catastrophic release through failure of the pit wall became a serious concern as the lake level continued to rise, prompting EPA to initiate a Time-Critical Removal Action in 2007 (EPA, 2007). In 2007, EPA prepared an Expanded Site Inspection Report (Tetra Tech, Inc. [Tetra Tech], 2007) and a Streamlined Remedy Assessment Report (U.S. Bureau of Reclamation, 2007) for the Site.

The Removal Action included treating the Pit Lake water to near neutral pH, grading and covering waste rock dumps on the southern margin of the pit, and constructing a spillway to control the lake level. The spillway, which was cut into bedrock along the northwestern margin of the pit, was sized to limit lake level rise to 2 ft during a 100 year storm event (Harrington et al., 2009). Excess water from the top of the lake is released to the North Tributary of Hawe Creek.

The Pit Lake was treated from February to May 2008 by neutralizing with the following: 1) 1,860 tons of hydrated carbide lime, 2) 23 tons of sodium hydroxide, 3) 21 tons methanol, 4) 1,300 tons of wood chips and 5) approximately 400 tons of molasses blends. This was done to stimulate the growth of sulfate-reducing bacteria and create reducing conditions within the lake (Harrington et al., 2009). Stimulating bacterial activity promoted the formation of iron monosulfide precipitates which are considered to be more stable than iron oxyhydroxide precipitates. The precipitates settled to the bottom of the lake.

An estimated 50,000 cubic yards (cy) of strongly acid-generating waste rock was pushed below the water line along the south side of the lake. The remaining 250,000 cy of waste rock in the dumps were graded to reduce their slope and capped following a Bureau of Reclamation design. The cap consisted of compacted soil and a geomembrane liner, which was covered with vegetation (Harrington et al., 2009). The liner covered most of the waste rock area as shown in Figure 1-3 (U.S. Bureau of reclamation, 2008).

Surface water runoff from the hill slope south of the Pit Lake (including the waste rock dumps) was controlled and managed by creating a series of small sediment detention ponds and riprap lined channels that convey runoff to the Pit Lake. Work on the Removal Action was completed in October 2008.

An innovative system to monitor conditions within the Pit Lake was installed in 2009. The system was to provide continuous, remote monitoring of field parameters with depth in the lake from a fixed, floating platform in the lake but system performance proved sporadic and data are considered unreliable. Quarterly vertical profiles of field parameters collected by Removal Branch personnel (or their contractors) and instituted as a check on the remote system provided data with higher quality.

The waste rock dumps were monitored by installation of monitoring wells. Two monitoring wells were installed in each of the two capped waste rock dumps (four wells total) to monitor water quality adjacent to the Pit Lake. These wells have been sampled periodically and indicate poor quality groundwater. Additional grading and seeding of the waste rock cap were conducted in 2009 and in 2010 to ensure that vegetation became established on the cap.

Monitoring indicated that conditions within the pit were not remaining stable. Consequently, in July, 2009, the Pit Lake was treated with approximately 12,000 gallons of 50 percent (%) sodium hydroxide (NaOH) solution. Another amendment with 3,500 gallons of 50% NaOH was conducted July 13-15, 2010 (Oneida Total Integrated Enterprises [OTIE], 2010). However, the lake continued to acidify and was dosed again on August 16 and 17, 2012 with 4,000 gallons of 25% NaOH and 5,000 gallons of methanol. These amendments were mixed with lake water and discharged to the lake surface. Further monitoring of the lake continued to show acidification over this time period and the lake was dosed again April 18-20, 2016 with approximately 46,000 pounds (lbs) of NaOH. Table 1-2 summarizes these amendments during each dosing period.

1.3 SUMMARY OF OU3 INVESTIGATION

A brief summary of the OU3 investigation is presented in this section due to the fact that OU3 is directly impacted by OU1 (surface water discharge from the Pit Lake and groundwater to surface water discharges). In January 2015, a RI report for the OU3 was completed (Black & Veatch, 2015) and the following discussion briefly highlights some of its major findings.

Most contamination to the North Tributary is provided by seepage at rates of about 10 to 35 liters per minute (L/min) which gains to the tributary from the first water in the Pit Branch to the Beaver Pond inlet. This inflow, equates to about 1.4 to 4.9 million gallons per year. Locations of the major seeps are shown on Figure 1-4. On an annual basis, this portion of the North Tributary receives more than 1,000 lbs each of dissolved aluminum, calcium, magnesium, sodium, total chloride, sulfate, and acidity and more than 200 lbs of dissolved copper, iron, manganese, potassium, and zinc. An estimated 1,800 to 4,700 lbs of iron are precipitated along this reach annually. Contaminated water from the Pit Lake occasionally discharges over the spillway; however, estimated volumes have not been quantified.

More than 1,000 lbs of dissolved aluminum and total acidity and more than 100 lbs of dissolved copper, iron, and zinc are lost annually from the Beaver Pond inlet downstream to above the Hawe Creek confluence. These constituents are thought to be primarily sequestered within the Beaver Pond itself.

The North Tributary discharges more than 10,000 lbs of dissolved calcium and hardness, total sulfate, and total dissolved solids and more than 1,000 lbs of dissolved magnesium, manganese, and sodium, and total chloride to Hawe Creek annually. Dissolved cadmium, cobalt, copper, manganese, and zinc combine to add 1,900 lbs of mass annually to Hawe Creek.

Surface water poses a severe risk to aquatic life due to low pH and high concentrations of several metals in the reach from the North Tributary headwaters to the Beaver Pond. In addition, cadmium and copper, with lesser contributions from zinc and manganese in surface water at the mouth of the North Tributary provide toxic effects to aquatic life in the lower part of the stream.

Cadmium, copper, iron, mercury, and zinc in sediment in and upstream of the beaver dam pose a significant risk to benthic organisms. Accumulated sediment within flowing reaches of the North Tributary system is periodically “flushed” by significant runoff events. However, sediment within the Beaver Pond sediment may sequester several metric tons of copper and zinc which could degrade downstream habitat and aquatic life if released. However, currently sediment quality in the North Tributary downstream of the beaver dam does not pose a significant risk to benthic organisms.

For human health, there are unacceptable non-cancer hazards to future residents exposed to cadmium, cobalt and manganese in surface water adjacent to known seeps. Cancer risk in OU3 was acceptable

under all exposure scenarios. In addition, exposure to sediment does not pose unacceptable human health risks under any exposure scenario.

1.4 REPORT ORGANIZATION

This FS is divided into eight sections. An accompanying compact disc (CD) provides the entire report, including all appendices. The sections in this report include:

- Section 2 – presents summaries of the findings from the OU1 RI report.
- Section 3 – identifies RAOs, Remedial Goals (RGs) and draft Applicable or Relevant and Appropriate Requirements (ARARs).
- Section 4 – identifies General Response Actions (GRAs) and presents a screening of available remedy technologies and process options.
- Section 5 – remedial alternatives are developed.
- Section 6 – detailed analysis of the remedial alternatives
- Section 7 – comparative analysis of remedial alternatives using the NCP criteria.
- Section 8 – recommended alternative.
- Section 9 – references cited.

2.0 Summary of OU1 Remedial Investigation

This section provides a summary of the OU1 and OU3 RI reports (Black & Veatch 2017, 2015). The RI summaries provide delineation of the COCs in surface water, sediment, soil and groundwater along with an overview of the baseline human health risk assessment (HHRA) and the baseline ecological risk assessment (ERA). All of this information serves to inform the conceptual site model (CSM). The CSM is a narrative and pictorial communication tool that links sources of contamination, chemical migration pathways, human and ecological receptors, and pathways of exposure (EPA 1988).

2.1 SITE DESCRIPTION

This section describes the Site and surrounding area. It presents general summaries of the physiographic setting, climate, geology, surface water hydrology, hydrogeology, ecology, and land use.

2.1.1 Physiography

The Site is situated within the Piedmont physiographic province. The gently rolling terrain is bisected by moderately incised stream valleys. Elevations vary from about 500 ft to 350 ft amsl. The area drains to the west-southwest via tributaries to Hawe Creek toward Lake Strom Thurmond (Clarks Hill Lake).

The Pit Lake covers about 7.75 acres with another 10 acres of reclaimed uplands (capped waste rock dumps) that drain into the lake. Most of the cap on the eastern side of the lake consists of a geomembrane liner while the southern portions were capped with a 3-foot layer of compacted clayey silt. Approximately 1.5 ft of topsoil was placed on top of the caps and seeded with a mixture of grasses and clovers. A series of small catch basins south of the lake assist in controlling runoff to the pit.

2.1.2 Climate

The Site is located in an area of moderately high precipitation with an average annual precipitation over the past five years of approximately 42 inches, with most falling as rain. The 100-yr, 24-hr storm event has been estimated at 8 inches while the 10-yr, 24-hr storm event is 5.5 inches (D.P. Engineering, Inc. et al., 1990).

Over the last five years, the mean average high and low annual temperatures are 69.1 degrees Fahrenheit (°F) and 48.4 °F, respectively. The highest average maximum monthly temperature occurs in August (88.9 °F) and the lowest average monthly temperature of 32.6 °F occurs in January.

Historically, June through August is the wettest time of year and October, November, and January are the driest months of year. During the five year period from 2012 through 2016, April, July, November and December were the wettest months. This was in part due to the large storms that impacted the region in 2015. During this period of time the highest average monthly precipitation occurred in December (6.34 inches) and the lowest occurred in September (2.27 inches).

2.1.3 Geology

Soils at the Site are those characteristic of upland terranes which have a silty surface layer that overlies clayey subsoil (Camp and Herren, 1980). Camp and Herren identified two soil series which are derived from Carolina Slate Belt rocks in the area. Soils of the Tatum-Goldston-Nason series are moderately permeable, well- to excessively well-drained soils on sloping to steep terrane. They consist of an upper brown silt loam that overlies red clay to silty clay loam. Soils of the Georgeville-Herndon-Kirksey series

are moderately permeable, moderately well- to well-drained soils on gently sloping terrane. They consist of an upper brown silt loam that overlies red silty clay.

Rocks comprising the Site are part of the Carolina Slate Belt, which extends from southern Virginia southwest into Georgia. The Slate Belt primarily is composed of intermediate-grade metamorphic rocks of Neoproterozoic to middle Cambrian age (Clark et al. 1999b; Hibbard et al., 2002). The belt is bounded on the west by igneous and high grade metamorphic rocks of the Charlotte Belt, and on the east by an extensive zone of ductile shearing and mylonitization (Modoc Fault; Clark et al., 1999a).

The Barite Hill deposit occurs within a stratigraphic assemblage of the Persimmon Fork Formation consisting of the basal Lincolnton metadacite conformably overlain by a northeast-trending sequence of metamorphosed felsic volcanic, intermediate volcanic, felsic volcaniclastic, and clastic metasedimentary rocks (Clark et al., 1999b). These rocks were formed in an island arc setting.

2.1.4 Surface Water Hydrology

Overland flow at the Site is directed down the slopes and out of the Site's drainage area through defined drainage courses in the topography and constructed diversion ditches. The most significant surface water drainage features at the Site are two unnamed perennial tributaries to Hawe Creek referred to as the North and Southwest Tributaries (OUs 3 and 4, respectively). The drainage divide between these streams follows the ridge from the main gate to the process plant area. Hawe Creek discharges to Lake Strom Thurmond along the Savannah River approximately 2 miles downstream of the Site.

2.1.4.1 Pit Lake (OU1)

The Pit Lake is a young feature that began forming when mining ceased in 1994. At its maximum elevation of 418.3 ft amsl (top of spillway), the lake covers about 7.75 acres and is approximately 50 ft deep at its deepest point. Harrington et al. (2009) estimated the volume of water in the Pit Lake at about 60 Mgal; work conducted in support of this RI suggests a volume of about 73 million gallons at full pool. Near-vertical bedrock highwalls extend 30 to 60 ft above the lake along the eastern and southwestern margins; a steep berm approximately 20 ft high forms the northern edge of the pit. Lake depth increases abruptly adjacent to these shores. In contrast, the southern shoreline is bounded by rock gabions installed at the toe of capped waste rock dumps which were graded and capped with either an impervious geo-membrane liner or a 3-ft compacted soil cap as part of the 2008 Removal Action. Lake depth increases more gradually along the southern shoreline. Approximately 25 to 30 ft of waste rock was backfilled into the pit by Nevada Goldfields at the end of mining operations; additional waste rock was submerged beneath the lake during the Removal Action.

Under full stage conditions, the Pit Lake is a flow-through system which receives storm water runoff and groundwater gain from a small watershed comprising approximately 25 acres; water is discharged across an engineered spillway to the North Tributary and through groundwater loss to bedrock (some of this water is manifested as springs along the North Tributary). During dry spells, evaporative loss lowers the pit elevation below that of the spillway. Under these conditions, the pit continues to gain and lose groundwater and to receive storm runoff, but the lake does not discharge to the North Tributary. Surface water gaining to the Pit Lake includes direct precipitation, runoff from pit walls exposed above the shoreline, surface drainage through a system of small sediment retention dams constructed in the soil borrow area during the 2008 Removal Action, and runoff through engineered diversions which collect water from the capped waste rock dump. Groundwater gains to the pit from up-gradient areas including the waste rock dumps on the south shore.

2.1.4.2 North Tributary (OU3)

The North Tributary is a small stream that flows along the northern boundary of the Site prior to joining Hawe Creek about 1.6 miles downstream of its origin (Figure 1-2). The stream is intermittent in its upper reaches but perennial above its confluence with Hawe Creek. The North Tributary originates as seeps emanating from bedrock fractures along the wooded northeastern side of the Pit Lake (referred to as the Pit Branch on Figure 1-2). The stream flows northwestward for about 2,400 ft where it is joined by a small stream flowing from a small reservoir on land adjacent to the Site. The combined flow turns to flow southwestward past the pit spillway then flows mostly westward collecting intermittent runoff and groundwater *en route* to Hawe Creek. At one time a 0.5-acre beaver pond interrupted the flow of the stream about midway to Hawe Creek. This Beaver Pond has been abandoned and no longer impedes flow. The North Tributary joins Hawe Creek slightly upstream of the State Road S-33-44 Bridge, about 200 ft upstream of the Southwest Tributary confluence.

Above the abandoned Beaver Pond, the stream may cease flowing during prolonged dry spells, with water present as stagnant pools only in areas of groundwater discharge. The North Tributary flows through a narrow, comparatively steep-walled, wooded valley that has been logged in a few areas. A small floodplain is intermittently present along the north side of the creek from the Pit Lake downstream to the abandoned Beaver Pond.

Upstream of the Beaver Pond, the substrate of the North Tributary is a thin, discontinuous layer of sand and gravel which rests on bedrock. Most of the substrate is coated with orange-brown iron precipitates. Stream width in this reach varies from less than 2 to about 10 ft, increasing downstream. Downstream of the Beaver Pond, the substrate is somewhat thicker and iron precipitates are less prominent. The Beaver Pond altered stream flow and captured sediment and metal precipitates. The dam is approximately 150 ft long and 5 to 10 ft high and impounds an area of about 0.5 acre. During seasonal wet periods, water depth in the pond ranges from 1 to 4 ft. The pond has also been observed to be dry at times. The beaver dam is old (>10 years) and is not currently maintained as suggested by a lack of recent vegetation cuttings or tracks. It may have been abandoned due to excessive iron precipitation on pond vegetation and detrital material. A smaller breached dam immediately downstream of the large dam also has not been maintained.

The State of South Carolina has not promulgated a designated beneficial use specifically for the North Tributary, but has provided Hawe Creek with a use classification of aquatic life (SCDHEC, 2014).

Detailed descriptions of the North Tributary and the extent of contamination in its various reaches are provided in the OU3 RI report (Black & Veatch, 2015).

2.1.5 Hydrogeology

Early hydrogeologic studies at the Barite Hill Site were conducted in support of the engineering design for Waste Disposal Area C (Environmental Technology Engineering, Inc. [ETE], 1989; DP Engineering et al. 1990). These studies identified hydraulically connected aquifers within the overlying regolith (overburden soils and saprolite) and underlying metamorphic bedrock (divided into weathered and competent bedrock zones). In a general sense, these are distinguished by combined porous media and fracture-controlled flow within the regolith and fracture-controlled flow within the weathered and competent bedrock. Ten monitoring wells, seven hand auger borings, and field hydraulic tests provided information on these aquifers in this part of the Site.

Thirty-one existing monitoring wells (including 6 of the 10 installed by ETE [1989]) were located on the Barite Hill Site. Most were constructed between 1989 and 1992; details including installation date, total depth, and screened interval were found for 23 of these wells. These wells were installed to monitor groundwater quality in the regolith and bedrock aquifers in the areas of Waste Disposal Area C, the Permanent Leach Pad and its ponds, the Reusable Leach Pad, the Process Plant Ponds, the Main Pit, and Rainsford Pit. Some of these wells were installed as clusters of 2 to 4 wells which were screened at different depths.

ETE (1989) and DP Engineering, et al. (1990) used the results of the field permeability tests to calculate hydraulic conductivity for each of the three aquifer zones. Hydraulic conductivity of the regolith was comparatively low (0.05 ft per day [ft/day]), consistent with significant clay-rich soil horizons present in this aquifer. In contrast, hydraulic conductivity in the weathered bedrock was calculated at 0.18 ft/day, while that in the underlying competent bedrock was estimated at 0.019 ft/day.

Vertical gradients computed from water elevations in the well clusters indicated that groundwater in the competent bedrock moves upward toward the weathered bedrock zone while that in the regolith moves downward. Because the weathered bedrock has the highest hydraulic conductivity of the three aquifer units, this zone plays an important role in the migration of groundwater in the area.

2.1.6 OU1 Hydrology

Four wells were installed as part of EPA's 2008 Removal Action to monitor the quality of groundwater flowing through and beneath the capped sulfide-bearing waste rock on the south end of the Pit Lake. In addition, seven wells were installed into the overburden and bedrock aquifers in October 2012 as part of the RI of the Site. These wells were installed to investigate potential groundwater discharge through fractures west of the Pit and groundwater quality within the former Rainsford Pit and beneath Waste Disposal Area A. In 2018 wells BH71 through BH74 were installed in 2018 to help identify fracture areas and aid in confirming groundwater flow direction in the area south of the Pit Lake.

Measurements of depth to water in on-site monitoring wells define the general potentiometric surface across the Site (incorporating D.P. Engineering's conclusion that the 3 aquifer zones are hydraulically connected) and identify a groundwater divide in the central part of the Site. Figure 2-1 shows a groundwater potentiometric map for OU1 in August 2016. Groundwater in OU1 flows generally northward, and northwestward on the western side of the Pit Lake.

2.2 SUMMARY OF NATURE AND EXTENT

2.2.1 OU1 Soils

Elevated concentrations of arsenic, barium, cadmium, chromium, copper, and lead are of potential concern in soil; however, there are no soil contamination patterns, trends, or multiple contaminant hotspots that were identified in this naturally mineralized area. Analytical results for COCs in soil are presented in Appendix A.

2.2.2 Groundwater

2.2.2.1 Groundwater Quality

Groundwater analysis has included total metals and classical parameters/nutrients in the 14 wells within OU1. Samples for organic compounds (VOCs, SVOCs, Pesticides, and PCBs) were collected from selected wells during two sampling events. Concentrations of metals above the MCL have occurred during most

sampling events (2011 to 2018). These metals included antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, selenium, and thallium. The highest concentrations of metals have been detected in the samples from the four wells installed within the waste rock area (BH26 through BH29). Exceedances of MCLs have also occurred in wells down-gradient of the Pit Lake (BH55, BH56, and BH64). The concentrations of these metals have remained relatively stable throughout the monitoring period. Groundwater upgradient of the Pit Lake (BH49, BH50, BH51, BH66, BH71, BH72, and BH73) have very few exceedances. Appendix A presents the analytical results for OU1 groundwater.

2.2.2.2 Groundwater Flow

Measurements of depth to water in the OU1 wells were used to contour the potentiometric surface in OU1, assuming that the various aquifers are hydraulically connected. Figure 2-1 illustrates the potentiometric surface developed from data collected in August 2016. The surface is poorly constrained due to an absence of wells in the southern waste rock dump area. In general, the potentiometric surface slopes north and northwest, indicating groundwater flow in these directions.

Geophysical surveys conducted in and around the area of the Pit Lake illustrate the complex pathways utilized by groundwater flowing into and out of the lake. In May of 2016, Willowstick® conducted a geophysical investigation at the site designed to identify, map, and model preferential groundwater flow paths into and out of the Pit Lake (Willowstick®, 2017).

The Willowstick® investigation identified two specific locations where preferential groundwater infiltrates the Pit Lake (Points A1 and A2 on Figure 2-2). One point of entry (A1 – south-southeast side of the Pit Lake) appears to lie along a faulted (and/or fractured) zone having approximate north/south orientation. Willowstick® concluded that "groundwater infiltrates the fault zone to the south and southeast up-gradient of the pit lake area." The second location (A2) is on the south-southwest side of the Pit Lake. Groundwater migrates to this point from the west-southwest through and beneath the waste rock dumps. Near the BH49, BH50, and BH51 well cluster, two groundwater flow paths converge at Point 1 and groundwater migrates east-northeast through and beneath the waste rock toward Point 2 and into the Pit Lake at Point A2. At Point 2, Willowstick® determined that the groundwater pathway appears to bifurcate northward toward Point 3 where it intersects an east/west oriented fracture zone running beneath both the waste rock and Pit Lake. Near Point 3, groundwater migrates downward through the waste rock into the fracture zone and from there flows westward away from the Pit Lake area.

Willowstick®, based upon the magnetic field data, identified an apparent faulted zone and two nearly-perpendicular fracture zones within the Pit Lake. These are depicted as thick dashed yellow lines inside the outline of the Pit Lake on Figure 2-2. Willowstick® interpreted these as weakened zones of preferential flow. Willowstick® concluded that groundwater migrating into the Pit Lake from both A1 and A2 converge at the south end of the lake in the denoted fault zone. Groundwater infiltrating the lake from Points A1 and A2 discharges from the lake along the geologic fractures or weakened zones at Points B1, B2, and B3.

At Point B1, water seeps out of the Pit Lake along a fracture zone and eventually daylights in the Pit Branch drainage in the area of previously identified seeps. Willowstick® notes that groundwater from the northeast may flow west along the fracture zones. But it does not appear to infiltrate the Pit Lake from this direction. Willowstick® concluded that groundwater could possibly migrate at depth beneath the lake along these fracture zones. This means that water within the lake could escape down and along the noted geologic features.

At Point B2, water migrates out of the bottom and side wall of the impoundment west toward the seep at sample location BH503 and the unnamed seep further to the west. Willowstick® did not identify any seepage pathways from beneath or around the pit spillway.

At Point B3, water seeps downward out of the Pit Lake into the south fracture zone and then migrates west away from the lake.

2.2.3 Pit Lake System

Data were collected from the Pit Lake on an irregular and limited basis (Appendix A). Given that the lake can reasonably be expected to be a complex, dynamic, and open chemical system, the available data are insufficient to completely understand these processes and their relative contributions to pit chemistry over time.

Bathymetric data coupled with soundings of water depth and Lidar topography were used to estimate a volume of water in the Pit Lake at 73 Mgal of water at full pool (spillway elevation).

2.2.3.1 Inflows to the Pit Lake

Water flows into the Pit Lake as direct precipitation, rainfall runoff from the pit walls directly to the lake, rainfall runoff that is shed from the waste rock cap and sedimentation pond area south of the lake which flows through rip rapped channels to the lake, and groundwater inflow from the southeast and southwest, including water entering from the waste rock dump area.

Rainfall runoff from oxidized to partly weathered pit walls contribute metals to the Pit Lake in total and dissolved forms. The concentrations of dissolved metals (especially copper) are higher from pit walls with remnant sulfide mineralization. Runoff samples are slightly acidic (pH 4.7 to 5.2) with low concentrations of sulfate.

Storm runoff conveyed to the pit from upslope areas contains dissolved metals including copper in concentrations lower than runoff from the sulfide-bearing pit walls and small amounts of alkalinity. Storm water originating from the sedimentation dams tends to have higher concentrations than water shed from the caps of the waste rock dumps.

Groundwater inflow to the Pit Lake is estimated at 10 to 16 gallons per minute (gpm), with large uncertainty.

Monitoring wells installed in the northern waste rock dump on the south shore of the Pit Lake lie close to the shoreline of the Pit Lake as it existed in 2006, but possibly on the outside of the pit wall. Water sampled by this well may include several components including groundwater, leachate from the waste rock and, possibly, water escaping from the Pit Lake. Wells in the southern dump appear to be located within the former pit walls and are expected to sample lake water that has flooded into waste rock backfill with the pit.

Water in the four waste rock dump wells, which contains extremely high concentrations of total metals, sulfate, and dissolved solids and low pH, is oxidized despite containing low concentrations of dissolved oxygen (DO); low ferrous/total iron ratios shows that most iron is present as ferric iron. These waters are very dense as a consequence of their high concentrations of total dissolved solids (TDS; 1009 to 1033 kilograms per cubic meter [kg/m^3]). Concentrations in the wells in the northern waste rock dump have been generally decreasing with time. In contrast, constituent concentrations in wells in the southern dump have varied irregularly without a clear trend.

Relatively clean groundwater migrating from the south, as seen in wells BH49, BH50, BH51, BH66, BH71, BH72, and BH73, becomes contaminated with metals after interacting with the waste rock or natural mineralization before discharging into the lake. Groundwater flowing toward the Pit Lake from the southeast is alkaline with low concentrations of metals.

2.2.3.2 Pit Lake Water

Monitoring of field parameters with depth over time captured the development of chemical stratification in the Pit Lake over the first few years after the Removal Action was completed. The stratification defines a chemocline/thermocline that exists at about 40 to 45 ft depth within the pit and represents a boundary in water density. The magnitude of the density contrast varies throughout the year, being greatest in late summer when the upper water column has warmed. The density contrast across the chemocline has grown with time; as the chemical density contrast continues to increase, mixing of the water layers will be further prohibited thereby promoting separate behavior in each water layer as they become isolated from one another. Consequently, the chemocline is expected to be a permanent feature of the Pit Lake. That the elevation of the chemocline has not apparently changed with time suggests that the volume of water comprising the lower water layer has remained relatively constant.

Water in the lower layer of the Pit Lake has median constituent concentrations that may be up to three orders of magnitude higher than water in the upper layer above the chemocline. The upper water layer is variably oxygenated and displays a range of pH values over time that contrasts with the consistently acidic pH and near anoxic conditions of the lower layer. Samples collected from the lower Pit Lake layer share many compositional similarities with water in the south waste rock dump; slightly lower concentrations in the deep layer water are consistent with mixing of water from the waste rock dumps with the more dilute water of the upper layers of the Pit Lake. As density stratification increases, the composition of water in the deep layer is likely to become more similar to that in the north and south dumps as mixing is increasingly limited.

Cadmium, copper, and manganese in Pit Lake water exceeded their surface water quality benchmark values with the greatest frequency and magnitude. Other COCs include aluminum, arsenic, barium, cobalt, iron and zinc.

Conductivity has been nearly constant in the upper water layer since 2010 and is relatively isocompositional in the upper 40 ft with values typically ranging from 2.5 to 3.5 millisiemens per centimeter (mS/cm). Conductivity in the lower water layer has been increasing over time. Median pH values measured over seven years in May indicate that the pit continues to acidify, consistent with the loss of system buffering even after the August 2010 and April 2016 dosing events. DO has shown a trend of increasing with time vertically through the upper water layer. Similarly, redox potential has become more oxidizing at depth and reducing conditions are no longer present throughout most of the water column.

Vertical profiles, especially of temperature, are suggestive that the pit may undergo some seasonal turnover and mixing; however, turnover has not been observed. If turnover does occur, it is unlikely to involve the entirety of the water column and is expected to exclude water from the lower layer (i.e., meromictic behavior).

The concentrations of dissolved cobalt, copper, and zinc at two depths in the upper water layer appear to have increased with time while those of dissolved manganese, hardness, and total sulfate appear to have decreased slightly or remain unchanged.

The Pit Lake does not receive significant inputs of natural organic matter. Since 2013, the concentration of total organic carbon (TOC) in the water column has been less than 1 milligram per liter (mg/L) with the exception of two samples collected from the lower water layer in 2016. TOC concentrations decline rapidly following amendment of the water column; TOC does not appear to remain in the upper water column for any significant period of time.

Alkalinity added during the various amendment events has not produced a long-term effect of increasing the lake pH or stabilizing acid generation.

Dissolved metals, acidity, and hardness are generally similar for samples collected at the same depth but different locations within the Pit Lake, suggesting that water within the upper layer is well mixed across the pit.

2.2.3.3 Outflows from the Pit Lake

The quality of Pit Lake water discharging to the North Tributary is poorly known due to limited sampling. Several constituents, however, may be present in concentrations exceeding ecological screening values including aluminum, cadmium, cobalt, copper, iron, lead, manganese, and zinc.

An unquantified flux of groundwater discharges from the Pit Lake; some of this water is manifested as seeps in the North Tributary and Pit Branch (OU3).

Most samples collected from wells on the outer slope of the mine pit exceeded South Carolina groundwater quality standards for cadmium and selenium, the Federal MCL action levels for copper and lead, and the Federal Secondary MCLs for aluminum, copper, iron, manganese, zinc, sulfate, TDS, and pH. The composition of water in these wells overlaps the compositions of samples from the lower layer of the Pit Lake indicating chemical similarity despite being screened at elevations significantly higher than the elevation of the chemocline in the Pit Lake. Chemical considerations suggest that water escapes from depth within the pit and then is forced upward perhaps by the hydraulic head imposed by the lake.

Groundwater in seeps and monitoring wells west of the Pit Lake share some chemical similarities to water in the Pit Lake, but comparisons are not straightforward and elevated concentrations of manganese distinguish these waters from Pit Lake water. High manganese is characteristic of groundwater sampled from wells in the north waste rock dump and water from the dump may influence the chemistry of groundwater downslope. The high concentration of mercury characteristic of well BH64, in contrast, cannot be explained by influence from the waste rock dump water and its cause remains unknown. Samples from well BH64 exceeded State groundwater standards for cadmium, mercury, and selenium, the Federal MCL action level for lead, and the Federal secondary MCL for zinc. Samples from wells BH64 and BH65 exceeded the Federal secondary MCLs for aluminum, iron, manganese, sulfate, and pH.

2.2.3.4 Sediment within the Pit Lake

Primary metals of concern in sediment are barium, cadmium, copper, iron, lead and zinc. Other metals which exceed the conservative benchmarks include aluminum, arsenic, cobalt, mercury, nickel, and silver. Crystalline phases identified by x-ray diffraction (XRD) in sediment samples from the Pit Lake were predominantly kaolinite and quartz with subordinate muscovite and gypsum. Although iron oxide or sulfide phases were not identified by XRD, scanning electron microscopy-energy dispersive spectrometry also identified heavy metals (e.g., cadmium, copper, zinc) associated with some particles and nanoparticles in the form of dense aggregates in all samples. Virginia Tech noted a rapid change in color as the samples were exposed to the atmosphere during sample preparation. Since none of the major

phases identified in the sediment are reactive, this may indicate that reduced transition metal sulfide nanoparticles are present in the Pit Lake sediment but were oxidized during sample preparation.

2.3 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

2.3.1 Conceptual Site Models

CSMs illustrate the physical, chemical, and biological relationships between contaminant sources and affected resources. As such, they provide a basis for interpreting contaminant fate and transport and assessments of risk to human and ecological receptors.

For ease of display, the CSM for the Pit Lake is divided into four aspects that together control or influence contaminant behavior in the lake (see Castendyk, 2009). These are the geological, geochemical, hydrological, and limnological CSMs displayed on Figures 2-3 to 2-6. Details of the contaminant release mechanisms, migration routes and other factors are described in the following sections. The CSMs are displayed on schematic cross-sections oriented north-south and east-west through the Pit Lake; these cross-sections are not drawn to scale.

Figure 2-3 depicts the influence of sulfide-rich acid generating waste rock that has been placed into the pit and that remains partly covered on the south shore of the pit. The surrounding bedrock varies from mineralized to slightly mineralized with variable amounts of sulfide minerals. The pit highwall on the east side consists of mineralized bedrock that ranges from intensely oxidized to partly oxidized with relict sulfide phases and secondary, water soluble salts.

Figure 2-4 depicts various geochemical exchanges that occur between the Pit Lake water column and inputs from and losses to the atmosphere, groundwater, and surface water; and diffusion and precipitation/adsorption between lake water and sediment and saturated waste rock.

Figure 2-5 illustrates dominant hydrological processes. These include precipitation and evaporation, inputs from groundwater and storm runoff, and groundwater loss to the fractured bedrock. Short and long-term precipitation and evaporation provide significant controls on discharge from the Pit Lake by flow across the spillway while loss to bedrock fractures provides seepage to the North Tributary.

Figure 2-6 depicts seasonal mixing within the oxygenated upper layer of the lake and the isolation of the lower water layer (>45 ft depth) which remains generally anoxic and does not mix into the upper layer.

Mass gain to the Pit Lake is depicted as storm water runoff to the Pit Lake from the pit walls, the waste rock cap and other upslope areas; the inflow of groundwater from waste rock dumps on the south shore of the lake and from mineralized to non-mineralized bedrock surrounding the Pit Lake; diffusion and exchange with submerged waste rock and sediments; and direct precipitation. Mass loss is shown as overflow discharge from via the emergency spillway; seepage loss to the fractured bedrock; precipitation of minerals on the substrate of the Pit Lake; and evaporative loss to the atmosphere. Contaminants are transported through the environment by surface water flow, sediment transport, and groundwater flow through fractured metamorphic bedrock. The dominant processes are described in more detail below.

2.3.2 Contaminant Sources and Migration

Contaminants from the waste rock dumps are transported to groundwater by infiltrating rain water that leaches contaminants and by groundwater that gains contaminants as it flows through the waste rock piles from up-gradient.

Waste rock submerged beneath the Pit Lake provides a direct connection to surface water through diffusive and advective exchange between the lake and water contained within the saturated waste rock backfill. Water contained within the waste rock has high TDS and a density significantly higher than the water column of the Pit Lake; consequently, it is expected to flow into the Pit Lake as a density current along the floor of the Pit Lake causing it to settle in the deepest portions of the lake. Geochemical relations suggest that the lower water layer in the Pit Lake is derived from waste rock dump water and forms a stagnant pool that does participate in circulation or turnover that occurs in the upper layer above the chemocline. Instead, the upper and lower water layers are likely to interact along the chemocline boundary primarily by diffusive exchange and limited mixing induced by advective transport in the upper layer.

Pit walls are a significantly smaller source than the waste rock dumps. Contaminants in the pit walls migrate to surface water and sediment in the Pit Lake during rainfall-runoff events which leach contaminants (including oxidation products and intermediate metal salts) and entrain particles. Contaminants also migrate from the pit walls by direct contact with wall rock and potentially through physical instability of the steep pit walls.

Contaminated sediment larger than silt is unlikely to migrate when the surface of the Pit Lake is below the elevation of the emergency spillway. However, during times when water flows across the spillway, increased water velocity may entrain sediment from the substrate near the spillway and convey it downstream as a particulate load. Chemical precipitates present as colloids and contaminants sorbed to small particles such as clay minerals may remain suspended in the water column and be released from the Pit Lake by flow across the spillway.

Contaminated surface water within the Pit Lake is a secondary source which affects sediment resources within the lake, groundwater resources within OU1 down-gradient of the Pit Lake, and surface water resources in the North Tributary and Pit Branch (OU3). Contaminants in the Pit Lake migrate directly to surface water in the North Tributary by discharge across the spillway.

Pit Lake contaminants migrate to groundwater through fractures in the bedrock walls and base of the mine pit. Flow to groundwater is expected to be anisotropic across the pit occurring primarily where geologic fractures (faults and joints) are present. The speed and volume of migration is anticipated to be a function of fracture length and aperture and hydraulic pressure gradients. Although historical blasting to loosen rock for excavation would create fractures on most pit wall surfaces, these fractures are expected to advance only a few meters into the bedrock.

The quality of water migrating from the Pit Lake depends on the depth within the lake from which water escapes. Water in the upper water layer has significantly lower contaminant concentrations and is less dense than water in the lower water layer. Water that discharges across the spillway is sourced from the upper water layer; water that escapes to groundwater may be sourced from either the upper or lower pit water layers.

2.3.3 Water Balance

The water balance of the Pit Lake has not been quantified. Calculations based on the approximate length of time to fill the pit indicate groundwater inflow of 10 to 16 gpm with large uncertainty (and does not include compensation for outflow). Outflow of groundwater to the north, northeast, and northwest is estimated at 2.5 to 10 gpm based on calculations of mass load addition to the North Tributary; the volume of outflow that does not gain to the creek is unknown.

2.3.4 Contaminant Behavior in the Pit Lake

The Barite Pit Lake is an open system which changes constantly in response to precipitation runoff, evaporation, groundwater flux, surface water discharge, microbial action, photooxidation/reduction, and other effects. That water chemistry would change over time is to be expected in the dynamic system given the interplay between the many variables that define chemical equilibrium.

Using a groundwater flux of 40 to 60 L/min, the waste rock dumps contribute an estimated 58 to 87 kilograms per day (kg/day) of aluminum, 26 to 40 kg/day of copper, 245 to 370 kg/day of iron, 1,025 to 1,540 kg/day of sulfate, and 800 to 1,200 kg/day of acidity to the Pit Lake. Even if the flux of groundwater through the dumps is as small as 1 L/min, the dumps contribute significant contamination to the Pit Lake: aluminum (Al) - 1.5 kg/day; copper (Cu) - 0.7 kg/day; iron (Fe) - 6.2 kg/day; sulfate (SO_4) - 25.6 kg/day; and Acidity - 20.3 kg/day. About 90% of the contributed iron is in the oxidized (ferric) state.

Assuming areas for partly weathered (sulfide-bearing) and oxidized (sulfide-free) pit walls, a 1 inch rain event would add less than 0.1 kg of dissolved heavy metals, 1.1 kg of sulfate, and 1.5 kg of acidity to the Pit Lake.

Ferrous and total iron measurements of the lower pit water layer yield a median ferrous/total iron ratio of 0.86, equivalent to a ferric iron concentration of 4.1 to 4.6 millimoles per liter (mmol/L). Based on a volume of water in the lower layer of 2.9 Mgal, 45,000 to 51,000 moles of ferric iron are present in the lower water layer. This is a significant amount of ferric iron that is available to generate acid through the oxidation of iron sulfide minerals in pit backfill, pit walls, and sediment. pH of the lower layer was measured in November 2016 at 3.6 suggesting that this ferric iron is expected to be present as ions in solution which could begin to breakdown the iron monosulfides in the Pit Lake sediment that were created as part of the Removal Action.

Given the current conditions in the lower water layer, reduction of sulfate and ferric iron may take place within the lower water layer but reactions are likely to be sluggish and it is unknown if they would occur at a rate sufficient to offset ferric iron gains from the waste rock dumps. Hydrogen sulfide production is unlikely to be significant and generation of iron and other metal sulfides will be curtailed as a result. pH of the lower layer is on the lower cusp of ferric hydroxide stability but is below the stability fields of oxides and hydroxides for metals such as aluminum and manganese. The high acidity of the lower layer suggests that most metals will be maintained in dissolved form where they may sorb or desorb to ferric iron precipitates.

2.3.5 Response of the Pit Lake System to Amendments

Water quality in the Pit Lake has improved substantially since the Removal Action was implemented; however, the effects of the amendment events have been short-lived. Although the rates at which microbially mediated reactions function are difficult to quantify, it is apparent that the rate at which acidity is added to the lake exceeds the rate at which microbial action produces alkalinity in the form of bicarbonate. Consequently, the pit water re-acidifies with time. Factors that may be influencing the rate of microbially mediated reactions include, but are not limited to, the availability of food and substrate, and the pH and redox conditions within the lake. Depletion of TOC in the upper water column leads to decreases in microbial activity and lower bicarbonate production; natural sources of TOC to the upper water layer are lacking and long-term carbon sources added to the Pit Lake (wood chips) cannot be accessed by microbes in the upper water layer.

The waste rock dumps contribute an estimated flux of 25,200,000 milliequivalents (mEq) per day (mEq/day) of acidity and 6,060,000 mmol/day of ferric iron to the Pit Lake. Given that the 2008 Removal Action graded and covered the waste rock dumps, present day influx from the dumps is likely to be significantly lower. Neutralization of this acid load would require a sulfate-reducing bioreactor with a substrate of 1,400 cubic meters (m^3).

2.3.6 Contaminant Migration from the Pit Lake System

Surface water from the upper pit layer periodically discharges from the Pit Lake to the North Tributary (OU3) via the spillway, however, the volume of water and the mass of contaminants discharged to the North Tributary has not been quantified. Given contaminant concentrations typical of surface water in the upper reach of the North Tributary, overflow from the Pit Lake is expected to dilute stream water. The increase in water volume within the North Tributary as a consequence of overflow may increase water velocity, which could lead to mobilization and transport of sediment from the streambed.

Seepage that gains to the North Tributary share many chemical characteristics with water in the lower water layer of the Pit Lake. Calculations of mass load changes in the North Tributary were used to estimate seepage inflow to the creek of 2.5 to 10 gpm; loss to other (deeper) groundwater resources that do not connect to surface water cannot be quantified from the present data.

2.4 TREATABILITY STUDY RESULTS

Sovereign Consulting, Inc., of Lakewood, Colorado, conducted Tier 1 testing on OU1 Pit Lake water, groundwater and waste rock to determine the potential of reducing acid generation at the site. The following sections summarize Sovereign's findings. The full findings and discussion can be found in Sovereign's treatability study report presented in Appendix B.

2.4.1 Acidothiobacillus ferrooxidans (ATBFO) Suppression

Data in the literature confirm that pyrite oxidation kinetics control acid rock drainage (ARD) generation and that pyrite oxidation are controlled by the pyrite's exposure to water, oxidizing reagents such as oxygen and ferric iron (Fe^{+3}), and a microbe, *Acidothiobacillus ferrooxidans* (*ATBFO*). It is a well-established fact that *ATBFO* can increase pyrite oxidation kinetics and ARD generation rates by many orders of magnitude (Sovereign, 2018).

Sodium lauryl sulfate (SLS) solution buffered with sodium bicarbonate (HCO_3) was effective at suppressing *ATBFO* in the OU1 waste rock unsaturated and transition zones test units. A dilute solution of milk, also buffered with HCO_3, was effective at neutralizing existing ARD and suppressing additional ARD generation in the OU1 waste rock saturated zone test unit without plugging (Sovereign, 2018).

2.4.2 Passive Treatment of Mine Water

Water from the upper part of the Pit Lake was collected by Sovereign from the uppermost 0.5 meters. This water is amenable to passive treatment with a biochemical reactor (BCR) filled with a typical mixture of organic materials such as wood chips, straw, and limestone (Sovereign, 2018).

Groundwater was collected from BH26, which contains more acidity and sulfate than the upper Pit Lake water. Sovereign determined that it would require a pre-treatment step for groundwater to remove acidity prior to its delivery to a BCR. Alternatively, the limestone component in the BCR media mixture may need to be increased. Pre-treating the iron and aluminum in the groundwater with an iron terrace might also reduce the acidity without the need for chemical addition (Sovereign, 2018).

2.4.3 Pit Lake Bottom Sediment Encapsulation

Bentonite-amended site soils and commercially-available products, such as AquaBlok®, are capable of producing an encapsulating layer on the bottom of the Pit Lake (Sovereign, 2018).

In summary, the technologies tested appear to produce conditions that can respectively suppress ARD generation, passively treat pit water, neutralize pit water with common reagents, and encapsulate the sediments on the Pit Lake floor (Sovereign, 2018).

2.5 SUMMARY OF ECOLOGICAL AND HUMAN HEALTH RISKS

2.5.1 Ecological Risks

- Water quality in the Pit Lake would pose a severe risk to aquatic life if it was present.
- Sediment quality in the lake would pose a risk to benthic organisms if they were present.
- If acidity could be controlled at pH >6, and if aquatic resources were introduced into the Pit Lake, then a viable aquatic community may become established.
- Soil quality does not pose an adverse risk to terrestrial receptors.
- Contaminated groundwater in OU1 that discharges via seeps to OU3 has resulted in significant risks to aquatic life in the upper reaches of the North Tributary.

2.5.2 Human Health Risks

- Cancer risks and non-cancer hazards are acceptable for all receptors exposed to sediment. There are no COCs for sediment.
- Cancer risks are unacceptable for future residents exposed to soil (via ingestion, dermal absorption and inhalation of dust), surface water (via ingestion and dermal absorption), and groundwater (via ingestion and dermal absorption), and for future industrial/commercial workers exposed to groundwater (via ingestion only). The only carcinogenic COCs for soil, surface water and groundwater are arsenic and chromium VI.
- Non-cancer hazard index (HIs) are unacceptable for future residents due to exposure to groundwater (via ingestion and dermal absorption) in the area surrounding the Pit Lake, and water (via ingestion and dermal absorption) in the lake. Non-cancer groundwater COCs for the future resident include: aluminum, antimony, arsenic, cadmium, cobalt, copper, iron, manganese, nickel, selenium, thallium, vanadium and zinc. Non-cancer surface water COCs include cadmium, cobalt, copper, iron and manganese.
- Non-cancer HIs are unacceptable for future industrial/commercial workers from exposure to OU1 groundwater (via ingestion only). Non-cancer groundwater COCs for the future industrial/commercial worker include: aluminum, antimony, arsenic, cadmium, cobalt, copper, iron, manganese, nickel, selenium, thallium, vanadium and zinc.
- Non-cancer HIs are unacceptable for future construction workers from exposure to groundwater (via ingestion and dermal absorption) in an excavation trench in OU1. Non-cancer groundwater COCs for the future construction worker include: cadmium, copper, and iron.
- Cancer risks and non-cancer hazards are acceptable for current/future trespasser/recreational users, exposed to all media in OU1. There are no COCs for current/future trespasser/recreational users.

- Exposure to lead in groundwater (via ingestion) is expected to result in an unacceptable risk to residents, industrial/commercial workers and construction workers.
- Contaminated groundwater in OU1 that discharges via seeps to OU3 has resulted in unacceptable non-cancer hazards to future residents exposed to cadmium, cobalt and manganese in surface water (via ingestion and dermal absorption) adjacent to known seeps.

3.0 Remedial Action Objectives and Preliminary Remedial Goals

This section provides information regarding the cleanup objectives for OU1. Section 3.1 discusses potential ARARs considered in developing this FS. RAOs are identified and discussed in Section 3.2. The basis for RGs is summarized, and RG values are identified in Section 3.3.

3.1 REMEDIAL ACTION OBJECTIVES

RAOs provide general descriptions of what the cleanup is expected to accomplish (EPA 2005a). Derived from the CSM, RAOs address the significant exposure pathways and risks associated with surface water, groundwater, soil/waste rock, and sediment contaminants. RAOs and RGs should reinforce each other, leading to the selection of a remedial action that meets the NCP threshold criteria by being protective of HH&E and meeting ARARs, while also providing the best balance among the remaining NCP criteria (EPA 2005a). The RAOs for this FS which were used to guide the development of remedial alternatives are listed below. The general remedial strategy is driven by the need to restore and protect the designated uses for the North Tributary.

Surface Water and Sediment

- ***RAO 1:*** Improve water quality in the Pit Lake to risk-based levels protective of wildlife drinking from the Pit Lake.

Groundwater

- ***RAO 2:*** Prevent or control the migration of contaminated groundwater to the Pit Lake and/or to seeps that discharge to the North Tributary.

Soil/Waste Rock

- ***RAO 3:*** Prevent ingestion, inhalation, or direct contact with soils containing constituents at concentrations exceeding EPA's acceptable risk range (10^{-4} to 10^{-6} for carcinogens) and/or HI of 1 (for non-carcinogens), which could result in adverse health effects to human and ecological receptors.
- ***RAO 4:*** Prevent or control migration of contaminants in soil or waste rock to groundwater.

3.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Pursuant to CERCLA §121(d)(4), remedial actions at CERCLA sites must be protective of HH&E. Designated on-site actions need to comply with the substantive portions of ARARs to the greatest extent practical unless the ARAR is waived. ARARs are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under state or federal law that specifically address the situation at a CERCLA site. ARARs may either be "applicable" or "relevant and appropriate" to remedial activities at a site, but not both.

The requirement is "applicable" if the jurisdictional prerequisites of the standard show a direct correspondence when objectively compared with the conditions at the site. Applicable requirements, as defined in 40 C.F.R. § 300.5, are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under State or Federal law

that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Relevant and appropriate requirements, as defined in 40 C.F.R. § 300.5 are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, although not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well suited to the conditions of the site.

Per 40 C.F.R. § 300.400(g)(5), only those state standards are promulgated, are identified in a timely manner, and that are more stringent than federal requirements may be applicable or relevant and appropriate. For purposes of identification and notification of promulgated state standards, the term promulgated means that the standards are of general applicability and are legally enforceable. State ARARs are considered more stringent where there is no corresponding federal ARAR, where the State ARAR provides a more stringent concentration of a contaminant, or the where a State ARAR is broader in scope than a federal requirement. See EPA, OSWER Pub. No. 9234.2-05/FS, *CERCLA Compliance with State Requirements* (December 1989).

In addition to ARARs, the lead and support agencies may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular release that may be useful in developing Superfund remedies. See 40 C.F.R. § 300.400(g)(3). The "to-be-considered" (TBC) category consists of advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states that may assist in determining, for example health-based levels for a particular contaminant for which there are no ARARs or the appropriate method for conducting an action. TBCs are not considered legally enforceable and, therefore, are not considered to be applicable for a site but typically are evaluated along with Chemical-specific ARARs as part of the risk assessment to determine protective cleanup levels. See EPA, OSWER Directives No. 9234.1-01 and 9234.1-02, CERCLA Compliance with Other Laws Manual: Parts 1 and Part II (August 1988 and 1989), Section 1.4.

ARARs are categorized as chemical-specific, location-specific, or action-specific.

- Chemical-Specific ARARs are usually health or risk based numerical values limiting the amount or concentration of a chemical that may be found in, or discharged to, the environment. The Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs) at 40 C.F.R. Part 141 and the state or federal ambient water quality criteria established under Section 303 or 304 of the Clean Water Act are examples of Chemical-Specific ARARs used to establish remediation levels for restoration of groundwater that are current or potential sources of drinking water and restoration of surface water to meet its designated uses or classifications, respectively. See 40 C.F.R. §§ 300.430(e)(2)(i)(B), (C), & (E).
- Location-specific ARARs are requirements related to the geographical location of the site or physical condition of the site, such as floodplains or wetlands where there could be “relevant and appropriate” requirements under §404 of the Clean Water Act. While specific permits would not be required, substantive requirements may limit the type of remedial action to be implemented or may impose additional constraints on some remedial alternatives. Potential federal and state location-specific ARARs are presented in Table 3-2.
- Action-specific ARARs are, for the most part, technology- or activity-based requirements or limitations on specific actions taken with respect to remediating hazardous sites. These requirements are triggered by the particular remedial activities that are selected to accomplish a

remedy. Action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative must be employed. Action-specific ARARs are triggered by types of remedial activities and types of wastes that are generated, stored, treated, disposed, emitted, discharged, or otherwise managed. For example, action ARARs may set restrictions for particular treatment and disposal activities. Action-specific ARARs for each alternative will vary depending on the technologies employed. Potential federal and state action-specific ARARs are presented in Table 3-3.

Hawe Creek at the Highway S-33-44 Bridge is listed as impaired for aquatic life due to elevated copper and zinc (SCDHEC, 2014a). The North Tributary at the confluence with Hawe Creek is listed as impaired due to low pH (SCDHEC, 2014a). A goal of SCDHEC is removal of the impaired classifications. The North Tributary is unclassified.

Intermittent and ephemeral streams are considered waters of the state and the State's water quality standards apply (SCDHEC, 2014b). The Pit Lake was not identified waters of the United States likely because it had no prior connection to a stream and it had been used several times as a treatment system in attempts to neutralize the lake water.

The purpose of the OU1 (Pit Lake System) feasibility study is to develop remedial alternatives that will prevent or control source contamination migration from the Pit Lake System to OU3 (North Tributary to Hawe Creek). Addressing site groundwater is not within the scope of the remedy for OU1. Groundwater will be addressed in a future remedial decision for OU2 (Overburden and Bedrock Groundwater). Achievement of RAO 2 will be assessed by monitoring each seep or groundwater discharge location against state ambient water quality criteria (AWQC) at the point entering the North Tributary. Achievement of RAO 1 will be assessed against ecological risk-based levels for wildlife drinking from the Pit Lake (Table 3-4).

Federal and South Carolina governments have not promulgated standards, requirements, criteria or limitations to control the levels of hazardous substances, pollutants, or contaminants in soil or sediment. However, potential exposure risks to humans and ecological receptors to soil and sediment have been evaluated in both HHRAs and ERAs for OUs 1 and 3. The evaluations presented in these documents form the basis for calculation of RGs protective of HH&E.

3.3 REMEDIAL GOALS

RGs are generally medium-specific chemical concentrations that will pose no unacceptable threat to HH&E. Cleanup levels for response actions under CERCLA are based on ARARs and site-specific risk assessments.

The EPA typically considers the results of the baseline risk assessments when establishing the basis for taking remedial action. Where the baseline HHRA indicates that a cumulative site risk to an individual using reasonable maximum exposure (RME) assumptions for either current or future land use exceeds the 1E-04 (one in 10,000) lifetime excess cancer risk or non-cancer risk exceed a HI of 1, action is generally warranted for a given media at the site (EPA, 1991). At sites where the carcinogenic risk is less than 1E-04 or the non-carcinogenic risk is less than 1, action may still be warranted when a chemical specific standard that defines acceptable risk is violated (i.e., a chemical exceeds a chemical-specific ARAR). In addition, the EPA may decide that a lower level of risk to human health is unacceptable and that remedial action is warranted where there are uncertainties in risk assessment results. Once a decision has been made to take remedial action at a site, the EPA has expressed preference for cleanup achieving the health

risk of less than 1E-06 (one in a million), although strategies achieving cleanups between 1E-04 and 1E-06 may be deemed acceptable. The EPA does not consider the 1E-04 risk to be a discrete line. Therefore, the EPA may consider risk estimates slightly greater than 1E-04 to be protective.

When an ARAR for a specific chemical defines an acceptable level of exposure, compliance with the ARAR will generally be considered protective even if it is outside the risk range. For example, MCLs and nonzero MCLGs promulgated for protection of drinking water under the National Primary Drinking Water Regulations are generally considered protective of human health even if the MCL or MCLG exceeds the site-specific concentration calculated during the Baseline HHRA.

South Carolina regulations specifically state that soil cleanup levels must be protective of groundwater (i.e., concentrations in soil must be below concentrations which would cause exceedances of groundwater). One method of calculating soil concentrations protective of groundwater recommended by EPA is to use a simplified linear equilibrium soil/water partition equation (EPA, 1996). This method provides a very conservative soil concentration because it conservatively idealizes site features and characteristics; it assumes an infinite source, uniformly distributed contamination from the ground surface to the top of the aquifer, no contaminant attenuation in the soil or groundwater, instantaneous and linear equilibrium of the contaminant between the soil and water phases, and a homogeneous and isotropic unconfined aquifer. In reality, the contaminant source is finite; there is substantial variation in contaminant concentration both laterally and vertically; and the aquifer has substantial heterogeneities.

Therefore, it is likely that groundwater cleanup levels for most contaminants could be attained even if soil exceeding these screening levels is left in place. Additionally, soil cleanup levels protective of groundwater screening levels are typically much lower (e.g., sometimes several orders of magnitude) than soil cleanup levels protective of direct contact/ingestion. Thus, soil screening values calculated using this equation may be useful in identifying contaminants and areas which may pose risk to groundwater, but use of the values as strict remediation goals could result in over estimation of contaminant extent. Over estimating extent could result in a corresponding increase in remediation cost with minimal decrease in risk. The calculated soil values for protection of groundwater may be used in areas with limited groundwater data as an indicator of potential groundwater impacts; however, ensuring that any contaminants remaining in soil are not adversely affecting groundwater is best demonstrated by monitoring groundwater directly.

3.3.1 Remedial Goals Protective of Human Health

Both current and reasonable likely future risk need to be considered in order to demonstrate that a site does not present an unacceptable risk to HH&E. In assessing potential future risk, the potential land use associated with the highest level of exposure and risk that can be reasonably expected to occur should be addressed. In general, undeveloped areas should be assumed to be residential in the future unless the site is in an area where residential land use is unlikely. Based on this guidance, property beyond the mining site is considered residential and remediation goals protective of residential exposure may be applicable.

In the case of the current partially reclaimed mine site at Barite Hill, the potential future land use must be considered before classification of the site as industrial. Because the OU1 portion of the mine site was reclaimed by placing waste rock back into the pit and installing a cover cap over the graded waste rock, future residential use of this land is unlikely. Given the surrounding wooded nature of the site and proximity to the town of McCormick, recreational use would also be a likely future land use following closure. Due to its wooded nature, trespassers may attempt to enter the site for recreational purposes. Thus, RGs protective of trespassers and recreational users are most appropriate for this area.

As discussed in Section 2.3.6, risks from exposure to the upper reaches of the North Tributary and seeps were identified. Risks from exposure to Pit Lake water and sediment were also identified. RGs protective of human health for exposure to these areas are discussed below.

Pit Lake water RG is based on the ecological risk-based values calculated by EPA to be protective of wildlife exposure from the Pit Lake. The alternatives evaluated do not propose restoring Pit Lake water to meet state AWQC within the pit water itself. However, RGs at the point groundwater seeps discharge to surface water (North Tributary) are based on South Carolina Quality Standards for Freshwaters.

3.3.2 Remedial Goals Protective of Ecological Receptors

RGs protective of receptors exposed to pit water and sediment in the Pit Lake and North Tributary are a combination of protective media concentrations developed in the Baseline Ecological Risk Assessment (BERA) for OU3 (Black & Veatch, 2016) and ARARS. As recommended in the OU3 ERA, media-specific RGs are based on the following:

- Surface Water, North Tributary – State of South Carolina water quality standards and background concentrations for aluminum and iron for protection of aquatic life.
- Pit Lake Water – Based on concentrations that would result in adverse risks to terrestrial wildlife that would ingest the pit water as the daily sole source for drinking.
- Sediment – Lowest observed adverse effect level (LOAEL) values for protection of aquatic and/or terrestrial invertebrates as derived from the OU3 BERA for the North Tributary.

A benthic community never existed in the pit and the transport of sediment from the pit over the spillway into the North tributary is not a pathway of concern; therefore, there are no RGs for Pit Lake sediment. As discussed in Section 2.5.1, no unacceptable risks to human or terrestrial ecological receptors from exposure to soil were identified.

3.3.3 Site-Specific Preliminary Remedial Goals

<u>Water Within the Pit</u>

As discussed in the sections above likely future land use for OU1 is a trespasser/ recreational user. The HHRA concluded that both cancer risks and non-cancer hazards are acceptable for current/future trespasser/recreational users. The ERA concluded Pit Lake water presented adverse risks to terrestrial wildlife that ingest pit water as the daily sole source for drinking. The RAO for Pit Lake water is to improve water quality in the Pit Lake to be protective of wildlife drinking from the lake. The ERA concluded Pit Lake water presented adverse risks to terrestrial wildlife that ingest pit water as the daily sole source for drinking. The RAO for Pit Lake water is to improve water quality in the Pit Lake to be protective of wildlife drinking from the lake. Therefore, the recommended preliminary remedial goal for the water within the Pit Lake will be the ecological RGs recommended in the BERA for OU1 (Black & Veatch, 2017) for wildlife drinking from the Pit Lake. COCs under this scenario were identified as: aluminum, copper, and iron. The purpose of this FS is to develop remedial alternatives for OU1 that will control or mitigate source contamination migration to the North Tributary. Restoration of Pit Lake water is outside of the scope of the OU1 source control remedy.

<u>Intermittent Discharge of Pit Water via Spillway Overflow to the North Tributary</u>

Intermittent discharges of pit water through spillway overflow (such as during 24 hr/25 year storm events) to the North Tributary should not cause the waters of the North Tributary to exceed water quality standards at the point of discharge. The HHRA indicated that water in the Pit Lake contained non-cancer hazards for any future residents exposed to water discharging from the pit. The HHRA identified the following COCs under these conditions: cadmium, cobalt, copper, iron, and manganese. The BERA (Black & Veatch, 2017) identified the following COCs within the North Tributary: aluminum and iron. The recommended preliminary goal for intermittent discharges of Pit Lake water through the spillway into the North Tributary will be the water quality standards for these COCs (Table 3-4).

Groundwater discharging into the North Tributary

Based upon the HHRA contaminated groundwater in OU1 that discharges via seeps to OU3 has resulted in unacceptable non-cancer hazards to future residents exposed to cadmium, cobalt and manganese in surface water adjacent to known seeps. The BERA identified the following ecological COCs within the North Tributary: aluminum and iron. Surface water quality standards will be the recommended preliminary RGs for groundwater discharging via seeps into the North Tributary. The preliminary recommended RGs are presented in Table 3-4.

3.4 IDENTIFICATION OF CONTAMINATED MEDIA ZONES

Soil and groundwater contamination at the Site were classified into four contaminated media zones (CMZs) that are the basis for remedial alternative screening and remedy selection. A CMZ represents a portion of the Site contamination which has a particular characteristic that defines the optimal remediation approach. Defining characteristics can include one or more parameters such as lithology, COCs, depth, and/or areal extent. Segregation of the Site into CMZs allows remedial alternatives to be tailored to these conditions, thereby resulting in a more economical and focused remedy. CMZs have been established to address contaminants in the Pit Lake (CMZ-1), capped waste rock (CMZ-2), and groundwater (CMZ-3). The CMZs are established based on existing data and may require refinement if additional data is collected in the future.

3.5 DELINEATION OF AREAS AND VOLUMES OF CONTAMINATED MEDIA

Based on the RAOs and RGs developed in the above sections, area and volumes (as appropriate) of contaminated media in OU1 in need of remedial action has been estimated. There are many uncertainties associated with these estimates such as groundwater discharge into and out of the Pit Lake, variable seasonal flow rates and COC concentrations from seeps, intermittent discharge over the spillway during precipitation events, and unknown volumes of acid generating material.

3.5.1 Extent of Contaminated Media in OU1

CMZ-1, Pit Lake Water. The current estimate of lake water volume is approximately 73 Mgal with a relative accuracy of 10%. This was based on merging bathymetric and Lidar data sets and estimating volume of the pit in 5 ft depth increments. The Pit Lake occupies an area of approximately 7.7 acres.

CMZ-2, Waste Rock. There are no definitive records of how much waste rock was covered with the existing caps or the volume of waste rock placed into the southeast area of the pit. However, based on estimates of material in previous reports it is estimated that approximately 250,000 cy remain beneath the cap and another 50,000 cy in the saturated zone or under water in the Pit Lake. The capped waste rock disposal area occupies approximately 6.6 acres.

CMZ-3, Groundwater. Groundwater quality in OU1 has been measured in monitoring wells BH49, BH50, BH51, BH55, BH56, BH64, BH65, BH66, BH71, BH72, BH73, and BH74 (Figure 3-1). Groundwater in OU1 exceeding the RGOs is concentrated in the waste rock area as shown in the COC concentrations in wells BH26 through BH29 (Appendix A Tables A-4.1 through A-4.13). Some exceedances have also been observed in the down gradient wells BH55, BH56, BH64, and BH74. All of the upgradient wells with the exception of BH72 are all below the RGOs. Only two COCs (arsenic and lead) exceed their respective RGO in BH72.

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4.0 Identification and Screening of General Response Actions and Technologies

This section identifies and initially screens remedial technologies to be assembled into remedial alternatives for the Site (Section 5). The technology and process screening approach described in this section is consistent with the EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988).

The evaluation of technologies potentially applicable to remedial alternatives for the Site was conducted in two steps consistent with CERCLA guidance (EPA 1988). The first evaluation step, presented in this section, identifies an array of possible remedial technologies and evaluates these technologies based on technical effectiveness, implementability, and cost. Technologies and process options that 1) have clearly not been demonstrated as effective in addressing similar conditions at other mining sites; 2) cannot be implemented due to site-specific conditions; or 3) do not meet the RAOs specified in Section 3 are eliminated from further consideration for the purposes of this FS. The exception is the No Action alternative, which is retained per the NCP in Title 40 Code of Federal Regulations (CFR) Part 300 (NCP, 1994) to serve as a basis for comparison to other effective and implementable technologies. The second evaluation step, presented in Sections 5 and 6, assembles the retained remedial technologies into a range of potentially viable remedial alternatives that are further evaluated based on the NCP criteria (EPA 1988).

4.1 GENERAL RESPONSE ACTIONS

Remedial technologies evaluated for possible application to OUs 1 and 3 at the Site were organized under GRAs. GRAs are broad categories of conceptual remediation technical processes or administrative methods to address contaminated media and attain the RAOs. Identification of GRAs is the first step in development of remedial alternatives for site restoration. The following GRAs were identified for the OUs:

- No action serves as a basis for comparison to other effective and implementable technologies (NCP 1994).
- Institutional controls (ICs) include instruments such as administrative and legal controls, to minimize the potential for exposure and to ensure the long-term integrity of the remedy.
- Containment technologies such as capping, encapsulation or creating impoundments.
- Excavation and disposal of contaminated material.
- *In situ* treatment such as biochemical reactors and constructed wetlands.
- *Ex situ* treatment such as pump and treatment of groundwater.
- Monitored natural actuation (MNA) that documents the effectiveness of natural physical, chemical, or biological processes in reducing contaminant concentrations to achieve RAOs.

These categories of remedial technologies and specific process options were identified based on a review of the literature, performance data, and experience in developing other mining-related FSs under CERCLA. Consistent with CERCLA guidance (EPA 1988), this initial screening of remedial alternatives evaluates the GRAs against the following NCP Criteria: effectiveness, implementability, and cost.

Effectiveness is evaluated based on the relative ability of the technology or process option to meet the RAOs in a reasonable timeframe, ensure long-term human health and environmental protection, protect

against short-term human and environmental effects during construction, and proven reliability at other sites with chemicals and conditions similar to those at the Site.

Implementability encompasses both the technical and administrative feasibility of implementing a technology or process option. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Technical feasibility also applies to the availability of necessary equipment, personnel, and services for implementation or construction, and industry experience in implementing the remedy. Administrative feasibility refers to the ability to obtain approvals to construct the remedy (on-site response actions defined under CERCLA are exempt from the procedural requirements of federal, state, and local environmental laws, though the action must nevertheless comply with the substantive requirements of such laws).

Costs are used to compare different technologies or alternatives. While the total cost of a given technology is not normally estimated during the initial screening described in this section, relative costs of technologies (i.e., whether they are low, moderate, or high) are evaluated and compared during the initial screening phase. This section does not formally evaluate costs. Rather, based on knowledge of relative costs, professional judgment is used to identify the relative cost-effectiveness of each alternative. Detailed cost evaluations are presented in Section 7 as part of the detailed evaluation of alternatives passing the screening process.

4.2 SCREENING OF REMEDIAL TECHNOLOGIES

This section preliminarily evaluates possible remedial technologies based on technical effectiveness, implementability, and cost. Other than the No Action alternative, which is retained as a basis for comparison to other effective and implementable technologies (NCP, 1994), only technologies and process options that: 1) have been demonstrated as effective in addressing similar conditions at other mining-related sites; 2) can be implemented at the Site; or 3) meet the RAOs specified in Section 3 are evaluated in this section. Although ICs are not expected to serve as stand-alone remedies, they may be combined with other technologies to enhance human health protectiveness.

Table 4-1 shows the technology screening process for the OU1 (Pit Lake area). Technologies and process options judged ineffective or not implementable were removed from further consideration. The technologies retained following screening represent an inventory of technologies considered suitable for remediation of contaminated media at the Site. Technologies and process options may be used either alone or integrated with other technologies to develop remedial alternatives.

4.2.1 Remedial Technologies and Process Options Eliminated

It is useful to document the rationale for eliminating some technologies from further consideration during the initial screening analysis. Remedial technology process options were eliminated if they: (1) did not satisfy the RAOs for the applicable media; (2) were inappropriate for the site-specific COCs; (3) were untenable for the given lithology of the area; (4) presented an unacceptable impact on the community; or (5) were considered cost prohibitive. The rationale for technologies removed from consideration is provided in Table 4-1.

4.2.2 Description of Retained Remedial Technologies

A general description of each retained technology is provided along with relevant site-specific detail regarding its implementation or applicability.

4.2.2.1 Institutional Controls

ICs include a series of administrative tools or engineering controls that limit exposure to contaminated media to protect HH&E. Examples include: (1) government administrative controls such as zoning restrictions, local ordinances (e.g., well field limitations); (2) proprietary controls such as environmental covenants; (3) enforcement options and permit controls for a site; and (4) informational tools such as public notices and advisories. By themselves, ICs are not effective at reducing contaminant T/M/V at the Site. These options could be used in combination with other technologies as a method for reducing the likelihood or frequency of direct exposure with contaminated media. The application of zoning restrictions and/or local ordinances on-facility was retained to limit exposure of COCs to the current and future receptors. Groundwater use restrictions incorporated into local land use zoning or construction permit requirements are an example of this type of IC. The use of shallow groundwater in the site vicinity is currently not restricted; however, the availability and use of a municipal water supply for residents in the vicinity of the Site supports the application of this control. The second IC retained for the Site is the use of public notices, advisories, and signage. This passive remedy may provide a visible and practical reminder for the local public to maintain awareness of the Site and to minimize exposure for a negligible cost. These controls have no effect on aquatic life in the North Tributary. These ICs were selected for both OUs 1 and 3. Currently the Site is fenced with no trespassing warning signs.

4.2.2.2 Pit Lake Floor Partial Encapsulation

In 2008, large volumes of waste rock were dumped back into the pit. The waste rock rubble in the shallower depths (< 25 ft) in the southern portion of the pit appears to be a major source of acid generation largely due to exposure to relatively high levels of DO. The lake floor in this area of the pit (approximately 1 acre) has a relatively gradual slope that would be conducive to adding slurry consisting of a neutralizing agent, grouting admixture and residual buffering agent (e.g., lime). Low-cost available compounds such as sodium lauryl sulfate (to kill pyrite oxidizing bacteria), and waste milk and/or whey (to promote biofilm coating preventing acid re-generation) may be used for the partial encapsulation. This technology can be used in conjunction with others to minimize contaminant releases from this source.

4.2.2.3 Groundwater Diversion

Based on the geophysical studies conducted by GEL Geophysics (2012), U.S. Geological Survey ([USGS], 2015), and Willowstick® Technologies, LLC ([Willowstick®], 2017), groundwater migrates through fracture zones around the pit and that a substantial pathway exists for groundwater migration through the capped waste rock (CWR) areas. This inflow of highly contaminated groundwater to the pit is of most concern in the re-acidification of the Pit Lake. Diverting groundwater may be possible by the installation of a grout curtain in the primary flow path from through the southwest CWR. Technical resources are readily available for design and implementation of grout curtain technology.

4.2.2.4 Hydraulic Containment

Hydraulic containment could be used to withdraw groundwater to prevent discharge to the Pit Lake or to contain or prevent down-gradient migration of groundwater through the waste rock. Groundwater withdrawal could be accomplished either by extracting shallow groundwater from wells installed upgradient of the waste rock in the southwest slope. The extracted groundwater would require management or treatment prior to discharge to the environment. This could be used with other containment barriers, in the form of clay-cored dams, grout or slurry walls, and similar features could be used to intercept shallow groundwater and force it to a collection area for treatment.

4.2.2.5 Expand and Enhance Existing Cap

Based on the geophysical studies conducted by Willowstick® (2017), a substantial groundwater migration pathway flows through the southern portion of the pit that also contains large quantities of waste rock. Although much of this area has been capped, an expansion and/or enhancement of the cap further to the southeast at higher elevations would minimize infiltration. In addition, the existing cap surrounding monitoring wells BH28 and BH29 (approximately 1 acre) is being compromised by shrub and tree growth. Repairs and/or enhancement to this cap to minimize infiltration would be beneficial. This is a common technology employed at former mining sites and resources are readily available for design and implementation of various cap designs.

4.2.2.6 Neutralization of Pit Lake

The seasonal and temporal changes in Pit Lake chemistry in relation to the various neutralization events are documented in the RI. One of the major factors affecting the success of raising the lake pH is the rapid re-acidification that appears to be dominated by groundwater inflow through the CWR. In addition, it appears that microbial activity in the water column is diminished in part due to depleted soluble carbon in the upper water column. Developing a means to provide carbon over the long term (e.g., large carbon "tea bags") may help to alleviate this issue and raise alkalinity that is necessary to sustain a pH >6. Other contributing factors to re-acidification include, but not limited to, the increase in redox conditions and DO levels in the lower water column. Since 2014, new lake bathymetry data was used to estimate 73 milligrams (mg) of water, which is higher than used previously (~ 50 mg). This technology should be used in combination with other technologies that reduce acid inputs to the lake. Technical capability and cost assumptions to deliver various amendments has been demonstrated.

4.2.2.7 Amendments to Waste Rock

Amendments to waste rock could be used as an *in situ* treatment process option and as a containment/source control strategy for solids in the waste rock dumps. This RTPO could be implemented in a manner that reduces future acid generation from sulfide minerals in the dumps. Given that the CWR appears to be a major source of contamination to the Pit Lake, various amendments could be delivered into the CWR to reduce acid generation and metals mobility. This technology can be used in conjunction with others such as partial removal of the CWR to minimize contaminant releases from this source. Sovereign Consulting has conducted treatability studies to determine the potential effectiveness of adding low-cost available amendment to the waste rock such as sodium lauryl sulfate (to destroy pyrite oxidizing bacteria), waste milk and whey (to promote biofilm coating of sulfide minerals to prevent acid re-generation). The results of these studies (Appendix B) show that sodium lauryl sulfate buffered with sodium bicarbonate appears to be effective at suppressing the pyrite oxidizing bacteria within the unsaturated and transition zones of the waste rock. A dilute solution of milk buffered with sodium bicarbonate appears to be effective at reducing acid rock drainage within the saturated zone. Details of the treatability studies are presented in Appendix B. Since the waste rock is covered by about 2 to 3 feet of compacted soil and a well-vegetated cover (and partly capped with a geomembrane liner), methods to deliver the amendments into the CWR will need to be evaluated. Potential delivery methods include surface application of amendments that infiltrate through the cap or injection through vertical or horizontal tubes inserted via directional drilling underneath the cap.

4.2.2.8 Amendments to Groundwater

Adding amendments to groundwater is an *in situ* treatment process option for groundwater within and up-gradient of the waste rock dumps. This strategy also could be applied to groundwater discharging from the Pit Lake. Current data suggest that as groundwater migrates through the CWR it becomes

acidified and dissolves metals released from the waste rock by sulfide oxidation. The addition of alkalinity (NaOH or similar compounds) into the CWR directly or into the groundwater flowing through the CWR should reduce acid generation. Carbon such as methanol could also be injected to spur microbial activity. This would require a network of injection wells to send compounds to the correct depth and radius. This RTPO would likely be used in conjunction with the groundwater diversion approach to minimize treatment of large volumes of groundwater.

4.2.2.9 Partial Excavation of Capped Waste Rock

Partial excavation of waste rock is a removal and source control process option that could be applied to the subaerial waste rock dumps. There is an existing soil cap of approximately 1 acre in the vicinity of monitoring wells BH28 and BH29. Waste rock beneath this cap is a source of acid generation due to the interchange of Pit Lake water and groundwater input through the waste rubble. This would entail pulling waste rock back from the lake. This may also include pulling some of the waste rock out of the lake (which would require temporarily lowering the lake level). Removing this source and replacing it with clean fill will reduce acid formation and improve water quality of the lake. The excavated material could be disposed of on the Barite Hill site or at an off-site repository. This RTPO could be used with other technologies such as putting a cutoff wall to force groundwater to the surface and treat it in a passive system within the excavated area.

4.2.2.10 On-Site Disposal of Excavated Material

This RTPO for disposal is linked to the excavation technologies. Waste rock, sediment, and other mine wastes can be disposed of in one or more repositories constructed on the Barite Hill site. Depending on the environmental behavior of the solids requiring disposal (e.g., leachability, acid generation potential), a repository may be constructed with or without a liner and wastes may be either contained or isolated. A facility constructed on site would be expected to comply with requirements for Subtitle D landfills. An on-site repository offers a high level of overall T/M/V reduction (albeit with a transference of volume to the repository location), but also has a substantial capital cost and a low level of long-term liability associated with the selected landfill.

4.2.2.11 Open Limestone Channel (OLC)

Open limestone channels are an *ex situ* passive treatment process option for oxygenated surface water with net acidity but generally low concentrations of iron. OLC technology could be used to treat intermittent pit water discharges via the spillway. Flow across the spillway would be diverted into a pipe and conveyed to an OLC which is a lined channel constructed of cobble- or gravel-sized limestone rock. A small settling basin may be required at the outlet of the channel to precipitate aluminum and other metal precipitates that form as pH is increased prior to discharge to the North Tributary. Depending on water quality in the upper pit water column, the length of the open channel and the contact time of water with limestone, water discharged from the system may or may not meet State water quality standards (WQS). The addition of water with residual alkalinity to OU3 could be expected to cause precipitates to form in the North Tributary as the alkalinity reacts with dissolved iron and other metals in the creek. This floc would continue downstream for a considerable (and unknown) distance until it settles out. There would not be any expected performance drop-off following dry periods when the Pit Lake does not discharge. Periodic monitoring of the channel would be required to ensure that the limestone does not become armored with iron precipitates and lose reactivity. The system could be sized to handle a variety of flows, but appropriate gradients would need to be determined to ensure a required minimum contact time.

4.2.2.12 Sulfate Reducing Bioreactor

Sulfate-reducing bioreactors are an *ex situ* treatment process option for surface water with net acidity and elevated concentrations of metals, sulfate, and other constituents. Flow across the spillway would be diverted into a pipe and conveyed to a passive treatment system to remove metals and raise pH. The system would require some area of relatively flat ground (approximately 0.5 acre) but they could also be installed in modular form in tanks or as permeable reactive barriers to treat other contaminated waters on site. Likely system components would include a surge pond or head tank to meter flow into the bioreactor, an aerobic settling pond or wetland to precipitate metals, remove BOD and add dissolved oxygen, and possibly a manganese rock filter. The system would be expected to create water that meets or is close to meeting WQS. However, the system performance is dependent on flow rates, influent water quality and available land area for construction. Sulfate-reducing bioreactors are a passive treatment option that would not require power or regular maintenance. However, they are not a "walk away" technology and would require periodic monitoring and maintenance of inlets/outlets to ensure system performance and efficiency. Replacement of the substrate and reconstruction of the system would be required every 20 to 30 years.

4.2.2.13 *Ex situ* Aerobic Wetland Pond

Constructed aerobic wetlands are shallow ponds filled with gravel, organic matter, and soil which are planted with wetland species such as cattails. Water ponds within the cells to depths of 6 to 12 inches and typically flows across the pond (rather than through the substrate). Aerobic wetlands permit oxidation and hydrolysis of iron and other metals at times assisted by plant uptake and microbial activity. The footprint required for an aerobic pond depends on flow rate but is typically rather large to permit sufficient residence time for oxidation and flow velocity that is low enough to allow fine-grained precipitates to settle.

As a primary treatment option, aerobic wetlands are generally inefficient at removing high concentrations of metals and neutralizing acidity; they are not expected to significantly remove manganese or sulfate. However, they are widely used as a polishing step to add oxygen, remove dissolved sulfide and biochemical oxygen demand, and promote iron hydrolysis and precipitation in water discharged from anaerobic bioreactors or wetlands. This RTPO would be used in conjunction with the sulfate reducing bioreactor as a polishing step for treated water.

4.2.2.14 Manganese Rock Filters

Manganese rock filters are a type of passive aerobic treatment. While constructed aerobic wetlands are ineffective at removing manganese due to the high pH (>8) required for Mn^{2+} to be oxidized to insoluble Mn^{4+}, rock filter technology utilizes bacteria or green algae to promote manganese oxidation in the presence of a limestone substrate, allowing manganese oxide to be precipitated onto the limestone fragments. Manganese rock filters are constructed as a bed of limestone gravel (18 to 24 inches thick) that is inoculated with bacteria or algae. Oxygenated manganiferous water that has been treated to remove iron and other metals is passed through the rock filter to remove manganese. Rock filters are seeing increased use at mine sites to remove manganese as the third step in a passive treatment train (anaerobic cell, aerobic cell, rock filter).

4.2.2.15 Drain and Treat Pit Lake Water

Drain lake by pumping at least 73 Mgal water through an on-site treatment facility and discharge clean water to North Tributary. An on-site treatment facility will be needed to raise pH and remove metals in order to meet State water quality standards. Several treatment options such as pH adjustment, ion-exchange, clarification and filtration are available. The system would require pumping water up from the lake to the treatment plant and treatment would need to accommodate large variations in water chemistry, particularly near bottom of water column. Treatment sludge would be temporally stored on-site for eventual placement back into the pit. Water treatment is a common technology at mine sites.

4.2.2.16 Constructed Anaerobic Wetlands

Constructed anaerobic wetlands are an *ex situ* treatment process option for treatment of net acidic water with high concentrations of metals and sulfate. Treatment is accomplished through sulfate reduction and precipitation of metals as sulfides and hydroxides under reducing conditions. Constructed anaerobic wetlands use biochemical processes to neutralize acidity and remove metals from acidic mining influenced water. They may be configured for water to flow horizontally or vertically through the substrate. Substrate composition varies but typically includes a mix of organic materials such as woody debris (e.g., chips or sawdust), compost (e.g., mushroom, manure), and other vegetative matter (e.g., hay); a bacteria source (most commonly fresh manure); and a source of alkalinity (e.g., limestone).

Sulfate-reducing bacteria within the substrate convert sulfate in untreated water to hydrogen sulfide, which reacts with dissolved divalent metals such as cadmium, copper, iron, and zinc to precipitate as sulfide minerals within the substrate. Other metals (e.g., aluminum, chromium) are removed as hydroxide phases as pH is raised by the dissolution of limestone and microbial bicarbonate production. Sulfate-reducing bacteria function optimally at pH of 5 or higher. Consequently, the rate at which acidity enters the treatment system is critical to its success; too much acidity will overwhelm microbial bicarbonate production and lead to a decrease in pH that causes sulfate reduction to slow or cease.

Treatment of storm runoff would require additional anaerobic wetland capacity. Maintaining a healthy microbial population capable of treating the additional load imparted by storm flow is critical to the success of any passive anaerobic system that relies on microbial activity to treat water. Consequently, constructed anaerobic wetlands would need to be designed with the capacity to treat storm flow, and then be operated during base flow in a manner that maintains microbial health.

This RTPO could be applied to the pit only in conjunction with elimination of the Pit Lake water. After the lake is drained, implementation would require other technologies such as excavating the backfilled waste rock in the pit or capping the pit bottom with a liner or other cap (e.g., Aquablok®) then an engineered wetland system would be designed on top to capture the residual contaminated groundwater and runoff. (Given the depth of the pit, backfilling and re-shaping the pit would be necessary to manage the predicted hydrology of the wetland; and the spillway would likely be lowered to allow the assumed clean water to be discharged into the North Tributary).

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5.0 Development of Remedial Alternatives

Remedial alternatives are developed to provide project/risk managers with a range of cleanup options, and sufficient detail of the viability and cost of the cleanup options, to adequately compare and select the most plausible and optimal alternative(s) to implement. The EPA guidance documents recommend that alternatives be developed that can achieve site and technologies described earlier. This section presents potentially viable remedial alternatives to address contaminated media and attain the RGs in OU 1. The potential alternatives are summarized in Table 5-1.

Because the contaminated Pit Lake water and OU1 groundwater migrates to the North Tributary via fractures and seeps or over the spillway, the top priority is to develop remedial alternatives that will prevent or control source contaminant migration to OU3. It is expected that after the source controls have been implemented, water and sediment quality in OU3 will improve. Thus, it would not be practical to implement measures in OU3 until the OU1 remedy has been completed and monitoring of the North Tributary indicates significant improvement. This sequential approach provides the means to monitor the seeps and tributary as a result of actions in OU1 as it may not be necessary or cost effective to implement activities in OU3 if there no longer is a major contaminant source. For example, to design and install a passive system in OU3 to treat the existing seeps would not be prudent if the seeps dry up or their water quality has increased.

If monitoring results indicate that residual contaminant inputs remain, then this adaptive management approach would allow for more cost-effective and design-specific alternatives to treat or control any remaining threats to HH&E in OU3.

In addition, the five year review requirement under CERCLA §121 will be used to evaluate the implementation and performance of the phased remedy to determine if it is or will be protective of HH&E. Under the EPA's interpretation contained in the NCP, the requirement is triggered when hazardous substances, pollutants, or contaminants remaining on-facility are above levels that allow for "unlimited use and unrestricted exposure" [40 CFR §300.430(f)(4)(ii)].

5.1 MANDATORY CONSIDERATIONS

There are two specific activities mandated (by statute) to be included in all CERCLA FSs. The first is the inclusion of a "No Action alternative" in every feasibility evaluation. This alternative is carried forward as the baseline condition for comparison to other alternatives. The second is a Five-Year Review (FYR) of the progress of the RAs implemented at a CERCLA site.

5.1.1 No Action Alternative

Section 300.430(e)(6) of the NCP directs that a "No Action Alternative" be developed for all FSs to provide a baseline scenario against which to compare all other alternatives. This alternative can typically only include compliance monitoring. In general, the No Action alternative is applicable when there is no current or potential threat to HH&E or when CERCLA exclusions preclude taking an action. Under No Action alternatives, no funds are expended to control or remediate the contaminated media. Funds would be expended for the statutory FYRs of the Site for site visits, minimal compliance sampling and analyses of select contaminated media, review of regulatory changes, and report preparation. A No Action alternative has been designated as Alternative #1 for each watershed and environmental medium.

5.1.2 Five-Year Review Requirement

The FYR requirement applies to all remedial actions selected under CERCLA §121. The FYR evaluates the implementation and performance of a remedy to determine if it is or will be protective of HH&E. Protectiveness is defined in the NCP by the cancer risk range and the HI. Evaluation of the remedy and the determination of protectiveness should be based on and sufficiently supported by data and observations. Under the EPA's interpretation contained in the NCP, the requirement is triggered when hazardous substances, pollutants, or contaminants remaining on-facility are above levels that allow for "unlimited use and unrestricted exposure" [40 CFR §300.430(f)(4)(ii)].

5.2 INSTITUTIONAL CONTROLS

The use of shallow groundwater in the site vicinity is currently not restricted; however the availability and use of a municipal water supply for residents in the vicinity of the Site supports the application of this control. The second IC for the Site is the use of public notices, advisories, and signage. This passive remedy may provide a visible and practical reminder for the local public to maintain awareness of the Site and to minimize exposure for a negligible cost. These controls have no effect on aquatic life in the North Tributary. Currently the Site is fenced with no trespassing warning signs.

5.3 CMZ-1 - PIT LAKE ALTERNATIVES

The alternatives for Pit Lake address the surface water within the pit as well as the submerged waste rock. None of the individual alternative for the Pit Lake will meet all of the proposed OU1 RAOs. A combination of the best individual alternatives designed to meet all of the proposed RAOs is presented in Section 8.0.

5.3.1 Pit Lake #1: No Action

Section 300.430(e)(6) of the NCP directs that a "No Action Alternative" be developed for all FSs to provide a baseline scenario to compare all other alternatives against. This alternative does not include any remedial action components or funds to reduce T/M/V of contaminants. This alternative is included for each of the three units to be addressed in OU1. This alternative does not meet any of the proposed RAOs.

5.3.2 Pit Lake #2: Drain Lake, Add Amendments to Pit Floor, and Backfill Pit

This alternative consists of the following components and is shown on Figure 5-1:

- Treat approximately 73 Mgal of lake water and other inflows through a temporary onsite treatment plant that will discharge clean water to the North Tributary.
- Amend the pit floor with lime and other reactants to reduce acid generation.
- Backfill pit by using on-site and off-site borrow sources.
- Recontour to minimize groundwater inflow and surface water runoff controls.
- Monitor seeps and North Tributary.

The treatment plant would likely be built in the former staging area as shown in Figure 5-1 and the outfall discharge would be located in the North Tributary downstream of the Beaver Pond. As the pit floor becomes exposed, oxidization of pyritic materials will need to be prevented or minimized to prevent acid generation. This would be accomplished by adding various amendments to kill bacteria that promote acid generation and coat the material with other reactants and/or lime application.

Management and treatment of water entering the pit during backfill operations is required. Backfill will be accomplished using clean materials from on-site and off-site soil borrow areas. The backfilling will be completed to re-contour the new "hill" with surface water runoff controls. It is estimated that approximately 400,000 cy of backfill will be needed.

This alternative would meet the RAO for the Pit Lake but would not address the RAOs for the capped waste rock or groundwater.

5.3.3 Pit Lake #3: Drain Lake, Cap Pit Floor, Partial Backfill, Create Wetland

This alternative consists of the following components and is shown on Figure 5-2:

- Treat approximately 73 Mgal of lake water and other inflows through a temporary onsite treatment plant that will discharge clean water to the North Tributary.
- Amend the pit floor with lime and other reactants to reduce acid generation and cover with impermeable cap.
- Reduce depth and size of pit by partially backfill with material from on-site and off-site borrow areas, lower spillway, and re-contour pit.
- Construct a wetland system to treat groundwater and surface water inflows.

The temporary treatment plant would be the same as described for Pit Lake #2. The exposed pit floor and walls would be treated with reactants to reduce acid generation prior to placement of an impermeable cap over the floor. Then material from borrow areas will be used to re-contour the pit and lower the spillway to allow clean water to discharge to the North Tributary. The shallower pit will be designed as a passive wetland to sequester metals from runoff and groundwater input.

This alternative would meet the RAO for the Pit Lake. It would aid in addressing the RAO for groundwater but would not address the RAO for the capped waste rock.

5.3.4 Pit Lake #4: Amendments to Pit Lake and Cap Pit Floor

This alternative consists of the following components and is shown on Figure 5-3:

- Amend the lake with alkalinity and organic carbon to increase the pH and reduce metals concentrations.
- Cover the pit floor with an impermeable cap to seal off from groundwater discharging into the Pit Lake. This would also seal off the Pit Lake water from fractures leading to the seeps near the North Tributary.
- Monitor lake water, seeps and North Tributary.

Lime-based amendments such as sodium hydroxide and substantial amounts of organic carbon from cost-effective sources such as wood chips, molasses, or liquid manure would be mixed into the Pit Lake based on accurate water volumes and titration techniques. Large carbon "tea bags" would be used to help prevent settling to the bottom. The pit floor would be encapsulated using an impermeable material such as AquaBlok® or a sodium bentonite/soil mixture.

This alternative would meet the RAO for the Pit Lake but would not address the RAOs for the capped waste rock or groundwater.

5.4 CMZ-2 - WASTE ROCK ALTERNATIVES

The alternatives for the capped waste rock were developed to address the acid production from the waste rock in order to reduce or eliminate its impact on the Pit Lake water and groundwater within the waste rock area. None of the individual alternative for the waste rock will meet all of the proposed OU1 RAOs. A combination of the best individual alternatives designed to meet all of the proposed RAOs is presented in Section 8.0.

5.4.1 Waste Rock #1: No Action

Section 300.430(e)(6) of the NCP directs that a "No Action Alternative" be developed for all FSs to provide a baseline scenario to compare all other alternatives against. This alternative does not include any remedial action components or funds to reduce T/M/V of contaminants. This alternative does not meet any of the proposed RAOs for the waste rock.

5.4.2 Waste Rock #2: Excavate and On-Site Disposal and Encapsulation of the Capped Waste Rock, Backfill, Cap Excavation

This alternative consists of the following components and is shown on Figure 5-4:

- Excavate the approximately 250,000 cy of capped waste rock and encapsulate on-site.
- Backfill the excavated area with clean materials.
- Cap backfilled excavation.
- Monitor lake water, seeps and North Tributary.

Would remove, through excavation, the 250,000 cy of capped waste rock. The waste rock would be transported to a location on-site and encapsulated. The excavated waste rock would be encapsulated in a geomembrane liner on top and bottom and finished with a clay cap. The encapsulation will be designed to prevent infiltration of water into the waste rock or seepage from the waste rock. A sheeting pile may be required along the edges of the Pit Lake during excavation activities to prevent the excavation from filling with Pit Lake water. The excavated area would be backfilled with clean material brought in from off-site. The backfilled excavation would be revegetated and contoured to control storm water runoff.

This alternative would address the capped waste rock and its associated RAO. It would also indirectly aid in addressing the RAOs for the Pit Lake and groundwater by removing the major source of acid generation in OU1.

5.4.3 Waste Rock #3: Amendments to Waste Rock, Enhancement of Existing Caps

This alternative consists of the following components and is shown on Figure 5-5a through Figure 5-5d:

- The capped waste rock would be amended with reactants (e.g., sodium lauryl sulfate and milk) to neutralize acid generation.
- An expansion and/or enhancement of the existing cap.
- Monitor lake water, seeps and North Tributary.

Amendments such as sodium lauryl surface buffered with sodium bicarbonate (used in Sovereign's treatability study) would be added to the unsaturated and transition zones of the waste rock. Amendments to the unsaturated zone would be applied through a series of shallow injection wells. Amendments such as milk buffered with sodium bicarbonate would be added to the saturated zone of

the waste rock to stop acid generation. The amendments would be added to the saturated waste rock through a series of injection wells that extend into the underlying bedrock. The existing cap would be expanded and/or enhanced to minimize rain and storm water infiltration. In addition, much of the area is compromised by shrub and tree growth. Removal would further minimize infiltration.

This alternative would address the RAO for the waste rock area and aid in addressing the RAOs for the Pit Lake and groundwater by reducing or stopping acid generation within the waste rock area.

5.5 CMZ-3 - OU1 GROUNDWATER ALTERNATIVES

The alternatives for OU1 groundwater were developed to reduce or eliminate contaminated groundwater from impacting the waters of the Pit Lake and the North Tributary. No individual alternative for OU1 groundwater will meet all of the proposed RAOs. A combination of the best individual alternatives designed to meet all of the proposed RAOs is presented in Section 8.0.

5.5.1 Groundwater #1: No Action

Section 300.430(e)(6) of the NCP directs that a "No Action Alternative" be developed for all FSs to provide a baseline scenario to compare all other alternatives against. This alternative does not include any remedial action components or funds to reduce T/M/V of contaminants. This alternative does not meet any of the proposed RAOs for OU1 groundwater.

5.5.2 Groundwater #2A: Groundwater Diversion and Dewatering of the Capped Waste Rock – Barrier Wall and Grout Curtain

This alternative consists of the following components and is shown on Figure 5-6a:

- Install a barrier wall and grout curtain in the upper end capped waste rock area to divert unimpacted groundwater from oxidizing the buried waste.
- Dewater the capped waste rock area by pumping groundwater into the Pit Lake.
- Install open limestone channels at the pit spillway and in channels where storm water discharges into the Pit Lake.
- Monitor lake water, seeps and North Tributary.

A barrier wall approximately 600 ft long and 70 ft deep would be installed on the upper slope of the southeast cap area as shown on Figure 5-6a. The barrier wall would be constructed by excavating a long, deep, and approximately 3-ft wide trench from ground surface to total depth (top of bedrock). It would be constructed by removing the existing native soils from the trench and backfilling the trench with a low permeability material.

The grout curtain would extend from the top of bedrock down to a total depth of 160 feet bls. It would consist of the installation of two grout lines offset 10 ft from the proposed centerline of the barrier wall. The grout line on the downstream (to groundwater flow) side of the barrier wall would be completed first, followed by the upstream line, and finally verification holes performed between the lines and water pressure tested to confirm the design intent of the drilling and grouting has been met.

Individual grout lines are performed using split spacing of holes. For example, Primary borings are performed at a given spacing. Upon completion of the Primary borings in a given area, Secondary borings

drilled halfway between the Primaries are performed. The split spacing process continues until the collective body of data indicates that the design intent has been met.

As a possible finishing step, the groundwater within the waste rock area could be extracted using a series of extraction wells. The groundwater would be pumped into the Pit Lake for in-situ treatment as part of Pit Lake alternatives 2 and 3 if they are chosen as the remedial option.

Although not addressing groundwater directly this alternative also recommends the installation of passive open limestone channels at the Pit Lake spillway and at areas where storm water runoff enters the Pit Lake. These would be considered as a passive ex situ treatment of water discharging from the Pit Lake at times of full pool. In addition, channels where storm water discharges into the Pit Lake would be lined with limestone to help add alkalinity to the Pit Lake to aid in raising the pH with in its waters.

This barrier wall and grout curtain would divert clean groundwater away from the waste rock area. This alternative would reduce the flow of groundwater into the waste rock area from the south-southwest which would aid in addressing the RAO for groundwater. It would not address groundwater already within the waste rock area or water discharging from the Pit Lake into fractures which feed the seeps. This alternative would not directly address the RAOs for the Pit Lake or the waste rock; however, it would prevent or minimize contamination of additional groundwater from upgradient sources.

5.5.3 Groundwater #2B: Groundwater Diversion and Dewatering of the Capped Waste Rock – Hydraulic Barrier

This alternative consists of the following components and is shown on Figure 5-6b:

- Install a series of groundwater extraction wells in the upper end capped waste rock area to create a hydraulic barrier and reducing or preventing the flow of groundwater through the buried waste.
- Dewater the capped waste rock area by pumping groundwater into the Pit Lake.
- Install open limestone channels at the pit spillway and in channels where storm water discharges into the Pit Lake.
- Monitor lake water, seeps and North Tributary.

A hydraulic barrier approximately 600 ft long would be created on the upper slope of the southeast cap area as shown on Figure 5-6b. The hydraulic barrier would be constructed by installing a series of groundwater extraction wells drilled into the underlying bedrock. Eight 6-inch wells would be installed to a total depth of 160 feet bls at 75-foot centers along the line depicted on Figure 5-6b. Groundwater would be extracted from these wells to drawdown groundwater on the upper slope of the capped waste rock thus preventing or greatly reducing groundwater flow through the waste rock. Extracted groundwater would be pumped into the Pit Lake provided the water quality of the groundwater would not negatively impact the Pit Lake water. An alternative would be to pump the groundwater into an infiltration pond or ponds. If extracted groundwater is found to be impacted it will need treatment prior to discharge to the Pit Lake or infiltration ponds

As a possible finishing step, the groundwater within the waste rock area could be extracted using a series of extraction wells. The groundwater would be pumped into the Pit Lake for in-situ treatment as part of Pit Lake alternatives 2 and 3 if they are chosen as the remedial option.

As describe for #2B, this remedy would also install open limestone channels at the Pit Lake spillway and storm water entry points to the Pit Lake.

This alternative would reduce the flow of groundwater into the waste rock area from the south-southwest which would aid in addressing the RAO for groundwater. It would not address groundwater discharging from fractures which feed the seeps. This alternative would not directly address the RAOs for the Pit Lake or the waste rock; however, it would prevent or minimize contamination of additional groundwater from upgradient sources.

5.5.4 Groundwater #3: Add Alkalinity to Groundwater

This alternative consists of the following components and is shown on Figure 5-7:

- Install a series of injection wells into the saturated capped waste rock area to add reactants and/or alkalinity to neutralize groundwater from oxidizing the buried waste.
- Monitor lake water, seeps and North Tributary.

A series of injection wells will be installed to add alkalinity-related amendments to the groundwater within the waste rock and major fracture zones zone near the lake to reduce acidity as shown on Figure 5-7. The wells would be installed into the regolith and bedrock at various depths. Final amendments and quantities, along with the number and spacing of injection wells would be developed at the design stage. This alternative may require multiple injections to address the RAO for groundwater.

This alternative would address the RAO for groundwater. It would not directly address the RAOs for the waste rock area or the Pit Lake

5.6 DESCRIPTION OF POTENTIAL ALTERNATIVES FOR OU3

As mentioned above, an adaptive management approach is taken to sequence remedial actions to focus on controlling contaminant migration from OU1 to OU3. Remedial components for OU1 include the addition of limestone channel at the Pit Lake spillway to mitigate potential impacts to North Tributary from intermittent spillway overflow (such as during 24 hr/25 year storm events) and monitoring over-topping of the spillway against state water quality standards. If EPA determines, after implementing OU1 remedial actions, that monitored levels of spillway overflow exceed state water quality standards and thus is not protective of the North Tributary, the EPA will evaluate and develop alternatives for OU3 (e.g., employing additional passive treatment technologies at the spillway). The following alternatives (except no action) are considered potential as they will be modified in the future to reflect conditions in the North Tributary after implementation of the selected remedy for OU1 and are presented only for informational purposes. It is expected that at least two years of monitoring seeps and the tributary will be needed before developing final remedial alternatives for OU3 that will meet the RAOs and RGs.

5.6.1 Alternative 1 (OU3-1): No Action

This alternative does not include any remedial action components to reduce T/M/V of contaminants in the North Tributary.

5.6.2 Alternative 2 (OU3-2): Construct bioreactors at seeps, excavate sediment behind beaver dam, stabilize dam, and reconstruct wetland

This alternative consists of the following components.

- Construct seep-specific bioreactors depending on water quality and quantity after implementation of the OU1 remedy. In general, if seep water is relatively anoxic with very high iron content, then an ALD with organic material could be used. If waters are relatively aerobic with low iron content, then an OLC or other organic bioreactor can be constructed.
- Excavate contaminated sediment behind the abandoned beaver dam to a distance approximately 250 ft upstream and place in an on-site repository.
- Stabilize dam with riprap and construct wetland in excavated portion.
- Placement of clean substrate in selected upstream tributary reaches to reduce exposure.
- MNR of downstream of beaver dam.

5.6.3 Alternative 3 (OU3-3): Construct bioreactors at seeps and excavate all tributary sediment upstream of beaver dam

This alternative consists of the following components:

- The site-specific bioreactors would be similar to Alternative OU3-2 depending on water quality and quantity after OU1 controls.
- Excavate contaminated sediment from behind the abandoned beaver dam upstream to the confluence with the reference reach and place in an on-site repository.

5.6.4 Alternative 4 (OU3-4): Stabilize beaver dam, excavate main sediment deposit and construct one passive wetland system behind dam to treat all seep water

This alternative consists of the following components:

- Excavate contaminated sediment from behind the abandoned beaver dam and place in an on-site repository.
- Design passive wetland treatment cell(s) upstream of dam to accommodate water quality and quantities of residual seep water, and allow for storm water discharges.
- Placement of clean substrate in selected upstream tributary reaches to reduce exposure.
- Monitored natural recovery downstream of former beaver dam.

This alternative largely depends on using the North Tributary as a passive treatment system upstream of the beaver dam.

6.0 Detailed Analysis of Remedial Alternatives

A detailed evaluation of the remedial alternatives using the CERCLA FS guidance criteria has been performed in order to recommend an appropriate remedial action to be selected for the Record of Decision (ROD). The remedial alternative evaluation criteria have evolved as a result of statutory requirements that must be addressed in the ROD. CERCLA requires that remedial alternatives meet the following criteria:

- Be protective of HH&E;
- Attain ARARs (or provide grounds for invoking a waiver);
- Be cost-effective;
- Use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and
- Satisfy the preference for treatment that reduces T/M/V as a principal element or provide an explanation in the ROD of why it does not.

The NCP and the *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies* (EPA, 1988) under CERCLA provide nine evaluation criteria to address the CERCLA statutory requirement considerations:

- Overall protection of HH&E.
- Compliance with ARARs.
- Long-term effectiveness and permanence.
- Reduction of T/M/V through treatment.
- Short-term effectiveness.
- Implementability.
- Cost.
- State acceptance.
- Community acceptance.

In this section, each individual alternative is evaluated against the first seven of the nine criteria. The last two criteria, State and Community acceptance, cannot be adequately assessed until after the Proposed Plan is released for regulatory and public review. These two criteria will be assessed in the ROD's Responsiveness Summary.

The following discussion presents the primary components of each of the seven criteria that are used to complete the detailed evaluation of alternatives. State acceptance and community acceptance are considered modifying criteria, and are used to identify the Preferred Alternative after the public comment period.

6.1 THRESHOLD CRITERIA

The first two criteria, overall protection of HH&E and compliance with ARARs, are considered threshold criteria. These criteria are statutory and must be met for an alternative to be considered a remedy for a

site. The overall protectiveness to HH&E focuses on whether an alternative would achieve adequate protection and how site risks would be eliminated, reduced, or controlled through treatment, engineering, or ICs.

Compliance with ARARs criterion assesses whether an alternative meets all federal and state ARARs for the site, including action-, chemical-, and location-specific ARARs, in addition to any other criteria, advisories, or guidance.

6.2 BALANCING CRITERIA

The following five criteria are considered balancing criteria.

1. **Long-Term Effectiveness and Permanence** - This balancing criterion assess the residual risk that would remain at the Site after the RAOs are achieved. The extent and effectiveness of the controls needed to manage any treatment residuals or untreated media are assessed by qualitatively determining the magnitude of any residual risk remaining at the Site at the conclusion of the remedial activities. Also, the adequacy and reliability of the controls that are used to manage any treatment residuals or monitor untreated media remaining at the Site are assessed.
2. **Reduction of T/M/V through Treatment** - This criterion assesses the degree to which site media would be treated to permanently and significantly reduce the T/M/V of site contaminants. This is accomplished by analyzing the destruction of toxic contaminants, the reduction of the total mass of toxic contaminants, the irreversible reduction in contaminant mobility, or the reduction in total volume of contaminated material. This criterion also evaluates the level of risk reduction and any potential residual risks.
3. **Short-Term Effectiveness** - This balancing criterion addresses the effects of an alternative on site surroundings during the construction and implementation phases of the remedial action, before RAOs are achieved. These effects include consideration of the protection of workers and the community during remedial action implementation, environmental impacts that might result from construction or implementation, and the length of time until the RAOs are achieved. This criterion primarily assesses whether the proposed alternative minimizes short-term risks to human health and the community, and whether those risks can be eliminated or controlled by remedy design and best management practices (BMPs). This criterion also includes identifying short-term risks that cannot be readily controlled, such as quality-of-life impacts (e.g., safety, noise, odors, and traffic) and physical disturbance to the environment such as destruction of vegetation and land form alterations.
4. **Implementability** - This balancing criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during implementation. Technical feasibility encompasses the technical difficulties and unknowns associated with the alternative, the reliability of the technologies, the ease of undertaking additional remedial actions if necessary, and monitoring requirements. Evaluation of implementability also considers the ability to monitor the effectiveness of the alternative and the difficulty in undertaking additional future remedial actions. Administrative feasibility includes the activities required for coordination with other offices and agencies. Availability of services and materials includes the availability of necessary equipment and specialists, the ability to obtain competitive bids, and the availability of prospective technologies.
5. **Costs** - The cost criterion involves an evaluation of the capital costs, the annual operations and maintenance (O&M) costs, and a present worth analysis. The cost estimates are order-of-

magnitude level estimates, which are defined by the American Association of Cost Engineers as approximate estimates made without detailed engineering data. It is normally expected that an estimate of this type would be accurate to +50% and -30%. The actual costs of the project would depend on the final scope of the remedial action, the schedule of implementation, actual labor, material costs at the time of implementation, competitive market conditions, and other variable factors that may impact the project costs. A cost summary is shown in Table 6-1 and cost backup sheets for each alternative are provided in Appendix C. The net present worth (NPW) for each alternative was developed using the Modified Uniform Present Value (UPV*) method. In accordance with current EPA guidance, Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-75, July 2000, a discount rate of 7% before taxes and after inflation (for a non-Federal facility) was used to account for the time value of money. Costs for the implementation of Five-Year-Reviews and monitoring are included as the Site-Wide Costs in Appendix C. These costs were estimated separately as they apply to all remedy alternatives since waste will remain in place at the Site.

6.3 ENVIRONMENTAL SUSTAINABILITY

The EPA has begun "examining opportunities to integrate sustainable practices into the decision-making processes and implementation strategies that carry forward to reuse strategies" (EPA 2008, 2010). Federal Executive Order 13423 (Federal Register 2007) defines sustainability as:

"*…the capacity to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans*."

Sustainable practices for site remediation emphasize six core elements (EPA 2008):

1. Energy requirements of the treatment system
2. Air emissions
3. Water requirements and impacts on water resources
4. Land and ecosystem impacts
5. Material consumption and waste generation
6. Long-term stewardship actions

The primary goal of the sustainability evaluation is to identify alternatives that minimize the environmental and energy footprints of site remediation while still achieving short- and long-term risk management goals specified in the RAOs and RGs. This assessment also evaluates whether:

- Passive-energy technologies can be used;
- Equipment will operate at peak efficiency;
- The use of fossil-fueled equipment can be minimized; or
- Renewable energy systems can replace or offset utility electricity requirements.

In addition, this assessment evaluates the ability to minimize the release of dust and toxins through waste generation, air emissions, and greenhouse gas production relative to short-term effectiveness; the

alternative's ability to minimize freshwater consumption and maximize reuse; recycling practices during daily operations; and factors such as the potential for soil and habitat disturbances.

6.4 ANALYSIS OF INDIVIDUAL ALTERNATIVES AGAINST NCP CRITERIA

This section evaluates Alternatives for the three areas within OU1 (the Pit Lake, the capped waste rock, and the OU1 groundwater) against the seven NCP criteria discussed in Section above. As discussed in Section 5, a detailed description of alternatives for OU3 is deferred depending on monitoring results of seeps and the North Tributary. Implementation of each OU1 alternative (except no action) is expected to reduce toxicity and mobility of contaminants in OU3. Given the adaptive phased approach to OU3, only the OU1 alternatives are considered here. Highlights of the evaluation for each alternative along with general advantages and disadvantages for the OU1 remedial alternatives are listed below.

6.4.1 CMZ-1 - Pit Lake Alternatives

6.4.1.1 Pit Lake #1: No Action

Alternative: Pit Lake #1	No Action
Criteria	**Analysis**
Description	Baseline alternative. Five-year reviews of the remedial action would be required.
Advantages	Low cost, no site disruption.
Disadvantages	• Site would remain in current condition, no additive protection of HH&E • The potential for ingestion or direct contact with contaminated media would remain. No improvement to the North Tributary expected.
Overall Protection of Human Health and Environment (HH&E)	The No Action alternative is not anticipated to be protective of HH&E in the short term or near (less than 30 years) long term. This alternative does not reliably eliminate exposure pathways or reduce the level of risk of the existing media contamination.
Compliance with ARARs	This alternative will not achieve the RAOs or chemical-specific ARARs established for the Site. Location- and action-specific ARARs do not apply to this alternative since remedial actions will not be conducted.
Long-Term Effectiveness and Permanence	Long-term effectiveness is deemed poor as the Site has not demonstrated a marginal restoration rate for natural attenuation.
T/M/V through Treatment	This remedy does nothing to reduce the T/M/V of COCs. The source area can be expected to marginally expand in volume without treatment, thus continuing the current conditions.
Short-Term Effectiveness	This remedy will have no short-term impacts on the community or workers as there is no remedial action. RAOs are not expected to be met with this alternative.
Implementability	The No Action alternative is easily implemented.
NPW Cost	$94,200

6.4.1.2 Pit Lake #2: Drain Lake, Amendments to Pit Floor and Backfill Pit

Alternative: Pit Lake #2	Drain Lake, Amendments to Pit Floor, Backfill Pit
Criteria	**Analysis**
Description	Drain the Pit Lake. Treat and discharge water from Pit Lake to the North Tributary. Add amendments to the pit floor. Backfill the pit with clean fill material.
Advantages	• The removal of the Pit Lake water may reduce or eliminate seepage flow through fractures to the North Tributary. Water treatment is a common technology at mine sites.

Alternative: Pit Lake #2	Drain Lake, Amendments to Pit Floor, Backfill Pit
Criteria	**Analysis**
Disadvantages	• Draining lake may not control seepage to the North Tributary due to contaminated groundwater beneath the pit and though the existing waste rock. It also would not prevent contamination of clean fill via groundwater flowing through the capped waste rock into the pit area. • Surface water treatment would require power and would be expensive. • High capital cost and O&M for questionable reduction of risk to the North Tributary. High capital risk if after backfilling the pit it is determined to have a poor outcome. Few options would remain should this alternative fail.
Overall Protection of HH&E	Would be protective of HH&E in the Pit Lake with the removal and treatment of contaminated lake water. Long term would not address groundwater beneath the pit or in waste rock which could continue to impact the North Tributary in the long term.
Compliance with ARARs	Would be in compliance with ARARs for the water in the Pit Lake. May not meet water quality standards at the discharge point of groundwater seeps to the North Tributary.
Long-Term Effectiveness and Permanence	Would be effective in eliminating water from within the Pit Lake. Long-term would not address impacted groundwater from beneath the Pit Lake or migrating through the waste rock from discharging into the North Tributary.
Reduction in T/M/V through Treatment	On-site reduction in T/M/V in the Pit Lake with the removal and treatment of water followed by backfilling. May not reduce T/M/V in groundwater discharging into the North Tributary.
Short-Term Effectiveness	Short-term would treat and remove 73 Mgal of water from the Pit Lake in approximately 1.5 years. Noise levels from the construction and operation of the treatment facility are not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented with minimal construction difficulty. Remedy is reliable and can be easily monitored. Numerous vendors have the capability to complete construction of the treatment facility and backfilling the Pit Lake.
NPW Cost	$17,778,500

6.4.1.3 Pit Lake #3: Drain Pit Lake, Cap Pit Floor, Partial Backfill, Create Wetland

Alternative Pit Lake #3	Drain Pit Lake, Cap Pit Floor, Partial Backfill, Create Wetland
Criteria	**Analysis**
Description	Drain the Pit Lake. Treat and discharge water from Pit Lake to the North Tributary. Add amendments, such as AquaBlok®, to the pit floor. Partially backfill the pit with clean fill material. Lower the spillway elevation. Create a wetland in partially backfilled pit.
Advantages	• The removal of the Pit Lake water may reduce seepage flow through fractures to the North Tributary; • Water treatment is a common technology at mine sites; • Capping the pit floor with AquaBlok® or similar material and partially backfilling with clean material will reduce groundwater inflow; • A constructed anaerobic wetland would aid in removal of metals and raise the pH of any waters flowing over the spillway thus reducing the risk to the North Tributary; • Engineered wetlands are relatively common technologies at mine sites and technical resources to implement are well known.

Alternative Pit Lake #3	Drain Pit Lake, Cap Pit Floor, Partial Backfill, Create Wetland
Criteria	**Analysis**
Disadvantages	• Draining lake may not control seepage to the North Tributary due to contaminated groundwater beneath the pit floor and though the existing waste rock; • Surface water treatment would require power and would be expensive; • Anaerobic wetlands would likely require treatability studies of contaminated groundwater inflow volumes and quality to determine wetland size; • Wetlands have high capital cost and O&M for minimal reduction of risk to the North Tributary; • Would require detailed monitoring of wetland system performance. A constructed wetland would also require an on-going source of water moving through the system. May also require periodic reconstruction.
Overall Protection of HH&E	This alternative would be protective of HH&E by eliminating the impact of the Pit Lake on the North Tributary. It would reduce the impact of the waste rock through passive treatment of groundwater discharging from the waste rock into the wetland area. May not reduce T/M/V in groundwater discharging into the North Tributary from the seeps.
Compliance with ARARs	This alternative is expected to achieve remedial goals in pit water discharging via the spillway into the North Tributary. Chemical and Action-specific ARARs would be met for water exiting the pit via the spillway. May not meet water quality standards at the discharge point of groundwater seeps to the North Tributary.
Long-Term Effectiveness and Permanence	Long-term this alternative should be effective for the Pit Lake but may require longer term O&M as a result of the wetland. The long-term impact on groundwater is unknown.
Reduction in T/M/V through Treatment	This alternative should show on-site reduction of T/M/V within the pit and thereby reducing the same within the North Tributary. Reduction of T/M/V within groundwater is suspect.
Short-Term Effectiveness	Short-term would treat and remove 73 Mgal of water from the Pit Lake in approximately 1.5 years. Noise levels from the construction and operation of the treatment facility are not anticipated to impact nearby properties. Noise levels from capping and backfilling the Pit Lake and the installation of a wetland within the pit should not impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented with minimal construction difficulty. Remedy is reliable and can be easily monitored. Numerous vendors have the capability to complete construction of the treatment facility partially backfilling the Pit Lake, and construction a wetland.
NPW Cost	$14,550,000

6.4.1.4 Pit Lake #4: Amendments to Pit Lake and Cap Pit Floor

Alternative: Pit Lake #4	Amendments to Pit Lake, Partial Removal and Amendments to Waste Rock, Groundwater Diversion
Criteria	**Analysis**
Description	Amendments would be added to the Pit Lake to raise the pH. Amendments (such as AquaBlok®) to the waste rock within the Pit Lake would be added to prevent water in the Pit Lake from contacting the waste rock. A barrier wall within the regolith and grout curtain within the bedrock would be installed upgradient of the waste rock area to divert groundwater away from the waste rock.

Alternative: Pit Lake #4	Amendments to Pit Lake, Partial Removal and Amendments to Waste Rock, Groundwater Diversion
Criteria	**Analysis**
Advantages	• Addition of amendments to the Pit Lake would likely raise pH to above 6 and reduce metals concentrations, thereby reducing threat to the North Tributary from discharge of contaminated water over the pit spillway; • Capping the pit floor with AquaBlok® or similar material and partially backfilling with clean material will reduce groundwater inflow; • The technical capability and cost assumptions to deliver various amendments to the Pit Lake has been demonstrated; • Low long-term O&M costs.
Disadvantages	• Pit Lake may require more than one amendment event, thus long-term monitoring and higher O&M costs are expected; • Groundwater diversion may not be able to divert significant groundwater volumes away from the waste rock area (e.g., if grout curtain cannot be adequately sized); • If fractured rock is extensive, this may limit level of effectiveness.
Overall Protection of HH&E	This alternative would be protective of HH&E by reducing the impact of the Pit Lake on the North Tributary. It would reduce the impact of the waste rock through both the addition amendments and diversion of groundwater migrating through the waste rock thus reducing acid generation. This alternative would reduce and possibly eliminate the discharge of contaminates to the North Tributary through the seeps.
Compliance with ARARs	This alternative is expected to achieve remedial goals in surface and groundwater discharging into the North Tributary over time. Chemical and Action-specific ARARs would be met.
Long-Term Effectiveness and Permanence	Long-term this alternative should be effective for the Pit Lake but may require longer term O&M due to the possible need for addition amendment applications. Long term effectiveness of capping the pit floor with AquaBlok® should be effective as suggested by the treatability study conducted by Sovereign.
Reduction in T/M/V through Treatment	This alternative should show on-site reduction of T/M/V and thereby reducing the same within the North Tributary.
Short-Term Effectiveness	RAOs should be met in the short-term within the Pit Lake. Noise levels from the installation of the pit floor cap are not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented without a great deal of construction difficulty. Remedy can be easily monitored. Numerous vendors have the capability to add amendments to the Pit Lake and capping the pit floor.
NPW Cost	$9,315,700

6.4.2 CMZ-2 - Waste Rock Alternatives

6.4.2.1 Waste Rock #1: No Action

Alternative: Waste Rock #1	No Action
Criteria	**Analysis**
Description	Baseline alternative. Five-year reviews of the remedial action would be required.
Advantages	Low cost, no site disruption.
Disadvantages	• Site would remain in current condition, no additive protection of HH&E • The potential for ingestion or direct contact with contaminated media would remain. No improvement to the North Tributary expected.

Alternative: Waste Rock #1	No Action
Criteria	**Analysis**
Overall Protection of Human Health and Environment (HH&E)	The No Action alternative is not anticipated to be protective of HH&E in the short term or near (less than 30 years) long term. This alternative does not reliably eliminate exposure pathways or reduce the level of risk of the existing media contamination.
Compliance with ARARs	This alternative will not achieve the RAOs or chemical-specific ARARs established for the Site. Location- and action-specific ARARs do not apply to this alternative since remedial actions will not be conducted.
Long-Term Effectiveness and Permanence	Long-term effectiveness is deemed poor as the Site has not demonstrated a marginal restoration rate for natural attenuation.
T/M/V through Treatment	This remedy does nothing to reduce the T/M/V of COCs. The source area can be expected to marginally expand in volume without treatment, thus continuing the current conditions.
Short-Term Effectiveness	This remedy will have no short-term impacts on the community or workers as there is no remedial action. RAOs are not expected to be met with this alternative.
Implementability	The No Action alternative is easily implemented.
NPW Cost	$91,100

6.4.2.2 Waste Rock #2: Excavation of Capped Waste Rock, On-Site Encapsulation, Backfill, and Cap

Alternative: Waste Rock #2	Excavation of Capped, On-Site Disposal and Encapsulation, Backfill Excavation, and Cap
Criteria	**Analysis**
Description	The capped waste rock material would be excavated and properly disposed and encapsulated on-site. Excavated area would be backfilled with clean fill and capped.
Advantages	• Removes the acid generating source material (waste rock) from impacting the Pit Lake and groundwater; • Excavation of waste rock is a common, easily implementable technology; • Relatively low long-term O&M costs.
Disadvantages	• Will require adequate space for on-site disposal area; • Will require long-term institutional controls to maintain integrity of encapsulated water rock; • Encapsulated waste rock will require long-term O&M to maintain its integrity.
Overall Protection of HH&E	This alternative would be protective of HH&E by eliminating the impact of capped waste rock through removal. This alternative would reduce and possibly eliminate the discharge of contaminated groundwater to the Pit Lake and to the North Tributary through the seeps.
Compliance with ARARs	This alternative is expected to help achieve remedial goals in surface and groundwater discharging into the Pit Lake and North Tributary over time. Chemical and Action-specific ARARs would be met.
Long-Term Effectiveness and Permanence	Long-term this alternative would remove the major source of acid generation within OU1. This should improve the water quality within the Pit Lake and groundwater.
Reduction in T/M/V through Treatment	This alternative should show on-site reduction of T/M/V and thereby reducing the same within the North Tributary.

Alternative: Waste Rock #2	Excavation of Capped, On-Site Disposal and Encapsulation, Backfill Excavation, and Cap
Criteria	**Analysis**
Short-Term Effectiveness	RAOs should be met in the short-term within the waste rock area. Noise levels from the excavation activities are not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented without a great deal of construction difficulty. Remedy can be easily monitored.
NPW Cost	$14,584,300

6.4.2.3 Waste Rock #3: Amendments to Waste Rock and Enhancement of Existing Cap

Alternative: Waste Rock #3	Amendments to Waste Rock, and Enhancement of Existing Cap
Criteria	**Analysis**
Description	Amendments would be added to the waste rock to reduce acid production. The existing cap over the waste rock would be enhanced to insure completed coverage and low permeability.
Advantages	• Addition of amendments to the capped waste rock should reduce or eliminate acid production; • Enhancement of the existing cap should reduce or eliminate surface water infiltration into the waste rock.
Disadvantages	• Amendments added to the waste rock is an uncommon technology at other mine sites; • May require pilot testing to insure technology will be effective on-site; • Number and sizing of waste rock treatments is unknown (e.g., amendment quantities and application rates); may require some O&M costs; • Distribution of amendments to waste rock above the saturated zone would be difficult to control.
Overall Protection of HH&E	This alternative would be protective of HH&E by reducing the impact of the Pit Lake on the North Tributary. It would reduce the impact of the waste rock through both the addition amendments and the in-situ treatment of groundwater migrating through the waste rock and out of the Pit Lake. This alternative would reduce and possibly eliminate the discharge of contaminates to the North Tributary through the seeps and over the pit spillway.
Compliance with ARARs	This alternative is expected to achieve remedial goals in surface and groundwater discharging into the North Tributary over time. Chemical and Action-specific ARARs would be met.
Long-Term Effectiveness and Permanence	Long term effectiveness of the amendments to the waste rock are unknown at this time but the treatability study conducted by Sovereign suggests that it should be effective. The enhancement of existing caps should be effective long-term.
Reduction in T/M/V through Treatment	This alternative should show on-site reduction of T/M/V and thereby reducing the same within the North Tributary.
Short-Term Effectiveness	RAOs should be met in the short-term within the waste rock. Noise levels from the implementation of amendments to the waste rock and the enhancement of the existing caps are not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented without a great deal of construction difficulty. Remedy can be easily monitored. Numerous vendors have the capability

Alternative: Waste Rock #3	Amendments to Waste Rock, and Enhancement of Existing Cap
Criteria	**Analysis**
	enhancing the existing caps. More specialized vendors would need to be employed to add amendments to the waste rock.
NPW Cost	$4,479,700

6.4.3 CMZ-3 - OU1 Groundwater Alternatives

6.4.3.1 OU1 Groundwater #1: No Action

Alternative: Groundwater #1	No Action
Criteria	**Analysis**
Description	Baseline alternative. Five-year reviews of the remedial action would be required.
Advantages	Low cost, no site disruption.
Disadvantages	• Site would remain in current condition, no additive protection of HH&E • The potential for ingestion or direct contact with contaminated media would remain. No improvement to the North Tributary expected.
Overall Protection of Human Health and Environment (HH&E)	The No Action alternative is not anticipated to be protective of HH&E in the short term or near (less than 30 years) long term. This alternative does not reliably eliminate exposure pathways or reduce the level of risk of the existing media contamination.
Compliance with ARARs	This alternative will not achieve the RAOs or chemical-specific ARARs established for the Site. Location- and action-specific ARARs do not apply to this alternative since remedial actions will not be conducted.
Long-Term Effectiveness and Permanence	Long-term effectiveness is deemed poor as the Site has not demonstrated a marginal restoration rate for natural attenuation.
T/M/V through Treatment	This remedy does nothing to reduce the T/M/V of COCs. The source area can be expected to marginally expand in volume without treatment, thus continuing the current conditions.
Short-Term Effectiveness	This remedy will have no short-term impacts on the community or workers as there is no remedial action. RAOs are not expected to be met with this alternative.
Implementability	The No Action alternative is easily implemented.
NPW Cost	$122,200

6.4.3.2 OU1 Groundwater #2A: Groundwater Diversion and Dewatering of Capped Waste Rock

Alternative: Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock – Barrier Wall
Criteria	**Analysis**
Description	A barrier wall within the regolith and grout curtain within the bedrock would be installed upgradient of the waste rock area to divert groundwater away from the waste rock. A series of extraction wells would be installed with the saturated zone of the capped waste rock. Groundwater within the capped waste rock would be removed and pumped into the Pit Lake for treatment as part of the Pit Lake alternative.

Alternative: Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock – Barrier Wall
Criteria	**Analysis**
Advantages	• Groundwater diversion by installation of a barrier wall and possible pressure grouting of fracture zones would reduce the infiltration of groundwater through the waste rock thereby reducing contaminated groundwater inflow into the pit; • Technical resources are available to design and implement grout curtain or similar technology; • Dewatering of the capped waste rock would further reduce groundwater discharge into the Pit Lake and possibly into the North Tributary through existing seeps; • Low long-term O&M costs.
Disadvantages	• Groundwater diversion may not be able to divert significant groundwater volumes away from the waste rock area (e.g., if grout curtain cannot be adequately sized); • Recharge of groundwater within the capped waste rock may occur if groundwater diversion is unsuccessful; • If fractured rock is extensive, this may limit level of effectiveness.
Overall Protection of HH&E	This alternative would be protective of HH&E by reducing the flow of groundwater through the waste rock area. Dewatering the waste rock area could possibly reduce the discharge of contaminates to the North Tributary through the seeps.
Compliance with ARARs	This alternative is expected to achieve remedial goals in surface and groundwater discharging into the North Tributary over time.
Long-Term Effectiveness and Permanence	The grout curtain should be quite effective long-term.
Reduction in T/M/V through Treatment	Over time this alternative should show on-site reduction of T/M/V by reducing the amount of groundwater flowing through the waste rock and thereby reducing the same within the North Tributary.
Short-Term Effectiveness	Noise levels from the construction of the grout curtain and the dewatering activities are not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented without a great deal of construction difficulty. Remedy can be easily monitored. More specialized vendors would need to be employed to construct the grout curtain.
NPW Cost	$7,506,800

6.4.3.3 OU1 Groundwater #2B: Groundwater Diversion and Dewatering of Capped Waste Rock

Alternative: Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock – Hydraulic Barrier
Criteria	**Analysis**
Description	A hydraulic barrier would be created upgradient of the waste rock area to reduce or prevent groundwater from migrating into the waste rock. A series of extraction wells would be installed the upper end of the capped waste rock area and pumped to create the barrier. Extracted groundwater would be pumped into the Pit Lake or infiltration ponds. Groundwater within the capped waste rock would be removed and pumped into the Pit Lake for treatment as part of the Pit Lake alternative.
Advantages	• Groundwater diversion by installation of a hydraulic barrier would reduce the infiltration of groundwater through the waste rock thereby reducing contaminated groundwater inflow into the pit; • Technical resources are available to design and implement a hydraulic barrier;

Alternative: Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock – Hydraulic Barrier
Criteria	**Analysis**
	• Dewatering of the capped waste rock would further reduce groundwater discharge into the Pit Lake and possibly into the North Tributary through existing seeps.
Disadvantages	• Groundwater extraction as part of the hydraulic barrier may not be able to divert significant groundwater volumes away from the waste rock area; • Recharge of groundwater within the capped waste rock may occur if groundwater diversion is unsuccessful; • Groundwater extracted at the barrier may require treatment prior to discharge; • Potentially impacted groundwater from Waste Area C may migrate to the extraction wells due to long-term pumping required to maintain the hydraulic barrier; • High Long-term O&M costs.
Overall Protection of HH&E	This alternative would be protective of HH&E by reducing the flow of groundwater through the waste rock area. Dewatering the waste rock area could possibly reduce the discharge of contaminates to the North Tributary through the seeps.
Compliance with ARARs	Over time this alternative would aid in achieving remedial goals in surface and groundwater discharging into the North Tributary over time.
Long-Term Effectiveness and Permanence	The hydraulic barrier should be quite effective long-term if properly maintained.
Reduction in T/M/V through Treatment	Over time this alternative should show on-site reduction of T/M/V by reducing the amount of groundwater flowing through the waste rock and thereby reducing the same within the North Tributary.
Short-Term Effectiveness	Noise levels from the construction of the hydraulic barrier and the dewatering activities are not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented without a great deal of construction difficulty. Remedy can be easily monitored.
NPW Cost	$3,521,100

6.4.3.4 OU1 Groundwater #3: In-Situ Treatment of Groundwater

Alternative: Groundwater #3	Add Alkalinity to Groundwater
Criteria	**Analysis**
Description	The addition of alkalinity (NaOH or similar compounds) into the capped waste rock area directly or into the groundwater flowing through the capped waste rock should reduce acid generation. Carbon such as methanol could also be injected to spur microbial activity.
Advantages	• The addition of alkalinity to groundwater should substantially reduce acid generation from the waste rock; • The effectiveness of adding neutralizing compound to acidic media is well documented; • The technical capability to deliver amendments to groundwater has been demonstrated; • Low long-term O&M costs.
Disadvantages	• The number and spacing of groundwater injection wells is unknown; • Adding alkalinity to the groundwater would require an alkalinity injection system for repeated amendment events, resulting in relatively high capital costs and O&M expenditures.

Alternative: Groundwater #3	Add Alkalinity to Groundwater
Criteria	**Analysis**
Overall Protection of HH&E	This alternative would be protective of HH&E by reducing the impact by groundwater on the Pit Lake on the North Tributary. This alternative would reduce the discharge of contaminates to the North Tributary through the seeps.
Compliance with ARARs	This alternative is expected to achieve remedial goals in pit water and groundwater discharging into the North Tributary over time.
Long-Term Effectiveness and Permanence	Long-term this alternative should be effective for the groundwater within the waste rock. Long term effectiveness of the amendments to the waste rock are unknown at this time but the treatability study conducted by Sovereign suggests that it should be effective.
Reduction in T/M/V through Treatment	This alternative should show on-site reduction of T/M/V and thereby reducing the same within the North Tributary.
Short-Term Effectiveness	RAOs should be met in the short-term within the groundwater. Noise levels from the installation and operation of injection wells is not anticipated to impact nearby properties. Engineering controls will minimize and prevent community or worker exposure.
Implementability	Remedy can be implemented without a great deal of construction difficulty. Remedy can be easily monitored. Numerous vendors have the capability to install and operate injection wells.
NPW Cost	$6,721,000

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7.0 Comparative Analysis of Alternatives

This section evaluates Alternatives for the three areas within OU1 (the Pit Lake, the capped waste rock, and OU1 groundwater). This analysis examines both the threshold and balancing evaluation criteria. The objective of this Section is to compare and contrast the remedial alternatives so that risk managers may select a preferred alternative. The relative rankings for these alternatives were subjectively determined based upon their concurrence with the detailed criteria requirements.

Tables 7-1 through 7-3 summarize the subjectively derived quantitative comparison analysis for remedial alternatives for the Pit Lake, capped waste rock, and OU1 groundwater respectively. Each of the six primary threshold/balancing criteria (excluding cost) were subdivided into the sub-criteria which help define it. These sub-criteria were developed in the CERCLA FS guidance (Section 6.2, EPA, 1988) for each criterion. Each group of sub-criteria was individually evaluated and given a subjective ranking of 'poor, 'fair', 'average', 'good', or 'very good' against the context of the Site RAOs. Following the ranking, these subjective rankings were converted to numeric rankings (for example, 'poor' is equal to "1"). In cases where a criterion has one or more sub-criteria, numeric scores assigned to the sub-criteria were averaged and the average score was assigned to the primary criterion. A higher score indicates better success or effectiveness at attaining the criterion's stated objective than a smaller score.

7.1 CMZ-1 - PIT LAKE REMEDIAL ALTERNATIVES

The following sections break down the perceived comparative order of each alternative developed for the Pit Lake with respect to each of the six threshold and balancing criteria. The comparative analysis for these remedial alternatives is summarized in Table 7-1. The qualitative relative rankings for these alternatives were subjectively determined based upon their concurrence with the sub-criteria.

7.1.1 Overall Protection of Human Health and the Environment

All of the alternatives, with exception of Pit Lake #1, No Action, scored average or above for protection of HH&E. All three active alternatives Pit Lake #2 (Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit), Pit Lake #3 (Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland), and Pit Lake #4 (Treat/Neutralize Pit Lake in place, Cap Pit Floor) were tied for the highest ranking. The following order reflects the qualitative relative ranking for this criterion. The qualitative relative rankings for these alternatives were subjectively determined based upon their concurrence with the detailed criteria requirements.

Pit Lake - Overall Protection of Human Health and the Environment

Order	Alternative #	Alternative Name	Relative Score
1	Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit	4.00
2	Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	4.00
3	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	4.00
4	Pit Lake #1	No Action	1.00

7.1.2 Compliance with ARARs

Compliance with ARARs can oftentimes be a challenging criterion to evaluate because of the number and multiple types of ARARs that can apply to a site. The most important ARAR for the detailed analyses was chemical-specific. In general, chemical-specific ARARs can be met most effectively by reducing

contaminant mass from a site (by treatment or by removal). In particular, the ability of a remedial alternative to meet the target cleanup level(s) for the COCs is important. Alternatives Pit Lake #2, Pit Lake #3, and Pit Lake #4 all received a score of 4.00 and are expected to have the successes at reducing the mass and concentration of contaminants in the Pit Lake.

Action-specific ARARs are expected to be primarily procedural and/or regulatory (for example dust control, emissions control, and injection control permits) and should be easily attainable. The action-specific ARARs provided little differentiation between the alternatives.

The following table reflects the order of the subjective and qualitative relative ranking for this criterion.

Pit Lake - Compliance with ARARs

Order	Alternative #	Alternative Name	Relative Score
1	Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit	4.00
2	Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	4.00
3	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	4.00
4	Pit Lake #1	No Action	1.00

7.1.3 Long-Term Effectiveness and Permanence

The Long-Term Effectiveness and Permanence criterion has particular importance for the Pit Lake remediation due to the RAO of preventing continued impact to OU3, specifically the North Tributary. Thus, aggressive and comprehensive technologies can be expected to provide better assurance of long-term effectiveness and permanence. The likelihood of the three active alternatives to meet performance specifications in the near term is high. The following order reflects the qualitative relative ranking for this criterion.

Pit Lake - Long-Term Effectiveness and Permanence

Order	Alternative #	Alternative Name	Relative Score
1	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	3.83
2	Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit	3.50
3	Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	3.50
4	Pit Lake #1	No Action	1.00

7.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternatives Pit Lake #3 and Pit Lake #4 offer the best reduction of the mass, volume, and concentration of COCs by directly addressing the Pit Lake and indirectly addressing groundwater in OU1. Pit Lake #2 only addresses the Pit Lake water. The following order reflects the qualitative relative ranking for this criterion.

Pit Lake - Reduction of Toxicity, Mobility, and Volume through Treatment

Order	Alternative #	Alternative Name	Relative Score
1	Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	4.10
2	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	4.10
3	Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit	3.80

		Floor, Backfill Pit	
4	Pit Lake #1	No Action	1.00

7.1.5 Short-Term Effectiveness

The short-term effectiveness of remedial alternatives considers how well HH&E is protected in the community or potential site workers, the projected environmental impacts, and the time to achieve RAOs during implementation. The effectiveness of remedy at ensuring short-term protection during implementation of a RA depends on the procedure and safeguards used by the remediation contractor. The No Action alternative and Pit Lake #4 were ranked the highest. No Action as it is the fastest and safest to implement. Pit Lake #4 was alongside No Action because it should have the smallest impact on the community and construction workers and has a relatively short implementation timeframe (one year). No Action will not be effective in the shout-term with respect to protecting wildlife drinking from the Pit Lake. The remaining alternatives should also have minimal impacts, but have longer projected timeframes. The following order reflects the qualitative relative ranking for this criterion.

Pit Lake - Short-Term Effectiveness

Order	Alternative #	Alternative Name	Relative Score
1	Pit Lake #1	No Action	4.00
2	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	4.00
3	Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit	3.88
4	Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	3.88

7.1.6 Implementability

Implementing remedial alternatives involves design, planning, construction or installation, and operational components of remedial actions. The overall reliability and operational flexibility is also considered in this criterion. The efficiency with which an alternative can be installed and operated impacts how well an alternative achieves its level of protection (the first threshold criterion) and attains ARARs (the second threshold criterion). In some cases, implementation of the alternative could be technically difficult or impossible given site-specific limitations. The No Action Site-wide alternative is the simplest alternative to implement.

All three active alternatives are considered to have good implementability. Alternative Pit Lake #4 was the most reliable for meeting the ARARs. Pit Lake #2 and Pit Lake #3 alternatives will involve extensive earthmoving efforts.

Pit Lake - Implementability

Order	Alternative #	Alternative Name	Relative Score
1	Pit Lake #1	No Action	4.50
2	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	4.14
3	Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit	3.86
4	Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	3.86

7.1.7 Cost

Cost is considered in both a comparative analysis and again as part of an overall cost-effectiveness evaluation for the prospective remedies. No Action involves the lowest cost while Pit Lake #2 is the highest. The following order reflects the quantitative ranking for this criterion from lowest to highest cost.

Pit Lake - Cost

Order	Alternative #	Alternative Name	Cost
1	Pit Lake #1	No Action	$94,200
2	Pit Lake #4	Amendments to Pit Lake, Cap Pit Floor	$9,315,700
3	Pit Lake #3	Drain Lake, Treat, Discharge, Amendments to Pit Floor, Wetland	$14,550,000
4	Pit Lake #2	Drain Lake, Treat, Discharge, Amendments to Pit Floor, Backfill	$17,778,500

7.2 CMZ-2 - WASTE ROCK REMEDIAL ALTERNATIVES

The following sections break down the perceived comparative order of each alternative developed for the waste rock with respect to each of the six threshold and balancing criteria. The comparative analysis for these remedial alternatives is summarized in Table 7-2. The qualitative relative rankings for these alternatives were subjectively determined based upon their concurrence with the sub-criteria.

7.2.1 Overall Protection of Human Health and the Environment

All of the alternatives, with exception of Waste Rock #1, No Action, scored average or above for protection of HH&E. Alternatives Waste Rock #2 (Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap) and Waste Rock #3 (Amendments to Waste Rock, Enhance Existing Cap) were tied with the highest ranking for relative overall protection of HH&E. The following order reflects the qualitative relative ranking for this criterion. The qualitative relative rankings for these alternatives were subjectively determined based upon their concurrence with the detailed criteria requirements.

Waste Rock - Overall Protection of Human Health and the Environment

Order	Alternative #	Alternative Name	Relative Score
1	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	4.50
2	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	4.50
3	Waste Rock #1	No Action	1.00

7.2.2 Compliance with ARARs

Compliance with ARARs can oftentimes be a challenging criterion to evaluate because of the number and multiple types of ARARs that can apply to a site. The most important ARAR for the detailed analyses was chemical-specific. In general, chemical-specific ARARs can be met most effectively by reducing contaminant mass from a site (by treatment or by removal). In particular, the ability of a remedial alternative to meet the target cleanup level(s) for the COCs is important. The two active waste rock alternatives (Waste Rock #2 and Waste Rock #3) both are projected to be aggressive treatment alternatives and are expected to have the most comprehensive successes at reducing the mass and concentration of contaminants, within a relatively short timeframe.

Action-specific ARARs are expected to be primarily procedural and/or regulatory (for example dust control, emissions control, and injection control permits) and should be easily attainable. The action-specific ARARs provided little differentiation between the alternatives.

The following order reflects the fairly subjective and qualitative relative ranking for this criterion.

Waste Rock - Compliance with ARARs

Order	Alternative #	Alternative Name	Relative Score
1	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	4.00
2	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	4.00
3	Waste Rock #1	No Action	1.00

7.2.3 Long-Term Effectiveness and Permanence

This criterion has particular importance for OU1 remediation due to the RAO of preventing continued impact to OU3, specifically the North Tributary. Thus, aggressive and comprehensive technologies can be expected to provide better assurance of long-term effectiveness and permanence. Alternatives that physically remove contaminants from the Site media and address the long-term impact of the waste rock provide the most protection for the longest period, which Waste Rock #2 remedial alternative offers. The likelihood of this alternative to meet performance specifications in the near term is high. The following order reflects the qualitative relative ranking for this criterion.

Waste Rock - Long-Term Effectiveness and Permanence

Order	Alternative #	Alternative Name	Relative Score
1	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	4.00
2	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	3.83
3	Waste Rock #1	No Action	1.00

7.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative Waste Rock #3 offers the best reduction of the mass, volume, and concentration of COCs. The following order reflects the qualitative relative ranking for this criterion.

Waste Rock - Reduction of Toxicity, Mobility, and Volume through Treatment

Order	Alternative #	Alternative Name	Relative Score
1	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	3.90
2	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	3.30
3	Waste Rock #1	No Action	1.00

7.2.5 Short-Term Effectiveness

The short-term effectiveness of remedial alternatives considers how well HH&E is protected in the community or potential site workers, the projected environmental impacts, and the time to achieve RAOs during implementation. The effectiveness of remedy at ensuring short-term protection during implementation of a RA depends on the procedure and safeguards used by the remediation contractor. The No Action alternative and Waste Rock #3 were ranked the highest. Waste Rock #3 was ranked high alongside No Action because it should have the smallest impact on the community and construction workers, has minimal environmental impacts and has a relatively short implementation timeframe. No Action was ranked as the fastest and safest to implement. The following order reflects the qualitative relative ranking for this criterion.

Waste Rock - Short-Term Effectiveness

Order	Alternative #	Alternative Name	Relative Score
1	Waste Rock #1	No Action	4.00
2	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	4.00
3	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	3.75

7.2.6 Implementability

Implementing remedial alternatives involves design, planning, construction or installation, and operational components of remedial actions. The overall reliability and operational flexibility is also considered in this criterion. The efficiency with which an alternative can be installed and operated impacts how well an alternative achieves its level of protection (the first threshold criterion) and attains ARARs (the second threshold criterion). In some cases, implementation of the alternative could be technically difficult or impossible given site-specific limitations. The No Action Site-wide alternative is the simplest alternative to implement.

The two active alternatives are considered to have good implementability. Waste Rock #2 will involve extensive earthmoving efforts.

Waste Rock - Implementability

Order	Alternative #	Alternative Name	Relative Score
1	Waste Rock #1	No Action	4.50
2	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	3.93
3	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	3.93

7.2.7 Cost

Cost is considered in both a comparative analysis and again as part of an overall cost-effectiveness evaluation for the prospective remedies. The following order reflects the quantitative ranking for this criterion from lowest to highest cost.

Waste Rock - Cost

Order	Alternative #	Alternative Name	Cost
1	Waste Rock #1	No Action	$91,000
2	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Caps	$4,479,700
3	Waste Rock #4	Excavate and On-site Encapsulation, Backfill Excavation	$14,584,300

7.3 CMZ-3 - OU1 GROUNDWATER REMEDIAL ALTERNATIVES

The following sections break down the perceived comparative order of each alternative developed for the OU1 groundwater with respect to each of the six threshold and balancing criteria. The comparative analysis for these remedial alternatives is summarized in Table 7-3. The qualitative relative rankings for these alternatives were subjectively determined based upon their concurrence with the sub-criteria.

7.3.1 Overall Protection of Human Health and the Environment

All of the alternatives, with exception of Groundwater #1, No Action, scored average or above for protection of HH&E. Alternatives Groundwater #2A (Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain) and Groundwater #3 (Groundwater In-Situ Neutralization) were tied with the highest ranking for relative overall protection of HH&E as they offer a more complete reduction of COCs. The following order reflects the qualitative relative ranking for this criterion. The qualitative relative rankings for these alternatives were subjectively determined based upon their concurrence with the detailed criteria requirements.

OU1 Groundwater - Overall Protection of Human Health and the Environment

Order	Alternative #	Alternative Name	Relative Score
1	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain	4.50
2	Groundwater #3	Groundwater In-Situ Neutralization	4.50
3	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Hydraulic Barrier	4.00
4	Waste Rock #1	No Action	1.00

7.3.2 Compliance with ARARs

Compliance with ARARs is a challenging criterion to evaluate because of the number and multiple types of ARARs that can apply to a site. The most important ARAR for the detailed analyses was chemical-specific. In general, chemical-specific ARARs can be met most effectively by reducing contaminant mass from a site (by treatment or by removal). In particular, the ability of a remedial alternative to meet the target cleanup level(s) for the COCs is important. Alternative Groundwater #3 is projected to be the most aggressive treatment alternative and expected to have the most comprehensive successes at reducing the mass and concentration of contaminants, and should do so in a short timeframe. Alternatives Groundwater #2A and Groundwater #2B followed closely in second.

Action-specific ARARs are expected to be primarily procedural and/or regulatory (for example dust control, emissions control, and injection control permits) and should be easily attainable. The action-specific ARARs provided little differentiation between the alternatives.

The following order reflects the fairly subjective and qualitative relative ranking for this criterion.

OU1 Groundwater - Compliance with ARARs

Order	Alternative #	Alternative Name	Relative Score
1	Groundwater #3	Groundwater In-Situ Neutralization	4.00
2	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring - Barrier Wall and Grout Curtain	3.75
3	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring - Hydraulic Barrier	3.75
4	Waste Rock #1	No Action	1.00

7.3.3 Long-Term Effectiveness and Permanence

This criterion has particular importance for OU1 remediation due to the RAO of preventing continued impact to OU3, specifically the North Tributary. Thus, aggressive and comprehensive technologies can be expected to provide better assurance of long-term effectiveness and permanence, which Groundwater #2A, Groundwater #2B, and Groundwater #3 remedial alternatives offer. The following order reflects the qualitative relative ranking for this criterion.

OU1 Groundwater - Long-Term Effectiveness and Permanence

Order	Alternative #	Alternative Name	Relative Score
1	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain	4.17
2	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring - Hydraulic Barrier	3.67
3	Groundwater #3	Groundwater In-Situ Neutralization	3.5
4	Waste Rock #1	No Action	1.00

7.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative Groundwater #3 offers the best reduction of the mass, volume, and concentration of COCs by directly addressing groundwater by in-situ treatment. Groundwater #2A diverts groundwater away from the waste rock area and then removes impacted water which is pumped into the Pit Lake. The following order reflects the qualitative relative ranking for this criterion.

OU1 Groundwater - Reduction of Toxicity, Mobility, and Volume through Treatment

Order	Alternative #	Alternative Name	Relative Score
1	Groundwater #3	Groundwater In-Situ Neutralization	4.10
2	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain	3.90
3	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Hydraulic Barrier	3.70
4	Waste Rock #1	No Action	1.00

7.3.5 Short-Term Effectiveness

The short-term effectiveness of remedial alternatives considers how well HH&E is protected in the community or potential site workers, the projected environmental impacts, and the time to achieve RAOs during implementation. The effectiveness of remedy at ensuring short-term protection during implementation of a RA depends on the procedure and safeguards used by the remediation contractor. Groundwater #2A, Groundwater #2B, and Groundwater #3 ranked highest. Groundwater #2A, and Groundwater #2B do not reduce, in the short-term, the impact of wildlife drinking from the pit water (RAO 1). The following order reflects the qualitative relative ranking for this criterion.

OU1 Groundwater - Short-Term Effectiveness

Order	Alternative #	Alternative Name	Relative Score
1	Groundwater #3	Groundwater In-Situ Neutralization	4.00
2	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain	4.00
3	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Hydraulic Barrier	4.00
4	Groundwater #1	No Action	3.00

7.3.6 Implementability

Implementing remedial alternatives involves design, planning, construction or installation, and operational components of remedial actions. The overall reliability and operational flexibility is also considered in this criterion. The efficiency with which an alternative can be installed and operated impacts how well an alternative achieves its level of protection (the first threshold criterion) and attains ARARs (the second threshold criterion). In some cases, implementation of the alternative could be technically difficult or impossible given site-specific limitations. The No Action Site-wide alternative is the simplest alternative to implement.

The three active alternatives are considered to have good implementability.

OU1 Groundwater - Implementability

Order	Alternative #	Alternative Name	Relative Score
1	Groundwater #1	No Action	4.50
2	Groundwater #3	Groundwater In-Situ Neutralization	4.00
3	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain	3.86
4	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Hydraulic Barrier	3.86

7.3.7 Cost

Cost is considered in both a comparative analysis and again as part of an overall cost-effectiveness evaluation for the prospective remedies. The following order reflects the quantitative ranking for this criterion from lowest to highest cost.

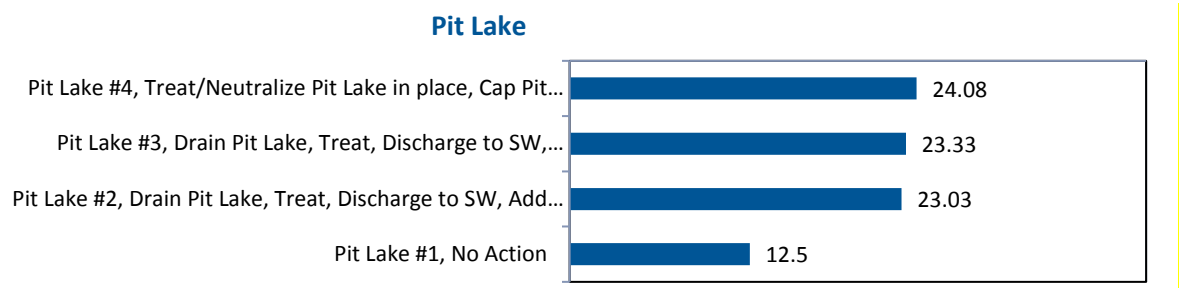
OU1 Groundwater - Cost

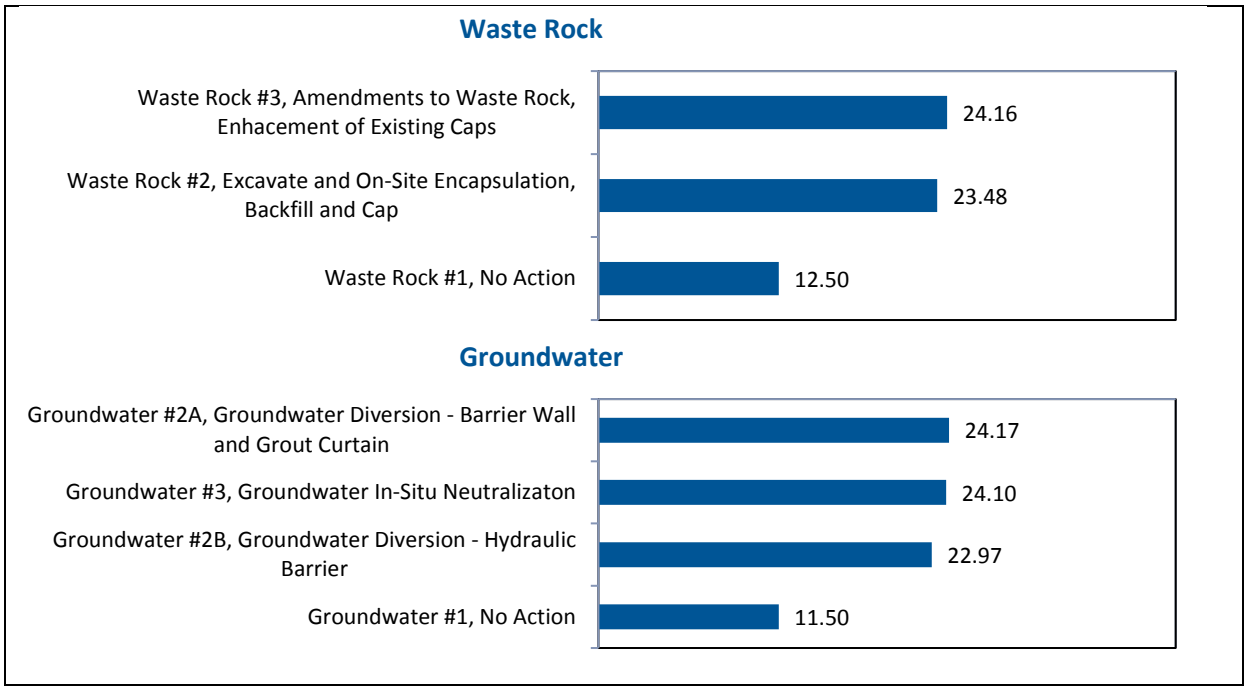
Order	Alternative #	Alternative Name	Cost
1	Groundwater #1	No Action	$122,200
2	Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Hydraulic Barrier	$3,521,100
3	Groundwater #3	Groundwater In-Situ Neutralization	$6,721,000
4	Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring – Barrier Wall and Grout Curtain	$7,506,800

7.4 SUMMARY OF THE QUANTITATIVE COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The results of the quantitative comparison of alternatives are summarized in Tables 7-1 to 7-3 for the Pit Lake, the Capped Waste Rock, and OU1 Groundwater and the overall rankings are illustrated below. These graphs plot the sum of the scores for the two threshold criteria and four of the five balancing criteria (excludes cost) as presented in the previous sections. Overall, the rankings are very similar as each of the retained remedial options has relative merits for specific criteria.

Summary of Quantitative Comparison of Alternatives (Excluding Cost)





7.5 COST EFFECTIVENESS ANALYSIS

Cost is a critical factor in the process of identifying a preferred remedy. CERCLA and the NCP require that every remedy selected must be cost-effective. A remedial alternative is cost-effective if its "costs are proportional to its overall effectiveness." An estimate of the overall effectiveness of a remedial alternative is provided by the summary of quantitative analysis presented in Section 7.4.

A comparison of overall effectiveness to cost determines whether a remedy is expected to be cost-effective. A cost-effectiveness ratio for each alternative is derived by calculating the ratio of the quantitative criteria score to the NPW cost expressed in millions of dollars. The most cost-effective alternatives will provide the higher ratio (i.e., a high total composite score over a low cost).

The cost estimates for the remedial alternatives for are summarized in Appendix C. For the alternatives evaluated for this Site, the ratio of combined effectiveness to cost (in millions of dollars) is shown below. The effectiveness to cost ratio should not be strictly interpreted as it is an over-simplified indicator. That is, a higher ratio does not necessarily indicate that a given alternative should be deemed the most favorable remedy. For every alternative, the evaluation of overall effectiveness, timeliness, implementability, and other factors must be considered.

Alternatives Effectiveness/Cost Rating Summary

Rank	Alternative #	Description	Composite Effectiveness Ranking[1]	Total NPW ($M)	Effectiveness / Cost Ratio[2]
Pit Lake					
1	Pit Lake #4	Treat/Neutralize Pit Lake in place, Cap Pit Floor	24.08	$9.3	**2.59**
2	Pit Lake #3	Drain, Treat, Discharge to SW; Amendments/Cap Pit Floor, Partial Backfill, Create Wetland	23.03	$14.5	1.58
3	Pit Lake #4	Drain, Treat, Discharge to SW; Amendments/Cap Pit Floor, Backfill	23.33	$17.7	1.32
4	Pit Lake #1	No Action	12.50	$0.072	173.6
Waste Rock					
1	Waste Rock #3	Amendments to Waste Rock, Enhance Existing Cap	24.16	$4.4	**5.49**
2	Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	23.48	$14.6	1.60
3	Waste Rock #1	No Action	12.50	$0.09	138.9
Groundwater					
1	Groundwater #2B	Groundwater Diversion (Hydraulic Barrier)	22.97	$3.5	**6.56**
2	Groundwater #3	Groundwater In-Situ Neutralization	24.10	$6.7	3.59
3	Groundwater #2A	Groundwater Diversion (Barrier Wall and Grout Curtain)	24.17	$7.5	3.22
4	Groundwater #1	No Action	11.5	$0.122	94.2

Notes: 1 Six threshold/balancing criteria excluding cost;
2 Composite effectiveness/cost (NPW in $Millions); value in bold considered most favorable ratio(s)

Alternative Pit Lake #4 has the highest Effectiveness/Cost ratio of the action alternatives for the Pit Lake (2.60). The effectiveness of this alternative rests on the ability of the amendments to raise the pH within the Pit Lake. The effectiveness also rests upon the ability of the cap to adequately seal the pit floor. Alternatives Pit Lake #2 and #3 have lower rankings due to the substantial earthwork that is required to backfill the pit.

Alternative Waste Rock #3 has the highest Effectiveness/Cost ratio of the action alternatives for the capped waste rock. The effectiveness of this alternative rests upon the ability to get the amendments into contact with the waste rock. The second active alternative has a lower ranking due in part the substantial earthwork that is required to excavate and backfill the waste rock area.

Alternative Groundwater #2B has the highest Effectiveness/Cost ratio of the action alternatives. The effectiveness of this alternative relies on the assumption that pumping clean groundwater from upgradient of the waste rock will prevent migration of groundwater into the waste rock. Groundwater #3 is ranked only slightly higher than #2B. The effectiveness of this alternative is dependent upon getting

amendments into groundwater throughout the waste rock area. Alternative #2A has the lowest ranking due to substantial earthwork.

7.5.1 Cost Sensitivity Analysis

There could be substantial overlap in the remedial alternative cost estimates and qualitative cost effectiveness if cost ranges and process variations are considered. A sensitivity analysis was prepared to assess the effect that variations in specific assumptions associated with the design basis, implementation, operation, discount rate, and effective life of the remedy can have on the estimated cost. Typically, the time to achieve cleanup goals is the largest variable. Additionally, the volume of mass to treat and ability of the selected remedy to make contact with that mass are also factors that could significantly impact the costs. Specific to the Barite Hill Site, several deductions relative to cost sensitivity can be developed:

The size of waste water treatment system for Pit Lake drainage is based on literature values, removal percentages achieved at similar sites, and professional experience. Recharge to the Pit Lake from groundwater and storm water runoff may impact the volume of water to be treated and the time to complete the drainage of the Pit Lake.

Treatability studies to identify cost effective options for the grout curtain, barrier wall, and in-situ treatment of groundwater have not been conducted. Changes in substrate composition could affect the cost to construct these systems.

Based on the available data the hydrogeologic characteristics of the capped waste rock are not fully understood. Additional testing to determine such characteristics as hydraulic conductivity, porosity, and permeability may be needed. This will impact the design of any treatment system for the waste rock and groundwater within the waste rock area.

- Costs will not be sensitive to issues with buildings, utilities, or other infrastructure as all facility buildings in OU1 have been demolished and removed.

Labor, material and equipment costs, including the cost of energy and chemicals are not expected to vary significantly within the next five years.

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8.0 Recommended Alternative

The selection of an appropriate waste management strategy is determined solely through the remedy selection process outlined in the NCP (i.e., all remedy selection decisions are site-specific and must be based on a comparative analysis of the alternatives using the nine criteria in accordance with the NCP). Selected remedies must be protective, ARAR-compliant, cost-effective, and use permanent solutions or treatment to the maximum extent practicable. The Recommended Alternative for the Site as a whole is a synergistic combination of the alternatives assembled for each media zone. Given the similarity in many of the rankings, and the subjective nature of these rankings, there are several possible combinations that are advantageous for the Site. The analysis of the cost-effectiveness ratio provides the clearest tool for deciphering the relative merits of the remedial cost and overall acceptability per the CERCLA criteria.

The most favorable remedial alternatives have been evaluated for their overall compatibility so that the zone-specific remedies make sense when combined as a whole for the Site. The Recommended Alternative for OU1 is presented below.

Recommended Alternatives

Zone	Alternative #	Alternative Name	Zone Only Cost	Combined Cost
CMZ-1	Pit Lake #4	Amendments to Pit Lake, Cap Pit Floor	$9,915,700	
CMZ-2	Waste Rock #3	Amendments to Waste Rock	$4,479,700	
CMZ-3	Groundwater #2A	Groundwater Diversion – Barrier Wall and Curtain.	$7,506,800	
			Total:	$21,902,200

8.1 CMZ-1 (PIT LAKE) RECOMMENDED ALTERNATIVE: PIT LAKE #4 – AMENDMENTS TO PIT LAKE, CAP PIT FLOOR

This alternative is recommended to address CMZ-1, the acidic and metals laden water in the Pit Lake along with the submerged acid-generating waste rock within the Pit Lake (Figure 5-3). The proposed amendments (hydrated lime slurry, organic materials and agricultural lime) that will be added to the lake are expected to raise the pH of the lake in both the short and long term resulting in the dissolved metals precipitating out of solution and depositing on the pit floor. The pit floor would subsequently be capped with an impermeable material (AquaBlok® and/or a sodium bentonite/clay soil mixture). This cap is expected to seal off the submerged waste rock from the waters of the Pit Lake aiding in raising the pH and preventing groundwater from discharging into the Pit Lake. It will also reduce or prevent lake water from escaping through the lake bottom into the underlying regolith and fractured bedrock, thus reducing or eliminating the source of seeps to the North Tributary. This alternative is expected to be relatively easy to implement and should produce results in the Pit Lake within a short time frame (less than a year). The implementation of this remedy is not expected to negatively impact surround properties.

8.2 CMZ-2 (CAPPED WASTE ROCK) RECOMMENDED ALTERNATIVE: WASTE ROCK #3 – AMENDMENTS TO THE WASTE ROCK, ENHANCE EXISTING CAPS

This recommended alternative will address CMZ-2 (Figures 5-5a through 5-5d). It will involve injecting either 1) sodium lauryl sulfate buffered with sodium bicarbonate or 2) milk buffered with sodium bicarbonate into the capped waste rock. The amendments will be injected across the 6.6 acre waste rock area through a series of both shallow and deeper wells, primarily targeting both the transition zone and groundwater saturated zones. Sodium lauryl sulfate was shown in the Tier 1 treatability study to work

better within the unsaturated zone of the waste rock area, but the beneficial effects in treating the unsaturated zone (at significant additional costs) seem marginal.

The treatability study showed that milk works more effectively within both the transition zone and the saturated zone. The treatability study demonstrated that these amendments were effective at suppressing *ATBFO* within the waste rock. This will result in the reduction of acid generation. With the reduction of acid generation there would be a reduction in the concentration of metals within the groundwater migrating through the waste rock into the Pit Lake and/or the seeps along the North Tributary. This alternative should be relatively easy to implement, although additional laboratory treatability studies should be conducted during the Remedial Design to optimize the dosing and application approach for the amendments. The implementation of this remedy should have no impact upon the surround properties. The treatability study is included in Appendix B.

8.3 CMZ-3 (OU1 GROUNDWATER) RECOMMENDED ALTERNATIVE: GROUNDWATER #2A – GROUNDWATER DIVERSION – BARRIER WALL AND GROUT CURTAIN

The recommended alternative for CMZ-3 is a barrier wall/grout curtain (Figure 5-6a). This alternative will consist of an approximate 600-foot long barrier wall installed to the top of bedrock (~70 ft bls) along the southern edge (hydraulically upgradient) of the capped waste rock. The grout curtain would extend from the top of bedrock down to a total depth of 160 feet bls. It would consist of the installation of two grout boring lines offset 10 ft from the proposed centerline of the barrier wall. The barrier wall and grout curtain is expected to prevent or significantly reduce the flow of groundwater into and through the buried waste rock, which in turn will eliminate or reduce the volume of acidic groundwater entering the Pit Lake. Although this alternative does not directly treat the groundwater, it is expected to prevent or significantly reduces contact with clean groundwater currently migrating into the waste rock. The continued migration of groundwater through the waste rock that would generate an on-going contaminated groundwater issue.

An option to dewater the waste rock after construction of the barrier wall and grout curtain would consist of a series of extraction wells installed within the waste rock area. Extracted groundwater would be pumped into the Pit Lake where it would be subjected to the recommended alternative for CMZ-1. This would further reduce the amount of groundwater in contact with the waste rock and discharging into the seeps near the North Tributary.

Although not addressing groundwater directly this alternative also recommends the installation of passive open limestone channels (OLC) at the Pit Lake spillway and at areas where storm water runoff enters the Pit Lake. These would be considered as a passive ex situ treatment of water discharging from the Pit Lake at times of full pool. Flow across the spillway would be diverted into a pipe and conveyed to an OLC which is a lined channel constructed of cobble or gravel-sized limestone rock. In addition, channels where storm water discharges into the Pit Lake would be lined with limestone to help add alkalinity to the Pit Lake to aid in raising the pH with in its waters.

This alternative is considered implementable but has some potential for challenges, especially with the grout curtain installation. Design investigation borings will be needed along the proposed barrier wall and grout curtain alignment, along with hydraulic testing to better characterize the bedrock fracture orientation and architecture. Hydraulic testing during implementation of the grout curtain will also be important to confirm design criteria and goals have been achieved. Experienced contractors in this specialty field will be necessary. Regardless, implementation is estimated to take less than one year. The

impact upon groundwater will be gradual, depending upon the seepage velocity of groundwater within OU1. The implementation of this remedy is not expected to have an impact upon the surrounding properties.

8.4 PROJECTED REMEDY PHASING

The preferred alternatives that are proposed to address the Pit Lake, the capped waste rock, and groundwater contamination are anticipated to be implemented in a phased-approach. This approach involves addressing the contamination identified within a specific CMZ before implementing the remedial action of another CMZ. This phased-approach creates an adequate opportunity to evaluate the effectiveness of each remedy component and to determine the needs of the next phase.

The recommended phasing for the overall remedy is as follows:

Proposed Remedial Phasing

Phase	Task Description	Action
I	Site preparation	Grub and fence the facility.
II	Install the Barrier Wall, Grout Curtain, and OLC	Install borings for the grout curtain. Inject grout for the bedrock grout curtain. Install the barrier wall. Install the OLC at the pit spillway and storm water drainage channels.
III	Amendments to the Capped Waste Rock	Install both shallow and deeper injection wells within the capped waste rock. Inject milk and sodium bicarbonate into the waste rock area wells. Enhance the existing caps over the waste rock. If determined to be warranted, install extraction wells within the waste rock and dewater.
IV	Amendments to the Pit Lake, Cap Pit Floor	Add amendments to the Pit Lake. Allow for metals to settle out. Install cap over the pit floor.
VI	Monitoring and FYR	Evaluate remedial progress and make recommendations for both OU1 and OU3.

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9.0 References

Black & Veatch, 2015. Black & Veatch Special Projects Corp. Remedial Investigation Report, Revision 1, Barite Hill / Nevada Goldfields Site OU3, McCormick County, South Carolina. January, 2015.

Black & Veatch, 2016. Black & Veatch Special Projects Corp. Baseline Ecological Risk Assessment for OU3, Barite Hill / Nevada Goldfields Site, McCormick County, South Carolina. 2016

Black & Veatch, 2017. Black & Veatch Special Projects Corp. Baseline Ecological Risk Assessment for OU1, Barite Hill / Nevada Goldfields Site, McCormick County, South Carolina. April, 2017

Black & Veatch, 2018. Black & Veatch Special Projects Corp. Remedial Investigation Report, Revision 1, Barite Hill / Nevada Goldfields Site OU1, McCormick County, South Carolina. May 2018.

Castendyk, D.N., 2009. Conceptual Models of Pit Lakes. In: Devin N. Castendyk and L. Edmond Eary (eds.), Mine Pit Lakes Characteristics, Predictive Modeling, and Sustainability, Management Technologies for Metal Mining Influenced Water, Volume 3, Society for Mining, Metallurgy, and Exploration, Littleton, CO, pp. 61-76.

Clark, et al., 1999a. Clark, S.H.B., Gray, K.J., and Back, J.M., 1999. Geology of the Barite Hill Gold-Silver Deposit in the Southern Carolina Slate Belt. *Economic Geolog*y, vol. 94, pp. 1329-1346. 1999.

Clark, et al., 1999b. Clark, S.H.B., Gray, K.J., and Back, J.M., *Geologic Maps and Block Diagrams of the Barite Hill Gold-Silver Deposit and Vicinity, South Carolina and Georgia*. U.S. Geological Survey Open-File Report 99-148A. 1999.

EPA, 1988. U.S. Environmental Protection Agency, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*. Office of Emergency and Remedial Response. EPA/540/G-89/004. October 1988.

EPA, 1989. U.S. Environmental Protection Agency. Risk Assessment Guidance for Superfund (RAGS): Volume I – Human Health Evaluation Manual (Part A), Interim Final. Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002. December 1989.

EPA, 1996. U.S. Environmental Protection Agency, Soil Screening Guidance: Technical Background Document, Office of Emergency Response: Washington, DC, EPA/540/R-95/128 PB96-963502, May 1996.

EPA, 2007. U.S. Environmental Protection Agency, Request for a Removal Action Ceiling Increase and an Exemption from the 12-Month and $2 Million Statutory Limits at the Barite Hill Mine Site, McCormick, McCormick County, South Carolina. Action Memorandum from Leo Francendese (On-Scene Coordinator) thru Shane Hitchcock (Chief, Emergency Response & Removal Branch) to Franklin Hill (Director, Superfund Division). September 19, 2007.

EPA. 2008. U.S. Environmental Protection Agency, Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites. EPA 542/R-08/002.

EPA, 2012. U.S. Environmental Protection Agency, *Aerial Photographic Analyses of Barite Hill/Nevada Goldfields Site, McCormick, South Carolina, Volumes 1 and 2*. Center of Environmental Computing, Office of Technology Operations & Planning, Office of Environmental Information, TS-OEI-21104013S. July, 2012.

GEL Geophysics LLC, 2011. Electrical Resistivity Imaging, Barite Hill Gold Mine, McCormick County, South Carolina. September, 2011.

Gobla, M., 2007. Site Features Inventory Report, Barite Hill Mine, McCormick, South Carolina. U.S. Bureau of Reclamation, Technical Service Center. July, 2007.

Harrington et al., 2009. Harrington, J., Gobla, M., Francendese, L., and Bates, E., Low Cost Treatment of a Highly Contaminated Pit Lake Using Innovative Technology, Barite Hill Mine, McCormick, SC. Unpublished manuscript. 2009.

NCP. 1994. Title 40 Code of Federal Regulations Part. 300, [59 FR 47473], National Contingency Plan Sept. 15.

Nevada Goldfields, Inc., 1993. Final Mine Plan for Barite Hill Project. Letter report from Richard Dye, Nevada Goldfields to Craig Kennedy, Mining and Reclamation Division, South Carolina Land Resources Conservation Commission. August 27, 1993.

Nevada Goldfields, Inc., 1995. Controlled Discharge of Process Solution to Main Pit. Letter report from Scott A. Wilkinson to Craig Kennedy, Bureau of Solid & Hazardous Waste, South Carolina Department of Health and Environmental Control. January 19, 1995.

Oneida Total Integrated Enterprises (OTIE), 2010 (December 23). Final Letter Report, Barite Hills Nevada Goldfields Site, McCormick, McCormick County, South Carolina. Prepared by Russell Henderson (OTIE) for Leo Francendese (EPA Region 4 On Scene Coordinator). OTIE Technical Direction Document (TDD) No.: TNA-05-003-0049.

Pardee, J.T. and Park, C.F., Jr., 1948. Gold Deposits of the Southern Piedmont. U.S. Geological Survey (USGS) Professional Paper 213, 156 pp.

SCDHEC, 1998. South Carolina Department of Health and Environmental Control, *Nevada Goldfields, Inc./Barite Hill Project*, Consent Order #98-049-W, McCormick County. Letter from Anthony R. Hatton (Bureau of Water) to Scott A. Wilkinson (Nevada Goldfields) with attachments. June 12, 1998.

SCDHEC, 2006. South Carolina Department of Health and Environmental Control, *Preliminary Assessment/Site Inspection, Barite Hills/Nevada Goldfields, McCormick County*, SCD 987 597 903. Prepared by Site Assessment Section, Bureau of Land & Waste Management. December 15, 2006.

SCDHEC, 2007. South Carolina Department of Health and Environmental Control, *Barite Hills/Nevada Goldfields – Main Pit Water pH*. Memorandum from Timothy Kadar, SC Bureau of Land and Waste Management to Leo Francendese, U.S. EPA Region 4. July 5, 2007.

SCDHEC, 2014a. South Carolina Department of Health and Environmental Control. South Carolina Regulation 61-68 Water Classifications and Standards. Bureau of Water. June 2014.

SCDHEC, 2014b. South Carolina Department of Health and Environmental Control. South Carolina Regulation 61-58. State Primary Drinking Water. Bureau of Water. September 2014.

Tetra Tech, 2007. Final Preliminary Scoring Strategy, Barite Hills Nevada Goldfields, McCormick, McCormick County, South Carolina. Prepared for EPA, Region 4. June 4, 2007.

U.S. Bureau of Reclamation, 2007. Streamlined Remedy Assessment, Barite Hill Pit, Barite Hill Mine, McCormick, South Carolina. Prepared for EPA Region 4. September 14, 2007.

U.S. Bureau of Reclamation, 2008. Waste rock cap map

Willowstick Technologies, LLC (Willowstick®), 2017. Willowstick Investigation of Barite Hill Mine, McCormick County, South Carolina: Identify, Map and Model Preferential Groundwater Flowpaths Infiltrating and Escaping the Main Pit Lake. Prepared for Black & Veatch, February 28, 2017.

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Tables

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Table 1-1
Summary of the Operational and Regulatory History of the Barite Hill Mine
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Date	Event	Reference
1852	Gold discovered in the Lincolnton-McCormick mining district	Clark et al. (1999)
Unknown, prob. Mid to late 1800s	At least 2 shafts and unknown underground workings constructed at Barite Hill	Clark et al. (1999)
1966	Exploration for gold and silver by Tennessee Copper Company	Padgett and Watkins (1988) cited in Clark et al. (1999)
1975-1977	Exploration for base metals by Conoco and Phelps Dodge	Padgett and Watkins (1988) cited in Clark et al. (1999)
1979	Drilling for barite by Dresser Industries	Padgett and Watkins (1988) cited in Clark et al. (1999)
1983-1988	Exploration for precious metals by Goldfields Mining Corp. and Amselco/BP	Clark et al. (1999)
1988	Property purchased for development by Gwalia (USA) Ltd.	Clark et al. (1999)
1991	Mining begins	South Carolina Department of Health & Environmental Control (SCDHEC, 2006)
1991	Sons of Gwalia buys controlling interest in Consolidated Nevada Goldfields Company; mine operation turned over to Nevada Goldfields, Inc.	Clark et al. (1999)
Jun. 1991	Leaks in cells 1, 2 and 3 of asphalt liner of reusable leach pad repaired by Gwalia (USA) Ltd.	DP Engineering (1991b)
Aug. 1991	Leak reported in cell 4 of asphalt liner of reusable leach pad	SCDHEC (1991b)
Jul. 1993	Nevada Goldfields issued a Notice of Violation for exceedances of permitted effluent limits at Outfalls 001 and 003 from October 1992 to June 1993	SCDHEC (1993b)
Oct. 1994	Mining completed	Clark et al. (1999); SC CHEC (1998)
Nov. 1994	Reclamation begins	SCDHEC (1998)
Jun. 1998	SCDHEC and Nevada Goldfields enter into a Consent Order for violations of effluent limits at NPDES outfalls 001, 01A, and 003.	SC DHEC (1998)
Jun. 1999	Nevada Goldfields Inc. files for Chapter 11 bankruptcy	SCDHEC (2006)
Jul. 1999	SCDHEC assumes control of the Site	SCDHEC (2006)
1999	Lake begins to form within the Barite Hill pit	SCDHEC (2006)
2004	SCDHEC collects samples of surface water and sediment from solution ponds and tributaries to Hawe Creek in support of a Preliminary Assessment/Site Investigation (PA/SI).	SCDHEC (2006)
2007	U.S. Environmental Protection Agency (EPA) finalizes an Action Memo to initiate a Time Critical Removal Action to treat pit lake water, cover waste materials, and construct an emergency spillway	EPA (2007)
Apr. 2009	Barite Hill site is added to the National Priorities List (NPL)	EPA (2014)
2010	EPA initiates a Remedial Investigation (RI) of the Barite Hill Site	

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Table 1-2
Amendments Added to the Pit Lake
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

	Initial Treatment Feb to May 2008	July 1 & 20, 2009	July 13-15, 2010	August 17-18, 2012	April 18-20, 2016
Hydrated Carbide Lime	1,860 tons				
Sodium Hydroxide	23 tons	4,000 gal 50% 8,000 gal 50%	3,500 gal 50%	4,000 gal 25%	45,700 pounds
Methanol	21 tons			5,000 gal	
Molasses Blends	~400 tons				
Wood Chips	1,300 tons				
Post-Amendment pH	5.5	5 8.7	6.25	6.7	4.7 - 9.8

Notes:
gal - gallon
pH - hydrogen ion concentration

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Table 3-1
Potential Chemical-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action/Media	Requirements	Prerequisite	Citation(s)
Protection of surface water	Freshwaters (FW) are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.	Surface waters classified as Class FW (fresh waters) – **relevant and appropriate**	SC R. 61-68.G.10
	Quality Standards for FW: b. No treated wastes, toxic wastes, deleterious substances, colored or other wastes, alone or in combination with other substances or wastes, in sufficient amounts to make the waters unsafe or unsuitable for primary contact recreation or to impair the waters for any other best usage as determined for the specific waters which are assigned to this class. c. Toxic pollutants listed in the *Appendix* [in SC R. 61-68] must meet the standards as prescribed in Section E of this regulation.		SC R. 61-68.G.10.b and c
	All ground waters and surface waters of the State shall at all times, regardless of flow, be free from: (d) High temperature, toxic, corrosive, or deleterious substances attributable to sewage, industrial waste, or other waste in concentrations or combinations which interfere with classified water uses, existing water uses, or which are harmful to human, animal, plant or aquatic life.		SC R. 61-68.E.5(d)
	Numeric criteria for the protection and maintenance of all classes of surface waters are adopted and are listed in Sections E, G, and the *Appendix*. b. Application of numeric criteria to protect human health. (1) If separate numeric criteria are given for organism consumption, water and organism consumption (W/O), and drinking water Maximum Contaminant Levels (MCLs), they shall be applied as appropriate. The *most stringent* of the criteria *shall be applied* to protect the existing and classified uses of the waters of the State.		SC R. 61-68.E.14.b.
	Numerical water quality standards (maximum permissible levels): - Cadmium = 5 µg/L (MCL) - Copper = 1300 µg/L (W/O)		SC R. 61-68. *Appendix:* Water Quality Criteria for Protection of Aquatic Life and Human Health

Table 3-1
Potential Chemical-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action/Media	Requirements	Prerequisite	Citation(s)
Protection of Surface Water *(discharges of pit water in spillway overflow event)*	Any discharge into waters of the State must be permitted by the Department and receive a degree of treatment and/or control which shall produce an effluent which is consistent with the Act, the Clean Water Act (P.L. 92-500, 95-217, 97-117, 100-4), this regulation, and related regulations. *Note:* Under CERCLA Section 121(e) permits are not required for on-site response actions. Instead discharges must meet any applicable effluent limits or other substantive requirements to protect the water quality of the receiving water.	Discharge of pollutants (including toxic substances) into waters of the State– **relevant and appropriate**	SCDHEC R. 61-68E.4.a

Table 3-2
Potential Location-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
Location encompassing aquatic ecosystem as defined in 40 *CFR* 230.3(c)	Except as provided under CWA §404(b)(2), no discharge of dredged or fill material is permitted if there is a practicable alternative that would have less adverse impact on the aquatic ecosystem or if it will cause or contribute to significant degradation of the waters of the United States.	Actions that involves discharge of dredged or fill material into *waters of the United States* including jurisdictional wetlands – **relevant and appropriate**	40 *CFR* 230.10(a) and (c)
	Except as provided under CWA §404(b)(2), no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem. 40 CFR 230.70 et seq. identifies such possible steps.		40 CFR 230.10(d)
Nationwide Permit Program	Must comply with the substantive requirements of the NWP 38, General Conditions, as appropriate.	Discharge of dredged or fill material into *waters of the United States*, including jurisdictional wetlands – **relevant and appropriate**	Nationwide Permit (38) – Cleanup of Hazardous and Toxic Waste 33 *CFR* 323.3(b)
Presence of wetlands	Requires Federal agencies to evaluate action to minimize the destruction, loss or degradation of wetlands and to preserve and enhance beneficial values of wetlands.	Actions that involve potential impacts to, or take place within, wetlands – **TBC**	Executive Order 11990 – *Protection of Wetlands* - Section 1(a)
Presence of floodplains	Shall consider alternatives to avoid, to the extent possible adverse effects and incompatible development in the floodplain.	Federal actions that involve potential impacts to, or take place within, floodplains –**TBC**	Executive Order 11988 – *Floodplain Management* Section 2. (a)(2)

Notes:
ARAR = applicable or relevant and appropriate requirement
CWA = Clean Water Act
CFR = *Code of Federal Regulations*
EPA = U.S. Environmental Protection Agency
SCDHEC = South Carolina Department of Health and Environmental Control
TBC = to be considered

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Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
General Construction Standards — All Land-disturbing Activities (i.e., excavation, clearing, grading, etc.)			
Managing storm water runoff from land-disturbing activities	Must comply with the substantive requirements for stormwater management and sediment control of *NPDES Construction General (CG) Permit for Stormwater Discharges No. SCR100000, issued under R.122.8 and developed consistent with the conditions in R.61-9.122.41 applicable to all permits*.	Large and small construction activities (as defined in R. 61-9 and SCR100000) of more than 1 acre of land – **applicable**	SCDHEC R. 61-9.122.41 and 122.28(a)(2)(i)
	Coverage under the CG Permit requires development of a stormwater management and sediment control plan which is to be consistent, at a minimum, to the substantive standards listed in SC Regulation 72-300, unless specifically exempted by SC Regulation 72-302.A	Large and small construction activities (as defined in R. 61-9 and SCR100000) of more than 1 acre of land – **TBC**	*NPDES Construction General (CG) Permit for Stormwater Discharges*, Permit No. SCR100000
	The stormwater management and sediment control plan shall contain at a minimum the information provided in the following subsections: • A plan for temporary and permanent vegetative and structural erosion and sediment control measures which specify the erosion and sediment control measures to be used during all phases of the land disturbing activity and a description of their proposed operation; • Provisions for stormwater runoff control during the land disturbing activity and during the life of the facility meeting the peak discharge rate and velocities requirements in subsections (e)1. and (e)2. of this section.	Activities involving more than two (2) acres and less than five (5) acres of actual land disturbance which are not part of a larger common plan of development or sale – **applicable**	SCDHEC R. 72-307I(3)(d) and (e) – *South Carolina Storm Water Management and Sediment Reduction Regulations*
Managing fugitive dust emissions from land disturbing activities	Emissions of fugitive particulate matter shall be controlled in such a manner and to the degree that it does not create an undesirable level of air pollution. Volatile organic compounds shall not be used for dust control purposes. Oil treatment is also prohibited.	Activities that will generate fugitive particulate matter (Statewide) –**applicable**	SCDHEC R. 61-62.6 Section III(a)- *Control of Fugitive Particulate Matter Statewide* SCDHEC R. 61-62.6 Section III(d)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Underground Injection Well - Installation, Operation and Abandonment			
Injection of fluids, solids, or mixtures into subsurface *(e.g. in situ groundwater treatment)*	No owner or operator shall construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation under 40 *CFR* Part 142 or may otherwise adversely affect the health of persons.	Underground injection into an underground source of drinking water –**applicable**.	40 CFR 144.12(a)
	The movement of fluids containing wastes or contaminants into underground sources of drinking water as a result of injection is prohibited if the presence of the waste or contaminant: • May cause a violation of any drinking water standard under R61-58.5; or, • May otherwise adversely affect the health of persons. As defined in R.61-87.2: ''Fluid'' means material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state. ''Well'' means any excavation which is cored, bored, drilled, jetted, dug, or otherwise constructed the depth of which is greater than its largest surface dimension; or, a dug hole whose depth is greater than the largest surface dimension; or, an improved sinkhole; or, a subsurface fluid distribution system.	Underground injection of any fluids into the subsurface or ground waters of the State of South Carolina – **applicable**.	SCDHEC R.61-87.5(A) and (B)
	No person shall construct, use or operate a Class V.A. well for injection in violation of R61-87.5. R.61-87.11(E)(1) - Class V.A. injection wells include: (g) Injection wells used in experimental technologies	Class V.A injection wells [as classified in R.61-87.11(E)(1)] – **applicable**	SCDHEC R.61-87.11(E)(2)(b)
Operation of underground injection wells	At a minimum, the following information concerning the injection formation shall be determined or calculated: (1) Fluid pressure; (2) Estimated fracture pressure; (3) Physical and chemical characteristics of the injection zone.	Operation of Class V.A. wells, [as classified in R.61-87.11(E)(1)] – **applicable**	SCDHEC R.61-87.14(D)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
	Shall at all times properly operate and maintain all facilities and systems of treatment and controls which are installed or used.		SCDHEC R.61-87.13(X)
	Shall report malfunction of injection system which may cause fluid migration into or between underground sources of drinking water; shall immediately stop injection upon determination that the injection system has malfunctioned and could cause fluid migration into or between underground sources of drinking water; shall not restart the injection system until the malfunction has been corrected.		SCDHEC R.61-87.13(EE)
Monitoring of underground injection wells	An appropriate number of monitoring wells shall be completed into the injection zone and into any underground sources of drinking water which could be affected by the injection operation. These wells shall be located in such a fashion as to detect any excursion of injection fluids, process by-products, or formation fluids outside the injection area or zone. If the operation may be affected by subsidence or catastrophic collapse the monitoring wells shall be located so that they will not be physically affected.	Monitoring of Class V.A. wells, [as classified in R.61-87.11(E)(1)]– **applicable**	SCDHEC R.61-87.14(G)(1)
Closure of Class V underground injections wells	Wells must be closed in a manner that complies with the prohibition of fluid movement in 40 CFR 144.82(a)(l). Also, any soil, gravel, sludge, liquids, or other materials removed from or adjacent to the well must be disposed or otherwise managed in accordance with substantive applicable Federal, State, and local regulations and requirements.	Closure of Class V wells [as defined in 40 CFR 144.6(e)] **– applicable**	40 CFR 144.82(b)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Monitoring Well Installation, Operation, and Abandonment			
Installation of Permanent and Temporary Monitoring Wells	All monitoring wells shall be drilled, constructed, maintained, operated, and/or abandoned to ensure that underground sources of drinking water are not contaminated.	Construction of permanent and temporary monitoring wells, as defined in R. 61-71B – **applicable**	SCDHEC R. 61-71H.1(b)
Installation of Permanent Conventionally Installed or Direct Push Monitoring Wells	Wells shall be grouted from the top of the bentonite seal to the land surface. Grout is to be composed of neat cement, a bentonite cement mixture, or high solids sodium bentonite grout.	Construction of permanent conventionally installed or direct push monitoring wells, as defined in R. 61-71B – **applicable**	SCDHEC R. 61-71H.2.a.(1),(2) *[conventionally installed wells]* SCDHEC R. 61-71H.3.b.(1),(2) *[direct push wells]*
	The diameter of the annular space shall be large enough to allow for forced injection of grout through a tremie pipe. All grouting shall be accomplished using forced injection to emplace the grout. When emplacing the grouting material, the tremie pipe shall be lowered to the bottom of the zone to be grouted. The tremie pipe shall be kept full continuously from start to finish of the grouting procedure, with the discharge end of the tremie pipe being continuously submerged in the grout until the zone to be grouted is completely filled.		SCDHEC R. 61-71H.2.a.(3),(4) *[conventionally installed wells]* SCDHEC R. 61-71H.3.b.(3),(4) *[direct push wells]*
	A cement or aggregate reinforced concrete pad at the ground surface of appropriate durability and strength, considering the setting and location of each well, that extends six inches beyond the borehole diameter and six inches below ground surface is required. The pad shall be capable of preventing infiltration between the surface casing and the borehole to the subsurface.		SCDHEC R. 61-71H.2.a.(5) *[conventionally installed wells]* SCDHEC R. 61-71H.3.b.(5) *[direct push wells]*

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Installation of Permanent Conventionally Installed or Direct Push Monitoring Wells (cont'd)	Well Construction and Materials Standards – (1) Casing shall be of sufficient strength to withstand normal forces encountered during and after well installation and be composed of material so as to minimally affect water quality analyses. (2) Casing shall have a sufficient diameter to provide access for sampling equipment. (3) A properly hydrated bentonite seal with a minimum thickness of twelve inches directly above the filter pack shall be used, if the well has a filter pack. (4) The monitoring well intake or screen design shall minimize formational materials from entering the well. The filter pack 17 shall be utilized opposite the well screen as appropriate in so that parameter analyses will be minimally affected. (5) A locking cap or other security devices to prevent damage and/or vandalism shall be used. (6) Monitoring wells completed below grade shall be in a watertight vault with a well cap to prevent infiltration of surface water into the well.	Construction of permanent conventionally installed or direct push monitoring wells, as defined in R. 61-71B – **applicable**	SCDHEC R. 61-71H.2.b. *[conventionally installed wells]* SCDHEC R. 61-71H.3.c *[direct push wells]*
	All monitoring wells shall be properly labeled with an identification plate immediately upon well completion. The identification plate shall be constructed of a durable, weatherproof, rustproof, material. The identification plate shall be permanently secured to the well casing or enclosure floor around the casing where it is readily visible and shall identify: (1) company name and certification number of the driller who installed the well; (2) date well was completed; (3) total depth (feet); (4) casing depth (feet); (5) screened Interval; (6) designator and/or identification number.		R. 61-71H.2.c. *[conventionally installed wells]* SCDHEC R. 61-71H.3.d *[direct push wells]*
Additional Requirements for Installation of Direct Push Monitoring Wells	Direct push wells cannot be installed below a confining layer unless it can be demonstrated to the satisfaction of the Department that cross-contamination of the aquifer systems can be prevented.	Construction of direct push monitoring wells, as defined in R. 61-71B – **applicable**	R. 61-71H.3.a.

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Installation of *Temporary* Monitoring Wells	Construction and Materials – (1) Casing shall be of sufficient strength to withstand normal forces encountered during and after well installation and be 20 composed of material so as to minimally affect water quality analyses. (2) Casing shall have a sufficient diameter to provide access for sampling equipment. (3) The monitoring well intake or screen design shall minimize formational materials from entering the well. The filter pack or intake shall be utilized opposite the well screen as appropriate so that parameter analyses will be minimally affected.	Construction of *temporary* monitoring wells, as defined in R. 61-71B – **applicable**	SCDHEC R. 61-71H.4.a.
	All temporary monitoring wells shall be sealed with a watertight cap or seal until abandoned. Temporary monitoring wells shall be maintained such that they are not a source or channel of contamination before they are abandoned.	Operation and maintenance of *temporary* monitoring wells, as defined in R. 61-71B – **applicable**	SCDHEC R. 61-71H.4.b.
Abandonment of *Permanent Conventionally Installed* Monitoring Wells	Abandonment of permanent conventionally installed monitoring wells shall be by forced injection of grout or pouring through a tremie pipe starting at the bottom of the well and proceeding to the surface in one continuous operation. The well shall be filled with either with neat cement, bentonite-cement, or 20% high solids sodium bentonite grout, from the bottom of the well to the land surface.	Abandonment of *permanent conventionally installed* monitoring wells – **applicable**	SCDHEC R. 61-71H.2.e.
Abandonment of *Permanent Direct Push* Monitoring Wells	(1) Permanent direct push wells that do not penetrate a confining layer shall be abandoned by removing all casing from the subsurface and be grouted by forced injection through a tremie pipe from the total depth to the land surface, or by forced injection or pouring of neat cement, bentonite-cement, or 20% high solids sodium bentonite grout through a tremie pipe starting at the bottom of the well and proceeding to the surface. (2) Direct push wells that penetrate a confining layer shall be abandoned by forced injection or pouring of neat cement, bentonite-cement, or 20% high solids sodium bentonite grout through a tremie pipe starting at the bottom of the well and proceeding to the surface in one continuous operation.	Abandonment of *permanent direct push* monitoring wells, as defined in R.61-71B – **applicable**	SCDHEC R. 61-71H.2.f.

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Abandonment of *Temporary* Conventionally Installed or Direct Push Monitoring Wells	(1) All temporary monitoring wells shall be abandoned within 5 days of borehole completion. (2) A conventionally drilled temporary well shall be abandoned by forced injection of neat cement, bentonite-cement, or 20% high solids sodium bentonite grout through a tremie pipe starting at the bottom of the well and proceeding to the surface in one continuous operation. (3) A temporary direct push well that does not penetrate a confining layer shall be abandoned by forced injection of neat cement, bentonite-cement, or 20% high solids sodium bentonite grout through a tremie pipe after the sampling device has been removed. (4) A temporary direct push well that penetrates a confining layer shall be abandoned by forced injection of neat cement, bentonite-cement, or 20% high solids sodium bentonite grout through the sampling device as the sampling device is removed from the sub-surface. Abandonment shall occur during the initial withdrawal from the original push borehole and not by a separate tremie tool after the sampling device has been removed to ensure the breech in the confining layer is permanently sealed.	Abandonment of *temporary* conventionally installed or direct push monitoring wells, as defined in R.61-71B – **applicable**	SCDHEC R. 61-71H.4.c.
Waste Characterization and Storage (e.g., soil cuttings from well installation, monitoring well purgewater, wastewaters)			
Characterization of solid waste	Must determine if solid waste is a hazardous waste using the following method: Should first determine if waste is excluded from regulation under 40 CFR §261.4; and	Generation of solid waste as defined in 40 CFR §261.2 – **applicable**	40 CFR §262.11(a) SCDHEC R. 61-79 §262.11*(a)*
	Must determine if waste is listed as hazardous waste under 40 CFR Part 261.	Generation of solid waste which is not excluded under 40 CFR §261.4(a) –**applicable**	40 CFR §262.11(b) SCDHEC R. 61-79 §262.11*(b)*
	Must determine whether the waste is (characteristic waste) identified in subpart C of 40 CFR Part 261 by either: (1) Testing the waste according to the methods set forth in subpart C of 40 CFR part 261, or according to an equivalent method approved by the Administrator under 40 CFR §260.21; or	Generation of solid waste which is not excluded under 40 CFR §261.4(a) –**applicable**	40 CFR §262.11(c) SCDHEC R. 61-79 §262.11*(c)*

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
	(2) Applying knowledge of the hazard characteristic of the waste in light of the materials or the processes used.		
Determinations for management of hazardous waste	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous waste –**applicable**	40 CFR §262.11(d) SCDHEC R. 61-79 §262.11*(d)*
	Must determine each EPA Hazardous Waste Number (waste code) applicable to the waste in order to determine the applicable treatment standards under 40 CFR 268 *et seq*.. *Note:* This determination may be made concurrently with the hazardous waste determination required in Sec. 262.11 of this chapter.	Generation of hazardous waste for storage, treatment or disposal – **applicable**	40 CFR 268.9(a) SCDHEC R. 61-79 268.9*(a)*
	Must determine the underlying hazardous constituents [as defined in 40 CFR 268.2(i)] in the characteristic waste.	Generation of RCRA characteristic hazardous waste (and is not D001 non-wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal – **applicable**	40 CFR 268.9(a) SCDHEC R. 61-79 268.9*(a)*
	Must determine if the hazardous waste meets the treatment standards in 40 CFR 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods or use of generator knowledge of waste. *Note:* This determination can be made concurrently with the hazardous waste determination required in 40 CFR 262.11.	Generation of hazardous waste for storage, treatment or disposal – **applicable**	40 CFR 268.7(a) SCDHEC R. 61-79 268.7*(a)* (1)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Temporary storage of hazardous waste in containers	A generator may accumulate hazardous waste at the facility provided that: • waste is placed in containers that comply with 40 CFR 265.171-173; and • the date upon which accumulation begins is clearly marked and visible for inspection on each container • container is marked with the words "hazardous waste"; or	Accumulation of RCRA hazardous waste on site as defined in 40 CFR 260.10 – **applicable**	40 CFR 262.34(a)(1) and (2) SCDHEC R. 61-79 262.34*(a)* (1) and (2) 40 CFR 264.34(a)(3) SCDHEC R. 61-79 262.34*(a)* (3)
	• container may be marked with other words that identify the contents.	Accumulation of 55 gal. or less of RCRA hazardous waste or 1 quart of acutely hazardous waste listed in 261.33(e) at or near any point of generation – **applicable**	40 CFR 262.34(c)(1) SCDHEC R. 61-79 262.34*(c)* (1)
Use and management of hazardous waste in containers	If container holding waste is not in good condition (e.g. severe rusting, structural defects), or if it begins to leak, must transfer waste into container in good condition.	Storage of RCRA hazardous waste in containers – **applicable**	40 CFR 265.171 SCDHEC R. 61-79 265.171
	Must use a container made or lined with materials which will not react with, and are otherwise compatible with, the hazardous waste to be stored, so that the ability of the container to contain the waste is not impaired.		40 CFR 265.172 SCDHEC R. 61-79 265.172
	A container holding hazardous waste must always be closed during storage, except when necessary to add or remove waste. A container holding hazardous waste must not be opened, handled, or stored in a manner which may rupture the container or cause it to leak.		40 CFR 265.173(a) and (b) SCDHEC R. 61-79 265.173*(a)* and *(b)*

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Storage of hazardous waste in container area	Area must have a containment system designed and operated in accordance with 40 CFR 265.175(b).	Storage of RCRA hazardous waste in containers ***with free liquids*** – **applicable**	40 CFR 264.175(a) SCDHEC R. 61-79 264.175*(a)*
	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or Containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage of RCRA-hazardous waste in containers that ***do not contain free liquids*** (other than F020, F021, F022, F023, F026 and F027) – **applicable**	40 CFR 265.175(c)(1) and (2) SCDHEC R. 61-79 265.175*(c)* (1) and (2)
Closure of RCRA container storage unit	At closure, all hazardous waste and hazardous waste residues must be removed from the containment system. Remaining containers, liners, bases, and soils containing or contaminated with hazardous waste and hazardous waste residues must be decontaminated or removed.	Storage of RCRA hazardous waste in containers in a unit with a containment system – **applicable**	40 CFR 264.178
Temporary on-site storage of remediation waste in staging piles (*e.g.*, excavated soils, waste rock)	Must be located within the contiguous property under the control of the owner/operator where the wastes are to be managed in the staging pile originated.	Accumulation of non-flowing hazardous remediation waste (or remediation waste otherwise subject to land disposal restrictions) as defined in 40 C.F.R. § 260.10 – **applicable**	40 C.F.R. § 264.554(a)(1)
	May be temporarily stored, (including mixing, sizing, blending or other similar physical operations intended to prepare the wastes for subsequent management or treatment) at a facility if used only during remedial operations provided that the staging pile:		40 C.F.R. § 264.554(a)(1)
	must facilitate a reliable, effective and protective remedy;		40 C.F.R. § 264.554(d)(1)(i)
	must be designed to prevent or minimize releases of hazardous wastes and constituents into the environment, and minimize or adequately control cross-media transfer as necessary to protect human health and the environment (*e.g.*, use of liners, covers, run-off/run-on controls); and		40 C.F.R. § 264.554(d)(1)(ii)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
	• must not operate for more than 2 years, except when an operating term extension under 40 CFR 264.554(i) is granted. *Note:* Must measure the 2-year limit (or other operating term specified) from first time remediation waste placed in staging pile. • Must not use staging pile longer than the length of time designated by EPA in appropriate decision document		40 C.F.R. § 264.554(d)(1)(iii) 40 C.F.R. § 264.554(i)(1)
	Extension of up to an additional 180 days beyond the operating term limit may be granted provided the continued operation of the staging pile: • Will not pose a threat to human health and the environment; and Is necessary to ensure timely and efficient implementation of remedial actions at the facility.		40 CFR 264.554(i)(1)(i) and (ii)
	In setting standards and design criteria, must consider the following factors: • Length of time pile will be in operation; • Volumes of waste you intend to store in the pile; • Physical and chemical characteristics of the wastes to be stored in the unit; • Potential for releases from the unit; • Hydrogeological and other relevant environmental conditions at the facility that may influence the migration of any potential releases; and • Potential for human and environmental exposure to potential releases from the unit.		40 C.F.R. § 264.554(d)(2)(i) –(vi)
Closure of staging piles of remediation waste	Must be closed within 180 days after the operating term by removing or decontaminating all remediation waste, contaminated containment system components, and structures and equipment contaminated with waste and leachate.	Storage of remediation waste in staging pile in *previously contaminated area* – **applicable**	40 C.F.R. §264.554(j)(1)
	Must decontaminate contaminated sub-soils in a manner that EPA determines will protect human and the environment.		40 C.F.R. §264.554(j)(2)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
	Must be closed within 180 days after the operating term according to 40 C.F.R. §§ 264.258(a) and 264.111, or 265.258(a) and 265.111.	Storage of remediation waste in staging pile in *uncontaminated area* – **applicable**	40 C.F.R. §264.554(k)
Waste treatment and disposal - e.g., contaminated soils, wastewaters, monitoring well purge water			
Disposal of solid waste	Shall ultimately dispose of solid waste at facilities and/or sites permitted or registered by the Department for processing or disposal of that waste stream.	Generation of solid waste intended for off-site disposal – **relevant and appropriate**	SCDHEC R. 61-107.5(D)(3)
Land disposal of RCRA-hazardous waste	May be land disposed if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at § 268.40 before land disposal.	Land disposal, as defined in 40 CFR 268.2, of restricted RCRA waste – **applicable**	40 CFR 268.40(a) SCDHEC R. 61-79 §268.40*(a)*
Land disposal of RCRA-hazardous waste	All underlying hazardous constituents (as defined in 268.2(i)) must meet the Universal Treatment Standards, found in § 268.48, Table Universal Treatment Standards, prior to land disposal as defined in § 268.2(c).	Land disposal of restricted RCRA characteristic wastes (D001-D043) that are not managed in a wastewater treatment system that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well – **applicable**	40 CFR 268.40(e) SCDHEC R. 61-79 §268.40*(e)*
	Must be treated according to the alternative treatment standards in 268.49(c) **<u>or</u>** must be treated according to the Universal Treatment Standards (UTS) [specified in 268.48 Table UTS] applicable to the listed and/or characteristic waste contaminating the soil prior to land disposal.	Land disposal, as defined in 40 CFR 268.2, of restricted hazardous soils –**applicable**	40 CFR 268.49(b) SCDHEC R. 61-79 268.49*(b)*
	To determine whether a hazardous waste identified in this section exceeds the applicable treatment standards of 40 CFR 268.40, the initial generator must test a sample of the waste extract or the entire waste, depending on whether the treatment standards are expressed as concentration in the	Land disposal of RCRA toxicity characteristic wastes (D004-D011) that are newly identified (i.e., wastes or soil identified by the TCLP but	40 CFR 268.34(f) SCDHEC R. 61-79 268.34*(f)*

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
	waste extract or waste, or the generator may use knowledge of the waste. If the waste contains constituents (including UHCs in the characteristic wastes) in excess of the applicable UTS levels in 40 CFR 268.48, the waste is prohibited from land disposal, and all requirements of part 268 are applicable, except as otherwise specified.	not the Extraction Procedure) – **applicable**	
Discharge of Wastewater from On-Site Groundwater or Surface Water Treatment Unit			
Disposal of wastewaters into CWA wastewater treatment unit	Wastes that are hazardous only because they exhibit a hazardous characteristic, and which are otherwise prohibited under this part, are not prohibited [from land disposal] if the waste meet any of the following criteria, unless the wastes are subject to a specified method of treatment other than DEACT in §268.40, or are D003 reactive cyanide: (i) The wastes are managed in a treatment system which subsequently discharges to waters of the U.S. pursuant to a permit issued under section 402 of the Clean Water Act [SC R.61-9 and R. 61-68]; or (ii) The wastes are treated for purposes of the pretreatment requirements of section 307 of the Clean Water Act [SC R. 61-9 and R.61-68]; or (iii) The wastes are managed in a zero discharge system engaged in Clean Water Act-equivalent treatment as defined in 268.37(a); and (iv) The wastes no longer exhibit a prohibited characteristic at the point of land disposal (i.e., placement in a surface impoundment).	Restricted RCRA characteristic hazardous wastewaters managed in a wastewater treatment system —**applicable**	40 CFR §268.1(c)(4) SCDHEC R. 61-79 §268.1(c)(4)
Monitoring requirements for discharges from on-site WWTU	To measure compliance with effluent limitations, must monitor, as provided in subsections (i) thru (iv) of 122.44(i)(1). *NOTE: Monitoring parameters, including frequency of sampling, will be developed as part of the CERCLA process and included in a Remedial Design, Remedial Action Work Plan, or other appropriate CERCLA document.*	Discharge of pollutants to surface waters – **applicable**	40 CFR §122.44(i)(1)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Construction of New On-site Waste Rock Disposal Unit			
Landfill closure performance standard	Must close the unit in a manner that: • minimizes the need for further maintenance; and • controls, minimizes, or eliminates to the extent necessary to protect human health and the environment, post–closure escape of hazardous waste, hazardous constituents, leachate, contaminated run–off, or hazardous waste decomposition products to ground or surface waters or to the atmosphere; and complies with the closure requirements of 40 CFR 264.310	Closure of a RCRA hazardous waste management facility – **relevant and appropriate**	40 CFR 264.111(a) thru (c)
Landfill cover design and construction	Must cover the landfill or cell with a final cover designed and constructed to: • provide long–term minimization of migration of liquids through the closed landfill; • function with minimum maintenance; • promote drainage and minimize erosion or abrasion of the cover; • accommodate settling and subsidence so that the cover's integrity is maintained; and • have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	Closure of a RCRA hazardous waste management facility – **relevant and appropriate**	40 CFR 264.310(a)(1) thru (5)
	This document recommends and describes a design for landfill covers that will meet the requirements of RCRA regulations. It is a multilayered system consisting, from the top down, of: • a top layer of at least 60 cm of soil, either vegetated or armored at the surface; • a granular or geosynthetic drainage layer with a hydraulic transmissivity no less than 3 x 10~5 cm /sec; and • a two–component low permeability layer comprised of (1) a flexible membrane liner installed directly on (2) a compacted soil component with an hydraulic conductivity no greater than 1 x 10~7 cm/sec. Optional layers may be added, e.g., a biotic barrier layer or a gas vent layer, depending on the need.	Construction of a RCRA hazardous waste landfill final cover – **TBC**	*EPA Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments,* EPA OSWER 530 – SW –89 – 047 (July 1989)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Action	Requirements	Prerequisite	Citation
Run–on/run-off control systems for closed landfill	Run–*on* control system must be capable of preventing flow onto the active portion of the landfill during peak discharge from a 25–year storm event.	Construction of a RCRA landfill – **relevant and appropriate**	40 CFR 264.301(g)
	Run–*off* management system must be able to collect and control the water volume from a runoff resulting from a 24–hour, 25–year storm event.		40 CFR 264.301(h)
Transportation of Wastes			
Transportation of hazardous waste *on-site*	The generator manifesting requirements of §262.20 and §262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in §§263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on public or private right-of-way within or along the border of contiguous property under control of same person – **applicable**	40 CFR §262.20(f) SCDHEC R. 61-79 §262.20*(f)*
Transportation of samples (i.e. solid waste, soils and wastewaters)	Are not subject to any requirements of 40 CFR Parts 261 through 268 or 270 when: • the sample is being transported to a laboratory for the purpose of testing; or • the sample is being transported back to the sample collector after testing. • the sample is being stored by sample collector before transport to a lab for testing.	Samples of solid waste <u>or</u> a sample of water, soil for purpose of conducting testing to determine its characteristics or composition – **applicable**	40 CFR §261.4(d)(1)(i)-(iii) SCDHEC R. 61-79 §261.4*(d)* (1)
	In order to qualify for the exemption in 40 CFR 261.4 (d)(1)(i) and (ii), a sample collector shipping samples to a laboratory must: • Comply with U.S. DOT, U.S. Postal Service, or any other applicable shipping requirements. • Assure that the information provided in (1) thru (5) of this section accompanies the sample. • Package the sample so that it does not leak, spill, or vaporize from its packaging.		40 CFR 261.4(d)(2) 40 CFR 261.4(d)(2) (ii)(A) and (B) SCDHEC R. 61-79 261.4*(d)* (2)(ii)(A) and (B)

Table 3-3
Potential Action-Specific ARARs
Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

Notes:
Alt = Alternative
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
CWA = Clean Water Act of 1972
DEACT = deactivation
DOT = U.S. Department of Transportation
EPA = U.S. Environmental Protection Agency
LDR = Land Disposal Restrictions
MCL = Maximum Contaminant Level under Safe Drinking Water Act
NPDES = National Pollutant Discharge Elimination System
RCRA = Resource Conservation and Recovery Act of 1976
SCDHEC = South Carolina Department of Health and Environmental Control
TBC = to be considered
TCLP = Toxicity Characteristic Leaching Procedure
UTS = Universal Treatment Standard

Table 3-4
Preliminary Recommended Remedial Goals
Barite Hill/Nevada Goldfields OU1
McCormick County, South Carolina

Ecological Based Remedial Goal			
Chemical of Concern	**Recommended Remedial Goal**		**Basis**
Water Withn the Pit Lake (µg/L)			
Aluminum	86,000		Black & Veatch, 2017
Copper	14,000		EPA Region 4
Iron	30,000		Black & Veatch, 2017
Pit Water Discharging from the Pit Lake into the North Tributary (µg/L)	Acute	Chronic	
Aluminum (pH 6.5 - 9.0)	750	87	EPA, 2006
Iron	-	1,000	EPA, 2006
Cadmium[a]	1.8	0.72	EPA, 2007
Copper[a]	3.8	2.9	SCDHEC, 2014

Human Health Based Remedial Goal		
Chemical of Concern	**Recommended Remedial Goal**	**Basis**
Groundwater Discharging Through Seeps into the North Tributary (µg/L)		
Cadmium	5[1]	SCDHEC, 2014
Cobalt	794	Black & Veatch, 2018
Manganese	50[2]	EPA, 2006
Pit Water Discharging from the Pit Lake into the North Tributary (µg/L)		
Cadmium	5[1]	SCDHEC, 2014
Cobalt	794	Black & Veatch, 2018
Copper	1,300[2]	SCDHEC, 2014

Notes:
Black & Veatch, 2018 - Remedial Investigatinon Report Revision 1, Barite Hill OU1
Black & Veatch, 2018 - Human Health Risk Assessment Revision 1, Barite Hill OU1 (for residential HQ=1)
Black & Veatch, 2017 - Baseline Ecological Risk Assessment Revision 0, Barite Hill OU1
EPA, 2006 - National Recommended Water Quality Criteria for Non Priority Pollutants
EPA Region 4 - Recommended value based on LOAEL of 6.79 and water ingestion rate of a shrew (0.48 L water/kg bw/d)
SCDHEC, 2014 - SCR.61-68, Water Classifications and Standards
1 - maximum contaminent level
2 - Human Health for Consumption of Water and Organism
a - COPCs based on human health; included to be protective of ecological receptors.

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Table 4-1

Screening of Remedial Technologies for OU1

Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

General Response Action	Remediation Technology and Process Option	Description of Process Option	Effectiveness	Implementability	Cost	Retained	Screening Comments
No Action	None	No action taken	Not effective	Implementable	No cost	Yes	Required for baseline comparison
Institutional Controls	**Access and Use Restrictions**						
	Deed covenants	Prohibit residential use of site including groundwater as potable water source. Restrict development of area around the pit lake through restrictive language in deeds and other instruments of property transfer.	Effective	Implementable	Low	**Yes**	Not effective to reduce risks to aquatic life in the North tributary. Would be used only in conjunction with other technologies. May apply use restriction to prevent using OU1 groundwater and pit lake as a potable water source.
	Signs	Restrict access to site areas or provide health advisories.	Effective	Implementable	Low	**Yes**	Would be used in conjunction with other technologies. Signs and fencing around the pit area in attempt to deter exposure.
	Fencing	Restrict access to site.	Effective	Implementable	Low	**Yes**	
Monitored Natural Attenuation	Monitor environmental parameters	Monitor surface water and sediment quality.	Will not attain RAOs for Pit Lake.	Implementable	Low	No	Not likely to reduce threat to North tributary due to continual recontamination by groundwater.
Containment	**Subaqueous Caps and Covers**	Cover acid generating waste rock in southern area of pit floor with a pumpable slurry consisting of a neutralization agent, grouting admixture and residual buffering agent (e.g., lime).	Potentially effective - would require treatability studies. May be less effective in highly irregular pit floor.	Implementable	High	**Yes**	Would be used in conjunction with other technologies. Lake sediment not expected to discharge over spillway. No risk reduction anticipated in the lake or in the North Tributary. Most acid inputs appear from groundwater that also flows beneath pit.
	Sediment solidification / stabilization	Addition of material to sediment such as cement kiln dust to stabilize and contain metals in sediment.	Not effective	Would need to drain lake to access specific fractures.	High	No	No additional risk reduction would be achieved.
	Grout fracture zones	Grout major fractures through pit related to seeps.	Not expected to be effective due to highly fractured bedrock.	May be limited depending on slurry wall depths.	High	No	Multiple fractures and seeps identified. Specific pathways unknown and may occur beneath the pit.
	Groundwater diversion	Use grout walls to divert majority of groundwater from flowing through buried waste rock.	Effective provided bedrock is not extensively fractured.	Implementable	Medium	**Yes**	Groundwater flow paths and waste rock areas are reasonably characterized. Can be used with other technologies.
	Hydraulic containment	Draw down groundwater to a level below the waste rock to prevent acidic inflow into the pit lake.	Effective	Implementable	Medium	**Yes**	Somewhat dependent on groundwater recharge rates after pumping in fractured bedrock. Can be used with other containment technologies
	Subaerial caps and covers	Expand and/or enhance cap in southwest portion of waste rock area to reduce infiltration to groundwater.	Effective	Implementable	Low	**Yes**	Would be used with other technologies to reduce area of likely infiltration.

Table 4-1

Screening of Remedial Technologies for OU1

Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

General Response Action	Remediation Technology and Process Option	Description of Process Option	Effectiveness	Implementability	Cost	Retained	Screening Comments
Containment	Drain lake and backfill	Drain lake by pumping water through an on-site treatment facility and discharge clean water to North Tributary. Backfill entire pit to form a mound with runoff controls.	Potentially effective	Difficult to implement with large volume of water to treat and large amount of backfill material.	High	No	Expensive to treat at least 75 million gallons water. Would need to blast highwalls to assist in backfill but would require large volumes of additional on-site and potentially off-site fill material. May not substantially reduce contaminated groundwater.
In situ Treatment	**Neutralization of pit lake**	Treat lake with alkalinity, organic carbon and other potential amendments.	Temporarily effective. Long-term effectiveness not expected without other controls.	Implementable	Medium	**Yes**	Would only be used in conjunction with other technologies such as groundwater controls. The pit lake has been treated several times (1998, 2008, 2009, 2010, 2012, and 2016). In each case, the median pH of the water degraded to <3.5 due to continued recontamination by poor groundwater quality.
	Amendments to waste rock	Inject chemicals (e.g., sodium lauryl sulfate, waste milk, whey) into waste rock to reduce acid generation.	Potentially effective - would require treatability studies.	May be difficult to amend beneath existing cap and in saturated waste rock zone.	Medium	**Yes**	Effectiveness largely unknown to site-specific waste rock (need treatability study). May be difficult to inject beneath, or infiltrate through, the existing cap over waste rock (another treatability study). Would likely be used in conjunction with other technologies.
	Amendments to groundwater	Install series of alkalinity injection wells in plume flowing through waste rock.	Potentially effective when combined with other technologies.	Implementable	High	**Yes**	May be used in conjunction with groundwater slurry wall and lake neutralization. Would likely require installation of new wells in affected flow paths.
Excavation	**Partial excavation of capped waste rock**	Pull back existing soil cap in selected areas and excavate waste rock using conventional earthmoving equipment. Amend remaining material and backfill.	Partially effective – removes source of acid-generating material.	Implementable	Low	**Yes**	Only removes a small portion of acid generating material but can readily be combined with other technologies.
Disposal	**On-site disposal**	Waste rock would be disposed of and managed (capped) within the former mine site.	Effective	Easy to implement	Low	**Yes**	There is sufficient space to place the expected quantities of material in an area not subject to groundwater infiltration.
	Off-site disposal	Disposal of material at a permitted landfill.	Effective	Implementable	High	No	Acid generating material would likely fail leach test requirements. High costs of transport and management.
Ex situ treatment of pit water discharging to North Tributary via the spillway	**Open limestone channel (OLC)**	Flow across the spillway would be diverted into a pipe and conveyed to an open limestone channel or a similar passive system to raise pH and precipitate metals.	Effective depending on pH, metals concentrations and flow volumes.	Implementable	Medium	**Yes**	Does not require continuous flow from lake. Short-term, large discharges from spillway may reduce effectiveness.
	Anoxic limestone drain (ALD)	Similar to the OLC, water would be piped from the spillway to an anoxic limestone drain.	May be effective depending on pH, oxygen, iron concentrations and flow volumes.	Implementable	Medium	No	Oxygenated pit water would need to be passed through a system to remove oxygen prior to entering the ALD.

Table 4-1

Screening of Remedial Technologies for OU1

Barite Hill/Nevada Goldfields Site OU-1, McCormick, McCormick County, South Carolina

General Response Action	Remediation Technology and Process Option	Description of Process Option	Effectiveness	Implementability	Cost	Retained	Screening Comments
Ex situ treatment of pit water discharging to North Tributary via the spillway	**Sulfate-reducing constructed bioreactor**	Flow across the spillway would be diverted into a pipe and conveyed to a passive treatment system to remove metals and raise pH.	Effective if combined with other technologies.	Implementable	Medium	**Yes**	Continued function of the system would require a nearly continuous flow of water; the system may not perform well if it is permitted to dry out when the pit lake does not discharge. Would need relatively flat area (0.5 - 1 acre).
	Aerobic wetland pond	A "polishing" passive treatment pond to remove dissolved sulfide, add oxygen and promote iron precipitation.	Effective if combined with other passive technologies to treat discharges.	Implementable	Medium	**Yes**	Aeration step required after treatment to remove dissolved sulfide and BOD and add oxygen prior to discharge to surface water.
	Manganese Rock Filters	A "polishing" passive treatment step to remove expected high levels of manganese prior to discharge to the North Tributary.	Effective if combined with other passive technologies to treat discharges.	Implementable	Medium	**Yes**	Considered a third step in passive treatment when manganese is elevated.
EX situ treatment of groundwater	Pump and treat groundwater	Pump contaminated groundwater and send through a treatment system that may include lime additions, zero-valent iron or other reactants.	Potentially effective	Implementable	High	No	Not practical due to large volumes to be treated with on-site active or passive treatment system, and potential disposal of precipitated sludge.
	Constructed anaerobic wetlands	Construct wetland in the pit after water has been drained to treat groundwater inflow and runoff to the pit.	Potentially effective	Requires implementing with series of other technologies	High	**Yes**	This RTPO could be applied to the pit only in conjunction with elimination of the pit lake water and re-configuring the pit floor.
Ex situ treatment of pit lake water	**Drain and treat pit lake water**	Drain lake by pumping water through an on-site treatment facility and discharge clean water to North Tributary. Several treatment options such as pH adjustment, ion-exchange, clarification and filtration.	Potentially effective	Requires implementing with series of other technologies	High	**Yes**	Only if used in conjunction with other technologies such as groundwater containment and encapsulation of exposed bottom sediments to minimize acid generation and mobilization of metals. Unknown how seeps may be affected. Estimated 73 Mgal water to be treated. Precipitated metals from treatment would require clarification and/or filtration. Disposal of treatment sludge also required. Metals potentially could be removed to WQS (would not include manganese). O&M of on-site treatment plant expected to be high. Expensive relative to minimal risk reduction to the North Tributary.

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Table 5-1
Remedial Alternatives
Barite Hill/Nevada Goldfields Site, McCormick County, South Carolina

CMZ-1, Pit Lake Alternatives	
Pit Lake #1	No Action
Pit Lake #2	Drain Pit Lake, Treat, Discharge to SW; Add Amendments/Cap Pit Floor, Backfill Pit
Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Amend/ Cap Pit Floor, Partial Backfill, Create Wetland
Pit Lake #4	Treat / Neutralize Pit Lake in-place, Cap Pit Floor
CMZ- 2, Waste Rock Alternatives	
Waste Rock #1	No Action
Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap
Waste Rock #3	Amendments to Waste Rock, Enhance Existing Caps
CMZ-3, OU1 Groundwater Alternatives	
Groundwater #1	No Action
Groundwater #2A	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring - Barrier Wall and Grout Curtain
Groundwater #2B	Groundwater Diversion and Dewatering of Capped Waste Rock, Monitoring - Hydraulic Barrier
Groundwater #3	Groundwater In-Situ Neutralization

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Table 6-1
Remedial Alternatives Cost Estimate Summary
Barite Hill/Nevada Goldfields Site, McCormick County, South Carolina

Contaminated Media Zone and Remedial Alternatives		Total Capital Cost	Total O&M Cost	O&M Period (years)	Total Alternative Cost
CMZ-1, Pit Lake					
Pit Lake #1	No Action	$0	$94,200	30+	**$94,200**
Pit Lake #2	Drain Lake, Treat, Discharge to SW; Add Amendments to Pit Floor, Backfill Pit	$17,636,097	$142,394	30	**$17,778,500**
Pit Lake #3	Drain Pit Lake, Treat, Discharge to SW; Cap Pit Floor, Partial Backfill, Create Wetland	$14,394,139	$155,863	30	**$14,550,000**
Pit Lake #4	Amendments to Pit Lake, Cap Pit Floor	$9,224,251	$91,476	30	**$9,315,700**
CMZ-2, Waste Rock					
Waste Rock #1	No Action	$0	$91,100	30+	**$91,100**
Waste Rock #2	Excavate and On-Site Encapsulation of Waste Rock, Backfill Excavation and Cap	$14,258,471	$325,587	30	**$14,584,100**
Waste Rock #3	Amendments to Waste Rock, Enhance Existing Caps	$4,400,646	$79,079	30	**$4,479,700**
CMZ-3, OU1 Groundwater					
Groundwater #1	No Action	$0	$122,200	30+	**$122,200**
Groundwater #2A	Groundwater Diversion - Barrier Wall and Grout Curtain	$7,432,326	$74,495	30	**$7,506,800**
Groundwater #2B	Groundwater Diversion - Hydraulic Barrier	$1,995,286	$1,525,832	30	**$3,521,100**
Groundwater #3	Groundwater In-Situ Neutralization	$1,467,917	$5,253,119	30	**$6,721,000**

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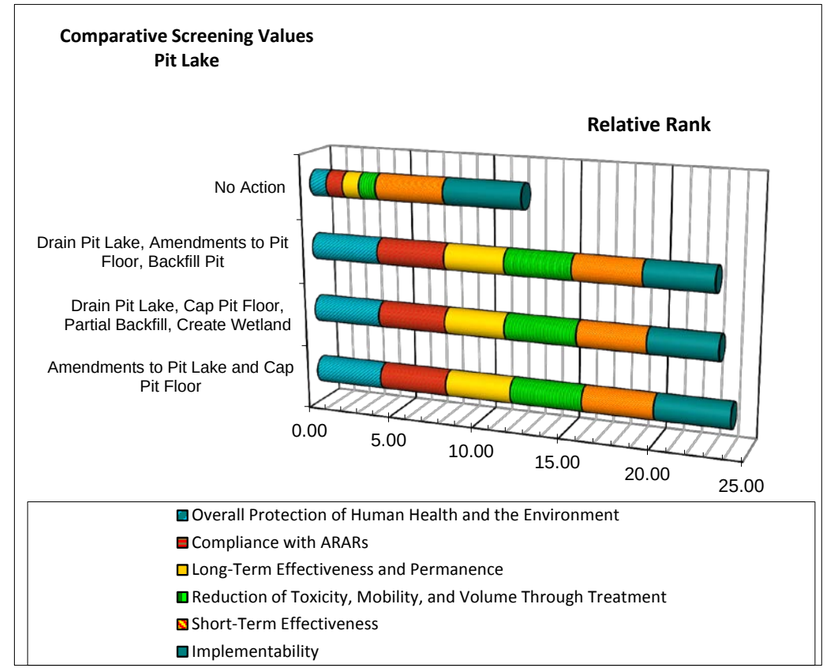
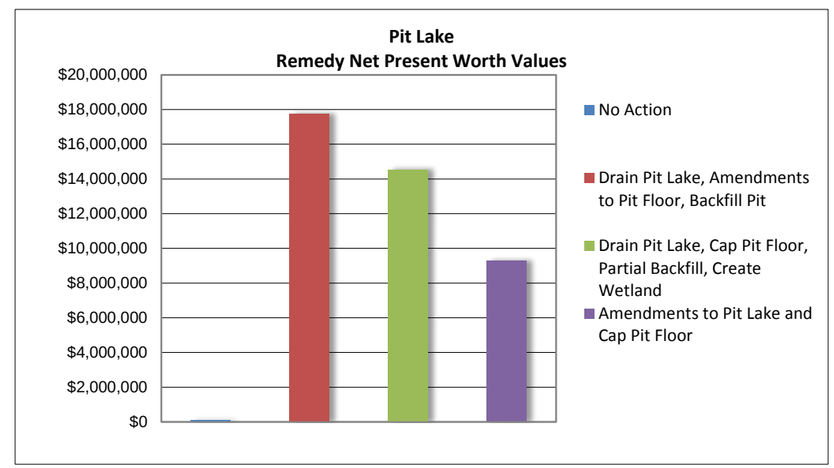
Table 7-1
Quantitative Comparison Analysis of Pit Lake Remedial Alternatives
Barite Hill/Nevada Goldfields Site Feasibility Study Report
McCormick, McCormick County, South Carolina

Criteria	Criterion Weight	Pit Lake #1 — No Action	Pit Lake #2 — Drain Pit Lake, Amendments to Pit Floor, Backfill Pit	Pit Lake #3 — Drain Pit Lake, Cap Pit Floor, Partial Backfill, Create Wetland	Pit Lake #4 — Amendments to Pit Lake and Cap Pit Floor
Overall Protection of Human Health and the Environment	**16.67%**	**1.00**	**4.00**	**4.00**	**4.00**
How alternative provides human health and environmental protection		1.00	4.00	4.00	4.00
Compliance with ARARs	**16.67%**	**1.00**	**4.00**	**4.00**	**4.00**
Compliance with Action-Specific ARARs		1.00	4.00	4.00	4.00
Compliance with Chemical-Specific ARARs		1.00	4.00	4.00	4.00
Compliance with Location-Specific ARARs		-	4.00	4.00	4.00
Compliance with To Be Considered /other criteria, advisories, and guidances		-	-	-	-
Long-Term Effectiveness and Permanence	**16.67%**	**1.00**	**3.50**	**3.50**	**3.83**
Magnitude of Residual (Post-Remediation) Risks		1.00	3.00	3.50	4.00
Adequacy and Reliability of Controls		-	4.00	3.50	4.00
Treatment Irreversibility		-	3.50	3.50	3.50
Reduction of Toxicity, Mobility, and Volume Through Treatment	**16.67%**	**1.00**	**3.80**	**4.10**	**4.10**
Treatment Process and Remedy		1.00	3.50	4.50	4.50
Amount of Hazardous Materials Destroyed or Treated		-	4.50	4.50	4.50
Degree of Expected Reductions in T/M/V		1.00	4.00	4.00	4.00
Type and Quantity of Treatment Residuals		-	4.00	4.00	4.00
Statutory Preference for Treatment		1.00	3.00	3.50	3.50
Short-Term Effectiveness	**16.67%**	**4.00**	**3.88**	**3.88**	**4.00**
Protection of Community During Remedial Action		5.00	5.00	5.00	5.00
Protection of Workers During Remedial Action		5.00	3.50	3.50	3.50
Environmental Impacts		5.00	4.00	4.00	4.00
Time Until Remedial Action Objectives are Achieved		1.00	3.00	3.00	3.50
Implementability	**16.67%**	**4.50**	**3.86**	**3.86**	**4.14**
Ability to Construct and Operate the Technology		5.00	4.00	4.00	4.00
Technology Reliability		-	4.00	3.50	4.50
Ease of Remedial Modifications		4.00	3.00	3.50	4.50
Ability to Monitor Remedial Effectiveness		-	4.00	4.00	4.00
Coordination with Other Agencies		-	4.00	4.00	4.00
Availability of Off-site TS&D Services and Capacity		-	-	-	-
Equipment and Specialist Availability		-	4.00	4.00	4.00
Availability of Prospective Technologies		-	4.00	4.00	4.00
Total Composite Score	**100%**	**12.50**	**23.03**	**23.33**	**24.08**
Cost					
Unit Rate ($/yd^3)		-	-	-	-
Capital Costs		$0	$17,636,097	$14,394,139	$9,224,251
NPW O&M Costs		$94,160	$142,394	$155,863	$91,476
O&M Period (yrs)		30	30	30	30
Net Present Worth Cost (@ 5% discount rate)		**$94,200**	**$17,778,500**	**$14,550,000**	**$9,315,700**





The "Criterion Weight" is the relative weight (quantified as a percentage) that each individual evaluation criterion or question has on the overall score.

The "Criterion Weight" for each evaluation criterion is multiplied by each evaluation criterion's score to arrive at a weighted score for that criterion.

Notes:
ARAR - Applicable or Relevant and Appropriate Requirements
NPW - Net Present Worth
O&M - Operation & Maintenance
T/M/V - Toxicity, Mobility and Volume
TS&D - Treatment, Storage, and Disposal

Key to Evaluation Ratings
Very Good - 5
Good - 4
Average - 3
Fair - 2
Poor - 1

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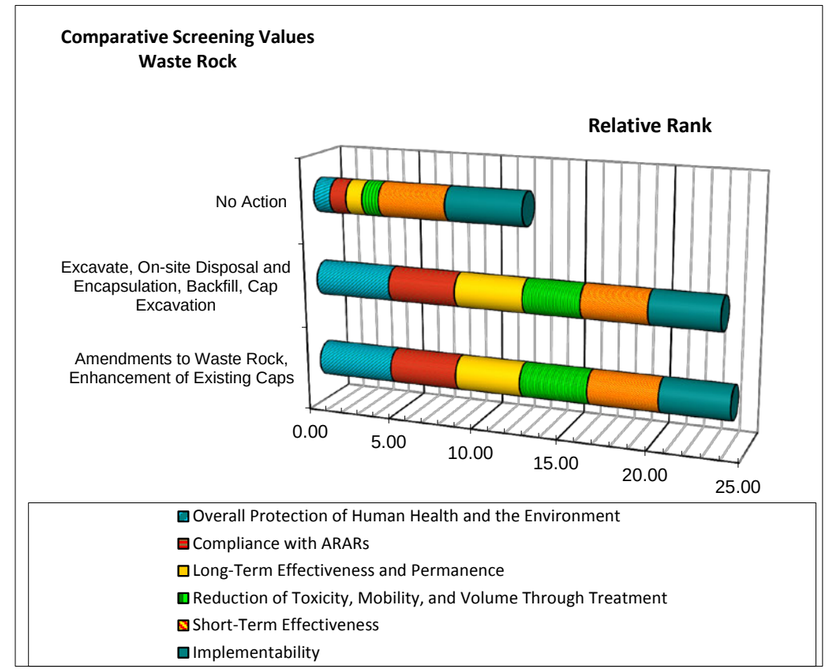
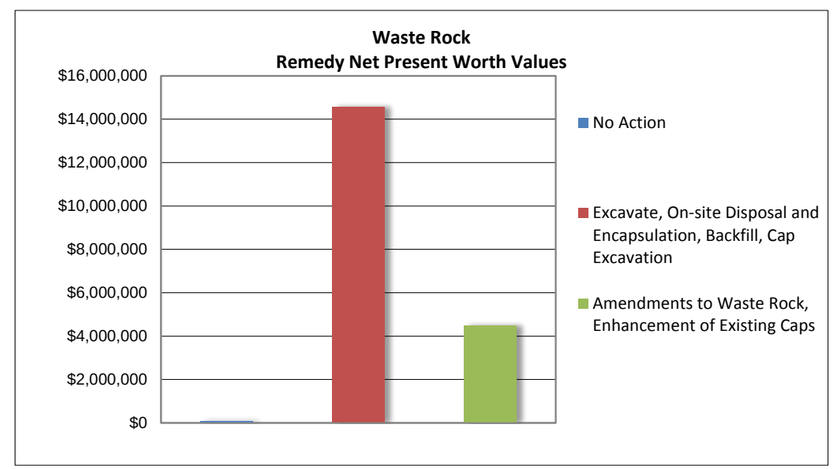
Table 7-2
Quantitative Comparison Analysis of CMZ-2 (Waste Rock) Remedial Alternatives
Barite Hill/Nevada Goldfields Site Feasibility Study Report
McCormick, McCormick County, South Carolina

Criteria	Criterion Weight	Waste Rock #1 — No Action	Waste Rock #2 — Excavate, On-site Disposal and Encapsulation, Backfill, Cap Excavation	Waste Rock #3 — Amendments to Waste Rock, Enhancement of Existing Caps
Overall Protection of Human Health and the Environment	**16.67%**	**1.00**	**4.50**	**4.50**
How alternative provides human health and environmental protection		1.00	4.50	4.50
Compliance with ARARs	**16.67%**	**1.00**	**4.00**	**4.00**
Compliance with Action-Specific ARARs		1.00	4.00	4.00
Compliance with Chemical-Specific ARARs		1.00	4.00	4.00
Compliance with Location-Specific ARARs		-	-	-
Compliance with To Be Considered /other criteria, advisories, and guidances		-	-	-
Long-Term Effectiveness and Permanence	**16.67%**	**1.00**	**4.00**	**3.83**
Magnitude of Residual (Post-Remediation) Risks		1.00	4.00	4.00
Adequacy and Reliability of Controls		-	4.00	4.00
Treatment Irreversibility		-	4.00	3.50
Reduction of Toxicity, Mobility, and Volume Through Treatment	**16.67%**	**1.00**	**3.30**	**3.90**
Treatment Process and Remedy		1.00	4.00	4.00
Amount of Hazardous Materials Destroyed or Treated		-	3.00	4.00
Degree of Expected Reductions in T/M/V		1.00	3.00	4.00
Type and Quantity of Treatment Residuals		-	3.00	4.00
Statutory Preference for Treatment		1.00	3.50	3.50
Short-Term Effectiveness	**16.67%**	**4.00**	**3.75**	**4.00**
Protection of Community During Remedial Action		5.00	5.00	5.00
Protection of Workers During Remedial Action		5.00	3.00	3.50
Environmental Impacts		5.00	3.50	4.00
Time Until Remedial Action Objectives are Achieved		1.00	3.50	3.50
Implementability	**16.67%**	**4.50**	**3.93**	**3.93**
Ability to Construct and Operate the Technology		5.00	4.00	4.00
Technology Reliability		-	4.00	3.50
Ease of Remedial Modifications		4.00	3.50	4.00
Ability to Monitor Remedial Effectiveness		-	4.00	4.00
Coordination with Other Agencies		-	4.00	4.00
Availability of Off-site TS&D Services and Capacity		-	-	-
Equipment and Specialist Availability		-	4.00	4.00
Availability of Prospective Technologies		-	4.00	4.00
Total Composite Score	**100%**	**12.50**	**23.48**	**24.16**
Cost				
Unit Rate ($/yd^3)		-		
Capital Costs		$0	$14,258,471	$4,400,646
NPW O&M Costs		$91,084	$325,857	$79,079
O&M Period (yrs)		30	30	30
Net Present Worth Cost (@ 5% discount rate)		**$91,100**	**$14,584,300**	**$4,479,700**





The "Criterion Weight" is the relative weight (quantified as a percentage) that each individual evaluation criterion or question has on the overall score.

The "Criterion Weight" for each evaluation criterion is multiplied by each evaluation criterion's score to arrive at a weighted score for that criterion.

Notes:
ARAR - Applicable or Relevant and Appropriate Requirements
NPW - Net Present Worth
O&M - Operation & Maintenance
T/M/V - Toxicity, Mobility and Volume
TS&D - Treatment, Storage, and Disposal

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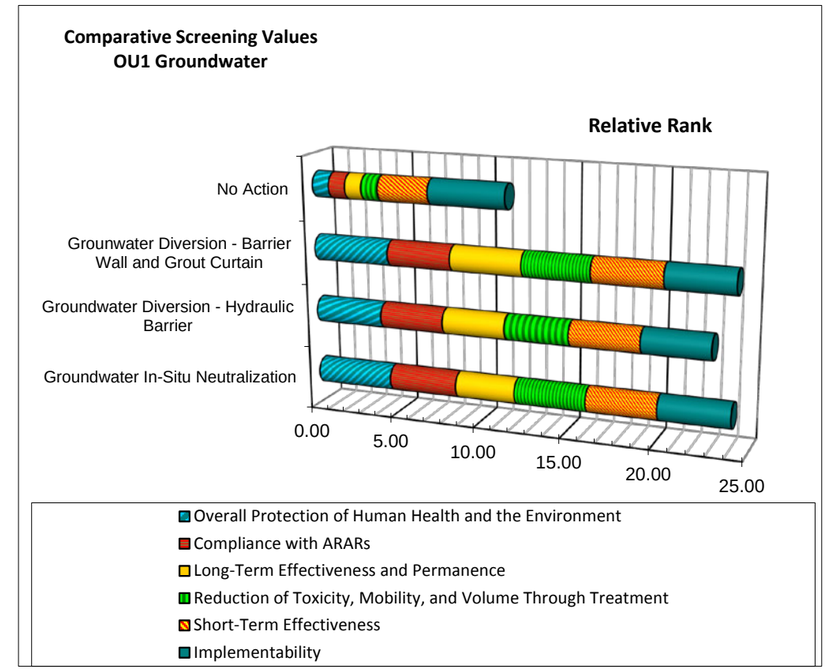
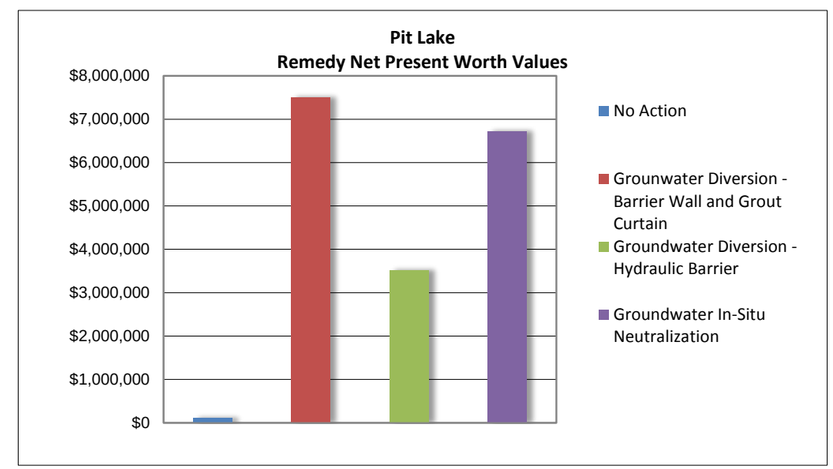
Table 7-3
Quantitative Comparison Analysis of CMZ-3 (OU1 Groundwater) Remedial Alternatives
Barite Hill/Nevada Goldfields Site Feasibility Study Report
McCormick, McCormick County, South Carolina

Criteria	Criterion Weight	Groundwater #1 — No Action	Groundwater #2A — Grounwater Diversion - Barrier Wall and Grout Curtain	Groundwater #2B — Groundwater Diversion - Hydraulic Barrier	Groundwater #3 — Groundwater In-Situ Neutralization
Overall Protection of Human Health and the Environment	**16.67%**	**1.00**	**4.50**	**4.00**	**4.50**
How alternative provides human health and environmental protection		1.00	4.50	4.00	4.50
Compliance with ARARs	**16.67%**	**1.00**	**3.75**	**3.75**	**4.00**
Compliance with Action-Specific ARARs		1.00	4.00	4.00	4.00
Compliance with Chemical-Specific ARARs		1.00	3.50	3.50	4.00
Compliance with Location-Specific ARARs		-	-	-	-
Compliance with To Be Considered /other criteria, advisories, and guidances		-	-	-	-
Long-Term Effectiveness and Permanence	**16.67%**	**1.00**	**4.17**	**3.67**	**3.50**
Magnitude of Residual (Post-Remediation) Risks		1.00	4.50	3.50	4.00
Adequacy and Reliability of Controls		-	4.00	4.00	3.00
Treatment Irreversibility		-	4.00	3.50	3.50
Reduction of Toxicity, Mobility, and Volume Through Treatment	**16.67%**	**1.00**	**3.90**	**3.70**	**4.10**
Treatment Process and Remedy		1.00	4.00	4.00	4.00
Amount of Hazardous Materials Destroyed or Treated		-	3.00	3.00	4.50
Degree of Expected Reductions in T/M/V		1.00	4.00	4.00	4.00
Type and Quantity of Treatment Residuals		-	4.50	4.00	4.00
Statutory Preference for Treatment		1.00	4.00	3.50	4.00
Short-Term Effectiveness	**16.67%**	**3.00**	**4.00**	**4.00**	**4.00**
Protection of Community During Remedial Action		5.00	5.00	5.00	5.00
Protection of Workers During Remedial Action		5.00	3.50	3.50	3.50
Environmental Impacts		1.00	3.50	3.50	4.00
Time Until Remedial Action Objectives are Achieved		1.00	4.00	4.00	3.50
Implementability	**16.67%**	**4.50**	**3.86**	**3.86**	**4.00**
Ability to Construct and Operate the Technology		5.00	4.00	4.00	4.00
Technology Reliability		-	4.00	3.50	4.00
Ease of Remedial Modifications		4.00	3.00	3.50	4.00
Ability to Monitor Remedial Effectiveness		-	4.00	4.00	4.00
Coordination with Other Agencies		-	4.00	4.00	4.00
Availability of Off-site TS&D Services and Capacity		-	-	-	-
Equipment and Specialist Availability		-	4.00	4.00	4.00
Availability of Prospective Technologies		-	4.00	4.00	4.00
Total Composite Score	**100%**	**11.50**	**24.17**	**22.97**	**24.10**
Cost					
Unit Rate ($/yd^3)		-	-	-	-
Capital Costs		$0	$7,432,326	$1,995,286	$1,467,917
NPW O&M Costs		$122,206	$74,495	$1,525,832	$5,253,119
O&M Period (yrs)		30	30	30	30
Net Present Worth Cost (@ 5% discount rate)		**$122,200**	**$7,506,800**	**$3,521,100**	**$6,721,000**





The "Criterion Weight" is the relative weight (quantified as a percentage) that each individual evaluation criterion or question has on the overall score.

The "Criterion Weight" for each evaluation criterion is multiplied by each evaluation criterion's score to arrive at a weighted score for that criterion.

Notes:
ARAR - Applicable or Relevant and Appropriate Requirements
NPW - Net Present Worth
O&M - Operation & Maintenance
T/M/V - Toxicity, Mobility and Volume
TS&D - Treatment, Storage, and Disposal

Key to Evaluation Ratings
Very Good - 5
Good - 4
Average - 3
Fair - 2
Poor - 1

Created by: R. Dawkins 5/20/18
Updated by: R. Dawkins 3/28/19
Checked by:A. Pitts 4/1/19

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Figures

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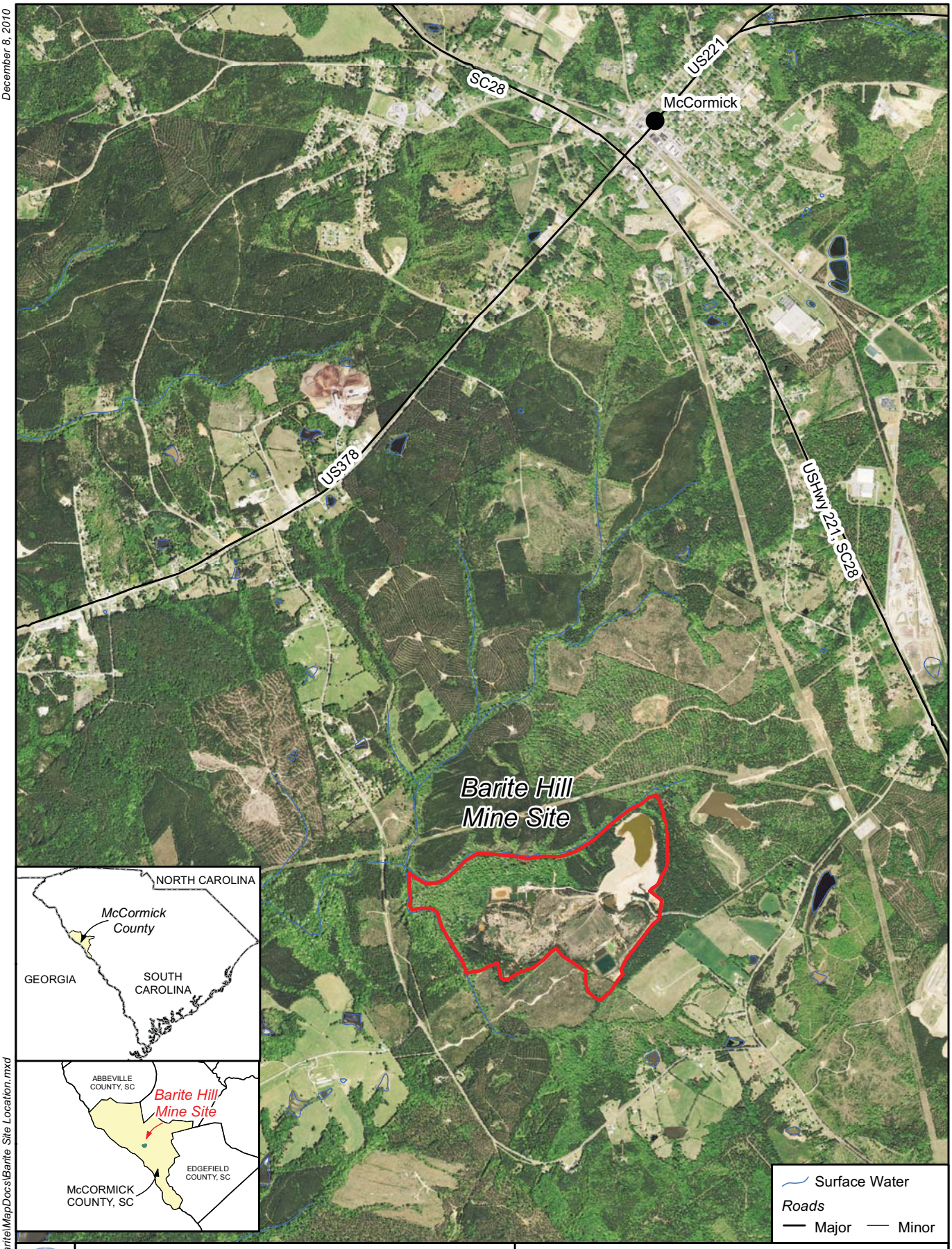

December 8, 2010

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Building a world of difference.

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NAD 1983 UTM Zone 17N Feet

FIGURE 1-1
Barite Hill Mine Site Location
McCormick County, South Carolina

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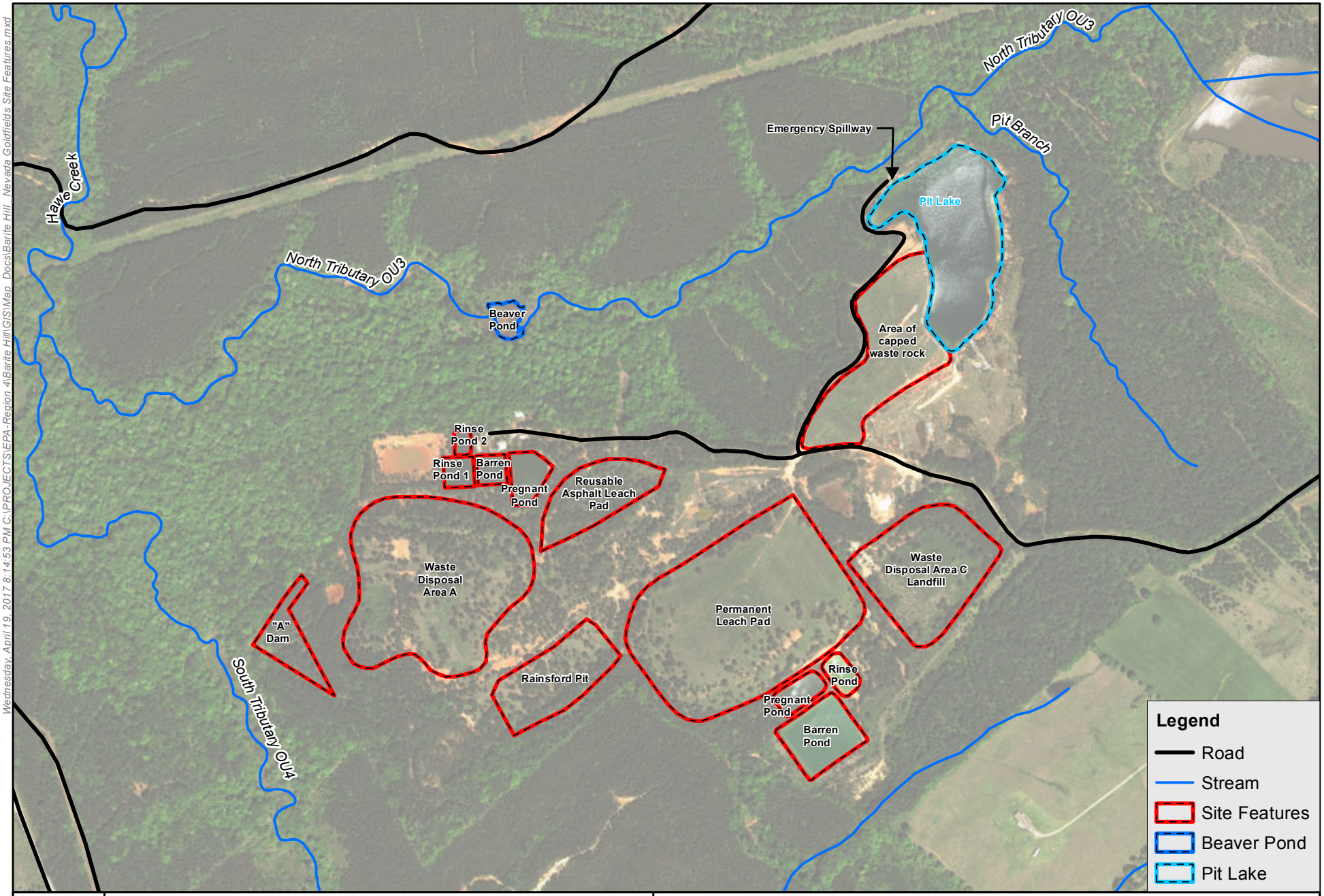

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NAD 1983 South Carolina State Plane - FIPS 3900 2015 NAIP Imagery

FIGURE 1-2

Barite Hill / Nevada Goldfields Site Features

Barite Hill Mine, McCormick County, South Carolina

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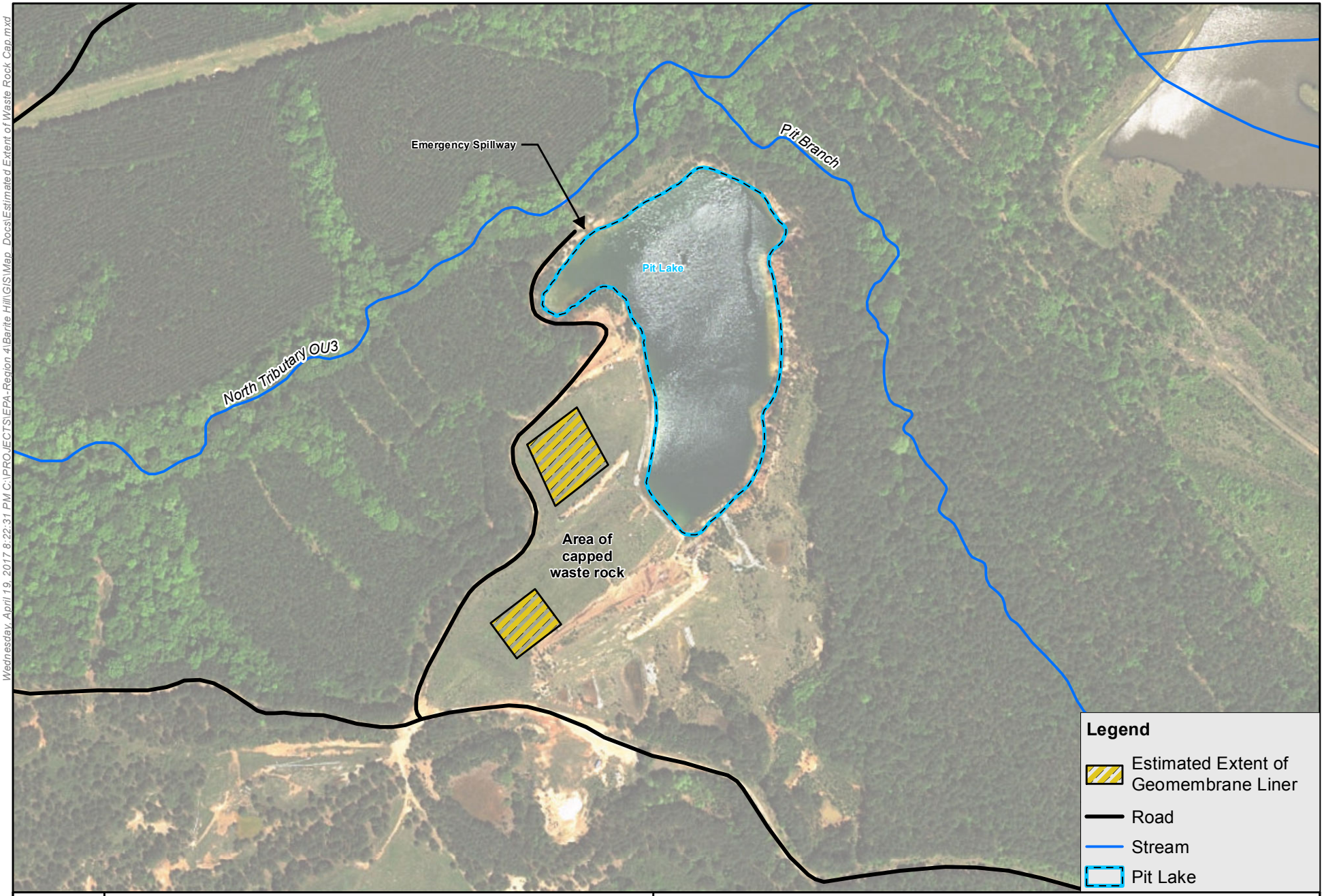

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FIGURE 1-3

Estimated Extent of Waste Rock Cap
Barite Hill Mine, McCormick County, South Carolina

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NAD 1983 South Carolina State Plane - FIPS 3900 2010 Bing Imagery

FIGURE 1-4

Identified Points of Seepage Inflow to the North Tributary
Barite Hill Mine, McCormick County, South Carolina

Wednesday, July 23, 2014 2:26:49 PM C:\Projects\EPA\Barite_Hill\mxd\RI\Figure 4-7 BariteHill_Identified Points of Seepage Inflow North Tributary.mxd

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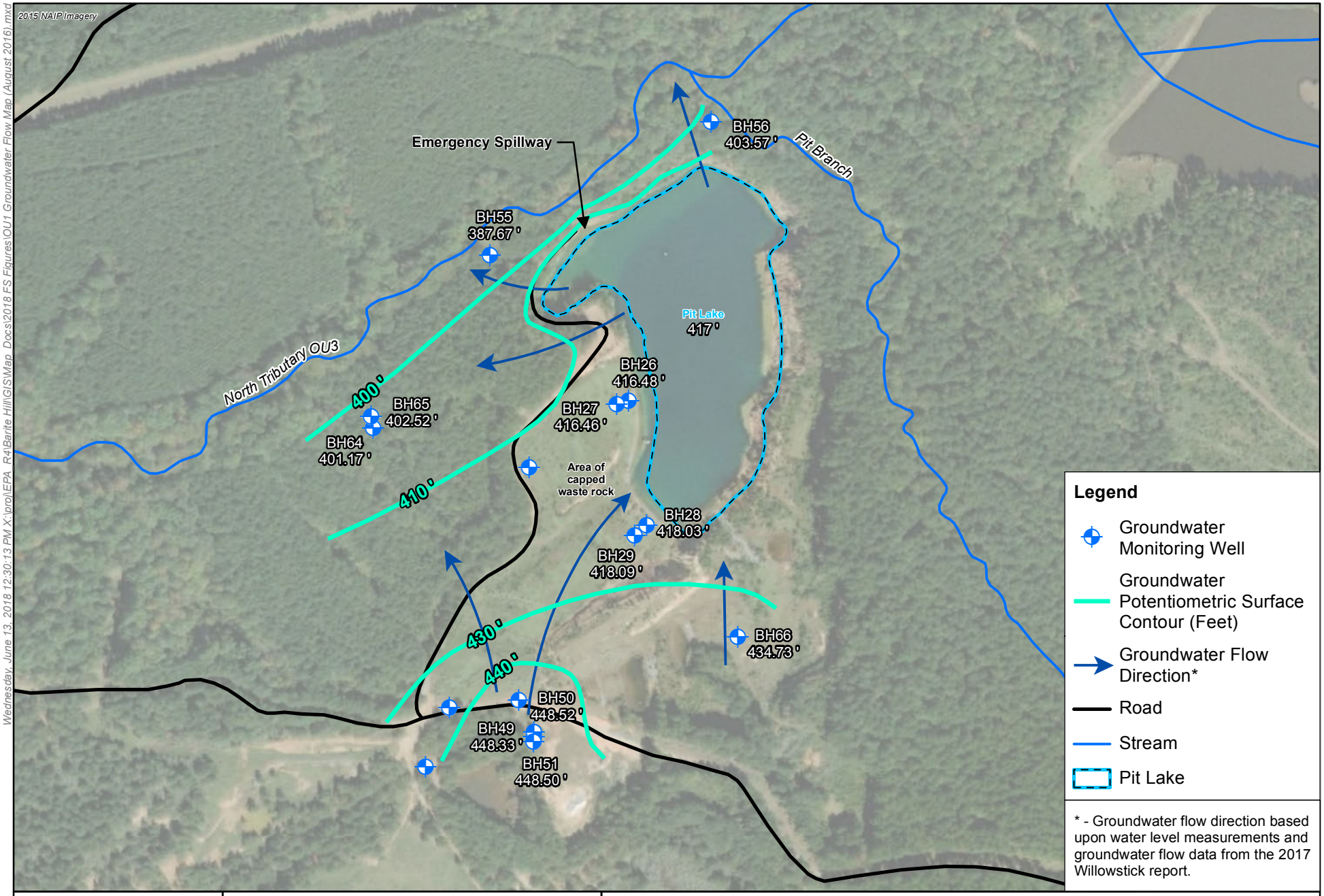

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FIGURE 2-1

OU1 Groundwater Flow Map (August 2016)
Barite Hill Mine, McCormick County, South Carolina

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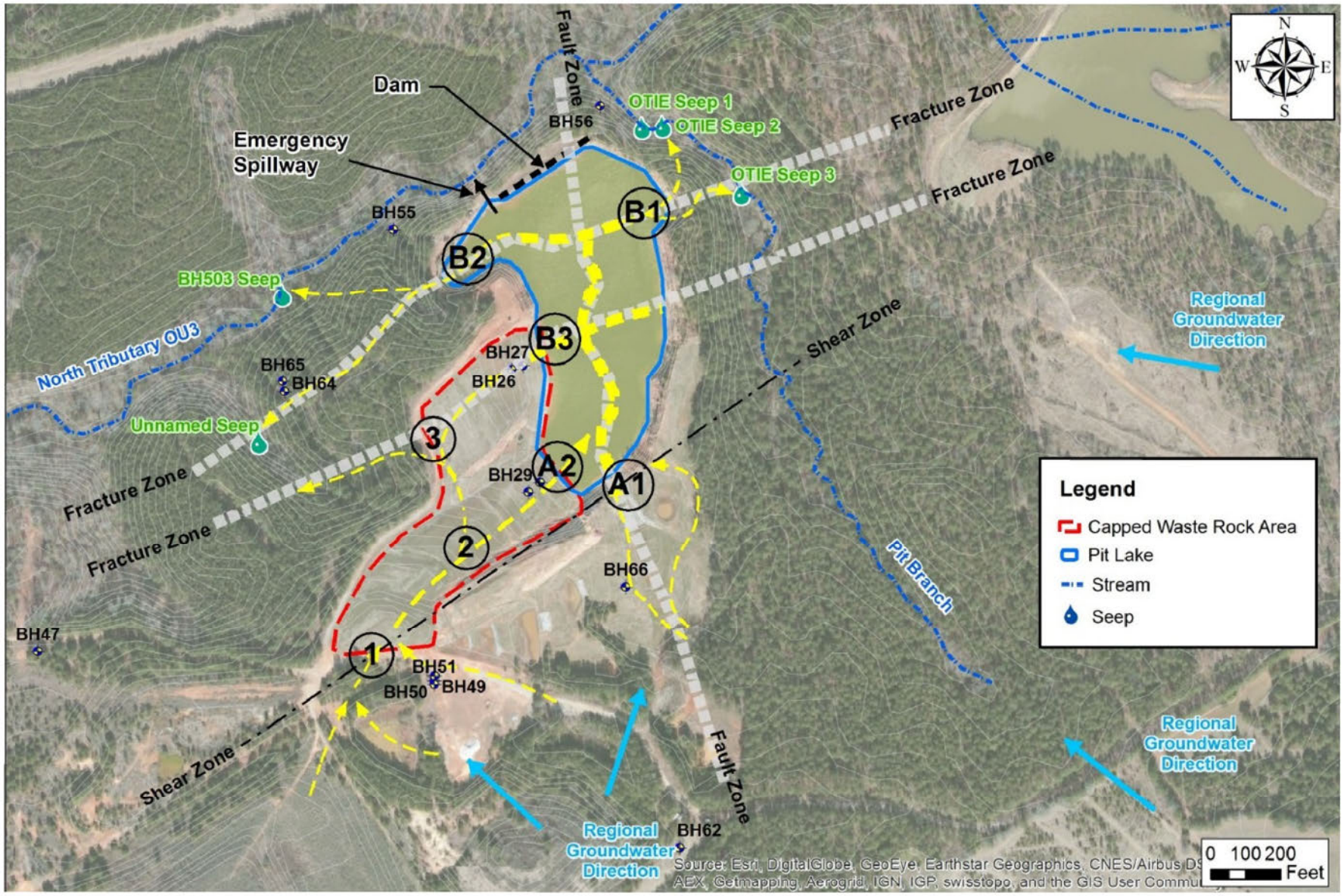

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willowstick

Figure 2-2

Willowstick Investigation Results - After Willowstick (2017)

Barite Hill Mine, McCormick County, South Carolina

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Figure 2-3. Barite Hill OU1 Geological Conceptual Site Model

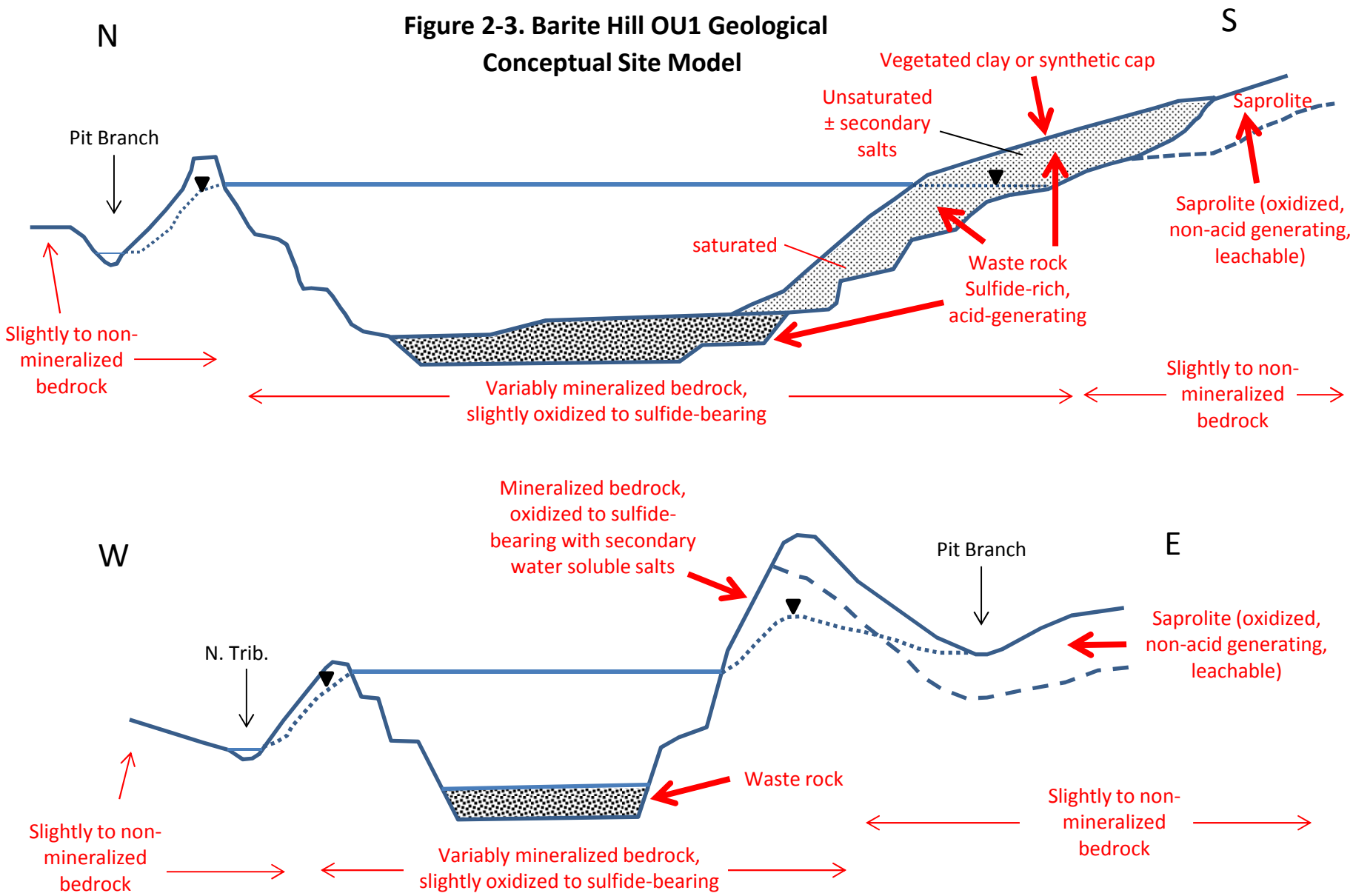

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Figure 2-4. Barite Hill OU1 Geochemical Conceptual Site Model

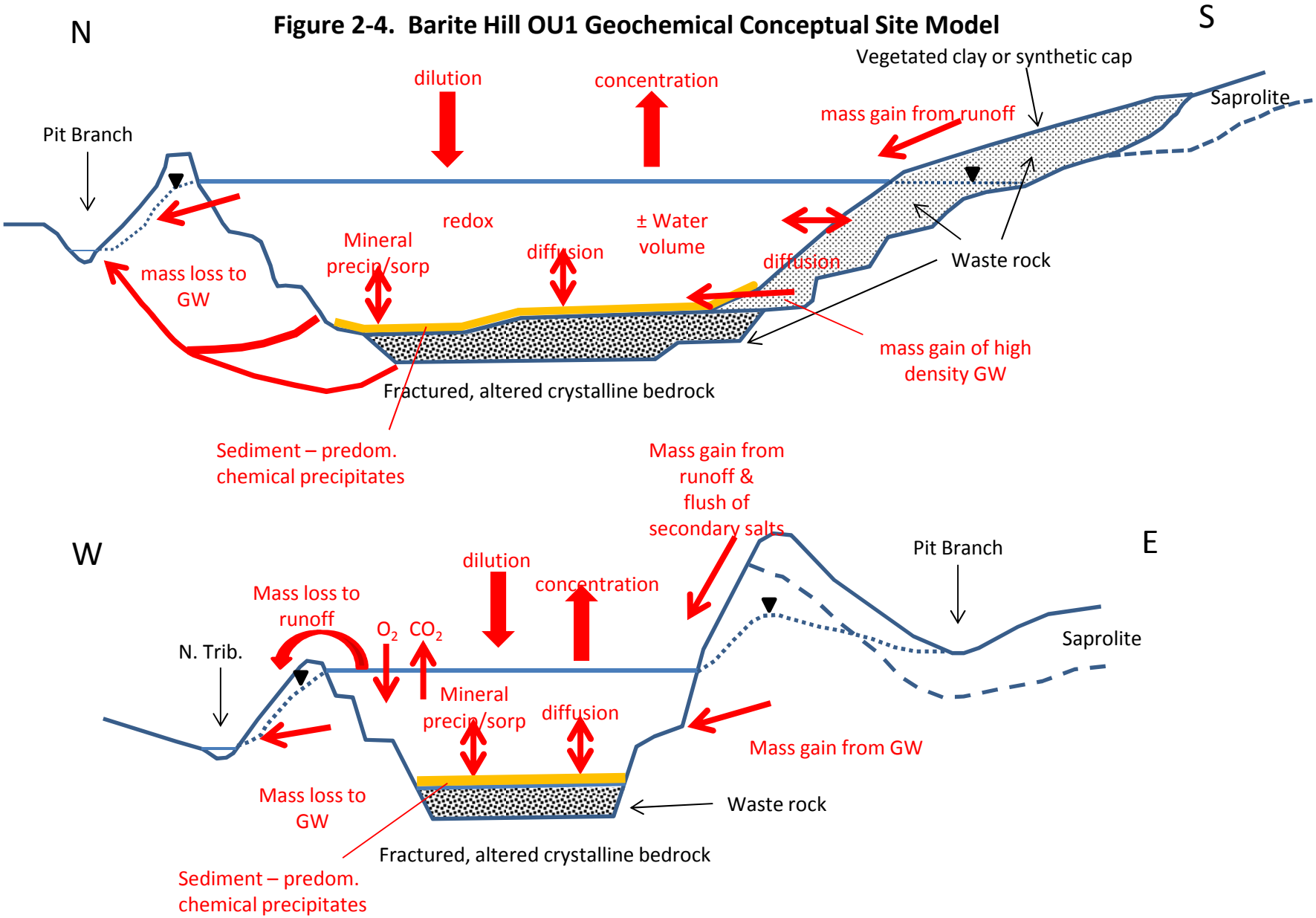

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Figure 2-5. Barite Hill OU1 Hydrologic Conceptual Site Model

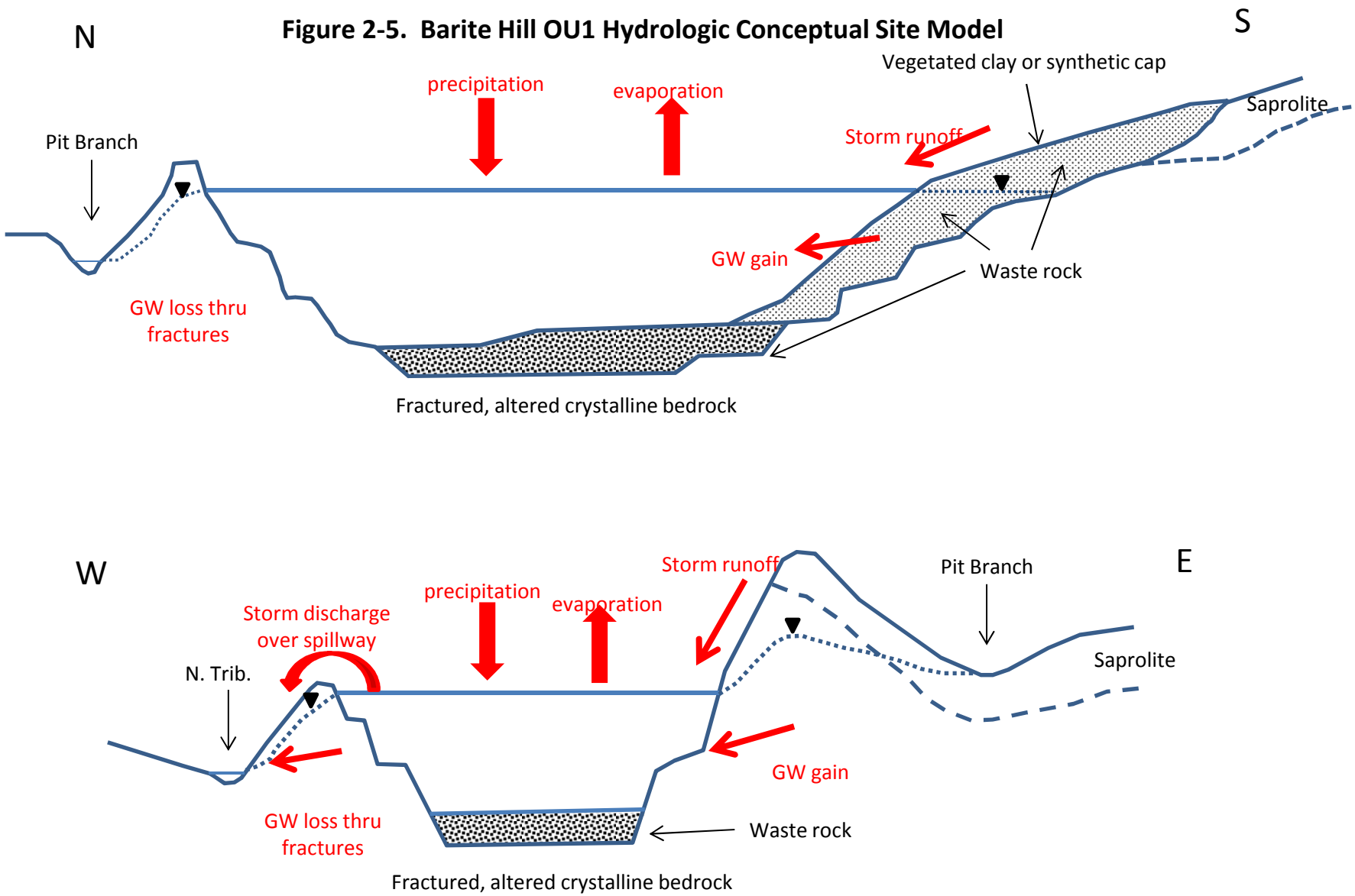

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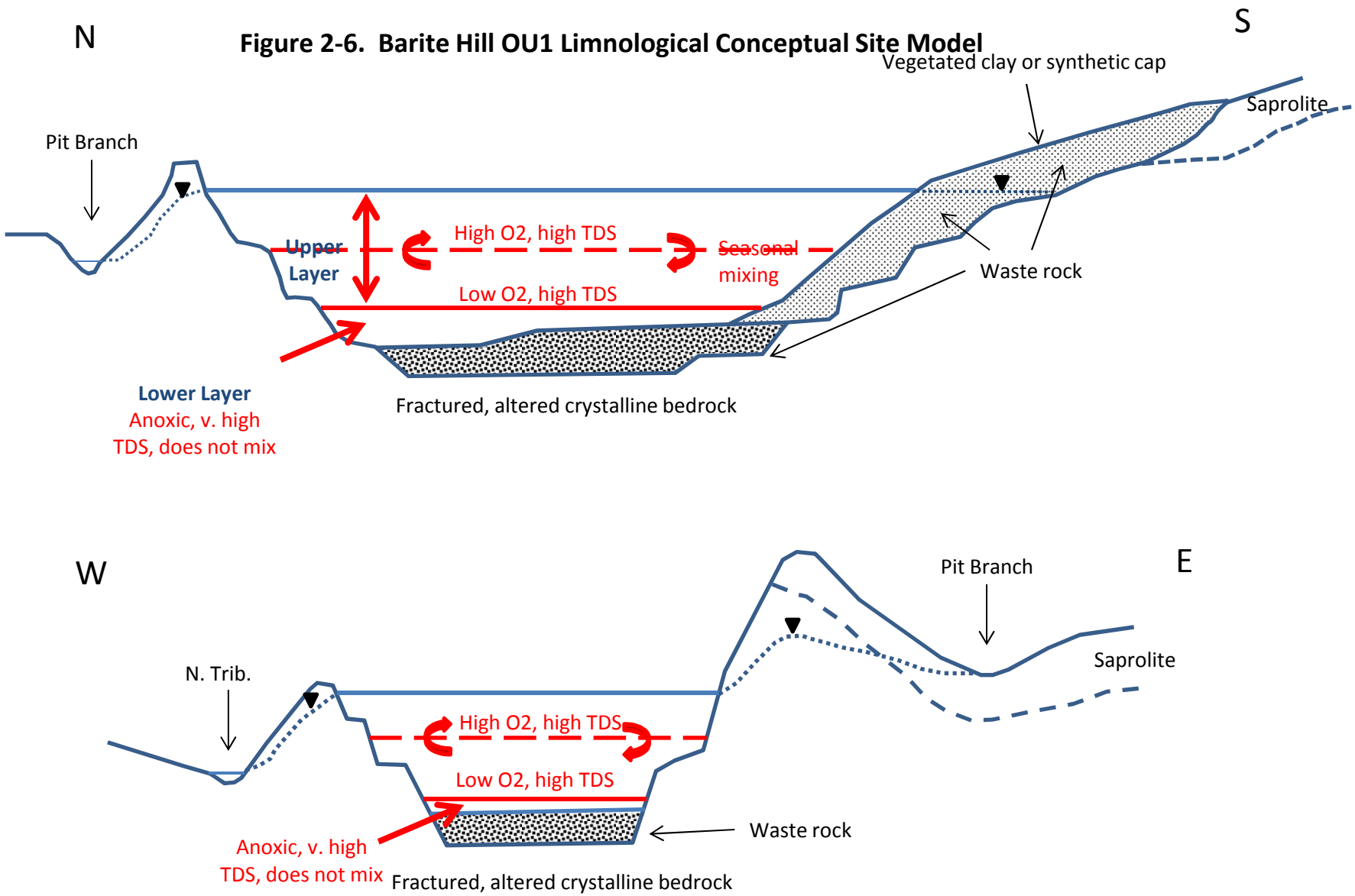
Figure 2-6. Barite Hill OU1 Limnological Conceptual Site Model



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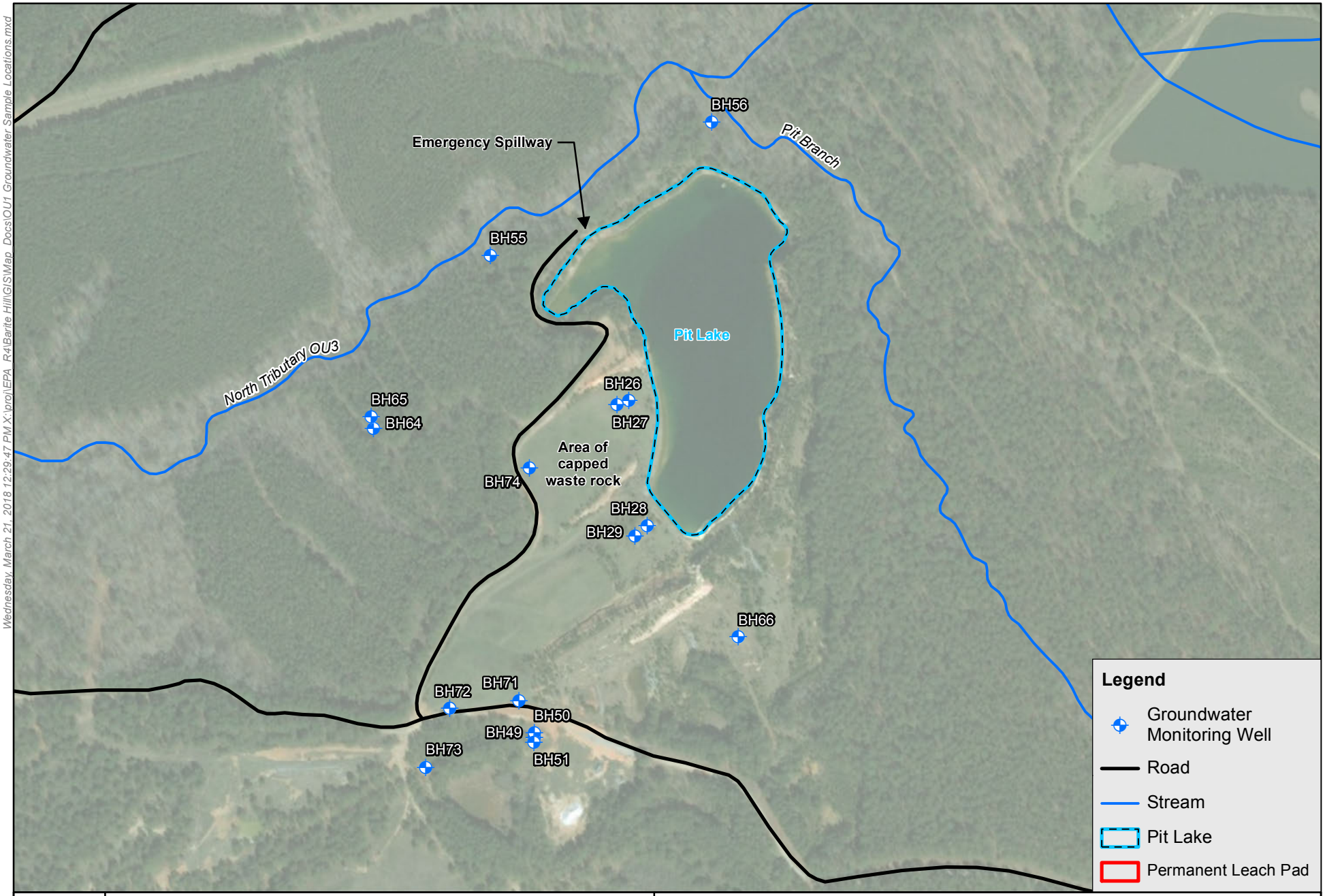

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NAD 1983 South Carolina State Plane - FIPS 3900 2015 NAIP Imagery

FIGURE 3-1

OU1 Groundwater Sample Locations

Barite Hill Mine, McCormick County, South Carolina

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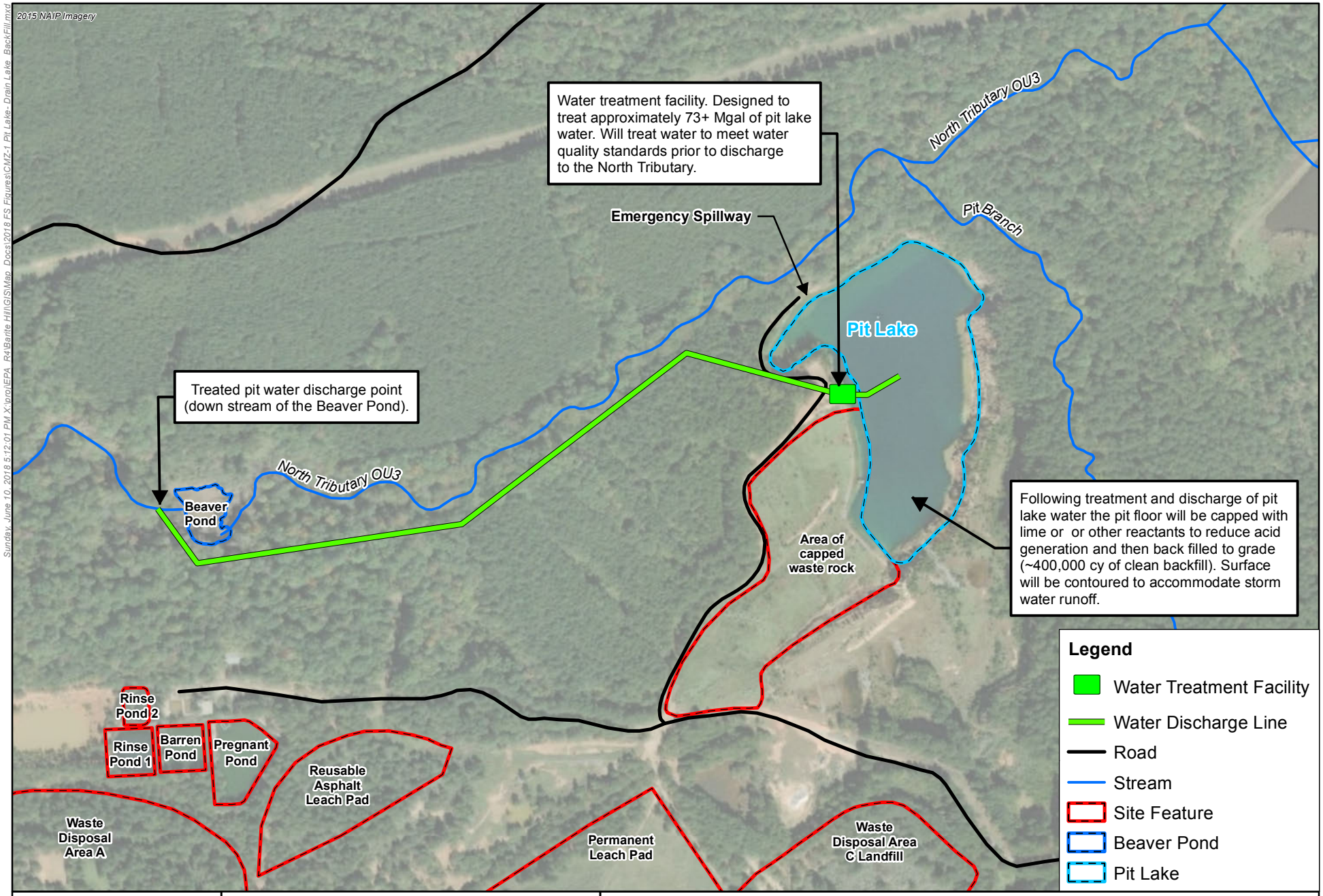

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FIGURE 5-1

CMZ-1 Pit Lake #2:

Drain Lake, Amendments to Pit Floor,Backfill

Barite Hill Mine, McCormick County, South Carolina

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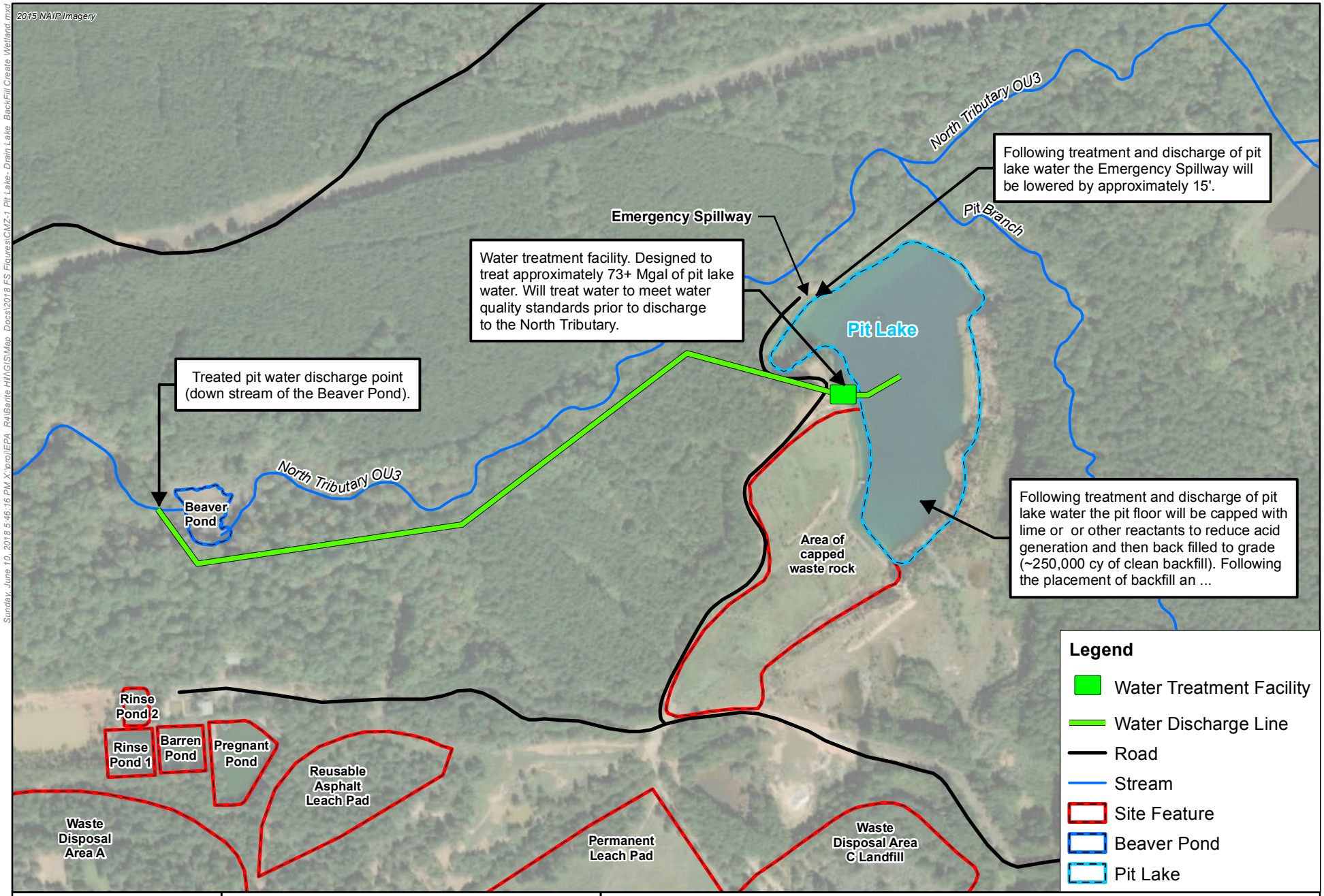

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FIGURE 5-2

CMZ-1 Pit Lake #3:

Drain Lake, Amendments to Pit Floor, Partial Backfill, Create Wetland

Barite Hill Mine, McCormick County, South Carolina

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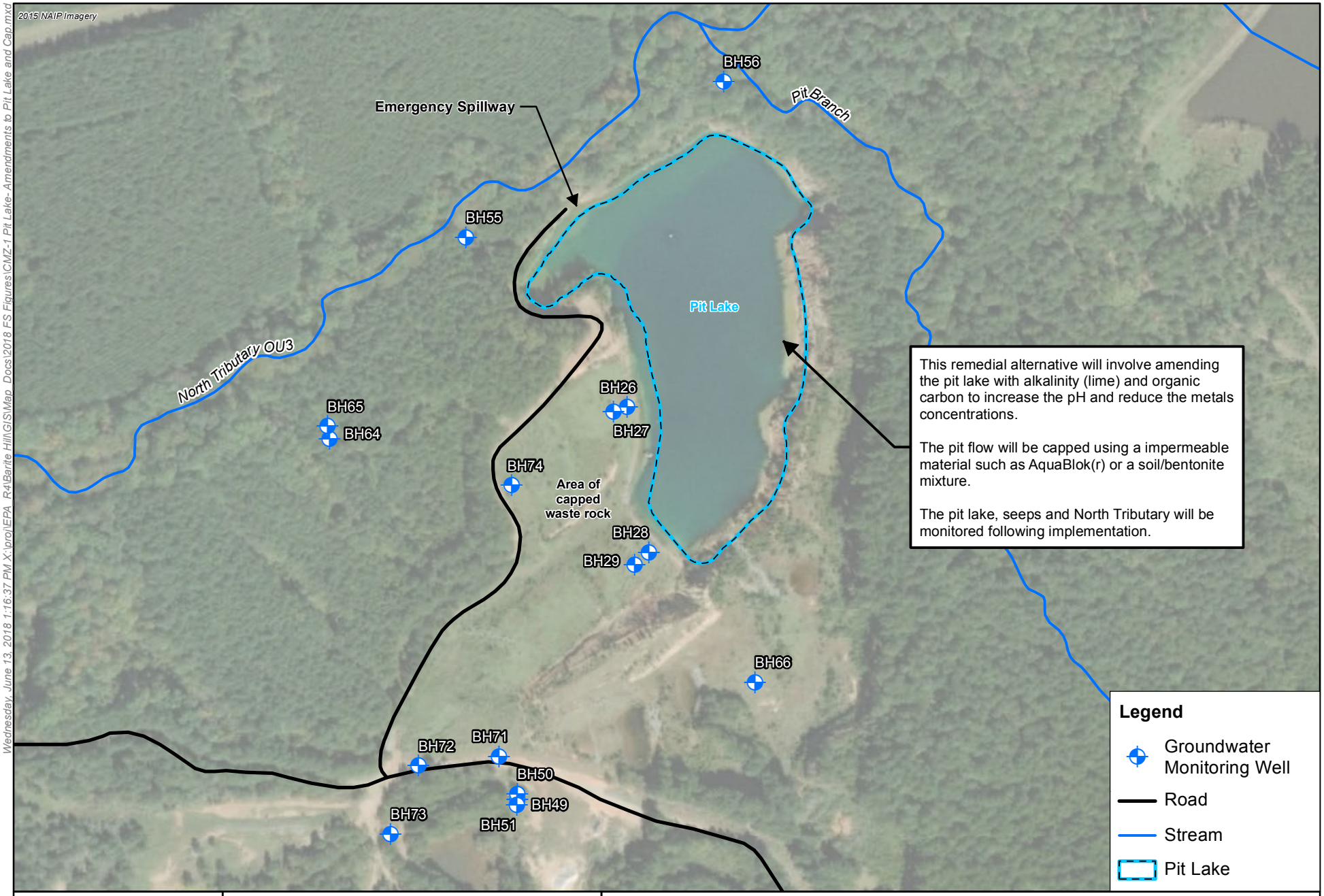

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NAD83 State Plane South Carolina, Feet

FIGURE 5-3

CMZ-1 Pit Lake #4:

Amendments to Pit Lake and Cap Pit Floor

Barite Hill Mine, McCormick County, South Carolina

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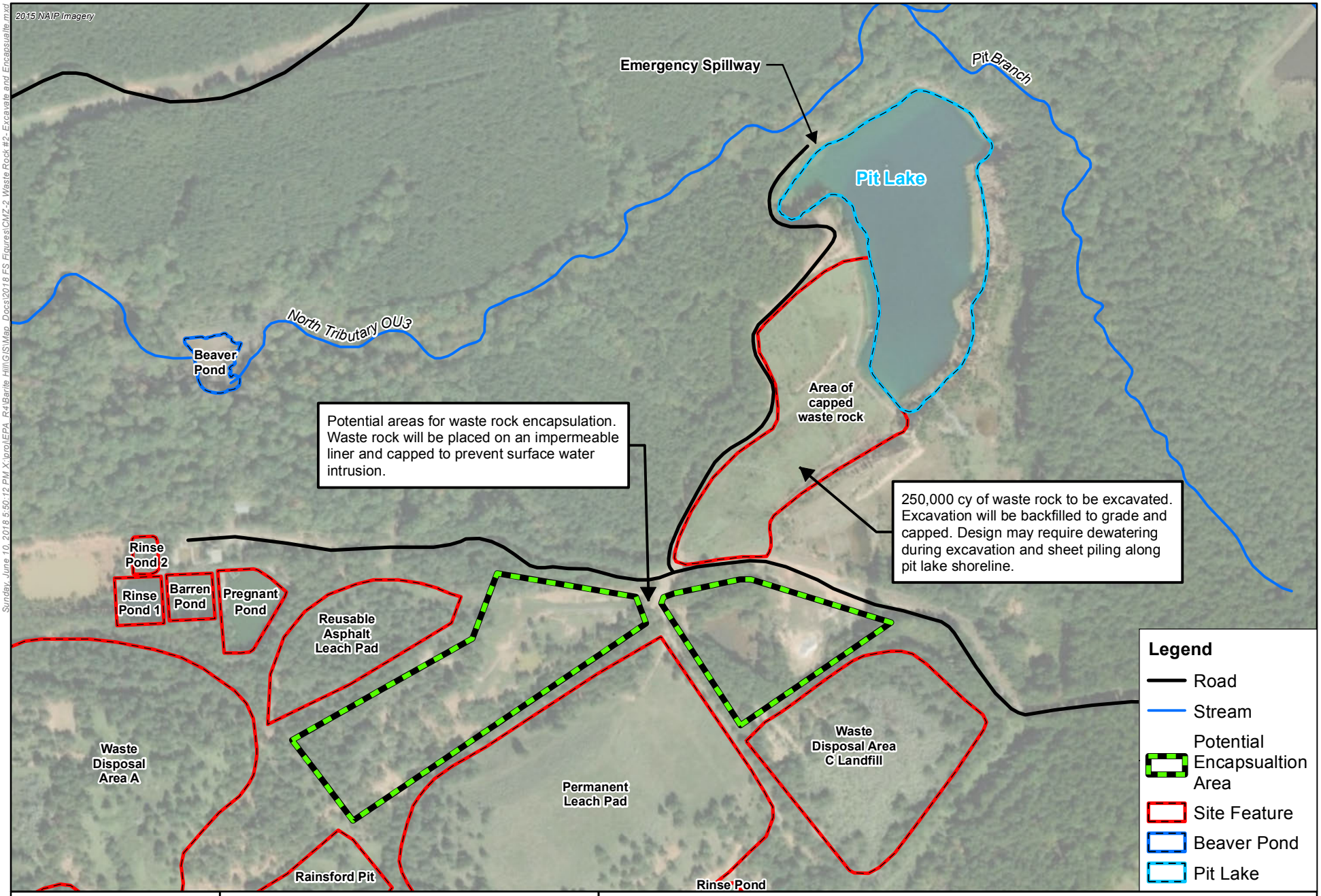

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FIGURE 5-4

CMZ-2 Waste Rock #2:

Excavate, On-Site Disposal and Encapsulation of Waste Rock

Barite Hill Mine, McCormick County, South Carolina

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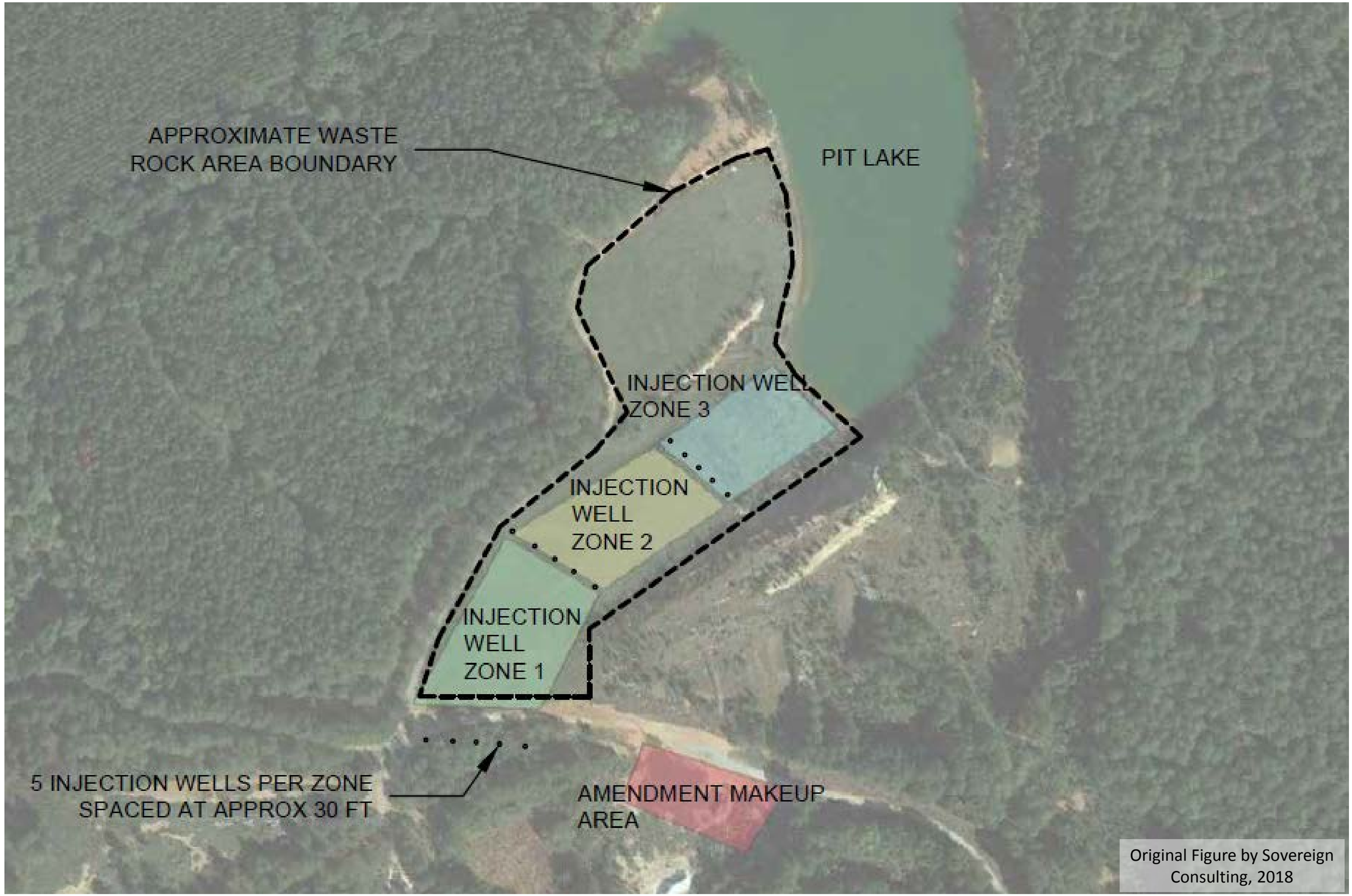

	Barite Hill Goldfields Site McCormick County, South Carolina	CMZ-2, Waste Rock 3 Deep Injection Well Plan View	Figure 5-5a

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	Barite Hill Goldfields Site McCormick County, South Carolina	CMZ-2, Waste Rock 3 Shallow Injection Well Plan View	Figure 5-5c

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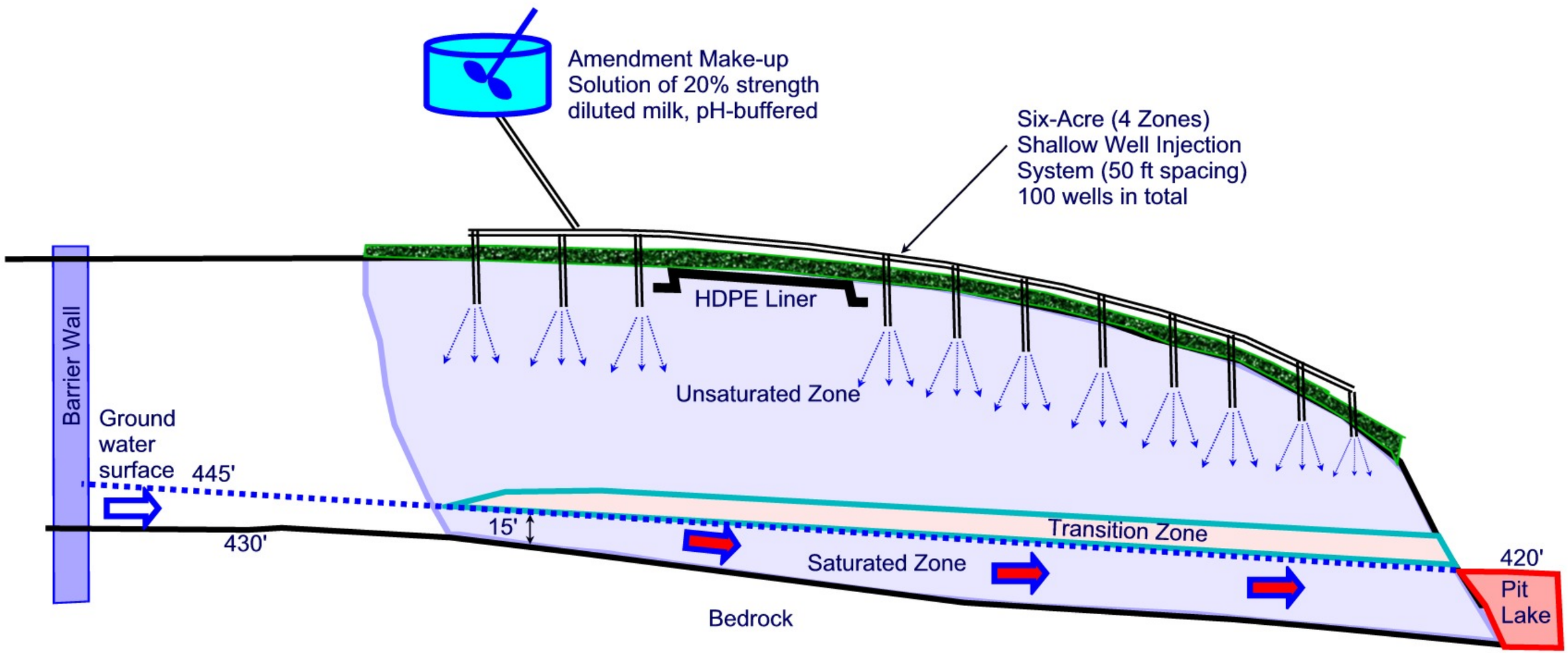

Original Figure by Sovereign Consulting, 2018

	Barite Hill Goldfields Site McCormick County, South Carolina	CMZ-2, Waste Rock 3 Shallow Injection Well Schematic	Figure 5-5d

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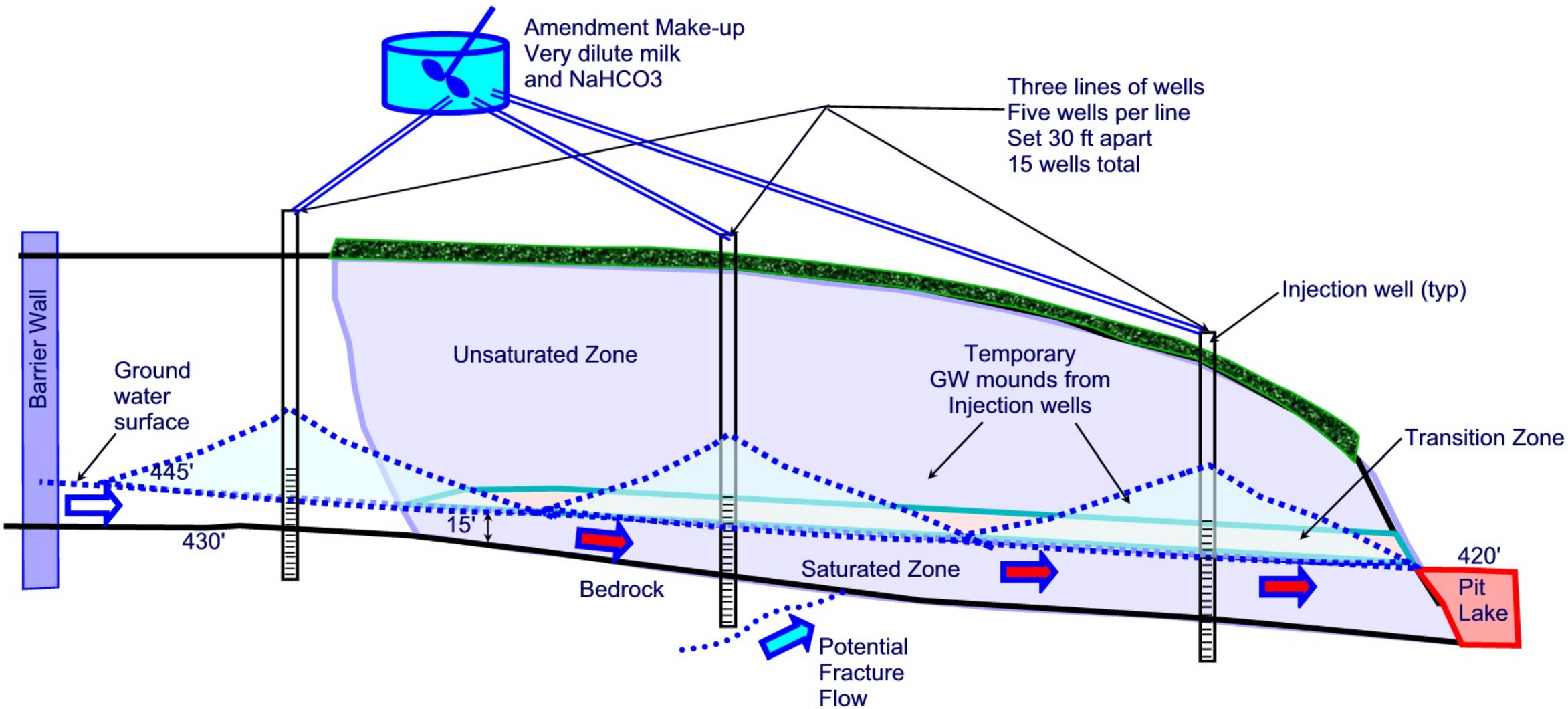

Original Figure by Sovereign Consulting, 2018

	Barite Hill Goldfields Site McCormick County, South Carolina	CMZ-2, Waste Rock 3 Deep Injection Well Schematic	Figure 5-5b

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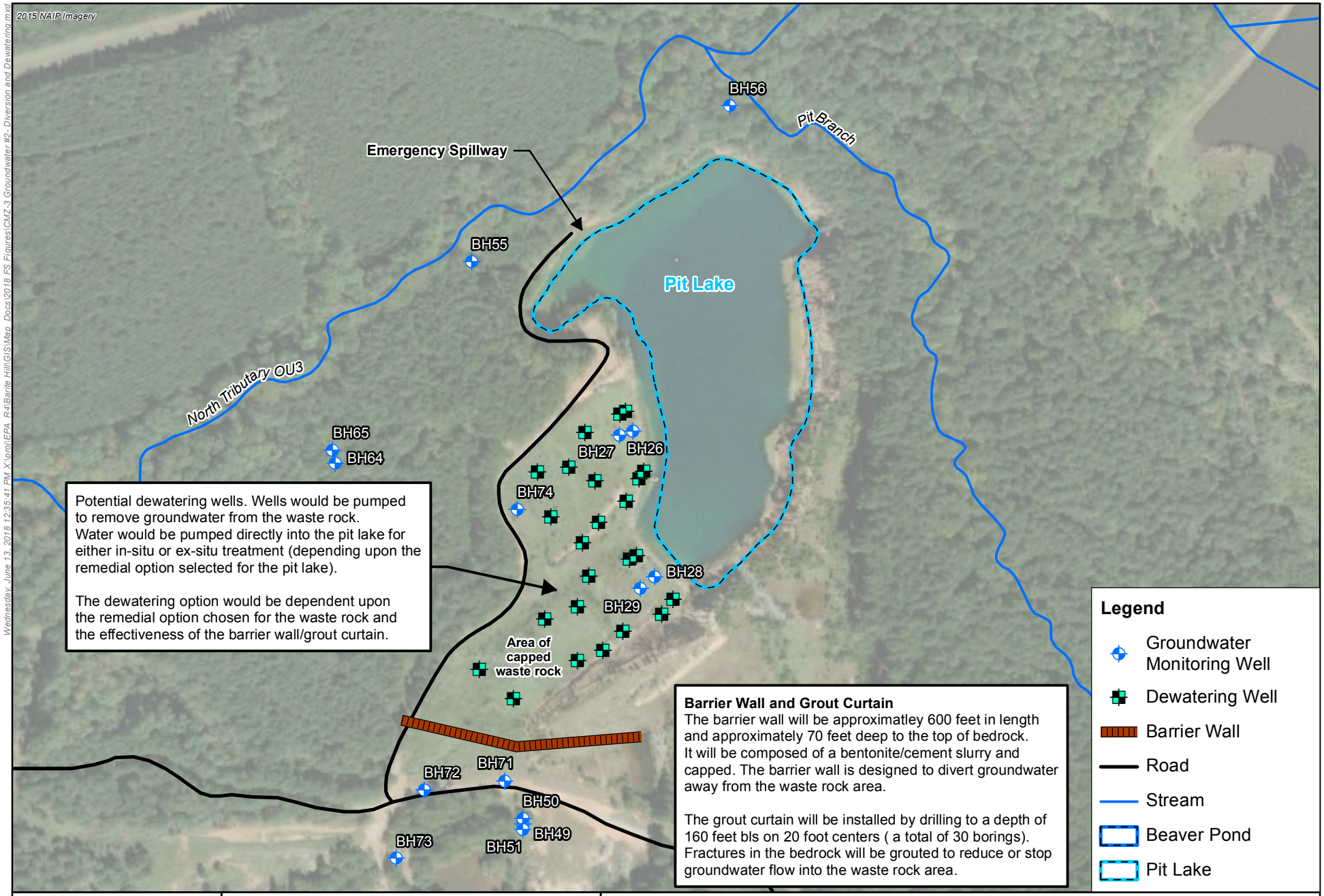

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FIGURE 5-6a

CMZ-3 Groundwater #2A:

Groundwater Diversion and Dewatering of the Capped Waste Rock

Barite Hill Mine, McCormick County, South Carolina

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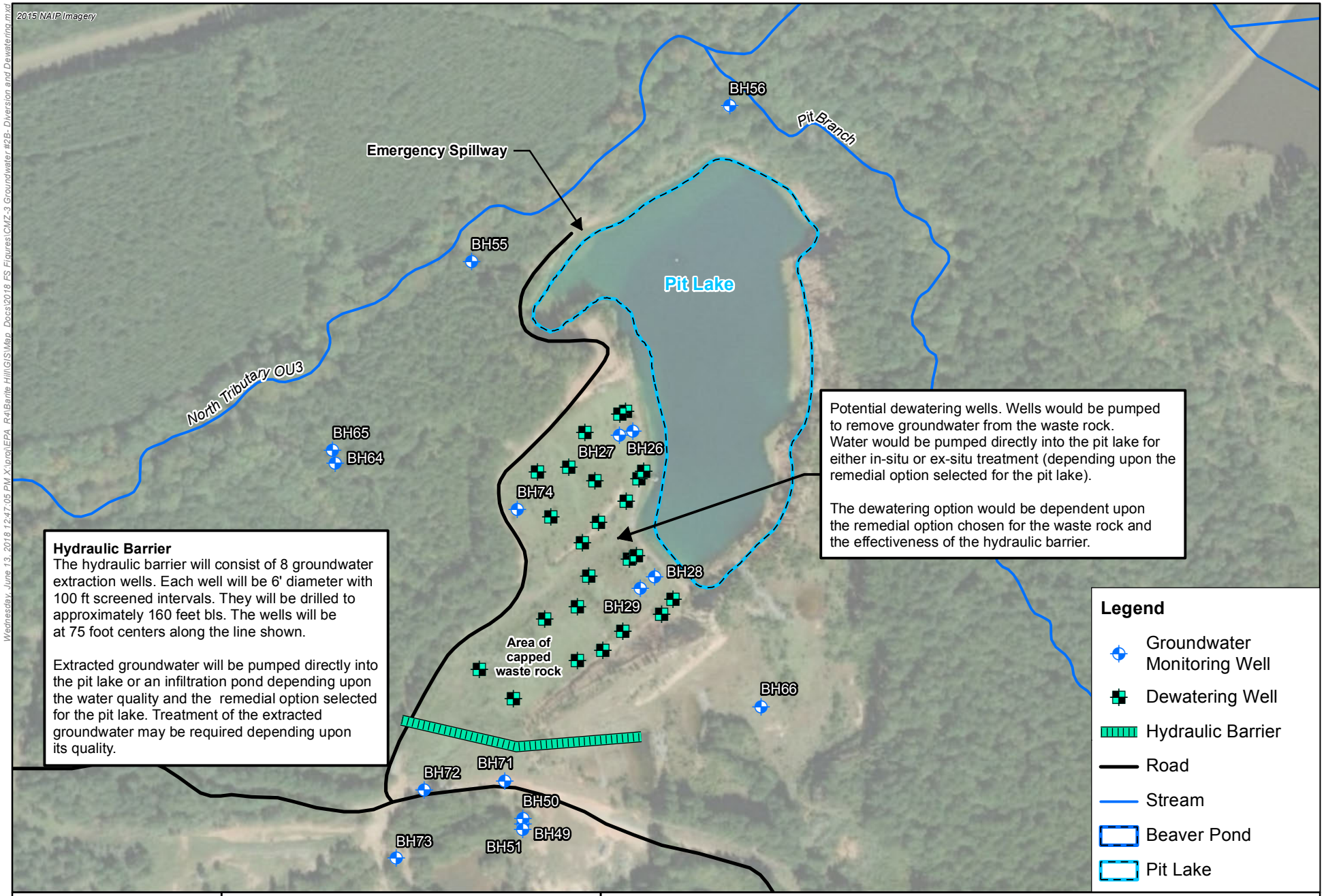

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FIGURE 5-6b

CMZ-3 Groundwater #2B:

Groundwater Diversion and Dewatering of the Capped Waste Rock

Barite Hill Mine, McCormick County, South Carolina

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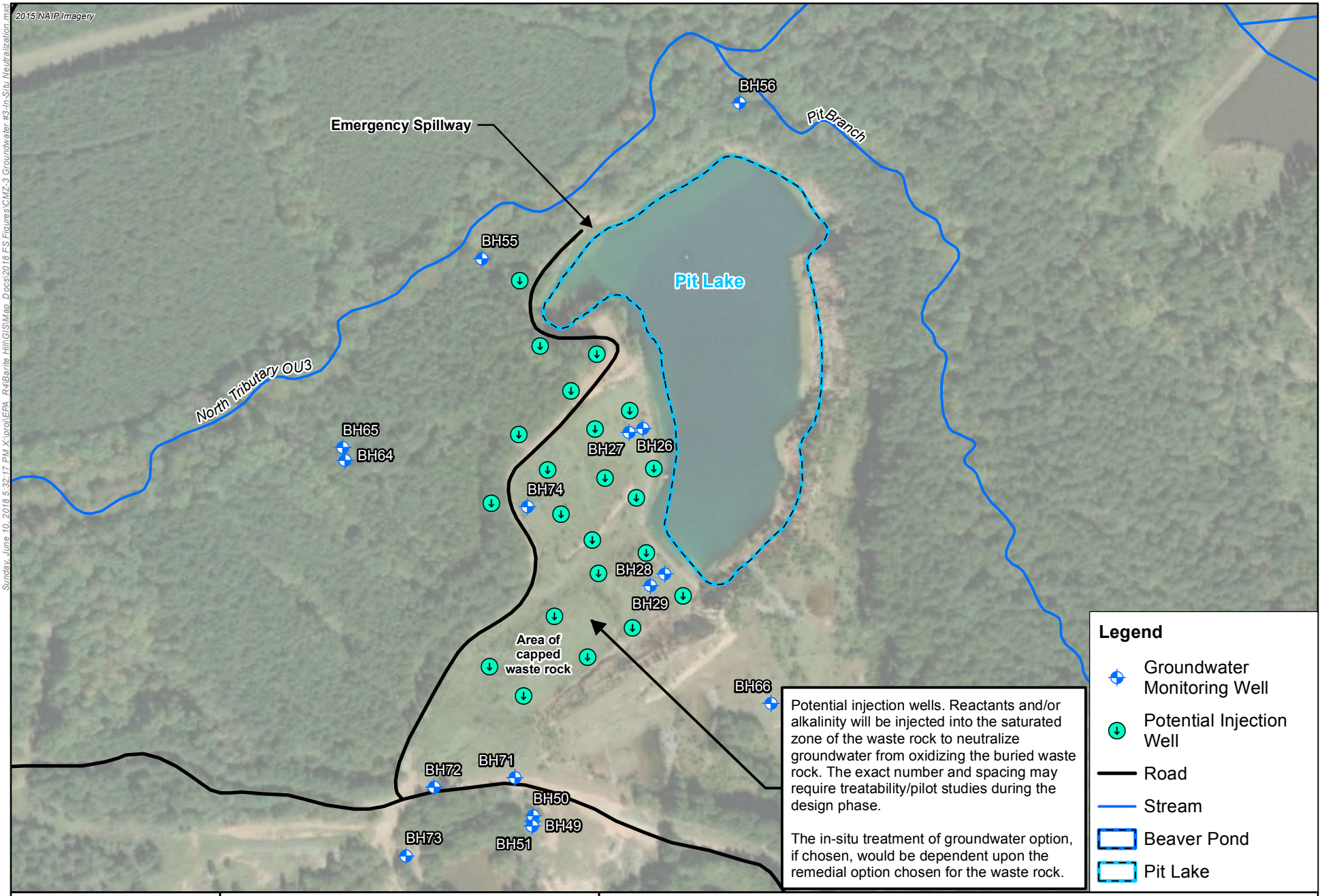

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NAD83 State Plane South Carolina, Feet

FIGURE 5-7

CMZ-3 Groundwater #3:

Groundwater In-Situ Neutralization

Barite Hill Mine, McCormick County, South Carolina

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Appendix A. Analytical Data Tables (On CD Only)

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Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
Total Metals (mg/kg)								
Aluminum	5800	3700 J,O	4100 J,O	*4200*	11600 J	15000 J	7560 J	*8100 J*
Antimony	0.5 U,J,O	0.5 U,J,O	0.5 U,J,O	*0.5 U*	1.8 J	1.5 U,J	1.9 J	*1.5 U,J*
Arsenic	12 J,O	5.2 J,O	4 J,O	*5.1 J,O*	35 J	53 J	32 J	*18 J*
Barium	430 J,O	460 J,O	570	*640*	1120 J	756 J	1120 J	*753 J*
Beryllium	0.25 J,O	0.25 U	0.25 U	*0.25 U*	0.22 U,J	0.35 J	0.22 U,J	*0.21 J*
Cadmium	2.1	12	1.3	*1.3*	73 J	25 J	10.9 J	*6.5 J*
Calcium	7800	2200 J,O	4100 J,O	*4100*	7300 J	1110 J	3260 J	*1430 J*
Chromium	14	7.7	8.5	*9.5*	12.9 J	13.7 J	10.6 J	*9.9 J*
Cobalt	13	20	7	*7.1*	69.1 J	20.8 J	8.6 J	*13.4 J*
Copper	290 J,O	460	240 J,O	*240*	1130 J	1980 J	561 J	*574 J*
Iron	32000	33000	33000	*35000*	46600 J	45500 J	42200 J	*39000 J*
Lead	86	49	49	*51*	78 J	60 J	100 J	*49 J*
Magnesium	890	930	540	*510*	989 J	1120 J	798 J	*900 J*
Manganese	320	110	190	*190*	157 J	211 J	115 J	*142 J*
Mercury	0.05 U,J,O	0.05 U,J,O	0.05 U,J,O	*0.05 U,J,O*	1.9 J	0.053 J	0.07 J	*0.03 J*
Molybdenum	2.4 J,O	1 U,J,O	2.2 J,O	*1.5*	NA	NA	NA	*NA*
Nickel	4.5	3.6	2.2	*2.2*	29.4 J	6.7 J	3 J	*1.7 J*
Potassium	580	270	500	*470*	429 J	375 J	334 J	*415 J*
Selenium	1 U,J,O	1 U,J,O	1 U,J,O	*1 U,J,O*	9 J	6.2 J	4.5 J	*3 J*
Silver	0.51	0.54	0.63	*0.6*	1.5 J	4.5 J	1.3 J	*0.894 J*
Sodium	220		130	*130*	143 J	132 J	193 J	*171 J*
Strontium	9.5	6	8.3	*8.9*	NA	NA	NA	*NA*
Thallium	0.5 U	0.5 U	0.5 U	*0.5 U*	0.073 J	0.062 J	0.059 J	*0.07 J*
Tin	1.5 U	1.5 U	1.5 U	*1.5 U*	NA	NA	NA	*NA*
Titanium	97	52 J,O	87 J,O	*80*	NA	NA	NA	*NA*
Vanadium	37	22	23	*20*	38.4 J	56.7 J	26.1 J	*27.6 J*
Yttrium	5.9	8.4	4.6	*4.4*	NA	NA	NA	*NA*
Zinc	96	240	65	*64*	1030 J	846 J	222 J	*195 J*
General Chemistry (mg/kg)								
% Solids	42	47	54	*54*	NA	NA	NA	*NA*
Acid generation potential	12.8	4.8	7.2	*7*	8.6 J	2.2 J	6.2 J	*5.9 J*
Acid neutralization potential acidity (ANPA)	0.3 U	0.3 U	2.6	*1.3*	6.4 J	0.3 U,J	7.7 J	*6.2 J*
Acid-base potential	-12.8	-4.8	-4.6	*-5.7*	-2.2 J	-2.2 J	1.4 J	*0.3 U,J*

Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
General Chemistry (mg/kg)								
Non-extractable sulfur	0.01 U	0.02 J	0.01 J	*0.008 J*	0.09 J	0.005 U,J	0.09 J	*0.09 J*
Non-sulfate Sulfur	0.42	0.17	0.24	*0.23*	0.37 J	0.07 J	0.29 J	*0.28 J*
pH	7.37	7.05	7.21	*7.32*	4.3 J	3.9 J	6 J	*6.4 J*
Pyritic Sulfur	0.41	0.15	0.23	*0.22*	0.27 J	0.07 J	0.2 J	*0.19 J*
Sulfate sulfur	1.35	0.53	0.73	*0.72*	0.87 J	0.26 J	0.46 J	*0.3 J*
Sulfur	1.77	0.7	0.97	*0.95*	1.24 J	0.33 J	0.75 J	*0.58 J*
Cyanide (total)	0.5 UJ	0.5 UJ	NA	*0.5 UJ*	NA	NA	NA	*NA*
Cyanide (WAD)	10 UJ	10 UJ	NA	*10 U*	NA	NA	NA	*NA*
Semi Volatile Organic Compounds (mg/kg)								
(3-and/or 4-)Methylphenol			530 U	*2700 U*				
1,1-Biphenyl			53 U	*270 U*				
1,2,4,5-Tetrachlorobenzene			530 U	*2700 U*				
1,2,4-Trichlorobenzene			530 U	*2700 U*				
2,3,4,6-Tetrachlorophenol			530 U,J,O	*2700 U,J,O*				
2,4,5-Trichlorophenol			530 U	*2700 U*				
2,4,6-Trichlorophenol			530 U	*2700 U*				
2,4-Dichlorophenol			530 U	*2700 U*				
2,4-Dimethylphenol			530 U,J,O	*2700 U,J,O*				
2,4-Dinitrophenol			530 U,J,O	*2700 U,J,O*				
2,4-Dinitrotoluene			530 U	*2700 U*				
2,6-Dinitrotoluene			530 U	*2700 U*				
2-Chloronaphthalene			530 U	*2700 U*				
2-Chlorophenol			530 U	*2700 U*				
2-Methyl-4,6-dinitrophenol			530 U	*2700 U*				
2-Methylnaphthalene			53 U	*270 U*				
2-Methylphenol			530 U	*2700 U*				
2-Nitroaniline			530 U	*2700 U*				
2-Nitrophenol			530 U	*2700 U*				
3,3'-Dichlorobenzidine			530 U	*2700 U*				
3-Nitroaniline			530 U	*2700 U*				
4-Bromophenyl phenyl ether			530 U	*2700 U*				
4-Chloro-3-methylphenol			530 U	*2700 U*				
4-Chloroaniline			530 U	*2700 U*				

Table A-1.1. Pit Lake Surface Water Data - 2011, 2013

Sys_Loc_Code		BH101										BH102		
Sample Date		5/3/2011	5/3/2011	5/4/2011	5/4/2011	5/3/2011	8/7/2013	8/7/2013	12/12/2013	12/12/2013		5/3/2011	5/3/2011	5/3/2011
Sample Name		BH101A-SW-001	BH101A-SW-901	BH101B-SW-001	BH101B-SW-901	BH101C-SW-001	BH101C-SW-003	BH101B-SW-002	BH101C-SW-004	BH101B-SW-003		BH102A-SW-001	BH102B-SW-001	BH102C-SW-001
End Depth		10 ft	10 ft	28 ft	28 ft	40 ft	35 ft	15 ft	50 ft	25 ft		1 ft	10 ft	19 ft
		Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform				
Field Parameters														
Temperature	°C	21.7		13.3		12.8	11.6	29.85	12.8	12.74		24.6	23.4	15.2
pH	su	5.93		6.03		6.46	3.77	3.53	3.29	4.12		6.43	6.24	6.20
Specific Conductance	µS/cm	3030		3310		3510	3067	2702	7428	3309		2820	2856	3200
Oxidation-Reduction Potential	mV	-131		-280		-282	360.2	497.7	266.2	375.2		-137	148	-176
Dissolved Oxygen	mg/L	7.3		0.28		0.14	1.02	6.4	0.92	9.36		8.4	8.4	6.0
Turbidity	NTU	3.2		8.5		5.2	4.9	4.5	9.49	5.51		2.7	2.9	4.1
Ferrous Iron	mg/L	0.03		3.85		6.87	2.33	0.07	3.30 U	2.51		0.02	0.02	0.24
Total Iron	mg/L	0.01		0.21		2.44	7.0	0.58	1.57	3.30 U		0.22	0.23	0.64
Total Metals														
Aluminum	µg/L	46.9	J	49.5 J	17 UR	17 U	500 U	1210	572	224000	711	64.9 J	40.7 J	39.7 J
Antimony	µg/L	2	U	2 U	2 U	2 U	2 U	2 U	20 U	2 U	2 U	2 U	2 U	2 U
Arsenic	µg/L	1.5	J	0.87 J	0.92 J	2 U	1.2 J	1.3 J	1 J	169	1.8 J	1.6 J	1.4 J	1.5 J
Barium	µg/L	43.8	J	44.7 J	54.6 J	54.7 J	53.4 J	37.4 J	39 J	13.8 J	33.1 J	52.5 J	50.7 J	52.2 J
Beryllium	µg/L	2	UJ	2 UJ	0.49 UR	0.49 UJ	2 UJ	2 U,J	2 U,J	1.9 J	2 U	2 UJ	2 UJ	2 UJ
Cadmium	µg/L	0.91	J	0.93 J	1.4 J	1.2 J	0.66 J	5.5	4.1	524	6.3	1.2 J	0.99 J	0.79 J
Calcium	µg/L	451000		433000	511000 J	495000	551000	483000	423000	380000	469000	455000	463000	498000
Chromium	µg/L	10	U	10 U	0.87 UR	0.87 U	10 U	0.97 J	1.1 J	86.9	4 J	10 U	10 U	10 U
Cobalt	µg/L	5.2	J	5.2 J	4.3 J	3.4 J	5 J	17.6	15.5	651 J	20.1 J	6.9 J	6.3 J	5.6 J
Copper	µg/L	69.7	J	68.6 J	21.6 J	15.2 J	29.1 J	283	147	62000	169	63.1 J	58.1 J	24.7 J
Iron	µg/L	211	J	226 J	23100 J	42900	105000	12700	551	1540000	6560	194 J	184 J	602
Lead	µg/L	0.28	J	0.26 J	0.14 J	0.09 J	0.1 J	1.9 J	5.1 J	18 J	6.3 J	0.23 J	0.26 J	0.3 J
Magnesium	µg/L	63800		63300	74800 J	74500	84300	71700	60100	172000	66900	67000	62300	74500
Manganese	µg/L	7790		7710	9990 J	10300	11800	8900	7490	18300	8010	8060	7570	9060
Mercury	µg/L	0.1	U	0.1 U	0.043 UR	0.043 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	µg/L	20	U	20 U	3 UR	3 U	20 U	22.8	12 J	312	20 U	20 U	20 U	20 U
Potassium	µg/L	31000		30100	35800 J	36000	39400	35300 J	29100 J	25400	30300	30900	32100	34800
Selenium	µg/L	3.8	J	2.9 J	5 U	5 U	2 J	1.4 J	1.3 J	34	1.3 J	4.4 J	3.4 J	4.2 J
Silver	µg/L	1	U	1 U	0.023 UR	0.024 J	0.056 J	1 U	1 U	0.053 J	1 U	1 U	1 U	1 U
Sodium	µg/L	150000		145000	159000 J	154000	166000	153000 J	127000 J	107000 J	147000 J	149000	155000	163000
Thallium	µg/L	0.018	J	0.014 J	0.012 UR	0.012 U	1 U	0.02 J	0.036 J	1 U	1 U	0.022 J	0.022 J	1 U
Vanadium	µg/L	10	U	10 U	0.75 UR	0.75 U	10 U	10 U	10 U	154	10 U	10 U	10 U	10 U
Zinc	µg/L	29.3	J	28.9 J	40.1 J	35.9	68.8 J	228 J	173 J	20600	231	55.3 J	47.9 J	18.9 J
Hardness	mg/L	1389	calc	1342 calc	1584 calc	1543 calc	1723 calc	1501 calc	1304 calc	1657 calc	1446 calc	1412 calc	1413 calc	1550 calc
Dissolved Metals														
Aluminum	µg/L	38.6	J	37.2 J	17.2 UR	17.2 U	42900	500 U	598	227000	668	51.8 J	19.3 J	53.1 J
Antimony	µg/L	2	U	2 U	2 U	2 U	2 U	0.13 J	0.16 J	2 U	2 U	2 U	2 U	2 U
Arsenic	µg/L	2	U	2 U	2 U	2 U	3.7	0.66 J	0.78 J	190	1.6 J	2 U	2 U	2 U
Barium	µg/L	48.2	J	52.7 J	55.7 J	52.3 J	53.8 J	33.2 J	37.2 J	13.3 J	32 J	48 J	48.8 J	50.7 J
Beryllium	µg/L	2	U	2 U	0.49 UR	0.49 UJ	2 U	0.25 U,J	2 U,J	2.2 J	2 U,J	2 U	2 U	2 U
Cadmium	µg/L	0.91	J	0.95 J	1.3 J	1.3 J	44.1 J	2.7	4.4	553	6.7	1.2 J	1 J	0.69 J
Calcium	µg/L	491000		508000	511000 J	538000	481000	480000	409000	364000	452000	441000	456000	460000
Chromium	µg/L	10.1	U	10.1 U	0.88 UR	0.88 U	8.9 J	10 U	10 U	87.8	3.6 J	10.1 U	10.1 U	10.1 U
Cobalt	µg/L	5.2	J	5.5 J	4.4 J	4.1 J	260	13.5	14.9	710 J	19.2 J	5.9 J	5.6 J	4.9 J
Copper	µg/L	56.5	J	57.5 J	14.5 J	14.3 J	1840 J	43	162	87200	178	44.2 J	44.6 J	18.6 J
Iron	µg/L	252	U	252 U	32700 J	32100	511000	5460	132 J	1620000	5730	252 U	252 U	235 J
Lead	µg/L	0.07	J	1 U	0.04 UR	0.04 U	0.27 J	0.55 J	5.4 J	19 J	6.6 J	1 U	1 U	1 U

Table A-1.1. Pit Lake Surface Water Data - 2011, 2013

Sys_Loc_Code		BH101										BH102		
Sample Date		5/3/2011	5/3/2011	5/4/2011	5/4/2011	5/3/2011	8/7/2013	8/7/2013	12/12/2013	12/12/2013		5/3/2011	5/3/2011	5/3/2011
Sample Name		BH101A-SW-001	BH101A-SW-901	BH101B-SW-001	BH101B-SW-901	BH101C-SW-001	BH101C-SW-003	BH101B-SW-002	BH101C-SW-004	BH101B-SW-003		BH102A-SW-001	BH102B-SW-001	BH102C-SW-001
End Depth		10 ft	10 ft	28 ft	28 ft	40 ft	35 ft	15 ft	50 ft	25 ft		1 ft	10 ft	19 ft
		Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform				
Dissolved Metals - continued														
Magnesium	µg/L	70800	69400 J	74900 J	75300	97200 J	70800	57400	168000	62500		57200 J	65800 J	72300 J
Manganese	µg/L	8810	8710	10200 J	10200	13300	8890	7370	19200	8050		7210	8220	9130
Mercury	µg/L	0.1 U	0.1 U	0.043 UR	0.043 U	0.1 U	0.1 U	0.1 J	0.1 U	0.1 U		0.1 U	0.1 U	0.1 U
Nickel	µg/L	20.2 U	20.2 U	3 UR	3 U	54.2	7.9 J	11.2 J	317	20.2 U		20.2 U	20.2 U	20.2 U
Potassium	µg/L	35500	36800	36000 J	36400	33800	34300 J	28100 U,J	24500	30100		32900	33300	35600
Selenium	µg/L	3 J	3.8 J	5 U	5 U	3.9 J	1.2 J	1.3 J	36 J	1.2 J		3.6 J	2.5 J	4.3 J
Silver	µg/L	1 U	1 U	0.023 UR	0.027 J	0.23 J	1 U	1 U	0.018 J	1 U,J		1 U	1 U	1 U
Sodium	µg/L	164000	171000	156000 J	162000	132000	156000 J	129000 J	104000 J	143000 J		153000	155000	165000
Thallium	µg/L	0.019 J	0.015 J	0.012 UR	0.012 U	0.087 J	0.011 J	0.038 J	0.86 J	0.045 J		0.023 J	0.024 J	0.015 J
Vanadium	µg/L	10.1 U	10.1 U	0.76 UR	0.76 U	16.6	10 U	10 U	144	10.1 U		10.1 U	10.1 U	10.1 U
Zinc	µg/L	28.6 J	31.8 J	41.2 J	38.1 J	1950 J	123 J	173 J	21300	225		46.4 J	42.3 J	15.2 J
Hardness	mg/L	1517 calc	1554 calc	1584 calc	1653 calc	1601 calc	1490 calc	1258 calc	1600 calc	1386 calc		1337 calc	1409 calc	1446 calc
Anions and Classicals														
Acidity	mg/L	10 U	10 U	2.5 U	2.5 U	10 U	52	80.6	4200	49.8		10 U	10 U	10 U
Alkalinity, Bicarbonate (as CaCO3)	mg/L	12.3	12	62.4	62.7	79.4	1 U	1 U	1 U	1 U		7.7	9.5	13.6
Alkalinity, Carbonate (as CaCO3)	mg/L	1 U	1 U	0.5 U	0.5 U	1 U	1 U	1 U	1 U	1 U		1 U	1 U	1 U
Alkalinity, Total (as CaCO3)	mg/L	12.3	12	62.4	62.7	79.4	1 U	1 U	1 U	1 U		7.7	9.5	13.6
Ammonia as N	mg/L	6.21	6.05	8.33	8.38	8.12						0.05 U	5.7	0.05 U
Chloride	mg/L	29.2	28.9	31.8	31.7	30.9	28.3	24.2	32.5	26.6		26.5	26.6	30.3
Cyanide (Free - ASTM D 7273)	µg/L	5 UJ	5 UJ	0.9 U	0.9 U	5 UJ						5 UJ	5 UJ	5 UJ
Cyanide (Total - EPA 335.4)	µg/L	15 U	15 U	13 J	16	20						3 J	2 J	8 J
Nitrate/Nitrite as N	mg/L	0.111	0.109	0.23 J	0.15 UJ	0.5 U	0.056 J	0.087 J	0.494 J	0.08 J		0.12	0.099	0.054
Sulfate as SO4	mg/L	1770	1780	1950	2010	1940	1920	1630	6560	1890		1590	1650	1860
Total Dissolved Solids	mg/L	2200 J	2190 J	2960	2590	2560 J	2700	2370	9420	2470		2010 J	1870 J	2390 J
Total Suspended Solids	mg/L	5 J	5 U	33 J	30 J	32 J	8 J	11 J	18	5 U		5 U	6 J	5 U
Semi-volatile Organic Compounds														
(3-and/or 4-)Methylphenol	µg/L	10 U	10 U											
1,1-Biphenyl	µg/L	2 U	2 U											
2,3,4,6-Tetrachlorophenol	µg/L	10 U	10 U											
2,4,5-Trichlorophenol	µg/L	10 U	10 U											
2,4,6-Trichlorophenol	µg/L	10 U	10 U											
2,4-Dichlorophenol	µg/L	10 U	10 U											
2,4-Dimethylphenol	µg/L	10 U	10 U											
2,4-Dinitrophenol	µg/L	10 U	10 U											
2,4-Dinitrotoluene	µg/L	10 U	10 U											
2,6-Dinitrotoluene	µg/L	10 U	10 U											
2-Chloronaphthalene	µg/L	10 U	10 U											
2-Chlorophenol	µg/L	10 U	10 U											
2-Methyl-4,6-dinitrophenol	µg/L	10 U	10 U											
2-Methylnaphthalene	µg/L	2 U	2 U											
2-Methylphenol	µg/L	10 U	10 U											
2-Nitroaniline	µg/L	10 U	10 U											
2-Nitrophenol	µg/L	10 U	10 U											
3,3'-Dichlorobenzidine	µg/L	10 U	10 U											
3-Nitroaniline	µg/L	10 U	10 U											

Table A-1.1. Pit Lake Surface Water Data - 2011, 2013

Sys_Loc_Code		BH101										BH102		
Sample Date		5/3/2011	5/3/2011	5/4/2011	5/4/2011	5/3/2011	8/7/2013	8/7/2013	12/12/2013	12/12/2013		5/3/2011	5/3/2011	5/3/2011
Sample Name		BH101A-SW-001	BH101A-SW-901	BH101B-SW-001	BH101B-SW-901	BH101C-SW-001	BH101C-SW-003	BH101B-SW-002	BH101C-SW-004	BH101B-SW-003		BH102A-SW-001	BH102B-SW-001	BH102C-SW-001
End Depth		10 ft	10 ft	28 ft	28 ft	40 ft	35 ft	15 ft	50 ft	25 ft		1 ft	10 ft	19 ft
		Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform				
Semi-volatile Organic Compounds														
4-Bromophenyl phenyl ether	µg/L	10 U	10 U											
4-Chloro-3-methylphenol	µg/L	10 U	10 U											
4-Chloroaniline	µg/L	10 U	10 U											
4-Chlorophenyl phenyl ether	µg/L	10 U	10 U											
4-Nitroaniline	µg/L	10 U	10 U											
4-Nitrophenol	µg/L	10 U	10 U											
Acenaphthene	µg/L	2 U	2 U											
Acenaphthylene	µg/L	2 U	2 U											
Acetophenone	µg/L	10 U	10 U											
Anthracene	µg/L	2 U	2 U											
Atrazine	µg/L	10 U	10 U											
Benzaldehyde	µg/L	10 U	10 U											
Benzo(a)anthracene	µg/L	2 U	2 U											
Benzo(a)pyrene	µg/L	2 U	2 U											
Benzo(b)fluoranthene	µg/L	2 U	2 U											
Benzo(g,h,i)perylene	µg/L	2 U	2 U											
Benzo(k)fluoranthene	µg/L	2 U	2 U											
Benzyl butyl phthalate	µg/L	10 U	10 U											
Bis(2-chloroethoxy)methane	µg/L	10 U	10 U											
bis(2-Chloroethyl) Ether	µg/L	10 U	10 U											
Bis(2-chloroisopropyl) ether	µg/L	10 U	10 U											
Bis(2-ethylhexyl) phthalate	µg/L	10 U	10 U											
Caprolactam	µg/L	10 U	10 U											
Carbazole	µg/L	2 U	2 U											
Chrysene	µg/L	2 U	2 U											
Dibenzo(a,h)anthracene	µg/L	2 U	2 U											
Dibenzofuran	µg/L	2 U	2 U											
Diethyl phthalate	µg/L	10 U	10 U											
Dimethyl phthalate	µg/L	10 U	10 U											
Di-n-butylphthalate	µg/L	10 U	10 U											
Di-n-octylphthalate	µg/L	10 U	10 U											
Fluoranthene	µg/L	2 U	2 U											
Fluorene	µg/L	2 U	2 U											
Hexachlorobenzene (HCB)	µg/L	10 U	10 U											
Hexachlorocyclopentadiene (HCCP)	µg/L	10 U	10 U											
Hexachloroethane	µg/L	10 U	10 U											
Indeno (1,2,3-cd) pyrene	µg/L	2 U	2 U											
Isophorone	µg/L	10 U	10 U											
Naphthalene	µg/L	2 U	2 U											
Naphthalene, 1-methyl-	µg/L	2 U	2 U											
Nitrobenzene	µg/L	10 U	10 U											
n-Nitroso di-n-Propylamine	µg/L	10 U	10 U											
n-Nitrosodiphenylamine/Diphenylamine	µg/L	10 U	10 U											
Pentachlorophenol	µg/L	10 U	10 U											
Phenanthrene	µg/L	2 U	2 U											
Phenol	µg/L	10 U	10 U											
Pyrene	µg/L	2 U	2 U											

Table A-1.1. Pit Lake Surface Water Data - 2011, 2013

Sys_Loc_Code		BH101										BH102		
Sample Date		5/3/2011	5/3/2011	5/4/2011	5/4/2011	5/3/2011	8/7/2013	8/7/2013	12/12/2013	12/12/2013		5/3/2011	5/3/2011	5/3/2011
Sample Name		BH101A-SW-001	BH101A-SW-901	BH101B-SW-001	BH101B-SW-901	BH101C-SW-001	BH101C-SW-003	BH101B-SW-002	BH101C-SW-004	BH101B-SW-003		BH102A-SW-001	BH102B-SW-001	BH102C-SW-001
End Depth		10 ft	10 ft	28 ft	28 ft	40 ft	35 ft	15 ft	50 ft	25 ft		1 ft	10 ft	19 ft
		Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform				
Organophosphorous Pesticides														
4,4'-DDD (p,p'-DDD)	µg/L	0.039	U	0.04	U									
4,4'-DDE (p,p'-DDE)	µg/L	0.02	U	0.02	U									
4,4'-DDT (p,p'-DDT)	µg/L	0.049	U	0.051	U									
Aldrin	µg/L	0.02	U	0.02	U									
alpha-BHC	µg/L	0.0099	U	0.01	U									
alpha-Chlordane	µg/L	0.02	U	0.02	U									
beta-BHC	µg/L	0.02	U	0.02	U									
delta-BHC	µg/L	0.02	U	0.02	U									
Dieldrin	µg/L	0.02	U	0.02	U									
Endosulfan I (alpha)	µg/L	0.02	U	0.02	U									
Endosulfan II (beta)	µg/L	0.039	U	0.04	U									
Endosulfan Sulfate	µg/L	0.049	U	0.051	U									
Endrin	µg/L	0.039	U	0.04	U									
Endrin aldehyde	µg/L	0.049	U	0.051	U									
Endrin ketone	µg/L	0.049	U	0.051	U									
gamma-BHC (Lindane)	µg/L	0.0099	U	0.01	U									
gamma-Chlordane	µg/L	0.02	U	0.02	U									
Heptachlor	µg/L	0.015	U	0.015	U									
Heptachlor epoxide	µg/L	0.02	U	0.02	U									
Methoxychlor	µg/L	0.099	U	0.1	U									
Toxaphene	µg/L	2	U	2	U									
PCB Aroclors														
PCB-1016 (Aroclor 1016)	µg/L	0.25	U	0.25	U									
PCB-1221 (Aroclor 1221)	µg/L	0.49	U	0.51	U									
PCB-1232 (Aroclor 1232)	µg/L	0.25	U	0.25	U									
PCB-1242 (Aroclor 1242)	µg/L	0.25	U	0.25	U									
PCB-1248 (Aroclor 1248)	µg/L	0.25	U	0.25	U									
PCB-1254 (Aroclor 1254)	µg/L	0.25	U	0.25	U									
PCB-1260 (Aroclor 1260)	µg/L	0.25	U	0.25	U									
PCB-1262 (Aroclor 1262)	µg/L	0.25	U	0.25	U									
PCB-1268 (Aroclor 1268)	µg/L	0.25	U	0.25	U									
Volatile Organic Compounds														
(m- and/or p-)Xylene	µg/L	1	U	1	U									
1,1,1,2-Tetrachloroethane	µg/L	0.5	U	0.5	U									
1,1,1-Trichloroethane	µg/L	0.5	U	0.5	U									
1,1,2,2-Tetrachloroethane	µg/L	0.5	U	0.5	U									
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	0.5	U	0.5	U									
1,1,2-Trichloroethane	µg/L	0.5	U	0.5	U									
1,1-Dichloroethane	µg/L	0.5	U	0.5	U									
1,1-Dichloroethene	µg/L	0.5	U	0.5	U									
1,1-Dichloropropene	µg/L	0.5	U	0.5	U									
1,2,3-Trichlorobenzene	µg/L	0.5	U	0.5	U									
1,2,3-Trichloropropane	µg/L	0.5	U	0.5	U									
1,2,4-Trichlorobenzene	µg/L	0.5	U	0.5	U									
1,2,4-Trimethylbenzene	µg/L	0.5	U	0.5	U									

Table A-1.1. Pit Lake Surface Water Data - 2011, 2013

Sys_Loc_Code		BH101										BH102		
Sample Date		5/3/2011	5/3/2011	5/4/2011	5/4/2011	5/3/2011	8/7/2013	8/7/2013	12/12/2013	12/12/2013		5/3/2011	5/3/2011	5/3/2011
Sample Name		BH101A-SW-001	BH101A-SW-901	BH101B-SW-001	BH101B-SW-901	BH101C-SW-001	BH101C-SW-003	BH101B-SW-002	BH101C-SW-004	BH101B-SW-003		BH102A-SW-001	BH102B-SW-001	BH102C-SW-001
End Depth		10 ft	10 ft	28 ft	28 ft	40 ft	35 ft	15 ft	50 ft	25 ft		1 ft	10 ft	19 ft
		Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform				
Volatile Organic Compounds														
1,2-Dibromo-3-Chloropropane (DBCP)	µg/L	1	U	1	U									
1,2-Dibromoethane (EDB)	µg/L	0.5	U	0.5	U									
1,2-Dichlorobenzene	µg/L	0.5	U	0.5	U									
1,2-Dichloroethane	µg/L	0.5	U	0.5	U									
1,2-Dichloropropane	µg/L	0.5	U	0.5	U									
1,3,5-Trimethylbenzene	µg/L	0.5	U	0.5	U									
1,3-Dichlorobenzene	µg/L	0.5	U	0.5	U									
1,3-Dichloropropane	µg/L	0.5	U	0.5	U									
1,4-Dichlorobenzene	µg/L	0.5	U	0.5	U									
2,2-Dichloropropane	µg/L	0.5	U	0.5	U									
Acetone	µg/L	4	U	4	U									
Benzene	µg/L	0.5	U	0.5	U									
Bromobenzene	µg/L	0.5	U	0.5	U									
Bromochloromethane	µg/L	0.5	U	0.5	U									
Bromodichloromethane	µg/L	0.5	U	0.5	U									
Bromoform	µg/L	1	U	1	U									
Bromomethane	µg/L	2	U	2	U									
Carbon disulfide	µg/L	0.5	U	0.5	U									
Carbon Tetrachloride	µg/L	0.5	U	0.5	U									
Chlorobenzene	µg/L	0.5	U	0.5	U									
Chloroethane	µg/L	0.5	U	0.5	U									
Chloroform	µg/L	0.5	U	0.5	U									
Chloromethane	µg/L	0.5	U	0.5	U									
cis-1,2-Dichloroethene	µg/L	0.5	U	0.5	U									
cis-1,3-Dichloropropene	µg/L	2	U	2	U									
Cyclohexane	µg/L	0.5	U	0.5	U									
Dibromochloromethane	µg/L	0.5	U	0.5	U									
Dibromomethane	µg/L	0.5	U	0.5	U									
Dichlorodifluoromethane	µg/L	0.5	U,J,O	0.5	U,J,O									
Ethyl Benzene	µg/L	0.5	U	0.5	U									
Hexachlorobutadiene	µg/L	0.5	U	0.5	U									
Isopropylbenzene	µg/L	0.5	U	0.5	U									
Methyl Acetate	µg/L	1	U	1	U									
Methyl Butyl Ketone	µg/L	4	U	4	U									
Methyl Ethyl Ketone	µg/L	1	U	1	U									
Methyl Isobutyl Ketone	µg/L	1	U	1	U									
Methyl T-Butyl Ether (MTBE)	µg/L	0.5	U	0.5	U									
Methylcyclohexane	µg/L	0.5	U	0.5	U									
Methylene Chloride	µg/L	0.5	U	0.5	U									
n-Butylbenzene	µg/L	0.5	U	0.5	U									
n-Propylbenzene	µg/L	0.5	U	0.5	U									
o-Chlorotoluene	µg/L	0.5	U	0.5	U									
o-Xylene	µg/L	0.5	U	0.5	U									
p-Chlorotoluene	µg/L	0.5	U	0.5	U									
p-Isopropyltoluene	µg/L	0.5	U	0.5	U									
sec-Butylbenzene	µg/L	0.5	U	0.5	U									
Styrene	µg/L	0.5	U	0.5	U									

Table A-1.1. Pit Lake Surface Water Data - 2011, 2013

Sys_Loc_Code		BH101										BH102		
Sample Date		5/3/2011	5/3/2011	5/4/2011	5/4/2011	5/3/2011	8/7/2013	8/7/2013	12/12/2013	12/12/2013		5/3/2011	5/3/2011	5/3/2011
Sample Name		BH101A-SW-001	BH101A-SW-901	BH101B-SW-001	BH101B-SW-901	BH101C-SW-001	BH101C-SW-003	BH101B-SW-002	BH101C-SW-004	BH101B-SW-003		BH102A-SW-001	BH102B-SW-001	BH102C-SW-001
End Depth		10 ft	10 ft	28 ft	28 ft	40 ft	35 ft	15 ft	50 ft	25 ft		1 ft	10 ft	19 ft
		Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform	Off platform				
Volatile Organic Compounds														
tert-Butylbenzene	µg/L	0.5	U	0.5	U									
Tetrachloroethene	µg/L	0.5	U	0.5	U									
Toluene	µg/L	0.5	U	0.5	U									
trans-1,2-Dichloroethene	µg/L	0.5	U	0.5	U									
trans-1,3-Dichloropropene	µg/L	5	U	5	U									
Trichloroethene (Trichloroethylene)	µg/L	0.5	U	0.5	U									
Trichlorofluoromethane (Freon 11)	µg/L	0.5	U	0.5	U									
Vinyl chloride	µg/L	0.5	U	0.5	U									

Notes:

°C - degrees Celsius

ft - feet

italicized - duplicate sample

mg/L - milligrams per liter

µg/L - micrograms per liter

µS/cm - microsiemens per centimeter

mV - millivolt

NTU - nephelometric turbidity units

su - standard units

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

UJ - the analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Table A-1.1. Pit Lake Surface Water Data - 2011, 20

Sys_Loc_Code		BH103			BH104								
Sample Date		5/2/2011	5/2/2011	5/2/2011	5/4/2011	5/4/2011	5/4/2011	8/7/2013	8/7/2013	8/7/2013	12/12/2013	12/12/2013	12/12/2013
Sample Name		BH103A-SW-001	BH103B-SW-001	BH103C-SW-001	BH104A-SW-001	BH104B-SW-001	BH104C-SW-001	BH104C-SW-002	BH104C-SW-902	BH104B-SW-002	BH104C-SW-003	BH104B-SW-003	BH104B-SW-903
End Depth		2 ft	10 ft	21 ft	5 ft 40 ft from cliff	20 ft 40 ft from cliff	32 ft 40 ft from cliff	35 ft	35 ft	15 ft	35 ft	20 ft	20 ft
Field Parameters													
Temperature	°C	26.1	23.4	17.4	25.5	15.1	13.7	12.09	12.09	29.89	12.7	12.74	12.74
pH	su	6.60	6.26	6.17	6.38	6.00	6.37	3.52	3.52	3.41	3.72	4.01	4.01
Specific Conductance	µS/cm	2824	2898	3120	2809	3190	3400	3053	3053	2685	3313	3313	3313
Oxidation-Reduction Potential	mV	284	129	163	-54	-80	-119	363.4	363.4	501.8	391.0	376.8	376.8
Dissolved Oxygen	mg/L	8.2	7.2	5.5	8.5	6.1	0.1	0.84	0.84	6.69	9.15	9.2	9.2
Turbidity	NTU	3.3	3.5	61.1	2.5	3.7	5.5	5.2	5.2	4.3	5.91	7.21	7.21
Ferrous Iron	mg/L	0.06	0.05	0.40	0.04	0.46	0.77	1.81		0.03	3.30 U	2.81	2.81
Total Iron	mg/L	0.26	0.30	0.31	0.21	0.84	1.61	6.8		0.58	3.30 U	3.30 U	3.30 U
Total Metals													
Aluminum	µg/L	79.2 J	40.6 J	35.6 J	59.7 J	29.4 J	17 U	250 J	203 J	568	690	686	692
Antimony	µg/L	2 U	2 U	2 U	0.07 U	0.07 U	0.07 U	2 U	2 U	2 U	2 U	2 U	2 U
Arsenic	µg/L	1.2 J	1.1 J	1.1 J	1.7 J	1.7 J	1.5 J	0.86 J	0.81 J	0.95 J	1.8 J	1.8 J	1.7 J
Barium	µg/L	46.5 J	45.7 J	49.7 J	52.6 J	53 J	61.7 J	33 J	31.7 J	38.1 J	32.2 J	32.9 J	32.6 J
Beryllium	µg/L	2 UJ	2 UJ	2 UJ	0.49 UJ	0.49 UJ	0.49 UJ	2 U,J	2 U,J	2 U,J	2 U	2 U	2 U
Cadmium	µg/L	1.1 J	1 J	0.82 J	1.1 J	0.87 J	0.13 J	2.7	2.6	4.1	6.4	6.3	6.2
Calcium	µg/L	477000	380000	516000	452000	505000	541000	509000	504000	412000	457000	463000	460000
Chromium	µg/L	10 U	10 U	10 U	0.87 U	0.87 U	0.87 U	0.91 J	10 U	10 U	3.8 J	3.7 J	3.5 J
Cobalt	µg/L	6.1 J	5.6 J	5.2 J	6.6 J	5.4 J	2.3 J	14.8	14.2	15.8	20 J	20.1 J	19.7 J
Copper	µg/L	64.4 J	74.2 J	28.9 J	61.9 J	30.6 J	11.9 J	45	42	149	176	172	167
Iron	µg/L	199 J	238 J	723	160 J	795	70500	5810	5610	537	6530	6350	6340
Lead	µg/L	0.25 J	0.29 J	0.2 J	0.43 J	0.19 J	0.13 J	0.64 J	0.64 J	5.1 J	6.4 J	6.4 J	6.2 J
Magnesium	µg/L	66900	59600	76100	61600	71400	78500	76600	76200	59300	64700	65100	65000
Manganese	µg/L	8120	7390	9360	7700	8910	11100	9380	9290	7420	7790	7900	7810
Mercury	µg/L	0.1 U	0.1 U	0.1 U	0.043 U	0.043 U	0.043 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	µg/L	20 U	20 U	20 U	3 U	3 U	3 U	14.1 J	13.8 J	10.1 J	20 U	20 U	20 U
Potassium	µg/L	33600	31900	37200	31600	35900	37300	38000 J	36600 J	29100 J	29200	29300	29300
Selenium	µg/L	3.7 J	2.9 J	3.1 J	5 U	5 U	5 U	1.4 J	1.3 J	1.4 J	1.2 J	1.2 J	1.2 J
Silver	µg/L	1 U	1 U	1 U	0.023 U	0.023 U	0.034 J	1 U	1 U	1 J	1 U	1 U	1 U
Sodium	µg/L	162000	140000	180000	156000	170000	161000	162000 J	161000 J	126000 J	141000 J	142000 J	141000 J
Thallium	µg/L	0.026 J	0.022 J	1 U	0.029 J	0.012 U	0.012 U	0.011 J	1 U	0.032 J	1 U	1 U	1 U
Vanadium	µg/L	10 U	10 U	10 U	0.75 U	0.75 U	0.75 U	10 U	10 U	10 U	10 U	10 U	10 U
Zinc	µg/L	49.8 J	41.4 J	18.3 J	51	18.8	18.5	123 J	121 J	177 J	224	228	225
Hardness	mg/L	1466 calc	1194 calc	1602 calc	1382 calc	1555 calc	1674 calc	1586 calc	1572 calc	1273 calc	1407 calc	1424 calc	1416 calc
Dissolved Metals													
Aluminum	µg/L	505 U	505 U	34.4 J	505 U	505 U	17.2 U	500 U	500 U	594	703	697	702
Antimony	µg/L	2 U	2 U	2 U	2 U	0.071 U	0.071 U	2 U	2 U	2 U	2 U	2 U	2 U
Arsenic	µg/L	2 U	2 U	2 U	2.1 J	2 U	2.3 J	0.63 J	0.66 J	0.75 J	1.6 J	1.6 J	1.6 J
Barium	µg/L	48.6 J	48.1 J	50.9 J	47.4 J	54 J	68.3 J	30.2 J	32 J	38.8 J	32.3 J	32.3 J	32.4 J
Beryllium	µg/L	2 UJ	2 UJ	2 UJ	0.49 UJ	0.49 UJ	0.49 UJ	0.25 U,J	2 U,J	0.25 U,J	2 U,J	2 U,J	2 U,J
Cadmium	µg/L	1.2 J	1 J	0.87 J	1.2 J	0.88 J	0.026 U	2.7	2.7	4.3	6.6	6.6	6.6
Calcium	µg/L	438000	461000	509000	425000	494000	519000	479000	482000	415000	462000	455000	474000
Chromium	µg/L	10.1 U	10.1 U	10.1 U	0.88 U	0.94 J	0.88 U	10 U	10 U	10 U	3.4 J	3.2 J	3.6 J
Cobalt	µg/L	6.9 J	7.3 J	5.4 J	6.5 J	6 J	2.5 J	12.4	13.7	15.7	19.8 J	19.3 J	20.2 J
Copper	µg/L	44.7 J	60 J	26.3 J	47.3 J	26.8 J	2 J	43	42	156	179	183	178
Iron	µg/L	252 U	252 U	712	27.3 U	487	67800	4580	4620	120 J	5850	5750	5750
Lead	µg/L	1 U	1 U	0.18 J	0.04 U	0.04 U	0.04 U	0.53 J	0.55 J	5.1 J	6.7 J	6.7 J	6.7 J

Table A-1.1. Pit Lake Surface Water Data - 2011, 20

Sys_Loc_Code		BH103			BH104								
Sample Date		5/2/2011	5/2/2011	5/2/2011	5/4/2011	5/4/2011	5/4/2011	8/7/2013	8/7/2013	8/7/2013	12/12/2013	12/12/2013	12/12/2013
Sample Name		BH103A-SW-001	BH103B-SW-001	BH103C-SW-001	BH104A-SW-001	BH104B-SW-001	BH104C-SW-001	BH104C-SW-002	BH104C-SW-902	BH104B-SW-002	BH104C-SW-003	BH104B-SW-003	BH104B-SW-903
End Depth		2 ft	10 ft	21 ft	5 ft 40 ft from cliff	20 ft 40 ft from cliff	32 ft 40 ft from cliff	35 ft	35 ft	15 ft	35 ft	20 ft	20 ft
Dissolved Metals - continued													
Magnesium	µg/L	63100 J	61100 J	70600 J	61300	69700	75700	70600	71800	59200	63100	62900	63500
Manganese	µg/L	7500	7310	8480	7580	8690	10800	8860	8930	7450	8090	8060	8060
Mercury	µg/L	0.1 U	0.1 U	0.1 U	0.043 U	0.043 U	0.043 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	µg/L	20.2 U	20.2 U	20.2 U	3 U	3 U	3 U	14.9 J	10.5 J	8.3 J	20.2 U	20.2 U	20.2 U
Potassium	µg/L	31900	33700	38400	31000	37100	37500	34100 J	34200 J	28000 J	29900	29800	29700
Selenium	µg/L	4.2 J	3.4 J	4.5 J	5 U	5 U	5 U	1.1 J	1.1 J	1.4 J	1.3 J	1.3 J	1.4 J
Silver	µg/L	1 U	1 U	1 U	0.023 U	0.023 U	0.026 J	1 U	1 U	1 U	1 U,J	1 U,J	1 U,J
Sodium	µg/L	155000	162000	186000	145000	171000	155000	155000 J	155000 J	128000 J	144000 J	143000 J	148000 J
Thallium	µg/L	0.025 J	0.025 J	0.012 J	0.028 J	0.012	0.012 U	0.01 J	0.012 J	0.033 J	0.039 J	0.041 J	0.039 J
Vanadium	µg/L	10.1 U	10.1 U	10.1 U	0.76 U	0.76 U	0.76 U	10 U	10 U	10 U	10.1 U	10.1 U	10.1 U
Zinc	µg/L	50	42.9	18.7	48.6 J	22.1 J	19.8 J	112 J	120 J	183 J	230	229	230
Hardness	mg/L	1353 calc	1403 calc	1562 calc	1314 calc	1520 calc	1608 calc						
Anions and Classicals													
Acidity	mg/L	10 U	10 U	10 U	2.5 U	2.5 U	2.5 U	31.8	11.7	60.5	39.8	39.8	39.8
Alkalinity, Bicarbonate (as CaCO3)	mg/L	7.8	10.9	13.1	8.8	13.4	77.4	1 U	1 U	1 U	1 U	1 U	1 U
Alkalinity, Carbonate (as CaCO3)	mg/L	1 U	1 U	1 U	0.5 U	0.5 U	0.5 U	1 U	1 U	1 U	1 U	1 U	1 U
Alkalinity, Total (as CaCO3)	mg/L	7.8	10.9	13.1	8.8	13.4	77.4	1 U	1 U	1 U	1 U	1 U	1 U
Ammonia as N	mg/L	5.59	0.05 U	6.83	5.91	6.65	8.09						
Chloride	mg/L	25.9	27.4	30.2	27.7	31	32	28.6	28.5	24.1	26.8	26.6	26.7
Cyanide (Free - ASTM D 7273)	µg/L	5 UJ	5 UJ	5 UJ	0.9 U	0.9 U	0.9 U						
Cyanide (Total - EPA 335.4)	µg/L	3 J	15 U	8 J	3 J	8 J	18						
Nitrate/Nitrite as N	mg/L	0.12	0.093	0.048 J	0.114 J	0.048 J	0.15 UJ	0.062 J	0.054 J	0.072 J	0.124 J	0.199 J	0.191 J
Sulfate as SO4	mg/L	1600	166	1840	1710	1960	2040	1970	1930	1630	1870	1870	1870
Total Dissolved Solids	mg/L	2360 J	1910 J	2140 J	2080	2430	2560	2620	2700	2290	2460	2510	2480
Total Suspended Solids	mg/L	5 U	5 J	5 U	5 U	6 J	58 J	10 J	9 J	5 U,J	7	5 U	5 U
Semi-volatile Organic Compounds													
(3-and/or 4-)Methylphenol	µg/L												
1,1-Biphenyl	µg/L												
2,3,4,6-Tetrachlorophenol	µg/L												
2,4,5-Trichlorophenol	µg/L												
2,4,6-Trichlorophenol	µg/L												
2,4-Dichlorophenol	µg/L												
2,4-Dimethylphenol	µg/L												
2,4-Dinitrophenol	µg/L												
2,4-Dinitrotoluene	µg/L												
2,6-Dinitrotoluene	µg/L												
2-Chloronaphthalene	µg/L												
2-Chlorophenol	µg/L												
2-Methyl-4,6-dinitrophenol	µg/L												
2-Methylnaphthalene	µg/L												
2-Methylphenol	µg/L												
2-Nitroaniline	µg/L												
2-Nitrophenol	µg/L												
3,3'-Dichlorobenzidine	µg/L												
3-Nitroaniline	µg/L												

Table A-1.1. Pit Lake Surface Water Data - 2011, 20

Sys_Loc_Code		BH103			BH104								
Sample Date		5/2/2011	5/2/2011	5/2/2011	5/4/2011	5/4/2011	5/4/2011	8/7/2013	8/7/2013	8/7/2013	12/12/2013	12/12/2013	12/12/2013
Sample Name		BH103A-SW-001	BH103B-SW-001	BH103C-SW-001	BH104A-SW-001	BH104B-SW-001	BH104C-SW-001	BH104C-SW-002	BH104C-SW-902	BH104B-SW-002	BH104C-SW-003	BH104B-SW-003	BH104B-SW-903
End Depth		2 ft	10 ft	21 ft	5 ft 40 ft from cliff	20 ft 40 ft from cliff	32 ft 40 ft from cliff	35 ft	35 ft	15 ft	35 ft	20 ft	20 ft
Semi-volatile Organic Compounds													
4-Bromophenyl phenyl ether	µg/L												
4-Chloro-3-methylphenol	µg/L												
4-Chloroaniline	µg/L												
4-Chlorophenyl phenyl ether	µg/L												
4-Nitroaniline	µg/L												
4-Nitrophenol	µg/L												
Acenaphthene	µg/L												
Acenaphthylene	µg/L												
Acetophenone	µg/L												
Anthracene	µg/L												
Atrazine	µg/L												
Benzaldehyde	µg/L												
Benzo(a)anthracene	µg/L												
Benzo(a)pyrene	µg/L												
Benzo(b)fluoranthene	µg/L												
Benzo(g,h,i)perylene	µg/L												
Benzo(k)fluoranthene	µg/L												
Benzyl butyl phthalate	µg/L												
Bis(2-chloroethoxy)methane	µg/L												
bis(2-Chloroethyl) Ether	µg/L												
Bis(2-chloroisopropyl) ether	µg/L												
Bis(2-ethylhexyl) phthalate	µg/L												
Caprolactam	µg/L												
Carbazole	µg/L												
Chrysene	µg/L												
Dibenzo(a,h)anthracene	µg/L												
Dibenzofuran	µg/L												
Diethyl phthalate	µg/L												
Dimethyl phthalate	µg/L												
Di-n-butylphthalate	µg/L												
Di-n-octylphthalate	µg/L												
Fluoranthene	µg/L												
Fluorene	µg/L												
Hexachlorobenzene (HCB)	µg/L												
Hexachlorocyclopentadiene (HCCP)	µg/L												
Hexachloroethane	µg/L												
Indeno (1,2,3-cd) pyrene	µg/L												
Isophorone	µg/L												
Naphthalene	µg/L												
Naphthalene, 1-methyl-	µg/L												
Nitrobenzene	µg/L												
n-Nitroso di-n-Propylamine	µg/L												
n-Nitrosodiphenylamine/Diphenylamine	µg/L												
Pentachlorophenol	µg/L												
Phenanthrene	µg/L												
Phenol	µg/L												
Pyrene	µg/L												

Table A-1.1. Pit Lake Surface Water Data - 2011, 20

Sys_Loc_Code		BH103			BH104								
Sample Date		5/2/2011	5/2/2011	5/2/2011	5/4/2011	5/4/2011	5/4/2011	8/7/2013	8/7/2013	8/7/2013	12/12/2013	12/12/2013	12/12/2013
Sample Name		BH103A-SW-001	BH103B-SW-001	BH103C-SW-001	BH104A-SW-001	BH104B-SW-001	BH104C-SW-001	BH104C-SW-002	BH104C-SW-902	BH104B-SW-002	BH104C-SW-003	BH104B-SW-003	BH104B-SW-903
End Depth		2 ft	10 ft	21 ft	5 ft 40 ft from cliff	20 ft 40 ft from cliff	32 ft 40 ft from cliff	35 ft	35 ft	15 ft	35 ft	20 ft	20 ft
Organophosphorous Pesticides													
4,4'-DDD (p,p'-DDD)	µg/L												
4,4'-DDE (p,p'-DDE)	µg/L												
4,4'-DDT (p,p'-DDT)	µg/L												
Aldrin	µg/L												
alpha-BHC	µg/L												
alpha-Chlordane	µg/L												
beta-BHC	µg/L												
delta-BHC	µg/L												
Dieldrin	µg/L												
Endosulfan I (alpha)	µg/L												
Endosulfan II (beta)	µg/L												
Endosulfan Sulfate	µg/L												
Endrin	µg/L												
Endrin aldehyde	µg/L												
Endrin ketone	µg/L												
gamma-BHC (Lindane)	µg/L												
gamma-Chlordane	µg/L												
Heptachlor	µg/L												
Heptachlor epoxide	µg/L												
Methoxychlor	µg/L												
Toxaphene	µg/L												
PCB Aroclors													
PCB-1016 (Aroclor 1016)	µg/L												
PCB-1221 (Aroclor 1221)	µg/L												
PCB-1232 (Aroclor 1232)	µg/L												
PCB-1242 (Aroclor 1242)	µg/L												
PCB-1248 (Aroclor 1248)	µg/L												
PCB-1254 (Aroclor 1254)	µg/L												
PCB-1260 (Aroclor 1260)	µg/L												
PCB-1262 (Aroclor 1262)	µg/L												
PCB-1268 (Aroclor 1268)	µg/L												
Volatile Organic Compounds													
(m- and/or p-)Xylene	µg/L												
1,1,1,2-Tetrachloroethane	µg/L												
1,1,1-Trichloroethane	µg/L												
1,1,2,2-Tetrachloroethane	µg/L												
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L												
1,1,2-Trichloroethane	µg/L												
1,1-Dichloroethane	µg/L												
1,1-Dichloroethene	µg/L												
1,1-Dichloropropene	µg/L												
1,2,3-Trichlorobenzene	µg/L												
1,2,3-Trichloropropane	µg/L												
1,2,4-Trichlorobenzene	µg/L												
1,2,4-Trimethylbenzene	µg/L												

Table A-1.1. Pit Lake Surface Water Data - 2011, 20

Sys_Loc_Code		BH103			BH104								
Sample Date		5/2/2011	5/2/2011	5/2/2011	5/4/2011	5/4/2011	5/4/2011	8/7/2013	8/7/2013	8/7/2013	12/12/2013	12/12/2013	12/12/2013
Sample Name		BH103A-SW-001	BH103B-SW-001	BH103C-SW-001	BH104A-SW-001	BH104B-SW-001	BH104C-SW-001	BH104C-SW-002	BH104C-SW-902	BH104B-SW-002	BH104C-SW-003	BH104B-SW-003	BH104B-SW-903
End Depth		2 ft	10 ft	21 ft	5 ft 40 ft from cliff	20 ft 40 ft from cliff	32 ft 40 ft from cliff	35 ft	35 ft	15 ft	35 ft	20 ft	20 ft
Volatile Organic Compounds													
1,2-Dibromo-3-Chloropropane (DBCP)	µg/L												
1,2-Dibromoethane (EDB)	µg/L												
1,2-Dichlorobenzene	µg/L												
1,2-Dichloroethane	µg/L												
1,2-Dichloropropane	µg/L												
1,3,5-Trimethylbenzene	µg/L												
1,3-Dichlorobenzene	µg/L												
1,3-Dichloropropane	µg/L												
1,4-Dichlorobenzene	µg/L												
2,2-Dichloropropane	µg/L												
Acetone	µg/L												
Benzene	µg/L												
Bromobenzene	µg/L												
Bromochloromethane	µg/L												
Bromodichloromethane	µg/L												
Bromoform	µg/L												
Bromomethane	µg/L												
Carbon disulfide	µg/L												
Carbon Tetrachloride	µg/L												
Chlorobenzene	µg/L												
Chloroethane	µg/L												
Chloroform	µg/L												
Chloromethane	µg/L												
cis-1,2-Dichloroethene	µg/L												
cis-1,3-Dichloropropene	µg/L												
Cyclohexane	µg/L												
Dibromochloromethane	µg/L												
Dibromomethane	µg/L												
Dichlorodifluoromethane	µg/L												
Ethyl Benzene	µg/L												
Hexachlorobutadiene	µg/L												
Isopropylbenzene	µg/L												
Methyl Acetate	µg/L												
Methyl Butyl Ketone	µg/L												
Methyl Ethyl Ketone	µg/L												
Methyl Isobutyl Ketone	µg/L												
Methyl T-Butyl Ether (MTBE)	µg/L												
Methylcyclohexane	µg/L												
Methylene Chloride	µg/L												
n-Butylbenzene	µg/L												
n-Propylbenzene	µg/L												
o-Chlorotoluene	µg/L												
o-Xylene	µg/L												
p-Chlorotoluene	µg/L												
p-Isopropyltoluene	µg/L												
sec-Butylbenzene	µg/L												
Styrene	µg/L												

Table A-1.1. Pit Lake Surface Water Data - 2011, 20

Sys_Loc_Code		BH103			BH104								
Sample Date		5/2/2011	5/2/2011	5/2/2011	5/4/2011	5/4/2011	5/4/2011	8/7/2013	8/7/2013	8/7/2013	12/12/2013	12/12/2013	12/12/2013
Sample Name		BH103A-SW-001	BH103B-SW-001	BH103C-SW-001	BH104A-SW-001	BH104B-SW-001	BH104C-SW-001	BH104C-SW-002	BH104C-SW-902	BH104B-SW-002	BH104C-SW-003	BH104B-SW-003	BH104B-SW-903
End Depth		2 ft	10 ft	21 ft	5 ft 40 ft from cliff	20 ft 40 ft from cliff	32 ft 40 ft from cliff	35 ft	35 ft	15 ft	35 ft	20 ft	20 ft
Volatile Organic Compounds													
tert-Butylbenzene	µg/L												
Tetrachloroethene	µg/L												
Toluene	µg/L												
trans-1,2-Dichloroethene	µg/L												
trans-1,3-Dichloropropene	µg/L												
Trichloroethene (Trichloroethylene)	µg/L												
Trichlorofluoromethane (Freon 11)	µg/L												
Vinyl chloride	µg/L												

Notes:

°C - degrees Celsius

ft - feet

italicized - duplicate sample

mg/L - milligrams per liter

µg/L - micrograms per liter

µS/cm - microsiemens per centimeter

mV - millivolt

NTU - nephelometric turbidity units

su - standard units

U - the analyte was analyzed for, but was not detected ab

J - the result is an estimated quantity. The associated num

UJ - the analyte was analyzed for, but was not detected. Tl

O - other qualifier defined by the Environmental Protectio

Table A-1.2. Surface Water Analytical Data 2014 Pit Lake Monthly Monitoring

Sample Location		BH101							
Sample Date		2/26/2014	2/26/2014	3/26/2014	3/26/2014	5/1/2014	5/1/2014	5/14/2014	5/14/2014
Sample Identification No.		049038-0002	049038-0001	BH101C-SW-006	BH101B-SW-005	BH101C-SW-007	BH101B-SW-006	BH101C_SW	BH101B_SW
End_Depth (ft)		50	40	50	25	50	25	50	25
Alkalinity, Total (as CaCO3)	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Carbon, Organic	mg/L	7.22 J	1 U,J	7.5	1 U	8.13	1 U	7.56	1 U
Ferrous Iron	mg/L					2310	3.3		
Total Iron	mg/L					3110	6.2		

Sample Location		BH104							
Sample Date		2/26/2014	2/26/2014	3/26/2014	3/26/2014	5/1/2014	5/1/2014	5/14/2014	5/14/2014
Sample Identification No.		049038-0004	049038-0003	BH-104C-SW-005	BH-104B-SW-005	BH104C-SW-006	BH104B-SW-006	BH104C_SW	BH104B_SW
End_Depth (ft)		40	30	37	20	37	20	35	20
Alkalinity, Total (as CaCO3)	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Carbon, Organic	mg/L	1 U,J	1 U,J	1 U	1 U	1 U	1 U	1.22	1 U
Ferrous Iron	mg/L					2.2	2.6		2.6
Total Iron	mg/L					3	3.2		3.2

Table A-1.2. Surface Water Analytical Data 2014 Pit Lake Monthly Monitoring

Sample Location		BH101							
Sample Date		6/25/2014	6/25/2014	7/27/2014	7/27/2014	8/26/2014	8/26/2014	9/23/2014	9/23/2014
Sample Identification No.		BH101C_SW	BH101B_SW	BH101C_SW	BH101B_SW	BH101C_SW	BH101B_SW	BH101C-SW	BH101B-SW
End_Depth (ft)		50	25	50	25	50	25	50	25
Alkalinity, Total (as CaCO3)	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Carbon, Organic	mg/L	8.12	1 U	8.66	1 U	8.48	1 U	7.59	1 U
Ferrous Iron	mg/L	2350	5.3	1890	3040			590	8
Total Iron	mg/L	2650	6.4	2770	3300			1465	14

Sample Location		BH104							
Sample Date		6/25/2014	6/25/2014	7/27/2014	7/27/2014	8/26/2014	8/26/2014	9/23/2014	9/23/2014
Sample Identification No.		BH104C_SW	BH104B_SW	BH104B_SW	BH104C_SW	BH104C_SW	BH104B_SW	BH104C-SW	BH104B-SW
End_Depth (ft)		35	25	20	37	35	20	30	20
Alkalinity, Total (as CaCO3)	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Carbon, Organic	mg/L	1 U	1 U	1 U	1.33	1 U	1 U	1 U	1 U
Ferrous Iron	mg/L	3.8		1.1	1.7	0.2	0.67	0.28	0.5
Total Iron	mg/L	5.6		1.8	7	4.1	0.81	1.34	0.95

Notes:

mg/L - milligrams per kilogram

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

sample

inaccurate or imprecise

Table A-1.3. Pit Lake Surface Water Data - 2015, 2016

		November 2015	June 2016				August 2016			
Sys_Loc_Code		BH502	BH520				BH520			
Sample Date		11/19/2015	6/9/2016	6/9/2016	6/9/2016	6/9/2016	8/12/2016	8/12/2016	8/12/2016	8/12/2016
Sample Name		BH502-SW001	BH520-SW001B	BH9520-SW001B	BH520-SW001C	BH520-SW001D	BH520-SW002B	BH9520-SW002B	BH520-SW002C	BH520-SW002D
End Depth		1 ft	15 ft	dup	30 ft	50 ft	25 ft	dup	40 ft	55 ft
Field Parameters										
Temperature	deg C		25.88		18.06	14.01	30.6		20.1	14.7
pH	su		5.87		3.22	3.62	3.87		2.97	3.99
Specific Conductance	µS/cm		5870		3220	3620	2624		2738	6429
Dissolved Oxygen	mg/L		7.97		10.75	0.05	4.78		6.58	1.11
Oxidation-Reduction Potential	mV		238		546	173	395		533	178
Total Metals										
Aluminum	µg/L	4,120	224 J	135 J	8490	51000	3350	3380 J	10600	368000
Antimony	µg/L	0.19 U	0.19 U	0.19 U	0.25 J	1.5 J	0.32 J	0.19 U	0.19 U	0.82 J
Arsenic	µg/L	1.9 J	1.5 J	0.94 J	1.9 J	59	0.69 J	0.72 J	1.9 J	58 J
Barium	µg/L	28.5	45.1 J	25.2 J	68.2 J	157	25.1 J	24.6 J	19.7 J	9.5 U,J
Beryllium	µg/L	0.94 U	0.99 U,J	0.99 U,J	0.99 U,J	0.99 U,J	0.99 U	0.99 U	0.99 U	9.9 U
Cadmium	µg/L	24.3	16	16	40	135	26	26	46	795
Calcium	µg/L	366,000	411000	404000	407000	407000	414000	418000	414000	362000
Chromium	µg/L	2.3 J	1.5 U	1.5 U	1.5 U	11.6	1.5 U	1.5 U	1.5 U	52.4 J
Cobalt	µg/L	42	23.9 J	22.8 J	63.8 J	225 J	39.8 J	39.5 J	76.3 J	1640 J
Copper	µg/L	754	1750	1210	2530	15300	861	873	2020	102000
Iron	µg/L	9,330	127 J	141 J	11700	673000	396	384	11800	2160000
Lead	µg/L	24.8	0.72 J	0.53 J	34	131	9.3	9.2 J	45	101
Magnesium	µg/L	47,200	46100	44800	53700	73000	49700	49900	56300	210000
Manganese	µg/L	6,400	2860	2810	8040	17500	4620	4660	10600	26500
Mercury	µg/L	NA	0.057 J	0.053 U	0.066 J	0.096 J	0.053 U	0.053 U	0.053 U	0.26
Nickel	µg/L	12 J	7.1 J	6.7 J	19.5 J	58.1	12.5 J	11.6 J	24.5	584
Potassium	µg/L	22,300	24800 J	24600 J	24800 J	24900 J	24200	24500	23800	22200
Selenium	µg/L	2.7 J	1.8 J	1.8 J	1.6 J	6.9 J	1.8 J	1.7 J	1.5 J	18
Silver	µg/L	0.021 U	0.07 J	0.042 J	0.025 U	0.18 J	0.058 J	0.025 U,J	0.025 U,J	0.042 J
Sodium	µg/L	104,000	190000	187000	115000	114000	169000	171000	114000	87900
Thallium	µg/L	0.086 J	0.1 J	0.13 J	0.12 J	0.35 J	0.33 J	0.1 J	0.14 J	1.1
Vanadium	µg/L	2.2 U	1.5 U	1.5 U	1.5 U	32.3	1.5 U	1.5 U	1.5 U	206
Zinc	µg/L	767	427 J	403 J	1170 J	4560 J	752 J	754 J	1400 J	37800 J
Hardness, calc	mg/L	1108	1,216	1,193	1,237	1,317	1,238	1,249	1,265	1,768
Dissolved Metals										
Aluminum	µg/L	3,970	63.9 J	85.9 J	8230	43500	3380 J	3390	10800	293000
Antimony	µg/L	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.24 J	0.19 U	0.92 J
Arsenic	µg/L	2.5	0.71 J	0.74 J	1.4 J	9.5	0.67 J	0.75 J	1.8 J	42 J
Barium	µg/L	27.4	25.1 J	24.5 J	23.8 J	15.5 J	24.4 J	24.8 J	18.7 J	9.6 U,J
Beryllium	µg/L	0.95 U	1 U,J	1 U	1 U,J	1 U,J	1 U	1 U	1 U	10 U

Table A-1.3. Pit Lake Surface Water Data - 2015, 2016

		November 2015	June 2016				August 2016			
Sys_Loc_Code		BH502	BH520				BH520			
Sample Date		11/19/2015	6/9/2016	6/9/2016	6/9/2016	6/9/2016	8/12/2016	8/12/2016	8/12/2016	8/12/2016
Sample Name		BH502-SW001	BH520-SW001B	BH9520-SW001B	BH520-SW001C	BH520-SW001D	BH520-SW002B	BH9520-SW002B	BH520-SW002C	BH520-SW002D
End Depth		1 ft	15 ft	dup	30 ft	50 ft	25 ft	dup	40 ft	55 ft
Cadmium	µg/L	27.8	17	17	38	122	26	27	48	729
Calcium	µg/L	347,000	404000	403000	401000	402000	417000	416000	411000	346000
Chromium	µg/L	2.3 J	1.5 U	1.5 U	2.4 J	1.5 U	1.5 U	1.5 U	1.5 U	23.3 J
Cobalt	µg/L	41.9	24.9 J	24.7	64.5 J	227 J	40.1 J	39.6	79.3 J	1270 J
Copper	µg/L	665	387	392	1600	10300	827	832	2020	157000
Iron	µg/L	8,780	39.4 U	46.4 J	10700	276000	234 J	194 J	11800	1820000
Lead	µg/L	21.1	0.71 J	0.74 J	33	74	8.9 J	8.9	45	111
Magnesium	µg/L	45,600	45900	45600	53300	74100	49900	50000	56300	182000
Manganese	µg/L	6,220	2960	2950	7820	14700	4640	4630	10500	26400
Mercury	µg/L	0.04 U	0.053 U	0.053 U	0.053 U	0.064 J	0.053 U	0.053 U	0.053 U	0.36
Nickel	µg/L	12 J	7.4 J	6.7 J	19.7 J	68.6	13.2 J	12.7 J	25.5	436
Potassium	µg/L	21,800	24800 J	24800	24700 J	24800 J	24600	24600	23800	20200
Selenium	µg/L	3.5 J	1.8 J	2 J	1.8 J	3 J	1.6 J	1.8 J	1.5 J	20
Silver	µg/L	0.021 U	0.025 U	0.025 U	0.025 U	0.025 U	0.025 U,J	0.025 U,J	0.025 U,J	0.025 U,J
Sodium	µg/L	99,700	185000	183000	113000	111000	170000	169000	112000	84200
Thallium	µg/L	0.081 J	0.089 J	0.08 J	0.034 U	0.25 J	0.1 J	0.11 J	0.14 J	1.1
Vanadium	µg/L	2.2 U	1.5 U	1.5 U	1.8 J	9.4 J	1.5 U	1.5 U	1.5 U	137
Zinc	µg/L	800	454 J	455	1180 J	4430 J	779 J	778 J	1480 J	28400 J
Hardness, calc	mg/L	1054	1,198	1,194	1,221	1,309	1,247	1,245	1,258	1,613
Classical/Nutrient Analyses										
Acidity	mg/L	99.9	NA	NA	162	283	123	41.1	2570	5130
Alkalinity, Bicarbonate (as CaCO3)	mg/L	1 U	3.6	2.8	1 U	1 U	1 U	1 U	1 U	1 U
Alkalinity, carbonate (as CaCO3)	mg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Alkalinity, Total (as CaCO3)	mg/L	1 U	3.6	2.8	1 U	1 U	1 U	1 U	1 U	1 U
Carbon, Organic	mg/L	NA	0.33 U	0.33 U	0.33 U	8.4	1 U	1 U	1.18	8.62
Chloride	mg/L	19.0	21.6	22	21.6	22	21	21.2	21.3	21.4
Sulfate as SO4	mg/L	1380	1700	1710	1710	1840	1720	1700	4120	6760
Total Dissolved Solids	mg/L	2030								
Total Suspended Solids	mg/L	7								

Notes:
°C - degrees Celsius
ft - feet
italicized - duplicate sample
mg/L - milligrams per liter
µg/L - micrograms per liter
µS/cm - microsiemens per centimeter
mV - millivolt
NTU - nephelometric turbidity units
su - standard units
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
UJ - the analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Table A-1.4. Pit Runoff Data - 2014

Sys_Loc_Code Sample Date Sample Name		BH154 5/15/2014 BH154_SW	BH155 5/15/2014 BH155_SW	BH156 5/15/2014 BH156_SW	BH156 5/15/2014 BH9156_SW	BH157 5/15/2014 BH157_SW
Field Parameters						
Temperature	deg C	22.45	21.34	22.49		22.6
pH	s.u.	6.80	7.46	4.66		5.16
Specific Conductance	µS/cm	265	107	122		54
Dissolved Oxygen	mg/L	7.87	8.58	8.47		7.33
Oxidation-Reduction Potential	mV	175	138	289		223
Total Metals						
Aluminum	µg/L	1470	1020	4780	32900	11800
Antimony	µg/L	0.52 J	0.26 U	0.39 J	1.1 J	0.69 J
Arsenic	µg/L	3.4	1.9 J	2	6.6	8.5
Barium	µg/L	290	196	257	1910	740
Beryllium	µg/L	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U
Cadmium	µg/L	0.048 J	0.23 J	0.6 J	0.99 J	0.21 J
Calcium	µg/L	33800	6190	3780	5030	271 J
Chromium	µg/L	1.7 J	1.5 U	2.8 J	27.9	1.5 U
Cobalt	µg/L	1.2 J	1.3 J	18.5	60.8	6.3 J
Copper	µg/L	33.4 J	72.6 J	1100 J	1400 J	94.3 J
Iron	µg/L	2760	1520	10600	98600	14200
Lead	µg/L	6.1 J	2.7 J	91.3 J	528 J	213 J
Magnesium	µg/L	2440	1320	2990	3410	250 U
Manganese	µg/L	18.3	15	288	749	353
Nickel	µg/L	3.2 U	3.2 U	3.2 U	4.6 J	3.2 U
Potassium	µg/L	5790	4950	451 J	799 J	647 J
Selenium	µg/L	1.9 J	1.2 J	6.3	5.6	0.73 J
Silver	µg/L	0.056 J	0.097 J	0.086 J	0.62 J	0.47 J
Sodium	µg/L	2090	1230 J	1700 J	1840 J	865 J
Thallium	µg/L	0.029 J	0.035 J	0.074 J	0.3 J	0.14 J
Vanadium	µg/L	4.8 J	2.6 J	23.8	215	5.8 J
Zinc	µg/L	8 J	10.3	208	423	131
Hardness, calc	mg/L	94	21	22	27	1.7

Table A-1.4. Pit Runoff Data - 2014

Sys_Loc_Code Sample Date Sample Name		BH154 5/15/2014 BH154_SW	BH155 5/15/2014 BH155_SW	BH156 5/15/2014 BH156_SW	BH156 5/15/2014 BH9156_SW	BH157 5/15/2014 BH157_SW
Dissolved Metals						
Aluminum	µg/L	46.2 J	165 J	436 J	539	92.9 J
Antimony	µg/L	0.26 U	0.26 U	0.26 U	0.26 U	0.26 U
Arsenic	µg/L	1.1 J	1 J	0.77 J	0.43 J	0.86 J
Barium	µg/L	165	180	155	154	371
Beryllium	µg/L	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U
Cadmium	µg/L	0.031 U,J	0.12 J	0.53 J	0.55 J	0.083 J
Calcium	µg/L	33000	5630	3710	4040	297 J
Chromium	µg/L	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U
Cobalt	µg/L	0.7 U	0.7 U	13.8	14.2	1.4 J
Copper	µg/L	21 J	59.6 J	1010 J	1040 J	14.7 J
Iron	µg/L	107 J	371	23.2 U	27.3 J	83.2 J
Lead	µg/L	0.12 J	0.5 J	22.6 J	29.8 J	14.7 J
Magnesium	µg/L	2420	1220	2890	2920	253 U
Manganese	µg/L	6.3 J	5.4 J	231	236	128
Nickel	µg/L	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U
Potassium	µg/L	5770	4910	337 J	385 J	568 J
Selenium	µg/L	1.8 J	1.8 J	7.5	6.4	0.94 J
Silver	µg/L	0.018 U	0.034 J	0.018 U	0.018 U	0.018 U
Sodium	µg/L	2070	1240 J	1700 J	1720 J	952 J
Thallium	µg/L	0.021 U	0.027 J	0.038 J	0.037 J	0.057 J
Vanadium	µg/L	1 U	1 U	1 U	1 U	1 U
Zinc	µg/L	4.1 J	6.1 J	186	198	25.8
Hardness, calc	mg/L	92	19	21	22	1.8
Classical/Nutrient Analyses						
Acidity	mg/L			35.9 J	25.8 J	15.8
Alkalinity, Bicarbonate (as CaCO3)	mg/L	47.8	14.9	1 U	1 U	1 U
Alkalinity, carbonate (as CaCO3)	mg/L	1 U	1 U	1 U	1 U	1 U
Alkalinity, Total (as CaCO3)	mg/L	47.8	14.9	1 U	1 U	1 U
Carbon, Organic	mg/L	14	23.8	4.78	5.9	5.89
Classical/Nutrient Analyses - continued						
Chloride	mg/L	1.99	2.32	1.54	1.53	1.42
Sulfate as SO4	mg/L	54.7 J	5.79 J	28.8 J	29 J	3.45 J
Total Dissolved Solids	mg/L	154	77	33	34	10 U
Total Suspended Solids	mg/L	7	18	423	465	1250

Notes:

°C - degrees Celsius

ft - feet

italicized - duplicate sample

mg/L - milligrams per liter

µg/L - micrograms per liter

µS/cm - microsiemens per centimeter

mV - millivolt

NTU - nephelometric turbidity units

su - standard units

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
Semi Volatile Organic Compounds (mg/kg) - continued								
4-Chlorophenyl phenyl ether			530 U	*2700 U*				
4-Nitroaniline			530 U	*2700 U*				
4-Nitrophenol			530 U	*2700 U*				
Acenaphthene			53 U	*270 U*				
Acenaphthylene			53 U	*270 U*				
Acetophenone			530 U	*2700 U*				
Anthracene			53 U	*270 U*				
Atrazine			530 U	*2700 U*				
Benzaldehyde			530 U	*2700 U*				
Benzo(a)anthracene			53 U	*270 U*				
Benzo(a)pyrene			53 U	*270 U*				
Benzo(b)fluoranthene			53 U	*270 U*				
Benzo(g,h,i)perylene			53 U	*270 U*				
Benzo(k)fluoranthene			53 U	*270 U*				
Benzyl butyl phthalate			530 U	*2700 U*				
Bis(2-chloroethoxy)methane			530 U	*2700 U*				
bis(2-Chloroethyl) Ether			530 U	*2700 U*				
Bis(2-chloroisopropyl) ether			530 U	*2700 U*				
Bis(2-ethylhexyl) phthalate			530 U	*2700 U*				
Caprolactam			530 U	*2700 U*				
Carbazole			53 U	*270 U*				
Chrysene			53 U	*270 U*				
Dibenzo(a,h)anthracene			53 U	*270 U*				
Dibenzofuran			53 U	*270 U*				
Diethyl phthalate			530 U	*2700 U*				
Dimethyl phthalate			530 U	*2700 U*				
Di-n-butylphthalate			530 U	*2700 U*				
Di-n-octylphthalate			530 U	*2700 U*				
Fluoranthene			53 U	*270 U*				
Fluorene			53 U	*270 U*				
Hexachlorobenzene (HCB)			530 U	*2700 U*				
Hexachlorobutadiene			530 U	*2700 U*				
Hexachlorocyclopentadiene (HCCP)			530 U	*2700 U*				
Hexachloroethane			530 U	*2700 U*				

Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
Semi Volatile Organic Compounds (mg/kg) - continued								
Indeno (1,2,3-cd) pyrene			53 U	*270 U*				
Isophorone			530 U	*2700 U*				
Naphthalene			53 U	*270 U*				
Naphthalene, 1-methyl-			53 U	*270 U*				
Nitrobenzene			530 U	*2700 U*				
n-Nitroso di-n-Propylamine			530 U	*2700 U*				
n-Nitrosodiphenylamine/Diphenylamine			530 U	*2700 U*				
Pentachlorophenol			530 U	*2700 U*				
Phenanthrene			53 U	*270 U*				
Phenol			530 U	*2700 U*				
Pyrene			53 U	*270 U*				
Organochlorine Pesticides (mg/kg)								
4,4'-DDD (p,p'-DDD)			2.6 U	*2.6 U*				
4,4'-DDE (p,p'-DDE)			1.3 U	*1.3 U*				
4,4'-DDT (p,p'-DDT)			3.2 U	*3.2 U*				
Aldrin			1.3 U	*1.3 U*				
alpha-BHC			0.64 U	*0.64 U*				
alpha-Chlordane			1.3 U	*1.3 U*				
beta-BHC			1.3 U	*1.3 U*				
delta-BHC			1.3 U	*1.3 U*				
Dieldrin			1.3 U	*1.3 U*				
Endosulfan I (alpha)			1.3 U	*1.3 U*				
Endosulfan II (beta)			2.6 U	*2.6 U*				
Endosulfan Sulfate			3.2 U	*3.2 U*				
Endrin			2.6 U	*2.6 U*				
Endrin aldehyde			3.2 U	*3.2 U*				
Endrin ketone			3.2 U	*3.2 U*				
gamma-BHC (Lindane)			0.64 U	*0.64 U*				
gamma-Chlordane			1.3 U	*1.3 U*				
Heptachlor			0.96 U	*0.96 U*				
Heptachlor epoxide			1.3 U	*1.3 U*				
Methoxychlor			6.4 U	*6.4 U*				
Toxaphene			130 U	*130 U*				

Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
PCB Aroclor (mg/kg)								
PCB-1016 (Aroclor 1016)			16 U	*16 U*				
PCB-1221 (Aroclor 1221)			32 U	*32 U*				
PCB-1232 (Aroclor 1232)			16 U	*16 U*				
PCB-1242 (Aroclor 1242)			16 U	*16 U*				
PCB-1248 (Aroclor 1248)			16 U	*16 U*				
PCB-1254 (Aroclor 1254)			16 U	*16 U*				
PCB-1260 (Aroclor 1260)			16 U	*16 U*				
PCB-1262 (Aroclor 1262)			16 U	*16 U*				
PCB-1268 (Aroclor 1268)			16 U	*16 U*				
Volatile Organic Compounds (mg/kg)								
(m- and/or p-)Xylene			2.4 U	*2.2 U*				
1,1,1,2-Tetrachloroethane			1.2 U,J,O	*1.1 U*				
1,1,1-Trichloroethane			1.2 U	*1.1 U*				
1,1,2,2-Tetrachloroethane			1.2 U,J,O	*1.1 U*				
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)			1.2 U	*1.1 U*				
1,1,2-Trichloroethane			1.2 U,J,O	*1.1 U*				
1,1-Dichloroethane			1.2 U	*1.1 U*				
1,1-Dichloroethene (1,1-Dichloroethylene)			1.2 U	*1.1 U*				
1,1-Dichloropropene			1.2 U	*1.1 U*				
1,2,3-Trichlorobenzene			1.2 U,J,O	*1.1 U*				
1,2,3-Trichloropropane			1.2 U,J,O	*1.1 U*				
1,2,4-Trichlorobenzene			1.2 U,J,O	*1.1 U*				
1,2,4-Trimethylbenzene			1.2 U,J,O	*1.1 U*				
1,2-Dibromo-3-Chloropropane (DBCP)			2.4 U,J,O	*2.2 U*				
1,2-Dibromoethane (EDB)			1.2 U,J,O	*1.1 U*				
1,2-Dichlorobenzene			1.2 U,J,O	*1.1 U*				
1,2-Dichloroethane			1.2 U,J,O	*1.1 U*				
1,2-Dichloropropane			1.2 U,J,O	*1.1 U*				
1,3,5-Trimethylbenzene			1.2 U,J,O	*1.1 U*				
1,3-Dichlorobenzene			1.2 U,J,O	*1.1 U*				
1,3-Dichloropropane			1.2 U,J,O	*1.1 U*				
1,4-Dichlorobenzene			1.2 U,J,O	*1.1 U*				
2,2-Dichloropropane			1.2 U	*1.1 U*				
Acetone			75 J,O	*65*				

Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
Volatile Organic Compounds (mg/kg)								
Benzene			1.2 U	*1.1 U*				
Bromobenzene			1.2 U,J,O	*1.1 U*				
Bromochloromethane			1.2 U,J,O	*1.1 U*				
Bromodichloromethane			1.2 U,J,O	*1.1 U*				
Bromoform			2.4 U,J,O	*2.2 U*				
Bromomethane			1.2 U	*1.1 U*				
Carbon disulfide			8.9 J,O	*6.9*				
Carbon Tetrachloride			1.2 U	*1.1 U*				
Chlorobenzene			1.2 U,J,O	*1.1 U*				
Chloroethane			1.2 U	*1.1 U*				
Chloroform			1.2 U	*1.1 U*				
Chloromethane			1.2 U	*1.1 U*				
cis-1,2-Dichloroethene			1.2 U	*1.1 U*				
cis-1,3-Dichloropropene			1.2 U,R,O	*1.1 U*				
Cyclohexane			1.2 U	*1.1 U*				
Dibromochloromethane			1.2 U,J,O	*1.1 U*				
Dibromomethane			1.2 U,J,O	*1.1 U*				
Dichlorodifluoromethane			1.2 U	*1.1 U*				
Ethyl Benzene			1.2 U	*1.1 U*				
Hexachlorobutadiene			1.2 U,J,O	*1.1 U*				
Isopropylbenzene			1.2 U,J,O	*1.1 U*				
Methyl Acetate			2.4 U,J,O	*2.2 U*				
Methyl Butyl Ketone			2.4 U	*2.2 U*				
Methyl Ethyl Ketone			24	*19*				
Methyl Isobutyl Ketone			2.4 U	*2.2 U*				
Methyl T-Butyl Ether (MTBE)			1.2 U,J,O	*1.1 U*				
Methylcyclohexane			1.2 U	*1.1 U*				
Methylene Chloride			1.2 U	*1.1 U*				
n-Butylbenzene			1.2 U,J,O	*1.1 U*				
n-Propylbenzene			1.2 U,J,O	*1.1 U*				
o-Chlorotoluene			1.2 U,J,O	*1.1 U*				
o-Xylene			1.2 U	*1.1 U*				
p-Chlorotoluene			1.2 U,J,O	*1.1 U*				
p-Isopropyltoluene			1.2 U,J,O	*1.1 U*				

Table A-2. Pit Lake Sediment Data

Sys_Loc_Code	BH203	BH204	BH251		BH520	BH521	BH523	
Sample Date	5/3/2011	5/4/2011	5/4/2011	*5/4/2011*	7/7/2016	7/7/2016	7/7/2016	*7/7/2016*
Sample Name	BH203-SD-001	BH204-SD-001	BH251-SD-001	*BH251-SD-901*	BH520-SD001	BH521-SD001	BH523-SD001	*BH9523-SD001*
End Depth	6 ft	36 ft	2 ft	*2 ft Dup*	49-50 ft	51-52 ft	33-34 ft	*33-34 ft Dup*
Start Depth					50	52	34	*34*
Volatile Organic Compounds (mg/kg)								
sec-Butylbenzene			1.2 U,J,O	*1.1 U*				
Styrene			1.2 U,J,O	*1.1 U*				
tert-Butylbenzene			1.2 U,J,O	*1.1 U*				
Tetrachloroethene (Tetrachloroethylene)			1.2 U	*1.1 U*				
Toluene			1.2 U	*1.1 U*				
trans-1,2-Dichloroethene			1.2 U	*1.1 U*				
trans-1,3-Dichloropropene			1.2 U,R,O	*1.1 U*				
Trichloroethene (Trichloroethylene)			1.2 U	*1.1 U*				
Trichlorofluoromethane (Freon 11)			1.2 U	*1.1 U*				
Vinyl chloride			1.2 U	*1.1 U*				

Notes:

italicized - duplicate sample

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

UJ - the analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

R - rejected

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Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
Metals (mg/kg)							
Aluminum	7700	4300	4800	*5700*	6900	4000	6800
Antimony	0.5 U	0.5 U	0.51	*0.62*	0.53	0.49 U	0.5 U
Arsenic	10	6.2	28	*28*	8	15	5
Barium	1800	1100	1500	*1400*	1400	1200	1300
Beryllium	0.25 U,J,O	0.25 U,J,O	0.25 U	*0.25 U*	0.39	0.25 U,J,O	0.26 J,O
Cadmium	0.25 U	0.25 U	0.4	*0.56*	1.6	0.25 U	0.25 U
Calcium	2100	650	5100	*7900*	20000	750	540
Chromium	20	9.2	12	*15*	100	11	35
Cobalt	6.9	1.3	1.1	*1.6*	5.3	0.98 U	7.2
Copper	56	150	69	*100*	67	88	23
Iron	25000	17000	18000	*24000*	27000	21000	27000
Lead	57	37	73	*72*	100	46	49
Magnesium	380	200	440	*320*	360	610	260
Manganese	760	150	77	*83*	610	66	760
Mercury	0.044	0.038	0.041	*0.04*	0.04	0.05 U,J,O	0.05 U,J,O
Molybdenum	4 U	2	2 U	*2*	2.1	2 U	2 U
Nickel	4 U	2 U	2 U	*2.1*	2 U	2 U	2 U
Potassium	180	130	400	*200 U*	200 U	590	120
Selenium	1 U,J,O	1 U,J,O	0.99 U	*0.99 U*	1 U	0.98 U,J,O	1 U,J,O
Silver	2 U	1 U	0.99 U	*0.99 U*	1 U	0.98 U	1 U
Sodium	50 U	50 U	200 U	*200 U*	200 U	130	50 U
Strontium	13	7.3	13	*14*	15	6.1	9.7
Thallium	0.5 U	0.5 U	0.49 U	*0.49 U*	0.5 U	0.49 U	0.5 U
Tin	6 U	3 U	3 U	*3 U*	3 U	3 U	3 U
Titanium	52	37	64	*35*	55	67	54
Vanadium	41	15	22	*29*	43	23	56
Yttrium	3.7	1.6	1.7	*2.4*	4	1.8	4.4
Zinc	15	5.6	16	*19*	27	19	10
General Chemistry							
% Solids	86	89	94	*94*	92	93	92
pH	6.95	4.67	6.9	*6.76*	11.9	4.68	5.29

Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
Semi-volatile Organic Compounds (mg/kg)							
(3-and/or 4-)Methylphenol			360 U	*360 U*	360 U		
1,1-Biphenyl			36 U	*36 U*	36 U		
1,2,4,5-Tetrachlorobenzene			360 U	*360 U*	360 U		
1,2,4-Trichlorobenzene			360 U	*360 U*	360 U		
2,3,4,6-Tetrachlorophenol			360 U,J,O	*360 U,J,O*	360 U,J,O		
2,4,5-Trichlorophenol			360 U	*360 U*	360 U		
2,4,6-Trichlorophenol			360 U	*360 U*	360 U		
2,4-Dichlorophenol			360 U	*360 U*	360 U		
2,4-Dimethylphenol			360 U,J,O	*360 U,J,O*	360 U,J,O		
2,4-Dinitrophenol			360 U,J,O	*360 U,J,O*	360 U,J,O		
2,4-Dinitrotoluene			360 U	*360 U*	360 U		
2,6-Dinitrotoluene			360 U	*360 U*	360 U		
2-Chloronaphthalene			360 U	*360 U*	360 U		
2-Chlorophenol			360 U	*360 U*	360 U		
2-Methyl-4,6-dinitrophenol			360 U	*360 U*	360 U		
2-Methylnaphthalene			36 U	*36 U*	36 U		
2-Methylphenol			360 U	*360 U*	360 U		
2-Nitroaniline			360 U	*360 U*	360 U		
2-Nitrophenol			360 U	*360 U*	360 U		
3,3'-Dichlorobenzidine			360 U	*360 U*	360 U		
3-Nitroaniline			360 U	*360 U*	360 U		
4-Bromophenyl phenyl ether			360 U	*360 U*	360 U		
4-Chloro-3-methylphenol			360 U	*360 U*	360 U		
4-Chloroaniline			360 U	*360 U*	360 U		
4-Chlorophenyl phenyl ether			360 U	*360 U*	360 U		
4-Nitroaniline			360 U	*360 U*	360 U		
4-Nitrophenol			360 U	*360 U*	360 U		
Acenaphthene			36 U	*36 U*	36 U		
Acenaphthylene			36 U	*36 U*	36 U		
Acetophenone			360 U	*360 U*	360 U		
Anthracene			36 U	*36 U*	36 U		

Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
Semi-volatile Organic Compounds (mg/kg) - continued							
Atrazine			360 U	*360 U*	360 U		
Benzaldehyde			360 U	*360 U*	68 J,O		
Benzo(a)anthracene			36 U	*36 U*	36 U		
Benzo(a)pyrene			36 U	*36 U*	36 U		
Benzo(b)fluoranthene			36 U	*36 U*	36 U		
Benzo(g,h,i)perylene			36 U	*36 U*	36 U		
Benzo(k)fluoranthene			36 U	*36 U*	36 U		
Benzyl butyl phthalate			360 U	*360 U*	360 U		
Bis(2-chloroethoxy)methane			360 U	*360 U*	360 U		
bis(2-Chloroethyl) Ether			360 U	*360 U*	360 U		
Bis(2-chloroisopropyl) ether			360 U	*360 U*	360 U		
Bis(2-ethylhexyl) phthalate			360 U	*360 U*	360 U		
Caprolactam			360 U	*360 U*	360 U		
Carbazole			36 U	*36 U*	36 U		
Chrysene			36 U	*36 U*	36 U		
Dibenzo(a,h)anthracene			36 U	*36 U*	36 U		
Dibenzofuran			36 U	*36 U*	36 U		
Diethyl phthalate			360 U	*360 U*	360 U		
Dimethyl phthalate			360 U	*360 U*	360 U		
Di-n-butylphthalate			360 U	*360 U*	360 U		
Di-n-octylphthalate			360 U	*360 U*	360 U		
Fluoranthene			36 U	*36 U*	36 U		
Fluorene			36 U	*36 U*	36 U		
Hexachlorobenzene (HCB)			360 U	*360 U*	360 U		
Hexachlorobutadiene			360 U	*360 U*	360 U		
Hexachlorocyclopentadiene (HCCP)			360 U	*360 U*	360 U		
Hexachloroethane			360 U	*360 U*	360 U		
Indeno (1,2,3-cd) pyrene			36 U	*36 U*	36 U		
Isophorone			360 U	*360 U*	130 J,O		
Naphthalene			36 U	*36 U*	36 U		
Naphthalene, 1-methyl-			36 U	*36 U*	36 U		

Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
Semi-volatile Organic Compounds (mg/kg) - continued							
Nitrobenzene			360 U	*360 U*	360 U		
n-Nitroso di-n-Propylamine			360 U	*360 U*	360 U		
n-Nitrosodiphenylamine/Diphenylamine			360 U	*360 U*	360 U		
Pentachlorophenol			360 U	*360 U*	360 U		
Phenanthrene			36 U	*36 U*	36 U		
Phenol			360 U	*360 U*	360 U		
Pyrene			36 U	*36 U*	36 U		
Organophosphorous Pesticides (mg/kg)							
4,4'-DDD (p,p'-DDD)			1.7 U	*1.7 U*	1.8 U		
4,4'-DDE (p,p'-DDE)			0.87 U	*0.87 U*	0.89 U		
4,4'-DDT (p,p'-DDT)			2.2 U	*2.2 U*	2.2 U		
Aldrin			0.87 U	*0.87 U*	0.89 U		
alpha-BHC			0.43 U	*0.43 U*	0.44 U		
alpha-Chlordane			0.87 U	*0.87 U*	0.89 U		
beta-BHC			0.87 U	*0.87 U*	0.89 U		
delta-BHC			0.87 U	*0.87 U*	0.89 U		
Dieldrin			0.87 U	*0.87 U*	0.89 U		
Endosulfan I (alpha)			0.87 U	*0.87 U*	0.89 U		
Endosulfan II (beta)			1.7 U	*1.7 U*	1.8 U		
Endosulfan Sulfate			2.2 U	*2.2 U*	2.2 U		
Endrin			1.7 U	*1.7 U*	1.8 U		
Endrin aldehyde			2.2 U	*2.2 U*	2.2 U		
Organophosphorous Pesticides (mg/kg) - continued							
Endrin ketone			2.2 U	*2.2 U*	2.2 U		
gamma-BHC (Lindane)			0.43 U	*0.43 U*	0.44 U		
gamma-Chlordane			0.87 U	*0.87 U*	0.89 U		
Heptachlor			0.65 U	*0.65 U*	0.67 U		
Heptachlor epoxide			0.87 U	*0.87 U*	0.89 U		
Methoxychlor			4.3 U	*4.3 U*	4.4 U		
Toxaphene			87 U	*87 U*	89 U		

Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
PCB Aroclors (mg/kg)							
PCB-1016 (Aroclor 1016)			11 U	*11 U*	11 U		
PCB-1221 (Aroclor 1221)			22 U	*22 U*	22 U		
PCB-1232 (Aroclor 1232)			11 U	*11 U*	11 U		
PCB-1242 (Aroclor 1242)			11 U	*11 U*	11 U		
PCB-1248 (Aroclor 1248)			11 U	*11 U*	11 U		
PCB-1254 (Aroclor 1254)			11 U	*11 U*	11 U		
PCB-1260 (Aroclor 1260)			11 U	*11 U*	11 U		
PCB-1262 (Aroclor 1262)			11 U	*11 U*	11 U		
PCB-1268 (Aroclor 1268)			11 U	*11 U*	11 U		
Volatile Organic Compounds (mg/kg)							
(m- and/or p-)Xylene			0.96 U	*1 U*	1.2 U		
1,1,1,2-Tetrachloroethane			0.48 U	*0.5 U*	0.59 U		
1,1,1-Trichloroethane			0.48 U	*0.5 U*	0.59 U		
1,1,2,2-Tetrachloroethane			0.48 U	*0.5 U*	0.59 U		
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)			0.48 U	*0.5 U*	0.59 U		
1,1,2-Trichloroethane			0.48 U	*0.5 U*	0.59 U		
1,1-Dichloroethane			0.48 U	*0.5 U*	0.59 U		
1,1-Dichloroethene (1,1-Dichloroethylene)			0.48 U	*0.5 U*	0.59 U		
1,1-Dichloropropene			0.48 U	*0.5 U*	0.59 U		
1,2,3-Trichlorobenzene			0.48 U	*0.5 U*	0.59 U		
1,2,3-Trichloropropane			0.48 U	*0.5 U*	0.59 U		
1,2,4-Trichlorobenzene			0.48 U	*0.5 U*	0.59 U		
1,2,4-Trimethylbenzene			0.48 U	*0.5 U*	0.59 U		
1,2-Dibromo-3-Chloropropane (DBCP)			0.96 U	*1 U*	1.2 U,J,O		
1,2-Dibromoethane (EDB)			0.48 U	*0.5 U*	0.59 U		
1,2-Dichlorobenzene			0.48 U	*0.5 U*	0.59 U		
1,2-Dichloroethane			0.48 U	*0.5 U*	0.59 U		
1,2-Dichloropropane			0.48 U	*0.5 U*	0.59 U		
1,3,5-Trimethylbenzene			0.48 U	*0.5 U*	0.59 U		
1,3-Dichlorobenzene			0.48 U	*0.5 U*	0.59 U		
1,3-Dichloropropane			0.48 U	*0.5 U*	0.59 U		

Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
Volatile Organic Compounds (mg/kg) - continued							
1,4-Dichlorobenzene			0.48 U	*0.5 U*	0.59 U		
2,2-Dichloropropane			0.48 U	*0.5 U*	0.59 U		
Acetone			1.9 U	*2 U*	2.3 U		
Benzene			0.48 U	*0.5 U*	0.59 U		
Bromobenzene			0.48 U	*0.5 U*	0.59 U		
Bromochloromethane			0.48 U	*0.5 U*	0.59 U		
Bromodichloromethane			0.48 U	*0.5 U*	0.59 U		
Bromoform			0.96 U	*1 U*	1.2 U,J,O		
Bromomethane			0.48 U	*0.5 U*	0.59 U		
Carbon disulfide			0.48 U	*0.5 U*	0.59 U		
Carbon Tetrachloride			0.48 U	*0.5 U*	0.59 U		
Chlorobenzene			0.48 U	*0.5 U*	0.59 U		
Chloroethane			0.48 U	*0.5 U*	0.59 U		
Chloroform			0.48 U	*0.5 U*	0.59 U		
Chloromethane			0.48 U	*0.5 U*	0.59 U		
cis-1,2-Dichloroethene			0.48 U	*0.5 U*	0.59 U		
cis-1,3-Dichloropropene			0.48 U	*0.5 U*	0.59 U		
Cyclohexane			0.48 U	*0.5 U*	0.59 U		
Dibromochloromethane			0.48 U	*0.5 U*	0.59 U		
Dibromomethane			0.48 U	*0.5 U*	0.59 U		
Dichlorodifluoromethane			0.48 U	*0.5 U*	0.59 U		
Ethyl Benzene			0.48 U	*0.5 U*	0.59 U		
Hexachlorobutadiene			0.48 U	*0.5 U*	0.59 U		
Isopropylbenzene			0.48 U	*0.5 U*	0.59 U		
Methyl Acetate			0.96 U	*1 U*	1.2 U		
Methyl Butyl Ketone			0.96 U	*1 U*	1.2 U		
Methyl Ethyl Ketone			0.96 U	*1 U*	1.2 U		
Methyl Isobutyl Ketone			0.96 U	*1 U*	1.2 U,J,O		
Methyl T-Butyl Ether (MTBE)			0.48 U	*0.5 U*	0.59 U		
Methylcyclohexane			0.48 U	*0.5 U*	0.59 U		
Methylene Chloride			0.48 U	*0.5 U*	0.59 U		

Table A-3.1. Barite Hill OU1 Soils Data

Sys_Loc_Code	BH402	BH403	BH405	*BH405*	BH406	BH407	BH408
Sample Date	5/2/2011	5/2/2011	5/4/2011	*5/4/2011*	5/4/2011	5/2/2011	5/2/2011
Sample Name	BH402-SL-001	BH403-SL-001	BH405-SL-001	*BH405-SL-901*	BH406-SL-001	BH407-SL-001	BH408-SL-001
End Depth	0.5	0.5	0.5	*0.5*	0.5	0.5	0.5
Start Depth	0	0	0	*0*	0	0	0
Volatile Organic Compounds (mg/kg) - continued							
n-Butylbenzene			0.48 U	*0.5 U*	0.59 U		
n-Propylbenzene			0.48 U	*0.5 U*	0.59 U		
o-Chlorotoluene			0.48 U	*0.5 U*	0.59 U		
o-Xylene			0.48 U	*0.5 U*	0.59 U		
p-Chlorotoluene			0.48 U	*0.5 U*	0.59 U		
p-Isopropyltoluene			0.48 U	*0.5 U*	0.59 U		
sec-Butylbenzene			0.48 U	*0.5 U*	0.59 U		
Styrene			0.48 U	*0.5 U*	0.59 U,J,O		
tert-Butylbenzene			0.48 U	*0.5 U*	0.59 U,J,O		
Tetrachloroethene (Tetrachloroethylene)			0.48 U	*0.5 U*	0.59 U		
Toluene			0.48 U	*0.5 U*	0.59 U		
trans-1,2-Dichloroethene			0.48 U	*0.5 U*	0.59 U		
trans-1,3-Dichloropropene			0.48 U	*0.5 U*	0.59 U		
Trichloroethene (Trichloroethylene)			0.48 U	*0.5 U*	0.59 U		
Trichlorofluoromethane (Freon 11)			0.48 U	*0.5 U*	0.59 U		
Vinyl chloride			0.48 U	*0.5 U*	0.59 U		

Notes:

ft - feet

italicized - duplicate sample

mg/kg - milligrams per kilogram

OU - operable unit

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-3.2. Barite Hill Refernce Background Soil Data

Sys_Loc_Code	BH401	BH409	BH442	BH444	BH404	Mean Reference	1.5X Reference
Sample Date	5/2/2011	5/3/2011	5/5/2011	5/5/2011	5/2/2011		
Sample Name	BH401-SL-001	BH409-SL-001	BH442-SL-001	BH444-SL-001	BH404-SL-001		
End Depth	0.5	0.5	0.5	0.5	0.5		
Start Depth	0	0	0	0	0		
Total Metals (mg/kg)							
Aluminum	6300	6800	4000	6100	8000	6240	9360
Antimony	0.5 U	0.49 U	0.49 U	0.5 U	0.49 U		
Arsenic	15	0.49 U	0.69 U,J,O	9.9	3.3	5.8	8.7
Barium	300	74	91	150	230	169	254
Beryllium	0.25 U,J,O	0.25 U,J,O	0.26	0.25 U	0.25 U,J,O		
Cadmium	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U		
Calcium	570	700	380	180 U,O	67	379	569
Chromium	20	12	7.9	7.5	9.5	11.4	17.1
Cobalt	1.8	6.7	7.2	1	0.49 U	3.4	5.2
Copper	34	6.6	3.8	7.5	21	14.6	21.9
Iron	23000	20000	8000	13000	22000	17200	25800
Lead	41	8.6	39	65	18	34.3	51.5
Magnesium	940	900	360	140	98	488	731
Manganese	320	520	930	280	24	415	622
Mercury	0.083	0.03	0.05 U,J,O	0.05 U,J,O	0.054	0.037	0.056
Molybdenum	1.3	0.99 U	0.99 U	0.99 U	1.4	0.8	1.3
Nickel	1.8	1.3	1.4	1	0.98 U	1.2	1.8
Potassium	150	67	99 U	130	120	113	170
Selenium	1 U,J,O	0.99 U,J,O	0.99 U	0.99 U	0.98 U,J,O		
Silver	0.5 U	0.49 U	0.49 U	0.5 U	0.49 U		
Sodium	50 U	49 U	99 U	99 U	49 U		
Strontium	6.6	11	5.3	3.4	1.8	5.6	8.4
Thallium	0.5 U	0.49 U	0.49 U	0.5 U	0.49 U		
Tin	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U		
Titanium	33	32	20	19	28	26.4	39.6
Vanadium	20	42	17	18	23	24	36
Yttrium	3.2	3.5	6.2	1.8	0.63	3.1	4.6
Zinc	18	18	13	15	7.1	14.2	21.3
General Chemistry							
% Solids	81	84	82	85	86	84	
pH	5.18	5.12	5.03	4.82	4.64	5.03	

Notes:
ft - feet
mg/kg - milligrams per kilogram
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
U,J - the analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.1. Groundwater Results for Monitoring Well BH26

Sample Location		BH26	BH26	*BH26*	BH26	BH26	BH26	BH26	BH26	BH26	BH26	BH26	BH26	BH26
Sample Date		2/16/2011	5/10/2011	*5/10/2011*	8/26/2011	11/10/2011	12/20/2012	7/10/2013	12/12/2013	12/8/2015	3/16/2016	8/3/2016	11/15/2016	3/28/2018
Sample Identification No.		GW26-0021	GW26-0511	*GW26-0511S*	GW26-0811	GW26-1111	GW26-1212	GW26-0713	GW26-1213	GW26-1215	GW26-0316	GW26-0816	GW26-1116	BH26
Water_Level_Depth			16.38	*16.38*	15.8	17.57	19.18	17.14	17.08			17.18		19.3
Total Metals														
Aluminum	µg/L	1900000	1900000	*1900000*	1800000	1800000	1700000 J,O	1600000	1500000	1100000	1100000	NA	NA	NA
Antimony	µg/L	14	19 J,O	*17 J,O*	25 U	12	9.8	11	15 J,O	14	12	NA	NA	NA
Arsenic	µg/L	1400 J,O	1900	*1800*	890	2100 J,O	1800	1800	1800	1400	1500	NA	NA	NA
Barium	µg/L	340	1000 U	*1000 U*	49	26	31	10 U	9.6 J,O	250 U	8.4 J,QI-1	NA	NA	NA
Beryllium	µg/L	180 U	6.5 J,O	*7.4 J,O*	12 U	5.6	6.7	6.4	4.6 J,O	150 U	6.6 J,QI-1	NA	NA	NA
Cadmium	µg/L	3900	4200	*4200*	4000	3900	3000	2400	2400	2200	2200	NA	NA	NA
Calcium	µg/L	320000	340000	*350000*	340000	330000	370000	380000	390000	290000	290000	NA	NA	NA
Chromium	µg/L	1600	1500	*1600*	1700	1500	1200	1300	1000	640	600	NA	NA	1900
Hexavalent Chromium	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5 U,J
Cobalt	µg/L	4900	5200	*5300*	5100	5000	4900	4700	4500	3200	2900	NA	NA	NA
Copper	µg/L	1200000	1200000	*1300000*	1100000	1100000	930000	800000	760000	220000	240000	NA	NA	NA
Iron	µg/L	7400000	7400000 J,O	*7800000*	7000000	7100000	6800000	6800000	6300000	4700000	4700000	NA	NA	NA
Lead	µg/L	42	58 J,O	*59 J,O*	32	30	21	28	24 J,O	18	19	NA	NA	NA
Magnesium	µg/L	760000	740000	*760000*	730000	730000	720000	690000	670000	510000	500000	NA	NA	NA
Manganese	µg/L	34000	35000	*35000*	33000	34000	36000	36000	35000	26000	NA	NA	NA	NA
Mercury	µg/L	0.27	0.3	*0.3*	0.3 J,O	0.33	0.22	0.2	0.27	0.68	0.54	NA	NA	NA
Molybdenum	µg/L	600 U	2000 U	*2000 U*	2000 U	1200 U	NA	500 U	1600 U	500 U	500 U	NA	NA	NA
Nickel	µg/L	2200	2500	*2500*	2200	2100	2100	2100	1900	1300	1200	NA	NA	NA
Potassium	µg/L	60000 U	200000 U	*200000 U*	2500 U	1000 U	1100	1100	780	50000 U	340 J,QI-1	NA	NA	NA
Selenium	µg/L	140 J,O	6400	*940 J,O*	85	180	160	210	220	160	180	NA	NA	NA
Silver	µg/L	300 U	5 U,J,O	*5 U,J,O*	5 U	5 U	2.5 U,J,O	10 U	2.5 U,J,O	250 U	2 J,QI-1	NA	NA	NA
Sodium	µg/L	60000 U	200000 U	*200000 U*	18000	26000	52000	59000	41000	50000 U	46000	NA	NA	NA
Strontium	µg/L	450	1000 U	*1000 U*	1000 U	600 U	NA	480	800 U	260	260	NA	NA	NA
Thallium	µg/L	12 U	10 U,J,O	*10 U,J,O*	25 U	2.8	2.1	2.8	2.1 J,O	10 U	2.8 J,QI-1	NA	NA	NA
Tin	µg/L	900 U	3000 U	*3000 U*	3000 U	1800 U	NA	750 U	2400 U	750 U	750 U	NA	NA	NA
Titanium	µg/L	300 U	1000 U	*1000 U*	1000 U	600 U	NA	250 U	800 U	250 U	250 U	NA	NA	NA
Vanadium	µg/L	1200	1000 U	*1000 U*	1400	1200	990	1100	940	730	630	NA	NA	NA
Yttrium	µg/L	1000	1100	*1100*	1100	1000	NA	950	860	600	530	NA	NA	NA
Zinc	µg/L	150000	160000 J,O	*160000*	150000	150000	140000	130000	120000	70000	63000	NA	NA	NA
Classical/Nutrient Analyses														
Acidity	mg/L	20000 L,O	24600	*24700*	27000	NA	24000 J,O	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA	1 U	*1 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, carbonate (as CaCO3)	mg/L	NA	1 U	*1 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	NA	1 U	*1 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia as N	mg/L	NA	5.3 O	*6 O*	NA	NA	NA	NA	NA	9.9	NA	NA	NA	NA
Chloride	mg/L	7.9 J,O	NA	*NA*	NA	NA	19	19	50 U,J,O	17	15	NA	NA	NA
Cyanide	µg/L	15 U,O	15 U,O	*15 U,O*	15 U,O	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate as SO4	mg/L	31000 J,O	NA	*NA*	NA	NA	26000	28000	25000 J,O	25000	26000	NA	NA	NA
Nitrate/Nitrite as N	mg/L	NA	NA	*NA*	NA	NA	NA	NA	NA	5 U	NA	NA	NA	NA
Total Dissolved Solids	mg/L	45000	45300	*43500*	46000	NA	NA	NA	NA	40000	40000	NA	NA	NA
Total Suspended Solids	mg/L	22	5 U	*16*	4 U	NA	NA	NA	NA	4 U	NA	NA	NA	NA
Field Instrument Result														
Dissolved Oxygen	mg/L	0.38	0.05	*NA*	0.08	0.56	0.31	0.17	0.19	0.18	0.13	0.1	0.06	2.7
Dissolved Oxygen (% Saturation)	%	4.1	0.6	*NA*	0.9	6.1	NA	1.9	2.5	NA	NA	NA	NA	NA
Ferrous Iron	mg/L	286	348	*NA*	2700	374	NA	NA	NA	NA	NA	NA	NA	NA
Oxidation Reduction Potential	mV	298.2	301.1	*NA*	291.7	292.6	228.4	130	260	300	310	310	300	286.5
pH	su	2.29	2.42	*NA*	2.5	2.36	2.44	2.46	2.38	2.47	2.36	2.42	2.47	1.98
Specific Conductivity	µS/cm	20310	20690	*NA*	20350	19850	19110	18570	18440	18980	18990	18790	18610	15590
Temperature	Deg C	18.1	19.6	*NA*	20.9	19.3	18.8	19.8	18.9	18.2	18.6	20.9	18.5	18
Total Iron	mg/L	7200	7520	*NA*	7200	4400	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	17.6	3.1	*NA*	5.48	4.97	9.37	2.74	2.78	0.97	1.63	1.08	6.8	1.39

Notes

µg/L - micrograms per liter
mg/L - milligrams per liter
mV - millivolts
su - standard units
µS/cm - microsiemens per centimeter
Deg C - degrees Celsius
NTU - nephelometric turbidity units
NA - not analyzed
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.2. Groundwater Results for Monitoring Well BH27

Sample Location		BH27	*BH27*	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27
Sample Date		2/17/2011	*2/17/2011*	5/10/2011	8/26/2011	11/10/2011	12/20/2012	7/10/2013	12/12/2013	12/8/2015	3/16/2016	8/3/2016	11/15/2016	3/28/2018	3/28/2018
Sample Identification No.		GW27-0211	*GW27-0211S*	GW27-0511	GW27-0811	GW27-1111	GW27-1212	GW27-0713	GW27-1213	GW27-1215	GW27-0316	GW27-0816	GW27-1116	BH27	BH927
Water_Level_Depth				22.02	22.62	23.06	24.98	22.2	22.35			22.46		23.67	23.67
Total Metals															
Aluminum	µg/L	1300000	*1200000*	1300000	1500000	1400000	1500000	1300000	1300000	940000	1100000	NA	NA	NA	NA
Antimony	µg/L	13	*12 U*	19 J,O	25 U	11	12	8	10 J,O	12	13	NA	NA	NA	NA
Arsenic	µg/L	1600	*1700*	1400	620	1500	1000	750	1500	1400	1300	NA	NA	NA	NA
Barium	µg/L	380	*440*	500 U	630	740	540	270	74	120 U	220	NA	NA	NA	NA
Beryllium	µg/L	45 U	*45 U*	10 J,O	12 U	5.1	5.7	5.7	5.3	75 U	5.6	NA	NA	NA	NA
Cadmium	µg/L	1700	*1800*	2200	2200	2100	1600	1900	2600	1200	1000	NA	NA	NA	NA
Calcium	µg/L	440000	*440000*	410000	400000	400000	530000	420000	440000	320000	350000	NA	NA	NA	NA
Chromium	µg/L	870	*870*	1300	1500	1800	1200	1300	940	550	460	NA	NA	460	480
Hexavalent Chromium	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6 J	1.5 U,J
Cobalt	µg/L	4000	*3900*	4600	4900	4700	3900	4200	4200	3100	2800	NA	NA	NA	NA
Copper	µg/L	180000	*180000*	430000	490000	480000	120000	360000	440000	46000	81000	NA	NA	NA	NA
Iron	µg/L	5400000	*5400000*	6000000	6200000	6300000	6000000	6100000	5900000	4100000	3800000	NA	NA	NA	NA
Lead	µg/L	170	*170*	400 J,O	350	540	160	200	170	95	93	NA	NA	NA	NA
Magnesium	µg/L	660000	*640000*	640000	680000	680000	710000	640000	690000	490000	640000	NA	NA	NA	NA
Manganese	µg/L	37000	*37000*	34000	35000	35000	42000	36000	35000	26000	28000	NA	NA	NA	NA
Mercury	µg/L	0.71	*0.73*	0.65	0.61	0.67	0.48	0.35	1.2	1.3	1.1	NA	NA	NA	NA
Molybdenum	µg/L	150 U	*150 U*	1000 U	800 U	800 U	NA	250 U	1000 U	250 U	50 U	NA	NA	NA	NA
Nickel	µg/L	2000	*1900*	2300	2200	2100	1800	1700	1900	1300	1300	NA	NA	NA	NA
Potassium	µg/L	15000 U	*15000 U*	100000 U	80000 U	1900	3800	1600	1000 U	25000 U	3900 J,QL-2	NA	NA	NA	NA
Selenium	µg/L	100 U	*100 U*	3000	77	93	56	160	230	50 U	52	NA	NA	NA	NA
Silver	µg/L	75 U	*75 U*	5 U,J,O	5 U	5 U	5 U	5 U	5 U	120 U	2 J,QL-1	NA	NA	NA	NA
Sodium	µg/L	92000	*90000*	100000 U	37000	47000	120000	78000	64000	61000	63000	NA	NA	NA	NA
Strontium	µg/L	400	*400*	500 U	400 U	400 U	NA	370	500 U	310	320	NA	NA	NA	NA
Thallium	µg/L	12 U	*12 U*	10 U,J,O	25 U	3.4	3.2	3.3	1.8	10 U	25 U	NA	NA	NA	NA
Tin	µg/L	220 U	*220 U*	1500 U	1200 U	1200 U	NA	380 U	1500 U	380 U	75 U	NA	NA	NA	NA
Titanium	µg/L	75 U	*75 U*	500 U	400 U	400 U	NA	120 U	500 U	120 U	25 U	NA	NA	NA	NA
Vanadium	µg/L	1000	*1000*	940	1100	1200	690	920	1000	650	610	NA	NA	NA	NA
Yttrium	µg/L	730	*740*	830	850	830	NA	800	740	520	520	NA	NA	NA	NA
Zinc	µg/L	110000	*110000*	130000	120000	110000	110000	120000	91000	65000	79000	NA	NA	NA	NA
Classical/Nutrient Analyses															
Acidity	mg/L	17000 J,O	*17000 J,O*	20300	23000	NA	16000 J,O	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA	*NA*	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, carbonate (as CaCO3)	mg/L	NA	*NA*	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	NA	*NA*	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia as N	mg/L	NA	*NA*	10 J,O	8 J,O	NA	NA	NA	NA	13	NA	NA	NA	NA	NA
Chloride	mg/L	22 J,O	*27 J,O*	NA	NA	NA	25	22	50 U,J,O	19	NA	NA	NA	NA	NA
Cyanide	µg/L	15 U,O	*15 U,O*	15 U,O	15 U,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	NA	*NA*	NA	NA	NA	NA	NA	NA	5.3	NA	NA	NA	NA	NA
Sulfate as SO4	mg/L	24000 J,O	*24000 J,O*	NA	NA	NA	19000	24000	23000 J,O	22000	21000	NA	NA	NA	NA
Total Dissolved Solids	mg/L	32000	*33000*	35900	41000	NA	NA	NA	NA	35000	32000	NA	NA	NA	NA
Total Suspended Solids	mg/L	28	*34*	37	18	NA	NA	NA	NA	9.3	9	NA	NA	NA	NA
Field Instrument Result															
Dissolved Oxygen	mg/L	0.25	*NA*	0.06	0.15	0.44	0.25	0.22	0.15	0.43	0.24	0.18	0.27	2.62	2.62
Dissolved Oxygen (% Saturation)	%	2.7	*NA*	0.7	1.8	4.8	NA	2.5	1.9	NA	NA	NA	NA	NA	NA
Dissolved Oxygen (% Saturation)	mg/L	NA	*NA*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ferrous Iron	mg/L	6,160	*NA*	1480	1480	2480	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oxidation Reduction Potential	mV	285.2	*NA*	264.1	316.1	236.3	135.2	60	340	240	280	290	300	386.9	386.9
pH	s.u.	2.59	*NA*	2.43	2.45	2.55	2.72	2.75	2.22	2.79	2.67	2.67	2.63	2.12	2.12
Specific Conductivity	µS/cm	16,140	*NA*	18100	17900	17560	15240	16000	17870	16450	15820	16370	16830	10610	10610
Temperature	Deg C	18.8	*NA*	21.1	23.6	18.5	18	21.7	18.9	19.3	20.1	22.1	17.1	18.43	18.43
Total Iron	mg/L	5,840	*NA*	6320	5280	6960	NA	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	24.6	*NA*	12	24.4	33.4	26.6	17.5	22	18.3	18.1	10.1	8.47	0	0

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Table A-4.2. Groundwater Results for Monitoring Well BH27

Sample Location		BH27	*BH27*	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27
Sample Date		2/17/2011	*2/17/2011*	5/10/2011	8/26/2011	11/10/2011	12/20/2012	7/10/2013	12/12/2013	12/8/2015	3/16/2016	8/3/2016	11/15/2016	3/28/2018	3/28/2018
Sample Identification No.		GW27-0211	*GW27-0211S*	GW27-0511	GW27-0811	GW27-1111	GW27-1212	GW27-0713	GW27-1213	GW27-1215	GW27-0316	GW27-0816	GW27-1116	BH27	BH927
Water_Level_Depth				22.02	22.62	23.06	24.98	22.2	22.35			22.46		23.67	23.67
Semi-volatile Organic Compounds															
1,1-Biphenyl	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,4,5-Tetrachlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Chloronaphthalene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Chlorophenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-4,6-dinitrophenol	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylphenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitroaniline	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitrophenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4,6-Tetrachlorophenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dichlorophenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylphenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dinitrophenol	µg/L	10 U,J,O	*10 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dinitrotoluene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,5-Trichlorophenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,6-Trichlorophenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,6-Dinitrotoluene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
(3-and/or 4-)Methylphenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Nitroaniline	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3,3'-Dichlorobenzidine	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Bromophenyl phenyl ether	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloro-3-methylphenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloroaniline	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chlorophenyl phenyl ether	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitroaniline	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitrophenol	µg/L	10 U,J,O	*10 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetophenone	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Atrazine	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzaldehyde	µg/L	5 U,J,O	*5 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl butyl phthalate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
bis(2-Chloroethyl) Ether	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl) ether	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Caprolactam	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diethyl phthalate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dimethyl phthalate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butylphthalate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-octylphthalate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Table A-4.2. Groundwater Results for Monitoring Well BH27

Sample Location		BH27	*BH27*	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27
Sample Date		2/17/2011	*2/17/2011*	5/10/2011	8/26/2011	11/10/2011	12/20/2012	7/10/2013	12/12/2013	12/8/2015	3/16/2016	8/3/2016	11/15/2016	3/28/2018	3/28/2018
Sample Identification No.		GW27-0211	*GW27-0211S*	GW27-0511	GW27-0811	GW27-1111	GW27-1212	GW27-0713	GW27-1213	GW27-1215	GW27-0316	GW27-0816	GW27-1116	BH27	BH927
Water_Level_Depth				22.02	22.62	23.06	24.98	22.2	22.35			22.46		23.67	23.67
Semi-volatile Organic Compounds - continued															
Hexachlorobenzene (HCB)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene (HCCP)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno (1,2,3-cd) pyrene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isophorone	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitroso di-n-Propylamine	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitrosodiphenylamine/Diphenylamine	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	µg/L	10 U,J,O	*10 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenol	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Organochlorine Pesticides															
4,4'-DDD (p,p'-DDD)	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDE (p,p'-DDE)	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT (p,p'-DDT)	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aldrin	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
alpha-BHC	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
alpha-Chlordane	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
beta-BHC	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
delta-BHC	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dieldrin	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan I (alpha)	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan II (beta)	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan Sulfate	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin aldehyde	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin ketone	µg/L	0.11 U,J,O	*0.11 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-Chlordane	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor epoxide	µg/L	0.054 U,J,O	*0.053 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methoxychlor	µg/L	0.54 U,J,O	*0.53 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toxaphene	µg/L	5.4 U,J,O	*5.3 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB Aroclors															
PCB-1016 (Aroclor 1016)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1221 (Aroclor 1221)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1232 (Aroclor 1232)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1242 (Aroclor 1242)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1248 (Aroclor 1248)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1254 (Aroclor 1254)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1260 (Aroclor 1260)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1262 (Aroclor 1262)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1268 (Aroclor 1268)	µg/L	1.1 U,J,O	*1.1 U,J,O*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds															
1,1-Dichloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene (1,1-Dichloroethylene)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Created by: Jim Eldridge
Updated by:
Checked by:

Table A-4.2. Groundwater Results for Monitoring Well BH27

Sample Location		BH27	*BH27*	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27	BH27
Sample Date		2/17/2011	*2/17/2011*	5/10/2011	8/26/2011	11/10/2011	12/20/2012	7/10/2013	12/12/2013	12/8/2015	3/16/2016	8/3/2016	11/15/2016	3/28/2018	3/28/2018
Sample Identification No.		GW27-0211	*GW27-0211S*	GW27-0511	GW27-0811	GW27-1111	GW27-1212	GW27-0713	GW27-1213	GW27-1215	GW27-0316	GW27-0816	GW27-1116	BH27	BH927
Water_Level_Depth				22.02	22.62	23.06	24.98	22.2	22.35			22.46		23.67	23.67
Volatile Organic Compounds - continued															
1,1,2,2-Tetrachloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane (DBCP)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromoethane (EDB)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloropropane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromochloromethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromoform	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromomethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulfide	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloromethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibromochloromethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichlorodifluoromethane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,2-Dichloroethene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,3-Dichloropropene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,3-Dichloropropene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethyl Benzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopropylbenzene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Acetate	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Butyl Ketone	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Ethyl Ketone	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Isobutyl Ketone	µg/L	10 U	*10 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl T-Butyl Ether (MTBE)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylcyclohexane	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene Chloride	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Styrene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene (Tetrachloroethylene)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene (Trichloroethylene)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane (Freon 11)	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
(m- and/or p-)Xylene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	µg/L	5 U	*5 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes

µg/L - micrograms per liter
mg/L - milligrams per liter
mV - millivolts
su - standard units
µS/cm - microsiemens per centimeter
Deg C - degrees Celsius
NTU - nephelometric turbidity units
NA - not analyzed
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Created by: Jim Eldridge
Updated by:
Checked by:

Table A-4.3. Groundwater Results for Monitoring Well BH28

Sample Location		BH28	BH28	BH28	BH28	BH28	BH28	BH28	BH28	BH28	BH28	BH28	BH28
Sample Date		2/11/2011	5/10/2011	8/26/2011	11/9/2011	12/20/2012	7/10/2013	12/12/2013	12/7/2015	3/16/2016	8/3/2016	11/16/2016	3/28/2018
Sample Identification No.		GW28-0211	GW28-0511	GW28-0811	GW28-1111	GW28-1212	GW28-0713	GW28-1213	GW28-1215	GW28-0316	GW28-0816	GW28-1116	BH28
WATER_LEVEL_DEPTH		11.94	11.09	11.38	11.94	13.62	11.32	11.33			11.48		12.75
Total Metals													
Aluminum	µg/L	510000	660000	590000	590000	510000	630000	870000	670000	620000	NA	NA	NA
Antimony	µg/L	19	17 J,O	25 U	14	13	11	26	19	15	NA	NA	NA
Arsenic	µg/L	3100	3400	2200	3700 O	2800	2500	3500	1900	2100	NA	NA	NA
Barium	µg/L	160	250 U	41	11	8.7	32	19	250 U	14	NA	NA	NA
Beryllium	µg/L	60 U	9.3 J,O	12 U	5 U	4.2	4.6	4.9 J,O	150 U	8.3 J,QI-1	NA	NA	NA
Cadmium	µg/L	3800	1900	1900	2000	2300	1600	1600	1500	1500	NA	NA	NA
Calcium	µg/L	310000	210000	190000	200000	180000	150000	180000	130000	120000	NA	NA	NA
Chromium	µg/L	180	420	360	340	290	340	530	390	320	NA	NA	230
Hexavalent Chromium	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5 U,J
Cobalt	µg/L	2000	2600	2200	2300	1800	2100	2900	2100	1900	NA	NA	NA
Copper	µg/L	340000	370000	310000	320000	240000	300000	460000	290000	290000	NA	NA	NA
Iron	µg/L	2700000	3E+06	2500000	2700000	2300000	3E+06	3700000	2600000	2200000	NA	NA	NA
Lead	µg/L	450	320 J,O	270	310	180	120	150	140	130	NA	NA	NA
Magnesium	µg/L	270000	230000	200000	200000	190000	230000	330000	250000	220000	NA	NA	NA
Manganese	µg/L	25000	22000	19000	19000	16000	19000	25000	22000	22000	NA	NA	NA
Mercury	µg/L	0.48	0.86	0.72	0.86	0.61	0.7	0.77	0.63	0.54	NA	NA	NA
Molybdenum	µg/L	200 U	500 U	400 U	400 U	NA	200 U	1000 U	500 U	500	NA	NA	NA
Nickel	µg/L	860	1100	810	900	750	830	1200	760	650	NA	NA	NA
Potassium	µg/L	20000 U	50000 U	12000	16000	16000	18000	28000	50000 U	18000 J,QL-2	NA	NA	NA
Selenium	µg/L	94	2200	120	150	120	250	310	140	200	NA	NA	NA
Silver	µg/L	100 U	5 U,J,O	5 U	5 U	1.2 U	10 U	5 U	250 U	1.3 J,QL-1	NA	NA	NA
Sodium	µg/L	32000	50000 U	28000	34000	33000	34000	34000	50000 U	33000	NA	NA	NA
Strontium	µg/L	590	590	510	570	NA	460	500 U	330	250	NA	NA	NA
Thallium	µg/L	12 U	10 U,J,O	25 U	4.4	3.5	3.4	3.8	10 U	3.5 J,QI-1	NA	NA	NA
Tin	µg/L	300 U	750 U	600 U	600 U	NA	300 U	1500 U	750 U	750 U	NA	NA	NA
Titanium	µg/L	100 U	250 U	200 U	200 U	NA	100 U	500 U	250 U	250 U	NA	NA	NA
Vanadium	µg/L	680	540	560	630	540	560	710	550	400	NA	NA	NA
Yttrium	µg/L	590	720	610	650	NA	630	740	570	490	NA	NA	NA
Zinc	µg/L	100000	63000	58000	62000	58000	55000	74000	56000	47000	NA	NA	NA
Classical/Nutrient Analyses													
Acidity	mg/L	7500 J,O	9880	8400	NA	7800 J,O	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, carbonate (as CaCO3)	mg/L	NA	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	NA	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia as N	mg/L	NA	5.3 O	4.2	NA	NA	NA	NA	5 U	NA	NA	NA	NA
Chloride	mg/L	12 J,O	NA	NA	NA	11	11	16 J,O	13	NA	NA	NA	NA
Cyanide	µg/L	15 U,O	15 U,O	15 U,O	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	NA	NA	NA	NA	NA	NA	NA	5 U	NA	NA	NA	NA
Sulfate as SO4	mg/L	9300 J,O	NA	NA	NA	8900	12000	15000 J,O	13000	15000	NA	NA	NA
Total Dissolved Solids	mg/L	13000	18100	16000	NA	NA	NA	NA	21000	23000	NA	NA	NA
Total Suspended Solids	mg/L	9.2	18	4 U	NA	NA	NA	NA	4 U	5.6	NA	NA	NA
Field Instrument Result													
Dissolved Oxygen	mg/L	0.41	0.06	0.1	0.12	0.17	0.13	0.16	0.53	0.16	0.14	0.07	2.06
Dissolved Oxygen (% Saturation)	%	2.2	0.7	1.1	1.4	NA	1.5	2	NA	NA	NA	NA	NA
Ferrous Iron	mg/L	203	160	123	114	NA	NA	NA	NA	NA	NA	NA	NA
Oxidation Reduction Potential	mV	314.6	290.2	307.1	298	301	290	330	330	340	320	290	309.8
pH	s.u.	2.47	2.39	2.47	2.24	2.25	2.28	1.96	2.15	2.26	2.4	2.6	2.78
Specific Conductivity	µS/cm	8,770	11480	10270	9880	9340	10650	14870	12790	13740	12160	10830	7489
Temperature	Deg C	16.6	19.4	20.5	19.5	18.8	20.5	18.7	18.1	18.9	20.9	19	15.59
Total Iron	mg/L	3,360	3200	2600	2920	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	14.3	9.22	4.58	2.63	8.31	8.57	6.26	2.14	6.32	4.36	6.81	6.53

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Created by: Jim Eldridge
Updated by:
Checked by:

Table A-4.4. Groundwater Results for Monitoring Well BH29

Sample Location		BH29	BH29	BH29	BH29	BH29	BH29	BH29	BH29	BH29	BH29	BH29	BH29	BH29
Sample Date		2/11/2011	5/10/2011	8/26/2011	11/10/2011	12/20/2012	7/10/2013	12/12/2013	12/12/2013	12/7/2015	3/16/2016	8/3/2016	11/16/2016	3/28/2018
Sample Identification No.		GW29-0211	GW29-0511	GW29-0811	GW29-1111	GW29-1212	GW29-0713	GW29-1213	GW29-1213S	GW29-1215	GW29-0316	GW29-0816	GW29-1116	bBH29
WATER_LEVEL_DEPTH		17.45	16.44	16.9	17.45	19.3	16.74	16.73	16.73			16.88		18.1
Total Metals														
Aluminum	µg/L	460000	270000	280000	290000	870000	380000	940000	960000	410000	490000	NA	NA	NA
Antimony	µg/L	15	9.7	9.1	10	25	10	65	68	15	14 J,QI-1	NA	NA	NA
Arsenic	µg/L	2900	1400	430	1800 O	9200	1100	8200	8700	830	1100	NA	NA	NA
Barium	µg/L	100 U	120 U	13	80	65	8.8	17	18	120 U	44	NA	NA	NA
Beryllium	µg/L	60 U	2.8 J,O	2.5	3.1	6.1	3.2	6.1	6.2	75 U	6.8 J,QI-1	NA	NA	NA
Cadmium	µg/L	2500	890	910	1300	2900	1200	2400	2500	1400	1300	NA	NA	NA
Calcium	µg/L	200000	220000	200000	230000	380000	160000	270000	280000	140000	170000	NA	NA	NA
Chromium	µg/L	260	170	180	150	480	200	560	600	230	260	NA	NA	170
Hexavalent Chromium	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5 U,J
Cobalt	µg/L	1600	950	930	1200	2700	1200	3100	3200	1400	1600	NA	NA	NA
Copper	µg/L	280000	150000	140000	150000	240000	240000	400000	410000	210000	250000	NA	NA	NA
Iron	µg/L	2200000	1300000	1200000	1400000	4000000	1500000	4200000	4300000	1600000	1900000	NA	NA	NA
Lead	µg/L	310	900	760	930	550	280	980	1000	200	190 J,QI-1	NA	NA	NA
Magnesium	µg/L	190000	130000	130000	140000	320000	170000	340000	350000	190000	220000	NA	NA	NA
Manganese	µg/L	16000	9900	9500	12000	25000	13000	27000	27000	18000	21000	NA	NA	NA
Mercury	µg/L	0.46	0.71	0.62	0.69	0.95	0.61	0.74	0.74	0.44	0.39	NA	NA	NA
Molybdenum	µg/L	200 U	250 U	200 U	200 U	NA	200 U	1000 U	1000 U	250 U	300 U	NA	NA	NA
Nickel	µg/L	690	470	400	500	1100	490	1300	1300	550	620	NA	NA	NA
Potassium	µg/L	20000 U	25000 U	1400	4700	29000	2800	33000	35000	25000 U	7200 J,QI-2	NA	NA	NA
Selenium	µg/L	110	870	21	58	100	120	220	240	79	110	NA	NA	NA
Silver	µg/L	100 U	2.5 U	1.2	2.5 U	1 U	5 U	5 U	5 U	120 U	1.2 J,QI-1	NA	NA	NA
Sodium	µg/L	34000	32000	34000	30000	45000	30000	32000	34000	28000	33000	NA	NA	NA
Strontium	µg/L	470	470	430	490	NA	350	720	750	310	300	NA	NA	NA
Thallium	µg/L	12 U	2.6 J,O	2.5 U	2.3	5.9	1.6	5	5.1	10 U	2.6 J,QI-1	NA	NA	NA
Tin	µg/L	300 U	380 U	300 U	300 U	NA	300 U	1500 U	1500 U	380 U	450 U	NA	NA	NA
Titanium	µg/L	100 U	120 U	100 U	100 U	NA	100 U	500 U	500 U	120 U	150 U	NA	NA	NA
Vanadium	µg/L	610	240	270	340	900	320	740	850	330	360	NA	NA	NA
Yttrium	µg/L	500	310	300	350	NA	420	830	860	450	490	NA	NA	NA
Zinc	µg/L	61000	33000	31000	40000	98000	42000	90000	93000	44000	46000	NA	NA	NA
Classical/Nutrient Analyses														
Acidity	mg/L	8500 J,O	4060	4200	NA	10000 J,O	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, carbonate (as CaCO3)	mg/L	NA	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	NA	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia as N	mg/L	NA	3.4 O	3.1 J,O	NA	NA	NA	NA	NA	5 U	NA	NA	NA	NA
Chloride	mg/L	11 J,O	NA	NA	NA	11	11	13 J,O	13 J,O	13	NA	NA	NA	NA
Cyanide	µg/L	15 U,O	15 U	15 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	NA	NA	0.05	NA	NA	NA	NA	NA	5 U	NA	NA	NA	NA
Sulfate as SO4	mg/L	10000 J,O	NA	NA	NA	12000	7600	17000 J,O	17000 J,O	1700	11000	NA	NA	NA
Total Dissolved Solids	mg/L	15000	7740	8400	NA	NA	NA	NA	NA	14000	16000	NA	NA	NA
Total Suspended Solids	mg/L	44 J,O	5 U	4 U	NA	NA	NA	NA	NA	4 U	4.2	NA	NA	NA
Field Instrument Result														
Dissolved Oxygen	mg/L	0.23	0.03	0.03	0.2	0.24	0.15	0.14	NA	0	0.18	0.12	0.16	0.79
Dissolved Oxygen (% Saturation)	%	2.4	0.3	0.4	2.4	NA	1.6	1.8	NA	NA	NA	NA	NA	NA
Ferrous Iron	mg/L	140	92	97	79	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oxidation Reduction Potential	mV	227.9	297.6	302	277.9	158	350	260	NA	340	350	290	290	553.4
pH	s.u.	2.92	2.71	2.72	2.61	2.4	2.42	1.97	NA	2.36	2.42	2.38	2.79	2.32
Specific Conductivity	µS/cm	7,430	5820	6150	6220	11020	7550	15880	NA	9014	10110	11840	74140	5614
Temperature	Deg C	18.2	19.9	20.9	21.2	19.3	19.9	19.2	NA	18.8	19	20	19.5	16.96
Total Iron	mg/L	3040	1180	1220	1600	NA	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	16.6	1.93	1.39	9.93	6.43	1.9	4.38	NA	3.64	7.31	7.75	5.22	1.55

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Created by: Jim Eldridge
Updated by:
Checked by:

Table A-4.5. Groundwater Results for Monitoring Well BH49

Sample Location		BH49		BH49		BH49		BH49		BH49		BH49		BH49		BH49		BH49		BH49		BH49	
Sample Date		2/10/2011		5/5/2011		8/24/2011		11/9/2011		12/20/2012		7/11/2013		12/10/2013		12/8/2015		3/15/2016		8/2/2016		11/15/2016	
Sample Identification No.		GW49-0211		GW49-0511		GW49-0811		GW49-1111		GW49-1212		GW49-0713		GW49-1213		GW49-1215		GW49-0316		GW49-0816		GW49-1116	
WATER_LEVEL_DEPTH		45.48		43.82		43.61		45.48		50.3		46.4		42.05						40.29			
Analyte	Units	Result	Qual	Result	Qua	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Total Metals																							
Aluminum	µg/L	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	NA		NA	
Antimony	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	NA		NA	
Arsenic	µg/L	1	U	1	U	1	U	1	U	1	U	2	U	1	U	1	U	1	U	NA		NA	
Barium	µg/L	120		120		120		120		110		120		120		110		80		NA		NA	
Beryllium	µg/L	3	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	3	U	0.5	U	NA		NA	
Cadmium	µg/L	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	0.5	U	0.5	U	NA		NA	
Calcium	µg/L	250	U	250	U	250	U	250	U	250	U	250	U	250	U	250	U	250	U	NA		NA	
Chromium	µg/L	5	U	5	U	5	U	7.8	U,O	5	U	5	U	5	U	8.4		5	U	NA		NA	
Cobalt	µg/L	35		5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Copper	µg/L	11		11		10	U	9.6		10	U	12		10	U	10	U	10	U	NA		NA	
Iron	µg/L	150		100	U	100	U	120		130	J,O	120		100	U	190		100	U	NA		NA	
Lead	µg/L	1	U	1	U	1	U	1	U	1.2		0.85		1	U	1	U	1	U	NA		NA	
Magnesium	µg/L	250	U	250	U	250	U	250	U	250	U	250	U	250	U	250	U	250	U	NA		NA	
Manganese	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Mercury	µg/L	0.11		0.13		0.14		0.14		0.11		0.11		0.25		0.35		0.65		NA		NA	
Molybdenum	µg/L	10	U	10	U	10	U	10	U	NA		10	U	10	U	10	U	10	U	NA		NA	
Nickel	µg/L	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	NA		NA	
Potassium	µg/L	1000	U	1000	U	1000	U	230		1000	U	1000	U	1000	U	1000	U	1000	U,J,QC-5	NA		NA	
Selenium	µg/L	2	U	2	U,J,	2	U	2	U	2	U	4	U	2	U	2	U	2	U	NA		NA	
Silver	µg/L	5	U	5	U	5	U	5	U	5	U	0.4	U	5	U	5	U	0.5	U	NA		NA	
Sodium	µg/L	7800		6600		7600		8000	J,O	7500		6600		8600		12000		14000		NA		NA	
Strontium	µg/L	5	U	5	U	5	U	5	U	NA		5	U	5	U	5	U	5	U	NA		NA	
Thallium	µg/L	1	U	1	U	1	U	1	U	1	U	0.4	U	1	U	1	U	1	U	NA		NA	
Tin	µg/L	15	U	15	U	15	U	15	U	NA		15	U	15	U	15	U	15	U	NA		NA	
Titanium	µg/L	5	U	5	U	5	U	5	U	NA		5	U	5	U	5	U	5	U	NA		NA	
Vanadium	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Yttrium	µg/L	3	U	3	U	3	U	3	U	NA		3	U	3	U	3	U	3	U	NA		NA	
Zinc	µg/L	10	U	10	U	10	U	16		20	J,O	10		10	U	10	U	10	U	NA		NA	
Classical/Nutrient Analyses																							
Acidity	mg/L	10	U	10	U	10	U	NA		10	U	10	U	NA		10	U,J,O	10	U	NA		NA	
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA		1.6		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, carbonate (as CaCO3)	mg/L	NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, Total (as CaCO3)	mg/L	1.2		1.6		1.9		NA		1.4		1	U	NA		3.1		4.2		NA		NA	
Ammonia as N	mg/L	0.05	U	0.05	U	0.05	U	NA		NA		NA		NA		NA		NA		NA		NA	
Chloride	mg/L	7.9	J,O	7.7		7.5		NA		7.2		6.7		8.3	J,O	9.3		10		NA		NA	
Cyanide	µg/L	15	U	15	U	15	U	NA		NA		NA		NA		NA		NA		NA		NA	
Nitrate/Nitrite as N	mg/L	0.5		0.43		0.51		NA		NA		NA		NA		NA		NA		NA		NA	
Sulfate as SO4	mg/L	2.4	J,O	2.8		2.1		NA		2.1		1.8		2.8	J,O	0.97		6.4		NA		NA	
Total Dissolved Solids	mg/L	41		36	J	40	U	NA		NA		NA		NA		46		57		NA		NA	
Total Suspended Solids	mg/L	4	U	5	U	4	U	NA		NA		NA		NA		4.2		4	U	NA		NA	
Field Instrument Result																							
Dissolved Oxygen	mg/L	3.97		4.13		4.01		4.09		4.14		4.29		3.37		3.75		3.8		3.75		3.64	
Dissolved Oxygen (% Saturation)	%	44.8		46.8		46.6		47.7		NA		50.3		45.3		NA		NA		NA		NA	
Ferrous Iron	mg/L	0.03		0.03		0.03		0.04		NA		NA		NA		NA		NA		NA		NA	
Oxidation Reduction Potential	mV	306.1		-163.8		244.8		286.6		302.4		270		190		170		350		20		50	
pH	s.u.	4.66		4.63		4.66		4.77		4.57		4.98		4.71		4.95		4.66		4.93		4.82	
Specific Conductivity	µS/cm	48.1		88.5		48		50		50.6		44.7		55.8		68.55		75.59		89.17		90.02	
Temperature	Deg C	20.6		21.1		21.3		22.2		23.4		22.7		20.7		21.3		21		22.1		21.4	
Total Iron	mg/L	0.03		0.05		0.06		0.09		NA		NA		NA		NA		NA		NA		NA	
Turbidity	NTU	3.87		1.25		3.09		3.99		1.17		2.71		0.38		3.72		1.25		2.4		2.52	

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Created by: Jim Eldridge
Updated by:
Checked by:

Table A-4.6. Groundwater Results for Monitoring Well BH50

Sample Location		BH50		BH50		BH50		BH50		BH50		BH50		BH50		BH50		BH50		BH50		BH50	
Sample Date		2/10/2011		5/5/2011		8/24/2011		11/9/2011		12/20/2012		7/11/2013		12/11/2013		12/8/2015		3/15/2016		8/2/2016		11/15/2016	
Sample Identification No.		GW50-0211		GW50-0511		GW50-0811		GW50-1111		GW50-1212		GW50-0713		GW50-1213		GW50-1215		GW50-0316		GW50-0816		GW50-1116	
WATER_LEVEL_DEPTH		45.83		44.26		44.2		45.83		50.89		47.19		43.37						41.12			
Analyte	Units	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Total Metals																							
Aluminum	µg/L	100	U	120		100	U	100	U	100	U	100	U	100	U	100	U	100	U	NA		NA	
Antimony	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	NA		NA	
Arsenic	µg/L	1	U	1	U	1	U	1	U	1	U	2	U	1	U	1	U	1	U	NA		NA	
Barium	µg/L	190		200		180		170		140		130		150		150		140		NA		NA	
Beryllium	µg/L	3	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	3	U	0.5	U	NA		NA	
Cadmium	µg/L	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	0.5	U	0.5	U	NA		NA	
Calcium	µg/L	18000		17000		17000		17000		17000		15000		15000		18000		17000		NA		NA	
Chromium	µg/L	5.5		8.8		5	U	6.2	U,O	5	U	5	U	5	U	5	U	5	U	NA		NA	
Cobalt	µg/L	5	U	5	U	5	U	19		5	U	5	U	5	U	5	U	5	U	NA		NA	
Copper	µg/L	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	NA		NA	
Iron	µg/L	100	U	180		100	U	100	U	100	U	100	U	100	U	150		100	U	NA		NA	
Lead	µg/L	1	U	1	U	1	U	1	U	1	U	0.8	U	1	U	1	U	1	U	NA		NA	
Magnesium	µg/L	8900		8100		8300		8500		8100		7400		7600		8300		7900		NA		NA	
Manganese	µg/L	25		55		36		20		13		14		6.6		13		8.6	J,QR-2	NA		NA	
Mercury	µg/L	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	NA		NA	
Molybdenum	µg/L	10	U	10	U	10	U	10	U	NA		10	U	10	U	10	U	10	U	NA		NA	
Nickel	µg/L	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	NA		NA	
Potassium	µg/L	1000	U	1000	U	1000	U	800		1000	U	1000	U	1000	U	1000	U	1000	U,J,QC-5	NA		NA	
Selenium	µg/L	5.9		5.9		6.2		6.2		7.1		8		5.3		8.4		8.1		NA		NA	
Silver	µg/L	5	U	5	U	5	U	5	U	5	U	0.4	U	5	U	5	U	0.5	U	NA		NA	
Sodium	µg/L	23000		22000		23000		22000	J,O	23000		21000		21000		25000		23000		NA		NA	
Strontium	µg/L	240		250		240		240		NA		210		220		260		230		NA		NA	
Thallium	µg/L	1	U	1	U	1	U	1	U	1	U	0.4	U	1	U	1	U	1	U	NA		NA	
Tin	µg/L	15	U	15	U	15	U	15	U	NA		15	U	15	U	15	U	15	U	NA		NA	
Titanium	µg/L	5	U	5	U	5	U	5	U	NA		5	U	5	U	5	U	5	U	NA		NA	
Vanadium	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Yttrium	µg/L	3	U	3	U	3	U	3	U	NA		3	U	3	U	3	U	3	U	NA		NA	
Zinc	µg/L	43		46		46		46		54		41		40		52		42		NA		NA	
Classical/Nutrient Analyses																							
Acidity	mg/L	10	U	10	U	NA		NA		NA		NA		NA		10	U	10	U	NA		NA	
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA		62.1		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, carbonate (as CaCO3)	mg/L	NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, Total (as CaCO3)	mg/L	63		62.1		64	O	NA		63		67		NA		69		69		NA		NA	
Ammonia as N	mg/L	0.05	U	0.05	U	0.05	U,O	NA		NA		NA		NA		NA		NA		NA		NA	
Chloride	mg/L	13	J,O	12		12	O	NA		12		12		12	J,O	12		12		NA		NA	
Cyanide	µg/L	15	U	15	U	15	U,O	NA		NA		NA		NA		NA		NA		NA		NA	
Nitrate/Nitrite as N	mg/L	0.82		0.77		0.87	O	NA		NA		NA		NA		NA		NA		NA		NA	
Sulfate as SO4	mg/L	50	J,O	46		47	O	NA		41		34		37	J,O	26		43		NA		NA	
Total Dissolved Solids	mg/L	200		199	J	200	O	NA		NA		NA		NA		200	U	200		NA		NA	
Total Suspended Solids	mg/L	4	U	5	U	4	U,O	NA		NA		NA		NA		4		4	U	NA		NA	
Field Instrument Result																							
Dissolved Oxygen	mg/L	1.47		2.09		1.4		1.46		1.29		0.78		0.83		1.16		0.67		0.53		0.73	
Dissolved Oxygen (% Saturation)	%	16.5		22.5		15.9		16.3		NA		8.8		10.6		NA		NA		NA		NA	
Ferrous Iron	mg/L	0.04		0.03		0.03		0.02	U	NA		NA		NA		NA		NA		NA		NA	
Oxidation Reduction Potential	mV	113.9		-222.6		198.8		188.9		143.1		150		-20		40		60		30		-150	
pH	s.u.	6.08		6.07		6.06		6.04		5.97		6.06		6		6		5.87		5.93		6.06	
Specific Conductivity	µS/cm	264		259.7		262		262.6		272.4		240.7		250.3		278.4		251.6		281.6		308.3	
Temperature	Deg C	20.5		18.7		20.8		19.9		19.7		20.4		18.6		19		19.8		20.3		19.1	
Total Iron	mg/L	0.04		0.1		0.08		0.1		NA		NA		NA		NA		NA		NA		NA	
Turbidity	NTU	4.04		9.75		4.05		3.18		2.85		3.71		1.19		2.77		1		2.8		0.65	

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

Created by: Jim Eldridge
Updated by:
Checked by:

Table A-4.7. Groundwater Results for Monitoring Well BH51

Sample Location		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51	
Sample Date		2/15/2011		5/5/2011		8/24/2011		11/9/2011		12/20/2012		7/11/2013		12/10/2013		12/9/2015		3/15/2016		8/4/2016		11/15/2016	
Sample Identification No.		GW51-0211		GW51-0511		GW51-0811		GW51-1111		GW51-1212		GW51-0713		GW51-1213		GW51-1215		GW51-0316		GW51-0816		GW51-1116	
WATER_LEVEL_DEPTH		44.56		43.03		42.88		44.56		49.65		45.9		41.83						39.93			
Analyte	**Units**	Result	Qual	Result	Qua	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Total Metals																							
Aluminum	µg/L	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	NA		NA	
Antimony	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	NA		NA	
Arsenic	µg/L	1	U	1	U	1	U	1	U	1	U	2	U	1	U	1	U	1	U	NA		NA	
Barium	µg/L	66		68		62		63		59		49		51		53		48		NA		NA	
Beryllium	µg/L	3	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	3	U	0.5	U	NA		NA	
Cadmium	µg/L	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	0.5	U	0.5	U	NA		NA	
Calcium	µg/L	36000		34000		34000		34000		34000		31000		33000		33000		32000		NA		NA	
Chromium	µg/L	5	U	5	U	5	U	2.4	U,O	5	U	5	U	5	U	5	U	5	U	NA		NA	
Cobalt	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Copper	µg/L	21		22		12		19		15	J,O	15		20		19		15	J,QR-2	NA		NA	
Iron	µg/L	100	U	100	U	100	U	100	U	100	U	100	U	100	U	120		100	U	NA		NA	
Lead	µg/L	1	U	1.7		1	U	1	U	1	U	0.8	U	1	U	1	U	1	U	NA		NA	
Magnesium	µg/L	10000		9700		9900		9700		9600		9200		9600		9000		9000		NA		NA	
Manganese	µg/L	6.8		14		9.2		18		22		8.3		5	U	5.2		8.7	J,QR-2	NA		NA	
Mercury	µg/L	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	NA		NA	
Molybdenum	µg/L	10	U	10	U	10	U	10	U	NA		10	U	10	U	10	U	10	U	NA		NA	
Nickel	µg/L	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	NA		NA	
Potassium	µg/L	1000	U	1000	U	1000	U	750		1000	U	1000	U	1000	U	1000	U	1000	U	NA		NA	
Selenium	µg/L	5.4		4.9	J,O	5.8		5.9		5.4		6.9		5.9		6.5		6.9		NA		NA	
Silver	µg/L	5	U	5	U	5	U	5	U	5	U	0.4	U	5	U	5	U	0.5	U	NA		NA	
Sodium	µg/L	27000		26000		27000		27000	J,O	26000		26000		26000		27000		26000		NA		NA	
Strontium	µg/L	260		260		260		260		NA		250		250		260		240		NA		NA	
Thallium	µg/L	1	U	1	U	1	U	1	U	1	U	0.4	U	1	U	1	U	1	U	NA		NA	
Tin	µg/L	15	U	15	U	15	U	15	U	NA		15	U	15	U	15	U	15	U	NA		NA	
Titanium	µg/L	5	U	5	U	5	U	5	U	NA		5	U	5	U	5	U	5	U	NA		NA	
Vanadium	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Yttrium	µg/L	3	U	3	U	3	U	3	U	NA		3	U	3	U	3	U	3	U	NA		NA	
Zinc	µg/L	55		58		67		59		55		57		46		53		48		NA		NA	
Classical/Nutrient Analyses																							
Acidity	mg/L	10	U	10	U	NA		NA		NA		NA		NA		10	U	10	U	NA		NA	
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA		55.7		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, carbonate (as CaCO3)	mg/L	NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, Total (as CaCO3)	mg/L	57		55.7		56		NA		58		60		NA		61		59		NA		NA	
Ammonia as N	mg/L	0.05	U	0.05	U	0.05	U	NA		NA		NA		NA		NA		NA		NA		NA	
Chloride	mg/L	15	J,O	15		14		NA		13		13		14		13		13		NA		NA	
Cyanide	µg/L	15	U	15	U	15	U	NA		NA		NA		NA		NA		NA		NA		NA	
Nitrate/Nitrite as N	mg/L	1.2		1.2		1.2		NA		NA		NA		NA		NA		NA		NA		NA	
Sulfate as SO4	mg/L	110	J,O	110		110		NA		97		96		110	O	71		94		NA		NA	
Total Dissolved Solids	mg/L	290		269	J	280		NA		NA		NA		NA		260		270		NA		NA	
Total Suspended Solids	mg/L	4	U	5	U	4	U	NA		NA		NA		NA		4	U	4	U	NA		NA	
Field Instrument Result																							
Dissolved Oxygen	mg/L	2.64		2.51		2.42		2.33		2.17		2.34		1.74		2.21		2.12		1.85		1.96	
Dissolved Oxygen (% Saturation)	%	NA		27		26.5		25.7		NA		25.8		22.6		NA		NA		NA		NA	
Ferrous Iron	mg/L	0.03		0.03		0.02	U	0.02	U	NA		NA		NA		NA		NA		NA		NA	
Oxidation Reduction Potential	mV	172		-270		158		230.7		57.7		40		170		80		120		80		180	
pH	s.u.	6.13		5.99		6.24		6.11		5.99		6.04		5.98		6.12		5.95		6.06		6.06	
Specific Conductivity	µS/cm	385		382		385		391		392		364		388		370		346.2		767.1		384.6	
Temperature	Deg C	18.8		18.8		19.2		19.3		19		19.2		18.8		18.7		18.9		19.4		18.6	
Total Iron	mg/L	0.08		0.07		0.05		0.04		NA		NA		NA		NA		NA		NA		NA	
Turbidity	NTU	2.25		2.44		1.06		0.35		2.09		1.78		0.4		1.08		0.34		0.7		0.39	
Semi Volatile Organics																							
1,1-Biphenyl	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
1,2,4,5-Tetrachlorobenzene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Chloronaphthalene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Chlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Methyl-4,6-dinitrophenol	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Methylnaphthalene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Methylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Nitroaniline	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Nitrophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,3,4,6-Tetrachlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dichlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dimethylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dinitrophenol	µg/L	10	U,J,O	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dinitrotoluene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4,5-Trichlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4,6-Trichlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,6-Dinitrotoluene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
(3-and/or 4-)Methylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
3-Nitroaniline	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
3,3'-Dichlorobenzidine	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Bromophenyl phenyl ether	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Chloro-3-methylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Chloroaniline	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Chlorophenyl phenyl ether	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Nitroaniline	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	

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Table A-4.7. Groundwater Results for Monitoring Well BH51

Sample Location		BH51		BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51
Sample Date		2/15/2011		5/5/2011	8/24/2011	11/9/2011	12/20/2012	7/11/2013	12/10/2013	12/9/2015	3/15/2016	8/4/2016	11/15/2016
Sample Identification No.		GW51-0211		GW51-0511	GW51-0811	GW51-1111	GW51-1212	GW51-0713	GW51-1213	GW51-1215	GW51-0316	GW51-0816	GW51-1116
4-Nitrophenol	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetophenone	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Atrazine	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzaldehyde	µg/L	5	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl butyl phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
bis(2-Chloroethyl) Ether	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl) ether	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Caprolactam	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diethyl phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dimethyl phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butylphthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-octylphthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobenzene (HCB)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene (HCCP)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno (1,2,3-cd) pyrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isophorone	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitroso di-n-Propylamine	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitrosodiphenylamine/Diphenylamine	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenol	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Organochlorine Pesticides													
4,4'-DDD (p,p'-DDD)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDE (p,p'-DDE)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT (p,p'-DDT)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aldrin	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
alpha-BHC	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
alpha-Chlordane	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
beta-BHC	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
delta-BHC	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dieldrin	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan I (alpha)	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan II (beta)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan Sulfate	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin aldehyde	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin ketone	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-Chlordane	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor epoxide	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methoxychlor	µg/L	0.5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toxaphene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB Aroclors													
PCB-1016 (Aroclor 1016)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1221 (Aroclor 1221)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1232 (Aroclor 1232)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1242 (Aroclor 1242)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1248 (Aroclor 1248)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1254 (Aroclor 1254)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1260 (Aroclor 1260)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1262 (Aroclor 1262)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1268 (Aroclor 1268)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Table A-4.7. Groundwater Results for Monitoring Well BH51

Sample Location		BH51		BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51
Sample Date		2/15/2011		5/5/2011	8/24/2011	11/9/2011	12/20/2012	7/11/2013	12/10/2013	12/9/2015	3/15/2016	8/4/2016	11/15/2016
Sample Identification No.		GW51-0211		GW51-0511	GW51-0811	GW51-1111	GW51-1212	GW51-0713	GW51-1213	GW51-1215	GW51-0316	GW51-0816	GW51-1116
Volatile Organic Compounds													
1,1-Dichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromoethane (EDB)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloropropane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromochloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromoform	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromomethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulfide	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibromochloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichlorodifluoromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,2-Dichloroethene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,3-Dichloropropene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,3-Dichloropropene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethyl Benzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopropylbenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Acetate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Butyl Ketone	µg/L	10	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Ethyl Ketone	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Isobutyl Ketone	µg/L	10	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl T-Butyl Ether (MTBE)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylcyclohexane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene Chloride	µg/L	5.6	U,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Styrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene (Tetrachloroethylene)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene (Trichloroethylene)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane (Freon 11)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
(m- and/or p-)Xylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes

µg/L - micrograms per liter
mg/L - milligrams per liter
mV - millivolts
su - standard units
µS/cm - microsiemens per centimeter
Deg C - degrees Celsius
NTU - nephelometric turbidity units
NA - not analyzed
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.7. Groundwater Results for Monitoring Well BH51

	Sample Location	BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51		BH51	
	Sample Date	2/15/2011		5/5/2011		8/24/2011		11/9/2011		12/20/2012		7/11/2013		12/10/2013		12/9/2015		3/15/2016		8/4/2016		11/15/2016	
	Sample Identification No.	GW51-0211		GW51-0511		GW51-0811		GW51-1111		GW51-1212		GW51-0713		GW51-1213		GW51-1215		GW51-0316		GW51-0816		GW51-1116	
	WATER_LEVEL_DEPTH	44.56		43.03		42.88		44.56		49.65		45.9		41.83						39.93			
Analyte	**Units**	Result	Qual	Result	Qua	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Total Metals																							
Aluminum	µg/L	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	NA		NA	
Antimony	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	NA		NA	
Arsenic	µg/L	1	U	1	U	1	U	1	U	1	U	2	U	1	U	1	U	1	U	NA		NA	
Barium	µg/L	66		68		62		63		59		49		51		53		48		NA		NA	
Beryllium	µg/L	3	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	3	U	0.5	U	NA		NA	
Cadmium	µg/L	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	1	U	0.5	U	0.5	U	0.5	U	NA		NA	
Calcium	µg/L	36000		34000		34000		34000		34000		31000		33000		33000		32000		NA		NA	
Chromium	µg/L	5	U	5	U	5	U	2.4	U,O	5	U	5	U	5	U	5	U	5	U	NA		NA	
Cobalt	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Copper	µg/L	21		22		12		19		15	J,O	15		20		19		15	J,QR-2	NA		NA	
Iron	µg/L	100	U	100	U	100	U	100	U	100	U	100	U	100	U	120		100	U	NA		NA	
Lead	µg/L	1	U	1.7		1	U	1	U	1	U	0.8	U	1	U	1	U	1	U	NA		NA	
Magnesium	µg/L	10000		9700		9900		9700		9600		9200		9600		9000		9000		NA		NA	
Manganese	µg/L	6.8		14		9.2		18		22		8.3		5	U	5.2		8.7	J,QR-2	NA		NA	
Mercury	µg/L	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U	NA		NA	
Molybdenum	µg/L	10	U	10	U	10	U	10	U	NA		10	U	10	U	10	U	10	U	NA		NA	
Nickel	µg/L	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	10	U	NA		NA	
Potassium	µg/L	1000	U	1000	U	1000	U	750		1000	U	1000	U	1000	U	1000	U	1000	U	NA		NA	
Selenium	µg/L	5.4		4.9	J,O	5.8		5.9		5.4		6.9		5.9		6.5		6.9		NA		NA	
Silver	µg/L	5	U	5	U	5	U	5	U	5	U	0.4	U	5	U	5	U	0.5	U	NA		NA	
Sodium	µg/L	27000		26000		27000		27000	J,O	26000		26000		26000		27000		26000		NA		NA	
Strontium	µg/L	260		260		260		260		NA		250		250		260		240		NA		NA	
Thallium	µg/L	1	U	1	U	1	U	1	U	1	U	0.4	U	1	U	1	U	1	U	NA		NA	
Tin	µg/L	15	U	15	U	15	U	15	U	NA		15	U	15	U	15	U	15	U	NA		NA	
Titanium	µg/L	5	U	5	U	5	U	5	U	NA		5	U	5	U	5	U	5	U	NA		NA	
Vanadium	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	NA		NA	
Yttrium	µg/L	3	U	3	U	3	U	3	U	NA		3	U	3	U	3	U	3	U	NA		NA	
Zinc	µg/L	55		58		67		59		55		57		46		53		48		NA		NA	
Classical/Nutrient Analyses																							
Acidity	mg/L	10	U	10	U	NA		NA		NA		NA		NA		10	U	10	U	NA		NA	
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA		55.7		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, carbonate (as CaCO3)	mg/L	NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, Total (as CaCO3)	mg/L	57		55.7		56		NA		58		60		NA		61		59		NA		NA	
Ammonia as N	mg/L	0.05	U	0.05	U	0.05	U	NA		NA		NA		NA		NA		NA		NA		NA	
Chloride	mg/L	15	J,O	15		14		NA		13		13		14		13		13		NA		NA	
Cyanide	µg/L	15	U	15	U	15	U	NA		NA		NA		NA		NA		NA		NA		NA	
Nitrate/Nitrite as N	mg/L	1.2		1.2		1.2		NA		NA		NA		NA		NA		NA		NA		NA	
Sulfate as SO4	mg/L	110	J,O	110		110		NA		97		96		110	O	71		94		NA		NA	
Total Dissolved Solids	mg/L	290		269	J	280		NA		NA		NA		NA		260		270		NA		NA	
Total Suspended Solids	mg/L	4	U	5	U	4	U	NA		NA		NA		NA		4	U	4	U	NA		NA	
Field Instrument Result																							
Dissolved Oxygen	mg/L	2.64		2.51		2.42		2.33		2.17		2.34		1.74		2.21		2.12		1.85		1.96	
Dissolved Oxygen (% Saturation)	%	NA		27		26.5		25.7		NA		25.8		22.6		NA		NA		NA		NA	
Ferrous Iron	mg/L	0.03		0.03		0.02	U	0.02	U	NA		NA		NA		NA		NA		NA		NA	
Oxidation Reduction Potential	mV	172		-270		158		230.7		57.7		40		170		80		120		80		180	
pH	s.u.	6.13		5.99		6.24		6.11		5.99		6.04		5.98		6.12		5.95		6.06		6.06	
Specific Conductivity	µS/cm	385		382		385		391		392		364		388		370		346.2		767.1		384.6	
Temperature	Deg C	18.8		18.8		19.2		19.3		19		19.2		18.8		18.7		18.9		19.4		18.6	
Total Iron	mg/L	0.08		0.07		0.05		0.04		NA		NA		NA		NA		NA		NA		NA	
Turbidity	NTU	2.25		2.44		1.06		0.35		2.09		1.78		0.4		1.08		0.34		0.7		0.39	
Semi Volatile Organics																							
1,1-Biphenyl	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
1,2,4,5-Tetrachlorobenzene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Chloronaphthalene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Chlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Methyl-4,6-dinitrophenol	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Methylnaphthalene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Methylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Nitroaniline	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2-Nitrophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,3,4,6-Tetrachlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dichlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dimethylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dinitrophenol	µg/L	10	U,J,O	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4-Dinitrotoluene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4,5-Trichlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,4,6-Trichlorophenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
2,6-Dinitrotoluene	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
(3-and/or 4-)Methylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
3-Nitroaniline	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
3,3'-Dichlorobenzidine	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Bromophenyl phenyl ether	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Chloro-3-methylphenol	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Chloroaniline	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Chlorophenyl phenyl ether	µg/L	5	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
4-Nitroaniline	µg/L	10	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	

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Table A-4.7. Groundwater Results for Monitoring Well BH51

Sample Location		BH51		BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51
Sample Date		2/15/2011		5/5/2011	8/24/2011	11/9/2011	12/20/2012	7/11/2013	12/10/2013	12/9/2015	3/15/2016	8/4/2016	11/15/2016
Sample Identification No.		GW51-0211		GW51-0511	GW51-0811	GW51-1111	GW51-1212	GW51-0713	GW51-1213	GW51-1215	GW51-0316	GW51-0816	GW51-1116
4-Nitrophenol	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetophenone	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Atrazine	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzaldehyde	µg/L	5	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl butyl phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
bis(2-Chloroethyl) Ether	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl) ether	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Caprolactam	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diethyl phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dimethyl phthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butylphthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-octylphthalate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobenzene (HCB)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene (HCCP)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno (1,2,3-cd) pyrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isophorone	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitroso di-n-Propylamine	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitrosodiphenylamine/Diphenylamine	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenol	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Organochlorine Pesticides													
4,4'-DDD (p,p'-DDD)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDE (p,p'-DDE)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT (p,p'-DDT)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aldrin	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
alpha-BHC	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
alpha-Chlordane	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
beta-BHC	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
delta-BHC	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dieldrin	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan I (alpha)	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan II (beta)	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endosulfan Sulfate	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin aldehyde	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin ketone	µg/L	0.1	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-Chlordane	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor epoxide	µg/L	0.05	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methoxychlor	µg/L	0.5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toxaphene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB Aroclors													
PCB-1016 (Aroclor 1016)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1221 (Aroclor 1221)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1232 (Aroclor 1232)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1242 (Aroclor 1242)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1248 (Aroclor 1248)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1254 (Aroclor 1254)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1260 (Aroclor 1260)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1262 (Aroclor 1262)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB-1268 (Aroclor 1268)	µg/L	0.95	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Table A-4.7. Groundwater Results for Monitoring Well BH51

Sample Location		BH51		BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51	BH51
Sample Date		2/15/2011		5/5/2011	8/24/2011	11/9/2011	12/20/2012	7/11/2013	12/10/2013	12/9/2015	3/15/2016	8/4/2016	11/15/2016
Sample Identification No.		GW51-0211		GW51-0511	GW51-0811	GW51-1111	GW51-1212	GW51-0713	GW51-1213	GW51-1215	GW51-0316	GW51-0816	GW51-1116
Volatile Organic Compounds													
1,1-Dichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromoethane (EDB)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloropropane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromochloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromoform	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromomethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulfide	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibromochloromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichlorodifluoromethane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,2-Dichloroethene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,3-Dichloropropene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,3-Dichloropropene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethyl Benzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopropylbenzene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Acetate	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Butyl Ketone	µg/L	10	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Ethyl Ketone	µg/L	10	U,J,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl Isobutyl Ketone	µg/L	10	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl T-Butyl Ether (MTBE)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylcyclohexane	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene Chloride	µg/L	5.6	U,O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Styrene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene (Tetrachloroethylene)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene (Trichloroethylene)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane (Freon 11)	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
(m- and/or p-)Xylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	µg/L	5	U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes

µg/L - micrograms per liter
mg/L - milligrams per liter
mV - millivolts
su - standard units
µS/cm - microsiemens per centimeter
Deg C - degrees Celsius
NTU - nephelometric turbidity units
NA - not analyzed
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.8. Groundwater Results for Monitoring Well BH55

Sample Location		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55		BH55	
Sample Date		2/16/2011		2/16/2011		5/9/2011		8/25/2011		11/10/2011		11/10/2011		12/20/2012		12/20/2012		7/8/2013		12/9/2013		12/8/2015		3/17/2016		8/4/2016		11/15/2016	
Sample Identification No.		GW55-0211		GW55-0211S		GW55-0511		GW55-0811		GW55-1111		GW55-1111S		GW55-1212		GW55-1212S		GW55-0713		GW55-1213		GW55-1215		GW55-0316		GW55-0816		GW55-1116	
WATER_LEVEL_DEPTH		23.64		23.64		23.39		24.09		23.64		23.64						22.86		23.42						23.76			
Analyte	Units	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Total Metals																													
Aluminum	µg/L	130000		130000		120000		110000		110000		120000		99000		96000		81000		61000		47000		37000		NA		NA	
Antimony	µg/L	5	U	5	U	1	U,J,O	2.5	U	1	U	1	U	1	U	1	U	2.5	U	1	U	1	U	1	U	NA		NA	
Arsenic	µg/L	5	U	5	U	4.1	J,O	2.5	U	1	U	1	U	3.5		3.2	J,O	2.5	U	3		1.1	J,O	5	U	NA		NA	
Barium	µg/L	25	U	25	U	50	U	9.9		9.7		9.3		9.8		10		7.3		8.8		25	U	8.5		NA		NA	
Beryllium	µg/L	15	U	15	U	1.2	U	1.2	U	0.5	U	0.5	U	0.65		0.5	U,J,O	1.2	U	0.5	U	15	U	0.5	U	NA		NA	
Cadmium	µg/L	880		870		710		780		750		780		640		620		490		430		360		260		NA		NA	
Calcium	µg/L	320000		310000		300000		320000		340000		360000		390000		390000		350000		270000		320000		190000		NA		NA	
Chromium	µg/L	25	U	25	U	50	U	2.5	U	3.2	U,O	3.2	U,O	5	U	1.9	J,O	5	U	1.3		25	U	5	U	NA		NA	
Cobalt	µg/L	580		570		530		510		470		490		380		370		360		330		220		190		NA		NA	
Copper	µg/L	58000		58000		50000		52000		51000		54000		41000		40000		33000		28000		18000		16000		NA		NA	
Iron	µg/L	430000		430000		370000		350000		350000		360000		280000		280000		220000		170000		130000		12000		NA		NA	
Lead	µg/L	9.3		9.2		6.8	J,O	8.2		11		10		8		8.4		7.5		5.1		5.6		8.2		NA		NA	
Magnesium	µg/L	72000		71000		63000		68000		68000		71000		72000		70000		65000		51000		48000		33000		NA		NA	
Manganese	µg/L	10000		10000		9500		9000		8800		9100		8300		8200		8500		8000		7800		6200		NA		NA	
Mercury	µg/L	1.3		1.2		0.76	O	1.2		1.5		1.5		0.73		0.73		0.42		0.9		1		1.1		NA		NA	
Molybdenum	µg/L	50	U	50	U	100	U	80	U	60	U	60	U	NA		NA		40	U	80	U	50	U	10	U	NA		NA	
Nickel	µg/L	190		180		200		160		160		170		120		120		99		87		54		44		NA		NA	
Potassium	µg/L	5000	U	5000	U	10000	U	4700		6400		6300		12000		12000		12000		9400		11000		7600		NA		NA	
Selenium	µg/L	40		41		280	J,O	37		68		68		65		45		56		55		34		15		NA		NA	
Silver	µg/L	25	U	25	U	0.5	U,J,O	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	1.2	U	0.5	U	25	U	0.5	U	NA		NA	
Sodium	µg/L	91000		90000		80000		100000		82000	J,O	80000	J,O	120000		120000		110000		88000		95000	J,O	64000		NA		NA	
Strontium	µg/L	250		250		230		250		270		270		NA		NA		230		190		220		130		NA		NA	
Thallium	µg/L	5	U	5	U	1	U	2.5	U	1.2		1.2		1	U	1	U	1		1	U	1	U	1	U	NA		NA	
Tin	µg/L	75	U	75	U	150	U	120	U	90	U	90	U	NA		NA		60	U	120	U	75	U,J,O	15	U	NA		NA	
Titanium	µg/L	25	U	25	U	50	U	40	U	30	U	30	U	NA		NA		20	U	40	U	25	U	5	U	NA		NA	
Vanadium	µg/L	25	U	25	U	50	U	40	U	5.8		5.7		6.2		4.6	J,O	5	U	1	U	25	U	5	U	NA		NA	
Yttrium	µg/L	290		290		250		260		250		260		NA		NA		200		160		130		96		NA		NA	
Zinc	µg/L	16000		16000		14000		14000		13000		14000		11000		11000		9100		7000		4900		3800		NA		NA	
Classical/Nutrient Analyses																													
Acidity	mg/L	1500	J,O	1400	J,O	1440		1500		NA		NA		1200	J,O	1200	J,O	990	O	NA		NA		350		NA		NA	
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA		NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, carbonate (as CaCO3)	mg/L	NA		NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Alkalinity, Total (as CaCO3)	mg/L	NA		NA		1	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Ammonia as N	mg/L	NA		NA		7.3	O	7.4		NA		NA		NA		NA		NA		NA		5.3		NA		NA		NA	
Chloride	mg/L	18	J,O	20	J,O	19		NA		NA		NA		22		22		21		20		19		15		NA		NA	
Cyanide	µg/L	15	U	15	U	15	U	15	U	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Nitrate/Nitrite as N	mg/L	NA		NA		0.058		0.055		NA		NA		NA		NA		NA		NA		0.056		NA		NA		NA	
Sulfate as SO4	mg/L	2800	J,O	2900	J,O	3600	J,O	NA		NA		NA		2600		2600		2500		2000	J,O	1600		1200		NA		NA	
Total Dissolved Solids	mg/L	4200		4200		2890	J	4000		NA		NA		NA		NA		NA		NA		2700		1600		NA		NA	
Total Suspended Solids	mg/L	4	U	4	U	8		4	U	NA		NA		NA		NA		NA		NA		4	U	4	U	NA		NA	
Field Instrument Result																													
Dissolved Oxygen	mg/L	1.01		NA		NA		0.23		0.27		0.27		0.06		NA		2.47		1.09		1.56		2.95		1.15		0.66	
Dissolved Oxygen (% Saturation)	%	10.1		NA		NA		2.4		2.8		2.8		NA		NA		26.7		13		NA		NA		NA		NA	
Ferrous Iron	mg/L	25.8		NA		59		50		44		46		NA		NA		NA		NA		NA		NA		NA		NA	
Oxidation Reduction Potential	mV	219.7		NA		252.3		263.6		243.5		243.5		130		NA		260		230		210		480		270		110	
pH	s.u.	3.72		NA		3.82		3.74		3.69		3.69		3.72		NA		3.86		3.68		3.88		3.1		3.83		4.06	
Specific Conductivity	µS/cm	3410		NA		3360		3490		3560		3560		3510		NA		3180		2762		2690		2046		2551		2615	
Temperature	Deg C	15.3		NA		17.6		17.5		17		17		16.2		NA		17.6		14.5		16.2		16		24.8		16.9	
Total Iron	mg/L	492		NA		280		364		408		412		NA		NA		NA		NA		NA		NA		NA		NA	
Turbidity	NTU	7.81		NA		2.46		10.2		3.38		3.38		2.32		NA		2.83		0.61		4.81		2.89		0.4		2.37	

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.9. Groundwater Results for Monitoring Well BH56

Sample Location		BH56	BH56	BH56	*BH56*	BH56	BH56	BH56	BH56	BH56	BH56	BH56	BH56	BH56
Sample Date		**2/16/2011**	**5/9/2011**	**8/26/2011**	***8/26/2011***	**11/10/2011**	**12/21/2012**	**7/8/2013**	**12/9/2013**	**12/9/2015**	**3/14/2016**	**8/2/2016**	**11/14/2016**	**3/28/2018**
Sample Identification No.		**GW56-0211**	**GW56-0511**	**GW56-0811**	***GW56-0811S***	**GW56-1111**	**GW56-1212**	**GW56-0713**	**GW56-1213**	**GW56-1215**	**GW56-0316**	**GW56-0816**	**GW56-1116**	**BH56**
WATER_LEVEL_DEPTH			**17.25**	**18.63**	***18.63***	**18.53**		**17.14**	**17.93**			**18.48**		**17.76**
Total Metals														
Aluminum	µg/L	130000	91000	110000	*110000*	120000	150000	87000	63000	48000	21000	NA	NA	NA
Antimony	µg/L	5 U	1 U,J,O	2.5 U	*2.5 U*	1 U	2.5 U	2.5 U	1 U	1 U	1 U	NA	NA	NA
Arsenic	µg/L	25 U	29 J,O	2.5 U	*2.5 U*	1.3	5.1	2.5 U	2.9	1 U	1 U	NA	NA	NA
Barium	µg/L	25 U	50 U	5.6	*5.9*	6.6	5.5	5.9	6	75 U	13	NA	NA	NA
Beryllium	µg/L	15 U	1.3 J,O	1.4	*1.3*	0.86	2.5 U	1.2 U	0.83	45 U	0.5 U	NA	NA	NA
Cadmium	µg/L	1100	720	960	*980*	1100	1400	760	590	400	180	NA	NA	NA
Calcium	µg/L	300000	250000	280000	*280000*	360000	350000	310000	260000	210000	100000	NA	NA	NA
Chromium	µg/L	25 U	50 U	15	*15*	27	52	21	12	75 U	10 U	NA	NA	17
Hexavalent Chromium	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5 U,J
Cobalt	µg/L	1100	660	920	*920*	1100	1900	780	510	420	160	NA	NA	NA
Copper	µg/L	85000	50000	65000	*66000*	82000	92000	44000	38000	20000	7700	NA	NA	NA
Iron	µg/L	980000	550000	720000	*720000*	910000	1E+06	610000	470000	320000	89000	NA	NA	NA
Lead	µg/L	9.6	11 J,O	9.3	*9.5*	23	24	10	3.1	5.8	6.9	NA	NA	NA
Magnesium	µg/L	78000	56000	70000	*70000*	80000	93000	67000	53000	41000	20000	NA	NA	NA
Manganese	µg/L	12000	8100	9800	*9800*	12000	15000	8800	6900	5100	2300	NA	NA	NA
Mercury	µg/L	0.21	0.62 O	0.53	*0.57*	1.5	1	1.5	0.54	0.25 J,O	0.17	NA	NA	NA
Molybdenum	µg/L	50 U	100 U	80 U	*100 U*	90 U	NA	40 U	120 U	150 U	20 U	NA	NA	NA
Nickel	µg/L	370	270	320	*320*	400	590	260	180	150 U	54	NA	NA	NA
Potassium	µg/L	8600	10000 U	4500	*4600*	9800	11000	11000	6800	15000 U	3700 J,QC-5	NA	NA	NA
Selenium	µg/L	50 U	89 J,O	23	*23*	69	46	51	49	17	12	NA	NA	NA
Silver	µg/L	25 U	0.5 U,J,O	0.5 U	*0.5 U*	0.5 U	2.5 U	1.2 U	0.5 U	75 U	0.5 U	NA	NA	NA
Sodium	µg/L	75000	59000	82000	*82000*	67000 J,O	110000	88000	69000	60000	29000	NA	NA	NA
Strontium	µg/L	440	310	320	*310*	310	NA	320	360	270	250	NA	NA	NA
Thallium	µg/L	5 U	1 U	2.5 U	*2.5 U*	1.6	2.5 U	1.2	1 U	1 U	1 U	NA	NA	NA
Tin	µg/L	75 U	150 U	120 U	*150 U*	140 U	NA	60 U	180 U	220 U	30 U	NA	NA	NA
Titanium	µg/L	25 U	50 U	40 U	*40 U*	45 U	NA	20 U	60 U	75 U	10 U	NA	NA	NA
Vanadium	µg/L	35	50 U	61	*70*	110	91	68	44	75 U	10 U	NA	NA	NA
Yttrium	µg/L	290	200	250	*260*	300	NA	210	150	110	46	NA	NA	NA
Zinc	µg/L	27000	18000	23000	*23000*	25000	37000	19000	12000	9500	4800	NA	NA	NA
Classical/Nutrient Analyses														
Acidity	mg/L	2300 J,O	1560	2200	*2200*	NA	3300 J,O	NA	NA	NA	400	NA	NA	NA
Alkalinity, Bicarbonate (as CaCO3)	mg/L	NA	1 U	NA	*NA*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, carbonate (as CaCO3)	mg/L	NA	1 U	NA	*NA*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	NA	1 U	NA	*NA*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia as N	mg/L	NA	6.1 O	7.9	*8.1*	NA	NA	NA	NA	4	NA	NA	NA	NA
Chloride	mg/L	20 J,O	16	NA	*NA*	NA	21	21	18	17	12	NA	NA	NA
Cyanide	µg/L	15 U	15 U	15 U	*15 U*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	NA	0.072	0.067	*0.071*	NA	NA	NA	NA	0.093	NA	NA	NA	NA
Sulfate as SO4	mg/L	3700 J,O	3300 J,O	NA	*NA*	NA	4500	3700	2600 J,O	2000	780	NA	NA	NA
Total Dissolved Solids	mg/L	5800	3970 J	5400	*5300*	NA	NA	NA	NA	3100	1200	NA	NA	NA
Total Suspended Solids	mg/L	4 U	5 U	4 U	*4 U*	NA	NA	NA	NA	4 U	4 U	NA	NA	NA
Field Instrument Result														
Dissolved Oxygen	mg/L	0.28	1.57	0.37	*NA*	6.21	4.18	6.15	0.99	0.49	3.9	2.39	2.62	1.73
Dissolved Oxygen (% Saturation)	%	2.8	15.8	4	*NA*	66.8	NA	65	12.4	NA	NA	NA	NA	NA
Ferrous Iron	mg/L	50.1	260	240	*210*	280	NA	NA	NA	NA	NA	NA	NA	NA
Oxidation Reduction Potential	mV	292.8	356.3	324.1	*NA*	304.6	256.3	270	360	350	360	290	270	184.5
pH	s.u.	3.09	3	3.03	*NA*	3.06	3.26	3.14	2.92	3.12	3.02	3.34	3.34	2.38
Specific Conductivity	µS/cm	4,810	3270	4840	*NA*	4860	5790	41700	3500	2977	1552	3339	4426	3684
Temperature	Deg C	15.4	15.8	19.5	*NA*	17.7	11.8	17.8	16.6	16	17.1	24.2	17.6	16.84
Total Iron	mg/L	1160	580	1000	*990*	990	NA	NA	NA	NA	NA	NA	NA	NA
Turbidity	NTU	3.45	1.83	3.4	*NA*	9.59	7.87	3.55	1.54	0.87	0.85	2.51	2.83	1.79

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

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Table A-4.10. Groundwater Results for Monitoring Well BH64

Sample Location		BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64
Sample Date		12/28/2012	7/9/2013	7/10/2013	12/12/2013	7/8/2014	12/8/2015	3/15/2016	8/2/2016	11/15/2016
Sample Identification No.		GW64-1212	GW64-0713	GW64B-0713	GW64-1213	GW64-0714	GW64-1215	GW64-0316	GW64-0816	GW64-1116
WATER_LEVEL_DEPTH		27.86	24.51		25.1				24.51	
Total Metals										
Aluminum	µg/L	5100	16000	13000 J,O	19000	NA	9600	6400	NA	NA
Antimony	µg/L	1 U	2.5 U	1 U	1 U	NA	1 U	1 U	NA	NA
Arsenic	µg/L	1 U	2.9	5	3.4	NA	2 J,O	1 U	NA	NA
Barium	µg/L	100	220	24	19	NA	25 U	62	NA	NA
Beryllium	µg/L	0.5 U	1.2 U	1 U	0.5 U	NA	15 U	0.5 U	NA	NA
Cadmium	µg/L	20	230	260	260	NA	240	190	NA	NA
Calcium	µg/L	30000	200000	210000	220000	NA	180000	150000	NA	NA
Chromium	µg/L	5 U	5.9 U,O	10 U	10 U	NA	25 U	10 U	NA	NA
Cobalt	µg/L	340	2500	2400	2600	NA	1500	1300	NA	NA
Copper	µg/L	36	250	230 J,O	270	NA	310	290	NA	NA
Iron	µg/L	4400	41000	37000 J,O	40000	NA	37000	26000	NA	NA
Lead	µg/L	11	58	13	14	NA	14	15	NA	NA
Magnesium	µg/L	16000	83000	86000	96000	NA	62000	57000	NA	NA
Manganese	µg/L	7600	52000	54000	57000	NA	37000	31000	NA	NA
Mercury	µg/L	3.8	12	9.6	11	NA	9	6.8	NA	NA
Molybdenum	µg/L	NA	50 U	20 U	20 U	NA	50 U	20 U	NA	NA
Nickel	µg/L	29	160	170	190	NA	130	110	NA	NA
Potassium	µg/L	2800	3300 J,O	3000	2300	NA	5000 U	2300 J,QC-5	NA	NA
Selenium	µg/L	18	99	100	110	NA	75	55	NA	NA
Silver	µg/L	5 U	1.2 U	0.4 U	10 U	NA	25 U	0.5 U	NA	NA
Sodium	µg/L	11000	45000	48000 J,O	51000	NA	51000	45000	NA	NA
Strontium	µg/L	NA	260	290 J,O	300	NA	300	260	NA	NA
Thallium	µg/L	1 U	1 U	0.4 U	1 U	NA	1 U	1 U	NA	NA
Tin	µg/L	NA	75 U	30 U	30 U	NA	75 U	30 U	NA	NA
Titanium	µg/L	NA	25 U	10 U	10 U	NA	25 U	10 U	NA	NA
Vanadium	µg/L	5 U	5.4	10 U	10 U	NA	25 U	10 U	NA	NA
Yttrium	µg/L	NA	180	200	200	NA	180	140	NA	NA
Zinc	µg/L	1000 J,O	10000	11000	11000	NA	8000	6600	NA	NA
Classical/Nutrient Analyses										
Acidity	mg/L	59	200	NA	NA	NA	240 J,O	130	NA	NA
Ammonia as N	mg/L	0.13	0.78	NA	NA	NA	NA	NA	NA	NA
Chloride	mg/L	4	8.6	NA	9.2 J,O	NA	9.8	9.4	NA	NA
Cyanide	µg/L	15 U	15 U,J,	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	0.05 U	0.068	NA	NA	NA	NA	NA	NA	NA
Sulfate as SO4	mg/L	240	1300	NA	1400 J,O	NA	1100	870	NA	NA
Total Dissolved Solids	mg/L	380	1800	NA	NA	NA	1600	1300	NA	NA
Total Kjeldahl Nitrogen	mg/L	NA	1	NA	NA	NA	NA	NA	NA	NA
Total Suspended Solids	mg/L	750	700	NA	NA	NA	29	29	NA	NA
Field Instrument Result										
Dissolved Oxygen	mg/L	0.91	7.05	NA	6.12	7.43	7.67	6.55	5.94	6.59
Dissolved Oxygen (% Saturation)	%	NA	78.4	NA	59.1	84.6	NA	NA	NA	NA
Ferrous Iron	mg/L	1.53	1.6	NA	NA	NA	34.5	NA	NA	NA
Oxidation Reduction Potential	mV	240	-50	NA	300	320	300	350	160	380
pH	s.u.	4.25	4.06	NA	3.99	3.96	3.94	3.75	3.85	3.69
Specific Conductivity	µS/cm	340	1914	NA	2131	1592	1812	1590	1932	1920
Temperature	Deg C	19.9	18.5	NA	14	21.1	15.7	16.3	18.2	15.2
Total Iron	mg/L	4.7	35	NA	NA	NA	51	NA	NA	NA
Turbidity	NTU	37.2	15.6	NA	10.1	7.66	23.8	27.3	15.1	6.36
Semi Volatile Organics										
1,1-Biphenyl	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
2-Chloronaphthalene	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2-Chlorophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2-Methyl-4,6-dinitrophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2-Methylnaphthalene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
2-Methylphenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2-Nitroaniline	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2-Nitrophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,3,4,6-Tetrachlorophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,4-Dichlorophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,4-Dimethylphenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,4-Dinitrophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,4-Dinitrotoluene	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,4,5-Trichlorophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
2,4,6-Trichlorophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA

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Table A-4.10. Groundwater Results for Monitoring Well BH64

Sample Location		BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64
Sample Date		12/28/2012	7/9/2013	7/10/2013	12/12/2013	7/8/2014	12/8/2015	3/15/2016	8/2/2016	11/15/2016
Sample Identification No.		GW64-1212	GW64-0713	GW64B-0713	GW64-1213	GW64-0714	GW64-1215	GW64-0316	GW64-0816	GW64-1116
WATER_LEVEL_DEPTH		27.86	24.51		25.1				24.51	
2,6-Dinitrotoluene	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
(3-and/or 4-)Methylphenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
3-Nitroaniline	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
3,3'-Dichlorobenzidine	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
4-Bromophenyl phenyl ether	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
4-Chloro-3-methylphenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
4-Chloroaniline	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
4-Chlorophenyl phenyl ether	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
4-Nitroaniline	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
4-Nitrophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Acenaphthene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Acenaphthylene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Acetophenone	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Anthracene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Atrazine	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Benzaldehyde	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Benzo(a)anthracene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Benzo(a)pyrene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Benzo(b)fluoranthene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Benzo(g,h,i)perylene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Benzo(k)fluoranthene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Benzyl butyl phthalate	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
bis(2-Chloroethyl) Ether	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Bis(2-chloroisopropyl) ether	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Caprolactam	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Carbazole	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Chrysene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Dibenzo(a,h)anthracene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Dibenzofuran	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Diethyl phthalate	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Dimethyl phthalate	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Di-n-butylphthalate	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Di-n-octylphthalate	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Fluoranthene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Fluorene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Hexachlorobenzene (HCB)	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Hexachlorocyclopentadiene (HCCP)	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Hexachloroethane	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Indeno (1,2,3-cd) pyrene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Isophorone	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Naphthalene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Naphthalene, 1-methyl-	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Nitrobenzene	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
n-Nitroso di-n-Propylamine	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
n-Nitrosodiphenylamine/Diphenylamine	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Pentachlorophenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Phenanthrene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Phenol	µg/L	NA	NA	NA	NA	9.7 U	NA	NA	NA	NA
Pyrene	µg/L	NA	NA	NA	NA	1.9 U	NA	NA	NA	NA
Organochlorine Pesticides										
4,4'-DDD (p,p'-DDD)	µg/L	NA	NA	NA	NA	0.04 U	NA	NA	NA	NA
4,4'-DDE (p,p'-DDE)	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
4,4'-DDT (p,p'-DDT)	µg/L	NA	NA	NA	NA	0.05 U	NA	NA	NA	NA
Aldrin	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
alpha-BHC	µg/L	NA	NA	NA	NA	0.0099 U	NA	NA	NA	NA
alpha-Chlordane	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
beta-BHC	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
delta-BHC	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
Dieldrin	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
Endosulfan I (alpha)	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
Endosulfan II (beta)	µg/L	NA	NA	NA	NA	0.04 U	NA	NA	NA	NA
Endosulfan Sulfate	µg/L	NA	NA	NA	NA	0.05 U	NA	NA	NA	NA
Endrin	µg/L	NA	NA	NA	NA	0.04 U	NA	NA	NA	NA

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Table A-4.10. Groundwater Results for Monitoring Well BH64

Sample Location		BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64
Sample Date		12/28/2012	7/9/2013	7/10/2013	12/12/2013	7/8/2014	12/8/2015	3/15/2016	8/2/2016	11/15/2016
Sample Identification No.		GW64-1212	GW64-0713	GW64B-0713	GW64-1213	GW64-0714	GW64-1215	GW64-0316	GW64-0816	GW64-1116
WATER_LEVEL_DEPTH		27.86	24.51		25.1				24.51	
Endrin aldehyde	µg/L	NA	NA	NA	NA	0.05 U	NA	NA	NA	NA
Endrin ketone	µg/L	NA	NA	NA	NA	0.05 U	NA	NA	NA	NA
gamma-BHC (Lindane)	µg/L	NA	NA	NA	NA	0.0099 U	NA	NA	NA	NA
gamma-Chlordane	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
Heptachlor	µg/L	NA	NA	NA	NA	0.015 U	NA	NA	NA	NA
Heptachlor epoxide	µg/L	NA	NA	NA	NA	0.02 U	NA	NA	NA	NA
Methoxychlor	µg/L	NA	NA	NA	NA	0.099 U	NA	NA	NA	NA
Toxaphene	µg/L	NA	NA	NA	NA	2 U	NA	NA	NA	NA
PCB Aroclors										
PCB-1016 (Aroclor 1016)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1221 (Aroclor 1221)	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
PCB-1232 (Aroclor 1232)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1242 (Aroclor 1242)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1248 (Aroclor 1248)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1254 (Aroclor 1254)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1260 (Aroclor 1260)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1262 (Aroclor 1262)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1268 (Aroclor 1268)	µg/L	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA
Volatile Organic Compounds										
1,1-Dichloroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1-Dichloroethene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1-Dichloropropene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,1-Trichloroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,1,2-Tetrachloroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,2-Trichloroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane	µg/L	NA	NA	NA	NA	1 U	NA	NA	NA	NA
1,2-Dibromoethane (EDB)	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dichlorobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dichloroethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dichloropropane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,3-Trichlorobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,3-Trichloropropane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,4-Trichlorobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,4-Trimethylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,3-Dichlorobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,3-Dichloropropane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,3,5-Trimethylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,4-Dichlorobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
2,2-Dichloropropane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Acetone	µg/L	NA	NA	NA	NA	4 U	NA	NA	NA	NA
Benzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromochloromethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromodichloromethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromoform	µg/L	NA	NA	NA	NA	1 U	NA	NA	NA	NA
Bromomethane	µg/L	NA	NA	NA	NA	2 U,J,O	NA	NA	NA	NA
Carbon disulfide	µg/L	NA	NA	NA	NA	2 U	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Chlorobenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Chloroethane	µg/L	NA	NA	NA	NA	2 U	NA	NA	NA	NA
Chloroform	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Chloromethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Cyclohexane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Dibromochloromethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Dibromomethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Dichlorodifluoromethane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
cis-1,2-Dichloroethene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
trans-1,2-Dichloroethene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
cis-1,3-Dichloropropene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
trans-1,3-Dichloropropene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Ethyl Benzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Hexachlorobutadiene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Isopropylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA

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Table A-4.10. Groundwater Results for Monitoring Well BH64

Sample Location		BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64	BH64
Sample Date		12/28/2012	7/9/2013	7/10/2013	12/12/2013	7/8/2014	12/8/2015	3/15/2016	8/2/2016	11/15/2016
Sample Identification No.		GW64-1212	GW64-0713	GW64B-0713	GW64-1213	GW64-0714	GW64-1215	GW64-0316	GW64-0816	GW64-1116
WATER_LEVEL_DEPTH		27.86	24.51		25.1				24.51	
Methyl Acetate	µg/L	NA	NA	NA	NA	1 U	NA	NA	NA	NA
Methyl Butyl Ketone	µg/L	NA	NA	NA	NA	1 U	NA	NA	NA	NA
Methyl Ethyl Ketone	µg/L	NA	NA	NA	NA	4 U	NA	NA	NA	NA
Methyl Isobutyl Ketone	µg/L	NA	NA	NA	NA	1 U	NA	NA	NA	NA
Methyl T-Butyl Ether (MTBE)	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Methylcyclohexane	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Methylene Chloride	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
n-Butylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
n-Propylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
o-Chlorotoluene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
p-Chlorotoluene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
p-Isopropyltoluene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
sec-Butylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Styrene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
tert-Butylbenzene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Tetrachloroethene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Toluene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Trichloroethene (Trichloroethylene)	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Trichlorofluoromethane (Freon 11)	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
Vinyl chloride	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA
(m- and/or p-)Xylene	µg/L	NA	NA	NA	NA	1 U	NA	NA	NA	NA
o-Xylene	µg/L	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.11. Groundwater Results for Monitoring Well BH65

Sample Location		BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65
Sample Date		12/28/2012	7/9/2013	12/11/2013	7/8/2014	12/9/2015	12/9/2015	3/15/2016	8/4/2016	11/17/2016
Sample Identification No.		GW65-1212	GW65-0713	GW65-1213	GW65-0714	GW65-1215	GW65-1215S	GW65-0316	GW65-0816	GW65-1116
WATER_LEVEL_DEPTH		24.88	23.67	23.34					22.37	
Total Metals										
Aluminum	µg/L	510	350	1200	NA	340	300	330	NA	NA
Antimony	µg/L	1 U	2.5 U	1 U	NA	1 U	1 U	1 U	NA	NA
Arsenic	µg/L	1 U	2.5 U	1 U	NA	1 U	1 U	1 U	NA	NA
Barium	µg/L	76	44	47	NA	28	28	27	NA	NA
Beryllium	µg/L	0.5 U	1.2 U	0.5 U	NA	3 U	3 U	0.5 U	NA	NA
Cadmium	µg/L	0.57	1.3	1.6	NA	3.5	3.4	3.6	NA	NA
Calcium	µg/L	78000	110000	120000	NA	210000	200000	210000	NA	NA
Chromium	µg/L	5 U	6.1	28	NA	5 U	5 U	5 U	NA	NA
Cobalt	µg/L	15	19	60	NA	28	27	29	NA	NA
Copper	µg/L	10 U	10 U	10 U	NA	10 U	10 U	14 J,QR-2	NA	NA
Iron	µg/L	2300	2700	4300	NA	3000	2900	3000	NA	NA
Lead	µg/L	1 U	2 U	1 U	NA	1 U	1 U	1 U	NA	NA
Magnesium	µg/L	35000	49000	57000	NA	91000	90000	83000	NA	NA
Manganese	µg/L	750	1200	1100	NA	1100	1100	1200	NA	NA
Mercury	µg/L	0.1 U	0.1 U	0.1 U	NA	0.1 U,J,O	0.1 U,J,O	0.1 U	NA	NA
Molybdenum	µg/L	NA	10 U	10 U	NA	10 U	10 U	10 U	NA	NA
Nickel	µg/L	14	21	52	NA	35	34	37	NA	NA
Potassium	µg/L	1000 U	1000	1000 U	NA	1200	1100	1100	NA	NA
Selenium	µg/L	2 U	5 U	2 U	NA	2 U	2 U	2 U	NA	NA
Silver	µg/L	5 U	1.2 U	5 U	NA	5 U	5 U	0.5 U	NA	NA
Sodium	µg/L	16000	16000	18000	NA	24000	24000	22000	NA	NA
Strontium	µg/L	NA	580	690	NA	1000	1000	960	NA	NA
Thallium	µg/L	1 U	1 U	1 U	NA	1 U	1 U	1 U	NA	NA
Tin	µg/L	NA	15 U	15 U	NA	15 U	15 U	15 U	NA	NA
Titanium	µg/L	NA	5 U	14	NA	5 U	5 U	5 U	NA	NA
Vanadium	µg/L	5 U	5 U	6.8	NA	5 U	5 U	5 U	NA	NA
Yttrium	µg/L	NA	5.8	8	NA	12	12	11	NA	NA
Zinc	µg/L	560	850	970 J,O	NA	1500	1500	1500	NA	NA
Classical/Nutrient Analyses										
Acidity	mg/L	NA	NA	NA	NA	10 U	10 U	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	25	25	NA	NA	23	23	22	NA	NA
Ammonia as N	mg/L	0.05 U	0.05 U,J,	NA	NA	NA	NA	NA	NA	NA
Chloride	mg/L	2.1	2.1	2.2 J,O	NA	2.3	2.2	2.3	NA	NA
Cyanide	µg/L	15 U	15 U	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	0.05 U	0.05 U	NA	NA	NA	NA	NA	NA	NA
Sulfate as SO4	mg/L	320	490	570 J,O	NA	880	880	880	NA	NA
Total Dissolved Solids	mg/L	540	750	NA	NA	1400	1400	1300	NA	NA
Total Kjeldahl Nitrogen	mg/L	NA	0.05 U	NA	NA	NA	NA	NA	NA	NA
Total Suspended Solids	mg/L	11	6.2	NA	NA	13	13	17	NA	NA
Field Instrument Result										
Dissolved Oxygen	mg/L	0.19	0.21	0.44	0.36	0.22	NA	0.06	0.15	0.11
Dissolved Oxygen (% Saturation)	%	NA	2.4	4.5	4.1	NA	NA	NA	NA	NA
Ferrous Iron	mg/L	1.77	1.52	NA	NA	2.2	1.94	NA	NA	NA
Oxidation Reduction Potential	mV	165	70	60	150	60	NA	150	-60	-30
pH	s.u.	5.56	5.61	5.53	5.55	5.42	NA	5.43	5.41	5.37
Specific Conductivity	µS/cm	742	946	1052	1285	1515	NA	1537	2462	1688
Temperature	Deg C	17.9	20.8	16.2	21.2	18.4	NA	18.8	20	18.7
Total Iron	mg/L	1.87	3	NA	NA	3.06	2.935	NA	NA	NA
Turbidity	NTU	6.55	6.07	25.4	20	7.14	NA	9	9.08	3.42
Semi Volatile Organics										
1,1-Biphenyl	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
2-Chloronaphthalene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2-Chlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2-Methyl-4,6-dinitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2-Methylnaphthalene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
2-Methylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2-Nitroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2-Nitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,3,4,6-Tetrachlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,4-Dichlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,4-Dimethylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,4-Dinitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA

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Table A-4.11. Groundwater Results for Monitoring Well BH65

Sample Location		BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65
Sample Date		12/28/2012	7/9/2013	12/11/2013	7/8/2014	12/9/2015	12/9/2015	3/15/2016	8/4/2016	11/17/2016
Sample Identification No.		GW65-1212	GW65-0713	GW65-1213	GW65-0714	GW65-1215	GW65-1215S	GW65-0316	GW65-0816	GW65-1116
WATER_LEVEL_DEPTH		24.88	23.67	23.34					22.37	
2,4-Dinitrotoluene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,4,5-Trichlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,4,6-Trichlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
2,6-Dinitrotoluene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
(3-and/or 4-)Methylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
3-Nitroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
3,3'-Dichlorobenzidine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
4-Bromophenyl phenyl ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
4-Chloro-3-methylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
4-Chloroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
4-Chlorophenyl phenyl ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
4-Nitroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
4-Nitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Acenaphthene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Acenaphthylene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Acetophenone	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Anthracene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Atrazine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Benzaldehyde	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Benzo(a)anthracene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Benzo(a)pyrene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Benzyl butyl phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
bis(2-Chloroethyl) Ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl) ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Caprolactam	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Carbazole	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Chrysene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Dibenzofuran	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Diethyl phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Dimethyl phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Di-n-butylphthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Di-n-octylphthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Fluoranthene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Fluorene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Hexachlorobenzene (HCB)	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene (HCCP)	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Hexachloroethane	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Indeno (1,2,3-cd) pyrene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Isophorone	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Naphthalene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Naphthalene, 1-methyl-	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Nitrobenzene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
n-Nitroso di-n-Propylamine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
n-Nitrosodiphenylamine/Diphenylamine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Pentachlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Phenanthrene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Phenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA	NA
Pyrene	µg/L	NA	NA	NA	2.1 U	NA	NA	NA	NA	NA
Organochlorine Pesticides										
4,4'-DDD (p,p'-DDD)	µg/L	NA	NA	NA	0.039 U	NA	NA	NA	NA	NA
4,4'-DDE (p,p'-DDE)	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
4,4'-DDT (p,p'-DDT)	µg/L	NA	NA	NA	0.049 U	NA	NA	NA	NA	NA
Aldrin	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
alpha-BHC	µg/L	NA	NA	NA	0.0099 U	NA	NA	NA	NA	NA
alpha-Chlordane	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
beta-BHC	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
delta-BHC	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
Dieldrin	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA

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Table A-4.11. Groundwater Results for Monitoring Well BH65

Sample Location		BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65
Sample Date		12/28/2012	7/9/2013	12/11/2013	7/8/2014	12/9/2015	12/9/2015	3/15/2016	8/4/2016	11/17/2016
Sample Identification No.		GW65-1212	GW65-0713	GW65-1213	GW65-0714	GW65-1215	GW65-1215S	GW65-0316	GW65-0816	GW65-1116
WATER_LEVEL_DEPTH		24.88	23.67	23.34					22.37	
Endosulfan I (alpha)	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
Endosulfan II (beta)	µg/L	NA	NA	NA	0.039 U	NA	NA	NA	NA	NA
Endosulfan Sulfate	µg/L	NA	NA	NA	0.049 U	NA	NA	NA	NA	NA
Endrin	µg/L	NA	NA	NA	0.039 U	NA	NA	NA	NA	NA
Endrin aldehyde	µg/L	NA	NA	NA	0.049 U	NA	NA	NA	NA	NA
Endrin ketone	µg/L	NA	NA	NA	0.049 U	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	µg/L	NA	NA	NA	0.0099 U	NA	NA	NA	NA	NA
gamma-Chlordane	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
Heptachlor	µg/L	NA	NA	NA	0.015 U	NA	NA	NA	NA	NA
Heptachlor epoxide	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA	NA
Methoxychlor	µg/L	NA	NA	NA	0.099 U	NA	NA	NA	NA	NA
Toxaphene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA	NA
PCB Aroclors										
PCB-1016 (Aroclor 1016)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1221 (Aroclor 1221)	µg/L	NA	NA	NA	0.49 U	NA	NA	NA	NA	NA
PCB-1232 (Aroclor 1232)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1242 (Aroclor 1242)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1248 (Aroclor 1248)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1254 (Aroclor 1254)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1260 (Aroclor 1260)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1262 (Aroclor 1262)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
PCB-1268 (Aroclor 1268)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA	NA
Volatile Organic Compounds										
1,1-Dichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1-Dichloroethene (1,1-Dichloroethylene)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1-Dichloropropene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1,1,2-Tetrachloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane (DBCP)	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA	NA
1,2-Dibromoethane (EDB)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2-Dichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2-Dichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2,3-Trichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,2,4-Trimethylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,3-Dichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,3,5-Trimethylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
2,2-Dichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Acetone	µg/L	NA	NA	NA	4 U	NA	NA	NA	NA	NA
Benzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Bromobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Bromochloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Bromodichloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Bromoform	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA	NA
Bromomethane	µg/L	NA	NA	NA	2 U,J,O	NA	NA	NA	NA	NA
n-Butylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
sec-Butylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
tert-Butylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Carbon disulfide	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Chlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Chloroethane	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA	NA
Chloroform	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Chloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
o-Chlorotoluene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
p-Chlorotoluene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Cyclohexane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA

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Table A-4.11. Groundwater Results for Monitoring Well BH65

Sample Location		BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65	BH65
Sample Date		12/28/2012	7/9/2013	12/11/2013	7/8/2014	12/9/2015	12/9/2015	3/15/2016	8/4/2016	11/17/2016
Sample Identification No.		GW65-1212	GW65-0713	GW65-1213	GW65-0714	GW65-1215	GW65-1215S	GW65-0316	GW65-0816	GW65-1116
WATER_LEVEL_DEPTH		24.88	23.67	23.34					22.37	
Dibromochloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Dibromomethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Dichlorodifluoromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
cis-1,2-Dichloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
cis-1,3-Dichloropropene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
trans-1,3-Dichloropropene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Ethyl Benzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Hexachlorobutadiene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Isopropylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
p-Isopropyltoluene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Methyl Acetate	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA	NA
Methyl Butyl Ketone	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA	NA
Methyl Ethyl Ketone	µg/L	NA	NA	NA	4 U	NA	NA	NA	NA	NA
Methyl Isobutyl Ketone	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA	NA
Methyl T-Butyl Ether (MTBE)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Methylcyclohexane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Methylene Chloride	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
n-Propylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Styrene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Tetrachloroethene (Tetrachloroethylene)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Toluene	µg/L	NA	NA	NA	0.19 J,O	NA	NA	NA	NA	NA
Trichloroethene (Trichloroethylene)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Trichlorofluoromethane (Freon 11)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Vinyl chloride	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
(m- and/or p-)Xylene	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA	NA
o-Xylene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.12. Groundwater Results for Monitoring Well BH66

Sample Location		BH66	BH66	BH66	BH66	BH66	BH66	BH66	BH66
Sample Date		12/26/2012	7/9/2013	12/11/2013	7/8/2014	12/8/2015	3/15/2016	8/3/2016	11/16/2016
Sample Identification No.		GW66-1212	GW66-0713	GW66-1213	GW66-0714	GW66-1215	GW66-0316	GW66-0816	GW66-1116
WATER_LEVEL_DEPTH		29.1	21.26	21.64				24.14	
Total Metals									
Aluminum	µg/L	100 U	110	420	NA	100 U	100 U	NA	NA
Antimony	µg/L	1 U	2.5 U	1 U	NA	1 U	1 U	NA	NA
Arsenic	µg/L	1 U	2.5 U	1 U	NA	1.5 J,O	1 U	NA	NA
Barium	µg/L	98	110	130	NA	140	140	NA	NA
Beryllium	µg/L	0.5 U	1.2 U	0.5 U	NA	3 U	0.5 U	NA	NA
Cadmium	µg/L	0.58	0.45	0.56	NA	0.5 U	0.52	NA	NA
Calcium	µg/L	11000	9400	11000	NA	8800	8500	NA	NA
Chromium	µg/L	5 U	5 U	5.3	NA	5 U	5 U	NA	NA
Cobalt	µg/L	5 U	5 U	5 U	NA	5 U	5 U	NA	NA
Copper	µg/L	130	110	150	NA	110	110	NA	NA
Iron	µg/L	100 U	100 U	580	NA	100 U	100 U	NA	NA
Lead	µg/L	1 U	2 U	1 U	NA	1 U	1 U	NA	NA
Magnesium	µg/L	4100	3300	4000	NA	3000	3100	NA	NA
Manganese	µg/L	260	190	290	NA	200	200	NA	NA
Mercury	µg/L	0.14	0.18	0.11	NA	0.23	0.16	NA	NA
Molybdenum	µg/L	NA	10 U	10 U	NA	10 U	10 U	NA	NA
Nickel	µg/L	10 U	10 U	10 U	NA	10 U	10 U	NA	NA
Potassium	µg/L	1000 U	1000 U	1000 U	NA	1000 U	1000 U,J,O	NA	NA
Selenium	µg/L	33	28	31	NA	27	30	NA	NA
Silver	µg/L	5 U	1.2 U	5 U	NA	5 U	0.5 U	NA	NA
Sodium	µg/L	35000	28000	32000	NA	29000	28000	NA	NA
Strontium	µg/L	NA	95	110	NA	100	99	NA	NA
Thallium	µg/L	1 U	1 U	1 U	NA	1 U	1 U	NA	NA
Tin	µg/L	NA	15 U	15 U	NA	15 U	15 U	NA	NA
Titanium	µg/L	NA	5 U	19	NA	5 U	5 U	NA	NA
Vanadium	µg/L	5 U	5 U	5 U	NA	5 U	5 U	NA	NA
Yttrium	µg/L	NA	3 U	3 U	NA	3 U	3 U	NA	NA
Zinc	µg/L	200	170	190	NA	170	170	NA	NA
Classical/Nutrient Analyses									
Acidity	mg/L	NA	NA	NA	NA	NA	NA	NA	NA
Alkalinity, Total (as CaCO3)	mg/L	43	43	NA	NA	40	38	NA	NA
Ammonia as N	mg/L	1.1	0.61	NA	NA	NA	NA	NA	NA
Chloride	mg/L	13	11	12 J,O	NA	10	11	NA	NA
Cyanide	µg/L	15 U	15 U	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite as N	mg/L	1.6	1.7	NA	NA	NA	NA	NA	NA
Sulfate as SO4	mg/L	58	41	56 J,O	NA	19	41	NA	NA
Total Dissolved Solids	mg/L	200	180	NA	NA	160	170	NA	NA
Total Kjeldahl Nitrogen	mg/L	NA	1.3	NA	NA	NA	NA	NA	NA
Total Suspended Solids	mg/L	4 U	4 U	NA	NA	9.5	8.8	NA	NA
Field Instrument Result									
Dissolved Oxygen	mg/L	0.19	0.22	0.23	0.34	0.51	0.19	0.22	0.41
Dissolved Oxygen (% Saturation)	%	NA	2.5	3	3.8	NA	NA	NA	NA
Ferrous Iron	mg/L	0.02	0.02	NA	NA	NA	NA	NA	NA
Oxidation Reduction Potential	mV	-205	100	140	190	200	220	200	190
pH	s.u.	6.01	5.88	5.93	6.04	5.97	5.87	5.95	5.95
Specific Conductivity	µS/cm	286.4	228.3	254.6	206	212.4	201.7	188.6	190.9
Temperature	Deg C	19.4	20.3	19.1	20.6	18.3	18.5	20.1	19.5
Total Iron	mg/L	0.05	0.05	NA	NA	NA	NA	NA	NA
Turbidity	NTU	3.03	7.69	26.7	4.57	9.34	5.23	3.68	19.4
Semi-volatile Organic Compounds									
1,1-Biphenyl	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
2-Chloronaphthalene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2-Chlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2-Methyl-4,6-dinitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2-Methylnaphthalene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
2-Methylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2-Nitroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2-Nitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,3,4,6-Tetrachlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA

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Table A-4.12. Groundwater Results for Monitoring Well BH66

Sample Location		BH66	BH66	BH66	BH66	BH66	BH66	BH66	BH66
Sample Date		12/26/2012	7/9/2013	12/11/2013	7/8/2014	12/8/2015	3/15/2016	8/3/2016	11/16/2016
Sample Identification No.		GW66-1212	GW66-0713	GW66-1213	GW66-0714	GW66-1215	GW66-0316	GW66-0816	GW66-1116
WATER_LEVEL_DEPTH		29.1	21.26	21.64				24.14	
2,4-Dichlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,4-Dimethylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,4-Dinitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,4-Dinitrotoluene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,4,5-Trichlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,4,6-Trichlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
2,6-Dinitrotoluene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
(3-and/or 4-)Methylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
3-Nitroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
3,3'-Dichlorobenzidine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
4-Bromophenyl phenyl ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
4-Chloro-3-methylphenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
4-Chloroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
4-Chlorophenyl phenyl ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
4-Nitroaniline	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
4-Nitrophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Acenaphthene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Acenaphthylene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Acetophenone	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Anthracene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Atrazine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Benzaldehyde	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Semi-volatile Organic Compounds - continued									
Benzo(a)anthracene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Benzo(a)pyrene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Benzo(b)fluoranthene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Benzo(g,h,i)perylene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Benzo(k)fluoranthene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Benzyl butyl phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
bis(2-Chloroethyl) Ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Bis(2-chloroisopropyl) ether	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Caprolactam	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Carbazole	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Chrysene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Dibenzo(a,h)anthracene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Dibenzofuran	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Diethyl phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Dimethyl phthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Di-n-butylphthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Di-n-octylphthalate	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Fluoranthene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Fluorene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Hexachlorobenzene (HCB)	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Hexachlorocyclopentadiene (HCCP)	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Hexachloroethane	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Indeno (1,2,3-cd) pyrene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Isophorone	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Naphthalene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Naphthalene, 1-methyl-	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Nitrobenzene	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
n-Nitroso di-n-Propylamine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
n-Nitrosodiphenylamine/Diphenylamine	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Pentachlorophenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Phenanthrene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Phenol	µg/L	NA	NA	NA	10 U	NA	NA	NA	NA
Pyrene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Organochlorine Pesticides									
4,4'-DDD (p,p'-DDD)	µg/L	NA	NA	NA	0.04 U	NA	NA	NA	NA

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Table A-4.12. Groundwater Results for Monitoring Well BH66

Sample Location		BH66	BH66	BH66	BH66	BH66	BH66	BH66	BH66
Sample Date		12/26/2012	7/9/2013	12/11/2013	7/8/2014	12/8/2015	3/15/2016	8/3/2016	11/16/2016
Sample Identification No.		GW66-1212	GW66-0713	GW66-1213	GW66-0714	GW66-1215	GW66-0316	GW66-0816	GW66-1116
WATER_LEVEL_DEPTH		29.1	21.26	21.64				24.14	
4,4'-DDE (p,p'-DDE)	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
4,4'-DDT (p,p'-DDT)	µg/L	NA	NA	NA	0.05 U	NA	NA	NA	NA
Aldrin	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
alpha-BHC	µg/L	NA	NA	NA	0.01 U	NA	NA	NA	NA
Organochlorine Pesticides - continued									
alpha-Chlordane	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
beta-BHC	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
delta-BHC	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
Dieldrin	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
Endosulfan I (alpha)	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
Endosulfan II (beta)	µg/L	NA	NA	NA	0.04 U	NA	NA	NA	NA
Endosulfan Sulfate	µg/L	NA	NA	NA	0.05 U	NA	NA	NA	NA
Endrin	µg/L	NA	NA	NA	0.04 U	NA	NA	NA	NA
Endrin aldehyde	µg/L	NA	NA	NA	0.05 U	NA	NA	NA	NA
Endrin ketone	µg/L	NA	NA	NA	0.05 U	NA	NA	NA	NA
gamma-BHC (Lindane)	µg/L	NA	NA	NA	0.01 U	NA	NA	NA	NA
gamma-Chlordane	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
Heptachlor	µg/L	NA	NA	NA	0.015 U	NA	NA	NA	NA
Heptachlor epoxide	µg/L	NA	NA	NA	0.02 U	NA	NA	NA	NA
Methoxychlor	µg/L	NA	NA	NA	0.1 U	NA	NA	NA	NA
Toxaphene	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
PCB Aroclors									
PCB-1016 (Aroclor 1016)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1221 (Aroclor 1221)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
PCB-1232 (Aroclor 1232)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1242 (Aroclor 1242)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1248 (Aroclor 1248)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1254 (Aroclor 1254)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1260 (Aroclor 1260)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1262 (Aroclor 1262)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
PCB-1268 (Aroclor 1268)	µg/L	NA	NA	NA	0.25 U	NA	NA	NA	NA
Volatile Organic Compounds									
1,1-Dichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1-Dichloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1-Dichloropropene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,1-Trichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,1,2-Tetrachloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-Trifluoroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,2-Trichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dibromo-3-Chloropropane	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA
1,2-Dibromoethane (EDB)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dichloroethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2-Dichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,3-Trichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Volatile Organic Compounds									
1,2,3-Trichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,4-Trichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,2,4-Trimethylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,3-Dichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,3-Dichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,3,5-Trimethylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
1,4-Dichlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
2,2-Dichloropropane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Acetone	µg/L	NA	NA	NA	4 U	NA	NA	NA	NA
Benzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromochloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Bromodichloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA

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Table A-4.12. Groundwater Results for Monitoring Well BH66

Sample Location		BH66	BH66	BH66	BH66	BH66	BH66	BH66	BH66
Sample Date		12/26/2012	7/9/2013	12/11/2013	7/8/2014	12/8/2015	3/15/2016	8/3/2016	11/16/2016
Sample Identification No.		GW66-1212	GW66-0713	GW66-1213	GW66-0714	GW66-1215	GW66-0316	GW66-0816	GW66-1116
WATER_LEVEL_DEPTH		29.1	21.26	21.64				24.14	
Bromoform	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA
Bromomethane	µg/L	NA	NA	NA	2 U,J,O	NA	NA	NA	NA
n-Butylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
sec-Butylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
tert-Butylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Carbon disulfide	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Carbon Tetrachloride	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Chlorobenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Chloroethane	µg/L	NA	NA	NA	2 U	NA	NA	NA	NA
Chloroform	µg/L	NA	NA	NA	0.45 J,O	NA	NA	NA	NA
Chloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
o-Chlorotoluene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
p-Chlorotoluene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Cyclohexane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Dibromochloromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Dibromomethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Dichlorodifluoromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
cis-1,2-Dichloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
trans-1,2-Dichloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
cis-1,3-Dichloropropene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
trans-1,3-Dichloropropene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Ethyl Benzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Hexachlorobutadiene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Isopropylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
p-Isopropyltoluene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Methyl Acetate	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA
Methyl Butyl Ketone	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA
Methyl Ethyl Ketone	µg/L	NA	NA	NA	4 U	NA	NA	NA	NA
Volatile Organic Compounds									
Methyl Isobutyl Ketone	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA
Methyl T-Butyl Ether (MTBE)	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Methylcyclohexane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Methylene Chloride	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
n-Propylbenzene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Styrene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Tetrachloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Toluene	µg/L	NA	NA	NA	0.11 J,O	NA	NA	NA	NA
Trichloroethene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Trichlorofluoromethane	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
Vinyl chloride	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
o-Xylene	µg/L	NA	NA	NA	0.5 U	NA	NA	NA	NA
(m- and/or p-)Xylene	µg/L	NA	NA	NA	1 U	NA	NA	NA	NA

Notes

µg/L - micrograms per liter
mg/L - milligrams per liter
mV - millivolts
su - standard units
µS/cm - microsiemens per centimeter
Deg C - degrees Celsius
NTU - nephelometric turbidity units
NA - not analyzed
U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit
J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample
O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Table A-4.13. Groundwater Results for Borings BH71 through BH74

Sample Location		BH71	BH72	BH72	BH73	BH73	BH74	BH74
Sample Date		3/7/2018	3/9/2018	3/10/2018	3/11/2018	3/11/2018	3/13/2018	3/13/2018
Sample Identification No.		BH71-136	BH72-86	BH72-136	BH73-96	BH73-136	BH74-85	BH74-115
Sample_Depth		136	86	136	96	136	85	115
Total Metals								
Aluminum	µg/L	11200	550	110	11100	47400	145000 O	689 O
Antimony	µg/L	1 U	3.41	10.5	3 U	1.01 J	3 U	1.15 U,O
Arsenic	µg/L	14.5	68.2	3.74	3.66	10.4	4.82 J,O	7.74 O
Barium	µg/L	96.1	1730	120	182	608	226 O	62.5 O
Beryllium	µg/L	2 U	2 U	2 U	2 U	2.3	20 U,O	17 U,O
Cadmium	µg/L	0.13 J	0.068 J	0.2 U	0.065 J	1.78	163 O	640 O
Calcium	µg/L	49700	3720	3730	5260	20300	723000 O	371000 O
Chromium	µg/L	4.7 J	6 U	6 U	6 U	14.5	40.3 O	277 O
Hexavalent Chromium	µg/L	NA	NA	NA	NA	NA	NA	NA
Cobalt	µg/L	2.8 J	4.6 J	6 U	3.5 J	13.4	502 O	2190 O
Copper	µg/L	11.5	13.6	189	84.3	322	16900 O	55300 O
Iron	µg/L	7710	6480	1600	11400	27500	558000 O	2610000 O
Lead	µg/L	3.27	194	1 U	4.69	45.4	45.7	3.46 O
Magnesium	µg/L	33000	980	1190	3720	7770	75000 O	355000 O
Manganese	µg/L	2220	139	183	199	654	5620 O	24200 O
Mercury	µg/L	0.2 U	0.17 J	0.2 U	0.2 U	0.2 U	0.25	2.26
Molybdenum	µg/L	NA	NA	NA	NA	NA	NA	NA
Nickel	µg/L	25.7	7.2 J	4.1 J	15.5	51	268 O	979 O
Potassium	µg/L	4610	9770	13600	3660	19400	4930 J,O	5170 O
Selenium	µg/L	1.2 J	55.5	1.4 J	0.8 J	8.6	10.9 O	21.4 O
Silver	µg/L	0.139	4.08	0.1 U	0.234	0.115	0.51	1.12 O
Sodium	µg/L	15700	20600	15800	18700	38000	28100 O	80700 O
Strontium	µg/L	NA	NA	NA	NA	NA	NA	NA
Thallium	µg/L	1 U	0.086 J	1 U	1 U	0.376 J	0.554 J	1.37 O
Tin	µg/L	NA	NA	NA	NA	NA	NA	NA
Titanium	µg/L	NA	NA	NA	NA	NA	NA	NA
Vanadium	µg/L	9.5	5 U	5 U	10.8	22.4	82.6 O	164 O
Yttrium	µg/L	NA	NA	NA	NA	NA	NA	NA
Zinc	µg/L	127	754	54	57	350	9720 O	42500 O
Field Instrument Result								
Dissolved Oxygen	mg/L	4.65	6	0.52	3.11	0.33	0.9	0.92
Oxidation Reduction Potential	mV	62.5	105.4	58.1	-35.8	-55.5	-38.8	-37.8
pH	su	7.39	5.95	6.08	6	6.21	4.93	5.11
Specific Conductivity	µS/cm	345	171	140	133	161	770	630
Temperature	Deg C	19.19	16.89	18.41	19.7	19.25	19.77	19.23
Turbidity	NTU	NM	NM	NM	NM	NM	41.3	NM

Notes

µg/L - micrograms per liter

mg/L - milligrams per liter

mV - millivolts

su - standard units

µS/cm - microsiemens per centimeter

Deg C - degrees Celsius

NTU - nephelometric turbidity units

NA - not analyzed

NM - not measured. Reading outside range of trubidity meter.

U - the analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit

J - the result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample

O - other qualifier defined by the Environmental Protection Agency. Defines what caused qualifiers mentioned above

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Appendix B. Sovereign Consulting Tier 1 – Treatability Test Report, May 2018 (On CD Only)

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BARITE HILL MINE
McCORMICK COUNTY, SOUTH CAROLINA

TIER 1 - TREATABILITY TEST REPORT

FOR

OU-1 - PIT LAKE SYSTEM

Submitted To: Black and Veatch & USEPA

Submitted By: Sovereign Consulting Inc.
12687 W. Cedar Drive, Suite 305
Lakewood, CO 80228

June 7, 2018 **DV031.002**

Executive Summary

An acidic pit lake at the Barite Hill Superfund site in McCormick County, South Carolina has received multiple remediation remedies whose beneficial effects have been temporary. The results of several investigations suggest that groundwater movement through a partially-capped pyritic mine waste repository adjacent to the southwest corner of the pit lake is the source of the continual re-acidification of the pit lake with a steady influx of acid rock drainage (ARD). A layer of metal-bearing sediment has formed on the bottom of the pit lake as a consequence of previous remediation attempts. This zone also comprises a potential source of pit lake contamination/ARD and must be considered in the development of remediation technologies.

For the purposes of evaluating Tier 1 remediation technologies for mitigating ARD generation, the waste rock repository was vertically portioned into three zones: a relatively dry, "unsaturated zone" immediately beneath the vegetated cap, a completely "saturated zone" whose piezometric surface correlates closely with the surface elevation of the pit lake, and a "transition zone" between the unsaturated and saturated zones that is periodically submerged and drained as the pit lake levels rise and fall in response to seasonal precipitation events or drought conditions.

Data in the literature confirm that pyrite oxidation kinetics control ARD generation and that pyrite oxidation are controlled by the pyrite's exposure to water, oxidizing reagents such as oxygen and ferric iron (Fe^{+3}), and a microbe, *Acidothiobacillus ferrooxidans* (*ATBFO*). It is a well-established fact that *ATBFO* can increase pyrite oxidation kinetics and ARD generation rates by many orders of magnitude.

The Tier 1 testing conducted during this study was specific to the Barite Hill mine waste and the site conditions. The test protocols are not found in typical standard methods documents; however, adherence to strict scientific investigative procedures appropriate to applied research and Tier 1 testing were followed. The testing focused on four primary technologies: 1) the suppression of *ATBFO* in the Barite Hill mine waste using bactericides or anti-microbial amendments, 2) the passive treatment of ground water and pit lake water, 3) neutralization of the pit lake using common alkaline reagents and combinations thereof, and 4) the encapsulation of the metal-bearing sediments with a layer of bentonite-amended site soil or a commercially-available pelletized media.

To insure uniformity in the testing, a thoroughly lab-homogenized mine waste sample was developed. This sample was found to contain a significant amount of clay-sized material that had the potential to compromise the ARD suppression tests that involved the percolation of remediation solution mixtures through the sample. Consequently, a phased testing strategy was followed to avoid sample plugging. The findings of this part of the study indicated that a self-agglomerated mine waste sample (no agglomerating reagents other than distilled water were used) provided a permeability suitable for testing. Also, it was found that certain reagents such as milk and sodium bicarbonate could potentially create conditions that plugged mine waste sample pore spaces. Preliminary guidelines for their usage at this site to avoid this were developed.

The results of this Tier 1 testing would be used to guide Tier 2 testing. The summary findings of each tested technology follow.

ATBFO Suppression:

Sodium lauryl sulfate (SLS) solution buffered with sodium bicarbonate (HCO_3) is effective at suppressing *ATBFO* in the unsaturated and transition zone test units. The buffering reagent appears to provide an SLS protective effect that allows lower SLS concentrations (i.e., 900–ppm) to be as effective as higher doses (i.e., 2% or 20,000 ppm) of unbuffered SLS that have been historically used for *ATBFO* suppression. A dilute solution of milk, also buffered with HCO_3, was effective at neutralizing existing ARD and suppressing additional ARD generation in the saturated zone test unit without plugging. The sequential application of buffered SLS solution followed by application of buffered diluted milk solution was not as effective as buffered SLS or buffered dilute milk solutions alone. It is suspected that the residual SLS in the sequential application cell also suppressed the beneficial microbes that were included with the milk application.

Tier 2 Bench scale (55-gallon drum) on-site test units are recommended to replicate the buffered SLS, buffered milk, and the sequential buffered SLS/milk application. Adjustments to the sequential application protocol may include additional fresh water rinsing between sequential applications to dilute the SLS concentration or to increase the amount of beneficial bacterial inoculum added to the milk application to counteract SLS-induced microbial mortality.

Passive Treatment of Mine Water:

The Upper Pit Water (UPW), collected from the uppermost 0.5 meters of the pit lake, is amenable to passive treatment with a biochemical reactor (BCR) filled with a typical mixture of organic materials such as wood chips, straw, and limestone.

The ground water collected from BH26 contains more acidity and sulfate than the upper pit lake water. It would require a pre-treatment step to remove acidity prior to its delivery to a BCR. Alternatively, the limestone component in the BCR media mixture may need to be increased. Pre-treating the iron and aluminum in the groundwater with an iron terrace might also reduce the acidity without the need for chemical addition.

BCR media candidates tested with the upper pit water appear to be capable of producing geochemically reducing conditions, i.e., negative ORP values. Consequently, BCR media could in theory be used to "geochemically" encapsulate the metal-laden sediments at the bottom of the pit lake in a chemically-reducing blanket similar to natural lakes that slowly infill with organic matter and sediment. Employing BCR media in this manner is not considered passive treatment per se.

Tier 2 Bench scale (55-gallon drum) on-site test units are recommended to replicate the best three BCR media mixtures in the SRB tests that received UPW. As it is unlikely that ground water from the waste rock repository would be pumped and treated, Tier 2 passive treatment testing is not warranted.

Neutralization of Pit Lake Water:

Should in-situ neutralization of pit water be required, multiple inexpensive options other than sodium hydroxide are available. The addition of powdered limestone may be especially attractive because one cannot overdose and unreacted limestone would provide a long-term reservoir of buffering alkalinity. Test results suggested that the sequential use of powdered limestone (calcium carbonate) to pH 4.9 followed by a final adjustment to circum-neutral pH with hydrated lime (calcium hydroxide) may be superior to a single neutralizing reagent approach because of the long-term buffering alkalinity that would be delivered.

Pit Lake Bottom Sediment Physical Encapsulation:

Bentonite-amended site soils and commercially-available products are capable of producing an encapsulating layer on the bottom of the pit lake. Additional Tier 2 studies may include tremie placement of these materials in a geomembrane-lined roll-off dumpster or similar large-scale container to quantitatively gage application methods and validate longevity.

In summary, the four technologies tested appear to produce conditions that can respectively suppress ARD generation, passively treat pit water, neutralize pit water with common reagents, and encapsulate the sediments on the pit lake floor. Combined, these technologies have a strong potential to break the seemingly perpetual chain of acidity loading to the pit lake that has frustrated the EPA for so long.

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List of Abbreviations

Abbreviation	Description
µS/cm	microsiemens per centimeter
ABA	acid base accounting
ABP	acid-base potential
AGP	acid generation potential
Al	Aluminum
amsl	above mean sea level
ANP	acid neutralization potential
Aq	Aqueous
ARD	acid rock drainage
As	Arsenic
ATBFO	*Acidithiobacillus ferrooxidans*
BART	biological activity reaction test
BCR	biochemical reactor
Ca	Calcium
$Ca(OH)_2$	Calcium Hydroxide
Cd	Cadmium
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
cm	Centimeters
cm/s	centimeters per second
CO	Colorado
CO_2	carbon dioxide
COC	chain of custody
CSM	Colorado School of Mines
Cu	Copper
cy	cubic yard
DO	dissolved oxygen
EPA	Environmental Protection Agency
Fe	Iron
FS	feasibility study
ft	Feet
g	Grams
gal	Gallons
HCO_3^-	bicarbonate ion
hr	Hour
IC	initial concentration
ICP	Inductively coupled plasma
kg	Kilogram
lbs	Pounds
LL	liquid limit
LLC	Limited Liability Company
MCL	maximum contaminant levels

meq	Milliequivalents
Mg	Magnesium
mg	Milligram
mg/L	milligrams per liter
Mgal	million gallons
MIW	mining influenced water
ml	Milliliters
mm	Millimeter
Mn	Manganese
MPN	most probable number
mV	Millivolts
Na	Sodium
$NaHCO_3$	Sodium bicarbonate
NaOH	Sodium Hydroxide
Ni	Nickel
No.	Number
ORP	oxidation-reduction potential
OTIE	Oneida Total Integrated Enterprises
OU	operating unit
PAG	potentially acid generating
Pb	Lead
PCB	polychlorinated biphenyls
pH	hydrogen ion concentration
PL	plasticity limit
POP	proof of principal
QUAPP	Quality Assurance Project Plan
RDI	Resource Development Inc.
RI	Risk Investigation
S	Sulfur
s.u.	standard units (pH)
SAP	Sampling and Analysis Plan
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SD	Sawdust
SESD	Science and Ecosystems Support Division
SLS	sodium lauryl sulfate
SRB	sulfate reducing bacteria or bioreactor
START	Superfund Technical Assessment and Response Team
SVOC	semi-volatile organic compounds
TBD	to be determined
TC	total carbon
$tCaCO_3/Kt$	tonnes calcium carbonate per kiloton
TCRA	Time-Critical Removal Action
TDS	total dissolved solids
TIC	total inorganic carbon
TOC	total organic carbon

TSS	total suspended solids
UPW	upper pit water
USBM	United States Bureau of Mines
USCS	Unified Soil Classification System
VOC	volatile organic compounds
WC	wood chips
WR	waste rock
XRD	X-ray diffraction
Yd^3	cubic yard
Zn	Zinc

1.0 INTRODUCTION

1.1 Site Description

1.1.1 Site Name and Location

The Barite Hill / Nevada Goldfields Site (Site; Comprehensive Environmental Response, Compensation, and Liability Information System [CERCLIS] ID: SCN000407714) is located approximately three miles southwest of the town of McCormick in McCormick County, South Carolina (SC). The 795-acre site is located west of U.S. Route 221 and north of State Road S-33-30 (Figure 1.1-1). Coordinates for the Site are: 33°52'25'N, 82°17'41"W (U.S. Environmental Protection Agency [EPA], 2012a). The Site is surrounded by forested and agricultural land and rural residential areas.

1.1.2 History of Operations

The Barite Hill Mine lies within the Lincolnton-McCormick Mining District. Gold was discovered in the district in 1852 and several small mines began operating shortly thereafter (Pardee and Park, 1948; Clark, et al., 1999a). Early mines consisting of at least two shafts and small underground workings were constructed at Barite Hill at an unknown time (Clark, et al., 1999b). Following intermittent exploration activities in the 1960s to early 1980s, the property was purchased by Gwalia (USA) Ltd. in 1988. Shortly after mining began in 1991, the mine operation was turned over to Nevada Goldfields, Inc. (Clark, et al., 1999a).

Nevada Goldfields, Inc. operated the Site as an open-pit, cyanide heap leach operation from 1991 to 1994. During that time, they recovered an estimated 64,700 ounces of gold and 119,500 ounces of silver from oxide and sulfide ore (Clark, et al., 1999a).

When mining activities ceased in 1994, Nevada Goldfields began site reclamation activities and they reclaimed large portions of the disturbed area (South Carolina Department of Health and Environmental Control [SCDHEC], 1998). Nevada Goldfields declared bankruptcy and abandoned the Site in June 1999. The State assumed control of the Site in July 1999. The Site has been inactive since that time.

The Main Pit is located at the former Barite Hill which was a small topographic high with a pre-mining elevation of approximately 510 feet (ft) above mean sea level (amsl; EPA, 2012). Prior to mining, topsoil was stripped and stockpiled on-site. Ore was loosened using standard drill-and-blast techniques, excavated and loaded onto haul trucks, then carried either to the ore processing facility, sub-ore stockpile, or waste rock dump. Benches cut along the mine pit walls were used as haul roads and to increase the stability of highwalls. The pit was excavated to a depth of about 340 ft amsl (Nevada Goldfields, 1993a); the present maximum depth is about 368 ft amsl, approximately 55 ft below the present water elevation at full pool.

Mined ore was trucked to the processing area located in the central part of the Barite Hill Site (Figure 1.1-2) which hosted a crusher, agglomerator, and conveyor system. The agglomerated ore was conveyed to an asphalt-lined reusable leach pad for cyanide leaching or to a permanent heap leach facility in the area between the reusable leach pad and waste area C (Figure 1.1-2). Various process ponds were used to collect the leachate, recycle the cyanide solution and for other water management operations. Detailed descriptions of ore beneficiation (including from the Rainsford Pit), processing, water management and other operations in the other OUs are presented in the Risk Investigation (RI) report for OU3 (Black & Veatch, 2015).

1.1.3 Prior Removal and Remediation Activities

<u>Post-Mining Reclamation</u>

Nevada Goldfields initiated post-mining reclamation of various disturbed areas of the Site in November 1994 (SCDHEC, 1998). Sulfide-bearing waste rock dumps on the south and southwest margins of the Main Pit were not reclaimed. Nevada Goldfields covered an unknown proportion of these waste rock piles with gunite prior to departing the Site (Gobla, 2007). The Main Pit was partly backfilled with rock

from the stockpiles along its southern margin. In January 1995, a controlled discharge of 2.8 million gallons of process water and 0.5 million gallons of water from the treatment pond was routed to the pit following a period of high rainfall that increased solution inventories to unacceptably high levels (Nevada Goldfields, 1995). The alkaline discharge mixed with acidic water already held by the pit neutralizing both (Nevada Goldfields, 1995). Prior to abandoning the Site, Nevada Goldfields neutralized the pit lake, which was smaller than the present lake, with lime to a hydrogen ion concentration (pH) of 11 (SCDHEC, 2006). No other reclamation work was completed at the pit. By November 2003, water in the pit had a measured pH of 2.0 to 2.2 (SCDHEC, 2006). This water was entering seeps and fractures in the pit walls where it negatively impacted groundwater.

EPA Removal Actions

When Nevada Goldfields abandoned the Site in June 1999, the Barite Hill Main Pit began to fill with water, eventually forming a lake; hereafter referred to as the pit lake. By 2007, the lake contained approximately 60 million gallons of water (Mgal) (Harrington et al., 2009) with a pH between 2.0 and 2.2 and a high content of dissolved metals; previous measurements by State personnel showed that lake pH decreased to values less than zero with depth (SCDHEC, 2007). The potential for overflow or a catastrophic release through failure of the pit wall became a serious concern as the lake level continued to rise, prompting EPA to initiate a Time-Critical Removal Action (TCRA) in 2007 (EPA, 2007). In 2007, EPA prepared an Expanded Site Inspection Report (Tetra Tech, Inc. [Tetra Tech], 2007a) and a Streamlined Remedy Assessment Report (U.S. Bureau of Reclamation, 2007) for the Site.

The Removal Action included treating the pit lake water to near neutral pH, grading and covering waste rock dumps on the southern margin of the pit, and constructing a spillway to control the lake level. The spillway, which was cut into bedrock along the northwestern margin of the pit, was sized to limit lake level rise to 2 ft during a 100-year storm event (Harrington et al., 2009). Excess water from the top of the lake is released to the North Tributary of Hawe Creek.

The pit lake was treated from February to May 2008 by neutralizing with the following: 1) 1,860 tons of hydrated carbide lime, 2) 23 tons of sodium hydroxide, 3) 21 tones methanol, 4) 1,300 tons of wood chips and 5) approximately 400 tons of molasses blends. This was done to stimulate the growth of sulfate-reducing bacteria and create reducing conditions within the lake (Harrington et al., 2009). Stimulating bacterial activity promoted the formation of iron monosulfide precipitates which are considered to be more stable than iron oxyhydroxide precipitates. The precipitates settled to the bottom of the lake.

An estimated 50,000 cubic yards (cy) of strongly acid-generating waste rock was pushed below the water line along the south side of the lake. The remaining 250,000 cy of waste rock in the dumps were graded to reduce their slope and capped following a Bureau of Reclamation design. The cap consisted of compacted soil and a geomembrane liner, which was covered with vegetation (Harrington et al., 2009). The liner covered most of the waste rock area as shown in Figure 1.1-3 (U.S. Bureau of Reclamation, 2008).

Surface water runoff from the hill slope south of the pit lake (including the waste rock dumps) was controlled and managed by creating a series of small sediment detention ponds and riprap lined channels that convey runoff to the pit lake. Work on the Removal Action was completed in October 2008.

An innovative system to monitor conditions within the pit lake was installed in 2009. The system was to provide continuous, remote monitoring of field parameters with depth in the lake from a fixed, floating platform in the lake but system performance proved sporadic and data are considered unreliable. Quarterly vertical profiles of field parameters collected by Removal Branch personnel (or their contractors) and instituted as a check on the remote system provided data with higher quality.

The waste rock dumps were monitored by installation of monitoring wells. Two monitoring wells were installed in each of the two capped waste rock dumps (four wells total) to monitor water quality within the dumps. These wells have been sampled periodically and show that the dumps contain poor quality groundwater. Electrical resistivity strings installed between the wells on each dump to provide

information on fluid movement have been ineffective. Additional grading and seeding of the waste rock cap were conducted in 2009 and in 2010 to ensure that vegetation became established on the cap.

Monitoring indicated that conditions within the pit were not remaining stable. Consequently, in July, 2009, the pit lake was treated with approximately 12,000 gallons of 50% sodium hydroxide (NaOH) solution. Another amendment with 3,500 gallons of 50 percent (%) NaOH was conducted July 13-15, 2010 (Oneida Total Integrated Enterprises [OTIE], 2010). However, the lake continued to acidify and was dosed again on August 16 and 17, 2012, with 4,000 gallons of 25% NaOH and 5,000 gallons of methanol. These amendments were mixed with lake water and discharged to the lake surface. Further monitoring of the lake continued to show acidification over this time period and the lake was dosed again April 18-20, 2016, with approximately 46,000 pounds (lbs) of NaOH. Table 1.1-1 summarizes these amendments during each dosing period.

Table 1.1-1. Amendments Added to the Pit Lake

	Initial Treatment Feb to May 2008	July 1 & 20, 2009	July 13-15, 2010	August 17-18, 2012	April 18-20, 2016
Hydrated Carbide Lime	1,860 tons				
Sodium Hydroxide	23 tons	4,000 gal 50% 8,000 gal 50%	3,500 gal 50%	4,000 gal 25%	45,700 pounds
Methanol	21 tons			5,000 gal	
Molasses Blends	~400 tons				
Wood Chips	1,300 tons				
Post-Amendment pH	5.5	5 8.7	6.25	6.7	4.7 - 9.8

Notes:
gal - gallon
pH - hydrogen ion concentration

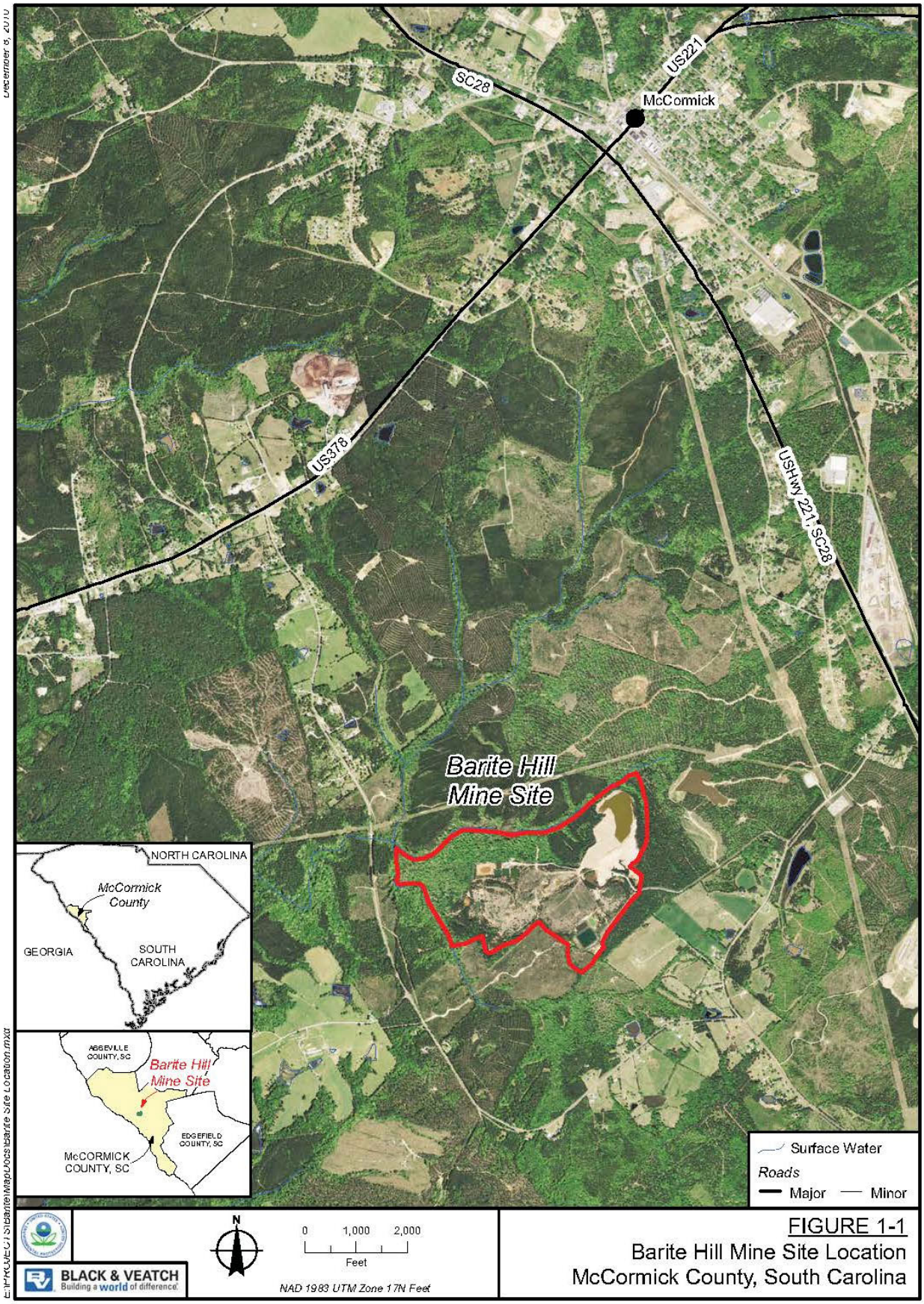


FIGURE 1-1
Barite Hill Mine Site Location
McCormick County, South Carolina

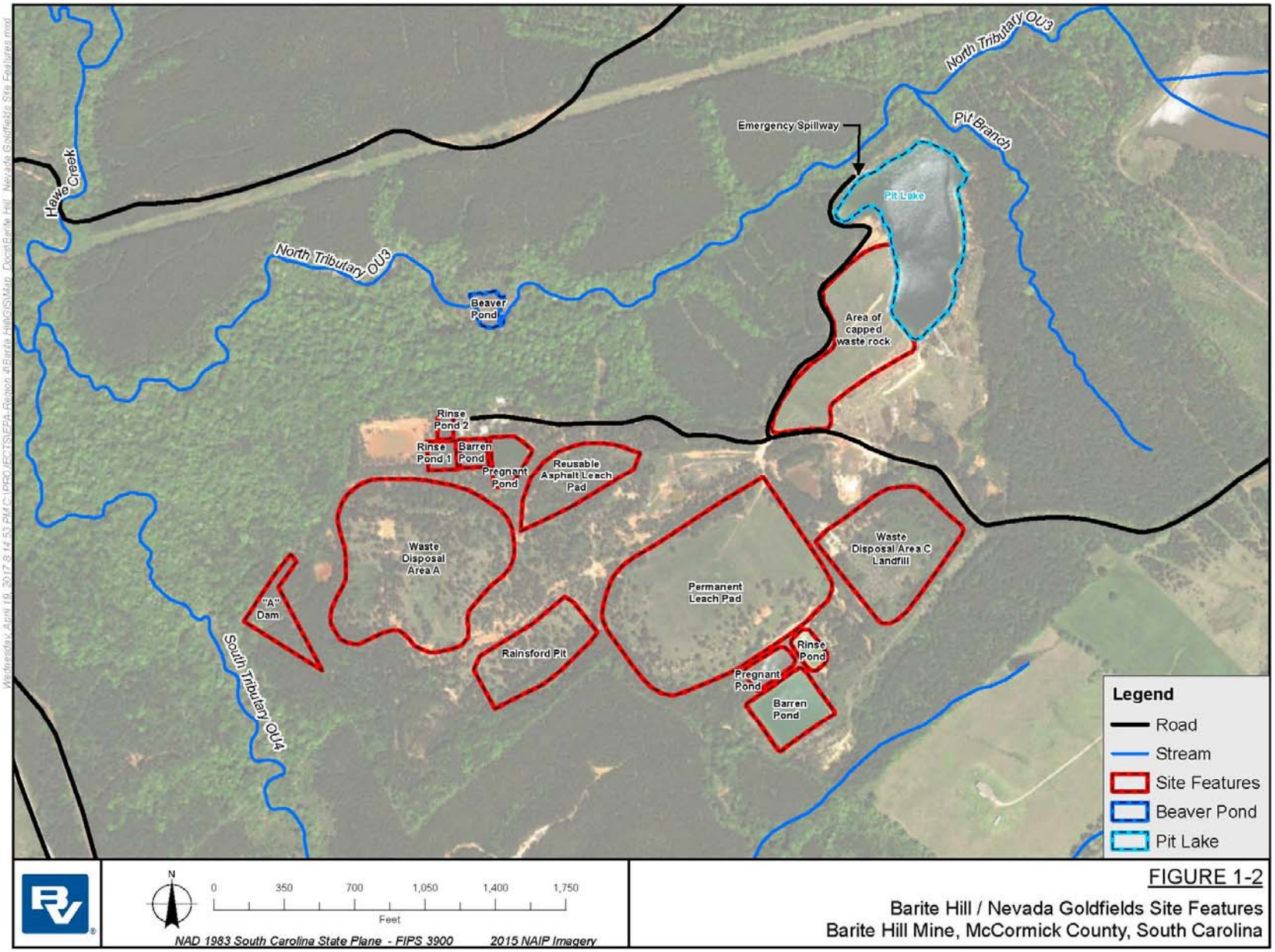


FIGURE 1-2
Barite Hill / Nevada Goldfields Site Features
Barite Hill Mine, McCormick County, South Carolina

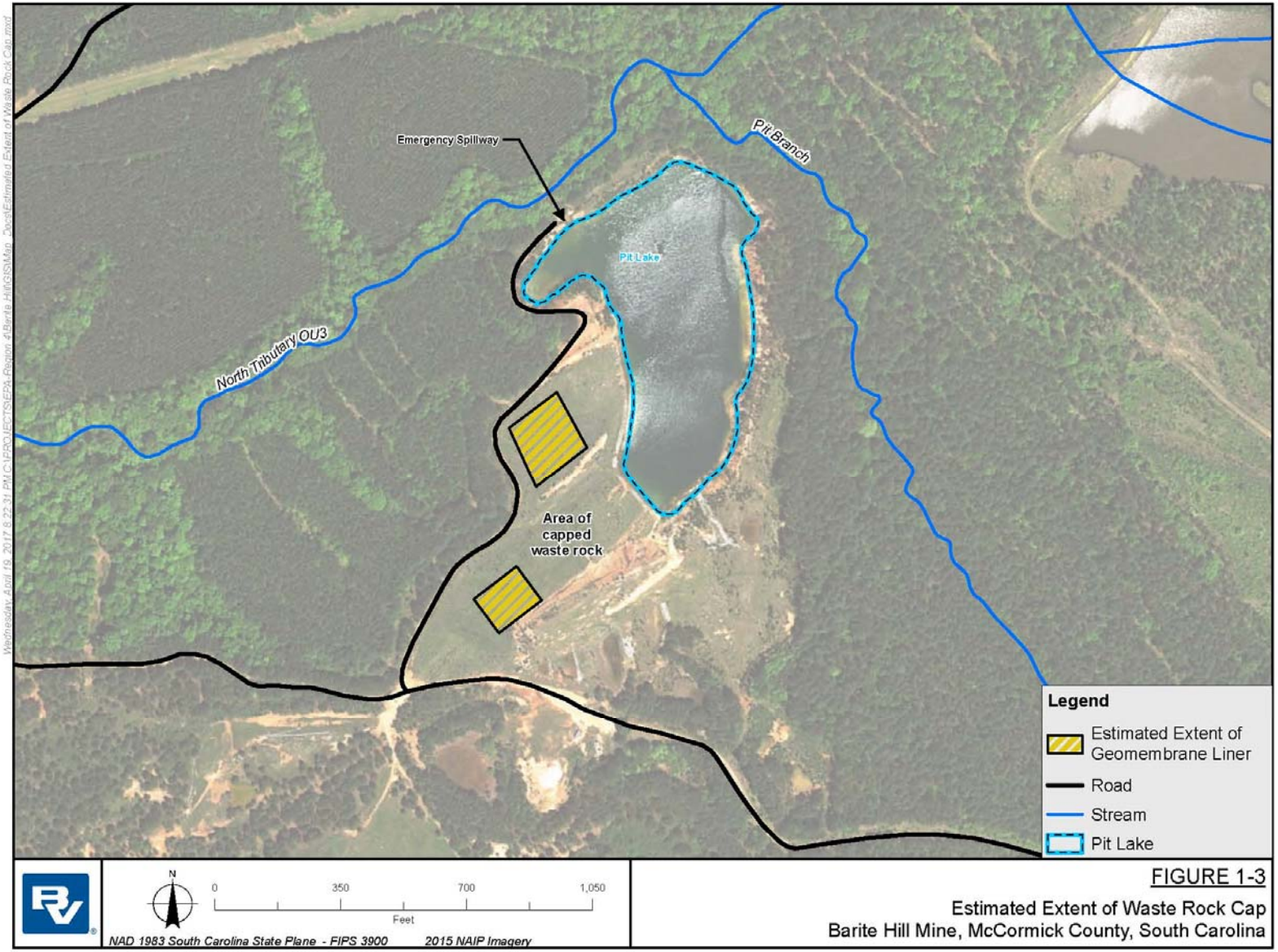


FIGURE 1-3
Estimated Extent of Waste Rock Cap
Barite Hill Mine, McCormick County, South Carolina

1.2 Waste Stream Description

1.2.1 Waste Matrices

Soil

Soil samples (0 – 6 inches depth) were collected around the pit lake in May 2011 from six locations. Five reference background soil samples were also collected for the entire Barite Hill Site. The soil samples were compared to soil quality screening benchmarks for human and ecological receptors. No organic chemicals exceeded screening levels. However, elevated concentrations of arsenic, barium, cadmium, chromium, copper, and lead were identified to be of potential concern with some elevations of antimony, iron, manganese, molybdenum and vanadium. Most of these metals are only slightly elevated above twice the background soil concentrations.

Groundwater

General Chemistry. There are twelve monitoring wells in OU1. Nine of the wells have been sampled 12 times between February 2011 and November 2016; three of the most recent installed wells were sampled 8 times. Samples were analyzed for metals, classical/nutrients, iron forms, and field parameters. Water level measurements were also collected during each sampling event. Three of the wells were sampled once for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) pesticides, and polychlorinated biphenyls (PCBs). The groundwater concentrations were compared to human health drinking water standards such as maximum contaminant levels (MCLs) and EPA's regional screening levels. Concentrations of metals above MCLs occurred during all sampling events. These metals included antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, selenium, and thallium. The highest concentrations of metals were detected in the samples from the four wells installed within the waste rock area. There were also a few exceedances of screening-levels in up-gradient wells. The pH levels in all twelve wells exceeded the secondary MCL for drinking water. No organic chemicals exceeded screening levels.

Groundwater Flow. Measurements of depth to water in the wells were used to contour the potentiometric surface in OU1. In general, the potentiometric surface slopes north and northwest, indicating groundwater flow in these directions. Fracture zones within the bedrock play an important role in groundwater movement at OU1, including the inflow of groundwater to and its discharge from the pit lake. Geophysical surveys were conducted at the site to supplement available geologic data and provide more information on fractures that may serve as preferential pathways for groundwater flow. These included surveys by GEL Geophysics in 2001 and 2002, the USGS in 2012, and by Willowstick® in 2016. Data from these investigations identified several specific groundwater flow paths into the pit lake and out of the lake via seeps in the North Tributary (OU3).

Surface Water

A variety of surface water data exists for the pit lake. EPA's START contractor collected laboratory and field analytical data in the lake from 2008 through 2013 related to actions to neutralize the lake; amendments were added to the lake in 2008, 2009, 2010, 2012 and 2016. In addition to the analytical data collected by START, numerous field parameters were collected by hand-lowering multi-probe sondes to measure temperature, specific conductivity, pH, oxidization-reduction potential (ORP), dissolved oxygen (DO) and turbidity. These data were generally collected at one-meter intervals from the surface to the bottom. The EPA Science and Ecosystems Support Division (SESD) and Black & Veatch continued to monitor the lake from May 2011 through November 2016. Each sampling event for analytical parameters were collected at different depths, generally in the upper 10 feet, the middle water column (15 to 25 feet) and near the bottom (>40 ft). Parameters sampled during most events included total and dissolved metals, chloride, sulfate, acidity, alkalinity, total dissolved solids (TDS), total suspended solids (TSS), total and ferrous iron concentrations, and total organic carbon (TOC). Storm water runoff samples were also collected from 4 locations around the pit including the highwalls.

Pit lake water quality was compared to screening level water quality benchmarks such as South Carolina water quality standards and human health benchmarks. The comparison indicated that cadmium, copper, and manganese exceeded their benchmark values with the greatest frequency and

magnitude. Other chemicals of concern in the lake include aluminum, arsenic, barium, cobalt, iron and zinc. The highest concentrations are generally near the lake bottom.

Sediment

A total of six sediment samples were collected from the pit lake; three in May 2011 and three in July 2016. Samples were analyzed for total metals, total and weak acid dissociable cyanide, paste pH, sulfur forms and acid-base accounting. Only one sample was analyzed for organic constituents. In addition, the 2016 samples were submitted to the Department of Geosciences at Virginia Tech for mineralogical analysis by X-ray diffraction (XRD) and scanning electron microscopy. The sediment concentrations were compared to screening-level benchmarks considered protective of human and ecological receptors. No organic chemicals exceeded the benchmarks. The primary metals of concern in sediment are barium, cadmium, copper, iron, lead and zinc. Primary crystalline phases identified by XRD included the clay mineral kaolinite, muscovite mica and quartz. One sample also contained minor amounts of gypsum. Iron oxide or sulfide phases were not identified by XRD. Other minor carbonate, sulfide and/or sulfate minerals were identified and heavy metals (e.g., cadmium, copper, zinc) were also associated with some particles.

1.2.2 Pollutants/chemicals

Chemicals of Concern include arsenic, cobalt, and vanadium in soil; aluminum, antimony, arsenic, cadmium, cobalt, copper, iron, manganese, mercury, nickel, selenium, thallium, vanadium, zinc in groundwater; arsenic, cadmium, cobalt, copper, iron, manganese, and vanadium in surface water; and, arsenic, cadmium, cobalt, and iron in sediment.

1.3 Treatment Technology Description

This section describes the source control technologies that were assessed in this Remedy Screening test.

1.3.1 *Sodium Lauryl Sulfate (SLS)*

The iron-oxidizing bacteria such as *Acidithiobacillus ferrooxidans* (ATBFO) have proven to play a critical role in creating acid rock drainage (ARD) and are strongly associated with the formation of acid mine drainage (Kleinmann, et.al., 1981; Schrenk et. al., 1998). Metals found in mine soils, including iron, manganese, aluminum, magnesium, lead, copper, zinc, cadmium, and selenium are solubilized, creating drainage that is toxic to the environment. Suppression of ATBFO has proven to significantly reduce the generation of ARD at mine sites (Rastogi 1996).

Anionic surfactants are effective inhibitors of ATBFO, as they destroy the integrity of the cytoplasmic membrane of the bacteria thus allowing the acid that they create to enter the cells and destroy them.
As of the mid-1990's, anionic surfactants had only been applied to surface sources of ARD. That changed when Plocus and Rastogi (1997) demonstrated that subsurface application of anionic surfactants using injection techniques could successfully reduce ARD at the Fisher Site in Banks Township, Indiana County, Pennsylvania. This was accomplished by identifying the acid-generating zones using geophysical techniques and designing a multiple-stage borehole-based injection program that targeted the ARD "hot spots".

Geophysical mapping with electromagnetic terrain conductivity meters and magnetometers were utilized to identify pyritic zones which were responsible for the high acid production on the Fisher Site.

SLS could be used in conjunction with waste milk (described below) to develop long term ARD source control. It might be applied with inexpensive drip irrigation technology used in mining operations.

Additional issues to be considered:

- Source control is always preferable to active or passive treatment because there is no permanent constructed infrastructure, and consequently no space considerations. Source control can also be a long term "cure" for ARD instead of a perpetual treatment for the symptoms (ARD) caused by an uncontrolled source.

- Application rates, doses, and methods need to be tested so that adequate penetration can be achieved without significant surface run off.
- When used in conjunction with waste milk and a strong vegetation cover, long-term acid generation reduction can be achieved.
- Cost is very low with virtually no maintenance costs.
- This source control technique would be most effectively applied to the unsaturated and transition zones of the waste rock dump.
- For the effects of this source control option to become permanent, it needs to be implemented with a robust vegetative cover which would be installed anyway to minimize erosion and water contact with the mine waste. This situation already exists at Barite Hill.
- Surficial drip irrigation application on the waste rock dump surface is impractical due to the existence of the cover. Subsurface injection or delivery techniques would be required.

1.3.2 *Milk*

Researchers at the Wyoming Research Institute (Jin, et al., 2008) determined that a biofilm nurtured by waste milk or other dairy products, inoculated with a "probiotic" bacterial community, could out-compete ATBFO on the surfaces of pyrite grains and thus suppress ARD.

In essence, the milk produces a biological environment unfavorable to acid-forming bacteria until a vegetative cover can be established to perpetuate the favorable environment. It can also be used in a saturated environment. When ATBFO are present, waste milk is best used in conjunction with Sodium Lauryl Sulfate (SLS) to develop long term source control; milk would probably be applied in a diluted solution (strength TBD) or in powder form that would be delivered to pyritic mine waste during a rainy interval.

The concept of introducing competing bacteria is not new. Sobek, Benedetti, and Rastogi (1990) suggested that a probiotic process would complement the application of a slow-release acidophilic bactericide, sodium lauryl sulfate:

"Inhibiting or destroying thiobacilli can significantly slow the rate of acid production. Anionic surfactants, organic acids and food preservatives (Onysko, et al., 1984) act as bactericides and kill these bacteria; however; bactericides degrade over time and are lost because of leaching and runoff. To overcome the inherent short duration effectiveness of spray applications, controlled release systems to provide the bactericide slowly over a long-time period were developed (Sobek, et al., 1985).
Control of acid generation for prolonged periods greatly enhances reclamation efforts and can reduce reclamation costs by reducing the amount of topsoil needed to establish vegetation. Three natural processes resulting from strong vegetative cover for three years or more can break the acid production cycle. These processes are:

1) A healthy root system that competes for both oxygen and moisture with acid-producing bacteria;
2) Populations of beneficial heterotrophic soil bacteria and fungi that are re-established, resulting in the formation of organic acids that are inhibitory to (now *A. ferrooxidans*) *T. ferrooxidans* (Tuttle, et al.,1977); and
3) The action of plant root respiration and heterotrophic bacteria increase CO_2 levels in the spoil, resulting in an unfavorable microenvironment for growth of *T. ferrooxidans*."

Sobek, Benedetti, and Rastogi viewed antibacterial application as a method to reduce the volume of topsoil needed to revegetate potentially acid generating or PAG waste. They believed that at least three years of acidophilic bacterial suppression was sufficient to accomplish this goal.

Additional issues to be considered:

- Source control is always preferable to active or passive treatment because there is no permanent constructed infrastructure, and consequently no space considerations.
- Application rates, doses, and methods (subsurface injection, infiltration, or horizontal migration), would need to be tested so that adequate penetration can be achieved.

- As with SLS, for the effects of this source control option to become permanent, it needs to be implemented with a robust vegetative cover as subsequently discussed. The root zone of the vegetative cover provides a sustainable supply of organic acids which produce the same effect as the waste milk for the long term.
- When used in conjunction with SLS, a long-term acid generation reduction can be achieved. Prevention is more desirable than perpetual treatment.
- Cost is very low with virtually no maintenance costs.
- Typical treatment process includes applying SLS first, then waste milk, depending on the situation. For example, SLS would not be used in a saturated zone because pyrite oxidation in that environment is abiotic, driven by the presence of ferric iron.
- As with the SLS technology, the mine waste must exhibit reasonable permeability to allow adequate penetration to be considered practical. Preliminary screening test results might show that the mine wastes may not be permeable and that the congealing of milk when it contacts the acidic material makes a nominal plugging situation worse.

1.4 Previous Treatability Studies at the Site

There have not been any Tier 1 treatability studies conducted at the Site of which we are aware. However, in 2008 Alexco was contracted to implement a three-pronged remediation plan at the Barite Hill site. The prongs were to neutralize the pit lake, backfill the pit lake with 50,000 yd3 of reactive material, and reclaim (cover) the waste rock pile after backfill was borrowed. Neutralization of the pit lake was done with lime and a soluble carbon source with the aim of creating a dense sludge layer with iron monosulfides. *Low Cost Treatment of a Highly Contaminated Pit Lake Using Innovative Technology Barite Hill Mine McCormick, SC* (Harrington, 2009)

1.5 Test Goals & Objectives - Preamble

Previous treatability testing appears to have focused on addressing the *physical* aspects of ARD production (disruption of water and air contact with pyrite-bearing mine waste) rather than disrupting the root ARD causes that involve the biologically-facilitated oxidation of pyrite. The screening studies conducted are meant to show whether or not an antibacterial-centered ARD-disruption strategy is an appropriate one at the Barite Hill site. As with any screening study, the goals of each test were to:

- Narrow the range of process-controlling parameters – determine minimum conditions for success;
- Determine what works and what does not - eliminate marginal or dead-end technologies from further consideration; and
- Identify potentially successful processes – if possible, improve those that exhibit the most promise.

1.6 Document Organization

This report is organized using the EPA Guidance for Conducting Treatability Studies Under CERCLA, EPA/540/R-92/071a, NOV92, Section 3.12 Reporting the Results, Table 13 - Suggested Organization of Treatability Study Report, as a guide. Because this report covers several unique testing groups the Section 2-Conclusions and Recommendations, Section 3-Treatability Study Approach, and Section 4-Results and Discussion sections are organized inside each of these testing groups:

- Initial Characterization Testing
- Beaker and Sieving Tests
- Utilization Testing Using the Amended USBM Method
- Source Control Treatment Testing (Waste Rock)
- Pit Lake Encapsulation

- Pit Water Treatment

Thus each testing group is kept whole so that the EPA standard report sections (listed below) can be presented together within each testing group.

- Conclusions and Recommendations (EPA Guide Section 2)
- Treatability Study Approach (EPA Guide Section 3)
    - Objectives
    - Experimental Design and Procedures (including materials and sampling)
    - Deviations from the Work Plan
- Results and Discussion (EPA Guide Section 4)
    - Data Analysis and Interpretation

Several general sections (that are common to all testing groups) that are normally part of EPA guidance in Sections 2, 3 and 4 are included outside of the individual testing group sections such as:

- Data Management (EPA Guidance 3.5)
- Quality Assurance/Quality Control (EPA Guidance 4.2)
- Cost/Schedule for Performing the Treatability Study (EPA Guidance 4.3)
- Key Contacts (EPA Guidance 4.4)

Information that is contained in other project documents (Work Plan, SAP, QAPP…) or report sections (Data Summary, Results, Laboratory Reports…) are referenced to those documents or Sections and for the most part not restated as recommended in the EPA guidance.

2.0 OVERALL TREATABILITY STUDY APPROACH

2.1 General Approach – All Tests

Testing was primarily focused on the feasibility of *in situ* treatment (source control) of the pyritic mine waste in the southwest corner of the pit (SW Waste Rock). This appears to be the major source of acidity and metals to the pit lake. This input must be controlled or the lake will require indefinite treatment to control pH and metals loadings. Two other technology screening concepts for OU1 address the pit lake itself.

- SW Waste Rock Source Control – Identified as the key reclamation issue for the pit lake, a significant amount of treatability testing is directed at finding the most practical and effective amendments for a long-term source control remedy. The stockpile has four distinct layers (or zones) having unique attributes and roles that will need to be considered in developing a successful long-term strategy for the site.
    - *Cover material*: a partial barrier for water and air (oxygen) helping to sequester ARD generation and a contributor for carbon (humic acid) that can help sustain a non-acidic bio-community.
    - *Unsaturated zone*: waste rock that is permanently above the ground water level that can be a significant contributor of ARD when exposed to infiltrating water.
    - *Transition zone:* waste rock that is subject to a wet-dry cycle as ground water levels fluctuate.
    - *Saturated zone:* waste rock that is permanently submerged that when exposed to acidic water contributes additional ARD.
- Pit Lake – The remedial focus of OU1 is the pit lake that potentially has influxes and seeps that influence the flow (spread) of ARD into and out of the lake. The lake also contains acidic water that ultimately needs to be neutralized.
    - Pit Lake Floor Encapsulation – Laboratory evaluations to assess materials that could be used for covering submerged acid generating rock on the floor of the pit lake.
- Bulk Pit Water Treatment – Laboratory evaluations to explore an economical and feasible method to neutralize the stored acidity in the lake and providing some long-term control.

Tier 1 treatability studies are a critical part of the remediation program to evaluate various remediation alternatives for viability to the site to determine if they should or should not be considered further. It builds the foundation for the feasibly study (FS) for the site and for more focused and meaningful testing. Most of the effort was done in a laboratory (proof of principle and bench) with some on-site field measurements and characterizations. No pilot scale or column work was planned or covered in this plan. Solfatara Laboratories, LLC, in Golden, CO, was the principal location for the lab work.

3.0 TESTING GROUPS

There are six testing groups covered in this report:

- 3.1 Initial Sample Characterization
- 3.2 Beaker and Sieving Tests
- 3.3 Utilization Testing Using Amended USBM Method
- 3.4 Source Control Treatment Testing (Waste Rock)
- 3.5 Pit Lake Encapsulation
- 3.6 Pit Water Treatment

Both the Beaker and Sieving Tests and Utilization Testing Using Amended USBM Methods (3.2 and 3.3) were preliminary analyses to help set up the quantiles, methods, dose amounts and rates for the Source Control Treatment Testing (3.4) on the waste rock. Because of this, the full discussion of these two testing groups have been moved to an appendix with only a summary contained in the main text of the document.

Each testing group is organized in accordance with the EPA Guidance for Conducting Treatability Studies in the following outline. Note that the Conclusions and Recommendations are discussed first.

- 3.X.1 Conclusions and Recommendations
- 3.X.2 Initial Characterization Approach
  - 3.X.2.1 Objectives and Rationale
  - 3.X.2.2 Experimental Design and Procedures
  - 3.X.2.3 Deviations from the Work Plan
- 3.X.3 Test Results and Discussion

3.1 Initial Sample Characterization

3.1.1 Initial Characterization - Conclusions and Recommendations

The goal of this first part of the testing program was to acquire the samples needed for the Tier 1 testing described herein and to perform the initial analysis (both field and analytical lab) on the testing materials to appropriately characterize them. This was accomplished. There was no real feasibility testing done in this test group and as such conclusions and recommendations are included in the subsequent testing groups that included the treatability testing scopes.

3.1.2 Initial Characterization Approach

3.1.2.1 Objectives and Rationale – Initial Characterization

The objective of the field sampling of bulk materials was to provide representative samples of mine waste solids and liquids from the site to support Tier 1 testing of potential remedies. Performing part of the initial characterization of the materials was also an objective utilizing field data collection.

3.1.2.2 Experimental Design and Procedures

A specific sampling and analysis plan was completed for this work (*Sampling and Analysis Plan (SAP) for Tier 1 – Remedy Screening* [Sovereign 2017]). A summary of the field work is described below. Samples included groundwater, surface water, waste rock, compacted silt layer, top soil, and vegetative cover.

Groundwater Sampling: A well pump was used to pull sample groundwater from monitoring wells BH26 and BH28. A five-gallon sample was pulled from each well and one five-gallon sample was prepared as a composite between the two wells. Depth to groundwater was measured at each well by the well pump. Approximately 5 gallons of water was pulled from each well and wasted prior to sample

collection. Samples were later transferred to gasketed screw top buckets and affixed with chain of custody (COC) forms for shipment.

Surface Water Sampling: Water was sampled from the pit lake surface and a location deep in the pit lake. Two five-gallon samples were pulled from the pit lake surface using the well pump. A five-gallon volume of surface pit water was pulled through the pump before sample collection. The deep pit lake sample was collected by taking a boat out onto the pit lake and using the well pump to pull sample from approximately two to five feet off the floor of the lake. In the approximate deepest point of the lake, as estimated by Black and Veatch and EPA personnel on site, the well pump was dropped to the bottom of the lake in a five-gallon bucket and then pulled up several feet before sampling. Again, a volume of deep pit water was pulled through the pump before a five-gallon sample was collected. Samples were later transferred to gasketed screw top buckets and affixed with COC forms for shipment.

Waste Rock, Compacted Silt Layer, Top Soil, and Vegetative Cover Sampling: Three test pits were excavated in the waste rock dump by a backhoe and operator supervised by Sovereign. Test pits were dug to approximately two feet deep in the waste rock layer. Excavated material was separated into piles by the backhoe operator by composition; waste rock, silt material, cover soil, and vegetation. Waste rock was then hand screened to 4" and hand shoveled into totes for shipment. Approximately 600 kg of waste rock material was collected, 300 kg each from test pits 1 and 3. Approximately 36 gallons of cover soil and 48 gallons of compacted silt were to be collected. Volumes and weights were visually estimated in the field. The samples were loaded directly into totes on site then affixed with COC forms and transferred via pallet to a freight courier. Plugs of vegetation, approximately one-foot square in size, were collected and shipped in small plastic totes with COC forms.

3.1.2.3 Deviations from the Work Plan

Field Sample Collection: Several extra samples were collected in the field to provide supplemental material for testing. These included a five gallon of high pyrite waste rock selectively screened by Sovereign staff on site. This pyrite material was sampled in case a need arose to supplement reactors with highly reactive material. An extra five-gallon sample of surface pit water was collected as a supplemental supply of site water for lab testing. Test pits were to be field located. The original plan included excavating two pits for composite sampling, but Sovereign field staff determined after excavating the second test pit that a third pit should be included. The material in test pit two appeared to be very oxidized and the third pit was dug in search of pyritic (hotter) material. Samples were collected from all three pits.

3.1.3 Initial Characterization - Test Results and Discussion

The laboratory reports are included in Appendix C-1

3.1.3.1 Waste Rock

Specific Gravity: The specific gravity of the waste rock ranged from 2.74 to 3.1, with an average of 2.85 (four samples).

Crushing/Sieve Analysis: The field waste rock sample was hand-screened to minus four inches to eliminate large rock from the shipment.

Field samples were delivered to RDI, Wheat Ridge, CO. This material was represented by 156.8 kg from Pit 1 and 223.6 kg from Pit 3, for a total of 380.4 kg. This material was supplemented with 127.34 kg of intact rock samples from BH Test Pit 1, sericite zone (42.32 kg), BH Test Pit 2 (41.84 kg) and BH Test Pit 3 (43.18 kg). This mix was crushed and distributed as described below.

Material was stage crushed to minimize fines generation. The material was wet screened at 60 mesh and the plus fraction dried. The plus 60 mesh fraction was dry screened (Ro-Tap) for 30 min. The minus 60 mesh fraction was settled, decanted, recovered by filtration and dried. Mass fractions are summarized below (Figure 3.1-1, Table 3.1-1).

The crushed sample was split into 20 x 20.25 kg subsamples, with representative 250 g samples removed from each bucket to generate 5 x 1000 g composite samples. The composites were crushed

to minus 10 mesh for analysis. A single 1002 g composite was prepared from each of the five composites by subsampling 200.4 g from each. This sample was submitted for compositional and elemental analysis, with a subsample of the minus 60 mesh fraction submitted for CEC analysis.

Fines content was a concern relative to the potential for plugging in the 20 kg POP tests. Therefore, it was of interest to further resolve this mass by size fraction. Roughly one-half kilogram of the minus 60 fraction was dry sieved using the following series of sieves: 50 mesh, 100 mesh, 140 mesh, 325 mesh and 400 mesh (Table 3.1-2).

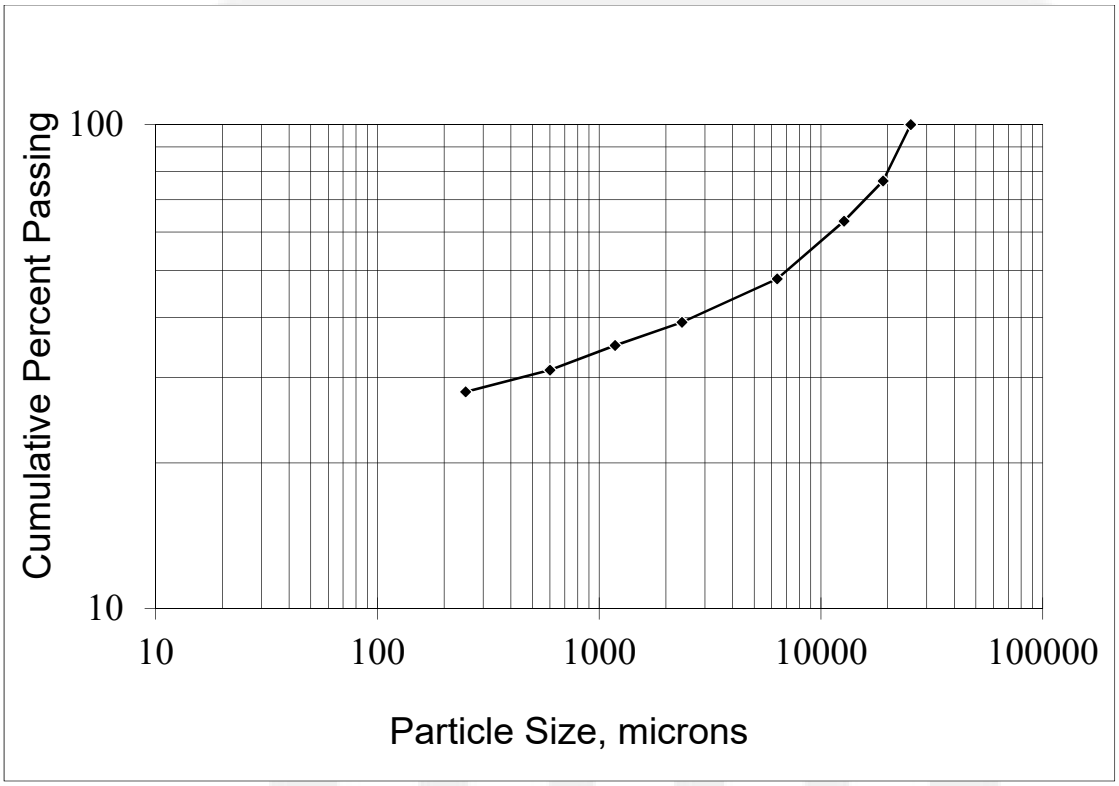


Figure 3.1-1 Particle Size Distribution of Waste Rock Feed

Table 3.1-1 Mass Distribution of Waste Rock Feed

Product		Weight			
Mesh (Retained)	Microns	Grams	%	Cumulative Passing	Cumulative Retained
Feed (Calculated)		7,105.2	100.0		
1"	25400	0.0	0.00	100.00	0.00
3/4"	19050	1670.5	23.51	76.49	23.51
1/2"	12700	944.8	13.30	63.19	36.81
1/4"	6350	1080.3	15.20	47.99	52.01
8	2360	635.2	8.94	39.05	60.95
14	1180	289.3	4.07	34.98	65.02
30	600	274.6	3.86	31.11	68.89
60	250	217.4	3.06	28.05	71.95
Pan	-250	1993.1	28.05	0.00	100.00

Table 3.1-2 Mass Distribution of Waste Rock Feed – Fines

Product		Weight			
Mesh (Retained)	Microns	Grams	%	Cumulative Passing	Cumulative Retained
Feed (Calculated)		518.85	100.0		
50	300	0.80	0.15	99.85	0.15
100	150	303.55	58.50	41.35	58.30
140	106	175.80	33.88	7.47	92.18
325	45	34.9	6.73	0.74	98.91
400	38	0.35	0.07	0.67	98.98
Pan	-38	0.70	0.13	0.00	99.11

Field Capacity: The field capacity of the waster rock was 0.126 kg water/kg dry solids.

Paste pH: The paste pH of the sample from the North Stock Pile and the South Stock Pile were measured at Solfatara labs as 2.6 and 3.1, respectively.

Cation Exchange Capacity (CEC): The CEC of the waste rock material was 2.49 meq/100g. Based on this result and comparison with typical ranges for CEC of soil materials, this rock material has high content of sand.

ABA: The ABA results are shown it Table 3.1-3 and indicates that the material has a high content of pyritic sulfide (3.36%). The Acid Base Potential is -105 $tCaCO_3$/Kt with no Acid Neutralization Potential. Based on the ABA results the material is classified as potentially acid generating (PAG). The lab results are included in Appendix C-1.

Table 3.1-3 Waste Rock ABA Results

Material	Total S	Sulfate	Sulfide	AGP	ANP	ABP	TC	TIC	TOC
	%	%	%	$tCaCO_3$/Kt	$tCaCO_3$/Kt	$tCaCO_3$/Kt	%	%	%
Waste	3.73	0.35	3.36	105	<1	-150	<0.1	<0.1	<0.1

Notes: AGP: Acid Generation Potential; **ANP**: Acid Generation Potential; **ABP**: Acid-Base Potential; **TC:** Total Carbon; **TIC**: Total Inorganic Carbon; **TOC:** Total Organic Carbon;

To gain a better appreciation of the nature of the pyrite occurrence in the WR, selected samples were examined with a 150X digital microscope. An image from this examination is provided in Figure 3.1-2 showing that the pyrite appears to coat the surface of the particle (note the 0.7mm pencil lead for scale). Panning of a WR sample that was passed through a 10 mesh (1.68 mm) sieve failed to produce evidence of fine-grained pyrite but this visual observation does not preclude the existence of framboidal pyrite in the minus 10 mesh fraction.

Figure 3.1-2 Pyrite observed on surface of coarse WR particle.

ICP-Metals: The results of the ICP aqua regia digestion indicated that the waste rock material had high content of metals. This data was used to develop amendment application rates. Table 3.1-4 shows the mg/kg of metals in this material.

Table 3.1-4 Waste Rock ICP Metals Results

Material	Al	As	Cd	Ca	Cu	Fe	Pb	Mg	Mn	Ni	Na	Zn
mg/Kg												
Waste Rock	6,590	90	1.9	520	458	39,800	237	4,540	94.4	501	50	232

3.1.3.2 Borrow Material

Sieve Analysis, Atterberg Limits & Specific Gravity: The percentage of fines passing through the No 200 sieve was 75%. The specific gravity of the borrow material was 2.83. The Atterberg Limit results indicated that the Liquid Limit (LL) was 44, with a Plasticity Index of 14 and Plasticity Limits (PI) of 30. A LL of 44 indicates that the material has a low plasticity, according to the Soil Classification System (USCS). The material was classified as silt with sand. The lab report of the Particle Size Distribution & Atterberg Limits is provided in Appendix C-1.

3.1.3.3 Pit Lake

The field parameters and laboratory results of the initial characterization of the Pit Lake and Wells BH26 & BH28 water are in Tables 3.1-5 and 3.1-6. The laboratory report is included in Appendix C-1.

Sulfate and alkalinity testing was also included in the work plan and are not included in Table 3.1-5 because the tests were not conducted. Sulfate and alkalinity water samples for the lab were not collected at the time of field sampling because the work plan was being updated and decisions were still being made as to which tests to run for the initial characterization.

The sulfate and alkalinity testing were not conducted on water from the bucket samples collected from the pit lake and the wells. The water chemistry would have likely been impacted when the water was mixed and exposed to air. When the water buckets were first opened, they had been aging in the lab for several months. This was corroborated by sending several repeat water samples to CSM for ICP analysis. As determined by ICP-AES, the elemental content of upper pit water was stable in regards to primary metals and metalloids of interest. In contrast, chemistry of the lower pit lake water and the BH26 and 28 for some constituents differed from the field water samples that were sent to CSM immediately following the field sampling (Tables 3.1.7 and 3.1.8). However, solution pH, conductivity

and sulfate content were reported for aged water samples as they were used in later applications. Table 3.1-5 includes a sulfate concentration that was calculated from the ICP sulfur data from CSM.

Table 3.1-5 Pit Lake & Wells BH26, BH28 Water Results

Sample Location	Sample Collection	Field Tested		Calculated[1]
		pH	Specific Conductivity	Sulfate
	Date	s.u.	µS/cm	mg/L
Upper PL Water	10/05/17	3.0	3000	2100
Lower PL Water	10/05/17	3.7	7700	9000
Well BH26	10/05/17	1.9	16000	23412
Well BH28	10/05/17	2.1	7900	9294

Note:

[1] Sulfate was calculated from the sulfur concentration. The date of the analysis was 10/25/2017.

Table 3.1-6 Pit Lake & Wells BH26, BH28 Water ICP Metals Results (Field Samples)

Parameter	Units	Upper PL Water (Diss.)	Upper PL Water (Total)	BH26 (Total)	BH26 (Diss.)	BH28 (Total)	BH28 (Diss.)	Lower PL Water (Total)	Lower PL Water (Diss.)
Al	mg/L	8.6	8.9	1408	1464	552	553	416	434
As	mg/L	0.04	0.03	2.1	2.1	2.1	2.0	0.51	0.50
Cd	mg/L	0.04	0.0	3.2	3.2	2.2	2.2	1.4	1.4
Cu	mg/L	2.2	2.3	329	333	271	271	164	170
Fe	mg/L	2.7	2.8	3249	3158	1666	1640	1703	1769
Mn	mg/L	6.5	6.5	34	34	21	21	24	24
Ni	mg/L	0.02	0.02	1.9	1.9	0.76	0.75	0.59	0.59
Pb	mg/L	0.03	0.04	2.4	2.4	1.8	1.9	1.2	1.3
Zn	mg/L	1.6	1.6	137	134	63	63	42	44

Table 3.1.7 Effect of Storage and Aging Pit Lake Water Samples on Composition by ICP-AES

Analyte	D.L[1]., mg/L	Upper PL Water, (mg/L)	Upper PL Water, Aged[2] (mg/L)	RPD[3]	Lower PL Water (mg/L)	Lower PL Water, Aged[2] (mg/L)	RPD[3]
Al	0.0011	8.65	8.15	2.98	434	Exceeds[3]	*
As	0.008	0.04	0.04	5.65	0.5	0.17	50.2
Ca	0.0254	403	407	0.52	276	279	0.55
Cd	0.0006	0.04	0.05	1.86	1.42	1.05	15.1
Cu	0.0029	2.23	2.03	4.63	170	144	8.33
Fe	0.0016	2.75	2.78	0.61	1769	465	58.4
K	0.1081	17.6	21.1	8.8	13.6	16.1	8.27
Mg	0.0044	62.7	54	7.46	216	230	3.1
Mn	0.0002	6.5	6.81	2.3	23.6	22.3	2.9
Na	0.0193	162	115	16.8	62.4	52.6	8.49
Ni	0.0015	0.02	0.02	2.34	0.59	0.56	2.63
P	0.0128	0.16	0.23	18.6	14.1	11.7	9.13
Pb	0.005	0.03	0.03	0.29	1.29	0.65	33.1
S	0.0148	700	644	4.18	3000	2269	13.9
Si	0.0266	5.86	7.37	11.4	47.4	46.9	0.53
Zn	0.0023	1.62	1.66	1.3	44.5	32.9	15

Notes:

[1] D.L. Detection Limit

[2] Water sitting in the container for several months. Aged samples were not diluted for ICP analysis, in contrast to field samples (1:10). Therefore, aluminum saturated the detector in some cases for the aged sample analyses.

[3] RPD Relative Percent Difference. The RPD also includes any impact from the difference in dilution prior to analysis.

Table 3.1.8 Effect of Storage and Aging Wells Water Samples on Composition by ICP-AES

Analyte	D.L.,[1] (mg/L)	BH26 (mg/L)	BH26 Aged[2] (mg/L)	RPD[3]	BH28 (mg/L)	BH28 Aged[2] (mg/L)	RPD[3]
Al	0.0011	1464	Exceeds[2]	*	553	Exceeds[2]	*
As	0.008	2.12	0.87	41.8	1.99	0.92	36.8
Ca	0.0254	383	317	9.41	151	148	1.13
Cd	0.0006	3.19	1.95	24.1	2.22	1.8	10.5
Cu	0.0029	333	249	14.5	271	206	13.6
Fe	0.0016	3158	530	71.3	1640	433	58.2
K	0.1081	1.72	BDL	*	13.3	2	73.9
Mg	0.0044	616	644	2.21	223	224	0.29
Mn	0.0002	33.9	27.9	9.69	21.2	19.7	3.65
Na	0.0193	49.5	53.3	3.67	31	24.2	12.4
Ni	0.0015	1.94	1.47	13.9	0.75	0.7	3.39
P	0.0128	22.1	19	7.76	31.8	29.1	4.35
Pb	0.005	2.38	1.22	32	1.86	0.89	35.2
S	0.0148	7804	3766	34.9	3098	2313	14.5
Si	0.0266	67.8	67.1	0.54	48.4	47.7	0.81
Zn	0.0023	134	62.1	4.37	62.7	42.3	19.4

Notes (1), (2), (3): See notes 1, 2 and 3 in Table 3.1.7.

3.2 Beaker and Sieving Tests

The beaker and sieve tests were preliminary to the section 3.4 Source Control Treatment Testing (Waste Rock) and as such not included in the main text of this report. The full description of this testing group is provided in attachment E-1.

The beaker and sieve tests were used to help develop the source control testing procedures by determine the general consistency of the materials, mixing characteristics, and approximate doses. The two major findings from this testing were that the waste rock samples needed to be agglomerated so they would have adequate permeability for the testing and that whey should be eliminated from further testing because it was not an economical source control agent.

3.3 Utilization Testing Using Amended USBM Method

The utilization testing was preliminary to the section 3.4 Source Control Treatment Testing (Waste Rock) and as such not included in the main text of this report. The full description of this testing group is provided in attachment E-2. The laboratory reports are included in Appendix C-2

The utilization testing was essentially used to gauge permeability, field capacity, and source control amendment “consumption” for the proposed amendments. It set up the initial dose volumes for the waste rock testing as well as provide insight to the movement and behavior of the source control amendments when applied to the waste rock.

3.4 Source Control Treatment Testing (Waste Rock)

3.4.1 Waste Rock Source Control Conclusions and Recommendations

Unsaturated Zone

Overall, every cell that received treatment exhibited measureable ARD suppression. WRU 2 demonstrated the best acid generation suppression. See Table 3.4.1 for more information on the unsaturated zone tests. The rank of performance was:

1. WRU 2 SLS w/ alkalinity
2. WRU 4 Milk w/ alkalinity
3. WRU 3 Milk
4. WRU 6 SLS w/ alkalinity + Milk

The criteria used to select WRU 2 as the best was a slightly higher pH in WRU 2 and greater reduction in metal concentrations. At the conclusion of the test, WRU 6 exhibited conditions worse than the control; the reasons for this situation are unknown.

The WRU 2 cell received SLS accompanied with buffering alkalinity. The results of the test were in agreement with No. 1 USBM test in that appears that sufficient SLS was present in the sample to decimate the ATBFO microbial community that it did not recover in the 14 weeks of testing.

Experience cited by Kleinmann and Erickson (1983) suggests that this might be a temporary condition and that ATBFO populations could "recover" within three months post SLS application. But Kleinmann and Erickson did not include sodium bicarbonate buffering alkalinity in their protocols.

Tier 2 testing should commence with a replication of the Unsaturated Zone test with slightly differing amounts of SLS and sodium bicarbonate with a prolonged test period of six months in larger test cells. The milk tests and sequential tests should also be replicated with a longer interval between the application of buffered SLS and milk (perhaps buffered) with a greater amount of inoculating microbes.

Transition Zone

The transition zone test results were similar to the Unsaturated Zone tests in that ARD suppression was observed in all test units. See Table 3.4.1 for more information on the transition zone tests. WRT 2 containing buffered SLS demonstrating the best at acid generation suppression. The rank of performance was:

1. WRT 2 SLS w/ alkalinity
2. WRT 4 Milk w/ alkalinity
3. WRU 3 Milk

The criteria used to select WRT 2 as the best was a higher pH and greater reduction in metals concentrations. WRU 4 had a higher pH and reduction in metals concentrations than WRU 3.

Again, it is possible that the effects of the treatment may be temporary. However, adding inoculated organic matter like milk may prove to be beneficial in prolonging the beneficial effects of SLS addition.

The Tier 2 testing protocol described above for the unsaturated zone should be replicated for the transition zone.

Saturated Zone

See Table 3.4.1 for more information on the saturated zone tests. As ARD generation in the saturated zone is assumed to be abiotic, ARD generation is likely due to the presence of dissolved ferric iron (Fe^{+3}) flowing through the zone from more aerobic zones. The organic amendment applied to WRS 2 was able to suppress ARD because the reducing conditions necessary for sulfate reduction were created. As a consequence of microbially augmented sulfate reduction, solution pH increased to within the circum-neutral range, the sulfate concentration decreased and concentrations of metals were lower in comparison to the WRS 1 control cell.

The reducing ORP conditions likely caused the Fe^{+3} to be reduced to ferrous iron (Fe^{+2}) which is incapable of chemically attacking pyrite. Thus, if the saturated zone does not receive any new influx of Fe^{+3} from the transition or unsaturated zones (assuming ARD production there is suppressed), then the pore water in the saturated zone should stabilize in a low metals, slightly reducing, elevated pH condition. The cycle of abiotic ARD production would be broken and the pit lake would no longer receive acidity from the groundwater passing through the mine waste.

In Tier 2 testing of the saturated zone, the timing of the introduction of buffered milk should be investigated as the pore water in the mine waste is very acidic and raising the pH too quickly could cause the pore spaces to plug with metal precipitates. Similarly, the amount and rate of milk introduction should be investigated to determine optimal implementation strategies.

3.4.2 Waste Rock Source Control Study Approach

3.4.2.1 Objectives and Rationale

The main objective of the proof of principal (POP) testing is remedy screening to determine if the 'Technology' is potentially feasible.

The screening effort was developed based on information contained in the Guidance for Conducting Treatability Studies under CERCLA document (USEPA, 1992), 3.2.2 Remedy Screening – "The Data Quality Objectives established for remedy screening are usually stated in qualitative terms. Remedy screening provides a qualitative engineering assessment of the potential feasibility of a technology (i.e., go/no go).

Objectives for each functional area/zone were based on a primary hypothesis for each selected functional area/zone of OU1 that describes how that zone contributes to contamination of the pit lake water. Objectives for remedy screening were then developed based on this underlying assumption/hypothesis and knowledge of the technologies that may be deployed (successfully and economically). To support resolution of the objectives a list of the needed information/data was derived. From that list each proof of principal (POP) test was developed to support the acquisition of the needed data. Note that some information/data is already available, effectively estimated, or beyond the scope of Tier 1 testing and not included as part of the POP testing. The main assumption, objectives, and information/data needs for each functional zone follow.

Unsaturated and Transition Zone

Objective - To demonstrate acid generation suppression in rock treated with different additives under conditions to simulate media in the unsaturated (weekly flooded/drained) and transition zone (alternately weekly flooded/ weekly drained). Acid generation is gauged by the "markers" (pH, sulfate, and metals concentrations) in the water purged through the cells. Cells demonstrating significantly less acid generation, based on the markers, compared to the control and other cells will be recommended for further quantitative Tier 2 or 3 testing.

Saturated Zone

Objective – To demonstrate suppression of acid generation in rock treated with different additives under conditions to simulate media in the saturated zone (continuously flooded, water displaced each week). Cells demonstrating significantly less acid generation, based on markers (pH, sulfate, and metals concentrations in a sample of the displaced water), compared to the control, other cells, and performance in the transition and unsaturated zones will be recommended for further quantitative Tier 2 or 3 testing.

3.4.2.2 Experimental Design and Procedures

See Appendix A-4 – Source Control Treatment Testing Procedure – Waste Rock.

3.4.2.3 Deviations from the Work Plan

The Work plan indicates that 350 kg of waste rock sample was going to be collected. While 450 kg were actually collected only 380 kg arrived at the metallurgical processing lab for crushing-RDI), Seventy (70) kg were lost during the shipping of the material. Plastic 27-gallons totes were used to ship the waste rock material instead of 55 gallons drums.

Whey: Whey was not included in the testing because it was concluded that it would be very expensive form of organic matter in the form of sugar; i.e., lactose, for the full-scale treatment of the waste rock. Other materials being tested, i.e., milk, contained lactose among other forms of organic matter and the addition of whey would have not introduced another variable per se into the test.

MPNs: Initially, weekly Most Probable Number (MPN) analyses were planned for aerobic iron-oxidizers. However, this approach was modified to including MPNs for aerobic iron-oxidizers and anaerobic sulfate reducing populations to more completely characterize changes to those populations

following the various amendment additions and rinsing cycles. The MPN sampling frequency was also reduced.

ICP metals water samples: The work plan indicated that 63 water samples were going to be tested by ICP metals (one sample every 4 weeks per each cell plus 3 duplicates). Due to time constrains the testing only run for 13-14 weeks, therefore, water samples were collected every two weeks and on week 1 and 3. In addition 8 duplicates were also collected for quality control and quality assurance. In total more than 100 ICP samples will have been taken and analyzed over the test.

3.4.3 Waste Rock Source Control Results and Discussion

The laboratory reports from CSM are included in Appendix C-3.

3.4.3.1 Data Analysis and Interpretation

The standard operating procedures, the field data and the laboratory reports are included in the Appendices A-4, B-4 and C-3. The summary matrix of the experimental conditions for the Source Control Treatment Testing is presented in Table 3.4-1.

Table 3.4-1 Summary of Testing Protocols

Test Identifier	Waste Rock Zone Simulated	Test Additive
WRU1	Unsaturated	Control
WRU2	Unsaturated	922 mg/L SLS w/ Alkalinity (33568 mg/L)
WRU3	Unsaturated	20% strength diluted milk (2% powdered milk solids by weight)
WRU4	Unsaturated	20% diluted strength milk w/ Alkalinity (33,568 mg/L)
WRU6	Unsaturated	922 mg/L SLS w/Alkalinity (33,568 mg/L) followed by 20% diluted strength milk
WRT1	Transitional	Control
WRT2	Transitional	922 mg/L SLS w/ Alkalinity (33568 mg/L)
WRT3	Transitional	20% strength diluted milk
WRT4	Transitional	20% diluted strength milk w/ Alkalinity (33568 mg/L)
WRS1	Saturated	Alkalinity only to slowly increase pH without plugging
WRS2	Saturated	20% diluted strength milk w/ Alkalinity (406 - 6480 mg/L), varied – slowly increased total loadings.

3.4.3.2 Unsaturated Zone

pH – The pH behavior of cells WRU 1 and WRU 3 during leaching was similar. Acidic conditions were generated in these two cells from the onset of leaching. Solution pH was fairly stable for 14 weeks, with an average pH of 2.6 in WRU 1 and 3.4 in WRU 3. In fact, the pH in cell WRU 3 (where only milk was applied) slightly increased although it remained acidic for the duration of the testing. Although the amendments differed, WRU 2 and WRU 4 also showed similar behavior in regards to solution pH. The initial pH was slightly alkaline (pH 8.2) in both reactors following full dosing with bicarbonate. Solution pH then slowly decreased to 5.8 and 5.4, respectively, by week 14. But they did not go fully acidic (pH < 3). Cell WRU 6 was dosed sequentially with amendments. Consequently, it behaved differently than all other cells. Solution pH decreased from an initial 8.1 and stabilized from week 3 to week 7 around pH 6.2. Afterward, it fell over a period of 5 weeks, finally reaching pH 2.7 at termination. Overall, the pH in all unsaturated cells where alkalinity was added increased initially and then eventually decreased. Figure 3.4-1 summarizes the WRU pH results.

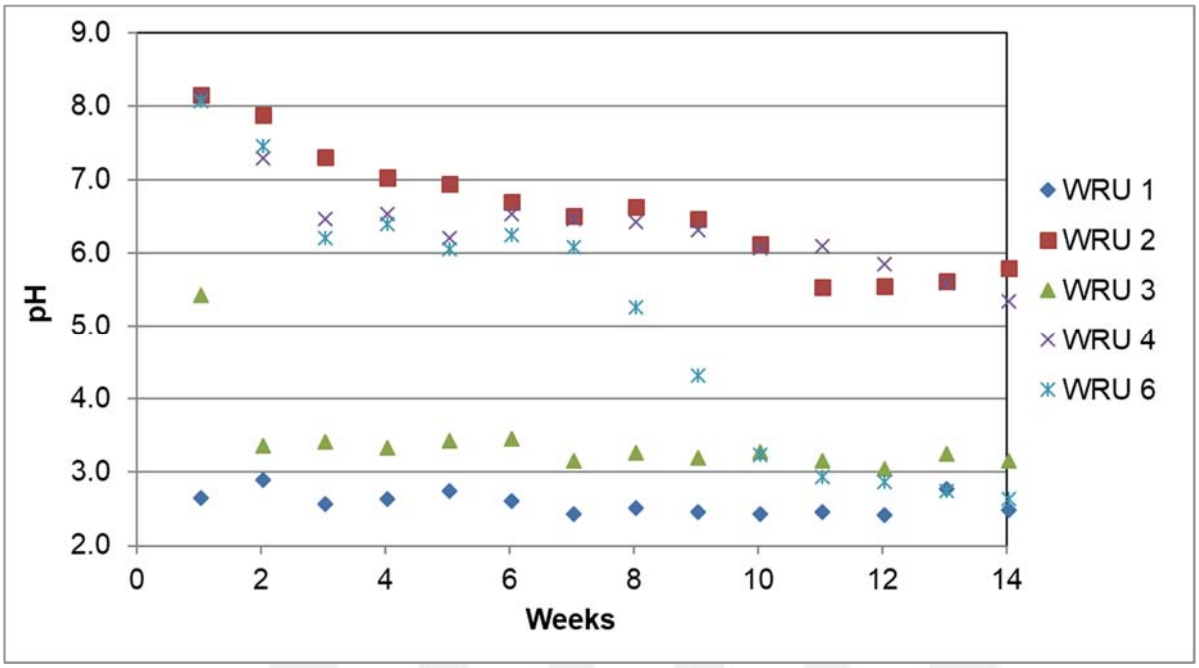


Figure 3.4-1 WRUs pH Results

Sulfate – The sulfate concentrations in cells WRU 1, WRU 3 and WRU 4 leachates fluctuated in a manner similar to each other (Figure 3.4-2). The concentration of sulfate in these cells decreased for a few weeks, then increased from about week 5 to week 9, finally decreasing again for the following four weeks. There was a slight uptick again at termination in week 14.. An inference can be made that these cells were being rinsed of residual sulfate (see compositional analysis) following the initial additions of amendments. And so, the sulfate concentrations decreased early in the program with each subsequent rinse. Some sulfide oxidation may have been occurring in isolated zones, resulting in additional sulfate mobilized, although the pH in these cells more or less plateaued during the mid-period of operation. The various amendments would have eventually inhibited isolated zones of sulfide oxidation and so a decrease in solution sulfate would have been observed as the cells entered another cycle that was essentially a rinse cycle. And that is what was observed. The amendments were effective. The up-tick at termination is difficult to characterize without additional downfield data.

WRU 1 (control) was clearly in a sulfide oxidation mode after week 8. The pH was always in the very acidic range and sulfate concentrations correspondingly began to increase rapidly at that point. WRU 6 was degrading by week 7 as the pH was seen to begin to plummet. The sulfate concentration then increased rapidly after week 10, eventually appearing much as WRU 1 did.

Comprehensive data are included in Appendix B-4.

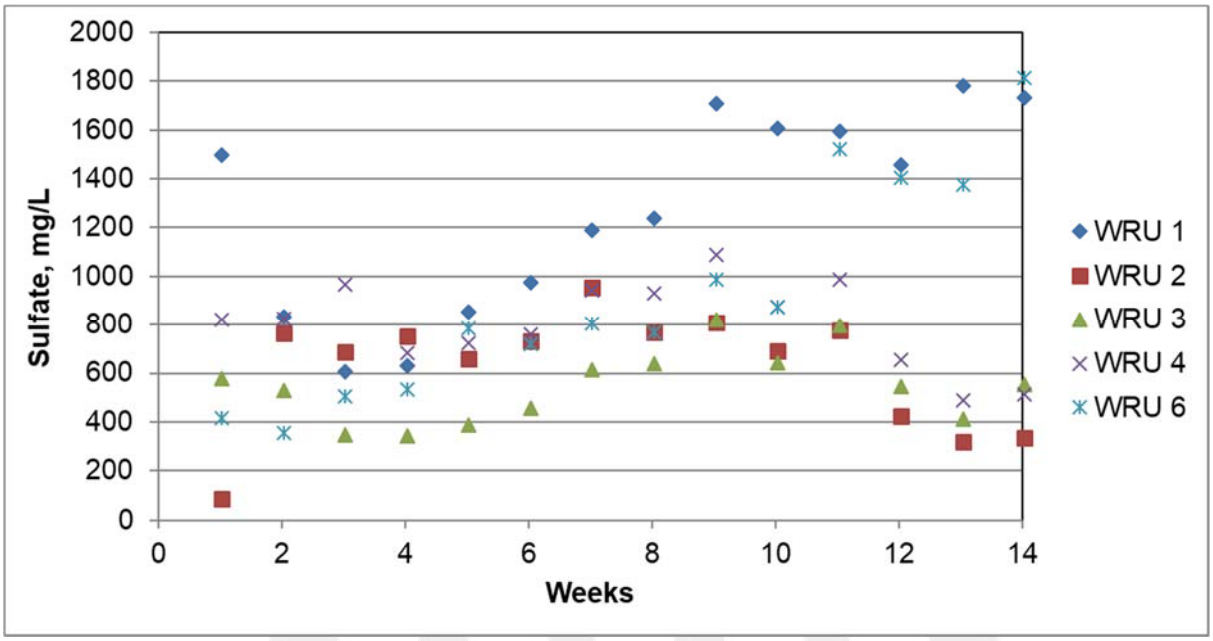


Figure 3.4-2 WRUs Sulfate Results

ORP – Based on the ORP data alone, sulfate reducing microbial populations were established in large areas of the bed in WRU 4 from week 7 to week 10. Even in this unsaturated test system, a reducing environment had been established – proving the concept that this was possible with Barite Hill waste rock in systems exposed to atmospheric oxygen. While bulk phase ORP values in WRU 3 and WRU 6 were not indicative of a reducing environment, microbiological data (see below) indicated that there must have been at least reducing zones in those reactors. In WRU 4, ORP slightly increased on week 11 (12 mV) and then decreased again to -65 mV. During the last two weeks of testing, all the cells had high ORP values. This indicates that the approach will function in principle, but that the amendment application strategy and timing may have to be optimized. Figure 3.4-3 shows the ORP results for all the WRUs cells.

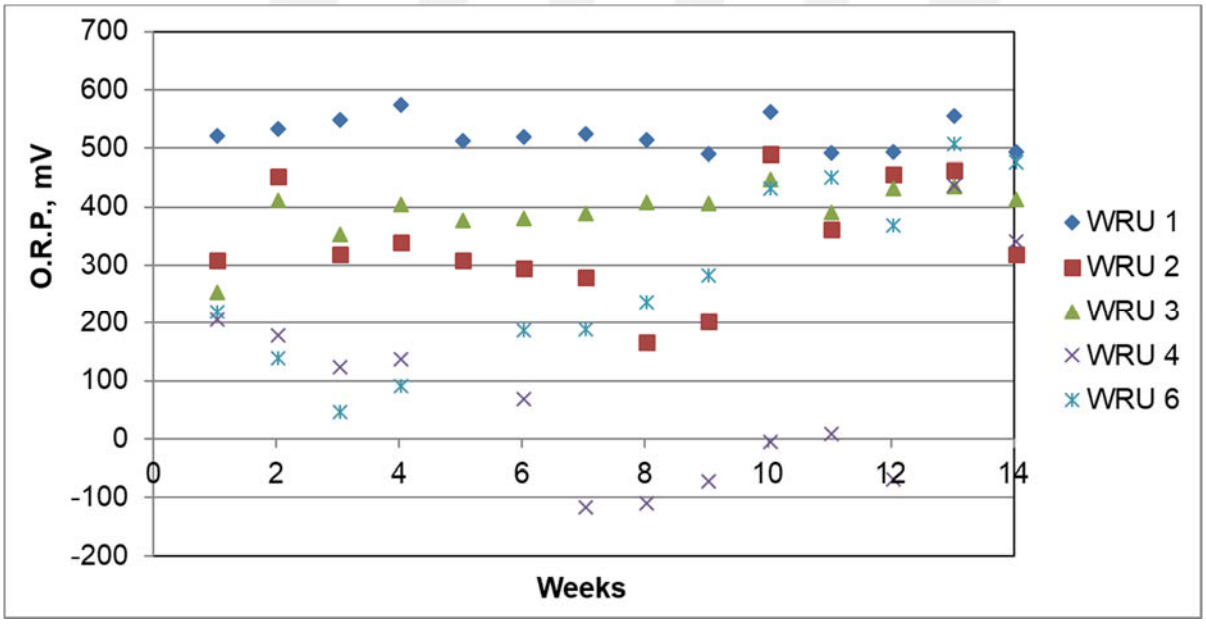


Figure 3.4-3 WRUs ORPs Results

Conductivity – The initial conductivity of the leachate from WRU 1 and WRU 3 is considerably lower (about 2100 µS/cm) than the conductivity of the reactors where alkalinity was added, indicative of the impact of the Na and bicarbonate ions: WRU 2, WRU 4, and WRU 6 (average 24450 µS/cm). The conductivity of WRU 2 and WRU 4 decreased to about 756 and 1131 µS/cm as the sodium

(bicarbonate) was rinsed away. WRU 1 and WRU 6 increased from week 9 to week 14, both again consistent with an initial rinsing phase followed by active microbially-augmented ARD production. Figure 3.4-4 and Appendix B-4 summarize the conductivity results.

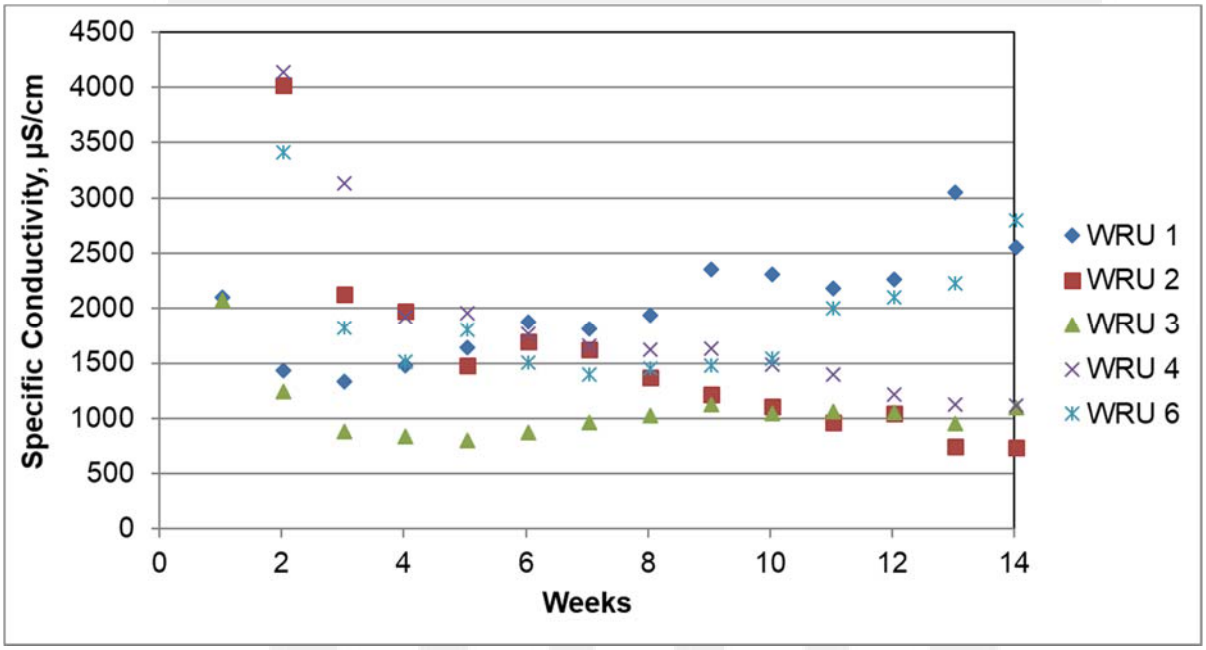


Figure 3.4-4 WRUs Conductivity Results.

Metals: The results indicate that metal concentrations significantly decreased by week 1 in all the cells. WRU 2 (SLS + alkalinity treated) exhibited decreased As, Cd, Ni, Pb, and Zn concentrations to below the detection limit. There were a few exceptions and the variances are explained below:

- Arsenic's percent decrease during the first week was low, but by week 14 it was significantly improved except for WRU 1 and WRU 6, where it increased.
- Manganese behavior was the opposite of arsenic; it ranged from a 63% to 94% concentration decrease during week 1, but from -9% to 88% in week 14, indicating that manganese was removed on week 1, but it was again being mobilized by week 14.
- Iron decreased significantly in week 1 in all the cells and then it was leached and increased on week 14 (except in WRU 2).
- Nickel, Lead and Zinc concentrations increased on week 1 in WRU 3 and then the concentrations of these metals decreased significantly in week 14, except in WRU 6 where all of these metals concentrations increased, indicating that iron was removed on week 1, but was again being mobilized by week 14.

Percent decreases in metal concentrations are presented in Table 3.4-2 (see below the section on saturated systems). The percent change was calculated based on the WRU 1 initial metal concentration (IC) of week 1 and the metals concentration of each cell of week 1 and week 14. The metals concentration at week 1 was used as IC for the WRUs due to the standard operation procedures for these cells. When the metal concentration was below the detection limit, complete removal of that metal was assumed (100%) for the purpose of calculation. The biweekly metals concentration data and graphical summaries are presented in Appendix B-4. Raw data from the lab are summarized in Appendix C-3.

Microbial Assessments

It was of interest to determine if viable iron-oxidizing microbial populations growing at acidic pH could readily be recovered from Barite solids before being placed into the test reactors. Figures 3.4-5 and 3.4-6 show the progression of solution pH and oxidation-reduction potential using Barite solids as a source of inoculum. Clearly, the solids were associated with viable iron- and sulfur-oxidizing acidophilic microbial populations. Solution pH increased during an initial phase of iron-oxidation, a proton

consuming reaction, and then decreased as organisms capable of elemental sulfur oxidation increased in activity. Solution potential increased into a highly oxidizing range as iron in solution was converted to ferric ion. Examination at 400 X by phase contrast microscopy showed a mix of non-spore forming, non-motile bacilli that were *Acidithiobacillus ferrooxidans* and *A. thiooxidans*-like in morphology. In part, the point of this exercise was to demonstrate the presence of what appeared to be viable ARD-promoting organisms associated with the Barite solids and that no constituents of those solids would preclude a microbial (biological) contribution to development of ARD at that site. The (scoping level) demonstration of a significant microbial contribution to ARD development at this site was technical support for the approach of including a surfactant in the test program. The preparation of this culture was also found to be unnecessary as a source of inoculum for starting the 20 kg POP tests.

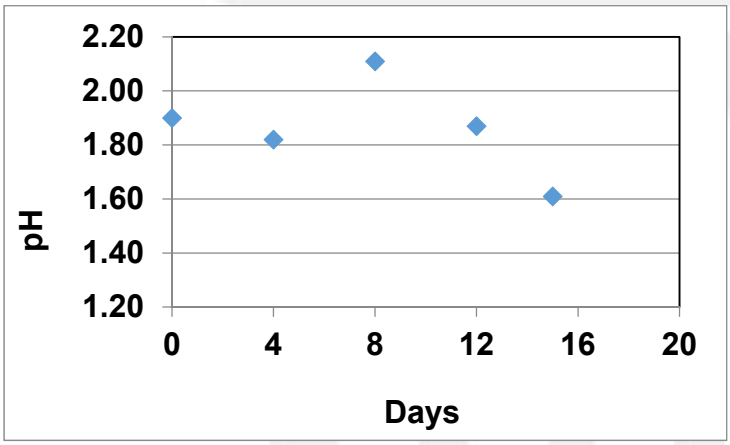


Figure 3.4-5 Microbial growth on Fe (II), FeS_2, S_0 and Barite solids - pH

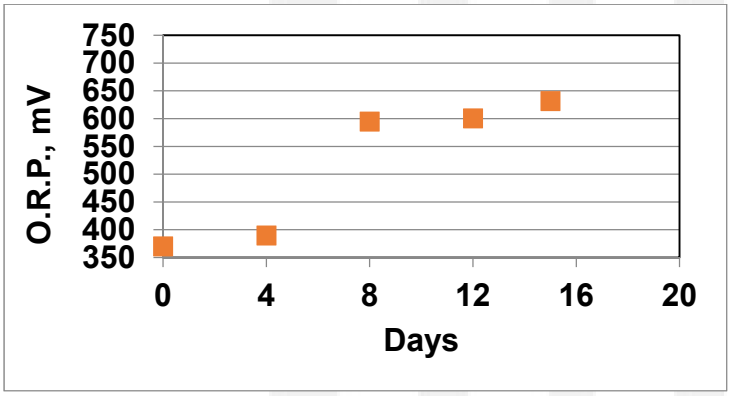


Figure 3.4-6 Microbial growth on Fe (II), FeS_2, S_0 and Barite solids ORP

A fundamental goal of this project was proof-of-concept that conditions within various zones of the Barite wastes could be rapidly "terraformed", replacing one chemical / biological system with another by adding the proper combinations of amendments. Conditions promoting continuous ARD generation would be radically altered and unsuitable for chemical or biological augmented oxidation of pyritic iron and sulfur.

To the end, microbial populations, both aerobic and anaerobic, were assessed at various points in the POP 20 kg tests. Early samples resulted in difficulties in assessing microbial growth because of high concentrations of amendments. Patterns exhibited were typical of the presence of inhibitors, with better growth seen at much high order-of-magnitude dilutions (data not shown). However, mid-program samples did not present such technical difficulties. Examples of such an assay after 21-days of incubation is shown below in Figures 3.4-7 and 3.4-8, with orange color indicating a positive test for microbial iron-oxidation and colorless wells indicating no growth or iron oxidation. All reactor vessels were examined for viable (recoverable) aerobic iron-oxidizing acidophiles and anaerobic sulfate-reducing microbial populations.

Table 3.4-3 for the unsaturated test cells showed an almost million-fold difference in suspended iron-oxidizers when comparing the untreated and alkaline-SLS biocidal amendment in week 3. Cells are almost below detection in WRU-2 solution. Intermediate levels of cells are present in WRU 3, 4 and 6, indicating that alkalinity and/or milk organics are not inherently biocidal to the acidophilic iron-oxidizers. Applying milk sequentially to SLS rendered the surfactant much less effective in decimating iron-oxidizer populations. This indicates that there were at least zones within reactors WRU 3, 4 and 6 where acidophiles could maintain activity. At week 13, the difference is still ten-thousand-fold less in the WRU 2 treated cell than in the WRU 1. What is obvious by week 13 is the degradation of the WRU-6 system, resulting in a higher viable iron-oxidizer cell number in that system than in WRU-1 vessel itself.

However, effluent was also examined for anaerobic sulfate reducers (Table 3.4-4). WRU-4 (milk + alkalinity), showed the lowest acidophile population of the milk-treated unsaturated reactors at weeks 3 and 13 and, as well, showed high cell populations of sulfate reducers comparable to the original populations of aerobic iron-oxidizers at week 3. Anaerobic sulfate reducers were still present in WRU-4 at week 13. The ecosystem of the test cell had been reversed from an aerobic ARD promoting zone to one highly unfavorable to ARD generation, at least within zones. This is the clearest indication that even with frequent rinses, relatively distinct aerobic and anaerobic zones have been established in the unsaturated system, demonstrating proof-of-concept (see also Figures 3.4-9 and 3.4-10 – the black color is an iron sulfide formed when the organisms begin producing hydrogen sulfide).

Figure 3.4-7 Example of a multi-well plate assay for iron oxidizers at acid pH showing high activity in untreated POP 20 kg vessels

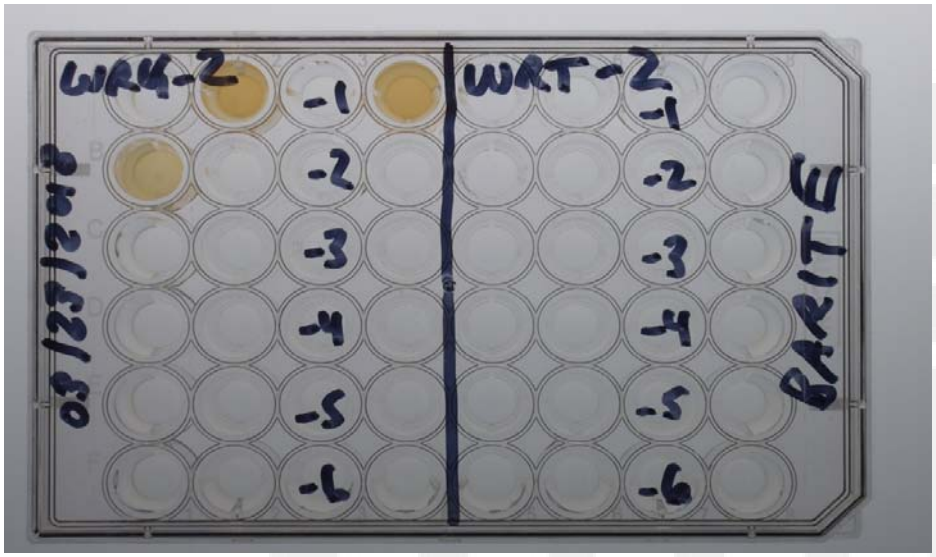


Figure 3.4-8 Example of a multi-well plate assay for iron oxidizers at acid pH showing poor growth in the presence of the SLS biocide w/ alkalinity

Table 3.4-3 Unsaturated Waste Rock POP 20 Kg Test Cells: MPNs of Viable Acidophilic Aerobic Iron-Oxidizers

Sample ID	Test Group	Type	Mesophilic and Acidophilic Fe-Oxidizers MPN (cells / mL)[1]	
			Week 3	Week 13
WRU-1	No Treatment	Aq	1.1×10^6	1.2×10^6
WRU-2	SLS + Alkalinity	Aq	9.0×10^0	9.3×10^2
WRU-3	Milk	Aq	4.3×10^4	9.3×10^4
WRU-4	Milk + Alkalinity	Aq	9.3×10^3	4.3×10^4
WRU-6	Sequential: SLS + Alkalinity (prior to Milk application)	Aq	2.4×10^5	$\geq 2.4 \times 10^6$
Positive controls			3 of 3 are (+)	6 of 6 are (+)
Negative controls			3 of 3 are (-)	6 of 6 are (-)

[1] Incubated 21 days at: Week 3 (03/21 – 03/22) - 29.1 C ± 0.8 C; Week 13 – (05/02 – 05/03) - 29.4 C ± 1.0 C. The MPN test protocol requires a higher incubation temperature than the test cells themselves to decrease incubation time.

Table 3.4-4 Sulfate Reducing Anaerobic Microbial Populations- Unsaturated POP 20 kg Vessels

Sample ID	Test Group	Sample Type	Anaerobic SO4- Reducers	
			MPN (cells / mL)[a, b]	
			03/20-03/21	04/03-04/04
WRU-1	No Treatment	Aq	< 1 x 10^0	< 1 x 10^0
WRU-2	SLS + Alkalinity	Aq	5 x 10^0	< 1 x 10^0
WRU-3	Milk	Aq	<1 x 10^0	< 5 x 10^0
WRU-4	Milk + Alkalinity	Aq	2.7 x 10^4	3.25 x 10^2
WRU-6	Sequential: SLS + Alkalinity (prior to Milk application)	Aq	7.5 x 10^1	< 1 x 10^0
Temperatures (mean ± s.d.)			21.7 ± 3.0 C	20.7 ± 1.5 C

[a]March samples assayed directly from POP 20 kg reactors; [b] April samples were refrigerated and stored prior to assay

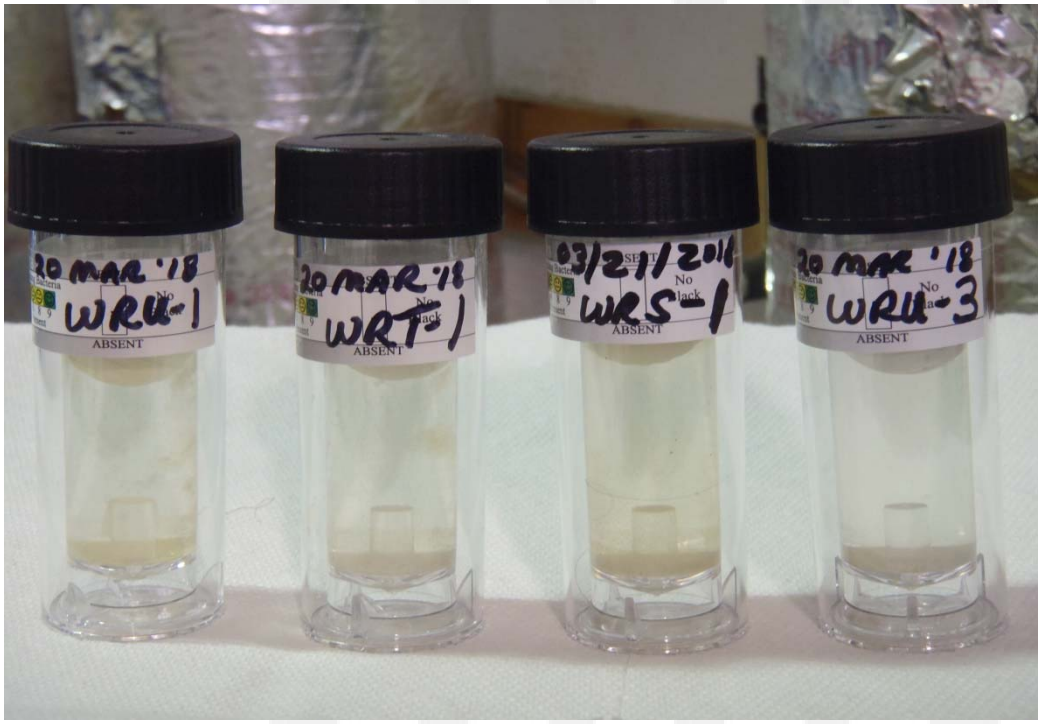


Figure 3.4-9. Examples of BART system semi-quantitation of sulfate reducers – NEGATIVE

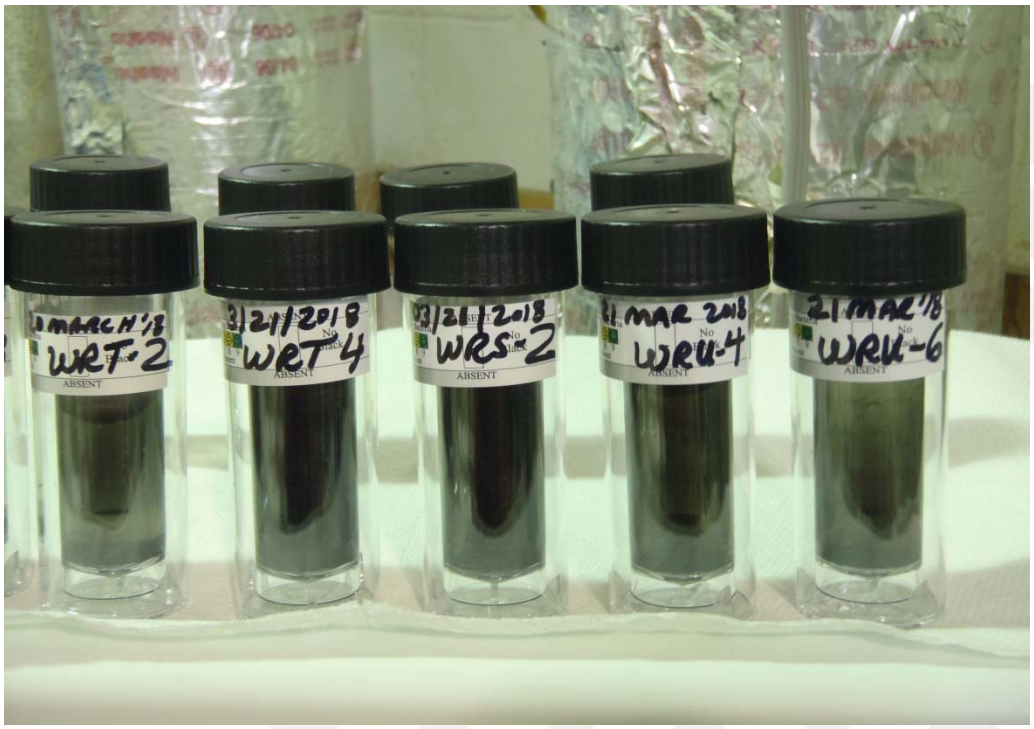


Figure 3.4-10. Examples of BART system semi-quantitation of sulfate reducers – POSITIVE

Observations: Qualitative assessments were made of effluent solutions during each sampling event. Color, odor and solids such as fungal/microbial masses or chemical precipitates were noted. Generally, the unsaturated reactors initially were highly turbid and colored (yellowish) by an initial rinse of the solids. The untreated reactor WRU-1 was somewhat consistent in this pattern. In the first rinses, some white coloration was noted in milk amended reactors. After the initial rinse, WRU-2, following treatment with alkalinity and SLS was, in contrast, clear and colorless throughout the test program. There was no real odor associated with the samples. On the other hand, WRU-3, WRU-4 and WRU-6, receiving some treatment that included organics (milk) eventually turned septic, indicative of anaerobic conditions, with WRU-3 and WRU-4 becoming septic within just a few weeks of operation, while WRU-6 did not exhibit septic characteristics until two months of operation (despite showing signs then of becoming an active sulfide oxidizing system) – indicative of the presence of discrete oxidizing and reducing zones in the reactor bed. Effluent "appearance" improved later in the program, as shown below in Figures 3.4-11–15. Chemical crusts were not noted. However, the milk amended reactors intermittently exhibited black or red floc, presumably fungal mass. The chemical degradation with time that characterized WRU-1 effluent (see below) was not readily apparent by visual inspection.

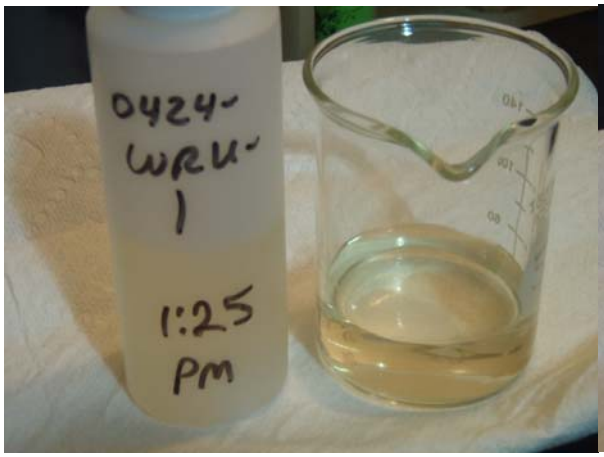


Figure 3.4-11 WRU-1 Effluent

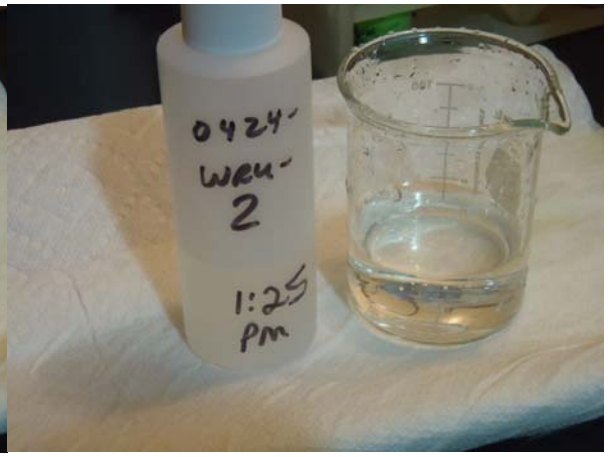


Figure 3.4-12 WRU-2 Effluent

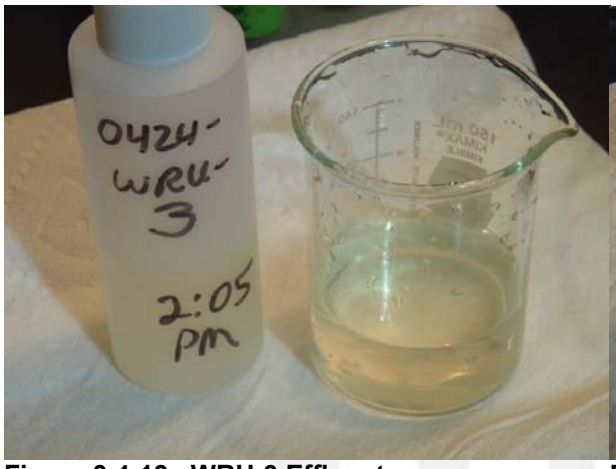


Figure 3.4-13. WRU-3 Effluent

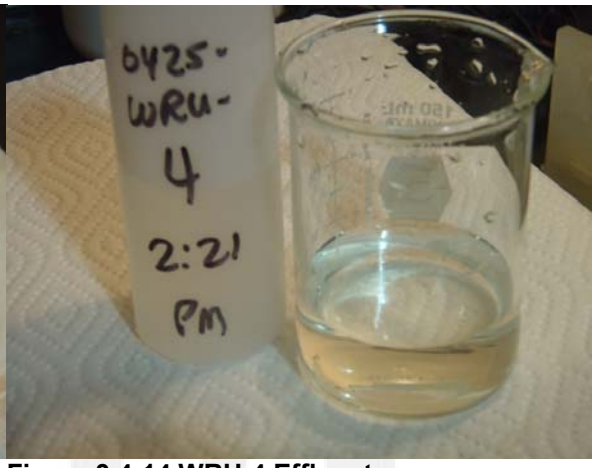


Figure 3.4-14 WRU-4 Effluent

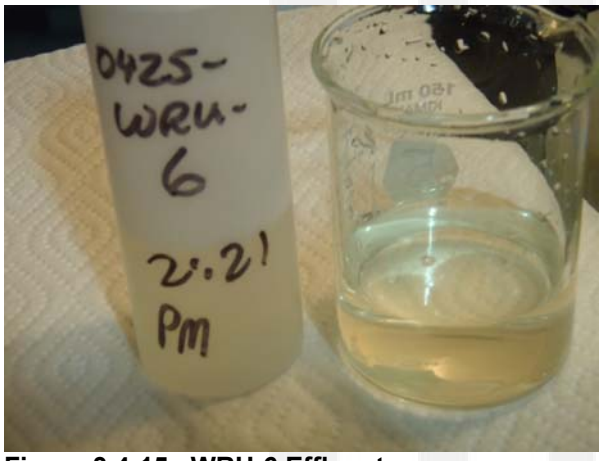


Figure 3.4-15. WRU-6 Effluent

3.4.3.3 Transition Zone

pH – Leach solution from WRT 1 exhibited an acidic pH from the onset of operation, the average pH being 2.6. Cells WRT 2 and WRT 4, having both been amended with alkalinity in addition to a second amendment, exhibited circum-neutral leachate pH values that gradually decreased: 8.1 to 7.0 (WRT 2), and from 7.7 to 6.5 (WRT 4). Yet, they are greatly increased in comparison to the untreated WRU 1 values. Cell WRT 3 leachate was also acidic for about 8 weeks and then increased to pH 6.0 on week 14. This indicated that WRT 3 was beginning to develop an alkalinity producing anaerobic ecosystem or, at the very least, that available pyrite was passivated by organic deposits. Thus, alkalinity addition with the milk jump-started the anaerobic system in WRT 4, but the use of milk alone, as in WRU 3, would eventually result in such an environment.

Overall, the pH in all cells that received treatment were higher in comparison to the un-amended control cell (WRT 1).

Figure 3.4-16 illustrates pH data for the transition vessels.

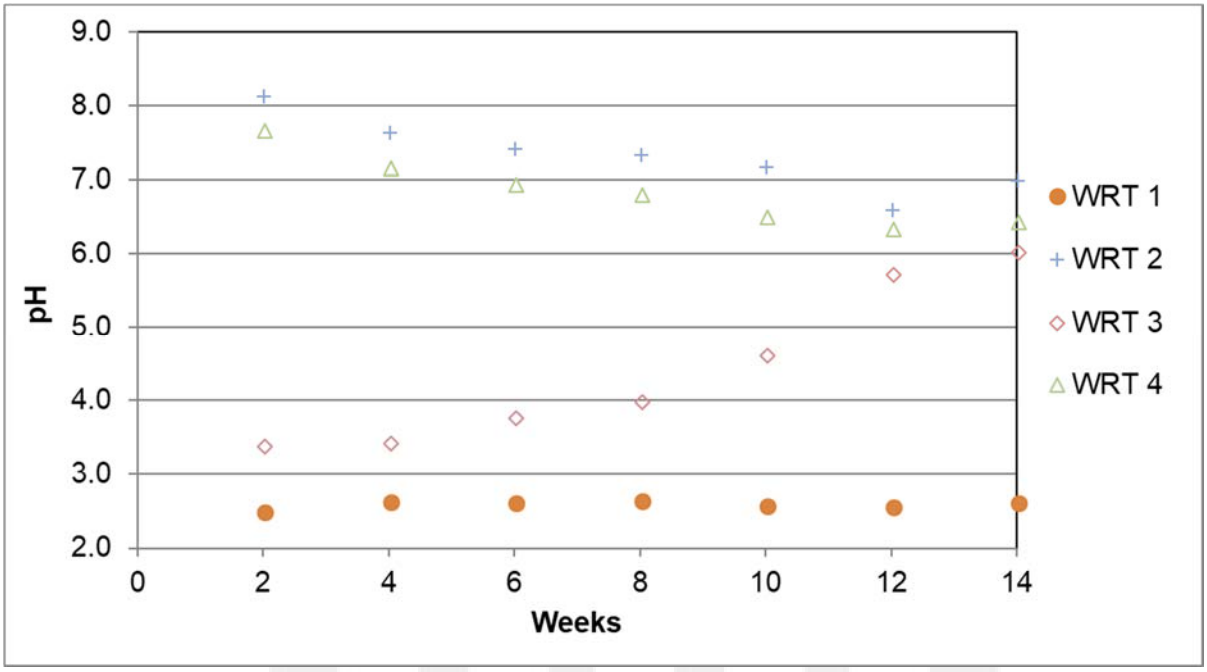


Figure 3.4-16 WRTs pH Results

Sulfate – All the WRT cells followed the same sulfate concentration trend: fluctuating up and down for eight weeks and then decreasing for the remaining test period. Cell WRT 3 was the only cell where the sulfate concentration was less in comparison to the control cell (WRT 1) during the entire duration of testing. Cell WRT 2 sulfate concentration was less than the control for only four weeks. By the end of the testing, all of the cell leachates exhibited pH values above that of the control. The sulfate results are shown in Figure 3.4-17. For the transition test cells, sulfate was a poor indicator of what was happening in each respective vessel, especially in comparison to the solution ORP values shown in Figure 3.4-18 which generally agree with the pH trends. For example, the pH of WRT 3 increased in the final weeks of the test while the WRT 3 ORP dropped. This is consistent with bacterial sulfate reduction.

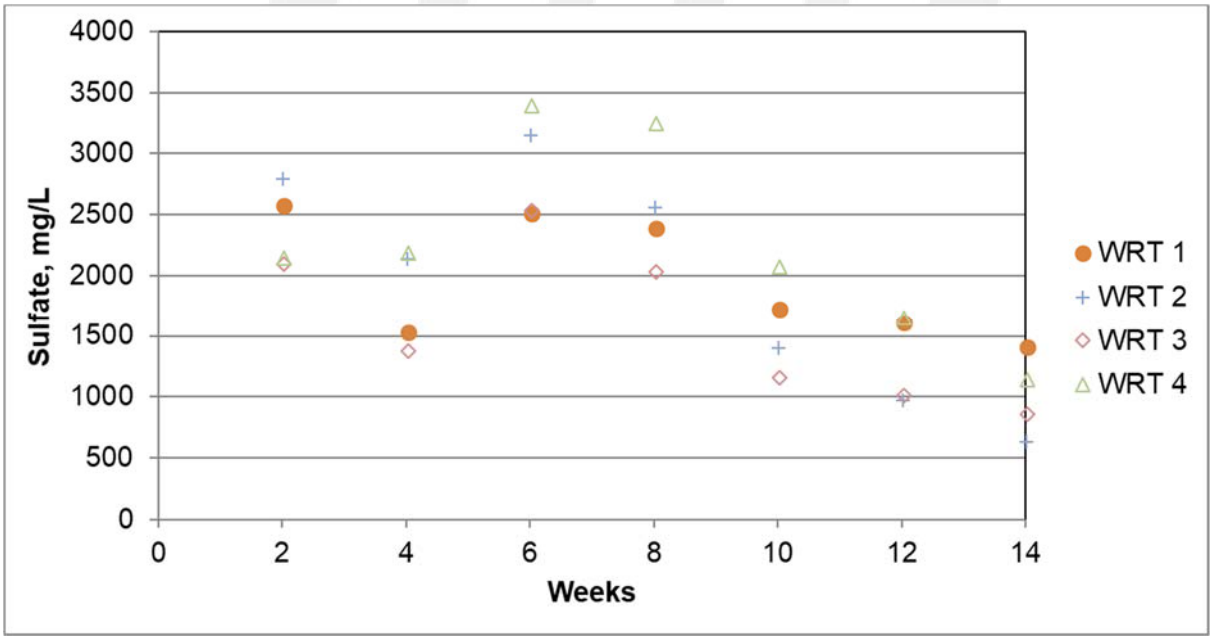


Figure 3.4-17 WRTs Sulfate Results

ORP – The ORP in WRT 1 was stable with an average of 469 mV. Based on the negative ORP (mV) values alone, an indirect chemical measure, sulfate reducing populations had been established in WRT 4 for the duration of the testing and this cell (WRU 4) was clearly the most distinctly different than WRT 1 ORP values were at opposite extremes for entire test period. The WRT 3 ORP was stable for 9 weeks and decreased to a negative value of -35 mV in week 12 and then slightly increased to 8.8 mV in week 14 (Figure 3.4-18). The ORP in cell WRT 2 fluctuated during the whole duration of the testing.

Overall, ORP values in transition cells that received any treatment, were lower than the corresponding control cell values (WRT 1).

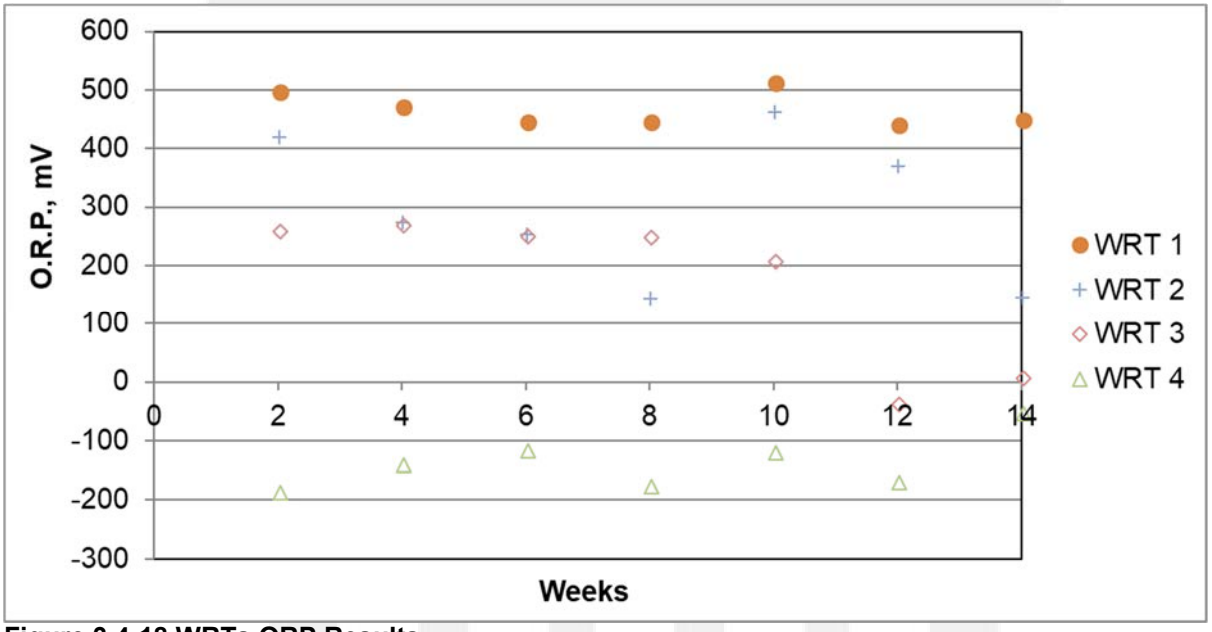


Figure 3.4-18 WRTs ORP Results

Conductivity – Conductivity data in all of the reactors was very similar, with initially high values to lower values on week 14. Higher initial conductivities in cells WRT 2 and WRT 4 were attributed to the alkalinity added as sodium bicarbonate, with the initial conductivities 22000 µS/cm and 22690 µS/cm, respectively. These then decreased during the duration of the testing, presumably due to a gradual rinsing out of the bicarbonate amendment. By the end of the test, all of the cells had conductivity values lower than the control cell (WRT 1). Conductivity data are presented in Figure 3.4-19.

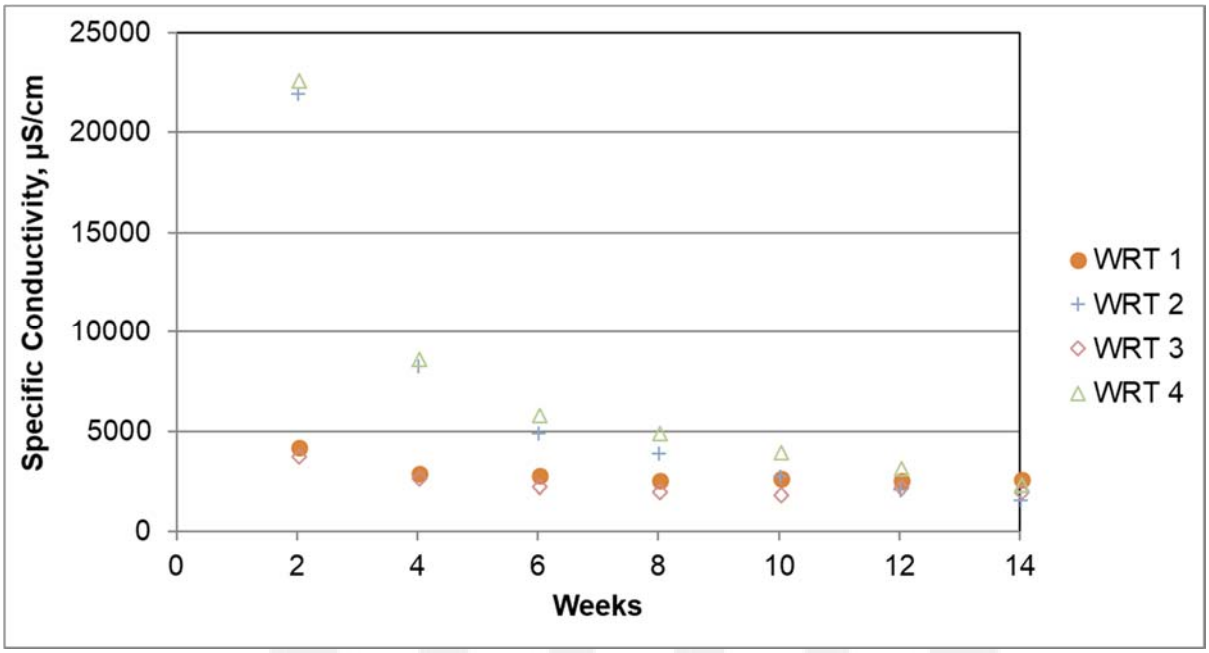


Figure 3.4-19 WRTs Conductivity Results

Metals: Metals concentrations were significantly reduced on week 1 in cells WRT 2 and WRT 4. At that point, concentrations of Cd, Ni, and Pb in WRT 2 were below the detection limit and Al, Cu, Fe, and Zn lower than the control by more than 99%. WRT 4 reduced Cu below the detection limits too, and Al and Zn were reduced more than 99% in week 14. WRT 3 metals percent reduction was less in week 1 but significantly improved by week 14. There were a few exceptions to these trends and the variances are explained below:

- The percent decrease in the arsenic concentration during the first week was low. By week 14, it decreased further, though WRT 1 showed a decrease comparable to that shown by WRT 3, a milk treated cell.
- In comparison to WRT 1, initial iron concentrations decreased in WRT 3 and WRT 4, although the percent decrease diminished by week 14.

Percent concentration reduction rates are summarized in Table 3.4-2 (see below the section on saturated systems). The percent reduction was calculated based on the WRT 1 initial metal concentration (IC) of week 2 and the metals concentration of each cell of week 2 and week 14. The metals concentrations of week 2 were used as the IC for the WRTs due to the standard operational procedures for these cells. When the metal concentrations were below the detection limit, it was assumed that complete (100%) removal had been achieved for that metal. The biweekly metals concentrations and graphs are presented in Appendix B-4. Raw data from the lab are presented in Appendix C-3.

Microbial Assessments – Transition

Again, aerobic iron-oxidizers and anaerobic sulfate reducers were quantified in the transition reactors at two time points during operations. The same pattern is noted here with transition (saturated/unsaturated) vessels that was described above with the unsaturated vessels: a 100,000-fold difference in acidophilic iron-oxidizers between the untreated WRT-1 and WRT-2, an alkalinity/surfactant treated vessel. And while the MPN value for the untreated transition cell increased by ten-fold at week 13, iron-oxidizers were still below the detection level in WRT-2. This was somewhat counter-intuitive since the commonly held believe was that the biocidal mechanism involved detergent induced damage to the cell membrane and cell integrity, allowing acid from the bulk phase to enter and kill the cell. Perhaps membrane damage alone is of sufficient magnitude to be largely biocidal to this physiological group – the acidophilic iron oxidizers. Milk without additional alkalinity (WRT-3) was again less effective in suppressing acidophile activity (Table 3.4-5) or encouraging the development of sulfate reducers in this time frame (Table 3.4-6). However, milk amended with alkalinity in WRT-4

lowered recoverable iron-oxidizers by 1,000-fold, even after 13-weeks. WRT-4 also had easily recoverable anaerobic sulfate reducing microbial populations at both time points (Table 3.4-6). Together, the microbial data are proof-of-concept that the subsurface ecology can also be "reversed" in the transition zone, at least in distinct areas within the waste rock bed, in a relatively short period of time given the proper combination of amendments.

Table 3.4-5 Transition POP 20 Kg Test Cells: MPNs of Viable Acidophilic Iron-Oxidizers

Sample ID	Test Group	Type	Mesophilic and Acidophilic Fe-Oxidizers MPN (cells / mL)[1]	
			Week 3	Week 13
WRT-1	No Treatment	Aq	4.6×10^5	4.6×10^6
WRT-2	SLS + Alkalinity	Aq	$< 3.0 \times 10^0$	$< 3.0 \times 10^0$
WRT-3	Milk	Aq	9.3×10^4	9.3×10^4
WRT-4	Milk + Alkalinity	Aq	2.3×10^2	2.3×10^3
Positive controls			3 of 3 are (+)	6 of 6 are (+)
Negative controls			3 of 3 are (-)	6 of 6 are (-)

[1] Incubated 21 days at: Week 3 (03/21 – 03/22) - 29.1 C ± 0.8 C; Week 13 – (05/02 – 05/03) - 29.4 C ± 1.0 C

Table 3.4-6 Sulfate Reducing Anaerobic Microbial Populations – Transition POP 20 kg Vessels

Sample ID	Test Group	Sample Type	Anaerobic SO4- Reducers MPN (cells / mL)[a, b]	
			03/20-03/21	04/03-04/04
WRT-1	No Treatment	Aq	$< 1 \times 10^0$	$< 1 \times 10^0$
WRT-2	SLS + Alkalinity	Aq	7.5×10^1	$< 1 \times 10^0$
WRT-3	Milk	Aq	$< 1 \times 10^0$	$< 1 \times 10^0$
WRT-4	Milk + Alkalinity	Aq	5.0×10^5	1.4×10^3
Temperatures (mean ± s.d.)			21.7 ± 3.0 C	20.7 ± 1.5 C

[a] March samples assayed directly from POP 20 kg reactors; [b] April samples were refrigerated and stored prior to assay

Observations:
Effluents for the transition reactor vessels were also inspected each week. Qualitative assessments were made for color, odor and solids. Figures 3.4-20 to 23 illustrate visual effluent quality at a single time point.

WRT-1 and 2 were initially turbid and yellowish, presumably due to initial rinsing of the solids. WRT-3 was malodorous (septic) within one week of operation, while WRT-4 did not go septic until five weeks of operation. By approximately 10 weeks of operation, WRT-3 and WRT-4 transiently exhibited some small suspended fungal clumps. WRT-4 effluent quality also visually degraded later in the program (see below).

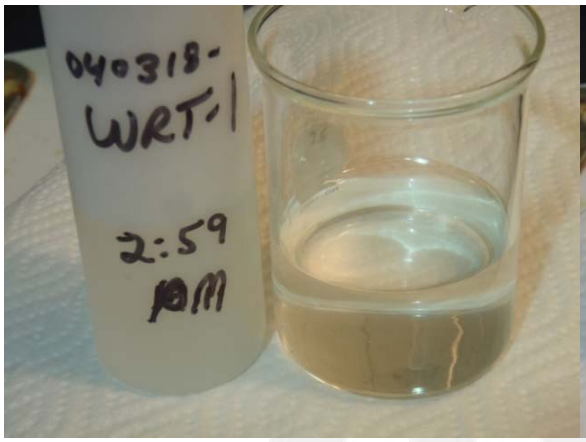


Figure 3.4-20 WRT-1 Effluent

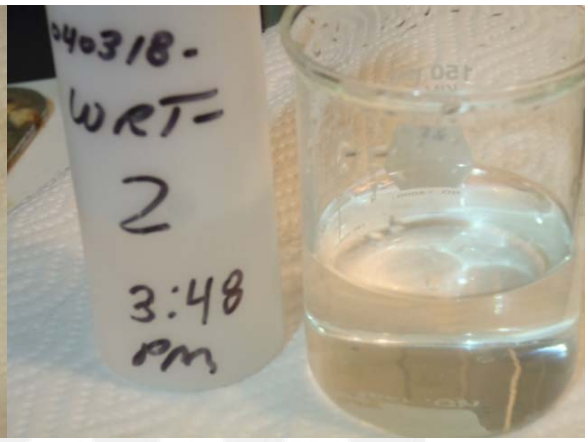


Figure 3.4-21 WRT-2 Effluent

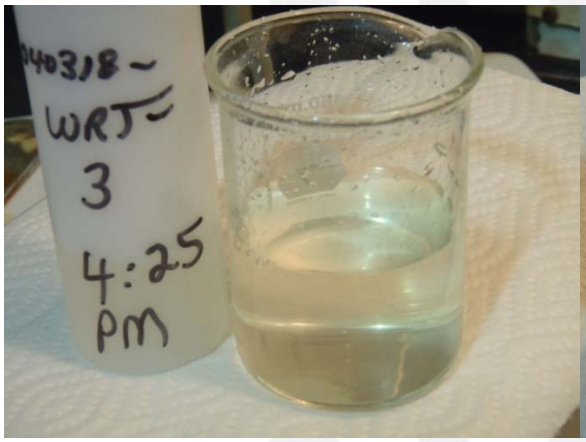


Figure 3.4-22 WRT-3 Effluent

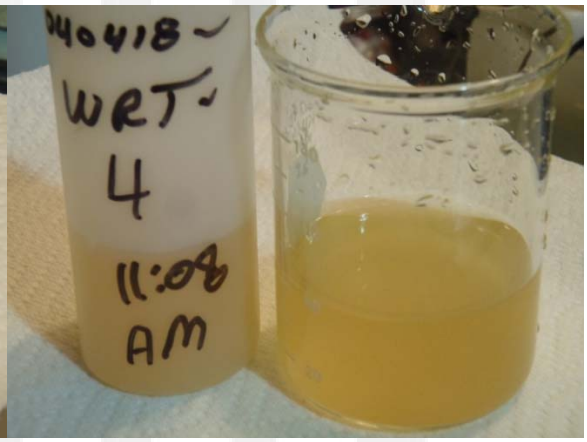


Figure 3.4-23 WRT-4 Effluent

3.4.3.4 Saturated Zone

pH – The pH of WRS 1 leachate (control) increased from 2.4 to 4.1 for over five weeks when it stabilized at an average pH of 3.9 for the remaining weeks of operation. WRS 2 cell leachate had an initial pH of 2.4, which was about the same as WRS 1 and kept increasing until it reached a pH of 6.8 on week 14. The WRS test cell pH results are presented in Figure 3.4-24. A critical observation was that the solution pH in WRS 2 increased to a much greater extent than that in WRS 1, though the alkalinity addition to WRS 2 was less. The pH was in fact circum-neutral at termination. It appeared that alkalinity-generating sulfate reducing microbial populations, growing on the milk-supplied organics, altered the saturated subsurface environment - another indicator of proof-of-principle.

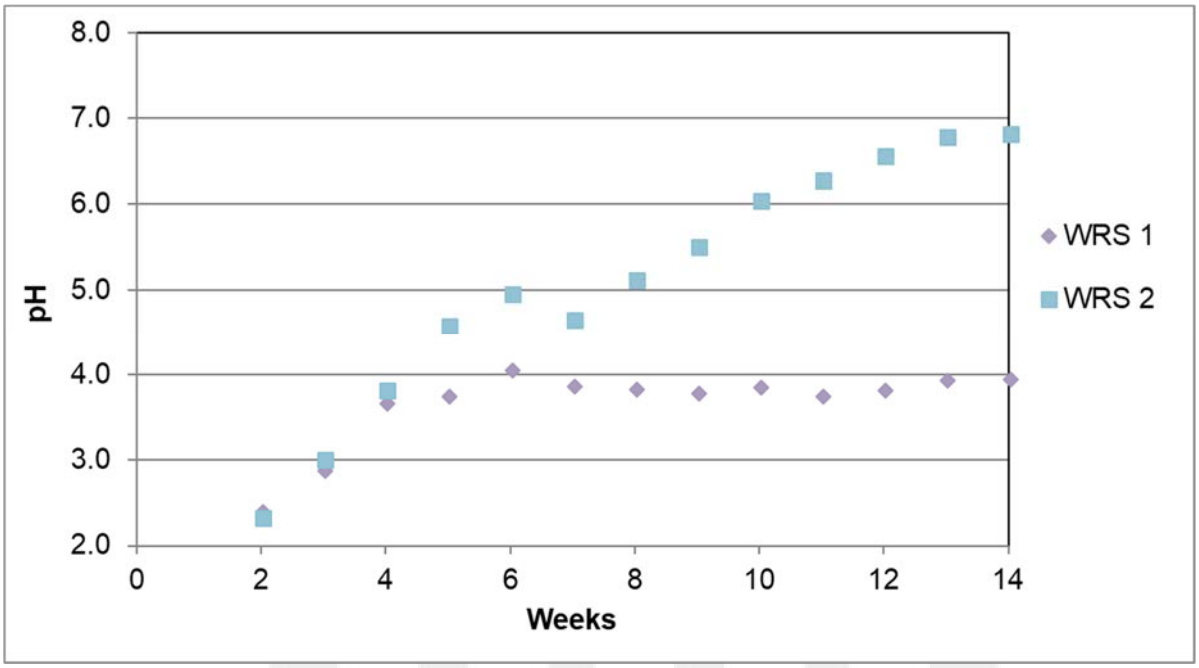


Figure 3.4-24 WRS pH Results

Sulfate – The trends of sulfate concentrations in WRS 1 and WRS 2 over the duration of the testing were very similar. The initial sulfate concentrations were 4952 and 4625 mg/L, decreasing to 3663 and 3510 mg/L on week 4, respectively. After week 4, sulfate values increased until week 9 and then decreased again to 906 mg/L (WRS 1) and 294 mg/L (WRS 2). The WRSs sulfate results are presented in Figure 3.4-25. These trends were partially a reflection of solution handling for these reactors early in operations (partial replacement each week, with some alkalinity added). However, alkalinity amendment had ended and yet the sulfate concentration in WRS-2 was much less than that in WRS-1 from week 9 to week 14, again indicative of the activity of sulfate reducing microbial populations.

Overall, sulfate was reduced on week 14 in comparison to cell WRT 1.

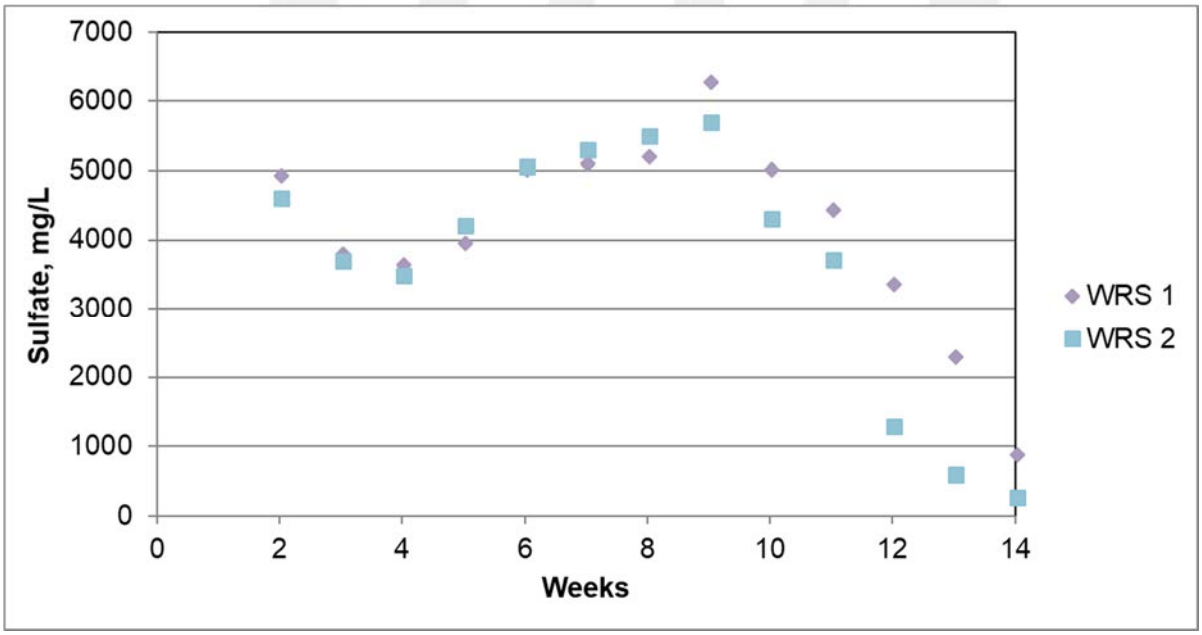


Figure 3.4-WRSs Sulfate Results

ORP – The initial ORP of WRS 1 leachate was not extremely oxidizing, but it was fairly high given that the waste rock bed was submerged @ +448 mV. It then decreased to 318 mV for a period of three weeks, after which it stabilized at an average of 278 mV for the next six weeks. After some weeks of less stable behavior, the potential eventually decreased again to 270 mV. WRS 2 leachate had a negative ORP for five of the final seven weeks of operation. Based on the ORP data and, consistent with sulfate data above, it's clear that cell WRS 2 demonstrated its successful conversion to a reducing environment.

ORP data for the saturated test cells are presented in Figure 3.4-26.

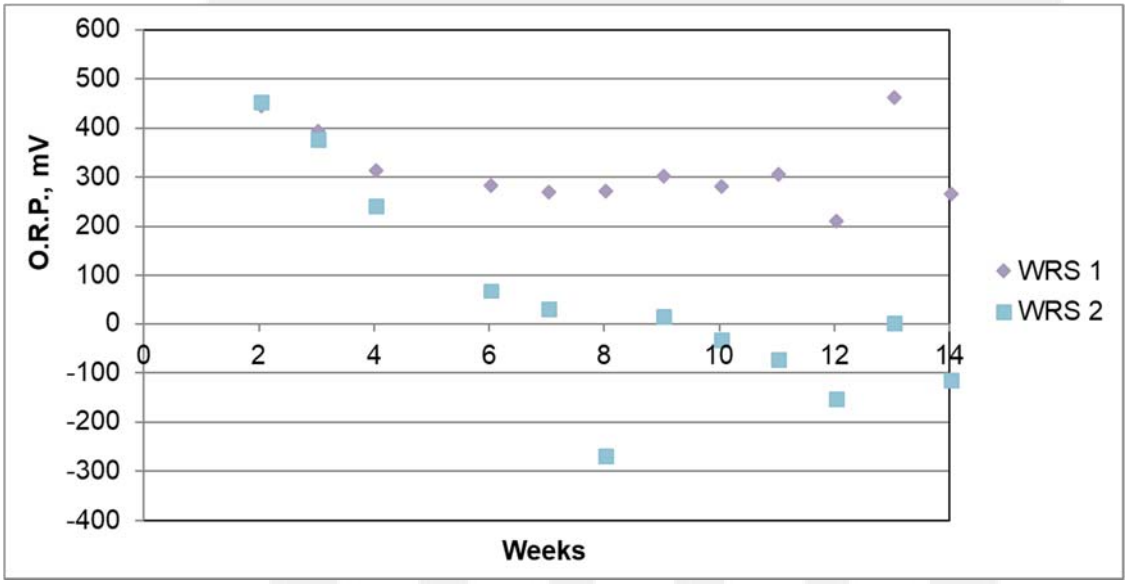


Figure 3.4-26 WRSs ORP Results

Conductivity – The conductivity of WRS 1 leachate was stable for a period of 10 weeks and then decreased for the following four weeks (solution handling changed as described in the procedures). The WRS 2 reactor's conductivity values increased from week 1 to week 10 and then decreased during the following four weeks. Again, the high initial conductivity in cells WRS 1 and WRS 2 was attributed to the alkalinity added, which contained sodium.

ORP data for the saturated reactors are presented in Figure 2.4-27.

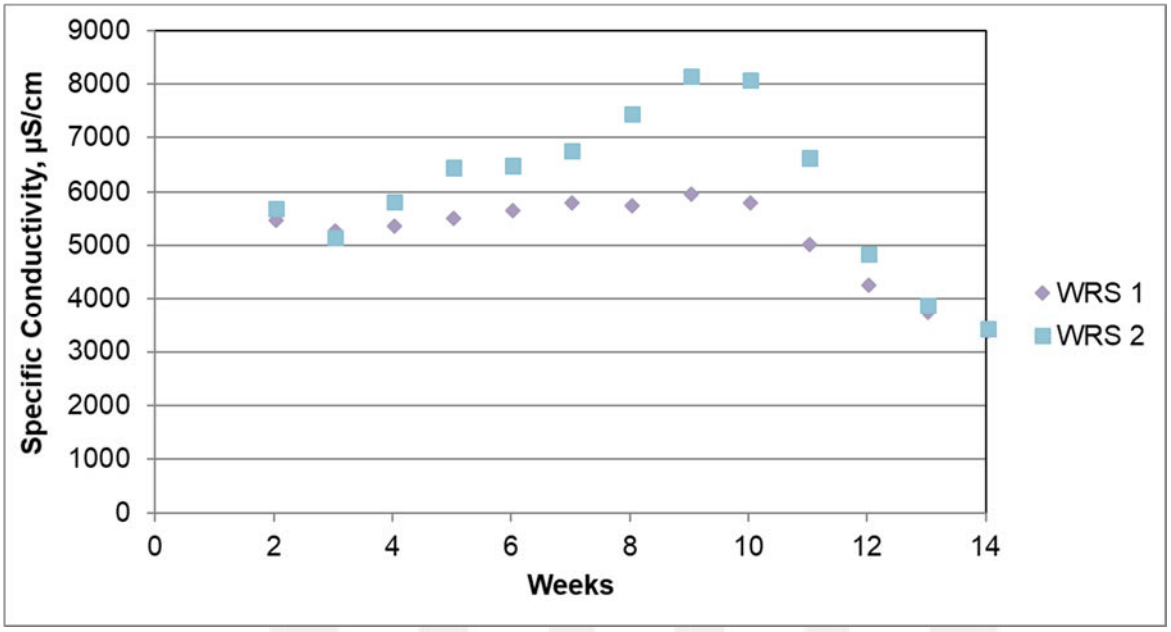


Figure 3.4-27 28 WRSs Conductivity Results

Metals: The results indicate that WRS 2 removed 98% to 100% of the initial concentrations of Al, Cu, Ni, Pb, Cd, and Zn. Arsenic and Mn percent reductions in concentration were 72% and 82% on week 14, respectively. The metals concentration improvements occurred largely from weeks 12 to 14. Metals concentrations also decreased in the control cell (WRS 1), but these reductions were less than those seen in WRS 2.

Percent reductions for the entire metals suite are presented in Table 3.4-2. The percent reduction was calculated based on the WRS 1 initial metal concentration (IC) of week 2 and the metals concentration of each cell of week 2 and week 14. The metals concentration of week 2 was used as IC for the WRSs due to the standard operation procedures for these cells. When the metal concentration was below the detection limit, it was assumed that, for purposes of calculation, complete (100%) removal had been achieved for that metal.

The biweekly metals concentrations and graphs are presented in Appendix B-4. Raw data from the lab is summarized in Appendix C-3.

Table 3.4-2. Metals Percent Removal

Test Cell	Al		As		Cd		Cu		Fe		Mn		Ni		Pb		Zn	
	% Reduction																	
	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14	Week 1/ Week2	Week 14
WRU 1	*IC=59*	34	*IC=0.09*	-153	IC=0.04	8	*IC=39*	41	*IC=125*	-64	*IC=4.5*	39	*IC=0.11*	28	*IC=0.17*	47	*IC=4.7*	51
WRU 2	95	99.6	0.0	***100***	***100***	98	97	99.4	97	99.97	94	88	***100***	96	***100***	***100***	***100***	97
WRU 3	73	93	33	70	75	69	69	95	94	0.6	63	58	-364	86	-188	83	-293	95
WRU 4	94	99.5	11	84	***100***	93	90	99.8	99.8	70	86	63	82	96	88	***100***	83	99
WRU 6	99	28	56	-123	***100***	6	96	27	97	-48	91	-9	91	-12	94	34	99	45
WRT 1	*IC=139*	70	*IC=0.19*	75	IC=0.09	71	*IC=47*	58	*IC=204*	43	*IC=18*	79	*IC=0.34*	76	*IC=0.41*	72	*IC=12*	82
WRT 2	99.7	99.8	79	95	***100***	***100***	99.6	99.9	99.9	99.99	99	98	***100***	***100***	***100***	***100***	99.8	99.96
WRT 3	26	99.8	32	79	33	81	17	***100***	55	16.2	29	82	26	99	29	95	22	99
WRT 4	98	99.8	53	87	***100***	97	94	***100***	97	76	92	91	94	***100***	93	***100***	95	99.8
WRS 1	*IC=198*	89	*IC=0.2*	71	IC=0.12	62.3	*IC=93*	92	*IC=241*	57	*IC=25*	52	*IC=0.43*	60	*IC=0.58*	93	*IC=15*	65
WRS 2	5	99.8	-5	72	8.3	98	7	***100***	-9	81	10	82	5	***100***	10	***100***	-2	***100***

Notes:
Values in bold and italics indicate a decrease to the detection limit. Therefore, it was assumed that 100 % of the analyte was removed.
A value of zero means that the input and output concentration was the same; negative values indicate the analyte was rinsed from the sample.
IC- Initial Concentration of metal in mg/L
Week 1/Week 2: the standard operation procedures were different for the cells. Therefore, the IC for the WRUs from week 1, and the IC of WRTs and WRS from week 2 were used.

Microbial Assessment – Saturated Vessels

Tables 3.4-7 and 3.4-8 summarize the results of a two time point assessment of microbiology in the saturated reactors. Table 3.4-7 shows that even under saturated conditions, a low level of iron-oxidizers are able to maintain themselves in WRS-1. Although supposition, we believe that since the waste rock charge is submerged, it is most likely that the aerobic acidophiles are maintaining themselves in the leach solution proximate to the bed surface where it would have contact with atmospheric oxygen in the head space of the test vessel.

However, note that the acidophiles are below detection in WRS-2, amended with an incremental full charge of milk but only a small fraction (<10%) of alkalinity added to unsaturated and transition vessels. The effluent contained numbers of anaerobic sulfate reducing bacteria comparable to almost any level seen for aerobic iron oxidizers in the untreated unsaturated and transition controls. This suggests that maintaining the high organic loading (in the absence of frequent and aggressive rinsing protocols) really was beneficial for establishing the sulfate reducers, raising the issue of how best to translate this finding to field application. Consistent with the results for the unsaturated and transition vessels, this demonstrates proof-of-concept for rapid subsurface terraforming. Solution from the saturated zone would no longer be able to feed ferric oxidant to pyritic material in other zones.

Table 3.4-7 Saturated POP 20 Kg Test Cells: MPNs of Viable Acidophilic Iron-Oxidizers

Sample ID	Test Group	Type	Mesophilic and Acidophilic Fe-Oxidizers MPN (cells / mL)[1]	
			Week 3	Week 13
WRS-1	Saturated, AG Incremental alkalinity	Aq	1.1×10^3	9.3 x 103
WRS-2	Saturated, AG, Milk + Incremental alkalinity	Aq	$< 3.0 \times 10^0$	9.3×10^2
Positive controls			3 of 3 are (+)	6 of 6 are (+)
Negative controls			3 of 3 are (-)	6 of 6 are (-)

[1] Incubated 21 days at: Week 3 (03/21 – 03/22) - 29.1 C ± 0.8 C; Week 13 – (05/02 – 05/03) - 29.4 C ± 1.0 C

Table 3.4-8 Sulfate Reducing Anaerobic Microbial Populations- Saturated POP 20 kg Vessels

Sample ID	Test Group	Sample Type	Anaerobic SO4-Reducers MPN (cells / mL)[a, b]	
			03/20-03/21	04/03-04/04
WRS-1	Minor Alkalinity – Partial	Aq	$< 1 \times 10^0$	$< 1 \times 10^0$
WRS-2	Minor Alkalinity + Milk– Partial	Aq	1.2×10^5	2.7×10^4
Temperatures (mean ± s.d.)			21.7 ± 3.0 C	20.7 ± 1.5 C

[a] March samples assayed directly from POP 20 kg reactors; [b] April samples were refrigerated and stored prior to assay

Observations: Qualitative assessments were made of effluent quality for the saturated reactors. WRS-1 was consistently yellowish and turbid, with almost no identifiable odor associated with the solution. Figure 3.4-28 is illustrative of that pattern. However, WRS-2 effluent contained suspended fungal clumps after one month of operation. After six-to-seven weeks, the effluent was extremely malodorous and a dark black color (see Figure 3.4-29). The intensity of the black color lessened during the latter partial solution replacement phase of operation.

Figure 3.4-28WRS-1 Effluent

Figure 3.4-29 WRS-2 Effluent

3.5 Pit Lake Encapsulation

3.5.1 Conclusions and Recommendations

Consistency Evaluations (tank tests) – Stiff, low water content slurry applications produced a tight cylindrical shape that sank to the bottom of the tanks in a pile that was fairly rigid. After several hours of saturating, the cylindrical shapes dissipated or flattened into a more uniform pile much like the watery (thin) slurry applications.

No particular mix of borrow clay or borrow soil/bentonite at various initial water contents exhibited slumping upon increase in slope angle of the test vessel. A commercial product used for comparative purposes also did not present problematic issues using the test protocol employed. In contrast to the other test groups, this product was applied in a dry fashion as per the manufacturer recommendations and it hydrated in place. The acidity of the water in the tank did not appear to affect any of the sealant/encapsulating materials tested.

Based on the spreading and cling characteristics observed from all the various mixes, further testing is recommended to quantitatively evaluate the application method that would be employed at a larger scale. Percent moisture in the slurry, drop distance, pit lake turbulence, % bentonite, and duration of settling all influence the spread and effective thickness of the encapsulation media once it is placed. The more uniform the media can be applied (density and thickness), the more protective it will be over the treated area and less bulk material will be required.

Encapsulation Effectiveness (falling head tests). The following generalities were observed.

- All tests with the borrow material (clayey soil) with various amounts of bentonite were able to achieve at least a permeability of less than 1.0 E-6 cm/s after 72 hours of settling time.
- The results were fairly similar between mixes that had different percentages of bentonite (3% & 8%), so the bentonite concentration may not have a significant influence on the mixture permeability once the material is saturated. When the test units were cleaned, higher bentonite content materials stuck to the bottom of the vessels more readily than lower content mixtures. At 5% and 8%, the material had to be scraped off the bottom of the glass tanks with a putty knife. This is encouraging, as it shows that the placed materials should adhere to whatever surface they contact, even sloping surfaces.

Recommendations for further Tier 2 testing should include:

1) Increasing the saturation interval before performing permeability tests to ensure the bentonite is fully saturated and the mixture fully “set”.
2) Performing additional stability tests that mimic the water movement and chemistry changes/gradients expected at the bottom of the pit lake. These tests would provide long term performance/stability of the encapsulation media.
3) Conducting field tests in a large roll-off dumpster to evaluate larger-scale mixing challenges and placement methods.

3.5.2 Pit Lake Encapsulation Study Approach

3.5.2.1 Test Objectives

The purpose of this test was to assess the practicality of covering submerged acid generating rock and/or metal precipitates deposited on the floor of the pit lake with a locally available clay-based layer (potentially amended with some bentonite) or a commercially available product specifically designed for this application (AquaBlok™). The current plan for the full-scale application of the concept would be to isolate potentially reactive wastes within the pit lake using a “media” applied *in-situ*. The evaluation consisted of two separate tests identified as:

- Consistency Evaluation – Observations of how the media disperses and “settles” *in-situ*
- Encapsulation Effectiveness – A hydraulic permeability test

Consistency Evaluation - To observe the *in-situ* placement characteristics (settling, spreading, consolidating) of AquaBlok and different mixtures of clayey soil, bentonite, and water blended into a "pumpable" slurry and applied with a simulated tremmie pipe. The AquaBlok application would follow the manufacturer's recommendations as practical. Here, the dry pellets were allowed to gravity settle through the water column, disperse and accumulate on the bottom of the test vessel. Assessments were made after 7 hours and 20 hours.

Encapsulation Effectiveness – Measure the hydraulic conductivity in a falling head test after *in-situ* placement of the material Comments. $K<=1X10^{-6}$ cm/s would be considered effective.

3.5.2.2 Experimental Design and Procedures

See Appendix A-5 - Pit Lake Encapsulation Study – Coating Evaluation

Table 3.5-1 Test Identification (Slurry Content)

Test #	Short Description	Moisture Content	Bentonite
PLE1	Soil; stiff; no B	Low/Stiff	none
PLE2	Soil; stiff; 3% B	Low/Stiff	3%
PLE4	Soil; med; no B	Med	none
PLE5	Soil; med; 3% B	Med	3%
PLE7	Soil; thin; no B	High/Thin	none
PLE8	Soil; thin; 3% B	High/Thin	3%
PLE9	Soil; thin; 8% B"	High/Thin	8%
PLE10	Soil; thin; 5% B	High/Thin	5%
PLE11	AquaBlok	None	none

Soil = locally available clayey soil from the barrow at the site; Moisture content: stiff = just enough water to be pumpable; thin = almost to point of water separation from slurry; med = in between stiff and thin.

3.5.2.3 Deviations from the Work Plan

PLE3 (Soil; stiff; 8%B) and PLE6 (Soil; med; 8% B) tests were not done because there was very little observed difference between no (0%), 3%, and 8% bentonite mixes after settling "in" for 20 hours at the bottom of the tanks. It was also very difficult to press the material out of the grout gun with the higher bentonite content which made it impractical for pumping. The higher bentonite ratios would also drive up applied cost significantly. A total of nine of ten tests originally planned were performed.

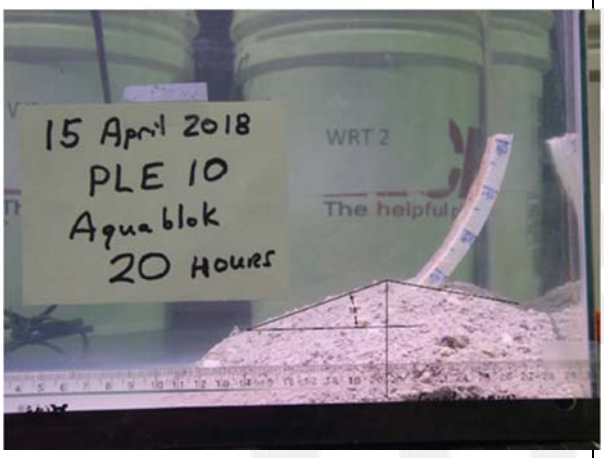
All of the falling head tests were completed, but three tests initially failed due to small pressure leaks in the apparatus. The tests were repeated with functional test vessels. Tests were also repeated on some of the same mixes over a period of weeks to examine the effect of time on permeability. A total of six discrete falling head tests were conducted, for a total of 20 individual rate determinations.

3.5.3 Pit Lake Encapsulation Results and Discussion

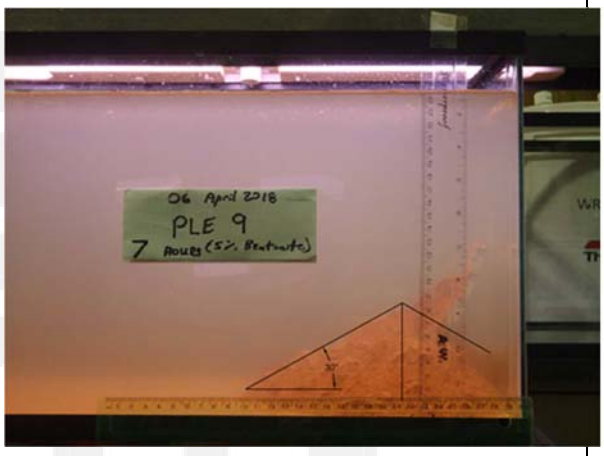
3.5.3.1 Consistency Evaluation photos.

Photos of the consistency tank test are presented in Figures 3.5-1. Lines were drawn on the photos to indicate the depth and angle of repose.

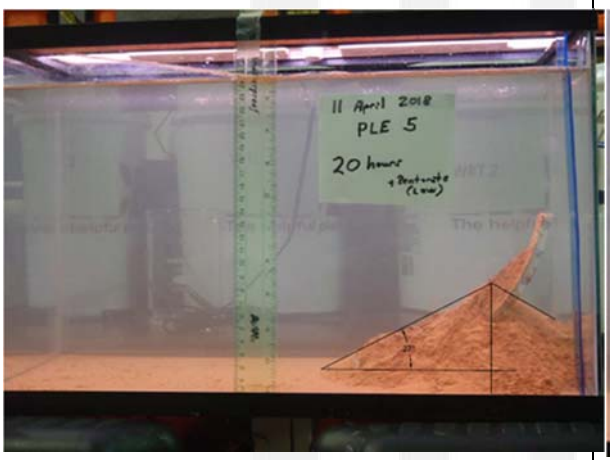
PLE 11 Aquablock after 20 hrs (note on tank PLE 10 is PLE11)



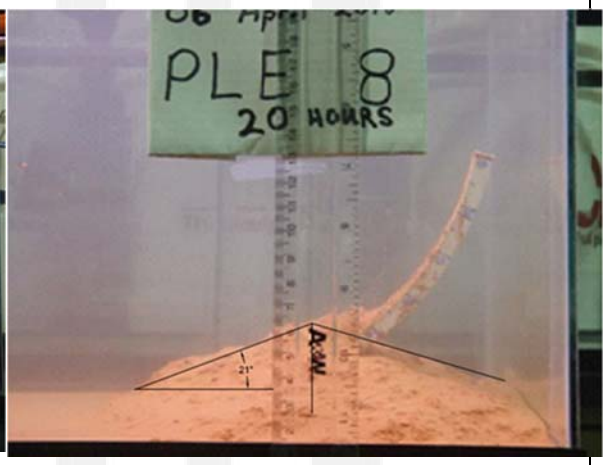
PLE9 after 7 hours



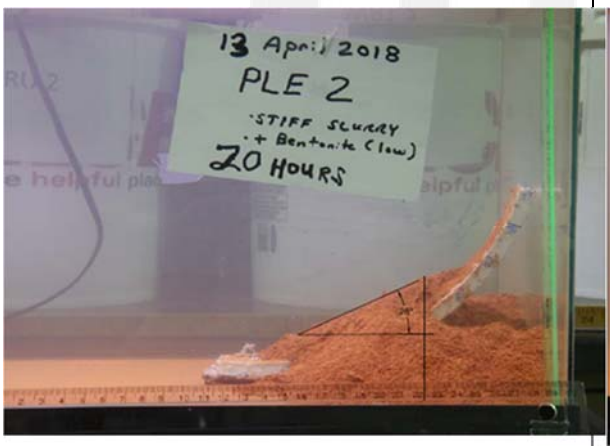
PLE5 after 20 hours



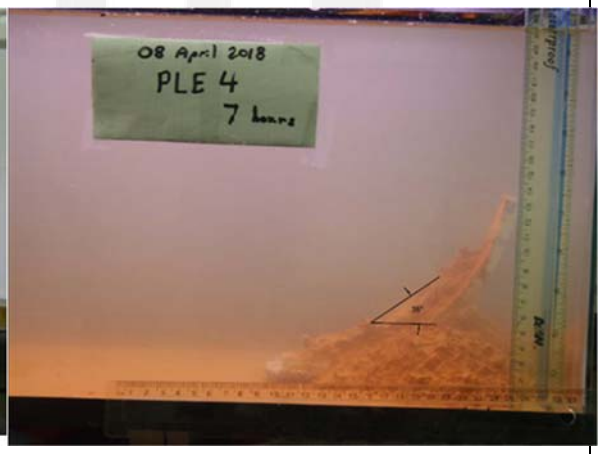
PLE8 after 20 hours



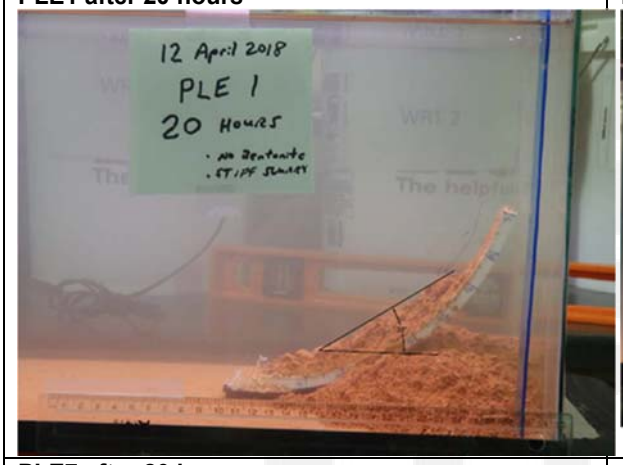
PLE 2 after 20 hours



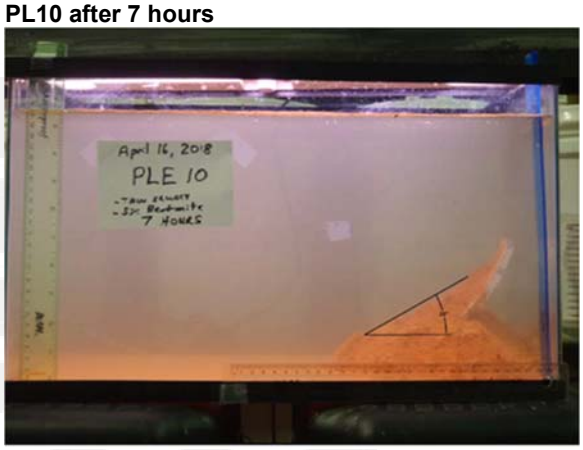
PLE4 after 7 hours



PLE1 after 20 hours



PL10 after 7 hours



PLE7 after 20 hours

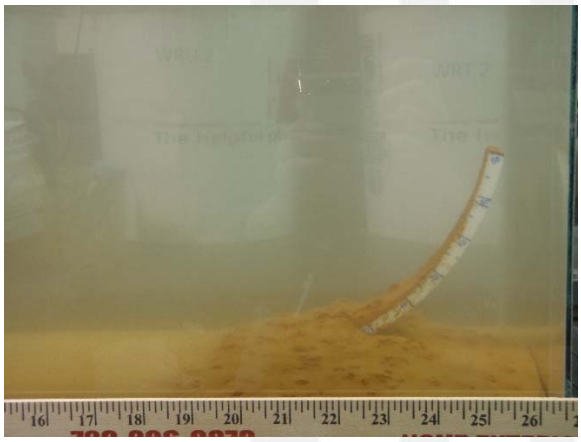


Figure 3.5-1 Photos of Consistency Tank Tests

The data showed a noticeable departure in the physical coating behavior of AquaBlok when compared to various borrow soil and bentonite slurries. The slurries demonstrated higher angles of cling and repose. The AquaBlok mounded less and maintained a lower profile in the tank. The results indicate that an AquaBlok application might not be suitable for steeper surfaces, though the manufacturer may have specific recommendations. The results are presented in Table 3.5-2.

Table 3.5-2 Pit Lake Encapsulation Results

Test (*1)	Material Tested	Barrier Material Quantity					After Application			
		Soil (g)	Water (ml)	Bentonite (g)	% solids in slurry	Date	Slurry depth (cm)	Spread dist. (cm)	Max Cling ∠	Repose∠
PLE1	Soil; stiff; no B	1000	350	0	74%	4/12/2018	6.1	11	62°	33°
PLE2	Soil; stiff; 3% B	968.8	350	31.2	74%	4/13/2018	7.7	9.9	55°	26°
PLE4	Soil; med; no B	1000	500	0	67%	4/8/2018	7.1	11.1	65°	35°
PLE5	Soil; med; 3% B	968.8	500	31.2	67%	4/11/2018	7.3	13.8	70°	27°
PLE7	Soil; thin; no B	1000	560	0	64%	4/5/2018	3.8*2	10*2	48*2	16*2
PLE8	Soil; thin; 3% B	968.8	560	31.2	64%	4/6/2018	5.2	8.2	45°	21°
PLE9	Soil; thin; 8% B	922	560	78	64%	4/6/2018	9.3	11.9	68°	30°
PLE10	Soil; thin; 5% B	950	560	50	64%	4/16/2018	8.5	11.1	71°	29°
PLE11	AquaBlok	1000	None	N/A	N/A	4/15/2018	7.9	10.8	45°	19°

Soil = locally available clayey soil from the barrow at the site
Moisture content: stiff = just enough water to be pumpable; thin = almost to point of water separation from slurry; med = in between stiff and thin. B = Bentonite clay
*1 – PLE3 (Soil; stiff; 8%B) and PLE6 (Soil; med; 8% B) were not done because there was very little observed difference between no, 3%, and 8% bentonite mixes after settling in for 20 hours at the bottom of the tanks. It was also very difficult to press the material out of the grout gun with the higher bentonite content which made it impractical for pumping. The higher bentonite ratios as this would drive up applied cost significantly.
*2 – Data taken from Lab notes after test. This was the first test and the photos taken were not suitable to be used for measurement.

3.5.3.2 Encapsulation Effectiveness (Falling Head Tests)

Permeability values were fairly similar for all the borrow soil tests. A value of < 1.0E-06 was considered to be a potentially acceptable barrier material. The mixtures have surpassed this goal. Data are summarized in Table 3.5-3. As a reminder, these tests were done at low pH (2.2) in surrogate or "artificial" deep pit water.

Table 3.5-3 Falling Head Test Results

Test	Corresponding previous test	Clay Borrow (g)	Bentonite (g)	Distilled Water (ml)	Number Determinations	K (cm/s)
PLE13	PLE9 Soil; thin; 8% B"	4200	221	2477	5	5.43E-06
PLE14	PLE8 Soil; thin; 3% B	4290	138	2477	6	2.97E-06
PLE15	PLE7 Soil, thin, 0% B	4424	0	2477	1	4.02E-06
PLE16	PLE5 Soil, med, 3% B	4286	138	2212	6	1.87E-06
PLE17	PLE11 AquaBlok	7980	0	0	1	9.08E-06
PLE 17B	PLE11 AquaBlok	7980	0	0	1	4.56E-06

*1 - PLE17, 17B – two separate preparations as a repeat, but using the same test vessel

3.6 Pit Water Treatment

3.6.1 Pit Water Treatment Conclusions and Recommendations

3.6.1.1 Titration

Four titrations of upper pit water were completed. Each of the reagents or reagent combinations was successfully applied in adjusting solution pH to the circum-neutral range. Limestone was effective, but it appeared to have a tendency to surface passivate and even the very fine particle size employed required days for complete pH adjustment, even with continuous mixing. Caustic pH required the least time to complete the adjustment. Hydrated lime required more time to effect adjustment than NaOH, but less than limestone. Hydrated lime was used very successfully in conjunction with limestone in a controlled fashion. Cost and time constraints would dictate the field approach.

3.6.1.2 BH26 Water

The organic media tested was unable to provide sulfate reducing conditions in the test interval using water from BH26, which had elevated concentrations of sulfate and metals/acidity. Test operation continues as the pH is gradually increasing and sulfate concentrations are slowly decreasing in comparison to the control (though the official test program has ended). This testing was conducted using extremely poor-quality water, but the onset of more rapid active sulfate reduction is expected when the pH reaches a critical threshold.

3.6.1.3 Upper Pit Water

All the organic media mixtures tested produced conditions favorable for sulfate reduction. In some cases, sulfate reducing conditions were established within a week of the start of the test. This relatively rapid response was likely due to the fact that the water chemistry of the Upper Pit Water (UPW) contained less acidity than the BH26 water. Thus, the acidity in the UPW was neutralized by the limestone component (typically 30% by as-received weight) in the media recipes which protected the sulfate reducing bacteria from acid attack. These bacteria require a pH of about 5.5 to survive (Wildeman *et al*. 1993).

Consequently, the test results indicate that if mine influenced water (MIW) with a chemistry similar to BH26 is to be passively treated, a pretreatment step that reduces the acidity would be prudent prior to treatment with a sulfate reducing biochemical reactor (BCR). An iron terrace might be considered in this situation. Alternatively, the media mixture proportions may need to be adjusted to include more limestone.

Conversely, MIW with a chemistry similar to UPW could be directed to a BCR filled with any number of mixtures without pretreatment. Similarly, it should be possible to use lignocellulosic carbon sources to generate a sulfate reducing system in the pit lake itself, creating a vastly prolonged *in situ* treatment process.

Tier 2 testing should include evaluations of the iron terrace technology for BH26-like MIW and standard bench scale testing of UPW-like MIW with several different organic media mixtures similar to the tested materials exhibiting the highest pH gain and the lowest ORP values.

3.6.2 Pit Water Study Approach

3.6.2.1 Objectives and Rationale

Objective – Identify a cost-effective method of neutralization that is feasible and may have some residual buffering capability and evaluate the ability of various organic media mixtures to create a quasi-permanent sulfate reducing zone in the pit lake (static tests). Based on the findings, develop recommendations for implementation and further testing.

3.6.2.2 Experimental Design and Procedures

See Appendix A-6 – Pit Water Treatment – Titration & Sulfate Reduction Bench

3.6.2.3 Deviations from the Work Plan

The Tier 1 program called for a single test matrix for neutralization and sulfate reduction in upper pit water. A second matrix was assembled and conducted in an identical fashion using BH26 water characterized by low pH and high TDS and sulfate to provide data: 1) in the event that a pump and treat approach is considered; and 2) to further assess the limits of microbial sulfate reduction in site waters. This represented an expansion of the original test program.

3.6.3 Pit Water Results and Discussion

3.6.3.1 Pit Water Treatment

Titration:

The Upper Lake water was titrated with various reagents including NaOH (crushed pellets), hydrated lime, fine limestone and hydrated lime or limestone alone until the pH increased to a circum-neutral range. Table 3.6-1 shows the results of the pit lake titration with different reagents. Titration curves are provided in Appendix B-5.

As indicated in Section 3.1.3.3, a re-analysis by ICP-AES of the upper pit water showed that its metal/metalloid content was not substantially altered by extended storage prior to use in these neutralization titrations. At the time of use, there were low concentrations of species likely to precipitate from solution as pH was raised to the circum-neutral range: Al (8 mg/L), Cu (2 mg/L), Zn (1.6 mg/L), As (0.04 mg/L) and Fe (3 mg/L). As noted, there was the development of turbidity as the pH increased, with the possible formation of colloidal compounds containing these metals/metalloids. Again, it is supposition, but some fraction of iron (III) sulfates or jarosites may have been deposited on the limestone surface, contributing to some extent to the almost 41 hours consumed by the titration. But evidently, there were insufficient concentrations available to produce a settled “sludge”.

Table 3.6-1 Titration of Upper Pit Lake Water

Test	Start Date, Time	Completion Date, Time	Temp., °C at t(0)	Solid Reagent	pH(i)	pH(f)	Consumption Kg/m^3
PLN1	16 March 2018, 12:21 pm	16 March 2018, 2:24 PM	18.0	NaOH	3.09	7.12	0.0955
PLN2	22 April 2018, 3:35 PM	23 April 2018, 12:01 PM	17.7	$Ca(OH)_2$	3.20	6.89	0.0983
PLN3	23 April 2018, 3:57 PM	24 April 2018, 1:35 PM	16.2	Sequential Limestone + $Ca(OH)_2$	3.20	6.94	0.0742 (LS) + 0.0255 (HL) – TOTAL 0.0997
PLN4	23 April 2018, 3:57 PM	25 April 2018, 8:48 AM	16.2	Limestone	3.20	7.59	0.1786

Each of the reagent combinations successfully resulted in production of circum-neutral water. The water sample was colorless and clear upon the start of each test. And in each case, the water became turbid and yellowish between pH 4.46 and pH 4.66. No bulk sludge or floc resulted in any case, although each sample became quite turbid by the end of the test.

Reagent contact was not an issue since all four test systems were continuously stirred, though use of highly soluble caustic (NaOH) resulted in the most time effective solution pH adjustment. Total mass

consumptions per cubic meter of water were quite similar for three reagents or reagent combinations. Limestone alone was the outlier. While the target pH was somewhat overshot in PLN4, it seems likely that limestone alone was armored by iron precipitates and this resulted in an extended reaction time and larger mass consumption in comparison to PLE3 (limestone followed by hydrated lime). A minute quantity of remaining limestone particles were noted at termination of the PLN 4 test.

Sulfate Reduction Bench – BH26 Water Treatment (PLN5 to PLN25)

The initial 20 cells were set up using water containing "high" levels of sulfate from Well BH26. Solution pH, sulfate, and ORP were measured in the cells. The best indirect indicator of change was ORP. Appendix B-5 includes the summary data.

The SRB test vessels were vented to prevent the development of overpressure and possible microbial inhibition from 1) high CO_2 concentrations as limestone reacted with the acidic waters and; 2) high H_2S concentrations generated once active microbial sulfate reduction commenced. The headspace of each lidded vessel was partially filled with polypropylene spheres as a cover to minimize evaporative loss of solution during extended incubation. The test vessels were a non-mixed system to allow for the development of gradients and micro-niches where cellulose-degrading and sulfate reducing microbial populations might thrive. And so, it was not a matter of generating homogeneity prior to sampling by simply adding distilled water to compensate for evaporation.

Sulfate – For the BH26 water, sulfate removal was modest and likely resulted from precipitation with iron or aluminum, or a low level of microbially mediate sulfate reduction at these pH levels. The percent removal ranged from 5.4% (PLN9) to 25% (PLN22) compared with the control cell (PLN5). In PLN5, the sulfate concentration had increased 14.1% due to evaporative loss and the consequent concentration of dissolved analytes. Noise in the weekly data may also have resulted from the use of small volume (grab) samples collected from a non-mixed system. Decreases in sulfate concentrations, when observed, were unmistakable, despite any concentrating effect due to evaporative loss or impact of sample size on weekly variation in data (Figure 3.6-1).

The percent reduction was calculated using the initial sulfate concentration of cell PLN5 and the cells sulfate concentration of week 10.

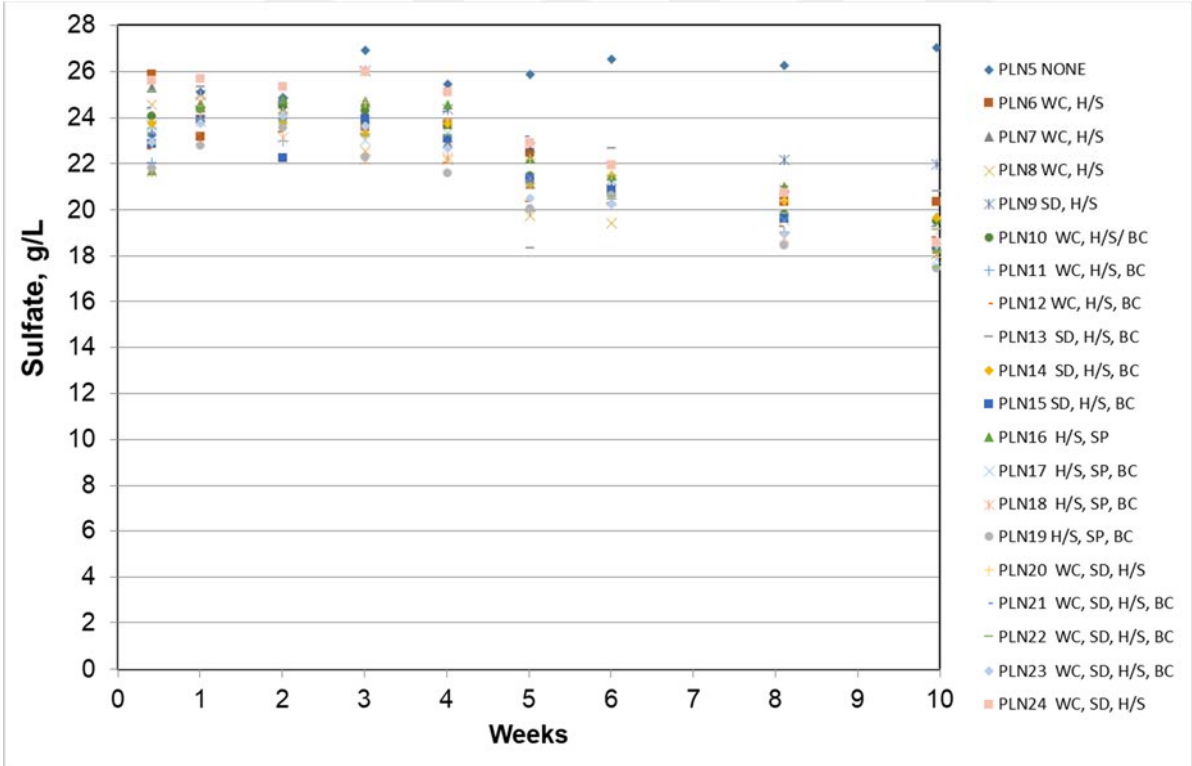


Figure 3.6-1 Sulfate PLNs (cells 5 to 24) Results using BH26 Water

pH - With the exception of the unamended control, solution pH had slightly increased in all cells for about 6 weeks. It then appeared to decrease in week 8 and week 10 by about one pH unit in cells PLN17, PLN18, and PLN19. The initial pH was 2.7 in the control cell (PLN5) and the pH in the cells ranged from 2.9 (PLN19) to 4.2(PLN23) at week 10. Figure 3.6-2 illustrates solution pH for the PLNs 5 to 24 cells.

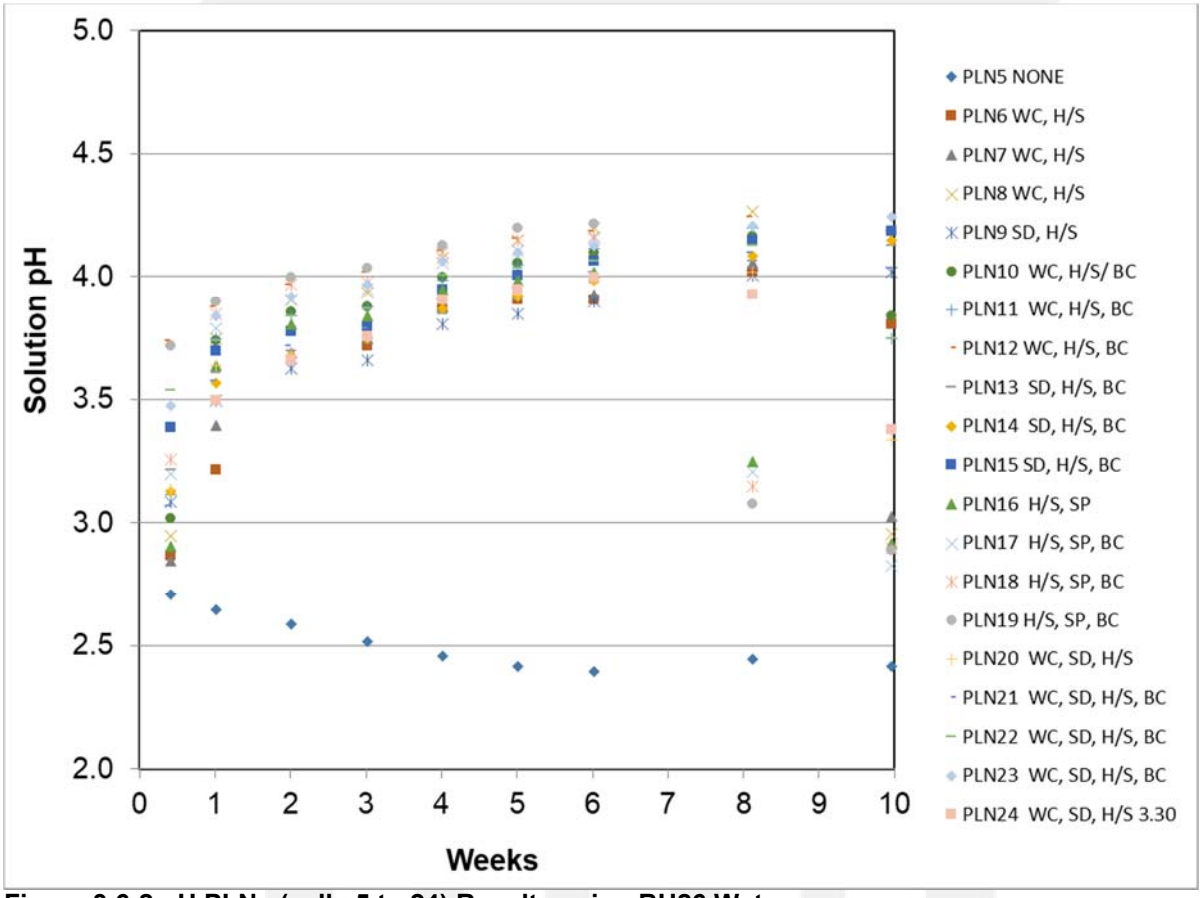


Figure 3.6-2 pH PLNs (cells 5 to 24) Results using BH26 Water

ORP – The ORP in all the PLNs (5 to 24) typically decreased for 5 weeks (except PLN6). By week 6, the potential started to increase in all the cells. By the end of the test (week 10), solution ORP was almost the same as in the first week. The ORP of the control cell has been nearly constant since start up, except on week 10 when it was higher. Figure 3.6-3 shows the ORP of the PLNs 5 to 24 cells. The following statement is offered without data support. But it is almost as if only a portion of the organics could be degraded in the BH26 water – potential first decreased as the cellulose degrading system was taking off, but then increased as some types of microbial activity were then inhibited, while others were not, resulting in a rapid pH drop in some of the vessels.

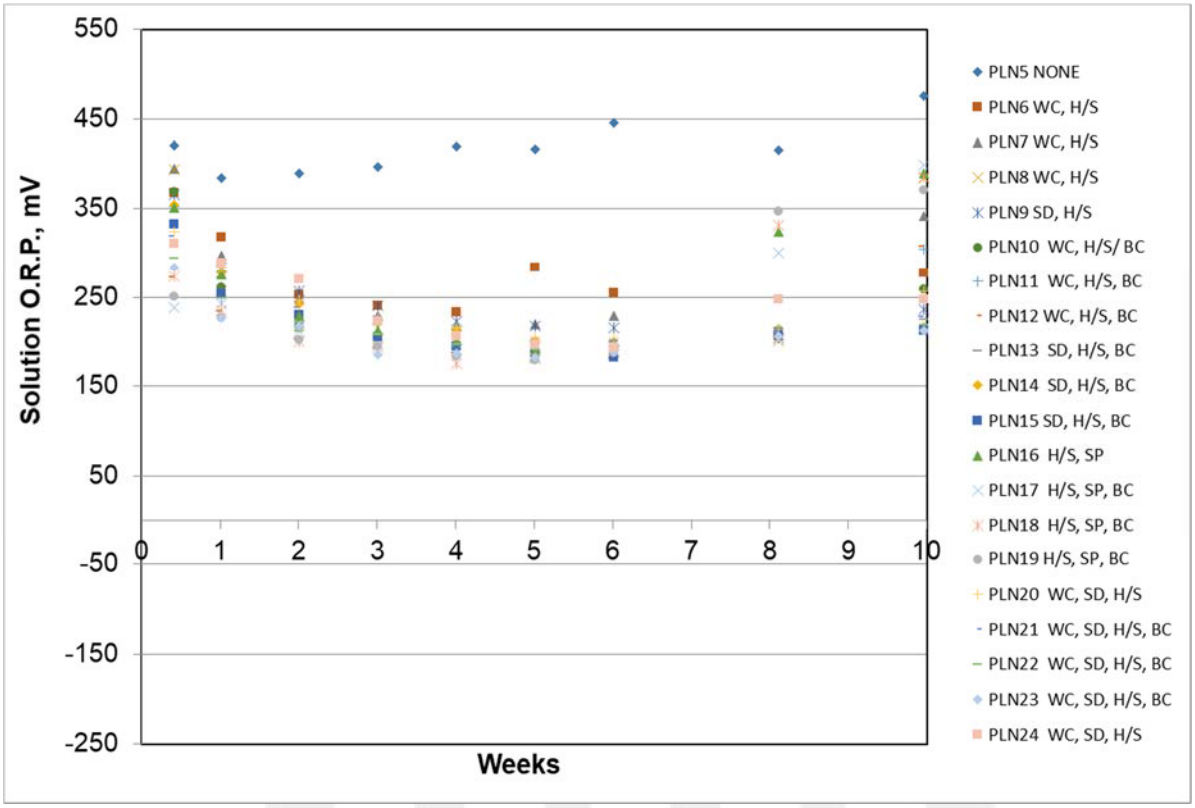


Figure 3.6-3 ORP PLNs (cells 5 to 24) Results using BH26 Water

<u>Sulfate Reduction Bench – Upper Pit Water Treatment (PLN25 to PLN39)</u>

Additional tests (12 cells) were conducted using the upper level pit lake water containing lower sulfate levels. This is where the full-scale sulfate reduction would be applied and so these tests would be more realistic of on-site conditions. Appendix B-5 includes the summary data.

As with the first test group, the SRB test vessels in this series were also vented to prevent the development of overpressure and possible microbial inhibition (see Section *Sulfate Reduction Bench – BH26 Water Treatment (PLN5 to PLN25)*

Sulfate – Figure 3.6-4 shows that sulfate slightly increased in concentration during weeks 1 and 2 and it then decreased during the following five weeks. These are non-mixed test systems employing small volume grab samples. Excluding the unamended control, microbial sulfate reduction was established in most of the cells, but in particular in PLN34 and PLN35, where the concentration of sulfate was reduced by approximately 80%. The percent reduction was calculated using the initial sulfate value of cell PLN25 and the cells' sulfate value at week 10. Some carbon mixes really did perform better than others and so choice of feeds at the site would be quite important. The trends indicated that the sulfate supply would have been largely exhausted in some vessels if the tests had been continued until week 9 or 10.

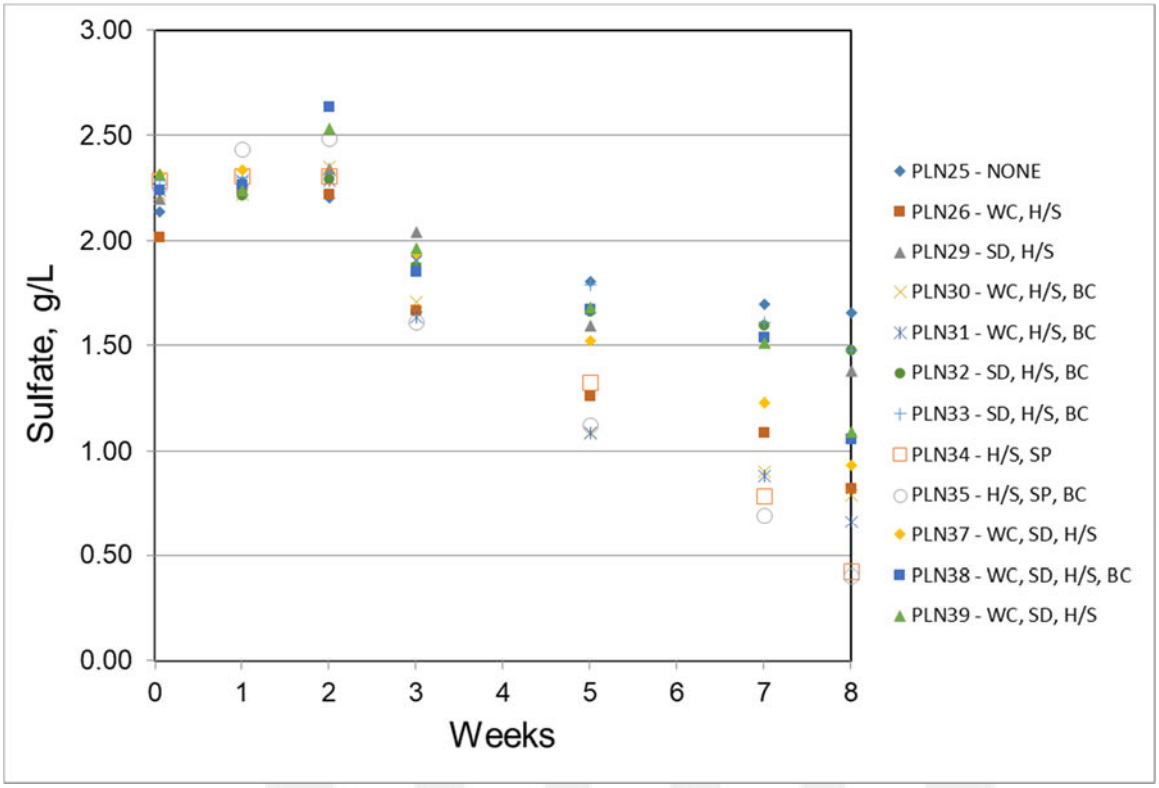


Figure 3.6-4 Sulfate PLNs (cells 25 to 39) Results using Upper Pit Lake Water

pH – Solution pH of the unamended pit water was generally stable over the eight-week test period (PLN25), where the initial pH was 3.2. Pit surface water was effectively neutralized by agricultural limestone, and the pH in those cells ranged from 6.0 (PLN32) to 7.1 (PLN39) at week 8. Figure 3.6-5 shows the pH of the PLNs 25 to 39 cells.

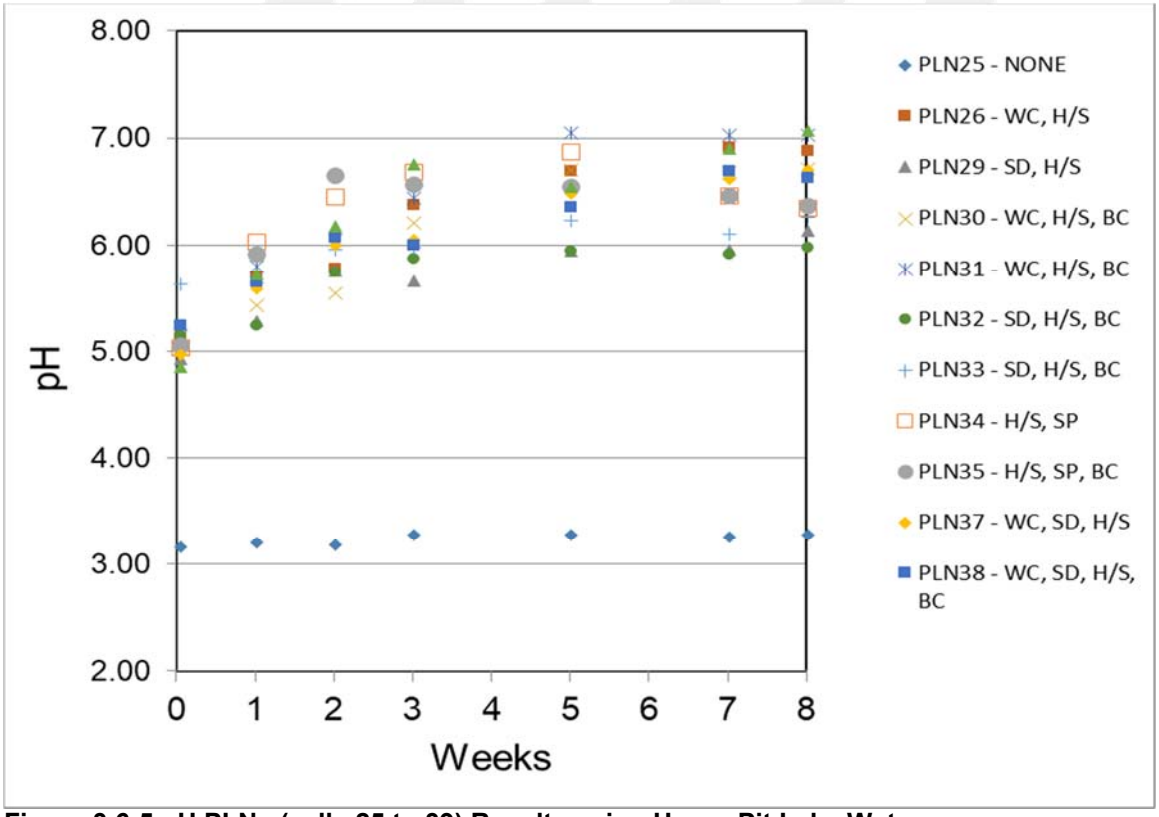


Figure 3.6-5 pH PLNs (cells 25 to 39) Results using Upper Pit Lake Water

ORP – Solution potential of the pit water unamended control (PLN25) was generally stable, with a single aberrant data point at Week 5, likely a result of probe fouling or a hysteresis-like effect from the very low potentials in the amended solutions. A gradual increase in potential over time in the control may indicate that iron was slowly oxidizing, even at moderately low pH. The low potentials were accompanied by the odor of hydrogen sulfide which is indicative of microbial sulfate reduction. Reducing conditions (negative ORP) had clearly been established in most carbon amended cells by week 8 (except PLN29 and PLN26). Figure 3.6-6 shows the ORP results of the PLNs 25 to 39 cells.

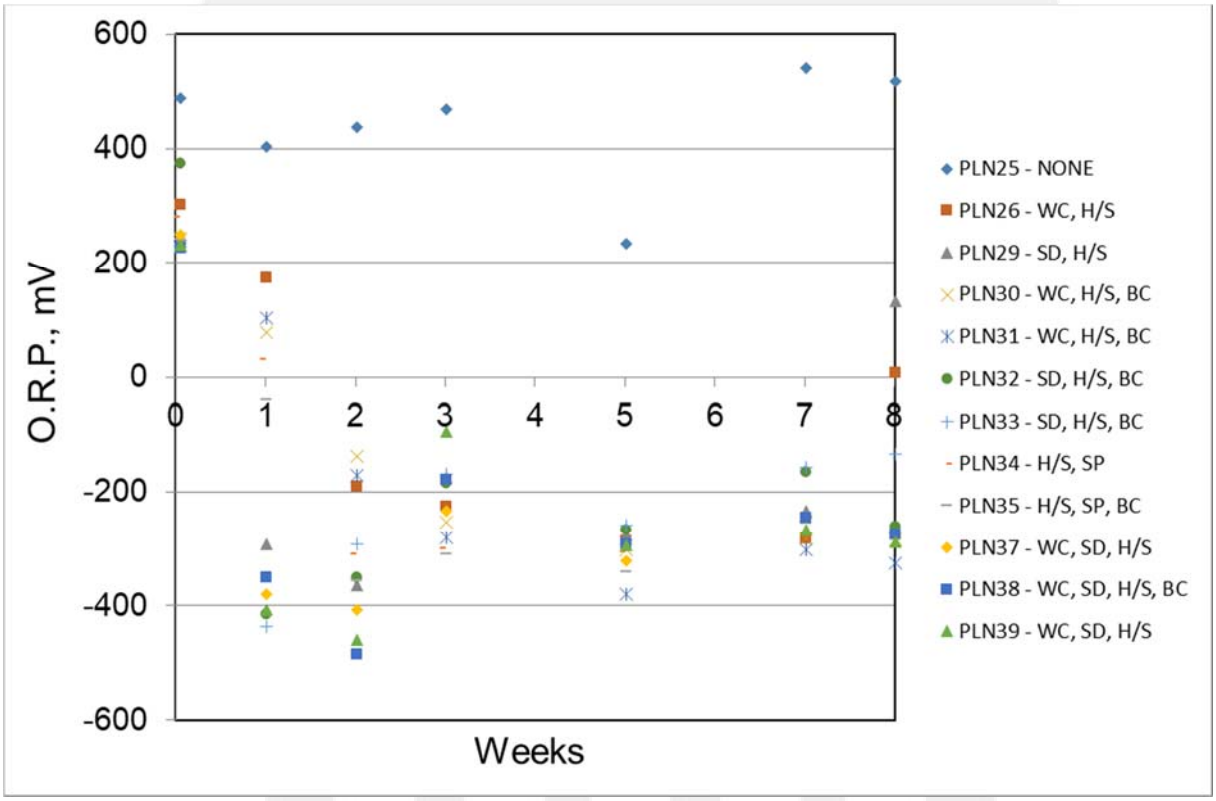


Figure 3.6-6 ORP PLNs (cells 25 to 39) Results using Upper Pit Lake Water

Metals - Table 3.6-2 summarizes results of an ICP analysis of the final sample set collected after eight weeks. Here, solution concentrations of Al, As, Cd, Cu, Fe, Mn, Ni, Pb and Zn in the (unamended) control vessel were compared to the amended test vessel solutions. Regardless of the mix of complex lignocellulosic carbon sources, solution Cd, Pb and Cu concentrations decreased to below detection limits. A single vessel (B-39) showed Cu at the detection limit. Aluminum decreased by a minimum of 92%, Zn by at least 98.6%, and Ni by at least 30.2%. Iron demonstrated somewhat more variable changes, with a range of 23.3 to 99.1% removal, with superior removal shown in B-32 (saw dust, hay, straw and biochar carbon amendments). Manganese and arsenic were not affected under any of these conditions, with some of the organic substrates contributing small amounts of Mn to solution.

The most important conclusion from this test series was the demonstration that lignocellulosic amendments and a community of cellulosic microbial populations could be utilized in Barite Hill upper pit water to supply sulfate reducing microbial populations with carbon to modulate sulfate and metals concentrations.

Table 3.6-2 Sulfate Reduction in Barite Hill Upper Pit Water. Final ICP-AES

Analyte	D.L. [1]	BC-20	B-21	B-24	B-25	B-27	B-28	B-30	B-31	B-32	B-35	B-36	B-39
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Al	0.0011	8.8351	0.4631	0.7313	0.4386	0.3032	0.5973	0.3721	0.3325	0.3676	0.4230	0.3035	0.4438
As	0.0080	0.0359	0.0469	0.0469	0.0425	0.0417	0.0473	0.0446	0.0553	0.0567	0.0513	0.0479	0.0469
Cd	0.0006	0.0401	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	0.0057	1.9453	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0062
Fe	0.0016	3.1823	0.0552	1.9155	0.0676	0.0422	2.4102	1.6299	0.0461	0.0292	0.0992	0.0824	0.0667
Mn	0.0002	6.4485	5.8904	10.004	5.7837	4.2096	10.244	9.7929	5.2314	5.7527	7.6307	7.5338	5.3234
Ni	0.0015	0.0205	0.0058	0.0110	0.0051	0.0042	0.0143	0.0090	0.0034	0.0035	0.0083	0.0094	0.0080
Pb	0.0050	0.0162	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.0023	1.5682	0.0180	0.0120	0.0174	0.0166	0.0155	0.0148	0.0152	0.0153	0.0206	0.0183	0.0214

[1] D.L.- detection limit, mg/L; BDL – below detection limit

4.0 RESULTS AND DISCUSSION - GENERAL SECTIONS

4.1 Data Management

Unique test numbers were assigned to each test unit in each testing group. This number was used for all sampling that was done on the individual sample vials and chain of custody form so that sample results had the same identifying number. A collection date was also added to each sample number. Data from the analytical labs was provided electronically and then reviewed and stored at both Solfatara labs and at the Sovereign offices.

Sovereign created data sheets for each testing group that identified each sample that was to be collected (the sample identifier) and the analytes that were to be tested. The data sheets served both as a form of organization for the data and/or a checklist for completeness.

Selective data were used for graphs and tables in the report. The comprehensive data set is Appendix B.

Photographs were taken and log entries were made to capture observations, timing, and testing nuances. A comprehensive project photo archive is provided in Appendix D.

4.2 Quality Assurance and Quality Control - General

Sovereign conducted weekly review of the data sheet and logs provided from Solfatara. Tables C 1 to C 10 (provided in the SAP) were used as a checklist. Deviations from the work plan were noted in each testing group section. Chain of Custody (COC) forms were also reviewed before the samples were sent to the analytical lab.

Sovereign conducted periodic meetings with Solfatara to verify that the test procedures were followed and to discuss any deviation from them. Sovereign also conducted visits to the Solfatara Laboratory to supervise the testing. Sovereign personnel also assisted Solfatara with the construction and implementation of some the equipment used in the testing.

Precision - Relative percent differences were determined for ICP-AES samples submitted to the Colorado School of Mines for analysis. Eight samples were submitted in duplicate. Of these, two sample sets resulted in unacceptable data reproducibility – 0321-WRS-1 (Cd and Fe) and 0418-WRU-4 (Al, Pb, Zn) showing variability, indicating that sample preparation was not careless, but the ICP data acquisition appeared to possibly be impacted by a previous sample. Except for a single datum, all values detected as “Below Detection Limit”, or BDL were consistent for the data pair. Most elements showed at least one deviation over the entire sample suite – there was no consistent pattern relative to a given element.

Table 4.2-1 Relative Percent Difference in ICP-AES Data using Duplicate Samples

	Sample Set		RPD	Sample Set		RPD
Element	0320-WRT-1a	0320-WRT-1b		0321-WRS-1a	0321-WRS-1b	
Al mg/L	49.2212	46.6549	5.4	42.1843	39.8889	5.6
As mg/L	0.0729	0.0646	12.1	0.1121	0.1103	1.6
Cd mg/L	0.043	0.042	2.4	0.1205	0.0420	96.6
Cu mg/L	35.0605	34.8576	0.6	40.2135	34.8576	14.3
Fe mg/L	119.3546	115.029	3.7	188.9208	115.029	48.6
Ni mg/L	0.129	0.1251	3.1	0.4371	0.4321	1.2
Pb mg/L	0.1372	0.1333	2.9	0.1601	0.1563	2.4
Mn mg/L	7.7216	7.613	1.4	26.4018	26.3054	0.4
Zn mg/L	4.4118	4.3395	1.7	14.029	13.9665	0.4

	Sample Set		RPD			
Element	0320-WRU-3a	0320-WRU-3b				
Al mg/L	3.4632	3.5104	1.4			
As mg/L	0.0334	0.0353	5.5			
Cd mg/L	0.0174	0.0171	1.7			
Cu mg/L	1.8376	1.8594	1.2			
Fe mg/L	118.8469	116.0059	2.4			
Ni mg/L	0.0471	0.0448	5.0			
Pb mg/L	0.0306	0.0314	2.6			
Mn mg/L	3.4497	3.4395	0.3			
Zn mg/L	0.9889	0.9652	2.4			
	Sample Set		RPD			RPD
Element	0417-WRU-1a	0417-WRU-1b		0417-WRT-1a	0417-WRT-1b	
Al mg/L	33.3674	31.4956	5.8	43.6107	43.0917	1.2
As mg/L	0.1735	0.1698	2.2	0.0489	0.0511	4.4
Cd mg/L	0.0279	0.0277	0.7	0.0283	0.0287	1.4
Cu mg/L	19.7088	19.3867	1.6	35.3772	35.6649	0.8
Fe mg/L	158.0661	156.0307	1.3	113.2526	114.8739	1.4
Ni mg/L	0.069	0.0673	2.5	0.0873	0.0902	3.3
Pb mg/L	0.0817	0.0832	1.8	0.1419	0.1362	4.1
Mn mg/L	2.7263	2.7278	0.1	4.3485	4.3922	1.0
Zn mg/L	2.0978	2.0739	1.1	2.8795	2.9725	3.2
	Sample Set		RPD	Sample Set		RPD
Element	0417-WRU-3a	0417-WRU-3b		0418-WRU-4a	0418-WRU-4b	
Al mg/L	3.6339	3.6219	0.3	0.2891	0.2013	35.8
As mg/L	0.0281	0.0338	18.4	0.0115	0.0118	2.6
Cd mg/L	0.0112	0.0113	0.9	0.0032	0.003	6.5
Cu mg/L	1.7503	1.7289	1.2	BDL	BDL	
Fe mg/L	113.2325	116.2132	2.6	43.0444	43.2383	0.4
Ni mg/L	0.0182	0.0184	1.1	0.0025	0.0026	3.9
Pb mg/L	0.028	0.0284	1.4	0.0078	0.0063	21.3
Mn mg/L	1.9048	1.9194	0.8	1.8588	1.8626	0.2
Zn mg/L	0.2312	0.2305	0.3	0.0386	0.0383	7.8
	Sample Set		RPD	Sample Set		RPD
Element	0418-WRT-4a	0418-WRT-4b		0418-WRS-2a	0418-WRS-2b	
Al mg/L	0.1805	0.3277	57.9	0.2098	0.2369	12.1
As mg/L	0.0332	0.0318	4.3	0.0983	0.0768	24.6
Cd mg/L	0.0069	0.0068	1.5	0.0149	0.0149	0.0
Cu mg/L	BDL	BDL		BDL	BDL	
Fe mg/L	88.0397	86.1478	2.2	156.2887	154.3303	1.3

Ni mg/L	0.0089	BDL		BDL	BDL	
Pb mg/L	0.0084	0.0096	13.3	0.0182	0.0183	0.5
Mn mg/L	2.3338	2.3173	0.7	8.6337	8.6685	0.4
Zn mg/L	0.0383	0.0386	0.8	0.0432	0.0442	2.3

Comparability - The POP 20 kg tests were the longest term and most extensive data source for ICP-AES sampling. Three “families” of test cells included the Unsaturated tests (n= 5 x 20 kg reactors), Transition tests (n = 4 x 20 kg reactors) and Saturated tests (n = 2 x 20 kg reactors).

Completeness - Of 162 possible analyses in this comparison, 24 total values (from 12 pairs) were above 6% relative percent difference, representing 85 % data reproducibility at that limit.

4.3 Key Contacts

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5.0 REFERENCES

APHA, 2012. Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 22nd Edition, Section 9-71.

Black & Veatch, 2015. Black & Veatch Special Projects Corp., Remedial Investigation Report, Revision 1, Barite Hill / Nevada Goldfields Site OU3, McCormick County, South Carolina. January, 2015.

Clark, et al., 1999a. Clark, S.H.B., Gray, K.J., and Back, J.M., 1999. Geology of the Barite Hill Gold-Silver Deposit in the Southern Carolina Slate Belt. Economic Geology, vol. 94, pp. 1329-1346. 1999.

Clark, et al., 1999b. Clark, S.H.B., Gray, K.J., and Back, J.M., Geologic Maps and Block Diagrams of the Barite Hill Gold-Silver Deposit and Vicinity, South Carolina and Georgia. U.S. Geological Survey Open-File Report 99-148A. 1999.

EPA, 2007. U.S. Environmental Protection Agency, Request for a Removal Action Ceiling Increase and an Exemption from the 12-Month and $2 Million Statutory Limits at the Barite Hill Mine Site, McCormick, McCormick County, South Carolina. Action Memorandum from Leo Francendese (On-Scene Coordinator) thru Shane Hitchcock (Chief, Emergency Response & Removal Branch) to Franklin Hill (Director, Superfund Division). September 19, 2007.

EPA, 2012. U.S. Environmental Protection Agency, Aerial Photographic Analyses of Barite Hill/Nevada Goldfields Site, McCormick, South Carolina, Volumes 1 and 2. Center of Environmental Computing, Office of Technology Operations & Planning, Office of Environmental Information, TS-OEI-21104013S. July, 2012.

Escobar, B. and I. Godoy. 1999. Determination of sulfur- and iron- oxidation bacteria by the most probable number technique. ***In***: Biohydrometallurgy and the Environment Toward the Mining of the 21st Century, Part A, Bioleaching, Microbiology. Proceedings of the International Biohydrometallurgy Symposium IBS'99, Amils, R. and A. Ballester (Eds.), Elsevier, Amsterdam, p. 681-687.

Gobla, M., 2007. Site Features Inventory Report, Barite Hill Mine, McCormick, South Carolina. U.S. Bureau of Reclamation, Technical Service Center. July, 2007.

HACH Company, 2013. Bacteria, sulfate-reducing. Visual determination, semi-quantitative. DOC 316.53.01326, Edition 2, July 2013.

Harrington, J., Gobla, M., Francendese, L., and Bates, E., 2009 (draft). Low Cost Treatment of a Highly Contaminated Pit Lake using Innovative Technology, Barite Hill Mine, McCormick, SC.

Jin, S. e*t al*., 2008a. Biological source treatment of acid mine drainage using microbial and substrate amendments: microcosm studies. *Mine Water Environ*. 27: 20-30.

Jin, S. *et al*. 2008b. Source treatment of acid mine drainage at a backfilled coal mine using remote sensing and biogeochemistry. *Water Air Soil Pollut*. 188: 205-212.

Jin, S. et al. 2012. Treatment and prevention systems for acid mine drainage and halogenated contaminants. US 8,105,489 (January 31, 2012).

Kleinmann, R.L.P. et. al., Full-scale field trials of a bactericidal treatment to control acid mine drainage, University of Kentucky Off. Eng. Serv. November 1, 1982

Kleinmann, R. L. P., D. A. Crerar, and R. R. Pacelli. The Biogeochemistry of Acid Mine Drainage and a Method to Control Acid Mine Drainage. Mining Engineering, v. 33, 1980, pp. 300-306.

Nevada Goldfields, Inc., 1993a. Final Mine Plan for Barite Hill Project. Letter report from Richard Dye, Nevada Goldfields to Craig Kennedy, Mining and Reclamation Division, South Carolina Land Resources Conservation Commission. August 27, 1993.

Onysko, S.J., R.L.P. Kleinmann and P.M. Erickson. 1984. Ferrous iron oxidation by *Thiobacillus ferrooxidans*: inhibition with benzoic acid, sorbic acid and sodium lauryl sulfate. Applied and Environmental Microbiology 28 (1).

Pardee, J. T., and Park, C. F., Jr., 1948, Gold deposits of the southern Piedmont: U.S. Geol. Survey Prof. Paper 213, 156 p.

OTIE, 2009. Oneida Total Integrated Enterprises, Surface Water Sampling Letter Report, EPA Barite Hills Nevada Goldfields Site, McCormick, McCormick County, South Carolina. Contract No. EP-W-05-053, Technical Direction Document (TDD) No.: TNA-05-003-0049, 43pp. July 16, 2009.

OTIE, 2012. Oneida Total Integrated Enterprises, Surface Water Sampling Letter Report, EPA Barite Hills / Nevada Goldfields Site, McCormick County, South Carolina. Contract No. EP-W-05-053, TDD No.: TNA-05-001-0042, 4 pp. plus attachments. October 9, 2012.

Plocus, V. G. and V. Rastogi. 1997. Geophysical Mapping and Subsurface Injection for Treatment of Post-Reclamation Acid Drainage. Proceedings American Society for Surface Mining and Reclamation, 1997. pp 34-42.

SCDHEC, 2006. South Carolina Department of Health and Environmental Control. PA/SI Report for Barite Hills/Nevada Gold Fields (Barite Hills). Prepared by the Site Assessment Section, Bureau of Land and Waste Management. December 2006.

Schrenk, M.O., K.J. Edwards, R.M. Goodman, R.J. Hamers, and J.F. Banfield. 1998. Distribution of *thiobacillus ferrooxidans* and *leptospirillum ferrooxidans*: implications for generation of acid mine drainage. Science 279(5356): 1519-1522. http://dx.doi.org/10.1126/science.279.5356.1519.

Sovereign, 2017. Sampling and Analysis Plan (SAP) for Tier 1 – Remedy Screening [Proof of Principal (POP) Testing]. November 8, 2017.

Sovereign, 2017. Sampling and Analysis Plan (SAP). September 29, 2017.

Sovereign 2017. Treatability Study Work Plan for Tier 1 – Remedy Screening [Proof of Principal (POP) Testing]. October 25, 2017.

Wildeman, T.R., G. Brodie, and J. Gusek, 1993. Wetland Design for Mining Operations, BiTech Publishers, LTD., Richmond, B.C., Canada, ISBN 0 021095 27 9.

APPENDIX A
STANDARD OPERATING PROCEDURE

A-1 Initial Qualitative (Beaker) Screening

A-2 Sieving vs Agglomeration

A-3 Utilization Testing Using Amended USBM Method

A-4 Source Control Treatment Testing - Waste Rock

A-5 Pit Lake Floor Encapsulation – Coating Evaluation & Falling Head Test

A-6 Pit Water Treatment – Titration & Sulfate Reduction Bench

Appendix A-1 - Initial Qualitative (Visual) Screening -Beaker Tests

1. Introduction

This section presents the procedure for the Initial Qualitative Screening – Beaker tests

2. Method

2.1 Material

Commercial plastic cups were used as beakers (89 and 532 ml). The bottoms of the cups were perforated to allow solutions to drain.

2.2 Sample Collection

Waste rock material was visually screened for pyritic rocks and the rocks were observed under a digital microscope. In addition, approximately 100 grams of fines were collected and distilled water was added to segregate the pyritic particles. The sample was then visually inspected and observed under the microscope to confirm that the fines contain pyrite (Figure A-1).

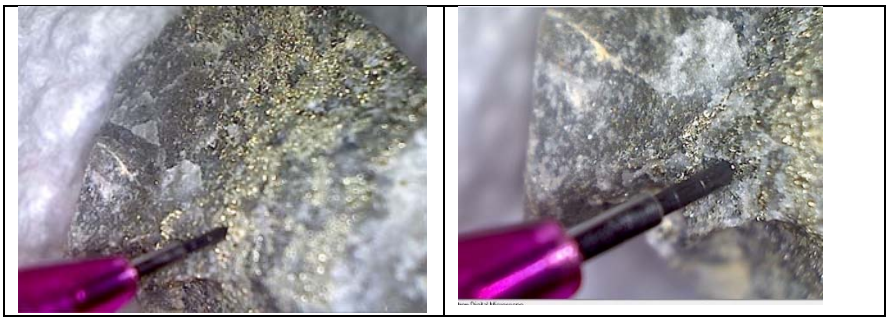

Figure A-1. Photo of the Material Observed under the Microscope

Seven 100 gram waste rock samples were weighed and placed in 89ml plastic cups (beakers) with perforated bottoms. The samples included mostly fines, big rocks were removed manually. One-500 grams of sample was placed in a 532ml plastic cup/beaker, including coarse rock fragments. See Figure A-2 for a comparison of the coarse rock size versus the fine-grained material.

Figure A-2. Photo of the Material Collected: Coarse vs Fines

2.3 Amendments Solution Preparation

A 2% solution of Sodium Lauryl Sulfate (SLS) was prepared by adding 2 grams of powdered SLS to 100 ml of distilled water and stirred.

A 5% milk solution was prepared by adding 1.44 grams of powdered full-strength milk to 300 ml of distilled water. A 25% milk solution was prepared by adding 3.8 grams of powdered full-strength milk to the remaining of the 5% milk solution (200 ml).

Two grams of sodium bicarbonate was weighed and dissolved in 40 ml of distilled water. Two grams of powdered limestone was weighed and set aside.

2.4 Amendments Addition

First, the amendment solutions where added to determine the initial sample moisture holding capacity (MHC) without exhibiting gravity drainage. Subsequently, 10 ml of the respective amendment solutions were added with a 10-ml syringe to their respective beaker sample. The powdered limestone was added on top of the dry sample and distilled water was added to satisfy the initial sample MHC and then 10 ml more of distilled water were added (Figure A-3).

Distilled water was also added to one of the samples (#3) in the same way as the other solutions, and used as a control.

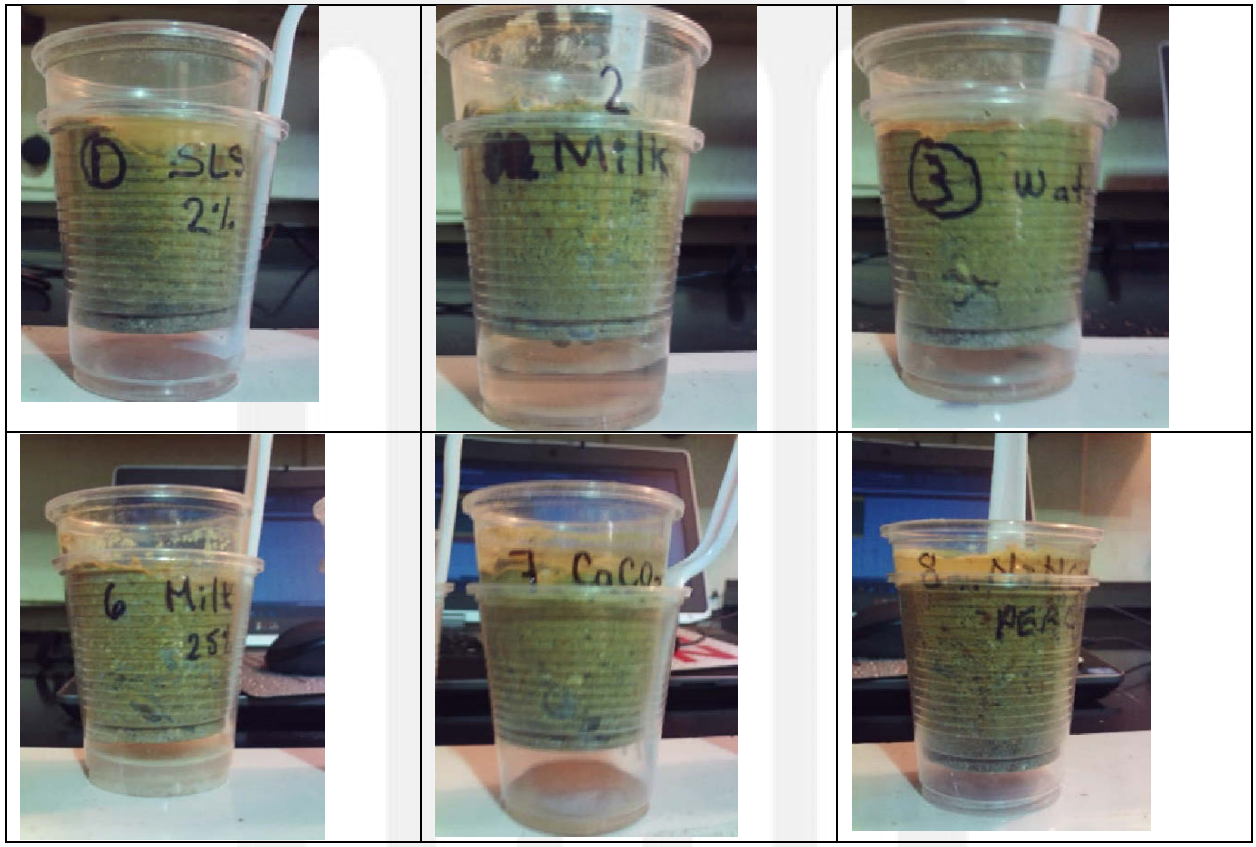

Figure A-3. Beakers with their Respective Amendments Added

2.5 Field Parameters Testing

The field parameters that were measured were:

- Initial sample MHC
- Volume of effluent
- pH
- Conductivity

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Scoping Tests Summary: Sieving vs. Agglomeration

Appendix A-2 – Sieving vs Agglomeration

28 December 2017

`**DRAFT**

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1. Objective

The primary objective of the current set of beaker tests was assessment of fine particle mobility with subsequent potential for bed clogging in the 20-kg reactors and, if possible, conducting a falling head test. Ancillary solution data were also captured. Here, crushed Barite Hill solids feed, sieved solids feed or agglomerated feed samples were subjected to various wetting sequences and the migration of particles quantified. This was an attempt to reach a decision point as to how, if at all, to further prepare the solids feed for use in the larger reactors. Fine particle migration with subsequent bed and line clogging are issues of concern for the larger reactors, which are scheduled to operate with periodic wetting over a period of four months.

2. Materials and Methods

2a. Test solutions.

1) Distilled water
2) 5% full strength milk (from powder)
3) 5% $NaHCO_3$
4) CaO (1.0 g / 1000 mL)
5) Tap water

2b. Solids preparations

1. Crushed feed, as provided by RDI
2. Crushed feed, with minus 50 mesh fraction rejected
3. Crushed feed, as provided by RDI, agglomerated with distilled water

The test system consisted of plastic vessels (532 mL) with pre-drilled drainage holes.

Solids in a five gallon plastic bucket were gently tumble mixed on a Dayton bottle roller to distribute particles evenly. Representative charges of solids were removed from this bulk sample. Four vessels were each charged with approximately 600 g of each solids type, as described in Section 2b, for a total of twelve tests.

Phase 1. The first series of tests involved adding 100 mL of one of four liquid amendments (Section 2a) by pipet in a top-down fashion to simulate unsaturated conditions. Each set included addition of either distilled water, dilute milk, sodium bicarbonate solution or CaO slurry. Drainage characteristics were noted by simple observation. After overnight drainage, effluent volume, pH and conductivity were measured. Effluent solids were recovered on

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Whatman #1 paper, dried at 103-105 C and weighed. Photographic records were also collected.

Phase 2. In addition to initial drainage characteristics, stability of the bed in transition or saturated environments was of interest, especially in regards to use of agglomerated material. To this end, these same vessels were placed in individual secondary containment vessels and slowly flooded with tap water. The vessels remained flooded for one day (>24 h). Afterward, tap water was slowly withdrawn in 50 mL volumes for a total of at least 250 mL per reservoir per effort and the beds allowed to gravity drain. Following an additional 24 h to completely drain, the beds were again slowly flooded in a top-down fashion, but with 100 mL distilled water. Effluent solution chemistry was not monitored as in Phase 1. The extent of fine particle loss was determined as described above.

The agglomerate approach appears to be a viable option. Stability over 120 days cannot be estimated from these scoping tests. However, this combined with biofilm development may further stabilize the agglomerates.

Note:

Text from this Solfatara report was abstracted for inclusion in Appendix E.

Appendix A-3
SCREENING PROCEDURE FOR THE CONSUMPTION OF BACTERICIDES AND DAIRY AMENDMENTS

Portions excerpted from Kleinmann and Erickson, USBM RI 8847, 1983. (MODIFIED)

Bactericide (SLS) Consumption Screening Procedure

Background - If, based on general visual and analytical considerations, the site or material appears appropriate for the surfactant treatment (i.e., un-oxidized pyrite is present), the obvious question is how much surfactant is required. The concentrations needed to kill *Acidothiobacillus ferrooxidans* in small volumes of pyritic mine waste are quite low (25 to 40 mg/L). Applying surfactant at these concentrations would only be partially effective at an actual mine site because it would fail to reach most of the oxidizing pyrite at the strength required. This is partially due to the degradation of the surfactant by the residual acidity in the waste, probable adsorption to mineral surfaces and other factors. Consequently, it is necessary to determine the "degradation" or sorptive capacity (consumption) of the material being treated and to compensate for those factors with either extra surfactant or an additive that can improve the effective distribution (such as pre-wetting or a buffering reagent to neutralize the acidity).

USBM Method – This is a fairly simple laboratory procedure that was developed to provide an estimate of adsorption potential for overburden and mine waste for surfactant applications. A representative sample of the material to be treated is placed in a large, tared Buchner funnel, tamped to a uniform depth of 2 in, and weighed. A surfactant, such as SLS, is applied evenly over the material at approximate loads of 60 mg SLS/kg of mine waste. Typical SLS concentrations range from 300 to 30,000 mg/L and are selected on the basis of the anticipated infiltration rate and the field capacity volume of the sample mass.

The primary goal of this screening test is to determine SLS consumption by adding a precise amount of SLS to a sample of mine waste and then rinsing the sample until all available or unused SLS is recovered. The amount of initial SLS added (in mg) will be a function of the dry sample mass, its field capacity, and the desired initial unit SLS content (baseline is 60 mg SLS/kg waste). For Barite, concentrations of 60mg/kg, 90 mg/kg, 120 mg/kg and 180 mg/kg were evaluated, with the 90 mg/kg loading evaluated with dry material and material pre-moistened to field capacity prior to addition of SLS. In the USMB method the rinsed SLS concentration was determined for every 200ml collected. In the Barite tests, 100 mL volumes were collected instead. For the modified test used for this project a **Baseline Solution Application Worksheet** (in Excel) has been developed for this purpose that can quickly be used to approximation of concentration of remaining SLS by setting up comparison "standards" for volume and decay time of foam produced and conductivity.

Modified Method - If the dry sample receives the field capacity volume that is infused with SLS, it is safe to assume that all the initial SLS it receives is retained within the sample until the first rinsing volume is delivered. Note: the rinsing volume should be equal to or greater than the field capacity volume for the sample mass.

After the surfactant application, the top section of a second funnel or a perforated plate is fitted onto the packed funnel to allow even distribution of a distilled water rinse. Tests here were typically run using the

clear perforated plate method as it allowed the operator to monitor surface accumulation of solution and avoid spillage.

The rinse solution was applied in sequential 100 mL aliquots through plastic tubing from a distilled water reservoir. The application rate was adjusted to balance influent and effluent flow rates; in relatively impermeable samples, inundation is unavoidable and effluent flow rates can be as slow as 100 mL/h. Rinse effluent was collected in 100-mL fractions until no sudsing was observed on shaking.

SLS Concentration Standard Development - For rapid Tier 1 testing of relative SLS consumption, sets of up to seven standard solutions of SLS were prepared, as outlined in Table A.

100 mL of each SLS standard solution will be subjected to rapid and vigorous mixing in a high speed magnetic stirrer or similar device to generate foam as a means of objectively and consistently assessing sudsing. In this test series, a high speed blender was used for timed mixing at a standard power setting. The stirring time and stirring speed will be held constant for this standardization step. Foam volumes from each standard solution will be measured to the nearest 25 mL in a graduated container and Table 1 below will be generated. As the SLS concentration falls, the time required for the foam to decay to the original 100 mL of standard solution will decrease as well. This foam decay time data was also observed and recorded to the nearest minute. From experience, the variations in foam decay time will be more indicative of SLS concentration than foam volume. Both foam decay time and foam volume were examined for possible use as standard markers.

Conductivity of the SLS solutions was also recorded for one set of standards to evaluate its ability to be used as a standard for SLS concentration.

Table A – SLS Concentration Standards Development

SLS Concentration	Foam Volume (mL)	Time for 100 mL liquid to reform (min.)	Specific Conductance (µS)
2%			
1%			
0.5%			
0.1%			
0.05%			
0.025%			
0.01%			

Other standard solutions may be prepared as needed.

Field Capacity Test

The field capacity needs to be calculated to estimate the volume of SLS solution that will be applied to saturate the waste rock initially. Overshooting the field capacity by 10 – 20% may be necessary to ensure good uniform saturation of the solution in the 2 inches of media but overshooting significantly will reduce the accuracy of the mass balance calculation for amount “consumed”

1) Place about 1,200 grams of waste rock into a microwavable container - Weigh _____ g
2) Dry in oven or microwave (no more than 5 min intervals on 20% power) Weigh_____ g
    a. Repeat drying step until weight is constant – record _____ g (dry mass)
3) Calculate water loss [(2) - (4)] = _____ g
4) Calculate moisture content (water loss/dry solids) [(3) / (2a)] = ____-%

Modified USBM Method

5) Weigh empty Buchner funnel and qualitative filter paper_____ g Mark 2" line above filter level.
6) Place/tamp 2" of dry sample in Buchner funnel on top of filter paper (position the funnel in a 1,000 mL beaker so it is stable
7) Weigh filter + solids = _____ g
8) Add 500 mL of distilled water, cover filter to minimize evaporation and wait about 2 hours for the water to bleed through
9) Measure vol. or mass of water bled-through + any water remaining on top (decant off) _____ mL or _____g; measure pH___ and conductivity _____.
10) Weigh funnel + solids + retained water _____g
11) Calculate mass and volume of water retained [(10) – (7)] = _____g = ml; compare to calculated water retained _____ [500ml – (9)] = _____ ml.
12) Calculate mass of dry solids [(7) - (5)] = _____ g
13) Calculate field capacity (mass water / mass dry soil) [(11) / (12)] = _____ %

Relative Hydraulic Conductivity Evaluation

The relative hydraulic conductivity test helps to provide a comparison between different solutions used in this testing and evaluate the extent of plugging that may occur. Because of the minimal capacity of the Buchner filters the solid sample size must be reduced to leave space for solution on top of the solids.

1) Measure the depth above the filter surface in the Buchner funnel (about 65 mm)
2) Place/tamp 500 g of dry solids in a Buchner funnel on top of a qualitative filter paper About 2 – 2.5 cm) and measure depth of the solids _____ mm
3) Measure 100 ml of the test solution and quickly pour into Buchner funnel. Note/mark solution level from lip of funnel ____mm, and start time _____.
4) Note when solution has effectively penetrated (gone).time:_____
    a. If the permeability is very slow note the solution level every every 15 minutes until gone
        i. 15 min _____mm
        ii. 30 min _____mm
        iii. 45 min _____mm
5) Calculate saturated hydraulic conductivity (K) _____ mm/min then / 60,000 = _____ m/s

Results Table – Relative Hydraulic Conductivity

Solution	Distilled Water	SLS solution	Milk Soln	Sodium bicarbonate sol'n	Limestone slurry	Limestone slurry, overnight
% soln	0.0%	2%	0.55% w/v	2.5 w/v	2.44 % w/v	2.44 % w/v
Hyd Cond. (m/s)						

SLS Consumption Tests

Four tests are planned to evaluate the SLS degradation or sorptive capacity of the waste rock using SLS alone and SLS with three different concentrations of $NaHCO_3$. Concentrations to be determined from the beaker tests.

For each test:

- A representative sample of (dry) waste rock was placed in a large Buchner funnel and tamped uniformly to a depth of 2 in. This was slightly modified in that the solids were agglomerated prior to placing in the Buchner funnel.
- Mass of the funnel and funnel + solids was recorded
- A solution of SLS is prepared and applied evenly over the material at a volume approximated by the field capacity. (The SLS concentration is initially established using 60 mg SLS/kg waste as the goal and then adjusted if needed during the test.)
- Mass of the funnel + solids + retained solution was recorded along with the volume of solution applied and recovered.
- 100 ml of rinse water was then applied over the material and recovered. The resulting solution is then
    - Measured for volume, pH, and conductivity
    - Run through a foaming test for estimation of remaining SLS concentration (using the same methods that were used for establishing the standards)
    - Retained for combining with all recovered water samples

Foaming Test Evaluation Process

If the no sudsing is observed after a single rinse, the initial SLS mass was considered fully consumed and the test needs to be repeated (using a fresh, dry sample) with a higher initial SLS content.

In contrast, if a full liter of rinsing solution produces sudsing, one can infer that the initial SLS content was too high and the test needs to be repeated (using a fresh dry sample) with a significantly lower initial SLS content.

In this way, the initial “target” SLS content which still yields sudsing can be bracketed. It is assumed that a solution that sudses will still contain enough SLS to provide bactericide characteristics. This will be evaluated during the initial SLS standard development step.

Once a successful SLS concentration has been bracketed (sudsing is observed after the first rinse but not after the 10th rinse) then combined volume of recovered solution/rinsate will be mixed and a sample submitted for anionic surfactants analysis (concentration) by the methylene blue technique (MBAS).

Pre-Wetting Test

To assess the effects of initial moisture content, the test was repeated with the solids sample pre-wetted to its field capacity prior to delivering the SLS solution. The subsequent recovered solution was also composited and submitted for analysis by the methylene blue technique.

Data Tables

Table 1A – SLS Consumption Test Set-up and SLS Application Data

Modified USBM Method

Parameter	Initial Test	Re-adjusted SLS conc. (if needed)	Re-adjusted SLS conc (if needed)	Pre-Wetting Test
Test Unit Number				
SLS % solution				
Test Date				
Test Start Time				
Test Person (initials)				
Mass Funnel (F)				
Mass F+Solids (S)				
Vol pre-wet water applied				
Vol SLS soln applied				
Vol SLS soln recovered				
Mass F+S+retained SLS soln				
Selected for methylene blue				

Tables 1B – Sample Rinsing Data Sheets – SLS only

Test Unit Number:		**SLS Conc:**		**Test Date:**		**Start Time:**		
Rinse #	**Rinse volume (ml)**	**Recovered volume (ml)**	**pH**	**Cond. (mS/cm)**	**Foam Volume (mL)**	**Decay time (min.)**	**Est. SLS Conc (mg/L)**	**Est. SLS mass (mg)**
1	100 mL							
2	100 mL							
3								
4								
5								
6								
7								
8								
9								
10								
TOTAL								

For subsequent SLS concentration adjustment tests and/or Pre-wetting test

Test Unit Number:		**SLS Conc:**		**Test Date:**		**Start Time:**		
Rinse #	**Rinse volume (ml)**	**Recovered volume (ml)**	**pH**	**Cond. (mS/cm)**	**Foam Volume (mL)**	**Decay time (min.)**	**Est. SLS Conc (mg/L)**	**Est. SLS mass (mg)**
1	100 mL							
2	100 mL							
3								
4								
5								
6								
7								
8								
9								

10								
TOTAL								

For subsequent SLS concentration adjustment tests and/or Pre-wetting test – use add'l pages as needed

Test Unit Number:		**SLS Conc:**		**Test Date:**		**Start Time:**		
Rinse #	**Rinse volume (ml)**	**Recovered volume (ml)**	**pH**	**Cond. (mS/cm)**	**Foam Volume (mL)**	**Decay time (min.)**	**Est. SLS Conc (mg/L)**	**Est. SLS mass (mg)**
1	100 mL							
2	100 mL							
3								
4								
5								
6								
7								
8								
9								
10								
TOTAL								

Set Up for SLS + Baking Soda ($NaHCO_3$) tests

SLS degradation is calculated as the difference between the mass of SLS applied to the sample and that eluted and it will be recorded as milligrams of SLS consumed per kilogram of sample. Alternatively, degradation can be reported as pounds SLS per acre inch, calculated from the known funnel area and sample thickness. The laboratory test provides only a relative measure of degradation capacity since field conditions are not duplicated.

Once the degradation mass is estimated, a second round of baking soda ($NaHCO_3$) buffered SLS solution applications to three duplicate samples of mine waste will be conducted.

A fundamental protocol difference between USBM1 and USBM2 was that the waste rock solids were not agglomerated prior to the test on order to ensure maximum solution/solids contact.

In this testing step, a series of buffered SLS solutions wasl prepared in accordance with the findings of previously-conducted beaker tests from which the concentration of baking soda required to neutralize the stored acidity in the mine waste to pH 7 will have been determined.

Foaming/sudsing tests wwere conducted on rinsates from three identical dry waste rock samples exposed to three concentrations of baking soda with SLS concentration held constant (at say 2X the "degradation loss concentration" as determined above). The data in Tables 3 to 5 were entered and the final rinsate samples submitted for methylene blue testing for confirmation.

The pre-wetting test was not conducted for these three test units

Data Tables

Table 2A, 3A, 4A – SLS Consumption Test Set-up and SLS + $NaHCO_3$ Application Data

Parameter	Initial Test	Re-adjusted SLS conc. (if needed)	Re-adjusted SLS conc (if needed)
Test Unit Number			
SLS % solution			
$NAHCO_3$ (mg/l)			
Test Person (initials)			
Test Date			
Test Start Time			
Mass Funnel (F)			
Mass F+Solids (S)			
Vol pre-wet water applied			
Vol SLS soln applied			
Vol SLS soln recovered			
Mass F+S+retained SLS soln			
Selected for methylene blue			

Table 2B, 3B, 4B – Sample Rinsing Data Sheets – SLS + $NaHCO_3$

Unit Number:		SLS %:	NaHCO3 (mg/l)		Test Date:		Start Time:	
Rinse #	**Rinse volume (ml)**	**Recovered volume (ml)**	**pH**	**Cond. (mS/cm)**	**Foam Volume (mL)**	**Decay time (min.)**	**Est. SLS Conc (mg/L)**	**Est. SLS mass (mg)**
1	100 mL							
2	100 mL							
3								
4								
5								
6								
7								
8								
9								
10								
TOTAL								

For subsequent SLS concentration adjustment tests and/or Pre-wetting test

Unit Number:		SLS %:	NaHCO3 (mg/l)		Test Date:		Start Time:	
Rinse #	**Rinse volume (ml)**	**Recovered volume (ml)**	**pH**	**Cond. (mS/cm)**	**Foam Volume (mL)**	**Decay time (min.)**	**Est. SLS Conc (mg/L)**	**Est. SLS mass (mg)**
1	100 mL							
2	100 mL							
3								
4								

5								
6								
7								
8								
9								
10								
TOTAL								

For subsequent SLS concentration adjustment tests and/or Pre-wetting test – use add'l pages as needed

Unit Number:		**SLS %:**	**NaHCO3 (mg/l)**		**Test Date:**		**Start Time:**	
Rinse #	**Rinse volume (ml)**	**Recovered volume (ml)**	**pH**	**Cond. (mS/cm)**	**Foam Volume (mL)**	**Decay time (min.)**	**Est. SLS Conc (mg/L)**	**Est. SLS mass (mg)**
1	100 mL							
2	100 mL							
3								
4								
5								
6								
7								
8								
9								
10								
TOTAL								

The data from this phase of the testing will be used to determine the reagent concentrations that will be used in the subsequent tests.

Equipment & Materials

- 15 kg of mine waste
- SLS powder (200 grams or as needed)
- Baking soda (200 grams or as needed)
- Magnetic stirrer
- 500 mL graduated cylinder (foam volumes)
- Balance (1kg cap.)
- pH & conductivity probes
- 4 each large Buchner funnels
- 8 each 1 liter bottles (for std SLS solutions)
- 10 each 250 mL beakers (for SLS make-up, rinsate collection)
- 1 each bucket for combining all recovered (pass through) solutions
- 5 each sample bottles for methylene blue testing
- DI water (4 liter reservoir)
-

Milk Consumption Protocol

Background - Exposing milk (a colloidal suspension of casein, whey proteins, and lactose) to acidic, pyrite-bearing mine waste should result in the separation of curds and whey. The "consumption" of curds is expected to be proportional to the micro-encapsulation of exposed pyrite grain surfaces in the unsaturated mine waste, creating an anaerobic microenvironment for desired microbial activities. This encapsulating layer has been proven to provide a substrate for heterotrophic microbes to out-compete *Acidothiobacillus ferrooxidans* under saturated conditions. It may also work in unsaturated conditions.

Milk Relative Hydraulic Conductivity and "Consumption" Tests
The following protocol can be used or modified as needed to quantitatively estimate how milk behaves when exposed to acidic mine waste.

1) Prepared 200 mL of non-fat milk using powdered milk: 190 mL tap water + 19.3 grams powdered milk – this can also be diluted to a lesser strength _____%
   _____ mL tap water + _____ grams powdered milk
2) Ran the Relative Hydraulic Conductivity test with the milk solution. It was very important to record the solution level over time with milk because it is expected to cause plugging (curds). The change in Hyd. Cond. over time will be calculated to evaluate results
   a. Wait until all the milk solution bleeds through sample into beaker; if it doesn't, (in 2 hrs) stop the test – sample is plugged with curds. Note time _____ hrs level____mm
3) Collect bleed through solution, measure volume (A) ____ cm and pH _____. Retain separately.
4) If all the milk has bled through add another 100ml of milk solution and record level over time again
   a. 15:00 _____cm
   b. 30:00 _____cm
   c. 45:00 _____cm
   d. 60:00 _____cm
   e. Wait until all the milk solution bleeds through sample into beaker; if it doesn't, (in 2 hrs) stop the test – sample is plugged with curds. Note time _____ hrs level____mm
5) Collect bleed through solution, measure volume (B) ____ cm and pH _____.
6) If the pH of the bleed through is <4.5 (curds should still form)
   a. Repeat with another 100ml of milk solution. Tests C and D (then stop)
7) Calculate relative hydraulic conductivity (K) for each 100 ml test
   a. _____ m/s
   b. _____ m/s
   c. _____ m/s
   d. _____ m/s
8) Placed 20ml of bleed through solution form each test in to separate 25 mL tip sealed and inverted plastic syringes. Added 20 drops of hydrochloric acid to each; waited four hours and measured amount of curds (solid white) and whey (cloudy solution)
   a. _____ mL curds ____ mL whey
   b. _____ mL curds ____ mL whey

c. _____ mL curds ____ mL whey
d. _____ mL curds ____ mL whey

9) Repeated with additional acid.
10) Compare values with **"baseline"** non-fat milk **11 mL curds**; **12 ml whey**.
11) Proportionally estimate remaining "unreacted" milk from the original milk volume
    a. _____ g
12) Optional - rinse the sample with deionized water to determine if milk proteins (which are soluble at neutral pH) can be mobilized.

Equipment & Materials

- 0.5 kg mine waste
- Microwave oven
- 2 each 250 mL glass beakers
- pH meter
- Buchner funnel & paper filter
- Balance (1kg cap.)
- Ruler (cm)
- Clock
- Muriatic acid (31% HCl)
- Powdered milk (100 grams)
- Tap water (500 mL or as needed)

Buffered Milk Consumption Protocol

In this test, the milk solution was be buffered with baking soda to determine if milk consumption could be reduced.

The same milk relative hydraulic conductivity and consumption protocol was followed except baking soda was added to the milk solution. Proportionally added enough baking soda to 100 mLs of non-fat milk to neutralize the stored acidity in the waste rock sample as determined in the beaker test screening. Followed the same protocol and compared the results

Examined impact of extra acid to neutralize added alkalinity to promote curdling. Examined impact of various curdling and settling times.

Equipment & Materials

- Same as non-buffer milk
- Baking soda (100 grams or as needed)

Appendix A-4 – Source Control Treatment Testing Procedure – Waste Rock Tests

1. Method

1.1 Cells Construction and Charging

Conventional 5-gallon plastic buckets with lids were used as reactor vessels. The vessel dimensions for height and width were, respectively, 36.2 cm (H) and 25.4 cm (W, bottom) to 28.6 cm (W, Top). Drainage plumbing was fabricated in-house from one-half inch PVC pipe that was modified by a drilled array of drainage holes (Figure A-4.1). Placement of the bottom plumbing array is illustrated in Figure A-4.2. The bottom array was the primary means of solution replacement and sample withdrawal. Various solids were weighed and loaded into the vessels. Pea gravel had been wet screened using a #8 mesh sieve to remove fines. A 3 kg layer of the washed pea gravel was added sufficient to cover and protect the bottom drainage array (Figure A-4.3). This was followed by a 1.0 kg drainage layer of sand. Void volume of the combined drainage layers was 0.995 L. Cumulative masses during assembly are summarized in Table A-4.1.

Figure A-4.1. Drainage Plumbing for 20 kg Vessels

Figure A-4.2. Bottom Drainage Plumbing Placement

Figure A-4.3. Washed Pea Gravel Drainage Layer

Solids Agglomeration. Barite solids for each test vessel were agglomerated as two separate 10.0 kg charges (Figure A-4.4). Distilled water was added (500 mL) by hand using spray bottles while the mass tumbled at low speed (setting 30, Dayton bottle roller, Dayton Electric Co., Chicago) for 3 min. Each agglomerated charge was added to the test vessel. Mass loadings are summarized below in Tables A-4.1 and A-4.2.

Figure A-4.4. Bottle Roller Agglomeration of 10 kg Charges of Waste Rock

Agglomerated solids were loaded into the vessels as 10 kg charges. The mid-bed drainage plumbing (Figure A-4.5) was placed and then covered directly by the second 10 kg charge (Figure A-4.6). Each reactor was covered (Figure A-4.7), with the taller exit pipe indicating the bottom array.

Figure A-4.5. POP Vessel Charged with 10 kg Waste Rock

Figure A-4.6. Addition of Second 10 kg Charge of Agglomerated Solids

Figure A-4.7. Covered 20-kg Charges in POP Vessel

Table A-4.1 Solids Loading During Assembly for 20 kg POP Tests

Test Cell	Mass Bucket + Plumbing, kg (A)	Mass, (A) + Pea Gravel, kg (B)	Mass, (B) + Sand , kg (C)	Mass, (C) + Barite Solids, kg
WRU-1	1.48	4.47	5.45	26.39
WRU-2	1.50	4.51	5.50	26.47
WRU-3	1.48	4.49	5.49	26.44
WRU-4	1.50	4.51	5.50	26.42
WRU-6[1]	1.50	4.52	5.52	26.67
WRT-1	1.49	4.49	5.49	26.45
WRT-2	1.49	4.49	5.50	26.46
WRT-3	1.50	4.49	5.51	26.48
WRT-4	1.49	4.50	5.51	26.47
WRS-1	1.51	4.51	5.51	26.46
WRS-2	1.52	4.52	5.52	25.66

[1] WRU-5 reactor vessel prepared but not used; [2] WRS-2 appeared to be 9.6% short on Barite solids

Table A-4.2. Net Solids Loadings of POP 20 Kg Test Vessels

Group	Vessel	Mass WR, kg	Agglom. Sol'n[b], L	Sand Bed, kg	Gravel Bed, kg	Calc. WR + Sol'n, kg
Unsaturated	WRU-1	20	1000	0.98	2.99	20.94
	WRU-2	20	1000	0.99	3.01	20.97
	WRU-3	20	1000	1.00	3.01	20.95
	WRU-4	20	1000	0.99	3.01	20.92
	WRU-6	20	1000	1.00	3.02	21.15
Transition	WRT-1	20	1000	1.00	3.00	20.96
	WRT-2	20	1000	1.01	3.00	20.96
	WRT-3	20	1000	1.02	2.99	20.97
	WRT-4	20	1000	1.01	3.01	20.96
Saturated	WRS-1	20	1000	1.00	3.00	20.95
	WRS-2	20	1000	1.00	3.00	20.14[a]

[a] WRS-2 was underweight with respect to waste rock (WR); b Agglomeration water added to two 10 kg batches of waste rock in two separate 0.5 L aliquots.

1.2 Solution Handling and Sampling

Eleven 20 kg test vessels were operated at room temperature which, over the course of the program (31 Jan.- 25 April) was 18.8 C ± 2.4 C. Amendment strategies are summarized below in Tables A-4.3, A-4.4 and A-4.5.

Tailored weekly rinsing strategies were conducted for each of the three groups – unsaturated, transition and saturated. However, all solution addition and removal was accomplished by means of a Masterflex peristaltic pump with 7518-10 heads, generally at 594 mL/min. A peristaltic pump was used for this purpose to produce non-turbulent flow during addition of leach solution to solids to avoid fines migration and possible reactor clogging (Figure A-4.8).

Figure A-4.8. Use of Peristaltic Pump to Flood / Drain Vessels

Anaerobic inoculum. All reactors amended with a carbon source (milk) were also inoculated with a mixed culture including anaerobic sulfate reducers. Carbon addition with the inoculum was considered insignificant. A 60 mL slurry was made with water, 21.5 g fresh horse manure and 0.12 g milk solids. To this mix was added 40 mL of active sulfate reducing bacteria from two positive BART systems (01/29/18). Aliquots of this suspension were added as follows: approximately 3000 mL of milk suspension was added to displace air in the relevant vessels. The culture was added directly to the fill tube. The remaining volume of milk suspension was then added. In the case of WRS-2, inoculum was added in a similar fashion, but over a period of weeks with each 1500 mL aliquot of milk suspension.

Unsaturated (WRU series). Measured volumes of distilled water were pumped in at the base of the solids mass with 0.61 cm I.D. Tygon runner tubing using a Masterflex peristaltic pump with 7518-10 heads. For the first rinse cycle, the application rate was 1187 mL/min, but that was reduced for all vessels to 594 mL/min after some resistance to flow was noted post-amendments. The solution was allowed to rise in level through the solids and to a volume sufficient to cover the surface of the bed. The leachate was immediately pumped out through the same orifice, slowly decreasing the solution level in the bed. Inflow and outflow volumes were monitored. Flushing volumes decreased from 5.8 liters to 4.0 liters by the third month of operation as the bed settled. Samples were collected for analysis on a weekly basis (pH, redox potential, conductivity, sulfate, odor/color, qualitative observation of precipitates and suspended particulates), with less frequent samples for a suite of elements by ICP and for microbial population estimates (anaerobic sulfate reducers or aerobic iron-oxidizers).

Transition (WRT series). Transition series reactors were intended to simulate periodic rising and falling of water levels such that pyritic surfaces were sometimes submerged while, at other times, drained and exposed to air while moist. In this case, the rinse solution was an artificial BH51 groundwater (AG). Please refer to Table A-4.3.6. Solution was pumped into the reactor as described above, but then allowed to remain undisturbed for one week, after which it was drained away. This was followed by a second one week cycle in which the solids would be in an “unsaturated” mode. Sampling was identical to that for the unsaturated series, except that the flood/drain weekly cycling produced only one-half the

number of water samples as the unsaturated series – samples were collected ~~on a bi-weekly basis~~ as part of each ~~flood~~ drain cycle.

Saturated (WRS series). The saturated (WRS) series was always, as the label implies, fully flooded. Here, 1500 mL of solution from WRS-1 and WRS-2 were removed weekly, sampled and adjusted in pH with small aliquots of $NaHCO_3$, as if the water phase were being deliberately replaced and modified, but within a time frame somewhat comparable to the natural groundwater flow and permeability rates. WRS-2 solution was also amended with a full charge of milk solids, but over a period of four weeks. Re-introduction or recycling of the leachate to the reactor was not done through the bottom port, but instead through the mid-bed port to simulate some extent of mixing. Subsamples for analysis were collected from leachate on a weekly basis, and the small lost sample volume replaced with fresh artificial groundwater (Table A-4.6). In the third month of operation, the entire 1500 mL volume was not recycled but instead replaced with fresh artificial groundwater (AG) to simulate gradual flushing.

Table A-4.3. Initial Amendment Loadings of POP 20 Kg Vessels

Group	Vessel	Distilled water, mL	Artificial GW, mL	$NaHCO_3$, g	SLS, g	Milk solids, g	Anaerobic Inoculum, mL
Unsaturated	WRU-1	5815		0	0	0	
	WRU-2	5815		195.2	5.36		
	WRU-3	5815				105.1	15.0
	WRU-4	5815		195.2		105.1	10.0
	WRU-6	5815		195.2	5.36		
Transition	WRT-1	5815		0	0	0	
	WRT-2	5815		195.2	5.36		
	WRT-3	5815				105.1	15.0
	WRT-4	5815		195.2		105.1	10.0
Saturated	WRS-1		5815	0	0	0	
	WRS-2		5815	0	0	0	

Table A-4.4. Secondary Amendment Loading of POP 20 Kg Vessels

Group	Vessel	Distilled water, mL	Artificial GW, mL	$NaHCO_3$, g	SLS, g	Milk solids, g	Anaerobic Inoculum, mL
Unsaturated	WRU-1						
	WRU-2						
	WRU-3						
	WRU-4						
	WRU-6	4565				105.1	10.0
Transition	WRT-1						
	WRT-2						
	WRT-3						
	WRT-4						
Saturated	WRS-1		1502	9.72	0	0	0
	WRS-2		1502	9.08	0	31.53	10.0

Table A-4.5. Subsequent Amendment Loading to Saturated WRS POP 20 Kg Vessels

Date	Program	Vessel	Artificial GW, mL	$NaHCO_3$, g[a]	SLS, g	Milk solids, g	Anaerobic Inoculum, mL
14 Feb. 2018	Week 3	WRS-1	1502	9.72	0	0	0
		WRS-2	1502	9.08	0	31.53	10.0
21 Feb.	Week 4	WRS-1	1500	5.62	0	0	0
		WRS-2	1500	3.66	0	31.53	5.0
28 Feb.	Week 5	WRS-1	1500	2.44	0	0	0
		WRS-2	1500	1.08	0	10.51	0
07 March	Week 6	WRS-1	1500	2.17	0	0	0
		WRS-2	1500	0.61	0	0	0
14 March	Week 7	WRS-1	1500	1.87	0	0	0
		WRS-2	1500	1.87	0	0	0

a WRS-1 -Total milk solids (0 g); Total $NaHCO_3$ (21.82 g); WRS-2- Total milk solids (105.1 g); Total $NaHCO_3$ (16.3 g)

Loadings as mol/kg WR. Based on the mass of waste rock in each test vessel and the amendment when added, vessels from each group received 2.42 mol C from the milk solids, or 0.121 mol C per kg WR. When added, sodium lauryl sulfate was added at 9.3 x 10-4 mol/kg WR. Sodium bicarbonate addition corresponded to 2.32 mol or 0.116 mol/kg. Cumulative bicarbonate addition to saturated reactors was, respectively, 0.017 and 0.014 mol/kg for WRS-1 and WRS-2.

Table A-4.6. Artificial Groundwater for POP 20 kg Test Transition and Saturated Test Cells (BH 51 Surrogate)

Compound	Grams or mL
$CaCl_2$*$2H_2O$	0.150
$MgSO_4$*$7H_2O$	0.101
$NaHCO_3$	0.095
Distilled H_2O	1000
11 N H_2SO_4	0.040
Target pH	6.05 – 6.10

1.3 Sampling and Analytical Methods

Two types of samples were collected: grab and total recoverable volume. Some samples presented issues of chemical instability and so grab samples at an intermediate collection point were sometimes used to assess oxidation/reduction potential (O.R.P.). Intermediate grab samples were also used to minimize the opportunity for microbial contamination prior to Most-Probable-Number (MPN) tests for acidophilic iron-oxidizers and BART tests for sulfate reducing (SRB) populations.

Weekly samples for unsaturated and saturated vessels and biweekly samples for transition vessels were collected and assessed for pH, oxidation-reduction potential, specific conductance, sulfate, odor/color, gross precipitates or fungal growth. Additional samples were collected intermittently for ICP-AES and growth dependent microbial characterization (MPNs). Photographic records were collected for each effluent sample during the course of the program.

Because of high alkalinity due to amendment addition, some initial samples for ICP-AES were stabilized by first centrifuging for 1 min at 12000 x g and then diluting a subsample of the supernatant in 2% HNO_3. However, subsequent samples were filtered through a Simsi or Advantec 25 mm MCE 0.45 µm syringe filter and acidified to 2% v/v HNO_3. Suite analysis was performed for each sample and included the following: aluminum (Al), arsenic (As), calcium (Ca), cadmium (Cd), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), lead (Pb) and zinc (Zn).

Appendix A-5 – Pit Lake Encapsulation Study – Coating Evaluation & Falling Head Test

1. Method

Surrogate (Artificial) Deep Pit Water

To better simulate the chemical environment at the bottom of the pit where the encapsulation would take place a surrogate pit water was "manufactured" to have very similar water chemistry to the deep pit water samples collected during the field work. Table A-5.1 provides the compounds that were blended to produce the surrogate water for the encapsulation consistency (tank) and effectiveness (permeability) testing.

Table A-5.1. Surrogate (Artificial) Deep Pit Water for Encapsulation Tests[d]

Target Element	Mean, mg/L[a]	Compound	Compound mg/L	Cumulative Sulfate, mg/L
Al	425	$Al_2(SO_4)_3*14H_2O$	4681	1513
Ca	283	$CaSO_4$	961	2191
Cu	167	$CuSO_4$	419	2444
Fe	1736	$FeSO_4*7H_2O$	8423	5430
K	14	KH_2PO_4	47	5430
Mg	210	$MgSO_4*7H_2O$	2125	6258
Mn	24	$MnSO_4$	66	6300
Na	61	$Na_2(SiO_2)_x$		6300
P	14	KH_2PO_4		6300
Zn	43	$ZnPO_4$	106	6363
Si[b]	47	$Na_2(SiO_2)_x$	82	6363
SO_4^{2-}-S[c]	2930	H_2SO_4	2465	8779

[a] based on average of Pit Deep T and Pit Deep F, CSM ICP analysis; [b] Si an estimate assuming x =1
[c] Sulfate was higher in actual tests as pH had to be decreased from target to ~pH 2.2 (0.015 N H_2SO_4) to maintain solubility and reduce turbidity; [d] Artificial deep water used for the effectiveness testing was 6.7% more concentrated than the listed concentrations.

Consistency Evaluation

A 20 gallon "aquarium" tank (approximately 25cm (w) x 50cm (l) x 35cm (h)) was used for the test vessel so that the characteristics of the media could be observed through the glass walls. A concave ramp was made (Figure A-5.1) that could measure the cling angle that the media could adhere to when applied (tremied) above the ramp. The ramp was pre-coated with sand using a spray adhesive to simulate a more natural surface and placed at one end of the tank (Figure A-5.2).

Figure A-5.1 Cling Angle Ramp and Bulk Caulk Gun

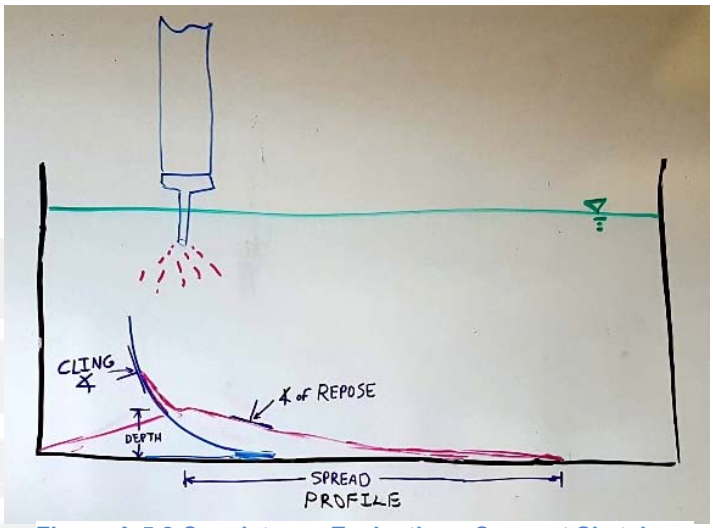

Figure A-5.2 Consistency Evaluation - Concept Sketch

The tank was then filled with 30 liters of surrogate deep pit lake water and the slurry to be applied was mixed (soil + water +/- bentonite) in a plastic bucket to a pumpable consistency (Figure A-5.3). Three different consistencies (moisture contents) were planned for use:

- Thick - Just wet enough to pump in a piston style grout pump
- Thin – Sufficient water added to be easily stirred and loaded into the grout pump
- Medium – In between thick and thin

Table A-5.2 below summarizes the mixes examined in this series.

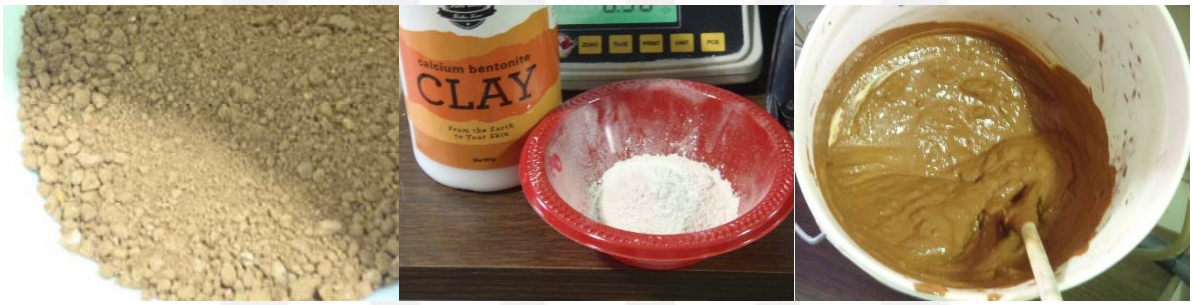

Figure A-5.3 Media Mix: Clayey Soil (larger pieces removed) + bentonite (if used) + water to form a "pumpable" slurry

The slurry was then placed in a bulk refillable caulk gun and tremied into the tank at one point above the ramp. After setting, the physical/slump behavior of the mixtures would be observed (spread, dispersion, consistency, settling, persistence…) at 7 hours and 20 hours (Figure A-5.4).

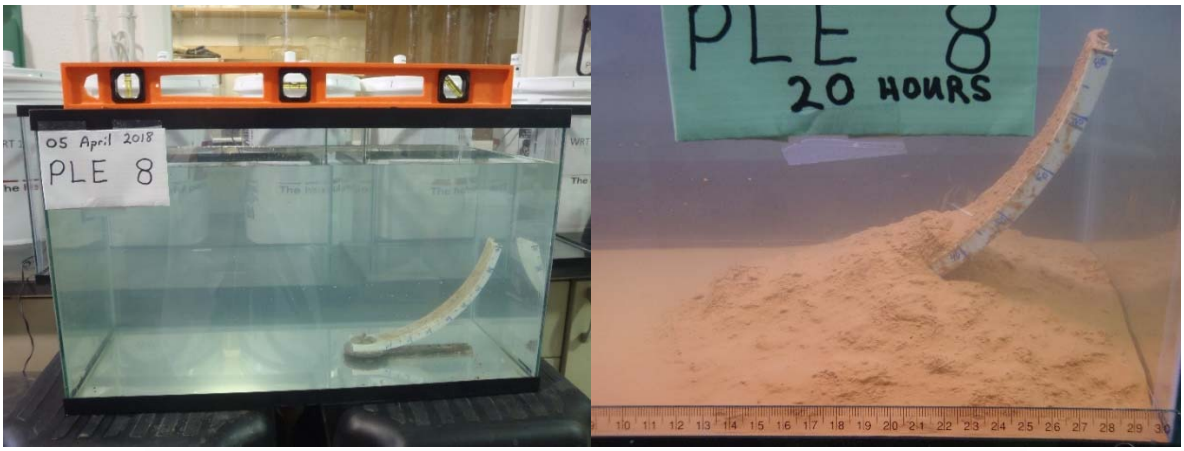

Figure A-5.4 Tank before and after media was applied and settled for 20 hours

The clay component required about 7 hours to settle effectively for observations (due to high turbidity). After about 5 hours the color changed from orange characterizing the clay particles to a lighter yellow (likely a result of colloidal Fe and Al oxy-hydroxides that can be present at pH 3.7). To remove most of the yellowish color sulfuric acid was added to adjust the tank pH to 2.2 (just sufficient to re-solubilize the colloids). This made it possible to take clear photographs of the ramp and settled clay. The acid addition did not appear to alter the media in any way. Photos were taken (straight-on) from the side and end views with clear measuring sticks in the frame to allow estimates to be made of slurry depths, spreading length, etc. (Figure A-5.5). Subsequent tests were done using surrogate water pre-adjusted to pH 2.2 prior to the start of the test.

Table A-5.2. Summary of Encapsulation Test Mixes

Test Designation	Clay Borrow, g	Ca Bentonite, g		AquaBlok, g	Water, mL
PLE 1	1000	0			350
PLE 2	968.8	31.2			350
PLE 3	Not done				
PLE 4	1000	0			500
PLE 5	968.8	31.2			500
PLE 6	Not done				
PLE 7	1000	0			560
PLE 8	968.8	31.2			560
PLE 9	922	78.0			560
PLE 10	950	50.0			560
PLE 11				1000	NA

One end of the tank was then raised to create a shear angle to test the media stability. For safety the tank could not be raised above an angle of about 10 degrees. This was done after the 7 and 20 hour settling durations.

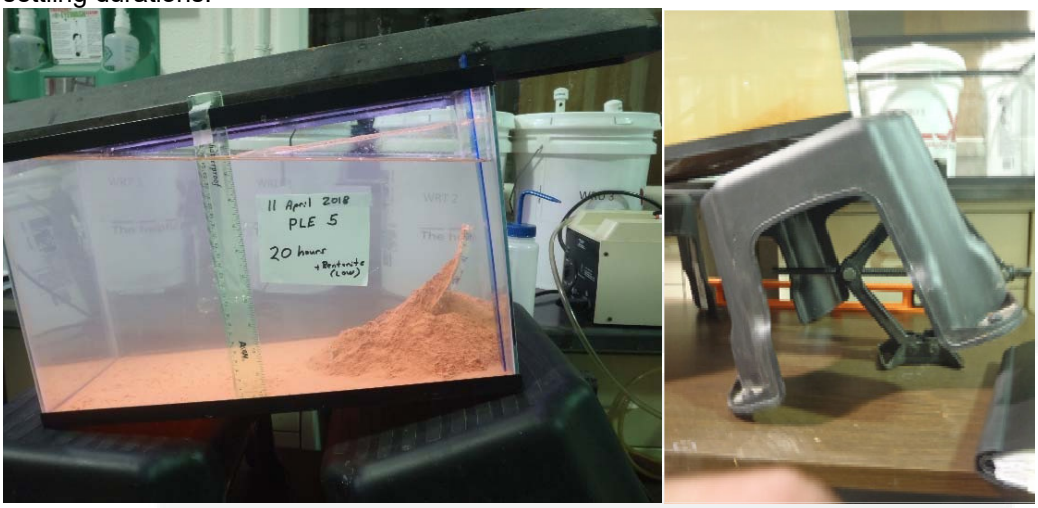

Figure A-5.5 Tipping of tank to test shear strength with car type jack used for tipping

The AquaBlock media was added dry – right out of the bucket – using a 600 mL beaker. This was in conjunction with the manufacture's recommended application instructions (dry from the water surface). Initially, it was planned to add the AquaBlock pellets using a funnel. However, a scoping test showed that the pellets hydrated so quickly that the funnel orifice clogged immediately. Hence, the pellets were applied to the surface of the water by decanting from a beaker.

<u>Falling Head Test - Encapsulation Effectiveness</u>

The best performing mixtures from the proof of principle testing were then used for the saturated hydraulic conductivity (falling head) test. The test consisted of a 5 gallon plastic bucket fitted with a low point side drain and a sealable lid with a vertical clear ½" schedule 40 PVC pipe for a water column. A concept sketch and a photo showing the setup of the six test units are illustrated in Figure A-5.6. Drainage sand (about 6 cm in depth) was placed on the bottom of the bucket and the bucket was filled with surrogate pit lake bottom water with the drain tube plugged (clamped). The media (about 3 inches) was then tremied into the bucket similar to the tank tests except it was spread evenly over the surface instead of applied at a single point. The lid was placed on the bucket (with vertical pipe installed) the void space in the bucket and column filled with water and the test allowed to rest for at least 24 hours. This allowed the media to settle and for the water pressure to equilibrate the plastic bucket. The drain was then opened and the falling head test started. The elevation of the water in the clear pipe was noted at the beginning and end of the test. The test was run over different time intervals, refilled and repeated for verification of the permeability data. A total of 20 determinations were made for six falling head tests.

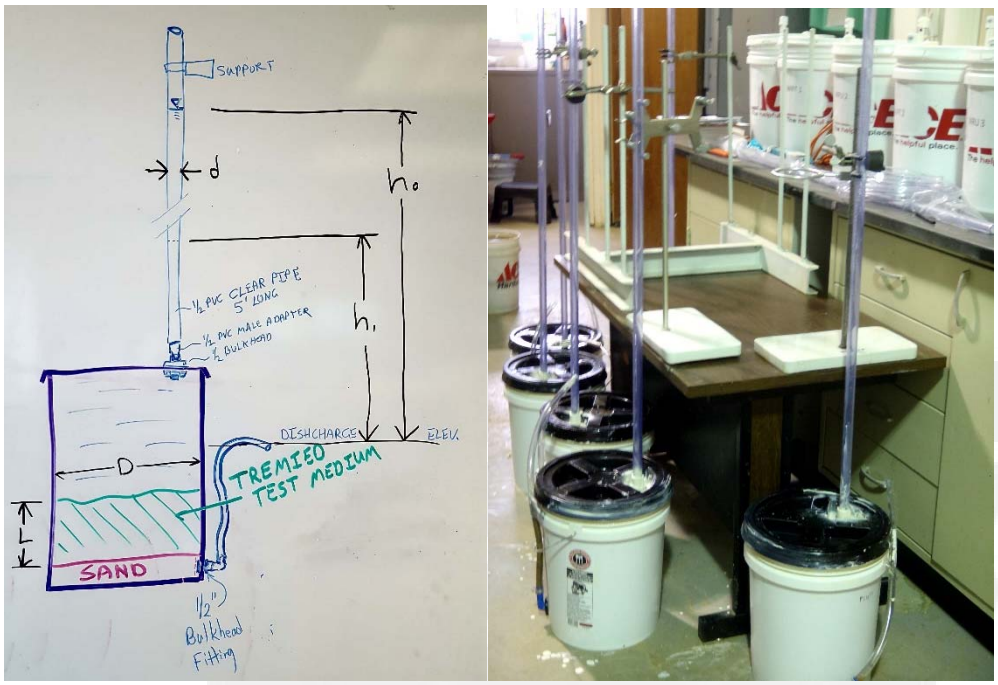

Figure A-5.6 Falling Head Test Concept Sketch and Setup of the Six Test Units

Appendix A-6 – Pit Water Treatment – Titration & Sulfate Reduction Bench

1. Method

1.1 Titrations

Equipment and Materials

Titration of the upper pit water involved addition of solid reagents (Table A-6.1) to a continuously stirred 1000 mL sample of upper pit water until the pH increased to a circumneutral range. A conventional stir plate and magnetic stir bar were used to provide continuous mixing (Figure A-6.1). Temperature was recorded at t(0).

Table A-6.1 Solids Reagents used for Titration

Reagent	Source
NaOH pellets (crushed)	Sigma-Aldrich
Hydrated lime- $Ca(OH)_2$	Mississippi Lime Co.
Limestone (low Si, fine powder)	Sovereign

NaOH pellets were crushed by hand using a mortar and pestle. No further physical alteration was done with any of the reagents. Reagents were added as small pre-weighed doses to the stirred system and time allowed for the solution pH to stabilize. The timing of additions was recorded. Qualitative visual assessments were made during the course of neutralization.

Three reagents were examined individually (NaOH, hydrated lime and limestone). One combination addition was tried (limestone addition to pH 4.88 followed by a quantity of hydrated lime estimated from the results of PLN 2). The experimental set-up is shown in Figure A-6.1.

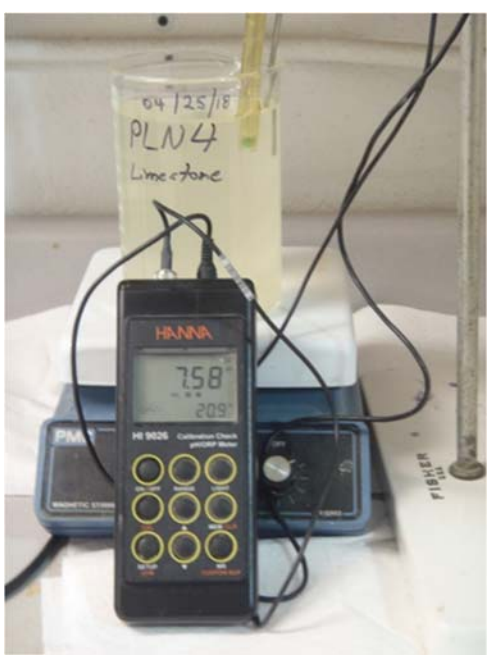

Figure A-6.1. Set-up for Titration of Upper Pit Water

Sampling and Analysis

Solution pH readings were taken at intervals to determine required quantities of neutralizing reagents. No sample volume was removed during the test. The pH and temperature compensation probes were inserted directly into the test vessel.

1.2 Sulfate Reduction Bench

Two matrices were assembled for examining neutralization and microbial sulfate reduction. Both Surface Pit Water (2684 µS/cm) and BH26 water (15290 µS/cm) were evaluated. An attempt was made to use commercially available feedstocks when possible for the purpose of uniformity in the small test vessels.

The following amendments were included in various proportions in each vessel: agricultural grade limestone (Figure A-6.2), pine wood chips (Figure A-6.3), sawdust from New Earth commercial pine wood pellets, hay and straw mix, shredded paper (Figure A-6.4) and biochar (provided by Ascension Soil Company).

Figure A-6.2. Commercially available agricultural grade limestone

Figure A-6.3. Untreated and unmodified pine shavings

Figure A-6.4. Commercially available and untreated, unmodified paper shred

Anaerobic inoculum preparation. Anaerobic inoculum for the SRB tests was prepared as a slurry in 300 mL of distilled water by co-mixing 102 g wet weight organic domestic compost and yard leaves (for cellulose degradative microbial activity), 25 mL of effluent from a pre-existing laboratory cellulosic SRB reactor, 15 mL from a BART SRB enrichment tube from one of the 20-kg POP tests (WRT-4, 02/21/18) and 30 g (wet weight) horse and cow manure. Inoculum was loaded into each vessel by drawing a pipet filled with the slurry from the base of the submerged organic charge to the surface.

Vessel charges. Tables A-6.2 and A-6.3 below summarize the loadings of individual test vessels. Each reactor charge was hand mixed dry and then loaded into the respective vessel. The site water sample containers had not been opened before this use to prevent oxidation. After the water sample was added, polypropylene balls were used to displace as much headspace as possible, while allowing pH/ORP monitoring without spillage (Figure A-6.5). The vessels were sealed and a 7/64 inch pressure release vent hole drilled in each cap (Figure A-6.6). The vessels were weighed, but because these are non-mixed systems, no attempt was made to compensate for any evaporative loss. Vessels were incubated at room temperature. At weekly intervals, 0.5 mL were collected using a pipetman. Samples were microfuged for 1 min at 12,000 x g prior to sulfate analysis. Solution pH and ORP data were acquired by direct insertion of the respective probes (and temperature compensation probes) into the bed, which necessitated opening the vessels.

Figure A-6.5. Fully Charged SRB Test Vessels

Figure A-6.6. Sealed SRB Test Vessels

Table A-6.2. Test Vessel Charges for Upper Pit Water Sulfate Reduction

Test Logic	Test ID	PLN	Lime-stone	Wood Chips (WC)	Saw-dust (SD)	Hay - Straw	Paper	Biochar	Mixed Inoc.	Total Amend. g or mL	Upper Pit Water (mL)	Vessel Total Mass, g
Control	BC20	PLN 25	0	0	0	0	0	0	0	0	405	667.30
Baseline	B21	PLN 26	15.0	27.5		5.0			5.0	53	400	706.00
Baseline B21 w/SD	B24	PLN 29	15.0		27.5	5.0			5.0	53	400	705.85
Baseline B21 w Biochar low	B25	PLN 30	15.0	26.3		3.8		2.5	5.0	53	400	708.85
Baseline B21 w Biochar High	B27	PLN 31	15.0	23.8		1.3		7.5	5.0	53	400	710.15
B24 with Low Biochar	B28	PLN 32	15.0		26.3	3.8		2.5	5.0	53	400	709.45
B24 with High Biochar	B30	PLN 33	15.0		23.8	1.3		7.5	5.0	53	400	707.50
Baseline B21 with paper	B31	PLN 34	15.0			5.0	27.5		5.0	53	400	707.95
B21 with Low Biochar	B32	PLN 35	15.0			3.8	26.3	2.5	5.0	53	400	709.30
50-50 WC-SD	B35	PLN 37	15.0	13.8	13.8	5.0			5.0	53	400	708.15
B35 with low Biochar	B36	PLN 38	15.0	13.2	13.2	3.8		2.5	5.0	53	400	706.80
75-25 WC-SD	B39	PLN 39	15.0	20.7	6.9	5.0			5.0	53	400	704.45

Table A-6.3. Test Vessel Charges for BH26 Water Sulfate Reduction

Test Logic	Test ID	PLN	Lime-stone	Wood Chips (WC)	Saw-dust (SD)	Hay - Straw	Shredded Paper	Biochar	SRB Mixed Inoc.	Total g or mL	BH26 Water	Vessel Total Mass, g
Control	BC	PLN 5	0	0	0	0	0	0	0	0	405	665.15
Baseline	B1	PLN 6	15.0	27.5		5.0			5.0	53	400	699.35
B-1 w more limestone	B2	PLN 7	20.0	22.5		5.0			5.0	53	400	719.00
B-2 w/lhigh limestone	B3	PLN 8	25.0	20.0		2.5			5.0	53	400	717.00
Baseline w/SD	B4	PLN 9	15.0		27.5	5.0			5.0	53	400	716.00
Baseline w Biochar low	B5	PLN 10	15.0	26.3		3.8		2.5	5.0	53	400	704.85
Baseline w Biochar Mod	B6	PLN 11	15.0	25.0		2.5		5.0	5.0	53	400	714.70
Baseline w Biochar High	B7	PLN 12	15.0	23.8		1.3		7.5	5.0	53	400	714.25
B4 with Low Biochar	B8	PLN 13	15.0		26.3	3.8		2.5	5.0	53	400	713.85
B4 with Mod Biochar	B9	PLN 14	15.0		25.0	2.5		5.0	5.0	53	400	720.70
B4 with High Biochar	B10	PLN 15	15.0		23.8	1.3		7.5	5.0	53	400	711.95
Baseline with paper	B11	PLN 16	15.0			5.0	27.5		5.0	53	400	719.95
B11 with Low Biochar	B12	PLN 17	15.0			3.8	26.3	2.5	5.0	53	400	730.70
B11 with Mod Biochar	B13	PLN 18	15.0			2.5	25.0	5.0	5.0	53	400	718.50
B11 with High Biochar	B14	PLN 19	15.0			1.3	23.8	7.5	5.0	53	400	731.05
50-50 WC-SD	B15	PLN 20	15.0	13.8	13.8	5.0			5.0	53	400	720.20
B15 with low Biochar	B16	PLN 21	15.0	13.2	13.2	3.8		2.5	5.0	53	400	727.40
B15 with mod Biochar	B17	PLN 22	15.0	12.5	12.5	2.5		5.0	5.0	53	400	723.00
B15 with high Biochar	B18	PLN 23	15.0	11.9	11.9	1.3		7.5	5.0	52	400	730.50
75-25 WC-SD	B19	PLN 24	15.0	20.7	6.9	5.0			5.0	53	400	728.45

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Standard Operating Procedure

Bio & Hydrometallurgy Development **Research and Development**

SOP Name

Solution pH

Process Owner/Approver	***Last Updated***
Thomas Clark	**2018**

Consequence Thinking Action Steps

1. Identify Hazards **2. Evaluate Risks** **3. Reduce Risks**

Purpose
Procedure determines the pH of environmental or biooxidation aqueous samples
Task Energy Sources/Hazards
Ensure all electrical equipment is properly ground tested
Environmental
Reject solution should be disposed of in acidic waste container for removal
Resources Required to Perform Task
HANNA 9026 pH meter with HI1230B PEI body electrode with BNC connector, pH standards
PPE
Safety glasses, latex/nitrile gloves

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Step by Step Procedure

Step	Step Description	Hazard/Behavior	Control
1	Ensure unit has new batteries for field use		Safety glasses, nitrile gloves
2	Two pH standard calibration (pH 2, pH 4, pH 7)	Chemical	Safety glasses, nitrile gloves
Standards: Use fresh standards daily			
Electrode Storage: pH 4 buffer or buffer amended with small quantity of KCL – change storage buffer regularly			

References

Standard Methods for the Examination of Water and Wastewater, 22nd Edition, APHA, AWWA, WEF, Section 4500 H.

Training Checklist List:

- ☐ Go over proper PPE, and MSDS
- ☐ Ensure Trainee has all proper PPE
- ☐ Has read and understands this SOP
- ☐ Standardizing meter
- ☐ Reading samples

Training Certification:

By signing below, the trainee indicates that they have read and understand the procedure and will conduct this task in a safe and effective manner according to the SOP. The supervisor indicates that the trainee has been observed by them performing the procedure with a degree of proficiency following the SOP and utilizing proper PPE.

Trainee Name (Print)	Employee ID#	Trainee Signature	Supervisor	Signature Date

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Standard Operating Procedure

Bio & Hydrometallurgy Development **Research and Development**

SOP Name

Solution Oxidation-Reduction Potential

Process Owner/Approver	***Last Updated***
Thomas Clark	**2018**

Consequence Thinking Action Steps

1. Identify Hazards **2. Evaluate Risks** **3. Reduce Risks**

Purpose
Procedure determines the ORP of aqueous solutions
Task Energy Sources/Hazards
Ensure all electrical equipment is properly ground tested
Environmental
Reject solution should be disposed of in acidic waste container for removal
Resources Required to Perform Task
Hanna 9126 meter with combination ORP electrode
PPE
Safety glasses, latex/nitrile gloves

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Step by Step Procedure

Step	Step Description	Hazard/Behavior	Control
1	Check batteries for field use		Safety glasses, nitrile gloves
2	Light's solution Std. (460-480 mV)	Chemical	Safety glasses, nitrile gloves
3	4M KCl electrolyte solution	Chemical	Safety glasses, nitrile gloves
4			
5	**CAUTION: very low O.R.P. hydrogen sulfide systems can negatively impact electrode performance**		

1. Ensure unit power source for field applications
2. Light's solution must be used fresh- unstable with temperature fluctuations and prone to sample contamination
3. If electrode performance degrades, change electrode solution using fresh 4M KCl solution; allow electrode to sit overnight prior to use
4. Always rinse with distilled water external electrode surface between samples and after use
5. STORAGE: If KCL unavailable – distilled water. Lab: 4 M KCL

References

Manufacturer- VLC Manuals/Combination ORP Electrode Instructions;
Standard Methods for the Examination of Water and Wastewater, 22nd Edition, APHA, AWWA, WEF. Section 2580.

Training Checklist List:

- ☐ Go over proper PPE, and MSDS
- ☐ Ensure Trainee has all proper PPE
- ☐ Has read and understands this SOP

Training Certification:

By signing below, the trainee indicates that they have read and understand the procedure and will conduct this task in a safe and effective manner according to the SOP. The supervisor indicates that the trainee has been observed by them performing the procedure with a degree of proficiency following the SOP and utilizing proper PPE.

Trainee Name (Print)	Employee ID#	Trainee Signature	Supervisor	Signature Date

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Standard Operating Procedure

Bio & Hydrometallurgy Development **Research and Development**

SOP Name

SPECIFIC CONDUCTIVITY

Process Owner/Approver	***Last Updated***
Thomas Clark	**2018**

Consequence Thinking Action Steps

1. Identify Hazards **2. Evaluate Risks** **3. Reduce Risks**

Purpose
Procedure determines the specific conductivity of a solution in µS/cm or mS/cm
Task Energy Sources/Hazards
No electrical hazard
Environmental
Reject solution should be disposed of waste container for removal
Resources Required to Perform Task
Symphony SP70 Conductivity meter, 1000 µS/cm and 10000 µS/cm standards
PPE
Safety glasses, latex/nitrile gloves

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Step by Step Procedure			
Step	**Step Description**	**Hazard/Behavior**	**Control**
1	Ensure Symphony SP70C meter has functional batteries		Safety glasses, nitrile gloves
2	Ensure calibration standards have not aged and expired		Safety glasses, nitrile gloves
3	Standardize meter (auto or manual calibration modes)		Safety glasses, nitrile gloves
4	Measure test solution	Chemical	Safety glasses, nitrile gloves
CAUTION: PROBE IS TO BE STORED CLEAN (DI RINSED) AND DRY			
5	**Electrode cleaning – refer to lab copy of VWR recommendations**		

1. Ensure Meter has functional batteries.

Before field sampling programs, check batteries for: 1) power; 2) no battery leakage; 3) spare battery pack

2. Ricca Conductivity Std. 10 mS/cm (5400 ppm TDS as NaCl); Ricca Conductivity Standard 1000 µS/cm (495 ppm TDS as NaCl)
3. Autocal or Manual Cal – Symphony User Guide p.28 for keyboard symbols
4. Symphony User Guide – p. 30 – for keyboard symbols

References

Technical review: Standard Methods for the Examination of Water and Wastewater, 22nd Edition, APHA, AWWA, WEF – Section 2510
Symphony Meter User Guide (VWR)

Training Checklist List:

- ☐ Go over proper PPE, and MSDS
- ☐ Ensure Trainee has all proper PPE
- ☐ Has read and understands this SOP
- ☐ Standardizing meter
- ☐ Reading samples

Training Certification:

By signing below, the trainee indicates that they have read and understand the procedure and will conduct this task in a safe and effective manner according to the SOP. The supervisor indicates that the trainee has been observed by them performing the procedure with a degree of proficiency following the SOP and utilizing proper PPE.

Trainee Name (Print)	Employee ID#	Trainee Signature	Supervisor	Signature Date

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Standard Operating Procedure

Bio & Hydrometallurgy Development **Research and Development**

SOP Name

MPN Procedure for Iron Oxidizers

Process Owner/Approver	***Last Updated***
Thomas Clark	**2018**

Consequence Thinking Action Steps

1. Identify Hazards **2. Evaluate Risks** **3. Reduce Risks**

Purpose

Procedure determines the number of viable iron oxidizing microorganisms per milliliter of solution

Task Energy Sources/Hazards

Ensure all electrical equipment is properly ground tested

Environmental

Reject solution should be disposed of in acidic waste container for removal

Resources Required to Perform Task

Autoclave, pipette, analytical balance, pH meter, reagents, 48-well cell plate, and 0.2µm filter

PPE

Safety glasses, latex/nitrile gloves

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Step by Step Procedure

Step	Step Description	Hazard/Behavior	Control
1	Ensure balance has a valid calibration label and the daily calibration has been completed		Safety glasses, nitrile gloves
2	Ensure pipette has been calibration according to procedures		Safety glasses, nitrile gloves
3	Ensure pH meter has been calibrated according to procedures		Safety glasses, nitrile gloves
4	Prepare solutions	Chemical	Safety glasses, nitrile gloves
5	Compose MPN	Chemical	Safety glasses, nitrile gloves

Preparing Solutions:

1. Mark cover of 48-well cell plate according to estimated cell count as shown in example below
   Fe-Ox – Sample 1 Fe-Ox – Sample 2

10^{-0} A	**10^{-1}**	**10^{-1}**	**10^{-1}**	**10^{-0} A**	**10^{-1}**	**10^{-1}**	**10^{-1}**
10^{-1} B	**10^{-2}**	**10^{-2}**	**10^{-2}**	**10^{-1} B**	**10^{-2}**	**10^{-2}**	**10^{-2}**
10^{-2} C	**10^{-3}**	**10^{-3}**	**10^{-3}**	**10^{-2} C**	**10^{-3}**	**10^{-3}**	**10^{-3}**
10^{-3} D	**10^{-4}**	**10^{-4}**	**10^{-4}**	**10^{-3} D**	**10^{-4}**	**10^{-4}**	**10^{-4}**
10^{-4} E	**10^{-5}**	**10^{-5}**	**10^{-5}**	**10^{-4} E**	**10^{-5}**	**10^{-5}**	**10^{-5}**
+	**+**	**+**			**-**	**-**	**-**

2. Label front of tray with sample ID and date, followed by “Fe” (Iron)

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3. Dissolve chemicals into 1 liter of DI water (2X MKM Solution)

Chemical	
0.8 g	$(NH_4)_2SO_4$
0.8 g	$MgSO_4*7H_2O$
0.08 g	KH_2PO_4
0.10 g	KCL

4. Titrate solution to pH of approximately 1.5 - 1.6
5. Distribute 100 mL to 125 mL Erlenmeyer flasks
6. Autoclave 2X MKM solution
7. Allow solution to cool
8. Add $CaSO_4$, $CuSO_4$ and 1000 X Trace metals sol'ns for mesophiles
9. Dissolve 4.983 g $FeSO_4*7H_2O$ into 10ml of 2XMKM basal media, pH 1.5 – 1.6
10. Syringe filter 5 mL ferrous sulfate solution using 0.2µm filter into 100 mL solution

Composing MPN (Dilution sequences adjustable):

1. Using a pipetman, transfer 0.9 mL of amended MKM into each well, except well A
2. Using a pipette, transfer 1 ml of initial cell dilution into cell labeled A
3. Create serial dilutions of cell A by transferring 0.1mL of A into cell B
4. Agitate solution in cell B (in order to prevent contamination with other cells, ensure that pipette tip remains below surface of solution during agitation)
5. Transfer 0.1 ml of solution from cell B into cell C
6. Agitate solution in cell C
7. Transfer 0.1ml of solution from cell C into cell D
8. Agitate solution in cell D
9. Transfer 0.1ml of solution from cell D into cell E
10. Agitate solution in cell E
11. Change pipette tip
12. Beginning with cell A, pipette 0.1ml of solution from cell A into each of the three cells to the right
13. Change pipette tip
14. Pipette 0.1ml of dilution from cell B into each of the three cells to the right
15. Change pipette tip
16. Pipette 0.1ml of dilution from cell C into each of the three cells to the right
17. Change pipette tip
18. Pipette 0.1ml of dilution from cell D into each of the three cells to the right
19. Change pipette tip
20. Pipette 0.1ml of dilution from cell E into each of the three cells to the right
21. Change pipette tip
22. Pipette 0.01 mL of actively growing culture into each of the cells marked "**+**" (Positive control)
23. Sterile solution should only be the cells marked "**-**"(negative control)
24. After 21 days check results of MPN by adding observing color change in the cells. Positive cells will be orange while negative cell will remain clear.

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References

Escobar, B. and I. Godoy. 1999. Determination of sulfur- and iron- oxidation bacteria by the most probable number technique. ***In***: Biohydrometallurgy and the Environment Toward the Mining of the 21st Century, Part A, Bioleaching, Microbiology. Proceedings of the International Biohydrometallurgy Symposium IBS'99, Amils, R. and A. Ballester (Eds.), Elsevier, Amsterdam, p. 681-687.

Training Checklist List:

- ☐ Go over proper PPE, and MSDS'
- ☐ Ensure Trainee has all proper PPE
- ☐ Has read and understands this SOP
- ☐ Preparing solutions
- ☐ Compose MPN

Training Certification:

By signing below, the trainee indicates that they have read and understand the procedure and will conduct this task in a safe and effective manner according to the SOP. The supervisor indicates that the trainee has been observed by them performing the procedure with a degree of proficiency following the SOP and utilizing proper PPE.

Trainee Name (Print)	Employee ID#	Trainee Signature	Supervisor	Signature Date

APPENDIX B

DATA SUMMARY

B-1 Initial Qualitative (Beaker) Screening

B-2 Sieving vs Agglomeration

B-3 Utilization Testing Using Amended USBM Method

B-4 Source Control Treatment Testing - Waste Rock

B-5 Pit Water Treatment – Titration & Sulfate Reduction Bench

1

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): James Gusek, Guadalupe Fatlaic, Tom Clark Start Time: 9:30 am Date: 12/1/17
Sampler(s) Initials: JG, GF, TC Finish Time: 2:14 pm

Objective Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID [circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	Waste Rock	Waste Rock	Waste Rock	Waste Rock	Waste Rock	
Amendment:	SLS	Milk	Whey	Bkg Soda	Limestone	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	Waste Rock	–	70	100gr	A.R.	Spooned in mostly fines	Y
Amendment	SLS	2%	~100mL	2gr	100gr		

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment amount of amendment added 16.5 ml how added with 10 ml syringe * photo? Y
time: 10:50am pH: N

Apparent field capacity

Clay chemistry needs to be accounted for

2nd Increment amount of amendment added 10 ml how added * photo? Y
ne: 11:00 pH:

After adding 10 ml is not percolating. Percolation started at 11:21 am ~3 drops

:15 → 2.65 − 1.5 = 1.15 g of solution at 12:15 pm

2.7 − 0 = 2.7g at 2:14pm

3rd Increment amount of amendment added how added photo?
time: pH:

4th Increment amount of amendment added how added photo?
time: pH:

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes] QC intls/data

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Jim Gusek, Guadalupe Fattore, Tom Clark
Sampler(s) Initials: JG, GF, TC

Start Time: 11:30 am Date: 12/1/17
Finish Time: 2:13 pm

Objective

Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID

[circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	Waste Rock	Waste Rock	Waste Rock	Waste Rock	Waste Rock	
Amendment:	SLS	Milk	Whey	Bkg Soda	Limestone	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	Waste Rock	—		100 g	AR	Spooned in Mostly fines	Y
Amendment	Milk	5%	300 ml	1.44 g	100 g	5% of full strength milk	

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment
time: 11:40 pH: _____ amount of amendment added 16.5 ml how added w/10ml syringe * photo? _____
apparent field capacity

2nd Increment
time: 11:44 pH: _____ amount of amendment added 10 ml how added * photo? _____

Solution percolated better than SLS 2%, and water cups

4.5 - 1.5 = 3 g at 12:10 pm
6.8 - 0 = 6.8 g at 12:46 pm
14.4 - 0 = 14.4 ml at 2:13 pm

* Apparent decrease in the FC due to the Na:Ca substitution... mechanism unknown

3rd Increment
time: _____ pH: _____ amount of amendment added 10 ml how added * photo? _____

4th Increment
time: _____ pH: _____ amount of amendment added _____ how added _____ photo? _____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data _____

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Jim Gusek, Guadalupe Fattore, Tom Clark
Sampler(s) Initials: J.G, G.F, T.C

Start Time: 11:16 am
Finish Time: 2:13 pm

Date: 12/1/17

Objective

Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID

[circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	Waste Rock	Waste Rock	Waste Rock	Waste Rock	Waste Rock	
Amendment:	SLS	Milk	Whey	Bkg Soda	Limestone	No amendment

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	Waste Rock			100 g	AR	Spooned in mostly fines	Y
Amendment	Destilled water	–	~100 ml	–	100 g		

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment

time: 11:16 am pH: _____ amount of amendment added 16.5 ml how added with 10 ml syringe * photo? Y

Tare of cup 1.5 g

water is wicking to the dry material

water started percolating at 11:21 am

2nd Increment

time: 11:36 pH: _____ amount of amendment added 10 ml how added * photo? _____

water is percolating a little faster than the one with 2% SLS

3.7 - 1.5 g = 2.2 g at 12:14 pm

5.2 - 0 = 5.2 ml at 2:13 pm

3rd Increment

time: _____ pH: _____ amount of amendment added _____ how added _____ photo? _____

4th Increment

time: _____ pH: _____ amount of amendment added _____ how added _____ photo? _____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data _____

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Tom Clark
Sampler(s) Initials: TC

Start Time: 12:00 pm
Finish Time: 3:00 pm

Date: 12/1/17

Objective

Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID

[circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	
Amendment:	*SLS*	*Milk*	*Whey*	*Bkg Soda*	*Limestone*	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	*Waste Rock*	–		100 g	AR		
Amendment	$NaHCO_3$				100 g		

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment amount of amendment added _____ how added _____ photo? ____

time: 12:00 pm pH: _____

Titration to get a pH of 7

See Tom's Spreadsheet titration results

2nd Increment amount of amendment added _____ how added _____ photo? ____

time: _____ pH: _____

3rd Increment amount of amendment added _____ how added _____ photo? ____

time: _____ pH: _____

4th Increment amount of amendment added _____ how added _____ photo? ____

time: _____ pH: _____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data _____

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Jim Gusek, Guadalupe Tattoie, Tom Clark
Sampler(s) Initials: J.G, G.T, T.C

Start Time: 11:55 pm
Finish Time: 2:15 pm

Date: 12/1/17

Objective

Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID

[circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	
Amendment:	*SLS*	*Milk*	*Whey*	*Bkg Soda*	*Limestone*	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	*Waste Rock*			500g	AR	Baseline Material	
Amendment	Destilled water	–	–	–	500g		

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment amount of amendment added ~750 ml how added w/rinse bottle photo? ☐

time: 11:55 pH:_____ The sample was stirred

few drops at 12:48

Sample was stirred to see if it help with the percolation problem.

Stiring the sample did not help.

2nd Increment amount of amendment added _____ how added _____ photo? ☐

time: _____ pH:_____

3rd Increment amount of amendment added _____ how added _____ photo? ☐

time: _____ pH:_____

4th Increment amount of amendment added _____ how added _____ photo? ☐

time: _____ pH:_____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data _____

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Jim Gusek, Guadalupe Fatlore, Tom Clark
Sampler(s) Initials: JG, GF, TC

Start Time: 12:30 pm Date: 12/1/17
Finish Time: 2:12 pm

Objective Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID [circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	
Amendment:	*SLS*	*Milk*	*Whey*	*Bkg Soda*	*Limestone*	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	*Waste Rock*			100 g	AR	Spooned in Mostly fines	Y
Amendment	Milk	25%	200 ml	3.8 g	100 g	25% of full strength milk	N

The 25% solution was prepared with the 5% solution.

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment amount of amendment added 17.5 ml how added w/10 ml syringe * photo? N
time: 12:32 pm pH:

The field capacity is a little greater than other cells
pH of milk only (only), 7.5

2nd Increment amount of amendment added 10 ml how added * photo? Y
time: 12:37 pH:

some scum on top of the supernatante
percolation - 1 drop at 12:40 pm
curds showing in the leachate from 1 drop
8.3 ml recoverd at 1:15 pm, curds, milk broke thru
8.5 ml - 0 = 8.5 ml at 2:12 pm

3rd Increment amount of amendment added ____ how added ____ photo? ____
time: ____ pH: ____

4th Increment amount of amendment added ____ how added ____ photo? ____
time: ____ pH: ____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data ____

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Jim Gusek, Guadalupe Fathoiz, Tom Clark
Sampler(s) Initials: J.G, G.F, T.C

Start Time: 1:30 pm
Finish Time: 2:11 pm

Date: 12/1/12

Objective

Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID

[circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	
Amendment:	*SLS*	*Milk*	*Whey*	*Bkg Soda*	*Limestone*	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	*Waste Rock*		70 ml	100 g	AR	Spooned in, mostly fines	Y
Amendment	Limestone	—	—	2 g	Dry	2g on the surface of sample	Y

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment amount of amendment added 16.5 ml how added w/10 ml syringe photo? ☐
time: 1:31 pm pH:_____

Percolation test

2nd Increment amount of amendment added 10 ml how added ~~X~~ photo? ☐
time: 1:36 pH:_____

2.1 − 0 = 2.1 ml at 2:11 pm

3rd Increment amount of amendment added _____ how added _____ photo? ☐
time: _____ pH:_____

4th Increment amount of amendment added _____ how added _____ photo? ☐
time: _____ pH:_____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data _____

Initial Qualitative (Beaker) Screening - Data Sheet

Table C2

Sampler(s) Name(s): Jim Gusek, Tom Clark, Guadalupe Fattore
Sampler(s) Initials: JG, GF, TC

Start Time: 2:00 pm
Finish Time: 2:37 pm

Date: 12/1/17

Objective

Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment. Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics). Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

Test ID

[circle the work plan test # that applies]

Test #	IQ1	IQ2	IQ3	IQ4	IQ5	(alternative?)
Subject Material	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	*Waste Rock*	
Amendment:	*SLS*	*Milk*	*Whey*	*Bkg Soda*	*Limestone*	

Initial Condition

	item	conc.	volume	mass	moisture	description/notes	photo?
Subject Material	*Waste Rock*			100 g	AR	Spooned in, mostly fines	
Amendment	$NaHCO_3$		40 ml	2 g	Dry	$NaHCO_3$ applied in solution	

Descriptions: changes/characteristics (color/odor/consistancy)(presence of biofilm/curds/coating/precipitate/separation/etc.)(faverable/adverse properties?)

1st Increment
time: 2:07 pm pH: _____
amount of amendment added 16.5 ml fild capacity
how added w/10 ml syringe *
photo? _____

Percolation test

2nd Increment
time: 2:10 pm pH: _____
amount of amendment added 10 ml
how added *
photo? _____

1 drop at 2:31 pm

0.75g − 0 = 0.75g at 2:37 pm

Some scum on top of supernatant

3rd Increment
time: _____ pH: _____
amount of amendment added _____
how added _____
photo? _____

4th Increment
time: _____ pH: _____
amount of amendment added _____
how added _____
photo? _____

[Only one test ID per sheet. Use additional sheets as as necessary for more increments/notes]

QC intls/data _____

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Appendix B-2

Scoping Tests Summary: Sieving vs. Agglomeration

28 December 2017

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Table 1. Phase 1: Amendment Top-Down Rinse and Drain

Test	Group	Amendment Test Group	Rock (g)	Effluent volume (mL)	pH	SPCOND, µS/cm	Dried Solids from Effluent (g)	Solids washed out (%)
1	Crushed waste rock from RDI	dI H2O	600.1	36.0	2.85	1018	2.29	0.381
2		5% milk	600.6	7.0	2.70	1531	0.05	0.008
3		5% NaHCO3	600.2	19.0	8.42	28810	0.81	0.134
4		CaO slurry	600.8	26.0	9.75	1455	2.18	0.363
5	Crushed waste rock from RDI without minus 50 mesh reject	dI H2O	600.4	76.0	3.08	1024	0.38	0.064
6		5% milk	601.4	62.0	3.12	1875	0.05	0.009
7		5% NaHCO3	600.7	61.0	8.52	34500	0.37	0.062
8		CaO slurry	600.1	67.0	8.36	1795	0.26	0.043
9	Crushed waste rock from RDI - Agglomerated	dI H2O	600.3	70.0	2.89	1779	2.45	0.408
10		5% milk	600.6	41.0	2.83	2646	1.02	0.170
11		5% NaHCO3	600.4	54.0	8.36	34000	4.30	0.717
12		CaO slurry	600.5	63.0	8.79	1861	2.57	0.429

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Phase 2: Upflow Flood/Drain and Top-Down Rinse

Test	Tap Water Flood (mL)	Drain Down Increments (mL)	Mass (g)	dIH2O Rinse, mL	Post dI Rinse Comments	Moist mass (g)	Volume Effluent (mL)	Dry Solids (g)	Solids washed out (%)
1	1750	250-500 mL	645.35	100	some ponding, but drained	668.00	71.0	0.6625	0.103
2	1750	250-500 mL	671.40	100	extended ponding, but drained	688.30	75.0	0.0008	0.000
3	1750	250-500 mL	664.15	100	extended ponding, but drained	676.20	83.0	0.1786	0.027
4	1750	250-500 mL	633.75	100	some ponding, but drained	664.50	64.0	0.3405	0.054
5	1750	250-500 mL	616.05	100	drained	632.15	80.0	0.1738	0.028
6	1750	250-500 mL	622.40	100	drained	642.10	75.5	0.0139	0.002
7	1750	250-500 mL	621.60	100	drained	650.90	65.0	0.2392	0.038
8	1750	250-500 mL	617.00	100	drained	640.75	71.0	0.1813	0.029
9	1750	250-500 mL	621.00	100	drained	653.70	59.5	1.7544	0.283
10	1750	250-500 mL	662.95	100	drained well	676.65	81.0	0.3774	0.057
11	1750	250-500 mL	647.05	100	drained	654.85	86.0	2.0534	0.317
12	1750	250-500 mL	626.00	100	drained	653.55	65.0	2.0465	0.327

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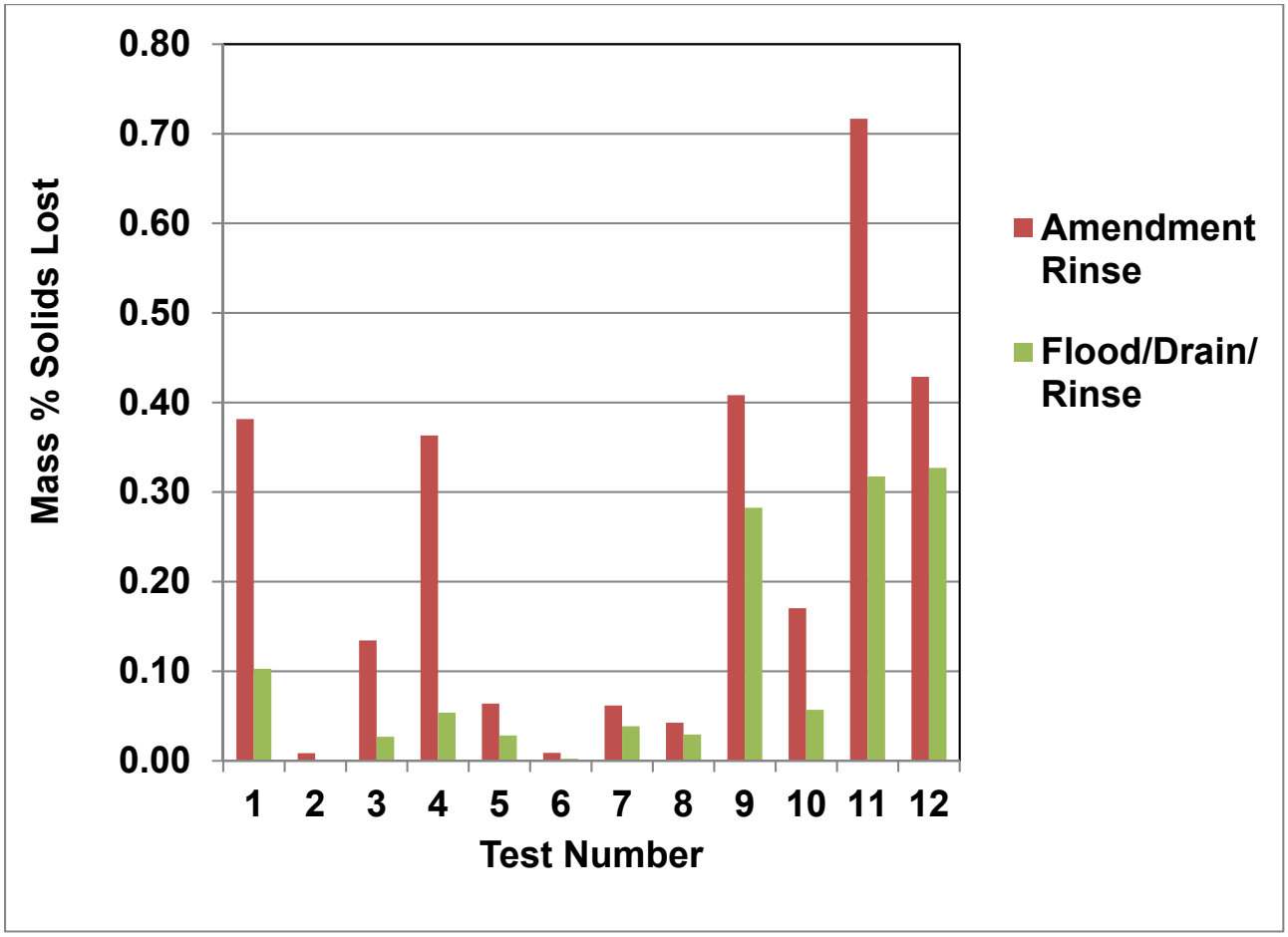
Figure 1. Fine Particle Losses



Apendix B3 - Utilization Testing Using Amended USBM Method
Crushing Data

Six buckets of pyritic reserve rock from Pits 1,2 and 3, originally delivered to Solfatara for archiving, were instead delivered to RDI on 08 Nov. 2017 for incorporation into the bulk crushing sample

			Solfatara Subsample	Mass Sent to RDI			Archived at Solfatara				
Date	Sample	Description	Designation	Total (kg)	Tare (kg)	Net (kg)	Sample Type	Tare (kg)	Net (kg)	Photos	Comments
08 Nov. 2017	**BH Test Pit 1, Sericite Zone, 10/04/17, 1400 Hours**	Bucket 1	1108-SOLF-BH-RESERVE-PIT 1- 1400-A	21.06	0.83	20.23	GRAB		2.21	292, 293, 294	
		Bucket 2	1108-SOLF-BH-RESERVE-PIT 1- 1400-B	22.91	0.82	22.09	GRAB		2.48	295, 296	
08 Nov. 2017	**BH Test Pit 2, 10/04/17, 1600 Hours**	Bucket 1	1108-SOLF-BH-RESERVE-PIT 2- 1600-A	20.98	1.08	19.90	GRAB		4.34	289, 290, 291	Lid label correct but paperwork attached was incorrect sheet (switched with BH Silt Layer Composite, 11:00, 10/05/17; bucket was extensively damaged and replaced with a new container
		Bucket 2	1108-SOLF-BH-RESERVE-PIT 2- 1600-B	23.02	1.08	21.94	GRAB		3.46	283, 284, 285, 286, 287, 288	Bucket damaged; replaced
08 Nov. 2017	**BH Test Pit 3, 10/04/17, 1730 Hours**	Bucket 1	1108-SOLF-BH-RESERVE-PIT 3- 1730-A	21.20	0.83	20.38	GRAB		1.99	299, 300	Bucket damaged; replaced
		Bucket 2	1108-SOLF-BH-RESERVE-PIT 3- 1730-B	23.59	0.79	22.80	GRAB		3.28	301, 302	
					Total Additional Rock to RDI (kg)	**127.34**					

Four totes delivered to RDI were damaged to one extent or another - RDI transferred contents of each individual tote to one of four barrels, which were inspected and subsampled by TRC on 08 Nov.

			Solfatara Subsample	Subsamples for Archiving at Solfatara					
	Sample	Description	Designation	Sample Type	Total (kg)	Tare (kg)	Net (kg)	Comments	Photos
08 Nov. 2017	**PIT 1**	Barrel 1	1108-SOLF-BH-PIT 1/1	GRAB	1.45	0.13	1.32		303
		Barrel 2	1108-SOLF-BH-PIT 1/2	GRAB	1.26	0.13	1.13	**Based on visual inspection, RDI estimates that approximatley 20 % by mass exceeds one-inch in diameter**	306
08 Nov. 2017	**PIT 3**	Barrel 1	1108-SOLF-BH-PIT 3/1	GRAB	1.33	0.13	1.20		304
		Barrel 2	1108-SOLF-BH-PIT 3/2	GRAB	1.38	0.13	1.25		305

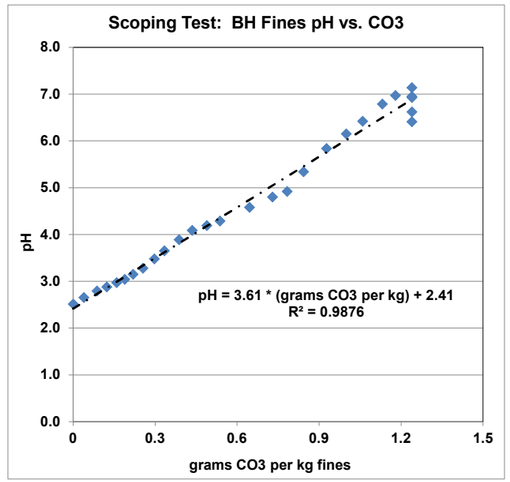
Apendix B3 - Utilization Testing Using Amended USBM Method
Scoping IQ1 - IQ5

1-Dec-17

Residual acidity of finer material from crush
Sample: 100 g of as received fines from the excess crush material (no rocks included)
Titrant: 0.050 M Na2CO3 (5.3 grams per liter) using 100 mL buret, with stirring

Operator: TRC

Date	Time	Buret (mL)	Δ, mL	CO3, g/kg	Cumulative CO3, g/kg	pH	
1-Dec-17	~11:30 AM	1.40				2.39	
		1.90	0.50	0.015	0.000	2.51	
		3.20	1.30	0.039	0.039	2.65	
		4.80	1.60	0.048	0.087	2.79	
		6.00	1.20	0.036	0.123	2.88	
		7.20	1.20	0.036	0.159	2.97	
		8.20	1.00	0.030	0.190	3.04	
		9.20	1.00	0.030	0.220	3.15	
		10.4	1.20	0.036	0.256	3.28	
		11.8	1.40	0.042	0.298	3.48	
		13.0	1.23	0.037	0.334	3.65	
		14.8	1.77	0.053	0.388	3.89	
		16.4	1.60	0.048	0.436	4.09	
		18.2	1.80	0.054	0.490	4.19	
		19.8	1.60	0.048	0.538	4.29	
		23.4	3.60	0.108	0.646	4.58	
		26.2	2.80	0.084	0.730	4.80	
		28.0	1.80	0.054	0.784	4.92	
		30.0	2.00	0.060	0.844	5.34	
		32.8	2.80	0.084	0.928	5.84	
		35.2	2.40	0.072	1.000	6.15	
		37.2	2.00	0.060	1.060	6.42	
		39.6	2.40	0.072	1.132	6.79	
		41.2	1.60	0.048	1.180	6.97	
		43.2	2.00	0.060	1.240	7.14	
		43.2			1.240	6.95	
	~2:30 PM	43.2			1.240	6.93	
2-Dec-17	11:30 AM	43.2			1.240	6.62	1.0 days
5-Dec-17	8:30 AM				1.240	6.41	3.9 days



Small Cup Tests (Operators - JG , GF and TRC)
04 Dec. 2017, 11:45:00 AM

Cup	Group	Volume Effluent (mL)	pH	SPCOND, mS/cm
1	2% SLS in solution	3.9	2.24	10.51
2	5% milk	13.0	2.27	6.56
3	Control, no amendment	4.3	2.30	6.52
4	Na2CO3 titration	*	*	*
5	Baseline, DW, sample stirred	26.0	2.21	7.97
6	25% Milk	7.7	2.42	5.79
7	Limestone on surface	6.9	2.47	7.08
8	NaHCO3 in solution	6.4	9.31	30.3

10.0 mS/cm STD read 10.37 mS/cm

16-Jan-18
Test No.

Neutralization of Mixed Waste Rock with Crushed Limestone

Operator: TRC **Limestone: pulverized; provided by Sovereign (no analysis provided)**
Experimental approach: Limestone will be intimately mixed with a sample of waste rock (reactor particle size
Test vessel: 2 liter plastic tray with lid; room temperature

Container:	63.55	grams
Container + rock:	663.75	grams
Waste rock	600.2	grams
Distilled water	600.2	grams
Limestone	2.9287	grams
Photos	Yes	

Date	Time	pH	SPCOND	COMMENTS
16-Jan	14:17	2.65		Initial; pH 4.0 STD: 4.02; pH 7 STD: 7.03
	14:23	4.44		Added limestone; mixed by hand
	14:26	4.93		
	14:29	5.13		
	14:34	5.40		
	16:14	5.95		
17-Jan	9:26	6.70		
	9:43	6.75		
	13:16	6.97	2070 µS/cm	pH 7 STD: 7.02; 10 mS/cm STD: 10.15
	END TEST			

Conclusions:

1. **Use of fines material in earlier tests or reactor particle size distribution in this test resulted in similar initial pH of slurry**
2. **Limestone demonstrated fairly rapid reactivity with waste rock slurry.**
3. **Loadings of NaHCO3, Na2CO3, and CaCO3 were all useful for pH adjustment. Limestone did not appear to passivate from Fe deposition.**

Appendix B3- Utilization Testing Using Amended USBM Method
Scoping Percent Moisture

5-Dec-17

Pan	Sample Description	No.	Tare(g)	Moist solids + pan (g)	Moist solids (g)	Dry solids + pan (g)	Dry solids (g)	Δ Mass (g)	% Moisture		Temp. @ t(0)	Time/Date t(0)	Temp. @ t(f)	Time t(f)	Comments
	(used previously unopened bucket overage solids)														
Al dish	fines only, grab	1	0.9698	7.3000	6.3302	7.1076	6.1378	0.1924	3.13					8:36 AM, 06 Dec. 2017	
Al dish	fines only, grab	2	0.9707	6.5420	5.5713	6.3736	5.4029	0.1684	3.12						
Al dish	fines only, grab	3	0.9714	6.1797	5.2083	6.0136	5.0422	0.1661	3.29						
Al dish	fines only, grab	4	0.9720	7.7342	6.7622	7.4832	6.5112	0.2510	3.85		103 C	2:42 PM, 05 Dec. 2017	104 C		During drying, definite odor of sulfur, very similar to an (extractive) biooxidized residue
							Mean ± s.d		3.35	0.35					
Ore Pan	"representative" grab sample, including rocks	1	404.20	817.80	413.60	806.85	402.65	10.95	2.72					9:55 AM, 06 Dec. 2017	
						806.90	402.70	10.90	2.71						
				Mass solids used:											
					437.47	grams									

Small Cup Tests (JG and GF)

11-Dec-17

Sieve analysis of crushed fines

Sample: - 60 mesh (< 250 µm) filter cake (pan) fraction from RDI bulk sieve analysis of crushed Barite Hill material

Starting mass (grams) 519.65

Corrected mass (grams) 518.85

Sieve(s)	Particle (µm)	Mass (g)	Mass %	Cumulative %	Comments
(+) 50	> 300 µm	0.80			filter paper fragments - subtracted from starting mass
(-)50 (+)100	(-) 300 µm (+) 150 µm	303.55	58.50	58.5	
(-) 100 (+) 140	(-) 150 µm (+) 106 µm	175.80	33.88	92.4	
(-) 140 (+) 325	(-) 106 µm (+) 45 µm	34.90	6.73	99.1	
(-) 325 + 400	(-) 45 µm (+) 38 µm	0.35	0.07	99.2	
(-) 400	minus 38 µm	0.70	0.13	99.3	
Spillage		> 0.072			

Error: < 0.67 %

Appendix B3 - Utilization Testing Using Amended USBM Method
Falling Head Beaker Scoping Tests

18-Dec-17

Falling Head Beaker Scoping Tests

1. Used bucket of RDI crushed waste rock (overage)
2. Rolled 5-gallon bucket on Dayton bottle roller for ~ 2 min (setting 10)
3. Subsampled ~ 600 g mixed material
4. Placed in 18 oz (538 mL) plastic cups with pre-drilled drainage holes
5. Tests 5-8: Hand sieved crushed waste rock with 50 mesh sieve; generated a common 2.84 kg sample used to fill cups 5-8
6. Tests 9-12: Agglomerated individually by hand in 1-gallon bucket (material agglomerated very well with < 30 mL distilled water)
7. Allowed agglomerates to "cure " overnight
8. 100 mL "Amendments" added primarily in small volumes by pipet
9. Solids in effluents recovered by filtration through Whatman #1 paper; rinsed with dI H2O
10. Solids dried overnight at 50C - 60 C and weighed

Test	Group	Rock + cup (g)	Tare(g)	Rock (g)	Mass (g) Wetted rock day 0	Mass (g) Wetted rock day 1	Net Agglom. Water at Treatment (mL)	Amendment Test Group	Final Mass (g)	Effluent volume (mL)	pH	SPCOND, µS/cm	Dried Solids from Effluent (g)	Solids washed out (%)
1		614.70	14.60	600.1				dI H2O	659.4	36.0	2.85	1018	2.29	0.3814
2	Crushed waste rock from RDI	615.55	15.00	600.6				5% full strength milk	688.8	7.0	2.70	1531	0.05	0.0084
3		615.00	14.80	600.2				5% NaHCO3	679.5	19.0	8.42	28810	0.81	0.1343
4		615.90	15.15	600.8				CaO slurry	671.1	26.0	9.75	1455	2.18	0.3630
5		615.30	14.95	600.4				dI H2O	627.9	76.0	3.08	1024	0.38	0.0639
6	Crushed waste rock from RDI without minus 50 mesh reject	616.35	15.00	601.4				5% full strength milk	636.4	62.0	3.12	1875	0.05	0.0089
7		615.30	14.65	600.7				5% NaHCO3	644.8	61.0	8.52	34500	0.37	0.0617
8		615.00	14.95	600.1				CaO slurry	635.6	67.0	8.36	1795	0.26	0.0425
9		615.35	15.05	600.3	643.0	630.7	15.3	dI H2O	641.3	70.0	2.89	1779	2.45	0.4082
10	Crushed waste rock from RDI - Agglomerated	615.05	14.45	600.6	643.4	635.8	20.7	5% full strength milk	674.0	41.0	2.83	2646	1.02	0.1704
11		615.35	14.95	600.4	644.1	633.1	17.7	5% NaHCO3	658.2	54.0	8.36	34000	4.30	0.7166
12		615.45	14.95	600.5	638.1	630.3	14.8	CaO slurry	647.9	63.0	8.79	1861	2.57	0.4286

Note: Vessels were air drying due to hot air blower from heater and so vessel masses presented for general inspection only

5% Milk (18 Dec.)			7.23	420
5% NaHCO3 (18 Dec.)			8.52	36300
CaO slurry (18 Dec.)			11.91	5390
Di H2O			6.42	2

Standards - Meter Checks	
pH 2.0	2.01
pH 7.0	7.03
1000 µS/cm	1044
10000 µS/cm	10290

Flood/Drain and Rinse

Test	Tap Water Flood (mL)	Photos	Drain Down Increments (mL)	Dry Mass (g)	dIH2O Rinse, mL	Comments	Photos	Moist mass (g)	Volume Effluent (mL)	Dry Solids (g)	Solids washed out (%)
1	1750	Yes	250-500 mL	645.35	100	some perching, but drained	Yes	668.00	71.0	0.6625	0.1027
2	1750	Yes	250-500 mL	671.40	100	extended perching, but drained	Yes	688.30	75.0	0.0008	0.0001
3	1750	Yes	250-500 mL	664.15	100	extended perching, but drained	Yes	676.20	83.0	0.1786	0.0269
4	1750	Yes	250-500 mL	633.75	100	perched liquid, but drained	Yes	664.50	64.0	0.3405	0.0537
5	1750	Yes	250-500 mL	616.05	100	drained	Yes	632.15	80.0	0.1738	0.0282
6	1750	Yes	250-500 mL	622.40	100	drained	Yes	642.10	75.5	0.0139	0.0022
7	1750	Yes	250-500 mL	621.60	100	drained	Yes	650.90	65.0	0.2392	0.0385
8	1750	Yes	250-500 mL	617.00	100	drained	Yes	640.75	71.0	0.1813	0.0294
9	1750	Yes	250-500 mL	621.00	100	drained	Yes	653.70	59.5	1.7544	0.2825
10	1750	Yes	250-500 mL	662.95	100	drained well	Yes	676.65	81.0	0.3774	0.0569
11	1750	Yes	250-500 mL	647.05	100	drained	Yes	654.85	86.0	2.0534	0.3173
12	1750	Yes	250-500 mL	626.00	100	drained	Yes	653.55	65.0	2.0465	0.3269

SUMMARY

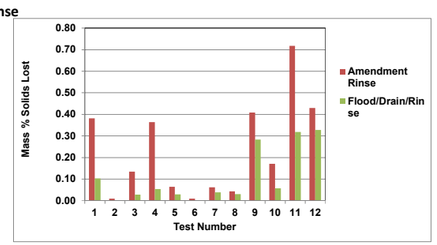
Table 1. Phase 1: Amendment Top-Down Rinse and Drain

Test	Group	Amendment Test Group	Rock (g)	Effluent volume (mL)	pH	SPCOND, µS/cm	Dried Solids from Effluent (g)	Solids washed out (%)
1	Crushed waste rock from RDI	dI H2O	600.1	36.0	2.85	1018	2.29	0.381
2		5% milk	600.6	7.0	2.70	1531	0.05	0.008
3		5% NaHCO3	600.2	19.0	8.42	28810	0.81	0.134
4		CaO slurry	600.8	26.0	9.75	1455	2.18	0.363
5	Crushed waste rock from RDI without minus 50 mesh reject	dI H2O	600.4	76.0	3.08	1024	0.38	0.064
6		5% milk	601.4	62.0	3.12	1875	0.05	0.009
7		5% NaHCO3	600.7	61.0	8.52	34500	0.37	0.062
8		CaO slurry	600.1	67.0	8.36	1795	0.26	0.043
9	Crushed waste rock from RDI - Agglomerated	dI H2O	600.3	70.0	2.89	1779	2.45	0.408
10		5% milk	600.6	41.0	2.83	2646	1.02	0.170
11		5% NaHCO3	600.4	54.0	8.36	34000	4.30	0.717
12		CaO slurry	600.5	63.0	8.79	1861	2.57	0.429

Phase 2: Upflow Flood/Drain and Top-Down Rinse

Test	Tap Water Flood (mL)	Drain Down Increments (mL)	Mass (g)	dIH2O Rinse, mL	Comments	Moist mass (g)	Volume Effluent (mL)	Dry Solids (g)	Solids washed out (%)
1	1750	250-500 mL	645.35	100	some ponding, but drained	668.00	71.0	0.6625	0.103
2	1750	250-500 mL	671.40	100	extended ponding, but drained	688.30	75.0	0.0008	0.000
3	1750	250-500 mL	664.15	100	extended ponding, but drained	676.20	83.0	0.1786	0.027
4	1750	250-500 mL	633.75	100	some ponding, but drained	664.50	64.0	0.3405	0.054
5	1750	250-500 mL	616.05	100	drained	632.15	80.0	0.1738	0.028
6	1750	250-500 mL	622.40	100	drained	642.10	75.5	0.0139	0.002
7	1750	250-500 mL	621.60	100	drained	650.90	65.0	0.2392	0.038
8	1750	250-500 mL	617.00	100	drained	640.75	71.0	0.1813	0.029
9	1750	250-500 mL	621.00	100	drained	653.70	59.5	1.7544	0.283
10	1750	250-500 mL	662.95	100	drained well	676.65	81.0	0.3774	0.057
11	1750	250-500 mL	647.05	100	drained	654.85	86.0	2.0534	0.317
12	1750	250-500 mL	626.00	100	drained	653.55	65.0	2.0465	0.327

Test	Amendment	Rinse/Flood/Drain/Rinse
1	0.381	0.103
2	0.008	0.000
3	0.134	0.027
4	0.363	0.054
5	0.064	0.028
6	0.009	0.002
7	0.062	0.038
8	0.043	0.029
9	0.408	0.283
10	0.170	0.057
11	0.717	0.317
12	0.429	0.327



Appendix B3 - Utilization Testing Using Amended USBM Method
AZC Composite Sample

12-Dec-17

Sovereign has requested that I prepare a single 1000 g composite sample of the five 1000 g composites (pulveriz

Purpose: Transfer to ACZ for ABA and ICP analyses

Composite	Cumulative (g)	grams
Buckets 1-4	801.65	200.45
Buckets 5-8	601.20	200.40
Buckets 9-12	1002.05	200.40
Buckets 13-16	200.40	200.40
Buckets 17-20	400.80	200.40
TOTAL		1002

Minus 60 mesh for Cation Exchange Capacity	
(sample -60 mesh reject from RDI sieve analysis)	
Sent 19 Dec. -Arrived ACZ on 20 December 2017	
TOTAL	1003

Appendix B3 - Utilization Testing Using Amended USBM Method

Table A. SLS Standards Development

Table A. SLS Standards Development

SLS Concentration 1,2,3	Foam Volume, mL	Time to Reform to 100 mL	Specific Conductance (µS/cm)
2%	700		2045
1%	720		1128
0.50%			677
0.10%			223
0.05%			114
0.025%			61
0.01%			25
1000 µS/cm STANDARD			1068
10000 µS/cm STANDARD			10350

1 06 January standards in distilled water using volumetric flasks; VWR Symphony SP70C

2 Foam very stable in distilled water, but salts from solids may change this

3 collected photos of standards

SLS Concentration 1	t(0)	t(f)	Minutes to Reform to ~ 100 mL	Foam Volume, mL 4	Final foam volume, mL	Final liquid volume, mL	Foam Vol. after Overnight Storage
2%	16:14	16:25	11	800	700	100	425
1%	16:09	16:18	9	800	700	100	600
0.50%	16:04	16:23	19	640	630	70	510
0.10%	15:40	15:57	17	450	300	100	
0.05%	15:35	15:48	13	390	190	100	
0.025%	15:30	15:36	6	190	125	100	
0.01%	15:27	15:36	9	110	60	90	

1 08 January 2018 standards in distilled water

2 Black and Decker BL1200 Series blender, Low setting, t = 15 seconds

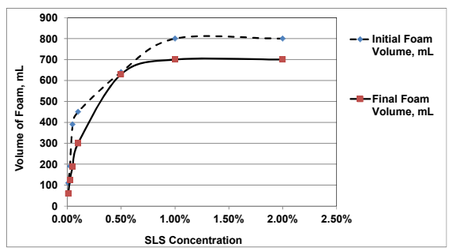
3 Foam tranferred immediately to 1000 mL beakers and monitored

4 19.1 C at t(0) on 09 Jan. 2018; 16.4 C after overnight (0918, 10 January 2018)

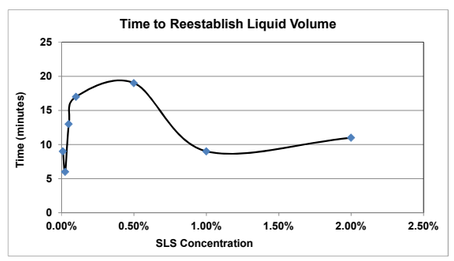
FINDINGS

1. Available water was consumed at 1% SLS; no more was available for additional foam generation at 2% SLS
2. Foam volume (initial) was indicative of SLS concentration
3. Foam volumes (at water reformation timepoint) would also be useful as indicators of SLS concentration
4. Foam decay time maximized at 0.5% SLS and then decreased
5. At higher SLS concentrations (0.5%, 1% and 2%) foam thinned but retained a substantial volume even after overnight storage (covered with SARAN wrap); lower concentrations were not tracked overnight
6. Suggest taking foam volume reading at uniform timepoint of t = 15 - 20 min

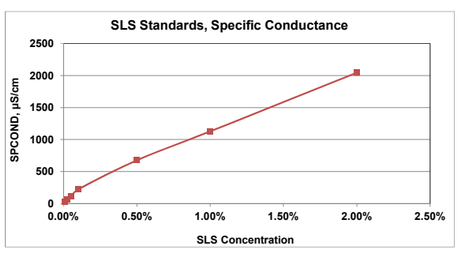
SLS Concentration	Initial Foam Volume, mL	Final Foam Volume, mL
2%	800	700
1%	800	700
0.50%	640	630
0.10%	450	300
0.05%	390	190
0.025%	190	125
0.01%	110	60



SLS Concentration	Minutes to Reform to ~ 100 mL
2%	11
1%	9
0.50%	19
0.10%	17
0.05%	13
0.025%	6
0.01%	9



SLS Concentration	Corresponding Concentration (mg/L)	Specific Conductance (µS/cm)
2%	20000	2045
1%	10000	1128
0.50%	5000	677
0.10%	1000	223
0.05%	500	114
0.025%	250	61
0.01%	100	25



LOW LEVEL SDS CONCENTRATIONS:
Sudsing/Foaming

The USBM SLS adsorption and degradation tests were actually done at much lower loadings than the above and so a second set of standards were assessed. A stock solution was made and diluted to the various concentrations.

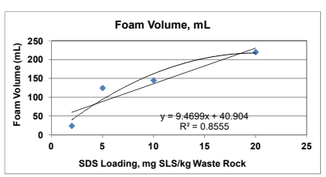
SLS Loading	Stock solution (mLs)	Total Vol. (mLs)	SP COND, µS/cm	Assay Time	Test volume, (mL)	Time (0)	Time (F)	Foam Decay To 100 mL (min)	Initial Foam Vol. (mL)	Final Liquid Vol. (mL)	Final Stable Foam Volume (mL)
5 mg SDS/kg waste rock	0.28	100	ND	15:00	100	15:00	15:10	10	125	93	25
10 mg SDS/kg waste rock	0.56	100	ND	14:42	100	14:44	14:54	10	145	90	34
20 mg SDS/kg waste rock	1.11	100	ND	15:14	100	15:14			220		
60 mg SDS/kg waste rock	3.33	100	ND	13:15	100	13:16	13:22	6.0	300	100	150
90 mg SLS/kg waste rock	5.00	100	ND	13:26	100	13:27	13:36	9.0	400	100	225
120 mg SLS/kg waste rock	6.67	100	ND	14:02	100	14:04	14:11	8.5	450	100	275
180 mg SLS/kg waste rock	10.0	100	ND	14:14	100	14:15	14:26	11	525	100	375
60 mg SDS/kg waste rock (REPEAT ASSAY				13:37	100	13:38	13:46	8.0	375	100	175
90 mg SLS/kg waste rock (REPEAT ASSAY)				13:49	100	13:50	13:57	6.75	400	100	200

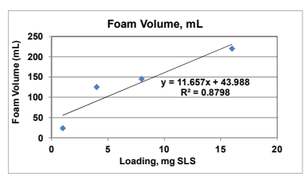
1. Stock solution 1441 mg SLS in 100 mL distilled water (volumetric flask)
2. Blendor - Setting "LOW" for 15 seconds
3. 1000 mL beaker settling vessel
4. Used a 15.0 min maximum cutoff for foam degradation monitoring
5. Archived SLS stock solution (<4 C)

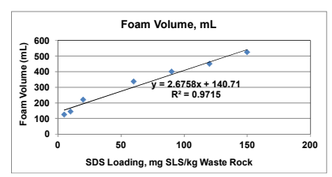
For an 800 g test sample:

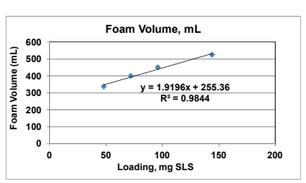
Solution (SDS content, mg SLS/kg waste rock	Foam Volume, mL	Foam Decay Time to 100 mL (min.)
2	24	10
5	125	10
10	145	10
20	220	10
60	338	7.0
90	400	7.9
120	450	8.5
150	525	11.0

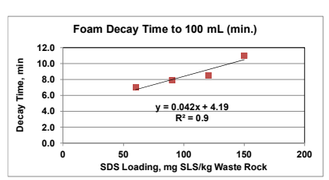
Solution (SDS content, mg)	Foam Volume, mL	Foam Decay Time to 100 mL (min.)
1	24	10
4	125	10
8	145	10
16	220	10
48	338	7.0
72	400	7.9
96	450	8.5
144	525	11.0

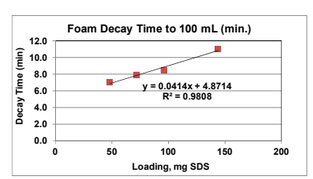












Appendix B3 - Utilization Testing Using Amended USBM Method
Field Capacity Test

Field Capacity Test

Moisture Content

Step	Description	Value
1	Reject bucket of waste rock tumbled on Dayton Bottle Roller for 1 min at setting 10 to distribute particles evenly	
2	Grab sample of mixed solids in Pyrex tray	2348.8 g
3	Mass empty tray	1151.0 g
4	Mass moist solids	1197.8 g
6	Dried solids overnight at 50 C - 56 C (18 hours)	
6	Cool and weigh solids + tray	
	t = 30 min	2332.3 g
	t= 60 min	2332.3 g
7	Mass dry solids	1181.3 g
8	Water loss	16.5 g
9	% Moisture	1.40%

Conclusion. Moisture content of mixed WR from RDI (wide particle size distribution) - Value somewhat lower than that of small masses of fines and small particles, as would be expected. Solids may also be gradually drying with storage.

Field Capacity

Step	Description	Value
1	Chose Buchner funnel (2.0 inch height x 4.5 inch (I.D.)	
2	Cut Whatman #1 paper to fit and moistened with distilled water	
3	Mass funnel + filter paper	524.0 g
4	Mass funnel + 2.0 inch layer of dry waste rock	1438.4 g
5	Mass dry solids	914.4 g
6	Funnel + solids placed on 1000 mL beaker, which served as a support and as a leachate collection vessel	
7	Incrementally added total of 500 mL distilled water to saturate bed, t(0) 11:20 AM	
8	PHOTOS	
9	All distilled water added (12:20 PM)	
10	Begin 2 hour gravity drain down	
11	Volume leachate	379 mL
12	Leachate pH	2.66
13	Leachate Specific Conductivity	1591
14	Mass funnel and wetted solids	1553.85 g
15	Mass water retained by solids	115.45 g
16	Field Capacity (kg water/kg dry solids)	0.126

Standards	pH 7.0	7.03
	pH 2.0	2.00
	10000 µS/cm	10080

Relative Hydraulic Conductivity
1/13/2018 - 1/14/2018

1. Waste rock not agglomerated
2. Waste rock not dried overnight in drying oven
3. VB-302A top loader
4. Buchner funnel- 2.0 inch height x 4.5 inch diameter (I.D.), ceramic
5. Whatman #1 qualitative filter paper support, not pre-moistioned
6. Waste rock from bucket previously tumbled to uniformly mix different particle sizes

Test Solutions (100 mL) @ 19.6 C

1. Distilled water
2. 2% SLS in distilled water (08 Jan. 2018)
3. Milk suspension (5% full strength milk)
4. NaHCO3 (0.49 g / 100 g solids to neutralize)
5. Powdered limestone slurry (0.49 g / 100 g solids)

Actual solutions

1. Same - 100 mL
2. Same - 100 mL
3. Made fresh - 0.5013 g + 99.5 mL dI H2O
4. Made fresh - 2.4491 g NaHCO3 in 100 mL dI H2O
5. Made fresh - 2.4411 g crushed limestone in 100 mL dI H2O

Note: We are not using whey for any applications

Quantity	Solution/Suspension	Distilled water	2% SLS	Milk suspension	NaHCO3	Limestone slurry	Limestone slurry (overnight, 21.2 h)
Buchner funnel + filter paper + ruler		525.60 g	526.05 g	525.85 g	525.60 g	525.85 g	525.85 g
Buchner funnel + filter paper + ruler + solids		1027.45 g	1026.55 g	1025.85 g	1025.75 g	1026.10 g	1026.10 g
Net solids		501.85 g	500.50 g	500.00 g	500.15 g	500.25 g	500.25 g
Waste rock bed height		22 mm	25 mm	25 mm	30 mm	25 mm	22 mm
Bed height inc. test solution/slurry		34 mm	34 mm	36 mm	38 mm	36 mm	36 mm
Δ Water column		12 mm	9 mm	11 mm	8 mm	11 mm	14 mm (Δ 8 mm drop)
Time to complete infiltration		7 min 2 sec	19 min 51 sec	6 min 7 sec	31 min 4 sec	11 min 27 sec	(60 min)
Time		7.03 min	19.85	7.12 min	31.06 min	11.9 min	60.0 min
Saturated hydraulic conductivity (K)		1.71	0.453	1.55	0.258	0.924	0.133
K, m/s		2.85E-05	7.55E-06	2.58E-05	4.29E-06	1.54E-05	2.22E-06
Supplemental							
Bed height at 15 min			25 mm		33 mm		36 mm, slow dripping
Bed height at 30 min					30 mm		34 mm, dripping accelerating
Bed height at 45 min							31 mm
Bed height at 60 min							28 mm, End test
End test							
Comments		Photos	Photos, Na salt of surfactant. High surfactant concentration resulted in order of magnitude decrease in hydraulic conductivity rate	Very dilute milk (5% of full strength milk) had little effect on hydraulic conductivity rate in comparison to distilled water	Na salt; Gas production still apparent at 26 min, small volume effluent. Again, Na salt decreased hydraulic conductivity. Possibly, effervescence also results in fine particle migration and plugging.	Limestone slurry had no immediate effect on hydraulic conductivity. Covered with saran wrap and stored overnight to repeat leach after limestone reacts	Previous day effluent - 37.5 mL; Leached after overnight reaction of limestone using 100 mL distilled water; 60 mL effluent collected - pH 3.01 (pH 7 STD: 7.02); Limestone slurry did react overnight. Effluent was circumneutral. But hydraulic conductivity decreased by order of magnitude. Photos

Appendix B3 - Utilization Testing Using Amended USBM Method
USBM U.1

SLS Consumption Tests
15-Jan-18

1 Samples will not be oven dried prior to tests because agglomeration requires the addition of water.
2 800 gram sampls waste rock
3 Moisture content: 11.2 mL
4 Agglomeration solution volume: 40 mL
5 Field capacity: 100.8 mL
6 No filter paper support
7 Samples tamped down in funnel
8 Buchner funnel 2inches x 4.5 inches (i.d.)
9 Calculated SLS Sol'n Volume: 49.6 mL
10. Funnel drain down time- 5 min
11. Sudsing: Blender, LOW, 15 sec.
12. Rapid transfer to 1000 mL beaker for lager volumes; 250 ml graduate for 10 and 20 mg/kg standards
13. SDS application - initial breakthrough reapplied to WR (due to flow through agglom solids)

Table 1A. SLS Consumption Test Set-Up and SLS Application Data

Parameter	Initial SLS Concentration	2nd SLS Concentration	3rd SLS Concentration	4th SLS Concentration	Pre-Wetting to Field Capacity
Test Unit Number	U.1.1	U.1.2	U.1.3	U.1.4	U.1.5
SLS Calculated Initial Sol'n Con., mg/L	968	2876	1917	1438	1438
SLS Concentration/Dose	60 mg/kg	180 mg/ kg	120 mg/Kg	90 mg/kg	90 mg/kg
Test Date	17 Jan. 2018	17 Jan. 2018	18 Jan. 2018	19 Jan. 2018	19 Jan. 2018
Test Start Time	NA	NA	NA	15:53 PM	15:53
Technician	TRC	TRC	TRC	TRC	TRC
Mass Funnel (F), g	521.40	496.85	476.15	476.60	497.65
Mass (F) + Solids (S), g	1359.05	1334.50	1313.85	1310.95	1334.25
Moist Solids, g	797.65	797.65	797.70	794.35	796.60
Volume Agglomeration Solution, mL	40	40	40	40	40
Agglomeration Cure Time, i	1/15/2018 16:01	1/15/2018 16:22	1/15/2018 16:33	1/18/2018 19:44	1/18/2018 20:00
Agglomeration Cure Time, f	1/17/2018 15:03	1/17/2018 15:03	1/18/2018, ND	1/19/2018; 15:23	1/19/2018; 15:23
Pre-Wetting Sol'n, mL(distilled water)	0	0	0	0	49.2
Volume SLS Sol'n Applied, mL	49.2	49.2	49.2	49.2	49.2
Volume Excess SLS Sol'n Recovered, mL	0	16.7	0	0	0
Final Mass F + S + Retained SLS Solution, mL	1392.05	1365.75	1347.65	1385.75	1348.3
Selected for Methylene Blue Test	No	Yes	Yes	Yes	Yes
Photos	Yes	Yes	Yes	Yes	Yes
Standards					
pH 2.0			2.01	1.99	1.99
pH 7.0	7.03	7.03	7.03	7.03	7.03
SPCOND					
1000 µS/cm	1064	1064	975	990	990
10000 µS/cm					
ACCUTEST-SGS MBAS SAMPLES	NO	YES	YES	YES	YES
ACCUTEST-SGS MBAS (mg/L)	*	27.6	24.8	56.4	33.3
Recalculated Ci, mg/L	*	143	96	71	71
Loss Based on Calculation, mg/L	*	115	71	15	38
Loss Based on Foam Volume, mg/L		131	90	67	56
Percent Agreement		88	79	22	68
SLS stock sol'n	193.5 mg SLS diluted to 200 mL in volumetric flask	1438 mg SLS diluted to 500 mL in volumetric flask	958.4 mg SLS diluted to 500 mL in volumetric flask	718.8 mg SDS + 500 m distilled water, volumetric flask	
Observations	At high SLS, a stable foam will form and, following a brief period of degradation, be relatively constant in volume - cut off time for assay foam degradation was t = 15 min.; After 4th rinse, foam broke up so quickly that it was not possible to get a high accuracy estimate of foam volume			Later rinses - foam immediatley discharged to leave no visible indication of the presence of surfactant	PRE-Moistening resulted in a much greater initial foam volume at 90 mg SLS/kg WR. Foam was breaking up so quickly that it was difficult to get an estimate of foam volume - while there was detectable foam by the later rinses, the foam broke almost immediately to leave no visible trace of bubbles to indicate the presence of surfactant

Table 1B. Sample Rinsing Data Sheets

Test Unit No. U.1.1. SLS Conc. 60 mg SLS/kg Test Date 17 Jan 2018 Start Time 15:03

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
1	100	95	2.58	1936	75	2	ND		*
2	100	98	2.80	934	10	5	ND		*
3	100	101	2.83	1027	25	2.5	ND		*
4	100	101	2.94	769	5	0.75	ND		CONSUMED, END TEST
5	ND	ND	ND	ND	ND	ND	ND		
6	ND	ND	ND	ND	ND	ND	ND		
7	ND	ND	ND	ND	ND	ND	ND		
8	ND	ND	ND	ND	ND	ND	ND		
9	ND	ND	ND	ND	ND	ND	ND		
10	ND	ND	ND	ND	ND	ND	ND		
Total	400	395							

Test Unit No. U.1.2. SLS Conc. 180 mg SLS/kg Test Date 17 Jan. 2018 Start Time

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
1	100	100	2.84	1266	120	15	65		6.52
2	100	95	2.95	1031	70	8	0		2.12
3	100	101	3.02	852	80	8	0		3.11
4	100	100	3.08	763	50	6	0		0.52
5	100	99	3.12	684	50	4	0		0.52
6	100	98	3.19	623	50	3	0		0.52
7	100	100	3.20	568	20	1	0		0
8	100	99	3.21	541	25	1	0		0
9	100	100	3.22	529	40	3	0		0
10	100	98	3.25	485	25	1	0		0
Total	1000	990							13.31

Loss: 131 mg

$y = 11.657x + 43.988$
$R^2 = 0.8798$

Test Unit No. U.1.3. SLS Conc. 120 mg SLS/kg Test Date 18 Jan. 2018 Start Time

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
1	100	99	2.68	1579	75	15	40		2.66
2	100	98	2.79	1205	40	15	0		0
3	100	101	2.86	1133	60	11	0		1.37
4	100	99	2.93	1029	50	6	0		0.52
5	100	99	2.97	882	30	4	0		0
6	100	100	2.96	918	30	4	0		0
7	100	97	3.04	777	50	3	0		0.52
8	100	97	3.07	692	50	1	0		0.52
9	100	98	3.11	634	30	2	0		0
10	100	98	3.14	580	40	1	0		0
Total	1000	986							5.59

Loss: 90 mg

Test Unit No. U.1.4. SLS Conc. 90 mg SLS/kg Test Date 18 Jan 2018 Start Time 15:53

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
1	100	102	2.88	1058	75	4.0	20		2.66
2	100	99	2.94	947	50	0.5	0		0.52
3	100	100	2.98	914	50	<0.5	0		0.52
4	100	100	3.02	839	50	<0.5	0		0.52
5	100	99	3.06	777	50	0.25	0		0.52
6	100	100	3.10	703	25	<0.25	0		
7	100	99	3.10	684	30	<0.25	0		
8	100	100	3.16	616	25	<0.25	0		
9	100	100	3.17	622	20	<0.25	0		
10	100	94	3.23	575	<20	<0.25	0		
Total	1000	993							4.74

Loss: 67 mg

Test Unit No. U.1.5. (PRE-MOIST TO Field.Cap.) SLS Conc. 90 mg SLS/kg Test Date 18 Jan 2018 Start Time 15:53

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
1	50.8	111	2.54	2459	200	1.5	100		13.38
2	100	97	3.00	716	50	5.25	0		0.52
3	100	98	3.09	580	60	3.1	0		1.37
4	100	102	3.11	614	50	2.3	0		0.52
5	100	99	3.13	594	50	2.25	0		0.52
6	100	102	3.19	550	20	1.25	0		
7	100	100	3.24	501	20	0.30	0		
8	100	97	3.27	456	20	0.50	0		
9	100	97	3.26	498	<10	0.75	0		
10	100	100	3.30	410	<5	<0.5	0		
Total	1000	1003							16.31

Loss: 56 mg

Appendix B3 - Utilization Testing Using Amended USBM Method
USBM U.2

Table 1A. SLS Consumption Test at Various Loadings of NaHCO3

Parameter	Initial SLS Concentration	SLS + 1st Bicarb Loading	SLS + 2nd Bicarb Loading	SLS + 3rd Bicarb Loading
Test Unit Number	U.2.1	U.2.2	U.2.3	U.2.4
SLS Stock Solution conc., mg/L	1196	1196	1196	1196
SLS Concentration/Dose (mg/kg)	134	134	134	134
NaHCO3, g/kg waste rock	0	2.44	4.88	7.31
Test Date	27-Jan-18	27-Jan-18	27-Jan-18	27-Jan-18
Test Start Time	2:49 PM	5:44 PM	6:21 PM	6:55 PM
Technician	TRC	TRC	TRC	TRC
Mass Funnel (F), Filter paperand Ruler, g	145.60	499.10	479.40	523.80
Mass (F) + Solids (S), g	941.85	1297.65	1275.70	1322.35
Solids, g	796.25	798.55	796.30	798.55
Bed Height, cm	3.5	4.0	4.5	4.5
Volume Agglomeration Solution, mL	0	0	0	0
Agglomeration Cure Time, i	NA	NA	NA	NA
Agglomeration Cure Time, f	NA	NA	NA	NA
Volume SLS Sol'n Applied, mL	1000	1000	1000	1000
Volume SLS Sol'n Recovered, mL	960	924	914	924
Mass F + S + Retained SLS Solution, mL	1046.6	1435.5	1422.2	1461.45
Selected for Methylene Blue Test	yes	yes	yes	yes
Photos	yes	yes	yes	yes
Sudsing Volumes (Influents)	470	370	290	230
Standards:				
pH 2.0	1.96			
pH 7.0	7.03			
SP COND (1000 µS/cm)	986			
ACCUTEST-SGS MBAS SAMPLE	YES	YES	YES	YES
ACCUTEST-SGS MBAS SAMPLES, mg/L	**44.8**	**34.4**	**40.8**	**60.4**
Recalculated Ci, mg/L	**111.6**	**116.0**	**117.2**	**116.0**
Loss Based on Calculation, mg/L	**66.8**	**81.6**	**76.4**	**55.6**
Loss Based on Foam Volume, mg/L	**2.1**	**-75.9**	**-114.7**	**-191.5**
Percent Agreement	*	*	*	*

Conclusions:

1. USBM foam assay was ineffective at estimating consumption in presence of high sodium bicarbonate.
2. MBAS assay showed loss at 134 mg/kg loading in line with USBM 120 mg/kg - absence of bicarbonate (~70 mg/kg consumption)
3. General trend of reduced loss of SLS with increasing bicarbonate

Notes:
1. Used previously unopened bucket of rejects from RDI;
2. Foam vessel switched to graduated cylinder (1000 mL, 500 mL or 250 mL as required) due to low SDS concentration
3. Whatman #1 filter paper used since solids transfer may occur and also transfer bound SDS
4. Solids not agglomerated to ensure uniform flow and particle contact in the four small scale tests
5. Solids not previously oven dried
6. Applied influent SDS solution with 5 or 10 mL pipet, with breakthrough re-applied - all retained

Table 1B. Sample Rinsing Data Sheets

Test Unit No. U.2.1 SLS Conc. 134 mg SLS/kg + 0 BICARB Test Date 27 Jan 2018 Start Time 2:49 PM

Foam Standards Rerun in Graduate Vessel

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Max, Foam Volume (mL)	Time (i)	Time (f)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
Field capacity sol'n	89.6	0	8.68	262.5	480	4:27 PM	4:42 PM	15	470	1196	107
1	100	72	2.57	2352	100	3:46 PM	4:03 PM	17	15		16.1
2	100	98	2.63	2165	80	4:11 PM	4:24 PM	13	0		17.5
3	100	100	2.80	2218	20	4:48 PM	4:55 PM	7	0		4.5
4	100	100	2.74	1943	25	5:00 PM	5:05 PN	4	0		5.6
5	100	96	2.80	1637	18	5:12 PM	5:14 PM	2	0		3.9
6	100	100	2.53	1673	100	7:40 PM	7:40 PM	<1	0		22.3
7	100	99	2.55	1516	100	7:43 PM	7:43 PM	<1	0		22.1
8	100	97	2.54	1463	20	7:47 PM	7:48 PM	1	0		4.3
9	100	99	2.58	1339	15	7:49 PM	7:54 PM	5	0		3.3
10	100	99	2.57	1347	25	7:55 PM	7:57 PM	2	0		5.5
Total	1000	960									105

Loss: 2.1

Test Unit No. U.2.2. SLS Conc. 134 mg SLS/kg + 2.44 g BICARB/ kg WR Test Date 27 Jan. 2018 Start Time 5:44 PM

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Time (i)	Time (f)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
Field capacity sol'n	89.6	0	8.30	17640	370	5:56 PM	6:13 PM	17	160	1196	107
1	100	69	2.31	7710	40	8:02 PM	8:07 PM	5	25		8.0
2	100	84	2.57	5740	48	8:17 PM	8:19 PM	2	30		9.0
3	100	96	3.06	5120	50	9:50 PM	9:58 PM	8	10		10.7
4	100	97	4.53	3010	10	11:00 PM	11:00 PM	< 1	0		2.2
5	100	96	5.52	2380	30	11:40 PM	11:41 PM	1	10		6.4
6	100	94	6.19	2295	125	12:17 AM	12:32 AM	15	29		26.2
7	100	94	6.41	2202	130	12:55 AM	1:10 AM	15	28		27.3
8	100	100	6.51	1849	150	1:52 AM	2:07 AM	15	36		33.5
9	100	95	6.49	1679	135	2:12 AM	2:26 AM	15	16		28.6
10	100	99	6.40	1334	140	2:35 AM	2:50 AM	15	10		31.0
Total	1000	924									182.9

LOSS: -76

Test Unit No. U.2.3. SLS Conc. 134 mg SLS/kg + 4.875 g BICARB/ kg WR Test Date 27 Jan. 2018 Start Time 6:21 PM

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Time (i)	Time (f)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
Field capacity sol'n	89.6	0	8.22	31300	290	6:37 PM	6:44 PM	7	100	1196	107
1	100	60	2.89	9860	64	8:27 PM	8:42 PM	15	34		14.2
2	100	86	4.17	5910	30	10:06 PM	10:08 PM	2	5		5.8
3	100	94	5.73	4580	65	10:30 PM	10:47 PM	15	27		13.6
4	100	98	6.40	6000	160	11:06 PM	11:21 PM	15	68		35.0
5	100	97	6.41	3320	135	11:28 PM	11:43 PM	15	38		29.2
6	100	98	6.47	2613	130	11:52 PM	12:07 AM	15	27		28.5
7	100	98	6.72	2822	45	12:28 PM	12:42 AM	15	27		9.8
8	100	88	6.87	3190	125	1:02 AM	1:17 AM	15	17		24.6
9	100	98	6.83	3280	140	1:22 AM	1:37 AM	15	28		30.6
10	100	97	6.71	2172	140	1:42 AM	1:57 AM	15	30		30.3
Total		914									221.7

LOSS: -115

Test Unit No. U.2.4. SLS Conc. 134 mg SLS/kg + 7.132 g BICARB / kg WR Test Date 27 Jan 2018 Start Time 6:55 pm

Rinse No.	Rinse Volume (mL)	Recovered Volume (mL)	pH	Cond. µS/cm	Foam Volume (mL)	Time (i)	Time (f)	Decay Time (min)	Stable Foam Vol., mL	Estimated SLS conc. mg/L)	Estimated SLS Mass (mg)
Field capacity sol'n	89.6	0	8.09	42500	230	7:01 PM	7:17 PM	16	25	1196	107
1	100	55	6.78	18100	47	8:54 PM	9:10 PM	16	20		12.0
2	100	89	6.72	6220	190	10:12 PM	10:28 PM	15	35		37.8
3	100	95	6.73	5340	140	10:37 PM	10:52 PM	15	46		29.7
4	100	94	6.67	4640	135	10:55 PM	11:10 PM	15	45		28.3
5	100	103	6.56	3650	155	11:19 PM	11:33 PM	15	50		35.7
6	100	97	6.66	3550	145	11:45 PM	12:00 AM	15	43		31.4
7	100	97	6.68	3380	140	12:04 AM	12:19 AM	15	35		30.3
8	100	98	6.62	2884	145	12:35 AM	12:50 AM	15	31		31.7
9	100	94	6.74	2862	130	1:15 AM	1:30 AM	15	22		27.3
10	100	102	6.83	2834	150	1:34 AM	1:49 AM	15	33		34.2
Total		924									298.5

LOSS -192

Appendix B3 - Utilization Testing Using Amended USBM Method
USBM U.3

Relative Hydraulic Conductivity and Milk Consumption (No additional alkalinity)
21-Jan-18

1. Waste rock not agglomerated
2. Waste rock not dried overnight in drying oven
3. VB-302A top loader balance
4. Test Solutions (100 mL)

380 mL tap water +38.6043 g non-fat dry milk powder (product not the Dairy Gold material)

5. Buchner funnel- 2.0 inch height x 4.5 inch diameter (I.D.), ceramic
6. Whatman #1 qualitative filter paper support, not pre-moistioned
7. Waste rock from bucket previously tumbled to uniformly mix different particle sizes
8. Solids gently tamped after placement in Buchner funnel
9. 100 mL Milk solution applied through perforated base of a plastic Buchner funnel
10. Drained for 2 hours for maximum drain down

Quantity	Milk Suspension 1st leach	Milk Suspension 2nd leach
Test Designation	U.3.1	U.3.2
Time (0)	1350	1601
Volume Milk Solutions, mL	100	100
Buchner funnel + filter paper + ruler, g	524.95	524.95
Buchner funnel + filter paper + ruler + solids, g	1025.05	1025.05
Net solids, g	500.1	500.1
Waste rock bed height, cm	2.0	2.0
Bed height inc. test solution/slurry, mm	22.7	22.7
Δ Water column, mm	17	12
Time to complete infiltration, min	22	88
Saturated hydraulic conductivity (K)	0.77	0.136
K, m/s	1.29E-05	2.27E-06
Initial Solution pH	6.76	
Final Solution pH	5.84	5.99

Leach 1		Leach 2	
Supplemental Raw Data: bed heights (cm)	Relative Solution Height, cm	Supplemental Raw Data: bed heights (cm)	Solution Height, cm
Leach Sol'n 1 Break through at 2:20 min		Leach Sol'n 2 Break through at 2:20 min	
0 min	22.7	0 min	22.7
3:52 min	21.7	1:00 min	22.6
5:20 min	21.6	3:06 min	22.4
7:00 min	21.5	8:22 min	22.3
12:00 min	21.3	16:00 min	22.3
22:00 min	21.0	30:00 min	22.2
2.0 hour drain down		56:00 min	22.0
		88:00 min	21.5
		107:00 min	[21.5]
		120:00 min	[21.5]
Volume leach solution recovered, mL	28.0		66.5
Final Mass Funnel + ruler + retained liquid, g	ND		1114.6
Photos	Yes		Yes
T(f)	ND		18:01 PM
Observations	Final pH of leachate suggests curdling was inhibited at such high C loadings, but see Leach 3.2		Standing milk on surface of bed at termination; bed clogged: FULL STRENGTH MILK, EVEN AT 20% VOL/WT LOADING, WILL LIKELY CLOG 20 KG TEST CELLS

Curdling tests
Original Assay - Initial acid loading

Test	Time	Observation, hours	Sample Volume, mL	Vol tap water, mL	Vol. 31% HCl, mL	Whey, mL	Curds, mL (Floating)	Curds, mL (Settled)	Curds, mL (Total)	% Loss Milk Components	Comments
U.3	1535 - 1930	4.0	5.0	15.0	1.0	3.0			18.5	Initial	
U.3.1	1535 - 1930	4.0	5.0	15.0	1.0	2.5			19.0	-3	Milk solids overwhelming acid addition
U.3.2	1535 - 1930	4.0	5.0	15.0	1.0	3.0			18.5	0	Milk solids overwhelming acid addition

Original Assay - Additional acid added to consolidate curds

Test	Time	Observation, hours	Sample Volume, mL	Vol tap water, mL	Vol. 31% HCl, mL	Whey, mL	Curds, mL (Floating)	Curds, mL (Settled)	Curds, mL (Total)	% Loss Milk Components	Comments
U.3	1935-0850	13.3	5.0	15.0	2.0	9.5			12.0	Initial	
U.3.1	1935-0850	13.3	5.0	15.0	2.0	11.0			11.0	8	Loss of 8% milk solids upon first pass
U.3.2	1935-0850	13.3	5.0	15.0	2.0	9.0			12.5	-4	Residual milk solids from 1st leach added to milk solids from 2nd leach overwhelmed acid - poor curdlings. But indicates that milk solids will not immediately form stable immobilized mass while passing through acidic solids - it will rinse out to some extent upon further leaching

Repeat Assay (Increased acid loading at time zero)

Test	Time	Observation, hours	Sample Volume, mL	Vol tap water, mL	Vol. 31% HCl, mL	Whey, mL	Curds, mL (Floating)	Curds, mL (Settled)	Curds, mL (Total)	% Loss Milk Components	Comments
U.3		4.0	5.0	15.0	2.0	7.0	14.5	0	14.5	Initial	
		13.3	5.0	15.0	2.0	9.0	13.0	0	13.0	Initial	
U.3.1		4.0	5.0	15.0	2.0	12.0	9.0	1.25	10.25	29	Given that 100 mL solution contained 10.1 g milk solids for treating 500 g WR, and approximately 31% was lost to curdling on the solids on a "pass through application". Based on ACZ solids analysis, 0.35% SO4-S, or 1.05 wt % SO4, stoichiometrically requiring minimum 52.4 g C, or 2.62 g C/ kg WR. Twice stoichiometric requirement 5.24 g C/ kg WR. But full strength milk will likely plug bed. However, soluble sulfate will likely be rinsed out of the system upon cyclic leach cycles, requiring less carbon for the sulfate reducers.
		13.3	5.0	15.0	2.0	14.0	8.0	1	9.0	31	
U.3.2		4.0	5.0	15.0	2.0	0	21.5	0	21.5	(*)	Both results show unconsolidated curds resulting from excess milk solids mobilized by the second leach, but deposited from the first leach)
		13.3	5.0	15.0	2.0	0	22.0	0	22.0	(*)	

Relative Hydraulic Conductivity and Milk Consumption (With Additional Alkalinity)
21-Jan-18

1. Waste rock not agglomerated
2. Waste rock not dried overnight in drying oven
3. VB-302A top loader balance
4. Test Solutions (100 mL)
5. Buchner funnel- 2.0 inch height x 4.5 inch diameter (I.D.), ceramic
6. Whatman #1 qualitative filter paper support, not pre-moistioned
7. Waste rock from bucket previously tumbled to uniformly mix different particle sizes
8. Solids gently tamped after placement in Buchner funnel
9. 100 mL Milk solution applied through perforated base of a plastic Buchner funnel
10. Drained for 2 hours for maximum drain down

2nd batch milk solution:
380 mL tap water + 38.6040 g non-fat dry milk powder (pH 6.76)
100 mL Leach sol'n 1: milk suspension + 2.45 g NaHCO3 (0.49 g/100 g waste rock)
100 mL Leach sol'n 2: milk suspension (no additional NaHCO3)
100 mL Leach sol'n 3: milk suspension (no additional NaHCO3)
100 mL Leach Sol'n 4: distilled water (overnight)

Quantity	Milk Suspension 1st leach	Milk Suspension 2nd leach	Milk Suspension 3rd leach	Distilled water 4th Leach
Time (0)	1500	1712	1913	2117
Volume Solutions, mL	100	100	100	100
Initial pH	8.53	7.66	7.24	7.36
Buchner funnel + filter paper + ruler, g	479.15			
Buchner funnel + filter paper + ruler + solids, g	979.15			
Net solids, g	500.0			
Waste rock bed height, cm	3.5			
Bed height inc. test solution/slurry, cm				
Δ Water column, mm	7	18	12	ND
Time to complete infiltration, min	22	36	50	ND
Saturated hydraulic conductivity (K)	0.32	0.500	0.24	ND
K, m/s	5.30E-06	8.33E-06	4.00E-06	ND

Final Solution pH

Leach 1		Leach 2		Leach 3		Leach 4 (distilled water)
Supplemental Raw Data: bed heights (cm)	Solution Height, cm	Supplemental Raw Data: bed heights (cm)	Solution Height, cm		Solution Height, cm	pH check
Leach Sol'n 1 Break through at 2:20 min		Leach Sol'n 2 Break through at 2 min				
0 min	15.6	0 min	14.6	0 min	15.4	
1:38 min	15.7	7:00 min	15.4	2:30 min	15.4	
2:16 min	15.9	20:15 min	15.7	5:00 min	15.45	
3:47 min	16.0	24:00 min	15.9	10:00 min	15.5	
6:24 min	16.1	31:00 min	16.2	15:00 min	15.6	
8:37 min	16.1	33:00 min	16.3	20:00 min	15.8	
11:55 min	16.15	36:00 min	16.4	25:00 min	15.8	
15:22 min	16.2			30:16 min	16.0	
22:09 min	16.3			40:00 min	16.4	
				45:00 min	16.55	
				50:00 min	16.6	6.85
2.0 hour drain downs						
Volume leach solution recovered, mL	22.5		80		89	
Final Bed Height, cm	ND		ND			
Final Mass Funnel + ruler + retained liquid, g			1061.65		1065	
Photos	Yes		Yes		Yes	
T(f)	1700		1904		2113	

Observations: 20 "drops" HCL equivalent to ~1000 uL — milk seems to interfere with the ability of NaHCO3 to permenantly reduce permeability

Leach 4 distilled water rinse was not monitored for leach rate and was used only as a final rinse to determine the quantity of milk solids that could still be mobilized

STANDARDS
pH 7.0: 7.00
pH 2.0: 2.00

Curdling test (Initial assay at standard acid loading)

Test	Sample	Time	Observation, hours	Sample Volume, mL	Vol tap water, mL	Vol. 31% HCl	Whey, mL	Curds, mL (Total)
U.4.1.	Milk Leach Solution		4.0	5.0	15.0	2.0	16	5
U4.1.a.1	Milk + Bicarb		4.0	5.0	15.0	2.0	16	5
U4.1.a.2	Milk		4.0	5.0	15.0	2.0	10	11
U4.1.a.3	Milk		4.0	5.0	15.0	2.0	3	19
U4.1.a.4	Distilled water		4.0	5.0	15.0	2.0	11	10

Reactor Vessel: Drain sealed 25 mL syringes

Initial Assay with Additional Acid

Test	Sample	Time	Observation, hours	Sample Volume, mL	Vol tap water, mL	Vol. 31% HCl	Whey, mL	Curds, mL (Total)
U.4.1.	Milk Leach Solution		13.3	5.0	15.0	2.0	13.0	9.0
U4.1.a.1	Milk + Bicarb		13.3	5.0	15.0	2.0	17.0	5.0
U4.1.a.2	Milk		13.3	5.0	15.0	2.0	12.0	10.5
U4.1.a.3	Milk		13.3	5.0	15.0	2.0	14.0	8.5
U4.1.a.4	Distilled water		13.3	5.0	15.0	2.0	17.0	5.0

Reactor Vessel: Drain sealed 25 mL syringes

Repeat Assay with Additional Acid at Time Zero

Test	Sample	Time	Observation, hours	Sample Volume, mL	Vol tap water, mL	Vol. 31% HCl	Whey, mL	Curds, mL
U.4.1.	Milk Leach Solution		4.0	5.0	15.0	2.0	8.0	14.0
			13.3				10.0	12.3
U4.1.a.1	Milk + Bicarb		4.0	5.0	15.0	2.0	15.0	6.0
			13.3				18.0	7.0
U4.1.a.2	Milk		4.0	5.0	15.0	2.0	16.8	6.3
			13.3				17.0	6.0
U4.1.a.3	Milk		4.0	5.0	15.0	2.0	13.0	9.5
			13.3				15.5	7.0
U4.1.a.4	Distilled water		4.0	5.0	15.0	2.0	18.5	3.5
			13.3				20.0	3.5

Appendix B3 - Utilization Testing Using Amended USBM Method
Acidophile Innoculum

28-Jan-18

Will a mesophilic acidophilic population arise quickly from Barite solids? Prepare this inoculum in the event that WRU 1 and WRT 1 do not exhibit active biooxidation in a reasonable amount of time.

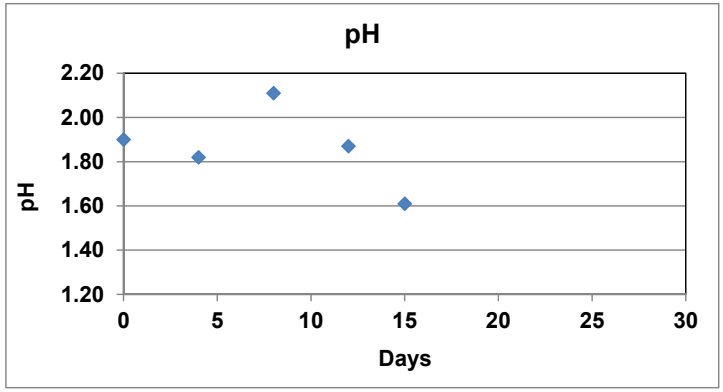
Culture:

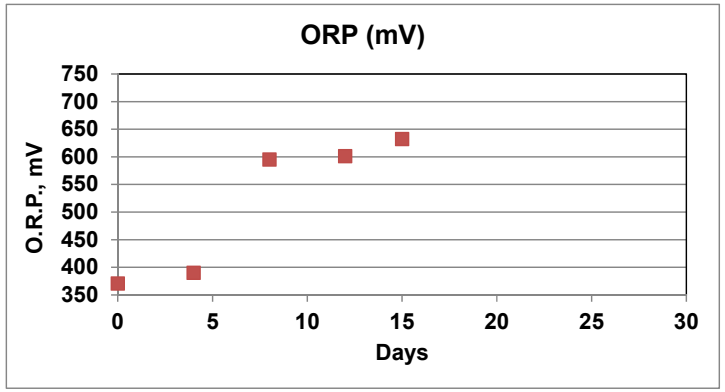
500 mL baffled flask
200 mL 2X MKM (+Cu, +Ca, + trace metals), non-sterile
1.0 g pulverized pyrite
0.5 g pulverized sulfur
2.0 g FeSO4*7H2O
1.75 g Barite fines (from previously unopened bucket)
175-185 RPM, 30 C
No intentional inoculum, except from Barite solids

0

Date	Day	pH	ORP (mV)	Comments
23-Jan-18	0	1.90	370	5 mL sacrificial samples
27-Jan	4	1.82	390	
1-Feb	8	2.11	595	
5-Feb	12	1.87	601	
8-Feb	15	1.61	632	Archived entire flask

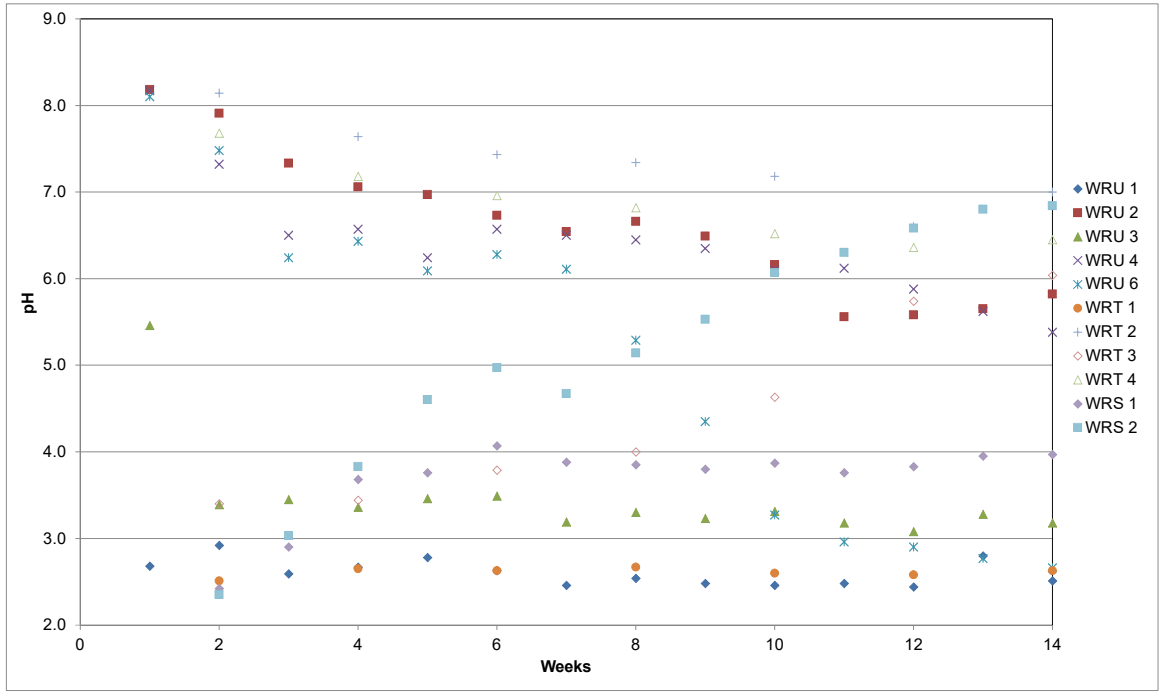
08 Feb: Phase contrast microscopy exam: 400X: bacilli of varying length, no obvious spore formation, no obvious motility, bacilli, single, few pairs, no clumps; At. ferrooxidans and At. thiooxidans - like





Effluent pH

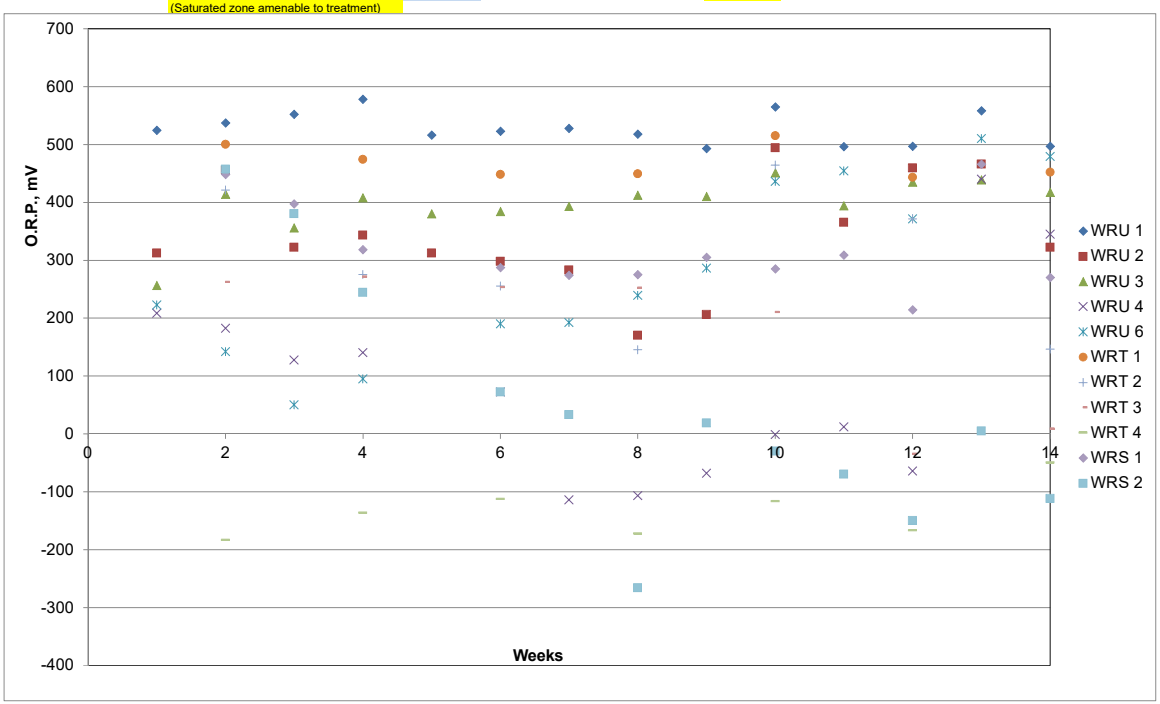
Test Cell	30-31 Jan Week 1	06-07 Feb Week 2	13-14 Feb Week 3	20-21 Feb Week 4	27-28 Feb Week 5	06-07 March Week 6	13-14 March Week 7	20-21 March Week 8	27-28 March Week 9	03-04 April Week 10	10-11 April Week 11	17-18 April Week 12	24-25 April Week 13	02-03 May Week 14
WRU 1	2.68	2.92	2.59	2.67	2.78	2.63	2.46	2.54	2.48	2.46	2.48	2.44	2.80	2.51
WRU 2	8.18	7.91	7.33	7.06	6.97	6.73	6.54	6.66	6.49	6.16	5.56	5.58	5.65	5.82
WRU 3	5.46	3.39	3.45	3.36	3.46	3.49	3.19	3.30	3.23	3.31	3.18	3.08	3.28	3.18
WRU 4	8.17	7.32	6.50	6.57	6.24	6.57	6.50	6.45	6.35	6.10	6.12	5.88	5.62	5.38
WRU 6	8.10	7.48	6.24	6.43	6.09	6.28	6.11	5.29	4.35	3.27	2.96	2.90	2.77	2.66
WRT 1		2.51		2.65		2.63		2.67		2.60		2.58		2.63
WRT 2		8.14		7.64		7.43		7.34		7.18		6.60		7.00
WRT 3		3.40		3.44		3.79		4.00		4.63		5.74		6.04
WRT 4		7.68		7.18		6.96		6.82		6.52		6.36		6.45
WRS 1		2.42	2.90	3.68	3.76	4.07	3.88	3.85	3.80	3.87	3.76	3.83	3.95	3.97
WRS 2		2.35	3.03	3.83	4.60	4.97	4.67	5.14	5.53	6.07	6.30	6.58	6.80	6.84



O.R.P., mV

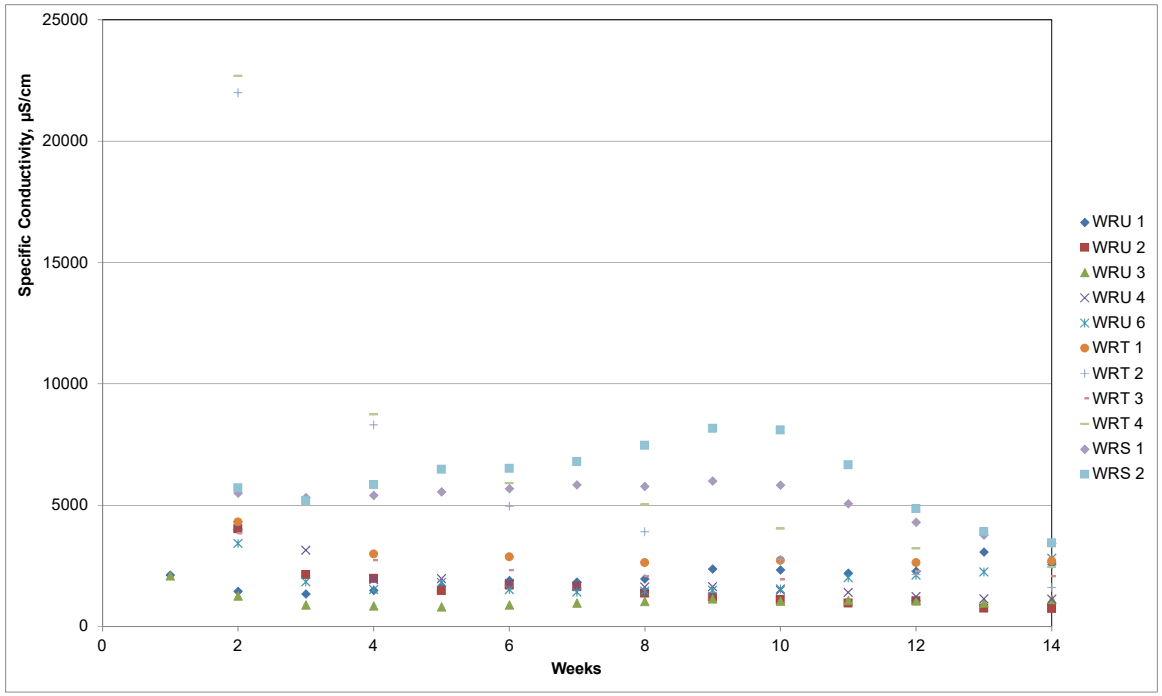
Test Cell	30-31 Jan Week 1	06-07 Feb Week 2	13-14 Feb Week 3	20-21 Feb Week 4	27-28 Feb Week 5	06-07 March Week 6	13-14 March Week 7	20-21 March Week 8	27-28 March Week 9	03-04 April Week 10	10-11 April Week 11	17-18 April Week 12	24-25 April Week 13	02-03 May Week 14
WRU 1	525	537	552	578	516	523	528	518	493	565	496	497	558	497
WRU 2	312	456	322	343	312	298	283	170	206	494	365	459	466	322
WRU 3	256	414	356	408	380	384	393	412	410	451	394	435	439	417
WRU 4	208	182	127	140		72	-114	-107	-68	-1.4	12	-65	440	345
WRU 6	222	142	50	95		190	192	239	286	436	454	371	510	479
WRT 1		500		474		448		449		515		443		452
WRT 2		421		275		255		145		464		371		146
WRT 3		262		271		253		252		210		-35		8.8
WRT 4		-184		-137		-113		-173		-117		-167		-49.8
WRS 1		448	397	318		287	274	275	305	285	309	214	466	270
WRS 2		457	380	244		72	33	-266	18.6	-30	-70	-150	4.6	-112

(Saturated zone amenable to treatment)



Effluent SPCOND

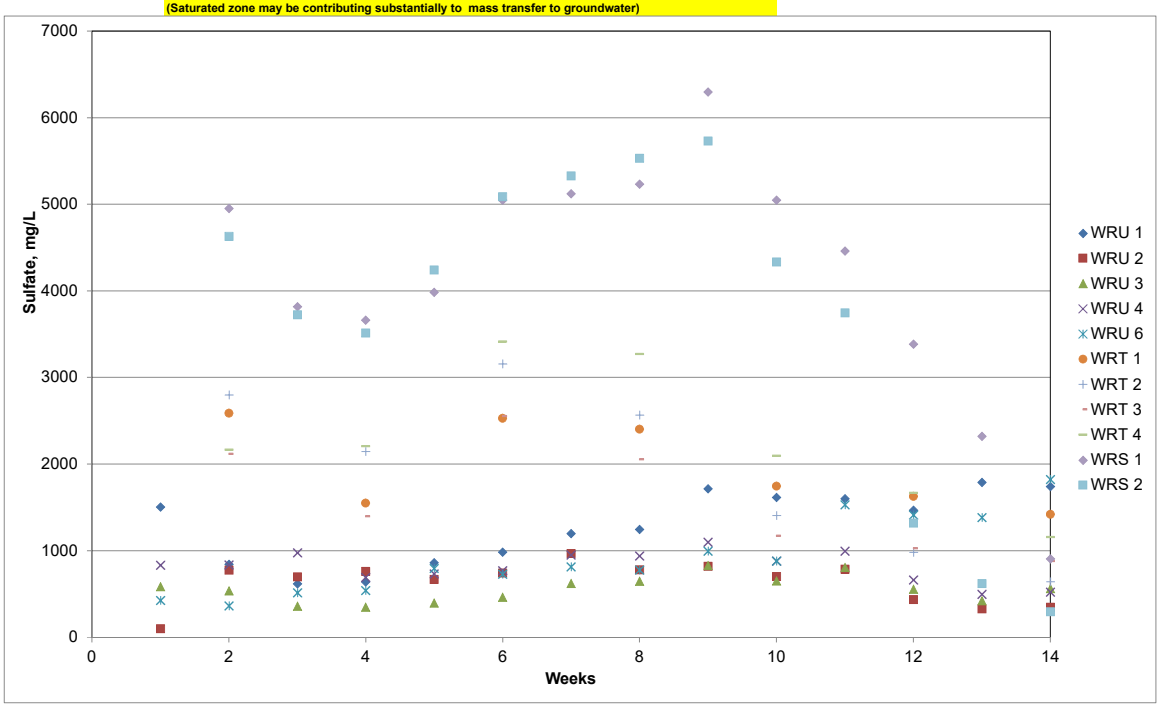
Test Cell	30-31 Jan Week 1	06-07 Feb Week 2	13-14 Feb Week 3	20-21 Feb Week 4	27-28 Feb Week 5	06-07 March Week 6	13-14 March Week 7	20-21 March Week 8	27-28 March Week 9	03-04 April Week 10	10-11 April Week 11	17-18 April Week 12	24-25 April Week 13	02-03 May Week 14
WRU 1	2123	1449	1349	1493	1656	1897	1832	1962	2371	2333	2204	2279	3070	2570
WRU 2		4040	2148	1996	1494	1709	1643	1390	1232	1124	978	1066	768	756
WRU 3	2093	1263	898	853	814	894	980	1042	1147	1059	1084	1071	973	1119
WRU 4		4160	3150	1936	1972	1786	1679	1638	1652	1505	1415	1234	1146	1131
WRU 6		3430	1842	1535	1824	1526	1419	1467	1500	1561	2018	2118	2251	2815
WRT 1		4310		2999		2870		2641		2733		2633		2705
WRT 2		22000		8320		4970		3920		2785		2146		1626
WRT 3		3840		2727		2321		2069		1938		2262		2076
WRT 4		22690		8740		5910		5020		4030		3220		2459
WRS 1		5500	5310	5400	5550	5680	5840	5780	6000	5830	5060	4300	3770	3430
WRS 2		5720	5190	5850	6490	6520	6800	7480	8180	8110	6670	4870	3920	3460



Sulfate, mg/L

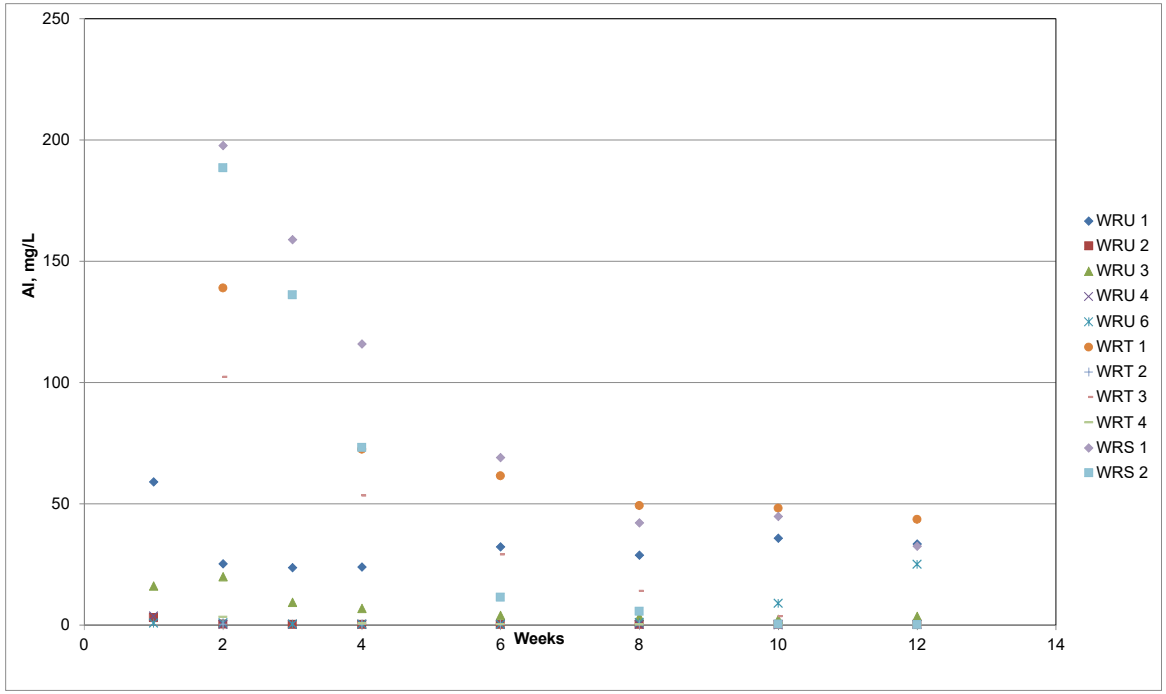
Test Cell	30-31 Jan Week 1	06-07 Feb Week 2	13-14 Feb Week 3	20-21 Feb Week 4	27-28 Feb Week 5	06-07 March Week 6	13-14 March Week 7	20-21 March Week 8	27-28 Mar Week 9	03-04 April Week 10	10-11 April Week 11	17-18 April Week 12	24-25 April Week 13	02-03 May Week 14
WRU 1	1506	843	616	639	863	982	1196	1246	1716	1614	1602	1467	1789	1740
WRU 2	95	772	695	759	666	738	964	775	816	699	784	431	325	343
WRU 3	586	538	357	349	396	464	622	646	828	652	805	554	420	562
WRU 4	830	834	974	691	731	769	952	940	1096	881	996	661	497	522
WRU 6	424	364	514	541	793	729	814	778	996	881	1531	1411	1383	1823
WRT 1		2586		1548		2529		2401		1743		1625		1420
WRT 2		2798		2144		3154		2566		1405		979		638
WRT 3		2113		1394		2548		2051		1169		1023		875
WRT 4		2163		2202		3412		3265		2090		1663		1155
WRS 1		4952	3817	3663	3982	5048	5121	5232	6298	5048	4460	3385	2319	906
WRS 2		4625	3721	3510	4239	5084	5324	5526	5728	4331	3743	1314	619	294

(Saturated zone may be contributing substantially to mass transfer to groundwater)



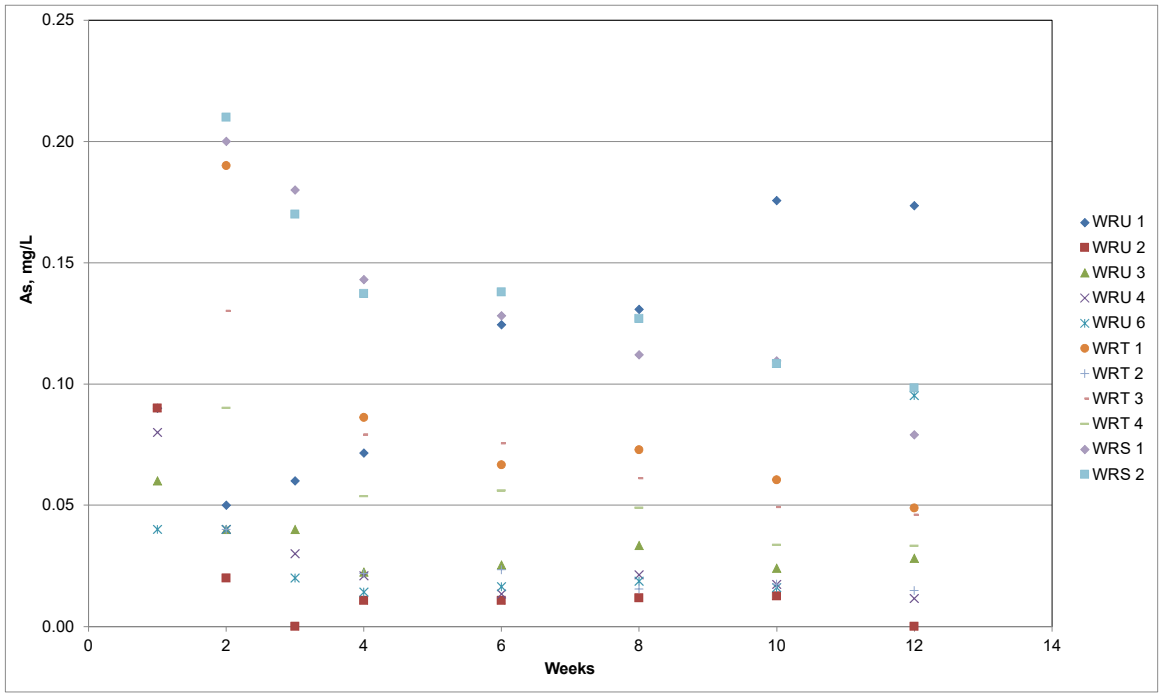
Effluent Al mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	59.04	25.25	23.68	23.8775		32.2455		28.8173		35.773		33.3674		38.6727
WRU 2	3.03	0.50	0.27	0.3499		0.301		0.2648		0.2643		0.2766		0.2449
WRU 3	16.17	20.01	9.36	6.9535		4.0312		3.4632		2.4794		3.6339		4.3527
WRU 4	3.75	0.38	0.29	0.3576		0.2815		0.2535		0.226		0.2891		0.3223
WRU 6	0.84	1.01	0.41	0.4154		0.3707		1.1026		9.0763		25.1793		42.7822
WRT 1		138.98		72.4901		61.5784		49.2212		48.2181		43.6107		41.0583
WRT 2		0.41		0.4514		0.4657		0.2534		0.3505		0.2684		0.2855
WRT 3		102.28		53.4097		29.1373		14.0514		3.6064		0.5344		0.2442
WRT 4		3.39		0.5832		0.3758		0.2359		0.2466		0.1805		0.2604
WRS 1		197.69	158.94	115.8432		69.0134		42.1843		44.7892		32.4828		22.4575
WRS 2		188.61	136.18	73.2657		11.5258		5.7772		0.4815		0.2098		0.3288



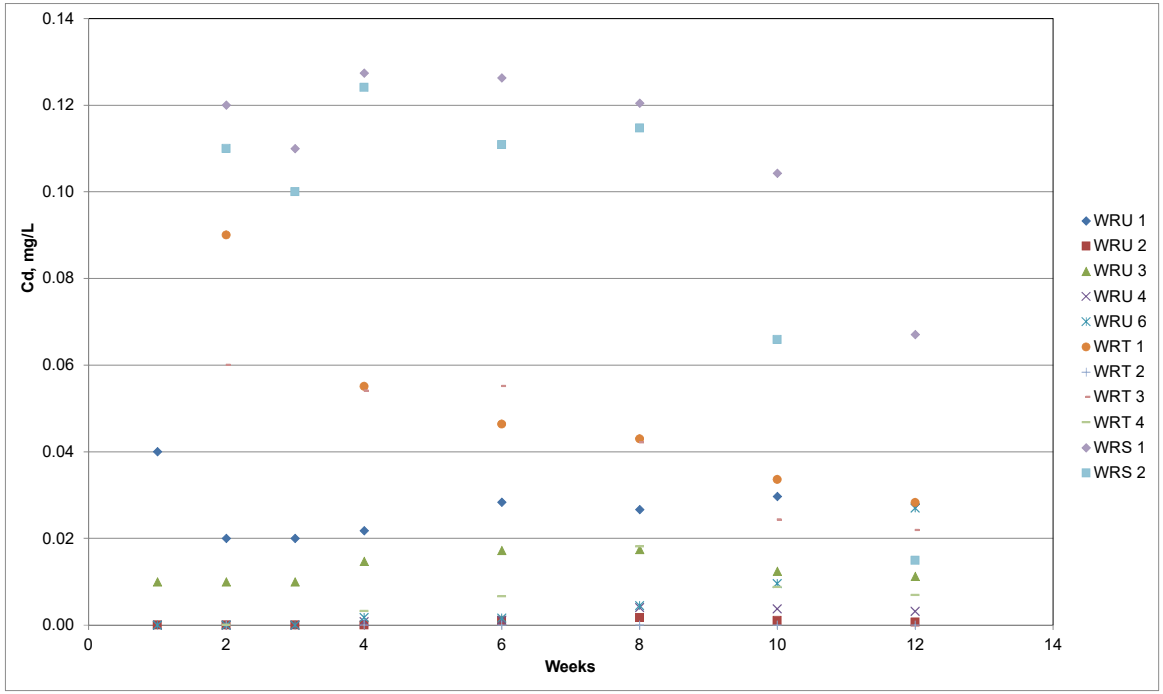
Effluent As mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	0.09	0.05	0.06	0.0716		0.1245		0.1308		0.1757		0.1735		0.2274
WRU 2	0.09	0.02	0	0.0107		0.0107		0.0118		0.0125		BDL		BDL
WRU 3	0.06	0.04	0.04	0.0224		0.0253		0.0334		0.0240		0.0281		0.0274
WRU 4	0.08	0.04	0.03	0.0209		0.0133		0.0213		0.0173		0.0115		0.0141
WRU 6	0.04	0.04	0.02	0.0142		0.0164		0.0186		0.0160		0.0952		0.2009
WRT 1		0.19		0.0862		0.0667		0.0729		0.0604		0.0489		0.0469
WRT 2		0.04		0.0218		0.0234		0.0154		0.0175		0.0148		0.0099
WRT 3		0.13		0.0791		0.0753		0.0610		0.0491		0.0459		0.0391
WRT 4		0.09		0.0536		0.0560		0.0489		0.0335		0.0332		0.0256
WRS 1		0.20	0.18	0.1430		0.1281		0.1121		0.1095		0.0790		0.0580
WRS 2		0.21	0.17	0.1372		0.1379		0.1269		0.1083		0.0983		0.0557



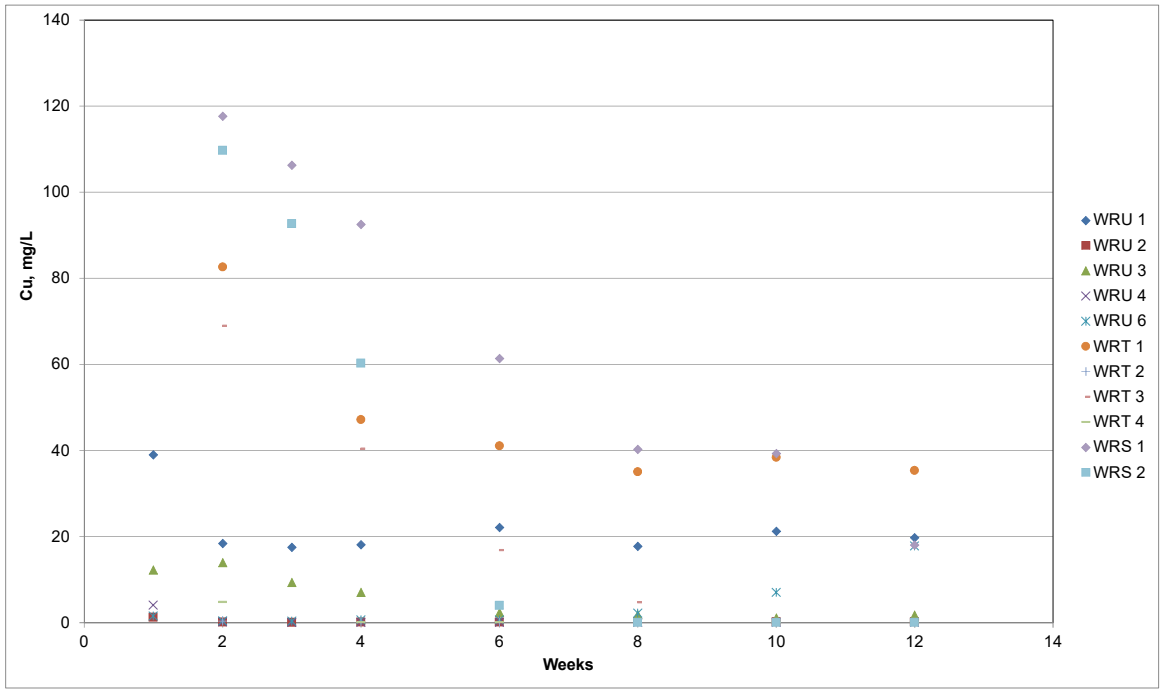
Effluent Cd mg/L

Test Cell	30-31 Jan Week 1	06-07 Feb Week 2	13-14 Feb Week 3	20-21 Feb Week 4	27-28 Feb Week 5	06-07 March Week 6	13-14 March Week 7	20-21 March Week 8	27-28-Mar Week 9	03-04 April Week 10	10-11 April Week 11	17-18 April Week 12	24-25 April Week 13	02-03 May Week 14
WRU 1	0.04	0.02	0.02	0.0218		0.0284		0.0267		0.0297		0.0279		0.0369
WRU 2	BDL	BDL	0	BDL		0.0010		0.0017		0.0010		0.0007		0.0010
WRU 3	0.01	0.01	0.01	0.0147		0.0172		0.0174		0.0124		0.0112		0.0123
WRU 4	BDL	BDL	0	0.0008		0.0011		0.0041		0.0038		0.0032		0.0029
WRU 6	BDL	BDL	0	0.0018		0.0016		0.0045		0.0096		0.0270		0.0375
WRT 1		0.09		0.0551		0.0464		0.0430		0.0336		0.0283		0.0260
WRT 2		BDL		BDL		BDL		BDL		BDL		BDL		BDL
WRT 3		0.06		0.0541		0.0551		0.0421		0.0243		0.0219		0.0174
WRT 4		BDL		0.0032		0.0066		0.0181		0.0087		0.0069		0.0030
WRS 1		0.12	0.11	0.1274		0.1263		0.1205		0.1043		0.0671		0.0452
WRS 2		0.11	0.10	0.1241		0.1109		0.1147		0.0659		0.0149		0.0027



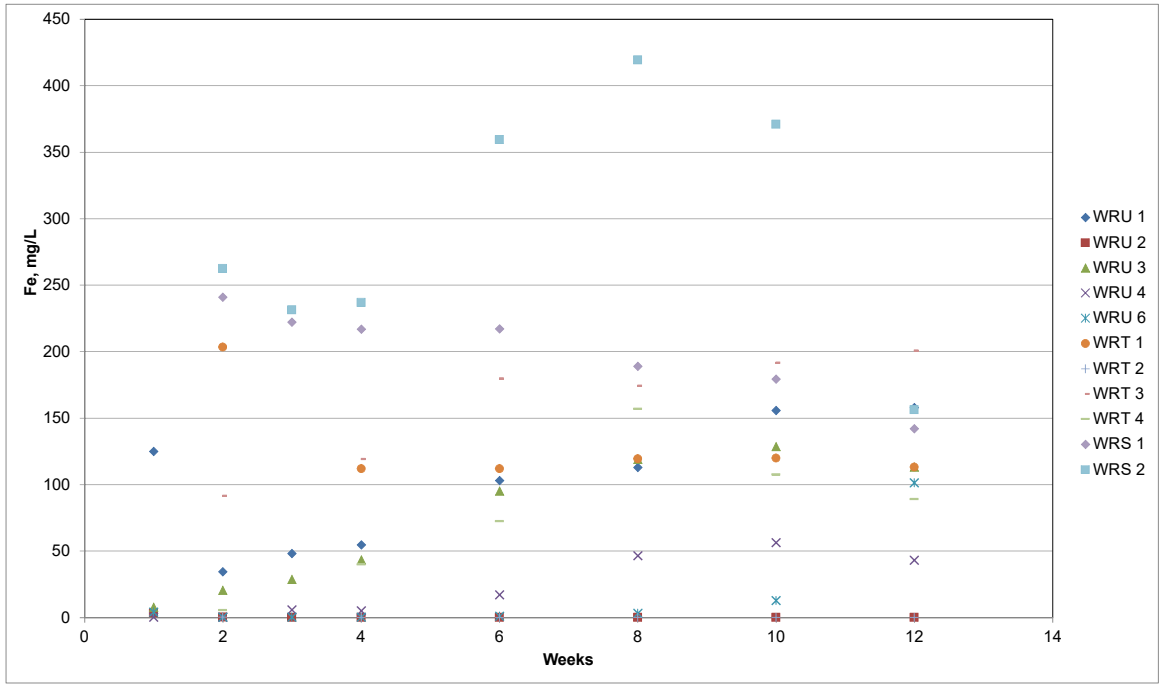
Effluent Cu mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	39.01	18.36	17.5	18.099		22.0806		17.6865		21.1984		19.7088		23.0743
WRU 2	1.23	0.12	0.03	0.0796		0.1324		0.1479		0.1957		0.1492		0.2511
WRU 3	12.18	13.96	9.3	6.9866		2.3246		1.8376		1.0668		1.7503		2.0395
WRU 4	4.01	0.14	0.02	BDL		BDL		BDL		BDL		BDL		0.0667
WRU 6	1.53	0.39	0.34	0.6073		0.6202		2.1706		7.0402		17.8297		28.4949
WRT 1		82.66		47.1969		41.0557		35.0605		38.3835		35.3772		34.7375
WRT 2		0.3		0.0986		0.0539		0.0239		0.0554		0.0587		0.0536
WRT 3		68.89		40.3554		16.7164		4.6362		BDL		BDL		BDL
WRT 4		4.69		0.0139		BDL		BDL		BDL		BDL		BDL
WRS 1		117.63	106.27	92.5225		61.3945		40.2135		39.2891		17.9893		9.0630
WRS 2		109.67	92.67	60.2538		3.9887		BDL		BDL		BDL		BDL



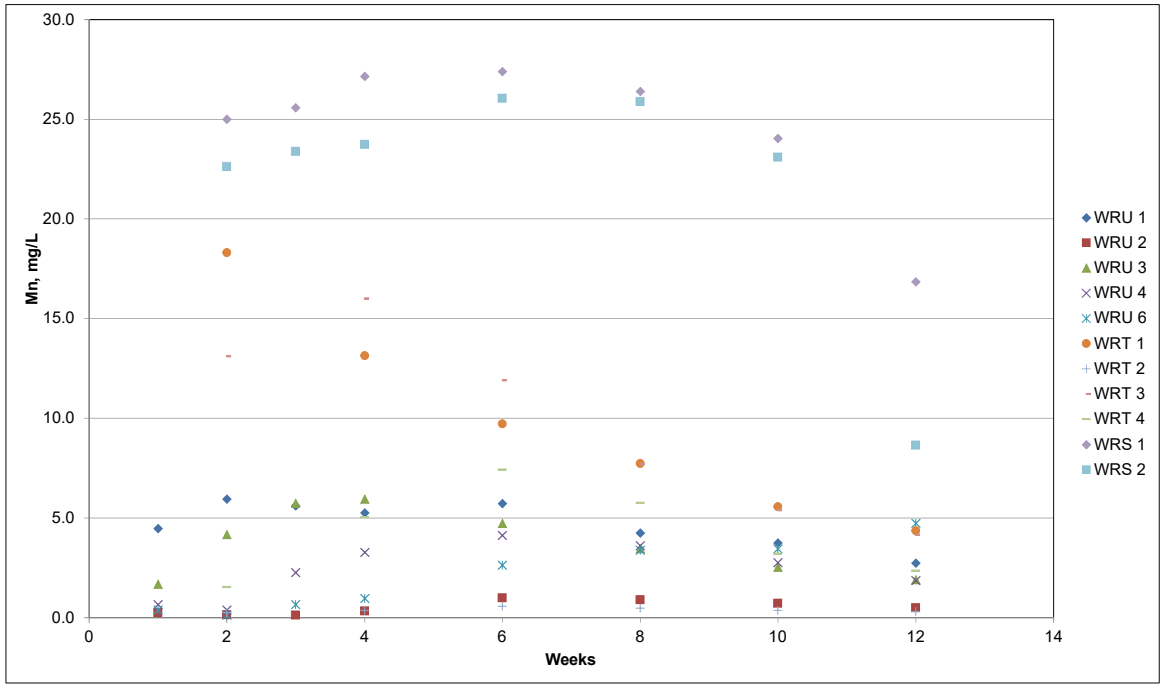
Effluent Fe mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	124.95	34.41	48.29	54.6673		103.0263		112.954		155.8261		158.0661		205.292
WRU 2	3.48	0.28	0.02	0.0194		0.0141		0.0251		0.0221		0.0197		0.03319
WRU 3	7.76	20.41	28.74	43.2745		95.1311		118.8469		128.519		113.2325		124.25
WRU 4	0.22	0.25	5.74	5.1934		17.2386		46.6336		56.4329		43.0444		37.4932
WRU 6	4.26	0.25	0.42	0.2186		1.0701		3.2648		12.8978		101.3149		184.7984
WRT 1		203.5		112.0061		111.9666		119.3546		120.0306		113.2586		116.7575
WRT 2		0.26		0.0711		0.0483		0.0143		0.0173		0.0203		0.0198
WRT 3		91.38		119.0038		179.6701		174.0072		191.5049		200.4689		170.6194
WRT 4		5.47		39.8345		72.2887		156.812		107.3532		88.8397		48.4503
WRS 1		240.96	222.23	216.8859		217.0389		188.9208		179.2791		141.9637		104.2579
WRS 2		262.33	231.44	236.8963		359.3693		419.3678		370.8386		156.2887		45.6028



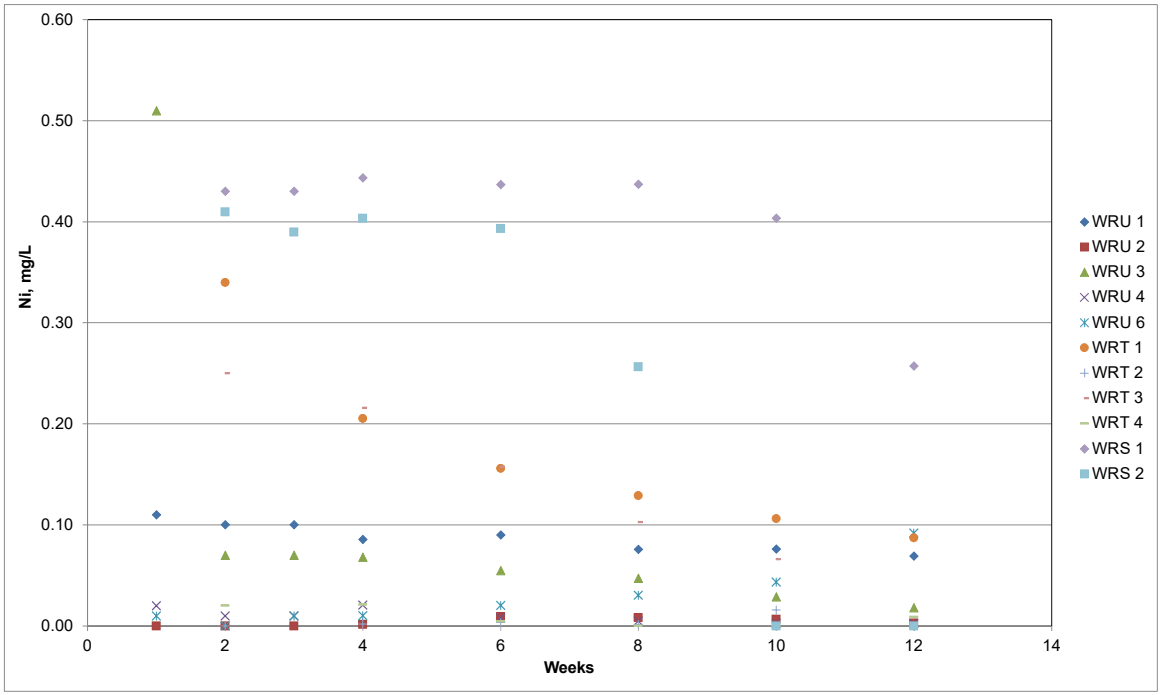
Effluent Mn mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	4.47	5.94	5.6	5.254		5.7225		4.2378		3.7404		2.7263		2.7469
WRU 2	0.25	0.13	0.12	0.3302		0.9811		0.8859		0.712		0.4925		0.5193
WRU 3	1.67	4.16	5.74	5.9446		4.7203		3.4497		2.5216		1.9048		1.8956
WRU 4	0.64	0.37	2.25	3.2642		4.1076		3.5956		2.7516		1.8588		1.6388
WRU 6	0.38	0.11	0.64	0.9451		2.6293		3.3809		3.4433		4.7236		4.8657
WRT 1		18.3		13.139		9.7093		7.7216		5.563		4.3485		3.8758
WRT 2		0.24		0.3583		0.5682		0.4725		0.3516		0.2885		0.2911
WRT 3		13.08		15.9858		11.8902		7.6778		5.3737		4.1355		3.3338
WRT 4		1.52		5.0182		7.4002		5.7301		3.1882		2.3338		1.6930
WRS 1		25.0	25.57	27.1547		27.398		26.4018		24.0322		16.8462		12.0037
WRS 2		22.62	23.38	23.7332		26.0401		25.8883		23.0879		8.6337		4.5081



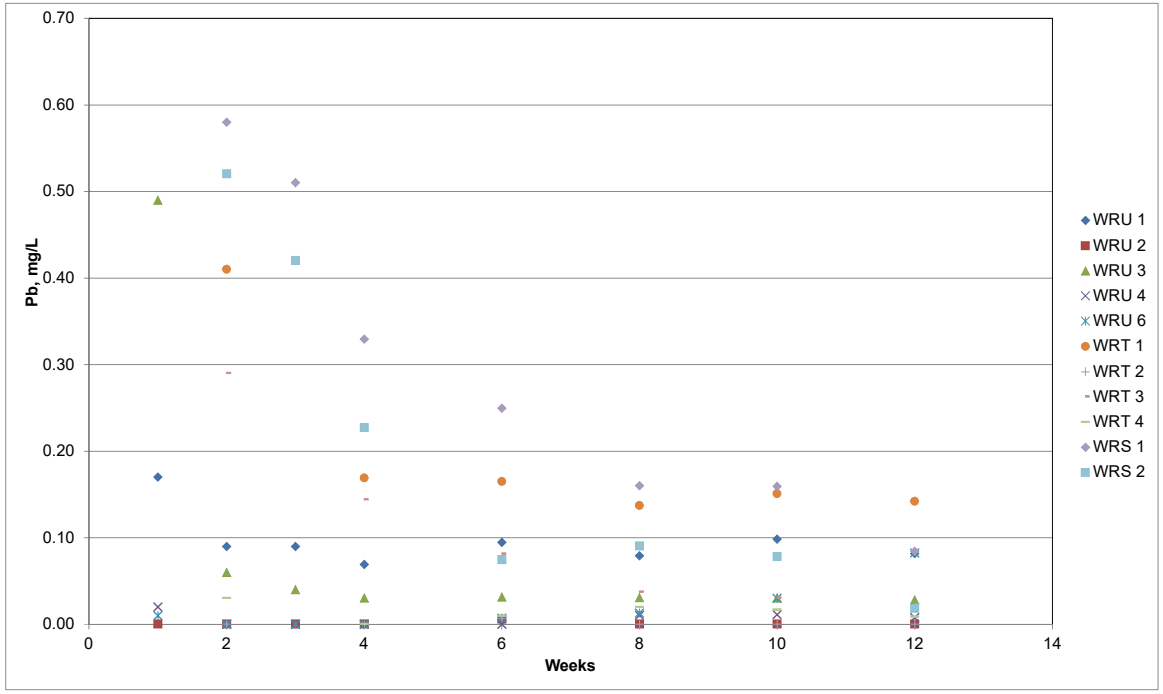
Effluent Ni mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	0.11	0.1	0.1	0.0857		0.0899		0.0758		0.0762		0.0690		0.0797
WRU 2	0	0	0	0.0018		0.0091		0.0084		0.0068		0.0029		0.0047
WRU 3	0.51	0.07	0.07	0.0682		0.0549		0.0471		0.0289		0.0182		0.0155
WRU 4	0.02	0.01	0.01	0.0205		0.0081		0.0047		0.0025		0.0025		0.0044
WRU 6	0.01	0	0.01	0.0102		0.0202		0.0305		0.0435		0.0918		0.1236
WRT 1		0.34		0.2052		0.1558		0.1290		0.1060		0.0873		0.0828
WRT 2		0		0.0021		0.0036		0.0018		0.0160		BDL		BDL
WRT 3		0.25		0.2157		0.1574		0.1026		0.0659		0.0082		0.0034
WRT 4		0.02		0.0211		0.0045		BDL		BDL		0.0089		BDL
WRS 1		0.43	0.43	0.4433		0.4368		0.4371		0.4034		0.2572		0.1733
WRS 2		0.41	0.39	0.4034		0.3933		0.2567		BDL		BDL		BDL



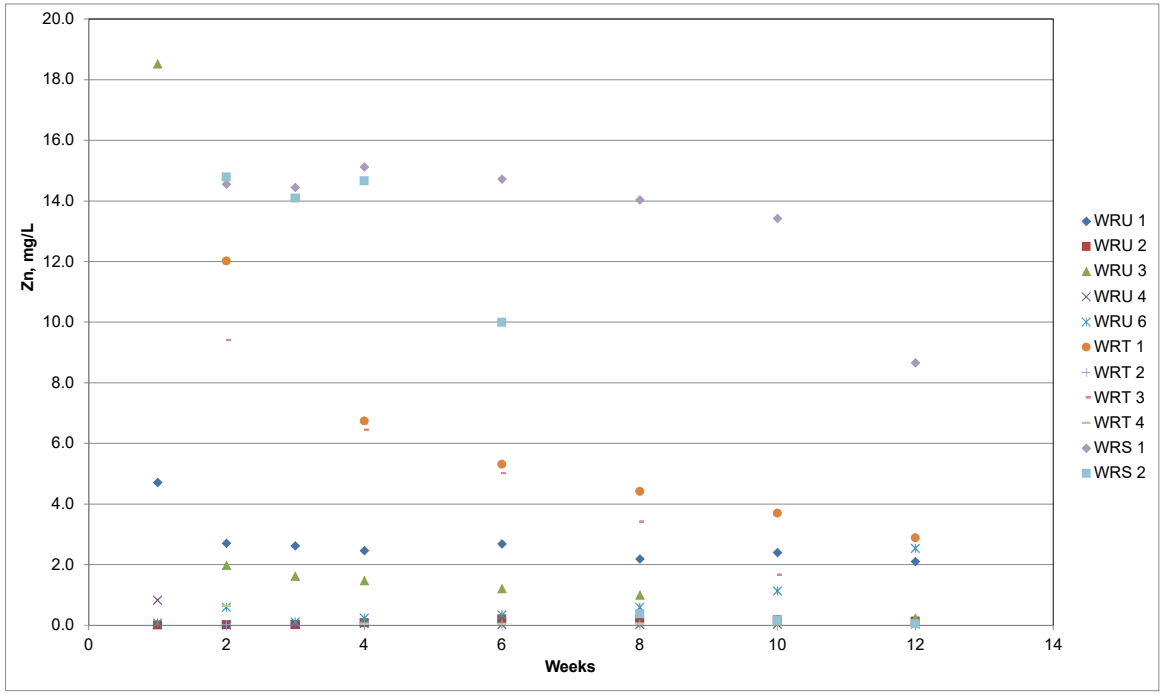
Effluent Pb mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	0.17	0.09	0.09	0.0691		0.0945		0.079		0.0984		0.0817		0.0901
WRU 2	0	0	0	BDL		0.0055		BDL		BDL		BDL		BDL
WRU 3	0.49	0.06	0.04	0.0305		0.0314		0.0306		0.0304		0.0280		0.0294
WRU 4	0.02	0	0	BDL		BDL		0.0104		0.0111		0.0078		BDL
WRU 6	0.01	0	0	BDL		0.007		0.0129		0.0300		0.0823		0.1114
WRT 1		0.41		0.1689		0.1649		0.1372		0.1510		0.1419		0.1145
WRT 2		0		BDL		0.0066		BDL		BDL		BDL		BDL
WRT 3		0.29		0.1437		0.0814		0.0375		0.0303		0.0227		0.0201
WRT 4		0.03		BDL		0.0093		0.0198		0.0166		0.0084		BDL
WRS 1		0.58	0.51	0.3294		0.2497		0.1601		0.1595		0.0845		0.0378
WRS 2		0.52	0.42	0.2272		0.0743		0.0901		0.0780		0.0182		BDL



Effluent Zn mg/L

	30-31 Jan	06-07 Feb	13-14 Feb	20-21 Feb	27-28 Feb	06-07 March	13-14 March	20-21 March	27-28-Mar	03-04 April	10-11 April	17-18 April	24-25 April	02-03 May
Test Cell	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
WRU 1	4.71	2.7	2.62	2.4635		2.6855		2.1912		2.3935		2.0978		2.3200
WRU 2	0	0.01	0.01	0.0732		0.1966		0.1908		0.1690		0.1244		0.1297
WRU 3	18.52	1.98	1.62	1.4675		1.2000		0.9889		0.1905		0.2312		0.2141
WRU 4	0.82	0.01	0.03	0.0667		0.0196		0.0227		0.0331		0.0383		0.0561
WRU 6	0.07	0.59	0.11	0.2354		0.3354		0.5923		1.1265		2.5306		2.5839
WRT 1		12.01		6.731		5.3098		4.4118		3.6974		2.8795		2.1683
WRT 2		0.02		0.0372		0.0454		0.0304		0.0169		0.0134		0.0052
WRT 3		9.40		6.4381		5.0101		3.4146		1.6595		0.099		0.0629
WRT 4		0.62		0.0426		0.0305		0.042		0.0273		0.0431		0.0181
WRS 1		14.55	14.44	15.1193		14.716		14.029		13.4145		8.6571		5.0642
WRS 2		14.78	14.08	14.6537		9.9842		0.3681		0.1626		0.0432		BDL



Appendix B-6 - Pit Water Treatment - Titration & Sulfate Reduction Bench and Analytical Data

Upper Pit Lake Water Solution Sulfate, g/L

	WEEK						
	27-Mar	5-Apr	12-Apr	19-Apr	4-May	17-May	24-May
Test	0.04	1.0	2.0	3.0	5.0	7.0	8.0
PLN25 - NONE	2.144	2.225	2.210	1.936	1.804	1.696	1.658
PLN26 - WC, H/S	2.019	2.240	2.225	1.668	1.265	1.088	0.827
PLN29 - SD, H/S	2.203	2.291	2.350	2.046	1.596	1.512	1.381
PLN30 - WC, H/S, BC	2.225	2.225	2.357	1.708	1.088	0.904	0.796
PLN31 - WC, H/S, BC	2.247	2.291	2.291	1.637	1.088	0.888	0.665
PLN32 - SD, H/S, BC	2.247	2.218	2.298	1.881	1.665	1.596	1.481
PLN33 - SD, H/S, BC	2.291	2.306	2.35	1.897	1.788	1.612	1.481
PLN34 - H/S, SP	2.291	2.313	2.313		1.327	0.788	0.427
PLN35 - H/S, SP, BC	2.262	2.438	2.49	1.613	1.127	0.696	0.404
PLN37 - WC, SD, H/S	2.320	2.343		1.944	1.527	1.235	0.935
PLN38 - WC, SD, H/S, BC	2.247	2.269	2.637	1.85	1.673	1.542	1.058
PLN39 - WC, SD, H/S	2.320	2.247	2.534	1.968	1.681	1.512	1.096

Solution pH

	27-Mar	5-Apr	12-Apr	**Week**		18-May	25-May
Test	**0.04**	**1.0**	**2.0**	**3.0**	**5.0**	**7.0**	**8.0**
PLN25 - NONE	**3.17**	**3.21**	**3.19**	**3.29**	**3.29**	**3.26**	**3.28**
PLN26 - WC, H/S	**5.13**	**5.70**	**5.79**	**6.39**	**6.70**	**6.92**	**6.89**
PLN29 - SD, H/S	**4.93**	**5.29**	**5.77**	**5.67**	**5.95**	**5.96**	**6.14**
PLN30 - WC, H/S, BC	**5.04**	**5.44**	**5.56**	**6.22**	**6.71**	**6.69**	**6.72**
PLN31 - WC, H/S, BC	**5.16**	**5.81**	**6.06**	**6.45**	**7.06**	**7.04**	**7.04**
PLN32 - SD, H/S, BC	**5.16**	**5.25**	**5.76**	**5.88**	**5.95**	**5.92**	**5.99**
PLN33 - SD, H/S, BC	**5.64**	**5.65**	**5.96**	**5.99**	**6.24**	**6.11**	**6.27**
PLN34 - H/S, SP	**5.04**	**6.04**	**6.46**	**6.69**	**6.88**	**6.47**	**6.35**
PLN35 - H/S, SP, BC	**5.06**	**5.92**	**6.66**	**6.57**	**6.55**	**6.47**	**6.38**
PLN37 - WC, SD, H/S	**4.98**	**5.60**	**6.01**	**6.06**	**6.49**	**6.63**	**6.71**
PLN38 - WC, SD, H/S, BC	**5.25**	**5.66**	**6.08**	**6.01**	**6.36**	**6.70**	**6.64**
PLN39 - WC, SD, H/S	**4.86**	**5.73**	**6.19**	**6.76**	**6.55**	**6.91**	**7.08**

Solution O.R.P., mV

	27-Mar	5-Apr	12-Apr	**Week**		18-May	25-May
Test	**0.04**	**1.0**	**2.0**	**3.0**	**5.0**	**7.0**	**8.0**
PLN25 - NONE	**490**	**406**	**439**	**471**	**235**	**542**	**520**
PLN26 - WC, H/S	**304**	**175**	**-189**	**-223**	**-284**	**-280**	**9**
PLN29 - SD, H/S	**246**	**-290**	**-363**	**-173**	**-274**	**-231**	**135**
PLN30 - WC, H/S, BC	**246**	**79**	**-135**	**-251**	**-300**	**-281**	**-282**
PLN31 - WC, H/S, BC	**231**	**104**	**-168**	**-279**	**-378**	**-300**	**-323**
PLN32 - SD, H/S, BC	**376**	**-414**	**-349**	**-182**	**-264**	**-164**	**-258**
PLN33 - SD, H/S, BC	**230**	**-434**	**-291**	**-167**	**-256**	**-156**	**-132**
PLN34 - H/S, SP	**283**	**32**	**-307**	**-297**	**-303**	**-252**	**-271**
PLN35 - H/S, SP, BC	**243**	**-37**	**-355**	**-307**	**-340**	**-253**	**-283**
PLN37 - WC, SD, H/S	**251**	**-378**	**-405**	**-232**	**-319**	**-243**	**-278**
PLN38 - WC, SD, H/S, BC	**228**	**-348**	**-484**	**-176**	**-290**	**-244**	**-272**
PLN39 - WC, SD, H/S	**234**	**-406**	**-459**	**-93**	**-293**	**-265**	**-286**

Appendix B-6 - Pit Water Treatment - Titration & Sulfate Reduction Bench and Analytical Data

BH26 Water Solution Sulfate, g/L

						Week		19-Apr	4-May	17-May
Test	**C-Sources**	**0.4**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**8.1**	**10.0**
PLN5	**NONE**	**23.279**	**25.132**	**24.912**	**26.934**	**25.5**	**25.904**	**26.571**	**26.288**	**27.058**
PLN6	**WC, H/S**	**25.926**	**23.22**	**24.581**	**23.625**	**23.698**	**22.522**	**21.964**	**20.404**	**20.404**
PLN7	**WC, H/S**	**25.338**	**24.654**	**24.324**	**24.765**	**22.926**	**21.162**	**21.571**	**20.981**	**19.750**
PLN8	**WC, H/S**	**24.603**	**24.728**	**24.434**	**22.596**	**22.191**	**19.765**	**19.484**	**19.712**	**18.096**
PLN9	**SD, H/S**	**23.72**	**25.022**	**24.691**	**26.051**	**24.397**	**22.743**	**21.335**	**22.212**	**22.019**
PLN10	**WC, H/S/ BC**	**24.088**	**24.397**	**24.544**	**24.324**	**23.698**	**21.529**	**20.941**	**19.865**	**19.558**
PLN11	**WC, H/S, BC**	**22.103**	**24.14**	**23.037**	**23.846**	**22.963**	**20.022**	**20.508**	**19.096**	**19.212**
PLN12	**WC, H/S, BC**	**22.691**	**23.331**	**23.404**	**23.331**	**22.044**	**20.390**	**20.311**	**19.327**	**18.865**
PLN13	**SD, H/S, BC**	**23.353**	**25.353**	**23.956**	**23.527**	**23.993**	**18.404**	**22.712**	**21.058**	**20.865**
PLN14	**SD, H/S, BC**	**23.794**	**23.882**	**23.772**	**23.331**	**23.772**	**21.162**	**21.531**	**20.442**	**19.712**
PLN15	**SD, H/S, BC**	**22.912**	**23.956**	**22.301**	**23.993**	**23.147**	**21.382**	**20.902**	**19.673**	**18.481**
PLN16	**H/S, SP**	**21.735**	**24.47**	**24.838**	**24.691**	**24.581**	**22.301**	**21.531**	**21.058**	**18.365**
PLN17	**H/S, SP, BC**	**23.426**	**23.882**	**24.287**	**23.074**	**23.368**	**21.456**	**20.508**	**19.596**	**17.865**
PLN18	**H/S, SP, BC**	**21.662**	**24.103**	**23.184**	**22.191**	**22.338**	**21.162**	**20.429**	**18.827**	**18.135**
PLN19	**H/S, SP, BC**	**21.882**	**22.816**	**23.588**	**22.338**	**21.64**	**20.096**	**20.665**	**18.519**	**17.481**
PLN20	**WC, SD, H/S**	**22.912**	**24.985**	**24.287**	**24.691**	**23.956**	**22.265**	**21.61**	**20.481**	**19.250**
PLN21	**WC, SD, H/S, BC**	**24.456**	**24.507**	**24.691**	**26.162**	**24.287**	**23.220**	**22.043**	**20.712**	**19.327**
PLN22	**WC, SD, H/S, BC**	**25.191**	**24.507**	**23.882**	**23.257**	**23.294**	**21.162**	**20.626**	**19.904**	**17.519**
PLN23	**WC, SD, H/S, BC**	**22.985**	**23.772**	**24.14**	**23.662**	**22.706**	**20.537**	**20.272**	**19.019**	**18.558**
PLN24	**WC, SD, H/S**	**25.632**	**25.72**	**25.353**	**26.015**	**25.132**	**22.926**	**21.964**	**20.788**	**18.635**

Solution pH

Week 17-May

Test	C-Sources	0.4	1	2.0	3.0	4.0	5.0	6.0	8.1	10.0
PLN5	NONE	2.71	2.65	2.59	2.52	2.46	2.42	2.40	2.45	2.42
PLN6	WC, H/S	2.87	3.22	3.66	3.72	3.87	3.91	3.91	4.02	3.81
PLN7	WC, H/S	2.85	3.4	3.69	3.75	3.88	3.94	3.93	4.06	3.03
PLN8	WC, H/S	2.95	3.75	3.91	3.94	4.08	4.15	4.20	4.27	2.96
PLN9	SD, H/S	3.09	3.5	3.63	3.66	3.81	3.85	3.90	4.01	4.02
PLN10	WC, H/S/ BC	3.02	3.74	3.86	3.88	4.00	4.06	4.10	4.17	3.84
PLN11	WC, H/S, BC	3.12	3.75	3.84	3.88	3.99	4.05	4.12	4.20	3.75
PLN12	WC, H/S, BC	3.74	3.88	3.97	4.02	4.11	4.16	4.19	4.25	4.19
PLN13	SD, H/S, BC	3.22	3.61	3.7	3.74	3.85	3.91	3.98	4.07	4.13
PLN14	SD, H/S, BC	3.13	3.57	3.68	3.75	3.87	3.92	3.99	4.09	4.15
PLN15	SD, H/S, BC	3.39	3.7	3.78	3.8	3.95	4.01	4.07	4.15	4.19
PLN16	H/S, SP	2.91	3.64	3.81	3.84	3.95	3.99	4.02	3.25	2.92
PLN17	H/S, SP, BC	3.20	3.79	3.91	3.95	4.06	4.11	4.16	3.21	2.83
PLN18	H/S, SP, BC	3.26	3.85	3.97	3.98	4.1	4.15	4.17	3.15	2.90
PLN19	H/S, SP, BC	3.72	3.9	4.00	4.04	4.13	4.20	4.22	3.08	2.89
PLN20	WC, SD, H/S	3.14	3.64	3.68	3.76	3.91	3.93	3.99	4.02	3.34
PLN21	WC, SD, H/S, BC	3.07	3.58	3.72	3.79	3.91	3.96	4.02	4.10	4.04
PLN22	WC, SD, H/S, BC	3.54	3.74	3.84	3.87	4.01	4.04	4.07	4.13	3.75
PLN23	WC, SD, H/S, BC	3.48	3.84	3.92	3.97	4.07	4.10	4.13	4.21	4.25
PLN24	WC, SD, H/S	3.30	3.50	3.66	3.76	3.91	3.95	4.00	3.93	3.38

Solution O.R.P., mV

Week

17-May

Test	C-Sources	0.4	1.0	2.0	3.0	4.0	5.0	6.0	8.1	10.0
PLN5	NONE	422	386	391	398	421	417	446	416	476
PLN6	WC, H/S	369	319	254	241	234	285	256	207	279
PLN7	WC, H/S	396	298	249	230	219	221	230	208	343
PLN8	WC, H/S	395	258	220	205	193	195	189	202	385
PLN9	SD, H/S	367	285	258	241	224	219	216	205	237
PLN10	WC, H/S/ BC	370	262	219	207	196	193	195	209	260
PLN11	WC, H/S, BC	353	251	223	208	198	192	192	208	306
PLN12	WC, H/S, BC	273	235	204	194	188	179	182	206	309
PLN13	SD, H/S, BC	347	273	245	229	214	203	202	214	226
PLN14	SD, H/S, BC	355	279	243	222	214	202	198	215	217
PLN15	SD, H/S, BC	334	255	231	206	196	188	183	212	213
PLN16	H/S, SP	352	277	230	213	202	192	201	325	390
PLN17	H/S, SP, BC	239	244	212	198	192	183	190	301	400
PLN18	H/S, SP, BC	274	236	201	195	176	182	191	332	386
PLN19	H/S, SP, BC	252	228	203	196	184	180	188	348	372
PLN20	WC, SD, H/S	325	285	247	227	216	206	205	214	258
PLN21	WC, SD, H/S, BC	320	287	239	220	208	201	200	211	229
PLN22	WC, SD, H/S, BC	295	249	212	209	198	192	188	216	220
PLN23	WC, SD, H/S, BC	285	228	219	186	187	183	189	207	213
PLN24	WC, SD, H/S	312	290	271	224	207	198	195	249	249

Pit Water Treatment - Titration - Data Sheet

Table C8

Sampler(s) Name(s):	TRC	Sampling Start Time:	12:21 PM
Sampler(s) Initials:	TRC	Sampling Finish Time:	2:24 PM
		Date:	3/16/2018

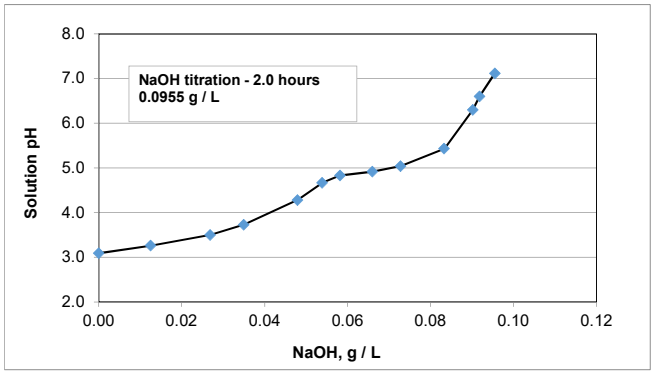
Objective To determine the chemical requirement to neutralize the pit water

Test ID	PLN1	PLN2	PLN3	PLN4
Subject Material	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water
Chemical	Caustic Soda -NaOH (CRUSHED PELLETS)	Lime	Hydrated lime followed by fine Limestone	Limestone

Titration - 1000 mL sample		
Added (g)	**Cumulative (g)**	**pH**
0	0	3.09
0.2182	0.2182	10.76
REPEAT ASSAY		
0	0	3.09
0.0125	0.0125	3.26
0.0144	0.0269	3.50
0.0081	0.0350	3.73
0.0129	0.0479	4.28
0.0060	0.0539	4.67
0.0043	0.0582	4.83
0.0078	0.0660	4.92
0.0068	0.0728	5.04
0.0105	0.0833	5.43
0.0069	0.0902	6.30
0.0016	0.0918	6.60
0.0037	0.0955	7.12
	0.0955 kg NaOH/m3 water	
Note 1. Photos		
2. no bulk precipitation - some turbidity		
3. slight yellow color following pH adjustment (colorless prior to treatment)		
Reagent: NaOH, Sigma-Aldrich		
4. 18 C		
pH 4 STD: 3.96	pH 7 STD: 7.01	SP Cond: 2684 µs/cm

Note: The titration test will be conducted once for each chemical

Cumulative	pH
0.0000	3.09
0.0125	3.26
0.0269	3.50
0.0350	3.73
0.0479	4.28
0.0539	4.67
0.0582	4.83
0.0660	4.92
0.0728	5.04
0.0833	5.43
0.0902	6.30
0.0918	6.60
0.0955	7.12



Pit Water Treatment - Titration - Data Sheet

Table C8

Sampler(s) Name(s): TRC
Sampler(s) Initials: TRC

Sampling Start Time: 04/22/18, 3:35:00 PM
Sampling Finish Time: 04/23/18, 12:01 PM
Date: 4/22/2018

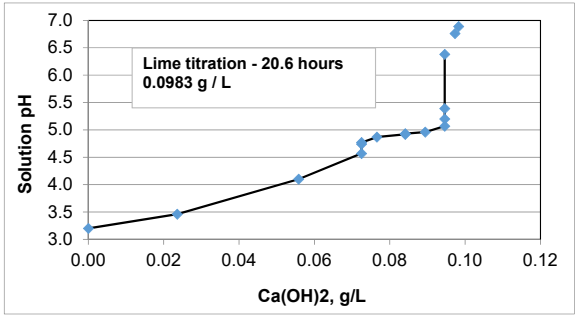
Objective To determine the chemical requirement to neutralize the pit water

Test ID	PLN1	PLN2	PLN3	PLN4
Subject Material	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water
Chemical	Caustic Soda -NaOH (CRUSHED PELLETS)	Hydrated Lime	Hydrated lime followed by fine Limestone	Limestone

Titration - 1000 mL sample			
Added (g)	**Cumulative (g)**	**pH**	**Time**
			4/22/2018
0	0	3.20	3:25 PM
0.0236	0.0236	3.46	3:44 PM
0.0322	0.0558	4.10	4:04 PM
0.0167	0.0725	4.57	4:10 PM
	0.0725	4.74	4:17 PM
	0.0725	4.77	4:19 PM
0.0041	0.0766	4.87	4:25 PM
0.0075	0.0841	4.92	4:27 PM
	0.0841	4.93	4:30 PM
0.0053	0.0894	4.96	4:33 PM
0.0052	0.0946	5.07	4:35 PM
	0.0946	5.20	6:10 PM
	0.0946	5.39	7:09 PM
	0.0946		4/23/2018
	0.0946	6.38	9:06 AM
0.0027	0.0973		9:10 AM
	0.0973	6.76	10:15 AM
0.0010	0.0983		10:20 AM
	0.0983	6.89	12:01 PM
	0.0983 kg Lime/m3 water		
Note 1. Photos			
2. 17.7 C			
3. Solution turned light yellow, clear at pH 4.57 (no sludge); turbid at pH 4.93			
4. Reagent: Hydrated Lime Ca(OH)2; Mississippi Lime Co.			
5. Overnight stirring to fully react lime at higher pH			
6. END- yellowish tint, no sludge, turbid			
pH 4 STD: 4.00	pH 7 STD: 7.03	SP Cond: ND	

Note: The titration test will be conducted once for each chemical

Ca(OH)2	pH
0	3.20
0.0236	3.46
0.0558	4.10
0.0725	4.57
0.0725	4.74
0.0725	4.77
0.0766	4.87
0.0841	4.92
0.0841	4.93
0.0894	4.96
0.0946	5.07
0.0946	5.20
0.0946	5.39
0.0946	6.38
0.0973	
0.0973	6.76
0.0983	
0.0983	6.89



Pit Water Treatment - Titration - Data Sheet

Table C8

Sampler(s) Name(s):	TRC	Sampling Start Time:	4/23/2018
Sampler(s) Initials:	TRC	Sampling Finish Time:	4/24/2018
		Date:	4/23/2018

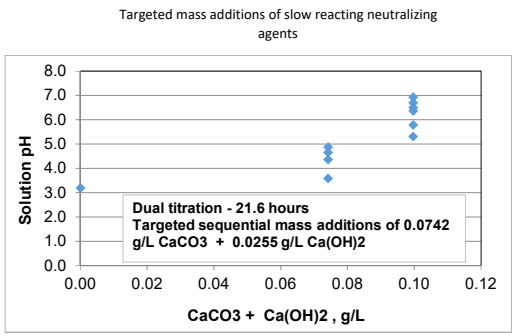
Objective To determine the chemical requirement to neutralize the pit water

Test ID	PLN1	PLN2	PLN3	PLN4
Subject Material	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water
Chemical	Caustic Soda -NaOH (CRUSHED PELLETS)	Hydrated Lime	Limestone followed by hydrated lime	Limestone

Titration - 1000 mL sample			
Added (g)	**Cumulative (g)**	**pH**	**Time**
LIMESTONE ADDITION			
23-Apr-18	0	3.20	3:57 PM
0.0742	0.0742		4:00 PM
	0.0742	3.59	4:06 PM
	0.0742	4.37	4:25 PM
	0.0742	4.66	4:41 PM
			only 1-2 particles limestone visible
24-Apr-18			
	0.0742	4.88	8:23 AM
HYDRATED LIME ADDITION			
0.0255	0.0997		8:40 AM
	0.0997	5.32	8:49 AM
	0.0997	5.79	9:05 AM
	0.0997	6.37	10:15 AM
	0.0997	6.50	11:00 AM
	0.0997	6.70	11:47 AM
	0.0997	6.94	1:35 PM
	0.0742 kg Limestone & 0.0255 KG Lime / m3 water		
Note 1. Photos			
2. 16.2 C @ t(0)			
3. Fine limestone provided by Sovereign			
4. Yellowish and slightly turbid at pH 4.66			
5. STIRRED OVERNIGHT			
6. At termination, yellowish, slightly turbid with (colloidal?) suspended particles			
pH 4 STD: 4.00	pH 7 STD: 7.03	SP Cond: ND	

Note: The titration test will be conducted once for each chemical

Cumulative (g)	**pH**
0.00	3.20
0.0742	
0.0742	3.59
0.0742	4.37
0.0742	4.66
0.0742	4.88
0.0997	
0.0997	5.32
0.0997	5.79
0.0997	6.37
0.0997	6.50
0.0997	6.70
0.0997	6.94



Pit Water Treatment - Titration - Data Sheet

Table C8

Sampler(s) Name(s):	TRC	Sampling Start Time:	4/23/2018
Sampler(s) Initials:	TRC	Sampling Finish Time:	4/24/2018
		Date:	4/23/2018

Objective To determine the chemical requirement to neutralize the pit water

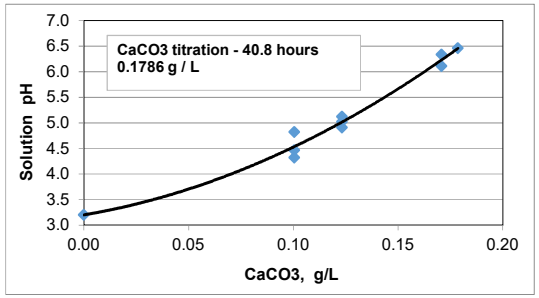
Test ID	PLN1	PLN2	PLN3	PLN4
Subject Material	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water	Upper Pit Lake Water
Chemical	Caustic Soda -NaOH (CRUSHED PELLETS)	Hydrated Lime	Hydrated lime followed by fine Limestone	Limestone

Titration - 1000 mL sample			
Added (g)	**Cumulative (g)**	**pH**	**Time**
			23-Apr-18
	0	3.20	3:57 PM
0.1005	0.1005		4:03 PM
	0.1005	4.32	4:30 PM
	0.1005	4.46	4:39 PM
	0.1005		**24-Apr-18**
	0.1005	4.82	8:28 AM
0.0228	0.1233	4.91	8:44 AM
	0.1233	5.02	10:30 AM
	0.1233	5.12	11:52 AM
0.0474	0.1707		11:54 AM
	0.1707	6.11	1:52 PM
	0.1707	6.33	3:12 PM
0.0079	0.1786	6.46	3:15 PM
	0.1786		**25-Apr-18**
	0.1786	7.59	8:48 AM
	0.1786 kg Limestone/m3 water		
Note 1. Photos			
2. 16.2 C @ t(0)			
3. Fine limestone provided by Sovereign			
4. Stirred continuously			
5. At pH 4.46, yellowish and turbid			
6. Temp final - 21 C 7. pH 7 STD final - 7.01 (25 April)			
7. 25 April Termination - a very small amount of very fine particles of limestone residue remains			
pH 4 STD: 4.00	pH 7 STD: 7.03	SP Cond: ND	

Note: The titration test will be conducted once for each chemical

CaCO3	**pH**
0	3.20
0.1005	
0.1005	4.32
0.1005	4.46
0.1005	
0.1005	4.82
0.1233	4.91
0.1233	5.02
0.1233	5.12
0.1707	
0.1707	6.11
0.1707	6.33
0.1786	6.46
0.1786	
0.1786	7.59

~31 hours



APPENDIX C
LABORATORY REPORTS
C-1 INITIAL CHARACTERIZATION
C-2 UTILIZATION TESTING USING AMENDED USBM METHOD
C-3 SOURCE CONTROL TREATMENT TESTING – WASTE ROCK

Date 10/25/2017

Method WaterCyclo

Client

Appendix C-1 Initial Characterization
ICP Metals

	Sovereign(10)		3	4						
			194	230						
ID	Analyte Name	DL (mg/l)	Upper PL Water (Diss)	Upper PL Water (total)	BH26 (Total)	BH26 (diss)	BH28 (Total)	BH28 (Diss)	Lower PL Water (total)	Lower PL Water (diss)
0	Ar 420.069 - A	% Concentration	85	90						
1	Sc 361.383 - R	% Concentration	91	90						
2	Sc 357.253 - A	% Concentration	85	84						
3	Al 396.153 - A	0.0011	8.6	8.9	1408	1464	552	553	416	434
4	As 188.979 - A	0.0080	0.041	0.034	2.1	2.1	2.1	2.0	0.5	0.5
5	B 249.677 - R	0.0161	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
6	Ba 233.527 - A	0.0003	0.02	0.02	0.11	0.05	BDL	BDL	BDL	BDL
7	Be 313.107 - R	0.0002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
8	Ca 317.933 - A	0.0254	403	413	390	383	152	151	290	276
9	Cd 214.440 - A	0.0006	0.04	0.04	3.2	3.2	2.2	2.2	1.4	1.4
10	Cu 324.752	0.0029	2.2	2.3	329	333	271	271	164	170
11	Cr 205.560 - A	0.0007	0.001	0.001	0.67	0.67	0.22	0.22	0.08	0.09
12	Fe 238.204 - A	0.0016	2.7	2.8	3249	3158	1666	1640	1703	1769
13	K 766.490 - R	0.1081	18.7	16.6	2.2	1.7	13.1	13.3	13.5	13.6
14	Li 670.784 - R	0.0049	0.023	0.019	0.51	0.31	0.12	0.12	0.09	0.10
15	Mg 285.213 - R	0.0044	62.7	62.7	780	616	215	223	203	216
16	Mg 279.077 - R	0.0203	57.9	56.6	714	611	211	213	201	206
17	Mn 257.610 - A	0.0002	6.5	6.5	34	34	21	21	24	24
18	Mo 202.031 - A	0.0012	0.002	0.003	BDL	BDL	BDL	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	167.6	155.8	70	49	30	31	59	62
20	Ni 231.604 - A	0.0015	0.022	0.022	1.9	1.9	0.8	0.7	0.6	0.6
21	P 213.617 - A	0.0128	0.16	0.16	24	22	32	32	13	14
22	P 177.434 - A	0.0231	BDL	BDL	10	10	13	13	5	5
23	Pb 220.353 - A	0.0050	0.03	0.04	2.4	2.4	1.8	1.9	1.2	1.3
24	S 181.975 - A	0.0148	700	700	7962	7804	3113	3098	2859	3000
25	S 180.669 - A	0.0072	594	629	6884	6735	2943	2949	2737	2867
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
28	Si 251.611 - A	0.0266	5.9	5.8	69	68	49	48	46	47
29	Sn 189.927 - A	0.0054	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
30	Sr 460.733 - A	0.0003	0.32	0.33	0.42	0.43	0.36	0.36	0.36	0.37
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	0.02	0.02	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	BDL	BDL	1.8	1.7	0.8	0.8	0.6	0.6
34	Zn 213.857 - A	0.0023	1.6	1.6	137	134	63	63	42	44
35	Zn 206.200	0.0023	1.6	1.5	132	127	60	59	40	42

Date	**4/15/2018**		start cell	elements						
Method	**WaterCyclo**		86	36						
Client										
	Solfatara(41)		0	1	46	47	48	49	52	
			86	122	1742	1778	1814	1850	1958	
ID	Analyte Name	DL (mg/l)	CCV Metals	CCV Nonmetal	032618-PLN5-A	032618-PLN5-B	032618-PLN5-C	032618-PLN5-D	032618-PLN5-E	
0	Ar 420.069 - A	% Concentration	98	100	96	70	84	100	85	
1	Sc 361.383 - R	% Concentration	94	95	91	80	86	95	88	
2	Sc 357.253 - A	% Concentration	95	98	95	77	86	99	91	
3	Al 396.153 - A	0.0011	20.5196	0.0092	8.1479	Exceeds	Exceeds	7.7838	Exceeds	
4	As 188.979 - A	0.0080	18.7282	0.0093	0.0418	0.8694	0.1651	0.0321	0.9195	
5	B 249.677 - R	0.0161	19.7142	0.2820	1.0839	BDL	BDL	0.4495	BDL	
6	Ba 233.527 - A	0.0003	9.5091	0.0027	0.0313	0.0365	0.0047	0.0263	BDL	
7	Be 313.107 - R	0.0002	9.7738	0.0023	BDL	0.0047	0.0034	BDL	0.0039	
8	Ca 317.933 - A	0.0254	18.7193	BDL	406.8258	317.4616	278.6660	393.5438	147.8282	
9	Cd 214.440 - A	0.0006	9.4984	0.0025	0.0452	1.9507	1.0473	0.0450	1.8011	
10	Cu 324.752 - A	0.0057	19.3349	0.0221	2.0340	248.7784	143.8424	1.9634	205.8912	
11	Cr 205.560 - A	0.0007	4.8924	0.0015	0.0013	0.5785	0.0370	0.0011	0.2143	
12	Fe 238.204 - A	0.0016	18.0019	0.0084	2.7811	529.8093	465.0833	3.3109	432.7481	
13	K 766.490 - R	0.1081	48.8860	0.1290	21.0537	BDL	16.0954	19.4735	1.9988	
14	Li 670.784 - R	0.0049	18.0123	0.0284	0.0129	0.3292	0.0793	0.0102	0.0911	
15	Mg 285.213 - R	0.0044	19.2477	BDL	53.9735	644.0271	230.2176	51.6117	223.8686	
16	Mg 279.077 - R	0.0203	18.9732	BDL	56.9154	702.5874	237.8821	53.9516	232.4209	
17	Mn 257.610 - A	0.0002	9.9973	0.0025	6.8081	27.9302	22.3009	6.6587	19.7020	
18	Mo 202.031 - A	0.0012	18.9406	0.0104	BDL	BDL	BDL	BDL	BDL	
19	Na 589.592 - R	0.0193	0.0778	81.8740	115.1041	53.2703	52.6306	108.8467	24.1742	
20	Ni 231.604 - A	0.0015	19.5177	0.0041	0.0208	1.4679	0.5588	0.0205	0.7004	
21	P 213.617 - A	0.0128	46.1373	BDL	0.2342	18.9574	11.7131	0.1998	29.1049	
22	P 177.434 - A	0.0231	48.8500	BDL	BDL	5.8488	1.4648	BDL	8.6091	
23	Pb 220.353 - A	0.0050	18.1976	0.0104	0.0336	1.2232	0.6467	0.0305	0.8942	
24	S 181.975 - A	0.0148	0.1369	52.8942	643.7207	3765.7320	2269.0913	611.1231	2313.4086	
25	S 180.669 - A	0.0072	0.6438	53.4998	609.4670	2409.2586	1681.3519	570.5264	1694.3888	
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	
27	Se 196.026 - A	0.0082	19.2531	BDL	BDL	BDL	BDL	BDL	BDL	
28	Si 251.611 - A	0.1031	0.2990	48.8619	7.3688	67.0611	46.8539	6.2241	47.6540	
29	Sn 189.927 - A	0.0054	0.0280	BDL	0.0128	0.0245	0.0194	BDL	0.0116	
30	Sr 460.733 - A	0.0003	25.5519	0.0057	0.4045	0.7834	0.7093	0.3803	0.5881	
31	Ti 334.940 - A	0.0001	0.0378	0.0027	BDL	BDL	BDL	BDL	BDL	
32	Tl 190.801 - A	0.0105	17.8795	0.0134	BDL	BDL	BDL	BDL	BDL	
33	V 292.402 - A	0.0004	9.5997	0.0022	BDL	0.9624	0.2124	BDL	0.3325	
34	Zn 213.857 - A	0.0023	9.5490	0.0042	1.6604	62.1102	32.8861	1.5659	42.3474	
35	Zn 206.200 - A	0.0023	9.4767	0.0033	1.5612	89.1296	38.1111	1.5202	55.7403	

ACZ Laboratories, Inc.
2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Analytical Report

January 19, 2018

Report to:
Guadalupe Fattore
Sovereign Consulting Inc.
12687 W. Cedar Dr.
Ste 305
Lakewood, CO 80228

cc: Jim Gusek

Bill to:
Lee Josselyn
Sovereign Consulting Inc
12687 W. Cedar Dr
Ste 305
Lakewood, CO 80228

Project ID: DV039
ACZ Project ID: L41891

Guadalupe Fattore:

Enclosed are the analytical results for sample(s) submitted to ACZ Laboratories, Inc. (ACZ) on December 20, 2017. This project has been assigned to ACZ's project number, L41891. Please reference this number in all future inquiries.

All analyses were performed according to ACZ's Quality Assurance Plan. The enclosed results relate only to the samples received under L41891. Each section of this report has been reviewed and approved by the appropriate Laboratory Supervisor, or a qualified substitute.

Except as noted, the test results for the methods and parameters listed on ACZ's current NELAC certificate letter (#ACZ) meet all requirements of NELAC.

This report shall be used or copied only in its entirety. ACZ is not responsible for the consequences arising from the use of a partial report.

All samples and sub-samples associated with this project will be disposed of after February 18, 2018. If the samples are determined to be hazardous, additional charges apply for disposal (typically $11/sample). If you would like the samples to be held longer than ACZ's stated policy or to be returned, please contact your Project Manager or Customer Service Representative for further details and associated costs. ACZ retains analytical raw data reports for ten years.

If you have any questions or other needs, please contact your Project Manager.

Max Janicek has reviewed and approved this report.

Sovereign Consulting Inc. January 19, 2018

Project ID: DV039
ACZ Project ID: L41891

Sample Receipt

ACZ Laboratories, Inc. (ACZ) received 2 soil samples from Sovereign Consulting Inc. on December 20, 2017. The samples were received in good condition. Upon receipt, the sample custodian removed the samples from the cooler, inspected the contents, and logged the samples into ACZ's computerized Laboratory Information Management System (LIMS). The samples were assigned ACZ LIMS project number L41891. The custodian verified the sample information entered into the computer against the chain of custody (COC) forms and sample bottle labels.

Holding Times

All analyses were performed within EPA recommended holding times.

Sample Analysis

These samples were analyzed for inorganic parameters. The individual methods are referenced on both the ACZ invoice and the analytical reports. The extended qualifier reports may contain footnotes qualifying specific elements due to QC failures. In addition the following has been noted with this specific project:

The Sulfur Sulfate results for L41891-01 have been qualified with the R1 flag on the extended qualifier report. The chemist noted that the Sulfate Sulfur RPD was outside the standard acceptance range for the associated sample and its sample duplicate. The chemist noted that the Sulfur Sulfate values are calculations generated from samples with passing RPD's.

The Acid Base Accounting calculations for L41891-01 were qualified with the N1 flag on the extended report. The chemist noted these calculations were based off of the Pyritic Sulfur values and Modified Neutralization Potential values.

ACZ Laboratories, Inc.
2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Inorganic Analytical Results

Sovereign Consulting Inc.
Project ID: DV039
Sample ID: WRC3

ACZ Sample ID: ***L41891-01***
Date Sampled: *12/19/17 17:00*
Date Received: *12/20/17*
Sample Matrix: *Soil*

Metals Analysis

Parameter	EPA Method	Dilution	Result	Qual	XQ	Units	MDL	PQL	Date	Analyst
Aluminum, total (3050)	M6010B ICP	100	6590		*	mg/Kg	3	20	01/04/18 5:07	aeh
Arsenic, total (3050)	M6010B ICP	100	90			mg/Kg	4	20	01/04/18 5:07	aeh
Cadmium, total (3050)	M6010B ICP	100	1.9	B		mg/Kg	0.5	2	01/04/18 5:07	aeh
Calcium, total (3050)	M6010B ICP	100	520			mg/Kg	10	50	01/04/18 5:07	aeh
Copper, total (3050)	M6010B ICP	100	458			mg/Kg	1	5	01/04/18 5:07	aeh
Iron, total (3050)	M6010B ICP	100	39800		*	mg/Kg	2	5	01/04/18 5:07	aeh
Lead, total (3050)	M6010B ICP	100	237			mg/Kg	3	20	01/04/18 5:07	aeh
Magnesium, total (3050)	M6010B ICP	100	4540			mg/Kg	20	100	01/04/18 5:07	aeh
Manganese, total (3050)	M6010B ICP	100	94.4		*	mg/Kg	0.5	3	01/04/18 5:07	aeh
Nickel, total (3050)	M6010B ICP	100	5.1		*	mg/Kg	0.8	4	01/04/18 5:07	aeh
Sodium, total (3050)	M6010B ICP	100	50	B		mg/Kg	20	100	01/04/18 5:07	aeh
Zinc, total (3050)	M6010B ICP	100	232		*	mg/Kg	1	5	01/04/18 5:07	aeh

Soil Analysis

Parameter	EPA Method	Dilution	Result	Qual	XQ	Units	MDL	PQL	Date	Analyst
Acid Generation Potential (calc)	M600/2-78-054 1.3	1	105		*	t CaCO3/Kt	0.31	3.1	01/18/18 14:42	bcc
Acid Neutralization Potential (calc)	M600/2-78-054 1.3	1		U	*	t CaCO3/Kt	1	5	01/18/18 14:42	bcc
Acid-Base Potential (calc)	M600/2-78-054 1.3	1	-105		*	t CaCO3/Kt			01/18/18 14:42	bcc
Carbon, total (TC)	ASA No.9 29-2.2.4 Combustion/IR	1		U	*	%	0.1	0.5	01/18/18 13:00	bcc
Carbon, total inorganic (TIC)	ASA No. 9 29-2.2.4 (calc TC - TOC)	1		U	*	%	0.1	0.5	01/18/18 13:00	bcc
Carbon, total organic (TOC)	ASA No.9 29-2.2.4 Combustion/IR	1		U	*	%	0.1	0.5	01/18/18 13:00	bcc
Neutralization Potential as CaCO3	M600/2-78-054 3.2.3 - Modified (No Heat)	1		U	*	%	0.1	0.5	12/29/17 9:54	jlw
Solids, Percent	D2216-80	1	99.8		*	%	0.1	0.5	01/15/18 19:15	ajm
Sulfur Forms	M600/2-78-054 3.2.4-MOD									
Sulfur HCl Residue		1	3.38		*	%	0.01	0.1	01/10/18 0:00	bcc
Sulfur HNO3 Residue		1	0.02	B	*	%	0.01	0.1	01/10/18 0:00	bcc
Sulfur Organic Residual		1	0.02	B	*	%	0.01	0.1	01/10/18 0:00	bcc
Sulfur Pyritic Sulfide		1	3.36		*	%	0.01	0.1	01/10/18 0:00	bcc
Sulfur Sulfate		1	0.35		*	%	0.01	0.1	01/10/18 0:00	bcc
Sulfur Total		1	3.73		*	%	0.01	0.1	01/10/18 0:00	bcc
Total Sulfur minus Sulfate		1	3.38		*	%	0.01	0.1	01/10/18 0:00	bcc

** Please refer to Qualifier Reports for details.*

Sovereign Consulting Inc.
Project ID: DV039
Sample ID: WRC3

ACZ Sample ID: ***L41891-01***
Date Sampled: *12/19/17 17:00*
Date Received: *12/20/17*
Sample Matrix: *Soil*

Soil Preparation

Parameter	EPA Method	Dilution	Result	Qual	XQ	Units	MDL	PQL	Date	Analyst
Air Dry at 34 Degrees C	USDA No. 1, 1972								12/22/17 12:30	dbt
Crush and Pulverize (Ring & Puck)	EPA-600/2-78-054 3.1.3								12/27/17 16:25	ajm
Digestion - Hot Plate	M3050B ICP								01/02/18 15:55	dbt

ACZ Laboratories, Inc.
2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Inorganic Analytical Results

Sovereign Consulting Inc.
Project ID: DV039
Sample ID: WRC3-60FINES

ACZ Sample ID: ***L41891-02***
Date Sampled: *12/19/17 17:00*
Date Received: *12/20/17*
Sample Matrix: *Soil*

Metals Analysis

Parameter	EPA Method	Dilution	Result	Qual	XQ	Units	MDL	PQL	Date	Analyst
Cation Exchange Capacity (CEC)	USDA No. 60 (19)	1	2.49		*	meq/100g	0.022	0.109	01/10/18 21:10	aeh

Soil Preparation

Parameter	EPA Method	Dilution	Result	Qual	XQ	Units	MDL	PQL	Date	Analyst
Air Dry at 34 Degrees C	USDA No. 1, 1972								12/22/17 12:35	dbt
Cation Exchange Capacity Extraction	USDA No. 60 (19)								01/05/18 18:20	ajm/klg
Crush and Pulverize (Ring & Puck)	EPA-600/2-78-054 3.1.3								12/27/17 16:35	ajm

** Please refer to Qualifier Reports for details.*

Report Header Explanations

Batch	A distinct set of samples analyzed at a specific time
Found	Value of the QC Type of interest
Limit	Upper limit for RPD, in %.
Lower	Lower Recovery Limit, in % (except for LCSS, mg/Kg)
MDL	Method Detection Limit. Same as Minimum Reporting Limit unless omitted or equal to the PQL (see comment #5). Allows for instrument and annual fluctuations.
PCN/SCN	A number assigned to reagents/standards to trace to the manufacturer's certificate of analysis
PQL	Practical Quantitation Limit. Synonymous with the EPA term "minimum level".
QC	True Value of the Control Sample or the amount added to the Spike
Rec	Recovered amount of the true value or spike added, in % (except for LCSS, mg/Kg)
RPD	Relative Percent Difference, calculation used for Duplicate QC Types
Upper	Upper Recovery Limit, in % (except for LCSS, mg/Kg)
Sample	Value of the Sample of interest

QC Sample Types

AS	Analytical Spike (Post Digestion)	*LCSWD*	Laboratory Control Sample - Water Duplicate
ASD	Analytical Spike (Post Digestion) Duplicate	*LFB*	Laboratory Fortified Blank
CCB	Continuing Calibration Blank	*LFM*	Laboratory Fortified Matrix
CCV	Continuing Calibration Verification standard	*LFMD*	Laboratory Fortified Matrix Duplicate
DUP	Sample Duplicate	*LRB*	Laboratory Reagent Blank
ICB	Initial Calibration Blank	*MS*	Matrix Spike
ICV	Initial Calibration Verification standard	*MSD*	Matrix Spike Duplicate
ICSAB	Inter-element Correction Standard - A plus B solutions	*PBS*	Prep Blank - Soil
LCSS	Laboratory Control Sample - Soil	*PBW*	Prep Blank - Water
LCSSD	Laboratory Control Sample - Soil Duplicate	*PQV*	Practical Quantitation Verification standard
LCSW	Laboratory Control Sample - Water	*SDL*	Serial Dilution

QC Sample Type Explanations

Blanks	Verifies that there is no or minimal contamination in the prep method or calibration procedure.
Control Samples	Verifies the accuracy of the method, including the prep procedure.
Duplicates	Verifies the precision of the instrument and/or method.
Spikes/Fortified Matrix	Determines sample matrix interferences, if any.
Standard	Verifies the validity of the calibration.

ACZ Qualifiers (Qual)

B	Analyte concentration detected at a value between MDL and PQL. The associated value is an estimated quantity.
H	Analysis exceeded method hold time. pH is a field test with an immediate hold time.
L	Target analyte response was below the laboratory defined negative threshold.
U	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

Method References

(1) EPA 600/4-83-020. Methods for Chemical Analysis of Water and Wastes, March 1983.
(2) EPA 600/R-93-100. Methods for the Determination of Inorganic Substances in Environmental Samples, August 1993.
(3) EPA 600/R-94-111. Methods for the Determination of Metals in Environmental Samples - Supplement I, May 1994.
(4) EPA SW-846. Test Methods for Evaluating Solid Waste.
(5) Standard Methods for the Examination of Water and Wastewater.

Comments

(1) QC results calculated from raw data. Results may vary slightly if the rounded values are used in the calculations.
(2) Soil, Sludge, and Plant matrices for Inorganic analyses are reported on a dry weight basis.
(3) Animal matrices for Inorganic analyses are reported on an "as received" basis.
(4) An asterisk in the "XQ" column indicates there is an extended qualifier and/or certification qualifier associated with the result.
(5) If the MDL equals the PQL or the MDL column is omitted, the PQL is the reporting limit.

For a complete list of ACZ's Extended Qualifiers, please click: http://www.acz.com/public/extquallist.pdf

Sovereign Consulting Inc.

ACZ Project ID: ***L41891***

Aluminum, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2		1.945	mg/L	97	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.09	0.09			
WG439131PBS	PBS	01/04/18 3:53				3	mg/Kg		-9	9			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	7480		8181	mg/Kg		3270	11700			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	7480		7955	mg/Kg		3270	11700	3	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	100.19	19900	21150	mg/Kg	1248	75	125			M3
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	100.19	19900	21420	mg/Kg	1517	75	125	1	20	M3

Arsenic, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	4		3.935	mg/L	98	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.12	0.12			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-12	12			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	153		145.5	mg/Kg		126	180			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	153		152.2	mg/Kg		126	180	5	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	100.1	10	101.3	mg/Kg	91	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	100.1	10	105.9	mg/Kg	96	75	125	4	20	

Cadmium, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2		1.923	mg/L	96	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.015	0.015			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-1.5	1.5			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	273		260.3	mg/Kg		223	323			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	273		267.5	mg/Kg		223	323	3	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	49.95	1.4	46.45	mg/Kg	90	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	49.95	1.4	47.21	mg/Kg	92	75	125	2	20	

Calcium, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	100		99.25	mg/L	99	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.3	0.3			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-30	30			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	5560		5582	mg/Kg		4500	6630			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	5560		5599	mg/Kg		4500	6630	0	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	6803.333	5720	14060	mg/Kg	123	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	6803.333	5720	12880	mg/Kg	105	75	125	9	20	

Carbon, total (TC) ASA No.9 29-2.2.4 Combustion/IR

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG440222													
WG440222PBS	PBS	01/18/18 9:00				U	%		-0.3	0.3			
WG440222LCSS	LCSS	01/18/18 11:00	PCN55053	3.75		3.2	%	85	80	120			
L41891-01DUP	DUP	01/18/18 15:00			U	U	%				0	20	RA

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ACZ Project ID: ***L41891***

Carbon, total inorganic (TIC) ASA No. 9 29-2.2.4 (calc TC - TOC)

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG440222													
WG440222PBS	PBS	01/18/18 9:00				U	%		-0.3	0.3			
L41891-01DUP	DUP	01/18/18 15:00			U	U	%				0	20	RA

Carbon, total organic (TOC) ASA No.9 29-2.2.4 Combustion/IR

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG440222													
WG440222PBS	PBS	01/18/18 9:00				U	%		-0.3	0.3			
L41891-01DUP	DUP	01/18/18 15:00			U	U	%				0	20	RA

Cation Exchange Capacity (CEC) USDA No. 60 (19)

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439736													
WG439736ICV	ICV	01/10/18 20:39	II171221-1	100		102	mg/L	102	90	110			
WG439736ICB	ICB	01/10/18 20:42				U	mg/L		-0.6	0.6			
WG439414PBS	PBS	01/10/18 21:06				.044	meq/100g		-0.065	0.065			
L41891-02DUP	DUP	01/10/18 21:14			2.49	3.16	meq/100g				24	20	RD
L42001-02AS	AS	01/10/18 21:26	IICECSPIKE	10.9	28.1	36.3	meq/100g	75	75	125			
L42001-02ASD	ASD	01/10/18 21:30	IICECSPIKE	10.9	28.1	37	meq/100g	82	75	125	2	20	

Copper, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2		1.909	mg/L	95	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.03	0.03			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-3	3			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	133		124.9	mg/Kg		110	156			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	133		130	mg/Kg		110	156	4	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	50	61	108	mg/Kg	94	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	50	61	110.7	mg/Kg	99	75	125	2	20	

Iron, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2		1.892	mg/L	95	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.06	0.06			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-6	6			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	13900		14170	mg/Kg		8260	19500			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	13900		14090	mg/Kg		8260	19500	1	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	100.11	28200	28500	mg/Kg	300	75	125			M3
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	100.11	28200	28950	mg/Kg	749	75	125	2	20	M3

Sovereign Consulting Inc.

ACZ Project ID: ***L41891***

Lead, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	4		3.716	mg/L	93	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.09	0.09			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-9	9			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	99.4		92.6	mg/Kg		81.4	118			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	99.4		95.7	mg/Kg		81.4	118	3	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	100.17	9	102.5	mg/Kg	93	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	100.17	9	103	mg/Kg	94	75	125	0	20	

Magnesium, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	100		99.16	mg/L	99	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.6	0.6			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-60	60			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	2480		2622	mg/Kg		1850	3110			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	2480		2559	mg/Kg		1850	3110	2	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	5005.743	10500	16010	mg/Kg	110	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	5005.743	10500	15220	mg/Kg	94	75	125	5	20	

Manganese, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2		1.919	mg/L	96	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.015	0.015			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-1.5	1.5			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	301		283.5	mg/Kg		245	357			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	301		289.9	mg/Kg		245	357	2	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	50	447	521.1	mg/Kg	148	75	125			M3
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	50	447	527.9	mg/Kg	162	75	125	1	20	M3

Neutralization Potential as CaCO3 M600/2-78-054 3.2.3 - Modified (No Heat)

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG438960													
WG438960PBS	PBS	12/28/17 18:51				U	%		-0.2	0.2			
WG438960LCSS	LCSS	12/28/17 21:22	PCN55250	4.66		4.25	%	91	80	120			
L41813-02MS	MS	12/29/17 4:53	SI141024-1	1	.5	1.5	%	100	70	130			
L41813-02DUP	DUP	12/29/17 7:24			.5	.48	%				4	20	RA

Nickel, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2.004		1.926	mg/L	96	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.024	0.024			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-2.4	2.4			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	102		101.8	mg/Kg		83.1	121			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	102		103.8	mg/Kg		83.1	121	2	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	49.95	34.4	80.56	mg/Kg	92	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	49.95	34.4	81.86	mg/Kg	95	75	125	2	20	

Sovereign Consulting Inc.

ACZ Project ID: ***L41891***

Sodium, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	100		97.97	mg/L	98	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.6	0.6			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-60	60			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	610		577	mg/Kg		445	775			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	610		590	mg/Kg		445	775	2	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	10000.62	530	11860	mg/Kg	113	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	10000.62	530	9909	mg/Kg	94	75	125	18	20	

Solids, Percent D2216-80

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG440008													
WG440008PBS	PBS	01/15/18 16:40				U	%		-0.1	0.1			
L41891-01DUP	DUP	01/15/18 21:51			99.8	99.8	%				0	20	

Sulfur Organic Residual M600/2-78-054 3.2.4-MOD

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439689													
L41834-21DUP	DUP	01/10/18 9:00			.01	.01	%				0	20	RA

Sulfur Pyritic Sulfide M600/2-78-054 3.2.4-MOD

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439689													
L41834-21DUP	DUP	01/10/18 9:00			3.86	4.05	%				5	20	

Sulfur Sulfate M600/2-78-054 3.2.4-MOD

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439689													
L41834-21DUP	DUP	01/10/18 9:00			.52	.32	%				48	20	R1

Sulfur Total M600/2-78-054 3.2.4-MOD

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439689													
L41834-21DUP	DUP	01/10/18 9:00			4.39	4.38	%				0	20	
L41834-21MS	MS	01/10/18 9:00	PCN54302	1.32	4.39	5.58	%	90	80	120			
WG439689LCSS	LCSS	01/10/18 9:00	PCN55053	3.82		3.85	%	101	80	120			
WG439689PBS	PBS	01/10/18 9:00				U	%		-0.03	0.03			

Total Sulfur Minus Sulfate M600/2-78-054 3.2.4-MOD

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439689													
L41834-21DUP	DUP	01/10/18 9:00			3.87	4.06	%				5	20	

Sovereign Consulting Inc.

ACZ Project ID: ***L41891***

Zinc, total (3050) M6010B ICP

ACZ ID	Type	Analyzed	PCN/SCN	QC	Sample	Found	Units	Rec	Lower	Upper	RPD	Limit	Qual
WG439285													
WG439285ICV	ICV	01/04/18 3:26	II171206-1	2		1.955	mg/L	98	90	110			
WG439285ICB	ICB	01/04/18 3:29				U	mg/L		-0.03	0.03			
WG439131PBS	PBS	01/04/18 3:53				U	mg/Kg		-3	3			
WG439131LCSS	LCSS	01/04/18 3:57	PCN55048	228		223.2	mg/Kg		182	275			
WG439131LCSSD	LCSSD	01/04/18 4:01	PCN55048	228		225.6	mg/Kg		182	275	1	20	
L41813-01MS	MS	01/04/18 4:09	II171220-5	49.42	148	206.4	mg/Kg	118	75	125			
L41813-01MSD	MSD	01/04/18 4:13	II171220-5	49.42	148	198	mg/Kg	101	75	125	4	20	

Sovereign Consulting Inc. ACZ Project ID: ***L41891***

ACZ ID	WORKNUM	PARAMETER	METHOD	QUAL	DESCRIPTION
L41891-01	WG440280	Acid Generation Potential (calc)	M600/2-78-054 1.3	N1	See Case Narrative.
		Acid Neutralization Potential (calc)	M600/2-78-054 1.3	N1	See Case Narrative.
		Acid-Base Potential (calc)	M600/2-78-054 1.3	N1	See Case Narrative.
	WG439285	Aluminum, total (3050)	M6010B ICP	M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to the spike level. The recovery of the associated control sample (LCS or LFB) was acceptable.
	WG440222	Carbon, total (TC)	ASA No.9 29-2.2.4 Combustion/IR	Q6	Sample was received above recommended temperature.
			ASA No.9 29-2.2.4 Combustion/IR	RA	Relative Percent Difference (RPD) was not used for data validation because the concentration of the duplicated sample is too low for accurate evaluation (< 10x MDL).
		Carbon, total inorganic (TIC)	ASA No. 9 29-2.2.4 (calc TC - TOC)	Q6	Sample was received above recommended temperature.
			ASA No. 9 29-2.2.4 (calc TC - TOC)	RA	Relative Percent Difference (RPD) was not used for data validation because the concentration of the duplicated sample is too low for accurate evaluation (< 10x MDL).
			ASA No. 9 29-2.2.4 (calc TC - TOC)	ZQ	Analyte was not evaluated in the laboratory control standard. Either the analyte is not included in the scope of the analytical method or a commercial standard containing the analyte is not available.
		Carbon, total organic (TOC)	ASA No.9 29-2.2.4 Combustion/IR	Q6	Sample was received above recommended temperature.
			ASA No.9 29-2.2.4 Combustion/IR	RA	Relative Percent Difference (RPD) was not used for data validation because the concentration of the duplicated sample is too low for accurate evaluation (< 10x MDL).
			ASA No.9 29-2.2.4 Combustion/IR	ZQ	Analyte was not evaluated in the laboratory control standard. Either the analyte is not included in the scope of the analytical method or a commercial standard containing the analyte is not available.
	WG439285	Iron, total (3050)	M6010B ICP	M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to the spike level. The recovery of the associated control sample (LCS or LFB) was acceptable.
		Manganese, total (3050)	M6010B ICP	M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to the spike level. The recovery of the associated control sample (LCS or LFB) was acceptable.
	WG438960	Neutralization Potential as CaCO3	M600/2-78-054 3.2.3 - Modified (No Heat)	RA	Relative Percent Difference (RPD) was not used for data validation because the concentration of the duplicated sample is too low for accurate evaluation (< 10x MDL).
	WG439285	Nickel, total (3050)	M6010B ICP	ZG	The ICP or ICP-MS Serial Dilution was not used for data validation because the sample concentration was less than 50 times the MDL.
	WG439689	Sulfur Organic Residual	M600/2-78-054 3.2.4-MOD	RA	Relative Percent Difference (RPD) was not used for data validation because the concentration of the duplicated sample is too low for accurate evaluation (< 10x MDL).
		Sulfur Sulfate	M600/2-78-054 3.2.4-MOD	R1	RPD exceeded the method or laboratory acceptance limit. See Case Narrative.
	WG439285	Zinc, total (3050)	M6010B ICP	ZG	The ICP or ICP-MS Serial Dilution was not used for data validation because the sample concentration was less than 50 times the MDL.
L41891-02	WG439736	Cation Exchange Capacity (CEC)	USDA No. 60 (19)	RD	For a solid matrix, the duplicate RPD (spike or matrix) exceeded the control limit, which is attributable to the non-homogeneity of the sample.

Metals Analysis

The following parameters are not offered for certification or are not covered by NELAC certificate #ACZ.

Cation Exchange Capacity (CEC)	USDA No. 60 (19)

Soil Analysis

The following parameters are not offered for certification or are not covered by NELAC certificate #ACZ.

Acid Generation Potential (calc)	M600/2-78-054 1.3
Acid Neutralization Potential (calc)	M600/2-78-054 1.3
Acid-Base Potential (calc)	M600/2-78-054 1.3
Carbon, total (TC)	ASA No.9 29-2.2.4 Combustion/IR
Carbon, total inorganic (TIC)	ASA No. 9 29-2.2.4 (calc TC - TOC)
Carbon, total organic (TOC)	ASA No.9 29-2.2.4 Combustion/IR
Neutralization Potential as CaCO3	M600/2-78-054 3.2.3 - Modified (No Heat)
Solids, Percent	D2216-80
Sulfur HCl Residue	M600/2-78-054 3.2.4-MOD
Sulfur HNO3 Residue	M600/2-78-054 3.2.4-MOD
Sulfur Organic Residual	M600/2-78-054 3.2.4-MOD
Sulfur Pyritic Sulfide	M600/2-78-054 3.2.4-MOD
Sulfur Sulfate	M600/2-78-054 3.2.4-MOD
Sulfur Total	M600/2-78-054 3.2.4-MOD
Total Sulfur minus Sulfate	M600/2-78-054 3.2.4-MOD

ACZ Laboratories, Inc.

2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Sample Receipt

Sovereign Consulting Inc.
DV039

ACZ Project ID:	L41891
Date Received:	12/20/2017 12:49
Received By:	mjj
Date Printed:	12/21/2017

Receipt Verification

	YES	NO	NA
1) Is a foreign soil permit included for applicable samples?			X
2) Is the Chain of Custody form or other directive shipping papers present?	X		
3) Does this project require special handling procedures such as CLP protocol?		X	
4) Are any samples NRC licensable material?			X
5) If samples are received past hold time, proceed with requested short hold time analyses?	X		
6) Is the Chain of Custody form complete and accurate?		X	
The date/time was entered on the COC per the information present on the sample containers for sample(s) 1 and 2.			
7) Were any changes made to the Chain of Custody form prior to ACZ receiving the samples?		X	

Samples/Containers

	YES	NO	NA
8) Are all containers intact and with no leaks?	X		
9) Are all labels on containers and are they intact and legible?	X		
10) Do the sample labels and Chain of Custody form match for Sample ID, Date, and Time?	X		
11) For preserved bottle types, was the pH checked and within limits? [1]			X
12) Is there sufficient sample volume to perform all requested work?	X		
13) Is the custody seal intact on all containers?			X
14) Are samples that require zero headspace acceptable?			X
15) Are all sample containers appropriate for analytical requirements?	X		
16) Is there an Hg-1631 trip blank present?			X
17) Is there a VOA trip blank present?			X
18) Were all samples received within hold time?	X		

NA indicates Not Applicable

Chain of Custody Related Remarks

Client Contact Remarks

Shipping Containers

Cooler Id	Temp(°C)	Temp Criteria(°C)	Rad(µR/Hr)	Custody Seal Intact?
NA27550	14.6	NA	15	N/A

Was ice present in the shipment container(s)?

No - Wet or gel ice was not present in the shipment container(s).

Client must contact an ACZ Project Manager if analysis should not proceed for samples received outside of their thermal preservation acceptance criteria.

ACZ Laboratories, Inc.
2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Sample Receipt

Sovereign Consulting Inc.
DV039

ACZ Project ID:	L41891
Date Received:	12/20/2017 12:49
Received By:	mjj
Date Printed:	12/21/2017

[1] The preservation of the following bottle types is not checked at sample receipt: Orange (oil and grease), Purple (total cyanide), Pink (dissolved cyanide), Brown (arsenic speciation), Sterile (fecal coliform), EDTA (sulfite), HCl preserved vial (organics), Na2S2O3 preserved vial (organics), and HG-1631 (total/dissolved mercury by method 1631).

ACZ Laboratories, Inc. L41891

2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

CHAIN of CUSTODY

Report to:

Name: Guadalupe Fattore
Company: Sovereign Consulting Inc.
E-mail: gfattore@sovcon.com
Address: 12687 W Cedar Dr. Ste 305
Lakewood, CO 80228
Telephone: 720-524-4908

Copy of Report to:

Name: Jim Gusek
Company: Sovereign Consulting Inc.
E-mail: jgusek@sovcon.com
Telephone: 720-524-4908

Invoice to:

Name: Lee Josselyn
Company: Sovereign Consulting Inc.
E-mail: josselynl@sovcon.com
Address: 12687 W Cedar Dr. Ste 305
Lakewood, CO 80228
Telephone: 720-524-4908

If sample(s) received past holding time (HT), or if insufficient HT remains to complete analysis before expiration, shall ACZ proceed with requested short HT analyses? YES ☒ NO ☐

If "NO" then ACZ will contact client for further instruction. If neither "YES" nor "NO" is indicated, ACZ will proceed with the requested analyses, even if HT is expired, and data will be qualified

Are samples for SDWA Compliance Monitoring? Yes ☐ No ☒

If yes, please include state forms. Results will be reported to PQL for Colorado.

Sampler's Name: Tom Clark **Sampler's Site Information** **State** CO **Zip code**_____ **Time Zone**_____

***Sampler's Signature:** Thom Clark

*I attest to the authenticity and validity of this sample. I understand that intentionally mislabeling the time/date/location or tampering with the sample in anyway, is considered fraud and punishable by State Law.

PROJECT INFORMATION

Quote #: ABA-CEC-Metals
PO#: DV039
Reporting state for compliance testing:
Check box if samples include NRC licensed material? ☐

ANALYSES REQUESTED *(attach list or use quote number)*

SAMPLE IDENTIFICATION	DATE:TIME	Matrix	# of Containers	ABA-Metals	CEC						
WRC3	12/12/17	WR	1	☒	☐	☐	☐	☐	☐	☐	☐
WRC3-60Fines	1	WR	1	☐	☒	☐	☐	☐	☐	☐	☐
	entered per containers			☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐

Matrix: SW (Surface Water) · GW (Ground Water) · WW (Waste Water) · DW (Drinking Water) · SL (Sludge) · SO (Soil) · OL (Oil) · Other (Specify)

REMARKS

The material is waste rock

Please refer to ACZ's terms & conditions located on the reverse side of this COC.

RELINQUISHED BY:	DATE:TIME	RECEIVED BY:	DATE:TIME
Thom Clark	12/19/17 5:00pm	Sandy McKinley	12.19.17 5:30pm
			12/20/17 12:49

FRMAD050.06.14.14 White - Return with sample. Yellow - Retain for your records.

L41891 Chain of Custody

04 January 2018 Our Ref.: 1793018.1

Sovereign Consulting Inc.
12687 W Cedar Drive
Suite 305
Lakewood, CO 80228

Attention: Ms. Guadalupe Fattore

RE: LABORATORY TEST RESULTS FOR SOVEREIGN CONSULTING INC.

Dear Ms. Fattore:

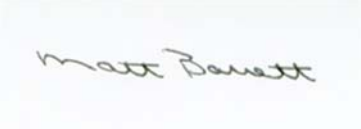
Golder Associates Inc. (Golder) has prepared this report to present the results of geotechnical laboratory testing conducted on a sample submitted by Sovereign Consulting Inc. The sample was tested at Golder's Geotechnical Laboratory in Lakewood, Colorado. This report includes the results of index testing (USCS soil classification, Atterberg Limits, Specific Gravity, and grain size distribution) on Sample: "Borrow Soil C2".

All assigned testing has been completed. Thank you for the opportunity to provide these laboratory testing services and we look forward to assisting you on future projects.

Should you have any questions or comments, please do not hesitate to call.

Sincerely,

GOLDER ASSOCIATES INC.



Matthew Barrett
Geotechnical Lab Manager

cc: File

mjb/MJB

Attachments (1 page)

Golder Associates Inc.
9197 West 6th Ave, Building C Suite 100
Lakewood, CO 80215 USA
Tel: (303) 980-0540 Fax: (303) 985-2080 www.golder.com

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ATTACHMENT

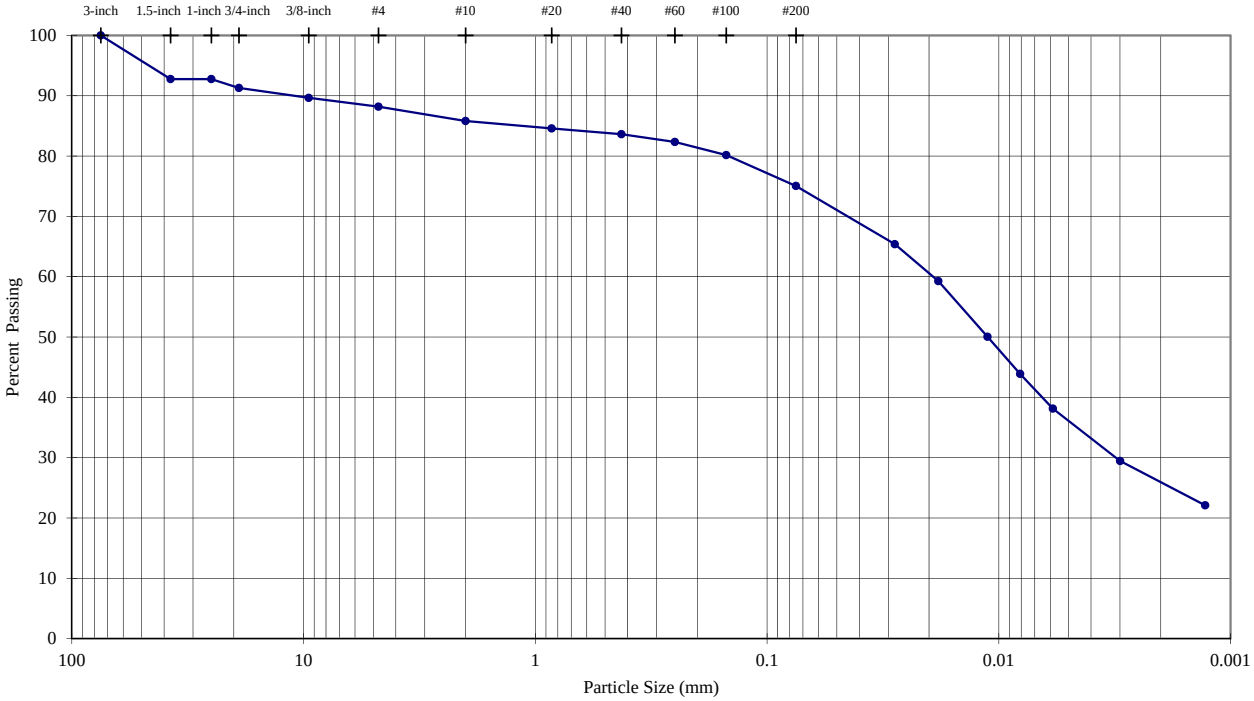
Golder Associates

January-18 **1793018.1**

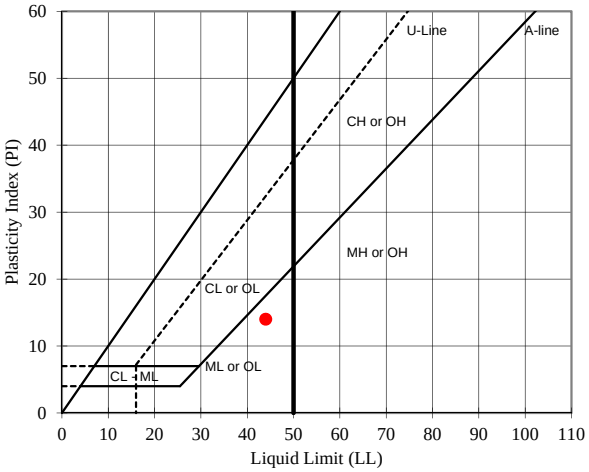
PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

PROJECT NAME: **Sovereign/Geotechnical Lab Testing/CO**
SAMPLE ID: **Borrow Soil C2** DEPTH (ft): --
TYPE: **Pail**



	Sieve	Particle Size (mm)	% Passing	Description	Percentage
Sieve Analysis (Initial Separation on No. 4 Sieve)	3-inch	75.0	**100.0**		
	1.5-inch	37.5	**92.8**	Coarse Gravel	**8.71**
	1-inch	25.0	**92.8**		
	3/4-inch	19.0	**91.3**		
	3/8-inch	9.5	**89.7**	Fine Gravel	**3.11**
	#4	4.75	**88.2**		
	#10	2.0	**85.8**	Coarse Sand	**2.37**
	#20	0.85	**84.6**	Medium Sand	**2.18**
	#40	0.425	**83.6**		
	#60	0.25	**82.3**	Fine Sand	**8.59**
	#100	0.15	**80.2**		
	#200	0.075	**75.0**		
Hydrometer Analysis		0.028	**65.4**	Silt or Clay Fines	**75.04**
		0.018	**59.3**		
		0.011	**50.1**		
		0.008	**43.9**		
		0.006	**38.1**		
		0.003	**29.5**		
		0.001	**22.1**		



USCS Description (ASTM D 2487):

Silt with sand, red, moist

LL	PL	PI	SpG
44	**30**	**14**	**2.83**

As-Received Moisture Content (%): --

USCS Group Symbol: ML

Notes: 0 g of particles up to 75.0 mm maximum size were removed from particle size analysis sample prior to testing
Particle size analysis sample mechanically dispersed using Stirring Apparatus A for about 1 minute
Sample prepared for Atterberg Limits testing by the dry method
Material retained on No. 40 sieve removed from Atterberg Limits sample by sieving
Plastic Limit test performed by hand rolling. Method A Liquid Limit test performed using mechanical device

TECH	MGC/PRH
DATE	17-Dec-2017
REVIEW	MB

The results set forth herein are provided by SGS North America Inc.

e-Hardcopy 2.0
Automated Report

Technical Report for

Solfatara Laboratories LLC

Barite/ Soverign

SGS Job Number: DA2691

Sampling Date: 02/14/18

Report to:

Solfatara Laboratories LLC
5916 McIntyre Street
Golden, CO 80403
tom.clark@solfataralabs.com

ATTN: Tom Clark

Total number of pages in report: **18**

Test results contained within this data package meet the requirements of the National Environmental Laboratory Accreditation Program and/or state specific certification programs as applicable.

Scott Heideman
Laboratory Director

Client Service contact: Jen Jorschumb 303-425-6021

Certifications: CO (CO00049), ID (CO00049), NE (NE-OS-06-04), ND (R-027), NJ (CO007), OK (D9942) UT (NELAP CO00049), LA (LA150028), TX (T104704511), WY (8TMS-L)

This report shall not be reproduced, except in its entirety, without the written approval of SGS.
Test results relate only to samples analyzed.

SGS is the sole authority for authorizing edits or modifications to this document.
Unauthorized modification of this report is strictly prohibited.
Review standard terms at: http://www.sgs.com/en/terms-and-conditions

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SGS North America Inc.

Sample Summary

Solfatara Laboratories LLC

Job No: DA2691

Barite/ Soverign

Sample Number	Collected Date	Time	By	Received	Matrix Code	Type	Client Sample ID
DA2691-1	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.1.2-011718
DA2691-2	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.1.3-011818
DA2691-3	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.1.4-011918
DA2691-4	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.1.5-011918
DA2691-5	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.2.1.1-012718
DA2691-6	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.2.1.2-012718
DA2691-7	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.2.1.3-012718
DA2691-8	02/14/18	15:45	TRC	02/14/18	AQ	Water	U.2.1.4-012718

2

Summary of Hits

Job Number: DA2691
Account: Solfatara Laboratories LLC
Project: Barite/ Soverign
Collected: 02/14/18

Lab Sample ID Analyte	Client Sample ID	Result/ Qual	RL	MDL	Units	Method
DA2691-1	**U.1.2-011718**					
Surfactants, MBAS as LAS [a]		27.6	5.0		mg/l	SM5540 C-11
DA2691-2	**U.1.3-011818**					
Surfactants, MBAS as LAS [a]		24.8	5.0		mg/l	SM5540 C-11
DA2691-3	**U.1.4-011918**					
Surfactants, MBAS as LAS [a]		56.4	5.0		mg/l	SM5540 C-11
DA2691-4	**U.1.5-011918**					
Surfactants, MBAS as LAS [a]		33.3	5.0		mg/l	SM5540 C-11
DA2691-5	**U.2.1.1-012718**					
Surfactants, MBAS as LAS [a]		44.8	5.0		mg/l	SM5540 C-11
DA2691-6	**U.2.1.2-012718**					
Surfactants, MBAS as LAS [a]		34.4	5.0		mg/l	SM5540 C-11
DA2691-7	**U.2.1.3-012718**					
Surfactants, MBAS as LAS [a]		40.8	5.0		mg/l	SM5540 C-11
DA2691-8	**U.2.1.4-012718**					
Surfactants, MBAS as LAS [a]		60.4	5.0		mg/l	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

Sample Results

Report of Analysis

SGS North America Inc.

Report of Analysis

Client Sample ID:	U.1.2-011718		
Lab Sample ID:	DA2691-1	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	27.6	5.0	mg/l	50	02/15/18 18:40	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

SGS North America Inc.

Report of Analysis

Client Sample ID:	U.1.3-011818		
Lab Sample ID:	DA2691-2	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	24.8	5.0	mg/l	50	02/15/18 18:40	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

Report of Analysis

Client Sample ID:	U.1.4-011918		
Lab Sample ID:	DA2691-3	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	56.4	5.0	mg/l	50	02/15/18 18:40	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

SGS North America Inc.

Report of Analysis

Client Sample ID:	U.1.5-011918		
Lab Sample ID:	DA2691-4	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	33.3	5.0	mg/l	50	02/15/18 18:40	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

Report of Analysis

Client Sample ID:	U.2.1.1-012718		
Lab Sample ID:	DA2691-5	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	44.8	5.0	mg/l	50	02/15/18 18:40	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

SGS North America Inc.

Report of Analysis

Client Sample ID:	U.2.1.2-012718		
Lab Sample ID:	DA2691-6	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	34.4	5.0	mg/l	50	02/15/18 18:40	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

SGS North America Inc.

Report of Analysis

Client Sample ID:	U.2.1.3-012718		
Lab Sample ID:	DA2691-7	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	40.8	5.0	mg/l	50	02/15/18 18:48	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

Report of Analysis

Client Sample ID:	U.2.1.4-012718		
Lab Sample ID:	DA2691-8	**Date Sampled:**	02/14/18
Matrix:	AQ - Water	**Date Received:**	02/14/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Surfactants, MBAS as LAS [a]	60.4	5.0	mg/l	50	02/15/18 18:48	ANJ	SM5540 C-11

(a) Analysis performed at SGS Dayton, NJ.

RL = Reporting Limit

Misc. Forms

Custody Documents and Other Forms

Includes the following where applicable:

- Chain of Custody
- Chain of Custody (SGS Dayton, NJ)

SGS

CHAIN OF CUSTODY

Page 1 of 1

4036 Youngfield Street, Wheat Ridge, CO 80033
TEL: 303-425-6021 FAX: 303-425-6854
www.accutest.com

Bottle Order Control #	FED-EX Tracking #
SGS Quote #	SGS Job # DA2691

Client / Reporting Information

Company: Solfatara Labs
Street: 5916 McIntyre St
City, State: Golden, Co 80403
Project Contact: Barite Hill
Phone: 518-361-8217
Email: tom.clark@solfataralabs.com
Sampler(s) Name(s):

Project Information

Project Name: Barite / Sovereign
Street:
City, State:
Project #:
Client Purchase Order #:
Project Manager:

Billing Information (If different from Report to)

Company: SAME
Street Address:
City, State ZIP:
Attention:

Requested Analysis (see TEST CODE sheet)

MBAS $210/sample

Matrix Codes

DW - Drinking Water
GW - Ground Water
WW - Water
SW - Surface Water
SO - Soil
SL- Sludge
SED-Sediment
OI - Oil
LIQ - Other Liquid
AIR - Air
SOL - Other Solid
WP - Wipe
FB-Field Blank
EB-Equipment Blank
RB- Rinse Blank
TB-Trip Blank

Field ID / Point of Collection	Collection Date	Collection Time	Sampled by	Matrix	# of bottles	NONE	HCl	NaOH	HNO3	H2SO4	DI Water	MEOH	ENCORE	Na2S2O4	LAB USE ONLY
U.1.2-011718	01/17/18	0345	TRC	AQ	1	1									01
U.1.3-011818			TRC	AQ	1	1									02
U.1.4-011918			TRC	AQ	1	1									03
U.1.5-011918			TRC	AQ	1	1									04
U.2.1.1-012718			TRC	AQ	1	1									05
U.2.1.2-012718			TRC	AQ	1	1									06
U.2.1.3-012718			TRC	AQ	1	1									07
U.2.1.4-012718			TRC	AQ	1	1									08
															09 (02/14/18)
															02/14/18
															02/14/18

Turnaround Time (Business days)

- [x] Std. 10 Business Days
- [ ] 5 Day RUSH
- [ ] 3 Day Emergency
- [ ] 2 Day Emergency
- [ ] 1 Day Emergency

Emergency & Rush T/A data available VIA LabLink. RUSH TAT approval needed.

Special Reporting Instructions

- [ ] Report in PPB
- [ ] Report in PPM
- [ ] Report MDLs

Data Deliverable Information

- [x] Commercial "A" (Level 1, Results Only)
- [ ] ~~Commercial "B" (Level 2, Results + QC Summary)~~
- [ ] COMMBN (Results/QC/Narrative)
- [ ] COMMBN+ [Results/QC/Narrative (+ chromatograms)]
- [ ] REDT2
- [ ] FULT1
- [ ] EDD Format _____

Comments / Special Instructions

Analyze outside of hold times conc. may be high (lab samples)

Sample Custody must be documented below each time samples change possession, including courier delivery.

Relinquished by Sampler:	Date/Time:	Received By:	Relinquished By:	Date/Time:	Received By:
1 John Clark	02/14/18 3:45 PM	1 [signature]	2		2
Relinquished by Sampler: 3	Date/Time:	Received By: 3	Relinquished By: 4	Date/Time:	Received By: 4

Custody Seal # Intact ☐ Not Intact ☐ Absent ☐ | Preserved where applicable ☒ | Cooler Temp. °C: 3.7° | Therm. ID: TD50 | On Ice ☒

Form MSQA 064-01, RV 6/19/17
http://www.sgs.com/terms-and-conditions

DA2691: Chain of Custody
Page 1 of 2

SGS Accutest Sample Receipt Summary

Job Number: DA2691 **Client:** SOLFATARA **Project:** BARITE/ SOVERIGN

Date / Time Received: 2/14/2018 3:45:00 PM **Delivery Method:** **Airbill #'s:** hd

Cooler Temps (Initial/Adjusted): #1: (3.7/3.7);

Cooler Security	Y	or	N		Y	or	N
1. Custody Seals Present:	☑		☐	3. COC Present:	☑		☐
2. Custody Seals Intact:	☑		☐	4. Smpl Dates/Time OK	☑		☐

Cooler Temperature	Y	or	N
1. Temp criteria achieved:	☑		☐
2. Cooler temp verification:	IR Gun;		
3. Cooler media:	Ice (Bag)		
4. No. Coolers:	1		

Quality Control Preservation	Y	or	N	N/A
1. Trip Blank present / cooler:	☐		☐	☑
2. Trip Blank listed on COC:	☐		☐	☑
3. Samples preserved properly:	☑		☐	
4. VOCs headspace free:	☐		☐	☑

Comments

Sample Integrity - Documentation	Y	or	N
1. Sample labels present on bottles:	☑		☐
2. Container labeling complete:	☑		☐
3. Sample container label / COC agree:	☑		☐

Sample Integrity - Condition	Y	or	N
1. Sample recvd within HT:	☑		☐
2. All containers accounted for:	☑		☐
3. Condition of sample:	Intact		

Sample Integrity - Instructions	Y	or	N	N/A
1. Analysis requested is clear:	☑		☐	
2. Bottles received for unspecified tests	☐		☑	
3. Sufficient volume recvd for analysis:	☑		☐	
4. Compositing instructions clear:	☐		☐	☑
5. Filtering instructions clear:	☐		☐	☑

4.1

4

DA2691: Chain of Custody
Page 2 of 2

SGS

CHAIN OF CUSTODY

4036 Youngfield Street, Wheat Ridge, CO 80033
TEL 303-425-6021 FAX 303-425-6854

FEDEX Tracking # 4727 4816 5914
Bottle Order Control #
SGS Quote #
SGS Job # DA2691

Client / Reporting Information

Company Name: SGS North America Inc.
Street Address: 4036 Youngfield Street
City State Zip: Wheat Ridge, CO 8003:
Project Contact E-mail: jeremy.dechant@sgs.com
Phone # 303-425-6021 Fax #
Sampler(s) Name(s) Phone: TRC

Project Information

Project Name: Barite/ Soverign
Street
City State
Project #
Client Purchase Order #
Project Manager

Billing Information (if different from Report to)
Company Name
Street Address
City State Zip
Attention:

Requested Analysis (see TEST CODE sheet)

Matrix Codes: DW - Drinking Water; GW - Ground Water; WW - Water; SW - Surface Water; SO - Soil; SL- Sludge; SED-Sediment; OI - Oil; LIQ - Other Liquid; AIR - Air; SOL - Other Solid; WP - Wipes; FB-Field Blank; EB-Equipment Blank; RB- Rinse Blank; TB-Trip Blank

SGS Sample #	Field ID / Point of Collection	MEOH/DI Vial #	Collection Date	Collection Time	Sampled by	Matrix	# of bottles	HCl	NaOH	HNO3	H2SO4	NONE	DI Water	MEOH	ENCORE	MBAS	LAB USE ONLY
1	U.1.2-011718		2/14/18	3:45:00 PM	TRC	AQ										X	C25
2	U.1.3-011818		2/14/18	3:45:00 PM	TRC	AQ										X	
3	U.1.4-011918		2/14/18	3:45:00 PM	TRC	AQ										X	
4	U.1.5-011918		2/14/18	3:45:00 PM	TRC	AQ										X	
5	U.2.1.1-012718		2/14/18	3:45:00 PM	TRC	AQ										X	
6	U.2.1.2-012718		2/14/18	3:45:00 PM	TRC	AQ										X	
7	U.2.1.3-012718		2/14/18	3:45:00 PM	TRC	AQ										X	
8	U.2.1.4-012718		2/14/18	3:45:00 PM	TRC	AQ										X	

Turnaround Time (Business days)

- [ ] Std. 10 Business Days
- [ ] 5 Day RUSH
- [ ] 3 Day EMERGENCY
- [ ] 2 Day EMERGENCY
- [ ] 1 Day EMERGENCY
- [X] other Due 2/28/2018

Approved By (SGS PM): / Date:

Emergency & Rush T/A data available VIA Lablink

Data Deliverable Information

- [ ] Commercial "A" (Level 1)
- [ ] Commercial "B" (Level 2)
- [ ] FULLT1 (Level 3+4)
- [ ] NJ Reduced
- [ ] Commercial "C"
- [ ] NYASP Category A
- [ ] NYASP Category B
- [ ] State Forms
- [ ] EDD Format
- [X] Other COMMB

Commercial "A" = Results Only
Commercial "B" = Results + QC Summary
NJ Reduced = Results + QC Summary + Partial Raw data

Comments / Special Instructions

INITIAL ASESSMENT
LABEL VERIFICATION

Sample Custody must be documented below each time samples change possession, including courier delivery.

Relinquished by Sampler:	Date Tir	Received By:	Relinquished By:	Date Time:	Received By:
1	2/14/18	1 FEDEX	2 FEDEX	2-15-18 945	2
Relinquished by Sampler: 3	Date Time:	Received By: 3	Relinquished By: 4	Date Time:	Received By: 4
Relinquished by: 5	Date Time:	Received By: 5	Custody Seals [ ] Intact [ ] Not intact	Preserved where applicable [ ]	On Ice [✓] Cooler Temp. 1.4c

IP

DA2691: Chain of Custody
Page 1 of 2
SGS Dayton, NJ

SGS Sample Receipt Summary

Job Number: DA2691 **Client:** _____ **Project:** _____

Date / Time Received: 2/15/2018 9:45:00 AM **Delivery Method:** _____ **Airbill #'s:** _____

Cooler Temps (Raw Measured) °C: Cooler 1: (1.4);

Cooler Temps (Corrected) °C: Cooler 1: (2.9);

Cooler Security	Y	or N		Y	or N
1. Custody Seals Present:	☑	☐	3. COC Present:	☑	☐
2. Custody Seals Intact:	☑	☐	4. Smpl Dates/Time OK	☑	☐

Cooler Temperature	Y	or N
1. Temp criteria achieved:	☑	☐
2. Cooler temp verification:	IR Gun	
3. Cooler media:	Ice (Bag)	
4. No. Coolers:	1	

Quality Control Preservation	Y	or N	N/A
1. Trip Blank present / cooler:	☐	☐	☑
2. Trip Blank listed on COC:	☐	☐	☑
3. Samples preserved properly:	☑	☐	
4. VOCs headspace free:	☐	☐	☑

Sample Integrity - Documentation	Y	or N
1. Sample labels present on bottles:	☑	☐
2. Container labeling complete:	☑	☐
3. Sample container label / COC agree:	☑	☐

Sample Integrity - Condition	Y	or N
1. Sample recvd within HT:	☑	☐
2. All containers accounted for:	☑	☐
3. Condition of sample:	Intact	

Sample Integrity - Instructions	Y	or N	N/A
1. Analysis requested is clear:	☑	☐	
2. Bottles received for unspecified tests	☐	☑	
3. Sufficient volume recvd for analysis:	☑	☐	
4. Compositing instructions clear:	☐	☐	☑
5. Filtering instructions clear:	☐	☐	☑

Test Strip Lot #s: pH 1-12: 216017 pH 12+: 208717 Other: (Specify) _____ _____

Comments

SM089-03
Rev. Date 12/7/17

DA2691: Chain of Custody
Page 2 of 2

The results set forth herein are provided by SGS North America Inc.

e-Hardcopy 2.0
Automated Report

Technical Report for

Solfatara Laboratories LLC

Barite/ Soverign

SGS Job Number: DA2790

Sampling Date: 02/19/18

Report to:

Solfatara Laboratories LLC
5916 McIntyre Street
Golden, CO 80403
tom.clark@solfataralabs.com

ATTN: Tom Clark

Total number of pages in report: 15

Test results contained within this data package meet the requirements of the National Environmental Laboratory Accreditation Program and/or state specific certification programs as applicable.

Scott Heideman
Laboratory Director

Client Service contact: Jen Jorschumb 303-425-6021

Certifications: CO (CO00049), ID (CO00049), NE (NE-OS-06-04), ND (R-027), NJ (CO007), OK (D9942) UT (NELAP CO00049), LA (LA150028), TX (T104704511), WY (8TMS-L)

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Test results relate only to samples analyzed.

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how we can serve you better at:
EHS.US.CustomerCare@sgs.com

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SGS North America Inc.

Sample Summary

Solfatara Laboratories LLC

Job No: DA2790

Barite/ Soverign

Sample Number	Collected Date	Time	By	Received	Matrix Code	Type	Client Sample ID
DA2790-1	02/19/18	10:25	TRC	02/19/18	AQ	Water	U3-021918A
DA2790-2	02/19/18	10:25	TRC	02/19/18	AQ	Water	U3-021918B

Summary of Hits

Job Number: DA2790
Account: Solfatara Laboratories LLC
Project: Barite/ Soverign
Collected: 02/19/18

Lab Sample ID Analyte	Client Sample ID	Result/ Qual	RL	MDL	Units	Method
DA2790-1	**U3-021918A**					
Total Organic Carbon		5530	1000		mg/l	SM 5310B-2011/9060A
DA2790-2	**U3-021918B**					
Total Organic Carbon		5670	1000		mg/l	SM 5310B-2011/9060A

Sample Results

Report of Analysis

SGS North America Inc.

Report of Analysis

Client Sample ID:	U3-021918A		
Lab Sample ID:	DA2790-1	**Date Sampled:**	02/19/18
Matrix:	AQ - Water	**Date Received:**	02/19/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Total Organic Carbon	5530	1000	mg/l	1000	03/02/18 12:35	JH	SM 5310B-2011/9060A

RL = Reporting Limit

SGS North America Inc.

Report of Analysis

Client Sample ID:	U3-021918B		
Lab Sample ID:	DA2790-2	**Date Sampled:**	02/19/18
Matrix:	AQ - Water	**Date Received:**	02/19/18
		Percent Solids:	n/a
Project:	Barite/ Soverign		

General Chemistry

Analyte	Result	RL	Units	DF	Analyzed	By	Method
Total Organic Carbon	5670	1000	mg/l	1000	03/02/18 12:48	JH	SM 5310B-2011/9060A

RL = Reporting Limit

Misc. Forms

Custody Documents and Other Forms

Includes the following where applicable:

- Chain of Custody

SGS

CHAIN OF CUSTODY

4036 Youngfield Street, Wheat Ridge, CO 80033
TEL: 303-425-6021 FAX: 303-425-6854
www.accutest.com

Page 1 of 1

Bottle Order Control #	FED-EX Tracking #
SGS Quote #	SGS Job # DA2790

Client / Reporting Information

Company: Solfatara Labs
Street: 5916 McIntyre St
City, State: Golden, Co
Project Contact: SOV - BH
Phone: 518-361-8817
Email: tom.clark@solfataralabs.com
Sampler(s) Name(s): TRC

Project Information

Project Name: Berik Hill
Street:
City, State:
Project #:
Client Purchase Order #:
Project Manager:
Attention:

Billing Information (If different from Report to)

Company: SAMIE
Street Address:
City, State ZIP:

Requested Analysis (see TEST CODE sheet)

Matrix Codes

DW - Drinking Water
GW - Ground Water
WW - Water
SW - Surface Water
SO - Soil
SL- Sludge
SED-Sediment
OI - Oil
LIQ - Other Liquid
AIR - Air
SOL - Other Solid
WP - Wipe
FB-Field Blank
EB-Equipment Blank
RB- Rinse Blank
TB-Trip Blank

Field ID / Point of Collection	Collection Date	Time	Sampled by	Matrix	# of bottles	NONE	HCl	NaOH	HNO3	H2SO4	DI Water	MEOH	ENCORE	Na2S2O4	Requested Analysis	LAB USE ONLY
U3-021918a	2/19/18	10:25 AM	TRC	Aq	1					X					TOC	01
U3-021918b	2/19/18	10:25 AM	TRC	Aq	1					X					TOC	02
																mg 2/19/18
																mg 2/19/18

Turnaround Time (Business days)

- [x] Std. 10 Business Days
- [ ] 5 Day RUSH
- [ ] 3 Day Emergency
- [ ] 2 Day Emergency
- [ ] 1 Day Emergency

Emergency & Rush T/A data available VIA LabLink. RUSH TAT approval needed.

Special Reporting Instructions

- [ ] Report in PPB
- [ ] Report in PPM
- [ ] Report MDLs

Data Deliverable Information

- [ ] Commercial "A" (Level 1, Results Only)
- [ ] Commercial "B" (Level 2, Results + QC Summary)
- [ ] COMMBN (Results/QC/Narrative)
- [ ] COMMBN+ [Results/QC/Narrative (+ chromatograms)]
- [ ] REDT2
- [ ] FULT1
- [ ] EDD Format _____

Comments / Special Instructions

* 125mL bottles. mg

Sample Custody must be documented below each time samples change possession, including courier delivery.

Relinquished by Sampler:	Date/Time:	Received By:	Relinquished By:	Date/Time:	Received By:
1	02/19/18 12:00PM	1	2		2
Relinquished by Sampler: 3	Date/Time:	Received By: 3	Relinquished By: 4	Date/Time:	Received By: 4

Custody Seal # Intact ☐ Not intact ☐ Absent ☐ Preserved where applicable ☐ Cooler Temp. °C: 1.2 Therm. ID: TR-01 On Ice ☒

Form MSQA 084-01, RV 6/19/17
http://www.sgs.com/terms-and-conditions

4.1
4

DA2790: Chain of Custody
Page 1 of 2

SGS Accutest Sample Receipt Summary

Job Number: DA2790 **Client:** SOLFATARA **Project:** BORIK HILL

Date / Time Received: 2/19/2018 12:00:00 PM **Delivery Method:** **Airbill #'s:** hd

Cooler Temps (Initial/Adjusted): #1: (1.2/1.2);

Cooler Security	Y	or	N		Y	or	N
1. Custody Seals Present:	☑		☐	3. COC Present:	☑		☐
2. Custody Seals Intact:	☑		☐	4. Smpl Dates/Time OK	☑		☐

Cooler Temperature	Y	or	N
1. Temp criteria achieved:	☑		☐
2. Cooler temp verification:	IR Gun;		
3. Cooler media:	Ice (Bag)		
4. No. Coolers:	1		

Quality Control Preservation	Y	or	N	N/A
1. Trip Blank present / cooler:	☐		☐	☑
2. Trip Blank listed on COC:	☐		☐	☑
3. Samples preserved properly:	☑		☐	
4. VOCs headspace free:	☐		☐	☑

Comments

Sample Integrity - Documentation	Y	or	N
1. Sample labels present on bottles:	☑		☐
2. Container labeling complete:	☑		☐
3. Sample container label / COC agree:	☑		☐

Sample Integrity - Condition	Y	or	N
1. Sample recvd within HT:	☑		☐
2. All containers accounted for:	☑		☐
3. Condition of sample:	Intact		

Sample Integrity - Instructions	Y	or	N	N/A
1. Analysis requested is clear:	☑		☐	
2. Bottles received for unspecified tests	☐		☑	
3. Sufficient volume recvd for analysis:	☑		☐	
4. Compositing instructions clear:	☐		☐	☑
5. Filtering instructions clear:	☐		☐	☑

General Chemistry

QC Data Summaries

Includes the following where applicable:

- Method Blank and Blank Spike Summaries
- Duplicate Summaries
- Matrix Spike Summaries

METHOD BLANK AND SPIKE RESULTS SUMMARY
GENERAL CHEMISTRY

Login Number: DA2790
Account: SOLFCOG - Solfatara Laboratories LLC
Project: Barite/ Soverign

Analyte	Batch ID	RL	MB Result	Units	Spike Amount	BSP Result	BSP %Recov	QC Limits
Total Organic Carbon	GP22274/GN42101	1.0	0.0	mg/l	6.8	6.94	102.1	90-110%

Associated Samples:
Batch GP22274: DA2790-1, DA2790-2
(*) Outside of QC limits

DUPLICATE RESULTS SUMMARY
GENERAL CHEMISTRY

Login Number: DA2790
Account: SOLFCOG - Solfatara Laboratories LLC
Project: Barite/ Soverign

Analyte	Batch ID	QC Sample	Units	Original Result	DUP Result	RPD	QC Limits
Total Organic Carbon	GP22274/GN42101	DA3040-4	mg/l	54.9	54.9	0.0	0-20%

Associated Samples:
Batch GP22274: DA2790-1, DA2790-2
(*) Outside of QC limits

MATRIX SPIKE RESULTS SUMMARY
GENERAL CHEMISTRY

Login Number: DA2790
Account: SOLFCOG - Solfatara Laboratories LLC
Project: Barite/ Soverign

Analyte	Batch ID	QC Sample	Units	Original Result	Spike Amount	MS Result	%Rec	QC Limits
Total Organic Carbon	GP22274/GN42101	DA3040-4	mg/l	54.9	100	157	102.1	80-120%

Associated Samples:
Batch GP22274: DA2790-1, DA2790-2
(*) Outside of QC limits
(N) Matrix Spike Rec. outside of QC limits

MATRIX SPIKE DUPLICATE RESULTS SUMMARY
GENERAL CHEMISTRY

Login Number: DA2790
Account: SOLFCOG - Solfatara Laboratories LLC
Project: Barite/ Soverign

Analyte	Batch ID	QC Sample	Units	Original Result	Spike Amount	MSD Result	RPD	QC Limit
Total Organic Carbon	GP22274/GN42101	DA3040-4	mg/l	54.9	100	154	1.9	20%

Associated Samples:
Batch GP22274: DA2790-1, DA2790-2
(*) Outside of QC limits
(N) Matrix Spike Rec. outside of QC limits

Appendix C-3 - Source Control Treatment Testing - Waste Rock
ICP Raw Data 1/13/18

Date 2/20/2018
Method WaterCyclo
Kalen
Client Rasmussen(25)
Yida Fang(8) Kate

			7	8	15	16	21	22	35	41
			338	374	626	662	842	878	1346	1562
ID	Analyte Name	DL (mg/l)	WRU-6-013118	WRU3-WRT-3-INF-013016	WRU-6-INF-013118	WRU4-WRT4-INF-013118	WRT-2-WRU-2-INF-013018	WRU-4-013118	WRU-3-013018	WRU-1-013118
0	Ar 420.069 - A	% Concentration	115	147	107	75	95	64	102	110
1	Sc 361.383 - R	% Concentration	94	97	99	100	116	99	112	112
2	Sc 357.253 - A	% Concentration	77	107	73	71	96	70	98	108
3	Al 396.153 - A	0.0011	0.8417	0.3750	0.3246	0.7191	0.3372	3.7536	16.1710	59.0389
4	As 188.979 - A	0.0080	0.0355	0.0386	0.0219	0.0444	BDL	0.0786	0.0555	0.0859
5	B 249.677 - R	0.0161	1.1254	1.1807	0.7048	1.6327	0.7467	1.1551	1.9204	0.3334
6	Ba 233.527 - A	0.0003	0.0182	0.0219	0.0237	0.0338	0.0066	0.3291	0.0639	0.0825
7	Be 313.107 - R	0.0002	BDL	BDL	BDL	BDL	BDL	BDL	0.0004	0.0024
8	Ca 317.933 - A	0.0254	28.3947	207.7072	1.9564	179.0040	0.4455	202.5596	218.5961	111.6527
9	Cd 214.440 - A	0.0006	BDL	BDL	BDL	BDL	BDL	BDL	0.0091	0.0364
10	Cu 324.752 - A	0.0057	1.5348	0.0166	0.0086	0.0216	0.0075	4.0119	12.1834	39.0059
11	Cr 205.560 - A	0.0007	BDL	BDL	BDL	BDL	BDL	BDL	0.0121	0.0524
12	Fe 238.204 - A	0.0016	4.2623	0.0370	0.0423	0.0149	0.0330	0.2245	7.7627	124.9469
13	K 766.490 - R	0.1081	39.1917	298.3762	77.3086	484.7589	2.8472	426.2691	221.4608	2.3029
14	Li 670.784 - R	0.0049	0.1289	0.0065	0.1353	0.1407	0.0062	0.1119	0.0052	0.0148
15	Mg 285.213 - R	0.0044	8.2356	19.5304	0.3274	18.3084	0.0398	33.8647	25.0122	18.0179
16	Mg 279.077 - R	0.0203	7.9482	23.9326	0.3085	16.6159	0.0381	29.4031	26.2290	19.9160
17	Mn 257.610 - A	0.0002	0.3778	0.0052	0.0038	0.0065	0.0011	0.6411	1.6701	4.4652
18	Mo 202.031 - A	0.0012	0.0086	0.0033	0.0044	0.0048	BDL	0.0107	BDL	BDL
19	Na 589.592 - R	0.0193		78.8513	2656.4324	2587.5750	637.7937	2715.2896	66.1811	31.0421
20	Ni 231.604 - A	0.0015	0.0119	0.0028	0.0020	0.0017	BDL	0.0179	0.0513	0.1105
21	P 213.617 - A	0.0128	0.4491	106.7428	0.2578	106.7262	0.0204	79.4223	66.0598	7.3908
22	P 177.434 - A	0.0231	0.1766	123.3554	0.3410	127.3054	BDL	97.2785	77.4317	1.2244
23	Pb 220.353 - A	0.0050	0.0085	0.0053	BDL	BDL	BDL	0.0157	0.0488	0.1655
24	S 181.975 - A	0.0148	232.0411	12.0436	24.9593	12.5886	2.1913	296.6710	208.6119	432.4067
25	S 180.669 - A	0.0072	233.8629	15.7086	25.3328	15.8372	2.2597	300.8076	216.2157	429.6920
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	0.0448	0.0449	0.0353	0.0728	BDL	0.1330	0.0633	BDL
28	Si 251.611 - A	0.1031	3.8091	1.1953	1.6102	1.8882	1.8421	4.4838	5.0282	6.6596
29	Sn 189.927 - A	0.0054	0.0848	0.0218	0.0304	0.0134	0.0317	0.0866	0.0679	0.0752
30	Sr 460.733 - A	0.0003	0.1548	0.0841	0.0139	0.1575	0.0021	1.2355	0.2484	0.2548
31	Ti 334.940 - A	0.0001	0.0037	BDL	0.0075	BDL	0.0003	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	0.0031	BDL	BDL	BDL	BDL	0.0093	0.0005	0.0234
34	Zn 213.857 - A	0.0023	0.0688	0.7996	0.0112	0.7954	BDL	0.8201	1.8517	4.7149
35	Zn 206.200 - A	0.0023	0.0646	0.9383	0.0082	0.6627	BDL	0.6287	1.7622	4.3512

ICP Raw Data 1/31/18

Date 2/20/2018
Method WaterCyclo Kalen
Client Rasmussen(25)
Yida Fang(8) Kate

ID	Analyte Name	DL (mg/l)	8	15	16	21	22	29	34	35	41
			374	626	662	842	878	1130	1310	1346	1562
			VRU3-WRT-3-INF-01301	WRU-6-INF-013118	WRU4-WRT4-INF-013118	WRT-2-WRU-2-INF-013018	WRU-4-013118	WRU-2-013018	WRS-1-INF-013118	WRU-3-013018	WRU-1-013118
0	Ar 420.069 - A	% Concentration	147	107	75	95	64	101	104	102	110
1	Sc 361.383 - R	% Concentration	97	99	100	116	99	116	109	112	112
2	Sc 357.253 - A	% Concentration	107	73	71	96	70	99	110	98	108
3	Al 396.153 - A	0.0011	0.3750	0.3246	0.7191	0.3372	3.7536	0.3025	0.2411	16.1710	59.0389
4	As 188.979 - A	0.0080	0.0386	0.0219	0.0444	BDL	0.0786	0.0087	0.0131	0.0555	0.0859
5	B 249.677 - R	0.0161	1.1807	0.7048	1.6327	0.7467	1.1551	0.5706	0.6007	1.9204	0.3334
6	Ba 233.527 - A	0.0003	0.0219	0.0237	0.0338	0.0066	0.3291	0.0049	0.0041	0.0639	0.0825
7	Be 313.107 - R	0.0002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0004	0.0024
8	Ca 317.933 - A	0.0254	207.7072	1.9564	179.0040	0.4455	202.5596	2.1823	31.1819	218.5961	111.6527
9	Cd 214.440 - A	0.0006	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0091	0.0364
10	Cu 324.752 - A	0.0057	0.0166	0.0086	0.0216	0.0075	4.0119	0.1226	0.0362	12.1834	39.0059
11	Cr 205.560 - A	0.0007	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0121	0.0524
12	Fe 238.204 - A	0.0016	0.0370	0.0423	0.0149	0.0330	0.2245	0.3478	0.0709	7.7627	124.9469
13	K 766.490 - R	0.1081	298.3762	77.3086	484.7589	2.8472	426.2691	5.4930	1.8150	221.4608	2.3029
14	Li 670.784 - R	0.0049	0.0065	0.1353	0.1407	0.0062	0.1119	BDL	BDL	0.0052	0.0148
15	Mg 285.213 - R	0.0044	19.5304	0.3274	18.3084	0.0398	33.8647	0.6827	8.7983	25.0122	18.0179
16	Mg 279.077 - R	0.0203	23.9326	0.3085	16.6159	0.0381	29.4031	0.7122	9.8516	26.2290	19.9160
17	Mn 257.610 - A	0.0002	0.0052	0.0038	0.0065	0.0011	0.6411	0.0245	0.0068	1.6701	4.4652
18	Mo 202.031 - A	0.0012	0.0033	0.0044	0.0048	BDL	0.0107	BDL	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	78.8513	2656.4324	2587.5750	637.7937	2715.2896	646.1586	48.1530	66.1811	31.0421
20	Ni 231.604 - A	0.0015	0.0028	0.0020	0.0017	BDL	0.0179	BDL	BDL	0.0513	0.1105
21	P 213.617 - A	0.0128	106.7428	0.2578	106.7262	0.0204	79.4223	0.0469	0.0371	66.0598	7.3908
22	P 177.434 - A	0.0231	123.3554	0.3410	127.3054	BDL	97.2785	0.0237	0.0298	77.4317	1.2244
23	Pb 220.353 - A	0.0050	0.0053	BDL	BDL	BDL	0.0157	BDL	BDL	0.0488	0.1655
24	S 181.975 - A	0.0148	12.0436	24.9593	12.5886	2.1913	296.6710	15.5522	31.4511	208.6119	432.4067
25	S 180.669 - A	0.0072	15.7086	25.3328	15.8372	2.2597	300.8076	15.5991	33.5216	216.2157	429.6920
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	0.0054	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	0.0449	0.0353	0.0728	BDL	0.1330	0.0088	BDL	0.0633	BDL
28	Si 251.611 - A	0.1031	1.1953	1.6102	1.8882	1.8421	4.4838	1.3790	0.8514	5.0282	6.6596
29	Sn 189.927 - A	0.0054	0.0218	0.0304	0.0134	0.0317	0.0866	0.0232	0.0142	0.0679	0.0752
30	Sr 460.733 - A	0.0003	0.0841	0.0139	0.1575	0.0021	1.2355	0.0138	0.0071	0.2484	0.2548
31	Ti 334.940 - A	0.0001	BDL	0.0075	BDL	0.0003	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	BDL	BDL	BDL	BDL	0.0093	BDL	BDL	0.0005	0.0234
34	Zn 213.857 - A	0.0023	0.7996	0.0112	0.7954	BDL	0.8201	BDL	0.0028	1.8517	4.7149
35	Zn 206.200 - A	0.0023	0.9383	0.0082	0.6627	BDL	0.6287	BDL	0.0049	1.7622	4.3512

ICP Raw Data 2/6/18

Date 2/20/2018
Method WaterCyclo Kalen
Client Rasmussen(25) Yida Fang(8) Kate

ID	Analyte Name	DL (mg/l)	WRU-1-020618	WRU4-020718	WRT-1-020618	WRS1-020718	WRU-2-020618	WRS2-020718	WRS2-020718	WRT2-020618	WRT-4-020718	WRU-6-020718	WRU-3-020618
			6	11	12	19	20	24	25	28	32	36	37
			302	482	518	770	806	950	986	1094	1238	1382	1418
0	Ar 420.069 - A	% Concentration	110	102	108	92	96	98	95	88	87	108	111
1	Sc 361.383 - R	% Concentration	108	107	109	112	117	123	117	102	92	106	113
2	Sc 357.253 - A	% Concentration	93	95	99	102	97	102	104	80	74	92	104
3	Al 396.153 - A	0.0011	25.2471	0.3808	138.9750	197.6866	0.4970	188.6085	178.2201	0.4073	3.3934	1.0051	20.0148
4	As 188.979 - A	0.0080	0.0491	0.0403	0.1863	0.2036	0.0170	0.2063	0.1982	0.0447	0.0940	0.0357	0.0378
5	B 249.677 - R	0.0161	0.6324	0.6272	0.1401	BDL	0.6104	0.0250	BDL	0.7210	1.1823	1.4960	0.6330
6	Ba 233.527 - A	0.0003	0.0865	0.1379	0.0335	0.0460	0.0233	0.0446	0.0434	0.1735	0.3042	0.0894	0.0954
7	Be 313.107 - R	0.0002	0.0030	BDL	0.0110	0.0149	BDL	0.0120	0.0126	0.0010	BDL	BDL	0.0010
8	Ca 317.933 - A	0.0254	129.2614	38.6471	337.7826	416.2713	14.8738	409.5453	407.3813	38.0275	163.7953	177.4005	122.3087
9	Cd 214.440 - A	0.0006	0.0193	BDL	0.0930	0.1154	BDL	0.1136	0.1121	BDL	BDL	BDL	0.0133
10	Cu 324.752 - A	0.0057	18.3561	0.1387	82.6597	117.6268	0.1174	109.6681	105.0625	0.3005	4.6891	0.3941	13.9554
11	Cr 205.560 - A	0.0007	0.0105	BDL	0.0711	0.1280	BDL	0.1154	0.1076	BDL	0.0052	BDL	0.0136
12	Fe 238.204 - A	0.0016	34.4061	0.2504	203.5044	240.9640	0.2806	262.3294	262.3390	0.2623	5.4656	0.2505	20.4096
13	K 766.490 - R	0.1081	2.5103	33.0536	4.8682	9.3625	6.9002	8.8195	8.6022	36.1031	265.2374	227.5746	30.7372
14	Li 670.784 - R	0.0049	0.0311	0.0225	0.0845	0.1080	0.0082	0.0840	0.0869	0.0546	0.0590	BDL	0.0126
15	Mg 285.213 - R	0.0044	22.8334	10.3330	63.0101	89.0887	7.4272	81.2636	82.1150	25.8952	35.3373	19.9680	20.5528
16	Mg 279.077 - R	0.0203	22.5464	11.5994	68.6851	91.4811	7.4181	81.8706	85.3458	25.2367	36.0079	21.0400	21.7007
17	Mn 257.610 - A	0.0002	5.9394	0.3725	18.3000	24.9959	0.1278	22.6161	22.4241	0.2425	1.5206	0.1116	4.1604
18	Mo 202.031 - A	0.0012	BDL	0.0058	BDL	BDL	0.0038	BDL	BDL	0.0282	0.0328	0.0081	BDL
19	Na 589.592 - R	0.0193	3.9528	802.4065	9.6522	39.9013	794.6722	44.7881	43.3582			441.4853	19.1247
20	Ni 231.604 - A	0.0015	0.1035	0.0051	0.3375	0.4296	BDL	0.4120	0.4065	0.0031	0.0240	0.0025	0.0722
21	P 213.617 - A	0.0128	4.4467	3.1161	19.5208	22.4530	0.0493	19.9001	19.4733	0.1406	37.9063	82.5677	3.7525
22	P 177.434 - A	0.0231	0.6224	3.9137	2.8895	3.2500	0.0287	2.8716	2.8037	0.1595	48.0643	100.4403	1.7322
23	Pb 220.353 - A	0.0050	0.0930	BDL	0.4123	0.5843	BDL	0.5211	0.5068	BDL	0.0264	BDL	0.0606
24	S 181.975 - A	0.0148	262.3550	342.9826	1066.8230	1386.9167	259.2434	1398.4933	1343.5749	989.9769	823.5693	125.5044	215.7713
25	S 180.669 - A	0.0072	261.4513	336.0700	912.5622	1137.5292	253.0812	1147.7602	1134.8955	884.7326	749.7243	132.3607	222.6106
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	BDL	0.1010	BDL	BDL	0.0543	BDL	BDL	0.1986	0.2102	0.0968	0.0134
28	Si 251.611 - A	0.1031	8.7230	2.6455	24.1336	34.4491	2.5482	32.8700	32.4905	7.6632	9.9268	3.4383	7.2215
29	Sn 189.927 - A	0.0054	0.0593	0.0451	0.1390	0.0372	0.0383	0.0246	0.0244	0.0464	0.0801	0.0419	0.0390
30	Sr 460.733 - A	0.0003	0.5582	0.2949	1.1758	1.4216	0.1379	1.4934	1.4141	0.5145	0.7755	0.1752	0.5832
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0094	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	0.0051	0.0038	0.0637	0.0900	BDL	0.1102	0.1082	0.0130	0.0200	BDL	0.0034
34	Zn 213.857 - A	0.0023	2.7030	0.0088	12.0077	14.5487	0.0105	14.7786	13.7060	0.0188	0.6188	0.5892	1.9846
35	Zn 206.200 - A	0.0023	2.5342	0.0138	11.2070	13.5961	0.0107	13.1405	12.8427	0.0152	0.5273	0.5909	1.8459

ICP Raw Data 2/13/18

Date 2/20/2018
Method WaterCyclo Kalen
Client Rasmussen(25) Yida Fang(8) Kate

ID	Analyte Name	DL (mg/l)	WRU-1-021318	WRU-4-021418	WRU-2-021318	WRU-6-021418	WRS-1-021418	WRU-2-013018	WRU-3-021318	WRS-2-021418
			9	10	17	18	23	29	30	31
			410	446	698	734	914	1130	1166	1202
0	Ar 420.069 - A	% Concentration	149	134	99	96	94	101	106	101
1	Sc 361.383 - R	% Concentration	109	113	120	115	109	116	119	107
2	Sc 357.253 - A	% Concentration	109	100	99	101	100	99	106	97
3	Al 396.153 - A	0.0011	23.6833	0.2935	0.2727	0.4092	158.9420	0.3025	9.3589	136.1778
4	As 188.979 - A	0.0080	0.0620	0.0308	BDL	0.0174	0.1826	0.0087	0.0372	0.1682
5	B 249.677 - R	0.0161	0.6239	0.5841	0.5540	0.5859	0.0473	0.5706	0.7441	0.1043
6	Ba 233.527 - A	0.0003	0.0727	0.1310	0.0312	0.0314	0.0312	0.0049	0.0444	0.0282
7	Be 313.107 - R	0.0002	0.0028	BDL	BDL	BDL	0.0139	BDL	0.0010	0.0105
8	Ca 317.933 - A	0.0254	109.1552	56.5074	12.4718	31.2645	388.8663	2.1823	93.3697	420.5631
9	Cd 214.440 - A	0.0006	0.0217	BDL	BDL	BDL	0.1096	BDL	0.0122	0.1026
10	Cu 324.752 - A	0.0057	17.5025	0.0239	0.0304	0.3424	106.2696	0.1226	9.3014	92.6723
11	Cr 205.560 - A	0.0007	0.0052	BDL	BDL	BDL	0.0343	BDL	0.0020	0.0190
12	Fe 238.204 - A	0.0016	48.2919	5.7411	0.0156	0.4159	222.2274	0.3478	28.7399	231.4370
13	K 766.490 - R	0.1081	3.0905	26.9093	5.7191	16.5045	13.3783	5.4930	16.9885	61.1089
14	Li 670.784 - R	0.0049	0.0221	0.0164	0.0070	0.0073	0.1150	BDL	0.0094	0.0958
15	Mg 285.213 - R	0.0044	16.8836	11.2656	4.8200	7.1907	88.7443	0.6827	13.2864	81.5386
16	Mg 279.077 - R	0.0203	19.4710	12.2690	4.8255	7.3307	92.8625	0.7122	13.9416	87.9246
17	Mn 257.610 - A	0.0002	5.6034	2.2478	0.1234	0.6357	25.5748	0.0245	5.7384	23.3847
18	Mo 202.031 - A	0.0012	BDL	0.0012	BDL	BDL	BDL	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	5.9490	564.5968	414.9294	331.3997	304.1140	646.1586	17.3761	337.0750
20	Ni 231.604 - A	0.0015	0.1001	0.0141	BDL	0.0070	0.4344	BDL	0.0709	0.3940
21	P 213.617 - A	0.0128	5.1216	0.4958	0.0731	0.6960	19.8567	0.0469	2.1205	18.5426
22	P 177.434 - A	0.0231	0.7587	0.6263	0.0844	0.7871	2.5974	0.0237	0.7248	4.3369
23	Pb 220.353 - A	0.0050	0.0931	BDL	BDL	BDL	0.5149	BDL	0.0427	0.4231
24	S 181.975 - A	0.0148	258.7003	417.6017	279.7149	211.7812	1322.0351	15.5522	156.9932	1342.0394
25	S 180.669 - A	0.0072	259.9225	409.7337	260.7147	210.3770	1147.6201	15.5991	162.6233	1147.5645
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	0.0054	BDL	BDL
27	Se 196.026 - A	0.0082	BDL	0.0435	0.0479	0.0244	BDL	0.0088	BDL	BDL
28	Si 251.611 - A	0.1031	8.3904	3.5798	2.2927	2.6668	36.7403	1.3790	5.5076	32.6958
29	Sn 189.927 - A	0.0054	0.0798	0.0517	0.0246	0.0343	0.0427	0.0232	0.0372	0.0431
30	Sr 460.733 - A	0.0003	0.3529	0.2862	0.1169	0.1841	1.4172	0.0138	0.3815	1.3355
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	0.0076	BDL	BDL	BDL	0.0816	BDL	0.0063	0.1004
34	Zn 213.857 - A	0.0023	2.6183	0.0269	0.0140	0.1136	14.4389	BDL	1.6152	14.0822
35	Zn 206.200 - A	0.0023	2.8309	0.0351	0.0144	0.1141	12.9871	BDL	1.5150	12.7560

ICP Raw Data 2/20/18

Date 4/15/2018

Method WaterCyclo

Client

Solfatara(41)

			32	33	34	35	36	40	41	42	43	44	45
			1238	1274	1310	1346	1382	1526	1562	1598	1634	1670	1706
ID	Analyte Name	DL (mg/l)	WRU-1-022018	WRU-2-022018	WRU-3-022018	022118-WRU-4	022118-WRU-6	WRT-1-022018	WRT-2-022018	WRT-3-022018	WRT-4-022118	022118-WRS-1	022118-WRS-2
0	Ar 420.069 - A	% Concentration	103	104	103	97	100	99	97	98	103	97	88
1	Sc 361.383 - R	% Concentration	101	101	101	100	99	99	92	94	91	91	85
2	Sc 357.253 - A	% Concentration	105	97	100	98	98	102	84	95	85	93	88
3	Al 396.153 - A	0.0011	23.8775	0.3499	6.9535	0.3576	0.4154	72.4901	0.4514	53.4097	0.5832	115.8432	73.2657
4	As 188.979 - A	0.0080	0.0716	0.0107	0.0224	0.0209	0.0142	0.0862	0.0218	0.0791	0.0536	0.1430	0.1372
5	B 249.677 - R	0.0161	0.8186	0.7611	0.7841	0.7850	0.7617	0.4492	0.8156	0.3804	1.0658	BDL	BDL
6	Ba 233.527 - A	0.0003	0.0611	0.0301	0.0440	0.0807	0.0358	0.0194	0.0960	0.0535	0.0970	0.0180	0.0220
7	Be 313.107 - R	0.0002	0.0030	BDL	0.0010	BDL	BDL	0.0078	BDL	0.0051	BDL	0.0096	0.0058
8	Ca 317.933 - A	0.0254	92.5026	23.2378	80.0707	47.4003	36.1897	230.3446	55.8347	275.7638	130.1590	411.4857	443.0369
9	Cd 214.440 - A	0.0006	0.0218	BDL	0.0147	0.0008	0.0018	0.0551	BDL	0.0541	0.0032	0.1274	0.1241
10	Cu 324.752 - A	0.0057	18.0990	0.0796	6.9866	BDL	0.6073	47.1969	0.0986	40.3554	0.0139	92.5225	60.2538
11	Cr 205.560 - A	0.0007	0.0158	BDL	0.0043	BDL	BDL	0.0385	BDL	0.0274	0.0008	0.0240	0.0125
12	Fe 238.204 - A	0.0016	54.6673	0.0194	43.2745	5.1934	0.2186	112.0061	0.0711	119.0038	39.8345	216.8859	236.8963
13	K 766.490 - R	0.1081	1.6278	2.2415	10.2842	10.3912	8.3585	2.0935	6.4051	47.8352	60.0498	6.5832	107.1063
14	Li 670.784 - R	0.0049	0.0148	BDL	0.0073	BDL	BDL	0.0374	0.0072	0.0322	0.0097	0.0766	0.0656
15	Mg 285.213 - R	0.0044	14.1697	6.0157	10.4216	7.8916	7.2859	45.4047	20.1538	45.3844	32.2036	93.3071	92.7543
16	Mg 279.077 - R	0.0203	14.2236	5.9282	10.2949	7.6951	7.2092	44.1634	19.3396	45.4940	31.5580	93.2367	95.3093
17	Mn 257.610 - A	0.0002	5.2540	0.3302	5.9446	3.2642	0.9451	13.1390	0.3583	15.9858	5.0182	27.1547	23.7332
18	Mo 202.031 - A	0.0012	BDL	0.0018	BDL	BDL	BDL	BDL	0.0158	BDL	0.0126	BDL	BDL
19	Na 589.592 - R	0.0193	2.5756	317.8669	4.8913	263.4715	223.7960	14.9804	1482.6372	29.7349	1323.0016	423.1942	452.7096
20	Ni 231.604 - A	0.0015	0.0857	0.0018	0.0682	0.0205	0.0102	0.2052	0.0021	0.2157	0.0211	0.4433	0.4034
21	P 213.617 - A	0.0128	2.2914	0.0129	1.2439	0.1042	0.1812	5.5405	0.0210	6.0281	1.2032	10.9335	12.0833
22	P 177.434 - A	0.0231	0.2349	BDL	0.5608	0.1008	0.0941	0.3970	BDL	2.1564	1.4027	0.7429	7.0765
23	Pb 220.353 - A	0.0050	0.0691	BDL	0.0305	BDL	BDL	0.1689	BDL	0.1437	BDL	0.3294	0.2272
24	S 181.975 - A	0.0148	246.0338	307.2947	140.8553	272.1809	225.2931	592.0250	1003.5100	583.8710	955.5259	1383.4424	1384.4238
25	S 180.669 - A	0.0072	244.3672	302.9930	143.7750	256.4903	226.0691	558.5979	889.1522	551.2035	839.3266	1165.5596	1168.6952
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	BDL	0.0528	BDL	BDL	0.0203	BDL	0.2314	BDL	0.0284	BDL	BDL
28	Si 251.611 - A	0.1031	10.7160	4.1446	6.9792	4.2096	3.9829	23.7852	9.2322	19.7532	9.9425	37.2824	36.2935
29	Sn 189.927 - A	0.0054	0.0900	0.0566	0.0613	0.0565	0.0579	0.0852	0.0370	0.0652	0.0343	0.0532	0.0588
30	Sr 460.733 - A	0.0003	0.2619	0.1359	0.2637	0.2106	0.1838	0.6031	0.3261	0.8478	0.6833	1.5221	1.4915
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	0.0019	BDL	0.0059	BDL	BDL	0.0192	BDL	0.0341	0.0019	0.0231	0.0459
34	Zn 213.857 - A	0.0023	2.4635	0.0732	1.4675	0.0667	0.2354	6.7310	0.0372	6.4381	0.0426	15.1193	14.6537
35	Zn 206.200 - A	0.0023	2.4030	0.0666	1.4626	0.0576	0.2384	6.4774	0.0252	6.0465	0.0254	14.7737	14.0714

ICP Raw Data 3/7/18

Date 4/15/2018

Method WaterCyclo

Client

Solfatara(41)

ID	Analyte Name	DL (mg/l)	030618-WRU-1	030618-WRU-2	030618-WRU-3	030718-WRU-4	030718-WRU-6	030618-WRT-1	030618-WRT-2	030618-WRT-3	030718-WRT-4	030718-WR5-1	030718-WR5-2	030618-WRU-2	030618-WRU-3a
			3	4	5	6	7	8	9	10	11	12	15	17	18
			194	230	266	302	338	374	410	446	482	518	626	698	734
0	Ar 420.069 - A	% Concentration	97	102	107	92	106	101	102	102	98	99	89	112	110
1	Sc 361.383 - R	% Concentration	96	97	100	98	94	98	91	95	93	88	88	97	100
2	Sc 357.253 - A	% Concentration	98	92	98	93	94	98	86	94	89	89	86	101	104
3	Al 396.153 - A	0.0011	32.2455	0.3010	4.0312	0.2815	0.3707	61.5784	0.4657	29.1373	0.3758	69.0134	11.5258	0.2648	3.4632
4	As 188.979 - A	0.0080	0.1245	0.0107	0.0253	0.0133	0.0164	0.0667	0.0234	0.0753	0.0560	0.1281	0.1379	0.0118	0.0334
5	B 249.677 - R	0.0161	0.4017	0.6909	0.4550	0.6031	0.7268	0.4168	0.8551	0.3247	0.6224	BDL	BDL	0.7735	0.2977
6	Ba 233.527 - A	0.0003	0.0369	0.0175	0.0264	0.0540	0.0352	0.0181	0.0475	0.0411	0.0413	0.0137	0.0245	0.0241	0.0236
7	Be 313.107 - R	0.0002	0.0035	BDL	0.0005	BDL	BDL	0.0059	BDL	0.0027	BDL	0.0060	0.0013	BDL	0.0003
8	Ca 317.933 - A	0.0254	96.6887	45.7806	65.0181	56.6173	59.0499	215.0129	85.2529	230.0997	143.1825	411.2546	484.0356	46.0932	55.5187
9	Cd 214.440 - A	0.0006	0.0284	0.0010	0.0172	0.0011	0.0016	0.0464	BDL	0.0551	0.0066	0.1263	0.1109	0.0017	0.0174
10	Cu 324.752 - A	0.0057	22.0806	0.1324	2.3246	BDL	0.6202	41.0557	0.0539	16.7164	BDL	61.3945	3.9887	0.1479	1.8376
11	Cr 205.560 - A	0.0007	0.0160	0.0007	BDL	BDL	BDL	0.0274	0.0011	0.0018	BDL	BDL	BDL	BDL	BDL
12	Fe 238.204 - A	0.0016	103.0263	0.0141	95.1311	17.2386	1.0701	111.9666	0.0483	179.6701	72.2887	217.0389	359.3693	0.0251	118.8469
13	K 766.490 - R	0.1081	1.5979	2.4426	7.7656	9.5683	7.3456	1.9583	5.2390	33.0556	40.5669	7.6971	178.1508	2.1463	5.9063
14	Li 670.784 - R	0.0049	0.0231	BDL	0.0071	BDL	BDL	0.0401	0.0053	0.0285	0.0082	0.0901	0.0633	BDL	BDL
15	Mg 285.213 - R	0.0044	14.5055	8.3653	8.1797	8.0116	9.2428	38.4644	18.4488	36.8806	29.1551	93.3548	98.5474	6.2684	6.6647
16	Mg 279.077 - R	0.0203	14.3475	7.9980	7.8285	7.6502	9.3092	37.6128	18.5851	36.1355	28.9172	94.5851	102.7936	6.4890	6.9212
17	Mn 257.610 - A	0.0002	5.7225	0.9811	4.7203	4.1076	2.6293	9.7093	0.5682	11.8902	7.4002	27.3980	26.0401	0.8859	3.4497
18	Mo 202.031 - A	0.0012	BDL	BDL	BDL	BDL	BDL	BDL	0.0106	BDL	BDL	BDL	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	2.2440	327.1169	5.0897	285.8937	273.8335	21.0340	1145.8027	38.1607	1094.9008	727.1733	663.8811	227.4993	4.2940
20	Ni 231.604 - A	0.0015	0.0899	0.0091	0.0549	0.0081	0.0202	0.1558	0.0036	0.1574	0.0045	0.4368	0.3933	0.0084	0.0471
21	P 213.617 - A	0.0128	2.7519	BDL	0.2264	BDL	0.0720	5.3309	BDL	2.0390	BDL	7.0931	5.0920	BDL	BDL
22	P 177.434 - A	0.0231	0.3971	BDL	0.1769	BDL	BDL	0.3879	BDL	0.6951	0.1028	0.5297	7.0994	BDL	BDL
23	Pb 220.353 - A	0.0050	0.0945	0.0055	0.0314	BDL	0.0070	0.1649	0.0066	0.0814	0.0093	0.2497	0.0743	BDL	0.0306
24	S 181.975 - A	0.0148	337.0480	299.0117	149.7231	273.7586	267.3204	533.1322	910.8618	522.7798	847.7758	1413.1081	1535.9264	240.2947	174.6432
25	S 180.669 - A	0.0072	327.1246	279.0145	151.1896	269.6369	264.8068	506.2236	810.0287	499.0191	757.2662	1169.3992	1269.1908	240.0472	176.2027
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	BDL	0.0406	BDL	BDL	0.0146	BDL	0.2411	BDL	BDL	BDL	BDL	0.0307	BDL
28	Si 251.611 - A	0.1031	12.9542	4.1916	7.2116	4.3995	4.5929	23.9746	10.5328	20.1072	10.6861	34.0765	36.2263	4.2822	5.5522
29	Sn 189.927 - A	0.0054	0.0865	0.0313	0.0371	0.0357	0.0577	0.0912	0.0280	0.0519	0.0214	0.0519	0.0535	0.0435	0.0425
30	Sr 460.733 - A	0.0003	0.2743	0.2012	0.1820	0.1920	0.2419	0.5080	0.3289	0.5573	0.5816	1.5488	1.5554	0.1262	0.1098
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	0.0104	BDL	0.0105	0.0009	BDL	0.0239	BDL	0.0289	0.0040	0.0193	0.0596	BDL	0.0071
34	Zn 213.857 - A	0.0023	2.6855	0.1966	1.2000	0.0196	0.3354	5.3098	0.0454	5.0101	0.0305	14.7160	9.9842	0.1908	0.9889
35	Zn 206.200 - A	0.0023	2.5329	0.1911	1.1778	0.0123	0.3383	5.1784	0.0358	4.8419	0.0133	14.4120	9.7095	0.1963	0.9972

ICP Raw Data 3/20/18

Date 4/15/2018

Method WaterCyclo

Client Solfatara(41)

ID	Analyte Name	DL (mg/l)	032018-WRU-1	032118-WRU-4	032118-WRU-6	032018-WRT-1a	032018-WRT-2	032018-WRT-3	032118-WRT-4	032118-WR5-1a	032118-WR5-2	032018-WRU-3b	032018-WRT-1b	032118-WR5-1b
			16	19	20	21	22	23	24	27	28	29	30	31
			662	770	806	842	878	914	950	1058	1094	1130	1166	1202
0	Ar 420.069 - A	% Concentration	109	111	106	108	98	92	96	96	88	103	101	102
1	Sc 361.383 - R	% Concentration	103	95	93	98	96	96	96	88	85	102	99	87
2	Sc 357.253 - A	% Concentration	106	98	98	102	92	97	90	86	85	106	100	88
3	Al 396.153 - A	0.0011	28.8173	0.2535	1.1026	49.2212	0.2534	14.0514	0.2359	42.1843	5.7772	3.5104	46.6549	39.8889
4	As 188.979 - A	0.0080	0.1308	0.0213	0.0186	0.0729	0.0154	0.0610	0.0489	0.1121	0.1269	0.0353	0.0646	0.1103
5	B 249.677 - R	0.0161	0.2298	0.5513	0.5179	0.3555	0.6027	0.0676	0.0950	0.3540	BDL	0.2586	0.2130	BDL
6	Ba 233.527 - A	0.0003	0.0311	0.0568	0.0351	0.0163	0.0295	0.0303	0.0248	0.0170	0.0317	0.0226	0.0153	0.0145
7	Be 313.107 - R	0.0002	0.0028	BDL	BDL	0.0047	BDL	0.0012	BDL	0.0039	0.0004	0.0004	0.0046	0.0039
8	Ca 317.933 - A	0.0254	87.5070	50.7384	66.8323	217.0311	87.0316	175.8229	136.4067	396.3287	461.8392	54.1754	208.0440	398.2057
9	Cd 214.440 - A	0.0006	0.0267	0.0041	0.0045	0.0430	BDL	0.0421	0.0181	0.1205	0.1147	0.0171	0.0420	0.1193
10	Cu 324.752 - A	0.0057	17.6865	BDL	2.1706	35.0605	0.0239	4.6362	BDL	40.2135	BDL	1.8594	34.8576	37.4335
11	Cr 205.560 - A	0.0007	0.0123	BDL	BDL	0.0178	BDL	BDL	BDL	BDL	BDL	BDL	0.0178	BDL
12	Fe 238.204 - A	0.0016	112.9540	46.6336	3.2648	119.3546	0.0143	174.0072	156.8120	188.9208	419.3678	116.0059	115.0290	189.6297
13	K 766.490 - R	0.1081	1.3002	10.6681	5.4613	1.8785	3.5508	18.8062	41.8342	8.0982	162.4514	5.7570	1.7955	7.9665
14	Li 670.784 - R	0.0049	0.0158	BDL	BDL	0.0297	BDL	0.0155	BDL	0.0797	0.0489	BDL	0.0285	0.0765
15	Mg 285.213 - R	0.0044	12.8016	6.5168	8.8793	33.9778	14.2717	26.7391	24.4636	91.0097	99.7796	6.6692	33.9849	89.0707
16	Mg 279.077 - R	0.0203	12.7909	6.9033	9.7907	35.4545	13.9215	26.6329	23.3268	92.3897	105.1625	6.7727	33.7568	93.0718
17	Mn 257.610 - A	0.0002	4.2378	3.5956	3.3809	7.7216	0.4725	7.6778	5.7301	26.4018	25.8883	3.4395	7.6130	26.3054
18	Mo 202.031 - A	0.0012	BDL	BDL	BDL	BDL	0.0047	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	1.8470	219.5811	197.8153	19.6380	706.0470	29.8558	747.1708	721.1697	661.2029	4.0902	18.1062	708.2625
20	Ni 231.604 - A	0.0015	0.0758	0.0047	0.0305	0.1290	0.0018	0.1026	BDL	0.4371	0.2567	0.0448	0.1251	0.4321
21	P 213.617 - A	0.0128	2.2902	BDL	0.2883	4.4189	BDL	0.2191	BDL	4.0437	1.2976	BDL	4.1647	3.8843
22	P 177.434 - A	0.0231	0.3535	BDL	BDL	0.3073	BDL	0.3398	BDL	0.2511	4.4626	0.0399	0.3285	0.2290
23	Pb 220.353 - A	0.0050	0.0790	0.0104	0.0129	0.1372	BDL	0.0375	0.0198	0.1601	0.0901	0.0314	0.1333	0.1563
24	S 181.975 - A	0.0148	324.0139	281.3255	268.2222	504.1695	664.7966	409.4912	846.8392	1416.1743	1448.7606	169.3115	498.6234	1399.5378
25	S 180.669 - A	0.0072	318.3762	278.3372	267.0198	484.7855	622.1367	397.3649	745.3514	1188.4256	1195.2684	171.3879	477.7297	1184.7562
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	BDL	BDL	0.0126	BDL	0.1776	BDL	BDL	BDL	BDL	BDL	BDL	BDL
28	Si 251.611 - A	0.1031	12.4956	4.4324	4.8921	24.7385	9.4963	16.1414	9.7271	31.6000	31.3106	5.6674	23.8572	30.3105
29	Sn 189.927 - A	0.0054	0.0840	0.0470	0.0567	0.0765	0.0242	0.0503	0.0249	0.0620	0.0264	0.0378	0.0669	0.0534
30	Sr 460.733 - A	0.0003	0.2002	0.1239	0.2038	0.4246	0.2477	0.3578	0.4226	1.4933	1.4580	0.1115	0.4073	1.3773
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	0.0113	0.0016	BDL	0.0187	BDL	0.0186	0.0075	0.0099	0.0675	0.0064	0.0171	0.0082
34	Zn 213.857 - A	0.0023	2.1912	0.0227	0.5923	4.4118	0.0304	3.4146	0.0420	14.0290	0.3681	0.9652	4.3395	13.9665
35	Zn 206.200 - A	0.0023	2.2129	0.0127	0.5962	4.3838	0.0217	3.2713	0.0109	13.9052	0.2015	0.9606	4.1490	13.6511

ICP Raw Data 4/4/18

Date	**4/26/2018**	start cell	elements	
Method	**WaterCyclo**	86	36	
Client				
	Tom Clark(28)	0	1	2
		86	122	158

ID	Analyte Name	DL (mg/l)	CCV Metals	CCV Nonmetal	1643f	040318-WRU-1	040318-WRU-2	040318-WRU-3	040318-WRU-4	040318-WRT-1	040318-WRT-2	040318-WRT-3	040418-WRT-4	040418-WRS-1
			3	4	5	6	7	8	9	10	11			
			194	230	266	302	338	374	410	446	482			
0	Ar 420.069 - A	% Concentration	97	94	97	85	88	92	94	85	92	82	90	85
1	Sc 361.383 - R	% Concentration	95	99	99	95	92	98	93	94	96	93	94	88
2	Sc 357.253 - A	% Concentration	91	96	96	97	93	95	89	88	86	92	87	79
3	Al 396.153 - A	0.0011	19.8761	0.0324	0.1286	35.7730	0.2643	2.4794	0.2260	48.2181	0.3505	3.6064	0.2466	44.7892
4	As 188.979 - A	0.0080	19.3695	0.0220	0.0608	0.1757	0.0125	0.0240	0.0173	0.0604	0.0175	0.0491	0.0335	0.1095
5	B 249.677 - R	0.0161	18.8282	0.1891	0.2178	0.2150	0.7016	0.2560	0.4864	0.2228	0.7068	0.2050	0.2695	0.0632
6	Ba 233.527 - A	0.0003	9.3536	0.0007	0.4927	0.0290	0.0233	0.0202	0.0413	0.0157	0.0228	0.0277	0.0163	0.0132
7	Be 313.107 - R	0.0002	9.7528	BDL	0.0128	0.0032	BDL	0.0002	BDL	0.0042	BDL	0.0004	BDL	0.0044
8	Ca 317.933 - A	0.0254	18.6775	0.0369	27.3908	79.6855	40.6480	45.2960	43.0119	199.2804	78.0380	138.6985	114.0236	373.9521
9	Cd 214.440 - A	0.0006	9.2698	BDL	0.0055	0.0297	0.0010	0.0124	0.0038	0.0336	BDL	0.0243	0.0087	0.1043
10	Cu 324.752 - A	0.0057	19.2352	0.0147	0.0273	21.1984	0.1957	1.0668	BDL	38.3835	0.0554	BDL	BDL	39.2891
11	Cr 205.560 - A	0.0007	5.0117	0.0011	0.0187	0.0121	BDL	BDL	BDL	0.0123	BDL	BDL	BDL	BDL
12	Fe 238.204 - A	0.0016	18.9272	0.0102	0.0831	155.8261	0.0221	128.5190	56.4329	120.0306	0.0173	191.5049	107.3532	179.2791
13	K 766.490 - R	0.1081	49.6444	BDL	1.9313	1.1253	1.9505	4.9287	10.8266	2.1056	3.0972	15.7397	42.1700	9.6149
14	Li 670.784 - R	0.0049	18.9236	BDL	0.0161	0.0280	BDL	BDL	BDL	0.0377	BDL	0.0151	0.0057	0.0959
15	Mg 285.213 - R	0.0044	19.2103	0.0074	6.9797	15.4589	5.1135	5.4500	5.0721	31.7083	11.4004	21.8376	18.9899	86.2216
16	Mg 279.077 - R	0.0203	19.5608	BDL	7.0661	16.0288	5.2574	5.5177	5.2181	32.3171	11.2153	22.1610	18.8303	86.2207
17	Mn 257.610 - A	0.0002	9.5607	BDL	0.0341	3.7404	0.7120	2.5216	2.7516	5.5630	0.3516	5.3737	3.1882	24.0322
18	Mo 202.031 - A	0.0012	18.9641	0.9470	0.1139	BDL	0.0016	BDL	BDL	BDL	0.0048	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	0.1171	82.3439	18.0995	2.0002	194.2142	4.2355	195.1565	22.9639	527.2941	32.2175	572.8497	860.6332
20	Ni 231.604 - A	0.0015	19.8666	BDL	0.0580	0.0762	0.0068	0.0289	0.0025	0.1060	0.0016	0.0659	BDL	0.4034
21	P 213.617 - A	0.0128	46.1986	BDL	BDL	2.7685	0.0161	BDL	BDL	4.9897	BDL	BDL	BDL	4.3962
22	P 177.434 - A	0.0231	48.2541	BDL	BDL	0.5350	BDL	BDL	BDL	0.4392	BDL	0.3333	BDL	0.3301
23	Pb 220.353 - A	0.0050	18.5641	BDL	0.0202	0.0984	BDL	0.0304	0.0111	0.1510	BDL	0.0303	0.0166	0.1595
24	S 181.975 - A	0.0148	0.1510	51.4093	0.0301	405.0906	193.8024	170.5834	259.7723	516.4214	471.9280	356.5557	676.9981	1431.6180
25	S 180.669 - A	0.0072	0.7869	52.0890	0.7333	388.1206	192.4029	170.8987	255.0794	490.1495	451.2935	346.5735	622.6076	1200.1765
26	Sb 217.582 - A	0.0037	BDL	BDL	0.0484	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	20.0420	BDL	0.0157	BDL	0.0316	BDL	BDL	BDL	0.1631	BDL	BDL	BDL
28	Si 251.611 - A	0.1031	0.3138	45.2741	BDL	14.7767	4.2670	4.5386	3.7780	24.9238	10.0648	15.3443	7.4288	33.0467
29	Sn 189.927 - A	0.0054	BDL	0.9961	BDL	0.1882	0.0394	0.0343	0.0720	0.3021	0.0339	0.0314	0.0270	0.0631
30	Sr 460.733 - A	0.0003	26.0641	1.4538	0.4015	0.2273	0.1237	0.0920	0.1139	0.4316	0.2023	0.2890	0.3123	1.5691
31	Ti 334.940 - A	0.0001	0.0038	0.9449	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	18.3035	BDL	0.0143	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	9.4053	BDL	0.0329	0.0247	BDL	0.0133	0.0051	0.0280	BDL	0.0257	0.0114	0.0207
34	Zn 213.857 - A	0.0023	9.6001	0.0051	0.0801	2.3935	0.1690	0.1905	0.0331	3.6974	0.0169	1.6595	0.0273	13.4145
35	Zn 206.200 - A	0.0023	9.3972	0.0033	0.0709	2.1461	0.1593	0.1644	0.0206	3.2226	0.0105	1.5006	0.0060	12.3284

ICP Raw Data 4/17/18

Date	**4/26/2018**	start cell	elements	
Method	**WaterCyclo**	86	36	
Client				
	Tom Clark(28)	0	1	2
		86	122	158

ID	Analyte Name	DL (mg/l)	CCV Metals	CCV Nonmetal	1643f	040318-WRU-1	0418-WRU	0417-WRU-3a	0417-WRU-3b	0418-WRU-4a	0418-WRU-4b	418-WRU-6	0417-WRU-1a	417-WRU-1	0417-WRU-2
0	Ar 420.069 - A	% Concentration	97	94	97	85	84	93	98	90	92	86	88	88	94
1	Sc 361.383 - R	% Concentration	95	99	99	95	93	100	114	96	95	93	94	97	100
2	Sc 357.253 - A	% Concentration	91	96	96	97	94	98	99	94	93	91	96	97	93
3	Al 396.153 - A	0.0011	19.8761	0.0324	0.1286	35.7730	9.0763	3.6339	3.6219	0.2891	0.2013	25.1793	33.3674	31.4956	0.2766
4	As 188.979 - A	0.0080	19.3695	0.0220	0.0608	0.1757	0.0160	0.0281	0.0338	0.0115	0.0118	0.0952	0.1735	0.1698	BDL
5	B 249.677 - R	0.0161	18.8282	0.1891	0.2178	0.2150	0.5761	0.3553	0.3113	0.6029	0.4777	0.3308	0.1906	0.0490	0.6193
6	Ba 233.527 - A	0.0003	9.3536	0.0007	0.4927	0.0290	0.0228	0.0218	0.0228	0.0406	0.0388	0.0146	0.0242	0.0229	0.0235
7	Be 313.107 - R	0.0002	9.7528	BDL	0.0128	0.0032	0.0004	0.0003	0.0006	BDL	BDL	0.0017	0.0024	0.0024	BDL
8	Ca 317.933 - A	0.0254	18.6775	0.0369	27.3908	79.6855	67.0433	38.1200	38.6660	37.2972	37.6669	89.0500	67.8363	66.7463	32.2548
9	Cd 214.440 - A	0.0006	9.2698	BDL	0.0055	0.0297	0.0096	0.0112	0.0113	0.0032	0.0030	0.0270	0.0279	0.0277	0.0007
10	Cu 324.752 - A	0.0057	19.2352	0.0147	0.0273	21.1984	7.0402	1.7503	1.7289	BDL	BDL	17.8297	19.7088	19.3867	0.1492
11	Cr 205.560 - A	0.0007	5.0117	0.0011	0.0187	0.0121	0.0052	BDL	BDL	BDL	BDL	0.0106	0.0112	0.0113	BDL
12	Fe 238.204 - A	0.0016	18.9272	0.0102	0.0831	155.8261	12.8978	113.2325	116.2132	43.0444	43.2383	101.3149	158.0661	156.0307	0.0197
13	K 766.490 - R	0.1081	49.6444	BDL	1.9313	1.1253	3.7999	3.5548	3.3435	8.2343	8.2455	2.6383	0.8115	0.7758	1.4504
14	Li 670.784 - R	0.0049	18.9236	BDL	0.0161	0.0280	0.0064	BDL	BDL	BDL	BDL	0.0120	0.0244	0.0226	BDL
15	Mg 285.213 - R	0.0044	19.2103	0.0074	6.9797	15.4589	8.4011	4.6160	4.4809	3.7454	3.7554	10.2629	14.6271	14.5433	3.4450
16	Mg 279.077 - R	0.0203	19.5608	BDL	7.0661	16.0288	8.5575	4.6199	5.2908	3.7676	3.8060	10.4111	15.1809	14.7463	3.3863
17	Mn 257.610 - A	0.0002	9.5607	BDL	0.0341	3.7404	3.4433	1.9048	1.9194	1.8588	1.8626	4.7236	2.7263	2.7278	0.4925
18	Mo 202.031 - A	0.0012	18.9641	0.9470	0.1139	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Na 589.592 - R	0.0193	0.1171	82.3439	18.0995	2.0002	170.2193	3.8297	3.4337	148.3635	147.1527	147.0275	1.8197	1.7295	123.2643
20	Ni 231.604 - A	0.0015	19.8666	BDL	0.0580	0.0762	0.0435	0.0182	0.0184	0.0025	0.0026	0.0918	0.0690	0.0673	0.0029
21	P 213.617 - A	0.0128	46.1986	BDL	BDL	2.7685	0.9315	BDL	BDL	BDL	BDL	2.3385	2.3792	2.3515	0.0136
22	P 177.434 - A	0.0231	48.2541	BDL	BDL	0.5350	0.0500	0.0464	0.0319	BDL	BDL	0.4777	0.5286	0.5092	BDL
23	Pb 220.353 - A	0.0050	18.5641	BDL	0.0202	0.0984	0.0300	0.0280	0.0284	0.0078	0.0063	0.0823	0.0817	0.0832	BDL
24	S 181.975 - A	0.0148	0.1510	51.4093	0.0301	405.0906	264.9754	162.1701	159.7368	206.4131	210.4610	419.9884	388.6247	382.5394	140.2499
25	S 180.669 - A	0.0072	0.7869	52.0890	0.7333	388.1206	260.7506	162.6980	160.6344	205.7109	209.0407	403.1277	372.6284	366.9958	140.5678
26	Sb 217.582 - A	0.0037	BDL	BDL	0.0484	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	20.0420	BDL	0.0157	BDL	0.0087	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0265
28	Si 251.611 - A	0.1031	0.3138	45.2741	BDL	14.7767	6.4944	4.4721	4.3902	3.6078	3.5334	11.8875	14.7736	14.4238	3.9606
29	Sn 189.927 - A	0.0054	BDL	0.9961	BDL	0.1882	0.0866	0.0402	0.0419	0.0275	0.0313	0.0498	0.0709	0.0665	0.0399
30	Sr 460.733 - A	0.0003	26.0641	1.4538	0.4015	0.2273	0.1919	0.0773	0.0731	0.0832	0.0893	0.2391	0.2053	0.2027	0.0776
31	Ti 334.940 - A	0.0001	0.0038	0.9449	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	18.3035	BDL	0.0143	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	9.4053	BDL	0.0329	0.0247	BDL	0.0110	0.0114	0.0032	0.0032	0.0121	0.0243	0.0241	BDL
34	Zn 213.857 - A	0.0023	9.6001	0.0051	0.0801	2.3935	1.1265	0.2312	0.2305	0.0383	0.0386	2.5306	2.0978	2.0739	0.1244
35	Zn 206.200 - A	0.0023	9.3972	0.0033	0.0709	2.1461	1.0081	0.2047	0.2036	0.0272	0.0270	2.2051	1.8566	1.8404	0.1074

Date 6/5/2018
Method WaterCyclo
Client Tom Clark (12)

			2	3	4	5	6	7	8	9	10	11	14	15
			158	194	230	266	302	338	374	410	446	482	590	626
ID	Analyte Name	DL (mg/l)	0524-BC20	0524-B21	0524-B24	0524-B25	0524-B27	0524-B28	0524-B30	0524-B31	0524-B32	0524-B35	0524-B36	0524-B39
0	Ar 420.069 - A	% Concentration	89	88	93	90	88	89	82	86	87	88	96	92
1	Sc 361.383 - R	% Concentration	96	88	90	95	92	90	95	92	94	91	87	92
2	Sc 357.253 - A	% Concentration	88	83	83	83	85	82	86	86	83	84	83	83
3	Al 396.153 - A	0.0011	8.8351	0.4631	0.7313	0.4386	0.3032	0.5973	0.3721	0.3325	0.3676	0.4230	0.3035	0.4438
4	As 188.979 - A	0.0080	0.0359	0.0469	0.0496	0.0425	0.0417	0.0473	0.0446	0.0553	0.0567	0.0513	0.0479	0.0469
5	B 249.677 - R	0.0161	0.6676	0.8729	0.9630	1.0053	0.8367	0.9279	0.7257	0.7384	0.8809	0.7412	0.6915	0.7629
6	Ba 233.527 - A	0.0003	0.0276	0.1946	0.1803	0.1671	0.1341	0.2389	0.1958	0.0662	0.1540	0.2571	0.2378	0.2045
7	Be 313.107 - R	0.0002	0.0003	BDL	0.0003	0.0003	BDL	BDL	BDL	0.0002	BDL	BDL	0.0003	0.0002
8	Ca 317.933 - A	0.0254	381.9644	493.9464	489.3671	506.0626	442.2581	520.7584	504.9959	488.0300	499.9705	525.8545	523.1479	466.9690
9	Cd 214.440 - A	0.0006	0.0401	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
10	Cu 324.752 - A	0.0057	1.9453	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0062
11	Cr 205.560 - A	0.0007	0.0013	0.0018	0.0026	0.0018	0.0012	0.0026	0.0020	0.0014	0.0016	0.0023	0.0019	0.0023
12	Fe 238.204 - A	0.0016	3.1823	0.0552	1.9155	0.0676	0.0422	2.4102	1.6299	0.0461	0.0292	0.0992	0.0824	0.0667
13	K 766.490 - R	0.1081	21.8325	425.9495	337.8350	323.0649	194.5501	286.1399	182.0439	299.9361	276.5799	351.1144	307.7039	351.8727
14	Li 670.784 - R	0.0049	0.0215	0.0590	0.4504	0.0555	0.0450	0.4069	0.3392	0.0515	0.0468	0.2322	0.2334	0.1405
15	Mg 285.213 - R	0.0044	52.1023	165.2106	144.2053	157.6524	106.1267	134.1886	110.5283	127.6273	110.7597	167.9297	155.6007	142.1927
16	Mg 279.077 - R	0.0203	52.8799	172.2256	151.6595	161.3991	111.0672	142.4250	111.7929	131.6508	111.4832	177.8892	163.2735	145.1213
17	Mn 257.610 - A	0.0002	6.4485	5.8904	10.0041	5.7837	4.2096	10.2444	9.7929	5.2314	5.7527	7.6307	7.5338	5.3234
18	Mo 202.031 - A	0.0012	0.0038	0.0051	0.0041	0.0039	0.0035	0.0035	0.0029	0.0038	0.0040	0.0033	0.0078	0.0061
19	Na 589.592 - R	0.0193	143.9036	203.5147	186.0390	183.9053	154.3712	164.9886	154.0792	214.8114	209.9190	194.6833	192.5525	213.1570
20	Ni 231.604 - A	0.0015	0.0205	0.0058	0.0110	0.0051	0.0042	0.0143	0.0090	0.0034	0.0035	0.0083	0.0094	0.0080
21	P 213.617 - A	0.0128	0.2265	7.2499	10.6731	6.2212	4.3698	9.1229	5.5957	3.1448	2.6497	7.9980	6.6085	6.4215
22	P 177.434 - A	0.0231	BDL	8.2860	12.1686	6.7826	4.7942	10.4786	6.0569	3.4026	2.9142	9.1463	7.6394	6.8793
23	Pb 220.353 - A	0.0050	0.0162	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
24	S 181.975 - A	0.0148	647.9833	369.3541	567.4921	362.4807	793.6921	600.7429	578.6056	1282.2149	1880.3982	428.5793	620.4675	537.4928
25	S 180.669 - A	0.0072	616.1115	372.6119	551.1627	366.3585	713.6108	582.6268	559.3735	1102.2700	1508.1150	426.7638	596.8158	522.5814
26	Sb 217.582 - A	0.0037	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Se 196.026 - A	0.0082	0.0084	0.0140	0.0373	0.0128	0.1794	0.0931	0.0696	0.1438	0.1317	0.0718	0.0940	0.0640
28	Si 251.611 - A	0.1031	6.9172	56.3837	31.3773	49.1089	43.3660	36.2768	35.1706	44.4518	45.3994	47.2144	42.3025	44.7056
29	Sn 189.927 - A	0.0054	BDL	0.0055	0.0140	0.0112	0.0067	0.0094	BDL	BDL	0.0120	BDL	BDL	0.0081
30	Sr 460.733 - A	0.0003	0.4219	1.9865	1.2387	2.1565	2.5333	1.6817	2.0674	1.2146	1.6915	1.6763	1.7305	1.5218
31	Ti 334.940 - A	0.0001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
32	Tl 190.801 - A	0.0105	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
33	V 292.402 - A	0.0004	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
34	Zn 213.857 - A	0.0023	1.5682	0.0180	0.0120	0.0174	0.0166	0.0155	0.0148	0.0152	0.0153	0.0206	0.0183	0.0214
35	Zn 206.200 - A	0.0023	1.4684	0.0081	0.0032	0.0075	0.0076	0.0060	0.0058	0.0060	0.0058	0.0112	0.0073	0.0114

APPENDIX D
PHOTOS

s PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Photos From Tom › Pictures › BARITE_2017-10 Solids

Name	Date modified	Type	Size
As Received Solids at RDI_12 Oct. 2017.JPG	10/12/2017 3:05 PM	JPG File	2,833 KB
Broken Tote at RDI_12 Oct. 2017.JPG	10/12/2017 3:02 PM	JPG File	2,859 KB
Damaged Tote at RDI_12 Oct. 2017.JPG	10/12/2017 3:04 PM	JPG File	2,903 KB
Silt tote _Damaged_13 Oct. 2017.JPG	10/13/2017 10:21 ...	JPG File	2,388 KB
SILT Tote_13 Oct. 2017.JPG	10/13/2017 10:21 ...	JPG File	2,484 KB
Solids as Received at RDI_12 Oct 2017.JPG	10/12/2017 3:05 PM	JPG File	2,577 KB
Top Soil Tote _Damaged_13 Oct. 2017.JPG	10/13/2017 10:21 ...	JPG File	2,423 KB
Tote at RDI_12 Oct. 2017.JPG	10/12/2017 3:02 PM	JPG File	2,757 KB
Tote Pallet at RDI_12 Oct. 2017.JPG	10/12/2017 3:03 PM	JPG File	2,794 KB
Totes at RDI_12 Oct. 2017.JPG	10/12/2017 3:03 PM	JPG File	2,763 KB
Vegetation Tote 2 of 3_13 Oct. 2017.JPG	10/13/2017 10:20 ...	JPG File	2,846 KB
Vegetation Tote Damaged_13 Oct. 2017.J...	10/13/2017 10:20 ...	JPG File	2,793 KB
Vegetation Tote_13 Oct. 2017.JPG	10/13/2017 10:20 ...	JPG File	2,914 KB
WR Solids as Received_12 Oct. 2017.JPG	10/12/2017 3:05 PM	JPG File	2,820 KB

SILT Tote_13 Oct. 2017.JPG

as Received at RDI_12 Oct 20

il Tote _Damaged_13 Oct. 20

Tote at RDI_12 Oct. 2017.JPG

e Pallet at RDI_12 Oct. 2017.J

otes at RDI_12 Oct. 2017.JPC

ation Tote 2 of 3_13 Oct. 2017

ion Tote Damaged_13 Oct. 20

getation Tote_13 Oct. 2017.JF

olids as Received_12 Oct. 201

eived Solids at RDI_12 Oct. 20

en Tote at RDI_12 Oct. 2017.

aged Tote at RDI_12 Oct. 2017

ote _Damaged_13 Oct. 2017.

PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Photos From Tom › Pictures › Barite_2017-10b Solids

Name	Date modified	Type	Size
Broken Tote at RDI, Image A, 12 Oct. 2017...	10/12/2017 8:02 AM	JPG File	2,859 KB
Broken Tote Lid at RDI, Image F, 12 Oct. 2...	10/13/2017 3:21 AM	JPG File	2,423 KB
Broken Totes at RDI with Spillage, Image ...	10/12/2017 8:03 AM	JPG File	2,794 KB
Broken Totes at RDI with Spillage, Image ...	10/12/2017 8:04 AM	JPG File	2,903 KB
Damaged Tote Lid at RDI, Image H, 12 Oc...	10/13/2017 3:21 AM	JPG File	2,388 KB
Plastic Wraped Totes at RDI, Image C, 12 ...	10/12/2017 8:03 AM	JPG File	2,763 KB
Remaining Tote Contents at RDI, Image I,...	10/12/2017 8:05 AM	JPG File	2,820 KB
Remaining Tote Contents at RDI, Image J,...	10/12/2017 8:05 AM	JPG File	2,833 KB
Remaining Tote Contents at RDI, Image K...	10/12/2017 8:05 AM	JPG File	2,577 KB
Tote Lid at RDI, Image B, 12 Oct. 2017.JPG	10/12/2017 8:02 AM	JPG File	2,757 KB
Tote Lid at RDI, Image G, 12 Oct. 2017.JPG	10/13/2017 3:21 AM	JPG File	2,484 KB
Vegetation from Destroyed Tote 3, 13 Oct...	10/13/2017 3:20 AM	JPG File	2,846 KB
Vegetation in Damaged Tote 1, 13 Octob...	10/13/2017 3:20 AM	JPG File	2,914 KB
Vegetation in Damaged Tote 2, 13 Octob...	10/13/2017 3:20 AM	JPG File	2,793 KB

n Damaged Tote 2, 13 Octobe

ote at RDI, Image A, 12 Oct. 2

e Lid at RDI, Image F, 12 Oct.

RDI with Spillage, Image D, 1

RDI with Spillage, Image E, 1

Lid at RDI, Image H, 12 Octo

d Totes at RDI, Image C, 12 C

Contents at RDI, Image I, 12

Contents at RDI, Image J, 12

Contents at RDI, Image K, 12

d at RDI, Image B, 12 Oct. 20

d at RDI, Image G, 12 Oct. 20

from Destroyed Tote 3, 13 Oct

n Damaged Tote 1, 13 Octobe

PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Photos From Tom › Pictures › Barite_2017-11 Rocks & Solids

Name	Date modified	Type	Size
BH Test Pit 1, Image 1A.JPG	11/8/2017 9:06 AM	JPG File	2,556 KB
BH Test Pit 1, Image 1B.JPG	11/8/2017 9:07 AM	JPG File	2,542 KB
BH Test Pit 1, Image 1C.JPG	11/8/2017 9:07 AM	JPG File	2,670 KB
BH Test Pit 1, Image 2A.JPG	11/8/2017 9:20 AM	JPG File	2,593 KB
BH Test Pit 1, Image 2B.JPG	11/8/2017 9:20 AM	JPG File	2,591 KB
BH Test Pit 2 Image 1A.JPG	11/8/2017 8:45 AM	JPG File	2,544 KB
BH Test Pit 2, Image 1B.JPG	11/8/2017 8:45 AM	JPG File	2,849 KB
BH Test Pit 2, Image 2A.JPG	11/8/2017 8:13 AM	JPG File	2,833 KB
BH Test Pit 2, Image 2B.JPG	11/8/2017 8:14 AM	JPG File	2,819 KB
BH Test Pit 2, Image 2C.JPG	11/8/2017 8:18 AM	JPG File	2,837 KB
BH Test Pit 2, Image 2E.JPG	11/8/2017 8:20 AM	JPG File	2,753 KB
BH Test Pit 2, Image 2F.JPG	11/8/2017 8:20 AM	JPG File	2,759 KB
BH Test Pit 3, Image 1A.JPG	11/8/2017 9:31 AM	JPG File	2,666 KB
BH Test Pit 3, Image 1B.JPG	11/8/2017 9:32 AM	JPG File	2,576 KB
BH Test Pit 3, Image 2A.JPG	11/8/2017 9:45 AM	JPG File	2,614 KB
RDI Totes, Recovered Contents Pit 1, 1st ...	11/8/2017 10:53 AM	JPG File	2,767 KB
RDI Totes, Recovered Contents Pit 1, 2nd ...	11/8/2017 10:54 AM	JPG File	2,831 KB
RDI Totes, Recovered Contents Pit 3, 1st ...	11/8/2017 10:54 AM	JPG File	2,771 KB
RDI Totes, Recovered Contents Pit 3, 2nd ...	11/8/2017 10:54 AM	JPG File	2,799 KB

BH Test Pit 2, Image 1B.JPG

BH Test Pit 2, Image 2A.JPG

BH Test Pit 2, Image 2B.JPG

BH Test Pit 2, Image 2C.JPG

BH Test Pit 2, Image 2E.JPG

BH Test Pit 2, Image 2F.JPG

BH Test Pit 3, Image 1A.JPG

BH Test Pit 3, Image 1B.JPG

BH Test Pit 3, Image 2A.JPG

Recovered Contents Pit 1, 1st

Recovered Contents Pit 1, 2nd

Recovered Contents Pit 3, 1st

Recovered Contents Pit 3, 2nd

BH Test Pit 1, Image 1A.JPG

BH Test Pit 1, Image 1B.JPG

BH Test Pit 1, Image 1C.JPG

BH Test Pit 1, Image 2A.JPG

BH Test Pit 1, Image 2B.JPG

BH Test Pit 2 Image 1A.JPG

PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Photos From Tom › Pictures › BARITE_2017-11B Rocks & Solids

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PB080321.JPG	11/8/2017 3:18 PM	JPG File	2,500 KB
PB080322.JPG	11/8/2017 3:20 PM	JPG File	2,753 KB
PB080323.JPG	11/8/2017 3:20 PM	JPG File	2,759 KB
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PB080325.JPG	11/8/2017 3:45 PM	JPG File	2,849 KB
PB080326.JPG	11/8/2017 3:46 PM	JPG File	2,424 KB
PB080327.JPG	11/8/2017 4:06 PM	JPG File	2,556 KB
PB080328.JPG	11/8/2017 4:07 PM	JPG File	2,542 KB
PB080329.JPG	11/8/2017 4:07 PM	JPG File	2,670 KB
PB080330.JPG	11/8/2017 4:20 PM	JPG File	2,593 KB
PB080331.JPG	11/8/2017 4:20 PM	JPG File	2,591 KB
PB080333.JPG	11/8/2017 4:31 PM	JPG File	1,198 KB
PB080334.JPG	11/8/2017 4:31 PM	JPG File	2,666 KB
PB080335.JPG	11/8/2017 4:32 PM	JPG File	2,576 KB
PB080336.JPG	11/8/2017 4:45 PM	JPG File	2,614 KB
PB080337.JPG	11/8/2017 4:45 PM	JPG File	2,571 KB
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PB080333.JPG

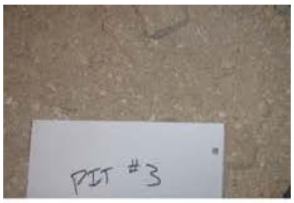
PB080334.JPG

PB080335.JPG

PB080336.JPG

PB080337.JPG

PB080338.JPG



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PB080341.JPG

PB080318.JPG

PB080319.JPG

PB080320.JPG

PB080321.JPG

PB080322.JPG

PB080323.JPG

PB080324.JPG

PB080325.JPG

PB080326.JPG

PB080327.JPG

PB080328.JPG

PB080329.JPG

PB080330.JPG

PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Beaker Screening Testing › Beaker Photos

Name	Date modified	Type	Size
1 Beaker #1 SLS.JPG	12/4/2017 1:38 PM	JPG File	2,925 KB
2 Beaker coarse vs fine.JPG	12/4/2017 1:37 PM	JPG File	2,833 KB
3 Beaker 100gr. baseline.JPG	12/4/2017 1:37 PM	JPG File	2,871 KB
4 Beaker #1 SLS.JPG	12/4/2017 1:37 PM	JPG File	2,909 KB
5 Beaker #1 SLSa.JPG	12/4/2017 1:37 PM	JPG File	2,903 KB
6 Beaker #1 SLSb.JPG	12/4/2017 1:37 PM	JPG File	2,760 KB
7 Beaker #3 H2O.JPG	12/4/2017 1:37 PM	JPG File	2,896 KB
8 Beaker #6 25%Milk.JPG	12/4/2017 1:37 PM	JPG File	2,913 KB
9 Beaker #6 25%Milk.JPG	12/4/2017 1:37 PM	JPG File	2,915 KB
10 Beaker #6 25%Milk.JPG	12/4/2017 1:37 PM	JPG File	2,913 KB
11 Beaker #7 CaCO3.JPG	12/4/2017 1:37 PM	JPG File	2,916 KB
12 Beaker #7 CaCO3.JPG	12/4/2017 1:37 PM	JPG File	2,910 KB
13 Beaker #1 SLS.JPG	12/4/2017 1:37 PM	JPG File	2,880 KB
14 Beaker #2 5%Milk.JPG	12/4/2017 1:37 PM	JPG File	2,762 KB
15 Beaker #3 H2O.JPG	12/4/2017 1:37 PM	JPG File	2,910 KB
16 Beaker #5 Baseline Stirreda.JPG	12/4/2017 1:37 PM	JPG File	2,875 KB
17 Beaker #5 500 gr Baseline Stirreda.JPG	12/4/2017 1:37 PM	JPG File	2,769 KB
18 Beaker #6 25% Milk.JPG	12/4/2017 1:37 PM	JPG File	2,910 KB
19 Beaker #7 CaCO3.JPG	12/4/2017 1:37 PM	JPG File	2,918 KB
20 Beaker #8 NaHCO3.JPG	12/4/2017 1:37 PM	JPG File	2,670 KB
21 Beaker All Tests.JPG	12/4/2017 1:37 PM	JPG File	2,911 KB
BH Pyrite particle 1 10x.JPG	12/1/2017 10:27 AM	JPG File	75 KB
BH Pyrite particle 2 10x.JPG	12/1/2017 10:30 AM	JPG File	67 KB
Contact sheet 1.JPG	12/4/2017 3:16 PM	JPG File	172 KB
Contact sheet 2.JPG	12/4/2017 3:17 PM	JPG File	68 KB

1 Beaker #1 SLS.JPG

2 Beaker coarse vs fine.JPG

3 Beaker 100gr. baseline.JPG

4 Beaker #1 SLS.JPG

5 Beaker #1 SLSa.JPG

6 Beaker #1 SLSb.JPG

7 Beaker #3 H2O.JPG

8 Beaker #6 25%Milk.JPG

9 Beaker #6 25%Milk.JPG

10 Beaker #6 25%Milk.JPG

11 Beaker #7 CaCO3.JPG

12 Beaker #7 CaCO3.JPG

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ards B_USBM U1, U2_06 Jan

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Flooding Process WRU-1_30

Cell Fabrication _ 25 Jan. 2018

ain Plumbing Configuration_25

BM 1.1 Leach_17 Jan. 2018.J

.2_180 mgkg SLS_17 Jan. 20

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M 2.1 Leachate_27 Jan. 2018

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__Milk Suspension_21 Jan.

BM 3.1 _Milk _21 Jan. 2018.J

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1 Milk Flooded Bed_21 Jan. 2

3.1 Perched Milk_ 21 Jan. 20

3.1_Floded Milk_21 Jan 201

Flooded Bed with Milk_21 Jan

3.1_Milk Draing_21 Jan. 201

3.1_Milk Draining__21 Jan. 20

Milk_ 4.1_Milk and ALK_21 Jan

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4.1 Milk Curdling_22 Jan. 201

1._Milk Flooded Bed_21 Jan. 2

M 4.1_3rd Rinse_21 Jan. 2018

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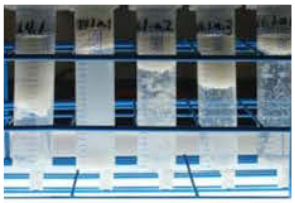
ilk Curdling Test 3.1_23 Jan. 2

Milk Curdling Test_b_22 Jan. 2

Milk Curdling Test_c_ 23 Jan 2


Milk Curdling Test_d_23 Jan. 2

Milk Curdling Test_e_23 jan. 2

Milk Curdling Test_g-23 Jan. 2

ng Test_Poorly Consolidated_

Milk Curdling Test-f-23 Jan. 20

ilk Curdling Tests_h_22 Jan. 2

urdling_Insufficient Acid_23 Ja

Draining_Bed Height_ 21 Jan

SBM Test 1.3_18 Jan. 2018.JP

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ies_Agglomerated_Curing_25

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I_2.1. 2nd Leach_27 Jan. 201

SBM_2.1.2_27 Jan. 2018.JP

BM_2.1.3 _c_27 Jan. 2018.JP

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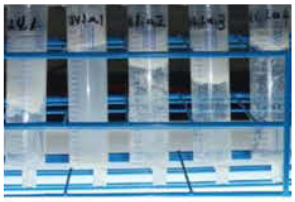
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SBM_U1_a_15 Jan. 2018.JP

SBM_U1_b_15 Jan. 2018.JP

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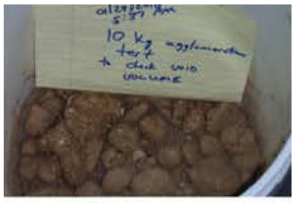
.1_Example Foaming_27 Jan.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mall Batches WR for USBM_1

sed Gravel for Test Cells_26 J

3 Activity of Test Cell Inoculum

ing Test Cell Inoculum_30 Jar

Test Cell Inoculum_30 jan. 20

est Cell Inoculum_b_30 Jan. 2

ll-Drain Plumbing in Test Cells

rated WR for USBM b_U1_15

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Field Capacity Test_12 Jan. 2

loles on Plumbing Array_25 Ja

gglomeration at 10 kg Scale_

arged and Closed Test Cell_ 2

e of a Flooded Bed_30 Jan. 20

est Cell Showing Plumbing Pc

Drilled Plumbing Line_ 25 Jar

rilled Test Cell Plumbing_25 J

mbing at Half Bed Height_26

g Test Cell Plumbing_25 Jan.

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n Test Cell Plumbing_25 Jan.

pacity Test Set-Up_12 Jan. 20

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l Capacity Test_12 Jan. 2018.

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l WRU-1 Test Cell_30 Jan. 20

WRU-1 Test Cell_b_30 Jan. 2

WRU-1 Test Cell_c_30 Jan. 2

ed in Test Cell_3 kg_ 26 Jan. 2

Drain Layer Test Cells_26 Jan.

l Flood WRT-2_30 Jan. 2018.

d WRU-1 and WRT-1_30 Jan.

od-Drain of WRU-2_30 Jan. 2

ood-Drain WRU-2_30 Jan. 20

R with Pulverized Limestone_a

R with Pulverized Limestone_b

anned Test_Not Used_15 Jar

nfiguration in Test Cells_25 Ja

PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Photos From Tom › Pictures › BARITE_2018-02 Reactors

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- WRU-1 and WRT-2 Drain Down_020618.JPG
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- WRU-6013118 Initial Effluent.JPG

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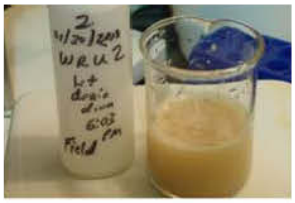
WRU-2-013018 Effluent.JPG

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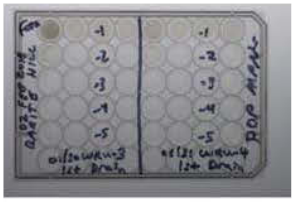
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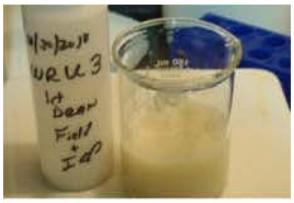
RU-3-013018 Initial Effluent.JF

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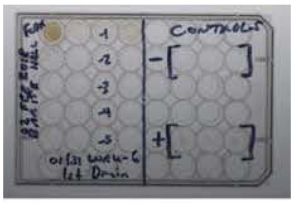
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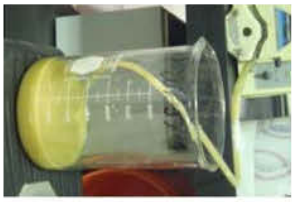
of WRT-3 Effluent_06 Feb. 2


ain Down of WRS-1_07 Feb. 2

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WRS-1-020718 Effluent.JPG

/RS-2-020718 B Effluent.JPG

WRS-2-020718 Effluent.JPG

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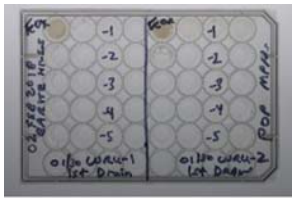
WRT-4-020718 Effluent.JPG



-1,2-013018 Day 0 Acid MPN

RU 2 Effluent_06 Feb. 2018.JP

and WRT-2 Drain Down_0206

PC › projects (\\192.168.87.1) (P:) › DV031 B&V_Barite hill › 30 Lab Testing › Photos From Tom › Pictures › BARITE_2018-02B Reactors

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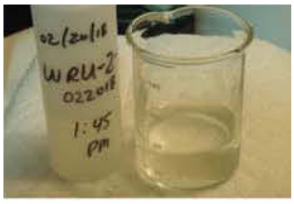
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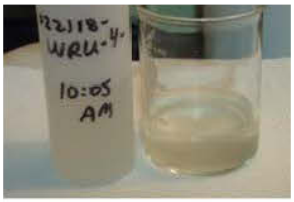
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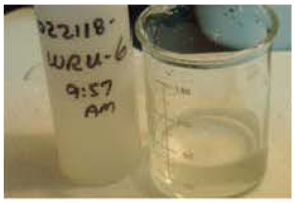
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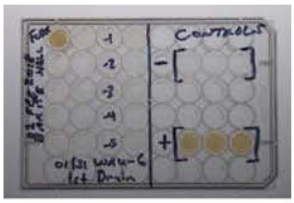

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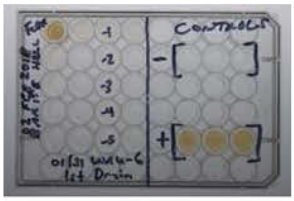

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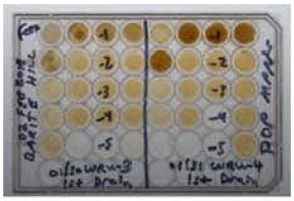
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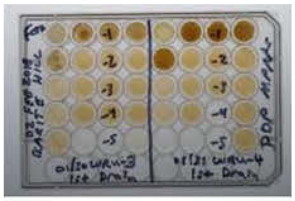
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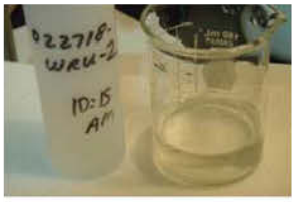
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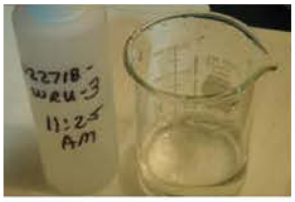
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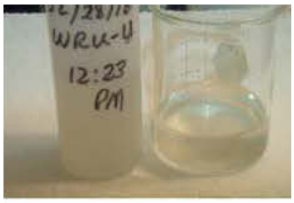

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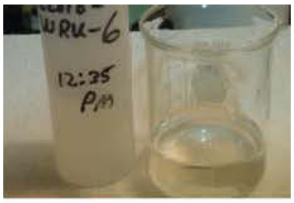

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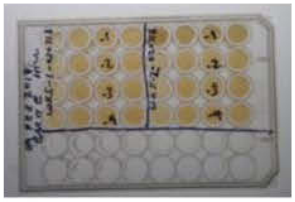
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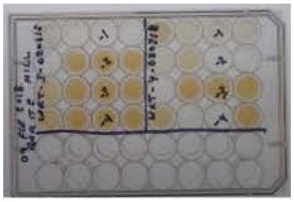
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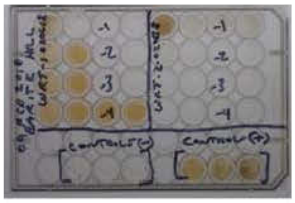
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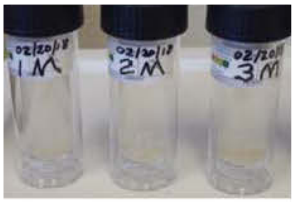

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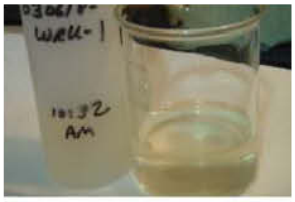
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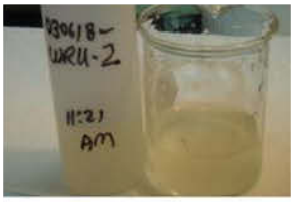
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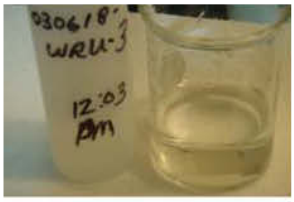
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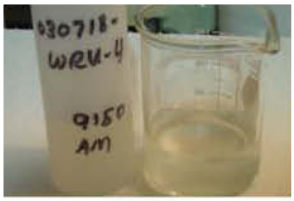
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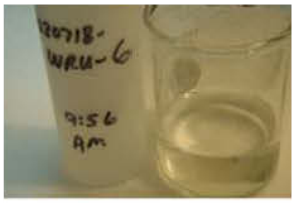

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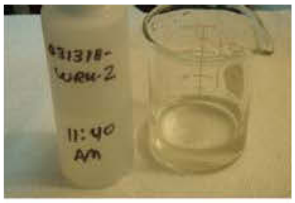
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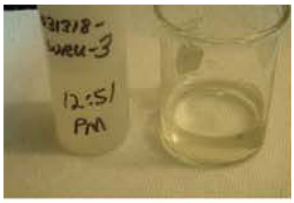
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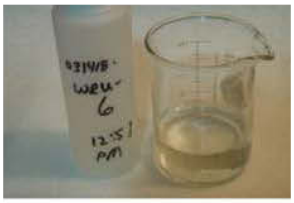
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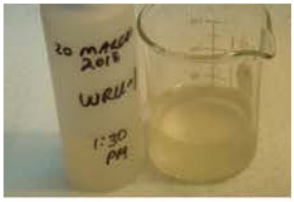

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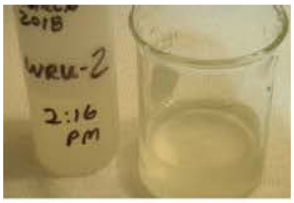

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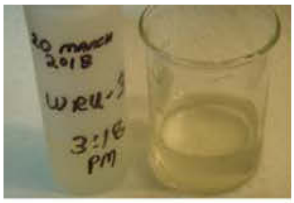

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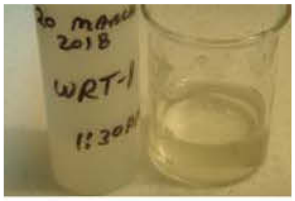

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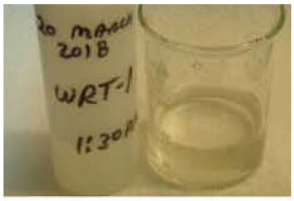

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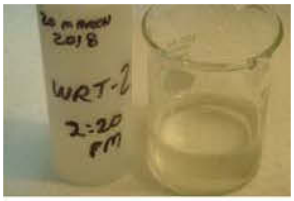

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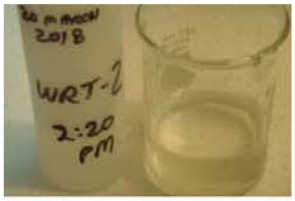

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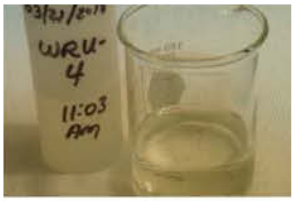

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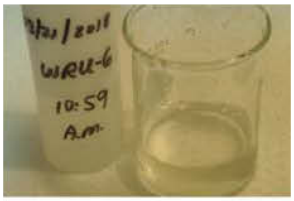

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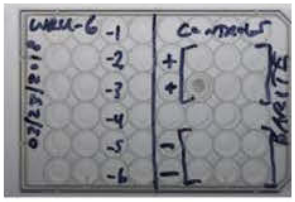

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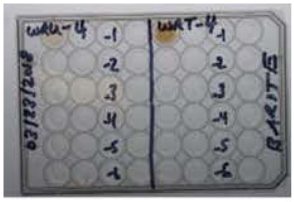

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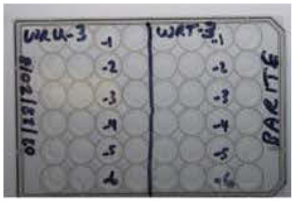

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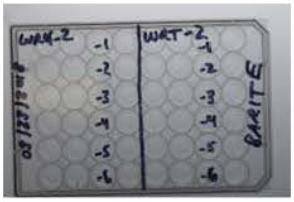

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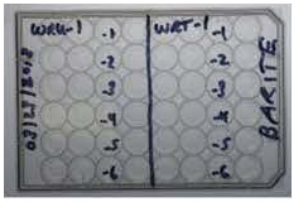

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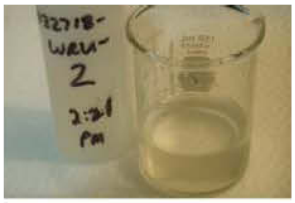
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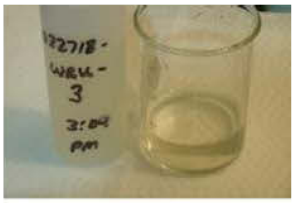
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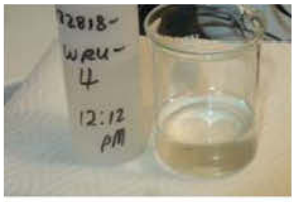
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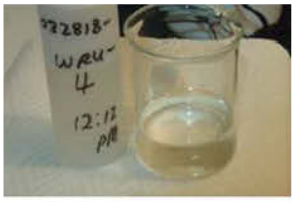
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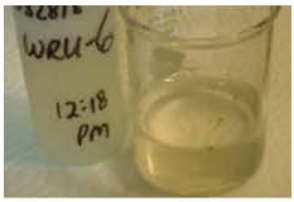
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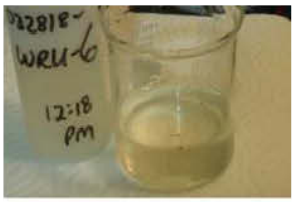
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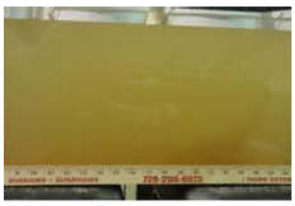
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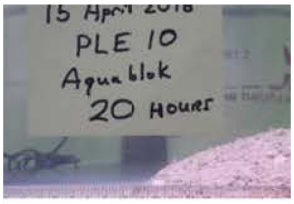

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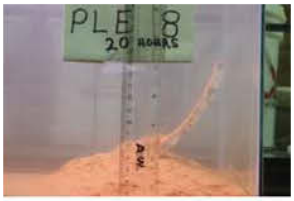

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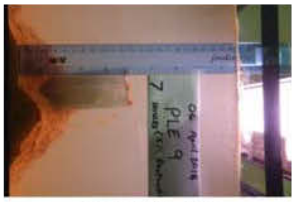
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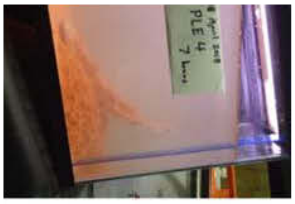

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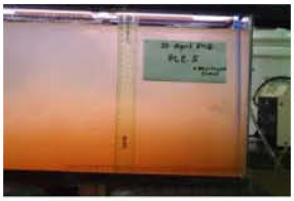

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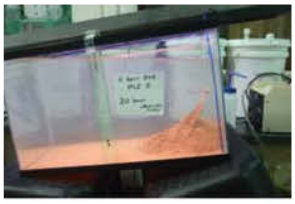
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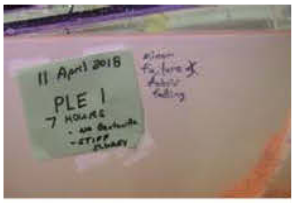

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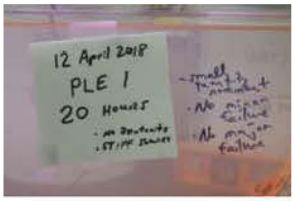

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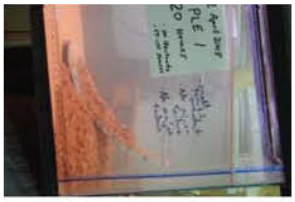
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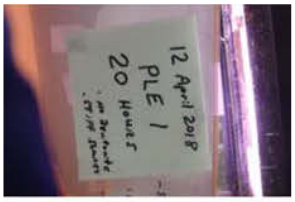

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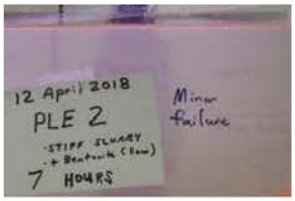

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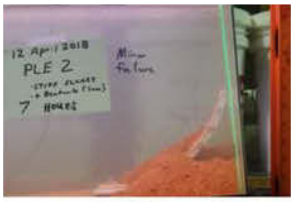

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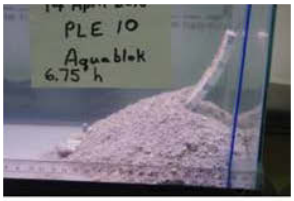

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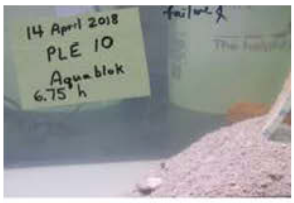

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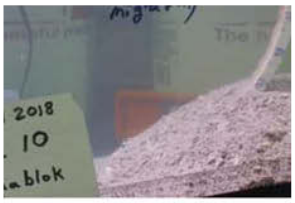
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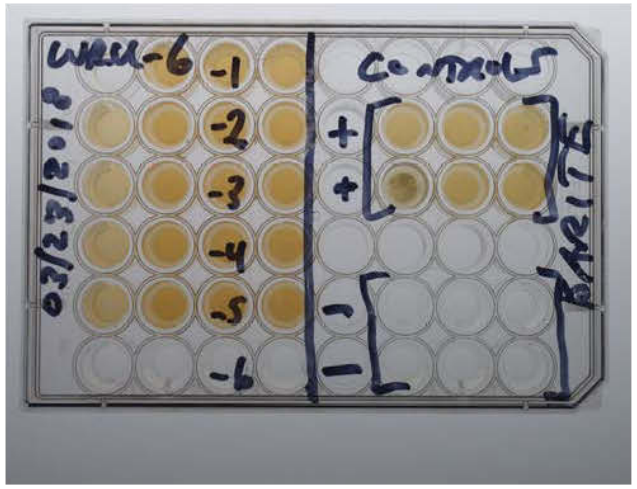
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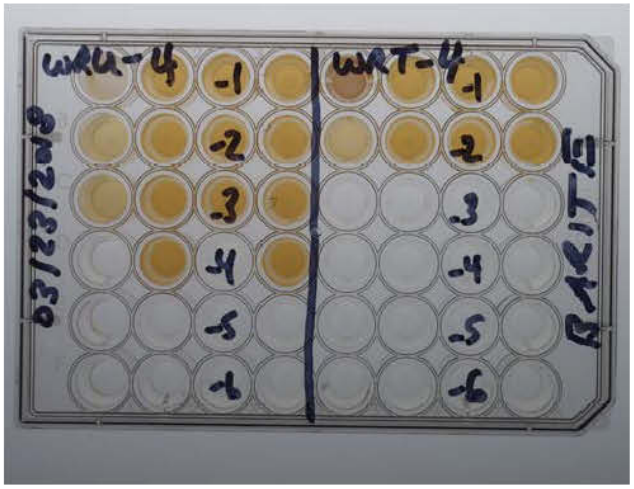
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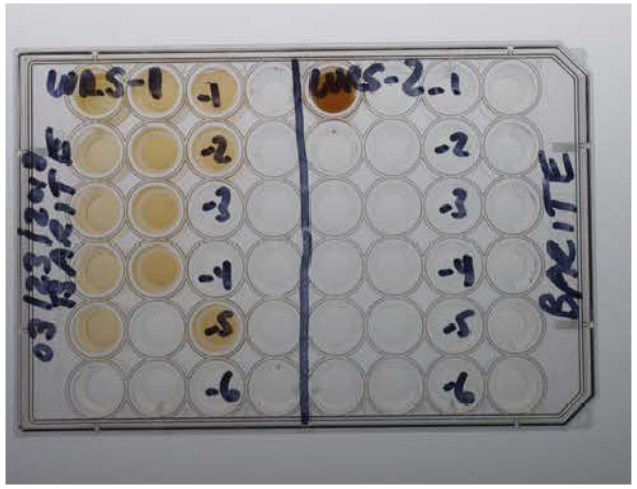
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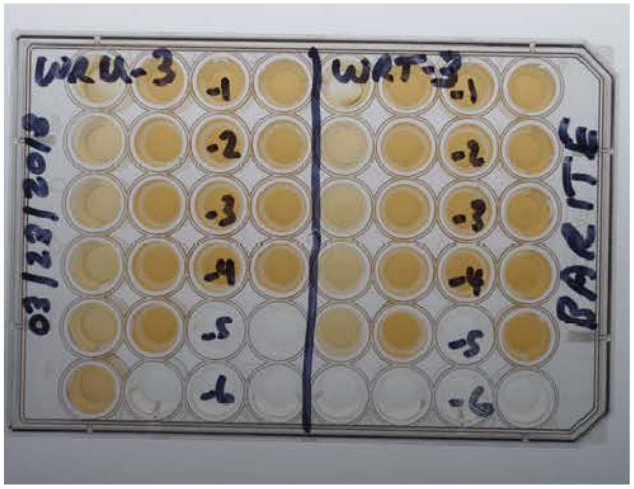
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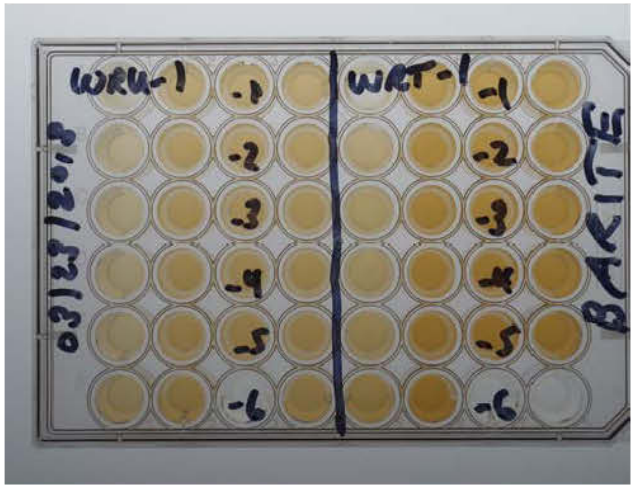
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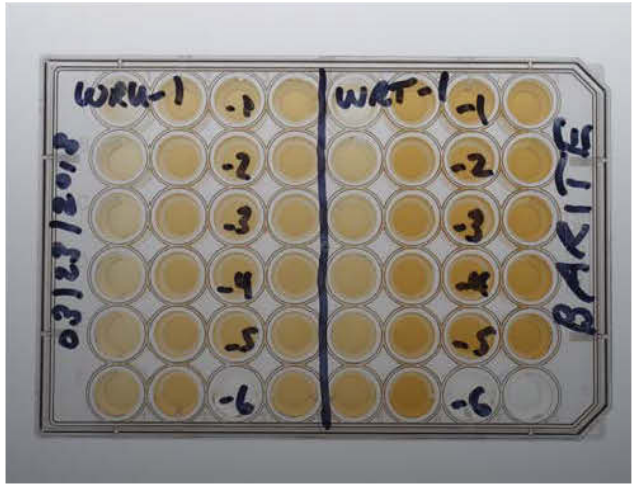
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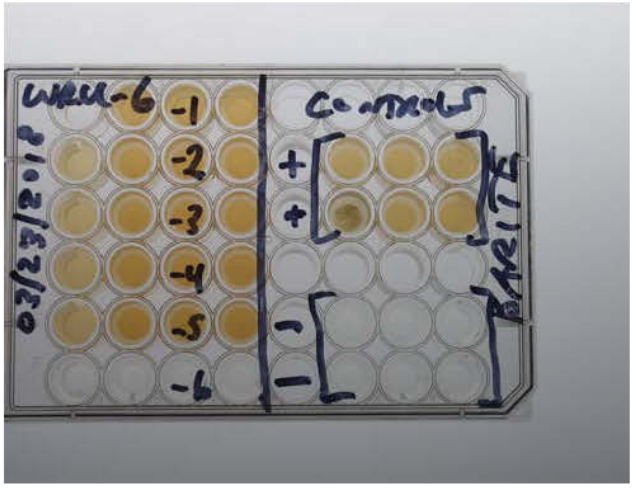
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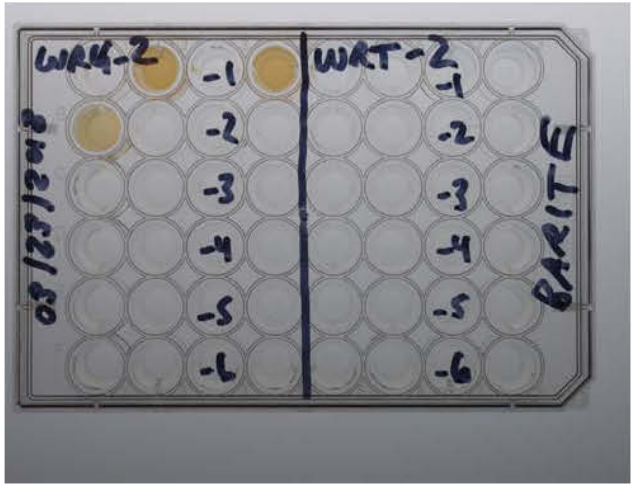
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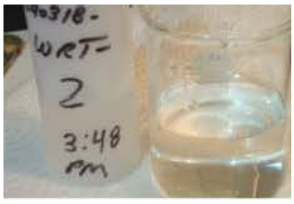

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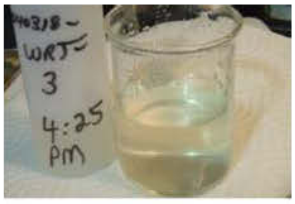

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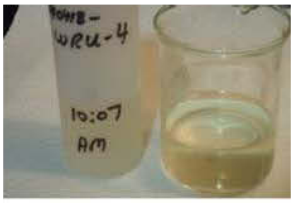

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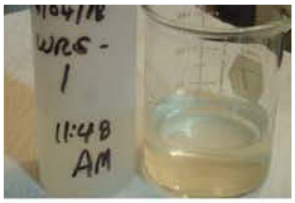

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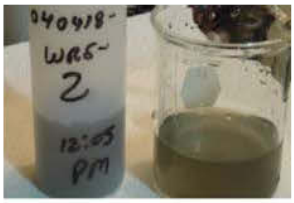

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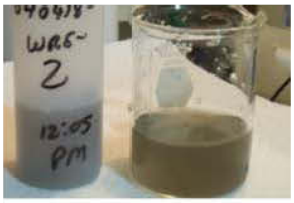

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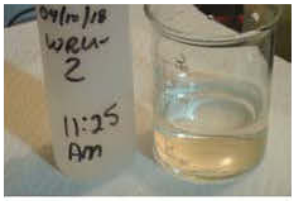

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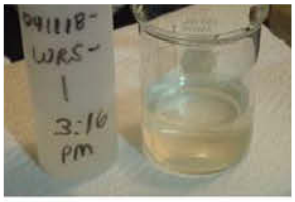

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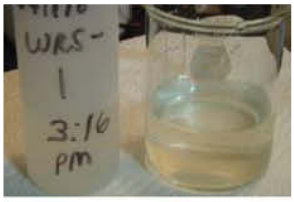

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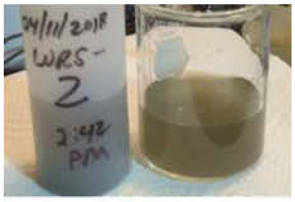

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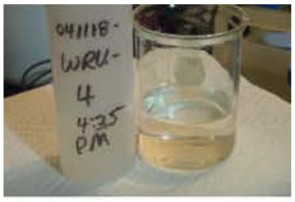

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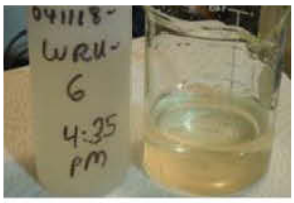

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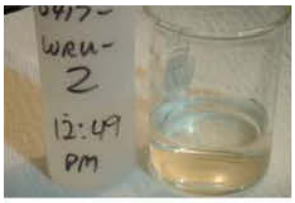

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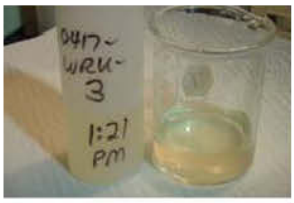

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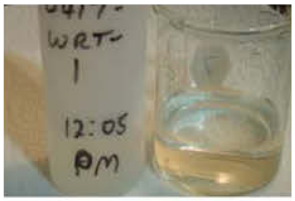

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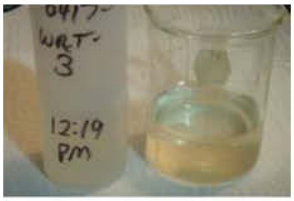

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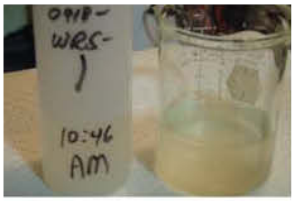

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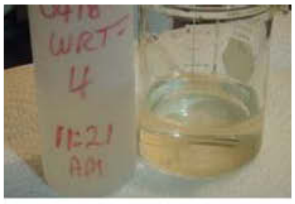

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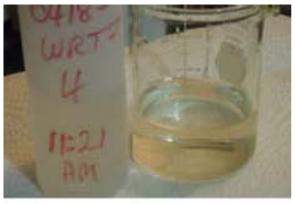

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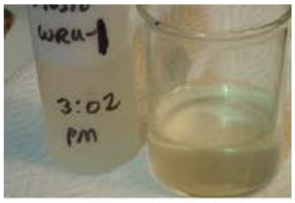

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APPENDIX E
PRELIMINARY TESTING GROUPS

3.0 TESTING GROUP – PRELIMINARY (NOT INCLUDED IN MAIN TEXT)

3.2 Beaker and Sieving Tests

3.2.1 Beaker and Sieving Test Conclusions and Recommendations

The Beaker Testing revealed two main findings:

- The waste rock contains a significant "clay" content that limits permeability. It was decided to agglomerate the samples for at least some of the USBM testing phase to enhance sample permeability. Agglomeration was conducted by wetting the material and tumbling it so the smaller particles coated the larger particles. There was no chemical change or addition.
- Whey did not show an ability to be effective as a source control agent (by inhibiting acidophiles) directly and worked more like a "sugar"/carbon source addition. Whey would be a very expensive form of "sugar". Whey was eliminated from further testing.

Sieving vs Agglomeration

Milk as an amendment clearly stabilized the beds through the initial top-down solution application and following the flood/drain sequence and final top down rinse. This was true for each of the three solids preparations – 1) as crushed, 2) sieved to remove the minus 50 fraction fines; or 3) agglomerated. Milk addition reduced fine solids loss in each case.

The agglomerate approach appeared to be a viable option to improve permeability. Stability over 120 days cannot be estimated from these scoping tests. However, benefits following addition of milk constituents may even be greater when combined with biofilm development. Microbial biomass may generate compounds that "glue" the macrostructure together - milk, cells and fine particles - and this may further stabilize the agglomerates.

3.2.2 Beaker and Sieving Treatability Study Approach

3.2.2.1 Objectives and Rationale - Sieving vs Agglomeration

The original objective of the Beaker Testing as cited on Table C2 of the SAP was to:

- Observe the characteristics and extent of change of the subject material mixed with incremental amounts of amendment.
- Evaluate the approximate dose that may be used for further testing (pH of 7.0 for caustics).
- Look for favorable or adverse effects that may guide or limit application techniques and effectiveness of the amendment.

3.2.2.2 Experimental Design and Procedures

See Appendix A-1, Initial Qualitative (Beaker) Screening. Please refer also to Appendix A-2.

3.2.2.3 Deviations from the Work Plan

The results of the Beaker Testing suggested that the materials exhibited a significant potential for clogging and two options were considered: 1) conducting subsequent tests on a sieved sample of the mine waste which necessitated discarding a portion of the sample; or 2) attempt to self-agglomerate the sample with distilled water to cause the fine-grained clay fraction to adhere to the surface of the coarse-grained fraction of the bulk sample in a manner that preserved the bulk sample composition and permeability. The sieving vs. agglomeration testing constituted a deviation from the original Work Plan.

The primary objective of these additional, secondary Beaker Tests was the assessment of fine particle mobility with subsequent potential for bed clogging in the 20-kg reactors and, if possible, conducting a falling head test. Here, crushed Barite Hill solids feed, sieved solids feed or agglomerated feed samples were subjected to various wetting sequences and the migration of particles quantified. This was an attempt to reach a decision point as to how, if at all, to further prepare the solids feed for use in the larger reactors.

In addition to the above expansion of the Beaker Testing, whey was not used in the testing because the sugar (lactose) content in the whey was replicated by the presence of lactose in the milk. Also, whey is much more expensive to procure.

3.2.3 Beaker and Sieve Test Results and Discussion

3.2.3.1 Beaker Tests

The results are presented in Table 3.2-1. Table 3.2-1 and the Field Notes (Appendix B-1) show that the 5% and 25% milk solution percolated faster than the SLS, sodium bicarbonate solutions and distilled water. This observation was corroborated at the end of the testing (Figure 3.2-1). There was no solution standing on top of the milk beakers, whereas, most of the other solutions (including the limestone beaker and the control) were still standing on top of the samples. A 25% milk solution percolated in less than an hour. The solutions that contained sodium exhibited slower percolation rates, even slower than the control sample which received distilled water alone.

Proof sheets of the photos taken during the Beaker tests are provided in Appendix D.

Figure 3.2-1 Photos of the beakers at test conclusion (L) & Close-up of Milk Test No. 2 (R)

Some of the milk applied to the 25% milk beaker broke through the sample and was observed in the beaker effluent. This means that the mechanism that “consumes” the milk proteins was satisfied.

The pH values of the beaker effluents were very similar and they typically ranged from 2.21 to 2.47. The effluent from the beaker that received the sodium bicarbonate amendment was a notable exception; the pH was 9.3. The titration results indicate that the material does not contain a lot of stored acidity. It only took 1.2 grams of sodium carbonate per kg of fines to raise the pH from approximately 2.5 to 7 (Appendix B-1).

The conductivity of the beakers effluent ranged from 5.79 to 30.3 mS/cm. The effluent of the beaker that received sodium bicarbonate exhibited the highest conductivity. This was likely due to the sodium that

was added to the sample. In addition, the beaker that received SLS was the second highest, again probably due to the sodium content of the SLS.

The beaker test observations suggest that more attention to the mineralogy and chemistry of the clay fraction of the material is appropriate. Also, the very low percolation rate of the control suggests that the tests planned for addressing the saturated and unsaturated conditions in the mine waste dump will be problematic.

Table 3.2-1 Initial Qualitative Screening – Beaker Test Results

		Amendment or Reagent					Results				
Beaker No.	**Mass of Sample (g)**	**SLS Conc.**	**Milk Conc.**	**$NaHCO_3$ Conc.**	**P.L.S. (g)**	**Distilled Water (ml)**	**Moisture Holding Capacity (ml)**	**Percolation in 1 hr (ml)**	**Final Effluent (ml)**	**pH**	**Conductivity (mS/cm)**
1	100	2%					16.5	2.1	3.9	2.24	10.51
2	100		5%				16.5	6.8	13	2.27	6.56
3	100					X	16.5	2	4.3	2.3	6.52
4	100						See Appendix B-1 for titration report				
5	500					750	NA	few drops	26	2.21	7.97
6	100		25%				17.5	8.3*	7.7	2.42	5.79
7	100				2%		16.5	3.6	6.9	2.47	7.08
8	100			5%			16.5	1.7	6.4	9.31	30.3

Note:

*This amount of effluent was collected in 38 min

SLS: Sodium Lauryl Sulfate; **$NaHCO_3$**: Sodium Bicarbonate; **P.L.S**: Powdered Limestone

3.2.3.2 Sieving vs Agglomeration

Phase 1. It was unexpected, but none of four test solutions resulted in pooling sufficient to permit a falling head test. The bicarbonate solution was observed to react with the acidic solids, resulting in effervescence. Milk solids migrated through the solids and appeared in the effluent. The calcium oxide slurry did not produce observable effervescence. Solution and solids data are presented in Appendix B-2. Overall solids losses were least for the pre-sieved charges, as might be expected, and generally higher for the agglomerated charges. However, solids losses were least for charges amended with milk in all three groups.

Phase 2. All test vessels could be successfully flooded with tap water, and then gravity drained. This was followed by a top-down application of distilled water. However, drainage characteristics of the top-down application differed from Phase 1. All four vessels charged initially with unmodified crushed fines showed some degree of ponding. Two of the vessels required approximately two hours for the surface ponding to dissipate. Unfortunately, timed drainage rates were not captured. Lower solids losses were again seen in charges initially amended with milk, even following the flood / drain sequence and secondary rinse. This at least suggests that milk components remain bound to the solids even with rinsing. Photos of the testing setup are provided in Figure 3.2-2. Solids losses are summarized in Figure 3.2-3.

Flooded samples prior to drainage/rinsing	Milk rinse through WR sample without – 50 mesh fraction (bottom upper container is perforated)

Figure 3.2-2 Sieving vs Agglomeration Setup Test

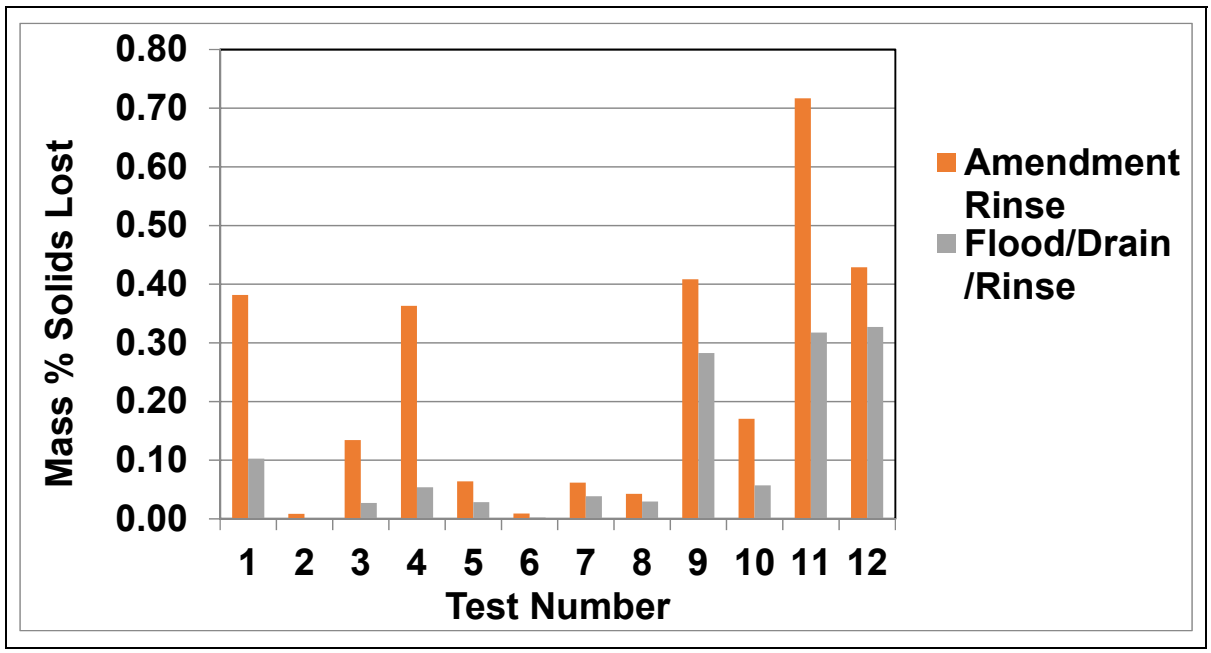


Figure 3.2-3 Fine Particle Losses

3.0 TESTING GROUP – PRELIMINARY (NOT INCLUDED IN MAIN TEXT)

3.3 Utilization Testing Using Amended USBM Method

The laboratory reports are included in Appendix C-2

3.4 USBM Utilization Conclusions and Recommendations

3.4.1.1 USBM Test No. 1 – SLS Consumption

SLS consumption ranged from 70 to 164 mg/kg of waste rock (WR) in four rinsing tests with an average loss of about 108 mg/kg. SLS concentration was estimated visually from volumetric foam production where possible and observations somewhat agreed with laboratory results. Interestingly, pre-moistening the sample resulted in a much greater initial foam volume at 90 mg SLS/kg WR. The losses were probably due to adsorption of the negatively charged "head" of the lauryl-sulfate colloid to the positively-charged edges of the clay minerals present in the sample. Acidification of the lauryl-sulfate colloid could also account for apparent SLS losses but it is uncertain what proportion of the SLS loss could be attributed to this.

If these two theories are responsible for SLS losses, buffering the solution with alkalinity might result in less SLS consumption. This assertion was evaluated in Test No. 2 which is described below.

3.4.1.2 USBM Test No. 2 – SLS Consumption in Buffered Solution

Visual observations of unbuffered solution revealed a lack of sudsing after only two rinses. In contrast, as little as 2.44 grams of sodium bicarbonate per kilogram of WR appeared to preserve sudsing (and by inference, SLS concentrations) for as many as 10 rinses. Increasing amounts of sodium bicarbonate appear to correlate with increasing SLS survival as judged by foam volumes persisting after 15 minutes of standing time.

All subsequent testing with SLS as a reagent should include buffering alkalinity in proportions consistent with the results of this test.

3.4.1.3 USBM Test No. 3 Relative Saturated Hydraulic Conductivity and Milk Consumption w/o Buffering

Full strength or even 20% strength unbuffered milk will likely plug the pore spaces of WR in the 20kg test cells with curdled proteins.

All subsequent testing with milk as a reagent should consider decreasing the concentration relative to full-strength milk to a value less than 20%. Considering the beneficial effects of buffering on SLS and the sensitivity of milk to curdling (which could induce sample plugging) when exposed to pH conditions less than 4.6 s.u., the effects of buffering alkalinity combined with low-strength milk addition should be assessed.

3.4.1.4 USBM Test No. 4 – Relative Saturated Hydraulic Conductivity and Milk Consumption with Buffering Alkalinity.

The addition of sodium bicarbonate (buffered solution) alone appears to permanently decrease the permeability of the WR. This may be due to the formation of iron oxyhydroxide and aluminum hydroxide which plug the sample pore spaces. The addition of milk (buffered) appears to reverse this effect. A theory for this might involve the substitution of calcium from the milk for the sodium in the clay matrix and the sodium in the sodium bicarbonate.

All subsequent testing with milk as a reagent should be buffered to a pH of at least 5.5 to prevent the formation of curds. Excess amounts of buffering reagent might cause sample plugging with metal precipitates.

3.5 USBM Utilization Study Approach

3.5.1.1 Objectives and Rationale

The original USBM work (Kleinmann and Erickson, 1983) attempted to quantify the losses of bactericide due to sorption and other phenomena. The intent of this portion of the study was to better understand sorption and other bactericide losses in the context of the Barite Hill WR and how those losses might be mitigated with inexpensive amendments such as buffering alkalinity.

It may be helpful to the reader to better understand sorption phenomena and why it is important in implementing bactericide ARD mitigation strategies at Barite Hill and perhaps elsewhere. Conventional research has shown that common clay particles are plate-shaped and the edges of the plate are typically positively charged and the flatter area of the plate is negatively charged. This is shown graphically in Figure 3.3-1 a). Thus, when a negatively charged "head" of a lauryl-sulfate colloid encounters a clay particle and its positively-charged edges, it becomes adsorbed to the clay as in Figure 3.3-1 b.

Kleinmann and Erickson were able to quantify this effect and with modifications, this study does so as well.

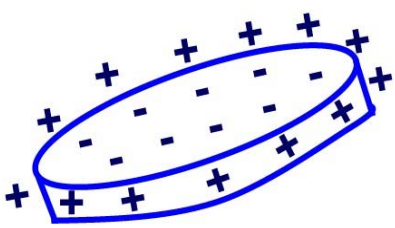
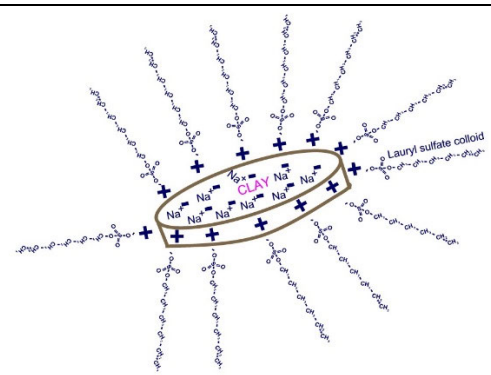
	
a) Charged clay particle sketch	b) Clay particle with lauryl sulfate colloid adsorbed to the positively-charged edge

Figure 3.3-1 Charged Clay Particles Sketches

With respect to SLS sorption, one theory to support this phenomenon is that the negatively charged bicarbonate ion [HCO_3^-] neutralizes the positively-charged edge of the clay particles. This could prevent the subsequent adsorption of the negatively charged lauryl sulfate colloid to the clay and thus enable the colloid to function as a bactericide. This is shown graphically in Figure 3.3-2. The bicarbonate ion could also neutralize acidity derived from metallic ions such as iron or aluminum in solution.

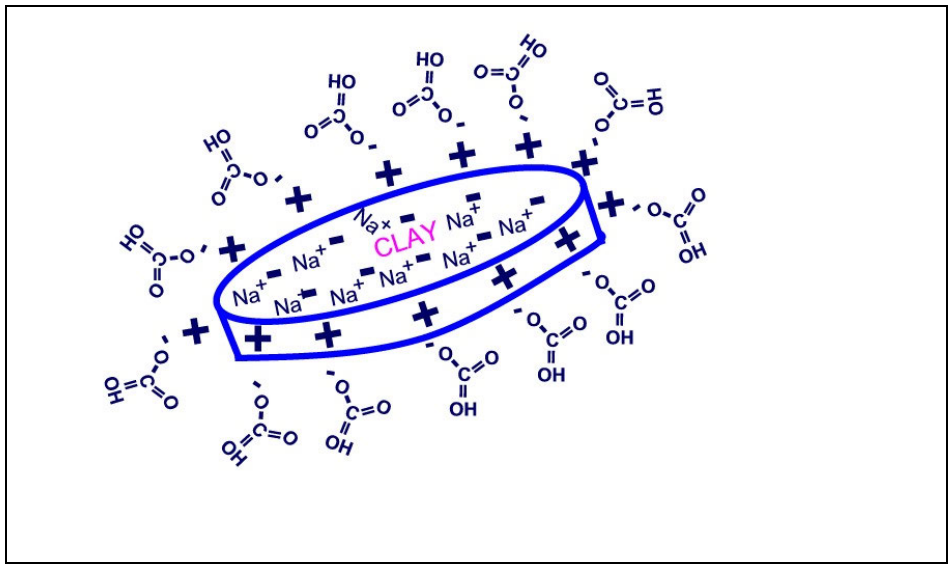


Figure 3.3-2 Bicarbonate ion neutralizing positive charges on edge of clay particle

Also, residual acidity in the sample could destroy the ability of the SLS to function as a bactericide by degrading the long-chain molecule/colloid into a series of shorter organic acids. If one assumes that the ability to create a foam is indicative of bactericide "strength", Figure 3.3-3 provides a qualitative comparison between the amount of foam generated with an off-the-shelf soap dispenser by identical amounts of SLS in solution with and without exposure to muriatic acid.

Figure 3.3-3 Foam without muriatic acid (L) & foam with muriatic acid (R)

The beaker testing results suggested that various amendments could affect the permeability of the Barite Hill test sample. As the practicality of the subsequent proof of principle testing and the implementation of an anti-bacterial source control strategy on a large scale is predicated on a relatively permeable WR, the effects of various amendments on sample permeability were assessed in the USBM testing protocols which are described in more detail below.

3.5.1.2 Experimental Design and Procedures

For the experimental design and procedure of this phase of the testing, please refer to the Sampling and Analysis Plan (SAP) for Tier 1 – Remedy Screening (Sovereign 2017). Individual tests are listed in Table 3.3-1.

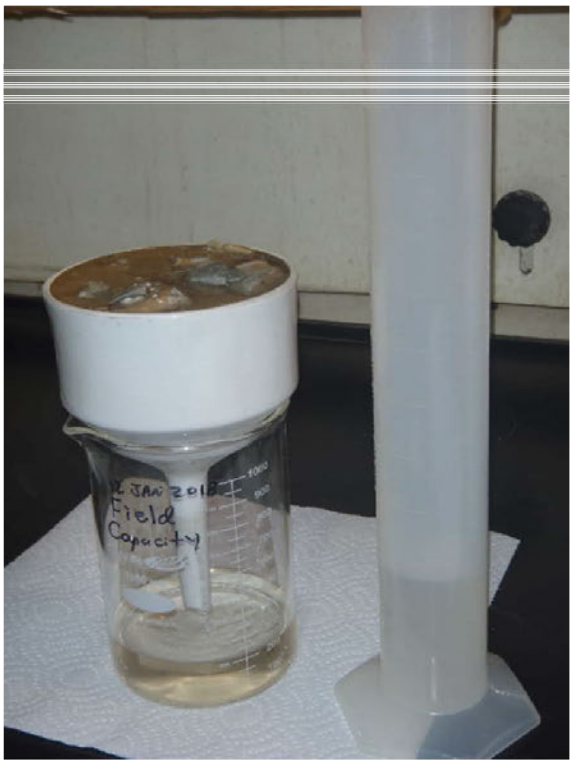
Table 3.3-1 Summary of USBM Testing Protocols

Sample/Test ID	SLS Added mg/Kg Sample	Milk Used	Alkalinity	Comments
U.1.1	60	0	0	Baseline Value SLS
U.1.2	180	0	0	3X Baseline
U.1.3	120	0	0	2X Baseline
U.1.4	90	0	0	1.5 X Baseline
U.1.5	90	0	0	1.5 X Baseline pre-moistened to field capacity
U.2.1	134	0	0	No sodium bicarbonate [$NaHCO_3$]
U.2.2	134	0	2.4 g $NaHCO_3$ per kg WR	Baseline
U.2.3	134	0	4.9 g $NaHCO_3$ per kg WR	2X Baseline
U.2.4	134	0	7.1 g $NaHCO_3$ per kg WR	3X Baseline
U.3	0	100 mL	0	milk added to sample followed by rinsing with water and muriatic acid
U3.1	0	100 mL	0	U.3 replicate
U.3.2	0	100 mL	0	U.3 replicate
U.4.1	0	100 mL	0	Milk leach solution
U.4.1.a.1	0	100 mL	2.45 g $NaHCO_3$ per kg WR	Milk & $NaHCO_3$ leach solution
U.4.1.a.2	0	100 mL	0	Milk leach solution
U.4.1.a.3	0	100 mL	0	Milk leach solution
U.4.1.a.4	0	0	0	Distilled water (overnight)

In the cases of USBM 1 and USBM 2, quantitative validation of the qualitative foaming assays was also done using Methylene Blue Active Substances (MBAS) analyses of rinse solutions completed at an accredited environmental analytical laboratory.

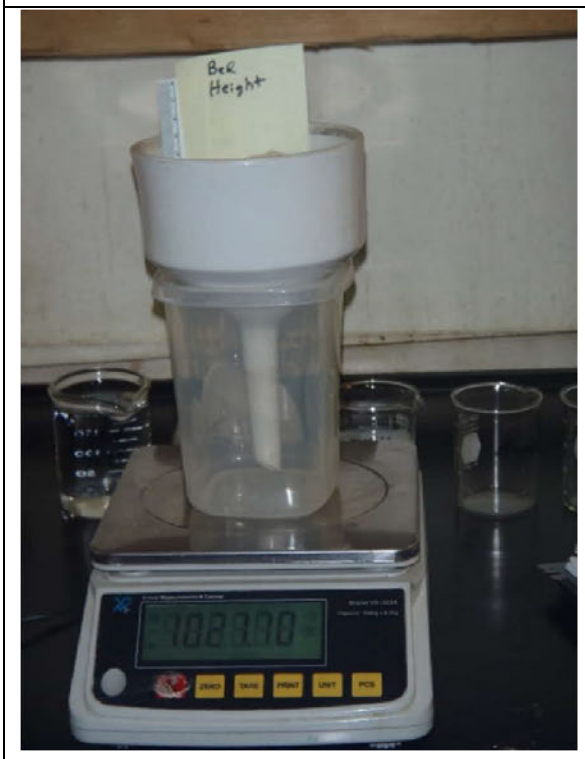
Equipment and Materials

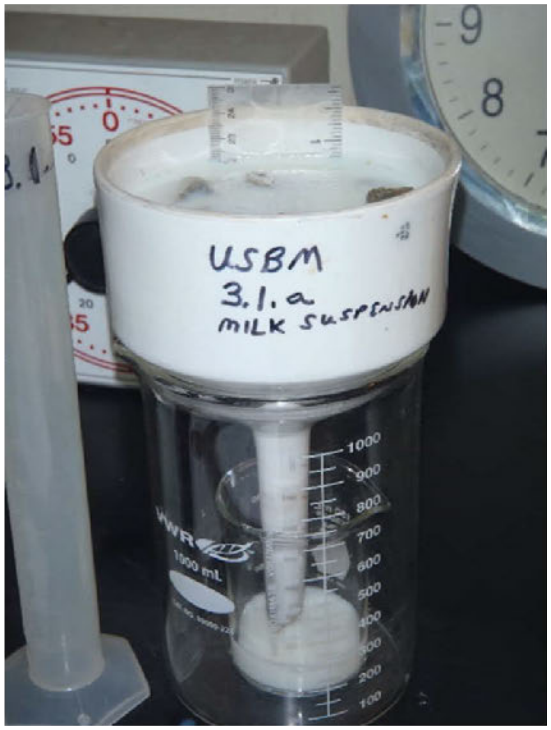
See Appendix A-3 - Utilization Testing Using Amended USBM Method. See also Figure 3.3-4.



Agglomerated samples curing in Buckner Funnels (SLS Consumption)

Draining Field Capacity Equipment





Relative Permeability Test Setup	Milk Curdling & Permeability Test

Figure 3.3-4 USBM Test Equipment Photos

Sampling and Analysis

See Appendix A-3 - Utilization Testing Using Amended USBM Method

3.5.1.3 Deviations from the Work Plan

Whey: Whey was not included in the USBM testing because it was concluded that it would be very expensive form of organic matter in the form of sugar; i.e., lactose, for the full-scale treatment of the waste rock. Other materials being tested, i.e., milk, contained lactose among other forms of organic matter and the addition of whey would not introduce another variable per se into the test.

As shown in the results of the U.4 "milk curdling" testing (see Appendix B-3), whey is shown to be present/retained in the milk-exposed sample when rinsed with muriatic acid (31% HCl).

Additional Testing - Several additional analytical tests were done (Methylene Blue Active Substances, Total Organic Carbon) to assess the amount of amendment that was being added to or flushed from the media.

3.6 USBM Utilization Results and Discussion

3.6.1.1 Data Analysis and Interpretation

In agreement with the Beaker Test observation, Utilization Testing (modified USBM consumption testing) verified the poor permeability characteristics of the waste rock material and the need to agglomerate. Initial dose amounts for the amendments were also determined. The results are included in Appendix B-3.

In the SLS rinsing tests (U.1.1 through U.1.5) varying amounts of SLS were added to a standard 800-gram mass of WR to bracket the amount of SLS that would be "sorbed" or consumed due to the unique characteristics of the prepared WR sample. This mass application rate would be the minimum threshold added in subsequent testing that involved SLS. Additional SLS would be included in those test solution applications assuming that the threshold mass is otherwise unavailable for functioning as a bactericide on *ATBFO* populations. Interestingly, the pre-wetting of the sample (U.1.5 test) returned significantly more foam after the first rinse with distilled water compared to the U.1.4 test which received an identical amount of SLS (90 mg/Kg). The reason for this difference in behavior is unknown.

Quantitative validation of the qualitative foaming assays in USBM1 tests was also done using Methylene Blue Active Substances (MBAS) analyses. Agreement on losses estimated by foam tests and that by quantitative MBAS analysis was 68% - 88%, with one outlier at 22%. However, the presence of residual surfactant following passage through the waste rock was chemically validated.

As previously discussed above, SLS sorption losses appear to be mitigated by the addition of bicarbonate alkalinity. The exact mechanisms are unknown but the U.2.1 through U.2.4 test suggests that at least 2.45 grams of $NaHCO_3$ per kilogram of WR greatly improves the preservation of foam and SLS in the rinsed samples and the addition of more sodium bicarbonate is unnecessary to observe the same results: foam/SLS was still being eluted from the WR samples after they received ten 100-mL rinses.

However, estimation of residual surfactant (or surfactant losses) by foam volume was rendered ineffective in the USBM2 tests following the addition of $NaHCO_3$, and the discrepancy increased with increasing amounts of the compound (data not shown). The residual surfactant was quantified instead by MBAS analysis.

The unbuffered milk leach tests (U.3) verified the Beaker Test results in that even 20% strength milk can reduce sample permeability when curdled milk (curds) plug the pore spaces in the agglomerated WR sample. Clearly, subsequent 20 Kg proof-of-principle tests that would receive unbuffered milk would need to do so at a significantly diluted strength to avoid plugging.

The buffered milk leach tests (U.4 series) examined the effects of the addition of the minimal amount of $NaHCO_3$ (2.45 grams per Kg) on the apparent permeability of agglomerated WR. Earlier sieve and agglomeration testing results suggest that the milk could lessen solids loss in the test unit and that the addition of sodium bicarbonate alone could clog the pore spaces with metal precipitates. In either situation, clogging in test unit could occur to the extent that sampling would be compromised.

Interestingly, the U.4 series tests revealed that the combination of milk and sodium bicarbonate (rinse 4.1.a.1) seemed to slightly improve the permeability of the WR compared to milk solution alone. The acid rinse data (Appendix B-3) suggest that a significant amount of curds and whey (the primary milk components) are retained in the sample from the initial addition and repeated application of milk rinses do not increase milk retention.

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Appendix C. Cost Summary and Cost Backup Sheets

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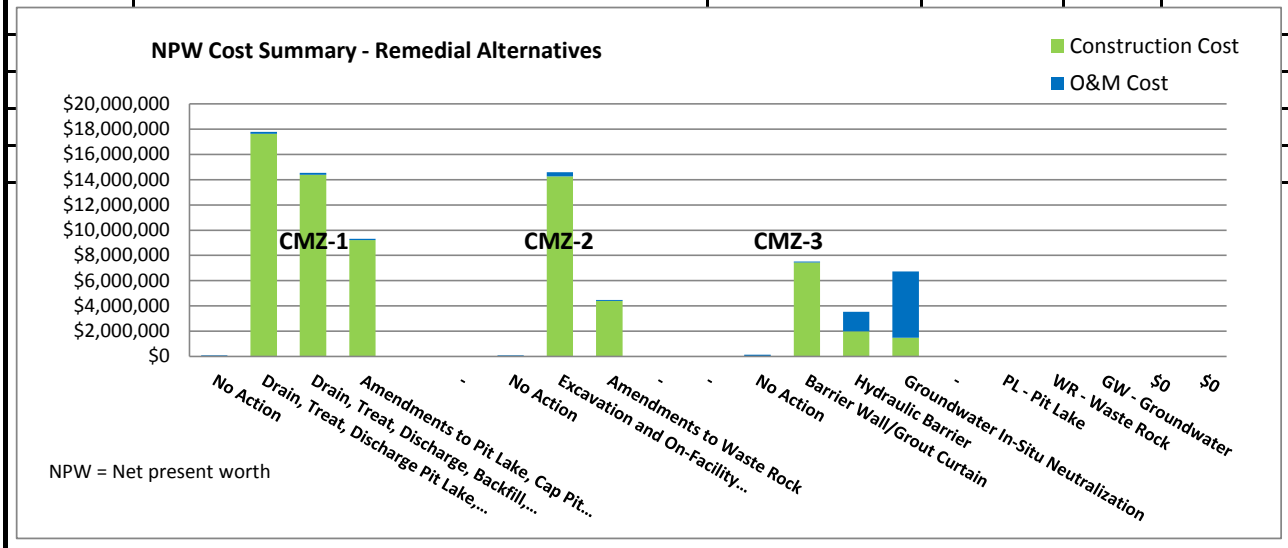
Feasibility Study Cost Estimate Summary

Project:	Barite Hill	**Report:**	Feasibility Study Cost Estimate		
Location:	McCormick, SC	**Project Number:**	049038	**Revision:**	0
Project Phase:	OU1 FS Rev 0	**Date:**	6/14/2018	**Stage:**	0
Operable Unit:	1	**Estimated By:**	RGD	**Checked By:**	ECH

Alternative	Description	Construction Cost	O&M Cost	Yrs	NPW Total
CMZ-1 Pit Lake					
PL#1	No Action	$0	$94,160	30	$94,200
PL#2	Drain, Treat, Discharge Pit Lake, Backfill	$17,636,097	$142,394	30	$17,778,500
PL#3	Drain, Treat, Discharge, Backfill, Wetland	$14,394,139	$155,863	30	$14,550,000
PL#4	Amendments to Pit Lake, Cap Pit Floor	$9,224,251	$91,476	30	$9,315,700
-	-	-	-	-	-
-	-	-	-	-	-
CMZ-2 Waste Rock Area					
WR#2	No Action	$0	$91,084	30	$91,100
WR#2	Excavation and On-Facility Encapsulation	$14,258,471	$325,857	30	$14,584,300
WR#3	Amendments to Waste Rock	$4,400,646	$79,079	30	$4,479,700
-	-	-	-	-	-
-	-	-	-	-	-
CMZ-3 Groundwater					
GW#1	No Action	$0	$122,206	30	$122,200
GW#2A	Barrier Wall/Grout Curtain	$7,432,326	$74,495	30	$7,506,800
GW#2B	Hydraulic Barrier	$1,995,286	$1,525,832	30	$3,521,100
GW#3	Groundwater In-Situ Neutralization	$1,467,917	$5,253,119	30	$6,721,000
-	-	-	-	-	-

Notes: PL - Pit Lake
WR - Waste Rock
GW - Groundwater



Feasibility Study Cost Estimate

Total NPW Cost: $94,200

		Alternative #:	PL#1	CMZ-1, Pit Lake #1	
Project:	Barite Hill	**Title:**	No Action		
Location:	McCormick, SC	**Project Number:**	049038	**Base Year:**	2016
Project Phase:	OU1 FS Rev 0	**Date:**	6/14/2018	**Revision:**	0

Task Description: Sitewide costs applicable to each remedial alternative. Includes costs for 5YRs, maintenance of land use restrictions, site inspections. Includes LTM costs for sampling COCs in pit lake every 5 years for 30 years.

Cost Basis: Detailed estimate

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
			Subtotal - Capital Costs:		$ -
Capital Contingency	30%	of Capital Cost			$ -
Legal Fees, Licenses & Permits[1]	0.5%				$ -
Engineering & Administrative[1]	8%				$ -
Contractor Fee[2]	10%	of Capital Cost			$ -
			Total Capital Cost:		$ -

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

O&M Costs

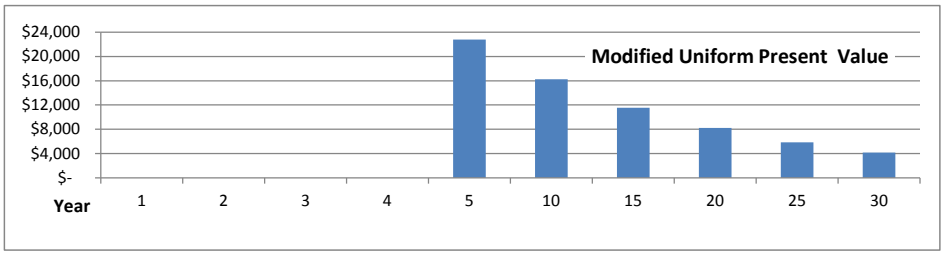
O&M Period		
30	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

1.0 Site-Wide Costs and Monitoring (Year 1 to Year 30) — **Annual Cost**

Sample surface water in pit lake at two locations from 3 depths field parameters, COCs every 5 years for 30 years (6 events); 8 hour day - 2 day effort, 6 hr travel, 4 hr prep. Site maintenance. Complete 5-Yr Reviews and general support to EPA.

Labor	30	yr	1	total	$	20,667	$	20,667
Travel	30	yr	1	total	$	4,230	$	4,230
Materials/Equipment/Subcontractors	30	yr	1	total	$	3,570	$	3,570
Analytical - Soil	30	yr	1	total	$	-	$	-
Analytical - Water	30	yr	1	total	$	3,473	$	3,473
							$	**31,940**

5 Frequency of Periodic Annual Cost (yrs)



Net Present Worth (NPW) Subtotal: **$ 68,921**

O&M Contingency	15%	of NPW Cost	$	10,338
Engineering & Administrative[1]	8%		$	6,341
Contractor Fee[2]	10%		$	8,560
		Subtotal - O&M Costs:	**$**	**94,160**

[1] Applied to O&M subtotal and contingency

[2] Applied to O&M subtotal, contingency, and E&A

Net Present Worth derived from summation of Modified Uniform Present Value

Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Total NPW Cost Estimate: **$ 94,200**

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $17,778,500

Alternative #: PL#2 **CMZ-1 Pit Lake #2**

Project: Barite Hill
Location: McCormick, SC
Project Phase: OU1 FS Rev 0

Title: Drain, Treat, Discharge Pit Lake, Backfill
Project Number: 049038
Date: 6/14/2018
Base Year: 2107
Revision: 0

Task Description: Construct temporary waste water treatment system. Drain and treat pit lake water (~73 Mgal). Discharge treated water to the North Tributary. Line pit floor with limestone and clay. Backfill pit with offsite borrow material to level of spillway (~400,000 cy)

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Labor	1	ls	$ 81,732		$ 81,732
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
			Design/Bench/Pilot Scale Subtotal:		**$ 82,232**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (1/1 days)					
Labor	1	ls	$ 27,945		$ 27,945
Travel	1	ls	$ 5,044		$ 5,044
Materials/Equipment/ Subcontractors	1	ls	$ 11,308		$ 11,308
			Mobilization Subtotal:		**$ 44,297**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (1 days);					
Materials/Equipment/ Subcontractors	1	ls	$ 12,935		$ 12,935
			Site Preparation Subtotal:		**$ 12,935**
4.0 Drain Pit Lake, Treat and Discharge Water					
Drain Pit Lake, Treat Lake Water, Discharge to North Tributary					
Treatment System Construction	1	ls	$ 610,000		$ 610,000
Treatment and Discharge	1	ls	$ 2,800,000		$ 2,800,000
			Drain, Treat Lake water, Discharge:		**$ 3,410,000**
5.0 Amendments to Pit Floor					
Add Amendments (Lime) to Pit Floor					
Labor	1	ls	$ 22,572		$ 22,572
Travel	1	ls	$ 4,824		$ 4,824
Materials/Equipment/ Subcontractors	1	ls	$ 1,623,500		$ 1,623,500
			Liner Installation Subtotal:		**$ 1,650,897**
8.0 Backfill Placement					
Clean backfill of all soils.					
Backfill with Clean Soil	400,000	lcy	$ 19.00		$ 7,600,000
			Backfill Subtotal:		**$ 7,600,000**
9.0 Site Restoration					
Contour Pit Cover, Restore vegetation					
Final grade and restore	8	acre	$ 4,500.00		$ 34,917
Restore Vegetation	7.76	acre	$ 1,818		$ 14,104
			Site Restoration Subtotal:		**$ 49,021**

Notes:

1)
2)

		Subtotal - Capital Costs:	**$ 12,849,382**
Capital Contingency	15%	of Capital Cost	$ 1,927,407
Legal Fees, Licenses & Permits[1]	0.5%		$ 73,884
Engineering & Administrative[1]	8%		$ 1,182,143
Contractor Fee[2]	10%	of Capital Cost	$ 1,603,282
		Total Capital Cost:	**$ 17,636,097**

[1] Applied to capital subtotal and contingency
[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC
Alternative #: PL#2 — CMZ-1 Pit Lake #2
Title: Drain, Treat, Discharge Pit Lake, Backfill

O&M Costs

O&M Period		
	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

10.0 Cover O&M Costs — **Annual Cost**

Maintenance of vegetation cover and inspect repair pit cover for 30 years.

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
Labor	30	yr	1	total	$ 4,733		$ 4,733
Travel	30	yr	1	total	$ 166		$ 166
Materials/Equipment/Subcontractors	30	yr	1	total	$ 3,500		$ 3,500
Analytical - Water	30	yr	1	total	$ -		$ -
		yr		total	$ -		$ -
		yr		total	$ -		$ -
							$ 8,399

Frequency of Periodic Annual Cost: 1 yrs

Net Present Worth (NPW) Subtotal: $ 104,226

O&M Contingency	15%	of NPW Cost	$ 15,634
Engineering & Administrative[1]	8%		$ 9,589
Contractor Fee[2]	10%		$ 12,945

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

Subtotal - O&M Costs: $ 142,394

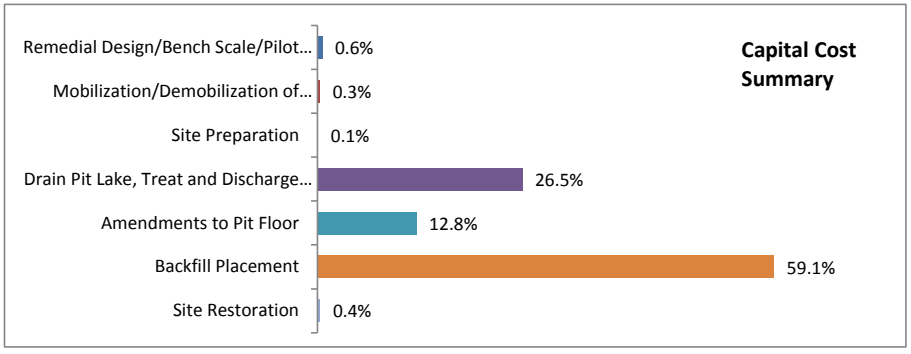
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 17,778,500



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $14,550,000

		Alternative #:	PL#3	CMZ-1, Pit Lake #3	
Project:	Barite Hill	**Title:**	Drain, Treat, Discharge, Backfill, Wetland		
Location:	McCormick, SC	**Project Number:**	049038	**Base Year:**	2017
Project Phase:	OU1 FS Rev 0	**Date:**	6/14/2018	**Revision:**	0

Task Description: Construct temporary waste water treatment system. Drain and treat pit lake water (~73 Mgal). Discharge treated water to the North Tributary. Line pit floor with lime. Partially backfill pit (~250,000 cy) with onsite fill material, Create wetland

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Labor	1	ls	$ 81,732		$ 81,732
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
			Design/Bench/Pilot Scale Subtotal:		**$ 82,232**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (1/1 days)					
Labor	1	ls	$ 27,945		$ 27,945
Travel	1	ls	$ 5,044		$ 5,044
Materials/Equipment/ Subcontractors	1	ls	$ 11,308		$ 11,308
			Mobilization Subtotal:		**$ 44,297**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (1 days);					
Materials/Equipment/ Subcontractors	1	ls	$ 12,935		$ 12,935
			Site Preparation Subtotal:		**$ 12,935**
4.0 Drain Pit Lake, Treat and Discharge Water					
Excavation of soils; staging of soils.					
Treatment System Construction	1	ls	$ 610,000		$ 610,000
Treatment and Discharge	1	ls	$ 2,800,000		$ 2,800,000
			Soil Excavation and Staging Subtotal:		**$ 3,410,000**
5.0 Amendments to Pit Floor					
Add amendments (lime) to pit floor					
Labor	1	ls	$ 22,572		$ 22,572
Travel	1	ls	$ 3,444		$ 3,444
Materials/Equipment/ Subcontractors	1	ls	$ 1,623,000		$ 1,623,000
			Liner Installation Subtotal:		**$ 1,649,017**
6.0 Backfill Placement					
Partially backfill pit					
Mobilization	1	ls	$ 4,750,000		$ 4,750,000
			Composite Cap Subtotal:		**$ 4,750,000**

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC

Alternative #: PL#3 — CMZ-1, Pit Lake #3
Title: Drain, Treat, Discharge, Backfill, Wetland

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
7.0 Wetland Construction					
Construct a wetland within the partially backfilled pit lake (~6 acres).					
Install wetland	1	ls	$ 489,840		$ 489,840
			Transport and Disposal Subtotal:		**$ 489,840**
8.0 Site Restoration					
Replace liner and restore vegetation					
Final grade and restore	8	bcy	$ 4,500.00		$ 34,917
Restore Vegetation	7.76	ls	$ 1,818		$ 14,104
			Site Restoration Subtotal:		**$ 49,021**
Notes:					
1)					
2)					
			Subtotal - Capital Costs:		**$ 10,487,342**
Capital Contingency	15%	of Capital Cost			$ 1,573,101
Legal Fees, Licenses & Permits[1]	0.5%				$ 60,302
Engineering & Administrative[1]	8%				$ 964,835
Contractor Fee[2]	10%	of Capital Cost			$ 1,308,558
			Total Capital Cost:		**$ 14,394,139**

[1] Applied to capital subtotal and contingency
[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**PL#3** — **CMZ-1, Pit Lake #3**
Location:	McCormick, SC	**Title:**	**Drain, Treat, Discharge, Backfill, Wetland**

O&M Costs

O&M Period		
	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
10.0 Wetland O&M Costs							**Annual Cost**
Maintenance of vegetation cover and inspect wetland for 30 years. Vist every 2nd year							
Labor	30	yr	1	total	$ 5,424		$ 5,424
Travel	30	yr	1	total	$ 269		$ 269
Materials/Equipment/Subcontractors	30	yr	1	total	$ 3,500		$ 3,500
Analytical - Water	30	yr	1	total	$ -		$ -
		yr		total	$ -		$ -
		yr		total	$ -		$ -
							$ 9,194
Frequency of Periodic Annual Cost:	1	yrs					
						Net Present Worth (NPW) Subtotal:	**$ 114,085**
O&M Contingency			15%	of NPW Cost			$ 17,113
Engineering & Administrative[1]			8%				$ 10,496
Contractor Fee[2]			10%				$ 14,169
						Subtotal - O&M Costs:	**$ 155,863**

[1] Applied to O&M subtotal and contingency

[2] Applied to O&M subtotal, contingency, and E&A

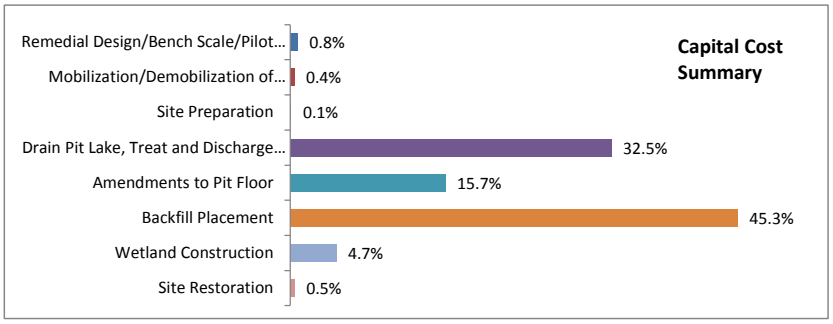
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: **$ 14,550,000**



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate					Total NPW Cost:	$9,315,700
		Alternative #:	PL#4	CMZ-1 Pit Lake #4		
Project:	Barite Hill	Title:	Amendments to Pit Lake, Cap Pit Floor			
Location:	McCormick, SC	Project Number:	049038	Base Year:	2017	
Project Phase:	OU1 FS Rev 0	Date:	6/14/2018	Revision:	0	
Task Description:	*Pit Lake Neutralization with Lime Addition followed by Alkalinity addition to Sustain Neutralization, Pit Lake Bottom Encapsulation*					
Cost Basis:	Detailed estimate provided by (Sovereign) with input from B&V					

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design, RD support tasks (plans, field investigation, coordination with agencies, permits), travel, treatability and/or pilot tests, site surveys, design vendor support.					
Labor	1	ls	$ 59,985		$ 59,985
RD Support	1	ls	$ 8,000		$ 8,000
Travel	1	ls	$ 7,020		$ 7,020
			Design/Bench/Pilot Testing Subtotal:		**$ 75,005**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days).					
Labor	1	ls	$ 28,360		$ 28,360
Travel	1	ls	$ 4,778		$ 4,778
Materials/Equipment/ Subcontractors	1	ls	$ 200		$ 200
			Mobilization Subtotal:		**$ 33,338**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days).					
Materials/Equipment/ Subcontractors	1	ls	$ 4,400		$ 4,400
			Site Preparation Subtotal:		**$ 4,400**
4.0 Pit Lake Neutralization					
Neutralization of the pit lake using lime, limestone, wood products and organic material.					
Bulk Neutralization	1	ls	$ 627,100		$ 627,100
Alkalinity Addition	1	ls	$ 3,328,800		$ 3,328,800
			Pit Lake Neutralizationl Subtotal:		**$ 3,955,900**

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**PL#4** — **CMZ-1 Pit Lake #4**
Location:	McCormick, SC	**Title:**	**Amendments to Pit Lake, Cap Pit Floor**

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
5.0 Pit Floor Encapsulation					
Install AquaBlok® within pit lake to encapsulate the pit floor.					
AquaBlock Subcontractor	1	ls	$ 2,652,000		$ 2,652,000
			Pit Floor Encapsulation Subtotal:		**$ 2,652,000**
Notes:					
1)					
			Subtotal - Capital Costs:		**$ 6,720,643**
Capital Contingency	15%	of Capital Cost			$ 1,008,096
Legal Fees, Licenses & Permits[1]	0.5%				$ 38,644
Engineering & Administrative[1]	8%				$ 618,299
Contractor Fee[2]	10%	of Capital Cost			$ 838,568
			Total Capital Cost:		**$ 9,224,251**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**PL#4** — **CMZ-1 Pit Lake #4**
Location:	McCormick, SC	**Title:**	**Amendments to Pit Lake, Cap Pit Floor**

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
8.0 Performance Monitoring/O&M	5						**Annual Cost**
Collect samples from pit lake. Two locations from two depths.							
Labor	5	yr	1	total	$ 1,729		$ 1,729
Travel	5	yr	1	total	$ 575		$ 575
Materials/Equipment/Subcontractors	5	yr	1	total	$ 12,000		$ 12,000
Analytical - Water	5	yr	1	total	$ 2,026		$ 2,026
							$ 16,330
				Net Present Worth (NPW) Subtotal:			**$ 66,957**
O&M Contingency			15%	of NPW Cost			$ 10,044
Engineering & Administrative[1]			8%				$ 6,160
Contractor Fee[2]			10%				$ 8,316
						Subtotal - O&M Costs:	**$ 91,476**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

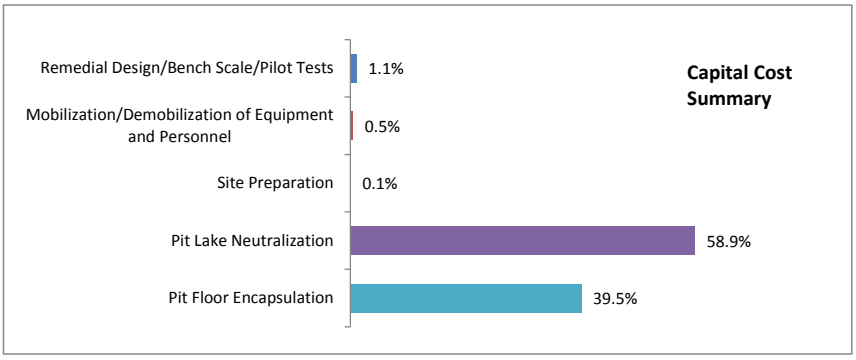
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 9,315,700



General Assumptions
1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $91,100

Alternative #:	WR#1	CMZ-2, Waste Rock #1			
Project:	Barite Hill	**Title:**	No Action		
Location:	McCormick, SC	**Project Number:**	049038	**Base Year:**	2016
Project Phase:	OU1 FS Rev 0	**Date:**	6/14/2018	**Revision:**	0

Task Description: Sitewide costs applicable to each remedial alternative. Includes costs for 5YRs, maintenance of land use restrictions, site inspections. Includes LTM costs for inspection and repair of waste rock cap for 30 years.

Cost Basis: Detailed estimate

Item	Qty.	Unit	Unit Cost	Note	Cost ($)

Capital Costs

Subtotal - Capital Costs: $ -

Capital Contingency	15%	of Capital Cost	$	-
Legal Fees, Licenses & Permits[1]	0.5%		$	-
Engineering & Administrative[1]	8%		$	-
Contractor Fee[2]	10%	of Capital Cost	$	-

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Total Capital Cost: $ -

O&M Costs

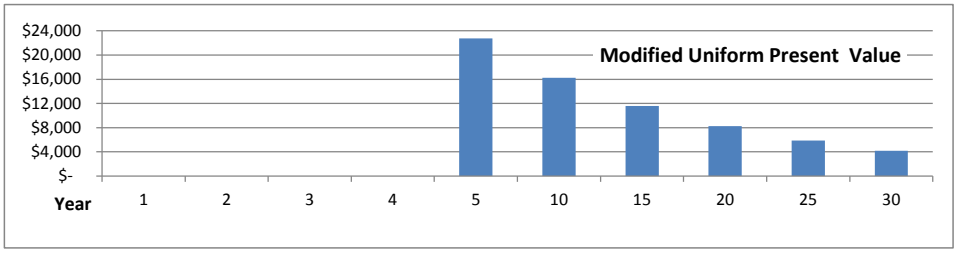
O&M Period		
30	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

1.0 Site-Wide Costs and Monitoring (Year 1 to Year 30) — **Annual Cost**

Inspect and repair, as needed, waste rock cap every 5 years for 30 years (6 events), 8 hour day - 2 day effort, 6 hr travel, 4 hr prep. Site maintenance. Complete 5-Yr Reviews and general support to EPA

Labor	30	yr	1	total	$	20,667	$	20,667
Travel	30	yr	1	total	$	4,230	$	4,230
Materials/Equipment/Subcontractors	30	yr	1	total	$	6,000	$	6,000
Analytical - Soil	30	yr	1	total	$	-	$	-
Analytical - Water	30	yr	1	total	$	-	$	-
							$	**30,897**

5 Frequency of Periodic Annual Cost (yrs)



Net Present Worth (NPW) Subtotal: $ 66,670

O&M Contingency	15%	of NPW Cost	$	10,000
Engineering & Administrative[1]	8%		$	6,134
Contractor Fee[2]	10%		$	8,280

[1] Applied to O&M subtotal and contingency

[2] Applied to O&M subtotal, contingency, and E&A

Subtotal - O&M Costs: $ 91,084

Net Present Worth derived from summation of Modified Uniform Present Value (UPV*)

Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Total NPW Cost Estimate: $ 91,100

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate						Total NPW Cost:	$14,584,300
		Alternative #:	WR#2	CMZ-2, Waste Rock #2			
Project:	Barite Hill	Title:	Excavation and On-Facility Encapsulation				
Location:	McCormick, SC	Project Number:	049038	Base Year:	2017		
Project Phase:	OU1 FS Rev 0	Date:	6/14/2018	Revision:	0		

Task Description: Excavation of capped waste rock and transport to designated area on-site. Encapsulation of excavated waste rock. Clean backfill, grade and vegetative cover.

Cost Basis: Detailed estimate with subcontractor quotes

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Labor	1	ls	$ 77,790	$	77,790
Travel	1	ls	$ 800	$	800
Materials/Equipment/Subcontractors	1	ls	$ 500	$	500
			Design/Bench/Pilot Scale Subtotal:	**$**	**79,090**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (1/1 days)					
Labor	1	ls	$ 27,945	$	27,945
Travel	1	ls	$ 5,044	$	5,044
Materials/Equipment/ Subcontractors	1	ls	$ 11,308	$	11,308
			Mobilization Subtotal:	**$**	**44,297**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (1 days);					
Labor	1	ls	$ 31,274	$	31,274
Materials/Equipment/ Subcontractors	1	ls	$ 53,984	$	53,984
			Site Preparation Subtotal:	**$**	**85,258**
4.0 Install Sheet Pile Wall					
Install 500-ft of sheet pile wall along the west side of excavation to 25 ft bls to keep out pit lake water.					
Shoring Subcontractor	500	ft	$ 1,678	$	839,000
			Sheet Pile Wall Subtotal:	**$**	**839,000**
5.0 Waste Rock Excavation and Staging					
Excavation of soils; staging of soils.					
Excavate Clean Overburden	1	ls	$ 385,200	$	385,200
Excavate Soils (Waste Rock)	1	ls	$ 3,358,500	$	3,358,500
			Waste Rock Excavation and Staging Subtotal:	**$**	**3,743,700**
6.0 Geosynthetic Clay Liner for Surface Soil Cap					
GCL Installation with clean soil cover					
Mobilization	1	ls	$ 25,000	$	25,000
Subcontract Labor	1	ls	$ 720,661	$	720,661
Liner and Geocomposite	1	ls	$ 480,000	$	480,000
			Composite Cap Subtotal:	**$**	**1,225,661**

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**WR#2** — **CMZ-2, Waste Rock #2**
Location:	**McCormick, SC**	**Title:**	**Excavation and On-Facility Encapsulation**

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
7.0 Backfill Placement					
Backfill waste rock excavation with clean soil from off-site.					
Backfill Overburden/Clean/Treated Soils	256,000	bcy	$ 16.62		$ 4,254,720
Place Impacted Soil on Cap		lcy	$ -		$ -
			Backfill Subtotal:		**$ 4,254,720**
8.0 Site Restoration					
Replace liner and restore vegetation					
Final grade and restore	7	bcy	$ 4,500.00		$ 29,752
Restore Vegetation	6.61	ls	$ 1,818		$ 12,017
Stormwater Controls	1.00	ls	$ 75,000		$ 75,000
			Site Restoration Subtotal:		**$ 116,769**
Notes:					
1)					
2)					
			Subtotal - Capital Costs:		**$ 10,388,496**
Capital Contingency	15%	of Capital Cost			$ 1,558,274
Legal Fees, Licenses & Permits[1]	0.5%				$ 59,734
Engineering & Administrative[1]	8%				$ 955,742
Contractor Fee[2]	10%	of Capital Cost			$ 1,296,225
			Total Capital Cost:		**$ 14,258,471**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**WR#2** — **CMZ-2, Waste Rock #2**
Location:	McCormick, SC	**Title:**	**Excavation and On-Facility Encapsulation**

O&M Costs

O&M Period	30 yrs	7.00%	Discount Rate	
		0.00%	Constant Escalation Factor	

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
9.0 Liner/Cover O&M Costs							**Annual Cost**
Maintenance of vegetation cover and inspect repair cap for 30 years.							
Labor	30	yr	1	total	$ 5,856		$ 5,856
Travel	30	yr	1	total	$ 1,364		$ 1,364
Materials/Equipment/Subcontractors	30	yr	1	total	$ 12,000		$ 12,000
Analytical - Water	30	yr	1	total	$ -		$ -
		yr		total	$ -		$ -
		yr		total	$ -		$ -
							$ 19,221
Frequency of Periodic Annual Cost:	5	yrs					
						Net Present Worth (NPW) Subtotal:	**$ 238,513**
O&M Contingency			15%	of NPW Cost			$ 35,777
Engineering & Administrative[1]			8%				$ 21,943
Contractor Fee[2]			10%				$ 29,623
						Subtotal - O&M Costs:	**$ 325,857**

[1] Applied to O&M subtotal and contingency

[2] Applied to O&M subtotal, contingency, and E&A

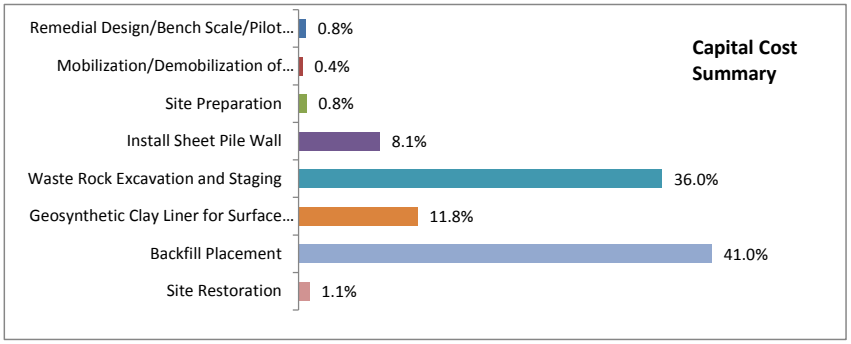
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: **$ 14,584,300**



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $4,479,700

Alternative #:	WR#3	CMZ-2, Waste Rock #3			
Project:	Barite Hill	**Title:**	Amendments to Waste Rock		
Location:	McCormick, SC	**Project Number:**	049038	**Base Year:**	2016
Project Phase:	FS	**Date:**	5/24/2018	**Revision:**	0

Task Description: Installation of both shallow and deep amendment injection wells. Construction of amendment mixing and delivery system. Add amendments to capped waste rock area.

Cost Basis: Detailed estimate with subcontractor quotes (Sovereign, 2018, Cascade, 2018)

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design, RD support tasks (plans, field investigation, coordination with agencies, permits), travel, treatability and/or pilot tests, site surveys, design vendor support.					
Labor	1	ls	$ 34,636		$ 34,636
RD Support	1	ls	$ 8,000		$ 8,000
Travel	1	ls	$ 645		$ 645
Treatability Testing	1	ls	$ 250,000		$ 250,000
			Design/Bench/Pilot Testing Subtotal:		**$ 293,281**
2.0 Clean Water Makeup System					
Construction of clean water makeup system for injections.					
Materials/Equipment/ Subcontractors	1	ls	$ 37,500		$ 37,500
			Mobilization Subtotal:		**$ 37,500**
3.0 Buffered Milk Amendment Makeup System					
Construction of bufferd milk makeup system for injections.					
Materials/Equipment/ Subcontractors	1	ls	$ 532,000		$ 532,000
			Site Preparation Subtotal:		**$ 532,000**
4.0 Deep Well Injections - Plus all amendments and amendments mix/injection system, and operations of system					
Install 15 deep injection wells. 5 in regolith. 10 into bedrock. Inject amendments into wells within waste rock area					
Treatment Subcontractor	1	ls	$ 1,240,555		$ 1,240,555
			Deep Well Subtotal:		**$ 1,240,555**
5.0 Shallow Well Injections					
Install approximately 100 shallow (~10 ft bls) injection wells. 2" diameter with 5-foot screens. Installed using DPT. Inject amendments into waste rock.					
Treatment Subcontractor	1	ls	$ 1,102,905		$ 1,102,905
			Shallow Well Subtotal:		**$ 1,102,905**

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**WR#3** — **CMZ-2, Waste Rock #3**
Location:	McCormick, SC	**Title:**	**Amendments to Waste Rock**

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Notes:					
1)					
			Subtotal - Capital Costs:		**$ 3,206,241**
Capital Contingency	15%	of Capital Cost			$ 480,936
Legal Fees, Licenses & Permits[1]	0.5%				$ 18,436
Engineering & Administrative[1]	8%				$ 294,974
Contractor Fee[2]	10%	of Capital Cost			$ 400,059
			Total Capital Cost:		**$ 4,400,646**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC
Alternative #: WR#3 — CMZ-2, Waste Rock #3
Title: Amendments to Waste Rock

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
6.0 Performance Monitoring/O&M	5						**Annual Cost**
Sample 4 monitoring wells within former waste rock areal for field parameters and COCs quarterly every year for 5 years (20 events); 9 hour day - 2 day effort, 6 hr travel, 4 hr prep.							
Labor	5	yr	1	total	$	5,491	$ 5,491
Travel	5	yr	1	total	$	2,060	$ 2,060
Materials/Equipment/Subcontractors	5	yr	1	total	$	4,250	$ 4,250
Analytical - Water	5	yr	1	total	$	2,315	$ 2,315
							$ 14,117
				Net Present Worth (NPW) Subtotal:			**$ 57,882**
O&M Contingency			15%	of NPW Cost			$ 8,682
Engineering & Administrative[1]			8%				$ 5,325
Contractor Fee[2]			10%				$ 7,189
						Subtotal - O&M Costs:	**$ 79,079**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

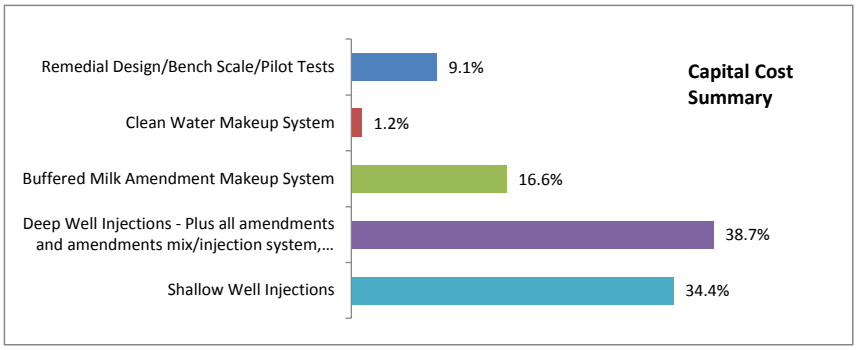
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: **$ 4,479,700**



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate

Total NPW Cost: $122,200

Alternative #:	GW#1	CMZ-2, Groundwater #1			
Project:	Barite Hill	**Title:**	No Action		
Location:	McCormick, SC	**Project Number:**	049038	**Base Year:**	2016
Project Phase:	OU1 FS Rev 0	**Date:**	6/14/2018	**Revision:**	0

Task Description: Sitewide costs applicable to each remedial alternative. Includes costs for 5YRs, maintenance of land use restrictions, site inspections. Includes LTM costs for sampling 14 goundwater montoring wells for COCs for 30 years.

Cost Basis: Detailed estimate

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
Subtotal - Capital Costs:					$ -
Capital Contingency	15%	of Capital Cost			$ -
Legal Fees, Licenses & Permits[1]	0.5%				$ -
Engineering & Administrative[1]	8%				$ -
Contractor Fee[2]	10%	of Capital Cost			$ -
Total Capital Cost:					$ -

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

O&M Costs

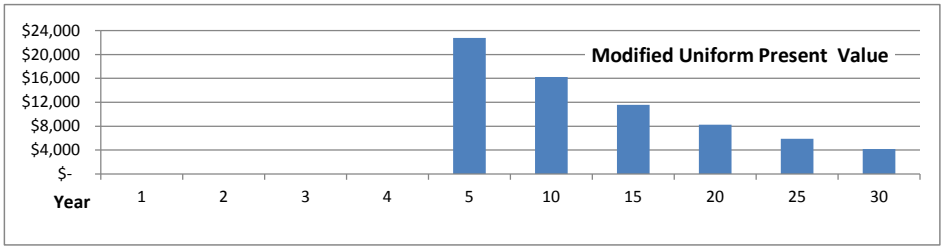
O&M Period		
30	7.00%	Discount Rate
	0.00%	Constant Escalation Factor

1.0 Site-Wide Costs and Monitoring (Year 1 to Year 30) — **Annual Cost**

Sample 14 groundwater monitoring wells every 5 years for 30 years (6 events); 8 hour day - 3 day effort, 6 hr travel, 4 hr prep. Site maintenance. Complete 5-Yr Reviews and general support to EPA.

Labor	30	yr	1	total	$	22,702	$	22,702
Travel	30	yr	1	total	$	4,648	$	4,648
Materials/Equipment/Subcontractors	30	yr	1	total	$	6,000	$	6,000
Analytical - Soil	30	yr	1	total	$	-	$	-
Analytical - Water	30	yr	1	total	$	8,104	$	8,104
							$	**41,454**

5 Frequency of Periodic Annual Cost (yrs)



Net Present Worth (NPW) Subtotal: **$ 89,450**

O&M Contingency	15%	of NPW Cost	$	13,417
Engineering & Administrative[1]	8%		$	8,229
Contractor Fee[2]	10%		$	11,110
Subtotal - O&M Costs:			**$**	**122,206**

[1] Applied to O&M subtotal and contingency

[2] Applied to O&M subtotal, contingency, and E&A

Net Present Worth derived from summation of Modified Uniform Present Value (UPV*)

Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Total NPW Cost Estimate: **$ 122,200**

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate | **Total NPW Cost:** $7,506,800

		Alternative #:	GW#2A	CMZ-3, Groundwater #2A	
Project:	Barite Hill	**Title:**	Barrier Wall/Grout Curtain		
Location:	McCormick, SC	**Project Number:**	049038	**Base Year:**	2017
Project Phase:	OU1 FS Rev 0	**Date:**	6/14/2018	**Revision:**	0

Task Description: Construct Vertical Engineered Barrier to divert GW away from Waste Rock Area and Pit Lake: Upgradient barrier wall (600-ft) to top of bedrock (70 ft bls). Grout Curtain within bedrock from 70 ft bls to 160 bls. Install open limestone-lined channels at pit lake spillway and storm water discharge points into Pit Lake. Includes dewatering capped waste rock.

Cost Basis: Experience (Brunswick, Camilla BW's, Boone Dam Site)

Capital Costs

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
1.0 Slurry Wall and Grout Curtain Design					
Remedial Design, RD support taks (plans, field investigation, coordination with agencies, permits), travel, treatability and/or pilot tests, site surveys, design vendor support.					
Remedial Design Professional Labor	1	ls	$ 31,447		$ 31,447
RD Support	1	ls	$ 55,500		$ 55,500
Travel	1	ls	$ 1,560		$ 1,560
Subcontractors/ODC	1	ls	$ 130,000		$ 130,000
Bench Scale Testing	1	ls	$ 38,300		$ 38,300
				Design Subtotal:	**$ 256,807**
2.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials					
Materials/Equipment/Subcontractors	1	ls	$ 35,213		$ 35,213
				per	**$ 35,213**
3.0 Grout Curtain					
Strip up 80-feet of railroad track along edges of treatment zone, stage and replace at end of project					
Grout Curtain Installation	1	ls	$ 3,588,273		$ 3,588,273
Roadway Removal/Replacement	1	ls	$ -		$ -
				Grout Curtan Subtotal:	**$ 3,588,273**
4.0 Slurry Wall Construction					
Procurement, planning, preparation, and installation of 600-ft slurry wall to an average depth of 70-ft bls.					
Trench Wall Thickness	3	ft			
Depth of Wall	70	ft			
Perimeter Linear Feet	600	ft			
Cap Area:	42,000	sf			
Mobilize/Demobilize Drilling Rig & Crew	1	ls	$ 15,003		$ 15,003
Field/Construction Oversight (Labor):	1	ls	$ 216,938		$ 216,938
Oversight Travel	1	ls	$ 32,250		$ 32,250
Prepare/Update Plans (Workplan, CM, CQAP, HASP)	1	ls	$ 25,000		$ 25,000
Perimeter Work Platform	4,500	cy	$ 7.00		$ 31,500
Excavation/Trenching, and Construction of Slurry Wall	42,000	sf	$ 18.00		$ 756,000
Miscellaneous	1	ls	$ 7,835		$ 7,835
Decon Rig, Augers, Screen (Rental Equipment)	1	ls	$ 7,940		$ 7,940
Stabilization of Trench Spoils	1	ls	$ 39,816		$ 39,816
				Slurry Wall Subtotal:	**$ 1,132,283**

Notes:

1)

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Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC

Alternative #: GW#2A — CMZ-3, Groundwater #2A
Title: Barrier Wall/Grout Curtain

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
5.0 OLC Installations					
Installation of open limestone channels at the pit lake spillway and channels where storm water discharges into the pit lake.					
Mobilization, Utility Locates/Demobilization	1	ls	$ 2,500		$ 2,500
Limestone	500	tons	$ 50		$ 25,000
Consturction of channel 181,120 sf	1	cy	$ 75,000.00		$ 75,000
					$ 102,500
6.0 Dewatering Waste Rock					
Dewatering system to remove groundwater from waste rock					
Dewatering System	1.00	acres	$ 200,000.0		$ 200,000
Dewatering System Monitoring	1.00	acres	$ 100,000		$ 100,000
					$ 300,000
			Subtotal - Capital Costs:		**$ 5,415,075**
Capital Contingency	15%	of Capital Cost			$ 812,261
Legal Fees, Licenses &	0.5%				$ 31,137
Engineering & Administrative[1]	8%				$ 498,187
Contractor Fee[2]	10%	of Capital Cost			$ 675,666
			Total Capital Cost:		**$ 7,432,326**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC

Alternative #: GW#2A — CMZ-3, Groundwater #2A
Title: Barrier Wall/Grout Curtain

Item			Qty.	Unit	Unit Cost	Note	Cost ($)
O&M Costs							
	O&M Period		7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
7.0 Cap Maintenance and Monitoring	30						**Annual Cost**
Inspect cap, restore vegetation, ever 2nd year. Gauge ~8 monitoring wells							
Labor	30	yr	0.5	total	$ 8,251		$ 4,125
Travel	30	yr	0.5	total	$ 538		$ 269
							$ 4,394
Frequency of Periodic Annual Cost:	1	yrs					
						Net Present Worth (NPW) Subtotal:	**$ 54,527**
O&M Contingency			15%	of NPW Cost			$ 8,179
Engineering & Administrative[1]			8%				$ 5,017
Contractor Fee[2]			10%				$ 6,772
						Subtotal - O&M Costs:	**$ 74,495**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

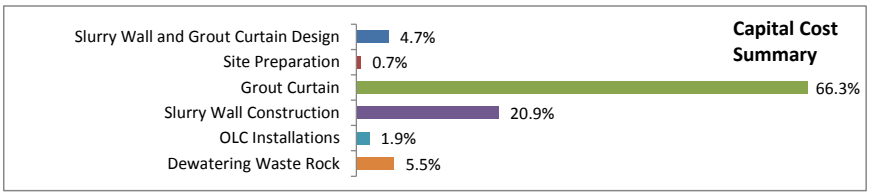
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where: P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: $ 7,506,800



Feasibility Study Cost Estimate						Total NPW Cost:	$3,521,100
		Alternative #:	GW#2B	CMZ-3, Groundwater #2B			
Project:	Barite Hill	Title:	Hydraulic Barrier				
Location:	McCormick, SC	Project Number:	049038	Base Year:	2017		
Project Phase:	OU1 FS Rev 0	Date:	6/14/2018	Revision:	0		
Task Description:	Installation of 8 groundwater extraction wells with pumps upgradient of capped waste rock to create a hydraulic barrier to GW flow through Waste Rock area and into Pit Lake.						
Cost Basis:	Detailed estimate						

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design, RD support taks (plans, field investigation, coordination with agencies, permits), travel, treatability and/or pilot tests, site surveys, design vendor support.					
Remedial Design Professional Labor	1	ls	$ 57,896		$ 57,896
Remedial Design Travel	1	ls	$ 1,740		$ 1,740
Materials/Equipment/Subcontractors	1	ls	$ 500		$ 500
Pilot Scale Testing	1	ls	$ 50,000		$ 50,000
			Design/Bench/Pilot Scale Subtotal:		**$ 110,136**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days).					
Labor	1	ls	$ 18,296		$ 18,296
Travel	1	ls	$ 3,427		$ 3,427
Materials/Equipment/ Subcontractors	1	ls	$ 2,990		$ 2,990
			Mobilization Subtotal:		**$ 24,713**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre drilling meeting, materials (3 days).					
Labor	1	ls	$ 2,709		$ 2,709
Travel	1	ls	$ 593		$ 593
Materials/Equipment/ Subcontractors	1	ls	$ 7,067		$ 7,067
			Site Preparation Subtotal:		**$ 10,369**
4.0 Install Extraction Wells					
Drilling of (8) 6-inch barrier extraction wells. Drilling to 160 ft bls. Wells screened from ~50 to ~160 ft bls.					
Labor	1	ls	$ 91,247		$ 91,247
Travel	1	ls	$ 28,949		$ 28,949
Drilling Subcontractor Per/Foot Rate	2560	feet	$ 132		$ 337,920
Drilling Subcontractor - Other	1	ls	$ 24,920		$ 24,920
			Install Injection Well Subtotal:		**$ 483,035**

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC

Alternative #: GW#2B — CMZ-3, Groundwater #2B
Title: Hydraulic Barrier

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
5.0 Construct and Startup storage and neutralizatin system					
Construct and operate a groundwater storage and neutralizaton system. Installation of infiltration pond.					
Labor	1	ls	$ 26,847		$ 26,847
Travel	1	ls	$ 7,671		$ 7,671
Pumps Piping,Controls, Gravity Tanks	1	ls	$ 50,000		$ 50,000
Storage/Neutralization System	1	ls	$ 500,000		$ 500,000
Infiltration Pond	2	ls	$ 100,000		$ 200,000
			EISB Delivery System Subtotal:		**$ 784,518**

Notes:

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		Subtotal - Capital Costs:	**$ 1,453,734**
Capital Contingency	15%	of Capital Cost	$ 218,060
Legal Fees, Licenses & Permits[1]	0.5%		$ 8,359
Engineering & Administrative[1]	8%		$ 133,744
Contractor Fee[2]	10%	of Capital Cost	$ 181,390
		Total Capital Cost:	**$ 1,995,286**

[1] Applied to capital subtotal and contingency
[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC

Alternative #: GW#2B — CMZ-3, Groundwater #2B
Title: Hydraulic Barrier

O&M Costs

	O&M Period					
		7.00%	Discount Rate			
		0.00%	Constant Escalation Factor			

Item	O&M Period	Qty.	Unit	Unit Cost	Note	Cost ($)
6.0 Performance Sampling, O&M Costs	30					**Annual Cost**
Site Visits 2 times per month	30	1		1		**$ 60,002**
Labor	30	12	ls	$ 1,308		$ 15,695
Travel	30	12	ls	$ 116		$ 1,393
Materials/Equipment/Subcontractors	30	12	ls	$ 576		$ 6,912
Analytical	30	12	ls	$ 500		$ 6,000
				Sampling Subtotal:		**$ 30,001**
				Net Present Worth (NPW) Subtotal:		**$ 1,116,844**
O&M Contingency		15%	of NPW Cost			$ 167,527
Engineering & Administrative[1]		8%				$ 102,750
Contractor Fee[2]		10%				$ 138,712
				Subtotal - O&M Costs:		**$ 1,525,832**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

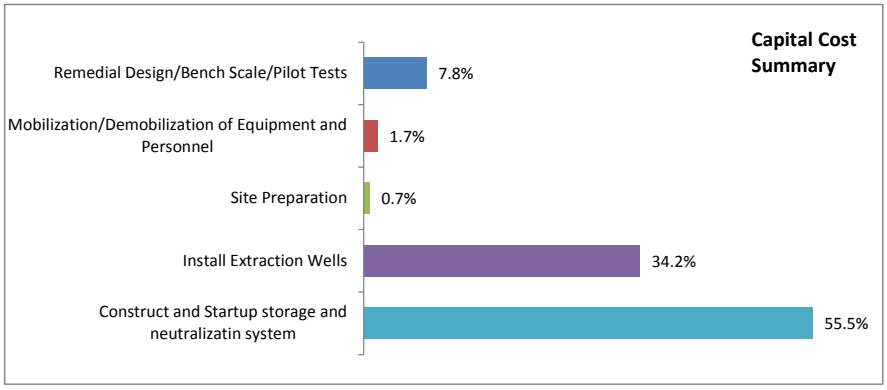
Net Present Worth Formula

$$P = A_o \times \left(\frac{1+e}{d-e}\right) \times \left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: **$ 3,521,100**



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

Feasibility Study Cost Estimate						Total NPW Cost:	$6,721,000
		Alternative #:	GW#3	CMZ-3, Groundwater #3			
Project:	Barite Hill	Title:	Groundwater In-Situ Neutralization				
Location:	McCormick, SC	Project Number:	049038	Base Year:	2107		
Project Phase:	OU1 FS Rev 0	Date:	6/14/2018	Revision:	0		
Task Description:	Installation of 22 injection wells within the capped waste rock. Injection system designed to neutralize low pH groundwater within the waste rock.						
Cost Basis:	Detailed estimate						

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
Capital Costs					
1.0 Remedial Design/Bench Scale/Pilot Tests					
Remedial Design, RD support taks (plans, field investigation, coordination with agencies, permits), travel, treatability and/or pilot tests, site surveys, design vendor support.					
Remedial Design Professional Labor	1	ls	$ 28,332		$ 28,332
Remedial Design Travel	1	ls	$ 870		$ 870
Materials/Equipment/Subcontractors	1	ls	$ 25,500		$ 25,500
Pilot Scale Testing	1	ls	$ 100,000		$ 100,000
			Design/Bench/Pilot Scale Subtotal:		**$ 154,702**
2.0 Mobilization/Demobilization of Equipment and Personnel					
Mobilization/Demobilization of equipment and personnel (2/2 days).					
Labor	1	ls	$ 18,296		$ 18,296
Travel	1	ls	$ 3,427		$ 3,427
Materials/Equipment/ Subcontractors	1	ls	$ 4,230		$ 4,230
			Mobilization Subtotal:		**$ 25,953**
3.0 Site Preparation					
Utility protection, grubbing, clearing, pre excavation meeting, materials (3 days).					
Labor	1	ls	$ 2,709		$ 2,709
Travel	1	ls	$ 593		$ 593
Materials/Equipment/ Subcontractors	1	ls	$ 14,303		$ 14,303
			Site Preparation Subtotal:		**$ 17,605**
4.0 Install Injection Wells					
Install 22, 2-inch injection wells in the waste rock area. Wells will have an average depth of 100 ft bls.					
Drilling Subcontractor Per/Foot Rate	2200	feet	$ 135		$ 297,000
Drilling Subcontractor - Other	1	ls	$ 44,110		$ 44,110
Well Materials	1	ls	$ 8,699		$ 8,699
Materials/Equipment/ Other Subs/Consumables	1	ls	$ 20,675		$ 20,675
			Install Injection Well Subtotal:		**$ 370,484**

Feasibility Study Cost Estimate

Project:	**Barite Hill**	**Alternative #:**	**GW#3** — **CMZ-3, Groundwater #3**
Location:	McCormick, SC	**Title:**	**Groundwater In-Situ Neutralization**

Item	Qty.	Unit	Unit Cost	Note	Cost ($)
5.0 Construct/Install Delivery System					
Construction and installment of delivery system					
Labor	1	ls	$ 113,687		$ 113,687
Travel	1	ls	$ 25,622		$ 25,622
Site Preparation	1	ls	$ 32,540		$ 32,540
Mixing Tanks	1	ls	$ 179,000		$ 179,000
Injection Main Header	1	ls	$ 38,808		$ 38,808
Injection Manifold	1	ls	$ 64,592		$ 64,592
Injection Wellhead Assembly	1	ls	$ 9,008		$ 9,008
			Construction of Delivery System Subtotal:		**$ 500,758**

Notes:

1)
2)

		Subtotal - Capital Costs:	**$ 1,069,501**
Capital Contingency	15%	of Capital Cost	$ 160,425
Legal Fees, Licenses & Permits[1]	0.5%		$ 6,150
Engineering & Administrative[1]	8%		$ 98,394
Contractor Fee[2]	10%	of Capital Cost	$ 133,447
		Total Capital Cost:	**$ 1,467,917**

[1] Applied to capital subtotal and contingency

[2] Applied to capital subtotal, contingency, fees, and E&A

Feasibility Study Cost Estimate

Project: Barite Hill
Location: McCormick, SC

Alternative #: GW#3 — CMZ-3, Groundwater #3
Title: Groundwater In-Situ Neutralization

O&M Costs

		O&M Period	7.00%	Discount Rate			
			0.00%	Constant Escalation Factor			
7.0	**System Operation , O&M Costs**	30					**Annual Cost**
	Site Visits For Reinjection, collection of groudwater samples						
	Labor	30	1	ls	$ 2,125		$ 2,125
	Travel	30	1	ls	$ 644		$ 644
	System Maintenance/Operation	30	1	ls	$ 100,000		$ 100,000
	Amendments/Analytical	30	1	ls	$ 207,090		$ 207,090
					Sampling Subtotal:		**$ 309,859**
					Net Present Worth (NPW) Subtotal:		**$ 3,845,058**
	O&M Contingency		15%	of NPW Cost			$ 576,759
	Engineering & Administrative[1]		8%				$ 353,745
	Contractor Fee[2]		10%				$ 477,556
					Subtotal - O&M Costs:		**$ 5,253,119**

[1] Applied to O&M subtotal and contingency
[2] Applied to O&M subtotal, contingency, and E&A

Net Present Worth Formula

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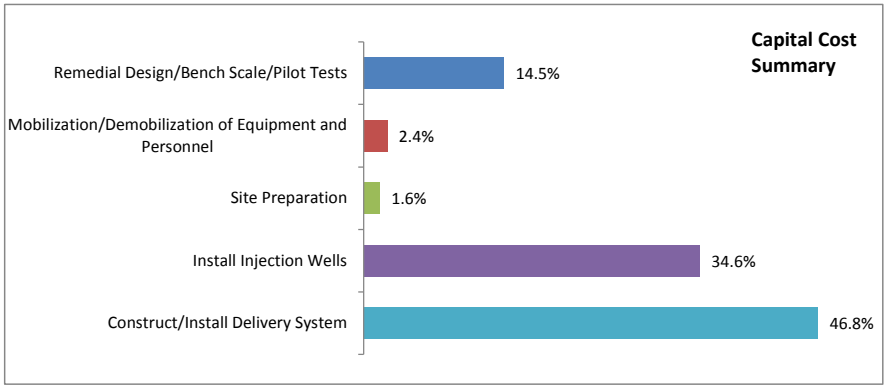
where:
P = Present Value ($)
Ao = Annual Amount ($)
d = discount rate
e = escalation factor
n = time period (yrs)

Note: Net Present Worth derived from summation of Modified Uniform Present Value (UPV*).

Total NPW Cost Estimate: **$ 6,721,000**



General Assumptions

1. Professional rates are averaged to reflect typical labor rates for personnel required for project.
2. Cost basis derived from professional judgment and experience unless specified directly.
3. Costs are derived to be (-30% to +50%)

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