INTEGRATED DISCHARGE PERMIT APPLICATION NARRATIVE
BLACK BUTTE COPPER PROJECT
MEAGHER COUNTY, MONTANA

Submitted by:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTEGRATED DISCHARGE PERMIT APPLICATION NARRATIVE
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MEAGHER COUNTY, MONTANA

1.0 INTRODUCTION

Tintina Montana, Inc. is submitting this application for an ‘Integrated’ Montana Pollutant Discharge Elimination System (MPDES) permit for a new discharge associated with its Black Butte Copper Project (Project). The ‘Integrated’ permit includes discharges from treated water from the mining and milling processes (MPDES) and storm water associated with industrial activities (Industrial Storm Water). This narrative provides additional details to support the information provided in the integrated permit application forms.

1.1 INTEGRATED PERMIT APPLICATION STRUCTURE

Tintina is submitting the MPDES permit and Storm Water permit as an ‘Integrated’ discharge application package at the request of the Department of Environmental Quality (DEQ), Water Protection Bureau. This ‘Integrated’ discharge application is for a new discharge permit which includes the following forms:

- MT DEQ Form 1, including topographic coverage of the area and activities of interest (Appendix A; Figures 1.2, 1.3, and 3.1).
- U.S. Environmental Protection Agency (EPA) Form 2D (New Dischargers of Process Wastewater), including a water flow diagram for processes at the Black Butte Copper Project (Appendix A; Figure 3.5) and effluent characterization (Table 3-4).
- DEQ Form 2F (Storm Water Associated with Industrial Activity), including site maps depicting the facility, outfall locations and drainage areas, and other relevant information as required by Form 2F (Appendix A; Figures 1.3 and 3.1).

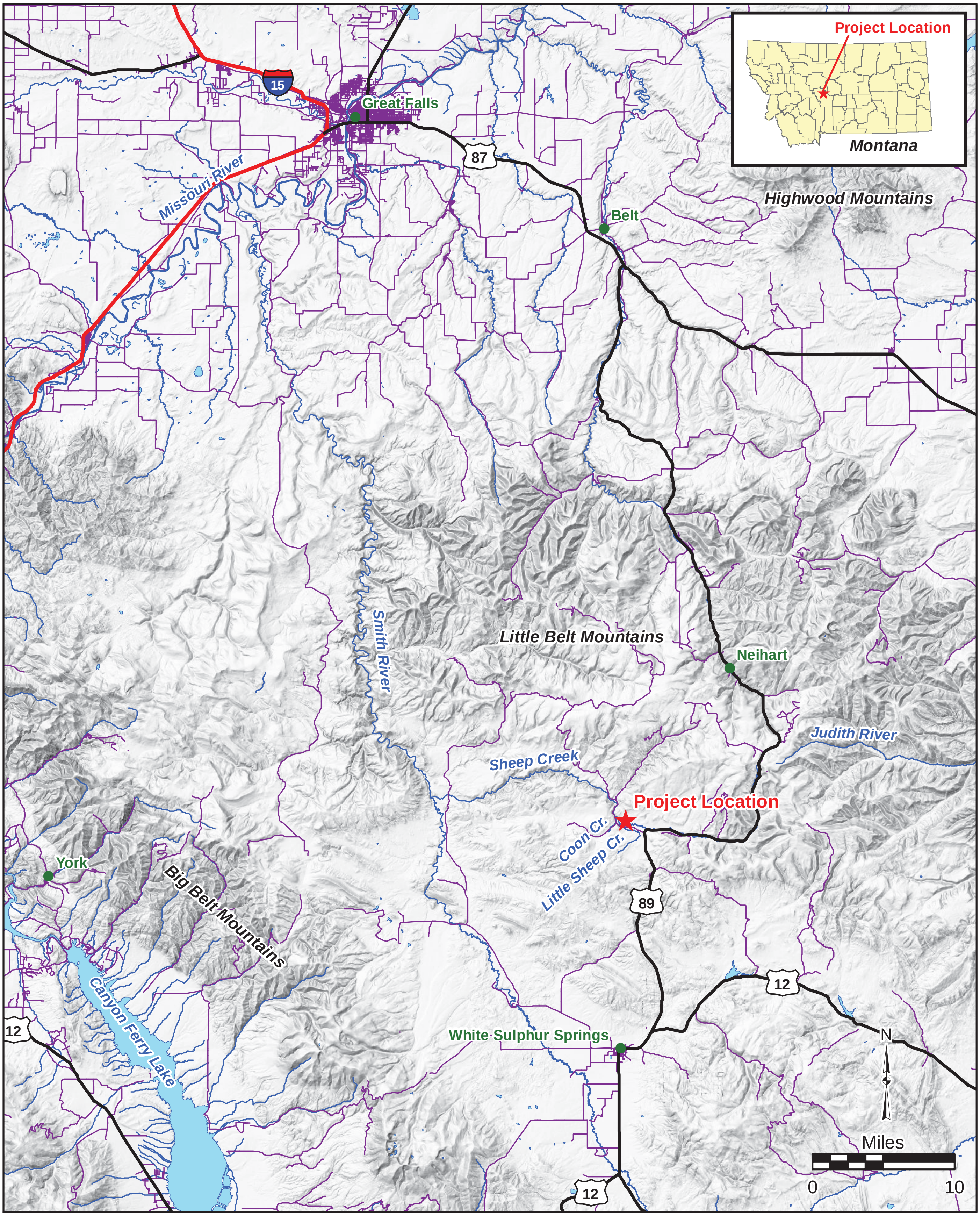
In addition to the forms listed above, Tintina is submitting this permit narrative to provide additional information on the proposed outfalls and hydrologic setting associated with each outfall. Much of the narrative is a summary of the Mine Operating Permit (MOP) Application, Revision 3 (Tintina, 2017) for the Project that was deemed complete and compliant by the DEQ Hard Rock Mining Bureau. This narrative includes multiple appendices that were used in the MOP application where they directly pertain to this integrated permit. The reader should refer to the MOP for greater detail on some supporting topics; recommended sections and/or appendices are referenced for the reader's convenience.

1.2 BRIEF PROJECT BACKGROUND

Tintina Montana, Inc. (Tintina) a wholly owned subsidiary of Tintina Resources, Inc., proposes to develop and operate a new underground mine and mill at its Black Butte Copper Project located 15 miles (24 km) north of White Sulphur Springs in Meagher County, Montana (Figure 1.1). The proposed mine permit area is located in Sections 24, 25, and 36 in Township 12N, Range 6E, and in Sections 19, 29, 30, 31, and 32 in Township 12N, Range 7E (Figure 1.2). The Project will produce and ship copper concentrate mined from both the upper and lower sulfide zones of the Johnny Lee copper deposit. All operations will occur within the Mine Permit Boundary encompassing 1,888 acres (763.9 hectares (ha)) of privately owned ranch land under lease to Tintina (Figure 1.2). Total surface disturbance required for construction and operation of all mine related facilities and access roads (Figure 1.3) comprises 295.9 acres (119.7 ha).

Tintina has been conducting exploration activities in the Project area since 2010. Numerous hydrogeologic investigations and ongoing baseline water resource monitoring have been conducted since 2011 under the exploration permit (see Appendix B of MOP for additional detail). The current baseline water resource monitoring program consists of monthly, quarterly, and annual monitoring of surface waters, groundwater, springs, and seeps.

The DEQ Hard Rock Mining Bureau issued a Draft Operating Permit (No. 00188) for the Project on September 18, 2017. The Project is currently in the beginning stages of the Montana Environmental Policy Act (MEPA) evaluation which will include a review of the Draft Operating Permit, this integrated discharge permit, and other required permits.



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Prepared by Tetra Tech, Inc. 2015

Legend

★	Project Location	▬	U.S. Route
●	City	—	Local Road
▬	Interstate	~	Stream
		▨	Lake

TINTINA RESOURCES

Figure 1.1

Project Location

Black Butte Copper Project

Meagher County, Montana

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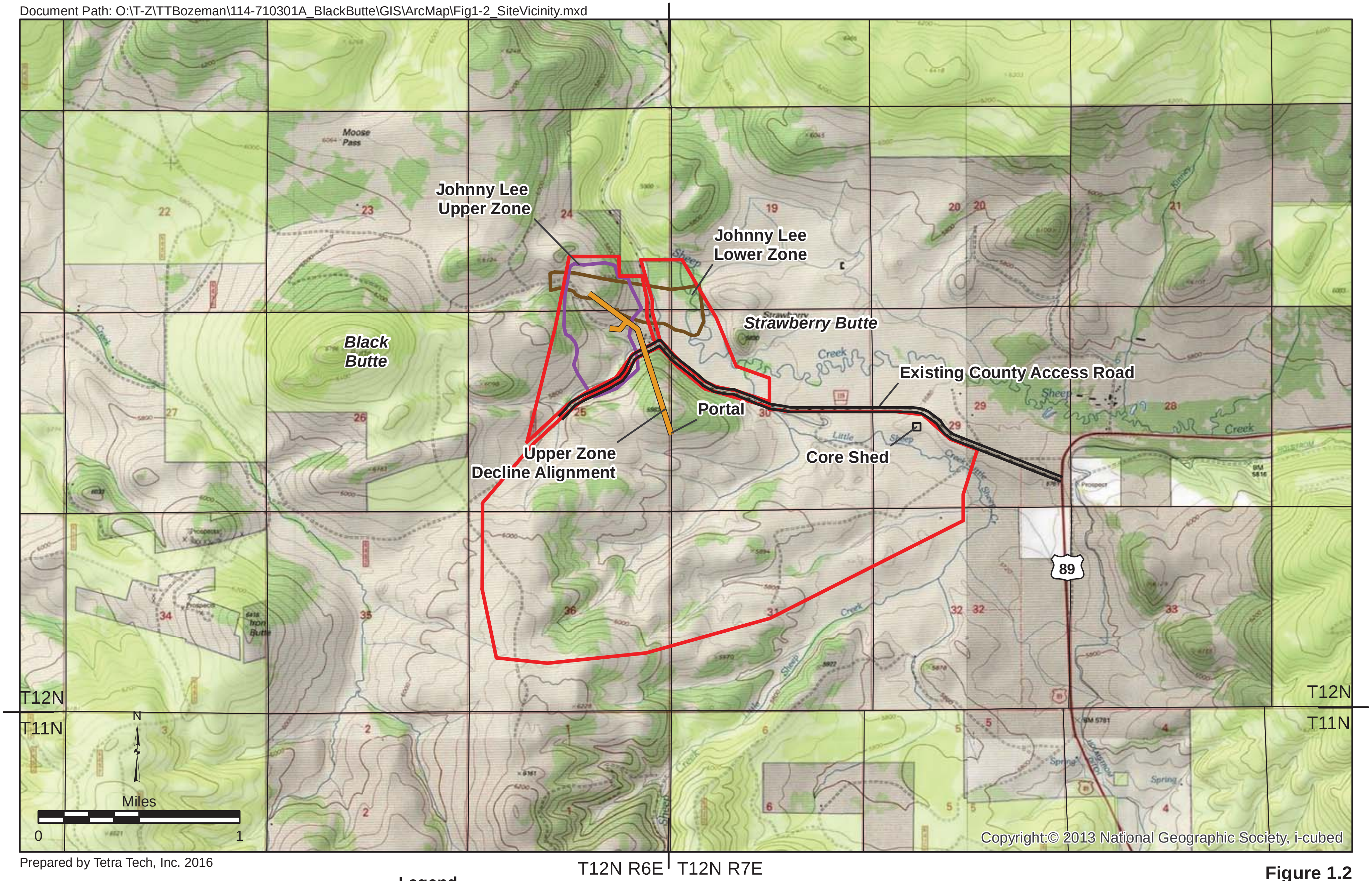

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🟧 Decline Alignment

▬ Existing Road

🟥 Mine Permit Boundary

🟫 Lower Zone

🟪 Upper Zone

🟩 US Forest Service

TINTINA RESOURCES

Figure 1.2

Site Vicinity Map with Mine Permit Boundary

Black Butte Copper Project

Mine Operating Permit Application

Meagher County, Montana

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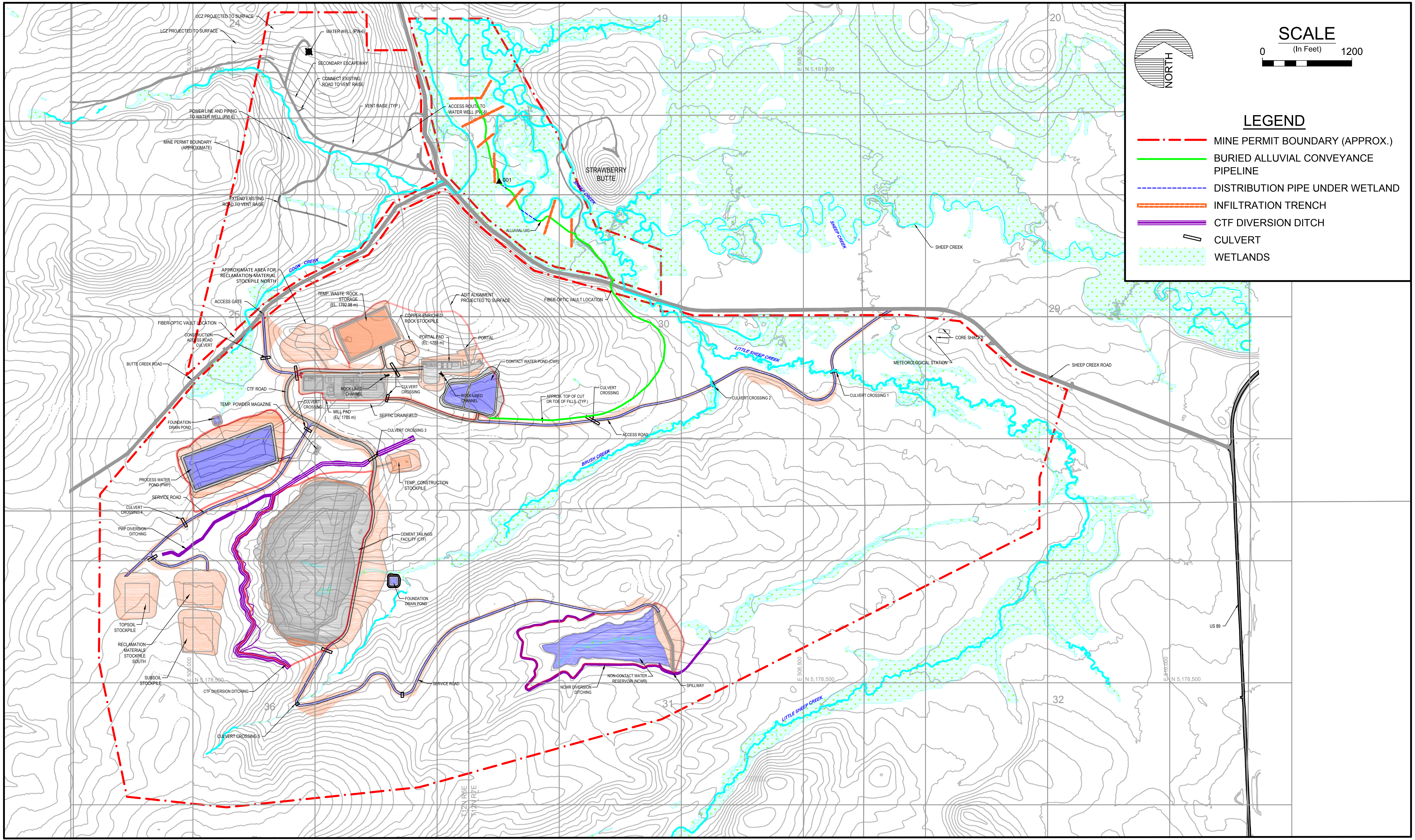

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Figure 1.3
Facilities Site Plan
Black Butte Copper Project
Meagher County, Montana

2.0 FORMS AND FOOTNOTES

The completed application forms used in this integrated discharge permit (listed in Section 1.1) are included in Appendix A. Each form has been completed with the information required; however, in some sections of the forms further explanation is necessary. Section 2.0 provides supplemental information as footnotes including explanation and references for specific items requested in each form. Figures and tables reference in Section 2 of this narrative are numbered based on the section of the form referenced. In addition, supporting information for the forms and development of the integrated permit is provided in Sections 3.0 (Form 2D) and 4.0 (Form 2F).

2.1 FOOTNOTES FOR FORM 1

Section D. Existing or Pending Permits, Certifications, or Approvals

As noted in Section 1.2, DEQ’s Hard Rock Bureau has issued a Draft Mine Operating Permit (#00188); a final operating permit is pending. Tintina currently has an Air Quality Permit (#4978-00) that was originally issued for an exploration decline, which was not constructed. Tintina is in the process of developing an air quality permit for the construction and operational phase of the overall Project.

Section E. Map

Figures 1.2 and 3.1 provide topographic views which include the information requested in Section E of Form 1. Greater detail on facilities may also be viewed on Figure 1.3.

Fees

Tintina has conducted an initial review of the permit rating for the Project based on EPAs National Pollutant Discharge Elimination System (NPDES) Permit Rating Work Sheet. Tintina’s initial review indicates the Project would be considered a minor facility. However, Tintina understands the final determination will be made by DEQ and EPA; therefore, the fees for a major facility determination are included to expedite the review process. If it is determined by the DEQ or EPA that the discharge is a minor facility please return the difference in fees to Tintina Montana, Inc. The fees submitted are based on the fees outlined by DEQ in correspondence to Hydrometrics, Inc. (DEQ, 2017) with the total fee being adjusted as the MPDES outfalls were reduced from 3 to 1 outfall. The fees submitted with this permit are as follows:

Major Facility Fee Estimates

• One process wastewater outfall ($5,000 per outfall)	$ 5,000
• Four storm water receiving waters (integrated, $1,500 per receiving water)	$ 6,000
• Significance determinations (1 process wastewater, 1 storm water; $5,000 per outfall)	$10,000
• One process wastewater outfall annual fee ($3,000 per outfall)	$ 3,000
• Four storm water outfalls (integrated) annual fee ($1,000 per outfall) (per named receiving water)	$ 4,000
Total:	**$28,000**

2.2 FOOTNOTES FOR FORM 2D

Section III. Flows, Sources of Pollution, and Treatment Technology Part A. and Part B.

A visual representation of the water balance is presented in Figure 3.5. The numbered flow streams on Figure 3.5 correspond to Table 3-2 (Site Wide Mass Balance) and water types (applicability to 40 CFR Part 440 Effluent Limitation Guidelines) are designated in the heading for each flow stream. Sections 3.3 and 3.4 below provide a discussion of proposed water management through the facility and treatment details.

Section V. Effluent Characteristics

The characteristic of the effluent was not modeled for Biological Oxygen Demand (BOD), Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) as the wastewater streams and proposed treatment are such that these parameters are not expected to be present. Water treatment plant (WTP) effluent water quality was projected through a detailed material balance model developed by Amec Foster Wheeler (2017a and 2017b contained in Appendix B). The projected water quality of treated effluent is presented in Table 3-4. Temperature is assumed to approach air temperature in storage. Air temperature data was derived from Black Butte Mine Meteorological

Monitoring from April 2012 - December 2016 (Appendix C). Strontium and uranium are the only pollutants listed in Table 2D-3 of Form 2D that are expected to be present in the discharge as they are present in the ambient groundwater that will be pumped from the mine portal. However, both strontium and uranium are expected to be present at concentrations below the detection limit in the treated water discharged to the outfalls. The water treatment design and projected effluent characteristics are summarized in Section 3.4 below.

Section VI. Engineering Report on Wastewater Treatment

Existing 'plants' which resemble the Project production facilities with respect to production processes, wastewater constituents, and wastewater treatment are few in the state of Montana. Sites that use explosives for mining ore and froth floatation for ore concentration include Stillwater Nye (palladium/platinum), Stillwater East Boulder (palladium/platinum), and Montana Resources (copper). These sites are likely to have similar concentrations of total nitrogen in their wastewater. There are no existing 'plants' that use reverse osmosis (RO) for wastewater treatment; however, both the Butte Highlands and Montanore Projects have proposed to use RO for wastewater treatment.

2.3 FOOTNOTES FOR FORM 2F

Form 2F addresses discharges of storm water associated with industrial activity. Tintina proposes to permit 10 storm water outfalls designated 002 through 011. The ten storm water outfalls will discharge to 4 receiving waters; Coon Creek, Brush Creek, an unnamed tributary to Little Sheep Creek, and Little Sheep Creek.

Section III. Site Drainage Map

Figures 1.3 and 3.1 provide the requested information regarding the facility, drainage areas, and potential storm water pollutants.

Section VII. Discharge Information

A review of data from surface water sites between 2011 to present was undertaken to develop a storm water quality estimate. Predicted storm water quality presented in Form 2F was determined using analytical results from surface water site SW-14. The storm water quality was estimated by removing the groundwater component from a high flow storm event as compared to a low flow sampling event. Estimated storm water quality is shown in Table 4-1.

3.0 PERMIT TO DISCHARGE PROCESS WASTEWATER – NEW SOURCE

Tintina proposes to dispose of treated water permitted under the MPDES program through an alluvial underground infiltration gallery (UIG) system in the Sheep Creek Valley (Figure 3.1). No direct discharge to surface water is proposed for the Project. Although the UIG system will discharge to groundwater, Tintina is applying for a surface water discharge permit (MPDES) due to the eventual hydrologic connection to Sheep Creek. Tintina is requesting a seasonal source specific mixing zone for total nitrogen, in surface water as part of this application. The details of the proposed source specific mixing zone are included in Appendix D. The details and supplemental information for the proposed MPDES portion of the integrated permit are included in this section of the application narrative. This information includes a description of the alluvial outfall, characterization of the receiving water, Project water balance, effluent characterization, and nondegradation nonsignificance criteria analysis.

3.1 ALLUVIAL OUTFALL DESCRIPTIONS

Tintina identified three potential UIGs for use in disposal of treated water back into the groundwater system in the MOP. For the purposes of this MPDES application, only the Sheep Creek alluvial UIG is proposed for use. The alluvial UIG is designated as Outfall 001 and will discharge treated water to unconsolidated sediment within the saturated alluvial system of the Sheep Creek Valley. Outfall 001 is located at 46° 46' 46.58" N latitude, 110° 54' 20.12" W longitude (center of UIG area). The UIG will consist of 14 individual galleries ranging between about 150 and 350 feet in length, 6 feet wide and 15 feet deep (Figure 3.2). Each individual gallery will have a control valve at the main distribution pipeline to allow for controlled application during operations. The total length of infiltration galleries in the alluvial UIG is about 3,140 feet. When constructed the trench will be backfilled with washed 2-inch plus to 6-inch minus gravels and cobbles. Water will be discharged to the coarse backfill through a perforated PVC pipe bedded 5 to 6 feet below ground surface (bgs). Water will be supplied to the individual galleries through a 6-inch plastic pipe. The supply line will be constructed at a depth of about 6 feet bgs. In areas outside of wetlands, the supply line

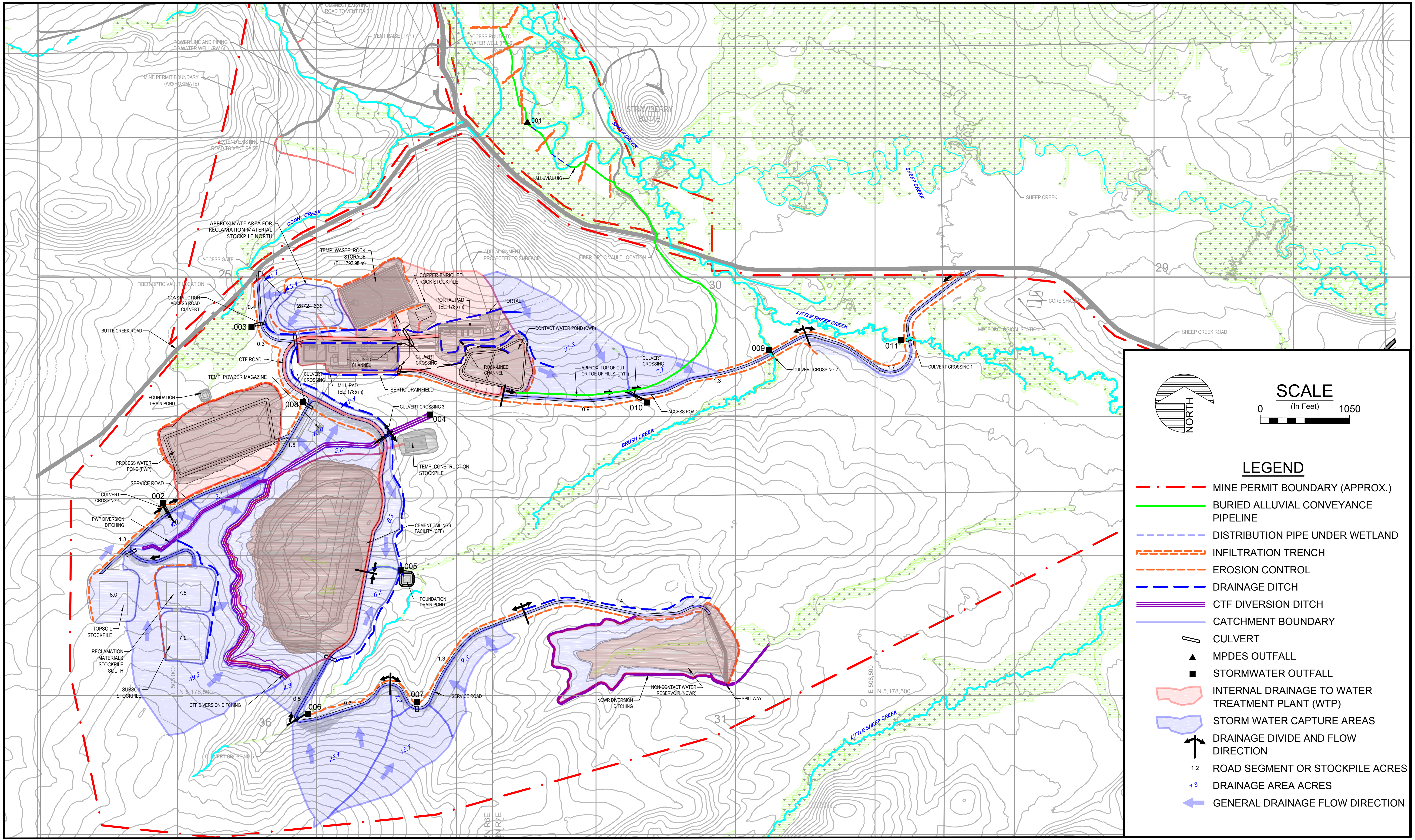

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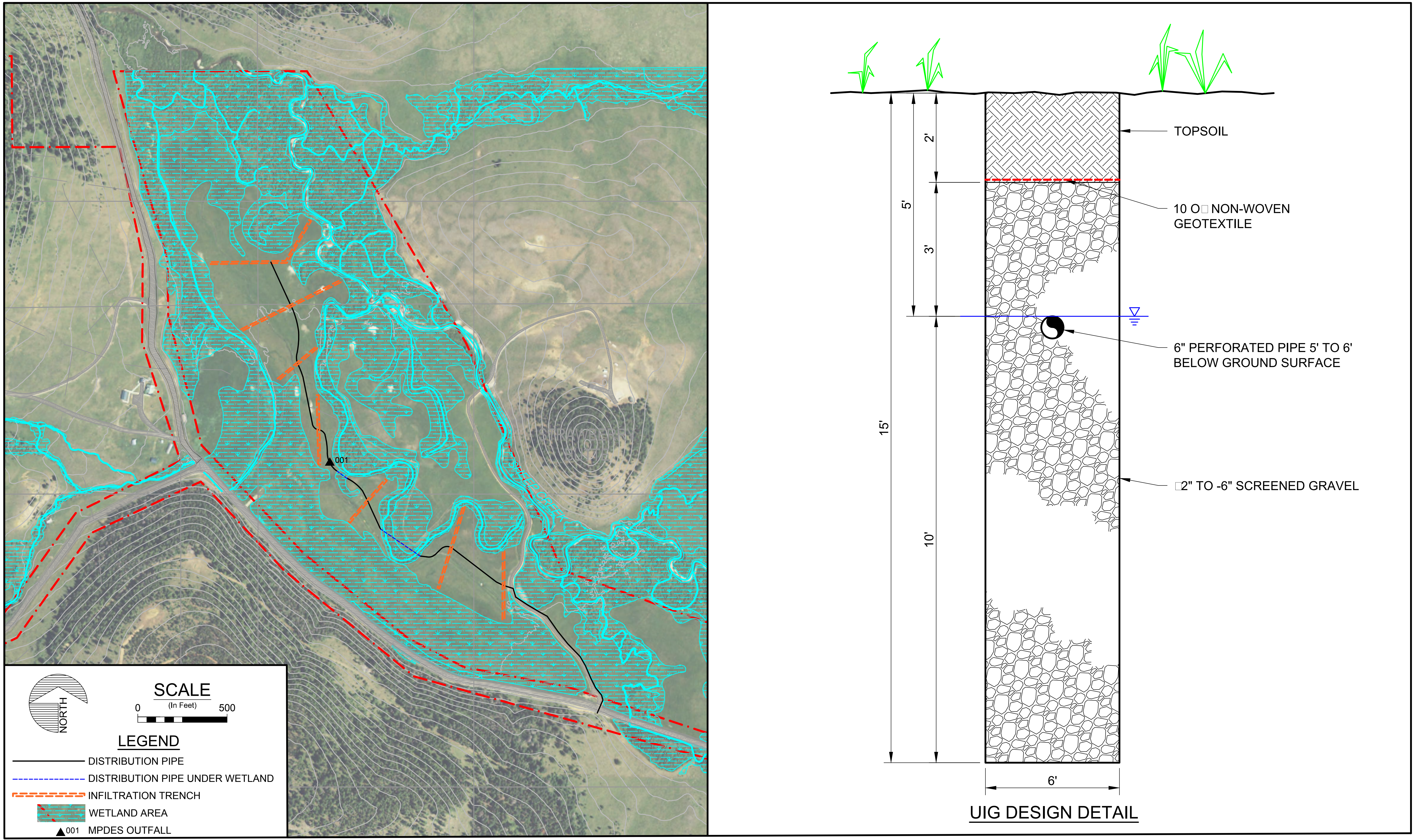
Figure 3.1
MPDES and Storm Water Discharge Systems
Black Butte Copper Project
Meagher County, Montana



UIG DESIGN DETAIL

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Figure 3.2
Alluvial Underground Infiltration Gallery
Black Butte Copper Project
Meagher County, Montana

will be constructed by excavation. No excavation will occur where the supply line is proposed to be installed beneath wetlands. In these areas the supply line will be installed using jack and bore methods to avoid any direct impacts to wetlands.

The capacity of the alluvial UIG is dependent on the infiltration rate of the individual galleries and the resulting mounding within the alluvial system. The infiltration capacity of the alluvial system was determined based on nine falling head infiltration tests conducted in the alluvial valley. The median infiltration rate from the nine falling head tests was 2.04 ft/day, which is equivalent to 0.41 gpm per linear foot of infiltration gallery. The details of the infiltration testing and analysis is summarized in Appendix E. Based on an infiltration rate of 0.41 gallons per minute (gpm)/linear foot the total disposal capacity of the alluvial UIG is about 1,285 gpm.

A three dimensional numerical groundwater flow model was developed to evaluate the mounding within the alluvial system under ambient conditions (Hydrometrics, 2017). The model encompasses the Sheep Creek alluvial system from approximately 2,700 feet upgradient of where Little Sheep Creek enters the valley to where the alluvial sediment system pinches out at the bedrock canyon near the proposed operating permit boundary. The model was calibrated to alluvial heads at 11 piezometers and wells in the alluvial system and flows within the system (including groundwater/surface water interaction). The mounding analysis was conducted by applying 575 gpm evenly distributed to all arms of the alluvial UIG. The model projects the mounding at each arm will be about 2.3 to 3.5 feet. Additional details of the model build and calibration are provided in Appendix F.

There is approximately 2-3 feet of shallow unsaturated zone within the alluvial system under ambient conditions. The project will discharge excess water from mine dewatering to the saturated portion of the alluvial UIG during mining operations. The mine dewatering modeling analysis (Hydrometrics, 2016b) projects there will be 5 to 10 feet of drawdown in the alluvial system during operations. This will result in approximately 7 to 13 feet of unsaturated zone beneath the alluvial system operationally. Based on the available unsaturated zone in alluvial system during operations, the alluvial system has sufficient capacity for the UIG to discharge the maximum discharge rate, without risking discharge at the surface.

Discharge of treated effluent in the alluvial system may have transit times of hundreds of days prior to discharging to Sheep Creek proper. Travel times in the alluvial aquifer is highly dependent on surface water flows and potential dewatering interaction associated with dewatering in the mine workings.

3.2 RECEIVING WATERS

Water resources in the vicinity of the proposed UIG consists of the alluvial groundwater and surface waters. A detailed ambient potentiometric surface is provided in Figure 3.3. The ambient alluvial potentiometric surface shows that groundwater flows generally parallel to Sheep Creek throughout most of the aquifer. In the lower portion of the alluvial aquifer groundwater discharges to Sheep Creek as the alluvial system pinches out at the bedrock canyon. Some localized deviations from the general flow path are evident where both Little Sheep Creek and Coon Creek enter the valley. The alluvial aquifer is recharged by Little Sheep Creek as it enters the valley in the upgradient portion of the ambient conceptual model area. Coon Creek typically enters the alluvial valley after being diverted to the east of its natural channel. The potentiometric surface and the synoptic surveys indicate Coon Creek intercepts groundwater when it flows through the diverted channel. The diverted channel is much lower in elevation than the original channel of Coon Creek, which likely creates a man-made discharge point for the alluvial groundwater system. If Coon Creek flows in its natural channel it would likely discharge water to the alluvial groundwater system as the natural channel is about 10 feet higher in elevation than the diverted channel.

Water proposed for discharge to the alluvial UIG is sourced from mine dewatering during mine construction and operations. The dewatering of the mine workings will cause the water levels in the western portion of the alluvial system to be 5 to 10 feet lower than the ambient water levels shown in Figure 3.3. A projected operational potentiometric map was constructed based on a cumulative analysis of the simulated drawdown in the alluvial system

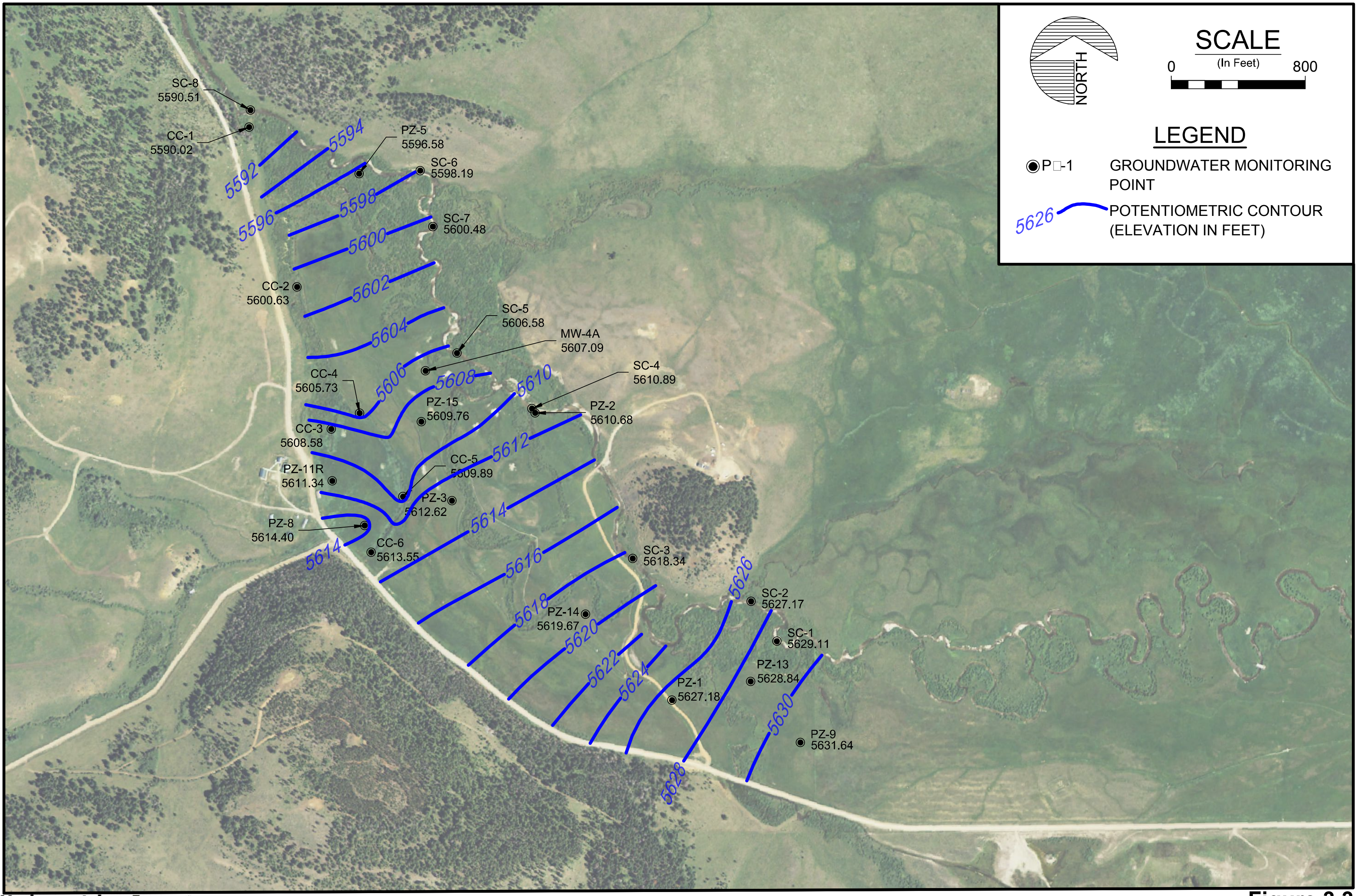

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Figure 3.3
Alluvial Potentiometric Surface
Black Butte Copper Project
Meagher County, Montana

during operations (Hydrometrics, 2016b) and the simulated mounding from the alluvial discharge (Figure 3.4). The constructed operational potentiometric surface shows that the alluvial groundwater will be lower than Coon Creek and it will discharge to approximately 3,500 lineal feet of Sheep Creek in the downgradient portion of the valley.

3.2.1 Receiving Water Quality

As noted in Section 3.0, it is assumed that all water discharged to the alluvial sediment outfalls will eventually be transported downgradient to discharge to Sheep Creek. Therefore, based on the operational potentiometric surface there are two different receiving waters that treated water will be discharged to: Sheep Creek alluvial aquifer, and Sheep Creek surface water. The water quality of each of these receiving waters has been characterized through the ongoing water resource monitoring program. The water resource monitoring is described in detail in Section 2.2 of the MOP. Water quality data and statistical analyses for each receiving water through 2016 are included (electronically) in Appendix G of this narrative. Table 3-1 summarizes the 75th percentile of each constituent from the two receiving waters.

The Sheep Creek alluvial UIG (Outfall 001) will discharge directly to the Sheep Creek Alluvium. The water quality of the Sheep Creek alluvial system is characterized by results from monitoring conducted at monitoring well MW-4A (Figure 3.2). Water in the Sheep Creek alluvium has near neutral pH with low to non-detectable concentration of dissolved metals. The alluvial aquifer is classified as a Class I groundwater.

It is assumed that all water that is discharged to the alluvial UIG will eventually discharge to Sheep Creek near the downgradient end (north end of the Project permit boundary area) of the Sheep Creek Valley where the alluvial system is pinched out at the canyon north of the Project site. Water quality of Sheep Creek in the vicinity of the Project is best characterized by the ongoing monthly monitoring at site SW-1. Sheep Creek surface water is a calcium/magnesium bicarbonate type water with low to moderate dissolved solids. Chronic aquatic criteria for dissolved aluminum (0.087 milligrams per liter [mg/L]) is often exceeded

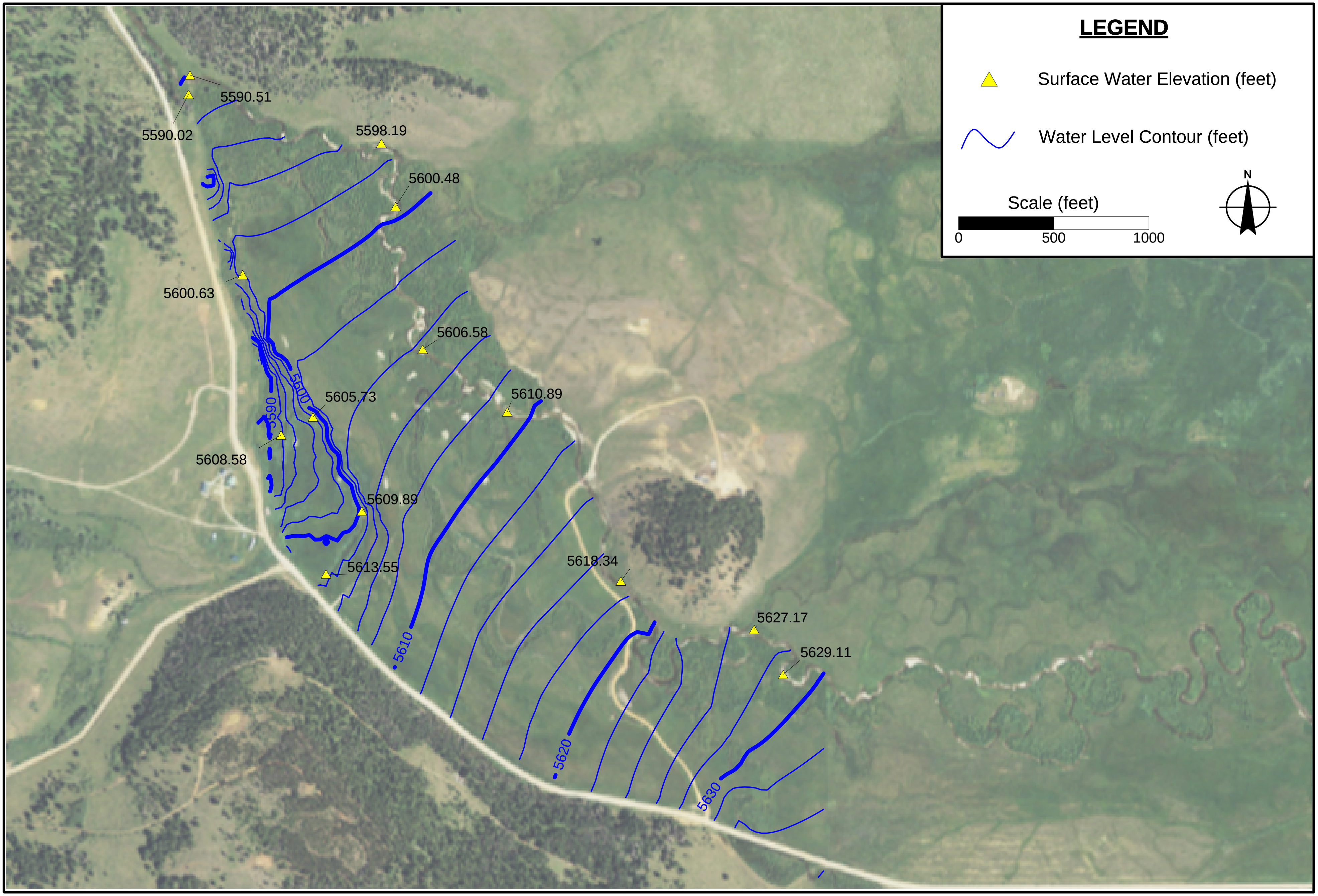

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Figure 3.4
Projected Operational Alluvial Potentiometric Surface
Black Butte Copper Project
Meagher County, Montana

TABLE 3-1. RECEIVING WATER QUALITY

Description	**75%ile Receiving Water Quality [1]**	
	Alluvial Groundwater	**Sheep Creek Surface Water**
Temperature, Deg C	7.6	8.78
Dissolved Oxygen	1.42	12.2
Specific Conductivity (umhos/cm)	522	321
Commons		
pH	7.35	8.30
Total Alkalinity	280	180
Nitrogen, Nitrate + Nitrite	< 0.01	0.03
Total Nitrogen [2]	NM	0.09
Phosphorus [2]	NM	0.011
Anions		
Bicarbonate	353	200
Chloride	2.9	2.0
Fluoride	0.2	0.1
Sulfate	17	6.1
Cations		
Aluminum	< 0.009	0.030
Antimony	< 0.0005	< 0.0005
Arsenic	< 0.001	< 0.001
Barium	0.189	0.110
Beryllium	< 0.0008	< 0.0008
Cadmium	< 0.00003	< 0.00003
Calcium	78	49
Chromium	< 0.01	< 0.01
Cobalt	< 0.01	< 0.01
Copper	< 0.002	< 0.002
Iron	0.04	0.39
Lead	< 0.0003	< 0.0004
Magnesium	22	13
Manganese	0.222	0.019
Mercury	< 0.000005	< 0.000006
Molybdenum	< 0.002	< 0.002
Nickel	< 0.001	< 0.001
Potassium	2	1
Selenium	< 0.0002	< 0.0002
Silver	< 0.0002	< 0.0003
Sodium	3	2
Strontium	0.173	0.1270
Thallium	< 0.0002	< 0.0002
Uranium	< 0.008	< 0.008
Zinc	< 0.002	0.005
Other		
Total Suspended Solids (TSS)	< 10	10
Total Dissolved Solids (TDS)	296	186
Total Hardness, mg/L CaCO3	285	176

All values in mg/L, unless otherwise noted

NM = Not Measured

1 - Receiving water data, May 2011 - December 2016 for Sheep Creek Alluvium (MW-4A) and surface water in Sheep Creek (SW-1).

2 - Receiving water Total Phosphorous and Total Nitrogen (Pesulfate Method) 75th percentile was calculated on a seasonal basis (Summer July 1 - September 30).

during periods of high runoff in Sheep Creek. Nutrients are relatively low, with total nitrogen (persulfate method) being below the nutrient criteria during the summer months (<0.04 to 0.15 mg/L).

3.2.2 Receiving Water Flows

Flow in the receiving water was quantified to evaluate different mixing analyses. The nondegradation analysis uses three flows for Sheep Creek; the annual 7-day low flow occurring once every 10 years (7Q10) for mixing of all constituents except nutrients, seasonal (July through October) 14-day low flow occurring once every 5 years (14Q5) for nutrients mixing analysis, and mean monthly flows for evaluation of nondegradation for flow. These flows were calculated based on data from the USGS gaging station on Sheep Creek (#06077000) and applying a multiplier (1.75) based on a watershed analysis to adjust for the larger watershed surface area for the SW-1 surface water site as documented in Sheep Creek 7Q10 Low Flow Estimation Technical Memorandum (Hydrometrics, 2013). The calculated 7Q10 and seasonal 14Q5 for site SW-1 are 8.6 cubic feet per second (cfs) and 21 cfs, respectively. The mean monthly flow ranges between 9.1 cfs and 115 cfs (Hydrometrics, 2017).

Groundwater flux was calculated based on Darcy's Law for the Sheep Creek Alluvial UIG. The aquifer parameters and resultant flow for the groundwater system has been summarized in Table 3-2.

TABLE 3-2.   GROUNDWATER FLUX CALCULATIONS

Parameter	**SC Alluvium UIGs (Outfall 001)**
Hydraulic Conductivity(1) (ft/d)	200
Thickness(2) (ft)	15
Width (ft)	1420
Gradient	0.008
Groundwater Flux (gpm)	177

(1) Lowest estimated hydraulic conductivity is used in this analysis.

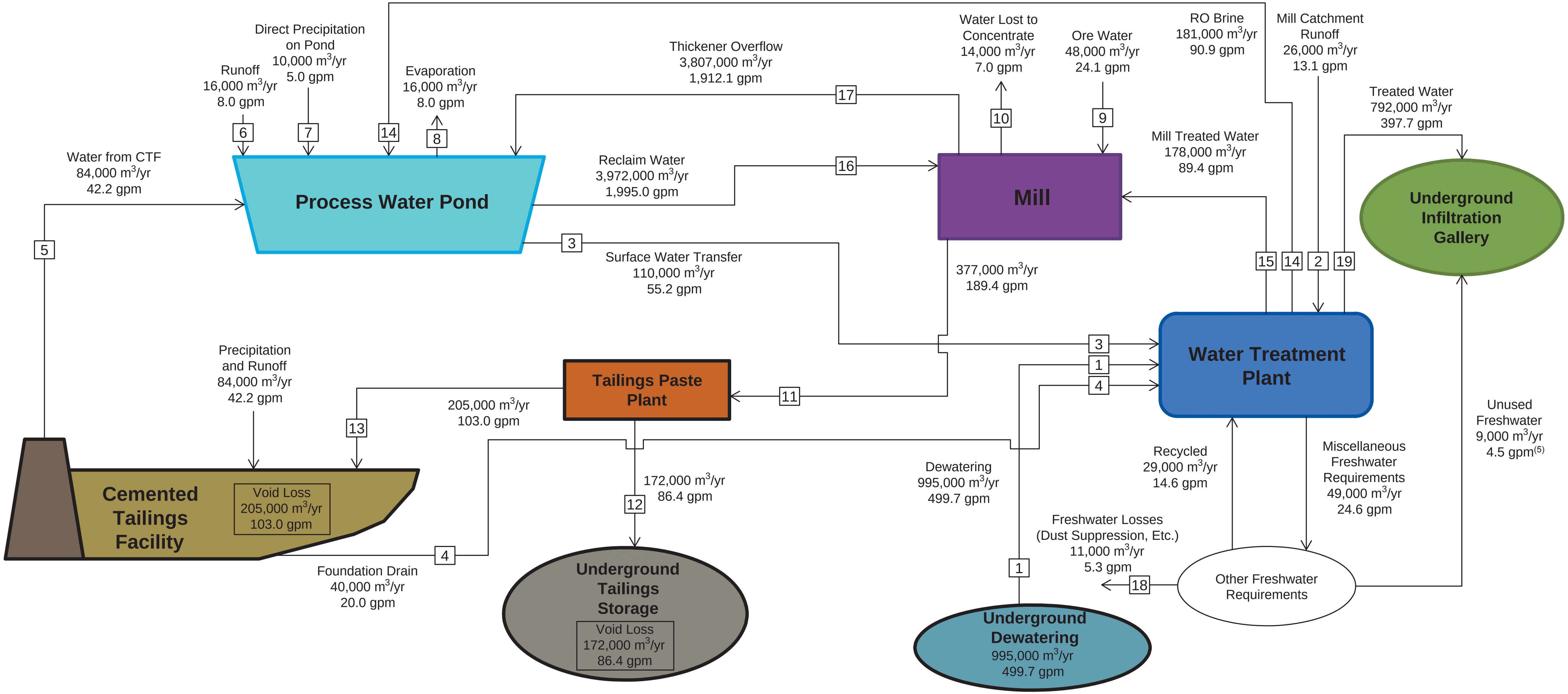
(2) Aquifer thickness is limited to the top 15 feet of saturation.

3.3 SITE WATER MANAGEMENT

With the exception of the Public Water Supply (PWS) well, Tintina's only source of water for use in mining and milling activities will be from groundwater inflow into the open mine workings. Water diverted through the portal will be used for the water needs for underground mining, the mill, tailings paste plant, and smaller miscellaneous uses (dust suppression, ice abatement, equipment wash bays, etc.). Mill water requirements and miscellaneous freshwater requirements (truck wash, dust control, etc.) were quantified by Tetra Tech based on the milling process and production rates of the mine.

An operational water balance model was developed using the GoldSim modeling software to assess mean hydrologic characteristics and variability of flows for all of the proposed facilities (Knight Piésold, 2017, Appendix L of MOP). Figure 3.5 shows a schematic of the average annual water balance for the Project. The volume of water in the Cemented Tailings Facility (CTF), Process Water Pond (PWP), and water reporting to the Contact Water Pond ("Mill Catchment Runoff," in the water balance model) were estimated on a monthly basis over 15 years (including two years for pre-production and 13 years of operations). Meteorological parameters for the model were developed using site specific data in conjunction with regional data (Bison Engineering, 2012 through 2016). The water balance model uses the mean monthly precipitation and evaporation values as inputs for each year. These account for rain and snow accumulation, snowmelt, evapotranspiration, and resulting run-off. The surface area was calculated for each time-step using the Depth-Area-Capacity data for the facility. Below is a summary of the proposed water management plan for the Project.

Prior to mill startup, water will be diverted from the portal and stored in the PWP to provide sufficient water for startup of the mill (65 acre-ft). The operational water storage for the PWP will range between 103 to 162 acre-ft. There is an additional 162 acre-ft of capacity built into the PWP to allow for storage of water from a probable maximum flood (PMF) storm event.



Estimated Groundwater Consumptive Use Components

Water Use	Consumptive Use		
	m^3/yr	gpm	acre*ft/year
PWP Evaporation	16,000	8	13
CTF Void Loss	205,000	103	166
Underground Tailings Void Loss	172,000	86	139
Water Loss to Concentrate	14,000	7	11
Freshwater Losses	11,000	6	9
Total Consumptive Use	**418,000**	**210**	**339**

NOTES:

1. ALL WATER VOLUMES ARE EXPRESSED IN UNITS OF CUBIC METRES PER YEAR AND GPM EQUIVALENTS.
2. WATER IN TAILINGS PASTE IS ASSUMED TO BE UNRECOVERABLE.
3. SEEPAGE IS ASSUMED TO BE ZERO AS THE FACILITIES ARE LINED.
4. THE NUMBERS IN THE BOXES CORRESPOND TO TABLE 3-3.

Reference: Modified after Knight Piesold (2017a): Report No. VA101-46-/3-2

5. PUBLIC WATER SUPPLY TO SEPTIC, NOT INCLUDED IN MPDES APPLICATION.

Prepared by Tetra Tech Inc. (March 2017)

FIGURE 3.5

Annual Water Balance Schematic for Mean Case - Year 6

Mine Operating Permit Application

Black Butte Copper Project

Meagher County, Montana

TINTINA RESOURCES

Once the minimal operational water volume is stored in the PWP and the mill goes on line, water will typically be diverted from the portal to the WTP. Only during times of low water storage in the PWP will water be directly diverted from the portal to the PWP. The mill design is based upon industry standard processing methods that will separate and concentrate the copper minerals. When operating the mill at design capacity the milling process requires the largest quantity of water for the Project with 1,995 gpm coming from the PWP, 24 gpm from water entrained in the ore, and 89 gpm from the WTP. The water management plan recycles more than 90% of the water used in the mill by returning it back to the PWP for future use. Water will be added to the PWP from the RO reject (brine) at an average annual rate of 91 gpm. Precipitation that falls on the CTF (42.2 gpm) will be diverted to the PWP; an additional 13 gpm of precipitation will be captured in the PWP. To avoid excess water in the PWP, water will be diverted from the PWP to the WTP at a volume equal to the sum of precipitation on the CTF and precipitation captured in the PWP. Groundwater retained in the ore after mining will be mixed with water from the PWP during the grinding process. Treated water reporting to the mill will be used for pump gland water and other ancillary processes in the mill.

Water will be diverted from the mill circuit for other uses, which include water that is retained in the copper concentrate that leaves the facility (7 gpm) and 189 gpm that is required for wetting the tailings in the paste plant. Water used in the tailings paste plant is used to mix the tailings with cement and other binders for deposition in the CTF and as paste backfill in the underground mine workings. Tailings deposited in the underground workings will be mixed with approximately 4% cement/binders and the tailings deposited in the CTF will be mixed with 0.5 to 2% cement/binders. The water needs for the paste plant are based on appropriate mixtures to allow for the tailings to be pumped to the underground workings or CTF. It is assumed that the water in the tailings/cement mixture will be bound in the tailings once the cemented tailings set up and there will not be any or only minimal discharge of water from the tailings/cement mixtures.

Approximately 20 gpm will be diverted from the WTP to be used for miscellaneous freshwater requirements. These include but are not limited to dust suppression, ice abatement, and equipment washing. It should be noted that this 20 gpm does not include the 4.5 gpm of unused freshwater that is associated with the PWS system (see notes on Figure 3.5). Approximately 14.6 gpm of the miscellaneous uses will be collected and recycled back to the WTP and 5.3 gpm will be consumed through dust suppression, ice abatement, etc. Water will also be used for underground activities (e.g., drilling) at a rate of 150 gpm; however, after the initial startup of the WTP 100% of water used underground will be collected in the underground sumps and pumped back to the surface and recycled through the WTP and/or become part of the discharge to the MPDES outfalls. For this reason, the underground water use was not included in the water balance developed by Knight Piésold.

The water balance shows that the average discharge to the MPDES outfall will be 398 gpm. The WTP is designed to handle 1.5 times the projected average flow rate to account for higher dewatering rates that may occur during dewatering of larger volume storage areas in the ore body and/or resulting from seasonal fluctuations. The maximum flow rate that will be discharged to the MPDES outfall is 575 gpm.

3.3.1 Technology Based Effluent Limitation Guidelines (ELGs)

Effluent discharged under the Project will be subject to 40 CFR 440 Subpart J Copper, Lead, Zinc, Gold, Silver, and Molybdenum ore's subcategory; specifically Section 104.00 new source performance standards (NSPS) and Subpart L General Provisions, Section 440.130. These sections describe technology based effluent standards for discharge of waters generated on site and the disposition of those waters. Section 440.104 states in part:

> "…any new source subject to this subsection must achieve the following NSPS representing the degree of effluent reduction attainable by the application of the best available demonstrated technology (BADT)".

Section 440.104(a) stipulates the requirement for mine drainage waters.

(a) The concentration of pollutants discharged in mine drainage . . . shall not exceed:

Effluent Characteristics	**Effluent Limitations**	
	Maximum for any one day	**Average of daily values for 30 consecutive days**
	Milligrams per liter	
Cu	0.30	0.15
Zn	1.5	0.75
Pb	0.6	0.3
Hg	0.002	0.001
Cd	0.10	0.05
pH	6.0 to 9.0	6.0 to 9.0
TSS	30.0	20.0

Mine drainage is defined as: "any water drained, pumped or siphoned from a mine." 40 CFR 440.132(h). EPA Region VIII defines mine drainage to include the following sources (EPA, 1993):

- Land Application area runoff;
- Crusher Area runoff;
- Spent Ore runoff;
- Surge Ore stockpile;
- Waste rock/overburden;
- Pit drainage pumped and unpumped;
- Mine water adit discharge;
- Mine water pumped;
- Seeps, French Drains;
- Onsite haul roads;
- Runoff/seepage from tailings dams/dikes when not constructed of waste rock or tailings; and
- Any unreclaimed disturbed area.

Section 440.104(b)(1) stipulated the disposition of process waters.

(b)(1) . . . there shall be no discharge of process wastewater to ***navigable waters*** (emphasis added) from mills that use the froth-flotation process alone, or in conjunction with other processes, for the beneficiation of copper . . .“A general ‘Process Wastewater’ definition is provided in 40 CFR 122.2 which states: any water which, during manufacturing or processing, comes in direct contact with or results from the production or use of any raw material, intermediate product, finished product, byproduct, or waste product.” (EPA, 2011). EPA Region VIII further defines process wastewater to include the following sources (EPA, 1993):

- Tailings impoundments/pile;
- Heap Leach Pile runoff/ seepage;
- Pregnant Pond;
- Polishing Pond; and
- Concentrate Pile (product storage).

Tintina is not proposing to discharge treated or untreated volumes of process wastewater from the froth flotation process to navigable waters as described in the ELG. Tintina is proposing to discharge treated wastewater as follows: First, all wastewater will be treated by advanced RO process to remove parameters of concern (POC), and second, all treated effluent will be discharged to the groundwater system via alluvial infiltration trenches (UIGs). The PWP volume is balanced when precipitation that falls on the CTF and PWP is diverted back to the WTP prior to discharge. A greater volume of water is discharged from the WTP back to the mill and PWP via the mill treated water stream and RO Brine makeup water.

As provided in 40 CFR 440.104 (b)(2)(i), Tintina will treat and process a comparable volume of wastewater and discharge that volume via the infiltration galleries. 40 CFR 440.104(B)(2)(i) states: “In the event that the annual precipitation falling on the treatment facility and the drainage area contributing surface runoff to the treatment facility exceeds the annual evaporation, a volume of water equal to the difference…may be discharged subject to the limitations set forth in paragraph (a) of this section."

Subpart L (General Provisions) furthers this allowance in 40 CFR 440.131 (a) *Combined Waste Streams*. "In the event that waste streams from various subparts or segments of subparts in part 440 are combined for treatment and discharge, the quantity and concentration of each pollutant or pollutant property in the combined discharge that is subject to effluent limitations shall not exceed the quantity and concentration of each pollutant or pollutant property that could have been discharged had each waste stream been treated separately. In addition, the discharge flow from the combined discharge shall not exceed the volume that could have been discharged had each waste stream been treated separately." This part allows for a comparable volume of process wastewater (which includes precipitation, storm water, and mine drainage waters which have come in contact with process wastewater) to be treated and discharged.

Wastewater treatment was designed to maintain effluent concentrations below NSPS effluent limitations. The water treatment process would use a double-pass RO system with clarifier pre-treatment and a post-treatment polishing (buffer addition) phase as described in Section 3.4. The effluent will also not exceed the estimated maximum allowable effluent concentrations based on nondegradation criteria. (The Nondegradation Analysis for MPDES Outfall 001 is described in Section 3.5.) Furthermore, Tintina has aggressively sought out and implemented a number of process variations and modifications to facility siting and construction to reduce the risks to human health and the environment. One such process variation employed will be use of cemented paste tailings (both underground and in the CTF) as an alternative to a classical sub-aqueous tailings impoundment. Therefore, the potential risk associated with dam failure and discharge water originating from process water stored on the CTF is minimized.

The Project will use a flotation process to recover and upgrade copper values in order to produce a saleable copper concentrate. Copper will be recovered from the flotation circuit in a froth and transferred to subsequent upgrading stages and dewatering within the processing plant. The reagents proposed for use in this process are common for copper flotation. They include sodium isopropyl xanthate (SIPX) and Aerophine 3418A as copper mineral collectors, and methyl isobutyl carbinol (MIBC) as a frothing agent. The pH will be managed by the use of lime, added at various points in the process, with a flotation process, pH typically in the range of 10 to 11.5 standard units. This reagent list may be modified operationally to optimize copper recovery. Safety Data Sheets (SDS) for reagents are contained in Appendix H.

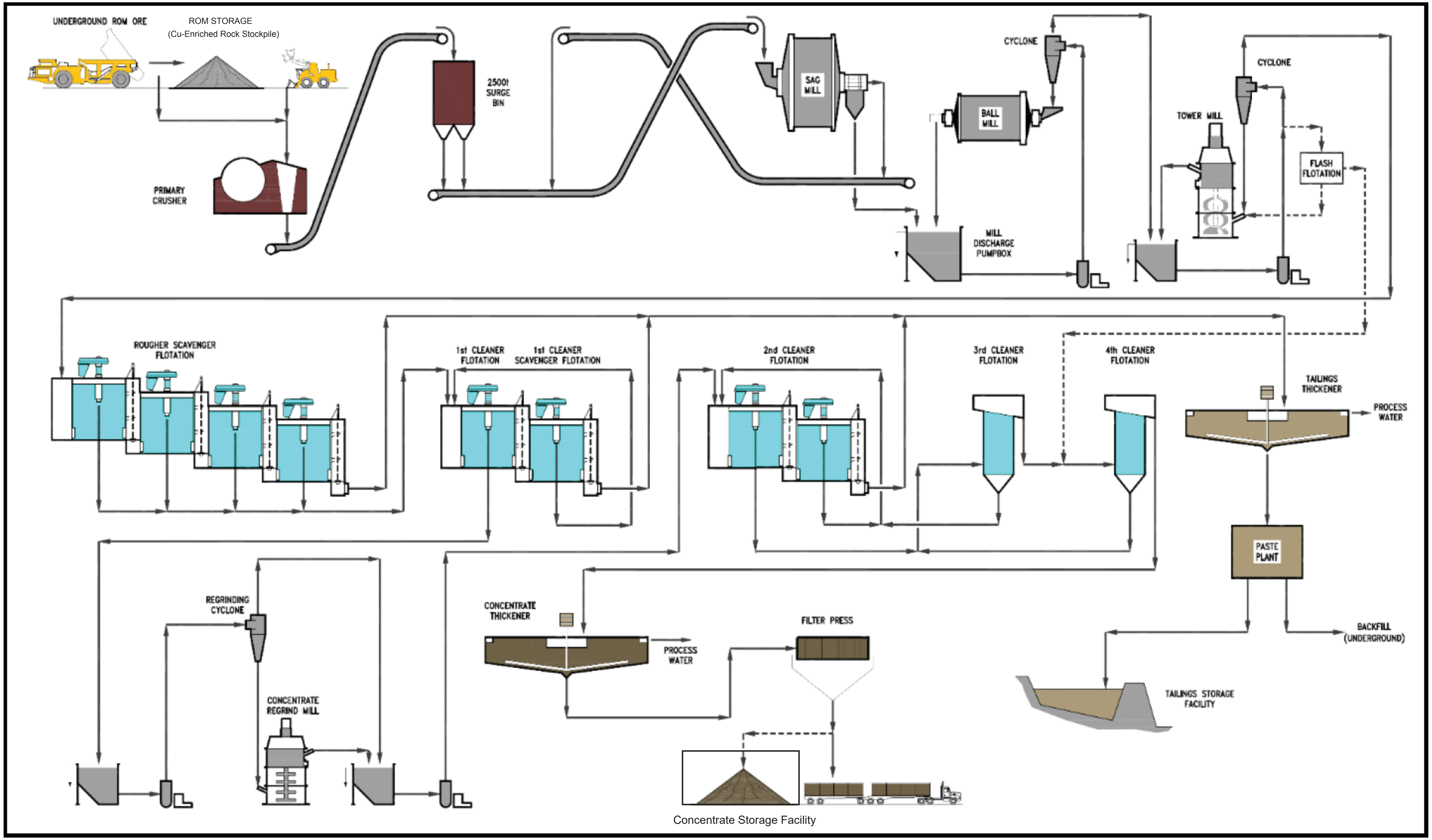
3.4 WATER TREATMENT

Tintina evaluated the need and the potential methods for water treatment at the Project site. The basis of design for water treatment incorporates the planned development of the Project, the water budget for the Project, the characteristics of the water that requires management, and the effluent treatment goals. Figure 3.6 provides a schematic of critical portions of the water flow-path at the Project site.

Water will require management during three phases of the mine life cycle: Construction Phase, Operational Phase, and Closure Phase. These three phases of mine life will have the same effluent goals. However, the water sources, flow rates, influent water quality, and facilities available for disposal of treatment residuals will vary. Section 3.7.3 of the MOP application describes the screening process used for assembling and evaluating water treatment alternatives, and the proposed water treatment processes for various stages of the life cycle of the mine. The following is a brief summary of that discussion.

3.4.1 Raw Water Quality

The raw water quality of the many sources used to estimate the water quality of the WTP influent during operations were derived from geochemical modeling of water quality for the underground mine dewatering, PWP, and CTF, along with estimated water quality for rain water and the mill catchment runoff. A visual representation of the water balance is presented in Figure 3.5. The numbered flow streams on Figure 3.5 correspond to those of Table 3-3 (Site Wide Mass Balance) and water types (applicability to 40 CFR Part 440



Revised February 7, 2017 (Tetra Tech)

TINTINA RESOURCES

Figure 3.6
Detailed Process Flow Sheet
Black Butte Copper Project
Meagher County, Montana

TABLE 3-3. SITE WIDE MASS BALANCE[2]

Stream ID (See Figure 3.5)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Description	**Underground Dewatering**	**Mill Catchment Runoff**	**Surface Water Transfer**	**CTF Foundation Drain**	**Water From CTF to PWP**	**Runoff to PWP**	**Direct Precip**	**PWP Evap**	**Ore Water to Mill**	**Water Loss to Conc**	**Cement/Paste Void Loss**	**Under-ground Tailings Storage**	**Cement Tailings**	**RO Brine Conc.**	**Mill Treated Water**	**Reclaim Water to Mill**	**Mill Thickener OF to PWP**	**Dust Supression**	**Treated Water Discharge (combined)**
Water Type [1]	**MD**	**SW**	**Mix**	**UC**	**MD**	**MD**	**SW**	**Mix**	**MD**	**PW**	**PW**	**PW**	**PW**	**Mix**	**Mix**	**Mix**	**PW**	**SW**	**Mix**
Flow, gpm	**499.7**	**13.1**	**55.2**	**20.0**	**42.2**	**8.0**	**5.0**	**7.0**	**24.1**	**7.0**	**189.4**	**86.4**	**103.0**	**90.8**	**89.4**	**1,995.8**	**1,912.9**	**5.3**	**402.3**
lb/min	4,170.78	109.33	461.3	166.8	352.4	66.7	41.7	58.5	201.2	58.5	1,582.5	1,582.5	1,582.5	761.4	746.3	16,678.6	15,982.9	44.2	3,355.5
Specific Gravity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.01	1.00	1.00	1.00	1.00	1.00
Temperature, Deg C	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.0	25.0	25.00	25.00	25.00	25.00	25.00	25.00
Commons																			
pH	6.7	7.1	6.0	7.4	4.1	7.0	7.0	6.0	6.7	10.4	10.4	10.4	10.4	6.7	8.4	6.0	10.4	5.9	8.1
Total Alkalinity	183.0	218.0	120.7	212.0	97.0	25.0	-	120.7	183.0	76.7	76.7	76.7	76.7	1,066.7	252.9	120.7	76.7	0.20	100.23
Nitrogen, Ammonia	4.40	-	11.40	-	-	-	-	11.40	4.40	11.04	11.04	11.04	11.04	25.83	4.81	11.40	11.04	0.10	0.10
Nitrogen, Nitrate	33.0	0.0	86.8	0.2	-	-	-	86.8	33.0	84.0	84.0	84.0	84.0	197.6	36.2	86.8	84.0	0.22	0.22
Silica	1.55	-	0.38	-	2.45	-	-	0.38	1.55	-	-	-	-	7.39	1.35	0.38	<0.001	<0.001	<0.001
Phosphorus	0.00	-	0.06	-	0.26	-	-	0.06	0.00	0.06	0.06	0.06	0.06	0.04	0.0	0.1	0.1	0.00	0.00
Anions																			
Bicarbonate	223	266	147	258	118	30	-	147	223	4	3.6	3.6	3.6	1,299.1	293	147	4	0	120
Carbonate	0.08	0.22	0.01	0.41	0.00	0.02	-	0.01	0.08	8.44	8.44	8.44	8.44	0.85	5.9	0.0	8.4	0.00	0.87
Chloride	1.38	1.28	135.59	-	34.30	-	-	135.59	1.38	129.15	129.15	129.15	129.15	337.43	20	136	129	0.01	0.01
Fluoride	1.14	0.70	0.52	0.10	0.66	-	-	0.52	1.14	0.28	0.3	0.3	0.3	5.7	1.0	0.5	0.3	<0.001	<0.001
Nitrate	146	0.09	384.2	0.66	-	-	-	384.2	146.1	372.0	372.00	372.00	372.00	875.17	160.3	384.2	372.0	0.98	0.98
Sulfate	304	265	904	12	765	5	-	904	304	865	864.90	864.90	864.90	1,917.88	350	904	865	<0.001	<0.001
Cations																			
Calcium	89	85	521	59	132	-	-	521	89	516	515.58	515.58	515.58	887.48	162	521	516	0.08	40.18
Magnesium	79	55	19	18	92	-	-	19	79	0.01	0.01	0.01	0.01	389.19	71	19	0.01	0.04	0.04
Potassium	11	3	29	-	-	-	-	29	11	28	28.17	28.17	28.17	66.29	12	29	28	0.08	0.08
Sodium	15	16	43	2	13	14	-	43	15	42	41.89	41.89	41.89	92.84	17	43	42	0.08	0.08
Ammonium	5.64	-	14.65	-	-	-	-	14.65	5.64	0.87	0.87	0.87	0.87	33.10	5.38	14.65	0.87	0.13	0.13
Aluminum	0.012	-	0.374	-	17.700	-	-	0.374	0.012	0.001	0.001	0.001	0.001	0.249	0.045	0.374	0.001	<0.001	<0.001
Arsenic	0.004	0.067	0.045	-	0.031	-	-	0.045	0.004	0.045	0.045	0.045	0.045	0.050	0.009	0.045	0.045	<0.001	<0.001
Barium	0.001	0.011	0.004	0.050	0.004	-	-	0.004	0.001	0.003	0.003	0.003	0.003	0.018	0.003	0.004	0.003	<0.001	<0.001
Cadmium	-	-	0.000	-	0.001	-	-	0.000	-	-	-	-	-	0.000	0.000	0.000	-	<0.001	<0.001
Chromium	-	-	0.004	-	0.012	-	-	0.004	-	0.004	0.004	0.004	0.004	0.002	0.000	0.004	0.004	<0.001	<0.001
Copper	-	-	4.003	-	61.300	-	-	4.003	-	2.930	2.930	2.930	2.930	0.549	0.100	4.003	2.930	<0.001	<0.001
Iron (+2)	0.002	1.130	0.000	-	-	-	-	0.000	0.002	-	-	-	-	0.005	0.001	0.000	-	<0.001	<0.001
Iron (+3)	-	-	0.014	-	0.636	-	-	0.014	-	-	-	-	-	0.027	0.005	0.014	-	<0.001	<0.001
Lead	-	-	0.092	-	0.027	-	-	0.092	-	0.096	0.096	0.096	0.096	0.048	0.009	0.092	0.096	<0.001	<0.001
Manganese	0.165	0.025	0.093	-	2.730	-	-	0.093	0.165	0.001	0.001	0.001	0.001	0.820	0.150	0.093	0.001	<0.001	<0.001
Nickel	0.007	0.001	0.195	-	8.500	-	-	0.195	0.007	0.016	0.016	0.016	0.016	0.133	0.024	0.195	0.016	<0.001	<0.001
Strontium	10.500	14.500	4.247	0.140	2.620	-	-	4.247	10.500	2.000	2.000	2.000	2.000	52.905	9.650	4.247	2.000	0.010	0.010
Zinc	0.030	0.010	0.259	-	0.826	-	-	0.259	0.030	0.248	0.248	0.248	0.248	0.275	0.050	0.259	0.248	<0.001	<0.001
Antimony	-	-	0.023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005
Beryllium	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0008
Cobalt	-	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01
Mercury	-	-	0.000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.000005
Molybdenum	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.002
Selenium	-	-	0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0002
Silver	-	-	0.000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0002
Thallium	-	-	0.009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0002
Uranium	-	-	0.009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.008
Gases																			
Ammonia	0	-	0.01	-	-	-	-	0.01	0.01	12.59	12.59	12.6	12.6	0.11	0.76	0.01	12.59	0.00	0.01
Carbon Dioxide	60	30	170	14	10,421	5	-	170	60	0	0	0.0	0.0	247	1	170	0	1	1
Other												-	-						
TSS	150	10	7	26	150	150	-	7	-	4	4	4.0	4.0	1	0	7	4	<0.001	<0.001
TDS (sum of ions)	889	708	2,209	350	1,258	49	-	2,209	889	1,979	1,979	1,978.7	1,978.7	5,973	1,110	2,209	1,979	1.7	163
TDS (180 Deg C)	777	575	2,136	221	1,199	34	-	2,136	777	1,977	1,977	1,976.9	1,976.9	5,323	963	2,136	1,977	1.6	103
Total Hardness, mg/L CaCO3	560.3	458.6	1,382.5	220.7	715.7	-	-	1,382.5	560.3	1,288.1	1,288.1	1,288.1	1,288.1	3,876.7	706.8	1,382.5	1,288.1	0.4	100.4
Scaling Indicies																			
Langelier Saturation Index	(0.7)	(0.2)	(0.9)	0.0	(3.4)	-	-	(0.9)	(0.7)	1.9	1.9	1.9	1.9	0.9	1.4	(0.9)	1.9	(7.1)	0.3

All values in mg/L, unless noted otherwise

[1] Water Types (applicability to 40 CFR Part 440 Effluent Limitation Guidelines).

MD - mine drainage; PW - process water (mill discharge or process including zero discharge ELG); Mix - mixture of any other water types

SW - storm water (subject to Storm Water Program not subject to 40 CFR 440 ELGs); UC - unclassified (not subject to Storm Water Program or 40 CFR 440 ELGs).

[2] Source: Mine Operating Permit (MOP) Application, Revision 3 (Tintina Resources, 2017), Appendix V, Table V-1 modified by the addition of additional parameters from Table V-2 (revised) and the addition of water types with applicability to 40 CFR Part 440 Effluent Limitation Guidelines.

Effluent Limitation Guidelines) are designated in the heading for each flow stream. The source and/or assumptions of the raw water quality used for each stream are summarized below:

- Geochemical model of water quality for underground dewatering was used for Mine Dewatering (1) and Ore Water quality (i.e., moisture and/or pore water in the copper-enriched rock) sent to the Mill (9);
- Geochemical model of CTF Sump was used for Water from CTF to PWP (5);
- Geochemical model of PWP was used for Surface Water Transfer (3); Water Loss to Concentrate (10), and Cemented Paste Void Loss (13), with exception of the nitrate concentration which was based on mass balance modeling;
- Water from the CTF foundation drain pond to the PWP (4) or the WTP; the average water quality from MW-12 was used for the water originating from CTF Foundation Drain Pond;
- Estimated water qualities for the Mill Catchment Runoff (2) is conservatively based on average water quality of the Upper Copper Zone (UCZ); and
- Water quality for Net Runoff to the PWP (6) was assumed to be similar to rain water with a small amount of dissolved salts.

POC for each phase were established by comparing the expected raw water quality to the estimated maximum allowable effluent concentrations (EMAECs). The EMAECs were established from the nondegradation and mixing analysis which is summarized in Section 3.5. The POC that need to be addressed by water treatment systems during the Construction, Operations, and Closure Phases are similar, but differ slightly due to the different mixtures of raw water sources.

The raw water quality is anticipated to be relatively stable for most parameters. However, ammonia, nitrate and total nitrogen are anticipated to vary during operations. The variability in these parameters is typically based on production rates, mine inflows, and/or blasting practices. Higher production rates may produce more nitrogen components resulting in higher concentrations at constant flow rates. If mine inflows increase the concentrations will likely decrease. Using Best Management Practices (BMPs) for blasting underground will be a large factor in maintaining low concentrations of nitrogen components in the raw water quality. A multiplied safety factor of 1.75 was applied to the average ammonia and nitrate/nitrite concentrations of the underground dewatering water quality to account for variabilities in nitrogen concentrations.

3.4.2 Selected Water Treatment System

RO with pre-treatment was selected over other options because it is a more robust and reliable treatment process that has lower overall costs (capital and operation and maintenance (O&M)) than other potential methods. RO systems apply water under pressure to semi-permeable membranes. Clean water permeates through the membrane, whereas dissolved constituents are retained by the membrane in a reject stream (RO reject is also referred to as brine because it contains these removed metals and salts that are concentrated from the feed water). RO provides simultaneous treatment of the POC that must be treated during each operating phase of this Project.

The treatment trains for each phase (Construction, Operation, and Closure) are similar and will meet effluent goals, given the specific constraints of each phase. Section 3.7.3 of the MOP provides additional details on influent concentrations and treatment trains for each phase. Each treatment train is also designed to allow flexible operation and to effectively treat influent with varying flow rates, water temperatures, and constituent concentrations, with a high degree of redundancy and availability. Each treatment train relies on clarification and filtration to reduce TSS concentrations, followed by RO to remove dissolved POC. The system will consist of a double pass RO system, with a nominal treatment rate of 500 gpm (1,893 liter per minute (L/min)), and a total treatment rate, with back-up RO unit, of 750 gpm (2,839 L/min).

A polishing phase will stabilize the treated effluent and prevent corrosion and leaching of host rock or sediments at the point of discharge, post treatment is necessary to return some calcium hardness and bicarbonate alkalinity to the water. For this application, the best approach is to pass the treated effluent through a bed of calcium carbonate (also known as calcite) or suitable alternative media, prior to discharge. Post treatment will only be applied to water that is diverted to the outfalls. The water that will receive post treatment is equal to the influx to the WTP minus the mill treated water and RO Brine (180 gpm). Post treatment will add both calcium and alkalinity (as carbonate) to the water which provides a dual benefit of raising the Langelier Saturation Index (LSI), a measure of “aggressiveness,” to dissolve constituents, above zero while adding buffering capacity to the water. Adding buffering capacity will also result in a more limited range of pH changes in the treated effluent.

3.4.3 Treated Effluent Water Quality

The quality of the water treatment effluent was determined using an iterative site wide material balance model to determine mixed water quality of the water treatment influent. The data from the material balance was used in a final analysis of the RO system. The final treated effluent water quality was simulated using RO vendor software from Dow Process and Water Solutions. The vendor software modeled the full-scale design of a two pass RO system at both 10 and 25 degrees Celsius. Additional modeling was conducted to optimize antiscalants and the Vibratory Shear Enhanced Processing (VSEP) treatment phase. See Appendix B for additional details on the WTP modeling. At the anticipated RO system recovery of 81.7%, 92 gpm (346 L/min) of RO reject and 408 gpm (1,548 L/min) of permeate (treated effluent) will be produced. Treated effluent from the RO system was determined through modeling (Amec Foster Wheeler, 2017a and 2017b [contained in Appendix B]). As noted in Section 3.4.1, concentrations of the nitrogen components (ammonia and nitrate/nitrite) were increased by 1.75 times the average influent concentration during evaluations as a safety factor. This results in a maximum total nitrogen concentration in the WTP effluent of 0.57 mg/L. Projected WTP effluent is shown in Table 3-3.

3.5 NONDEGRADATION ANALYSIS

The proposed underground copper mine will generate water from mine dewatering, process water, and other minor sources. Once treated, the combined water will be reused or discharged to state waters through infiltration to groundwater. As a new discharge, the level of treatment required by the Project is determined by the nondegradation statute (75-5-303 Montana Code Annotated MCA) and rule (Administrative Rules of Montana (ARM) 17.30

Subchapter 7) for nonsignificant activities. With the overarching purpose to identify the water quality needed to prevent effects to all current and anticipated beneficial uses in groundwater and surface water.

3.5.1 Water Protection Classification

The groundwater system within the alluvial UIG is high-quality waters. Sheep Creek surface water is listed on the 2016 303(d) list of impaired waters because aquatic life and primary contact recreation uses are not supported due to water quality exceedances of dissolved aluminum and bacterial concentration. While Sheep Creek does not meet the above definition of a high-quality water for these parameters, it supports all other uses and meets the definition of high-quality waters for other beneficial uses.

3.5.2 Nonsignificance Criteria and Analysis

Subchapter 7 of ARM 17.30 Rule 715 identifies the process for application of significance criteria for new or increased sources. Dependent on how each discharged parameter is classified and the condition of the surface water, certain increases are not considered significant and may be allowed by statute and rule. The nondegradation rules to evaluate increases in the receiving waters are summarized below:

- Carcinogenic parameters and those with bioconcentration factors greater than 300 – no increases are allowed in the receiving water.
- Toxic parameters – increases are allowed up to the trigger value contained in Circular DEQ-7. If changes in water quality are greater than the trigger value, the change is not significant if the resulting concentration at the edge of a mixing zone does not exceed 15% of the lowest applicable standard.
- Harmful and nutrient parameters – changes in water quality at the edge of a mixing zone are allowed when the existing concentration in the receiving water is less than 40% of the applicable standard and the water quality change outside a mixing zone is less than 10% of the applicable water quality standard.
- Changes in the quantity of surface water – increases or decreases in surface water flows that are less than 15% of the mean monthly flow or less than 10% of the seven-

day ten-year low flow (7Q10). Nonsignificance criteria are not applied to quantity of groundwater discharges.

- Nitrate – changes in the concentration of nitrate in groundwater will not exceed 7.5 mg/L.
- Narrative standards – changes in water quality will not have a measurable effect on beneficial uses or cause measurable changes in aquatic life or ecological integrity.

Nonsignificance criteria were calculated based on the 75th percentile of each constituent from the receiving water quality data (Table 3-1). For parameters that were less than detect, the detection limit was used as the concentration. Table 3-4 summarizes the calculated nondegradation nonsignificance criteria for each receiving water in comparison to the projected effluent water quality. All of the potential pollutants that may be in the water treatment effluent are below the nondegradation nonsignificance criteria of the alluvial groundwater system. Total nitrogen, during the growing season, is the only pollutant that is projected to be above the surface water nondegradation nonsignificance criteria. Nondegradation criteria for flow are summarized in Table 3-5. The nondegradation nonsignificance criteria calculations are shown in Appendix I.

Total nitrogen, after its initial mixing with groundwater will remain above the nondegradation nonsignificance criteria for surface water in Sheep Creek. Therefore, Tintina is requesting a source specific mixing zone in surface water for total nitrogen during the months of July through September.

The proposed surface water mixing zone is shown in Figure 3.7 and is approximately 3,500 feet long. The source specific mixing zone starts at $46^0$46’50.02” N latitude $110^0$54’7.31” W longitude and ends at $46^0$47’7.71” N latitude $110^0$54’35.72” W longitude, or at the confluence of Coon Creek with Sheep Creek. This reach of Sheep Creek represents the gaining reach prior to the canyon mouth where alluvial sediment pinches out at the canyon mouth. Based on the diffuse nature of the groundwater infiltration into Sheep Creek (0.24 gpm per linear foot of mixing zone) mixing will be evaluated with the entire 14Q5 (9,140 gpm - ARM 17.30.516(3)(e)). A request for a source specific mixing zone in Sheep Creek is provided in Appendix D.

TABLE 3-4. NON-DEGRADATION LIMITS VERSUS TREATED DISCHARGE WATER

Description	Receiving Water Non-Degradation Limits(1)		Estimated Treated Water Discharge(2)	
	Sheep Creek Alluvium	Sheep Creek	Average	Maximum(3)
Flow, gpm		See Table 3-5.	398.0	575
Temperature, Deg C	NA	(4)	25.00	25.00
Dissolved Oxygen	NA	NA		
Specific Conductivity (umhos/cm)	<1000	NA		
Commons				
pH	6.5-8.5	6.5-8.5	8.1	8.1
Total Alkalinity	NA	NA	100.2	100.2
Nitrogen, Ammonia	NA	0.35	0.10	0.18
Nitrogen, Nitrate + Nitrite	7.5	7.5	0.22	0.39
Total Nitrogen(5)	NA	0.09	0.32	0.57
Phosphorus (5)	NA	0.01	0.0005	0.0005
Anions				
Bicarbonate	NA	NA	120.4	120.4
Carbonate	NA	NA	0.87	0.87
Chloride	250 (6)	250 (6)	0.01	0.01
Fluoride	0.8	0.7000	<0.001	<0.001
Sulfate	250 (6)	250 (6)	-	-
Cations				
Aluminum	NA	0.0300	<0.001	<0.001
Antimony	0.0014	0.00134	<0.0005	<0.0005
Arsenic	0.001	0.001	<0.001	<0.001
Barium	0.33875	0.260	<0.001	<0.001
Beryllium	0.0008	0.0008	<0.0008	<0.0008
Cadmium	0.00078	0.0001	<0.00003	<0.00003
Calcium	NA	NA	40.18	40.18
Chromium	0.025	0.025	<0.001	<0.001
Cobalt	NA	NA	<0.01	<0.01
Copper	0.197	0.004	<0.001	<0.001
Iron	NA	0.3875	<0.001	<0.001
Lead	0.00255	0.00105	<0.0003	<0.0003
Magnesium	NA	NA	0.04	0.04
Manganese	NA	NA	<0.001	<0.001
Mercury	0.000005	0.000006	<0.000005	<0.000005
Molybdenum	NA	NA	<0.002	<0.002
Nickel	0.016	0.010	<0.001	<0.001
Potassium	NA	NA	0.08	0.08
Selenium	0.0077	0.0010	<0.0002	<0.0002
Silver	0.0152	0.0010	<0.0002	<0.0002
Sodium	NA	NA	0.08	0.08
Strontium	0.773	0.727	0.010	0.010
Thallium	0.0005	0.0002	<0.0002	<0.0002
Uranium	0.008	0.008	<0.008	<0.008
Zinc	0.302	0.03	<0.001	<0.001
Other				
Total Suspended Solids (TSS)	NA	26	<0.001	<0.001
Total Dissolved Solids (180 Deg C)	NA	500(6)	103	103
Total Hardness, mg/L CaCO3	NA	NA	100.4	100.4

All values in mg/L, unless otherwise noted.
NA = Not Applicable, no applicable standard.

(1) Estimated non-degradation limits (allowable change to existing water quality with no significant impact) were calculated using the 75th %ile of ambient data (Refer to Table 3-1).

(2) Water Treatment Plant Mass Balance, Estimated Treated Water Discharge (combined), Stream 19 shown on Figure 3.5. Source: Table V-2 (revised 9-26-17) .

(3) Maximum effluent concentrations and flows are based on projected increases in flows at 1.5 X the average flow. Nitrogen concentrations in the WTP influent are the only constituent that is projected to very significantly. A maximum nitrogen (ammonia and nitrate+nitrite) was estimated based on 1.75X the

(4) ARM 17.30.623(2).

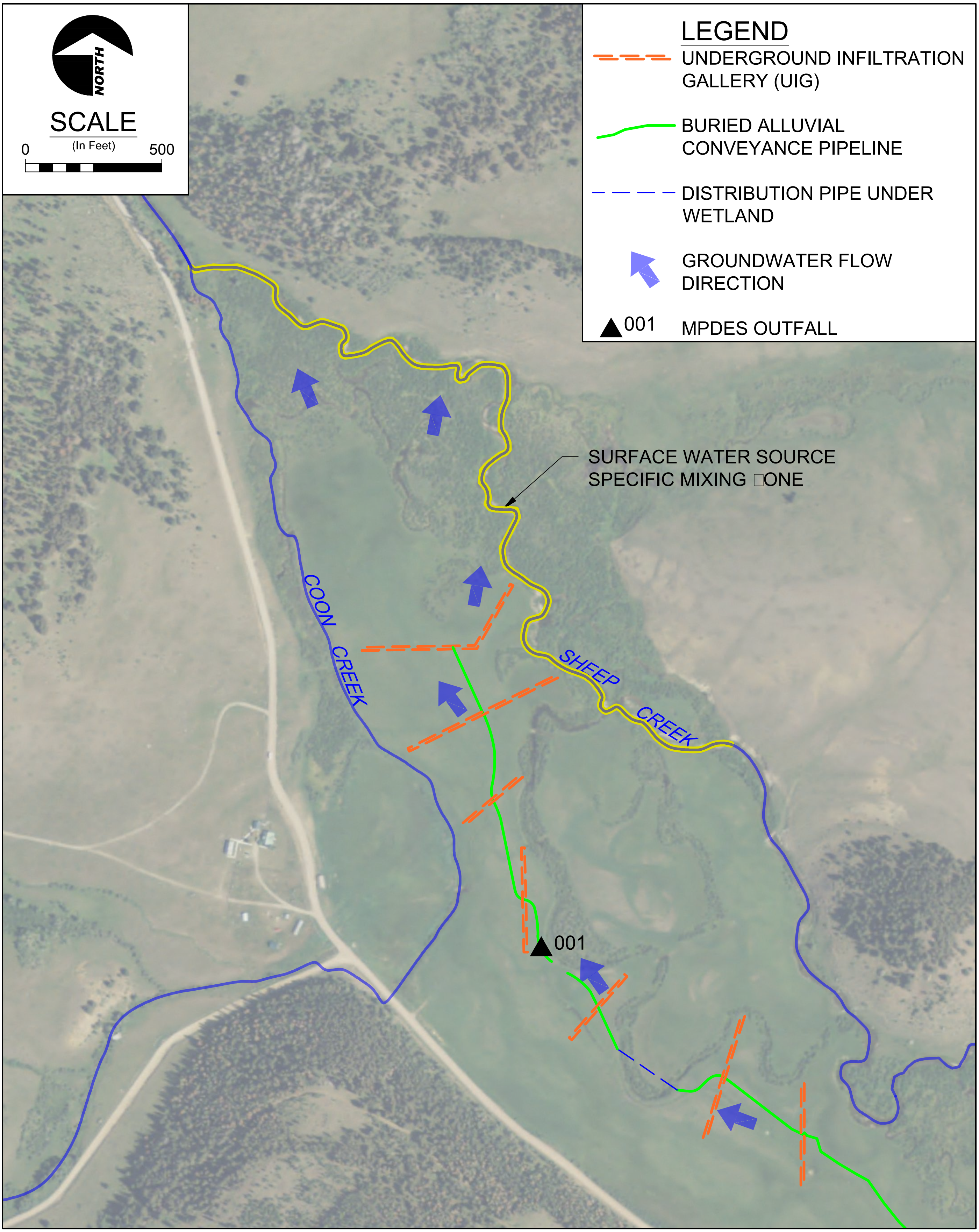
(5) Receiving water Total Phosphorous and Total Nitrogen (Pesulfate Method) 75th percentile was calculated on a seasonal basis (Summer July 1 - September 30).

(6) Based on EPA Secondary Standard (SMCL).

TABLE 3-5. SHEEP CREEK NONDEGRADATION FLOW ANALYSIS FOR SW-1

Nondegradation Analysis Mean Monthly Flow				
Month	**SW-1**	**15% MMy Flow**		**USGS 6077000**
	(cfs)	**(cfs)**	**(gpm)**	**(cfs)**
Jan	16.1	2.41	1082	9.2
Feb	15.9	2.39	1070	9.1
Mar	16.4	2.46	1105	9.4
Apr	36.7	5.51	2469	21
May	166.0	24.90	11170	95
Jun	201.0	30.15	13521	115
Jul	75.1	11.27	5056	43
Aug	40.2	6.03	2704	23
Sep	31.5	4.72	2116	18
Oct	28.0	4.19	1881	16
Nov	22.7	3.41	1528	13
Dec	17.5	2.62	1176	10
Nondegradation Analysis 7Q10 Flow				
	SW-1	10% 7Q10 Flow		USGS 6077000
	(cfs)	(cfs)	(gpm)	(cfs)
7Q10	8.6	0.86	384	4.9

SW-1 Mean Monthly and 7Q10 Flows Calculated based on ratio of watershed area compared to USGS gage 6077000 watershed area per Q2= Q1*(A2/A1); MM: Mean Monthly
A1= 42.8 miles^2 A2= 74.8 miles^2



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Hydrometrics, Inc.
Consulting Scientists and Engineers

Figure 3.7
Source Specific Mixing Zone
Black Butte Copper Project
Meagher County, Montana

As noted in Section 3.2, although groundwater discharges to Coon Creek under ambient conditions, the dewatering modeling analysis shows there will be approximately 10 feet of unsaturated soils (as a result of mine dewatering) in the vicinity of Coon Creek during operations. The maximum mounding from the discharge is projected to be 3.5 feet; therefore, there will still be about 6.5 feet of unsaturated zone beneath Coon Creek. Since groundwater will not discharge to Coon Creek during operations, a mixing zone is not being requested for this surface water resource.

4.0 STORM WATER

Storm water management for the Project will use the integrated permitting approach. This is typically implemented by permitting the applicable storm water outfalls in the MPDES discharge permit, using the regulatory requirements of the Multi-Sector General Permit for Storm Water Discharges Associated with Industrial Activities. Industrial activities covered by the storm water regulations include: runoff from topsoil stockpiles, off site haul/access roads, on site haul/access roads, runoff from tailings embankments when not constructed from waste rock, runoff from concentrator building, runoff from the mill site, chemical storage areas, docking facilities, explosive storage areas, fuel storage areas, vehicle / equipment maintenance areas / buildings, parking lots, truck wash areas, power plant areas, and reclaimed areas not released from reclamation bonds. Storm water which has come in contact with mine drainage, mined materials, or process waters is not included in this portion of the integrated permit application. These comingled storm waters are collected and treated (RO plant) prior to discharge under the MPDES outfalls. Storm water best management will include diverting storm water run-off around disturbed areas, or by collecting run-off for treatment prior to discharge. The majority of storm water run-off at the Project site will be controlled by diversion around disturbed soils. Figure 3.1 shows drainage control and storm water outfall locations. Storm water flow rates were derived through SEDCAD modeling of the 10-year, 24-hour storm event as described in Section 4.2 below.

4.1 STORM WATER OUTFALL DESCRIPTIONS

Storm water Outfall 002 discharges storm water from approximately 0.02 square miles (13.2 acres) including stockpile service roads, a topsoil stockpile, and vegetated ground between the CTF diversion ditch and the service road. Storm water flow rates discharged from this outfall were estimated to be 11.38 cfs at peak discharge with a runoff volume of 0.8 acre-feet (ac-ft).

The drainage basin for storm water Outfall 003 encompasses approximately 0.02 square miles (15.2 acres) of access road, the Reclamation Material Stockpile North, surrounding ground, and a drainage ditch along the northeast side of the CTF road shoulder. The CTF road will not be regulated under this storm water action; discharge from the CTF road will be collected and processed through the WTP under the MPDES program. The reclamation stockpile materials will largely come from the waste rock storage (WRS) basin excavation. The north reclamation materials will be used in year two or three to mostly reclaim the WRS facility, but materials will also be used in closure to reclaim the other northern mine facilities. Peak flow rates from this outfall were estimated to be 19.2 cfs, and a runoff volume of 1.0 ac-ft from a 10-year, 24-hour storm event.

The total area discharging to Outfall 004 will be approximately 0.10 square miles (65.7 acres). Outfall 004 discharge will primarily be comprised of storm water drainage from vegetated and undisturbed ground to the west and northwest of the CTF that flows into the CTF Diversion Ditch. Runoff from a service road (south of PWP), subsoil stockpile and the Reclamation Materials Stockpile South (materials coming from the CTF basin excavation) will also flow to the CTF Diversion Ditch via a drainage ditch constructed along the east side of the stockpiles. The southern reclamation material stockpile will be used for various mine closure requirements, but principally for the closure cover on the CTF and closure of the southern mine facilities. Peak flow rates from this outfall were estimated to be 35.53 cfs, and a runoff volume of 2.8 ac-ft from a 10-year, 24-hour storm event.

Storm water Outfall 005 discharges water from approximately 0.02 square miles (13.0 acres). Discharge will primarily originate along the CTF embankment (constructed from non-waste rock materials) east of the CTF road. Discharge will include portions of native land and a service road south of the CTF. A diversion ditch collects runoff from the drainage area and directs flow to Outfall 005. Peak flow rates discharged from this outfall were estimated to be 11.99 cfs with a total runoff volume of 0.8 ac-ft.

There is an area of sheet flow passing under the service road to the north of Outfall 006. Run-on from undisturbed ground and a small section of service road will flow through a culvert and be dispersed through an energy dissipater to the east.

Outfall 006 collects storm water from the access road to the east of Brush Creek a short distance to the divide with Outfall 007, and from undisturbed ground south of the road. The total area of the drainage basin contributing storm water to the outfall will be approximately 0.04 square miles (25.9 acres). Flow rates discharged from this outfall were estimated to be 0.87 cfs with runoff volume of 0.3 ac-ft from a 10-year, 24-hour event.

Outfall 007 storm water will consist of approximately 0.04 square miles (27.6 acres) of the Non-Contact Water Reservoir (NCWR) access road and undisturbed hillside to the south. Flow rates discharged from this outfall were estimated to be 15.4 cfs (1.2 ac-ft).

Storm water from Outfall 008 discharges from approximately 0.02 square miles (13.5 acres) of native ground between a topsoil stockpile service road and the CTF diversion ditch. Peak flow rates were estimated to be 6.1 cfs with a runoff volume of approximately 0.5 ac-ft.

There is an area of sheet flow leaving the service road to the east Outfall 007 drainage and north of the NCWR Reservoir. Run-on to the road will be captured in a diversion ditch and dispersed through an energy dissipater to the east. A small amount of runoff from the road will enter the NCWR.

Outfall 009 storm water is collected from a portion of the access road to the east and west of the crossing on Brush Creek and a small area of undisturbed hillside. The total drainage area is approximately 0.01 miles square (9.0 acres). The runoff volume is approximately 0.5 ac-ft at a peak discharge rate of 10.7 cfs.

The total area discharging to Outfall 010 will be approximately 130,635 square meters (32.3 acres). The drainage area is primarily comprised of undisturbed ground north of the access road. A portion of the access road also flows to Outfall 007. The peak discharge for Outfall 010 is 12.4 cfs with a runoff volume of 1.1 ac-ft from a 10-year, 24-hour event.

Storm water from approximately 0.003 square miles (1.7 acres) of unpaved access road will be directed to Outfall 011. The peak discharge for Outfall 011 was calculated to be 2.94 cfs, with a runoff volume of 0.142 ac-ft from a 10-year, 24-hour event.

4.2 OUTFALL FLOW CALCULATIONS

Hydrometrics calculated runoff flow volumes and peak runoff flow rates for undisturbed watersheds within the operating permit boundary of the Project. Flow rates were calculated using SEDCAD4 and incorporated the Black Butte Baseline Soils Inventory (Baker, 2017), Baseline Vegetation Inventory (Scow, 2017), LIDAR and Topographic Maps. Flow calculations and SEDCAD4 output are contained in Appendix J.

Curve Numbers were calculated based on a weighted average of preexisting soil type and vegetative cover with Curve Numbers for different vegetative types taken from the USDA (1988). Time of concentration was calculated as the sum of channel flow and overland flow. The time of concentration for overland flow was calculated using the SEDCAD4 software. The time of concentration for overland flow was calculated using the NRCS watershed lag method (NRCS, 2010).

A 10-year, 24-hour storm event was assumed for flow calculations; 2.28 inches of precipitation within a 24-hour period. Flow calculations were completed using a SCS Type II storm event curve distribution.

4.3 STORM WATER QUALITY

A review of data from surface water sites between 2011 to current was undertaken to develop a storm water quality estimate. Predicted storm water quality presented in Form 2F was determined using analytical results from surface water site SW-14. The storm water quality was estimated by removing the groundwater component from a high flow storm event as compared to a low flow sampling event. Estimated storm water quality is shown in Table 4-1.

TABLE 4-1. STORM WATER QUALITY

	SW-14 Storm Water Estimate	Surface Water Aquatic Standard (Chronic)	Surface Water Human Health
Dissolved Oxygen	14.06	--	--
Field pH	7.63	--	--
Field Specific Conductance	251.31	--	--
Flow	2.51	--	--
Water Temperature	-0.64	--	--
Total Dissolved Solids	166.36	--	--
Total Suspended Solids	10.36	--	--
Alkalinity as CACO3	142.3	--	--
Calcium (DIS)	32.1	--	--
Chloride	1.4	--	--
Fluoride	0.04	--	4
Magnesium (DIS)	11.1	--	--
Potassium (DIS)	2.6	--	--
Sodium (DIS)	2.0	--	--
Sulfate	8.3	--	--
Total Hardness	--	--	--
Nitrate + Nitrite as n	0.19	--	10
Phosphorus (TOT)	0.06	--	--
Total Persulfate Nitrogen	0.59	--	--
Aluminum (DIS)	0.069	0.087	--
Antimony (TRC)	<0.0005	--	--
Arsenic (TRC)	<0.001	0.15	0.01
Barium (TRC)	0.070	--	1
Beryllium (TRC)	<0.0008	--	0.004
Cadmium (TRC)	<0.00003	0.0012	0.005
Chromium (TRC)	<0.01	--	0.1
Cobalt (TRC)	<0.01	--	--
Copper (TRC)	<0.002	0.0152	1.3
Iron (TRC)	0.62	1.0	--
Lead (TRC)	<0.0003	0.0066	0.015
Manganese (TRC)	0.007	--	--
Mercury (TRC)	<0.000005	0.00091	0.00005
Molybdenum (TRC)	<0.002	--	--
Nickel (TRC)	<0.001	0.0845	0.1
Selenium (TRC)	<0.0002	0.005	0.05
Silver (TRC)	<0.0002	--	0.1
Strontium (TRC)	0.065	--	4
Thallium (TRC)	<0.0002	--	0.00024
Uranium (TRC)	<0.008	--	0.03
Zinc (TRC)	<0.002	0.1942	2

Aquatic Chronic based on minimum hardness of 177 (hardness at SW-3).

4.4 DRAINAGE CONTROL

During Tintina's preparation of a Storm Water Pollution Prevention Plan (SWPPP), a water control and a storm water management plan will be prepared and implemented at the site to prevent commingling of unaffected water with water affected by construction activities and later by mining and milling. This plan will also develop controls for run-off from the site and adjacent areas. Figure 3.1 displays general storm water controls for the site.

Diversion structures will consist of drainage ditches or swales, spreaders, sediment traps, rock berms, straw wattles, and slash windrows. Drainage structures will be sized to safely convey the 24-hour, 100-year storm event. Interceptor or major diversion ditches will be installed uphill from the WRS, portal pad, mill facility, PWP, and CTF (Figure 3.1) to intercept non-contact water drainage, and convey it to existing drainage outfalls.

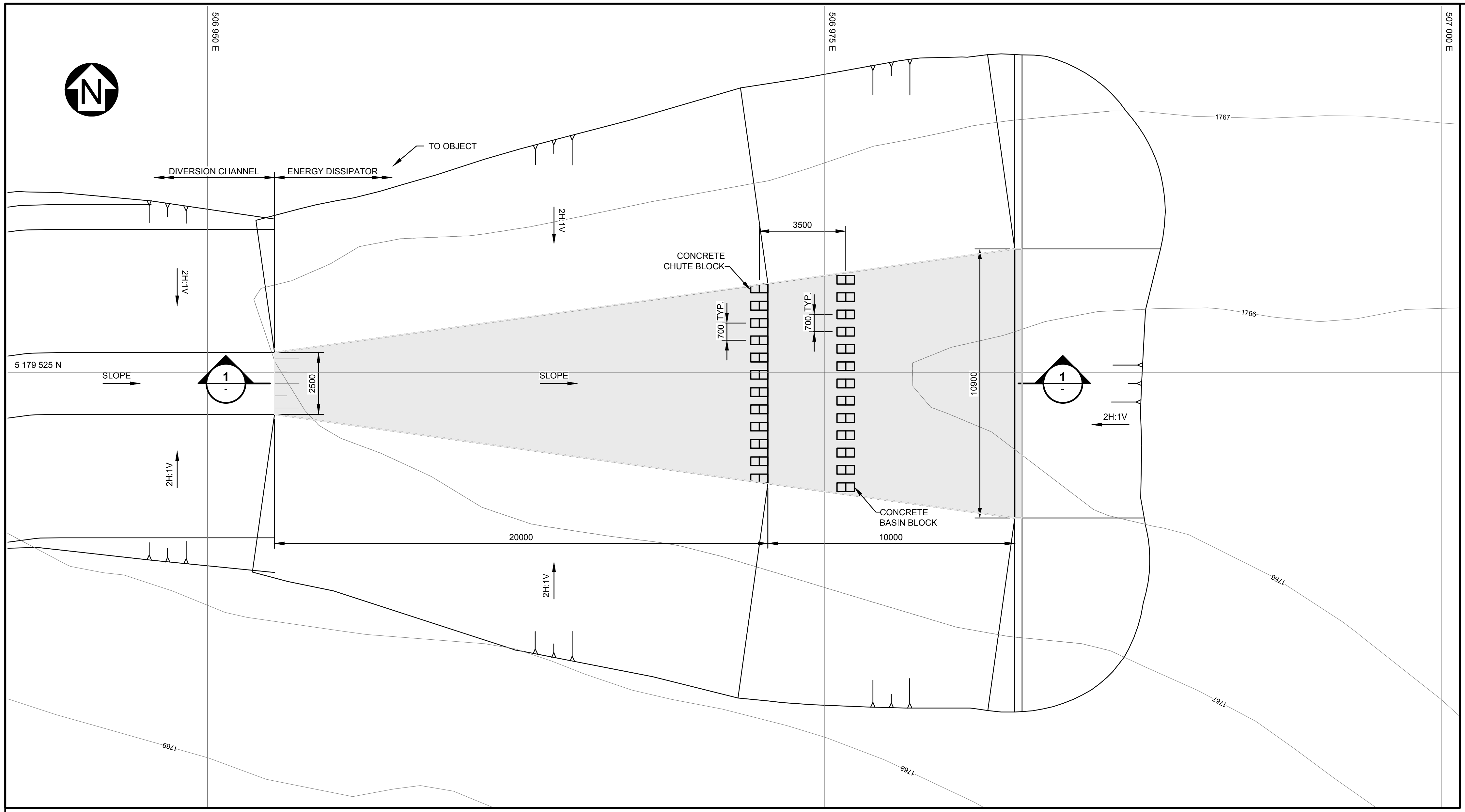
All storm water controls will be constructed prior to, or in conjunction with, soil removal and stockpiling. Storm water controls are passive systems that require regular inspection for areas of erosion and sediment build-up in the slash windrow or sediment traps. With proper maintenance and inspection, each storm water control will remain in place until completion of the construction phase, and where required throughout the operational stages of the Project. Many BMPs will remain in place through mine closure and until subsequent stabilization and revegetation of disturbed areas is complete.

A surface water diversion ditch around the upper sides and side slopes of disturbed areas will be used to divert clean storm water from the disturbed facility areas within the site. The diversion ditches reduce the amount of run-off contributing to the mine facilities by diverting their respective upstream catchments. This reduces the capacity required in the facilities to meet storm water probable maximum precipitation (PMP) and PMF storage requirements of 22 inches (560 mm) and 33.46 inches (850 mm), respectively. Diversion ditches also reduce the overall consumptive use and reduces flow impacts downstream of the Project.

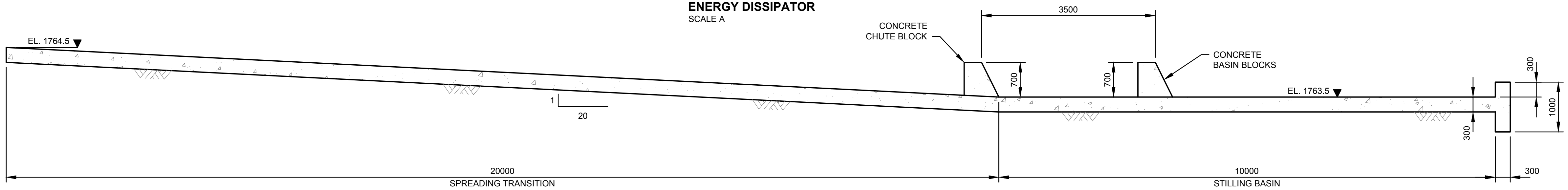
Energy dissipation features or spreaders (Figure 4.1) will be constructed where the surface water diversion outlets meet undisturbed ground. The spreaders will convert the flow concentrated in the diversion ditch to sheet flow and discharge it over an erosion blanketed lip to an undisturbed area at non-erosive velocities. The spreaders will be located such that the discharge water will not be collected by the down-slope berms or concentrated in down-slope channels. If site conditions determine that the spreaders are not appropriate for the site, down-slope drainage channels and energy dissipating outlets or infiltration basins will be specified. Sediment carried from diversions around facilities by storm water run-off will be periodically removed from the ditches and sump(s) collection drains or infiltration basins and stored for use in reclamation on the sub-soil or reclamation materials stockpiles as appropriate. Water captured in the toe ditches surrounding the waste rock pads will be directed through HDPE lined ditches or pipelines to the contact water pond for subsequent treatment before discharge.

Run-on drainage ditches would be cut / fill ditches much like diversion channels, but smaller. Drainage control is sized for the 10-year, 24-hour event peak flow. Culverts will have inlet / outlet protection to prevent scour.

The Storm Water Discharge System Map (Figure 3.1) shows the general location of surface water, run-on ditches, and run-off ditches developed for the Project's construction areas, mine site and its supporting facilities. Typical cross-sections of diversion ditches are illustrated on Figure 4.2 from the CTF and PWP areas. A SWPPP will be developed for the Project site illustrating the final layout with respect to storm water management. The SWPPP will be updated as needed to accurately reflect actual site BMPs conditions.



PLAN
ENERGY DISSIPATOR
SCALE A



1 - **SECTION**
SCALE B

LEGEND:
▨ CONCRETE

NOTES:

1. DIMENSIONS ARE IN MILLIMETERS AND ELEVATIONS ARE IN METERS, UNLESS NOTED OTHERWISE.

SCALE B 1000 500 0 1000 2000 3000 4000 5000 mm
SCALE A 2 1 0 2 4 6 8 10 m

TINTINA RESOURCES

BLACK BUTTE COPPER PROJECT

MEAGHER COUNTY, MT

FIGURE 4.1
TYPICAL DIVERSION CHANNEL
ENERGY DISSIPATION PLAN MAP

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED	APPROVED
0	15OCT'15	ISSUED FOR MOP APPLICATION	MH	NSD		

REVISIONS

REVISED DATE: OCTOBER 15, 2015
REVISION 0

DRAWING BY KNIGHT PIESOLD: VA101-460/3
SOURCE FIGURE NUMBERS: C5004

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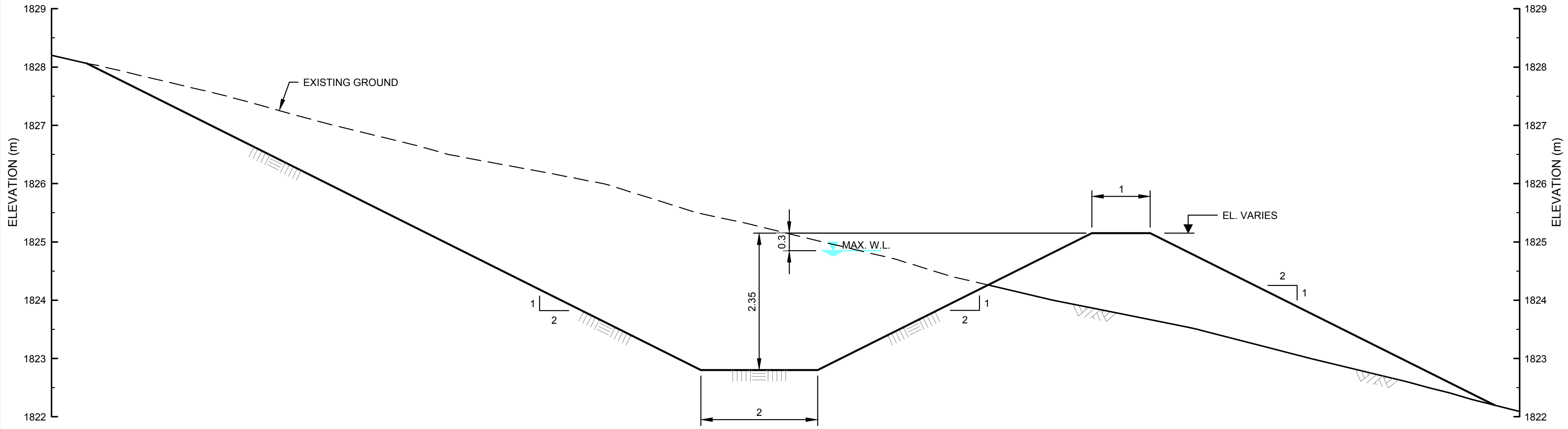
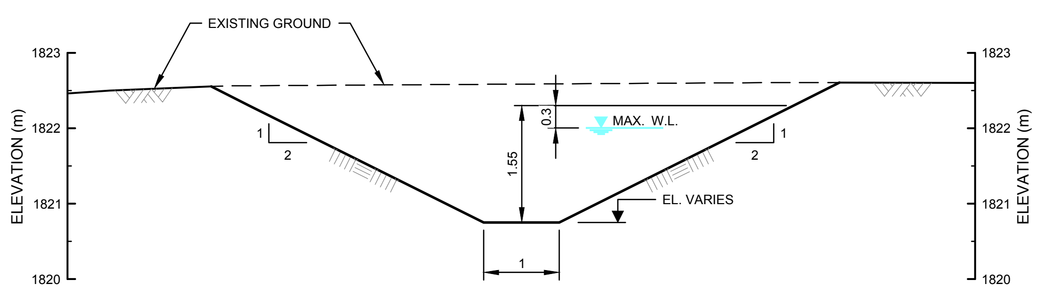
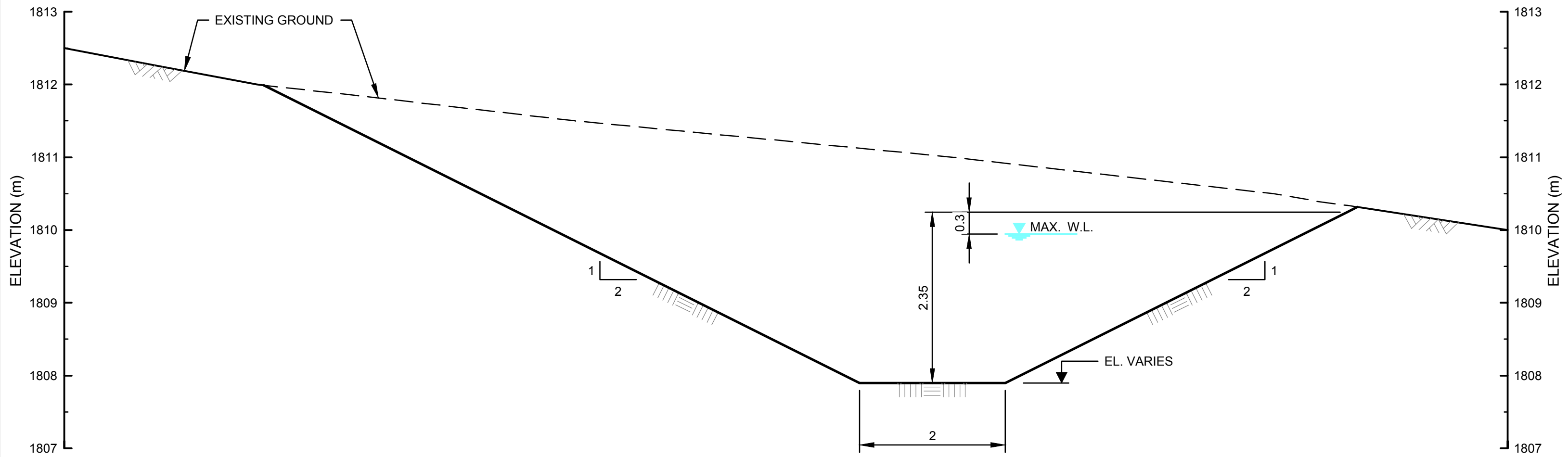


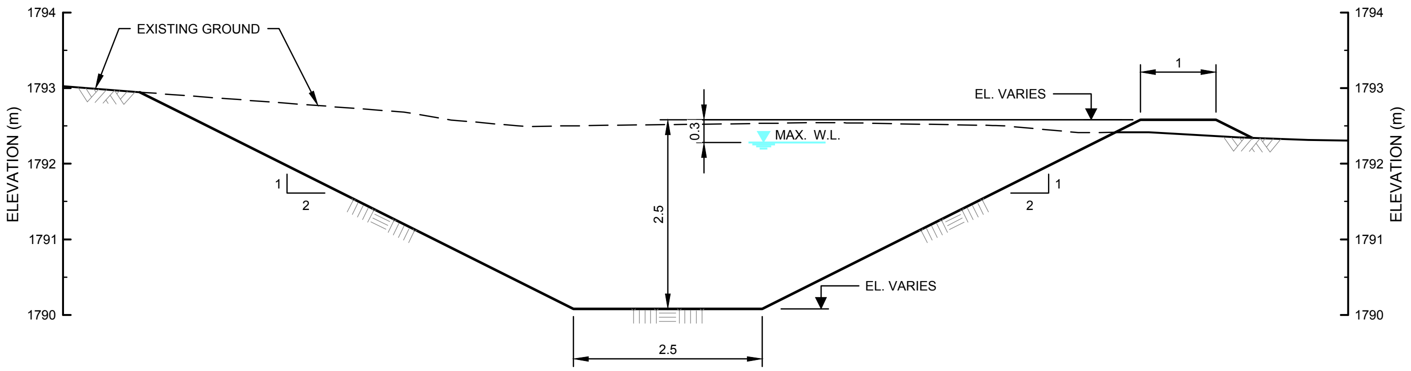
1 C5001 **SECTION TYPE 1**
CTF DIVERSION CHANNEL (CUT AND FILL)
SCALE A



3 C5002 **SECTION TYPE 3**
PWP DIVERSION CHANNEL
SCALE A



2 C5001 **SECTION TYPE 2**
CTF DIVERSION CHANNEL (ALL CUT)
SCALE A



4 C5002 **SECTION TYPE 4**
CTF AND PWP DIVERSION CHANNEL
SCALE A

SCALE A 1 0.5 0 1 2 3 4 5 m

TINTINA RESOURCES

NOTES:

1. DIMENSIONS AND ELEVATIONS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. MAXIMUM WATER LEVEL (MAX. W.L.) BASED ON ANTICIPATED WATER DEPTH DURING THE PROBABLE MAXIMUM FLOOD (PMF).

BLACK BUTTE COPPER PROJECT M

MEAGHER COUNTY, MT

FIGURE 4.2
TYPICAL CROSS-SECTIONS OF DIVERSION CHANNELS FOR PROCESS WATER POND AND CEMENTED TAILINGS FACILITY

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED	APPROVED
0	15OCT'15	ISSUED FOR MOP APPLICATION	MH	NSD		

REVISIONS

REVISED DATE: OCTOBER 15, 2015
REVISION 0

DRAWING BY KNIGHT PIESOLD: VA101-460/3
SOURCE FIGURE NUMBERS: C5003

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4.5 EROSION CONTROL METHODS AND BEST MANAGEMENT PRACTICES (BMPs)

During the construction, operations, and closure phases, a number of erosion control techniques, methods, or features will be used. The bulleted list that follows identifies and defines them.

- Vegetation Management and Revegetation - Natural vegetation is one of the best and most cost effective methods of reducing the potential for erosion and sedimentation by keeping soil secure and providing ground cover to reduce raindrop velocities.
- Mulching - This is the application of a uniform protective layer of straw, wood fiber, wood chips, or other acceptable material on the soil surface of a seeded area to allow for the immediate protection of the seed bed during revegetation. Mulching can be used in areas that require temporary or permanent covers.
- Rolled Erosion Control Products - Tintina will use products that consist of primarily organic materials composed of two layers of coarse mesh with a central layer of permeable fibres. These are used to cover un-vegetated cut or fill slopes when vegetation or mulching alone may be unsuccessful.
- Slope Roughening - Cut and fill slopes can be roughened with tracked machinery or other means to reduce run-off velocities, increase water infiltration rates, and helps facilitate future revegetation. It is simple, inexpensive, and provides immediate short-term erosion control for bare soil where vegetative cover is not yet established.
- Recontouring - This method can reduce the effect of erosion by shortening the length of the accumulation and movement of water as well as decreasing the angle of the erosional slope. Recontouring is easily planned and constructed on site.
- Silt Fencing - This is a perimeter control type BMP used to intercept sheet flow run-off in conjunction with other BMPs. Typical silt fencing comprises a geotextile fabric partially buried in the ground (on the disturbed side of the fence) and anchored to posts driven into the ground. It promotes sediment control by filtering water that passes through the fabric and increases short term retention time, allowing suspended sediments to settle. Silt fences will be placed parallel to slope contours in order to maximize ponding efficiency.

- Temporary Sediment Traps and Sediment Basins - A sediment trap / basin is a temporary structure used to detain run-off from small drainage areas (generally < 5 acres) to allow sediment to settle out. A sediment trap / basin can be created by excavating a basin, utilizing an existing depression, or constructing a small dam on a slight slope downward from the work area.
- Filter Bags - Filter bags are generally constructed from a sturdy non-woven geotextile capable of filtering particles larger than 150 microns. Filter bags are typically installed at the discharge end of pumped diversions, via fabric flange fittings, and remove fine grained materials before discharging to the environment.
- Flocculants - Flocculation systems are installed in sediment control ponds and use chemical or natural additives (e.g., corn starch, chitosan, guar gum, etc.) to accelerate the natural settling process as sediment-laden water flows through the pond. These systems reduce the required pond retention time.
- Collection Ditches - A collection ditch intercepts contact water run-off from disturbed areas and diverts it to a stabilized area where it can be effectively managed. Coarse non-acid generating rock and equipment to build ditches and dams will be easily obtained on site, and require little further maintenance, making them effective improvements. Contact water will be collected in HPDE lined ditches and routed to the CWP for storage and treatment prior to discharge.
- Diversion Ditches - Diversion ditches are constructed up-gradient of disturbed areas to intercept clean surface water run-off and discharge it through a stabilized outlet designed to handle the expected run-off velocities and flows from the ditch without scouring.
- Culverts - Culverts are used in tandem with collection or diversion ditches to pass water flow beneath disturbed areas, typically roadways, to prevent the erosion of these constructed structures.
- Water Bars - Water bars serve to reduce sheet flow and surface erosion of areas of exposed soil and/or roads by diverting run-off towards a stable vegetated area or collection ditch. Water bars may require regular maintenance when subjected to frequent traffic crossings.

4.5.1 Specific Construction BMPs

Erosion control BMPs will be implemented prior to and during construction at the Project. Erosion control BMPs reduce erosion by stabilizing exposed soil, or by reducing surface run-off flow velocities. There are generally two types of erosion control BMPs:

- Source control BMPs for protection of exposed surfaces; and
- Conveyance BMPs for control of run-off.

Examples of BMPs that will be implemented are included in “Water Quality BMPs for Montana Forests” (MSU Extension Service, 2001). The BMPs listed below will likely be used to minimize erosion, sedimentation, and to control surface and storm water run-off at the Project site.

1. Staged development to allow “green-up” or re-establishment of vegetation and minimize erosive areas.
2. Suspension of construction dirt work during periods of heaviest precipitation and run-off to minimize soil disturbance and erosion.
3. Restrict vehicular and equipment access to construction areas, or provide working surfaces / pads.
4. Minimize clearing of rights-of-way and stripping of building sites.
5. Physically mark clearing boundaries on the construction site.
6. Hydroseed or revegetate cut and fill slopes and disturbed natural slopes as early as possible.
7. Use mulches and other organic stabilizers to minimize erosion until vegetation is established on sensitive areas or soils.
8. Plan seeding and planting to allow establishment before end of growing season.
9. Isolate cleared areas and building sites with diversion channels, ditches, and swales to redirect run-off.
10. Retain natural drainage patterns wherever possible.
11. Install run-off diversions that are primarily located at surface facilities and separate contact storm water and non-contact storm water.

12. Line unavoidably steep interceptor or conveyance ditches with filter fabric, rock, polyethylene lining, or armoring to prevent channel erosion.
13. Construct stable, non-erodible ditches, and inlet and outlet structures.
14. Sediment / silt fencing or other similar methods such as straw bales, sediment traps, and berms will be used to control sediment from disturbed areas.
15. Provide bed load clean-outs at culverts and ditches.
16. Construct, operate, and maintain sediment control ponds.
17. Develop and follow a maintenance and inspection schedule as part of the development plan. Regular inspections will occur after major precipitation or other run-off events, and also on a routinely scheduled basis to ensure that BMPs are functioning properly.
18. Stockpile the required erosion / sediment control materials including: filter cloth, rock, seeding, drain rock, culverts, staking, matting, polyethylene, used tires, etc.
19. Plow snow off of the Project access roads as required. Good drainage will be established along all access roads and travel surfaces before each winter. Particular attention will be paid during the spring snowmelt / run-off season to ensure that water is controlled along access roads and in disturbed area of the site. This will minimize erosion and the transport of sediment.

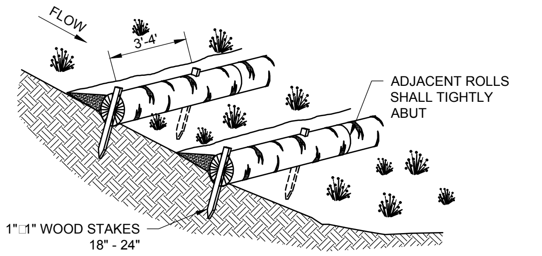
Tintina commits to marking by flagging and / or staking all disturbance boundary limits for construction of surface facilities to prevent inadvertent disturbances of land surfaces that should not be impacted during Project implementation. In addition, silt fencing could be installed around most disturbance area boundaries during the earliest phase of construction to eliminate sediment transport off of disturbed sites and would serve as an additional marker of disturbance area boundaries.

Topsoil and subsoil will be removed from the sites and stockpiled. Small shrubs and herbaceous vegetation will be mowed or chip and salvaged with topsoil. Non- commercial trees, slash tall shrubs and small stumps will be chipped and salvaged with topsoil. Larger stumps will be stored at the toe of soil and reclamation stockpiles to aid in erosion control and ultimately for distribution as part of reclamation. Figures 4.3 through 4.6 illustrate a variety of typical erosional control BMPs that will be implemented at the Project site.

STRAW WATTLES:

INSTALLATION - OPTION A:

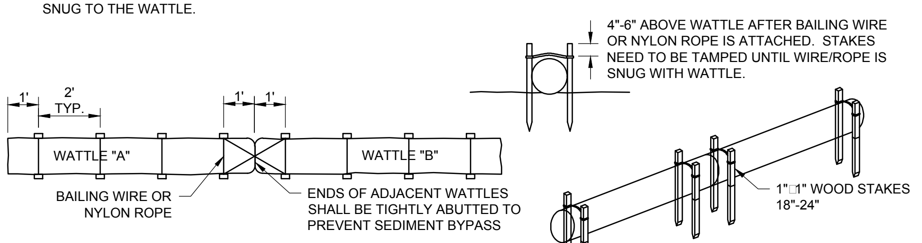
1. WHEN INSTALLING RUNNING LENGTHS OF WATTLES, BUTT THE SECOND WATTLE TIGHTLY AGAINST THE FIRST, DO NOT OVERLAP THE ENDS. STAKE THE WATTLES AT EACH END AND THREE TO FOUR FOOT ON CENTER.
2. STAKES SHOULD BE DRIVEN THROUGH THE MIDDLE OF THE WATTLE. LEAVING 2 - 3 INCHES OF THE STAKE PROTRUDING ABOVE THE WATTLE. A HEAVY SEDIMENT LOAD WILL TEND TO PICK THE WATTLE UP AND COULD PULL IT OFF THE STAKES IF THEY ARE DRIVEN DOWN TOO LOW. IT MAY BE NECESSARY TO MAKE A HOLE IN THE WATTLE WITH A PICK END OF YOUR MADDOX IN ORDER TO GET THE STAKE THROUGH THE STRAW. WHEN STRAW WATTLES ARE USED FOR FLAT GROUND APPLICATIONS, DRIVE THE STAKES STRAIGHT DOWN□WHEN INSTALLING WATTLES ON SLOPES, DRIVE THE STAKES PERPENDICULAR TO THE SLOPE.
3. DRIVE THE FIRST END STAKE OF THE SECOND WATTLE AT AN ANGLE TOWARD THE FIRST WATTLE IN ORDER TO HELP ABUT THEM TIGHTLY TOGETHER. IF YOU HAVE DIFFICULTY DRIVING THE STAKE INTO EXTREMELY HARD OR ROCKY SLOPES, A PILOT BAR MAY BE NEEDED TO BEGIN THE STAKE HOLE.



WATTLES - OPTION A

INSTALLATION - OPTION B:

1. STAKES SHOULD BE DRIVEN ACROSS FROM EACH OTHER AND ON EACH SIDE OF THE WATTLE. LEAVING 4"-6" OF STAKE PROTRUDING ABOVE THE WATTLE. BAILING WIRE OR NYLON ROPE SHOULD BE TIED TO THE STAKES ACROSS THE WATTLE. STAKES SHOULD THEN BE DRIVEN UNTIL THE BAILING WIRE OR NYLON ROPE IS SUFFICIENTLY SNUG TO THE WATTLE.
2. WHEN INSTALLING RUNNING LENGTHS OF WATTLES, TO PREVENT SHIFTING, BUTT THE SECOND WATTLE TIGHTLY AGAINST THE FIRST. DO NOT OVERLAP THE ENDS. STAKES SHOULD BE DRIVEN 1 FT. FROM END, ACROSS FROM AND ON EACH SIDE OF WATTLE LEAVING 4"-6" OF STAKE PROTRUDING ABOVE THE WATTLE. BAILING WIRE OR NYLON ROPE SHOULD BE TIED TO STAKES IN AN HOUR GLASS FORMATION (FRONT TO BACK OF WATTLE "A", ACROSS TO FRONT OF WATTLE "B", ACROSS TO BACK AND BACK TO FRONT OF WATTLE "A"). STAKES SHOULD THEN BE DRIVEN IN UNTIL BAILING WIRE OR NYLON ROPE IS SUFFICIENTLY SNUG TO THE WATTLE.



WATTLES - OPTION B

BMP LEGEND

▨ SCL SEDIMENT CONTROL LOG

1 DETAIL
STRAW WATTLES
NTS

OPTION A AND B INSTALLATION NOTES:

1. THE LOCATION AND LENGTH OF WATTLE IS DEPENDENT ON THE CONDITIONS OF EACH SITE.
2. WATTLES SHALL BE INSTALLED PRIOR TO ANY LAND-DISTURBING ACTIVITIES.
3. WATTLES SHALL CONSIST OF STRAW, COMPOST, EXCELSIOR, OR COCONUT FIBER.
4. NOT FOR USE IN CONCENTRATED FLOW AREAS.
5. THE WATTLES SHALL BE TRENCHED INTO THE GROUND A MINIMUM OF TWO (2) INCHES.
6. WATTLES SHALL BE INSTALLED PER MANUFACTURERS SPECIFICATIONS.
7. ON SLOPES, WATTLES SHOULD BE INSTALLED ON CONTOUR WITH A SLIGHT DOWNWARD ANGLE AT THE END OF THE ROW IN ORDER TO PREVENT PONDING AT THE MID SECTION.
8. RUNNING LENGTHS OF WATTLES SHOULD BE ABUTTED FIRMLY TO ENSURE NO LEAKAGE AT THE ABUTMENTS.
9. SPACING - DOWNSLOPE:

VERTICAL SPACING FOR SLOPE INSTALLATIONS SHOULD BE DETERMINED BY SITE CONDITIONS. SLOPE GRADIENT AND SOIL TYPE ARE THE MAIN FACTORS. A GOOD RULE OF THUMB IS:

1:1 SLOPES □ 10 FEET APART
2:1 SLOPES □ 20 FEET APART
3:1 SLOPES □ 30 FEET APART
4:1 SLOPES □ 40 FEET APART, ETC.

HOWEVER, ADJUSTMENTS MAY HAVE TO BE MADE FOR THE SOIL TYPE: FOR SOFT, LOAMY SOILS - ADJUST THE ROWS CLOSER TOGETHER□FOR HARD, ROCKY SOILS - ADJUST THE ROWS FURTHER APART. A SECONDARY WATTLE PLACED BEHIND THE ABUTMENT OF TWO WATTLES IS ENCOURAGED ON STEEP SLOPES OR WHERE JOINTS HAVE FAILED IN THE PAST.

10. STAKING: WOOD STAKES ARE RECOMMENDED TO SECURE THE WATTLES. 1/2" TO 5/8" REBAR IS ALSO ACCEPTABLE. BE SURE TO USE A STAKE THAT IS LONG ENOUGH TO PROTRUDE SEVERAL INCHES ABOVE THE WATTLE: 18" IS A GOOD LENGTH FOR HARD, ROCKY SOIL. FOR SOFT LOAMY SOIL USE A 24" STAKE.

WATTLE MAINTENANCE NOTES:

1. INSPECT WATTLES AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□AND MAKE REPAIRS OR REMOVE SEDIMENT ACCUMULATED BEHIND WATTLE AS NECESSARY.
2. SEDIMENT ACCUMULATED BEHIND WATTLE SHALL BE REMOVED WHEN THE SEDIMENT HAS ACCUMULATED TO ONE HALF THE DIAMETER OF THE WATTLE.
3. WATTLES SHALL REMAIN IN PLACE UNTIL THE UPSTREAM DISTURBED AREA IS STABILIZED.

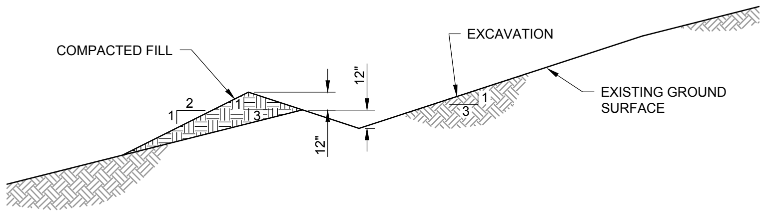
RUNOFF COLLECTION DITCH AND BERM

INSTALLATION:

1. THE DIVERSION DITCH AND BERM SHOULD BE PLACED ACROSS THE SLOPE PERPENDICULAR TO THE DIRECTION OF FLOW. THE DITCH SHOULD BE LOCATED AT LEAST 3-FEET FROM THE TOE OF STEEP SLOPES.
2. THE MAXIMUM SLOPE OF THE DRAINAGE DITCH SHALL BE 3□. IF THE SLOPE OF THE DITCH EXCEEDS 3□ THE DITCH MUST BE LINED WITH ROCK WITH A D50 □ 6-INCHES TO PREVENT EROSION.
3. THE DIVERSION DITCH SHALL HAVE A MAXIMUM GRADE OF 1□ FOR A LENGTH OF 5 FEET BEFORE ENTERING A SEDIMENT TRAP.
4. THE FILL MATERIAL FOR THE EMBANKMENT SHALL BE FREE OF ROOTS OR OTHER WOODY VEGETATION AS WELL AS OVER-SIZED STONES, ROCKS, ORGANIC MATERIAL OR OTHER OBJECTIONABLE MATERIAL. THE EMBANKMENT SHALL BE COMPACTED BY TRAVERSING WITH EQUIPMENT WHILE IT IS BEING CONSTRUCTED.
5. ALL CUT AND FILL SLOPES SHALL BE 2:1 OR FLATTER.
6. ELEVATION OF THE TOP OF ANY DITCH OR BERM DIRECTING WATER INTO TRAP MUST EQUAL OR EXCEED THE HEIGHT OF TRAP EMBANKMENT.

INSPECTION AND MAINTENANCE:

1. INSPECT DITCH AND BERM IN ACCORDANCE WITH SWPPP SCHEDULE□ CHECK FOR AREAS WHERE RUNOFF HAS CAUSED EROSION.
2. CLEAN ANY REMOVE ANY OBSTRUCTIONS FROM THE DITCH WHEN NECESSARY.

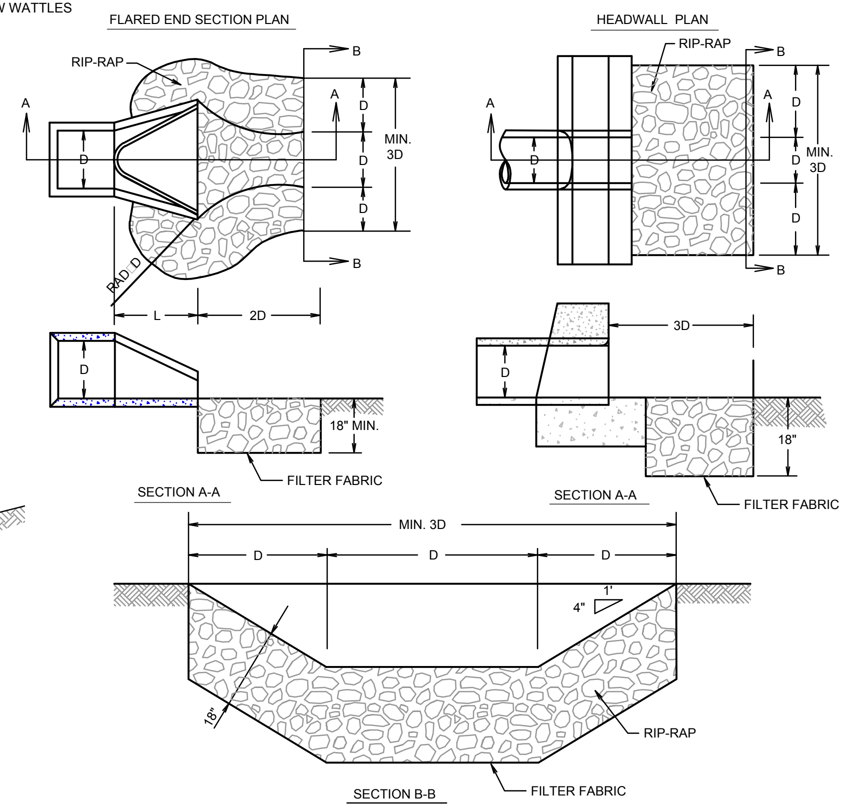


3 DETAIL
RUNOFF COLLECTION DITCH AND BERM
NTS

BMP LEGEND

CDB COLLECTION DITCH AND BERM

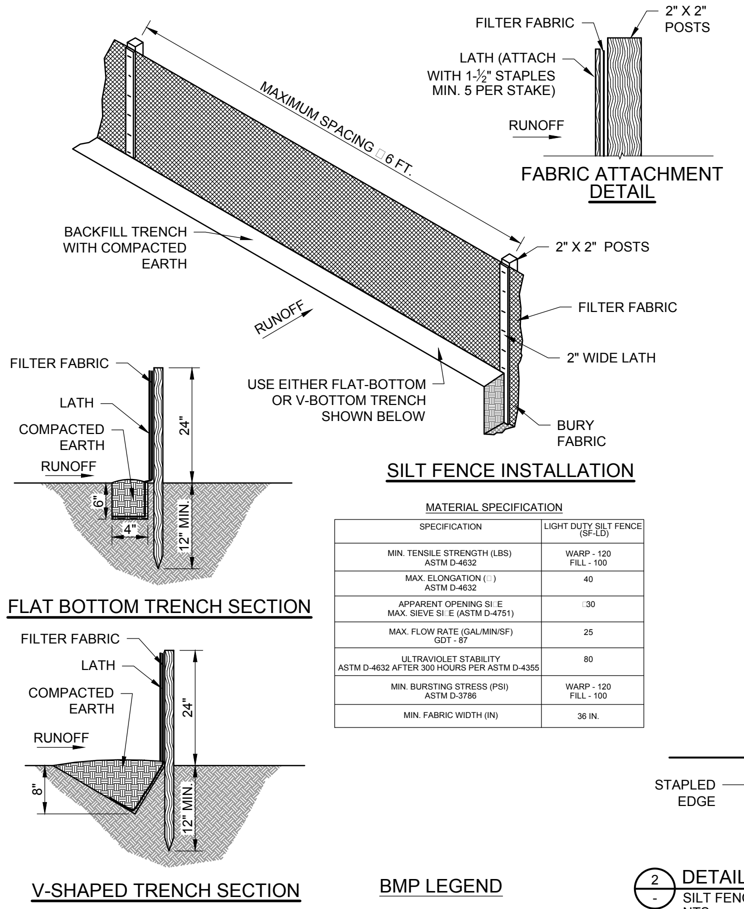
RIPRAP OUTLET PROTECTION



BMP LEGEND

OP OUTLET PROTECTION

4 DETAIL
INLET OUTLET PROTECTION
NTS



SILT FENCE INSTALLATION

MATERIAL SPECIFICATION

SPECIFICATION	LIGHT DUTY SILT FENCE (SF-LD)
MIN. TENSILE STRENGTH (LBS) ASTM D-4632	WARP - 120 FILL - 100
MAX. ELONGATION (□) ASTM D-4632	40
APPARENT OPENING SIZE MAX. SIEVE SIZE (ASTM D-4751)	□30
MAX. FLOW RATE (GAL/MIN/SF) GDT - 87	25
ULTRAVIOLET STABILITY ASTM D-4632 AFTER 300 HOURS PER ASTM D-4355	80
MIN. BURSTING STRESS (PSI) ASTM D-3786	WARP - 120 FILL - 100
MIN. FABRIC WIDTH (IN)	36 IN.

BMP LEGEND

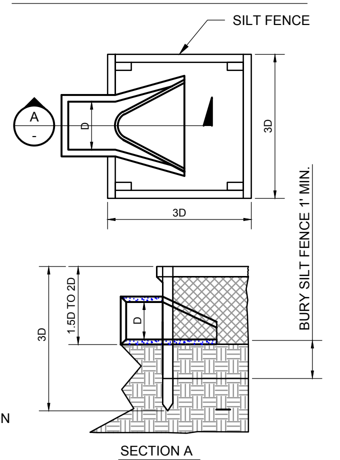
SF SILT FENCE

2 DETAIL
SILT FENCE
NTS

TABLE 1. RIPRAP GRADATIONS

D50 MEDIAN STONE SIZE (INCHES)	% OF MATERIAL SMALLER THAN TYPICAL STONE	TYPICAL STONE EQUIVALENT DIAMETER (INCHES)	TYPICAL STONE WEIGHT (POUNDS)
6	70 – 100 50 – 70 35 – 50 2 – 10	12 9 6 2	85 35 10 0.4
9	70 – 100 50 – 70 35 – 50 2 – 10	15 12 9 3	160 85 35 1.3
12	70 – 100 50 – 70 35 – 50 2 – 10	21 18 12 4	440 275 85 3
18	100 50 – 70 35 – 50 2 – 10	30 24 18 6	1280 650 275 10
24	100 50 – 70 35 – 50 2 – 10	42 33 24 9	3500 1700 650 35

SILT FENCE INLET PROTECTION



SECTION A

BMP LEGEND

IP INLET PROTECTION

INLET INSTALLATION:

1. CONSTRUCT THE FRAME AND POSTS USING 2" X 4" WOOD. USE A MAXIMUM SPACING OF 3-FT BETWEEN POSTS.
2. FOLD FABRIC TO OVERLAP ENDS AND SECURE TO POSTS WITH STAPLES. ATTACH FILTER FABRIC TO FRAME AND POSTS WITH STAPLES □ 8-INCHES O.C.
3. BURY SILT FENCE AT LEAST 1-FT DEEP AND POSTS AT LEAST 18-INCHES DEEP.

INLET PROTECTION MAINTENANCE NOTES:

1. INSPECT INLET PROTECTION AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□AND MAKE REPAIRS OR CLEAN OUT AS NECESSARY. MORE FREQUENT INSPECTIONS AND REPAIRS SHALL BE REQUIRED DURING WINTER CONDITIONS DUE TO FREEZE/THAW PROBLEMS.
2. SEDIMENT ACCUMULATED UPSTREAM OF INLET PROTECTION SHALL BE REMOVED WHEN THE SEDIMENT DEPTH UPSTREAM OF ROCK BERM IS WITHIN $2\frac{1}{2}$ INCHES OF THE CREST.
3. INLET PROTECTION IS TO REMAIN IN PLACE UNTIL THE UPSTREAM DISTURBED AREA IS STABILIZED AND GRASS COVER IS APPROVED, UNLESS THE COUNTY APPROVES EARLIER REMOVAL OF INLET PROTECTION IN STREETS.
4. WHEN INLET PROTECTION AT AREA INLETS ARE REMOVED, THE DISTURBED AREA SHALL BE DRILL SEEDED AND CRIMP MULCHED OR OTHERWISE STABILIZED IN AN APPROVED MANNER.

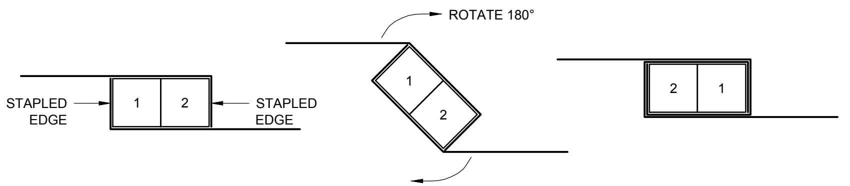
SILT FENCE

INSTALLATION:

1. THE FENCE SHOULD BE PLACED ACROSS THE SLOPE ALONG A LINE OF UNIFORM ELEVATION (PERPENDICULAR TO THE DIRECTION OF FLOW). THE FENCE SHOULD BE LOCATED AT LEAST 3-FEET FROM THE TOE OF STEEP SLOPES TO PROVIDE SEDIMENT STORAGE AND ACCESS FOR MAINTENANCE AND CLEANOUT.
2. A FLAT-BOTTOM TRENCH APPROXIMATELY 4-INCHES WIDE AND 8-INCHES DEEP, OR A V-SHAPED TRENCH 8-INCHES DEEP SHOULD BE EXCAVATED. ON THE DOWN-SLOPE SIDE OF THE TRENCH, DRIVE THE 2-IN. X 2-IN. WOOD POSTS AT LEAST 18-LNCHES INTO THE GROUND, SPACING THEM NO FURTHER. THAN 6-FEET APART.
3. POSTS SHOULD BE INSTALLED, WITH 1- TO 2-INCHES OF THE POST PROTRUDING ABOVE THE TOP OF THE FABRIC AND NO MORE THAN 3-FEET OF THE POST SHOULD PROTRUDE ABOVE THE GROUND. THE MINIMUM FENCE HEIGHT (HEIGHT OF FILTER FABRIC ABOVE GRADE) SHALL BE 18-INCHES. THE MAXIMUM FENCE HEIGHT (HEIGHT OF FILTER FABRIC ABOVE GRADE) SHALL BE 24-INCHES.
4. THE FILTER FABRIC SHOULD BE PURCHASED IN A CONTINUOUS ROLL AND CUT TO THE LENGTH OF THE BARRIER TO AVOID THE USE OF JOINTS. WHEN JOINTS ARE NECESSARY, FILTER CLOTH SHOULD BE WRAPPED TOGETHER ONLY AT A SUPPORT POST WITH BOTH ENDS SECURELY FASTENED TO THE POST, WITH A MINIMUM 6-INCH OVERLAP.
5. EXTRA-STRENGTH FILTER CLOTH (50 POUNDS / LINEAR INCH MINIMUM TENSILE STRENGTH) SHOULD BE USED. A 2-INCH WIDE LATH SHALL BE STAPLED OVER THE FILTER FABRIC TO SECURELY FASTEN IT THE TO THE UP-SLOPE SIDE OF THE POSTS. THE STAPLES USED SHOULD BE 1.5-INCH HEAVY-DUTY WIRE STAPLES SPACED A MAXIMUM OF 8-INCHES APART.
6. PLACE THE BOTTOM 12-INCHES OF THE FILTER FABRIC INTO THE 8-INCH DEEP TRENCH, EXTENDING THE REMAINING 4-INCHES TOWARDS THE UP-SLOPE SIDE OF THE TRENCH AND BACKFILL THE TRENCH WITH SOIL OR GRAVEL AND COMPACT.

INSPECTION AND MAINTENANCE:

1. INSPECT SILT FENCE IN ACCORDANCE WITH SWPPP SCHEDULE□ CHECK FOR AREAS WHERE RUNOFF HAS ERODED A CHANNEL BENEATH THE FENCE, OR WHERE THE FENCE WAS CAUSED TO SAG OR COLLAPSE BY RUNOFF OVERTOPPING THE FENCE OR BY WIND.
2. IF THE FENCE FABRIC TEARS, BEGINS TO DECOMPOSE, OR IN ANY WAY BECOMES INEFFECTIVE, REPLACE THE AFFECTED SECTION OF FENCE IMMEDIATELY.
3. SEDIMENT MUST BE REMOVED WHEN IT REACHES APPROXIMATELY 1/3 THE HEIGHT OF THE FENCE, ESPECIALLY IF HEAVY RAINS ARE EXPECTED.
4. SILT FENCE SHOULD BE REMOVED WITHIN 30 DAYS AFTER FINAL SITE STABILIZATION IS ACHIEVED OR AFTER TEMPORARY BMPS ARE NO LONGER NEEDED. TRAPPED SEDIMENT SHOULD BE REMOVED OR STABILIZED ON SITE. DISTURBED AREAS RESULTING FROM FENCE REMOVAL SHALL BE PERMANENTLY STABILIZED.



FENCE SPLICING DETAIL

INSTALLATION:

1. OUTLET PROTECTION SHOULD BE CONSTRUCTED FOR PERMANENT POST-MINING ROADWAYS.
2. FILTER CLOTH SHALL BE PLACED OVER THE BOTTOM AND SIDES OF THE OUTLET CHANNEL PRIOR TO PLACEMENT OF STONE. SECTION OF FABRIC MUST OVERLAP AT LEAST 1' WITH SECTION NEAREST THE ENTRANCE PLACED ON TOP. FABRIC SHALL BE EMBEDDED AT LEAST 6" INTO EXISTING GROUND AT ENTRANCE OF OUTLET CHANNEL.
3. CAREFULLY PLACE RIPRAP TO AVOID DAMAGING THE FILTER FABRIC.
4. FOR PROPER OPERATION OF APRON:
   - ALIGN APRON WITH RECEIVING STREAM SUCH THAT A STRAIGHT LINE IS CREATED. IF A CURVE IS NEEDED TO FIT SITE CONDITIONS, PLACE IT IN UPPER SECTION OF APRON.
   - IF SIZE OF APRON RIPRAP IS LARGE, PROTECT UNDERLYING FILTER FABRIC WITH A GRAVEL BLANKET.
5. OUTLETS ON SLOPES STEEPER THAN 10 PERCENT SHALL HAVE ADDITIONAL PROTECTION.
6. STONE USED IN THE OUTLET CHANNEL SHALL BE 4 INCHES TO 12 INCHES PLACED 18 INCHES THICK.
7. OUTLET (IF NEEDED) - AN OUTLET SHALL BE PROVIDED, WHICH INCLUDES A MEANS OF CONVEYING THE DISCHARGE IN AN EROSION FREE MANNER TO AN EXISTING STABLE CHANNEL. PROTECTION AGAINST SCOUR AT THE DISCHARGE END SHALL BE PROVIDED AS NECESSARY.

INSPECTION AND MAINTENANCE:

1. INSPECT DITCH, BERM, AND SEDIMENT TRAP AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□
2. INSPECT APRON FOR DISPLACEMENT OF DISSIPATION DEVICES AND/OR DAMAGE TO THE UNDERLYING FABRIC AND REPAIR AS NEEDED.
3. INSPECT FOR SCOUR BENEATH THE DISSIPATION DEVICES AND AROUND THE OUTLET. REPAIR DAMAGE TO SLOPES OR UNDERLYING FILTER FABRIC IMMEDIATELY.
4. TEMPORARY DEVICES SHALL BE COMPLETELY REMOVED AS SOON AS THE SURROUNDING DRAINAGE AREA HAS BEEN STABILIZED, OR AT THE COMPLETION OF CONSTRUCTION.

□INSPECTIONS WILL BE CONDUCTED WITHIN 72 HOURS OF SIGNIFICANT RAINFALL (□0.5" OVER 24 HOURS) OR SNOWMELT (PRODUCING DISCHARGE WITH EROSION), AND SELECTED ROUTINE SCHEDULE, IN ACCORDANCE WITH THE SWPPP FOR THE MULTI-SECTOR GENERAL PERMIT FOR STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY.

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BLACK BUTTE COPPER PROJECT
TINTINA RESOURCES

BEST MANAGEMENT PRACTICES
STANDARD NOTES
(SHEET 1 OF 4)

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AUTOCAD 2000 DRAWING (DWG)
FIGURE
4.3

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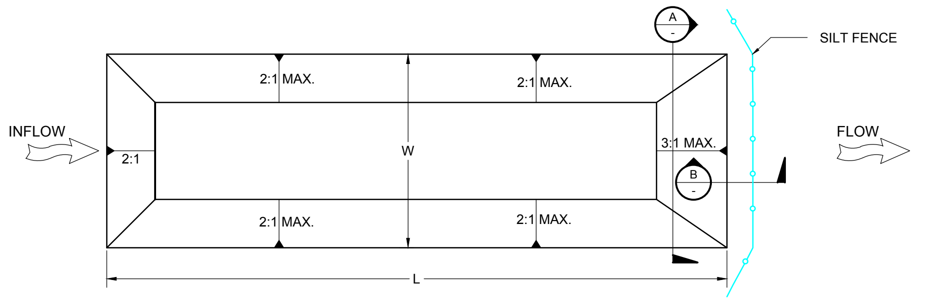
SEDIMENT TRAP

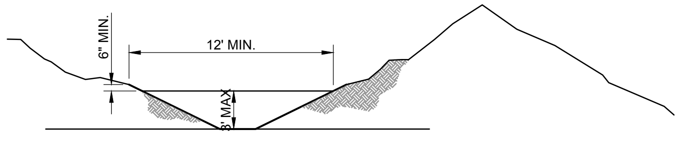
INSTALLATION:

1. THE AREA INCLUDING THE SEDIMENT TRAP SHALL BE CLEARED, GRUBBED AND STRIPPED OF ANY VEGETATION AND ROOT MAT. THE POOL AREA SHALL BE CLEARED.
2. ALL CUT SLOPES SHALL BE 2:1 OR FLATTER.
3. ELEVATION OF THE TOP OF ANY DITCH OR BERM DIRECTING WATER INTO TRAP MUST EQUAL OR EXCEED THE HEIGHT OF TRAP EMBANKMENT.
4. THE TOP OF THE SEDIMENT TRAP SHALL BE A MINIMUM OF 6" HIGHER THAN THE TOP OF THE OUTLET STRUCTURE. THE EXCAVATION SHALL BE LESS THAN 3FT DEEP.
5. SILT FENCE SHALL BE INSTALLED AS SPECIFIED IN SILT FENCE DETAILS.
6. NEVER CONSTRUCT A SEDIMENT TRAP ON A FLOWING STREAM OR IN WETLANDS.
7. TRAPS SHOULD NOT BE LOCATED CLOSER THAN 20 FEET FROM A PROPOSED BUILDING FOUNDATION OR EDGE OF ROAD.
8. A RECTANGULAR AND SHALLOW TRAP, WITH A LENGTH-TO-WIDTH RATIO OF 2:1 OR GREATER IS RECOMMENDED.
9. INLETS TO SEDIMENT TRAP SHALL ENTER AT THE FURTHEST DISTANCE TO OUTLET DESIGNED SO AS NOT TO ERODE SIDE SLOPES OF SEDIMENT BASIN.

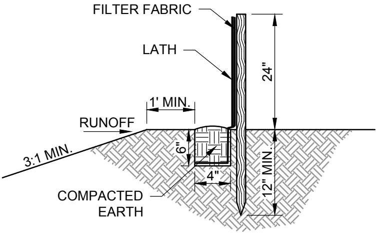
INSPECTION AND MAINTENANCE:

1. INSPECT SEDIMENT TRAP IN ACCORDANCE WITH SWPPP SCHEDULE*. CHECK FOR AREAS WHERE RUNOFF HAS CAUSED EROSION.
2. OUTLET CHANNEL MUST HAVE POSITIVE DRAINAGE FROM THE TRAP. SEDIMENT SHALL BE REMOVED AND TRAP RESTORED TO ITS ORIGINAL DIMENSIONS WHEN THE SEDIMENT HAS ACCUMULATED TO 1/4 OF THE WET STORAGE DEPTH OF THE TRAP. REMOVED SEDIMENT SHALL BE DEPOSITED IN A SUITABLE AREA AND IN SUCH A MANNER THAT IT WILL NOT ERODE.
3. CONSTRUCTION OF TRAPS SHALL BE CARRIED OUT IN SUCH A MANNER THAT SEDIMENT POLLUTION IS ABATED. ONCE CONSTRUCTED, THE TOP AND OUTSIDE FACE OF THE EMBANKMENT SHALL BE STABILIZED WITH SEED AND MULCH. POINTS OF CONCENTRATED INFLOW SHALL BE PROTECTED IN ACCORDANCE WITH GRADE STABILIZATION STRUCTURE CRITERIA. THE REMAINDER OF THE INTERIOR SLOPES SHOULD BE STABILIZED (ONE TIME) WITH SEED AND MULCH UPON TRAP COMPLETION AND MONITORED AND MAINTAINED EROSION FREE DURING THE LIFE OF THE TRAP.
4. THE STRUCTURE SHALL BE DEWATERED BY APPROVED METHODS, REMOVED AND THE AREA STABILIZED WHEN THE DRAINAGE AREA HAS BEEN PROPERLY STABILIZED.





A SECTION
OUTLET
NTS



B SECTION
SILT FENCE
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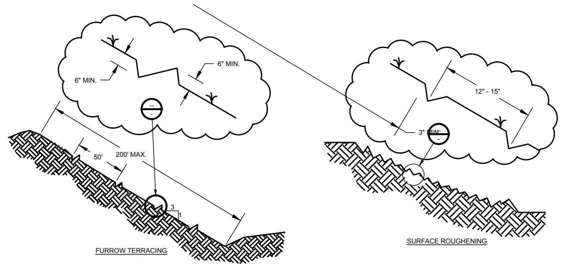
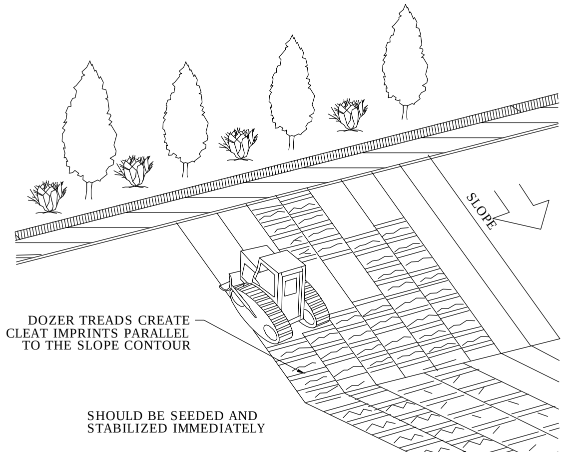
SEE EXHIBIT 6 FOR INSTALLATION NOTES

BMP LEGEND

ST SEDIMENT TRAP

1 DETAIL
SEDIMENT TRAP
NTS





DOZER TREADS CREATE CLEAT IMPRINTS PARALLEL TO THE SLOPE CONTOUR

SHOULD BE SEEDED AND STABILIZED IMMEDIATELY

TRACKING

BMP LEGEND

SR SURFACE ROUGHENING

3 DETAIL
SURFACE ROUGHENING
NTS

SURFACE ROUGHENING, FURROW TERRACING, AND TRACKING

INSTALLATION:

1. TO SLOW EROSION, SURFACE ROUGHENING, FURROW TERRACING, AND/OR TRACKING SHOULD BE DONE WITHIN 7 DAYS AFTER THE VEGETATION HAS BEEN REMOVED FROM A SLOPE.
2. SURFACE ROUGHENING, FURROW TERRACING, AND/OR TRACKING SHALL BE PROVIDED ON ALL FINISHED GRADES (SLOPES AND FLAT AREAS) WITHIN 2 DAYS OF COMPLETION OF FINISHED GRADE (FOR AREAS NOT RECEIVING TOPSOIL) OR WITHIN 2 DAYS OF TOPSOIL PLACEMENT.
3. DISTURBED SURFACES SHALL BE ROUGHENED USING ANY IMPLEMENT THAT CAN BE SAFELY OPERATED ON THE SLOPE AND WILL NOT CAUSE UNDUE COMPACTION. AS FEW PASSES AS POSSIBLE SHOULD BE MADE WITH THE MACHINERY IN ORDER TO MINIMIZE COMPACTION.
4. SURFACE ROUGHENING GROOVES SHOULD BE A MINIMUM OF 3-INCHES DEEP AND NO FURTHER THAN 15-INCHES APART.
5. FURROW TERRACES SHOULD NOT BE CONDUCTED WHEN THE GRADE EXCEEDS 3H:1V. FURROWS SHOULD BE A MINIMUM OF 6-INCHES DEEP AND NO FARTHER THAN 50-FEET APART.
6. AREAS THAT ARE GRADED IN THIS MANNER SHOULD BE SEEDED WITHIN 14 DAYS.

INSPECTION AND MAINTENANCE:

1. INSPECTIONS SHOULD BE CONDUCTED IN ACCORDANCE WITH SWPPP SCHEDULE*.
2. IF RILLS (SMALL WATERCOURSES THAT HAVE STEEP SIDES) APPEAR. THEY SHOULD BE RE-GRADED AND RE-SEEDED IMMEDIATELY.

EROSION CONTROL BLANKET

INSTALLATION:

1. ALL EROSION CONTROL BLANKETS AND NETTING SHALL BE MADE OF 100% NATURAL AND BIODEGRADABLE MATERIAL□SHALL BE NONTOXIC TO VEGETATION AND TO THE GERMINATION OF SEED, AND NO PLASTIC OR OTHER SYNTHETIC MATERIAL SHALL BE ALLOWED.. NETTING SHOULD BE INTERTWINED WITH THE MULCHING MATERIAL/FIBER TO MAXIMIZE STRENGTH AND PROVIDE FOR EASE OF HANDLING.
2. TOPSOIL PLACEMENT, FINAL GRADING, SURFACE PREPARATION, AND SEEDING SHALL BE PERFORMED PRIOR TO BLANKET PLACEMENT. SUBGRADE SHALL BE SMOOTH AND MOIST PRIOR TO BLANKET INSTALLATION AND THE BLANKET SHALL BE IN FULL CONTACT WITH SUBGRADE, NO GAPS OR VOIDS SHALL EXIST UNDER THE BLANKET.
3. PERIMETER ANCHOR SHALL BE USED AT OUTSIDE PERIMETER OF ALL BLANKET AREAS.
4. JOINT ANCHOR TRENCH SHALL BE USED TO JOIN ROLLS OF BLANKETS TOGETHER (LONGITUDINALLY AND TRANSVERSELY) FOR ALL BLANKETS EXCEPT STRAW, WHICH MAY USE AN OVERLAPPING JOINT.
5. INTERMEDIATE ANCHOR TRENCH SHALL BE USED AT SPACING OF ONE-HALF THE ROLL LENGTH FOR COCONUT AND EXCELSIOR BLANKETS.
6. THE OVERLAPPING JOINT DETAIL SHALL BE USED TO JOIN ROLLS OF BLANKETS TOGETHER FOR BLANKETS ON SLOPES.
7. MATERIAL SPECIFICATIONS OF EROSION CONTROL BLANKET SHALL CONFORM TO TABLE BELOW.
8. ANY AREAS OF SEEDING AND MULCHING DISTURBED IN THE PROCESS OF INSTALLING EROSION CONTROL BLANKET SHALL BE RESEEDED AND MULCHED IMMEDIATELY.

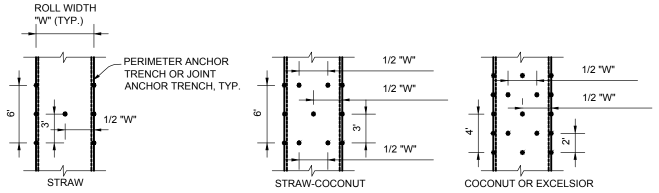
INSPECTION AND MAINTENANCE:

1. INSPECTIONS SHALL BE CONDUCTED IN ACCORDANCE WITH SWPPP SCHEDULE*.
2. ANY EROSION CONTROL BLANKET PULLED OUT, TORN, OR OTHERWISE DAMAGED SHALL BE RE-INSTALLED. ANY SUBGRADE AREAS BELOW THE BLANKET THAT HAVE ERODED TO CREATE A VOID UNDER THE BLANKET, OR THAT REMAIN DEVOID OF GRASS SHALL BE REPAIRED, RESEEDED, AND MULCHED AND THE EROSION CONTROL BLANKET REINSTALLED.

TABLE - EROSION CONTROL BLANKET TYPE

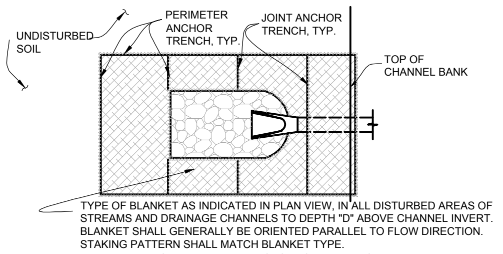
TYPE	COCONUT CONTENT	STRAW CONTENT	EXCELSIOR CONTENT	NETTING MIN.
STRAW*	-	100%	-	DOUBLE/NATURAL
STRAW-COCONUT	30% MIN.	70% MAX.	-	DOUBLE/NATURAL
COCONUT	100%	-	-	DOUBLE/NATURAL
EXCELSIOR	-	-	100%	DOUBLE/NATURAL

*FOR OUTSIDE OF STREAMS AND DRAINAGE CHANNELS



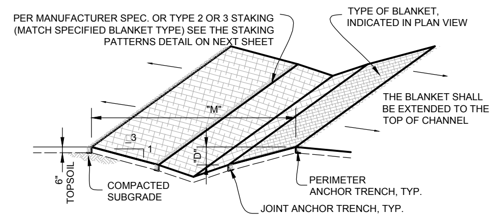
STAKING PATTERNS

SHALL BE IN ACCORDANCE WITH MANUFACTURER'S SPECIFICATION. IF NO MANUFACTURER'S SPECIFICATION IS AVAILABLE USE THE ACCEPTABLE STAKING PATTERN (AS SHOWN ABOVE)

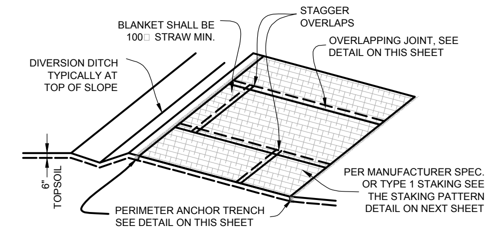


TYPE OF BLANKET AS INDICATED IN PLAN VIEW, IN ALL DISTURBED AREAS OF STREAMS AND DRAINAGE CHANNELS TO DEPTH "D" ABOVE CHANNEL INVERT. BLANKET SHALL GENERALLY BE ORIENTED PARALLEL TO FLOW DIRECTION. STAKING PATTERN SHALL MATCH BLANKET TYPE.

AT PIPE OUTLET AREAS OF STREAMS AND DRAINAGE CHANNELS - DETAIL A

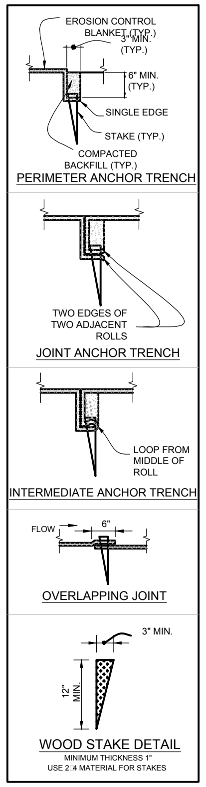


IN DIVERSION DITCH OR SMALL DITCH DRAINAGE WAY - DETAIL B



OUTSIDE OF STREAMS AND DRAINAGE CHANNELS - DETAIL C

ANCHOR DETAILS



PERIMETER ANCHOR TRENCH

JOINT ANCHOR TRENCH

INTERMEDIATE ANCHOR TRENCH

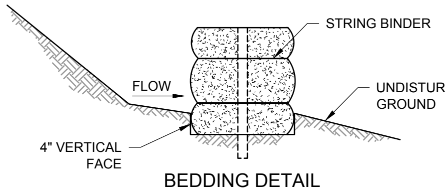
OVERLAPPING JOINT

WOOD STAKE DETAIL
MINIMUM THICKNESS 1"
USE 2□4 MATERIAL FOR STAKES

BMP LEGEND

▨ ECB EROSION CONTROL BLANKET

2 DETAIL
EROSION CONTROL BLANKET
NTS



BEDDING DETAIL
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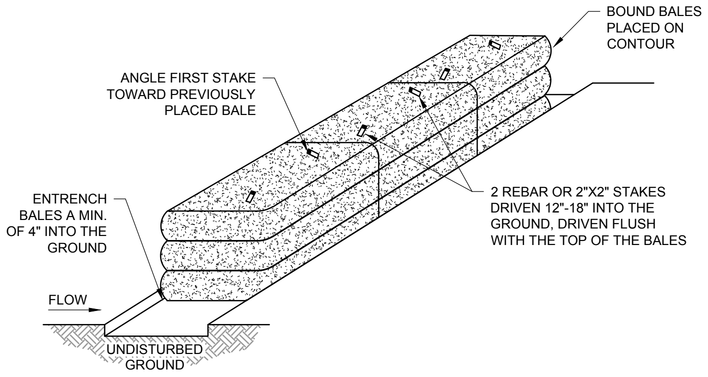

ANCHORING DETAIL
NTS

BMP LEGEND

SBB STRAW BALE BARRIER

4 DETAIL
STRAW BALE BARRIER
NTS

STRAW BALE BARRIERS INSTALLATION:

1. BALES SHALL BE PLACED AT THE TOE OF A SLOPE, ON THE CONTOUR, AND IN A ROW WITH THE ENDS OF EACH BALE TIGHTLY ABUTTING THE ADJACENT BALES.
2. EACH BALE SHALL BE ENTRENCHED IN THE SOIL A MINIMUM OF 4" AND PLACED SO THE BINDINGS ARE HORIZONTAL.
3. BALES SHALL BE SECURELY ANCHORED IN PLACE BY EITHER TWO STAKES OR RE-BARS DRIVEN THROUGH THE BALE 12" TO 18" INTO THE GROUND. THE FIRST STAKE IN EACH BALE SHALL BE DRIVEN TOWARD THE PREVIOUSLY LAID BALE AT AN ANGLE TO FORCE THE BALES TOGETHER. STAKES SHALL BE DRIVEN FLUSH WITH THE TOP OF THE BALE.

INSPECTION AND MAINTENANCE:

1. STRAW BALE LINE SHALL BE INSPECTED FREQUENTLY AND AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE*.
2. INSPECT STRAW BALE LINE FOR SEDIMENT ACCUMULATIONS AND REMOVE SEDIMENT WHEN DEPTH REACHES $\frac{1}{3}$ THE BARRIER HEIGHT.
3. REPLACE OR REPAIR DAMAGED BALES, WASHOUTS, OR OTHER DAMAGE AS NEEDED.
4. BALES CAN BE SCATTERED WHEN THEIR FUNCTION AS A STORM WATER BARRIER IS COMPLETE.

*INSPECTIONS WILL BE CONDUCTED WITHIN 72 HOURS OF SIGNIFICANT RAINFALL (□0.5" OVER 24 HOURS) OR SNOWMELT (PRODUCING DISCHARGE WITH EROSION), AND SELECTED ROUTINE SCHEDULE, IN ACCORDANCE WITH THE SWPPP FOR THE MULTI-SECTOR GENERAL PERMIT FOR STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY.

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BLACK BUTTE COPPER PROJECT
TINTINA RESOURCES

BEST MANAGEMENT PRACTICES
STANDARD NOTES
(SHEET 2 OF 4)

DRAWING FILE NUMBER
1104801H042
AUTOCAD 2000 DRAWING (DWG)
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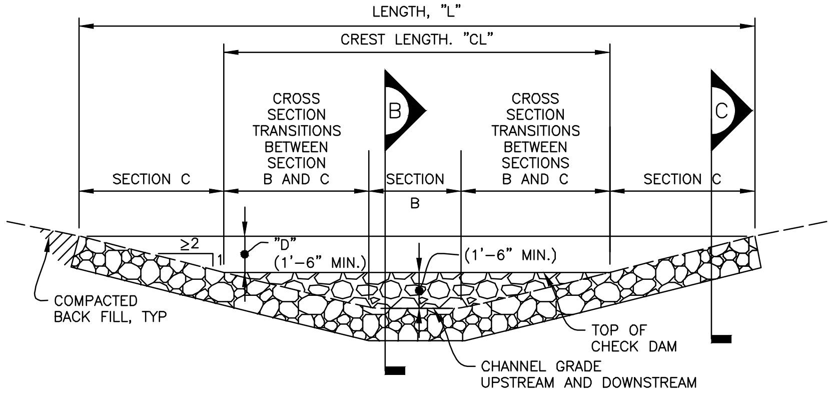

ELEVATION
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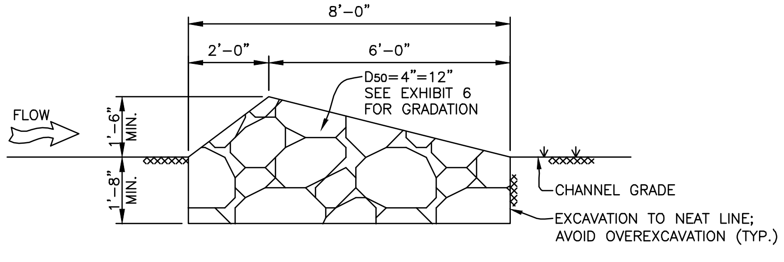

SECTION B
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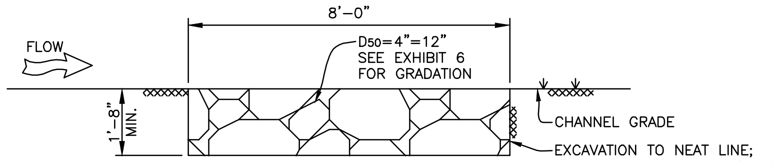


SECTION C
SCALE: 1/4" = 1'-0"

BMP LEGEND

CD CHECK DAM

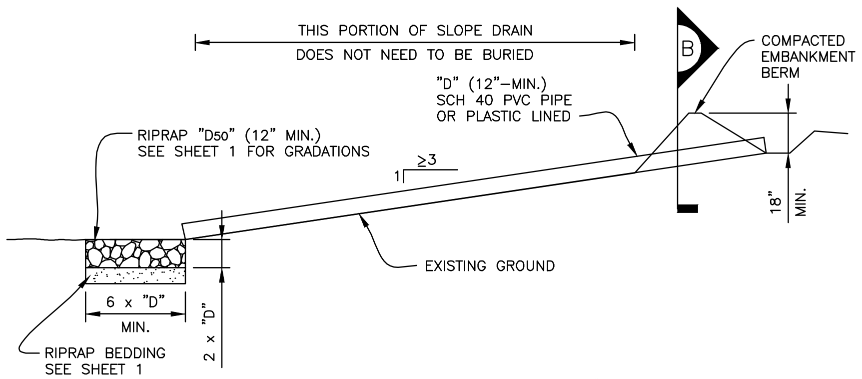
1 DETAIL CHECK DAM NTS

CHECK DAMS

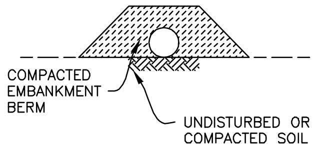
1. A CHECK DAM IS A SMALL DEVICE CONSTRUCTED OF ROCK, SANDBAGS, OR FIBER ROLLS, PLACED ACROSS A NATURAL OR MAN-MADE CHANNEL OR DRAINAGE DITCH.
2. CHECK DAMS MAY BE INSTALLED IN THE FOLLOWING:
   - IN SMALL OPEN CHANNELS WHICH DRAIN HA 10 ACRES OR LESS.
   - IN STEEP CHANNELS WHERE STORM WATER RUNOFF VELOCITIES EXCEED (5 FT/S).
   - DURING THE ESTABLISHMENT OF GRASS LININGS IN DRAINAGE DITCHES OR CHANNELS.
   - IN TEMPORARY DITCHES WHERE A SHORT LENGTH OF SERVICE DOES NOT WARRANT ESTABLISHMENT OF EROSION-RESISTANT LININGS.
3. CHECK DAMS SHALL BE PLACED AT A DISTANCE AND HEIGHT TO ALLOW SMALL POOLS TO FORM BEHIND THEM.
4. INSTALL THE FIRST CHECK DAM APPROXIMATELY 15 FT FROM THE OUTFALL DEVICE AND AT REGULAR INTERVALS BASED ON SLOPE GRADIENT AND SOIL TYPE.
5. HIGH FLOWS (TYPICALLY A 2-YEAR STORM OR LARGER) SHALL SAFELY FLOW OVER THE CHECK DAM WITHOUT AN INCREASE IN UPSTREAM FLOODING OR DAMAGE TO THE CHECK DAM.
6. WHERE GRASS IS USED TO LINE DITCHES, CHECK DAMS MAY BE REMOVED WHEN GRASS HAS MATURED SUFFICIENTLY TO PROTECT THE DITCH OR SWALE IF THE REMOVAL DOES NOT JEOPARDIZE THE ESTABLISHED VEGETATION.

INSPECTION AND MAINTENANCE

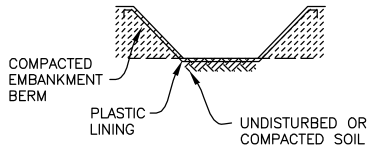
1. INSPECT CHECK DAMS AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□ REPAIR DAMAGE AS NEEDED OR AS REQUIRED BY THE PLAN.
2. REMOVE SEDIMENTS WHEN DEPTH REACHES 1/3 OF THE CHECK DAM HEIGHT.
3. REMOVE ACCUMULATED SEDIMENT PRIOR TO PERMANENT SEEDING OR SOIL STABILIZATION OR SEED ACCUMULATED SEDIMENT TO STABILIZE.
4. REMOVE CHECK DAMS AND ACCUMULATED SEDIMENT WHEN CHECK DAMS ARE NO LONGER NEEDED OR WHEN REQUIRED BY THE PLAN. CHECK DAMS CAN BE LEFT IN PLACE FOLLOWING CONSTRUCTION ACTIVITIES AND ALLOWED TO ACCUMULATE SEDIMENT AND VEGETATION AS APPROVED BY THE PLAN.
5. REMOVED SEDIMENT SHALL BE INCORPORATED IN THE PROJECT AT LOCATIONS DESIGNATED BY THE PLAN.



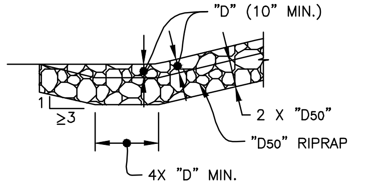
SLOPE DRAIN - DETAIL A
SCALE: 1" = 10'-0"



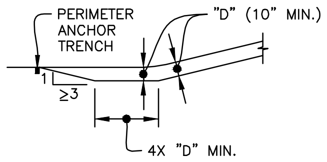
SLOPE DRAIN - SECTION B
SCALE: 1" = 10'-0"



PLASTIC LINED DRAIN - SECTION E
SCALE: 1" = 10'-0"



TERMINATION OF RIPRAP LINED SLOPE DRAIN - DETAIL D
SCALE: 1" = 10'-0"



TERMINATION OF PLASTIC LINED SLOPE DRAIN - DETAIL C
SCALE: 1" = 10'-0"

BMP LEGEND

TSD TEMPORARY SLOPE DRAIN

2 DETAIL SLOPE DRAIN NTS

SLOPE DRAINS

INSTALLATION

1. WHEN USING SLOPE DRAINS (TEMPORARY PIPE), LIMIT DRAINAGE AREA TO 10 ACRE PER PIPE. FOR LARGER AREAS, USE A ROCK-LINED CHANNEL OR A SERIES OF PIPES.
2. MAXIMUM SLOPES ARE GENERALLY LIMITED TO 21 AS ENERGY DISSIPATION BELOW STEEPER SLOPES IS DIFFICULT.
3. DIRECT SURFACE RUNOFF TO AND FROM SLOPE DRAINS WITH INTERCEPTOR DIKES.
4. SLOPE DRAINS CAN BE PLACED ABOVE OR BURIED UNDERNEATH THE SLOPE SURFACE.

5. WHEN INSTALLING SLOPE DRAINS:
   - INSTALL SLOPE DRAINS PERPENDICULAR TO SLOPE CONTOURS.
   - COMPACT SOIL AROUND AND UNDER ENTRANCE, OUTLET, AND ALONG LENGTH OF PIPE.
   - SECURELY ANCHOR AND STABILIZE PIPE AND APPURTENANCES INTO SOIL.
   - CHECK TO ENSURE THAT PIPE CONNECTIONS ARE WATERTIGHT.
   - PROTECT OUTLET WITH RIPRAP OR OTHER ENERGY DISSIPATION DEVICE. FOR HIGH ENERGY DISCHARGES, REINFORCE RIPRAP WITH CONCRETE OR USE REINFORCED CONCRETE DEVICE.
   - PROTECT INLET AND OUTLET OF SLOPE DRAINS: USE STANDARD FLARED END SECTIONS AT ENTRANCES AND EXISTS FOR PIPES 300 MM (12 IN) AND LARGER IN DIAMETER.

INSPECTION, MAINTENANCE, AND REMOVAL

1. INSPECT AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□ FOLLOW ROUTINE INSPECTION PROCEDURES FOR INLETS THEREAFTER.
2. INSPECT OUTLET FOR EROSION AND DOWNSTREAM SCOUR. IF ERODED, REPAIR DAMAGE AND INSTALL ADDITIONAL ENERGY DISSIPATION MEASURES. IF DOWNSTREAM SCOUR IS OCCURRING, IT MAY BE NECESSARY TO REDUCE FLOWS BEING DISCHARGED INTO THE CHANNEL UNLESS OTHER PREVENTATIVE MEASURES ARE IMPLEMENTED.
3. INSPECT SLOPE DRAINAGE FOR ACCUMULATIONS OF DEBRIS AND SEDIMENT.
4. REMOVE BUILT-UP SEDIMENT FROM ENTRANCES AND OUTLETS AS REQUIRED. FLUSH DRAINS IF NECESSARY□CAPTURE AND SETTLE OUT SEDIMENT FROM DISCHARGE.
5. MAKE SURE WATER IS NOT PONDING ONTO INAPPROPRIATE AREAS (E.G., ACTIVE TRAFFIC LANES, MATERIAL STORAGE AREAS, ETC.).

DUGOUT DITCH BASIN

INSTALLATION

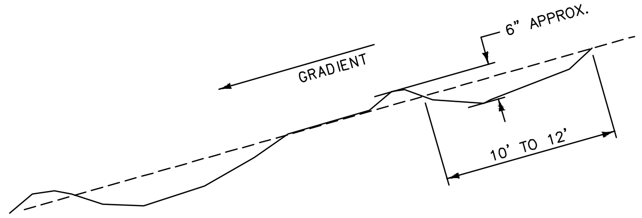
1. DUGOUT DITCH BASINS CONSIST OF ONE OR A SERIES OF SMALL DUGOUT BASINS LOCATED WITHIN A FLOW CHANNEL.
2. DUGOUT DITCH BASINS ARE USED FOR LONGITUDINAL SLOPE STEEPNESS (GRADE) SEDIMENT RETENTION. APPLICATIONS INCLUDE DITCH SEDIMENT TRAPS, INTERCEPTOR DITCHES, AND TOE OF SLOPE PROTECTION.
3. THE DESIGNER DETERMINES THE LOCATIONS REQUIRING DITCH SEDIMENT TRAPS AND THE PROPER PLACEMENT INTERVALS OF THE BASINS.
4. DUGOUT DITCH BASINS SHALL BE PLACED AT A DEPTH THAT ALLOWS SMALL POOLS TO FORM IN THEM.
5. THE MAXIMUM HEIGHT FOR DUGOUT DITCH BASINS USED INSIDE THE ERRANT VEHICLE RECOVERY AREA IS 6 IN.
6. THE DISTANCE BETWEEN DUGOUT DITCH BASINS IS DEPENDENT ON THE LENGTH OF DITCH SECTION RELATING TO THE GRADE THAT NEEDS SEDIMENT RETENTION. THE INTERVAL IS AS FOLLOWS:

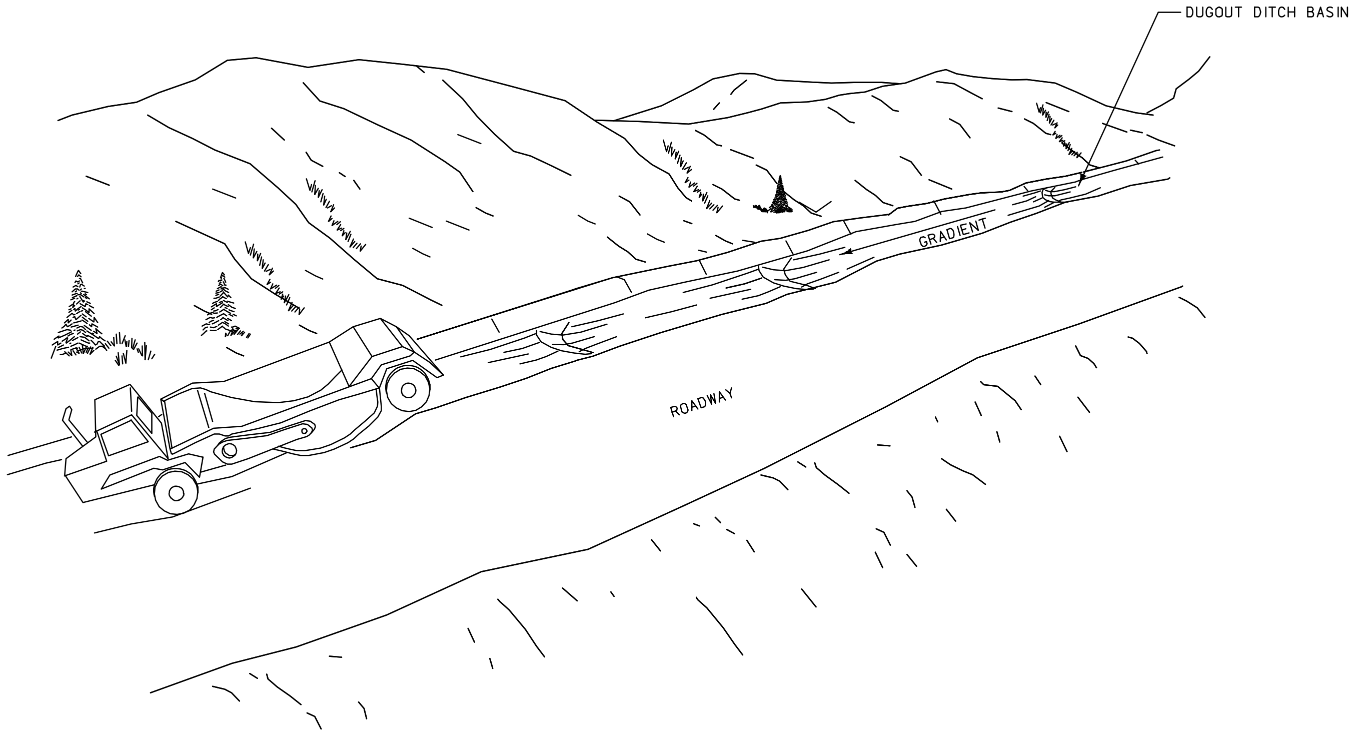
DITCH SLOPE	DUGOUT DITCH BASIN SPACING
2□ - 3□	300 FT.
3□ - 4□	150 FT.
4□ □	50 FT.

7. THE DUGOUT DITCH BASIN SPACING VALUES ARE EMPIRICAL AND ARE THE MAXIMAL INTERVAL DISTANCES FOR A 2 YEAR, 24-HOUR RAIN EVENT. INTERVALS MAY BE SHORTENED IF SOIL CONDITIONS AND/OR PRECIPITATION INDICATE A NEED TO DO SO.
8. DUGOUT DITCH BASINS CAN REMAIN IN PLACE AND BE SEEDED DURING PERMANENT SEEDING OF THE DITCH.

INSPECTION AND REMOVAL

1. INSPECT BASINS AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□ REPAIR DAMAGE AS NEEDED OR AS REQUIRED BY THE PLAN.
2. REMOVE SEDIMENTS WHEN REQUIRED BY THE PLAN.
3. REMOVED SEDIMENT SHALL BE INCORPORATED IN THE PROJECT AT LOCATIONS DESIGNATED BY THE PLAN.





BMP LEGEND

DDB DUGOUT DITCH BASIN

3 DETAIL DUBOUT DITCH BASIN NTS

□INSPECTIONS WILL BE CONDUCTED WITHIN 72 HOURS OF SIGNIFICANT RAINFALL (□0.5" OVER 24 HOURS) OR SNOWMELT (PRODUCING DISCHARGE WITH EROSION), AND SELECTED ROUTINE SCHEDULE, IN ACCORDANCE WITH THE SWPPP FOR THE MULTI-SECTOR GENERAL PERMIT FOR STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY.

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BLACK BUTTE COPPER PROJECT
TINTINA RESOURCES

BEST MANAGEMENT PRACTICES
STANDARD NOTES
(SHEET 3 OF 4)

DRAWING FILE NUMBER
1104801H043
AUTOCAD 2000 DRAWING (DWG)
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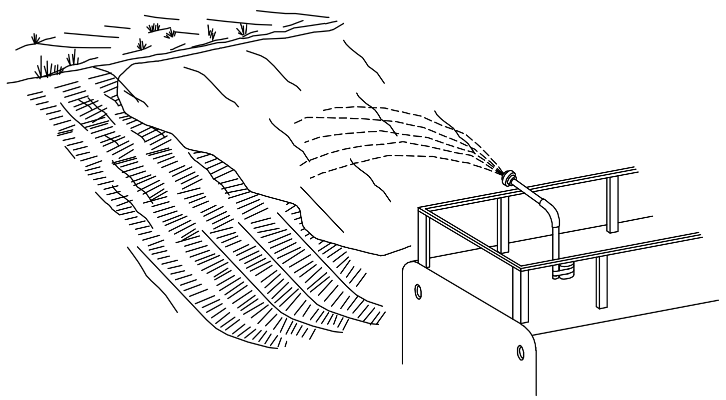


BMP LEGEND

SYMBOL: ——— HM ———

① DETAIL
HYDRAULIC MULCH
NTS

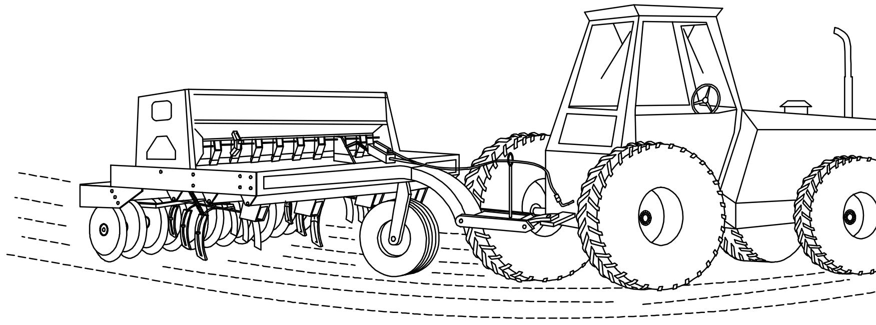
HYDRAULIC MULCH

APPLICATION GUIDELINES

1. CONSISTS OF APPLYING A MIXTURE OF SMALL PIECES OF CELLULOSE FIBERS THAT CAN BE MADE FROM SHREDDED WOOD FIBER OR RECYCLED PAPER AND A STABILIZING EMULSION AND TACKIFIER (IF DESIRED) WITH HYDRO-MULCHING EQUIPMENT.
2. MULCHING CAN PROVIDE IMMEDIATE AND INEXPENSIVE EROSION CONTROL. APPLIED TO DISTURBED AREAS REQUIRING TEMPORARY PROTECTION UNTIL PERMANENT VEGETATION IS ESTABLISHED OR TO DISTURBED AREAS THAT MUST BE RE-DISTURBED.
3. MOST EFFECTIVE WHEN USED IN CONJUNCTION WITH EROSION OR TEMPORARY SEEDING APPLICATIONS. COMPLETE SEEDING APPLICATIONS PRIOR TO MULCH APPLICATION.
4. PRIOR TO APPLICATION, ROUGHEN EMBANKMENT AND FILL AREAS BY ROLLING WITH A CRIMPING, PUNCHING TYPE ROLLER, OR BY TRACK WALKING. TRACK WALKING SHALL ONLY BE USED WHERE OTHER METHODS ARE IMPRACTICAL.
5. HYDROMULCH WILL BE APPLIED AT A MINIMUM RATE OF 500 LBS/ACRE.
6. AVOID MULCH OVER-SPRAY ONTO THE TRAVELED WAY, SIDEWALKS, LINED DRAINAGE CHANNELS, AND EXISTING VEGETATION.

MAINTENANCE AND INSPECTION

1. MAINTAIN AN UNBROKEN, TEMPORARY MULCHED GROUND COVER THROUGHOUT THE PERIOD OF CONSTRUCTION WHEN SOILS ARE NOT BEING REWORKED. INSPECT MULCH BEFORE EXPECTED RAIN STORMS AND REPAIR ANY DAMAGED GROUND COVER AND RE-MULCH EXPOSED AREAS.
2. REAPPLY HYDRAULIC MULCH, AS NEEDED, FOLLOWING RAINFALL EVENTS FOR MAINTAINING ALL SLOPES TO PREVENT EROSION.

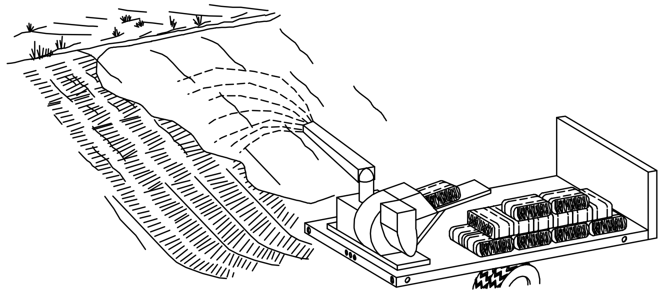


BMP LEGEND

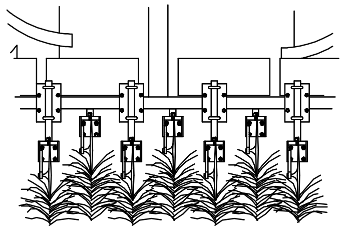
SLOPES 3:1 OR FLATTER

SYMBOL: ——— TS ———

② DETAIL
TEMPORARY SEEDING
NTS



STRAW BLOWER



STRAW CRIMPING

BMP LEGEND

SYMBOL: ——— SM ———

④ DETAIL
STRAW MULCH
NTS

TEMPORARY SEEDING

APPLICATION GUIDELINES

1. TEMPORARY SEEDING IS THE ESTABLISHMENT OF A TEMPORARY VEGETATIVE COVER ON AREAS WITH A SLOPE OF 3:L OR FLATTER THAT WILL BE EXPOSED FOR LONGER THAN 14 DAYS AND THAT WILL UNDERGO FURTHER DISTURBANCE.
2. CEREAL BARLEY IS USED AS THE VEGETATIVE COVER FOR TEMPORARY SEEDING.
3. TEMPORARY SEEDING SHOULD ONLY BE UTILIZED WHEN THERE IS SUFFICIENT TIME AND CONDITIONS ARE FAVORABLE FOR THE VEGETATION TO BECOME ESTABLISHED.
4. NORMAL SEEDING PERIODS INCLUDE:
   SEPTEMBER-NOVEMBER
   MARCH-MAY
   SHOULD SUFFICIENT SOIL MOISTURE AND TEMPERATURES EXIST, THIS PERIOD MAY BE EXTENDED. REFER TO WECO REVEGETATION PLAN FOR SEED MIX AND APPLICATION RATES.
5. DRILL SEED SLOPES OF 3H:1V OR FLATTER.
6. PRIOR TO SEEDING, SLOPES SHALL BE ROUGHENED (REFER TO SURFACE ROUGHENING TECHNIQUES, EXHIBIT 8)
7. MULCH SHOULD BE CONSIDERED IN COMBINATION WITH TEMPORARY SEEDING TO ENHANCE PLANT ESTABLISHMENT. MULCH WILL HELP KEEP SEEDS IN PLACE AND WILL MODERATE SOIL MOISTURE AND TEMPERATURE UNTIL THE SEEDS GERMINATE, WHICH TAKES SEVERAL WEEKS.
8. EACH SEED BAG SHALL BE DELIVERED TO THE SITE SEALED AND CLEARLY MARKED AS TO SPECIES, PURITY, PERCENT GERMINATION, MANUFACTURE'S GUARANTEE, AND DATES OF TEST.
9. FOLLOW-UP APPLICATIONS SHALL BE MADE AS NEEDED TO COVER SPOTS OF POOR GERMINATION, AND TO MAINTAIN ADEQUATE SOIL PROTECTION.

INSPECTION AND MAINTENANCE

1. ALL SEEDED AREAS SHALL BE INSPECTED FOR FAILURES, RE-SEEDED, AND MULCHED WITHIN THE PLANTING SEASON AND AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□, USING NO LESS THAN HALF THE ORIGINAL APPLICATION RATES. ANY TEMPORARY SEEDING EFFORTS THAT DO NOT PROVIDE ADEQUATE COVER MUST BE REVEGETATED AS REQUIRED.

STRAW MULCH

APPLICATION GUIDELINES

1. MULCH IS REQUIRED ON SLOPES 3H:1V OR GREATER. MULCH MAY ALSO BE USED ON LESSER SLOPES AS CONDITIONS WARRANT.
2. TYPICALLY USED IN COMBINATION WITH TEMPORARY AND/OR PERMANENT SEEDING STRATEGIES TO ENHANCE PLANT ESTABLISHMENT.
3. STRAW (OR NATIVE GRASS HAY) SHALL BE CERTIFIED WEED FREE.
4. EVENLY DISTRIBUTE LOOSE STRAW (OR NATIVE GRASS HAY) AT A RATE OF 1500 TO 3000 LBS/ACRE EITHER BY MACHINE OR BY HAND DISTRIBUTION.
5. WHEN STRAW BLOWERS ARE USED TO APPLY STRAW MULCH, THE TREATMENT AREAS MUST BE WITHIN 45 M (150 FT) OF A ROAD OR SURFACE CAPABLE OF SUPPORTING TRUCKS.
6. METHODS FOR HOLDING THE STRAW MULCH IN PLACE DEPEND UPON THE SLOPE STEEPNESS, ACCESSIBILITY, SOIL CONDITIONS, AND LONGEVITY. IF THE SELECTED METHOD IS INCORPORATION OF STRAW MULCH INTO THE SOIL, THEN DO AS FOLLOWS:

   - ON SMALL AREAS, A SPADE OR SHOVEL CAN BE USED.

   - ON SLOPES WITH SOILS, WHICH ARE STABLE ENOUGH, AND OF SUFFICIENT GRADIENT TO SAFELY SUPPORT CONSTRUCTION EQUIPMENT WITHOUT CONTRIBUTING TO COMPACTION AND INSTABILITY PROBLEMS, STRAW CAN BE "PUNCHED" INTO THE GROUND USING A STRAIGHT BLADED COULTER, KNOWN AS A "CRIMPER."

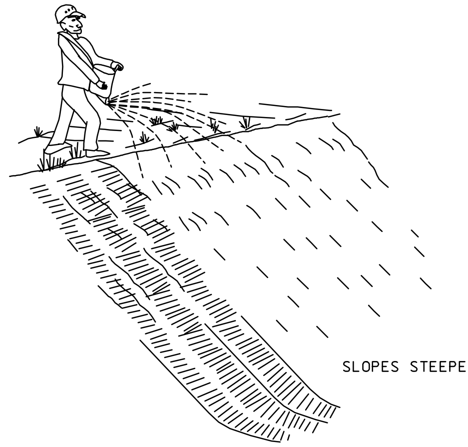
   - ON SMALL AREAS AND/OR STEEP SLOPES, STRAW CAN ALSO BE HELD IN PLACE USING PLASTIC NETTING OR JUTE. THE NETTING SHALL BE HELD IN PLACE USING WIRE STAPLES, GEOTEXTILE PINS OR WOODEN STAKES.

7. AVOID PLACING STRAW ONTO THE TRAVELED WAY, SIDEWALKS, LINED DRAINAGE CHANNELS, SOUND WALLS, AND EXISTING VEGETATION.

INSPECTION AND MAINTENANCE

1. THE KEY CONSIDERATION IN MAINTENANCE, INSPECTION, AND REMOVAL IS THAT THE STRAW NEEDS TO LAST LONG ENOUGH TO ACHIEVE EROSION CONTROL OBJECTIVES UNTIL SOILS CAN BE PREPARED FOR RE-VEGETATION AND PERMANENT VEGETATION IS ESTABLISHED.

2. REAPPLICATION OF STRAW MULCH MAY BE REQUIRED TO MAINTAIN EFFECTIVE SOIL STABILIZATION OVER DISTURBED AREAS AND SLOPES.



SLOPES STEEPER THAN 3:1

BMP LEGEND

SYMBOL: ——— ES ———

③ DETAIL
EROSION SEEDING
NTS

EROSION SEEDING

APPLICATION GUIDELINES

1. IMMEDIATE SEEDING OF FRESHLY EXPOSED CUT AND FILL SLOPES STEEPER THAN 3:1 THAT WILL NOT UNDERGO FURTHER DISTURBANCE. EROSION SEEDING USES A MIXTURE OF SEED. REFER TO WECO REVEGETATION PLAN FOR SEED MIX.
2. EROSION SEEDING VEGETATION MAY HAVE TO BE REMOVED BEFORE PERMANENT VEGETATION IS APPLIED.
3. FRESHLY EXPOSED SLOPES ARE TO BE SEEDED DAILY, REGARDLESS OF THE TIME OF YEAR.
4. ACCOMPLISH SEEDING BY MANUAL BROADCASTING WITH A SHOULDER-HARNESSED SPREADER SEEDER OR ITS EQUIVALENT.
5. STORE THE RECOMMENDED MIX ON-SITE PRIOR TO INITIATION OF SLOPE EXCAVATION.
6. THE FOLLOWING CONSIDERATIONS SHOULD BE ADDRESSED IF A HYDROSEEDER IS USED:

   - HYDROSEEDING TYPICALLY CONSISTS OF APPLYING A MIXTURE OF FIBER, SEED, FERTILIZER, AND STABILIZING EMULSION WITH HYDRO-MULCH EQUIPMENT, WHICH TEMPORARILY PROTECTS EXPOSED SOILS FROM EROSION BY WATER AND WIND. HYDROSEEDING MIXTURES SHALL BE SELECTED BASED ON AN EVALUATION OF SITE CONDITIONS WITH RESPECT TO SOIL CONDITIONS, MAINTENANCE REQUIREMENTS, SITE TOPOGRAPHY, SENSITIVE ADJACENT AREAS, SEASON AND CLIMATE, WATER AVAILABILITY, VEGETATION TYPES, AND PLANS FOR PERMANENT VEGETATION.
   - HYDROSEEDING MIXTURES AS IDENTIFIED IN THE RECLAMATION PLAN SHALL BE SELECTED.

7. EACH SEED BAG SHALL BE DELIVERED TO THE SITE SEALED AND CLEARLY MARKED AS TO SPECIES, PURITY, PERCENT GERMINATION, DEALER'S GUARANTEE, AND DATES OF TEST. THE CONTAINER SHALL BE LABELED TO CLEARLY REFLECT THE AMOUNT OF PURE LIVE SEED (PLS) CONTAINED.
8. FOLLOW-UP APPLICATIONS SHALL BE MADE AS NEEDED TO COVER WEAK SPOTS AND TO MAINTAIN ADEQUATE SOIL PROTECTION.
9. AVOID OVER-SPRAY ONTO THE TRAVEL WAY, SIDEWALKS, LINED DRAINAGE CHANNELS, AND EXISTING VEGETATION.

INSPECTION AND MAINTENANCE

1. ALL SEEDED AREAS SHALL BE INSPECTED FOR FAILURES AND RE-SEEDED WITHIN THE PLANTING SEASON AND AFTER STORM EVENTS IN ACCORDANCE WITH SWPPP SCHEDULE□. ANY TEMPORARY REVEGETATION EFFORTS THAT DO NOT PROVIDE ADEQUATE COVER MUST BE REVEGETATED AS REQUIRED.

□INSPECTIONS WILL BE CONDUCTED WITHIN 72 HOURS OF SIGNIFICANT RAINFALL (□0.5" OVER 24 HOURS) OR SNOWMELT (PRODUCING DISCHARGE WITH EROSION), AND SELECTED ROUTINE SCHEDULE, IN ACCORDANCE WITH THE SWPPP FOR THE MULTI-SECTOR GENERAL PERMIT FOR STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY.

Hydrometrics, Inc. Consulting Scientists and Engineers Helena, Montana 59601 3020 Bozeman Avenue (406) 443-4150	BLACK BUTTE COPPER PROJECT TINTINA RESOURCES	**BEST MANAGEMENT PRACTICES STANDARD NOTES (SHEET 4 OF 4)**	DRAWING FILE NUMBER 1104801H044 AUTOCAD 2000 DRAWING (DWG) FIGURE **4.6**

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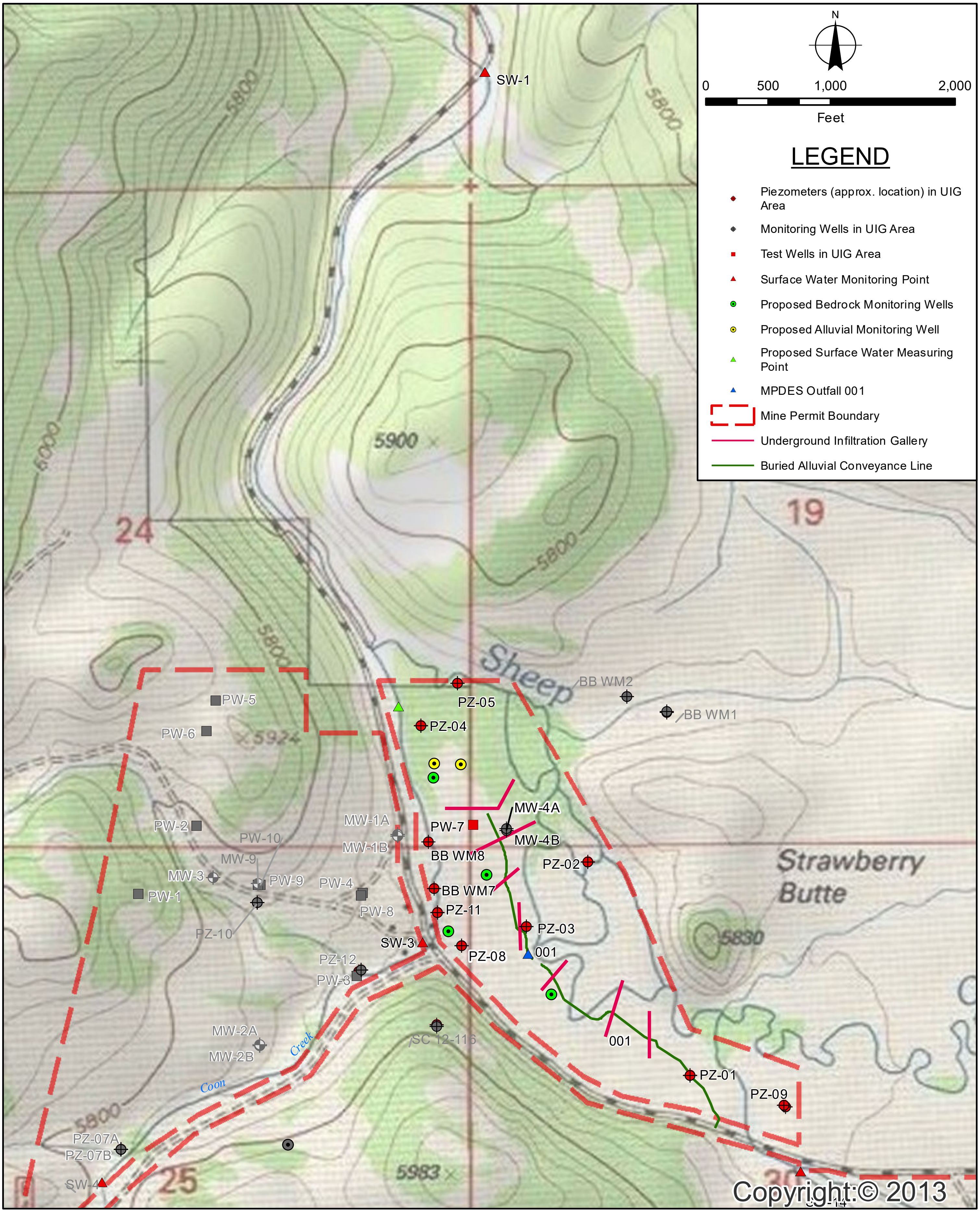
5.0 WATER RESOURCE AND COMPLIANCE MONITORING

Tintina initiated baseline water resource monitoring in May of 2011. This monitoring characterizes existing conditions at the site, and provides a baseline against which to identify potential impacts to resources. The program includes measurement of flow, water levels, and water quality at surface water, groundwater, and spring and seep monitoring sites in the Project area (Hydrometrics, 2017). The existing Baseline water resource monitoring network includes 12 surface water sites, 22 monitoring well sites, 16 springs, 10 seeps, and 34 additional test wells and piezometer sites (note four additional wetland piezometers have been installed since submittal of MOP). Appendix K contains the Sampling and Analysis Plan for water resource monitoring activities (Hydrometrics, 2016a). Baseline monitoring will continue throughout the mine permitting period to assess environmental conditions prior to surface disturbing activities.

Proposed water resource monitoring applicable to the MPDES portion of this integrated permit application is presented below. Monitoring of storm water outfalls will be developed during the preparation of the SWPPP (as stated in Section 4.4) and in coordination with DEQ. See Section 6.3 of the MOP for additional details of the proposed monitoring plan that applies to the mine facilities outside the area of the MPDES outfalls.

5.1 OPERATIONAL WATER RESOURCE MONITORING PLAN

The current and proposed water resource monitoring sites in the vicinity of the proposed MPDES outfalls 001 is shown on Figure 5.1. Tintina currently conducts monthly monitoring on Sheep Creek and quarterly monitoring at the monitoring wells in the vicinity of the proposed outfalls. As permitting proceeds and construction of new mine support facilities are anticipated, additional water resource monitoring of these facilities will be warranted. Tintina proposes new facility monitoring sites to provide a technically sound and regulatory sufficient monitoring program. These sites will be monitored on a quarterly basis for the same surface water and groundwater parameters as for the current baseline study programs (Table 5-1).



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Date: December 2017, Source: Hydrometrics, Inc. (2017)

Hydrometrics, Inc.
Consulting Scientists and Engineers

Figure 5.1
Water Resource Monitoring Sites
Black Butte Copper Project
Meagher County, Montana

TABLE 5-1. PARAMETERS, METHODS, AND DETECTION LIMITS FOR BASELINE WATER RESOURCE MONITORING

Parameter	Analytical Method(1)	Project-Required Detection Limit (mg/L)
Physical Parameters		
TDS	SM 2540C	4
TSS	SM 2540C	4
Common Ions		
Alkalinity	SM 2320B	4
Sulfate	300.0	1
Chloride	300.0/SM 4500CL-B	1
Fluoride	A4500-F C	0.1
Calcium	215.1/200.7	1
Magnesium	242.1/200.7	1
Sodium	273.1/200.7	1
Potassium	258.1/200.7	1
Nutrients		
Nitrate+Nitrite as N	353.2	0.003
Total Persulfate Nitrogen	A 4500-N-C	0.04
Total Phosphorus	E365.1	0.003
Trace Constituents (SW - Total Recoverable except Aluminum [Diss])(2)		
Aluminum (Al)	200.7/200.8	0.009
Antimony (Sb)	200.7/200.8	0.0005
Arsenic (As)	200.8/SM 3114B	0.001
Barium (Ba)	200.7/200.8	0.003
Beryllium (Be)	200.7/200.8	0.0008
Cadmium (Cd)	200.7/200.8	0.00003
Chromium (Cr)	200.7/200.8	0.01
Cobalt (Co)	200.7/200.8	0.01
Copper (Cu)	200.7/200.8	0.002
Iron (Fe)	200.7/200.8	0.02
Lead (Pb)	200.7/200.8	0.0003
Manganese (Mn)	200.7/200.8	0.005
Mercury (Hg)	245.2/245.1/200.8/SM 3112B	0.000005
Molybdenum (Mo)	200.7/200.8	0.002
Nickel (Ni)	200.7/200.8	0.001
Selenium (Se)	200.7/200.8/SM 3114B	0.0002
Silver (Ag)	200.7/200.8	0.0002
Strontium (Sr)	200.7/200.8	0.0002
Thallium (Tl)	200.7/200.8	0.0002
Uranium	200.7/200.8	0.008
Zinc (Zn)	200.7/200.8	0.002
Field Parameters		
Stream Flow	HF-SOP-37/-44/-46	NA
Water Temperature	HF-SOP-20	0.1 °C
Dissolved Oxygen (DO)	HF-SOP-22	0.1 mg/L
pH	HF-SOP-20	0.1 s.u.
Specific Conductance (SC)	HF-SOP-79	1 µmhos/cm

(1) Analytical methods are from *Standard Methods for the Examination of Water and Wastewa*ter (SM) or EPA's *Methods for Chemical Analysis of Water and Waste* (1983).

(2) Samples to be analyzed for dissolved constituents will be field-filtered through a 0.45 µm filter.

Existing piezometers will service the alluvial infiltration gallery. During operations underground infiltration gallery site will be visually inspected to ensure that surface ponding, seep and spring development, and surface water run-off is not occurring. The piezometers water levels will be used to track groundwater mounding and to avoid soil saturation. It is expected that monthly adjustments will be required to the amount / time water is applied to each arm of the UIG. Because the mine discharge rate is expected to be low during the initial first two year of development (<300 gpm), there will be an opportunity to better understand and calibrate infiltration rates and cell rotation using piezometer water level measurements of soil saturation. Piezometers in Outfall 001) will be monitored monthly, and areas with active discharge will initially be monitored weekly until such time that DEQ determines sampling frequency can be decreased. Two additional groundwater monitoring wells are proposed in the Sheep Creek alluvial system as part of this MPDES permit. These wells will be sited 500 feet down gradient from the last UIG in the alluvial system. These wells will be completed and screened across first water contact and monitored at the frequency necessary to determine permit compliance.

Tintina has been conducting water resource monitoring at two upgradient sites and one downgradient site on Sheep Creek since 2011. There is about six years of baseline data (monthly since 2012) at the downgradient site (SW-1) on Sheep Creek, which includes a gaging station to collect continuous streamflow measurements. Tintina proposes to use site SW-1 to monitor surface water quality downgradient of the proposed mixing zone. This site is appropriate as there is a robust baseline dataset already established and there are no tributaries between the proposed mixing zone and Sheep Creek.

5.2 WATER TREATMENT PLANT EFFLUENT COMPLIANCE MONITORING

Tintina proposes to conduct compliance monitoring of the end of the WTP after the polishing phase and prior to entering the pipeline to the MPDES Outfalls. In the MOP application, the compliance monitoring schedule for the water treatment effluent was initially proposed to be at a weekly basis in the MOP. Tintina would like to work with DEQ-WPB to establish a more comprehensive compliance monitoring program to establish detailed schedule that may vary for specific parameters.

5.3 TRIGGER LEVEL VALUES FOR IMPLEMENTATION OF MITIGATIONS AND DEQ NOTIFICATIONS

Tintina will notify DEQ within 48 hours if any of the monitoring results indicate an operating condition outside the permitted effluent limits. If a preliminary laboratory report showing that a contaminant has exceeded local background non-degradation criteria for groundwater at any of the groundwater monitoring sites is received, Tintina will notify DEQ within 48 hours and submit a corrective action plan for addressing the exceedance.

6.0 SAGE GROUSE

The greater sage-grouse (sage-grouse) is considered to be a sagebrush-dependent species (e.g., Connelly et al., 2011). There are known sage-grouse leks (display sites) 10 to 13 miles from the Project area, but there are no known occurrences recorded within 10 miles (MTNHP, 2015).

7.0 CERTIFICATION AND SIGNATORY PAGE

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

_______________ (Signature) 12/8/2017 (Date)

JERRY ZIEG (Printed Name)

SR. VICE PRESIDENT (Title)

TINTINA MONTANA, INC. (Company)

8.0 REFERENCES

Amec Foster Wheeler, 2017a. Technical Memo: Water Treatment Plant Modeling for Black Butte Copper Project. May 2, 2017. In Appendix V of the MOP application document (Revision 3, July 14, 2017).

Amec Foster Wheeler, 2017b. Technical Memo: Projected Removal of Trace Metals in RO System, Tintina Montana Mine Operating Permit. September 26, 2017. In Appendix B of the 2017 Integrated Discharge Permit application narrative.

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Connelly, J.W., E.T. Rinkes and C.E. Braun. 2011. *Characteristics of greater sage grouse habitats.* In S.T. Knick and J.W. Connelly (eds.). Greater sage grouse: ecology and conservation of landscape species and its habitats. Cooper Ornith. Soc., Univ. California Press.

DEQ, 2017. Pre-application meeting follow-up; Montana Pollutant Discharge Elimination System (MPDES) for Tintina Montana Black Butte Copper Project. Correspondence to Jim Lloyd, Hydrometrics, Inc. from Rainie DeVaney, DEQ Water Protection Bureau. September 18, 2017.

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USDA, 1988. Urban Hydrology for Small Watersheds. Washington, DC: US Department of Agriculture Conservation Engineering Division.

APPENDIX A

APPLICATION FORM 1, FORM 2D, AND FORM 2C

Montana Department of
ENVIRONMENTAL QUALITY

WATER PROTECTION BUREAU

Agency Use
Permit No.:

Date Rec'd
Amt Rec'd
Check No.
Rec'd By

FORM
1

GENERAL INFORMATION

(See instructions before completing)

Section A – Montana Pollutant Discharge Elimination System

SPECIFIC QUESTIONS	MARK 'X'			SPECIFIC QUESTIONS	MARK 'X'		
	YES	NO	FORM ATTACHED		YES	NO	FORM ATTACHED
1. Is this facility a publicly owned treatment works which results in a discharge to state surface waters or waters of the U.S.? (FORM 2A)	○	●	☐	2. Does or will this facility (*either existing or proposed)* include a concentrated animal feeding operation or aquatic animal production facility which results in a discharge to state surface waters or waters of the U.S.? (FORM 2B)	○	●	☐
3. Is this a facility which currently results in a discharge of industrial wastewater to state surface water other than those described in 1 or 2 above? (FORM 2C)	○	●	☐	4. Is this a proposed facility *(other than those described in 1 or 2 above*) which will result in a discharge of industrial wastewater to state surface waters? (FORM 2D)	●	○	☑
5. Does this facility discharge only non-process wastewater, not subject to federal effluent guidelines or new source performance standards to state surface waters? (FORM 2E)	○	●	☐	6. Does this facility discharge or propose to discharge storm water associated with industrial activity either alone or in combination with non-storm water discharges? (FORM 2F)	●	○	☑

Montana Ground Water Pollution Control System (MGWPCS)

7. Does this facility discharge sewage to ground water through infiltration, percolation or other methods of subsurface disposal? (GW-1)	○	●	☐	8. Does this facility discharge industrial wastes, or other wastes, to ground water through infiltration, percolation, or other methods of subsurface disposal? (GW-2)	●	○	☐

Section B – Facility or Activity Information

Facility Name Black Butte Copper Project
Facility Location 15 miles (24 km) north of White Sulphur Springs
City, State, Zip Meagher County, Montana, 59645
Telephone Number (406) 547-3466 County: Meagher
Township: 12N Range: 6E and 7E Section: various ; ______1/4 ______1/4 ______1/4
Latitude: 46°46' 17.33"N Longitude: 110°54' 36.43"W
Is the facility located on Indian lands? ☐ YES ☒ NO

Section C – Facility Contact

Facility Contact Name/Title Jerry Zieg, Vice President of Exploration, Tintina Montana, Inc.
Mailing Address PO Box 431
City, State, Zip White Sulphur Springs, MT 59645
Telephone Number (406) 547-3466 Email jerry.zieg@tintinaresources.com

Section D – Existing or Pending Permits, Certifications, or Approvals

☐ MPDES Permit ____________________
☐ UIC # ____________________
☐ Plat Approval EQ # ____________________
☐ 404 Permit (dredge & fill) ____________________
☐ MGWPCS # ____________________
☐ Other Draft Operating #00188; DEQ Air #4978-00

Section E – Nature of Business (provide a brief description)

underground copper mine and mill

SIC CODES (4-digit, in order of priority)

	Code	A. First		Code	B. Second
1	1021	Copper Ore mining and milling	2		
	Code	**C. Third**		**Code**	**D. Fourth**
3			4		

MAP: Attach to this application a topographic map of the area extending to at least one mile beyond property boundaries. The map must show the outline of the facility, the location of each of its existing and proposed intake and discharge structures (outfalls), each of its hazardous waste treatment, storage, or disposal facilities, and each well where it injects fluids underground. Include all springs, rivers and other surface water bodies in the map area. `See Figures 1.2, 1.3 and 3.1`

Section F – Applicant (Owner/Operator) Information

Applicant (Operator) Name Tintina Montana, Inc.

Mailing Address PO Box 431

City, State, Zip White Sulphur Springs, MT 59645

Telephone Numbers (406) 547-3466

Is the 'Operator' listed above also the owner? ☒ YES ☐ NO

Status of Applicant *(Check One)*

☐ Federal ☐ State ☒ Private ☐ Public ☐ Other *(specify)* ____________________

CERTIFICATION

Section G – Applicant Information: This application must be completed, signed, and certified as follows:

- For a corporation, by a principal officer of at least the level of vice president;
- For a partnership or sole proprietorship, by a general partner or the proprietor, respectively; or
- For a municipality, state, federal, or other public facility, by either a principal executive officer or ranking elected official.

All Applicants Must Complete the Following Certification.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the persons who manage the system or those persons directly responsible for gathering the information, it is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violation.

A. Name and Official Title (Type or Print) Jerry Zieg, Vice President of Exploration	**B. Phone No.** (406) 547-3466
C. Signature	**D. Date Signed** 12/8/2017

Form Approved. OMB No. 2040-0086. Approval expires 8-31-98.

Please print or type in the unshaded areas only	EPA I.D. NUMBER (*copy from Item 1 of Form 1*)	

Form 2D NPDES EPA

New Sources and New Dischargers
Application for Permit to Discharge Process Wastewater

I. Outfall Location

For each outfall, list the latitude and longitude of its location to the nearest 15 seconds and the name of the receiving water.

Outfall Number (*list*)	Latitude			Longitude			Receiving Water (*name*)
	Deg.	Min.	Sec.	Deg.	Min.	Sec.	
001	46.00	46.00	47.00	110.00	54.00	20.00	Alluvial Aquifer, Sheep Creek

II. Discharge Date (When do you expect to begin discharging?)

06/20/2019

III. Flows, Sources of Pollution, and Treatment Technologies

A. For each outfall, provide a description of: (1) All operations contributing wastewater to the effluent, including process wastewater, sanitary wastewater, cooling water, and storm water runoff; (2) The average flow contributed by each operation; and (3) The treatment received by the wastewater. Continue on additional sheets if necessary.

Outfall Number	1. Operations Contributing Flow (*List*)	2. Average Flow (*Include Units*)	3. Treatment (*Description or List codes from Table 2D-1*)
001	Underground Dewatering	499.7 gpm	
	PWP Surface Water Transfer	55.2 gpm	
	Cement Tailing Facilit drain	20.0 gpm	
	Mill Catchment Runoff	13.1 gpm	
	Recycled Freshwater	14.6 gpm	
	Max Annual Avg above to WTP	588 gpm	1-G, 1-U, 1-Q, 1-S, 2-K
	Refer to Figure 3.5, Table	3-3, and Sections 3.3 & 3.4	
	of the application narrative		

B. Attach a line drawing showing the water flow through the facility. Indicate sources of intake water, operations contributing wastewater to the effluent, and treatment units labeled to correspond to the more detailed descriptions in Item III-A. Construct a water balance on the line drawing by showing average flows between intakes, operations, treatment units, and outfalls. If a water balance cannot be determined (e.g., for certain mining activities), provide a pictorial description of the nature and amount of any sources of water and any collection or treatment measures. See Figure 3.5

C. Except for storm runoff, leaks, or spills, will any of the discharges described in Items III-A be intermittent or seasonal?

☐ YES (*complete the following table*) ☑ NO (*go to Section IV*)

Outfall Number	1. Frequency		2. Flow		
	a. Days Per Week (*specify average*)	b. Months Per Year (*specify average*)	a. Maximum Daily Flow Rate (*in mgd*)	b. Maximum Total Volume (*specify with units*)	c. Duration (*in days*)

IV. Production

If there is an applicable production-based effluent guideline or NSPS, for each outfall list the estimated level of production (projection of actual production level, not design), expressed in the terms and units used in the applicable effluent guideline or NSPS, for each of the first 3 years of operation. If production is likely to vary, you may also submit alternative estimates (attach a separate sheet).

Year	A. Quantity Per Day	B. Units Of Measure	c. Operation, Product, Material, etc. (*specify*)
		Not Applicabl	40 CFR 440.104 NSPS Not Production Based

CONTINUED FROM THE FRONT	EPA I.D. NUMBER (*copy from Item 1 of Form 1*)	Outfall Number 001, 002, 003

V. Effluent Characteristics

A and B: These items require you to report estimated amounts (*both concentration and mass*) of the pollutants to be discharged from each of your outfalls. Each part of this item addresses a different set of pollutants and should be completed in accordance with the specific instructions for that part. Data for each outfall should be on a separate page. Attach additional sheets of paper if necessary.

General Instructions *(See table 2D-2 for Pollutants)*
Each part of this item requests you to provide an estimated daily maximum and average for certain pollutants and the source of information. Data for all pollutants in Group A, for all outfalls, must be submitted unless waived by the permitting authority. For all outfalls, data for pollutants in Group B should be reported only for pollutants which you believe will be present or are limited directly by an effluent limitations guideline or NSPS or indirectly through limitations on an indicator pollutant.

1. Pollutant	2. Maximum Daily Value *(include units)*	3. Average Daily Value *(include units)*	4. Source *(see instructions)*
BOD	<2.0 mg/L	<2.0 mg/L	Effluent Not Modeled for These Parameters
TOC	<0.5 mg/L	<0.5 mg/L	"
COD	<4.0 mg/L	<4.0 mg/L	"
TSS	<1 mg/L	<1 mg/L	"
Flow	575 gpm	398 gpm	Mine Operating Permit (MOP) Rev. 3, 7/14/17
Temperature (winter)	24.2 °C	-3.4 °C	Black Butte Mine Meteorological Monitoring
Temperature (summer)	31.5 °C	11.6 °C	(Appendix C) April 2012 - December 2016
			Temp. 2 meters - Water will approach
			air temp in storage
For all constituents See	Table 3-4.	Estimated	Treated Water Discharge Concentrations

CONTINUED FROM THE FRONT	EPA I.D. NUMBER (*copy from Item 1 of Form 1*)	

C. Use the space below to list any of the pollutants listed in Table 2D-3 of the instructions which you know or have reason to believe will be discharged from any outfall. For every pollutant you list, briefly describe the reasons you believe it will be present.

1. Pollutant	2. Reason for Discharge
Strontium Uranium	Ambient water contains both constituents (See Table 3-1.)

VI. Engineering Report on Wastewater Treatment

A. If there is any technical evaluation concerning your wastewater treatment, including engineering reports or pilot plant studies, check the appropriate box below.

Water Treatment Plant Modeling, 2017 (Appendix V of Operation Plan, July 2017)

Nondegradation Analysis for MPDES Outfalls, 2017 (Appendix V-1 of Operation Plan, July 2017)

☑ Report Available ☐ No Report

B. Provide the name and location of any existing plant(s) which, to the best of your knowledge resembles this production facility with respect to production processes, wastewater constituents, or wastewater treatments.

Name	Location
Proposed Plants	
Butte Highlands	South of Butte, MT (proposed RO system)
Montanore	Near Libby, MT (proposed RO system)
Rock Creek	Near Noxon, MT
Existing Plants	
Stillwater Nye	Nye, MT (explosives and froth flotation)
Stillwater East Boulder	Southwest of Billings, MT (explosives and froth flotation)
Montana Resources	Butte, Montana (explosives and froth flotation)
	See Section 2.2 of narrative for more detail.

EPA I.D. NUMBER (*copy from Item 1 of Form 1*)

VII. Other Information *(Optional)*

Use the space below to expand upon any of the above questions or to bring to the attention of the reviewer any other information you feel should be considered in establishing permit limitations for the proposed facility. Attach additional sheets if necessary.

Tintina Montana Inc. is requesting a Source Specific Mixing Zone (3,500 feet, 1,066 m in length) for Total Nitrogen during the summer months to meet the seasonal nutrient standard for total nitrogen in surface water (Sheep Creek).

Mixing Analysis - Attached Appendix D

III.B. Line Drawing - Refer to Figures 3.5 (Water Balance) and 3.6 (Process Flow Diagram) for a more complete understanding of facility activities.

See Narrative Description which accompanies this application.

VIII. CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

A. Name and Official Title (*type or print*) Jerry Zieg, Vice President of Exploration	B. Phone No. (406) 547-3466
C. Signature	D. Date Signed 12/8/2017

Please print or type in the unshaded areas only.

EPA ID Number (*copy from Item 1 of Form 1*)

Form Approved. OMB No. 2040-0086
Approval expires 5-31-92

FORM
2F
NPDES

U.S. Environmental Protection Agency
Washington, DC 20460

Application for Permit to Discharge Storm Water Discharges Associated with Industrial Activity

Paperwork Reduction Act Notice

Public reporting burden for this application is estimated to average 28.6 hours per application, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate, any other aspect of this collection of information, or suggestions for improving this form, including suggestions which may increase or reduce this burden to: Chief, Information Policy Branch, PM-223, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, Washington, DC 20460, or Director, Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, DC 20503.

I. Outfall Location

For each outfall, list the latitude and longitude of its location to the nearest 15 seconds and the name of the receiving water.

A. Outfall Number (*list*)	B. Latitude			C. Longitude			D. Receiving Water (*name*)
002	46.00	45.00	58.40	110.00	55.00	19.50	Coon Creek
003	46.00	46.00	18.90	110.00	55.00	4.50	Coon Creek
004	46.00	46.00	8.70	110.00	54.00	35.50	Brush Creek
005	46.00	45.00	50.70	110.00	54.00	39.70	Brush Creek
006	46.00	45.00	33.90	110.00	54.00	55.20	Brush Creek
007	46.00	45.00	35.20	110.00	54.00	36.80	Brush Creek
008	46.00	46.00	10.20	110.00	54.00	55.80	Coon Creek
009	46.00	46.00	16.10	110.00	53.00	37.30	Brush Creek
010	46.00	46.00	10.00	110.00	53.00	57.70	Brush Creek
011	46.00	46.00	17.30	110.00	53.00	14.70	Little Sheep Creek

II. Improvements

A. Are you now required by any Federal, State, or local authority to meet any implementation schedule for the construction, upgrading or operation of wastewater treatment equipment or practices or any other environmental programs which may affect the discharges described in this application? This includes, but is not limited to, permit conditions, administrative or enforcement orders, enforcement compliance schedule letters, stipulations, court orders, and grant or loan conditions.

1. Identification of Conditions, Agreements, Etc.	2. Affected Outfalls		3. Brief Description of Project	4. Final Compliance Date	
	number	source of discharge		a. req.	b. proj.
Not Applicable					
		II. B.	Groundwater from mine dewatering and		
			Contact Water Pond will require treatmen		
			during the second year of construction.		
			The water treatment plant and undergroun		
			infiltration galleries will be		
			constructed early in the Project.		
			Treated water will be discharged through		
			the MPDES permit,separate from storm wtr		

B: You may attach additional sheets describing any additional water pollution (or other environmental projects which may affect your discharges) you now have under way or which you plan. Indicate whether each program is now under way or planned, and indicate your actual or planned schedules for construction.

III. Site Drainage Map

Attach a site map showing topography (or indicating the outline of drainage areas served by the outfalls(s) covered in the application if a topographic map is unavailable) depicting the facility including: each of its intake and discharge structures; the drainage area of each storm water outfall; paved areas and buildings within the drainage area of each storm water outfall, each known past or present areas used for outdoor storage of disposal of significant materials, each existing structural control measure to reduce pollutants in storm water runoff, materials loading and access areas, areas where pesticides, herbicides, soil conditioners and fertilizers are applied; each of its hazardous waste treatment, storage or disposal units (including each area not required to have a RCRA permit which is used for accumulating hazardous waste under 40 CFR 262.34); each well where fluids from the facility are injected underground; springs, and other surface water bodies which received storm water discharges from the facility.

See Figures 1.3 and 3.1

Continued from the Front

IV. Narrative Description of Pollutant Sources

A. For each outfall, provide an estimate of the area (include units) of imperious surfaces (including paved areas and building roofs) drained to the outfall, and an estimate of the total surface area drained by the outfall.

Outfall Number	Area of Impervious Surface *(provide units)*	Total Area Drained *(provide units)*	Outfall Number	Area of Impervious Surface *(provide units)*	Total Area Drained *(provide units)*
002	No Impervious Surfaces	13.24 acres	007	No Impervious Surfaces	27.57 acres
003		15.23 acres	008		13.54 acres
004		65.68 acres	009		9.00 acres
005		13.01 acres	010		32.30 acres
006		25.86 acres	011		1.70 acres

B. Provide a narrative description of significant materials that are currently or in the past three years have been treated, stored or disposed in a manner to allow exposure to storm water; method of treatment, storage, or disposal; past and present materials management practices employed to minimize contact by these materials with storm water runoff; materials loading and access areas, and the location, manner, and frequency in which pesticides, herbicides, soil conditioners, and fertilizers are applied.

-Not Applicable

C. For each outfall, provide the location and a description of existing structural and nonstructural control measures to reduce pollutants in storm water runoff; and a description of the treatment the storm water receives, including the schedule and type of maintenance for control and treatment measures and the ultimate disposal of any solid or fluid wastes other than by discharge.

Outfall Number	Treatment	List Codes from Table 2F-1
All as Needed	Diversion structures will consist of drainage ditches or swales, spreaders, sediment traps, rock berms, straw wattles, and slash windrows. Erosion control may include vegetation management and revegetation, mulching, rolled products for slope cover, slope roughening, recontouring,silt fencing, temporary sediment traps and basins, filter bags, flocculants, collection ditches, diversion ditches, culverts, and water bars. BMPs will be used to reduce erosion by stabilizing exposed soil (source control), or by reducing surface runoff flow velocies (conveyance control).	BMPs 4-A Discharge to SW See Section 4 and Figure 3.1

V. Nonstormwater Discharges

A. I certify under penalty of law hat the outfall(s) covered by this application have been tested or evaluated for the presence of nonstormwater discharges, and that all nonstormwater discharged from these outfall(s) are identified in either an accompanying Form 2C or From 2E application for the outfall.

Name and Official Title (*type or print*)	Signature	Date Signed

B. Provide a description of the method used, the date of any testing, and the onsite drainage points that were directly observed during a test.

VI. Significant Leaks or Spills

Provide existing information regarding the history of significant leaks or spills of toxic or hazardous pollutants at the facility in the last three years, including the approximate date and location of the spill or leak, and the type and amount of material released.

No past spills or leaks from facilities.

Continue on Page 3

Continued from Page 2

EPA ID Number *(copy from Item 1 of Form 1)*

VII. Discharge Information

A, B, C, & D: See instructions before proceeding. Complete one set of tables for each outfall. Annotate the outfall number in the space provided.
Table VII-A, VII-B, VII-C are included on separate sheets numbers VII-1 and VII-2.

E. Potential discharges not covered by analysis – is any toxic pollutant listed in table 2F-2, 2F-3, or 2F-4, a substance or a component of a substance which you currently use or manufacture as an intermediate or final product or byproduct?

☑ Yes *(list all such pollutants below)* ☐ No *(go to Section IX)*

copper

VIII. Biological Toxicity Testing Data

Do you have any knowledge or reason to believe that any biological test for acute or chronic toxicity has been made on any of your discharges or on a receiving water in relation to your discharge within the last 3 years?

☐ Yes *(list all such pollutants below)* ☑ No *(go to Section IX)*

IX. Contract Analysis Information

Were any of the analyses reported in Item VII performed by a contract laboratory or consulting firm?

☑ Yes *(list the name, address, and telephone number of, and pollutants analyzed by, each such laboratory or firm below)* ☐ No *(go to Section X)*

A. Name	B. Address	C. Area Code & Phone No.	D. Pollutants Analyzed
Energy Labs	3161 E Lyndale Ave, Helena, MT 59601	877-472-0711	All

X. Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

A. Name & Official Title *(Type Or Print)* Jerry Zieg, Vice President of Exploration	B. Area Code and Phone No. (406) 547-3466
C. Signature Jerry Zieg	D. Date Signed 12/8/2017

EPA ID Number (*copy from Item 1 of Form 1*)

Form Approved. OMB No. 2040-0086
Approval expires 5-31-92

VII. Discharge information *(Continued from page 3 of Form 2F)*

Part A – You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.

Pollutant and CAS Number *(if available)*	Maximum Values *(include units)*		Average Values *(include units)*		Number of Storm Events Sampled	Sources of Pollutants
	Grab Sample Taken During First 20 Minutes	Flow-Weighted Composite	Grab Sample Taken During First 20 Minutes	Flow-Weighted Composite		
Oil and Grease		N/A				Sample Not Analyzed for parameter
Biological Oxygen Demand (BOD5)						"
Chemical Oxygen Demand (COD)						"
Total Suspended Solids (TSS)						"
Total Nitrogen	0.59 mg/L		0.59 mg/L			Estimated Storm Water Quality
Total Phosphorus	0.06 mg/L		0.06 mg/L		1.00	See Table 4-1. & Narrative
pH	Minimum 7.60	Maximum 7.60	Minimum 7.60	Maximum 7.60	1.00	

Part B – List each pollutant that is limited in an effluent guideline which the facility is subject to or any pollutant listed in the facility's NPDES permit for its process wastewater (if the facility is operating under an existing NPDES permit). Complete one table for each outfall. See the instructions for additional details and requirements.

Pollutant and CAS Number *(if available)*	Maximum Values *(include units)*		Average Values *(include units)*		Number of Storm Events Sampled	Sources of Pollutants
	Grab Sample Taken During First 20 Minutes	Flow-Weighted Composite	Grab Sample Taken During First 20 Minutes	Flow-Weighted Composite		
Cu TRC	<0.002 mg/L		<0.002 mg/L		1.00	Estimated Storm Water Quality
Zn TRC	<0.002 mg/L		<0.002 mg/L		1.00	See Table 4-1. & Narrative
Pb TRC	<0.0003 mg/L		<0.0003 mg/		1.00	
Hg TRC	<0.000005 mg/L		<0.000005 m		1.00	
Cd TRC	<0.00003 mg/L		<0.00003 mg		1.00	

Continued from the Front

Part C - List each pollutant shown in Table 2F-2, 2F-3, and 2F-4 that you know or have reason to believe is present. See the instructions for additional details and requirements. Complete one table for each outfall.

Pollutant and CAS Number *(if available)*	Maximum Values *(include units)*		Average Values *(include units)*		Number of Storm Events Sampled	Sources of Pollutants
	Grab Sample Taken During First 20 Minutes	Flow-Weighted Composite	Grab Sample Taken During First 20 Minutes	Flow-Weighted Composite		
Fecal Coli					0.00	Not Human Caused
Fluoride	0.04 mg/L		0.04 mg/L		1.00	Estimated Storm Water Quality
NO2+NO3	0.19 mg/L		0.19 mg/L		1.00	See Table 4-1. & Narrative
P (Tot)	0.06 mg/L		0.06 mg/L		1.00	
Sulfate	8.3 mg/L		8.3 mg/L		1.00	
Al (DIS)	0.069 mg/L		0.069 mg/L		1.00	
Ba (TRC)	0.070 mg/L		0.070 mg/L		1.00	
Fe (TRC)	0.62 mg/L		0.62 mg/L		1.00	
Mg (DIS)	11.1 mg/L		11.1 mg/L		1.00	
Mn (TRC)	0.007 mg/L		0.007 mg/L		1.00	
Sr (TRC)	0.065 mg/L		0.065 mg/L		1.00	

Part D – Provide data for the storm event(s) which resulted in the maximum values for the flow weighted composite sample.

1. Date of Storm Event	2. Duration of Storm Event *(in minutes)*	3. Total rainfall during storm event *(in inches)*	4. Number of hours between beginning of storm measured and end of previous measurable rain event	5. Maximum flow rate during rain event *(gallons/minute or specify units)*	6. Total flow from rain event *(gallons or specify units)*
		Not Applicable			

7. Provide a description of the method of flow measurement or estimate.

Flow rates were calculated using SEDCAD4 as described in Section 4.2 of the accompanying narrative discussion.

APPENDIX B

WATER TREATMENT MODELING

APPENDIX V: Water Treatment Modeling

Technical Memo

Date: May 2, 2017

To: Tintina Resources, Inc.

From Bob Kimball, Amec Foster Wheeler

Subject: Water Treatment Plant Modeling for Black Butte Copper Project

This appendix provides a summary of the mass balance modeling results for the water treatment system for the Black Butte Copper Project. This includes:

Appendix V-1. Site Wide Mass Balance: Amec Foster Wheeler used an iterative spreadsheet-based model to conduct a site-wide material balance around the entire mine water circuit. Figure V-1 shows the flow diagram for the water circuit and Table V-1 shows a summary of the flows and chemistry of each stream in the circuit. The numbers on the figure refer to the stream numbers in the Table V-1. Using all known inputs of flow and water chemistry, the model predicts the flow and water quality resulting from specific unit operations and treatment steps, such as mixing of different streams, pH adjustment and water treatment. Recycle streams are also included, which causes the model to be iterative. The model uses chemical equilibrium equations and constants to complete water chemistry calculations for each stream in the model. A key requirement for accurately estimating the resultant water chemistry is to begin with a complete and electrically balanced feed water. Minor adjustments to balance the water were made by adding calcium or sulfate ions when necessary to complete the charge balance of the water. The calculations utilize appropriate activity coefficients, pK values, ionization fractions, solubility constants, and appropriate temperature corrections. All calculations are made using a Microsoft® EXCEL-based spreadsheet.

The mass balance around the PWP was then checked using the PHREEQC (pH-REdox- EQuilibrium-C {computer language}) model and found to be very similar with only minor differences. The differences are largely the result of the iterative nature of the calculations. PHREEQC (Parkhurst and Appelo, 1999) is a thermodynamic equilibrium program designed to model chemical speciation in aqueous solutions, determine the saturation states of solutions with minerals and gases, and predict the results of various reactions, such as dissolution of minerals and oxidation.

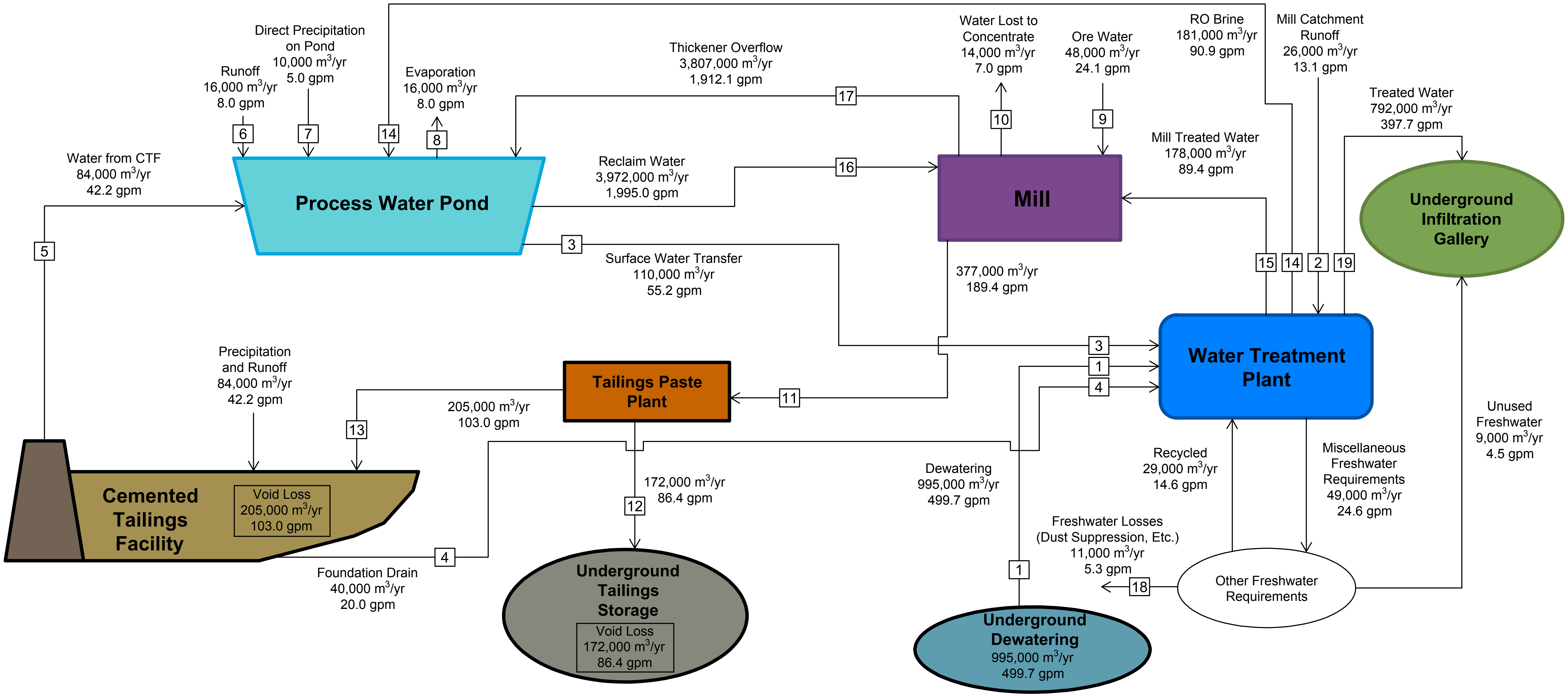
Appendix V-2. Water Treatment Plant Mass Balance: Amec Foster Wheeler used the same iterative spreadsheet-based model described above to prepare a detailed mass balance model for the water treatment plant. Figure V-2 shows the flow diagram for the water treatment process and Table V-2 shows a summary of the flows and chemistry of each stream in the water treatment system. Please note that the numbers on the figure refer to the stream numbers in the Table V-2.

Appendix V-3. RO and Antiscalant Vendor Software Projections: Using the feed water chemistry to the RO system from Table V-2, RO vendor software from Dow Process and Water Solutions was used to evaluate and model the full-scale design of a two-pass RO system. This was conducted for a single skid at both 10 Deg C and 25 Deg C to calculated the anticipated operating pressures, fluxes, brine water quality and effluent water quality produced by the RO system. The selected membrane and overall configuration was selected and optimized to achieve all discharge limits, especially for total nitrogen. In addition, vendor software from Avista Chemical was used to evaluate various antiscalants for use in the RO system to minimize/prevent membrane scaling. The software uses the feed water chemistry and RO configuration to predict the type of dosage of antiscalant required to ensure that sparingly soluble salts do not exceed their solubility limits. This analysis was conducted at the two operating temperatures. The results of this analysis show that a small dose of Vitec 3000 will prevent salts from precipitating in the membrane system.

Appendix V-4. VSEP Vendor Software Projections: VSEP software was used to perform a similar evaluation on RO concentrate. The results of vendor software in this section shows the design configuration, operating pressure, and water quality of the final brine concentrate and treated effluent.

APPENDIX V-1

Overall Site Material Balance



Estimated Groundwater Consumptive Use Components

Water Use	Consumptive Use		
	m^3/yr	gpm	acre*ft/year
PWP Evaporation	16,000	8	13
CTF Void Loss	205,000	103	166
Underground Tailings Void Loss	172,000	86	139
Water Loss to Concentrate	14,000	7	11
Freshwater Losses	11,000	6	9
Total Consumptive Use	**418,000**	**210**	**339**

NOTES:

1. ALL WATER VOLUMES ARE EXPRESSED IN UNITS OF CUBIC METRES PER YEAR AND GPM EQUIVALENTS.
2. WATER IN TAILINGS PASTE IS ASSUMED TO BE UNRECOVERABLE.
3. SEEPAGE IS ASSUMED TO BE ZERO AS THE FACILITIES ARE LINED.
4. THE NUMBERS IN THE BOXES CORRESPOND TO TABLE V-1 in APPENDIX V-1.

Reference: Modified after Knight Piesold (2017): Report No. VA101-46-/3-2

Prepared by Tetra Tech Inc. (March 2017)

FIGURE V-1

Annual Water Balance Schematic for Mean Case - Year 6

Black Butte Copper Project

Meagher County, Montana

TINTINA RESOURCES

Table V-1
Site Wide Mass Balance

Stream ID (See Figure V-1)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Description	**Underground Dewatering**	**Mill Catchment Runoff**	**Surface Water Transfer**	**CTF Foundation Drain**	**Water From CTF to PWP**	**Runoff to PWP**	**Direct Precip**	**PWP Evap**	**Ore Water to Mill**	**Water Loss to Conc**	**Cement/ Paste Void Loss**	**Under-ground Tailings Storage**	**Cement Tailings**	**RO Brine Conc.**	**Mill Treated Water**	**Reclaim Water to Mill**	**Mill Thickener OF to PWP**	**Dust Supression**	**Treated Water Discharge (combined)**
Flow, gpm	**499.7**	**13.1**	**55.2**	**20.0**	**42.2**	**8.0**	**5.0**	**7.0**	**24.1**	**7.0**	**189.4**	**86.4**	**103.0**	**90.8**	**89.4**	**1,995.8**	**1,912.9**	**5.3**	**402.3**
lb/min	4,170.78	109.33	461.3	166.8	352.4	66.7	41.7	58.5	201.2	58.5	1,582.5	1,582.5	1,582.5	761.4	746.3	16,678.6	15,982.9	44.2	3,355.5
Specific Gravity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.01	1.00	1.00	1.00	1.00	1.00
Temperature, Deg C	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.0	25.0	25.00	25.00	25.00	25.00	25.00	25.00
Commons																			
pH	6.7	7.1	6.0	7.4	4.1	7.0	7.0	6.0	6.7	10.4	10.4	10.4	10.4	6.7	8.4	6.0	10.4	5.9	8.1
Total Alkalinity	183.0	218.0	120.7	212.0	97.0	25.0	-	120.7	183.0	76.7	76.7	76.7	76.7	1,066.7	252.9	120.7	76.7	0.20	100.23
Nitrogen, Ammonia	4.40	-	11.40	-	-	-	-	11.40	4.40	11.04	11.04	11.04	11.04	25.83	4.81	11.40	11.04	0.10	0.10
Nitrogen, Nitrate	33.0	0.0	86.8	0.2	-	-	-	86.8	33.0	84.0	84.0	84.0	84.0	197.6	36.2	86.8	84.0	0.22	0.22
Silica	1.55	-	0.38	-	2.45	-	-	0.38	1.55	-	-	-	-	7.39	1.35	0.38	<0.001	<0.001	<0.001
Phosphorus	0.00	-	0.06	-	0.26	-	-	0.06	0.00	0.06	0.06	0.06	0.06	0.04	0.0	0.1	0.1	0.00	0.00
Anions																			
Bicarbonate	223	266	147	258	118	30	-	147	223	4	3.6	3.6	3.6	1,299.1	293	147	4	0	120
Carbonate	0.08	0.22	0.01	0.41	0.00	0.02	-	0.01	0.08	8.44	8.44	8.44	8.44	0.85	5.9	0.0	8.4	0.00	0.87
Chloride	1.38	1.28	135.59	-	34.30	-	-	135.59	1.38	129.15	129.15	129.15	129.15	337.43	20	136	129	0.01	0.01
Fluoride	1.14	0.70	0.52	0.10	0.66	-	-	0.52	1.14	0.28	0.3	0.3	0.3	5.7	1.0	0.5	0.3	<0.001	<0.001
Nitrate	146	0.09	384.2	0.66	-	-	-	384.2	146.1	372.0	372.00	372.00	372.00	875.17	160.3	384.2	372.0	0.98	0.98
Sulfate	304	265	904	12	765	5	-	904	304	865	864.90	864.90	864.90	1,917.88	350	904	865	<0.001	<0.001
Cations																			
Calcium	89	85	521	59	132	-	-	521	89	516	515.58	515.58	515.58	887.48	162	521	516	0.08	40.18
Magnesium	79	55	19	18	92	-	-	19	79	0.01	0.01	0.01	0.01	389.19	71	19	0.01	0.04	0.04
Potassium	11	3	29	-	-	-	-	29	11	28	28.17	28.17	28.17	66.29	12	29	28	0.08	0.08
Sodium	15	16	43	2	13	14	-	43	15	42	41.89	41.89	41.89	92.84	17	43	42	0.08	0.08
Ammonium	5.64	-	14.65	-	-	-	-	14.65	5.64	0.87	0.87	0.87	0.87	33.10	5.38	14.65	0.87	0.13	0.13
Aluminum	0.012	-	0.374	-	17.700	-	-	0.374	0.012	0.001	0.001	0.001	0.001	0.249	0.045	0.374	0.001	<0.001	<0.001
Arsenic	0.004	0.067	0.045	-	0.031	-	-	0.045	0.004	0.045	0.045	0.045	0.045	0.050	0.009	0.045	0.045	<0.001	<0.001
Barium	0.001	0.011	0.004	0.050	0.004	-	-	0.004	0.001	0.003	0.003	0.003	0.003	0.018	0.003	0.004	0.003	<0.001	<0.001
Cadmium	-	-	0.000	-	0.001	-	-	0.000	-	-	-	-	-	0.000	0.000	0.000	-	<0.001	<0.001
Chromium	-	-	0.004	-	0.012	-	-	0.004	-	0.004	0.004	0.004	0.004	0.002	0.000	0.004	0.004	<0.001	<0.001
Copper	-	-	4.003	-	61.300	-	-	4.003	-	2.930	2.930	2.930	2.930	0.549	0.100	4.003	2.930	<0.001	<0.001
Iron (+2)	0.002	1.130	0.000	-	-	-	-	0.000	0.002	-	-	-	-	0.005	0.001	0.000	-	<0.001	<0.001
Iron (+3)	-	-	0.014	-	0.636	-	-	0.014	-	-	-	-	-	0.027	0.005	0.014	-	<0.001	<0.001
Lead	-	-	0.092	-	0.027	-	-	0.092	-	0.096	0.096	0.096	0.096	0.048	0.009	0.092	0.096	<0.001	<0.001
Manganese	0.165	0.025	0.093	-	2.730	-	-	0.093	0.165	0.001	0.001	0.001	0.001	0.820	0.150	0.093	0.001	<0.001	<0.001
Nickel	0.007	0.001	0.195	-	8.500	-	-	0.195	0.007	0.016	0.016	0.016	0.016	0.133	0.024	0.195	0.016	<0.001	<0.001
Strontium	10.500	14.500	4.247	0.140	2.620	-	-	4.247	10.500	2.000	2.000	2.000	2.000	52.905	9.650	4.247	2.000	0.010	0.010
Zinc	0.030	0.010	0.259	-	0.826	-	-	0.259	0.030	0.248	0.248	0.248	0.248	0.275	0.050	0.259	0.248	<0.001	<0.001
Gases																			
Ammonia	0	-	0.01	-	-	-	-	0.01	0.01	12.59	12.59	12.6	12.6	0.11	0.76	0.01	12.59	0.00	0.01
Carbon Dioxide	60	30	170	14	10,421	5	-	170	60	0	0	0.0	0.0	247	1	170	0	1	1
Other												-	-						
TSS	150	10	7	26	150	150	-	7	-	4	4	4.0	4.0	1	0	7	4	<0.001	<0.001
TDS (sum of ions)	889	708	2,209	350	1,258	49	-	2,209	889	1,979	1,979	1,978.7	1,978.7	5,973	1,110	2,209	1,979	1.7	163
TDS (180 Deg C)	777	575	2,136	221	1,199	34	-	2,136	777	1,977	1,977	1,976.9	1,976.9	5,323	963	2,136	1,977	1.6	103
Total Hardness, mg/L CaCO3	560.3	458.6	1,382.5	220.7	715.7	-	-	1,382.5	560.3	1,288.1	1,288.1	1,288.1	1,288.1	3,876.7	706.8	1,382.5	1,288.1	0.4	100.4
Scaling Indicies																			
Langelier Saturation Index	(0.7)	(0.2)	(0.9)	0.0	(3.4)	-	-	(0.9)	(0.7)	1.9	1.9	1.9	1.9	0.9	1.4	(0.9)	1.9	(7.1)	0.3

All values in mg/L, unless noted othewise

APPENDIX V-2

Water Treatment Plant Material Balance (Operational Phase)

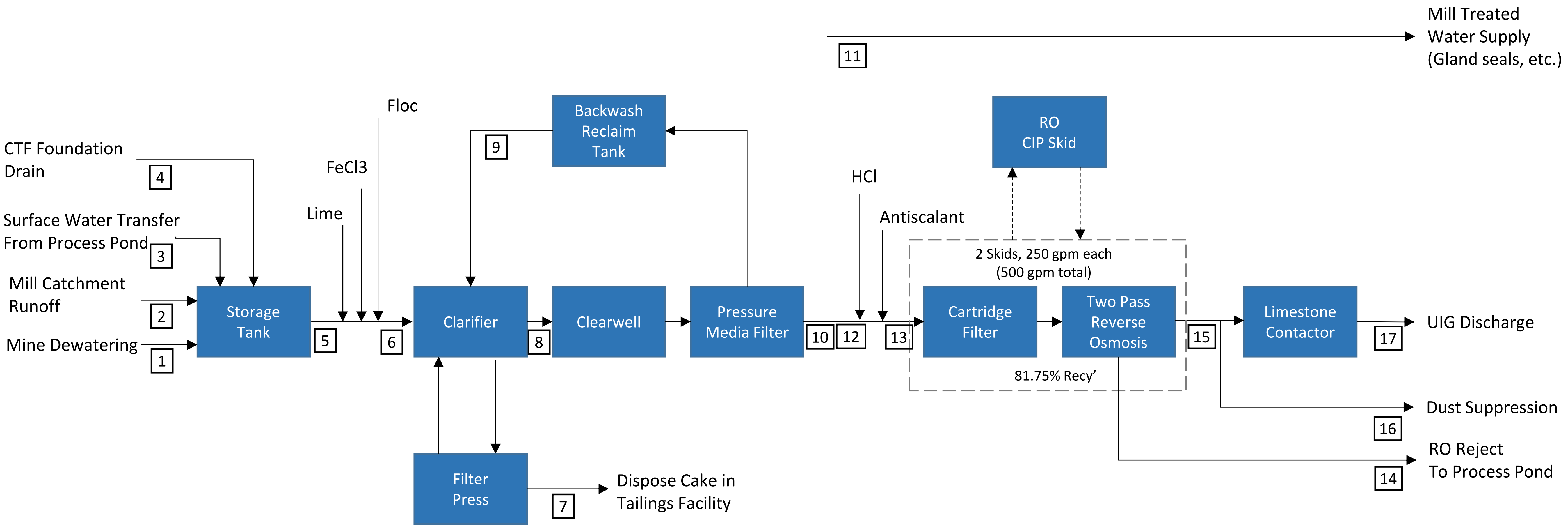


Figure V-2
Water Treatment Operational Phase Flow Diagram
Black Butte Copper Project
Meagher County, Montana

Table V-2
Water Treatment Plant Mass Balance

Stream ID (See Figure V-2)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Description	Underground Dewatering	Mill Catchment Runoff	Surface Water Transfer	CTF Foundation Drain	Combined WTP Feed	Clarifier Feed	Filter Press Cake	Clarifier Overflow	Sand Filter Backwash	Sand Filter Effluent	Mill Treated Water	Filtered Effluent to RO	RO Feed Water	RO Brine Conc.	Treated Effluent (RO Perm)	Dust Supression	Treated Water Discharge (combined)
Flow, gpm	**499.7**	**13.1**	**55.2**	**20.0**	**588.0**	**588.0**	**0.15**	**587.7**	**21.8**	**587.7**	**89.4**	**498.3**	**498.4**	**90.8**	**407.4**	**5.3**	**402.3**
lb/min	4,170.78	109.33	461.3	166.8	4,908.2	4,908.7	1.5	4,906.5	182.2	4,906.5	746.3	4,160.1	4,160.6	761.4	3,398.0	44.2	3,355.5
Specific Gravity	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00
Temperature, Deg C	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Commons																	
pH	6.7	7.1	6.0	7.4	6.6	8.4	8.4	8.4	8.4	8.4	8.4	8.4	6.8	6.7	5.9	5.9	8.1
Total Alkalinity	183.0	218.0	120.7	212.0	178.9	262.1	252.9	252.9	252.9	252.9	252.9	252.9	194.6	1,066.7	0.2	0.2	100.2
Nitrogen, Ammonia	4.40	-	11.40	-	4.81	4.81	4.81	4.81	4.81	4.81	4.81	4.81	4.81	25.83	0.12	0.10	0.10
Nitrogen, Nitrate	33.0	0.0	86.8	0.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2	197.6	0.22	0.22	0.22
Silica	1.55	-	0.38	-	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	7.39	<0.001	<0.001	<0.001
Phosphorus	0.00	-	0.06	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	<0.001	0.00	0.00
Anions																	
Bicarbonate	223	266	147	258	218	304	293	293	293	293	293	293	237	1,299	1.2	0.3	120.4
Carbonate	0.08	0.22	0.01	0.41	0.07	6.09	5.87	5.87	5.87	5.87	5.87	5.87	0.12	0.85	0.00	0.00	0.87
Chloride	1.38	1.28	135.59	-	13.93	20.49	20.49	20.49	20.16	20.16	20.16	20.16	61.49	337.43	0.01	0.01	0.01
Fluoride	1.14	0.70	0.52	0.10	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	5.69	<0.001	<0.001	<0.001
Nitrate	146	0.09	384.2	0.66	160.3	160.3	160.3	160.3	160.3	160.3	160.3	160.3	160.3	875.2	0.98	0.98	0.98
Sulfate	304	265	904	12	350	350	350	350	350	350	350	350	349	1,918	-	-	-
Cations																	
Calcium	89	85	521	59	128	162	162	162	162	162	162	162	162	887	0.08	0.08	40.18
Magnesium	79	55	19	18	71	71	71	71	71	71	71	71	71	389	0.04	0.04	0.04
Potassium	11	3	29	-	12	12	12	12	12	12	12	12	12	66	0.08	0.08	0.08
Sodium	15	16	43	2.0	17	17	17	17	17	17	17	17	17	93	0.08	0.08	0.08
Ammonium	5.64	-	14.65	-	6.17	5.38	5.38	5.38	5.38	5.38	5.38	5.38	6.16	33.10	0.13	0.13	0.13
Aluminum	0.012	-	0.374	-	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.249	<0.001	<0.001	<0.001
Arsenic	0.004	0.067	0.045	-	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.050	<0.001	<0.001	<0.001
Barium	0.001	0.011	0.004	0.050	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.018	<0.001	<0.001	<0.001
Cadmium	-	-	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	<0.001	<0.001	<0.001
Chromium	-	-	0.004	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	<0.001	<0.001	<0.001
Copper	-	-	4.003	-	0.376	0.376	1,090	0.100	0.100	0.100	0.100	0.100	0.100	0.549	<0.001	<0.001	<0.001
Iron (+2)	0.002	1.130	0.000	-	0.027	0.027	101	0.001	0.001	0.001	0.001	0.001	0.001	0.005	<0.001	<0.001	<0.001
Iron (+3)	-	-	0.014	-	0.001	3.438	13,567	0.005	0.005	0.005	0.005	0.005	0.005	0.027	<0.001	<0.001	<0.001
Lead	-	-	0.092	-	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.048	<0.001	<0.001	<0.001
Manganese	0.165	0.025	0.093	-	0.149	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.149	0.820	<0.001	<0.001	<0.001
Nickel	0.007	0.001	0.195	-	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.133	<0.001	<0.001	<0.001
Strontium	10.500	14.500	4.247	0.140	9.650	9.650	9.650	9.650	9.650	9.650	9.650	9.650	9.649	52.905	0.010	0.010	0.010
Zinc	0.030	0.010	0.259	-	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.275	<0.001	<0.001	<0.001
Gases																	
Ammonia	0	-	0.01	-	0.01	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.02	0.11	0.00	0.00	0.01
Carbon Dioxide	60	30	170	14	68	1	1	1	1	1	1	1	46	247	1	1	1
Other																	
TSS	150	10	7	26	129	129	477,899	15	400	0.1	0.1	0.1	0.0	0.8	<0.001	<0.001	<0.001
TDS (sum of ions)	889	708	2,209	350	990	1,127	1,110	1,110	1,110	1,110	1,110	1,110	1,090	5,973	2.6	1.7	163
TDS (180 Deg C)	777	575	2,136	221	881	975	964	964	963	963	963	963	971	5,323	2.0	1.6	103
Total Hardness, mg/L CaCO3	560.3	458.6	1,382.5	220.7	623.6	706.9	706.8	706.8	706.8	706.8	706.8	706.8	706.7	3,876.7	0.4	0.4	100.4
Scaling Indicies																	
Langelier Saturation Index	(0.7)	(0.2)	(0.9)	0.0	(0.6)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	(0.3)	0.9	(7.1)	(7.1)	0.3

All values in mg/L, unless noted othewise

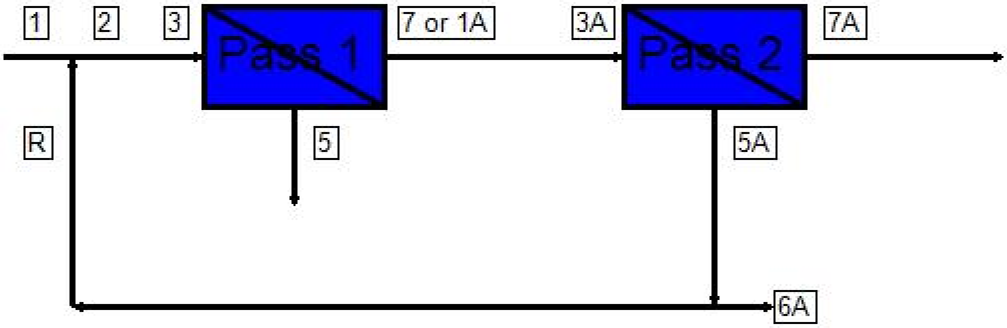
APPENDIX V-3

Reverse Osmosis and Antiscalant Model Outputs (Operational Phase)

Project: Tintina Reject to Pond rev22
Prepared By:

ROSA 9.1 ConfigDB u399339_282
Case: 1
9/15/2015

System Design Overview



Raw Water TDS	1088.19 mg/l	% System Recovery (7A/1)	81.84 %
Water Classification	Surface Supply SDI < 5	Flow Factor (Pass 1)	0.85
Feed Temperature	25.0 C	Flow Factor (Pass 2)	0.85

Pass #	**Pass 1**			**Pass 2**	
Stage #	**1**	**2**	**3**	**1**	**2**
Element Type	ECO-440i	ECO-440i	ECO-440i	ECO-440i	ECO-440i
Pressure Vessels per Stage	5	3	1	4	2
Elements per Pressure Vessel	6	6	6	6	6
Total Number of Elements	30	18	6	24	12
Pass Average Flux	14.70 gfd			18.57 gfd	
Stage Average Flux	15.53 gfd	14.49 gfd	11.14 gfd	19.52 gfd	16.67 gfd
Permeate Back Pressure	50.00 psig	30.00 psig	15.00 psig	15.00 psig	15.00 psig
Booster Pressure	0.00 psig	0.00 psig	0.00 psig	0.00 psig	0.00 psig
Chemical Dose	-			-	
Energy Consumption	1.54 kWh/kgal			1.12 kWh/kgal	

Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED,AND NO WARRANTY OF MERCHANTABILITY OR FITNESS, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume liability for results obtained or damages incurred from the application of this information. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

Project: Tintina Reject to Pond rev22
Prepared By:

ROSA 9.1 ConfigDB u399339_282
Case: 1
9/15/2015

Pass 1				**Pass 2**			
Stream #	**Flow (gpm)**	**Pressure (psig)**	**TDS (mg/l)**	**Stream #**	**Flow (gpm)**	**Pressure (psig)**	**TDS (mg/l)**
1	249.62	0.00	1088.19	1A	242.49	-	16.36
2	287.81	0.00	0.00	3A	242.49	119.20	16.36
3	287.81	143.38	958.67	5A	38.19	86.45	94.36
5	44.58	88.18	6079.27	6A	1.60	0.00	0.00
7	242.49	-	16.36	7A	204.29	-	2.56
7/2	**% Recovery**	84.25		R	37.32	0.00	0.00
				7A/1A	**% Recovery**	84.25	

Project Information:
Tintina Black Cloud WTP

Design Warnings:
-- Pass 1
-None-
-- Pass 2
-None-

Solubility Warnings:
-- Pass 1
Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
$CaSO_4$ (% Saturation) > 100%
$SrSO_4$ (% Saturation) > 100%
CaF_2 (% Saturation) > 100%
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.
-- Pass 2
-None-

Reverse Osmosis System Analysis for FILMTEC™ Membranes	ROSA 9.1 ConfigDB u399339_282
Project: Tintina Reject to Pond rev22	Case: 1
,	9/15/2015

Project Information: Tintina Black Cloud WTP

Case-specific: Temp = 25 C 50% Capacity x 2 81.75% Recovery Reject to Paste Plant

System Details -- Pass 1

Feed Flow to Stage 1	287.81 gpm	Pass 1 Permeate Flow	242.49 gpm	Osmotic Pressure:	
Raw Water Flow to System	249.62 gpm	Pass 1 Recovery	84.25 %	Feed	0.00 psig
Feed Pressure	143.38 psig	Feed Temperature	25.0 C	Concentrate	32.15 psig
Flow Factor	0.85	Feed TDS	0.00 mg/l	Average	16.08 psig
Chem. Dose	None	Number of Elements	54	Average NDP	109.37 psig
Total Active Area	23760.00 ft^2	Average Pass 1 Flux	14.70 gfd	Power	22.38 kW
Water Classification: Surface Supply SDI < 5				Specific Energy	1.54 kWh/kgal
System Recovery	81.84 %			Conc. Flow from Pass 2	38.19 gpm

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	ECO-440i	5	6	287.81	138.38	0.00	144.71	125.40	142.36	15.53	50.00	0.00	7.60
2	ECO-440i	3	6	144.71	120.40	0.00	65.00	110.52	79.71	14.49	30.00	0.00	21.61
3	ECO-440i	1	6	65.00	105.52	0.00	44.58	88.18	20.42	11.14	15.00	0.00	58.38

Pass Streams
(mg/l as Ion)

Name	Feed	Adjusted Feed		Concentrate			Permeate			
		Initial	After Recycles	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Total
NH4+ + NH3	6.13	6.15	5.65	11.04	23.82	33.97	0.22	0.61	1.65	0.47
K	12.00	12.00	10.85	21.29	46.47	66.81	0.24	0.75	2.09	0.56
Na	17.00	17.00	15.31	30.07	65.80	94.78	0.30	0.93	2.53	0.70
Mg	71.00	71.00	62.28	123.26	273.29	397.34	0.29	0.91	2.49	0.68
Ca	162.00	162.00	142.08	281.21	623.55	906.62	0.65	2.04	5.61	1.52
Sr	9.65	9.65	8.46	16.75	37.14	54.00	0.04	0.12	0.33	0.09
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.16	0.16	0.12	0.56	3.46	8.16	0.00	0.00	0.00	0.00
HCO3	237.00	237.00	208.69	412.09	908.07	1312.76	2.04	4.34	10.98	3.43
NO3	160.10	160.10	144.59	283.75	619.85	891.63	3.13	9.67	26.56	7.25
Cl	61.00	61.00	53.39	105.74	234.71	341.49	0.18	0.57	1.61	0.43
F	1.00	1.00	0.88	1.74	3.85	5.60	0.00	0.01	0.04	0.01
SO4	349.75	349.75	305.15	604.83	1344.46	1958.29	0.52	1.66	4.49	1.23
SiO2	1.40	1.40	1.22	2.42	5.38	7.84	0.00	0.01	0.02	0.01
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	43.33	43.33	43.36	43.56	44.85	46.86	42.85	43.56	45.34	43.38
TDS	1088.19	1088.21	958.67	1894.74	4189.83	6079.27	7.60	21.61	58.38	16.36
pH	6.80	6.80	6.75	7.00	7.27	7.37	4.89	5.20	5.57	5.10

*Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED, AND NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume any obligation or liability for results obtained or damages incurred from the application of this information. Because use conditions and applicable laws may differ from one location to another and may change with time, customer is responsible for determining whether products are appropriate for customer's use. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

Reverse Osmosis System Analysis for FILMTEC™ Membranes
Project: Tintina Reject to Pond rev22
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ROSA 9.1 ConfigDB u399339_282
Case: 1
9/15/2015

Design Warnings -- Pass 1

-None-

Solubility Warnings -- Pass 1

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
CaSO4 (% Saturation) > 100%
SrSO4 (% Saturation) > 100%
CaF2 (% Saturation) > 100%
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details -- Pass 1

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	5.21	5.03	57.41	958.67	138.38
2	0.10	5.00	5.78	52.20	1053.95	135.45
3	0.10	4.81	6.71	47.20	1165.00	132.86
4	0.11	4.64	7.91	42.40	1296.35	130.57
5	0.12	4.48	9.48	37.76	1454.57	128.58
6	0.13	4.34	11.60	33.28	1649.21	126.86

Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.11	5.13	11.78	48.24	1894.74	120.40
2	0.11	4.87	14.40	43.11	2118.80	118.06
3	0.12	4.60	17.93	38.23	2386.87	116.03
4	0.13	4.31	22.82	33.63	2710.93	114.28
5	0.14	4.00	29.71	29.32	3106.24	112.80
6	0.14	3.65	39.68	25.32	3591.85	111.55

Stage 3 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.06	4.11	39.60	65.00	4189.83	105.52
2	0.06	3.80	46.31	60.89	4469.75	102.04
3	0.06	3.52	54.14	57.08	4764.20	98.82
4	0.06	3.25	63.24	53.57	5072.92	95.85
5	0.06	2.99	73.82	50.32	5395.53	93.10
6	0.06	2.75	86.06	47.33	5731.27	90.55

Reverse Osmosis System Analysis for FILMTEC™ Membranes ROSA 9.1 ConfigDB u399339_282
Project: Tintina Reject to Pond rev22 Case: 1
, 9/15/2015

Project Information: Tintina Black Cloud WTP

Case-specific: Temp = 25 C 50% Capacity x 2 81.75% Recovery Reject to Paste Plant

System Details -- Pass 2

Feed Flow to Stage 1	242.49	gpm	Pass 2 Permeate Flow	204.29	gpm	Osmotic Pressure:		
Raw Water Flow to System	249.62	gpm	Pass 2 Recovery	84.25	%	Feed	0.12	psig
Feed Pressure	119.20	psig	Feed Temperature	25.0	C	Concentrate	0.00	psig
Flow Factor	0.85		Feed TDS	16.36	mg/l	Average	0.06	psig
Chem. Dose	None		Number of Elements	36		Average NDP	102.01	psig
Total Active Area	15840.00	ft²	Average Pass 2 Flux	18.57	gfd	Power	13.74	kW
Water Classification: RO Permeate SDI < 1						Specific Energy	1.12	kWh/kgal
System Recovery	81.84	%						

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	ECO-440i	4	6	242.49	114.20	0.00	99.31	101.27	143.17	19.52	15.00	0.00	2.28
2	ECO-440i	2	6	99.31	96.27	0.00	38.19	86.45	61.12	16.67	15.00	0.00	3.20

Pass Streams
(mg/l as Ion)

Name	Feed	Adjusted Feed		Concentrate		Permeate		
		Initial	After Recycles	Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4+ + NH3	0.47	0.45	0.45	0.98	2.29	0.11	0.17	0.13
K	0.56	0.56	0.56	1.28	3.16	0.07	0.11	0.08
Na	0.70	0.70	0.70	1.61	4.01	0.07	0.12	0.08
Mg	0.68	0.68	0.68	1.62	4.12	0.03	0.05	0.04
Ca	1.52	1.52	1.52	3.62	9.23	0.07	0.11	0.08
Sr	0.09	0.09	0.09	0.22	0.55	0.00	0.01	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	3.43	3.43	3.43	7.77	19.66	1.13	1.27	1.17
NO3	7.25	7.25	7.25	16.52	40.77	0.82	1.37	0.98
Cl	0.43	0.43	0.43	1.04	2.68	0.01	0.01	0.01
F	0.01	0.01	0.01	0.03	0.07	0.00	0.00	0.00
SO4	1.23	1.23	1.23	3.01	7.82	0.00	0.00	0.00
SiO2	0.01	0.01	0.01	0.01	0.04	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	43.38	43.38	43.38	43.57	43.67	42.74	42.84	42.77
TDS	16.36	16.36	16.36	37.69	94.36	2.28	3.20	2.56
pH	5.10	5.10	5.10	5.44	5.82	4.65	4.70	4.66

*Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED, AND NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume any obligation or liability for results obtained or damages incurred from the application of this information. Because use conditions and applicable laws may differ from one location to another and may change with time, customer is responsible for determining whether products are appropriate for customer's use. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

Reverse Osmosis System Analysis for FILMTEC™ Membranes
Project: Tintina Reject to Pond rev22
,

ROSA 9.1 ConfigDB u399339_282
Case: 1
9/15/2015

Design Warnings -- Pass 2

-None-

Solubility Warnings -- Pass 2

-None-

Stage Details -- Pass 2

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.10	6.25	1.96	60.62	16.36	114.20
2	0.11	6.08	2.07	54.37	18.09	111.10
3	0.12	5.95	2.19	48.30	20.18	108.40
4	0.14	5.87	2.33	42.34	22.81	106.09
5	0.16	5.82	2.49	36.48	26.22	104.14
6	0.19	5.83	2.68	30.65	30.88	102.54

Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.11	5.47	2.78	49.66	37.69	96.27
2	0.12	5.32	2.93	44.18	42.12	93.86
3	0.13	5.17	3.09	38.87	47.61	91.78
4	0.15	5.02	3.28	33.70	54.57	90.02
5	0.17	4.87	3.49	28.68	63.71	88.55
6	0.20	4.72	3.74	23.81	76.21	87.37

Scaling Calculations

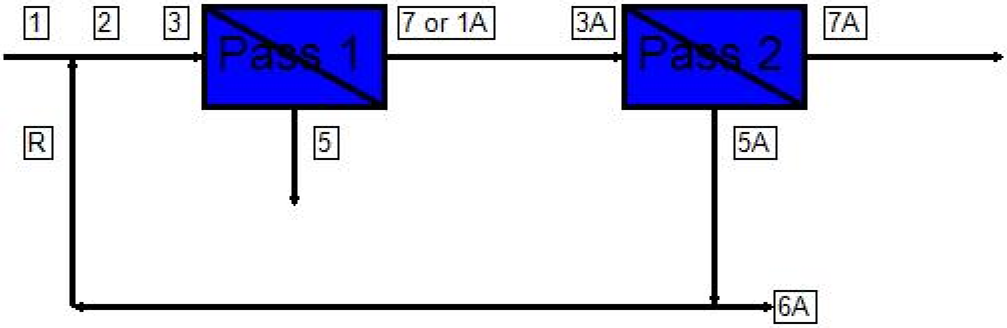
	Raw Water	Pass 1 Adjusted Feed	Pass 1 Concentrate	Pass 2 Concentrate
pH	6.80	6.80	7.37	0.00
Langelier Saturation Index	-0.23	-0.23	1.78	0.00
Stiff & Davis Stability Index	0.03	0.03	1.40	0.00
Ionic Strength (Molal)	0.03	0.03	0.15	0.00
TDS (mg/l)	1088.19	1088.21	6079.27	0.00
HCO3	237.00	237.00	1312.76	0.00
CO2	43.32	43.32	46.85	0.00
CO3	0.16	0.16	8.16	0.00
CaSO4 (% Saturation)	10.71	10.71	116.37	0.00
BaSO4 (% Saturation)	0.00	0.00	0.00	0.00
SrSO4 (% Saturation)	45.48	45.48	289.77	0.00
CaF2 (% Saturation)	21.54	21.54	3775.48	0.00
SiO2 (% Saturation)	1.09	1.09	6.27	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.01	0.00

To balance: 0.00 mg/l Na added to feed.

Project: Tintina Reject to Pond rev3
Prepared By:

ROSA 9.1 ConfigDB u399339_282
Case: 2
5/1/2017

System Design Overview



Raw Water TDS	1088.15 mg/l	% System Recovery (7A/1)	81.85 %
Water Classification	Surface Supply SDI < 5	Flow Factor (Pass 1)	0.85
Feed Temperature	10.0 C	Flow Factor (Pass 2)	0.85

Pass #	**Pass 1**			**Pass 2**	
Stage #	**1**	**2**	**3**	**1**	**2**
Element Type	ECO-440i	ECO-440i	ECO-440i	ECO-440i	ECO-440i
Pressure Vessels per Stage	5	3	1	4	2
Elements per Pressure Vessel	6	6	6	6	6
Total Number of Elements	30	18	6	24	12
Pass Average Flux	14.70 gfd			18.58 gfd	
Stage Average Flux	15.78 gfd	13.91 gfd	11.68 gfd	19.16 gfd	17.40 gfd
Permeate Back Pressure	40.00 psig	30.00 psig	15.00 psig	15.00 psig	15.00 psig
Booster Pressure	0.00 psig	0.00 psig	0.00 psig	0.00 psig	0.00 psig
Chemical Dose	-			-	
Energy Consumption	2.22 kWh/kgal			2.06 kWh/kgal	

Project: Tintina Reject to Pond rev3
Prepared By:

ROSA 9.1 ConfigDB u399339_282
Case: 2
5/1/2017

Pass 1			
Stream #	**Flow (gpm)**	**Pressure (psig)**	**TDS (mg/l)**
1	249.66	0.00	1088.15
2	287.86	0.00	0.00
3	287.86	206.15	949.33
5	45.33	135.84	5991.20
7	242.54	-	6.86
7/2	**% Recovery**	84.26	

Pass 2			
Stream #	**Flow (gpm)**	**Pressure (psig)**	**TDS (mg/l)**
1A	242.54	-	6.86
3A	242.54	206.62	6.86
5A	38.20	165.31	39.89
6A	0.88	0.00	0.00
7A	204.34	-	1.27
R	37.32	0.00	0.00
7A/1A	**% Recovery**	84.25	

Project Information:
Tintina Black Cloud WTP

Design Warnings:
-- Pass 1
-None-
-- Pass 2
-None-

Solubility Warnings:
-- Pass 1
Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
CaSO4 (% Saturation) > 100%
SrSO4 (% Saturation) > 100%
CaF2 (% Saturation) > 100%
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.
-- Pass 2
-None-

Reverse Osmosis System Analysis for FILMTEC™ Membranes ROSA 9.1 ConfigDB u399339_282
Project: Tintina Reject to Pond rev3 Case: 2
, 5/1/2017

Project Information: Tintina Black Cloud WTP

Case-specific: Temp = 10 C 50% Capacity x 2 81.84% Recovery

System Details -- Pass 1

Feed Flow to Stage 1	287.86 gpm	Pass 1 Permeate Flow	242.54 gpm	Osmotic Pressure:	
Raw Water Flow to System	249.66 gpm	Pass 1 Recovery	84.26 %	Feed	0.00 psig
Feed Pressure	206.15 psig	Feed Temperature	10.0 C	Concentrate	30.13 psig
Flow Factor	0.85	Feed TDS	0.00 mg/l	Average	15.06 psig
Chem. Dose (100% H2SO4)	0.00	Number of Elements	54	Average NDP	168.16 psig
Total Active Area	23760.00 ft²	Average Pass 1 Flux	14.70 gfd	Power	32.27 kW
Water Classification: Surface Supply SDI < 5				Specific Energy	2.22 kWh/kgal
System Recovery	81.85 %			Conc. Flow from Pass 2	38.20 gpm

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	ECO-440i	5	6	287.86	201.15	0.00	143.22	183.58	144.64	15.78	40.00	0.00	3.63
2	ECO-440i	3	6	143.22	178.58	0.00	66.74	165.04	76.48	13.91	30.00	0.00	9.05
3	ECO-440i	1	6	66.74	160.04	0.00	45.33	135.84	21.41	11.68	15.00	0.00	21.47

Pass Streams
(mg/l as Ion)

Name	Feed	Adjusted Feed		Concentrate			Permeate			
		Initial	After Recycles	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Total
NH4+ + NH3	6.14	6.15	5.48	10.94	23.20	33.87	0.08	0.24	0.61	0.18
K	12.00	12.00	10.59	21.19	45.14	66.10	0.09	0.29	0.76	0.21
Na	17.00	17.00	14.97	29.98	63.90	93.64	0.12	0.37	0.94	0.27
Mg	71.00	71.00	61.80	124.09	265.88	391.05	0.11	0.36	0.89	0.26
Ca	162.00	162.00	140.99	283.13	606.64	892.25	0.25	0.80	2.00	0.58
Sr	9.65	9.65	8.40	16.86	36.13	53.14	0.01	0.05	0.12	0.03
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.11	0.11	0.08	0.39	2.21	5.38	0.00	0.00	0.00	0.00
HCO3	237.00	237.00	206.91	414.93	885.79	1298.04	1.52	2.27	4.30	1.94
NO3	160.10	160.10	141.20	282.61	602.08	881.94	1.19	3.80	9.65	2.76
Cl	61.00	61.06	53.09	106.65	228.59	336.30	0.07	0.22	0.57	0.16
F	1.00	1.00	0.87	1.75	3.75	5.51	0.00	0.01	0.01	0.00
SO4	349.75	349.75	303.73	610.26	1308.78	1926.27	0.20	0.65	1.61	0.47
SiO2	1.40	1.40	1.22	2.44	5.24	7.71	0.00	0.00	0.01	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	56.23	56.23	56.28	56.43	57.24	58.61	55.58	56.09	57.37	55.93
TDS	1088.15	1088.22	949.33	1905.21	4077.32	5991.20	3.63	9.05	21.47	6.86
pH	6.80	6.80	6.75	7.00	7.26	7.38	4.77	4.93	5.19	4.87

*Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED, AND NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume any obligation or liability for results obtained or damages incurred from the application of this information. Because use conditions and applicable laws may differ from one location to another and may change with time, customer is responsible for determining whether products are appropriate for customer's use. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

Reverse Osmosis System Analysis for FILMTEC™ Membranes
ROSA 9.1 ConfigDB u399339_282
Project: Tintina Reject to Pond rev3
Case: 2
,
5/1/2017

Design Warnings -- Pass 1

-None-

Solubility Warnings -- Pass 1

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
CaSO4 (% Saturation) > 100%
SrSO4 (% Saturation) > 100%
CaF2 (% Saturation) > 100%
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details -- Pass 1

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	5.11	2.70	57.57	949.33	201.15
2	0.09	4.98	2.96	52.46	1041.66	197.19
3	0.10	4.86	3.29	47.48	1150.68	193.66
4	0.11	4.75	3.71	42.62	1281.62	190.56
5	0.12	4.66	4.27	37.87	1442.13	187.85
6	0.14	4.57	5.04	33.21	1643.84	185.53
Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.10	4.63	5.63	47.74	1905.21	178.58
2	0.10	4.49	6.55	43.11	2109.45	175.44
3	0.11	4.34	7.74	38.62	2353.94	172.68
4	0.12	4.19	9.36	34.28	2651.08	170.29
5	0.13	4.02	11.58	30.09	3018.43	168.23
6	0.15	3.83	14.77	26.07	3481.49	166.49
Stage 3 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.06	4.02	15.53	66.74	4077.32	160.04
2	0.06	3.83	17.60	62.72	4337.67	155.18
3	0.06	3.65	19.99	58.89	4618.34	150.68
4	0.06	3.47	22.73	55.25	4921.50	146.52
5	0.06	3.30	25.89	51.78	5249.50	142.67
6	0.06	3.14	29.55	48.47	5605.09	139.12

Reverse Osmosis System Analysis for FILMTEC™ Membranes ROSA 9.1 ConfigDB u399339_282
Project: Tintina Reject to Pond rev3 Case: 2
, 5/1/2017

Project Information: Tintina Black Cloud WTP

Case-specific: Temp = 10 C 50% Capacity x 2 81.84% Recovery

System Details -- Pass 2

Feed Flow to Stage 1	242.54 gpm	Pass 2 Permeate Flow	204.34 gpm	Osmotic Pressure:	
Raw Water Flow to System	249.66 gpm	Pass 2 Recovery	84.25 %	Feed	0.05 psig
Feed Pressure	206.62 psig	Feed Temperature	10.0 C	Concentrate	0.00 psig
Flow Factor	0.85	Feed TDS	6.86 mg/l	Average	0.02 psig
Chem. Dose	None	Number of Elements	36	Average NDP	185.81 psig
Total Active Area	15840.00 ft²	Average Pass 2 Flux	18.58 gfd	Power	25.28 kW
Water Classification: RO Permeate SDI < 1				Specific Energy	2.06 kWh/kgal
System Recovery	81.85 %				

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	ECO-440i	4	6	242.54	201.62	0.00	102.00	183.98	140.54	19.16	15.00	0.00	1.16
2	ECO-440i	2	6	102.00	178.98	0.00	38.20	165.31	63.80	17.40	15.00	0.00	1.51

Pass Streams
(mg/l as Ion)

Name	Feed	Adjusted Feed		Concentrate		Permeate		
		Initial	After Recycles	Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4+ + NH3	0.18	0.17	0.17	0.39	0.98	0.02	0.04	0.03
K	0.21	0.21	0.21	0.49	1.27	0.01	0.02	0.02
Na	0.27	0.27	0.27	0.63	1.63	0.01	0.03	0.02
Mg	0.26	0.26	0.26	0.61	1.60	0.01	0.01	0.01
Ca	0.58	0.58	0.58	1.35	3.57	0.01	0.02	0.02
Sr	0.03	0.03	0.03	0.08	0.21	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	1.94	1.94	1.94	3.96	10.07	0.96	1.12	1.01
NO3	2.76	2.76	2.76	6.36	16.52	0.14	0.27	0.18
Cl	0.16	0.16	0.16	0.39	1.03	0.00	0.00	0.00
F	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00
SO4	0.47	0.47	0.47	1.12	2.98	0.00	0.00	0.00
SiO2	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	55.93	55.93	55.93	56.23	56.41	55.38	55.54	55.42
TDS	6.86	6.86	6.86	15.37	39.89	1.16	1.51	1.27
pH	4.87	4.87	4.87	5.17	5.55	4.58	4.65	4.60

Reverse Osmosis System Analysis for FILMTEC™ Membranes ROSA 9.1 ConfigDB u399339_282
Project: Tintina Reject to Pond rev3 Case: 2
, 5/1/2017

Design Warnings -- Pass 2

-None-

Solubility Warnings -- Pass 2

-None-

Stage Details -- Pass 2

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.10	6.05	1.04	60.63	6.86	201.62
2	0.11	5.94	1.08	54.59	7.55	197.43
3	0.12	5.86	1.12	48.64	8.38	193.76
4	0.14	5.79	1.17	42.79	9.43	190.61
5	0.16	5.75	1.23	36.99	10.80	187.94
6	0.18	5.74	1.30	31.24	12.67	185.73

Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.11	5.55	1.35	51.00	15.37	178.98
2	0.12	5.45	1.40	45.45	17.17	175.61
3	0.13	5.36	1.46	40.00	19.42	172.70
4	0.15	5.27	1.52	34.64	22.31	170.24
5	0.18	5.18	1.60	29.38	26.19	168.20
6	0.21	5.10	1.70	24.20	31.65	166.57

Scaling Calculations

	Raw Water	Pass 1 Adjusted Feed	Pass 1 Concentrate	Pass 2 Concentrate
pH	6.80	6.80	7.38	0.00
Langelier Saturation Index	-0.57	-0.57	1.44	0.00
Stiff & Davis Stability Index	-0.26	-0.26	1.12	0.00
Ionic Strength (Molal)	0.03	0.03	0.15	0.00
TDS (mg/l)	1088.15	1088.22	5991.20	0.00
HCO3	237.00	237.00	1298.04	0.00
CO2	56.23	56.23	58.59	0.00
CO3	0.11	0.11	5.38	0.00
CaSO4 (% Saturation)	10.71	10.71	114.03	0.00
BaSO4 (% Saturation)	0.00	0.00	0.00	0.00
SrSO4 (% Saturation)	45.48	45.48	284.63	0.00
CaF2 (% Saturation)	21.54	21.54	3598.05	0.00
SiO2 (% Saturation)	1.44	1.44	8.12	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.01	0.00

To balance: 0.06 mg/l Cl added to feed.

Project Details

Project:	Tintina RO Plant Design
Permeate Flowrate:	410USGPM This is split into 2 trains of 205.0USGPM
System Recovery:	82%

Antiscalant

Vitec 3000 is the selected product at a dose of 2.08mg/l. Assuming the plant operates continuously, then this will require 4551lb of antiscalant per year. This may be supplied in 2 x 2500lb Totes, 10 x 500lb Drums, or 102 x 45lb Pails.

Chemical Cleaning

The chemical cleaning calculation has not been completed for this project.

Biocide

No biocide has been selected for this system. It is always recommended that a biocide injection point be included to allow for the retrofit of a biocide system at a later date.

Coagulant

No coagulant has been selected for this system. It is always recommended that a coagulant injection point be included to allow for the retrofit of a coagulant system at a later date.

Dechlorination

No dechlorination has been selected for this system.

avista technologies

Avista Advisor

Project Details

Project: Tintina RO Plant Design
Permeate Flowrate: 410USGPM This is split into 2 trains of 205.0USGPM
System Recovery: 82%

Antiscalant Projection

The projection is based on the following feed water analysis. The adjusted feed is the analysis after pH correction, and any ions have been added to balance the analysis. The concentrate analysis has been manually input.

Ion	Feed Water	Adjusted Feed	Concentrate	
Sodium	17.00	19.31	106.23	mg/l
Potassium	12.00	12.00	65.81	mg/l
Calcium	162.00	162.00	898.61	mg/l
Magnesium	71.00	71.00	393.70	mg/l
Iron	0.01	0.01	0.03	mg/l
Manganese	0.15	0.15	0.83	mg/l
Barium	0.00	0.00	0.02	mg/l
Strontium	9.65	9.65	53.53	mg/l
Aluminium	0.00	0.00	0.00	mg/l
Chloride	20.10	20.10	110.67	mg/l
Sulfate	350.00	350.00	1941.44	mg/l
Bicarbonate	293.00	293.00	1598.19	mg/l
Nitrate	160.20	160.20	851.85	mg/l
Fluoride	1.04	1.04	5.73	mg/l
Phosphate	0.01	0.01	0.07	mg/l
Silica	1.35	1.35	7.43	mg/l
CO2	74.80	74.80	74.80	mg/l
TDS		1099.82	6034.13	
pH	6.80	6.80	6.70	

Water Source: Surface Water

Water Temperature: 25º C

Product Choice

Vitec Choice: Vitec 3000
Dosage: 2.08mg/l
Usage: 12.47 lb per day.

Application

Dosed Solution Strength: 100%
Pump Rate: 1.20USGPD
3.15ml/m

There is one dosing pump per membrane train, using a common chemical tank for all trains.
With 2 trains, each pump will deliver 1.20USGPD

Avista Advisor

Project Details

Project: Tintina RO Plant Design
Permeate Flowrate: 410USGPM This is split into 2 trains of 205.0USGPM
System Recovery: 82%

Scaling Potential.

Langelier Saturation Index (LSI)

The reject stream has a LSI of 0.89.
Vitec 3000 has a limit of 3.00

Calcium Carbonate Precipitation Potential (CCPP)

The concentrate has a CCPP of 599mg/l.
This is within the limits of Vitec 3000.

Calcium Sulfate

The concentrate has a calcium sulphate saturation of 112.86%.
This is within the limits of Vitec 3000.

Barium Sulfate

The concentrate has a barium sulphate saturation of 187.38%.
This is within the limits of Vitec 3000.

Strontium Sulfate

The concentrate has a strontium sulphate saturation of 342.34%.
This is within the limits of Vitec 3000.

Calcium Fluoride

The concentrate has a calcium fluoride saturation of 1386.18%.
This is within the limits of Vitec 3000.

Silica

The concentrate has a silica level of 7.43mg/l.
Silica has a solubility of 141.9mg/l at this temperature and brine pH.

Magnesium Hydroxide

The concentrate has a magnesium hydroxide saturation of 0.00%.

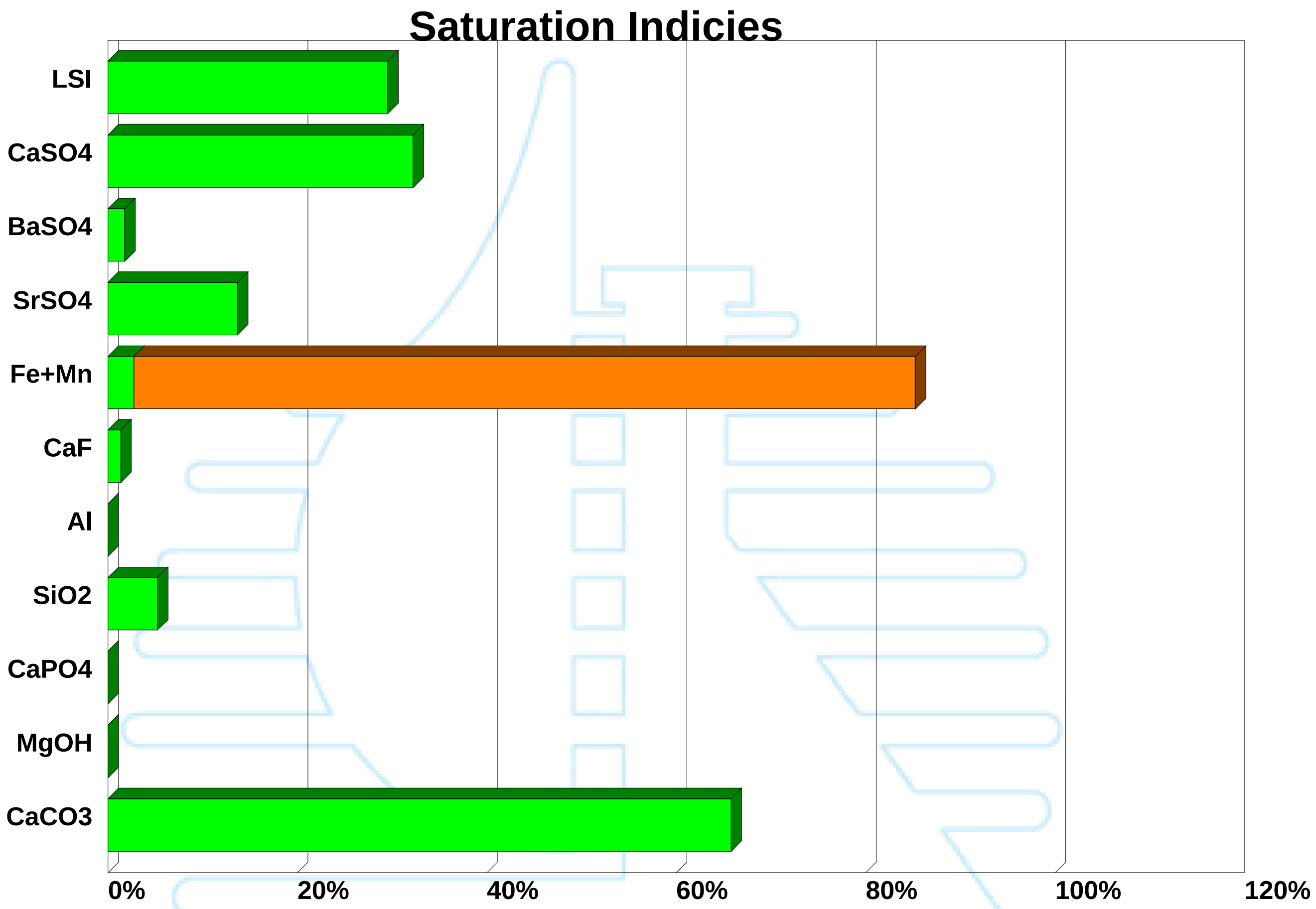
Calcium Phosphate

The concentrate has a calcium phosphate saturation of 0.00%.
This is within the limits of Vitec 3000.

Avista Advisor

Project Details

Project: Tintina RO Plant Design
Permeate Flowrate: 410USGPM This is split into 2 trains of 205.0USGPM
System Recovery: 82%



Product Choice

Vitec Choice: Vitec 3000
Dosage: 2.08mg/l
Usage: 12.47 lb per day.

Application

Dosed Solution Strength: 100%
Pump Rate: 1.20USGPD
3.15ml/m

There is one dosing pump per membrane train, using a common chemical tank for all trains.
With 2 trains, each pump will deliver 1.20USGPD

Project Details

Project: Tintina RO Plant Design
Permeate Flowrate: 410USGPM This is split into 2 trains of 205.0USGPM
System Recovery: 82%

Antiscalant

Vitec 3000 is the selected product at a dose of 2.00mg/l. Assuming the plant operates continuously, then this will require 4375lb of antiscalant per year. This may be supplied in 2 x 2500lb Totes, 9 x 500lb Drums, or 98 x 45lb Pails.

Chemical Cleaning

The chemical cleaning calculation has not been completed for this project.

Biocide

No biocide has been selected for this system. It is always recommended that a biocide injection point be included to allow for the retrofit of a biocide system at a later date.

Coagulant

No coagulant has been selected for this system. It is always recommended that a coagulant injection point be included to allow for the retrofit of a coagulant system at a later date.

Dechlorination

No dechlorination has been selected for this system.

Avista Advisor

Project Details

Project:	Tintina RO Plant Design
Permeate Flowrate:	410USGPM This is split into 2 trains of 205.0USGPM
System Recovery:	82%

Antiscalant Projection

The projection is based on the following feed water analysis. The adjusted feed is the analysis after pH correction, and any ions have been added to balance the analysis. The concentrate analysis has been manually input.

Ion	Feed Water	Adjusted Feed	Concentrate	
Sodium	17.00	19.31	106.23	mg/l
Potassium	12.00	12.00	65.81	mg/l
Calcium	162.00	162.00	898.61	mg/l
Magnesium	71.00	71.00	393.70	mg/l
Iron	0.01	0.01	0.03	mg/l
Manganese	0.15	0.15	0.83	mg/l
Barium	0.00	0.00	0.02	mg/l
Strontium	9.65	9.65	53.53	mg/l
Aluminium	0.00	0.00	0.00	mg/l
Chloride	20.10	20.10	110.67	mg/l
Sulfate	350.00	350.00	1941.44	mg/l
Bicarbonate	293.00	293.00	1598.19	mg/l
Nitrate	160.20	160.20	851.85	mg/l
Fluoride	1.04	1.04	5.73	mg/l
Phosphate	0.01	0.01	0.07	mg/l
Silica	1.35	1.35	7.43	mg/l
CO2	96.59	96.59	74.80	mg/l
TDS		1099.82	6034.13	
pH	6.80	6.80	6.70	

Water Source: Surface Water

Water Temperature: 10º C

Product Choice

Application

Vitec Choice:	Vitec 3000	Dosed Solution Strength: 100%	
Dosage:	2.00mg/l	Pump Rate:	1.15USGPD
Usage:	11.99 lb per day.		3.03ml/m

There is one dosing pump per membrane train, using a common chemical tank for all trains.
With 2 trains, each pump will deliver 1.15USGPD

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Project Details

Project:	Tintina RO Plant Design
Permeate Flowrate:	410USGPM This is split into 2 trains of 205.0USGPM
System Recovery:	82%

Scaling Potential.

Langelier Saturation Index (LSI)

The reject stream has a LSI of 0.56.
Vitec 3000 has a limit of 3.00

Calcium Carbonate Precipitation Potential (CCPP)

The concentrate has a CCPP of 440mg/l.
This is within the limits of Vitec 3000.

Calcium Sulfate

The concentrate has a calcium sulphate saturation of 131.35%.
This is within the limits of Vitec 3000.

Barium Sulfate

The concentrate has a barium sulphate saturation of 187.38%.
This is within the limits of Vitec 3000.

Strontium Sulfate

The concentrate has a strontium sulphate saturation of 342.34%.
This is within the limits of Vitec 3000.

Calcium Fluoride

The concentrate has a calcium fluoride saturation of 1386.18%.
This is within the limits of Vitec 3000.

Silica

The concentrate has a silica level of 7.43mg/l.
Silica has a solubility of 107.8mg/l at this temperature and brine pH.

Magnesium Hydroxide

The concentrate has a magnesium hydroxide saturation of 0.00%.

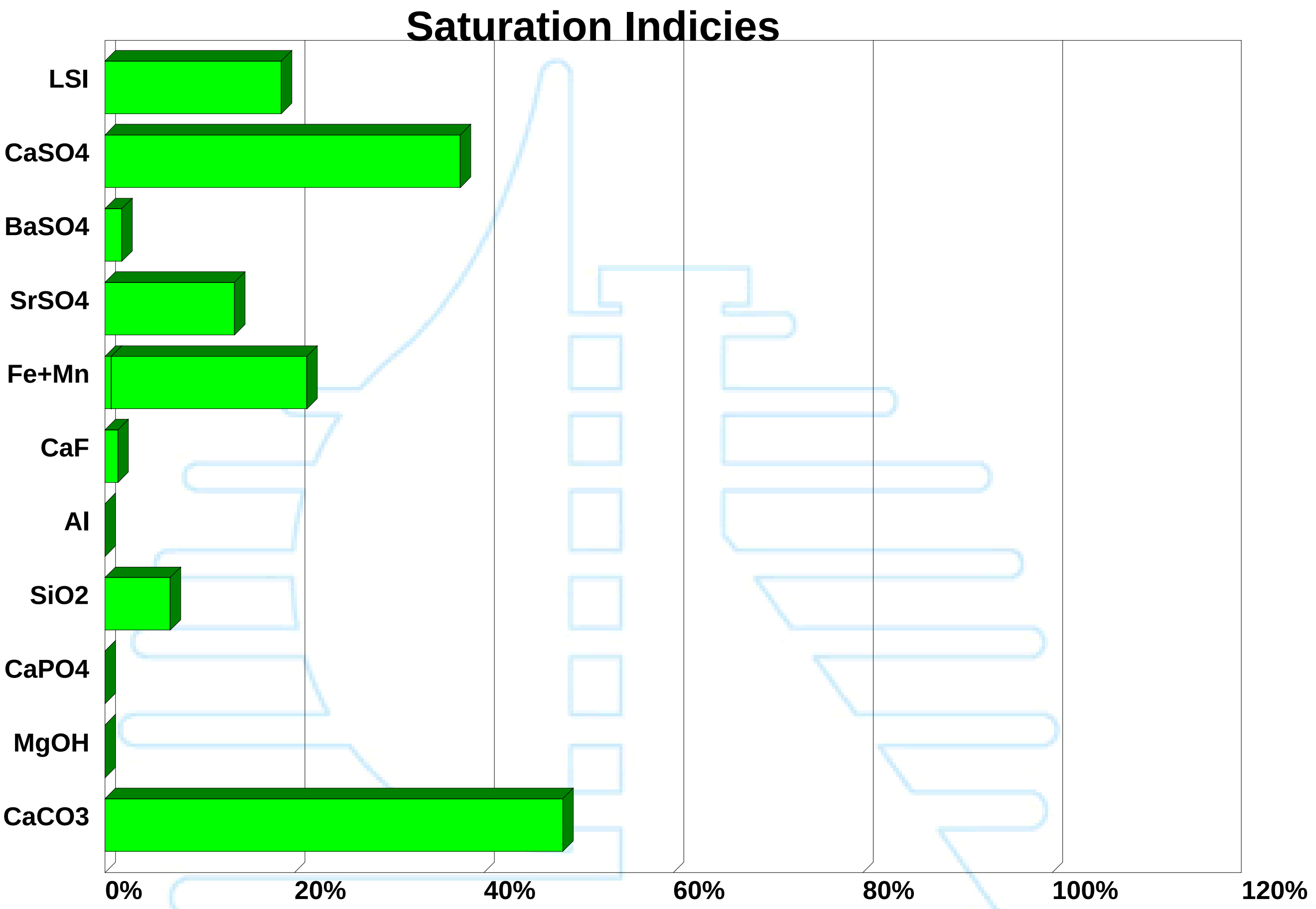
Calcium Phosphate

The concentrate has a calcium phosphate saturation of 0.00%.
This is within the limits of Vitec 3000.

Avista Advisor

Project Details

Project: Tintina RO Plant Design
Permeate Flowrate: 410USGPM This is split into 2 trains of 205.0USGPM
System Recovery: 82%



Product Choice

Vitec Choice: Vitec 3000
Dosage: 2.00mg/l
Usage: 11.99 lb per day.

Application

Dosed Solution Strength: 100%
Pump Rate: 1.15USGPD
3.03ml/m

There is one dosing pump per membrane train, using a common chemical tank for all trains.
With 2 trains, each pump will deliver 1.15USGPD

APPENDIX V-4

VSEP Projections (Closure Phase)

Customer:	AMEC
Application:	RO reject
Prepared by:	Josh Miller
Date:	3/28/2017

Project Information

Stage 1

Modify Values in Blue Only

Design Temperature	15	**°C**
Feed Flow	69	**GPM**
Operating Pressure	550	**PSI**
Estimated Recovery	85%	
Estimated Flux	18	**GFD**
Membrane Area/Module	1400	**FT2**
Estimated Membrane Life	2.5	**Years**
Time Between Cleanings	2880	**Minutes**

Customer:	**AMEC**
Application:	**RO reject**
Prepared by:	**Josh Miller**
Date:	**3/28/2017**

NEW LOGIC RESEARCH, INC.

Estimates of VSEP Performance*

Design Basis Temp. °C	***Stage***	***GPM Feed***	***Recovery***	***GPM Permeate***	***GPD Permeate***	***GPM Reject***	***GPD Reject***	GPD Feed	***GFD***	***Gal Perm/22 Hrs***	***Safe. Fac.***	***Total Area (ft2)***	***# of i84 Mods***	***Round up #***	***Eff. Safety Factor***
15.00	1	69	0.85	59	84,456	10	14,904	99,360	18.00	5,100.00	0.30	6,630	5	5	0.36

* All values are estimates only. No warranty is expressed or implied. Costs are budgetary and expressed as USD.

Customer:	**AMEC**
Application:	**RO reject**
Prepared by:	**Josh Miller**
Date:	**3/28/2017**

Stage 1 Quality Estimates
Membrane: RO

		Initial Raw Feed ppm (mg/l)	**Estimated RO Permeate** ppm (mg/l)	**Estimated Reject** ppm (mg/l)	**Estimated % Reduction**
Silver	**Ag**	0.0800	0.0067	0.50	91.66%
Arsenic	**As**	0.0290	0.0019	0.18	93.50%
Barium	**Ba**	0.0010	0.0000	0.01	98.65%
Chromium	**Cr**	0.0080	0.0000	0.05	99.56%
Copper	**Cu**	7.9820	0.0111	53.15	99.86%
Molybdenum	**Mo**	0.0200	0.0004	0.13	98.20%
Nickel	**Ni**	1.0160	0.0192	6.66	98.11%
Lead	**Pb**	0.1680	0.0001	1.12	99.96%
Zinc	**Zn**	0.7630	0.0156	5.00	97.96%
Calcium	**Ca**	1824.0000	114.0000	11,514.0	93.75%
Fluoride	**F**	6.4000	0.7727	38.3	87.93%
Iron	**Fe**	24.1850	0.0117	161.2	99.95%
Magnesium	**Mg**	437.0000	21.5804	2,791.0	95.06%
Manganese	**Mn**	2.8900	0.1445	18.4	95.00%
Sodium	**Na**	112.0000	14.8400	662.6	86.75%
Potassium	**K**	80.0000	16.0000	442.7	80.00%
Phosphorous	**P**	0.1000	0.0140	0.6	86.00%
Chloride	**Cl**	2029.0000	70.8324	13,125.3	96.51%
Silica	**SiO2**	20.9000	1.0002	133.7	95.21%
Sulfate	**SO4**	2902.0000	10.2179	19,288.8	99.65%
Ammonia	**NH4**	26.8000	5.1257	149.6	80.87%
Total Nitrogen	**TN**	137.8000	26.9608	765.9	80.43%
Bicarbonate	**HCO3**	813.0000	32.5200	5,235.7	96.00%
tal Dissolved Solids	**TDS**	8867.0000	1057.6292	53,120.1	88.07%
Conductivity	**µS**	16762.0000	1508.5800	103,198.0	91.00%

APPENDIX C

BLACK BUTTE MINE METEOROLOGICAL MONITORING TEMPERATURE DATA

Temperature at 2 Meters*

	Summer		**Winter**	
	May thru Sept		***Oct thru Apr***	
	Avg	**Max**	**Avg**	**Max**
2012				
April			1.9	2.0
May	5.6	24.4		
June	10.8	25.5		
July	16.9	29.7		
August	15.1	31.5		
September	9.8	26.7		
October			1.5	19.4
November			-2	13.8
December			-8	8.2
2013				
January			-8	5.5
February			-7.2	4.1
March			-4	8.7
April			-0.3	17.3
May	7.5	25.2		
June	11.6	27		
July	16.7	30.2		
August	16.1	27.7		
September	11.2	28.7		
October			-0.3	14.4
November			-3.3	13.6
December			-10.2	7.8
2014				
January			-7.8	6.1
February			-13.2	4.3
March			-3.9	8.3
April			0.8	12.8
May	7.0	24.1		
June	8.9	19.3		
July	16	27.4		
August	13.8	29.4		
September	8.7	27.7		
October			5.1	20.5
November			-6	16.8
December			-6.6	10.7
2015				
January			-8.3	8.6
February			-4.6	10.6
March			0.3	17.4
April			1.9	20.3

	Summer		**Winter**	
	May thru Sept		***Oct thru Apr***	
	Avg	**Max**	**Avg**	**Max**
May	6.7	21.9		
June	14.2	30.8		
July	14.2	28.8		
August	14.2	30.7		
September	9.7	27.6		
October			5	24.2
November			-6.1	11.3
December			-7.9	8.2
2016				
January			-7.1	6.6
February			-3.9	8.9
March			-1.5	12.3
April			3.9	21.3
May	6.7	21.8		
June	13.2	27.7		
July	14.8	29.1		
August	13.7	31.4		
September	8.1	27.8		
October			4.2	18.4
November			0.2	16.6
December			-12.2	2.3

	Summer	**Winter**
Average	11.6	-3.4
Max	31.5	24.2

*April 2012 - December 2016 Temperature data (at 2 meters) in Celsius gathered from Black Butte Mine Meteorological Monitoring Station, presented in Appendix A-3 of the Mine Operating Permit Application for Black Butte Copper Project, Revision 3 Date: July 14, 2017.

APPENDIX D

APPLICATION FOR SOURCE SPECIFIC MIXING ZONE IN SURFACE WATER FOR TOTAL NITROGEN

APPLICATION FOR SOURCE SPECIFIC MIXING ZONE IN SURFACE WATER FOR TOTAL NITROGEN

TINTINA BLACK BUTTE COPPER PROJECT

Prepared for:

Tintina Montana, Inc.
Black Butte Copper Project
P.O. Box 431
White Sulphur Springs, MT 59645
406-547-3466

Prepared by:

Hydrometrics, Inc.
3020 Bozeman Ave.
Helena, MT 59601

December 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPLICATION FOR SOURCE SPECIFIC MIXING ZONE IN SURFACE WATER FOR TOTAL NITROGEN
TINTINA BLACK BUTTE COPPER PROJECT

1.0 INTRODUCTION

1.1 PURPOSE

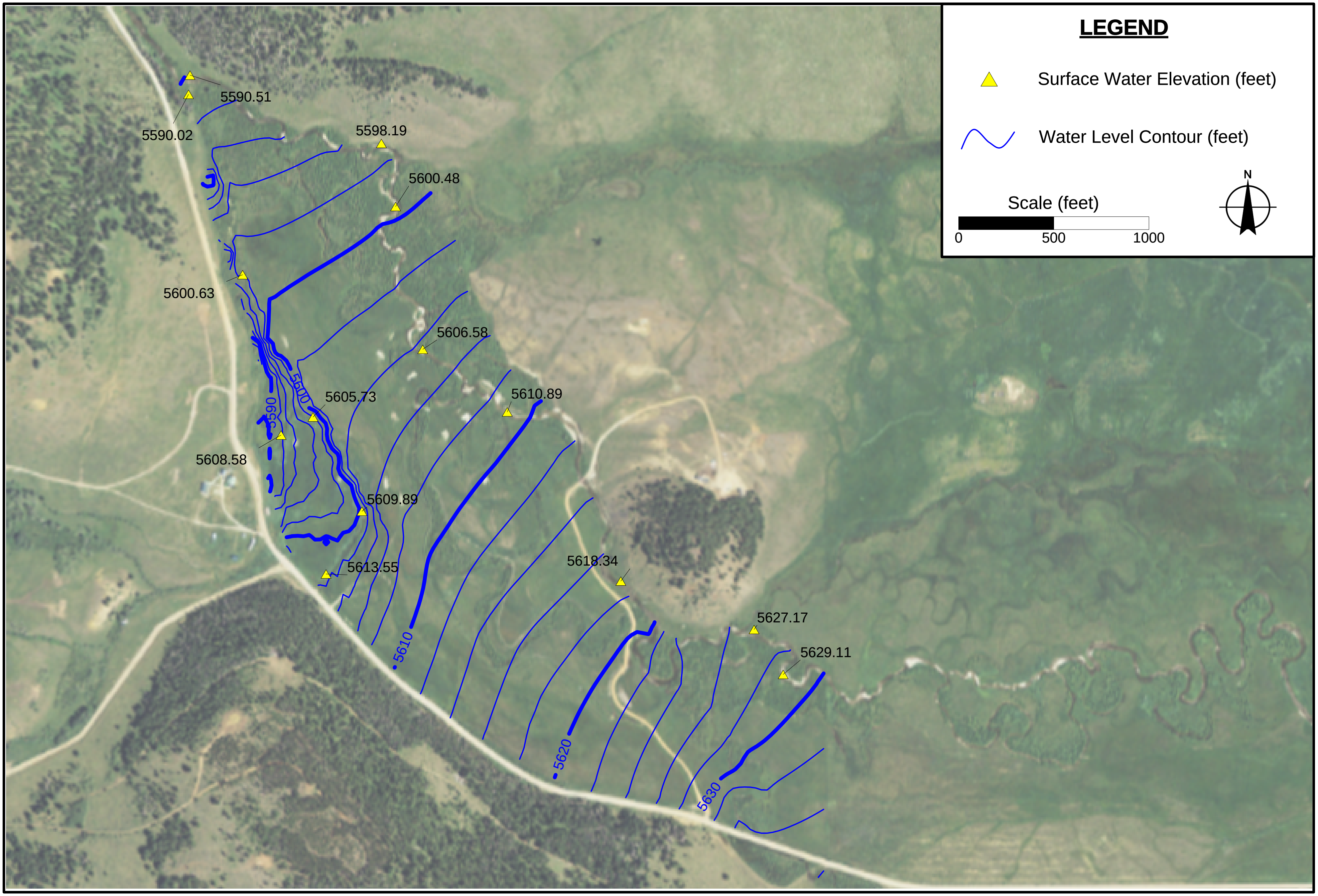
This Source Specific Mixing Zone Application is requested by Tintina Resources for a mixing zone in surface water for the parameter total nitrogen associated with discharges from its Black Butte Copper Project (Project). The requested mixing zone is associated with discharges of treated water from the reverse osmosis treatment works to the alluvial aquifer beneath Sheep Creek (Outfall 001). This source specific mixing zone is requested in Sheep Creek for total nitrogen as the total nitrogen concentrations in treated Project waters may range up to 0.57 mg/L. At these levels, total nitrogen would exceed nondegradation nonsignificant criteria for nutrients (DEQ-12) in Sheep Creek. While the discharge will be to the alluvial groundwater system, there is a hydrologic connection between the alluvial groundwater systems and Sheep Creek. This mixing analysis presents the necessary information as specified in the Administrative Rules of Montana (ARM) 17.30.500.

This request for a source specific mixing zone is being submitted as an appendix to the integrated permit application for new MPDES and storm water discharges. The integrated permit includes an application narrative to provide additional detail and supporting information in the permit. Many of the figures and appendices used in the application narrative are pertinent to this request for a mixing zone. Duplicate figures are provided in both the application narrative and mixing zone request; however, appendices included in the application narrative are referenced in this mixing zone.

1.2 SUMMARY OF NEED AND APPROPRIATENESS OF MIXING ZONE FOR TOTAL NITROGEN

This application describes and delineates a source specific mixing zone for total nitrogen in surface water as allowed and regulated under the Montana Water Quality Act. There are no groundwater quality standards or human health standards for total nitrogen in Montana Statute (circular DEQ-7). Total nitrogen is regulated in Montana under the surface water nutrient criteria. The nutrient criteria for total nitrogen was used as the basis for the nondegradation criteria for this mixing analysis. This application documents no impairment of existing or anticipated uses by Tintina's proposed groundwater discharge of treated effluent and associated source specific mixing zone in surface water. A mixing zone for discharge of total nitrogen from Outfall 001 is needed to allow mixing and transport to occur to comply with nondegradation nonsignificance criteria of Administrative Rules of Montana (ARM) 17.30.700 et seq. and circular DEQ-12A.

During active mine dewatering, water will be removed from underground mine workings. A portion of this mine water will be used for milling of ore (when milling is active). Excess mine water will be treated to remove most chemical constituents prior to release to the groundwater systems. Water released from Outfall 001 will be discharged directly to the groundwater within the Sheep Creek Alluvial valley. The alluvial aquifer is assumed to interact with surface water in Sheep Creek as the small canyon to the north creates a choke point where the alluvial aquifer is pinched out, causing alluvial groundwater to discharge to Sheep Creek as it approaches the canyon. Based on Darcy's law and aquifer tests in the alluvial aquifer (MW-4), upwards to 200 gpm flows into Sheep Creek from this aquifer system. The projected operational alluvial potentiometric surface and aerial photos show the gaining reach of Sheep Creek extends over approximately 3,500 feet (see Figure 1-1). It is this gaining reach of Sheep Creek that Tintina is requesting a source specific mixing zone for total nitrogen in surface water.



K:\project\11048\Discharge Permit\Integrated Permit Revised_One UIG\Figures\Figure 3.5.srf

Hydrometrics, Inc.
Consulting Scientists and Engineers

Figure 1-1
Projected Operational Alluvial Potentiometric Surface
Black Butte Copper Project
Meagher County, Montana

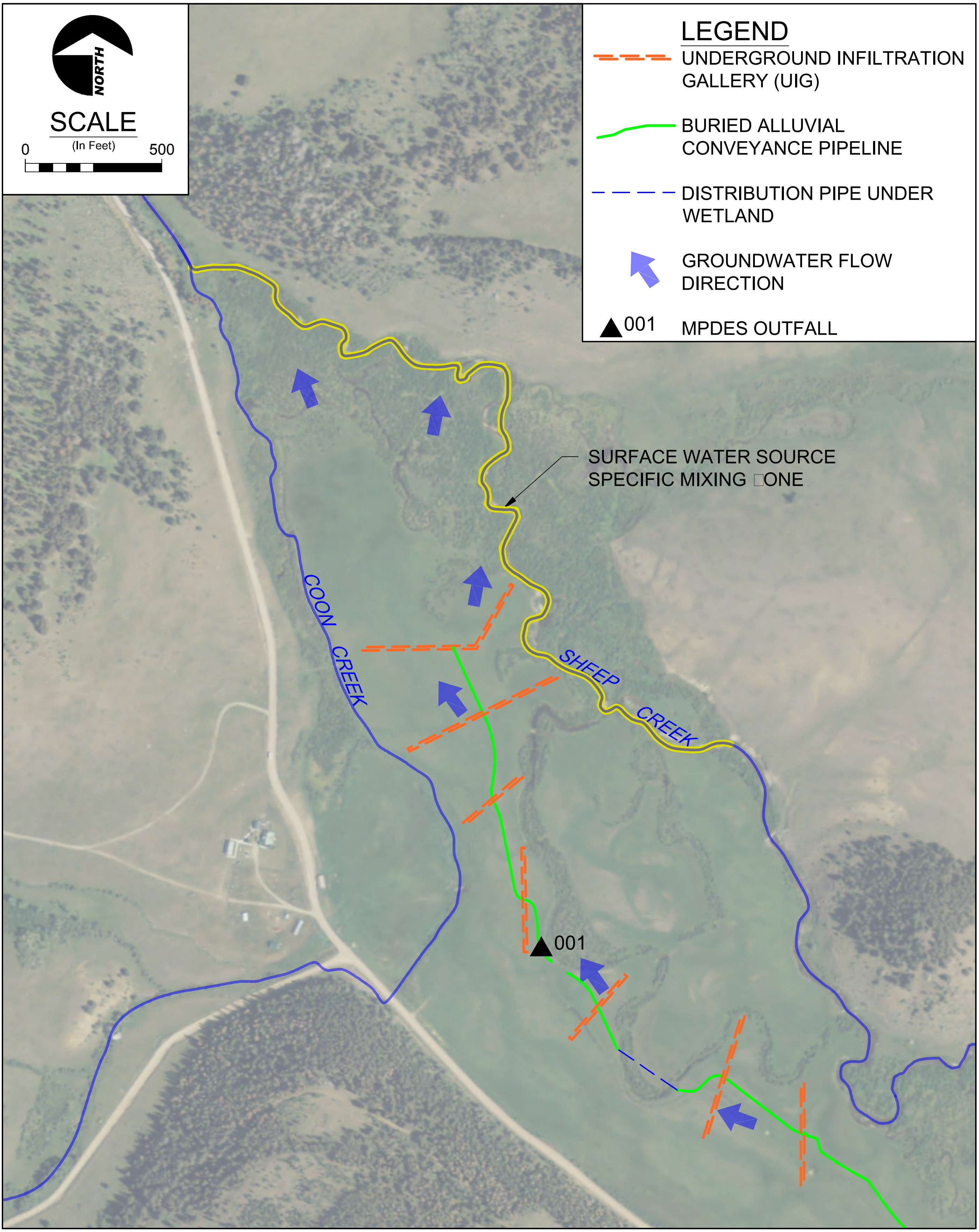
1.3 DISCHARGE WATER MANAGEMENT

Water treated in the reverse osmosis treatment plant will be discharged to the alluvial groundwater system through a series of underground infiltration galleries (UIG) in the Sheep Creek valley. The location and orientation of the UIG is shown in Figure 1-2. The Water Treatment Plant (WTP) will have an average discharge rate of 398 gpm with a design maximum discharge rate of 575 gpm to the outfalls (see Section 3.3 of the application narrative and 3.7.3.2 of the Mine Operating Permit (MOP; Tintina Resources, 2017) for further detail). The alluvial UIG totaling approximately 3,140 feet of infiltration galleries is designed to infiltrate 1,285 gpm of treated effluent into the alluvial system on a continuous basis. On a Project wide basis, the disposal system will have 124% of excess capacity at full treatment plant throughput.

A numerical groundwater model was developed as part of the mine operating permit to project the influences to the groundwater system due to mine dewatering. The model included analysis of groundwater/surface water interaction to quantify drawdown in the Project area. Based on the model results, the mine dewatering will deplete the groundwater and surface water in the vicinity of the Sheep Creek Valley by about 160 gpm (Hydrometrics, 2016). The numerical model used a conservative approach of only discharging water to the upland bedrock areas (not included in this application). The model would likely show less dewatering of the alluvial and surface water systems in the vicinity of the project area if discharges were simulated to the alluvial UIG (Outfall 001). It is also likely that a portion of the water discharged to the UIGs will be captured by the mine dewatering and will not report to Sheep Creek.

1.4 ORGANIZATION OF APPLICATION

This mixing zone application is organized in sequence with the Administrative Rules of Montana for mixing zones. Tables 1-1 and 1-2 provide the layout of the mixing zone application and corresponding mixing zone rules (ARM 17.30.500 et seq.).



Hydrometrics, Inc.
Consulting Scientists and Engineers

Figure 1-2
Source Specific Mixing Zone
Black Butte Copper Project
Meagher County, Montana

TABLE 1-1. SUMMARY OF INFORMATION PROVIDED FOR SOURCE SPECIFIC MIXING ZONE IN SURFACE WATER

ARM Citations	Information	Report Section
17.30.518(4)(a)	Quantity, toxicity, and persistence of pollutants	5.1
17.30.518(4)(b)	Rate of flow	5.2
17.30.518(4)(c)	Volume of flow	5.2
17.30.518(4)(d)	Concentration of pollutants within the mixing zone	5.3
17.30.518(4)(e)	Length of time pollutant will be present	5.4
17.30.518(4)(f)	Proposed boundaries of the mixing zone	5.5
17.30.518(4)(g)	Potential impacts to water uses	5.6
17.30.518(4)(h)	Compliance monitoring	5.7
17.30.518(4)(i)	Contingency plan	5.8

TABLE 1-2. SUMMARY OF INFORMATION PROVIDED FOR WATER QUALITY ASSESSMENT

ARM Citations	Information	Report Section
17.30.506(2)(a)	Biologically Important Areas	6.1
17.30.506(2)(b)	Drinking Water or Recreational Areas	6.2
17.30.506(2)(c)	Attraction of Aquatic Life to Mixing Zone	6.3
17.30.506(2)(d)	Toxicity/persistence of antimony	6.4
17.30.506(2)(e)	Passage of aquatic organisms	6.5
17.30.506(2)(f)	Cumulative Effects of multiple mixing zones	6.6
17.30.506(2)(g)	Aquifer characteristics	6.7
17.30.506(2)(h)	Groundwater discharges to surface water	6.8
17.30.506(2)(i)	Discharges to intermittent and ephemeral streams	6.9

2.0 TOTAL NITROGEN OVERVIEW

2.1 DESCRIPTION AND OCCURRENCE

Total nitrogen is not listed by the Agency for Toxic Substances and Disease Registry (ATSDR, 2017). However, the Montana Department of Environmental Quality (DEQ-12A) identifies total nitrogen as:

> *"Total nitrogen means the sum of all nitrate, nitrite, ammonia, and organic nitrogen, as N, in an unfiltered water sample. Total nitrogen in a sample may also be determined via persulfate digestion or as the sum of total kjeldahl nitrogen plus nitrate plus nitrite."*

The EPA (Total Nitrogen Fact Sheet, EPA 2013) further defines total nitrogen as:

> *"Total Nitrogen is an essential nutrient for plants and animals. However, an excess amount of nitrogen in a waterway may lead to low levels of dissolved oxygen and negatively alter various plant life and organisms. Sources of nitrogen include: wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges."*

2.2 WATER QUALITY STANDARDS, NUTRIENT CRITERIA

Montana has established nutrient criteria for separate ecoregions to control total nitrogen discharges. The Black Butte Copper Project is located in the Middle Rockies Ecoregion Big Snowy-Little Belt Carbonate Mountain (17q) group. This ecoregion has a total nitrogen nutrient criterion of 0.3 mg/L as N during the growing season (July through September). The MDEQ has set these criteria to be protective of all beneficial uses within the ecoregion.

2.3 POTENTIAL TOXICITY

Toxicity is defined as the "deleterious or adverse biological effects elicited by a chemical, physical, or biological agent" (EPA, 2011). Depending upon the nitrogen species present, toxicity (due to total nitrogen) is a secondary effect to nitrogen presence. Ammonia, nitrate, and nitrite (constitutes of total nitrogen) are classified as toxics in DEQ-7, whereas total nitrogen is classified as a nutrient. Primary toxicity of ammonia is dependent on pH and temperature. Whereas excessive nitrogen concentrations can reduce dissolved oxygen to levels deemed toxic to aquatic life by promoting plant growth and decay.

3.0 DISCHARGE SYSTEM AND EFFLUENT

3.1 GROUNDWATER DISCHARGE SYSTEM OUTFALLS 001

The Black Butte Copper Project is proposing to discharge from the following outfalls to groundwater:

- Outfall 001 – Sheep Creek Alluvial UIG to the Sheep Creek alluvial aquifer.

Locations of the outfall and individual infiltration galleries are shown on Figure 1-2.

3.2 QUANTITY OF GROUNDWATER DISCHARGE (EFFLUENT)

Average flow from Outfall 001 is estimated to be 398 gpm. Design maximum flows from the treatment works is 575 gpm. Outfall 001 will receive water from mine dewatering, runoff captured in the contact water pond, direct precipitation, and the Cemented Tailings Facility (CTF) foundation drain. The outfall is discussed in Section 3.1 of the application narrative.

4.0 SURFACE WATER CONDITIONS AND PROPOSED SOURCE SPECIFIC SURFACE WATER MIXING ZONE

This source specific mixing zone for surface water is being requested as the discharge will first pass through the ground and discharge to surface water over a distance that is greater than 10 times the stream width per ARM 17.30.508 (3). Below is a summary of the mixing that will take place in the groundwater system prior to discharging to surface water.

The mixing analysis within the groundwater system was conducted using the following conservative assumptions:

- The analysis was conducted at maximum flow rates and maximum projected concentrations of treated discharge water. This is conservative for the following reasons:
    - Maximum concentrations will likely be present at lower flow rates as the larger water quantity will dilute the total nitrogen concentrations.
    - The discharge will equilibrate to the average flow and concentrations of total nitrogen discharging to surface water due to the distance between the discharge to groundwater and where it will eventually discharge to Sheep Creek.
    - Hydrologic assessments of the mine dewatering model, suggest a portion of the alluvial system will be dewatered during the life of the mine. This will result in a portion of the discharges to the alluvial system to likely be captured by mine dewatering. However, this capture is not included in the mixing analysis.

The conceptual model of the discharge and mixing within the groundwater system was evaluated based on the above assumptions. This analysis uses the maximum flow (575 gpm) and concentration (0.57 mg/L) projected for the water treatment plant to assess mixing in groundwater. The flow of groundwater in the upper 15 feet of the alluvial system is estimated at 177 gpm. Total nitrogen is not included in the groundwater monitoring program as there is not a standard for total nitrogen in groundwater. Therefore, the total nitrogen in surface water (0.09 mg/L, 75th percentile) was used as the groundwater concentration. This is another conservative assumption as the groundwater will most likely have less total nitrogen than surface water. Based on this conceptual mixing model, the concentration of groundwater water discharging to Sheep Creek will be approximately 0.46 mg/L which is above the surface water nondegradation significance criteria of 0.12 mg/L as N.

The requested surface water mixing zone is selected to coincide with the gaining reach of Sheep Creek. The groundwater and mixed treated water will discharge to Sheep Creek in a diffuse manner, over a distance of approximately 3,500 feet (Figure 1-2). The mixing of Project water and groundwater with surface water will be "nearly instantaneous" as defined by ARM 17.30.501. This ARM defines nearly instantaneous as "an area where dilution of a discharge to water by the receiving water occurs at a nearly instantaneous rate, with the result that its boundaries are either at the point of discharge or are within two stream widths downstream of the point of discharge." The instantaneous nature of mixing is realized by the dispersed nature of discharge due to the low channel conductance rate (0.24 gpm per liner foot of mixing zone) causing the discharge to occur over an extended length. The point of discharge to the receiving water (Sheep Creek) is the area of stream over which the groundwater containing Project water discharges to Sheep Creek.

4.1 QUANTITY, TOXICITY, AND PERSISTENCE OF POLLUTANTS IN SURFACE WATER

4.1.1 Quantity of Total Nitrogen

The quantity (i.e., concentration) of total nitrogen in Sheep Creek will vary temporally and spatially due to variations of groundwater discharging to the stream and due to seasonal variations in stream flow in Sheep Creek. Water quality data for Sheep Creek at monitoring stations downstream of the outfalls is provided in the application. Ambient total nitrogen concentration (75th percentile) in Sheep Creek is quantified at 0.09 mg/L as N.

As further described in Section 4.3 (below), concentration of total nitrogen at the downstream boundary of the mixing zone is predicted to range from background concentrations to 0.118 mg/L as N. Concentration of total nitrogen within the mixing zone (i.e., in Sheep Creek adjacent the outfalls) is predicted to be somewhat less than concentrations at the end of the mixing zone, as complete discharge of effluent and groundwater to Sheep Creek will not be achieved until the alluvial system fully pinched out at the upper end of the canyon. Downstream of the mixing boundary, total nitrogen concentrations will be reduced further due to increasing streamflow from additional groundwater and surface water tributary sources.

4.1.2 Toxicity of Total Nitrogen

A summary of available information on the toxicity of total nitrogen is provided in Section 2.0, above. The maximum concentration of total nitrogen predicted to occur in the surface water mixing zone is 0.118 mg/L as N. This concentration of total nitrogen is not considered to pose any toxicity risk to humans or aquatic life as it is better than all available water quality standards and guidelines. At this concentration, the N:P ratio is 7.1:1, which is within the range where phosphorus limits instream biological growth. At these low phosphorus and nitrogen concentrations instream, and with no additional phosphorus loading from the Project, excessive biological growth instream is not expected.

4.1.3 Persistence of Total Nitrogen

“Persistence” is not defined in Montana rules and laws. A persistent chemical is described by EPA (1991) as one that is “not subject to decay, degradation, transformation, volatilization, hydrolysis, or photolysis.” Organic and inorganic nitrogen species are not considered to be persistent under most ambient environmental conditions. Nitrogen follows a first order decay equation due to biological assimilation. Ammonia can be reduced in groundwater systems given the proper conditions; ammonia is converted to nitrate which is persistent in groundwater systems. Nitrate can be in-situ converted by bacterial action, but requires seeding and careful management to facilitate conversion. For the purpose of this mixing analysis, total nitrogen is considered persistent to retain a conservative analysis.

4.2 RATE AND VOLUME OF FLOW

For this mixing analysis, the critical stream flow for Sheep Creek is the estimated seasonal 14Q5 (14-day, 5-year low flow) flow of 20.5 cfs. The 14Q5 for Sheep Creek in the vicinity of the mixing zone was established by using the statistical data from USGS gaging station (#06077000) and applying a multiplier (1.75) based on a watershed analysis to adjust for the larger water shed for the SW-1 surface water site. See Section 3.2.2 of the application narrative for how the 14Q5 was determined. DEQ has adopted the 14Q5 as the flow statistic for nutrient calculations (DEQ-12A).

4.3 CONCENTRATION OF TOTAL NITROGEN WITHIN THE MIXING ZONE

Concentration of total nitrogen within the mixing zone and at the mixing zone boundary is predicted to range from background concentrations (0.09 mg/L as N) to 0.118 mg/L as N. Predicted concentrations assume nearly instantaneous, complete mixing of effluent (1.28 cfs discharge flow with total nitrogen concentrations of 0.57 mg/L) with ambient groundwater flow (0.39 cfs) and critical (14Q5) stream flow of 20.5 cfs. Complete and nearly instantaneous mixing is anticipated as the groundwater diffuses into Sheep Creek over 3,500 feet.

4.4 LENGTH OF TIME TOTAL NITROGEN WILL BE PRESENT

Total nitrogen will be present in the mixing zone throughout the duration of the mine operational and closure period. At some time after mine closure and reclamation is completed, total nitrogen concentrations in mine water may approach ambient groundwater concentrations and surface water within the mixing zone may approach ambient surface water concentrations.

4.5 PROPOSED BOUNDARIES OF THE MIXING ZONE

The proposed boundary of the source specific mixing zone in Sheep Creek is shown in Figure 1-2. The source specific mixing zone starts at 46^{0}46’50.02” N latitude 110^{0}54’7.31” W longitude and ends at 46^{0}47’7.71” N latitude 110^{0}54’35.72” W longitude, or at the confluence of Coon Creek with Sheep Creek. This reach of Sheep Creek represents the gaining reach prior to the canyon mouth where the alluvial system pinches out. Based on the diffuse nature of the groundwater infiltration into Sheep Creek (0.24 gpm per linear foot of mixing zone) mixing will be evaluated with the entire 14Q5 (9149.4 gpm - ARM 17.30.516(3)(e)).

4.6 POTENTIAL IMPACTS TO WATER USES

Sheep Creek is located within the Upper Smith River watershed in U.S. Geological Survey (USGS) Hydrological Unit Code (HUC) 10030103. The designated water-use classification for the drainage is B-1. Beneficial uses for waters classified as B-1 are "drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply." (ARM 17.30.623(1))

No impacts to existing or anticipated water supply uses will occur as the water quality within the mixing zone will be maintained at total nitrogen concentrations that are far better than all available water quality standards for public and private water supplies. Total Nitrogen concentrations within and outside the mixing zone will not exceed Montana nondegradation nonsignificance level of increases of less than 10 percent of the lowest applicable water quality standard (i.e., less than 0.12 mg/L as N, instream).

No impacts to existing or anticipated aquatic life and wildlife uses will occur as the water quality within the mixing zone will be maintained at total nitrogen concentrations that are far better than concentrations of known observed effects. Instream concentrations after mixing the maximum effluent flow and concentrations with the 14Q5 flow in Sheep Creek result in a total nitrogen concentration of 0.118 mg/L as N. As noted above, the actual discharge to Sheep Creek will likely be lower than the maximum rate and concentration as the discharge will equilibrate to average flow and concentrations as it transports through the groundwater system.

4.7 COMPLIANCE MONITORING

Proposed compliance monitoring consists of effluent monitoring and water resource monitoring as described in Section 5.0 of the integrated application narrative and Section 6.3

of the MOP. Proposed monitoring sites for compliance with discharge permit requirements are shown in Figure 4-1.

4.8 CONTINGENCY PLAN

Migration of total nitrogen beyond the mixing zone boundary at concentrations greater than the nonsignificance criteria (0.12 mg/L as N, in Sheep Creek) is unlikely due to the conservative assumptions built into this analysis, high level of dilution available instream, compliance monitoring, and active engineering controls. Although it is unlikely that total nitrogen would exceed the nonsignificance criteria, the below contingency actions would include the following:

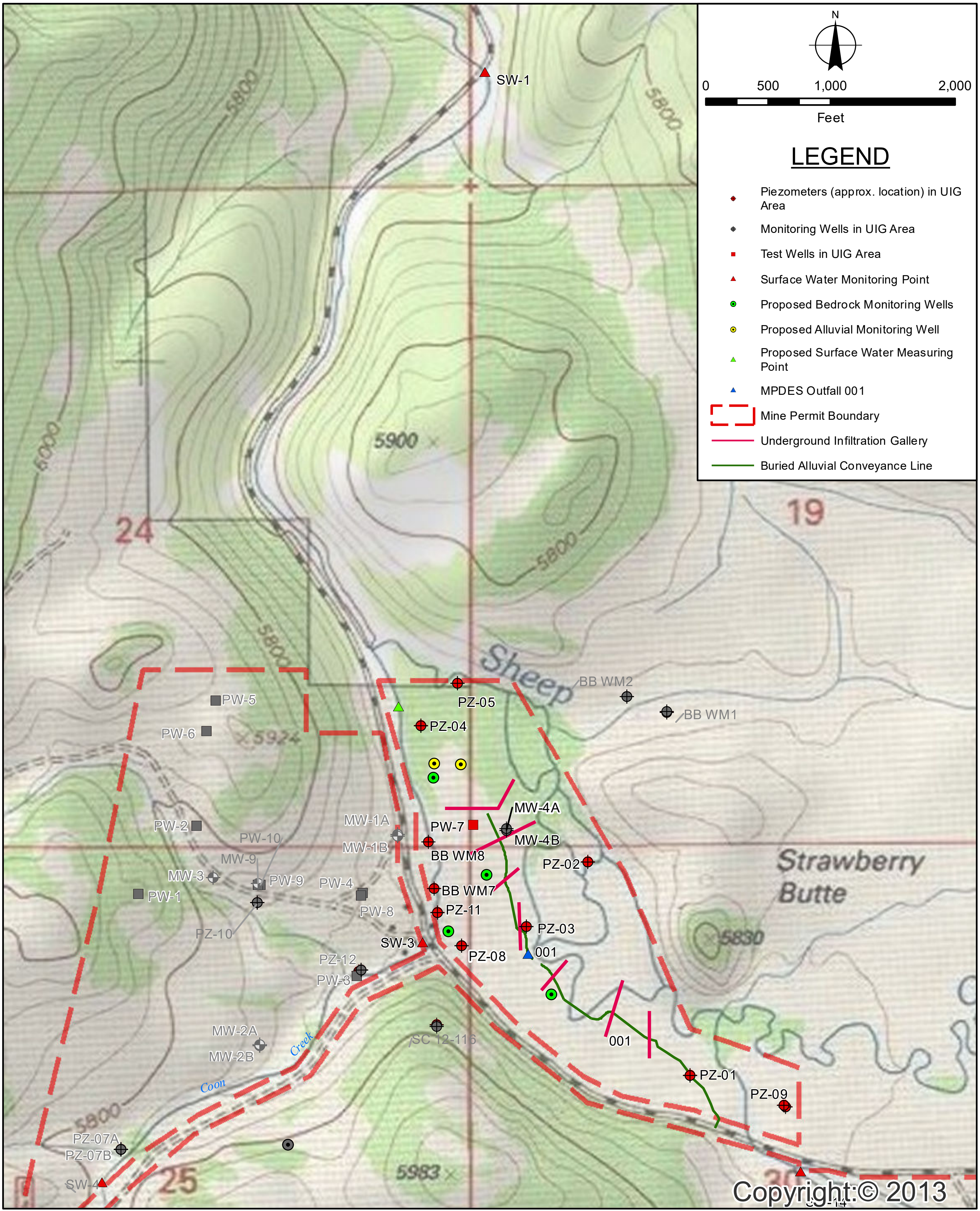
- Halting or reducing Project activities if necessary to maintain compliance with mixing zone limits; and
- All reasonable steps to minimize or prevent violation of mixing zone limits.

Reasonable steps to correct non-compliance with mixing zone boundaries would depend on the cause of the condition, but might reasonably include:

1. Additional monitoring and evaluation to identify the cause or source of the non-compliance.
2. Additional actions to improve the effectiveness of water treatment.
3. Additional actions to minimize the volume of water discharged, or augmentation of instream flows.

4.9 SMALLEST PRACTICAL MIXING ZONE AND MINIMUM PRACTICABLE EFFECT ON WATER USERS

The area of the requested mixing zone is selected to coincide with the gaining reach of Sheep Creek for discharges from Outfall 001 and is as small as practicable. Direct discharges (Outfall 001) to the alluvial groundwater system will discharge to Sheep Creek where the alluvial system is pinched out near the head of the canyon to the north. The mixing zone will



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Date: December 2017, Source: Hydrometrics, Inc. (2017)

Hydrometrics, Inc.
Consulting Scientists and Engineers

Figure 4-1
Water Resource Monitoring Sites
Black Butte Copper Project
Meagher County, Montana

have no practicable effect on water users as total nitrogen concentrations within the groundwater mixing zone will be maintained at levels that are better than all established water quality standards and nondegradation requirements.

The mixing zone is the smallest practicable size for the following reasons:

1. Effluent will be treated to a very high level prior to release to groundwater. Using a conservative analysis (100% of the maximum treated effluent) predicts compliance with the nondegradation policy and rules.
2. The mixing zone is the area within which the groundwater flow of effluent to Sheep Creek will occur.
3. The end of the mixing zone corresponds with the end of the gaining reach of Sheep Creek at the head of the canyon. It is assumed that 100% of the alluvial aquifer groundwater reports to Sheep Creek by that point.

5.0 WATER QUALITY ASSESSMENT

The Montana Water Quality Act allows and regulates mixing zones. This application describes and delineates a source specific mixing zone for total nitrogen in surface water. This application documents no impairment of existing or anticipated uses by Tintina's proposed groundwater discharge and associated source specific mixing zone in surface water.

5.1 BIOLOGICALLY IMPORTANT AREAS

Biologically important areas for purposes of consideration of the proposed mixing zone are defined in ARM 17.30.506 (2)(a) as follows:

> "the presence of fish spawning areas or shallow water nursery areas within the proposed mixing zone or a "shore hugging" effluent plume in an aquatic life segment will support a finding that the mixing zone may be inappropriate during the spawning or nursery periods."

Habitat and spawning locations in Sheep Creek are summarized in the baseline fisheries report. Annual fisheries monitoring (since 2014) is ongoing and is presented as Appendix G of the MOP.

Due to the low stream channel conductance value, the average rate of groundwater flow into the stream water column is 0.25 gpm per linear foot of mixing zone. At these low rates mixing will be nearly instantaneous.

5.2 DRINKING WATER OR RECREATIONAL AREAS

Drinking water or recreational areas and activities for purposes of consideration of the proposed mixing zone are defined in ARM 17.30.506 (2)(b) as follows:

> "the existence of a drinking water intake, a zone of influence around a drinking water well or a well used for recreational purposes, or a recreational area within or immediately adjacent to the proposed mixing zone will support a finding that a mixing zone is not appropriate. For purposes of these rules, "recreational" refers to swimming and

> “recreational area” refers to a public beach or swimming area, including areas adjacent to streams or lakes.”

There are no existing or anticipated drinking water uses in the proposed mixing zone. No impacts to existing or anticipated water supply uses will occur as the water quality within the mixing zone will be maintained at total nitrogen concentrations that are far better than all available water quality standards for public and private water supplies. Total nitrogen concentrations within and outside the mixing zone will not exceed Montana nondegradation limits of 10 percent of the lowest applicable water quality standard (i.e., less than 0.12 mg/L as N).

There are no designated public beaches or swimming areas within or near the mixing zone. However, other types of recreational uses may occur in Sheep Creek downstream of the mixing zone within the Helena National Forest. There are fishing access points where access to fishing or secondary contact recreation may occur. No impacts to existing or anticipated water supply uses will occur as the water quality within the mixing zone will be maintained at total nitrogen concentrations that are far better than all available water quality standards for public and private water supplies.

5.3 ATTRACTION OF AQUATIC LIFE TO MIXING ZONE

Attraction of aquatic life to mixing zone for purposes of consideration of the proposed mixing zone is defined in ARM 17.30.506 (2)(c) as follows:

> “where currently available data support a conclusion that fish or other aquatic life would be attracted to the effluent plume, resulting in adverse effects such as acute or chronic toxicity, it may be appropriate to adjust a given mixing zone for substances believed to cause the toxic effects.”

There is no known or currently available data suggesting that aquatic life would be attracted to the effluent plume. Moreover, no toxic effects would occur if attraction were to occur as total nitrogen concentrations within the mixing zone will be far below applicable water quality standards and observed effects levels.

5.4 TOXICITY AND PERSISTENCE OF TOTAL NITROGEN

Toxicity/persistence of the substance discharged for purposes of consideration of the proposed mixing zone is defined in ARM 17.30.506 (2)(d) as follows:

> "where a discharge of a parameter is at a concentration that is both toxic and persistent, it may be appropriate to deny a mixing zone. Toxicity and persistence will be given added weight to deny a mixing zone where the parameter is expected to remain biologically available and where a watershed-based solution has not been implemented. For ground water, this factor will also be considered in areas where the parameter may remain in the ground water for a period of years after the discharge ceases."

In the proposed discharges and mixing zone, total nitrogen will not be present at toxic concentrations. Projected instream concentrations of total nitrogen at 0.118 mg/L as N will not allow for biological growth to achieve detrimental levels.

5.5 PASSAGES OF AQUATIC ORGANISMS

Passage of aquatic organisms for purposes of consideration of the proposed mixing zone is defined in ARM 17.30.506 (2)(e) as follows:

> "where currently available data indicate that a mixing zone would inhibit migration of fish or other aquatic species, no mixing zone may be allowed for the parameters that inhibit migration. In making this determination, the department will consider whether any parameter in the effluent plume will block migration into tributary segments."

No significant tributaries to Sheep Creek are present within the proposed mixing zone. Concentrations of total nitrogen within the mixing zone will be low and are not expected to inhibit migration of organisms. Diffusion of groundwater into the stream channel is limited by channel conductance values. Groundwater will flow into Sheep Creek over approximately 3,500 feet.

5.6 CUMULATIVE EFFECTS OF MULTIPLE MIXING ZONES

There are no existing or anticipated mixing zones in Sheep Creek. Thus, no cumulative effects will occur.

5.7 AQUIFER CHARACTERISTICS

Aquifer characteristics for purposes of consideration of the proposed mixing zone is defined in ARM 17.30.506 (2)(g) as follows:

> "when currently available data indicate that the movement of ground water or pollutants within the subsurface cannot be accurately predicted, such as the movement of ground water through fractures, and also indicate that this unpredictability might result in adverse impacts due to a particular concentration of a parameter in the mixing zone, it may be appropriate to deny the mixing zone for the parameter of concern."

The aquifer that will receive discharges from Outfall 001 is an alluvial aquifer composed of granular sediment (gravel, silt, sand, and cobbles). Flow of groundwater through this porous media is predictable and is not influenced by fractures. A detailed analysis of the aquifer has been conducted based on aquifer tests and infiltration tests at 10 sites in the alluvial system. A detailed potentiometric map provides the necessary information on groundwater flow directions and the modeling analysis shows how discharges to the alluvial system will affect where groundwater discharges to Sheep Creek (Figure 1-1). A detailed report from the characterization study is attached to the permit application narrative as Appendix E.

5.8 GROUNDWATER DISCHARGES TO SURFACE WATER

Groundwater discharges to surface water for purposes of consideration of the proposed mixing zone is defined in ARM 17.30.506 (2)(h) as follows:

> "In the case of a discharge to ground water which in turn discharges to surface water within a reasonably short time or distance, the mixing zone may extend into the surface water, and the same considerations which apply to setting mixing zones for direct

> discharges to surface water will apply in determining the allowability and extent of the mixing zone in the surface water."

The proposed groundwater mixing zone extends into adjacent surface water where nearly instantaneous mixing occurs along the length of the mixing zone.

5.9 DISCHARGES TO INTERMITTENT AND EPHEMERAL STREAMS

There will be no discharges to intermittent of ephemeral streams associated with the proposed mixing zone.

6.0 REFERENCES

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APPENDIX E

INFILTRATION STUDY REPORT

Hydrometrics, Inc.
consulting scientists and engineers

TECHNICAL MEMORANDUM

DATE: December 6, 2017

TO: Jerry Zieg, Tintina Montana

FROM: Greg Bryce, Hydrometrics

SUBJECT: ALLUVIAL INFILTRATION TESTING AND ANALYSIS

Tintina is proposing to dispose of treated water at the Black Butte Copper Project through an alluvial underground infiltration gallery (UIG), located in the Sheep Creek alluvial aquifer (Figure 1). The average discharge to the UIG is estimated to be about 398 gpm with a design maximum discharge up to 575 gpm. Infiltration testing was conducted in the alluvial system to evaluate the capacity of the proposed alluvial infiltration gallery. Testing was conducted at nine infiltration trenches from November 8th through 11th, 2017. This memorandum provides a summary of the methods used, results and analysis of the infiltration capacity.

INFILTRATION TESTING

Infiltration testing was performed at nine infiltration trenches within the Sheep Creek alluvial aquifer (Figure 1). Infiltration trenches were excavated on November 6, 2017 with each trench being constructed about 3 to 4 feet wide and having approximately 15 to 20 feet that is excavated to depth and approximately 7 to 10 feet escape ramps on one end of the trench. The trench dimensions were measured by surveying the total trench length and escape ramp length and manual measurements of the trench depth using the excavator. The unsaturated volumes in each trench are summarized in Table 1. The trenches were logged during excavation by a geologist and the trench lithologies are summarized in Table 2.

TABLE 1. TRENCH UNSATURATED VOLUME

Trench #	Unsaturated Depth (ft)	Main Trench Area (ft^2)	Escape Ramp Area (ft^2)	Main Trench Volume (ft^3)	Escape Ramp Volume (ft^3)	Total Volume (ft^3)	Total Volume (gal)
1	2.9	110	32	316	46	362	2,705
2	2.9	98	43	284	62	347	2,592
3	3.4	89	49	303	83	386	2,887
4	2.4	78	43	186	51	237	1,771
5	3.1	73	32	223	49	271	2,030
6	2.9	100	55	293	81	374	2,794
7	2.4	86	25	206	30	236	2,794
8	2.8	123	57	344	80	424	2,794
9	2.89	81	37	234	53	288	2,151

TABLE 2. TRENCH LITHOLOGY

Trench	Depth (ft)	Lithology
1	0-2	Topsoil
	2-4	Sandy gravel; fine gravel (40-60%) with dark grey sand and silt matrix, and orange silty clay lens.
	4-10	Sandy gravel; fine to coarse gravel (60%) with grey silty sand, (<10 % silt)
2	0-1	Topsoil
	1-3	Gravelly sand; buff tan to orange-brown silty sand with <10% fine gravel
	3-8	Sandy Gravel; well-rounded to subround and flat coarse gravel with 30% brown to orange-brown sand matrix. Grain size increased below 7-feet.
3	0-1.5	Topsoil
	1.5-4.5	Silty Sand; light to medium brown sand with <10% silt to 3-feet (dry) and medium brown clayey silt to 4.5 feet (damp)
	4.5-10	Sandy Gravel; rounded to subround coarse gravel and <10% cobbles and 20-40% brown to orange-brown sand matrix
4	0-1	Topsoil
	1-4	Gravelly Sand; light to medium brown silty sand with orange-brown silty lenses, up to 40% angular to rounded fine to medium gravel.
	4-7	Gravel; coarse gravel with few boulders up to 14-inches and 30-40% medium brown sand with <10% silt.
5	0-1	Topsoil
	1-6	Sandy Gravel; coarse flat subround gravel (60%) with medium brown silty sand matrix.
6	0-1.5	Topsoil
	1.5-4	Sandy Gravel; subround coarse gravel (50-60%) and medium brown to orange-brown silty sand.
	4-8	Sandy Gravel; round to subround coarse gravel (50%) and brown-grey silty sand matrix.
7	0-1	Topsoil
	1-2.5	Silty Sand; medium brown clayey silty sand
	2.5-7	Sandy Gravel; coarse round to flat subround gravel (40-60%) and silty sand matrix (10% silt).
8	0-1.5	Topsoil
	1.5-6	Sand and Gravel; fine to coarse subround gravel (40-60%) and brown silty sand matrix with 6-8” grey-black clay lens at 2-feet. Water at 4-feet.
9	0-1	Topsoil
	1-4	Gravelly Sand; coarse subround gravel (30-50%) and coarse sand (30%) with silty sand matrix.
	4-7	Sandy Gravel; coarse subround gravel (50-70%) and 5% cobbles with silty sand matrix.

Water level monitoring stations were established in each trench prior to the start of the infiltration trench. Monitoring stations consisted of a staff gauge and a stilling well instrumented with a pressure transducer. Additional water-level monitoring included manual measurements from three new piezometers (PZ-12, PZ-13, and PZ-14) installed approximately 10 feet away from trenches 3, 5, and 7, and established monitoring well MW-4A in the vicinity of trenches 7, 8, and 9. Infiltration testing was conducted at one trench at a time, starting at Area 1 and ending at Area 3. Water used in the testing was sourced from Tintina’s core shed well and was transported to the testing areas by a water truck. Water was discharged through 4-inch HDPE pipe to the infiltration trenches during testing and flow rates were monitored by a flowmeter. Each infiltration test was conducted by the following methods:

- Install monitoring station;
- Record static and background water levels in trenches (and piezometer if present);
- Start discharging water from truck and monitor discharge rate;
- Monitor mounding within trench during infiltration;
- Adjust discharge rate to maintain a steady-state condition at approximately 1-foot of free board for at least 30 minutes or when the water truck is empty; and
- Shut off flow to trench and monitor falling head in the trench until the water level has recovered to within 10% of background.

Pre-soaking the infiltration trenches was not conducted as the trenches encountered groundwater at approximately 2 to 3 feet below ground surface. It was assumed that the majority of the water will move through the saturated aquifer and only a minor amount of water would transport through the unsaturated soils in the trench. In addition, temperatures were near freezing for the majority of the daylight hours and below freezing during the night. Each trench was covered with visqueen after excavation and until testing to ensure infiltration testing was conducted in non-frozen conditions.

WATER LEVEL MONITORING

Three new piezometers were installed approximately 10-feet away from trenches 3, 5, and 7 to monitor groundwater mounding. The measuring point elevations of new piezometers were surveyed to a common datum. The completion data for the new piezometers is located in Table 3. Water level in the piezometers ranged from approximately 2.4 to 4.9 feet below ground surface.

TABLE 3. PIEZOMETER COMPLETION DATA

Site Name	Measuring Point Elev.	Ground Water Elev.	Well Total Depth	Screen Interval	Hydro-stratigraphic Unit	Year Drilled	Purpose
	(feet, amsl)		(feet)				
PZ-13	5637.579	5628.84	7.5	5-7.5	Alluvium	2017	Infiltration Test Monitoring
PZ-14	5625.956	5619.67	5.5	3-5.5	Alluvium	2017	Infiltration Test Monitoring
PZ-15	5614.711	5609.76	8.5	6-8.5	Alluvium	2017	Infiltration Test Monitoring

Water levels in each trench were measured manually and with pressure transducers (installed in stilling tubes). Each trench was allowed to fill, by maximum flow, to approximately 1.5 feet below ground surface, and then the flow was reduced to maintain constant head in the trench at steady-state. Water levels were continuously monitored to assess the rate of change in head at a specified flow rate. At the conclusion of the steady-state infiltration, the flow was shut off to the trench and water levels were recorded. Monitoring continued until water levels were recovered to within 10% of the initial water level.

RESULTS

Infiltration test field data indicate moderate variability within the Sheep Creek alluvial aquifer, with no apparent trend between the trenches of each area (Table 4). The total volume of water introduced to each trench ranged from approximately 2,000 gallons to 4,424 gallons. Estimating the steady state infiltration rate was limited due to the pump used to discharge from the water truck which could not discharge at rates lower than 10 gpm. Steady-state infiltration rates ranged from <10 gpm to approximately 33 gpm. The increase in head in each trench ranged from 2.2 feet to 3.4 feet, and the time required for water levels to recover to within 10% of background ranged from 4 to 83 hours.

TABLE 4. INFILTRATION TEST RESULTS SUMMARY

Trench ID	Total Volume (gallons)	Maximum Head (feet)	Steady State Flow (gpm)	Initial Recovery Time[1] (min)	Initial Infiltration Rate[2] (gpm)	Initial Infiltration Rate/Area[3] (gpm/ft^2)
1	3,792	2.87	20	48.5	19	0.7
2	2,800	2.9	NM[4]	38	24	1.1
3	3,432	3.4	NM[4]	109	8	0.3
4	2,006	2.38	<10	842	1	0.04
5	2,132	3.05	<10	142	5	0.3
6	2,717	2.93	<10	204.5	4	0.2
7	2,285	2.21	14	121	6	0.3
8	2,927	2.5	<10	237	5	0.2
9	4,424	2.89	33	29	26	1.1

1) Initial recovery time for 1 foot of recovery
2) Initial infiltration rate calculated based on the approximate dimensions of each trench and initial recovery time.
3) Initial infiltration rate per area is based on aerial area only (trench sides are not included).
4) NM: Not measured

DATA ANALYSIS

The falling head portion of the infiltration tests were used to determine the long-term effective infiltration rate at each trench. Transducer data collected from the infiltration pits were evaluated according to procedures developed by the USGS (USGS, 1963) and described by the USEPA (EPA, 2002) for a falling head test. The maximum water level in each infiltration trench was used as the initial head for each falling head test. The rate of infiltration was calculated based on the change in head at 5-minute time intervals for the first 200 minutes. Data collected after 200 minutes is too noisy for appropriate and meaningful analysis. This is likely due to the vertical gradient in the infiltration trench being much less than 1after the water levels have dropped in the infiltration trench. The effective infiltration rate was evaluated by plotting the rate of infiltration versus time. Attachment 1 shows the plots of the resulting infiltration rate versus elapsed time. The effective infiltration rate is evaluated at a 24-hour time period. A power function regression line was fitted to the data and extended out to a 24-hour period (1,440 minutes). The effective infiltration rate was determined by the intercept of the regression line at 1,440 minutes. The effective infiltration rate was used in the design of the infiltration galleries. The effective infiltration rates for each trench are summarized in Table 5.

TABLE 5. SUMMARY OF INFILTRATION TEST DATA

Trench	1	2	3	4	5	6	7	8	9	Median
Effective Infiltration Rate (ft/day)	2.07	3.14	0.75	0.19	2.08	3.04	2.60	1.75	2.44	2.08
Infiltration capacity (gpm/ft)	0.41	0.62	0.15	0.04	0.41	0.60	0.51	0.35	0.48	0.41

SUMMARY

Trench 3 and 4 show lower rates than the other seven trenches, which could be due to heterogeneities in the alluvial system or excessive sluffing of the topsoil into the trenches which could inhibit infiltration capacity of the trench. In general, the Sheep Creek alluvial aquifer exhibits moderate spatial variability though generally consistent infiltration rates for 7 of 9 trenches. The median infiltration rate is approximately 2 ft/day, representing an infiltration capacity per linear foot of trench of approximately 0.4 gpm/ft. At the median infiltration rate a minimum of about 1,400 feet is necessary to discharge the designed maximum discharge rate of the alluvial UIGs.

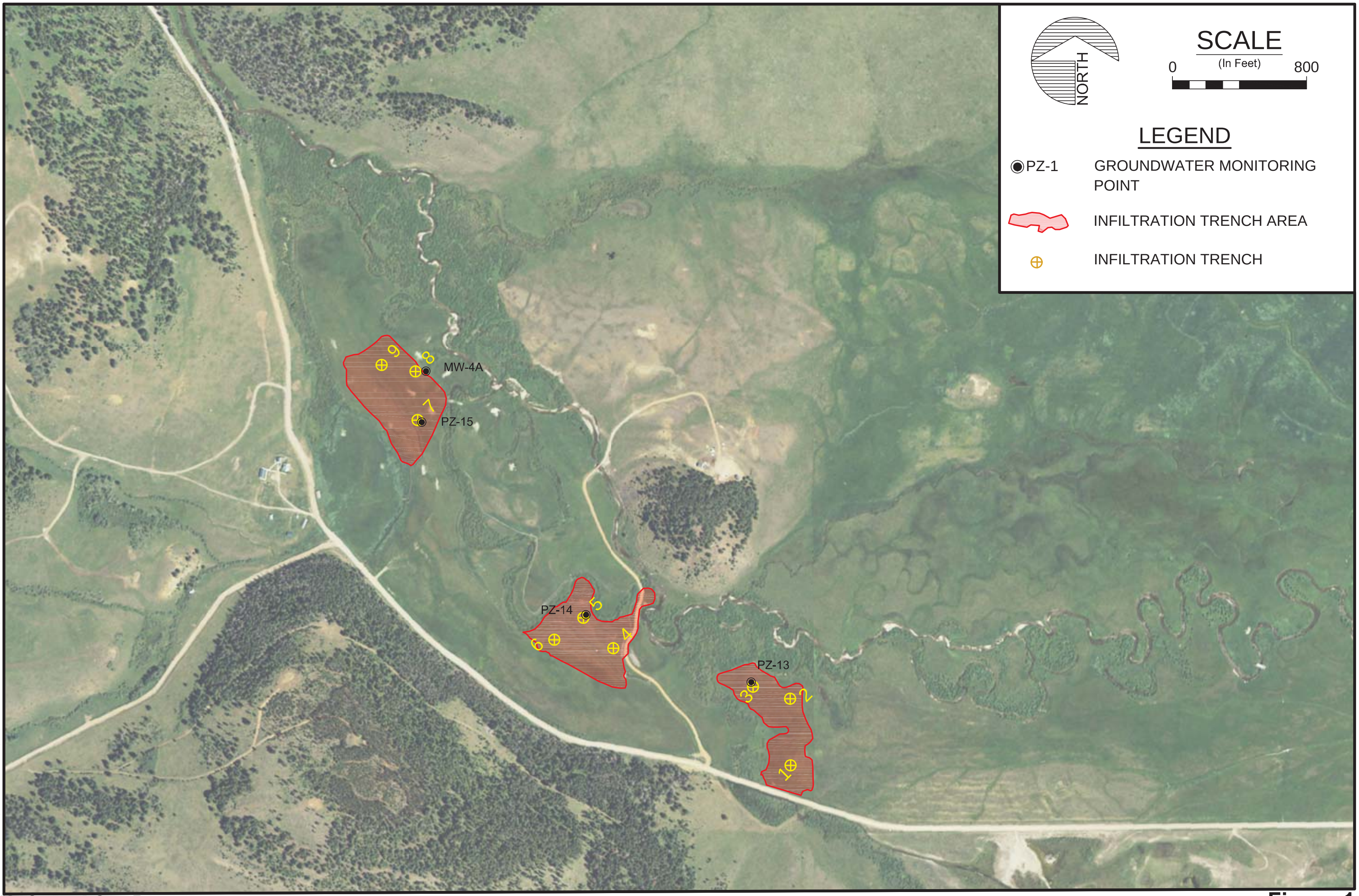

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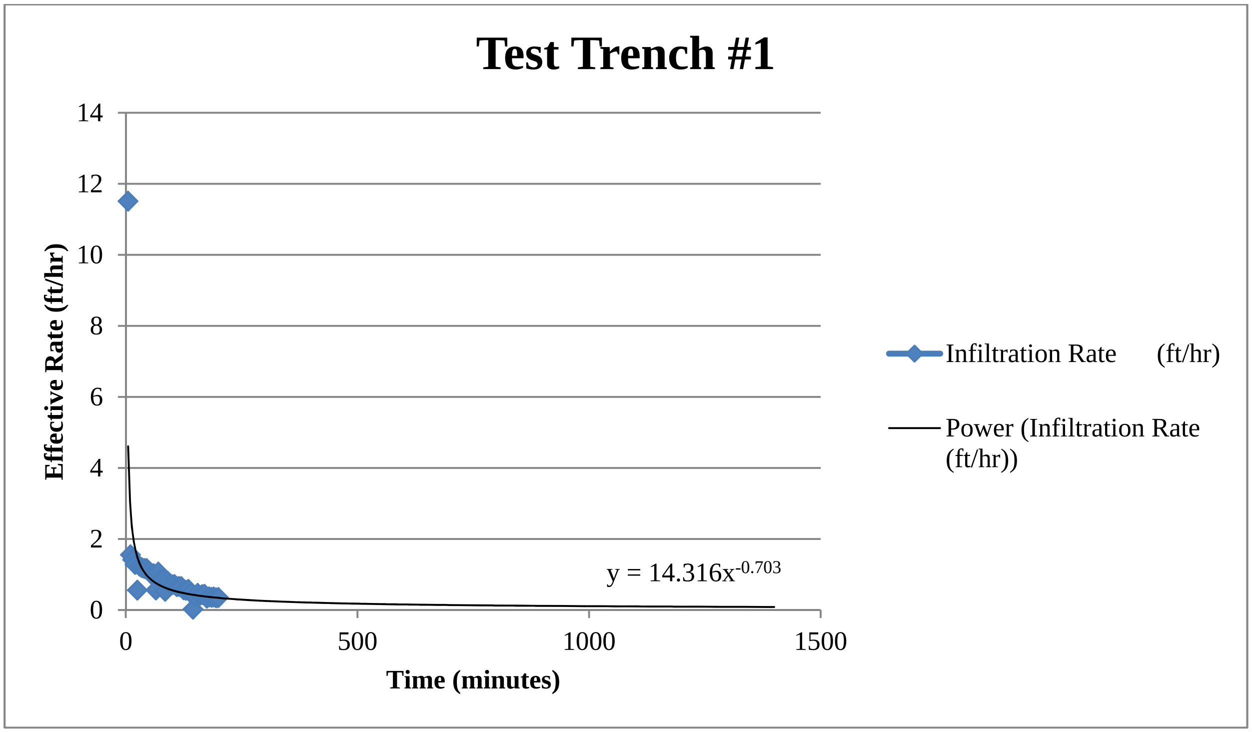
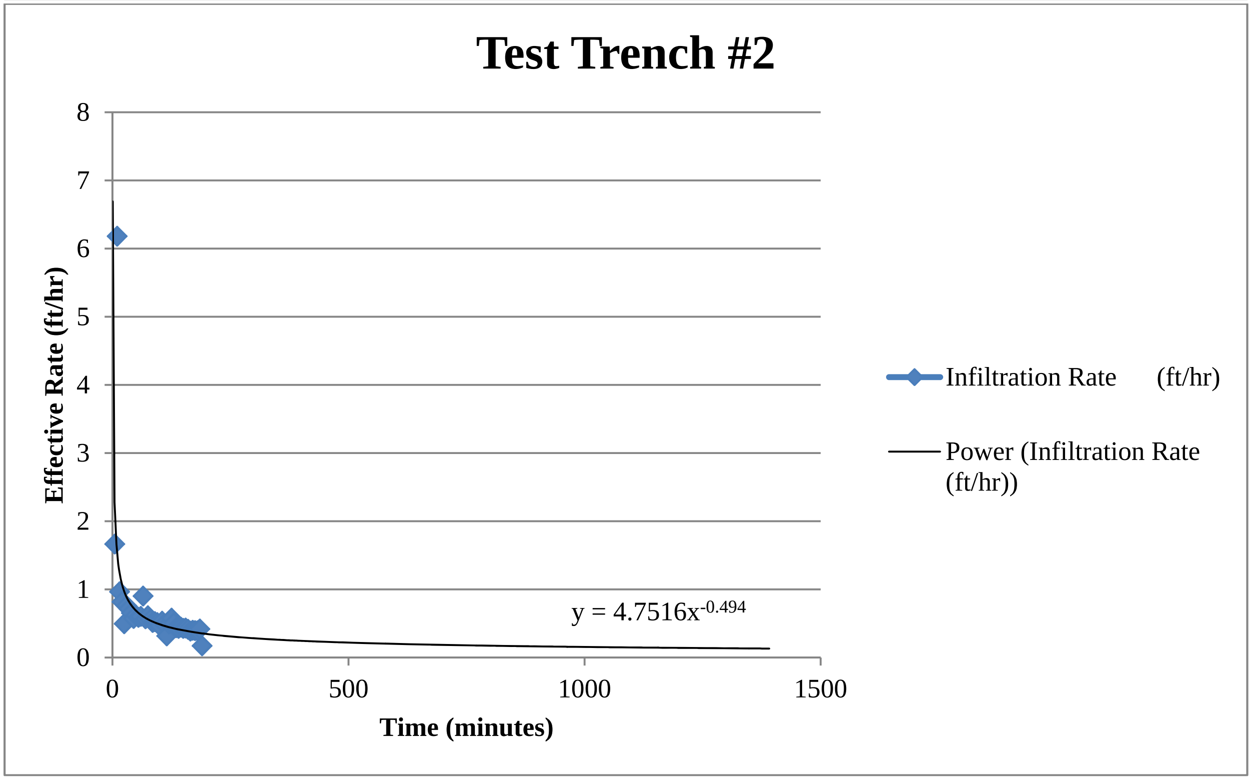
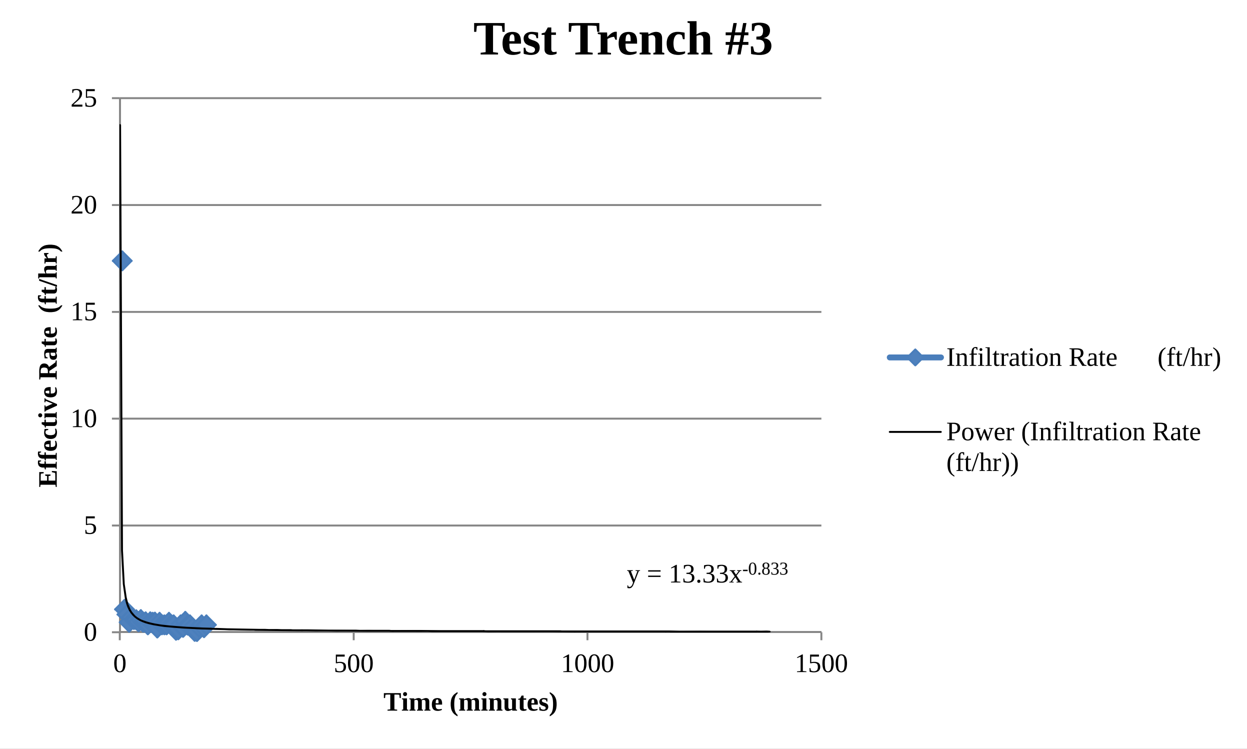
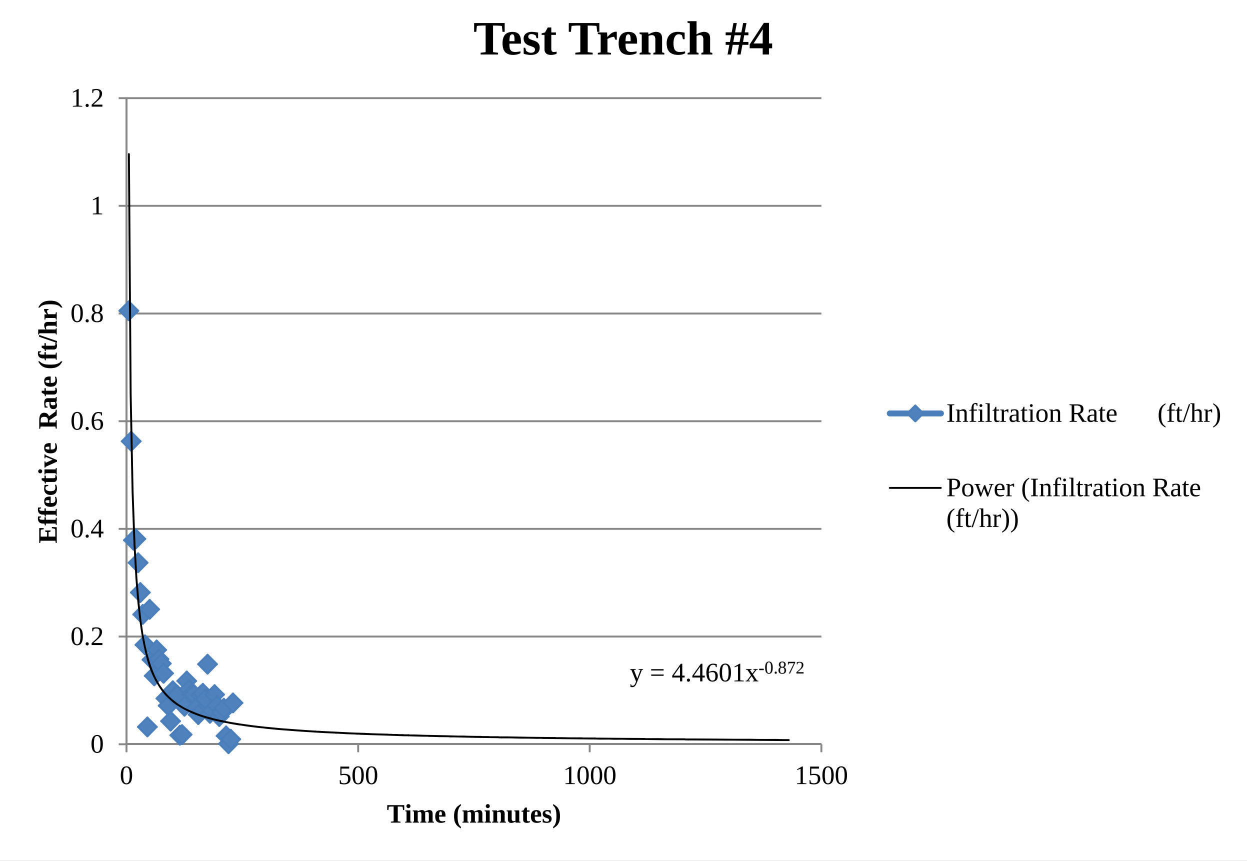
Figure 1
Infiltration Testing Layout
Black Butte Copper Project
Meagher County, Montana

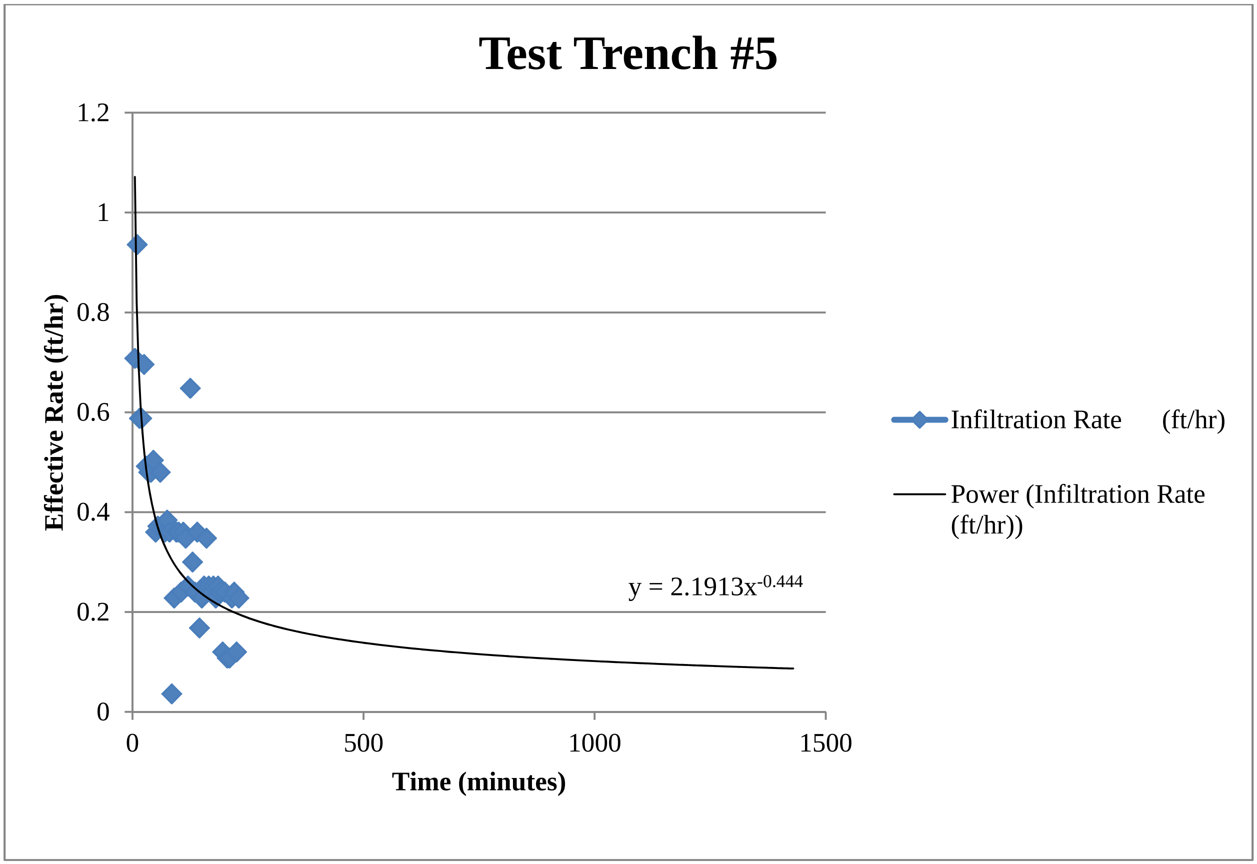
ATTACHMENT 1. INFILTRATION DATA ANALYSIS

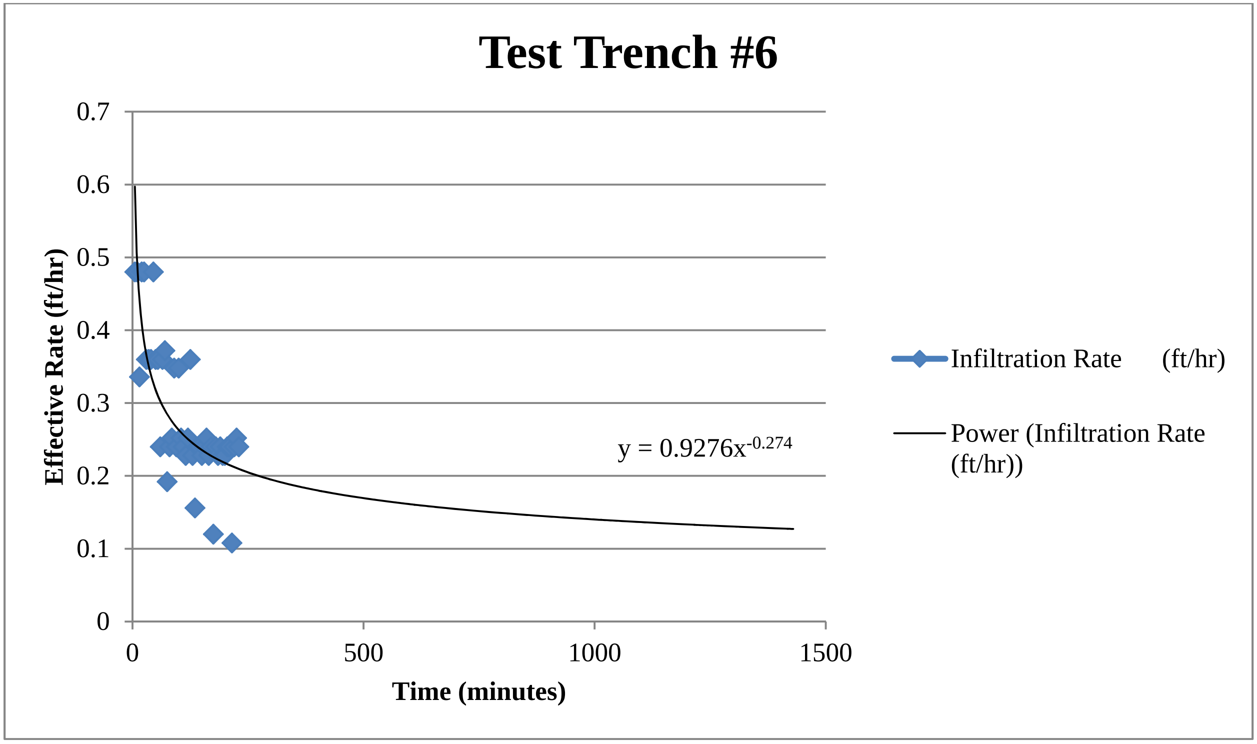


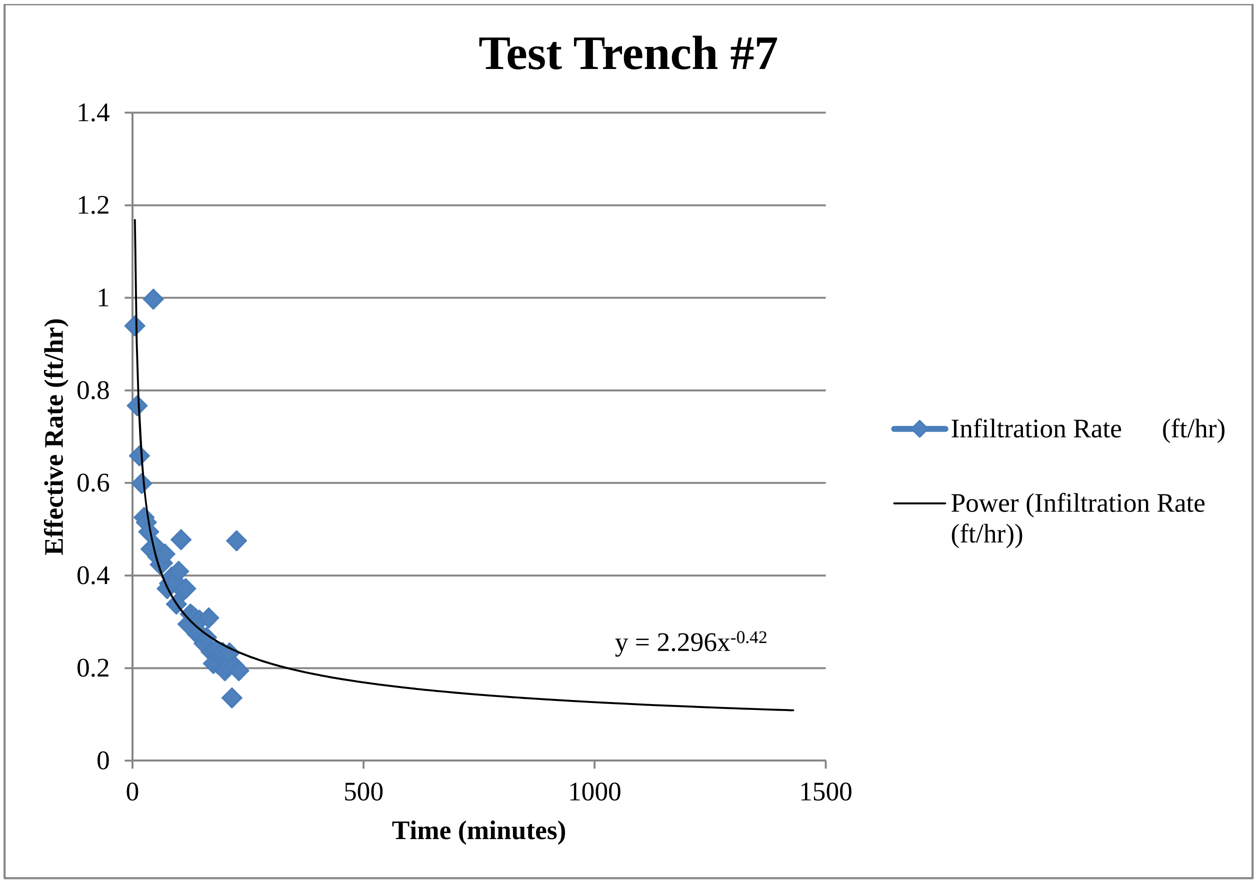


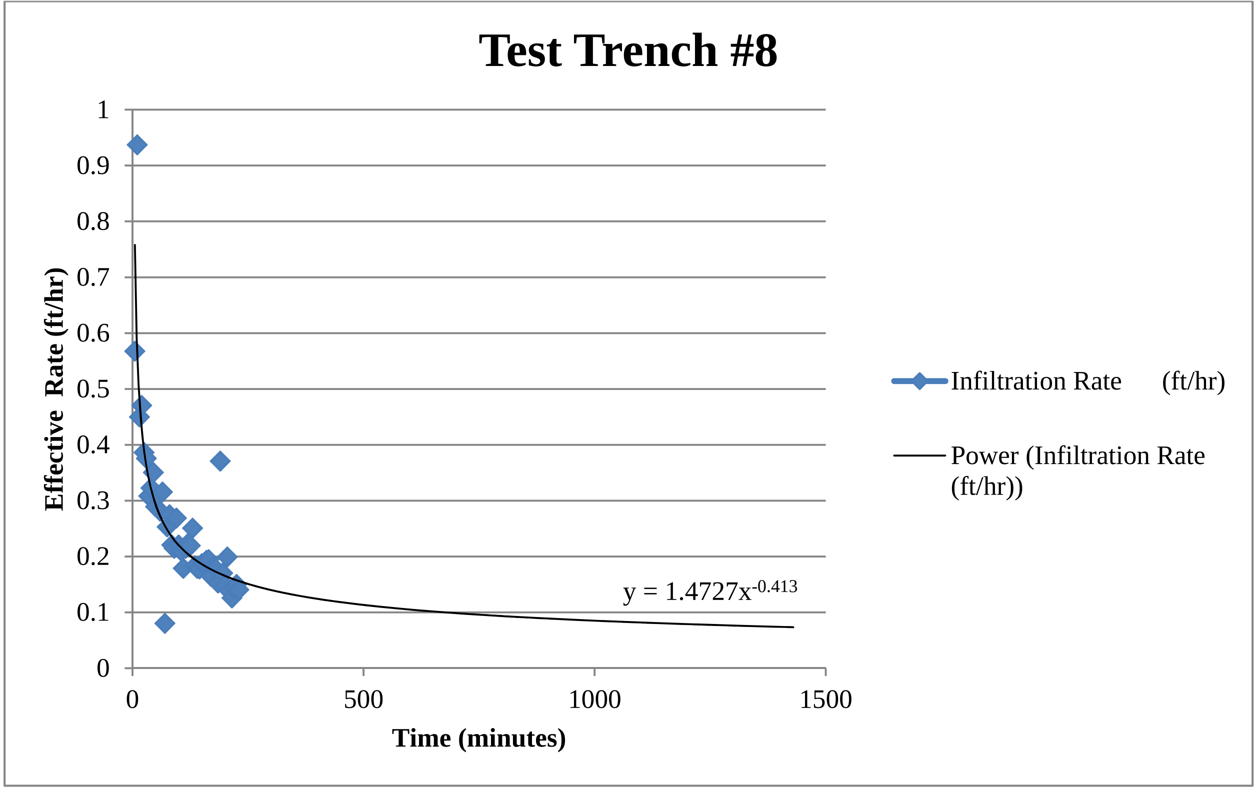

Test Trench #3
25
20
15
10
5
0
Effective Rate (ft/hr)
0
500
1000
1500
Time (minutes)
y = 13.33x^-0.833
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))


Test Trench #4
1.2
1
0.8
0.6
0.4
0.2
0
Effective Rate (ft/hr)
0
500
1000
1500
Time (minutes)
y = 4.4601x^-0.872
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))


Test Trench #5
Effective Rate (ft/hr)
1.2
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
Time (minutes)
y = 2.1913x^-0.444
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))


Test Trench #6
Effective Rate (ft/hr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
Time (minutes)
y = 0.9276x^-0.274
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))


Test Trench #7
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Effective Rate (ft/hr)
0
500
1000
1500
Time (minutes)
y = 2.296x^-0.42
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))


Test Trench #8
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Effective Rate (ft/hr)
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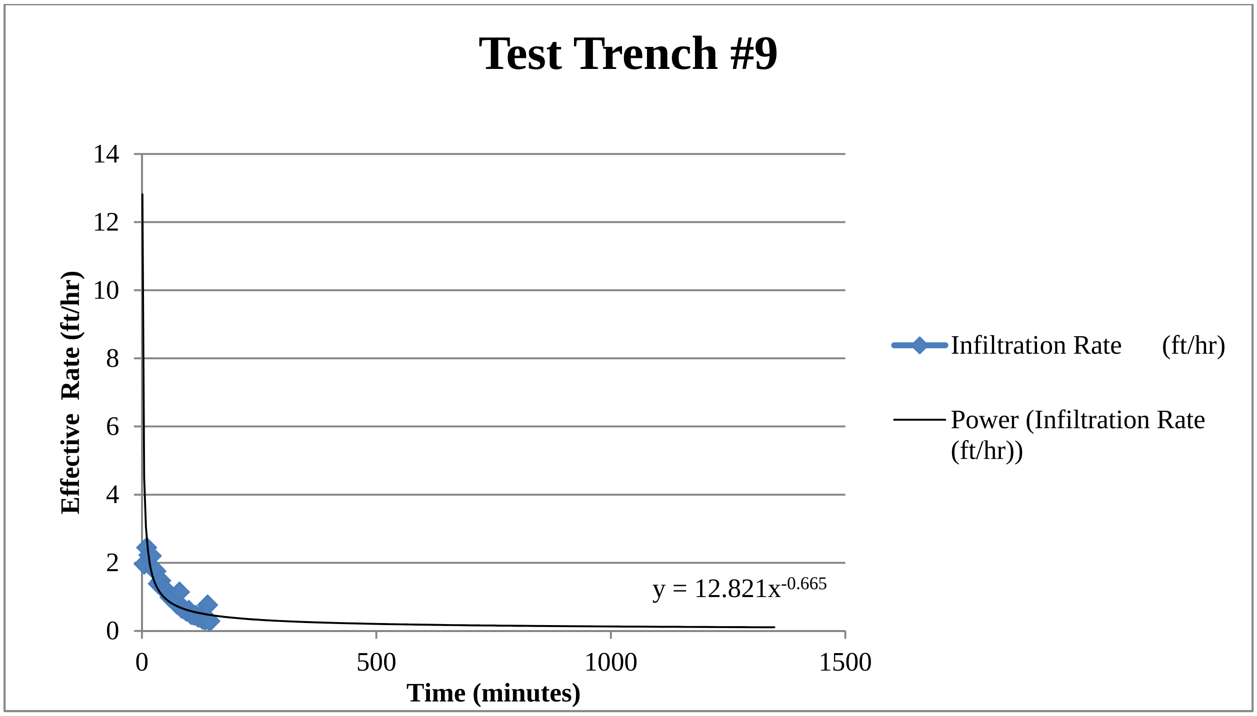
1000
1500
Time (minutes)
y = 1.4727x^-0.413
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))


Test Trench #9
Effective Rate (ft/hr)
14
12
10
8
6
4
2
0
0
500
1000
1500
Time (minutes)
y = 12.821x-0.665
Infiltration Rate (ft/hr)
Power (Infiltration Rate (ft/hr))

REFERENCES

United States Geological Survey, (USGS), 1963. A Field Method for Measurement of Infiltration; Geological Survey Water-Supply Paper 1544-F.

Environmental Protection Agency (EPA), 2002. Falling Head Percolation Test Procedure. Design Manual; Onsite Wastewater Treatment and Disposal Systems, EPA/625/1-80-012, pg. 41.

APPENDIX F

NUMERIC GROUNDWATER MODEL REPORT

SHEEP CREEK ALLUVIAL FLOW MODEL REPORT
BLACK BUTTE COPPER PROJECT
TINTINA MONTANA

Prepared for:

Tintina Montana, Inc.
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White Sulphur Springs, MT 59645

Prepared by:

Hydrometrics, Inc.
3020 Bozeman Avenue
Helena, MT 59601

December 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SHEEP CREEK ALLUVIAL FLOW MODEL REPORT
BLACK BUTTE COPPER PROJECT
TINTINA MONTANA

1.0 INTRODUCTION

Tintina Montana (Tintina) is in the process of permitting and subsequently developing an underground copper mine and milling facility known as the Black Butte Copper (BBC) Project. The BBC Project is located about 17 miles north of White Sulphur Springs, Montana. Tintina is proposing to discharge treated water to the Sheep Creek alluvial aquifer north of the proposed surface facilities through an underground infiltration gallery (UIG). Infiltration testing was conducted to evaluate the effective infiltration rate for the UIGs. The capacity of the alluvial system to receive and transport the discharged water is also dependent on the groundwater mounding resulting from the discharge. This numerical groundwater model was developed to simulate the groundwater flow and surface water interaction with the following objectives:

- Estimate the mounding associated with the alluvial UIG discharge;
- Provide data that could be combined with the dewatering simulations to evaluate where groundwater will discharge to surface water during operations; and
- Provide a tool to assess the alluvial system for potential future evaluations.

1.1 PREVIOUS MODELING

A regional three-dimensional numerical groundwater flow model was developed to project the dewatering rates of the underground workings at the BBC Project and evaluate the effects on water resources in the vicinity of the mine (Hydrometrics, 2016). This analysis incorporated both alluvial and bedrock aquifers and encompassed the middle third of the Sheep Creek watershed. The projected drawdown in the alluvial aquifer from the regional model provides data that can be used in conjunction with these modeling results to evaluate the groundwater flow within the alluvial system during operations.

1.2 MODEL SELECTION AND APPROACH

MODFLOW 2005 (Harbaugh, 2005) was selected to simulate groundwater flow as it provides an accurate and efficient solution for alluvial systems. The groundwater flow model was created using the graphical user interface software GMS (Ver. 10.2.3; Aquaveo, 2017) to facilitate model development and data processing. This model was selected because of its capability to simulate groundwater flow in heterogeneous aquifers and groundwater-surface water interaction.

2.0 CONCEPTUAL MODEL

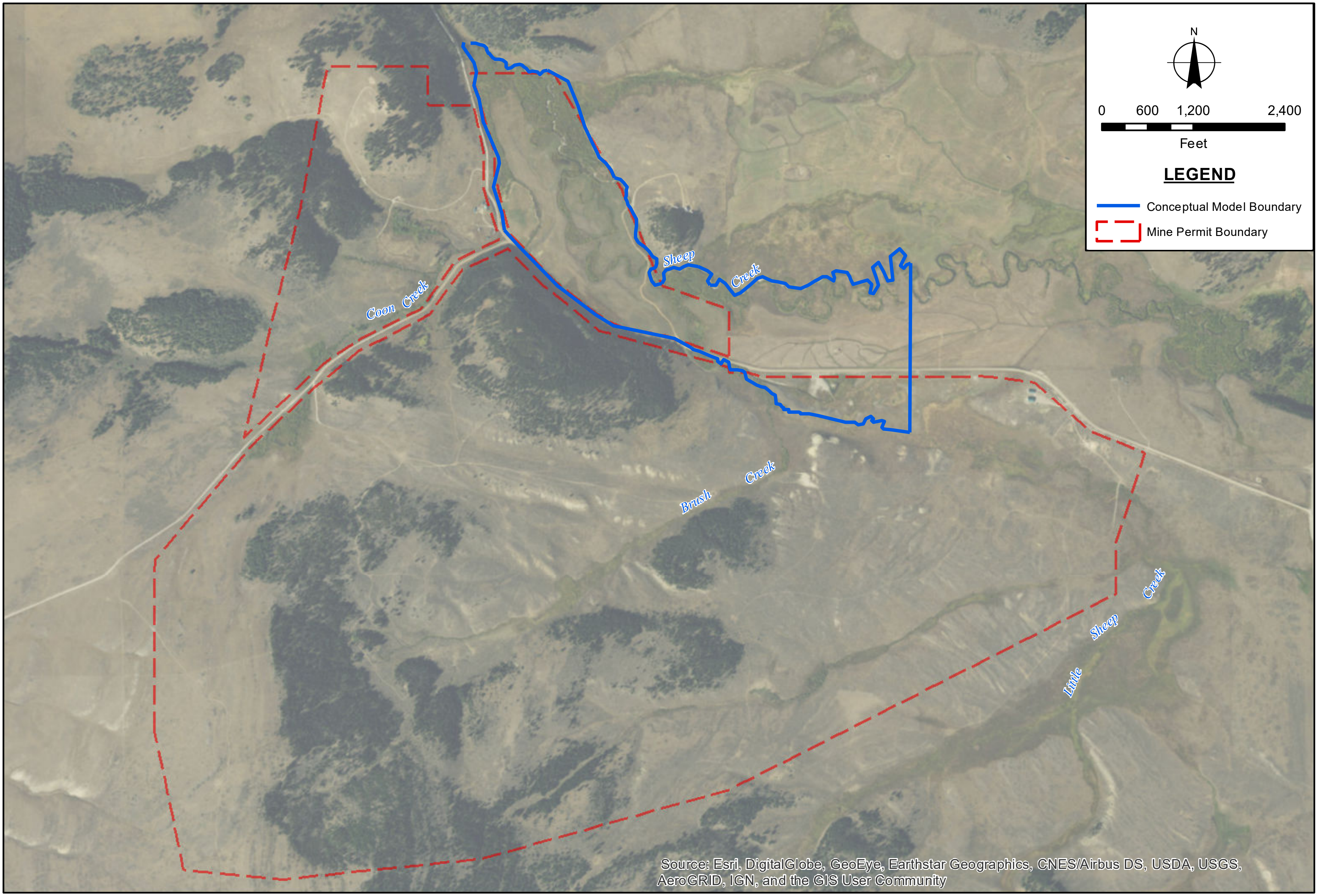
2.1 REGIONAL SETTING

The regional setting of the BBC Project is well documented in the Groundwater Modeling Assessment Report of the regional groundwater model (Hydrometrics, 2016). A brief discussion of the regional setting is included in this report to provide a general understanding of the area.

In the vicinity of the project, Sheep Creek flows from east to west and then shifts to the northwest adjacent to the project area. The project area lies on the southern side of Sheep Creek and is located 17.7 river miles from the head of the drainage and about 18 miles from the confluence with the Smith River (see Figure 2-1 of the regional model report). Numerous tributaries provide additional flow to Sheep Creek along its entire length. There are two tributaries (Little Sheep Creek and Coon Creek) to Sheep Creek in the Project area. Little Sheep Creek is located southeast of the project area. Coon Creek is located west of Sheep Creek and flows along the western edge of the alluvial valley adjacent to the Project area. Figure 2-1 shows the conceptual model area and surface water resources evaluated in the alluvial conceptual model.

2.2 HYDROGEOLOGIC SETTING

The BBC Project will target the Johnny Lee ore body, which is within the lower Newland Formation and lies between two northeast trending thrust faults, the Volcano Valley Fault (VVF) to the north and the Black Butte Fault to the south. The mine working are located to the east and more than 1,000 feet beneath the Sheep Creek Valley. The surface facilities for the mine are located south of the Sheep Creek Valley. The Sheep Creek Valley consists of a relatively thin package of alluvial sediments that consist of poorly sorted silty, sand and gravels in the upper 5-10 feet of the alluvial deposits. Coarser sand, gravel and cobbles are typically encountered below 10 feet to the base of the alluvial aquifer. The base of the aquifer is estimated to be 20 to 25 feet below ground surface (bgs). The alluvial sediments are pinched out by a narrow bedrock canyon north of the valley.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 2-1
Conceptual Model Area
Black Butte Copper Project
Meagher County, Montana

2.3 GROUNDWATER FLOW CONDITIONS

Groundwater is present at about 2 to 3 feet bgs throughout most of the valley with shallower depths to water as the valley is pinched out by the canyon. A detailed potentiometric map of the alluvial groundwater system was developed based on water levels measurements from November 7, 2017 and a survey of Sheep Creek and Coon Creek on November 8, 2017 (Figure 2-2). The potentiometric surface shows water generally flows parallel to Sheep Creek throughout most of the aquifer and discharges to Sheep Creek as the valley is pinched out to the north. The alluvial aquifer is recharged by Little Sheep Creek as it enters the valley in the upgradient portion of the conceptual model area. Coon Creek typically enters the alluvial valley after being diverted to the east of its natural channel.

The November 2017 potentiometric surface and the synoptic survey conducted in October 2012 indicate Coon Creek intercepts groundwater when it flows through the diverted channel. The diverted channel is much lower in elevation than the original channel of Coon Creek, which likely creates an artificial discharge point for the alluvial groundwater system. If Coon Creek flows in its natural channel it would likely discharge water to the alluvial groundwater system as the natural channel is about 10 feet higher in elevation than the diverted channel.

One monitoring well (MW-4A) and 10 piezometers are completed in the alluvial aquifer (Figure 2-2). Aquifer testing at well MW-4A indicates the alluvial material has a hydraulic conductivity of about 200 ft/day in the lower portion of the aquifer. This is consistent with the literature values for coarse sand aquifers (30 to 300 ft/day; Fetter 2001). It is likely that there are vertical and horizontal heterogeneities throughout the alluvial aquifer. However, the observed lithology from drilling MW-4A and trench excavations suggest the hydraulic conductivity near MW-4A is likely representative of the average permeability of the alluvial aquifer. Typical specific yields for coarse grained alluvial aquifers range from 0.13 to 0.44 (Freeze and Cherry, 1979).

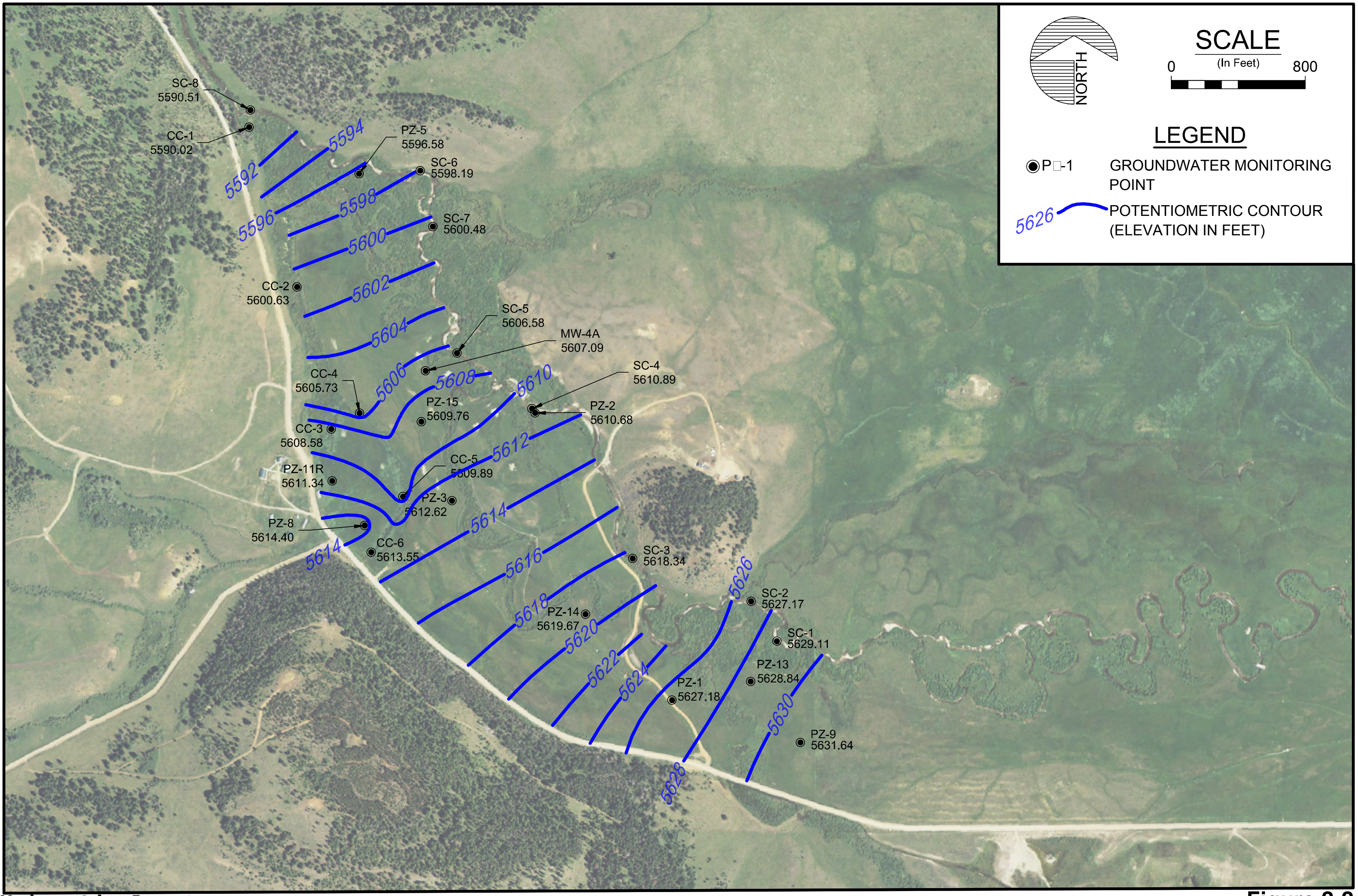

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Figure 2-2
November 2017 Potentiometric Surface
Black Butte Copper Project
Meagher County, Montana

During operations, the mine working will be dewatered by collecting water that enters the mine workings in a series of sumps along the declines and drifts used to access the orebodies. The dewatering model, discussed in Section 1.1, simulated that the mine dewatering would cause about 1 to 10 feet of drawdown in the alluvial system. The greatest drawdown was simulated on the western edge of the alluvium with it decreasing to the west as it approached Sheep Creek. Drawdown during active dewatering will likely result in changes to the groundwater-surface water interaction within the alluvial aquifer. With 10 feet of drawdown in the vicinity of Coon Creek, the groundwater will not discharge to the diverted channel of Coon Creek during operations. Without additional recharge to the alluvial system the dewatering model suggests streams adjacent to the mine will be depleted by 177 gpm.

Water collected in the underground sumps will be pumped to surface where it will be used in the milling process or diverted to the water treatment plant (double pass Reverse Osmosis system). Tintina proposes to discharge the treated water to the Sheep Creek alluvial UIG as shown on Figure 2-3. The average discharge rate is estimated to be 398 gpm with a design maximum discharge rate of 575 gpm.

2.4 GROUNDWATER RECHARGE

In addition to surface water recharging the aquifer within the alluvial valley, the alluvial aquifer also receives some recharge from direct infiltration of precipitation (rain and snowmelt). An analysis of the average Sheep Creek Hydrograph at USGS gaging station #6077000 shows the steady state base flows (November to March) in Sheep Creek account for approximately 10% of the precipitation in the watershed (Hydrometrics, 2016). The average precipitation in the vicinity of the alluvial aquifer is 18 in/yr; resulting in an infiltration rate of about 1.8 in/yr. This accounts for approximately 22 gpm of recharge across the conceptual model domain.

2.5 GROUNDWATER FLUX

Groundwater flows into the conceptual model domain through the upgradient alluvial system and to a lesser degree from Coon Creek alluvium and surrounding bedrock. The

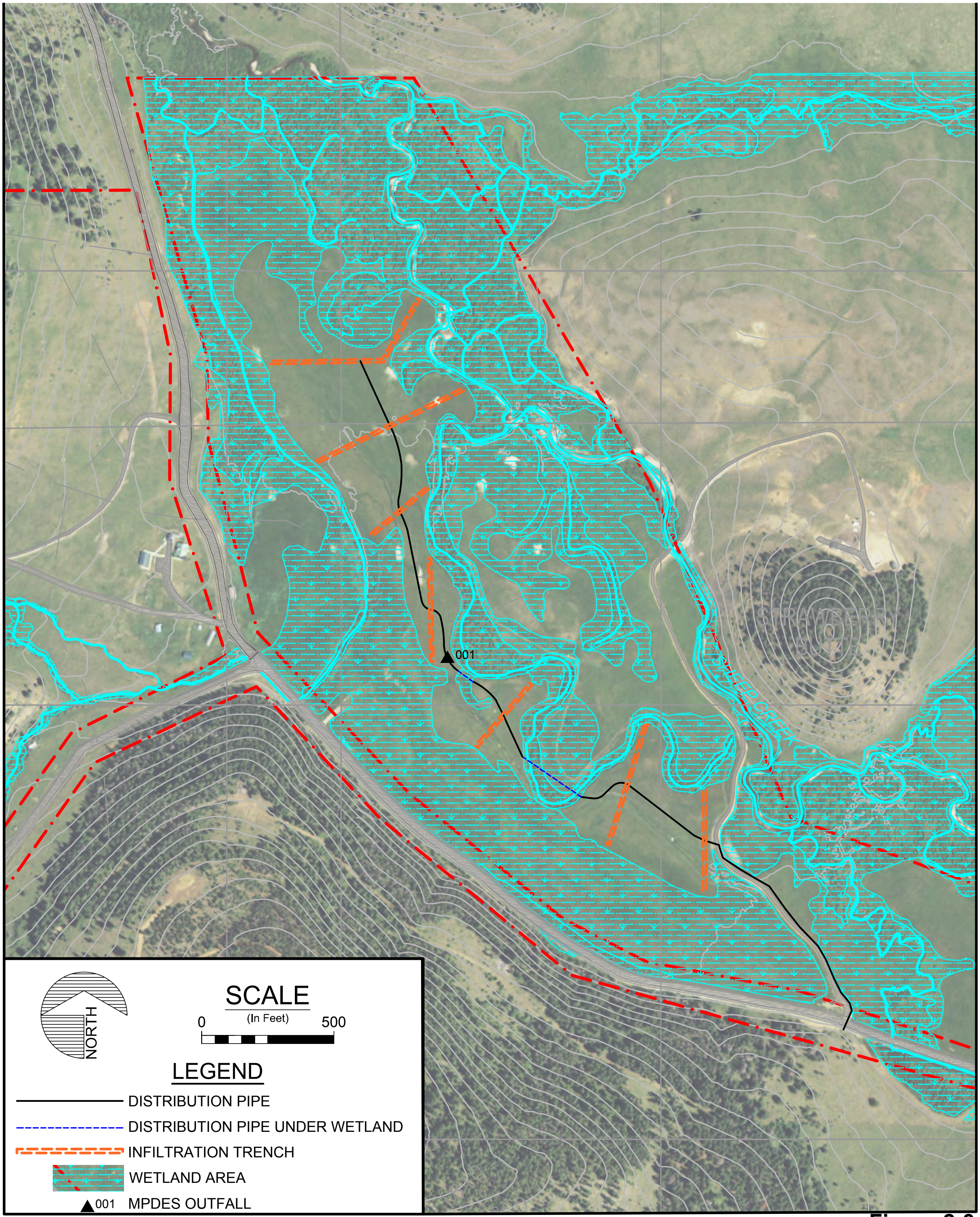

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Figure 2-3
Alluvial Underground Infiltration Gallery
Black Butte Copper Project
Meagher County, Montana

groundwater flux flowing through the middle of the model domain was estimated based on Darcy's Law (Q=KAi). The aquifer parameters and resultant flow for the groundwater system is summarized in Table 2-1.

TABLE 2-1. GROUNDWATER FLUX CALCULATIONS

Parameter	SC Alluvium UIGs
Hydraulic Conductivity (ft/d)	200
Thickness (ft)	15 - 20
Width (ft)	1420
Gradient	0.008
Groundwater Flux (gpm)	177 - 208

3.0 MODEL DESIGN

3.1 MODEL DOMAIN

The groundwater flow model encompasses the Sheep Creek valley from about 3,300 east of the confluence of Little Sheep Creek and Sheep Creek to where Sheep Creek enters the canyon (Figure 3-1). The southern boundary is coincident with Little Sheep Creek on the eastern end of the model and then along the alluvial and bedrock contact after Little Sheep Creek crosses the valley. The western boundary of the model continues along the alluvial contact with bedrock. The northern and northeastern boundary of the model is coincident with Sheep Creek except where Sheep Creek flows into the valley. The contact between the alluvial valley and bedrock is used as the northeastern boundary when Sheep Creek does not flow along the edge of the valley. The downgradient boundary (north/northwest) is located where the alluvial material pinches out as Sheep Creek enters the canyon to the north. The top of the model is set within 1-5 feet of the water table. The base of the model is about 25 feet below the top of the water table from the eastern boundary to approximately where Coon Creek enters the valley. The base of the model ranges between 20 feet (near Coon Creek) to 15 feet at the downgradient end of the model. The model was set within GMS using imperial units of feet and days in UTM coordinate system (UTM, Zone: 12N, NAD83, feet).

The model domain is divided into four layers and discretized with a structured grid into about 45,000 cells. The cells are uniform across the model domain with each cell being approximately 30 feet x 30 feet. The layers in the model range from approximately 3 feet to 10 feet thick.

3.2 BOUNDARY CONDITIONS

No flow boundaries are used to represent the contact between the alluvial sediments and bedrock. No flow boundaries were used in layers 1 through 4 for the western boundary, southwestern boundary downgradient of Little Sheep Creek, and northeastern boundary where Sheep Creek enters the middle of the valley for approximately 1,400 feet. A constant head boundary was used in layers 1 through 4 to simulate flow into the model from the

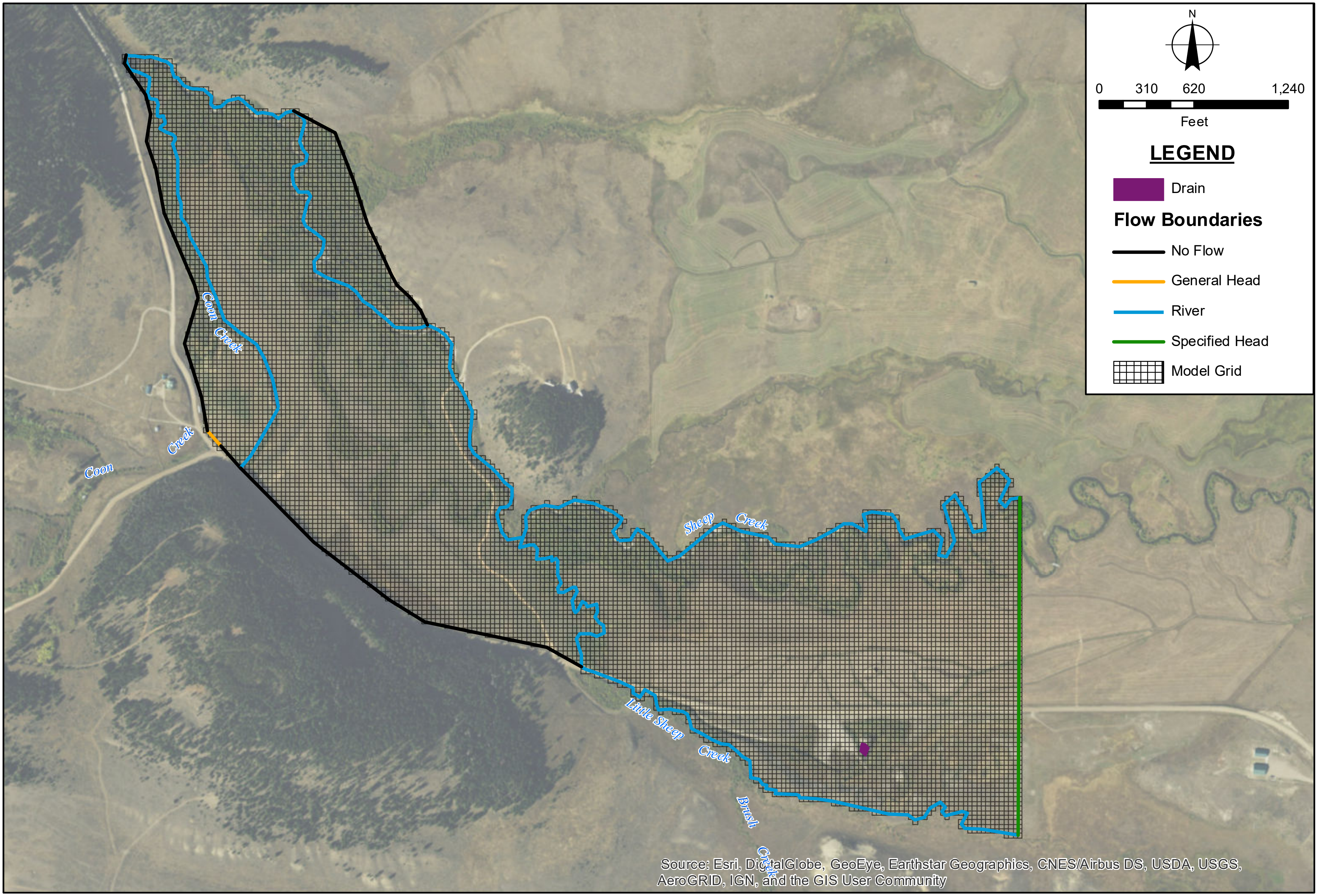

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Figure 3-1
Model Layout and Boundary Conditions
Black Butte Copper Project
Meagher County, Montana

upgradient alluvial aquifer. River boundaries were used in layers 1 through 3 to simulate Sheep Creek as it flows along the northern portion of the model domain; no flow boundaries are used in layer 4 as it is assumed that Sheep Creek is only in direct connection with the upper 3 layers. River boundaries were used in layers 1 and 2 to simulate Little Sheep Creek on the southern domain and the creek crosses the alluvial valley and Coon Creek within the model domain. Layers 3 and 4 on the southern portion of the model are simulated as no flow boundaries. A general head boundary (GHB) is used to simulate groundwater flow from the Coon Creek drainage. Parameterization of the boundaries used in the model is discussed below.

Constant head boundaries are assigned a head value in the model and the flow into the model is calculated by the model based on internal head conditions. The constant heads assigned to the eastern edge of the model were based on the estimated water elevation of Sheep Creek and Little Sheep Creek (5648 feet) at the boundary.

The GHB used to simulate Coon Creek groundwater flow are assigned head values and conductance values, which are used to calculate the groundwater flux at the model boundary based on fixed conditions at a more distant head. The heads assigned to the GHB near Coon Creek were estimated based on the approximate elevation of Coon Creek (5,626 feet) at about 250 feet upgradient of the GHB. The conductance for the GHB is calculated based on the following equation:

$$C_{GHB} = \frac{T*W}{b*D}$$

where:

C = Conductance (ft^2/day);

T = Transmissivity (ft^2/day);

W = width (ft);

b = thickness (ft); and

D = Distance between model boundary and reference head (ft).

In GMS, the model calculates the width of the boundary that intersects a cell; therefore, the initial conductance assigned to the boundary in GMS was calculated based on the hydraulic conductivity of the material (20 ft/day, estimate) times the total length of the boundary (134 feet), divided by the distance to the reference head (250 feet). The conductance was adjusted to a final value of 10 ft/day during model calibration until the heads at observation sites and estimated flows from the boundary were within the calibration targets.

The river boundaries are used to simulate groundwater and surface water interaction within the Sheep Creek Valley. Figure 3-1 shows the river boundaries used in the model. Interaction between groundwater and surface water within the model is based on the difference in head within the model and the stream stage, and the conductance of the streambed. The streambed conductance is calculated based on the following equation:

$$C_{Riv} = \frac{K_v * L * W}{b}$$

where:

C_{Riv} = Conductance of stream bed (ft^2/day);
K_v = Vertical conductivity of streambed (ft/day);
W = width of stream (ft);
b = streambed thickness (ft); and
L = River length (calculated by GMS; ft).

The river conductance was set arbitrarily high for Sheep Creek to assure it does not limit the interaction between the river and the groundwater. This was done as it is assumed that Sheep Creek is the dominant boundary of the groundwater system. The river conductance assigned to Little Sheep Creek along the southern boundary and Coon Creek in GMS were based on an assumed K_v of 1 ft/day, widths ranging between 3 to 10 feet, and a streambed thickness of 1 foot. The riverbed conductance assigned to Little Sheep Creek was increased to 200 ft/day as it crosses the alluvial valley as both the width of the river the riverbed K_v are assumed to be much larger in this area. River stage were set based on the surveyed stage from November 2017 for Sheep Creek and Coon Creek and estimated stages (based on topographic maps and general stream gradients) for Little Sheep Creek and the upgradient portion of Sheep Creek. The riverbed conductance used in the map module for each river reach were adjusted during model calibration until heads and groundwater and surface water fluxes were within the calibration targets.

Drain cells were used to simulate groundwater discharge from a former gravel pit between Little Sheep Creek and Sheep Creek in the upgradient portion of the model. The Drain cells are similar to a GHB and river boundary as they use a difference in head and an assigned conductance value to simulate the flow out of the model to the drains. However, drain cells only remove water from the groundwater system as the drains turn off if the water level drops below the drain elevation. The drains used to simulate the gravel pit outfall were assigned using a polygon within GMS. The drain was assigned an elevation of 5,640 feet, and an initial conductance of 5,000 ft^2/day per area of the polygon of the drain in GMS. The conductance applied in GMS is then multiplied by the area of the drain within each cell in MODFLOW. The conductance value was lowered during model calibration until the flux leaving through the drain was similar to that observed in the field during low flow (45 to 90 gpm). The final conductance applied to the GMS conceptual model was 3280 ft^2/day per ft^2 of the polygon.

Specified flow boundaries were used in the mounding analysis to simulate the underground infiltration galleries (Figure 3-2). Line specified head boundaries were setup in the conceptual model within GMS for each arm of the alluvial UIG. A total of 3,140 feet of UIG is located within the alluvial valley. A discharge rate of 0.18 gpm per linear foot (total flow 575 gpm) of UIG was applied to each arm.

3.3 FLOW MODEL INPUT VARIABLES

Model input variables for the flow model are assigned to each cell and consist of hydraulic conductivity, anisotropy (horizontal and vertical), specific storage, specific yield, and recharge. The input parameters used in the flow model are discussed below.

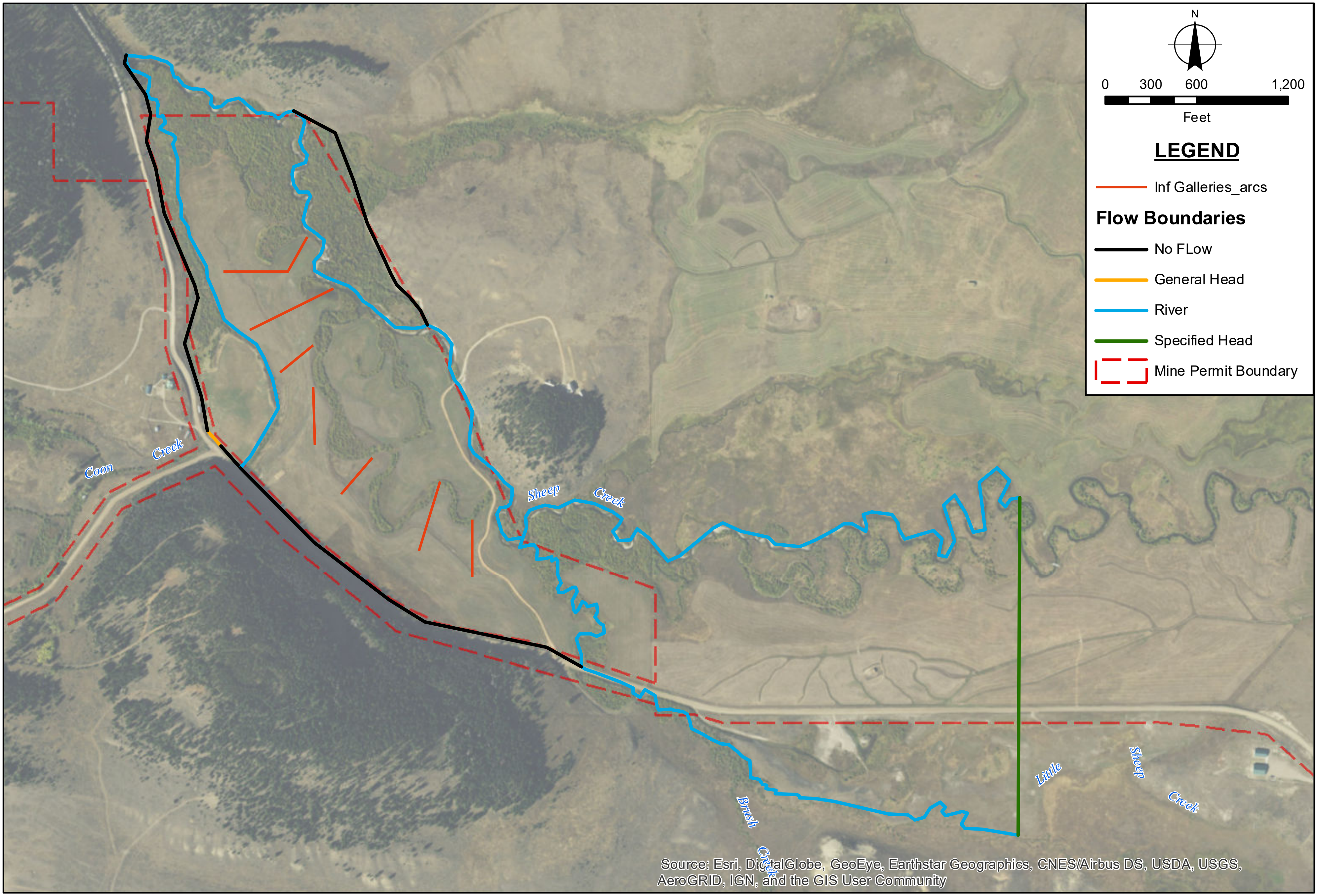

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Figure 3-2
Simulated Infiltration Galleries
Black Butte Copper Project
Meagher County, Montana

Recharge Rate

Areal recharge was used to simulate infiltration of direct precipitation and snowmelt to groundwater. Due to the small area of the model domain, a uniform recharge was assigned to the model domain. The model was calibrated to November 2017 water level data; therefore, a recharge rate of 10% of precipitation (1.8 in/yr) was applied to the model domain. The recharge accounts for approximately 20% of the flow.

Aquifer Properties

The model was assigned aquifer properties based on aquifer testing and lithology observations in trenches within the valley. One aquifer test was conducted at well MW-4A; which is located in lower portion of the aquifer. Based on the aquifer test data (see Section 2.2) layers 3 and 4 were assigned an initial hydraulic conductivity of 200 ft/day. Lithology observations indicate the shallower material has more fine grained sand and silt than in the lower portion of the aquifer. The initial hydraulic conductivity applied to layer 1 of the aquifer was set at 50 ft/day to account for the higher content of finer grained material. Layer 3 was assigned an initial hydraulic conductivity of 100 ft/day as it is assumed to be a transition layer between layers 1 and 3. Although there are likely some horizontal heterogeneities within the alluvial aquifer; the use of average hydraulic conductivities is appropriate for a groundwater flow model in this setting. Vertical hydraulic conductivities were assigned assumed to be 1/5 of the horizontal hydraulic conductivities throughout the model. The hydraulic conductivities were adjusted slightly during model calibration until the simulated heads and flux between groundwater/surface water were within the calibration targets. Model calibration and mounding simulations were both evaluated at steady state conditions; therefore, storage coefficients were not used in the modeling analysis. The final aquifer properties assigned to the model are summarized in Table 3-1.

TABLE 3-1. SUMMARY OF HYDROLOGIC PROPERTIES

Layer	Hydraulic Conductivity (ft/day)	Vertical Anisotropy
1	75	5
2	150	10
3	210	10
4	210	10

4.0 MODEL CALIBRATION

The flow model was calibrated to pre-determined calibration targets based on the observed heads and groundwater-surface water interactions. Head calibration targets were based on the well and piezometers completed in the alluvial valley. Calibration of flow between groundwater and surface water was based on observed and assumed discharge rates based on the assumption that all the groundwater discharges to Sheep Creek at the downgradient end of the model. A manual calibration process was conducted by adjusting the model parameters within established ranges from aquifer test data and literature values to optimize the degree to which the model simulations match observed data. The calibration targets for the steady state flow model and the transport model are as follows:

- Simulated Heads – within 1.5 feet of the observed heads (<5% of the change in head across the model domain) and Mean Absolute Error ≤ 1.5 feet;
- Groundwater-Surface Water Interaction – within 20% of observed flux;
- Groundwater flux within estimated range; and
- Match general flow direction and gradient.

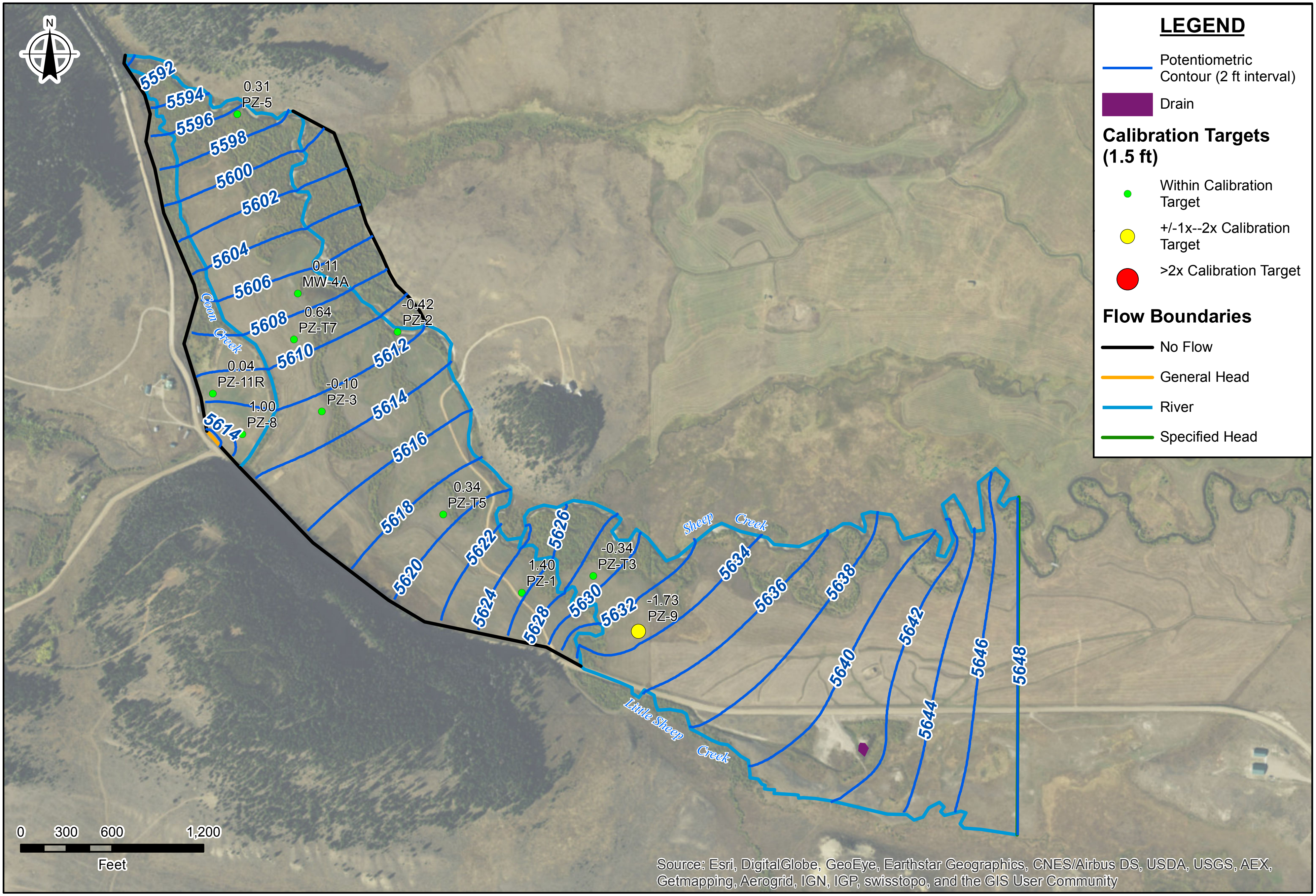
The final flow model was calibrated to groundwater flow parameters as discussed in Sections 4.1.

4.1 FLOW CALIBRATION

The steady state flow model was calibrated to November 7, 2017 water level elevations from 11 observation sites. Calibration of groundwater-surface water interaction on Coon Creek was evaluated based on the October 2012 synoptic survey on Coon Creek. Synoptic surveys conducted on Sheep Creek were not able to quantify the flow between the groundwater and Sheep Creek as the change in flow from the confluence of Little Sheep Creek to the head of the canyon were less than the measurement error (Hydrometrics, 2017). Therefore, the estimated groundwater flux (177 to 208 gpm) was used to calibrate the groundwater discharge to Sheep Creek. The calibration of the steady state flow model is evaluated based on qualitative and quantitative analyses.

The qualitative analysis consisted of an evaluation of the general flow direction and hydraulic gradients in the observed versus the simulated potentiometric surfaces. The simulated steady state potentiometric surface compares well to the potentiometric surface developed from the onsite observation sites. The simulated potentiometric surface correctly indicates that groundwater flow directions are generally parallel to or slightly towards Sheep Creek throughout the valley (Figure 4-1). As seen in the observed potentiometric map, there are some discrete flow paths in the vicinity of where Little Sheep Creek and Coon Creek enters the valley. Water levels show groundwater flow directions away from Little Sheep Creek as it enters the valley; indicating Little Sheep Creek is recharging the groundwater system in this area. The simulated potentiometric map in the vicinity of Coon Creek shows groundwater conditions as the observed potentiometric surface with groundwater flow toward the diverted portion of the stream as it enters the valley. In the downgradient end of the model, groundwater discharges to Sheep Creek approximately 3,000 to 3,500 feet along Sheep Creek prior to entering the canyon.

The residual heads (observed heads minus simulated heads) for each observation site are shown in Figure 4-1. Sites with green symbols indicate the residual head is within the calibration target. Yellow symbols indicate the residual heads are 1 to 2 times greater than the calibration target. There were not any residual heads greater than 2 times the calibration target. The steady state simulated heads at 10 of the 11 observation sites were within the calibration target ($^{+}$/-1.5 feet). The residual at piezometer PZ-9 was about 1.7 feet. Observation sites within the area of the proposed alluvial UIG matched very well to the observed heads; with only one site (PZ-1) having a residual greater than $^{+}$/-1 foot. The remaining observation sites in the vicinity of the proposed alluvial UIG had residuals between $^{+}$/-0.1 and $^{+}$/-0.6 feet. Figure 4-2 shows the observed versus simulated heads for each observation point. The graph shows that as a whole, the observation sites are distributed on either side of the 1:1 correlation line with no evidence of distribution bias throughout the range of water levels.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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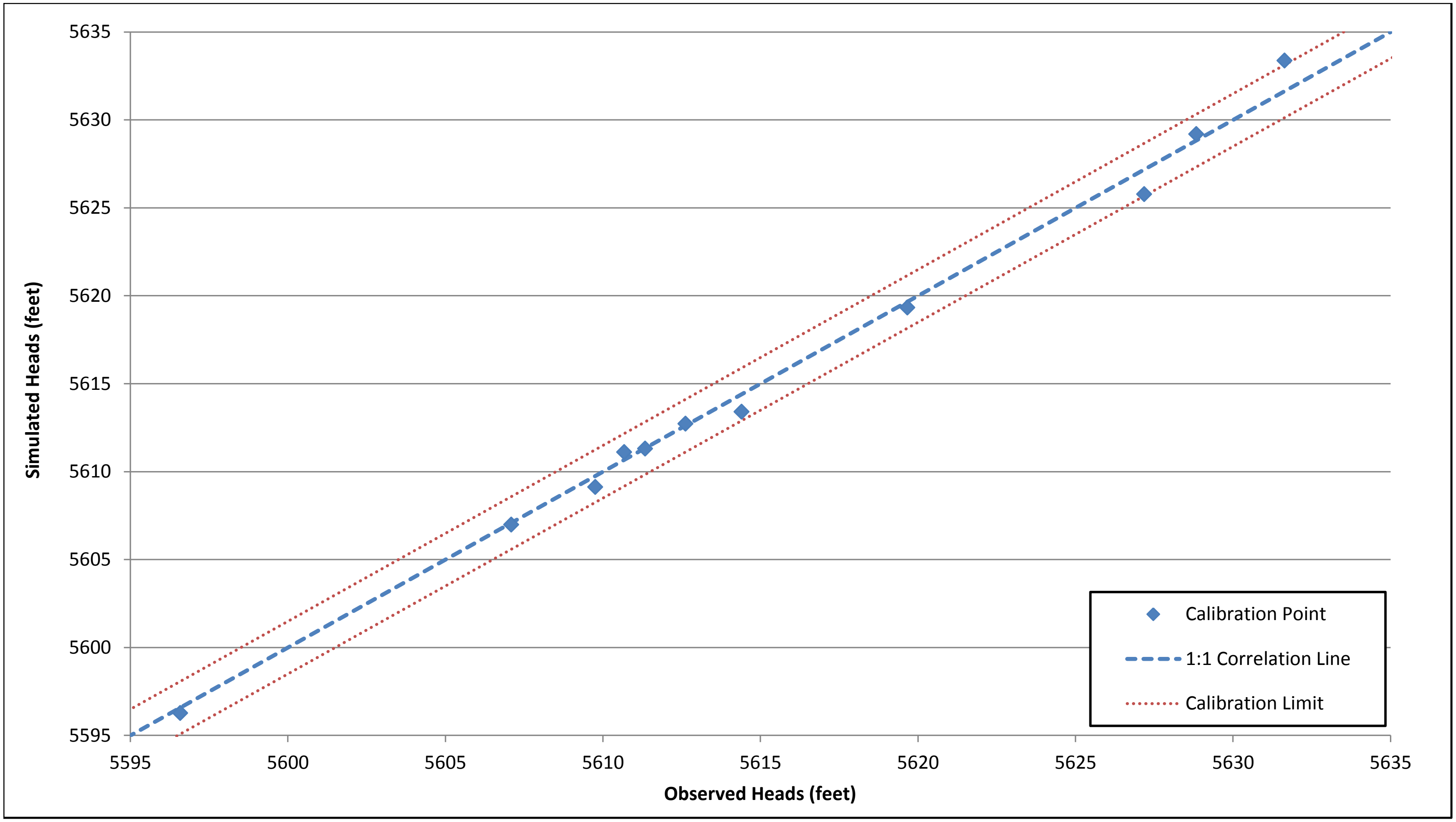
Figure 4-1
Calibrated Potentiometric Surface and Residuals
Black Butte Copper Project
Meagher County, Montana



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Consulting Scientists and Engineers

Figure 4-2

Observed Versus Simulated Heads

Black Butte Copper Project
Meagher County, Montana

Statistical analyses of the residual heads at the observation points were performed to further evaluate the steady state model calibration. The statistical evaluation indicate a mean absolute error (MAE) of 0.58, which is well within the calibration target (≤1.5 feet). Although the root mean squared error (RMSE) is not identified as a target for calibration, it is provided as a comparison to the MAE. The RMSE can be affected by outlier residuals and is typically higher than the MAE (Anderson et al., 2015). A RMSE of 0.79 feet for all of the observation points is similar to the MAE, which indicates there are no significant outlier residuals in the dataset.

A comparison of simulated and observed interaction of groundwater and surface water provides another conventional calibration metric. The model was calibrated to the groundwater-surface water interaction observed during November 2017 on Coon Creek and the estimated groundwater flux for Sheep Creek as it is assumed that all groundwater discharges to Sheep Creek. Table 4-1 summarizes the simulated versus observed groundwater-surface water interaction. Although the interaction between Little Sheep Creek and the groundwater system has not been quantified in the field the simulated data is provided in Table 4-1. The groundwater discharge to Coon Creek was slightly larger than the observed discharge; however, it was within the calibration target. Discharge to Sheep Creek was slightly less than the estimated discharge and slightly exceeded the calibration target with the percent difference being -21%. This difference is likely attributable to Coon Creek removing more water from the groundwater system than observed leaving less water to discharge to Sheep Creek at the downgradient end of the model. Little Sheep Creek lost about 80 gpm from where it crosses the valley to its confluence with Sheep Creek. This is a reasonable quantity of water for a stream of its size to lose in this setting.

TABLE 4-1. SIMULATED VERSUS OBSERVED GROUNDWATER-SURFACE WATER INTERACTION

Stream Reach	GW-SW Interaction[1]		Difference (gpm)	Calibration Target (gpm)	Percent Difference
	Observed (gpm)	Simulated (gpm)			
Sheep Creek below Little Sheep Creek	177-208	140	38	$^+$/-20%	-21%
Coon Creek (diverted section)	45	57	12	$^+$/-20%	+16%
Little Sheep Creek within Valley	NA	80	NA	NA	NA

[1] Negative value indicates flow from groundwater to river.

As an additional calibration check, the simulated groundwater flux through the model was compared to groundwater flux estimates from Darcy Law calculations. The simulated discharge from the gravel pit outfall (66 gpm) is similar to that observed during low flow (45-90 gpm). The simulated flux evaluated in the middle of the model between where Little Sheep Creek crosses the Valley and where Coon Creek enters the valley. The simulated flux in the model was about 160 gpm which is slightly less than the lower estimated value based on Darcy's Law.

In summary, the calibrated flow model met the head calibration criteria throughout the model domain with only one of the observation points being slightly higher than the calibration target. The simulated fluxes in the model were near those observed/estimated. Similarly the groundwater fluxes in the model were similar to those calculated based on Darcy's Law. Overall, the model calibration results suggest that the steady state groundwater flow model provides a reasonable representation of the groundwater flow system and its interaction with surface water within the Sheep Creek Valley.

5.0 ALLUVIAL UNDERGROUND INFILTRATION GALLERY ANALYSIS

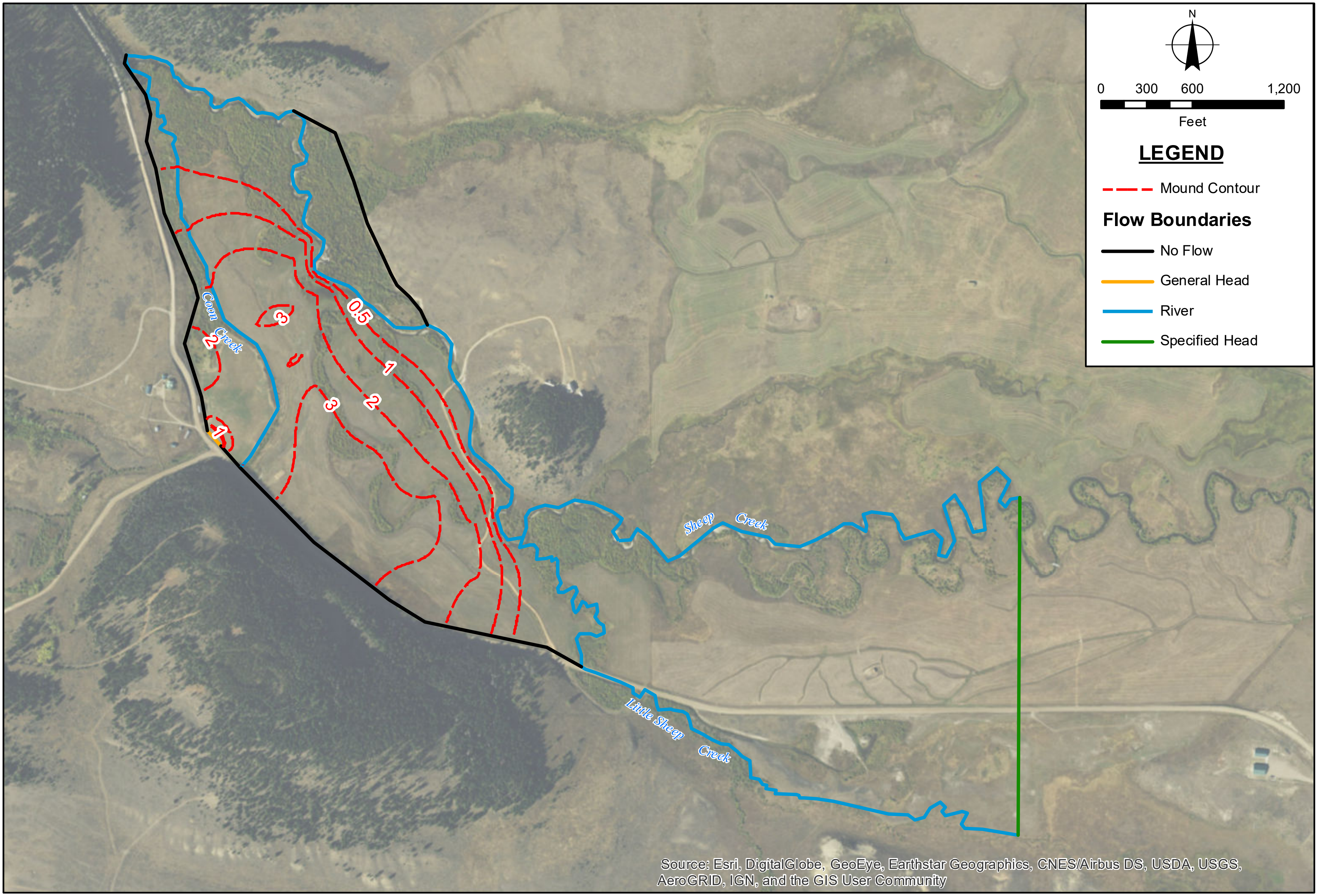
5.1 MOUNDING SIMULATION

The calibrated model was used to simulate the mounding from the maximum discharge to the alluvial valley. The maximum design discharge rate (575 gpm) from the WTP was applied to the specified flow boundaries evenly across the UIGs. This analysis was conducted to steady state conditions, which provide a conservative analysis as the steady state mounding during operations will be based on the average discharge rate. The projected average discharge rate is approximately 70% of the maximum discharge rate.

The steady state mounding analysis simulated the maximum mounding at the UIGs ranging from 2.3 feet to 3.9 feet. The mound dissipates quickly to the east towards Sheep Creek and to the west towards Coon Creek. In the middle of the UIG system the simulated mound is less than 1 foot at approximately 300 feet west of Sheep Creek. There is approximately 0.5 feet of mounding adjacent to Sheep Creek. The simulated mound under current conditions is shown on Figure 5-1.

5.2 PROJECTED OPERATIONAL POTENTIOMETRIC

Discharge to the alluvial system will only occur when the mine is being actively dewatered; therefore, the transport of water discharged to the alluvial UIG must be evaluated with the combination of drawdown from mine dewatering as simulated in the regional groundwater model and the mounding from the alluvial discharge. A projected operational potentiometric map was developed based on a cumulative analysis of the simulated drawdown in the alluvial system during operations and the simulated mounding from the alluvial discharge (Figure 5-2). The maximum dewatering rate occurs in year 4 of the mine operations (Hydrometrics, 2016); therefore, the water table within the alluvium at the end of year 4 from the regional model was used in cumulative analysis. The operational potentiometric surface shows that the alluvial groundwater will be lower than Coon Creek during operations. The operational projected potentiometric surface shows groundwater and water discharge to the groundwater will flow towards the mine workings and towards Sheep Creek in the downgradient portion of the valley. During operations groundwater will discharge over approximately 3,500 feet of Sheep Creek in the downgradient portion of the valley.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 5-1
Simulated Mounding
Black Butte Copper Project
Meagher County, Montana

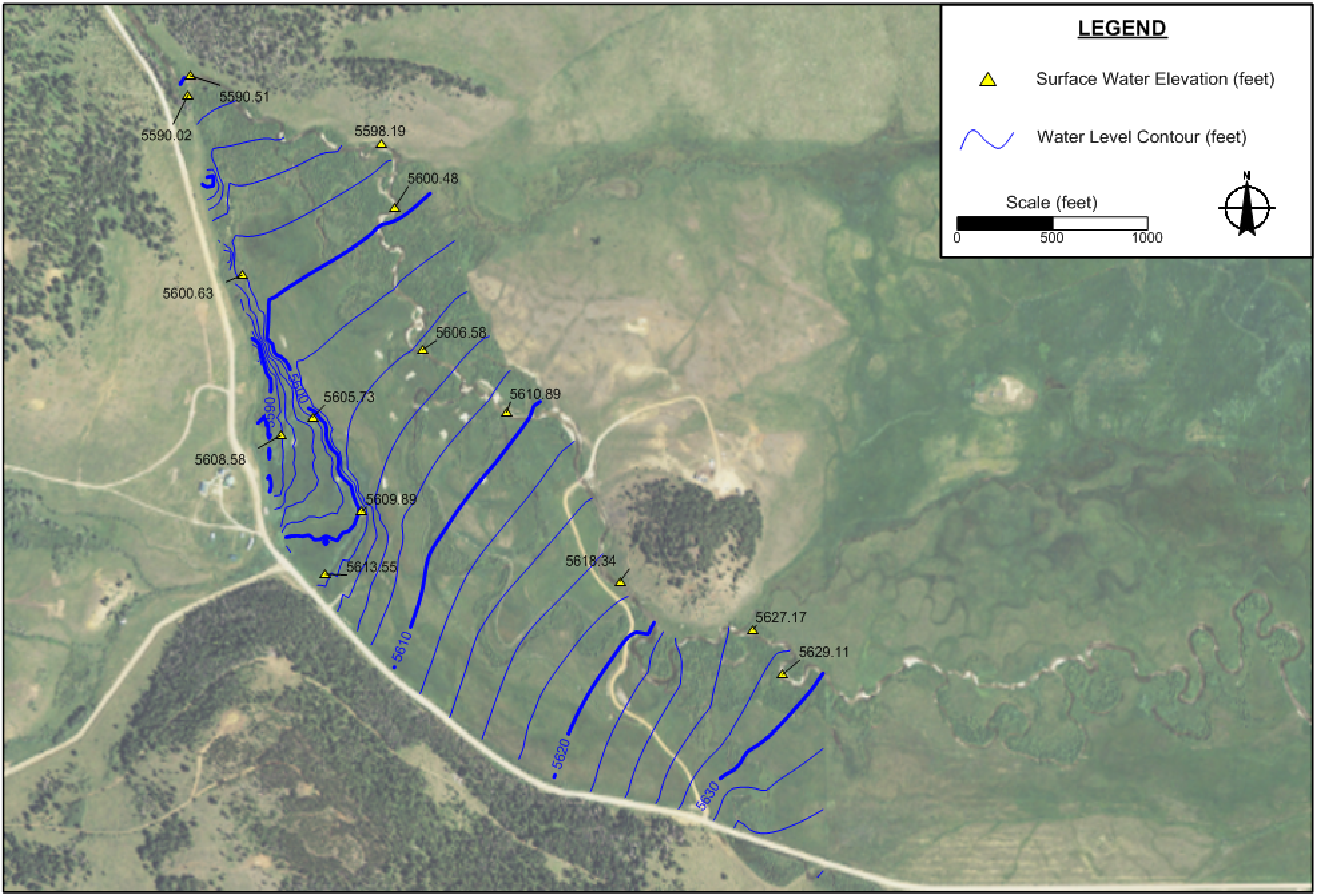

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Figure 5-2
Projected Operational Alluvial Potentiometric Surface
Black Butte Copper Project
Meagher County, Montana

6.0 SENSITIVITY

A formal sensitivity analysis has not been conducted where the change in model results (i.e., heads, groundwater flux, and groundwater/surface water interaction) was quantified based on changes in specific model parameters. However, the general sensitivity of the model was noted during model calibration. Below is a summary of which parameters the model was sensitive to during model calibration.

The flow model calibration process provided important information on the sensitivity of the model with respect to specific parameters used in the model. The model was most sensitive to changes in horizontal hydraulic conductivities and riverbed conductance. Increases in hydraulic conductivity resulted in slightly lower heads and greater flows within the groundwater system and two and from surface water boundaries. Heads increased with lower hydraulic conductivity values with groundwater flow becoming much lower than estimated. Similarly interaction between groundwater and surface water showed decreased flux both to and from surface water boundaries. Heads further from river boundaries showed the largest effects from changes in hydraulic conductivity.

Riverbed conductance was the other parameter that showed the largest sensitivity during model calibration. Lower conductance values assigned to the riverbed resulted in decreased fluxes in and out of the river boundaries used in the model. Lower conductance values also resulted in lower heads where Little Sheep Creek crosses the alluvial valley and higher heads near Coon Creek and the downgradient portions of Sheep Creek. Opposite affects were noted when higher conductance values were assigned to the riverbed.

Areal recharge was not adjusted during model calibration; therefore, the sensitivity of the model with respect to recharge was not evaluated. As noted in Section 3.3, recharge of precipitation is a minor component of the flow in the groundwater beneath the site and small increases or decreases in the percent of precipitation that recharges the aquifer are assumed to not have a significant effect on the model calibration or mounding analysis.

7.0 DISCUSSION

This modeling analysis was conducted to evaluate the effects the alluvial UIG discharge may have on water resources in the vicinity of the BBC Project. Modeling objectives were developed to ensure the model would address current and future analyses within the alluvial aquifer. The objectives are as follows:

- Estimate the mounding associated with the alluvial UIG discharge;
- Provide data that could be combined with the dewatering simulations to evaluate where groundwater will discharge to surface water during operations; and
- Provide a tool to assess the alluvial system for potential future evaluations.

The model is calibrated based on November 2017 water level data, and October 2012 synoptic data on Coon Creek. The calibrated flow model is able to reasonably match observed heads, estimated groundwater flux and groundwater-surface water interactions throughout the model domain. Overall the model provides a good representation of the alluvial groundwater flow system.

The alluvial discharge simulations showed there would be up to 3.9 feet of mounding at the galleries and the mounding would dissipate relatively quickly as you moved away from the discharge location. The simulated mound was used in conjunction with the simulated year 4 water levels in the alluvial system from the dewatering model to develop a projected operational potentiometric surface. The projected operational potentiometric surface showed that the groundwater was below Coon Creek throughout the valley and water discharged to the alluvial UIGs would transport to the mine workings or to approximately 3,500 feet of the Sheep Creek in the lower portion of the valley.

8.0 REFERENCES

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APPENDIX G

RECEIVING WATER QUALITY DATA AND STATISTICAL ANALYSIS

(LOCATED ON MAIN CD)

APPENDIX H

SAFETY DATA SHEETS

Use of AEROPHINE® 3418A Promoter in the Flotation of Complex Lead, Copper and Zinc Minerals with High Silver Content

1. Lead and Copper Flotation

AEROPHINE 3418A promoter is an effective primary collector in the selective flotation of:

- Lead/gold/silver minerals with low copper content
- Complex lead minerals with high silver content
- Lead minerals where the copper mineralization is secondary and the head grade of lead does not exceed 1.50 percent.

Typically, when the lead in heads exceeds 1.50 percent and/or copper exceeds 0.20 percent, auxiliary collectors are required for both metals. These collectors must be selective, so as to avoid excessive use of sodium cyanide, which could reduce the recovery of the minerals.

AEROPHINE 3418A promoter is highly selective against iron and arsenic minerals (such as pyrite and arsenopyrite) and non-activated zinc minerals. Current practice in several Mexican beneficiation plants is to use this promoter to selectively float lead minerals in the presence of iron, arsenic and non-activated zinc minerals. The flotation circuits operate at neutral to slightly alkaline pH. Consumption of sodium cyanide is low to zero, depending on the arsenic content in the heads.

Recommended Auxiliary Collectors for Lead

AERO XD504 promoter, AERO XD202 promoter.

Recommended Auxiliary Collectors for Copper

AERO XD3000 promoter, AERO XD601 promoter, AERO XD600 promoter.

1.1 Collector Dosages for Lead

AEROPHINE 3418A Promoter

Dosages of 0.5 to 1.0 g/tonne are recommended for each 0.1 percent of lead in the heads, fed neat in the rougher and scavenger flotation (80 percent and 20 percent respectively). When AEROPHINE 3418A promoter replaces xanthate, use one gram of AEROPHINE 3418A promoter in place of every three grams of xanthate.

Auxiliary Collectors

These replace 50 percent of the total AEROPHINE 3418A promoter dose, with typical consumptions of one to two g/tonne for each gram of AEROPHINE 3418A promoter being fed into the mill.

1.2 Collector Dosages for Copper

AEROPHINE 3418A Promoter

Dosages are the same as those used for lead (see above).

Auxiliary Collectors

AERO XD3000, AERO XD600 and AERO XD601 promoters should be fed to the mill at a rate of one to two grams of product for each 0.1 percent of copper in the heads, at a pH ranging from neutral to 8.5. Avoid the use of sodium cyanide, since this depressant will hinder the recovery of the copper minerals and could also result in the evolution of poisonous hydrogen cyanide. However, a zinc depressant is required.

Use zinc sulfate as a zinc depressant. Add at your discretion in the mill, in the rougher and scavenger flotation and to the cleaners.

2. Zinc Flotation

Zinc is floated after the lead-copper minerals have been recovered through selective collectors. If a xanthate is used as the primary collector instead of AEROPHINE 3418A promoter, the iron not floated at that stage may cause problems in the subsequent flotation of zinc. In such cases, it is recommended that a selective flotation be conducted again.

The zinc minerals should be floated in the traditional manner, replacing the xanthate with a thionocarbamate (such as the AERO XD600 or XD601 promoters) or an XD5000 collector. Dithiophosphates can be used as auxiliary collectors when xanthates, thionocarbamates, or the XD5000 collectors are used as primary collectors.

When the xanthate is replaced with a thionocarbamate or an XD5000 collector, the latter should be dosed at a ratio of one gram for every three grams of xanthate, while for dithiophosphates the ratio should be one to one.

Alkalinity

The pH of the circuit will depend on the zinc concentration in the marmatite ore. Higher concentrations will require higher alkalinity, ranging from pH 9.5 to 10.5. The pH level should be adjusted with lime.

Activation

Activation of the zinc mineral is achieved with copper sulfate at a dosage of about 50 g/tonne for each one percent of zinc in the heads.

Recommended Collectors for Zinc Flotation

AERO XD601 promoter, AERO XD600 promoter and AERO XD201 promoter, among others.

2.1 Collector Dosages for Zinc

The XD5000 collectors and the thionocarbamates are fed at a dosage of 0.5 to 1.0 g/tonne for each 0.1 percent of zinc in heads, with the pH between 9.0 and 9.5. The dithiophosphates require higher alkalinity (pH 10.0 to 10.5), with dosages ranging from one to two g/tonne for each 0.1 percent of zinc in heads.

The zinc associated with sphalerite generally requires lower dosages of collector and frother, and a lower dosage of lime.

Safety Data Sheet

Hydrated Lime

Revision date:
June 24, 2015

1. Identification

Product Name: Hydrated Lime

Synonyms:

Chemical Hydrate
Commercial Hydrate
Hyd Chem SS,
Hyd Lime Chem,
Hydrate Tailings,
Hydrated Lime Kiln Dust,
Industrial Hydrate,
Pink Hydrate,

Recommended Uses: Water treatment, steel flux, caustic agent, pH adjustment, acid gas absorption, construction

Manufacturer: Carmeuse Lime & Stone

US Office
11 Stanwix Street, 21st Floor
Pittsburgh, PA 15222
Phone: (412) 995-5500
Fax: (412) 995-5594

Canadian Office
PO Box 190
Ingersoll, ON N5C 3K5
Phone: (519) 423-6283
Fax: (519) 423-6545

Emergency Contact: Infotrac: (800) 535-5053 (24 hrs a day, 7 days a week)

2. Hazards Identification

GHS classification

Physical Hazards

None

Health Hazards

Skin Irritation	Category 2
Eye Damage	Category 1
Carcinogenicity	Category 1A
Specific Target Organ Toxicity – Single Exposure	Category 3

GHS Label Elements:

Signal Word: Danger

Hazard Statements:

Causes skin irritation.
Causes serious eye damage.
May cause respiratory irritation.
May cause cancer through inhalation

Precautionary Statements:

Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
Keep container tightly closed
Do not breathe dust.
Wash thoroughly after handling.
Do not eat, drink or smoke when using this product.
Use only outdoors or in well-ventilated area
Wear protective gloves, clothing and eye protection

Pictograms:

3. Composition

Chemical name	% by weight	CAS#
Calcium hydroxide	> 85	1305-62-0
Silica-crystalline quartz	< 1	14808-60-7

4. First Aid Measures

Eyes: Immediately flush eyes with generous amounts of water for at least 15 minutes. Pull back the eyelid to ensure that all lime dust has been washed out. Seek medical attention immediately. Do not rub eyes.

Skin: Wash exposed area with large amounts of water. Seek medical attention immediately.

Ingestion: Do not induce vomiting. Seek medical attention immediately. Never give anything by mouth unless instructed to do so by medical personnel.

Inhalation: Move victim to fresh air. Seek medical attention if necessary. If breathing has stopped, give artificial respiration

Most Important Symptoms: Irritation of skin, eyes, gastrointestinal tract or respiratory tract.

Immediate medical attention / special treatment? See first aid information above. Note to Physicians: Provide general supportive measures and treat symptomatically.

5. Fire Fighting Measures

Suitable (and unsuitable) fire extinguishing media: Use dry chemical fire extinguisher. Do not use water or halogenated compounds, except that large amounts of water may be used to deluge small quantities of this product.

Specific hazards arising from the product Inhalation, skin or eye contact, can result in serious injury. This product is not combustible or flammable. This product is not considered to be an

	explosion hazard, although reaction with water or other incompatible materials may rupture containers. When this product is wet, it can be very slippery and can result in a slip hazard. Hazardous Combustion Products: None.
Special protective equipment and precautions for fire fighters	Wear full fire-fighting turn-out gear (full Bunker gear), and respiratory protection (SCBA) to prevent inhalation, skin or eye contact.

6. Accidental Release Measures

Personal precautions, protective equipment, emergency procedures:

Avoid inhalation, eye and skin contact. Avoid generating airborne dust. Wear appropriate protective clothing as described in section 8.

Methods and materials for containment and clean up:

Utilize cleanup methods that minimize generating dust: vacuum. Avoid dry sweeping. Residue on surfaces may be removed with copious amount of water or vinegar.

7. Handling & Storage

Safe Handling: Avoid inhalation, skin and eye contact. Avoid generating airborne dust. An eye wash station should be readily available when this product is handled.

Safe Storage: Keep in tightly closed containers. Protect containers from physical damage. Store in a cool, dry, and well-ventilated location. Do not store near incompatible materials (see Section 10 below). Keep away from moisture. Long-term storage in aluminum containers is not recommended, as calcium oxide may corrode aluminum over long periods of time

8. Exposure Controls/Personal Protection

Occupational Exposure Limits

	OSHA PEL (mg/m^3)	ACGIH TLV (mg/m^3)	Ont. Reg. 833 TWAEV (mg/m^3)
Calcium hydroxide	15 (total) 5 (respirable)	5	5
silica - crystalline quartz	30 / (% silica +2) (total) 10 / (% silica +2) (respirable)	0.025 (respirable)	0.1

Engineering Controls: Use with adequate general or local exhaust ventilation and to maintain exposure below occupational exposure limits.

Individual Protection Measures (Personal Protective Equipment):

Specific Eye / Face Protection:	Safety glasses with side shields. In windy conditions, or if work activity generates elevated airborne dust levels, dust proof or chemical goggles are recommended. Contact lenses should not be worn.
Specific Skin Protection:	When there is a risk of skin contact, wear appropriate clothing and gloves to prevent contact.

Specific Respiratory Protection:	If exposure limits are exceeded, an approved particulate respirator, or supplied air respirator, appropriate for the airborne concentrations, should be used. Selection and use of the respiratory protective equipment must be in accordance with applicable regulations and good industrial hygiene practices.
Other:	An emergency eye wash fountain and shower are recommended.

9. Physical & Chemical Properties

Appearance:	White powder
Odor:	Odorless
Odor threshold:	Not Applicable
pH at 25 degrees C:	12.45
Melting Point:	1076 °F (580 °C)
Boiling Point and range:	5162 °F (2850 °C)
Flash Point:	Not Applicable
Evaporation Rate:	Not Applicable
Flammability:	Not Applicable
Upper/lower flammability or explosive limits	Not Applicable
Vapor pressure/density:	Non Volatile
Relative density:	2.24
Solubility:	Slightly soluble in water: 0.2% @ 0 °C. Soluble in acids, glycerin, and sugar solutions
Partition coefficient: n-octanol/water	Not applicable
Auto-ignition temperature:	Not Available
Decomposition temperature:	Not available
Viscosity:	Not Applicable

10. Stability & Reactivity

Reactivity:	Reacts with acids to form calcium salts, releasing heat. Reacts with carbon dioxide in air to form calcium carbonate. See also Incompatibility below.
Chemical stability:	Stable under normal storage and handling conditions.
Possibility of Hazardous Reactions:	See “reactivity” above.
Conditions to avoid:	Vicinity of incompatible materials.

Incompatibility:	This product should not be mixed or stored with the following materials, due to the potential for violent reaction and release of heat: • acids • reactive fluoridated compounds • reactive brominated compounds • reactive powdered metals • reactive phosphorous compounds • aluminum powder • organic acid anhydrides • nitro-organic compounds • interhalogenated compounds
Hazardous decomposition products:	None

11. Toxicological Information

Likely routes of exposure & symptoms:

Eyes:	Contact can cause severe irritation or burning of eyes, including permanent damage.
Skin:	Contact can cause severe irritation or burning of skin, especially in the presence of moisture.
Ingestion:	This product can cause severe irritation or burning of gastrointestinal tract if swallowed.
Inhalation:	This product can cause severe irritation of the respiratory system.

Chronic health effects:	This product contains trace amounts of crystalline silica. Prolonged or repeated inhalation of respirable crystalline silica can cause silicosis, as serious lung disease.
Respiratory or skin sensitization:	This material is not known to cause sensitization
Germ cell mutagenicity:	No data available.
Carcinogenicity:	This product is not listed as carcinogenic by OSHA, IARC, NTP, ACGIH, or the EU Directives. This product may contain trace amounts of crystalline silica quartz which is listed by IARC as “Carcinogenic to Humans” (Group 1) and “Known to be a Human Carcinogen" by NTP (National Toxicology Program).
Reproductive toxicity:	No Data Available.
Numerical Measures of Toxicity	Crystalline Silica: Oral Rat LD_{50} > 22,500 mg/kg Calcium Hydroxide: Oral (rat) LD_{50}: 7340 mg/kg

12. Ecological Information

Because of the elevated pH of this product, it might be expected to produce some ecotoxicity upon exposure to certain aquatic organisms and aquatic systems in high concentrations
This material shows no bioaccumulation effect or food chain concentration toxicity.

13. Disposal Considerations

Dispose of contents in accordance with federal, state, provincial and local regulations.

14. Transport Information

Not regulated by Department of Transportation, Transport of Dangerous Goods

15. Regulatory Information

CERCLA Hazardous Substances	Not listed
SARA Toxic Chemical (40 CFR 372.65)	Not listed
SARA Section 302 Extremely Hazardous Substances (40 CFR 355)	Not listed
SARA 311/312	Not listed
SARA Section 313 Toxic Chemicals reporting requirements	None
Threshold planning quantity (TPQ)	Not listed
RCRA Hazardous Waste Classification (40 CFR 261)	Not Classified
EPA Toxic Substances Control Act (TSCA) Status	All of the components of this product are listed on the TSCA
California Proposition 65	Airborne crystalline silica particulates of respirable size are known to the State of California to cause cancer.
NFPA ratings	Health: 3 Fire: 0 Reactivity: 0
HMIS Ratings	Health: 3 Fire: 0 Reactivity: 0 Personal protection: E
OSHA Specifically regulated substance (29 CFR 1910)	Not listed
OSHA Air contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A)	Listed
MSHA	Not listed
Canada DSL	Listed
Canadian WHMIS Classification	D2A, Materials Causing other toxic effects. E, Corrosive Material
Canada CPR	This product has been classified in accordance with the hazard criteria of the Controlled Products Regulation of a Canada and this SDS contains all the required information.

16. Other Information

List of GHS Hazard Statements:	H315: Causes skin irritation H318: Causes serious eye damage H335: May cause respiratory irritation. H350: May cause cancer through inhalation
List of GHS Precautionary Statements:	P201: Obtain special instructions before use. P202: Do not handle until all safety precautions have been read and understood. P233: Keep container tightly closed P260: Do not breathe dust. P264: Wash thoroughly after handling. P270: Do not eat, drink or smoke when using this product. P271: Use only outdoors or in well-ventilated area P280: Wear protective gloves, clothing and eye protection

Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act	RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act	IARC	International Agency for Research on Cancer
NTP	National Toxicology Program		

SAFETY DATA SHEET

THE DOW CHEMICAL COMPANY

THE DOW CHEMICAL COMPANY encourages and expects you to read and understand the entire (M)SDS, as there is important information throughout the document. We expect you to follow the precautions identified in this document unless your use conditions would necessitate other appropriate methods or actions.

1. IDENTIFICATION

Product name: Methyl Isobutyl Carbinol

Recommended use of the chemical and restrictions on use
Identified uses: Chemical additive. Chemical intermediate. Frothing agent.

COMPANY IDENTIFICATION
THE DOW CHEMICAL COMPANY
2030 WILLARD H DOW CENTER
MIDLAND MI 48674-0000
UNITED STATES

Customer Information Number:	800-258-2436 SDSQuestion@dow.com

EMERGENCY TELEPHONE NUMBER
24-Hour Emergency Contact: CHEMTREC +1 703-527-3887
Local Emergency Contact: 800-424-9300

2. HAZARDS IDENTIFICATION

Hazard classification
This material is hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200.
Flammable liquids - Category 3
Eye irritation - Category 2A
Specific target organ toxicity - single exposure - Category 3

Label elements
Hazard pictograms

Signal word: **WARNING!**

Hazards
Flammable liquid and vapour.
Causes serious eye irritation.
May cause respiratory irritation.

Precautionary statements

Prevention
Keep away from heat/sparks/open flames/hot surfaces. No smoking.
Keep container tightly closed.
Ground/bond container and receiving equipment.
Use explosion-proof electrical/ ventilating/ lighting/ equipment.
Use only non-sparking tools.
Take precautionary measures against static discharge.
Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
Wash skin thoroughly after handling.
Use only outdoors or in a well-ventilated area.
Wear protective gloves/ eye protection/ face protection.

Response
IF ON SKIN (or hair): Remove/ Take off immediately all contaminated clothing. Rinse skin with water/ shower.
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/ physician if you feel unwell.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
If eye irritation persists: Get medical advice/ attention.
In case of fire: Use dry sand, dry chemical or alcohol-resistant foam for extinction.

Storage
Store in a well-ventilated place. Keep container tightly closed.
Store in a well-ventilated place. Keep cool.
Store locked up.

Disposal
Dispose of contents/ container to an approved waste disposal plant.

Other hazards
No data available

3. COMPOSITION/INFORMATION ON INGREDIENTS

Synonyms: 4-methylpentan-2-ol
This product is a substance.

Component	CASRN	Concentration
Methylisobutylcarbinol	108-11-2	> 98.0 %
2,6-Dimethyl-4-heptanone	108-83-8	< 2.0 %

Methyl isobutyl ketone	108-10-1	< 1.0 %

4. FIRST AID MEASURES

Description of first aid measures
General advice: First Aid responders should pay attention to self-protection and use the recommended protective clothing (chemical resistant gloves, splash protection). If potential for exposure exists refer to Section 8 for specific personal protective equipment.

Inhalation: Move person to fresh air. If not breathing, give artificial respiration; if by mouth to mouth use rescuer protection (pocket mask, etc). If breathing is difficult, oxygen should be administered by qualified personnel. Call a physician or transport to a medical facility.

Skin contact: Wash off with plenty of water.

Eye contact: Immediately flush eyes with water; remove contact lenses, if present, after the first 5 minutes, then continue flushing eyes for at least 15 minutes. Obtain medical attention without delay, preferably from an ophthalmologist. Suitable emergency eye wash facility should be immediately available.

Ingestion: Do not induce vomiting. Call a physician and/or transport to emergency facility immediately.

Most important symptoms and effects, both acute and delayed: Aside from the information found under Description of first aid measures (above) and Indication of immediate medical attention and special treatment needed (below), any additional important symptoms and effects are described in Section 11: Toxicology Information.

Indication of any immediate medical attention and special treatment needed
Notes to physician: Repeated excessive exposure may aggravate preexisting lung disease. Skin contact may aggravate preexisting dermatitis. Maintain adequate ventilation and oxygenation of the patient. May cause asthma-like (reactive airways) symptoms. Bronchodilators, expectorants, antitussives and corticosteroids may be of help. If lavage is performed, suggest endotracheal and/or esophageal control. Danger from lung aspiration must be weighed against toxicity when considering emptying the stomach. The decision of whether to induce vomiting or not should be made by a physician. No specific antidote. Treatment of exposure should be directed at the control of symptoms and the clinical condition of the patient.

5. FIREFIGHTING MEASURES

Suitable extinguishing media: Water fog or fine spray. Dry chemical fire extinguishers. Carbon dioxide fire extinguishers. Foam. Alcohol resistant foams (ATC type) are preferred. General purpose synthetic foams (including AFFF) or protein foams may function, but will be less effective.

Unsuitable extinguishing media: No data available

Special hazards arising from the substance or mixture
Hazardous combustion products: During a fire, smoke may contain the original material in addition to combustion products of varying composition which may be toxic and/or irritating. Combustion products may include and are not limited to: Carbon monoxide. Carbon dioxide.

Unusual Fire and Explosion Hazards: Violent steam generation or eruption may occur upon application of direct water stream to hot liquids. Vapors are heavier than air and may travel a long distance and accumulate in low lying areas. Ignition and/or flash back may occur.

Advice for firefighters
Fire Fighting Procedures: Keep people away. Isolate fire and deny unnecessary entry. Stay upwind. Keep out of low areas where gases (fumes) can accumulate. Use water spray to cool fire exposed containers and fire affected zone until fire is out and danger of reignition has passed. Do not use direct water stream. May spread fire. Eliminate ignition sources. Burning liquids may be moved by flushing with water to protect personnel and minimize property damage. Avoid accumulation of water. Product may be carried across water surface spreading fire or contacting an ignition source.

Special protective equipment for firefighters: Wear positive-pressure self-contained breathing apparatus (SCBA) and protective fire fighting clothing (includes fire fighting helmet, coat, trousers, boots, and gloves). If protective equipment is not available or not used, fight fire from a protected location or safe distance.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures: Eliminate all sources of ignition in vicinity of spill or released vapor to avoid fire or explosion. Vapor explosion hazard. Keep out of sewers. Isolate area. Refer to section 7, Handling, for additional precautionary measures. Keep unnecessary and unprotected personnel from entering the area. Keep personnel out of low areas. Keep upwind of spill. Ventilate area of leak or spill. No smoking in area. Eliminate all sources of ignition in vicinity of spill or released vapor to avoid fire or explosion. Ground and bond all containers and handling equipment. Use appropriate safety equipment. For additional information, refer to Section 8, Exposure Controls and Personal Protection.

Environmental precautions: Prevent from entering into soil, ditches, sewers, waterways and/or groundwater. See Section 12, Ecological Information.

Methods and materials for containment and cleaning up: Small spills: Absorb with materials such as: Sand. Vermiculite. Large spills: Contain spilled material if possible. Collect in suitable and properly labeled containers. Pump with explosion-proof equipment. If available, use foam to smother or suppress. See Section 13, Disposal Considerations, for additional information.

Removal of ignition sources: Keep away from sources of ignition.

Dust Control: Not applicable

7. HANDLING AND STORAGE

Precautions for safe handling: Use of non-sparking or explosion-proof equipment may be necessary, depending upon the type of operation.

Keep away from heat, sparks and flame. Avoid contact with eyes. Avoid breathing vapor. No smoking, open flames or sources of ignition in handling and storage area. Vapors are heavier than air and may travel a long distance and accumulate in low lying areas. Ignition and/or flash back may occur. Containers, even those that have been emptied, can contain vapors. Do not cut, drill, grind, weld, or perform similar operations on or near empty containers. Electrically ground and bond all equipment. See Section 8, EXPOSURE CONTROLS AND PERSONAL PROTECTION. Wash thoroughly after handling. Keep container closed. Use with adequate ventilation.

Conditions for safe storage: Minimize sources of ignition, such as static build-up, heat, spark or flame.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters
Exposure limits are listed below, if they exist.

Component	Regulation	Type of listing	Value/Notation
Methylisobutylcarbinol	ACGIH	TWA	25 ppm
	ACGIH	STEL	40 ppm
	ACGIH	TWA	SKIN
	OSHA Z-1	TWA	100 mg/m3 25 ppm
	ACGIH	STEL	SKIN
	OSHA Z-1	TWA	SKIN
2,6-Dimethyl-4-heptanone	Dow IHG	TWA	25 ppm
	Dow IHG	STEL	35 ppm
	ACGIH	TWA	25 ppm
	OSHA Z-1	TWA	290 mg/m3 50 ppm
	OSHA P0	TWA	150 mg/m3 25 ppm
Methyl isobutyl ketone	ACGIH	TWA	20 ppm
	ACGIH	STEL	75 ppm
	OSHA Z-1	TWA	410 mg/m3 100 ppm
	ACGIH	TWA	BEI
	ACGIH	STEL	BEI

Exposure controls
Engineering controls: Use engineering controls to maintain airborne level below exposure limit requirements or guidelines. If there are no applicable exposure limit requirements or guidelines, use only with adequate ventilation. Local exhaust ventilation may be necessary for some operations.

Individual protection measures

Eye/face protection: Use chemical goggles. If exposure causes eye discomfort, use a full-face respirator.

Skin protection

Hand protection: Use gloves chemically resistant to this material. Examples of preferred glove barrier materials include: Butyl rubber. Chlorinated polyethylene. Natural rubber ("latex"). Neoprene. Polyethylene. Ethyl vinyl alcohol laminate ("EVAL"). Polyvinyl chloride ("PVC" or "vinyl"). Examples of acceptable glove barrier materials include: Nitrile/butadiene rubber ("nitrile" or "NBR"). Polyvinyl alcohol ("PVA"). Viton. NOTICE: The selection of a specific glove for a particular application and duration of use in a workplace should also take into account all relevant workplace factors such as, but not limited to: Other chemicals which may be handled, physical requirements (cut/puncture protection, dexterity, thermal protection), potential body reactions to glove materials, as well as the instructions/specifications provided by the glove supplier.

Other protection: Use protective clothing chemically resistant to this material. Selection of specific items such as face shield, boots, apron, or full body suit will depend on the task.

Respiratory protection: Respiratory protection should be worn when there is a potential to exceed the exposure limit requirements or guidelines. If there are no applicable exposure limit

requirements or guidelines, use an approved respirator. Selection of air-purifying or positive-pressure supplied-air will depend on the specific operation and the potential airborne concentration of the material. For emergency conditions, use an approved positive-pressure self-contained breathing apparatus.
The following should be effective types of air-purifying respirators: Organic vapor cartridge.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	
Physical state	Liquid.
Color	Colorless
Odor	Mild
Odor Threshold	No test data available
pH	No test data available
Melting point/range	Not applicable to liquids
Freezing point	-90 °C (-130 °F) *Literature*
Boiling point (760 mmHg)	132 °C (270 °F) *Literature*
Flash point	40.56 °C (105.01 °F) *open cup*
Evaporation Rate (Butyl Acetate = 1)	0.43 *Literature*
Flammability (solid, gas)	Not applicable to liquids
Lower explosion limit	1.0 % vol *Literature*
Upper explosion limit	5.5 % vol *Literature*
Vapor Pressure	No data available
Relative Vapor Density (air = 1)	3.5 *Literature*
Relative Density (water = 1)	0.807 at 20 °C (68 °F) / 20 °C *Literature*
Water solubility	1.7 % at 20 °C (68 °F) *Literature*
Partition coefficient: n-octanol/water	log Pow: 1.57 *estimated*
Auto-ignition temperature	335 °C (635 °F) at 1,013 hPa *Literature*
Decomposition temperature	No test data available
Dynamic Viscosity	5.2 mPa.s at 20 °C (68 °F) *Literature*
Kinematic Viscosity	6.4 mm2/s at 20 °C (68 °F) *Literature*
Explosive properties	Not explosive
Oxidizing properties	No
Molecular weight	No data available
Molecular formula	$(CH_3)_2CHCH_2CH(OH)CH_3$

NOTE: The physical data presented above are typical values and should not be construed as a specification.

10. STABILITY AND REACTIVITY

Reactivity: No data available

Chemical stability: Thermally stable at recommended temperatures and pressures.

Possibility of hazardous reactions: Polymerization will not occur.

Conditions to avoid: Exposure to elevated temperatures can cause product to decompose.

Incompatible materials: Avoid contact with: Acid chlorides. Acids. Oxidizers.

Hazardous decomposition products: Decomposition products depend upon temperature, air supply and the presence of other materials.

11. TOXICOLOGICAL INFORMATION

Toxicological information appears in this section when such data is available.

Acute toxicity

Acute oral toxicity
Low toxicity if swallowed. Small amounts swallowed incidentally as a result of normal handling operations are not likely to cause injury; however, swallowing larger amounts may cause injury.

LD50, Rat, 2,590 mg/kg OECD 401 or equivalent

Acute dermal toxicity
Prolonged skin contact is unlikely to result in absorption of harmful amounts.

LD50, Rabbit, 2,870 mg/kg OECD 402 or equivalent

Acute inhalation toxicity
Prolonged excessive exposure may cause adverse effects. Excessive exposure may cause irritation to upper respiratory tract (nose and throat) and lungs. Symptoms of excessive exposure may be anesthetic or narcotic effects; dizziness and drowsiness may be observed.

LC50, Rat, male and female, 4 Hour, vapour, > 16 mg/l

Skin corrosion/irritation
Brief contact may cause slight skin irritation with local redness.
May cause drying and flaking of the skin.

Serious eye damage/eye irritation
May cause moderate eye irritation.
May cause moderate corneal injury.
Vapor may cause eye irritation experienced as mild discomfort and redness.

Sensitization
Did not cause allergic skin reactions when tested in guinea pigs.

For respiratory sensitization:
No relevant data found.

Specific Target Organ Systemic Toxicity (Single Exposure)

May cause respiratory irritation.
Route of Exposure: Inhalation
Target Organs: Respiratory Tract

Specific Target Organ Systemic Toxicity (Repeated Exposure)
In animals, effects have been reported on the following organs:
Kidney.

Carcinogenicity
For the minor component(s) Has caused cancer in some laboratory animals. However, the relevance of this to humans is unknown.

Teratogenicity
For similar material(s): Has been toxic to the fetus in laboratory animals at doses toxic to the mother. Did not cause birth defects in laboratory animals.

Reproductive toxicity
For similar material(s): In animal studies, did not interfere with reproduction.

Mutagenicity
In vitro genetic toxicity studies were negative.

Aspiration Hazard
May be harmful if swallowed and enters airways.

Carcinogenicity

Component	**List**	**Classification**
Methyl isobutyl ketone	IARC	Group 2B: Possibly carcinogenic to humans
	ACGIH	A3: Confirmed animal carcinogen with unknown relevance to humans.

12. ECOLOGICAL INFORMATION

Ecotoxicological information appears in this section when such data is available.

Toxicity

Acute toxicity to fish
Material is practically non-toxic to aquatic organisms on an acute basis (LC50/EC50/EL50/LL50 >100 mg/L in the most sensitive species tested).

LC50, Oncorhynchus mykiss (rainbow trout), semi-static test, 96 Hour, 359 mg/l, OECD Test Guideline 203 or Equivalent

Acute toxicity to aquatic invertebrates
EC50, Daphnia magna (Water flea), semi-static test, 48 Hour, 337 mg/l, OECD Test Guideline 202 or Equivalent

Acute toxicity to algae/aquatic plants
EbC50, Pseudokirchneriella subcapitata (green algae), 96 Hour, Biomass, 147 mg/l, OECD Test Guideline 201 or Equivalent

ErC50, Pseudokirchneriella subcapitata (green algae), 96 Hour, Growth rate inhibition, 334 mg/l, OECD Test Guideline 201 or Equivalent

Toxicity to bacteria
EC50, Bacteria, static test, 3 Hour, Respiration rates., > 100 mg/l, activated sludge test (OECD 209)

Persistence and degradability

Biodegradability: Material is readily biodegradable. Passes OECD test(s) for ready biodegradability.
10-day Window: Pass
Biodegradation: 85 %
Exposure time: 28 d
Method: OECD Test Guideline 301F or Equivalent

Theoretical Oxygen Demand: 2.82 mg/mg

Chemical Oxygen Demand: 2.43 mg/mg

Biological oxygen demand (BOD)

Incubation Time	BOD
5 d	38 - 50 %
10 d	67 - 72 %
20 d	67 - 94 %

Photodegradation
Test Type: Half-life (indirect photolysis)
Sensitizer: OH radicals
Atmospheric half-life: 10 Hour
Method: Estimated.

Bioaccumulative potential

Bioaccumulation: Bioconcentration potential is low (BCF < 100 or Log Pow < 3).
Partition coefficient: n-octanol/water(log Pow): 1.57 estimated

Mobility in soil

Potential for mobility in soil is very high (Koc between 0 and 50).
Partition coefficient(Koc): 13 Estimated.

13. DISPOSAL CONSIDERATIONS

Disposal methods: DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. All disposal practices must be in compliance with all Federal, State/Provincial and local laws and regulations. Regulations may vary in different locations. Waste characterizations and compliance with applicable laws are the responsibility solely of the waste generator. AS YOUR SUPPLIER, WE HAVE NO CONTROL OVER THE MANAGEMENT PRACTICES OR MANUFACTURING PROCESSES OF PARTIES HANDLING OR USING THIS MATERIAL. THE INFORMATION PRESENTED HERE PERTAINS ONLY TO THE PRODUCT AS SHIPPED IN ITS

INTENDED CONDITION AS DESCRIBED IN MSDS SECTION: Composition Information. FOR UNUSED & UNCONTAMINATED PRODUCT, the preferred options include sending to a licensed, permitted: Incinerator or other thermal destruction device. As a service to its customers, Dow can provide names of information resources to help identify waste management companies and other facilities which recycle, reprocess or manage chemicals or plastics, and that manage used drums. Telephone Dow's Customer Information Group at 1-800-258-2436 or 1-989-832-1556 (U.S.), or 1-800-331-6451 (Canada) for further details.

14. TRANSPORT INFORMATION

DOT

Proper shipping name	Methyl isobutyl carbinol
UN number	UN 2053
Class	3
Packing group	III

Classification for SEA transport (IMO-IMDG):

Proper shipping name	METHYL ISOBUTYL CARBINOL
UN number	UN 2053
Class	3
Packing group	III
Marine pollutant	No
Transport in bulk according to Annex I or II of MARPOL 73/78 and the IBC or IGC Code	Consult IMO regulations before transporting ocean bulk

Classification for AIR transport (IATA/ICAO):

Proper shipping name	Methyl isobutyl carbinol
UN number	UN 2053
Class	3
Packing group	III

This information is not intended to convey all specific regulatory or operational requirements/information relating to this product. Transportation classifications may vary by container volume and may be influenced by regional or country variations in regulations. Additional transportation system information can be obtained through an authorized sales or customer service representative. It is the responsibility of the transporting organization to follow all applicable laws, regulations and rules relating to the transportation of the material.

15. REGULATORY INFORMATION

OSHA Hazard Communication Standard
This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

Superfund Amendments and Reauthorization Act of 1986 Title III (Emergency Planning and Community Right-to-Know Act of 1986) Sections 311 and 312
Fire Hazard
Acute Health Hazard
Chronic Health Hazard

Superfund Amendments and Reauthorization Act of 1986 Title III (Emergency Planning and Community Right-to-Know Act of 1986) Section 313
This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

Pennsylvania Worker and Community Right-To-Know Act:
The following product components are cited in the Pennsylvania Hazardous Substance List and/or the Pennsylvania Environmental Substance List, and are present at levels which require reporting.

Components	**CASRN**
Methylisobutylcarbinol	108-11-2
2,6-Dimethyl-4-heptanone	108-83-8

California Proposition 65 (Safe Drinking Water and Toxic Enforcement Act of 1986)
WARNING: This product contains a chemical(s) known to the State of California to cause cancer.

Components	**CASRN**
Methyl isobutyl ketone	108-10-1

United States TSCA Inventory (TSCA)
All components of this product are in compliance with the inventory listing requirements of the U.S. Toxic Substances Control Act (TSCA) Chemical Substance Inventory.

16. OTHER INFORMATION

Hazard Rating System
NFPA

Health	Fire	Reactivity
1	2	0

Revision
Identification Number: 101234033 / A001 / Issue Date: 03/09/2016 / Version: 7.1
Most recent revision(s) are noted by the bold, double bars in left-hand margin throughout this document.

Legend

ACGIH	USA. ACGIH Threshold Limit Values (TLV)
BEI	Biological Exposure Indices
Dow IHG	Dow Industrial Hygiene Guideline
OSHA P0	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
OSHA Z-1	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
SKIN	Absorbed via skin

STEL	Short term exposure limit
TWA	Time weighted average

Information Source and References
This SDS is prepared by Product Regulatory Services and Hazard Communications Groups from information supplied by internal references within our company.

THE DOW CHEMICAL COMPANY urges each customer or recipient of this (M)SDS to study it carefully and consult appropriate expertise, as necessary or appropriate, to become aware of and understand the data contained in this (M)SDS and any hazards associated with the product. The information herein is provided in good faith and believed to be accurate as of the effective date shown above. However, no warranty, express or implied, is given. Regulatory requirements are subject to change and may differ between various locations. It is the buyer's/user's responsibility to ensure that his activities comply with all federal, state, provincial or local laws. The information presented here pertains only to the product as shipped. Since conditions for use of the product are not under the control of the manufacturer, it is the buyer's/user's duty to determine the conditions necessary for the safe use of this product. Due to the proliferation of sources for information such as manufacturer-specific (M)SDSs, we are not and cannot be responsible for (M)SDSs obtained from any source other than ourselves. If you have obtained an (M)SDS from another source or if you are not sure that the (M)SDS you have is current, please contact us for the most current version.

Safety Data Sheet

1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

Product Name:	**SIPX**
Other name(s):	Sodium isopropyl xanthate; Carbonodithioic acid, O-isopropyl ester, sodium salt.
Recommended Use of the Chemical and Restrictions on Use	Mineral floatation.
Supplier:	Ixom Operations Pty Ltd
ABN:	51 600 546 512
Street Address:	Level 8, 1 Nicholson Street East Melbourne Victoria 3002 Australia
Telephone Number:	+61 3 9906 3000
Emergency Telephone:	**1 800 033 111 (ALL HOURS)**

Please ensure you refer to the limitations of this Safety Data Sheet as set out in the "Other Information" section at the end of this Data Sheet.

2. HAZARDS IDENTIFICATION

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Self-heating substances and mixtures - Category 1
Acute Oral Toxicity - Category 4
Skin Irritation - Category 2
Acute Aquatic Toxicity - Category 2
Chronic Aquatic Toxicity - Category 2

SIGNAL WORD: DANGER

Hazard Statement(s):
H251 Self-heating; may catch fire.
H302 Harmful if swallowed.
H315 Causes skin irritation.
H411 Toxic to aquatic life with long lasting effects.

Precautionary Statement(s):

Prevention:
P235+P410 Keep cool. Protect from sunlight.
P264 Wash hands thoroughly after handling.
P270 Do not eat, drink or smoke when using this product.
P273 Avoid release to the environment.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

Response:
P301+P312 IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P330 Rinse mouth.
P302+P352 IF ON SKIN: Wash with plenty of soap and water.
P321 Specific treatment (see First Aid Measures on Safety Data Sheet).
P332+P313 If skin irritation occurs: Get medical advice/attention.
P362 Take off contaminated clothing and wash before reuse.
P391 Collect spillage.

Storage:
P407 Maintain air gap between stacks/pallets.
P420 Store away from other materials.

Disposal:
P501 Dispose of contents and container in accordance with local, regional, national, international regulations.

Poisons Schedule (SUSMP): None allocated.

3. COMPOSITION AND INFORMATION ON INGREDIENTS

Components	CAS Number	Proportion	Hazard Codes
Sodium isopropyl xanthate	140-93-2	>=90%	H302 H315 H411

4. FIRST AID MEASURES

For advice, contact a Poisons Information Centre (e.g. phone Australia 131 126; New Zealand 0800 764 766) or a doctor.

Inhalation:
Remove victim from area of exposure - avoid becoming a casualty. Remove contaminated clothing and loosen remaining clothing. Allow patient to assume most comfortable position and keep warm. Keep at rest until fully recovered. If patient finds breathing difficult and develops a bluish discolouration of the skin (which suggests a lack of oxygen in the blood - cyanosis), ensure airways are clear of any obstruction and have a qualified person give oxygen through a face mask. Apply artificial respiration if patient is not breathing. Seek immediate medical advice.

Skin Contact:
If skin or hair contact occurs, immediately remove any contaminated clothing and wash skin and hair thoroughly with running water. If swelling, redness, blistering or irritation occurs seek medical assistance.

Eye Contact:
If in eyes, hold eyelids apart and flush the eye continuously with running water. Continue flushing until advised to stop by a Poisons Information Centre or a doctor, or for at least 15 minutes.

Ingestion:
Rinse mouth with water. If swallowed, give a glass of water to drink. If vomiting occurs give further water. Seek immediate medical assistance.

Indication of immediate medical attention and special treatment needed:
Treat symptomatically.

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media:
Coarse water spray, fine water spray, normal foam, dry agent (carbon dioxide, dry chemical powder).

Hazchem or Emergency Action Code: 1Y

Specific hazards arising from the chemical:
Substance liable to spontaneous combustion.

Special protective equipment and precautions for fire-fighters:
Heating can cause expansion or decomposition of the material, which can lead to the containers exploding. If safe to do so, remove containers from the path of fire. Decomposes on heating emitting toxic fumes, including those of hydrogen sulfide , and carbon disulfide . Fire fighters to wear self-contained breathing apparatus and suitable protective clothing if risk of exposure to products of decomposition.

6. ACCIDENTAL RELEASE MEASURES

Emergency procedures/Environmental precautions:
Shut off all possible sources of ignition. Clear area of all unprotected personnel. If contamination of sewers or waterways has occurred advise local emergency services.

Personal precautions/Protective equipment/Methods and materials for containment and cleaning up:
Wear protective equipment to prevent skin and eye contact and breathing in vapours/dust. DO NOT allow material to get wet. Air-supplied masks are recommended to avoid inhalation of toxic material. Vacuum solid spills instead of sweeping. Collect and seal in properly labelled containers or drums for disposal.

7. HANDLING AND STORAGE

Precautions for safe handling:
Avoid skin and eye contact and breathing in dust. In common with many organic chemicals, may form flammable dust clouds in air. For precautions necessary refer to Safety Data Sheet "Dust Explosion Hazards".

Conditions for safe storage, including any incompatibilities:
Store in a cool, dry, well ventilated place and out of direct sunlight. Store away from sources of heat or ignition. Store away from foodstuffs. Store away from incompatible materials described in Section 10. Keep dry - reacts with water, may lead to drum rupture. Keep containers closed when not in use - check regularly for spills.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control Parameters: No value assigned for this specific material by Safe Work Australia. However, supplier recommended Workplace Exposure Standard(s):

TWA = 5 ppm (skin)

However, Workplace Exposure Standard(s) for decomposition product(s):

Carbon disulfide: 8hr TWA = 31 mg/m^3 (10 ppm), Sk
Hydrogen sulfide: 8hr TWA = 14 mg/m^3 (10 ppm), 15 min STEL 21 mg/m^3 (15 ppm)

As published by Safe Work Australia Workplace Exposure Standards for Airborne Contaminants.

TWA - The time-weighted average airborne concentration of a particular substance when calculated over an eight-hour working day, for a five-day working week.

STEL (Short Term Exposure Limit) - the airborne concentration of a particular substance calculated as a time-weighted average over 15 minutes, which should not be exceeded at any time during a normal eight hour work day. According to current knowledge this concentration should neither impair the health of, nor cause undue discomfort to, nearly all workers.

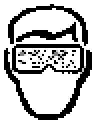
`Sk' (skin) Notice - absorption through the skin may be a significant source of exposure. The exposure standard is invalidated if such contact should occur.

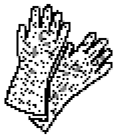
These Workplace Exposure Standards are guides to be used in the control of occupational health hazards. All atmospheric contamination should be kept to as low a level as is workable. These workplace exposure standards should not be used as fine dividing lines between safe and dangerous concentrations of chemicals. They are not a measure of relative toxicity.

Appropriate engineering controls:
Ensure ventilation is adequate and that air concentrations of components are controlled below quoted Workplace Exposure Standards. Avoid generating and breathing in dusts. Use with local exhaust ventilation or while wearing dust mask. Keep containers closed when not in use.

Individual protection measures, such as Personal Protective Equipment (PPE):
The selection of PPE is dependent on a detailed risk assessment. The risk assessment should consider the work situation, the physical form of the chemical, the handling methods, and environmental factors.

OVERALLS, SAFETY SHOES, CHEMICAL GOGGLES, GLOVES, DUST MASK.





Wear overalls, chemical goggles and impervious gloves. Avoid generating and inhaling dusts. If determined by a risk assessment an inhalation risk exists, wear a dust mask/respirator meeting the requirements of AS/NZS 1715 and AS/NZS 1716. Always wash hands before smoking, eating, drinking or using the toilet. Wash contaminated clothing and other protective equipment before storage or re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	Powder or Pellets
Colour:	Yellow
Odour:	Slight Characteristic
Molecular Formula:	$(CH_3)_2CH-O-(C=S)S.Na$
Solubility:	Soluble in water.
Specific Gravity:	ca. 0.8
Relative Vapour Density (air=1):	Not available
Vapour Pressure (20 °C):	Not available
Flash Point (°C):	Not available
Flammability Limits (%):	1.25-50 (for carbon disulfide gas)

Autoignition Temperature (°C):	Not available
Melting Point/Range (°C):	150-250
pH:	>12

10. STABILITY AND REACTIVITY

Reactivity:	Reacts with moisture liberating highly flammable carbon disulfide vapours.
Chemical stability:	No information available.
Possibility of hazardous reactions:	Reacts exothermically with water .
Conditions to avoid:	Avoid exposure to moisture. Avoid exposure to heat.
Incompatible materials:	Incompatible with acids , oxidising agents , and moisture .
Hazardous decomposition products:	Carbon disulfide.

11. TOXICOLOGICAL INFORMATION

No adverse health effects expected if the product is handled in accordance with this Safety Data Sheet and the product label. Symptoms or effects that may arise if the product is mishandled and overexposure occurs are:

Ingestion:	Swallowing may result in irritation of the gastrointestinal tract.
Eye contact:	May be an eye irritant. Exposure to the dust may cause discomfort due to particulate nature. May cause physical irritation to the eyes.
Skin contact:	Contact with skin will result in irritation. Will liberate carbon disulfide upon contact with moist skin. Carbon disulfide can be absorbed through the skin with resultant adverse effects.
Inhalation:	Breathing in dust may result in respiratory irritation. May cause coughing and shortness of breath.

Acute toxicity:
Oral LD50 (rat): 1500 mg/kg.

Chronic effects: No information available for the product.

12. ECOLOGICAL INFORMATION

Ecotoxicity	Avoid contaminating waterways.
Aquatic toxicity:	Toxic to aquatic organisms. May cause long lasting harmful effects to aquatic life.

13. DISPOSAL CONSIDERATIONS

Disposal methods:
Refer to Waste Management Authority. Dispose of material through a licensed waste contractor. Advise flammable nature.

14. TRANSPORT INFORMATION

Road and Rail Transport

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

UN No:	3342
Transport Hazard Class:	4.2 Spontaneously Combustible
Packing Group:	II
Proper Shipping Name or Technical Name:	XANTHATES
Hazchem or Emergency Action Code:	1Y

Marine Transport

Classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea; DANGEROUS GOODS.

UN No:	3342
Transport Hazard Class:	4.2 Spontaneously Combustible
Packing Group:	II
Proper Shipping Name or Technical Name:	XANTHATES

IMDG EMS Fire:	F-A
IMDG EMS Spill:	S-J

Air Transport

Classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air; DANGEROUS GOODS.

UN No:	3342
Transport Hazard Class:	4.2 Spontaneously Combustible
Packing Group:	II
Proper Shipping Name or Technical Name:	XANTHATES

15. REGULATORY INFORMATION

Classification:
This material is hazardous according to Safe Work Australia; HAZARDOUS CHEMICAL.

Classification of the chemical:
Self-heating substances and mixtures - Category 1
Acute Oral Toxicity - Category 4
Skin Irritation - Category 2
Acute Aquatic Toxicity - Category 2
Chronic Aquatic Toxicity - Category 2

Hazard Statement(s):
H251 Self-heating; may catch fire.
H302 Harmful if swallowed.
H315 Causes skin irritation.
H411 Toxic to aquatic life with long lasting effects.

Poisons Schedule (SUSMP): None allocated.

This material is listed on the Australian Inventory of Chemical Substances (AICS).

16. OTHER INFORMATION

This safety data sheet has been prepared by Ixom Operations Pty Ltd Toxicology & SDS Services.

Reason(s) for Issue:
Revised Primary SDS
Alignment to GHS requirements

This SDS summarises to our best knowledge at the date of issue, the chemical health and safety hazards of the material and general guidance on how to safely handle the material in the workplace. Since Ixom Operations Pty Ltd cannot anticipate or control the conditions under which the product may be used, each user must, prior to usage, assess and control the risks arising from its use of the material.

If clarification or further information is needed, the user should contact their Ixom representative or Ixom Operations Pty Ltd at the contact details on page 1.

Ixom Operations Pty Ltd's responsibility for the material as sold is subject to the terms and conditions of sale, a copy of which is available upon request.

APPENDIX I

NONDEGRADATION CRITERIA CALCULATIONS

Table I-1. Estimated Groundwater Non-Degradation Criteria: Sheep Creek Alluvium

Constituent	Groundwater Wells (MW-4A)			Groundwater Human Health Standard	Ambient/ HH Std	Category	Non Deg Trigger Level	Ambient + Trigger	Applicable Nonsignificance Factor ARM 17.30.715	Non Deg Threshold	Required Reporting Limit (RRL) or DL	Estimated Non-Degradation Criteria
	25%tile	75%tile	Average									
ALUMINUM (Al)	< 0.009	< 0.009	< 0.017	--	--	Toxic	0.03	--	--	--	0.009	--
ANTIMONY (Sb)	< 0.0005	< 0.0005	< 0.0008	0.006	8%	Toxic	0.0004	0.0009	0.15	0.0009	0.0005	0.0014
ARSENIC (As)	< 0.001	< 0.001	< 0.001	0.010	10%	Carcinogen	NAI	NAI	NAI	NAI	0.001	0.001
BARIUM (Ba)	0.182	0.189	0.185	1.0	18%	Toxic	0.002	0.184	0.15	0.1500	0.005	0.33875
BERYLLIUM (Be)	< 0.0008	< 0.0008	< 0.0008	0.004	20%	Carcinogen	NAI	NAI	NAI	NAI	0.001	0.0008
CADMIUM (Cd)	< 0.00003	< 0.00003	< 0.00004	0.005	1%	Toxic	0.0001	0.0001	0.15	0.0008	0.00008	0.00078
CHROMIUM (Cr)	< 0.01	< 0.01	< 0.008	0.1	10%	Toxic	0.001	< 0.01	0.15	0.0150	0.001	0.025
COBALT (Co)	< 0.01	< 0.01	< 0.01	--	--	--	--	--	--	--	0.01	--
COPPER (Cu)	< 0.002	< 0.002	< 0.002	1.3	0%	Toxic	0.0005	0.0025	0.15	0.1950	0.001	0.197
FLUORIDE (F)	0.1	0.2	0.1	4.0	3%	Toxic	0.005	0.1050	0.15	0.6000	0.001	0.8
IRON (Fe)	0.03	0.04	0.04	--	--	Harmful	--	--	--	--	0.05	--
LEAD (Pb)	< 0.0003	< 0.0003	< 0.0003	0.015	2%	Toxic	0.0001	0.0004	0.15	0.00225	0.00050	0.00255
MANGANESE (Mn)	0.168	0.222	0.185	--	--	--	--	--	--	--	0.005	--
MERCURY (Hg)	< 0.000005	< 0.000005	< 0.000006	0.002	0%	Toxic w/ BCF >300	NAI	NAI	NAI	NAI	0.00001	0.000005
MOLYBDENUM (Mo)	< 0.002	< 0.002	< 0.002	--	--	--	--	--	--	--	0.002	--
NICKEL (Ni)	< 0.001	< 0.001	< 0.002	0.1	1%	Toxic	0.0005	0.0015	0.15	0.0150	0.010	0.016
SELENIUM (Se)	< 0.0002	< 0.0002	< 0.0003	0.05	0%	Toxic	0.0006	0.0008	0.15	0.0075	0.0010	0.0077
SILVER (Ag)	< 0.0002	< 0.0002	< 0.0002	0.1	0%	Toxic	0.0002	< 0.0002	0.15	0.0150	0.001	0.0152
STRONTIUM (Sr)	0.167	0.173	0.173	4.0	4%	Toxic	0.1	0.2673	0.15	0.6000	0.0002	0.773
THALLIUM (Tl)	< 0.0002	< 0.0002	< 0.0002	0.002	10%	Toxic	0.0003	0.0005	0.15	0.0003	0.0002	0.0005
URANIUM (U)	< 0.008	< 0.008	< 0.0063	0.03	27%	Carcinogen	NAI	NAI	NAI	NAI	0.008	0.008
ZINC (Zn)	< 0.002	< 0.002	< 0.004	2.0	0%	Toxic	0.005	0.007	0.15	0.3000	0.01	0.302
NITRATE + NITRITE AS N	< 0.01	< 0.01	< 0.01	10	0%	Toxic	7.5	7.5	0.15	7.5	0.01	7.5
NITROGEN (N) TOT	NM	NM	NM	--	--	Nutrient	--	--	--	--	0.01	--
PHOSPHORUS (P) TOT	NM	NM	NM	--	--	Nutrient	--	--	--	--	0.001	--
PH FLD (S.U.)	7.16	7.35	7.20	6.5-8.5	--	Harmful	--	--	--	--	--	6.5-8.5
SPECIFIC CONDUCTIVITY (UMHOS/CM)	490	522	508	<1000	--	Class I GW	--	--	--	--	1	<1000
SULFATE (SO4)	12	17	15	250*	--	SMCL	--	--	--	--	1	250*
CHLORIDE (Cl)	2.0	2.9	2.4	250*	--	SMCL	--	--	--	--	1	250*
CALCIUM (Ca)	75	78	76	--	--	--	--	--	--	--	1	--
SODIUM (Na)	3	3	3	--	--	--	--	--	--	--	1	--
MAGNESIUM (Mg)	21	22	21	--	--	--	--	--	--	--	1	--
TOTAL ALKALINITY AS CaCO3	263	280	271	--	--	--	--	--	--	--	4	--
TOTAL SUSPENDED SOLIDS (TSS)	< 10	< 10	< 11	--	--	--	--	--	--	--	10	--
TOTAL HARDNESS AS CaCO3	278	296	288	--	--	--	--	--	--	--	--	--

Units in mg/L unless otherwise noted

NAI = No Allowable Increase (applies to all Carcinogen and Toxics with BCF >300); -- = Not Applicable

Statistics calculated using the value of detection limit when less that detection results. Average value assigned < when 50% or more of samples below detect.

* Based on EPA Secondary Standard (SMCL)

Table I-2. Estimated Surface Water Non-Degradation Criteria: Sheep Creek

SITE CODE	Surface Water Monitoring site SW-1			Lowest Applicable Surface Water Standard	Ambient/ Standard	Category	Non Deg Trigger Level	Ambient + Trigger	Applicable Nonsignificance Factor ARM 17.30.715	Non Deg Threshold	Required Reporting Limit (RRL) or DL	Nondegradation Nonsignificance Criteria
	25%tile	75%tile	Average									
ALUMINUM (Al)	< 0.009	0.030	0.043	0.087	34%	Toxic	0.03	0.0600	0.015	0.0013	0.009	0.0300
ANTIMONY (Sb)	< 0.0005	< 0.0005	< 0.0009	0.0056	9%	Toxic	0.0004	0.0009	0.15	0.0008	0.0005	0.00134
ARSENIC (As)	< 0.001	< 0.001	< 0.001	0.010	10%	Carcinogen	NAI	NAI	NAI	NAI	0.001	0.001
BARIUM (Ba)	0.099	0.110	0.105	1.0	11%	Toxic	0.002	0.1120	0.15	0.1500	0.005	0.260
BERYLLIUM (Be)	< 0.0008	< 0.0008	< 0.0008	0.004	20%	Carcinogen	NAI	NAI	NAI	NAI	0.001	0.0008
CADMIUM (Cd)	< 0.00003	< 0.00003	< 0.00004	0.00032	9%	Toxic	0.0001	0.0001	0.15	0.0000	0.00008	0.0001
CHROMIUM (Cr)	< 0.009	< 0.010	< 0.008	0.10	10%	Toxic	0.001	0.0110	0.15	0.0154	0.001	0.025
COBALT (Co)	< 0.010	< 0.010	< 0.010	--	--	--	--	0.0100	--	--	0.01	--
COPPER (Cu)	< 0.002	< 0.002	< 0.002	0.011	18%	Toxic	0.0005	0.0025	0.15	0.0017	0.001	0.004
FLUORIDE (F)	< 0.1	0.1	0.1	4.0	3%	Toxic	0.005	0.1050	0.15	0.6000	0.001	0.7000
IRON (Fe)	0.15	0.39	0.33	1	--	Harmful	--	0.3875	0.1	0.1000	0.05	0.3875
LEAD (Pb)	< 0.0003	< 0.0004	< 0.0004	0.0042	10%	Toxic	0.0001	0.000525	0.15	0.00063	0.00050	0.00105
MANGANESE (Mn)	0.014	0.019	0.018	--	--	--	--	0.0193	--	--	0.005	--
MERCURY (Hg)	< 0.000005	< 0.000006	0.000007	0.00091	1%	Toxic w/ BCF >300	NAI	NAI	NAI	NAI	0.00001	0.000006
MOLYBDENUM (Mo)	< 0.002	< 0.002	< 0.002	--	--	--	--	0.0020	--	--	0.002	--
NICKEL (Ni)	< 0.001	< 0.001	< 0.002	0.063	2%	Toxic	0.0005	0.0015	0.15	0.0094	0.010	0.010
SELENIUM (Se)	< 0.0002	< 0.0002	< 0.0003	0.005	4%	Toxic	0.0006	0.0008	0.15	0.0008	0.0010	0.0010
SILVER (Ag)	< 0.0002	< 0.0003	< 0.0003	0.0047	6%	Toxic	0.0002	0.0005	0.15	0.0007	0.001	0.0010
STRONTIUM (Sr)	0.1008	0.1270	0.1156	4.0	3%	Toxic	0.1	0.2270	0.15	0.6000	0.0002	0.727
THALLIUM (Tl)	< 0.0002	< 0.0002	< 0.0002	0.00024	83%	Toxic	0.0003	0.0005	0.15	0.00004	0.0002	0.0002
URANIUM (U)	< 0.0061	< 0.0080	< 0.0061	0.03	27%	Carcinogen	NAI	NAI	NAI	NAI	0.008	0.008
ZINC (Zn)	< 0.002	0.005	< 0.004	0.144	3%	Toxic	0.005	0.0100	0.15	0.0216	0.01	0.03
NITRATE + NITRITE AS N	< 0.01	0.03	< 0.03	10	0%	Toxic	5.0	5.03	0.15	1.5	0.01	7.5
NITROGEN (N) TOT (Persulfate method) Seaso	0.06	0.09	0.08	0.3	30%	Nutrient	0.01	0.10	0.1	0.03	0.07	0.12
PHOSPHORUS (P) TOT (Seasonal)	0.009	0.011	0.010	0.03	37%	Nutrient	0.001	0.01	0.1	0.003	0.003	0.01
PH FLD (S.U.)	7.73	8.30	7.91	6.5-8.5	--	Harmful	--	8.30	--	--	--	6.5-8.5
SPECIFIC CONDUCTIVITY (UMHOS/CM)	238	321	282	--		--	--	321	--	--	--	--
TOTAL DISSOLVED SOLIDS (TDS)	154	186	170	500*	--	SMCL	--	186	--	--	1	500*
SULFATE (SO4)	4.0	6.1	5.2	250*	--	SMCL	--	6	--	--	1	250*
CHLORIDE (Cl)	1.0	2.0	1.4	250*	--	SMCL	--	2	--	--	1	250*
CALCIUM (Ca)	36	49	43	--	--	--	--	49	--	--	1	--
SODIUM (Na)	2	2	2	--	--	--	--	2	--	--	1	--
MAGNESIUM (Mg)	9	13	11	--	--	--	--	13	--	--	1	--
TOTAL ALKALINITY AS CACO3	130	180	155	--	--	--	--	180	--	--	4	--
TOTAL SUSPENDED SOLIDS (TSS)	< 4	10	10	25.7	--	(1)	--	10	--	--	10	26
TOTAL HARDNESS AS CACO3	124	176	149	--	--	--	--	176	--	--	--	--
TEMPERATURE ©	0.09	8.78	5.12	(1)	--	Harmful	--	9	--	--	0.1	(1)
FLOW (cfs)	20	103	72	(2)	--	(2)	--	103	--	--	--	See Tbl 4a

(1) ARM 17.30.623(2)

(2) ARM 17.30.715(2)(a) Nondeg apply

Units in mg/L unless otherwise noted

NAI = No Allowable Increase (applies to all Carcinogen and Toxics with BCF >300); -- = Not Applicable; DL = Detection Limit

Statistics calculated using the value of detection limit when less that detection results. Average value assigned < when 50% or more of samples below detect.

* Based on EPA Secondary Standard (SMCL); ** Total Nitrogen was calculated based on nitrate plus nitrate and TKN analyses prior to April 2015 the total nitrogen persulfate method was used following the use of TKN

Hardness based metals standards (ppb) using 25%tile hardness value

	Acute= exp(ma(ln(hardness))+ba)			chronic = exp(mc(ln(hardness))+bc)		
	ma	ba	Acute std	mc	bc	Chronic Std
Cd	1.0166	-3.924	2.65	0.7409	-4.719	0.317
Cu	0.9422	-1.7	17.14	0.8545	-1.702	11.211
Cr +++	0.819	3.7256	2150.40	0.819	0.6848	102.782
Pb	1.273	-1.46	167.67	1.273	-4.705	4.184
Ni	0.846	2.255	562.82	0.846	0.0584	62.575
Ag	1.72	-6.52	5.88			
Zn	0.8473	0.884	143.77	0.8473	0.884	143.771

APPENDIX J

STORM WATER FLOW CALCULATIONS AND SEDCAD OUTPUT

Outfall 002		
Drainage Areas	**1**	**2**
Total Acres	5.20	8.04
Channel Flow*		
Slope %	14.2	2.7
Horizontal Distance (ft)	154	513.36
Vertical Distance (ft)	21.93	14
Time (hr)	0.014	0.108
Soil Type (1)	Woodhall	Topsoil
Soil Type (2)	Poin	
Hydraulic Soil Group	WH(C) P(D)	
Vegetation Type	Grassland	Grass Cover
Upland Flow ***		
CN	78	80
Slope %	10.9	3.0
Horizontal Distance (ft)	100	100
Vertical Distance (ft)	11	3
S (in)	2.821	2.500
Time (hr)	0.027	0.048
Tc (Total)	**0.041**	**0.156**

Outfall 003			
Drainage Areas	**1**	**2**	**3**
Total Acres	2.00	10.50	2.70
Channel Flow*			
Slope %	16.9	12.7	3.3
Horizontal Distance (ft)	197	402	1619.43
Vertical Distance (ft)	33.2	50.98	53.27
Time (hr)	0.052	0.039	0.31
Soil Type (1)	Woodhall	Poin	Cheadle
Soil Type (2)	Poin		Poin
Hydraulic Soil Group	WH(C) P(D)	D	D
Vegetation Type	Conifer	Grassland	50% Juniper, 50% Grassland
Upland Flow ***			
CN	76	83.5	76
Slope %	25.8	23.4	2.5
Horizontal Distance (ft)	100	100	100
Vertical Distance (ft)	26	23	3
S (in)	3.158	1.976	3.158
Time (hr)	0.019	0.016	0.060
Tc (Total)	**0.071**	**0.055**	**0.370**

Outfall 004		
Drainage Areas	**1**	**2**
Total Acres	63.64	2.04
Channel Flow*		
Slope %	7.1	
Horizontal Distance (ft)	1676.89	
Vertical Distance (ft)	118.7	
Time (hr)	0.218	
Soil Type (1)	Woodhall	Poin
Soil Type (2)		
Hydraulic Soil Group	C	D
Vegetation Type	25% Forest, 50% Grassland 50% stockpile	Juniper
Upland Flow ***		
CN	75	71
Slope %	12.6	6.8
Horizontal Distance (ft)	100	76.81
Vertical Distance (ft)	13	5
S (in)	3.333	4.085
Time (hr)	0.027	0.034
Tc (Total)	**0.245**	**0.034**

Outfall 005		
Drainage Areas	**1**	**2**
Total Acres	6.73	6.28
Channel Flow*		
Slope %	9.3	16.4
Horizontal Distance (ft)	1117.35	432
Vertical Distance (ft)	103.98	71.01
Time (hr)	0.127	0.037
Soil Type (1)	Kimpton	Poin
Soil Type (2)		
Hydraulic Soil Group	C	D
Vegetation Type	Grassland/Shrubland	Shrubland
Upland Flow ***		
CN	75	85
Slope %	10.8	14.3
Horizontal Distance (ft)	100	100
Vertical Distance (ft)	11	14
S (in)	3.333	1.765
Time (hr)	0.030	0.019
Tc (Total)	**0.157**	**0.056**

Outfall 006	
Drainage Areas	**1**
Total Acres	25.86
Channel Flow*	
Slope %	15.5
Horizontal Distance (ft)	1787.94
Vertical Distance (ft)	277.8
Time (hr)	0.501
Soil Type (1)	Kimpton
Soil Type (2)	
Hydraulic Soil Group	C
Vegetation Type	Forest
Upland Flow ***	
CN	61
Slope %	7.6
Horizontal Distance (ft)	100
Vertical Distance (ft)	8
S (in)	6.393
Time (hr)	0.051
Tc (Total)	**0.552**

Outfall 008		
Drainage Areas	**1**	**2**
Total Acres	2.81	10.73
Channel Flow*		
Slope %	4.9	7.7
Horizontal Distance (ft)	62.2	377.4
Vertical Distance (ft)	3.07	29.17
Time (hr)	0.03	0.149
Soil Type (1)	Poin	Poin
Soil Type (2)		
Hydraulic Soil Group	D	D
Vegetation Type	Forest/Conifer Forest	Juniper
Upland Flow ***		
CN	76	71
Slope %	4.9	8.8
Horizontal Distance (ft)	100	100
Vertical Distance (ft)	5	9
S (in)	3.158	4.085
Time (hr)	0.043	0.037
Tc (Total)	**0.073**	**0.186**

Outfall 007			
Drainage Areas	**1**	**2**	**3**
Total Acres	10.66	15.74	1.17
Channel Flow*			
Slope %	11.7	15.0	14.9
Horizontal Distance (ft)	496.71	1669.58	201.01
Vertical Distance (ft)	57.998	250.7	29.98
Time (hr)	0.05	0.15	0.018
Soil Type (1)	Houlihan	Kimpton	Kimpton
Soil Type (2)		Houlihan	
Hydraulic Soil Group	Unranked (D)	C	C
Vegetation Type	Upper Shrubland	and/Conifer	Upper Shrubland
Upland Flow ***			
CN	80	70.1	74
Slope %	7.6	11.8	9.5
Horizontal Distance (ft)	100	100	100
Vertical Distance (ft)	8	12	10
S (in)	2.500	4.265	3.514
Time (hr)	0.030	0.033	0.032
Tc (Total)	**0.080**	**0.183**	**0.050**

Outfall 009	
Drainage Areas	**1**
Total Acres	9.00
Channel Flow*	
Slope %	8.3
Horizontal Distance (ft)	524
Vertical Distance (ft)	43.27
Time (hr)	0.063
Soil Type (1)	Cheadle
Soil Type (2)	
Hydraulic Soil Group	D
Vegetation Type	Grassland
Upland Flow ***	
CN	79.4
Slope %	4.7
Horizontal Distance (ft)	100
Vertical Distance (ft)	5
S (in)	2.594
Time (hr)	0.039
Tc (Total)	**0.102**

Outfall 010	
Drainage Areas	**1**
Total Acres	32.30
Channel Flow*	
Slope %	11.0
Horizontal Distance (ft)	2338.01
Vertical Distance (ft)	256.61
Time (hr)	0.245
Soil Type (1)	Poin
Soil Type (2)	Caseypeak
Hydraulic Soil Group	P (D) CP (B)
Vegetation Type	50% Conifer, 50% Grassland
Upland Flow ***	
CN	72
Slope %	5.0
Horizontal Distance (ft)	100
Vertical Distance (ft)	5
S (in)	3.889
Time (hr)	0.047
Tc (Total)	**0.292**

SF-01	
Drainage Areas	**1**
Total Acres	4.33
Channel Flow*	
Slope %	24.8
Horizontal Distance (ft)	394.04
Vertical Distance (ft)	97.9
Time (hr)	0.087
Soil Type (1)	Caseypeak
Soil Type (2)	
Hydraulic Soil Group	B
Vegetation Type	Forest
Upland Flow ***	
CN	41
Slope %	16.4
Horizontal Distance (ft)	100
Vertical Distance (ft)	16
S (in)	14.390
Time (hr)	0.058
Tc (Total)	**0.145**

SF-2	
Drainage Areas	**1**
Total Acres	1.35
Channel Flow*	
Slope %	3.8
Horizontal Distance (ft)	1995.913
Vertical Distance (ft)	75.33
Time (hr)	0.357
Soil Type (1)	Poin
Soil Type (2)	
Hydraulic Soil Group	D
Vegetation Type	50% Forest 50% Grassland
Upland Flow ***	
CN	74.5
Slope %	6.6
Horizontal Distance (ft)	100
Vertical Distance (ft)	7
S (in)	3.423
Time (hr)	0.038
Tc (Total)	**0.395**

Outfall 011	
Drainage Areas	**1**
Total Acres	1.70
Channel Flow*	
Slope %	2.4
Horizontal Distance (ft)	1666.8
Vertical Distance (ft)	40.34
Time (hr)	0.0198
Soil Type (1)	Cheadle
Soil Type (2)	Duckcreek
Hydraulic Soil Group	D
Vegetation Type	Shale 50% Grassland 50%
Upland Flow ***	
CN	85
Slope %	25.3
Horizontal Distance (ft)	100
Vertical Distance (ft)	25
S (in)	1.765
Time (hr)	0.014
Tc (Total)	**0.034**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	5.200	0.041	0.000	0.000	78.000	TR55	5.57	0.281
	2	8.040	0.156	0.011	0.466	80.000	TR55	8.00	0.504
	Σ	**13.240**						**11.38**	**0.785**
#2	Σ	**13.240**						**11.38**	**0.785**

Subwatershed Muskingum Routing Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	2	9. Small streams flowing bankfull	6.67	65.61	984.01	23.230	0.011
#1	**2**	**Muskingum K:**					**0.011**

Outfall 003

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	2.300	0.069	0.000	0.000	78.200	TR55	2.50	0.126
	2	10.500	0.055	0.000	0.000	83.500	TR55	16.56	0.804
	3	2.430	0.372	0.000	0.000	75.000	TR55	1.13	0.106
	Σ	**15.230**						**19.23**	**1.036**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	63.640	0.245	0.084	0.401	75.000	TR55	36.77	2.779
	2	2.040	0.034	0.000	0.000	71.000	TR55	1.13	0.066
	Σ	**65.680**						**35.53**	**2.844**
#2	Σ	**65.680**						**35.53**	**2.844**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	6.730	0.157	0.000	0.000	75.000	TR55	4.52	0.300
	2	6.280	0.056	0.000	0.000	85.000	TR55	10.86	0.526
	Σ	**13.010**						**11.99**	**0.825**
#2	Σ	**13.010**						**11.99**	**0.825**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	25.860	0.552	0.000	0.000	61.000	TR55	0.87	0.288
	Σ	**25.860**						**0.87**	**0.288**
#2	**Σ**	**25.860**						**0.87**	**0.288**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	10.660	0.080	0.000	0.000	80.000	TR55	13.28	0.657
	2	15.740	0.183	0.000	0.000	70.100	TR55	6.02	0.470
	3	1.170	0.050	0.000	0.000	74.000	TR55	0.88	0.048
	Σ	**27.570**						**15.40**	**1.174**
#2	Σ	**27.570**						**15.40**	**1.174**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	2.810	0.073	0.051	0.364	76.000	TR55	2.55	0.132
	2	10.730	0.186	0.000	0.000	71.000	TR55	4.56	0.344
	Σ	**13.540**						**6.12**	**0.477**
#2	Σ	**13.540**						**6.12**	**0.477**

Subwatershed Muskingum Routing Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	2.29	19.20	839.00	4.530	0.051
#1	**1**	**Muskingum K:**					**0.051**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	9.000	0.102	0.008	0.462	79.400	TR55	10.73	0.533
	Σ	**9.000**						**10.73**	**0.533**
#2	**Σ**	**9.000**						**10.73**	**0.533**

Subwatershed Muskingum Routing Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	9. Small streams flowing bankfull	5.13	32.80	639.00	20.390	0.008
#1	**1**	**Muskingum K:**					**0.008**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	32.300	0.292	0.000	0.000	72.000	TR55	12.44	1.117
	Σ	**32.300**						**12.44**	**1.117**
#2	Σ	**32.300**						**12.44**	**1.117**

Outfall 011

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	1.700	0.034	0.000	0.000	85.000	TR55	2.94	0.142
	Σ	**1.700**						**2.94**	**0.142**
#2	Σ	**1.700**						**2.94**	**0.142**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	4.330	0.145	0.000	0.000	41.000	TR55	0.00	0.000
	Σ	**4.330**						**0.00**	**0.000**
#2	Σ	**4.330**						**0.00**	**0.000**

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	1.350	0.395	0.000	0.000	75.000	TR55	0.61	0.059
	∑	**1.350**						**0.61**	**0.059**
#2	∑	**1.350**						**0.61**	**0.059**

APPENDIX K

WATER RESOURCES MONITORING
FIELD SAMPLING AND ANALYSIS PLAN

WATER RESOURCES MONITORING
FIELD SAMPLING AND ANALYSIS PLAN
BLACK BUTTE COPPER PROJECT

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June 2016

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

WATER RESOURCES MONITORING
FIELD SAMPLING AND ANALYSIS PLAN
BLACK BUTTE COPPER PROJECT

1.0 INTRODUCTION

Baseline water resource monitoring has been conducted at the Black Butte Copper Project (Project) since 2011. The monitoring to date has been conducted in accordance with the 2013 Water Resource Monitoring Field Sampling and Analysis Plan (Hydrometrics, 2013). This Field Sampling and Analysis Plan (FSAP) provides an updated summary of the groundwater, spring/seep, and surface water monitoring activities to be conducted as part of the continued baseline water resource monitoring program for the BBC Project. The FSAP will also provide a basis for monitoring that will be conducted during future activities such as construction, operations, and closure for the proposed BBC Project. These future monitoring programs are will be finalized through the Mine Operating Permit application and development of the Environmental Impact Statement; once the future monitoring programs are finalized the FSAP will be updated in conjunction with the Record of Decision.

The FSAP is intended to provide guidance regarding sampling locations, sample collection methodologies, sample handling, documentation, and custody, and analytical requirements for groundwater, spring, and surface water samples collected as part of routine water resources monitoring. Any additional groundwater and/or surface water monitoring performed at the site will be conducted in accordance with the procedures set forth in this FSAP.

The water resources FSAP is structured as follows:

- Section 1.0 – Introduction;
- Section 2.0 – Sampling Locations and Frequency;

- Section 3.0 – Sampling Methodology;
- Section 4.0 – Sample Handling and Documentation;
- Section 5.0 – Laboratory Analytical Procedures and Reporting; and
- Section 6.0 – References.

1.1 PROJECT BACKGROUND

The Project is located approximately 16 miles north of White Sulphur Springs, Montana in Meagher County (Figure 1). The project is in the early stages of permitting an underground copper deposit and is collecting baseline data for use in project development. The ore body consists of a massive sulfide deposit within the Newland Formation of the Precambrian Belt Supergroup. The Newland Formation can be divided into a lower member that consists of primarily dolomitic shale and an upper member of interstratified shales and carbonates (Nelson, 1963). The project site lies within the Sheep Creek drainage.

Water resource monitoring conducted at the site will be used to establish baseline data including surface water flows, groundwater level elevations, and water quality in the vicinity of the project area to be used in project development and future permitting. Monitoring events will be conducted during each calendar quarter (i.e., January-March, April-June, July-September, and October-December time periods).

Groundwater, including springs and seeps, and surface water monitoring will be conducted in accordance with Hydrometrics' Standard Operating Procedures (SOPs). Water quality samples will be submitted to Energy Laboratories in Helena, MT for analyses of physical parameters, common constituents, nutrients, and a comprehensive suite of trace constituents. With the exception of aluminum, trace constituents will be analyzed for the total recoverable fraction for surface water samples; aluminum will be analyzed for the dissolved fraction. All trace constituents for groundwater samples will be analyzed for the dissolved fraction.

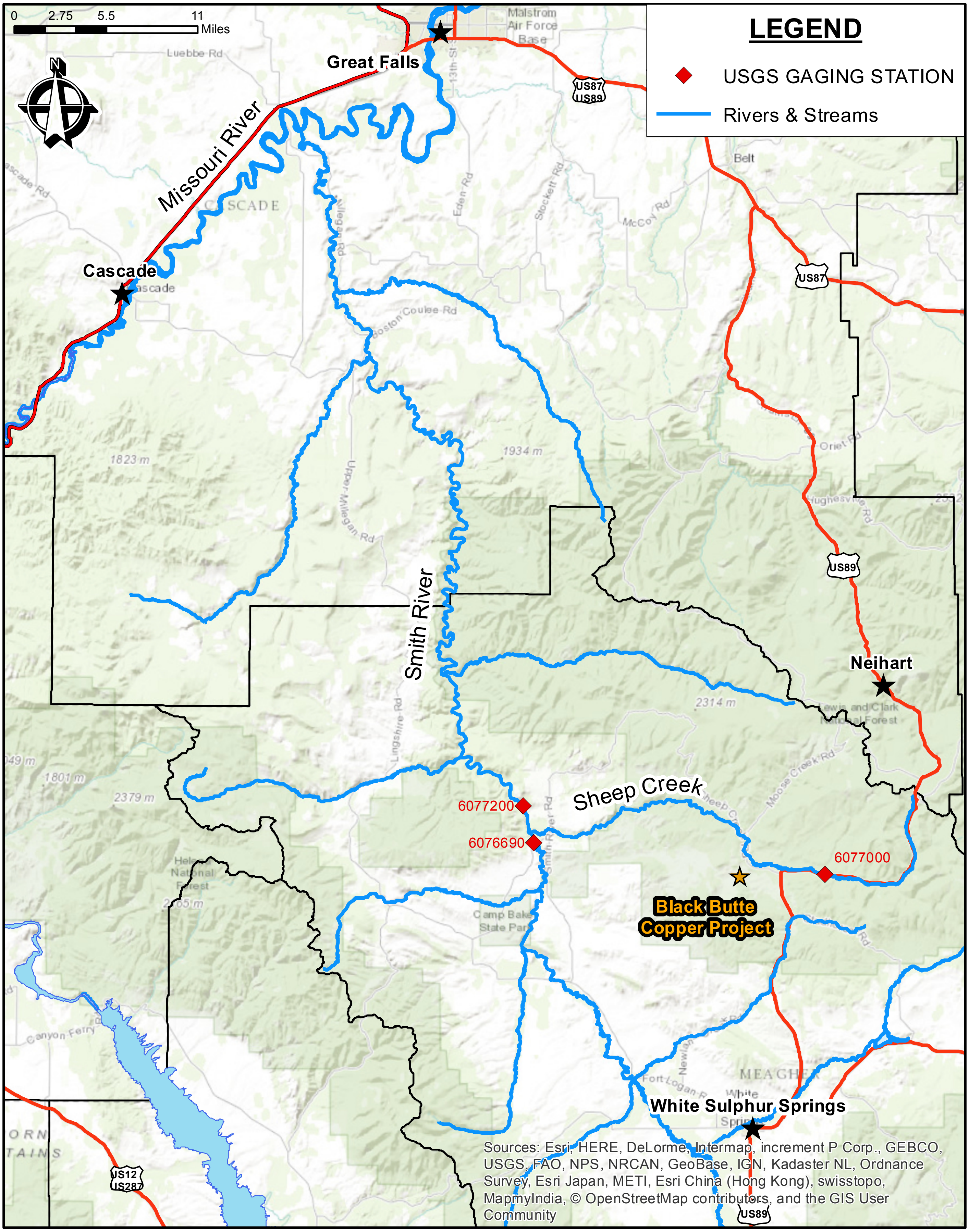

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Figure 1
Project Location Map
Black Butte Copper Project
Meagher County, Montana

2.0 SAMPLING LOCATIONS AND FREQUENCY

This section of the FSAP describes groundwater, spring/seep, and surface water sampling locations. Details on sampling methodologies, sample handling, and analytical requirements are presented in Sections 3.0, 4.0, and 5.0, respectively.

2.1 GROUNDWATER MONITORING

The groundwater quality monitoring will be conducted to establish pre-mining conditions in the vicinity of the proposed mine with an emphasis on the area surrounding the underground workings. The proposed underground mine will be accessed through a single decline which will penetrate dolomitic and silicic shales of the Newland Formation. There are upper (UCZ) and lower (LCZ) ore zones within the Johnny Lee copper-cobalt deposit hosted within the Upper and Lower Sulfide Zones (USZ, LSZ) of the lower Newland Formation. The upper ore zone lies at a depth of approximately 250 to 350 feet below ground surface and is overlain by shale and dolostone (Ynl A), and dolomite (Ynl 0) interbeds. The upper ore zone is underlain by the lower Newland shale and conglomerate (Ynl B). Quaternary alluvial deposits are present beneath the stream channels and along the axis of the drainages.

Quarterly groundwater monitoring is currently conducted at a total of 17 monitoring wells (Figure 2). A series of paired monitoring wells (MW-1A,-1B, MW-2A, -2B, MW-4A, -4B, and MW-6A, -6B) were installed between 2011 and 2013 to document baseline conditions within the unconsolidated Quaternary/Overburden and in the underlying shallow bedrock groundwater system. Monitoring well MW-3 was completed in November 2011 near the proposed terminus of the exploration decline within the UCZ. Paired wells MW-6A and MW-6B and two single wells (MW-7 and MW-8) were completed as groundwater quality and water level monitoring wells to document baseline water quality in the vicinity of the proposed underground LAD/infiltration system where treated mine water will be discharged. MW-6A is completed in shallow alluvial gravels, and MW-6B, MW-7, and MW-8 are completed in shallow YNL dolostone bedrock. In 2014, an additional monitoring well, MW-9, was installed in the YNL-A zone above the sulfide and ore zones as a monitoring

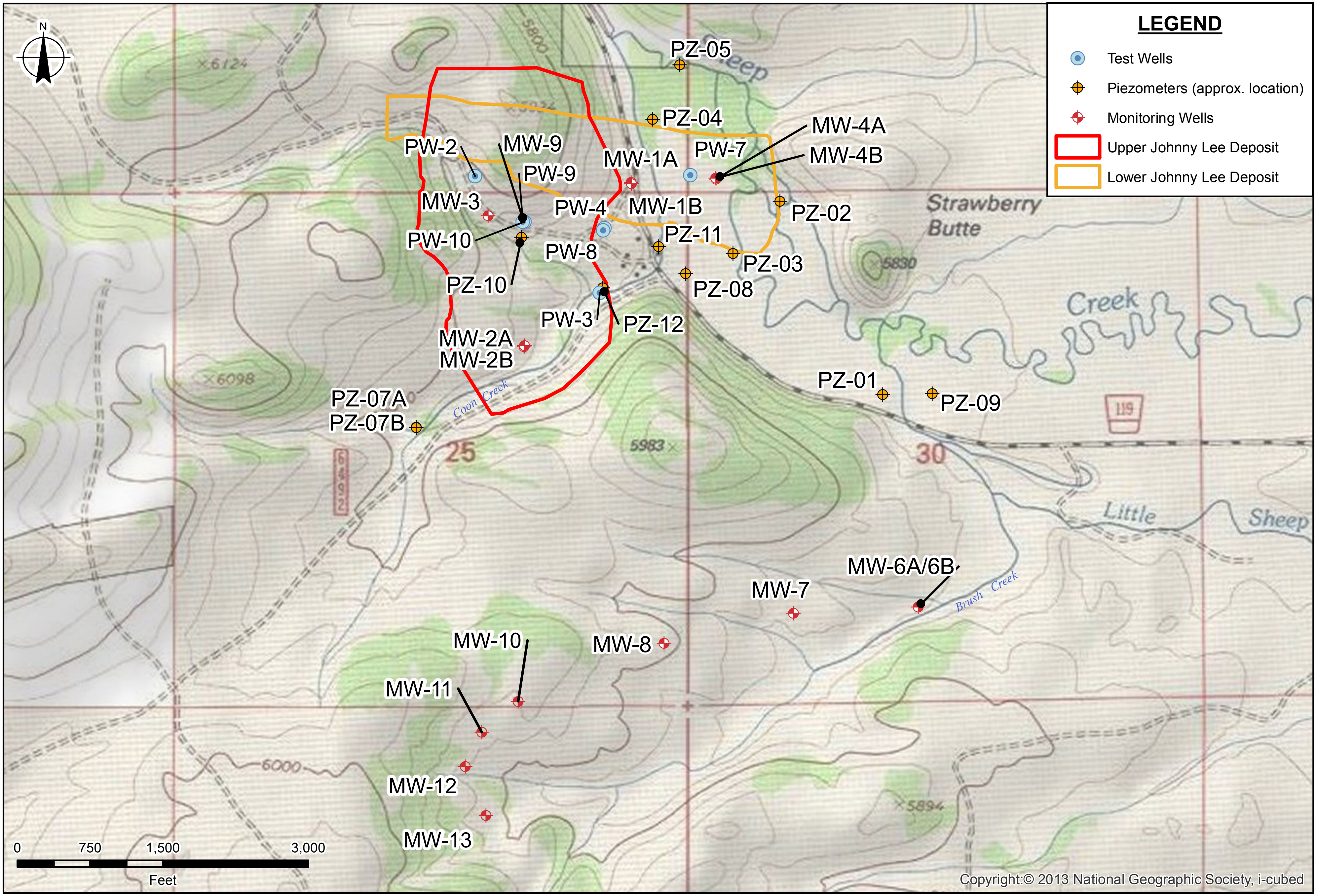

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Figure 2
Groundwater Monitoring Locations
Black Butte Copper Project
Meagher County, Montana

point to assess the effects of ore zone dewatering on overlying units during mine development. MW-10, MW-11, MW-12, and MW-13 were installed in 2016 to assess water quality and quantity in the area of the proposed cemented tailings facility. MW-10, MW-11, and MW-12 are completed in granodiorite and MW-13 is completed in dolomitic shale. Well completion details for the monitoring wells are included in Table 1.

Seven additional test wells (PW-2, PW-3, PW-4, PW-7*, PW-8, PW-9, and PW-10) will be added to the quarterly monitoring during the third quarter of 2016 and thereafter to provide further water quality data for the groundwater resources in the vicinity of the proposed underground facilities. Well PW-7 has been observed to be contaminated with drill mud; therefore, it will not be included in the quarterly monitoring until it has cleaned and purged and shows no signs of drill mud in the water quality results. Wells PW-3 and PW-8 will provide additional data for the Ynl-A. Wells PW-2, PW-4, and PW-9 are completed in the USZ and UCZ. Additional data from the Ynl-B and LCZ will be provided from wells PW-10 and PW-7, respectively. The test wells are deep, four to six-inch wells and will produce significant volumes of water during purging; therefore, the wells will not be sampled during freezing conditions as water disposal is not possible during freezing conditions.

2.2 SPRING AND SEEP MONITORING

As a part of the initial water resource evaluation, nine seeps and 13 springs in the Project area have been identified, mapped, and some monitored for water quality and flow as a part of an inventory completed in 2011 (Hydrometrics, 2012). Seeps and springs are listed in Table 2 and their location is shown on Figure 3.

The majority of the identified sites consist of small springs or seeps located in ephemeral channels in the headwaters of small unnamed tributaries. These springs form small boggy areas with limited flow and generally re-infiltrate within a few hundred feet downstream. A number of these springs have been developed for stock watering (indicated by a DS designator in Figure 3 and Table 2) and feed small livestock watering tanks. The seeps are similar to springs, but are typically more disperse and have little to no measurable flow.

TABLE 1. WELL COMPLETION SUMMARY

Well Name	Northing (meters)	Easting (meters)	Ground Surface Elev.	Measuring Point Elev.	Borehole Total Depth	Well Total Depth	Screen Interval	Hydro-stratigraphic Unit	Year Drilled	Purpose
			(feet, amsl)							
	UTM Zone 12 North				(feet, bgs)					
Monitoring Wells										
MW1A	5180841.55	506935.22	5635.81	5637.73	38	34	25 - 34	Overburden	2011	Baseline
MW1B	5180845.46	506934.19	5636.14	5637.9	98	98	88 - 98	YNL-A		East of USZ
MW2A	5180331.93	506598.18	5743.72	5745.31	62	62	52 - 62	Shallow Bedrock	2011	Baseline East of Coon Creek
MW2B	5180328.73	506596.96	5743.44	5745.53	80	80	70 - 80	YNL-A		
MW3	5180740.22	506484.07	5760.06	5762.17	305	305	285 - 305	USZ	2011	Baseline USZ
MW4A	5180855.43	507201.47	5610.12	5612.12	23	23	14-23	Sheep Creek Alluvium	2012	Baseline Sheep Cr. Alluvium
MW4B	5180858.49	507200.12	5610.07	5612.07	59	59	39-59	YNL-B	2012	Baseline YNL-B below Sheep Cr. Alluvium
MW-5	Not Drilled									
MW-6A	5179492.85	507809.18	5680.08	5681.87	20	15	5-15	Quarternary	2013	Proposed UG Infiltration Gallery
MW-6B	5179490.71	507792.76	5683.41	5685.31	50	50	40-50	Dolostone	2013	
MW-7	5179500.71	507451.7	5747.48	5749.46	50	50	40-50	Dolostone	2013	
MW-8	5179398.31	507036	5809.1	5810.93	80	80	70-80	Dolostone	2013	
MW-9	5180725.46	506592.96	5744.35	5745.8	143.7	128	108-128	YNL-A	2014	Baseline YNL-A Characterization
MW-10	5179215.05	506578.57	5882.78	5886.11	90	90	70-90	Granodiorite	2016	Baseline CTF
MW-11	5179117.47	506464.72	5854.74	5857.86	70	70	50-70	Granodiorite	2016	
MW-12	5179010.38	506412.82	5841.51	5844.75	60	60	40-60	Granodiorite	2016	
MW-13	5178855.81	506477.79	5819.07	5822.48	40	40	20-40	Dolostone	2016	
Test Wells										
PW-2	5180865.03	506443.15	5793.08	5794.88	215	212	132 - 212	USZ	2011	Previous Decline
PW-3	5180479.42	506846.43	5655.21	5657.42	131	127	90-127	YNL-A	2012	Baseline near Decline
PW-4	5180701.75	506849.44	5678.13	5680.01	242	239	200-239	USZ	2012	
PW-7	5180867.59	507122.89	5609.11	5611.15	1350	1346	1306-1346	LCZ	2013	Baseline LCZ Characterization
PW-8	5180695.53	506846.19	5679.12	5680.6	184	178.5	138.5-178.5	YNL-A	2014	Baseline YNL-A Characterization
PW-9	5180721.88	506598.38	5743.59	5745.05	255.5	255.5	215.5-255.5	UCZ	2014	Baseline UCZ Characterization
PW-10	5180721.88	506593.55	5743.57	5744.84	369.5	358.5	318.5-358.5	YNL-B	2014	Baseline YNL-B Characterization

TABLE 2. SPRING AND SEEP SITES

Monitoring Site	Easting (meters)	Northing (meters)	Monitoring Frequency	Flow or Water Level	Field Parameters	Water Quality
	UTM-WGS 1984 Zone 12 North					
Developed Springs						
DS-1	506507.08	5178870.81	Annual	X	X	X
DS-2	505263.49	5180150.61	Annual	X	X	--
DS-3	505037.62	5181520.61	Annual	X	X	X
DS-4	506056.53	5181588.64	Annual	X	X	X
DS-5	504761.45	5182484.96	Annual	X	X	--
DS-6	504949.66	5182827.88	Annual	X	X	--
Seeps						
Seep-1	507876.19	5179570.54	Annual	--	X	--
Seep-2	506310.60	5180089.20	Annual	--	X	--
Seep-3	507821.16	5180537.25	Annual	--	X	--
Seep-4	507530.57	5182486.29	Annual	--	X	--
Seep-5	507768.38	5182748.77	Annual	--	X	--
Seep-6	507853.49	5182587.27	Annual	--	X	--
Seep-7	507155.40	5182821.06	Annual	--	--	--
Seep-8	506701.44	5180381.64	Annual	--	X	--
Seep-9	504825.48	5182475.68	Annual	--	X	--
Seep-10	507270.05	5179164.80	Annual	--	X	--
Springs						
SP-1	506273.00	5180099.00	Annual	X	X	--
SP-2	505833.97	5180907.34	Annual	X	X	--
SP-3	506370.58	5182241.55	Annual	X	X	X
SP-4	506425.17	5180468.94	Annual	X	X	X
SP-5	506478.82	5178985.42	Annual	X	X	X
SP-6	506219.58	5181027.89	Annual	X	X	X
SP-7	507693.69	5181137.92	Annual	X	X	X
SP-8	507995.89	5178745.24	Annual	X	X	--
SP-9	507502.03	5178577.92	Annual	X	X	--
SP-10	506335.42	5178351.00	Annual	X	X	--

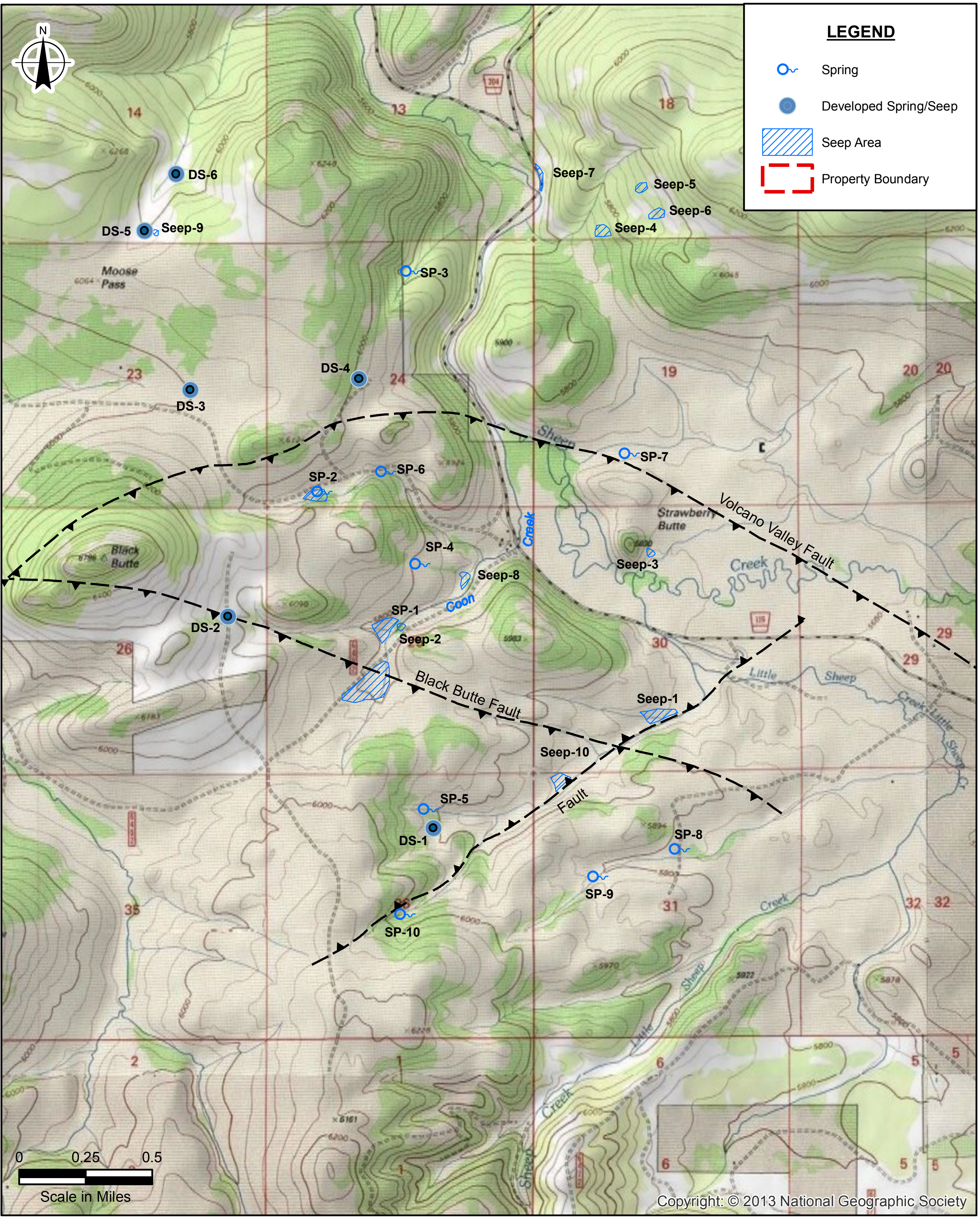

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Figure 3
Spring & Seep Monitoring Locations
Black Butte Copper Project
Meagher County, Montana

Slightly larger spring and seep areas were identified along the lower reaches of Coon Creek and on Little Sheep Creek and support perennial flow on these lower stream reaches.

Springs and seeps are monitored annually during the third quarter water resource monitoring event. Field parameters are collected at all spring and seep sites and flow is measured at all springs. In addition, water quality samples are collected at select springs (Table 2).

2.3 SURFACE WATER MONITORING

The project site lies within the Sheep Creek drainage. Sheep Creek originates in the Little Belt Mountains at an elevation of about 7,600 feet and discharges to the Smith River approximately 34 river miles to the west at an elevation of 4,380 feet. The project area is approximately 17 miles above the confluence with the Smith River. Sheep Creek flows in a meandering channel through a broad alluvial valley upstream of the project site but enters a constricted bedrock canyon just downstream.

Primary tributaries to Sheep Creek in the immediate project area are Little Sheep Creek, and Coon Creek (Figure 4). There are also two un-named tributaries that collect flow from the far side of the valley (to the northeast) and discharge to Sheep Creek immediately upstream and downstream of Strawberry Butte. Black Butte Creek lies just to the southwest of the project area and flows to the west away from the site until it discharges to Sheep Creek further downstream.

Baseline surface water monitoring is conducted on thirteen surface water stations within the project vicinity on a quarterly basis. Quarterly monitoring is intended to document surface water conditions at a range of flows. All thirteen sites will be monitored for field parameters and flow (as described in Section 3.2); eight sites will be samples for water quality monitoring. The location and monitoring conducted at each surface water monitoring site is listed in Table 3. Figure 4 shows the location of each site.

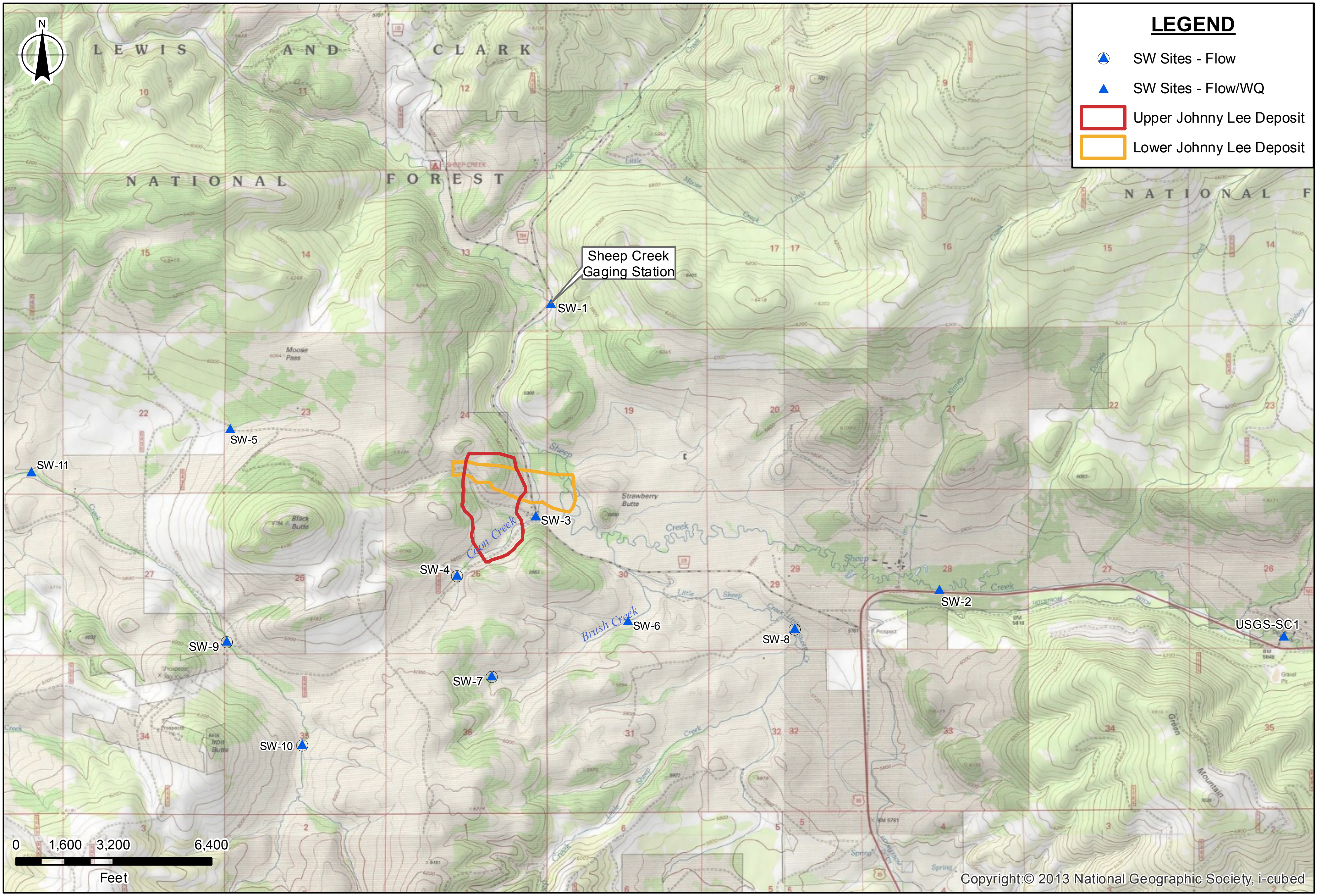

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Figure 4
Surface Water Resource Monitoring Locations
Black Butte Copper Project
Meagher County, Montana

TABLE 3. SURFACE WATER MONITORING SITES

Site	Location	Northing	Easting	Field Parameters	Laboratory Analyses
		UTM - WRS 1984 (meters)			
SW-1	Sheep Creek - Downgradient site; at bridge on county road 119	5182710	507148	**X**	**X**
SW-2	Sheep Creek - Upgradient site; Highway 89 right away approximately 0.6 miles east of county road intersection	5179844	511040	**X**	**X**
SW-3	Unnamed Trib. to Sheep Creek - at intersection of county road 119 and forest service road.	5180581	506996	**X**	**X**
SW-4	Unnamed Trib. to Sheep Creek - approximately 0.6 miles southwest of Co. Rd/USFS Rd intersection	5180114	506308	**X**	
SW-5	Unnamed Trib. To Butte Creek - West of Moose Pass, where jeep trail crosses drainage.	5181465	503914	**X**	**X**
SW-6	Unnamed Trib to Little Sheep Creek - approximately 0.25 miles south of county road.	5179536	507919	**X**	**X**
SW-7	Unnamed Trib to Little Sheep Creek - Upgradient site, approximately 1-mile upgradient of SW-6.	5179000	506420	**X**	
SW-8	Little Sheep Creek - Approximately 0.5 miles from Highway 89.	5179476	509575	**X**	
SW-9	Butte Creek - at USFS road crossing.	5179271	503944	**X**	
SW-10	Butte Creek - approximately 0.7 miles upstream of SW-9.	5178322	504665	**X**	
SW-11	Butte Creek - Downgradient of confluence with Unnamed Trib to Butte Creek (west of Moose Pass).	5181021	501951	**X**	**X**
SW-14	Little Sheep Creek- Approximately 0.25 miles upstream of confluence with Sheep Creek	5180050	507876	**X**	**X**
USGS-SC1	Historical USGS station 06077000 ; approximately 4 miles upstream of the project site on Sheep Creek	514462	5179373	**X**	**X**

2.4 ADDITIONAL/FUTURE MONITORING

Additional water resource monitoring has consisted of spring and seep, surface water monitoring during spring runoff, and additional groundwater monitoring associated with hydrological investigations. As noted in Section 1.0, future monitoring programs are being developed in conjunction with the Mine Operating Permit application and the Environmental Impact Statement for different phases of the project (construction, operations, and closure). The monitoring conducted under these programs and any future programs will be conducted in accordance with this FSAP. A new FSAP will be developed for the different phases of the project once the future monitoring programs are completely developed and a record of decision has been finalized.

3.0 SAMPLING METHODOLOGY

The sampling methodologies to be utilized for groundwater, spring/seep, and surface water monitoring conducted as part of the quarterly monitoring program are detailed below: Groundwater Monitoring Section 3.1, Spring and Seep Monitoring 3.2, and Surface Water Monitoring Section 3.3. Spring and seep monitoring will be conducted in accordance with surface water monitoring for field parameters and sample collection methods; however, sample containers and preservation will be conducted in accordance with groundwater procedures. SOPs for performing field activities are located in Appendix A. Collection of field quality control (QC) samples for all sample media is discussed in Section 3.3.

3.1 GROUNDWATER MONITORING

Groundwater monitoring will include collection of field parameters and water quality samples from seven monitoring wells subsequent to well completion. The collection of groundwater samples from site monitoring wells will generally consist of three steps:

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

3.1.1 Static Water Level Measurement

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

3.1.2 Field Parameters and Water Quality Sample Collection

Dedicated HDPE tubing will be installed in monitoring wells, and a submersible pump will be used to purge and sample the monitoring well. Purging consisted of removing three well volumes while routinely monitoring field parameters (pH, dissolved oxygen (DO), temperature, specific conductance (SC)) during removal of each well volume. Field meters will be calibrated daily according to factory instructions, with calibration results recorded on calibration forms. Purge water will be discharged in such a manner that it will not discharge to surface water.

Samples for laboratory analysis will be collected after one of the following purge conditions are met:

- A minimum of three well volumes have been removed and successive field parameter measurements agree to within the stability criteria given below; or
- At least five well volumes have been removed although field parameter stabilization criteria are not yet met; or
- The well has been pumped dry and allowed to recover sufficiently such that adequate sample volumes for rinsing equipment and collecting samples can be removed.

Criteria for field parameter stabilization are as follows:

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

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

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

Groundwater sampling equipment reused between monitoring locations (e.g., 12-volt sampling pump and short piece of discharge line) will be thoroughly decontaminated between uses. Equipment decontamination will consist of the following steps:

- Rinse with about two gallons of soapy water (Alconox or other non-phosphate detergent); and
- Rinse with about two gallons of distilled water.

3.2 SPRING AND SEEP MONITORING

Spring and seep monitoring will include generally consist of three steps:

- Collecting field parameters
- Water quality sample collection
- Flow measurement (excluding seeps)

3.2.1 Field Parameters

Spring and seep monitoring includes the collection of field parameters that consist of pH, SC, DO, and water temperature. Field parameters will be collected before spring flow measurements, or upstream of the location that spring flows will be measured to ensure the measurements are not affected by streambed disturbance.

Field meters will be calibrated daily according to factory instructions, with calibration results recorded in the field notebook and/or on calibration forms. Field parameter measurements will be obtained directly in the spring; however, in developed springs, field parameters will be taken in a clean container filled with sample water. Results will be recorded in the field notebook.

3.2.2 Water Quality Sampling

Water quality grab samples will be collected from spring and seep monitoring sites by passing an uncapped sample container across the area of flow. Water quality samples will be collected in containers and preserved. Samples for trace constituents will be filtered through a 0.45 µm filter prior to preservation, to allow analysis for the dissolved fraction. Sample containers will be rinsed three times with sample water prior to sample collection, then preserved as appropriate for the intended analysis (e.g., nitric acid preservation to pH <2 for metals analysis), and stored on ice in coolers at approximately 4±2°C during transport.

3.2.3 Flow Measurement

Spring flow measurements will be collected using an appropriate flume (e.g., 90° v-notch cutthroat flume) or visually estimated when the flow is too low to be able to use a flume. To measure spring flow, the flume will be placed and leveled in the channel of spring flow in a location where the full spring flow can be directed through the flume throat. Water depth or head measurements will then be collected at specified locations in the converging and (if applicable) diverging sections of the flume. The head measurements will be used to verify proper functioning of the flume and to calculate stream flow based on the water depth. When it is impracticable to use a flume, a visual flow estimate will be made. Visual flow estimates are typically less than two gallons per minute.

3.3 SURFACE WATER MONITORING

Surface water monitoring will include the collection of flows and field parameters at all 11 sites; water quality samples will be collected at six of the 11 monitoring sites. Below is a summary of the methodologies to be used for the surface water monitoring, which consists of the following steps:

1. Measurement of stream flow and stage (at sites instrumented with staff gages);
2. Collection of field parameters; and
3. Water quality sample collection (if required).

3.3.1 Flow Measurement

Surface water flow measurements will be collected using a Marsh-McBirney current meter and wading rod (area-velocity method), appropriate flume, or estimated using the float method (when it is unsafe to wade in the river).

The Marsh-McBirney current meter is used to measure stream flow at larger, wadeable stream sites. Measurement of stream flow will be performed in accordance with the area-velocity method developed by the USGS (USGS, 1977). In general, the entire stream width is divided into subsections and the stream velocity is measured at the midpoint of each subsection at a depth equivalent to six-tenths of the total subsection depth. The velocity in each subsection is then multiplied by the cross-sectional area to obtain the flow volume through each subsection. The subsection flows are then summed to obtain the total stream flow rate. Stream flow measurements are typically collected in a stream reach as straight and free of obstructions as possible, to minimize potential measurement error introduced by converging or turbulent flow paths.

Stream flow measurements on smaller streams will be obtained by using a portable 90° v-notch cutthroat flume. To measure stream flow, the flume will be placed and leveled in the streambed, and the full stream flow directed through the flume throat. Water depth or head measurements will then be collected at specified locations in the converging and (if applicable) diverging sections of the flume. The head measurements will be used to verify proper functioning of the flume and to calculate stream flow based on the water depth.

The float method can be used when larger streams are not safe to wade due to strong flow. This method tends to underestimate the flow due to slower velocity near the surface, but it is more accurate than a visual estimate.

This method requires a straight and uniform stretch within a stream reach for best results. Stakes or flagging will be placed at the high water line at a distance apart of approximately twice the length of the mean wetted width (>50 feet is preferred). The mean width (from the water's edge) and the mean depth are then estimated and recorded in the field notebook. The measured distance between stakes and a description and sketch of each stake's location is recorded in the field notebook. Photographs of both stakes are taken to record their location along the streambank and the water level.

Toss a small stick or other biodegradable floating object (i.e., an orange) heavy enough to stay in and move consistently with the main current into the middle of the stream above the upstream marker of the measured reach. Begin timing when the object passes the upstream marker. Count (with a watch or stopwatch) the seconds it takes the object to reach the downstream marker. The object must stay in the main current. If it does not, repeat the measurement. Complete three measurable floats.

Record the following information:

- Reach length (ft or m);
- Mean depth (ft or m);
- Mean width (ft or m); and
- Float times (sec).

Complete the following calculations on the Total Discharge Form for high flow:

- Cross-sectional area (m^2 or ft^2) = Mean width x Mean depth;
- Average float time (sec) = (Float time 1 + Float time 2 + Float time 3) / 3;
- Float velocity (ft/sec or m/s) = Reach Length / Average float time; and
- Discharge (ft^3/sec or m^3/sec) = Cross-sectional area x Float velocity.

3.3.2 Field Parameters

Surface water monitoring includes the collection of field parameters that consist of pH, SC, DO, and water temperature. Field parameters will be collected before stream flow measurements, or upstream of the location that stream flows will be measured to ensure the measurements are not affected by streambed disturbance.

Field meters will be calibrated daily according to factory instructions, with calibration results recorded in the field notebook and/or on calibration forms. Field parameter measurements will be obtained directly in the stream; however, in high velocity areas pH may be measured in a clean container filled with sample water to limit possible errors due to streaming potentials. Results will be recorded in the field notebook.

3.3.3 Water Quality Sampling

Water quality grab samples will be collected from surface water monitoring sites by passing an uncapped sample container across the area of flow. Sample containers will be rinsed three times with sample water prior to sample collection. Water quality samples will be collected in containers and preserved as summarized in Table 4.

TABLE 4. SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Parameters	Sample Containers	Preservative
Field Parameters	None	None
Common Constituents	500 mL HDPE	Cool to 4°C
Nutrients (Nitrate+Nitrite)	250 mL HDPE	H_2SO_4 to pH <2 Cool to 4°C
Surface Water Trace Constituents (total recoverable, **except dissolved for aluminum**)	250 mL HDPE	Filter dissolved samples (0.45 µm) HNO_3 to pH <2 Cool to 4°C

Following preservation, samples will be stored on ice in coolers at approximately 4±2°C for transport. Dissolved trace constituents will be filtered by passing unpreserved sample water through a 0.45 µm filter using a peristaltic pump. All raw sample containers, tubing and filters will be discarded after each use to eliminate any cross contamination.

All water quality sampling information, including sample sites, sample numbers, date and time of sample collection, field parameter measurements, flow measurements, and other notes and observations, will be documented in waterproof ink in a dedicated project field notebook. Photos will be taken at each site to document conditions at the time of sampling and to provide reference for future monitoring events.

3.4 FIELD QUALITY CONTROL

Field QC samples will be used to provide quality assurance for field sampling and subsequent laboratory analysis. Field QC samples will include collection of field duplicates, rinsate blanks, D.I. blanks.

Field Duplicates

Field duplicate samples are replicate samples from a single sampling location submitted to a laboratory for the same set of analyses. For the purposes of this project, field duplicates will be collected by filling two samples containers consecutively from the sampling location. Duplicates will be sent to the same laboratory, but identified with different sample numbers. One field duplicate for each sample type (groundwater, spring, surface water) will be collected during each monitoring event to evaluate the reproducibility of the field sampling protocols.

Field Blanks (Rinsate Blanks and D.I. Blanks)

Rinsate (equipment) blanks will be collected for groundwater samples as there is not any equipment that is reused to collect spring or surface water samples. For groundwater samples, rinsate blanks will be collected each day and consist of deionized water processed through decontaminated sampling equipment (including filtration equipment as appropriate), collected into sample bottles and preserved. D.I. blanks will be collected for each monitoring event, and will consist of deionized water placed into sample containers and preserved.

4.0 SAMPLE HANDLING AND DOCUMENTATION

All samples transferred to the laboratory for analysis will follow standard documentation, packing, and chain-of-custody procedures. Samples will be stored in iced coolers or refrigerated following collection, then hand-delivered to the laboratory in iced coolers to maintain sample temperatures of approximately 4±2°C. The SOPs for sample labeling, documentation and chain-of-custody procedures are in Appendix A of this document.

Sample custody (responsibility for the integrity of samples and prevention of tampering) will be the responsibility of sampling personnel until samples are shipped or delivered to the laboratory. Any containers used to ship samples via independent courier will be sealed with custody seals prior to shipping and the receiving laboratory will record the condition of the seals upon arrival to ensure that the containers have not been opened during transport. Custody seals are not required for samples that are maintained under the direct custody of sampling personnel until being hand-delivered to the laboratory. Upon arrival at the laboratory, sample custody shifts to laboratory personnel, who are responsible for tracking individual samples through login, analysis, and reporting. At the time of sample login, the laboratory will assign a unique laboratory sample number, which can be cross-referenced to the field sample number and used to track analytical results.

Documents generated during sample collection will consist of:

1. Sample collection field notes and forms;
2. Chain-of-Custody forms; and
3. Shipping receipts in the event that samples are sent to a laboratory via independent courier.

Sampling activities will be recorded in a project-specific field notebook. Each sample will be identified with a unique sample number, along with the date and time of collection, on adhesive labels attached to sample bottles. All labels will be completed using waterproof ink.

Field notebooks used to record pertinent sampling information will include, at a minimum, the following:

- Project name;
- Date and time;
- Sample location;
- Sample number;
- Sample depth (if applicable);
- Media type;
- Field meter calibration information;
- Sampling personnel present;
- Analyses requested;
- Sample preservation;
- Field parameter measurements;
- Weather observations; and
- Other relevant project-specific site or sample information.

Entries will be made in permanent ink. Corrections to field notebooks will be made by crossing out erroneous information with a single line and initialing the correction. Field books will be signed and dated at the bottom of each page by personnel making entries on that page.

Individual samples (including QC samples) will be assigned unique sample numbers according to the following sample numbering scheme:

AAA[A]-YYMM-XXX

where AAA[A] is a three- or four-character code denoting the project, YYMM is a four-digit code denoting the year and month (e.g., 1109 for September 2011), and XXX is a three-digit code that is incremented sequentially for each successive sample.

5.0 LABORATORY ANALYTICAL PROCEDURES AND REPORTING

Laboratory analysis will be conducted by Energy Laboratories' Helena, Montana branch. Energy Laboratories is certified by EPA Region 8 and the State of Montana under the Safe Drinking Water Act. Field parameters will be analyzed by Hydrometrics' field personnel using the procedures outlined in Sections 3.1.2 and 3.2.2 above, and in the applicable SOPs collected in Appendix A of this document. All laboratory analysis will be fully documented and conducted in accordance with EPA-approved and/or industry standard analytical methods.

5.1 GROUNDWATER, SPRING, AND SEEP ANALYSES

Required parameters, analytical methods, and project-required detection limits for groundwater quality samples collected from wells and springs are shown in Table 5. Groundwater samples, including spring samples, will be analyzed for physical parameters, common constituents, Nitrite + Nitrate, and a comprehensive suite of trace constituents. The project required detection limits (PRDLs) for individual parameters have been set at concentrations normally achievable by routine analytical testing in the absence of unusual matrix interference (laboratory's practical quantitation limit). It must be recognized that the PRDL is a detection limit goal, which may not be achieved in all samples due to sample matrix interference or other problems. If a PRDL is not met by the laboratory, the data will be reviewed to determine if any actions (e.g., sample reanalysis or selection of an alternative analytical method) are required.

TABLE 5. ANALYTICAL METHODS AND DETECTION LIMITS FOR GROUNDWATER SAMPLES

Parameter	Analytical Method[1]	Project-Required Detection Limit (mg/L)
Physical Parameters		
TDS	SM 2540C	10
TSS	SM 2540C	10
Common Ions		
Alkalinity	SM 2320B	4
Sulfate	300.0	1
Chloride	300.0/SM 4500CL-B	1
Fluoride	A4500-F C	0.1
Calcium	215.1/200.7	1
Magnesium	242.1/200.7	1
Sodium	273.1/200.7	1
Potassium	258.1/200.7	1
Nutrients		
Nitrate+Nitrite as N	353.2	0.01
Trace Constituents (Dissolved)[2]		
Aluminum (Al)	200.7/200.8	0.009
Antimony (Sb)	200.7/200.8	0.0005
Arsenic (As)	200.8/SM 3114B	0.001
Barium (Ba)	200.7/200.8	0.003
Beryllium (Be)	200.7/200.8	0.0008
Cadmium (Cd)	200.7/200.8	0.00003
Chromium (Cr)	200.7/200.8	0.01
Cobalt (Co)	200.7/200.8	0.01
Copper (Cu)	200.7/200.8	0.002
Iron (Fe)	200.7/200.8	0.02
Lead (Pb)	200.7/200.8	0.0003
Manganese (Mn)	200.7/200.8	0.005
Mercury (Hg)	245.2/245.1/200.8/SM 3112B	0.000005
Molybdenum (Mo)	200.7/200.8	0.002
Nickel (Ni)	200.7/200.8	0.001
Selenium (Se)	200.7/200.8/SM 3114B	0.0002
Silver (Ag)	200.7/200.8	0.02
Strontium (Sr)	200.7/200.8	0.0002
Thallium (Tl)	200.7/200.8	0.0002
Uranium	200.7/200.8	0.008
Zinc (Zn)	200.7/200.8	0.002
Field Parameters		
Stream Flow	HF-SOP-37/-44/-46	NA
Water Temperature	HF-SOP-20	0.1 °C
Dissolved Oxygen (DO)	HF-SOP-22	0.1 mg/L
pH	HF-SOP-20	0.1 s.u.
Specific Conductance (SC)	HF-SOP-79	1 µmhos/cm

(1) Analytical methods are from *Standard Methods for the Examination of Water and Wastewa*ter (SM) or EPA's *Methods for Chemical Analysis of Water and Waste* (1983).

(2) Samples to be analyzed for dissolved constituents will be field-filtered through a 0.45 µm filter.

5.2 SURFACE WATER ANALYSES

Required parameters, analytical methods, and project-required detection limits for surface water quality samples collected at in the vicinity of the Project are shown in Table 6. Similar to groundwater, samples will be analyzed for physical parameters, common constituents, nutrients, and a comprehensive suite of trace constituents. As for groundwater, the PRDLs for individual parameters have been set at concentrations normally achievable by routine analytical testing in the absence of unusual matrix interference (laboratory's practical quantitation limit). If a PRDL is not met by the laboratory, the data will be reviewed to determine if any actions (e.g., sample reanalysis or selection of an alternative analytical method) are required.

TABLE 6. PARAMETERS, METHODS, AND DETECTION LIMITS FOR BASELINE SURFACE WATER MONITORING

Parameter	Analytical Method(1)	Project-Required Detection Limit (mg/L)
Physical Parameters		
TDS	SM 2540C	4
TSS	SM 2540C	4
Common Ions		
Alkalinity	SM 2320B	4
Sulfate	300.0	1
Chloride	300.0/SM 4500CL-B	1
Fluoride	A4500-F C	0.1
Calcium	215.1/200.7	1
Magnesium	242.1/200.7	1
Sodium	273.1/200.7	1
Potassium	258.1/200.7	1
Nutrients		
Nitrate+Nitrite as N	353.2	0.003
Total Persulfate Nitrogen	A 4500-N-C	0.04
Total Phosphorus	E365.1	0.003
Trace Constituents (SW - Total Recoverable except Aluminum [Diss], GW - Diss)(2)		
Aluminum (Al)	200.7/200.8	0.009
Antimony (Sb)	200.7/200.8	0.0005
Arsenic (As)	200.8/SM 3114B	0.001
Barium (Ba)	200.7/200.8	0.003
Beryllium (Be)	200.7/200.8	0.0008
Cadmium (Cd)	200.7/200.8	0.00003
Chromium (Cr)	200.7/200.8	0.01
Cobalt (Co)	200.7/200.8	0.01
Copper (Cu)	200.7/200.8	0.002
Iron (Fe)	200.7/200.8	0.02
Lead (Pb)	200.7/200.8	0.0003
Manganese (Mn)	200.7/200.8	0.005
Mercury (Hg)	245.2/245.1/200.8/SM 3112B	0.000005
Molybdenum (Mo)	200.7/200.8	0.002
Nickel (Ni)	200.7/200.8	0.001
Selenium (Se)	200.7/200.8/SM 3114B	0.0002
Silver (Ag)	200.7/200.8	0.02
Strontium (Sr)	200.7/200.8	0.0002
Thallium (Tl)	200.7/200.8	0.0002
Uranium	200.7/200.8	0.008
Zinc (Zn)	200.7/200.8	0.002
Field Parameters		
Stream Flow	HF-SOP-37/-44/-46	NA
Water Temperature	HF-SOP-20	0.1 °C
Dissolved Oxygen (DO)	HF-SOP-22	0.1 mg/L
pH	HF-SOP-20	0.1 s.u.
Specific Conductance (SC)	HF-SOP-79	1 µmhos/cm

(1) Analytical methods are from *Standard Methods for the Examination of Water and Wastewa*ter (SM) or EPA's *Methods for Chemical Analysis of Water and Waste* (1983).

(2) Samples to be analyzed for dissolved constituents will be field-filtered through a 0.45 µm filter.

5.3 DATA REVIEW AND REPORTING

All data deliverables containing analytical data and QC information will be reviewed for overall completeness of the data package. Completeness checks will be administered on all data to determine whether deliverables identified in this FSAP are present. At a minimum, deliverables will include field notes and/or forms, transmittal information, sample chain-of-custody forms, analytical results, methods and PQLs, and laboratory QC summaries. The reviewer will determine whether all required items are present and request copies of missing deliverables. Procedures for data review, validation, and reporting are discussed in HSOP-58 located in Appendix A.

The number and type of samples collected will be compared with project specifications. Review of sample collection and handling procedures will include verification of the following:

- Completeness of submittal packages;
- Completeness of field documentation, including chain-of-custody documentation;
- Field equipment calibration and maintenance and/or quality of field measurements; and
- Adherence to proper sample collection procedures.

Data validation will include a detailed review of all analytical results, including:

- Reporting limits (RLs) and PQLs vs. PRDLs;
- Holding times;
- Analytical methods;
- Field QC sample results; and
- Laboratory QC sample results.

6.0 REFERENCES

EPA, 1983. Methods for Chemical Analysis of Water and Wastes. EPA-600/14-79-020. Revised March 1983.

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USGS, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Chapter 1: Surface Water.

USGS, 1999. National Field Manual for the Collection of Water Quality Data: Chapter A4, Collection of Water Samples. September.

APPENDIX A

STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURES

HSOP-4	Chain-of-Custody Procedures, Packing and Shipping Samples
HSOP-29	Labeling and Documentation of Samples
HSOP-31	Field Notebooks
HSOP-58	Guidelines for Quality Assurance of Environmental Data Collection Activities Data Quality Planning, Review, and Management
HF-SOP-3	Preservation and Storage of Inorganic Water Samples
HF-SOP-10	Water Level Measurement With An Electric Probe
HF-SOP-11	Sampling Monitoring Wells For Inorganic Parameters
HF-SOP-19	Obtaining Water Quality Samples from Streams
HF-SOP-20	Field Measurement of pH Using a pH Meter
HF-SOP-22	Field Measurement of Dissolved Oxygen
HF-SOP-37	Streamflow Measurement Using a Marsh-McBirney Water Current Meter
HF-SOP-49	Use of a Flow Cell For Collecting Field Parameters
HF-SOP-73	Filtration of Water Samples
HF-SOP-79	Field Measurement of Specific Conductivity
HF-SOP-84	Field Measurement of Temperature

HSOP-4

CHAIN-OF-CUSTODY PROCEDURES, PACKING, AND SHIPPING SAMPLES

Prepared by: Mark T Walker **Date:** 6/04

Reviewed by: Walter Crane **Date:** 6/04

Approved by: **Date:** 6/04

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REVISION HISTORY

Revised by: Mark T Walker **Date:** 10/2010

TABLE OF CONTENTS

1.0 SCOPE AND APPLICATION

HSOP-4 presents procedures to be followed when shipping samples of environmental media (e.g., air, water, soil, waste material) to a laboratory for analysis. All samples submitted should be accompanied by chain-of-custody documentation.

2.0 SUMMARY OF METHOD

Samples of environmental media submitted to laboratories for analysis are often shipped via commercial carrier. Samples are packed in shipping containers to minimize the potential for container breakage or leaking. Each shipment will be accompanied by sample documentation, including chain-of-custody forms and a list of required analytical parameters, methods, and detection limits. Samples are cooled with ice during transport, to maintain temperature at approximately 4°C (±2°C). Shipments of hazardous materials must conform to International Air Transport Association (IATA) Dangerous Goods regulations and/or Department of Transportation (DOT) regulations, as well as any carrier-specific requirements.

3.0 HEALTH AND SAFETY WARNINGS

Field personnel should be aware of the health and safety precautions to be followed during any field event, and should be familiar with any project-specific hazards. This may include review of project-specific health and safety plans, site-specific and/or organization-specific safety requirements and training.

- Care should be exercised when handling samples of hazardous or potentially hazardous waste. Personal protective equipment (PPE) should be utilized (gloves, safety glasses, coveralls) as appropriate.
- Glass sample containers should be handled with extreme care to avoid breakage, loss of sample, and possible injury.

4.0 INTERFERENCES

Not Applicable

5.0 PERSONNEL QUALIFICATIONS

Personnel should be familiar with the project work plan and objectives, and with the operation of equipment listed in Section 6.0 below. Personnel should also familiarize themselves with the schedule of the shipping location to be used for shipping samples. For projects involving hazardous materials, consult the project work plan, courier regulations, and any state and federal air or ground shipping regulations for details on shipping hazardous material.

6.0 EQUIPMENT AND SUPPLIES

- Shipping container (metal or plastic cooler);
- Packing material (bubble wrap, Styrofoam peanuts);
- Absorbent material (clay absorbents, rock wool);
- Shipping tape;
- Shipping strap;
- Custody seals;
- Chain-of-custody (COC) forms;
- Heavy-duty or contractor grade garbage bags or similar plastic bags;
- Ziploc bags; and
- Ice.

7.0 CHAIN-OF-CUSTODY PROCEDURE

1. Chain-of-custody involves ensuring that samples are traceable from the time of collection until received by the analytical laboratory. The laboratory is responsible for custody during processing and analysis. A sample is under custody if:

    - It is in your possession;
    - It is in your view, after being in your possession; or
    - It was in your possession and you then placed it in a designated secure or locked area to prevent tampering.

2. When ready to ship samples, set out samples in a clean, secure area to complete chain-of-custody forms. Chain-of-custody forms may be obtained from the project laboratory, or from Hydrometrics' Data Quality Department. An example COC form is shown in Attachment 1. Each sample should be identified on the form by its sample number, date and time of collection, and analysis requested. Check sample labels against information recorded in field notebook and on chain-of-custody to ensure consistency and guard against transcription errors (HSOP-29). It is usually best to use one chain-of-custody form per shipping container, covering the samples included in the container. When shipping multiple coolers to the laboratory, label chain-of-custody forms as “Cooler 1 of 3,” “Cooler 2 of 3,” etc. While chain-of-custody forms obtained from various sources may differ, certain information regarding sampling dates and times, sample identification, contact information, and requested parameters for analysis should be included on all acceptable forms. Complete all fields on the chain-of-custody form, as applicable to the

particular sampling event. Examples of typical COC information to be completed are as follows:

a) **Company Name:** Enter "Hydrometrics, Inc."

b) **Project Name:** Enter the project name and Hydrometrics' project number

c) **Report Mail Address:** Enter the name, address, and e-mail address of the person who should receive the laboratory report.

d) **Contact Name:** Enter the name of the project manager, sampling personnel, or other responsible contact.

e) **Phone/Fax:** Enter the phone and fax number of the contact person for the project.

f) **E-mail:** Enter the e-mail address for the contact person.

g) **Sampler:** Print the name of the person who collected the samples.

h) **Invoice Address:** Enter the address where the invoice should be sent.

i) **Invoice Contact and Phone:** Enter the name and phone number of the person responsible for approving the invoice.

j) **Purchase Order:** Enter the Hydrometrics' Purchase Order number for the sample order.

k) **Quote/Bottle Order:** Enter the laboratory quote number for the project or bottle order number provided with the sample bottle order.

l) Note any special reporting requirements or formats.

m) **Sample Identification:** Enter the unique sample number assigned to the sample.

n) **Collection Date:** Enter the date each sample was collected. Do not use ditto (") marks, arrows or lines to represent the same date.

o) **Collection Time:** Enter the time each sample was collected. Do not use ditto (") marks, arrows or lines to represent the same time.

p) **Number of Containers and Matrix:** Enter the number of bottles the sample is contained in followed by a dash and then a letter representing the type of sample matrix (i.e. A=Air, W=Water, S=Soil/Solid, V=Vegetation, B=Bioassay, O=Other).

q) **Analysis Requested:** Write the analysis to be performed on each sample and check the box for each sample you want to receive this analysis. Also include an analytical parameter list.

r) **Remarks:** Use this field to make notes or comments to the laboratory.

(Note: If a laboratory-provided COC form is used, be sure to follow any additional instructions included from the laboratory.)

3. Record shipping information (tracking numbers, name of courier, other pertinent information) on chain-of-custody form. Sign and date chain-of-custody form, and retain one copy of form for project file.

8.0 PACKING AND SHIPPING PROCEDURE

1. Seal drain holes in bottom of shipping cooler (inside and out) to prevent leakage. Check sample container lids to ensure they are tightly sealed.

2. Line bottom of cooler with packing material (bubble wrap). Open and place two heavy-duty plastic bags in cooler (one inside the other).

3. Seal samples within individual plastic or bubble wrap bags, as necessary. All glass containers (VOAs, amber glass bottles, glass soil jars) should be placed in individual bubble wrap bags. Place sealed sample containers in shipping cooler, inside double plastic bags. In most instances, a labeled temperature blank should be included with the samples to allow the laboratory to check the sample temperature upon arrival. The temperature blank is generally a small vial or bottle filled with tap water and labeled “Temperature Blank.” Ensure that temperature blank meets temperature requirements upon receipt by laboratory.

4. Cover samples with ice, inside double plastic bags.

5. Close and seal double plastic bags, by knotting or with shipping tape. Fill any empty space in cooler with additional packing material or absorbent material.

6. Record shipping information (tracking numbers, name of courier, other pertinent information) on chain-of-custody form. Sign and date chain-of-custody form, and retain one copy of form for project file.

7. Place original chain-of-custody, sample parameter list, cover letter, and any other documentation needed by the laboratory into a plastic Ziploc bag. Seal Ziploc bag and tape to the inside of the shipping container lid.

8. Label outside of shipping container with sampling organization name, address, and phone number, laboratory destination name, address, and phone number, and any required DOT shipping labels.

9. Place custody seals on front and back of cooler (see Attachment 2) and tape in place with shipping tape to avoid accidental breakage. Wrap cooler securely in at least two places with a minimum of three wraps of shipping tape. Shipping strap may also be used to provide additional insurance against the cooler opening during shipment.

10. Deliver sample containers to the shipping location. Since samples should reach the laboratory as soon as possible to protect sample integrity, **overnight shipping is required,** unless unavailable at the shipping location. Retain copies of shipping receipts for the project file. Shipping receipts and tracking numbers serve as chain-of-custody documentation during sample transport from the sampler to the laboratory.

11. Additional guidance may be found in the EPA's *Contract Laboratory Program Guidance for Field Samplers* (EPA, 2004). More stringent shipping requirements may apply to samples collected under CLP protocols. The project work plan should be consulted to determine any special requirements.

9.0 DATA AND RECORDS MANAGEMENT

The following documents generated during sample packing and shipping will be retained in the project file:

- Chain-of-custody form;
- Analytical parameter list;
- Cover letter; and
- Shipping receipts.

10.0 QUALITY CONTROL/QUALITY ASSURANCE

- Field personnel should cross-reference information on sample labels, in the field notebook, and on sample chain-of custody forms during the sample packing and shipping process.
- Data quality review will include checking of sample documentation to ensure consistency.
- Temperature blank measurements by the laboratory upon arrival of samples will document that samples were maintained at the appropriate temperature during shipping.

11.0 REFERENCES

EPA, 2004. Contract Laboratory Program Guidance for Field Samplers (Draft Final). EPA 540-R-00-003. January, 2004.

Hydrometrics HSOP-29: Labeling and Documentation of Samples

CHAIN OF CUSTODY RECORD

Hydrometrics, Inc.
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Attachment 1
Example Chain-of-Custody Form

PROJ. NO.

PROJECT NAME

SAMPLERS: *(Signature)*

DATE	TIME	COMP	GRAB	SAMPLE NUMBER	NO. OF CON-TAINERS	Commons UF / RAW	Nutrients UF / H_2SO_4	Diss. Metal F / HNO_3	CN UF / NaOH	Total Metals UF / HNO_3	Total Recoverable Metals UF / HNO_3	BTEX	TPH									REMARKS

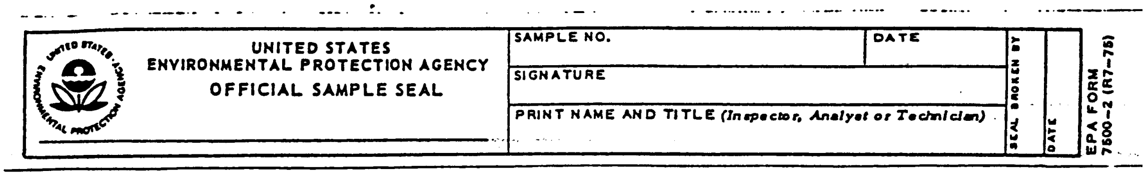
Relinquished *(Signature)*	Date / Time	Received by *(Signature)*	Lab	P.O. #	Shipped via: Bus FedEx UPS Other ____ Air Bill # ____
Relinquished *(Signature)*	Date / Time	Received by *(Signature)*	Remarks		
Relinquished *(Signature)*	Date / Time	Received for Laboratory by *(Signature)*	Date / Time	Enclosed: ☐ Parameter sheet w/detection limits ☐ QA / AC standard mixing instructions ☐ Cover letter ☐ Other ____	

Split Samples:
☐ Accepted ☐ Declined ____
Signature

HFORM-1 07/11
TNO 406-443-8550

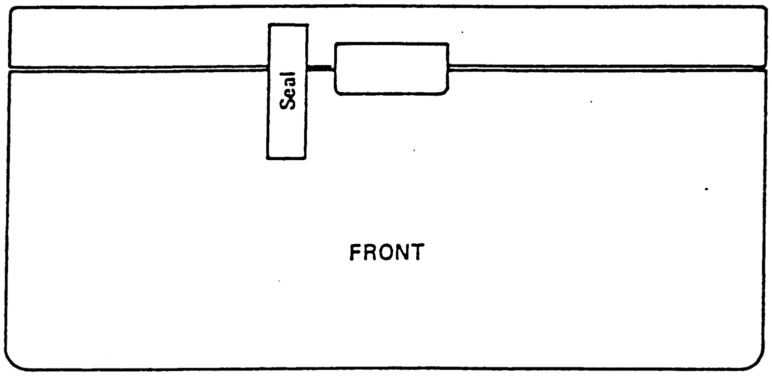
Return results & electronic copy to:
QA / QC Dept. at address at top of page

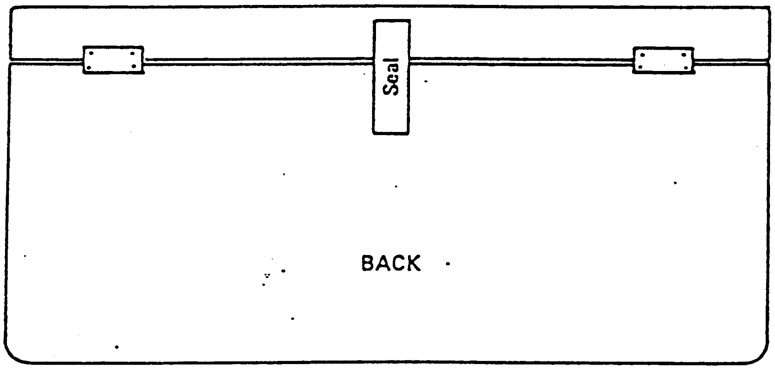
Attachment 2: Example of Custody Seals and Placement



UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
OFFICIAL SAMPLE SEAL

SAMPLE NO.
DATE
SIGNATURE
PRINT NAME AND TITLE *(Inspector, Analyst or Technician)*
SEAL BROKEN BY
DATE
EPA FORM 7500-2 (R7-75)





HSOP-29

LABELING AND DOCUMENTATION OF SAMPLES

Prepared by: ______________________ **Date:** 6/04

Reviewed by: ______________________ **Date:** 6/04

Approved by: ______________________ **Date:** 6/04

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TABLE OF CONTENTS

1.0 SCOPE AND APPLICATION

HSOP-29 describes typical procedures used to label sample containers, to ensure that information on the label is complete and correct, and to document the number and type of samples collected at a particular site. Samples must be thoroughly documented so that analytical data received from the laboratory can be correlated to the correct sampling site.

2.0 SUMMARY OF METHOD

Hydrometrics uses unique sample codes to identify individual samples. Sample codes are distinct from site identification codes, to ensure that the laboratory is unaware of the sample source, and whether the sample is a quality control (QC) or routine sample. Sample codes and other pertinent information is written on adhesive labels affixed to the sample container, or directly on the sample container in some cases. Sample documentation includes recording information in the field notebook (and on sampling forms if required), and completing chain-of-custody documentation for sample storage and shipping.

3.0 HEALTH AND SAFETY WARNINGS

Field personnel should be aware of the health and safety precautions to be followed during any field event, and should be familiar with any project-specific hazards. This may include review of project-specific health and safety plans, site-specific and/or organization-specific safety requirements and training.

4.0 INTERFERENCES

Some common problems with sample labeling and documentation might include the following:

- Use of incorrect sample numbers;
- Transcription errors during sample labeling or recording information in the field notebook; and
- Duplication of sample numbers.

These errors may be avoided by having an additional member of the sampling team check the labeling and documentation during the field event. If one person is conducting the sampling event, information entered on the sample label and in the field notebook should be double-checked for accuracy.

5.0 PERSONNEL QUALIFICATIONS

Labeling and documentation of samples should be conducted by personnel familiar with the project work plan and the proposed sample numbering scheme.

6.0 EQUIPMENT AND SUPPLIES

- Sample ID tag or label;
- Permanent marker;
- Container seals;
- Chain-of-custody form;
- Sampling forms; and
- Field notebook.

7.0 PROCEDURE

1. Determine appropriate sample number to be assigned to the sample. Hydrometrics' numbering convention is as follows:

   XXXX-YYMM-ZZZ

   where XXXX=three- or four-letter project prefix;
   YYMM=last two digits of year followed by month (e.g., 0407 for July 2004);
   ZZZ=sequential numbers, starting with 100.

   This convention may be modified as necessary; most Quality Assurance Project Plans (QAPPs) contain information on sample numbering to be used for a particular project. For some projects, sample numbers for each site to be sampled may be pre-assigned by Hydrometrics' Data Quality Department, to facilitate sample entry into the project database.
2. Fill out information on sample ID tag or label. ID tags are typically serially numbered, and may be used for samples that are likely to be the subject of litigation, or as mandated by EPA, other agency, or work plan requirements. Sample labels are similar to ID tags, but are not numbered.
3. Waterproof permanent markers (such as Sharpie pens) should be used to complete sample ID tag or label information. Information to be included on the sample ID tag or label **<u>must</u>** include:

   - Date and time (24-hour style, e.g. 1400 for 2:00 p.m.);
   - Unique sample number;
   - Sample processing and preservative (whether the sample has been field-filtered, whether a preservative has been used, and the type of preservative); and
   - Sampling personnel names or initials.

   Optional information that may also be included on the sample label or tag as warranted could include the type of analysis requested, or whether the sample is a grab or composite. In no case should a QC sample (blank, duplicate, or blind performance evaluation sample, used to evaluate lab performance with a standard of known concentration) be identified as such on the sample label. QC samples are assigned sample numbers in the same manner as other samples.

4. When multiple sample containers are used at the same site due to differing preservation requirements or additional volume requirements, the same sample numbers should be used on each container.
5. Due to requirements for cooling samples and field conditions, sample containers often become wet. If possible, it is advisable to place clear shipping tape over the label to ensure that it stays on the container. In addition, some sample information may be written on the sample lid, to aid in sample identification should the label become separated from the container.
6. If required by the project, signed and dated seals may be placed over the container lid to prevent opening without breaking the seal.
7. Sample information is recorded in the field notebook, including the same information recorded on the sample label (date and time, sample number, etc.), as well as identifying information for the sampling site, and QC sample information (see HSOP-31). If desired, sampling forms may also be used to record sampling information.
8. On large projects, with multiple field sampling activities occurring at the same time, multiple field notebooks may be used to document sampling activities. Each notebook should clearly state in the initial entry what tasks will be recorded in the particular book.
9. After collection and documentation, samples should be handled in accordance with standard chain-of-custody procedures (see HSOP-4).
10. Any corrections made to sample labels, field notebooks, or chain-of-custody documentation should be made by crossing out the incorrect information with a single line, entering the correct information, and signing and dating the correction.

8.0 DATA AND RECORDS MANAGEMENT

Copies of all sample documentation, including field notebooks, sampling forms, and chain-of-custody forms will be maintained in the project file. Sampling crews are responsible for submitting this information to the Data Quality Department for filing at the completion of each sampling event.

9.0 QUALITY CONTROL/QUALITY ASSURANCE

- At the conclusion of the sampling event, field personnel should collate and review all sampling documentation materials for accuracy, prior to submitting the information to the Data Quality Department.
- Sample codes and associated sampling sites will be cross-referenced during data review and validation procedures stipulated by the project work plan and QAPP.
- Field samplers should ensure that complete documentation of samples has occurred prior to the close of sampling activities each day, by counting the number of samples collected and checking the field notebook for entries related to each sample.

10.0 REFERENCES

Hydrometrics HSOP-4: Chain-of-Custody Procedures, Packing, and Shipping Samples

Hydrometrics HSOP-31: Field Notebooks

HSOP-31

FIELD NOTEBOOKS

Prepared by: ______________________ **Date:** 6/04

Reviewed by: ______________________ **Date:** 6/04

Approved by: ______________________ **Date:** 6/04

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TABLE OF CONTENTS

1.0 SCOPE AND APPLICATION

HSOP-31 presents general guidance on recording field activities in a dedicated project notebook. Field books are intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the implementation of the project. In legal proceedings, field notes are typically admissible as evidence and subject to cross-examination.

2.0 SUMMARY OF METHOD

Bound notebooks with sequentially numbered pages are used to record observations, sampling information, weather conditions, and other pertinent information during field activities. Entries are made in permanent ink, and signed and dated at the bottom of each page. Both original notebooks and copies of field notes are retained as part of the project file.

3.0 HEALTH AND SAFETY WARNINGS

Field personnel should be aware of the health and safety precautions to be followed during any field event, and should be familiar with any project-specific hazards. This may include review of project-specific health and safety plans, site-specific and/or organization-specific safety requirements and training.

4.0 INTERFERENCES

The primary potential problem with recording information in field notebooks is dealing with incorrect entries. In no case should erasures be made or information be obliterated or made illegible. Errors should simply be crossed out with a single line, dated, and initialed by the person making the original entry.

5.0 PERSONNEL QUALIFICATIONS

No specific qualifications are necessary for recording information in field notebooks. Personnel should be familiar with the scope and objectives of the project in order to record more meaningful field observations.

6.0 EQUIPMENT AND SUPPLIES

- Bound notebook with water resistant, sequentially numbered pages
- Pen (indelible ink)

7.0 PROCEDURE

1. New field notebooks should be labeled with the project title and number on the cover. Inside the front cover, write Hydrometrics' address and phone number as contact

information, in case the notebook is lost. Multiple field notebooks may be required for large or ongoing projects; these should be assigned sequential numbers or labeled on the cover with the inclusive dates of observations recorded in the notebook (e.g., Project X, May 2002 through May 2004).

2. Notebook entries should begin on a fresh page for each day during a field event. While specific entry formats may vary with personal preference, the intent of the field notebook is to provide a daily record of significant events, observations, and measurements, as well as sampling information. All entries should be accompanied by date and time. Examples of information to be recorded in the field notebook includes:

   - Weather conditions;
   - Personnel on-site, including arrival and departure times and identities of visitors and observers;
   - Purpose of daily activities;
   - Site sketch maps;
   - Health and safety briefing information;
   - Field meter calibration information;
   - Identification and description of sampling sites (see HSOP-2); and
   - Descriptions of photos taken;
   - Communication logs;
   - Documentation of deviation from methods;
   - Sampling instrument decontamination records.

   Sampling-specific information should include (see also HSOP-29):

   - Sample number, date, and time;
   - Site identifier;
   - Description of sample containers, preservation, and sample collection method;
   - Sample tag number (if applicable);
   - Field parameter measurements and water calibration (static water level, total well depth, pH, specific conductance, water temperature, turbidity, color, odor, etc.); and
   - Soil depth intervals and descriptions.

   This list is not meant to be exhaustive, and other pertinent information should also be recorded in the field notebook as determined by field personnel.

3. The field notebook will be used to record communication with individuals on-site and on the phone that could result in a deviation from the SAP or that could impact the quality of the data being collected as part of the investigations.

4. Observations and measurements should be recorded in indelible ink, at the time they are made.

5. If erroneous entries are recorded, corrections should be made by deleting incorrect information with a single line, and dating and initialing the deletion in the notebook. Do not erase or obliterate incorrect entries, or remove pages from the notebook.
6. Blank and unused portions of notebook pages should be crossed out with a single line.
7. At the conclusion of the field event, review notebook entries, sign and date each page (if not already done), and photocopy notebook pages for inclusion in the project file. Original notebooks may be maintained in the project file, or in the files of individual field personnel at the discretion of the project manager.

8.0 DATA AND RECORDS MANAGEMENT

Copies of field notes are retained in the project file. Original field notebooks are maintained in the project file, or in the files of individual field personnel at the discretion of the project manager. Completed (filled) notebooks should be placed in the project files or the Data Quality Department notebook library, at the discretion of the project manager. Copies of field notebooks should be updated in project files at the end of each field event.

9.0 QUALITY CONTROL/QUALITY ASSURANCE

Standard procedure requires review of field notes by a person other than the person who recorded the field notes, prior to entering the information into the project files, to check for inaccurate, incomplete, or unclear entries, blank pages, or other problems with documentation. Peer review of notebook entries should also be conducted at least once per day during field activities.

10.0 REFERENCES

Hydrometrics HSOP-2: Determination, Identification, and Description of Field Sampling Sites

Hydrometrics HSOP-29: Labeling and Documentation of Samples

HSOP-58

GUIDELINES FOR QUALITY ASSURANCE OF ENVIRONMENTAL DATA COLLECTION ACTIVITIES

DATA QUALITY PLANNING, REVIEW, AND MANAGEMENT

Prepared by: Jenny Vanek **Date:** October 27, 2011

Reviewed by: Kris Adler **Date:** October 2011

Approved by: Mark Walker **Date:** January 5, 2012

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 PURPOSE AND APPLICABILITY

This Standard Operating Procedure (SOP) outlines Hydrometrics' standard data review and data management policies and procedures. These policies and procedures provide a general framework to guide the collection, analysis, technical review, and management of data obtained during an environmental investigation. Although the required level of rigor will vary based on individual project goals and objectives, some provisions for assessment of data quality and data usability should be incorporated into all projects involving collection and analysis of environmental samples. This SOP describes aspects of data review, validation, and management that are applicable throughout the full duration of a typical environmental investigation, from initial project planning through preparation and submittal of any final reports. Note that project-specific requirements for data review, data validation, and data management are frequently detailed in project planning documents such as Work Plans, Sampling and Analysis Plans (SAPs), and/or Quality Assurance Project Plans (QAPPs). The procedures outlined in this SOP are intended to function as a basis for development of project-specific requirements, and also to provide a fundamental set of review, validation, and management practices applicable to all environmental investigations.

2.0 ORGANIZATION AND RESPONSIBILITY

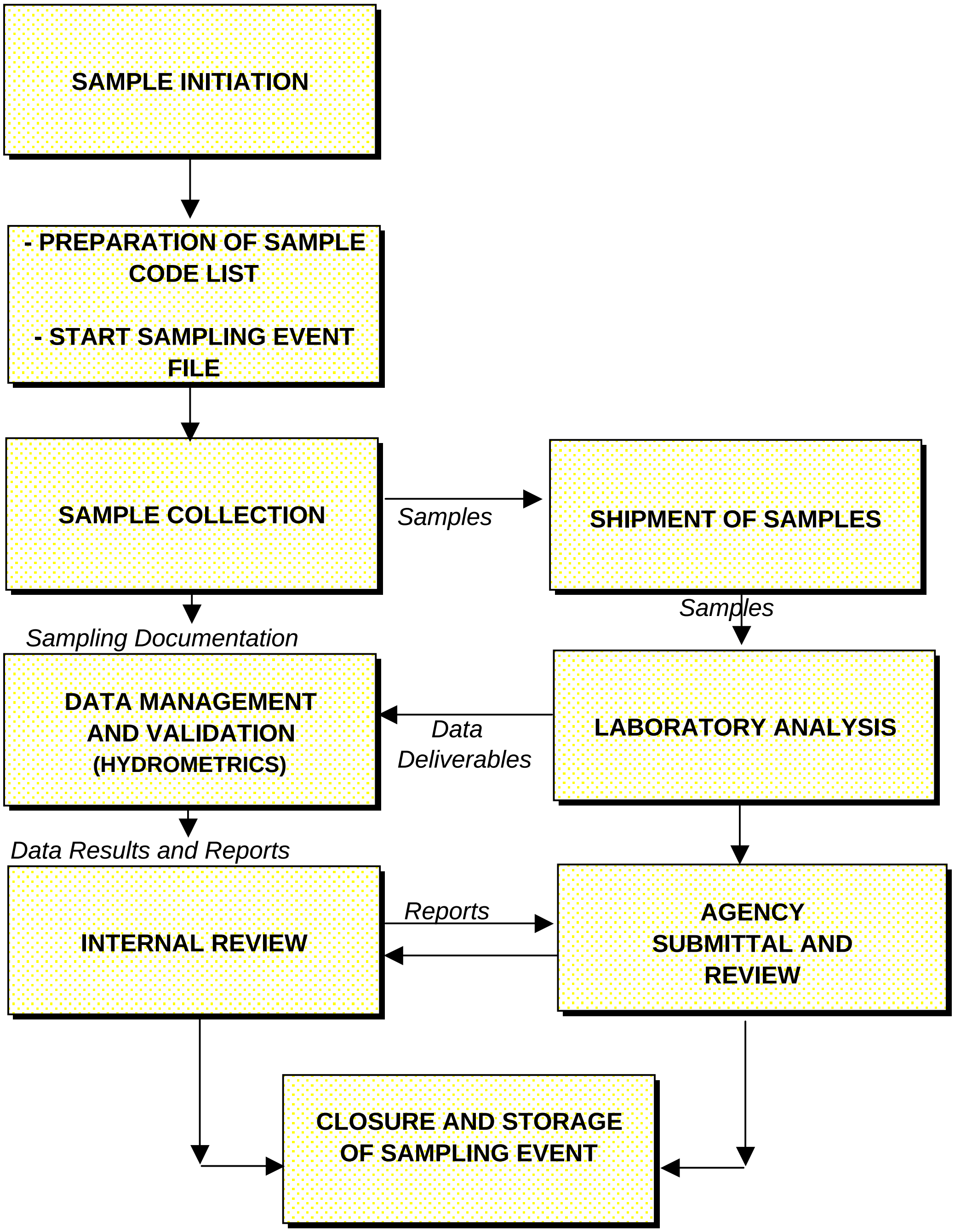
A QA manager is assigned to each individual project. The QA manager has the primary responsibility of overseeing implementation of field activities and laboratory analysis, to ensure that requirements in the project planning documents (Work Plan, SAP, QAPP) are met. These requirements may include specified field and laboratory methodologies, sample types and locations, data quality objectives, quality control sample types and frequencies, and data review, validation, and management procedures. At the direction of the client or QA manager, periodic audits may be performed to evaluate project-specific QA/QC and data management procedures and to provide an avenue for corrective actions.

The QA manager and project manager are responsible for assigning personnel to additional roles, including field team leaders and data quality review and management coordinators. Maintenance of complete and accurate field and laboratory documentation should be a focus of the QA team throughout the life of the project. The integrity of the data is maintained throughout all transfers and manipulations between principal data handlers/users. The flow of information is shown in Figure 1.

3.0 DATA QUALITY OBJECTIVES

Project-specific Data Quality Objectives (DQOs) should be developed during the project planning phase. The DQO process is designed to ensure that the type, quantity and quality of data collected during the investigation are appropriate for the intended application (EPA, 2006). The DQO process sets the stage for development and implementation of the project work plan.

FIGURE 1. SAMPLE INFORMATION AND DOCUMENTATION FLOW CHART



4.0 DATA REVIEW AND VALIDATION

Data review and validation involve the evaluation of the completeness, correctness and conformance of a specific data set against requirements set forth in the project planning documents (EPA, 2002). The level of review used for a particular data set will therefore depend on a comprehensive consideration of not only the intended end use and project objectives but also of project documentation requirements, QA/QC procedures, and inherent limitations in various sampling techniques and analytical methods. These levels are fairly fluid and can be customized to meet project requests/requirements. Table 1 lists Hydrometrics' established validation levels and their applications. Additionally, for any Montana Department of Environmental Quality CECRA site, the MDEQ's Data Validation Guidelines will be performed and will take precedence over any inconsistencies with this SOP. The MDEQ guidance document is located at http://deq.mt.gov/StateSuperfund/PDFs/DataValidationReport.pdf.

- **Level I - Visual Validation** - At this level the verification of completeness and accuracy of all sampling information takes place. This includes the following: confirming all results (both field and lab); all parameters, units and measurement basis, as being correct; cross checking of field notes and forms; and the verification of flow calculations. The results of this validation, at this level, are documented in a data review report memo. This level of validation generally corresponds to "data verification" as discussed in EPA (2002).
- **Level II - Standard Validation** - This level of validation encompasses the visual validation plus a more comprehensive review of all of the sampling information. The additional review includes the following: an examination of both field and laboratory QC (any laboratory QC that is included within the analytical package) using validation criteria limits as specified in the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic/Organic Data Review (EPA, 2010; 2008); a survey of the achievement of the project data quality objectives; qualification of the data per project requirements; data evaluation; historic trend comparison and/or graphs; ion balance; and statistical comparisons. The results of this validation, at this level, are documented in a comprehensive data review report.
- **Level III - (Contract Laboratory Program) CLP Validation** - At this level of review, both the visual and standard validation tasks are performed. Analytical data is characterized by rigorous QA/QC protocols and documentation. Validation procedures utilize such documentation as necessary to support project needs. Additional review requirements are: verification of the laboratory's raw data and quality control for frequency; accuracy; completeness; and procedures as required by the criteria limits specified in the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic/Organic Data Review.

Performance criteria for the following sampling and analytical specific data quality indicators (DQIs) for the precision, accuracy, representativeness, completeness and comparability

TABLE 1. VALIDATION LEVELS AND APPLICATIONS

VALIDATION LEVELS	APPLICATION
Level I - Visual Validation	• Verify Completeness and Accuracy of Input Data: - Results - Sampling Information - Parameters - Units - Measurement Basis • Cross Check Field Notes and Forms • Verify Flow Calculations • Report via Validation Memo
Level II - Standard Validation	• Visual Validation • Quality Control Review - Field Quality Control - Laboratory Batch Quality Control • Data Quality Objectives(DQO) Summary for Precision, Accuracy, Representativeness Comparability, Completeness (PARCC) • Qualify Data as per Project Requirements • Data Evaluation - Statistical Comparison - Ion Balance - Trend Comparison and Graphs • Report via Standard Comprehensive Data Review Report
Level III - CLP Validation (EPA, 2010; 2008)	• Visual • Standard • Quality Control Validation - Laboratory Quality Control - Field Quality Control • Verification with Raw Data - Frequency - Accuracy - Completeness - Procedure • Quality Data as per Project Requirements • Report via Standard Comprehensive Data Review Report

(PARCC) parameters are typically specified in the project SAP or QAPP. Assessment of these non-direct measurements provides the basis for the evaluation of overall data quality.

Precision Objective

Precision is defined as a measure of reproducibility of replicate measurements, and is inversely related to the variability among the results obtained (e.g., highly variable results have low precision). Precision of field duplicates is a measure of both field sampling variability and the laboratory analytical variability. Precision will be assessed using field and laboratory duplicates, and laboratory matrix spike duplicates.

Accuracy Objective

Accuracy is the agreement between a measured value and a 'true' value. Accuracy will be assessed using field trip blanks, field equipment/rinsate blanks, laboratory matrix spikes, laboratory control standards (LCS), laboratory method blanks, laboratory fortified blanks, and laboratory surrogate standard checks.

Representativeness Objective

Representativeness is the extent to which discrete measurements and testing accurately describe the environmental system. Representative data are achieved through careful selection of sampling sites, and proper sampling and analytical procedures.

Completeness Objective

Completeness is achieved when the number of valid measurements is sufficient to satisfactorily address all-important issues about the site. Completeness is assessed as the number of "valid" measurements. A "valid" measurement is one in which the sample was properly collected and considered representative of the material sampled, and which was not rejected during the data quality review process. Results qualified during the data quality review process as estimated will be considered valid measurements, unless extenuating circumstances or professional judgment indicate otherwise.

Comparability Objective

Comparability is the degree to which two or more data sets from the same site are generated using consistent procedures. Inherent compositional differences aside, discrete data sets may differ as a result of non-random (biased) sampling, variability in sampling technique, and variations in methods of analysis. To ensure comparability of data collected under the plan, the following actions will be implemented:

1. Standard Operating Procedures (SOPs) will be employed for sampling and analytical activities, as appropriate;
2. Field personnel will be thoroughly trained in sampling techniques;
3. Data results will be reported in standard units;
4. Data qualifiers will be consistent for all project data;

5. All sampling sites will be accurately delineated and recorded (HSOP-2); and
6. Analyses will be performed using EPA-accepted methods, as available and appropriate.

5.0 DATA MANAGEMENT ACTIVITIES

The process of collecting, analyzing, managing, tracking, evaluating, and reporting data involves many steps. The data management system for a project should address documentation requirements, document control and storage, and reporting formats. Figure 2 gives an overview of typical data management activities.

5.1 DOCUMENTATION

All sampling and analytical related project documents, field notes, laboratory analyses and/or testing results, as well as supporting documentation, should be maintained as part of the data management records organized by sampling events in the project file. Figure 3 outlines the flow of data documentation. The types of documentation that may be part of the data management records are as follows.

5.1.1 Field Sampling Documents

Field sampling documents contain all pertinent information recorded in the field and/or associated with samples collected in the field they include:

Calculated Flow Sheets	Field Sampling Forms	Transmittal Letter(s)
Calibration Logs	Shipping Records	Pump Tests
Parameter Lists	Well Logs	Sample Code List
Site Maps	Field Notebooks	

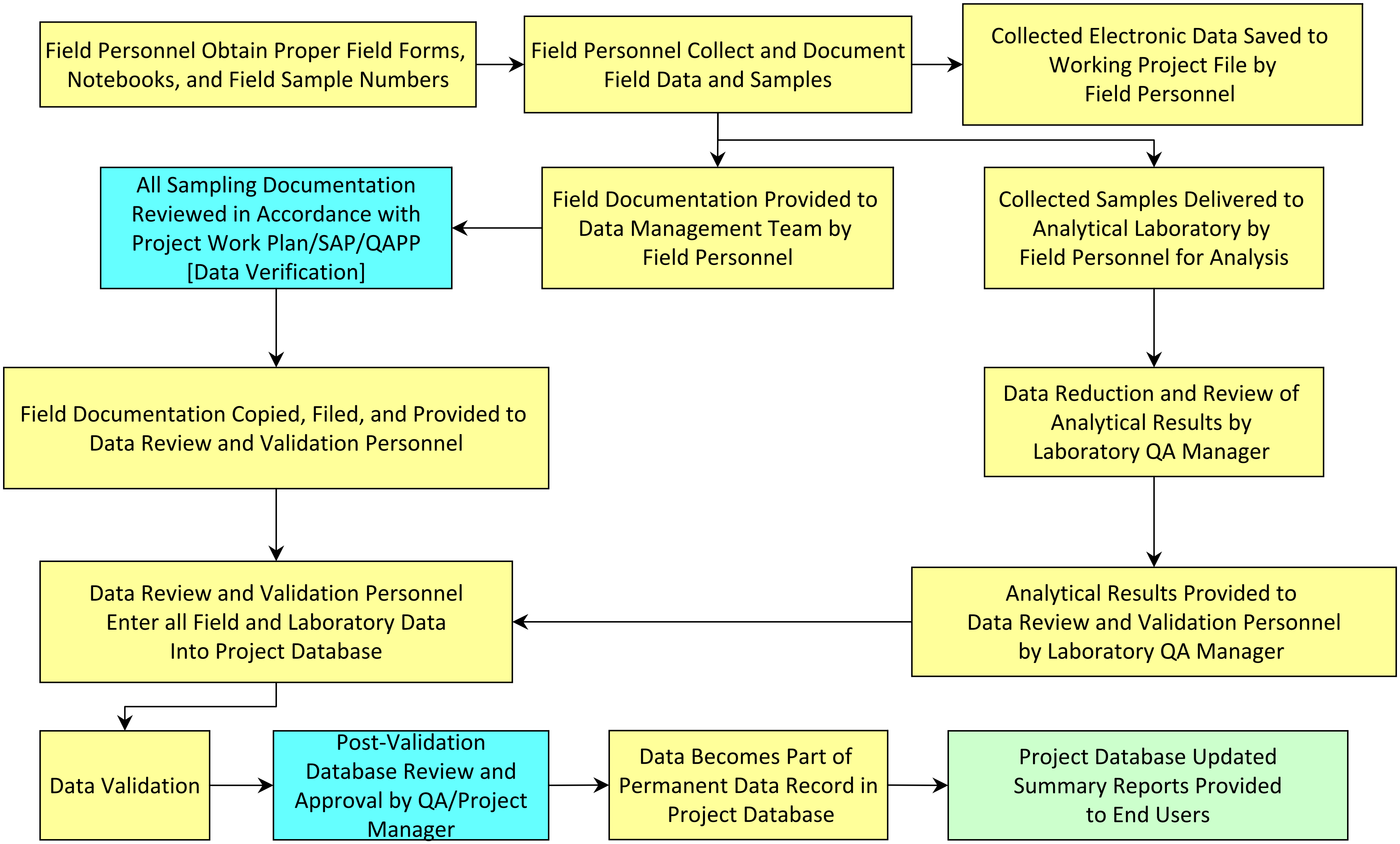
5.1.2 Laboratory Documents

Laboratory documents contain all pertinent information relating to the handling, processing, and subsequent analysis of the samples. Laboratory documents fall within the following categories:

- **Transmittal Records** - allow for tracking of the samples, and aid in communication between the laboratory and the Hydrometrics QA/QC personnel.

Cover Letter	Parameter List
Case Narrative	Sample Login Records
Chain of Custody Documents	Sample Preservation Check

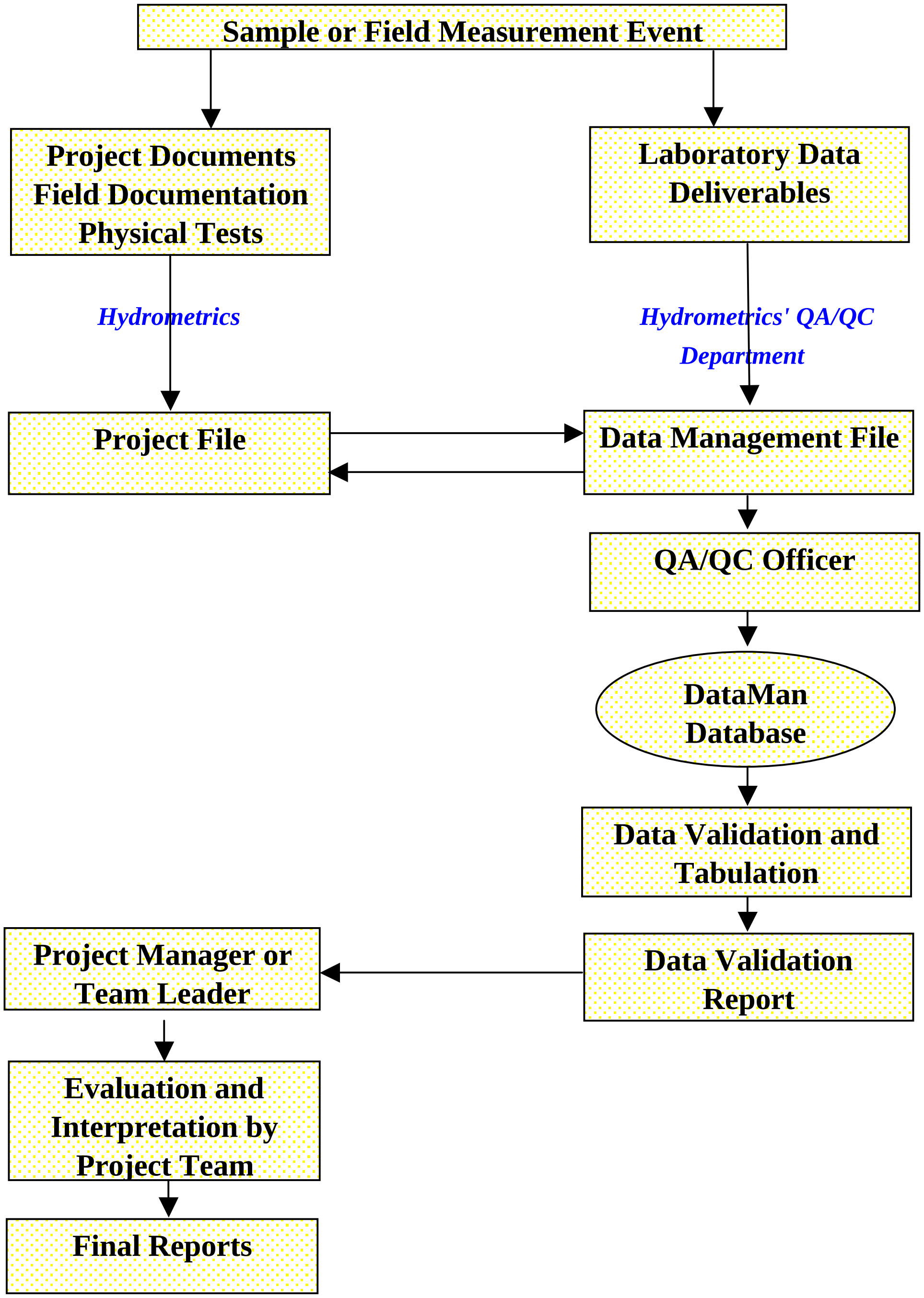
- **Hard Copy Data Deliverables** - all deliverables received as part of the analytical package. The amount and type are dependent on the level of analysis and may range from a summarization of results to complete CLP deliverables (e.g., raw instrument output, lab bench logs, etc.).



GUIDELINES FOR QUALITY ASSURANCE OF ENVIRONMENTAL DATA COLLECTION ACTIVITIES DATA QUALITY PLANNING, REVIEW, AND MANAGEMENT	TYPICAL DATA MANAGEMENT ACTIVITIES	FIGURE 2

H:\admin\HSOP\2005 New HSOPs\HSOP-58 Figure 2.ppt\HLN\01/05/2012

FIGURE 3. DATA DOCUMENTATION FLOW



- **Electronic Data Deliverables -** allows for rapid transfer of laboratory data results into the specific client project database. Electronic deliverables contain analytical results and associated quality control data. Analytical results can be converted either into the Microsoft® FoxPro database program DataMan, developed by Hydrometrics, or data can be converted to other spreadsheet or database software.

5.1.3 Data Management Records

Data management records integrate client and project information with the field and laboratory data documentation for specific sampling events. The data management files may contain the following information.

A. **Project specific client project information**

- Work Plan
- Sampling and Analysis Plan (SAP)
- Quality Assurance Project Plan (QAPP)
- Site List
- Map
- Well Inventory
- Project Detection Limits
- Communications
- Any Other Relevant Project Information

B. **Event specific files**

- Field Documentation
- Laboratory Hard Copy Deliverables
- Electronic Deliverables
- Supporting Documentation
- Retest Requests
- Validation Reports
- Correspondence
- Communications

5.2 DATA STORAGE

Formats for handling data storage involve both electronic formats via the database system or spreadsheets, and physical hard copy files. The finalized data records and documents are always unique. A complete set of all project documents and data analyses will be stored in accordance with Hydrometrics' records management procedures, and/or as stipulated in the project QAPP or Data Management Plan. A set of project documents related to data or data analyses will also be stored at the originating Hydrometrics' office along with associated electronic files. All data documentation will be received by the Hydrometrics' QA/QC data management department to be entered into the data management files as appropriate, to allow efficient retrieval of information.

5.3 DATA/DOCUMENT RETRIEVAL

Retrieval of documents will be accomplished through the use of the data management filing system. Project data are maintained in project information files, and sampling event files, as well as the client database. Retrieval is quick and efficient with the use of these tools and can readily be provided in hard copy format and/or electronic format depending on client needs.

5.4 EXTERNAL DOCUMENT SOURCES

In order to maintain project information flow, it will be necessary to include any relevant project analytical/physical testing information generated by contractors or subcontractors. Analyses and documentation generated by external sources can be maintained in the data management system.

5.5 REPORTING

A schedule for reports will be established by the client and the project manager. The reporting schedule and specific report formats and content are normally outlined in the project work plan or contract.

Reports may include any of the following formats:

- General Information Summary - summarizes overall activity of the project.
- Status Report - updates the recipient as to the progress of specific activities.
- Data Evaluation/Interpretive Reports - includes and elaborates on topics covered in the General Information Summary; additionally, these reports highlight and may attempt to explain any data anomalies or trends that have been noted.
- Data Validation Reports - summarizes data quality in a formal report that is distributed both in-house and to external agencies.

5.6 SYSTEMS AUDIT/CONTROL

Database and electronic file security is controlled via network access limitations. Only authorized personnel have access to create or revise data files based on assigned user rights. A change log form documents all changes to the DataMan database files. Electronic data and document files are backed up daily.

Periodic system audits, if required by the client or oversight agencies, may be performed on field collection activities, laboratories and the data management activities. System audits are qualitative evaluations conducted for the purpose of determining compliance with the organizational and work element requirements for the specific client project activities. Performance will be assessed and non-compliance will be addressed and/or corrected. The schedule and content of the audits will be dictated by the client and QA or project manager.

6.0 REFERENCES

EPA, 2002. Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8). EPA/240/R-02/004. Office of Environmental Information. November 2002.

EPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4). EPA/240/B-06/001. Office of Environmental Information. February 2006.

EPA, 2008. USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review. USEPA-540-R-08-01. Office of Superfund Remediation and Technology Innovation. June 2008.

EPA, 2010. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review. USEPA-540-R-10-011. Office of Superfund Remediation and Technology Innovation. January 2010.

STANDARD OPERATING PROCEDURE

PRESERVATION AND STORAGE OF INORGANIC WATER SAMPLES©
HF-SOP-3

1.0 PURPOSE

An important factor in obtaining representative water quality data is the preservation and storage of samples. Preservation is designed to:

1. Retard biological activity;
2. Retard chemical reactions; and
3. Reduce volatility of constituents.

Preservation generally includes chemical additives, pH control, refrigeration, proper container materials, and immediate field filtration for dissolved constituents.

2.0 EQUIPMENT

Table 1 (attached) lists recommended preservatives, containers and holding times for various parameters. Be sure to assemble all the required containers, preservatives, and filters, as required, before leaving for the field.

3.0 PROCEDURE

In all cases where dissolved constituents are to be measured, the sample will be field-filtered through a 0.45 micron filter prior to addition of a preservative. Samples will be preserved according to guidelines presented in **Table 1**, and will remain refrigerated or in coolers with ice until analysis.

Complete sampling form for groundwater or surface water **(HF-FORM-430**).

4.0 REFERENCES

U.S. EPA, 1983. Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, 3rd Edition.

TABLE 1. REQUIRED CONTAINERS, PRESERVATION TECHNIQUES AND HOLDING TIMES

Parameters	Container[1]	Preservative	Maximum Holding Time
Specific Electrical Conductivity	T, P, G	Field determined	None
Total Dissolved Solids (TDS)	P, G	Cool, 4°C	7 Days
Total Suspended Solids (TSS)	P, G	Cool, 4°C	7 Days
pH	T, P, G	Field determined	None
Dissolved Oxygen (DO)	G bottle and top	None required	Analyze immediately
Temperature	P, G	None required	Analyze immediately
Eh	P, G	None required	Analyze immediately
Alkalinity	P, G	Cool, 4°C	14 days
Calcium (Ca)	P, G	HNO_3 to pH <2	6 months
Magnesium (Mg)	P, G	HNO_3 to pH <2	6 months
Sodium (Na)	P, G	HNO_3 to pH <2	6 months
Potassium (K)	P, G	HNO_3 to pH <2	6 months
Bicarbonate (HCO_3)	P, G	Cool, 4°C	14 days
Carbonate (CO_3)	P, G	Cool, 4°C	14 days

[1] T = Teflon; P = Polyethylene; G = Glass

TABLE 1 (Continued). REQUIRED CONTAINERS, PRESERVATION TECHNIQUES AND HOLDING TIMES

Parameters	Container[1]	Preservative	Maximum Holding Time
Sulfate (SO_4)	T, P, G	Cool, 4°C	28 days
Chloride (Cl)	T, P, G	Cool, 4°C	28 days
Silica (Si)	P	Cool, 4°C	28 days
Fluoride (F)	T, P	HNO_3 to pH <2	28 days
METALS*			
Aluminum (Al)	T, P	HNO_3 to pH <2	6 months
Antimony (Sb)	T, P	HNO_3 to pH <2	6 months
Arsenic (As)	T, P	HNO_3 to pH <2	6 months
Barium (Ba)	T, P	HNO_3 to pH <2	6 months
Beryllium (Be)	T, P	HNO_3 to pH <2	6 months
Cadmium (Cd)	T, P	HNO_3 to pH <2	6 months
Chromium (Cr)	T, P	HNO_3 to pH <2	6 months
Cobalt (Co)	T, P	HNO_3 to pH <2	6 months
Copper (Cu)	T, P	HNO_3 to pH <2	6 months
Iron (Fe)	T, P	HNO_3 to pH <2	6 months
Lead (Pb)	T, P	HNO_3 to pH <2	6 months
Manganese (Mn)	T, P	HNO_3 to pH <2	6 months

[1] T = Teflon; P = Polyethylene; G = Glass

* Dissolved metals are filtered on site with 0.45 micron filter. Total metals are not filtered.

TABLE 1 (Continued). REQUIRED CONTAINERS, PRESERVATION TECHNIQUES AND HOLDING TIMES

Parameters	Container[1]	Preservative	Maximum Holding Time
Mercury (Hg)	T, P	HNO_3 to pH <2	28 days
Nickel (Ni)	T, P	HNO_3 to pH <2	6 months
Selenium (Se)	T, P	HNO_3 to pH <2	6 months
Silver (Ag)	T, P	HNO_3 to pH <2	6 months (in dark place)
Tin (Sn)	T, P	HNO_3 to pH <2	6 months
Thallium (Th)	T, P	HNO_3 to pH <2	6 months
Vanadium (V)	T, P	HNO_3 to pH <2	6 months
Zinc (Zn)	T, P	HNO_3 to pH <2	6 months
PHOSPHORUS (P)			
Orthophosphate (PO_4), Dissolved	P, G	Filter on site, Cool, 4°C	48 hours
Orthophosphate, Total	P, G	Cool, 4°C	48 hours
Hydrolyzable	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
Total	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
Total, Dissolved	P, G	Filter on site Cool, 4°C H_2SO_4 to pH <2	24 hours

[1] T = Teflon; P = Polyethylene; G = Glass

TABLE 1 (Continued). REQUIRED CONTAINERS, PRESERVATION TECHNIQUES AND HOLDING TIMES

Parameters	Container[1]	Preservative	Maximum Holding Time
NUTRIENTS			
Ammonia	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
Kjeldahl, Tota l	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
Nitrate plus Nitrite	P, G	Cool, 4°C H_2SO_4 to pH <2	28 days
Nitrate (NO_3)	T, P, G	Cool, 4°C or	48 hours
		Cool, 4°C H_2SO_4 to pH <2	14 days
Nitrite (NO_2)	P, G	Cool, 4°C	48 hours

[1] T = Teflon; P = Polyethylene; G = Glass

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: ____________________
Project Code: ____________________
Sample Team Member(s): ____________________
Laboratory Used: ____________________

Site Designation: ____________________
Sample Code Number: ____________________
Sample Date: ____________________
Sample Time: ____________________ (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #: ____________________
Duplicate Sample Time: ____________________

Site Conditions

New Site: Yes No   Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other: ____________________
Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C °F

For Groundwater Samples

well volume formula: $V = \frac{(TD-SWL)x(Dia.^2)}{25}$ Comments
TD (ft): ____________________
SWL (ft): ____________________   no access/pumping
Casing Diameter (I.D.") ____________________
Water Volume (V) (gal): ____________________
x 3=(gal.) ____________________
Actual Vol. Removed (gal.) ____________________
Water Level Recovery: slow moderate rapid

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description: ____________________
Flow: gpm cfs   Staff Gage:

Field Parameter Stabilization

Time (military)	Oxidation Reduction **Potential** (mV)	**Dissolved Oxygen** (mg/l)	**pH**	**S.C.** (μmhos/cm)	**Turbidity** (n.t.u.)	**Temperature** (°C)	**Additional Parameters or Notes**

Turbidity: (circle) clear moderate slight very

Sample Method: (describe) grab composite pump bailer other
large peristaltic

Field Parameters

	Sample	Duplicate
ORP (mV)		
DO (mg/l)		
pH		
SC (μmhos/cm)		
Turbidity (ntu)		
H_2O Tmp. (°C)		
Color		
Other: ________		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			

Comments: ____________________

Sample Team Member Signature: ____________________   Page of

STANDARD OPERATING PROCEDURE

WATER LEVEL MEASUREMENT WITH AN ELECTRIC PROBE

HF-SOP-10

1.0 PURPOSE

This procedure applies to all water level measurements obtained using an electric probe. Normally, this procedure is used for measurement of water levels in wells. All electrical probes used, such as an Olympic Well Probe or Solinst, must have permanent depth markers placed at a minimum of every five feet on the probe wire or must have a direct reading tape.

2.0 EQUIPMENT

- Electronic probe;
- Water level measurement form (**HF-FORM-430**, Water Sampling Form);
- Field notebook; and
- Probe calibration data.

3.0 PROCEDURE

The water level is obtained by lowering the probe until contact is made between the probe tip and the water surface. The contact point is carefully checked by a slight lowering and raising of the probe and simultaneously observing the needle deflection, buzzer or light on the meter. For accurate measurements, the wire line must be straight as the probe is lowered. This is particularly important for the first few feet of line. Water depth is determined by direct reading of the probe wire or by measurement of the wire to the center of the nearest large marker and addition or subtraction from the marker value.

Water level measurements are referenced to the measuring point (MP). Normally, the MP is the top of a well casing but may be some other point. The MP used must be described. The north edge of the casing is usually marked or notched and all water level measurements are referred to this marked point.

3.1 CALIBRATION

All electric probes must be periodically calibrated. Normally, calibration is once or twice per year but, if the probe has been rebuilt, stretched, or replaced, it also must be recalibrated. For recalibration, the electrical line is laid out on a flat surface and stretched to approximate its normal hanging weight. A steel tape graduated in 0.01 foot increments is used to determine probe accuracy. Additionally, the probe must be placed in wells with differing water levels and water depth measured and compared with a steel tape. A calibration record with correction factor is developed and placed in the equipment calibration file. This calibration record is used in the field to correct probe readings.

3.2 MEASUREMENT ACCURACY

All water levels and calibrations are normally measured to the nearest 0.01 foot. Probe data are considered accurate to 0.05 feet under good measurement and calibration conditions and to 0.10 feet under normal conditions. For deep or difficult conditions, accuracy may be less than 0.10 feet.

3.3 PROBE DECONTAMINATION

For projects where cross-contamination of wells may be a problem, the well probe and line must be decontaminated between measurement sites. This is particularly important when measuring wells containing substances such as PAH (polyaromatic hydrocarbons), pesticides, petroleum products and some metals.

Decontamination must include cleaning the probe and wire line. Most organics can be removed by wiping the line, then using detergent in water followed by acetone or methanol, followed by rinsing with DI (deionized) water.

Many inorganics can be removed by wiping the wire line and rinsing the probe in DI water. Specific attention must be paid to any sediment, rust or dirt on the wire line.

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: ______________________
Project Code: ______________________
Sample Team Member(s): ______________________
Laboratory Used: ______________________

Site Designation: ______________________
Sample Code Number: ______________________
Sample Date: ______________________
Sample Time: ______________________ (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #: ______________________
Duplicate Sample Time: ______________________

Site Conditions

New Site: Yes No Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other: ______________________

Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C °F

For Groundwater Samples

well volume formula: V = $\frac{(TD-SWL)x(Dia.^2)}{25}$

Comments

TD (ft): ______________________
SWL (ft): ______________________ no access/pumping
Casing Diameter (I.D.") ______________________
Water Volume (V) (gal): ______________________
x 3=(gal.) ______________________
Actual Vol. Removed (gal.) ______________________
Water Level Recovery: slow moderate rapid

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description: ______________________

Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	**Oxidation Reduction Potential** (mV)	**Dissolved Oxygen** (mg/l)	**pH**	**S.C.** (µmhos/cm)	**Turbidity** (n.t.u.)	**Temperature** (°C)	**Additional Parameters or Notes**

Turbidity: (circle) clear slight moderate very

Sample Method: (describe) grab composite pump bailer other
large peristaltic

Field Parameters

	Sample	Duplicate
ORP (mV)		
DO (mg/l)		
pH		
SC (µmhos/cm)		
Turbidity (ntu)		
H_2O Tmp. (°C)		
Color		
Other: ______		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			

Comments: ______________________

Sample Team Member Signature: ______________________ Page of

STANDARD OPERATING PROCEDURE

SAMPLING MONITORING WELLS FOR INORGANIC PARAMETERS

HF-SOP-11

1.0 PURPOSE

This procedure describes the methods to be used in collection of groundwater samples from wells. The procedure is designed for wells where inorganic constituents are of primary concern. Methods presented in this SOP are based on recent USGS guidance (USGS, 1999).

2.0 EQUIPMENT

Bailers, submersible pumps, sample containers and water level electric probe. Other sampling equipment may be required for specific tasks. Other general equipment may include:

- Distilled or deionized water;
- Sampling sheets;
- Samplers notebook;
- Coolers;
- Preservatives;
- 0.45 µm filter apparatus with inert filters;
- Chemical-free paper towels;
- Properly cleaned sample containers of an appropriate volume; and
- Stopwatch or watch with second hand.

3.0 PROCEDURE

A. Unlock and open well.

B. Obtain water level measurement (see water level **HF-SOP-10**). If total well depth is unknown, measure total depth by sounding well. NOTE: electric water level probes are typically not recommended for sounding wells; instead, use a weighted measuring tape or other equipment.

C. Calculate well volume (see calculation on HF-FORM-430) as $[(H) \times (D)^2] / 25$, where H = height of water column (feet), and D = well diameter (inches).

D. Purge well using an appropriate device (bailer, pump, etc.). Standard procedure involves removal of a minimum of three well volumes of water while monitoring field measurements and water level over time. In addition, purge volume should be adequate to remove water from the well annulus (filter pack). Record all pertinent purging information in field notebook and/or on field sampling forms, including:

- Purge method, rate, and total volume;
- Field parameter measurements;
- Water level changes (drawdown/recovery);
- Location of pump intake; and
- Other information.

The USGS (1999) recommends pumping or otherwise purging at a rate that does not significantly lower the water level. Toward the end of purging, a minimum of five sets of field parameters should be collected at regular intervals while pumping at the rate to be used for sampling. Use of a flow cell for field parameter monitoring is recommended. Field parameters are considered “stable” when the variability between five sequential measurements is as follows:

Parameter	Stability Criteria
pH	±0.1
Temperature (°C)	±0.2
SC (µmhos/cm)	±5% (SC ≤ 100) or ±3% (SC > 100)
Dissolved oxygen (mg/L)	±0.3
Turbidity (NTU)	±10% (NTU < 100)

Modifications of the standard purge procedure are allowable if site conditions, the project work plan, or study objectives dictate such modifications. At a minimum, sufficient water must be removed to rinse equipment and sample bottles, and field measurements must be monitored prior to sampling. Low-flow (micropurge) techniques are discussed in a separate procedure (HF-SOP-105).

E. Samples are collected after a sufficient purge volume is withdrawn and/or field parameters have stabilized and final field measurements have been collected. Bottles are filled directly from discharge from the well or from another clean container. Considerable care should be taken to minimize entrainment of air, particularly if bailers are used for sampling.

F. Preserve and store samples as appropriate for the intended laboratory analysis. Collect final water level measurements if desired to determine water level recovery following purging.

4.0 DECONTAMINATION

If cross contamination of sampled wells is a potential problem, the following procedure should be followed:

A. Design sampling to proceed from the best quality water to the poorest quality water; and

B. Rinse the pumping apparatus or bailer between holes if well yields are too low to supply sufficient water to purge the pump, water hose or bailer.

If contamination is a problem, dedicated pumps or bailers should be used to ensure the samples are representative of site conditions (see Decontamination of Sampling Equipment **HF-SOP-7**).

5.0 ASSOCIATED DOCUMENTS

A. Decontamination of Sampling Equipment **(HF-SOP-7)**
B. Water Level Measurement with an Electric Probe **(HF-SOP-10)**

The following forms will be completed and retained in the project file:

A. Water Sampling Form **(HF-FORM-430)**;
B. Chain-of-Custody Form **(HF-FORM-1)**; and
C. Shipping receipts.

6.0 REFERENCES

USGS, 1999. National Field Manual for the Collection of Water-Quality Data: Chapter A4, Collection of Water Samples. USGS TWRI Book 9, September 1999.

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: ____________________
Project Code: ____________________
Sample Team Member(s): ____________________
Laboratory Used: ____________________

Site Designation: ____________________
Sample Code Number: ____________________
Sample Date: ____________________
Sample Time: ____________________ (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #: ____________________
Duplicate Sample Time: ____________________

Site Conditions

New Site: Yes No Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other: ____________________
Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C °F

For Groundwater Samples

well volume formula: $V = \frac{(TD-SWL)x(Dia.^2)}{25}$

Comments

TD (ft): ____________________
SWL (ft): ____________________ no access/pumping
Casing Diameter (I.D.") ____________________
Water Volume (V) (gal): ____________________
x 3=(gal.) ____________________
Actual Vol. Removed (gal.) ____________________
Water Level Recovery: slow moderate rapid

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description: ____________________
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	**Oxidation Reduction Potential** (mV)	**Dissolved Oxygen** (mg/l)	**pH**	**S.C.** (µmhos/cm)	**Turbidity** (n.t.u.)	**Temperature** (°C)	**Additional Parameters or Notes**

Turbidity: (circle) clear slight moderate very

Sample Method: (describe) grab composite pump bailer other
large peristaltic

Field Parameters

	Sample	Duplicate
ORP (mV)		
DO (mg/l)		
pH		
SC (µmhos/cm)		
Turbidity (ntu)		
H_2O Tmp. (°C)		
Color		
Other: ________		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			

Comments: ____________________

Sample Team Member Signature: ____________________ Page of

Hydrometrics, Inc.

3020 Bozeman Avenue - Helena, Montana 59601 - (406)443-4150

CHAIN OF CUSTODY RECORD

PROJ. NO

PROJECT NAME

SAMPLERS: (*Signature)*

DATE	**STA #**	**TIME**	**COMP**	**GRAB**	**SAMPLE NUMBER**	**NO. OF. CON- TAINERS**										Remarks

Relinquished (*Signature*)	Date/Time	Received by: (*Signature)*	Lab	Shipped via: Bus, Fed Ex, UPS or Other__________ Air Bill #______________
Relinquished (*Signature*)	Date/Time	Received by: (*Signature)*	Remarks	
Relinquished (*Signature*)	Date/Time	Received for Laboratory by: (*Signature)*	Date/Time	Enclo Parameter list wth DTLs Cover Letter ☐

Split Samples:
[ ]Accepted [ ]Declined________________
Signature

Return results & electronic copy to:
QA/QC Department at address at top of page

HFORM-1-10/98
h:\admin\hsop\sec 6.0\hf-001.xls

STANDARD OPERATING PROCEDURE

OBTAINING WATER QUALITY SAMPLES FROM STREAMS©
HF-SOP-19

1.0 PURPOSE

The type of samples described in the following are "grab samples". They represent the water quality at one point for one time period. This is a commonly employed method of water quality sampling and the purpose of this procedure is to standardize sampling.

2.0 EQUIPMENT

- Sampler's field notebook;
- Water Sampling Form (**HF-FORM-430**);
- Clean sample bottles and labels;
- Preservatives;
- Coolers, ice;
- 0.45 micron filter apparatus with inert filters;
- Distilled, deionized water; and
- Custody seals if required by project.

3.0 PROCEDURE

3.1 Select a station where the water quality sample would best represent the hydrochemistry of the stream segment. This could be a rapids or fast moving section of a stream. Avoid stagnant areas. Do not sample downstream from a tributary unless complete mixing has occurred. If possible, choose an accessible site for streams to be monitored regularly. Avoid sampling downstream of road crossings, sample upstream if at all possible.

3.2 Measure and record stage and/or flow (see appropriate stage and streamflow measurement Standard Operating Procedure).

3.3 Label each sample bottle with the appropriate information in accordance with the field procedure. Complete the Water Sampling Form **(HF-FORM-430)** (a copy of which is attached).

3.4 If the sample bottle does not contain preservatives, bottle and cap should be rinsed three times with sample water before the actual sample is collected. A distilled, deionized water rinse can be used as an alternative in some situations.

3.5 Conditions at the surface of stream environments may differ significantly from conditions within the water column due to the presence of buoyant contaminants (dust, pollen, leaves, etc.). In most cases, inclusion of the surface layer in the integrated sample is desirable. However, if conditions indicate that surface layer contamination would seriously compromise the representativeness of the sample, the sample bottle may be uncapped, filled, and recapped while submerged.

3.6 Obtain a stream width and depth integrated sample by collecting water while moving the open sample bottle up and down and across the width of the stream. Raise and lower the bottle through the entire depth while proceeding across the stream to assure a representative sample where needed or use an isokinetic depth-integrating sampler such as the USGS US DH-81, DH-48, or D-77 sampler (USGS, 1998). Be sure to leave sufficient volume in sample bottles such that required preservatives may be added without overfilling bottles. Total suspended sediment samples should always be collected using the depth and cross-section integration method. **When wading, be sure to collect the sample upstream of wading personnel to avoid sampling resuspended bed sediments caused by bed disturbances.**

3.7 Filter and preserve samples as required.

3.8 Immediately place filled sample bottles in cooler chest that is kept at the appropriate temperature.

4.0 ASSOCIATED REFERENCES

HF-FORM-430 Water Sampling Form

USGS, 1998. Techniques of Water-Resources Investigations, Book 9, Chapter AZ: Selection of Equipment for Water Sampling. August 1998.

Water Sampling Form ~~ HF-430

Hydrometrics, Inc.
Consulting Scientists and Engineers

Project Name: ____________________
Project Code: ____________________
Sample Team Member(s): ____________________
Laboratory Used: ____________________

Site Designation: ____________________
Sample Code Number: ____________________
Sample Date: ____________________
Sample Time: ____________________ (military)

If Duplicate Sample Collected, Please Record Below

Duplicate Sample Code #: ____________________
Duplicate Sample Time: ____________________

Site Conditions

New Site: Yes No Photo taken: Yes No
Site Type: DRY surface water process water
monitoring well domestic well adit seep
spring– other: ____________________
Weather Conditions: calm breeze windy
no precip. rain snow
clear p. cloudy overcast
Air Temperature: °C °F

For Groundwater Samples

well volume formula: V = (TD-SWL)x(Dia.^{2}) / 25

Comments

TD (ft): ____________________
SWL (ft): ____________________ no access/pumping
Casing Diameter (I.D.") ____________________
Water Volume (V) (gal): ____________________
x 3=(gal.) ____________________
Actual Vol. Removed (gal.) ____________________
Water Level Recovery: slow moderate rapid

For Surface Water Samples

Flow Method: Marsh McBirney Volumetric Flume Weir Estimate
Other Flow or Description: ____________________
Flow: gpm cfs Staff Gage:

Field Parameter Stabilization

Time (military)	**Oxidation Reduction Potential** (mV)	**Dissolved Oxygen** (mg/l)	**pH**	**S.C.** (µmhos/cm)	**Turbidity** (n.t.u.)	**Temperature** (°C)	**Additional Parameters or Notes**

Turbidity: (circle) clear moderate slight very

Sample Method: (describe) grab composite pump bailer other
large peristaltic

Field Parameters

	Sample	Duplicate
ORP (mV)		
DO (mg/l)		
pH		
SC (µmhos/cm)		
Turbidity (ntu)		
H_2O Tmp. (°C)		
Color		
Other: ______		

Bottles Collected

Quantity	Size	Filter or Unfilt.	Preservative	Parameter	Additional Notes
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			
	ml	F or UF			

Comments: ____________________

Sample Team Member Signature: ____________________ Page of

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF pH USING A pH METER
HF-SOP-20

1.0 PURPOSE

The purpose of this procedure is to obtain accurate field measurements of the pH of water samples.

2.0 EQUIPMENT

This procedure written for Beckman pH meters is applicable to a variety of pH meters. Specific operating instructions accompanying each pH meter should be followed where in variance with the following.

2.1 INSTRUMENTS

- Beckman I-10 or I-21 pH meter or similar instrument;
- Beckman pH electrode/probe, Model 39841 or equivalent;
- Beckman temperature probe, Model 598115 or equivalent; and
- Field notebook.

2.2 REAGENTS

- Buffers pH 4.0, 7.0 and 10.0 (other buffers may be used in unusual waters);
- Deionized water; and
- Beckman filling and storage solution - 4 Molar KCl (potassium chloride).

3.0 PROCEDURE

Calibration of the instrument should be performed at least once per day, before sampling activities commence. Field calibration forms must be completed at this time, and calibration verification should be documented in field notebooks.

While field instruments are manufactured to be rugged and dependable, a reasonable amount of care is still required to ensure that instruments function properly and give accurate readings.

Field instruments must be cleaned and stored in accordance with established guidelines (see operating instructions) in order to maintain instrument integrity.

3.1 EQUIPMENT SET UP

3.1.1 Instrument Check

- Turn instrument on by pressing pH button, check display and confirm the low battery light is not illuminated; and

- Visually inspect probe for damage and fluid level. If damage is evident, replace probe. If low on fluid, refill using 4 Molar KCl potassium chloride. Be sure to leave vent hole uncovered while taking measurement so that liquid junction flows freely.

3.1.2 Connecting Electrodes

- Insert the pH electrode connector into the large input jack on the top of the instrument and twist to the locked position.

- Insert temperature electrode connector into the small input jack on the instrument top. Instrument is now ready to use.

3.2 pH MEASUREMENT

3.2.1 Select two buffers, one with a pH of 7.0. Select a second buffer (pH 4.0 or 10.0) so that the two buffers bracket the anticipated sample pH (use fresh buffers for calibration).

3.2.2 Uncap pH electrode, remove stopper from vent hole, rinse both pH probe and temp probe with deionized water and place in pH 7.0 buffer.

3.2.3 Depress the CLR button, then depress the ↓ button. The meter will automatically temperature adjust the reading and compensate to read the buffer in which it is reading. This reading will lock in memory and display on the bottom of the screen.

3.2.4 Remove electrodes from the solution. Rinse with distilled water and place in the second buffer.

3.2.5 Repeat step 3.2.3 with the second buffer.

3.2.6 Remove electrodes from the second buffer, rinse with distilled water then a portion of sample and place in sample. The instrument is calibrated daily or anytime a pH is measured, which is not in the buffer range for which the instrument is calibrated.

3.2.7 Record the pH of the sample in sample field notebook.

3.2.8 When measurements are complete, rinse probe with distilled water. Add a few drops of 4 Molar KCl solution to the protective cap and store probe in the protective cap. Replace cover over vent hole.

4.0 ASSOCIATED REFERENCES

Beckman Instruments, 1992. Instruction manuals for specific ion meter, models I-10, I-11, I-12; and I-21 pH meters.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF DISSOLVED OXYGEN

HF-SOP-22

1.0 PURPOSE

The purpose of this procedure is to obtain accurate field measurements of dissolved oxygen (DO) in water.

2.0 EQUIPMENT

2.1 INSTRUMENTS

- YSI Model 55 Dissolved Oxygen Meter

2.2 REAGENTS

- Deionized water (DI H_2O); and
- Oxygen probe solution.

2.3 OTHER

- Flow Cell (strongly recommended)
- Field Notebook

3.0 PROCEDURE

When collecting measurements in surface water, the probe can be placed directly into the water body. **Similarly, the best method for measuring DO in groundwater is by using a downhole probe.** However, if this is not feasible, alternate acceptable methods are available. When measuring ground water, care should be taken to avoid adding oxygen to the water during sample collection. To avoid this condition, bailers should be moved slowly across the water surface and pumping rates should be reduced to avoid splashing or otherwise aerating the sample upon collection in the sample cup. Pumps which cause air to contact the water should not be used. **Use of a flow-through cell is strongly encouraged over collection in a sample cup.** A flow-through cell reduces potential sample aeration and allows for selection of a standard flow rate to proceed across the probe.

3.1 EQUIPMENT SET-UP AND CALIBRATION

3.1.1. Switch probe on and allow to warm up for at least 15 minutes. Check probe storage chamber to ensure that sponge in chamber is moist.

3.1.2. Press up and down arrow keys simultaneously to enter calibration mode. Input approximate elevation in feet above mean sea level and press Enter.

3.1.3. Allow meter reading to stabilize. Record "Cal #" shown in lower area of display, as well as meter readout following stabilization. These numbers should be similar (i.e., for "Cal #" equal to 82, stabilized meter reading should be 80-84). Press Enter.

3.1.4. Input salinity correction value (leave at 0.0 for fresh water, or input approximate salinity for brines, seawater, etc.) Press Enter. Meter is ready for use. If "Cal #" and stabilized meter reading are not similar, recalibrate.

3.2 DISSOLVED OXYGEN MEASUREMENT

3.2.1 Lower probe into sample. NOTE: Some motion of water past probe membrane is required, so if water sample is quiescent, manual movement of probe is required (do not aerate sample during movement).

3.2.2. Allow reading to stabilize. MODE key selects unit readout (% saturation or mg/L). Record reading and temperature.

3.2.3. Replace probe in storage chamber after decontamination. If meter is shut off, recalibration is required each time meter is turned on. Recalibration will also be required if elevation changes significantly (>200 ft) between sample locations.

4.0 ASSOCIATED REFERENCES

Yellow Springs Instrument Company. Instrument manual for YSI Model 55 dissolved oxygen meter.

HF-SOP-49 - Use of a Flow Cell for Collecting Field Parameters.

TABLE 1. SOLUBILITY OF OXYGEN IN FRESH WATER

Temperature °C	mg/L Dissolved Oxygen	Temperature °C	mg/L Dissolved Oxygen
0	14.60	23	8.56
1	14.19	24	8.40
2	13.81	25	8.24
3	13.44	26	8.09
4	13.09	27	7.95
5	12.75	28	7.81
6	12.43	29	7.67
7	12.12	30	7.54
8	11.83	31	7.41
9	11.55	32	7.28
10	11.27	33	7.16
11	11.01	34	7.05
12	10.76	35	6.93
13	10.52	36	6.82
14	10.29	37	6.71
15	10.07	38	6.61
16	9.85	39	6.51
17	9.65	40	6.41
18	9.45	41	6.31
19	9.26	42	6.22
20	9.07	43	6.13
21	8.90	44	6.04
22	8.72	45	5.95

Source: Derived from 15th Edition "Standard Methods for the Examination of Water and Wastewater".

TABLE 2. ALTITUDE CORRECTION FACTOR

Atmospheric Pressure mmHg	or	Equivalent Altitude Ft.	=	Correction Factor
775		-540		1.02
760		0		1.00
745		542		.98
730		1094		.96
714		1688		.94
699		2274		.92
684		2864		.90
669		3466		.88
654		4082		.86
638		4756		.84
623		5403		.82
608		6065		.80
593		6744		.78
578		7440		.76
562		8204		.74
547		8939		.72
532		9694		.70
517		10472		.68
502		11273		.66

Source: Derived from 15th Edition "Standard Materials for the Examination of Water and Wastewater".

STANDARD OPERATING PROCEDURE

STREAMFLOW MEASUREMENT USING A MARSH-McBIRNEY WATER CURRENT METER ©

HF-SOP-37

1.0 PURPOSE

The purpose of this procedure is to obtain an accurate streamflow measurement. The method described is the "midsection method" with a Marsh-McBirney current meter.

2.0 PROCEDURE

2.1 SITE SELECTION

2.1.1 Choose a stream section with the following conditions:

A. A straight reach with stable streambed free of large rocks, weeds and protruding obstructions such as boulders which would create non-parallel flow.

B. A uniformly sloped streambed profile to eliminate vertical components of velocity.

It is usually not possible to satisfy all these conditions, but select the best possible site using these criteria.

2.1.2 Modify the stream channel above the measuring cross-section to best approximate these conditions.

2.1.3 If the site is to be revisited, permanently mark cross-section location.

2.2 CALIBRATION PROCEDURE

2.2.1 Set scale knob to "CAL" and time constant switch to 2.

2.2.2 After approximately ten seconds, the digital readout should be on or between 9.8 and 10.2.

A. If readout is not within limits, change batteries and repeat calibration. If the unit fails to calibrate (readout between 9.8 and 10.2) after the battery change, the unit is malfunctioning and should be returned to the manufacturer for repair.

B. If readout is within limits, the instrument is correctly calibrated.

3.0 MEASUREMENT PROCEDURE

3.1 Place a measuring tape or tag line across the selected section at right angles (if possible) to direction of flow. If it is not possible to establish a line perpendicular to flow, record the angle between the perpendicular and the actual flow measurement line. Record the total channel width. Estimate the number of sections needed to allow no more than 5 percent of the total flow in each section. For small streams, 10 percent of flow is permitted. Twenty-five to thirty sections are needed for a good measurement to get less than 5 percent of flow in each section. For less stringent accuracy, a lesser number of stations can be used.

3.2 Fill out the required information on stream gaging on the **Stream Gaging - Current Meter Form (HF-FORM-438)**. Much of the form is self-explanatory; however, the following explanation will assist in completing some parts of the form.

A. Site: List the site number and its name.

B. Distance from Initial Point: This is the measured distance from the initial point. For example: A measuring tape may be used and the edge of water may be several feet from the tape zero point.

C. Width: Width of the cross section in feet.

D. Depth: Depth of water in feet measured by wading rod or other measuring device.

E. Area: Product of WIDTH x DEPTH in square feet.

F. Point Velocity: Velocity as read from meter.

G. Discharge: Product of area times the point velocity. This is the computed flow in cfs with attention paid to significant numbers and the error limits.

H. Measurement Conditions and Rating: Estimate conditions.

Good (5%): Bottom slightly rough, flow not completely straight and smooth.

Fair (8%): Moderately rough bottom flow velocity varies across channel.

Poor (over 12%):	Rough bottoms; significant velocity variation across channel.
Very Poor (20%):	Very rough bottom; channel divided by boulders or weed-filled or other problems.
Other (EXPLAIN):	Some channels are rocky or weedy and are otherwise difficult to measure. Estimate error. Error can range from 20% to over 100%.

I. Gage Height: Record reading of staff gage or other measuring device placed in the stream. This is a measurement of stream stage.

3.3 Identify stream bank by either LEOW or REOW (left or right edge of water, respectively, when facing downstream) and record starting time.

3.4 Note any changes in stage height during measurement.

3.5 To begin measurement note distance from end of tape to beginning edge of water. Try to start at an even increment.

3.6 Measure and record water depth at the edge of the water.

3.7 Move out to center of the first section.

3.8 Record the distance from the initial point.

3.9 Using the top-setting wading rod, measure and record the depth at that point.

3.10 Mean velocity of flow at the point is determined by measuring velocity at 0.6 depth from the surface, for depths less than 2.5 feet. To set the sensor at 0.6 depth using the top-setting wading rod, line up the foot scale on the sliding rod with the tenth scale at the top of the depth gauge rod so that the combined scales match the depth of water at the measuring point. For depths greater than 2.5 feet, measurements are collected at 0.2 and 0.8 depth below the surface and the average of these values is used as the average velocity for the cross-section.

3.11 Set wading rod so the sensor is facing directly into flow (record any angles). Be sure you are not disturbing flow around the meter, stand to the side and downstream while taking the measurement.

3.12 Allow meter readout to stabilize. Start with the smallest time constant setting. If, after a period of time (in seconds) equal to 5 times the time constant setting (e.g. 10, 30 and 100 seconds for settings of 2, 6 and 20), the readout has not stabilized move to the next highest time constant settling.

3.13 Record velocity.

3.14 Move to the center of the next section.

3.15 Continue through the sections using steps 8 through 15.

3.16 For streams with a fairly uniform flow regime, the section can remain of equal width.

3.17 In areas where velocity varies or flow is concentrated in a narrow area, divide the high flow sections up into smaller widths to account for higher velocities (discharge).

3.18 Record the distance at the edge of water and ending time and note which edge this is - either LEOW or REOW.

3.19 Compute flow using the mid-section technique (USGS, 1977).

4.0 MAINTENANCE PROCEDURES

- Keep sensor free of dirt and coatings such as grease. Clean sensor with mild soap and water.
- Routinely check batteries by calibrating the meter.

5.0 REFERENCES

USGS, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Chapter 1: Surface Water.

HYDROMETRICS, INC. Consulting Scientists, Engineers, & Contractors

STREAM GAGING - MARSH MCBIRNEY METER

PROJECT NAME________________________________ /#__________

SAMPLE #______________________SITE__________DATE__________

DIST FROM INITIAL POINT (ft)	WIDTH (FT)	DEPTH (FT)	OBSER-VATION DEPTH			AREA (W x D)	POINT VELOCITY (FT/SEC)	DISCHARGE (CFS)
							TOTAL CFS________	

MEAS CONDITIONS	STREAM BOTTOM prioritize 1-3		WEATHER	
___ GOOD (5%)	___BOULDERS	CALM	BREEZE	WIND
___ FAIR (8%)	___COBBLES	NO PRECIP	RAIN	SNOW
___ POOR (12%)	___GRAVEL	CLEAR	P. CLOUDY	O. CAST
___ V. POOR (20%)	___SAND			
	___SILT			

Angle X-Sec W/Stream 90°_____ Other_____

GAGE HT__________ AIR TEMP__________°C H2O TEMP__________°C

COMP BY____________ PERSONNEL____________________________

HYDROMETRICS, INC. Consulting Scientists, Engineers, & Contractors

STREAM GAGING - MARSH MCBIRNEY METER

PROJECT NAME________________________________ /#__________

SAMPLE #______________________SITE__________DATE__________

DIST FROM INITIAL POINT (ft)	WIDTH (FT)	DEPTH (FT)	OBSER-VATION DEPTH			AREA (W x D)	POINT VELOCITY (FT/SEC)	DISCHARGE (CFS)
							TOTAL CFS________	

MEAS CONDITIONS	STREAM BOTTOM prioritize 1-3		WEATHER	
___ GOOD (5%)	___BOULDERS	CALM	BREEZE	WIND
___ FAIR (8%)	___COBBLES	NO PRECIP	RAIN	SNOW
___ POOR (12%)	___GRAVEL	CLEAR	P. CLOUDY	O. CAST
___ V. POOR (20%)	___SAND			
	___SILT			

Angle X-Sec W/Stream 90°_____ Other_____

GAGE HT__________ AIR TEMP__________°C H2O TEMP__________°C

COMP BY____________ PERSONNEL____________________________

DIST FROM INITIAL POINT (ft)	WIDTH (FT)	DEPTH (FT)	OBSER-VATION DEPTH			AREA (W x D)	POINT VELOCITY (FT/SEC)	DISCHARGE (CFS)
							TOTAL CFS________	

COMMENTS:

DIST FROM INITIAL POINT (ft)	WIDTH (FT)	DEPTH (FT)	OBSER-VATION DEPTH			AREA (W x D)	POINT VELOCITY (FT/SEC)	DISCHARGE (CFS)
							TOTAL CFS________	

COMMENTS:

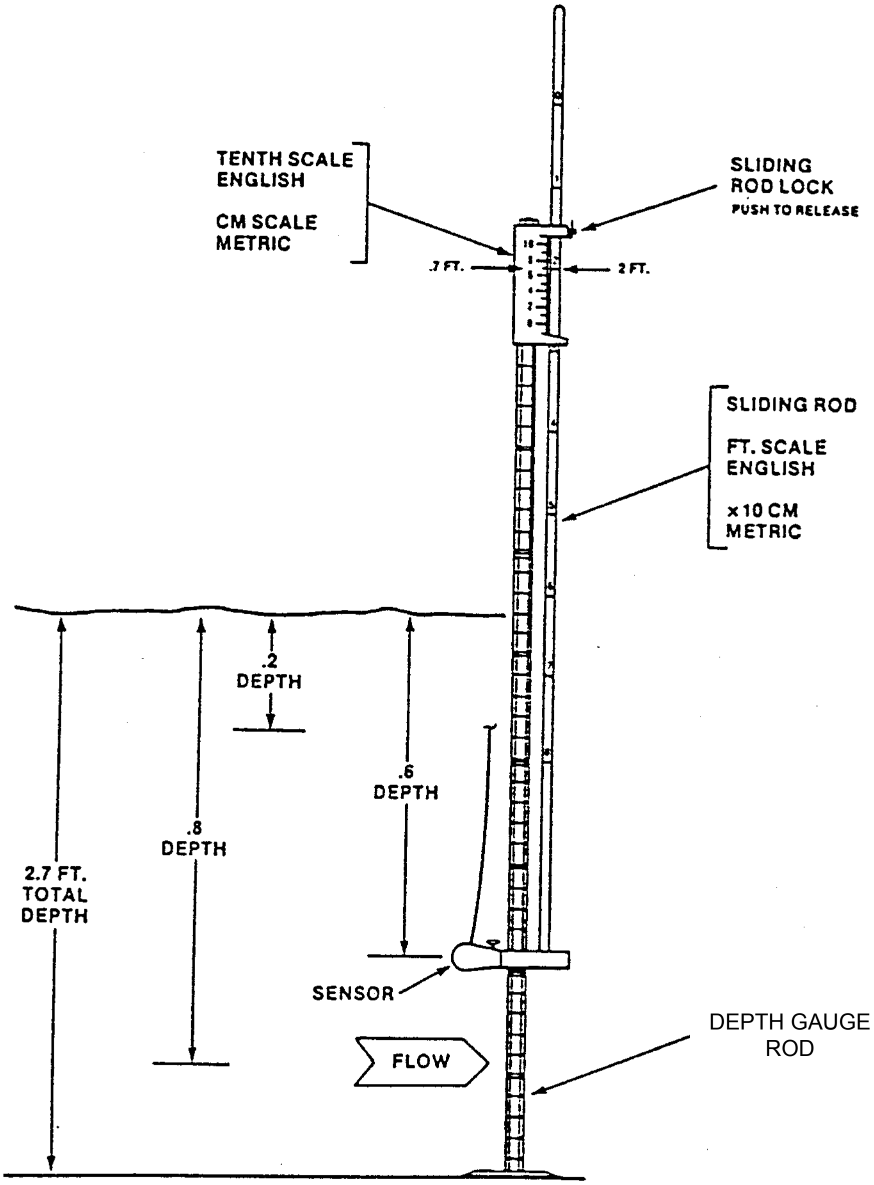


FIGURE 1. TOP SETTING WADING ROD

STANDARD OPERATING PROCEDURE

USE OF A FLOW CELL FOR COLLECTING FIELD PARAMETERS©

HF-SOP-49

1.0 PURPOSE

The purpose of using a flow cell is to increase the accuracy of field parameter values while sampling groundwater. The flow cell is designed to allow field personnel the ability to obtain field parameters from groundwater that are, with the exception of the pumping equipment, undisturbed. Specifically, use of a flow cell isolates the water sample from contact with the atmosphere at ground surface, providing a better representation of *in situ* groundwater chemistry for field parameter measurement.

2.0 EQUIPMENT

A) Flow cell

Necessary fittings to connect pumping system to the flow cell.

3.0 PROCEDURE

A) Connect flow cell to discharge tubing of pump system.

B) Connect or place meter (YSI 556 or similar) in the flow cell

C) Take readings as necessary from the field meter, according to the requirements outlined in the project work plan or sampling and analysis plan

D) If performing low flow sampling, reference HSOP-105 for instruction on use of a flow cell during low flow sampling.

STANDARD OPERATING PROCEDURE

FILTRATION OF WATER SAMPLES©

HF-SOP-73

1.0 PURPOSE

Water is filtered to obtain a sample for analysis of dissolved constituents. Dissolved constituents are operational, defined as those which pass a 0.45 micron filter. This SOP describes three methods in which filtered water samples can be prepared in the field. Other types of filtering equipment can be employed. The essential points are use of the proper filter and adequate decontamination of reusable equipment.

2.0 EQUIPMENT

Filter Barrel or

- Tire pump
- Filter barrel
- Clean sample bottles
- Prefilters (where needed)
- 0.45 µm filter membranes
- Distilled or deionized water
- Plastic tweezers

Plate Filter or

- Peristaltic Pump
- Plate filter
- 0.45 µm membrane filters
- Prefilters (where needed)
- Plastic tubing
- Clean sample bottles
- Distilled or deionized water
- Plastic tweezers

Disposable Filter Cartridges

- 0.45 µm filter cartridges
- Peristaltic Pump
- Plastic tubing
- Clean sample bottles
- Distilled or deionized water

3.0 PROCEDURE

A) General

1. Have at hand clean sample bottle pre-labeled with appropriate information.

2. Use a new filter membrane or disposable cartridge for each sampling site.

3. If water is very turbid, it must be first run through a larger pore size pre-filter.

4. Be sure you know the volume of sample required for analysis, check with laboratory if in doubt.

5. If collecting samples for low level analysis, rinse filter with an appropriate amount (usually 100 to 200 ml) of DI water prior to filtering any sample. This step should

remove contaminants (particularly zinc) which may be entrained within the filter matrix. Record the amount of DI water used to rinse the filter.

6. Rinse sample bottle with filtered water three times, before collecting actual sample. However, if water is hard to filter or of limited quantity, distilled or deionized water rinses are acceptable.

7. Avoid dusty locations and vehicle motor exhaust while filtering.

8. When a peristaltic pump is used, the pump and tubing should be cleaned immediately after obtaining a sample by pumping 500 ml of deionized water. After pumping 500 ml deionized water, remove inlet tubing from DI source and continue pumping until tubing is drained.

B) **Filter Cartridge** These are single-use, self-contained membrane filtration devices with inlet and outlet hose barbs designed for use when samples are pumped.

1. Examine a new filter cartridge and note direction of flow arrow imprinted on it.

2. Slip hose from pump over inlet nipple of cartridge. Sample may be collected directly from filter outlet (optional, place another short piece of tubing over outlet, if this is more convenient). Keep tubing length as short as possible.

3. It is important that water flow through filter in direction of imprinted arrow, as filter failure will likely result if flow direction is reversed. Also, inlet pressure should not exceed 25 PSI (pounds per square inch) for most filters of this type.

4. Turn pump on, discard initial 30 ml of filtrate (filter purge), then begin collecting sample.

C) **Filter Barrel** Filter barrels are reusable plastic cylinders with removable endcaps and fitted with a replaceable filter at one end (the outlet) and an air inlet at the opposite end by which the barrel is pressurized. Filter barrels are used where samples cannot be pumped.

1. Filter barrels must be decontaminated prior to going to the field. Remove both end caps, O-rings, and filter support. Wash components thoroughly with a non-phosphate detergent and water, thoroughly rinse with distilled or deionized water, re-assemble and store in plastic bag.

2. Ideally, the filter barrel should be rinsed with the water to be sampled. If an inadequate volume of sample water is available, a distilled or deionized water rinse is acceptable.

3. After rinsing, fill filter barrel 2/3 full with sample water.

4. Place clean 0.45 μm filter on filter support (do not touch filter with hands, use plastic tweezers or blue divider papers to move or adjust filter). Wet filter support will hold filter in place.

5. Assemble filter barrel carefully so as not to twist or put folds in filter paper.

6. Turn filter barrel over so sample water comes in contact with filter paper.

7. Connect tire pump to Shrader valve and pump several times. Do not allow static pressure on tire pump to go over 20 PSI.

8. Purge filter by draining approximately 100 ml of water from lower side of filter support. Discard this initial filtrate.

9. Once sample bottle is full, preserve sample as needed and place in cooler with ice. (see **HF-SOP-3, Preservation and Storage of Inorganic Water Samples**).

10. Before leaving the sampling site, disassemble filter barrel, remove and dispose of filter paper, and immediately rinse with distilled or deionized water. Partial decontamination, consisting of three successive distilled or deionized water rinses between sites is acceptable.

D) **Plate Filter** Plate filter is a reusable membrane filter holder, generally fitted with three removable legs. The filter holder is disassembled to replace the large diameter (typically 14.2 cm) membrane filter. Water is pumped through the filter, entering at the top and exiting through a port at the bottom.

1. Plate filters must be decontaminated prior to use. Disassemble plate filter, wash components thoroughly with a non-phosphate detergent and water, thoroughly rinse with distilled or deionized water, re-assemble and store in plastic bag.

2. Ideally, the plate filter should be rinsed with the water to be sampled. If an inadequate volume of sample water is available, a distilled or deionized water rinse is acceptable.

3. Place clean 0.45 μm membrane filter on filter support (do not touch filter with hands, use plastic tweezers or blue divider papers to move or adjust filter). Wet filter support will hold filter in place.

4. Assemble plate filter carefully so as not to twist or put folds in filter paper.

5. Connect plastic tubing from pump to top hose barb on filter. Sample may be collected directly from outlet, or keep tubing lengths as short as possible. A short piece of tubing may be connected to outlet barb at bottom.

6. Purge filter by pumping approximately 100 ml of water through the filter. Discard this initial filtrate.

7. Once sample bottle is full, preserve sample as needed and place in cooler with ice. (see **HF-SOP-3, Preservation and Storage of Inorganic Water Samples**).

8. Before leaving the sampling site, disassemble plate filter, remove and dispose of filter paper, and rinse with distilled or deionized water.

NOTES

- Use a new filter membrane for each sample.

- Run very turbid or muddy water through prefilter first and then a 0.45 micron filter.

- Check with lab performing analysis for adequate quantity and holding time for sample. Complete all appropriate documentation.

- Completely decontaminate filtering equipment after each day of use and whenever partial decontamination doesn't visually clean all filter parts.

- Do not attempt filtration in dusty locations or while your vehicle motor is running (due to exhaust).

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF SPECIFIC CONDUCTIVITY
HF-SOP-79

1.0 PURPOSE

The purpose of this procedure is to obtain accurate field measurements of specific electrical conductance of water samples. This procedure is written for the Hydac Digital type meter; other meters may be used if they are calibrated and used according to manufacturer's recommendations.

2.0 EQUIPMENT

2.1 Instrument

- Hydac Digital Conductance Meter or equivalent meter.

2.2 Reagents

- Potassium Chloride (KCl) standard solutions with known conductivities: (e.g., 50, 74, 147, 400, 718, 1413, 6668, 12990 µmhos/cm at 25°C).

2.3 Other Materials

- Distilled or deionized water for rinsing
- Field Sampling Notebook

3.0 PROCEDURE

3.1 Calibration

3.1.1 Rinse sample cup with distilled water before and after each conductivity standard used.

3.1.2 Select a standard with a conductivity value in the approximate range of the samples to be measured. After rinsing the sample cup with distilled water, rinse with the selected standard. Fill the cup with the standard, set function selector to TEMPERATURE and depress READ button. Set the temperature compensation knob on the conductivity side of the meter to the displayed temperature.

3.1.3 Switch function selector to CONDUCTIVITY and depress the READ button (READ button must be held down for display). Move the range selector to the lowest setting which will give a reading.

3.1.4 If the reading is not that of the standard, with a small screwdriver, adjust the calibration screw at the bottom of the meter (only small turns are required for fine-tuning).

3.1.5 Record reading, temperature, and time of calibration.

3.2 Sample Specific Conductivity Measurement

3.2.1 Rinse the sample cup with distilled water prior to filling with the sample. Rinse and fill with sample water.

3.2.2 Switch function selector to temperature scale and measure temperature of sample.

3.2.3 Adjust temperature compensator knob on the conductivity side of the meter to the displayed temperature.

3.2.4 Switch function selector to conductivity and depress READ button. Move the range selector to the lowest setting which will give a reading. Read conductivity and multiply by range. Record in field sampling notebook.

3.2.5 When measurements are complete, rinse probe with distilled water.

3.3 Calibration Check

3.3.1 At least once per day (or about once per every ten samples collected, whichever is more frequent), or when measuring conductivities of samples significantly different from the initial calibration solution, the meter should be checked against a standard of known conductivity. Record the check standard conductivity, temperature, and meter reading on appropriate documentation.

3.3.2 If the check standard reading differs from the true value by more than 10%, the meter should be recalibrated according to Section 3.1 of this SOP.

4.0 ASSOCIATED REFERENCES

Hydac Instruments -Instruction Manual for Digital Conductance, Temperature, and pH Tester.
Hydrometrics' Video Training Library -- Measurement of Conductivity.

STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF TEMPERATURE©
HF-SOP-84

1.0 PURPOSE

This procedure outlines the protocol for measurement of water temperature in the field. The procedure is applicable to lotic systems (rivers and streams), lentic systems (lakes, ponds, reservoirs, and impoundments), and groundwater systems. Special considerations for the various types of water environments are included in this procedure.

2.0 EQUIPMENT

- Liquid-filled thermometer, with scale divisions marked at a minimum of 1.0°C;
- Standard field meter equipped with a thermometer (for example, ph meters and conductivity meters often include temperature readout option);
- Temperature readout device with a remote probe (necessary for measuring temperature at depth in lakes or groundwater wells); and
- Field notebook.

3.0 PROCEDURE

Calibrate temperature measurement devices prior to field use with NIST-certified thermometers. When two methods of temperature measurement are available in the field (glass thermometer and pH water thermometer, for example) they may be used to cross-check one another.

It is preferable to measure temperature directly in the source to be sampled by immersing the thermometer into the stream, pond, etc., and allowing the reading to stabilize, when practical. Procedures for each of the main types of water samples are given below. If temperature must be measured on a sample that has been removed from the source, it is critical to measure and record the temperature immediately after collection, since equilibration with ambient air and container temperature will immediately begin to affect sample temperature.

A. Rivers and Streams

Wade stream and measure temperature directly, or measure from bank if unwadable. Temperature should be measured at multiple points across the stream transect, expecially in large, slow-moving river systems or immediately downgradient of tributaries. The average of all measurements is taken as the water temperature and recorded in the field notebook.

B. Lakes and Ponds

Measure temperature from bank and record. Recall that static water bodies often stratify. If samples are collected at various depths, temperature should be recorded at each depth. Depth profiling of temperature should occur at 1 foot or smaller intervals, in most cases.

C. Groundwater

Measure temperature of pumped or bailed water while purging well to monitor stabilization of temperature. Record temperature immediately after obtaining sample. If a remote, “down-the-hole” temperature probe is available, its use is preferred.

4.0 ASSOCIATED REFERENCES

“Standard Methods for the Examination of Water and Wastewater,” 18th edition (1992), page 2-59.