3.4. GROUNDWATER HYDROLOGY

This section describes the potential impacts that the proposed Project (Proposed Action) might have on groundwater. This section also provides an evaluation of such impacts in case the Project is executed following an AMA.

3.4.1. Analysis Methods

Analyses of the potential Project impacts on groundwater were completed considering (1) Project design, (2) regulatory framework, (3) baseline monitoring, (4) hydraulic testing, (5) tracer studies, and (6) groundwater modeling analysis.

3.4.1.1. Regulatory Context of the Analysis

The following groundwater-related acts, regulations, required permits/certificates, and enforcing agencies are relevant and applicable to the Project:

- Federal Clean Water Act – USEPA, U.S. Army Corps of Engineers (USACE);
- Montana Water Quality Act – Montana Department of Environmental Quality, Water Quality Division, Water Protection Bureau;
- Montana Pollution Discharge Elimination System – Montana Department of Environmental Quality, Water Quality Division, Water Protection Bureau;
- Montana Groundwater Pollution Control System – Montana Department of Environmental Quality, Water Quality Division, Water Protection Bureau;
- Certificate of Water Rights/Groundwater Appropriations – DNRC;
- Public Water Supply Act/Permit – Montana Department of Environmental Quality, Public Water and Subdivisions Bureau; and
- Montana Water Use Act – DNRC.

3.4.1.2. Spatial Boundaries of the Analysis

The impacts assessment evaluated the groundwater system within spatial boundaries of a watershed-scale Conceptual Model Domain, which includes the Local Study Area (LSA) and, the Regional Study Area (RSA). The LSA is defined as an area where direct impacts of the Project on groundwater could occur. Beyond the LSA boundary, direct impacts are not expected. The area covered by **Figure 3.4-1** represents the LSA. The RSA is defined as an area where secondary impacts of the Project could occur (e.g., groundwater impacts to surface water); beyond the RSA boundary, no substantive Project-related groundwater impacts are expected. The RSA is described here as an area that could experience groundwater drawdown of more than 2 feet due to mine dewatering, as computed by the groundwater model. Two feet of drawdown is within the typical range of seasonal groundwater level fluctuations observed in the monitoring wells of the Project area. Such a defined RSA also covers all of the Project infrastructure that has the potential to impact groundwater. **Figure 3.4-2** shows the Project area and the extent of the RSA, which are both contained within the Conceptual Model Domain.

3.4.1.3. Temporal Boundaries of the Analysis

Predictive analyses based on numerical and analytical groundwater modeling were carried out for the periods of mine construction, operations, and post-closure. These analyses are described in Section 3.4.1.2, Spatial Boundaries of the Analysis, and Section 3.4.3.2, Proposed Action. Section 3.4.3.1 below states that the No Action Alternative would not result in any changes to baseline groundwater conditions.

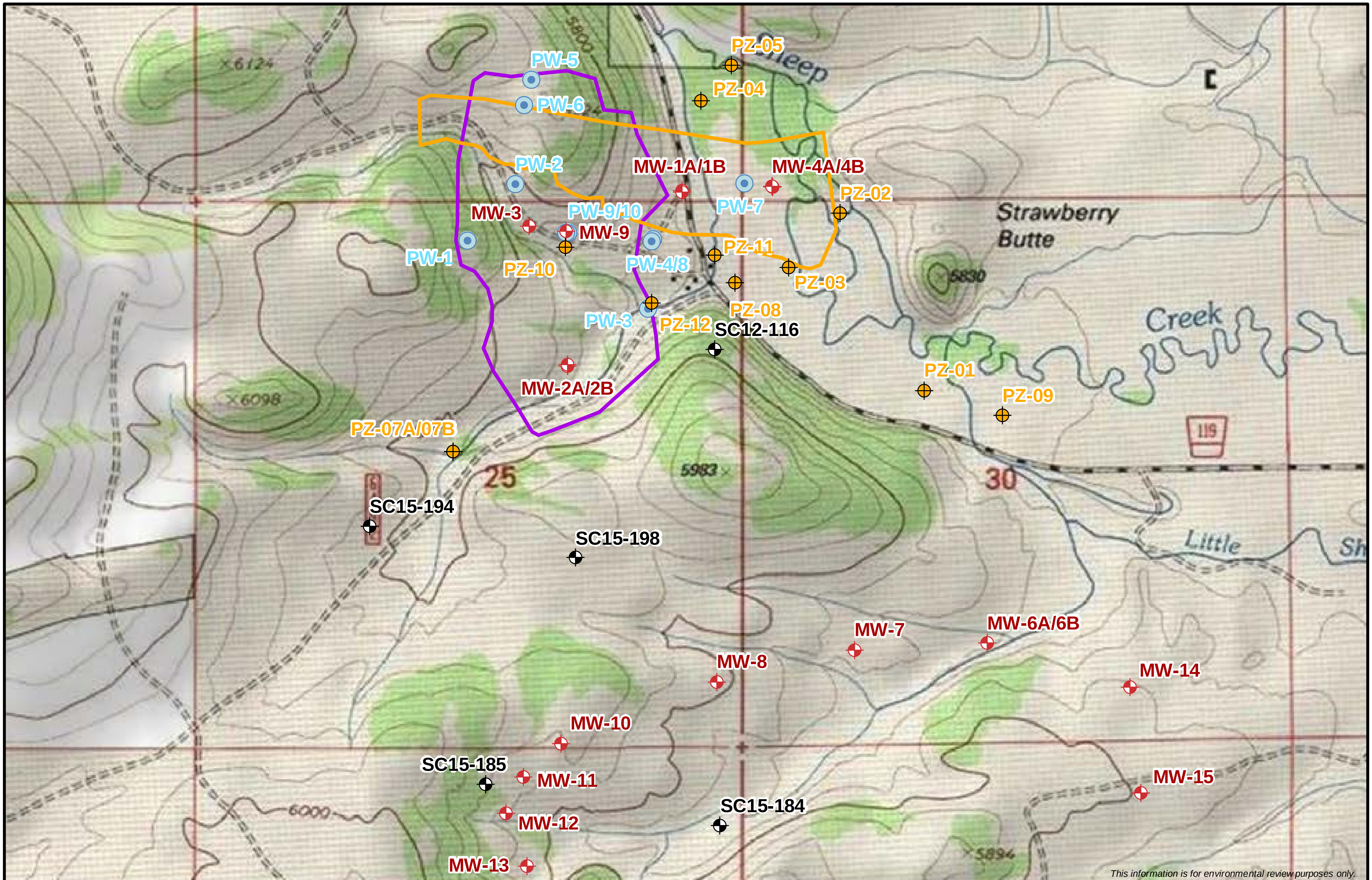
Below is a summary of methods used to complete the groundwater-focused tests, studies, and analyses.

3.4.1.4. Baseline Monitoring, Aquifer, and Permeability Tests

Extensive analyses have been carried out to characterize quantity and quality of groundwater around the proposed mine site, the results of which inform this section of the EIS. The following paragraphs summarize the scope and methodology used for each study.

Monitoring Wells, Seeps, and Springs

Water resource baseline monitoring and hydrologic investigations for the Project have been carried out since 2011 and are ongoing. Most of this information is presented in Appendix B of the MOP Application (Tintina 2017). Monitoring has involved measurements of surface water flow, groundwater-level elevations, and water temperatures. In addition, surface and groundwater samples have been collected and chemically analyzed following protocols described in the “Actual Water Resource Sampling and Analysis Plan” (Hydrometrics, Inc. 2016b). The groundwater part of this monitoring program involves quarterly (or in some cases less frequent) measurements of water levels in 34 monitoring wells and piezometers, and collection of water samples from 29 monitoring wells and piezometers. The locations of these wells and piezometers are shown on **Figure 3.4-1**. **Table 3.4-1** lists chemical parameters, methods, and detection limits used for baseline groundwater monitoring. Water quality sampling and analytical methods for the Project are summarized in the “Water Resources Monitoring Field Sampling and Analysis Plan” (Hydrometrics, Inc. 2016b), which is included as Appendix U of the MOP Application (Tintina 2017).



Piezometer
Monitoring Well
SC Well
Test Well
Lower Johnny Lee Deposit
Upper Johnny Lee Deposit

0 1,000 2,000 Feet

N

Figure 3.4-1
Black Butte Copper Project
Groundwater Hydrology Baseline Monitoring Sites/Local Study Area
Meagher County, Montana

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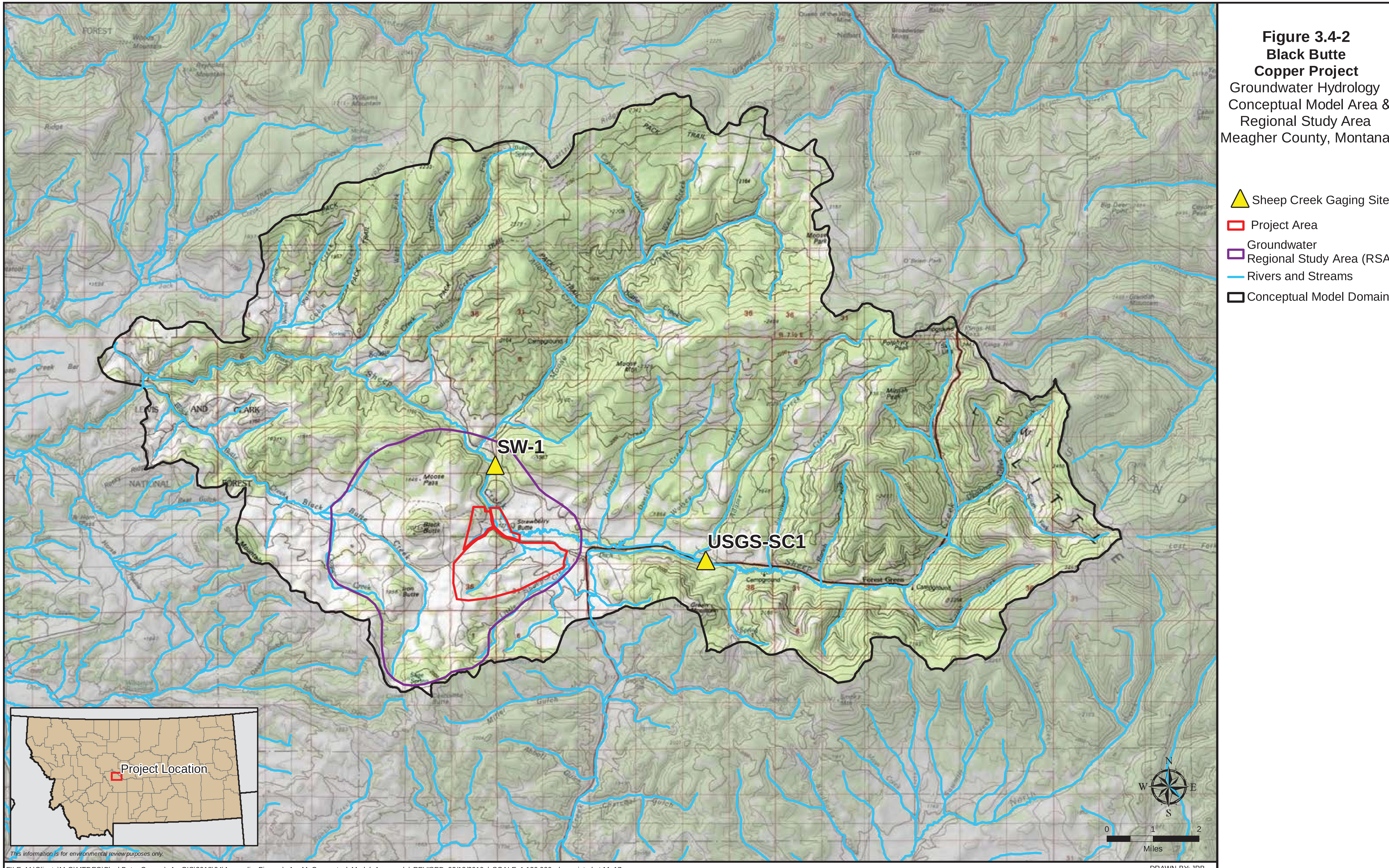
Source: Hydrometrics, Inc. 2017c



Source: Hydrometrics, Inc. 2016f

Table 3.4-1
Parameters, Methods, and Detection Limits for Baseline Groundwater Monitoring

Parameter	Analytical Method[a]	Project-Required Detection Limit (mg/L)
Physical Parameters		
Total Dissolved Solids	SM 2540C	10
Total Suspended Solids	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)[b]		
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

Parameter	Analytical Method[a]	Project-Required Detection Limit (mg/L)
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[c]	HF-SOP-20	0.1 s.u.
Specific Conductance (SC)	HF-SOP-79	1 µmhos/cm

Source: Hydrometrics, Inc. 2017c (Table 3)

°C = degree Celsius; mg/L = milligram per liter; NA = not applicable; s.u. = standard unit (pH); µmhos/cm = micro mho per centimeter
Notes:
[a] Analytical methods are from “Standard Methods for the Examination of Water and Wastewater” or the U.S. Environmental Protection Agency’s “Methods for Chemical Analysis of Water and Waste” (1983).
[b] Samples were field-filtered through a 0.45 micrometer filter and analyzed for dissolved constituents.
[c] The pH scale is a logarithmic scale used to measure the acidity or alkalinity of a system. Distilled or pure water has a neutral pH of 7. Liquids with a pH less than 7 are acidic (gastric acid, pH=1; orange juice, pH=3), while liquids with a pH greater than 7 are alkaline, or basic (ammonia, pH=11; bleach, pH=13). Rainfall that is not affected by air pollutant emissions typically has a pH of 5.3 to 5.6 in the western United States.

Monitoring wells and test wells completed within the shallow and deep hydrostratigraphic units (HSU’s described in Section 3.4.2.3) allow characterization of baseline water levels, groundwater flow directions, and groundwater quality within the LSA. Seeps and springs are expressions of groundwater discharging to surficial environments. Nine seeps and 13 springs near the Project were identified and mapped, and some were sampled for water quality and flow as a part of an inventory completed in 2011. A second series of flow measurements and water quality samples was conducted in July 2012 (Hydrometrics, Inc. 2017c).

Aquifer and Permeameter Tests

Aquifer tests were conducted at the site, which included both slug tests and pumping tests to characterize the hydraulic conductivity (K) of the principal HSUs. Five samples of gouge material from the Volcano Valley Fault (VVF) zone were collected from three separate exploration cores and tested in the laboratory for hydraulic conductivity using a Flexible Wall Permeameter (Hydrometrics, Inc. 2017c).

3.4.1.5. Groundwater Modeling

Regional Groundwater Flow Model

In 2015, Hydrometrics on behalf of Tintina, developed a three-dimensional numerical groundwater flow model using the MODFLOW-USG program to characterize existing conditions. The model extent covered the area shown as the Conceptual Model Domain (**Figure 3.4-2**), which includes the RSA and LSA (Hydrometrics, Inc. 2016f). The Conceptual Model Domain encompasses the upper two thirds of the Sheep Creek watershed, which extends from the headwaters of Sheep Creek downstream to the confluence of Black Butte Creek. The model was subsequently refined and used to assess potential impacts of the proposed mine on groundwater and surface water resources.

Using the numerical model, Hydrometrics performed a series of predictive simulations to evaluate the following for the Proposed Action:

- Groundwater inflow (dewatering) rates to mine workings;
- Changes in surrounding groundwater levels (drawdowns) caused by mine dewatering;
- Potential location and magnitude of stream depletion impacts; and
- Time required for post-mining groundwater levels to recover.

The reliability of the model predictions was assessed considering data limitations and results of a model sensitivity analysis (Hydrometrics, Inc. 2016f).

Water Quality Model

Water quality models were developed to evaluate water chemistry in the underground workings and in vicinity of the other Project facilities. These evaluations are reported in Appendix N (Enviromin 2017) of the MOP Application (Tintina 2017) and Technical Memorandum on the Black Butte Copper Project Water Quality Model of Agency Modified Closure Alternative (Sandfire Resources America, Inc. 2018). Among other tools and methods, the minteq.dat thermodynamic database option in the U.S. Geological Survey equilibrium model, PHREEQC, and published sulfide sorption isotherm data, were used to predict mineral precipitation, metal sorption, and resulting water quality. The focus of the modeling was to estimate chemical concentrations in the post-mine contact groundwater. The analyses considered equilibrium solubility and sorption constraints.

Sheep Creek Alluvial Flow Model

Hydrometrics developed a smaller scale, three-dimensional numerical groundwater flow model to evaluate the impacts of operating the alluvial UIG. The model domain encompasses the Sheep Creek valley from about 3,300 feet east of the confluence of Little Sheep Creek and Sheep Creek to where Sheep Creek enters the narrow part of the valley (**Figure 3.4-1**). The modelers utilized the results of field infiltration tests to evaluate the recharge capacity of the UIG (Hydrometrics, Inc. 2017b).

The model objectives were to:

- Estimate the groundwater mounding associated with UIG recharge to groundwater;
- Provide data that could be combined with the dewatering simulations to evaluate where groundwater would discharge to surface water during operations; and
- Provide a tool to assess the alluvial system for potential future evaluations (Hydrometrics, Inc. 2018c).

Sheep Creek Mixing Zone Evaluations for Total Nitrogen

Hydrometrics used a Source Specific Mixing Zone Application to complete calculations related to mixing of the UIG water discharge with groundwater of the alluvial aquifer within the Sheep Creek valley. The calculation was done to evaluate the potential impact the expected elevated concentration of total nitrogen might have upon Sheep Creek and Coon Creek (Hydrometrics, Inc. 2018a, 2018b). However, based on the results of the analysis, the MPDES permit will not authorize a mixing zone.

3.4.1.6. Hydrological Studies Focused on the Areas of Various Proposed Project Facilities

In addition to groundwater hydrology studies for the entire Conceptual Model Domain (including the RSA and LSA), several additional focused studies were conducted to characterize smaller areas in the vicinity of specific Project facilities.

Hydrological Assessment of Proposed Cement Tailings Facility

This study was performed to characterize the groundwater system beneath the proposed CTF, and is included as Appendix B-1 (Hydrometrics, Inc. 2016c) of the MOP Application (Tintina 2017). The study involved installation of four monitoring wells to the lowest depth of the planned CTF excavation, slug testing these wells, groundwater level monitoring, and collection and analysis of groundwater samples. Calculations were performed to estimate the flow rate of the underlying groundwater system, and inflow rates to the designed CTF underdrain system using the AQTESOLV program. Evaluation of this facility's planned construction design features and their impact on predicted seepage analysis during operations and closure of the facility are provided in Geomin Resources, Inc. (2018). The potential impacts of this Facility on groundwater are discussed in Section 3.4.3.2.

Hydrogeologic Investigation of the Sheep Creek Alluvial Aquifer Underground Infiltration Gallery

This field study involved infiltration testing at nine trenches excavated in the Sheep Creek alluvium to evaluate the recharge capacity of the proposed alluvial UIG. The investigators excavated trenches, installed three new piezometers, pumped water into the trenches, and monitored recharge flow rates and nearby groundwater levels. Monitoring continued until water levels recovered to within 10 percent of the initial water level (Hydrometrics, Inc. 2017b).

Temporary WRS Facility Percolation (HELP) Model

This modeling study was carried out to evaluate hydraulic behavior at the proposed temporary WRS facility, and is included as Appendix M-1 (Hydrometrics, Inc. 2016a) of the MOP Application (Tintina 2017). The study was performed using the Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07. The primary purpose of the modeling was to estimate the rate of downward water percolation through the waste rock. It was assumed in the analysis that all percolating water reaching the bottom of the waste rock would be collected and conveyed laterally by bedding material and piping on top of the bottom liner. The collected seepage would be channeled into an outlet pipe at the south edge of the WRS. The average discharge flow rate from the facility was estimated to be less than 1 gpm. The evaluation did not consider the possible impacts of liner failure.

Facility Embankment Percolation (HELP) Model

This modeling study evaluated hydraulic behavior of embankment areas, and is included as Appendix M-2 (Hydrometrics, Inc. 2016d) of the MOP Application (Tintina 2017). The analyzed embankments included those located at the (1) CTF, (2) PWP, (3) mill pad, (4) temporary WRS, (5) portal pad, and (6) CWP. The analyses were carried out using the HELP model, version 3.07. The analyses predicted percolation rates through compacted gravels placed on top of liners and the flow rates that would be collected and either used for mine operations or treated and discharged via the UIG. While the study did not consider the impacts of liner defects, the estimated rates represent an upper limit of percolation to the underlying water table in the unlikely event of a complete liner failure.

Evaluation of Open Access Ramps and Ventilation Raises in Closure

This study focused on estimating the potential impacts of open (non-backfilled) mine workings (e.g., access tunnels and ventilation shafts) on the groundwater system during the Project post-closure phase, and is included as Appendix M-3 (Hydrometrics, Inc. 2017a) of the MOP Application (Tintina 2017). The results of this evaluation supplemented the regional numerical groundwater flow model discussed in Section 3.4.1.2. Analytical models were developed to evaluate (1) the potential for water table mounding above the access decline and (2) upward flow from deeper to shallower HSU’s via open ventilation shafts. These post-closure analyses assumed that the groundwater table was fully recovered in the three shallowest HSUs.

Evaluation of Tunnel and Shaft Plugs for Controlling Groundwater Flow at Closure

This analysis evaluated the merit of installing plugs in post-mine tunnels and shafts that would not be backfilled, and is included as Appendix D of this EIS. Plugs are concrete blocks, 10 to 30 feet long, which selectively seal mine workings that are otherwise open. Open tunnels and shafts could provide conduits for upward flow of contact groundwater, bypassing the containment afforded by the natural (undisturbed) geologic materials. The sealing provided by plugs in otherwise open tunnels and shafts was considered an important closure issue for this EIS. The hydraulic analysis of a hypothetical plug in a ventilation shaft was performed using an analytical model.

3.4.2. Affected Environment

The various methods and tools described in Section 3.4.1 were used to characterize baseline (pre-mining) conditions in the groundwater system that could be affected by the Project. The following sections provide a summary of the pre-mining conditions.

3.4.2.1. Conceptual Model Domain and Regional Study Area

The Project’s groundwater Conceptual Model Domain encompasses the upper two thirds of the Sheep Creek watershed on the southern edge of the Little Belt Mountains, which extends from the headwaters of Sheep Creek downstream to the confluence of Black Butte Creek (**Figure 3.4-2**). Sheep Creek is a perennial stream that originates in the eastern part of the model domain at an elevation of about 7,400 feet amsl, flows through the RSA and Project area (LSA) and exits the model domain on its western boundary at an elevation of about 5,000 feet amsl.

Sheep Creek continues west to where it flows into the Smith River at an elevation of 4,380 feet amsl. The Project area is approximately 19 river miles above the confluence with the Smith River.

Sheep Creek has a number of named and unnamed tributaries. Little Sheep Creek and Black Butte Creek (the latter also referred to as Big Butte Creek or Butte Creek) are two of the larger perennial tributaries in the immediate Project area. Little Sheep Creek is located southeast of the Project area and converges with an unnamed tributary (referred to here as Brush Creek) before flowing into Sheep Creek in the lower Project area at Sheep Creek meadows. Black Butte Creek lies southwest and west of the Project area and joins Sheep Creek near the western edge of the regional model domain (Hydrometrics, Inc. 2016f). As shown on **Figure 3.4-2**, Sheep Creek surface water gaging station USGS-SC1 is located upstream of the Project site and gaging station SW-1 is located downstream of the Project site.

Only a portion of the Conceptual Model Domain's area is evaluated in the groundwater impact analysis. This sub-area is set as the RSA, which is defined in Section 3.4.1.2 above.

3.4.2.2. Geological Settings

This subsection provides a summary description of geological settings within the Conceptual Model Domain, which includes the RSA and LSA. See Section 3.6, Geology and Geochemistry, for more details of the area geology.

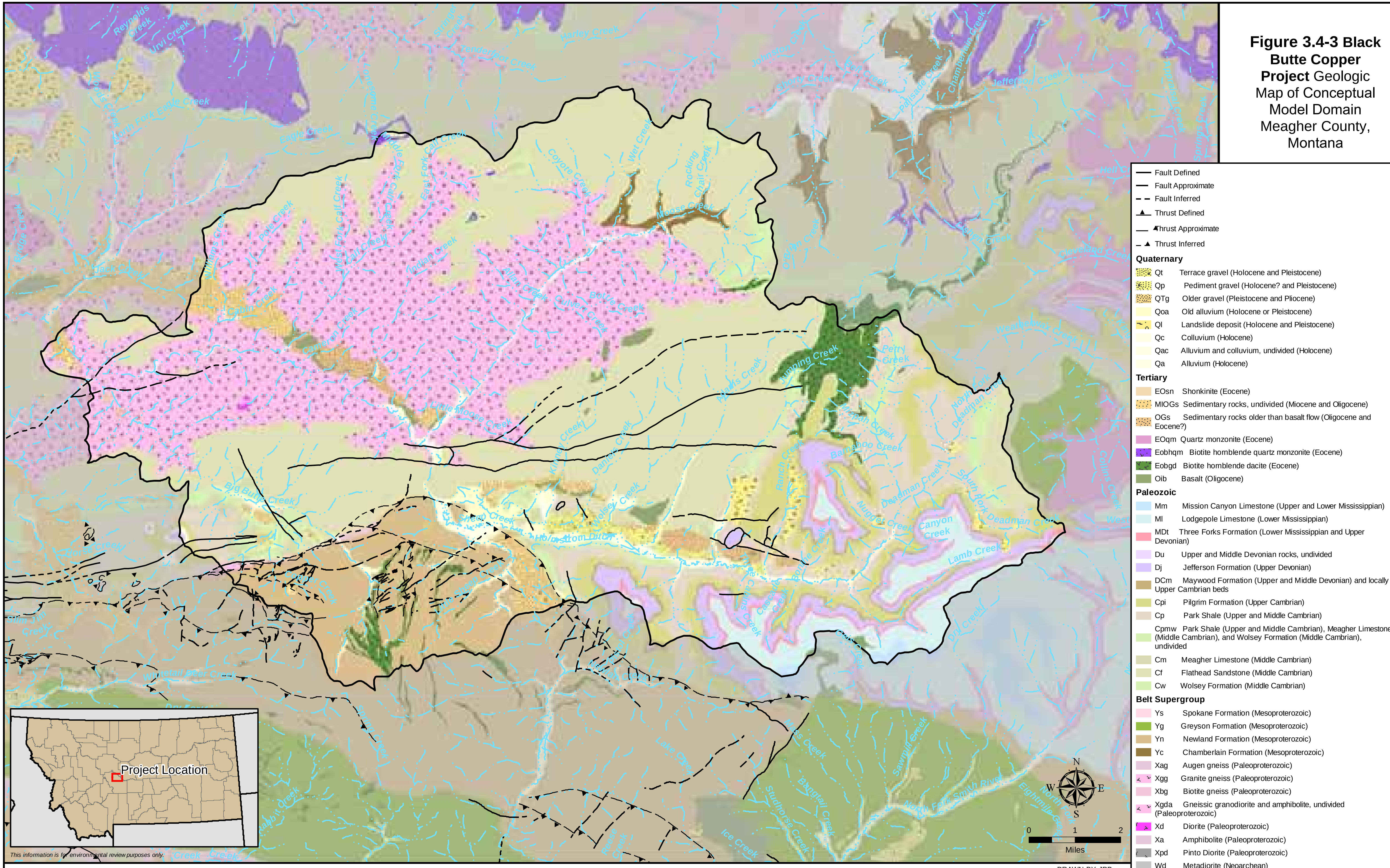
The prominent east-west trending fault (VVF) runs through the southern part of the Sheep Creek drainage. The geology to the south of the VVF consists largely of Precambrian Lower Newland Formation shales (see **Figure 3.4-3**), which extend to the southernmost boundary of the Sheep Creek drainage. The Lower Newland Formation is often greater than 2,500 feet thick and consists mainly of gray dolomitic and non-dolomitic shales that dip gently to the south-southwest. North of the VVF is the younger Flathead Sandstone, which unconformably overlies strata that are older than the Lower Newland Formation.

Bedded pyrite horizons within dolomitic shale of the Lower Newland Formation host tabular sheets of copper mineralization. Exploration drilling delineated two separate lenses containing copper resources: the Johnny Lee Deposit Upper Copper Zone (UCZ) and the Johnny Lee Deposit Lower Copper Zone (LCZ) (Tintina 2017). The cross-sections on **Figure 3.4-4** illustrate the positions of the UCZ and LCZ relative to geologic formations and structures. Both deposits are located close to the VVF; the UCZ just south of the fault and the LCZ just north of the fault. The LCZ is bounded to the north by the older Buttress Fault, which appears to be cut by the VVF and does not extend to ground surface.

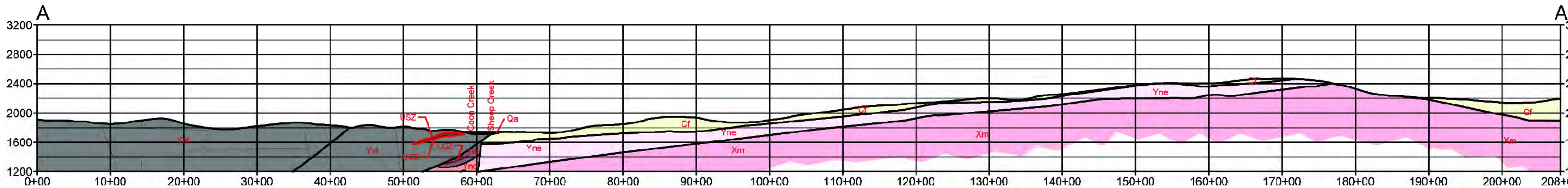
Unconsolidated surficial deposits within the Conceptual Model Domain include alluvial deposits present along the axis of the major drainages and older (Quaternary/Tertiary) basin-fill sediments that form terraces flanking these drainages in a few areas (see **Figure 3.4-3**). The most prominent alluvial deposits are present in the middle reach of the Sheep Creek drainage where the valley is comparatively wide. Significant portions of the upper and lower reaches of Sheep Creek cut through narrow bedrock canyons where surficial deposits are minor or absent (Hydrometrics, Inc. 2016f).

3.4.2.3. Hydrostratigraphic Units

Major HSUs identified for the Conceptual Model Domain, RSA, and LSA generally coincide with the principal geologic units, but also include fault zones. Hydraulic properties of the important LSA units have been determined through aquifer testing and are detailed in technical reports (see Section 3.4.1.4, Baseline Monitoring, Aquifer, and Permeability Tests). The hydraulic properties of units outside of the LSA have been estimated considering values quoted in literature for similar formations. **Figure 3.4-5** diagrammatically shows the spatial relationships between the HSUs, copper ore zones, and nearby faults. **Table 3.4-2** summarizes the hydraulic properties of all the HSUs described in this section.

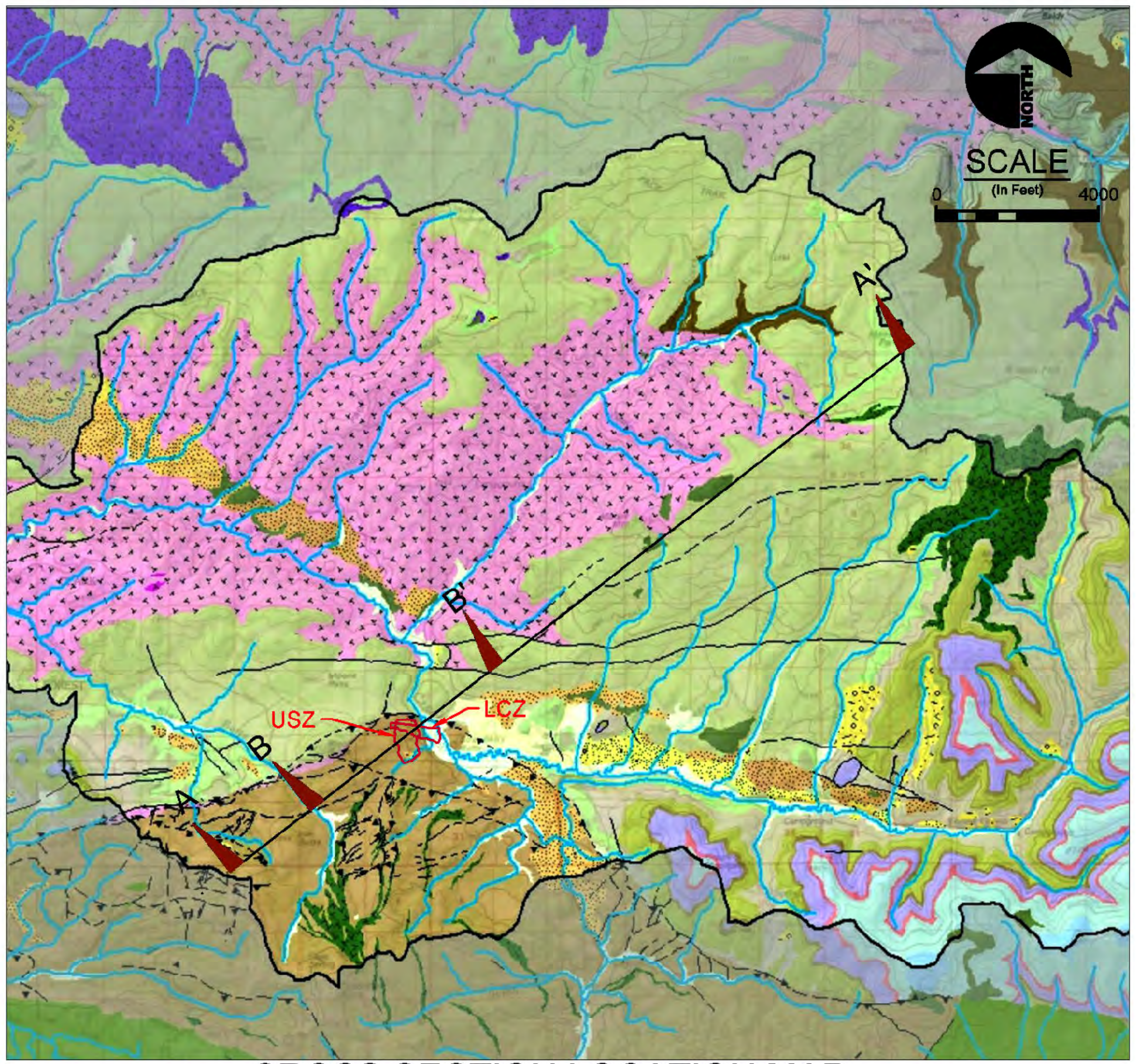


Source: Hydrometrics, Inc. 2016f

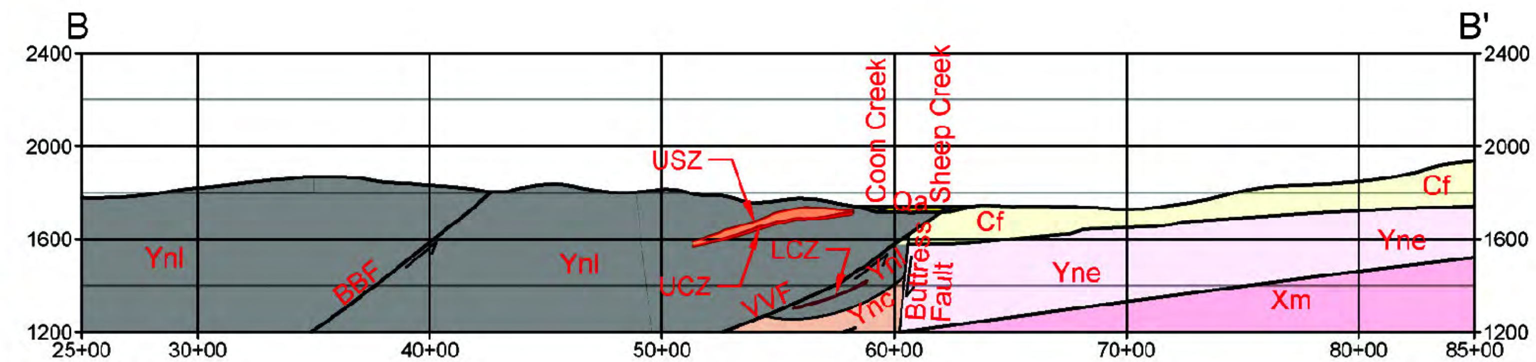


CROSS SECTION A - A'

1"=1400'



CROSS SECTION LOCATION MAP



CROSS SECTION B - B'

1"=800'

LEGEND

Qal	Quaternary Alluvial Deposits
Cf	Flathead Sandstone
Ynl	Lower Newland Shales
USZ	Upper Sulfide Zone
UCZ	Upper Copper Zone
LCZ	Lower Copper Zone
Yc	Chamberlain Shale
Yne	Neihart Quartzite
Xm	Crystalline Bedrock
VVF	Volcano Valley Fault
BBF	Black Butte Fault

Figure 3.4-4
Black Butte
Copper Project
Geologic Cross Sections of
Conceptual Model Domain
Meagher County, Montana

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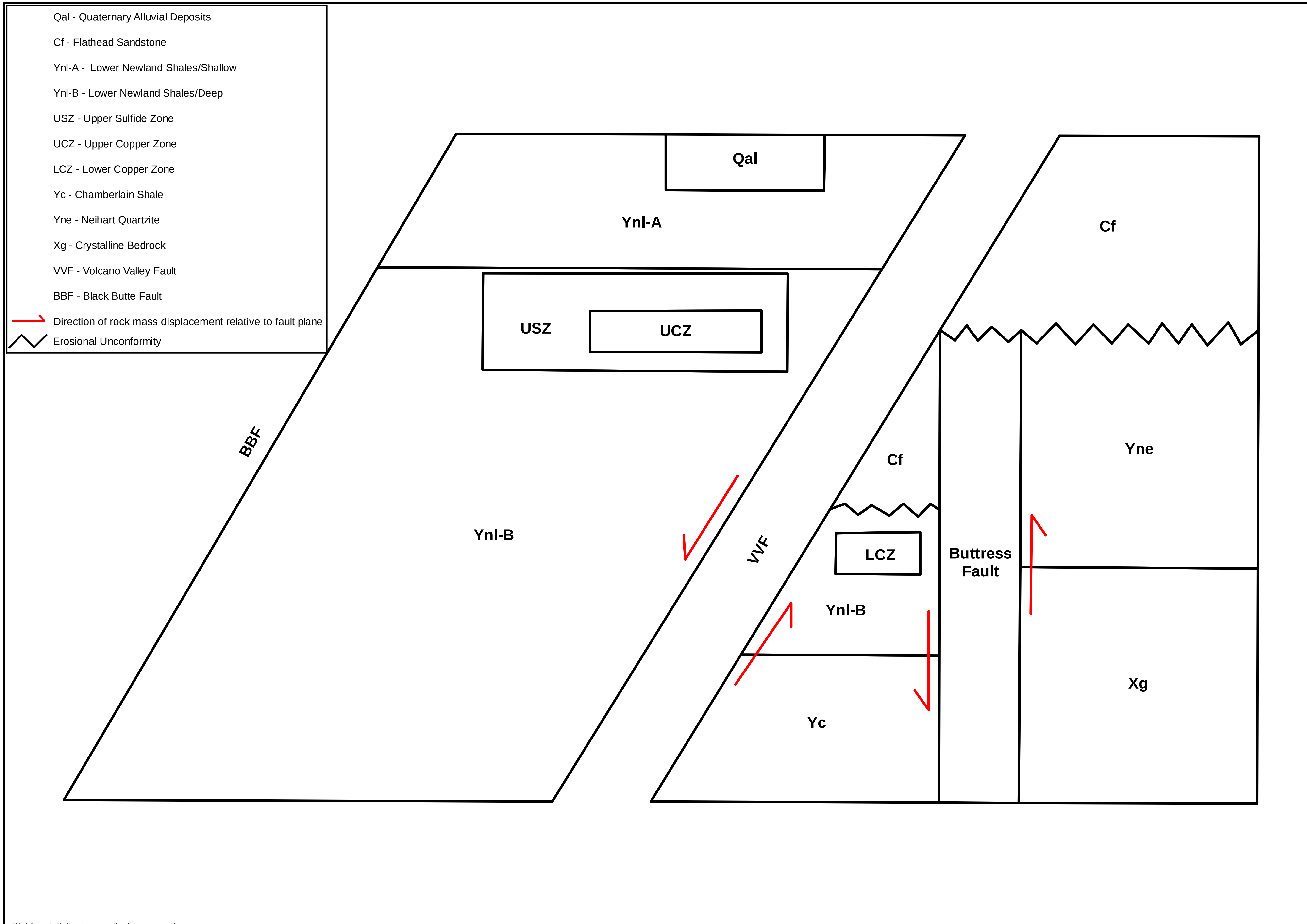

Figure 3.4-5
Black Butte
Copper Project
Hydro-Stratigraphic Units
Meagher County, Montana

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Source: Hydrometrics, Inc. 2016f

Table 3.4-2
Hydraulic Properties of Hydrostratigraphic Units

Unit	Description	Thickness (ft)	Hydraulic Conductivity (ft/day)	Storage Coefficient	Source of Hydraulic Properties
Geologically-Based Hydrostratigraphic Units					
Quaternary Deposits (QaL)	coarse-grained sand and gravel alluvium	17	200	0.2 to 0.35	slug test; literature
Lower Newland Formation shallow (Ynl A)	calcareous and non-calcareous shale and siltstone bedrock	30-50	1 to 2.3 GM: 1.5	1×10^{-4} to 8×10^{-6}	pumping test
Upper Sulfide Zone (USZ)	highly mineralized zone	30-150	0.01 to 0.7 GM: 0.08	6×10^{-5} to 9×10^{-5}	pumping test
Upper Copper Zone (UCZ)	Shallower copper ore zone (within USZ)				
Lower Copper Zone (LCZ)	Deeper copper ore zone	30-50	1.9×10^{-4}	NA	pumping test
Lower Newland Formation deep (Ynl B)	dolomitic and non-dolomitic shale and siltstone bedrock	150 north of the VVF; up to 2,000 south of the VVF	0.001 to 0.007	NA	pumping test
Flathead Sandstone (Cf)	sandstone bedrock	100	10^{-5} to 1.5	NA	literature
Chamberlain Formation Shale (Yc)	siliceous, locally arenaceous shale	500	0.001 to 0.007	NA	assumed
Neihart Formation Quartzite (Yne)	recrystallized sandstone	800	low; NA	NA	assumed
Crystalline Bedrock (Xbc)	metamorphic crystalline rock	to depth	10^{-3} to 10^{-1}	NA	literature
Structurally Defined Hydrostratigraphic Units					
Volcano Valley Fault (VVF)	fault; clay gouge core; variable associated fracturing	150	1.5×10^{-5} to 7.1×10^{-4} GM: 2.8×10^{-5}	NA	lab permeameter tests
Black Butte Fault		10 - 14			assumed
Buttress Fault		5			
Brush Creek Fault		44			

Source: Adapted from Tintina 2017 (Table 4-1)

GM = geometric mean value (typically used when property values range over more than one order of magnitude); ft = foot; ft/day = foot per day; FW = footwall; NA = not available or not applicable; VVF = Volcano Valley Fault
Notes:
[a] hydraulic conductivity (K) values determined from the aquifer testing.

Quaternary Deposits (Qal)

This unit corresponds to the alluvial sand and gravel deposits that lie along the axes of the major drainages. Slug-testing of MW-4A completed in sand and gravel of the alluvial aquifer in Sheep Creek Meadow yielded a hydraulic conductivity of 200 feet per day. None of the proposed underground workings penetrate alluvial deposits; however, the alluvium is used as a water supply source for mine operations and as a medium for discharge of treated water via the UIG. The storage coefficient (specific yield) of this unconfined HSU is estimated to range from 0.20 to 0.35 based on literature values.

Shallow Lower Newland Shales (Ynl A)

The shallow Lower Newland Formation subunit (Ynl A) typically consists of calcareous and non-calcareous shale and siltstone with discrete weathered intervals that exhibit oxidized surfaces within the upper 130 to 150 feet. The base of the Ynl A is at the contact with the USZ. Boreholes that penetrated the Ynl A produced yields of 5 to 30 gpm within discrete zones during drilling. Pumping tests conducted in wells completed in this unit yielded K values ranging from 1 to 5.8 feet per day, and the geometric mean hydraulic conductivity is taken to be 1.5 feet per day. Storativity results obtained from one pumping test ranged from 8×10^{-6} to 1×10^{-4}.

Within the mineralized shales of the USZ and UCZ, well yields are typically low. K values range from 0.01 to 0.7 foot per day and two measured values of the storage coefficient are 6×10^{-5} and 9×10^{-5}.

Deep Lower Newland Shales (Ynl B)

The deeper bedrock in the Lower Newland Formation subunit (Ynl B) consists of dolomitic and non-dolomitic shales and siltstones similar to the Ynl A unit. However, the deeper bedrock typically produces lower well yields than the shallower Ynl A. The Ynl B is more than 2,000-feet thick south of the VVF. In general, wells penetrating the lower Ynl B unit produced little water. The measured K values ranged from 0.001 to 0.007 foot per day. No storage coefficient estimates are available for this unit.

Within the mineralized LCZ, a K value of 1.9×10^{-4} was estimated from a pumping test.

Flathead Sandstone (Cf)

Flathead Sandstone is present north of the VVF and is composed of fine- to medium-grained sand that is generally well cemented, but the degree of cementation can vary locally. This unit is approximately 100-feet thick where it has been encountered in exploration boreholes next to the VVF. There are no test wells within the Flathead sandstone in the Project area to establish hydraulic parameters for this unit. Literature values for hydraulic conductivity of sandstone show a large potential range, with reported K values for sandstone ranging from 10^{-5} to 1.5 feet per day. Hydraulic conductivity values set in the calibrated groundwater model for this unit range from 0.0003 foot per day to 3.85 feet day.

Chamberlain Shale (Yc)

Chamberlain shale underlies the Ynl B and has only been encountered in exploration boreholes on the north side of the VVF where it appears to be up to 500-feet thick. There are no test wells that penetrate the Chamberlain shale. It is assumed that the Chamberlain shale has hydraulic conductivity similar to the deep Lower Newland shales (0.33 to 1 foot per day). None of the proposed mine workings intercept the Chamberlain Shale.

Neihart Quartzite (Yne)

Neihart quartzite is up to 800-feet thick. Quartzites are recrystallized sandstones that typically have low hydraulic conductivity except in highly fractured zones. No quantitative data were collected to characterize hydrologic properties of this unit; however, it generally exhibited low permeability characteristics when encountered in exploration holes. Somewhat higher permeabilities were suggested in localized zones of fracturing adjacent to the Buttress Fault. In the numerical groundwater model, the unit was assigned a bulk hydraulic conductivity values ranging from 0.0003 to 1.31 feet per day. None of the proposed mine workings intercept the Neihart Quartzite.

Crystalline Bedrock (Xg)

Precambrian metamorphic crystalline bedrock forms the core of the Little Belt Mountains and is present at ground surface north of the VVF (**Figure 3.4-4**). Since crystalline rocks have negligible primary porosity, groundwater is only present within joints and fractures in the rock. The permeability of the joints and fractures typically decreases rapidly with depth due to the combined impact of the weight of the overlying rock and the tendency for weathering and surface disturbances to penetrate only a short distance into the bedrock. Representative K values for crystalline rock are on the order of 10^{-3} to 10^{-1} foot per day with values for weathered crystalline rocks ranging up to several orders of magnitude higher. It is assumed that the K values of crystalline basement rocks decrease with depth by approximately three orders of magnitude in the upper 300 feet. None of the proposed underground workings penetrate the crystalline bedrock.

Structurally Defined Hydrostratigraphic Units

Fault zones that bound the Johnny Lee Deposit influence groundwater flow through the Project area. The BBF and VVF bound the upper orebody (UCZ) to the north, south, and west. The LCZ is bounded to the south and north by the VVF and Buttress Fault, respectively, and above by the VVF. Exploration drilling has indicated that fault zones generally contain gouge, which is finely pulverized rock that typically alters to clay and exhibits low permeability. Thus, fault zones are considered lateral barriers to groundwater flow and do not operate as conduits for enhanced flow. The only quantitative data come from lab permeameter tests of five gouge samples taken from exploration core. The measured hydraulic conductivities ranged from 1.5×10^{-5} to 7.1×10^{-4} foot per day. The geometric mean of these values (2.8×10^{-5} foot per day) is applied to the core of all major fault zones in the LSA.

In hard brittle rocks, low permeability gouge may exist in the core of a fault zone, but rocks with enhanced fracturing and higher permeability may be present on either side of the gouge zone. While this situation is unlikely in shale formations (Ynl A and Ynl B), it could be present in the Neihart quartzite adjacent to the Buttress Fault. In the spring of 2015, the well PW-6 was deepened into the Neihart Formation adjacent to the Buttress Fault (renaming it PW-6N). Air-lift pumping of the open borehole produced more than 500 gpm and confirmed that there are high permeability fractures in the Neihart Formation quartzite adjacent to the fault (Tintina 2017).

3.4.2.4. Groundwater Flow Conditions

The groundwater potentiometric map shown for the Conceptual Model Domain on **Figure 3.4-6** is a generalized interpretation generated from the regional numerical groundwater flow model that was calibrated to groundwater levels measured in wells or indicated by perennial streams. In addition to the Tintina monitoring well network, water level data outside of the Project area were obtained from a search of Montana’s Groundwater Information Center database maintained by the Montana Bureau of Mines and Geology. The search identified 20 wells with water level data reported in their well logs at the time of well completion; 13 in bedrock and 7 in alluvium. The stage elevations of perennial streams reflect the groundwater levels adjacent to the stream channels. The potentiometric contours on **Figure 3.4-6** indicate that recharge takes place in upland areas and groundwater flow converges toward the major drainages, including Sheep Creek, Moose Creek, Little Sheep Creek, and Black Butte Creek (Hydrometrics, Inc. 2016f). It is also interpreted that groundwater no-flow boundaries generally coincide with the major surface water drainage divides.

A more detailed potentiometric map of the LSA (**Figure 3.4-7)** was developed using water level data collected from the network of monitoring wells and piezometers installed by Tintina (Hydrometrics, Inc. 2016f). **Figure 3.4-7** depicts the bedrock potentiometric surface in the Lower Newland Formation, as well as elevations of the water table in the shallow alluvial system. Groundwater flow in bedrock is topographically controlled and converges toward Sheep Creek. Groundwater flow in the alluvium is roughly parallel to the stream but converges toward Sheep Creek at the northern end of the Sheep Creek meadows where the alluvium pinches out as Sheep Creek enters a narrow bedrock canyon (Hydrometrics, Inc. 2016f).

Most paired wells show upward hydraulic gradients, with the exception of wells MW-1A/1B and piezometers PZ-07A/07B. The downward gradient at MW-1A appears to reflect the presence of a shallow perched groundwater body within the clayey gravel terrace deposits that overlie the shale bedrock in this area. The downward gradient at PZ-07A and PZ-07B suggest that the springs feeding the headwaters of Coon Creek are also likely a perched system. In the areas of lower elevation, the wells tend to show upward gradients between the deeper bedrock and shallower units, which is consistent with the interpretation of groundwater converging and discharging to the stream channels (Hydrometrics, Inc. 2016f).

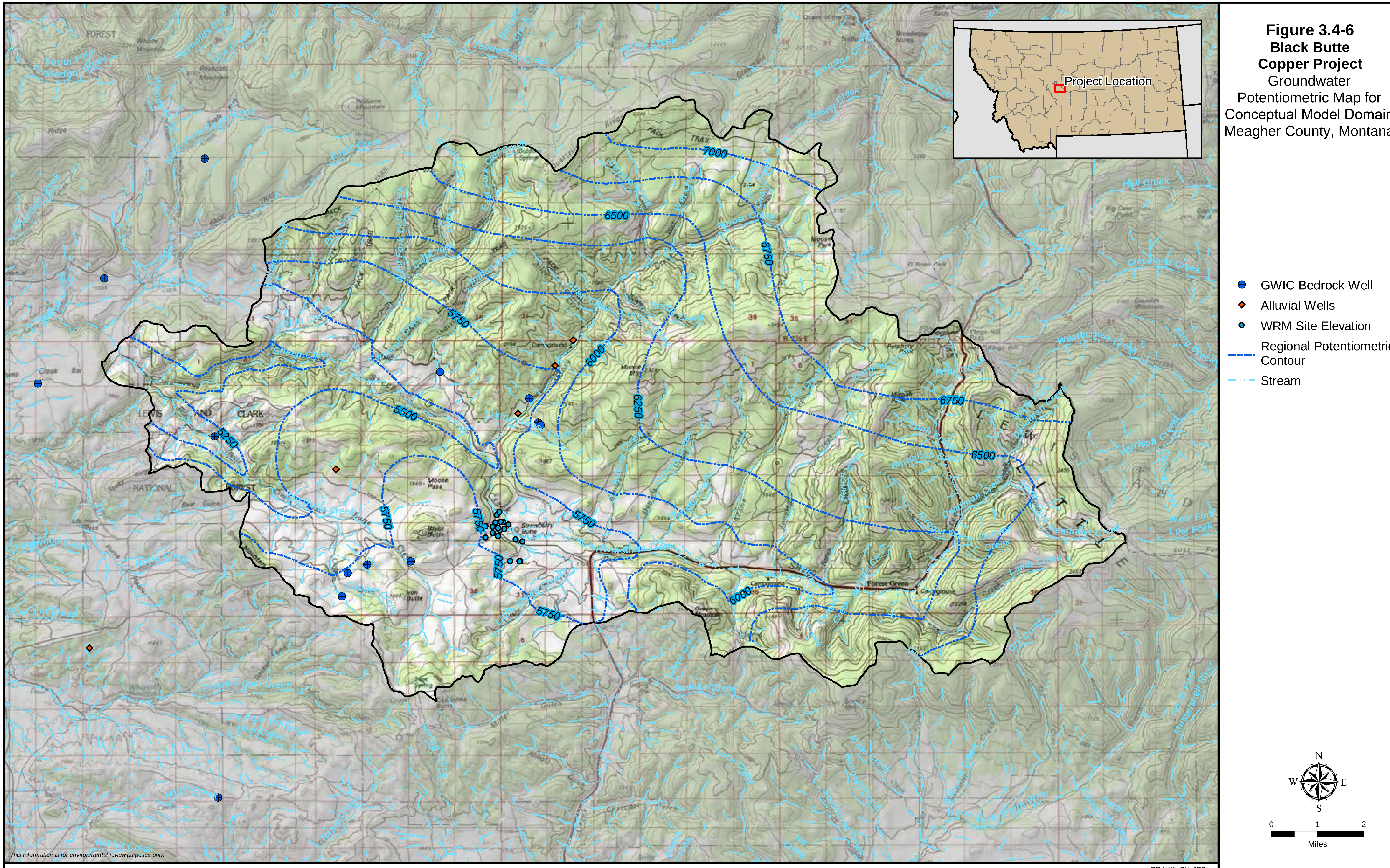
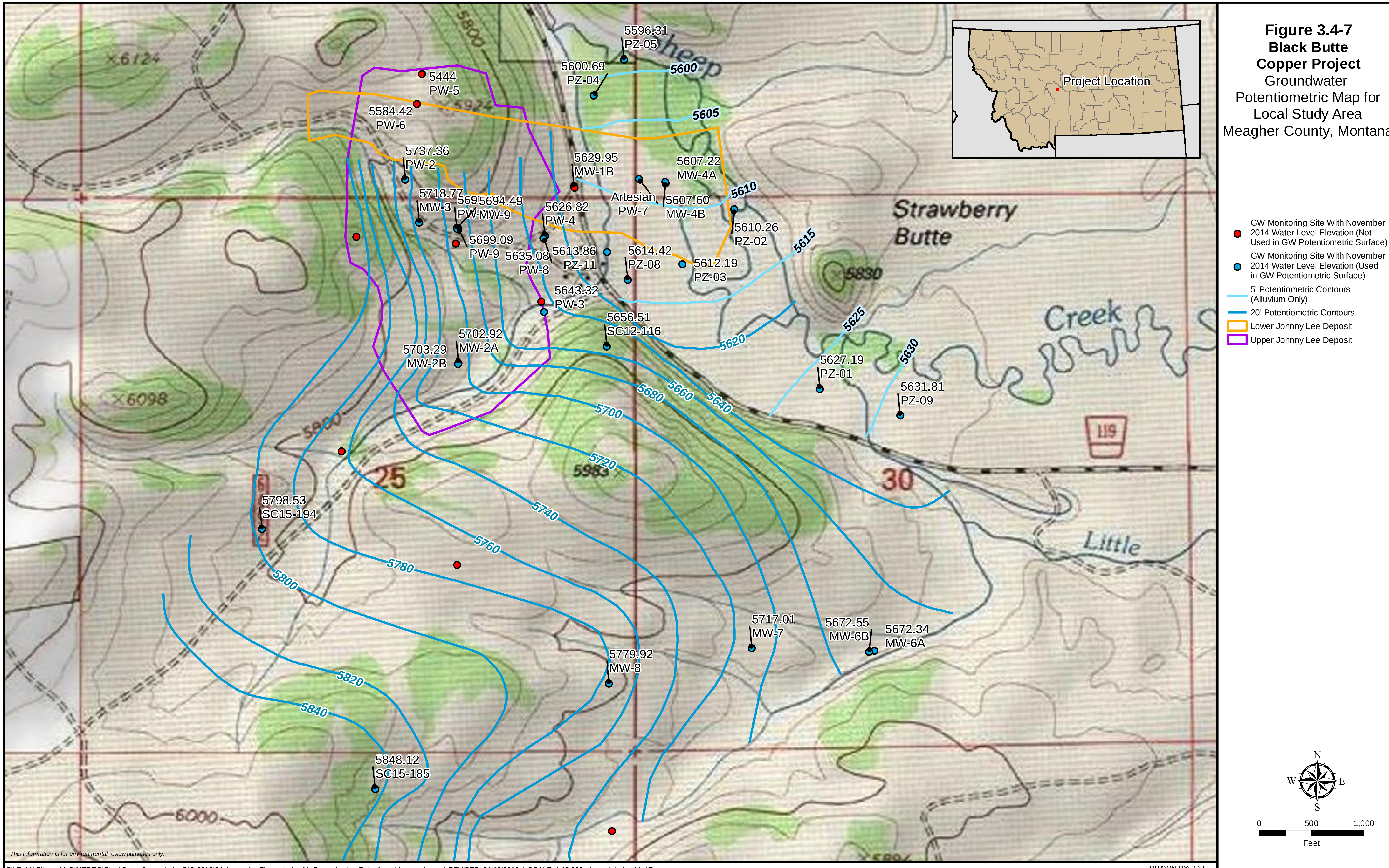


Figure 3.4-6
Black Butte Copper Project
Groundwater Potentiometric Map for Conceptual Model Domain
Meagher County, Montana

Source: Hydrometrics, Inc. 2016f



Source: Hydrometrics, Inc. 2016f

Groundwater levels typically show seasonal fluctuations in the bedrock wells of 1 to 3 feet, peaking in early June and declining through the summer months. The levels continue to decrease at a slower rate through the fall and winter months and reach seasonal lows in February and March. The shallow alluvial system fluctuates 1 to 1.5 feet seasonally with similar seasonal trends, except the early June spike tends to be more pronounced, building up and tailing off more rapidly compared to the bedrock system (Hydrometrics, Inc. 2016f).

Water levels indicate confined or leaky confined conditions in the bedrock aquifers and unconfined conditions in the shallow alluvial system. Low permeability shale layers appear to produce confined or semi-confined conditions in the Lower Newland Shale group (Hydrometrics, Inc. 2016f).

Figure 3.4-8 shows the results of simple Darcy's Law calculations estimating groundwater flow rates through shallow bedrock units within the footprint of the upper orebody, and through the downgradient alluvial system towards Sheep Creek. Within this area, groundwater flow through the USZ is estimated to be 0.4 gpm, and flow in the adjacent shallow bedrock (Ynl A) is estimated to be 90 gpm. Estimated flow through the Quaternary Alluvial Deposits (Qal) is 200 gpm. Due to upward hydraulic gradients, it is assumed that all flow in shallow bedrock (including the USZ) eventually discharges to the alluvium. The calculations estimate that flow through the shallow bedrock accounts for about 45 percent of the alluvial groundwater flow, but flow through the USZ is only 0.2 percent of the alluvial flow. Deeper bedrock (Ynl B), including the lower ore body (LCZ), is interpreted to have significantly lower hydraulic conductivity compared to shallower units. The flow through deeper bedrock is very small and estimated to account for less than 0.2 percent of the alluvial groundwater flow. Groundwater flow through the lower ore body (LCZ) is essentially negligible when compared to the alluvial flow.

Groundwater in the mine-area alluvium eventually discharges to Sheep Creek surface water and adds to the stream base flow (the typical annual minimum flow derived exclusively from groundwater). As shown on **Figure 3.4-8**, the Sheep Creek base flow in the mine area is 6,700 gpm (Hydrometrics, Inc. 2016f), so groundwater flow in the mine-area alluvium is about 3 percent of the base flow that accumulates in the stream channel. The rest of the base flow originates from areas in the watershed that are upstream of the mine area. The groundwater flow through shallow bedrock contributes less than half (45 percent) of the alluvial groundwater component of base flow, and the flow through the ore bodies (USZ and LCZ) is negligible when compared to the Sheep Creek base flow (about 0.2 percent of the alluvial groundwater component of base flow in the Sheep Creek).

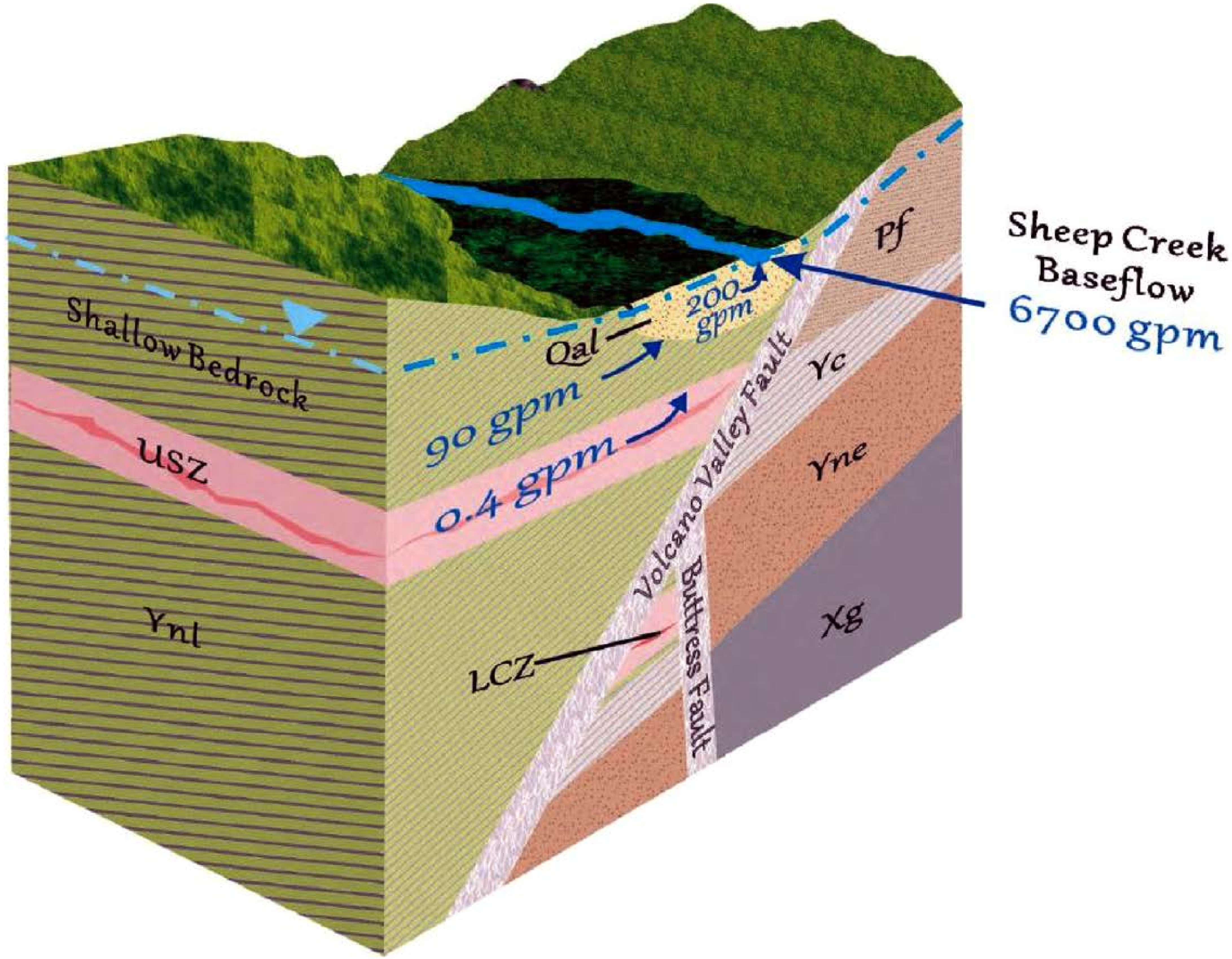


Figure 3.4-8
Black Butte Copper Project
Block Groundwater Flow Diagram
Meagher County, Montana

This information is for environmental review purposes only.

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DRAWN BY: JPB

Source: Hydrometrics, Inc. 2016f

3.4.2.5. Groundwater – Surface Water Interactions

Groundwater within the Sheep Creek alluvium is in direct hydraulic communication with the Sheep Creek stream channel. Where alluvium is not present, the stream is in direct or indirect hydraulic communication with bedrock. Except for peak stream levels during May and June, the Sheep Creek water level is typically lower than groundwater levels in the adjacent alluvium and bedrock, and thus acts as a sink for groundwater discharge. Most of the time, the alluvial sands and gravels receive groundwater from adjacent and underlying bedrock systems, and also from alluvial systems in tributary drainages (Hydrometrics, Inc. 2016f). Due to these processes, Sheep Creek is generally a gaining stream within the watershed, with significant base flow supported by groundwater discharge. Except for its uppermost reaches, Sheep Creek is perennial throughout the Conceptual Model Domain.

The upper reaches of some of the tributary drainages have small springs that are likely fed by perched groundwater systems. This water commonly re-infiltrates the ground within the alluvium-filled stream valleys, and re-emerges as groundwater discharge to streams. Many of the tributary streams are ephemeral in their upper reaches and perennial in their lower reaches before flowing into Sheep Creek.

Groundwater discharging to Sheep Creek at the mine site constitutes only 3 percent of the Creek's base flow and deeper bedrock (subject to mining) contributes only about 0.1 percent of that water—see discussion in Section 3.4.2.4 above (Hydrometrics, Inc. 2016f).

3.4.2.6. Groundwater Quality

Groundwater chemistry data for the LSA is compiled in Hydrometrics (2017d) for water samples collected from 2011 through 2015. DEQ's third-party contractor performed a review of more recent data collected during 2016 and 2017. The review for this EIS of newer water chemistry data showed no substantial differences with the earlier data compiled by Hydrometrics except at one well (PW-7). Monitoring wells are grouped according to the primary HSUs:

- Alluvial/Overburden wells (Qal)
- Shallow bedrock wells (Ynl A)
- Upper sulfide ore zone wells (USZ/UCZ)
- Lower copper zone (LCZ)

Table 3.4-3 provides a summary of groundwater quality in each group of wells, while **Table 3.4-3a to Table 3.4-3d** present more detailed information about chemistry for wells representative of each of those groups.

Alluvial/Overburden Wells

Groundwater in the shallow alluvial and unconsolidated overburden wells (MW-1A, MW-2A and MW 6A) is a calcium/magnesium bicarbonate type with near neutral pH of 6.24 to 7.66 standard units (s.u.), moderately low total dissolved solids of 176 to 302 mg/L, and low to non-detected concentrations of dissolved metals (Hydrometrics, Inc. 2017c).

Samples from MW-1A exhibited variable water quality with a small number of samples having concentrations of arsenic, barium, lead, and thallium above Montana human health standards (hhs) (DEQ 2017), and a small number of samples exceeding the secondary (non-health) standards for iron and manganese. MW-1A is screened in fine-grained sediments and has exhibited high turbidity in many water samples. The results from monitoring events showing metals at higher concentrations could reflect the breakthrough of particulates through the sampling filters due to high turbidity (Hydrometrics, Inc. 2017c).

Shallow Bedrock Wells

Wells completed in shallow bedrock above the USZ include MW-1B, MW-2B, MW-4B, MW-6A, MW-6B, MW-7, MW-8, MW-9, MW-10, MW-11, MW-12, MW-13, MW-14, MW-15, SC15-184, SC15-185, SC15-194, SC15-195, SC15-198, and test wells PW-1, PW-2, PW-3, PW-8, PW-9, and PW-10 (see **Figure 3.4-1**). Groundwater samples from these wells tend to have chemistry similar to alluvial groundwater. The shallow bedrock groundwater is a calcium/magnesium bicarbonate type with near neutral pH of 6.02 to 8.27 s.u. and moderately low total dissolved solids of 54 to 548 mg/L. Dissolved trace constituents that are present at detectable concentrations in the shallow bedrock wells include arsenic, barium, iron, manganese, strontium, thallium, and uranium. **Table 4.3-2** shows exceedances of groundwater quality standards in some wells for antimony, arsenic, iron, lead, manganese, strontium, and thallium All other trace constituents in the shallow aquifer met applicable regulatory standards.

MW-1B is a shallow bedrock well with an anomalous water chemistry. It has a calcium/magnesium sulfate water type, pH of 6.02 to 6.51 s.u., and exceeds the secondary drinking water standard for manganese. MW-1B water samples have arsenic in the reduced (III) form, which might be expected in groundwater that interacts with sulfide mineralization under reducing conditions. Concentrations of thallium at MW-1B (0.0145 mg/L) also exceed the Montana human health groundwater standard (0.002 mg/L). Water quality at MW-1B is similar to MW-3 and test well PW-4, both of which are completed in the sulfide ore zone (Hydrometrics, Inc. 2017c). Although completed in shallow bedrock, MW-1B has water that is chemically more similar to that of the USZ.

Upper Sulfide Ore Zone Wells

Wells completed in sulfide ore zone include MW-3, PW-4, and PW-9. Groundwater around those wells is a calcium/magnesium sulfate type with near neutral pH (6.11 to 7.33 s.u.) and somewhat higher total dissolved solids (380 to 607 mg/L). These wells generally have higher concentrations of total dissolved solids and sulfate compared to the shallow bedrock and alluvial wells.

Dissolved trace constituents that were present at detectable concentrations include antimony, arsenic, barium, iron, lead, manganese, mercury, molybdenum, nickel, strontium, thallium, uranium, and zinc. All of the ore zone wells exceed the secondary drinking water standard for iron, and PW-4 exceeds the secondary drinking water standard for manganese (Hydrometrics, Inc. 2017c). Thallium is detected in MW-3 and PW-4, but the concentrations do not exceed the Montana human health standard of 0.002 mg/L (DEQ 2017). Strontium concentrations at MW-3, PW-4, and PW-9 are elevated (8.08 to 16.2 mg/L), exceeding the Montana human health standard of 4 mg/L (DEQ 2017). Arsenic concentrations at the same wells range from 0.054 mg/L to 0.09 mg/L, also exceeding the Montana human health standard of 0.010 mg/L. Arsenic speciation in samples from MW-3 indicated that the most of arsenic is present in the reduced (III) form (Hydrometrics, Inc. 2017c).

Lower Copper Zone

The analytical results from PW-7, the only well completed in the LCZ, indicate a sodium/potassium bicarbonate type water with relatively high pH (8.07 to 11.58 s.u.) and total dissolved solids (317 to 359 mg/L). Compared to other wells at the mine site, PW-7 has higher concentrations of chloride (5.9 to 52 mg/L) and sulfate 12 to 45 mg/L). Detected trace constituents include aluminum, antimony, arsenic, barium, molybdenum, selenium, strontium, and zinc. Dissolved aluminum concentrations (0.187 to 1.03 mg/L) were much higher than observed at other wells on the site. Antimony (0.0077 mg/L) is the only trace constituent that exceeds the Montana human health standard of 0.006 mg/L (DEQ 2017). Iron and manganese exceeded the secondary drinking water standards in samples collected during the June 2017 sampling event.

3.4.2.7. Spring Flow Rates and Water Quality

Springs are expressions of groundwater discharging to surficial environments and are discussed in this Section, Groundwater Hydrology. Locations of springs present around the proposed mine site are presented on **Figure 3.5-3** of Section 3.5, Surface Water Hydrology.

Flow rates observed at the springs ranged from less than 1 gpm to over 100 gpm (Hydrometrics, Inc. 2017c). Detailed spring flow rates are presented in **Table 3.5-3** of Section 3.5, Surface Water Hydrology. In total, 237 water samples were collected at spring sites: SP-1, SP-2, SP-3, SP-4, SP-5, SP6, SP-7, DS-1, DS-2, DS-3, and DS-4, which surround the proposed mine site. These samples were collected during 41 sampling events conducted from May 2011 to December 2017. The springs generally exhibited slightly acidic to slightly alkaline pH (5.46 to 8.87 s.u.) and moderate to high alkalinities (17 to 240 milligram per liter [mg/L]). Background nitrate concentrations were relatively low (<0.1 to 0.68 mg/L) at all the spring sites. Metals concentrations were below water quality standards with the following exceptions:

- Aluminum was measured in 31 out of 237 collected samples at concentrations exceeding the Aquatic Life Chronic Standard of 0.087 mg/L (DEQ 2017) at the following sampling locations: DS-3, DS-4, and SP-3; and
- Iron was measured in 23 out of 237 collected samples at concentrations exceeding the Aquatic Life Chronic Standard of 1 mg/L at the following sampling locations: DS-3, DS-4, and SP-3 (the same locations as aluminum exceedances).

Table 3.4-3
Summary of Existing Groundwater Quality

Grouping	Geology	General Water Type	Wells	pH	Total Dissolved Solids	Exceedances	Comments
Alluvium / Overburden	Qal	Calcium/ magnesium bicarbonate	MW-1A, MW-2A, MW-4A	6.24 to 7.66	176 to 302 mg/L	• Arsenic, barium, iron, lead, manganese, and thallium above hhs in MW-1A. • Thallium above hhs in MW-2A.	• High turbidity in MW-1A may be responsible for elevated metals concentrations in this well. • Sulfate concentrations are relatively low (from 8 to 51 mg/L).
Shallow Bedrock	Ynl A Ynl B above USZ	Calcium/ magnesium bicarbonate	MW-1B, MW-2B, MW-4B, MW-6A, MW-6B, MW-7, MW-8, MW-9, MW-10, MW-11, MW-12, MW-13, MW-14, MW-15, PW-1, PW-2, PW-3, PW-8, PW-9 PW-10, SC15-184, SC15-185, SC15-194, SC15-195, SC15-198	6.02 to 8.27	54 to 548 mg/L	• Antimony above hhs in MW-08. • Arsenic above hhs in MW-1B, MW-2B, MW-9, PW-8, PW-9. • Iron above secondary standard in MW-1B, MW-2B, MW-9, MW-10, MW-11, PW-1, PW-2, PW-3, PW-9. • Lead above hhs in PW-8. • Manganese above secondary standard in MW-1B, MW-6B, MW-7, MW-8, MW-9, MW-10, MW-11, PW-1, PW-3, PW-8, PW-10, SC15-185. • Strontium above hhs in PW-10. • Thallium above hhs in MW-1B, MW-2B, MW-9, PW-8.	Sulfate concentrations range from 1 to 247 mg/L.

hhs = human health standards (for water quality)

Table 3.4-3a
Groundwater Quality Summary Statistics—MW-4A (Well Completed in Alluvium)

MW-4A (Well Completed in Alluvium)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Field Parameters										
Depth To Water	Feet	34	NA	3.36	6.02	4.90	4.46	4.97	5.51	0.76
pH - Field	s.u.	22	NA	6.24	7.53	7.22	7.17	7.26	7.37	0.28
Field Specific Conductivity	umhos/cm	22	NA	481	551	510	490	512	525	20
Water Temperature	Deg C	22	NA	4.3	8.5	6.4	4.7	6.9	7.6	1.5
Dissolved Oxygen	mg/L	22	NA	0.01	3.57	1.00	0.27	0.84	1.37	0.92
Physical Parameters										
Total Dissolved Solids	mg/L	24	24	270	302	287	278	288	296	9
Total Suspended Solids	mg/L	20	1	<4	23	NA	NA	NA	NA	NA
Major Constituents - Common Ions										
Alkalinity as CaCO3	mg/L	24	24	250	290	269	260	270	280	11
Bicarbonate as HCO3	mg/L	4	4	330	360	342	330	340	357	15
Carbonate as CO3	mg/L	4	0	<1	<1	NA	NA	NA	NA	NA
Chloride	mg/L	24	24	2	4	2.	2	2	3	0.5
Fluoride	mg/L	24	24	0.1	0.2	0.1	0.1	0.1	0.2	0.05
Sulfate	mg/L	24	24	8	21	14	12	14	15	3
Hardness as CaCO3	mg/L	24	24	253	292	277	272	279	282	10
Calcium (DIS)	mg/L	24	24	70	80	76	74	76	78	3
Magnesium (DIS)	mg/L	24	24	19	23	21	20	21	22	0.9
Potassium (DIS)	mg/L	24	24	1	2	1	1	1	2	0.5
Sodium (DIS)	mg/L	24	24	2	3	3	3	3	3	0.3
Nutrients										
Kjeldahl Nitrogen as N	mg/L	1	0	<0.5	<0.5	NA	NA	NA	NA	NA
Nitrate + Nitrite as N	mg/L	24	2	<0.01	0.02	0.01	0.01	0.01	0.01	0.002

MW-4A (Well Completed in Alluvium)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Total Persulfate Nitrogen	mg/L	1	0	<0.04	<0.04	NA	NA	NA	NA	NA
Phosphorus (TOT)	mg/L	2	1	<0.006	0.01	NA	NA	NA	NA	NA
Metals - Trace Constituents										
Aluminum (DIS)	mg/L	24	3	<0.009	0.087	0.015	0.009	0.009	0.009	0.017
Antimony (DIS)	mg/L	24	0	<0.0005	<0.003	NA	NA	NA	NA	NA
Arsenic (DIS)	mg/L	24	0	<0.001	<0.003	NA	NA	NA	NA	NA
Barium (DIS)	mg/L	24	24	0.17	0.203	0.1844	0.181	0.185	0.189	0.007
Beryllium (DIS)	mg/L	24	0	<0.0008	<0.001	NA	NA	NA	NA	NA
Cadmium (DIS)	mg/L	24	0	<0.00003	<0.00008	NA	NA	NA	NA	NA
Chromium (DIS)	mg/L	24	0	<0.001	<0.01	NA	NA	NA	NA	NA
Cobalt (DIS)	mg/L	24	0	<0.01	<0.01	NA	NA	NA	NA	NA
Copper (DIS)	mg/L	24	0	<0.001	<0.002	NA	NA	NA	NA	NA
Iron (DIS)	mg/L	24	18	<0.02	0.16	0.037	0.022	0.03	0.04	0.028
Lead (DIS)	mg/L	24	1	<0.0003	0.0005	NA	NA	NA	NA	NA
Manganese (DIS)	mg/L	24	24	0.057	0.291	0.195	0.171	0.187	0.239	0.054
Mercury (DIS)	mg/L	24	1	<0.000005	0.00001	NA	NA	NA	NA	NA
Molybdenum (DIS)	mg/L	24	0	<0.001	<0.005	NA	NA	NA	NA	NA
Nickel (DIS)	mg/L	24	0	<0.001	<0.01	NA	NA	NA	NA	NA
Selenium (DIS)	mg/L	24	0	<0.0002	<0.001	NA	NA	NA	NA	NA
Silicon (DIS)	mg/L	1	1	13.3	13.3	NA	NA	NA	NA	NA
Silver (DIS)	mg/L	24	0	<0.0002	<0.0005	NA	NA	NA	NA	NA
Strontium (DIS)	mg/L	24	24	0.163	0.2	0.172	0.167	0.170	0.173	0.009
Thallium (DIS)	mg/L	24	1	<0.0002	0.0003	NA	NA	NA	NA	NA
Uranium (DIS)	mg/L	24	5	<0.0004	0.008	0.0064	0.008	0.008	0.008	0.003
Zinc (DIS)	mg/L	24	1	<0.002	0.01	NA	NA	NA	NA	NA

DIS = dissolved concentrations; mg/L = milligram per liter; NA = not analyzed or not applicable; PCTL = percentile
Note: The reporting period for this table is May 2012 to December 2017.

Table 3.4-3b
Groundwater Quality Summary Statistics—MW-4B (Well Completed in Shallow Bedrock)

MW-4B (Well Completed in Shallow Bedrock)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Field Parameters										
Depth To Water	Feet	35	NA	3.02	7.26	4.56	4.09	4.47	5.075	0.924
pH - Field	s.u.	22	NA	6.84	7.76	7.45	7.413	7.50	7.59	0.228
Field Specific Conductivity	umhos/cm	22	NA	419	510	460.41	446	459	473.9	23.22
Water Temperature	Deg C	22	NA	5.3	6.86	6.18	5.9	6.15	6.5	0.351
Dissolved Oxygen	mg/L	22	NA	0.03	3.39	0.55	0.16	0.31	0.51	0.78
Physical Parameters										
Total Dissolved Solids	mg/L	24	24	217	275	250.3	244	249.5	259.8	12.9
Total Suspended Solids	mg/L	19	0	<4	<10	NA	NA	NA	NA	NA
Major Constituents - Common Ions										
Alkalinity as CaCO3	mg/L	24	24	220	270	242.5	230	240	250	14.5
Bicarbonate as HCO3	mg/L	5	5	300	330	316.0	300	320	330	15.2
Carbonate as CO3	mg/L	5	0	<1	<1	NA	NA	NA	NA	NA
Chloride	mg/L	24	24	1	2	1.8	1.7	2	2	0.41
Fluoride	mg/L	24	24	0.1	0.2	0.1	0.1	0.1	0.1	0.02
Sulfate	mg/L	24	24	11	26	14.9	13	14	16.8	3.6
Hardness as CaCO3	mg/L	24	24	167	265	244.9	237	250	257	20.6
Calcium (DIS)	mg/L	24	24	59	70	65.4	62	66	68	3.31
Magnesium (DIS)	mg/L	24	24	19	23	20.8	20	21	22	1.13
Potassium (DIS)	mg/L	24	24	1	2	1.19	1	1	1	0.385
Sodium (DIS)	mg/L	24	24	2	3	2.21	2	2	2	0.415
Nutrients										
Kjeldahl Nitrogen as N	mg/L	1	0	0.5	<0.5	NA	NA	NA	NA	NA
Nitrate + Nitrite as N	mg/L	24	18	<0.01	0.06	0.03	0.01	0.03	0.058	0.02

MW-4B (Well Completed in Shallow Bedrock)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Total Persulfate Nitrogen	mg/L	1	1	0.05	0.05	NA	NA	NA	NA	NA
Phosphorus (TOT)	mg/L	2	1	0.004	0.01	NA	NA	NA	NA	NA
Metals - Trace Constituents										
Aluminum (DIS)	mg/L	24	1	<0.009	0.03	NA	NA	NA	NA	NA
Antimony (DIS)	mg/L	24	0	<0.0005	<0.003	NA	NA	NA	NA	NA
Arsenic (DIS)	mg/L	24	0	<0.001	<0.003	NA	NA	NA	NA	NA
Barium (DIS)	mg/L	24	24	0.117	0.147	0.1278	0.123	0.127	0.131	0.008
Beryllium (DIS)	mg/L	24	0	<0.0008	<0.001	NA	NA	NA	NA	NA
Cadmium (DIS)	mg/L	24	0	<0.00003	<0.00008	NA	NA	NA	NA	NA
Chromium (DIS)	mg/L	24	0	<0.001	<0.01	NA	NA	NA	NA	NA
Cobalt (DIS)	mg/L	24	0	<0.01	<0.01	NA	NA	NA	NA	NA
Copper (DIS)	mg/L	24	0	<0.001	<0.002	NA	NA	NA	NA	NA
Iron (DIS)	mg/L	24	0	<0.02	<0.03	NA	NA	NA	NA	NA
Lead (DIS)	mg/L	24	0	<0.0003	<0.0005	NA	NA	NA	NA	NA
Manganese (DIS)	mg/L	24	3	<0.002	0.006	0.0049	0.005	0.005	0.005	0.001
Mercury (DIS)	mg/L	24	1	<0.000005	0.000012	NA	NA	NA	NA	NA
Molybdenum (DIS)	mg/L	24	0	<0.001	<0.005	NA	NA	NA	NA	NA
Nickel (DIS)	mg/L	24	0	<0.001	<0.01	NA	NA	NA	NA	NA
Selenium (DIS)	mg/L	24	0	<0.0002	<0.02	NA	NA	NA	NA	NA
Silicon (DIS)	mg/L	1	1	10.6	10.6	NA	NA	NA	NA	NA
Silver (DIS)	mg/L	24	0	<0.0002	<0.0005	NA	NA	NA	NA	NA
Strontium (DIS)	mg/L	24	24	0.161	0.2	0.177	0.17	0.173	0.184	0.011
Thallium (DIS)	mg/L	24	4	<0.0002	0.0004	0.0002	0.0002	0.0002	0.0002	0.000
Uranium (DIS)	mg/L	24	5	<0.0007	0.008	0.0065	0.008	0.008	0.008	0.003
Zinc (DIS)	mg/L	24	0	<0.002	<0.01	NA	NA	NA	NA	NA

DIS = dissolved concentrations; hhs = human health standards; mg/L = milligram per liter; NA = not analyzed or not applicable; PCTL = percentile
Note: The reporting period for this table is May 2012 to December 2017.

Table 3.4-3c
Groundwater Quality Summary Statistics—MW-3 (Well Completed in Sulfide Ore Zone)

MW-3 (Well Completed in Sulfide Ore Zone)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Field Parameters										
Depth To Water	Feet	28	NA	26.74	46.13	38.72	32.33	40.63	43.42	5.82
pH - Field	s.u.	24	NA	6.77	7.31	7.07	6.99	7.06	7.16	0.115
Field Specific Conductivity	umhos/cm	24	NA	769	883	835	817	834	857	29.9
Water Temperature	Deg C	24	NA	8.1	10.3	9.29	8.82	9.45	9.80	0.60
Dissolved Oxygen	mg/L	24	NA	0	2.09	0.34	0.11	0.255	0.348	0.464
Physical Parameters										
Total Dissolved Solids	mg/L	28	28	535	607	577	555	580	598	22
Total Suspended Solids	mg/L	21	0	<4	<10	NA	NA	NA	NA	NA
Major Constituents - Common Ions										
Alkalinity as CaCO3	mg/L	28	28	210	230	217.5	210	220	220	5.2
Bicarbonate as HCO3	mg/L	7	7	260	290	271	270	270	270	9
Carbonate as CO3	mg/L	7	0	<1	<1	NA	NA	NA	NA	NA
Chloride	mg/L	28	28	1	2	1.25	1	1	1.2	0.407
Fluoride	mg/L	28	28	0.6	0.8	0.74	0.7	0.7	0.8	0.063
Sulfate	mg/L	28	28	219	280	257.39	242	260	278	20.01
Hardness as CaCO3	mg/L	28	28	375	523	428.89	407	430	440	28.01
Calcium (DIS)	mg/L	28	28	71	124	82.96	77.25	82.5	84	9.71
Magnesium (DIS)	mg/L	28	28	48	58	53.61	51	54	55.75	2.67
Potassium (DIS)	mg/L	28	28	3	4	3.21	3	3	3	0.42
Sodium (DIS)	mg/L	28	28	14	18	15.96	16	16	16	0.881
Nutrients										
Kjeldahl Nitrogen as N	mg/L	2	0	<0.5	<0.5	NA	NA	NA	NA	NA
Nitrate + Nitrite as N	mg/L	28	3	<0.01	0.02	0.01	0.01	0.01	0.01	0.002

MW-3 (Well Completed in Sulfide Ore Zone)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Total Persulfate Nitrogen	mg/L	1	1	0.07	0.07	NA	NA	NA	NA	NA
Phosphorus (TOT)	mg/L	3	3	<0.006	0.01	0.009	NA	0.009	NA	NA
Metals - Trace Constituents										
Aluminum (DIS)	mg/L	28	0	<0.009	<0.03	NA	NA	NA	NA	NA
Antimony (DIS)	mg/L	28	0	<0.0005	<0.003	NA	NA	NA	NA	NA
Arsenic (DIS)	mg/L	28	28	0.062	0.078	0.0675	0.0653	0.068	0.07	0.004
Barium (DIS)	mg/L	28	28	0.01	0.013	0.0110	0.01	0.011	0.011	0.001
Beryllium (DIS)	mg/L	28	0	<0.0008	<0.001	NA	NA	NA	NA	NA
Cadmium (DIS)	mg/L	28	0	<0.00003	<0.00008	NA	NA	NA	NA	NA
Chromium (DIS)	mg/L	28	0	<0.001	<0.01	NA	NA	NA	NA	NA
Cobalt (DIS)	mg/L	28	0	<0.01	<0.01	NA	NA	NA	NA	NA
Copper (DIS)	mg/L	28	0	<0.001	<0.002	NA	NA	NA	NA	NA
Iron (DIS)	mg/L	28	28	1	1.23	1.114	1.033	1.125	1.2	0.082
Lead (DIS)	mg/L	28	0	<0.0003	<0.0005	NA	NA	NA	NA	NA
Manganese (DIS)	mg/L	28	28	0.018	0.035	0.024	0.02	0.023	0.026	0.005
Mercury (DIS)	mg/L	28	1	<0.000005	0.00001	NA	NA	NA	NA	NA
Molybdenum (DIS)	mg/L	28	1	<0.001	0.005	NA	NA	NA	NA	NA
Nickel (DIS)	mg/L	28	6	<0.001	0.01	0.002	0.001	0.001	0.001	0.003
Selenium (DIS)	mg/L	28	0	<0.0002	<0.001	NA	NA	NA	NA	NA
Silicon (DIS)	mg/L	1	1	8.3	8.3	NA	NA	NA	NA	NA
Silver (DIS)	mg/L	28	0	<0.0002	<0.0005	NA	NA	NA	NA	NA
Strontium (DIS)	mg/L	28	28	13	16.2	14.3	13.7	14.2	15	0.800
Thallium (DIS)	mg/L	28	28	0.0003	0.0006	0.0004	0.0004	0.0004	0.0004	0.000
Uranium (DIS)	mg/L	28	7	<0.001	0.008	0.006	0.003	0.008	0.008	0.003
Zinc (DIS)	mg/L	28	1	<0.002	0.01	NA	NA	NA	NA	NA

DIS = dissolved concentrations; mg/L = milligram per liter; NA = not analyzed or not applicable; PCTL = percentile
Note: The reporting period for this table is November 2011 to November 2017.

Table 3.4-3d
Groundwater Quality Summary Statistics—PW-7 (Well Completed in Lower Copper Zone)

PW-7 (Well Completed in Lower Copper Zone)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Field Parameters										
Depth To Water	Feet	1	NA	51.93	51.93	NA	NA	NA	NA	NA
pH - Field	s.u.	5	NA	8.7	11.58	9.97	9	9.5	11.175	1.17
Field Specific Conductivity	umhos/cm	5	NA	525	842	622.2	537.5	557	739.5	129.8
Water Temperature	Deg C	5	NA	5.3	13.36	10.63	7.4	12	13.18	3.34
Dissolved Oxygen	mg/L	4	NA	0.08	0.39	0.19	0.085	0.15	0.343	0.142
Physical Parameters										
Total Dissolved Solids	mg/L	5	5	317	359	326.8	317.5	319	340	18.1
Total Suspended Solids	mg/L	5	1	<10	19	NA	NA	NA	NA	NA
Major Constituents - Common Ions										
Alkalinity as CaCO3	mg/L	5	5	170	290	244	175	290	290	63
Bicarbonate as HCO3	mg/L	0	NA	<NA	NA	NA	NA	NA	NA	NA
Carbonate as CO3	mg/L	0	NA	<NA	NA	NA	NA	NA	NA	NA
Chloride	mg/L	5	5	5.9	52	20.4	6.0	6.1	42	20.9
Fluoride	mg/L	5	5	1.4	1.6	1.5	1.4	1.5	1.6	0.071
Sulfate	mg/L	5	5	12	45	20.4	12	12	33	14.3
Hardness as CaCO3	mg/L	5	4	<7	91	59.2	15.5	86	89.5	40.4
Calcium (DIS)	mg/L	5	5	1	10	7.2	4.5	8	9.5	3.6
Magnesium (DIS)	mg/L	5	3	<1	16	10.0	1	16	16	8.2
Potassium (DIS)	mg/L	5	5	8	25	14.0	8	9	22.5	8.0
Sodium (DIS)	mg/L	5	5	93	113	99.4	94	95	107	8.2
Nutrients										
Kjeldahl Nitrogen as N	mg/L	0	NA	<NA	NA	NA	NA	NA	NA	NA
Nitrate + Nitrite as N	mg/L	5	0	<0.01	<0.01	NA	NA	NA	NA	NA

PW-7 (Well Completed in Lower Copper Zone)										
Parameters	**Units**	**No. of Measurements**	**No. of Detects**	**Min.**	**Max.**	**Mean**	**25% PCLT**	**50% PCLT**	**75% PCLT**	**SD.**
Total Persulfate Nitrogen	mg/L	0	NA	<NA	NA	NA	NA	NA	NA	NA
Phosphorus (TOT)	mg/L	0	NA	<NA	NA	NA	NA	NA	NA	NA
Metals - Trace Constituents										
Aluminum (DIS)	mg/L	5	2	<0.009	1.03	0.25	0.01	0.01	0.61	0.44
Antimony (DIS)	mg/L	5	2	<0.0005	0.0077	0.0026	0.00	0.0005	0.01	0.0032
Arsenic (DIS)	mg/L	5	3	<0.001	0.004	0.002	0.001	0.001	0.003	0.001
Barium (DIS)	mg/L	5	4	<0.003	0.219	0.089	0.006	0.075	0.18	0.091
Beryllium (DIS)	mg/L	5	0	<0.0008	<0.0008	NA	NA	NA	NA	NA
Cadmium (DIS)	mg/L	5	0	<0.00003	<0.00003	NA	NA	NA	NA	NA
Chromium (DIS)	mg/L	5	0	<0.005	<0.01	NA	NA	NA	NA	NA
Cobalt (DIS)	mg/L	5	0	<0.005	<0.01	NA	NA	NA	NA	NA
Copper (DIS)	mg/L	5	0	<0.002	<0.002	NA	NA	NA	NA	NA
Iron (DIS)	mg/L	5	4	<0.02	1.01	0.40	0.03	0.30	0.83	0.43
Lead (DIS)	mg/L	5	0	<0.0003	<0.0003	NA	NA	NA	NA	NA
Manganese (DIS)	mg/L	5	3	<0.001	0.097	0.052	0.003	0.074	0.09	0.045
Mercury (DIS)	mg/L	5	0	<0.000005	<0.000005	NA	NA	NA	NA	NA
Molybdenum (DIS)	mg/L	5	5	0.003	0.033	0.01	0.00	0.01	0.03	0.01
Nickel (DIS)	mg/L	5	0	<0.001	<0.001	NA	NA	NA	NA	NA
Selenium (DIS)	mg/L	5	2	<0.0002	0.0006	0.0003	0.0002	0.0002	0.0004	0.0002
Silicon (DIS)	mg/L	0	0	0.002	<0.033	NA	NA	NA	NA	NA
Silver (DIS)	mg/L	5	0	<0.0002	<0.0002	NA	NA	NA	NA	NA
Strontium (DIS)	mg/L	5	5	0.0119	0.342	0.175	0.0153	0.208	0.319	0.154
Thallium (DIS)	mg/L	5	0	<0.0002	<0.0002	NA	NA	NA	NA	NA
Uranium (DIS)	mg/L	5	0	<0.0002	<0.0002	NA	NA	NA	NA	NA
Zinc (DIS)	mg/L	5	5	0.0119	0.342	0.175	0.0153	0.208	0.319	0.154

DIS = dissolved concentrations; mg/L = milligram per liter; NA = not analyzed or not applicable; PCTL = percentile
Note: The reporting period for this table is August 2014 to June 2017.

3.4.2.8. Water Balance for the Conceptual Model Domain Area

Groundwater Recharge

Infiltration of precipitation and snow melt are the primary sources of recharge to the groundwater system. Hydrologists typically assume aerially distributed recharge rates of 10 to 15 percent of mean annual precipitation in numerical groundwater models of inter-montane basins in western Montana. Hydrometrics provides a more thorough discussion of groundwater recharge over the Conceptual Model Domain (Hydrometrics, Inc. 2016f). Based on measured base flows in Sheep Creek at gaging stations USGS-SC1 and SW-1, average recharge used in the regional numerical groundwater model is about 2.59 inches per year, equivalent to 10 percent of mean annual rainfall (see **Table 3.4-4**).

Table 3.4-4
Observed Base Flow and Calculated Groundwater Recharge

Sheep Creek Gaging Stations	**USGS-SC1**	**SW-1**
Watershed Area (acres)	27,676	50,162
Watershed Area (m^2)	1.12E+08	2.03E+08
Average Annual Precipitation (in/yr) [a]	28.3	26.4
Average Annual Precipitation (m/yr) [a]	0.72	0.671
Volume (ac-ft/yr)	6.53E+04	1.10E+05
Volume (m^3/yr)	8.06E+07	1.36E+08
Base Flow observed (cfs)	9.1	15
Base Flow observed (m^3/day)	22,300	36,700
Recharge as percent of precipitation (%)	10.1%	9.8%

Source: Adapted from Tintina 2017 (Table 4-3)

% = percent; ac-ft/yr = acre-foot per year; cfs = cubic foot per second; in/yr = inch per year; m/yr = meter per year; m2 = square meter; m3/yr = cubic meter per year
Note:
[a] These average values were calculated from a 30-year average PRISM model. PRISM Climate Data (http://prism.oregonstate.edu/) provides estimates of the spatial distribution of precipitation. The estimates are obtained with the use of a PRISM (Parameter-elevation Relationships on Independent Slopes Model, Daly et al. 2008).

Widespread irrigation can be a major source of recharge to shallow groundwater systems. There is some irrigated acreage adjacent to Sheep Creek in the middle reach of the watershed; however, it represents a very small fraction of the watershed area (less than 2 percent). Hydrographs do not indicate that return flows contribute significantly to stream base flow in the late winter/early spring. Given the limited acreage that is under irrigation and the timing of irrigation returns, irrigation is unlikely to be a significant factor in simulating regional groundwater flow conditions during base flow periods (Hydrometrics, Inc. 2016f). Irrigation in areas close to the Project would likely cease, once the mining operations start.

Groundwater Discharge

Groundwater flow within the shallow and deeper groundwater systems is topographically controlled, with groundwater divides coinciding with surface water drainage divides and discharge occurring along perennial streams. Base flow at a stream location is considered to represent the groundwater discharge rate exiting from the associated upstream watershed. Where not directly measured, it is assumed that base flow at a stream location is equal to 10 percent of mean annual rainfall multiplied by the associated upstream watershed area. For selected stream locations, calculated base flow (groundwater discharge) values are provided in **Table 3.4-5**.

Table 3.4-5
Groundwater Discharge (Base Flow) Estimates for Selected Sheep Creek Watershed Areas

Watershed	Watershed Area (acres)	Estimated Average Annual Precipitation within the Watershed [a] (ft/yr)	Measured Base Flow (cfs)	Estimated Base Flow [b] (cfs)
Sheep Creek at USGS-SC1	27,700	2.36	9.1	9.0
Sheep Creek at SW-1	50,200	2.2	15	15.3
Sheep Creek at confluence of Black Butte Creek	112,000	2.1		32.3
Moose Creek	23,200	2.41		7.7
Black Butte Creek	14,700	1.57		3.2
Calf Creek	6,470	2.3		2.1
Adams Creek	4,730	2.55		1.7

Source: Estimated values adapted from Tintina 2017 (Table 4-4)

ac-ft/yr = acre-foot per year; cfs = cubic foot per second; ft/yr = foot per year
Notes:
[a] Elevation dependent
[b] Calculated as 10 percent of annual precipitation multiplied by the watershed area and converted to cfs.

3.4.3. Environmental Consequences

This section discusses potential impacts of the Project on groundwater resources of the area.

3.4.3.1. No Action Alternative

The No Action Alternative would result in no change to groundwater levels, groundwater flow paths, and stream base flows when compared to baseline conditions. As such, the No Action Alternative would not have any impacts on groundwater resources and would not alter baseline conditions discussed in Section 3.4.2, Affected Environment.

3.4.3.2. Proposed Action

The Project MOP Application (Tintina 2017) describes in detail the Project-planned operations that have the potential to affect groundwater quantity and quality. These Project operations include:

- Dewatering of the underground workings (access decline and tunnels, ventilation shafts, and stopes);
- Groundwater pumping for mine water supply, potable water supply, and wet well for water diversion (note: three separate water supply systems consisting of a process water supply, fresh water supply, and potable water supply would be used to meet the water supply needs of the Project; make-up water would be provided directly by dewatering of the mine, or from the WTP; fresh water (for the fresh / fire water tank) would be obtained from the WTP, and would be used for other milling purposes; and potable water would be derived from a public water supply);
- Disposal of excess (treated) mine water to the alluvial UIG;
- Ore stockpiles (copper-enriched rock stockpile);
- Tailings disposal facility (CTF);
- Waste rock facilities (WRS);
- Treated Water Storage Pond (TWSP); and
- Non-Contact Water Reservoir (NCWR).

Of these, dewatering of the underground workings would have the greatest impacts on the groundwater system. Construction and operation of other facilities and elements of Project infrastructure, such as the mill facility or roads, are not likely to affect groundwater resources in a measurable way.

The following subsections discuss the potential Project impacts on groundwater resources organized by each of the planned operations.

Dewatering Associated with Underground Mine Operations

Groundwater Inflow Rates

Tintina applied the numerical groundwater model to estimate mine inflow and evaluate its impacts on water resources throughout the life of the mine and during the post-mining period (Hydrometrics, Inc. 2016f). A series of predictive simulations were used to assess different phases in the mine development:

- Phase I (Year 1) – Surface Decline construction to UCZ;
- Phase II (Years 2-4) – Lower Decline construction to LCZ, further construction of access tunnels and ramps, first full year of mining in the UCZ;

- Phase III (Years 5-15) – Mining of the UCZ and LCZ: dewatering to progressively greater depths; and
- Phase IV (Years 16+) – Post-Mining: rinsing of mine workings, installation of plugs, re-fill of underground workings, and mine flooding followed by a long-term groundwater level recovery.

Table 3.4-6 presents the simulation results showing projected groundwater inflows to the underground workings (dewatering rates). Estimated average inflow to the Surface Decline at the end of Phase I is 223 gpm, with over 90 percent coming from Ynl A. The simulated inflows increase during Phase II to approximately 497 gpm in Year 4, at which time approximately 80 percent comes from Ynl A and the USZ/UCZ, which is expected because these HSU's have higher permeabilities compared to deeper units (Hydrometrics, Inc. 2016f). During Phase III, the mine inflows progressively decrease to 421 gpm as the shallower geologic units are depressurized and mined stopes are backfilled with low-permeability cemented tailings. At the end of mining (Year 15), approximately 80 percent of the flow comes from Ynl A and the USZ/UCZ, and 20 percent comes from Ynl B and LCZ. Of the simulated 421 gpm inflow rate at the end of mining, it is estimated that 213 gpm would come from the USZ/UCZ and only 1 gpm would come from the LCZ, reflecting the large hydraulic conductivity contrast between these ore-bearing (mined out) HSUs.

Table 3.4-6
Groundwater Model-Simulated Annual Average Inflow to Mine Workings

Mining Progress	**Phase I: Surface Decline to UCZ**	**Phase II: Lower Decline to LCZ, additional access tunnels and ramps, 1 year of mining in UCZ**			**Phase III: Mining in UCZ and in LCZ to progressively greater depths**										
Project Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mine Structure	**Inflow (gpm)**														
Surface Decline Total	**223**	**159**	**106**	**105**	**108**	**106**	**110**	**110**	**110**	**111**	**113**	**111**	**110**	**113**	**125**
Surface Decline (Ynl A)	203	146	97	96	98	97	101	101	101	102	103	101	101	104	116
Surface Decline (UCZ)	20	12	9	9	9	9	9	9	9	9	9	9	9	9	9
Upper Access and Stopes Total	**0**	**141**	**279**	**292**	**262**	**272**	**249**	**248**	**247**	**244**	**238**	**240**	**239**	**233**	**215**
UCZ Access/Stopes (USZ/UCZ)	0	129	268	282	251	261	238	237	236	233	227	229	228	222	204
UCZ Access (Ynl B)	0	12	12	10	11	11	11	11	11	11	11	11	11	11	11
Lower Decline Total	**0**	**83**	**84**	**85**	**83**	**80**	**79**	**78**	**78**	**77**	**77**	**76**	**75**	**75**	**75**
Lower Decline (Ynl B)	0	83	84	85	83	80	79	78	78	77	77	76	75	75	75
Lower Access and Stopes Total	**0**	**0**	**2**	**15**	**12**	**9**	**8**	**8**	**7**	**7**	**7**	**7**	**7**	**6**	**6**
LCZ Access/Stopes (LCZ)	0	0	0	5	4	3	2	2	2	2	2	2	2	2	1
LCZ Access (Ynl B)	0	0	2	10	7	6	6	6	5	5	5	5	5	5	5
Total Mine Inflow	**223**	**382**	**472**	**497**	**465**	**467**	**447**	**445**	**442**	**439**	**434**	**433**	**431**	**427**	**421**

Source: Hydrometrics, Inc. 2016f (Table 5-1)

Lowering of Groundwater Levels

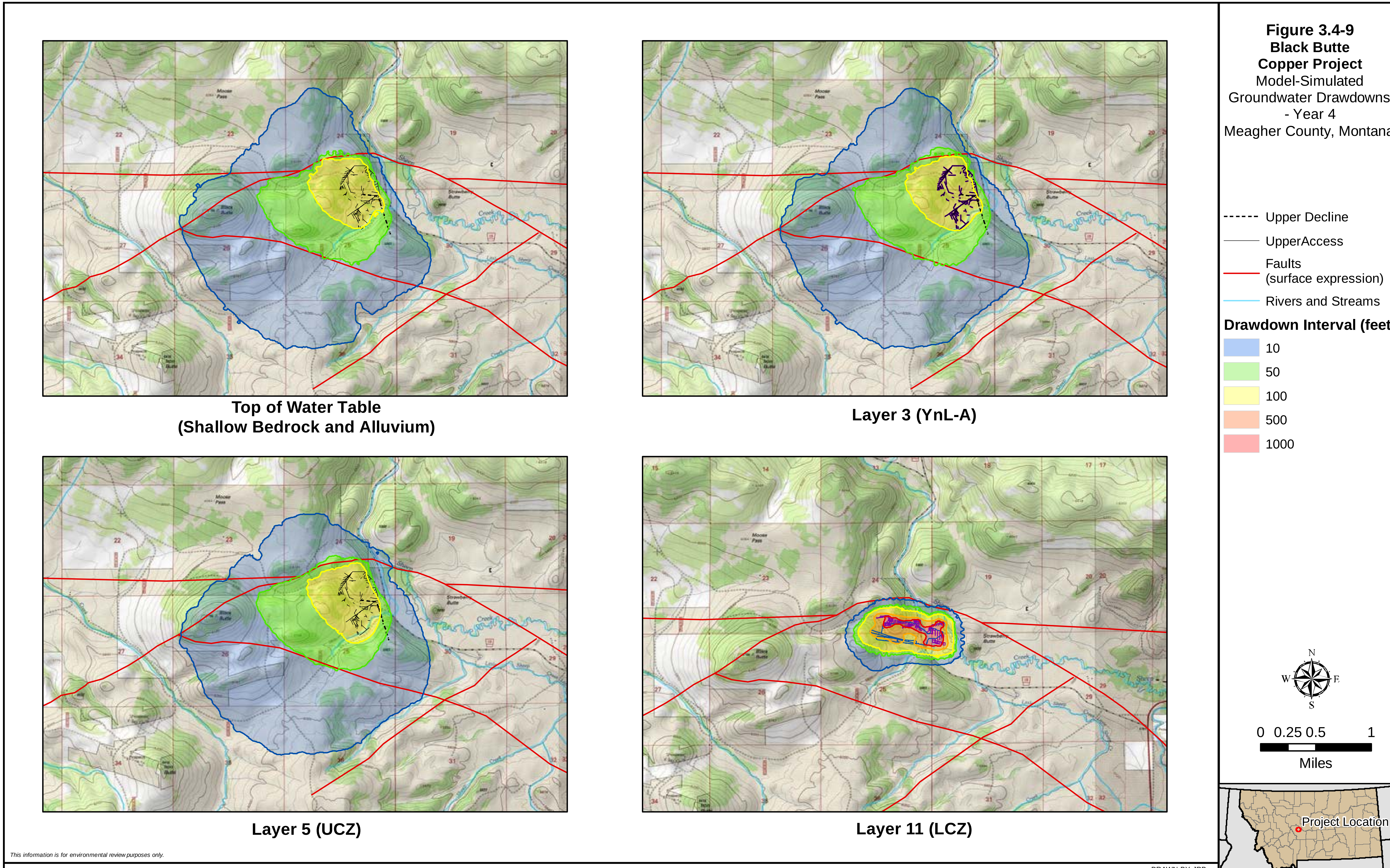
Mine dewatering would result in lowering groundwater levels within the Project area (LSA). **Figures 3.4-9** and **3.4-10** show model-predicted drawdowns in the shallow and deeper HSU's at mine Years 4 and 15, respectively.

For shallow HSUs (Alluvium, Ynl A, and UCZ), simulations predict that the greatest drawdowns occur in Year 4 corresponding to the initial mining stage when the model predicts the highest inflows to the upper mine workings. At Year 15, the drawdowns are comparable, but somewhat less because the dewatering rate decreases due to backfilling of the stopes. Regardless of the time period, the higher-end drawdowns adjacent to the mine workings appear to be on the order of 100 to 200 feet. The maximum water-table drawdown directly over the center of the mine area is predicted to be approximately 290 feet (Hydrometrics, Inc. 2016f). The 10-foot drawdown contour is predicted to extend approximately 8,000 feet southwest of the mine area and does not appear to be greatly affected by the presence of faults. Northeast of the mine area, the 10 feet contour extends a distance of only about 1,000 feet, and is situated within and oriented parallel to the Sheep Creek alluvium. This configuration suggests that perennial Sheep Creek operates as a recharge boundary to the Alluvium, Ynl A, and UCZ, and would provide some recharge to these units during the mining period. However, because of a large contrast between hydraulic conductivity of the alluvium (within which Sheep Creek flows near the proposed mine) and shallow bedrock, loss of water by Sheep Creek caused by the mine-dewatering-formed cone of depression would be limited. Groundwater model simulations show the decrease of groundwater discharge to Sheep Creek would be 157 gpm by the end of the mining period (Hydrometrics, Inc. 2016f); this represents about 37 percent of the rate of pumping from the mine at that time. As such, the model indicates that the remaining 63 percent of water entering the mine workings would be contributed by bedrock formations, not the creek or its alluvium.

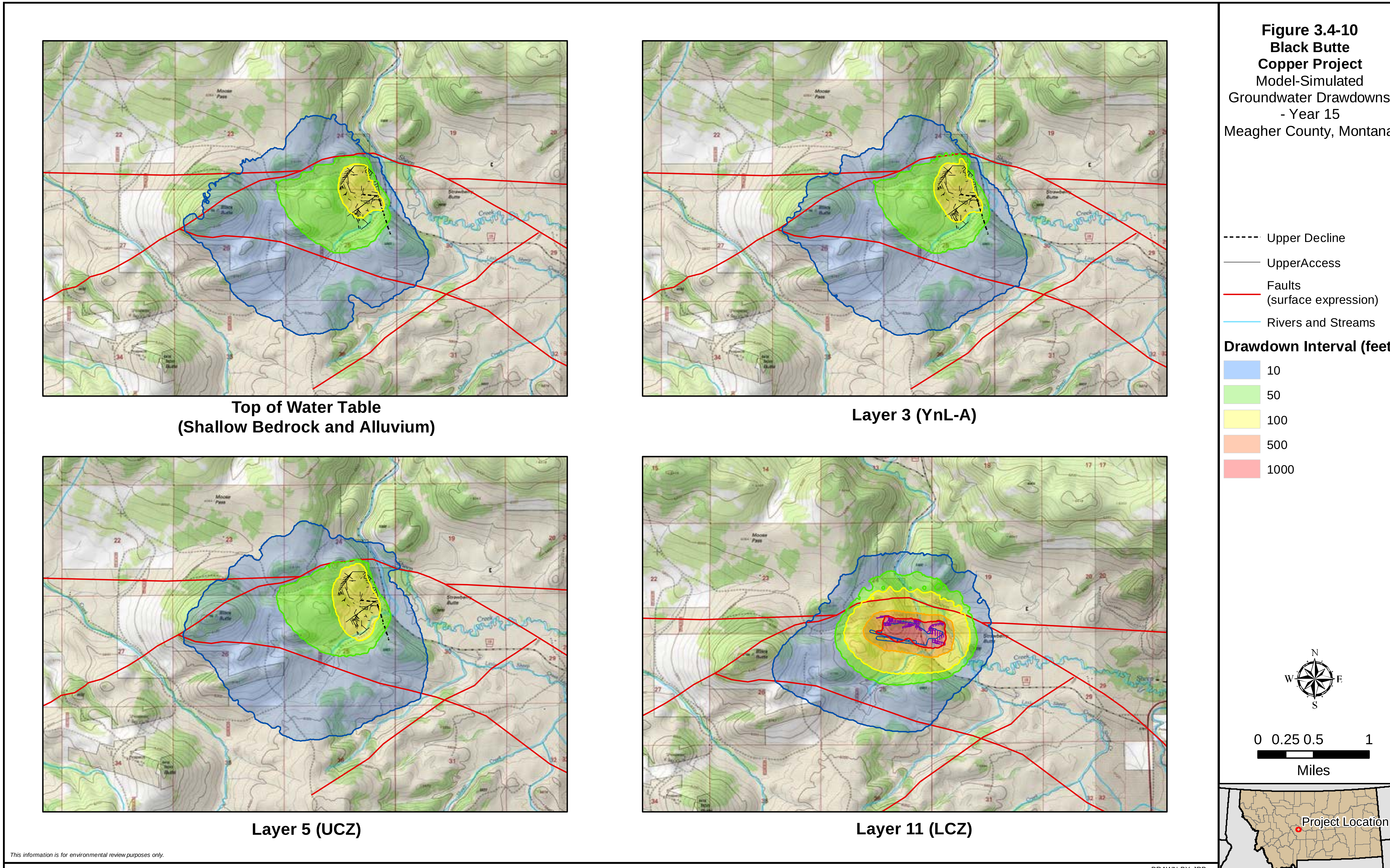
While visually less apparent, **Figures 3.4-9** and **3.4-10** suggest that the extent of the ten-foot contour may be limited by perennial Black Butte Creek to the southwest and an unnamed tributary of Little Sheep Creek to the southeast.

The RSA shown in **Figure 3.4-2** is defined as an area that could experience groundwater drawdown of more than 2 feet due to mine dewatering, as computed by the groundwater model. Two feet of drawdown is within the typical range of seasonal groundwater level fluctuations observed in the monitoring wells of the Project area (see discussion in Section 3.4.1.2 above).

For the deep HSUs (as indicated by LCZ), **Figures 3.4-9** and **3.4-10** show drawdowns on the order of 500 feet at the perimeter of the mine workings. Compared to shallow HSUs, greater drawdown is expected in the deeper units because the LCZ is dewatered to a greater depth below ground surface. At Year 4, the 10-foot drawdown contour is predicted to extend 1,000 to 2,100 feet from the mine workings, which is explained in part by the limited excavation of the LCZ stopes at that time. At Year 15, the 10-foot contour is predicted to expand to 3,200 to 5,600 feet from the workings. Compared to the shallow HSU's, transient lateral expansion of the drawdown cone in the deeper HSU's is expected to be slower due to the lower hydraulic conductivity of the deeper units.



Source: Hydrometrics, Inc. 2016f



Source: Hydrometrics, Inc. 2016f

Spring and Seep Flows

Baseline investigations identified nine seeps and 13 springs in the Project area, and some of the sites are located within the area that could be affected by the mine drawdown cone, including springs developed for stock use (**Figure 3.5-3** of Section 3.5, Surface Water Hydrology). Some springs and seeps located within the mine drawdown cone might experience decreased flow, and some might dry up. Many of the springs and seeps appear to be connected to perched groundwater bodies and, also, may only flow seasonally; these would not likely be directly affected by creation of the deeper groundwater drawdown cone. The Proponent would have to provide replacement water for any springs that are being put to beneficial use and are depleted by dewatering (§ 82-4-355, MCA). Vegetation and wildlife may be affected at the springs or seeps depleted by dewatering. Spring flow would be anticipated to reestablish when shallow groundwater recovers to baseline conditions, within 2 years after the cessation of dewatering. See further discussion in Section 3.5, Surface Water, and Section 3.15, Wildlife.

Base Flow in Nearby Creeks

During mining, the cone of depression associated with the upper HSUs would capture some groundwater that currently reports to perennial streams as base flow. The captured portion of the current base flow would become part of the mine dewatering discharge and this would lead to a reduction in stream base flow compared to baseline conditions. **Table 3.4-7** presents the model-simulated groundwater discharges to surface waters over mine Years 0 to 15.

A discussion of the impacts that dewatering would have on the base flow of nearby streams is provided in Section 3.5.3.1 (see the subsection titled "Dewatering Associated with Underground Mine Operations"). Groundwater model simulations indicate that only Coon Creek could potentially be significantly affected by mine dewatering.

Dewatering of the mine would result in a consumptive use of water by the Project. This use would be offset by water rights acquired under lease agreements with landowners (Tintina 2017). Tintina submitted a Water Right Application Package to the DNRC on September 7, 2018. This package included applications for a new groundwater beneficial use permit for water put to use in the mining and milling process, a new high season flow surface water beneficial use permit and six change applications.

The new high season flow surface water beneficial use permit and six change applications would be used to mitigate potential adverse impacts from the consumptive use of groundwater in the mining and milling process and mitigate potential indirect impacts to wetlands.

Post-Closure Recovery of Groundwater Levels

Figure 3.4-11 shows the model-predicted groundwater level recovery after the mine ceases dewatering operations at the end of mine Year 15 (Hydrometrics, Inc. 2016f). After 1 additional year of rinsing, plugging, and decommissioning the workings, water levels in the Ynl A, USZ/UCZ, and Ynl B would recover very quickly and approach pre-mining conditions within a few years. Due to the low hydraulic conductivity of the LCZ, the groundwater level recovery in this deep HSU (hydraulic conditions that only marginally affect surface waters) would be slower and not approach the pre-mining level until about 100 years after closure.

Table 3.4-7
Model-Simulated Groundwater Discharge to Surface Waters

Mining Progress		**Pre-Mining/Steady State Calibration**	**Surface Decline**	**Declines and Access Ramps**			**Mining**										
Project Year		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Basin	**Observed Current Base Flow (cfs)**	**Simulated Groundwater Discharge to Surface Water (cfs)**															
Sheep Creek Upstream of SW-1	6.2	5.76	5.70	5.44	5.47	5.49	5.46	5.45	5.44	5.43	5.43	5.42	5.42	5.42	5.41	5.41	5.41
Black Butte	2.6 to 3.2	2.40	2.40	2.35	2.31	2.29	2.29	2.29	2.29	2.29	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Moose Creek	7.7	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08
Model Domain	23.2	24.02	23.96	23.66	23.64	23.64	23.61	23.60	23.59	23.59	23.59	23.58	23.58	23.58	23.57	23.57	23.57

Source: Hydrometrics, Inc. 2016f (Table 5-3)

cfs = cubic foot per second

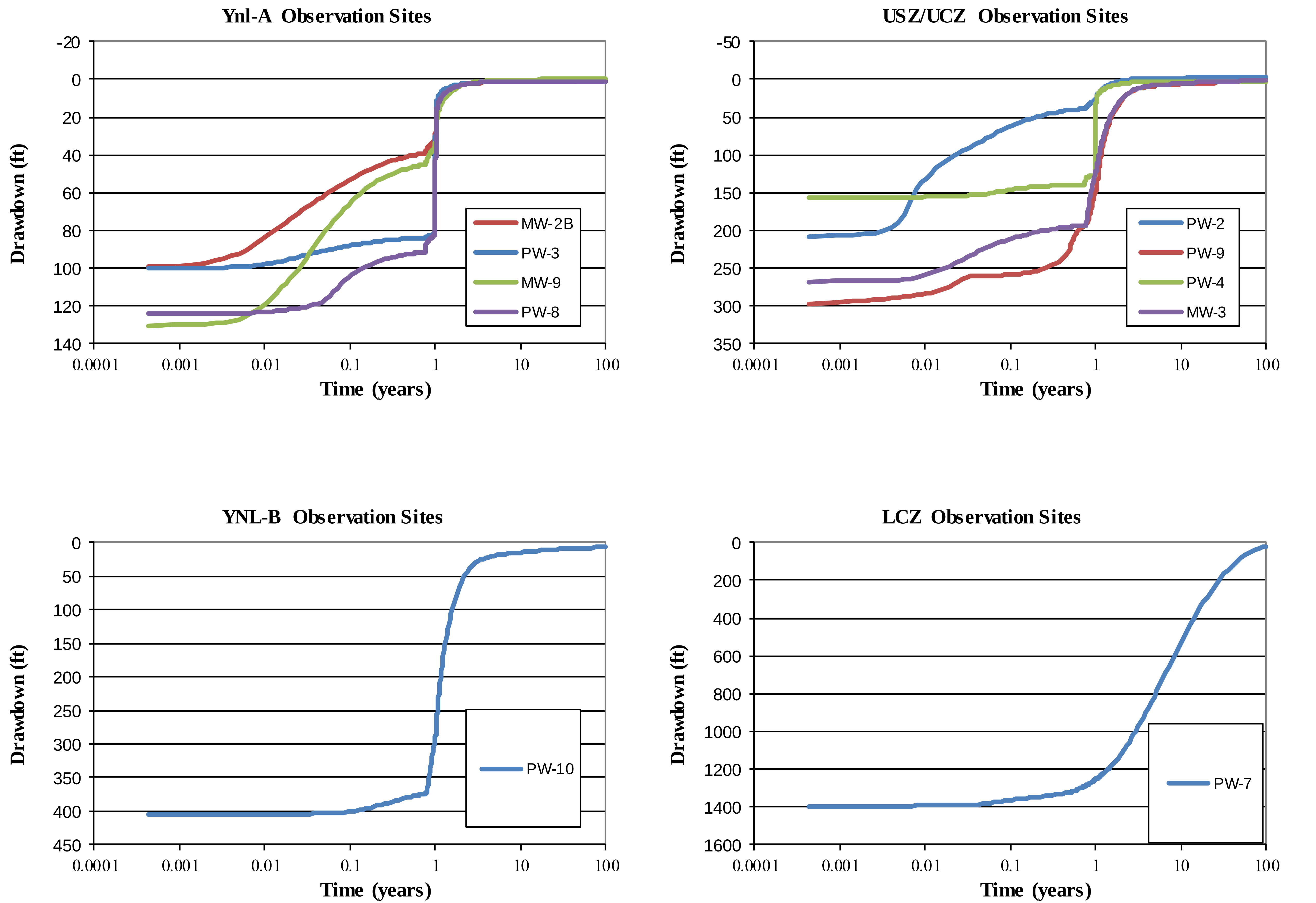


Figure 3.4-11
Black Butte Copper Project
Groundwater Model-Simulated Water Level Recovery – Post-Mining
Meagher County, MT

This information is for environmental review purposes only.

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Source: Hydrometrics, Inc. 2016f

In addition to the numerical modeling analysis, Hydrometrics developed analytical models to evaluate the potential impacts that the open mine workings (declines, access ramps, ventilation raises) could have on groundwater after water-level recovery (Hydrometrics, Inc. 2017a). These steady-state analyses assumed that the water table is fully recovered, which is a condition under which the potential impacts of open mine workings would be the greatest. The results of the analyses indicated the following:

- Possible groundwater mounding associated with the Surface Decline would not result in any surface seepage of groundwater via new springs and seeps (above what normally occurs in the natural system).
- In the absence of tunnel/shaft plugs, upward groundwater flow through open mine workings could cause contact water from the UCZ and/or LCZ to migrate into the Ynl A and ultimately into the Sheep Creek Alluvium. However, the upward flow rate of this contact water would be low: likely less than a total of 1 or 2 gpm for the Surface Decline and four ventilation shafts.

These analyses are judged to be conservative (that is, overestimating the impacts) because they considered fully open mine workings. The analyses did not consider the strategically placed tunnel and shaft plugs that are specified in the Proposed Action. Based on this analysis, the open mine workings are not predicted to have significant impacts on groundwater availability and surface water flow rates.

The analysis did not evaluate the chemical impacts that upward migrating contact water could have on the shallow HSUs. However, considering long groundwater travel time and a range of attenuating processes, such impacts are judged negligible (see discussion provided in subsection “Post-Closure Groundwater Quality” below).

Underground Infiltration Galleries

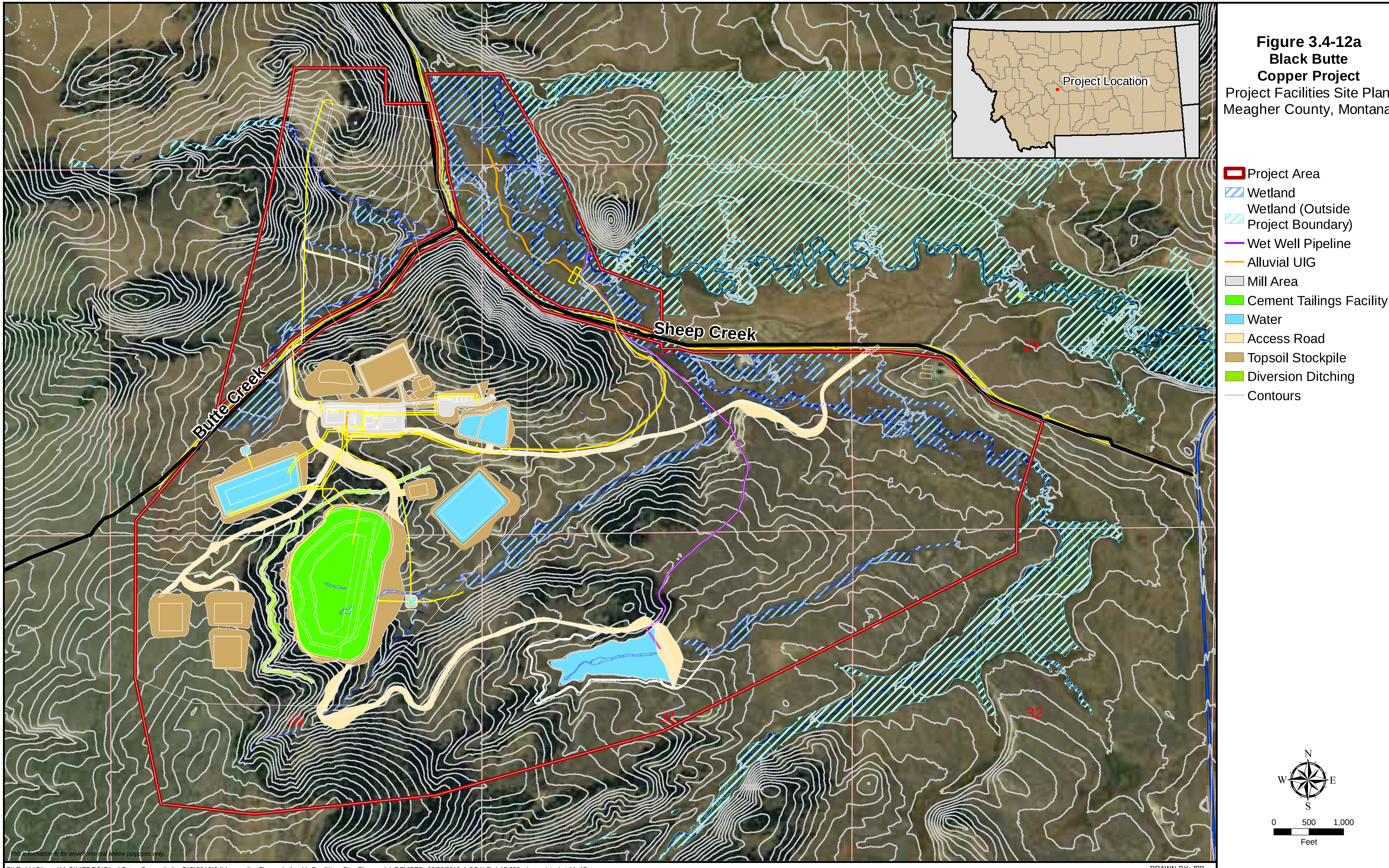
Excess water not used in the milling or mining process would be discharged back to the groundwater system using alluvial UIGs (**Figure 3.4-12a**). The UIGs are designated as the MPDES outfall (Outfall 001). As specified in the MOP Application (Tintina 2017) and in the MPDES permit application (Hydrometrics, Inc. 2018a; Tintina 2018a), all water would be treated to meet applicable discharge standards (except total nitrogen) prior to groundwater recharge. Anticipated average and maximum total flow rate to the UIG is 398 gpm (Hydrometrics, Inc. 2018a, Response to Comment 3, Form 2D, Part III.A). The alluvial UIG is designed for maximum total discharge of 575 gpm (Hydrometrics, Inc. 2018a, Appendix F).

Infiltration testing reported in Hydrometrics (2018a, Appendix E) (**Figure 3.4-12b**) showed that the Sheep Creek alluvial aquifer exhibits moderate spatial variability, but had generally consistent infiltration rates for 7 of the 9 test trenches. The median infiltration rate was approximately 2 feet per day (representing an infiltration capacity of 0.4 gpm per foot of trench. For this infiltration capacity, a minimum 1,450 feet of trenching would be necessary to discharge the design maximum discharge flow rate of 575 gpm through the alluvial UIG system (Hydrometrics, Inc. 2017b).

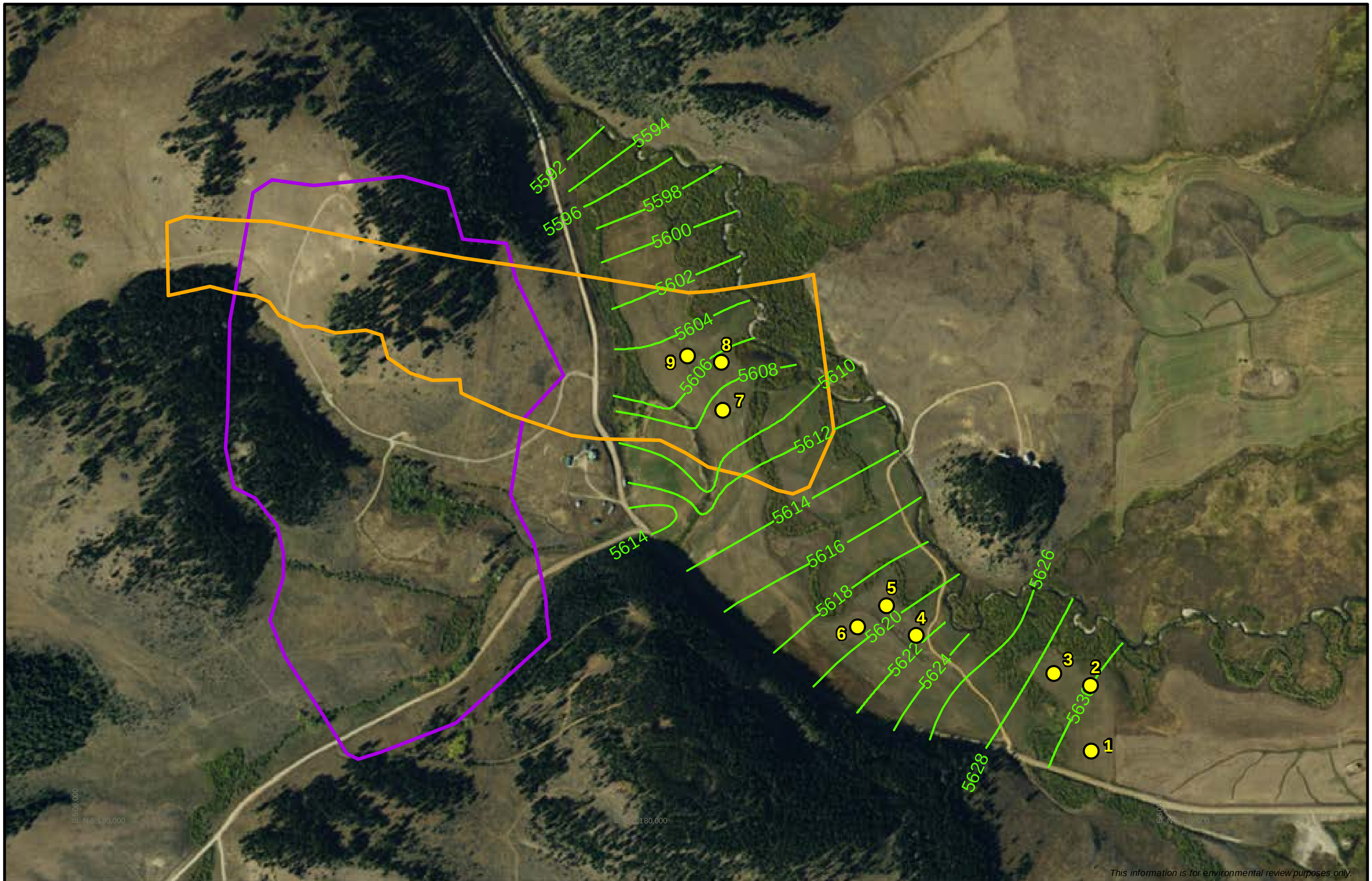
Hydrometrics developed a separate groundwater model for analysis of the proposed alluvial UIG design, which included a series of trenches excavated in the Sheep Creek alluvium (Hydrometrics, Inc. 2017b). The model was calibrated using measured groundwater levels and results of the alluvium infiltration testing program. The analyses simulated the maximum design discharge rate (575 gpm) distributed evenly within the proposed infiltration trenches shown on **Figure 3.4-12c**. The simulation showed there could be up to 3.9 feet of groundwater mounding directly below the trenches, but the mounding would mostly dissipate over short distances to the east towards Sheep Creek and to the west towards Coon Creek. Near the central area of the UIG system, the simulated mound is less than 1 foot high approximately 300 feet southwest of Sheep Creek and 0.5 feet high adjacent to Sheep Creek.

The analyses predict that operating the alluvial UIG would not result in negative impacts on groundwater and surface water quality in the vicinity of Sheep Creek, except total nitrogen. The UIG discharged water could occasionally exceed the seasonal surface water quality nutrient criterion for total nitrogen. The maximum concentration would be 0.57 mg/L, which is higher than the 0.09 mg/L— non-degradation criterion set for Sheep Creek (Hydrometrics, Inc. 2018a, Table 3-2: Receiving Water Quality). This criterion would be in effect every year between July 1 and September 30 to prevent nuisance algal growth in surface waters. For this reason, water released from the WTP during that period would be directed to the TWSP and not to the alluvial UIG. The water accumulated in the TWSP would then be discharged via the alluvial UIG when the criterion is not in effect (see a brief discussion provided in the subsection below, “Surface Facilities”).

UIG recharge would partially compensate for the loss of base flow in Sheep Creek caused by mine dewatering. Without UIG recharge, the groundwater model predicts a 160 gpm decrease in groundwater discharge to Sheep Creek (see the difference between the model-simulated groundwater discharge to Sheep Creek Upstream of SW-1 during the pre-mining period and mining Year 15 in **Table 3.4-7**); however, the average UIG recharge to the Sheep Creek Alluvium via the UIG would be about 398 gpm (increased to 531 gpm from October to June each year, by release of water stored in the TWSP during that period), and most of that water would eventually become streamflow (Hydrometrics, Inc. 2017b). The net increase in Sheep Creek flow downstream of the UIG would be about 240 gpm or less, as some of the UIG-discharged water might be intercepted by the cone of depression from dewatering and migrate downward toward the mine. Such flow compensation from the UIG would be too far away to benefit the base flow in Black Butte Creek, which would also be affected by mine dewatering. However, the model-simulated depletion of base flow in Black Butte Creek is a modest 3 percent to 4 percent of the steady state base flow in the stream (Hydrometrics, Inc. 2016f).



Source: Tintina 2017



Infiltration Trench

Equipotential Surface Contour

Lower Johnny Lee Deposit

Upper Johnny Lee Deposit

0 500 1,000 Feet

N

Figure 3.4-12b

Black Butte Copper Project

Alluvium Infiltration Testing

Meagher County, Montana

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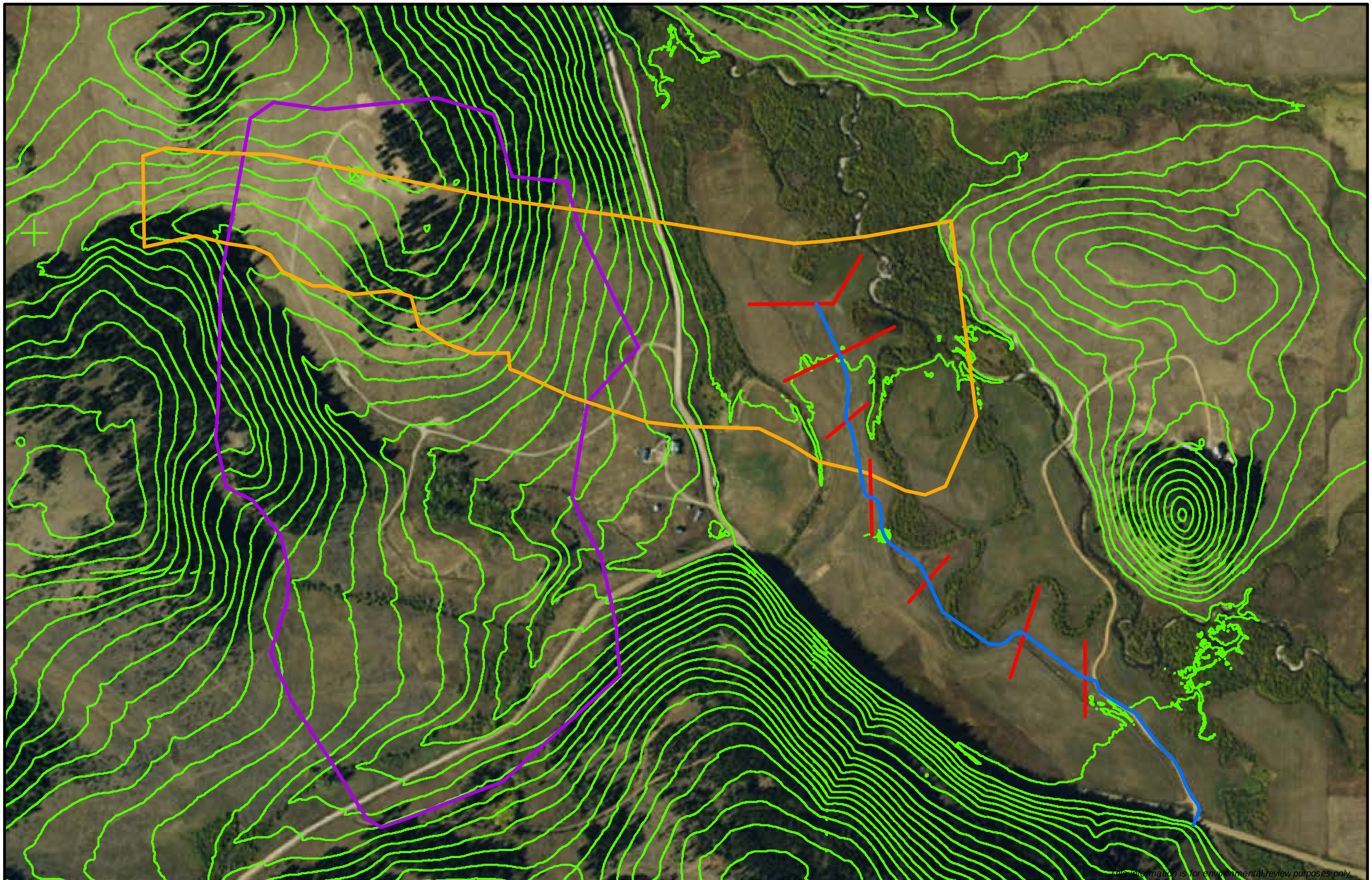
Source: Hydrometrics, Inc. 2017b



Distribution Pipe
Infiltration Trench
Equipotential Surface Contour
Lower Johnny Lee Deposit
Upper Johnny Lee Deposit

N

0 500 1,000 Feet

Figure 3.4-12c
Black Butte Copper Project
Alluvial Underground Infiltration Gallery
Meagher County, Montana

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Source: Hydrometrics, Inc. 2018c

Surface Facilities

The MOP Application (Tintina 2017) describes construction of the following proposed surface facilities for storing water, waste rock, tailings, and various other materials: NCWR, PWP, CWP, CTF, WRS, and TWSP (for storing treated water that would not be released from July to September). All of these facilities have the potential to produce seepage that could migrate downward to groundwater.

Water stored in the NCWR would be allowed to seep through its unlined bottom to groundwater and the downstream catchment. Seepage from the NCWR is expected and is intended to offset a portion of mine site water consumptive use. Analyses indicate an average seepage rate of less than 50 gpm. Because the reservoir would contain non-contact water, it would not have the potential to chemically degrade groundwater. The seepage water would mix with shallow groundwater present in highly weathered shale below the NCWR (Tintina 2017). Saturated conditions would likely be present directly beneath the NCWR.

The PWP would be double-lined, with a leak detection system consisting of a 0.3-inch, high-flow geonet layer sandwiched between two 0.1-inch (100 mil) HDPE liners. Any seepage through the upper liner into the geonet would be directed via gravity to a sump and pump reclaim system at a low point in the PWP basin. This flow (if any) would be pumped back into the PWP. Any seepage below the lower liner would be collected by a foundation collection drain and conveyed by gravity to a lined toe pond, and this water would be pumped back to the PWP. Experience with similar ponds suggest that, if the system is properly constructed, seepage below the facility would be minimal, or non-measurable.

The CWP would be constructed with an HDPE liner placed over a 1 foot (300 mm) thick protective layer of granodioritic sub-grade bedding material. The portion of the CWP storing brine would be double-lined with a leak detection system (as described for the PWP). Seepage from the base of this system is expected to be minimal or non-measureable.

The base of the CTF would have a double liner system with leak detection (as described for the PWP), and this liner system would extend up the upstream embankment face. Above the double liner would be a permeable bedding layer comprised of crushed waste rock. The bedding layer would collect downward seepage through the tailings material and convey this flow laterally to a sump. An important function of the bedding layer is to maintain low head on the liner, thereby minimizing the potential for seepage through the liner. Seepage below the double liner system is expected to be minimal to non-measureable (Geomin Resources, Inc. 2018).

After closure, several construction steps will be executed prior to beginning the placement of the final cover package on the CTF, including: (1) hardening of the final upper layers of cement paste; (2) dewatering by pumping back any water from the geonet/liner sump and the basin drain water reclaim sump to the PWP; (3) ground shaping and/or filling of the final upper surface of the tailings; and (4) installation of protective sub-grade bedding layer below the proposed HDPE cover. The analysis indicates that seepage from the CTF during both operational and post-closure phases would be negligible (Geomin Resources, Inc. 2018).

While performing HELP analysis of the WRS pad (see Section 3.4.1.6), the analyst assumed placement of a bedding material and piping on top of the bottom liner. Seepage reaching the bottom of the waste rock would collect and flow on top of the upper liner to an outlet pipe on the south side of the facility. Flow from the outlet pipe would be sent to the WTP and either disposed via the UIG, or temporarily stored in the TWSP. Based on climate and properties of waste rock and cover materials, the HELP model was used to estimate downward percolation of meteoric water into the WRS. The facility-wide percolation flow rate was estimated to be less than 1 gpm (Hydrometrics, Inc. 2016a).

Hydraulic analyses using the HELP model were also performed for the embankment areas of the CTF, PWP, CWP, mill pad, WRS, and portal pad (Hydrometrics, Inc. 2016d). The estimated annual percolation through the embankments ranged from 1.68 to 2.47 in/yr, or 9 to 13 percent of mean annual precipitation. Considering the footprint areas of these embankments, the total percolation rates would be no more than a few gpm. Most of that flow would be intercepted by drains and re-routed to the WTP.

Operations Groundwater Quality

Predictive geochemical analyses were completed for the mixed water that would be collected in sumps and pumped from the underground mine in Year 6 of operations. Modeling showed that the water would be near neutral, with a pH of about 6.7, abundant alkalinity (183 mg/L), and a moderately elevated (above background conditions) sulfate content (up to 304 mg/L) (Enviromin 2017, Table 4-4). The highest local contributions of acidity, metals, and sulfate would come from the LCZ. However, the rate of groundwater flow from the LCZ would be low, so the net contribution of that water to the overall mixed water would be minor.

Modeling predicted that the following minerals would precipitate from the mixed mine water: alunite, barium arsenate ($Ba_3(AsO_4)_2$), chromium(III) oxide (Cr_2O_3), ferrihydrite, and quartz. Formation of these minerals and the subsequent sorption of metals and solutes to the mineral surfaces would remove some mobile constituents from the water. Analysis of the humidity cell testing data and additional sensitivity analyses predicted that the following metals would sorb to ferrihydrite: barium, beryllium, zinc, copper, lead, and arsenic.

The modeling work included several sensitivity analyses of the predicted underground water quality, addressing uncertainty in model inputs for: (1) All humidity cell testing data (i.e., all data vs. weeks 1 to 4 data), (2) fracture density, (3) fracture zone thickness, (4) estimated surface area, and (5) sulfide oxidation rate (see Enviromin 2017, Table 4-4). In general, the assumptions about fracture density and reactive-zone thickness were found to have the greatest impact on predicted metal release from rock surfaces. Also, inclusion of all weekly humidity cell testing data was found to have the greatest impact on the estimated pH.

Alkalinity was found to be abundant in all sensitivity scenarios, including the analysis of several upper bound estimates of rim thickness, sulfide oxidation rated, and fracture density. Together those estimates resulted in a conservative evaluation of the reactive mass. Predicted pH ranges from 4.87 to 6.68, and sulfate ranges from 262 to 672 mg/L across the various sensitivity analyses (see Enviromin 2017, Table 4-4). Nitrate, arsenic, and uranium were predicted to exceed the DEQ groundwater quality standards in the operational base case as well as in several sensitivity scenarios (see Enviromin 2017, Table 4-4). Antimony, strontium, and thallium were predicted to exceed the groundwater standard only under select scenarios evaluated by sensitivity analyses, including conservative (upper bound) estimates of input parameters. All the mixed water that would be pumped from the underground mine (subject to the analysis discussed above) would be sent to WTP for treatment.

Post-Closure Groundwater Quality

There are two sources that could provide chemicals to the shallow HSUs and affect groundwater chemistry:

- Upward migration of LCZ and UCZ contact groundwater through open mine workings that flows into the Ynl A.
- Downward seepage from the bottom of surface facilities that reaches the Ynl A water table.

Water quality modeling and analysis completed for the proposed mine underground workings (Enviromin 2017) indicate that all the potential contaminants of concern (COCs) would be dissolved in post-mine contact groundwater at concentrations below the Estimated Groundwater Non-degradation Criteria (Hydrometrics, Inc. 2016e). Thallium was predicted to exceed the DEQ groundwater standard of 0.002 mg/L by a factor of less than 2.0 (see discussion in Section 3.5, Surface Water, subsection 3.5.3.2 titled “Underground Mine”, post-closure); however, the non-degradation limit for thallium in the USZ would be higher than the standard because the average ambient (baseline) thallium concentration (0.0039 mg/L) in groundwater in the USZ also exceeds the standard. Consequently, migration of the post-mine contact groundwater from the LCZ to the UCZ might lower the concentrations of some chemicals in the UCZ.

As such, migration of the post-mine contact groundwater toward surface environments would not result in any impacts. This would be the case even if no attenuation processes (such as dispersion, mixing, or retardation) were to operate on such contact groundwater, which is highly unlikely.

The combined groundwater flow rate of potential chemical sources (i.e., contact groundwater) from the surface mine facilities during both mine operations and post-closure periods are expected to be less than about 3 gallons per minute. Referring to **Figure 3.4-8**, the groundwater flow rate in Ynl A within the mine area is estimated to be about 90 gpm, while groundwater flow in that area within the Sheep Creek alluvium is about 200 gpm. The alluvial groundwater eventually becomes groundwater discharge to Sheep Creek, which has an average base flow rate of 6,700 gpm. Complete mixing of the contact groundwater with Sheep Creek surface water would dilute the original solutes by a factor of 1,000 or more.

Surface water quality is expected to be the same or similar to surface water quality under current (baseline), pre-mining conditions. This conclusion is based on consideration of the substantial mixing of waters, as explained above, and a projection that groundwater flow paths during post-closure period would be similar to flow paths present under current conditions.

The groundwater potentially affected by surface mine facilities that discharges to Coon Creek might undergo less mixing compared to Sheep Creek. However, the combined groundwater flow rate from the surface mine facilities during both mine operations and post-closure periods are expected to be on the order of a few gallons per minute. The potential of groundwater impacts from the surface facilities would further decrease during a post-mine period due to attenuating mechanisms.

In summary, the completed analyses indicate that impacted water from the mine's surface facilities is unlikely to cause adverse impacts to ambient groundwater in the Ynl A, Sheep Creek Alluvium, or Sheep Creek surface waters.

Water Supply

Project operations would require three separate water supply systems: (1) process water supply, (2) fresh water supply, and (3) potable water supply. Recycled water from the PWP to the process water tank would be the primary water source for mill operations. Additional water would be provided by mine dewatering and from the WTP. Fresh water (from the fresh/fire water tank) would be obtained from the WTP and used for other milling purposes. Finally, the Project could obtain water from a public water supply well (PW-6; see the northwest corner of **Figure 3.4-7** and discussion provided below) and treat it, as necessary, for human consumption (Tintina 2017).

The Proponent would need to supply potable water for drinking, showers, and restroom facilities for 145 people at a rate of about 30 gallons per person per day. As such, the daily potable water demand would be 4,350 gallons (equivalent to an average flow rate of about 3 gpm). To meet this demand, the Proponent would either pump the PW-6 test well, or install a new well drilled in the vicinity. Initial water quality samples collected from PW-6 showed that all the chemical constituents met human health standards. In the future, the Proponent would collect and analyze PW-6 water quality samples to comply with permitting this well for use as a Public Water Supply (Tintina 2017).

In the spring of 2015, the well PW-6 was deepened into the Neihart Formation quartzite adjacent to the Buttress Fault (renaming it PW-6N). Air-lift pumping of the open borehole at this location produced more than 500 gpm and confirmed that there are high permeability fractures within the Neihart Formation quartzite adjacent to the Buttress Fault (Tintina 2017). As such, pumping this, or an adjacent new well to produce water at an average rate of 3 gpm for the Project Public Water Supply would have a negligible impact on the associated groundwater system.

In addition to the three water supplies discussed above, the wet well constructed adjacent to Sheep Creek (discussed in Section 3.4.3.2, subsection: Base Flow in Nearby Creeks) would be pumped only during the creek's high season flow to supply water to the NCWR during high flow conditions (Tintina 2018c). Considering the limited capacity of any well completed in the alluvial aquifer and Sheep Creek's flow/discharge during high flow conditions, pumping from that well would have a negligible impact on that flow.

Grouting Access Declines and Tunnels During Construction

The Proposed Action indicates that the walls of access tunnels and declines may be grouted during their initial construction. Depending on subsurface conditions, the process could include pressure grouting via boreholes drilled into the tunnel wall or application of shotcrete to the wall surface. The decision to perform grouting at any given location within the mine would mostly depend on groundwater inflows and rock stability observed during the initial excavation of the mine openings. The proponent intends to grout to the extent needed for safe and efficient execution of mine operations and to avoid the need to manage excessive volumes of water. The extent of grouting could range from spot applications to control inflows and rock stability at discrete fault/facture zones, to application along substantial lengths of tunnels if inflow and rock stability issues are pervasive. Note that mine stopes would be backfilled with cemented tailings, so wall grouting is not planned for these excavations.

While grouting would mainly be performed to address underground construction issues, it could also provide long-term benefits in reducing hydrologic impacts to the groundwater system. If mine inflows are reduced, one would expect (1) the magnitude and extent of groundwater drawdowns to decrease and (2) smaller reductions in stream base flows associated with the Project.

To study the impacts that grouting might have on mine inflows and stream base flows, Hydrometrics performed a subsidiary groundwater model evaluation for the extreme case where the entire Surface Decline was grouted. The Surface Decline was selected for this evaluation because it would be excavated mostly through Ynl A, which has much higher hydraulic conductivity compared to deeper bedrock units. For this model simulation, it was assumed that grouting would be conducted as the Surface Decline is advanced and the hydraulic conductivity along the wall would be 2.8 x 10^{-4} feet per day, or two orders of magnitude lower than undisturbed bedrock (Hydrometrics, Inc. 2016f). In the model, this was accomplished by adjusting the conductance values for drain cells used to simulate dewatered mine workings. It is assumed that grouting would not be performed in deeper low-permeability unit (Ynl B, LCZ).

The model simulation predicted that grouting would reduce the inflow to the Surface Decline by an order of magnitude during Phase I (from 220 gpm without grouting to 22 gpm with grouting). Total mine inflow rates would be sharply reduced only during the first 2 years of mine development. In subsequent years the relative impact of grouting would be less pronounced as the mine workings are deepened and Ynl A is depressurized/dewatered adjacent to the Surface Decline. It is estimated that after the mine Year 2, the grouted decline would have the impact of reducing the mine dewatering rate by 66 to 84 gpm, or about 15 to 25 percent of the predicted total dewatering rate without grouting (Hydrometrics, Inc. 2016f).

During construction of the Surface Decline, reduced inflows associated with grouting would decrease the initial drawdown in Ynl A to less than 10 feet. However, during Phases II and III when the dewatered underground workings are extended and deepened, the drawdown in bedrock would be similar to decline construction without grouting.

Drawdown in the alluvium near Coon Creek and reduction in the creek base flow would be somewhat less throughout the mine life if grouting was implemented (Hydrometrics, Inc. 2016f).

The groundwater model predicts that with grouting there would be no substantive base flow changes in the larger perennial streams (Sheep Creek and Black Butte Creek) when compared to the Proposed Action without grouting (Hydrometrics, Inc. 2016f).

Installation of Plugs in Declines and Shafts

The Proponent proposes to install 14 cement plugs at strategic locations in the surface decline, deeper access ramps, and four ventilation shafts. The stated primary purpose of the plugs would be to segment the mine at certain elevations so the mine can be more efficiently pumped and rinsed during closure (Tintina 2018b). One plug would be installed at the portal of the surface decline to prevent human access, rather than to create a hydraulic barrier, as groundwater levels are expected to always be below the portal during the post-closure period.

While the decision to install plugs is dictated mainly by operational issues, the plugs could provide environmental benefits by reducing the flow of contact water through open tunnels and shafts. Baseline data indicate the general presence of upward hydraulic gradients, which would provide for an upward flow of the post-mine contact groundwater toward the surface environments. Open tunnels and shafts could create high permeability conduits that covey this flow at higher rates compared to the upward flow that would occur through the undisturbed, natural system. In this sense, the open tunnels and shafts could be viewed as potentially “short-circuiting” the natural groundwater flow system.

To evaluate the impact of plugs on post-closure mine flow, a scoping-level calculation was performed for a hypothetical plug installed in a vertical shaft near the contact between Ynl A and Ynl B using current baseline groundwater levels (Appendix D). The calculation considered the presence of a disturbed zone adjacent to the shaft having hydraulic conductivity equal to or greater than the hydraulic conductivity of undisturbed rock.

The calculation predicted that flow up the shaft would be mostly controlled by the hydraulic properties of the penetrated rock materials above and below the plug location, rather than the high permeability nature of the shaft itself. If no plug were present (i.e., the shaft operating essentially as a vertical pipe), the computed upward flow is only 0.27 gpm, which is the same value predicted by a similar calculation presented in the MOP Application (Tintina 2017). Calculations predicted that this flow rate could be reduced by installing a plug if the disturbed zone adjacent to the shaft did not have unrealistically high hydraulic conductivity. However, because the flow rate for the no-plug case is low to begin with, presence or absence of a plug is largely irrelevant from an environmental impact perspective. The decision to install plugs in the Proposed Action rests mostly on operational considerations, not on impacts relevant to the EIS.

3.4.3.2.1 Smith River Assessment

The water released to the alluvial aquifer via the UIG during the Mine Construction and Production Phases would be treated to assure compliance with groundwater standards and non-degradation criteria per the MPDES permit (Hydrometrics, Inc. 2018a; Tintina 2018a). As discussed in previous sections, it is highly unlikely that chemical source water generated at the site (mine contact water and surface facility seepage) would lead to the concentration of any constituent exceeding its estimated groundwater non-degradation standards in shallow groundwater or surface water. There is no direct hydrogeologic connection between groundwater in the Project area and the Smith River or its alluvium. All the potentially Project-affected shallow groundwater would be discharging to Sheep Creek and Coon Creek either within boundaries of the LSA, or a short distance downgradient (with regard to Sheep Creek's direction of flow) from the LSA.

The only chemical pathway from the site to the Smith River is via Sheep Creek surface water, a river distance of 19 miles from the mine site. Since the proposed Project would not cause Sheep Creek surface water to exceed water quality standards, the mine would also not cause standards to be exceeded in the Smith River (see discussion presented in Section 3.5, Subsection 3.5.3.2, Smith River Assessment).

3.4.3.3. Agency Modified Alternative

The AMA would require the Proponent to backfill additional mine workings with a low hydraulic conductivity material (see **Figure 3.4-13**). Approximately 106,971 cubic yards of cemented tailings would be needed to backfill the mine workings and access tunnels (except the upper portion of the access decline crossing Ynl A). While the AMA would result in impacts similar to those described for the Proposed Action, it would provide additional benefits as discussed below.

The regional groundwater model constructed to evaluate the proposed mine (Hydrometrics, Inc. 2016f) was used to simulate backfilling of the mined-out stopes only. Drain cells were used to simulate the hydraulic impacts of dewatered open mine workings during the mining period. The model however did not simulate the impacts of flooded open mine workings (declines, ramps, and shafts) during post-closure period. The structure of a regional model would make such simulations impractical. For the post-closure period, the Proponent's model essentially assumed that the tunnels and shafts contained the same geologic material existing adjacent to the openings (mostly Ynl A and Ynl B). There was no accounting for delayed flooding of the mine due to the volume of water required to saturate the open mine workings.

Two more scenarios were evaluated by Zieg et al. (2018). The first of those scenarios assumed the walls of unfilled mining stopes would be composed of paste backfill instead of bedrock. A version of the water quality model used to evaluate this scenario is called the Revised Base Case with Cement Walls, and it represents a 52.5 percent net increase in reactive surface area (exposed wall rock) compared to the original Base Case. The second of those scenarios assumed the previously un-backfilled zones would be backfilled with cemented paste and represents a 7.7 percent net increase in the reactive surface area of the backfill from the original Base Case. The results of analyzing those scenarios showed only slight increases (if any) for most dissolved constituents compared to the original Base Case. According to the analysis, all concentrations would meet Montana groundwater standards and non-degradation criteria in post-closure groundwater (Zieg et al. 2018).

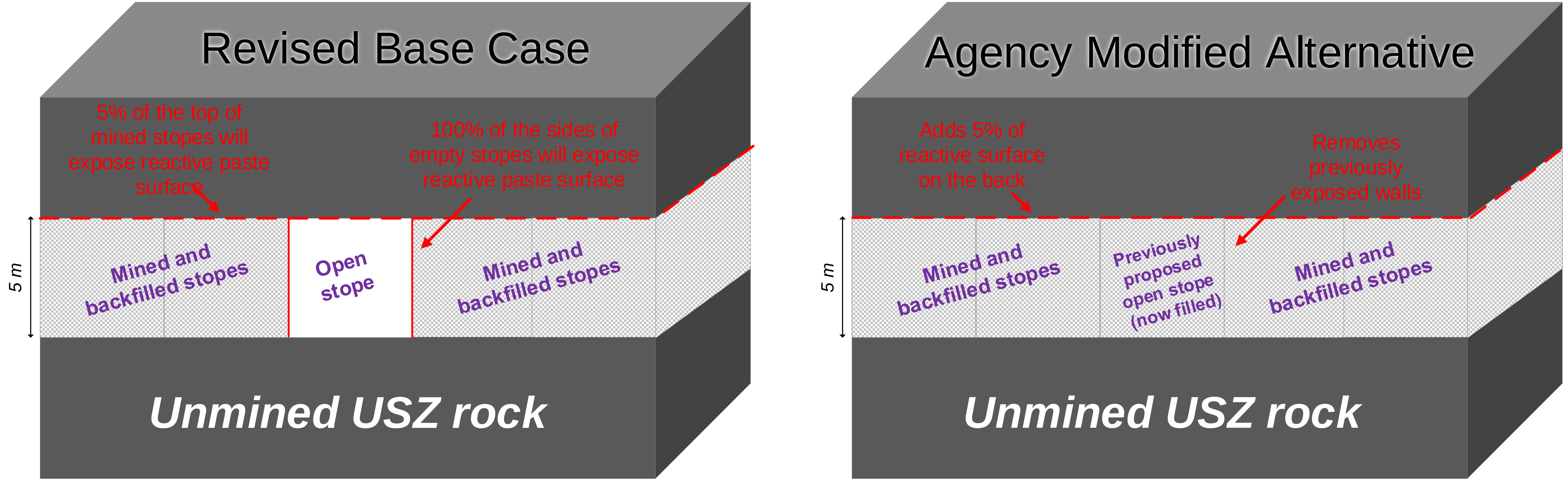

Figure 3.4-13
Black Butte Copper Project
Schematic Comparison of Revised Base Case (Proposed Action) and Agency Modified Alternative Meagher County, Montana

File: M:\Clients\M-O\MTDEQ\BlackBute_Copper_ArcGIS\2019\01\DEQEditstoWaterSections\Figure_3.4-13.pdf Revised: 01/18/2019

Drawn By: CJL

Source: Zieg et al. 2018

Calculations performed in the MOP Application by Tintina (2017) and Zieg et al. (2018) predict that the Proposed Action is unlikely to affect shallow groundwater water quality or Sheep Creek surface water quality regardless of whether:

- The access tunnels/shafts are backfilled, plugged, or left completely open;
- The walls of unfilled mining stopes would be composed of paste backfill instead of bedrock; or
- The previously un-backfilled zones would be backfilled with cemented paste.

The benefits of the AMA include (1) additional assurance that water quality would not be degraded, (2) greater consistency with how the Proponent's model simulated the post-closure period, and (3) a slower rate of post-mine migration of the deep groundwater to the shallower bedrock (Ynl A). For several chemicals, groundwater non-degradation criteria are lower for the Ynl A groundwater than for the LCZ and UCZ groundwater.

3.4.3.3.1 Smith River Assessment

Implementation of the AMA would offer more protection of water resources compared to the Proposed Action. However, as concluded in Section 3.4.3.2.1 above, it is highly unlikely that the Proposed Action itself would have any measurable impact on water quality in the Smith River. Consequently, implementing the AMA would not be required to ensure that Smith River water quality is not impacted.

3.4.3.4. Summary

Table 3.4-8 provides a summary assessment of the potential consequences with regard to groundwater quantity and quality for both the Proposed Action and AMA. The only adverse impact on groundwater would be caused by mine dewatering. Such dewatering would create a large cone of depression around the mine workings, reaching into surficial environments for many years. As **Figures 3.4-9** and **3.4-10** illustrate, the water table cone of depression would expand thousands of feet around the mine workings in all directions, touching a segment of the Sheep Creek alluvium near the proposed mine. Groundwater levels within the cone of depression would result in a decrease of stream base flow by up to a few percent. Some springs and seeps located within the cone of depression might experience decreased flow, and some might dry up. The maximum impacts are predicted to occur at the end of the initial mine construction (mine Year 4), but impacts would persist to the end of mining (mine Year 15).

After mine dewatering ends (mine Year 16), shallow groundwater levels would likely recover to within 1 to 2 feet of baseline (pre-mining) levels within a few years. Decreases in the Sheep Creek base flow would almost disappear 2 years after mine dewatering stops. However, some of the springs and seeps within the LSA might be permanently affected. No alternative actions being considered would significantly decrease such impacts, except for the No Action Alternative.

Table 3.4-8
Project Potential Consequences with regard to Groundwater Quantity and Quality

Project Phase	Project Activities	Potential Impacts	
		Change in Groundwater Quantity (Water Levels, Flow Patterns)	**Change of Groundwater Quality due to Seepage of Contact Groundwater**
Mine Construction and Operation, Phases I - III	Mine Dewatering	Would extensively lower groundwater levels around the mine, somewhat reducing base flow in nearby creeks, impacting springs and seeps within the cone of depression	Would not affect groundwater quality
	Underground Infiltration Galleries (UIGs)	Would increase groundwater discharge, partially compensating mine-dewatering caused by decreased base flow	Would not affect groundwater quality (based upon following conditions of the MPDES permit for the alluvial UIGs)
	Process Water Pond (PWP)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Treated Water Storage Pond (TWSP)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Cemented Tailings Facility (CTF)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Non-Contact Water Reservoir (NCWR)	Would potentially increase groundwater discharge - partially compensating mine-dewatering caused decrease in base flow	Would not affect groundwater quality
	Waste Rock Storage (WRS)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Copper-enriched Rock Stockpile	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Contact Water Pond (CWP)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Material Stockpiles	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality

Project Phase	Project Activities	Potential Impacts: Change in Groundwater Quantity (Water Levels, Flow Patterns)	Potential Impacts: Change of Groundwater Quality due to Seepage of Contact Groundwater
	Public Water Supply System	Would not appreciably affect groundwater system	Would not affect groundwater quality
Post-Mine Period (Mine Closure and Post-Closure; Phase IV)	Mine Dewatering	Shallow groundwater levels would recover to within 1 - 2 feet of baseline conditions within a few years after mine dewatering stops; recovery of loss to base flow would be almost complete 2 years after mine dewatering stops; contact water would slowly migrate to surficial environments undergoing mixing; some springs might be permanently affected	Post-mine voids (the space from which the ore was removed) contact groundwater would not contain COCs dissolved at concentrations above the estimated groundwater non-degradation criteria. In addition, while migrating via shallow bedrock toward discharge zones, that contact groundwater would be mixing with non-contact groundwater; transport of chemicals dissolved in contact groundwater would be retarded by process of adsorption; groundwater discharging to Sheep Creek would not affect its water quality
	Underground Infiltration Galleries (UIGs)	Would increase groundwater discharge, partially compensating mine-dewatering caused by decreased base flow during closure phase; would be inactive during post-closure phase	Would not affect groundwater quality (based upon following conditions of the MPDES permit for the alluvial UIGs) during closure phase; would be inactive during post-closure phase
	Process Water Pond (PWP)	Would not appreciably affect groundwater system; would be inactive later during post-closure phase	Unlikely to affect groundwater quality; would be inactive later during post-closure phase
	Cemented Tailings Facility (CTF)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Non-Contact Water Reservoir (NCWR)	Would be inactive	Would be inactive
	Treated Water Storage Pond (TWSP)	Would not appreciably affect groundwater system	Unlikely to affect groundwater quality
	Waste Rock Storage (WRS)	Would not appreciably affect groundwater system; any potential small impacts would	Unlikely to affect groundwater quality; any potential small impacts would further

Project Phase	Project Activities	Potential Impacts: Change in Groundwater Quantity (Water Levels, Flow Patterns)	Potential Impacts: Change of Groundwater Quality due to Seepage of Contact Groundwater
		further decrease with time during the closure and post-closure phases	decrease with time during the closure and post-closure phases
	Copper-enriched Rock Stockpile	Would not appreciably affect groundwater system; groundwater would recover to pre-mine conditions a few years after the mine closure	Unlikely to affect groundwater quality; groundwater would recover to pre-mine conditions a few years after the mine closure
	Contact Water Pond (CWP)	Would not appreciably affect groundwater system; would be reclaimed later during the post-closure phase	Unlikely to affect groundwater quality; would be reclaimed later during the post-closure phase Would be inactive
	Material Stockpiles	Would not appreciably affect groundwater system; groundwater would recover to pre-mine conditions a few years after the mine closure	Unlikely to affect groundwater quality; groundwater would recover to pre-mine conditions a few years after the mine closure
	Public Water Supply System	Would not appreciably affect groundwater system	Would not affect groundwater quality

After groundwater levels recover to near pre-mining conditions, mine contact water could start migrating up the open tunnels and shafts toward surficial environments. However, water quality modeling indicates that COCs would be dissolved in that water at concentrations below the estimated groundwater non-degradation criteria. In addition, this water would have a very low flow rate and would experience strong dilution by non-impacted shallow bedrock groundwater and Sheep Creek alluvial groundwater. Given the contrast in flows, there is little to no potential for mine contact water to impact groundwater and surface water quality. The dilution that occurs when shallow groundwater discharges to Sheep Creek surface water is very large. Thus, there is no realistic potential for surface water quality to be impacted in Sheep Creek or the Smith River. However, to verify that impacts do not occur, the Proponent would be required to implement a long-term groundwater and surface water monitoring plan (Tintina 2017).

Below and downgradient of surface facilities (ponds, tailings storage, waste rock storage), there is little potential for chemical impacts to shallow groundwater or Sheep Creek surface water. The total seepage flow rate would be at most a few gpm, and this flow would be greatly diluted by groundwater in the shallow bedrock and in the Sheep Creek alluvium. As with mine contact water, there is virtually no likelihood that facilities seepage could impact Sheep Creek or Smith River surface water quality.

Operation of UIGs could have some mitigating impacts on groundwater quantity and partially compensate for the loss of groundwater discharge to surface waters resulting from the mine dewatering. No impacts on groundwater or surface water quality are expected as water discharged to the UIGs would be treated and retained seasonally in the TWSP to meet non-degradation standards under an MPDES permit. Still, the Proponent would be required to monitor the WTP operation and the chemistry of water sent to the UIG from the WTP and TWSP (between July and September) to ensure that it meets non-degradation criteria for groundwater and surface water (Tintina 2018a).

Section 6 of the MOP Application provides information regarding the proposed monitoring plan (Tintina 2017).