TECHNICAL MEMORANDUM: COMPLETENESS REVIEW OF THE MINE OPERATING PERMIT APPLICATION

Black Butte Copper Project, Meagher County MT

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SUMMARY OF COMPLETENESS REVIEW

The Mine Operating Permit Application submitted by Tintina lacks sufficient data to support adequate hydrologic analysis of the environmental impacts of developing the proposed mine. The application also includes hydrologic analysis that is not adequately supported by the data and that includes a couple fatal errors. This technical memorandum provides discussion about the application and supporting documents and makes many recommendations for needed improvements. The primary factors that render the application insufficient for the commencement of environmental analysis are as follows:

- The report provides insufficient monitoring and observation well data to adequately parameterize the formations, understand seasonal variability in water levels, estimate flow paths including vertical flow based on vertical gradients, and the effect of faults and fractures.
- Many more test and monitoring wells with the ability to evaluate fracture flow, especially at depth below the uppermost higher conductivity zone in the bedrock, are necessary. Monitoring wells should be able to monitor water levels in each geologic formation and each level in the bedrock through which there may be substantial flow. All wells need geophysical logging to characterize fractures, shale and clay stringers, and areas of saturation. This is needed to accurately assess changes in properties with depth.
- The design of the surface water monitoring system will not help to determine the source of contaminants discharging from the mine site. There are just two sampling sites on Sheep Creek but several tributary sources between the sites which means that it is not possible to determine the source of leaks or where dewatering may be drawing water from the streams.
- All monitoring sites, surface and groundwater, have been sampled much too infrequently to establish a useful baseline. The sampling will not establish season trends or even distinguish among characteristics present during periods when flow rates are increasing or decreasing.
- The designs of infiltration galleries and land application disposal sites are based on sparse infiltration test data. Lysimeter data, presented in a report not included with the application, does not show there is no percolation or runoff nor estimate evapotranspiration to verify the LAD sizing. Much additional percolation data is required to improve confidence in infiltration gallery design.
- The analysis also must consider the scale factors of pump tests, meaning that the estimated properties are representative of only a small volume of the aquifer and should not be applied to an entire formation. A couple of small-scale pump or slug tests effectively samples only a very small portion of an aquifer. Dozens of observations are necessary to understand the variability. Additionally, small-scale observations control localized flow but generally conductivity increases

as the scale of the tested volume increases so higher representative values control the regional flow.

- The groundwater model is more sophisticated than there is available data for parameterization. The remedy is to collect the additional data as outlined in the previous bullet point. However, a number of deep model layers, below the lowest ore body, could be at least partially combined because there is little gained from simulating numerous layers beneath the mine extent.
- The groundwater model has at least one fatal error – the recharge is estimated incorrectly and applied to the model using a grossly inaccurate method. In summary of the detailed discussion below, recharge equals baseflow, but baseflow has been underestimated by assuming it equals only an annual low flow. Additionally, the report errs by assuming that a constant percent of annual precipitation becomes recharge regardless of the total precipitation or the underlying geology. Finally, the model assumes that recharge enters the groundwater where the precipitation falls which is not accurate; it ignores runoff and recharge that occurs through tributary stream bottoms and at the mountain front where runoff from bedrock meets the alluvium of the valley bottom.

Tintina's application is insufficient with respect to hydrogeology. The Montana DEQ should require Tintina to collect additional groundwater and aquifer data and outlined herein and require them to reconceptualize their model with a better description and application of recharge.

INTRODUCTION

Tintina Montana, Inc. (Tintina) has submitted a Mine Operating Permit Application for their proposed Black Butte Project (Application) to the Montana Department of Environmental Quality (MDEQ) for review. This technical memorandum reviews the application with respect to the level of data and analyses regarding whether the application is "complete" or whether additional data is needed along with improved analysis before commencing environmental review.

This review focuses on hydrogeology and water resources issues. Therefore, the review focuses on specific sections of the Application and various appendices including:

- Appendix A: Climate and Meteorology (App A)
- Appendix B: Baseline Water Resources Monitoring and Hydrogeological Investigations Report (App B)
- parts of Appendix C: Wetland Resources (App C)
- Appendix K: Waste and Water Management Design (App K)
- Appendix L: Water Balance - Surface Water Transfer to Water Treatment Plant (App L)
- Appendix M: Hydrologic Modeling (App M)

WATER DISPOSAL

The proposed mine would use land application disposal (LAD) and infiltration galleries to dispose of excess water. Water is excess if it is not used for processing at the mine. The review of the mine water balance below considers the amounts of water expected and need for various features.

An LAD system would spray apply water to the ground at rates supposed to be less than the evapotranspiration rate at the time of application. This is why the system is used only during summer. The soils must hold the water, neither allowing it to percolate deeply nor run off, until it evapotranspires. The application does not provide adequate data to assess whether the design is adequate.

The application (p 220) describes tests used to characterize an LAD area. The description of the location of the LAD discharge area refers to Figure 1.3 to show the location of the LAD, but the figure is not clear at all. Tintina disposed of water from its groundwater pump tests through the test LAD system (Hydrometrics 2015). Application Figure 3.39 shows the layout of the test, but the scale is so large that it is not possible to determine exactly where it was located. The Application describes in detail the LAD test and Figure 3.39 shows the layout, as noted, including the location of spur lines and seven lysimeters. The application refers to "water resource monitoring" conducted on a "weekly basis while the LAD system was in operation" (Id.). They state that "water discharge to the LAD system did not impact surface or groundwater water resources" (Application, p 221) without justification. Tintina (2013) summarized data collected for what they called LAD sites[1], and provided a map showing where the lysimeters were located (Tintina 2013, Figure 15), but no data.

Hydrometrics (2015) provided lysimeter data, but it does not support the development of LAD sites in that it would estimate ET rates and show that runoff and percolation would not occur. The Hydrometrics lysimeter data includes the amount of water removed from each lysimeter (Hydrometrics 2015, Table 3-6), but it is not clear what this value represents. The amount of water collected is quite variable among the lysimeters. A lysimeter can be used to estimate evapotranspiration by collecting detailed data on precipitation, change in weight of material in the lysimeter, and percolation through the bottom – ET can be estimated from the determined water balance. Hydrometrics (2015) does not include additional analysis of water balance from the lysimeters nor provide any discussion regarding runoff or percolation.

Additionally, the water quality data (Hydrometrics 2015, Table 3-7) shows that the sample water quality has been diluted through the lysimeter. The samples collected on 8/7/14 (two far left columns) show SC values for pre-test samples that decrease with time through the test. Similar trends appear through the table, but there should not be too much confidence in these results because of the tendency for using composite samples and the lack of consistency in collecting field parameters. Chemistry has been determined for composite samples which are combined samples from various lysimeters, but it is not possible to consider a variation for a given set of lysimeters due to the randomness of compositing. Field parameters were not collected for seven of 16 samples, not counting the offsite LS 6, 7 composite samples. Trends are not as obvious with this data they could be with proper sampling.

Recommendation: Provide the lysimeter data in the application with analysis showing there was no runoff or percolation. ET rates should be estimated. Provide a map in the current application that shows the location of lysimeters.

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[1] Tintina (2013) describes land application disposal as a system for infiltration into the soils, which is not correct. LAD is application of water to be disposed of on the soil surface where it can evapotranspiration. Infiltration galleries are used to allow disposable water to enter the soils and aquifers.

Underground infiltration galleries would be used to discharge treated excess water to the groundwater but with the idea it will discharge to the streams to make up water lost to dewatering. The Application does not adequately describe where the infiltration galleries will actually be constructed, describing it in relation to two ridges shown on Figure 1.3 (Application, p 221) without actually showing the galleries. None of the hydrogeologic support is provided in the Application or any associated appendix. "The potentiometric surface map indicates that groundwater beneath the first ridge is approximately 40 to 100 feet below the ground surface. Discharges to the underground infiltration gallery will be introduced from 4 to 6 feet below the surface in highly fractured bedrock with high infiltration rates (32 feet/day… average)" (Id.). There are no references to or data provide to support the 32 ft/d bedrock infiltration rates in the application. "As discussed in Soil Section 2.5.2 above, soils and shallow bedrock underlying map units Ch-b and Wg-b are able to transmit or infiltrate large volumes of water, and are therefore, well suited for construction of subsurface infiltration systems." (Id.). The report continues to estimate "an overall disposal capacity of 6,000 gpm" (Id.) based on the 32 ft/d estimate. Section 2.5.2 mentions deep "falling head percolation test pits [that] allowed measurement of hydraulic conductivity of underlying geologic materials" (Application, p 76) but does not provide the data.

The Application apparently relies on an earlier application, Tintina Alaska (2012), for the data needed to support the analysis of the infiltration basins. Appendix E in Tintina (2013) provides three tables showing infiltration rates for surface (Table 1) and subsurface (B-horizon) (Table 2), and deep parent material test pit percolation rates. A Figure 1 in Attachment 2 (to Appendix E in Tintina (2013)) shows the locations. The data tables report rates as either a minimum or a min, mean and max. Regarding bedrock percolation rates, Table 3 would be the useful data; the table shows min, mean, and max for Locations A, F, H, and K. The mean is the average of the min and max since as verified in Figure 1, there are at most two test pits in any of the areas. Tintina (2013, p 38-39) notes that one test had a "high percolation rate of 450 ft/day … due to isolated fracture conditions in the underlying bedrock", so the smaller rate, 32 ft/day, is the "conservative" choice for sizing the basins. With just two observations over as much as 44.8 acres (area F), two tests provide far too little data to characterize the percolation properties of an area. Presumably, the areas were based on similar characteristics, but no description of how this was determined was provided. The data on which the infiltration basins were sized is grossly insufficient and does not account for the huge variability inherent in fractured bedrock. Tintina does not present a basic understanding of the variability of rates. An adequate sampling regime could possibly find a much broader distribution such that a representative value would be much less than the lesser of two tests.

Recommendation: Complete at least seven infiltration and percolation rate tests in the potential infiltration basin areas. This will allow an estimate of variability in rates and allow for better design. It will also allow for a better estimate of how much water may need to be disposed of in an LAD site.

CLIMATE, METEOROLOGY, AND AIR POLLUTION (APP A)

The application presents Climate, Meteorological and Air Quality data collection and analysis in Section 2.1 and Appendix A-1 and A-2. The application should discuss the uses to which the data will be put because it affects the type of data which should be presented.

The application compares precipitation at the proposed mine site, which had been collected for a little less than three years, to longer term records at Bozeman (1892-2015) and Millegan (1984-2015). They compared the records using a mass balance analysis which simply sets a ratio for total depth between the study site and the two longer records. This method is appropriate only if the ratio does not vary on a seasonal basis. In other words, the ratio of summer thunderstorm precipitation between sites has to be the same as the ratio of snowmelt between sites. Black Butte is more mountainous and therefore may actually have more summer thunderstorm precipitation and more snow; however, an alternative could be that being farther north and farther from a summer source of moisture, there could be less precipitation during the summer. The analysis itself presents a potential problem – the proposed mine site received over 4 inches of precipitation during one event in March 2013 that was not observed at the other sites. The authors did not address whether the data was accurate. It however suggests that the study area may have significantly more precipitation that the other two sites in a way not captured by the ratio method used in the application. The application simply provides no justification for a constant year-round ratio. **The precipitation data developed for the mine site is not supported by actual data or by theory and should not be used for mine planning.**

The application uses pond evaporation and potential evapotranspiration (PET) interchangeably, although they mean different things. Pond evaporation is the potential evaporation that would occur from a pond (or extensive free water surface (Shuttleworth 1992)) at the given site and PET is the evapotranspiration that would occur if the amount of water was not limiting[2], or the "amount of water that would be removed from the land surface by evaporation and transpiration processes if sufficient water were available in the soil to meet the demand (Freeze and Cherry, 1979 , p 207). A critical difference not accounted for by the application is that PET includes transpiration from plants as well as evaporation from the ground surface. PET may exceed pond evaporation because the ground surface may warm more than a pond so ET may exceed free pond evaporation.

The application recommends that the mean annual pond evaporation values of 514 mm/y be used for "long-term mean annual pond evaporation" for water balance analyses because it is the highest estimate and therefore the most conservative (Appendix A-1, p 9). Whether it is conservative depends on the water balance being calculated. Higher evaporation or ET estimates in an analysis for a liner will result in less estimated seepage through the liner and in the water balance for tails will dry the tails sooner and also result in less seepage through the bottom of the tails. However, it could result in a higher (more conservative) estimate for needed production water. The application should specify the uses for the estimate.

The application also presents return periods up to 100 years for wet years and dry years based on the mean annual precipitation for the site plus or minus the product of various factors and the standard deviation of annual precipitation (Appendix A-1, Table 7). The factors and use of standard deviation is based on an assumption that annual precipitation follows a normal distribution. The authors had more than 120 years of precipitation data for Bozeman (which they do not present) and could therefore assess whether annual precipitation in this area is normally distributed. Annual precipitation is most likely not normally distributed because it is bounded by zero on the low end. In other words, there is no upper limit but it cannot go below zero, a situation which usually results in a distribution with a longer tail to the right (higher precipitation values) and a median value less than the average.

BASELINE WATER RESOURCES (APP B)

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[2] Actual evapotranspiration is always less than or equal to PET because there are times during the year that water availability will limit the amount of evaporation.

Sampling Frequency

With some exceptions, water resources monitoring sites were sampled or measured on a quarterly basis (p 26). This is grossly insufficient for both surface and groundwater because it does not capture temporal variability. At most, sites will have been monitored for just four years which means just four samples for each season at each site. During the spring, the peak runoff may vary based on snowpack and the temperatures during snowmelt. One year, the spring sample may be during the rising leg of a hydrograph (as the flow rate is increasing toward the peak) and during another year, the spring sample may occur after the snowmelt peak. Water quality relations vary substantially pre- and post-peak during snowmelt, with the rising leg often having high concentrations of parameters subject to first-flush leaching.

Surface Water

Tintina increased the frequency to bi-weekly and weekly during spring runoff for the three sites on Sheep Creek, but this is too little. The relations may differ between Sheep Creek, the largest study area stream, and the nearby tributaries (which may be more affected by proposed mining). The peak may occur at different times on the tributaries as compared to Sheep Creek due to differences in the watersheds including area, elevation, and aspect (the direction the slopes point towards; northeastern-facing slopes melt later than do southern slopes). Because of the potential differences in timing, it may not even be possible to complete correlation analyses among the sites.

Recommendation: Quarterly data on surface water sites is not useful and not sufficient for mine planning. Tintina should increase sampling on all sites to a minimum of biweekly for at least two years to improve the definition of the annual hydrograph and the variation of basic chemistry with that hydrograph.

The monitoring strategy for surface water is grossly insufficient, both in the sites that are monitored and/or sampled and in the frequency with which data is collected. Application Figure 2.2 and App B Figure 2 show project monitoring sites for both surface and groundwater sites. Most sites are clustered near the project area but the map's scale is too small to adequately show the sites' locations; the scale is small because the map shows a few surface sites up and downstream on Sheep Creek and Black Butte Creek

Recommendation: Add a larger scale figure showing monitoring site within a mile of the proposed mine site to better demonstrate the areas being monitored. Add surface water sites to the map showing spring and seep monitoring (App B Figure 3).

There are just two monitoring sites on Sheep Creek, SW-1 downstream and SW-2 upstream of the proposed mine site. Additionally, tributary Coon Creek has two sites, SW-3 and SW-4 and Little Sheep Creek has one site, SW-8. Sites SW-6 and SW-7 are up and downstream on Brush Creek, but App B Table 4 labels them as unnamed tributaries to Black Butte Creek, which is incorrect Application Figure 2.2 is correct. Brush Creek merges with LIttle Sheep Creek before it reaches Sheep Creek. Black Butte Creek has three monitoring sites, SW-11, -9, and -10 in a down to upstream direction, Site SW-5 is on an unnamed tributary to Black Butte Creek.

Facilities location map Application Figure 1.3 show that all of the mine facilities occur in the Sheep Creek drainage. While there may be a southward dip in some of the formations, there is no strong indication that contaminants would flow through groundwater across the topographic divide. Additionally, the Black Butte Fault may be a barrier to some groundwater flow to the south. Thus, from a water quality and quantity perspective, there is no reason for Black Butte Creek to have more monitoring than Sheep Creek.

The Sheep Creek monitoring sites, SW1 and SW2 complete span the site so any changes in flow or water quality from pre- to during mining could be due to inputs from anywhere along the mine. The sites on the tributaries may assess whether there is mining-influenced-water in tributary runoff, but if the changes in Sheep Creek are not explainable by tributary surface water, it could be due to groundwater inflow. Leaks at proposed mine facilities could contaminate groundwater flowing toward Sheep Creek but the monitoring is inadequate to determine the source of contamination. Groundwater monitoring is upstream and is essentially a point source of groundwater that cannot be used to estimate plumes or the load reaching the creek. Monitoring above and below a contaminant source would allow an estimate of contaminant load. The current sites would allow only an estimate of load entering Sheep Creek but not provide an ability to estimate the exact source of the contamination.

Recommendation: At least four additional monitoring points should be added to Sheep Creek between the existing sites. These sites should be up and downstream of the two tributaries. The distance from the tributaries should be chosen based on the width of the alluvial aquifer associated with the tributaries.

Tintina discusses a gaging station that had previously operated on Sheep Creek upstream from the study site (gage 06077000) (p 32). The "average monthly base flows" range from 9 to 115 cfs (Id.). Tintina also discusses two current stations on the Smith River, up and downstream of the confluence with Sheep Creek (gages 06076690 and 06077200, respectively). They report a much higher range of "base flows" than at the Sheep Creek gage (Id.). The problems with the statements made by Tintina regarding flows at these gages include:

- There is no definition of baseflow
- There is no discussion of how human activities, such as irrigation, may affect the flow. The Holmstrom Ditch downstream of the site is mentioned but flows into that ditch are not discussed.
- Gage 06076690 on the Smith River had only "intermittent data" since 1996 but Tintina did not define intermittent so the value of the data cannot be determined.
- The difference in flow between the Smith River gages cannot be used to estimate the total flow from Sheep Creek because there are additional tributary inflows. Tintina made no effort to estimate the other flows so they do not know how much flow enters the Smith River from Sheep Creek. Therefore Tintina does not have sufficient data to estimate the effect of flow changes to the mine on flows in the Smith River.

Recommendation: The following recommendations are essential for Tintina to have sufficient data to analyze surface flows and to estimate the effect of the proposed mine on Sheep Creek and the Smith River.

- Complete a series of synoptic flows measurements on the Smith River between the gaging stations to estimate in more detail the effect of Sheep Creek flows on the Smith River.

- Analyze the flows on Holmstrom Ditch to estimate the actual flow on Sheep Creek in the study area.
- Reestablish the gaging station on Sheep Creek and complete synoptic measurements on Sheep Creek below the gage and on the tributaries so that correlation analyses using the measurements and gage station flow data can provide flow data on the tributaries to assess current flows and predict future impacts to these flows.

Groundwater

Tintina describes the basic stratigraphy, lithology, and structural geology of the site in Application section 1.4 and expands the description to include basic discussion of hydrogeology in section 2.2.3. These simple descriptions depict a highly complex stratigraphy with several dipping formations offset by several faults. Figure 1 summarizes the stratigraphy as discussed in the application. The monitoring and sampling regimes applied to this complexity have not been sufficient to characterize it.

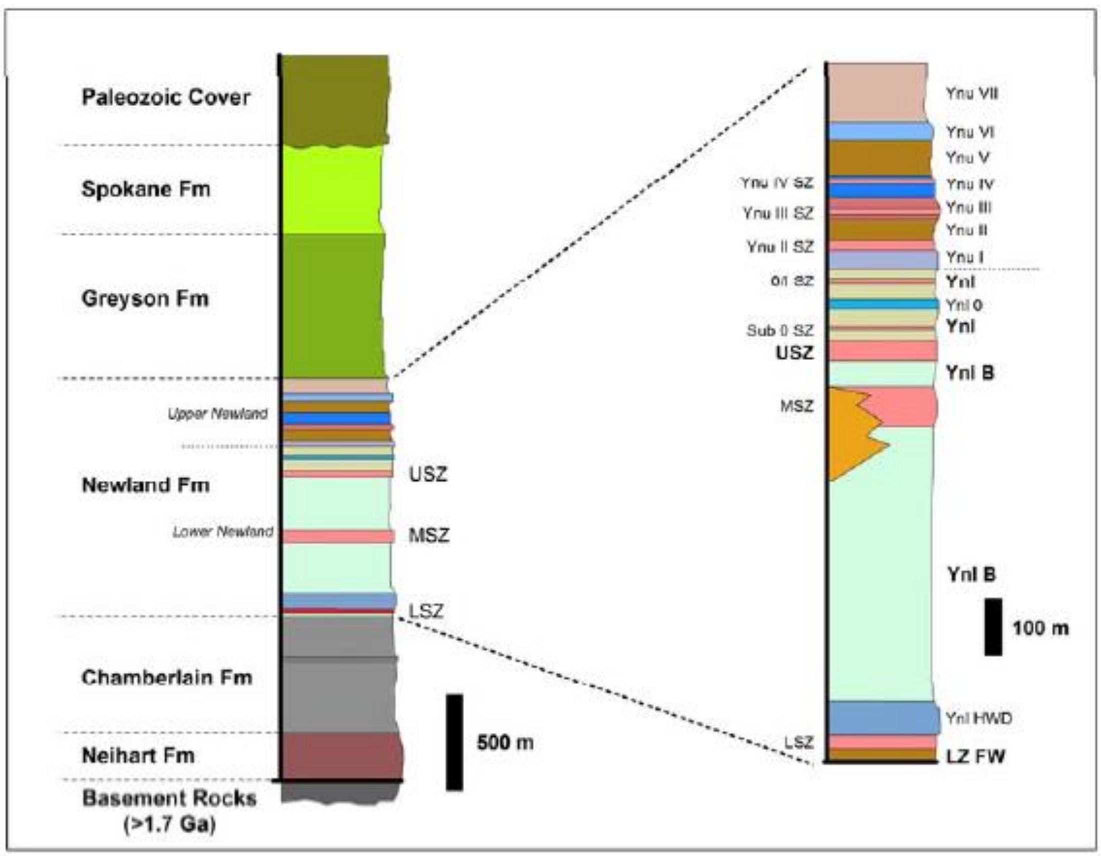

FIGURE 1-4. Black Butte Copper Project, Generalized Stratigraphic Column

Figure 1: Figure 1-4 from App D, Environmental Geochemistry Evaluation

Tintina reports that two well pairs, MW-1A/1B and PZ-07A/7B, have downward hydraulic gradients (Application, p 39), but does not provide a reference to water level data that can be used to independently assess this data. The application notes that water level data is collected quarterly, but a search through the application and Appendix B found groundwater levels reported only on App B Figure 12, which shows "water level data from the May 2015 sampling round" (App B, p 2-14). Various tables show well completion data but no water level data and the well logs show depth to static water level for the monitoring wells during completion. The statement appears to be based on one observation or on data not otherwise presented in the Application or its appendices. The application is essentially missing key data for assessing flow directions and velocities.

Recommendation: In addition to other recommendations regarding collecting more water level data made elsewhere, the application should provide a table or an Excel spreadsheet with depth to water and water surface elevation for the monitored wells with time.

The application does not provide completion data or well logs for the piezometers. This makes the assessment of water levels and gradients impossible at those locations. For example, piezometers PZ-07A/7B show a downward hydraulic gradient (Application, p 39) which App B Figure 12 shows is less than one foot. Without completion data, it is not possible to estimate whether this gradient represents recharge or perched water.

Recommendation: The application should include completion data and well logs for the piezometers, in addition to the data provided for the monitoring and pumping wells.

Paired monitoring wells MW-1*, MW-2*, MW-4*, and MW-6* were intended to "document baseline conditions within the unconsolidated Quaternary/Tertiary clayey gravel deposits and in the underlying shallow bedrock groundwater system" (App B, p 2-12). Each pair included an A and B for shallow gravel deposits and the underlying shallow bedrock.

MW-1A had static water level at the top of a pvc pipe, so it was discharging at the surface (screen 25-34 in shallow bedrock[3], App B Table 5) whereas the static water level in MW-1B was 21.73 feet bgs (screen 88-98 in competent shale (Well log MW-1B). The discharge from MW-1A was low. The well logs showed up to 50% clay for the next 50 feet, so the water in the shallow well is likely perched, not representing recharge. Well MW-2B was completed in hard shale (YNL-A from 70 to 80 feet bgs and MW-2A from 52 to 62 feet bgs in gravelly clay, described as shallow bedrock (App B, Table 5)). The 2015 water level was 0.4 higher in the B well.

MW-4B was 0.36 feet higher than MW-4A. MW-4A was screened from 14 to 23 feet bgs in sandy gravel transitioning to gravelly sand, called Sheep Creek alluvium (producing 30 gpm) and MW-4A was screened from 39 to 59 feet bgs in shale which began at 27 feet bgs. Thus upper 16 screened feet produced very little water but the 55-59 foot interval produced about 6 gpm.

MW-6B was completed from 40 to 50 feet bgs in dolostone which produced 2 gpm. MW-6A was screened from 5 to 15 feet bgs in dolostone, labeled as Quaternary in App B Table 5, and produced just a trace amount of water. The upward gradient and trace flow may reflect the low permeability rock controlling upward flow. The well pair is on Brush Creek near an inferred fault (App B Figure 12). Being near a fault, permeability may be highly heterogeneous. MW-7 and MW-8 are also developed in Ynl dolostone (App B Figure 11). The well bore did not produce water until 45 to 50 and 65 to 70 feet, respectively, and did so at just 1 to 2 gpm. At MW-7, the well log describes the dolostone as having

[3] The well log show clay, 40% fine coarse sand, and 10% fine gravel.

"intermittent broken zones". Wells MW-6, -7, and -8 are very shallow, having been completed in the upper several tens of feet below the groundwater table. Although the zones produce only low flow rates, the water level rises several tens of feet above the screen suggesting there is some pressure – that the dolostone aquifer is recharged at higher elevations on the mountain. MW-6 is not very useful.

MW-7 and MW-8 were intended to document the baseline water quality near the proposed underground LAD/infiltration system into which MIW could be discharged (App B, p 2-12).

Twelve piezometers are used to monitor the alluvial systems near the creeks – Sheep Creek, Coon Creek, and Dry Creek. The application states the completion details are in App B Table 5 (App B, p 2-14), but the table does not actually include the completion details.

Recommendation: provide completion details for the piezometer in the application.

Groundwater Contours

App B Figure 12 (Figure 2.7 in the Application) shows bedrock groundwater contours with solid blue lines. However, there are far too few bedrock water level observations to have confidence in the contours. At best, the contours represent only the uppermost water-producing zone in the bedrock, with observations mixed over all of the formations. The well logs show that most of the monitoring wells were screened in the first zone that produced water. There are too few observations to have confidence in the contours. Because changes in formation type and faults can cause abrupt changes in properties, the hydraulic gradient could vary significantly among formations and across faults. To estimate a hydraulic gradient, a minimum of three observations is necessary because it cannot be assumed that groundwater flows along a straight line between just two wells; a gradient can be calculated between two wells, but it is not possible to estimate whether it representative of groundwater flow within the formation.

Contours drawn based on wells screened at deeper levels could be different from those drawn based on the shallowest occurrence of groundwater at the site. The pumping wells demonstrate this. Wells PW-5, PW-6, PW-6N, and PW-7 have a much deeper perforated screen level. App B Figure 12 shows that the water level in PW-5 and PW-6 was much deeper than a northward extension of the contours drawn just to the south. Well PW-7 was very deep and did not encounter water at depth, possibly because its lower couple hundred feet was in the Volcano Valley Fault. These deeper wells cluster near the ore bodies but represent water levels in various deeper bedrock layers. They suggest that contours and therefore groundwater flow paths (and contaminant transport paths) would differ among layers. There are also vertical hydraulic gradients among the layers that could drive vertical flow.

The current ensemble of monitoring and pumping well water levels is insufficient to accurately predict flow paths, either horizontally or vertically. They are insufficient to accurately calibrate a numerical groundwater flow model.

Recommendation: Tintina should establish many more groundwater monitoring wells and deep piezometers, with the goal of having a minimum of three monitoring points in each formation and at each depth level within those formations that could have different properties or different gradients or flow paths. The deepest level over the entire study area must be as deep as the lower ore body because it will be dewatered and having baseline water levels and calibrated modeling at those levels is essential for estimating the effects of dewatering. Deep wells with multiple ports, individually open to each significant fracture zone that produces water on drilling, would be desirable.

The conceptual regional flow model relies on the bedrock aquifers being fault and fracture controlled (App M). The baseline report included 14 instances of the word "fractured" and 7 instances of "fractures" in the well logs (App B). Pump test solutions for fractured rock applied most often in deep well pump tests. At well PW-6N, an air test caused the well to produce very high flow, about 500 gpm (App B, p 3-6). The groundwater model report assumes that the permeability of fractures decreases with depth due to the weight of the overlying rock (App M, p 2-10), but the fractures in PW-6N suggest this assumption may be incorrect at this site (App M does not discuss this high-yielding well). Although fracture flow clearly dominates at this site, the baseline report actually does little to examine the properties of fractures (away from faults). There is apparently no geophysical logging that could yield more data on the properties of the fractures.

Recommendation: Existing wells and the needed new wells should all undergo the following geophysical logging to better characterize the fractures.

- Caliper logs should be used before casing the wells to establish the locations and extent of secondary permeability features, such as fractures and solution openings.
- Neutron or gamma-gamma logs should be used to estimate the total porosity and how it varies in the rock surrounding the wells.
- Gamma logs should be used to estimate the clay and/or shale content of the formations. Many of the logs show clay or shale and gamma logs would yield significant information on the extent of the stratification.
- Electrical conductivity logs should be used to determine saturated zone which could help to identify different flow zones and determine the levels to be monitored.

Tintina discusses the water quality and water chemistry at many of the wells in the project area. However with only an exception for the sulfide zone, they do not break the chemistry down among aquifer formation or segments.

Recommendation: Provide a breakdown by aquifer formation for the groundwater chemistry and quality and assess whether chemistry indicates the formations are segmented (little groundwater flow interconnection) or whether some of the low conductivity fault zones effectively segregates the groundwater.

Monitoring Frequency

Groundwater quality and well levels could vary temporally based on recharge events and the source of contaminants. Initial sampling frequency should be sufficient to determine this temporal variability at wells located based on an assessment of site-specific conditions. Specifically, the "appropriate sampling frequency requires a balancing of several factors including, among others ,the chemical characteristics of the contaminants of concern, distance to potential receptors, ground-water seepage velocity, solute transport velocity, the amount of historical data, and how well the contaminant plume is understood" (Wiedemeier et al. 2006, p 598). In general, small sites with shorter distances between source and monitoring point should be monitored more frequently so that plumes do not pass undetected. Initially, the seasonal characteristics should be determined with more frequent monitoring.

Springs and seeps were sampled on an annual basis (Application, Table 2-7), but the measured flows show a wide range of variability (App B, Table 6). For example, spring DS-3 has minimum and maximum flows of 4.9 and 117 gpm with an average of 38. App B Table 6 does not provide the number of observations but annual sampling beginning in 2011 suggests the maximum number of observations would be 5. These flow statistics for the springs provide very little context for the flow to be expected from the springs. It is not even known the time of year the data was collected. Seasonal variation is unknown. Statistics based on a few measurements collected annually is not a baseline.

Recommendation: Well water and spring flow should be sampled at least monthly for two years to determine seasonal variability. Based on monthly flows, it could be possible to determine a less frequent measurement regime that could be used as a baseline for analysis and future comparisons.

Aquifer Tests

The application provides the results of several types of tests intended to estimate the hydraulic conductivity of the specified formation. Application Table 2-13 presents the estimated conductivity and storativity for a set of tests for which App B presents the data. The number of rows in the table should not be mistaken as representing a separate test. Each set of observation wells (column 1) and pumping tests (column 3) represents an individual test. Some observation wells, such as MW-3, were used with more than one pumping test (PW-2, PW-9, and MW-3 slug). For each test, in most cases Tintina presents parameter data for more than one analysis method, without selecting the method which is most appropriate[4]. It is difficult to discern which tests in App B apply to which data on Table 2-13.

Recommendation: Tests in App B should be labeled with the label added to the appropriate line in Table 2-13. Also, the table should include pumping rates, duration of pumping, and formation as apropos for the presented test. This helps to access the relevant scale of the test as discussed in the next section.

Based on the number of pumping tests (column 3) there were 25 tests completed of formation properties at the site. There are approximately seven different formation types, including unconsolidated and consolidated formations, and faults, so at most the average is just over three property tests per formation type. Even if all of the tests were equally valid in providing information regarding the properties, this would not be sufficient observations to determine natural variability for the site. It certainly would not be enough to estimate flow paths. However, some of the tests represent a very small scale of aquifer and provide very little information about the overall formation, therefore they are not very useful at describing flow in the study area, as described in the next section.

Slug tests and short-term tests – scaling issues

The application contains hydraulic conductivity data provided for a few short-term and longer-term pump tests for the various formations present near and potentially affected by the proposed mine. Short-term tests represent properties over only a very small volume. In general the representative volume is the amount of water pumped divided by the effective porosity (Schulz-Makuch et al. 1999); this effectively means a sample volume including all pore spaces affected by the pumping. Figure 2 shows an example from the literature of variability for a fracture-flow media, the type of media that controls the flow at Black Butte. Hydraulic conductivity varies over seven orders of magnitude in this

[4] The Theis and Theis-recovery methods are estimates with similar assumption made on different parts of the pumping test data – during pumping and during recovery – and are appropriate to consider together.

example; Schulz-Makuch et al. (1999) present data from other fracture flow examples. The single-well tests with water removed over only a few minutes presented in App B would have volumes similar to those presented for packer tests in Figure 2. The conductivity represented in Figure 2 for those tests is about four orders of magnitude less than that observed at the point where the relation becomes stable. Becoming stable means that conductivity is relatively constant even as volume is added to the sample for which K is being estimated. This is tantamount to the relative elemental volume concept which is the volume at which the effective porosity no longer changes as volume is added to the sample (Bear 1979). However, if sufficient additional volume is added to the sample, the conductivity will again vary with volume because it will begin to include an influence from surrounding formations. From the perspective of flow and transport prediction, the small-scale measurements control local flow while the larger-scale measurements control regional flow, which can be estimated without understanding localized details. A mine that intersects and excavates significant portions of a formation affects flow at a regional level and therefore needs property measurements at that scale. Tintina presents just two large-scale pump tests that may provide a property estimate at the scale necessary to estimate the effects of dewatering.

PW-8 31-day Aquifer Test: PW-8 is completed in YNL-A shale just above the USZ, with perforations from 138.5 to 178.5 feet bgs, which spans the first zone from which water entered the well bore. PW-8 lies near the east boundary of the upper ore deposit (App B Figure 12). PW-4, 23 feet to the NE, had maximum drawdown of 6.5 feet and PW-3, 709 feet south, had maximum drawdown of 2.4 feet. PW-4 and -3 were screened from 200-239 and 90-127 feet bgs in USZ and YNL-A, respectively. This test shows a connection between the formations.

PW-9 19-day Aquifer Test: PW-9 was completed in the USZ from 215.5 to 255.5 bgs, as well as MW-3 from 285 to 305 feet bgs. MW-9 and -10 are completed above and below the USZ, with MW-9 completed in YNL-A from 108 to 128 feet bgs. There is not completion information for MW-10 in the reports. The screen for MW-9 is vertically separated from that for PW-9 by more than 80 feet, so it may not be appropriate to attribute the small drawdown in MW-9 as evidence of a lack of connection between the formations. Otherwise, there is a significant drawdown of 12.4 feet in MW03 which is 380 feet west which suggests that drawdown would propagate through the USZ.

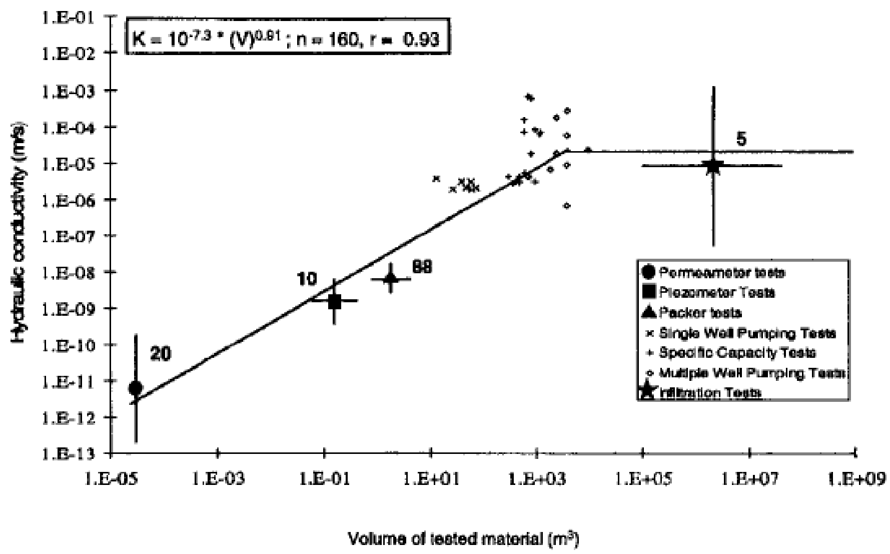

Figure 6. Relationship of hydraulic conductivity to scale of measurement in the Racine Formation of the carbonate aquifer of southeastern Wisconsin. Permeameter, piezometer, packer, and passive infiltration tests were plotted as geometric means with 95% confidence intervals; pumping tests and specific capacity data as single values. Number of observations are given adjacent to means. Passive infiltration tests are derived from the infiltration of Lake Michigan water into the Racine Formation due to the construction of a sewage tunnel. The regression line is derived from all individual values (n = 160) below the infiltration scale. The 95% confidence interval about the slope is 0.91 ± 0.06, and r is the correlation coefficient.

Figure 2: Figure 6 from Schulz-Makuch et al. (1999) showing the variation of hydraulic conductivity with volume of material used for testing. The Racine Formation a fracture-flow formation and is used here only as an example of the variability.

Recommendation: The recommendation above was for Tintina to establish many more groundwater monitoring wells and deep piezometers to improve the development of groundwater contours for all formations and all significant aquifer levels within those formations. New wells should be located also based on the need to determine aquifer properties for different formations at different aquifer levels, since properties change with depth. Tintina should perform pump tests designed to estimate aquifer properties in all flow zone identified by well logs and geophysical logs performed as recommended above.

GROUNDWATER MODELING (APP M)

The description of the formations appears accurate based on geology, but is very data limited because of the scarcity of pump-test and other formation property tests, as described above. As discussed below the lack of storage coefficient data may severely limit the ability of the model to accurately predict dewatering rates and the effect dewatering has on streams.

The basic structure of the numerical model is much too complex for the data available to parameterize it. The model has 16 layers but Tintina has not developed enough monitoring wells, performed tests or geophysical logging to adequately describe the layers. Calibration of the formation properties especially in the deeper layers occurs without any observation data. The appendix attached to App M shows the model grid and the formations in each layer. The figures should also show boundary conditions for each layer including horizontal flow barriers to help the reviewer see on which formations the streams lie and to see which formations the HFBs separate (displaying these boundaries would not clutter the figures). Also, the report does not describe or tabulate model layer thicknesses. The formations in the deeper layers, 11 to 16, are much less detailed than in shallower layers; this is common but because there is little data and these layers go well below the mine facilities it is questionable whether these layers are needed or useful.

The descriptions of the aquifer formations ignore the potential for high flow preferential flow zones including at significant depth. Several instances throughout the reports refer to high yielding fracture zones within very low conductivity formations. For example, the well passing through the Buttress Fault encountered a "fractured interval in the Neihart approximate 175 feet after passing through the Buttress fault that produced high yields and resulted in artesian flow conditions" (App M, p 2-13). There was also the high yield after testing at PW-6N discussed above. Based on scale considerations (Schulz-Makuch et a. 1999) as discussed above, these high-yielding fracture zones may be more prevalent than otherwise assumed by Tintina. Failing to consider these in the modeling would cause the model to not estimate flow paths and rates properly; a majority of flow could occur through preferential flow zones.

Recommendations: The report fails to provide various information about its structure. To adequately describe the modeling effort, Hydrometrics should add the following data or descriptions of the model structure to the report:

- The report should specify the layer thicknesses. If they vary, the report should include sufficient cross-section diagrams so that the reviewer can understand the thicknesses provided to each formation.
- The figures should show the location of the monitoring or observation wells in each layer.
- The figures should show the model boundary conditions, including the stream boundaries, HFBs, and constant head boundaries (there is just one at the upstream end of Sheep Creek).
- Layers should be combined so that there is sufficient data to support the parameterization of those layers. However, as recommended above, substantial additional data should be collected by developing additional monitoring wells and piezometers, performing additional pump tests, and completing geophysical logging to better assess the fractures and presence of clay or shale layers.

The model does not have sufficient groundwater level information to accurately describe flows in the area. The watershed-scale groundwater contour map is not unreasonable considering the available data with proper assumptions regarding topographic influences (App M Figure2-5), but it does not account for different water levels for different bedrock levels, as discussed above regarding the site groundwater contour. App M Figure 2-6 uses the site-scale contour map for contours at the site and the comments above regarding variable contours at different levels applies here. App M (p 2-18) notes the presence of flowing conditions in coreholes. Failing to conceptualize and calibrate the groundwater model with differing groundwater contours at different bedrock depths would cause the model to not accurately predict upward flow or artesian pressure.

Recommendation: Develop potentiometric maps for different bedrock levels. If there are substantial head differences among layers, develop maps of vertical gradient within the bedrock aquifers.

The conceptualization of recharge and baseflow is grossly inaccurate and leads to potentially major errors in the model calibration and predictive capacity. The model used a simple very low-flow baseflow estimate to justify the assumption of recharge being 10% of the annual precipitation (App M, p 2-25 – 2-27). Baseflow was calculated by assuming that 10% of annual precipitation becomes recharge and then becomes baseflow (App M, p 2-25). The recharge depth multiplied by basin area gives a flow estimate referred to as the baseflow estimate at various locations (Table 2-3). Thus, **rather than using baseflow to estimate recharge, Tintina assumed baseflow would equal their assumption of recharge without reference or other support**. Tintina used one flow measurement on various streams to compare to the baseflow estimates, after accounting for the difference between September and late winter flows (p 2-26). Because the adjusted flows are within 20% measurement error of the baseflow estimate, Tintina deemed it an accurate estimate of baseflow and that 10% of precipitation becomes recharge. Of course, a 20% error allows for a range in recharge of 8 to 12% of precipitation becoming recharge.

It is likely that 10% is a low estimate of baseflow because Tintina failed to account for all of the baseflow. Baseflow is not just a late season or wintertime low flow, but is always part of the streamflow hydrograph. During wet periods, groundwater may discharge to the stream at much higher rates than it does during low flow or dry periods. This simply represents the higher recharge that may be occurring near the stream during wet periods. This higher recharge reaches the stream while there is still some runoff occurring. The higher baseflow still should be counted as recharge (Cherkauer 2004). Assuming that late winter flows represent baseflow, as done by Tintina's consultants, may discount groundwater flow from parts of the watershed close enough to the river that much of the higher recharge has already drained away to the river. Baseflow should be estimated based on measured streamflow hydrographs using baseflow separation techniques, and not estimated as some low flow occurring at the gage (Myers 2016, Cherkauer 2004). The recharge then equals the total baseflow from at the site.

Recommendation: Tintina should collect sufficient surface water flow data at the various sites to do regression analyses with a nearby gage station to extend the record. Tintina should account for the effect of diversions and return flow as part of this streamflow reconstruction. Using the simulated hydrograph, baseflow should be estimated using an appropriate baseflow separation technique.

The groundwater model used recharge based on 10% of the precipitation without regard to the total amount of precipitation falling at the site. This resulted in recharge varying from 1.8 to 3.7 inches/year, depending on annual precipitation estimates which varied with elevation (higher precipitation at higher elevations) (App M Figure 3-6). App M does not provide a reference which justifies the broad assumption that 10% recharge occurs regardless of the precipitation rates. The assumptions regarding recharge totals and the distribution around the watershed, or model domain (App M Figure 3-6) are wrong for at least three reasons.

- The distribution of recharge ignores geology. App M Figure 3-6 shows that recharge is forced into the model domain based on zones of approximately equal precipitation, varying from 1.8 to 3.7 in/y of recharge. In reality, different geology types will accept different percentages of precipitation. Unfractured granite may reject almost all precipitation even at the highest precipitation rates whereas fractured carbonate rock may accept large proportions of the precipitation. The best evidence that failing to do this is an error was that initial model runs using assumed K values caused the heads to rise more than 1000 feet above ground surface (p 3-11); this occurred because the model tried to push an amount of recharge into the ground that the geology would not accept.

- The method also does not account for the general concept that the proportion of recharge as a proportion of precipitation increases with precipitation amount. This has been observed in many parts of the West (Maxey and Eakin 1949, Anderson et al. 1992) and also should simply be expected as precipitation increases through semiarid and semihumid climate zones. Ten percent could be grossly low by comparison to the method formerly used in the Great Basin (Maxey and Eakin 1949) for which precipitation zones of 15 to 20 and greater than 20 inches/year were determined to have 15 and 25% of the total become recharge.
- The method of evenly distributing recharge over an area also ignores mountainfront recharge, which is the tendency of runoff from mountainous areas to become recharge at the base of the mountain especially in drainages. Often the total from an area, as estimated using baseflow as equal to recharge, includes both distributed recharge and recharge occurring through the stream bottom. Flow relations and calibrated parameters are significantly affected by the location where recharge occurs.

Recommendation: Tintina should make more appropriate estimates of recharge as based on accurate baseflow estimates. For modeling, they should distribute the recharge accounting for precipitation, geology, and the potential for runoff becoming recharge further down the topography and closer to the baseflow measurement point.

The model used horizontal flow barriers to slow the passage of groundwater through faults which have been identified to contain gouge which limits flow across the fault. The model fails to consider the potential for vertical flow along the fault although the discussion indicates this is possible (App M, p 3-19). The discussion suggests that not simulating a higher permeability damage zone is conservative with respect to dewatering: “Since the extent and connectivity of damage zones in these other units are unknown; damage zones were not simulated in the fault zones within the model; this **results in a more conservative assessment of drawdown effects** since representing both gouge and a high permeability damage zone would effectively simulate two barriers to drawdown” (Id., emphasis added). A high permeability damage zone allows vertical flow along the fault which allows drawdown to propagate among model layers; this is not a “barrier to drawdown”. It appears simply that the model design does not accurately conceptualize the flow near the faults or the effect that faults have on the flow and therefore the numerical model inappropriately simulates them.

Recommendation: The modelers should better justify the modeling of the faults. While an HFB may be appropriate to limit flow across the fault, it is possible that the K of model cells near the HFB should be increased to allow vertical flow along the fault, unless evidence is presented to refute the idea.

Transient calibration was done by simulating the two longer-term pump tests. Therefore, the model at best can be said to be calibrated at a small scale centered on those pump test wells. The actual information content of this calibration is also minimal because the pump tests were analyzed and parameters determined. There were no more wells monitored for use in the calibration. If the transient calibration yields different parameters, the value of the aquifer tests is suspect.

- The transient calibration however demonstrated the importance of simulating transient recharge because a rainfall event caused some recovery in monitoring wells before the end of the pumping and also caused water levels during recovery to go above the levels at the start of the simulation (presumably the initial condition was the steady state water levels).
- The transient simulation for PW-8 also pulls water from Coon Creek which was not observed during the pump test. Inducing seepage could limit the predicted drawdown due to dewatering because it indicates the water table intersects the stream bottom and seepage is induced by changing the gradient through bottom of the creek, not by lowering the water level below the creek bottom. This was observed in the dewatering simulations (p 5-7). Also, the report inappropriately suggests that the "transient calibration shows the model over predicts the influence drawdown has on Coon Creek" (p 5-12).

The steady state calibration fit is not bad, but there are too few observations so confidence in the calibration should be poor. Several high residuals occur in areas with some very low residuals which indicates small scale factors control the flow in these areas. Hydrometrics correctly notes that larger residuals occur in "transition zones [which] are difficult to fully simulate in watershed scale models" (App M, p 4-9). These small scale flow factors occur in areas near the mine features so they could be important in local drawdown or dewatering prediction. Thus, these high residuals indicate the conceptual model of flow in the area is not yet accurate at a minesite scale. This is due to there being insufficient monitoring wells and/or piezometers including there being too few observations at different bedrock levels. There are also too few pump tests and geophysical logs of fractures to help define the flow at depth.

Hydrometrics credits "complex geology" and the simulation of the upper reaches of Brush Creek as connected to the regional groundwater table with causing the simulation of MW-7 and MW-8 heads low (48.9 and 35.6 feet, respectively) as compared with observed values. This is the area where there would be surface discharge of excess mine water in the south of the minesite. Hydrometrics attempted to reduce the residuals unsuccessfully by changing the properties of lower ore zone. This is probably another location where the scale of the model is just too large to accurately simulate the flow details. Hydrometrics chose to leave "Brush Creek's upper reach … in the model as a conservative approach to evaluating potential effects from mine dewatering on surface water resources near the mine workings" (App M, p 4-10). Whether this conceptualization is "conservative" depends on whether simulating seepage from the creek is important because simulating the stream as a flux boundary allows water to enter the model domain and maintain the water level which would prevent the expansion of a drawdown cone beyond Brush Creek.

Hydrometrics predicts that the "quantity of water necessary to offset depletion effects is assumed to be equal to the consumptive use of the project (210 gpm)" (p 5-20). This of course assumes perfection in the water balance analysis (reviewed in the next section) and that water applied to the infiltration basins returns to the stream system undepleted. The report and presentation of model results does not provide evidence supporting that conclusion.

Recommendation: The following are needed to provide evidence that the infiltration basins are replacing water to the creek that had been lost:

- A MODPATH analysis should be completed to show flow paths and rates from the infiltration basins to their final destination and demonstrate at least in the model whether that is the stream system.
- There should be a detailed water balance analysis for the model domain around the infiltration basins to show the directions and rate the model predicts the flow will go. This would show also whether the infiltrated water goes deep and is pumped for dewatering again.
- The report should show a seepage by stream reach length graphic to show exactly where seepage enters and leaves the streams. Based on the location of the infiltration basin, seepage would enter Little Sheep Creek or Sheep Creek upstream of the point at which dewatering would induce seepage.

The sensitivity analysis (App M Section 6) shows expected results, including that increased K leads to increased dewatering. The most important observation is that increases in storage coefficients lead to an increase in the dewatering rates (App M, p 6-6). This is important because few of the pump tests provide information regarding storage coefficients and the transient calibration is too small-scale and short duration to provide adequate information about the storage coefficients. This essentially supports the discussion regarding the baseline data that there are far too few monitoring wells for adequate calibration and far too little long-term pump test data.

The sensitivity analysis shows how property changes could affect dewatering rates but fails to assess the effects on streamflows. High storage coefficients mean that more groundwater is removed from a given area for a given drawdown. If the drawdown still propagates to the streams the higher storage capability could cause more water to be drawn from the creek. This further demonstrates the need for improved storage coefficient data. It is also not acceptable to suggest that a "conservative" storage coefficient could be used for predicting impacts because storage coefficients affect the amount of dewatering and the linkage to the streams in complicated ways.

WATER BALANCE MODELING (APP L AND APP K)

The application discusses water management in several locations, including section 3.7 with a water balance specifically discussed in section 3.7.2, App L which is titled "Water Balance – Surface Water Transfer to Water Treatment Plant, and App K which generally describes mine processes including Water Management in Chapter 10 with section 10.1 covering water balance and an Appendix D titled Site Wide Water Balance. The document in App L is the same as that in App K Appendix D. None of these documents have sufficient data regarding water balance to adequately review it or have confidence that the proposed mine will not require more water than generally reported here.

The reports should present tables that show by year the amount of water used for processing and the water needed to start the process. The flowchart for year 6 (App L Figure 2) is relatively self-explanatory, except it refers to 3,972,000 m^3/y of reclaim water going from the process water pond (PWP) to the mill and 3,807,000 m^3/y of thickener overflow going from the mill to the PWP. Application Table 3-21 shown as a component in the mill process water balance ranges of 938,000 to 4,107,000 and 979,000 to 4,286,000 m^3/y for thickener overflow and required water from the PWP, respectively. The terms are not explained but obviously these values almost balance each other and the back and forth flow represents recycling; some actual water parcels may pass back and forth many times during a year. The reports do not answer the question of where this water is produced initially. The amount of water that is in circulation appears to be much more than the amount pumped. The application is deficient in explaining the sources of water to be used in the water balance.

Recommendation: Provide more and better detail of the mine site water balance to better assess where process water will be obtained and when. A specific explanation of the up to 4,286, 000 m3/y is needed.

WETLANDS

This review did not focus on wetlands as regards classification. However, the application notes that the wetlands near Sheep Creek and Little Sheep Creek are “sub-irrigated” (p 56) and that the hydrology in wetlands near tributaries to Sheep and Little Sheep Creek are “primarily groundwater driven” (Id.). This indicates the wetlands tend to be groundwater discharge points. Wetland categories I and II include groundwater recharge/discharge as important uses.

The application fails to collect sufficient groundwater data to establish baseline water levels for the wetlands, even though the application acknowledges the importance of groundwater to the wetlands. The annual sampling of field parameters in nine seeps (Table 2-7), which coincide with wetland areas, is not a substitute. In addition to monitoring of the wetlands, groundwater level monitoring in the wetlands would help to assess surface water/groundwater interactions. Without groundwater level data to assess gradients, the discussion regarding groundwater discharge to the streams (p 52 & 53) is mere speculation. The application should include sufficient shallow groundwater monitoring wells within the wetlands to assess natural groundwater level variability. Monitoring points should be established on a grid throughout the wetland zone.

Figure 2.9 shows that wetlands along Sheep Creek were assessed only within the project boundary. The survey misses obvious wetlands along a very meandering section of Sheep Creek just north of the primary access road to the project area.

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