APPENDIX A

Technical Memorandum 1

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To: Montana Department of Environmental Quality

From: Environmental Resources Management

Date: December 29, 2017

Subject: Black Butte Copper Project - Whether there is an advantage to increasing the cement content in tailings placed in the impoundment and underground workings

INTRODUCTION

The basis for this technical memorandum is the Mine Operating Permit Application (Tintina Montana, Inc. 2017) submitted to the Montana Department of Environment Quality on July 14, 2017. That document is referenced in the body of this memo as “MOP”, with the particular section and page numbers as appropriate.

BACKGROUND

PRODUCTION MINE WORKINGS

During mine operations, the production workings (stopes) would be backfilled with cemented tailings, pumped and piped as a paste to final placement. Over the life of the mine, it is expected that the process would place 5.8 million tons (MT) (45percent of total tailings). The stopes would be extracted and then backfilled. The backfill would be pumped in two or more blocks as shown in the MOP (Figures 3-4, 3-5, pp. 145, 146), allowing reasonable handling and complete placement along the horizontal length of each stope. The backfill is pumped to refusal, with complete contact across the sill (floor) and the ribs (walls).

Adjacent stopes are taken only after the fill has set and reached its projected 28-day strength. Typically, this entails a multiple-pass sequence where primary stopes are bounded by virgin ground on both ribs (sides), and secondary stopes have either one or both ribs comprised of previously placed backfill.

In the designed overhand scheme, the stopes are taken from the bottom up. An entire sublevel, or significant amount thereof, is mined and backfilled before mining proceeds in the overlying stopes. The overhand stopes are mined with the working sill (floor) being the previously placed and hardened cemented backfill. When backfilled, the new fill is placed across that subjacent fill, assuring intimate contact and support with no air gap between fill levels.

CEMENTED TAILINGS FACILITY

During mill operations, the cemented tailings facility (CTF) would be filled with both waste rock from the mine development phase and with cemented tailings. The waste rock would be used in the construction of a drain blanket and sump before the tailings are placed. Waste rock also would be used in constructing a vehicle access ramp within the lined basin. In total, approximately 770,000 tons of waste rock would be placed in these areas. Across the life of the mill, a total of 7.1MT of cemented tailings (55 percent of total tailings) would be placed in the CTF.

The CTF composite underliner would include foundation drains, engineered fill subgrade bedding protective layer, double underliner (geotextile-high density polyethylene (HDPE)-geotextile-geonet-geotextile-HDPE-geotextile), engineered fill protective layer, and waste rock drainage layer (MOP Figure 3.33, p. 248).

Following placement of the cemented tailings within this lined basin and upon initiation of closure construction, the composite overliner would be installed directly on the cemented and hardened tailings. That closure system would include the primary overliner (geotextile-HDPE-geotextile), engineered fill protective layer, excess construction or fill material, subsoil, and topsoil (MOP Figure 7.3, p. 418).

CURRENT MOP

The proponent proposes to mix thickened tailings with cementitious binder(s) to create cemented tailings paste. The underground paste will be mixed to a 4-percent cement content and pumped to final placement in mined-out stopes. That would entail approximately 232,000 tons of binder across the life of mine. The tailings scheduled for surface placement would be mixed to 0.5 to 2 percent cement content and pumped to final placement in the CTF. That would entail up to another 142,000 tons, for a total of 374,000 tons of binder across the life of the mine.

The variability in cement content is projected to comport to operational requirements at the time, as well as with tailings properties, which may vary depending on ore characteristics. Operational flexibility in cement content is recommended to allow optimizing performance in pumping and final behavior.

The selected cement content ranges are based on the distinct requirements for each final placement area. The cement contents have been developed through extensive bench tests run on exploration samples (MOP, Section 3.3.2.5, pp. 166-168; Section 3.5.9, pp. 205-211). The proposal to continue further testing follows prudent practice for all long-term engineering and construction. That allows changes to accommodate varying ore and tailings characteristics, as well as changes in binder and admixture sources and requirements.

CONSTRUCTION ISSUES

Overall, both paste backfill and paste surface deposition are readily constructible. Tailings in cemented paste systems are common in the mining industry.

Pumpability of the cement paste is critical for the success of this method. A long set or flash time can be critical in maintaining pumpable flow. Low to moderate cement contents are a primary means to achieve pumpability and avoid system upsets. Rheology and strength testing has been conducted to support the selected cement contents.

These investigations include consideration of admixtures of fly ash and/or slag. Typically, these are used to reduce cement requirements, but they also can provide benefits such as improved pumpability and sulfate resistance. Tests of specific materials establish their utility, and the proponent is investigating their suitability and availability. Type C and F fly ash and a suite of possible slag sources are under review.

Chemical retarders can be added during mixing as means of achieving and maintaining pumpability with high cement content. These do lead to process complications, which must function to maintain operability. In addition to increasing costs, the added complexity elevates risks of system upsets.

Normal mine and mill operating practice is to assay and evaluate the tailings for varying chemical characteristics. That will allow adjusting binder, admixtures, and chemical agents to optimize the mix and assure consistent and desirable properties. One aspect is to monitor pyrite to avoid excessive exothermic reactions whether underground or in the CTF (Landriault 2001; Beamish & Theiler 2016).

EIS ENVIRONMENTAL ISSUES

CEMENTED BACKFILL COMMON USAGE

Cemented backfill is a common and proven concept for a wide range of mining methods and applications (CIM 1978; Crandall 1992). It has been used underground in coal, industrial minerals and metal mining for decades, domestically and internationally (Hassani et al. 1989; Stone 2001).

Hydraulic backfill has a long history and is common and proven across a number of commodities and mining methods. The first hydraulic backfill documented was at a coal mine in Shenandoah, Pennsylvania in 1864 (Crandall 1992) with the goal of controlling subsidence beneath a church foundation. The paste fill now common in underground mining is an evolution using modern pump characteristics and material science, with a primary intent to minimize the amount of water required to transport the cemented media.

There are challenges in handling high-sulfur materials, but many base-metal mines are so characterized and have been using mill tailings as the basis or major components of their fill systems (Landriault 2001, Palkovits 2010). It is not expected that the addition of cement to tailings would completely buffer the acid-generating potential of the tailings (Bertrand et al. 2000). That said, the physical contributions of cementing the material minimize infiltration and the release of contained water, contributing overall to positive environmental performance of cemented backfill.

Black Butte Copper tested paste backfill with 2 and 4 percent cement. These are reasonable take-off levels and fit with Carlin-type geologies, where host rocks are characteristically pyrite-rich silty limestone or limey siltstone (Cline et al. 2005). Those tailings are characteristically pyrite-rich, and the backfill mix ranges are reasonably applicable to the Black Butte Copper Project.

In paste, the 20-micron particle size seems to be more critical to performance than binder content, in that an envelope of fines is necessary to assure consistent paste flow (Landriault 2001). That said, binder is important as if it sets too soon – paste does not move rapidly – the entire process halts. Generally, an overhand design does not require the strength of an underhand, and the cut and fill geometry requires only a 16-foot-tall rib rather than the 50- to 150-foot-tall ribs common in long hole open stopping. Suitable rheology – maintaining Bingham or pseudoplastic flow behavior – is a driving goal in paste fill methods. The 30-micron grind of the Black Butte ore would assure sufficient percentage of 20-micron particle size fraction to maintain desired paste flow conditions.

UNDERGROUND-PLACED CEMENTED BACKFILL

Historically, backfill has been primarily a ground control technique to allow safe mining and avoid surface subsidence. Uncemented and cemented fill has been used with the aggregate or ground ranging from mine waste rock, quarried rock, or sand and mill tailings. Coarse-grained fill typically is transported by haul trucks and worked to final placement with construction or mining equipment. Fine-grained fill typically is transported either by transit mixers or through pipelines, using boreholes where applicable.

In recent decades, the use of mill tailings has become more common as a full-circle means for disposing them underground rather than in typically large surface tailing impoundments. A given volume of rock or soil expands when fragmented through excavation. Due to the increase in void ratio, commonly termed “swell” (USBM 1968), not all the tailings can be returned to the original underground space, and a third or more of the mass will require storage elsewhere.

The proposed Black Butte Copper Project appears to combine the best of both these proven techniques. The ore, now processed to cemented tailings, would be returned underground. The balance of tailings that would not fit underground would be cemented and placed in a modern environmental containment facility. Like the underground fraction, the solidification would render the mass relatively inert chemically as compared to uncemented tailings. Being cemented, the tailings would behave mechanically as a rock formation rather than a substantially saturated soil mass.

SURFACE-PLACED CEMENTED TAILINGS

Though some mineral assemblages in some tailings are cementitious, mixing cement into tailings prior to surface storage is a relatively new and still-innovative technique. It follows logically from the mechanical and environmental benefits of dry-stacked and subaerially-deposited tailings. Those techniques use dewatering and densification to increase the mechanical qualities of tailings while reclaiming significant amounts of tailwater for recycling into the milling process.

The mechanical quality improvements essentially include increasing cohesion and friction angle with a commensurate increase in resistance to seismicity, with or without impounding embankments.

With the adoption of common concrete mixing equipment to the tailings handling process, the proposed CTF would further extend the reliability and robust nature of both operational placement and long-term storage of the tailings. Rather than storing a mass that may be subject to liquefaction, the CTF would hold a solid cement mass.

During operation, the susceptibility of the placed and set cement to both water infiltration and release of contained moisture would be lower than uncemented tailings. Since the contained moisture potentially would carry metals and salts, the cementation provides a desirable environmental benefit in chemical as well as mechanical terms.

The CTF would have a composite underliner during operation. During the closure phase, a composite overliner would be added and welded to the underliner where the liners meet along the perimeter of the facility. These robust containment systems further protect the environment from a solid mass of concrete, which would have minimal water available for release.

POTENTIAL DEGRADATION OF CEMENTED MATERIAL – WATER QUALITY CONSEQUENCES

Sulfate Attack

Sulfate attack is an expected form of degradation given the tailings mineralogy. Sulfate attack generally presents as either external or internal (DePuy 1994). External is when sulfates originate from groundwater or are leached from soils. Internal is when sulfates are present in the aggregate (i.e. tailings), or sulfates dissolve in the mix water, additives, and admixtures. The predominant form of sulfate attack on the tailings is internal.

The cemented backfill is not expected to deteriorate hydrologically or structurally under anoxic conditions. The fill would not be exposed to cyclical wetting and drying, which induce repeated sulfate attacks progressing to significant deterioration. Those cycles typically are associated with conventional construction of infrastructure and buildings, with surface and meteoric phenomenon being the principal setting.

Further, due to the sequential construction (local geometry) and overall geometry, the cemented backfill would be physically constrained from expansion, thus minimizing cracking.

The cemented tailings deposited in the CTF are not expected to deteriorate significantly. Due to the essentially continuous layered flow of cemented paste into the CTF, repeated wetting and drying cycles would be localized in the area and few in number. Due to its own mass and confinement of the lower portion, significant crack propagation from deterioration is not expected within the CTF mass. Coupled with its operational liner and closure encapsulation, groundwater degradation is not expected.

Whether potential sulfate attack is external or internal in each setting (i.e., underground fill or surface CTF), there are established tests and procedures for estimating and evaluating performance (DePuy 1994; MOP Section 3.5.9.3, p. 206). Not all cracking is deleterious, as some reaction products simply fill the cracks, retaining hydrologic and even structural integrity. By the same token, in both settings potential reduction of structural strength from sulfate attack is not a system failure. The underground cemented tailings would remain substantially incompressible and a strength reduction would not induce failure of surrounding rock into the backfill mass. The surface cemented tailings would be fully contained within the CTF basin and require little structural integrity. The embankment stability analyses are acceptable during construction, operation, and closure, considering a full floodwater pool during the final two phases (MOP, Section 3.5.5.4, pp. 192-194).

The waste rock (MOP, Section 2.4.2.2, pp. 80-81) will be encapsulated within cemented tailings in the CTF to remove that material from potential degradation of water quality.

Arsenic Mobilization versus Cement Content

The underground cement content of 4 percent is not expected to significantly offset the pyrite contents, which are expected to be consistently much higher in the tailings. Thus, it is not expected that the cement content would drive the pH into ranges where arsenic mobilization is significantly increased (Zaman 1985). If local (small quantity) underground construction-grade concrete or grout – both requiring high cement content – is planned using tailings as the aggregate, numerous analyses provide guidance in treatment of arsenic (Reddy and Ramachandran 2005).

CONCLUSIONS AND RECOMMENDATIONS

PROPONENT PROPOSES APPLICATION OF PROVEN TECHNOLOGY

Cemented backfill is a proven and common technology in underground mining. The extension to a CTF on the surface is practical, logical, and combines positive elements of underground and surface tailings management practices. To date, the testing regimen supports the selected cement content levels and does not indicate a need for or benefit from increased cement contents.

CONFIRM BMPS

The proponent presented best management practices (BMPs) throughout the MOP as benchmarks for design and operation. BMPs proposed for the use of cemented backfill include geological engineering analyses, hydrologic modeling, ongoing material property testing, and diligent monitoring to confirm closure with design assumptions, compliance standards, and goals.

REVIEW SYSTEM OPTIMIZATION POTENTIALS

Varying Ore Characteristics

The ore, and subsequently tailings, are expected to vary between and within the Upper and Lower Zones. Diligent sampling and process controls optimize copper recovery. These include tailings analyses, which can then be used to optimize cemented tailings preparation and handling. Rapid sample turnaround can inform mix arrangements and fill scheduling. Treating backfill and tailings management as fundamental aspects of mine and mill management, which they are, go a long way toward optimizing both short- and long-term mining and milling processes.

Available Binder Media

The proponent has identified a number of sources for available binder media. With standard tests and comparisons, the possible sources can be characterized, ranked, and selected with confidence. Both short- and long-term behavior can be incorporated in the selection process, with possible distinctions between underground and surface applications. It is prudent to initiate selection based on drill hole samples, but contingent (6 months) or conventional (1 year) selections can be developed with actual milling experience.

In these discussions, admixes such as fly ash and slag must be considered. In addition to potential cost reductions, these materials may improve performance under short- and/or long-term sulfate attack and other phenomenon characteristic to mine backfill and tailings storage applications.

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