PIT BACKFILL: YEA or NAY, A MONTANA EXAMPLE[1]

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Abstract: Following a complex legal history after a permit expansion in 1990, a Montana District Court ruled in 2002 that the Golden Sunlight's reclamation plan must include backfilling the pit in compliance with the Montana State Constitution and the Metal Mine Reclamation Act. The Golden Sunlight Mine submitted a proposed partial pit backfill plan in December of 2002. This presentation will detail the analysis and conclusions of the detailed studies that were undertaken to evaluate the impacts of backfilling the open pit at the mine with 33 million tons of acidic waste rock.

[1] Paper presented at the 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, 2006, St. Louis MO. R.I. Barnhisel (ed.) Published by the American Society of Mining and Reclamation (ASMR), 3134 Montavesta Road, Lexington, KY 40502

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7th International Conference on Acid Rock Drainage, 2006 pp 2397-2410
DOI: 10.21000/JASMR06022397
https://doi.org/10.21000/JASMR06022397

Introduction

The backfilling of pits created by large-scale open cut mines can be an emotional issue. Open cut mines can leave extensive scars on the landscape, and can have related long-term environmental and visual impacts. These issues are highlighted when the mine waste is highly acidic and the site is immediately adjacent to a major river system and highway. This paper details how this issue has unfolded at Placer Dome's Montana Golden Sunlight gold mine.

History and Background

The Golden Sunlight Mine is a Au mine located approximately 50 kilometers east of Butte, Montana in Jefferson County at the southern end of the Bull Mountains (Fig. 1). The mine is immediately north of Interstate 90, a major east-west through fare and is highly visible from the highway (Fig. 2).

The Golden Sunlight Mine (GSM) is operated by Golden Sunlight Mines, Inc, a wholly owned subsidiary of Placer Dome U.S., Inc. itself a subsidiary of Placer Dome, Inc. a Canadian Company. GSM mines and processes ore and waste from private land and federal lands administered by the U.S. Bureau of Land Management (BLM) as well as state lands administered the Montana Department of Natural Resources and Conservation. The mine is permitted jointly by the Montana Department of Environmental Quality (DEQ) and the BLM.

Early mining activity in the area was carried out in the late 1800s and early 1900s. Extensive exploration was conducted in the 1960s and 1970s. GSM began major operations in 1982 following preparation of an Environmental Impact Statement (EIS) in1981. In March 1988 GSM applied for a permit for a major expansion extending the mine life to 2003.

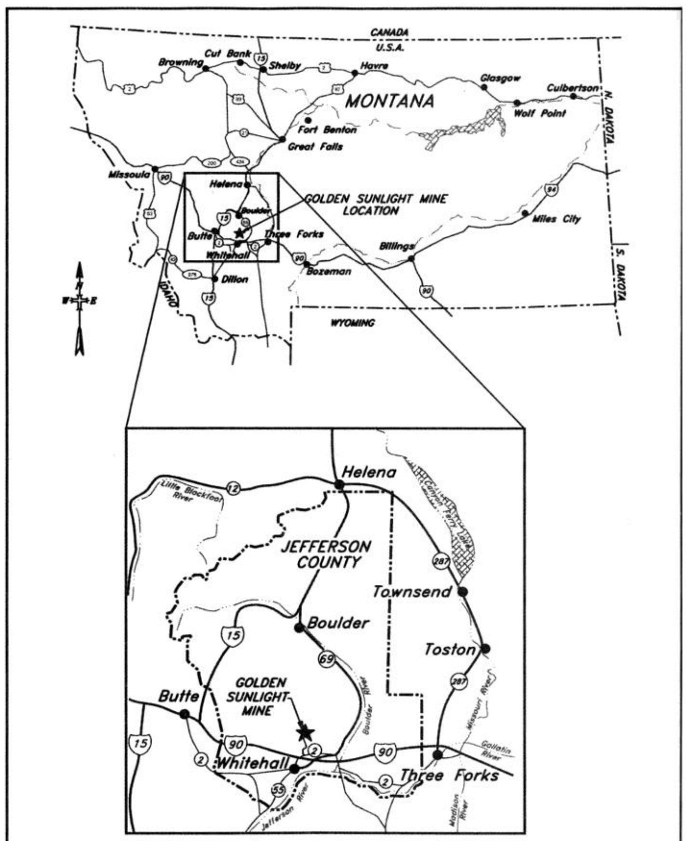

Figure 1. General Location of the Golden Sunlight Mine, Montana.

This expansion was permitted as Amendment 8 to the Operating Permit in July 1990 following preparation of an extensive Environmental Assessment (EA) (DSL and BLM, 1990).

Figure 2. A telephoto view of Golden Sunlight Mine viewed from I-90 Southeast of the mine.

Golden Sunlight Mine is a conventional truck and shovel mine moving as much as 23,000 tonnes of waste and 7,300 tonnes of ore per day from a nearly 600 meter deep open cut (Fig. 3). Waste from the open cut has been placed in constructed dumps west, south and east of the pit. The west and south dumps, totaling over 200 hectares have been reclaimed. The east dumps remain active (Fig. 3). The ore is milled using a vat cyanide (CN) leach process with the tailings going to the second of two tailings impoundments. The first tailings impoundment was reclaimed in 2000. Underground mining below the pit was undertaken from 2002 to 2004.

The ore body is a breccia pipe in the late Precambrian host rocks of the Belt Supergroup (LaHood, Greyson and Newland formations). The breccia pipe is an irregular 250 meter oval and dips to the southwest. It is cut through and bounded principally by a highly complex series of north, south, east and northeast trending high angle faults (Foster and Chadwick, 1990; Foster and Smith, 1995). The top of the breccia pipe has been offset to the east by the Corridor fault and a gentle anticline. The breccia pipe includes disseminated Au-bearing sulfide mineralization, including pyrite and minor tellurides. Stockworks extend more than 30 meters into the wallrock.

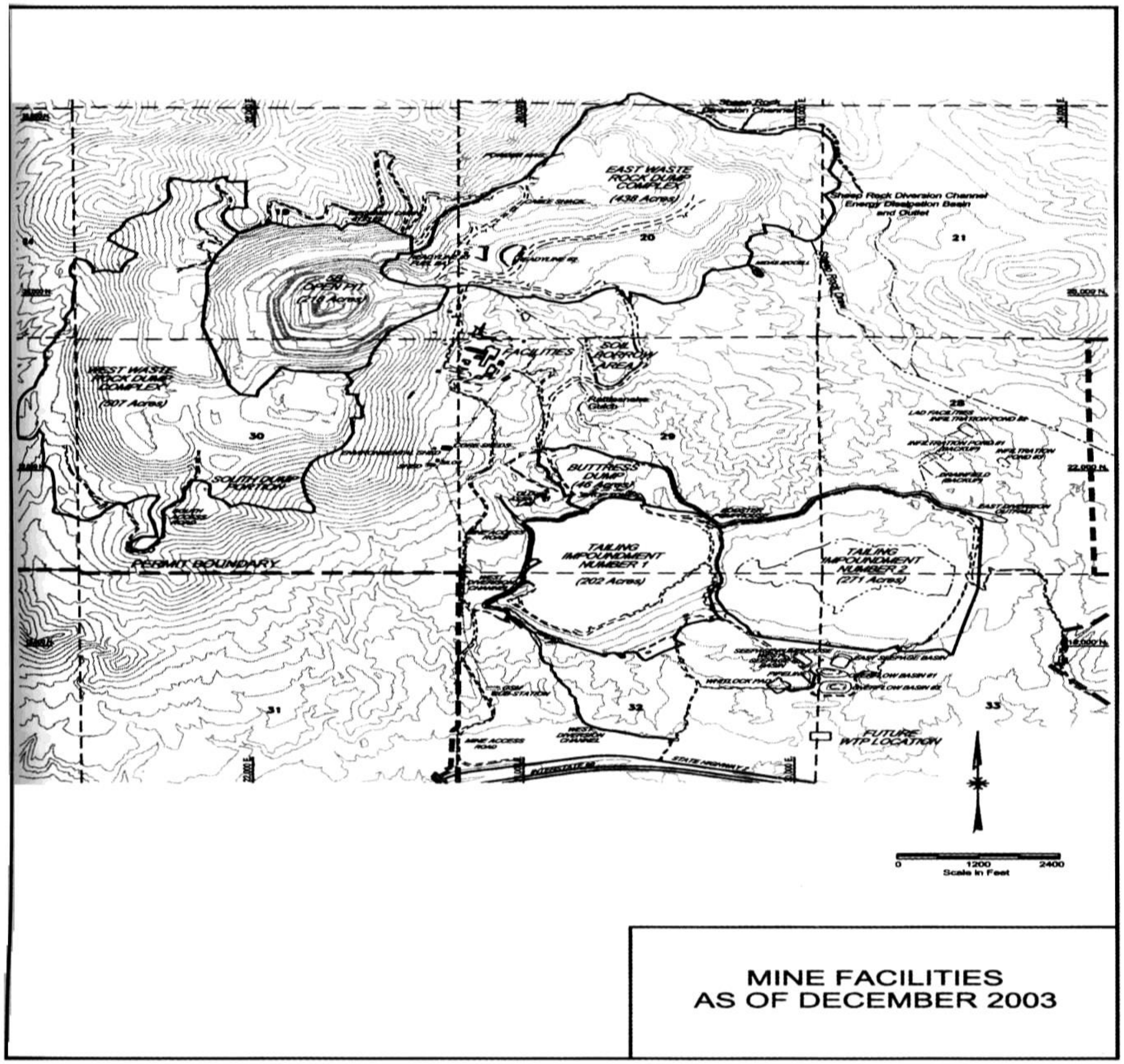

Figure 3. Mine Facilities, Golden Sunlight Mine, Montana. (Contour interval 50 ft.)

The wallrock itself is hydrothermally altered containing sulfides, principally pyrite. Northeast trending Au-quartz veins are superimposed on the entire complex and are predominantly pyrite, with very rare galena, sphalerite and barite. This highly complex geology and the presence of extensive sulfides highlight the environmental concerns regarding acid rock drainage (ARD) at the site. Waste rock at the site is highly acidic with pH values ranging from 2.0 to 3.0 in samples collected from pore waters in waste rock; SO_4^{-2} values can be as high as 30,000 mg/L with associated high Fe values (Telesto, 2003b). The mine currently dewaters at the rate of approximately 114 L/m. All reclamation alternatives envision long term water collection and treatment of the acidic waters characteristic of effluent from the pit and waste dumps at GSM.

The areas east and west of the Bull Mountains consist of Tertiary valley fill sediments. Because the pit opens to the east, and the mine facilities are located below the pit, the geology east of the mine is of critical importance regarding potential ARD flow pathways. The geology here includes the Tertiary Bozeman Group sediments up to 500 meters thick (Hanneman, 1990). The Bozeman Group includes a wide variety of lithologies, including, clays sandstones and carbonates. In the vicinity of the mine, the unit includes lithologies characteristic of the higher energy environment one would expect to find adjacent to the ancestral Bull Mountains. Fluvial and alluvial facies present here form a complex link of loosely interconnected channels and higher permeability zones. Superimposed on this assemblage are late Tertiary mass-wasting deposits including landslide and debris flows (Golder, 1995). To the south of the mine Quaternary alluvial deposits of the Jefferson River alluvial system connect directly to some of the flow paths in the Bozeman Group. Highlighting the complexity of the geology around the site, historic ferricrete deposits are found, south, east and west of the mine associated with many of the springs surrounding the mine site (Gallagher, 2003; Taylor 1997; HSI, 2003). These deposits are evidence of pre-mining ARD at the site and can be important indicators of potential pre-existing flow paths and geochemistry. Historic ARD may have consumed potential neutralizing capacity along flow paths, complicating future environmental concerns. The general concerns regarding flow paths and characteristics in the Tertiary and Quaternary systems are critical to any discussion of pit backfill and are discussed below.

A Complex Legal History

Following the approval of the Amendment 8 expansion in 1990 a complex legal challenge began with groups opposed to the mine initiating legal action against the mine and the agencies based on the failure to select a backfill alternative in the 1990 Environmental Assessment (EA). Initial legal action consisted of an appeal of the permit approval to the Interior Board of Land Appeals (IBLA), an Interior Department administrative review body, based on the BLM's approval of the plan. IBLA largely upheld the BLM's decision (IBLA 90-537) and the five environmental groups (National Wildlife Federation, Montana Environmental Information Center, Gallatin Wildlife Association, Mineral Policy Center, and the Sierra Club) then initiated legal proceedings in state court. The plaintiff groups alleged that the approval violated the Montana Metal Mine Reclamation Act (MMRA) and the Montana Constitution and an Environmental Impact Statement (EIS) should have been prepared rather than the 1990 EA. On September 1, 1994 the Montana District Court ruled in favor of the plaintiffs stating among other things, that an EIS should have been prepared. A judgment was entered with the plaintiffs resulting in the submission of a revised reclamation plan and DEQ and BLM would prepare an EIS. The various legal maneuverings lead the Montana legislature in 1995 to attempt to provide standards for the reclamation of open pits. The new EIS process began in October 1995, with DEQ and BLM authorizing an Interim Mine Plan with the concurrence of the plaintiffs so GSM could continue mining during the preparation of the EIS. The Draft EIS was completed in November 1997 (DEQ and BLM, 1997). The Draft EIS was followed by the Final EIS in April 1998 (DEQ and BLM 1998a) and a Record of Decision in June 1998 (DEQ and BLM, 1998b). DEQ and BLM attempted to apply the factors laid out by the legislature in 1995 and selected the No Pit Pond Alternative in approving the mine expansion. A Partial Pit Backfill was not analyzed in detail and was not selected.

In a February 2000 decision the District Court found that DEQ erred in attempting to use the factors laid out in the legislation and should have selected the Partial Pit Backfill Alternative.

In 2000, the Montana Legislature again attempted to amend the open pit reclamation provisions of MMRA. DEQ subsequently determined that the No Pit Pond Alternative met the requirements of the 2000 legislation. The plaintiffs responded by challenging this new determination.

In March 2002 the District Court held the 2000 Amendments to the MMRA were unconstitutional because they did not comply with the Montana Constitution, which required that "all lands disturbed by the taking of natural resources shall be reclaimed. The District Court ordered DEQ to begin implementation of the Partial Pit Backfill Alternative in accordance with the MMRA.

In September 2002, BLM notified DEQ that the Partial Pit Backfill may result in "unnecessary or undue degradation of public lands" due to the disturbance of reclaimed lands on BLM to provide pit backfill material. BLM stated that before the Partial Pit Backfill can be selected BLM must prepare a supplemental review under the National Environmental Policy Act (NEPA).

In October 2002, DEQ ordered GSM to submit a modified partial pit backfill plan. GSM submitted a proposed partial pit backfill plan in December of 2002. It is this plan that triggered the current Supplemental Environmental Impact Statement (SEIS).

The 2003 legislature, ever mindful of the legal maneuverings on this issue, once again attempted to provide language in the statute giving the DEQ the flexibility to not backfill pits if backfilling is not "appropriate under the site-specific circumstances and conditions". This language has not been tested in court, yet.

Current (December 2002) Supplemental Environmental Impact Statement

The plan submitted by GSM in December 2002 included the following provisions:

- A key cut on the east side at 1630 meters (5350 feet) establishing the minimum backfill required to creating a free draining backfilled pit.
- A final pit depth of 1380 meters (4,525 feet).
- All waste would be hauled from the East Waste Dump Complex. The west and south dump complexes would not be a source of backfill material. Approximately 45 million tonnes of waste would be moved to backfill the pit.

- Cast blasting and dozing would be used to reduce slopes in the upper pit highwall to limit the amount of backfill material required.
- 30 meters (100 feet) of crusher reject material would be placed in the bottom of the pit to aid in water collection and pumping.
- Four dewatering wells would be drilled and used to maintain the pit as a hydrologic sink. These wells would be maintained, redrilled and used as long as necessary to meet water quality requirements.

The backfilled pit would use the same one meter cover soil and reclamation requirements developed for the East Waste Rock Dump Complex. Following completion of mining and reclamation activities GSM will maintain ownership of the site, potentially making portions of the site available for post-mining land uses, if compatible with the reclamation objectives. The provisions above became the proposed action.

The SEIS was designed to look specifically at the issues related to pit backfill. Issues unrelated to pit backfill remain adequately covered by the 1998 EIS. Because of the extensive controversy surrounding the pit backfill issue an extensive public participation process was developed. A public scoping meeting was held in Whitehall near the mine was held on July 16, 2003 and 75 comment letters were received by the agencies.

The agencies felt a more substantive approach to issue evaluation and alternative development than a simple scoping meeting was needed and turned to the Multiple Accounts Analysis (MAA) process (Robertson Geonconsultants, 2003). The MAA process is a means of identifying issues and comparing alternatives by scoring the effects of different alternatives using a consensus process to identify where there are clear delineations in the effects of differing alternatives. The participants in the MAA process included representatives from the agencies, GSM, the Environmental Protection Agency (EPA), the plaintiffs, and Spectrum Engineering (the SEIS contractor), and Spectrum's subcontractor, Robertson GeonConsultants. This group consisted of technical staff and formed the Technical Working Group (TWG). The TWG met several times through 2003. While the MAA process and the TWG meetings were instrumental in identifying technical, environmental, socioeconomic, and economic issues and alternatives, ultimately the group did not reach consensus. Complex issues that could not be resolved through the MAA process included geotechnical issues regarding pit wall stability and a range of environmental issues related to ultimate groundwater quality and fate following pit backfill. Pit wall stability is unlikely to be a long term geotechnical or environmental issue because of the nature of the rocks and structural elements in the pit (Telesto, 2003c). The zones of structural weakness are well known in the pit and the rocks in the pit, being well indurated weakly metamorphosed clastic sedimentary rocks, are likely to be subject only to raveling and physical decomposition. Comparisons to other pits developed in rocks subject to both physical and chemical weathering are not accurate. The ultimate quality and fate of groundwater in a backfilled pit however is a major concern and it is this issue that will be explored more fully.

Alternatives Evaluated in the Supplemental Environmental Impact Statement

No Action Alternative

The No Action alternative is the No Pit Pond alternative analyzed in the 1998 EIS. This alternative did not propose or evaluate pit backfill.

Partial Pit Backfill With In-Pit Collection (GSM Proposal, as ordered by state court):

This is GSM's proposal, as ordered by the court, as discussed above. The pit would be backfilled with up to nearly 300 meters of acidic waste material from the East Waste Dump Complex. This material would not be amended. Additional features of this proposal include backfilling of portions of the underground mine and a proposal for up to 270 (800 ft.) meter dewatering wells to limit water in the backfilled acidic waste material. Fifty seven L/m would be pumped from the backfilled pit.

Partial Pit Backfill With Downgradient Collection

The pit backfill and the underground mine closure would be the same as in the first alternative. This alternative avoids the problem of having to maintain deep wells in the acidic pit backfill by instead relying on a series of collection wells in native ground below the pit. Water in the pit would be allowed to equilibrate to something close to its pre-mining level. Twenty-six new wells would be added in addition to the existing series of wells below the decommissioned Tailings Impoundment I. Sixty L/m of pit seepage would need to be captured, which would require the collection of from 100 to 400 L/m of additional ambient groundwater.

Underground Sump Alternative

The underground sump alternative is similar to the No Pit Pond Alternative (Current No Action Alternative) evaluated in the 1998 EIS except no backfill would be placed in the pit and the underground workings would be improved and maintained for continual pit dewatering. There is no proposed timeframe for termination of pumping and treatment and a financial guarantee is in place to assure treatment in perpetuity, if necessary. One hundred and twenty L/m would need to be pumped and treated on an annual basis under this alternative.

Alternatives Considered But Dismissed

Three alternatives were considered but dismissed due to technical or environmental concerns that placed them outside the scope of achievable technology:

Partial Pit Backfill Without Collection Alternative

This alternative was similar to the backfill alternatives considered in detail, but no water would be collected and treated in an attempt to avoid long-term water treatment. Natural mixing and attenuation would be relied on to meet water quality standards. A detailed evaluation of the potential flow paths and attenuation showed that primary groundwater standards for several metals would not be met for this alternative (Telesto, 2003a).

Partial Pit Backfill With Amendment Alternative

This alternative was another attempt to avoid or limit long-term water treatment by mixing in a sufficient amount of lime or $CaCO_3$ at the rate of approximately 200 tonnes per 1,000 tonnes of mine waste. The lime would be added as an engineered feature in controlled 0.7 meter lifts and then ripped to assure mixing. This alternative had a fairly high level of worker safety risk and also a high level of environmental uncertainty. Some level of groundwater risk remained with this alternative and that, coupled with the other elements of uncertainty lead to its dismissal from further consideration.

Pit Pond Alternative

This alternative would have created a pit pond with biologic mitigation. While there has been some preliminary work that suggests this might be a viable alternative at GSM, there were too many uncertainties to propose it as an alternative. In the event future research supports the idea that a pit pond could be developed that would sustain aquatic life and provide beneficial uses this might be a possibility if the pit is not backfilled.

Analysis in the SEIS

The main focus of the SEIS of course was the environmental consequences of the various alternatives, but through the MAA process other items came up as potential issues. These include whether or not the proposed alternative was a "proven design", and whether it was "feasible to construct the alternative". This was an important consideration for some of the alternatives as they included proposed measures which remain untested or have not been proven effective at the scale required at GSM.

All the alternatives did have the ability to be constructed at GSM, though some of the alternatives have never been attempted at such a large scale. A pit backfill analog study (Kuzel and Gallagher, 2003) found no cases of large hardrock open pits being backfilled and subsequently allowed to become saturated with groundwater. No cases of dewatering wells in 270 m of pit backfill (Kuzel and Gallagher, 2003, HCI, 2002) could be found. Some of the agencies technical staff and consultants believe that wells could be drilled, installed and pumped initially but would fail repeatedly due to settling and corrosion in the highly acidic backfill. For some of the specialists there remain critical questions about the feasibility of drilling and maintaining cased wells in 270 m of backfilled waste. All of the alternatives are proven designs except the 270 m dewatering wells, as discussed above.

Through the MAA and the SEIS analysis environmental issues common to all alternatives were developed and researched. The most critical issue for all pit backfill alternatives concerned the groundwater flow path from the backfilled open pit. This flow path to the east and south, leads to the Jefferson River via alluvial channels south of the mine. The alternatives that do not backfill the pit, the No Pit Pond and the Underground Sump alternative, allow the pit to continue to function as a hydrologic sink. In these alternatives water is collected in the pit or the underground workings and so has no opportunity to escape the pit, thus assuring no impacts to the Jefferson River alluvial channels.

Another issue common to all the alternatives that do not backfill the pit is highwall stability. This is a potential safety issue in the event access is needed into the pit. The agencies felt this was a relatively predictable issue and could be mitigated through operational measures (Telesto, 2003c).

The Flow Path Critical Issue

The central environmental question for the pit backfill alternatives is whether or not groundwater quality below Tailings Impoundment I will be impacted by waters flowing through the backfilled pit, and if so, where, when and to what extent will it be impacted.

The first aspect of this issue is what will the water quality be in the backfilled pit? Pore water in the pit will have all the characteristics of typical acid drainage, pH of 2.3, SO_4^{-2} 22,400 mg/L and high in a variety of metals (Schafer, 2001, Telesto, 2003b). Values for As, 0.056 mg/L, Cd, 0.138mg/L, Cu, 55.88 mg/L, Fe, 508 mg/L, Mn, 37.78 mg/L, Ni, 13.03 mg/L, Se, 0.0563 mg/L, and Zn, 21.33 mg/L all exceed relevant groundwater quality standards.

The waste material from the east dump complex includes a wide range of weathered acidic material. There are extensive oxidation products from material that has been in place for several years as well as material that is relatively fresh and can be expected to oxidize. This mix will be further homogenized as it is rehandled and placed as backfill. Material in the backfilled pit will not only continue to oxidize, driven both by O_2 and Fe^{+3} iron, but also stored oxidation products would be subject to dissolution and mobilization as groundwater fluxes through the backfilled pit (Telesto, 2003b). Other than time, estimated to be on the order of hundreds to thousands of years before the entire sequence of oxidation has been exhausted, there are no mechanisms for improved water quality in the backfilled pit.

The Partial Pit Backfill With In-Pit Collection Alternative would attempt to avoid the potential impacts to groundwater by collecting the water in the pit using the in-pit wells noted above. The problem with the in-pit collection alternative centered, on the likelihood of successfully drilling and maintaining the 270 m pump-back wells in highly acidic, settling waste rock. The likelihood that this could be successfully accomplished was judged to be low. In addition to the potential maintenance problems of such deep wells, other potential problems concern potential development of low permeability zones in the backfilled waste rock as it weathers and changes physically and geochemically. The overall level of uncertainty is high for this alternative.

The effluent from the backfilled pit will most likely reactivate and utilize the pre-existing flow paths from the pit area. The primary flow path is believed to flow east and south, first through structures and then through valley fill before joining existing flow in the Rattlesnake Gulch east of the pit. This flow path is the Tdf/colluvial aquifer, consisting of Tertiary debris flows and colluvial material (Fig. 4)(HSI, 2003) described below. An analysis was made of the ability of materials in the Tdf/colluvial aquifer to attenuate ARD (Telesto, 2003a). The amount of neutralizing capacity in the lower Tdf/colluvial aquifer is not sufficient to neutralize the estimated 61 liters/minute (16 gpm) effluent that would flow from the backfilled pit and mix with the existing rattlesnake drainage flow (Telesto, 2003a). Calculations (HSI, 2003, Telesto, 2003a) show that groundwater quality standards within the Jefferson alluvial aquifer would be exceeded for copper and nickel.

The mine maintains an extensive pump-back system below decommissioned Tailings Impoundment I. This system was necessitated by an early cyanide leak from the Impoundment caused by misinterpretation of geotechnical work prior to constructing the Impoundment. Additionally the mine maintains an extensive series of monitoring wells throughout the area. The analysis in the MAA and SEIS forced a reevaluation of all the well data in the area to attempt to determine a flow path for water that might flow from a backfilled pit. This flow path also probably represents the pre-mine flow path noted above as the Tdf/colluvial primary flow path. There are other flow paths from the pit that may account for as much as 10% of the total flow from the backfilled pit. These flow paths are along fractures, faults and geologic structures principally in the Precambrian LaHood formation, which has little to no attenuation capacity (Schafer, 1994). Any pit effluent migrating out via these secondary flow paths will not be attenuated sufficiently. Backfill alternatives would require at least 10 additional monitoring wells (SEIS) to monitor these secondary flow paths.

The Partial Pit Backfill with Downgradient Collection Alternative would require 95% efficiency of the collective capture system in order to prevent groundwater contamination. Based on GSM's experience with the Tailings Impoundment I pump-back system, a capture efficiency of 95% is not likely, thus it is likely that groundwater quality standards would be violated under this alternative.

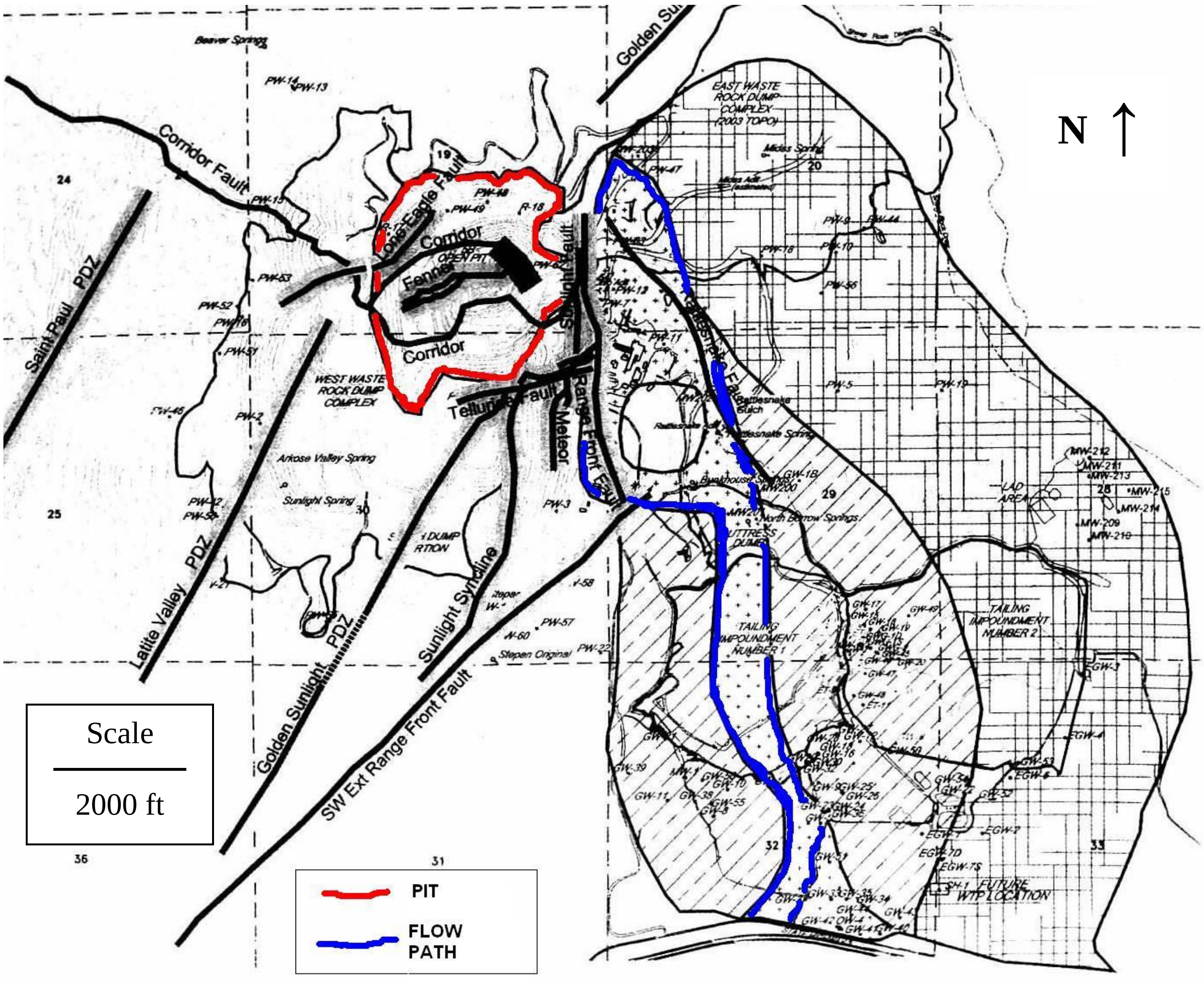

Figure 4. Primary flow path from pit south to the Jefferson River alluvial aquifer, Golden Sunlight Mine, Montana.

Alternative Selection

The agencies technical staff unanimously recommended the Underground Sump Alternative as the alternative that gives the mine the most control over water entering the pit, and thus the greatest assurance that groundwater quality can be protected. This alternative also provides the greatest flexibility in terms of future treatment technologies.

Predictably the decision to select the Underground Sump Alternative as the preferred alternative was not met with enthusiasm by everyone. The EPA's comments focused on differing groundwater collection alternatives both upgradient and downgradient of the pit to limit the flows exiting the pit to the point where water quality impacts would be acceptable. The plaintiffs concerns were considerably more wide ranging; including additional means of capturing groundwater, questions concerning waste rock geochemistry and geohydrology, pit highwall safety, fairness of the MAA process, pore water geochemistry and stoichiometry in the backfilled waste, amount of time required before water quality in the backfilled pit improves, public safety issues and reclamation costs. Many of these issues are the result of disagreements between the plaintiff's technical reviewers and agency and consultancy staffs. Responses to these comments are currently being developed and will be in the final SEIS. The Final SEIS is currently being prepared and should be out in early 2006.

Conclusion

The permitting of environmentally contentious mine projects, particularly those that involve pit backfill and groundwater issues must focus on a transparent science based process, fully open to public involvement, as exemplified here by the Multiple Accounts Analysis. Even if a process such as the Multiple Accounts Analysis is used, it does not assure consensus can be reached on the project. It should help identify all relevant technical and social issues which can then lead to a better environmental review document better able to withstand any potential legal challenges.

Acknowledgements

Thanks to all my co-workers, both at the Bureau of Land Management, the Montana Department of Environmental Quality, Golden Sunlight Mine and the participants in the MAA process for their tireless work on this project. Special thanks to Joan Gabelman of the BLM and Shannon Dunlap at Golden Sunlight for reviewing drafts of the paper.

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