A GREENER BUTTE! REVEGETATION THROUGH IRRIGATION USING TREATED MINE WATER FROM THE BELMONT MINE'S FLOODED UNDERGROUND WORKINGS

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Abstract

Historic mining activities in Butte, Montana have degraded much of the local landscape and vegetation. During the last 5 years, mine tailings located near the Belmont Mine have been successfully capped and reseeded in an effort to "green" and spark redevelopment in the area. The Belmont mine is located to the west of the Berkeley Pit and adjacent to the current Berkeley Pit viewing stand location. Due to increasing costs, the new vegetation may become impractical to irrigate using municipal water. A practical alternative source of irrigation water is needed. One potential source of irrigation water lies directly below the Belmont Mine in the abandoned mine workings. Initial sampling of the mine water indicate a neutral pH and elevated metals including iron, manganese, arsenic, and zinc that exceed maximum permissible non-agricultural irrigation discharge levels. A treatment system that will reduce metals concentrations to below requirements for agriculture-type irrigation is being developed. Resource recovery potential and project details will be presented and discussed.

Summary

For over 140 years, Butte, Montana has been the site of hard rock mining activities earning the nickname "Richest Hill on Earth" due to the wealth generated from its highly mineralized ore deposits. During most of this time, sustainable development was not considered. Many people benefited from Butte's historic mining activities that supplied critical metals to several war efforts and provided copper to electrify America's infrastructure during the growth of the industrial revolution.

For a century, over 400 underground mines were developed in Butte earning it another nickname "A Mile High and a Mile Deep" in reference to its elevation and its underground mined depth. There are over 10,000 miles of underground mine workings in the Butte mining district. During active mining, large-scale pumping was used to remove groundwater from these extensive workings. When mining stopped in 1982, pumping was discontinued. Groundwater began to return to its pre-mining level. Over the past 25 years, the abandoned underground workings have flooded and water has infiltrated much of the Berkeley Pit. These waters became the Butte Mine Flooding Operable Unit of the Butte Silver Bow Creek Superfund site and were discarded as technically impracticable for full remediation by EPA in a 1994 Record of Decision.

Post-mining issues of land and surface utilization now serve to accentuate how important it is to incorporate sustainable development aspects into hard rock mining. In an effort to revitalize lands degraded by historic mining, 10-acres of mine tailings near the Belmont Mine have been successfully capped and reseeded with vegetation leading to development of the area. However, the future of this vegetation is dependent on a limited and costly domestic water supply. Alternative water sources like the water in the flooded mine workings have the potential to sustain the new vegetation and at the same time decrease the demands on the municipal water supply.

Initial sampling of Belmont Mine water indicates a neutral pH and elevated concentrations of metals including iron, manganese, arsenic, and zinc that exceed non-agricultural irrigation discharge levels. A treatment system that will reduce metal concentrations to below levels suitable for irrigation is being developed. Potential technologies for upgrading the water to meet irrigation standards are to be evaluated through treatability testing.

Additionally, the feasibility of using the flooded underground workings as a supplementary heat source for nearby buildings will be evaluated during this project. Heat recovery from the water will be pursued based on the fact that Butte's underground mines were "hot" in geothermal terms. Belmont working temperatures were documented to have reached 130 ^{o}F. Ambient water temperature at the 600-foot level was recently measured at 60 ^{o}F[1]. The mineshaft extends an additional 3,500 feet and the temperature may be higher at this depth.

Consequently, there is potential for much warmer waters. A long term pumping test is being planned to characterize the Belmont hydrogeologic system and the temperature profile of the aquifer. Results from this test will be used to develop recommendations related to using the recovered heat along with estimated cost savings that could be used to offset increased operational costs of an irrigation water production and treatment system.

Additionally, characterization of the Belmont water quality will allow recommendations to be made on applicable water treatment technologies.

Resource Potentials

Based on a database developed by the Montana Bureau of Mines and Geology (MBMG), there are over 10,000 miles of mine workings underlying the city of Butte[2]. Figures 1 and 2 are MBMG maps indicating the extent of workings in the Butte mining district.

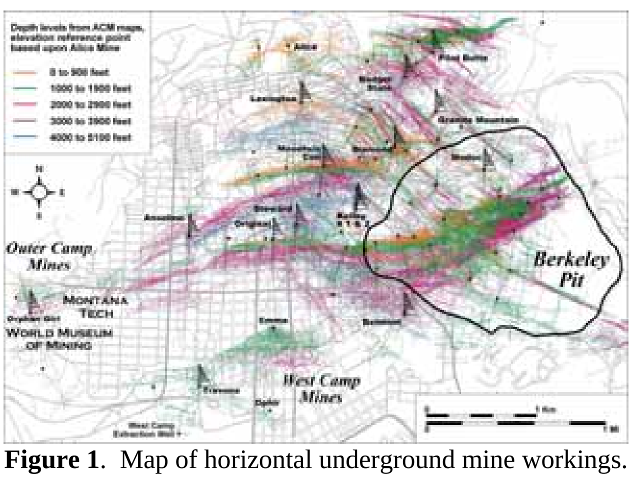

Figure 1. Map of horizontal underground mine workings.

EPA, as part of its Mine Waste Technology Program (MWTP), is considering funding a project with the purpose of exploring the feasibility of recovering resources for beneficial use from underground mine workings, including: irrigation water and geothermal heat.

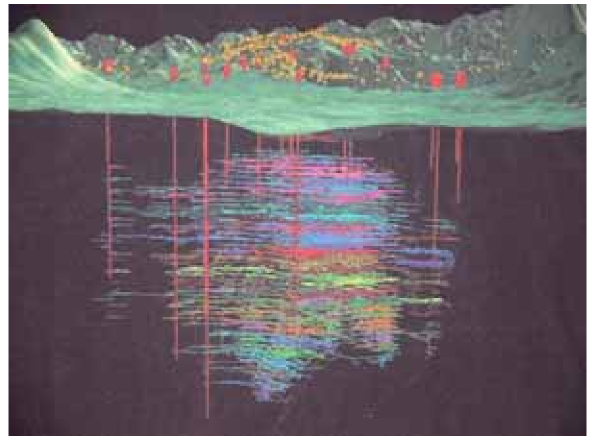

Figure 2. Map of vertical underground mine workings.

This project will take place at the Belmont Mine in the Butte Mine Flooding Operable Unit, which is one of seven operable parts of the Silver Bow Creek/Butte Area National Priorities List (NPL) site.

The Belmont Mine is located to the west of the Berkeley Pit and adjacent to the current Berkeley Pit viewing stand as shown in Figure 3.

Figure 3. East Butte photo of Belmont Mine headframe and the Berkeley Pit viewing stand on the pit highwall.

Heat Recovery

The underground mines in Butte were historically "hot". Working temperatures in the Belmont were documented to have reached about 130 °F[3].

In January 2006, ambient water temperatures in the 600-foot deep irrigation well were measured at just above 60 °F[4]. Historical mine maps indicate that the Belmont shaft extends below the 3,500-foot level and has the potential for much warmer waters.

[1] Manchester 2006.
[2] Duaime 2004.
[3] http://deq.mt.gov/AbandonedMines/linkdocs/techdocs/183tech.asp
[4] Manchester 2006

Heat recovered from the water could be used to reduce the energy consumption of nearby facilities such as the Butte-Silver Bow County-owned Belmont Senior Citizen Center and the Butte Central School Foundation-owned Maroon Activities Center (MAC). Cost savings for heating these facilities could be significant. Additionally, the cost savings from heat recovery could offset funding the operational costs of an irrigation water generation system. Figure 4 shows the Belmont headframe adjacent to the Belmont Senior Citizen Center located in the old hoist house. The photo also shows the MAC and nearby athletic and green fields.

Figure 4. Belmont Mine area aerial photo.

Water Recovery

The area shown in Figure 4 is mostly void of significant vegetation due to past activities and the high desert like arid climate. To green the area, grass sod has been installed in large areas near the Belmont Mine. These include the Belmont Mine Amphitheater that is located just to the east of the mine and a football field located to the west behind the MAC. Figure 5 shows the sodded area that needs irrigation.

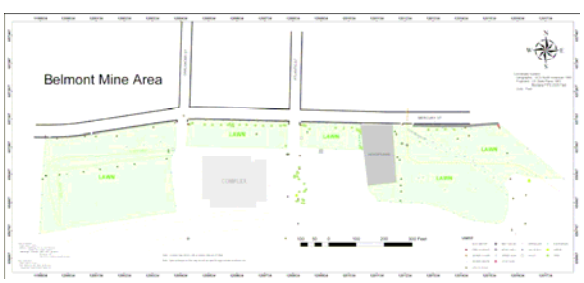

Figure 5. Grass areas near Belmont Mine.

Due to city water restrictions, it is becoming impractical to use municipal water for the sod – due to cost and drought stressing the municipal supply.

As mentioned, there are thousands of miles of flooded underground mine workings in Butte. Water recovered from the mines would be a possible source to replace municipal water consumption for vegetated areas.

If feasible, using the treated water for irrigation could benefit economic development in Butte's Brownfields areas and it could decrease demand on municipal water supply pumped 20 miles from the Big Hole River.

In addition to the already sodded area, a new area to be greened is the new Berkeley Pit visitor and interpretive center being built near the Belmont by the Butte Chamber of Commerce through a donation of funds and land from Washington Corporation. A schematic of the new center is shown in Figure 6.

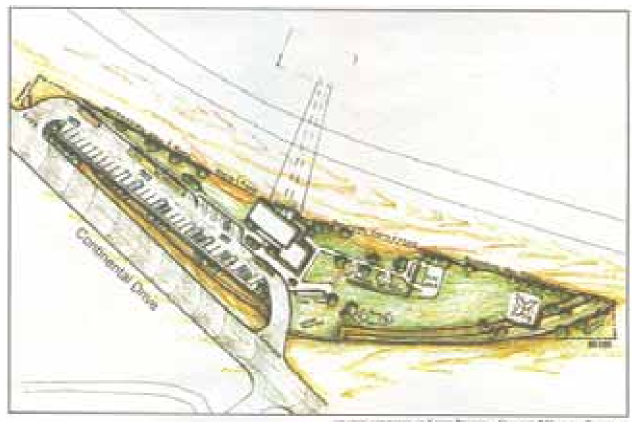

Figure 6. Proposed new visitor center with grass areas.

The Berkeley Pit viewing stand improvements and the newly grassed areas are part of a larger effort to reclaim the Continental Drive corridor as a gateway to historic uptown Butte. The calculated water requirements for the current grassed areas are 1-inch per month per 10 acres for five months per year. The costs for water from each of the two possible sources are shown in Table 1 along with an estimate for Belmont Mine water treatment.

Table 1. Irrigation water source costs and estimated dollars available for Belmont water treatment.

Belmont Water Pumping	City Water	Available for Treatment
$0.17	$1.72	$1.55

An estimated cost to treat the Belmont mine water calculated using "AMD Treat[5]" is shown in Table 2. AMD Treat is a software model available from EPA's Office of Surface Mining. The calculated estimated treatment cost is $1.20 per 1,000 gallons. The current comparable cost to use city water is $1.75; but the cost to run the irrigation well is $0.17. This means that about $1.55 might be available to treat the Belmont water. So, the cost of $1.20 appears promising.

5 http://amd.osmre.gov/amdtreat.asp

Table 2. Estimated treatment cost to obtain irrigation water from Belmont Mine irrigation well.

Treatment Technology	Cost ($/1,000 Gallons)
Estimated Available for Treatment of Belmont Mine Water	<$1.55 (from Table 1)
"AMD Treat" EPA Office of Surface Mining Software	$1.20

Berkeley Pit Water Treatment

The Butte Mine Flooding Operable Unit was issued a Technical Impracticability Waiver[6]. These means that Berkeley Pit water and the less contaminated flooded mine waters will never be fully remediated. However, the long-term plan is to ensure that any contaminated groundwater flows into the Berkeley Pit and this water will require removal and treatment in perpetuity once a safe water level is reached.

Berkeley Pit water could be considered a worst-case for the treatment of the less contaminated Belmont Mine water. For the Berkeley Pit water, the EPA has determined that the Best Demonstrated Available Technology (BDAT) is lime treatment consisting of 4 unit operations:

1) lime, either CaO or $Ca(OH_2)$, addition;
2) dissolved metal species precipitation;
3) liquid/solid separation; and
4) sludge disposal.

Due to the variety of metal species in the Berkeley Pit water, particularly aluminum and manganese, a two-stage lime treatment process is used. The first stage is used to precipitate most metals by increasing the water to a pH near 6.5. Then a second stage is used to precipitate manganese at a pH near 10.

The Horseshoe Bend Treatment Plant, located on the opposite side of the Berkeley Pit from the Belmont Mine, was commissioned in 2004 to treat Horseshoe Bend water. This mining impacted water from Horseshoe Bend is diverted to prevent it from entering the Berkeley Pit.

The treatment plant was designed to treat up to 7,000,000 gallons per day. Currently between 2 and 3.5 million gallons per day are treated[7]. All of the treated water is used in mine operations by Montana Resources, as makeup water at the concentrator. Residual sludge from the treatment process is piped into the Berkeley Pit at a rate of 250,000 gallons per day.

This facility was designed so that it will require only minor changes and upgrades to also treat water from the Berkeley Pit, which is estimated to start in 2018 or when monitoring wells approach the Critical Water Level.

Figure 7 is a flow diagram of the Horseshoe Bend Treatment Plant.

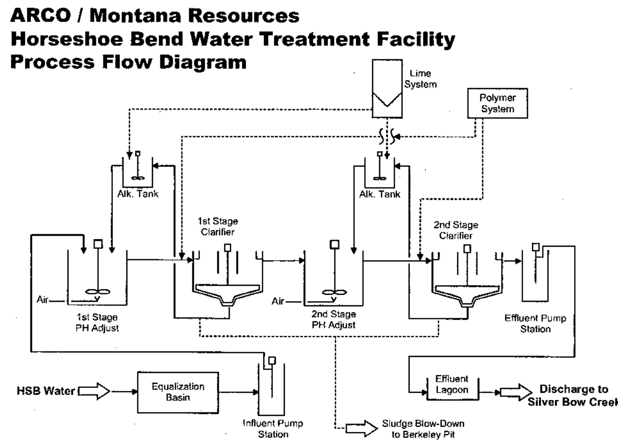

Figure 7. Diagram of Berkeley Pit water treatment.

Belmont Mine Water Quality

Belmont Mine water has been monitored by the MBMG and has consistently shown a pH near neutral with relatively low dissolved metals concentrations. As such, in the summer of 2004, a well, 600 feet in depth, was installed to pump groundwater from the workings of the Belmont Mine for use as irrigation water for a newly sodded football field. Initially, the water quality of this well was similar to a nearby well that had met the EPA irrigation standards. Once pumping started, however, the arsenic, iron, manganese, and zinc concentrations increased, exceeding EPA's recommended irrigation standards. Consequently, pumping ceased and further evaluation is now necessary to determine whether it is economically feasible to treat this water to required irrigation standards.

For comparison, Table 3 shows the major dissolved metals and pH associated with several samplings of the Belmont Mine well, the corresponding Berkeley Pit values at a depth equivalent to the level of the well, and the irrigation standard approved by EPA for the 2004 test. The three dates reported for the Belmont Mine water correspond to samples before and after the 2004 irrigation test and a sampling event conducted in 2006.

[6] EPA 1994

[7] www.pitwatch.org

Table 3. Irrigation standard and water quality data for three dates for the Belmont Mine and the Berkeley Pit.

	STD	Mar04	Aug04	Jan06	Pit
pH	none	6.8	6.7	6.95	2.4
As µg/L	100	58.1	1,100	49	408
Fe µg/L	20,000	9,770	155,000	10,800	997,000
Mn µg/L	10,000	3,650	20,800	1,880	242,000
Zn µg/L	10,000	4,644	21,500	366	629,279

Belmont Mine Pumping Tests

To fully evaluate water treatment options and associated costs, the quality of the water being produced from the Belmont irrigation well is the single most important factor. Characterization work performed to date has shown that the irrigation water quality deteriorates over time during pumping. Figure 8 is a schematic showing the Belmont Mine irrigation well in relationship to the Berkeley Pit.

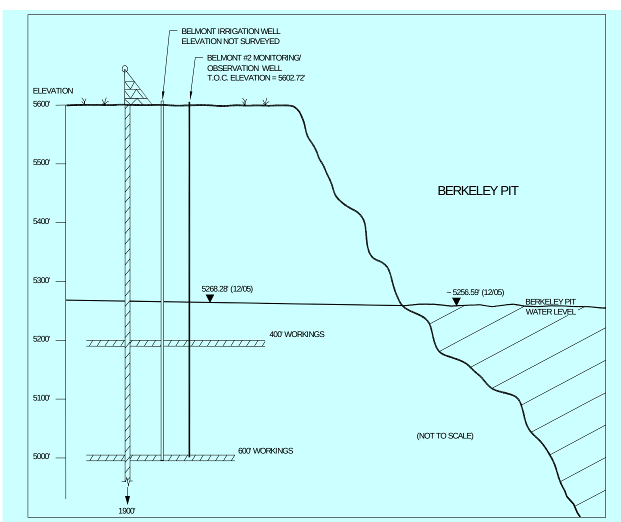

Figure 8. Schematic showing the Belmont Mine irrigation well in depth relationship to the Berkeley Pit.

In general, water characterization work performed around the Butte mining district has indicated that there are three distinct water quality zones.[8] The first zone is the moderately oxidized, metal rich, strongly acidic Berkeley Pit water. The second zone consists of Butte's West Camp mines and has water that is strongly reduced, metal-poor, with a neutral pH. The third is the area between the two zones. This is know as the transitional zone where the waters tend to be moderately reduced, with some dissolved metals and a slightly acidic pH.

The Belmont Mine is in the transitional zone. However, with the consistently neutral pH, the Belmont Mine may be able to provide water very suitable to treatment for irrigation purposes. The first step in making this determination is to conduct pumping tests. The four main steps of this work are: 1) a step-drawdown test; 2) a long-term pumping test; 3) a recovery test; and 4) analysis of the test data.

Pumping Test Objectives

A long duration pumping test is necessary to collect a sufficient number of temporal water samples to determine water quality as a function of the volume produced.

There are three primary objectives of the Belmont mine pumping tests. The first objective is to determine the quality of water and temperature as functions of volume produced. The second and third objectives are to collect sufficient quantities of representative water for treatability testing and to develop a better understanding of the hydrogeologic system supplying water to the well.

In addition to the three primary objectives, there are also three secondary objectives in conducting the Belmont mine pumping tests. These are to evaluate hydraulic parameters of the hydraulic system (mine infrastructure and bedrock) that supplies water to the pumping well; to determine the optimum pumping rate for the production well; and, to determine if there are correlations between water quality changes and changes in hydraulic system response.

Resource Characterization

Primary and secondary water sampling events will be conducted as follows.

- Before the step-drawdown pumping test is started
- 2 hours after the step-drawdown test is started
- At the end of the step-drawdown pumping test
- 12 hours after the start of the long-duration test
- Weekly up to 6 weeks
- At the end of the pumping test

Laboratory analyses to be preformed are:

- major cations and anions;
- total recoverable;
- dissolved metals;
- alkalinity and hardness;
- total suspended solids;
- speciation of iron; and
- speciation of arsenic.

[8] Gammons 2005

Major cations and anions will include calcium, magnesium, sodium, potassium, sulfate, nitrate, bicarbonate, and chloride. Metals analysis will include aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, uranium, and zinc.

Field parameters to be measured at the time laboratory samples are collected will include:

- pH;
- specific conductivity;
- temperature;
- dissolved oxygen; and
- oxidation-reduction potential.

Treatment Issues for Belmont Water

Technical issues or difficulties that might be present when attempting to treat Belmont mine water for agricultural irrigation standards include large batch flows, limited space, and changing chemistry of the water requiring treatment.

As water is pumped from the mine workings, arsenic, iron, manganese, and zinc concentrations may exceed the guidelines for water reuse. Arsenic may be mostly present as arsenate, which is more difficult to remove. An oxidation unit operation followed by a solid/liquid separation unit operation appears most promising.

Current Project Status

The project specific work plan and a quality assurance plan have been approved by EPA. This allows for the pumping tests to proceed, as well as hydro-geological characterization and water quality and water temperature characterization. MSE has an access agreement with the Belmont Mine owner, Montana Economic Revitalization and Development Institute (MERDI).

This access includes approval to drill into the shaft cap in order to monitor water temperatures and determine feasibility of heat recovery. MERDI is in the process of securing access agreements with Montana Resources and British Petroleum-Atlantic Richfield Company (BP/ARCO) for use of the storm drain system for diversion of the water pumped from the Belmont workings during the pump tests.

MSE has initiated Geoprobe drilling through the Belmont shaft cap to a depth of 70 feet. Per design drawings, the cap is 40 feet. Plans are to use a down-hole camera to characterize the shaft condition. Immediate future plans include: securing agreements for discharge of water from the pump tests; conducting the pumping tests; collecting the water for treatability tests; and conducting treatability tests.

Acknowledgements

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