RESULTS OF 2005 FINANCIAL SECURITY REVIEW AT THE EQUITY SILVER MINE

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Bill Price, Mining and Mineral Sciences Lab., Natural Resources Canada
The Equity Silver mine is 35 km southeast of the town of Houston.

Equity Silver is perhaps the most studied mine site in the world and has contributed more to the knowledge of acid rock drainage than any other site.
Of the thousands of similar sized clear cuts in the area, it is the only one that spends $millions/yr protecting the environment.

The primary protection goals are fish in the creeks and people living next to Buck Creek a short distance below the mine.
Overview of Metal Leaching and Acidic Drainage from Sulphidic Geological Materials
• Metal leaching and acid rock drainage are terms used to describe drainage from sulphidic geological materials exposed to the weathering agents oxygen and water.

• In a process analogous to the decomposition of a leaf when it falls from a tree, rock physically and chemically degrades when exposed to air and water.
Most weathering reactions are very slow, taking millions of years.

Sulphide oxidation and the dissolution of sulphide oxidation products are relatively fast.

**Pyrite**

\[
\text{FeS}_2 + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+
\]
Sulphide oxidation and the dissolution of its products are environmentally important because:

- sulphide minerals contain potentially toxic elements
- oxidation transforms relatively insoluble sulphide minerals into far more soluble chemical compounds.

**Sphalerite:**
\[
\text{ZnS} + \text{O}_2 \rightarrow \text{Zn}^{2+} + \text{SO}_4^{2-}
\]

**Chalcopyrite:**
\[
\text{CuFeS}_2 + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 + \text{Cu}^{2+} + 2\text{SO}_4^{2-} + 2\text{H}^+
\]
Dissolution is important because dissolved elements can be transported by surface and ground water, and come in contact and readily absorbed by sensitive receptors.
The term ‘metal leaching (ML)’ is used because major metals such as Fe and Al and trace metals such as Cu, Ni, Pb and Zn are the most common environmental problems associated with sulphidic mine drainage.
The other mechanism by which the oxidation of sulphide minerals can have an adverse impact on drainage chemistry is through the production of acid, which if not neutralized, will lower the pH.

**Acid generation by pyrite oxidation**

\[
\text{FeS}_2 + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+
\]

**Acid neutralization by calcite**

\[
\text{CaCO}_3 + \text{H}^+ \rightarrow \text{Ca}^{2+} + \text{HCO}_3^- \quad (\text{pH} > 6.3)
\]
Metal solubility vs. pH (from Gammons, 2009)

The diagram illustrates the solubility of various metal ions (Fe(II), Fe(III), Al, Cu, Zn) as a function of pH. The solubility is plotted on a logarithmic scale, with metal solubility given in molar concentration. The graph shows the optimal treatment pH range for each metal, indicated by the horizontal lines. The solubility values range from $10^{-15}$ to $10^{15}$ molal, with specific pH values of 2, 4, 6, 8, 10, and 12 marked on the x-axis.

Key chemical species include:
- Fe(OH)$_2$
- Zn(OH)$_2$
- Cu(OH)$_2$
- Al(OH)$_3$
- Fe(OH)$_3$

The graph highlights the influence of pH on metal solubility, which is crucial for understanding and managing water quality in mining and environmental contexts.
The rate of sulphide oxidation increases exponentially with a decrease in pH below 3.5

From Williamson et al., 2006
Overview of the Mine
Equity Silver operated between 1980 and 1994, producing silver with lesser amounts of gold and copper.
Components include:
- three open pits
- a small underground,
- a contiguous series of waste rock dumps,
- a plant site,
- a tailings impoundment.
Tailings

– Cyanide tailings were placed in a flooded impoundment.
– Inco SO2 process and natural degradation quickly lowered cyanide concentrations.
– It took far longer to reduce the levels of ammonium and nitrate produced by cyanide degradation.
– Tailings will not produce ARD if the water cover is maintained.
Waste Rock Dumps
• Main source of ARD, 77 million tonnes covering 110 ha
## Acidic Drainage

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<th>pH</th>
<th>Acidity</th>
<th>Cu</th>
<th>Fe</th>
<th>Zn</th>
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<td><strong>Avg</strong></td>
<td>2.6</td>
<td>8080</td>
<td>96</td>
<td>1209</td>
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<td><strong>Min</strong></td>
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<td>84</td>
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<td><strong>Max</strong></td>
<td>3.2</td>
<td>17200</td>
<td>283</td>
<td>2730</td>
<td>394</td>
</tr>
</tbody>
</table>

All values in mg/L except pH

- Require 100,000 times reduction in metal loading and concentration
- Must collect and treat
Dump ARD Collection

Drainage constrained by underlying clayey till.

The collection system consists of toe ditches, plus secondary downstream ditches and sumps.
...with piezometer and stream monitoring to check their effectiveness.

- 4° stream surveys
- 3° piezometers with sumps and wells
- 2° toe ditches
- 1° toe ditches
Intercepted dump drainage feeds by gravity or is pumped into ponds at base of the dump complex and then is pumped up to ponds next to the treatment plant.
ARD treatment is with lime (CaO) which raises the pH causing iron to precipitate and co-precipitate trace elements. The resulting treatment sludge was stored in the tailings impoundment when the mine was operating and since closure has been deposited in the largest flooded pit.
Additional treatment cells, water storage, structures for spill containment, spare parts, power, pumps and pipelines are all important safeguards.

For example, generators are available to provide back-up power in the event an ice storm damages transmission lines.
The addition of sludge to the pit lake improves water quality sufficiently to allow discharge of the drainage.

Drainage discharge is to Buck and Foxy Creeks but only when there is sufficient dilution.
Every 4 years, the mine conducts extensive studies of the environmental health of Foxy Creek, Buck Creek and Goosly Lake.
Results of 2005 Financial Security Review at the Equity Silver Mine
Liability and cost are important concerns at Equity Silver as a result of the size and uncertainty regarding the costs of collecting and treating drainage from sulphidic minerals and their weathering and treatment products.
The *Mines Act* requires that mine operators provide a financial security that will provide reasonable assurance that the government will not have to contribute to the costs of reclamation and environmental protection if a company defaults on its obligation.

Multinational mining companies with a good credit rating can provide letters of credit from a major bank. Small mining companies are unable to get letters of credit and have to provide cash.
2005 was the fourth security review. Participants:

- BC Ministry of Mines - Kim Bellefontaine, Victoria
- Local resident - Glenda Ferris
- Company - Mike Aziz,
- Company - Ross Gallinger, formerly Placer Dome
- Myself

Other members of the Equity Public Advisory Group declined to participate.
The first step is to review trends in the performance and costs of all site components and mitigation activities.

Potential Failure Modes and Preventative Measures were documented to ensure all potential costs items, risks and unknowns are identified and recorded.
The features contributing to costs at the site are divided into four categories.

- Annual Lime Costs
- Other Annual Operating Costs
- Periodic Costs
- Broader Economic and Financial Issues
Annual Lime Costs
• Lime to treat acidic drainage from waste rock is the largest single reclamation cost item.
• The 77 million tonnes of waste rock produces 500,000 to 950,000 m³ of ARD each year.
• Supplemental mitigation measures includes a compacted soil cover and upslope ditches to divert clean water.
The unit cost for delivered lime in 2005 was $208.68/tonne. The delivered lime cost includes rail and truck transportation and energy surcharges.
- Previous lime use is reviewed to check for changes that might impact future lime use
- Significant variation is evident in past annual lime use
From 85 to 90, drainage acidity and lime use steadily increased. Construction of a compacted soil cover over the waste rock dump from 91 to 94 reduced the drainage volume and lime use by approximately 30%.
Since the cover was completed, lime use fluctuated from 3000 to 6000 t/yr. Much of the fluctuation is due to precipitation, especially the magnitude of spring snow melt.
To reduce the impact of annual fluctuations in precipitation, a rolling average of the past 3 years was used to evaluate existing lime use. The 2005 3 year average lime use was \(~4200 \text{ t/yr} (\$876,456/\text{yr})\).
The prognosis regarding future lime use was that a decline in acidity would eventually occur. However, the large number of properties and processes made it hard to predict the timing and form of the decrease, or whether this might be preceded by a short-term increase in lime use.
Evidence from studies at other sites suggested that only a portion of the dump is being leached and acid weathering products will build up within the rest of the dump.
Evaluation of the past Equity monitoring results suggested that even within the flow paths, acid weathering products build up during dry years and flush out during large leaching events.
Evidence of sustained or slightly increasing acidity was provided by lime use data normalized for differences from the long-term average precipitation (655.3 mm/yr).
Other evidence of sustained or slightly increasing acidity was the slightly increasing acidity during snow melt, the period of highest acid loads and lime use.
Based on cyclical flushing and uncertainty about the geochemistry, hydrogeology and the effectiveness of the cover on the dump, the following projection was adopted for calculating future lime use:

- present lime use (4200 t) continues for 20 years;
- the subsequent lime use reduction rate is 5%; and
- post-reduction lime use is 25% of present (1050 t).
Annual Non-Lime Operating Costs
• Non-lime operating costs includes supervision, monitoring, operating the treatment plant, sludge removal, equipment maintenance, road maintenance, heating buildings and power and parts for pumps and pipes.

• The largest costs are salaries, services purchased and power.
Total operating costs over the last 5 years (2001-2004 and 2005) were not used to estimate future operating costs because they included costs associated with the major site improvements following the 2002 spring flood. Although there will be site improvements in the future, no additional costs of this magnitude are expected.

Consequently, the mine’s currently predicted future operating budget of $596,475 was used to calculate the reclamation security.
The ~$100,000 increase in the non-lime operating costs over the amount used in 2000 was due to:

- Cerio daphnia toxicity tests required by MOE on discharge from Main Zone Pit,
- increased natural gas costs and the cost of heating the new High Density Sludge (HDS) plant, and
- worker and other insurance costs.

The addition of insurance costs was based on the likelihood that if the Province had to take over the site, it would contract out work in the same manner used at the Britannia Mine. All the insurance for the Britannia operation is carried by the contractor.
Periodic Costs
Past periodic costs included:

- additional sump construction,
- removal of buildings,
- completion of the soil cover, &
- improvements to clean water diversions.
Following the 2002 flood, $15 million in unanticipated periodic costs was spent on site improvements including:

- dam raises; sludge removal; construction of an emergency ARD storage pond;
- construction of a new high density sludge treatment plant and improvements to the old low density sludge plant; and
- new pumps, pipelines, and a new genset and lime silo.
Projected future periodic costs used in the 2005 security review for maintenance and site improvements were:

– $50,000 every 5 yr for major equipment
– $50,000 every 10 yr for general site improvement
– $500,000 every 20 yr for major infrastructure
Other projected periodic costs

- $15,000 every 5 years for lime to maintain the neutral pH of the tailings pond

- $100,000 every 4 years for studies of the environmental effects of discharge to the receiving environment
$250,000 in 2015 and $100,000 every 10 yr thereafter to repair the soil cover, collection, diversion and discharge systems.

Due to the limited industry wide information about maintenance and the long-term durability for soil covers, the mine relies heavily on monitoring and monitoring costs are included in the security.
Major questions regarding maintenance of dry covers.

Present annual costs:
- $1,000 to remove woody shrubs
- $1,000s for ice removal from ditches

Projected future costs are an educated guess

Herbaceous vegetation preferred to avoid tree throw and maintain sight lines.
To deal with uncertainty, detailed ongoing monitoring is in place to provide early warning of potential problems and inform corrective measures for a number of site components.

Considerable money is also spent on periodic studies. The cost of these studies was not included in the security because these studies reduce the overall risk and the committee did not want the security to discourage this activity.
Broader Economic and Financial Issues
A major issue in any security calculation is the discount rate used in calculating the net present value of costs. Based on the present low rates of return of Government of Canada bonds, the discount rate used in the security was:

- 2.0 % until next review in 2010
- 2.5 % from 2011 until 2036
- 3.0% from 2036 onwards
The Resulting Estimate of the Total Liability
Based on the previously outlined cost estimates and discount rates, the net present value (NPV) of the reclamation liability was $45.767 million;
- $21.657 million for lime,
- $21.293 million for annual operating costs and
- $2.817 million for periodic costs.

Approximately half the increase from the total NPV estimate of $23.55 million in 2000 was due to increases in the projected costs and half was due to a decrease in the projected discount rates.
Triggers for Recalculation of the Security before the Next 5 Year Review
Triggers for Lime

- if unit lime cost increases or decreases by more than 10% or
- if three year rolling lime use increases or decreases by 1000 t/a.

In the case of a decrease in lime use, there will only be a reduction in the size of the security if there is evidence that the reduced acid release has not resulted in a build-up of acid weathering products in the dump, increasing the likelihood of a large future flushing event.
Other Triggers

- Security costs for power should be recalculated if cumulative increases or decreases in 2 year rolling average electricity costs exceed 50%.

- Triggers were also included for changes in bond yields, inflation and the financial status of parent company. MEMPR will annually review these items.

- The company reports cost data relevant to the triggers in its annual environmental report.

- The Ministry of Mines should annually review bond yields, inflation and the financial status of parent company.

- Since the committee felt that the security should create incentives for cost-effective detection, resolution and reduction of risks, it decided not add triggers for site management or general operating costs.
The revised *Mines Act* permit that required the new security and set the triggers also required the operator to develop a work plan for addressing potential major costs items and significant risks and unknowns identified in the *Document of Potential Failure Modes, Preventative Measures and Potential Additional Requirements*.

The work plan is reviewed by the regular public advisory committee that meets one or more times each year.
Conclusion
Productive use of Canada’s mineral resource can only be sustained through environmentally sound, economically viable mining practices.

Assessment of the reclamation and environmental costs is therefore very important, both to the mining sector and neighboring communities to mine sites.
In Canada, a failure to adequately assess reclamation and environmental costs has resulted in impacts to community resources and the public paying many $100s of millions to prevent additional impacts.
Estimating the liability of mine sites potentially with major costs is an important undertaking, especially as 80% are closed.
Estimating the liability of mine sites is also a major technical challenge as a result of:

– the complexity of mine sites;
– large information requirements;
– many properties in flux;
– difficulties in measuring many processes; and
– our limited experience.
The 2005 Equity financial security review included a comprehensive assessment of monitoring results. It also included some educated guess work about un-measured and un-measurable properties and processes. Future monitoring and analysis will hopefully allow us to revisit these assumptions and make reasoned and timely adjustments. The next scheduled security review is in 2010.
Properly Qualified, Motivated and Resourced Personnel are Needed for Mine Review

Participants need a detailed knowledge of the site and technical issues.

Gaining the necessary understanding of the project history and monitoring data takes considerable time and determination.

No one individual has all the required areas of expertise and a team approach on the project is important.

Future performance of operating and closed mines is not a topic that catches the attention of the general public.

The effort is onerous, but the costs are minimal compared to the millions of dollars for remediation and the impacts to industry as a whole and communities that depend on the impacted resources.
Acknowledgements

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