

RECLAMATION MEASURES AT EQUITY SILVER MINES LIMITED

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ABSTRACT

Acid generating waste rock at Equity Silver Mines Limited is placed to minimize environmental impact and to accomodate progressive reclamation. Reclamation includes sealing of dumps with glacial till material followed by revegetation to assist in reducing oxygen transfer. A decrease in oxidation rates through reclamation techniques can have a major impact on reducing water treatment costs.

The purpose of this paper is to summarize rehabilitation measures, reclamation programmes, costs, equipment selection, and research carried out at Equity Silver Mines Limited.

INTRODUCTION

Equity Silver Mines Limited is located in the Central Interior of British Columbia, 35 kilometers southeast of Houston and approximately 575 kilometers by air, north-northwest of Vancouver (Figure 1).



Figure 1
Location of Equity Silver Mines Limited

The minesite area experiences a cold continental climate. Summers are short (less than 60 frost free days) moderately dry and warm, while winters are long and cold. Seventy percent of precipitation occurs as snow. Annual precipitation ranges from 65 to 75 cm while the November to March snowpack ranges from 100 cm to 280 cm. Forest cover is composed of Engelmann Spruce, Subalpine Fir and Lodgepole Pine.

The ore deposit consists of three economic mineralized zones: the Southern Tail, Main and Waterline Zones. Conventional open pit mining methods are utilized for mineral extraction. Mining at the Southern Tail pit commenced in April, 1980 and was completed in the first quarter of 1984. Main Zone pit production was initiated during the last quarter of 1983 and Waterline Zone stripping commenced during the winter of 1987.

Copper-silver-gold mineralization occurs predominantly as tetrahedrite and chalcopyrite. Pyrite, which occurs in disseminated, massive and crystalline forms is the dominant sulphide mineral throughout the waste and ore zones. Current mining reserves have been estimated at 14 million tonnes with a mine life extending to 1992.

Mineral processing is accomplished by standard crushing, grinding, and flotation methods at a rate of 9,000 tonnes per day. Additional gold extraction is achieved through a cyanide leaching circuit utilizing carbon-in-leach technology.

Oxidation of sulphide minerals results in the formation of Acid Mine Drainage (A.M.D). The presence of moisture, oxygen, sulphides, and oxidizing bacteria are key parameters for the reaction mechanism. Reduction of any of these constituents will help to reduce acid mine drainage production.

The primary reclamation objective at Equity Silver Mines Limited is to slow down the oxidation process through reclamation measures and to return the site for forestry/wildlife habitat utilization. The reclamation programme, along with a discussion on research and A.M.D., will be outlined in this paper.

ACID MINE DRAINAGE

Exposure of sulphide materials through mining results in a natural oxidation process and release of ions. Without neutralization, these ions are capable of uniting to form sulphuric acid thereby forming Acid Mine Drainage (A.M.D).

The degree to which acid generation occurs varies with the nature and concentration of available sulphide (pyrite) material. Pyrite mineralization at Equity Silver ranges from disseminations to the massive form. Blasting activities expose these massive forms along fracture planes thus initiating the oxidation process. Fine-grained iron sulphides, such as pyrite, are oxidized by oxygen according to reactions 1 and 2. (Figure 2).

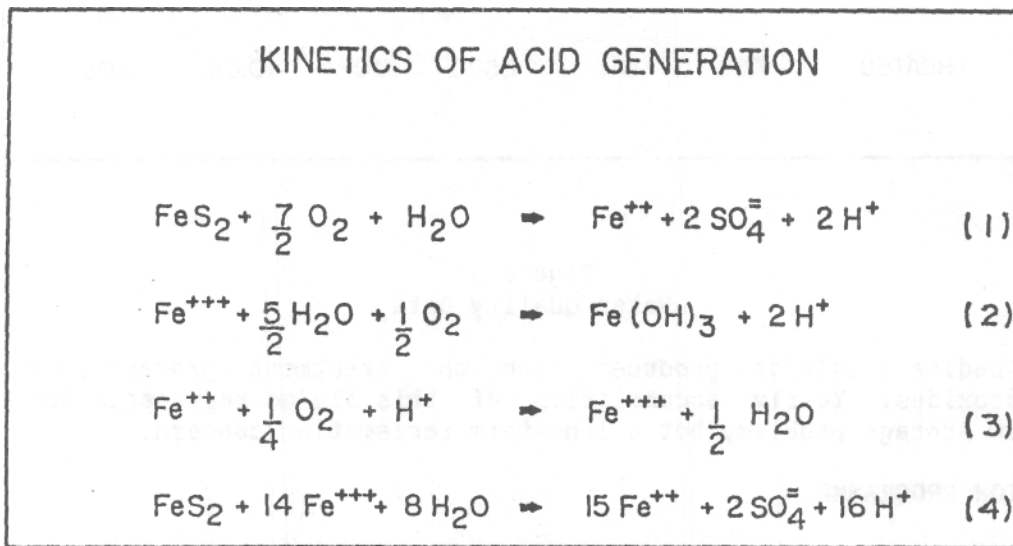


Figure 2
Kinetics of Acid Generation

Ions liberated combine with alkaline materials associated with host rock and settle out of solution as soluble metal precipitates. Once available alkalinity is depleted, metal precipitates return to solution with the lowering of solution pH (Reaction 3). Below pH 2.5, iron oxidation and acid generation are produced biochemically by *Thiobacillus ferrooxidans*.

Further reduction of ferric iron (Fe³⁺) by pyrite and bacteria (reaction 4) form ferric sulphates and hydroxyl complexes. The acid produced by bacteria in reaction 3 and 4 account for at least 75 percent of the total. If the reactions proceed uncontrolled, the cycle will continue until the sulphide supply is depleted.

To minimize potential impact on the environment, an extensive collection and treatment system was developed to contain acid seepages. Approximately 800,000 cubic metres of A.M.D. must be collected annually and processed through a lime neutralization treatment plant. Treated water from the plant complies with stringent water quality objectives and is discharged to the receiving environment at dilution ratios governed by metal content and stream flow rates. Typical water quality data is shown in Figure 3,

A.M.D. TREATMENT STATISTICS						
		VALUES IN mg / L				
	ph	ACIDITY	SO ₄	Cu(d)	Zn(d)	Fe(d)
RAW A.M.D.	2.35	10,000	8,500	120	80	800
TREATED	7.80	NIL	1,600	0.01	0.04	0.03

Figure 3
Water Quality Data

The sediment (sludge) produced from the treatment process consists of metal hydroxides. Yearly accumulation of this sludge represents not only a short term storage problem, but a long term reclamation concern.

RECLAMATION PROGRAMME

Pre-mining land use was limited to forestry, moderate wildlife habitation and minimal recreation. Some logging has taken place within five kilometers of the minesite, however use of the timber resource at the minesite has been confined to clearing of designated mining areas. Recreational activities for the general area include hunting and fishing.

Reclamation objectives have been based upon pre-mining activity as well as the potential for post-mining land use. Objectives of Equity Silver Mines Limited reclamation programme are:

- 1) Development of a long-term, water management programme to ensure water quality control;
- 2) Reduction in erosion and acid mine drainage through sequential rehabilitation and revegetation;
- 3) Development of a productive post-mining landscape which includes limited forestry, wildlife habitation, and recreation.

The presence of acid generating wastes imposes major restrictions to conventional reclamation techniques. Vegetation establishment directly on acid wastes is prohibited by toxic elements and acidity. The alternatives are top dressings or covers in order to create conditions suitable for vegetation establishment and growth. Because there is an abundance of glacial till in the area, Equity Silver encapsulates wastes with 1 meter of till to restrict moisture and oxygen infiltration, and to provide a medium for vegetation establishment.

Initially, the waste dump was constructed by disposal along a common horizon. This construction technique produced high dump faces with static loads in excess of shear strengths of underlying glacial till and resulted in minor localized failures. Through a geotechnical investigation it was concluded that dump faces should be reduced from the natural angle of repose (37 degrees) to an overall slope of 20 degrees to attain a safe weight distribution. To achieve this design slope angle, the dump had to be reconstructed from the lower limits upwards in individual lifts of 10 meter thickness (figure 4).

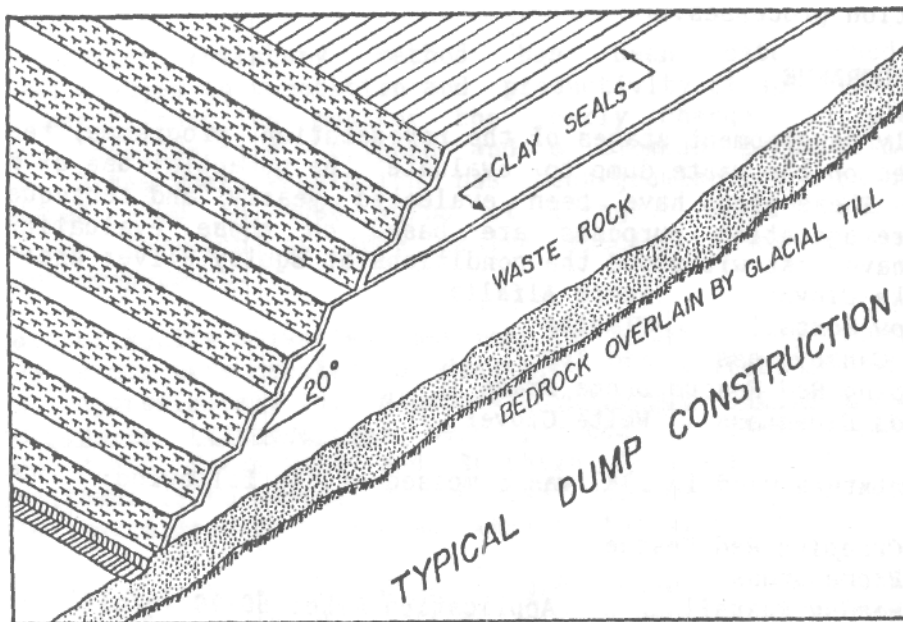


Figure 4
Waste Dump Construction

As waste dump construction progresses, completed berms and side slopes

are top-dressed with a one meter layer of glacial till and seeded to establish a protective vegetative cover. This waste dump design allows direct placement of till removed from pit stripping thereby reducing the need for stockpiling and re-handling costs. The placement of glacial till is included as a mining cost since this material must be removed to accommodate mine production.

The terraced-style dump design allows easy access for revegetation. The short slopes decrease erosion problems and are easy to seed. The one meter capping of glacial till and vegetative cover acts as a seal preventing moisture and oxygen into acid generating wastes. A contaminant loading programme was established to evaluate this seal by monitoring the flows and water quality of seepages originating from the waste dump. Monthly samples are collected at eleven sites within the confines of A.M.D. collection ditches. Metal balances are used to define problematic areas as well as compiling data for evaluating the long term trends of acid generation within waste fills.

To accommodate waste disposal demands, the dump will be extended easternly to backfill the Southern Tail pit. Oxidation processes will be eliminated on the portion of waste placed below water within the pit. Wastes, especially the fine fraction, placed below the water table provide a supply of available alkalinity. Provided the acid generating processes within the area are minimized, residual alkalinity will maintain suitable water quality for discharge to the environment. A spillway, constructed at the south end of the pit ensures a constant water level to flood wastes while materials placed above this water table are covered with glacial till to decrease oxidation processes.

REVEGETATION PROGRAMME

In the early development stages of the revegetation programme, test plots were established on the waste dump to evaluate the potential use of nineteen plant species. These plots have been evaluated yearly and subsequent seed mixtures for revegetation purposes are based on these evaluations. The species which have best withstood the conditions at Equity Silver are:

Alsike Clover	Peace Alfalfa
Meadow Foxtail	Timothy
Reed Canarygrass	Red Top
Creeping Red Fescue	Brome Grass
Canada Bluegrass	White Clover

The seed mixture used in 1987 was composed of the following:

25% Creeping Red Fescue	
10% Brome Grass	
10% Meadow Foxtail	Application Rate;; 50-90 kg/ha
10% Timothy	
5% Red Top	
10% White Clover	
30% Alsike Clover	

Glacial till used for covering the waste dump is predominantly composed

of clay with lesser amounts of silt and sand. Till pH ranges between 6 and 8 with a nutrient status of 10 kg/ha nitrogen, 152 kg/ha phosphorus and 152 kg/ha potassium. A randomized block design was selected to test various rates of fertilizer additions. Results of these tests indicate that a fertilizer rate of 200 to 300 kg/ha of 21-7-14 produces high yielding vegetation.

A variety of seeding methods have been evaluated at Equity Silver Mines Ltd. to determine the most economical and effective method for establishing vegetation. Hand broadcasting, Aerial broadcasting and Hydraulic Seeding have all been used. Broadcasting methods have been highly successful on flat areas, but disappointing on steep slopes. In 1984, Equity Silver experimented with hydroseeding on the waste dump. The results of this test proved that hydroseeding was beneficial in creating a dense plant cover and in reducing surface erosion on steep slopes. Therefore in 1985, a Finn T150 1500 U.S. gallon hydroseeder was purchased. It has performed well and has been used for other applications including: core contacting for dam construction; dust control; fire suppression; for applying lime solutions on pit walls; and plantsite clean-up. The equipment is skid mounted and is towed easily through wet glacial till with a Caterpillar D-6. The application cost for hydroseeding is approximately \$200 per hectare (excluding materials).

Aerial fertilizing was conducted in 1987 to increase the nutrients for vegetation growing on the waste dump. The application cost ranges between \$50 to \$100 per hectare and is a fast, cost effective method for fertilizing large areas, that are awkward to access.

A Vegetation Inventory method has been established to monitor successional changes in vegetation and productivity of specific sites. Plots have been established to monitor the yearly changes in plant types and quantities. Samples are clipped and a biomass productivity value is calculated. Areas where vegetation has been growing for more than two years have produced 3500 to 4000 kg/ha of forage. Recent inventories have identified the invasion of some native species which include fireweed, lupines, and cowparsnip.

As part of Equity Silver's commitment to establishing natural vegetative covers, test plots were created to determine the suitability of native trees and shrubs. Approximately 100 Ninebark (*Physocarpus capitatus*) and 100 Black Cottonwood (*Populus trichocarpus*) were planted in three locations: A.M.D. Storage Dam, A.M.D. Surge Pond, and Southern Tail Waste Dump. The objective of this programme is to assess the survival of native bare root stock woody species that could provide browse and shelter for wildlife.

These shrubs were germinated in a greenhouse in Vancouver from native B.C. seed during the winter of 1984-85. They were grown in Tinus containers during the first year, then field planted in the following year. They were lifted and stored as bare root stock in 1987. The shrubs were planted at Equity sites in late September, 1987.

In addition to nursery stock plantings, Contour Wattling was tested. Contour Wattling is a method of establishing vegetation (woody species) for slope stabilization. Wattling consists of tied bundles of plant stems or

branches(usually willow), laid in trenches on contour along the slope face. The bundles are staked in position, then the trenches are backfilled.

A small plot was established to test the effectiveness of Contour Wattling for propagation of woody species. The construction sequence is shown in figure 5. The bundles were made up of willow(*salix* spp.) which grow near the Siltcheck Dam, below the minesite. Four rows, approximately 15 meters in length were installed in October, 1987.

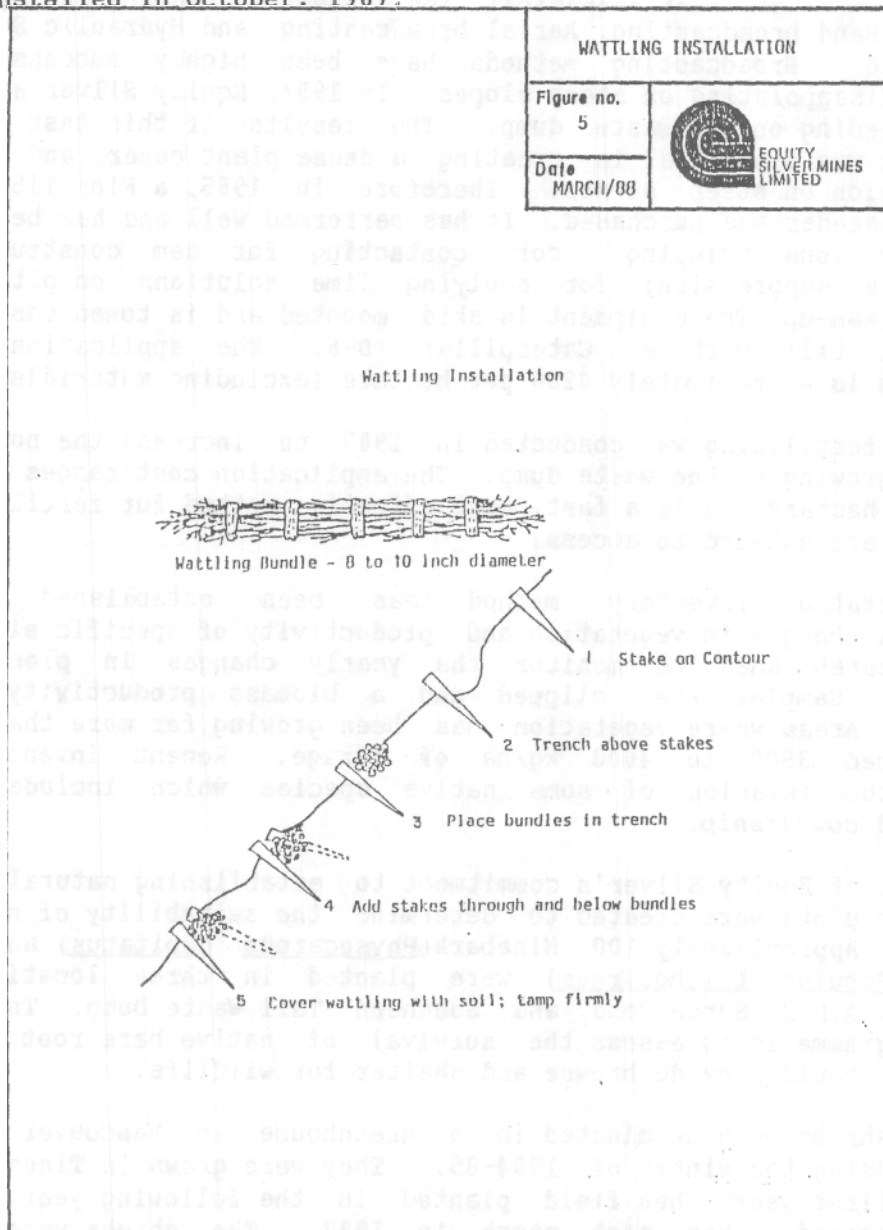


Figure 5
Wattling Installation

As stated previously, oxidation of sulphidic waste rock forms A.M.D. and liberates heavy metals. To reduce this oxidation process, Equity Silver Mines Limited covers acid generating wastes with 0.5 meters to 1.0 meters of glacial till, followed by a cover of grasses and legumes. Some concern has been expressed over the possible uptake of heavy metals by vegetation and the impact of such uptakes. A study was initiated to examine the metal levels in vegetation and the implications to plant and animal nutrition.

A previous study examining the possibility of upward migration of acids in till covers determined that acid contamination occurred at the soil-rock interface, but not higher in the soil profile. Results of the vegetation study indicated that molybdenum values were elevated, while copper-molybdenum ratios were low. Although these results have no impact upon plant growth, there is a potential for animal nutrition problems. High molybdenum values could yield nutritional copper deficiencies, however, it is doubtful that animals (both wildlife and domestic species) would graze this vegetation for extended periods. Animals tend to migrate between revegetated and natural meadows thus diluting any adverse effects from a continuous diet.

RECLAMATION TEST PLOTS

Test plots representing scaled down versions of the waste dump have been developed to evaluate present reclamation measures (figure 6). Seven test plots have been constructed to simulate glacial till covers on the waste rock dumps. Infiltrate and run-off water are collected and analyzed to assess the effect of present till thicknesses. A summary of the test plots is as follows:

<u>Plot</u>	<u>Waste Material</u>	<u>Till Thickness</u>	<u>Other</u>
1	Southern Tail Pyritic Waste	1.0m	Infiltrate Coll.
2	Southern Tail Pyritic Waste	0.5m	Infiltrate Coll.
3	Southern Tail Pyritic Waste	0 (control)	
4	Southern Tail Pyritic Waste	0 (control)	
5	Main Zone Pit Pyritic Waste	1.0m	
6	Main Zone Pit Pyritic Waste	0.5m	
7	Main Zone Pit Pyritic Waste	0 (control)	

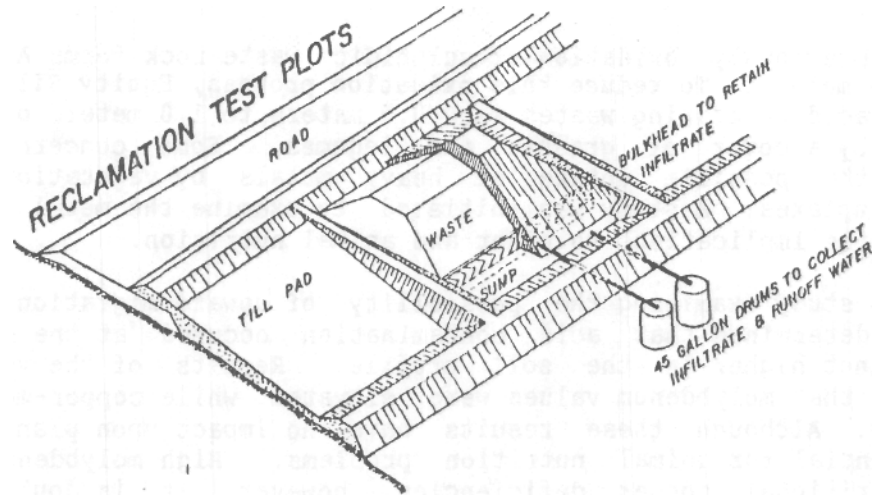


Figure 6
Reclamation Test Plots

Observations made during the summer of 1987 identified that a lesser quantity of infiltrate was being collected compared to surface run-off. In July, volume records were collected to compare relative volumes of infiltrate and run-off accumulated. A preliminary analysis of data indicate that there may be a significant reduction in metal loading as a result of till caps. A 0.5 meter or 1.0 meter cap of till reduced water infiltration by 72 percent. The sulphate and acidity levels were lowered by 68 percent and 62 percent respectively, with a corresponding reduction in metal levels. The results are shown in the following table.

Comparison of Metal Loadings with Till Thickness
ppm

Till Thickness	SO4	Acidity	Cu(t)	Fe(t)	Zn(t)
none (control)	1393	1213	5.40	333	2.91
0.5 meter	461	548	3.55	144	2.35
1.0 meter	423	384	2.32	106	1.39

CONCLUSIONS

Reclamation measures at Equity Silver Mines Limited have been effective in minimizing the environmental impact of mining operations. Successful reclamation methods have been developed through research to rehabilitate disturbed areas in a cost-effective manner. Further research and development at Equity is focused on the following objectives:

- 1) Development of a long-term, water management programme to ensure water quality control;
- 2) Reduction in erosion and acid mine drainage through sequential rehabilitation and revegetation;
- 3) Development of a productive post-mining landscape which includes limited forestry, wildlife habitation, and recreation.