

WATER MANAGEMENT AT EQUITY SILVER  
MINES LTD.

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## **INTRODUCTION**

Equity Silver is located in the central interior of British Columbia, 35 kilometers southeast of the town of Houston and approximately 575 km by air north-northeast of Vancouver.

The orebody was discovered in 1968, and after being handled by several mining companies was put into production by Equity Silver Mines in 1980. Economic Cu-Ag-Au mineralization occurs in three distinct zones and is being mined by open pit methods. Minerals are concentrated by conventional milling practice and cyanidation in a leach circuit to remove trace gold from final tailing.

Predominantly all wastes, both tailing and blasted rock, contain pyrite and are classified acid generating. Acid generation occurs within waste rock fills around the property however not within tailing thus far due to sub-aqueous disposal of the product. The presence of acid mine drainage (A.H.D.) complicates water management at the minesite and represents a high cost to treat and monitor discharges to assess environmental impact.

Since identifying the problem with A.M.D. in 1982, detailed records have been maintained on meteorological data, snow pack, pump records, treatment statistics and water chemistry. This data provides a base for making operating decisions and allocating operating funds.

## **SITE DESCRIPTION**

The Equity Minesite is located on an alpine plateau that dissects two watersheds; Foxy Creek lies to the north and the Bessemer-Buck Creek systems to the south (Figure 1). Both systems eventually join the Bulkley River. Failing proper water management on the property it would be possible to have a significant environmental impact on both these streams.

Major features on the property include: a tailing pond of 1.0 square kilometer, a water treatment reservoir of 0.50 square kilometers capable of holding 2 million cubic meters of treated water, a drainage system for collecting A.M.D. from 1.7 square kilometers and three open pits covering an area of 1.2 km<sup>2</sup>.

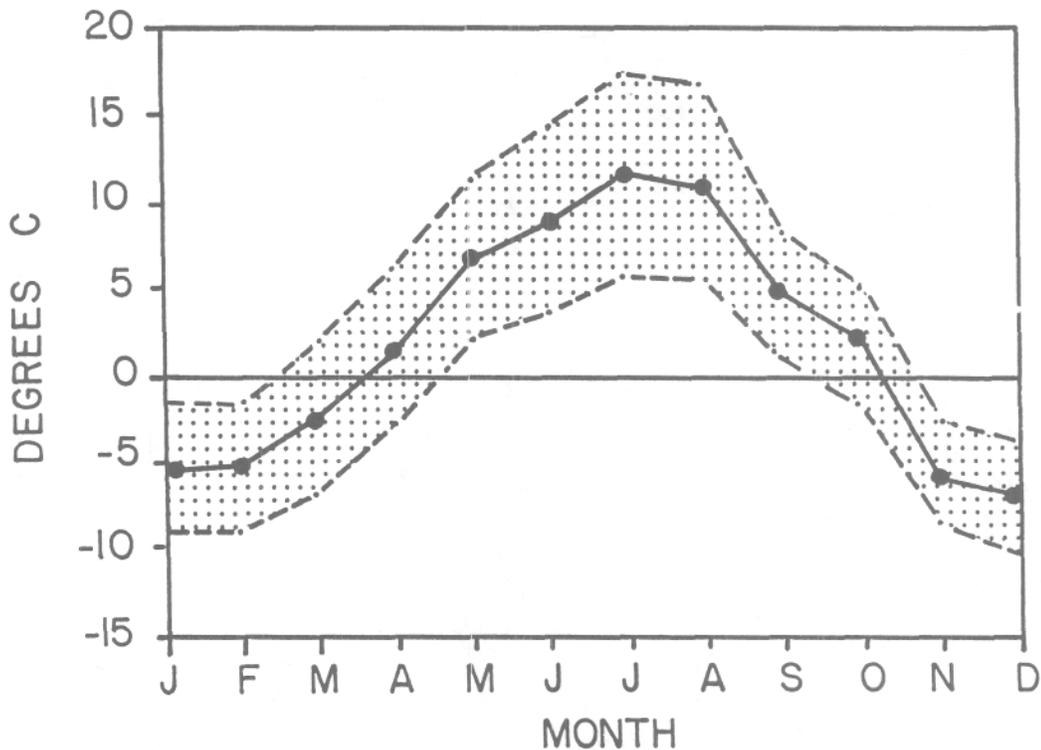


Support structures include a primary and secondary crusher, fine and coarse ore piles, concentrator, concentrate leach system (shut down), leach system to extract trace values of gold from tailing, cyanide destruction circuit, heavy equipment maintenance shop, administration building, tailing water reclaim system, numerous A.M.D. pumping systems and a treatment plant.

### **HYDROLOGY BASE**

Equity entered into a program of recording and reporting weather and precipitation data to Environment Canada (climate data services) during the preproduction period and has been continued through to present. Data obtained has been useful in predicting hydrology patterns and runoff factors.

Mean annual temperatures range between -7 degrees C to +12 degrees C. Average monthly minimum and maximum values are illustrated in Figure 2. These are the average variance in temperature and do not represent isolated extremes which can vary between -35 degrees C to +25 degrees C.



**Figure 2: Five year Average Temperature Range**

Average annual precipitation and snow pack in water equivalent with minimum and maximum limits for the period 1983-1987 inclusive is illustrated in Figures 3 & 4 respectively. Note that maximum and minimum precipitation values are selected randomly to reflect extremes.

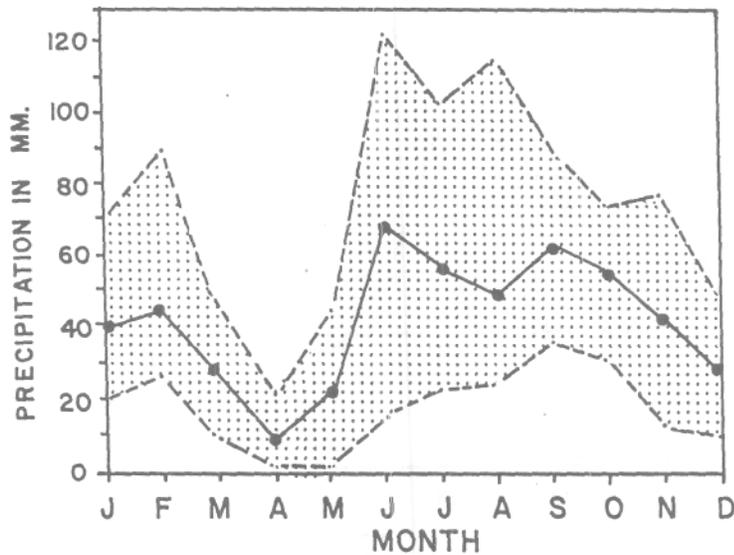


Figure 3 : Mean Annual Precipitation For The Periods 1983 To 1987 with Maximum fi Minimum Recorded Precipitation By Month

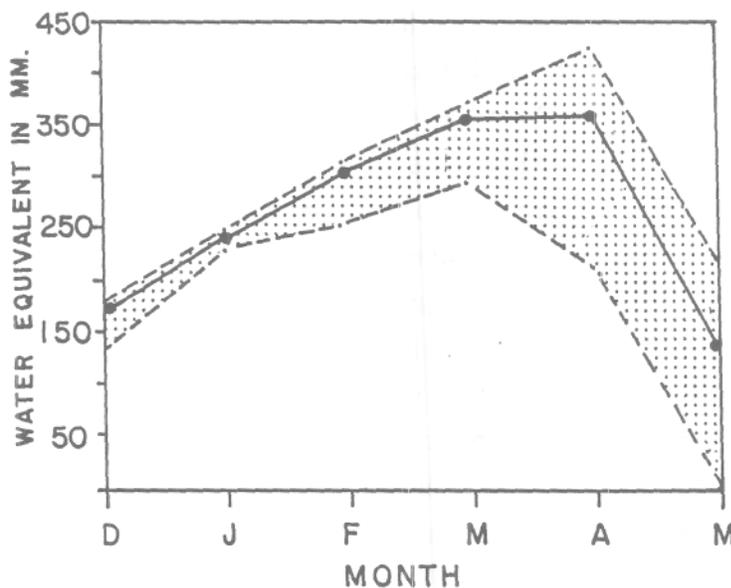


Figure 4: Mean Annual Snow Pack Water Equivalent with Low & High Years For The Period 1983-1987

A mean monthly index hydrograph was developed on the basis of stream gauging and pump records maintained on watersheds of known area. Average mean flow was worked out to be 14 L/second/km<sup>2</sup>. This mean distribution is illustrated in Figure 5.

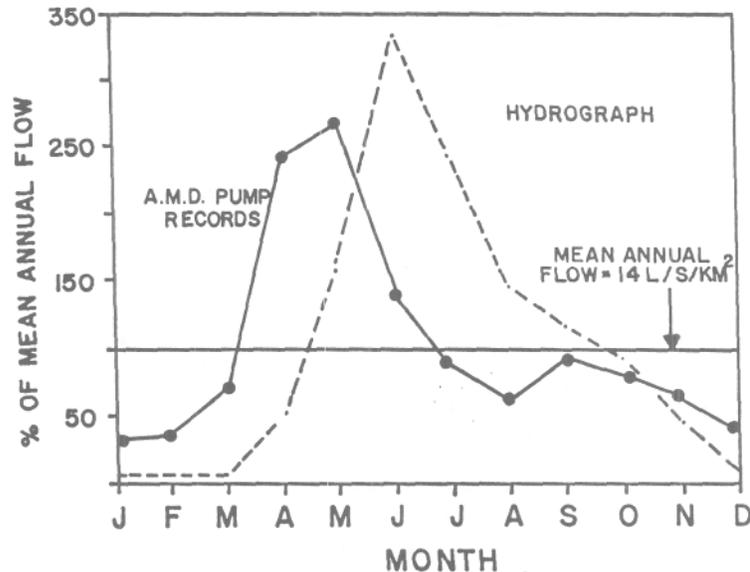


Figure 5: Mean Monthly Hydrograph

Monthly distribution of flow is illustrated as a percentage of this index base. With time and refinement of data it was found that this mean annual flow was correct, however the hydrograph was skewed with peak flows occurring in April and May rather than June. The difference is by in large a product of working with two data sets. Flow generated within the confines of the A.M.D. collection system (A.M.D. pump records) occurs about 1 month in advance of flow realized in neighbouring watersheds. This offset is a product of accelerated snow melt within well travelled and disturbed areas from which A.M.D. is generated. This differential melt pattern can cause water chemistry upsets if seepage out of the system is in advance of the diluting potential of the surrounding countryside. Conversely the lag time can benefit operations as a good portion of the A.M.D. collected and treated can be held then discharged during peak stream flows a month later.

During this period streams into which treated water is discharged are gauged daily and dilution ratios (permit requirement) set according to flow and metal

analysis of the treated water. Normally this setting can be established mid-day to average out daily fluctuations. Concern that streams may undergo a diurnal fluctuation has recently been dispelled through detailed stream gauging using continuous level recorders. Change in flow was found to be slow enough such that a mid day reading, between 11:00 A.M. and 1:00 P.M., adequately portray average flow for the day. It is however imperative during this period to gauge streams daily to optimize dilution ratios and water discharge.

### **DIVERSION      STRUCTURES**

Like any mining operation, Equity must divert excess runoff away from the tailing pond and mining area. With the presence of A.M.D. it is increasingly important to minimize as much runoff as possible to defray pumping and treatment costs.

Four major diversion structures are in place to accomplish these requirements. Three of these systems exist above (east side) the tailing pond and mining areas. Berzelius and Lu Creek diversions, built during the pre-production stages, service the tailing pond complex by diverting flow from the hillside to the east and from Lu Lake to the west to Foxy Creek. Design of these two systems meet criteria to withstand a 1000 year, 96 hour storm event.

Bessemer Creek required diversion with the advent of acid generation and mining in the Main Zone pit. Although this system meets with the design criteria mentioned, it has overtopped its embankments on one occasion during the freshet period. This was caused by excessive snow accumulation in the ditch and with the rapid snow melt blocked the system in several areas. It is now standard practice to clean snow from this structure prior to spring runoff.

A fourth diversion ditch is located above the S.T. pit. This structure does not meet with the 1000 year 96 storm event criteria however is not as critical. Bypass would merely flow into the completed S.T. pit where discharge is directed to the adjoining streams.

## **TAILING POND**

Tailing from the milling and cyanidation circuits is discharged to an impermeable storage basin. Containment dams are constructed with glacial till barriers (upstream) backed with fine filter and bulk rock fill to provide stability to the structure. The facility operates in closed circuit to provide process water needs of the concentrator.

Care must be exercised, especially with make-up water, to maintain a water balance such that dam heights provide adequate free board through to the following construction season. Approximate distribution of process water demand is 90% recycle from the tailing pond and 10% fresh water make-up.

To inhibit seepage loss, foundations of dams are stripped of all organics, soft swamp deposits and other objectionable materials to expose dense foundation soils or bedrock. Materials that have been loosened by frost action in winter are removed from the fill surface and foundations prior to commencement of earthfill placement at the dams. Exposed bedrock surfaces in the core contact areas require cleaning with high pressure air/waterjets and placement of concrete to cover the rock surface. This provides a smooth contact surface on which glacial till can be compacted. The glacial till barrier is placed and compacted in relatively thin horizontal layers starting at the lowest part of the dam. Oversize boulders greater than the required lift thickness are removed as till is placed.

What seepage exists is collected by a recovery system consisting of a dam and pumping station. Seepage is returned to the tailing pond although piping is in place to return flow to the treatment plant.

Tailing produced in the concentrator circuit are processed with cyanide to remove trace gold prior to disposal in the tailing pond. Cyanide in tailing must be destroyed prior to final discharge to the tailing pond as values upward of 10 mg/l in the process water decreases efficiency of the flotation circuit. For this reason the INCO S02 air destruction process was selected.

Two options existed, either treat clear tailings supernatant being reclaimed from the pond or treat gold plant slurry (tailing). Although the simplest and

most cost effective route would be to treat the supernatant, the decision was made to treat the slurry. This process decision had the distinct advantage of using the tailings pond as a buffer should intermittent failure of the cyanide destruction system occur.

Implementation of the INCO SO<sub>2</sub> Air process was at the time a relatively new process, however was being used successfully at a number of different Canadian mining operations. The reaction is a three stage process with the free cyanide being removed first, then the metal cyanide complexes, and finally with sufficient time the thiocyanate species. The metal cyanide complexes are removed in the order Zn>Fe>Ni>Cu as metal hydroxides at the process pH of 8.5. Reaction kinetics are controlled by aeration rate and catalyst concentration. By increasing the copper catalyst in solution the oxidation efficiency improves resulting in lower SO<sub>2</sub> consumption.

Natural degradation of Cyanide occurs during summer months as the pond is shallow and relatively clear providing for excellent ultra violet penetration. During this period the destruction circuit can be shut down for short periods to save on reagent consumption.

Seepage from the tailing pond is acidic because of the pyrite content in rock fill used to construct Il Dam. By introducing this flow back into the system, the pH of tailing supernatant is reduced from its normal level of pH 8.5 back to 6.5-7.0. This practice has the distinct advantage of dissociating cyanide species to Hydrogen Cyanide (HCN). In this form, Cyanide has little effect on the flotation process even if cyanide values encroach on 10 mg/L. This depression in pH also assists in dissociating cyanide during the summer through volatilization of HCN to atmosphere.

Tailing pond operating practices are reviewed annually by a geotechnical consulting firm to insure construction standards and water balance criteria are met.

## **OPREPIT AREAS**

As a rule all water produced in the open pits, both groundwater and surface runoff, can be direct discharged to the receiving environment. There is however occasions when heavy metal contamination is noted requiring discharges to be rerouted to the A.M.D. collection and treatment system.

Over the years it has been noted that water quality generally remains within discharge specification as long as mining is being actively pursued. However once completed, water quality can deteriorate to a point where treatment is required. There is no permit guideline in place for these discharges but rather a clause stating that if these discharges impact water quality downstream (Bessemer Creek) a contingency plan must be in place to accommodate collection and treatment.

It is apparent from data that as long as mining is in progress and fresh rock surfaces are continually exposed/ there is a replenishment of material that has the capacity to add alkalinity to runoff. The process can increase pH of pit water to 8.0 or better and effectively precipitate metals common to A.M.D. Metals such as antimony and aluminum can redissolve at this end of the pH scale however are of lesser concern as they are not as toxic as other metals (ie. Cu, Zn and Cd) found in A.M.D.

With termination of mining in the Southern Tail (S.T.) pit, water quality gradually deteriorated to a pH of 3.00 (Figure 6), Prior to backfilling the pit with waste from the M.Z. pit, tests indicated that these wastes would improve this pH to a range of 7.5-8.0.

Although wastes removed from the M.Z. pit are acid generating, disposal below water inhibits oxygen transfer and assists in liberating the alkaline fraction of the material. It took about a year from the start of the backfill operation for water to improve to discharge quality which has in part been attributed to water levels in the pit in relationship to finer materials at the dump head. Discharge has been directed to Bessemer Creek since June 1987 and has had no detectable impact on water quality downstream. A.M.O. continues to be generated from unconsolidated wastes in slide areas however alkalinity within the pool of water is sufficient to treat these disturbances.

Zinc shows some increase over the last year although at 1.5 mg/l is not viewed as a problem at this stage.

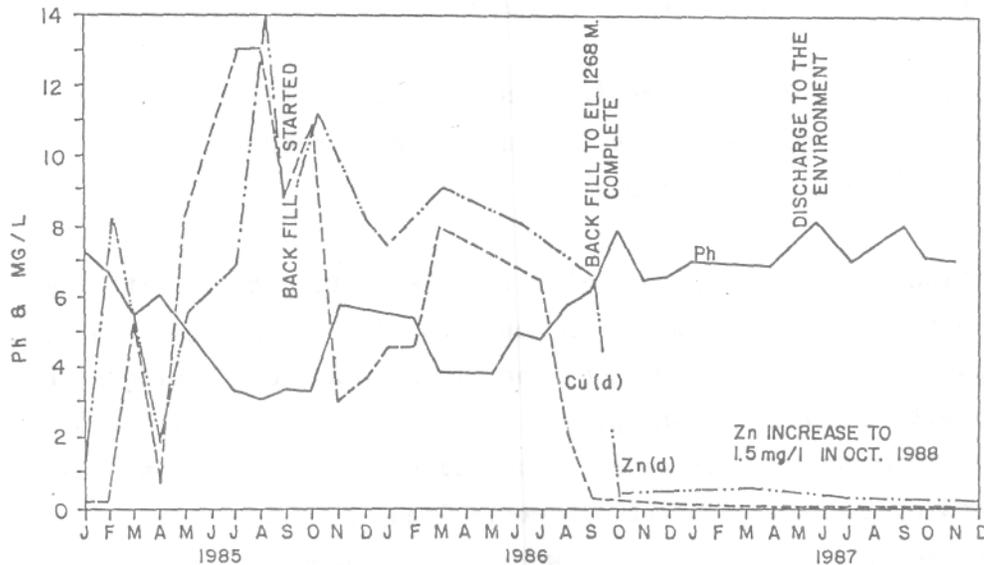


Figure 6: S.T. Pit Water Statistics

A similar proposal is being considered for the M.Z. pit whereby waste from the Waterline pit will be used to increase alkalinity of the system.

### **A.M.D. COLLECTION & TREATMENT**

All drainage generated from the waste dumps, haulage roads, and plant area must be centrally collected within a catchment system and pumped to a treatment plant. Collection is achieved with a peripheral ditch system excavated in impervious glacial till. Two collection ponds receive flow although only the lower pond has been outfitted with a pump system. The upper pond serves as a storage system to attenuate peak flows and is manually released (valving) to the lower pond as pumping capacity permits.

Pumping facilities consist of 3-75 H.P. in-line centrifugal pumps capable of handling 1300 USG/M. These are used throughout the year to deliver A.M.D. to the treatment plant. Two more pumps (150 H.P.) are contained within the same system however are used on a standby basis during freshet and storm events. These units are capable of handling 2500 USG/M. A.M.D. handled with these standby units is normally discharged to a storage pond adjacent the treatment plant although piping is in place to deliver flow to the treatment plant.

Treatment from the storage pond progresses after the peak runoff. By storing a good portion of the runoff in a common pond, acidity peaks are smoothed out and treatment control is easier to achieve.

Several satellite or mini collection systems exist outside the confines of the collection system and serve to collect minor seepage. This seepage is returned to the collection ditches.

Neutralization of the A.M.D. is relatively easy to achieve with lime addition to pH 8.0-8.5. Lime is brought in by bulk carrier and stored in a silo of 240 tonnes capacity. Auger systems feed the lime to a dual slaking system, where when mixed with water reach an optimum slaking temperature of 55-60 degrees C. Temperature is controlled by water flow to the feed end of the slakers. All start-up and shut-down sequences are controlled by a computer system. Slaked lime is stored in a holding tank where on demand is metered to reaction vessels for treatment of A.M.D. pH control can be operated on a manual or automatic mode. Once neutralized treated solutions are passed via ditching to one of two sludge settling ponds where metal hydroxides settle out of solution and treated supernatant decants to a reservoir. Capacity of this reservoir can adequately handle in excess of 2 years treated water.

For the time being, A.M.D. treatment sludge is pumped from the settling ponds during the spring and summer and mixed with tailing. Tests are in progress to evaluate methods to consolidate sludge such that land fill options can be implemented for post closure disposal.

Treated water is discharged to the receiving environment (Foxy & Bessemer Creeks) as soon as streams open up and sufficient dilution is available. The dilution ratio, treated water discharge to stream flow, is stipulated in the discharge permit and has been calculated on the basis of copper values. Ratios are assessed on net loading to insure that provincial receiving water objectives are not exceeded downstream of the discharge point. The permit maximum of 0.05 mg/l for copper discharge has not been difficult to attain and as a rule ranges between 0.01-0.03 mg/l.

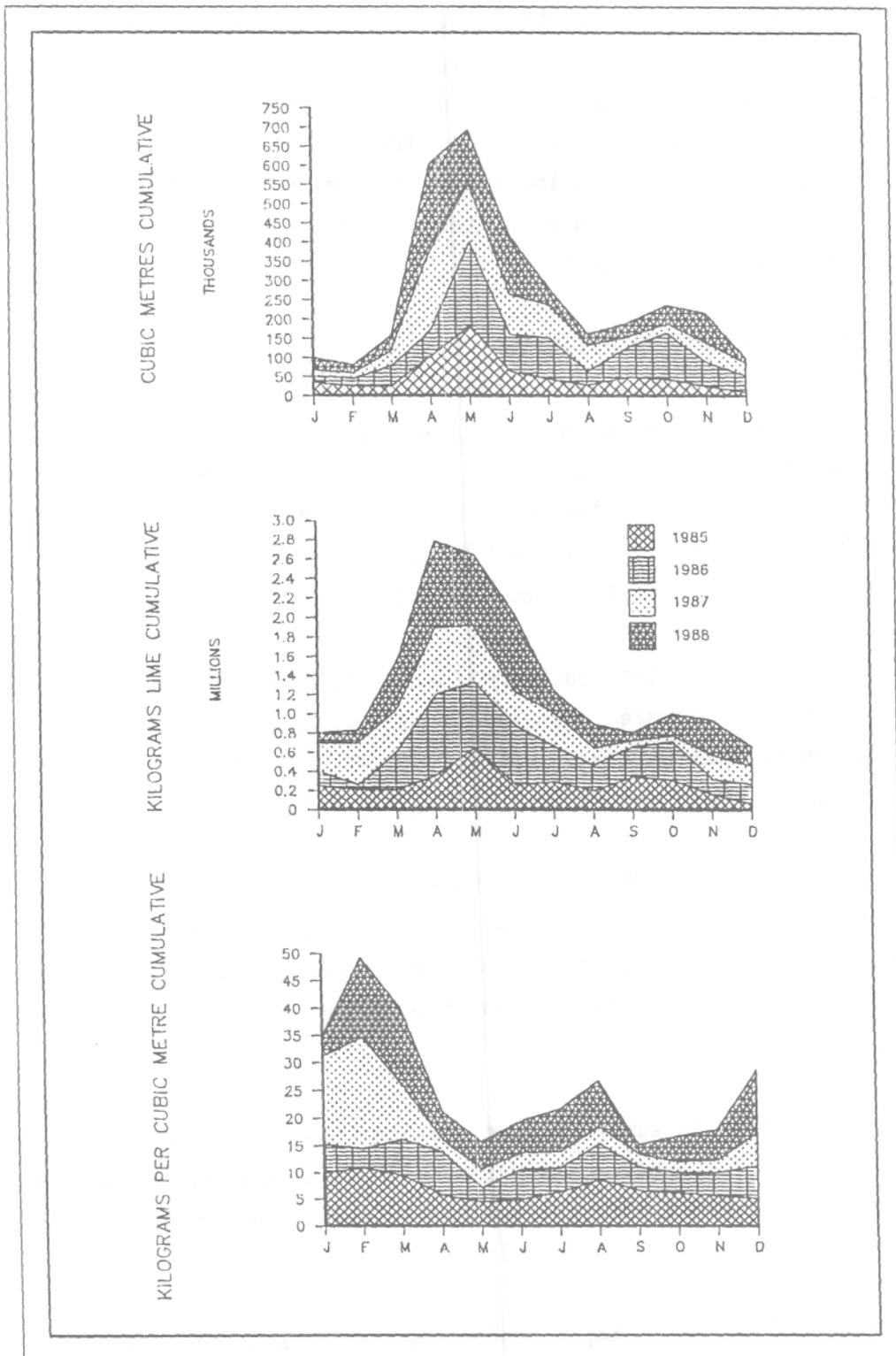


Figure 7: Composite Statistics On Treatment Plant Feed, Total Lime & Unit Consumption

Statistics are maintained on treatment plant feed volumes, lime consumption and unit consumption of lime per cubic meter of A.M.D. treated. This data is presented as a 4 year composite in Figure 7. From the graphs we note that total lime consumption in kilograms is in direct relationship to flow whereas unit consumption in kilograms is inversely proportionate to flow. This trend is a product of high acidities during the low flow periods and with increase in flow this acidity is diluted.

### **MONITORING PROGRAMS**

Monitoring programs at Equity Silver can be broken down into five categories. Of highest priority is a program listed within an effluent discharge permit. Because most of the sample collection pertains to streams and groundwater draining the minesite, particular care in sampling and analysis is required to achieve the low detection limits. For this reason, Equity Silver must have this work done at a contract lab specializing in this type of work.

This regional program has been in place for the past eight years to serve as a base for present and future assessment of minesite drainage. Although a permit requirement, flexibility is offered in that changes to the program are reviewed annually by Waste Management and Equity Silver.

Parameters evaluated on the Foxy and Buck Creek sites include chemical and physical analysis for the following: pH, conductance, temperature, non-filterable residues, alkalinity, total sulphates, nitrates, total cyanide, dissolved and total copper, zinc, aluminum, arsenic, antimony, cadmium and iron.

Groundwater is checked in seven active piezometers; three exist on the Foxy Creek side to evaluate seepage loss from the tailing pond and the remaining four on the Bessemer Creek side to evaluate impact of A.M.D. from the waste dump.

Many of the sites routinely sampled under the permit schedule are also checked through Equity Silver's lab. There is no official schedule set-up for this work although frequencies as often as daily are used if there is a suspected problem within the system.

Samples are commonly analyzed for ph, conductance, dissolved and total copper, iron and zinc. Any significant change in these parameters triggers further investigation within the system. The volume of data produced by this program far exceeds that generated by the permit program, however is not commonly published due to detection limit restraints of equipment used by Equity Silver.

A quantitative monitoring program, commonly termed as Contaminant Loading, has been in place since October 1987 and was implemented at the recommendation of the Waste Management Branch. Flow and water analysis are collected monthly at eleven sites within the A.M.D. collection system. Through metal balances, problematic areas are defined and provide a data base for evaluating the long term trends of acid generation within waste fills. All samples are analyzed on-site as metal levels are elevated and well within the detection capability of Equity's equipment. Samples are analysed for ph, conductance, acidity, sulphates, dissolved copper, iron and zinc, along with the ferrous iron species. Determination of the latter provides valuable data for water treatment requirements and depict the general state of oxidation and bacterial action within the waste pile.

Aside from the odd special waste extraction, most testwork is carried out and analyzed on-site. Again the basic parameters ph, conductance, acidity, sulphates, dissolved and total metals (Cu, Fe, Zn) are used to estimate quality changes under test scenarios. Most samples contain sufficient metal in solution to accommodate the capability of on-site detection limits. On less contaminated samples one cannot expect any further accuracy than 0.03 mg/L for Cu and Zn. Testwork performed on-site include: Acid Generation/Neutralizing Potential, Column and Lysimeter Tests (Kinetic), Sludge Characterization and Reclamation test plots to assess A.M.D. measures using till covers.

Fish tissue collection for metal analysis has been carried out annually since the early stage of operation. Samples are collected by a contract biologist and sent to Equity's contract lab for analysis. Individual samples are aged and analyzed for Cu, Pb, Zn, Cd, As and Sb. Fish density surveys are conducted in Foxy and Buck Creeks. Although this type of survey is not projected to be

an annual event, periodic checks are thought to be necessary for following trends of habitation in streams draining the minesite.

## RECLAMATION

Equity's reclamation mandate has been to cover waste dumps with 0.75 to 1.0 meter of glacial till to inhibit transfer of oxidation ingredients that promote acid generation (precipitation & oxygen). These seals are reclaimed annually and where required receive a maintenance application of fertilizer and seed. While the mitigative properties of this technique is not fully understood at this time, the aesthetic benefits are rewarding. Predominantly all waste dump surfaces and a good portion of the surrounding area supports healthy stands of grass and clover.

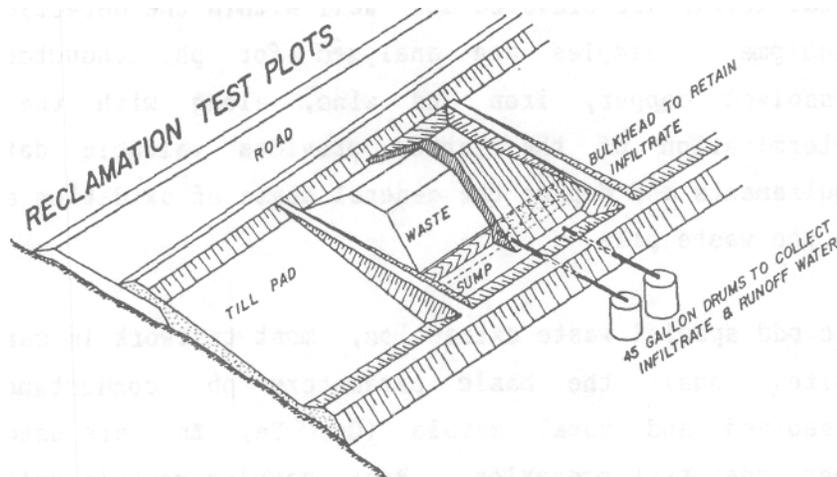


Figure 8: Reclamation Test Plots

Test plots containing acid generating wastes (Figure 8) are being used to evaluate the acid generation inhibiting properties of glacial till covers. From data collected thus far it appears that covers of 0.5 to 1.0 meter thickness can reduce metal loading (Cu, Fe & Zn) by 41% and sulphate and acidity loading by 38%. Further tests are planned during 1989 to substantiate these findings.

Where possible, acid generating wastes have been removed from isolated areas and deposited on the the waste dump to minimize zones of contamination. With pending closure of the mine, more cleanup work of this nature is planned.

### **SUMMARY**

Control measures at Equity Silver Mines Ltd. have been effective in minimizing the environmental impact of A.M.D. Those reclamation measures practiced, at least from results indicated by testwork, appear to be reducing net metal, sulphate and acidity loading by 40 %. Monitoring will be continued to substantiate these reductions.

Research work continues at the mnesite to optimize treatment processes such that post closure operating costs are maintained within a manageable range. Details are now being worked on to secure funds to accomodate inperpetuity treatment of A.M.D.. There is however legislative and tax changes required to accomodate tax exemption within the program.

With all conditions realized, water management could be a real operating burden if not for for the undivided support of management and operating crews at Equity Silver Mines Ltd. For this the writer extents much appreciation.