A DISCUSSION OF SOME ASPECTS OF COPPER LOADING AND STREAM FLOW BELOW THE ABANDONED COPPER MINE ON MOUNT WASHINGTON, BRITISH COLUMBIA

Jamie Birtwistle
Sean Campbell
Laura Carleton
Simon Fodor

Camosun College
3100 Foul Bay Rd
Victoria BC, V8P 5J2

ABSTRACT

This paper is an excerpt from the report "Loading and Stream Flow Below the Abandoned Mount Washington Copper Mine, British Columbia", written in the Spring (2005) and submitted as part of a sustainability project in Camosun College, Victoria, BC. In the 1980s, studies attributed a decline in salmon populations in the Tsolum river to poor water quality caused by acid mine drainage and high copper concentrations in the creeks flowing off the Mount Washington mine site. Various remediation projects were initiated, with studies conducted to measure their effectiveness. The subject of this paper is the relationship between flow and copper loadings. The study uses historical data and the results of sampling, and analysis in 2005. The results show a clear relationship between flow and copper loadings at most times of year. When discharge is low to moderate, the supply of soluble, weathered copper on the mine site is ample, and the loading-discharge relationship is discharge-dependent and linear. However, through the high discharge of the late spring *freshet* and winter rains, the supply of soluble, weathered copper appears to become depleted. At such times, the relationship between loading and flow is apparently non-linear.

INTRODUCTION

This paper discusses the relationship between copper concentrations and stream flow in waters flowing from the abandoned copper mine located on Mount Washington, British Columbia. This relationship affects water quality, and thus the health of fish populations in the Tsolum River near Courtney, B.C. The paper will begin with an introduction to the Mount Washington mine, an overview of the hydrology at the mine site and project rational.

Study Site

The mineral deposits are located at approximately 1350 meters above sea level on the north face of Mt. Washington, 1 km north west of the summit. The primary ore extracted was the copper-bearing sulphide, chalcopyrite ($CuFeS_2$). Surface mining techniques were used to extract ore from two locations, resulting in a north and south open pit and three waste rock piles. The ore was processed at a mill located at a lower elevation on the mountain (SRK 2000). The mine was orphaned in 1967 after two years of operation by Mt. Washington Milling Co. Ltd (SRK 2000). Many of the original features of the mining operation still exist today.

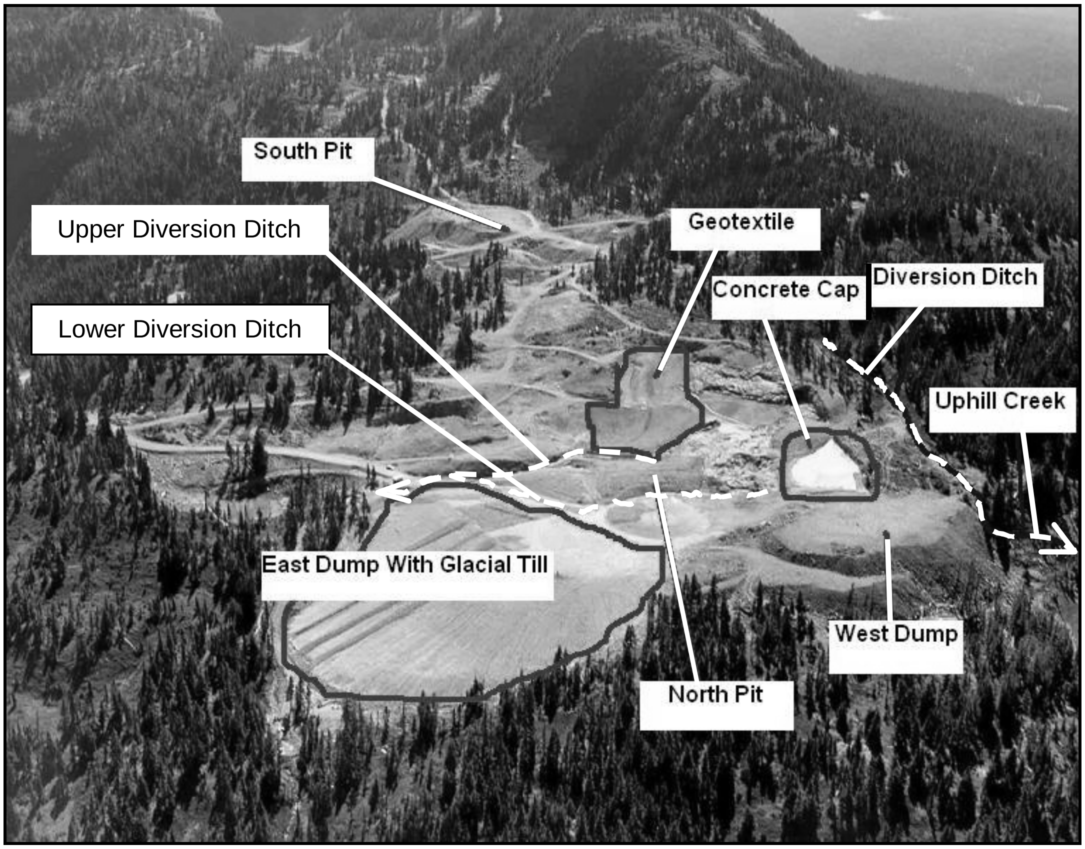
The South pit does not contribute significantly to copper levels in the Tsolum River. The gross area of the North Pit complex is approximately 10 ha. The North Pit is very shallow, free draining, and approximately 4 ha in size (Figure 1). The East Dump is approximately 3 ha and the West Dump 2.5 ha.

Remediation

An interest in remediation of the mine was sparked in the 1970s by the decline in salmon stocks in the Tsolum River (Galbraith 2005, pers. comm.). Water quality assessments at the time showed dissolved copper concentration to be well above safe levels for fish. The concentrations were traced back to the tributaries of the Tsolum River; McKay, Murex, and Pyrrotite Creeks. These creeks receive the AMD-affected surface waters from the mine.

In 1988, the Ministry of Energy and Mines (MEM) launched a five-year program aimed at reducing the release of copper into surface waters draining from the mine. The approach of the MEM remediation project was primarily preventative, in that it focused on excluding water and air from sulphide minerals present in waste rock and the pit, thus decreasing the amount of AMD. In 1988 and 1989, rubble from the pit floor was collected, mixed with limestone, spread over the East dump and covered with a layer of low-permeable glacial till (see Figure 1). As well, three diversion ditches were constructed to channel surface runoff away from the encapsulated East dump. The diversion ditch above the headwall is the source of Uphill Creek and the two diversion ditches within and below the pit channel surface waters to weir 3. A fibre blanket made of coconut matting and propylene fibre netting laced with grass seed was placed on the lower half of the East Dump cover in an effort to control erosion. However, the short growing season resulting from the large snow pack was thought to have prevented the seed from germinating. Further remediation work, including experimentation with asphalt impregnated geo-textiles and capping of rubble in the pit with concrete. In 1994, in view of the apparent ineffectiveness of the control measures undertaken and demands for other work, the program was suspended indefinitely (Galbraith 2005, pers. comm.). No further on-site remediation has taken place since that time, though various reviews have been conducted and the results published (cf. SRK, 2000).

Figure 1: Mt. Washington Mine Site Remediation



<u>Hydrology</u>

The South Pit complex drains to McKay Lake, then to McKay Creek, Murex Creek and the Tsolum River. The North Pit complex drains to Pyrrhotite Creek (see Figure 2).

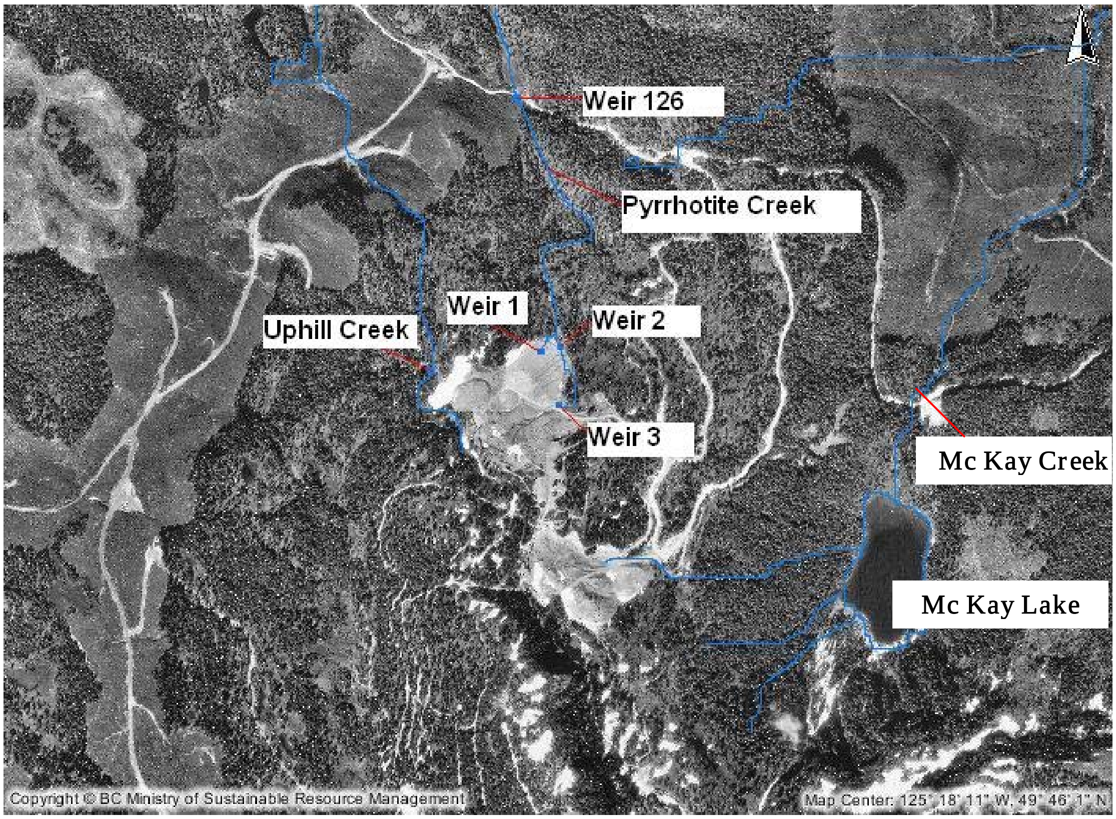
Uphill Creek lies in a steep gully up slope of the North Pit headwall and diverts surface drainage from higher on the mountain into Piggot Creek and then to the Oyster River. It is suspected that groundwater from higher levels emerges as seepage in the pit

The mine sits at the top of the Pyrrhotite Creek watershed. Approximately one kilometre downstream of the mine, just upstream of its crossing of Branch 126 logging road, the Ministry of Environment constructed a weir. This location was chosen for several reasons: the site was constricted; there is a good foundation; and it is accessible from logging roads for most of the year. The drainage basin above the weir has never been accurately delineated, but its area is estimated at approximately 25 ha. It is very steep and heavily wooded between the Br. 126 weir and the mine (Galbraith 2005, pers. comm.).

The lower Tsolum watershed, with a median elevation of 230m, has an average runoff of 1250 mm, with 70% due to rainfall. The Pyrrhotite Creek watershed, with a median elevation of

1300m, has an average runoff of 2030mm, with 50% due to spring snowmelt. Spring freshet occurs at the mine site later than it does on the lower Tsolum River. Pyrrhotite Creek and the Tsolum River both have very low flows in the summer (Deniseger, 1987).

Figure 2: Mt. Washington Mine Site Remediation



PROJECT RATIONALE

In the past, the Tsolum River supported healthy populations of rainbow and cutthroat trout, steelhead, coho and pink salmon. It is thought that reducing trace metal discharge, predominantly copper, from the Mt. Washington mine site is integral in re-introducing and protecting the Tsolum fish populations. With respect to dissolved copper, there is debate over which measurement is of greater value: concentration or loading. In their report regarding “Monitoring Results” Galbraith et al. (1992) state:

“The effectiveness of ARD control work can be assessed by measuring annual loading of acid or metals for the site as it existed prior to reclamation, and comparing this to the post reclamation condition.”

Loading is expressed as a unit mass per unit of time, typically milligrams per second (mg/s). It is obtained by multiplying stream discharge and concentration of metal in the stream and is a measurement of the amount of copper leaving the mine site per unit time. In contrast, concentration has is the mass of substance per unit volume and has no time component. Concentration is an important water quality parameter, but without flow data cannot be used to estimate downstream problems resulting from mine drainage.

Historical data suggests there is a relationship between copper loading and stream discharge (Galbraith pers. comm.). If this relationship exists "...then remedial work will be reflected by a change in the slope of the Loading vs Discharge curve (Galbraith et al. 1992)." This project seeks to explore this relationship, and the hypothesis that the load of dissolved copper flowing from the mine via Pyrrhotite creek is proportional to stream discharge.

METHODS

The Ministry of Energy and Mines (MEM) and the Ministry of Water, Land and Air Protection (MWLAP) provided historic data for statistical analysis. This data was used in combination with field data collected during the month of May 2005.

Field data

Four trips were made to the mine site in spring, 2005, to collect discharge data and water samples. The team camped below the mine site and collected samples over a period of one to three days. Trips were made during the periods of May 3-5, 13-15, 26-28 and June 6.

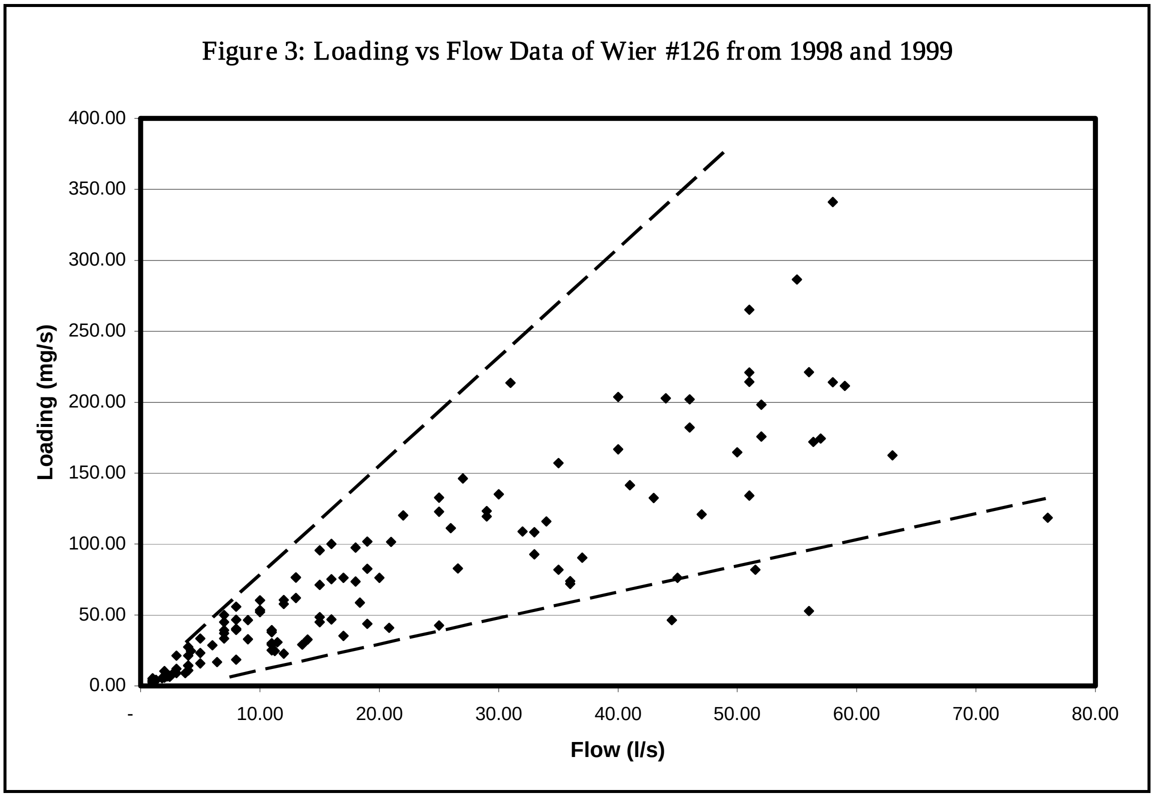
Water samples and stream discharge measurements were collected one to three times a day at Weirs 1, 2, 3 and 126. When possible, samples were collected in the morning and afternoon, in an attempt to characterize diurnal differences in flow and loading during each sample day.

RESULTS

This section will outline the steps we took in developing a model that describes the relationship between copper loading and stream discharge. It will also present the field data obtained from Weirs 1, 2, 3, and 126 in 2005.

Weir 126 Data from 1998, 1999, 2004, and 2005

It was decided that the analysis of the relationship between copper load and stream discharge would focus on Weir 126 due to the greater amount of data and longer period of record. Initially, loading was plotted against flow at Weir 126 on an x, y scatter plot (Figure 3). Although a linear correlation appears to occur at lower discharge, there is far more scatter at higher flows, suggesting that loading and discharge are not directly proportional.



The next step was to plot stream discharge and copper load versus time using the data from 1998 and 1999 (Figure 4). In both years, copper load and water discharge track each other during the build up to the spring *freshet*. As the *freshet* continues, the lines diverge with discharge continuing to increase, while the copper load declines dramatically. After the spring *freshet* and throughout the following winter, the copper load again tracks discharge. This graph led us to believe that the system is governed by two limiting factors: the amount of soluble copper, and sustained volume of the *freshet* discharge.

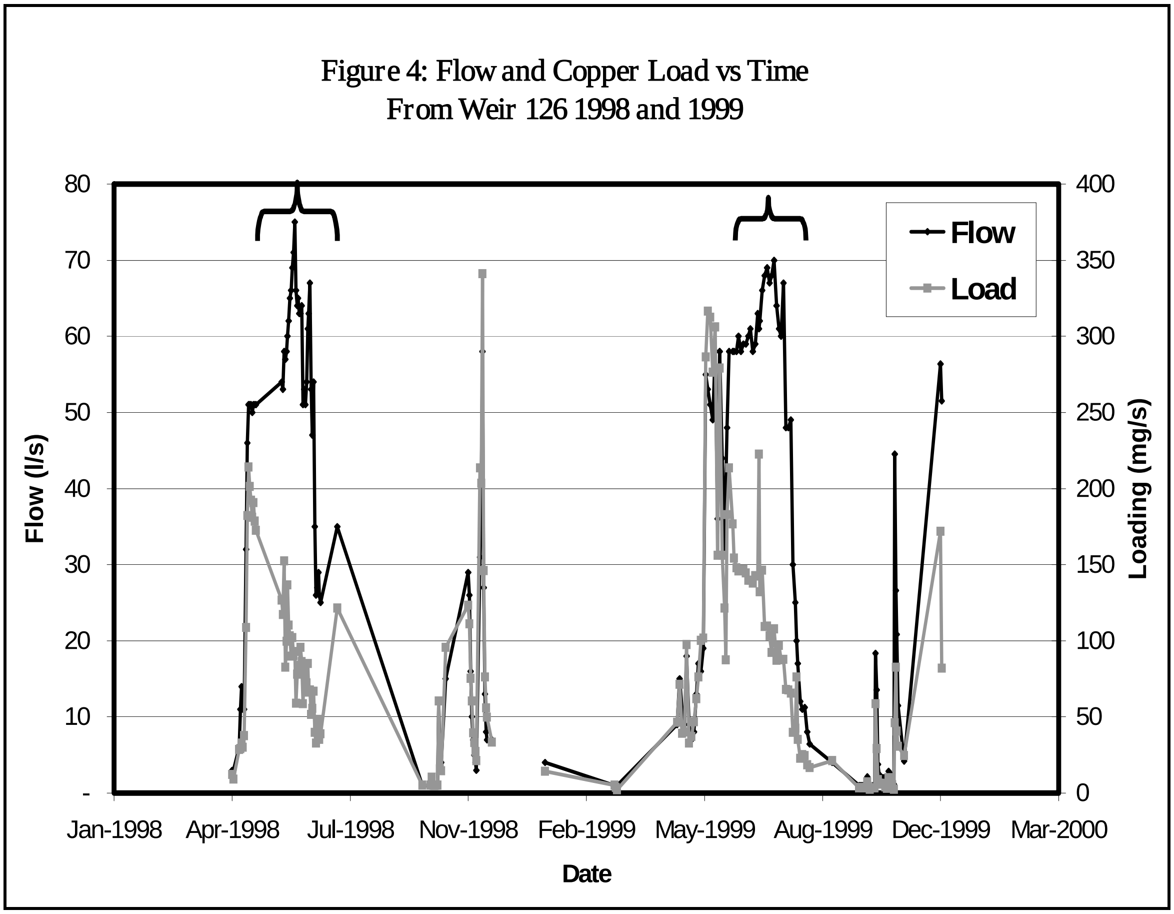
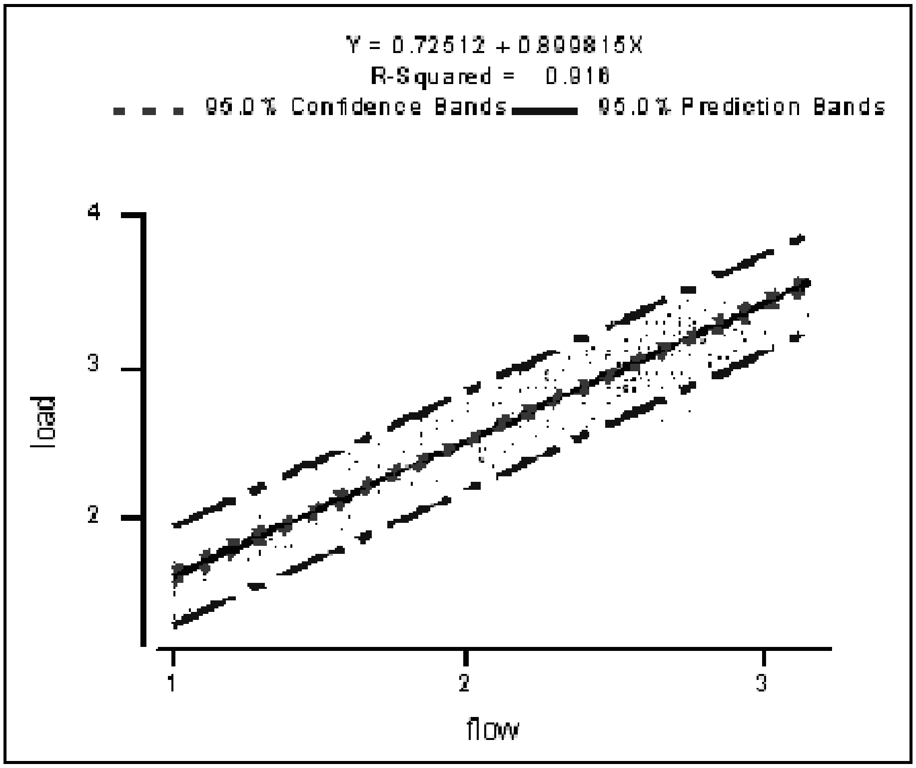


Figure 4: Flow and Copper Load vs Time
From Weir 126 1998 and 1999

Next, data from the periods in the latter half of the *freshet* for 1998 and 1999 where the lines in Figure 4 diverge (indicated by the brackets in Figure 4) were removed. With the data set truncated to include only the discharge-limited periods of the years, a new X, Y scatter plot was produced. This scatter plot is shown in Figure 5. This figure shows that during this time the relationship between loading and discharge was roughly proportional at all levels of water discharge.

Figure 5: Fitted Line Plot for the Data Set that Represents the Discharge-Dependent Portions of the Years 1997, 1998, 1999, 2004, and 2005



Loading and Flow at Weirs #1, #2, #3 and #126 in 2005

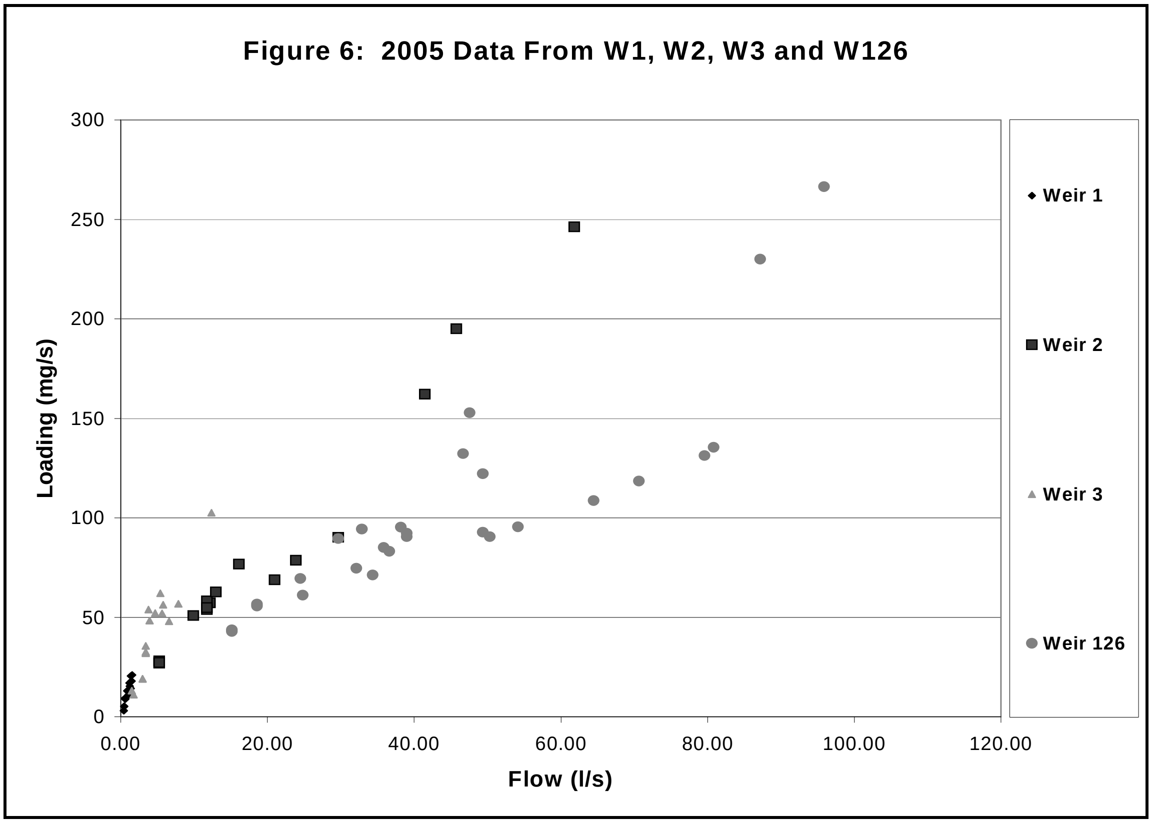
Figure 6 shows a plot of loading vs. flow for 2005 for the three weirs on the site plus that at branch 126.

Weir #3 is at the end of the diversion ditch and drains: surface runoff from the cleaned pit floor area; most of the headwall; several seepages exiting bedrock; and a large pocket of waste in the south half of the North pit - about half of which is (or was at one time) covered by waterproof sheeting. The flow from this weir dominates site drainage during storm events, spring freshet and fall rains.

Weir #1 measures discharge exiting the east dump which includes: incident precipitation that infiltrates through the till blanket; an unknown amount of shallow groundwater originating upslope in the pit; and an unknown amount of deeper groundwater originating higher up in the mountain. Flow from this weir dominates the overall site discharge in the brief dry summer period, following cessation of surface runoff. Notably, the south branch of the internal drain within the East Dump has failed, and, during peak flow, an unknown amount of drainage exits the toe unmeasured.

Weir #2 is fed largely by Weir #3, but also picks up some perimeter drainage and some groundwater.

Although these relationships were not proven statistically, Figure 6 suggests a roughly linear relationship between discharge and loading. The slopes of the various lines on the graph might describe the rate of loading and changes in concentration.



CONCLUSION

The results of this project show that copper loading is positively correlated with discharge during periods of low to moderate discharge; at such times, the system may be considered flow-limited, with an ample supply of soluble (weathered) copper readily available for transport off the mine The data from 1998 and 1999 indicate that after extended periods of high flow, copper loading and flow diverge from one another, suggesting that the available supply of soluble copper has been used up. At these times, the system may be considered weathering-limited, and the relationship between loading and discharge is too variable to be predicted.

If it is possible to reduce water from contacting exposed sulphide minerals in the mine pit, making a perpetually low flow situation, the copper load entering the Tsolum River via Pyrrhotite Creek would be dramatically reduced. In this situation, the relationship of load vs. flow could be used to assess the effectiveness of remediation by comparing the slope of the line over time. For example a stable slope may indicate that the relationship between copper load and discharge has not changed, meaning that remediation has had no effect. In contrast, a decreasing slope likely indicates successful remediation.

Recommendations

- Establish a relationship between discharge and copper loading in Weirs 1, 2 and 3; replicating what was done for Weir 126 study.
- Develop a detailed copper loading model for Weirs 1, 2 and 3 and determine for what parts of the year the model of loading vs. discharge and discharge vs. time can be applied within the mine pit.
- Use the flows at the mine site and in the drainage basin to determine how frequently the required copper concentration criteria are met during different periods of the year, using the loading discharge methods in this report.
- Design a hydrological model of the Tsolum drainage basin (Murex and Mackay Creek) to determine the affect of background copper levels in surrounding streams.

ACKNOWLEDGEMENTS

This project would not have been possible without the generous support of Murray Galbraith (P.Eng), John Deniseger (MWLAP), Lynn Campo (Water Survey of Canada) and Father Charles Brandt and Jack Minard from the Tsolum River Restoration Society. We would like to express our sincere gratitude to these individuals at Camosun College: Chris Ayles (Faculty Advisor), David Blundon (Statistician), Tark Hamilton (Geochemistry), Neil Meanwell (Chemistry), Carol Chalmers (Chemistry Technician.), Warren Drinnan (QA/QC), Dianne Humphrey (Environmental Technology Program Chair) and Tony Dorling (Environmental Technology Program Assistant). We would also like to thank our editors Bill Price and Peter Jarman.

REFERENCES

Deniseger, J.H. and Erickson, L.J. 1987. Impact assessment of acid mine drainage from an abandoned Copper mine on Mt. Washington. Report: B.C. Ministry of Environment & Parks, Nanaimo, B.C., Canada.

Envipro Miljoteknik AB, 2000, Review of SRK Final Report “Hydrogeological and Hydrological Evaluations for the Development of Remediation Options for Mount Washington, Courtney BC”

Galbraith, M. 2005. Verbal and written communication.

Galbraith, M., M. Chaudhry and T. Schwab. 1992. Monitoring Results. Internal MEM report.

Steffen, Robertson and Kirsten. 1988. Report on 1988 Construction Activities, Mt. Washington Minesite Reclamation.

Steffen, Robertson and Kirsten (Canada) INC. 2000. Hydrological and Hydrogeological Evaluations for Development of Remediation Options for Mount Washington, Courtenay, B.C: http://www.pyr.ec.gc.ca/georgiabasin/reports/Mt_Wash_Report/EC-00-0018_E.PDF