Gartner Lee Limited

memorandum

to: Eric Denholm
from: Neil Hutchinson
date: November 14, 2003
ref: GLL 23843
re: **Site Specific Water Quality Standards for Anvil Range Site**

Introduction

The current Water Licence for the Faro mine site specifies the CCME Water Quality Guideline for the Protection of Freshwater Aquatic Life as the closure water quality objective in receiving waters and it is reasonable to consider this standard applicable to the Vangorda Plateau site also, as was raised at the Water Licence Renewal Hearing. The CCME documentation, however, allows for modification of a generic water quality objective to derive a site-specific objective for application to specific sites with unique characteristics. Documentation by CCME (2003) and the Government of British Columbia (1997) provides protocols for the derivation of site specific objectives.

The purpose of this document is to review the rationale, methods and information requirements to derive site specific water quality objectives for the Anvil Range sites.

Contaminants of Concern

The objective development process will focus on zinc and on sulphate as the contaminants of concern, as these are the only contaminants discharged from the mine that :

- Show concentrations in receiving water that exceed those in reference waters for the sites,
- Show concentrations in receiving waters that exceed either or both of the CCME or BC Environment Guidelines for protection of freshwater life, and
- Have the potential to be toxic at the observed concentrations (i.e. Mn is also found at concentrations above reference levels but there is no CCME guideline for Mn and Mn concentrations in receiving waters are below the BC Environment Guideline (hardness adjusted).

Receiving Water Protection Strategy

Two distinct strategies are commonly used to establish Water Quality Objectives in Canada : the antidegradation strategy and the use protection strategy. The antidegradation strategy is used to avoid any degradation of existing water quality where aquatic resources have national or regional significance. The receiving waters at the Anvil Range site, namely Rose and VanGorda Creeks, have not been identified as having any national or regional significance as they are not known to exhibit exceptional water quality or to support any rare or endangered species of aquatic or terrestrial life. In addition, both have been subject to discharge of mine effluents over a 30 year period, such that any original significance will have been altered.

The use protection strategy is therefore appropriate for these sites. This strategy states that Water Quality Objectives are established to protect the designated uses of the aquatic system and that some degradation of water quality is permitted, so long as the designated uses are protected. The history of mining at the Anvil Range site and the potential that some discharges from the mine site will continue at closure support the application of the use protection strategy for deriving water quality objectives at the site.

Most Sensitive Water Use

The CCME and the BC Ministry of the Environment recognize the following water uses :

- Drinking Water
- Recreation and Aesthetics
- Livestock Watering
- Irrigation
- Freshwater Life
- Marine Life.

The Anvil Range sites do not support marine life or irrigation as water uses. Recreation and Aesthetics are valid uses of these water bodies. Livestock Watering does not occur in the study area but that use would presumably protect wildlife that use the water for drinking. VanGorda and Rose Creeks provide potential sources of drinking water to First Nation users, potentially to recreational users and potentially to the Town of Faro (although the latter has not been confirmed and is the subject of a proposed study). Protection of Freshwater Life is an important use, as fish and aquatic invertebrates have been documented in Rose and VanGorda Creeks.

The Water Quality Objectives for Freshwater Aquatic Life for Zn are :

- CCME (2003) = 0.03 mg/L
- BC (2001) – maximum concentrations not to exceed 33 + 0.75 * (hardness - 90)
- BC (2001) – 30-day average concentration not to exceed 7.5 + 0.75 * (hardness –90)

For Drinking Water, the Objectives are :

- CCME (2003) = 5.0 mg/L
- BC (2001) = 5.0 mg/L

Therefore, protection of freshwater life from Zn will also protect other, less sensitive uses.

The Water Quality Objectives for Freshwater Aquatic Life for dissolved sulphate are :

- CCME (2003) = no objective
- BC (2001) – maximum concentration not to exceed 100 mg/L
- BC (2001) – Alert Level to protect aquatic moss populations = 50 mg/L

BC Environment states that hardness may alleviate sulphate toxicity.

For Drinking Water, the Objectives are :

- CCME (2003) = 500 mg/L
- BC (2001) = 500 mg/L

Therefore, protection of freshwater life from sulphate will also protect other, less sensitive uses.

Summary – The Development of Site Specific Water Quality Objectives for the Anvil Range Site will focus on zinc and sulphate as Contaminants of Concern, will adopt the Use Protection Strategy and will focus on protection of freshwater aquatic life as the most sensitive water use.

Rationale for Development of Site Specific Objectives

The existing CCME and BC Objectives are “generic” water quality objectives, developed to cover a wide range of environmental conditions, to protect the most sensitive forms of aquatic life and developed using accepted scientific protocols. While adoption of generic Objectives represents the primary procedure for water quality protection, the presence of unique water quality characteristics or species assemblages at certain sites may necessitate the derivation of site adapted or site specific water quality objectives.

Several characteristics of the Anvil Range Site make it necessary to develop site specific water quality objectives. The first (and likely the most significant) is that the hardness and alkalinity of the receiving waters are variable, thus modifying the toxicity of zinc and sulphate. Two factors account for the variance – the first is the spring and summer freshet, during which meltwater from snow dilutes baseflow, thus reducing hardness and alkalinity levels from those which occur during the winter and late summer periods. The second is that the most significant source of zinc and sulphate is discharge of minewater that has been treated with lime, thus elevating pH, hardness and alkalinity in the discharge itself, and hence the receiving water. The complex interaction of the effluent discharge with variable receiving water quality will alter the toxicity of zinc and sulphate at the site.

The second factor for consideration is the freshwater aquatic community at the site. Arctic grayling are the species of greatest abundance, and are known to spawn downstream of the site in Rose and VanGorda Creeks. Burbot and slimy sculpin are also present. These species are not represented in the toxicity database used to derive the CCME and BC water quality objectives for zinc and sulphate. The significance of this is not clear, as many of the most sensitive coldwater species of fish and invertebrate were used for objective development and the database, at least for zinc, is robust. The database also contains data from numerous studies of salmonids. Arctic grayling are members of the salmonid family so that toxicity values from the database are likely applicable. Chinook salmon are present in the receiving waters and are represented in the toxicity database, as are several invertebrate species which are relevant to the site. Therefore, although the toxicity database does not contain data for grayling, it does contain data from representative coldwater species for the site.

Methods for Deriving Site Specific Objectives

Four procedures are recommended in CCME (2003) for deriving site specific water quality objectives.

Background Concentration Procedure

The background concentration procedure uses various statistical representations to determine the natural background concentrations of the contaminants of interest in the subject waters. Although it is useful to determine the background concentrations to help interpret other water quality objectives, in this procedure, the background concentration is the Water Quality Objective. Its use is based on the premise that superior water quality should not be degraded.

Several factors argue against use of this method at the Anvil Range Site.

- The natural background varies seasonally, in response to the freshet and so sampling requirements would be intensive and interpretation could be confounded,
- Natural background levels in the receiving portions of Rose and VanGorda Creeks have been altered by runoff and discharge from the mine site. No data exist from the period prior to mine operations and so background conditions cannot be established for the receiving waters.

- Background water quality was established for the EA Report using data collected from creeks upstream of the mine site. This approach is useful, but may not completely reflect background water quality for lower reaches of the creeks. The original background water quality may well have been changed between headwater areas, upstream of mineralized areas, and the downstream areas which are now receiving waters. Local geology will influence natural water quality. This can be seen in the differences between water quality in Anvil Creek and the headwaters for Rose Creek that were presented in the EA Report.

The background concentration method is not, therefore, recommended for the development of site specific water quality objectives for the Anvil Range Site.

Recalculation Procedure

The recalculation procedure uses the toxicity database used to derive the generic Water Quality Objective, but modifies the database by omitting data on species that are not relevant to the site in question. It therefore accounts for any real differences in the sensitivity range of the aquatic species in the complete toxicological data set and that in the species that occur at the study site.

The Water Quality Objective Development process is intended to protect the most sensitive life stages of the most sensitive species inhabiting a water body. Water quality objectives are therefore most influenced by the most sensitive species in the toxicity database used to derive the generic water quality objective. The recalculation procedure is most relevant where the most sensitive species in the database does not reside at the site under question. (i.e. the recalculation generally results in increasing the Water Quality Objective to account for waters where more sensitive species do not reside). The recalculation procedure cannot, by definition, result in an objective that is more sensitive than the generic objective.

Examination of the database used to derive the CCME objective for zinc shows that the most sensitive species and life stages are salmonid fish, and that chinook salmon are among the most sensitive species. Salmonids (grayling and chinook salmon) are present in the receiving waters at the Anvil Range site and the generic objective is set at a level to protect them. There is not, therefore, any real difference in the sensitivity range of the species used to develop the generic objectives, and those species present in Rose and VanGorda Creeks. Both sets contain sensitive species.

Use of the recalculation procedure would not, therefore, result in any change to the generic objective and would not accommodate differences that are significant to the receiving waters. It is not, therefore, recommended for the derivation of site specific water quality objectives for the Anvil Range Site.

Water Effect Ratio Procedure

The Water Effect Ratio (WER) procedure is based on the premise that physical and chemical characteristics of water can vary among sites and thus influence the bioavailability and toxicity of contaminants. For example, the toxicity of zinc is highly dependent on the pH, hardness and alkalinity of water. These factors are not considered in the CCME generic objective for zinc, although the BC objective does account for the effect of hardness on toxicity. The toxicity database used to derive the generic objective may contain studies done at water quality conditions that differ from those at the site. The WER procedure provides a powerful means of accounting for such differences to modify the generic objective to make it more relevant to a specific site.

The WER Procedure requires conducting toxicity studies in both the site water and in “standard” laboratory water, using either indicator species (i.e. those species for which standard toxicity testing procedures exist and which are representative of species found at the study site) or species that are resident at the study site. The WER is the ratio of the toxicity of the contaminant of concern in water from the study site to its toxicity in the standard lab water. The site specific objective is then calculated by multiplying the generic water quality objective by the WER. This provides a direct measure of the influence of physical and chemical characteristics of water from the study site on the toxicity of the contaminant of concern. For example, if hardness reduced the toxicity of zinc by a factor of two in water from the study site, then the WER of 2 would be applied to double the numeric value of the generic water quality objective.

The WER procedure is directly relevant to conditions on the Anvil Range site, where hardness and alkalinity vary seasonally. In addition, the aquatic species of concern are salmonids and these are well represented with standard toxicity testing procedures for salmonids and other sensitive species such as fathead minnows. There are therefore suitable test species and methods available at commercial labs to apply the WER procedure using water from the site on a routine basis, reducing the costs.

Use of the WER procedure at the Anvil Range Site would involve shipping volumes of Rose and VanGorda Creek waters to toxicity labs in order to run the comparative toxicity tests. Toxicity tests could be run as static tests with water replacement to reduce the volumes required. The protocol would have to be adapted, however to accommodate the seasonal variations in water quality (hardness and alkalinity) in the receiving waters on site. Several sets of toxicity tests would be required.

Use of the WER Procedure would generate the information necessary to develop site specific objectives for the Anvil Range site. It is the most cost effective means to address changes on water characteristics on the site and the species used are likely to generate results that are sufficiently protective of the aquatic communities in Rose and VanGorda Creeks.

Resident Species Procedure

The resident species procedure is designed to directly account for the sensitivity of species that occur at the study site and for the influence of site water characteristics on toxicity. It involves generating a complete toxicity data set, using established national protocols, for the contaminant of concern using site water and resident species. As such, it represents a direct and complete derivation of a site specific water quality objective.

The Resident Species Procedure is very costly and intensive. CCME protocol requires the use of six species (three fish, two invertebrate and one algal or plant species) and the annual variation in water characteristics at the Anvil Range site means that tests would have to be repeated to cover the ranges on water quality. In addition it is very costly and time intensive to develop care and culture techniques for a new species. There are no existing protocols or experience for the culture and testing of Arctic grayling, slimy sculpin or burbot. These would need to be developed with no assurance that these species would survive transit from the site, or adapt well enough to culture facilities, to produce reliable toxicity data. Finally, arctic grayling are a salmonid species, and the toxicity database is well represented with data on other salmonids. The effort and cost required to generate data specific to the species may not result in information that does not already exist in the salmonid database. Effects of water characterisitcs on toxicity can be addressed by the WER Procedure.

The Resident Species Procedure is not, therefore, recommended for development of site specific receiving water objectives for the Anvil Range Site.

Conclusions and Recommendations

The Water Effects Ratio Procedure is recommended for the development of site specific closure objectives for quality in receiving waters at the Anvil Range Site. The following toxicity tests are recommended :

- rainbow trout juvenile survival
- rainbow trout egg, larval and alevin survival
- fathead minnow larval hatch, survival and growth
- reproduction, survival and growth of the water flea (Ceriodaphnia dubia) or
- survival of a mayfly species.

Test should be conducted in waters collected from Rose and VanGorda Creeks during the freshet (June, when fish spawning and early development occur) and in the late summer, when baseflow conditions are present. These will cover the range of receiving water qualities.

A survey of receiving water quality is recommended, to establish the ranges of pH, hardness and alkalinity in the creeks prior to toxicity testing. This will ensure that the samples that are collected for toxicity testing cover the necessary range of receiving water characteristics.

Commercial toxicity labs use stock solution of zinc to dose the toxicity tests, and any reactions that modify toxicity will occur in the test waters. Testing protocol should consider the use of the actual effluents discharged from the Anvil Site to dose the test waters. These effluents will be specific to the actual conditions on site in terms of Ca, hardness and alkalinity, ensuring that zinc speciation and bioavailability in the toxicity tests is similar to that in the field.

There may be labs in North America that maintain stocks of arctic grayling for toxicity testing (D. MacDonald, pers. comm. Nov. 12. 2003). If these can be contacted, the WER procedure should be modified to include a toxicity test of early life stages of Arctic grayling. This would allow the response of a resident species to be included to modify the site specific objective to account for its sensitivity.

The Site Specific Objectives for each of the freshet and baseflow periods could then be calculated as:

Generic CCME Water Quality Objective
x WER(toxicity of mine effluent in Rose Creek Water/toxicity of zinc in standard lab water)
x (toxicity of mine effluent to Arctic grayling/toxicity of mine effluent to most sensitive lab species).

I have provided a sample calculation below.

Example :

CCME Generic objective for zinc = 0.03 mg/L

Baseflow period – toxicity in Rose Creek Water = 0.20 mg/L
Standard lab water – toxicity = 0.10 mg/L
WER = 0.2/0.1 = 2.0

Toxicity to most sensitive species = 0.2 mg/L
Toxicity to Arctic grayling fry = 0. 3 mg/L
Arctic grayling ration = 0.3/0.2 = 1.5

Therefore Rose Creek Closure Objective = 0.03 x 2.0 x 1.5 = 0.09 mg/L.

Next Steps

There are still more details to be worked out and costs to be derived. I would recommend that we discuss this approach with the client and the agencies and, if they approve of the approach, then I will proceed with the detailed protocol.

NJH:njh