# Appendix V5-4C

## Hope Bay Copper Site Specific Water Quality Objective

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**Memo:** **Hope Bay Copper Site Specific Water Quality Objective**



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**Introduction**

The Hope Bay Project is a proposed high-grade gold mine located in Nunavut, Canada. As part of the environment assessment process, ERM and partners have modeled anticipated water quality conditions for the life cycle of the mine resulting from mine development, operation and closure. Based on the modeled data, copper (Cu) is expected to exceed the Canadian Council of Ministers of the Environment (CCME) water quality guideline (WQG) of 2 µg/L in three of the water bodies that are affected by mine operations: Doris Creek, Wolverine Lake, and Stickleback Lake. Maximum modeled concentrations of copper approach 8 µg/L. In order to evaluate the ecological risk of these anticipated exceedances, the available data were reviewed to determine whether a site specific water quality objective (SSWQO) would be appropriate for copper, and one that would be protective of aquatic life in the vicinity of the project and accommodate site-specific conditions.

Copper toxicity has been shown to vary significantly between waterbodies as a result of the influence of a number of physico-chemical characteristics on the toxicity of copper. For example, the concentrations of dissolved organic carbon (DOC), alkalinity and pH, have been shown to substantially affect the bioavailability of copper and, therefore, its toxicity. In order to provide a predictive tool to model the effect of various water quality characteristics on the toxicity of copper, a Biotic Ligand Model (BLM) has been developed. The BLM uses a variety of inputs (see Table 1) of water chemistry to predict the influence that these water chemistry characteristics will have on bioavailability and toxicity of copper (Santore et al. 2001; de Schamphelaere and Janssen 2002).

The United States Environmental Protection Agency (USEPA) has recognized the effect of water chemistry on copper bioavailability and toxicity and has incorporated the use of a Biotic Ligand Model (BLM) into the water quality guideline for copper (USEPA, 2007). In contrast, the CCME water quality guideline only incorporates water hardness as a toxicity modifying factor for copper. Subsequent to development of the CCME guideline, it has been demonstrated that, in fact, the effect of water hardness on toxicity of copper is much less significant than the effect of DOC, pH and alkalinity (Santore et al. 2001; de Schamphelaere and Janssen 2002; Hyne et al. 2005; Ryan et al. 2009).

The CCME has described four approaches for development of SSWQOs for freshwater environments (CCME 2003), which take into consideration unique characteristics associated with individual sites, such as the presence of toxicity modifying factors or unique characteristics of the biological community at the site. The Background Procedure can be used in cases where background concentrations of a constituent are naturally elevated; the Recalculation Procedure can be used in cases where the biological community that is present at the site is different from that used in development of the guideline; a Water Effect Ratio (WER) Procedure can be used in cases where toxicity modifying factors are present that alter the bioavailability and toxicity of a constituent; and the Resident Species Procedure can be used where information is available on sensitivity of resident species.

For this project, toxicity modifying factors are present in the environment which would be expected to alter the bioavailability and toxicity of copper. In particular, the receiving environment in which copper concentrations are predicted to exceed the CCME water quality guideline for copper contains naturally-elevated concentrations DOC; median baseline DOC concentrations at the three sites where exceedences of the water quality guideline are predicted range from 4.7 to 5.7 mg/L. The DOC that is present in the site water would be expected to reduce the toxicity of copper relative to that observed in tests that were used in derivation of the copper guideline; DOC in laboratory water tests would generally be less than 1 mg/L. Thus, a WER value of greater than one would be expected on this basis.

A WER approach involves conducting bioassays in site water and in standard laboratory water dosed with the contaminant of interest. After calculating the effect concentration (e.g., LC50 value) for each water type, the WER is calculated by divided the site water LC50 by the laboratory water LC50. The site specific water quality objective is then calculated by multiplying the WQG by the WER.

$$WER = \frac{Site\ water\ LC_{50}}{Laboratory\ water\ LC_{50}}$$

$$SSWQO = WQG \times WER$$

In order to assess the extent to which DOC in waterbodies proximate to the Hope Bay Project Area would be expected to alter the toxicity of copper, the BLM for copper was used here to model what the WER is expected to be for the site waters. These predicted WER values were then used to establish SSWQO values that would be expected to be protective at the sites.

**Methods**

Estimated WER values were calculated using the copper BLM. Physicochemical properties of the site waters of interest were entered into a BLM application developed by Windward Environmental (Table 1). The BLM was run in the application under "toxicity mode" and incorporated two separate scenarios, the first where DOC was entered as 1 mg/L to represent standard laboratory water (where limited organic matter is present, and DOC would be generally expected to be less than 1 mg/L) and a second scenario where DOC was entered as a range, from minimum measured baseline values to the $95^{th}$ percentile of the DOC values measured during baseline characterization. Thus, the difference in the scenarios was restricted to changing DOC values, while holding the remaining parameters constant.

Estimated WER values were calculated by dividing the estimated toxic concentration of copper under elevated DOC conditions associated with the site by the toxic copper concentrations estimated using a DOC concentration of 1 mg/L. The SSWQO was then calculated by multiplying the calculated WER by the current CCME WQG (2 µg/L).

**Table 1. BLM parameters and data sources**

| Parameter | Data source[1] |
|---|---|
| pH | Measured baseline data |
| Cu | Set to WQG (2 µg/L) |
| Dissolved organic carbon | Measured baseline data |
| Humic acid | Default value of 10% |
| Calcium | From measured baseline hardness data and Ca:Mg ratio |
| Magnesium | From measured baseline hardness data and Ca:Mg ratio |
| Sodium | Modeled data |
| Potassium | Data not available; 1 mg/L value assumed |
| Sulphate | Measured baseline data |
| Chloride | Measured baseline data |
| Alkalinity | Measured baseline data |
| Sulfide | Default value of 1e-10 mg/L |

[1] Except for DOC, mean baseline data or mean operational modeled data were used, where available

**Table 2. Values for BLM parameters**

| Parameter | | Stickleback Lake | Wolverine Lake | Doris Creek |
|---|---|---|---|---|
| pH | Units | 7.2 | 7.2 | 6.9 |
| Cu | mg/L | 0.002 | 0.002 | 0.002 |
| Dissolved organic carbon | mg/L | 4.65 | 5.05 | 5.70 |
| Humic acid | % | 10 | 10 | 10 |
| Calcium | mg/L | 24.0 | 15.9 | 8.5 |
| Magnesium | mg/L | 9.9 | 11.7 | 6.2 |
| Sodium | mg/L | 6.9 | 42.4 | 37.2 |
| Potassium | mg/L | 1.0 | 1.0 | 1.0 |
| Sulphate | mg/L | 1.5 | 1.4 | 2.7 |
| Chloride | mg/L | 57.4 | 122.2 | 60.2 |
| Alkalinity | mg/L | 53.3 | 56.6 | 27.8 |
| Sulfide | mg/L | 1e-10 | 1e-10 | 1e-10 |

**Results and Discussion**

The ratio between the estimated toxic concentrations of copper under site DOC concentrations and low DOC (i.e., laboratory water conditions) were generally similar across sites, since the sites had a generally similar range of DOC values. These ratios, or modeled WER values, were calculated across the range of baseline DOC concentrations from the minimum to the 95$^{th}$ percentile of measured DOC values for each site (Figure 1). Under median DOC conditions, the modeled WER values were 4.53, 4.94 and 5.78 for Stickleback Lake, Wolverine Lake and Doris Creek, respectively.

The modeled WER values for median DOC conditions were multiplied by the CCME WQG of 2 µg/L, resulting in an estimated SSWQO of 9.1, 9.9 and 11.6 µg/L copper for Stickleback Lake, Wolverine Lake and Doris Creek, respectively (Table 3).

The results presented here demonstrate that DOC that is present in Stickleback Lake, Wolverine Lake and Doris Creek would be expected to produce a WER of 4.53 to 5.78. These modeled WER values can be validated in the future using samples collected from these sites. It should be noted that the effect of other constituents that are present under baseline conditions, such as hardness and alkalinity, would be expected to provide additional reduction in the toxicity of copper in the site waters, over and above that provided by DOC, since the water quality that has been modeled for these sites (which has been based on water chemistry for the region rather than the individual sites) predicts a lower ionic strength than is actually present. Thus, the

SSWQO values presented in Table 3 are likely a conservative determination of safe concentrations of copper at these three locations.

The approach taken here in developing a SSWQO evaluated the role of a site modifying factor (i.e., DOC) in influencing the bioavailability and toxicity of the constituent of interest, and incorporated that toxicity modifying factor into calculation of the benchmark. Thus, the proposed SSWQO would be expected to have the same degree of protection for aquatic life as the guideline itself, after recognizing the characteristics of the site water with respect to DOC concentrations that reduces the bioavailability and toxicity of copper.

**Figure 1. Modeled Water Effect Ratios across a range of DOC concentrations (minimum to 95th percentile) associated with the sites.**

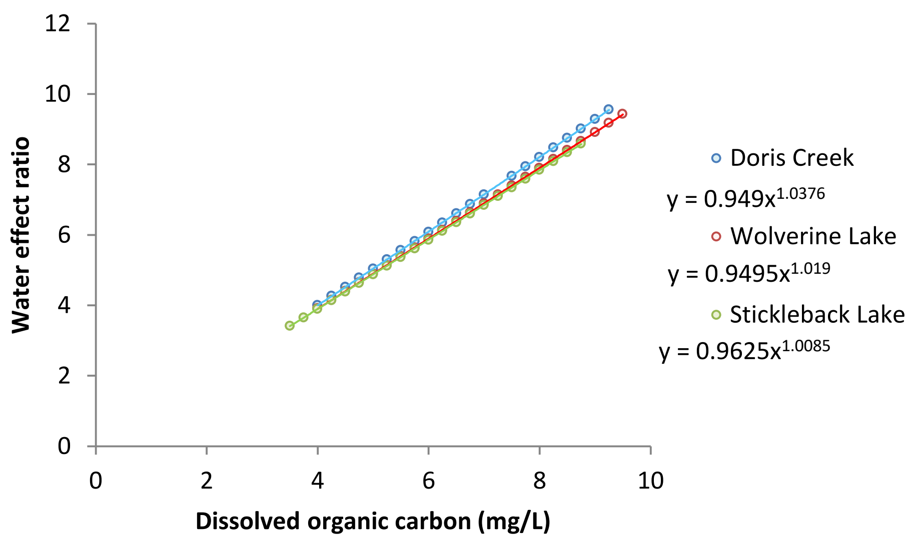


**Table 3. Water Effect Ratio and SSWQO estimates**

| | Median DOC (mg/L) | WER | SSWQO (μg/L Cu) |
|---|---|---|---|
| Stickleback Lake | 4.65 | 4.53 | 9.1 |
| Wolverine Lake | 5.05 | 4.94 | 9.9 |
| Doris Creek | 5.70 | 5.78 | 11.6 |

**References**


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