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Technical Memorandum

Date: **March 15, 2018**

To: **John Roesch (Kitikmeot Inuit Association); Heather Bears (Zoetica)**

From: **Richard Nesbitt, Neil Hutchinson (HESL)**

Re: **J180015 - Boston-Madrid Final Environmental Impact Statement and Water Licence Arsenic Site Specific Water Quality Objective**

1. Opening

This Technical Memorandum is intended to supplement the review comments provided by Hutchinson Environmental Sciences Ltd.'s (HESL's) as part of our review of the Boston-Madrid Project Final Environmental Impact Statement (FEIS) and Water Licence application to the Nunavut Impact Review Board (NIRB) and Nunavut Water Board (NWB) respectively. The FEIS and Water Licence submission represents the final stages of permitting Phase Two developments along the Hope Bay Belt by TMAC Resources (TMAC). HESL's review was completed on behalf of the Kitikmeot Inuit Association (KitIA).

2. Introduction

Modelled water quality from operations through post closure associated with the Boston-Madrid Project indicates arsenic concentrations will be elevated above the Canadian Council of Ministers of the Environment (CCME) water quality objective (WQO) for the protection of aquatic life of 0.005 mg/L in the Doris Tailings Impoundment Area (TIA), contact water associated with the Boston Tailings Management Area (TMA) and in the freshwater (Doris Creek) receiving environment under all modelled scenarios. Arsenic will also exceed the CCME WQO in Windy Lake under the most conservative modelled scenario. TMAC's modelled results are summarized in Figure 1.

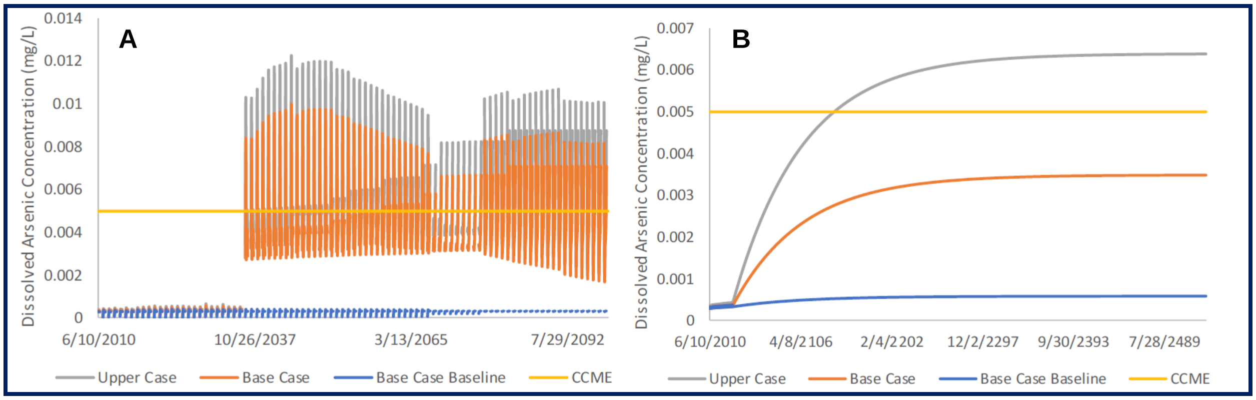

Figure 1. Doris Creek (A) and Windy Lake (B); Baseline, Base Case and Upper Case Arsenic Predictions[1].

TMAC has evaluated the risk of these elevated arsenic concentrations against the CCME WQO of 0.005 mg/L as well as a site-specific water quality objective (SSWQO) prepared by Golder Associates for the Back River Project of 0.028 mg/L. This SSWQO has in part been used to justify that while site and mine contact water from the Project will result in moderate irreversible effects in the local study area, the significance rating of those changes is considered "not significant"[2].

This SSWQO of 0.028 mg/L was derived by Golder Associates Ltd. (Golder) to evaluate environmental impacts of elevated arsenic concentrations resulting from Sabina Gold and Silver's Back River Project and Agnico Eagle Mines Ltd.'s (AEM's) Whale Tail Project. In both cases, HESL provided review comments which resulted in final applied SSWQOs of 0.01 mg/L and 0.025 mg/L respectively for those projects.

3. SSWQO

We provide the following in depth review of *"Golder. 2017. Back River Project - Development of a Site-Specific Water Quality Objective for Arsenic. Technical Memorandum Prepared for Sabina Gold & Silver Corporation by Golder Associates. February 2017"*, the SSWQO derivation document cited by TMAC in the Boston-Madrid Project FEIS[2].

Golder summarized the methodology used to derive a new long-term arsenic SSWQO for Goose Lake, the primary freshwater receiving environment for the Back River Project, in four steps:

1. *"Toxicity data compilation – Available freshwater chronic toxicity data for arsenic was compiled into a database with a focus on data for algae, aquatic plants, aquatic invertebrates, fish and amphibians;*
2. *Toxicity data evaluation, categorization and endpoint selection – The available toxicity data was evaluated for suitability and categorized as acceptable or unacceptable for developing a long-term SSWQO. Once the data was evaluated and categorized, preferred endpoints were selected;*

[1] *Modified from Figures 7-11 and 7-14 in: SRK Consulting (Canada) Inc. 2017. Package P5-4 Madrid-Boston Project Water and Load Balance, Hope Bay Project. Prepared for TMAC Resources Inc.*

[2] *TMAC 2017. Volume 5: Freshwater and Marine Environments. Boston-Madrid Final Environmental Impact Statement.*

3. *Determination of the applicable SSWQO derivation approach – Depending on the adequacy of the toxicity data, it was determined whether the Statistical Derivation Approach or the Lowest Endpoint Derivation Approach should be used to develop the SSWQO for arsenic; and*
4. *Development of the SSWQO for arsenic using either the Statistical Derivation Approach or the Lowest Endpoint Derivation Approach."*

Golder's method accurately followed standard methodology for derivation by the *Statistical Derivation Approach* as outlined by the CCME in the guidance document *"A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life 2007"*. Through review of available toxicity data, Golder was able to collect sufficient high-quality **primary** and **secondary data** appropriate for application in the context of the Back River project with **preferred endpoints**. The available **chronic toxicity** dataset was comprised of 28 species including 3 fish species, 1 amphibian species, 10 aquatic invertebrate species, 2 aquatic plant species and 12 algal species. This successfully met the CCME criteria to statistically derive a **Type A** SSWQO through generation of a **Species Sensitivity Distribution** (SSD) curve. Note that all bolded terms are defined by the CCME[3].

A "Type A" guideline derived using a SSD curve modelled with software developed by the CCME[4] is the preferred guideline when sufficient data is available. This statistical derivation approach is preferred by the CCME over a lowest endpoint derivation approach which would have been required in the event insufficient data was available; the current generic CCME guideline for protection of aquatic life for arsenic of 0.005 mg/L was derived following a lowest endpoint derivation approach. HESL was able to review Golder's approach objectively to determine if they had:

1. Accurately followed CCME protocols, and
2. Arrived at a scientifically defensible SSWQO using available and applicable high quality chronic toxicity data.

Golder has derived a long-term SSWQO for arsenic for application at the Back River Project of 0.028 mg/L using a normal model to calculate the SSD curve (Figure 2).

[3] Canadian Council of Ministers of the Environment. 2007. *A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007.* In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, 1999, Winnipeg.

[4] SSD Master Version 3.0. Developed by the CCME in 2013.

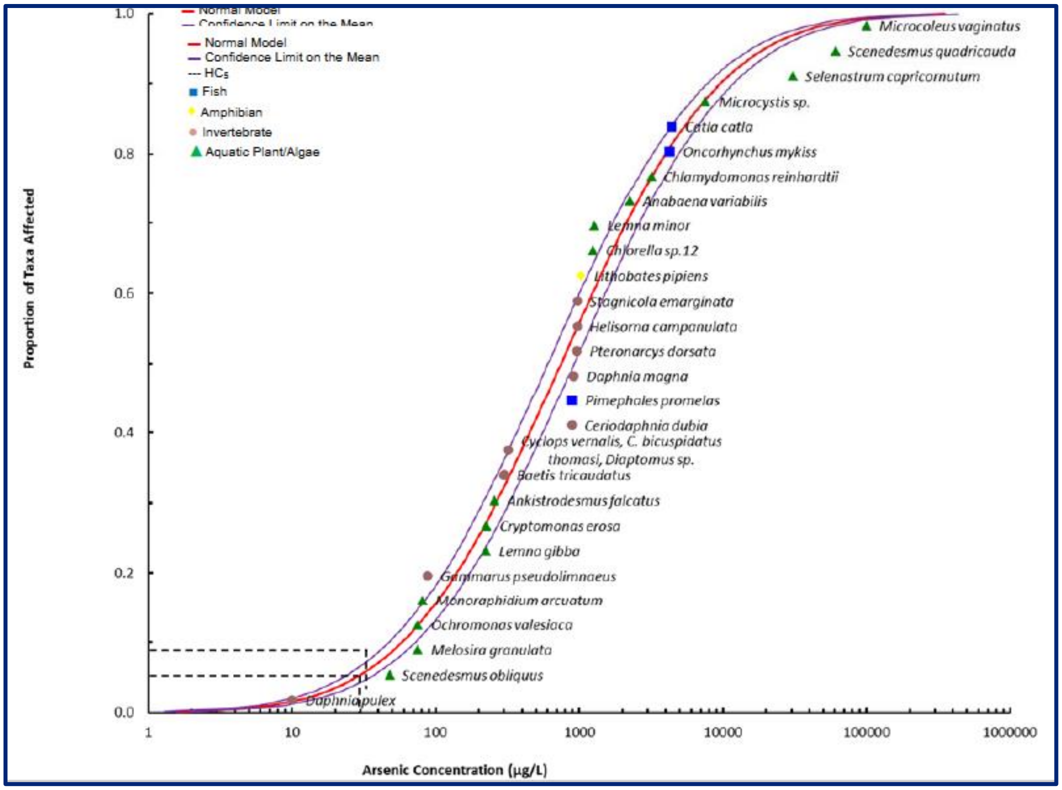

Figure 2. Species Sensitivity Distribution derived by Golder to calculate the long-term SSWQO for arsenic.

This proposed objective represents a concentration of arsenic, which may have a potential negative impact on up to 5% of species present. This level of acceptable risk is in line with CCME guidance stating:

> *"For substances with adequate data… the recommended guideline derivation method involves modelling the cumulative species sensitivity distribution (SSD) with estimating the 95% confidence interval. The guideline is defined as the intercept of the 5th percentile of the SSD."*

The dataset Golder used to derive the updated SSWQO included 28 high quality primary and secondary studies as recent as 2010. Only studies and data that could be categorized as of primary or secondary data as per the CCME were included in the dataset.

HESL has conducted our own literature search and are satisfied that no apparent studies were overlooked. Although arctic species such as lake trout or whitefish are not represented in the dataset, we accept that the dataset covers the data that are available and includes similar species (same family) to characterize the potential risk to resident species in the Project area.

3.1 Concerns

HESL's review of the SSWQO derivation has highlighted two concerns with Golder's methodology. We do not raise a concern with the overall dataset as presented in their memo, but our analysis shows that use of a more conservative statistical model and elimination of non-resident amphibians from the data set would produce a different SSWQO, as shown below.

3.1.1 Concern 1: Inclusion of Amphibian Species in Dataset

The statistical derivation of a Type A guideline suitable for application across Canada includes data applicable across the country and may include species not present at given locations. The generic guideline may not then account for real differences between the sensitivity range of the species of aquatic organisms represented in the complete toxicological dataset used to derive a guideline, and that of the species that occur at the site under consideration. The recalculation protocol to derive a SSWQO requires modellers to only include species in the toxicological dataset that meet the following criteria:

- Usually present at the site;
- Present at the site only seasonally due to migration;
- Present intermittently because they periodically return to or extend their range into the site;
- Not currently at the site due to degraded conditions;
- Are present in nearby bodies of water; or,
- Were present at the site in the past and are expected to return to the site when conditions improve.

Guidance provided by the CCME further clarifies these criteria by stating:

> *"If a member of a family of freshwater fish occurs or could occur at a site (e.g., rainbow trout from the family Salmonidae), then the toxicity data on any of the fish species within that family (e.g., rainbow trout, coho salmon, mountain whitefish, arctic grayling, arctic char, etc.) must be included in the site-specific toxicological data set."*[5]

Golder has included data on one amphibian species *Lithobates pipiens*, the Leopard Frog, within the toxicological dataset used to derive the SSWQO. While a derivation of a generic guideline requires the inclusion of at least one amphibian species in the dataset, no amphibian species meet the CCME criteria for inclusion. That is, amphibian species are not native or potentially native to the Project area.

As the derived guideline is intended to be site specific for the Back River project area (and the relatively proximal Hope Bay Belt), Golder's SSWQO should be recalculated to exclude the Leopard Frog from the dataset.

3.1.2 Concern 2 – Non-Conservative Selection of Model for SSWQO Derivation

The CCME software SSD Master 3.0 generates SSDs using five separate models (Normal, Logistic, Extreme Value, Weibull and Gumbel). One of the models is then chosen as the "best fit" to the data relying on several metrics:

1. A goodness-of-fit statistical test (Anderson-Darling Goodness-of-Fit); the results for this test are reported as an A^2 value. Lower values are preferred.
2. The means sum of squared error terms (MSE) and the MSE in the lower tail. Lower values are preferred.

[5] Canadian Council of Ministers of the Environment. 2003. Canadian water quality guidelines for the protection of aquatic life: Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

3. The spread between the upper and lower confidence limits on the mean expected at the HC5 (the concentration at which 5% of potentially modelled organisms are affected). A smaller spread is preferred to a larger one.

The reported 5th percentile of the selected model is then used as the Type A guideline.

Golder selected the normal model stating that *"Of the models tested, the normal model was considered to provide the best fit of the data".* The Weibull model was not applicable to this dataset.

HESL remodeled the SSD following the CCME protocols to review Golder's interpretation of the SSD Master 3.0 results and disagrees with the use of the normal model based on the CCME guidance document which accompanies SSD Master 3.0[6]. Modeled results are presented in Table 1. The relative ranks of each model on the metrics used to select the best fitting model is provided in Table 2.

Table 1. Arsenic SSD Statistical Summary Generated with Entire Golder Dataset

Formulas	Model			
	Normal	Logistic	Extreme Value	Gumbel
$\sum e_i^2$	0.0609	0.0586	0.0745	0.0725
MSE	0.0023	0.0023	0.0029	0.0028
MSE Lower Tail	0.0374	0.0386	0.0335	0.0520
A^2	0.456	0.370	1.794	0.489
HC50 (µg/L)	747.674	752.061	820.161	675.754
HC5 (µg/L)	28.38	22.27	11.19	47.89
Lower confidence limit on the mean (expected HC5)	22.96	16.30	5.52	34.45
Upper confidence limit on the mean (expected HC5)	35.07	30.42	22.67	66.57
Confidence Limit Spread	12.11	14.12	17.15	32.12

Table 2. Ranked Derivation Outputs Determining Best Statistical Model from Original SSWQO

Formulas	Model Ranks			
	Normal	Logistic	Extreme Value	Gumbel
MSE	1	1	4	3
MSE Lower Tail	1	2	3	4
A^2	2	1	4	3
Confidence Limit Spread	1	2	3	4
Total	**6**	**6**	15	13

Each model is ranked on each metric from 1 through 4 where 1 is considered the best fit (lowest value or smallest confidence limit spread) and 4 is considered the poorest fit. The lowest overall rank is considered the best fitting model.

From the original dataset, the normal and logistic models have the lowest cumulative scores and differ only slightly on all four metrics. The more conservative choice for the derived SSWQO presented in the Golder

[6] Intrinsik Environmental Sciences Inc. 2013. Determination of Hazardous Concentrations with Species Sensitivity Distributions. SSD Master 3.0. May, 2013. In: Canadian Environmental Quality Guidelines. Prepared for the Canadian Council of Ministers of the Environment.

Memo and proposed for the Hope Bay and Boston-Madrid projects would therefore be the lower of the two HC5 values: 22.27 µg/L.

3.2 Updated SSWQO

HESL has recalculated the arsenic SSWQO accounting for the concerns presented in Section 2.1 of this memo. We have removed the amphibian species *Lithobates pipiens*, the Leopard Frog, from the dataset and selected the resulting SSWQO from the model outputs based on the lowest cumulative score. Modeled results are presented in Table 3. The relative ranks of each model on the metrics used to select the best fitting model are provided in Table 4. The logistic modelled SSD is presented in Figure 3.

Table 3. Arsenic SSD Statistical Summary Generated without *Lithobates pipiens*

Formulas	Model			
	Normal	Logistic	Extreme Value	Gumbel
$\sum e_i^2$	0.0491	0.0475	0.0657	0.0568
MSE	0.0020	0.0019	0.0026	0.0023
MSE Lower Tail	0.0308	0.0324	0.0306	0.0421
A^2	0.392	0.323	1.598	0.400
HC50 (µg/L)	734.200	737.283	810.782	658.678
HC5 (µg/L)	24.86	19.21	9.32	43.49
Lower confidence limit on the mean (expected HC5)	19.79	13.85	4.39	31.14
Upper confidence limit on the mean (expected HC5)	31.23	26.64	19.80	60.73
Confidence Limit Spread	11.44	12.80	15.41	29.58

Table 4. Ranked Derivation Outputs Determining Best Statistical Model from Updated Derivation

Formulas	Model Ranks			
	Normal	Logistic	Extreme Value	Gumbel
MSE	2	1	4	3
MSE Lower Tail	2	3	1	4
A^2	2	1	4	3
Confidence Limit Spread	1	2	3	4
Total	**7**	**7**	12	14

Each model is ranked on each metric from 1 through 4 where 1 is considered the best fit (lowest value or smallest confidence limit spread) and 4 is considered the poorest fit. The lowest overall rank is considered the best fitting model.

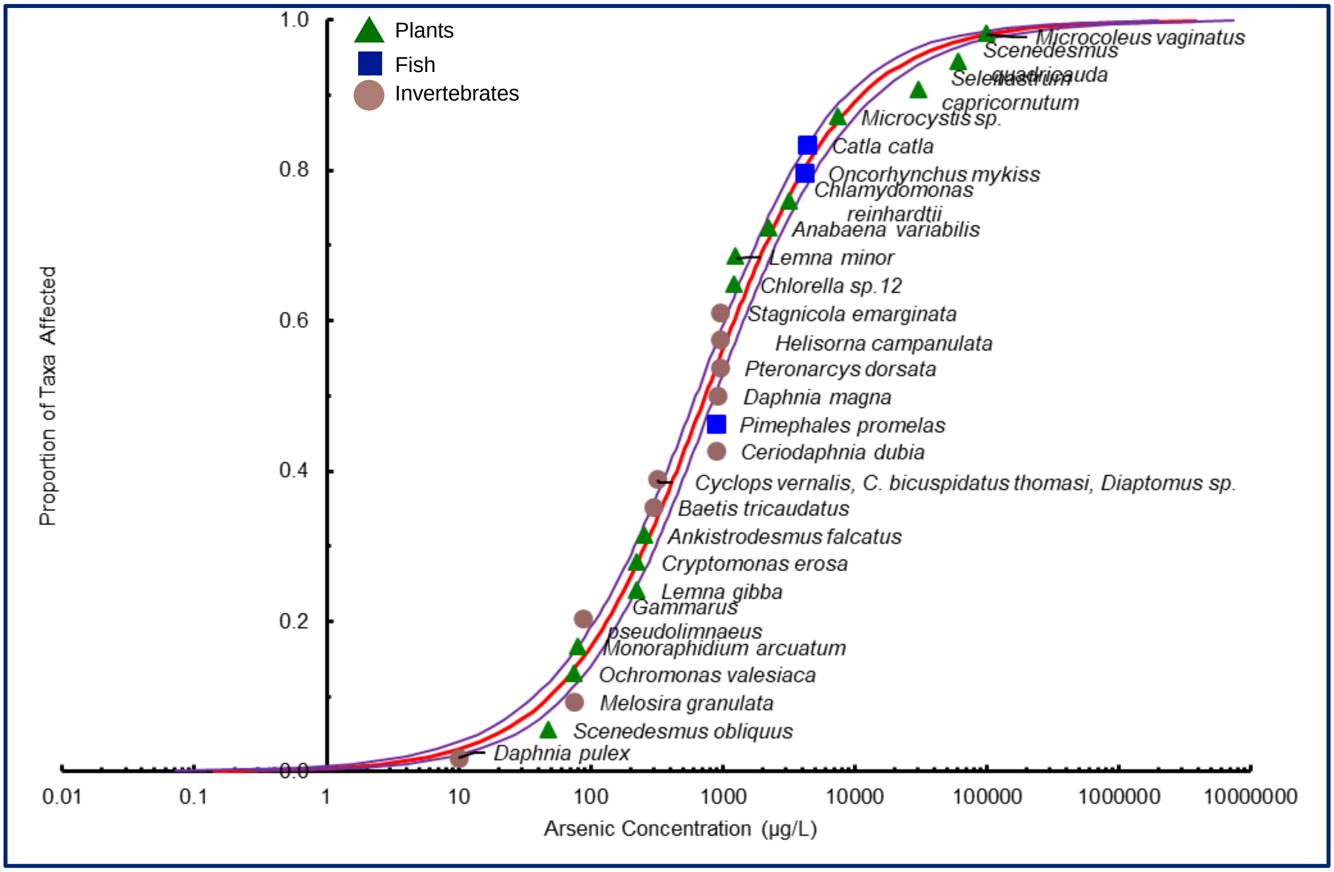

Figure 3. Arsenic Species Sensitivity Distribution Logistic Model Output

The normal and logistic models have the lowest cumulative scores and differ only slightly on all four metrics. Note that both the logistic and normal models produce statistically valid results; these outputs have been agreed upon by AEM and their consultants for the Whale Tail project though the value used for the water licence and FEIS was the less conservative 0.025 mg/L. Sabina has used a more conservative value of 0.010 mg/L to evaluate the effects of their project as part of the FEIS and carried this value forward to water licencing.

We recommend the conservative approach of selecting the logistic model which provides the lower of the two HC5 values. This is also a compromise between the SSWQOs applied by AEM for the Whale Tail project and Sabina for the Back River project.

Recommendation 1: We recommend an arsenic SSWQO for application at the Hope Bay project of **19 µg/L (0.019 mg/L)** using a logistic model to fit data to the SSD curve. This represents a statistically defensible and conservative SSWQO which only includes resident, potentially resident or related species in the dataset.

4. Implications

Section 3.1 presents rationale as to why HESL disagrees with TMAC's proposed SSWQO of 0.028 mg/L for arsenic at the Hope Bay project and not that the document cited in their FEIS was ultimately amended prior to application on any other project in Nunavut. We have recommended 0.019 mg/L as an alternative. However, neither HESL's recommended SSWQO nor TMAC's proposed SSWQO invalidates the conclusions as presented in the FEIS that there will be no significant adverse effects resulting from changes to arsenic concentrations as a result of project activities.

5. Recommendation and Conclusion

HESL recommends that the KitIA request TMAC adopt a long-term total arsenic SSWQO of 0.019 mg/L for application throughout the freshwater environment of the Hope Bay belt. This objective was derived following accepted CCME protocols; considers newly generated, high quality, applicable toxicity data[7]; and is sufficiently protective of the aquatic life in the Project area.

While the recommended SSWQO does not change the conclusions as presented in the Boston-Madrid FEIS, it highlights a diminished difference between the modeled changes resulting from the project and a change that would constitute a significant impact to the aquatic environment. This more limited operational flexibility underscores the need for robust environmental monitoring through the Aquatic Effects Monitoring Program (AEMP) and Surveillance Network Program (SNP) to ensure any changes to the aquatic environment are in line with those presented in the FEIS and any divergences are effectively adaptively managed in a timely manner.

We hope this technical memorandum meet your current needs. Should you have any questions, please do not hesitate to contact Richard Nesbitt (Richard.Nesbitt@environmentalsciences.ca; 519-576-1711 x 305). We would be happy to answer any questions you may have.

RAN, NJH

[7] *Relative to the CCME long-term arsenic WQO for the protection of aquatic life.*