GOLDER

REPORT

Water Quality Management and Optimization Plan

Implementation Plan for Total Dissolved Solids

Submitted to:

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1.0 INTRODUCTION

This report provides a Water Quality Management and Optimization Plan (WQ-MOP) for effluent discharges associated with the Meliadine Mine located in the Kivalliq Region of Nunavut. The objective is to formalize a procedure for management of effluent discharges that follows a systematic and science-based framework for determining acceptable effluent quality conditions.

The WQ-MOP presented herein is focussed on development of interim targets for total dissolved solids (TDS) for treated effluent discharge and receiving environment at the edge of the mixing zone, but within a framework that can be extended to longer-term management of site water. Although currently specific to the Meliadine Mine, it is intended to align with a process that can be generalized to other Agnico Eagle Mines Limited (Agnico Eagle) projects in Nunavut.

To prepare the WQ-MOP, Golder Associates Ltd. (Golder) was requested to build from existing work performed on TDS benchmarks (i.e., Golder 2019a), including the following:

- Incorporation of site-specific toxicity data.
- Integration with the framework discussed with regulators for developing interim water quality targets for TDS that reflect the site-specific mixture of ions, confirmed through standardized toxicity tests (acute and chronic toxicity testing) and evaluation of assimilative capacity (Section 2.3).
- Establishment of a process for validation of interim targets in summer 2020.

The development of interim water quality targets for Agnico Eagle Nunavut operations was discussed with Environment and Climate Change Canada (ECCC) in several recent meetings and associated reviews:

- *Meeting on 9 December 2019 (Agnico Eagle 2019)*. This meeting discussed the technical approach to development of site-specific water quality objectives (SSWQO) for multiple projects (and constituents of interest) in Nunavut.
- *TDS Technical Memorandum (Golder 2019a)*. This memorandum was prepared as a draft document to support a technical approach to development of SSWQOs for TDS.
- *Meeting on 9 January 2019 (Agnico Eagle 2020)*. This meeting discussed the technical approach to development of SSWQOs specific to TDS and its components, following from the ECCC review of Golder (2019b).
- *Final Public Hearings for the Whale Tail Expansion Project, Baker Lake NU, February 13–14, 2020*. The hearings included contributions from ECCC (as Intervenors), and from Agnico Eagle (in the Proponent's concluding statements) and included areas of general agreement regarding a conceptual approach to regulation of TDS.

1.1 Site-Specific Benchmark Development Procedure

The guiding principle for the WQ-MOP is that water quality benchmarks should be developed that satisfy the following conditions:

- protective of the environment
- satisfy regulatory requirements
- based on science (rather than strictly on considerations of policy or precedent)
- customized to the site-specific conditions of water quality and quantity

Adoption of fixed numerical benchmarks, either as static discharge limits or generic water quality guidelines, is unlikely to satisfy some parts of the above guiding principle. TDS benchmarks can, however, be developed using a toxicity-based approach that satisfies all the above conditions. TDS represent a “soup” of multiple component ions, and the behavior of this mixture in the environment is influenced by the relative toxicities of the component ions and the ability of some ions (e.g., calcium) to ameliorate the toxicity of others. For effective regulation of TDS, an approach is required that considers the toxicological potential of the mixture, and the point of compliance for different types of responses.

From our communications with ECCC, a conceptual approach has been developed that is consistent with the guiding principle, and that has three main components in the development of numerical targets:

- Effluent discharges must not result in acute toxicity at the point of release.
- Effluent discharges must not result in unacceptable chronic toxicity at the edge of the mixing zone following initial dilution.
- Effluent discharges must not exceed the capacity of the receiving environment to accommodate long-term loadings of constituents (i.e., assimilative capacity).

For broader management of TDS in Nunavut, instead of promulgating an uncertain numerical value for TDS or its individual component(s), we recommend development of interim targets for managing TDS in the effluent discharge and receiving environment (to apply at the edge of the mixing zone) that reflect the site-specific mixture of ions, confirmed through standardized toxicity tests and evaluation of assimilative capacity. Much of this information has already been collected for Meliadine, and Agnico Eagle proposes to develop a validation program to validate interim targets and provide data to inform development of effluent quality criterion (EQC) and site-specific water quality objective (SSWQO) benchmarks for long-term application (see Section 3.0 for a draft conceptual design). The EQC and SSWQO benchmarks can be applied to guide an adaptive management approach to processing of site water.

1.2 Phasing the Water Quality Management and Optimization Plan

As communicated to ECCC by Agnico Eagle, the upcoming 2020 freshet season will result in accumulation of site water that exceeds the water storage capacity of the mine, requiring a managed release of site water to the environment. In anticipation of this condition, an interim approval is desired for the Meliadine freshet discharge, avoiding the need for an “emergency” approval requirement. The operational needs dictate a phased approach to the WQ-MOP, in which short-term needs are met, while remaining consistent with the overall WQ-MOP framework.

- **Phase 1: Develop Interim Targets**—Application of the general process described in Section 1.1, entailing review of literature and results of site-relevant toxicity testing, and subsequent establishment of science-based TDS targets, for use on an interim basis.
- **Phase 2: Conduct Validation Study**—In conjunction with the upcoming freshet releases at Meliadine, conduct supporting studies in 2020 to validate and/or refine the science-based interim targets and produce additional information on receiving environment assimilation.
- **Phase 3: Finalize Meliadine Benchmarks**—Integrate the results of Phase 1 and Phase 2 to formalize the science-based interim targets as EQC and SSWQO benchmarks, with a framework for their implementation (e.g., adaptive management), that is applicable to future conditions at Meliadine Mine. Phase 3 will be submitted as part of the amendment application of the existing Meliadine Water Licence to the Nunavut Water Board.

This document emphasizes Phase 1 of the WQ-MOP (Section 2.0), with elements of Phase 2 (Validation Study) included in conceptual form (Section 3.0).

2.0 PHASE 1: DEVELOP INTERIM TARGETS

2.1 Interim TDS Target for Effluent

This section presents the proposed interim target for effluent of 3,500 mg/L calculated TDS for the Meliadine Mine, as a Maximum Average Effluent Concentration (MAEC). This target is proposed as an interim value, pending implementation of Phase 2 and Phase 3 of the WQ-MOP. A proposed interim target of 3,500 mg/L calculated TDS was proposed following a review of site acute toxicity data collected for Meliadine Mine (Appendix A).

As presented in Appendix A (Section A1.0), the toxicity of TDS varies by ionic composition and the relative proportion of ions in the mixture. Low effect concentrations for acute endpoints (e.g., survival) have been reported for individual ions for select species, but these tests reflect exposure conditions accounting for a single ion, and not a balanced TDS mixture representative of most field conditions. Considering this, the proposal of an interim target focussed on review of site-specific acute toxicity data collected for site-relevant mixtures (e.g., treated effluent, influent, Collection Pond water; Appendix A, Section A2.0).

The proposed interim TDS target for effluent of 3,500 mg/L is supported by:

- No acute toxicity to *D. magna* or rainbow trout was observed with influent and effluent TDS concentrations of equal to or less than 4,465 mg/L (measured TDS concentrations of equal to or less than 4,830 mg/L)—details are provided in Appendix A.
- No mortality to other organisms has been observed in tests using fathead minnows or *C. dubia* in chronic exposures; as of January 2020, these tests covered calculated TDS concentrations up to 2,357 mg/L (measured TDS concentrations of 2,490 mg/L). Chronic test endpoints are not used in a regulatory context to evaluate the acute toxicity of the effluent, but the lack of mortality in chronic tests provides encouraging information.
- The record of acute toxicity depicted in Appendix A (Table A-4) provides evidence of the lack of acute toxicity even at high TDS concentrations. However, only four acute toxicity tests have been conducted with calculated TDS concentrations above 3,000 mg/L. For this reason, some caution is recommended in the development of the interim TDS target for effluent. The no effect concentration of 4,465 mg/L calculated TDS was therefore reduced by 20% and rounded down to the value of 3,500 mg/L.

Additional validation of the proposed interim target is recommended to understand if an EQC is required or to derive an EQC that is protective under the expected range of TDS conditions. Validation of the interim TDS target to demonstrate that the effluent is consistently not acutely lethal will be conducted through comprehensive monitoring during the discharge period as presented in Section 3.0. Sensitive species that form the basis for the validation would include test species *D. magna* and rainbow trout, as these are the species used to assess compliance for acute lethality under the Metal and Diamond Mining Effluent Regulations (MDMER; Government of Canada 2002). Lethality to other species, such as *C. dubia,* will also be monitored to support the characterization of the effluent.

2.2 Interim TDS Target at the Edge of the Mixing Zone

An interim target of 1,000 mg/L (as calculated TDS) to apply in the receiving environment at the edge of the mixing zone is proposed for the protection against chronic toxicity to representative aquatic species. This interim target is intended to evaluate the condition (from Section 1.1) that effluent discharges must not result in unacceptable chronic toxicity at the edge of the mixing zone following initial dilution. The target is proposed as an interim value for use in the short-term, pending implementation of Phase 2 and Phase 3 of the WQ-MOP.

The proposed interim target was derived using methods described in Appendix A and summarized below:

- Characterization of the Meliadine TDS profile (Section A1.1)—water chemistry data collected at the Meliadine Mine were used to profile the anticipated water quality in the receiving environment, including composition of major component ions in the TDS mixture.
- Review of water quality benchmarks (Section A1.2)—review of TDS benchmarks developed for locations with a similar TDS composition to Meliadine Mine.
- Literature review (Section A1.3)—review of peer-reviewed literature to determine the threshold for chronic toxicity with a focus on TDS mixtures of similar composition to Meliadine (i.e., dominance of chloride, sodium, and calcium ions).
- Review of site-specific chronic toxicity data (Section A1.4)—review of site toxicity data and corresponding TDS and major ion chemistry for Meliadine treated effluent and influent samples, as collected during routine and regulatory compliance toxicity testing.
- Weight of Evidence (Section A1.5)—integration of the above information to justify the interim target of 1,000 mg/L TDS to apply at the edge of the mixing zone.

The interim TDS target includes the following assumptions:

- Ambient water hardness should remain within the current range to ameliorate potential chloride toxicity (i.e., through demonstration of non-toxicity of chloride under site-relevant ranges of hardness).
- Additional site-specific validation of the TDS threshold should be conducted to confirm that the mixture of ions represented by the effluent and near-field exposure conditions does not result in acute or chronic toxicity. Such studies are planned, as discussed in Section 3.0.
- Effluent chemistry profiles, particularly with respect to the proportions of major ions, will remain generally consistent in the future.

There is already strong scientific evidence to support the interim target as protective of the aquatic community. The results of toxicity testing do not indicate that an exceedance above 1,000 mg/L TDS will result in harm to aquatic life but provide reasonable certainty of no harm up to 1,000 mg/L. The key lines of evidence as presented in Appendix A, and are supported by the following considerations:

- The Meliadine effluent contains a balance of major ions that is advantageous for limiting the toxic potency of the TDS mixture (Section A1.5.1).
- The Snap Lake site, which applies the same TDS concentration as a SSWQO, provides similar ionic mixtures and biological communities (Section A1.5.2).
- The chronic toxicity data set for Meliadine site water, which includes a battery of four sensitive aquatic species, supports the interim TDS target as a defensible no-effect concentration (Section A1.5.3).
- The ionic balance has been stable in Meliadine water, such that an interim TDS target can be developed without requiring development of targets for individual component ions (Section A1.5.4).

2.3 Assimilation Capacity Evaluation

The ability of the receiving environment to assimilate the concentrations and loading of constituents in effluent is the last component of the WQ-MOP implementation. Consideration of assimilation capacity provides confidence that constituents will not gradually accumulate to concentrations that would degrade the receiving environment.

The approach to TDS management set out in the WQ-MOP will not affect the quality, quantity, or flow of the waters in Meliadine Lake. TDS levels during and after the 2020 discharge will continue to be managed to minimize any adverse effects of the licenced deposit of effluent on the aquatic ecosystem of Meliadine Lake, and all discharges would continue to meet the stringent requirements set by the MDMER. Confidence in this conclusion comes from plume delineation surveys, preliminary dilution estimates from dispersion models, and consideration of the Meliadine Lake hydrology.

The evidence for sufficient assimilation efficiency in Meliadine Lake to accommodate the proposed interim TDS target for effluent of 3,500 mg/L comes from:

- **Consistency with Previous Impact Assessment Outcomes**—Based on the predictions included in the Final Environmental Impact Statement (FEIS) for the Meliadine Gold Project (Golder 2014), the one-time release of mine wastewater to Meliadine Lake under this amendment would not be expected to result in potential additional project effects. That is, water quality in the receiver and downstream environment would remain within the predictions included in the FEIS. For the FEIS assessment, a Maximum Allowable Effluent Concentration (MAEC) of TDS in the discharge of 4,685 mg/L was calculated based on the approach applied in the province of Quebec (MDDEP 2007), where the mixing ratio in a lake is set to a value of 10 to 1. The calculation of the MAEC is dependent on the background concentrations (BG) in the lake, the water quality criteria (WQG; the guideline), and the mixing ratio (MR), as established by the following equation:

  MAEC = MR(WQG − BG) + BG.

  Where for TDS:

  MR = 10 (as per MDDEP)

  WQG = 500 mg/L (Guidelines for Canadian Drinking Water Quality [GCDWQ; HC 2010], aesthetic objective)

  BG = 35 mg/L

  Therefore:

  MAEC = 10 (500 – 35) + 35 = 4,685 mg/L

  This MAEC is well above the proposed interim target of 3,500 mg/L proposed in this amendment.

Plume Delineation Results—Under operating conditions, a plume delineation survey based on specific conductivity results was conducted in 2018 in the near-field region of Meliadine Lake as part of the Environmental Effects Monitoring (EEM)/Aquatic Effects Monitoring Program (AEMP). The EEM plume delineation study used field surveys of specific conductivity to evaluate effluent dispersion with distance from the diffuser. The study evaluated dilution factors at a series of monitoring stations up to, and extending beyond, 250 m from the diffuser, based on the specific conductivity of the effluent and the measured field values through the water column at each the stations. To account for background values, two scenarios were used:

- Scenario A: near-field average specific conductivity for 2015 to 2016; and
- Scenario B: near-field average specific conductivity for 2017

An observed slight increase in specific conductivity between 2015 to 2016 (pre-construction) and 2017 (construction) was the impetus for considering the two scenarios.

Observations from the survey indicated a minimum dilution factor of 53 at 50 m away from the diffuser, and a minimum dilution factor range of 56 (Scenario A) and 85 (Scenario B) at the edge of the 100 m mixing zone boundary (Table 1). This study was also useful because it served to validate the performance of the submerged diffuser, which had been previously been assessed by Tetra Tech as part of their design (Tetra Tech 2017) and re-assessed in 2018 (Tetra Tech 2018). As part of their reassessment in 2018, Tetra Tech concluded that the predicted minimum dilution of 23:1 was achieved at the edge of the 100 m mixing zone and that water quality criteria were met. Note, this minimum dilution factor was more than twice the mixing ratio of 10 to 1 that was used to derive the MAEC in the 2014 FEIS; however, it was based on a multi-year modelling scenario[1] where the minimum dilution at 100 m at the end of the first year of discharge was 72:1. The latter is consistent with earlier modelling work to support a conceptual diffuser in 2015 (Agnico Eagle 2015), which indicated that the minimum dilution factor was 65:1. The range of dilution factors at 100 m distance from the diffuser (representing the edge of the mixing zone) determined from the EEM plume delineation study are a little larger than the minimum dilution factor (23:1) developed in the performance assessment of the diffuser completed by Tetra Tech in 2018 based on multi-year simulations, but in line with Tetra Tech's assessment for the first year of discharge (72:1) and that developed in the early work completed by Golder (65:1).

Table 1: Dilution Factors in the Near-field Exposure Area at Meliadine Lake[(a)]

Sampling Station	Maximum Specific Conductivity in 2018 (µS/cm)	Dilution Factor – Scenario A	Dilution Factor – Scenario B
50-01	99.8	63	104
50-03	105.5	53	79
100-01	93.4	80	159
100-03	104	56	85
100-04	102.6	58	90
100-05	98.9	65	109
100-06	88.5	101	266
100-08	96.6	71	125

(a) Listed data represent a portion of the data listed in Table 2.4-10 of Golder (2019b)
µS/cm = microsiemens per centimetre

These EEM plume delineation results suggest that the effluent concentration observed at the 100 m mixing zone boundary was less than 2% of concentrations observed at end of pipe. Furthermore, the survey results showed that the plume remained at depths of roughly between 3 and 7 m, indicating that the receiving water and the effluent discharged had similar densities and/or intense mixing. The measured data showed that at the time of the survey, the plume was more noticeable were to the south-west of the diffuser, which indicates

[1] The multi-year simulation included annual diffuser discharge to Lake Meliadine over the 14 year construction and operations timeline (Year -3 to Year 11). This scenario was included to assess the effects of water quality constituent build-up in the lake on the dilution factor.

a preferential direction of plume advection during the time the survey was completed. Changes in wind speed and direction including current direction and speed are key factors determining the plume dispersion direction on any given day.

- **Mixing Ratio Calculations**—Preliminary calculations of the MAEC have been completed based on standard industry practices as well as the results of the near-field modeling completed by Golder, as shown in Table 2.

Table 2: Calculations of Maximum Average Effluent Concentrations

Report	Guideline for Canadian Drinking Water Quality for TDS (HC 2010) (mg/L)	Assumed Meliadine Lake Average Background TDS concentration (mg/L)	Assumed Mixing Factor	Maximum Average Effluent TDS Concentration (mg/L)
2014[(a)]	500 mg/L	35 mg/L	10:1	4,685
2015[(b)]			65:1	30,260[(c)]
2018[(d)]			23:1	10,730[(c)]
2019[(e)]			56:1	26,075[(c)]

Notes:

(a) Golder 2014. Water and Sediment Quality Model – Meliadine Gold Project, Nunavut. Appendix 7.4-A.

(b) Agnico Eagle. 2015. (see Appendix E, Water Management Plan)

(c) Concentration of maximum average effluent TDS is conceptual only; effluent would **not** be discharged at TDS concentrations of this magnitude as it could result in acute toxicity at the point of discharge.

(d) Tetra Tech. 2018.

(e) Golder. 2019b. Appendix G – Field Data in the Near-field Exposure Area at Meliadine Lake Under the Plume Delineation Study, 2018.

For the preliminary calculations, the mixing ratio (MR) was established as:

2014—reflects the approach applied by the province of Quebec ([MDDEP 2007), where the mixing ratio in a lake is set a value of 10:1.

2015—reflects the minimum mixing factor predicted by the near-field modeling

2018—reflects the minimum mixing factor as modelled for the diffuser design (Tetra Tech 2017, 2018).

2019—reflects the minimum mixing factor calculated from the observations of the plume delineation survey at the edge of the 100 m mixing zone.

TDS = total dissolved solids; mg/L = milligrams per litre.

Based on the model calculations and the observation of the plume delineation study, it is likely that the discharge of effluent with a TDS concentration at 3,500 mg/L, even at the lowest measured mixing ratio of 72, would result in negligible risk that sublethal toxicity would be measured at the edge of the mixing zone and would not be expected to result in potential additional project effects. This mixing potential at the edge of the mixing zone boundary limits any potential for a sublethal response.

Beyond the mixing zone, into the near- and far-field in Meliadine Lake, effluent will be carried by currents within the lake and further mixed with ambient water. The location of the effluent outfall diffuser is also within the expected main flow channel of the lake, which will act to convey and further disperse the effluent toward the lake outlet.

The assimilative capacity of the 100 m mixing zone will be validated through a comprehensive monitoring program, for which a conceptual design is provided in Section 3.0. Samples will be collected to ensure that the effluent is not acutely toxic, and that no sublethal effects occur at the edge of the mixing zone.

3.0 PHASE 2: CONDUCT VALIDATION STUDY

In conjunction with the upcoming freshet releases at Meliadine, supporting studies will be conducted in 2020 to validate the science-based interim targets and produce additional information on receiving environment assimilation. This section presents the general conceptual design for a proposed monitoring study in spring/summer 2020, to be undertaken both as a monitoring design for the anticipated water releases to Meliadine Lake, and for use as validation component of the WQ-MOP.

A freshet effluent discharge event from Collection Pond 1 (CP1) is anticipated to occur at the Mine site in the spring/summer of 2020. Elevated TDS concentrations in the effluent and the potential for elevated TDS in the receiving environment may occur during this discharge event, presenting an opportunity to conduct site validation for the interim TDS targets for effluent and at the edge of the mixing zone and provide additional information for the potential development of TDS EQC and SSWQO benchmarks, for use in adaptive management. The conceptual design for the proposed validation would consist of three components: plume delineation, water quality monitoring, and toxicity testing.

An overview of the conceptual design is presented in Table 3 and discussed below.

- **Plume Delineation Study**—A plume delineation study during the spring release to characterize the effluent plume configuration. Specific conductivity and temperature depth profiling at different spatial intervals from the effluent diffuser (e.g., locations at 50 m, 100 m, 200 m, and 600 m distances around the diffuser) will inform this study and also provide a basis for identifying candidate samples for water quality and toxicity testing. Water quality samples would be collected at a subset of the profile stations and analyzed for TDS and major ions. These data will inform if the conditions at the edge of the mixing zone are consistent with predictions of TDS and major ion concentrations, as estimated using existing water quality from effluent and modeling of the receiving environment, and the rate of effluent dispersion in the near-field region in Meliadine Lake. This study would occur over one to two days during the effluent discharge event.
- **Water Quality Monitoring**—Water quality samples will be collected at a subset of stations within and/or at the edge of the mixing zone and analyzed for a suite of parameters (routine, major ions, TDS, and total and dissolved metals) to characterize the condition of the mixing zone and edge of mixing zone. The water quality results for samples collected at the edge of mixing zone will inform selection of samples for toxicity testing for site-specific validation of the interim target at the edge of the mixing zone. Samples of effluent for water chemistry analysis should be collected on the same day as receiving environment samples and analyzed for the same suite of parameters. Three sampling events are recommended to adequately characterize the potential range in effluent quality and receiving environment conditions during the discharge period.
- **Toxicity Testing**—The freshet discharge event provides an opportunity to evaluate TDS toxicity under site-relevant conditions. During the freshet discharge event, representative water samples will be collected and tested for toxicity. The toxicity testing program will include separate test protocols for effluent and receiving water samples:
  - Effluent samples will be collected and tested using the suite of toxicity test species and standard protocols conducted for acute lethality testing and Environmental Effects Monitoring under the MDMER. It is recommended that testing be conducted at a minimum on two samples collected at set intervals (e.g., 15 days apart) during discharge to adequately characterize toxicity.

- Edge of mixing zone samples will be collected from three locations and tested for chronic toxicity using a multi-species approach that uses standardized tests and a tailored study design:
  - Test species will include one representative planktonic crustacean (*C. dubia* or *D. magna*), one representative epibenthic or aquatic insect species (e.g., *Hyalella azteca*, mayfly, or chironomid), one representative plant/alga (*Lemna minor* or *Pseudokirchneriella subcapitata*), and one early life-stage (ELS) fish development test (7-d rainbow trout embryo, 32-d rainbow trout embryo-alevin, or 21-d fathead minnow). Finalization of the suite of tests will be selected based on a review of the most representative surrogate species for aquatic taxa in Meliadine Lake, consideration of the strengths and limitations of each candidate test, and input from ECCC.
  - For data evaluation, the results of chronic toxicity tests above will be considered in combination with previous tests of chronic toxicity of site water, including 7-d *C. dubia* reproduction, 7-d fathead minnow, duckweed growth, and green algae growth tests.
- Prior to toxicity testing, water quality analysis of the edge of the mixing zone samples will be conducted to identify the samples with the highest TDS concentration. The 1–2 sample(s) with the highest relative TDS will be retained for toxicity testing.
- To achieve the validation objective, the edge of the mixing zone sample(s) collected for chronic toxicity testing would be amended with ionic salts in an ionic composition relevant to the edge of mixing zone and tested as a dilution series. The purpose to be to facilitate testing at concentrations both above and below the concentrations measured at the time of sampling, for the purpose of developing a concentration-response curve. This approach has been applied at other northern mine sites to better understand the concentration-response and define the lower bound of where TDS may cause chronic toxicity in site-specific mixtures. Although multiple chronic toxicity tests have been conducted in recent years, and these support the proposed interim target at the edge of the mixing zone, there is interest in identifying the nature of TDS concentration-response, including what higher TDS concentrations could elicit chronic responses.
- Two sampling and testing events, each with a battery of chronic tests, are recommended to adequately capture the range of potential conditions at the edge of the mixing zone during the discharge period. Timing of sampling will occur as close to the beginning and end of discharge as feasible, subject to the logistic constraints identified below.
- Additional sampling events may be necessary for renewal of water during ELS fish tests. The ELS fish tests sometimes require that large volumes of water be collected for testing, and in some circumstances require that fresh sample be collected during testing to use in water renewals. The type of ELS fish test and customization of the test will balance validation needs with logistical constraints.
- A far-field Meliadine Lake will be sampled for use as a field reference condition, and possibly for use as dilution water in the exposure series used for the site samples.

The following assumptions apply to the conceptual study design:

- Field monitoring and data collection will be conducted by Mine personnel, with support from Golder, on an as needed basis. Golder will provide the detailed study design for each component, work instructions, program coordination, data analysis and reporting.
- Due to the timing of effluent discharge during freshet, safe access to Meliadine Lake may pose a challenge due to melting ice conditions. It is anticipated that effluent discharge would occur before the lake is completely ice-free to alleviate on-site water storage capacity limitations. Therefore, the monitoring work conducted as part of this study will occur as soon as the sampling area of the lake is ice free and safely accessible.
- A final study design will be developed prior to deployment of the sampling crew, including specific work instructions and health and safety plans.

We recognize the importance of collecting the confirmatory information above and would seek to prepare a submission in Summer 2020 that reports on the key findings of the validation study and provides a basis for a submission of Phase 3 of WQ-MOP. To this end, the data available from the first month of the validation program, inclusive of the three components (plume delineation, water quality, toxicity testing) will be submitted to ECCC for review and it will be part of the amendment application of the existing Meliadine Water License to the Nunavut Water Board. Longer-term monitoring of the receiving environment will continue during submission of the Phase 3 WQ-MOP.

Table 3: Conceptual Design for the Proposed Validation of the Interim TDS Limits for Effluent and the Receiving Environment

(a) Plume Delineation Study		
Sampling Media	Effluent	Receiving Environment
Sample Timing	During plume delineation study	During effluent discharge[(a)]
Sampling Locations	End-of-pipe	10 to 20 survey locations set out at progressive intervals from 50 m from the diffuser, including at 100 m (i.e., edge of mixing zone), up to 600 m from the edge of the mixing zone[(a)] A far-field area (~1 km downstream of the mixing zone) will be included in the survey
Frequency of Program	1 event during discharge	1 event during discharge
Test Parameters	▪ Routine ▪ Major ions and TDS ▪ Nutrients ▪ Total and dissolved metals	▪ Field physico-chemical water column profile measurements (temperature, and specific conductivity) ▪ Water quality samples collected at a subset (5 to 10 stations) alongside profile measurements and analyzed for routine, major ions and TDS
(b) Water Quality Monitoring		
Sampling Media	Effluent	Receiving Environment
Sample Timing	During effluent discharge and during collection of effluent samples for toxicity testing	During effluent discharge[(b)]
Sampling Locations	—	At least 3 locations on the edge of the mixing zone; additional locations within the mixing zone may be identified
Number of Samples	Per regulatory and operational requirements	1 sample per station
Frequency of Sampling	Per regulatory and operational requirements	3 events during discharge
Test Parameters	▪ Routine ▪ Major ions and TDS ▪ Nutrients ▪ Total and dissolved metals	▪ Routine ▪ Major ions and TDS ▪ Nutrients ▪ Total and dissolved metals
(c) Toxicity		
Sampling Media	Effluent	Receiving Environment
Sample Timing	During effluent discharge	During effluent discharge[(b)]
Sampling Locations	—	3 locations on the edge of the mixing zone
Number of Samples	Per regulatory and operational requirements	1 sample per station
Frequency of Sampling	Per regulatory and operational requirements; at least 2 sampling events during discharge period	2 events during discharge[(c)]
Test Parameters	Acute toxicity tests with: ▪ Rainbow trout ▪ *Daphnia magna* Chronic toxicity tests with: ▪ *Ceriodaphnia dubia* ▪ Fathead minnow ▪ Alga ▪ Duckweed	Chronic toxicity tests with: ▪ Pelagic crustacean (*Ceriodaphnia dubia* or *Daphnia magna*) ▪ Epibenthic/Benthic Insect (*Hyalella azteca*, mayfly, or chironomid) ▪ Plant or Alga (*Pseudokirchneriella subcapitata* or duckweed) ▪ ELS fish (Fathead minnow or Rainbow Trout)

Notes:

(a) The maximum extent of plume delineation monitoring may be extended should the proportion of effluent be estimated to consistently comprise >10% of the ambient lake water quality at 500 m (based on field specific conductivity measurements).

(b) Sample timing will be dependent on lake access. The period of anticipated discharge will likely coincide with the transition period between ice covered and open water conditions on Meliadine Lake. Access of the lake will occur as soon as open water conditions permit safe access.

(c) Additional sampling events may be required to collect water that will be used to renew test solutions for chronic ELS fish tests. These tests require large volumes of water be collected and may require that fresh sample be collected and used for water renewals during toxicity testing.

ELS = Early life-stage; TDS = total dissolved solids

4.0 CONCLUSIONS

The application of the WQ-MOP framework provides a basis for management of Meliadine effluent releases that:

- is protective of the environment (both in the mixing zone and broader ecological condition of Meliadine Lake), as demonstrated in this memorandum, which provides Phase 1 and the conceptual elements of Phase 2 of the WQ-MOP)
- will satisfy regulatory requirements for the short-term (Phase 1 and 2) and long-term (Phase 3) management of TDS:
  - interim targets for TDS proposed herein satisfy short-term regulatory requirements for management of TDS during the 2020 freshet discharge, subject to the approval of the requested Amendment, and endorsement of the interim targets for effluent and at the edge of the mixing zone
  - interim targets for TDS proposed herein form the basis for development of TDS targets for effluent (EQC) and receiving environment (SSWQO), following validation monitoring, for future application under an adaptive management framework
- is based on science, including both site-specific evaluations of toxicity and comparison to other project approvals with similar composition of TDS
- is customized to the site-specific conditions of water quality and quantity (with revisions as appropriate should these conditions change)

It is acknowledged that the aspects of the interim targets for TDS and, if required, future development of EQC and SSWQO would benefit from additional confirmatory study. The upcoming 2020 freshet release event provides an opportunity to collect the data necessary for this validation (i.e., Phase 2 of the WQ-MOP).

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REFERENCES

Agnico Eagle Mines Ltd. 2015. Water Management Plan Version 1. Type A Water Licence Application, Meliadine Gold Project. APHA (American Public Health Association). 2005. Standard Methods for the Examination of Water and Wastewater, 21st ed. American Public Health Association, Washington, DC.

Agnico Eagle Limited. 2019. Type A Water License Amendment—SSWQO Meeting Minutes. Meeting of Agnico Eagle Limited, Environment and Climate Change Canada, and Golder Associates Ltd. 9 December 2019.

Agnico Eagle Limited. 2020. Meliadine Total Dissolved Solids Benchmark Meeting Minutes. Teleconference of Agnico Eagle Limited, Environment and Climate Change Canada, and Golder Associates Ltd. 9 January 2019.

Golder. 2014. Final Environmental Impact Statement (FEIS)—Meliadine Gold Project. Volume 7.0, Freshwater Environment. Golder. 2018. Aquatic Effects Monitoring Program—2017 Annual Report. Agnico Eagle Mines Limited – Meliadine Gold Project. Submitted to Agnico Eagle Mines Limited. March 2018.

Golder Associates Ltd. (Golder). 2019a. Proposed Site-Specific Water Quality Objective and Effluent Discharge Criterion for Total Dissolved Solids Threshold for Meliadine Gold Mine. Technical Memorandum submitted to Michel Groleau and Jamie Quesnel, Agnico Eagle Mines Limited. Project No. 19127573-SSWQO-TDS-Rev0. 20 December 2019.

Golder. 2019b. Cycle 1 Environmental Effects Monitoring Report and 2018 Aquatic Effects Monitoring Program Annual Report. Agnico Eagle Mines Limited—Meliadine Gold Mine. Submitted to Agnico Eagle Mines Limited. March 2019.

Government of Canada. 2002. Metal and Diamond Mining Effluent Regulations SOR/2002-222. Current to October 10, 2018. Last amended on June 1, 2018. Minister of Justice. Ottawa, ON.

MDDEP (Ministère du Développement Durable, de l’Environnement et des Parcs). 2007. Calculation and interpretation of effluent discharge objectives for contaminants in the aquatic environment, 2nd Edition, Quebec, 54 p.

Tetra Tech. 2017. Design Report for Effluent Water Treatment Plant, Pumping Stations, Pipelines & Associated Berm, and Diffuser Available at: ftp://ftp.nwb-oen.ca/registry/2%20MINING%20MILLING/2A/2AM%20-%20Mining/2AMMEL1631%20Agnico/3%20TECH/5%20CONSTRUCTION%20(D)/Final%20Effluent%20System/

Tetra Tech. 2018. Effluent Discharge Modelling for the As-Built Diffuser at the Meliadine Gold Project, Nunavut. Prepared for Agnico Eagle Mines Limited. May 2018.

APPENDIX A

Supporting Information for the Interim TDS Targets

APPENDIX A: SUPPORTING INFORMATION FOR INTERIM TDS TARGETS

This Appendix presents the supporting information and rationale for the proposed interim targets of: (a) 1,000 mg/L calculated TDS to apply at the edge of the mixing zone (Section A1.0) and (b) 3,500 mg/L calculated TDS to apply for effluent discharge (Section A2.0).

A1.0 INTERIM TDS TARGET AT THE EDGE OF THE MIXING ZONE

The benchmark of 1,000 mg/L calculated TDS is proposed as an interim value for use in the short-term, pending implementation of Phase 2 and Phase 3 of the WQ-MOP.

The proposed interim target was derived as summarized below and detailed in the subsequent sections:

- Characterization of the Meliadine TDS profile (Section A1.1)—water chemistry data collected at the Meliadine Mine were used to profile the anticipated water quality in the receiving environment, including composition of major component ions in the TDS mixture.
- Review of water quality benchmarks (Section A1.2)—review of TDS benchmarks developed for locations with a similar TDS composition to Meliadine Mine.
- Literature review (Section A1.3)—review of peer-reviewed literature to determine the threshold for chronic toxicity with a focus on TDS mixtures of similar composition to Meliadine (i.e., dominance of chloride, sodium, and calcium ions).
- Review of site-specific chronic toxicity data (Section A1.4)—review of site toxicity data and corresponding TDS and major ion chemistry for Meliadine treated effluent and influent samples, as collected during routine and regulatory compliance toxicity testing.
- Weight of Evidence (Section A1.5)—integration of the above information to justify an interim target TDS concentration of 1,000 mg/L to apply at the edge of the mixing zone.

A1.1 Characteristics of Total Dissolved Solids

A1.1.1 Definition

The TDS parameter is defined as the sum of the concentrations of all common dissolved ions in freshwaters (e.g., sodium [Na^+], calcium [Ca^{2+}], magnesium [Mg^+], potassium [K^+], sulphate [SO_4^{2-}], bicarbonate [HCO^{3-}], chloride [Cl^-], nitrate [NO^{3-}], fluoride [F^-], and silicate [SiO_3^{2-}]), and is essentially an expression of salinity. TDS can be calculated using the following equation (APHA 2005):

$$TDS_{calculated\ (mg/L)} = \sum[Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, F^-, SO_4^{2-}, SiO_3^{2-}, 4.42 \times NO_3^-\ (as\ N), 0.6 \times total\ alkalinity\ (as\ CaCO_3)]$$

Concentrations of TDS may also be measured gravimetrically by analytical laboratories. However, calculated TDS is used herein as the primary basis for derivation of interim targets for TDS and screening because:

- Laboratory interference can reduce the accuracy of measured TDS (Evaristo-Cordero 2011). In particular, waters with high calcium, magnesium, and chloride concentrations can form hydroscopic residues that absorb water under normal laboratory conditions, potentially biasing the measured TDS higher than actual concentrations (APHA 2005; Evaristo-Cordero 2011). In contrast, calculated TDS is based on the major ions that can measurably contribute to TDS and is therefore, not influenced by any changes that may occur from those ions being taken out of solution.

- Calculated TDS incorporates explicit consideration of the ionic composition, which is important for evaluating the toxicity of the TDS mixture (as discussed below).
- Calculated TDS is forecasted, using predictive modelling, to estimate potential TDS concentrations in effluent and receiving environment under future mine conditions; use of calculated TDS for the interim target provides an equivalence for comparison relative to modelled conditions.

In recent meetings, ECCC expressed a preference that concentrations of TDS be expressed on a measured concentration basis. Agnico Eagle has committed to presenting monitoring results using both methods (calculated and measured).

A1.1.2 General Fate and Effects

Dissolved solids occur naturally in water, with the composition and concentration of individual ion constituents varying by location based on natural factors, such as the geology and soil in the watershed, atmospheric precipitation and the water balance (evaporation-precipitation) (Weber-Scannell and Duffy 2007). Anthropogenic activities can alter the concentration of TDS in the aquatic environment, with effluent from mining or industrial treatment of water identified as common sources of elevated TDS (Soucek 2007; Weber-Scannell and Duffy 2007). Differences in the ratios of calcium to magnesium (Ca:Mg) or relative contribution of sulphate or chloride to the total TDS concentration are common indicators of anthropogenic influence.

The primary toxicity modifying factor for TDS is ionic composition, reflecting the fact that individual ionic components exhibit different potential to exert toxicity. For example, Mount et al. (1997) reported 48-hr LC_{50} values ranging from 390 to >5,610 mg/L in *C. dubia* and 96-hr LC_{50} values ranging from <510 to 7,960 mg/L in the fathead minnow exposed to various ion combinations, respectively. In general, a balanced mixture of ions results in lower toxicity than strong dominance by an individual ion, particularly dominance by an individual ion with relatively high toxicity. Mount et al. (1997) reported that the relative ion toxicity to freshwater biota was generally potassium > carbonate ≈ magnesium > chloride > sulphate, with calcium and sodium exhibiting relatively low toxicity. Therefore, the toxicity of a TDS mixture depends largely on the composition of ions within the mixture, rather than the total TDS concentration, which on its own is not an accurate predictor of toxicity. If the mixture is well characterized, and the composition of that mixture is similar to samples for which mixture-based toxicity testing has already been conducted, the confidence in predictions of toxicological potential increases substantially.

A1.1.3 Site-Specific Composition

Monitoring data for Meliadine effluent (MEL-14) were compiled for surface water samples collected between September 2017 and October 2019 and monitoring data for the near-field in Meliadine Lake (MEL-01; stations MEL-01-01 and MEL-01-06 to MEL-01-08) were compiled for surface water samples collected between July 2015 and September 2019. The date range selected for the effluent TDS data begins in 2017 because it coincides with period of increasing effluent TDS concentrations. The near-field TDS composition has been relatively stable over time; data were included for a broader time period to reflect the chronic exposure condition. Summary statistics for major ion chemistry, TDS, and water hardness are presented in Table A-1.

The interim target was developed considering that the ionic composition would fall within the bounds of the ionic composition of the effluent and near-field receiving water. In other words, the effluent and near-field receiving environment samples bracket the range of mixture types expected for future samples of water upon initial mixing. Average measured TDS in the effluent was approximately 930 mg/L and consisted predominantly of chloride (470 mg/L; 52% of TDS), sodium (167 mg/L; 18% of TDS), calcium (125 mg/L; 13% of TDS), sulphate (56 mg/L; 6% of TDS), carbonate (20 mg/L; 2% of TDS), and relatively low concentrations of magnesium, potassium, fluoride, nitrate, and reactive silica (combined 9% of TDS; Figure A-1). Average measured TDS in the near-field receiving environment (MEL-01) was lower (44 mg/L) with a broadly similar ionic composition to the effluent but with a higher overall proportion of carbonate and lower proportion of chloride, sodium, and calcium. TDS in the near-field consisted predominantly of chloride (12 mg/L; 28% of TDS), carbonate (18 mg/L; 24% of TDS), sodium (5.8 mg/L; 13% of TDS), calcium (7.7 mg/L; 18% of TDS), sulphate (4.5 mg/L; 10% of TDS), and relatively low concentrations of magnesium, potassium, fluoride, nitrate, and reactive silica (combined 6% of TDS; Figure A-2). On a site-wide basis, TDS composition relevant to the Meliadine interim TDS target is an ionic composition dominated by chloride, sodium, and calcium (from highest to lowest concentration), with lower contribution from carbonate. It is anticipated that, should TDS increase in the receiving environment relative to current conditions, the relative proportion of carbonate would decline as the relative proportions of chloride, sodium and calcium increase. Dominant ions of chloride, sodium, and calcium represent the lower range of toxicity potential relative to potassium, carbonate, and magnesium (Mount et al. 1997).

Hardness may modify ion-specific toxicity, thereby ameliorating the toxicity of a mixture by reducing the toxicity of individual ions (Kennedy et al. 2005). For example, calcium has been identified as a specific component of hardness that ameliorates sulphate toxicity (Davies and Hall 2007; Mount et al. 2016). Hardness is not considered a toxicity modifying factor in the case of TDS, because hardness is a component of the TDS mixture and is therefore not an independent factor distinct from ionic composition. However, hardness can be considered for the evaluation of ion-specific toxicity, given that some ions (e.g., chloride, sulphate) are less toxic in hard water. Water hardness was calculated as calcium carbonate ($CaCO_3$) using the following equation:

$$[CaCO_3] = 2.5 \times [Ca^{2+}] + 4.1 \times [Mg^{2+}]$$

Average calculated water hardness in the effluent was 408 mg/L as $CaCO_3$ (i.e., very hard water), compared to 25 mg/L (i.e., soft water) in the near-field receiving environment.

Table A-1: Water chemistry results for TDS and associated constituents in Meliadine Mine effluent (MEL-14) collected between September 2017 to October 2019 and near-field (MEL-01) collected between July 2015 and September 2019

Parameter (mg/L)	MEL-14					MEL-01[(a)]				
	Median	Average	Maximum	Minimum	Sample Count	Median	Average	Maximum	Minimum	Sample Count
Calculated TDS	923	930	1,213	634	28	42	44	69	33	43
Measured TDS	1,185	1,203	1,760	860	28	52	54	94	25	43
Carbonate[(b)]	20	20	34	4	28	10	11	17	8	43
Chloride	470	487	660	300	28	12	12	19	8	43
Sodium	167	165	236	94	28	5.6	5.8	9.4	4.1	43
Calcium	125	122	220	17	28	7.3	7.7	13	5.8	43
Sulphate	53	56	90	7	28	4.3	4.5	6.6	3.4	43
Magnesium	26	25	36	4	28	1.3	1.4	2.4	1.0	43
Potassium	14	14	17	10	28	1.0	1.0	1.7	0.8	43
Fluoride	— (c)	— (c)	— (c)	— (c)	0	0.03	0.03	0.03	0.02	43
Nitrate (as N)	11	9	15	3	28	0.01	0.01	0.08	0.01	43
Reactive Silica	0.73	0.79	3.60	0.05	28	— (d)	— (d)	— (d)	— (d)	1
Calculated Water Hardness (as $CaCO_3$)[(e)]	407	408	698	59	28	24	25	41	19	43

Notes:

All concentrations expressed in milligrams per litre.

(a) MEL-01 measurements are from near-field stations MEL-01-01, MEL-01-06, MEL-01-07, MEL-01-08, and MEL-01-09.

(b) Calculated from total alkalinity as total alkalinity (as $CaCO_3$) × 0.6

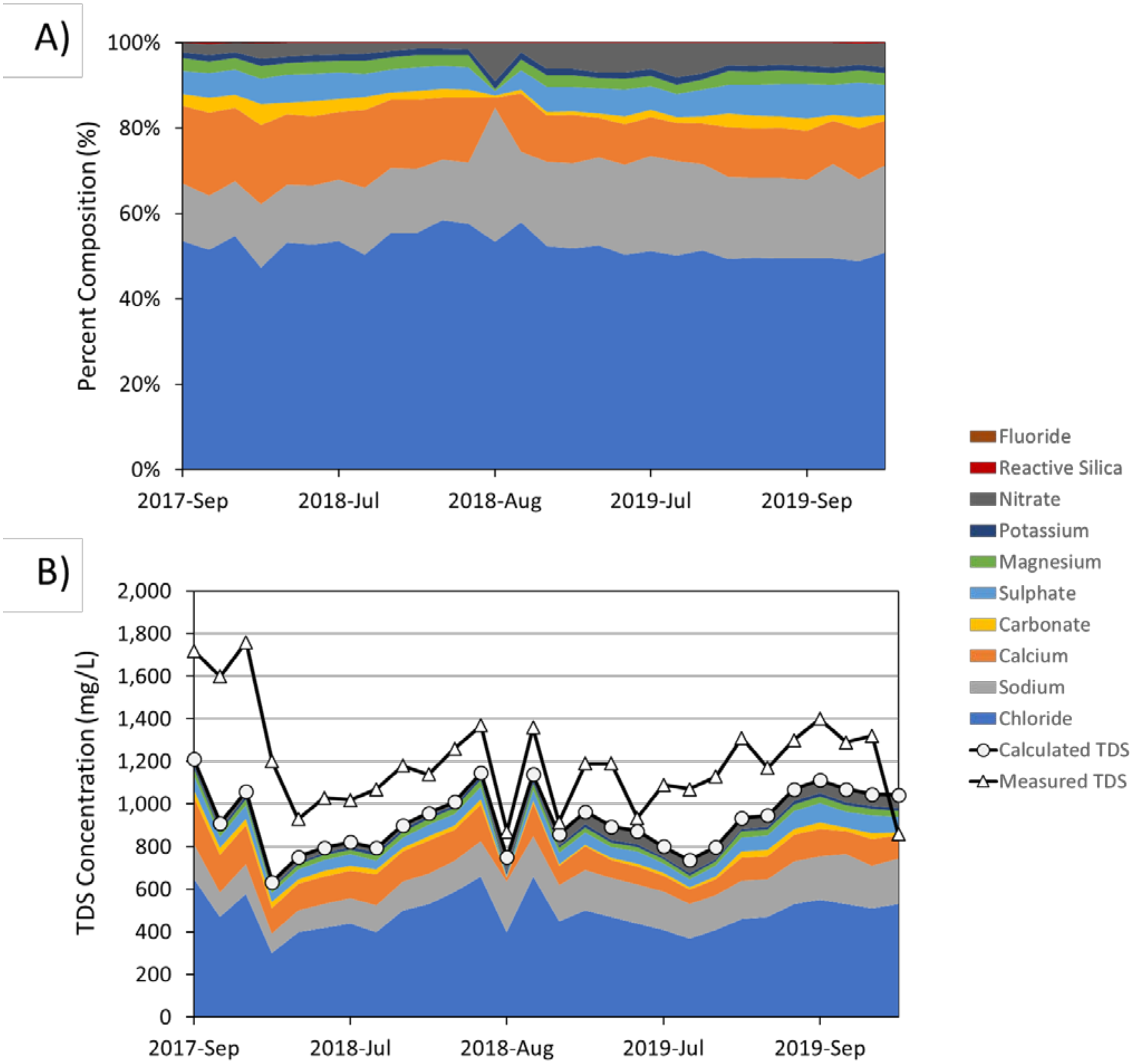
(c) Fluoride was not measured for data collected between September 2017 and October 2019, which precluded the calculation of summary statistics. However, these data would not result in significant changes to the understanding of ionic composition, given that fluoride provides only a trace component of both halides and TDS in Meliadine water samples.

(d) Reactive silica was only measured in one sample for data collected between September 2017 and October 2019, which precluded the calculation of summary statistics.

(e) Calculated as (2.5 × [Ca^{2+}]) + (4.1 × [Mg^{2+}])

mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate; N = Nitrogen; — = not measured.

Figure A-1: Percent composition of TDS (%) (Panel A) and TDS concentration (mg/L) (Panel B) at station MEL-14 (treated effluent) for samples collected between September 2017 and October 2019 at Meliadine Mine.

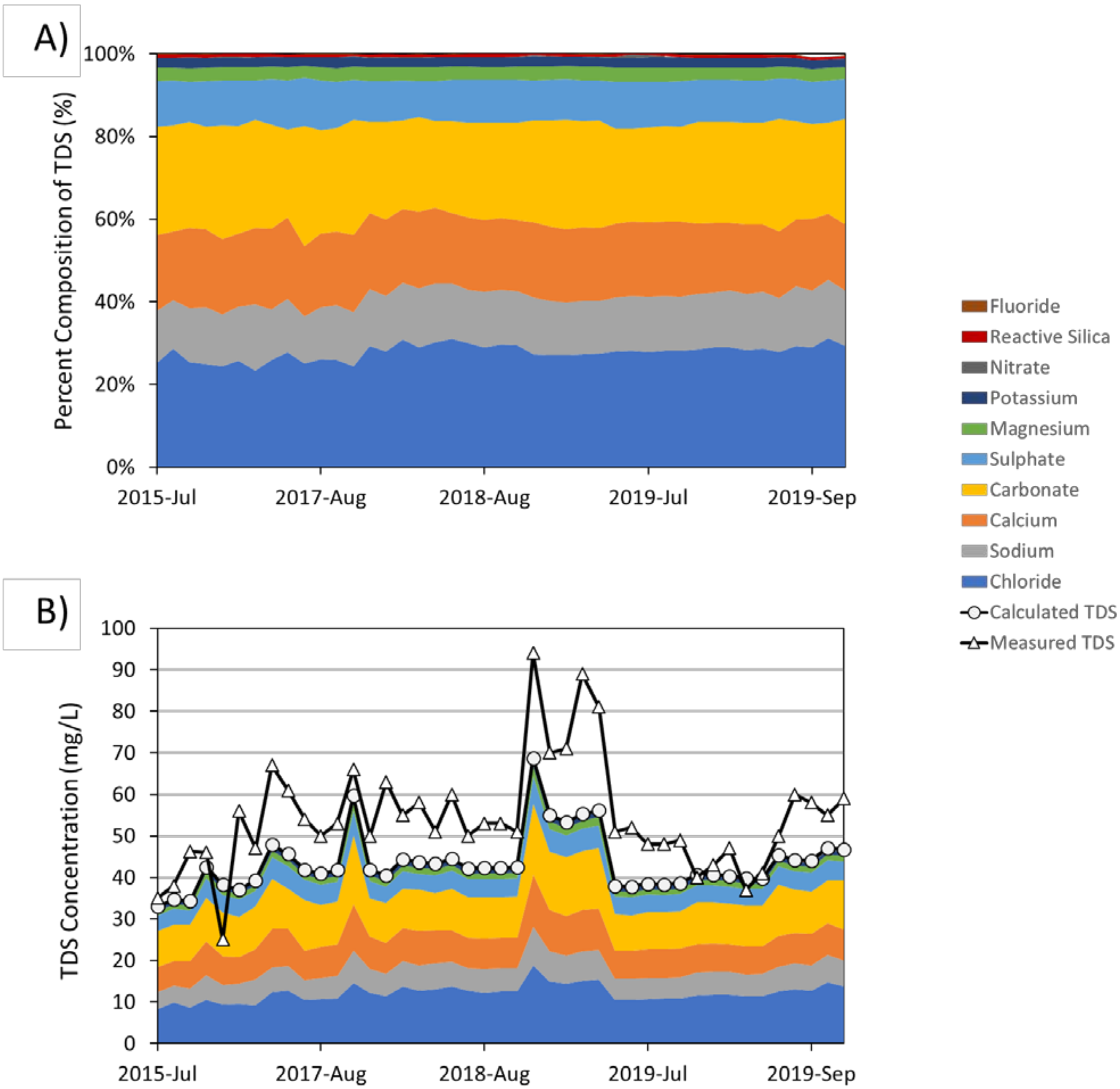


Notes:

Ionic composition was calculated as: $TDS_{calculated\ (mg/L)} = \sum[Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, F^{-}, SO_4^{2-}, SiO_3^{2-}, 4.42 \times NO_3^{-}\ (as\ N), 0.6 \times total\ alkalinity\ (as\ CaCO_3)]$.

Data for ionic composition from effluent (MEL-14) was collected between September 2017 and October 2019.

Figure A-2: Percent composition of TDS (%) (Panel A) and TDS concentration (mg/L) (Panel B) at station MEL-01 (near-field) for samples collected between July 2015 and September 2019 at Meliadine Mine.



Notes:

Ionic composition was calculated as: $TDS_{calculated\ (mg/L)} = \sum[Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, F^-, SO_4^{2-}, SiO_3^{2-}, 4.42 \times NO_3^- \ (as\ N), 0.6 \times total\ alkalinity\ (as\ CaCO_3)]$.

Data for ionic composition from near-field (MEL-01) was collected from stations MEL-01-01, MEL-01-06, MEL-01-07, and MEL-01-08 between July 2015 and September 2019.

A1.2 Benchmarks from Other Sites

Currently, there is no federal, provincial or territorial water quality guideline for TDS in Canada. Several US States have developed state or site-specific TDS criteria focussed on the protection of aquatic life. In Alaska, TDS criteria range from 500 to 1,500 mg/L (ADEC 2009), depending on the TDS composition and whether the receiving environment is potential salmon spawning habitat. Permits are required for discharges to receiving water that result in an increase in TDS concentration in the waterbody between 500 and 1,000 mg/L. Chapman et al. (2000) reported that studies conducted for Coeur Alaska's Kensington Mine site resulted in the first site-specific TDS permit in Alaska. The permit states that TDS may not exceed 1,000 mg/L in Sherman Creek, the receiving waterbody of Kensington Mine effluent (ADEC 2017). Alaska also granted a site-specific permit for Red Dog Mine effluent (ADEC 2013; Brix et al. 2010). Concentrations of TDS up to 1,500 mg/L are permitted during periods when salmonids are not spawning, provided calcium is greater than 50% by weight of the total cations (ADEC 2013; Brix et al. 2010). During spawning periods, the limit was set at 500 mg/L (Brix et al. 2010). However, the studies used to establish the Alaskan TDS water quality criterion were based on ionic compositions dominated by calcium sulphate, whereas the Meliadine effluent and near-field TDS is predominantly sodium chloride and calcium chloride (Chapman et al. 2000; Brix et al. 2010). Therefore, these benchmarks are not directly applicable to Meliadine Mine.

In 2004, the Iowa Department of Natural Resources (IDNR) adopted an interim TDS standard of 1,000 mg/L in receiving streams; the standard was used as a screening value to determine whether site-specific toxicity testing was required (IDNR 2009). However, IDNR since recommended replacing the TDS standard with numerical sulphate and chloride criteria (IDNR 2009) under the assumption that the individual ions provide a more defensible basis for evaluating toxicity relative to the sum of the ions.

The Snap Lake Mine in the Northwest Territories currently has a site-specific water quality objective (SSWQO) for TDS of 1,000 mg/L (Golder 2014; Chapman and McPherson 2015). The SSWQO was derived following toxicity testing with multiple receptor groups (fish, invertebrates, and plants) using a TDS ionic composition specific to Snap Lake Mine dominated by chloride, calcium, and sodium. The typical composition of Snap Lake water includes ~45% to 47% chloride, 20% to 21% calcium, 10% to 11% sodium, 9% sulphate, 5% to 7% carbonate, 4% nitrate, and 2% to 3% magnesium, with minor contributions from potassium and fluoride. This composition is broadly similar to that of Meliadine effluent. The test species and effects endpoints for the TDS SSWQO dataset, as reported by Chapman and McPherson (2015) and discussed in detail in Golder (2014), are presented in Table A-2. Additional testing was also conducted with the non-resident water flea, *Ceriodaphnia dubia*. As discussed by Chapman (2014a) the results from multiple rounds of testing with *C. dubia* were highly variable (potentially confounded by laboratory artifacts) and could not be relied upon to derive a protective SSWQO for Snap Lake Mine. Because species of the genus *Ceriodaphnia* do not reside in Snap Lake, species of the genus *Daphnia* are observed in Snap Lake, the chronic reproduction *D. magna* results were considered more representative of daphnids in Snap Lake. Following a resident taxa approach for deriving a SSWQO using the dataset in Table A-2, the TDS SSWQO for Snap Lake was set as 1,000 mg/L. The SSWQO was considered protective of aquatic life, and “if not exceeded, will avoid harm to the Snap Lake ecosystem” (Chapman 2014a, p.5). As discussed by Chapman (2014c), the results of toxicity testing do not indicate that an exceedance above 1,000 mg/L TDS will result in harm to aquatic life but provide “reasonable certainty of no harm up to 1,000 mg/L” (Chapman 2014a, p.5).

Table A-2: Chronic toxicity testing dataset for Snap Lake TDS SSWQO as summarized by Chapman and McPherson (2015)

Test Species	Common Name	Life stage	Test Duration	Endpoint	Test Statistic[(a)]	Result (mg/L TDS)	Reference
Salvelinus namaycush	Lake Trout	early life-stage		dry fertilization survival	LC_{20}	990	Baker et al. 2015
				dry fertilization growth	IC_{20}	>1,490	
				wet fertilization survival	LC_{20}	>1,480	
				wet fertilization growth	IC_{20}	>1,480	
Daphnia magna	water flea	<24 hr	21-d	reproduction	IC_{20}	>1,100	Chapman 2014b
Brachionus calyciflorus	rotifer		48-hr	population	IC_{10}	>1,330	Chapman 2014c
Chironomus dilutus	chironomid		10-d	growth	IC_{10}	>1,390	Chapman 2014c
Thymallus arcticus	Arctic Grayling	early life-stage		dry fertilization survival	LC_{20}	>1,420	Baker et al. 2015
				dry fertilization growth	IC_{20}	>1,420	
				wet fertilization survival	LC_{20}	>1,410	
				wet fertilization growth	IC_{20}	>1,410	
Pseudokirchneriella subcapitata	green alga	population	72-h	growth	IC_{10}	>1,470	Chapman 2014c
Navicula pelliculosa	diatom	population	120-h	growth	IC_{10}	>1,490	Chapman 2014c
Cyclops vernalis	copepod		20-d	growth	IC_{20}	>1,510	Marus et al. 2015; Chapman 2014c; Chapman 2014a
Pimephales promelas	Fathead Minnow	early life-stage	32-d	hatching, survival and growth	IC_{20}	>2,200	Chapman 2014c

Notes:

(a) As reported in Chapman and McPherson (2015) for the "*lowest reliable, technically defensible endpoint for each test*." A discussion of the selection of endpoints is provided in Golder (2014).

mg/L = milligrams per litre; TDS = total dissolved solids; LC_X = lethal concentration causing a lethal effect to x% of the test population; IC_X = inhibitory concentration that causes an x% inhibitory effect in the sublethal endpoint being measured.

The Snap Lake SSWQO validation excluded test results for the water flea, *C. dubia,* because multiple rounds of testing produced highly variable effect concentrations that were not reliable. Variability in the reproductive endpoint for *C. dubia* was attributed to confounding factors associated with the testing laboratory (e.g., dilution and acclimation water), and such variations have also been reported elsewhere (Lasier et al. 2006; Pacholski et al. 2016; Mount et al. 2016). Golder (2011; 2014) and Chapman and McPherson (2015) concluded that *D. magna* are more relevant surrogate for resident cladoceran species in Snap Lake mine because zooplankton surveys in Snap Lake reported the genus *Daphnia* but not the genus *Ceriodaphnia*. The same logic would apply for Meliadine Lake, where zooplankton surveys conducted as part of Aquatic Effects Monitoring in 2015, 2016, and 2017 reported *Daphnia* presence but not *Ceriodaphnia* (Golder 2019).

A1.3 Review of Chronic Toxicity Literature

Golder (2011; 2014) conducted an extensive literature review for total dissolved solids that was updated by Chapman and McPherson (2015); the literature review is presented in Appendix A of Golder (2011; 2014) and summarized in Chapman and McPherson (2015). This literature is separate from the values derived from site-specific toxicity testing at Snap Lake Mine as reported in Table A-2. Golder (2011; 2014) and Chapman and McPherson (2015) concluded that the toxicity of TDS was highly dependent on the ionic composition, the species tested, and the life stage; they identified the following trends for generic TDS mixtures:

- Phytoplankton—overall high tolerance of phytoplankton to TDS toxicity with effect concentrations higher than 1,000 mg/L.
- Benthic invertebrates—in general, adverse effect concentrations were above 1,000 mg/L, with the following exceptions. Relatively high sensitivity was reported for oligochaete worms (96-hour immobilization EC_{50} of 281 mg/L calcium chloride to the oligochaete worm *Tubifex tubifex*; Khangarot 1991), and the glochidia of a freshwater mussel (48-hour EC_{50} of 560 mg/L sodium chloride to glochidia of *Lampsilis fasciola*; Bringolf et al 2007). Lower effect concentrations were also reported for the fingernail clam (*Sphaerium simile*; 96-hour survival LC_{50} of 740 mg/L; GLEC and INHS 2008; Soucek et al. 2011) but these represented individual ion exposure, which may not accurately predict chloride toxicity under mixture conditions.
- Zooplankton—cladoceran species were generally the most sensitive to TDS. Effect concentrations for calcium chloride salts ranged from 600 to 7,000 mg/L. A review of the chronic dataset presented by Golder (2011; 2014) indicated that effect concentrations for sodium chloride generally ranged from 750 mg/L (7-d reproduction no-effect concentration (NOEC) for *C. dubia*; Cooney et al. 1992) to 2,400 mg/L (7-d survival lowest effect concentration for *C. dubia*; Cooney et al. 1992).
- Fish—the sensitivity of fish to TDS toxicity varied by life-stage, with fertilization and egg-hardening life stages identified as the most sensitive toxicological endpoints. Fish were also generally less sensitive to TDS toxicity than zooplankton, with effect concentrations for calcium chloride ranging from 4,600 mg/L to greater than 15,000 mg/L. A review of the chronic dataset presented by Golder (2011; 2014) indicated that effect concentrations for sodium chloride generally ranged from 800 mg/L (8-d NOEC *Oncorhynchus mykiss*; Camargo and Tarazona 1991) to 8,000 mg/L (7-d NOEC *Pimephales promelas*; Pickering et al. 1996).

Lower effect concentrations have been reported for individual ions for select species, but these tests reflect exposure conditions accounting for a single ion, and not a balanced TDS mixture representative of most field conditions. A review of the literature indicates that when accounting for toxicity for TDS the following observations apply as summarized by Chapman and McPherson (2015):

- TDS toxicity is lower with the presence of more than one cation.
- Hardness may ameliorate TDS toxicity and the toxicity of individual ions (e.g., chloride and sulphate).
- The relative ratios of ions within the TDS mixture may affect TDS toxicity (e.g., Ca^{2+}:Mg^{2+}).

More recent research by Mount et al. (2016) support the conclusions by Chapman and McPherson (2015). Following extensive toxicity testing exposing *C. dubia* to different salt mixtures, Mount et al. (2016) concluded that inferring toxicity from individual ions is difficult due in part to interdependence among ions. Buchwalter et al. (2013) concluded that TDS toxicity is complicated by the findings that:

1) individual ions vary in toxicity;

2) some ions in solution can modify the toxicity of other ions; and

3) relative toxicities of ions are not consistent across species.

The results from Mount et al. (2016) also support the conclusion that toxicity of TDS mixtures varies by ionic composition, and that the characteristics of the TDS mixture influence the toxicity of other ions in the mixture.

A1.4 Site-Specific Chronic Toxicity Data

The information from the literature discussed in Section A1.3, particularly for Snap Lake, provides an indication of chronic exposure levels for TDS that are protective of aquatic life in a northern freshwater ecosystem. However, the identified importance of ionic composition means that site-specific results should carry the greatest weight in the interpretation of biological and ecological significance.

Chronic toxicity testing data and corresponding water chemistry data have been collected by Agnico Eagle as part of routine and regulatory monitoring at stations MEL-14 (treated effluent), and MEL-12 (influent from the water treatment plant). Chronic toxicity tests performed (all standard Environment Canada test protocols commonly applied in the Canadian environmental effects monitoring framework) were:

- Biological Test Method: Test of Reproduction and Survival Using the Cladoceran, *Ceriodaphnia dubia* (EC 2007a)
- Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows (EC 2011)
- Biological Test Method: Growth Inhibition Test Using a Freshwater Alga (EC 2007b)
- Biological Test Method: Test for Measuring the Inhibition of Growth Using the Freshwater Macrophyte, *Lemna minor* (EC 2007c)

Chronic toxicity test results and corresponding water chemistry data for calculated TDS (and measured) and chloride are presented in Table A-3. The results of the chronic testing indicate:

- No effects to *C. dubia* survival at TDS concentrations up to and including 2,357 mg/L (measured TDS of 2,450 mg/L). Reduced *C. dubia* reproduction was observed at TDS concentrations between 1,140 mg/L to 2,202 mg/L (measured TDS of 1,360 to 2,490 mg/L).
- No effects to fathead minnow survival or growth at TDS concentrations up to and including 2,357 mg/L (measured TDS of 2,450 mg/L).
- Growth inhibition to *P. subcapitata* was observed in two samples collected in September and October 2019 at TDS concentrations of 2,202 mg/L and 2,357 mg/L, respectively (measured TDS of 2,490 mg/L and 2,450 mg/L, respectively). However, follow up testing conducted in October indicated no effect to growth inhibition at a TDS concentration of 2,350 mg/L (measured TDS of 2,370 mg/L). No effect to growth inhibition was observed in remaining samples at TDS concentrations up to and including 1,140 mg/L (measured TDS of 1,360 mg/L).

- Effects to *L. minor* frond count were observed at TDS concentrations between 2,202 mg/L to 2,357 mg/L (measured TDS of 2,490 mg/L to 2,450 mg/L). Although effects to *L. minor* frond count were occasionally observed at TDS concentrations of approximately 1,000 mg/L the effect was not consistently observed. For example, no effect to frond count (IC_{25} >97% vol/vol) was observed on three occasions at TDS concentrations ranging between 800 to 1,140 mg/L (measured TDS of 1,130 to 1,360 mg/L). Effects to *L. minor* biomass were observed in two of eight samples at TDS concentrations of 1,011 mg/L and 2,357 mg/L (measured TDS 1,260 mg/L to 2,450 mg/L). No effects to *L. minor* biomass were observed in six of eight samples at TDS concentrations of 800 to 2,350 mg/L (measured TDS of 1,130 mg/L to 2,370 mg/L).

In summary, multiple rounds of chronic toxicity testing indicate no effects to survival of fish or crustaceans across a wide range of TDS concentrations (i.e., unbounded no-effect level of 2,357 mg/L), and no reliable indications of sublethal toxicity have been observed at 1,000 mg/L. Moderate to high magnitude sublethal responses to *C. dubia* and aquatic plants/algae are evident at calculated TDS concentrations that exceed 2,000 mg/L. Collectively, these results provide evidence that the interim TDS target for Snap Lake of 1,000 mg/L remains protective for Meliadine Lake. A higher threshold TDS concentration protective of aquatic life may be supportable once the validation study (Phase 2 of WQ-MOP) is complete.

Table A-3: Chronic toxicity data for MEL-14 and MEL-12 samples collected between 2018 to 2019 with corresponding total dissolved solids and chloride concentrations

Sample Location	Sample Date	Chronic Toxicity							Water Chemistry (mg/L)		
		Water flea *Ceriodaphnia dubia*		Fathead minnow *Pimephales promelas*		Green alga *P. subcapitata*	Duckweed *Lemna minor*				
		3-brood Survival LC_{50} (% vol/vol)	3-brood Reproduction IC_{25} (% vol/vol)	7-d Survival LC_{50} (% vol/vol)	7-d Growth IC_{25} (% vol/vol)	72-hr Cell Inhibition IC_{25} (% vol/vol)	7-d Frond Count IC_{25} (% vol/vol)	7-d Biomass IC_{25} (% vol/vol)	Measured TDS	Calculated TDS	Chloride
MEL-14	07 August 2018	>100	>100	>100	>100	>90.9	72.3	>97	1,140[(a)]	958[(a)]	530[(a)]
	13 August 2018	—	—	>100	>100	>90.9	38.2	42	1,260	1,011	590
	3 September 2018	>100	90.1	>100	>100	>90.9	>97	>97	1,360	1,140	660
	9 July 2019	—	—	—	—	—	>97	>97	1,190	965	500
	13 August 2019	—	—	—	—	—	>97	>97	1,130	800	410
MEL-12	24 September 2019	>100	24.3	>100	>100	60.8	26.3	>97	2,490	2,202	1,100
	1 October 2019	>100	58.8	>100	>100	88.2	29.4	66.2	2,450	2,357	1,200
	8 October 2019	>100	20.1	>100	>100	>90.9	59	>97	2,370	2,350	1,200

Notes:

(a) Corresponding water chemistry data was not collected for this sample. However, a sample collected on 5 August 2018 from the same location is reported here for comparison.

mg/L = milligrams per litre; vol/vol = volume per volume; TDS = total dissolved solids; LC_X = lethal concentration causing a lethal effect to x% of the test population; IC_X = inhibitory concentration that causes a x% inhibitory effect in the sublethal endpoint being measured.

A1.5 Weight of Evidence Summary for Proposed Site-Specific Water Quality Objective

An interim TDS target of 1,000 mg/L to apply at the edge of the mixing zone was proposed following integration of information obtained through characterization of the Meliadine TDS profile (Section A1.1), review of water quality benchmarks for TDS developed for similar mixtures (Section A1.2), a literature review of TDS toxicity (Section A1.3), and a review of site-specific chronic toxicity data for Meliadine treated effluent and influent samples (Section A1.4). Sections A1.5.1 to 1.5.4 summarize the weight of evidence behind the proposed interim TDS target.

Several considerations, summarized in Sections A1.5.1 through A1.5.4, provide confidence in the application of the interim TDS target and also bode well for outcomes of the Phase 2 validation studies. The literature and site-specific data review provide a basis to propose an interim target for TDS; implementation of Phase 2 validation studies will provide increased precision and reliability in the interim target.

A1.5.1 Ionic Balance is Favorable

Effect concentrations reported in the Snap Lake dataset were derived from exposures using a balanced TDS mixture, whereas effect concentrations from the literature are generally derived from exposures using single salt mixtures (e.g., sodium chloride or calcium chloride) that do not consider TDS mixture effects. Meliadine TDS ionic composition resembles the ionic composition evaluated during the validation of the Snap Lake TDS SSWQO of 1,000 mg/L. As indicated in Section A1.0, Meliadine TDS contains a high relative proportion of calcium and sodium ions (on average 31% of TDS); these dominant ions are among the least toxic according to Mount et al. (1997), and have been identified as key components of TDS that ameliorate toxicity of other ions (Davies and Hall 2007, Mount et al. 2016, Soucek et al. 2018, Scheibener et al. 2017). Concentrations of the relatively toxic potassium and magnesium ions are predicted to remain low in Meliadine effluent; potassium and magnesium ions make up approximately 4% to 5% of TDS in effluent and the near-field. The information from the ionic composition analysis (Section A1.0), and comparison to the Snap Lake TDS SSWQO dataset (Section A2.0), although not conclusive, suggests that the Meliadine TDS mixture would not exhibit chronic toxicity from TDS components at concentrations of TDS below approximately 1,000 mg/L. Some literature studies indicate toxicity to select invertebrate species at concentrations below 1,000 mg/L TDS, but these toxicity tests are limited to test solutions that contain predominantly one or two ions, which do not apply to the complex mixture conditions of Meliadine TDS, nor incorporate the beneficial effect of calcium and sodium for ameliorating toxicity of other ions in these mixtures.

A1.5.2 Comparability to Well-Validated Snap Lake

Effect concentrations derived from extensive validation of the SSWQO at Snap Lake mine indicated no effects to site-resident or relevant surrogate species below 1,100 mg/L TDS. The effect concentration for *D. magna*, the most sensitive species in the dataset, was unbounded indicating no effects at the highest tested TDS concentration. Unbounded effect concentrations were also reported for all other test species in the Snap Lake dataset. Therefore, concentrations of TDS above 1,000 mg/L may pose no risk to aquatic life but there is uncertainty in proposing an interim TDS target to apply at the edge of the mixing zone of higher than 1,000 mg/L because exposure concentrations used in the Snap Lake dataset did not reach toxicity thresholds for the species tested.

A1.5.3 Available Site-Specific Toxicity Data Support the Benchmark

The chronic toxicity data tested with Meliadine mixtures supports the proposed interim target to apply at the edge of the mixing zone of 1,000 mg/L (Section A4.0). During routine and regulatory chronic toxicity testing with MEL-14 and MEL-12 samples, no chronic effects to *C. dubia* survival, early life-stage fathead minnow survival or growth, or growth of the green alga *P. subcapitata* were observed at TDS concentrations of approximately 1,140 mg/L (measured TDS of 1,360 mg/L). The reduction of *C. dubia* reproduction at 1,140 mg/L (measured TDS of 1,360 mg/L) was not large (IC_{25} for reproduction of 90.1% vol/vol at TDS concentrations of 1,140 mg/L). Overall, these results support the proposed interim TDS target of 1,000 mg/L to apply at the edge of the mixing zone, but site-specific validation is necessary to verify these results and develop a TDS SSWQO for long-term application.

A1.5.4 Ionic Balance is Stable

The stable ionic balance over several years of monitoring (Figure 2) is suited to development of a single benchmark for TDS, without requiring development of individual benchmarks for component ions. The TDS interim target incorporates contributions from chloride and sulphate (along with other ionic components) and it is not recommended at this time that separate benchmarks be developed for chloride and sulphate as individual ions. However, the concentrations of individuals ions can be prorated from the recommended TDS interim target of 1,000 mg/L. For Meliadine TDS, the relative proportion of chloride at the recommended interim target of 1,000 mg/L would range between 280 to 520 mg/L, depending on the ionic composition. The upper bound of chloride proportion is based on an ionic composition derived from TDS in the effluent; it is anticipated that the ionic composition for TDS in the receiving environment would not have as high a proportion of chloride as effluent. For comparison, Snap Lake TDS including chloride of up to approximately 450 to 470 mg/L demonstrated negligible toxicity.

The proposed TDS interim target to apply at the edge of the mixing zone was derived from the anticipated ion composition for Meliadine based on monitoring data for effluent and near-field. Modelled chemistry data are not available for the ionic composition anticipated under future discharge conditions at Meliadine, requiring confirmation that ionic mixtures are expected to remain consistent in terms of proportions of major ions. If future effluent quality with respect to TDS constituents is markedly different, then re-evaluation of the proposed TDS threshold may be warranted.

A2.0 INTERIM TDS TARGET FOR EFFLUENT—SITE-SPECIFIC ACUTE TOXICITY RESULTS

Acute toxicity testing data and corresponding water chemistry data were collected by Agnico Eagle as part of routine and regulatory monitoring at stations MEL-14 (treated effluent), MEL-12 (influent from the water treatment plant), and CP1 (Collection Pond 1). Acute toxicity tests performed were:

- Biological Test Method: Reference Method for Determining Acute Lethality of Effluent to *Daphnia magna* (EC 2000a).
- Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout (EC 2000b).
- Biological Test Method: Acute Lethality Test Using Threespine Stickleback (*Gastrosteus aculeatus*) (ECCC 2017).

Acute toxicity test species include the standard protocols (*D. magna* and rainbow trout) used to assess compliance for acute lethality under the Metal and Diamond Mining Effluent Regulations (Government of Canada 2002). Two additional tests were conducted with threespine stickleback in November and December 2019. The threespine stickleback results were included for comparative purposes, although this species is currently not a required standard test species for regulatory testing related to discharge of effluent to Meliadine Lake. Acute toxicity test results and corresponding water chemistry data for TDS (measured and calculated) and chloride are presented in Table A-4.

Acute toxicity testing conducted between 2017 to 2020 with influent (MEL-12 and CP1) and effluent (MEL-14) has indicated no acute toxicity (i.e., LC_{50} >100% vol/vol) to *D. magna* or rainbow trout survival with TDS concentrations of up to and including 4,465 mg/L (measured TDS concentrations of up to 4,830 mg/L). Reduced survival (60% in full-strength sample) in rainbow trout was observed in a CP1 sample collected 17 December 2017 at TDS concentration of 3,150 mg/L. However, mortality did not exceed 50%, and since 2017 several samples have been tested with measured and TDS concentrations greater than 3,150 mg/L, all of which indicated no acutely toxic effects to rainbow trout.

Threespine stickleback were tested on two occasions in November and December 2019 with CP1 sample. Measured TDS concentrations of up to and including 3,410 mg/L did not result in acutely toxic effects in threespine stickleback.

Table A-4: Acute toxicity data for MEL-14, MEL-12, and CP1 samples collected between 2017 to 2020 with corresponding total dissolved solids and chloride concentrations

Sample Location	Sample Date	Acute Toxicity			Water Chemistry (mg/L)		
		Daphnia magna	Rainbow trout *Oncorhynchus mykiss*	Threespine stickleback *Gastrosteus aculeatus*	Measured TDS	Calculated TDS	Chloride
		48-hour Survival LC_{50} (% vol/vol)	96-hour Survival LC_{50} (% vol/vol)	96-hour Survival LC_{50} (% vol/vol)			
MEL-14	9 August 2017	>100	>100	—	1,600	911	470
	27 August 2017	>100	>100	—	1,760	1,061	580
	24 June 2018	>100	>100	—	1,200	634	300
	1 July 2018	>100	>100	—	930	752	400
	5 August 2018	>100	>100	—	1,140	958	530
	3 September 2018	>100	>100	—	1,360	1,140	660
	24 June 2019	>100	>100	—	915	859	450
	9 July 2019	>100	>100	—	1,190	965	500
	3 September 2019	>100	>100	—	1,300	1,070	530
CP1	21 June 2017	>100	>100	—	1,190	575	290
	12 July 2017	>100	>100	—	908	707	350
	05 November 2017	—	>100	—	2,230	— (b)	— (b)
	11 November 2017	>100	>100	—	2,791	— (b)	— (b)
	19 November 2017	>100	>100	—	— (c)	— (b)	— (b)
	17 December 2017	>100	NC (60% survival)(d)	—	3,150	— (b)	— (b)
	10 June 2018	>100	>100	—	685	477	210
	17 June 2018	>100	>100	—	540	281	180
MEL-12	24 September 2019	>100	>100	—	2,490	2,202	1,100
	01 October 2019	— (e)	>100	—	2,450	2,357	1200
	08 October 2019	>100	>100	—	2,370	2,350	1,200
CP1	25 November 2019	—	—	>100	2,960	3,055	1,500
	15 December 2019	—	—	>100	3,410	— (b)	— (b)
	05 January 2020	>100	>100	—	4,830	4,465	2,400
	12 January 2020	>100	>100	—	4,150	3,815	1,900
	26 January 2020	>100	>100	—	4,160	3,659	1,900

Notes:

(a) Test was conducted with full-strength sample (100% vol/vol) and laboratory control.

(b) Corresponding major ion chemistry data were not measured in this sample and therefore, calculated TDS could not be determined.

(c) Corresponding water chemistry data was not collected for this sample.

(d) A 96-hour LC_{50} could not be calculated because this test was conducted as a screening (pass/fail) test, whereby full-strength (100% vol/vol effluent) sample was tested with a laboratory control. To estimate the LC_{50} a multi-concentration dilution series must be conducted. The result reported here in brackets is percent survival in the full-strength effluent sample.

(e) Due to a laboratory error during testing with *Daphnia magna* the results of the 1 October 2019 test were invalidated and were not reported by the laboratory.

TDS = total dissolved solids; MEL-14 = treated effluent; MEL-12 = untreated influent; CP1 = Collection Pond 1; mg/L = milligrams per litre; LC_X = lethal concentration causing a lethal effect to x% of the test population; vol/vol = volume per volume; NC = not calculable.

APPENDIX A REFERENCES

ADEC (Alaska Department of Environmental Conservation). 2009. Water Quality Standards. 18 AAC 70. Updated October 2009. Alaska Department of Environmental Conservation, Juneau, AK, USA.

ADEC. 2013. Alaska Pollutant Discharge Elimination System. Permit No. AK0038652. Authorization to discharge under the Wastewater Discharge Authorization Program. Permit provided to Teck Alaska, Incorporated, Red Dog Mine.

ADEC. 2017. Alaska Pollutant Discharge Elimination System. Permit No. AK0050571. Authorization to discharge under the Wastewater Discharge Authorization Program. Permit provided to Coeur Alaska, Inc., Juneau, Alaska 99801.

APHA (American Public Health Association). 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. Washington, DC, USA.

Baker JA, Elphick JR, McPherson CA, Chapman PM. 2015. Effect of total dissolved solids (TDS) on fertilization and development of two salmonids species. Bulletin of Environmental Contamination and Toxicology 95(4):488–493.

Bringolf RB, Cope WG, Eads CB, Lazaro PR, Barnhart MC, Shea D. 2007. Acute and chronic toxicity of technical grade pesticides to glochidia and juveniles of freshwater mussels (*Unionidae*). Environmental Toxicology and Chemistry 26:2086–2093.

Brix KV, Gerdes R, Curry N, Kasper A, Grosell M. 2010. The effects of total dissolved solids on egg fertilization and water hardening in two salmonids – Arctic Grayling (*Thymallus arcticus*) and Dolly Varden (*Salvelinus malma*). Aquatic Toxicology 97:109–115.

Buchwalter D. 2013. Aquatic Life Study – Final Report. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS). Prepared for San Joaquin Valley Drainage Authority. North Carolina State University. 9 October 2013.

Camargo JA, Tarazona JV. 1991. Short-term toxicity of fluoride ion in soft water to rainbow trout and brown trout. Chemosphere 22:605–611.

Chapman PM, Bailey H, Canaria E. 2000. Toxicity of total dissolved solids associated with two mine effluents to Chironomid larvae and early life stages of rainbow trout. Environmental Toxicology and Chemistry 19:210–214.

Chapman PM, McPherson CA. 2015. Development of a total dissolved solids (TDS) site-specific water quality objective for a Canadian diamond mine. Integrated Environmental Assessment and Management 12(2):371–379.

Chapman PM. 2014a. Snap Lake Mine: Additional toxicity testing to determine site-specific water quality objective for total dissolved solids in Snap Lake. Technical Memorandum. Submitted to De Beers Canada Inc. and Mackenzie Valley Land and Water Board. Yellowknife, NWT.

Chapman PM. 2014b. Additional *Daphnia magna* 21-day TDS toxicity test results. Technical Memorandum. Submitted to De Beers Canada Inc. and Mackenzie Valley Land and Water Board. Yellowknife, NWT.

Chapman PM. 2014c. Copepod TDS toxicity test results. Submitted to De Beers Canada Inc. and Mackenzie Valley Land and Water Board. Yellowknife, NWT.

Cooney JD, DeGraeve GM, Moore EL, Lenoble BJ, Pollock TL, Smith GJ. 1992. Effects of environmental and experimental design factors on culturing and toxicity testing of *Ceriodaphnia dubia*. Environ Toxicol Chem 11:839–850.

Davies TD, Hall KJ. 2007. Importance of calcium in modifying the acute toxicity of sodium sulfate to *Hyalella azteca* and *Daphnia magna*. Environmental Toxicology and Chemistry 26:1243–1247.

EC (Environment Canada). 2000a. Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to *Daphnia magna*. Method and Development and Applications Unit. Environment Canada. EPS1/RM/14. Amended February 2016.

EC. 2000b. Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout. Method and Development and Applications Unit. Environment Canada. EPS1/RM/13. Amended May 2007 and February 2016.

EC. 2007a. Biological Test Method: Test of Reproduction and Survival Using the Cladoceran, *Ceriodaphnia dubia*. Method and Development and Applications Unit. Environment Canada. EPS1/RM/21. Amended February 2007.

EC. 2007b. Biological Test Method: Growth Inhibition Test Using a Freshwater Alga. Method and Development and Applications Unit. Environment Canada. EPS1/RM/25. Amended March 2007.

EC. 2007c. Biological Test Method: Test for Measuring the Inhibition of Growth Using the Freshwater Macrophyte, *Lemna minor*. Method and Development and Applications Unit. Environment Canada. EPS1/RM/37. Amended January 2007.

EC. 2011. Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows. Method and Development and Applications Unit. Environment Canada. EPS1/RM/22. Amended February 2011.

ECCC (Environment and Climate Change Canada). 2017. Biological Test Method: Reference Method for Determining Acute Lethality using Threespine Stickleback. Method and Development and Applications Unit. Environment Canada. EPS1/RM/10. Amended December 2017.

Evaristo-Cordero C. 2011. Senior Account Manager. ALS Laboratory Group, Edmonton, AB, Canada. Email to Tasha Hall (Golder Associates Ltd). September 30, 2011.

GLEC (Great Lakes Environmental Center) and INHS (Illinois Natural History Survey). 2008. Acute Toxicity of Chloride to Select Freshwater Invertebrates. Prepared for the US Environmental Protection Agency. USEPA Contract Number 68-C-04-006.

Golder (Golder Associates Ltd.). 2011. Total dissolved solids (TDS) study – Task 1 – Literature review Final. Submitted by De Beers Canada Inc. to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Golder. 2014. Snap Lake Mine: Additional Toxicity Testing to Determine a Site-Specific Water Quality Objective for Total Dissolved Solids in Snap Lake. Submitted by De Beers Canada Inc. to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Golder. 2019. Proposed Site-Specific Water Quality Objective and Effluent Discharge Criterion for Total Dissolved Solids Threshold for Meliadine Gold Mine. Technical Memorandum submitted to Michel Groleau and Jamie Quesnel, Agnico Eagle Mines Limited. Project No. 19127573-SSWQO-TDS-Rev0. 20 December 2019.

Government of Canada. 2002. Metal and Diamond Mining Effluent Regulations SOR/2002-222. Current to October 10, 2018. Last amended on June 1, 2018. Minister of Justice. Ottawa, ON.

IDNR (Iowa Department of Natural Resources). 2009. Water Quality Standards Review: Chloride, Sulfate and Total Dissolved Solids. Iowa Department of Natural Resources. Consultation Package. February 9, 2009.

Kennedy AJ, Cherry DS, Zipper CE. 2005. Evaluation of Ionic Contribution to the Toxicity of Coal-Mine Effluent Using *Ceriodaphnia dubia.* Environmental Toxicology and Chemistry 49:155–162.

Khangarot BS. 1991. Toxicity of metals to a freshwater tubificid worm, *Tubifex tubifex* (Muller). Bulletin of Environmental Contamination and Toxicology 46: 906–912.

Lasier PJ, Winger PV, Hardin IR. 2006. Effects of hardness and alkalinity in culture and test waters on reproduction of *Ceriodaphnia dubia*. Environmental Toxicology and Chemistry 25(10):2781–2786.

Marus EM, Elphick JR, Bailey HC. 2015. A new toxicity test using the freshwater copepod *Cyclops vernalis*. Bulletin of Environmental Contamination and Toxicology 95(3):357‑362.

Mount DR, Gulley DD, Hockett JR, Garrison TD, Evans JM. 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphia dubia*, *Daphnia magna*, and *Pimephales promelas* (Fathead minnows). Environmental Toxicology and Chemistry 16:2009–2019.

Mount DR, Erickson RJ, Highland TL, Hockett JR, Hoff DJ, Jenson CT, Norberg-King TJ, Peterson KN, Polaske Z, Wisniewski S. 2016. The acute toxicity of major ion salts to *Ceriodaphnia dubia*: I. influence of background water chemistry. Environmental Toxicology and Chemistry 35(12):3039–3057.

Pacholski L, Chapman P, Hood A, Peters M. 2016. A Cautionary Note: *Ceriodaphnia dubia* Inter-laboratory test variability. Bulletin of Environmental Contamination and Toxicology 98(1):53–57.

Pickering QH, Lazorchak JM, Winks KL. 1996. Subchronic sensitivity of one-, four-, and seven-day-old fathead minnow. Environmental Toxicology and Chemistry 15:353–359.

Scheibener S, Conley JM, Buchwalter D. 2017. Sulfate transport kinetics and toxicity are modulated by sodium in aquatic insects. Aquatic Toxicology 190:62–69.

Soucek DJ. 2007. Comparison of hardness- and chloride-regulated acute effects of sodium sulfate on two freshwater crustaceans. Environmental Toxicology and Chemistry 26:773–779.

Soucek DJ, Linton TK, Tarr CD, Dickinson A, Wickramanayake N, Delos CG, Cruz LA. 2011. Influence of water hardness and sulfate on the acute toxicity of chloride to sensitive freshwater invertebrates. Environmental Toxicology and Chemistry 30:930–938.

Soucek DJ, Mount DR, Dickinson A, Hockett JR. Influence of dilution water ionic composition on acute major ion toxicity to the mayfly, *Neocloeon triangulifer*. 2018. Environmental Toxicology and Chemistry 37(5):1330–1339.

Weber-Scannell PK, Duffy LK. 2007. Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species. American Journal of Environmental Science 3:1–6.

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