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Mason Mantla, Chair
Wek'èezhìi Land and Water Board
PO Box 32 Wekweètì, NT 0XE 1W0
Canada

21 April 2022

Dear Mr. Mantla:

**Subject: DDMI Submission – AEMP Design Plan Version 6.0**

Please find attached Diavik Diamond Mines (2012) Inc.'s (DDMI) Aquatic Effects Monitoring Program (AEMP) Design Plan Version 6.0. The AEMP Design Plan Version 6.0 largely follows the Version 5.2, with revisions that address Directives outlined by the Wek'èezhìi Land and Water Board (WLWB or Board) in its 31 January 2022 Decisions following its review of the 2017 to 2019 Aquatic Effects Re-evaluation Report[1] and the AEMP 2020 Annual Report[2].

Key changes for Version 6.0 of the AEMP Design Plan are as follows (a summary of all changes is provided in Appendix A of this submission):

- Updated Action Level reporting schedule details
- Updated details related to the MDMER and expectations of equivalency
- Updated weight-of-evidence endpoints for fish (i.e., abnormalities, CPUE)
- Added commitment to update effects benchmarks within annual reports as they are published by CCME and Health Canada
- Updated to reflect changes in number of water quality sampling stations since version 5.2 (i.e., addition of 2 stations)
- Updated to reflect removal of ash-free dry mass (AFDM) as a Eutrophication Indicators variable
- Clarified variables selected for the cumulative effects assessment
- Updated AEMP sampling schedule

A table of conformity of Version 6.0 with Directives and Recommendations from the Board are provided in Table 8.1-1 of Section 8 of this submission. Revisions outside those related to the Board Directives and Recommendations are summarized in Table 8.1-2.

[1] Diavik - AEMP 2017 to 2019 Re-eval WLWB Reasons for Decision 31, January 2022
[2] Diavik - AEMP 2020 Annual Report WLWB Reasons for Decision, 31 January 2022

Rio Tinto

Please do not hesitate to contact the undersigned or kyla.gray@riotinto.com if you have any questions related to this submission.

Yours sincerely,

Kofi Boa-Antwi
Superintendent, Environment

cc: Marie-Eve Cyr, WLWB
Anneli Jokela, WLWB

Attached: AEMP Design Plan Version 6.0

**REPORT**

# Aquatic Effects Monitoring Program Design Plan Version 6

*Diavik Diamond Mines (2012) Inc.*

Submitted to:

**Diavik Diamond Mines (2012) Inc.**

P.O. Box 2498
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Submitted by:


**Golder Associates Ltd.**

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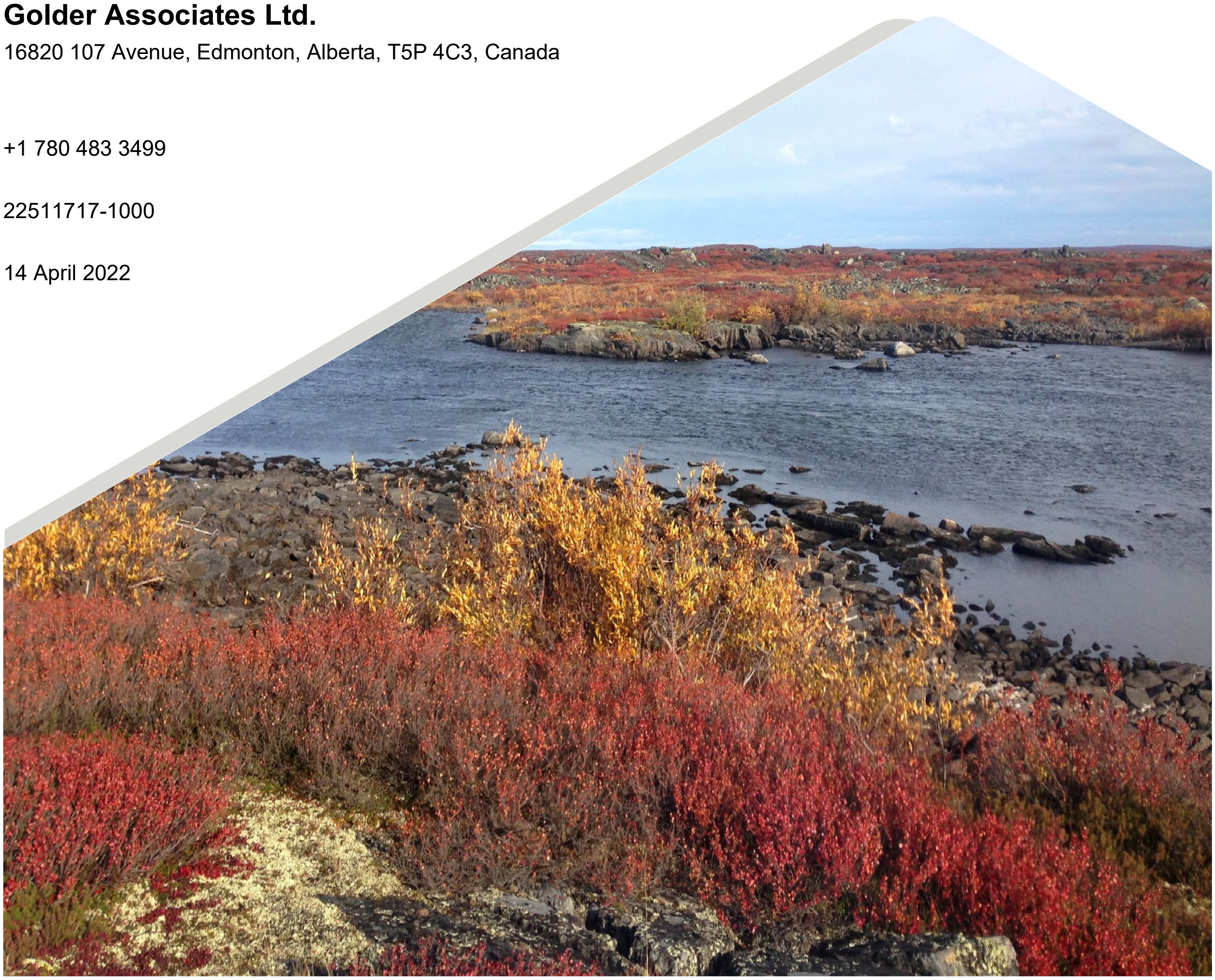
14 April 2022



# Distribution List

1 Electronic Copy - Diavik Diamond Mines (2012) Inc.

1 Hard Copy - WSP Golder

# Plain Language Summary

This summary is intended for both technical and non-technical readers.

## Introduction and Background

This AEMP Design Plan describes how water, sediment and biological monitoring studies will be conducted under the Aquatic Effects Monitoring Program for the Diavik Diamond Mine. In this report, the Aquatic Effects Monitoring Program is also called "the AEMP", and the Diavik Diamond Mine is referred to as "the Mine". The AEMP is the main program described in the Water Licence for monitoring the aquatic environment of Lac de Gras. The AEMP consists of monitoring the following components: dust; effluent; water quality; eutrophication indicators (nutrients such as phosphorus); plankton (small animals and plants living in the lake water, like algae and water fleas); benthic invertebrates (small animals living in the lake sediments, like snails, clams, worms and insects); and fish. An explanation of each of the AEMP components is given below in the "Summary of the AEMP Design Plan by Component" section.

The Water Licence (W2015L2-0001) for the Mine requires that Diavik Diamond Mines (2012) Inc. (also called "DDMI" in this report) review and update the AEMP Design Plan every three years, or as directed by the Wek'èezhìı Land and Water Board (also called "the WLWB" in this report). The purpose of updating the AEMP design is to make changes to the existing program based on results and findings to date. An updated AEMP design is provided herein as the *AEMP Design Plan Version 6.0*, which will be implemented in 2020 following WLWB approval.

## Changes for the AEMP Design Plan Version 6.0

The *AEMP Design Plan Version 6.0* will largely follow the Version 5.2 design; however, a number of updates have been made, which are based on directives from the WLWB. Key updates reflected in *AEMP Design Plan Version 6.0* are as follows:

- updates to the text related to the dust zone of influence, which is the area that could be affected by dust deposition; reference to specific stations (i.e., MF1-1, MF2-1, MF3-1, and MF3-2) has been removed in case the stations change in the future
- updates to Water Quality Effects Benchmarks for pH, and total aluminum, barium, cadmium, iron, lead, manganese (total and dissolved), selenium, strontium and zinc (total and dissolved)
- removal of organic matter from the list of analytical parameters for sediment quality
- removal of zooplankton biomass as ash-free dry mass from the list of variables for eutrophication indicators
- clarification of the circumstances for when a parameter would not be included in the cumulative effects assessment (Section 6.1)
- inclusion of Fish abnormalities and CPUE in the Weight of Evidence assessment

- the Effects Benchmark for zinc was updated based on the CCME guideline that considers dissolved organic carbon (DOC).
- updates to details regarding the timelines for Action Level exceedance notifications

## Summary of the AEMP Design Plan by Component

The *AEMP Design Plan Version 6.0* consists of the components described below. Each of these components will undergo a separate detailed assessment and the results will be provided in a scientific report with a plain language summary. An explanation of the methods used to evaluate effects on each component is provided below.

### *Traditional Ecological Knowledge*

Traditional ecological knowledge (TK) will play an important role in the AEMP for *AEMP Design Plan Version 6.0*. The objective of the TK component is to provide an opportunity for community input and participation in designing and carrying out the AEMP. A second objective is to provide training and development opportunities for the communities. During the AEMP Version 3.0, a series of meetings were held to gather community input on how TK should be incorporated into the AEMP. This was an effort to expand on the previous fish palatability component of the AEMP and incorporate more discussion and documentation of TK relating to fish and water quality. Diavik proposed to fund the use of a third-party consultant, Thorpe Consulting Services, to engage with the Indigenous working groups. Participants for these working groups were to be selected by the Indigenous organizations. This process was supported by the Tłįchǫ Government, Yellowknives Dene First Nation, Kitikmeot Inuit Association, Łutselk’e Dene First Nation, and the North Slave Metis Alliance. During the planning session for the 2018 TK program, participants expressed their satisfaction with the approach taken as an outcome of the community meetings held during the AEMP Version 3.0, and affirmed that they would like to see a similar approach continued for future programs. Therefore, the *AEMP Design Plan Version 6.0* will include a similar role of TK in aquatic monitoring.

The TK component will include fish tasting and texture studies, and water quality and quantity studies. The fish tasting and texture studies and the water quality and quantity studies will take place in 2024. Details of where and when the camp will occur and which community members will attend will be discussed at planning meetings held in 2024, in advance of the program.

### *Dust Deposition*

Many of the mining activities at the Mine site generate dust. The dust in the air can be transported by wind, but it eventually settles onto the ground or water. The objective of the dust monitoring program is to measure the amount of dustfall at various distances from the Mine site and determine the chemical characteristics of the dustfall that may settle on Lac de Gras. The information from the dust monitoring component will be used to see if there are links between air quality and aquatic effects in Lac de Gras.

Two methods are used to monitor dustfall from the Mine – “snow core surveys” and “dustfall gauges”. In a snow core survey, snow is collected by drilling into the snow pack with a hollow tube. The melted snow is then analyzed for nutrients and metals. A dustfall gauge is a hollow cylinder surrounded by a fiberglass shield with the shape of an inverted bell. Dust transported by wind is collected in the gauge and the weight of the collected dust is recorded.

Snow core surveys will continue to take place every year during April at the same 27 survey stations sampled during the AEMP Version 4.1. Dustfall gauges will be deployed year-round and will continue to be sampled every three months at 14 stations.

## *Effluent and Water Quality*

The objective of the effluent and water quality monitoring component of the AEMP is to see if the Mine is having an effect on the water quality in Lac de Gras. Treated water from the open pits, underground workings and mine infrastructure is called "effluent". Effluent is sampled to monitor the types and amounts of substances discharged from the Mine. Water is also collected near the point where effluent has mixed with lake water (called the "mixing zone boundary" in Lac de Gras).

Sampling of effluent will occur at a frequency of approximately every six days. The effluent will also be tested for toxicity, which means that samples of effluent are tested in the laboratory to see if they harm laboratory-grown fish and plankton. In these tests, test organisms are exposed to effluent for a specified period to determine the effluent's effect. Water quality sampling at the mixing zone boundary will continue monthly at three stations, which are located along a semi-circle, 60 metres from the pipe where effluent is released into Lac de Gras (also called the "diffusers").

Water quality will continue to be sampled every year in the near-field and mid-field sampling areas and every three years at all sampling stations in Lac de Gras. As an update that started in Version 5.2 of the design, sampling will also occur every year at far-field stations FF1-2 and FFD-1. Sampling will occur during both the winter when the lake is covered by ice and in the summer when it is ice-free. Water samples will be analyzed for salts, nutrients and metals. Water quality field measurements will also be made at AEMP stations by lowering a specialized sampling meter slowly down to the bottom of the lake while recording temperature, dissolved oxygen, conductivity (the ability of water to conduct electricity), turbidity (a measure of "cloudiness" of the water), and pH (a measure of how acidic the water is).

The AEMP water quality results will be compared to the Water Licence limits (also called "Effluent Quality Criteria" in this report) and to Effects Benchmarks, which are concentrations above which effects on fish and other aquatic life could occur. The results will be assessed to see if Action Levels in the AEMP Response Framework are triggered. This is explained further below in the "Response Framework" section.

## *Sediment Quality*

The objective of the sediment quality monitoring component is to see if the Mine effluent is having an effect on sediment quality in Lac de Gras. A second objective is to see if the sediment quality of the lake can support a healthy benthic invertebrate community. The AEMP sediment quality survey will continue to occur every three years. Sediment will be sampled at the same time as benthic invertebrates. Sediments will also be collected each comprehensive year at the mixing zone boundary. This will be done to serve as an early warning of possible changes in sediment quality in Lac de Gras, which would first occur near the diffusers. The AEMP sediment quality results will be compared to Effects Benchmarks and will be assessed to see if Action Levels in the Response Framework are triggered.

## Eutrophication Indicators

Eutrophication indicators measured in the AEMP are nutrients (i.e., phosphorus, nitrogen, soluble reactive silica), chlorophyll *a* (the green pigment in algae, which are tiny floating plants), phytoplankton (tiny floating plants, called algae) and zooplankton (tiny floating animals, including water fleas). Nutrients are a key component of the AEMP, because one of the predicted effects of the discharge of effluent in the Environmental Assessment (EA) for the Mine was an increase in productivity in Lac de Gras. This can be first seen by the growth of algae, which is determined by measuring chlorophyll *a.* The total amount of algae (measured as the weight, or biomass, of all algae in a cubic metre of lake water) will also be evaluated by the eutrophication indicators component.

Variables used as indicators of eutrophication will continue to be sampled each year during both the summer (all variables) and winter (nutrients only) in the near-field and mid-field sampling areas and every three years at all sampling stations in Lac de Gras. Sampling of indicators of eutrophication will also occur every year at far-field stations FF1-2 and FFD-1. The results will be assessed to see if the amount of chlorophyll *a* and the nutrient phosphorus in the lake water trigger an Action Level in the Response Framework.

## Plankton

The objective of the plankton component is to assess whether there are any changes to phytoplankton and zooplankton in Lac de Gras. These are together referred to as plankton. Changes in plankton can affect fish in the lake, because plankton are part of the food chain upon which fish can rely. Such changes can happen before fish are affected, which makes plankton a good early warning indicator.

Plankton sampling will continue to occur each year during the summer in the near-field and mid-field areas at the same stations sampled for the eutrophication indicators component. All AEMP stations will be sampled every three years. Sampling of plankton will also occur every year at far-field stations FF1-2 and FFD-1. Data analysis will focus on a gradient analysis and the results will be evaluated to see if an Action Level in the Response Framework is triggered.

## Benthic Invertebrates

The goal of the benthic invertebrate component of the AEMP is to see if the discharge of effluent into Lac de Gras has caused changes in the numbers and types of small animals that live on the bottom of Lac de Gras. These animals are referred to as benthic (bottom-dwelling) invertebrates (animals without backbones), and include snails, clams, worms and insects. They provide food for fish. Changes in the numbers and types of bottom-dwelling invertebrates can cause changes in the numbers and types of fish in the lake.

Benthic invertebrates will continue to be sampled every three years at the same stations sampled for water and sediment quality. The stations will be located in water that is approximately 20 m deep. Data analysis will focus on finding trends with distance from the diffusers, and the benthic invertebrate results will be analyzed to see if an Action Level is triggered.

## Fish Health and Fish Tissue Chemistry

The objective of the fish health survey is to see if the treated Mine effluent is having an effect on the growth, reproduction, survival, and condition (a measure of the weight of fish relative to the length) of small fish (Slimy Sculpin) in Lac de Gras. The objective of the fish tissue chemistry component is to see whether the effluent has increased the amount of metals in tissues of Slimy Sculpin. A second objective is to confirm that fish in Lac de Gras are safe for people and wildlife to eat. Slimy Sculpin have been monitored every three years in Lac de Gras since 2007.

Monitoring for Slimy Sculpin will continue to occur every three years in the same areas of the lake sampled since the AEMP Version 4.1. This sampling frequency strikes a balance between the need for monitoring and the mortality caused by monitoring. Fish health results will be assessed to see if Action Levels in the AEMP Response Framework are triggered. This is explained further below in the “Response Framework” section

Slimy Sculpin tissues will be analyzed for metal concentrations as part of the fish health study. The Slimy Sculpin results will be used as an early warning of potential changes to the health and tissue quality of Lake Trout. A Lake Trout health special study will occur only if the results of the Slimy Sculpin survey suggest an effect of the Mine. Similarly, a mercury in Lake Trout special study will occur only if the small-bodied fish tissue chemistry results indicate an increasing trend in mercury due to the Mine.

### *Weight-of-Evidence*

The weight-of-evidence section of the AEMP combines the information and conclusions of the water quality, sediment chemistry, eutrophication indicators, plankton, benthic invertebrate community, fish health and fish tissue chemistry sections. A process is used to estimate the strength (or weight) of evidence for two possible types of effects that may occur in Lac de Gras: “nutrient enrichment” or “toxicological impairment”. Nutrient enrichment can occur when the amount of nutrients, such as nitrogen and phosphorus (which are released in the Mine effluent), increase in the lake. This can cause effects such as an increase in the amount of algae in the lake, which can then result in greater numbers of floating and bottom-dwelling animals that serve as fish food. Toxicological impairment refers to possible toxic effects (for example, fewer animals in the lake) that can happen when chemical contaminants such as metals are released in the effluent.

## AEMP Response Framework

The AEMP “Response Framework” is a method of evaluating and responding to the findings of the AEMP. The purpose of the Response Framework is to ensure that unacceptable effects to the Lac de Gras aquatic ecosystem never occur. This is done by requiring that Diavik take actions at specific “Action Levels”, which are triggered well before unacceptable effects could occur. An Action Level is triggered when a certain level of change is measured in an AEMP variable in the lake. The required seriousness of the change and the corresponding management action that must be taken when that level of change is measured are identified at each Action Level.

The seriousness of the change is assessed by comparing the AEMP results to Effects Benchmarks and to “reference conditions” for Lac de Gras. Reference conditions consist of approved background ranges for AEMP variables, which are listed in a report called the *AEMP Reference Conditions Report*. Management actions may include confirmation of the effect, special studies to better understand the effect and the reasons for it, operational changes (such as reducing the amount of a substance in the effluent) or implementing mitigation (activities that eliminate or lessen the effects). The specific responses to be taken will depend on the type and seriousness of effect(s) reported by the AEMP.

If an Action Level in the Response Framework is exceeded, Diavik will implement notification procedures, as required by the WLWB. Under conditions detailed in the Response Framework, Diavik may also be required to prepare a plan to respond to the exceedance (called an “AEMP Response Plan”) and will submit that plan to the WLWB for review and approval.

# Table of Contents

**TABLES**

**FIGURES**



**APPENDICES**

# Acronyms and Abbreviations

| Term | Definition |
|---|---|
| ANOSIM | analysis of similarities |
| AEMP | Aquatic Effects Monitoring Program |
| AIC | Akaike's information criterion |
| AICc | Akaike’s information criterion corrected for small sample size |
| CCME | Canadian Council of Ministers of the Environment |
| CES | critical effect size |
| CFU | colony forming unit |
| CPUE | catch-per-unit-effort |
| CRP | Closure and Reclamation Plan |
| CWQG | Canadian Water Quality Guideline |
| DDC | Dominion Diamond Corporation |
| DDEC | Dominion Diamond Ekati Corporation |
| DDMI | Diavik Diamond Mines (2012) Inc. |
| DL | detection limit |
| DO | dissolved oxygen |
| Dominion | Dominion Diamond Ekati ULC |
| EA | Environmental Assessment |
| EEM | Environmental Effects Monitoring |
| Ekati Mine | Ekati Diamond Mine |
| EMAB | Environmental Monitoring Advisory Board |
| EOI | Evidence of Impact |
| EQC | Effluent Quality Criteria |
| FF | far-field |
| GNWT-ENR | Government of the Northwest Territories Environment and Natural Resources |
| GSI | gonadosomatic index |
| HSEQ | Health, Safety and Environment Quality |
| IC | ice-cover |
| ISO | International Standards Organization |
| ISQG | Interim Sediment Quality Guideline |
| *K* | Fulton’s condition factor |
| LDG | Lac du Sauvage |
| LDS | Lac de Gras |
| LEL | lowest effect levels |
| LOE | line of evidence |
| LOEL | lowest observable effect level |
| LSI | liversomatic index |
| MDS | multidimensional scaling |
| MF | mid-field |
| Mine | Diavik Diamond Mine |
| mMDS | metric multidimensional scaling |
| MMER TGD | Metal Mining Effluent Regulations Technical Guidance Document |
| MZ | mixing zone |
| NF | near-field |
| NI | North Inlet |
| NIWTP | North Inlet Water Treatment Plant |
| nMDS | non-metric multidimensional scaling |
| No. | number |
| NT | Northwest Territories |
| NTU | nephelometric turbidity unit |
| OMOEE | Ontario Ministry of the Environment and Energy |

| Term | Definition |
|---|---|
| OW | open-water |
| PEL | Probable Effects Level |
| PK | processed kimberlite |
| PKCF | Processed Kimberlite Containment Facility |
| QA | quality assurance |
| QAPP | Quality Assurance Project Plan |
| QC | quality control |
| SD | standard deviation |
| SIMPROF | similarity profile |
| SNP | Surveillance Network Program |
| SOI | substance of interest |
| SOP | Standard Operating Procedure |
| sp. | species |
| SQG | sediment quality guideline |
| TDS | total dissolved solids |
| TK | Traditional Ecological Knowledge |
| TOC | total organic carbon |
| TPM | total particulate matter |
| USEPA | United States Environmental Protection Agency |
| UTM | Universal Transverse Mercator |
| VEC | valued ecosystem component |
| WRSA-NCRP | Waste Rock Storage Area – North Country Rock Pile |
| WLWB | Wek'èezhìı Land and Water Board |
| WOE | weight-of-evidence |
| YOY | young-of-the-year |

# Units of Measure and Symbols

| Unit | Definition |
|---|---|
| % | percent |
| ‘ | minute |
| ± | plus or minus |
| < | less than |
| > | greater than |
| ≥ | greater than or equal to |
| ° | degree |
| °C | degree Celsius |
| µg/g ww | micrograms per gram wet weight |
| µg/L | micrograms per litre |
| µg-N/L | micrograms nitrogen per litre |
| µg-P/L | micrograms phosphorus per litre |
| µm | micrometre |
| µS/cm | microsiemens per centimetre |
| cm | centimetre |
| d | day |
| dm$^2$ | square decimetre |
| dw | dry weight |
| g | gram |
| ha | hectare |
| ind/L | individuals per litre |
| kg/month | kilograms per month |
| kg/yr | kilograms per year |
| km | kilometre |
| km$^2$ | square kilometre |
| L | litre |
| M | million |
| m | metre |
| m$^2$ | square metre |
| m$^3$ | cubic metre |
| m$^3$/d | cubic metres per day |
| mg | milligram |
| mg/dm$^2$/d | milligrams per square decimetre per day |
| mg/dm$^2$/yr | milligrams per square decimetre per year |
| mg/kg dw | milligrams per kilogram dry weight |
| mg/L | milligrams per litre |
| mL | millilitre |
| mg/m$^3$ | milligrams per cubic metre |
| mm | millimetre |
| Mm$^3$ | million cubic metres |
| mm$^3$/m$^3$ | cubic millimetres per cubic metre |
| Mt | million tonnes |
| ng/g ww | nanograms per gram wet weight |

# 1.0 INTRODUCTION

Part I, Condition 2 of Water Licence W2015L2-0001 (WLWB 2021a) requires that Diavik Diamond Mines (2012) Inc. (DDMI) review and revise, as necessary, the Aquatic Effects Monitoring Program (AEMP) Design Plan every three years, or as directed by the Wek'èezhìi Land and Water Board (WLWB). The last design plan for the Diavik Diamond Mine (referred to herein as the Mine) was first submitted in April 2018 as *AEMP Design Plan Version 5.0* and underwent two subsequent revisions resulting in the submission of *AEMP Design Plan Version 5.2* (Golder 2020a), which was approved on 22 October 2020. Per the Water Licence, the submission of the next design plan was scheduled in 2021 (following submission of Version 5.0 in 2018); however, due to the extended regulatory process associated with *AEMP Design Plan Version 5.2*, a new AEMP design plan was not submitted. In January 2022, the WLWB directed DDMI to prepare and submit the next version of the design plan (i.e., Version 6.0) as soon as possible. This document represents *AEMP Design Plan Version 6.0* and satisfies the conditions specified in Part I Condition 1, and Schedule 8, Condition 1 of Water Licence W2015L2-0001 (WLWB 2021a). Appendix A presents the changes of substance that were made from Version 5.2 to Version 6.

## 1.1 Background

DDMI has been conducting studies and monitoring programs relating to the aquatic ecosystem of Lac de Gras since 1994. Results obtained from these studies, up to and including results from 2000, represented the baseline or pre-development conditions in Lac de Gras. The original AEMP (Version 1.0) comprised the period of monitoring from 2001 to 2006 and included one year of monitoring prior to initiation of Mine effluent discharge to Lac de Gras, which occurred in March 2002.

In 2007, the monitoring programs were expanded as described in Version 2.0 of the AEMP design. Version 2.0 of the AEMP design was approved in July 2007 and was implemented from 2007 to 2011. The intensive monitoring conducted under Version 2.0 of the AEMP design provided an opportunity to describe the range of variability in AEMP component variables throughout a monitoring year and describe background conditions in reference areas in Lac de Gras.

Results from Version 2.0 of the AEMP design were used to guide Version 3.0 of the AEMP design. Key updates made for Version 3.0 included development of an AEMP Response Framework, changes to sampling locations and revisions to the AEMP sampling schedule. The final Version 3.0 AEMP design was approved in May 2014 (as Version 3.5). Version 3.0 of the AEMP comprised the period of monitoring from 2012 to 2016 under AEMP Study Design Versions 3.0 to 3.5.

In 2015, the WLWB directed DDMI to develop the *AEMP Reference Conditions Report*, which presented the approved "reference conditions" for all AEMP variables, to be used in subsequent AEMP reports to evaluate effects of the Mine. The currently approved version of the *AEMP Reference Conditions Report* is Version 1.4, which was submitted to the WLWB in July 2019 and was approved in October 2019.

Results from Version 3.0 of the AEMP design were used to develop the *AEMP Design Plan Version 4.0*. Key updates made for Version 4.0 included refinements to the AEMP response framework and incorporation of reference conditions, as defined by the *AEMP Reference Conditions Report,* into the spatial and temporal data analyses completed for the AEMP. The final Version 4.0 AEMP design was approved in September 2017 (as *AEMP Design Plan Version 4.1*). Monitoring under AEMP Version 4.0 comprised the period of 2017 to 2020 under AEMP Design Plan Versions 4.0 and 4.1.

In 2018, Version 5.0 of the AEMP design plan was submitted and largely followed *AEMP Design Plan Version 4.0* (Golder 2017a). Version 5.0 was not approved by the WLWB and subsequent versions were submitted (i.e., Version 5.1 and 5.2) which incorporated several updates based on comments and Directives from the WLWB review process. While some aspects of Versions 5.0 and 5.1 were approved as specific directives to be applied in addition to the monitoring efforts described under AEMP Version 4.1, Versions 5.0 and 5.1 of the AEMP design were not approved at the time. Therefore, monitoring continued under Version 4.1 until October 2020, at which time *AEMP Design Plan Version 5.2* was approved and implemented.

As defined in the Water Licence W2015L2-0001 (WLWB 2021a), DDMI must submit a modified AEMP Design Plan every three years, or as directed by the WLWB. The intent of periodically updating the AEMP Design Plan is to provide DDMI's AEMP an opportunity to make modifications according to the findings of the previous version of the AEMP. Therefore, *AEMP Design Plan Version 6.0* is provided herein and will replace Version 5.2 (Golder 2020) when approved by the WLWB.

## 1.2 Changes to the AEMP Design Plan

### 1.2.1 Version 6.0

Similar to Version 5.2, the *AEMP Design Plan Version 6.0* largely follows the Version 4.1 design plan (Golder 2017a). However, Version 6.0 incorporates several updates that are based on Directives from the WLWB review process and decisions regarding *AEMP 2020 Annual Report* (WLWB 2022c) and *2017 to 2019 Aquatic Effects Re-evaluation Report* (WLWB 2022b). Key Changes for Version 6.0 of the AEMP design are as follows:

- updates to the text related to the dust zone of influence, which is the area that could be affected by dust deposition; reference to specific stations (i.e., MF1-1, MF2-1, MF3-1, and MF3-2) has been removed in case the stations change in the future
- updates to Water Quality Effects Benchmarks for pH, and total aluminum, barium, cadmium, iron, lead, manganese (total and dissolved), selenium, strontium and zinc (total and dissolved)
- removal of organic matter from the list of analytical parameters for sediment quality
- removal of zooplankton biomass as ash-free dry mass from the list of variables for eutrophication indicators
- clarification of the circumstances for when a parameter would not be included in the cumulative effects assessment (Section 6.1)
- inclusion of fish abnormalities in the Weight-of-Evidence assessment
- updates to details regarding the timelines for Action Level exceedance notifications

### 1.2.2 Version 5.2

The *AEMP Design Plan Version 5.2* largely followed the Version 4.1 design (Golder 2017a). However, Version 5.2 incorporated a number of updates that were based on Directives from the WLWB review process and decision regarding *AEMP Design Plan Version 5.1*. Key changes for Version 5.2 of the AEMP design are as follows:

- Biological Action Levels were updated in Version 5.2 from design Version 4.1 to reflect comparison of NF and MF data to the mean of the reference condition data set, per WLWB Direction (WLWB 2020).
- Action Levels were developed for total phosphorus (TP) as part of the eutrophication indicators component in Version 5.1 of the design. An effects benchmark of 7.5 µg/L was defined for TP within Version 5.2, following

direction provided by the WLWB in the June 2020 decision document following review of the TP effects benchmark proposed in Version 5.1 of the design (WLWB 2020).

## 1.3 Conformity with Water Licence

Water Licence W2015L2-0001 (WLWB 2021a) Part I Condition 1 stipulates that the AEMP Design Plan must be developed in accordance with the criteria defined in Schedule 8, Condition 1. Concordance of the proposed *AEMP Design Plan Version 6.0* with these criteria is outlined in Table 1.3-1. The location(s) where each Water Licence requirement has been addressed in the AEMP Design Plan is indicated in the final column of the table. Concordance items for the *AEMP Design Plan Version 6.0* related to other WLWB directives and recommendations are presented in Section 8.0.

**Table 1.3-1: Concordance of the *AEMP Design Plan Version 6.0* with Schedule 8, Condition 1 of Water Licence W2015L2-0001**

| Section in Water Licence W2015L2-0001 | Requirement | Section in *AEMP Design Plan Version 6.0* |
|---|---|---|
| Schedule 8, Condition 1 | *The AEMP Design Plan referred to in Part J, Item 3, shall include but not be limited to the following:* | n/a |
| Schedule 8, Condition 1a | *a process for measuring Project-related effects on the following components of the Receiving Environment:*<br>*i) water quality, quantity, and rate of flow*<br>*ii) sediment quality; plankton abundance, taxonomic richness, and diversity*<br>*iii) benthic invertebrate abundance, taxonomic richness, and diversity*<br>*iv) fish health and chemistry* | This requirement is broadly met by the objectives of the AEMP.<br><br>Sampling methods and effects analyses specific to each AEMP component are provided in Sections 4.3 (effluent and water quality), 4.4 (sediment quality), 4.5 (indicators of eutrophication), 4.6 (plankton), 4.7 (benthic invertebrates), 4.8 (fish health) and 4.9 (fish tissue chemistry). |
| Schedule 8, Condition 1b | *plume characterization* | Results of the most recent plume delineation study undertaken in 2010 are presented in Section 4.2.2 of *AEMP Study Design Version 3.5* |
| Schedule 8, Condition 1c | *a description of the AEMP components including dust monitoring* | Section 4 |
| Schedule 8, Condition 1d | *a description of the area to be monitored including maps showing all sampling and reference locations in the AEMP* | Section 3.4 |
| Schedule 8, Condition 1e | *a description of procedures to minimize the impacts of the AEMP on fish populations and fish habitat* | Sections 3.4.2 and 4.8 |
| Schedule 8, Condition 1f | *a description of the approaches to be used to evaluate and adjust the AEMP* | Section 7.4 |
| Schedule 8, Condition 1g | *a summary of how Traditional Knowledge has been collected and incorporated into the AEMP, as well as a summary of how Traditional Knowledge will be incorporated into further studies relating to the AEMP* | Section 3.3; Section 4.1 |

**Table 1.3-1: Concordance of the *AEMP Design Plan Version 6.0* with Schedule 8, Condition 1 of Water Licence W2015L2-0001**

| Section in Water Licence W2015L2-0001 | Requirement | Section in *AEMP Design Plan Version 6.0* |
|---|---|---|
| Schedule 8, Condition 1h | *a description of an AEMP Response Framework which shall include:*<br>*i) definitions, with rationale, for Significance Threshold and tiered Action Levels applicable to the aquatic Receiving Environment of the Project*<br>*ii) for each Action Level:*<br>*a. a description of the rationale including, but not limited to, a consideration of the predictions and conclusions of the Environmental Assessment as well as AEMP results to date*<br>*b. a description of how exceedances of Action Levels will be assessed*<br>*c. a general description of what types of actions may be taken if an Action Level is exceeded* | Section 5.0 |
| Schedule 8, Condition 1i | *a plain language description of the program objectives, methodology, and interpretive framework* | Plain Language Summary |
| Schedule 8, Condition 1j | *a summary of changes to the AEMP design since the last approved design and rationale for the changes* | Section 8.0 |

n/a = not applicable.

## 1.4 Report Objective and Organization

The main objective of the *AEMP Design Plan Version 6.0* is to describe how water, sediment and biological monitoring studies (e.g., plankton, benthic invertebrates, fish health, fish tissue chemistry and fish palatability) will be conducted. A secondary objective of the AEMP Design Plan described herein is to address the requirements specified in Part I Condition 1 of the Water Licence (Table 1.3-1).

The *AEMP Design Plan Version 6.0* is organized as follows:

- Section 1.0 – Introduction
- Section 2.0 – Project description, general regulatory environment, Water Licence history, and environmental protection practices
- Section 3.0 – Presentation of the AEMP study design, including the following information:
  - AEMP background and objectives
  - valued ecosystem components (VECs) and receptors of potential concern
  - incorporation of Traditional Ecological Knowledge (TK)
  - overall sampling design
  - location, number and type of sampling sites, sampling frequency
  - quality assurance /quality control procedures
- Section 4.0 – Details relating to the monitoring components of the AEMP

- Section 5.0 – Description of the Response Framework and Effects Benchmarks
- Section 6.0 – Alignment of AEMPs in Lac de Gras
- Section 7.0 – Description of AEMP reporting
- Section 8.0 – Concordance with WLWB directives and other recommendations
- Section 9.0 – Closure, followed by the list of references cited

# 2.0 PROJECT DESCRIPTION

## 2.1 Project Overview

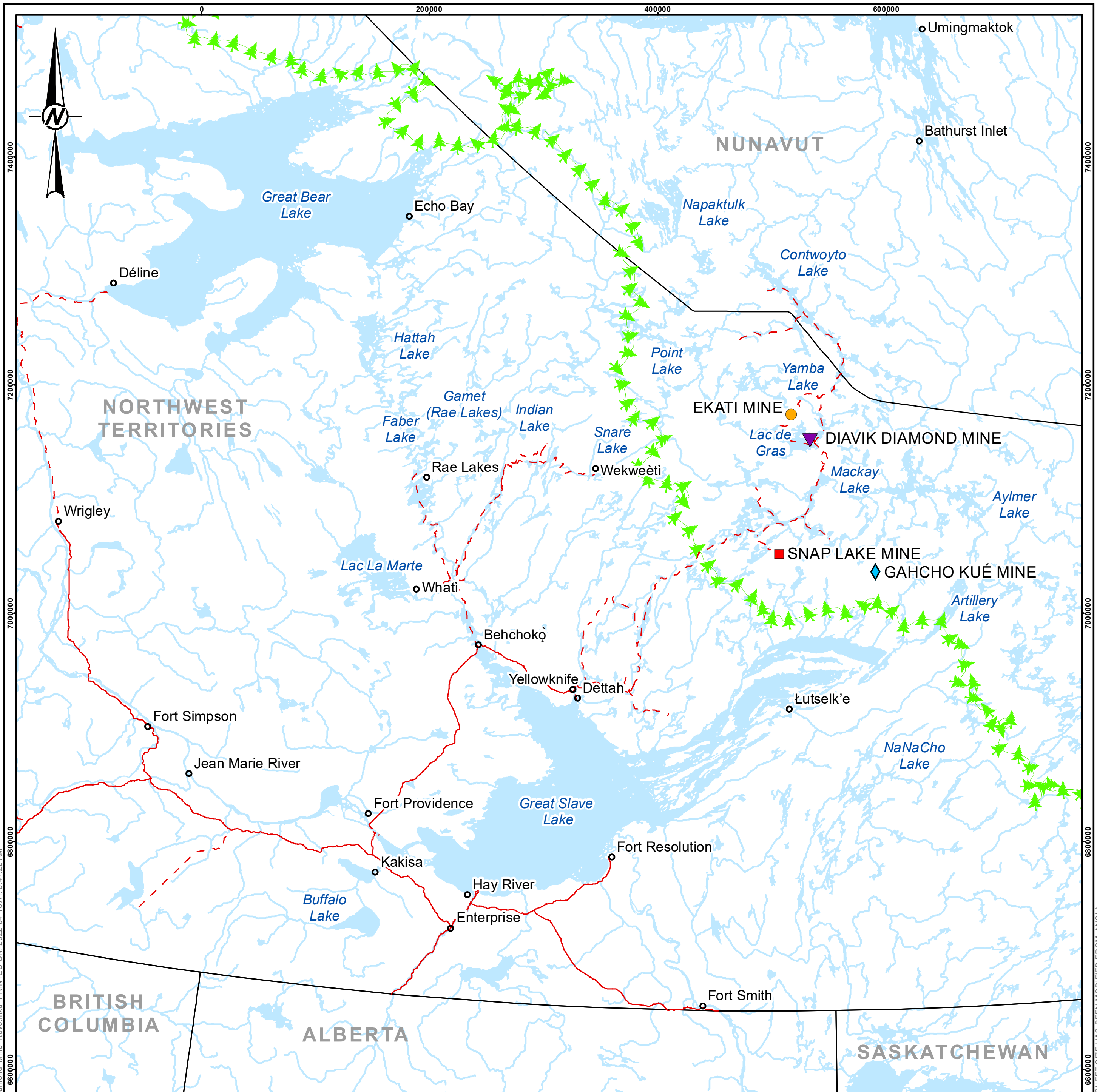
The Mine is operated and wholly-owned by DDMI, a wholly owned subsidiary of Rio Tinto Fer et Titane Inc., a company incorporated in Canada, and is a member of the Rio Tinto group.

The Mine is located on East Island, a 17 $km^2$ island in Lac de Gras, Northwest Territories (NT), approximately 300 km northeast of Yellowknife (64° 31' North, 110° 20' West) (Figure 2.1-1). The area is remote, and major freight must be trucked over a seasonal winter road from Yellowknife. Worker access is by aircraft to the Mine's private airstrip.

Overall, DDMI have a mineral claim to an area that includes portions of Lac de Gras, the East and West Islands, and portions of the mainland to the southeast and northwest. Lac de Gras is about 100 km north of the tree line in the central barren ground tundra of the NT, at the headwaters of the Coppermine River. This river, which flows north to the Arctic Ocean east of Kugluktuk, Nunavut, is 520 km long and has a drainage area of approximately 50,800 $km^2$.

The Mine involves the mining of four diamond-bearing kimberlite pipes. The pipes, designated as A154North, A154South, A418 and A21, are located directly offshore of East Island (Figure 2.1-2). All mining, diamond recovery, support activities and infrastructure are located on the East Island.

Construction of the mine infrastructure began on East Island in the year 2000. A kimberlite processing plant, power plant, boiler plant, accommodation building, sewage treatment facility and administration/maintenance building were constructed on the south east part of the island (Figure 2.1-2). An airstrip is located on the northern edge of the island. In total, the mine site at full development was expected to have a footprint of 12.76 $km^2$. The footprint at the end of 2015 was 10.55 $km^2$. Key project milestones are summarized in Table 2.1-1.




**LEGEND**

- COMMUNITY
- ALL WEATHER ROAD
- WINTER ROAD
- TREELINE
- WATERCOURSE
- WATERBODY
- PROVINCIAL / TERRITORIAL BOUNDARY
- DIAVIK DIAMOND MINE
- EKATI MINE
- GAHCHO KUÉ MINE
- SNAP LAKE MINE

0 100 200

1:5,000,000 KILOMETRES

**REFERENCE(S)**

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

PROJECT
AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE
**LOCATION OF THE DIAVIK MINE**

CONSULTANT
WSP GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-13 |
| DESIGNED | RS |
| PREPARED | LMS |
| REVIEWED | RS |
| APPROVED | ZK |

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000 | 0 | 2.1-1 |

PATH: I:\CLIENTS\DIAVIK\22511717\Mapping\Products\DesignPlan6_0\Fig2_1-1_22511717_Location_of_Diavik_Diamond_Mine_Rev0.mxd PRINTED ON: 2022-04-13 AT: 8:47:22 AM

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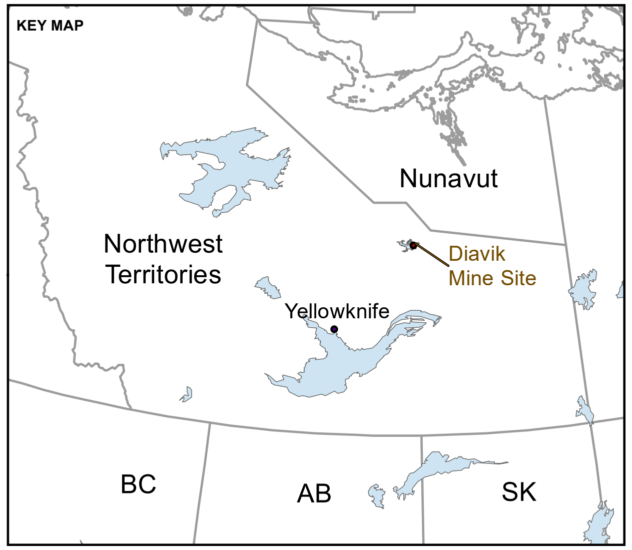
25mm 0


LEGEND

INFRASTRUCTURE

KEY MAP




0 500 1,000

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REFERENCE(S)
1. 2018 WORLDVIEW IMAGE OBTAINED FROM CLIENT
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

RioTinto

PROJECT
AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE
**SITE PLAN**

CONSULTANT

wsp GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-13 |
| DESIGNED | MC |
| PREPARED | LMS |
| REVIEWED | RS |
| APPROVED | ZK |

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000 | 0 | 2.1-2 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

**Table 2.1-1: Summary of Key Project Milestones at the DDMI Diamond Mine from 1998 to 2021**

| Year | Activity |
|---|---|
| 1998 | Environmental Assessment report submitted. |
| 1999 | Federal Government approves project for permitting and licensing. |
| 2000 | DDMI receives all necessary permits and licences to bring the Mine into production.<br>Initial construction activities take place:<br>■ lay-down areas for storage of construction materials and equipment prepared<br>■ main airstrip partially completed<br>■ sedimentation ponds partially completed<br>■ plant site excavated<br>■ fuel tank erected<br>■ quarry established<br>■ 450-person camp constructed |
| 2001 | Construction expands:<br>■ airstrip approved by Transport Canada<br>■ A154 dike earthworks completed<br>■ temporary facilities expanded to accommodate more workers<br>■ external structure of process plant completed<br>■ sedimentation ponds completed and used for storing lakebed sediments<br>■ North Inlet Dike embankment constructed<br>■ North Inlet Water Treatment Plant construction began<br>■ Phase I of PKC area completed |
| 2002 | A154 dike completed:<br>■ waterproofing finished<br>■ dewatering commenced<br>Mine facilities virtually completed:<br>■ process plant commissioned<br>■ PKC area dam completed<br>■ North Inlet Water Treatment Plant commissioned<br>■ maintenance complex and office, permanent power plant, Arctic corridors, power pole installation and road completed<br>■ explosive mixing and storage plant installed and commissioned |
| 2003 | Diamond production began<br>First sale of rough diamonds occurred |
| 2004 | First full year of production:<br>■ 11 $Mm^3$ of waste rock mined<br>■ 2.1 Mt of kimberlite mined<br>■ 7.5 M carats recovered<br>■ no environmental non-compliances occurred |
| 2005 | Re-certification of Environmental Management System to the ISO 14001:2004 standard.<br>DDMI commenced a new phase of construction work, including the new A418 dike, underground feasibility studies of the A154 and A418 pipes, as well an underground bulk sampling program on the A21 pipe. |
| 2006 | Completed construction of following elements of A418 dike:<br>■ water retaining element<br>■ dewatering<br>Began trial underground mining in the A418 kimberlite. |

**Table 2.1-1: Summary of Key Project Milestones at the DDMI Diamond Mine from 1998 to 2021**

| Year | Activity |
|---|---|
| 2007 | A418 dike construction complete:<br>■ pre-stripping advancing<br>A21 bulk sampling program completed.<br>DDMI water licence renewal approved:<br>■ covers an eight year period<br>■ effective 1 November 2007<br>AEMP redesign implemented |
| 2008 | Open pit mining of the A154 North pipe concluded<br>Underground mining infrastructure construction commenced<br>■ crusher & paste plant buildings<br>■ 2nd power house<br>■ water treatment plant expansion<br>■ additional fuel storage tank<br>■ underground mine dry and essential support facilities (ventilation facilities, rescue bays, repair shops etc.)<br>PKC dam raise |
| 2009 | ■ Planned six week production shut down occurred<br>■ Water treatment plant expansion completed<br>■ 2nd treated effluent diffuser online<br>■ 2nd powerhouse completed construction<br>■ Underground mining infrastructure construction continued<br>■ crusher & paste plant |
| 2010 | Open pit mining in the A154 pit concluded<br>■ “Open Sky” mining method used to remove A154 South crown pillar<br>Official opening of underground mine<br>■ opening ceremony 25 March 2010<br>■ commenced processing of underground ore<br>North inlet to process plant pipeline commissioned<br>■ increase in mine water utilized for processing<br>Health, Safety and Environment Quality certification received<br>Aligns ISO 14001 and Rio Tinto Standards |
| 2011 | ■ M-Lakes fish habitat program completed |
| 2012 | ■ Open pit mining in the A418 pit concludes<br>■ Completely underground mining operation<br>■ West Island fish habitat program completed<br>■ Four turbine wind farm constructed |
| 2013 | ■ PKCF dam raise commences |
| 2014 | ■ A21 Approval to Proceed from Joint Venture Partners |
| 2015 | ■ Commencement of A21 dike construction<br>■ Completion of PKC dam raise |
| 2016 | ■ Continuation of A21 dike construction (on 29 September 2016 the pit was closed off from the lake) |
| 2017 | ■ Continuation of A21 dike construction<br>■ Construction of A21 dike completed |
| 2018 | ■ A21 Pit dewatering activities<br>■ Open pit mining of the A21 Pipe commenced<br>■ PKCF Phase 7 dam raise commences |

**Table 2.1-1: Summary of Key Project Milestones at the DDMI Diamond Mine from 1998 to 2021**

| Year | Activity |
|---|---|
| 2019 | ■ No key project milestones in 2019 |
| 2020 | ■ Ministerial approval of Water Licence amendment for the A21 Underground |
| 2021 | ■ Rio Tinto obtains whole ownership of DDMI<br>■ Ministerial approval of Water Licence amendment for the PKMW Project |

PKC = processed kimberlite containment; DDMI = Diavik Diamond Mines (2012) Inc.; M = million; Mt = million tonnes; $Mm^3$ = million cubic metres.

The most recent Closure and Reclamation Plan (CRP) Version 4.1 has been prepared per the requirements of Water Licence WL2015L2-0001 and directives from the WLWB and provides the most recent description of the current state of the Mine plan and intentions for the future (Golder 2019a). The CRP Version 4.1 was submitted to the WLWB 17 December 2019 and was approved (with directives) on 10 June 2021 (WLWB 2021b).

## 2.2 Regulatory Environment

### 2.2.1 General Regulatory History

Since its inception, the Mine has existed in a regulatory environment that has continually increased in complexity. The initial regulatory context focused on mineral claims and leases per the *Canadian Mining Regulations* under the *Territorial Lands Act*, and land leases issued by the Department of Indian and Northern Affairs. At the time of submission of the original EA in 1998, the proposed Mine was subject to both federal and territorial legislation including the *Canadian Environmental Assessment Act*, which served as the legal basis for the EA, the *Fisheries Act*, the *Navigable Waters Protection Act*, the *Northwest Territories Water Act*, and the *Territorial Lands Act*.

Changes have occurred in the regulatory environment over time. Since the submission of the EA in 1998, new legislation has been proclaimed, including the *Mackenzie Valley Resource Management Act* and the *Species at Risk Act*. In March 2000, DDMI signed an Environmental Agreement with Indian and Northern Affairs Canada, the Government of the Northwest Territories, and Indigenous signatories/parties. This Environmental Agreement allowed for the establishment of the Environmental Monitoring Advisory Board (EMAB) for the Mine and provided a forum to address environmental issues that were not covered under established legislation.

On 1 June 2018, diamond mines became subject to the *Metal and Diamond Mining Effluent Regulations* (Government of Canada 2002). A first study design under the MDMER was to be submitted by the earlier of 1 June 2021 and the day on which an equivalent document was required to be submitted under territorial laws (per Section 38[1] of the MDMER). The Government of the Northwest Territories (GNWT) and the Government of Canada (i.e., Environment and Climate Change Canada [ECCC]) were, however, already considering an equivalency agreement for operating mines in the Northwest Territories such that duplication between the MDMER (e.g., Environmental Effects Monitoring [EEM]) and water licence requirements (e.g., AEMP) could be avoided. Due to the expectations of equivalency, application of the EEM-related components of the MDMER to the Mine (i.e., both monitoring and reporting requirements) have not been described herein.

Table 2.2-1 provides a list of the authorizations, permits, licences, and agreements for the Mine.

### 2.2.2 Water Licence

The Type "A" Water Licence W2015L2-0001 (WLWB 2021a) for the Mine issued by the WLWB sets out several conditions with respect to DDMI's right to alter, divert or otherwise use water for the purpose of mining. The AEMP is the primary program specified in the Water Licence for monitoring the aquatic environment of Lac de Gras

(Part I). The Surveillance Network Program (SNP), also specified in the Water Licence (Part G, Annex A), is a source monitoring program intended to collect data to be used to determine the volume and chemistry of various waters generated at the Mine site or by Mine activities. The AEMP examines changes in Lac de Gras that may result from this source water leaving the Mine site.

Monitoring at the Mine has also been conducted on dust and seepage/runoff, which represent two other potential sources of Mine-related effects to the aquatic ecosystem of Lac de Gras and have been summarized in the AEMP Annual Reports, where applicable.

**Table 2.2-1: Environmental Authorizations, Permits, Licences, and Agreements Currently Pertaining to the DDMI Mine**

| Legislative Act or Parties to Agreements | Authorizations, Permits, Licences, and Agreements |
|---|---|
| **Federal** | |
| *Fisheries Act* | Fisheries Authorization – Harmful Alteration, Disruption or Destruction of Fish Habitat |
| | Fisheries Authorization – Destroy Fish By Any Means Other Than Fishing |
| | Fisheries Authorization – Water Intake |
| Wek'èezhìı Land and Water Board | Water Licence W2015L2-0001 |
| *Navigable Waters Protection Act* | Navigable Water Protection – Dikes |
| *Territorial Lands Act* | Land Leases for A21 Dike, Air Strip, Infrastructure, Quarry/PKC/North Inlet, A154/418 Dikes |
| Natural Resources Canada | Explosives Permit |
| **Territorial** | |
| *Science Act* | Scientific Research Permit |
| **Other** | |
| Indian and Northern Affairs Canada, Government of the Northwest Territories, and Indigenous signatories/parties | Environmental Agreement |

## 2.3 Environmental Protection Practices

### 2.3.1 Water Management

Water management is the collection, storage, recycling, treatment and controlled release of water in a safe and compliant manner. The DDMI Water Management Plan (DDMI 2020) discusses the Drainage and Collection Control System constructed around East Island. Through a system of sumps, all-weather water interception and pump-back systems, piping, storage ponds and reservoirs, DDMI collects runoff water and groundwater seepage which can be used in the Processing Plant or is treated in the North Inlet Water Treatment Plant (NIWTP) before being released to Lac de Gras.

The Water Management Plan summarizes the current water sources. Water sources are divided into two areas as shown in Figure 2.3-1:

- North Inlet (NI) Subsystem
- Processed Kimberlite Containment Facility (PKCF) Subsystem

The water inflows reporting to the NI are:

- direct precipitation
- runoff from the till storage area and the NI watershed
- runoff from the Waste Rock Storage Area - North Country Rock Pile (WRSA-NCRP)
- runoff transferred from collection ponds
- pit inflows from the A154 pit
- dike seepage collected at the toe of the A154 dike
- pit inflows from the A418 pit
- dike seepage collected at the toe of the A418 dike
- A21 dike construction and dredging
- pit inflows from the A21 pit
- dike seepage collected at the toe of the A21 dike
- groundwater inflows to underground development and mining the A418 and A154

Pit inflows, underground inflows and dike seepage are essentially continuous flows to the NI, while the other flows described above are intermittent.

The water sources reporting to the PKC pond include:

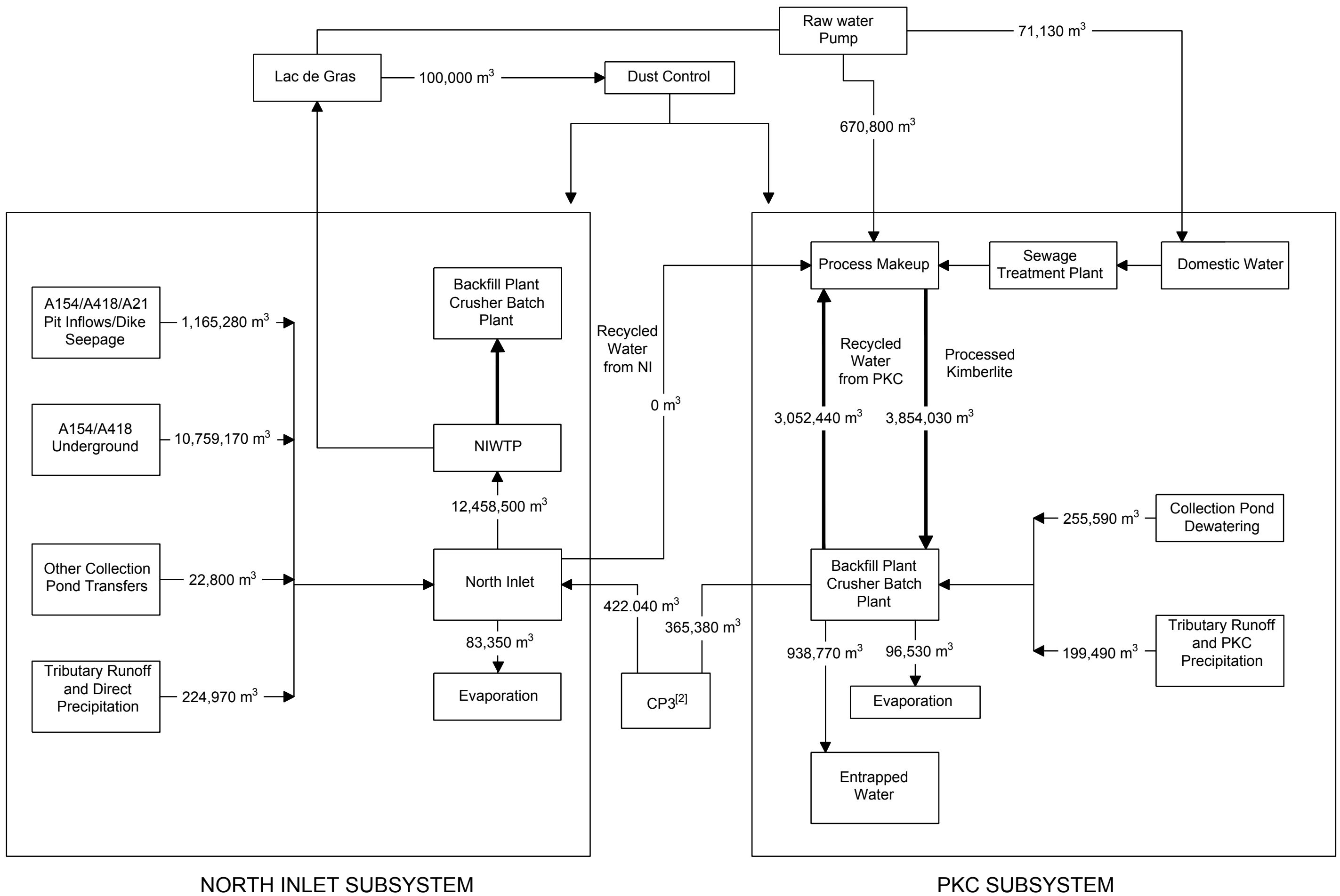
- fine Processed Kimberlite (PK) transport water (PK Slurry)
- pumped runoff from site collection ponds
- direct precipitation
- runoff from within the footprint of the PKCF
- groundwater inflows from the A21 underground exploration decline

Water outflows include treated water to Lac de Gras, surface runoff and evaporation.

Freshwater is drawn from Lac de Gras. Freshwater volume requirements will reduce as reclaim water and Mine water are further utilized in kimberlite processing. The following are current uses of freshwater:

- potable water
- processing plant makeup water as required
- fire suppression
- dust suppression
- drill water for underground drilling if necessary
- water used for construction activities

FLOW PROPORTIONS BASED ON 2015 MODEL TABLES




SCHEMATIC ONLY, NOT TO SCALE

**NOTE(S)**

1. VALUES BASED ON 2015 TABLES.
2. COLLECTION POND 3 (CP3) ALSO HAS INFLOWS FROM RUNOFF AND DIRECT PRECIPITATION THAT ARE NOT SHOWN.

CLIENT
RioTinto

CONSULTANT
WSP GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-3 |
| DESIGNED | RS |
| PREPARED | SL |
| REVIEWED | RS |
| APPROVED | ZK |

PROJECT
AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE
**CONCEPTUAL WATER MANAGEMENT SYSTEM**

| PROJECT NO. | CONTROL | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000-GC-0003 | 0 | 2.3-1 |

The NI is located between the waste rock area and the airstrip (Figure 2.1-2). The NI is an inlet of Lac de Gras that has been dammed off to use as a sedimentation/equalization basin before treatment at the NIWTP. The NI water storage reservoir currently has a live capacity of about 2.5 $Mm^3$.

The NIWTP was constructed at the northeast end of the NI to treat Mine water to meet compliance requirements before discharge to the environment. The NIWTP is designed for removal of fine solids and dissolved phosphorus in cold water conditions with a proven treatment capacity of 90,000 $m^3$/d. The NIWTP has contingency design to reduce pH through the addition of acid if required. Major system components include coagulant and flocculent preparation equipment, and four high-capacity clarifiers.

A by-product of the water treatment process is clarifier thickener underflow or “sludge” material. Sludge is removed from the bottom of the thickeners and transported hydraulically to the NI for deposition at the bottom of the NI. Up until June 2010, the NIWTP had produced about 46.5 $m^3$ of sludge. For the remainder of the Mine life, an additional 182,000 $m^3$ of sludge is expected to be produced and deposited in the NI.

Treated Mine water is discharged into Lac de Gras via two submerged outfalls located 200 m offshore at a depth of 20 m. Treatment flow rates, influent and treated effluent quality values of pH, turbidity and specific conductivity are monitored continuously and alarmed if outside acceptable limits. Equipment faults and pH levels at points within the circuit are also monitored and alarmed. Effluent is physically tested by the operator regularly for turbidity, pH, conductivity and alkalinity. The NI water levels and inflow rates from Mine areas are regularly monitored. Treatment rates are adjusted to maintain water levels within planned levels.

### Collection Ponds

The Collection Pond characteristics are summarized in Table 2.3-1. Water levels in the ponds are inspected daily during May and June. Ponds are pumped down as required during the spring freshet period. Water quality is monitored when water is present. The ponds are pumped substantially dry by October each year to provide additional storage capacity for the following spring freshet.

**Table 2.3-1: Runoff Collection Pond Summary**

| Drainage Area | Pond No. | Drainage Basin Area (ha) | Basin Design Capacity for 1:100 Year Freshet ($m^3$) |
|---|---|---|---|
| WRSA-NCRP | 1 | 86 | 41,500 |
| | 2 | 106 | 20,000 |
| | 3 | 60 | 1,100,000 |
| PKCF Dam Toes | 4 | 15 | 28,000 |
| | 5 | 20 | 37,000 |
| | 7 | 40 | 231,000 |
| Plant Site Area | 10 | 21 | 11,700 |
| | 11 | 7 | 12,500 |
| | 12 | 20 | 54,000 |
| North Site - Underground Area | 13 | 15 | 26,500 |

PKC = processed kimberlite containment.

### 2.3.2 Dust Management

The primary source of dust at the Mine is from ongoing construction (e.g., dikes, PKC). The amount of dust deposition around East Island and in Lac de Gras is monitored through the AEMP.

Several techniques are used to manage dust at the Mine. Water is the primary dust control method and is applied on the main haul roads and the airstrip during warm dry weather to reduce dust caused by vehicle travel. Road watering trucks are filled directly from Lac de Gras using portable pumps. The volume extracted is recorded by counting truck loads. A fish screen was added to the pumping system in 2013.

The Mine also uses an environmentally safe chemical dust suppressant called EK35 on the airport apron and helipad, and in laydowns and on roads near buildings Dust associated with crushing is mitigated by containment in a building (e.g., bag house dust). Dust Management details are covered in the Dust Management Section of the Waste Management Plan.

### 2.3.3 Waste and Hazardous Materials Management

The main disposal methods for solid wastes generated on-site include incineration of all food wastes, categorical segregation of all non-food waste for storage and subsequent removal from site, and the on-site disposal of non-burnable inert wastes. DDMI's Waste Management Plan and Hazardous Materials Management Plan are updated annually, or as necessary.

Some of the materials used at the Mine are considered hazardous and are subject to special storage and handling protocols. These materials include fuel, lubricants, process chemicals, and explosives. DDMI's Hazardous Materials Management Plan provides guidance in their management and is updated annually or as necessary. As originally proposed in the EA, DDMI has implemented safe handling practices and spill containment procedures at the site, both within and outside the closed-circuit areas, to ensure that any fuels and other chemicals are contained and not released to the environment. For aquatic resources, two levels of protection from potential contamination are provided by:

- containment areas established around individual storage and loading areas
- the perimeter collection system

# 3.0 STUDY DESIGN

## 3.1 AEMP Background and Objectives

DDMI conducts environmental monitoring programs under the terms and conditions of Water Licence W2015L2-0001 and the Fisheries Authorization issued by Fisheries and Oceans Canada. The AEMP is the primary program specified in the Water Licence for monitoring the aquatic environment of Lac de Gras. Mine water discharge represents the principal stressor of potential concern to Lac de Gras (DDMI 2007). Therefore, Mine water discharge, and its potential impact on aquatic resources, is the principal focus of the AEMP; however, the AEMP is intended to provide an integrated monitoring program that considers all major pathways for potential effects. The AEMP has also been designed to include the results of other sources of information on potential effects to the lake, specifically the results of TK studies.

The principal goal of the AEMP is to monitor the Mine water discharge and other stressors from the Mine and assess potential ecological risks so that appropriate actions can be taken in the Mine operations to mitigate any possible adverse effects. As defined in Water Licence W2015L2-0001, the specific objectives of the AEMP are "*to* *determine the short- and long-term effects in the aquatic environment resulting from the Project, to evaluate the accuracy of impact predictions, to assess the effectiveness of impact mitigation measures, and to identify additional impact mitigation measures to reduce or eliminate environmental effects of the licensed undertaking*", particularly in relation to the primary VECs of Lac de Gras. The VECs and assessment endpoints have been evaluated in previous site investigations, including the EA (DDMI 1998a), and consist of water quality, sediment quality, lake productivity, planktonic and benthic invertebrate communities, fish, fish habitat, and the use of fisheries resources in Lac de Gras. DDMI's AEMP encompasses all aquatic related aspects of the Mine including the monitoring of groundwater, mine water discharge, runoff, dust emissions, surface water and aquatic biota.

The AEMP Design Plan described herein is an update to the previous AEMP Version 5.2, which presented details of the core aspects of the AEMP study design, including:

- the broad AEMP framework and objectives
- the problem formulation, including review of EA predictions and VECs, identification of receptors of potential concern and contaminants of potential concern, pathways, the conceptual model, and assessment and measurement endpoints
- the technical study design for monitoring components, including sample sites, sample types and data analysis

## 3.2 Assessment and Measurement Endpoints

Assessment endpoints are formal narrative expressions of the actual environmental value that is to be protected (Suter 1993; Suter et al. 2000). Measurement endpoints are measurable environmental characteristics related to the assessment endpoints. They are measures of the potential for adverse ecological effects, and may include measures of exposure (e.g., comparison of chemistry to environmental quality guidelines) and effects (e.g., biomass, community, toxicity relative to reference condition) (USEPA 1998).

Assessment and measurement endpoints are listed in Table 3.2-1 for each VEC for the *AEMP Design Plan Version 6.0*, and remain the same as those defined for the AEMP Version 5.2. Supplemental technical investigations (supporting studies) are also noted where they are not a formal component of the AEMP but are useful for evaluating the assessment endpoint.

**Table 3.2-1: Valued Ecosystem Components and Measurement Endpoints Associated with the AEMP**

| Valued Ecosystem Component | Assessment Endpoints | Measurement Endpoints | Supporting Lines of Evidence |
|---|---|---|---|
| Water quality | Maintenance of water quality that does not pose a risk to aquatic life and/or humans | Concentrations of metals in:<br>■ Whole effluent<br>■ Surface water<br>■ Surficial sediments | Concentrations of modifying water quality parameters (e.g., pH, hardness)<br>Effluent toxicity tests[a] |
| | | Concentrations of nutrients (ammonia, nitrite, nitrate and total phosphorus) in:<br>■ Whole effluent<br>■ Surface water<br>■ Surficial sediments | Concentrations of other water quality parameters<br>Chlorophyll *a* |
| | Maintenance of the pristine nature of Lac de Gras. | Concentrations of metals, nutrients, ions in;<br>■ Whole effluent<br>■ Surface water<br>■ Surficial sediments<br>■ Fish tissues | |
| Lake productivity (phytoplankton and zooplankton) | Maintenance of an oligotrophic zooplankton community | Zooplankton species composition[b] | Effluent toxicity[a], water chemistry |
| | | Zooplankton abundance and biomass[b] | |
| | Maintenance of a phytoplankton community characteristic of an oligotrophic lake (maintain historic trophic status) | Phytoplankton species composition[b] | Effluent toxicity[a], water chemistry – especially concentrations of total phosphorus |
| | | Phytoplankton abundance and biomass[b] | |
| | | Concentration of surface water chlorophyll *a* | |
| Fish habitat | Maintain productivity of fish habitat | Habitat quality and quantity[c] | Water chemistry<br>Habitat use<br>Sediment chemistry<br>Zooplankton community metrics<br>Benthic invertebrate community metrics<br>Lake productivity |

**Table 3.2-1: Valued Ecosystem Components and Measurement Endpoints Associated with the AEMP**

| Valued Ecosystem Component | Assessment Endpoints | Measurement Endpoints | Supporting Lines of Evidence |
|---|---|---|---|
| Additional aquatic community components | Maintenance of a benthic invertebrate community characteristic of an oligotrophic lake. | Total benthic invertebrate density and densities of dominant invertebrate groups | Water chemistry<br>Sediment chemistry |
| | | Benthic invertebrate richness | |
| | | Benthic invertebrate dominance | |
| | | Simpson's diversity index | |
| | | Simpson's evenness index | |
| | | Ecological distances between communities subject to varying levels of effluent exposure, as quantified by the Bray-Curtis Index | |
| | | Multivariate summary of the benthic community | |
| | Maintenance of sediment chemistry that does not pose a risk to the benthic invertebrate community | Sediment total metal concentrations (2 cm profile) | Water chemistry<br>Benthic invertebrate community metrics |
| Fish health and abundance | Maintenance of fish health and abundance in Lac de Gras | Sentinel species abundance (Catch per unit effort[d], length-frequency distribution) | Water chemistry<br>Sediment chemistry<br>Benthic invertebrate community metrics<br>Plankton community metrics |
| | | Sentinel species length/weight | |
| | | Sentinel species condition | |
| | | Sentinel species relative liver and gonad weight | |
| Fish quality for consumption | Maintenance of fish tissue metal concentrations that do not pose a risk to human health (exceed consumption guidelines) | Lake Trout tissue chemistry in Lac de Gras[e] | Water chemistry<br>Slimy Sculpin tissue chemistry |
| | Maintenance of fish tissue metal concentrations that do not pose a risk to predatory fish. | Slimy Sculpin tissue chemistry | Water chemistry<br>Sediment chemistry |
| | Maintenance of game fish quality (palatability) | Palatability testing (Lake Trout) | Water chemistry<br>Tissue chemistry |
| | Lack of diseases or deformities attributable to Mine discharge | Slimy Sculpin, Lake Trout[e] and Round Whitefish[e] abnormalities (e.g., wounds, tumours, parasites, fin fraying, gill parasites or lesions) | Water chemistry<br>Sediment chemistry |

a) Toxicity data are collected as part of the Mine's Surveillance Network Program (SNP), as required by the Water Licence.
b) Measurement endpoints adopted for the AEMP.
c) Measurement endpoints related to Fisheries Authorization studies.
d) Refer to Section 4.8 for definition.
e) Not currently monitored as part of the AEMP design but may be initiated as part of an AEMP Response Plan (see Sections 3.5, 4.81 and 4.91 for more information).

## 3.3 Traditional Ecological Knowledge

Indigenous communities have consistently spoken about the importance of the fish and water of Lac de Gras. They spoke of this during the initial consultation about the project during the EA (DDMI 1998a), during community visits to review the Mine development and monitoring results, and at the Water Licence Renewal public hearings.

DDMI has used community information gathered during the public consultation process and the different TK studies to guide the development of the environmental baseline studies, the project design process, the development of the Environmental Management System, mitigation measures and the development of monitoring programs (Government of Canada 1999). In particular, elders who visited the proposed Mine site provided valuable information that influenced the project design. Their knowledge of caribou movements, wildlife habitat, natural drainage patterns, blowing snow, and seasonal changes in ice conditions assisted DDMI in determining specific locations and design features for various project components.

The “key questions” that were defined for the EA were defined largely from community input. These key questions as they relate to Lac de Gras established the VECs for the EA and the AEMP.

Indigenous communities remain involved in the design, review and implementation of the AEMP. This involvement continues to be supported by DDMI through involvement in meetings to explain or review annual programs, training in monitoring techniques, participation with EMAB, the Community-based Monitoring Program, and through the employment and/or contracting of community members to conduct aquatic monitoring (DDMI 2006a).

DDMI hosts community and TK monitoring programs (DDMI 1998a, 2006a). Past programs have included both aquatics and wildlife. The programs have been running for several years and many were conducted in cooperation with EMAB. Previous aquatics programs have focused on training in aquatic monitoring techniques and monitoring of fish palatability (DDMI 2006a, 2010). DDMI intends to continue community and TK studies.

DDMI will work with communities and EMAB to identify methods for including TK monitoring as a component of the AEMP. While it is clearly DDMI’s responsibility to lead this initiative, it would be inappropriate for DDMI to design the TK monitoring programs; the designs must come from the knowledge holders. A design for a TK program has been developed by a Traditional Studies Specialist and included in this document (see Section 4.1); however, it will be up to the Indigenous communities to specifically determine, in consultation with DDMI, how and when to conduct the monitoring. DDMI anticipates continued support from EMAB in relation to program design and implementation.

## 3.4 Sampling Design and Locations

### 3.4.1 Sampling Design

The most important source of potential Mine-related effects on the aquatic ecosystem of Lac de Gras is the discharge of Mine effluent (Section 3.1). Other stressors (e.g., dust deposition, dikes) have effects of much lower magnitude on Lac de Gras. The objective of the AEMP is to evaluate the potential effects from all Mine-related stressors. Accordingly, AEMP reporting will integrate all monitoring results for a reporting period and evaluate the potential combined effects from all Mine-related stressors (see Section 4.10).

The sampling design used for the AEMP was initially established for Version 2.0 of the AEMP design and incorporated elements of both the multiple control-impact and radial gradient designs. Under the Version 2.0 study design, the Mine effluent-exposed near-field (NF) area was compared with four unexposed far-field (FF) areas (FF1, FF2, FFA, FFB) to evaluate potential effects (i.e., a control-impact analysis), and was complemented by a gradient analysis to evaluate the spatial extent of effects. Since Mine-related stressors other than the effluent discharge also originate at the Mine site, this analysis also evaluated the combined effects from the Mine. The gradient portion of the AEMP sampling design consisted of three mid-field (MF) transects (MF1, MF2, MF3) extending away from the diffusers and the Mine area, in combination with the NF and corresponding FF areas. The stations in these areas represent the full range of exposure of biological communities to Mine-related stressors.

During the AEMP Version 3.0, it was determined that the FF areas in Lac de Gras had become exposed to low-levels of Mine effluent. The summary of Mine effects presented in the *2014 to 2016 Aquatic Effects Re-evaluation Report* also confirmed that low level effects were occurring in the FF areas in certain variables evaluated by the AEMP. Although the concentrations measured in lake water remained well below any benchmarks or guidelines, the FF areas could no longer be treated as reference areas in a control-impact comparison. As a result, refinements to the AEMP data analysis approach were made to account for low-level effluent exposure of the FF areas. Reference conditions for Lac de Gras now consist of the approved baseline data sets and normal ranges established in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).

Version 6.0 of the AEMP follows the sampling design used during previous versions of the AEMP. However, future cycles of the AEMP will emphasize the gradient aspect of the design, which has been a fundamental component of the program since the AEMP Version 2.0, while continuing to make comparisons of annual data to reference conditions. This shift in focus is required because it is no longer possible or appropriate to conduct a current-day control-impact analysis to assess Mine effects. The recommendation to place a greater emphasis on spatial gradients was first made in the AEMP Version 4.0 and was approved by the WLWB. More recently, the WLWB approved the change of comparing NF and MF data to reference condition data instead of FF data to evaluate Action Level triggers (WLWB 2020).

Reflecting the greater emphasis of the AEMP data analyses on spatial gradients, the AEMP Version 5.2 described some adjustments to sampling locations, which improved the spatial coverage of stations in Lac de Gras and filled gaps along existing gradients in the lake. Two new sampling locations, one (FFD-1) located between the existing FF1 and MF3 areas and one (FFD-2) located between the FFB and FFA areas, were added to improve delineation of effects along the MF3 transect and to better assess the extent of effects extending from the existing MF1/FF1 areas extending into the northern channel area of Lac de Gras, east of the East Island. Full details on the number and locations of stations sampled for the AEMP are provided in Section 3.4.2.

Station LDS-1 in Lac du Sauvage near the outflow to Lac de Gras will continue to be sampled to provide information for Lac du Sauvage, upstream of Lac de Gras, and to maintain the long-term data record that is available for this station. Station LDS-4 at the narrows between Lac du Sauvage and Lac de Gras will continue to provide information on the quality of the water flowing into Lac de Gras.

The dust deposition component of the AEMP will retain the radial gradient design adopted in 2001 (Golder 2011a), and as documented in the *AEMP Design Plan Version 4.1* (Golder 2017a).

### 3.4.2 Sampling Locations

The AEMP evaluates three general areas of Lac de Gras defined by distance from the Mine effluent diffusers, referred to as NF, MF and FF areas; all of these areas are considered exposure areas. They consist of one NF area, three FF areas (i.e., FF1, FFA and FFB) and three MF areas (i.e., MF1, MF2-FF2, and MF3; Figure 3.4-1). The MF areas are located along transects between the NF and FF areas. Stations in the FF2 exposure area (formerly a full FF reference area consisting of five stations, but now reduced to two stations, FF2-2 and FF2-5) are included in the MF2 transect, because the FF2 area stations are located at the far northeast end of the MF2 transect. In addition to these areas in Lac de Gras, the AEMP also samples selected variables at one station in Lac du Sauvage (LDS-1), one station at the Lac du Sauvage narrows (LDS-4), and one station at the outlet of Lac de Gras to the Coppermine River (LDG-48). Water quality, nutrients, chlorophyll *a*, phytoplankton and zooplankton will be sampled at LDS-1, upstream of the lake outlet.

Consistent with AEMP Version 5.2, Station FFD-1 and Station FFD-2 will continue to be sampled. Station FFD-1 is located between the existing FF1 and MF3 areas and forms a part of the existing MF1 transect. Station FFD-2 is located between the FFB and FFA areas and forms part of the existing MF3 transect.

The *AEMP Design Plan Version 6.0* sampling stations are shown in Figure 3.4-1 and Table 3.4-1. The majority of these stations were established during *AEMP Study Design Version 2.0* and specific locations were chosen in the field to minimize physical variation among stations to the extent possible. Since the primary physical variable that influences sediment composition and benthic invertebrate communities in lakes is water depth, station locations were selected to be within the relatively narrow depth range of 18 to 22 m. The locations of a number of the MF stations were adjusted for the *AEMP Study Design Version 3.0* to better delineate the extent of effects in the lake (Golder 2011b). These adjustments have been retained for the *AEMP Design Plan Version 6.0*. The station at the Lac du Sauvage narrows was added for *AEMP Study Design Version 4.1* (Golder 2017a) and is retained to capture incoming water quality to Lac de Gras, and to allow for estimating concentrations of key water quality parameters entering the lake. Finally, Stations FFD-1 and FFD-2 were added for *AEMP Study Design Version 5.2* to improve the spatial coverage of stations in Lac de Gras and to fill gaps along existing gradients in Lac de Gras.

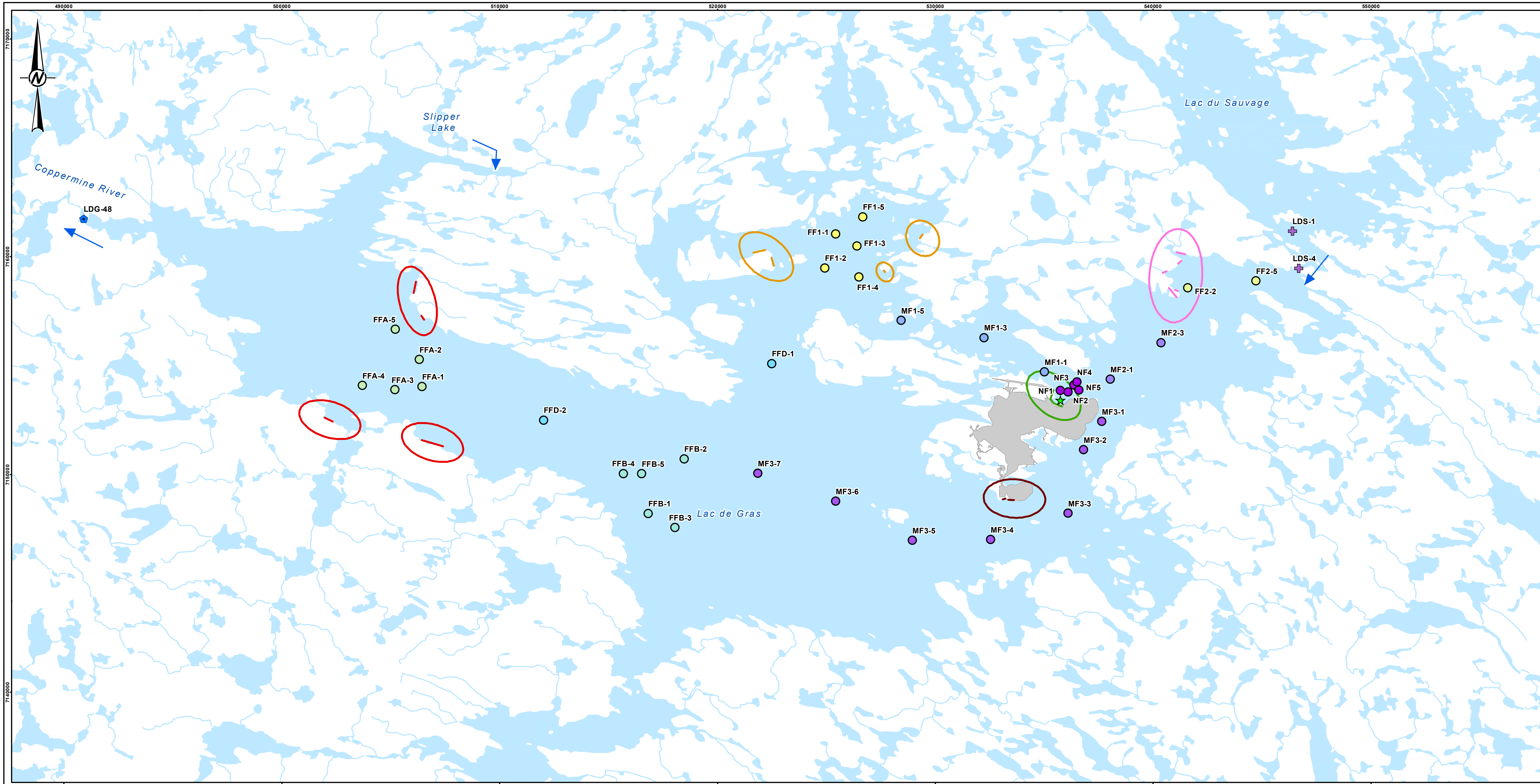
Within Lac de Gras, water quality, indicators of eutrophication, sediment quality, plankton and benthic invertebrates will be sampled at the same locations. Small-bodied fish (Slimy Sculpin, *Cottus cognatus*) will be collected along the shoreline, close to the AEMP stations (Figure 3.4-1).

Water quality, nutrients, chlorophyll *a* and phytoplankton will be sampled at the Lac de Gras outlet to the Coppermine River (Station LDG-48) using the methods employed since 2000, and according to the commitments made with the community of Kugluktuk. Monitoring of zooplankton biomass under both the eutrophication indicators component and the plankton component will not occur at LDG-48 because it is characterized by shallow, flowing water and is ecologically dissimilar to the open-water lake habitat represented by other AEMP stations.

Water quality, nutrients, chlorophyll *a* and phytoplankton will be sampled at one station in Lac du Sauvage (LDS-1) upstream of the lake outlet. Water quality, nutrients, chlorophyll *a* and phytoplankton will also be sampled during the open-water season at the narrows (LDS-4), where the Lac du Sauvage outflow enters Lac de Gras. Due to unstable ice conditions at the outlet, sampling during the ice-cover season is not possible. Inflowing water from Lac du Sauvage is more productive than that of Lac de Gras and has the potential to affect the FF2 stations, which are located at the far northeast end of the MF2 transect; therefore, sampling at the narrows allows an evaluation of whether changes occurring at the FF2 stations are due to exposure to Mine effluent or are related to the quality of water entering Lac de Gras. Monitoring of zooplankton biomass under both the eutrophication indicators component and the plankton component will not occur at LDS-4, because it is characterized by shallow, flowing water and is ecologically dissimilar to the open-water lake habitat represented by other AEMP stations.

For the AEMP small-bodied fish surveys, an attempt will be made to capture fish at the locations sampled in 2007, 2010, 2013, 2016 and 2019 (DDMI 2008, 2011; Golder 2014a, 2017b, 2020b). Slimy Sculpin will be collected along the shoreline near the NF, FF2, and MF3 areas, and near the FF1 and FFA areas. Slimy Sculpin are successfully captured along shallow (<40 cm deep) natural shorelines with small cobble substrate (DDMI 2008, 2011; Golder 2014a). Only two of the three FF areas will be targeted to reduce the overall mortality of sculpin in Lac de Gras (per Schedule 8 Condition 1e of Water Licence W2015L2-0001; Table 1.3-1).

Dust samples, including snow core and dustfall samples, will be collected under the AEMP. Snow core samples will be collected along five transects from 27 stations, including three control stations (see Section 4.2.2.1), and dustfall collection gauges will collect samples at 14 stations (including two control stations; see Section 4.2.2.2).




**LEGEND**

**SAMPLING LOCATIONS**
- LAC DU SAUVAGE
- LAC DE GRAS

**EXPOSURE**
- NEAR-FIELD
- MID-FIELD 1
- MID-FIELD 2
- MID-FIELD 3
- FAR-FIELD 2
- FAR-FIELD 1
- FAR-FIELD B
- FAR-FIELD A
- FAR-FIELD D

**SAMPLING SITES FOR SLIMY SCULPIN**
- NEAR-FIELD
- MID-FIELD 3
- FAR-FIELD 2
- FAR-FIELD 1
- FAR-FIELD A

- DIFFUSER
- FLOW DIRECTION
- WATERCOURSE
- DIAVIK FOOTPRINT
- WATERBODY

0 5 10
1:175,000 KILOMETRES

REFERENCE(S)
1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

CONSULTANT
WSP GOLDER

| | |
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| YYYY-MM-DD | 2022-04-13 |
| DESIGNED | RS |
| PREPARED | LMS |
| REVIEWED | RS |
| APPROVED | ZK |

PROJECT
AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE
**AEMP DESIGN PLAN VERSION 6.0 SAMPLING STATIONS**

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000 | 0 | 3.4-1 |

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**Table 3.4-1: Locations of *AEMP Design Plan Version 6* Sampling Stations**

| Area | Station | UTM Coordinates | | Distance from Diffusers[a] (m) |
|---|---|---|---|---|
| | | Easting | Northing | |
| Near-field | NF1 | 535740 | 7153854 | 394 |
| | NF2 | 536095 | 7153784 | 501 |
| | NF3 | 536369 | 7154092 | 936 |
| | NF4 | 536512 | 7154240 | 1,131 |
| | NF5 | 536600 | 7153864 | 968 |
| Mid-field 1 | MF1-1 | 535008 | 7154699 | 1,452 |
| | MF1-3 | 532236 | 7156276 | 4,650 |
| | MF1-5 | 528432 | 7157066 | 8,535 |
| Mid-field 2 | MF2-1 | 538033 | 7154371 | 2,363 |
| | MF2-3 | 540365 | 7156045 | 5,386 |
| Far-field 2 | FF2-2 | 541588 | 7158561 | 8,276 |
| | FF2-5 | 544724 | 7158879 | 11,444 |
| Mid-field 3 | MF3-1 | 537645 | 7152432 | 2,730 |
| | MF3-2 | 536816 | 7151126 | 4,215 |
| | MF3-3 | 536094 | 7148215 | 7,245 |
| | MF3-4 | 532545 | 7147011 | 11,023 |
| | MF3-5 | 528956 | 7146972 | 14,578 |
| | MF3-6 | 525427 | 7148765 | 18,532 |
| | MF3-7 | 521859 | 7150039 | 22,330 |
| Far-field 1 | FF1-1 | 525430 | 7161043 | 13,571 |
| | FF1-2 | 524932 | 7159476 | 12,915 |
| | FF1-3 | 526407 | 7160492 | 12,788 |
| | FF1-4 | 526493 | 7159058 | 11,399 |
| | FF1-5 | 526683 | 7161824 | 12,823 |
| Far-field A | FFA-1 | 506453 | 7154021 | 36,769 |
| | FFA-2 | 506315 | 7155271 | 38,312 |
| | FFA-3 | 505207 | 7153887 | 38,734 |
| | FFA-4 | 503703 | 7154081 | 40,211 |
| | FFA-5 | 505216 | 7156657 | 39,956 |
| Far-field B | FFB-1 | 516831 | 7148207 | 26,355 |
| | FFB-2 | 518473 | 7150712 | 24,991 |
| | FFB-3 | 518048 | 7147557 | 25,245 |
| | FFB-4 | 515687 | 7150036 | 27,591 |
| | FFB-5 | 516533 | 7150032 | 26,761 |
| -[c] | FFD-1 | 522495[b] | 7155084[b] | 17,315[b] |
| | FFD-2 | 512017[b] | 7152491[b] | 31,687[b] |
| Outlet of Lac de Gras | LDG-48 | 490900 | 7161750 | 55,556 |
| Lac du Sauvage | LDS-1 | 546398 | 7161179 | - |
| Outlet of Lac du Sauvage | LDS-4 | 547191 | 7160256 | - |

UTM = Universal Transverse Mercator, NAD83, Zone 12V; - = not applicable; stations are upstream of Lac de Gras.

a) Approximate distance from the Mine effluent diffusers along the most direct path of effluent flow.

b) Locations are approximate and will be confirmed during the first sampling at these stations.

c) Stations designated FFD do not represent a distinct FF sampling area.

## 3.5 Sampling Schedule

The frequency and timing of sampling in Lac de Gras has changed over time as modifications to the AEMP design have been introduced. With the exception of the fish surveys, the monitoring frequency for *AEMP Study Design Version 2.0* was annual. The first four years of monitoring under *AEMP Study Design Version 2.0* (i.e., 2007 to 2010) provided data of consistent quality, providing reliable estimates of within-year, among-year and among-station variation. During these four years of monitoring, water quality, indicators of eutrophication and plankton were sampled monthly during the open-water season, over three distinct sampling events. An additional ice-cover sampling event was included for water quality and indicators of eutrophication. These data also allowed for a detailed assessment of Mine-related effects (Golder 2011a).

In the *2007 to 2010 AEMP Summary Report* (Golder 2011a), variability in water quality and plankton data during the open-water season was evaluated over the four years of *AEMP Study Design Version 2.0* (DDMI 2007). An objective of this evaluation was to determine if a single open-water sample was adequate to characterize variability during open-water conditions. Analysis of the data demonstrated that the variability among the three open-water periods was, for most variables, small relative to that observed between ice-cover and open-water conditions or between exposure and reference areas. Moreover, results of the assessment of effects were typically consistent across all three open-water periods. The ice-cover season was the most sensitive time of year to assess effects on water quality (i.e., if effects were observed, they usually occurred during ice-cover conditions, regardless of whether effects occurred during the open-water periods). These findings were considered in the A*EMP Study Design Version 3.0* and the frequency of open-water sampling was reduced to single sampling event from 15 August to 15 September, in addition to the ice-cover season.

The sampling schedule for the *AEMP Study Design Version 6.0* will follow that of the *AEMP Study Design Version 5.2* (Golder 2020a). Variables used as indicators of eutrophication, including plankton, will continue to be sampled on an annual basis in the NF and MF (including FF2) areas (Table 3.5-1). In addition, water quality monitoring will continue at a monthly frequency at the mixing zone boundary and at an annual frequency in the NF and MF (including FF2) areas to retain the ability to detect early-warning changes and any unexpected change in a water quality variable. Sediments (with the exception of annual sampling at the mixing zone boundary under the SNP), benthic invertebrates and small-bodied fish will be monitored at a frequency of once every three years.

Water quality, eutrophication indicators and plankton variables will be sampled annually at the newest FFD-1 station, located in the northern channel, east of the East Island, and at the FF1-2 station in the FF1 area (Figure 3.4-1). These Stations provide an opportunity to evaluate the spatial extent of effects in the FF1 area (as represented by annual sampling at Station FF1-2), through the northern channel, on an annual basis. Station FFD-2 will be sampled every three years during the comprehensive sampling program.

The Slimy Sculpin survey is conducted at a frequency of once every three years to balance the lethal effects of the program against the sampling requirements. If fish health assessment endpoints demonstrate effects equivalent to Action Level 2 (Table 5.2-4), it is expected a Lake Trout (*Salvelinus namaycush*) survey would be initiated, if appropriate, to assess effects in the broader fish community.

The specific timing of a Lake Trout fish health survey would be defined in an AEMP Response Plan, which would be implemented as and when approved by the WLWB. It is possible that such a program would be limited to a non-lethal tissue chemistry sampling program (e.g., for mercury analyses from tissue plugs) or could be a lethal fish health survey, dependent on the Action Level trigger which initiated the study. The mercury in Lake Trout survey would only occur if the small-bodied fish tissue chemistry results indicate an increasing trend in mercury due to the Mine. Additional sampling of biological components may be required if an Action Level in the Response Framework (Section 5.0) is triggered. For example, at Action Level 1, the follow-up action for biological components is confirmation of the effect. The specific timing of a follow-up study, however, would be defined in an AEMP Response Plan (Section 7.5), which would be implemented as and when approved by the WLWB.

The comprehensive sampling program, when all AEMP components will be sampled at all stations, will occur every three years (i.e., next program in 2022; Table 3.5-2) and the report will be submitted in the following year (Section 7.3). The Aquatic Effects Re-evaluation Report summarizing the 2020 to 2022 monitoring period (Section 7.4) will be submitted on or before 31 December 2023. The next AEMP Design Plan (Version 7.0; Section 7.2) is proposed to be submitted in 2024. This schedule aligns submission of the AEMP reports and allows for a detailed assessment of effects trend analyses concurrent to development of the AEMP Design Plan.

The AEMP Annual Report for interim sampling years (i.e., the years in which comprehensive sampling is not undertaken; e.g., 2023, 2024; Section 7.3) will assess effects on water quality variables, indicators of eutrophication, and plankton, by determining if an Action Level has been triggered (Section 5.0). This approach follows the concept of the tiered, three-year cycle approach that has been successfully applied in regulatory-driven, national-scale AEMPs, such as the federal pulp and paper, and metal and diamond mining EEM programs (Environment Canada 2010, 2012).

**Table 3.5-1: Summary of the *AEMP Design Plan Version 6.0***

| Component | Timing | Sampling Depth | Sample Type | Number of Samples per Station | Locations[a] (Number of Stations) | Frequency[c] |
|---|---|---|---|---|---|---|
| Dust Deposition<br>-Snow Monitoring | Once:<br>▪ ice-cover | not applicable | Composite of required number of cores for analysis | 1 | Control (3)<br>Exposure (24) | Annually |
| Dust Deposition<br>-Dust Gauge Monitoring | 4 per year:<br>▪ March<br>▪ June<br>▪ September<br>▪ December | not applicable | Discrete | 1 | Control (2)<br>Exposure (12) | Annually |
| Water Quality<br>-Mixing Zone Boundary | Monthly | 2-m intervals<br>(5 depths) | Discrete | 5 | SNP 1645-19A, B2, C | Annually |
| Sediment Quality<br>-Mixing Zone Boundary | Once:<br>▪ open-water | Top 5 cm (core) for chemistry | Composite of (minimum) 3 cores | 1 | SNP 1645-19A, B2, C | Annually |
| Effluent Plume<br>-Conductivity | Twice:<br>▪ open-water<br>▪ ice-cover | 2-m intervals | Profile | Profile | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2, FFD-1, LDS-4[d] and LDG-48<br>Once every 3 years at all stations |
| Water Quality<br>-Routine Variables<br>-Nitrogen<br>-Metals | Twice:<br>▪ open-water<br>▪ ice-cover | NF, MF and FF2: 3 depths<br>▪ 2 m from surface<br>▪ mid-depth<br>▪ 2 m from bottom<br><br>FF, LDS-1, LDS-4, LDG-48: 1 depth<br>▪ mid-depth | Discrete | NF, MF and FF2: 3<br>FF: 1 | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2, FFD-1, LDS-4[d] and LDG-48<br>Once every 3 years at all stations |
| Indicators of Eutrophication<br>-Phosphorus<br>-Nitrogen<br>-Soluble Reactive Silica<br>-Chlorophyll *a* | Twice:<br>▪ open-water<br>▪ ice-cover[b] | Ice-cover: NF, MF and FF2: 3 depths<br>▪ 2 m from surface<br>▪ mid-depth<br>▪ 2 m from bottom<br><br>FF, LDS-1, LDS-4, LDG-48: 1 depth<br>▪ mid-depth | Open-water:<br>▪ depth-integrated<br><br>Ice-cover:<br>▪ discrete | 2 chlorophyll *a*<br>2 nutrients | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2, FFD-1, LDS-4[d] and LDG-48<br>Once every 3 years at all stations |
| Phytoplankton | Once:<br>▪ open-water | 10 m | Depth-integrated | 1 taxonomy/ biomass | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2 and FFD-1<br>Once every 3 years at all stations |

**Table 3.5-1: Summary of the *AEMP Design Plan Version 6.0***

| Component | Timing | Sampling Depth | Sample Type | Number of Samples per Station | Locations[a] (Number of Stations) | Frequency[c] |
|---|---|---|---|---|---|---|
| Zooplankton[e] | Once:<br>■ open-water | full water column | Depth-integrated Composite of 3 hauls | 2 taxonomy/ biomass | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (1) | Annually at NF, MF and FF2, FF1-2 and FFD-1<br>Once every 3 years at all stations |
| Sediment Quality | Once:<br>■ open-water | Top 10 to 15-cm (full Ekman grab) for TOC and particle size | Composite of 5 grabs | 1 of each type | NF (5)<br>MF and FF2 (14)<br>FF (17) | Once every 3 years |
| | | Top 1-cm (core) for chemistry | Composite of (minimum) 3 cores | | | |
| Benthic Invertebrates | Once:<br>■ open-water | 18 to 22 m | Composite of 6 grabs | 1 | NF (5)<br>MF and FF2 (14)<br>FF (17) | Once every 3 years |
| Small-bodied Fish<br>- Fish Health | Once:<br>■ open-water | not applicable | Lethal survey | 30 adult male<br>30 adult female<br>30 juvenile | NF (1)<br>MF and FF2 (2)<br>FF (2) | Once every 3 years |
| | | | Non-lethal survey | additional 50 fish | | |
| | | | Non-lethal relative abundance survey | Indeterminate[f] | | |
| Small-bodied Fish<br>- Fish Tissue Chemistry | Once:<br>■ open-water | not applicable | Composite by size, whole body, (excluding stomach, otoliths and gonad) | Minimum of 8 | NF (1)<br>MF and FF2 (2)<br>FF (2) | Once every 3 years |
| Large-bodied Fish<br>- Fish Health or Fish Tissue Mercury | Once:<br>■ open-water | not applicable | To be determined as part of the AEMP Response Plan | | | Occurs only when triggered by results of small-bodied fish survey (i.e., Action Level 2 or mercury in small-bodied fish tissue) |
| TK<br>-Fish Palatability<br>-Fish Tissue Chemistry | Once:<br>■ open-water | not applicable | Individual fish, muscle and organs | 10 fish | Lac de Gras | Once every 3 years |

SNP = Surveillance Network Program; TOC = total organic carbon.

a) Refer to Figure 3.4-1 for sampling locations.

b) Chlorophyll *a* samples are not collected during the ice-cover season.

c) Additional sampling of biological components may be required if an Action Level in the Response Framework (Section 5.0) is triggered. Timing of a follow-up study would be defined in the AEMP Response Plan (Section 7.5), which would be implemented as and when approved by the WLWB.

d) Sampling for water quality and nutrients is not conducted at Station LDS-4 during the ice-cover season due to unsafe access conditions at the outlet.

e) Zooplankton samples are not collected at stations LDS-4 and LDG-48, due to the shallow depth and flowing water at these stations, which makes them inappropriate for zooplankton sampling.

f) There are no defined sample size targets for the non-lethal relative abundance survey.

**Table 3.5-2: AEMP Sampling Schedule**

| Component[(a)] | 2022 | | 2023 | | 2024 | | 2025 | | 2026 | | 2027 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IC | OW | IC | OW | IC | OW | IC | OW | IC | OW | IC | OW |
| Dust Deposition | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Water Quality – Mixing Zone Boundary[(b)] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Sediment Quality – Mixing Zone Boundary | | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | | ✓ |
| Effluent Plume – Conductivity | ✓̲ | ✓̲ | ✓ | ✓ | ✓ | ✓ | ✓̲ | ✓̲ | ✓ | ✓ | ✓ | ✓ |
| Water Quality – Routine, Nitrogen and Metals | ✓̲ | ✓̲ | ✓ | ✓ | ✓ | ✓ | ✓̲ | ✓̲ | ✓ | ✓ | ✓ | ✓ |
| Indicators of Eutrophication – Phosphorus, Nitrogen, SRSi, Chlorophyll *a* and Zooplankton Biomass[(c)] | ✓̲ | ✓̲ | ✓ | ✓ | ✓ | ✓ | ✓̲ | ✓̲ | ✓ | ✓ | ✓ | ✓ |
| Sediment Quality | | ✓̲ | | | | | | ✓̲ | | | | |
| Phytoplankton | | ✓̲ | | ✓ | | ✓ | | ✓̲ | | ✓ | | ✓ |
| Zooplankton | | ✓̲ | | ✓ | | ✓ | | ✓̲ | | ✓ | | ✓ |
| Benthic Invertebrates | | ✓̲ | | | | | | ✓̲ | | | | |
| Small-bodied Fish – Fish Health and Tissue Chemistry | | ✓̲ | | | | | | ✓̲ | | | | |
| TK Program | | | | | | ✓ | | | | | | ✓ |
| AEMP Annual Report[(d)] | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | |
| Aquatic Effects Re-evaluation Report | | | | ✓ | | | | | | ✓ | | |
| AEMP Design Plan[(e)] | ✓ | | | | | ✓ | | | | | | |

IC = ice-cover season OW = open-water season ✓ = sampling or report required; ✓̲ = underlined check mark indicates that sampling is conducted under the comprehensive sampling program; SRS = soluble reactive silica. TK = traditional ecological knowledge.

a) See Table 3.5-1 for sampling locations and frequency descriptions.

b) Water quality sampling at the mixing zone boundary (SNP 19) is conducted on a monthly basis.

c) Sampling for chlorophyll a and zooplankton biomass is not conducted during the ice-cover season.

d) AEMP Annual Reports will be submitted by 31 March of the following year. For example, the AEMP Annual Report for 2022 will be submitted by 31 March 2023.

e) The schedule for the AEMP Design Plan beyond 2024 is to be determined based on closure activities and WLWB direction.

## 3.6 Quality Assurance / Quality Control Procedures

Quality assurance (QA) refers to plans or programs encompassing internal and external management and technical practices designed to collect data of known quality, and that such collections match the intended use of those data (Environment Canada 2012). Quality control (QC) is an internal aspect of quality assurance. It includes the techniques used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized. QA/QC procedures ensure that all field sampling, laboratory analyses, data entry, and data analysis and report preparation produce technically sound and scientifically defensible results.

Part I, Condition 4 of the Water Licence W2015L2-0001 specifies that DDMI must comply with the approved AEMP Quality Assurance Project Plan (QAPP). Every three years, or as directed by the WLWB, DDMI is required to review and revise the QAPP for WLWB approval. The QAPP was last updated in December 2020 (as Version 4.0; Golder 2020c). The QAPP for the Mine's AEMP encompasses the SNP QA/QC plan. The plan outlines the QA/QC procedures to support the collection of scientifically defensible and relevant data, and to facilitate meeting AEMP objectives. The QAPP outlines the planning, implementation and assessment procedures used to apply specific QA/QC activities and criteria to the AEMP. QA/QC procedures are reviewed and revisited annually to address potential issues arising from the previous year of monitoring.

The QAPP includes the following components:

- field program (e.g., staff training, procedures and responsibilities; Standard Operating Procedures [SOPs])
- sample collection (e.g., equipment calibration and cleaning; avoidance of cross contamination; dust; water; zooplankton; benthic invertebrates; fish; duplicate samples; and field, trip, and equipment blanks)
- documentation (e.g., field logs, labeling; chain of custody)
- sample handling and shipping
- sample analysis (e.g., equipment calibration and cleaning; avoidance of cross contamination; dust; water; zooplankton; benthic invertebrates; fish; duplicate samples; field, trip, and equipment blanks; detection limits [DLs]; analytical spikes)
- assessment of data adequacy and decision rules for acceptance/rejection
- data entry, initial data screening, manipulations and analyses
- report preparation

A brief description of QA/QC procedures for each major component of the program is provided in Section 4.0.

# 4.0 DESCRIPTION OF AEMP COMPONENTS

## 4.1 Traditional Ecological Knowledge

### 4.1.1 TK Framework

The development of a methodology by which TK has been incorporated into the AEMP was initiated at community meetings that took place during the AEMP Version 3.0 (Golder 2011b). During the planning session for the 2018 TK program, participants expressed their satisfaction with the approach taken as an outcome of the community meetings held during the AEMP Version 3.0, and affirmed that they would like to see a similar approach continued for future programs. Therefore, the *AEMP Design Plan Version 6.0* will include a similar role of TK in aquatic monitoring with the aim of identifying potential links between TK and overall mine operations, planning and management.

### 4.1.2 Description of the TK Program

TK is expected to play an important role in both the fish and water quality components of the AEMP. To achieve this imperative, the following objectives have been identified:

- Incorporate significant community participation and input into the design and implementation of the AEMP TK program, including fish palatability and texture studies, and water quality and quantity studies.
- Provide training and capacity-building opportunities for communities.

### 4.1.3 Scheduling for Community Input, Training, and Field Studies

The fish palatability and texture studies and the water quality and quantity studies will be conducted in 2024. Details of when the camp will occur as well as which community members will attend will be discussed at the planning meetings held in 2024, in advance of the camp. Table 4.1-1 presents the schedule for the meetings, training and field studies. This process is similar to that undertaken for the previous TK programs.

**Table 4.1-1: Schedule for the TK Components of the AEMP**

| Timeline | Events | Purpose | Outcome |
|---|---|---|---|
| Spring 2024 | 2024 Planning Meetings | ■ Discuss plans and arrange logistics for studies [(a)].<br>■ Discuss desired outcomes of studies.<br>■ Discuss training and capacity building priorities and goals.<br>■ Review TK questionnaire for studies and methods for documenting and communicating TK.<br>■ Confirm participants, Elders and youth for studies.<br>■ Identify what, if any, special “props” are required by Elders for teaching during studies.<br>■ Review concept of environmental “indicators” as part of monitoring programs.<br>■ Submit applications for required research permits to Aurora Research Institute. | ■ Logistics, plans and methods and documentation for studies reviewed and finalized; includes questionnaires, informed consent, field sheets, TK indicators etc.<br>■ List of participants for studies finalized.<br>■ Desired outcomes of studies finalized.<br>■ Teaching props required for studies identified.<br>■ Training and capacity building priorities and goals identified.<br>■ Permit applications submitted and obtained. |
| August, 2024 | 2024 AEMP Studies | ■ Collection of TK and scientific data on health of fish and water.<br>■ Elder-youth connection and exchange of knowledge.<br>■ Intercultural experience and exchange (including drumming, ceremonies, and storytelling). | ■ Completed Fish Field Forms.<br>■ Completed Water Field Forms.<br>■ Completed Fish Palatability Rating Forms.<br>■ Provided comments and observations as part of Tea Test.<br>■ Shared stories and cultural experiences. |

**Table 4.1-1: Schedule for the TK Components of the AEMP**

| Timeline | Events | Purpose | Outcome |
|---|---|---|---|
| November/ December 2024 | Verification & Finalization Meeting in Yellowknife | ■ Present and seek feedback from communities to support finalization of report with results from studies.<br>■ Gather and evaluative feedback on activities.<br>■ Present documentary film to communities.<br>■ Seek feedback on future AEMP activities. | ■ Finalized video and report to be distributed to community organizations and participants in the new year.<br>■ Questions, comments and revisions of results from studies documented.<br>■ TK data verified, corrected and finalized.<br>■ Studies and activities evaluation process completed.<br>■ Recommendations for future AEMP activities provided for consideration in AEMP Annual Report. |

a) "Studies" refers to the fish palatability and texture studies, and the water quality and quantity studies.
TK = Traditional Ecological Knowledge

# 4.2 Dust Deposition

## 4.2.1 Background

Air and water quality issues associated with airborne fugitive dust caused by mining activities has been identified as being of concern; therefore, a dust monitoring component is required to be included in the DDMI environmental monitoring programs (DDMI 2006b,c). Since dust from the Mine falls into Lac de Gras, the dust deposition monitoring program has been included as a component of the AEMP.

The objective of the dust deposition monitoring program is to monitor the levels of dust fall in the area surrounding the Mine and to confirm EA predictions (DDMI 1998a). More specifically, the program has been designed and implemented to identify:

- total particulate deposition rates (as fixed dust) at various distances from the Mine to compare the observed deposition rates to predictions outlined in DDMI (1998a)
- the physical and chemical characteristics of particulate material that may be deposited into Lac de Gras from mining activities

Dust deposition monitoring has been conducted since 2001. The design of the program for the *AEMP Design Plan Version 6.0* follows the same design as the monitoring programs completed under the AEMP Version 5.2.

## 4.2.2 Field Methods

The dust deposition monitoring program consists of two components: snow surveys and sampling using dustfall gauges. The snow surveys consist of collecting snow core samples to identify the quantity of dustfall during winter and to determine the rate of particulate deposition. Chemical characteristics of the particulate material are determined from a chemical analysis of snow core subsamples. Dustfall collection gauges are used to gather samples of deposited particulate to identify the quantity of dust fall over the course of the monitoring period and to estimate the rate of particulate deposition.

### *4.2.2.1 Snow Cores*

A snow core sample is a cylindrical section of snow obtained by drilling into the snowpack with a snow corer. A snow corer is a hollow tube with a cutting apparatus at the bottom end of the drilling barrel that, when inserted into the snowpack, causes a sample to be pushed into the tube. Multiple core samples will be collected at each survey station, dependent upon snow quantity, to collect a representative snow sample. As in previous years, snow samples will be collected in April of each year. Snow core samples will be collected according to the protocols described in DDMI's SOP ENVR-512-0213.

Snow core samples will be collected along five transects from 27 stations, including three control stations (Figure 4.2-1). The snow sampling stations consist of 11 "on land" locations (including 3 control stations) and 16 "on ice" locations (Table 4.2-1). Composite samples collected at "on ice" stations will be subsampled for snow water chemistry analysis and dust fall deposition analysis. Samples collected at "on land" stations will be analyzed solely for dust fall deposition. Snow water chemistry samples associated with each of the three land-based control stations will also be collected and extra care will be taken to minimize possible contamination associated with soil materials.

Duplicate samples will be collected at three stations for QA/QC purposes. Location of the duplicate samples is randomly selected and, therefore, changes each year. Composite snow core samples collected for the duplicates will also be subsampled to provide the minimum volume of snow water required to conduct sample analyses (Section 4.2.4). There are no trip or field blanks collected for snow cores. One equipment blank is prepared each year using de-ionized water to assess potential for equipment-related contamination of snow samples.

Snow samples collected during the survey will be transported to the on-site environment laboratory where they will be analyzed for fixed dust. Fixed dust is determined by pouring the melted sample through a pre-weighed filter and reweighing the filter following combustion of the sample. The gain in weight is the dry weight of the mineral particulates present in the sample. The dry weight of particulates in each sample is then used to calculate the rates of daily and annual dust fall deposition at each sampling location.

Daily dust fall deposition for each station is calculated as follows:

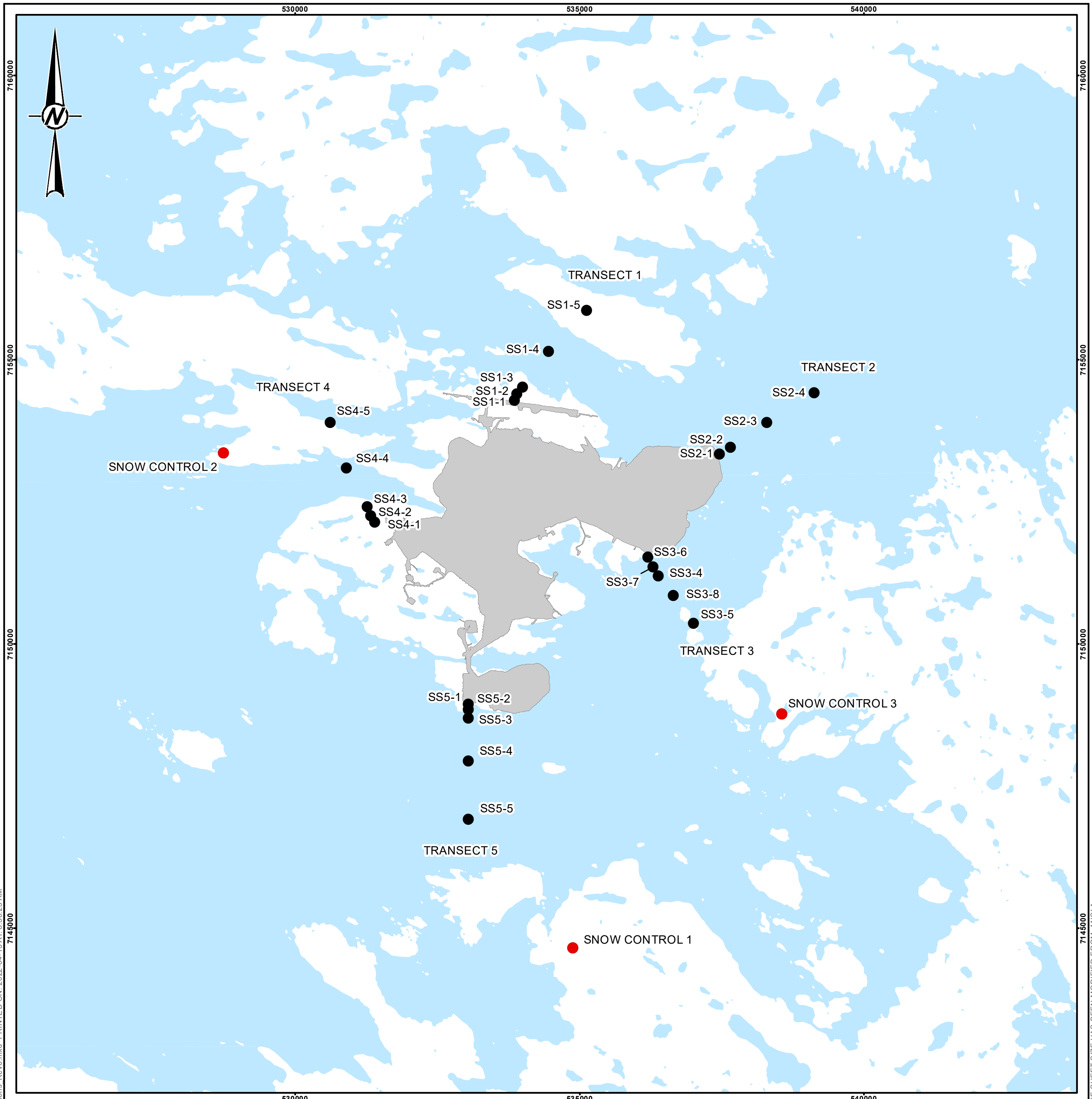
Daily Dustfall Deposition ($mg/dm^2/d$) = (TPM / SA) / TSD

where,

- TPM (milligrams [mg]) = total particulate matter
- SA (square decimetre [$dm^2$]) = surface area of snow sample
  - where, surface area of snow sample = surface area of core ($dm^2$) × no. of cores
- TSD (day [d]) = total snow accumulation days
  - where, "on land" locations = number of days from first snowfall to sample collection
  - "on ice" locations = number of days from freeze-up to sample collection

Annual dust fall deposition for each station will be calculated as follows:

Annual Dustfall Deposition ($mg/dm^2/yr$) = Daily Dustfall Deposition × 365




**LEGEND**

- SNOW CONTROL STATION
- SNOW SURVEY STATION
- DIAVIK FOOTPRINT
- WATER

0 2 4

1:100,000 KILOMETRES

CLIENT

Rio Tinto

PROJECT

AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE

**SNOW SURVEY STATIONS**

CONSULTANT

wsp GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-13 |
| DESIGNED | RS |
| PREPARED | LMS |
| REVIEWED | RS |
| APPROVED | ZK |

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000 | 0 | 4.2-1 |

**REFERENCE(S)**

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

**Table 4.2-1: Snow Survey Stations**

| Transect Line | Station Name | UTM Co-ordinates | | Location Description |
|---|---|---|---|---|
| | | Easting | Northing | |
| 1 | SS1-1 | 533911 | 7154288 | Land |
| | SS1-2 | 533924 | 7154367 | Land |
| | SS1-3 | 533966 | 7154517 | Land |
| | SS1-4[(a)] | 534485 | 7155094 | Ice |
| | SS1-5[(a)] | 535099 | 7156279 | Ice |
| 2 | SS2-1[(a)] | 537553 | 7153473 | Ice |
| | SS2-2[(a)] | 537829 | 7153476 | Ice |
| | SS2-3[(a)] | 538484 | 7153939 | Ice |
| | SS2-4[(a)] | 539151 | 7154685 | Ice |
| 3 | SS3-4[(a)] | 536585 | 7151002 | Ice |
| | SS3-5[(a)] | 537623 | 7150817 | Ice |
| | SS3-6[(a,b)] | 536305 | 7151564 | Ice |
| | SS3-7[(a,b)] | 536344 | 7151366 | Ice |
| | SS3-8[(a,b)] | 536688 | 7150810 | Ice |
| 4 | SS4-1 | 531491 | 7152211 | Land |
| | SS4-2 | 531356 | 7152261 | Land |
| | SS4-3 | 531331 | 7152434 | Land |
| | SS4-4[(a)] | 531141 | 7153167 | Ice |
| | SS4-5[(a)] | 531405 | 7154116 | Ice |
| 5 | SS5-1 | 533150 | 7148295 | Land |
| | SS5-2 | 533150 | 7148875 | Land |
| | SS5-3[(a)] | 533150 | 7148700 | Ice |
| | SS5-4[(a)] | 533150 | 7147950 | Ice |
| | SS5-5[(a)] | 533150 | 7146950 | Ice |
| Control 1 | Control 1 | 534983 | 7144271 | Land |
| Control 2 | Control 2 | 528714 | 7153281 | Land |
| Control 3 | Control 3 | 538650 | 7148750 | Land |

UTM = Universal Transverse Mercator, NAD83, Zone 12V.
a) Stations subsampled for snow water chemistry analysis.
b) Stations added during AEMP Version 3.0.

#### 4.2.2.2 Dustfall Gauges

Dustfall gauges are containers used to collect deposited particulates. Each dust gauge consists of a hollow acrylic cylinder, 52 cm long and 12.7 cm in diameter, surrounded by a fiberglass shield that is the shape of an inverted bell. The shield is placed around the mouth of the gauge to prevent the accumulation of materials that could be carried horizontally by high winds and blowing snow. Dustfall gauge samples will be collected according to the protocols described in DDMI's SOP ENVR-508-0112. Dustfall collection gauges will be placed at 14 stations (including 2 control stations; Figure 4.2-2, Table 4.2-2).

The number and location of the dustfall gauges were recently reviewed and two new dustfall gauges were added to the southwest of the Mine (Dustfall Gauge 11 and Dustfall Gauge 12) as part of Version 4.1 of the AEMP design. These two new dustfall gauges are intended to address potential under-sampling of dust falling southwest of the Mine infrastructure as a result of prevailing winds from the north and east.

Dustfall gauges will be deployed in early January each year and will be retrieved and re-deployed on four occasions over the course of the monitoring year (e.g., in March, June, September and December) before being retrieved for the final time in December. Dustfall gauge retrieval consists of replacing the cylinders in each dust gauge with clean cylinders. The retrieved cylinders will then be processed in the DDMI environment laboratory to determine the quantity of particulate material deposited. There are no trip or field blanks for dustfall samples.

The dry weight measures of particulate matter deposited into dustfall gauges will be used to calculate the rates of daily and annual dustfall deposition for each sampling location.

Daily dustfall deposition at each dustfall gauge station will be calculated as follows:

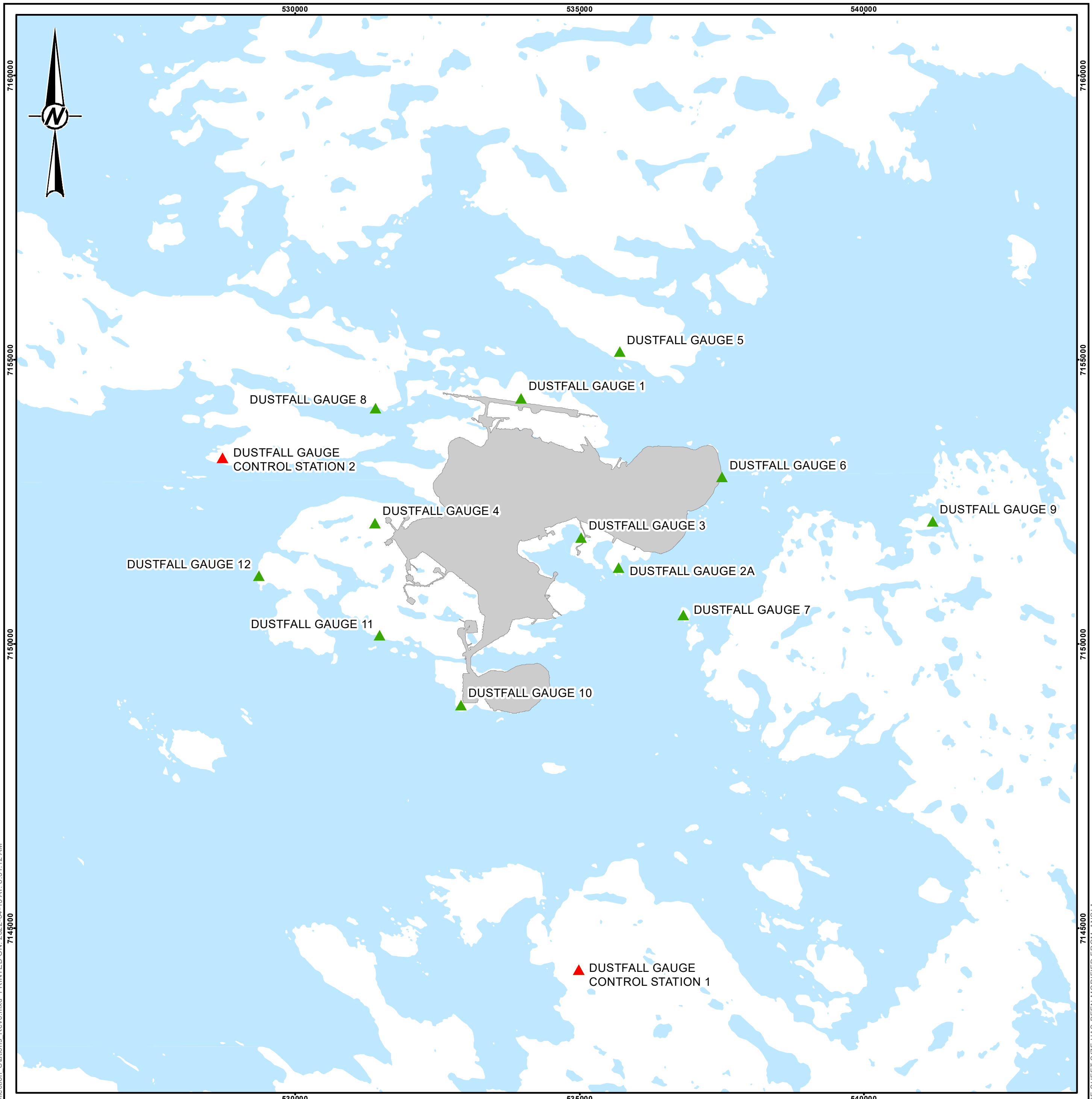
Daily Dustfall Deposition ($mg/dm^2/d$) = (TPM / SA) / TDD

where,

- TPM (mg) = total particulate matter
- SA (dm2) = surface area of dustfall gauge collection tube
- TDD (d) = total days gauge was deployed

Annual dustfall deposition for each station will be calculated as follows:

Annual Dustfall Deposition ($mg/dm^2/yr$) = Daily Dustfall Deposition × 365




**LEGEND**

- DUSTFALL GAUGE LOCATION
- DUSTFALL GAUGE CONTROL STATION LOCATION
- DIAVIK FOOTPRINT
- WATER

0 2 4

1:100,000 KILOMETRES

**REFERENCE(S)**

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

Rio Tinto

PROJECT

AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE

**DUSTFALL GAUGE COLLECTION STATIONS**

CONSULTANT

wsp GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-13 |
| DESIGNED | RS |
| PREPARED | LMS |
| REVIEWED | RS |
| APPROVED | ZK |

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000 | 0 | 4.2-2 |

**Table 4.2-2: Dustfall Gauge Collection Stations**

| Station Name | UTM Co-ordinates | |
|---|---|---|
| | Easting | Northing |
| Dustfall Gauge 1 | 533964 | 7154321 |
| Dustfall Gauge 2A | 535678 | 7151339 |
| Dustfall Gauge 3 | 535024 | 7151872 |
| Dustfall Gauge 4 | 531397 | 7152127 |
| Dustfall Gauge 5 | 535696 | 7155138 |
| Dustfall Gauge 6 | 537502 | 7152934 |
| Dustfall Gauge 7 | 536819 | 7150510 |
| Dustfall Gauge 8 | 531401 | 7154146 |
| Dustfall Gauge 9 | 541204 | 7152154 |
| Dustfall Gauge 10 | 532908 | 7148924 |
| Dustfall Gauge 11 | 531493 | 7150156 |
| Dustfall Gauge 12 | 529323 | 7151191 |
| Dustfall Gauge Control Station 1 | 534979 | 7144270 |
| Dustfall Gauge Control Station 2 | 528714 | 7153276 |

UTM = Universal Transverse Mercator, NAD83, Zone 12V.

### 4.2.3 Laboratory Methods

Composite snow core samples collected from each survey station will be submitted to the contract analytical laboratory for analysis of the same suite of variables listed under "nutrients" and "metals[1]" for water quality variables summarized in Table 4.3-1 of Section 4.3.3. The snow water chemistry samples, however, will not be filtered as this could remove insoluble particulate matter from the snow water. Analysis of the snow water samples will be conducted by an independent analytical laboratory, using the lowest available analytical DLs achieved by a commercial analytical laboratory.

### 4.2.4 Data Analysis and Interpretation

#### *4.2.4.1 Data Screening*

Prior to data analysis, the data set will be screened according to the following steps:

- A summary of all snow core and dustfall gauge information will be produced, which will include sample dates, the variables list and the locations sampled.
- Initial screening of the snow core data set will be completed to identify unusual values and decide whether to retain or exclude anomalous data from further analyses. Screening of dustfall and snow chemistry data employs a Q-test (Z-score) to identify individual data that are greater than three standard deviations (SD) from the arithmetic mean of all data collected at that station. The identification and removal of outliers for dustfall and snow dust data has been very infrequent (e.g., maximum of 2 in any year, and none since 2012).

#### *4.2.4.2 Data Interpretation*

The dust monitoring program is not designed to assess effects in the context used for most of the AEMP components (Section 3.4). Rather, it is intended to monitor the relative level of dust loading in the vicinity of the Mine site. Spatial patterns in dust deposition will be compared qualitatively among years, and in relation to

[1] The term “metal” includes metalloids (e.g., arsenic) and non-metals (e.g., selenium).

changes in mining activity. Chemistry data from the snow water will be used to characterize the chemical content of the dust. Estimates of phosphorus loadings from dustfall will be presented in the AEMP Annual Reports and will be used to evaluate the potential contribution of dustfall deposition to nutrient enrichment in Lac de Gras.

## 4.3 Water Quality

### 4.3.1 Background

Water is a fundamental monitoring medium for the AEMP. Material released from the Mine must enter the water of Lac de Gras before aquatic organisms can become exposed and be potentially affected by Mine-related inputs. Water quality represents a measurement endpoint identified as valuable for early warning monitoring of potential effects related to the Mine (Section 3.2) and, therefore, requires detailed investigation as part of the AEMP.

Water quality monitoring in Lac de Gras has been completed as a component of various monitoring programs since 1994 (e.g., baseline programs; AEMP Versions 1.0 through 5.2; SNP). To the extent possible, sampling methods and laboratory procedures have been retained from baseline to allow comparisons of data over time. However, improvements in analytical DLs and changes to sampling stations have been made to allow the program to meet the goals of the AEMP. The methods for the water quality component for the *AEMP Design Plan Version 6.0* will be the same as those used during previous versions of the AEMP.

The main focus of the *AEMP Design Plan Version 6.0* will be to monitor Mine-related effects over space and time. To this end, water quality samples will be collected throughout Lac de Gras at the stations specified in Section 3.4. In addition, water samples will be collected from effluent from the NIWTP (SNP stations 1645-18, 1645-18B) and from the edge of the mixing zone, located 60 m from the Mine effluent diffusers (SNP stations 1645-19A, B2, C).

### 4.3.2 Field Methods

Sampling will be conducted once during late ice-cover conditions (i.e., April and/or May) and once during open-water conditions (i.e., 15 August to 15 September). Water quality sampling during both the ice-cover and open-water seasons will occur at the same locations as the sampling for other AEMP components (Section 3.4.2). Sampling will occur monthly at the SNP mixing zone stations and annually at the NF and MF exposure stations, according to the schedule presented in Section 3.5. Water quality samples will also be collected annually from Stations FF1-2 and FFD-1 (Section 3.5). This information will be used to characterize the spatial extent of effects along the MF1 transect, which includes stations FF1-2 and FFD-1, on an annual basis. Water samples will be collected from all stations every three years to re-assess the magnitude and extent of effects.

Methods for collecting water samples will be the same as those used in earlier versions of the AEMP, and will include the following steps:

- Vertical profiles of limnological variables (e.g., water temperature, dissolved oxygen [DO], specific conductivity and pH) will be measured using a field-calibrated water quality meter at each station.
- Secchi depth will be measured at each station.
- Water samples will be collected from discrete depths using a Beta Bottle, Van Dorn or Kemmerer water sampling device.
- Depth-integrated water samples will be collected for analysis of phosphorus, nitrogen, and chlorophyll a (see Section 4.5 for details).

- Certified laboratory sample bottles will be used, and each sample will be collected, preserved and stored according to laboratory instructions.
- Water samples will be submitted to an accredited laboratory for analysis.

Sampling will occur at three depths (i.e., 2 m from top of water column, mid-depth, and 2 m from bottom) at each station in the NF and MF areas and at mid-depth in the FF areas (including the two new FF stations, FFD-1 and FFD-2). Sampling will occur at three depths in the NF and MF areas, because the position of the effluent plume may vary with depth in the water column (DDMI 2005, 2011; Golder 2011a, 2016a). Collection of water samples will follow the protocols described in Standard Operating Procedure (SOP) ENVI-923-0119 “AEMP SOP Combined Open Water and Ice Cover”. Water samples will be handled according to ENVI-902-0119 “SOP Quality Assurance Quality Control” and ENVI-900-0119 “SOP Chain of Custody”.

The water quality sampling program will include collection of *in situ* water quality measurements. Water column profile measurements will be collected with a multi-parameter water quality meter following the methods described in ENVI-684-0317 “SOP YSI ProDSS”.

QA/QC specific to this component will include collection of field blanks, trip blanks, equipment blanks and duplicate samples at selected stations during each sampling event. QA/QC samples will comprise about 10% of the total number of samples collected. These samples will be analyzed for the full water quality parameter list. Water quality meters will be calibrated in the field as required by the standard procedures in the QAPP Version 4.0 (Golder 2020c). Detailed results of the QA/QC sampling program will be provided in the AEMP Annual Reports.

### 4.3.3 Laboratory Methods

Water quality samples will be submitted to an accredited analytical laboratory for analyses of the variables listed in Table 4.3-1. Due to the low concentrations of water quality constituents in Lac de Gras, DDMI has historically utilized analytical facilities that can provide the best, most reliable DLs, particularly for trace metals and nutrients. These facilities have a dedicated Inductively Coupled Plasma Mass Spectrometer specifically for ultra-low trace metal analysis. The ultra-low analytical DLs can only be obtained on water samples with very low particulate matter (i.e., turbidity less than 0.5 nephelometric turbidity units [NTU]). The DL for total dissolved solids (TDS, measured) will be adjusted to the level that can be achieved by the analytical laboratory (i.e., from 0.5 to 1 mg/L), which is appropriate as TDS in Lac de Gras is well above 1 mg/L. Only TDS (calculated) is used in the AEMP data analysis, because it has been found to be more reliable than TDS (measured) at the concentrations measured in Lac de Gras.

**Table 4.3-1: Water Quality Variables for the *AEMP Design Plan Version 6.0***

| Variable | Unit | Detection Limit |
|---|---|---|
| **Conventional Parameters** | | |
| Total alkalinity | mg/L | 0.5 |
| Specific conductivity – lab | µS/cm | 1 |
| Total hardness | mg/L | 0.5 |
| pH – lab | pH units | - |
| Total dissolved solids, calculated | mg/L | - |
| Total dissolved solids, measured | mg/L | 1 |
| Total suspended solids | mg/L | 1 |
| Total organic carbon | mg/L | 0.2 |
| Turbidity – lab | NTU | 0.1 |
| **Major Ions** | | |
| Bicarbonate | mg/L | 0.5 |
| Calcium | mg/L | 0.01 |
| Carbonate | mg/L | 0.5 |
| Chloride | mg/L | 0.5 |
| Fluoride | mg/L | 0.01 |
| Hydroxide | mg/L | 0.5 |
| Magnesium | mg/L | 0.005 |
| Potassium | mg/L | 0.01 |
| Sodium | mg/L | 0.01 |
| Sulphate | mg/L | 0.5 |
| **Nutrients** | | |
| Ammonia | µg-N/L | 5 |
| Nitrate | µg-N/L | 2 |
| Nitrite | µg-N/L | 1 |
| Nitrate + nitrite | µg-N/L | 2 |
| Total Kjeldahl nitrogen | µg-N/L | 20 |
| Total dissolved nitrogen | µg-N/L | 20 |
| Total nitrogen | µg-N/L | 20 |
| Soluble reactive phosphorus | µg-P/L | 1 |
| Total dissolved phosphorus | µg-P/L | 2 |
| Total phosphorus | µg-P/L | 2 |

| Variable | Unit | Detection Limit |
|---|---|---|
| **Total Metals** | | |
| Aluminum | µg/L | 0.2 |
| Antimony | µg/L | 0.02 |
| Arsenic | µg/L | 0.02 |
| Barium | µg/L | 0.02 |
| Beryllium | µg/L | 0.01 |
| Bismuth | µg/L | 0.005 |
| Boron | µg/L | 5 |
| Cadmium | µg/L | 0.005 |
| Calcium | mg/L | 0.01 |
| Chromium | µg/L | 0.05 |
| Cobalt | µg/L | 0.005 |
| Copper | µg/L | 0.05 |
| Iron | µg/L | 1 |
| Lead | µg/L | 0.005 |
| Lithium | µg/L | 0.5 |
| Magnesium | mg/L | 0.005 |
| Manganese | µg/L | 0.05 |
| Mercury | µg/L | 0.0019 |
| Molybdenum | µg/L | 0.05 |
| Nickel | µg/L | 0.02 |
| Potassium | mg/L | 0.01 |
| Selenium | µg/L | 0.04 |
| Silicon | µg/L | 50 |
| Silver | µg/L | 0.005 |
| Sodium | mg/L | 0.01 |
| Strontium | µg/L | 0.05 |
| Sulphur | mg/L | 0.5 |
| Thallium | µg/L | 0.002 |
| Tin | µg/L | 0.01 |
| Titanium | µg/L | 0.5 |
| Uranium | µg/L | 0.002 |
| Vanadium | µg/L | 0.05 |
| Zinc | µg/L | 0.1 |
| Zirconium | µg/L | 0.05 |

µS/cm = microsiemens per centimetre; NTU = nephelometric turbidity unit; µg-N/L = micrograms nitrogen per litre; µg-P/L = micrograms phosphorus per litre.

### 4.3.4 Data Analysis and Interpretation

#### *4.3.4.1 Overview*

All water quality variables will be assessed for a Mine-related effect according to Action Levels (Section 5.2.1). This analysis, along with an analysis of constituents in effluent, will be used to select a subset of variables with potential effects. These variables are designated Substances of Interest (SOIs; Section 4.3.4.3). The intent of selecting SOIs is to arrive at a meaningful set of variables that will undergo additional analyses (e.g., statistical testing and trend analysis), while limiting analyses of variables that have no potential to be affected.

The following analyses will be conducted on SOIs in the AEMP reports:

- an examination of loads in Mine effluent, effluent chemistry and toxicity data (i.e., from SNP Stations 1645-18 and 1645-18B; Sections 4.3.4.4 to 4.3.4.6)
- an examination of water chemistry at the edge of the mixing zone (i.e., from SNP Stations 1645-19A, B2, C; Section 4.3.4.7)
- a comparison of lake water quality data at the mixing zone and in the NF, MF, and FF areas with AEMP Effects Benchmarks (Section 5.3.1)
- an assessment of magnitude and extent of effects, as defined by the Action Levels in the Response Framework for water quality (Section 5.2.1)
- an examination of potential effects from dust deposition (Section 4.3.4.8)
- gradient analysis of SOI concentrations along the NF to FF gradients (Section 4.3.4.9). Finding decreasing trends in concentration of a variable (i.e., one that is present in the effluent at a greater concentration compared to lake water) with increasing distance from the diffusers will provide confirmation that changes detected by the Action Level evaluation are related to the Mine water discharge
- for the Aquatic Effects Re-evaluation Report only, a comparison of results for each year with results from previous AEMP cycles. In addition, temporal trend analyses completed as part of Aquatic Effects Re-evaluation Reports will be continued (Section 4.3.4.10)
- for the comprehensive report and the Aquatic Effects Re-evaluation Report only, an evaluation of potential across-project effects in Lac de Gras (Section 6.1)

#### *4.3.4.2 Data Screening*

Prior to data analysis, the data set will be screened according to the following steps:

- A summary of all water quality information will be produced, which will include sample dates, the variable list and the water column depths sampled.
- Initial screening of the AEMP water quality data set will be completed to identify unusually large (or small) values and decide whether to retain or exclude anomalous data from further analyses. An explanation of the objectives and approach taken to complete the initial data screening is provided in the QAPP Version 4.0 (Golder 2020c). The results of the anomalous data screening will be summarized according to the procedures identified in the QAPP.

- Values below the DL will be multiplied by 0.5; substitution with half the DL is a common approach used to deal with censored data (USEPA 2000). The proportion of data below the DL is taken into consideration during subsequent analyses.

#### 4.3.4.3 Substances of Interest

The process of selecting SOIs will consider concentrations in final effluent (Stations SNP 1645-18 and 1645-18B) and in the NF and MF exposure areas:

- Criterion 1: Effluent chemistry data collected at stations SNP 1645-18 and 1645-18B will first be evaluated. Variables with concentrations in individual grab samples greater than Effluent Quality Criteria (EQC) defined in the Water Licence (Section 4.3.4.4) for Maximum Average Concentration will be included as SOIs.
- Criterion 2: Variables with mixing zone concentrations greater than water quality Effects Benchmarks (Section 5.3.1) will be included as SOIs.
- Criterion 3: Variables that trigger Action Level 1 or greater in the Response Framework (Section 5.2.1) will be included as SOIs. Under this criterion, NF median concentration of variables that biomagnify (i.e., mercury and selenium) will be compared to the current detection limit in addition to two times the reference data set median concentrations, resulting in a more stringent comparison for mercury and no change for selenium.
- Criterion 4: Variables that trigger an effect equivalent to Action Level 1 at MF stations that fall within the zone of influence from dust deposition in Lac de Gras will be included as SOIs, where the AEMP sampling stations that fall within the zone of influence from dust deposition include those stations identified in the dust ZOI (Section 4.3.4.8).

#### 4.3.4.4 Effluent Assessment

Treated effluent from the NIWTP is sampled within the NIWTP at SNP 1645-18 and 1645-18B. Station SNP 1645-18 is for the original diffuser in Lac de Gras and station SNP 1645-18B is for the second diffuser, which became operational on 13 September 2009. Sampling is completed approximately every six days at these stations.

The effluent discharged to Lac de Gras will be assessed in terms of quality and quantity. Trends in effluent quantity will be evaluated by plotting discharge volumes and loading rates of constituents in effluent as bar charts. Concentrations in effluent will be evaluated graphically by plotting sample results for the annual effluent discharge period. The quality of the effluent will be assessed by comparing water chemistry results at Stations SNP 1645-18 and SNP 1645-18B with the EQC defined in Part G, Condition 32 of the Water Licence, and in Table 4.3-2. In addition to the criteria listed in Table 4.3-2, Part G, Condition 35 of the Water Licence specifies that authorized discharges to Lac de Gras must have a pH between 6.0 and 8.4. Total phosphorus is the only variable with a discharge criterion specified in terms of load, rather than concentration (Part G, Condition 38 of Water Licence W2015L2-0001). Part G, Condition 38 specifies that the load of TP should not exceed a maximum of 300 kg/month, an average annual loading of 1,000 kg/yr during the life of the Mine, and a maximum loading of 2,000 kg/yr in any year during the life of the mine.

**Table 4.3-2: Effluent Quality Criteria for Effluent Discharged to Lac de Gras**

| Variable | Units | Maximum Average Concentration | Maximum Concentration of Any Grab Sample |
|---|---|---|---|
| Total ammonia | µg-N/L | 6,000 | 12,000 |
| Total aluminum | µg/L | 1,500 | 3,000 |
| Total arsenic | µg/L | 50 | 100 |
| Total copper | µg/L | 20 | 40 |
| Total cadmium | µg/L | 1.5 | 3 |
| Total chromium | µg/L | 20 | 40 |
| Total lead | µg/L | 10 | 20 |
| Total nickel | µg/L | 50 | 100 |
| Total zinc | µg/L | 10 | 20 |
| Nitrite | µg-N/L | 1,000 | 2,000 |
| Total suspended solids | mg/L | 15.0 | 25.0 |
| Turbidity | NTU | 10 | 15 |
| Biochemical oxygen demand | mg/L | 15.0 | 25.0 |
| Total petroleum hydrocarbons | mg/L | 3.0 | 5.0 |
| Fecal coliforms | CFU/100 mL | 10 | 20 |

µg-N/L = micrograms nitrogen per litre; NTU = nephelometric turbidity unit; CFU = colony forming unit.

#### 4.3.4.5 Effluent Toxicity

Part G, Condition 36 and Annex 1 (Surveillance Network Program) of the Water Licence (W2015L2-0001) requires toxicity testing of the effluent discharged to Lac de Gras (i.e., both acute and chronic toxicity testing). The following toxicity testing is completed on a quarterly basis:

- acute lethality to Rainbow Trout, *Oncorhynchus mykiss*, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/13
- acute lethality to the crustacean, *Daphnia magna,* as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/14
- chronic toxicity to the early life stages of salmonid fish, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/28
- chronic toxicity to the crustacean, *Ceriodaphnia dubia,* as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/21
- chronic toxicity to the alga, *Pseudokirchneriella subcapitata*, as per Environment Canada's Environmental Protection Series Biological Test Method EPS/1/RM/25

*Hyalella azteca* chronic toxicity testing was removed from the Water Licence in 2017 and is, therefore, not included in Version 6.0 of the AEMP Design. Chronic toxicity testing with *H. azteca* will only be initiated if the maximum average concentration of total ammonia exceeds 3 mg/L at the point of compliance. Effluent samples will be submitted to an accredited laboratory for toxicity testing. The effluent toxicity data will be used to evaluate whether Mine effluent has the potential to cause toxic responses in biota in Lac de Gras.

#### 4.3.4.6 Effluent Dispersion

Calculated TDS is used as a tracer element of the Mine effluent in Lac de Gras. Calculated TDS was selected as a tracer because it is a relatively conservative water quality variable and TDS concentration in the effluent is relatively high compared to the background concentration in Lac de Gras. Calculated TDS also correlates well with many other water quality SOIs, making it a potentially useful tracer of treated effluent and for representing the general rate of change in concentrations of many SOIs in Lac des Gras.

Calculated TDS concentration will be used to verify the exposure of each area to Mine effluent. During the comprehensive program, calculated TDS concentrations from the ice-cover season will be used to assess the presence and magnitude of exposure of the FF area stations to Mine effluent. FF area stations with calculated TDS concentrations that are greater than the normal range obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c) will be considered affected by effluent from the Mine.

#### 4.3.4.7 Water Chemistry at Edge of Mixing Zone

Water quality samples are collected monthly at the mixing zone boundary at three stations (SNP stations 1645-19A, B2, C), which are located along a semi-circle, 60 m from the effluent diffusers. These stations represent the edge of the mixing zone, which covers an area of approximately 0.01 $km^2$. Samples are collected at surface and at 5 m intervals to the lake bottom at each station. These water chemistry data will be summarized graphically and are considered in the assessment of Action Level 3 (Section 5.2.1).

#### 4.3.4.8 Effects from Dust Deposition in Lac de Gras

Concerns have been raised regarding the potential for dust emissions to affect water quality in Lac de Gras. To address these concerns, the water quality component includes an analysis of effects at stations potentially affected by dust emissions. The zone of influence from dust deposition in Lac de Gras was estimated to be approximately 4 km from the geographic centre of the Mine, or approximately 1 km from the Mine boundary, extending radially from the source. These distances were estimated based on gradient analysis of dust deposition relative to distance from the Mine site and encompass the area of the lake where potential effects would be expected to be measurable (see Figures 3-5 and 3-6 and Table 3-1 in Golder 2016a). Beyond this estimated zone, dust deposition levels are similar to background levels. The AEMP sampling stations that fall within the expected zone of influence from dust deposition include those stations identified in the dust ZOI.

The combined effects from discharge of Mine effluent and potentially dust deposition on water quality in the NF exposure area will be assessed at Action Level 1 in the Response Framework for water quality (Section 5.2.1). As described in Section 4.3.4, variables that trigger Action Level 1 will be included in the detailed effect analyses conducted on SOIs. A similar analysis will be used to evaluate potential effects from dust emissions at affected stations in the MF area. Water quality variables at the aforementioned four MF area stations with median concentrations (i.e., of top, middle, and bottom samples) that exceed two times the reference data set median concentration (i.e., the same criterion used in the assessment of Action Level 1 in the NF area, which is obtained from the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]; Section 5.2.1) will be considered potentially affected by dust emissions (in addition to potential effluent effects), and will be included in the list of SOIs. This comparison would only be done on the open-water season data, because dust deposition to lake water under ice (where samples are collected) is prevented by ice cover during winter. If a variable triggers an effect equivalent to Action Level 1 in the MF area, but not the NF area (i.e., where the concentration of effluent is greatest), it is possible that the effects at these stations may result from dust deposition, or a combination of dust deposition and effluent discharge.

#### 4.3.4.9 Gradient Analysis

The main objective of the gradient analysis will be to evaluate trends in SOI concentrations along the effluent exposure gradients (or transects) represented by the three MF areas in Lac de Gras. Each of the three gradients analyzed will include the NF stations, MF stations and corresponding FF stations. The analysis will be conducted using a combination of graphical and statistical methods.

During interim years, gradients will be assessed based on the NF stations and MF stations, which are sampled annually. The corresponding FF stations will be incorporated into the analysis during comprehensive years only. The exception is that Stations FF1-2 and FFD-1, which are sampled annually for water quality, eutrophication indicators and plankton, will be included in the spatial analysis for the MF1 transect, on an annual basis.

Station LDS-4, located at the narrows between Lac du Sauvage and Lac de Gras, and Station LDG-48, located at the Lac de Gras outflow to the Coppermine River, will be incorporated into the spatial analysis annually. Station LDG-48 will be included in the statistical gradient analysis during comprehensive years, when data for the FFB and FFA areas are available. During interim years, data from station LDG-48 will be considered graphically. Station LDS-4 cannot be included in the statistical analysis because it is located upstream of Lac de Gras and is not influenced by the Mine. Therefore, concentrations at station LDS-4 will be presented graphically to assist in the interpretation of water quality at other AEMP stations.

Spatial gradients will be analyzed using linear regression. Due to the spatial span of the MF3 transect, variables along this gradient may be non-linear with distance from the diffusers; therefore, the analysis will allow for a piecewise regression (also referred to as segmented, or broken stick regression). Three models will be constructed:

- Model 1: a linear multiplicative model, with main effects of distance from diffusers, gradient (MF1, MF2, and M3), and their interaction
- Model 2: a linear multiplicative model, with main effects of distance from diffusers, gradient (only MF1 and MF2), and their interaction
- Model 3: a linear piecewise model with distance of MF3 data only

For each variable in each season, Model 1 will be used to test for presence of a significant ($P<0.05$) breakpoint using the Davies test. If a significant breakpoint is identified, Models 2 and 3 will be used. If no significant breakpoint is identified, Model 1 will be used.

Following the initial fit of the model, the residuals (of either Model 1 or Model 2, as applicable) will be examined for normality. Model 3 will not be used to establish data transformations, since the addition of a breakpoint is expected to resolve non-linear patterns. For each response variable, the data will undergo Box-Cox transformations (Box and Cox 1964).

Box-Cox transformations are a family of transformations that include the commonly used log and square root transformations. The Box-Cox transformation process tests a series of power values, usually between -2 and +2, and records the log-likelihood of the relationship between the response and the predictor variables under each transformation. The transformation that maximizes the log-likelihood is the one that will best normalize the data. Therefore, the data are transformed using a power value identified by the transformation process. For a power value of zero, the data are natural log transformed. The transformation rules can be described using the following definitions:

$$\text{Transformed value} = \frac{\text{value}^{\lambda} - 1}{\lambda} \quad \text{if } \lambda \neq 0$$

$$\text{Transformed value} = \ln(\text{value}) \quad \text{if } \lambda = 0$$

The selected transformation will be applied to all data (i.e., a transformation selected based on Model 2 will also be applied to MF3 data).

Following data transformation (if required), the selected models will be fitted to the data. Statistical outliers will be identified using studentized residuals with absolute values of 3.5 or higher, or due to consideration of leverage (where a single point could strongly influence the overall fit of the model). All values removed from analysis will be retained in the model prediction plots, where they will be shown as a different symbol to identify them as statistical outliers from the rest of the data.

Following removal of outliers, breakpoint significance and data transformation will be re-examined. Residuals from the refitted models will be examined for normality and heteroscedasticity. Three models will be constructed to assess the effect of heteroscedasticity for each response variable in each season:

- heteroscedasticity by gradient (applied only to Models 1 and 2)
- heteroscedasticity by predicted value (accounting for the classic trumpet shape of heteroscedastic data)
- heteroscedasticity by distance from the diffuser

The three heteroscedasticity models will be compared to the original models (i.e., the models that did not account for heteroscedasticity), using Akaike's information criterion (AIC), corrected for small sample size (AICc). The model with the lowest AICc among a set of candidate models will be interpreted to have the strongest support, given the set of examined models and the collected data (Burnham and Anderson 2002), and thus will be selected for interpretation. If using AIC, not corrected for small sample size, models with AIC scores within 2 units of each other are considered to have similar levels of support (Arnold 2010). Since the small sample size correction will be used in the analysis, where appropriate, the cut-off value will be adjusted to reflect the higher penalization of model parameters (i.e., the adjustment will depend on the number of data points and model parameters).

The constructed models will be used to produce the following outputs:

- Estimates and significance of slopes (i.e., distance effects) for each gradient. In the case of MF3 data, which will use a piecewise regression, the significance of the first slope, extending from the NF to the breakpoint, will be calculated.
- The $r^2$ value of each model will be used to examine the explained variability.
- Fitted prediction lines and 95% confidence intervals (back-transformed to original scale of the variable) will be presented.

All analyses will be performed using the R statistical environment and "segmented" package (Muggeo 2003). Data will be plotted by gradient for each SOI, with regression lines superimposed on the plots.

#### 4.3.4.10 Temporal Trend Analysis

For the Aquatic Effects Re-evaluation Report, time series plots will be generated for each SOI for each season using available data from 1996 to the latest available comprehensive year data set. These plots will represent extensions to those already developed as part of previous re-evaluation reports and will show data in each sampling area in relation to the normal range for Lac de Gras. Normal ranges for Lac de Gras are presented in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c). Stations FFD-1 and FFD-2 will be excluded from the trend analysis because these stations are not part of established sampling areas of Lac de Gras, and because there are no long-term data for these locations.

Linear mixed effects models will be used to analyze temporal trends. The temporal trend analysis will focus on areas and stations with available long-term data. The models will include both stations and areas since in the case of NF and FF areas, the stations within the areas may be subject to similar levels of exposure to the effluent. Stations within the MF areas are subject to varying levels of exposure to the effluent, which necessitates the selection of individual stations in the analysis. Mixed effects models will comprise two constituents: fixed variables (i.e., time and area/station) and random variables (i.e., station within area [applicable for NF and FF areas]). The use of random variables will allow for variability in the different data components to be correctly assigned (i.e., to stations within areas, instead of to areas). Since this analysis is focused on temporal trends, the distance of stations from the diffuser and the ordinality of the stations along the gradients are not considered. Instead, temporal trends estimated by the model are interpreted within each station, and trends will be compared between stations using multiple comparisons following the modeling step. All analyses will be performed using the R statistical environment and nlme package (Pinheiro et al. 2017).

The linear mixed effects model analysis will proceed as follows (although component-specific deviations may be necessary):

1) Data transformations will be applied, when necessary, to normalize residuals, as required by model assumptions.
2) The data will be used to fit a set of candidate models and the best-supported model will be selected.
3) Outliers will be removed when necessary; if outliers are removed, steps 1 and 2 will be repeated.
4) Heteroscedasticity (i.e., inequality of variance in errors or residuals) will be examined, and if there is heteroscedasticity after data transformation and outlier removal, heteroscedasticity terms will be added to the best-supported model.
5) Autocorrelation will be examined, and if there are signs of autocorrelation between residuals, an autocorrelation term will be added to the model.
6) The final model will be examined for normality and heteroscedasticity of residuals (i.e., normality of the distribution of errors and equality of variance across fitted values, sampling stations/areas, and years).
7) The final models, which meet assumptions of normality and homoscedasticity, and fit of the observed data, will be used to predict annual values at each station/area, and the results will be used to interpret temporal and spatial trends.

Details of the trend analysis will be provided in the Aquatic Effects Re-evaluation Report.

#### *4.3.4.11 Censored Data*

Observations below the analytical DL are considered censored data. Censored data can potentially bias summary statistics calculated using parametric statistics, because of violation of underlying assumptions. Based on United States Environmental Protection Agency (USEPA) guidance, a screening value of greater than 15% censoring will be used to flag data sets that may require an alternative data analysis method (USEPA 2000). The decision of how to analyze the data sets, however, will be determined on a variable-by-variable basis during data analysis. The intent of this process will be to select the appropriate method for each variable and season, based on the amount of censoring within each data set.

## 4.4 Sediment Quality

### 4.4.1 Background

The amount of metals in sediments provides information regarding chemical stressors present in the sediments and may help explain effects observed on benthic invertebrates. Sediment particle size distribution is an important factor influencing benthic community structure. Total organic carbon (TOC) aids in assessing occurrence and potential bioavailability of metals in sediment and food availability to benthic invertebrates. Therefore, an objective of the sediment survey will be to provide supporting environmental information for the interpretation of results obtained in the benthic invertebrate community survey.

A second objective will be to assess the effects of Mine effluent on sediment quality. Sediment data will be analyzed to evaluate potential spatial trends in sediment quality, and whether those trends explain patterns observed in the benthic invertebrate community.

### 4.4.2 Field Methods

Sediment sampling will be conducted at the same locations as the other AEMP components (Section 3.4) and will take place once every three years, during the comprehensive sampling program, when all AEMP components will be sampled and analyzed (Section 3.5). Sediment will be sampled concurrently with AEMP benthic invertebrate sampling (i.e., between 15 August and 15 September). In addition, sediment cores will be collected every year at the mixing zone boundary (SNP Stations 1645-19A, B2, C). Similar to methods employed during previous versions of the AEMP, sediment samples will be collected by Ekman grab and core sampling according to the protocols described in DDMI’s ENVI-923-0119 “AEMP SOP Combined Open Water and Ice Cover”.

#### *4.4.2.1 Grab Samples*

An Ekman grab will be used to collect samples for particle size and TOC analyses. Prior to sampling at each station, all sampling equipment will be rinsed with ambient water to remove any residual material from sampling at the previous station. A composite sample (consisting of five Ekman grabs; top 10 to 15 cm) will be collected from each replicate station during benthic invertebrate sampling. This will be done using a clean trowel to scoop the material. The material from each of the five grabs will be placed in a pre-cleaned plastic bucket and mixed thoroughly. The composite sample will be transferred to two pre-labeled bags provided by the analytical laboratory. These bags will then be refrigerated at 4°C for storage and shipping. As per QA/QC protocols under the QAPP, duplicate samples will be collected from approximately 10% of the sediment stations.

#### 4.4.2.2 Core Samples

A gravity-feed core sampling device (as described in DDMI's SOP, ENVR-003-0702 "AEMP Ice-cover and Open-water Sampling") will be used to collect sediment samples for the analysis of metals, total nitrogen (TN) and TP. This device will be equipped with an extruder mechanism to extract the contents of the corer. Prior to sampling, the core tubes and seals will be washed with phosphate-free, biological disinfectant soap and rinsed several times with deionized water. The tubes will then be rinsed with 10% nitric acid and rinsed several more times with deionized water. The sediment corer will be cleaned with ambient water prior to and between sample collections, as well as after use at each station, to remove residual material.

Once collected, each intact sediment core will be photographed inside the core tube and notes will be made regarding the length of the core, and the colour and character of the sediment. The top 1 cm from three cores collected at each sampling location will be placed into a pre-labeled bag provided by the analytical laboratory. At this point, if the bag does not contain sufficient sample, additional cores will be collected to provide sufficient material for analysis. Once a enough sediment has been collected, it will be mixed until the samples are uniform in colour and texture (i.e., a homogeneous composite sample). These bags will then be refrigerated at 4°C for storage and shipping. As per QA/QC protocols outlined in the QAPP, additional cores will be taken to collect duplicate samples at approximately 10% of the total number of sediment sampling stations. Detailed results of the QC sampling program will be provided.

### 4.4.3 Laboratory Methods

Sediment samples will be submitted to an accredited analytical laboratory for analysis. Ekman grab samples will be analyzed for TOC, moisture content and particle size distribution (i.e., supporting variables for the benthic invertebrate survey). Sediment core samples will be analyzed for metals and nutrients. The target DLs for sediment analysis are listed in Table 4.4-1. These have been adjusted to the lowest values achievable by the analytical laboratory, after verifying that increased DLs will not interfere with detecting concentrations known to be characteristic of Lac de Gras based on the 2016 AEMP sediment quality data set.

**Table 4.4-1: Sediment Quality Variables for the AEMP Design Plan Version 6.0**

| Sample Type | Variable | Unit | Detection Limit |
|---|---|---|---|
| **Ekman Grab (Top 5-cm)** | **Nutrients** | | |
| | Total organic carbon | % dw | 0.05 |
| | **Particle Size and Moisture Content** | | |
| | Sand (2.0 mm to 0.063 mm) | % dw | 2 |
| | Silt (0.063 mm to 0.004 mm) | % dw | 2 |
| | Clay (<0.0004 mm) | % dw | 2 |
| | Moisture | % | 0.3 |
| **Sediment Core (Top 1-cm)** | **Nutrients** | | |
| | Total organic carbon | % dw | 0.05 |
| | Total nitrogen | % dw | 0.2 |
| | Total phosphorus | mg/kg dw | 10 |
| | **Total Metals** | | |
| | Aluminum | mg/kg dw | 100 |
| | Antimony | mg/kg dw | 0.1 |
| | Arsenic | mg/kg dw | 0.2 |
| | Barium | mg/kg dw | 0.1 |
| | Beryllium | mg/kg dw | 0.2 |
| | Bismuth | mg/kg dw | 0.1 |
| | Boron | mg/kg dw | 1 |
| | Cadmium | mg/kg dw | 0.05 |
| | Calcium | mg/kg dw | 100 |
| | Chromium | mg/kg dw | 0.5 |
| | Cobalt | mg/kg dw | 0.1 |
| | Copper | mg/kg dw | 0.5 |

| Sample Type | Variable | Unit | Detection Limit |
|---|---|---|---|
| **Sediment Core (Top 1-cm)** | **Nutrients** | | |
| | Cadmium | mg/kg dw | 0.05 |
| | Calcium | mg/kg dw | 100 |
| | Chromium | mg/kg dw | 0.5 |
| | Cobalt | mg/kg dw | 0.1 |
| | Copper | mg/kg dw | 0.5 |
| | Iron | mg/kg dw | 100 |
| | Lead | mg/kg dw | 0.1 |
| | Lithium | mg/kg dw | 0.5 |
| | Magnesium | mg/kg dw | 100 |
| | Manganese | mg/kg dw | 0.2 |
| | Mercury | mg/kg dw | 0.05 |
| | Molybdenum | mg/kg dw | 0.1 |
| | Nickel | mg/kg dw | 0.5 |
| | Potassium | mg/kg dw | 100 |
| | Selenium | mg/kg dw | 0.5 |
| | Silver | mg/kg dw | 0.05 |
| | Sodium | mg/kg dw | 100 |
| | Strontium | mg/kg dw | 0.1 |
| | Thallium | mg/kg dw | 0.05 |
| | Tin | mg/kg dw | 0.1 |
| | Titanium | mg/kg dw | 1 |
| | Uranium | mg/kg dw | 0.05 |
| | Vanadium | mg/kg dw | 1 |
| | Zinc | mg/kg dw | 1 |

<= less than; mm = millimetre;% dw = percent dry weight; mg/kg dw = milligrams per kilogram dry weight.

### 4.4.4 Data Analysis and Interpretation

Initial screening of the AEMP sediment quality data set will be completed before data analyses using the procedures described for the water quality component in Section 4.3.4.2. Sediment quality variables will be assessed for a Mine-related effect according to defined Action Levels (Section 5.2.2), with the exception of percent moisture. Percent moisture is not relevant to sediment chemistry data analysis, which uses data provided on a dry weight basis. All variables with spatial trends consistent with a Mine-related effect in Lac de Gras (i.e., exhibiting a trend of decreasing concentration with distance from the Mine effluent diffusers; or an elevated concentration in the NF area compared to the FF areas) will be retained as SOIs and included in gradient analysis, which will use the methods described in Section 4.3.4.9 for the water quality component.

The physical characteristics of sediments (i.e., TOC, and particle size expressed as percent fines) have the potential to influence sediment chemistry. To address this potential confounding factor, visual evaluation of scatter plots and Pearson correlation analysis will be used to investigate relationships between these physical variables and sediment chemistry variables, including metals and nutrient variables. This analysis will also serve as a QC step to verify that known relationships among sediment variables (e.g., between TN and TOC, percent fines and many metals) are observed as expected. If the data do not meet normality assumptions of parametric (Pearson) correlation analysis, the Spearman rank correlation coefficient ($r_s$) will be used for this analysis. Correlations of SOIs with physical variables will be considered significant at $P < 0.05$. All non-detect values will be removed from the data set prior to calculating the correlations, as well as previously identified anomalous data. No grouping will be performed prior to analysis; therefore, each individual concentration (representing a composite sample from a station) will be used in the analysis. Variables with strong correlations to TOC or percent fines will be normalized to the relevant physical variable before statistical analysis.

Elevated metal concentrations have the potential to influence the benthic invertebrate community. Therefore, sediment quality data (i.e., the un-normalized data) will be compared against the AEMP Effects Benchmarks defined in Section 5.3.2.

Finally, as part of aquatic effects re-evaluation, temporal trend analysis of the sediment data will follow the methods described in Section 4.3.4.10 for the water quality component.

## 4.5 Eutrophication Indicators

### 4.5.1 Background

An increase in trophic status (a classification of productivity) in up to 20% of Lac de Gras as a result of nutrient enrichment was one of the principal effects predicted to occur as a result of the discharge of Mine effluent (DDMI 1998a). As required by Water Licence W2015L2-0001, DDMI has been monitoring indicators of eutrophication in Lac de Gras as a component of the AEMP since 2007. The overall objective of the eutrophication indicators component is to determine if effluent from the Mine is having an effect on concentrations of nutrients, chlorophyll *a*, and phytoplankton and zooplankton biomass in Lac de Gras. To this end, samples for nutrients, chlorophyll *a* and zooplankton biomass will be collected throughout Lac de Gras at the stations specified in Section 3.4, and plankton biomass data generated by the plankton component will be included in the data analysis. Potential plankton community level effects, as evaluated by the plankton component, will also be considered in the interpretation of results for this component.

### *Change to Evaluated Variables for Zooplankton*

The Eutrophication Indicators section of the *2017 to 2019 Aquatic Effects Re-evaluation Report* (Golder 2020d) evaluated relationships between biological variables used as eutrophication indicators, and showed strong linear relationships between zooplankton biomass measured as ash-free dry mass (AFDM) and based on enumeration (Section 7.3.4.1). A strong overall relationship was found ($r$ = 0.81) despite using different samples for each method to estimate biomass; i.e., separate samples collected from the same stations at the same time were used in the analysis, rather than analyzing taxonomy and AFDM in the same samples, which would be expected to yield an even stronger relationship. Relationships within individual years were moderate to strong between 2009 and 2019 ($r$ values ranging from 0.55 to 0.90). Based on this information, Golder (2020d) commented that zooplankton biomass measured as AFDM could be removed as a eutrophication indicator variable, because it is redundant with zooplankton biomass based on enumeration.

This comment was highlighted by EMAB during the public review of the re-evaluation report, and EMAB indicated that they agreed with DDMI's recommendation (EMAB comment 25, as summarized by WLWB 2022b). Although this recommendation was not formally made in the *2017 to 2019 Aquatic Effects Re-evaluation Report*, the WLWB indicated in the Reasons for Decision attached to their letter of 31 January 2022, that DDMI could include this proposed change along with supporting rationale in Version 6 of the AEMP Design Plan (WLWB 2022b). In accordance with the WLWB's suggestion, and based on the rationale provided by Golder (2020d) and summarized above, the removal of zooplankton biomass as AFDM has been included in this Design Plan to allow full review of this recommended change. The methods provided below do not include zooplankton biomass as AFDM, but rather assume that biomass based on enumeration, as reported by the Plankton component, will be used to represent zooplankton biomass in the eutrophication indicators analysis under *AEMP Design Plan Version 6.0*.

## 4.5.2 Field Methods

Sampling for nutrients will be conducted once during the late ice-cover season (i.e., April and/or May) and once during the open-water season (i.e., 15 August to 15 September). Sampling for chlorophyll *a* will occur during the open-water season only. Water quality sampling during both the ice-cover and open-water seasons will be conducted at the same locations as the sampling for other AEMP components (Section 3.4). Sampling will be conducted in the NF and MF areas, including Stations FF1-2 and FFD-1, on an annual basis and in the remaining FF areas and at LDS-1 every three years during the comprehensive sampling program, according to the schedule presented in Section 3.5.

During the ice-cover season, water samples for nutrients from the NF and MF areas will be collected from three depths (i.e., top, middle and bottom). Three depths are sampled in these areas because vertical gradients in water chemistry have been observed as a result of the Mine discharge. Water samples will be collected from the middle of the water column in the FF areas and at Stations LDS-4 and LDG-48.

During the open-water season, depth-integrated samples will be collected for nutrients and chlorophyll *a* from all sampling areas, as described in Table 3.5-1, to provide a better estimate of the concentrations of nutrients to which phytoplankton are exposed. Depth-integrated samples will be collected from the top 10 m of the water column. At Stations LDS-4 and LDG-48, one discrete sample will be collected at mid-depth from each station.

Twelve subsamples (or depth-integrated grabs) will be collected at one time and combined into a collection jar to form a sample. Aliquots from this collection jar will be placed into chlorophyll *a* and nutrient jars provided by the laboratories. A second set of twelve subsamples will be collected and combined into a collection jar to form a second sample. Aliquots from this collection jar will be placed into chlorophyll *a* and nutrient jars to produce duplicate samples for analysis. Phytoplankton and zooplankton biomass data (as biovolume) will be generated by the plankton component (Section 4.6).

Sample collection will follow the protocols described in ENVI-923-0119 "AEMP SOP Combined Open Water and Ice Cover". Water samples will be handled according to ENVI-902-0119 "SOP Quality Assurance Quality Control" and ENVI-900-0119 "SOP Chain of Custody".

QC specific to this component will be similar to that of the water quality component (Section 4.3.2). The procedures outlined in the QAPP will verify that field sampling, laboratory analysis, data entry, data analysis and report preparation activities produce technically sound and scientifically defensible results. Detailed results of the QC sampling program will be provided in the report.

### 4.5.3 Laboratory Methods

Nutrient samples will be submitted to an accredited analytical laboratory for analyses of the variables listed in Table 4.5-1. The determination of chlorophyll *a* and plankton biomass will be conducted by a qualified laboratory.

**Table 4.5-1: Eutrophication Indicators for the *AEMP Design Plan Version 6.0***

| Variable | Unit | Detection Limit |
|---|---|---|
| **Biomass Indicators** | | |
| Chlorophyll *a* | µg/L | 0.05 |
| Phytoplankton biomass as biovolume[(a)] | mg/m$^3$ | - |
| Zooplankton biomass based on enumeration[(a)] | mg/m$^3$ | - |
| **Nutrients** | | |
| Total phosphorus | µg-P/L | 2 |
| Total dissolved phosphorus | µg-P/L | 2 |
| Soluble reactive phosphorus | µg-P/L | 1 |
| Soluble reactive silica | µg/L | 5 |
| Total nitrogen | µg-N/L | 20 |
| Total dissolved nitrogen | µg-N/L | 20 |
| Ammonia | µg-N/L | 5 |
| Nitrate | µg-N/L | 2 |
| Nitrite | µg-N/L | 1 |
| Nitrate + nitrite | µg-N/L | 2 |
| Total Kjeldahl nitrogen | µg-N/L | 20 |
| Dissolved Kjeldahl nitrogen | µg-N/L | 20 |

a) Phytoplankton and zooplankton biomass data will be obtained from the Plankton component.

µg/L = micrograms per litre; mg/m$^3$ = milligrams per cubic metre; µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre.

### 4.5.4 Data Analysis and Interpretation

Initial screening of the eutrophication indicators data set will be completed before data analyses begins, using the procedures described for the water quality component (Section 4.3.4.2). Censored data will be handled as described by the water quality component in Section 4.3.4.11.

Nutrients in the effluent and the mixing zone will be evaluated graphically by plotting the total monthly loads. The daily load from each diffuser will be calculated by multiplying the effluent discharge rate by the nutrient concentration at each effluent diffuser station (i.e., SNP 1645-18 and SNP 1645-18B). The total daily load will be calculated as the sum of loads from the two diffusers. Total monthly loads represent the sum of the total daily loads for a given month. Time series plots will show the concentrations of nutrients in effluent and at the mixing zone boundary.

Spatial analysis of the data will be conducted for biomass indicators and selected nutrient variables (i.e., TP, TN, total dissolved phosphorus, soluble reactive phosphorus, soluble reactive silica, total dissolved nitrogen, ammonia, and nitrate + nitrite) using the gradient analysis methods described for the water quality component (Section 4.3.4.9). Station LDG-48, located at the outlet of Lac de Gras into the Coppermine River and Station LDS-4, located in the narrows between Lac du Sauvage and Lac de Gras will be included in the spatial analysis, as described in Section 4.3.4.9.

The spatial extent of Mine effects will be determined by comparing the concentrations of TP, TN, chlorophyll *a*, and zooplankton and phytoplankton biomass in each sampling area to the normal range (as defined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]). To provide the most conservative view of effluent effects, the depth with the greatest extent of effects will be selected for this evaluation. Both seasons (i.e., ice-cover and open-water) will be evaluated. Based on the extent of effects, the area of the lake represented by the affected stations will be estimated. This will include evaluation of FF1-2 and FFD-1. Maps will be provided to illustrate the spatial extent of effects in Lac de Gras for each variable assessed. The maps for chlorophyll *a* and TP will also show the lake area where the concentration representing 25% of the difference between the top of the normal range and the Effects Benchmark is exceeded (i.e., the Action Level 3 criterion). In the event that Action Level 3 is exceeded for chlorophyll *a* or TP, this plot would change to allow evaluation of the next Action Level criterion, and subsequently may change again, as required by the Action Level criteria.

To assess potential effects from dust emissions, phosphorus concentrations at stations within the estimated zone of influence from dust deposition (see Section 4.3.4.8) will be evaluated graphically and compared to results at other nearby stations and to reference conditions for Lac de Gras (as defined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]). If phosphorus concentrations at the potentially dust-affected stations are elevated beyond the expected range based on exposure to effluent alone, this may indicate an additional effect from dust deposition.

The percentage change from baseline and the previous year will be calculated for each eutrophication indicator as part of the annual analyses. Median value will be calculated for each eutrophication indicator, for each area (i.e., NF, MF1, MF2-FF2, MF3, and LDG-48) and season (i.e., ice-cover and open-water). The baseline median will be taken from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c).

In the comprehensive year report, relationships among eutrophication indicators will be explored using Pearson correlations. A spatial analysis of TN, TDS, and chlorophyll *a* across the spatial extent of increased chlorophyll *a* in Lac de Gras will be included as part of the comprehensive reports. This evaluation will consider relationships among these variables across the spatial extent of the increased chlorophyll *a* in Lac de Gras. The relationships between phytoplankton biomass and chlorophyll *a* concentrations will also be examined. Molar nutrient ratios will be calculated for each station in Lac de Gras and plotted to evaluate spatial variation in Lac de Gras. Nutrient limitation will be evaluated by comparing the N to P ratios calculated for Lac de Gras to those reported by Hecky et al. 1993 and Redfield (as described in Wetzel 2001).

For the Aquatic Effects Re-evaluation Report, the size of the affected area of the lake will be compared to the affected areas calculated in previous years (Golder 2011a, 2016b). Temporal trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10).

## 4.6 Plankton

### 4.6.1 Background

“Plankton” is a general term that refers to both phytoplankton and zooplankton. In the context of the AEMP, “phytoplankton” refers to the pelagic, or open-water, algal component (i.e., cyanobacteria, chlorophytes, chrysophytes, cryptophytes, euglenophytes, dinoflagellates and diatoms) and does not include the microbial component. The term “zooplankton” refers to crustaceans (i.e., cladocerans and copepods) and rotifers.

The treated effluent discharged into Lac de Gras is expected to result in changes to the phytoplankton community. Increased concentrations of nutrients, particularly phosphorus, are linked to increased primary productivity (Wetzel 2001). An increase in primary productivity may also lead to a change in phytoplankton community composition, which may result in alteration of the zooplankton community composition. Zooplankton community structure is largely determined by the presence or absence of fish, but it can also be affected by changes in phytoplankton community composition.

### 4.6.2 Field Methods

Sampling for the plankton component of the AEMP will occur at the same locations as the sampling for other AEMP components (see Section 3.4), with the exceptions of zooplankton biomass samples which will not be collected at LDG-48 and LDS-4 because it is characterized by shallow, flowing water and is ecologically dissimilar to the open-water lake habitat represented by other AEMP stations. The full plankton program will be undertaken during the comprehensive sampling program of the AEMP, which will occur once every three years (Section 3.5). Sampling in the NF and MF (including FF2) areas of Lac de Gras will occur on an annual basis to allow a full evaluation of Action Levels 1 and 2 for biological effects (Section 5.2.4), in the event of an Action Level 1 trigger during an interim monitoring year. Sampling for plankton will also occur annually at Stations FF1-2 and FFD-1 (Section 3.5). This information will be used to characterize the spatial extent of effects along the MF1 transect, which includes stations FF1-2 and FFD-1, on an annual basis. In addition, phytoplankton and zooplankton samples will be collected at one station in Lac du Sauvage (LDS-1) upstream of the outlet. Phytoplankton samples will be collected at the Lac de Gras outlet to the Coppermine River (LDG-48) and at the narrows (LDS-4), where the Lac du Sauvage outflow enters Lac de Gras.

Plankton sampling will be undertaken in conjunction with the sampling for indicators of eutrophication (Section 4.5.2) and in accordance with the relevant ENVI-923-0119 “AEMP SOP Combined Open Water and Ice Cover”. Phytoplankton will be sampled using a depth integrated sampler, which collects water from the surface to a depth of 10 m. Twelve depth-integrated samples from each station will be composited into a collection jar, and an aliquot from this jar will be placed into a bottle for phytoplankton taxonomy. Duplicate zooplankton samples will be collected at each station using a 75 µm mesh plankton net with a mouth diameter of 30 cm. A sample will consist of a single vertical haul taken from a depth of 1 m above the lake bottom.

Phytoplankton taxonomy samples will be field-preserved according to laboratory requirements and will be kept cool, but not frozen. Each zooplankton sample will be treated with one-half of an Alka-Seltzer tablet to prevent the zooplankton from contorting, which makes taxonomic identification difficult. The samples will then be preserved with 10% buffered formalin and kept cool, but not frozen.

Following the procedures outlined in the QAPP Version 4.0 (Golder 2020c) will verify that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically sound and scientifically defensible results. Detailed results of the QC sampling program will be provided in the AEMP Annual Reports.

### 4.6.3 Laboratory Methods

#### *4.6.3.1 Phytoplankton*

Phytoplankton samples will be submitted to a qualified taxonomist for analysis of taxonomic composition as both abundance and biomass. Samples will be analyzed according to the methods summarized below.

Aliquots of 7 mL of the preserved phytoplankton samples will be allowed to settle overnight in sedimentation chambers following the procedure of Lund et al. (1958). Algal units will be counted from randomly selected transects on an inverted microscope. Counting units will be individual cells, filaments or colonies, depending on the organization of the algae. A minimum of 400 units will be counted for each sample. The majority of the samples will be analyzed at 500 times magnification (500×), with initial scanning for large and rare organisms (e.g., *Ceratium* sp.) completed at 250×. Taxonomic identifications will be based on current literature, taxonomic keys and nomenclature.

Fresh weight biomass will be calculated from recorded abundance and specific biovolume estimates based on geometric solids (Rott 1981), assuming a specific gravity of 1. The biovolume (cubic millimetres per cubic metre [$mm^3/m^3$] wet weight) of each species will be estimated from the average dimensions of 10 to 15 individuals. The biovolumes of colonial taxa will be based on the number of individuals within each colony.

#### *4.6.3.2 Zooplankton*

Zooplankton samples will be submitted to a qualified taxonomist for analysis of taxonomic composition. Samples will be analyzed for both abundance and biomass of crustaceans and rotifers according to the methods summarized below:

- Fractions (1/40 or 1/80) of each sample will be examined under a compound microscope at 63× to 160×, and all specimens of crustaceans and rotifers will be identified to the lowest taxonomic level (typically species) and assigned to size categories as indicated in the species list.
- A second fraction will be examined under a stereoscope at 12× for the large species (i.e., Heterocope septentrionales, Holopedium gibberum, Daphnia middendorffiana, and D. longiremis) and rare species (e.g., Eubosmina longispina, Diaptomus ashlandi, Epischura nevadensis, Chydorus sphaericus, and Cyclops capillatus), which will be enumerated and assigned to size classes.
- The entire sample will be examined under the stereoscope to improve abundance estimates for the largest species (i.e., adult male and female *Heterocope septentrionales, Holopedium gibberum, Daphnia middendorffiana* and *D. longiremis*).

All Cyclopoida and Calanoida specimens (mature and immature) will be identified to the species level, with the exception of nauplii, which will be classified as either Calanoida or Cyclopoida, as appropriate. Cladocera will be identified to the species level, and rotifers will be identified to genus. Zooplankton abundance will be reported as individuals per litre (ind/L). Taxonomic identifications will be based primarily on Brooks (1957), Wilson (1959) and Yeatman (1959).

Biomass estimates for each taxon will be obtained using mean adult sizes determined during the analysis of the 2007 zooplankton samples (Golder 2008a) and length-weight regression equations developed by Malley et al. (1989). Additional measurements will be made on newly encountered species and to validate consistency of adult sizes. Biomass of non-planktonic species that can be found in zooplankton samples (e.g., *Lepidurus couesii*, incidental Chironomidae and Trichoptera larvae) will not be determined.

#### *4.6.3.3 Quality Control*

Approximately 10% of both the phytoplankton and zooplankton samples will be re-counted by the same taxonomist to verify counting efficiency. The data will be entered into electronic format by the taxonomist and will be double-checked by the same taxonomist upon entry; errors will be corrected as necessary before transferring the electronic files to DDMI. The inherent variability associated with plankton samples makes the establishment of a definite QC threshold value difficult. For the purposes of the plankton QC, samples will be flagged if there is a >50% difference in total biomass and total abundance between the original results and duplicate samples. In addition, the proportion of each taxon will be calculated, and the occurrence of dominant species will be assessed for consistency between the field samples and duplicate samples analyzed for QC purposes. The QC data will be evaluated on a case by case basis, as some level of within-site variability is expected for plankton samples.

### 4.6.4 Data Analysis and Interpretation

The following methods will be used to summarize both the phytoplankton and zooplankton data:

- Abundance and biomass data will be divided into major taxonomic groups.
- Relative abundance and biomass accounted for by each major taxonomic group will be calculated separately for each sampling area to assess spatial variability in community structure.
- Richness will be calculated at the genus-level for phytoplankton and the lowest taxonomic level for zooplankton to provide an indication of the diversity of these communities in each area.
- Summary statistics will be calculated for total phytoplankton and zooplankton abundance and biomass.

Spatial analysis of the data will be conducted annually using the gradient approach described for the water quality component (Section 4.3.4.9). The magnitude of effect on plankton communities will be evaluated by comparing plankton variables (i.e., total biomass, richness, and the total biomass of each major ecological group) in the NF area to the normal range. Normal ranges will be based on the adjusted 2013 normal range as defined in the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2019b).

Data analysis in the annual reports will also include statistical tests of biomass to assess effects as described in the Action Levels for Biological Effects (Section 5.2.4), which will be completed by comparing NF area results to the reference condition. The plankton component is concerned with the Toxicological Impairment hypothesis; toxicological impairment would be expected to result in declines in most plankton variables relative to the reference condition. Before statistical analyses are completed, the duplicate zooplankton data will be averaged to provide a single value for each combination of year, area, and station. Data will be analyzed using mixed effects models, where *Type* (NF versus reference condition) is the only fixed variable, and the random factor is a random intercept of *Year* nested in *Area*. Both *Year* and *Area* are treated as random factors and are implicitly nested within *Type*. The analysis output will include a *P*-value for the coefficient assessing whether NF data are significantly lower than the mean of the reference condition data set for the FF areas. A power analysis was conducted for total biomass and taxonomic richness of both phytoplankton and zooplankton data, to assess the statistical power of the proposed analyses (see Appendix C of Golder 2020a).

The model used for the analysis is provided below:

$$\mu_{i,j} = \beta_0 + \beta_1 \times Type_j + b_{1i} + b_{2j}$$

where,

$\mu_{i,j}$ is the expected value at the $i^{th}$ year in the $j^{th}$ area
$\beta_0$ is the intercept of each equation (corresponding to the reference level of each categorical variable)
$\beta_1$ is the main effect of *Type* of the $j^{th}$ area
$b_{1i}$ is a random effect of the $i^{th}$ year
$b_{2j}$ is the random effect of the $j^{th}$ area

During comprehensive AEMP years, and as part of the aquatic effects re-evaluation, multivariate analysis of the plankton communities will be conducted using the non-parametric ordination method of multidimensional scaling (MDS; Clarke 1993). The MDS data will be scaled in Primer (Clarke and Gorley 2016), or a similar program. The data will be transformed, if appropriate to improve the separation of the data among stations on the MDS plots and to reduce weighting of the analysis by the most abundant taxa and a Bray-Curtis resemblance matrix will be generated. The MDS procedure will be applied to this matrix. Using rank order information, MDS determines the relative positions of stations in two dimensions based on community composition. Goodness-of-fit is determined by examining the Shepard diagrams as well as the stress values, which are calculated from the deviations in the Shepard diagrams. Lower stress values (i.e., less than 0.10) indicate less deviation and a greater goodness-of-fit; higher stress values (i.e., greater than 0.20) must be interpreted with caution, and often higher dimensions (i.e., 3-D) are needed to described the data (Clarke 1993). Points that fall close together on the MDS ordination plot represent samples with similar community composition; points that are far apart from each other represent samples with dissimilar community composition. Where stress is low, metric MDS (mMDS) will be employed; however, if stress values are higher, a non-metric MDS (nMDS) will be used.

A similarity profile (SIMPROF) test will also be carried out on the ordination data to identify meaningful clusters of important taxa (i.e., those taxa that behave in a coherent manner across areas) and to prevent over-interpretation of the MDS plots (Clarke et al. 2014). These SIMPROF clusters will be superimposed on the MDS plots. In addition, an overall one-way analysis of similarities (ANOSIM) test will be carried out on the Bray-Curtis resemblance matrix to confirm interpretation of the separation of the points on the MDS ordination plot, and to investigate whether differences in community composition observed in the nMDS or mMDS ordination plots are significant.

The relationships between the nutrient variables and plankton community structure will also be explored using MDS results. Nutrient concentrations at each station will be superimposed on the MDS plots based on biological data, as bubbles scaled to the concentrations.

The Aquatic Effects Re-evaluation Report will provide details of the trend analysis; trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10).

## 4.7 Benthic Invertebrates

### 4.7.1 Background

Benthic invertebrates have been included as a component of DDMI's AEMP since Version 1.0 of the AEMP design. There are many attributes that make benthic invertebrates a desirable component of a monitoring program (Rosenberg and Resh 1993):

- They represent an intermediate level in the food web, between primary producers and fish, thus providing an indication of the quality and quantity of food available to certain species of fish.
- They are sedentary, thereby providing site-specific information on the presence or absence of effects.
- They are ecologically diverse (i.e., communities consist of algal feeders, filter-feeders, collector-gatherers, predators, etc.).
- They integrate effects over the period of their life cycle (i.e., months to years).
- They are relatively simple to collect and identify.
- They respond to environmental disturbances in a graded manner.
- Benthic invertebrate monitoring methods are well established.

The primary objective of the benthic invertebrate survey will be to determine whether the benthic invertebrate community of Lac de Gras is affected by effluent discharged from the Mine and, if so, to classify and evaluate the type of effect.

### 4.7.2 Field Methods

Sampling will be conducted in the late open-water season, because a period of long days and warmer water temperatures during summer will allow for greater growth and development of the invertebrates. As a result, benthic invertebrates are expected to be present at close to their maximum density and diversity, which will result in easier taxonomic identification. Benthic invertebrate sampling will be conducted at the same locations as the other AEMP components (Section 3.4) and will take place once every three years, during the comprehensive sampling program, when all AEMP components will be sampled and analyzed (Section 3.5). Benthic invertebrates will be sampled concurrently with sediment sampling (Section 4.4.2).

Benthic invertebrate samples will be collected using a standard Ekman grab (15 cm x 15 cm x 15 cm; bottom sampling area = 0.023 $m^2$). Six Ekman grab samples will be collected at each station from 18 to 22 m depth and combined to form a single composite sample. Previous benthic invertebrate studies in Lac de Gras (Golder 2011b, 2014a), including a baseline study (Golder 1997), have demonstrated that six subsamples are sufficient to collect representative benthic invertebrate community data from a station in Lac de Gras. Each composite sample will be sieved through a 500-µm mesh Nitex screen, as recommended by the 2010 Mesh Size Pilot Study (Golder 2011c). Material retained in the mesh will be placed into a separate 1 L plastic bottle and preserved with 10% buffered formalin. Samples will be shipped to a qualified taxonomist for enumeration and taxonomic identification of invertebrates.

#### 4.7.2.1 Supporting Information

Supporting environmental variables, such as water chemistry, sediment chemistry and substrate characteristics (i.e., TOC, particle size) will be provided by the sediment and water quality components (Sections 4.4 and 4.3, respectively). Water depth will be measured at each station, and field water quality parameters (i.e., temperature, DO, specific conductivity, and pH) will be measured as vertical profiles at each station. These measurements will provide information regarding habitat variation among stations and areas, as well as information regarding potential confounding factors.

### 4.7.3 Laboratory Methods

Samples will be processed according to standard protocols (i.e., Environment Canada 2012) and Glozier et al. (2002). Processing of the benthic invertebrate samples will be performed by the contracted taxonomist. Sample material will first be washed through a 500-µm sieve to remove the preservative and fine sediments remaining after field sieving. Elutriation will be used to separate the lighter organic material from the heavier inorganic material. The inorganic material will be checked for any remaining shelled or cased invertebrates, which will be removed and added to the organic material. The organic material will be split into coarse and fine fractions using a set of nested sieves of 1 mm and 500 µm mesh size. Samples likely will be small (typically containing <500 organisms), thus not requiring subsampling.

All organisms will be identified to the lowest practical taxonomic level (typically genus) using current literature, taxonomic keys and nomenclature. Organisms that cannot be identified to the desired level of taxonomic precision (e.g., immature or damaged specimens) will be reported as a separate category at the lowest level of taxonomic resolution possible. This will typically be the family level, which is the lowest level recommended by Environment Canada (2012). Organisms that require detailed microscopic examination for identification (e.g., Chironomidae and Oligochaeta) will be mounted on microscope slides using an appropriate mounting medium. DDMI's existing reference collection will be updated as required if new taxa are identified. Benthic invertebrate biomass will also be measured as the total wet weight of the organisms in each subsample.

QA/QC specific to this component will include applying specific acceptance criteria for grab samples in the field (e.g., minimum sampler fullness, intact sediment surface in sample), checking laboratory subsampling accuracy and precision (if applicable), verifying invertebrate removal efficiency and maintaining a reference collection for Lac de Gras, according to procedures outlined in the QAPP (Golder 2020c).

### 4.7.4 Data Analysis and Interpretation

The objective of the analysis and interpretation of benthic invertebrate data is to determine whether a Mine-related change in benthic community structure has occurred and, if so, to estimate the spatial extent of the effect. These objectives will be addressed using a combination of graphical and statistical methods. Analysis will focus on a number of key benthic community variables, including total invertebrate density, richness, densities of dominant invertebrate groups, and dominance. In addition, community composition summarized as presence/absence, relative abundances of major groups, and indices of evenness, diversity and similarity (i.e., Simpson's evenness index, Simpson's diversity index and Bray-Curtis index) will be examined to evaluate potential Mine-related effects. Variation in community structure will also be evaluated using multivariate analysis.

Potential changes in community structure will be evaluated in consideration of habitat data (i.e., sediment particle size and TOC content) to attempt to determine whether observed effects are due to the Mine or other potential causes. Although habitat variation will be minimized to the extent possible in the field, an analysis of relationships between biological variables and habitat variables will also be conducted to identify potential confounding factors.

Spatial analysis of the data will be conducted using the gradient analysis methods described for the water quality component (Section 4.3.4.9). The magnitude of effect on the benthic community will be evaluated by comparing benthic community variables (i.e., total density, richness, and the total abundance major groups) in the NF area to the normal range. Multivariate analysis of benthic community data will follow methods described in the plankton component (Section 4.6.4), using appropriate habitat-related and exposure variables.

Data analysis in the annual reports will also include statistical tests of invertebrate densities and richness to evaluate Action Level triggers (Section 5.2.4). These tests will compare NF area results to the mean of the reference condition data set for the FF areas. Methods will follow those described in Section 4.6.4 for plankton. A power analysis was conducted for total density, richness and the densities of dominant taxa, to assess the statistical power of the analyses for benthic invertebrate variables (see Appendix C of Golder 2020a).

The Aquatic Effects Re-evaluation Report will provide details of the trend analysis; trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10).

## 4.8 Fish Health

### 4.8.1 Background

Fish were identified as a Valued Ecosystem Component in the 1998 EA (DDMI 1998b) and a Receptor of Potential Concern during the problem formulation of Version 2.0 of the AEMP design (DDMI 2007). Moreover, there is a requirement under the Fisheries Authorization to conduct monitoring of fish populations and indices of fish health.

As in previous versions of the AEMP, the fish survey will be based on Slimy Sculpin. Surveys of Slimy Sculpin have now been conducted on six occasions: 2004 (Gray et al. 2005), 2007 (Golder 2008b), 2010 (Golder 2011d), 2013 (Golder 2014a), 2016 (Golder 2017c) and 2019 (Golder 2020b). Slimy Sculpin are good sentinel species because they tend to have small home range sizes relative to larger fish (Gray et al. 2004) and better integrate local site conditions and exposure to effluent. Lake Trout are used for the fish palatability studies (Section 4.1) and have been used for monitoring mercury (Section 4.9) under DDMI's AEMP in the past.

The Slimy Sculpin survey will continue at a frequency of once every three years, during the comprehensive sampling program (i.e., when all AEMP components will be sampled and analyzed), balancing the lethal effects of the program on the local population against the AEMP sampling requirements.

If Slimy Sculpin fish health assessment endpoints demonstrate effects equivalent to Action Level 3 (i.e., a statistically significant difference in one or more effect endpoints is determined with a direction indicative of impairment to fish health and a magnitude of difference equal to or above the critical effects size [defined by EEM] that was beyond normal range, and that was observed in two consecutive sampling events; Table 5.2-4), it is expected a Lake Trout survey may be initiated. The specific scope and timing of a Lake Trout survey would be specifically defined in an AEMP Response Plan (Section 7.5) and would be determined by the nature of the Action Level exceedance. Lake Trout are known to have large home ranges and have been shown to move between Lac de Gras and Lac du Sauvage (Golder 2014a). This means they would be able to move in and out of the Mine effluent and their exposure time would not be known with any certainty. The inclusion of a Lake Trout survey would be considered only if results from the Slimy Sculpin surveys indicated that Mine-related effects on fish are of concern. In this instance, Lake Trout would serve as an overall indicator of the health of large-bodied fish in Lac de Gras. If initiated, the Lake Trout program may be limited to a non-lethal tissue chemistry sampling program (e.g., for mercury analyses from tissue plugs) or may be a lethal fish health survey, dependent on the Action Level trigger which initiated the study. The mercury in Lake Trout survey would only occur if AEMP results (including small-bodied fish tissue chemistry) indicated an increasing trend in mercury due to the Mine.

### 4.8.2 Field Methods

The fish survey will be based on comparisons of NF area data and the reference condition data set. Multiple locations within an area will be sampled (Figure 3.4-1). Results from the previous AEMP studies indicate that Slimy Sculpin were most easily captured along a shallow (i.e., less than 40 cm in depth) natural shoreline with smaller cobble substrate. The shoreline of the two FF areas to be sampled will be in the same area of the lake as the water quality, sediment and benthic invertebrate sampling locations. The timing for the Slimy Sculpin survey will be late-August to early September to allow time for the fish gonads to begin developing again, following the under-ice spring spawning event.

Backpack electrofishing will be used to capture Slimy Sculpin. The sampling will begin with a relative abundance non-lethal survey, whereby the first portion of the fish sampling will be completed as a random field sampling effort of standard duration at each of the four fish study areas. No specific location within each area will be targeted, but fishing effort will be expended along each shoreline area in suitable habitat where it is safe to wade and electrofish. At each location, approximately 500 m will be fished for a standard duration (e.g., 1 h which will result in approximately 1,000 seconds of electrofishing time). The relative abundance survey will be completed on the first visit to each sampling area, and after its completion, targeted lethal and non-lethal sampling will commence. All Slimy Sculpin captured during the relative abundance survey will be held in a recovery bin prior to processing, when they will be measured for length and weight and examined for the presence of external abnormalities and parasites. Following processing they will be released at the capture area. All non-target fish species captured will also be measured for length and weight and released live. There are no specific sample size targets for the non-lethal relative abundance survey. Representative photos of each species captured, as well as young-of-the-year (YOY) and non-YOY juvenile fish will be taken at each sampling area.

Following the completion of the relative abundance survey, the targeted Slimy Sculpin lethal survey will be initiated. A total of 20 to 30 Slimy Sculpin in each of the following groups will be targeted: adult male, adult female, and juvenile. Adults are considered those fish that are sexually mature (i.e., have spawned before or will spawn the next spring), and juveniles are considered sexually immature (i.e., have not spawned before and will not spawn the next spring). An additional 50 Slimy Sculpin from each sampling area will be targeted for a non-lethal assessment (i.e., length and weight measurements). Slimy Sculpin to be included in the lethal survey will be sacrificed from each sampling area for the purposes of completing an internal fish health assessment. Only fish that are uninfected by tapeworms will be included in the sample size target counts.

All Slimy Sculpin captured will be given a unique sample number. Non-target species will be identified, counted and released alive. Total body length (± 1 mm) and body weight (± 0.01 g) will be recorded for all captured Slimy Sculpin, and an external health examination will be conducted. The presence of abnormalities such as wounds, tumours, parasites, fin fraying, gill parasites or lesions will be recorded. Photographs will be taken of all abnormalities, and representative photographs will be taken of normal fish. Information on maturity or sex will be recorded as possible. External and internal examinations will be completed following DDMI’s SOP, ENV SOP 509 (Fish Health Assessment), which is based on Golder’s Technical Procedure 8.15-0: Fish Health Assessment (unpublished file information). These procedures have consistently been used for baseline and AEMP fish surveys, and their continued use will allow for consistency among fish surveys over time.

An internal examination will be completed on each sacrificed fish according to the foregoing technical procedure documents. Sex and state of maturity will be confirmed at the time of sampling. The internal organs will be examined for general appearance and the presence of any abnormalities (e.g., tumours, parasites). If abnormalities are observed, they will be documented. The following will be recorded during the internal examination:

- sex and state-of-maturity
- internal health (including observations of parasites, internal organs and mesenteric fat)
- liver weight
- gonad weight
- stomach fullness

Photographs will be taken of internal abnormalities, and gonad photographs will be taken for each dissected fish. Stomach fullness will be recorded, and a general description of gut contents and parasite load will be noted. Liver weight and gonad weight will be measured. Aging structures (i.e., sagittal otoliths) will be collected from each sacrificed fish and archived. Slimy Sculpin ages derived from otolith sections are unreliable (CRI 2014); therefore, otolith-based age has not been included as a fish variable.

Other organs (e.g., spleen, kidney) will be examined for their general appearance and the presence of any abnormalities. If abnormalities, such as tumours, necrosis, or heavy parasite load are observed, their appearance will be noted, and photographs will be taken.

To prevent cross-contamination, fish will be dissected on a cutting board covered with a clean sheet of plastic wrap, which will be changed after each dissection. All dissecting equipment will be cleaned after each fish. Other QA/QC procedures will include the use of standard documentation of field results and verification of field records.

#### *4.8.2.1 Supporting Information*

Supporting environmental variables will be collected in each of the sampling areas. *In situ* water quality parameters (i.e., specific conductivity, DO, temperature, and pH) will be collected each day. Of particular importance are the effects of temperature on spawning, growth and other aspects of energy utilization. For this reason, temperature loggers will be installed at each sampling area during the winter preceding the sampling program. Once the ice is off the lake, the temperature loggers will be repositioned to similar depths, if necessary, in each area to improve comparability of data. Temperature loggers will be retrieved in the fall.

### 4.8.3 Laboratory Methods

#### *4.8.3.1 Gonad Histology*

Gonads from approximately half of the Slimy Sculpin captured will be sent to a qualified histopathologist for histology analysis. The tissue samples will be mounted on slides, sectioned, and stained for microscopic analysis. The histology codes and associated definitions to be used for categorizing the stages of Slimy Sculpin gonadal development are presented in Table 4.8-1.

**Table 4.8-1: Macroscopic and Histological Maturity Categories**

| Sex | Stage | Macroscopic features | Histological features |
|---|---|---|---|
| Unknown sex | | Unable to determine sex. | Unable to determine sex. |
| Female | Unknown stage | Unable to determine stage. | Unable to determine stage. |
| | Immature | Small ovaries, often clear, blood vessels indistinct. | Only oogonia and PG oocytes present. No atresia or muscle bundles. Thin ovarian wall and little space between oocytes. |
| | Early Stage Development | Enlarging ovaries, blood vessels more distinct. Granular in appearance. | PG, CA, Vtg1, and Vtg2 oocytes present. No evidence of POFs or Vtg3 oocytes. Some atresia can be present. |
| | Late Stage Development | Large ovaries filling the body cavity, prominent blood vessels. Individual oocytes visible. | Vtg3 oocytes present or POFs in batch spawners. Atresia of vitellogenic and/or hydrated oocytes may be present. Early stages of OM can be present. |
| | Ripe | Eggs released with gentle pressure on abdomen. | Oocytes undergoing late OM including GVM, GVBD and hydration, or ovulation. |
| | Spent | Deflated ovaries, blood vessels prominent. | Presence of oocyte atresia and, in some species, POFs. Few if any Vtg2 or Vtg3 oocytes. |
| | Reabsorbing | Small atretic oocytes throughout the ovaries, which are hard and white. | Advanced stage oocytes are atretic and no POFs are present. |
| | Resting | Small ovaries, blood vessels reduced but present. | Only oogonia and PG oocytes present. Muscle bundles, enlarged blood vessels, thick ovarian wall, atresia and degenerating POFs may be present. |
| Male | Unknown stage | Unable to determined stage. | Unable to determine stage. |
| | Immature | Small testes, often clear and threadlike. | Sg1 only; no lumen in lobules. |
| | Early Stage Development | Small testes, semi-translucent, but easily identified. | Spermatocysts evident along lobules. Sg2, Sc1, Sc2, St and Sz can be present in spermatocysts. Sz not present in lumen of lobules or in sperm ducts. GE continuous throughout. |
| | Late Stage Development | Testes large, firm and lobate. White to purplish in colour. Granular appearance. | Sz in lumen of lobules and/or sperm ducts. All stages of spermatogenesis (Sg2, Sc, St, Sz) can be present. Spermatocysts throughout the testis, active spermatogenesis. GE may be continuous or discontinuous. |
| | Ripe | Milt released with gentle pressure on abdomen. | Based on macroscopic observation only. |
| | Spent | Small and deflated testes. Blood vessels obvious. Violet-pink in colour. | Residual Sz present in lumen of lobules and in sperm ducts. Widely scattered spermatocysts near periphery containing Sc2, St, Sz. Little to no active spermatogenesis. Spermatogonial proliferation and regeneration of GE common in periphery of testes. |
| | Reabsorbing | Not typically observed in males. | Not typically observed in males. |
| | Resting | Small testes, often threadlike. | No spermatocysts. Lumen of lobule often nonexistent. Proliferation of spermatogonia throughout testes. GE continuous throughout. Small amount of residual Sz occasionally present in lumen of lobules and in sperm duct. |

X = the stage code, if stage can be determined, when sex is unknown.

CA = cortical alveolar; GVBD = germinal vesicle breakdown, GVM = germinal vesicle migration, OM = oocyte maturation, PG = primary growth, POF = postovulatory follicle complex, Vtg1 = primary vitellogenic, Vtg2 = secondary vitellogenic, Vtg3 = tertiary vitellogenic, GE = germinal epithelium, Sc1 = primary spermatocyte, Sc2 = secondary spermatocyte, Sg1 = primary spermatogonia, Sg2 = secondary spermatogonia, St = spermatid, Sz = spermatozoa.

#### 4.8.3.2 *Stomach Contents*

Slimy Sculpin stomachs with an estimated fullness ≥50% will be sent to a qualified benthic invertebrate taxonomist for enumeration and taxonomic identification of contents. Organisms within the stomach will be identified to the genus level using recognized taxonomic keys. Organisms that cannot be identified to the desired taxonomic level will be reported as “other”.

### 4.8.4 Data Analysis and Interpretation

Two types of data will be obtained from the non-lethal relative abundance survey: random catch-per-unit-effort (CPUE) and associated length-frequency histograms for each area. The CPUE is calculated as the total catch of fish divided by effort (i.e., electrofishing time). The length-frequency histogram is a type of plot showing the total length of sculpin captured grouped into bin sizes (i.e., lengths). These plots will show both the relative abundance data and the targeted lethal Slimy Sculpin data as distinct data sets (i.e., the length-frequency plots will be stacked and/or colour-coded, so those collected in each program are discernable from the total). This plot will allow consideration of total catches and size ranges and aid in age-assignments (as described below), while the relative abundance survey results will be compared (qualitatively) to the lethal sampling program results to further inform understanding of the fish population in each area and size classes of fish present during the random and targeted surveys.

Catch-per-unit-effort will be calculated as the number of Slimy Sculpin per 100 seconds of electrofishing effort. For fish collected during the initial relative abundance survey described in Section 4.8.2, CPUE will provide an unbiased measure of relative abundance of Slimy Sculpin among sampling areas by standardizing the Slimy Sculpin catch data to a standard fishing effort (e.g., 500 m sections fished over a standardized time duration) versus the targeted lethal fishing effort (the duration of which is determined by when target sample sizes are achieved). The standardized CPUE values will be visually compared among areas for any observable differences. Similarly, differences in length-frequency distributions between sampling areas will be assessed qualitatively based on the plots and summary statistics (e.g., arithmetic mean, median, and SD). The CPUE and length-frequency histograms will be considered in the WOE assessment but will not be included in the response framework. Should population-level effects (e.g., missing size class[es]) be observed in the length-frequency assessment, the length-frequency distributions will be considered alongside the other AEMP results (e.g., water quality and lower trophic level biological responses) and the overall conclusions and recommendations for the fish health component, not just the overall WOE, will be made inclusive of the evidence provided by the CPUE and length-frequency data.

Slimy Sculpin data from the targeted lethal sampling program will be sub-divided into male, female, and juvenile data sets, which will be analyzed separately. This separation is important because the different energetic requirements associated with reproduction tend to result in differences in growth rates and energy storage (as measured by liver size and condition factor). Stage classification (i.e., adult and juvenile) will be performed using the method outlined in the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2019b). Length-frequency histograms will be used to differentiate YOY sculpin from older fish. Fish less than approximately 30 mm total length and without a GSI value will be considered to be YOY and will be removed from analysis. For the remaining fish, maturity curves (constructed to describe fish maturity [age-1+/adult] as a function of total length) will be used to determine the total length at which 50% of the Slimy Sculpin are expected to be mature (i.e., the size at maturity); this will be determined by sampling area and year. Fish smaller than the determined size at maturity, or with a GSI value less than 1.2% will be considered to be age-1+ fish. Fish larger than the size at maturity, or with a GSI greater than 1.2%, will be assigned to the age-2+ group. Fish with no known GSI will not be assigned an age. As the methods for fish age assignments have been updated as part of the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2019b), the consistent normal ranges provided in *AEMP Reference Conditions Report Version 1.4* (Golder 2019c) will be used going forward.

For data collected in the targeted lethal sampling program, summary statistics (e.g., sample size, arithmetic mean, median, minimum, maximum, SD, and standard error) will be calculated for each biological variable and summarized by area, sex and maturity. Common fish indices, as described in the Metal Mining Technical Guidance for Environmental Effects Monitoring (MMER TGD) (Environment Canada 2012), describing relationships between body metrics (i.e., Fulton's condition factor [K], liversomatic index [LSI] and gonadosomatic index [GSI]) will be calculated as follows:

$$\text{Fulton's Condition Factor (Age-1+)}\ \ K = \frac{total\ body\ weight}{total\ length^3} \times 100{,}000$$

$$\text{Fulton's Condition Factor (adults)}\ \ K = \frac{carcass\ weight}{total\ length^3} \times 100{,}000$$

$$\text{Liversomatic Index}\ \ LSI = \frac{liver\ weight}{carcass\ weight} \times 100\%$$

$$\text{Gonadosomatic Index}\ \ GSI = \frac{gonad\ weight}{carcass\ weight} \times 100\%$$

Condition factor for the relative abundance survey will be calculated using the equation above for Age-1+ fish, while lethally sampled fish condition factor will be calculated using the equation above for adults. Data will be screened to detect possible errors (i.e., anomalous data) using box-and-whisker and scatter plots. Residuals will be used to estimate studentized residual values and calculate statistics of normality and homoscedasticity; these values, together with a visual assessment of quantile-quantile plots and scatterplots of residuals relative to explanatory variables, will be used to assess the parametric assumptions of normality and equality of variance. The statistical comparisons among areas will be performed, and statistical outliers will be identified by analyzing test residuals. Statistical tests will subsequently be rerun without outliers.

Biological variables included in the statistical analyses will be the following:

- physical abnormalities (e.g., tumours, surficial lesions, obvious parasites)
- stomach content analysis
- total body weight
- carcass weight
- total length
- gonad weight (adults only)
- liver weight

Biological variables will also be used to estimate the following:

- length-frequency distribution
- size (weight and length)

- condition
- relative liver size
- relative gonad size

Differences in parameter endpoints among areas will be determined by either analysis of variance, analysis of covariance (i.e., for condition, GSI, LSI), or the appropriate non-parametric test. Differences in the length-frequency distributions between sampling locations will be assessed using the non-parametric, two-sample Kolmogorov-Smirnov test. Reproductive performance will be assessed by comparing the relative abundance of young/small Slimy Sculpin among sampling areas using length-frequency histograms.

Slimy Sculpin collected from various sites in Lac de Gras have historically been infected with tapeworms (Golder 2017b, 2018). There is evidence that some of the response variables measured in Slimy Sculpin are negatively affected by tapeworm infection. Golder (2011d) demonstrated that fish infected with tapeworm can typically be distinguished from those that are parasite-free using a visual external assessment. As a result, parasitized Slimy Sculpin are not included in target sample size counts during the field program (Section 4.8.2), and data analysis and interpretation will exclude parasitized fish.

Data analysis in the annual reports will also include statistical tests of fish health variables to evaluate potential Action Level triggers (Section 5.2.4). These tests will compare NF area results to the mean of the reference condition data set. Methods will follow those described in Section 4.6.4 for plankton. A power analysis was conducted for total length, weight, condition (analyzed as relative weight), relative liver weight, and relative gonad weight, to assess the statistical power of the analyses for fish (see Appendix C of Golder 2020a).

## 4.9 Fish Tissue Chemistry

### 4.9.1 Background

The objective of the AEMP fish tissue chemistry survey is to determine whether effluent discharged from the Mine has altered fish in such a way as to limit their use by humans. Fish usability can be affected by altered flavour or odour (i.e., tainting), or contaminant (e.g., metal) concentrations above consumption guidelines. In addition, body burdens of various contaminants can confirm exposure and may support potential effects observed during the fish health survey.

Analysis of fish tissues for metal concentrations will be conducted on Slimy Sculpin collected as part of the fish health study (and separately on Lake Trout collected during the fish palatability study, see Section 4.1). The Slimy Sculpin results will be used as an early warning indicator of potential effects on tissue quality of all fish in the lake, including large bodied fish (e.g., Lake Trout), and as part of the interpretation of the fish health study. An increase in tissue metal concentrations in Slimy Sculpin relative to reference conditions will be used as an early warning indicator of actual effects on fish usability.

A fish palatability study of Lake Trout from Lac de Gras is also conducted under the TK component, as described in Section 4.1. This study is distinct from the AEMP fish tissue chemistry survey and was completed each year between 2002 and 2007, and again in 2009, 2012, 2015, 2018 and 2021. The purpose of the TK study is to have members from surrounding communities conduct fish tasting to confirm that palatability and texture are not degraded by mining activity, as well as to assess metal concentrations in Lake Trout flesh. The approach of analyzing metals in fish caught for palatability testing is also intended to minimize the number of fish sacrificed (Water Licence W2015L2-0001, Schedule 8, Condition 1e). Future palatability studies will continue to include an analysis of metals in fish. These studies will be conducted every three years, with the next study expected to take place in 2024 (Section 3.5).

### 4.9.2 Field Methods

Slimy Sculpin will be sampled as described in Section 4.8.2. Fish captured and sacrificed during the health assessment surveys will be used in the tissue analysis in order to reduce additional Slimy Sculpin mortality (Water Licence W2015L2-0001, Schedule 8, Condition 1e). Eight composite tissue samples from fish captured at each of the four study areas will be submitted for analysis. Each sample will be a composite of whole fish (excluding otoliths, stomach and gonads as these tissues are submitted for alternate analyses, see Section 4.8.3) and will be based on fish of the same sex and of the same size class. The mean length and weight of the fish comprising these samples will be recorded. Analysis will be conducted on a homogenized sample of the whole fish, best reflecting the correct exposure pathway for piscivorous fish.

Analysis of Lake Trout muscle tissue as part of the TK study will be conducted on a minimum of 10 fish collected during the palatability study (see Section 4.1). The samples will be of one sex and age/size class if possible. Methods used for collection and analysis of Lake Trout tissues will be the same as those currently employed during palatability testing; however, angling may be considered as a less damaging sampling strategy. Individual fish will be selected for analysis of metal concentrations.

In addition to the QA/QC measures described by Golder (2017c), duplicate composite tissue samples for metals analysis will be collected if possible (i.e., where sample volumes allow); it is anticipated this will only be possible as part of the palatability study (Section 4.1) for large-bodied fish.

### 4.9.3 Laboratory Methods

Samples will be analyzed by an accredited analytical laboratory for the metals listed in Table 4.9-1. In addition, five Slimy Sculpin samples will be selected after the initial analysis to represent a range of fish lengths, where possible (given limitations in sample volume), and sent to Flett Research Ltd. (Winnipeg, MB) for QC of the mercury results.

**Table 4.9-1: Variables Analyzed in Slimy Sculpin and Lake Trout Tissue for the *AEMP Design Plan Version 6.0***

| Variable | Detection Limit (µg/g ww) | Variable | Detection Limit (µg/g ww) | Variable | Detection Limit (µg/g ww) |
|---|---|---|---|---|---|
| % Moisture | 0.25 | Copper | 0.020 | Selenium | 0.010 |
| Aluminum | 0.40 | Iron | 0.60 | Silver | 0.0010 |
| Antimony | 0.0020 | Lead | 0.0040 | Sodium | 4.0 |
| Arsenic | 0.0040 | Lithium | 0.10 | Strontium | 0.010 |
| Barium | 0.010 | Magnesium | 0.4 | Tellurium | 0.004 |
| Beryllium | 0.0020 | Manganese | 0.010 | Thallium | 0.00040 |
| Bismuth | 0.0020 | Mercury[(a)] | 0.0010 | Tin | 0.020 |
| Boron | 0.20 | Molybdenum | 0.004 | Titanium | 0.020 |
| Cadmium | 0.0010 | Nickel | 0.04 | Uranium | 0.00040 |
| Calcium | 4.0 | Phosphorus | 2.0 | Vanadium | 0.020 |

**Table 4.9-1: Variables Analyzed in Slimy Sculpin and Lake Trout Tissue for the *AEMP Design Plan Version 6.0***

| Variable | Detection Limit (µg/g ww) | Variable | Detection Limit (µg/g ww) | Variable | Detection Limit (µg/g ww) |
|---|---|---|---|---|---|
| Cesium | 0.0010 | Potassium | 4.0 | Zinc | 0.10 |
| Chromium | 0.010 | Rubidium | 0.010 | Zirconium | 0.040 |
| Cobalt | 0.0040 | | | | |

a) Detection limit for mercury analysis completed by Flett Research Ltd. = 0.1 ng/g ww.
µg/g ww = micrograms per gram wet weight; ng/g ww = nanograms per gram wet weight.

### 4.9.4 Data Analysis and Interpretation

Initial screening of the AEMP fish tissue chemistry data set will be completed before data analyses, using the procedures described for the water quality component in Section 4.3.4.2. The rationale and procedures for conducting statistical analyses are the same as those described for fish health (Section 4.8.4).

Slimy Sculpin summary statistics, including sample size, percentage of metal concentrations greater than the DL, minimum, median, maximum, and SD values will be reported for each area. Metal concentrations will be compared to the normal range in each AEMP Annual Report. Temporal trend analysis of the fish tissue chemistry data will follow the approach in Golder (2018) and will be provided in the Aquatic Effects Re-evaluation Report.

All metals analyzed as part of the palatability study (Section 4.1) standard tissue metals scan will be provided in the TK report. Summary statistics, including sample size, percentage of metal concentrations greater than the DL, minimum, median, maximum, and SD values will be included in the TK report. Statistical analyses of the fish tissue chemistry collected as part of the TK program will not be performed because the sampling protocols, sample size, fishing locations, and size of fish selected for the analyses are not consistent between years, making these results unsuitable as an early warning trigger for conducting a larger mercury in Lake Trout program.

## 4.10 Weight-of-Evidence

### 4.10.1 Background

The AEMP presented herein incorporates exposure and effects assessments within a tiered framework, which will culminate in a WOE analysis. The WOE assessment provides a systematic and transparent method for integrating the complexity of data generated in environmental assessment and monitoring programs. The basis for decision-making within a WOE assessment is a combination of statistical analyses and scoring systems incorporated into a logic system. Best professional judgment is also a key component of a WOE assessment (Chapman et al. 2002).

The objectives of the WOE assessment are two-fold:

- to apply a standardized process to evaluate strength of evidence for potential toxicological impairment and nutrient enrichment effects in the aquatic ecosystem of Lac de Gras
- to summarize the AEMP findings in a semi-quantitative manner that provides broad AEMP conclusions, to inform decision-making for ongoing environmental stewardship of Lac de Gras

The goal of DDMI's AEMP is to assess and monitor the effects of Mine-related stressors (primarily metals and nutrients) that are released to Lac de Gras. Related to these stressors, the AEMP identifies two broad impact hypotheses for Lac de Gras:

- Toxicological Impairment Hypothesis: toxicity to aquatic organisms could occur due to chemical contaminants (primarily metals) released to Lac de Gras
- Nutrient Enrichment Hypothesis: eutrophication could occur due to the release of nutrients (phosphorus and nitrogen) to Lac de Gras

The WOE analysis is structured to distinguish between these two hypotheses. It will provide the strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes. The products of the WOE analysis will be estimates of the Evidence of Impact (EOI) associated with Mine operations. Note that the term "impact" is used in a generic sense to indicate a change (positive or negative) in Lac de Gras related to the Mine or Mine activities. It is not intended to reflect the ecological significance or level of concern associated with a given change, nor is it intended to indicate that "pollution" of Lac de Gras has occurred.

Since the WOE requires the results of all endpoints for exposure and effects (i.e., biological responses), the WOE analysis will be conducted every three years, in conjunction with the comprehensive sampling program, when all components and all locations are sampled.

This section presents the method by which data collected during the comprehensive field programs will be integrated into a WOE analysis. The WOE will integrate the following field components: water quality, sediment quality, benthic invertebrates, lake productivity (i.e., nutrients, chlorophyll *a*, plankton biomass, and community structure), and fish population health.

#### 4.10.1.1 Assessment and Measurement Endpoints

The problem formulation for the AEMP identified multiple assessment and measurement endpoints that form the basis for evaluating potential changes, responses or effects in Lac de Gras as they relate to the Mine (DDMI 2007). Assessment endpoints are characteristics of the aquatic ecosystem that may be affected by the Mine. Measurement endpoints are measurable responses to the stressor that are related to the valued characteristics chosen as the assessment endpoint (Section 3.2). Measurement endpoints may include measures of **exposure** (e.g., constituent concentrations in water and sediments) and measures of **effects** (e.g., plankton biomass and benthic invertebrate community structure). Measurement endpoints are operationally defined and can be assessed using appropriate field and laboratory studies.

The VECs for Lac de Gras and their corresponding assessment and measurement endpoints are described in Section 3.2. The components that will be applicable to the WOE framework, which include some VECs and assessment endpoints, are:

- water quality
- sediment quality
- fish tissue chemistry
- lake productivity
- benthic invertebrate community
- fish health

These components will be integrated to assess the evidence for nutrient enrichment and toxicological impairment. Separate WOE analyses and conclusions will be made for each impact hypothesis because, in many cases, nutrient enrichment may act in opposition to toxicological impairment. For example, nutrient enrichment is likely to increase biological productivity whereas toxicological impairment is likely to decrease biological productivity.

The WOE analysis for each impact hypothesis will focus on three major ecosystem components of Lac de Gras: lake productivity, benthic invertebrate community health, and fish population health. The assessment of these components will be supported by the measures of water chemistry, sediment chemistry, and tissue chemistry, all of which had also been identified as VECs, or as assessment endpoints of VECs.

The strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes will be evaluated using an array of measurement endpoints specific to the WOE analysis. Measurement endpoints will be selected to reflect the endpoints formulated in the AEMP and shall be directly linked to the Mine. For example, measures of water quality provide an indication of exposure to toxicants or nutrients and can be linked to effluent release. Similarly, increases or decreases in plankton biomass provide an indication of a biological response to increases in nutrients or toxicants. The various endpoints will be integrated in the WOE framework to yield overall assessments for each ecosystem component under each impact hypothesis (i.e., Toxicological Impairment versus Nutrient Enrichment).

### 4.10.2 Weight-of-Evidence Framework

Key components that make up the design of the WOE framework for the AEMP are the following:

- line of evidence (LOE) groups and measurement endpoints included in the WOE analysis
- the process for evaluating the effect levels observed for the endpoints in each LOE group
- the process for determining the appropriate weighting of each endpoint towards the overall WOE conclusions

#### *4.10.2.1 Lines of Evidence and Measurement Endpoints*

The endpoints and ecosystem components included in the WOE framework for each impact hypothesis are summarized in Tables 4.10-1 and 4.10-2. Within each ecosystem component, two distinct LOE groups will be assessed in order to integrate exposure and effects in the WOE:

- **Exposure group**: measures of the potential exposure of receptors to Mine-related SOIs, including surface water, sediment, and tissue chemistry; and
- **Biological response group**: observationally-based measures of potential ecological changes, including measures of primary productivity, zooplankton biomass, benthic invertebrate community structure, and fish population health.

These two LOE groups bring distinct types of information to the WOE analysis. For example, sediment chemistry analyses (i.e., exposure endpoints for benthic invertebrates) provide information on contamination but not on biological effects. Measuring the diversity of the benthic invertebrate community (i.e., a biological response endpoint) provides evidence of substance-related effects in the environment; however, any observed alterations may also be due to biological (e.g., predation, seasonal abundance, competition) and/or physical (e.g., habitat alteration) effects unrelated to contaminants or nutrient enrichment. Results that demonstrate a high degree of linkage between the two LOE groups provide stronger evidence regarding potential Mine-related ecological effects than reliance on one type of LOE in isolation. *A posteriori* weighting factors are applied in the WOE to account for the degree of linkage between endpoints in the exposure and biological response LOE groups.

Within each LOE group there are one or more lines of evidence that encompass different stressor types, media, levels of biological organization, and data analysis methods (Tables 4.10-1 and 4.10-2):

- Exposure LOEs: nutrient exposure, contaminant exposure, and biological productivity[2]
- Biological Response LOEs: biological productivity, benthic invertebrates, and fish population health

**Table 4.10-1: Endpoints and Lines of Evidence for Each Ecosystem Component – Nutrient Enrichment Hypothesis**

| Ecosystem Component | Line of Evidence Group | Line of Evidence | Endpoints |
|---|---|---|---|
| Lake Productivity | Exposure | Nutrient Exposure | Water Chemistry – Total Nitrogen (N), Total Phosphorus (P), and Soluble Reactive Silica (SRS) |
| | Biological Response | Biological Productivity | Chlorophyll *a* |
| | | | Phytoplankton Biomass |
| | | | Zooplankton Biomass |
| | | | Relative Biomass of the Major Phytoplankton Groups |
| | | | Relative Biomass of the Major Zooplankton Groups |
| Benthic Invertebrate Community | Exposure | Nutrient Exposure | Water Chemistry – Total N, Total P, and SRS |
| | | | Sediment Chemistry – Total Organic Carbon (TOC) |
| | | Primary Productivity | Chlorophyll *a* |
| | | | Phytoplankton Biomass |
| | Biological Response | Benthic Invertebrate Community | Total Invertebrate Density |
| | | | Dominant Taxa Densities |
| | | | Richness |
| | | | Relative Abundances of Major Benthic Invertebrate Groups |
| Fish Community | Exposure | Nutrient Exposure | Water Chemistry – Total N, Total P, and SRS |
| | | | Sediment Chemistry – TOC |
| | | Biological Productivity | Chlorophyll *a* |
| | | | Total Invertebrate Density |
| | Biological Response | Fish Population Health | Growth - Total Length, Fresh Weight and/or Carcass Weight |
| | | | Energy Stores – Condition (K) |
| | | | Energy Stores – Liversomatic Index (LSI) |
| | | | Reproductive Investment – Gonadosomatic Index (GSI) and Length-frequency Distributions |
| | | | Abnormalities – Occurrence |
| | | | Fish Capture Data - CPUE |

[2] Some biological productivity endpoints (e.g., chlorophyll *a* and total invertebrate density) are used as indicators of both exposure (for higher levels of biological organization) and biological response.

**Table 4.10-2: Endpoints and Lines of Evidence for Each Ecosystem Component –Toxicological Impairment Hypothesis**

| Ecosystem Component | Line of Evidence Group | Line of Evidence | Endpoints |
|---|---|---|---|
| Lake Productivity | Exposure | Contaminant Exposure | Water Chemistry |
| | | | Sediment Chemistry |
| | Biological Response | Biological Productivity | Chlorophyll *a* |
| | | | Phytoplankton Biomass |
| | | | Zooplankton Biomass |
| | | | Relative Biomass of the Major Phytoplankton Groups |
| | | | Relative Biomass of the Major Zooplankton Groups |
| Benthic Invertebrate Community | Exposure | Contaminant Exposure | Water Chemistry |
| | | | Sediment Chemistry |
| | Biological Response | Benthic Invertebrate Community | Total Invertebrate Density |
| | | | Dominant Taxa Densities |
| | | | Richness |
| | | | Relative Abundance of Major Benthic Invertebrate Groups |
| Fish Community | Exposure | Contaminant Exposure | Water Chemistry |
| | | | Sediment Chemistry |
| | | | Fish Tissue Chemistry |
| | Biological Response | Fish Population Health | Growth – Total Weight, Fresh Weight and/or Carcass Weight |
| | | | Energy Stores – Condition (K) |
| | | | Energy Stores – Liversomatic Index (LSI) |
| | | | Reproductive Investment – Gonadosomatic Index (GSI) and Length-frequency Distributions |
| | | | Abnormalities – Occurrence |
| | | | Fish Capture Data - CPUE |

- For many LOEs, multiple endpoints will be measured in Lac de Gras providing a “battery” approach for assessing the degree of effect associated with each LOE. For example, several benthic invertebrate endpoints will be analyzed covering aspects of density, richness, and relative abundance of major taxa. These endpoints will be assessed for gradients with effluent exposure in Lac de Gras, and in statistical comparisons as part of the Action Level assessment.

Per Directives received from the WLWB, the following WOE assessment endpoints have been added to AEMP Version 6.0:

- Abnormalities – Occurrence was added as a fish population health endpoint. The assessment of abnormalities is a qualitative assessment of captured fish, documenting unusual external features, such as external wounds, lesions, tumours, parasites, fin fraying, or gill parasites and internal features such as abnormalities of the liver, spleen, gall bladder, kidney, and gonads. Due to statistical limitations when using qualitative data, the occurrence of abnormalities was considered as an early-warning indicator only, based on relative comparisons between the NF and FF areas.
- CPUE – Catch data as CPUE was added as a fish population health endpoint because it provides a quantitative estimate of fish abundance. While CPUE is somewhat limited by sampling bias (which is introduced by fishing methods and locations), it provides a direct estimate of fish abundance that is comparable across time and study areas.

The evaluation of multiple endpoints for each LOE means that a wide variety of possible changes are considered in the overall analysis. The LOEs and endpoints are discussed in further detail in previous sections:

- Water Quality (Section 4.3)
- Sediment Chemistry (Section 4.4)
- Eutrophication Indicators (Section 4.5)
- Plankton (Section 4.6)
- Benthic Invertebrates (Section 4.7)
- Fish Population Health (Section 4.8)
- Fish Tissue Chemistry (Section 4.9)

The WOE framework includes weighting factors that account for the ability of a particular endpoint to detect and indicate changes in Lac de Gras (i.e., *a priori* weighting factors). The weighting factors also consider the relevance of the endpoint with regards to the impact hypothesis (Nutrient Enrichment versus Toxicological Impairment). With separate WOE analyses for each impact hypothesis, these direction weighting factors indicate the degree of support that a given endpoint response provides to each hypothesis.

In general terms, the endpoint results are *rated* according to a series of decision criteria, *weighted* to reflect the strength and relevance of the evidence they brought to the analysis, and then *integrated* to provide an overall assessment. This integration is accomplished using a WOE assessment framework based on McDonald et al. (2007), including guidance from Chapman and co-authors (Chapman et al. 2002; Chapman and Anderson 2005; Chapman and Hollert 2006). An example of a WOE process and framework is presented in Figure 4.10-1.

| Ecosystem Component | Line of Evidence Group | LOE/Endpoints | Effect Level Rating | Mathematical Representation | *A Priori* Weighting: *A Priori* Weighting Factor | *A Priori* Weighting: Weighted LOE Score | Direction Weighting: Direction of Observed Effect or Correlation | Direction Weighting: Support for Toxicity Hypothesis | Direction Weighting: Weighted LOE Score | *A Posteriori* Weighting: Strength of Linkage | *A Posteriori* Weighting: Coherence of Response | *A Posteriori* Weighting: Overall (Sum of Factors) | *A Posteriori* Weighting: Weighted LOE Score | Final LOE Score | Total WOE Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benthic Invertebrates | Contaminant Exposure | Sediment Quality | ↑ | 0.5 | 7.5 | 3.8 | n/a | n/a | n/a | 0.75 | 0.75 | 1.50 | 5.6 | 5.6 | 6.6 |
| | | Water Quality | ↑ | 0.5 | 3.8 | 1.9 | n/a | n/a | n/a | 0.75 | 0.75 | 1.50 | 2.8 | | |
| | Benthic Invertebrates - Gradient with Distance from the Mine | Total Invertebrate Density | ↓ | 0.5 | 20.0 | 10.0 | Decrease | 0.00 | 0.0 | | | | | 0.9 | |
| | | Pisidiidae Density | 0 | 0 | 18.8 | 0.0 | | | | | | | | | |
| | | *Procladius* Density | ↓ | 0.5 | 15.0 | 7.5 | Decrease | 0.25 | 1.9 | 0.25 | 0.25 | 0.50 | 0.9 | | |
| | | *Heterotrissocladius* Density | 0 | 0 | 15.0 | 0.0 | | | | | | | | | |
| | | *Micropsectra* Density | ↓ | 0.5 | 15.0 | 7.5 | Decrease | 0.25 | 1.9 | 0.25 | 0.25 | 0.50 | 0.9 | | |
| | | *Abiskomyia* density | 0 | 0 | 15.0 | 0.0 | | | | | | | | | |
| | | Richness | 0 | 0 | 25.0 | 0.0 | | | | | | | | | |

1. Individual endpoints for each LOE are assigned a categorical rating based on a set of decision criteria that correspond to the observed level of effect.

2. Each rating is converted to a numerical equivalent to allow mathematical calculation. Numerical equivalents are:
   - Negligible (0) = 0
   - Low/Marginal (/) = 0.5
   - Moderate (/) = 1
   - High (/) = 2

   Note that "" signs indicated increases or positive gradients while "" signs indicate decreases or inverse gradients.

3. Each endpoint has an overall *a priori* weighting factor, which is based on the representativeness, methodological robustness, clarity of interpretation, and permanence of effect for the particular endpoint. Qualitative equivalents of the numerical *a priori* factors range from 1 to 3 as follows:
   - Poor = 1
   - Satisfactory = 2
   - High = 3

   The numerical equivalents from Step 2 are multiplied by the overall *a priori* weighting score.

4. Direction weighting factors represent the degree of support for a particular hypothesis (i.e. nutrient enrichment vs. toxicological impairment) indicated by the direction of observed changes/relationships in effect/response endpoints. Qualitative equivalents of the numerical direction factors are:
   - High = 1
   - Moderate = 0.75
   - Neutral = 0.5
   - Low = 0.25
   - None = 0

   The numerical equivalents for effect/response endpoints from Step 3 are multiplied by the direction weighting factors.

5. *A posteriori* weighting factors for coherence and strength of linkage are applied to the WOE integration. Scores of low, medium, and high are assigned based on the results for exposure and effect/response endpoints (described annually in the AEMP report chapters for each exposure and ecosystem component). Qualitative equivalents of the numerical causality and coherence weighting factors are:
   - Low = 0.25
   - Medium/Neutral = 0.5
   - High = 0.75

   The numerical equivalents from Step 2 or Step 3 are multiplied by the *a posteriori* weighting factors.

6. The final scores for each endpoint are the vlues from Step 5. Overall, more weight was assigned to those endpoints with high *a priori* and *a posteriori* weighting scores and a direction of change/relationship that supports the hypothesis being examined.

   The final score for each LOE is the maximum endpoint score within that LOE.

7. The final score for each ecosystem component was the sum of the LOE Scores for that component (i.e., Exposure Final LOE Score + Effect/Response Final LOE Score). This numerical value is converted to an EOI Rank representing the strength of evidence for a particular impact hypothesis.

EOI Ranking Scale:

| | |
|---|---|
| **EOI Rank 3** | >40.0 |
| **EOI Rank 2** | >20.0 |
| **EOI Rank 1** | >10.0 |
| **EOI Rank 0** | <10 |

NOTES

EOI = evidence of impact

LOE = line of evidence

WOE = weight of evidence

The WOE integration for the toxicological impairment hypothesis is illustrated above using the Benthic Invertebrate Community ecosystem component (Lake Productivity and Fish Community are not shown) as an example. The LOE Groups, endpoints, and effect levels and results are presented for illustrative purposes only.

CLIENT

RioTinto

PROJECT

AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE

**EXAMPLE OF A WEIGHT-OF-EVIDENCE FRAMEWORK**

CONSULTANT

wsp GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-3 |
| DESIGNED | RS |
| PREPARED | SL |
| REVIEWED | RS |
| APPROVED | ZK |

| PROJECT NO. | CONTROL | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000-GC-0001 | 0 | 4.10-1 |

#### 4.10.2.2 Rating the Magnitude of Observed Effects

The results for each of the endpoints within each LOE group will be assessed relative to a set of decision criteria, resulting in a rating for the endpoint. Rating schemes in WOE frameworks can vary from assessment to assessment. WOE frameworks by Chapman and coauthors (e.g., Chapman et al. 2002) use non-numerical rating systems in which endpoint results are assigned to one of a ranked series of categories (e.g., "↑", "↑↑", "↑↑↑"). Conversely, Menzie et al. (1996) proposed numerical ratings based on a set of attributes scored between 1 and 5 according to a series of causal criteria.

The WOE framework applied in DDMI's AEMP uses a hybrid of the numerical and non-numerical systems to exploit the strengths of each:

1) Each endpoint will initially be rated according to a non-numerical scheme (i.e., 0, ↓/↑, ↓↓/↑↑, ↓↓↓/↑↑↑). This approach emphasizes the semi-quantitative nature of rating each endpoint.

2) These semi-quantitative ratings will then be temporarily transformed into an arbitrary scale of numerical values to facilitate weighting and integration using simple mathematical functions (i.e., addition, multiplication). This approach is highly systematic as all cases use the same formulae. This approach is also highly transparent (especially with respect to the application of professional judgment) as stakeholders and reviewers can see the effect of each assumption and decision on the outcome of the WOE analysis.

3) After weighting and integration, the numerical output of the WOE analysis will be transformed back into a non-numerical set of categories termed EOI Rankings.

Observed changes, differences or gradients in exposure and biological response endpoints will be classified in the AEMP using a rating scale. The decision criteria used to assign an effect level rating for exposure endpoints and for biological response endpoints will be based on the categories (i.e., Action Levels) in Section 5.2.

#### 4.10.2.3 Weighting of Endpoints Prior to Integration

In the WOE framework, greater weight is given to endpoints that accommodate natural variability, produce reliable and robust data, and that have strong association with ecological effects (Menzie et al. 1996; Chapman et al. 2002; Chapman and Anderson 2005). Conversely, lower weight is given to endpoints subject to high natural variability, that rely on new or inherently variable techniques, or that have unclear relevance to ecological effects. In addition, in the WOE evaluation for each impact hypothesis, higher weighting will be given to endpoint results that support the particular hypothesis being examined. Three sets of weighting factors will be applied to the endpoint results:

- *a priori* weighting factor
- direction weighting factors
- *a posteriori* weighting factors

## *A Priori* Weighting Factors

This first set of weighting factors will be established *a priori* based on professional judgment regarding the strength and relevance of the evidence contributed by each endpoint. All *a priori* weighting factors will be evaluated on a score ranging from 1 to 3 (i.e., 1 = poor; 2 = satisfactory; 3 = good). *A priori* weighting factors for each endpoint will be established based on the following criteria:

- **Representativeness**: This factor reflects the replicability of an endpoint, and its ability to capture natural variability or stochasticity. Techniques that integrate spatial or temporal variation, or that measure relatively homogeneous parameters, will be up-weighted. Highly temporally- or spatially-variable endpoints will be down-weighted.
- **Methodological Robustness**: This factor reflects the degree of confidence in the quality of data (e.g., accuracy, statistical power) produced by the sampling and analysis techniques employed. Precise and well-established methods with accepted QA/QC measures will be up-weighted. Experimental (i.e., new) or inherently variable techniques will be down-weighted.
- **Clarity of Interpretation**: This factor reflects the strength of association between a measurement endpoint and effects to VECs (i.e., assessment endpoints). Endpoints with unclear ecological relevance, many confounding factors, or that require uncertain laboratory-to-field extrapolation will be down-weighted.
- **Permanence of Effects**: This factor reflects the relevance of the endpoint to long-term ecological effects. Transient effects or effects on a highly resilient ecosystem component (i.e., one that is able to rapidly re-colonize or recover following a disturbance or upon removal of a chronic stressor) will be down-weighted.

*A priori* weighting factors for each criterion will be established through internal discussions and review among senior professionals within Golder specializing in risk assessment and environmental monitoring.

## Direction Weighting Factors

Direction weighting factors for endpoints in biological response LOE groups will be established to reflect the degree of support that an observed biological response contributes to each of the impact hypotheses. Weighting factors for various contingencies will be established *a priori*, and then specific weighting factors will be selected *a posteriori* based on the endpoint results. Direction weighting factors will be scaled from 0 to 1. The considerations for establishing the direction weighting factors will be the following:

- The factor applied for a given endpoint will be contingent on the observed direction of change or relationship.
- The factors will represent proportional support for each impact hypothesis indicated by the direction of change in an endpoint or the direction of the relationship of an endpoint with effluent exposure.
- The factors for all contingencies (increase/positive and decrease/inverse) will be established *a priori* and then applied *a posteriori*, contingent on the endpoint results.

Direction weighting factors will not be applied for endpoints in exposure LOE groups because the Nutrient Enrichment WOE analysis will use different exposure endpoints than the Toxicological Impairment WOE analysis. Furthermore, the direction of effect is implicit in the effect ratings for these endpoints.

### *A Posteriori* Weighting Factors

A final set of weighting factors will be established *a posteriori* to reflect additional insight gained during collection and analyses of the data. Two *a posteriori* criteria will be developed and applied to integrate information about the pattern of findings and inter-relationships among endpoints and LOE groups:

- **Coherence of Response**: This factor reflects consistency in response among the individual endpoints within a LOE group (i.e., similarity of findings from multiple exposure endpoints or biological response endpoints). Coherence of response will be scaled from 0.25 to 0.75 for all LOEs. The endpoint results within a LOE group will be down-weighted if the constituent endpoints in the LOE group respond inconsistently.

- **Strength of Linkage**: This factor reflects correspondence between endpoint results and their causative agents. For exposure endpoints, this includes evidence that changes in constituent concentrations are related to Mine activities (e.g., spatial gradients). For biological response endpoints, this includes exposure-effect relationships in endpoints that showed effects, and especially in the endpoint with the highest weighted score. An endpoint is down-weighted if there is no evidence for a linkage between observed responses and causative agents. Strength of linkage will be scaled from 0.25 to 0.75 for all LOEs.

### *4.10.2.4 Integrating Observed Effects and Weighting Factors*

WOE rankings will be estimated for each impact hypothesis by integrating the observed effects with applicable weighting factors. Within the analysis for each impact hypothesis, integrated WOE numerical scores for each of the ecosystem components will be calculated as the sum of the highest scores (after weighting) for individual endpoints in each LOE group. The final WOE score will be based on the addition of the final scores from the exposure and biological response endpoint results.

The numerical scores for each ecosystem component will be converted back to a final, semi-quantitative ranking (i.e., EOI). The EOI will consist of four rankings:

- EOI Rank 0 – Negligible Evidence of Impact
- EOI Rank 1 – Low Evidence of Impact
- EOI Rank 2 – Moderate Evidence of Impact
- EOI Rank 3 – Strong Evidence of Impact

The EOI rankings provide an indication of the strength of evidence associated with apparent Mine-related effects on a particular ecosystem component. This strength of evidence serves to inform, along with other considerations such as ecological significance and feasibility of solutions/actions, response plans when Action Levels are reached under the AEMP Response Framework. An important consideration is that the EOI rankings do not necessarily indicate the magnitude or ecological significance of observed effects. For example, it is possible that there could be strong evidence (EOI Rank 3) for a particular impact hypothesis in Lac de Gras but that the magnitude and significance with respect to the ecological integrity of Lac de Gras could be relatively mild.

# 5.0 RESPONSE FRAMEWORK

## 5.1 Overview

An “effect” is a change that follows an event or cause. An effect is not inherently negative or positive. A linkage must be established between a measured change and a cause (e.g., mining activity) for the change to be deemed an effect. The DDMI AEMP is designed to detect changes in Lac de Gras. Changes are not deemed “effects” until a link to the Mine has been established.

The importance of possible effects to an assessment endpoint has been categorized according to Action Levels. The Action Level classifications were developed to meet the goals of the *Guidelines for Adaptive Management – A Response Framework for Aquatic Effects Monitoring* (WLWB 2010) and Racher et al. (2011). The goal of the Response Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at defined Action Levels, which are triggered well before significant adverse effects could occur. A level of change that, if exceeded, would result in a significant adverse effect is termed a *Significance Threshold*. The Significance Threshold for Diavik was defined in the Comprehensive Study Report (Government of Canada 1999).

Magnitude of effects will be determined by comparing measurement endpoints between exposure areas and reference conditions or benchmark values. Reference conditions for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. The normal ranges that will be used in the Response Framework are described in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c). Values that exceed the normal range are exceeding what would be considered natural levels for Lac de Gras. Although unnatural for this lake, these values do not necessarily represent levels that are harmful.

During the EA, the ecological tolerance of changes in Lac de Gras were evaluated based on benchmark concentrations (termed ecological thresholds in the EA). These benchmarks were defined as concentrations at which a specific use could begin to be affected and were generally based on published guidelines, such as the Canadian Water Quality Guidelines (CWQGs; CCME 1999). The EA benchmarks have been carried through the AEMP process at Diavik and are herein referred to as *Effects Benchmarks*. This naming convention has been adopted because several of the CWQGs upon which EA benchmarks were based have changed over the years, and the Effects Benchmarks used in the AEMP are generally based on the revised CWQGs. In addition, some of the guidelines (e.g., aluminum and cadmium) have been adapted to the specific conditions of Lac de Gras (see Section 5.3.1). The Effects Benchmarks represent values that are protective of aquatic life and are intended to be conservative. They represent a level which, if exceeded, could cause adverse effects, not a level which, if exceeded, would cause adverse effects.

As described in the Action Levels presented below, an *Effects Threshold* will be defined once a certain magnitude of effect occurs (i.e., at Action Level 3). In contrast to the Effects Benchmarks, which are based on broad-scale guidelines that are applied to all waterbodies in Canada, the Effects Threshold would be based on the specific conditions of Lac de Gras. An Effects Threshold is a water chemistry value at which unacceptable biological effects could occur, or in the case of biological endpoints, it is an unacceptable biological effect.

The Action Levels presented below indicate the magnitude of effect required for each action (including mitigation) to take place. In general, a magnitude of effect that falls outside of the normal range and is approaching Effects Threshold values in areas close to the Mine will require an investigation of mitigation options (i.e., at Action Level 4). If values or effects exceed Effect Thresholds in any area of Lac de Gras as a result of Mine effluent discharge, EQC should be re-assessed with consideration of the AEMP results and the results of the mitigation investigations. This re-assessment would be outside the scope of the AEMP and would be coordinated by the WLWB. DDMI would be responsible for determining and implementing operational changes to ensure compliance with revised EQC.

This AEMP addresses two broad impact hypotheses for Lac de Gras: the Toxicological Impairment Hypothesis and the Nutrient Enrichment Hypothesis (see Section 4.10). Toxicity to aquatic organisms is the hypothetical response to the majority of constituents released from the Mine (such as metals). Hence, the Action Levels for water quality, sediment quality and biological effects only address the Toxicological Impairment Hypothesis.

The process of eutrophication is the response to inputs of nutrients such as phosphorus and nitrogen. Rather than the nutrients themselves, it is this response to inputs of nutrients that is of specific relevance to Lac de Gras. In contrast to constituents that can elicit a toxicological response at a certain concentration (e.g., metals), there is no threshold (or concentration) of nutrients at which a eutrophication response can be expected. Theoretically, any input of nutrients to an oligotrophic waterbody can result in some response (e.g., increase in algal biomass). In Lac de Gras, the primary response to the discharge of nutrients from the Mine has been the increase in phytoplankton biomass (as indicated by chlorophyll *a*) and the spatial expansion of this increase (Golder 2020d). Action Levels related to indicators of eutrophication apply to the concentrations of TP and chlorophyll *a*.

The WOE assessment is the process that will be used to evaluate the strength of evidence for toxicological impairment and nutrient enrichment effects (Section 4.10). The WOE assessment will also be used to establish a link between observed effects and the Mine. Both the evidence for the type of effect and for a link to the Mine must be strong for the effect to be deemed Mine-related. Hence, in the years when the WOE assessment is completed (i.e., comprehensive years), even if the Action Level conditions appear to have been met, the overall WOE conclusions must indicate a linkage to the Mine *and* support the impact hypothesis prior to concluding that an Action Level has been met.

If an Action Level in the Response Framework is exceeded, DDMI will be required to report the exceedance to the WLWB and submit an AEMP Response Plan (if required) that satisfies the requirements set out in Schedule 8, Condition 3 of Water Licence W2015L2-0001. The reporting requirements associated with submission and implementation of the AEMP Response Plan are discussed in Section 7.5.

## 5.2 Action Levels

### 5.2.1 Water Quality

The Action Levels for water quality variables will be applied to all measured variables (Table 5.2-1). Given that the EA predicted there would be no toxic effects to aquatic biota of Lac de Gras, the Action Levels are set to be relatively sensitive to the first indication of Mine influence on water chemistry. Since Effects Benchmarks and Effects Thresholds for water are established to protect biota, exceedances of Action Levels 1 to 4 observed for water quality should not be reflected in effects in the biological components of the AEMP. Biological monitoring will determine if effects are occurring on aquatic organisms, and the magnitude of effects will be classified according to the Action Levels defined for biological endpoints in Section 5.2.4, as defined and approved in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c).

Changes in water chemistry are expected to occur first in the NF area, where exposure to Mine-effluent is expected to be highest, or, in the case of dust exposure, at NF and MF stations within about 1 km of the Mine boundary. Detectable differences relative to reference conditions for Lac de Gras (obtained from the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]) will be used as the first indicator of Mine-induced changes. For an Action Level 1 to occur, there has to be a two-fold difference between NF median concentration (calculated based on all samples from all depths; parameters are not evaluated for individual depths due to limited sample size) and reference data set median concentrations (calculated using the procedure outlined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]). For variables that biomagnify (i.e., mercury and selenium) comparisons will be made to the current detection limit in addition to two times the reference data set median concentrations, resulting in a more stringent comparison for mercury and no change for selenium. As a result of this change, mercury and selenium will be included as SOIs when their concentrations are consistently greater than the detection limit. For all variables, the increase in the NF area must also be linked to the Mine (e.g., present in the Mine effluent or in dust deposited from mining activities). This Action Level represents the first indication that DDMI is having an effect on an endpoint (Table 5.2-1).

Action Level 2 occurs if the 5$^{th}$ percentile concentration in the NF area is greater than both two times the reference data set median concentration, and the normal range for Lac de Gras (obtained from the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]). In other words, 95% or more of NF values are greater than both two times the reference data set median concentration and the normal range at Action Level 2. If an Action Level 2 is triggered, an Effects Benchmark will be defined if an Effects Benchmark for that variable has not yet been established.

Given that, at Action Level 2, an effect has been documented in the lake and 95 percent of concentrations in the NF area are greater than both two times the reference data set median concentration and the normal range, concentrations at the edge of the mixing zone will be assessed as a means of predicting a potential escalation of the effect. An Action Level 3 would occur if the 75$^{th}$ percentile concentration of mixing zone values are greater than the normal range and also greater than 25% of the distance between the top of the normal range and the Effects Benchmark. At Action Level 3 the Effects Benchmark will be assessed for its applicability to Lac de Gras (e.g., is the Effects Benchmark overly conservative?). A site-specific Effects Threshold will be defined for the measurement endpoint in question. This value could be either the Effects Benchmark or a different value based on additional information applicable to Lac de Gras. This Effects Threshold will then be used going forward through the Action Levels. In addition to defining the Effects Threshold, the Significance Threshold will also be defined or confirmed at Action Level 3. At an Action Level 3 exceedance that is related to effluent discharge, the WLWB would likely consider developing an EQC for the variable in question, if one did not already exist.

At Action Level 4, values at the edge of the mixing zone have increased to greater than 50% of the distance between the top of the normal range and the Effects Threshold. If this level is triggered, mitigation options will be investigated. These investigations would be considered outside the scope of the AEMP.

At Action Level 5 the highest values (as quantified by the 95$^{th}$ percentile concentration) have now exceeded the Effects Threshold in the mixing zone. The appropriate response at this Action level would be for the WLWB to re-assess the EQC related to the AEMP variable in question, establish new water-quality based EQC, and for DDMI to determine any operational changes necessary to ensure compliance with the new EQC.

If concentrations exceeding Effects Threshold values extend beyond the edge of the mixing zone, additional revisions to EQCs could be required resulting in possible additional changes in Mine operations. The aerial expansion of effects that exceed Effects Thresholds through Lac de Gras are captured in Action Levels 6 to 9.

This series of Action Levels provides several opportunities to make changes to EQC and consequently the effluent discharge so that the Significance Threshold is never exceeded.

The Significance Threshold for Lac de Gras was defined in the EA. Termed a “significant adverse effect” in the EA, it is an effect that has a high probability of a permanent or long-term effect of high magnitude, within the regional area that cannot be technically or economically mitigated (Government of Canada 1999). With respect to water quality, a high magnitude effect was defined as a concentration that exceeds an established guideline by more than 20%. The regional area was defined as the drainage basin of Lac de Gras. Hence, an Action Level equivalent to the Significance Threshold would occur if the 95$^{th}$ percentile concentration in the FFA area exceeded the Effects Threshold by 20%.

**Table 5.2-1: Action Levels for Water Chemistry, Excluding Indicators of Eutrophication**

| Action Level | Magnitude of Effect[(a)] | Extent of Effect | Action/Note |
|---|---|---|---|
| 1 | Median of NF greater than two times the median of the reference data set[(b)] (open-water or ice-cover) and strong evidence of link to Mine | Near-field (NF) | Early warning. |
| 2 | 5$^{th}$ percentile of NF values greater than two times the median of the reference data set AND normal range[(b)] | NF | Establish *Effects Benchmark* if one does not exist. |
| 3 | 75$^{th}$ percentile of MZ values greater than normal range plus 25% of Effects Benchmark[(c)] | Mixing zone (MZ) | Confirm site-specific relevance of Effects Benchmark. Establish *Effects Threshold*. Define the Significance Threshold if it does not exist. The WLWB to consider developing an Effluent Quality Criteria (EQC) if one does not exist |
| 4 | 75$^{th}$ percentile of MZ values greater than normal range plus 50% of Effects Threshold[(c)] | MZ | Investigate mitigation options. |
| 5 | 95$^{th}$ percentile of MZ values greater than Effects Threshold | MZ | The WLWB to re-assess EQC.<br>Implement mitigation required to meet new EQC if applicable. |
| 6 | 95$^{th}$ percentile of NF values greater than Effects Threshold + 20% | NF | The WLWB to re-assess EQC.<br>Implement mitigation required to meet new EQC if applicable. |
| 7 | 95$^{th}$ percentile of MF values greater than Effects Threshold + 20% | Mid-field (MF) | The WLWB to re-assess EQC.<br>Implement mitigation required to meet new EQC if applicable. |
| 8 | 95$^{th}$ percentile of FFB values greater than Effects Threshold + 20% | Far-field B (FFB) | The WLWB to re-assess EQC.<br>Implement mitigation required to meet new EQC if applicable. |
| 9 | 95$^{th}$ percentile of FFA values greater than Effects Threshold + 20% | Far-field A (FFA) | Significance Threshold[(d)] |

a) Calculations are based on pooled data from all depths.

b) Normal ranges and reference data set median values are obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c); the normal range for open-water will be based on the 15 August to 15 September period.

c) Indicates 25% or 50% of the difference between the benchmark/threshold and the top of the normal range.

d) Although the Significance Threshold is not an Action Level, it is presented as the highest Action Level to show escalation of effects towards the Significance Threshold.

### 5.2.2 Sediment Quality

No predictions were made in the EA specific to sediment quality; however, with respect to water quality, the EA predicted that that there would be no toxic effects to the aquatic biota of Lac de Gras. This prediction is relevant to sediment quality because, similar to water, sediment is an important monitoring medium that provides information regarding chemical stressors that may affect aquatic organisms. Therefore, the Action Levels for sediment quality (Table 5.2-2) will follow the structure described in Section 5.2.1 for water quality. The Action Levels for water quality are set to be relatively sensitive to the first indication of Mine influence on water chemistry. This is also appropriate for sediment, as changes in sediment chemistry have the potential to affect the benthic invertebrate community.

A description of the Action Levels for Water quality is provided in Section 5.2.1 and is applicable to sediment quality; however, the following exceptions are noted:

- The Extent of Effect required for an Action Level 3 to occur will be the NF area instead of the mixing zone boundary, which is sampled as part of the Mine's SNP. Sediment collection methods for the AEMP are not comparable to those used for the SNP (i.e., for the AEMP, sediments are analyzed from the top 1-cm layer of core samples, whereas for the SNP, a deeper 5-cm layer is analyzed); hence, the sediment data in the NF area will be used so that the results are comparable among the Action Levels.
- The management action required if a sediment variable triggers Action Level 3 includes three of the four conditions stipulated for water quality (confirm site-specific relevance of Effects Benchmark, establish Effects Threshold, define the Significance Threshold if it does not exist). The fourth action considered at Action Level 3 for water quality (i.e., developing an EQC) assumes the cause of effects observed at Action Levels 1 through 3 is effluent related. Although the primary mechanism of effects on both water and sediment quality in Lac de Gras is the discharge of Mine effluent, other potential stressors such as dust deposition or dike construction may also influence sediment quality to a greater extent than water quality. The sediment quality component will, therefore, include a condition that an evaluation of cause must be conducted to identify the main source(s) of effects. The appropriate management action(s) could subsequently be identified, depending on the outcome of the evaluation of cause.
- The management actions required at Action Levels 4 and higher will be determined if an Action Level 3 is triggered. Information obtained from the evaluation of cause conducted at Action Level 3 will be used to identify appropriate actions at Action Levels 4 and higher.

**Table 5.2-2: Action Levels for Sediment Chemistry**

| Action Level | Magnitude of Effect[(a)] | Extent of Effect | Action/Notes |
|---|---|---|---|
| 1 | Median of NF greater than two times the median of the reference data set and strong evidence of link to Mine | Near-field (NF) | Early warning. |
| 2 | 5$^{th}$ percentile of NF values greater than two times the median of the reference data set AND normal range[(a)] | NF | Establish *Effects Benchmark* if one does not exist. |
| 3 | 75$^{th}$ percentile of NF values greater than normal range plus 25% of Effects Benchmark[(b)] | NF | Confirm site-specific relevance of Effects Benchmark. Establish *Effects Threshold*. Define the Significance Threshold if it does not exist. Investigate cause. |

**Table 5.2-2: Action Levels for Sediment Chemistry**

| Action Level | Magnitude of Effect[(a)] | Extent of Effect | Action/Notes |
|---|---|---|---|
| 4 | 75th percentile of NF values greater than normal range plus 50% of Effects Threshold[(a)] | NF | Investigate mitigation options. |
| 5 | 95th percentile of NF values greater than Effects Threshold | NF | To be determined. |
| 6 | 95th percentile of NF values greater than Effects Threshold + 20% | NF | To be determined. |
| 7 | 95th percentile of MF values greater than Effects Threshold + 20% | Mid-field (MF) | To be determined. |
| 8 | 95th percentile of FFB values greater than Effects Threshold + 20% | Far-field B (FFB) | To be determined. |
| 9 | 95th percentile of FFA values greater than Effects Threshold + 20% | Far-field A (FFA) | Significance Threshold.[(c)] |

a) Normal ranges are obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c).

b) Indicates 25% or 50% of the difference between the benchmark/threshold and the top of the normal range.

c) Although the Significance Threshold is not an Action Level, it is shown as the highest Action Level to show escalation of effects towards the Significance Threshold.

### 5.2.3 Eutrophication Indicators

An increase in the supply of nutrients typically results in enhanced algal growth, providing increased food supply to zooplankton and benthic invertebrates, which in turn increases the amount of food for fish. However, if enrichment progresses to extreme levels, the likelihood increases for a shift in overall trophic status of the lake, harmful alteration of the plankton community to less edible species for invertebrates and, in turn, for fish, or possible oxygen depletion. It is at this stage that enrichment could lead to harmful alteration of the Lac de Gras ecosystem.

The EA predicted the occurrence of nutrient enrichment in Lac de Gras, with some mild effects on biological communities but no change in trophic status of the lake as a whole. Because nutrient enrichment will often lead to enhanced productivity of the fisheries, its effects are sometimes viewed as being positive rather than negative; therefore, the Action Levels for responses to enrichment are set to be less sensitive than for toxicological impairment and focus on the initial increased productivity that results from nutrient addition (Table 5.2-3). In contrast to toxicological impairment responses to water chemistry (e.g., concentrations of metals), initial, mild eutrophication responses are difficult to link to nutrient concentrations. As demonstrated by years of monitoring in Lac de Gras, concentrations of phosphorus in the lake do not predict the actual biological response to nutrient enrichment (Golder 2020d). Rather, the increase in the biomass of algae as measured by chlorophyll *a* has been a good measure of the effects of nutrient enrichment.

A Significance Threshold for TP was defined in the EA. Consistent with the definition stated earlier, the magnitude of effect for TP at the Significance Threshold was defined as a concentration that exceeds the EA benchmark (5 ug/L) by more than 20%. Therefore, in keeping with the intent of this definition, the Significance Threshold for indicators of eutrophication will be a concentration of chlorophyll *a* and TP that exceeds the Effects Threshold by more than 20% in the FFA area of Lac de Gras.

Elevated concentrations of nutrients were expected in approximately 20% of Lac de Gras (Government of Canada 1999). Specifically, up to 20% (116 $km^2$) of the surface area of Lac de Gras was expected to exceed the EA Benchmark for phosphorus (i.e., 5 µg/L) during peak operations in open-water (and up to 11% [64 $km^2$] of the lake during ice-cover). The "extent of effect" for the chlorophyll *a* Action Levels reflects this prediction (Golder 2020d). An Effects Benchmark for chlorophyll *a* has been defined (Section 5.3.3) and is used in the Action Levels defined for chlorophyll *a* (Table 5.2-3).

Action Levels for TP were developed as part of the Eutrophication Indicators component under AEMP Version 5.2. While there is sufficient evidence to support the use of chlorophyll *a* in the Action Level assessment, reviewers have expressed concern that there are limitations associated with it being the sole indicator of eutrophication considered in the Action Levels (WLWB 2019a). Therefore, incorporating an exposure indicator into the Response Framework is prudent and would provide a metric that can be directly addressed by management actions. The Action Levels proposed for TP follow the same approach as used for chlorophyll *a*. An Effects Benchmark for TP is defined in Section 5.3.3 and will be used in the Action Level criteria for TP (Table 5.2-3).

**Table 5.2-3: Action Levels for Chlorophyll *a* and Total Phosphorus**

| Action Level | Magnitude of Effect | Extent of Effect | Action/Notes |
|---|---|---|---|
| 1 | 95th percentile of MF values greater than normal range[(a)] | Mid-field (MF) station | Early warning. |
| 2 | Near-field (NF) and MF values greater than normal range | 20% of lake area or more | Establish *Effects Benchmark*. |
| 3 | NF and MF values greater than normal range plus 25% of Effects Benchmark[(b)] | 20% of lake area or more | Confirm site-specific relevance of existing benchmark. Establish *Effects Threshold*. |
| 4 | NF and MF values greater than normal range plus 50% of Effects Threshold[(b)] | 20% of lake area or more | Investigate mitigation options. |
| 5 | NF and MF values greater than Effects Threshold | 20% of lake area or more | The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable. |
| 6 | NF and MF values greater than Effects Threshold +20% | 20% of lake area or more | The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable. |
| 7 | 95th percentile of MF values greater than Effects Threshold +20% | All MF stations | The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable. |
| 8 | 95th percentile of FFB values greater than Effects Threshold +20% | Far-field B (FFB) | The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable. |
| 9 | 95th percentile of FFA values greater than Effects Threshold+20% | Far-field A (FFA) | Significance Threshold.[(c)] |

a) Normal ranges are obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c), from the 15 August to 15 September period only.

b) Indicates 25% or 50% of the difference between the benchmark and the top of the normal range.

c) Although the Significance Threshold is not an Action Level, it is shown as the highest Action Level to show escalation of effects towards the Significance Threshold.

### 5.2.4 Biological Components

Action Levels for biological effects address the Toxicological Impairment Hypothesis. Conditions required for Action Levels 1 to 3 have been defined (Table 5.2-4), and incorporate normal ranges specified in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c). Action Level 4 and potentially additional Action Levels will be identified for a biological component if Action Level 3 is triggered. Identifying higher Action Levels after initial effects are encountered is consistent with the draft guidelines for preparing a Response Framework in AEMPs (WLWB 2010; Racher et al. 2011). All Action Levels require reasonable evidence that the biological changes observed are linked to the Mine, as indicated by chemistry-related monitoring components and supporting biological data.

A significant adverse effect, as it pertains to aquatic biota, was defined in the EA as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras. The Significance Thresholds for all aquatic biota, therefore, are related to impacts that could result in a change in fish population(s) that is greater than 20%.

During previous AEMP design versions, biological Action Levels 1 and 2 were based on statistical comparisons of the NF area to the FF1, FFA and FFB areas (formerly referred to as FF reference areas). However, during the AEMP Version 3.0, it was determined that the three former FF reference areas have become exposed to the Mine effluent and, therefore, can no longer be treated as valid reference areas in a control-impact comparison. Therefore, consistent with AEMP Design Version 5.2, the statistical comparisons to FF area data to evaluate Action Level triggers have been changed to use the mean of the 2007 to 2013 FF area data set, referred to as the reference condition data set, that was used to generate normal ranges in the approved *Reference Conditions Report Version 1.4* (Table 5.2.4).

**Table 5.2-4: Action Levels for Biological Effects**

| Action Level | Plankton | Benthic Invertebrates | Fish[a] | Extent | Action |
|---|---|---|---|---|---|
| 1 | Mean phytoplankton or zooplankton biomass or richness significantly less than the mean of the reference condition data set[a] | The mean of a community variable[b] significantly less than the mean of the reference condition data set[a] | Statistical difference from the mean of the reference condition data set[a] indicative of a toxicological response | NF | Confirm effect |
| 2 | Mean phytoplankton or zooplankton biomass or richness significantly less than the mean of the reference condition data set[a] | The mean of a community variable[b] significantly less than the mean of the reference condition data set[a] | Statistical difference from the mean of the reference condition data set[a] indicative of a toxicological response | Nearest MF station, or MF area (fish only) | Investigate cause<br>Initiate large-bodied fish health survey |
| 3 | Mean phytoplankton or zooplankton biomass or richness less than the normal range[c] | The mean of a community variable less than normal range[c] | A measurement endpoint beyond the normal range[c] | NF | Examine ecological significance, including an assessment of plankton edibility<br>Set Action Level 4<br>Identify mitigation options |
| 4 | TBD[d] | TBD[d] | TBD[d] | TBD[d] | TBD[d] |
| 5[e] | Decline in biomass likely to cause a >20% change in fish population(s) | Decline in invertebrate density likely to cause a >20% change in fish population(s) | Indications of severely impaired reproduction or unhealthy fish likely to cause a >20% change in fish population(s) | FFA | Significance Threshold[e] |

a) The mean of the reference condition is the mean of the reference condition data set, as approved in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c).
b) Refers to benthic invertebrate community variables listed in Section 4.7.4.
c) Normal range as defined and approved in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019c).
d) To be determined (TBD) if Action Level 3 is triggered.
e) Although the Significance Threshold is not an Action Level, it is shown as the highest Action Level to demonstrate the escalation of effects towards the Significance Threshold.

## 5.3 Effects Benchmarks

### 5.3.1 Water Quality

"Water quality" is the biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses and provides a measure of potential exposure for receptors. Water quality benchmarks represent levels of water quality variables below which a body of water is expected to be suitable for its designated use. Numeric benchmarks were previously developed in the EA (DDMI 1998a), and they represented concentrations intended to protect human health or aquatic life. The EA benchmarks were also used in the Comprehensive Study Report to define the magnitude of effect of the Mine on the water quality of Lac de Gras (Government of Canada 1999).

Aquatic life benchmarks adopted for the AEMP (herein termed "*Effects Benchmarks*") are based on the CWQGs for the protection of aquatic life (CCME 1999), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2020), Federal Environmental Quality Guidelines, guidelines from other jurisdictions (e.g., provincial and state guidelines), adaptations of general guidelines to site-specific conditions at Lac de Gras (Appendix IV.1 in DDMI 2007) or when appropriate, values from the primary literature (Table 5.3-1). The Effects Benchmarks used for the AEMP are generally consistent with those established during the EA (referred to as ecological thresholds in the EA), but have incorporated a number of revisions so that they are up-to-date and suitable for the Lac de Gras environment. Effects benchmarks will be updated within AEMP annual reports as they are published by CCME and Health Canada, and updates will be reflected in the next AEMP Design Plan update (per the schedule described in Section 3.5). For variables with both aquatic life and drinking water values, the Effects Benchmark is the lower of the two. As described in Section 5.2.1, a site-specific *Effects Threshold* will be defined for a water quality measurement if its concentration approaches the Effects Benchmark.

The CWQGs are intended to provide protection to freshwater life from anthropogenic stressors such as chemical inputs or physical changes (CCME 1999). These guidelines are based on current, scientifically-defensible toxicological data and are meant to protect all forms of aquatic life and all aspects of aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term. They are based on the lowest concentration shown to have any adverse effect (Lowest Observable Effects Level [LOEL]) on the most sensitive aquatic organism. A ten-fold safety factor is then applied to the LOEL, to provide added assurance that the guideline will protect aquatic life.

The Canadian Drinking Water Quality Guidelines are based on published scientific research related to health effects, aesthetic effects and operational considerations (Health Canada 1996, 2020). Health-based guidelines are established on the basis of comprehensive review of the known health effects associated with each chemical, exposure levels and availability of treatment and analytical technologies. Aesthetic effects (e.g., taste, odour) are taken into account when these play a role in determining whether consumers will consider the water drinkable.

The approach of basing benchmarks for water quality on the CWQGs is appropriate for two reasons:

- It relies on nationally-endorsed guidelines that reflect the best available information on the toxicity of each variable.
- It is conservative, as dictated by the method used to develop CWQGs.

Under the Response Framework for water chemistry (Section 5.2.1), an Effects Benchmark must be established for water quality variables that trigger Action Level 2 if an Effects Benchmark does not exist. During the AEMP Version 3.0, Effects Benchmarks were added for three water quality variables (i.e., TDS, barium, strontium) that triggered Action Level 2 and for one additional SOI (i.e., sulphate). Rationale for development of these benchmarks was provided in the A*EMP Study Design Version 3.5* (Golder 2014b). During the period covered by AEMP designs Version 4 and Version 5.2, seven additional water quality variables that did not have existing Effects Benchmarks (i.e., turbidity, dissolved calcium, dissolved sodium, total aluminum, total antimony, total silicon, and total tin) have triggered Action Level 2. These exceedances were identified during analyses completed for the *AEMP Version 3.0 (2011 to 2013) Summary Report* (Golder 2014c), the *2014 AEMP Annual Report* (Golder 2016b) and the *2018 AEMP Annual Report* (Golder 2019d). As required in the Response Framework, DDMI developed Effects Benchmarks for these seven variables, which are included in Table 5.3-1. Table 5.3-1 reflects benchmarks under AEMP Version 6.0, which are consistent with existing benchmarks under *AEMP Design Plan 5.2*, and also includes updates to benchmarks based on updated guidelines (i.e., pH, total aluminum, barium, cadmium, iron, lead, manganese [total and dissolved], selenium, strontium and zinc [total and dissolved]).

**Table 5.3-1: Effects Benchmarks for Water Quality Variables**

| Variable | Units | Effects Benchmarks[o] | |
|---|---|---|---|
| | | Protection of Aquatic Life | Drinking Water |
| **Conventional Parameters** | | | |
| pH | pH Units | 6.5 to 9.0 | 7.0 to 10.5 |
| Dissolved oxygen | mg/L | Cold water: | - |
| | | early life stages = 9.5 | |
| | | other life stages = 6.5 | |
| Total dissolved solids | mg/L | 500[a] | 500 |
| Total Alkalinity | mg/L | n/a[b] | - |
| Total suspended solids | mg/L | +5 (24 h to 30 days); | - |
| | | +25 (24-h period)[c] | - |
| Turbidity | NTU | 2.2 (long-term, IC)[d] | - |
| | | 2.3 (long-term, OW)[d] | |
| **Major Ions** | | | |
| Calcium (dissolved) | mg/L | 60[e] | - |
| Chloride | mg/L | 120 | 250 |
| Fluoride | mg/L | 0.12 | 1.5 |
| Sodium | mg/L | 52[d] | 200 |
| Sulphate | mg/L | 100[f] | 500 |
| **Nutrients** | | | |
| Ammonia as nitrogen | µg/L | 4,730[g] | - |
| Nitrate as nitrogen | µg/L | 3,000 | 10,000 |
| Nitrite as nitrogen | µg/L | 60 | 1,000 |
| **Total Metals** | | | |
| Aluminum (total) | µg/L | Variable with pH, hardness, and DOC[h] | 100/200[i] |
| Aluminum (dissolved) | µg/L | Variable with pH[f] | - |
| Antimony | µg/L | 33[d] | 6 |
| Arsenic | µg/L | 5 | 10 |
| Barium | µg/L | 1,000[f] | 2,000 |
| Boron | µg/L | 1,500 | 5,000 |
| Cadmium | µg/L | 0.1[g] | 7 |
| Chromium | µg/L | 1 (Cr VI)[j] | 50 |

**Table 5.3-1: Effects Benchmarks for Water Quality Variables**

| Variable | Units | Effects Benchmarks[o] | |
|---|---|---|---|
| | | Protection of Aquatic Life | Drinking Water |
| Copper | µg/L | 2 | 1,000 |
| Iron | µg/L | Variable with pH and DOC[k] | 300 |
| Lead | µg/L | 1 | 5 |
| Manganese (total) | µg/L | - | 20 |
| Manganese (dissolved) | µg/L | Variable with pH and hardness[l] | - |
| Mercury | µg/L | 0.026 (inorganic);<br>0.004 (methyl) | 1 |
| Molybdenum | µg/L | 73 | - |
| Nickel | µg/L | 25 | - |
| Selenium | µg/L | 1 | 50 |
| Silicon | µg/L | 2,100[d] | - |
| Silver | µg/L | 0.25 | - |
| Strontium | µg/L | 2,500[m] | 7,000 |
| Thallium | µg/L | 0.8 | - |
| Tin | µg/L | 73[d] | - |
| Uranium | µg/L | 15 | 20 |
| Zinc (total) | µg/L | - | 5,000 |
| Zinc (dissolved) | µg/L | Variable with pH, hardness, and DOC[n] | - |

\- = benchmark not available.

a) Adopted from Alaska DEC (2012) and as dictated by the WLWB (2013).

b) Alkalinity should be no lower than 25% of natural background level. There is no maximum guideline (USEPA 1998).

c) Average increase of 5 (24 hours to 30 days) or maximum increase of 25 mg/L in a 24 h-period).

d) See Appendix B in Golder 2017a for description.

e) See AEMP Response Plan for Diavik Diamond Mine – Proposed Calcium Effects Benchmark (Golder 2019e) for description.

f) BCMOE (2013).

g) See Appendix IV.1 in DDMI (2007) and BC MOE (2001) for description.

h) Benchmark value (µg/L) = e^([0.645 × ln(DOC)] + [2.255 × ln(hardness)] + [1.995 × pH] + [-0.284 × (ln(hardness) × pH)] -9.898) (ECCC 2021).

i) 100 µg/L for conventional treatment and 200 µg/L for other treatment types.

j) Total chromium concentrations will be compared to the benchmark for chromium VI.

k) Benchmark value (µg/L) = e^(0.671[ln(DOC)] + 0.171[pH] + 5.586) (ECCC 2019).

l) The CWQG for manganese (i.e., long-term guideline) is found using the CWQG calculator in Appendix B of the Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life: Manganese (CCME 2019).

m) ECCC (2020).

n) Benchmark value (µg/L) = e^(0.947[ln(hardness mg/L)] - 0.815[pH] + 0.398[ln(DOC mg/L)] + 4.625) (CCME 2018).

o) Unless noted, benchmarks are derived from current CWQGs and Canadian Drinking Water Quality Guidelines; the Effects Benchmark is selected as the lower of the two values.

## 5.3.2 Sediment Quality

Effects Benchmarks for sediment quality variables are defined in Table 5.3-2. Sediment quality benchmarks for the AEMP are relevant to the protection of aquatic life and are based on the Canadian Council of Ministers of the Environment (CCME) and Ontario Ministry of the Environment and Energy (OMOEE) sediment quality guidelines (SQGs; CCME 2002; OMOEE 1993), and in some cases on the primary literature. The OMOEE guidelines are used because they provide a broader set of guidelines for inorganic contaminants (CCME guidelines are currently only available for seven metals analyzed for the AEMP).

The CCME SQGs consist of an Interim Sediment Quality Guideline (ISQG) and a Probable Effects Level (PEL). The ISQG represents the level below which adverse effects rarely occur. The PEL represents the concentration above which adverse biological effects frequently occur. Similarly, the OMOEE SQGs consist of a Lowest Effect Level (LEL) and a Severe Effect Level. Effects Benchmarks assessed in the AEMP Response Framework for sediment quality will be the CCME ISQGs and the OMOEE LELs. For sediment variables with both an ISQG and a LEL, the Effects Benchmark will be the ISQG, because the federal guideline is more broadly representative of conditions across Canada. These SQGs represent concentrations that could be toxic to less than 5% of the sediment-dwelling fauna. By design, these are conservative guidelines and are generally considered intentionally overprotective of the aquatic environment (O'Connor 2004). Thus, if concentrations are below SQGs, then there is likely negligible ecological risk.

Under the Response Framework for sediment quality (Section 5.2.2), an Effects Benchmark must be established for sediment quality variables that trigger Action Level 2 if an Effects Benchmark does not exist. Results of the screening of sediment quality SOIs from the 2013 comprehensive monitoring program against the Action Levels defined in Section 5.2.2 demonstrated that bismuth triggered Action Level 2. A scientifically based benchmark derivation approach was undertaken to identify a benchmark for bismuth, but based on available information to date, it was not possible to develop a toxicity-based benchmark for this metal. Guidelines or other benchmarks have not been developed for bismuth in North America or elsewhere, which indicates that bismuth in sediments is generally not a constituent of concern for national or international regulatory authorities. Given the stable concentrations of bismuth observed in Lac de Gras sediments (including at the SNP-19 Mixing Zone) since 2006, the low aqueous concentrations of bismuth (generally non-detected in lake water), and the relatively low aquatic toxicity of bismuth documented in the available literature, bismuth is not considered to be a constituent of concern in Lac de Gras sediments.

**Table 5.3-2: Effects Benchmarks for Sediment Quality Variables**

| Variable | Unit | Effects Benchmark[(a)] |
|---|---|---|
| **Physical Properties** | | |
| Total organic carbon[(b)] | % | 1 |
| **Nutrients** | | |
| Total nitrogen[(b)] | % | 0.055 |
| Total phosphorus[(b)] | mg/kg dw | 600 |
| **Total Metals** | | |
| Arsenic[(c)] | mg/kg dw | 5.9 |
| Bismuth[(d)] | mg/kg dw | n/a[(d)] |
| Cadmium[(c)] | mg/kg dw | 0.6 |
| Chromium[(c)] | mg/kg dw | 37.3 |
| Cobalt[(b)] | mg/kg dw | 50 |
| Copper[(c)] | mg/kg dw | 35.7 |
| Iron[(b)] | mg/kg dw | 20,000 |
| Lead[(c)] | mg/kg dw | 35 |
| Manganese[(b)] | mg/kg dw | 460 |
| Mercury[(c)] | mg/kg dw | 0.17 |

**Table 5.3-2: Effects Benchmarks for Sediment Quality Variables**

| Variable | Unit | Effects Benchmark[a] |
|---|---|---|
| Nickel[b] | mg/kg dw | 16 |
| Silver[b] | mg/kg dw | 0.5 |
| Zinc[c] | mg/kg dw | 123 |

mg/kg dw = milligrams per kilogram dry weight.

a) Unless noted, benchmarks are derived from current Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guidelines (ISQGs) and Ontario Ministry of Environment and Energy (OMOEE) Lowest Effect Levels (LELs). For sediment variables with both an ISQG and a LEL, the Effects Benchmark is the ISQG.

b) Effects Benchmark is the OMOEE LEL.

c) Effects Benchmark is the CCME ISQG.

d) Numeric Effect Benchmark could not be defined due to lack of sediment toxicity data for bismuth (Appendix B in Golder 2017a); however, review of the literature indicates that bismuth is of relatively low toxicity through aquatic exposures, and is not considered a parameter of concern in Lac de Gras.

### 5.3.3 Eutrophication Indicators

Increased productivity in Lac de Gras due to phosphorus input was one of the predicted effects of the Mine (DDMI 1998a). The EA threshold for TP of 5 µg/L in the whole lake was selected to maintain trophic status (DDMI 1998a). Total phosphorus concentrations were predicted to increase above the EA threshold of 5 µg/L in 20% of the surface area of Lac de Gras, and a maximum concentration of 11.7 µg/L was predicted at the limit of the smallest assessment boundary (0.01 $km^2$ around the effluent diffusers). Therefore, nutrient enrichment, primarily due to phosphorus in the Mine water discharge, was predicted to potentially increase the productivity in part of Lac de Gras.

Total phosphorus concentration alone is not sufficient to evaluate changes to lake productivity. In fact, the measure of TP can only evaluate the *potential* for an increase in lake productivity. Ideally, some direct measure of biological response to nutrient enrichment can be made. Several years of monitoring in Lac de Gras have shown that the concentration of chlorophyll *a* (an indicator of phytoplankton biomass and/or standing crop) has been a sensitive and robust measure of biological response to nutrient inputs from the Mine (Golder 2019b, 2020d). Paired measures of chlorophyll *a* are generally very close to one another, indicating this variable can be measured with sufficient precision for use as an indicator or productivity.

Based on reference area samples collected over four years (from 2007 to 2010), the median background concentration of TP in Lac de Gras was 3.3 µg/L during the open-water season and 3.6 µg/L during the ice-cover season (Golder 2019c). The normal range of TP concentration for Lac de Gras is 2.0 to 5.3 µg/L during open-water seasons and 2.0 to 5.0 µg/L during the ice-cover season. This suggests that the EA benchmark of 5 µg/L is within the natural background range and is, therefore, not appropriate as a benchmark.

As discussed in Section 5.2.3, Action Levels for the eutrophication response are based on chlorophyll *a* concentrations. Therefore, an Effects Benchmark for chlorophyll *a* was developed for the AEMP under Version 3.0. Rationale for development of the chlorophyll *a* Effects Benchmark of 4.5 µg/L is provided in the *AEMP Study Design Version 3.5* (Golder 2014b). That assessment determined that a chlorophyll *a* Effects Benchmark concentration of 4.5 µg/L is appropriate in terms of both the aesthetic quality and food web functionality in Lac de Gras. Aesthetic qualities are likely to be preserved at chlorophyll *a* concentrations up to 10 µg/L, while a benchmark of 4.5 µg/L maintains the trophic classification of the lake as oligotrophic. Further, it is anticipated that even if chlorophyll *a* concentrations surpassed 4.5 µg/L in Lac de Gras, the lake would recover to baseline conditions shortly after the end of mining operations. Evidence from other northern oligotrophic lakes enriched with nutrients to yield chlorophyll *a* concentrations greater than 4.5 µg/L have shown a quick recovery, with a return to baseline concentrations within about two years after the cessation of nutrient enrichment.

While an Effects Benchmark does not need to be established until Action Level 2 has been triggered (per the Action Level system for eutrophication indicators), an Effects Benchmark was developed for TP in AEMP Design Version 5.1. It is known that nutrient enrichment is occurring in Lac de Gras, and the EA benchmark of 5 µg/L is within the normal range and is, therefore, not appropriate as a benchmark. Therefore, the proposed effects benchmark for TP in Version 5.1 (i.e., 10 µg/L) was derived using a similar approach as for chlorophyll *a* (Golder 2014b), in that the benchmark was the concentration representing the upper boundary of oligotrophic trophic status; however, for TP, a greater reliance was placed on trophic boundaries defined by Canadian regulatory agencies. Given that Lac de Gras has been classified as oligotrophic, a desired benchmark for Lac de Gras would be one that is representative of the boundary between oligotrophic and mesotrophic lakes. According to CCME (2004), the Canadian trigger ranges for TP are 4 to 10 µg/L for oligotrophic lakes, and 10 to 20 µg/L for mesotrophic lakes. In their decision regarding Version 5.1 of the AEMP design, the WLWB provided direction that the effects benchmark for TP was to be set at 7.5 µg/L in Version 5.2 of the AEMP design; this benchmark was carried forward to Version 6.0.

### 5.3.4 Biological Components

As described in Section 5.2.4, the Significance Thresholds for the biological components of the AEMP are related to impacts that could result in a change in fish population(s) that is greater than 20%. Should any of the monitoring results indicate that toxicological impairment is occurring, benchmarks for those endpoints in question would be set so that observed effects would not result in a 20% change to fish population(s).

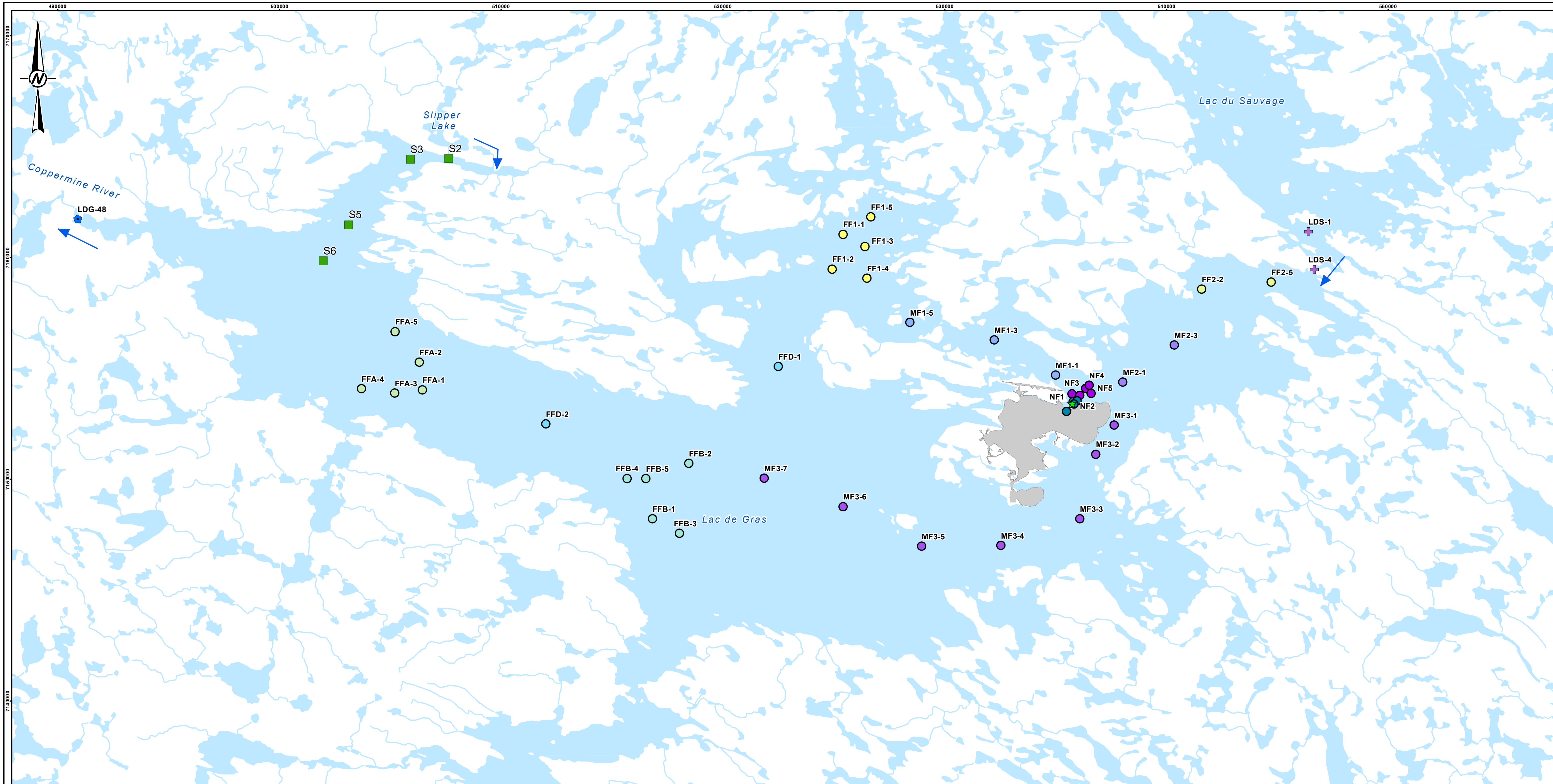
# 6.0 ALIGNMENT OF AEMPS IN LAC DE GRAS

The WLWB directed DDMI and Dominion Diamond Ekati ULC (Dominion) to work together in the development of the AEMP design to address concerns about potential across-project effects of the two mining operations on the aquatic receiving environment (WLWB 2015b). The WLWB later clarified that the intent of the directive was to create alignment between the two AEMP programs and, where possible, to facilitate the ability to evaluate potential across-project effects in Lac de Gras. On 16 May 2016, DDMI and Dominion met to discuss their respective AEMPs. Both DDMI and Dominion monitor multiple components of the aquatic ecosystem in Lac de Gras and Lac du Sauvage as part of their respective AEMPs. Figure 6.1-1 shows the combined sampling stations monitored for the DDMI AEMP and the Dominion AEMP.

The DDMI AEMP monitors 39 water quality stations within Lac de Gras, including 5 NF stations, 14 MF stations (including FF2), 17 FF stations (Figure 6.1-1), one site (LDG-48) at the outlet of Lac de Gras, one station in Lac du Sauvage (LDS-1), and one station in the narrows between Lac de Gras and Lac du Sauvage (LDS-4) (Figure 6.1-1).

The Ekati Diamond Mine (Ekati Mine) AEMP water quality program includes sampling at two stations in the northern arm of Lac de Gras near the inflow from Slipper-Lac de Gras stream (S2 and S3). Two additional water quality sampling stations (S5 and S6) towards the main body of the lake were added in 2013. Water quality in Lac du Sauvage, which flows into Lac de Gras, is monitored at stations LdS1 and LdS2 (which are not shown on Figure 6.1-1) as part of the Ekati Mine AEMP.

Both AEMPs sample water quality from mid-water column under-ice in April and during the open-water season in August/September (Table 6.1-1). The water quality variables and associated DLs are generally comparable between the two AEMP sampling programs (Table 6.1-2), and the DLs from both programs are sufficiently low to allow for the detection of potential mine-related effects. For three water quality variables (i.e., nitrite, magnesium and vanadium), DLs were lowered for *AEMP Design Plan Version 4.1* (Golder 2017a) to match those used for the Ekati Mine AEMP. Similarly, Dominion has been directed by the WLWB (WLWB 2017b) to implement revised DLs for eight variables (i.e., fluoride, nitrate, antimony, cadmium, cobalt, iron, silver and zinc; Table 6.1-2). Consistency in DLs between the two programs is expected to allow for improved ability to identify potential Project-related effects in the western portion of Lac de Gras, which receives Mine effluent from both the DDMI and Ekati Mines. The combined water quality data set from both Mines provides extensive spatial coverage in Lac de Gras, and could be used to detect water quality gradients across the lake. When combined, the AEMP data from both mines allow for the ability to understand across-project effects in Lac de Gras.




**LEGEND**

**EKATI AEMP**
- SLIPPER

**SAMPLING LOCATIONS**
- LAC DU SAUVAGE
- LAC DE GRAS

**EXPOSURE**
- NEAR-FIELD
- MID-FIELD 1
- MID-FIELD 2
- MID-FIELD 3
- FAR-FIELD 2
- FAR-FIELD 1
- FAR-FIELD B
- FAR-FIELD A
- FAR-FIELD D

- DIFFUSER
- SURVEILLANCE NETWORK PROGRAM
- FLOW DIRECTION
- WATERCOURSE
- DIAVIK FOOTPRINT
- WATERBODY

0 5 10
1:175,000 KILOMETRES

**REFERENCE(S)**
1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

CONSULTANT
wsp GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-04-13 |
| DESIGNED | RS |
| PREPARED | LMS |
| REVIEWED | RS |
| APPROVED | ZK |

PROJECT
AQUATIC EFFECTS MONITORING PROGRAM
DESIGN PLAN VERSION 6.0

TITLE
**DIAVIK AND EKATI AEMP SAMPLING STATIONS IN LAC DE GRAS**

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 22511717 | 1000 | 0 | 6.1-1 |

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**Table 6.1-1: Comparison of DDMI and Ekati AEMP Sampling Methods**

| Component | Ekati Diamond Mine | | | | | | Diavik Diamond Mine | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Timing | Locations | Frequency | Number of Samples | Sample Type | Sampling Depth | Timing | Locations (Number of Stations) | Frequency | Number of Samples per Station | Sample Type | Sampling Depth |
| Physical limnology (conductivity, temperature and DO profiles, Secchi depth) | Twice:<br>- Under-ice (April)<br>- Open-water (early August/September) | S2, S3, S5, S6, LdS1, LdS2[(a)] | Annually | n = 1 | Profile | Entire water column | Twice:<br>- Under-ice (April)<br>- Open-water (August/September) | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2, FFD-1, LDS-4[(b)] and LDG-48<br>Once every 3 years at all stations | Profile | Profile | Entire water column |
| Water quality | Twice:<br>- Under-ice (April)<br>- Open-water (early August/September) | S2, S3, S5, S6, LdS1, LdS2[(a)] | Annually | n = 2 per depth | Discrete | April: mid-depth; 2 m from the bottom<br>August: 1 m; mid-depth | Twice:<br>- Under-ice (April)<br>- Open-water (August/September) | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2, FFD-1, LDS-4[(b)] and LDG-48<br>Once every 3 years at all stations | NF and MF and FF2: 3<br>FF: 1 | Discrete | NF, MF and FF2: 2 m from the surface; mid-depth; 2 m from the bottom FF, LDS-4, LDG-48: mid-depth |
| Indicators of Eutrophication - Total Phosphorus and Total Nitrogen | Twice:<br>- Under-ice (April)<br>- Open-water (August/September) | S2, S3, S5, S6, LdS1, LdS2[(a)] | Annually | n = 2 per depth | Discrete | April: mid-depth; 2 m from the bottom<br>August: 1 m; mid-depth | Twice:<br>- Under-ice (April)<br>- Open-water (August/September) | NF (5)<br>MF and FF2 (14)<br>FF (17)<br>LDS (2)<br>LDG-48 | Annually at NF, MF and FF2, FF1-2, FFD-1, LDS-4[(b)] and LDG-48<br>Once every 3 years at all stations | 2 | Open-water: depth-integrated;<br>Ice-cover: discrete | Ice cover: NF, MF and FF2: 2 m from the surface; mid-depth; 2 m from the bottom FF, LDS-4, LDG-48: mid-depth<br>Open-water: depth integrated (10 m) |

DO = dissolved oxygen, NF = near-field, MF = mid-field, FF = far-field, LdS or LDS = Lac du Sauvage, LdG or LDG = Lac de Gras.

a) LdS2 is not sampled under-ice due to shallow depth.

b) Sampling for water quality, nutrients and chlorophyll *a* is not conducted at Station LDS-4 during the ice-cover season due to unsafe ice conditions at the outlet; LDS-1 is included in the “all stations” sampling every 3 years.

**Table 6.1-2: Comparison of DDMI *AEMP Design Plan Version 6.0* and Ekati Mine AEMP Water Quality Variables**

| Variable | Unit | Detection Limit | |
|---|---|---|---|
| | | DDMI | Ekati |
| **Conventional Parameters** | | | |
| Total alkalinity | mg/L | 0.5 | 0.5 |
| Specific conductivity – lab | µS/cm | 1 | 1 |
| Total hardness | mg/L | 0.5 | 0.5 |
| pH – lab | pH units | - | 0.1 |
| Total dissolved solids, calculated | mg/L | - | - |
| Total dissolved solids, measured | mg/L | 1 | 1 |
| Total suspended solids | mg/L | 1 | 1 |
| Total organic carbon | mg/L | 0.2 | 0.5 |
| Turbidity – lab | NTU | 0.1 | 0.1 |
| **Major Ions** | | | |
| Bicarbonate | mg/L | 0.5 | 0.5 |
| Calcium | mg/L | 0.01 | 0.01 |
| Carbonate | mg/L | 0.5 | 0.5 |
| Chloride | mg/L | 0.5 | 0.5 |
| Fluoride | mg/L | 0.01 | 0.01 |
| Hydroxide | mg/L | 0.5 | 0.5 |
| Magnesium | mg/L | 0.005 | 0.005 |
| Potassium | mg/L | 0.01 | 0.01 |
| Sodium | mg/L | 0.01 | 0.01 |
| Sulphate | mg/L | 0.5 | 0.3 |
| **Nutrients** | | | |
| Ammonia | µg-N/L | 5 | 5 |
| Nitrate | µg-N/L | 2 | 2 |
| Nitrite | µg-N/L | 1 | 1 |
| Nitrate + nitrite | µg-N/L | 2 | - |
| Total Kjeldahl nitrogen | µg-N/L | 20 | 20 |
| Total dissolved nitrogen | µg-N/L | 20 | - |
| Total nitrogen | µg-N/L | 20 | - |
| Soluble reactive phosphorus | µg-P/L | 1 | 1 |
| Total dissolved phosphorus | µg-P/L | 2 | - |
| Total phosphorus | µg-P/L | 2 | 2 |
| **Total Metals** | | | |
| Aluminum | µg/L | 0.2 | 0.2 |
| Antimony | µg/L | 0.02 | 0.02 |
| Arsenic | µg/L | 0.02 | 0.02 |
| Barium | µg/L | 0.02 | 0.02 |
| Beryllium | µg/L | 0.01 | 0.01 |
| Bismuth | µg/L | 0.005 | - |
| Boron | µg/L | 5 | 5 |
| Cadmium | µg/L | 0.005 | 0.005 |
| Calcium | mg/L | 0.01 | 0.01 |
| Chromium | µg/L | 0.05 | 0.05 |
| Cobalt | µg/L | 0.005 | 0.005 |
| Copper | µg/L | 0.05 | 0.05 |
| Iron | µg/L | 1 | 1 |
| Lead | µg/L | 0.005 | 0.005 |
| Lithium | µg/L | 0.5 | - |

**Table 6.1-2: Comparison of DDMI *AEMP Design Plan Version 6.0* and Ekati Mine AEMP Water Quality Variables**

| Variable | Unit | Detection Limit | |
|---|---|---|---|
| | | DDMI | Ekati |
| Magnesium | mg/L | 0.005 | 0.005 |
| Manganese | µg/L | 0.05 | 0.05 |
| Mercury | µg/L | 0.0019 | 0.0019 |
| Molybdenum | µg/L | 0.05 | 0.05 |
| Nickel | µg/L | 0.02 | 0.02 |
| Potassium | mg/L | 0.01 | 0.01 |
| Selenium | µg/L | 0.04 | 0.04 |
| Silicon | µg/L | 50 | 50 |
| Silver | µg/L | 0.005 | 0.005 |
| Sodium | mg/L | 0.01 | 0.01 |
| Strontium | µg/L | 0.05 | 0.05 |
| Sulphur | mg/L | 0.5 | - |
| Thallium | µg/L | 0.002 | - |
| Tin | µg/L | 0.01 | - |
| Titanium | µg/L | 0.5 | - |
| Uranium | µg/L | 0.002 | 0.002 |
| Vanadium | µg/L | 0.05 | 0.05 |
| Zinc | µg/L | 0.1 | 0.1 |
| Zirconium | µg/L | 0.05 | - |

µS/cm = microsiemens per centimetre; NTU = nephelometric turbidity unit; µg-N/L = micrograms nitrogen per litre; µg-P/L = micrograms phosphorus per litre.

## 6.1 Data Analysis Approach to Detect Across-Project Effects in Lac de Gras

A spatial gradient approach will be used to evaluate across-project effects in Lac de Gras from the Ekati and Diavik mines. This will be done as part of the comprehensive reports, which will present a spatial analysis of results from the comprehensive sampling program where all stations will be sampled, including the FF areas. Effects will be assessed for water quality SOIs and eutrophication indicators along the gradient of exposure at stations in the MF3, FFB and FFA areas and at Station LDG-48. Only variables that have concentrations greater than the normal range in the far-field areas (i.e., FFA and FFB) and are consistently measured by both AEMP programs in Lac de Gras will be included in the cumulative effects assessment. The presence of a spatial trend with distance from the Diavik diffusers that is reversed as one moves west from the MF3 or FFB areas would suggest that effluent from both mines are a potential influence on the variable in question. Magnitude of effects will be evaluated by comparing the results to the normal range (as defined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019c]). The AEMP results will be qualitatively compared to data collected at the Ekati Slipper Bay monitoring stations in Lac de Gras (e.g., S2, S3, S5 and S6) to further evaluate the potential contribution of Ekati to across-project effects in Lac de Gras. A temporal assessment of trends at relevant stations will be provided in the Aquatic Effects Re-evaluation Report and will follow the approach in Golder (2016a).

# 7.0 AEMP REPORTING

## 7.1 Overview

As described in the Water Licence W2015L2-0001, four different types of documents are required to be submitted under the AEMP. These include AEMP Design Plans, AEMP Annual Reports, Aquatic Effects Re-evaluation Reports and AEMP Response Plans. The AEMP Design Plan, as represented by this document, describes how the aquatic effects monitoring programs in Lac de Gras will be executed. The AEMP Design Plan is updated at a regular interval so that the monitoring programs continue to meet the goals of the AEMP. The annual reports present a summary of the results obtained during each year of monitoring. The AEMP Annual Reports for the comprehensive monitoring years provide a detailed assessment of effects from years when all AEMP components and stations are sampled. The AEMP Annual Report for interim monitoring years provides an assessment of effects on water quality variables, indicators of eutrophication and plankton. The Aquatic Effects Re-evaluation Report presents a summary of the key findings of the monitoring program, including updates to the temporal trends established during the AEMP Versions 2.0 and 3.0. If effects of a specified magnitude are encountered as a result of the monitoring activities conducted under the AEMP (e.g., Action Level 2 [biological effects] or Action Level 3 [water or sediment chemistry] is exceeded), an AEMP Response Plan will be generated, describing the management actions that will be taken, including a timeline for implementing those actions.

The aforementioned reports will be submitted to the WLWB for review and approval according to the schedule presented in Section 3.5. Each report will include the objectives, methods and results associated with the AEMP components (described in Section 4.0) monitored in that year. DDMI will also report Action Level exceedances annually per the separate reporting schedule described in Section 7.5. Electronic versions of the AEMP data and reports will be provided through posting of appropriate files to the WLWB Registry on the WLWB public registry. DDMI acknowledges that various parties will review the reports and will work as directed by the WLWB to facilitate this review.

In addition to the reporting requirements discussed above, DDMI will inform the WLWB if the AEMP determines that there are any imminent potential risks to the ecosystem or to humans requiring immediate action. Such notification to the WLWB will initially be via e-mail and phone and subsequently by an appropriate Technical communication (e.g., a Technical Memorandum), together with recommended remedial actions. An example of such imminent potential risk occurred early in the operations of the Ekati Mine where discharge of treated sewage resulted in lake eutrophication and oxygen depletion under ice. While there is no reason to suspect that imminent potential risks will occur, this additional reporting option is outlined as a precautionary measure.

## 7.2 AEMP Design Plan

While this document presents *AEMP Design Plan Version 6.0*, updates to the AEMP design will be submitted over the life of the Mine, as required by the Water Licence W2015L2-0001. Part I, Condition 2 of the Water Licence requires that DDMI review and revise, as necessary, the AEMP Design Plan every three years, or as directed by the WLWB. The Water Licence also stipulates that the AEMP Design Plan must meet the specific criteria defined in Schedule 8, Condition 1, which are summarized in Table 1.3-1. The AEMP re-design will be conducted based on comments and recommendations received from the WLWB and from other stakeholders. When updates are made to the AEMP Design Plan, a summary of changes since the last approved design will be included in the revised plan, together with a rationale for the changes.

The next AEMP Design Plan will be prepared as and when directed by the WLWB but is anticipated to be submitted in 2023, following submission of the 2022 comprehensive AEMP annual report and the 2020 to 2022 re-evaluation report (Section 3.5). The AEMP Design Plan will consider the annual AEMP results during the interim and comprehensive monitoring years, and the results of temporal analyses completed for the re-evaluation report.

## 7.3 AEMP Annual Report

The AEMP Annual Report for each year of monitoring under the *AEMP Design Plan Version 6.0* will provide results for the components monitored in each year. The annual reports will be submitted no later than 31 March of the following year, as required by the Water Licence W2015L2-0001, and will incorporate the specific conditions defined in Schedule 8, Condition 4. The annual reports for the interim (e.g., 2023, 2024) and comprehensive (e.g., 2025) sampling years will follow the same structure as the reports submitted under previous AEMP design plans. The report for the comprehensive sampling program will include an assessment of effects for all AEMP components in all sampling areas and a weight-of-evidence assessment. The reports for interim sampling years will assess effects on water quality variables, indicators of eutrophication, and plankton, by determining if an Action Level has been triggered.

To better communicate AEMP results to the range of technical and non-technical parties who are interested in the results, the main body of the comprehensive and interim AEMP reports will provide a plain language summary of the most important results. This summary will be presented with very little technical discussion and will include results that are applicable for a given year of monitoring based on the requirements for that year. The structure of the main body of the report will be as follows:

- Section 1 Introduction
- Section 2 Dust Deposition
- Section 3 Effluent and Water Chemistry
- Section 4 Eutrophication Indicators
- Section 5 Sediment Chemistry
- Section 6 Plankton
- Section 7 Benthic Invertebrates
- Section 8 Fish
- Section 9 Fisheries Authorization and Special Effects Studies
- Section 10 Traditional Ecological Knowledge Studies
- Section 11 Weight-of-Evidence
- Section 12 Adaptive Management Response Actions
- Section 13 Conclusions and Recommendations
- Section 14 Contributors

The AEMP Annual Report will also include a series of technical appendices consisting of individual scientific reports, which will provide a full technical and scientific description of the analyses conducted and the results obtained. Any deviations from the Board-approved AEMP Design Plan will be identified and explained in the AEMP Annual Reports, and any required changes will be proposed as updates to the AEMP Design Plan, if necessary. Appendices will be pre-assigned in the AEMP reports (i.e., they will appear in the same order and use the same appendix number in each year) to help track available information on a year-to-year basis, even though not all appendices may be required in a given year. The appendices will consist of the following:

- Appendix I Dust Deposition Report
- Appendix II Water Chemistry Report
- Appendix III Sediment Report
- Appendix IV Benthic Invertebrate Report
- Appendix V Fish Report[3]
- Appendix VI Plume Delineation Survey
- Appendix VII Dike Monitoring Study
- Appendix VIII Fish Salvage Program
- Appendix IX Fish Habitat Compensation Monitoring
- Appendix X Fish Palatability, Fish Health, and Fish Tissue Chemistry Survey[4]
- Appendix XI Plankton Report
- Appendix XII Special Effects Study Reports
- Appendix XIII Eutrophication Indicators Report
- Appendix XIV Traditional Knowledge Studies[5]
- Appendix XV Weight-of-Evidence Report

All raw data for all variables monitored as part of the AEMP will be provided in Excel spreadsheet format as part of the submission for all AEMP reports. Laboratory reports (i.e., raw data) for toxicity tests will also be provided.

## 7.4 Aquatic Effects Re-evaluation Report

Part I, Condition 9 of Water Licence W2015L2-0001 requires that an Aquatic Effects Re-evaluation Report (formerly referred to as the Three-year Summary Report) be submitted for WLWB approval every three years, or upon direction from the WLWB. The objective of this report will be to meet the requirements set out in Schedule 8, Condition 5 of the Water Licence, which are discussed below.

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[3] Appendix V includes the Slimy Sculpin fish health and fish tissue survey report and may include a Lake Trout survey report, if a Lake Trout study was initiated.

[4] Appendix X is a placeholder for Fisheries Authorization surveys (e.g., Fish Habitat Utilization surveys).

[5] Appendix XIV includes the fish palatability data from Lake Trout collected as part of the TK program.

The Aquatic Effects Re-evaluation Report will provide a review and summary of AEMP data collected to date, including a description of overall trends in the data and other key findings of the monitoring program. The report will also present temporal analysis trends for the three-year re-evaluation period and from Project inception. Such trends reflect the combined effects of Mine activities on a given variable over time. These trends may also reflect combined effects from within and across-projects, because the data collected at a given location in a given year represent the sum of Mine-related effects on the aquatic environment at each sampling station, and, potentially, effects from other developments.

The Aquatic Effects Re-evaluation Report will include an analysis that integrates the results of individual monitoring components to date and describes the overall significance of the results. Examples of integration may include the following:

- Various types of information, including water chemistry data (chlorophyll *a*, TP, TN), and results from the plankton, benthic invertebrate monitoring, and potentially TK studies, would be evaluated to identify if eutrophication is occurring in Lac de Gras.
- An evaluation of potential changes to the fish community in Lac de Gras would involve joint consideration of the results from all AEMP components (water, sediment, benthic invertebrates, fish palatability, fish health, and fish tissue chemistry surveys) and possibly studies conducted to comply with the Fisheries Authorization (e.g., fish habitat utilization surveys).

The Aquatic Effects Re-evaluation Report will also include a comparison of measured Project-related aquatic effects to EA predictions and/or provide updated predictions based on AEMP results to date; i.e., is the AEMP collecting the right data in the right areas and at the appropriate frequency within Lac de Gras? The Aquatic Effects Re-evaluation Report provides an opportunity to answer this question and will present the following information:

- major findings, trends over time, and comparisons to predicted impacts
- use of the WOE to assess whether or not the AEMP has documented Mine-related effects on Lac de Gras
- changes to Mine management as a result of AEMP findings
- the next steps in AEMP implementation

The technical information presented in the report will be summarized in a plain language summary which will describe the major results of the analyses discussed above and provide an interpretation of the significance of those results. Recommendations for changes to aspects of the AEMP design will be made, if applicable, along with a rationale for these recommendations.

## 7.5 AEMP Response Plan

Part I, Condition 6 of the Water Licence specifies that "*if any Action Level defined in the approved Response Framework is exceeded, the licensee shall a) notify the Board within thirty (30) days of when the exceedance is detected; and, b) within ninety (90) days of when the exceedance is detected, submit an AEMP Response Plan that satisfies the requirements of Schedule 8, Condition 3 to the Board for approval*." On 16 December 2016, DDMI submitted a *Schedule Update Request* for consideration by the WLWB to revise Schedule 8 of the Water Licence, which pertains to the requirements for AEMP Response Plans (WLWB 2015b). The Schedule 8 Amendment was approved by the WLWB on 28 August 2017 in a form which maintains the requirement for a

Response Plan under most circumstances, but reduces reporting requirements for lower Action Levels, and recognizes the difference between Action Levels established for biological variables and those established for water chemistry, sediment chemistry, and eutrophication indicators. DDMI will implement reporting procedures for AEMP Response Plans as required by the WLWB.

In addition, per WLWB directives, DDMI proposed modified reporting timelines for Action Levels, which were approved on 31 January 2021 (WLWB 2022a), and require the following:

- Water Quality Action Levels will be reported by 31 August of the same year for ice-cover sampling, and by 20 December of the same year for open-water sampling
- Sediment Quality Action Levels will be reported by 20 December of the same year for open-water sampling (there is no ice-cover sampling for sediment)
- Biological (i.e., Eutrophication Indicators, Plankton, Benthic Invertebrate Community, and Fish) Action Levels will be reported by 31 March of the following year, with the AEMP Annual Report.

# 8.0 CONCORDANCE WITH WLWB DIRECTIVES AND RECOMMENDATIONS

Concordance of the *AEMP Design Plan Version 6.0* with relevant WLWB recommendations and Directives are summarized in Table 8.1-1. In addition, DDMI has made some additional revisions; these items are summarized in Table 8.1-2. References to sections of the report where items have been addressed are indicated in the final column of each table.

**Table 8.1-1: Concordance of the *AEMP Design Plan Version 6.0* with Directives and Recommendations from the WLWB.**

| Source | Statement of Direction, Comment, or DDMI Commitment | Component or Location in Report | Location in Report |
|---|---|---|---|
| WLWB 2016 AEMP Response Plans and 2016 AEMP Fish Response Plan - Supplemental Report 24 January 2018 (WLWB 2018) | Require DDMI to include relevant updates to Canadian Water Quality Guidelines as part of the proposed changes to the AEMP Design to be submitted with the 2014 to 2016 Aquatic Effects Re-evaluation Report | Water Quality | Section 5.3.1 |
| WLWB 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report WLWB 25 March 2019 (WLWB 2019b) | DDMI stated it will include a requirement for DDMI to provide the raw toxicity data as part of the AEMP report when the AEMP Design is updated (GNWT-ENR comment 5). | Toxicity | Section 7.3 |
| WLWB Letter re. the 2017 to 2019 Aquatic Effects Re-evaluation Report 31 January 2022 (WLWB 2022b) | Proposed text related to the dust zone of influence | Water Quality | Sections 4.3.4.8 and 4.3.4.3 |
| | Updated Water Quality Effects Benchmarks for barium, cadmium, lead, manganese, selenium, and strontium; | Water Quality | Section 5.3.1, Table 5.3-1 |
| | Removal of organic matter from the list of analytical parameters for sediment quality | Sediment Quality | Section 4.4.3, Table 4.4-1; Section 4.4.4 |
| | Clarification in Section 6.1 of the circumstances for when a parameter would not be included in the cumulative effects assessment; and | Alignment of AEMPs in Lac de Gras | Section 6.1 |
| | Fish abnormalities in the Weight-of-Evidence | Fish | Section 4.10.2.1, Tables 4.10-1 and 4.10-2 |
| WLWB Decision Letter re. 2019 AEMP Annual Report 16 April 2021 | 2. To direct DDMI to include a discussion in the next version of the AEMP Design on whether different criteria for selecting SOIs should be considered for substances that can biomagnify | Water Quality | Sections 4.3.4.3 and 5.2.1 |
| WLWB Letter re. the 2020 AEMP Annual Report 31 Jan 2022 (WLWB 2022c) | DDMI to include a comparison between the Effects Benchmark for zinc and the CCME guideline in consideration of DOC concentrations in Version 6 of the AEMP Design Plan. If DDMI determines a change to the Effects Benchmark for zinc is not required, provide the rationale for why not in Version 6. | Water Quality | Section 5.3.1, Table 5.3-1 |

**Table 8.1-1: Concordance of the *AEMP Design Plan Version 6.0* with Directives and Recommendations from the WLWB.**

| Source | Statement of Direction, Comment, or DDMI Commitment | Component or Location in Report | Location in Report |
|---|---|---|---|
| WLWB Letter re. AEMP Response Framework – Notification of Action Level Exceedances 3 Mar 2021 (WLWB 2022d) | The Board is requiring updated timelines for Action Level exceedance notifications (as described in the letter submitted by DDMI on 6 July 2021) be reflected in AEMP Design Plan Version 6.0. | AEMP Reporting | Section 7.5 |
| WLWB Letter re. the 2017 to 2019 Aquatic Effects Re-evaluation Report 31 January 2022 (WLWB 2022a) | The Board indicated that although DDMI made no specific recommendations to the AEMP design or data analysis related to eutrophication indicator variables, a statement in the *2017 to 2019 AEMP Re-evaluation Report* regarding removing zooplankton biomass as ash-free dry mass from the list of eutrophication indicator variables could become a recommended change in the *AEMP Design Plan Version 6.0*, with appropriate rationale. | Eutrophication Indicators | Section 4.5.1 |

AEMP = Aquatic Effects Monitoring Plan; DDMI = Diavik Diamond Mines Inc.; GNWT-ENR = Government of the Northwest Territories Environment and Natural Resources; WLWB = Wek'èezhìı Land and Water Board

**Table 8.1-2: List of Additional Edits to *AEMP Design Plan Version 6.0* Proposed by DDMI**

| Item Number | Explanation of the Edits Proposed for Version 6.0 | Component or Location in Report | Location in Report |
|---|---|---|---|
| 1 | Relative abundance (Slimy Sculpin) and CPUE should be added as exposure endpoints to fish, as they provide additional relevant information for the WOE assessment | Weight-of-Evidence | Section 4.10.2.1, Tables 4.10-1 and 4.10-2 |
| 2 | Effects Benchmarks adopted for the AEMP are based on CWQG for the protection of aquatic life (CCME 1999 + updates), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2006), guidelines from other jurisdictions (e.g., provincial and state guidelines), adaptations of general guidelines to site-specific conditions in Lac de Gras (Appendix IV.1 in DDMI 2007), or values from the scientific literature. Six water quality variables (i.e., barium, cadmium, lead, manganese, selenium, and strontium) have updated Health Canada drinking water guidelines, which are not yet reflected in the design plan (i.e., neither AEMP Versions 4.1 or 5.2). Effects Benchmarks will be updated within AEMP annual reports (and this approach will be indicated in the next AEMP design plan update). | Water Quality | Section 5.3.1 |
| 3 | Project Description section updated to reflect new activities or details since submission of Version 5.2. | Project Description | Section 2.0 |

AEMP = Aquatic Effects Monitoring Plan; CPUE = Catch Per Unit Effort; CWQG = Canadian Water Quality Guidelines; DDMI = Diavik Diamond Mines Ltd.; WLWB = Wek'èezhìı Land and Water Board; WOE = Weight-of-Evidence

# 9.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or requirements, please contact the undersigned.

**Golder Associates Ltd.**

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https://golderassociates.sharepoint.com/sites/157917/phase 1000/05 technical work/03_aemp_design_ver6/21452119-2328-r-reva-1000-ddmi_aemp_design_plan_ver 6.docx

# 10.0 REFERENCES


Arnold TW. 2010. Uninformative Parameters and Model Selection using Akaike's Information Criterion. The Journal of Wildlife Management 74: 1175-1178.

Alaska DEC (Alaska Department of Environmental Conservation). 2012. Water Quality Standards. Amended as of April 8, 2012.

BCMOE (British Columbia Ministry of Environment). 2001. http://www.env.gov.bc.ca/wat/wq/BCguidelines/aluminum/aluminum.html

BCMOE. 2013. A Compendium of Working Water Quality Guidelines for British Columbia. Retrieved on 13 May 2013.

Box GEP, Cox DR. 1964. An Analysis of Transformations (with discussion). Journal of the Royal Statistical Society B, 26, 211–252.

Brooks JL. 1957. The systematics of North American Daphnia. Mem Connect Acad Arts Sci 13: 1-180.

Burnham KP, Anderson DR. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. New York: Springer Science+Business Media, Inc.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Water Quality Guidelines. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Ministers of the Environment. With updates to 2006. Ottawa, ON.

CCME. 2002. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Environmental Quality Guidelines. Winnipeg, MB.

CCME. 2004. Canadian water quality guidelines for the protection of aquatic life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. In: Canadian environmental quality guidelines, 2004, Canadian Council of Ministers of the Environment, Winnipeg, MB.

CCME. 2018. Canadian water quality guidelines for the protection of aquatic life: zinc. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

CCME. 2019. Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life: Manganese. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Chapman PM, Hollert H. 2006. Should the sediment quality triad become a tetrad, a pentad, or possibly even a hexad? J Soil Sed 6:4-8.

Chapman PM, Anderson J. 2005. A decision making framework for sediment contamination. Integr Environ Assess Manage 1:163-173.

Chapman PM, McDonald BG, Lawrence GS. 2002. Weight-of-evidence issues and frameworks for sediment quality (and other) assessments. Human Ecol Risk Assess 8:1489-1515.

Clarke KR. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18:117-143.

Clarke KR, Gorley RN, Somerfield PJ, Warwick RM. 2014. Change in marine communities: an approach to statistical analysis and interpretation, 3rd edition. Plymouth, UK: PRIMER-E. 260 pp.

Clarke KR, Gorley RN. 2016. PRIMER v7.0.11. Plymouth, UK: PRIMER-E Ltd.

CRI. 2014. Age, Growth, and Movement of Freshwater Slimy Sculpin in Northern Canada. 38 p.

DDMI (Diavik Diamond Mines Inc.). 1998a. Integrated Environmental and Socio-Economic Baseline Report. Yellowknife, NT.

DDMI. 1998a. Environmental Effects Report, Air Quality. Diavik Diamonds Project. Yellowknife, NT. Canada. September 1998.

DDMI. 1998b. Environmental Effects Report, Fish and Water. Diavik Diamonds Project. Yellowknife, NT, Canada. September 1998.

DDMI. 2005. Sustainable Development Report. Yellowknife, NT.

DDMI. 2006a. Fish Palatability and Texture Study. Yellowknife, NT

DDMI. 2006b. 2005 Dust Deposition Monitoring Report. Yellowknife, NT. March 2006.

DDMI. 2006c. 2005 Annual Environmental Agreement Report. Yellowknife, NT. June 2006.

DDMI. 2007. Diavik Diamond Mine – Aquatic Effects Monitoring Program – AEMP Design Document, Version 2.0. Yellowknife, NT. December 2007.

DDMI. 2008. Diavik Diamond Mine - Aquatic Effects Monitoring Program - 2007 Annual Report. Submitted to the Wek'èezhìı Land and Water Board. Yellowknife, NT. April 2008.

DDMI. 2010. Diavik Diamond Mine - Aquatic Effects Monitoring Program - 2009 Annual Report. Submitted to the Wek'èezhìı Land and Water Board. Yellowknife, NT. April 2010.

DDMI. 2011. Diavik Diamond Mine - Aquatic Effects Monitoring Program - 2010 Annual Report. Submitted to Wek'èezhìı Land and Water Board. Yellowknife, NT. March 2011.

DDMI. 2020. Water Management Plan. Version 15. Yellowknife, NT. January 2020.

Environment Canada. 2010. Pulp and Paper Technical Guidance for Environmental Effects Monitoring. Environment Canada, Ottawa, Ontario.

Environment Canada. 2012. Metal Mining Technical Guidance for Environmental Effects Monitoring. Environment Canada, Ottawa, Ontario.

Environment and Climate Change Canada (ECCC). 2019. Federal environmental quality guidelines – Iron. Under the Canadian Environmental Protection Act, 1999. Environment and Climate Change Canada.

ECCC. 2020. Federal environmental quality guidelines - strontium. Under the Canadian Environmental Protection Act, 1999. Environment and Climate Change Canada.

ECCC. 2021. Canadian Environmental Protection Act, 1999 - Federal environmental quality guidelines - aluminium. Environment and Climate Change Canada.

Glozier NE, Culp JM, Reynoldson TB, Bailey RC, Lowell RB Trudel L. 2002. Assessing metal mine effects using benthic invertebrates for Canada's Environmental Monitoring Program. Water Quality Res. J. Can 37: 251-278.

Golder (Golder Associates Ltd.). 1997. Technical Memorandum #24-2. Benthic Invertebrate Survey. 1996 Environmental Baseline Program. Prepared for Diavik Diamond Mines Inc., Yellowknife, NT.

Golder. 2008a. Plankton Report in Support of the 2007 AEMP Annual Report for the Diavik Diamond Mine, NT. Prepared for Diavik Diamond Mine Inc., Yellowknife, NT. April 2008.

Golder. 2008b. Fish Report in Support of the 2007 AEMP Annual Report for the Diavik Diamond Mine, NT. Prepared for Diavik Diamond Mine Inc., Yellowknife, NT. April 2008.

Golder. 2011a. 2007 to 2010 AEMP Summary Report. Prepared for Diavik Diamond Mines Inc., Yellowknife, NT. July 2011.

Golder. 2011b. Diavik Diamond Mines Inc. – Aquatic Effects Monitoring Program – Study Design Version 3.0. Prepared for Diavik Diamond Mines Inc., Yellowknife, NT. October 2011.

Golder. 2011c. Benthic Invertebrate Report in Support of the 2010 AEMP Annual Report for the Diavik Diamond Mine, Northwest Territories. Prepared for Diavik Diamond Mines Inc., Yellowknife, NT. March 2011.

Golder. 2011d. Fish Report in Support of the 2010 AEMP Annual Report for the Diavik Diamond Mine, Northwest Territories. Prepared for Diavik Diamond Mines Inc. Yellowknife, NT. March 2011.

Golder. 2014a. Diavik Diamond Mines (2012) Inc. – Aquatic Effects Monitoring Program – 2013 AEMP Annual Report. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. March 2014.

Golder 2014b. Diavik Diamond Mines Inc. – Aquatic Effects Monitoring Program – AEMP Study Design Version 3.5. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. May 2014.

Golder 2014c. AEMP Version 3.0 (2011 to 2013) Summary Report for the Diavik Diamond Mine, NT. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. October 2014.

Golder. 2016a. 2011 to 2013 Aquatic Effects Re-evaluation Report Version 3.2. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. June 2016.

Golder. 2016b. Diavik Diamond Mine - Aquatic Effects Monitoring Program – 2014 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. March 2016.

Golder. 2017a. Aquatics Effect Monitoring Program Design Plan Version 4.1. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. June 2017.

Golder 2017b. AEMP Reference Conditions Report, Version 1.2. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. September 2015.

Golder. 2017c. 2014 to 2016 AEMP Response Plan Fish – Supplemental Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife. NT. August 2017.

Golder. 2018. Aquatic Effects Monitoring Program 2017 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. April 2018.

Golder. 2019a. Closure and Reclamation Plan - Version 4.1. Yellowknife, NT. Submitted December 2019.

Golder. 2019b. 2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. June 2019.

Golder. 2019c. AEMP Reference Conditions Report, Version 1.4. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. July 2019.

Golder. 2019d. AEMP 2018 Annual Report. Submitted to Diavik Diamond Mines (2012) Inc., Yellowknife, Northwest Territories. March 2019.

Golder. 2019e. AEMP Response Plan for Diavik Diamond Mine – Proposed Calcium Effects Benchmark. Prepared for Diavik Diamon Mines (2012) Inc. Yellowknife, NT, Canada. June 2019.

Golder. 2020a. Aquatics Effect Monitoring Program Design Plan Version 5.2. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. July 2020.

Golder. 2020b. Aquatic Effects Monitoring Program 2019 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. April 2020.

Golder. 2020c. Diavik Diamond Mine - Aquatic Effects Monitoring Program – Quality Assurance Project Plan (QAPP). Version 4.0. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. December 2020.

Golder 2020d. 2017 to 2019 Aquatic Effects Re-evaluation Report for the Diavik Diamond Mine, Northwest Territories. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. December 2020.

Government of Canada. 1999. The Canadian Environmental Assessment Act Comprehensive Study Report. Diavik Diamonds Project. June 1999.

Government of Canada. 2002. Metal and Diamond Mining Effluent Regulations (current to 23 February 2022 and last amended on 21 February 2022). SOR/2002-222. Available at: http://laws-lois.justice.gc.ca/eng/regulations/SOR-2002-222/. Accessed: 16 March 2022.

Gray M, Cunjak R, Munkittrick K. 2004. Site fidelity of slimy sculpin (Cottus cognatus): insights from stable carbon and nitrogen analysis. Can J Fish Aquat Sci 61:1717-1722.

Gray MA, Munkittrick K, Palace V, Baron C. 2005. Assessment of Slimy Sculpin (Cottus cognatus) collected from East Island, Lac de Gras, NT.

Health Canada. 1996. Guidelines for Canadian Drinking Water Quality, Sixth Edition.

Health Canada. 2020. Guidelines for Canadian Drinking Water Quality Summary Table. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. www.healthcanada.gc.ca/waterquality.

Hecky RE, Campbell P, Hendzel LL. 1993. The stoichiometry of carbon, nitrogen, and phosphorus in particulate matter of lakes and oceans. Limnol. Oceanogr. 38(4): 709 – 724.

HydroQual. 2009. Aquatic Toxicity Assessment on Strontium. Reported prepared for Golder Associates Ltd., Calgary, AB, by HydroQual Laboratories Ltd., Calgary, AB. May 8, 2009.

Lund JWG, Kippling C, le Cren ED. 1958. The inverted microscope method of estimating algal numbers and the statistical basis for the estimation by counting. Hydrobiologia 11: 144-170.

Malley DF, Lawrence SG, MacIver MA, Findlay WJ. 1989. Range of variation in estimates of dry weight for planktonic Crustacea and Rotifera from temperate North American lakes. Can Tech Rep Fish Aquat Sci 1666: 49 p.

McDonald BG, de Bruyn AMH, Wernick BG, Patterson L, Pellerin N, Chapman PM. 2007. Design and application of a transparent and scalable weight-of-evidence framework: an example from Wabamun Lake, Alberta, Canada. Integr Environ Assess Manage 3(4): 476–483.

Menzie C, Henning MH, Cura J, Finkelstein K, Gentile J, Maughan J, Mitchell D, Petron S, Potoceki B, Svirsty S, Tyler P. 1996. Special report of the Massachusetts Weight-of-Evidence Workgroup: A weight-of-evidence approach for evaluating ecological risks. Hum Ecol Risk Assess 2 (2): 277-304.

Muggeo VMR. 2003. Segmented: an R Package to Fit Regression Models with Broken-line Relationships. R News, 8/1, 20-25. URL https://cran.r-project.org/doc/Rnews/.

O'Connor TP. 2004. The sediment quality guideline, ERL, is not a chemical concentration at the threshold of sediment toxicity. Mar Pollut Bull 49: 383-385.

OMOEE (Ontario Ministry of Environment and Energy). 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Toronto, ON.

Pacholski L. 2009. Toxicity of Stable Strontium in Surface Freshwaters of the Oil Sands Region in Alberta, Canada – Deriving an Aquatic Guideline and Refined Chronic Effects Benchmark. University of Ulster, Londonderry, Northern Ireland.

Pinheiro J, Bates D, DebRoy S, Sarkar D, R Core Team. 2017. nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-131, https://CRAN.R-project.org/package=nlme.

R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Racher K, Hutchinson N, Hart D, Fraser B, Clark B, Fequet R, Ewaschuk P, Cliffe-Phillips M. 2011. Linking environmental assessment to environmental regulation through adaptive management. Integr Environ Assess Manag 7: 301-302

Rosenberg DM, Resh VH. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, Inc. New York, NY.

Rott E. 1981. Some results from phytoplankton counting inter-calibrations. Schweiz Z Hydrol 24: 15-24.

Suter GW, Efroymson RA, Sample BE, Jones DS. 2000. Ecological Risk Assessment for Contaminated Sites. Lewis Publishers, New York, NY, USA.

Suter GW. 1993. Ecological Risk Assessment. Chelsea, MI: Lewis Publishers.

USEPA (United States Environmental Protection Agency). 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC, USA. EPA/630/R-95/002F. April 1998.

USEPA. 2000. Guidance for Data Quality Assessment. Practical Methods for Data Analysis. EPA QA/G-9. QA00 Update. Office of Environmental Information, Washington, DC, USA. EPA/600/R-96/084.

Wetzel RG. 2001. Limnology, Lake and River Ecosystems. Third Edition. Academic Press, San Diego. 1006 p.

Wilson MS. 1959. Calanoida. *In*: W. T. Edmondson (ed). Fresh-water Biology. 2nd ed. John Wiley and Sons, New York, NY. p. 738- 794.

WLWB (Wek'èezhìı Land and Water Board). 2010. Guidelines for Adaptive management – a Response framework for Aquatic Effects Monitoring. Wek'èezhìı Land and Water Board, October 17, 2010. Draft document.

WLWB. 2013. Decision from Wek'èezhìı Land and Water Board Meeting of August 12, 2013: Diavik Diamond Mines Inc. (DDMI), AEMP – Version 3.1 – Response Framework. Wek'èezhìı Land and Water Board, File W2009L2-0001 (Type "A").

WLWB. 2015b. Aquatic Effects Monitoring Program (AEMP) Reference Conditions Report, Version 1.1. Letter to David Wells (Diavik Diamond Mines Inc.) from Violet Camsell-Blondin (Wek'èezhìı Land and Water Board), dated November 27, 2015.

WLWB. 2017b. Decision from Wek'èezhìı Land and Water Board Meeting of 22 September 2017: Version 4.1 of the AEMP Design Plan. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2017c. Decision from Wek'èezhìı Land and Water Board Meeting of 16 August 2017: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2018. Decision from Wek'èezhìı Land and Water Board Meeting of 24 January 2018: 2016 AEMP Response Plans and 2016 AEMP Fish Response Plan – Supplemental Report. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2019a Decision from Wek'èezhìı Land and Water Board Meeting of 25 March 2019: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan Version 5.0. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2019b. Decision from Wek'èezhìı Land and Water Board Meeting of 25 March 2019: 2017 AEMP Annual Report. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").WLWB. 2020. Decision from Wek'èezhìı Land and Water Board Meeting of 1 June 2020: AEMP Design Document Version 5.1. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2021a. Wek'èezhìı Land and Water Board Type A Water Licence #W2015L2-0001, Effective October 19, 2015, Amended for PKMW on June 8, 2021. Yellowknife, NT, Canada.

WLWB. 2021b. Decision from the Wek'èezhìi Land and Water Board Meeting of June 10, 2021. Regarding Interim Closure and Reclamation Plan (CRP) Version 4.1. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2022a. Decision from Wek'èezhìı Land and Water Board Meeting of 17 November 2021: 2020 AEMP Annual Report. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type "A").

WLWB. 2022b. Decision from Wek’èezhìı Land and Water Board Meeting of 28 October 2021: 2017 to 2019 Aquatic Effects Re-evaluation Report and Version 4.0 of the Quality Assurance Project Plan. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type “A”).

WLWB. 2022c. Decision from Wek’èezhìı Land and Water Board Meeting of 17 November 2021: 2020 AEMP Annual Report. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type “A”).

WLWB. 2022d. Decision from Wek’èezhìı Land and Water Board Meeting of 24 February 2022: AEMP Response Framework – Notification of Action Level Exceedances. Wek'èezhìı Land and Water Board, File W2015L2-0001 (Type “A”).

Yeatman HC. 1959. Cyclopoida. In: W. T. Edmondson (ed). Fresh-water Biology. 2nd ed. John Wiley and Sons, New York, NY. p. 795- 815.

**APPENDIX A**

# Summary of Changes Reflected in AEMP Design Plan Version 6.0

## Changes Between AEMP Design Plan Version 5.2 and Version 6

To provide transparency and assist with the efficient review of the Aquatic Effects Monitoring Program (AEMP) Design Plan Version 6.0, changes between *AEMP Design Plan Version 5.2* (Golder 2020) and Version 6.0 have been documented in Table B-1. Minor typographical or editorial corrections (e.g., will be/has been, misspelled words, updated reference to version numbers or Water Licence conditions) and details of such changes made in *AEMP Design Plan Version 6.0* are not included in Table B-1.

## References

Golder. 2020. Aquatics Effect Monitoring Program Design Plan Version 5.2. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. July 2020.

**Table B-1: Changes Between AEMP Design Plan Version 5.2 and Version 6.0**

| Section | Text in Version 5.2 | Text in Version 6.0 | Rationale for Change |
|---|---|---|---|
| Plain Language Summary<br>Action Level Reporting | If an Action Level in the Response Framework is exceeded, Diavik will be required to tell the WLWB about the exceedance within 30 days of finding the exceedance. Diavik will also be required to prepare a plan to respond to the exceedance (called an "AEMP Response Plan") and submit the plan to that WLWB for review and approval if certain types of effects occur. | If an Action Level in the Response Framework is exceeded, Diavik will implement notification procedures for Action Level exceedances as required by the WLWB. Under conditions detailed in the Response Framework, Diavik may also be required to prepare a plan to respond to the exceedance (called an "AEMP Response Plan") and will submit that plan to the WLWB for review and approval. | Updated per the 15 April 2021 WL Amendment Application: Reason for Decision. |
| 2.2 Regulatory Environment<br>2.2.1 General Regulatory History | - | On 1 June 2018, diamond mines became subject to the Metal and Diamond Mining Effluent Regulations (Government of Canada 2002). A first study design under the MDMER was to be submitted by the earlier of 1 June 2021 and the day on which an equivalent document was required to be submitted under territorial laws (per Section 38[1] of the MDMER). The Government of the Northwest Territories (GNWT) and the Government of Canada (i.e., Environment and Climate Change Canada [ECCC]) were, however, already considering an equivalency agreement for operating mines in the Northwest Territories such that duplication between the MDMER (e.g., Environmental Effects Monitoring [EEM]) and water licence requirements (e.g., AEMP) could be avoided. Due to the expectations of equivalency, application of the EEM-related components of the MDMER to the Mine (i.e., both monitoring and reporting requirements) have not been required to date and are not described further herein. | Updated to reflect the current Regulatory environment. |
| 3.4 Sampling Design and Locations<br>3.4.1 Sampling Design | Reflecting the greater emphasis of the AEMP data analyses on spatial gradients, the AEMP Version 5.2 described some adjustments to sampling locations which improved the spatial coverage of stations in Lac de Gras and filled gaps along existing gradients in the lake. Two new sampling locations, one located between the existing FF1 and MF3 areas and one located between the FFB and FFA areas, were added to improve delineation of effects along the MF3 transect and to better assess the extent of effects extending from the existing MF1/FF1 areas extending into the northern channel area of Lac de Gras, east of the East Island. Full details on the number and locations of stations sampled for the AEMP are provided in Section 3.4.2 and a summary of the proposed adjustments is provided below. | Reflecting the greater emphasis of the AEMP data analyses on spatial gradients, the AEMP Version 5.2 described some adjustments to sampling locations which improved the spatial coverage of stations in Lac de Gras and filled gaps along existing gradients in the lake. Two new sampling locations, one located between the existing FF1 and MF3 areas and one located between the FFB and FFA areas, were added to improve delineation of effects along the MF3 transect and to better assess the extent of effects extending from the existing MF1/FF1 areas extending into the northern channel area of Lac de Gras, east of the East Island. Full details on the number and locations of stations sampled for the AEMP are provided in Section 3.4.2 | Condensed information from Design Plan 5.2. |
| 3.4 Sampling Design and Locations<br>3.4.2 Sampling Locations | The AEMP Design Plan Version 6.0 sampling stations are shown in Figure 3.4-1 and Table 3.4-1. The majority of these stations were established during AEMP Study Design Version 2.0 and specific locations were chosen in the field to minimize physical variation among stations to the extent possible. Since the primary physical variable that influences sediment composition and benthic invertebrate communities in lakes is water depth, station locations were selected to be within the relatively narrow depth range of 18 to 22 m. The locations of a number of the MF stations were adjusted for the AEMP Study Design Version 3.0 to better delineate the extent of effects in the lake (Golder 2011b). These adjustments have been retained for the AEMP Design Plan Version 6.0. The station at the Lac du Sauvage narrows was added for AEMP Study Design Version 4.1 (Golder 2017a) and is retained to capture incoming water quality to Lac de Gras, and to allow for estimating concentrations of key water quality parameters entering the lake. | The AEMP Design Plan Version 6.0 sampling stations are shown in Figure 3.4-1 and Table 3.4-1. The majority of these stations were established during AEMP Study Design Version 2.0 and specific locations were chosen in the field to minimize physical variation among stations to the extent possible. Since the primary physical variable that influences sediment composition and benthic invertebrate communities in lakes is water depth, station locations were selected to be within the relatively narrow depth range of 18 to 22 m. The locations of a number of the MF stations were adjusted for the AEMP Study Design Version 3.0 to better delineate the extent of effects in the lake (Golder 2011b). These adjustments have been retained for the AEMP Design Plan Version 6.0. The station at the Lac du Sauvage narrows was added for AEMP Study Design Version 4.1 (Golder 2017a) and is retained to capture incoming water quality to Lac de Gras, and to allow for estimating concentrations of key water quality parameters entering the lake. Finally, Stations FFD-1 and FFD-2 were added for AEMP Study Design Version 5.2 to improve the spatial coverage of stations in Lac de Gras and to fill gaps along existing gradients in Lac de Gras. | Continued condensing information about the new stations that were explained in detail in Design Plan 5.2. |
| 4.5 Eutrophication Indicators<br>4.5.1 Background | - | Change to Evaluated Variables for Zooplankton<br><br>The Eutrophication Indicators section of the 2017 to 2019 Aquatic Effects Re-evaluation Report (Golder 2020d) evaluated relationships between biological variables used as eutrophication indicators, and showed strong linear relationships between zooplankton biomass measured as ash-free dry mass (AFDM) and based on enumeration (Section 7.3.4.1). A strong overall relationship was found (r = 0.81) despite using different samples for each method to estimate biomass; i.e., separate samples collected from the same stations at the same time were used in the analysis, rather than analyzing taxonomy and AFDM in the same samples, which would be expected to yield an even stronger relationship. Relationships within individual years were moderate to strong between 2009 and 2019 (r values ranging from 0.55 to 0.90). Based on this information, Golder (2020d) commented that zooplankton biomass measured as AFDM could be removed as a eutrophication indicator variable, because it is redundant with zooplankton biomass based on enumeration.<br><br>This comment was highlighted by EMAB during the public review of the re-evaluation report, and EMAB indicated that they agreed with DDMI's recommendation (EMAB comment 25, as summarized by WLWB 2022a). Although this recommendation was not formally made in the 2017 to 2019 Aquatic Effects Re-evaluation Report, the WLWB indicated in the Reasons for Decision attached to their letter of 31 January 2022, that DDMI can include this proposed change along with supporting rationale in Version 6 of the AEMP Design Plan (WLWB 2022a). In accordance with the WLWB's suggestion, and based on the rationale provided by Golder (2020d) and summarized above, the removal of zooplankton biomass as AFDM has been included in this Design Plan to allow full review of this recommended change. The methods provided below do not include zooplankton biomass as AFDM, but rather assume that biomass based on enumeration, as reported by the Plankton component, will be used to represent zooplankton biomass in the eutrophication indicators analysis under AEMP Design Plan Version 6.0. | Updated following WLWB comments in the Reasons for Decision document attached to their letter of 31 January 2022. |
| 4.6 Plankton<br>4.6.4 Data Analysis and Interpretation | The Aquatic Effects Re-evaluation Report will provide an update to the temporal trends described during Version 2.0 and 3.0 of the AEMP design. Temporal trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10). | The Aquatic Effects Re-evaluation Report will provide details of the trend analysis, and trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10). | Updated for clarity and consistency. |

**Table B-1: Changes Between AEMP Design Plan Version 5.2 and Version 6.0**

| Section | Text in Version 5.2 | Text in Version 6.0 | Rationale for Change |
|---|---|---|---|
| 4.7 Benthic Invertebrates<br>4.7.4 Data Analysis and Interpretation | The Aquatic Effects Re-evaluation Report will provide an update to the temporal trends described during Version 2.0 and 3.0 of the AEMP design. Temporal trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10). | The Aquatic Effects Re-evaluation Report will provide details of the trend analysis, and trends will be evaluated using the methods described for the water quality component (Section 4.3.4.10). | Updated for clarity and consistency. |
| 4.8 Fish Health<br>4.8.4 Data Analysis and Interpretation | Condition factor for the relative abundance survey will be calculated using the equation above for Age-1+ fish. Data will be screened to detect possible errors (i.e., anomalous data) using box-and-whisker and scatter plots. Residuals will be used to estimate studentized residual values and calculate statistics of normality and homoscedasticity; these values, together with a visual assessment of quantile-quantile plots and scatterplots of residuals relative to explanatory variables, will be used to assess the parametric assumptions of normality and equality of variance. The statistical comparisons among areas will be performed, and statistical outliers will be identified by analyzing test residuals. Statistical tests will subsequently be rerun without outliers. | Condition factor for the relative abundance survey will be calculated using the equation above for Age-1+ fish, while lethally sampled fish condition factor will be calculated using the equation above for adults. Data will be screened to detect possible errors (i.e., anomalous data) using box-and-whisker and scatter plots. Residuals will be used to estimate studentized residual values and calculate statistics of normality and homoscedasticity; these values, together with a visual assessment of quantile-quantile plots and scatterplots of residuals relative to explanatory variables, will be used to assess the parametric assumptions of normality and equality of variance. The statistical comparisons among areas will be performed, and statistical outliers will be identified by analyzing test residuals. Statistical tests will subsequently be rerun without outliers. | Updated for clarity to support two different equations presented for calculating condition. |
| 4.10 Weight-of-Evidence<br>4.10.2 Weight -of-Evidence Framework | The endpoints that were removed from the WOE approach (i.e., the benthic invertebrate and fish community endpoints discussed above) will continue to be reported and discussed as part of the applicable AEMP component, but they are not appropriate for inclusion as WOE endpoints. | Per Directives received from the WLWB, the following WOE assessment endpoints have been added to AEMP Version 6.0:<br>- Abnormalities – Occurrence was added as a fish population health endpoint. The assessment of abnormalities is a qualitative assessment of captured fish, documenting unusual external features, such as external wounds, lesions, tumours, parasites, fin fraying, or gill parasites and internal features such as abnormalities of the liver, spleen, gall bladder, kidney, and gonads. Due to statistical limitations when using qualitative data, the occurrence of abnormalities was considered as an early-warning indicator only, based on relative comparisons between the NF and FF areas.<br>- CPUE – Catch data as CPUE was added as a fish population health endpoint because it provides a quantitative estimate of fish abundance. While CPUE is somewhat limited by sampling bias (which is introduced by fishing methods and locations), it provides a direct estimate of fish abundance that is comparable across time and study areas. | Updated per the WLWB Directives relating to including these fish endpoints in the weight-of-evidence. |
| 5.3 Effects Benchmarks<br>5.3.1 Water Quality | Aquatic life benchmarks adopted for the AEMP (herein termed "Effects Benchmarks") are based on the CWQGs for the protection of aquatic life (CCME 1999), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2020), guidelines from other jurisdictions (e.g., provincial and state guidelines), adaptations of general guidelines to site-specific conditions at Lac de Gras (Appendix IV.1 in DDMI 2007) or when appropriate, values from the primary literature (Table 5.3-1). The Effects Benchmarks used for the AEMP are generally consistent with those established during the EA (referred to as ecological thresholds in the EA), but have incorporated a number of revisions so that they are up-to-date and suitable for the Lac de Gras environment. For variables with both aquatic life and drinking water values, the Effects Benchmark is the lower of the two. As described in Section 5.2.1, a site-specific Effects Threshold will be defined for a water quality measurement if its concentration approaches the Effects Benchmark. | Aquatic life benchmarks adopted for the AEMP (herein termed "Effects Benchmarks") are based on the CWQGs for the protection of aquatic life (CCME 1999), the Canadian Drinking Water Quality Guidelines (Health Canada 1996, 2020), Federal Environmental Quality Guidelines, guidelines from other jurisdictions (e.g., provincial and state guidelines), adaptations of general guidelines to site-specific conditions at Lac de Gras (Appendix IV.1 in DDMI 2007) or when appropriate, values from the primary literature (Table 5.3-1). The Effects Benchmarks used for the AEMP are generally consistent with those established during the EA (referred to as ecological thresholds in the EA), but have incorporated a number of revisions so that they are up-to-date and suitable for the Lac de Gras environment. Effects benchmarks will be updated within AEMP annual reports as they are published by CCME and Health Canada, and updates will be reflected in the next AEMP design plan update (per the schedule described in Section 3.5). For variables with both aquatic life and drinking water values, the Effects Benchmark is the lower of the two. As described in Section 5.2.1, a site-specific Effects Threshold will be defined for a water quality measurement if its concentration approaches the Effects Benchmark. | Updated per the 31 January 2022 WLWB Directive. |
| 5.3 Effects Benchmarks<br>5.3.1 Water Quality | Since the last AEMP designs Version 4.2, study design update, six additional water quality variables that did not have existing Effects Benchmarks (i.e., turbidity, dissolved sodium, total aluminum, total antimony, total silicon, and total tin) have triggered Action Level 2. These exceedances were identified during analyses completed for the AEMP Version 3.0 (2011 to 2013) Summary Report (Golder 2014c), and the 2014 AEMP Annual Report (Golder 2016b). As required in the Response Framework, DDMI developed Effects Benchmarks for these six seven variables. Table 5.3-1 reflects the addition of new benchmarks as part of the AEMP Design Plan 4.1 and an update to the benchmark for total silver, based on the updated CWQG for this variable. | During the period covered by AEMP designs Version 4 and Version 5.2, seven additional water quality variables that did not have existing Effects Benchmarks (i.e., turbidity, dissolved calcium, dissolved sodium, total aluminum, total antimony, total silicon, and total tin) have triggered Action Level 2. These exceedances were identified during analyses completed for the AEMP Version 3.0 (2011 to 2013) Summary Report (Golder 2014c), and the 2014 AEMP Annual Report (Golder 2016b) and the 2018 AEMP Annual Report (Golder 2019d). As required in the Response Framework, DDMI developed Effects Benchmarks for these six seven variables. Table 5.3-1 reflects existing benchmarks under AEMP Design Plan 5.2 which are consistent with AEMP Version 6.0. | Updated per the 31 January 2022 WLWB Directive. |
| 6.0 Alignment of AEMPS in Lac de Gras | The DDMI AEMP monitors 37 water quality stations within Lac de Gras, including 5 NF stations, 14 MF stations (including FF2), and 17 FF stations (Figure 6.1-1), and one site (LDG-48) at the outlet of the lake. One water quality station in Lac du Sauvage (LDS-1) is also monitored (LDS-1), and one station in the narrows between Lac de Gras and Lac du Sauvage (LDS-4) was added as part of the updates for Version 4.0 of the AEMP design (Figure 6.1 1). | The DDMI AEMP monitors 39 water quality stations within Lac de Gras, including 5 NF stations, 14 MF stations (including FF2), 17 FF stations (Figure 6.1-1), one site (LDG-48) at the outlet of Lac de Gras, one station in Lac du Sauvage (LDS-1), and one station in the narrows between Lac de Gras and Lac du Sauvage (LDS-4) (Figure 6.1 1). | Updated to reflect changes in sampling stations since AEMP Design Plan Version 5.2. |

**Table B-1: Changes Between AEMP Design Plan Version 5.2 and Version 6.0**

| Section | Text in Version 5.2 | Text in Version 6.0 | Rationale for Change |
|---|---|---|---|
| 6.0 Alignment of AEMPS in Lac de Gras<br>6.1 Data Analysis Approach to Detect Across-Project Effects in Lac de Gras | A spatial gradient approach will be used to evaluate across-project effects in Lac de Gras from the Ekati and Diavik mines. This will be done as part of the comprehensive reports, which will present a spatial analysis of results from the comprehensive sampling program where all stations will be sampled, including the FF areas. Effects will be assessed along the gradient of exposure at stations in the MF3, FFB and FFA areas and at Station LDG-48. The presence of a spatial trend with distance from the Diavik diffusers that is reversed as one moves west from the MF3 or FFB areas would suggest that effluent from both mines are a potential influence on the variable in question. Magnitude of effects will be evaluated by comparing the results to the normal range (as defined in the AEMP Reference Conditions Report Version 1.4 [Golder 2019b]). The AEMP results will be qualitatively compared to data collected at the Ekati Slipper Bay monitoring stations in Lac de Gras (e.g., S2, S3, S5 and S6) to further evaluate the potential contribution of Ekati to across-project effects in Lac de Gras. A temporal assessment of trends at relevant stations will be provided in the Aquatic Effects Re-evaluation Report and will follow the approach in Golder (2016b). | A spatial gradient approach will be used to evaluate across-project effects in Lac de Gras from the Ekati and Diavik mines. This will be done as part of the comprehensive reports, which will present a spatial analysis of results from the comprehensive sampling program where all stations will be sampled, including the FF areas. Effects will be assessed for water quality SOIs and eutrophication indicators along the gradient of exposure at stations in the MF3, FFB and FFA areas and at Station LDG-48. Only variables that have concentrations greater than the normal range in the far-field areas (FFA and FFB areas) and are consistently measured by both AEMP programs in Lac de Gras will be included in the cumulative effects assessment. The presence of a spatial trend with distance from the Diavik diffusers that is reversed as one moves west from the MF3 or FFB areas would suggest that effluent from both mines are a potential influence on the variable in question. Magnitude of effects will be evaluated by comparing the results to the normal range (as defined in the AEMP Reference Conditions Report Version 1.4 [Golder 2019b]). The AEMP results will be qualitatively compared to data collected at the Ekati Slipper Bay monitoring stations in Lac de Gras (e.g., S2, S3, S5 and S6) to further evaluate the potential contribution of Ekati to across-project effects in Lac de Gras. A temporal assessment of trends at relevant stations will be provided in the Aquatic Effects Re-evaluation Report and will follow the approach in Golder (2016a). | Updated per the 31 January 2022 WLWB Directive. |
| 7.0 AEMP Reporting<br>7.1 Overview | The aforementioned reports will be submitted to the WLWB for review and approval according to the schedule presented in Section 3.5. Each report will include the objectives, methods and results associated with the AEMP components (described in Section 4.0) monitored in that year. Electronic versions of the AEMP data and reports will be provided through posting of appropriate files to the WLWB Registry on the WLWB public registry. DDMI acknowledges that various parties will review the reports and will work as directed by the WLWB to facilitate this review. | The aforementioned reports will be submitted to the WLWB for review and approval according to the schedule presented in Section 3.5. Each report will include the objectives, methods and results associated with the AEMP components (described in Section 4.0) monitored in that year. DDMI will also report Action Level exceedances annually per the separate reporting schedule described in Section 7.5. Electronic versions of the AEMP data and reports will be provided through posting of appropriate files to the WLWB Registry on the WLWB public registry. DDMI acknowledges that various parties will review the reports and will work as directed by the WLWB to facilitate this review. | Updated per the 3 March 2021 WLWB Letter. |
| 7.0 AEMP Reporting<br>7.3 AEMP Annual Report | The AEMP Annual Report for each year of monitoring under the AEMP Design Plan Version 6.0 will provide results for the components monitored in each year. The annual reports will be submitted no later than 31 March of the following year, as required by the Water Licence W2015L2-0001, and will incorporate the specific conditions defined in Schedule 8, Condition 4. The annual reports for the comprehensive (e.g., 2019) and interim sampling years (e.g., 2017, 2018, 2020) will follow the structure of the reports submitted under previous AEMP design plans. The report for the comprehensive sampling program will include an assessment of effects for all AEMP components in all sampling areas. The reports for interim sampling years will assess effects on water quality variables, indicators of eutrophication, and plankton, by determining if an Action Level has been triggered. | The AEMP Annual Report for each year of monitoring under the AEMP Design Plan Version 6.0 will provide results for the components monitored in each year. The annual reports will be submitted no later than 31 March of the following year, as required by the Water Licence W2015L2-0001, and will incorporate the specific conditions defined in Schedule 8, Condition 4. The annual reports for the 2022 interim (e.g., 2023, 2024) and comprehensive (e.g., 2025) sampling years will follow the same structure of the reports submitted under previous AEMP design plans. The report for the comprehensive sampling program will include an assessment of effects for all AEMP components in all sampling areas. The reports for interim sampling years will assess effects on water quality variables, indicators of eutrophication, and plankton, by determining if an Action Level has been triggered. | Updated to reflect existing schedule. |
| 7.0 AEMP Reporting<br>7.3 AEMP Annual Report | All raw data for all variables monitored as part of the AEMP will be provided in Excel spreadsheet format as part of the submission for all AEMP reports. | All raw data for all variables monitored as part of the AEMP will be provided in Excel spreadsheet format as part of the submission for all AEMP reports. Laboratory reports (i.e., raw data) for toxicity tests will also be provided. | Updated to reflect existing raw data submission requirements. |
| 7.0 AEMP Reporting<br>7.5 AEMP Response Plan | Response Plan under most circumstances, but reduces reporting requirements for lower Action Levels, and recognizes the difference between Action Levels established for biological variables and those established for water chemistry, sediment chemistry, and eutrophication indicators. DDMI will implement reporting procedures for AEMP Response Plans as required by the WLWB. | Response Plan under most circumstances, but reduces reporting requirements for lower Action Levels, and recognizes the difference between Action Levels established for biological variables and those established for water chemistry, sediment chemistry, and eutrophication indicators. DDMI will implement reporting procedures for AEMP Response Plans as required by the WLWB.<br>In addition, per WLWB directives, DDMI proposed modified reporting timelines for Action Level which were approved on 31 January 2021 (WLWB 2022a), which require the following:<br>□ Water Quality Action Levels will be reported by 31 August of the same year for ice-cover sampling, and by 20 December of the same year for open-water sampling<br>□ Sediment Quality Action Levels will be reported by 20 December of the same year for open-water sampling (there is no ice-cover sampling for sediment)<br>□ Biological (i.e., Eutrophication Indicators, Plankton, Benthic Invertebrate Community, and Fish) Action Levels will be reported by 31 March of the following year, with the AEMP Annual Report. | Updated as per 31 January 2021 WLWB Directive |

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