Diavik Diamond Mines (2012) Inc.
P.O. Box 2498
Suite 300, 5201-50th Avenue
Yellowknife, NT X1A 2P8
Canada
T (867) 669 6500
F 1-866-313-2754

Joseph Mackenzie, Chair
Wek'èezhìı Land and Water Board
PO Box 32
Wekweètì, NT X1A 3S3
Canada

27 October 2020

Dear Mr. Joseph Mackenzie:

Subject: 2019 Annual AEMP Report – Part J Item 8

The 2019 Aquatic Effects Monitoring Plan (AEMP) Annual Report is attached as required under the Wek'èezhìı Land and Water Board (WLWB) Water Licence W2015L2-0001 Part J Item 8. Sampling for the AEMP in 2019 was carried out according to the requirements specified in the *AEMP Study Design Version 4.1* for a comprehensive monitoring year, which included sampling in the Near-field, Mid-field and Far-field areas of the lake. The comprehensive monitoring program allows for detailed spatial assessment of Mine-related effects. DDMI notes that this submission is an update to the original submission to the WLWB on April 30, 2020 and is to address WLWB's conformity check comments issued to DDMI on September 10, 2020.

Although *AEMP Study Design Version 4.1* was the approved version of the AEMP design for the 2019 AEMP Annual Report, a number of updates outlined in the proposed *AEMP Design Plan Version 5.1* and in WLWB directives have been incorporated into the 2019 AEMP Annual Report. Specific updates are outlined in Section 1 of each AEMP component (see Appendix I through XV).

Under Water Licence W2015L2-0001, Action Level exceedance reporting (Part J Item 6) is required as part of the 2019 AEMP Annual Report. Action Level exceedances documented by the AEMP in 2019 are summarized in Table 1 attached to this letter and detailed within the 2019 AEMP Annual Report. 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. Action levels for water quality, sediment quality and eutrophication indicators range from 1 to 9. Action levels for biological components (plankton, benthics and fish) range from 1 to 5. 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 at Action Level4.

The results of the Action Level evaluation completed for the 2019 AEMP identified 16 water quality variables that triggered Action Level 1 and nine variables that triggered Action Level 2 (Table 1). None of the water quality variables triggered Action Level 3. Under the approved AEMP Response Framework, no action is required when a water quality variable triggers Action Level 1. When a variable triggers Action Level 2, the required management action is to develop an AEMP Effects Benchmark for that variable if one does not already exist. Since all nine variables that triggered Action Level 2 have existing Effects Benchmarks, no further action is required based on the results of the Action Level evaluation for water quality in 2019.

Three sediment quality variables triggered Action Level 1 (total bismuth, total molybdenum and total uranium) and one variable (total bismuth) triggered an Action Level 2. Establishing an Effects Benchmark for bismuth was attempted in the *AEMP Design Plan Version* 4.1 (Golder 2017a); however, based on a review of the toxicological literature, data suitable for developing a numerical sediment quality guideline or benchmark for bismuth were not available. Based on the lack of toxicological guidelines for bismuth for surface waters and the relatively low aquatic toxicity of bismuth documented in the available literature, this metal is not considered to be a constituent of concern in Lac de Gras sediments; therefore, no follow-up action in response to the Action Level 2 trigger for total bismuth is anticipated.

The 2019 fish health study triggered Action Level 2 for juvenile fish (i.e., Age-1+ fish carcass weight and relative liver weight compared to reference conditions) but not adult fish of either sex. Factors contributing to these differences were evaluated in the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* following a similar Action Level in 2016. The response plan concluded that differences in fish size and relative liver weight were inconsistent with a Mine effect, and likely driven by localized habitat variation among study areas. Given the direction and magnitude of the differences observed in 2019 in Age 1+ fish are consistent with those reported previously and the absence of an Action Level 2 trigger for adult fish in 2019, no follow-up action for fish health is anticipated in response to the Action Level 2 trigger.

The following variables did not exceed any Action Level (i.e. Action Level 0 out of 9 or 0 out of 5) in 2019. The list includes only the variables that are within the Action Level Assessment:

> Water Quality: total alkalinity, total suspended solids, total organic carbon, fluoride, potassium, nitrite, antimony, arsenic, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, mercury, nickel, selenium, silver, sulphur, thallium, tin, titanium, vanadium, zinc, zirconium
>
> Sediment Quality: total organic carbon, total organic matter, total nitrogen, total phosphorus, aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, strontium, thallium, tin, titanium, vanadium, zinc
>
> Eutrophication Indicators: chlorophyll a
>
> Plankton: phytoplankton richness, total zooplankton biomass, zooplankton richness
>
> Benthic Invertebrates: total invertebrate density, richness, dominance, Simpson's diversity index, evenness index, Bray-Curtis index, densities of Pisidiidae, Procladius, Heterotrissocladius, Micropsectra, Microtendipes, Stictochironomus
>
> Fish: Age-1+ fish: condition; male and female fish: total length, total weight, carcass weight, condition, relative liver weight, relative gonad weight

In addition, to help tease apart the effects of dust deposition versus effluent on phosphorus concentrations in the lake, in 2019 DDMI decided to undertake a Special Study on Dust in Lac de Gras. In general, the geochemical signature of lake water was similar to that of effluent in all areas of the lake, and the influence of dust could not be differentiated from the effect of the effluent. Dissolution of phosphorus-bearing minerals in dustfall was found to be unlikely under the pH and redox conditions in lake water, suggesting that dust-associated phosphorus is more likely to settle to sediments than to be available as a nutrient to phytoplankton. These conclusions were consistent with conclusions drawn from routine AEMP Monitoring.

To assist the Board's review of this document, the attached Table 2 provides a Concordance Table outlining the sections of the report in which the applicable WLWB directives, commitments and comments have been addressed. DDMI has also attached a Memo from ERM regarding an assessment of the potential influence of mine-generated dust on dustfall monitoring stations located near the A21 pit and includes a discussion on whether any of the A21 dust stations should no longer be considered as background.

DDMI would like to take this opportunity to remind reviewers that, as directed by the WLWB, the *2017 to 2019 Aquatic Effects Re-evaluation Report* is due within six months following the approval of the 2019 AEMP Annual Report.

If you have any questions regarding the attached submission, please contact the undersigned (867) 447-3001 kofi-boa.antwi@riotinto.com or Kyla Gray at (867) 669-6500 ext. 5428 kyla.gray@riotinto.com.

Yours sincerely,

Kofi Boa-Antwi
Superintendent, Environment

cc: Anneli Jokela, WLWB
Kassandra DeFrancis, WLWB
Meghan Schnurr, WLWB

Attachments:

- Table 1 - Summary of Action Level Exceedances and Required Management Actions, 2019 AEMP
- Table 2- Concordance Table for the 2019 AEMP Annual Report
- Memo: Diavik Diamond Mine, Dustfall Stations Near A21

Table 1. Summary of Action Level Exceedances and Required Management Actions, 2019 AEMP

Component	Variable	Action Level	How the Action Level Exceedance was Determined	Detailed Results of Action Level Evaluation	Relation to Significance Threshold	Action Required[a]
Water Quality	Total Dissolved Solids - Ice Cover and Open Water	2	See Appendix II, Section 2.3.6.1	See Appendix II, Section 3.5	Below Significance Threshold	None
	Turbidity – lab - Ice Cover	1				None
	Calcium (dissolved) - Ice Cover and Open Water	1				None
	Chloride - Ice Cover and Open Water	2				None
	Magnesium (dissolved) - Ice cover	1				None
	Sodium (dissolved) - both	2				None
	Sulphate - open water	2				None
	Suplhate - ice cover	1				None
	Ammonia - open water	2				None
	Nitrate - Open Water	2				None
	Nitrate - Ice Cover	1				None
	Aluminum - Ice Cover	1				None
	Barium - Ice Cover	1				None
	Manganese - Ice Cover	1				None
	Molybdenum - Ice Cover and Open Water	2				None
	Silicon - Ice Cover	1				None
	Strontium - Ice Cover and Open Water	2				None
	Uranium - Ice Cover and Open Water	2				None
Sediment Quality	Total Bismuth	2	See Appendix III, Section 2.3.6, 2.4	See Appendix III, Section 3.7		None
	Total Molybdenum	1				None
	Total Uranium	1				None
Fish	Fish	2	See Appendix V, Section 2.9	See Appendix V, Section 3.5		None

(a) Management action required under the AEMP Response Framework

(b) Variable added to the list of substances of interest, because it triggered an effect equivalent to Action Level 1 at one or more mid-field stations located within the estimated zone of influence from dust deposition (see Section 3.6), but not in the near-field area

Table 2. Concordance Table for the 2019 AEMP Annual Report

Item #	Location of Direction	Type	Description	Location in Report and Associated Technical Appendices
1	26 May 2016 Letter re: 2011 to 2013 Aquatic Effects Re-evaluation Report, Version 3.1	Request	Outliers identified during the initial screening step will be included in the publically available datasets submitted annually and will be clearly identified (e.g., highlighted and bolded within the raw data appendices). This was a request from EMAB that DDMI acknowledged.	Appendix I, no outliers identified. Appendix II, Attachment D, Tables D-1 to D-4 Appendix IV, Attachment B Appendix V, Attachment B
2	26 May 2016 Letter re: 2011 to 2013 Aquatic Effects Re-evaluation Report, Version 3.1	Recommendation	EMAB comment #13 - Any waterbody or landmark that is mentioned in the text, tables or figures should be labeled on study area maps as appropriate.	Main Report, Figure 1-1 Appendix I, Figure 2-1 Appendix II, Figure 2-1 Appendix III, Figure 2-1 Appendix IV, Figure 2-1 Appendix V, Figure 2-1 Appendix XI, Figure 2-1 Appendix XII, Figure 2-1 Appendix XIII, Figure 2-1
3	21 October 2019 Letter re: 2018 AEMP Annual Report	Decision	2 - The Board requires DDMI to include a description of all blank sample types in future AEMP annual Reports *Background: EMAB id'd confusions about the various blanks included as part of DDMI's QA/QC protocol (i.e. all applicable components). DDMI agreed they would include these descriptions in future AEMP reports.*	Appendix II, Attachments A and B Appendix III, Attachment C Appendix V, Section 2.8.3 and 3.4.3.1
4	W2015L2-0001 Part J, Item 8	Water Licence Condition	This Report shall satisfy the requirements of Schedule 8, Item 4, and include information relating to data collected in the preceding calendar year	Generally practiced throughout
5	W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	Water Licence Condition	a) a summary of activities conducted under the Aquatic Effects Monitoring Program;	Main Report, Section 2.2, 3.2, 4.2, 5.2, 6.2, 7.2, 8.2, 9.3.1, and 11.2 Appendix I, Section 2 Appendix II, Section 2 Appendix III, Section 2 Appendix IV, Section 2 Appendix V, Section 2 Appendix XI, Section 2 Appendix XII, Section 2 Appendix XIII, Section 2 Appendix XV, Section 2
6	W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	Water Licence Condition	b) tabular summaries of all data and information generated under the AEMP in an electronic and printed format acceptable to the Board	Appendix I, Attachments B to D Appendix II, Attachments D* and E* Appendix III, Attachments D* and F* Appendix IV, Attachment B* Appendix V, Attachments C*, D*, E*, F* and G* Appendix XI, Attachments B* and C* Appendix XII, Attachment A* Appendix XIII, Attachments F* Appendix XV, Attachment A *(*also provided in attached electronic files)*
7	W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	Water Licence Condition	c) An interpretation of the results, including an evaluation of any identified environmental changes that occurred as a result of the Project	Main Report, Sections 3.3, 4.3, 5.3, 6.3, 7.3, 8.3, 9.3.1.3, 11.3, 13.1 Appendix I, Sections 3 and 4 Appendix II, Sections 3 and 4 Appendix III, Sections 3 and 4 Appendix IV, Sections 3 and 4 Appendix V, Sections 3 and 4 Appendix XI, Sections 3 and 4 Appendix XII, Section 3 and 4 Appendix XIII, Sections 3 and 4 Appendix XV, Sections 3 and 4
8	W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	Water Licence Condition	d) an evaluation of any adaptive management response actions implemented during the year	Main Report, Section 12 Appendix II, Section 5 Appendix IV, Section 5 Appendix V, Section 5 Appendix XI, Section 5 Appendix XIII, Section 5
9	W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	Water Licence Condition	e) recommendations for refining the Aquatic Effects Monitoring Program to improve its effectiveness as required; and,	Main Report, Section 13.2
10	W2015L2-0001 Schedule 8, Item 4 (REQUIREMENTS)	Water Licence Condition	f) an evaluation of the overall effectiveness of the Aquatic Effects Monitoring Program to date; and, any other information specified in the approved Aquatic Effects Monitoring Program or that may be requested by the Board.	Main Report, Section 13.3

11	27 October 2014 Letter re: 2013 AEMP Annual Report	Request	Report when any action levels are triggered, as well as the proposed management response and associated timelines	Main Report, Section 12 Appendix II, Sections 3.5, 5 Appendix III, Section 3.7, 5 Appendix IV, Sections 3.9,5 Appendix V, Sections 3.5, 5 Appendix XI, Sections 3.3, 5 Appendix XIII, Sections 3.10, 5
12	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1a. DDMI stated that it will include maps that illustrate the A21 dike (EMAB comments 5 and 32).	Main Report, Figure 1-1
13	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1b. DDMI stated that it will include labelling of project infrastructure on figures showing the DDMI mine site (EMAB comment 8).	Main Report, Figure 1-1
14	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	6B. Provide full rationale for deviations to general statistical methods in all future AEMP-related reports; and	Generally practiced throughout Appendices IV, V and XI (no deviations in Appendices I, II and XIII beyond those detailed herein [e.g., Item #18])
15	25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Decision	3B - Directs DDMI to identify and explain any deviations from the Board-approved AEMP Design Plan in future Annual Reports and to propose required changes as updates to the AEMP Design Plan if necessary	Generally practiced throughout Appendices I, IV, V and XI (no deviations in Appendices II and XIII beyond those detailed herein (e.g., Item #18)
16	21 October 2019 Letter re: 2018 AEMP Annual Report	Decision	6 - The Board requires DDMI to identify erroneous data in future AEMP Annual Reports *Background: WLWB comment 5 identified an example of where erroneous values were excluded from a graphical summary of the data but were not described or identified clearly. In response, DDMI explained why sometimes data is considered to be erroneous (for example, due to equipment failure) and indicated that if required by the Board, they could highlight these erroneous values in future reports.*	Generally practiced throughout 2019 AEMP Report in relevant tables and figures.
17	21 October 2019 Letter re: 2018 AEMP Annual Report	Decision	4 - The Board reminds DDMI to provide a discussion of all potential mine effects, regardless of their cause, including those related to the construction or dewatering of A21, in future AEMP Annual Reports *Background: The Board reminds DDMI that the AEMP should measure and evaluate all aquatic effects resulting from mine activities, including effects associated with dewatering and construction activities.*	Main Report, Section 13.1 Appendix I, Sections 3 and 4 Appendix II, Sections 3 and 4 Appendix III, Sections 3 and 4 Appendix IV, Sections 3 and 4 Appendix V, Sections 3 and 4 Appendix XI, Sections 3 and 4 Appendix XII, Section 3 and 4 Appendix XIII, Sections 3 and 4 Appendix XV, Sections 3 and 4
18	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	The Board has decided to approve the change for comparisons to reference conditions, as opposed to FF area means, in Biological Action Levels 1 and 2 and believes this can be implemented during the 2019 AEMP season.	Main Report, Sections 4.2, 6.2, 7.3, and 8.2 Appendix IV, Section 3.9 Appendix V Section 3.3.14 Appendix XI, Section 3.3 Appendix XIII, Section 3.10
19	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	6A. Provide more information in future Aquatic Effects Re-evaluation Reports to support the continued assumption that dust monitoring control stations are not affected by the mine	Appendix I
20	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3A. Assess the potential influence of dust on stations near A21 since the beginning of development and mining activities in that area as part of the 2019 AEMP Annual Report. This assessment should include a consideration of whether any of those stations should no longer be considered as background (either for all years, or during peak construction/activity years);	Main Report, Section 2.3.1 Appendix I, Section 3.0, 3.1, and 3.2
21	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Decision	4B. Provide all raw data for all variables monitored as part of the AEMP in excel spreadsheet format;	Appendix I, Attachments B to D Appendix II, Attachments D and E Appendix III, Attachments F Appendix IV, Attachment B Appendix V, Attachments C, D ,F and G Appendix XI, Attachments B and C Appendix XIII, Attachment F
22	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1e. DDMI will remove reference to an 80% threshold in the RPD calculations for snow water chemistry (EMAB comment 25).	Reference removed from Appendix I
23	24 April 2017 Letter re: 2015 AEMP Annual Report	Directive	2C) Clarify the meaning of ‘slight increase in trophic status	Text no longer occurs in Appendix XIII
24	25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Decision	3A The Board directs DDMI to consider how to better detect and evaluate the influence of dust deposition on water quality in Version 5.1 of the AEMP Design Plan. This consideration should include a discussion of whether improvements to the dust monitoring program should be implemented to better quantify loadings from dust versus effluent.	Main Report, Section 9.3.1 Appendix XIII, Attachment D Appendix XII
25	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3B. Include a spatial analysis of TN, TDS, and chlorophyll a across the spatial extent of increased chlorophyll a in Lac de Gras as part of the 2019 AEMP Annual Report;	Appendix XIII, Section 3.8
26	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3D. Be informed that the onus is on the company to ensure proper monitoring of mine-related effects and that additional sampling to help tease apart the effects of dust deposition versus effluent on TP concentrations should be considered by DDMI for the 2019 season	Main Report, Section 9.3.1 Appendix XIII, Section 3.9 Appendix XII

27	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3C. Include eutrophication indicators sampled at LDG-48 as part of its cumulative effects analysis in the 2019 AEMP Annual Report	Appendix XIII, Section 3.11
28	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3J.Implement the approved removal of zooplankton biomass monitoring under the Eutrophication Indicators component of the AEMP at site LDS-4 starting with the 2019 AEMP season;	Appendix XIII (Zooplankton biomass removed)
29	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3K. Implement the approved inclusion of soluble reactive silica (SRS), total Kjeldahl nitrogen (TKN), and dissolved Kjeldahl nitrogen (DKN) monitoring under the Eutrophication Indicators component of the AEMP starting with the 2019 AEMP season;	Appendix XIII
30	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3L. Implement the approved discontinuation of bicarbonate and pH reporting under the Eutrophication Indicators section of the AEMP Annual Report starting with the 2019 AEMP Annual Report	Appendix XIII (Bicarbonate and pH removed)
31	25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Decision	2B - Directs DDMI to present the spatial extent of effects of eutrophication indicators for both the ice-covered and open-water seasons in future AEMP Annual Reports.	Main Report, Section 4.3.2 Appendix XIII, Section 4.3 and Attachment E
32	25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Decision	2D - Directs DDMI to provide a tabular summary of results for eutrophication indicators, with percent change from baseline and the previous year, for 2017 (included in Table 1) and in future AEMP Annual Reports.	Appendix XIII, Section 3.5
33	24 April 2017 Letter re: 2015 AEMP Annual Report	Directive	2D) Include a footnote to Figures 3.1-1 to 3.3-1 explaining the absence of any medians from the 0 to 100m zone;	Appendix I, Section 3.3
34	24 April 2017 Letter re: 2015 AEMP Annual Report	Directive	2E) Include an explanation of the lower and upper range of the BC dustfall objective for the mining industry.	Appendix I *Note: BC objective not considered in 2019*
35	27 October 2014 Letter re: 2013 Annual AEMP Report 14 November 2016 Letter re: 2014 AEMP Annual Report	Request	DDMI to include a subsection which considers the potential impacts of dust, in addition to the effect of effluent, on the water quality of Lac de Gras	Appendix II, Section 3.9 Appendix XIII, Section 3.9
36	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1d. DDMI will consider including seasonal dust deposition data (EMAB comment 21).	Appendix XIII, Section 3.9
37	21 October 2019 Letter re: 2018 AEMP Annual Report	Decision	5 - The Board requires DDMI to include a discussion of the role that dust plays in nutrient enrichment in the main body of future AEMP Annual Reports. *Background: It its review of the 2018 AEMP Annual Report, EMAB id'd that the main body of the Eutrophication chapter does not include a discussion of the role that dust loadings play towards nutrient enrichment i nLac de Gras; this discussion is included in an Appendix. DDMI provided this discussion in response to EMAB's comment, and the Board requires DDMI to be included in future reports.*	Main Report, Section 4.3.4 Appendix XIII, Section 2.3.8 and 3.9
38	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1g. DDMI will consider excluding Slimy Sculpin from the catch-per-unit-effort (CPUE) calculated for all fish species because the CPUE are heavily influence by the abundance of the target species, Slimy Sculpin (EMAB comment 77).	Appendix V, Table 3-4
39	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1h. DDMI will consider presenting CPUE for different sex/age class categories separately in future reports (EMAB comment 78).	Appendix V, Section 3.3.1 (Table 3-5)
40	24 January 2018 Letter re: 2016 AEMP Annual Report, Version 1.1	Requirement	The Board has... approved Version 1.1 of the 2016 AEMP Annual Report, however, requires that in any future reference to fish results from the 2016 AEMP Annual Report, DDMI be clear about conclusions related to metal concentrations in fish tissue and avoid suggesting that they were below those known to be of toxicological concern	Appendix V, Section 4.2 Appendix XV, Sections 3.2 and 4.1
41	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1f. DDMI has stated that it will consider including photos of infected and non-infected fish in future AEMP Annual Reports (EMAB comment 73).	Appendix V, Section 2.5.3
42	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3O. Implement the non-lethal Slimy Sculpin sampling program as described in DDMI's comment and IR responses during the 2019 AEMP season	Appendix V, Section 2.5 and 3
43	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3P. Include a consideration of how the results of the non-lethal Slimy Sculpin survey could be integrated into the WOE analysis as part of the 2019 AEMP Annual Report;	Appendix XV, Section 2.3
44	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3M. Implement the approved inclusion of annual sampling for plankton variables (i.e., taxonomy and biomass for both phytoplankton and zooplankton) at stations in the MF and FF2 areas starting with the 2019 AEMP season;	Appendix XI, Section 2
45	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3N. Implement the approved removal of plankton variable monitoring (i.e., taxonomy and biomass for both phytoplankton and zooplankton) under the Plankton component of the AEMP at site LDS-4 starting with the 2019 AEMP season;	Taxonomy and biomass for both bioplankton and zooplankton removed from Appendix XI
46	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3Q. Implement the approve change for comparisons to reference conditions, as opposed to FF area means, in Biological Action Levels 1 and 2 starting with the 2019 AEMP season.	Main Report, Sections 4.2, 6.2, 7.2, and 8.2 Appendix IV, Section 3.9 Appendix V, Section 3.3.14 Appendix XI, Section 3.3 Appendix XIII, Section 3.10
47	21 October 2019 Letter re: 2018 AEMP Annual Report	Decision	7 - The Board requires DDMI to include the QA/QC analysis for phytoplankton biomass in future AEMP Annual Reports *Background: DDMI indicated (in its response to EMAB requests of the 2017 and 2018 AEMP Annual Reports to include the QA/QC data) that it could provide this data in future reports.*	Appendix XI, Attachment A
48	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3H. Engage with ECCC on the issue of sediment sampling replication prior to the 2019 AEMP. The onus is on the company to ensure proper monitoring of mine-related effects;	Appendix III, Section 2.1

49	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3I. Implement the following approved updated sediment quality DLs starting with the 2019 AEMP season: • Total organic carbon (TOC; from 0.02 to 0.05 % dry weight [dw]); • Total organic matter (TOM; from 1 to 0.086 % dw); • Moisture (from 0.1 to 0.3 %); • Aluminum (from 50 to 100 mg/kg dw); • Magnesium (from 20 to 100 mg/kg dw); • Potassium (from 20 to 100 mg/kg dw); and • Sand, silt, and clay (from 0.1 to 2 % dw for all three size classes);	Appendix III, Section 2.2
50	21 October 2019 Letter re: 2018 AEMP Annual Report	Decision	3 - The Board requires DDMI to continue to monitor pH and evaluate for trends. Should DDMI observe more sites exhibiting a trend of increasing pH with depth, DDMI should discuss potential causes and impacts of this observation *Background: The Board understands that that the anomalous observations could have been the result of a problem with the sampling equipment; however, is of the opinion that DDMI should monitor these sites (MF2-3 and FF2-3) in future AEMP sampling periods for emerging trends*	Main Report, Section 3.3 Appendix II, Section 3
51	25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Commitment	DDMI stated that it will add dissolved oxygen and pH benchmark values to the depth profile plots in future AEMP annual reports and will examine and evaluate evidence related to any potential mine-effects (EMAB comment 6).	Appendix II, Section 3.3
52	25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Commitment	DDMI agreed to add results for LDS-4 to figures in future AEMP reports (EMAB comments 17 and 18).	Main Report, Sections 3.3, 4.3 and 5.3 Appendix II, Section 3 Appendix III, Section 3 Appendix XIII, Section 3
53	14 November 2016 Letter re: 2014 AEMP Annual Report	Commitment	The Board notes that DDMI made one commitment for future reports in response to one of EMAB's comments. EMAB noted that "Several elements are listed under both "major ions" and "total metals" (e.g., calcium and sodium) but different concentrations are given. Presumably this is because the concentrations listed under "major ions" are dissolved concentrations and the latter are total concentrations; however, this is not clearly defined for the reader." (EMAB Comment #10). DDMI responded that "Concentrations listed under "major ions" will be clearly indicated as dissolved in future reports."	Main Report, Section 3.3.1, and 3.3.4 Appendix II, Section 2
54	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Comment	1b. EMAB comment 37 recommended that depth profile figures for each NF station be provided. As part of the 2015 AEMP Annual Report, the Board has directed to DDMI to include vertical profile data collected at all stations as part of data appendices in future AEMP Annual Reports.31 This inclusion will begin with the 2017 AEMP Annual Report	Appendix II, Section 3.3 and Attachment D
55	26 May 2016 Letter re: 2011 to 2013 Aquatic Effects Re-evaluation Report, Version 3.1	Recommendation	WLWB comment 35 - Please consider including EQCs, guideline, and/or benchmarks on figures in future Re-evaluation reports.	Appendix II, Section 3
56	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3 24 April 2017 Letter re: 2015 AEMP Annual Report 25 March 2019 Letter re: 2017 Aquatic Effects Monitoring Program (AEMP) Annual Report	Decision	2. DDMI is to include the results of its investigation and proposed recommendations regarding ammonia contamination issues	Appendix II, Section 2.4.1 and Attachment B
57	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3E. Start monitoring at the approved LDS-4 location during the 2019 AEMP season	Main Report, Sections 3.2 and 4.2 Appendix II, Section 2 Appendix XIII, Section 2
58	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3F. Implement the approved updated detection limit (DL) for total dissolved solids (TDS) (i.e., 1 mg/L) starting with the 2019 AEMP season	Appendix II, Table 2-2, Section 3, and Attachment B
59	25 March 2019 Letter re: 2014 to 2016 Aquatic Effects Re-evaluation Report and AEMP Design Plan, Version 5.0	Decision	3G. Implement the approved updated water quality Effects Benchmark for silver (from 0.1 µg/L to 0.25 µg/L) starting with the 2019 AEMP season;	Appendix II, Section 2.3.4.3, Table 2-5 and Table 3-3
60	24 April 2017 Letter re: 2015 AEMP Annual Report	Commitment	Section 3.12 Commitments: The GNWT-ENR recommended that DDMI provide the raw toxicity test data as part of the AEMP reports (GNWT-ENR comment 9). In its response, DDMI stated that they would consider including these results as an appendix to the annual AEMP reports.	Appendix II, Attachment E
61	24 April 2017 Letter re: 2015 AEMP Annual Report	Commitment	Section 3.12 Commitments: Board staff recommended that DDMI consider including definitions of "T", "M", and "B" in footnote for Figure 4-3 (Board staff comment 1). In its response, DDMI stated that this will be added in future reports.	Main Report, Section 3.3.2 and 4.3.3 Appendix II, Sections 3.2.7, 3.6.1, 3.9, and 3.10 Appendix XIII, Section 3.8.2
62	24 April 2017 Letter re: 2015 AEMP Annual Report	Directive	2A)Include the vertical profile data and Secchi depth data collected at all AEMP stations in the data appendices;	Appendix II, Attachment D Appendix XIII, Attachment F
63	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1c. Because Secchi depth data will be included in future AEMP Annual Reports following a previous Board directive, DDMI has stated that it will use this information, as appropriate, in the interpretation of results for phytoplankton biomass, taxonomy, and chlorophyll a (EMAB comments 13 and 45).	Appendix XIII, Section 3.2, 3.6.1 and 4.2
64	24 April 2017 Letter re: 2015 AEMP Annual Report	Directive	2B) Include all relevant information, such as changes in detection limits, necessary to interpret monitoring results;	Appendix II, Section 2 Appendix III, Section 2 Appendix V, Section 2 Appendix XIII, Section 2
65	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1j. DDMI has noted that it will use a screening value of greater than 15% censoring to flag data sets that may require alternative analysis methods in future AEMP Annual Reports (Board staff comment 13).	Appendix II, Sections 2.3.3 and 2.3.6 Appendix III, Section 2.3.2, and 2.3.4 Appendix XIII, Section 2.3.2 and 2.3.4

66	28 August 2017 Letter re: 2016 AEMP Annual Report and Update to Schedule 8, Condition 3	Commitment	1i. DDMI has stated that it will consider using a non-parametric alternative to the one-sample t-test in cases where non-detect values occur in the NF area in future AEMP Annual Reports (GNWT-ENR comment 14).	Appendix II, Section 2.3.3, and 2.3.6 Appendix V, Section 2.7.5

ERM

1111 West Hastings Street, 15th Floor
Vancouver, BC
Canada V6E 2J3

Telephone: +1 604 689 9460
Fax: +1 604 687 4277

www.erm.com

Memo

To	Mark Nelson and Kofi Boa-Antwi (Diavik Diamond Mines (2012) Inc.)
From	Andres Soux and Trevor Newton (ERM)
Cc:	Carol Adly (ERM)
Date	October 13, 2020
Reference	0207514
Subject	Diavik Diamond Mine, Dustfall Stations Near A21

The purpose of this memo is to provide additional information for the Diavik Diamond Mines Inc. (DDMI) 2019 Aquatic Effects Monitoring Program Report (Golder, 2020), specifically to assess the potential influence of mine-generated dust on dustfall monitoring stations located near the A21 pit at the Diavik Diamond Mine (the Project). The goal of this assessment is to determine whether observed annual dustfall rates in recent years (2016-2019) were significantly higher than in earlier years (2008-2015), which could indicate that stations near A21 should no longer be considered as background stations because they are now influenced by the Project.

There are two dustfall stations located near the A21 pit: Dust 10 and Dust 11 stations. Annual observed dustfall rates at both stations are presented in Table 1, along with rates from the Dust C1 station, which is located 5 km south southeast of A21. Dust C1 is a control station; in the Diavik reports on air quality and dust deposition, the terms ‘control’ and ‘background’ are used interchangeably to indicate stations that are sufficiently distant from the Project that they will not normally be influenced by Project activities.

Results

Table 1 shows that during 2008 through 2014, the observed annual dustfall rate at Dust 10 was at or below 237 mg/dm^2/year. During those years, mining had not yet begun at the A21 pit. In 2015, a new maximum dustfall rate of 282 mg/dm^2/year was observed; this was a transitional year, with pre-construction activity at A21. The maximum annual dustfall rate of 799 mg/dm^2/year was observed in 2016 when construction was conducted. Annual observed rates were higher between 2017 and 2019, coincident with construction and/or active mining at A21, than in the early or transitional years.

At Dust 11, observed annual dustfall rates recorded since 2017 are comparable to those at Dust 10, with high year-to-year variability and rates in recent years in the 400 – 700 mg/dm^2/year range. The observed rates at the Dust C1 station are lower than at Dust 10 and Dust 11 each year (except 2012), and they are often much lower (e.g., > 600 mg/dm^2/year at Dust 10 and Dust 11 in 2019 compared to 115 mg/dm^2/year at C1).

Table 1: Observed Annual Dustfall, 2008 - 2019

Year	Dust 10 (mg/dm^2/year)	Dust 11 (mg/dm^2/year)	Dust C1 (mg/dm^2/year)
2008	215		199
2009	137		114
2010	237		101
2011	152		95
2012	31		55
2013	122		49
2014	133		105
2015	282		98
2016	799		45
2017	318	85	34
2018	645	391	85
2019	683	667	115

Conclusions

Even before 2016, when construction started at the A21 pit, the observed annual dustfall rates at the Dust 10 station were higher than at the nearest control/background station, likely due to other Project components such as roads and the other pits. ERM recommends that the Dust 10 and Dust 11 stations not be considered representative of background conditions, for all years of data.

Reference

Golder. 2020. *Diavik Diamond Mine: Aquatic Effects Monitoring Program – 2019 Annual Report.* Prepared for Diavik Diamond Mines (2012) Inc. by Golder Associates Ltd.: Calgary, British Columbia.

Regards,

Andres Soux, M.Sc.
ERM Consultants Canada Ltd.

DIAVIK DIAMOND MINES (2012) INC.

AQUATIC EFFECTS MONITORING PROGRAM
2019 ANNUAL REPORT

Submitted to:

Diavik Diamond Mines (2012) Inc.
PO Box 2498
300 - 5201 50th Avenue
Yellowknife, NT
X1A 2P8, Canada

DISTRIBUTION

1 Copy – Diavik Diamond Mines (2012) Inc., Yellowknife, NT
1 Copy – Golder Associates Ltd., Calgary, AB
1 Copy – Wek'èezhìı Land and Water Board

April 2020
19115664/8000

Doc No. RPT-1922 Ver. 0
PO No. 3103966486

Executive Summary

Diavik Diamond Mines (2012) Inc. (DDMI) conducts environmental monitoring programs under the terms and conditions of Water Licence W2015L2-0001 issued for the Diavik Diamond Mine (Mine). The Aquatic Effects Monitoring Program (AEMP) is the primary program specified in the Water Licence for monitoring the aquatic environment of Lac de Gras.

The AEMP is a monitoring program "designed to determine the short and long-term effects on 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" (WLWB 2015). The goal of the AEMP is to protect the valued ecosystem components of Lac de Gras, which consist of water chemistry, sediment chemistry, lake productivity, plankton and benthic invertebrate communities, fish, fish habitat, and the use of fisheries resources in Lac de Gras.

To accomplish these objectives, aquatic effects monitoring conducted by DDMI has included an east island-based monitoring program of source waters, represented by the Surveillance Network Program (SNP), and a lake-based monitoring program, represented by the AEMP. The lake monitoring program includes the following components:

- water chemistry monitoring in Lac de Gras
- aquatic biota monitoring in Lac de Gras (including fish surveys, plankton and benthic invertebrate community studies, and supporting sediment and water chemistry data collection)
- monitoring water and sediment chemistry, plankton and benthic invertebrate communities in Lac du Sauvage, immediately upstream of the outflow (the Narrows) to Lac de Gras
- monitoring water quality at the Lac de Gras inflow from Lac du Sauvage (the Narrows), and the lake outflow near the mouth of the Coppermine River
- dust deposition monitoring on the east island and on ice in Lac de Gras during winter
- special effects studies (SES), as required

The lake monitoring program in Lac de Gras generally occurs in three areas:

- the near-field (NF) area located near the effluent diffusers
- three mid-field (MF) areas, MF1, MF2-FF2, and MF3, generally surrounding the east island, and extending away from the NF area
- three far-field (FF) areas, FF1, FFA, and FFB

All AEMP sampling areas were exposed to Mine effluent to varying degrees, with the greatest exposure in the NF area, least exposure in the FF1, FFA and FFB areas (former reference areas), and intermediate levels of exposure in the MF1, MF2-FF2 and MF3 areas. The 2019 AEMP was carried out according to the requirements specified in the *AEMP Design Plan Version 4.1* for a comprehensive monitoring year, which

requires sampling in all designated sampling areas in the lake. All FF areas in Lac de Gras are sampled every third year during the comprehensive monitoring program to allow a detailed assessment of Mine-related effects. During the interim monitoring program, sampling is carried out in the NF and MF sampling areas.

The focus of the assessment for a comprehensive year annual report is the analysis of potential effects of the Mine on water quality, nutrients, sediment quality, as well as effects on the plankton, benthic invertebrate, and fish communities. The assessment determines whether actions are required to manage effects by evaluating the presence and magnitude of each effect (e.g., is the concentration of a water quality variable greater than the background range and is it reaching a guideline?) and spatial extent of effects (e.g., how much of the lake is affected?). Information from all components is combined in a weight-of-evidence integration to evaluate the type of effects observed (i.e., nutrient enrichment or toxicological impairment) and the strength of evidence for each. The importance of effects is evaluated by comparisons to Action Levels, which are part of a Response Framework. The goal of the Response Framework is to ensure that significant adverse effects never occur in Lac de Gras. A detailed spatial analysis and an assessment of trends over time will be provided in the next Aquatic Effects Re-evaluation Report, covering the 2017 to 2019 period, to be submitted by 31 December 2020.

To better communicate AEMP results to the range of technical and non-technical parties who are interested in the results, we have provided information in two ways. First, the main body of the report provides a non-technical summary of the most important results from the 2019 studies. Second, technical appendices provide a full description of the analyses conducted and results obtained. These appendices are intended for parties with more technical interests.

Key findings from the 2019 AEMP include the following:

- No Action Levels were triggered in 2019 for the eutrophication indicators, benthic invertebrate community and plankton AEMP components. Action Level triggers for effluent and water chemistry, sediment quality and fish were triggered in 2019, as described below.
- There are 9 defined Action Levels. Mine effluent triggered Action Level 1 (which is considered an early-warning indicator of effects in the NF area) for 16 water quality variables, including total dissolved solids (TDS), turbidity, calcium, chloride, magnesium, sodium, sulphate, ammonia, nitrate, aluminum, barium, manganese, molybdenum, silicon, strontium, and uranium. All 16 water quality variables were included as substances of interest (SOIs) in 2019. Of the sixteen SOIs that triggered Action Level 1, nine also triggered Action Level 2, and included TDS, chloride, sodium, sulphate, ammonia, nitrate, molybdenum, strontium, and uranium. None of the water quality variables reached Action Level 3. Regulated effluent parameters were all below applicable effluent quality criteria (EQC). The 2019 effluent toxicity results indicated that the effluent discharged to Lac de Gras in 2019 was non-toxic.
- No Action Levels were triggered for eutrophication indicators based on chlorophyll *a* results in 2019. Elevated concentrations of nutrients and chlorophyll *a* in the NF and MF areas indicate that the Mine is having a nutrient enrichment effect in Lac de Gras, but in 2019, the effect on phosphorus and biological communities was smaller than in most previous years. This is attributed to lower phosphorus loading by the Mine effluent, which was lower in 2019 than measured during the last decade. In 2019, concentrations of total phosphorus (TP) were below the normal range at all stations for both seasons and all depths; therefore, the area of the lake affected by TP was 0%. The extent of effects on total nitrogen (TN) was the entire lake area during the open-water season and 85% of the lake area during

the ice-cover season. The extent of effects on phytoplankton and zooplankton was 0% and 29%, respectively, of Lac de Gras. The extent of effects on chlorophyll *a* was 0.1% of the lake area.

- Mine-related effects on bottom sediments in the NF area of Lac De Gras were identified for 12 variables, which were retained as SOIs (i.e., bismuth, lead, lithium, molybdenum, phosphorus, potassium, silver, sodium, strontium, tin, titanium, total uranium). Concentrations in the NF area of bismuth, lead, molybdenum, strontium and uranium exceeded normal ranges. Of the 12 sediment quality SOIs evaluated, total molybdenum and total uranium triggered Action Level 1 and bismuth triggered Action Level 2.
- No Action Levels were triggered for plankton in 2019. The 2019 phytoplankton results provided no indication of a Mine-related toxicological effect in Lac de Gras. However, zooplankton results suggest that changes are occurring in the NF area that may be the result of a community shift caused by nutrient enrichment. No Action Levels were triggered for plankton based on total phytoplankton biomass, zooplankton biomass, and zooplankton taxonomic richness. Phytoplankton taxonomic richness, in all areas of Lac de Gras, was below the reference condition mean and the normal range. However, the quality control (QC) evaluation of the 2019 phytoplankton data suggested that the 2019 data should be interpreted with caution, and for taxonomic richness, comparison of the 2019 data to previous years is unreliable.
- No Action levels were triggered for the benthic invertebrate community in 2019. The benthic community monitoring results suggest that the Mine discharge resulted in a low level nutrient enrichment effect on the benthic invertebrate community in Lac de Gras. All analyzed variables in the NF area were within or above their respective normal ranges. Differences were observed among sampling areas for total density, dominance, Simpson's diversity index, *Procladius* density and *Microtendipes* density. Decreasing trends with distance from the diffuser were observed for evenness and the majority of density variables analyzed. In the NF area, the majority of variables had mean values at or above their respective reference condition mean values.
- Fish were healthy and exhibited similar reproductive success and prevalence of internal and external abnormalities among sampling areas. The prevalence of parasites, specifically tapeworms, varied among areas but was not associated with proximity to the Mine. Relative to the FF areas, differences were observed for male gonad weight and female total length, total weight and relative liver weight in the NF area. Relative to reference conditions, differences were observed for age-1+ total length, total weight, carcass weight, condition, and relative liver weight, as well as male and female gonad size. Differences in the NF area were not consistent between comparisons to the FF area and reference conditions, with the exception of male gonad weight. Mean values of all examined fish health variables were within normal ranges. The differences observed in length, weight and relative liver size of juvenile fish between the NF and MF areas compared to reference conditions may be indicative of a toxicological response as defined under the Action Level assessment and triggered Action Level 2 in 2019. Factors contributing to similar effects in 2016 were determined to be inconsistent with a Mine effect, and were likely driven by localized habitat variation among study areas.
- Fish tissue concentrations of molybdenum, silver, strontium and uranium in the NF area were significantly greater when compared to the FF area, and exceeded normal ranges in samples collected from the NF and MF areas; however, concentrations of these metals have remained relatively stable since 2013, with the exception of molybdenum which exhibited an increase of 34%.

- Overall, the weight-of-evidence integration indicated a stronger nutrient enrichment response in Lac de Gras, compared to a toxicological impairment response. There appears to be a clear link between nutrient releases (i.e., TP and TN) to Lac de Gras via the Mine effluent, resulting in greater nutrient concentrations and greater productivity in the NF and MF area. There is also a consistent response of greater invertebrate density and a mild community shift in the benthic invertebrate community that can be linked to the observed enrichment. Although there are statistically significant differences between the NF (and in some cases MF) areas and the FF areas for indicators of enrichment, the severity with respect to the ecological integrity of Lac de Gras associated with these changes appears to be low.

Other findings from the 2019 AEMP include the following:

- Dust deposition rates were greatest close to the Mine infrastructure and decreased with distance from the Mine. Comparisons of dustfall rates between the control and control-assessment sites suggested that dustfall rates at the control sites were potentially affected by the Mine and may not reflect background values.
- A special effects study under which additional water quality sampling was completed at four stations located in potentially high Mine-related dust generating areas indicated no greater concentrations of dust-associated major ions and metals, or eutrophication indicators, than at AEMP stations located farther away. Effluent and dustfall samples had distinct geochemical signatures. The geochemical signature of lake water was similar to that of effluent in all areas of the lake, and the influence of dust could not be differentiated from the effect of the effluent. Dissolution of phosphorus-bearing minerals in dustfall is unlikely under the pH and redox conditions in lake water, suggesting that dust-associated phosphorus is more likely to settle to sediments than to be available as a nutrient to phytoplankton. Results of the special study provide additional evidence that the effect of the Mine in Lac de Gras is through the release of effluent, rather than dust deposition.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF APPENDICES

Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
AFDM	ash-free dry mass
ALS	ALS Laboratories
BV Labs	Bureau Veritas Laboratories
CCME	Canadian Council of Ministers of the Environment
DDMI	Diavik Diamond Mines (2012) Inc.
DO	dissolved oxygen
EA	Environmental Assessment
EOI	evidence of impact
EQC	effluent quality criteria
ERM	ERM Consultants Canada Ltd.
FF	far-field
GSI	gonadosomatic index
Golder	Golder Associates Ltd.
ISQG	interim sediment quality guideline
LDG	Lac de Gras
LDS	Lac du Sauvage
LEL	lowest effect level
LOE	line of evidence
LSI	liver somatic index
Maxxam	Maxxam Analytics Inc.
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
NIWTP	North Inlet Water Treatment Plant
OMOEE	Ontario Ministry of the Environment and Energy
PEL	probable effect level
SD	standard deviation
SEL	severe effect level
SES	special effects study
SNP	Surveillance Network Program
SOI	substance of interest
SRP	soluble reactive phosphorus
TDS	total dissolved solids
TDP	total dissolved phosphorus
TOC	total organic carbon
TN	total nitrogen
TP	total phosphorus
WLWB	Wek'èezhìı Land and Water Board

WOE	Weight-of-Evidence
ZOI	zone of influence

Symbols and Units of Measure

+	plus
%	percent
>	greater than
<	less than
μg/L	micrograms per litre
μg-N/L	micrograms nitrogen per litre
μg-P/L	micrograms phosphorus per litre
mm	millimetre
cm	centimetre
km	kilometre
km^2	square kilometre
m	metre
no./m^2	number of organisms per square metre
mg/L	milligrams per litre
g	gram
kg	kilogram
kg/yr	kilograms per year
mg/dm^2/d	milligrams per square decimetre per day
mg/dm^2/y	milligrams per square decimetre per year
mg/m^3	milligrams per cubic metre
mg/kg dw	milligrams per kilogram dry weight
mg/kg wwt	milligrams per kilogram wet weight

1 INTRODUCTION

1.1 Background Information

Diavik Diamond Mines (2012) Inc. (DDMI) conducts environmental monitoring programs under the terms and conditions of Water Licence W2015L2-0001 (WLWB 2015) issued for the Diavik Diamond Mine (Mine). The Mine is an open-pit diamond mining operation which discharges effluent to Lac de Gras following treatment at an on-site water treatment plant, the North Inlet Water Treatment Plan (NIWTP) (Figure 1-1). The Aquatic Effects Monitoring Program (AEMP) is the primary program described in the Water Licence for monitoring the aquatic environment of Lac de Gras.

The Water Licence for the Mine requires that DDMI review and update the AEMP design plan every three years, or as directed by the Wek'èezhìı Land and Water Board (WLWB). The current AEMP design is described in the *AEMP Design Plan Version 4.1* (Golder 2017a). The design plan describes the updated AEMP design, and provides a summary of how water, sediment, and biological monitoring studies are to be conducted under the AEMP. The reader is encouraged to review the document for specifics regarding the current AEMP design. Although *AEMP Design Plan Version 4.1* (Golder 2017a) is the approved version of the AEMP design at the time this report was written, a number of updates outlined in the proposed *AEMP Design Plan Version 5.1* (Golder 2019a) and in Wek'èezhìı Land and Water Board (WLWB) directives (28 August 2017, 24 January 2018, 25 March 2019, and 21 October 2019 Decision Packages) have been incorporated into the 2019 AEMP Report. Specific updates have been outlined in Section 1 of each AEMP component (see Appendix I through XV).

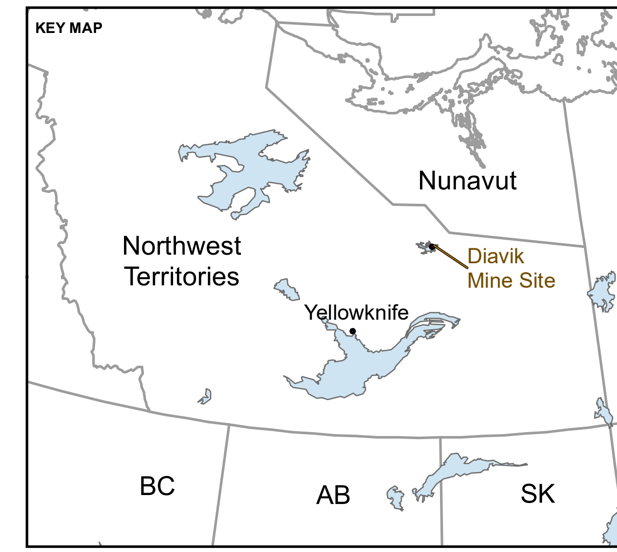
As summarized in the *AEMP Design Plan Version 4.1* (Golder 2017a), Mine effluent discharge (i.e., effluent) represents the main concern for Lac de Gras. The effluent, combined with other Mine-related stressors (e.g., dust deposition) and their potential impact on the lake ecosystem, is the principal focus of the AEMP. The AEMP has also been designed to include the results of other sources of information on potential effects on the lake, specifically, the results of Traditional Knowledge studies. A summary of all AEMP data collected since before mining began, up to and including 2016, was provided in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c). The report evaluated trends over time in AEMP components, and as such, the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c) is an important reference when considering ongoing monitoring results.

Sampling for the AEMP is required once during late ice-cover conditions (i.e., April and/or May) and once during open-water conditions (i.e., between 15 August and 15 September). The magnitudes of effects are evaluated by comparing water chemistry and biological results for the near-field (NF) and mid-field (MF) areas to "reference conditions". 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 used to assess effects of the Mine on individual components of the AEMP are described in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). Values that exceed the normal range are considered different from what would be considered natural levels for Lac de Gras, but do not represent levels that are harmful. To evaluate whether water quality variables are reaching potentially harmful concentrations, results are compared to AEMP Effects Benchmarks (as defined in the *AEMP Design Plan Version 4.1* [Golder 2017a]). Similar to water quality guidelines, AEMP Effects Benchmarks are intended to protect fish and other aquatic life in Lac de Gras. Comparison of water quality results to Effects Benchmarks provides an indication of how close the concentrations of water quality variables (e.g., metals[1]) are to concentrations that could be harmful to aquatic life in the lake.

[1] The term metal is used throughout this report and includes non-metals (e.g., selenium) and metalloids (e.g., arsenic).

LEGEND

INFRASTRUCTURE



0 500 1,000

1:30,000 METRES

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

CLIENT
RioTinto

PROJECT
DIAVIK DIAMOND MINES INC.

TITLE
SITE PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	2020-04-28
DESIGNED	LJ
PREPARED	LMS
REVIEWED	LJ
APPROVED	ZK

PROJECT NO.	PHASE	REV.	FIGURE
19115664	8000	0	1-1

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

1.2 Purpose and Objectives

As defined in the Water Licence, the AEMP is a monitoring program designed 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” (WLWB 2015). The AEMP is focused on the valued ecosystem components of Lac de Gras, which have been evaluated in previous site investigations, including the Environmental Assessment, and consist of fish, fish habitat, water quality, sediment quality, lake productivity, plankton and benthic invertebrate communities, and the use of fisheries resources in Lac de Gras (DDMI 1998).

In 2015, DDMI’s Water Licence was renewed for a period of eight years, effective 19 October 2015. This AEMP 2019 Annual Report addresses the requirements specified in Part J Item 8 (Table 1-1) of the Water Licence (WLWB 2015).

Table 1-1 Aquatic Effects Monitoring Program Annual Reporting Requirements Specified in Part J, Item 8 of the Water Licence

Item	Location in Report
a) a summary of activities conducted under the AEMP;	Main Report, Section 2.2, 3.2, 4.2, 5.2, 6.2, 7.2, 8.2, 9.3.1, and 11.2 Appendix I, Section 2 Appendix II, Section 2 Appendix III, Section 2 Appendix IV, Section 2 Appendix V, Section 2 Appendix XI, Section 2 Appendix XII, Section 2 Appendix XIII, Section 2 Appendix XV, Section 2
b) tabular summaries of all data and information generated under the AEMP in an electronic and printable format acceptable to the Board;	Appendix I, Attachments B to D Appendix II, Attachments D* and E* Appendix III, Attachments F Appendix IV, Attachment B* Appendix V, Attachments C*, D*,F* and G* Appendix XI, Attachments B* and C* Appendix XII, Attachment A Appendix XIII, Attachments F Appendix XV, Attachment A (*also provided in attached electronic files)

Table 1-2 Aquatic Effects Monitoring Program Annual Reporting Requirements Specified in Part J, Item 8 of the Water Licence (continued)

Item	Location in Report
c) an interpretation of the results, including an evaluation of any identified environmental changes that occurred as a result of the Project;	Main Report, Section 13.1 Appendix I, Sections 3 and 4 Appendix II, Sections 3 and 4 Appendix III, Sections 3 and 4 Appendix IV, Sections 3 and 4 Appendix V, Sections 3 and 4 Appendix XI, Sections 3 and 4 Appendix XII, Section 3 and 4 Appendix XIII, Sections 3 and 4 Appendix XV, Sections 3 and 4
d) an evaluation of any adaptive management response actions implemented during the year;	Main Report, Section 12 Appendix II, Section 5 Appendix III, Section 5 Appendix IV, Section 5 Appendix V, Section 5 Appendix XI, Section 5 Appendix XIII, Section 5
e) recommendations for refining the AEMP to improve its effectiveness as required; and	Main Report, Section 13.2
f) an evaluation of the overall effectiveness of the AEMP to date; and, any other information specified in the approved AEMP or that may be requested by the Board.	Main Report, Section 13.3

An objective of the AEMP is to monitor the Mine effluent discharge and assess potential ecological risks, so that appropriate actions can be taken to prevent adverse effects from occurring in the environment. The AEMP is updated at regular intervals and incorporates new information and findings as they become available. The AEMP compares effluent quality to effluent quality criteria (EQC), as defined in the Water Licence, and evaluates compliance monitoring and the effectiveness of operational management (e.g., mitigation) measures.

The AEMP consists of the following components:

- a water and sediment chemistry program in Lac de Gras
- an aquatic biota monitoring program in Lac de Gras, including fish surveys, benthic invertebrate surveys, and plankton surveys
- a dust deposition monitoring program
- special effects studies as required as part of the Water Licence and the Fisheries Authorization for the Mine

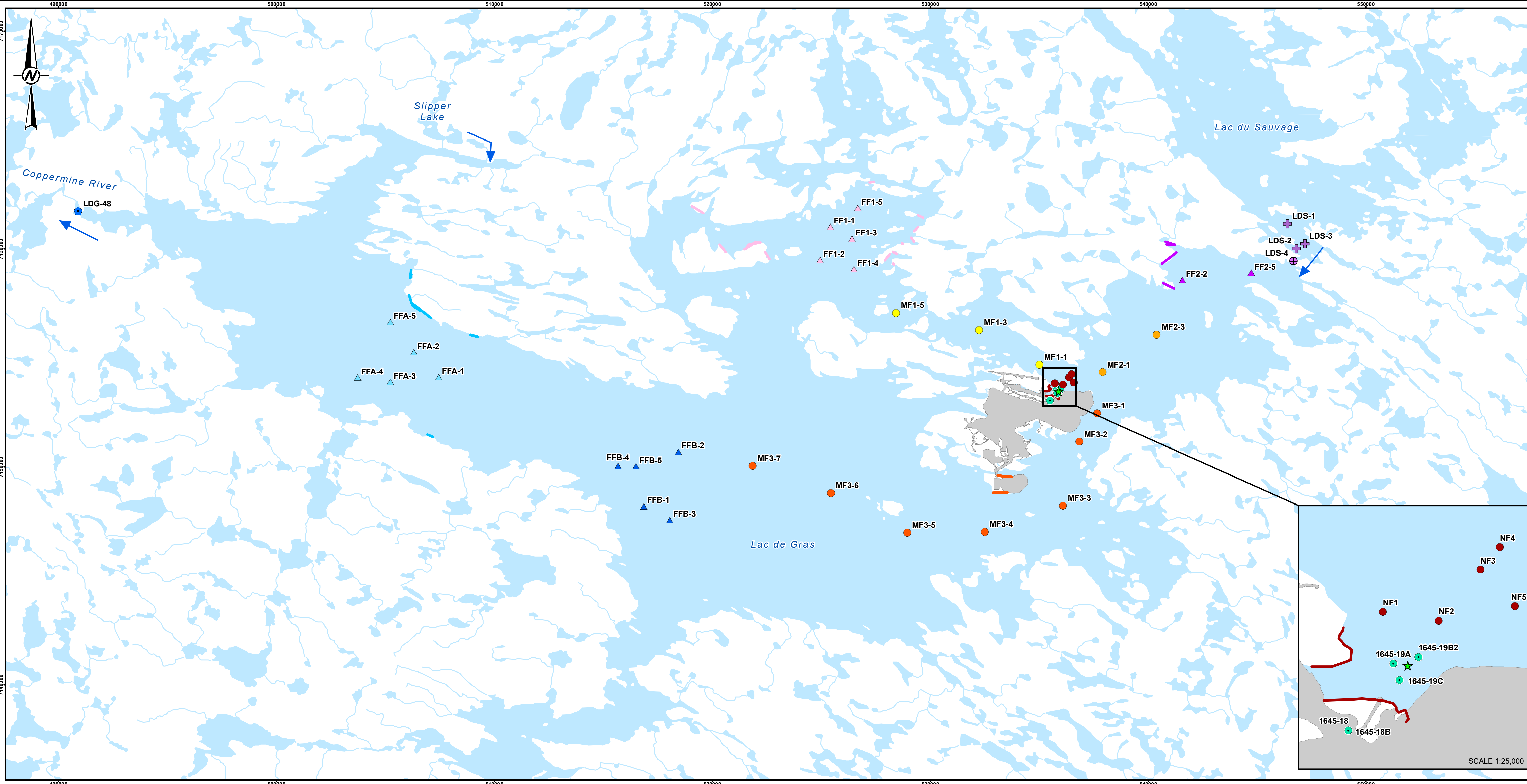
Three general areas of Lac de Gras are monitored under the AEMP:

- the NF exposure area, located near the effluent diffusers (Figure 1-2)
- the MF exposure areas (i.e., MF1, MF2-FF2, and MF3), generally surrounding the east island and extending away from the NF area (Figure 1-2)
- the far-field (FF) exposure areas (i.e., FF1, FFA, and FFB), located further from the Mine

The FF1, FFA and FFB areas were formerly reference areas, and data from these areas were used to develop normal ranges as presented in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). In addition to sampling in the above areas of Lac de Gras, water, sediment quality and eutrophication indicators are also sampled at the inflow to Lac de Gras from Lac du Sauvage (i.e., Station LDS-4 located at the Narrows), at Stations LDS-1, LDS-2 and LDS-3 in Lac du Sauvage near the outflow to Lac de Gras, and at the Lac de Gras outflow to the Coppermine River (i.e., Station LDG-48). Plankton is also sampled at Stations LDS-1, LDS-2 and LDS-3 in Lac du Sauvage near the outflow to Lac de Gras.

Sampling for the AEMP in 2019 was carried out according to the requirements specified in the *AEMP Design Plan Version 4.1* (Golder 2017a) for a comprehensive monitoring year, which requires sampling in the NF, MF and FF areas of the lake. During interim monitoring years, the three FF areas (i.e., FF1, FFA, FFB) are not sampled. The comprehensive monitoring program allows for a detailed spatial assessment of Mine-related effects.

The objective of this annual report is to present the results of the 2019 comprehensive monitoring program. Similar annual reports containing results of the 2007 through to 2017 AEMP years were prepared by DDMI (2008, 2009, 2010, 2011a, 2012, 2013) and Golder (2014a, 2016a,b, 2017b, 2018, 2019d). Every third year, AEMP results from the previous three years are integrated in an Aquatic Effects Re-evaluation Report, which includes detailed spatial analysis of effects, analyses of trends over time, and a comparison of results to predicted effects (Government of Canada 1999). The last re-evaluation report was submitted in June 2019 as the *2014 to 2016 Aquatic Effects Re-evaluation Report. Version 1.1* (Golder 2019c). The 2017 to 2019 re-evaluation report is scheduled for submission on 31 December 2020.



LEGEND

★ DIFFUSERS
SURVEILLANCE NETWORK PROGRAM

STATION LOCATIONS

- FAR-FIELD 1
- FAR-FIELD 2
- FAR-FIELD A
- FAR-FIELD B
- LAC DE GRAS OUTLET
- LAC DU SAUVAGE
- LAC DU SAUVAGE OUTLET
- MID-FIELD 1
- MID-FIELD 2
- MID-FIELD 3
- NEAR-FIELD

2019 FISH SAMPLING AREA TRANSECTS

- FAR-FIELD 1
- FAR-FIELD 2
- FAR-FIELD A
- MID-FIELD 3
- NEAR-FIELD
- FLOW DIRECTION
- WATERCOURSE
- DIAVIK FOOTPRINT
- WATERBODY

0 5 10
1:175,000 KILOMETRES

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

CLIENT
RioTinto

PROJECT
DIAVIK DIAMOND MINES INC.

CONSULTANT
GOLDER

YYYY-MM-DD	2020-04-28
DESIGNED	LJ
PREPARED	LMS
REVIEWED	LJ
APPROVED	ZK

TITLE
SAMPLING STATIONS, 2019 AEMP

PROJECT NO.	PHASE	REV.	FIGURE
19115664	8000	0	1-2

1.3 AEMP Annual Report Content and Organization

The organization of this report follows the outline provided in Section 7.3 of the *AEMP Design Plan Version 4.1* (Golder 2017a). To better communicate the results of the AEMP to the range of technical and non-technical parties who are interested, we have provided information in two ways. First, this main body of the report provides a summary of the most important results from the 2019 studies, presented in a non-technical way. Second, the appendices provide a full technical description of analyses conducted and results obtained. These appendices are intended for parties with more technical interests. The technical appendices prepared for the 2019 annual report include:

- Appendix I – Dust Deposition Report
- Appendix II – Effluent and Water Chemistry Report
- Appendix III – Sediment Report
- Appendix IV – Benthic Invertebrate Report
- Appendix V – Fish Report
- Appendix XI – Plankton Report
- Appendix XII – Special Effects Study – Dust Deposition
- Appendix XIII – Eutrophication Indicators Report
- Appendix XV – Weight-of-Evidence Report

Appendix I was prepared by ERM Consultants Canada Ltd. (ERM) and technical appendices II through XV were prepared by Golder Associates Ltd. (Golder).

The order in which the appendices appear in the annual report and the appendix number for a given component is the same from year to year, even though there may not be a technical report for a given component in each year. This was done to meet reporting commitments stated in the *AEMP Design Plan Version 4.1* (Golder 2017a) and as a means of tracking available information. The technical report "placeholder" appendices, which do not contain a technical report for 2019 include:

- 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
- Appendix XIV – Traditional Knowledge Studies

There are no technical reports for these components in 2019, therefore, a note has been inserted in the appropriate appendix placeholder stating that the component was not monitored in 2019.

2 DUST DEPOSITION

2.1 Introduction and Objectives

Many of the activities at the Mine generate dust, in particular, trucks travelling on roads, the dumping of Mine rock on the waste rock piles, and activities associated with construction. The dust in the air can be transported by wind, but eventually settles on the ground or the water surface. In accordance with the Environmental Assessment and requirements associated with the AEMP, a dust monitoring program was initiated in 2001. The objective of the dust monitoring program is to measure the amount of dustfall at various distances from the Mine footprint and to describe the chemical characteristics of the dustfall deposited into Lac de Gras and the surrounding area.

The detailed technical report on the findings from the 2019 dust deposition monitoring program is provided in the *Dust Deposition Report* (Appendix I). An overview of the dust deposition monitoring program and a summary of the 2019 results are provided herein. A *Special Effects Study – Dust Deposition* (Appendix XII), or SES, was also conducted in August 2019 to further investigate dust-related effects on water quality and aquatic life in Lac de Gras (see Section 9.3.1).

2.2 Methods

The 2019 dustfall monitoring program used three sampling methods: dustfall gauges, snow surveys, and snow water chemistry. Sampling was completed at varying distances around the Mine along five transects, including three reference stations (referred to as "control stations") intended to measure the background dust deposition rate. In addition, four additional stations (referred to as "control-assessment stations") located farther from the Project footprint were added to the 2019 monitoring program to assess the suitability of the control stations.

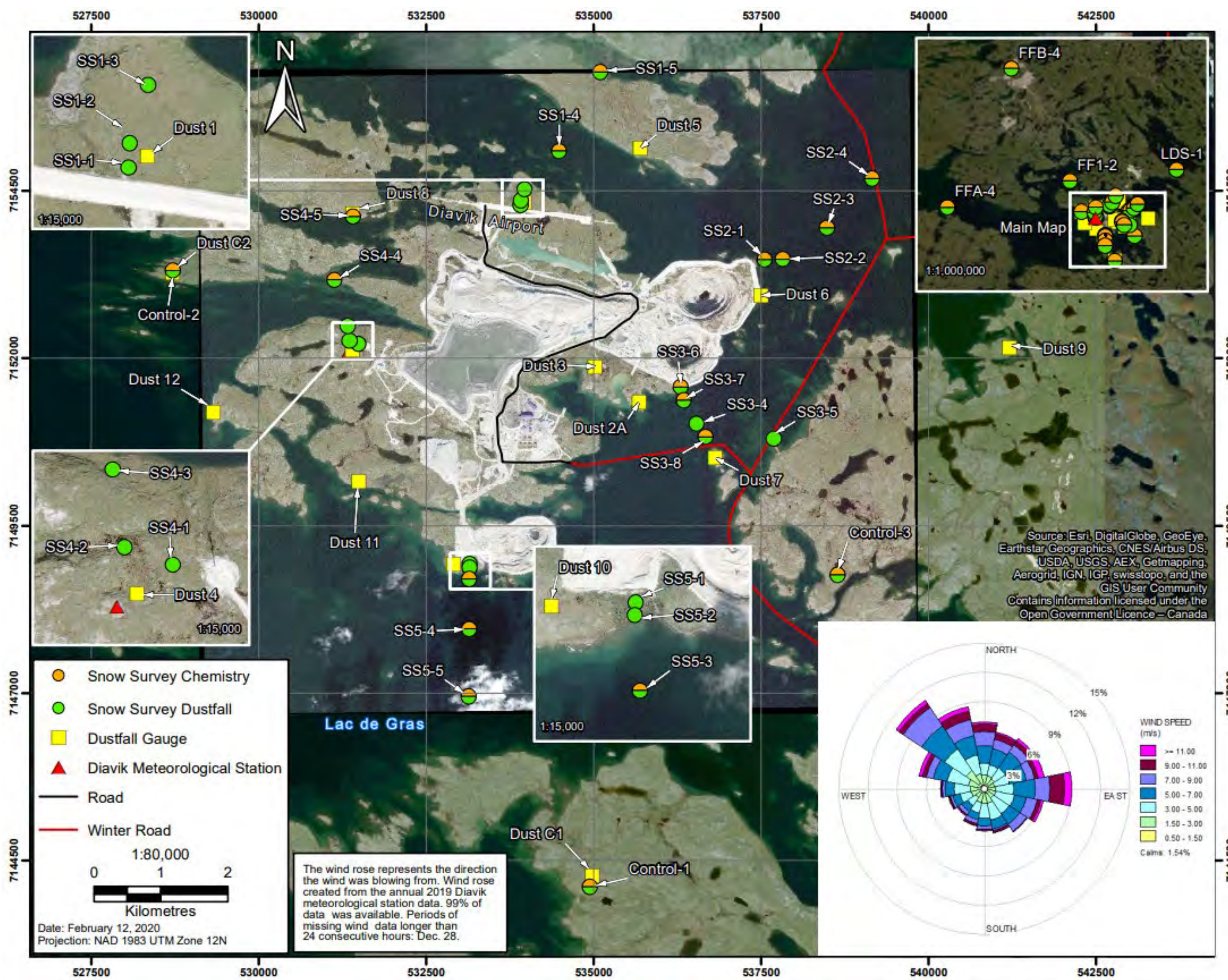
2.2.1 Dustfall Gauges

Passive sampling of airborne particles was done using dust collection gauges. A dust gauge is a hollow brass cylinder, 52 cm in length and 12.5 cm in diameter, surrounded by a fibreglass shield with the shape of an inverted bell (Photo 2-1). Dustfall gauges were placed at 14 stations (including two control stations) around the Project at distances ranging from approximately 13 to 4,646 m from mining operations (Figure 2-1). All fourteen stations collected dustfall year-round, with samples collected every three months from January to December 2019, for an average total sampling period of 361 days. The dry weight of the material collected in the gauges was recorded, and the mean daily dustfall rate over the collection period was estimated.

The Northwest Territories has no guidelines or objectives for dustfall deposition. Estimated dustfall rates were therefore compared to the Alberta Ambient Air Quality Objectives and Guidelines for dustfall (AEP 2019), which are used only as general performance indicators and are not a regulatory requirement in compliance evaluation. The Alberta Ambient Air Quality Guidelines for dustfall include a guideline for residential and recreational areas (i.e., 53 mg/dm^2 per 30 days, or 646 mg/dm^2/y, respectively), and a guideline for commercial and industrial areas where higher dustfall rates are expected (i.e., 158 mg/dm^2 per 30 days, or 1,924 mg/dm^2/y, respectively).

Photo 2-1 **Dustfall gauge during sample collection. The dustfall gauge consisted of a hollow brass cylinder (centre) housed inside a Nipher snow gauge (right).**

Figure 2-1 2019 Dustfall Gauge and Snow Core Survey Sampling Stations



2.2.2 Snow Core Surveys

In the snow core surveys, a cylindrical section of snow was collected by drilling into the snowpack with a hollow tube (Photo 2-2). The collected snow was then brought back to the laboratory, thawed, filtered, and the residue was dried, and weighed. Mean daily dustfall was calculated over the collection period, and dustfall rates were compared to the Alberta Ambient Air Quality Objectives and Guidelines for dustfall, which are used only as general performance indicators and are not a regulatory requirement in compliance evaluation.

Snow survey samples were collected along five transects at 31 stations, including three control stations and four control-assessment stations (Figure 2-1). The average total sampling season in 2019 was 155 days for on-ice stations, and 214 days for land stations. The start dates correspond to the first snowfall for land stations on 3 September 2018, and the period shortly after freeze-up for on-ice stations, on 2 November 2018.

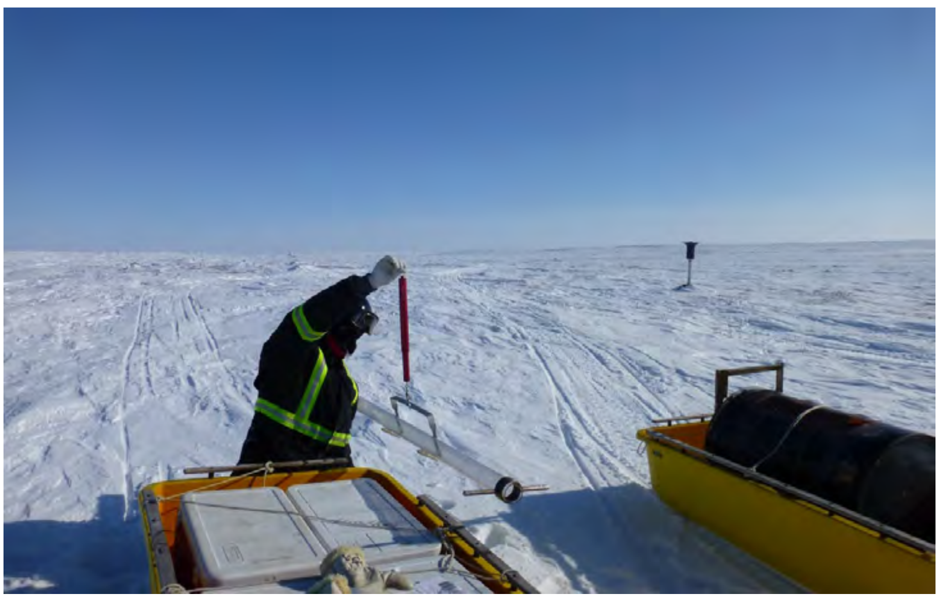


Photo 2-2 Snow core sampling

2.2.3 Snow Water Chemistry

Samples for snow water chemistry analysis were collected using a snow corer at 23 locations located on ice, including 16 dustfall snow survey stations, 3 control locations (on ice adjacent to the control stations), and the 4 control-assessment stations (Figure 2-1). On average, for the 16 sampling locations, the total sampling season was 155 days in 2019 (control and control-assessment stations not included). Snow cores were processed and shipped to Bureau Veritas Laboratories (BV Labs, previously Maxxam Analytics) for water chemistry analyses. Snow water chemistry results were compared to the EQCs outlined in DDMI's Water Licence. Snow chemistry analytes of interest included variables with EQCs (i.e., aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, and zinc).

2.3 Results and Discussion

2.3.1 Dustfall Gauges

The total dustfall collected from each dustfall gauge is summarized in Table 2-1 and Figure 2-2. As expected, measured dustfall levels generally decreased with distance from the Mine site. Annual dustfall estimated from each of the 14 dustfall gauges ranged from 65 to 982 mg/dm^2/y. The greatest estimated dustfall rate was measured at Dust 3 (982 mg/dm^2/y), 22 m from the Mine perimeter. The second highest estimated dustfall rate was measured at Dust 10 (683 mg/dm^2/y). The lowest dustfall rate was recorded at Dust 9 (65 mg/dm^2/y). Control stations Dust C1 (115 mg/dm^2/y; 4,646 m to the south) and Dust C2 (82 mg/dm^2/y; 3,031 m to the west) recorded higher dustfall rates than Dust 9. This is explained by the distance of Dust 9 from the Project footprint (3,796 m to the east), which places it within the control station zone

The dustfall rates estimated from dustfall gauges in 2019 were comparable to the 2018 rates, which were the highest recorded since 2008. The higher recorded dustfall values in both 2018 and 2019 suggest that dustfall rates in these two years were likely influenced by the surface activity at the Mine, particularly at the A21 open pit. The 2019 annualized dustfall rates estimated from gauges at all stations were below the upper limit of the Alberta Ambient Air Quality Objectives and Guideline for dustfall (1,924 mg/dm^2/y), which is applied to commercial and industrial areas (AEP 2019).

2.3.1 Snow Core Surveys

The total dustfall collected from each snow survey station is summarized in Table 2-1 and Figure 2-2. Annual dustfall rates estimated from 2019 snow survey data ranged from 9 to 1,545 mg/dm^2/y. In general, dustfall rates decreased with increasing distance from the Mine site, with the greatest dust deposition rate recorded at SS1-1 (1,545 mg/dm^2/y) followed by SS5-2 (591 mg/dm^2/y) and SS5-1 (530 mg/dm^2/y). All three stations were located within 55 m of the Project footprint, with SS1-1 located north of the airstrip and SS5-2 and SS5-1 located adjacent to the A21 open pit (Figure 2-2).

Annualized dustfall rates estimated from snow survey stations in 2019 were generally lower than the 2018 dustfall estimates. Annualized dustfall rates measured at all stations during the 2019 snow survey were below the Alberta Ambient Air Quality Objectives and Guidelines for commercial and industrial areas.

Comparisons of dustfall rates between the control and control-assessment sites in 2019 found greater rates of dustfall at the existing control sites, suggesting that dustfall deposition rates at the control sites were potentially affected by the Project and may not reflect background values.

2.3.2 Snow Water Chemistry

In general, analyte concentrations in snow meltwater decreased with distance from the Mine site. Concentrations in 2019 were lower than measured during recent years for all parameters except ammonia, nitrite, and phosphorus. The highest concentrations of all variables were less than their corresponding EQC.

Table 2-1 2019 Dustfall Deposition Results

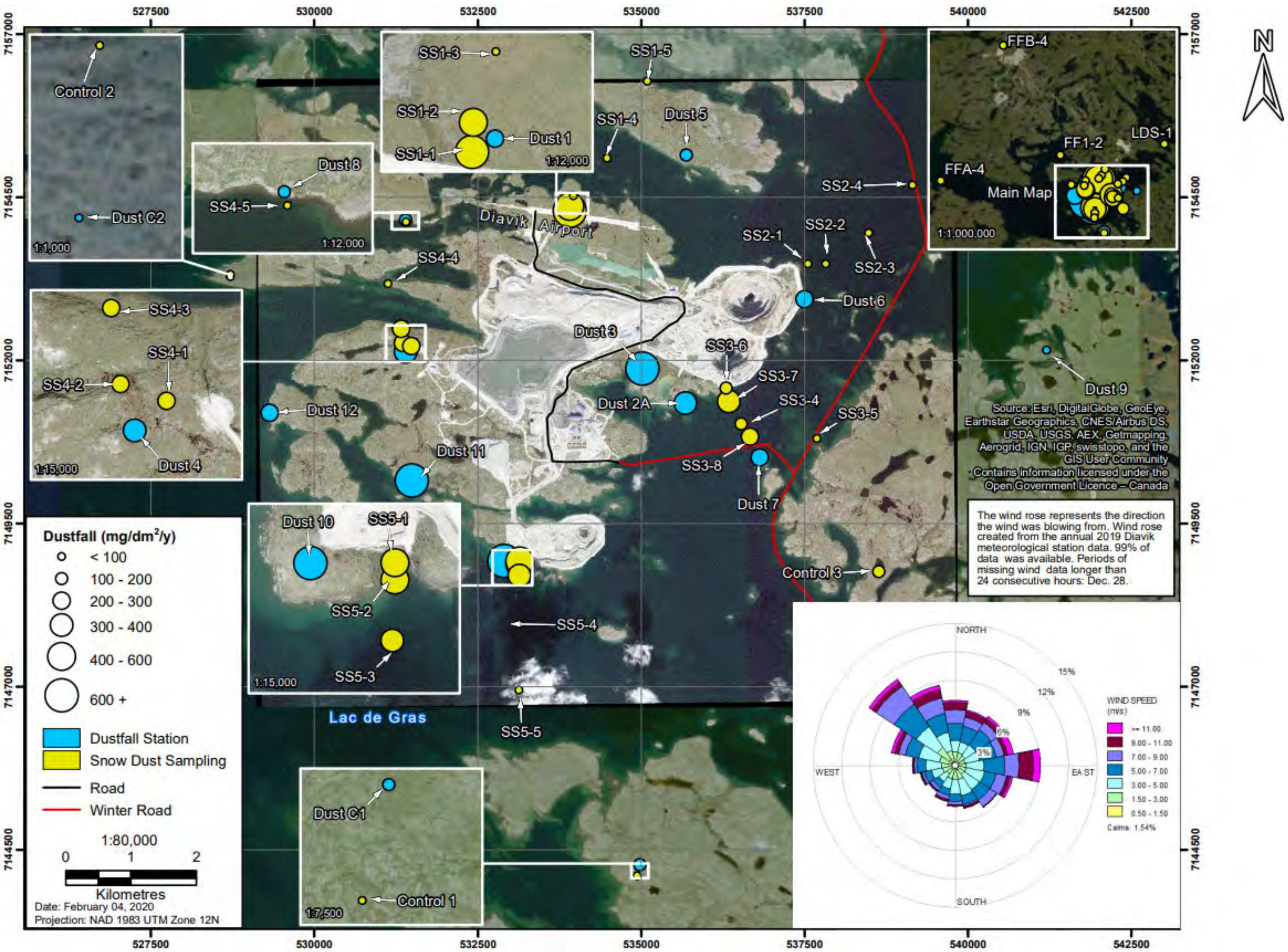
Zone	Station	Approximate Distance from 2019 Mine Footprint (m)	Dustfall (mg/dm²/y)
0 to 100 m	Dust 1	70	260
	Dust 3	22	982
	Dust 6	13	266
	Dust 10	46	683
	SS1-1	30	1,545
	SS3-6	35	199
	SS4-1	61	228
	SS5-1	26	530
	SS5-2	55	591
	Mean (SD)		587 (444)
	95% Confidence Interval (Mean ±)		341
	Lower to Upper Limit of 95% Confidence Interval		(246 – 928)
	Median		530
101 to 250 m	Dust 4	173	392
	SS1-2	115	515
	SS2-1	145	25
	SS3-7	239	312
	SS4-2	196	250
	Mean (SD)		299 (182)
	95% Confidence Interval (Mean ±)		227
	Lower to Upper Limit of 95% Confidence Interval		(72 – 525)
	Median		312
251 to 1,000 m	Dust 2A	425	355
	Dust 11	747	667
	SS1-3	260	45
	SS1-4	899	69
	SS2-2	427	32
	SS3-4	585	179
	SS3-8	826	214
	SS4-3	335	225
	SS5-3	259	346
	SS5-4	941	72
	Mean (SD)		237 (201)
	95% Confidence Interval (Mean ±)		154
	Lower to Upper Limit of 95% Confidence Interval		(83 – 391)
	Median		214

Table 2-1 2019 Dustfall Deposition Results (continued)

Zone	Station	Approximate Distance from 2019 Mine Footprint (m)	Dustfall ($mg/dm^2/y$)
1,001 to 2,500+ m	Dust 5	1,183	111
	Dust 7	1,147	298
	Dust 8	1,213	173
	Dust 12	2,326	212
	SS1-5	2,175	61
	SS2-3	1,194	29
	SS2-4	2,164	29
	SS3-5	1,325	36
	SS4-4	1,022	87
	SS4-5	1,214	99
	SS5-5	1,894	29
	Dust 9	3,796	65
	Mean (SD)		102 (85)
	95% Confidence Interval (Mean ±)		54
	Lower to Upper Limit of 95% Confidence Interval		(48 – 156)
	Median		76
Control	Dust C1	4,646	115
	Dust C2	3,031	82
	Control 1	4,802	38
	Control 2	3,042	94
	Control 3	3,550	101
	Mean (SD)		86 (29)
	95% Confidence Interval (Mean ±)		36
	Lower to Upper Limit of 95% Confidence Interval		(50 – 123)
	Median		94
Control-assessment	FFA-4	27,909	9
	FFB-4	30,711	37
	FF1-2	7,614	18
	LDS-1	11,897	15
	Mean (SD)		20 (12)
	95% Confidence Interval (Mean ±)		20
	Lower to Upper Limit of 95% Confidence Interval		(0.33 – 39)
	Median		17
Reference Levels[(a)]			646 and 1,924

a) Alberta Ambient Air Quality Objectives and Guidelines for dustfall for residential and commercial or industrial areas, respectively.
SD = standard deviation; ± = plus or minus; $mg/dm^2/y$ = milligrams per square decimetre per year.

Figure 2-2 Dustfall Results, 2019



Golder Associates

3 EFFLUENT AND WATER CHEMISTRY

3.1 Introduction and Objectives

Substances released from the Mine must enter the water of Lac de Gras before aquatic organisms can be exposed to the substances, and potentially be affected. Water quality represents a valuable early-warning indicator of potential effects on aquatic life in Lac de Gras. The objective of the water quality monitoring component of the AEMP is to assess the effects of Mine effluent and other Mine-related stressors on water quality in Lac de Gras.

The following is a summary of the 2019 effluent and water chemistry program. The *Effluent and Water Chemistry Report* (Appendix II) provides a more complete analysis and presents detailed results.

3.2 Methods

In total, water quality samples were collected at 39 stations in 2019 (Figure 1-2). Sampling occurred at five stations in the NF area (i.e., NF1 to NF5), multiple stations located along transects in the MF areas (i.e., MF1, MF2-FF2, and MF3) and three FF areas (i.e., FF1, FFA, and FFB). Three stations were located in the MF1 area (i.e., MF1-1, MF1-3, MF1-5), four stations in the MF2-FF2 area (i.e., MF2-1, MF2-3, FF2-2, FF2-5), and seven stations in the larger MF3 area (i.e., MF3-1 to MF3-7). Five stations were sampled in each of the three FF areas. Additional stations were sampled at the Lac de Gras outflow to the Coppermine River (LDG-48), in Lac du Sauvage (LDS-1, LDS-2, LDS-3), and the Lac du Sauvage outflow to Lac de Gras (LDS-4).

The AEMP water quality sampling was carried out over two monitoring seasons: ice-cover and open-water. During the ice-cover season, samples were collected in late winter, from 22 April to 10 May 2019. Open-water sampling was completed from 15 August to 5 September 2019. The same locations were sampled in each season, with the exception of LDS-4, which was sampled in the open-water season only.

Stations in the NF and MF areas were approximately 20 m deep and sampled at three depths (i.e., top, middle, and bottom) during each season, as these stations are likely to have differences in water quality at the different depths due to the Mine discharge (i.e., reflecting the vertical position of the effluent plume). Near-surface water samples (i.e., top) were collected at a depth of 2 m below the water surface or top of the ice, and bottom samples were collected at 2 m above the lake bottom. Middle samples were collected from the mid-point of the total water column depth. Stations in the FF areas and stations LDG-48, LDS-1, LDS-2, and LDS-3 were sampled at mid-depth only.

Data from the Surveillance Network Program (SNP) were incorporated into the 2019 AEMP report. Effluent samples were collected approximately once every six days from the NIWTP from both diffusers (i.e., stations SNP 1645-18 and SNP 1645-18B), and monthly at the mixing zone boundary (i.e., stations SNP 1645-19A SNP 1645-19B2, and SNP 1645-19C). The SNP sampling period summarized in this report extended from 1 November 2018 to 31 October 2019.

Water samples were sent to BV Labs in Burnaby, British Columbia, or Calgary, Alberta, Canada for chemical analysis. Field measurements of water quality were also taken at AEMP stations by lowering a water quality meter (YSI) slowly down to the bottom of the lake while recording the measurements of temperature, dissolved oxygen (DO) concentration, conductivity, turbidity, and pH.

Initial data analyses were conducted to identify substances of interest (SOIs), which are a subset of variables with the potential to show Mine-related effects. The intent of defining SOIs was to identify a meaningful set of variables that would undergo further analyses, while limiting analyses on variables that were less likely to be affected. The selection of SOIs considered concentrations in the final effluent (i.e., at stations SNP 1645-18 and SNP 1645-18B), and in the fully-mixed exposure area of Lac de Gras, according to four criteria based on comparisons to EQC, comparisons of mixing zone data to AEMP Effects Benchmarks, Action Level assessment results, and the potential for dust deposition effects.

The following analyses were completed on SOIs:

- an examination of loads in Mine effluent and effluent chemistry (i.e., from SNP 1645-18 and 1645-18B)
- an examination of water chemistry at the edge of the mixing zone (i.e., from SNP 1645-19A, 1645-19B2, and 1645-19C)
- an assessment of magnitude and extent of effects, as defined by the Action Levels in the Response Framework for water quality
- an evaluation of spatial trends in SOI concentrations with distance from the diffusers, including an evaluation of spatial trends in SOI concentrations along the MF transects
- statistical comparisons between the NF and FF areas
- an evaluation of the potential cumulative effects in Lac de Gras from the Ekati and Diavik mines.
- an examination of potential effects from dust deposition, for SOIs that exceeded Action Level 1 in the zone of influence (ZOI) from dust deposition in Lac de Gras

Water quality variables were assessed for a Mine-related effect according to the Response Framework for water chemistry (Table 3-1). Magnitude of effects on water chemistry variables was evaluated by comparing variable concentrations between NF, MF, and FF sampling areas, reference conditions, and 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 used in the Action Level screening for water quality are described in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).

The water quality benchmark values used in the Action Level assessment, otherwise known as Effects Benchmarks, are intended to protect human health or aquatic life. They are based on the Canadian Water Quality Guidelines (CWQGs) for the protection of aquatic life (CCME 1999), 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 (DDMI 2007), or values from the scientific literature. Effects were assessed separately for the ice-cover and open-water seasons.

Effluent was tested for toxicity to evaluate whether Mine effluent was causing toxic responses in the biota in Lac de Gras. The results of toxicity testing were carried out on effluent samples from stations SNP 1645-18 and SNP 1645-18B. Effluent samples were submitted to BV Labs and Nautilus Environmental in Burnaby, BC, Canada, for toxicity testing.

An analysis of dust effects at stations potentially affected by dust emissions was also conducted. The ZOI from dust deposition in Lac de Gras was estimated to be approximately 1.5 km from the Mine footprint boundary. The AEMP sampling stations that fall within the expected ZOI from dust deposition include the five stations in the NF area and stations MF1-1, MF2-1, MF3-1, and MF3-2.

Table 3-1 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 2 times the median of reference dataset[b] (open-water or ice-cover) and strong evidence of link to Mine	NF	Early warning.
2	5th percentile of NF values greater than 2 times the median of reference areas AND normal range[b]	NF	Establish Effects Benchmark if one does not exist.
3	75th percentile of MZ values greater than normal range plus 25% of Effects Benchmark[c]	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 EQC if one does not exist
4	75th percentile of MZ values greater than normal range plus 50% of Effects Threshold[c]	MZ	Investigate mitigation options.
5	95th percentile of MZ values greater than Effects Threshold	MZ	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
6	95th percentile of NF values greater than Effects Threshold + 20%	NF	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
7	95th percentile of MF values greater than Effects Threshold + 20%	MF	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
8	95th percentile of FFB values greater than Effects Threshold + 20%	FFB	The WLWB to re-assess EQC. Implement mitigation required to meet new EQC if applicable.
9	95th percentile of FFA values greater than Effects Threshold + 20%	FFA	Significance Threshold.[d]

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

b) Normal ranges and reference datasets are obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b); the normal range for open-water was based on the 15 August to 15 September period. In cases where the reference area median value reported in the reference conditions report was equal to the detection limit, half the detection limit was used to calculate the 2 x reference area median criterion, to be consistent with data handling methods used for the AEMP.

c) Indicates 25% or 50% of the difference between the Effects 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.

NF = near-field; MZ = mixing zone; MF = mid-field; FF = far-field; WLWB = Wek'èezhìı Land and Water Board; EQC = Effluent Quality Criteria.

3.3 Results and Discussion

3.3.1 Substances of Interest

Water quality variables measured in Lac de Gras as part of the 2019 AEMP were assessed for a Mine-related effect according to Action Levels. Sixteen variables met the criteria for inclusion as SOIs in 2019 (Table 3-2).

Table 3-2 Water Quality Substances of Interest, 2019

Substance of Interest	Substances of Interest Criteria			
	1 Effluent Screening	2 Mixing Zone Screening	3 Action Level 1	4 Potential Dust Effects
Conventional Parameters				
Total dissolved solids, calculated	-	-	X	X
Turbidity – lab	-	-	X	X
Major Ions				
Calcium (dissolved)	-	-	X	X
Chloride	-	-	X	X
Magnesium (dissolved)	-	-	X	-
Sodium (dissolved)	-	-	X	X
Sulphate	-	-	X	X
Nutrients				
Ammonia	-	-	X	X
Nitrate	-	-	X	X
Total Metals				
Aluminum	-	-	X	-
Barium	-	-	X	-
Manganese	-	-	X	-
Molybdenum	-	-	X	X
Silicon	-	-	X	-
Strontium	-	-	X	X
Uranium	-	-	X	X

X = criterion met; - = criterion not met.

3.3.2 Effluent Quality

The monthly loads of TDS and associated ions (i.e., calcium, chloride, magnesium, sodium and sulphate) from the NIWTP remained within a similar range from November to April, reflecting the monthly volume of effluent discharged (Figure 3-1). The loads of these SOIs increased during the late ice-cover and early open-water seasons, peaking in August, before decreasing through the remainder of the open-water season as flow rates from the NIWTP decreased.

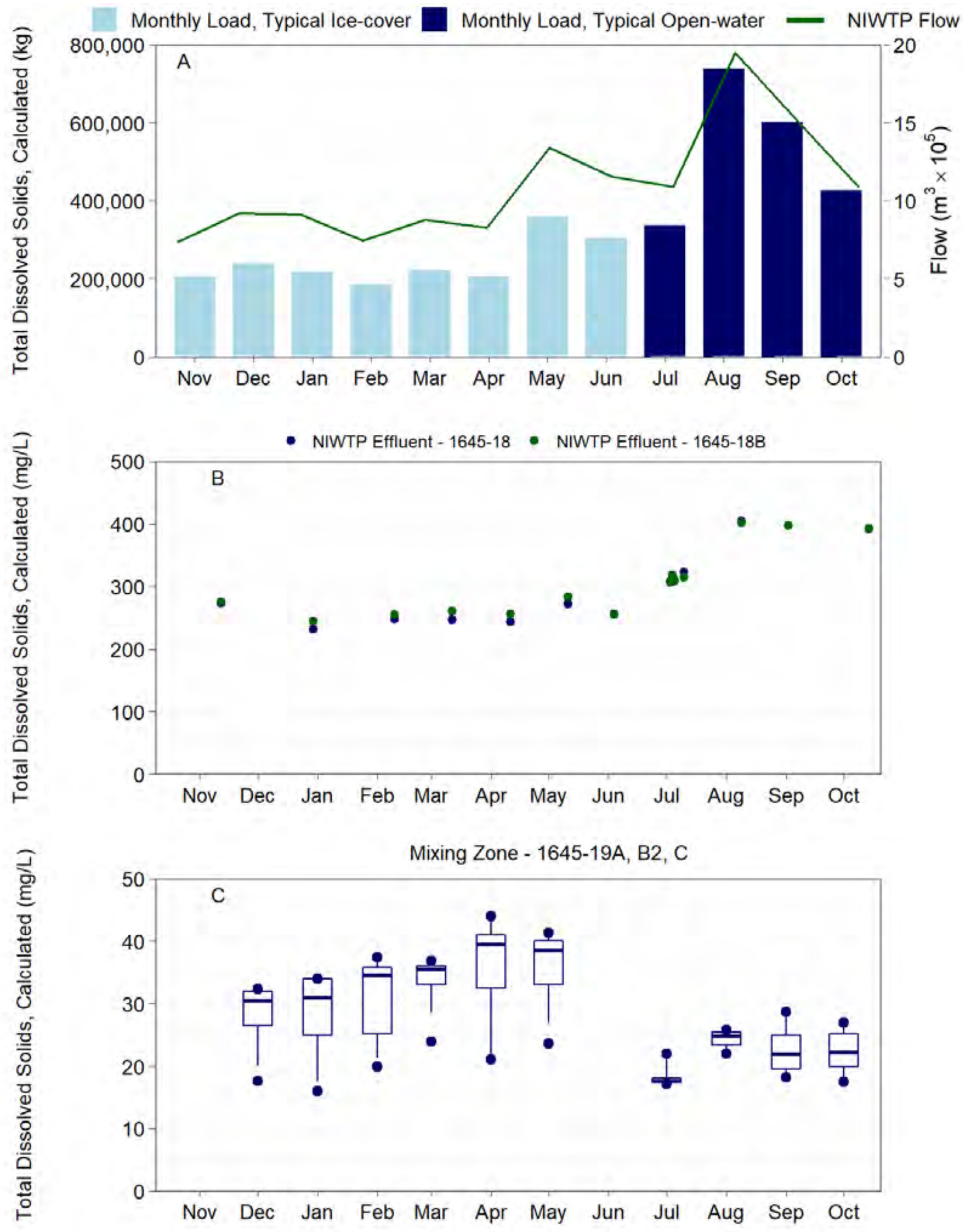
The monthly loads of ammonia varied within a similar range from November to April, and increased in May. Monthly loads of ammonia decreased through the late ice-cover and early open-water seasons, and then peaked in August before declining again in the late open-water season. The seasonal trend in the loading rate of ammonia reflected trends both in the effluent flow rate and in effluent concentration. The load and concentration of nitrate generally declined through the early ice-cover season from November to February, and then increased through late ice-cover and early open-water seasons, peaking in August, before decreasing again in October.

In general, the monthly loading rates of total metal SOIs either reflected trends in the effluent flow rate or chemistry, or were influenced by a combination of the two. The seasonal pattern in the concentrations of variables in the effluent over the reporting period were variable-specific. Concentrations of total metal SOIs in the effluent were greater than the concentrations measured at the mixing zone boundary, indicating that the Mine effluent is a source of these variables to Lac de Gras. The concentrations of most of these SOIs at the mixing zone boundary were generally greater and more variable during the ice-cover season than during the open-water season.

The water chemistry monitoring data collected from the NIWTP final discharge (i.e., SNP 1645-18 and SNP 1645-18B) were compared to the EQC defined in the Water Licence. Concentrations of variables in effluent with EQC were below applicable EQC.

Water chemistry at the mixing zone boundary was compared to the relevant AEMP water quality Effects Benchmarks for the protection of aquatic life and drinking water. No pH values at the mixing zone boundary in 2019 exceeded the upper bounds of the Effects Benchmarks; however, pH values measured at the mixing zone boundary in 2019, particularly during July to October 2019, were measured below the Effects Benchmark value. Because the pH of the Mine effluent was slightly alkaline (i.e., pH more than 7) and the pH throughout Lac de Gras was often below the Effects Benchmark in both seasons at various depths and over time, pH was not considered a SOI.

Figure 3-1 Total Dissolved Solids, Calculated: A) Monthly Loading Rate from the North Inlet Water Treatment Plant and Concentration in B) Effluent (SNP 1645-18 and SNP 1645-18B) and at C) the Mixing Zone Boundary (SNP 1645-19), 1 November 2018 to 31 October 2019



Notes: Effluent values represent concentrations in individual samples. Mixing zone boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations at three stations (i.e., 1645-19A, 1645-19B2, 1645-19C) and five depths (i.e., 2 m, 5 m, 10 m, 15 m, and 20 m); circles represent the 5th and 95th percentile concentrations. The mixing zone samples could not be collected in November 2018 as well as June 2019 due to hazardous ice conditions.
NIWTP = North Inlet Water Treatment Plant; SNP = Surveillance Network Program.

3.3.2.1 Effluent Toxicity

Toxicity testing results in 2019 indicated that effluent samples were generally not toxic to aquatic organisms. These results are consistent with results in previous years, which have also indicated that the Mine effluent is non-toxic.

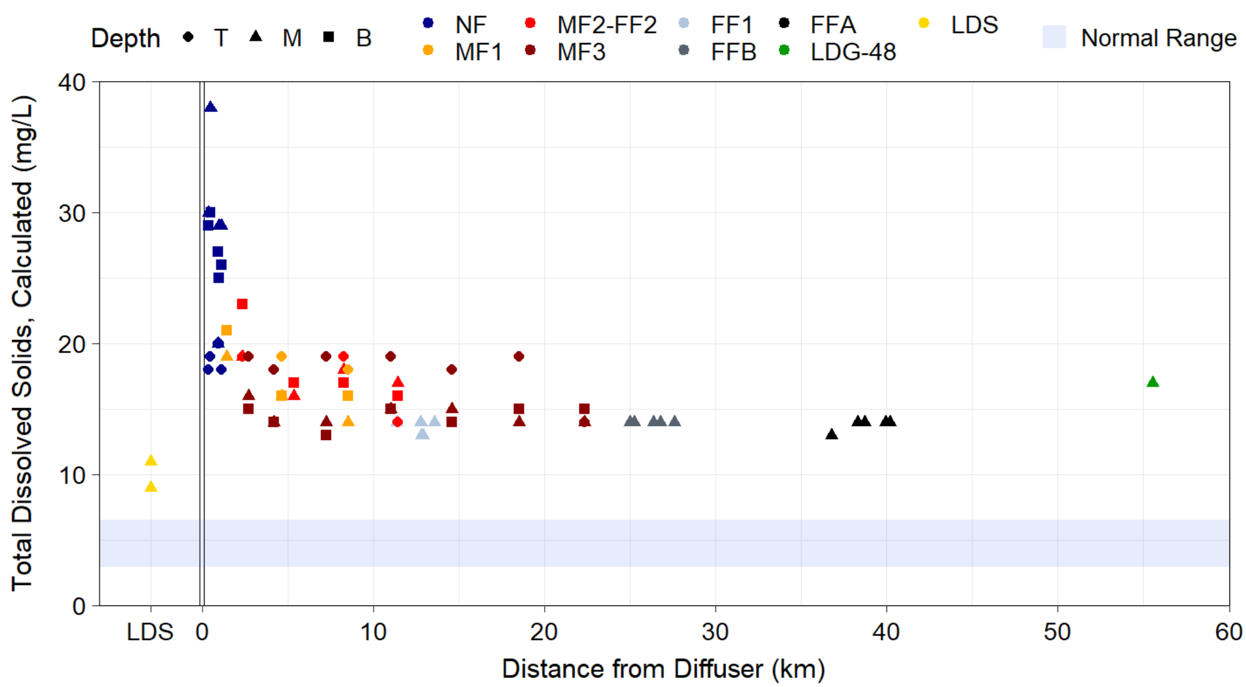
3.3.2.2 Effluent Dispersion

Concentrations of TDS in the effluent ranged from 232 to 404 mg/L throughout the 2019 monitoring period. The peak concentration of TDS in the effluent occurred in August, which coincided with the peak in effluent flow. At the mixing zone boundary, TDS concentrations ranged from 16 to 44 mg/L. Concentrations measured at the mixing zone indicate that the plume was situated between 10 and 20 m depth.

The distribution of TDS concentrations during the 2019 ice-cover season indicated that the effluent was detectable in all sampling areas in Lac de Gras (Figure 3-2). Concentrations of all TDS samples collected during the ice-cover sampling program in 2019 were greater than the normal range for Lac de Gras. However, TDS concentration and the concentration of Mine effluent in the FF areas has remained low.

During the ice-cover season, the TDS concentration measured at LDG-48 was slightly greater than those encountered at the far end of the MF3 transect (i.e., the FFA area). This response may indicate a cumulative effect on water quality in Lac de Gras, resulting from the combined influence of the Diavik and Ekati mine effluent discharges. A summary of the evaluation of potential cumulative effects in Lac de Gras is provided in Section 3.3.7.

Figure 3-2 Spatial Variation in Total Dissolved Solids, Calculated Concentration with Distance from the Mine-effluent Diffusers, Ice-cover Season, 2019



Notes: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data.

T = top depth; M = middle depth; B = bottom depth; NF = near-field; MF = mid-field; FF = far-field; LDG = Lac de Gras; LDS = Lac du Sauvage.

3.3.3 Depth Profiles

Depth profiles were prepared for conductivity, DO, water temperature pH and turbidity at AEMP stations. The greater specific gravity of the effluent combined with the absence of wind and wave-driven mixing during ice-cover conditions, resulted in elevated conductivity in the bottom two thirds of the water column in the NF area. Complete vertical mixing of the effluent was observed at most stations along the MF transects. During the open-water season, specific conductivity was typically uniform throughout the water column.

During the ice-cover season, water temperature in Lac de Gras increased gradually with depth at most stations. Turbidity was uniform throughout the water column, while DO and pH decreased with depth, with the exception of the NF stations where pH was uniform throughout the water column. During the open-water season, temperature, turbidity, DO and pH were typically uniform throughout the water column.

3.3.4 Assessment of Effects and Action Levels

Sixteen variables triggered Action Level 1, which is considered an early-warning indication of effects in the NF area (Table 3-3). Of the 16 SOIs that triggered Action Level 1, 15 had elevated concentrations in the NIWTP effluent compared to Lac de Gras, indicating a link to the Mine. At times, turbidity had similar concentrations in the effluent to Lac de Gras. No management action is required under the Response Framework when a water quality variable triggers Action Level 1.

Of the 16 variables that triggered Action Level 1, 9 also triggered Action Level 2 (Table 3-3). In most cases, Action Level 2 was triggered during both the ice-cover and open-water seasons. Exceptions were sulphate, ammonia and nitrate, which triggered Action Level 2 only during the open-water season. Under the Response Framework, when a water quality variable triggers Action Level 2, the required management action is to establish an AEMP Effects Benchmark for that variable if one does not already exist. Each of the nine variables that triggered Action Level 2 in 2019 have existing Effects Benchmarks, and no action was required. None of the SOIs evaluated triggered Action Level 3 in 2019.

Table 3-3 Action Level Summary for Water Quality Substances of Interest, 2019

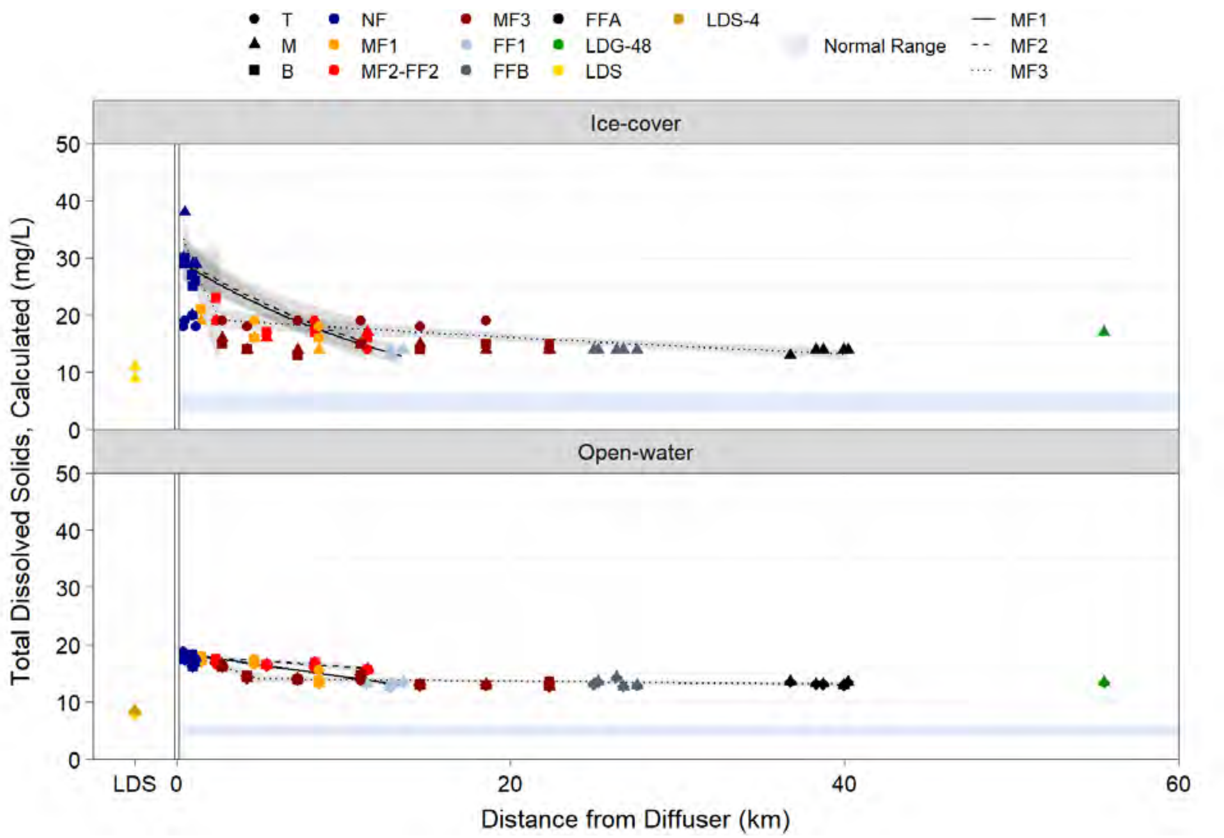
2019 SOIs	Action Level Classification
Conventional Parameters	
Total dissolved solids, calculated	2
Turbidity – lab	1
Major Ions	
Calcium (dissolved)	1
Chloride	2
Magnesium (dissolved)	1
Sodium (dissolved)	2
Sulphate	2
Nutrients	
Ammonia	2
Nitrate	2
Total Metals	
Aluminum	1
Barium	1
Manganese	1
Molybdenum	2
Silicon	1
Strontium	2
Uranium	2

SOI = substance of interest; 1 = Action Level 1 triggered; 2 = Action Level 2 triggered.

3.3.5 Gradient Analysis

Spatial trends of decreasing concentrations with distance from the Mine effluent discharge were evident for all 16 SOIs that triggered Action Level 1 or greater in 2019, based on a graphical and statistical evaluation of the data. In addition, most of the SOIs had greater concentrations in the NF area compared to the FF areas. The results of these analyses provided confirmation that the changes for these variables observed in the NF area (i.e., at Action Levels 1 and 2) were related to the Mine effluent discharge. An example showing the plot developed for TDS is provided in Figure 3-3.

Figure 3-3 Concentrations of Total Dissolved Solids (Calculated) According to Distance from the Effluent Discharge, 2019



Note: Values represent concentrations in individual samples collected at top, middle and bottom depths. Open symbols represent non-detect data. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

T= top depth; M = middle depth; B = bottom depth; NF = near-field; MF = mid-field; FF = far-field; LDG = Lac de Gras; LDS = Lac du Sauvage.

3.3.6 Effects from Dust Deposition and A21 Dike

In 2019, 11 variables triggered Action Level 1 at one or more of the four MF area stations located within the estimated ZOI from dust deposition. All of these SOIs also triggered Action Level 1 in the NF area, indicating that the exceedances at the MF stations were at least partly caused by dispersion of Mine effluent into the lake. Analysis of the 2019 AEMP water quality data did not provide evidence to suggest an effect of dust deposition from the Mine site on water quality in Lac de Gras. These findings were consistent with the findings of the *Special Effects Study – Dust Deposition* (Appendix XI)

3.3.7 Cumulative Effects in Lac de Gras

In 2019, potential cumulative effects of the Diavik and Ekati mines were identified in 13 SOIs (i.e., TDS, calcium, chloride, magnesium, sodium, sulphate, aluminum, barium, manganese, molybdenum, silicon, strontium and uranium). These SOIs either had a pattern of increasing concentration extending from the FFB area to the FFA area, with a further increase at the outlet of Lac de Gras at Station LDG-48; or they had greater concentrations at the outflow of Lac de Gras compared to one of either FFA or FFB. These responses may indicate a cumulative effect on water quality at the northwest end of Lac de Gras, resulting from the combined influence of the Diavik and Ekati mine effluent discharges.

4 EUTROPHICATION INDICATORS

4.1 Introduction and Objectives

One of the more important predictions from the environmental assessment (EA) was that operation of the Mine would release nutrients (i.e., nitrogen and phosphorus) into Lac de Gras. Phosphorus naturally occurs in the groundwater that seeps into the Mine workings. Nitrogen enters minewater as a residue from ammonium nitrate used as an explosive during mining. While phosphorus is reduced to the lowest levels practical in the NIWTP and nitrogen is managed to the extent practical through blasting and water management practices, both phosphorus and nitrogen are found at substantially greater concentrations in the NIWTP effluent compared to baseline concentrations in Lac de Gras.

Lac de Gras is a nutrient-poor (i.e., oligotrophic) lake. Aquatic organisms in the lake, including algae, invertebrates, and fish, live with limited nutrient availability, but have low abundances compared to more productive lakes. It is expected, and was predicted, that increasing the nutrient levels in Lac de Gras would affect aquatic organisms (Government of Canada 1999). The primary effect of nutrient enrichment on Lac de Gras was expected to be an increase in primary productivity (i.e., greater abundance of microscopic plants called algae or phytoplankton), sometimes referred to as eutrophication.

The objective of the eutrophication indicators assessment is to describe the AEMP results for nutrients, chlorophyll *a*, phytoplankton biomass, and zooplankton biomass, which are monitored as indicators of eutrophication. Chlorophyll *a* is what gives plants their green colour and can be used to measure the amount of algae in the water. Algae or phytoplankton are small aquatic plants, which are the first aquatic organisms to respond to a change in nutrient levels. Zooplankton biomass is a measure of the total mass of these tiny animals that live in the water and feed on algae and is measured as ash-free dry mass (AFDM).

The following is a summary of the 2019 eutrophication indicators program. The *Eutrophication Indicators Report* (Appendix XIII) provides a more complete analysis and presents detailed results.

4.2 Methods

The AEMP eutrophication indicators program was completed over two sampling seasons. The ice-cover sampling was conducted from 22 April to 10 May 2019, and the open-water sampling was conducted between 15 August and 15 September 2019. Nutrient samples were collected during both ice-cover and open-water conditions from the NF area, three MF areas (i.e., MF1, MF2-FF2, and MF3), and three FF areas (i.e., FFA, FFB, and FF1) in Lac de Gras, the outlet of Lac de Gras to the Coppermine River (LDG-48), the narrows between Lac de Gras and Lac du Sauvage (LDS-4), and three stations in Lac du Sauvage (LDS; Figure 1-2). Chlorophyll *a*, phytoplankton biomass, and zooplankton biomass samples were collected during the open-water season, when biological activity was greatest; however, plankton samples were not collected from LDG-48 and LDS-4 due to the shallow depth (i.e., less than 1 m) at these AEMP stations.

During the ice-cover season, nutrient samples were collected at three depths (i.e., top, middle, and bottom) at each NF, MF, and FF2 station, and at a single depth (i.e., middle) at each of the FF1, FFB, FFA and LDS stations, and at LDG-48.

During the open-water season, nutrient samples, chlorophyll *a* and phytoplankton biomass were collected using a depth-integrated sampler. This device collected lake water over a range of sample depths. The top 10 m of the water column was sampled for nutrients, chlorophyll *a* and phytoplankton biomass during the open-water season, because this is the depth where most of the algae are found. Zooplankton samples were collected using a specially designed fine mesh net (i.e., a plankton net) that was pulled up through the entire water column.

The 2019 nutrient and zooplankton biomass samples were analyzed by BV Labs in Burnaby, British Columbia, or Calgary, Alberta, Canada. Analysis of samples for total ammonia were completed by both BV Labs and ALS Laboratories (ALS), Edmonton, Alberta, Canada. Ice-cover ammonia results are from ALS, and open-water from BV Labs. Chlorophyll *a* samples were analyzed by the Biogeochemical Analytical Service Laboratory at the University of Alberta, Edmonton, Alberta. Phytoplankton biomass samples were analyzed by Advanced Eco-Solutions Inc. (Advanced Eco-Solutions), Newman Lake, Washington, United States of America.

Nutrient data from the SNP were incorporated into the *Eutrophication Indicators Report* (Appendix XIII). Treated effluent samples were collected approximately once every six days from the NIWTP from both diffusers (i.e., stations SNP 1645-18 and SNP 1645-18B), and monthly at the mixing zone boundary (i.e., stations SNP 1645-19A, SNP 1645-19B2, and SNP 1645-19C). Samples were not collected during ice-off (June) and ice-on (November) at the mixing zone stations due to unsafe ice conditions. The quality of the effluent was assessed in Section 3 of the *Effluent and Water Chemistry Report* (Appendix II); however, results for the key nutrient variables (e.g., total phosphorus) are presented herein.

The 2019 AEMP results were analyzed to identify and understand spatial patterns in relation to the Mine effluent discharge. Data were compared to the background values (i.e., normal range) to determine if they fell within the natural range of variability. To assess potential effects from dust emissions on nutrient enrichment in Lac de Gras, open-water phosphorus and chlorophyll *a* concentrations within the estimated ZOI from dust deposition were evaluated visually and compared to results at other nearby stations and the normal range. If phosphorus or chlorophyll *a* concentrations at the dust-affected stations (i.e., all NF stations and MF1-1, MF2-1, MF3-1 and MF3-2) were above the normal range, a potential dust effect was assumed. The magnitude of effects for chlorophyll *a* was evaluated according to Action Levels (Table 4-1). Finally, the potential for cumulative effects in Lac de Gras from the Ekati and Diavik Mines was evaluated.

Table 4-1 Action Levels for Chlorophyll *a*

Action Level	Magnitude of Effect	Extent of Effect	Action/Notes
1	95th percentile of MF values greater than normal range[(a)]	MF station	Early warning.
2	NF and MF values greater than normal range[(a)]	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[(c)]	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%	FFB	The WLWB to re-assess EQC for phosphorus. Implement mitigation required to meet new EQC if applicable.
9[(d)]	95th percentile of FFA values greater than Effects Threshold+20%	FFA	Significance Threshold[(d)].

a) The normal range for chlorophyll *a* was obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
b) Indicates 25% of the difference between the Effects Benchmark and the top of the normal range.
c) Indicates 50% of the difference between the Effects Threshold and the top of the normal range.
d) Although the Significance Threshold is not an Action Level, it is shown as the greatest Action Level to demonstrate escalation of effects towards the Significance Threshold.
NF = near-field; MF = mid-field; FF = far-field; WLWB = Wek'èezhìı Land and Water Board; EQC = Effluent Quality Criteria.

4.3 Results and Discussion

4.3.1 Nutrients in Effluent and the Mixing Zone

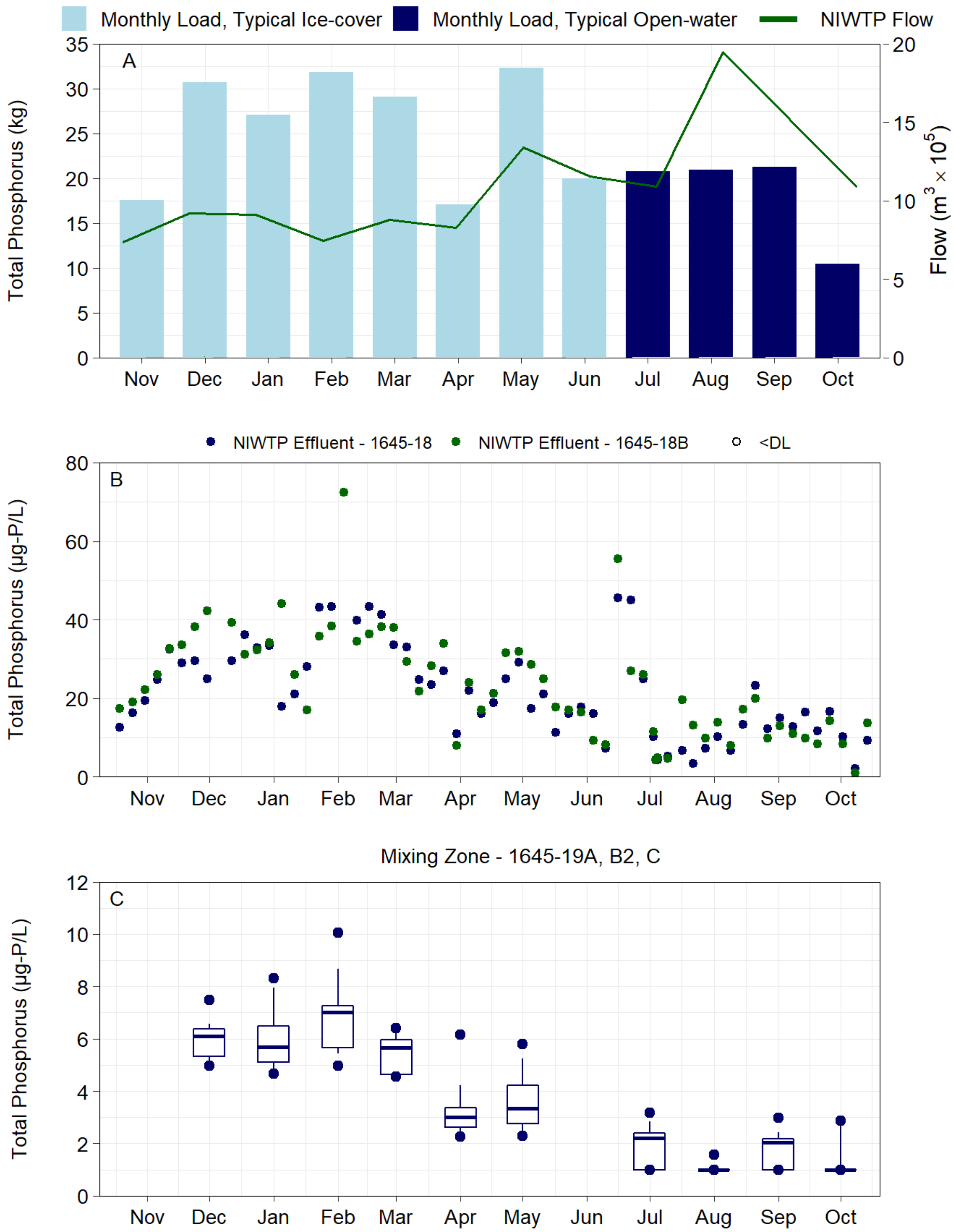
During 2019, phosphorus loads to Lac de Gras and concentrations in effluent tended to be variable throughout the year. Concentrations of total phosphorus (TP), total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) in effluent were generally greater during the ice-cover season, which resulted in greater monthly loads during that period and were reflected in concentrations at the mixing zone boundary (e.g., Figure 4-1 for TP). The annual TP load in 2019 was 279 kg, which was less than the 2018 annual load of 375 kg, and was less than both the monthly and average annual loading criteria of the 300 kg/mo and 1,000 kg/yr, respectively, defined in the Water Licence.

In contrast, loads and effluent concentrations of TN, nitrate, and nitrite concentrations were greater in the open-water season and followed a similar trend to effluent volume (Figure 4-2). Most of the TN was present as nitrate in the effluent.

Total ammonia monthly loads followed the same pattern as other nitrogen species but effluent concentrations did not (Figure 4-3), with greater concentrations during the ice-cover season, and smaller concentrations during the open-water season, with the exception of August.

The decreases in concentrations of TN, nitrate, nitrite, and total ammonia at the mixing zone boundary between May and July 2019 reflects quick assimilation (i.e., uptake and use) by algae and bacterial nitrification (Wetzel 2001).

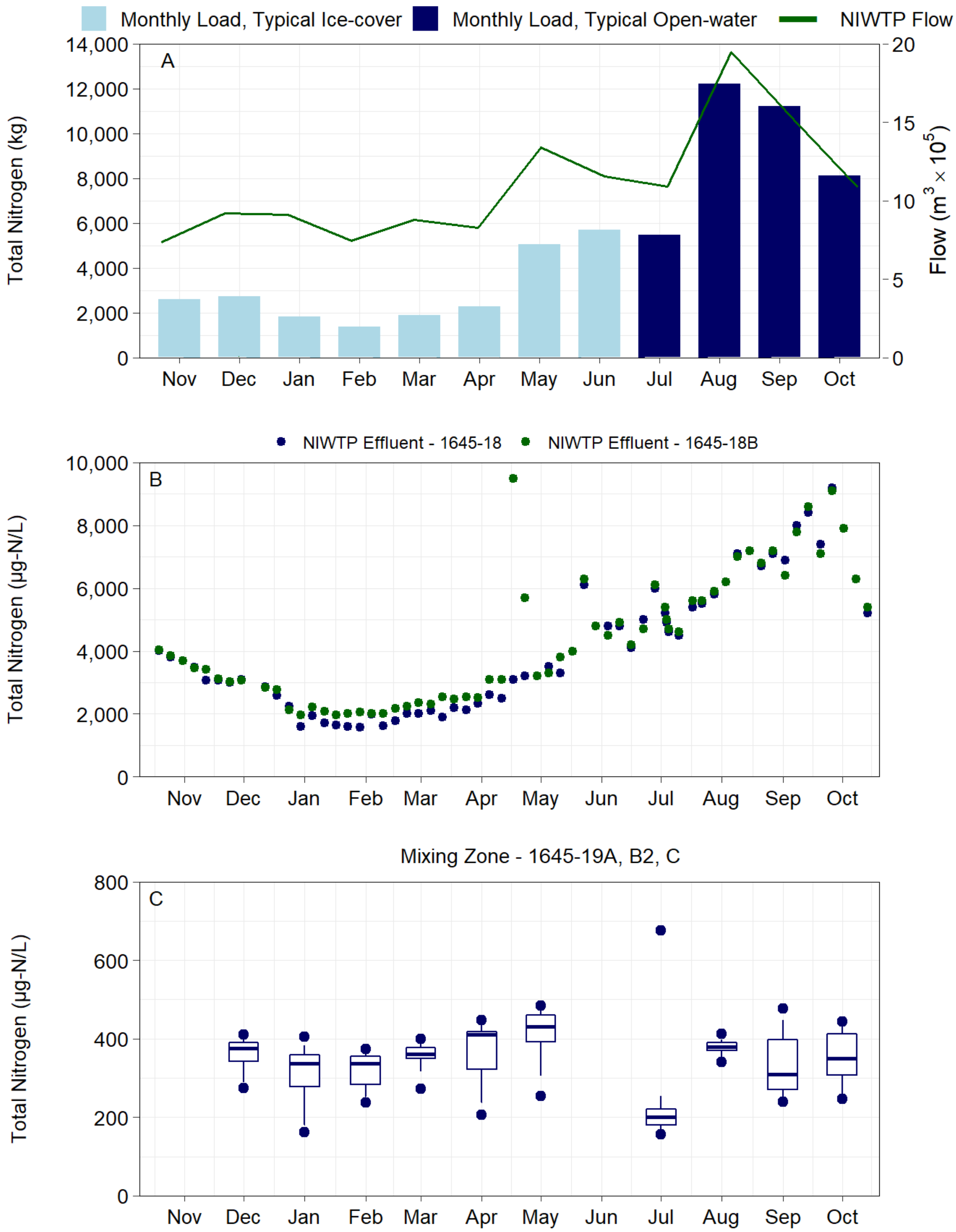
Figure 4-1 Total Phosphorus: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019



Notes: Concentrations in effluent are for individual samples. Mixing zone values represent the monthly 5th percentile, median, and 95th percentile concentrations at three stations (1645-19A, 1645-19B2, 1645-19C) and five depths (2 m, 5 m, 10 m, 15 m and 20 m). The mixing zone samples could not be collected in November 2018 and June 2019 due to hazardous ice conditions.

µg-P/L = micrograms phosphorus per litre; NIWTP = North Inlet Water Treatment Plant.

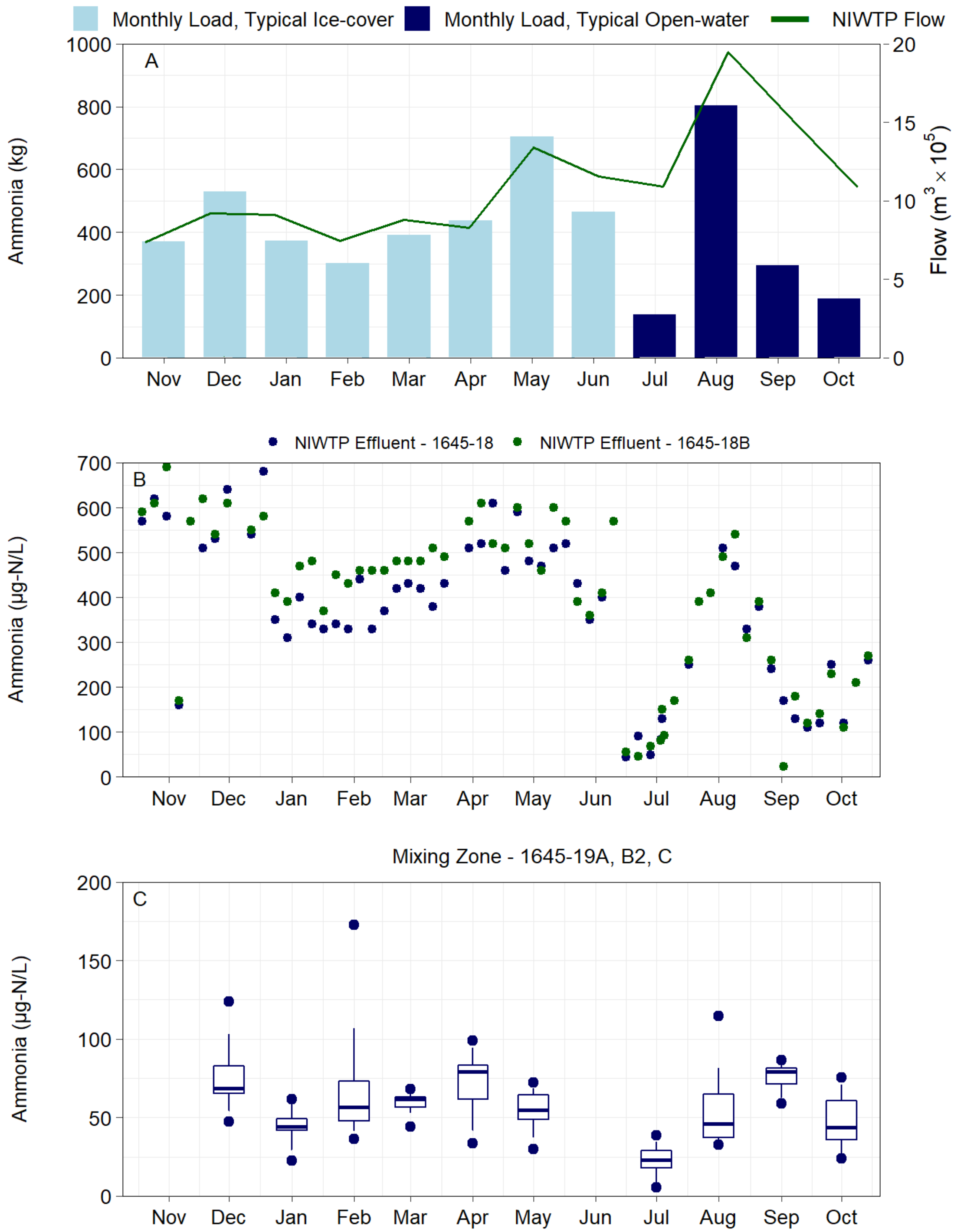
Figure 4-2 Total Nitrogen: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019



Notes: Concentrations in effluent are for individual samples. Mixing zone values represent the monthly 5th percentile, median, and 95th percentile concentrations at three stations (1645-19A, 1645-19B2, 1645-19C) and five depths (2 m, 5 m, 10 m, 15 m and 20 m). The mixing zone samples could not be collected in November 2018 and June 2019 due to hazardous ice conditions.

µg-N/L = micrograms nitrogen per litre; NIWTP = North Inlet Water Treatment Plant.

Figure 4-3 Total Ammonia: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019



Notes: Concentrations in effluent are for individual samples. Mixing zone values represent the monthly 5th percentile, median, and 95th percentile concentrations at three stations (1645-19A, 1645-19B2, 1645-19C) and five depths (2 m, 5 m, 10 m, 15 m and 20 m). The mixing zone samples could not be collected in November 2018 and June 2019 due to hazardous ice conditions.

µg-N/L = micrograms nitrogen per litre; NIWTP = North Inlet Water Treatment Plant.

4.3.2 Eutrophication Indicators in Lac de Gras

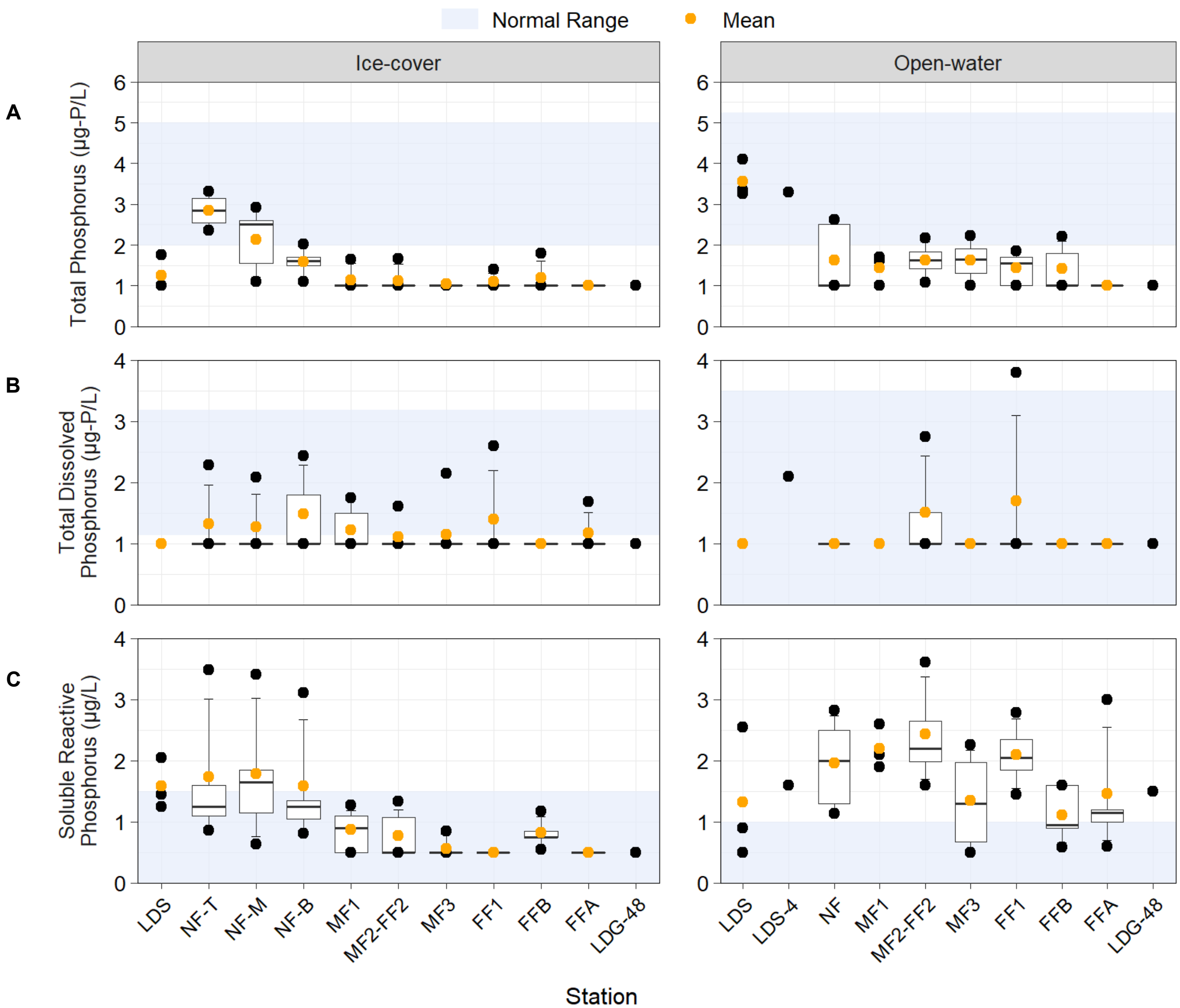
Secchi depth measurements showed good light penetration in all areas of Lac de Gras, indicating that a large proportion of the total volume of Lac de Gras was within the euphotic zone, and could support phytoplankton growth.

Phosphorus and nitrogen enter Lac de Gras from Mine effluent throughout the year; however, seasonal cycles are apparent in nutrient concentrations in effluent. Although phosphorus concentrations at the mixing zone boundary were less during the open-water season compared to the ice-cover season, no apparent seasonal differences in nutrient concentrations in Lac de Gras were observed for phosphorus species. Phosphorus concentrations were relatively small in 2019 compared to previous years, likely due to the smaller phosphorus load from effluent. Concentrations were greater in the NF area, but all concentrations in the lake were below the normal range (Figure 4-4). Nitrogen species, with the exception of nitrite, had concentrations that were greater during the ice-cover season compared to the open-water season. Concentrations were greater in the NF area, generally greater than normal range, and decreased with distance from the diffuser (Figure 4-5 and Figure 4-6). The 2019 loads of nitrogen parameters to Lac de Gras, and concentrations in AEMP sampling areas, were similar or greater in 2019 compared to 2018.

Seasonal differences in SRSi were observed, with greater concentrations during the ice-cover season compared to the open-water season. Concentrations were greater in the NF area, and decreased with distance from diffuser (Figure 4-7). The smaller concentrations of dissolved inorganic nutrients (i.e., total ammonia, nitrate+ nitrite, SRSi) in Lac de Gras during the open-water season may be the result of quick assimilation of nutrients by bacteria and algae.

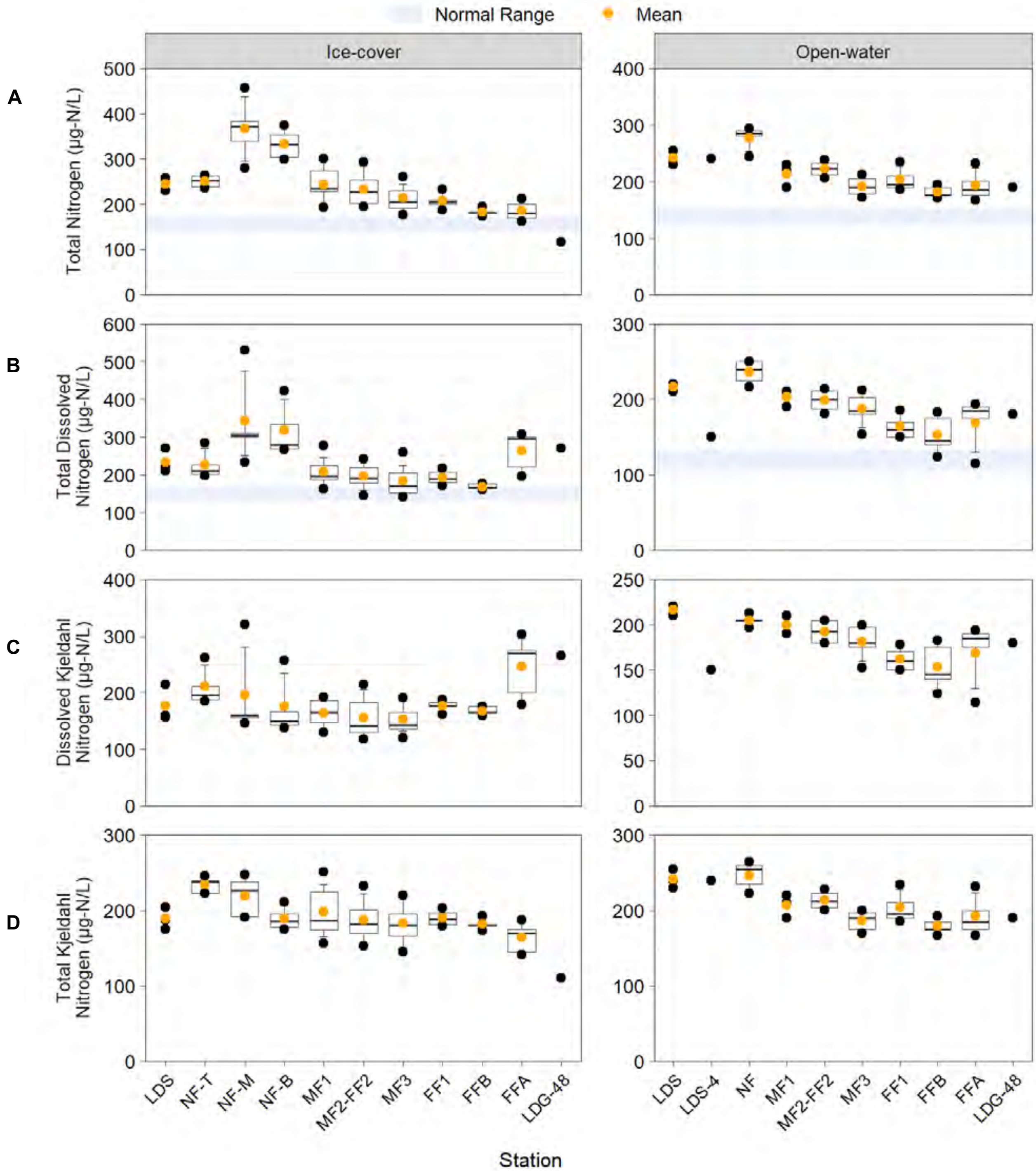
A low-level Mine-related nutrient enrichment effect on the primary producers in Lac de Gras was evident in 2019, as indicated by the gradient analysis results and spatial trends apparent along transects sampled in Lac de Gras. Although chlorophyll *a* concentrations were greater in the NF area and decreased with distance from the diffuser (Figure 4-8), concentrations were less than those observed in previous years, and generally within or below the normal range. This is consistent with the lower TP concentrations, which are likely due to lower TP loading from effluent. No effects on total phytoplankton biomass were observed in 2019 (Figure 4-9). As nitrogen loads and concentrations in Lac de Gras were similar or greater than those in previous years, these results underline the importance of phosphorus limitation in this lake, which is also indicated by nutrient ratios summarized by Golder (2019c). Zooplankton biomass was greater in 2019 than in recent years, and above the normal range at all of the NF stations and several MF stations, with a decreasing trend with distance from the diffuser (Figure 4-10). The 2019 zooplankton community displayed a response consistent with nutrient enrichment, in agreement with the chlorophyll *a* results.

Figure 4-4 Concentrations of Total Phosphorus (A), Total Dissolved Phosphorus (B), and Soluble Reactive Phosphorus (C) in Lac de Gras during the Ice-Cover and Open-Water Season, 2019



Notes: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles. Non-detect values are plotted at half detection limit.
µg/L = micrograms per litre; µg-P/L = micrograms phosphorus per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth; TDN = total dissolved nitrogen.

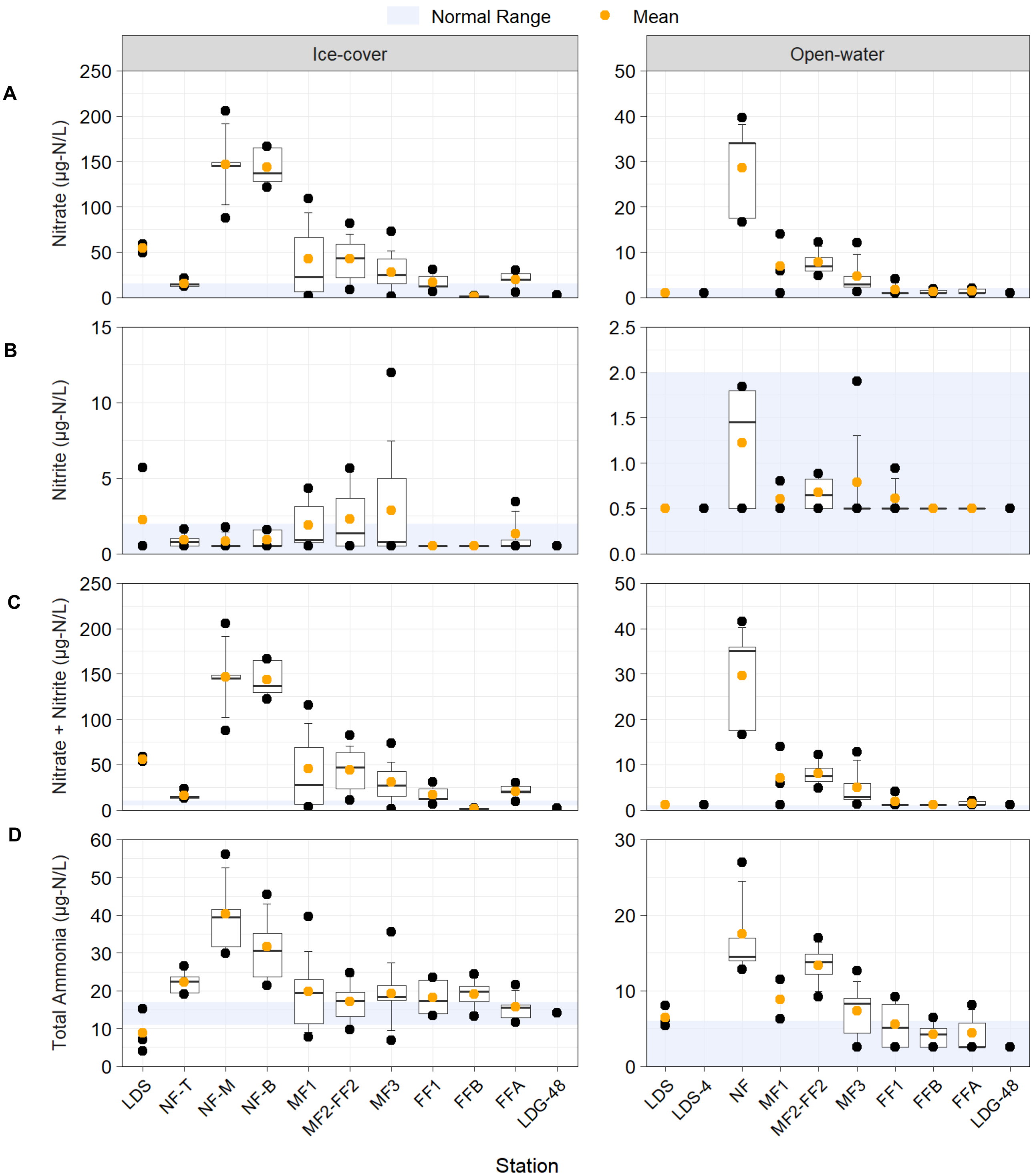
Figure 4-5 Concentrations of Total Nitrogen (A), Total Dissolved Nitrogen (B), Dissolved Kjeldahl Nitrogen (C), and Total Kjeldahl Nitrogen (D) in Lac de Gras during the Ice-Cover and Open-Water Season, 2019



Notes: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles. As noted in Appendix XIII, TDN concentrations during the ice-cover season in the FFA area and at LDG-48 were suspected to be biased high. The data were retained in the boxplots for information purposes.

µg-N/L = micrograms nitrogen per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth.

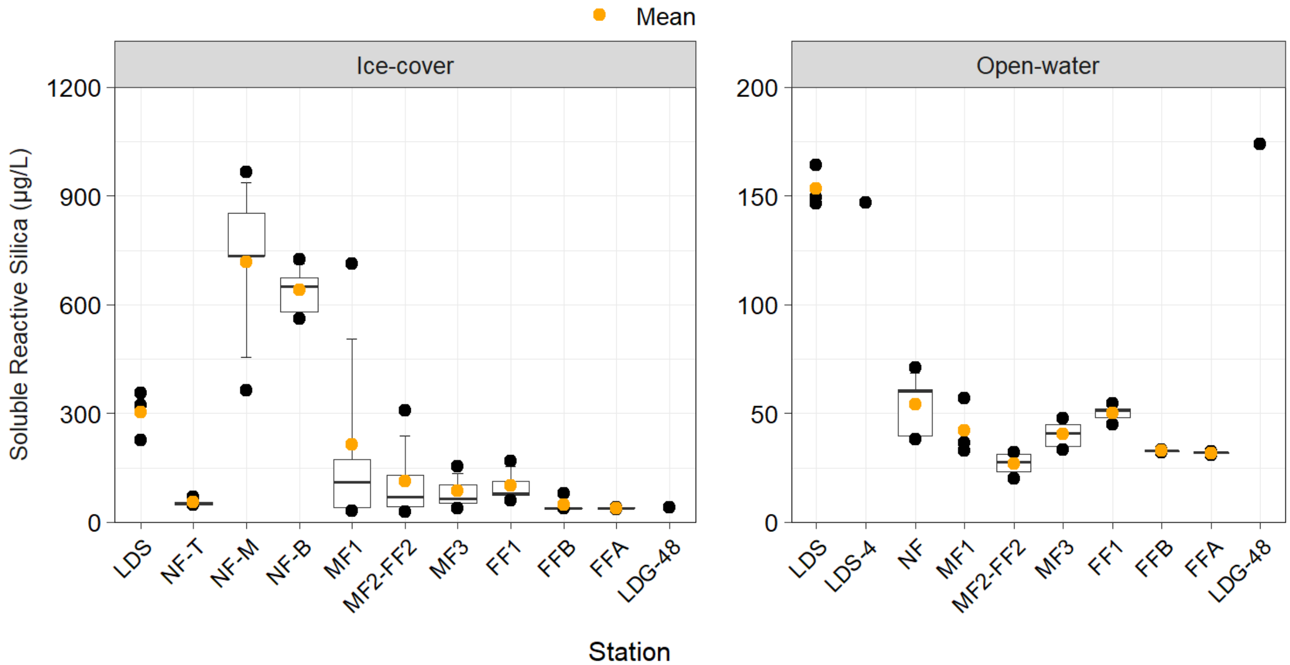
Figure 4-6 Concentrations of Nitrate (A), Nitrite (B), Nitrate + Nitrite (C) and Total Ammonia (D) in Lac de Gras during the Ice-Cover and Open-Water Season, 2019



Notes: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles. Non-detect values are plotted at half detection limit.

µg-N/L = micrograms nitrogen per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth.

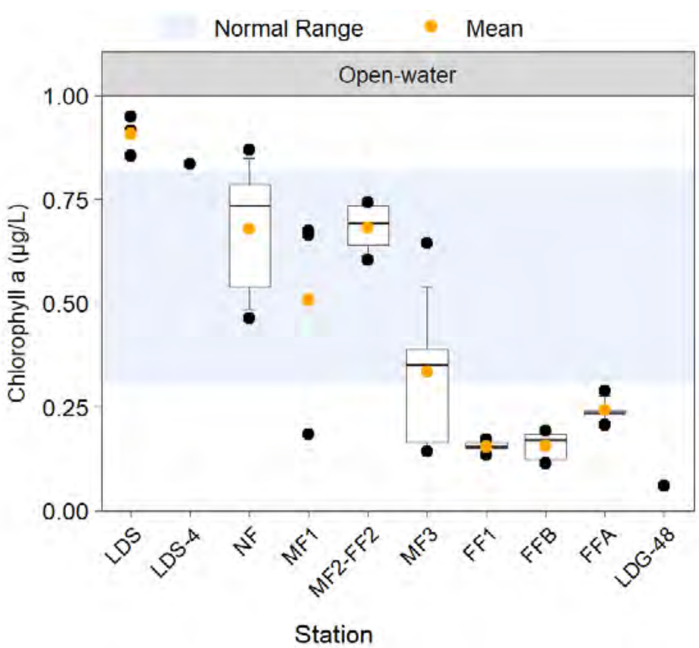
Figure 4-7 Concentrations of Soluble Reactive Silica in Lac de Gras during the Ice-Cover and Open-Water Season, 2019



Notes: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles.

µg/L = micrograms per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth.

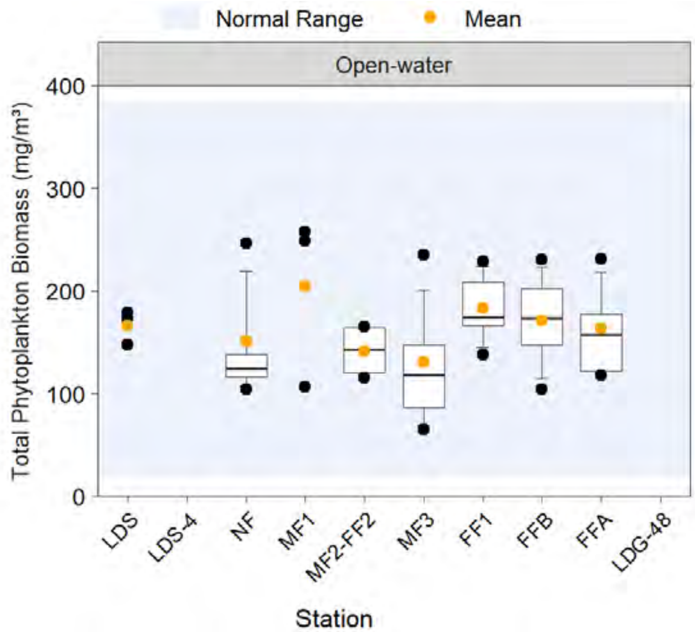
Figure 4-8 Chlorophyll *a* Concentrations in Lac de Gras during the Open-Water Season, 2019



Note: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles.

µg/L = micrograms per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet.

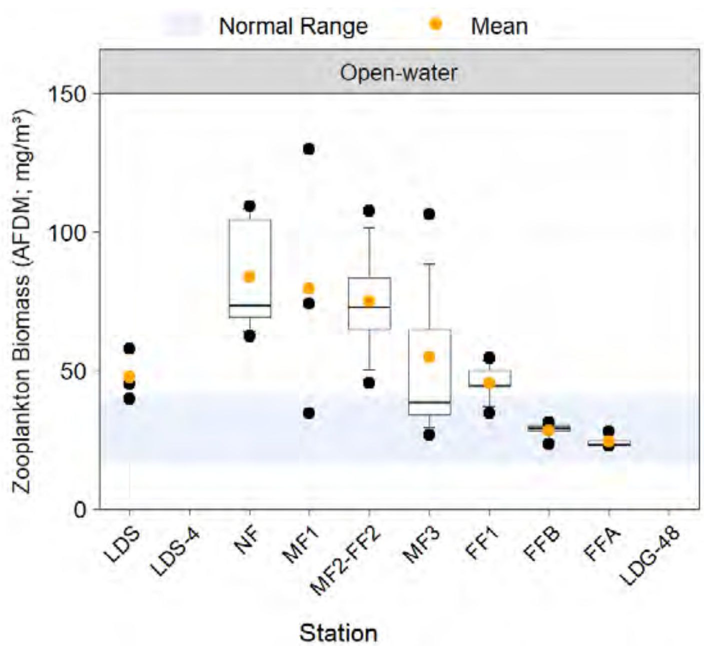
Figure 4-9 Total Phytoplankton Biomass in Lac de Gras during the Open-Water Season, 2019



Note: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles.

mg/m^3 = milligrams per cubic metre; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage.

Figure 4-10 Total Zooplankton Biomass (as AFDM) in Lac de Gras during the Open-Water Season, 2019



Notes: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles.

AFDM = ash-free dry mass; mg/m^3 = milligrams per cubic metre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet.

4.3.3 Extent of Effects

Concentrations of TP were below the normal range at all stations in both seasons and at all depths. Therefore, the area of the lake affected was 0%.

Concentrations of TN were greater in the NF area during the ice-cover season at the middle and bottom depths than at the top depth, or during the open-water season. All NF stations had TN concentrations above normal range. Concentrations were above the normal range at all stations along the three transects with the exception of two stations in the FFA area during the ice-cover season. Concentrations of TN were also above the normal range at LDG-48 during the open-water season, but not during the ice-cover season. Therefore, when LDG-48 was included in the calculations, the entire lake was affected using the open-water data, and 484 km^2 or 85% of the lake was affected using the ice-cover data.

Chlorophyll *a* concentrations were less than or within the normal range at all stations with the exception of NF3. Therefore, the extent of lake affected was much less than in previous years, at 0.5 km^2 or 0.1%. This result is consistent with the smaller extent of effects observed for TP. No Action Levels were triggered for eutrophication indicators based on chlorophyll *a* results. Therefore, no further action is required.

Total phytoplankton biomass was below the normal range at all stations. Therefore, the area of the lake affected was 0%. This smaller extent of effects was consistent with the results for TP and chlorophyll *a*.

Effects on zooplankton biomass were observed in the NF area and along all three transects. The boundary of effects on zooplankton biomass to the northwest (i.e., MF1 transect) extended to the FF1 area, and potentially beyond. The extent of effects past the FF1 area could not be reliably estimated, because there are no stations between the FF1 area and MF3-7. The boundary of effects to the northeast of the Mine (i.e., MF2 transect) extended to FF2-2. The boundary to the south of the Mine (i.e., MF3 transect) extended past MF3-3. Compared to the total surface area of the lake (573 km^2), the area demonstrating effects on zooplankton biomass represents greater than or equal to 168 km^2, or greater than or equal to 29% of the lake area. Because there is uncertainty in the extent of the effect to the northwest, comparisons to the affected areas calculated in recent years should be made with caution. However, the spatial extent of effects on zooplankton biomass in 2019 appears to represent an increase compared to recent years, when the affected area was smaller (i.e., greater than or equal to 12.8%); however, the 2019 affected area based on zooplankton biomass remains below that documented in 2013 (i.e., 62%).

4.3.4 Effects from Dust Deposition

The amount of dust deposition, based on data collected using dust gauges during the open-water season and snow cores during the ice-cover season, was similar between the two seasons. The rate of dust deposition was greatest within the Mine footprint and declined with distance from the Mine. In the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2019c), it was determined that the ZOI from dust deposition extends to approximately 4.2 km from the Mine centroid, or approximately 1.5 km from the boundary of the Mine footprint (Golder 2018a).

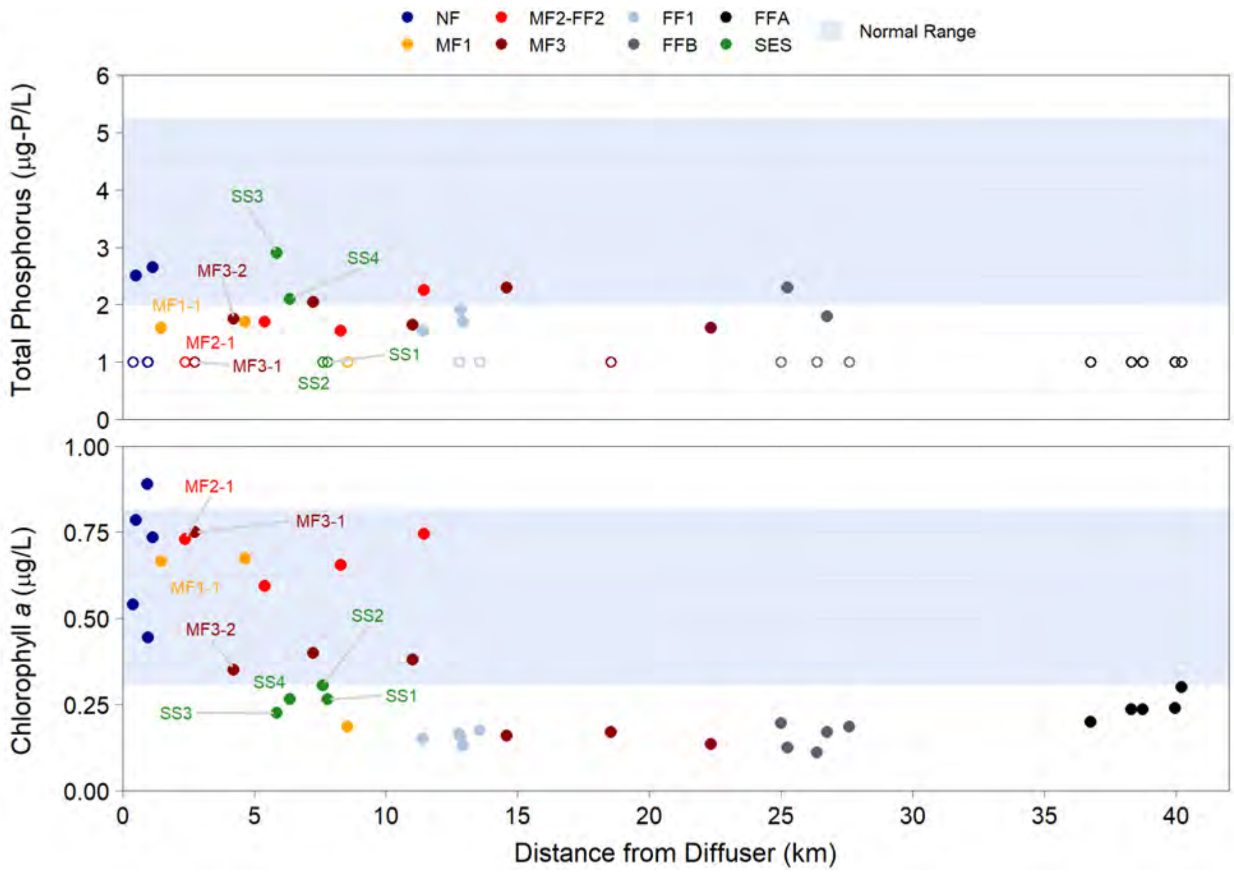
Concentrations of TP during the open-water season in 2019 were within or below the normal range at all stations, including stations located within the ZOI from dust deposition (i.e., stations NF1 to NF5, MF1-1, MF2-1, and MF3-1) (Figure 4-11).

Chlorophyll *a* concentrations were greater than the normal range at one station in the NF area (i.e., NF3), but all other concentrations were within or below the normal range. Chlorophyll *a* concentrations were greater in the NF area and at MF stations closest to the diffuser (i.e., MF1-1, MF1-2, MF2-1, and MF3-1) (Figure 4-11). Other stations within the dust ZOI (e.g., MF3-2) had lower concentrations, with an overall declining trend in concentrations with distance from the diffuser along the MF1 and MF3 transects. This trend is consistent with an effluent-related, rather than a dust-related, effect.

The results at the AEMP stations were consistent with the findings of the *Special Effects Study – Dust Deposition* (Appendix XI), which sampled four additional stations located within the dust ZOI and closer to dust-generating Mine activities. These stations were expected to have a greater potential for dust deposition than the AEMP stations. Concentrations of TP and chlorophyll *a* at the SES stations were similar to those measured in other areas of Lac de Gras (Figure 4-11), and were also within or below the normal range.

Overall, despite the TP load from effluent being smaller in 2019, and potential TP load from Mine-related dust being greater, there was no evidence that TP in dust had an additional measurable effect on concentrations of TP or chlorophyll *a* in Lac de Gras, on top of the effect apparent from the Mine effluent discharge. This finding is consistent with the potential bioavailability of TP in dust. As discussed in the *Special Effects Study – Dust Deposition* (Appendix XII), the potential for mobilization of phosphorus from Mine-related dustfall is low. The mineralogical source of phosphorus in dustfall is likely the phosphate mineral apatite, which has low solubility under the pH and redox conditions in lake water and is, therefore, unlikely to contribute dissolved phosphorus in amounts that would result in a measurable contribution to the nutrient enrichment observed in the lake.

Figure 4-11 Concentrations of Total Phosphorus and Chlorophyll *a* in Lac de Gras during the Open-water Season, 2019



Note: MF stations in the zone of influence from dust deposition are labelled (i.e., MF1-1, MF2-1, MF3-1, MF3-2); all NF stations are within the zone of influence. Special Effects Study stations are also labelled (i.e., SS1, SS2, SS3, SS4).
µg-P/L = micrograms phosphorus per litre; µg/L = micrograms per litre; NF = near-field; MF = mid-field; FF = far-field.

4.3.5 Cumulative Effects in Lac de Gras

In 2019, no cumulative effects of the Diavik and Ekati mines were identified for eutrophication indicators.

5 SEDIMENT CHEMISTRY

5.1 Introduction and Objectives

The primary objective of the sediment quality survey is to assess the effects of Mine effluent on sediment quality. Sediment quality data were analyzed to evaluate whether there were differences in sediment chemistry among the NF, MF and FF sampling areas, compared to reference conditions, and to determine whether concentrations of metals in sediment were greater closer to the Mine.

The concentrations of metals in sediments can provide information about chemical stressors in an aquatic ecosystem and may help explain effects on benthic invertebrates. Substrate particle size is an important factor affecting benthic community structure, and organic carbon concentration in sediments can influence the bioavailability of metals. Therefore, a secondary objective of the sediment quality survey was to provide supporting environmental information to help interpret findings in the *Benthic Invertebrate Report* (Appendix IV).

The following is a summary of the 2019 sediment chemistry results. The *Sediment Quality Report* (Appendix III) provides a more complete analysis and presents detailed results.

5.2 Methods

Sediment quality sample collection took place from 17 August to 5 September 2019, at the same time that benthic invertebrates were sampled. Sediment samples were collected from the NF, MF, and FF areas of Lac de Gras (Figure 1-2). Sediment quality data from the Mine's 2019 SNP were also included where appropriate.

Sediment samples were collected with two sampling devices, which allowed for sampling different layers of sediment. The first method used a gravity-fed core sampling device, which was used to obtain a thin (1 cm) slice of the top layer of the sediment (Photo 5-1). If changes are occurring in the sediment due to mining activities, it is expected that they would be most noticeable closest to the surface. The top 1-cm layer from a minimum of three cores was collected at each AEMP station and combined to form a single sample that was analyzed for TOC, organic matter, nutrients (i.e., TN, TP) and metals (as total metals).

The second method used a bulk-sampling device called an Ekman grab (Photo 5-2). The Ekman grab was lowered into the bottom sediments, triggered to close its jaws, and the top 10 to 15 cm of the sediments were brought to the surface. This was done three times at each location. Sediments from the three grabs were combined to form a single composite sample. The sample was analyzed for particle size (i.e., percentages of sand, silt and clay) and concentrations of total organic carbon (TOC) and total organic matter. Sediment samples were analyzed by BV labs, Burnaby, BC.

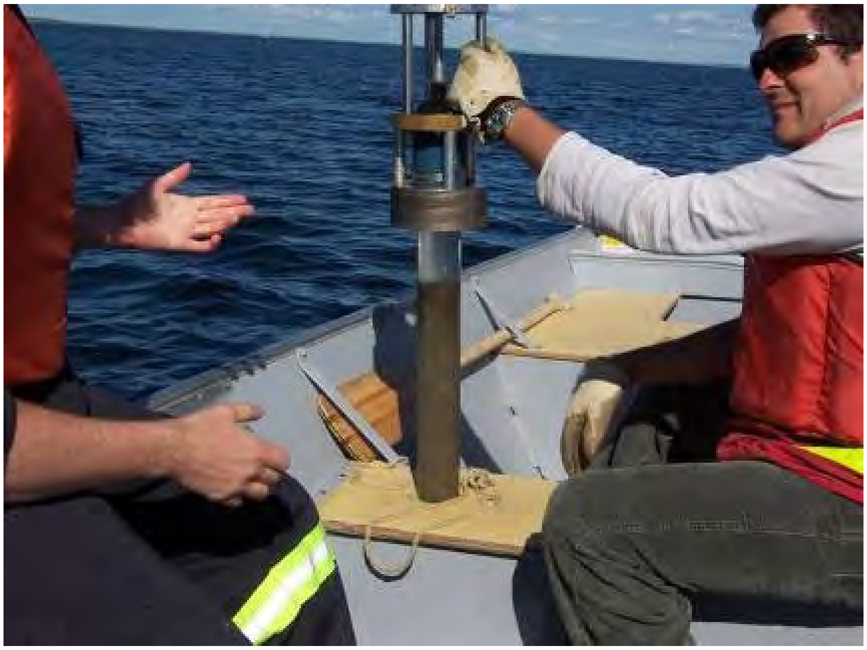


Photo 5-1 Sediment coring device

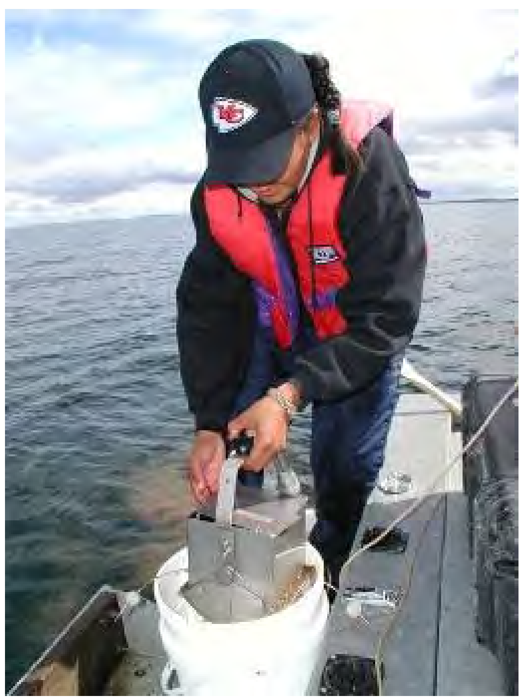


Photo 5-2 Ekman grab sediment sampling device

The top 1 cm core dataset was examined to identify sediment chemistry variables with greater concentrations in the NF area compared to the FF areas. Variables with greater concentrations in the NF area relative to the FF areas and normal ranges were identified as SOIs.

Differences in physical characteristics of sediments that are unrelated to the Mine discharge (i.e., particle size and TOC) have the potential to influence sediment chemistry in Lac de Gras. To address this source of uncertainty, correlation analysis was used to evaluate whether sediment chemistry was related to physical characteristics of sediments measured from the Ekman grabs. For sediment chemistry variables that were correlated to physical characteristics, concentrations were normalized prior to statistical analysis.

Elevated metal concentrations in sediment have the potential to affect the benthic invertebrate community. To evaluate potential effects, the concentrations of SOIs were compared to sediment quality guidelines (CCME 2002; OMOEE 1993). An exceedance of a sediment quality guideline does not necessarily indicate that the benthic invertebrate community was affected, as these guidelines are conservative and developed to protect the most sensitive species and life stages in the aquatic environment (O'Connor 2004). The importance of a Mine-related effect was categorized according to Action Levels, which are listed in Table 5-1.

Table 5-1 Action Levels for Sediment Chemistry

Action Level	Sediment Chemistry	Extent	Action
1	Median of NF greater than two times the median of the reference dataset and strong evidence of link to Mine	NF	Early Warning
2	5th percentile of NF values greater than two times the median of the reference dataset AND normal range(a)	NF	Establish *Effects Benchmark* if one does not exist.
3	75th 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.
4	75th percentile of NF values greater than normal range plus 50% of Effects Threshold(b)	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%	MF	To be determined.
8	95th percentile of FFB values greater than Effects Threshold + 20%	FFB	To be determined.
9	95th percentile of FFA values greater than Effects Threshold + 20%	FFA	Significance Threshold.(c)

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

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.

NF = near-field; MF = mid-field; FF = far-field.

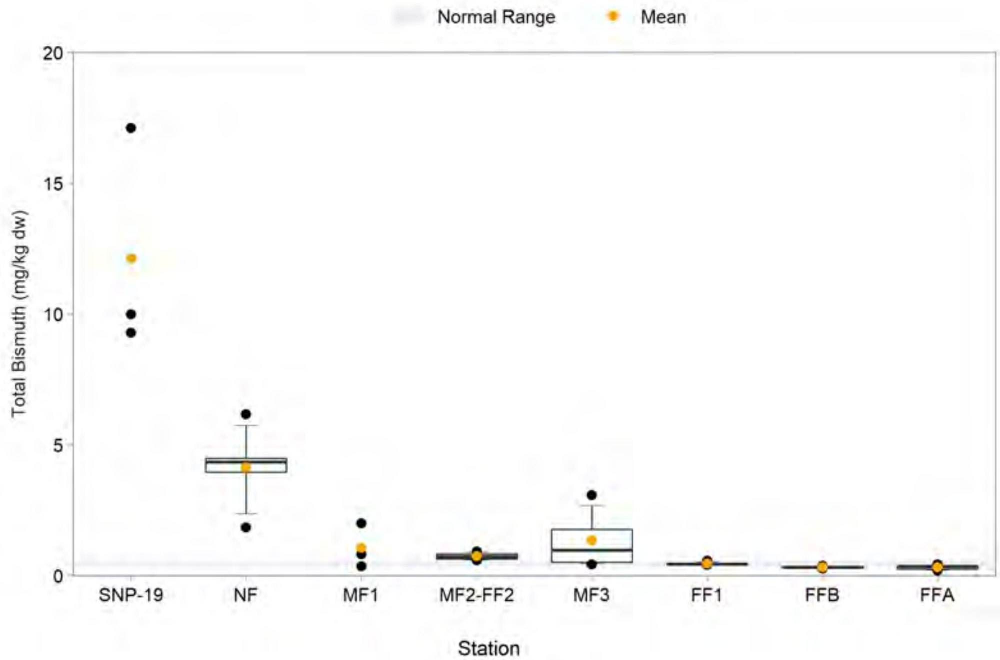
5.3 Results and Discussion

Mine-related effects on bottom sediments in the NF area of Lac De Gras were identified for twelve variables, which were retained as SOIs (i.e., bismuth, lead, lithium, molybdenum, phosphorus, potassium, silver, sodium, strontium, tin, titanium, uranium). Median concentrations in the NF area of bismuth, lead, molybdenum, strontium and uranium exceeded normal ranges (Figure 5-1 to Figure 5-5, respectively). Among the parameters exceeding the normal range, bismuth and uranium had greater concentrations in sediments at Station SNP-19 (i.e., at the edge of the effluent mixing zone) compared to the NF, MF, and FF areas. However, the SNP data were collected from a deeper sediment layer (i.e., top 5 cm) than the AEMP samples (i.e., top 1 cm) and may reflect a longer period of deposition.

Spatial trends were assessed for all SOIs along the three transects. With the exception of phosphorus, all SOIs had a decreasing trend along at least one of the three transects, although some trends were weak. Concentrations of bismuth (Figure 5-6), lead, and uranium in 2019 were similar to previous AEMP surveys and dike monitoring studies (DDMI 2003, 2005, 2007, 2011b), which showed decreases in the concentrations of these metals with distance from the diffuser and the A154 and A418 dikes. Results of the most recent dike monitoring study indicated that bismuth, lead, and uranium concentrations were greatest closer to the diffusers (DDMI 2011b), suggesting Mine effluent may be the primary source of these metals in the NF area. However, increased concentrations of these metals near the dikes, as observed during previous dike monitoring studies, suggest they may also be potential sources of these metals. These results suggest that Mine effluent has contributed to increases in the concentrations of bismuth, uranium and lead in NF sediments.

Of the 12 sediment quality SOIs evaluated, bismuth, molybdenum and uranium triggered an Action Level. Bismuth was the only SOI to trigger Action Level 2, which requires establishment of an effects benchmark; molybdenum and uranium triggered Action Level 1, which represents an early warning. Establishing a bismuth effect benchmark was attempted in the *AEMP Design Plan Version 4.1* (Golder 2017a); however, based on a review of the toxicological literature, data suitable for developing a numerical sediment quality guideline or benchmark for bismuth were not available. Therefore, a sediment effects benchmark could not be developed. Based on the lack of toxicological guidelines for bismuth for surface waters and the relatively low aquatic toxicity of bismuth documented in the available literature, this metal is not considered to be a constituent of concern in Lac de Gras sediments. No follow-up action in response to the Action Level 2 trigger for bismuth is anticipated.

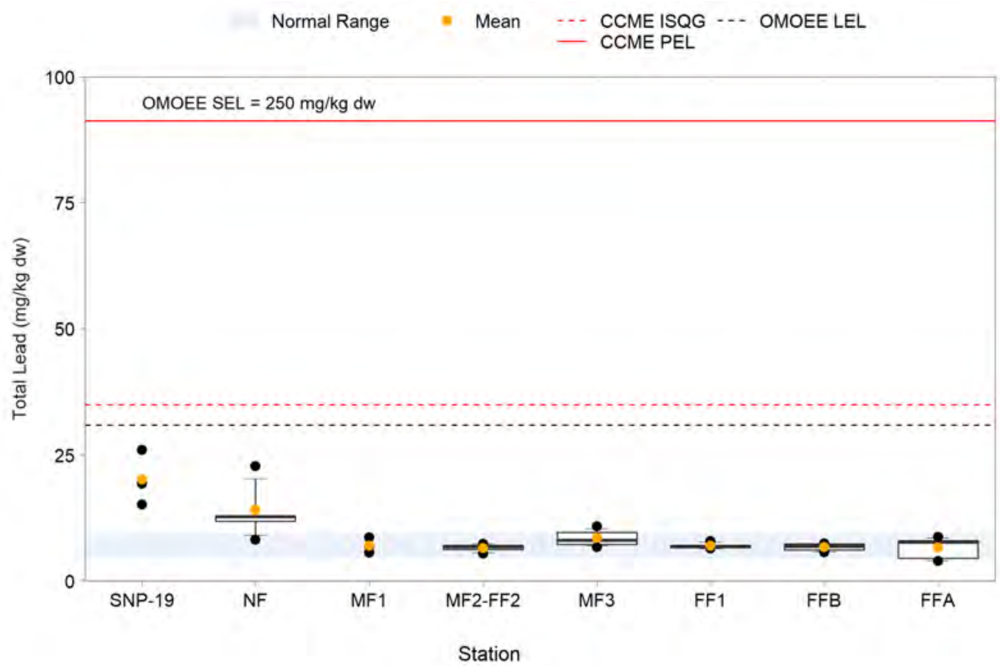
Figure 5-1 Bismuth Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. If less than 5 samples were collected, individual data points are plotted instead of boxplots.

mg/kg dw = milligrams per kilogram dry weight; SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

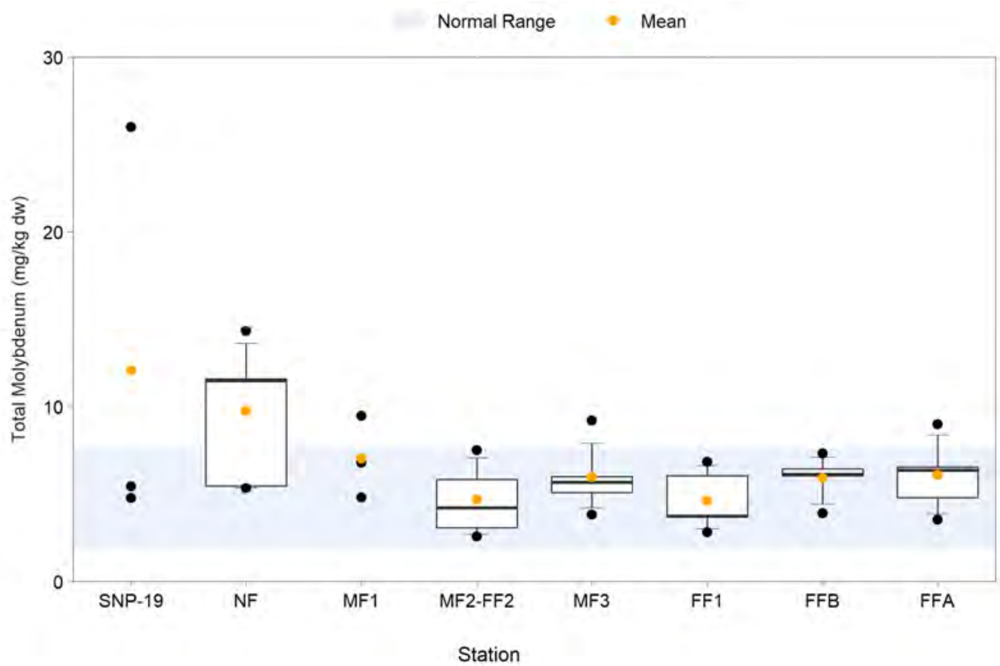
Figure 5-2 Lead Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. If less than 5 samples were collected, individual data points are plotted instead of boxplots.

mg/kg dw = milligrams per kilogram dry weight; SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field; OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level; SEL = Severe Effect Level; CCME = Canadian Council of Ministers of the Environment; ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level.

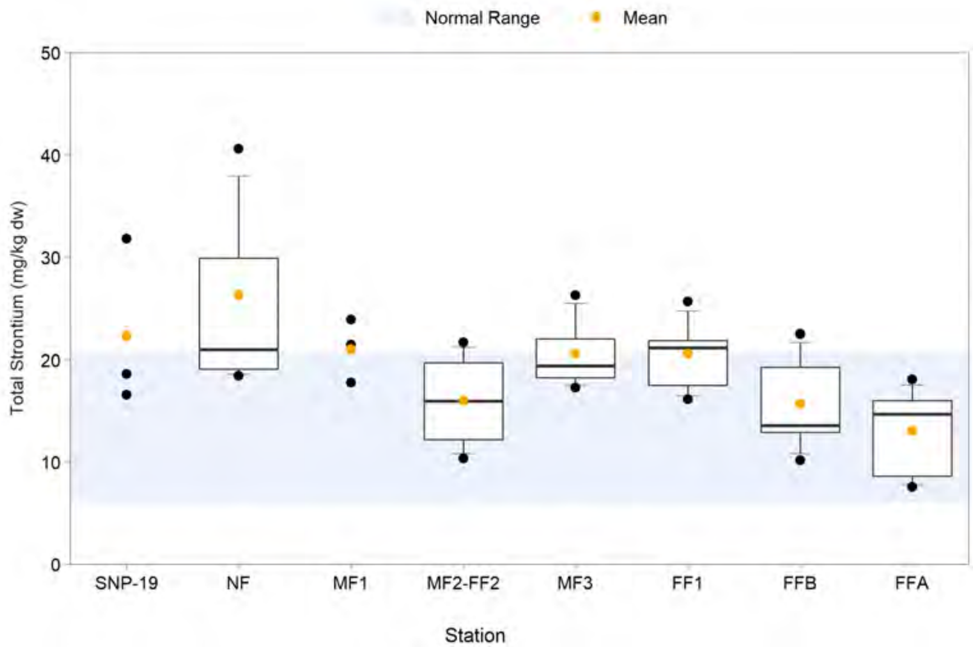
Figure 5-3 Molybdenum Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



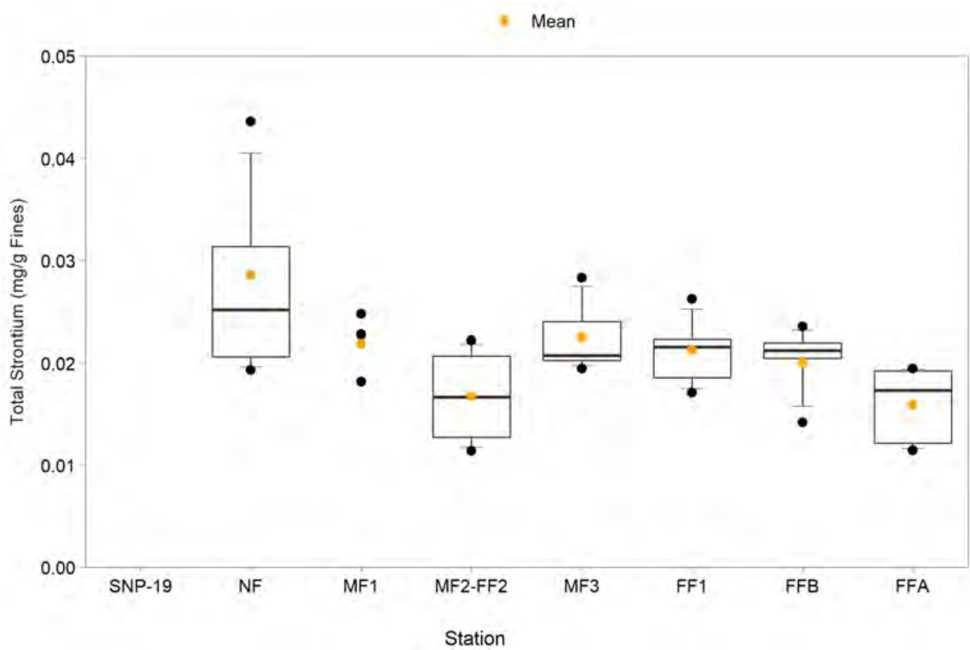
Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. If less than 5 samples were collected, individual data points are plotted instead of boxplots.
mg/kg dw = milligrams per kilogram dry weight; SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 5-4 Strontium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

A — Non-normalized Strontium



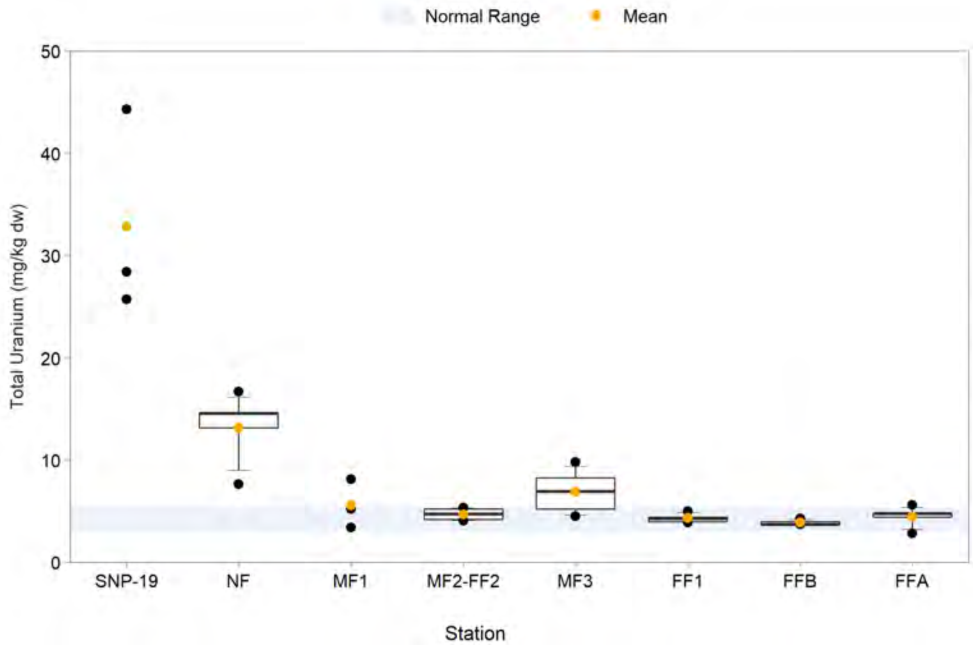
B — Fine Sediments-normalized Strontium



Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. If less than 5 samples were collected, individual data points are plotted instead of boxplots. SNP-19 was not considered in the correlation analysis and thus could not be normalized.

mg/kg dw = milligrams per kilogram dry weight; mg/g Fines = milligrams per gram fine sediments; SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

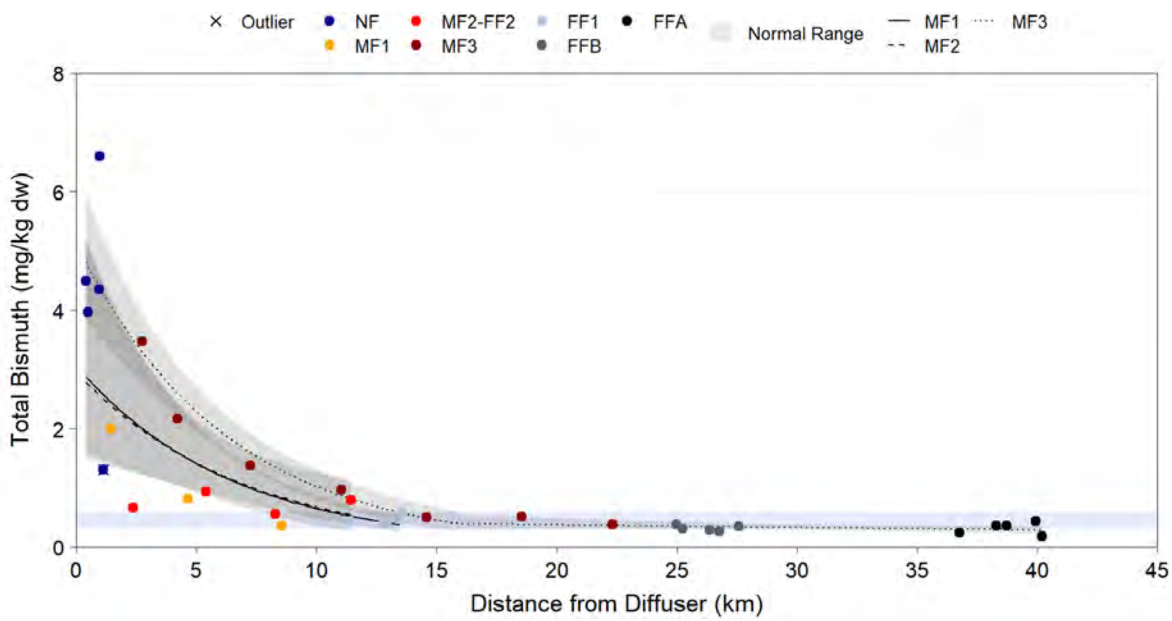
Figure 5-5 Uranium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. If less than 5 samples were collected, individual data points are plotted instead of boxplots.

mg/kg dw = milligrams per kilogram dry weight; SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 5-6 Concentrations of Bismuth with Distance from the Effluent Discharge, 2019



Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).
NF = near-field; MF = mid-field; FF = far-field.

The following generalizations can be made regarding the likelihood of toxicological effects on aquatic life resulting from elevated concentrations of SOIs:

- Sediment quality guidelines for bismuth do not currently exist and information on aquatic toxicity is not available in the primary literature. Results of the 2010 dike monitoring study (DDMI 2011b), and the past six AEMP benthic invertebrate surveys (Golder 2008, 2009, 2010, 2011, 2012, 2014b) detected no toxicity-related effects on the benthic invertebrate or fish communities in areas of Lac de Gras with bismuth concentrations above the background range.
- In 2019, concentrations of lead in the NF area were below the OMOEE LEL and the CCME ISQG for lead. Therefore, sediment toxicity to aquatic biota in the NF area due to lead is unlikely.
- Sediment quality guidelines for uranium do not exist in Canada. Sheppard et al. (2005) predicted a no-effect level for freshwater benthos of 100 mg/kg dw. In Lac de Gras, sediment uranium is unlikely to pose a toxicological risk to aquatic biota at a median concentration of 14.6 mg/kg dw (maximum of 17.2 mg/kg dw) in the NF area.
- Of the SOIs, lead, phosphorus and silver have applicable SQGs. Lead and silver did not exceed the CCME or OMOEE guidelines in any of the sampling areas in Lac de Gras. Phosphorus concentrations were between OMOEE LEL and SEL at all but two stations: one station close to the diffuser (SNP 1645-19A) and one station in the FFA area. This is not considered to represent a concern to aquatic life, because phosphorus concentration in Lac de Gras sediments is naturally elevated and it is unlikely that bottom sediments in this lake would be a significant source of phosphorus to the water column.
- Molybdenum toxicity to *Hyalella azteca* was tested by Liber et al. (2011), but the authors were not able to detect any effects of molybdenum on either survival or growth of the amphipod tested, even at concentrations of up to 3,742 mg/kg. Median concentration in the NF area in 2019 was 11.5 mg/kg.

The above information suggests that sediments in Lac de Gras exhibiting increased concentrations of SOIs that may be attributed to the Mine do not pose a toxicological risk to aquatic life. Consistent with this interpretation, the 2019 *Benthic Invertebrate Report* (Appendix IV) did not detect toxicity-related effects on the benthic community in Lac de Gras. Furthermore, the results summarised above are consistent with observations reported in previous AEMP years, as summarised in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c).

The Action Level 2 was triggered for bismuth in 2019, the same was observed for the 2016 AEMP results screened against the Action Levels in the *AEMP Design Plan Version 4.1* (Golder 2017a).

6 PLANKTON

6.1 Introduction and Objectives

Plankton are small, usually microscopic plants and animals that live suspended in open water. For the purpose of the AEMP, phytoplankton refers to algae and zooplankton refers to microscopic animals, such as crustaceans (i.e., animals with hard shells similar to, but much smaller than, crabs or shrimp) that live suspended in lake water.

The overall objective of the plankton component of the AEMP is to monitor the potential effects of the Mine on the phytoplankton and zooplankton communities in Lac de Gras. The plankton component monitors phytoplankton and zooplankton community endpoints (i.e., abundance, biomass, and taxonomic composition) as indicators of potential effects.

The following is a summary of the 2019 plankton program. The *Plankton Report* (Appendix XI) provides a more complete analysis and presents detailed results.

6.2 Methods

A total of 34 phytoplankton and zooplankton samples were collected in three general areas (i.e., NF, MF, and FF) of Lac de Gras and at three stations in Lac du Sauvage (Figure 1-2). Samples were collected from 15 August to 5 September 2019. A depth-integrated sampler, which collects water from the surface to a depth of 10 m, was used to collect phytoplankton samples. Zooplankton samples were collected using a plankton net that was pulled up through the entire water column three times at each station. Phytoplankton samples were sent to Advanced Eco-Solutions Inc. in Newman Lake, Washington, USA, in 2018 and 2019, which differed from the taxonomist used from 2013 to 2017. The taxonomist at Advanced Eco-Solutions was trained as an employee by the taxonomist of the previous taxonomy lab (Eco-Logic Ltd. [Eco-Logic], Vancouver, British Columbia, Canada) who retired in 2017. Because the same methods were employed by both taxonomists and the taxonomist from Eco-Logic trained the taxonomist at Advanced Eco-Solutions, it was concluded that data from the two taxonomists would be comparable. Zooplankton samples were sent to Salki Consultants Inc. in Winnipeg, MB, for analysis of taxonomic composition, abundance, and biomass.

The importance of effects on phytoplankton or zooplankton biomass and taxonomic richness (i.e., the number of different types of organisms) has been categorized according to Action Levels (Table 6-1). The magnitude of effect was evaluated by comparing community endpoints in the NF area to reference conditions. To visually evaluate spatial trends relative to the Mine discharge, total phytoplankton and zooplankton biomass and taxonomic richness at individual stations were plotted against distance from the effluent discharge. Similarity, community assemblages were assessed by comparing sampling areas using multivariate analysis.

Table 6-1 Action Levels for Plankton Effects

Action Level	Plankton	Extent	Action
1	Mean biomass or richness significantly less than *reference condition mean*[(a)]	NF	Confirm effect
2	Mean biomass or richness significantly less than *reference condition mean*[(a)]	Nearest MF station	Investigate cause
3	Mean biomass or richness less than normal range[(b)]	NF	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD[(c)]	TBD[(b)]	Define conditions required for the Significance Threshold
5[(d)]	Decline in biomass or richness likely to cause a >20% change in fish population(s)	FFA	Significance Threshold

a) The reference condition dataset was obtained from the AEMP Reference Conditions Report Version 1.4 (Golder 2019b).
b) Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).
c) To be determined if Action Level 3 is triggered.
d) Although the Significance Threshold is not an Action Level, it is shown as the highest Action Level to demonstrate escalation of effects towards the Significance Threshold.
Note: Text in *italics* has been changed relative to wording in the *AEMP Design Plan Version 4.1* (Golder 2017a), to reflect the approved change in the biological Action Level assessment method by WLWB (2019) in Directive 3Q.
> = greater than; TBD = to be determined; NF = near-field; MF = mid-field; FF = far-field.

6.3 Results and Discussion

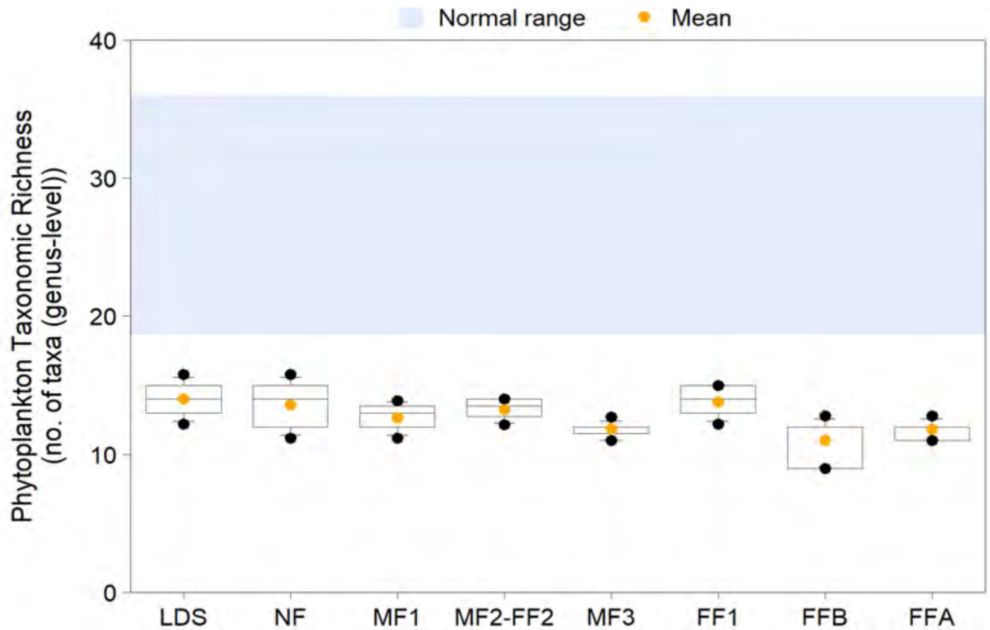
6.3.1 Phytoplankton

Phytoplankton taxonomic richness was below the lower bound of the normal range in all areas of Lac de Gras, and the NF area mean was less than the reference condition mean in 2019 (Figure 6-1). An evaluation of the 2019 phytoplankton data and input from the taxonomist indicated that there were issues with sample preservation, which did not allow reliable comparisons of taxonomic richness with previous years' data. Therefore, this variable was not included in the Action Level evaluation in 2019.

Phytoplankton communities in all areas of Lac de Gras were dominated by microflagellates based on their relative abundance and biomass. Phytoplankton biomass in the NF and FF areas were within the normal range and similar to each other and the reference condition (Figure 6-2). Phytoplankton richness, biomass and the biomass of the major ecological groups did not show a spatial gradient and were similar among stations close to the effluent diffusers and more distant stations (Figure 6-3), with the exception of microflagellate and cyanobacteria biomass, both of which increased with increasing distance from the effluent discharge. Results of multivariate analysis suggest that phytoplankton community composition does not differ among areas in Lac de Gras and does not differ between Lac de Gras and Lac du Sauvage.

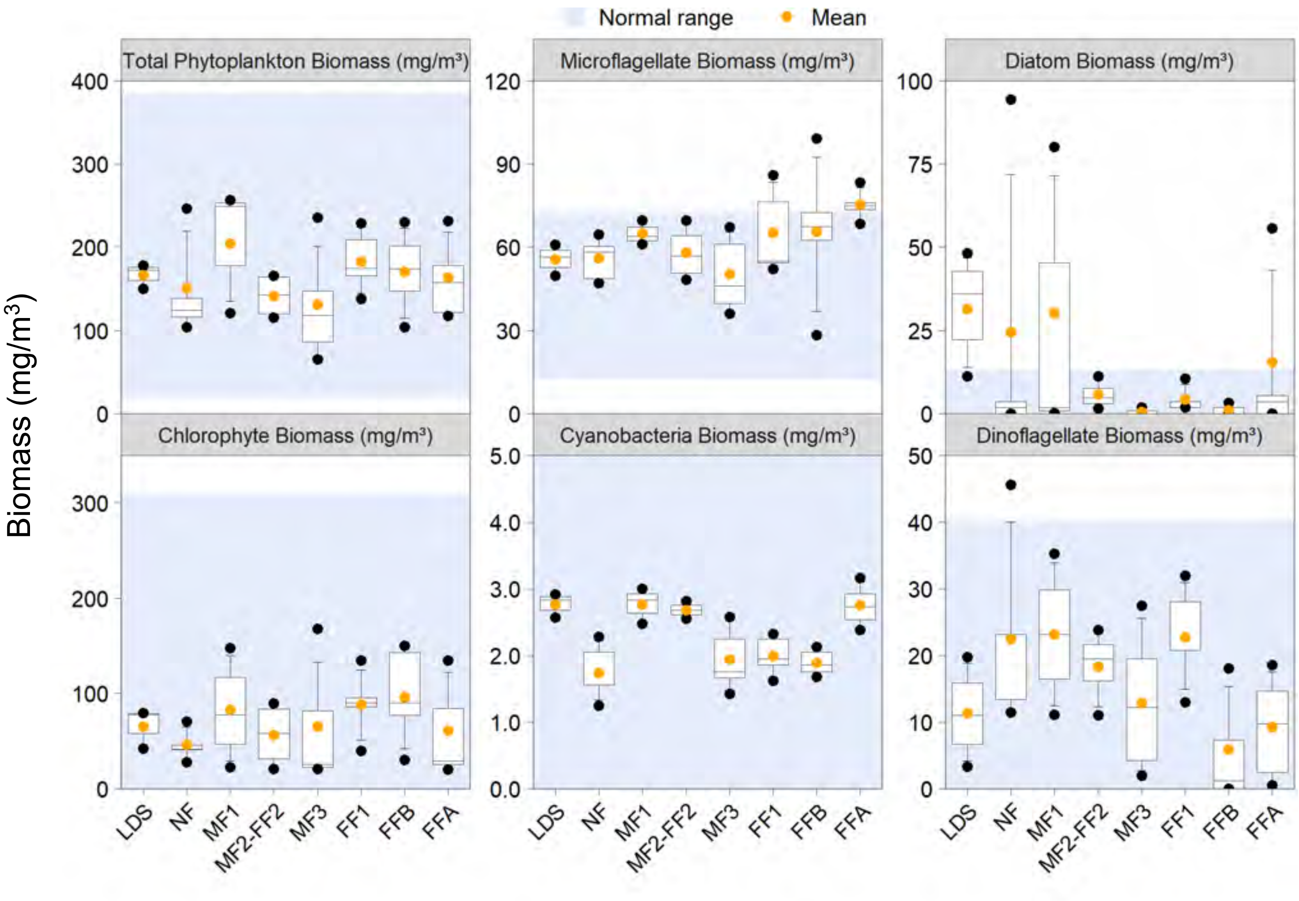
Overall, the 2019 phytoplankton results did not provide evidence of toxicological impairment and no Action Levels were triggered. The 2019 phytoplankton biomass results were within the normal range in 2019, similar to the chlorophyll *a* results presented in the 2019 *Eutrophication Indicators Report* (Appendix XIII).

Figure 6-1 Phytoplankton Taxonomic Richness by Sampling Area in Lac de Gras and Lac du Sauvage, 2019



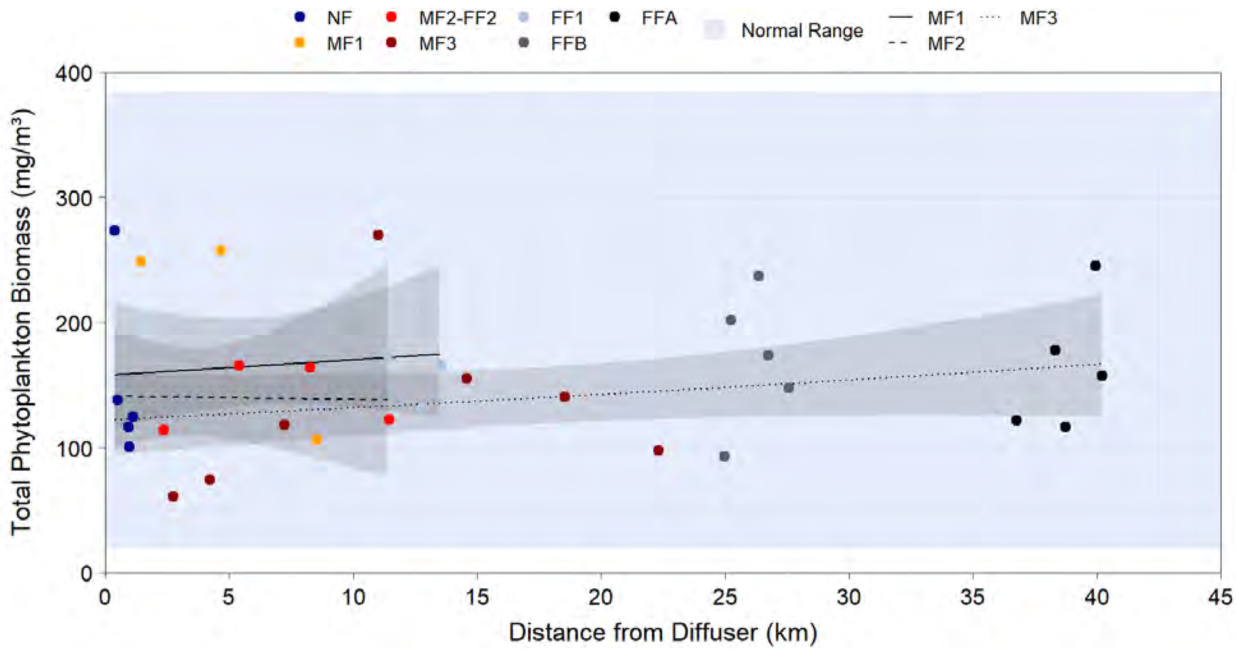
NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Figure 6-2 Phytoplankton Biomass of Major Ecological Groups by Sampling Area in Lac de Gras and Lac du Sauvage, 2019



mg/m[3] = milligrams per cubic metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Figure 6-3 Phytoplankton Biomass in Lac de Gras and Lac du Sauvage Relative to Distance from the Effluent Discharge, 2019



NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

6.3.2 Zooplankton

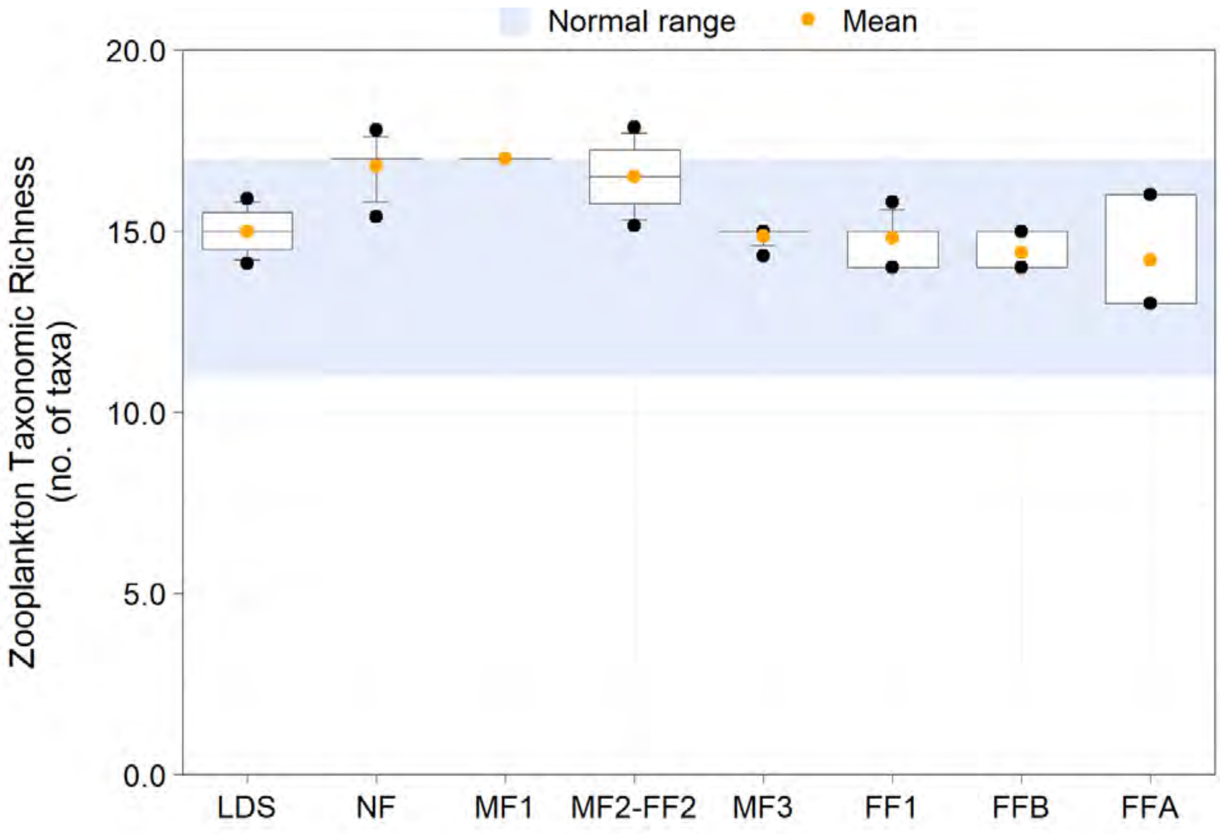
Zooplankton taxonomic richness was greatest at stations closest to the effluent diffusers in 2019 (Figure 6-4). Zooplankton taxonomic richness in the NF area was greater than in the FF areas, but did not differ from reference conditions. Based on relative abundance, zooplankton communities in the NF and FF areas were dominated by rotifers and cyclopoid copepods (Figure 6-4). In terms of relative biomass, the zooplankton community in the NF area was dominated by cladocerans and cyclopoid copepods, while the FF areas were dominated by cladocerans, followed by cyclopoid copepods.

Zooplankton biomass and the biomass of cladocerans, cyclopoid copepods, and rotifers were also greater at stations closer to the diffusers than in the FF areas. Zooplankton biomass in the NF area was greater than in the FF areas, and greater than the normal range and the reference condition mean (Figure 6-5). Zooplankton richness, biomass and the biomass of the major ecological groups showed a spatial gradient with stations closer to the effluent diffusers having larger values than more distant stations (Figure 6-6).

Results of multivariate analysis suggest zooplankton community composition differs between Lac de Gras and Lac du Sauvage and between the NF and FF areas in Lac de Gras. Stations along the MF transects closer to the NF area were similar (i.e., MF1-1, MF1-3 and MF2-1), while the stations along the MF3 transect from MF3-4 to MF3-7 and station MF1-5 were similar to the FF area.

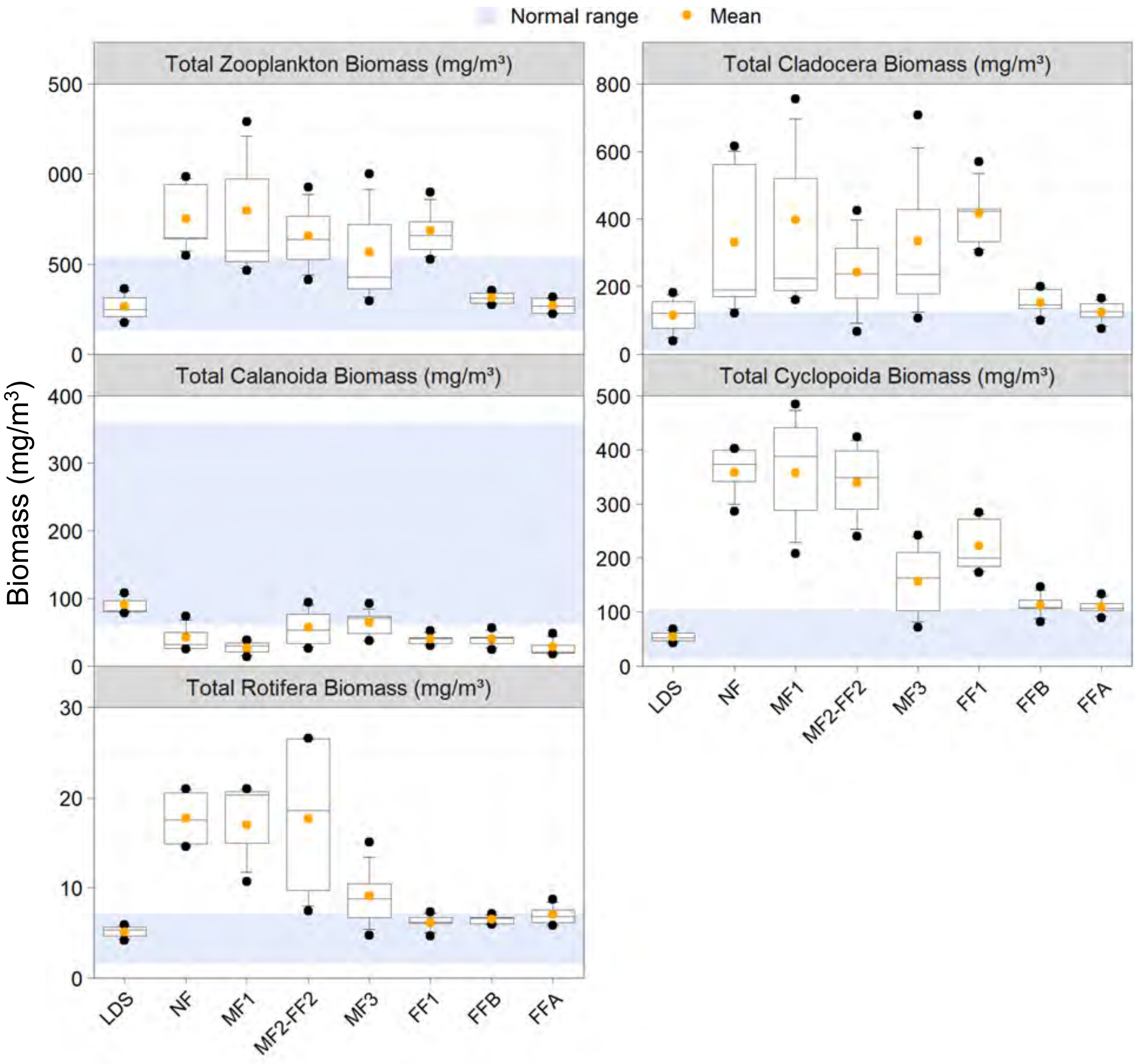
The 2019 zooplankton community did not show a response consistent with toxicological impairment and no Action Levels were triggered. Results were consistent with low level nutrient enrichment, as demonstrated by greater zooplankton biomass in NF area compared to the FF areas, the reference condition mean and the normal range. Results reported in the *Eutrophication Indicators Report* (Appendix XIII) also indicated that low level nutrient enrichment was occurring in Lac de Gras in 2019.

Figure 6-4 Zooplankton Taxonomic Richness by Sampling Area in Lac de Gras and Lac du Sauvage, 2019



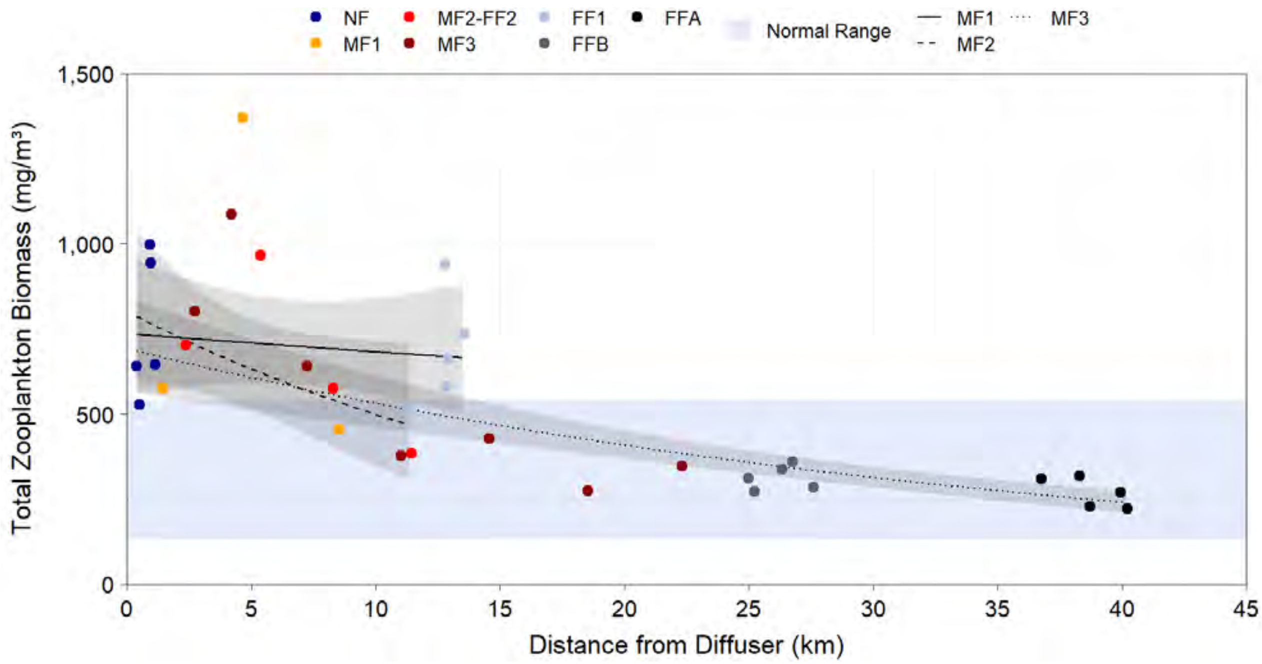
NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Figure 6-5 Zooplankton Biomass of Major Ecological Groups by Sampling Area in Lac de Gras and Lac du Sauvage, 2019



mg/m³ = milligrams per cubic metre; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Figure 6-6 Zooplankton Biomass in Lac de Gras and Lac du Sauvage Relative to Distance from the Effluent Discharge, 2019



NF = near-field; MF = mid-field; FF = far-field.

7 BENTHIC INVERTEBRATES

7.1 Introduction and Objectives

Benthic invertebrates are very small organisms without backbones (e.g., insect larvae, snails, clams, worms) that spend at least part of their life living in or on the bottoms of rivers and lakes. Many different types of benthic invertebrates live on the lake bottom. The types of benthic invertebrates found at a location in Lac de Gras and their abundances can provide information on the effects of Mine operations.

The objective of the benthic invertebrate component of the AEMP is to evaluate whether the benthic invertebrate community of Lac de Gras is affected by effluent discharged from the Mine and, if so, to estimate the type, magnitude, and spatial extent of the effect.

The following is a summary of the 2019 benthic invertebrate program. The *Benthic Invertebrate Report* (Appendix IV) provides a more complete analysis and presents detailed results.

7.2 Methods

Benthic invertebrate community samples were collected from thirty-four stations in three general areas (i.e., NF, MF, and FF) of Lac de Gras (Figure 1-2) between 15 August to 5 September 2019. Six subsamples were collected at each station using an Ekman grab (Figure 5-2) and were combined to form a single composite sample. The numbers and types of invertebrates present in the samples were determined by Dr. J. Zloty, Summerland, BC.

A number of variables were selected that describe various aspects of the benthic community at each sampling location:

- total invertebrate density (number of organisms per square metre)
- richness (total number of taxa per station at the lowest level of taxonomic identification)
- dominance (percentage of the dominant taxon at a station)
- Simpson's Diversity Index (a means of measuring taxonomic diversity)
- evenness index (a means of measuring the balance among numbers of different invertebrates present at a location)
- Bray-Curtis distance (an ecological distance measure based on pair-wise comparisons of communities present at NF and FF stations)
- densities of common taxa (consistent with those evaluated during previous AEMP benthic invertebrate community reports): Pisidiidae, *Procladius* sp., *Heterotrissocladius* sp., and *Micropsectra* sp. As well as two additional taxa that were common in the 2019 samples: *Microtendipes* sp. and *Stictochironomus* sp.
- community composition as relative abundances of major invertebrate groups

Mine-related effects were assessed by comparing these variables in the NF area to those in the FF areas, reference conditions and to the normal range. In addition, a gradient analysis based on three transects was used to detect changes related to proximity to the Mine. Similarity in community assemblages were assessed by comparing sampling areas using multivariate analysis. The importance of a Mine-related effect was categorized according to Action Levels, which are listed in Table 7-1.

Table 7-1 Action Levels for Benthic Invertebrate Community Effects

Action Level	Benthic Invertebrates	Extent	Action
1	The mean of a community variable[(a)] significantly less than *reference condition mean*[(b)]	NF	Confirm effect
2	The mean of a community variable[(a)] significantly less than *reference condition mean*[(b)]	Nearest MF station	Investigate cause
3	The mean of a community variable[(a)] less than normal range[(c)]	NF	Examine ecological significance Set Action Level 4 Identify mitigation options
4	To be determined[(d)]	-	Define conditions required for the Significance Threshold
5	Decline of community indices[(a)] likely to cause a >20% change in fish population(s)	FFA	Significance Threshold[(e)]

a) Refers to variables such as total density, richness, Simpson's diversity index, Bray-Curtis index and densities of dominant taxa. The criterion for the Bray-Curtis index is a significantly larger mean value compared to the reference areas.
b) The reference condition dataset was obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).
c) Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).
d) To be determined 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 escalation of effects towards the Significance Threshold.
Note: Text in *italics* has been changed relative to wording in the *AEMP Design Plan Version 4.1* (Golder 2017a), to reflect the approved change in the biological Action Level assessment method by WLWB (2019) in Directive 3Q.
NF = near-field; MF = mid-field; FF = far-field.

7.3 Results and Discussion

Densities of four common taxa (i.e., Pisidiidae, *Procladius*, *Microtendipes* and *Stictochironomus*) exceeded normal ranges in the NF area, consistent with the low level nutrient enrichment effect observed near the Mine in previous years. Fingernail clam (Pisidiidae) density was above the normal range in the NF, MF1, MF2-FF2 and FF1 areas. The midges *Procladius* and *Microtendipes* had densities above the normal range in the NF, MF1, MF2-FF2 and FF1 areas. *Procladius* density was also above the normal range in the MF3 area. Density of the midge *Stictochironomus* was above the normal range in all areas sampled. Total density was also above the normal range in the MF1, MF2 and FF1 areas. All other variables had NF area means within the normal range. No significant differences were detected for any of the benthic invertebrate variables tested that would result in toxicological impairment of the community.

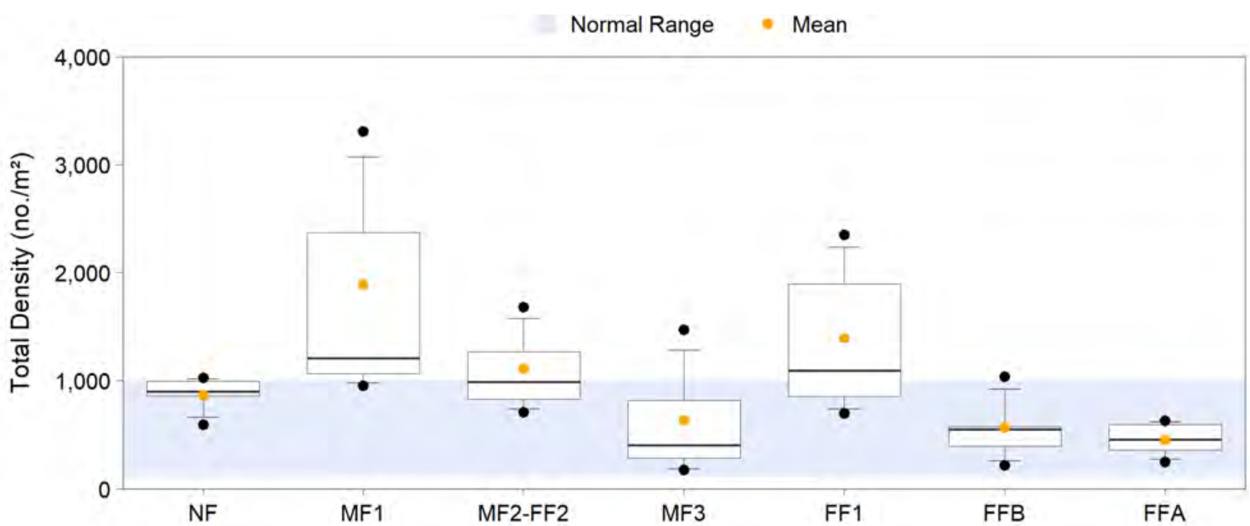
Differences among sampling areas were observed in total density, dominance, Simpson's diversity index, *Procladius* density and *Microtendipes* density (Figure 7-1 to Figure 7-3). These variables were also different among the three reference areas, likely reflecting physical differences in habitat (i.e., the FF1 area is located closer to shore within a sheltered bay, where as other sampling areas are located within the main body of the lake). These results did not provide evidence of Mine-related effects, because the NF area mean was observed to fall between the largest and smallest FF area means.

Spatial gradients were detected for eight of the thirteen benthic invertebrate variables assessed in 2019, including richness, evenness, percent Chironomidae midges, Pisidiidae density, *Procladius* density, *Heterotrissocladius* density, *Micropsectra* density and *Microtendipes* density. These results were consistent with Mine-related nutrient enrichment in Lac de Gras, with values decreasing with distance from the Mine (Figure 7-4). Variables related to community structure (i.e., richness and community indices) showed a more subtle trend, which was consistent with a low level nutrient enrichment effect of increased densities of some invertebrates, without substantial changes in the community.

Results of multivariate analysis suggest that two community types exist in Lac de Gras: one in the eastern portion of the lake, which is subject to a Mine-related nutrient enrichment effect; and one in the part of the lake west of the East Island, where Mine effects are less apparent.

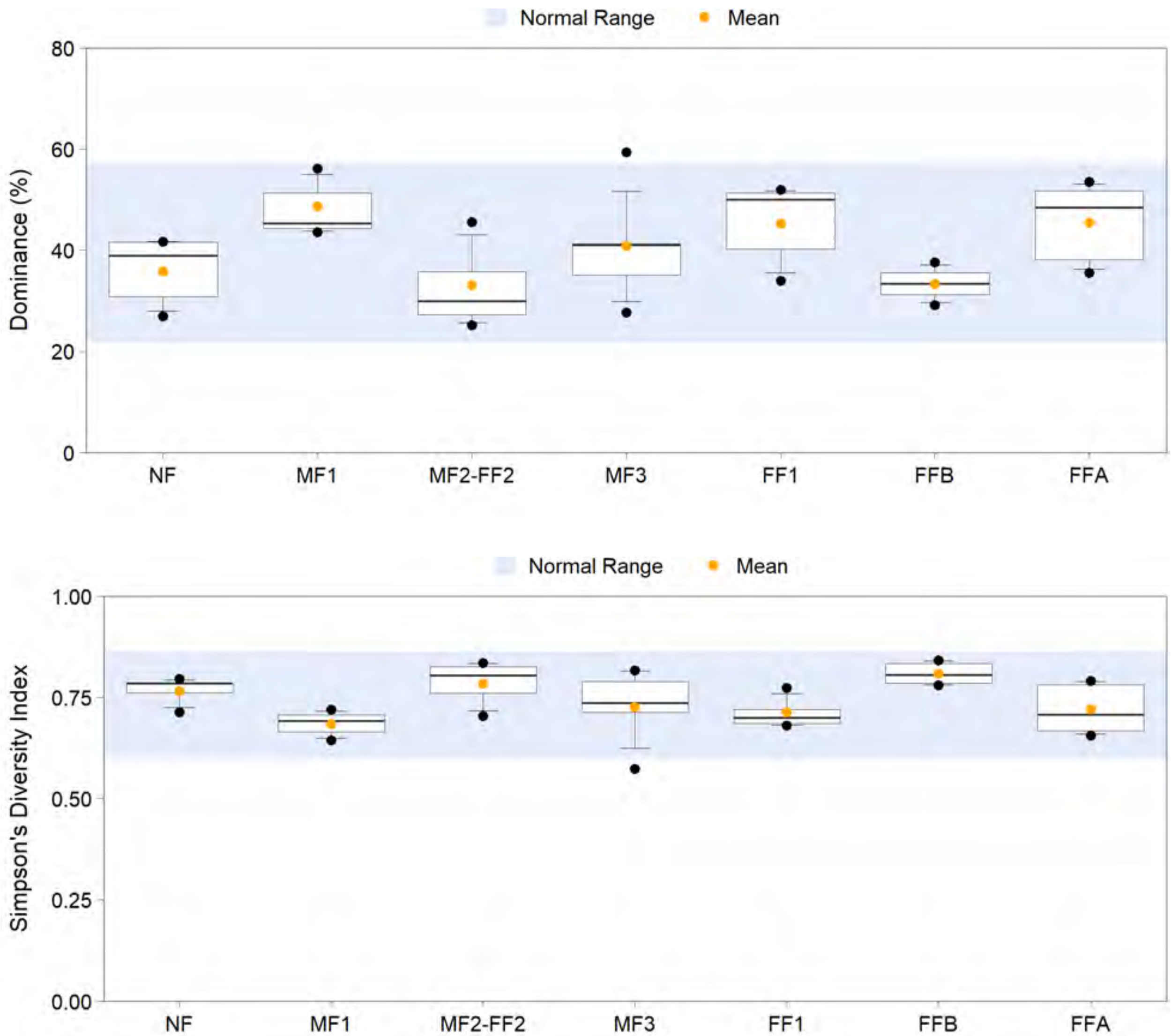
Overall, the 2019 benthic invertebrate community results were consistent with a low level nutrient enrichment effect resulting from Mine effluent discharge (Golder 2019c). A similar response was observed in the *Effluent and Water Chemistry Report* (Appendix II), *Plankton Report* (Appendix XI) and the *Eutrophication Indicators Report* (Appendix XIII), and was consistent with observations made in previous years. However, no Action Levels related to toxicological impairment were triggered in 2019 for the benthic invertebrate community, and no changes in water quality were identified that would suggest toxicological impairment of aquatic life in Lac de Gras. The *Sediment Report* (Appendix III) reported NF area concentrations of total bismuth, total lead, total molybdenum, total strontium, and total uranium were above normal ranges; Action Level 1 was triggered for total molybdenum and total uranium, and Action Level 2 was triggered for total bismuth. However, as described in Section 5, concentrations of these metals are not anticipated to have detectable toxicological effects on the benthic invertebrate community.

Figure 7-1 Total Invertebrate Density at Sampling Areas in Lac de Gras, 2019



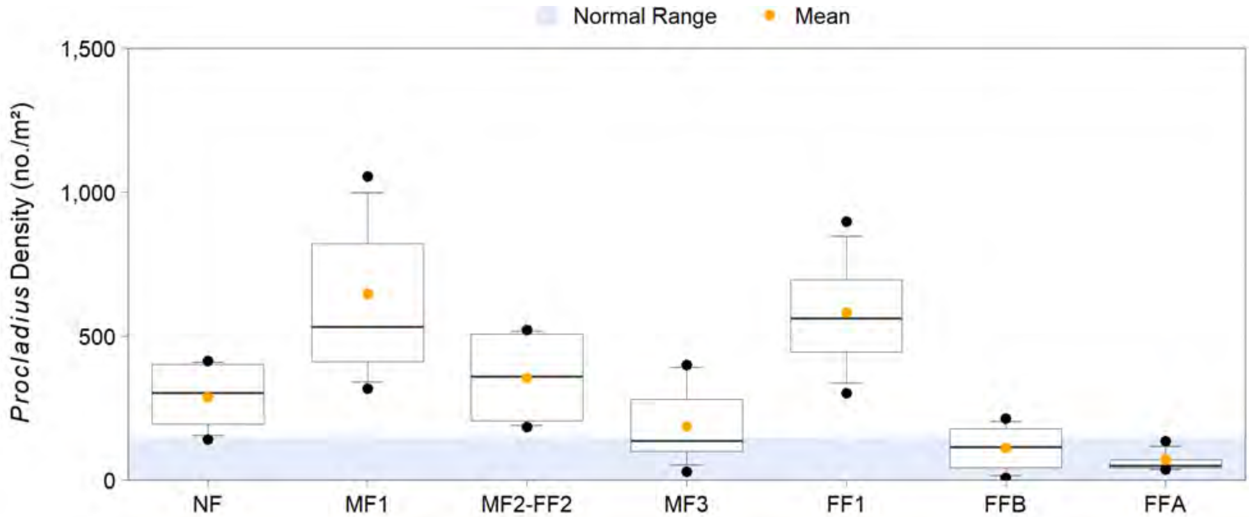
Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

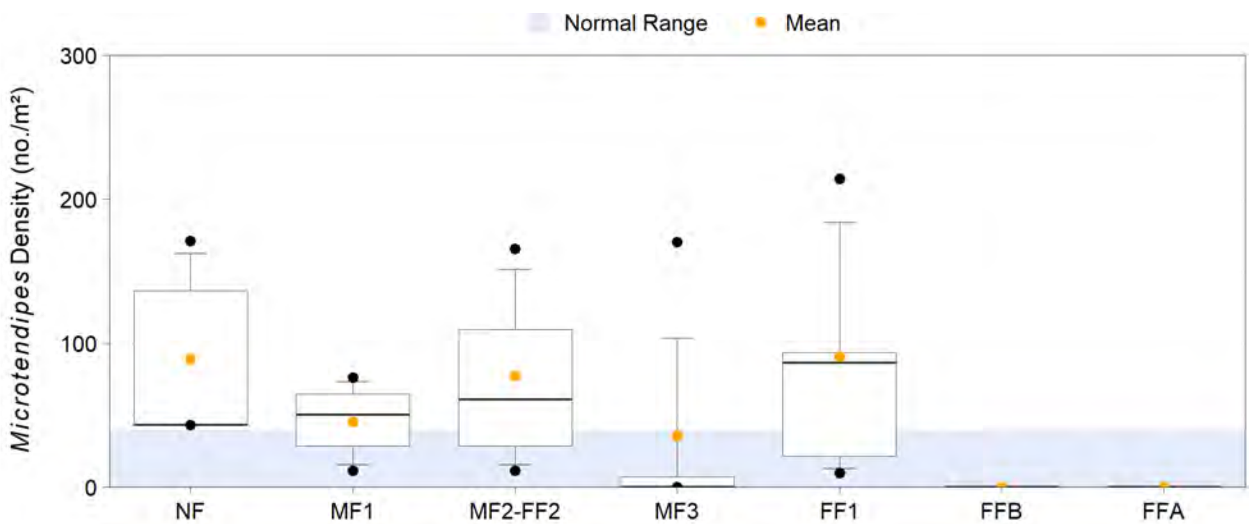
Figure 7-2 Dominance and Simpson's Diversity Index at Sampling Areas in Lac de Gras, 2019



Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).
NF = near-field; MF = mid-field; FF = far-field.

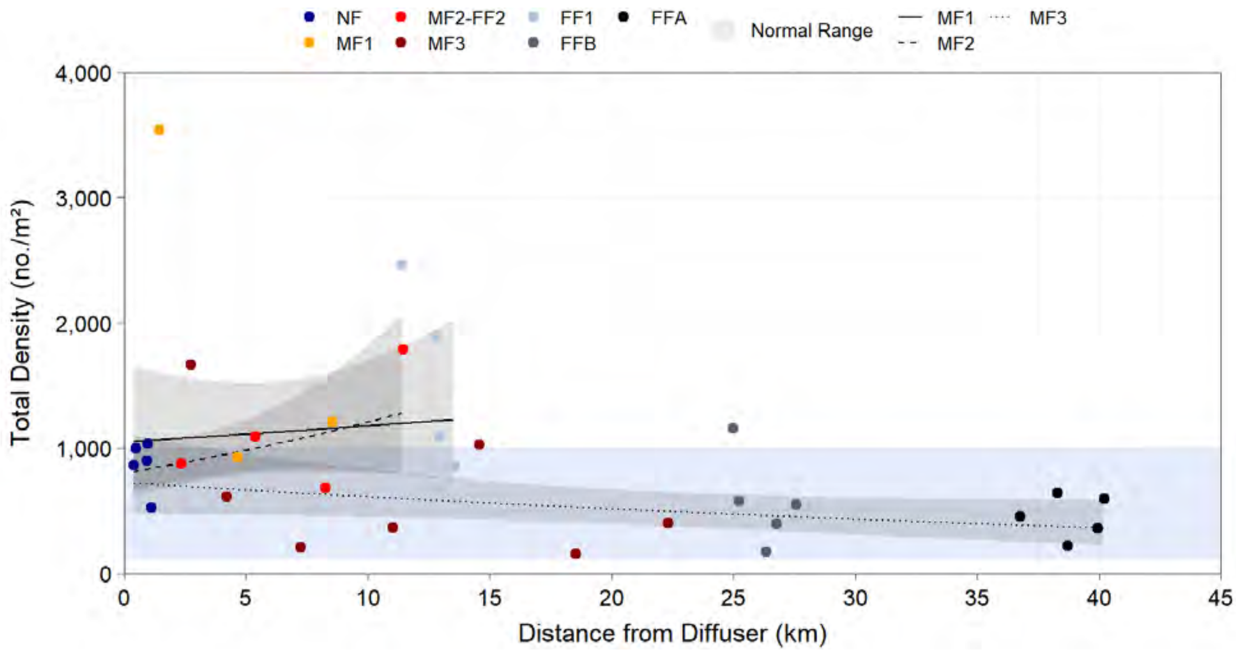
Figure 7-3 Densities of *Procladius* and *Microtendipes* at Sampling Areas in Lac de Gras, 2019





Note: The normal range for *Micropsectra* density was obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). The normal range for *Microtendipes* density was calculated in 2019 according to the methods described by Golder (2019b).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

Figure 7-4 Total Invertebrate Density in Lac de Gras According to Distance from the Effluent Discharge, 2019



no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

8 FISH

8.1 Introduction and Objectives

The fish program samples a small-bodied fish species called Slimy Sculpin (*Cottus cognatus*) in Lac de Gras with the objective to determine if the Mine is having an effect on fish in the lake. Slimy Sculpin were selected for this program because they can be found in most areas of Lac de Gras, but unlike Lake Trout (*Salvelinus namaycush*) or Round Whitefish (*Prosopium cylindraceum*), Slimy Sculpin stay in one area for their entire lives and do not travel throughout the lake. This is an important consideration because it means that the sediment, food, and water quality conditions in which Slimy Sculpin are found are likely the conditions in which they spend most of their lives. In this way, fish collected near the Mine site can be compared with fish collected far from the Mine site to evaluate whether changes to the health of the fish population are occurring. Also, since small-bodied fish are usually more abundant than bigger fish such as Lake Trout, there is less concern that the population will be harmed by the sampling itself.

Slimy Sculpin tissues were also analyzed for metals as part of the fish health study. The tissue chemistry results were used in the interpretation of the fish health study results, and as an early warning indicator of potential effects on tissue quality of Lake Trout.

The following is a summary of the 2019 fish program. The *Fish Report* (Appendix V) provides a more complete analysis and presents detailed results.

8.2 Methods

Slimy Sculpin were collected from five areas in Lac de Gras: NF, FF2, MF3, FFA and FF1 (Figure 1-2) between 28 August and 16 September 2019. Sampling area FF2 is considered a mid-field area due to presence of Mine effluent. With the exception of MF3, sampling areas in 2019 were similar to those sampled during the 2016 small-bodied fish survey (Golder 2017b).

The fish were collected by stunning them with electricity and then retrieving the fish with a net. The electrical current was provided by a backpack electrofisher (Photo 8-1). Shocking the fish in this way is a common method for collecting fish in shallow nearshore areas for scientific purposes.

Photo 8-1 Electrofishing at FF2 in Lac de Gras, September 2016

At each of the five sampling areas, the goal was to collect 30 male, 30 female, and 30 juvenile (i.e., age-1+) Slimy Sculpin for lethal analysis. This number was determined based on the estimated sample size required to interpret differences in fish measurements among locations using statistics. Fish infected with tapeworms were not included in the analysis as the influence of these parasites can mask differences between sampling areas. Since some fish variables did not require lethal sampling, an additional 50 fish were targeted at each site that were released back to Lac de Gras after measurements of length and weight were taken. In addition, a relative abundance survey was completed in 2019 to compare the number of Slimy Sculpin from each of the sampling areas using standardized sampling methods.

The following summarizes the different measurements recorded for Slimy Sculpin:

- external examination: length, weight and any observations of wounds, lesions, tumours, parasites, fin fraying, or gill parasites
- internal examination: sex, state of maturity, life stage, abnormalities in liver, spleen, gall bladder, kidney and gonads. Fish weight was recorded along with gonad, liver, and carcass weight. Gonads were sent for histological analysis of sex and state of maturity to the Aquatic Diagnostic Services, Atlantic Veterinary College, at the University of Prince Edward Island, Charlottetown, PE
- stomach contents: analyzed by Dr. J. Zloty (Summerland, BC)

- fish tissue chemistry: fish tissue metals were analyzed in fish carcasses by ALS Canada, Burnaby, British Columbia

From these measurements, additional metrics were calculated, including catch-per-unit-effort (i.e., a measure of number of fish in an area relative to sampling efforts), biological indices that help describe fish health, energy storage (e.g., condition and liver weight) and reproductive potential.

Mine-related effects were assessed by comparing measurements in fish from the NF area to those in the FF areas. The importance of a Mine-related effect was categorized according to the Action Levels, which are listed in Table 8-1.

Table 8-1 Action Levels for Fish Health Effects

Action level	Fish Health	Extent	Action
1	Statistical difference from mean of reference dataset[(a)] indicative of toxicological response[(b)]	NF	Confirm effect
2	Statistical difference from mean of reference[(a)] dataset indicative of toxicological response[(b)]	Nearest MF station	Investigate cause
3	A measurement endpoint beyond the normal range[(c)]	NF	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD[(d)]	TBD	Define conditions required for the Significance Threshold
5	Indications of severely impaired reproduction or unhealthy fish, likely to cause a >20% change in fish population(s)	FFA	Significance Threshold [(e)]

a) Action Levels were assessed by comparing NF and MF areas to the FF1, FFA and FFB areas, which formerly served as reference areas.
b) Such a response could include a decrease in recruitment (fewer young fish), smaller gonads, reduced fecundity, and changes to liver size, changes in condition, increased incidence of pathology, reduced growth, and reduced survival.
c) Reference conditions were quantified as the normal range for each variable; normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).
d) To be determined if an Action Level 3 effect is reached.
e) Although the Significance Threshold is not an Action Level, it is shown as the highest Action Level to demonstrate escalation of effects towards the Significance Threshold.
NF = near-field; MF = mid-field; FF = far-field; TBD = to be determined.

8.3 Results and Discussion

8.3.1 Fish Health

A total of 1,339 Slimy Sculpin were captured in 2019. Of these fish, 645 were infected with adult tapeworms and were excluded from statistical analyses. Of the remaining 694 fish captured, 434 were sacrificed and underwent a full internal examination (i.e., 82 fish at NF, 85 fish at FF2, 87 fish at MF3, 87 fish at FF1, and 93 fish at FFA). The remaining 260 individuals were measured for total length and wet weight, examined for external abnormalities, and released back in the area from which they were captured.

Slimy Sculpin sampled during the 2019 fish survey were considered healthy and in good physical condition. Sampling areas had similar numbers of fish, reproductive success, and internal and external abnormalities. The number of fish infected with tapeworms was different among sampling areas but was not associated with distance from the Mine. Stomach contents were dominated by midges (Diptera: Chironomidae) in all sampling areas, followed by other flies (Diptera), water fleas (Cladocera), beetles (Coleoptera) and caddisflies (Trichoptera). Some differences in fish health variables were detected at the NF area when compared to both the FF areas and reference conditions (Table 8-2). Relative to the FF areas, differences were observed for male gonad weight and female length, weight and liver weight. Relative to reference conditions, differences were observed for juvenile length, weight, condition, and liver weight, as well as male and female gonad size. Mean values did not exceed normal ranges (Figure 8-1 and Figure 8-2).

Differences in fish health variables were not consistent with either a toxicity or a nutrient enrichment response. Differences in fish health variables were not consistent when compared to both the FF areas and reference conditions; only male gonad weight was different in both comparisons indicating greater reproductive investment in the NF area 2019. This finding suggests that there were differences in fish health variables between the FF areas and reference condition, likely influenced by variation among years in regional environmental factors such as weather or temperature.

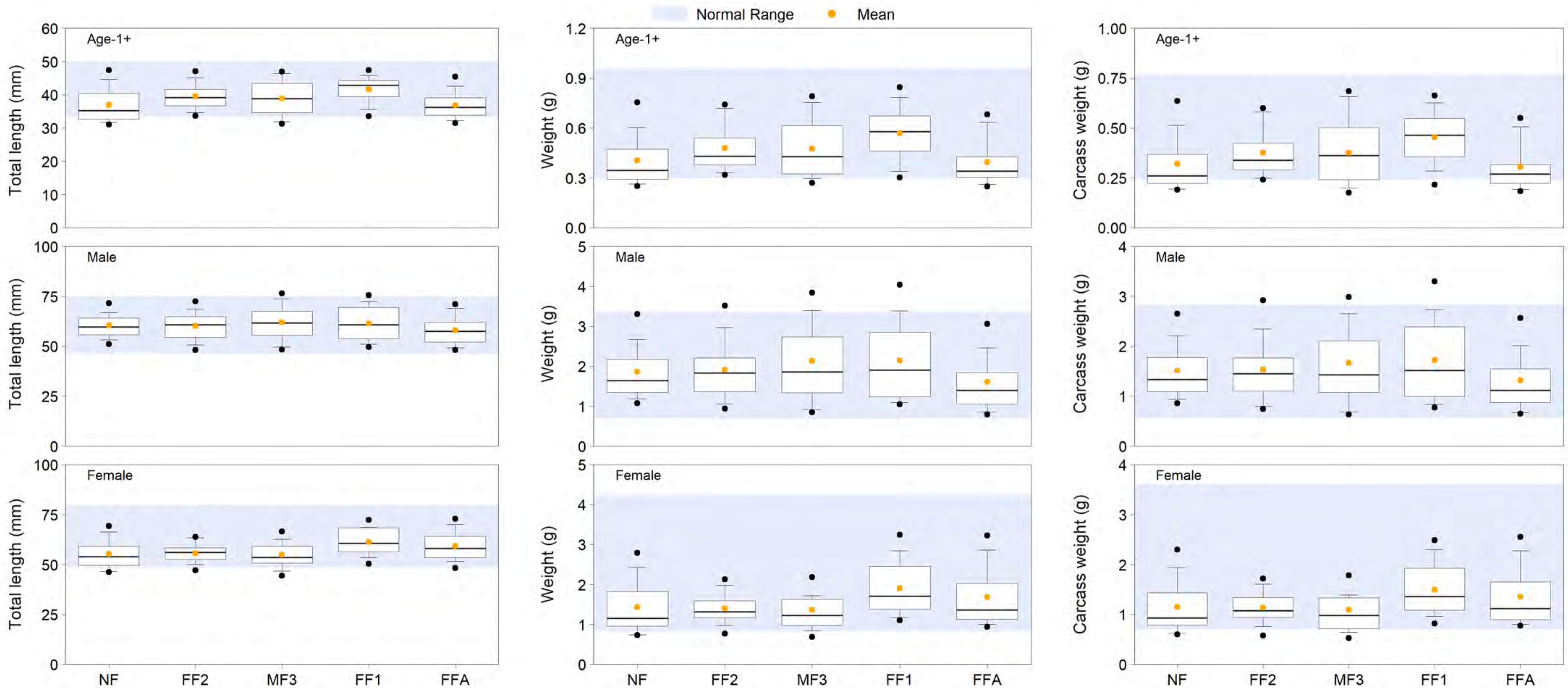
Results of the 2019 fish health survey triggered Action Levels 1 and 2. Juvenile fish were significantly shorter, weighed less in the NF area, and had greater relative liver weights compared to reference conditions, thereby triggering Action Level 1 for toxicological impairment. In addition, juvenile fish in the MF3 area weighed less and had larger relative liver weights than reference conditions, thereby triggering Action Level 2 for toxicological impairment. Action level 2 was previously triggered during the 2016 AEMP based on similar differences in Slimy Sculpin length, weight and liver size, as described in the *2014 to 2016 AEMP Response Plan Fish* (Golder 2017c). Factors contributing to these differences were evaluated in the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017d), which concluded that differences were not consistent with a Mine effect and were likely driven by differences in habitat among sampling areas. Given that direction and magnitude of the differences in 2019 were consistent with those reported in 2016, it is anticipated no new Response Plan is required at this time.

Table 8-2 Summary of Statistical Differences in Fish Health Endpoints, 2019

Variable	NF vs FF			NF vs Reference Condition		
	Juvenile	Male	Female	Juvenile	Male	Female
Total length (mm)	-	-	↓ (-8%)	↓ (-14%)	-	-
Total weight (g)	-	-	↓ (-23%)	↓ (-37%)	-	-
Carcass weight (g)	-	-	-	↓ (-39%)	-	-
Condition	-	-	-	↑ (10%[a])	-	-
Relative liver weight (g)	-	-	↓ (-19%)	↑ (26%)	-	-
Relative gonad weight (g)	-	↑ (12%)	-	-	↑ (44%)	↑ (111%[b])

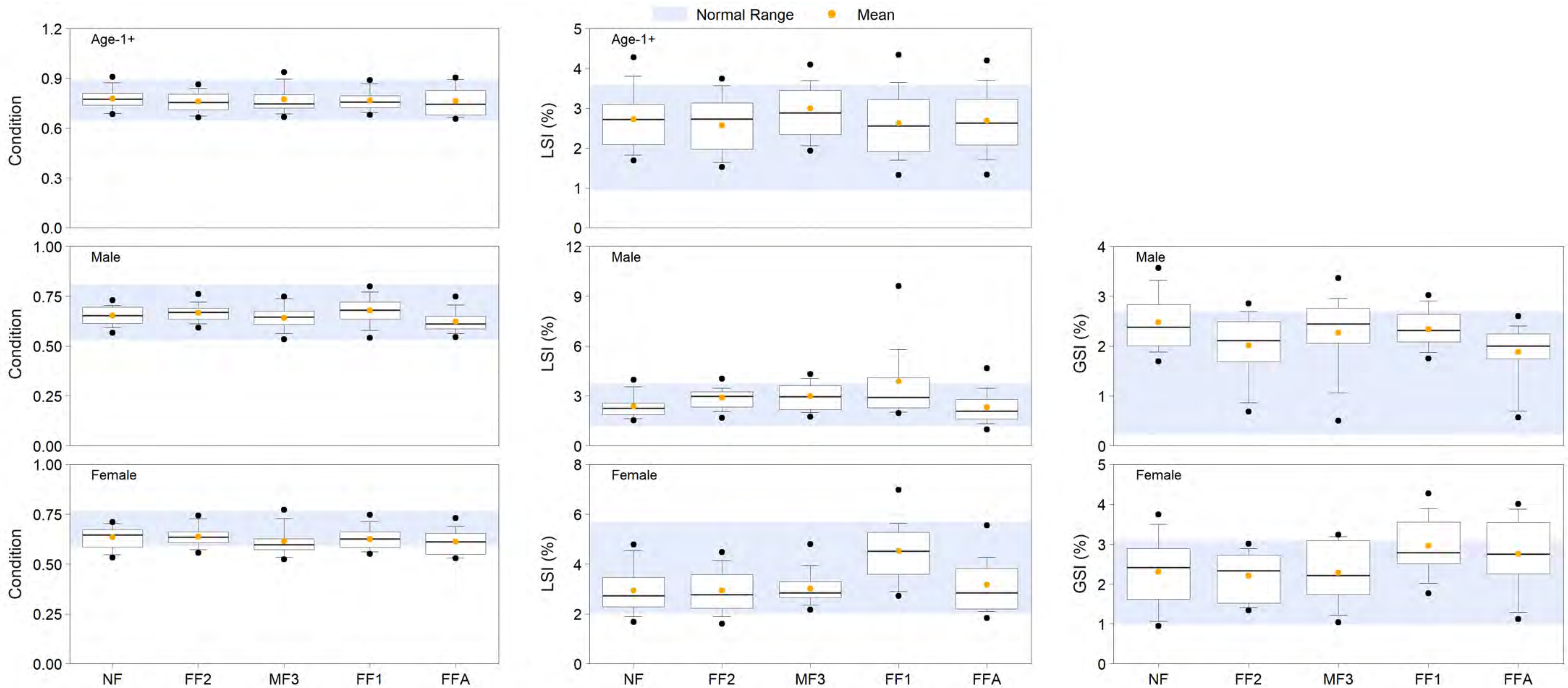
a) Significant interaction, comparison based on response at the maximum value of the covariate.
b) Significant interaction, comparison based on response at the minimum value of the covariate.
Note: all endpoints were within their respective normal ranges.
NF = near-field; FF = far-field.

Figure 8-1 Boxplots of Total Length (Left), Total Weight (Middle), and Carcass Weight (Right) of Slimy Sculpin in Lac de Gras, 2019



NF = near-field; MF = mid-field; FF = far-field.

Figure 8-2 Boxplots of Condition (Left), Liversomatic Index (LSI; Middle), and Gonadosomatic Index (GSI; Right) of Slimy Sculpin in Lac de Gras, 2019



NF = near-field; MF = mid-field; FF = far-field; LSI = liversomatic index; GSI = gonadosomatic index.

8.3.2 Fish Tissue Chemistry

Slimy Sculpin from the NF area had greater concentrations of lead, molybdenum, silver, strontium, uranium, and vanadium compared to the FF areas, and exceeded normal ranges for molybdenum, silver, strontium, and uranium (Figure 8-3). Similar differences were observed in the MF areas for lead, molybdenum, strontium and uranium, which were significantly greater and exceeded normal ranges in either the FF2 or MF3 area.

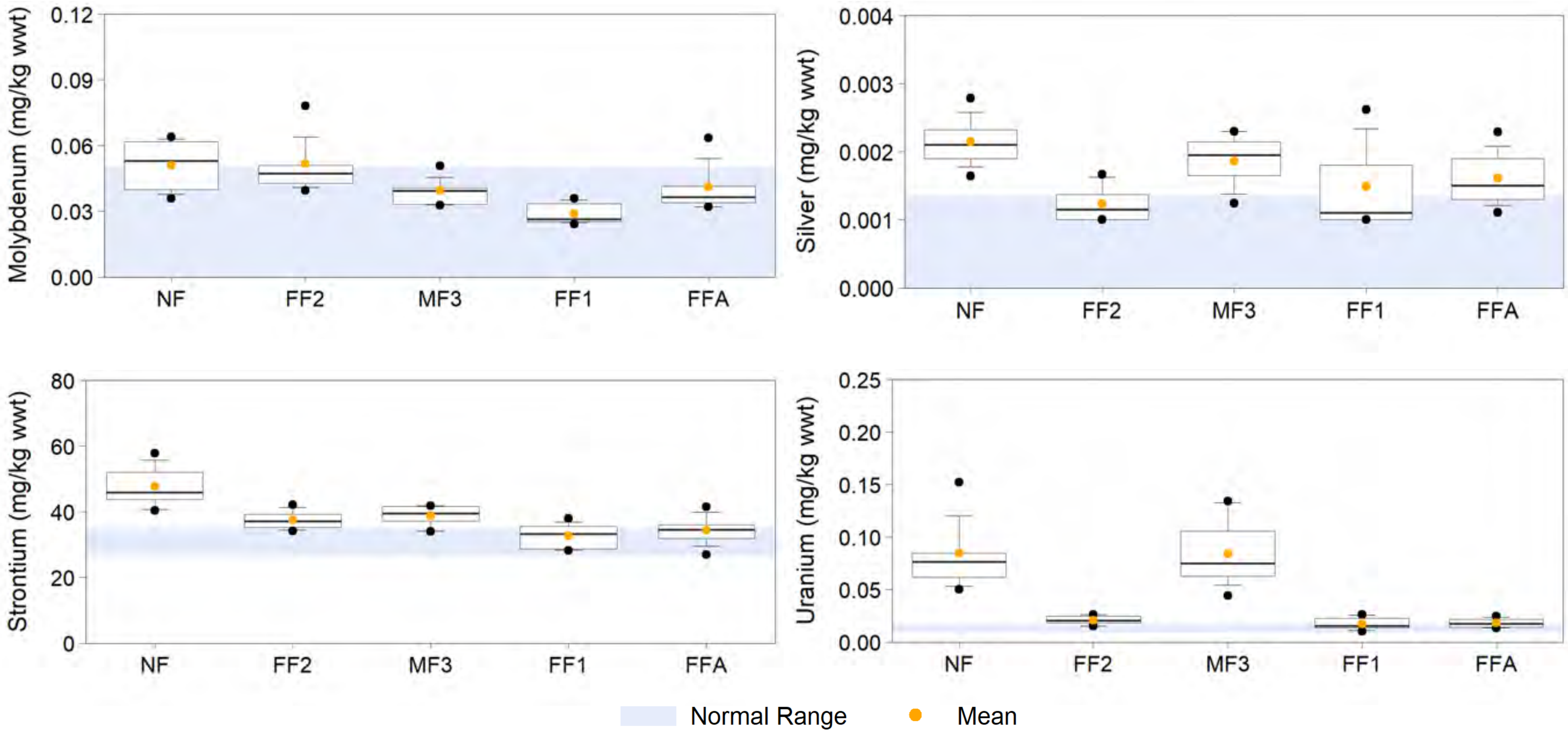
Concentrations of molybdenum, strontium and uranium were also greater in surface water in the NF and MF areas when compared to reference conditions, and triggered Action Level 2 for water quality (Section 3.3.5 in the *Effluent and Water Chemistry Report* [Appendix II]). Water quality Action Level triggers were not observed for lead, silver or vanadium. Concentrations of molybdenum and uranium were also greater in sediment in 2019 (Sediment Report [Appendix III]). Molybdenum concentrations in fish tissue have increased by 34% since 2013, while tissue concentrations of lead, silver, strontium, uranium, and vanadium have remained stable over time (Table 8-3). Considering the slight increase in molybdenum and relatively stable concentrations of lead, silver, strontium, uranium, and vanadium over time, it is unlikely the response patterns observed in fish health were linked to concentrations of these metals in fish tissue.

Table 8-3 Mean Concentrations of Elevated Metals in NF Fish Tissue Over Time, 2019

Variable	Units	2013	2016	2019
Lead	mg/kg wwt	0.012 (117%)	0.005 (na)	0.014 (68%)
Molybdenum	mg/kg wwt	0.038 (32%)	0.041 (60%)	0.051 (45%)
Silver	mg/kg wwt	0.002 (28%)	0.001 (na)	0.002 (51%)
Strontium	mg/kg wwt	46.4 (33%)	46.1 (21%)	47.8 (43%)
Uranium	mg/kg wwt	0.108 (719%)	0.047 (410%)	0.085 (356%)
Vanadium	mg/kg wwt	0.04 (4%)	0.03 (9.1%)	0.05 (34%)

Note: magnitude of difference relative to the far-field areas in the respective year indicated in brackets.
mg/kg wwt = milligrams per kilogram wet weight; na = magnitude not calculated.

Figure 8-3 Normal Range and Boxplots for Concentrations of Molybdenum, Silver, Strontium, and Uranium, Concentrations in Slimy Sculpin Tissue in Lac de Gras, 2019



mg/kg wwt = milligrams per kilogram wet weight; NF = near-field; MF = mid-field; FF = far-field.

9 FISHERIES AUTHORIZATION AND SPECIAL EFFECTS STUDIES

9.1 Plume Delineation Survey

Plume delineation surveys did not take place in 2019. Consequently, Appendix VI is a place-holder in this AEMP Annual Report.

9.2 Fisheries Authorization Studies

9.2.1 Dike Monitoring Studies

Dike monitoring did not take place in 2019. Consequently, Appendix VII is a place-holder in this AEMP Annual Report.

9.2.2 Fish Salvage Programs

A fish salvage program did not take place in 2019. Consequently, Appendix VIII is a place-holder in this AEMP Annual Report.

9.2.3 Fish Habitat Compensation Monitoring

A fish habitat compensation monitoring program was not conducted in 2019. Consequently, Appendix IX is a place-holder in this AEMP Annual Report.

9.2.4 Fish Palatability, Fish Health, and Fish Tissue Chemistry Survey

A fish palatability survey was not completed in 2019. Consequently, Appendix X is a place-holder in this AEMP Annual Report. Fish health and fish tissue chemistry information were included as part of the Fish Report (Appendix V).

9.3 AEMP Special Effects Study Reports

9.3.1 Special Effects Study - Dust Deposition

9.3.1.1 Introduction and Objectives

Although water quality and biological monitoring results to date have not shown a clear dust-related effect, concerns have been raised by reviewers that dust-related effects on water quality in Lac de Gras are not being fully addressed by the design of the AEMP. The concerns about dust are partially based on the imprecise estimates of phosphorus loading from dust that suggest Mine-generated dust contributes an appreciable loading of TP to Lac de Gras (e.g., Attachment D in the *Eutrophication Indicators Report* [Appendix XIII]). These concerns led to the WLWB issuing Decisions #3A and #3D in 2019:

- Decision #3A from the 25 March 2019 Directive: "*The Board directs DDMI to consider how to better detect and evaluate the influence of dust deposition on water quality in Version 5.1 of the AEMP Design Plan. This consideration should include a discussion of whether improvements to the dust monitoring program should be implemented to better quantify loadings from dust versus effluent*".
- Decision #3D from the 25 March 2019 Directive: "*DDMI is informed that the onus is on the company to ensure proper monitoring of mine-related effects and that additional sampling to help tease apart the effects of dust deposition versus effluent on TP concentrations should be considered by DDMI for the 2019 season*".

To address the WLWB Decisions #3A and #3D, the *Special Effects Study – Dust Deposition* (Appendix XII) was conducted in August 2019 to further investigate dust-related effects on water quality and aquatic life in Lac de Gras. The SES was designed to address the following objectives:

- to investigate whether dust and effluent can be differentiated by the use of geochemical signatures
- to evaluate relative influence of Mine-related dust deposition and effluent discharge on water quality in Lac de Gras
- to evaluate the fate of dust-related phosphorus in lake water
- to inform the next Design Plan update in 2020 with respect to the following questions:
  - how to improve the detection and evaluation of the influence of dust deposition on water quality, if necessary
  - how to differentiate between the effects of dust deposition versus effluent on TP concentrations in Lac de Gras

9.3.1.2 Methods

Relationships between major ions, total metals, and nutrients in water were evaluated to identify differences between dust and effluent based sources and to develop geochemical signatures, or fingerprints, for dust and effluent in lake water. The geochemistry evaluation made use of the 2019 snow core chemistry dataset, the 2019 effluent chemistry dataset, the 2019 AEMP water quality and eutrophication indicators dataset, and the 2019 SES water quality and eutrophication indicators dataset.

Water quality and biological data (including indicators of eutrophication) were collected at four stations in Lac de Gras within the dust ZOI. These stations were located closer to potentially high dust generating areas than the AEMP stations, and therefore, would be expected to be more impacted by dust deposition than other stations at a similar distance from the effluent discharge. Concentrations of major ions, metals and eutrophication indicators at these potentially high dust deposition stations were compared to those at nearby AEMP stations subject to the same level of effluent exposure to evaluate whether dust deposition had an additional measurable effect.

Finally, a high level review of the fate of dust-related phosphorus in lake water was performed to evaluate the potential for mobilization of phosphorus from Mine-related dustfall.

9.3.1.3 Results and Discussion

Distinct geochemical signatures could be identified for effluent and dustfall using relationships between major ions and metals. Effluent samples had a calcium-chloride and calcium-sulphate composition whereas the major ion composition of the dustfall samples varied; calcium was generally the major cation, and major anions were bicarbonate, sulphate and chloride (Figure 9-1). The major ion and metal composition of lake water (represented by water quality samples collected as part of the SES and AEMP) and effluent samples generally overlap, but dustfall samples have unique characteristics with respect to the aluminum, calcium, magnesium, silicon, and sulphate content.

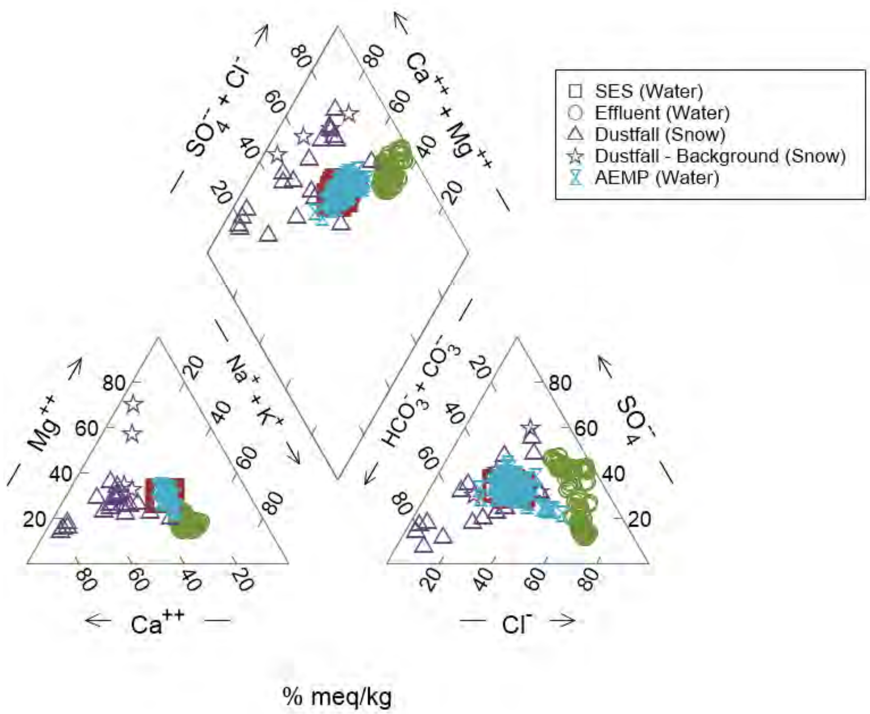
The relationships between potassium and silicon, and magnesium and silicon are well defined, and could be used to fingerprint the influence of dust versus effluent; in general, the molar ratio of major ions to silicon was one order of magnitude greater in effluent than dustfall, and two orders of magnitude greater in lake water than dustfall (Figure 9-2). The molar ratio of aluminum to silicon was not as well defined, and was not consistent with magnesium or potassium; in general, dustfall samples had the highest average molar ratio, followed by lake water samples, then effluent samples (Figure 9-2). Potassium, magnesium and aluminum correlated well with sulphate (Figure 9-3). Similar to silicon, there was an order of magnitude distinction between dustfall versus effluent and lake water molar ratios. The molar ratio of major ions to sulphate was generally one order of magnitude less in effluent than dustfall, and two orders of magnitude less in lake water than dustfall. Although there were some relationships between soluble reactive phosphorus and other key parameters, including aluminum, calcium, and silicon, the relationships were not strong enough to use for the purpose of geochemical fingerprinting.

Overall, the geochemical signature of lake water (represented by water quality samples collected as part of the SES and AEMP) is similar to that of effluent, and the influence of dust could not be differentiated from that of effluent. The influence of dust could not be differentiated in the lake water samples because the SES and AEMP water quality samples formed tight clusters that nearly completely overlapped on all plots, whereas the dustfall samples showed a wider range of variation in major ion and metal chemistry.

With respect to the relative influence of dust vs effluent on water quality in Lac de Gras, the SES did not find evidence that dust deposition affected water quality on top of the effect of Mine effluent discharge. Concentrations of major ions, metals, and nutrients at the SES stations, which were located in potentially high dust generating areas, were similar to those concentrations measured at AEMP stations MF3-1 to MF3-4 (TP and SRP concentrations are shown in Figure 9-4). Chlorophyll *a* concentrations, total phytoplankton biomass, and total zooplankton biomass were also similar between the two areas (Figure 9-4). This finding is consistent with the geochemistry evaluation, which also found that the geochemical signature of lake water is similar to that of effluent.

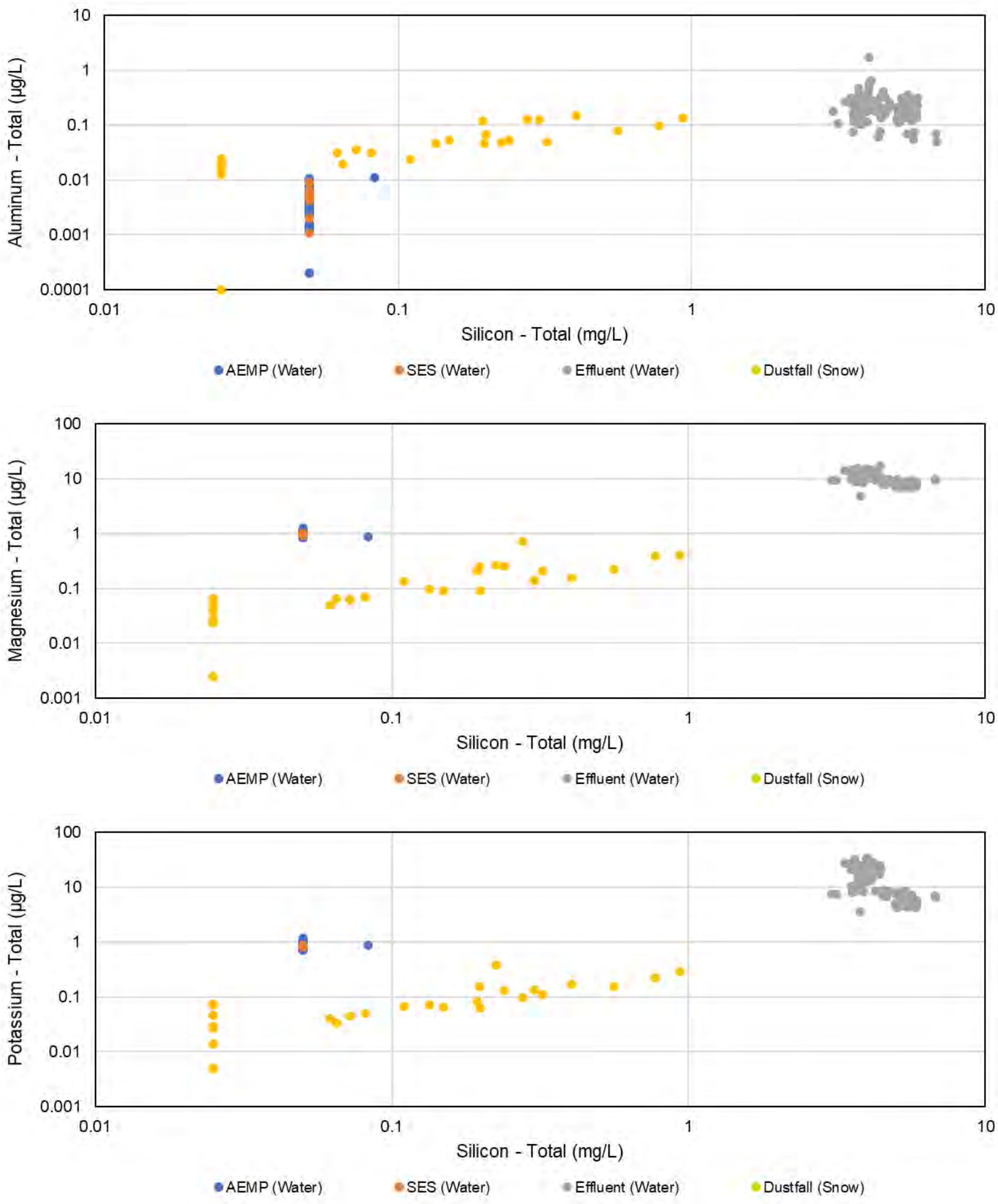
A high level review of the fate of dust-related phosphorus in lake water indicates that the potential for mobilization of phosphorus from Mine-related dustfall is low. It is likely that the mineralogical source of phosphorus in dustfall is the phosphate mineral apatite, which has low solubility in the pH and redox conditions in lake water. Therefore, dust-associated phosphorus is unlikely to dissolve in the lake water and settles to the sediment. Therefore, it is not available for algae to take up and use. This evaluation of the fate of phosphorus in dust supports the observed lack of effects due to phosphorus-related dust on water quality in Lac de Gras, particularly in 2019, when TP concentrations and productivity indicators were lower in Lac de Gras despite a greater estimated phosphorus load from dust compared to 2018.

Figure 9-1 Major Ion Content of Effluent, Dustfall, SES and AEMP Samples, 2019



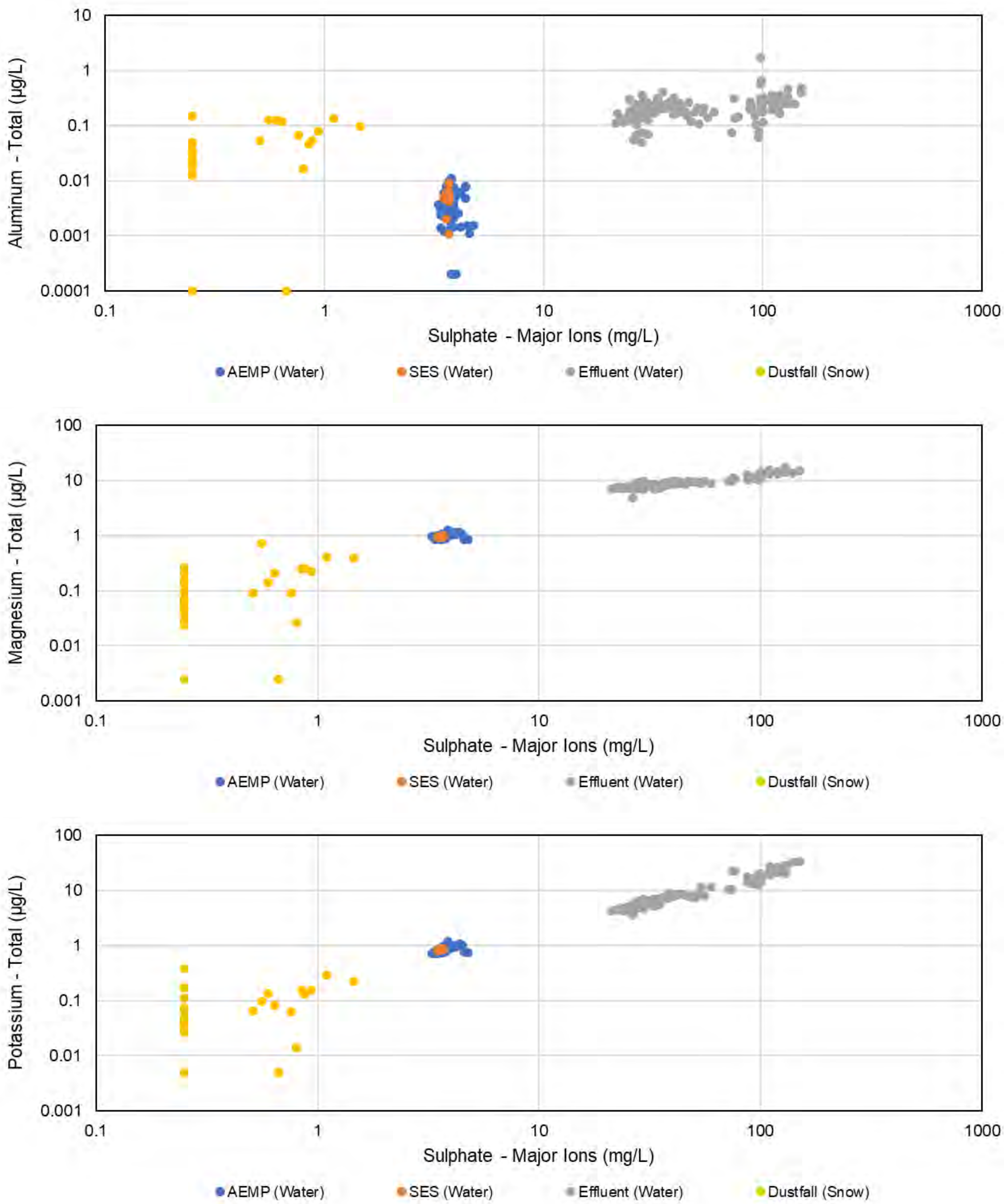
meq/kg = milliequivalents per kilogram.

Figure 9-2 Bivariate Plots of Silicon versus Aluminum, Magnesium and Potassium, 2019



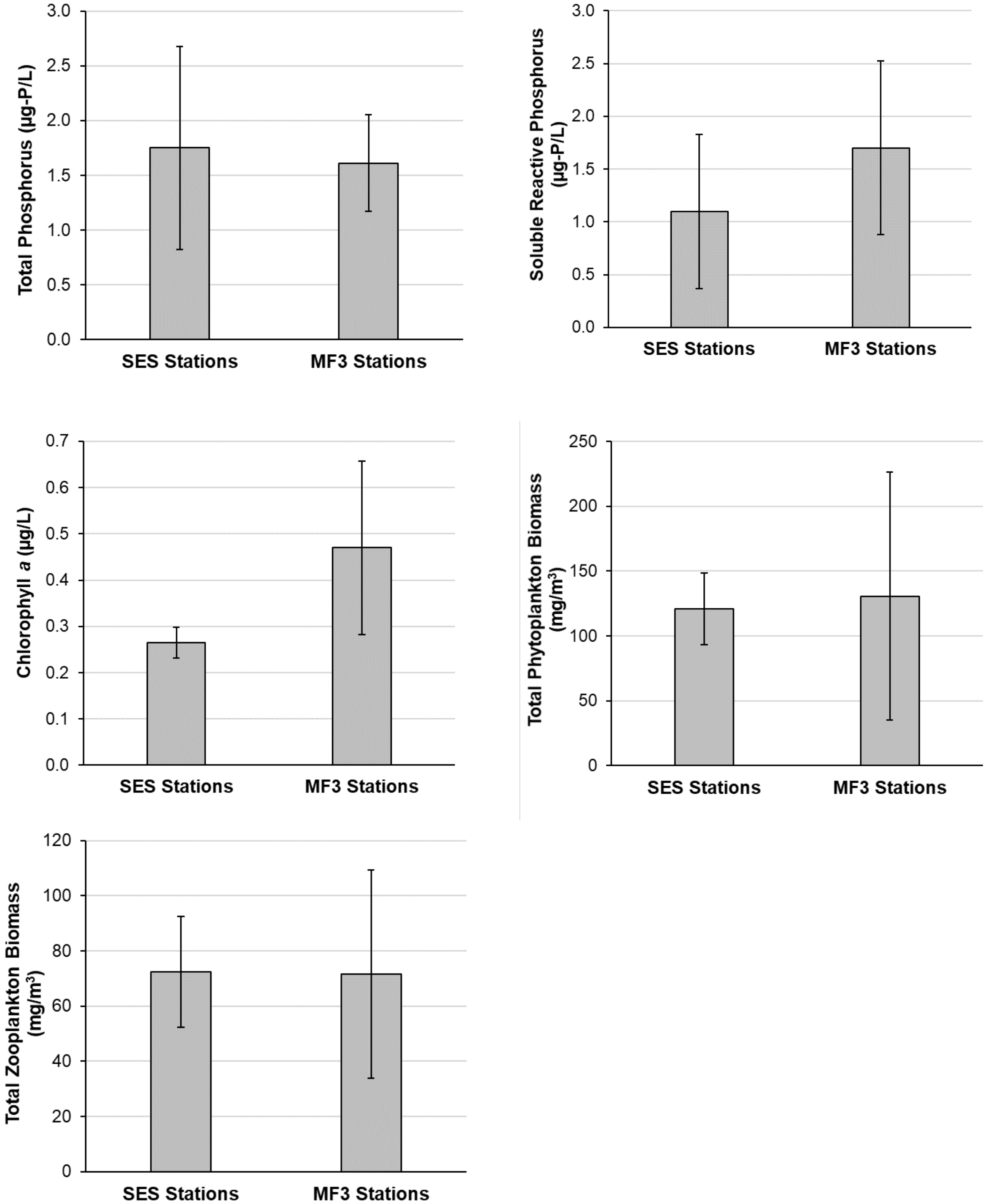
mg/L = milligrams per litre; µg/L = micrograms per litre.

Figure 9-3 Bivariate Plots of Sulphate versus Aluminum, Magnesium and Potassium, 2019



mg/L = milligrams per litre; µg/L = micrograms per litre.

Figure 9-4 Mean Concentrations of Selected Eutrophication indicators at the Special Effect Study Stations and AEMP Stations MF3-1 to MF3-4, 2019



9.3.1.4 Conclusions

The main conclusions of the SES are as follows:

- Effluent and dustfall samples have distinct geochemical signatures.
- The geochemical signature of lake water (represented by water quality samples collected as part of the SES and AEMP) is similar to that of effluent, and the influence of dust could not be differentiated from that of effluent.
- Although the SES stations were located closer to potentially high dust generating areas than the MF3 stations, there was no indication that the SES stations were impacted by dust deposition on top of the effect of the Mine effluent.
- Dissolution of phosphorus-bearing minerals in dustfall is unlikely in the pH and redox conditions in lake water. Therefore, only a small proportion of the estimated phosphorus load in dust is likely to contribute to nutrient enrichment in Lac de Gras, because most of the dust-associated phosphorus is expected to deposit to sediments rather than dissolve and become bioavailable.

Based on the results of the SES, the AEMP sampling design provides sufficient and appropriate data to evaluate the effects in Lac de Gras from all Mine-related sources, including dustfall, and additional sampling effort in Lac de Gras to further investigate dust-related effects is not warranted.

10 TRADITIONAL KNOWLEDGE STUDIES

Traditional knowledge studies did not take place in 2019. Consequently, Appendix XIV is a place-holder in this AEMP Annual Report.

11 WEIGHT-OF-EVIDENCE

11.1 Introduction and Objectives

The objective of the weight-of-evidence (WOE) integration was to bring together the key findings from the 2019 AEMP to make conclusions as to the overall effects observed and whether there is a strong link between the effects observed and the Mine. The two types of effects for Lac de Gras considered in the WOE analysis are:

- **Nutrient Enrichment:** Enrichment could occur due to the release of nutrients (i.e., phosphorus and nitrogen) to Lac de Gras
- **Toxicological Impairment:** Toxicity to aquatic organisms could occur due to chemical contaminants (primarily metals) released to Lac de Gras

Results of AEMP monitoring components were used in the WOE analysis. For each type of impact, the WOE analysis integrated the results of exposure (e.g., water and sediment chemistry) and biological effects (e.g., on plankton, benthic invertebrates or fish). The WOE provided a ranking of the strength of evidence. A higher rank represented a stronger strength of evidence for a Mine-related impact.

The following is a summary of the 2019 WOE analysis. The *Weight-of-Evidence Report* (Appendix XV) provides a more complete analysis and presents detailed results.

11.2 Methods

The WOE analysis begins by summarizing the key findings from each of the 2019 AEMP component results. These are referred to as endpoints, and the endpoints are organized into groups called Lines of Evidence (LOE). Two types of evidence were assessed for each AEMP component to integrate exposure and effects in the WOE:

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

Within each LOE group, multiple endpoints were measured in Lac de Gras. Results that demonstrate a high degree of agreement among several endpoints or among LOE groups provide a stronger WOE regarding potential ecological effects than reliance on a single endpoint. The results from individual AEMP components were rated according to a series of decision criteria and weighted to reflect the strength and relevance of the evidence they brought to the assessment.

The effect rating and the before and after weighting were then combined in the calculation of an overall evidence of impact (EOI) ranking. The EOI ranking provides an indication of the strength of evidence associated with apparent impacts to a particular ecosystem component.

The following summarizes the EOI ranking scheme used:

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

A full description of the process used to integrate the findings from the different AEMP endpoints and the weightings applied can be found in the *Weight-of-Evidence Report* (Appendix XV).

11.3 Results and Discussion

11.3.1 Toxicological Impairment Hypothesis

The AEMP findings for water quality, sediment quality, and fish tissue chemistry indicate that effluent releases from the Mine have resulted in increases in the concentrations of metals and other potentially toxic substances in Lac de Gras. In some cases, the observed concentrations exceeded the normal range, but none of the observed exposure concentrations exceeded Effects Benchmarks, or reached concentrations that would be considered to have toxic effects.

For 2019, toxicological impairment effects to lake productivity (i.e., primary productivity and the plankton community) and benthic invertebrates were not apparent (Table 11-1). The pattern of response in fish health endpoints measured for Slimy Sculpin in the NF area included smaller body size and a greater condition factor for age-1+ fish compared to the FF areas. Although body size changes were in the direction of a toxicological impairment response, increased condition factor does not support the Toxicological Impairment hypothesis. Fish population health responses for 2019 were inconsistent and are likely due to natural variability in Lac de Gras.

Based on the results of the Toxicological Impairment WOE analysis, EOI Rankings were developed for lake productivity, benthic invertebrate community, and fish community in Lac de Gras, and are summarized below (Table 11-1):

- Lake Productivity: EOI Rank 0 (Negligible)
  - Exposure: Greater concentrations of sixteen effluent SOIs in the water column of the NF area compared to FF areas, presence of gradients in concentrations, and concentrations above normal ranges.
  - Biological Response: Minor shift in zooplankton community structure may be consistent with the Toxicological Impairment hypothesis; however, this response is likely to be due to nutrient enrichment, and in line with other responses in the LOE group (i.e., chlorophyll *a* and zooplankton biomass).

- Benthic Invertebrate Community: EOI Rank 0 (Negligible)
  - Exposure: Greater concentrations of twelve parameters in sediments in the NF area relative to FF areas.
  - Biological Response: There was increased effluent exposure in the NF area, which extended along the MF transects. Richness, Pisidiidae density and *Micropsectra* density exhibited significant increasing gradients with distance from the diffusers along one of three transects, but NF area values remained within normal ranges. A community shift towards increased midge dominance and changes in dominance was also observed along the MF3 transect. No significant differences were observed between the NF area mean and the reference condition mean in the direction consistent with toxicological impairment for any of the benthic invertebrate variables.
- Fish Community: EOI Rank 2 (Moderate)
  - Exposure: Tissue concentrations of six metals were significantly greater in the NF area compared to the FF areas; lead and vanadium concentrations did not exceed normal ranges in the NF area. Molybdenum concentrations exceeded the normal range in the NF area, but not the MF area. Silver, strontium and uranium had tissue concentrations in the NF and MF areas that were greater than the normal range.
  - Biological Response: Significantly smaller size at age (i.e., decreased growth) in the NF area relative to FF area or reference condition may be a result of toxicological impairment whereas increase in energy store (condition factor) in NF area is supportive of Nutrient Enrichment hypothesis.

Table 11-1 Weight-of-Evidence Results, 2019

Ecosystem Component	Exposure LOE			Biological Response LOE			Total Score	EOI Ranking
	Key Endpoint(s)[(a)]	Effect Rating	Weighted Score	Key Endpoint(s)[(a)]	Effect Rating	Weighted Score		
Toxicological Impairment								
Lake Productivity	Water Quality – several parameters	↑	2.8	Zooplankton Community Structure / Richness	↑/↓	2.8	5.6	**0**
Benthic Invertebrate Community	Sediment Quality – several parameters	↑	5.6	*Procladius* Density[(b)]	↑↑↑	3.8	9.4	**0**
Fish Community	Sculpin Tissue Chemistry – strontium, uranium	↑↑↑	21.1	Growth – Size at Age	↓	6.3	27.3	**2**
Nutrient Enrichment								
Lake Productivity	Water Quality - total nitrogen	↑↑↑	14.1	Zooplankton Biomass (AFDM)	↑↑↑	37.5	51.6	**3**
Benthic Invertebrate Community	Water Quality - total nitrogen	↑↑↑	14.1	*Procladius* Density	↑↑↑	33.8	47.8	**3**
Fish Community	Water Quality - total nitrogen	↑↑↑	11.3	Energy Stores - K	↑	12.5	23.8	**2**

a) These endpoints resulted in the highest weighted score for the ecosystem component.

b) Procladius density weighted score of 3.8 provided the greatest mathematical support for the Toxicological Impairment hypothesis among the biological response LOEs. The next two scores providing greatest mathematical support in this category were associated with Pisidiidae density (weighted score of 3.5), and richness (weighted score of 3.1). The EOI ranting outcome from these two endpoints would also result in negligible support (EOI ranking = 0) for the Toxicological Impairment hypothesis.

AFDM = ash-free dry mass; EOI = evidence of impact; LOE = line of evidence; 0 = Negligible; ↑/↓ = Early warning/low; ↑↑/↓↓ = Moderate; ↑↑↑/↓↓↓ = High; n/a = not applicable.

11.3.2 Nutrient Enrichment Hypothesis

Results suggest that Mine discharge has contributed to changes in lake productivity and the benthic invertebrate community consistent with nutrient enrichment. In the NF area, there appears to be a consistent response between release of nutrients from the Mine and increases in primary productivity in the water column, combined with a zooplankton community shift. This response is also consistent with increases in density of some of the dominant benthic invertebrate taxa, total invertebrate density, and a shift in community structure. Mean zooplankton biomass in the NF area exceeded the upper limit of the normal range, and the area of the lake with biomass above the normal range was greater than 20% of the lake.

Fish health results were inconsistent; the increased primary productivity (i.e., zooplankton biomass) in the NF area suggested the potential for increased food supply to fish that can result in an increase in fish growth, reproduction and energy storage. The smaller size of juvenile fish at the NF area was not consistent with this response and may have been caused by other factors such as natural variation.

Based on the results of the Nutrient Enrichment WOE analysis, EOI Rankings have been derived for lake productivity, benthic invertebrates, and fish population health in Lac de Gras. The EOI Rankings, and key supporting endpoint results and weighting considerations that formed the basis for the rankings are summarized below (Table 11-1):

- Lake Productivity: EOI Rank 3 (Strong)
  - Exposure: Concentrations of TN in water in the NF area exceeded the upper bound of the normal range and the extent of the affected area covered most of the lake. Declining concentration gradients were detected in nitrogen variables and SRP with increasing distance from the effluent discharge. Because phosphorus is the limiting nutrient in Lac de Gras, the increase in TN is not expected to result in a nutrient enrichment effect in the Lake. Given challenges in measuring TP (e.g., concentrations close to detection limits, lack of response due to timing of TP measurements and large TP uptake due to large consumption rate of plankton communities), spatial trends and gradients observed in SRP may be more sensitive and reliable indicator of nutrient enrichment in comparison to TP and TN.
  - Biological Response: Chlorophyll *a* concentrations were greater in the NF area compared to the FF areas, decreasing with distance from the Mine. However, the mean concentrations in the NF area were within the normal range.
- Benthic Invertebrate Community: EOI Rank 3 (Strong)
  - Exposure: Chlorophyll *a* concentrations were significantly greater in the NF area compared to the FF areas and there was a significant gradient along the MF1 and MF3 transects. However, the mean concentrations in the NF area were within the normal range.
  - Biological Response: *Procladius, Heterotrissocladius* and *Microtendipes* densities exhibited significant decreasing gradients with distance from the diffusers. Mean *Procladius* and *Microtendipes* densities exceeded the upper limit of the normal range in the NF area, and this spatial pattern extended into the MF and some FF areas, respectively.

- Fish Community: EOI Rank 2 (Moderate)
  - Chlorophyll *a* concentrations were significantly greater in the NF area compared to the FF areas and there was a significant gradient along the MF1 and MF3 transects. However, the mean concentrations in the NF area were within the normal range.
  - Biological Response: smaller size at age (i.e., decreased growth) in the NF area relative to FF area or reference condition may be a result of toxicological impairment whereas increase in energy store (condition factor) in NF area relative to reference conditions is supportive of the Nutrient Enrichment hypothesis.

12 ADAPTIVE MANAGEMENT RESPONSE ACTIONS

A summary of the adaptive management responses and actions for each section of the 2019 AEMP comprehensive report are summarized below.

Dust Deposition

There are no Action Levels for Dust Deposition in the Response Framework.

Effluent and Water Chemistry

Water quality variables were assessed for a Mine-related effect according to Action Levels in the Response Framework. Sixteen variables triggered Action Level 1. No management action is required under the Response Framework when a variable triggers Action Level 1. Of the 16 variables that triggered Action Level 1, nine also triggered Action Level 2. The required management action when a water quality variable triggers Action Level 2 is to establish an AEMP Effects Benchmark for that variable if one does not already exist. All nine variables that triggered Action Level 2 have existing Effects Benchmarks; therefore, no action was required. No water quality variables triggered Action Level 3 in 2019.

Eutrophication Indicators

Current conditions indicate that no Action Levels have been triggered for eutrophication indicators based on chlorophyll *a* results. Therefore, no further action is required.

Sediment Chemistry

Of the 12 sediment quality SOIs evaluated, total bismuth, total molybdenum and total uranium triggered an Action Level. Total bismuth was the only SOI to trigger Action Level 2, which requires establishment of an effects benchmark; total molybdenum and total uranium triggered Action Level 1, which represents an early warning change. Establishing a bismuth effect benchmark was attempted in the *AEMP Design Plan Version 4.1* (Golder 2017a); however, based on a review of the toxicological literature, data suitable for developing a numerical sediment quality guideline or benchmark for bismuth were not available. Therefore, a sediment effects benchmark could not be developed. Based on the lack of toxicological guidelines for bismuth for surface waters and the relatively low aquatic toxicity of bismuth documented in the available literature, this metal was not considered to be a constituent of concern in Lac de Gras sediments. No follow-up action in response to the Action Level 2 trigger for total bismuth is anticipated.

Plankton

No Action Levels were triggered for plankton based on total phytoplankton and zooplankton biomass and zooplankton taxonomic richness results. Therefore, no further action is required.

Phytoplankton taxonomic richness, in all areas of Lac de Gras, was below the reference condition mean and the normal range. However, the QC evaluation of the 2019 phytoplankton data suggested that the 2019 data should be interpreted with caution, and for taxonomic richness, comparison of 2019 data to previous years' results is unreliable.

Benthic Invertebrates

The 2019 benthic invertebrate monitoring results did not meet the criteria for biological Action Level 1 (toxicological impairment), for any of the benthic invertebrate variables analyzed. There were no significant differences in benthic invertebrate community variables between the NF area mean and the reference condition mean in a direction that would be consistent with toxicological impairment.

Fish

Age-1+ in the NF area were significantly shorter and lighter (i.e., total length, total weight and carcass weight) with greater liver weight when compared to reference conditions. These results triggered Action Level 1 for toxicological impairment. Age-1+ fish in the MF area were also significantly smaller (i.e., carcass weight) with greater relative liver weight when compared to reference conditions. These results triggered Action Level 2 for toxicological impairment.

While adult male and female Slimy Sculpin in both the NF and MF areas exhibited larger gonad sizes relative to reference conditions, an increase in gonad size is not considered indicative of a toxicological response and was, therefore, not considered part of the Action Level triggers. Similarly, increased condition of Age-1+ fish is not considered indicative of a toxicological response and was not considered part of the Action Level 1 trigger. Of the examined fish health variables, none had area-specific mean values beyond the normal range as defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). Therefore, Action Level 3 was not triggered in 2019.

Action level 2 was previously triggered during the 2016 AEMP based on similar differences observed in Slimy Sculpin length, weight and relative liver size and further described in the *2014 to 2016 AEMP Response Plan Fish* (Golder 2017c). Factors contributing to these differences were evaluated in the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017d), which concluded that differences in fish size and relative liver weight were inconsistent with a Mine effect, and likely driven by localized habitat variation among study areas. Given the direction and magnitude of the differences observed in 2019 in Age 1+ fish are consistent with those reported previously and the absence of an Action Level 2 trigger for adult fish in 2019, it is anticipated a new Response Plan is not required at this time.

Fisheries Authorization and Special Effects Studies

There are no Action Levels for the Fisheries Authorization Studies or Special Effects Studies in the Response Framework.

Traditional Knowledge

There are no Action Levels for Traditional Knowledge in the Response Framework.

Weight-of-Evidence

There are no Action Levels for weight-of-evidence in the Response Framework.

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

Conclusions for each section of the 2019 AEMP comprehensive report are summarized below.

Dust Deposition

- Dustfall rates decreased with distance from the Mine, as observed in previous years[2].
- Although there are no dustfall standards for the Northwest Territories, 2019 dustfall rates were below the commercial and industrial objective of 1,924 mg/dm^2/y documented in the Alberta Ambient Air Quality Objectives Guideline (AEP 2019)[2].
- Snow water chemistry variables of interest included aluminum, ammonia, arsenic, cadmium, chromium, copper, lead, nickel, nitrite, phosphorus, and zinc. All 2019 concentrations were below the corresponding EQC values[2]. DDMI compares the measured total metals levels for dust with EQC only because these criteria provide concentrations that can serve as general performance indicators. There is no intention or requirement that snow samples must meet the EQC or Alberta dustfall objectives.
- Comparisons of dustfall rates between the control and control-assessment sites found greater rates of dustfall at the existing control sites; suggesting that dustfall rates at the control sites were potentially affected by the Project and may not reflect background values[3].

Effluent and Water Chemistry

- The 2019 effluent toxicity results indicated that the effluent discharged to Lac de Gras in 2019 was non-toxic[2]; all effluent samples submitted for lethal and sublethal toxicity testing passed test criteria.
- The concentrations of all regulated effluent variables were below applicable EQC values[2].
- Nearly all concentrations (>99%) measured in samples collected at the mixing zone boundary were within the relevant AEMP water quality Effects Benchmarks for the protection of aquatic life and drinking water[2].
- In the ice-cover season, elevated conductivity was measured in the bottom two-thirds of the water column in the NF area, indicating the depth range where the effluent plume was located. During the open-water season, *in situ* water quality measurements were typically uniform throughout the water column[2].
- Concentrations of the majority of variables in samples collected during the 2019 AEMP were below the relevant Effects Benchmarks for the protection of aquatic life and drinking water[2].
- In 2019, 16 water quality variables demonstrated an effect equivalent to Action Level 1 (i.e., TDS [calculated], turbidity, calcium, chloride, magnesium, sodium, sulphate, ammonia, nitrate, aluminum,

[2] This is consistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

[3] This is inconsistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

barium, manganese, molybdenum, silicon, strontium, and uranium) [2], and were included in the list of SOIs.

- Of the 16 SOIs that triggered Action Level 1, nine also triggered Action Level 2 (i.e., TDS [calculated], chloride, sodium, sulphate, ammonia, nitrate, molybdenum, strontium, and uranium; Table 6-1) [2]; these nine variables already have existing Effects Benchmarks.
- None of the SOIs triggered Action Level 3[2].
- Spatial trends of decreasing concentrations with distance from the Mine effluent diffuser were evident for most SOIs[2].
- Most of the SOIs had NF area concentrations that were significantly greater than the FF area concentrations, indicating that the increases observed in the NF area for these variables were related to the Mine effluent discharge[2].
- Eleven variables triggered an effect equivalent to Action Level 1 at one or more of the four MF area stations located within the estimated ZOI from dust deposition from the Mine site; however, all of these SOIs also triggered Action Level 1 for water quality. Analysis of the 2019 AEMP water quality data did not provide clear evidence to suggest an effect of dust deposition from the Mine site on the water quality of Lac de Gras[2].
- Some water quality variables in 2019 exhibited a spatial trend with distance from the Diavik diffusers that reversed as one moves west from the MF3 or FFB areas, indicating the potential for cumulative effects from Diavik and Ekati mines on these variables[2].

Eutrophication Indicators

- The Mine is having a nutrient enrichment effect in Lac de Gras[2], as evidenced by greater nutrient concentrations in the NF area and greater zooplankton biomass.
- Although greater in the NF area compared to the rest of the lake, phosphorus concentrations were below the normal range in Lac de Gras, likely due to lower TP loads from Mine effluent in 2019 compared to previous years. Total phytoplankton biomass and chlorophyll *a* concentrations were also small, which is consistent with the lower phosphorus concentrations.
- Chlorophyll *a* concentrations were greater in the NF area and decreased with distance from the diffuser, and were generally within or below the normal range with the exception of one NF station. No effects were observed on total phytoplankton biomass in 2019.
- Nitrogen concentrations were above the normal range in most of Lac de Gras, with significant decreasing trends in concentrations with distance from the diffuser. Significant decreasing trends were also detected in SRP and SRSi concentrations.
- The extent of effects on TP was 0% of Lac de Gras, based on no concentrations at any station above the normal range[2].

---

[2] This is consistent with observations reported in previous AEMP years, as summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c).

[3] This is inconsistent with observations reported in previous AEMP years, as summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c).

- Considering the elevated TN concentration at LDG-48 during the open-water season, the entire lake was affected using the open-water data, and 484 km^2 or 85% of the lake was affected using the ice-cover data[2].
- The extent of effects on phytoplankton biomass and zooplankton biomass (as AFDM) were 0% and greater than or equal to 29% of Lac de Gras, respectively[2].
- The extent of effects on chlorophyll *a* was greater than or equal to 0.1% of the lake area[2].
- Spatial trends in productivity indicators and concentrations of nutrients were consistent with the Mine effluent being the main source of nutrients[2]. There was no evidence that TP deposited from dust had an additional measurable effect on concentrations of TP or chlorophyll *a* in Lac de Gras, on top of the effect resulting from the Mine effluent discharge.
- The magnitude of the effect on chlorophyll *a* in 2019 did not trigger any Action Levels in the Response Framework[5].
- In 2019, no cumulative effects of the Diavik and Ekati mines were identified for eutrophication indicators.

Sediment Chemistry

- Twelve sediment quality parameters had spatial trends consistent with a Mine-related effect in Lac de Gras and were identified as SOIs (i.e., bismuth, lead, lithium, molybdenum, phosphorus, potassium, sodium, silver, strontium, tin, titanium, and uranium). Three SOIs (i.e., bismuth, lead, and uranium) had significant decreasing trends extending away from the Mine effluent diffuser along all three transects.
- Bismuth, lead, uranium, molybdenum, and strontium had NF median concentrations in sediments that exceeded the upper bound of their respective normal ranges[2].
- Sediment quality monitoring results indicate that effluent discharge is likely the primary source of elevated concentrations of SOIs in bottom sediments[2], although other factors, such as construction of, and seepage from, the dike may also contribute to the observed patterns.
- The toxicological risks associated with elevated bismuth concentrations in the NF area sediments are subject to uncertainty, because no guidelines exist and no sediment toxicity data were available in the primary literature when development of an effects benchmark was attempted (Golder 2017a); however, the lack of regulatory guidelines and the relatively low aquatic toxicity of bismuth documented in the available literature suggest that this metal is not a constituent of concern in Lac de Gras sediments.
- Lead, molybdenum and uranium concentrations are unlikely to pose a toxicological risk to biota based on comparisons to SQGs and information from the primary literature. Benthic invertebrate data collected to date in Lac de Gras do not suggest a toxic effect.

---

[2] This is consistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

[3] This is inconsistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

- Lead, phosphorus and silver are the only SOI in 2019 with applicable SQGs; lead and silver concentrations in Lac de Gras sediments did not exceed CCME or OMOEE guidelines. Phosphorus exceeded the OMOEE LEL at all stations and the SEL at two stations. This is not considered to represent a concern to aquatic life, because phosphorus concentration in Lac de Gras sediments is naturally elevated[2], and it is unlikely that bottom sediments in this lake would be a significant source of phosphorus to the water column.
- Concentrations of a number of other variables in sediments throughout Lac de Gras were above SQGs. These variables have naturally elevated concentrations, and do not exhibit clear spatial trends related to the Mine[2].
- Molybdenum and uranium triggered Action Level 1[4], which represents an early warning change.
- Bismuth triggered Action Level 2, which requires establishment of an effects benchmark. This was attempted in the *AEMP Design Plan Version 4.1* (Golder 2017a) but was not successful due to insufficient toxicological data in the available literature. No follow-up action in response to the Action Level 2 trigger for bismuth is anticipated.

Plankton

- The 2019 monitoring results suggest that the Mine discharge has resulted in a low-level nutrient enrichment effect on the plankton community in Lac de Gras[2].
- Greater zooplankton biomass was observed in the NF area compared to the FF areas, the reference condition mean and the normal range[2].
- The NF area mean values for total phytoplankton and zooplankton biomass and zooplankton taxonomic richness were not significantly less than the reference condition mean, indicating that Action Level 1 was not triggered[2].
- Differences in phytoplankton community composition were not observed between areas within Lac de Gras, or between Lac de Gras and Lac du Sauvage, based on multivariate analysis[3].
- Differences in zooplankton community composition between Lac de Gras and Lac du Sauvage, and between the NF and FF areas in Lac de Gras, were revealed by multivariate analysis: stations along the MF transects closer to the NF area were similar, while the stations along the MF3 transect from MF3-4 to MF3-7 and station MF1-5 were similar to the FF area[2].
- The QC evaluation of the 2019 phytoplankton data suggested that the 2019 data should be interpreted with caution, and for taxonomic richness, the comparison of 2019 to previous years is unreliable. Efforts will be made to eliminate the phytoplankton data quality issue documented in 2019 in future years.

---

[2]This is consistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

[3]This is inconsistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

[4] Action Levels were not defined, and therefore not applied to sediment quality in 2016.

Benthic Invertebrates

- The 2019 monitoring results suggest that the Mine discharge has resulted in a low level nutrient enrichment effect on the benthic invertebrate community in Lac de Gras[2].
- All analyzed variables in the NF area (and in some of the FF areas) were within or above their respective normal ranges. Densities of Pisidiidae and three of the five dominant midges were above normal ranges[2].
- Overall significant differences among sampling areas were observed in total density, dominance, Simpson's diversity index, *Procladius* density and *Microtendipes* density. However, in all cases where a significant difference was detected, the NF area mean was observed to fall in an intermediate position between FF area means[3].
- Decreasing trends with distance from the diffuser were observed along the MF3 gradient for the majority of density variables analyzed, and evenness. Increasing trends were observed along MF transects MF1 or MF2 for richness, Pisidiidae density and *Micropsectra* density.
- Similarities in community composition among the NF, MF1, MF2-FF2 and FF1 areas were revealed by multivariate analysis[2]; the benthic invertebrate communities in these areas were different compared to the FFA and FFB areas, and the MF3 area with the exception of the MF3 station closest to the diffusers[3].
- In the NF area, the majority of variables had mean values at or above their respective reference condition mean values. Variables with means below the reference condition mean were not significantly lower[2].
- Results of the benthic invertebrate component of the AEMP are consistent with findings of other AEMP components (i.e., water quality, sediment quality, eutrophication indicators) and indicate minimal risk of toxicological impairment[2].
- No Action Levels were triggered for the benthic invertebrate community based on the 2019 AEMP results. In 2016, Pisidiidae density and evenness triggered Action Level 1 (Golder 2017b).

Fish

- Fish exhibited similar reproductive success and prevalence of internal and external abnormalities among sampling areas[2]. The prevalence of parasites, specifically tapeworms, varied among areas but was not associated with proximity to the Mine[3].

[2] This is consistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

[3] This is inconsistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

- Relative to the FF areas, significant differences were observed for male gonad weight[3] and female total length[2], total weight[3] and relative liver weight[3] in the NF area. Relative to reference conditions, significant differences were observed for age-1+ total length, total weight, carcass weight, condition, and relative liver weight, as well as male and female gonad size.
- Differences in fish health endpoints were not consistent between NF and the FF areas and reference conditions, with the exception of male gonad weight, suggesting the presence of a temporal interaction (i.e., fish health endpoints in the FF areas appeared to differ in 2019 relative to reference conditions).
- Concentrations of molybdenum[2], silver[3], strontium[2] and uranium[2] were significantly greater when compared to the FF area and exceeded normal range in fish tissue samples collected from the NF and MF areas; however, concentrations of these metals have remained relatively stable since 2013 with the exception of molybdenum, which exhibited a marginal increase of 34%.
- The differences observed in length, weight and relative liver size of juvenile fish between the NF and MF areas compared to reference conditions may be indicative of a toxicological response as defined under the Action Level assessment and triggered Action Level 2 in 2019[2]. Factors contributing to similar effects observed in 2016 were evaluated in the *2014 to 2016 AEMP Response Plan Fish* (Golder 2017c) and *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017d), which concluded that differences in fish size and relative liver weight were inconsistent with a Mine effect, and likely driven by localized habitat variation among study areas.

Weight-of-Evidence

- Comparison of the EOI Rankings indicates that the evidence for a response to nutrient enrichment in Lac de Gras is much stronger than the evidence for toxicological impairment. There appears to be a clear link between nutrient releases to Lac de Gras as a result of Mine effluent, higher nutrient concentrations in the NF area, and greater lake productivity in the NF area. There is also a consistent response of higher invertebrate density and a mild community shift in the benthic invertebrate community that can be linked to the observed enrichment[2].
- The magnitude and type of response in Lac de Gras appears to be an increase in lake productivity due to nutrient enrichment. Although there are statistically significant differences between the NF (and in some cases MF) areas and the FF areas for indicators of enrichment, the severity with respect to the ecological integrity of Lac de Gras associated with these changes appears be low[2].
- In the case of fish population health, decreased size at age (i.e., decreased growth) in the NF area relative to FF area or reference condition may be a result of toxicological impairment[2], whereas the increase in energy store (condition factor) in NF area relative to reference conditions is supportive of the Nutrient Enrichment hypothesis[3]. The increased primary productivity (i.e., zooplankton biomass) in the NF area suggested the potential for increased food supply to fish that can result in an increase in fish energy stores. The observed decrease in growth at age may be due to random fluctuation or caused by other ecological or abiotic factors[2].

---

[2] This is consistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

[3] This is inconsistent with observations reported in previous AEMP years, as summarized in the ***2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1*** (Golder 2019c).

Special Effects Study – Dust Deposition

- Effluent and dustfall samples have distinct geochemical signatures.
- The geochemical signature of lake water (represented by water quality samples collected as part of the SES and AEMP) is similar to that of effluent, and the influence of dust could not be differentiated from that of effluent.
- Although the SES stations were located closer to potentially high dust generating areas than the MF3 stations, there was no indication that the SES stations were impacted by dust deposition on top of the effect of the Mine effluent.
- Dissolution of phosphorus-bearing minerals in dustfall is unlikely under the pH and redox conditions in lake water.

13.2 Recommendations

Based on the 2019 AEMP results, no recommendations are provided for the dust deposition, effluent and water chemistry, sediment quality, eutrophication indicators, plankton, benthic invertebrates, fish, and weight-of-evidence components of the AEMP.

13.3 Summary

The AEMP is effective at monitoring the Mine effluent discharge and assessing potential ecological risks so that appropriate actions can be taken in the Mine operations to prevent adverse effects from occurring in the environment. Under the Response Framework, the AEMP is subject to response actions, if triggered, to confirm, further investigate, or mitigate effects documented by the AEMP. The AEMP design will be updated as new information and findings indicate it necessary, or as directed by the WLWB. No response actions are required as a result of the 2019 AEMP monitoring results.

14 CONTRIBUTORS

This document has been prepared by DDMI in association with ERM, and Golder Calgary AB, Edmonton AB, Whitby, Ottawa and Mississauga ON, Saskatoon SK, Vancouver and Castlegar BC, and Richmond, Australia.

Golder staff included:

Name	Title	Office
Zsolt Kovats, M.Sc.	Project Director; Associate, Senior Aquatic Ecologist	Calgary
Rainie Sharpe, M.Sc., Ph.D.	Project Manager; Senior Ecotoxicologist, Fish Biologist	Edmonton
Carmen Johanson, B.E.	Report Technical Coordinator	Saskatoon
Leah James, M.Sc.	Aquatic Biologist	Calgary
Rebecca Staring, B.A.Sc.	Water Resources Specialist	Mississauga
Kelly Hille, M.Sc.	Aquatic Biologist	Calgary
Kerrie Serben, M.Sc.	Senior Environmental Scientist	Saskatoon
Jill LaPorte, B.Sc.	Aquatic Biologist	Whitby
Sima Usvyatsov, Ph.D.	Biological Scientist	Castlegar
Collin Arens, Ph.D.	Fisheries Biologist, Ecotoxicologist	Edmonton
Breda Rahmanian, M.Sc., BIT	Toxicologist	Edmonton
Golnar Zandpour, M.ET.	Environmental Scientist	Vancouver
Eduardo Richard, M.Sc.	Water Quality Scientist	Edmonton
Kristin Salzsauler, M.Sc.	Associate, Senior Geochemist	Vancouver
Thais Amaral, B.Sc.	Environmental Engineer	Vancouver
Zimu Yu, Ph.D.	Air Quality Scientist	Ottawa
Cameron McNaughton, Ph.D.	Principal Air Quality Consultant	Richmond, Australia

15 REFERENCES

AEP (Alberta Environment and Parks). 2019. Alberta Ambient Air Quality Objectives and Guidelines Summary. Air Policy, 2016, No. 2. Air Policy Branch. Government of Alberta. January 2019. https://open.alberta.ca/dataset/0d2ad470-117e-410f-ba4f-aa352cb02d4d/resource/4ddd8097-6787-43f3-bb4a-908e20f5e8f1/download/aaqo-summary-jan2019.pdf

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, Canada.

DDMI (Diavik Diamond Mines Inc.). 1998. Environmental Effects Report, Fish and Water. Diavik Diamonds Project. Yellowknife, NT, Canada. September 1998.

DDMI. 2003. Lakebed Sediment, Water Quality and Benthic Invertebrate Study – A154 Dike, Mine Water Discharge. Year 1 Results. Version #1. Yellowknife, NT, Canada.

DDMI. 2005. Lakebed Sediment, Water Quality and Benthic Invertebrate Study – A154 Dike Year 2 Results A418 Baseline Results. Yellowknife, NWT.

DDMI. 2007. Lakebed Sediment, Water Quality and Benthic Invertebrate Study – A154 Dike Year 3 Results A418 Year 1 Results. Yellowknife, NT, Canada.

DDMI. 2008. Aquatic Effects Monitoring Program. 2007 Annual Report. Yellowknife, NT. April 2008.

DDMI. 2009. Aquatic Effects Monitoring Program. 2008 Annual Report. Yellowknife, NT. April 2009.

DDMI. 2010. Aquatic Effects Monitoring Program. 2009 Annual Report. Yellowknife, NT. March 2010.

DDMI. 2011a. Aquatic Effects Monitoring Program. 2010 Annual Report. Yellowknife, NT. March 2011.

DDMI. 2011b. Lakebed Sediment, Water Quality and Benthic Invertebrate Study – A154 Dike Year 4 Results A418 Year 2 Results. Version #0. Yellowknife, NT, Canada.

DDMI. 2012. Aquatic Effects Monitoring Program. 2011 Annual Report. Yellowknife, NT. March 2012.

DDMI. 2013. Aquatic Effects Monitoring Program. 2012 Annual Report. Yellowknife, NT. March 2013.

Golder. 2008. Benthic Invertebrate Report in Support of the 2007 AEMP Annual Report for the Diavik Diamond Mine, NWT. Prepared for Diavik Diamond Mines Inc. (DDMI). Yellowknife, NT, Canada

Golder. 2009. Benthic Invertebrate Report in Support of the 2008 AEMP Annual Report for the Diavik Diamond Mine, NWT. Prepared for Diavik Diamond Mines Inc. (DDMI). Yellowknife, NT, Canada.

Golder. 2010. Benthic Invertebrate Report in Support of the 2009 AEMP Annual Report for the Diavik Diamond Mine, NWT. Prepared for Diavik Diamond Mines Inc. (DDMI). Yellowknife, NT, Canada.

Golder. 2011. Benthic Invertebrate Report in Support of the 2010 AEMP Annual Report for the Diavik Diamond Mine, NWT. Prepared for Diavik Diamond Mines Inc. (DDMI). Yellowknife, NT, Canada.

Golder. 2012. Benthic Invertebrate Report in Support of the 2011 AEMP Annual Report for the Diavik Diamond Mine, NWT. Prepared for Diavik Diamond Mines Inc. Yellowknife, NT.

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

Golder. 2014b. Benthic Invertebrate Report in Support of the 2013 AEMP Annual Report for the Diavik Diamond Mine, NWT. Prepared for Diavik Diamond Mines (2012) Inc. (DDMI). Yellowknife, NT, Canada

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

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

Golder. 2016b. Aquatic Effects Monitoring Program. 2015 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. (DDMI). Yellowknife, NT. June 2017.

Golder. 2017b. Aquatic Effects Monitoring Program 2016 Annual Report. Diavik Diamond Mines (2012) Inc. (DDMI). Yellowknife, NT. March 2017.

Golder. 2017c. Diavik Diamond Mines (2012) Inc. – 2014 to 2016 AEMP Response Plan Fish. Yellowknife, NT. June 2017.

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

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

Golder. 2019a. Aquatic Effects Monitoring Program Design Plan Version 5.1, Prepared for Diavik Diamond Mines (2012) Inc. (DDMI) Yellowknife, NT. October 2019.

Golder. 2019b. Aquatic Effects Monitoring Program - Reference Conditions Report, Version 1.4. Prepared for Diavik Diamond Mines (2012) Inc. (DDMI). Yellowknife, NT. July 2019.

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

Golder. 2019d. Aquatic Effects Monitoring Program 2018 Annual Report. Diavik Diamond Mines (2012) Inc. (DDMI). Yellowknife, NT. March 2019.

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

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

Health Canada. 2006. 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. ww.healthcanada.gc.ca/waterquality.

Liber K, Doig LE, White-Sobey SL. 2011. Toxicity of uranium, molybdenum, nickel, and arsenic to *Hyalella azteca* and *Chironomus dilutus* in water-only and spiked-sediment toxicity tests. Ecotoxicol Environ Saf 74:1171–1179.

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, Canada.

Sheppard SC, Sheppard MI, Gallerand MO, Sanipelli B. 2005. Derivation of ecotoxicity thresholds for uranium. Sci Total Environ 79:55-83.

WLWB (Wek'èezhìı Land and Water Board). 2015. Wek'èezhìı Land and Water Board Type A Water Licence #W2015L2-0001, effective October 19, 2015. Yellowknife, NT, Canada.