APPENDIX III
SEDIMENT REPORT

SEDIMENT REPORT IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

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Executive Summary

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2015L2-0001, according to the *AEMP Design Plan Version 4.1* approved by the Wek'èezhìı Land and Water Board (WLWB). This report presents the analysis and interpretation of sediment chemistry data collected during the 2019 field program. The objectives of the sediment quality monitoring component of the AEMP were to assess effects of the Mine effluent on sediment quality in Lac de Gras and to provide supporting environmental information to help interpret findings from the AEMP benthic invertebrate community survey.

Sediment samples were collected from 34 stations in Lac de Gras. Samples were analyzed for moisture content, particle size (sand, silt, clay), total organic carbon, total organic matter, total nitrogen, total phosphorus, and total metals.

Twelve variables (bismuth, lead, lithium, molybdenum, total phosphorus, potassium, silver, sodium, strontium, tin, titanium, and uranium) had spatial trends consistent with a Mine-related effect in Lac de Gras or had an elevated concentration in the near-field (NF) area compared to the far-field (FF) areas. These variables were retained as Substances of Interest (SOIs). Of these twelve variables, total bismuth, total lead, total molybdenum, total strontium and total uranium had NF area median concentrations above normal ranges. With the exception of total phosphorus, all SOIs had a significant decreasing trend with distance from the diffuser along at least one of the three transects extending away form the NF area. Total Bismuth, total lead and total uranium had significant decreasing trend along all three transects. These results indicate that effluent discharge is likely the primary source of these metals in the NF area[1].

Total molybdenum and total uranium triggered Action Level 1, and total bismuth triggered Action Level 2. Action Level 1 is an indication of an early warning change. Action Level 2, however, requires establishment of an effects benchmark if one does not exist. The development of an effects benchmark for bismuth was attempted in the *AEMP Design Plan Version 4.1*, but was not successful due to insufficient toxicological data.

Based on information in the primary literature and available sediment quality guidelines, concentrations of total bismuth, total lead, total molybdenum, total strontium, and total uranium encountered in NF area sediments are considered unlikely to pose a toxicological risk to biota[1]. Benthic invertebrates collected in Lac de Gras do not demonstrate toxicological effects as a result of exposure to SOIs.

Among the SOIs, only total lead, total phosphorus and total silver have applicable sediment quality guidelines. Lead and silver did not exceed the Canadian Council of Ministers of the Environment (CCME) or Ontario Ministry of the Environment and Energy (OMOEE) guidelines in Lac de Gras. Total phosphorus concentration in sediments exceeded the OMOEE lowest effect level guidelines in all samples, and the OMOEE severe effect level in one sample collected in the Far-Field A (FFA) area. Concentrations of several other nutrients and metals in sediments were above sediment quality guidelines in Lac de Gras; however, the variables that exceeded guidelines did so throughout the lake, and had no clear spatial trends related to the Mine[1]. The understanding of sediment quality in Lac de Gras and the Mine-related impacts on sediments have not changed since the last comprehensive year.

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[1] 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).

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
ANOVA	analysis of variance
BV Labs	Bureau Veritas Laboratory (former Maxxam Analytics Inc.)
CCME	Canadian Council of Ministers of the Environment
DDMI	Diavik Diamond Mines (2012) Inc.
DL	detection limit
DQO	data quality objective
FF	far-field
Golder	Golder Associates Ltd.
HSD	honestly significant difference
ISQG	Interim Sediment Quality Guideline
LEL	Lowest Effect Level
Maxxam	Maxxam Analytics Inc.
Mine	Diavik Diamond Mine
MF	mid-field
NF	near-field
OMOEE	Ontario Ministry of the Environment and Energy
P	probability
PC	principal component
PCA	principal component analysis
PEL	Probable Effect Level
QA/QC	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RPD	relative percent difference
SD	standard deviation
SEL	Severe Effect Level
SNP	Surveillance Network Program
SOI	substance of interest
SOP	standard operating procedure
SQG	sediment quality guideline
TOC	total organic carbon
UTM	Universal Transverse Mercator
WLWB	Wek'èezhìı Land and Water Board
WOE	weight-of-evidence

Symbols and Units of Measure

°C	degrees Celsius
±	plus or minus
%	percent
% dw	percent dry weight
<	less than
cm	centimetre
m	metre
mg/kg dw	milligrams per kilogram dry weight
mL	millilitre
mm	millimetre

1 INTRODUCTION

1.1 Background

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2015L2-0001 (WLWB 2015). This report presents the analysis of sediment chemistry data collected during the 2019 field program, which was carried out by DDMI according to the *AEMP Design Plan Version 4.1* (Golder 2017a).

1.2 Objectives

The primary objective of the sediment quality survey is to assess the effects of Diavik Diamond Mine (Mine) effluent on sediment quality. Sediment quality data were analyzed to evaluate whether there were differences in sediment chemistry between (1) areas exposed to Mine-related inputs and (2) reference conditions for Lac de Gras (as defined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019a]), and whether declining gradients in concentrations existed along each of the three transects sampled in Lac de Gras.

The concentrations of metals[2] in sediments provides information regarding the presence of chemical stressors and supports the interpretation of effects observed on benthic invertebrates. Substrate particle size is an important factor influencing benthic invertebrate community structure, and organic carbon aids in assessing the occurrence and potential bioavailability of metals in sediment. Therefore, a secondary objective of the sediment quality survey was to provide supporting environmental information to help interpret findings from the AEMP benthic invertebrate community survey (Benthic Invertebrate Report [Appendix IV]).

1.3 Scope and Approach

The 2019 AEMP sediment quality survey in Lac de Gras was carried out according to the requirements specified in the *AEMP Design Plan Version 4.1* (Golder 2017a) for a comprehensive monitoring year and with consideration of subsequently issued WLWB Directives (e.g., WLWB 2019). The objective of the annual report for a comprehensive year is to assess effects on sediment quality in Lac de Gras and evaluate whether an Action Level has been triggered. A second objective is to provide a spatial analysis of effects, whereby trends in sediment quality variables are assessed in relation to the diffusers in Lac de Gras. Temporal analyses and an assessment of trends over time are provided every three years in the aquatic effects re-evaluation reports rather than in the annual reports.

The focus of the sediment quality assessment provided herein is a gradient analysis, whereby variation in sediment quality along three transects (i.e., MF1, MF2 and MF3) extending away from the NF area is assessed using linear models. Temporal analyses and an assessment of trends over time will be provided in the *2017 to 2019 Aquatic Effects Re-evaluation Report* (to be submitted in 2021).

The sediment chemistry gradient analysis commenced with a graphical evaluation of spatial trends in concentrations of variables among the NF, MF, and FF areas. Those sediment chemistry variables that

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

were identified by graphical evaluation as exhibiting trends consistent with Mine-related effects were selected as Substances of Interest (SOIs). The intent of selecting SOIs is to arrive at a meaningful set of variables that will undergo additional analysis, while limiting analysis of variables that are unlikely to be affected.

The magnitude of effects on SOIs was also assessed by comparing concentrations of sediment quality parameters in the NF area to normal ranges, guidelines and Action Levels. Values that exceed the normal range are greater than what would be considered natural concentrations for Lac de Gras. Although unnatural for this lake, these values do not necessarily represent concentrations that are harmful to aquatic life. Elevated metals concentrations have the potential to impact the benthic invertebrate community; therefore, the importance of effects observed on SOIs was determined by screening SOI concentrations against sediment quality guidelines (CCME 2002; OMOEE 1993). By design, these are conservative guidelines and are considered intentionally overprotective of the aquatic environment (O'Connor 2004).

2 METHODS

2.1 Field Sampling

Sediment sampling at AEMP stations in 2019 was carried out by DDMI staff as part of the comprehensive monitoring program, which is undertaken every third year (Golder 2014a). Sediment sample collections took place between 17 August and 5 September 2019, concurrent with benthic invertebrate sample collections. Relevant sediment quality data from the Mine's 2019 Surveillance Network Program (SNP) were also incorporated herein, as appropriate.

Sediment quality sampling at AEMP stations in 2019 was carried out in the following areas (Table 2-1; Figure 2-1):

- the near-field (NF) area, which consisted of five stations, located near the effluent diffusers
- two mid-field (MF) areas MF1 and MF3, which consisted of three and seven stations, respectively, located along transects extending away from the NF area
- a MF area MF2 and a far-field (FF) area FF2, which consisted of two stations each and were grouped together, because they form a single transect (hereafter referred to as the MF2 area)
- three FF areas FF1, FFB, and FFA, which consisted of five stations each

The AEMP sediment quality stations were located at water depths of approximately 20 m.

Sediment samples were collected with two sampling devices, a gravity-feed core and an Ekman grab, which allowed sampling of different sediment layers, specifically:

- A gravity-feed core sampling device (as described in DDMI SOP SOP-ENVR-003-0702) was used at the AEMP stations to collect sediment samples for analyses of metals, total nitrogen, total phosphorus, total organic carbon (TOC), and total organic matter (TOM). The top 1 cm layer from a minimum of three cores was collected at each AEMP station and placed into a pre-labelled 532 mL WhirlPak™ bag. Samples were mixed thoroughly until the content was uniform in colour and texture, to provide a homogeneous composite sample. Samples were stored at 4°C until they were shipped to the analytical laboratory.

- An Ekman grab (as described in DDMI Standard Operating Procedure [SOP]: SOP ENVR-003-0702) was used at the AEMP stations to collect sediment samples for analyses of particle size, moisture content, TOC, and TOM. A composite sample, consisting of the top 10 to 15 cm of sediment from at least three Ekman grabs, was collected at each station during benthic invertebrate sampling. The material from each of the three grabs was placed in a pre-cleaned plastic bucket and mixed thoroughly. The composite sample was transferred to two pre-labelled 532-mL WhirlPak™ bags and then refrigerated at 4°C for storage and shipping to the analytical laboratory.

Following the WLWB (2019) directive, DDMI has engaged with ECCC on the issue of sediment replication prior to the 2019 AEMP sampling program. The replication in the program exists regarding the sampling areas, with five stations at each area, as per recommendation from EC (1994).

Stations SNP 1645-19a, 1645-19b2, and 1645-19c represent the mixing zone boundary of the North Inlet Water Treatment Plant effluent within Lac de Gras, and are located along the semicircle defined by a 60 m radius from the diffusers. Station 1645-19b2 was established to replace Station 1645-19b after the second diffuser became active in Lac de Gras, and maintains the 60 m radius from the diffusers. Composite sediment samples were collected once at each SNP mixing zone station (top 5 cm from each of three core samples combined) on 15 August 2019. Hereafter, data from these SNP mixing zone stations are collectively referred to as Station SNP-19 in this report.

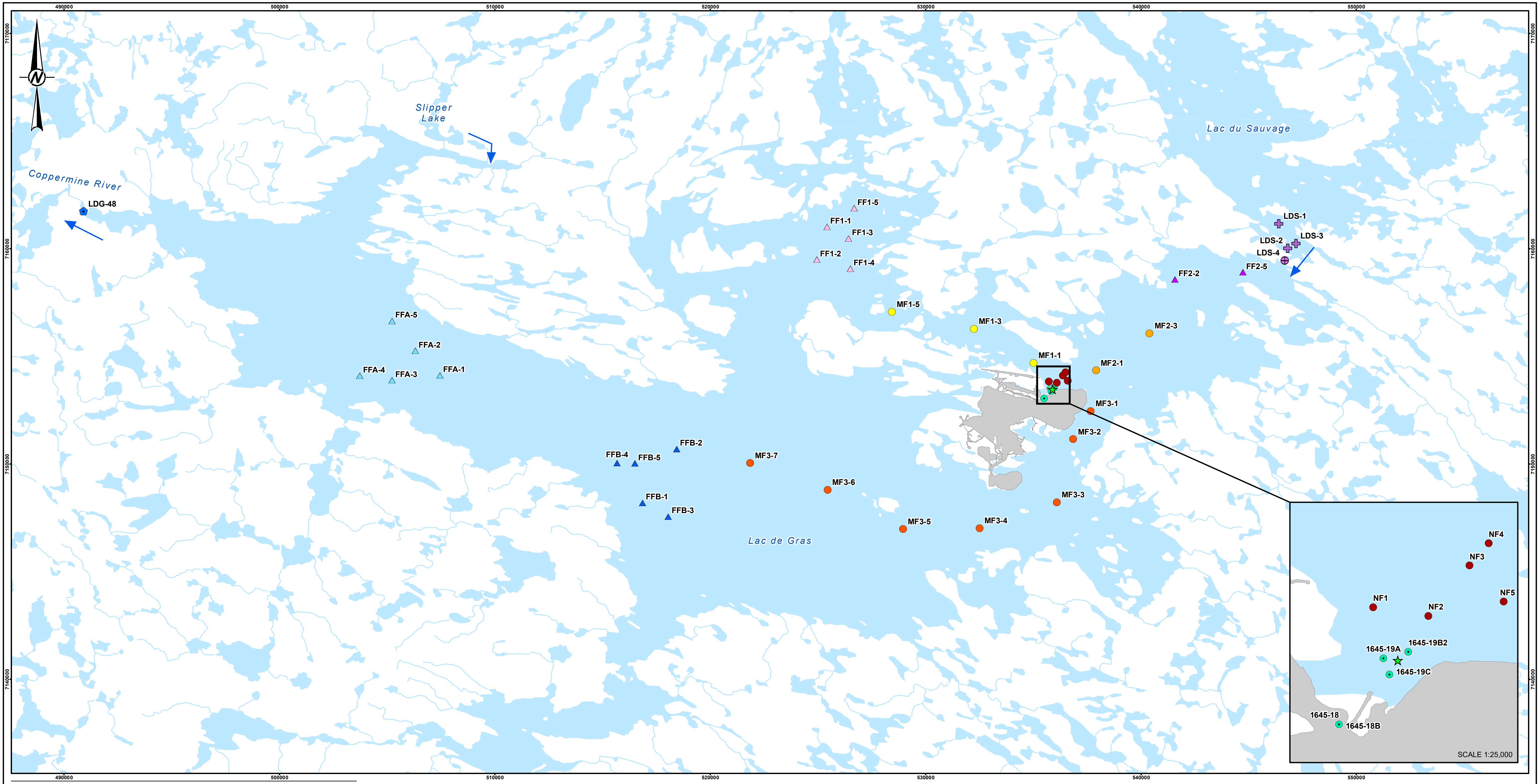
Table 2-1 Locations of AEMP Sediment Quality Monitoring Stations, 2019

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

a) Stations are shown in Figure 2-1.

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

UTM = Universal Transverse Mercator, NAD83, Zone 12V; AEMP = Aquatic Effects Monitoring Program; NF = near-field; MF = mid-field; FF = far-field.



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

→	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
LOCATIONS OF AEMP SEDIMENT QUALITY SAMPLING STATIONS, 2019

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

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2.2 Laboratory Analyses

Sediment samples were shipped to Bureau Veritas Laboratory (BV Labs, formerly Maxxam Analytics Inc.), Burnaby, British Columbia, for analysis of physical and chemical variables. Composite samples collected by the Ekman grab were analyzed for moisture content, TOC, TOM, and particle size distribution (sand: 0.053 to 2 mm; silt: 0.002 to 0.053 mm; and, clay: less than 0.002 mm). Composite sediment core samples were analyzed for nutrients (i.e., total phosphorus and total nitrogen), TOM, TOC, and total metals. Recommended laboratory analytical methods used in these analyses are provided in the *AEMP Design Plan Version 4.1* (Golder 2017a). Detection limits (DLs) achieved by BV Labs in 2019 are provided in Table 2-2, where applicable these DLs were equal to or less than the ones recommended by WLWB (2019).

2.3 Data Analysis

2.3.1 Data Screening

Initial screening of the SNP and AEMP datasets was completed prior to completing data analyses to identify anomalous data (i.e., unusually large or small values); subsequent data analyses following this initial screening determined whether to exclude anomalous data from further analysis. An explanation of the objectives and approach taken to complete the initial screening is provided in the *Quality Assurance Project Plan Version 3.1* (Golder 2017b), or QAPP, and in Attachment A.

Data screening for anomalous values did not identify any anomalous values in the 2019 sediment chemistry dataset (Table A-1). In cases where unusual values were identified during the initial screening, scatter-plots were generated to allow a visual review of the data and provide transparency. This review indicated that spatial trends were not affected by the presence of unusual data. Therefore, no data were excluded from further analysis.

2.3.2 Censored Data

For the purposes of the AEMP, censored data are concentrations of a variable reported below the analytical DL (referred to as non-detect values). A commonly used, simple approach to deal with censored data is the substitution of a surrogate value (e.g., the DL or some fraction of the DL) for non-detect data, which is considered generally acceptable in cases when a relatively small proportion of the data (e.g., less than 15%) are below the DL (US EPA 2000).

Prior to data analyses, non-detect values were replaced with 0.5 times the DL. Substitution with half the DL is consistent with the approved methods applied in the calculation of the normal range in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a). Handling of censored data in the statistical analysis of sediment quality datasets is discussed in Section 2.3.6.3.

Table 2-2 Detection Limits for Sediment Chemistry Analyses, 2019

Variable	Unit	Detection Limit
Particle Size and Moisture Content		
Sand (2.0 mm to 0.053 mm)	% dw	0.01
Silt (0.053 mm to 0.002 mm)	% dw	0.01
Clay (<0.004 mm)	% dw	0.01
Moisture	% dw	0.3
Nutrients		
Total organic carbon	% dw	0.05
Total organic matter	% dw	0.035
Total nitrogen	% dw	0.2
Total phosphorus	mg/kg dw	10
Total Metals		
Aluminum	mg/kg dw	100
Antimony	mg/kg dw	0.1
Arsenic	mg/kg dw	0.2
Barium	mg/kg dw	0.1
Beryllium	mg/kg dw	0.2
Bismuth	mg/kg dw	0.1
Cadmium	mg/kg dw	0.05
Calcium	mg/kg dw	100
Chromium	mg/kg dw	0.5
Cobalt	mg/kg dw	0.1
Copper	mg/kg dw	0.5
Iron	mg/kg dw	100
Lead	mg/kg dw	0.1
Lithium	mg/kg dw	0.5
Magnesium	mg/kg dw	100
Manganese	mg/kg dw	0.2
Mercury	mg/kg dw	0.05
Molybdenum	mg/kg dw	0.1
Nickel	mg/kg dw	0.5
Potassium	mg/kg dw	100
Selenium	mg/kg dw	0.5
Silver	mg/kg dw	0.05
Sodium	mg/kg dw	100
Strontium	mg/kg dw	0.1
Thallium	mg/kg dw	0.05
Tin	mg/kg dw	0.1
Titanium	mg/kg dw	1.0
Uranium	mg/kg dw	0.05
Vanadium	mg/kg dw	1.0
Zinc	mg/kg dw	1.0

dw = dry weight.

2.3.3 Substances of Interest

Following the approach outlined in the *AEMP Design Plan Version 4.1* (Golder 2017a), SOIs were selected based on the initial assessment of raw sediment quality data. All variables with spatial trends consistent with a Mine-related effect in Lac de Gras (i.e., a trend of decreasing concentration with distance from the Mine effluent diffusers, or an elevated concentration in the NF area compared to the FF areas) were retained as SOIs, and subjected to detailed graphical and statistical analyses.

The presence of a gradient of decreasing concentration with distance for the Mine diffuser was assessed by graphical comparison of raw concentrations. Graphical comparisons were made for the full suite of sediment chemistry variables (i.e., nutrients, total metals, TOC, and TOM) analyzed from the top 1 cm of the core samples, and particle-size analysis parameters analyzed from the top 10 to 15 cm Ekman samples. This initial graphical comparison was used to identify variables that exhibited greater concentrations in the NF area compared to the FF areas, and thus to retain these as SOIs. Potential effects from dust deposition were also evaluated at a subset of MF stations which can be found in the Effluent and Water Chemistry Report (Section 2.3.1 Appendix II).

2.3.4 Statistical Analysis

2.3.4.1 Approach

The main objective of the sediment quality statistical analyses was to evaluate spatial trends in SOI concentrations along the three gradients sampled in Lac de Gras. A comparison among the NF exposure area and the three FF areas was also performed (consistent with the analyses for biological variables) using an Analysis of Variance (ANOVA). This approach was taken for all variables retained as SOIs.

2.3.4.2 Normalization

Prior to conducting statistical analyses, the sediment data were normalized to account for the influence physical properties of sediments (i.e., particle-size) and organic matter content on sediment chemistry. Initially, these supporting variables were analyzed to confirm no Mine-related effect was observed, which was confirmed based on a graphical assessment; these variables have not been retained as SOIs in the past (Golder 2019c).

Spearman's coefficient of rank correlation (r_s) was calculated for each SOI against percent fines (i.e., silt + clay) and TOC, and results were considered significant at $P<0.01$. No grouping was performed prior to analysis; therefore, each individual concentration (representing a composite sample from a station) was used in the analysis. Data from the SNP stations were not included in the correlation analysis as there were no particle-size analysis data, and metals were analyzed from a different sediment depth (i.e., top 5 cm vs top 1 cm for AEMP samples). If a significant correlation was observed with more than one parameter, the one with the largest r_s was selected. Negative correlations between percent fines or TOC and the SOIs were not considered for normalization. The analysis was completed using the statistical environment R v. 3.6.0 (R Core Team 2019). Raw data were divided by the concentration of the normalizing factor, where applicable, and this dataset was used for further statistical analyses. If neither of the correlations against percent-fines or TOC met the criteria for significance, the raw data were used for analyses.

2.3.4.3 Gradient Analysis

Spatial gradients in sediment quality variables along the various transects were analyzed using linear regressions, per the *AEMP Design Plan Version 4.1* (Golder 2017a). The NF area data were included in the linear regression for each of the three transects (i.e., MF1, MF2, MF3). Linear regressions were completed using the statistical environment R v. 3.6.0 (R Core Team 2019). All 34 stations were included in the analysis. If appropriate, sediment variables were log-transformed prior to regression analyses and regression analyses were considered significant at $\alpha = 0.1$.

Due to the inherent variability in sediment quality datasets, variables often had non-linear patterns with distance from the diffusers. Therefore, the analysis method allowed for piecewise regression (also referred to as segmented or broken-stick regression). The following approaches were used:

- Model 1: a linear multiplicative model, with main effects of distance from diffusers, gradient (MF1, MF3 transects), and their interactions
- Piecewise modelling to account for changes in spatial gradients, where individual transects were analyzed separately from one another:
  - Model 2: a linear multiplicative model with main effects of distance from diffusers, gradient (MF1 and MF2 transect) and their interaction
  - Model 3: a linear piecewise (broken stick) model with distance (MF3 only)

For each variable, Model 1 was used to test for the presence of a significant ($P<0.05$) breakpoint using the Davies test (Davies 1987, 2002). If a significant breakpoint was identified, Models 2 and 3 were used for that variable in that season. If no significant breakpoint was identified, Model 1 was used.

Following the initial fit of the model, the residuals (of either Model 1 or Model 2, as applicable) were examined for normality. Model 3 was not considered for transformations, since the addition of a breakpoint was expected to resolve non-linear patterns. For each response variable, the data underwent Box-Cox transformations (Box and Cox 1964). The Box-Cox transformations are a family of transformations that include the commonly used log and square root transformations. The Box-Cox transformation process tests a series of power values, usually between -2 and +2, and records the log-likelihood of the relationship between the response and the predictor variables under each transformation. The transformation that maximizes the log-likelihood is the one that will best normalize the data. Therefore, the data are transformed using a power value identified by the transformation process. For a power value of zero, the data are natural log transformed. The transformation rules can be described using the following definitions:

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

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

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

Following data transformation (if required), the selected models were fitted to the data. Statistical outliers were identified using studentized residuals with absolute values of 3.5 or greater, or due to consideration of leverage (where a single point could strongly influence the overall fit of the model). All values removed from the analysis were retained for plots of model predictions, where they were presented using a different symbol from the rest of the data.

Following removal of outliers, breakpoint significance and data transformation was re-examined. Residuals from the refitted models were examined for normality and heteroscedasticity, and evidence of nonlinear patterns. If non-linearity was evident from residual examination, the analysis was terminated and data were presented qualitatively. If normality was evident, then three models were constructed to assess the effect of heteroscedasticity for each response variable:

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

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

The constructed models were used to produce the following outputs:

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

Analyses were performed using the statistical environment R v. 3.6.0 (R Core Team 2019) and package “segmented” (Muggeo 2008).

Based on US EPA (2000) guidance, a screening value of greater than 15% censoring was used to flag datasets that may not be amenable to the linear regression analysis. The decision of whether to analyze the data using linear regression was based on review of the number of values less than the DL according to variable. No sediment SOI had more than 15% censored data. In addition, regression analysis was not performed for any variables that did not meet the linear regression assumption of a linear relationship between x and y. The assumption of linearity was met for all SOIs in 2019, and scatter-plots of concentrations according to distance from the effluent discharge have been included for all SOIs.

2.3.4.4 Near-Field Versus Far-Field Area Comparisons

Testing Assumptions for Analysis of Variance

An ANOVA assumes that data fit the normal distribution, because the residuals (or error terms of the variates) are assumed to fit the normal distribution. If a variable is not normally distributed, there is an increased chance of a false positive (i.e., Type I error). An ANOVA is not sensitive to moderate deviations from normality, because when a large number of random samples are taken from a population, the means of those samples are approximately normally distributed even when the population is not normal (Sokal and Rohlf 1995).

The goodness-of-fit of the data to the normal distribution was tested with the Kolmogorov-Smirnov test. Many data sets that are significantly non-normal will still be appropriate for an ANOVA; therefore, issues with non-normality were only addressed with a *P*-value less than 0.01. Another important assumption of ANOVA is that group variances are equal (i.e., homogeneity of variances). When variances differ markedly, various data transformations will typically remedy the problem. As with normality, the consequences of moderate deviations from the assumption of equal variances do not compromise the overall test of significance by ANOVA.

If the data for a particular variable did not fit the normal distribution, the data were log-transformed and reassessed for normality (the Kolmogorov-Smirnov test) and homogeneity of variances (Bartlett's and Levene's tests).

Analysis of Variance

The means of the four sampling areas (i.e., NF, FF1, FFA and FFB) were compared to one another in an overall ANOVA. Within the overall ANOVA, an *a priori* comparison (i.e., planned contrast) was conducted to test the differences of means among specific areas (e.g., NF area versus the FF areas).

Multiple comparison techniques that were not planned prior to undertaking the analysis (i.e., *a posteriori*) are frequently used when analyzing environmental data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear orthogonal contrasts by formulating meaningful comparisons among treatments (e.g., sampling areas) prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the NF area of Lac de Gras.

In some cases, there were unforeseen differences among the FF areas. To assess this natural variability, the FF areas were also compared statistically to one another, thereby quantifying "natural" differences among different areas of Lac de Gras. Such comparisons are considered unplanned or *a posteriori* comparisons. The procedure used for these comparisons was Tukey's honestly significant difference (HSD) method, also known as the T-method. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). The significance for both planned contrasts and Tukey's HSD was evaluated at $P = 0.1$.

2.3.5 Comparisons to Normal Ranges

Magnitude of effects to sediment chemistry were determined by comparing SOI concentrations in the NF area to the normal range, which represents an estimate of the background range of variation for a variable (Golder 2015). Owing to the potential for the North Inlet Water Treatment Plant effluent to reach the FF areas of Lac de Gras, normal ranges for most previously-identified SOIs were calculated using FF area data collected from 2007 to 2010. Details of the exact method used for each variable are provided in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a) and the normal ranges are summarized in Table 2-3.

Table 2-3 Normal Ranges for Sediment Chemistry

Variable	Unit	Reference Median Value	Normal Range	
			Lower Limit	Upper Limit
Total organic carbon	%	3.0	0.7	4.7
Organic Matter	%	5.1	5.1	1.1
Fine sediment (silt + clay)	%	77.5	29.5	97.0
Total nitrogen	%	0.23	0.05	0.41
Total phosphorus	mg/kg dw	1,100	681	1,650
Aluminum	mg/kg dw	14,950	10,723	18,433
Antimony	mg/kg dw	<0.17	0	0.28
Arsenic	mg/kg dw	53.5	12.99	269.4
Barium	mg/kg dw	121	64.1	263.9
Beryllium	mg/kg dw	0.58	0.38	0.75
Bismuth	mg/kg dw	0.42	0.31	0.59
Boron	mg/kg dw	4.2	2.2	7.0
Cadmium	mg/kg dw	0.41	0.06	1.09
Calcium	mg/kg dw	1,425	800	1,978
Chromium	mg/kg dw	46.5	32.5	67.4
Cobalt	mg/kg dw	56.3	26.89	258.83
Copper	mg/kg dw	57.75	36.68	91.35
Iron	mg/kg dw	43,300	20,463	100,595
Lead	mg/kg dw	7.2	4.5	9.5
Lithium	mg/kg dw	38.5	24.9	54.2
Magnesium	mg/kg dw	6,180	4,180	9,127
Manganese	mg/kg dw	6,360	684.9	57,532.5
Mercury	mg/kg dw	<0.05	0	0.05
Molybdenum	mg/kg dw	3.76	1.85	7.63
Nickel	mg/kg dw	79.4	46.96	268.6
Potassium	mg/kg dw	2,895	1,969	4,644
Selenium	mg/kg dw	0.8	0	1.69
Silver	mg/kg dw	<0.2	0	0.2
Sodium	mg/kg dw	195	100	259
Strontium	mg/kg dw	11.8	6.0	20.8
Thallium	mg/kg dw	0.284	0	0.951
Tin	mg/kg dw	<2	0	2
Titanium	mg/kg dw	677	366	1,066
Uranium	mg/kg dw	4.2	3.0	5.4
Vanadium	mg/kg dw	38.7	27.3	51.8
Zinc	mg/kg dw	95.4	58.1	151.4

Source: *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
mg/kg dw = milligrams per kilogram dry weight.

2.3.6 Comparison of Sediment Chemistry to Sediment Quality Guidelines

Elevated sediment metal concentrations have the potential to influence the benthic invertebrate community. Therefore, sediment variables were screened against Canadian Council of Ministers of the Environment (CCME) and Ontario Ministry of the Environment and Energy (OMOEE) sediment quality guidelines (SQGs) (CCME 2002; OMOEE 1993). The OMOEE guidelines were used in the assessment because they provide a broader set of guidelines for inorganic contaminants. The CCME Interim Sediment Quality Guideline (ISQG) and OMOEE Lowest Effect Level (LEL) represent lower-bound SQGs, concentrations at which adverse biological effects are rare or not expected to occur in the majority of sediment-dwelling organisms. Conversely, the CCME Probable Effects Level (PEL) and OMOEE Severe Effect Level (SEL) represent concentrations at or above which adverse effects frequently occur. As guidelines were developed for the purpose of screening, and not for quantitative evaluation of ecological risk, exceedances of one or more guidelines should not be interpreted as a direct indication of probability or magnitude of harm. By design, these are conservative guidelines and are considered intentionally overprotective of the aquatic environment (O'Connor 2004). If concentrations are below SQGs, there is likely negligible ecological risk.

Effects of the Mine on the incidence of SQG exceedances in Lac de Gras were evaluated to determine whether the Mine discharge has resulted in a greater number of SQG exceedances in the NF area compared to FF areas of Lac de Gras. This was done by comparing the percentage of exceedances observed in the NF area with those in the FF areas.

2.4 Action Level Evaluation

Sediment quality variables were assessed for a Mine-related effect as described in the *AEMP Design Plan Version 4.1* (Golder 2017a) Response Framework. Although no predictions specific to sediment quality were made during the EA, it was predicted that there would be no toxic effects to aquatic biota in Lac de Gras. The Action Levels for sediment quality were developed following the same logic as the water quality component; water quality Action Levels were set to be relatively sensitive to the first indication of Mine influence on water chemistry. This is also appropriate for sediment, as changes in sediment chemistry have the potential to affect the benthic invertebrate community.

The main goal of the Response Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at pre-defined Action Levels, which are triggered well before significant adverse effects could occur. The Action Levels for sediment chemistry are provided in Table 2-4.

Magnitude of effects to sediment chemistry variables was determined by comparing concentrations of parameters between NF, MF, and FF sampling areas, reference conditions, and benchmark values. Reference conditions for Lac de Gras are defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a) and are considered to represent the range of natural variability, referred to as the normal range. The magnitude of effect was classified according to the appropriate Action Level as described in Table 2-4.

Box and whisker plots were generated for SOIs that triggered an Action Level, to illustrate spatial variation in sediment quality in Lac de Gras and to present the 2019 results relative to the Action Levels. The box was bound by the 25th and 75th quantiles, with a thick line showing the median value. The whiskers depicted the 10th and 90th quantiles, and points were used to show the 5th and 95th quantiles. Non-detect values were plotted at half the DL, to be consistent with data handling procedures used in the evaluation of Action Levels and the estimation of the normal range (Golder 2019a).

Table 2-4 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 2019a).

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.

2.5 Quality Assurance/Quality Control

The *Quality Assurance Project Plan Version 3.1* (QAPP; Golder 2017b) details the quality assurance and quality control (QA/QC) procedures employed to support the collection of scientifically-defensible and relevant data for the AEMP (Golder 2017b). The QAPP represents an expansion of the SNP QA/QC plan. It facilitates creation of a technically-sound and scientifically-defensible report by standardizing field sampling methods, laboratory analysis methods, data entry and storage, data analysis and report preparation activities.

A description of QA/QC practices applied to the sediment quality component of the 2019 AEMP and an evaluation of the QC data are provided in Attachment C. Based on the results of the QA/QC analysis, the sediment quality data collected were deemed to be of acceptable quality for the purposes of the program

2.6 Weight-of-Evidence Input

The results of the sediment survey are integrated through the weight-of-evidence (WOE) analysis to determine the strength of evidence supporting the two broad impact hypotheses for Lac de Gras (i.e., nutrient enrichment and toxicological impairment), as described in the *AEMP Design Plan Version 4.1* (Golder 2017a). The WOE is not intended to determine the ecological significance or level of concern associated with a given change, and is described fully in the Weight-of-Evidence Report (Appendix XV).

3 RESULTS

3.1 Substances of Interest

Based on the criteria outlined in Section 2.3.3, the following twelve parameters were retained as SOIs in the 2019 sediment quality dataset:

- total bismuth
- total molybdenum
- total silver
- total tin
- total lead
- total phosphorus
- total sodium
- total titanium
- total lithium
- total potassium
- total strontium
- total uranium

Eight out of 12 parameters (i.e. total bismuth, total lead, total molybdenum, total potassium, total sodium, total strontium, total tin and total uranium) had been retained as SOIs in 2016 (Golder 2017c). Following the same approach used in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c), total phosphorus was retained as an SOI to assess a potential effect of nutrient discharges to Lac de Gras on sediment quality. A spatial trend in the raw total phosphorus data was not evident upon initial review, however given the relevance of the parameter to the type of Mine-related effect that has been observed in Lac de Gras, it was retained as an SOI. The greater total phosphorus concentrations observed at some MF stations, as well as the presence of an outlier identified during the spatial analysis (but not identified as an anomalous data point), prevented a trend in total phosphorus from being more apparent. Box-plots used to evaluate the presence of potential Mine-related effects on concentrations of SOIs are presented in Attachment E.

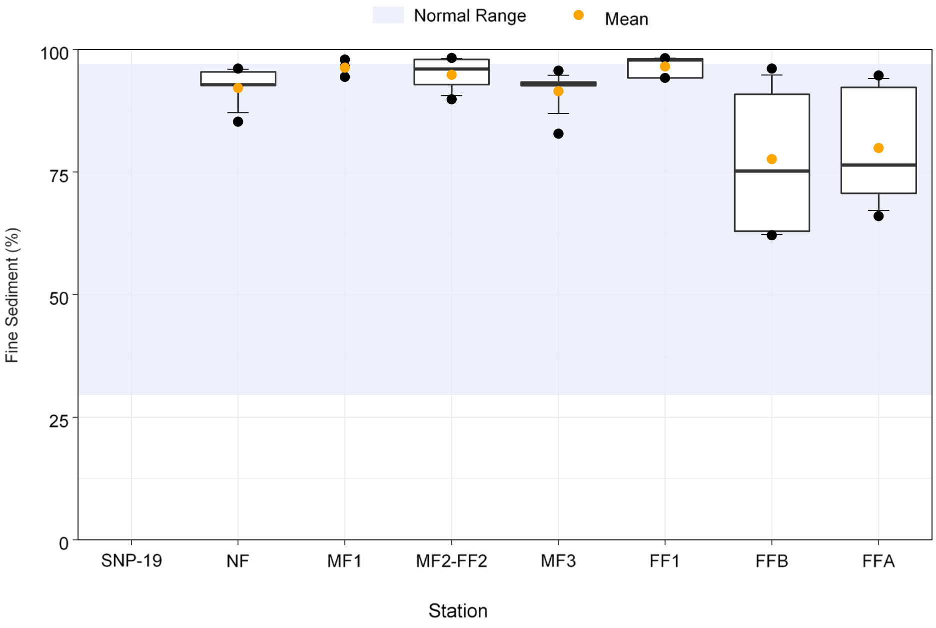
3.2 Physical Characteristics of Sediments

The sediment in all sampling areas was dominated by fine-grained sediments, with greater contributions of coarser sediments towards the west (i.e., FFA and FFB); percent fine values were approximately 10% to 20% lower in the west relative to other areas of Lac de Gras (Figure 3-1). With the exception of the FFA and FFB areas, median percent fines (i.e., silt and clay) contribution in the top 10 to 15 cm exceeded 90% in all areas; FFA and FFB median percent fines were 79% and 71%, respectively. The largest median percent fines was 98%, reported in the FF1 area, which also reported 15% clay and 63% silt.

The TOC content ranged from a median of 2.4% in the MF2 transect sediments, to 6.2% in FFA area sediments (Figure 3-2). The TOC content at stations in the NF and MF1 areas was generally similar, with a median TOC of 3.6% and 3.4% respectively, with little variability within each area. Stations in the MF3, FF1, FFA, and FFB areas had greater median TOC content (i.e., 4.0% to 6.2%) and greater variability within each area.

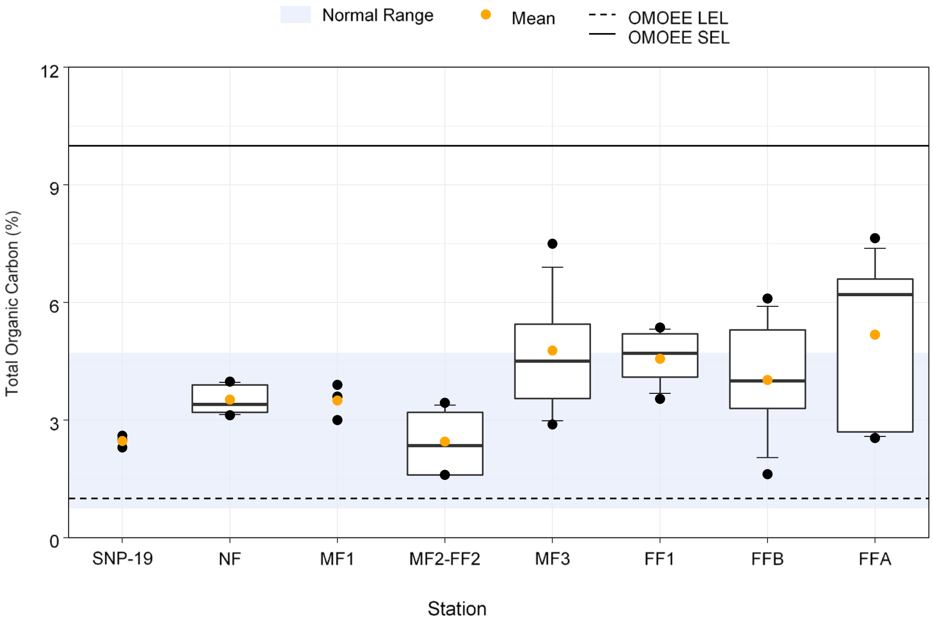
A qualitative evaluation of TOC in sediments relative to distance from the effluent diffuser indicated that the Mine was not having an organic carbon enrichment effect in Lac de Gras sediment (Figure 3-2). This result is consistent with previous AEMP sediment quality surveys (Golder 2008a; 2009a; 2010a, 2011a, 2014b, 2017c). However, variability in TOC content and particle size among stations is a potential factor influencing metal concentrations in sediments in Lac de Gras. Therefore, the correlation between the SOIs and supporting variables (i.e., percent fines and TOC) was investigated.

Figure 3-1 Fine Sediments (Silt + Clay) at 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.
SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-2 Total Organic Carbon Content at Mixing Zone (SNP-19) and AEMP Stations, 2019



Note: Boxplots represent the 10th, 25th, 50th (i.e., 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 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

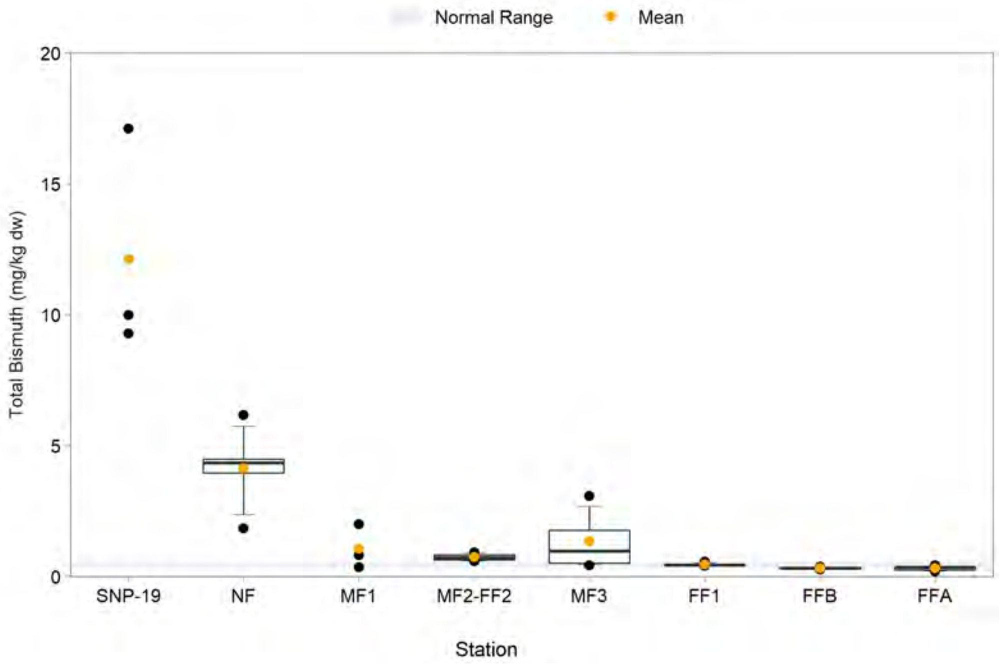
3.3 Correlations Between SOIs and Supporting Variables and Data Normalization

As outlined in Section 2.3.4.2, prior to conducting the statistical analysis, the correlations between raw sediment quality data, physical properties (e.g., percent fines) and organic matter content (i.e., TOC) were investigated. A table summarizing the Spearman rank correlations is provided in Attachment B (Table B-1); scatter plots of SOIs versus percent fines or TOC are also provided in Attachment B (Figures B-2 to B-7).

Of the twelve parameters retained as SOIs, eight were not normalized due to lack of significant positive correlations with either TOC or percent fines; these SOIs included total bismuth (Figure 3-3), total lead (Figure 3-4), total lithium (Figure 3-5), total molybdenum (Figure 3-6), total phosphorus (Figure 3-7), total tin (Figure 3-12), total titanium (Figure 3-13) and total uranium (Figure 3-14). For the remaining SOIs, the normalizing variable was selected as the one with a significant positive correlation, or the one with the strongest significant positive correlation. Three variables were normalized to percent fines (i.e., total potassium, total sodium, and total strontium), and total silver was normalized to TOC.

Non-normalized (i.e., raw) data were used for the evaluation of guideline and Action Level exceedances.

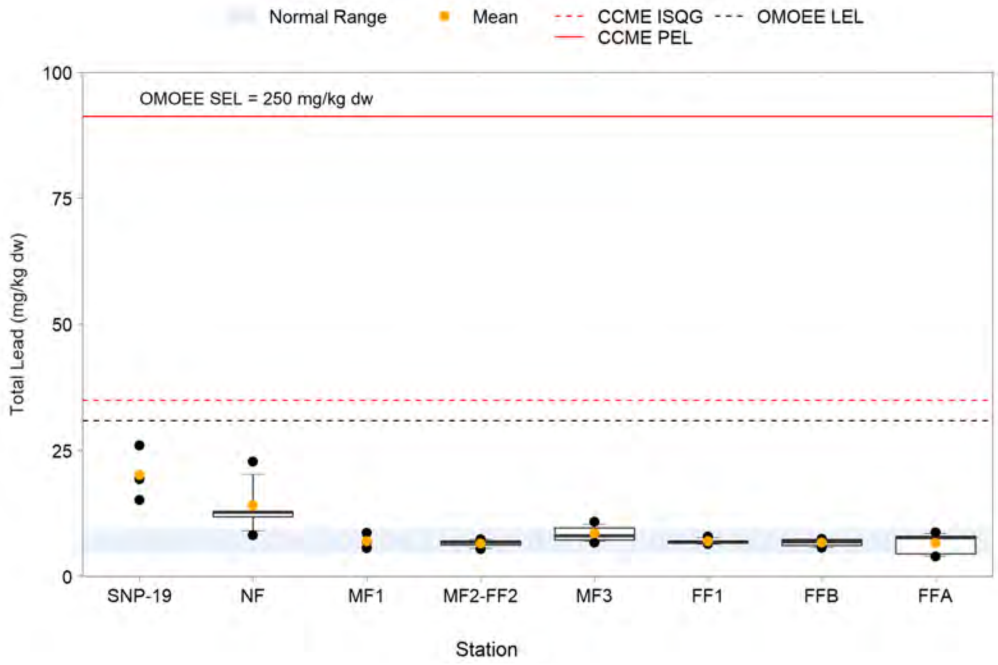
Figure 3-3 Total Bismuth Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



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.

SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

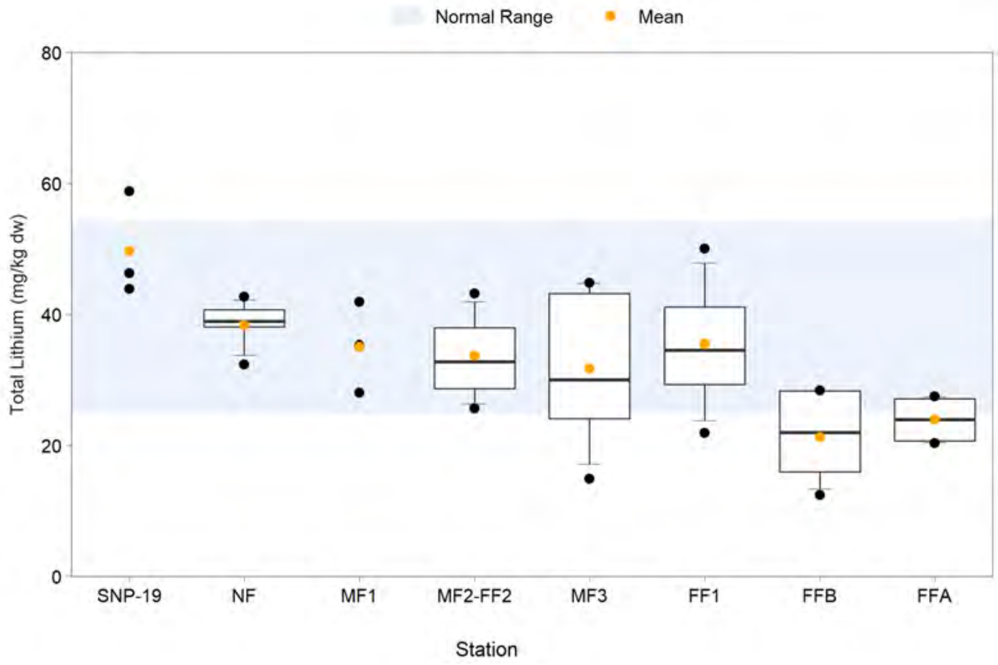
Figure 3-4 Total Lead Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



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.

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

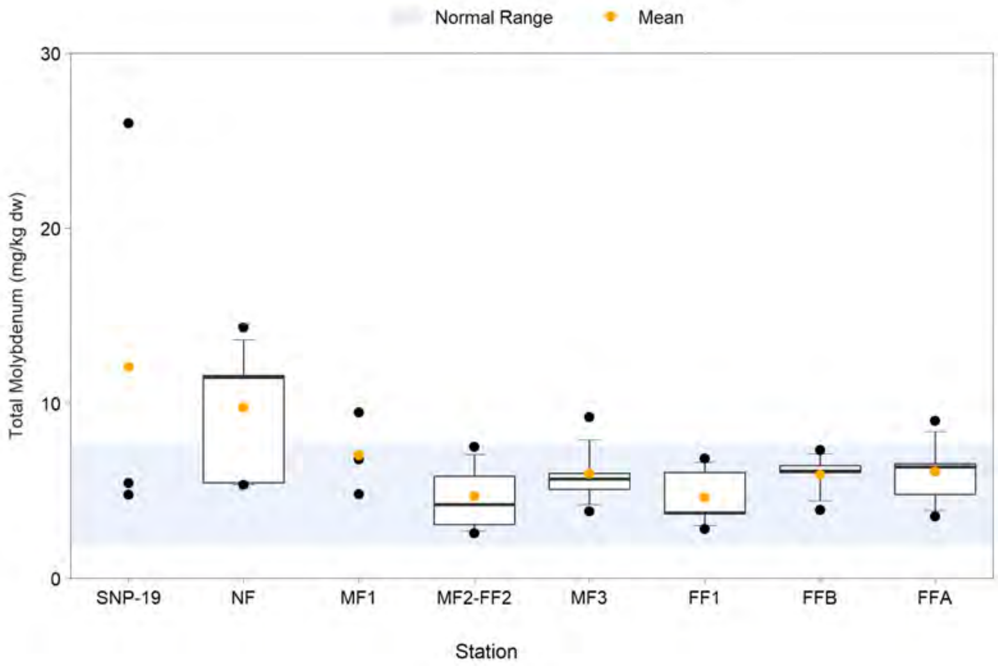
Figure 3-5 **Total Lithium Concentration at Mixing Zone (SNP-19) and AEMP Stations, 2019**



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.

SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

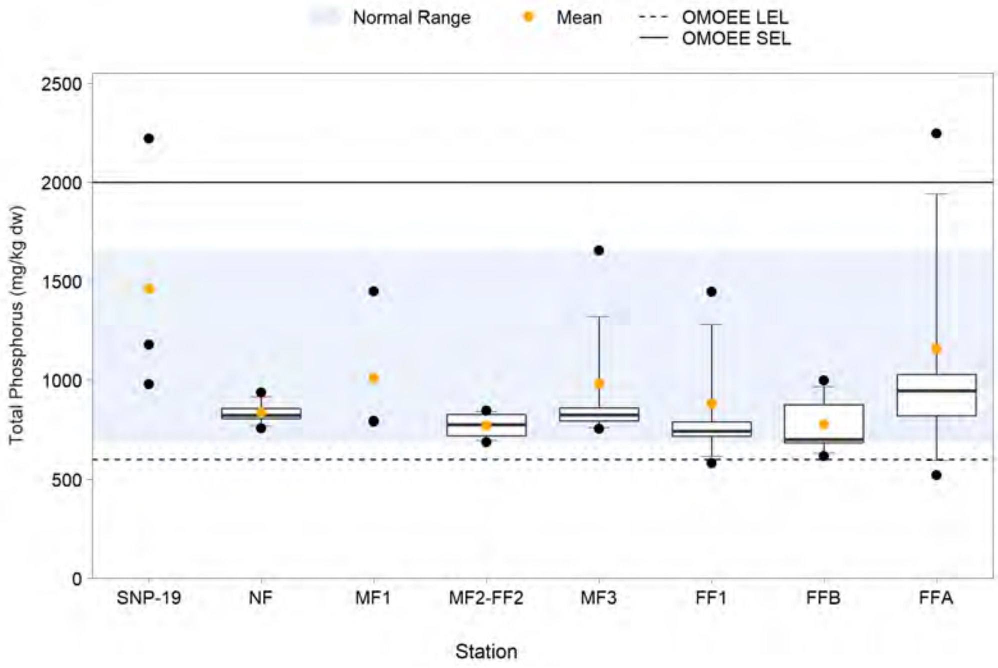
Figure 3-6 Total Molybdenum Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



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.

SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-7 **Total Total Phosphorus Concentration at Mixing Zone (SNP-19) and AEMP Stations, 2019**

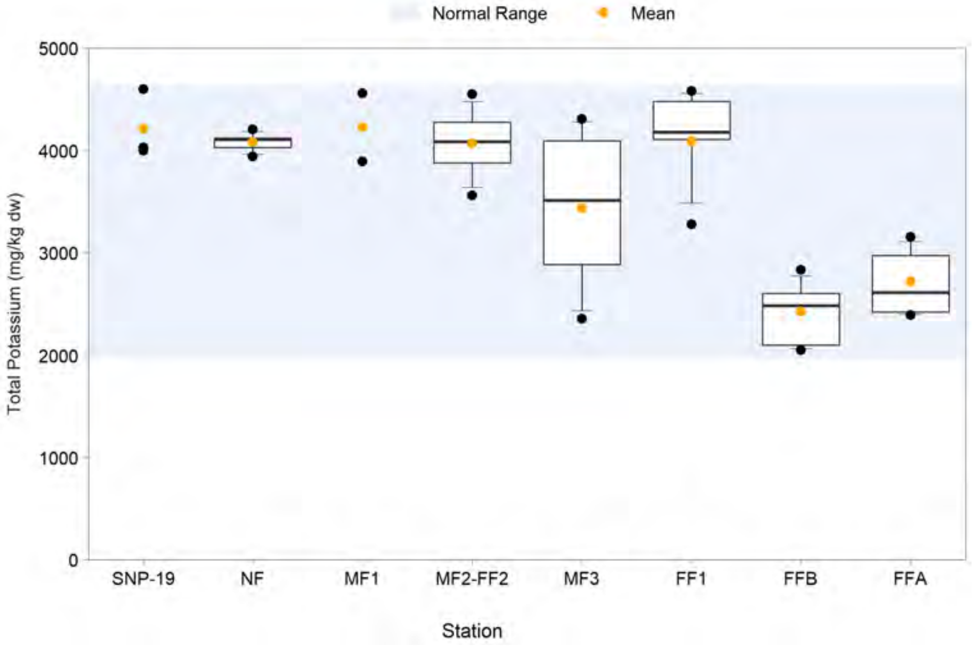


Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. If less than 5 samples were collected, individual data points are plotted instead of boxplots.

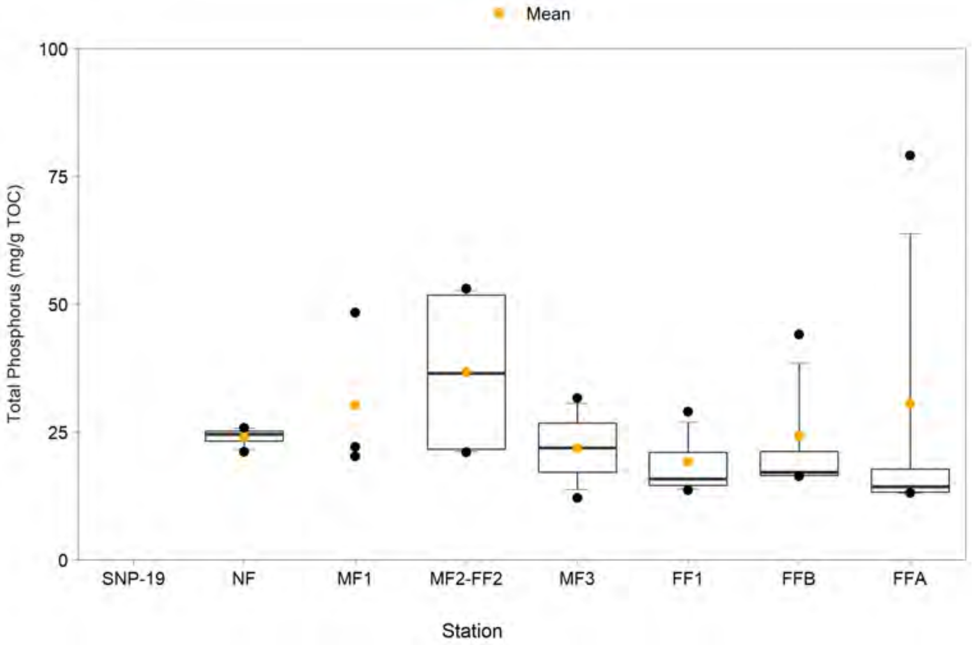
SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field; OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level; SEL = Severe Effect Level

Figure 3-8 Total Potassium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

A — Non-normalized Potassium



B — Fine Sediments-normalized Potassium

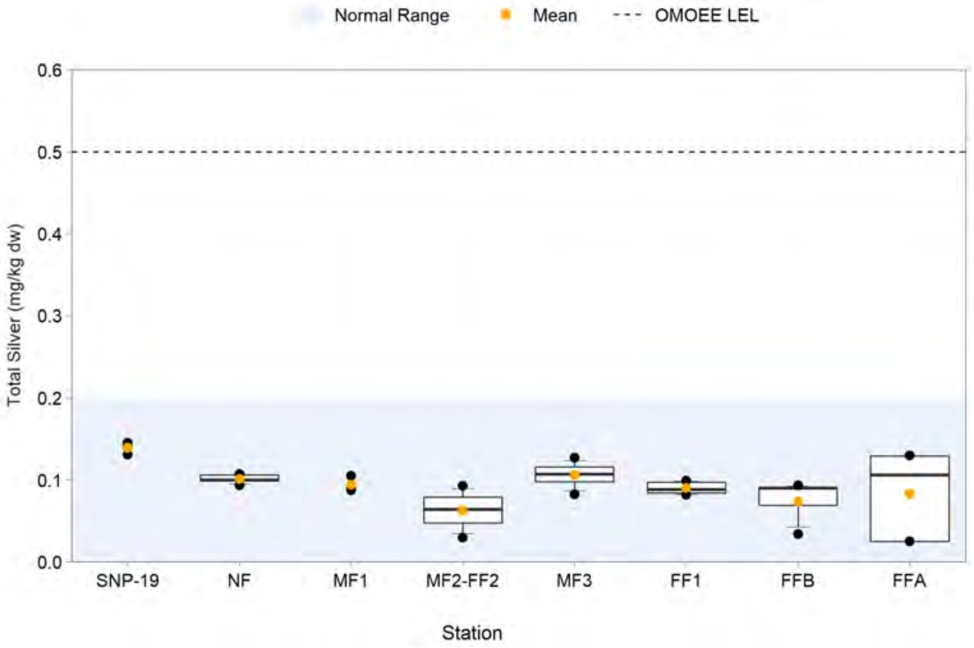


Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Data from Station SNP-19 was not considered in the correlation analysis and thus be normalized. If less than 5 samples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

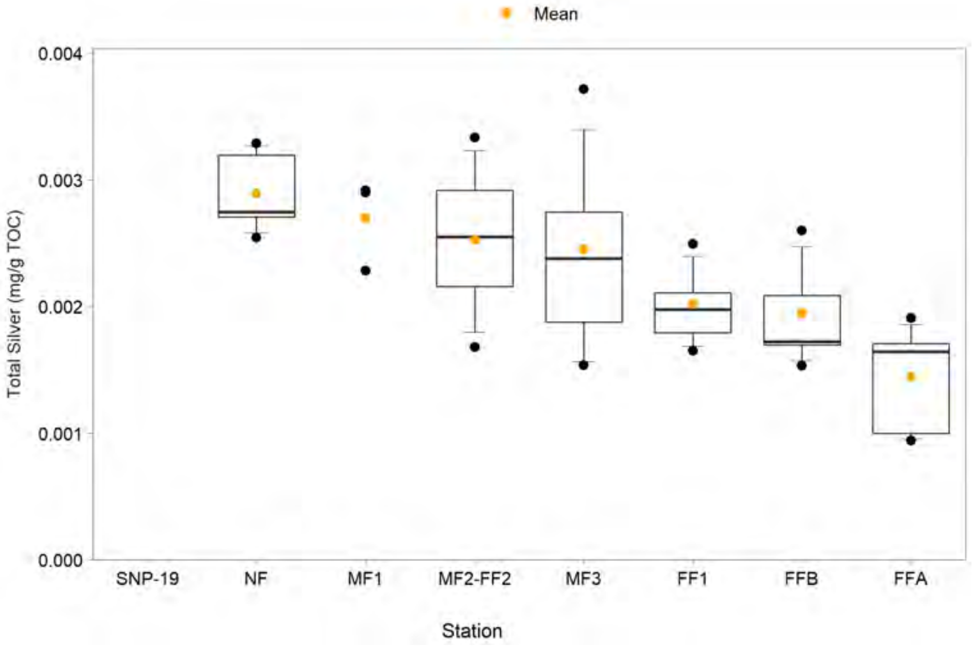
SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-9 Total Silver Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

A — Non-normalized Silver



B — TOC-normalized Silver

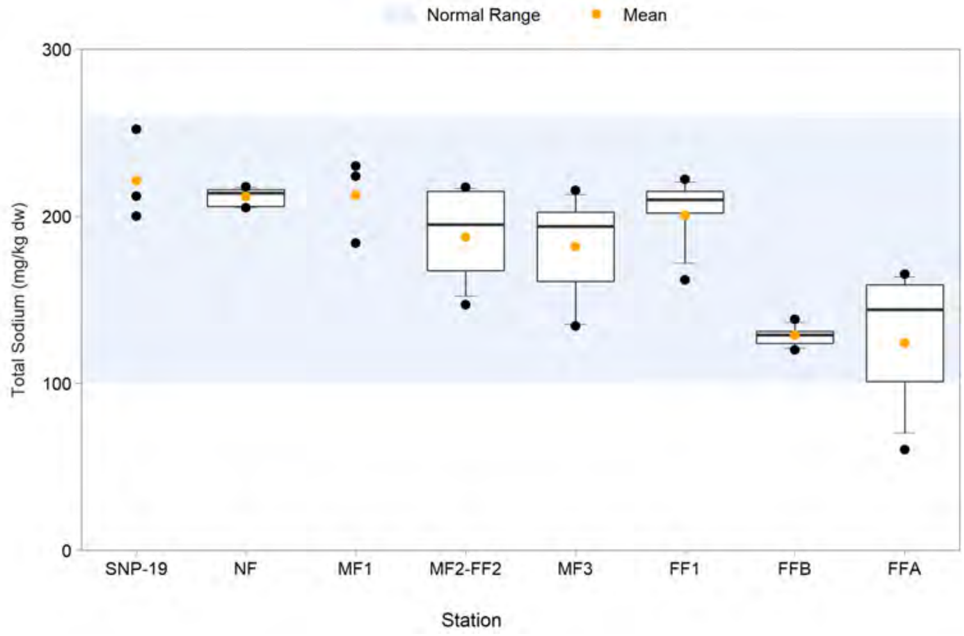


Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Data from Station SNP-19 was not considered in the correlation analysis and thus could not be normalized. If less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

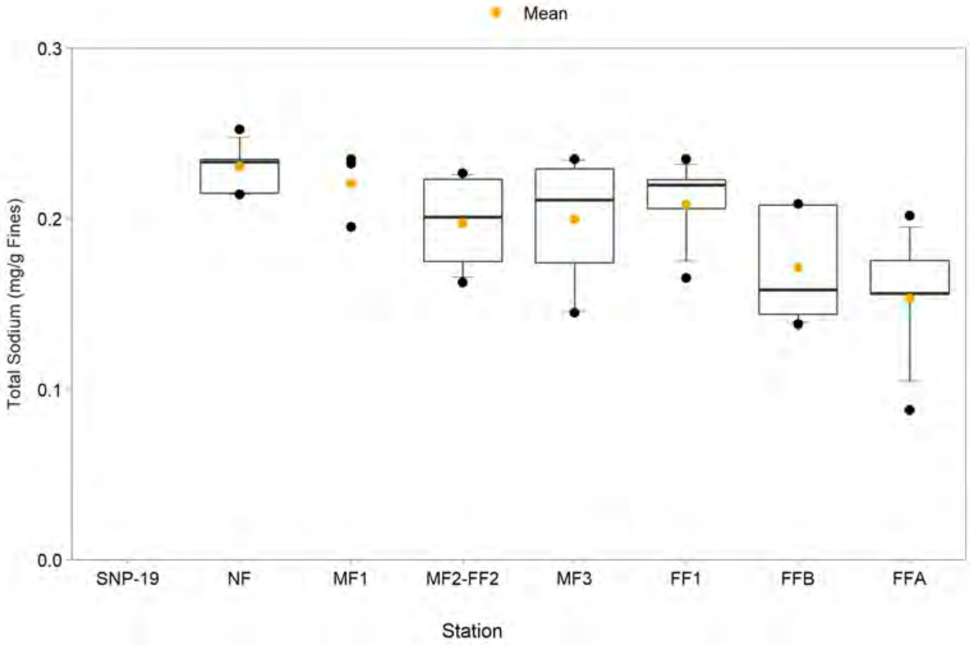
SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field; OMOEE = Ontario Ministry of the Environment and Energy; LEL = Lowest Effect Level.

Figure 3-10 Total Sodium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

A — Non-normalized Sodium



B — Fine Sediments-normalized Sodium

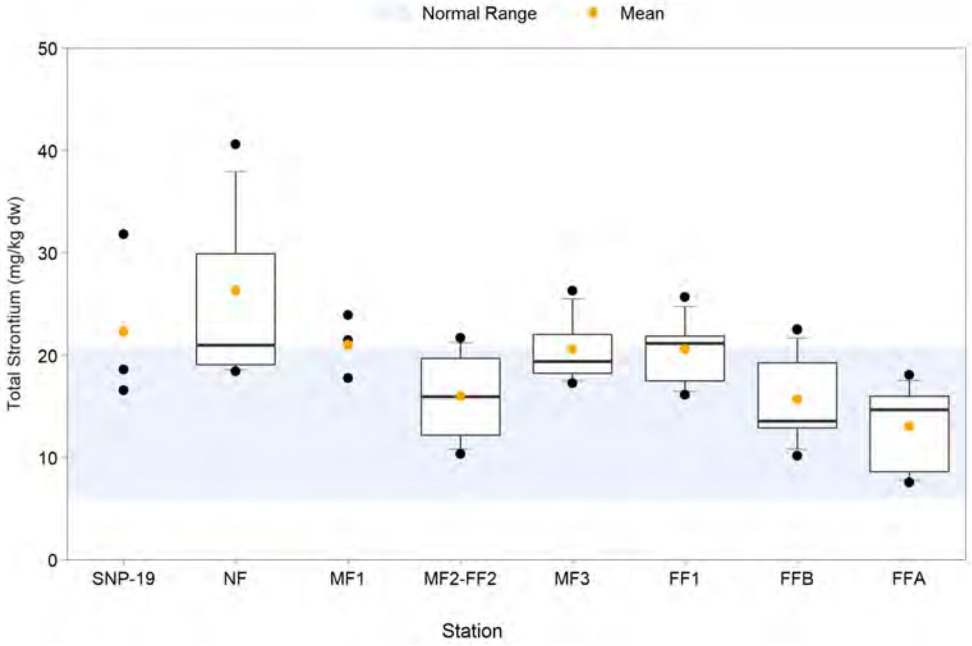


Note: Boxplots represent the 10th, 25th, 50th (median), 75th, and 90th percentile concentrations in each sampling area. Black circles represent the 5th and 95th percentile concentrations. Data from Station SNP-19 was not considered in the correlation analysis and thus could not be normalized. If less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

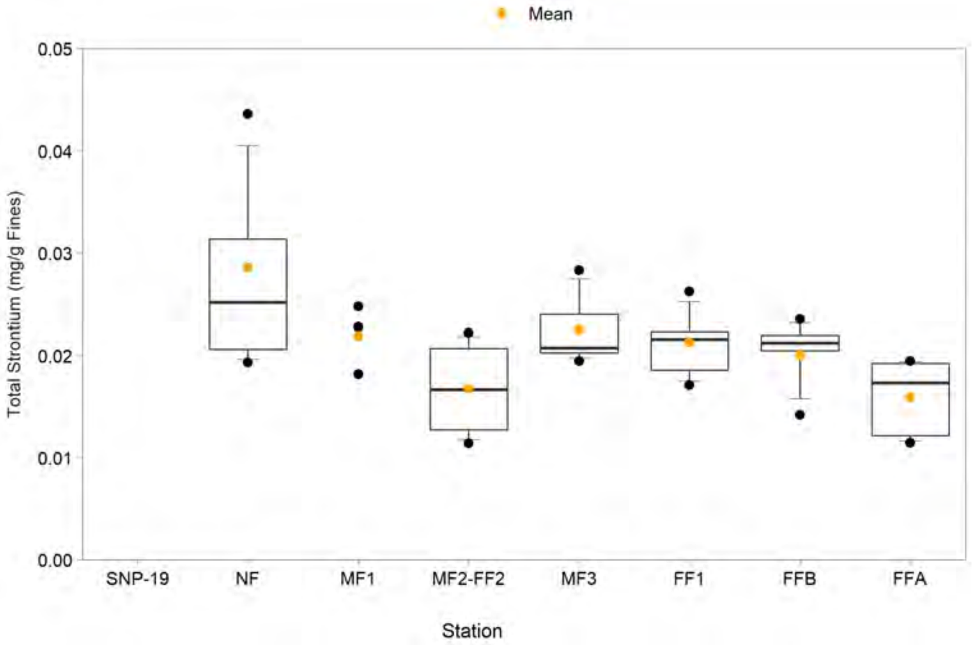
SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-11 Total Strontium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

A — Non-normalized Strontium



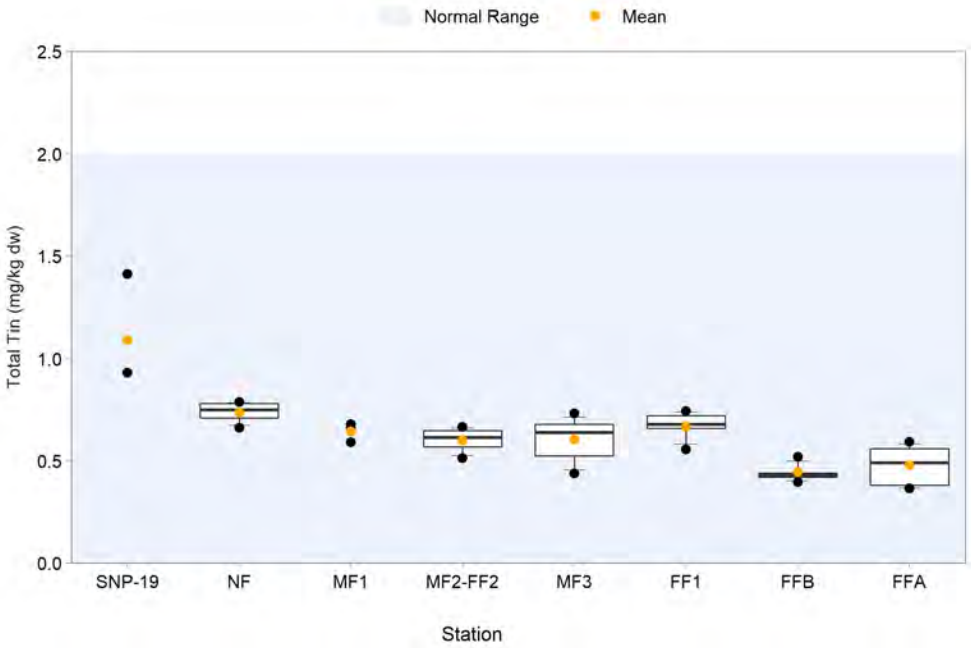
B — Fine Sediments-normalized Strontium



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. SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

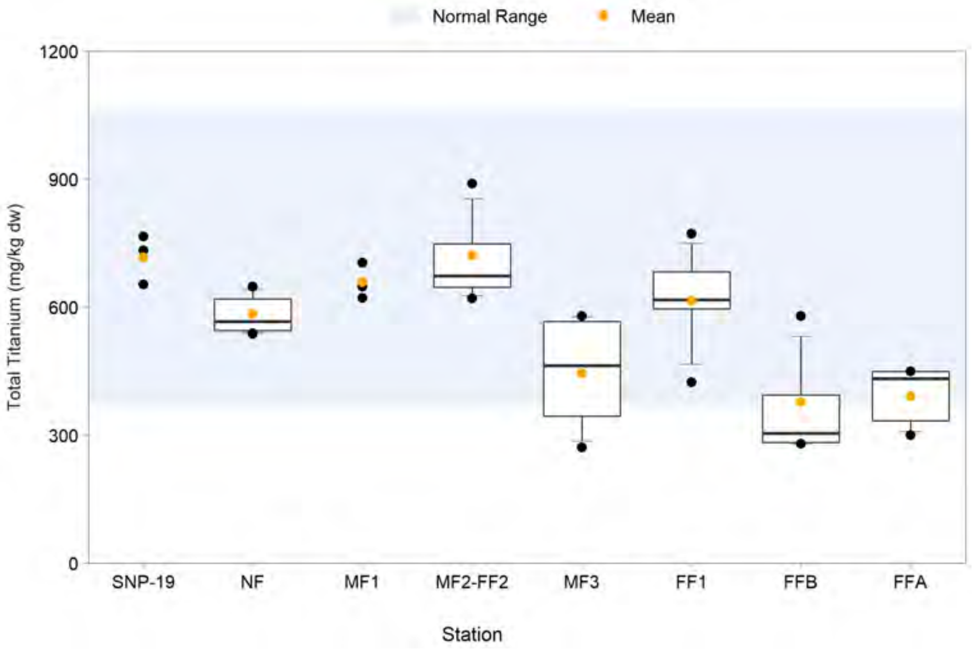
Figure 3-12 Total Tin Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



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.

SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

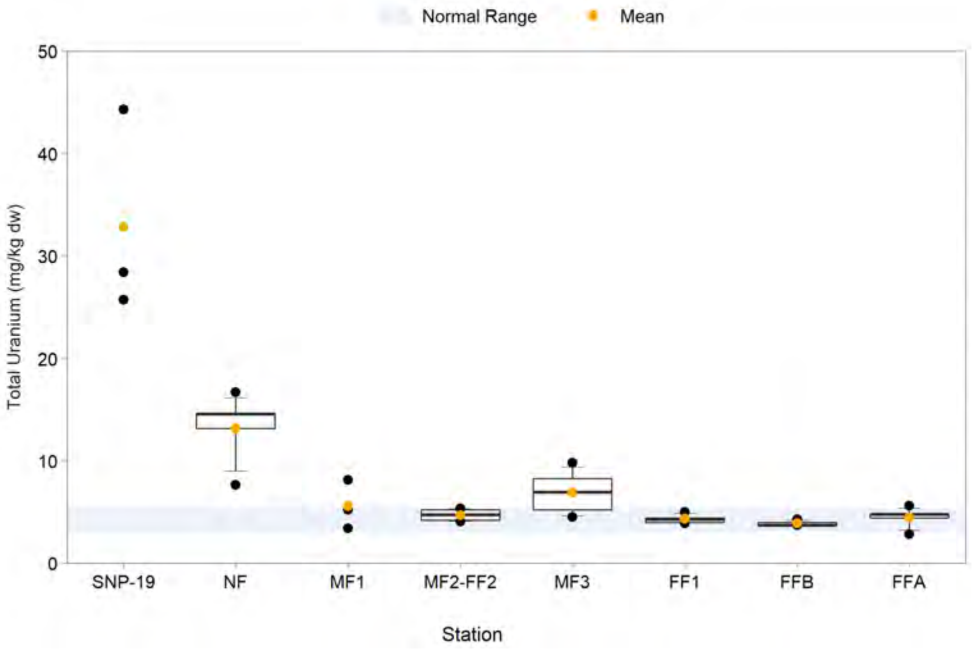
Figure 3-13 Total Titanium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019



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.

SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-14 Total 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.

SNP-19 = Mixing Zone; NF = near-field; MF = mid-field; FF = far-field.

3.4 Gradient Analysis

To determine whether there were trends in variable concentrations along the three MF area transects, SOIs analyzed from the top 1 cm of core samples were evaluated statistically. Before evaluating spatial variation in sediment quality parameters, the relationships between the SOIs and supporting variables (i.e., TOC and particle-size) were evaluated through a correlation analysis, and data were normalized as appropriate. As described in Section 3.3, three variables were normalized to percent fines, one was normalized to TOC, and eight were not normalized. Scatter plots of SOI concentrations with distance from the diffuser are presented in Figures 3-15 to 3-26.

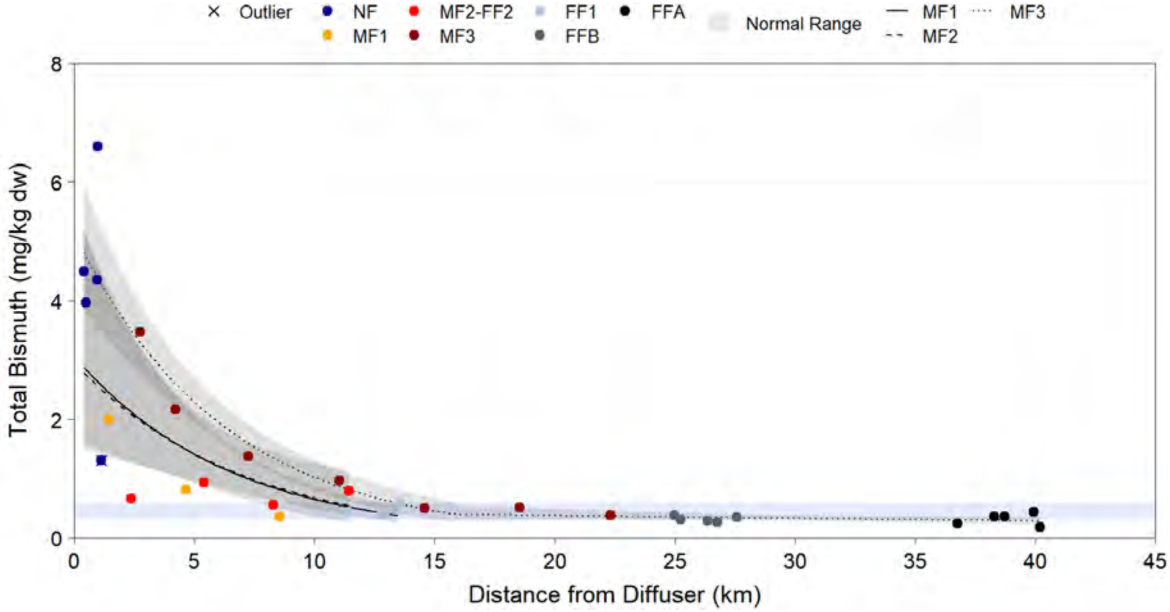
With the exception of total phosphorus, all SOIs had a significant decreasing trend along at least one of the three transects assessed (Table 3-1). Some of the regression models had low r^2 values, which indicated large variability of the data and a poor fit to the model. In general, SOIs had clear spatial trends (i.e., decreasing trends) along the MF3 transect, whereas along the MF1 and MF2 transects, fewer significant trends were detected. Increasing trends were occasionally observed for MF1 and MF2 or for the second slope for the MF3 transect, when Model 3 was selected.

Significant decreasing trends were observed along all transects for total bismuth, lead and uranium. These three SOIs have been reported previously as having Mine-related effects in bottom sediments (Golder 2008a; 2009a; 2010a, 2011a, 2014b, 2017c, 2019c). Given the strong relationships commonly observed between metals and TOC or percent fines (Ho et al. 2012), the weak correlations observed for bismuth, lead and uranium (Section 3.4) may indicate that, to a certain extent, the natural relationships between metal concentration and physical variables have been affected by the enrichment of sediment by these metals.

For total bismuth, total tin, total titanium, total uranium and normalized total potassium, the piecewise model (Model 3) was selected. The breakpoint for these models varied from 16 to 24 km from the diffusers and the first slope was significant, indicating decreasing concentrations with distance. With the exception of bismuth, there was a change in trend direction from a decreasing trend for the first slope, extending from the NF area to the breakpoint, to an increasing trend for the second slope. There was an abrupt change in the slope for bismuth at 16 km (Figure 3-15, Table 3-9); however, the direction of the trend remained the same (i.e., decreasing).

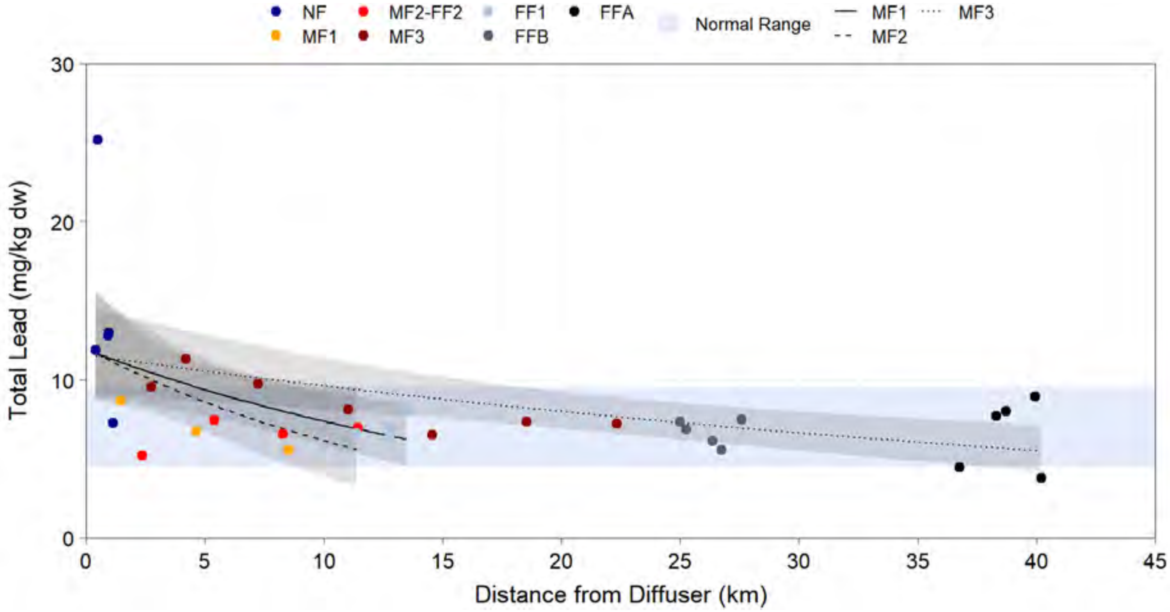
Mine-related total phosphorus was the only parameter with no significant trends observed for any of the transects. This parameter has not been identified as showing a Mine-related effect in bottom sediments during previous years. Due to its weak correlation with both percent-fines and TOC, raw total phosphorus data was used. Phosphorus concentrations in sediments may be more related to iron content, due to sorption of phosphorus by iron-oxide minerals, rather than organic matter (represented by TOC) (Randall et al. 2019).

Figure 3-15 Concentrations of Total Bismuth with Distance from the Effluent Diffusers, 2019



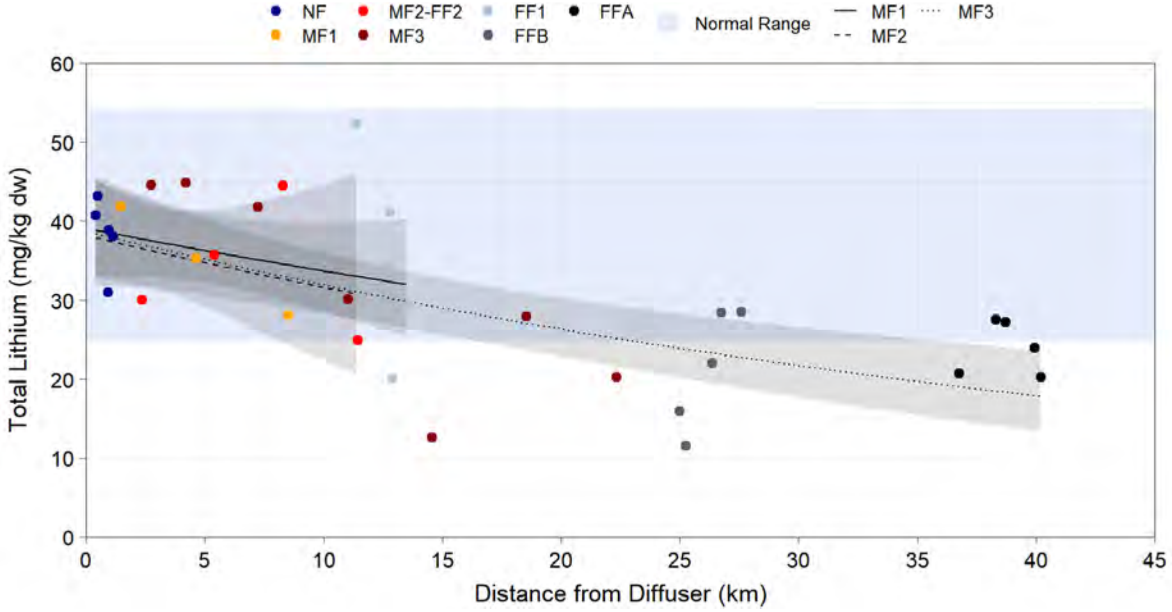
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-16 Concentrations of Total Lead with Distance from the Effluent Diffusers, 2019



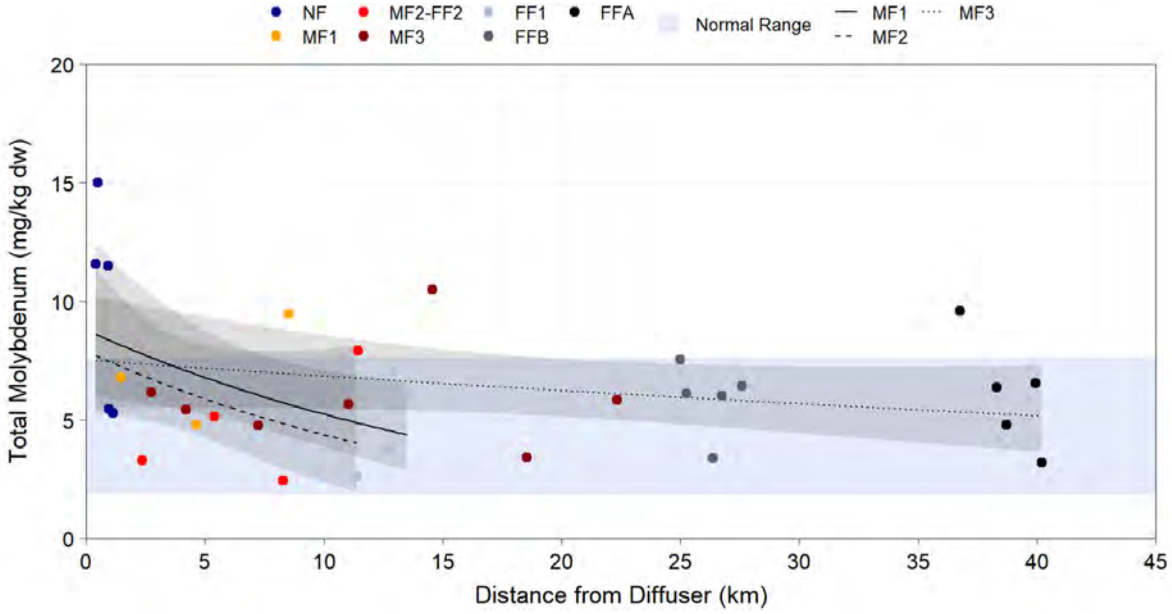
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-17 Concentrations of Total Lithium with Distance from the Effluent Diffusers, 2019



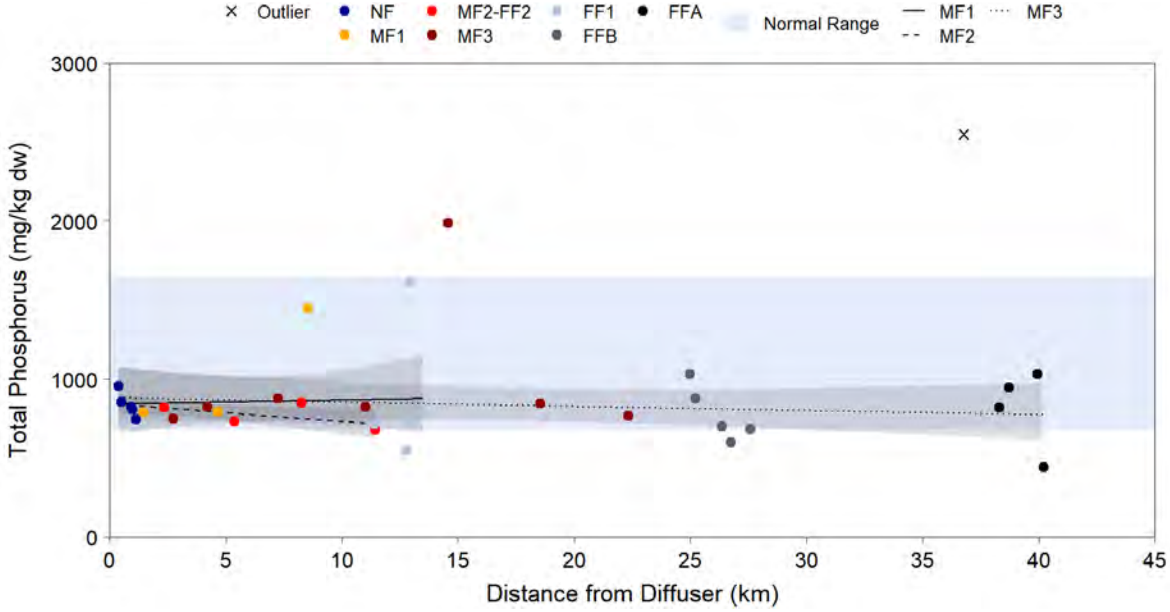
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-18 Concentrations of Total Molybdenum with Distance from the Effluent Diffusers, 2019



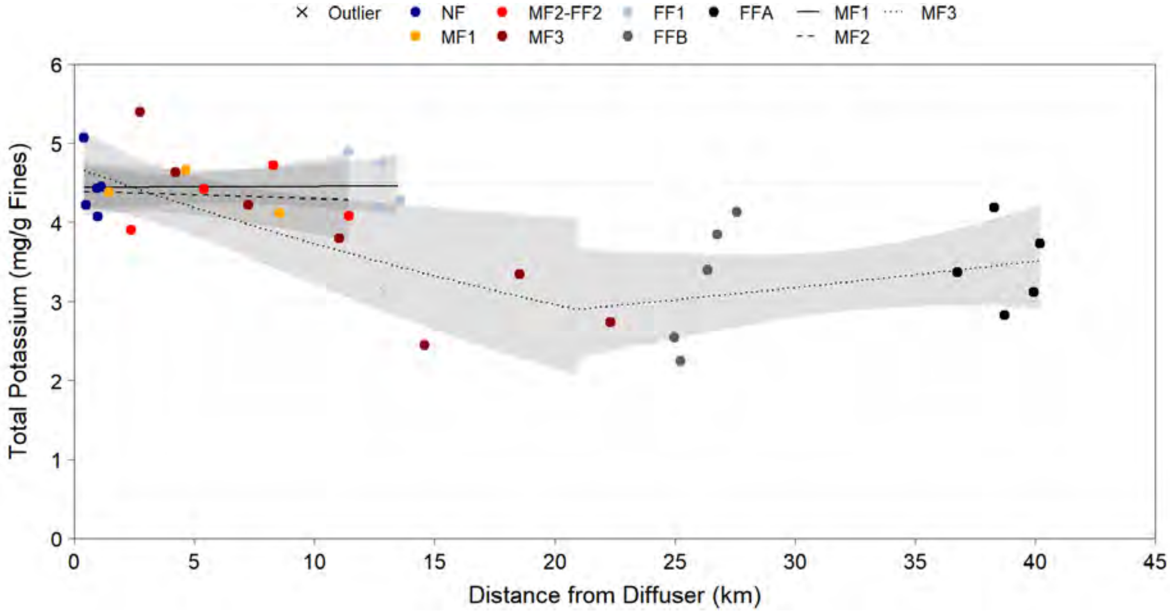
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-19 Concentrations of Total Phosphorus with Distance from the Effluent Diffusers, 2019



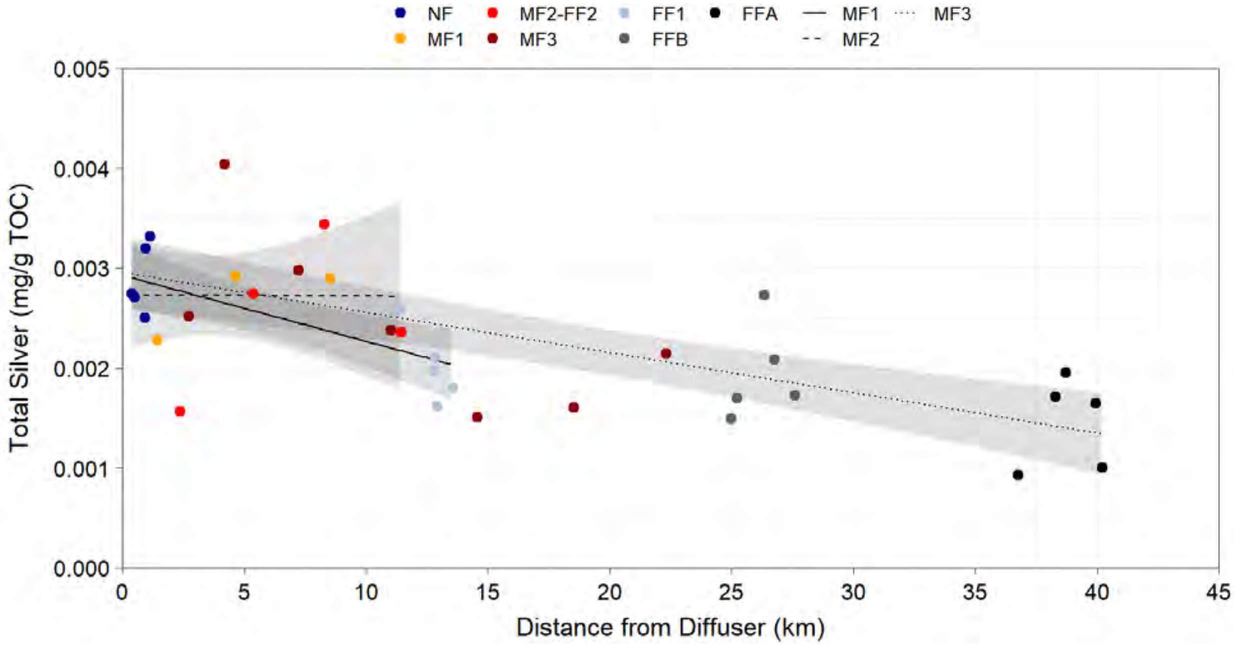
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-20 Concentrations of Normalized Total Potassium with Distance from the Effluent Diffusers, 2019



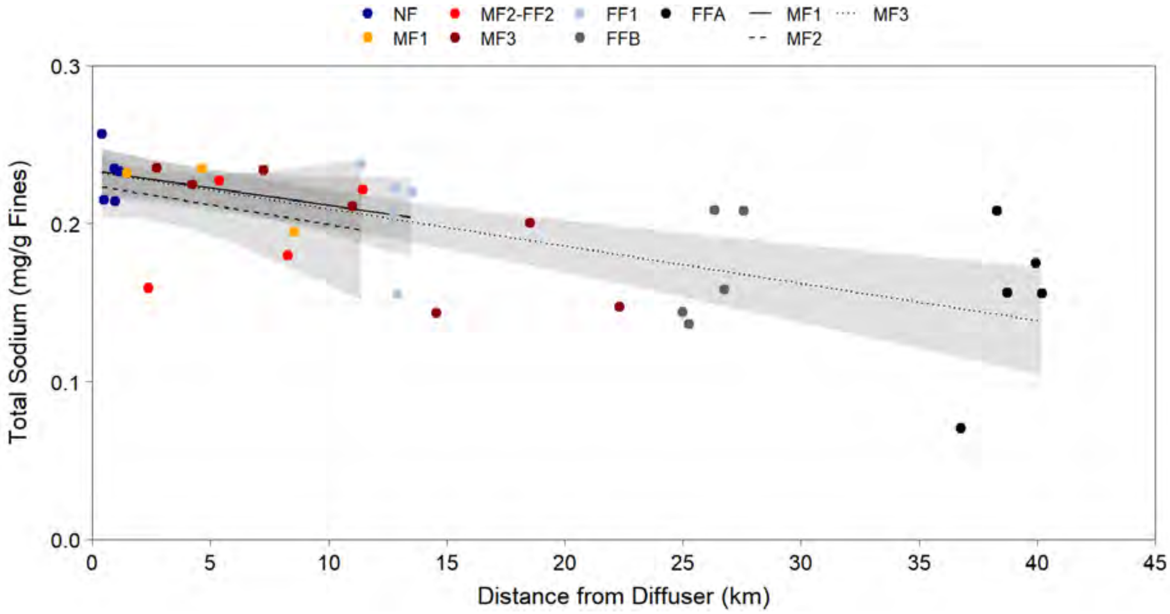
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-21 Concentrations of Normalized Total Silver with Distance from the Effluent Diffusers, 2019



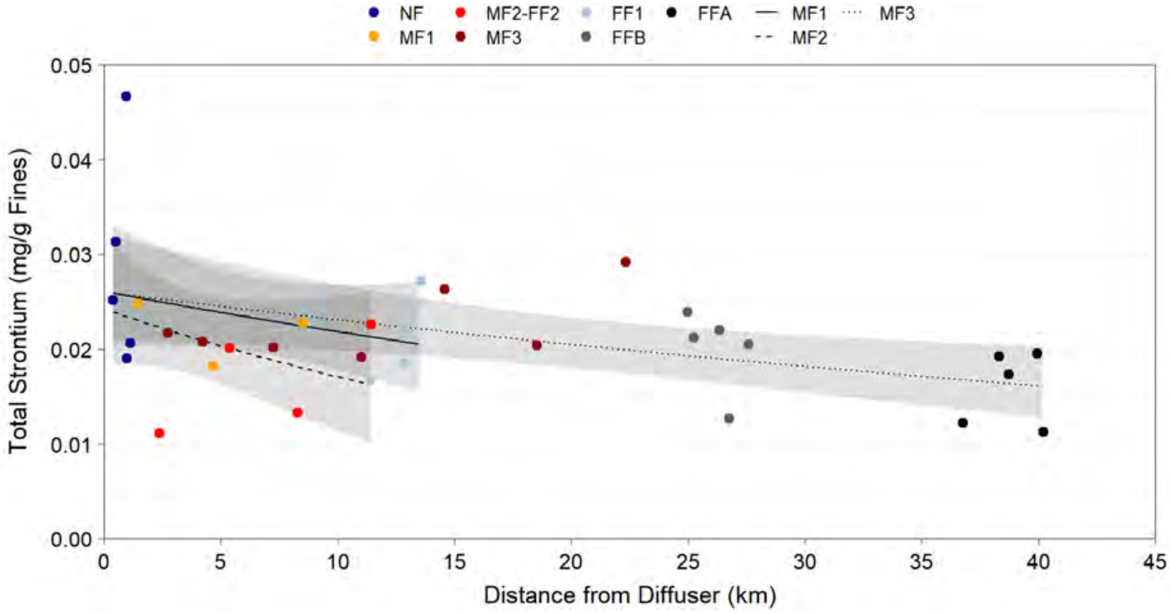
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).
NF = near-field; MF = mid-field; FF = far-field.

Figure 3-22 Concentrations of Normalized Total Sodium with Distance from the Effluent Diffusers, 2019



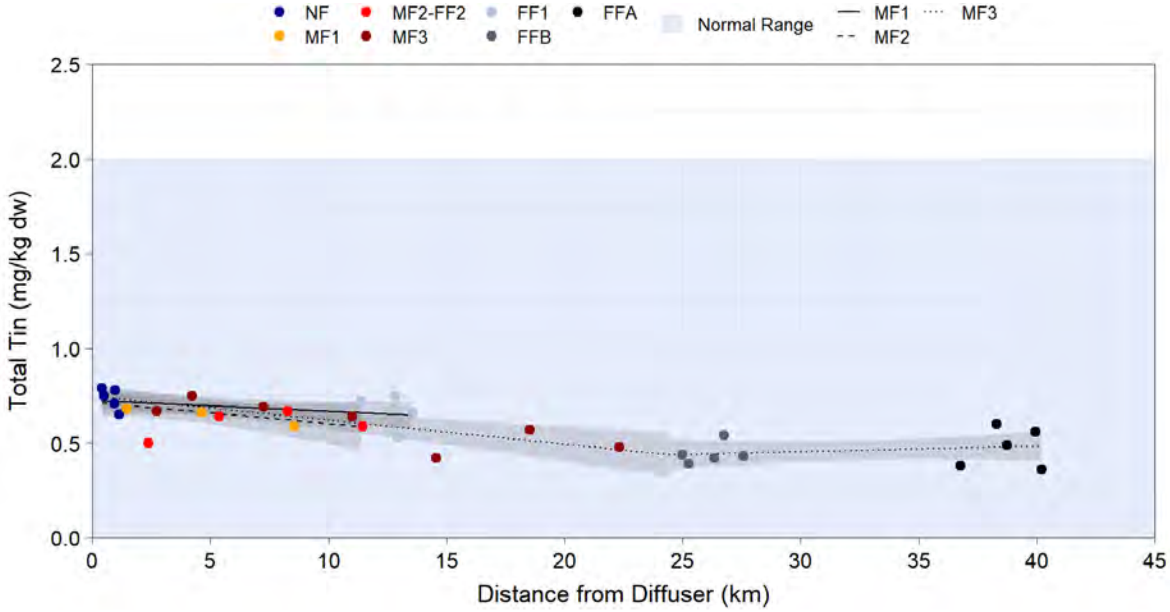
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).
NF = near-field; MF = mid-field; FF = far-field.

Figure 3-23 Concentrations of Normalized Total Strontium with Distance from the Effluent Diffusers, 2019



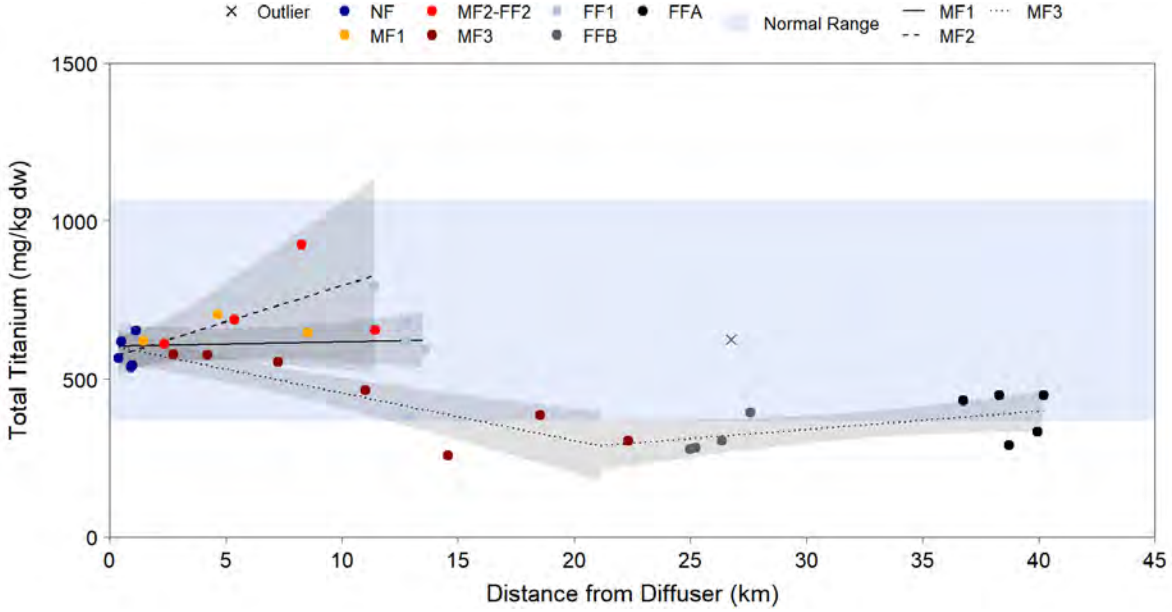
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-24 Concentrations of Total Tin with Distance from the Effluent Diffusers, 2019



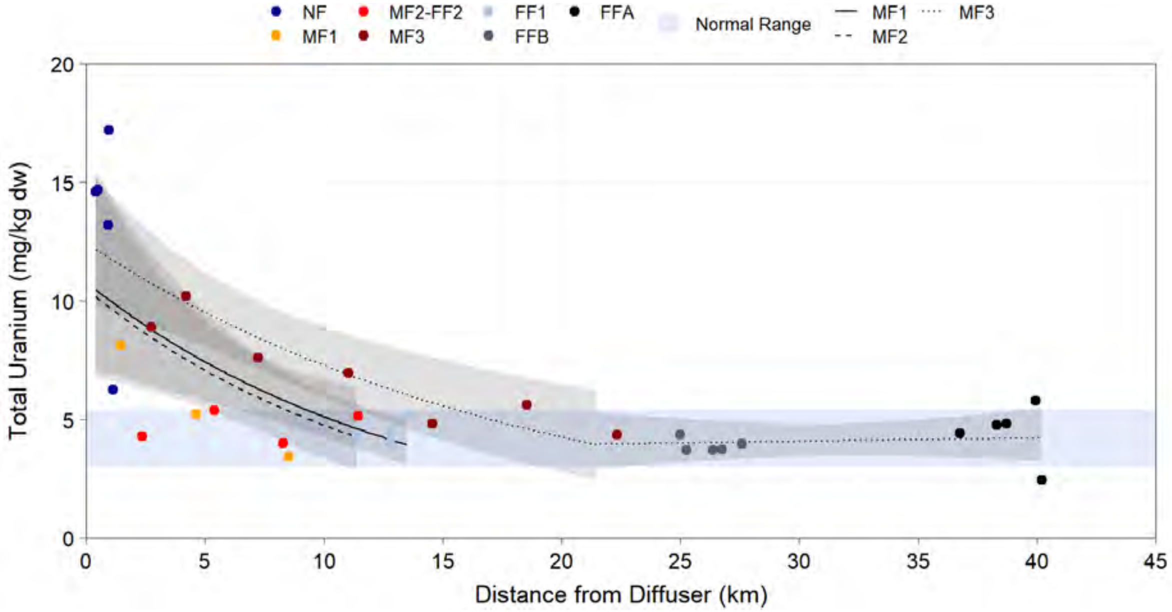
Notes: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field.

Figure 3-25 Concentrations of Total Titanium with Distance from the Effluent Diffusers, 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.

Figure 3-26 Concentrations of Total Uranium with Distance from the Effluent Diffusers, 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.

Table 3-1 Trend Analysis for Sediment Quality Substances of Interest in Lac de Gras, 2019

Variable	Model	Box-Cox Transformation[a]	Gradient	Outliers	Slope Direction[b]	Breakpoint (km)[c]	*P*-value[d]	r^2 or R^2 [e]
Total Bismuth	Model 2	0	MF1	1	↓	-	**<0.001**	0.69
Total Bismuth			MF2		↓	-	**0.005**	
Total Bismuth	Model 3		MF3 (1st slope)		↓	16	**0.004**	0.96
Total Bismuth			MF3 (2nd slope)		↓		-	
Total Lead	Model 1	0	MF1	-	↓	-	**0.008**	0.35
Total Lead			MF2		↓	-	**0.031**	
Total Lead			MF3		↓	-	**0.001**	
Total Lithium	Model 1	0	MF1	-	↓	-	0.201	0.33
Total Lithium			MF2		↓	-	0.384	
Total Lithium			MF3		↓	-	**<0.001**	
Total Molybdenum	Model 1	0	MF1	-	↓	-	**0.028**	0.09
Total Molybdenum			MF2		↓	-	0.142	
Total Molybdenum			MF3		↓	-	0.164	
Total Phosphorus	Model 1	0	MF1	1	↑	-	0.848	0
Total Phosphorus			MF2		↓	-	0.060	
Total Phosphorus			MF3		↓	-	0.460	
Normalized Total Potassium	Model 2	0	MF1	1	↑	-	0.949	-0.15
Normalized Total Potassium			MF2		↓	-	0.754	
Normalized Total Potassium	Model 3		MF3 (1st slope)		↓	21	**0.018**	0.52
Normalized Total Potassium			MF3 (2nd slope)		↑		-	
Normalized Total Silver	Model 1	-	MF1	-	↓	-	**0.002**	0.48
Normalized Total Silver			MF2		↓	-	0.978	
Normalized Total Silver			MF3		↓	-	**<0.001**	
Normalized Total Sodium	Model 1	-	MF1	-	↓	-	0.072	0.36
Normalized Total Sodium			MF2		↓	-	0.303	
Normalized Total Sodium			MF3		↓	-	**<0.001**	
Normalized Total Strontium	Model 1	0	MF1	-	↓	-	0.251	0.13
Normalized Total Strontium			MF2		↓	-	0.196	
Normalized Total Strontium			MF3		↓	-	**0.010**	
Total Tin	Model 2	-	MF1	-	↓	-	0.062	0.09
Total Tin			MF2		↓	-	0.052	
Total Tin	Model 3		MF3 (1st slope)		↓	24	**0.004**	0.72
Total Tin			MF3 (2nd slope)		↑		-	
Total Titanium	Model 2	-	MF1	1	↑	-	0.302	0.22
Total Titanium			MF2		↑	-	0.089	
Total Titanium	Model 3		MF3 (1st slope)		↓	21	**<0.001**	0.53
Total Titanium			MF3 (2nd slope)		↑		-	
Total Uranium	Model 2	0	MF1	-	↓	-	**0.001**	0.54
Total Uranium			MF2		↓	-	**0.009**	
Total Uranium	Model 3		MF3 (1st slope)		↓	21	**0.018**	0.76
Total Uranium			MF3 (2nd slope)		↑		-	

a) Models used and transformation rules are described in Section 2.3.4; 0 = log-transformation, - = no transformation (i.e., raw data).

b) Slope direction is represented by an upward arrow (↑) indicating increasing trend with distance from the diffuser, or a downward arrow indicating a decreasing trend with distance from the diffuser.

c) The breakpoint is the location from the diffuser where the slopes of the linear regressions along the MF3 transect changed values.

d) *P*-values were not calculated for the second slope.

e) For the MF3 broken stick model, r^2 was calculated because there is only one predictor, which is distance; for the other models R^2, was calculated because there is more than one predictor (i.e., distance and gradient).

Notes: Bold indicates *P*-value significant at <0.05. The *P*-value relevant to the second slope is not reported by the statistical software because it cannot be estimated (Muggeo 2008).

MF = mid-field.

3.5 Near-Field Versus Far-Field Area Comparisons

The comparison among sampling areas was performed as supporting information towards the evaluation of Mine-related effects on sediment quality SOIs. The comparison followed the approach outlined in Section 4.4.4 of the *AEMP Design Plan Version 4.1* (Golder 2017a).

The assumptions of ANOVA were tested prior to conducting the analysis; data were normally distributed and met the assumption of homogeneity of variances without need for transformation. For total lithium, total tin, total titanium, normalized total potassium and normalized total sodium, a significant difference among FF areas was identified, and thus the planned contrasts were adjusted to test that the NF areas exceeded the greatest FF area mean (i.e., FF1) for a difference to be considered significant. For the other nine SOIs, the NF results were compared to the three FF area results combined.

With the exception of total phosphorus, all SOIs had significant overall ANOVA results (Table 3-2); multiple comparisons following the overall ANOVA detected significant differences between NF and FF areas for seven parameters (i.e., total bismuth, total lead, total molybdenum, total silver, total strontium, total tin and total uranium). Total tin was the only variable that was significantly greater at NF relative to FF1, the remaining variables that were compared to FF1 (i.e., total lithium, total titanium, total potassium and normalized total sodium) were not significantly different. Overall, these results were consistent with 2016 results (Golder 2017c).

Table 3-2 Results of Statistical Comparisons of Mean Sediment Chemistry Concentrations in Lac de Gras, 2019

Variable(a)	Statistical Test(b)	Overall Comparison	NF vs. FF Area Comparison	FF Area Comparisons		
			NF vs. FF1+FFB+FFA(c)	FF1 vs FFA	FF1 vs FFB	FFA vs FFB
		P	*P*	*P*	*P*	*P*
Total Bismuth	ANOVA	**<0.001**	**<0.001**	0.260	0.271	1
Total Lead	ANOVA	**0.004**	**<0.001**	0.977	0.989	1
Total Lithium	ANOVA	**0.006**	0.281	**0.089**	**0.030**	0.932
Total Molybdenum	ANOVA	**0.046**	**0.008**	0.783	0.848	0.999
Total Phosphorus	ANOVA	ns	-	-	-	-
Total Potassium$^{\text{Fines}}$	ANOVA	**0.018**	0.310	0.172	**0.062**	0.934
Total Silver$^{\text{TOC}}$	ANOVA	**0.001**	**<0.001**	0.135	0.991	0.217
Total Sodium$^{\text{Fines}}$	ANOVA	**0.014**	0.168	**0.080**	0.319	0.827
Total Strontium$^{\text{Fines}}$	ANOVA	**0.085**	**0.065**	0.205	0.962	0.405
Total Tin	ANOVA	**<0.001**	**0.096**	**0.005**	**0.001**	0.880
Total Titanium	ANOVA	**0.006**	nt	**0.021**	**0.014**	0.996
Total Uranium	ANOVA	**<0.001**	**<0.001**	0.998	0.870	0.794

a) Where appropriate, data were normalized to either total organic carbon or fine sediments, as indicated by superscript ("TOC" or "Fines").

b) ANOVA = Analysis of Variance (log-transformed data indicated by superscript).

c) If a significant result was observed for the comparison of FF areas, the NF area was compared to the FF area with the greatest concentration.

NF = near-field; FF = far-field; *P* = probability; TOC = total organic carbon; Fines = percent fine sediments; ns = not significant, - = not applicable, because the overall comparison was not significant; nt = not tested as the three FF areas differed from each other and the NF mean was within the range of the FF areas.

3.6 Comparisons to Guidelines and Normal Ranges

Concentrations of SOIs were screened against SQGs to assess the potential for toxicological effects on aquatic life. Screening results for all sediment variables at individual stations and sampling areas are presented in Attachment F; Tables F-1 and F-2. Of the twelve SOIs, total lead, total silver and total phosphorus have SQGs. Lead and silver did not exceed the CCME or OMOEE guidelines in the NF, MF, and FF areas of Lac de Gras. Total phosphorus exceeded the OMOEE LEL guidelines in all samples and the OMOEE SEL in one sample collected from the FFA area, which is consistent with the interpretation that total phosphorus concentrations in Lac de Gras sediments are naturally elevated throughout the lake.

Concentrations of a number of other parameters in sediments throughout Lac de Gras were above SQGs (Attachment F, Tables F-1 and F-2). These parameters have naturally elevated concentrations, and do not exhibit clear spatial trends related to the Mine.

Comparisons of SOI concentrations in the NF area to normal ranges indicated that median total bismuth, total lead, total molybdenum, total strontium and total uranium concentrations in the NF area were above normal ranges (Figures 3-3 to 3-14). Concentrations of these SOIs were also elevated at SNP-19, which suggests that the elevated concentrations in the NF area are related to the Mine. 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, therefore, may be less representative of recent deposition. For total bismuth, exceedances of the normal range were also apparent in the MF areas. Median concentrations of total strontium in the FF1 area (Figure 3-11) and total uranium in the MF3 area (Figure 3-14) were also above the normal range.

3.7 Action Level Evaluation

Mine-related effects on sediment quality were categorized according to Action Levels (Table 2-4). The twelve variables selected as SOIs were carried forward to the Action Level evaluation, which was done based on raw data (i.e., non-normalized) to allow comparisons to the reference conditions dataset.

Of the twelve sediment quality SOIs, total bismuth, total molybdenum and total uranium triggered an Action Level (Table 3-3). Total bismuth, total molybdenum and total uranium had NF median concentrations that were greater than two times their respective reference median, which triggered Action Level 1. However, the data for total molybdenum and uranium did not meet the criteria to trigger Action Level 2 (i.e., 5th percentile of NF values greater than two times the median of the reference dataset and normal range). Total bismuth median concentration in the NF area (4.4 mg/kg) exceeded two times the reference dataset median (0.84 mg/kg), which triggered the Action Level 1. The 5th percentile of the NF total bismuth concentration (1.8 mg/kg) also exceeded two times the reference dataset median, and the normal range upper bound (0.59 mg/kg); therefore, bismuth triggered Action Level 2. The response to Action Level 2 trigger is to development an effects benchmark, if one does not already exist.

The development of an effects benchmark for bismuth was attempted in the *AEMP Design Plan Version 4.1* (Golder 2017a). However, based on the review of the toxicological literature, data suitable for developing a numerical sediment quality guideline or benchmark for bismuth were not available, and an effects benchmark could not be calculated for bismuth in sediment. Guidelines or other benchmarks have not been developed for bismuth in North America or elsewhere. This indicates that bismuth in sediments is generally not a constituent of concern for national or international regulatory authorities. Given the stable concentrations of bismuth observed in Lac de Gras sediments (including Station SNP-19 at the edge of the mixing zone) since 2006, the low aqueous concentrations of bismuth (i.e., it is generally non-detected in lake water), and the lack of evidence of aquatic toxicity of bismuth as documented in the available literature, bismuth 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.

Table 3-3 Action Level Evaluation for Sediment Quality Substances of Interest, 2019

Parameter	NF Area Median (mg/kg dw)	NF 5th Percentile (mg/kg dw)	Two Times Median of Reference Dataset[(a)] (mg/kg dw)	Normal Range Upper Bound (mg/kg dw)	Action Level Triggered
Total Bismuth	4.4	1.8	0.84	0.59	Action Level 2
Total Lead	13	8.2	14	9.5	-
Total Lithium	39	32	77	54	-
Total Molybdenum	12	5.3	7.5	7.6	Action Level 1
Total Phosphorus	824	757	2,200	1,650	-
Total Potassium	4,110	3,942	5,790	4,644	-
Total Silver	0.10	0.09	0.40	0.20	-
Total Sodium	214	205	390	259	-
Total Strontium	21	18	24	20.8	-
Total Tin	0.75	0.66	4.0	2.0	-
Total Titanium	566	539	1,354	1,066	-
Total Uranium	15	7.7	8.4	5.4	Action Level 1

dw = dry weight; - = Action Level not triggered.

a) Source: Golder (2019a).

NF = near-field.

3.8 Weight-of-Evidence Input

As described in Section 2.5, the results reported in the preceding sections also contribute to the WOE analysis presented in the Weight-of-Evidence Report (Appendix XV). The results of the WOE analysis relevant to sediment quality and related components are described in Section 3.1 of Appendix XV.

4 SUMMARY AND DISCUSSION

Mine-related effects on bottom sediments in the NF area of Lac De Gras were apparent for twelve parameters, which were retained as SOIs (i.e., total bismuth, total lead, total lithium, total molybdenum, total phosphorus, total potassium, total silver, total sodium, total strontium, total tin, total titanium, and total uranium). These variables had spatial trends consistent with a Mine-related effect in Lac de Gras. With the exception of total phosphorus, each SOI had at least one transect with a significant decreasing trend with distance from the diffuser. For three SOIs (i.e., total bismuth, total lead and total uranium), all three transects had significant decreasing trends. Along with molybdenum and strontium, these three SOIs also had NF area median concentrations that were greater than their normal ranges. Among the parameters exceeding the normal range, bismuth and uranium also had notably 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, therefore, may be less representative of recent deposition.

Spatial trends identified for total bismuth, total lead, and total uranium in 2019 were consistent with the results of previous AEMP surveys and dike monitoring studies (DDMI 2003, 2005, 2007, 2011), which showed similar increases in the concentrations of these metals in the vicinity of 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 along the two transects closest to the diffusers (DDMI 2011), suggesting an effluent-related pattern, rather than a dike-related pattern. This suggests that the Mine discharge could be the primary source of these metals in the NF area. Gradual, but less pronounced decreases in concentration with increasing distance from the dikes at transects located away from the diffuser were also apparent, suggesting that the dikes are also a potential source of these metals. These results indicate that Mine effluent has caused an increase in concentrations of bismuth, uranium and lead in bottom sediments, to concentrations that are beyond the normal range for Lac de Gras, although other factors, such as dike construction and possible leaching from dikes may also have contributed to this finding.

Of the twelve 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. 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 total bismuth is anticipated.

Results of the Effluent and Water Chemistry Reports have indicated clear Mine-related spatial and temporal trends in water for uranium (Golder 2019b, Appendix II), and lead was identified as an SOI in 2018 (Golder 2019b) but not retained as an SOI in 2019 (Appendix II). Effluent-related patterns for bismuth have not been identified in water in Lac de Gras.

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

- Sediment quality guidelines for bismuth do not currently exist and information regarding bismuth toxicity in aquatic sediments is not present in the available literature. Results of the 2010 dike monitoring study (DDMI 2011), and the past six AEMP benthic invertebrate surveys (Golder 2008b, 2009b, 2010b, 2011b, 2014c, 2016a) 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, the median and maximum concentrations observed for lead in the NF area were 12.8 mg/kg dw and 25.2 mg/kg dw, respectively. These concentrations were below the OMOEE LEL for total lead of 31 mg/kg dw and the CCME ISQG of 35 mg/kg dw. 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, although Sheppard et al. (2005) reported a predicted no-effect level for freshwater benthos of 100 mg/kg dw. More recently Goulet and Thompson (2018) predicted median lethal concentrations for uranium to juvenile and adult *Hyalella azteca* of 48 and 214 mg/kg respectively, a much lesser concentration than observed in other studies (Liber et al 2011). Goulet and Thompson (2018), however, had intentionally increased porewater concentrations by spiking sodium carbonate which made uranium available for uptake. In Lac de Gras, sediment total 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, and ranging up to 10.2 mg/kg dw at stations in the MF area, particularly as uranium bioavailability is reduced by complexation with humic substances and inorganic ligands found in sediments (Lenhart et al. 2000; Markich 2002; Liber et al 2011; Trenfield et al. 2011a, b, 2012; Goulet and Thompson 2018).
- Of the SOIs, total lead, total phosphorus and total 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. Total 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 exceeded the SEL. Phosphorus is an essential and non-toxic element, hence the guideline is designed to protect the aquatic environment from substances that could promote growth of algae (OMOEE 1993). The AEMP results indicate that total phosphorus is naturally elevated in bottom sediments throughout the lake.
- Total phosphorus has exceeded the normal range in lake water in the NF area in recent years and increases in chlorophyll *a* concentration have also been observed (Golder 2019b); therefore, phosphorus is a key parameter in the assessment of Mine-related effects. Once released to lake water, phosphorus may reach the lakebed by different biotic and abiotic process, and over time, phosphorus accumulation in sediments may cause sediments to become an important source of phosphorus to lake water (Søndergaard et al. 2003; CCME 2004; Wang and Lian 2015; Randall et al. 2019). However, given the overall depth and abundant oxygenation of the water column in Lac de Gras, it is unlikely that the sediments in Lac de Gras could be a source of phosphorus for the water column. Furthermore, no evidence of relevant accumulation of phosphorus in Lac de Gras sediments has been observed in recent years (Golder 2019c).
- 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, as observed in previous reports (Golder 214b, 2017a), 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 AEMP benthic invertebrate survey did not detect toxicity-related effects on the benthic community in Lac de Gras (Benthic Invertebrate Report [Appendix IV]).

5 RESPONSE FRAMEWORK

Sediment quality variables were assessed for a Mine-related effect according to Action Levels in the Response Framework. Three variables triggered an Action Level 1 (total bismuth, total molybdenum and total uranium). No management action is required under the Response Framework when a variable triggers Action Level 1. Of these three variables, only total bismuth met the criteria to trigger an Action Level 2. The response required following an Action Level 2 trigger is to develop an effects benchmark. The development of such a benchmark for bismuth was attempted in the *AEMP Design Plan Version 4.1* (Golder 2017a). However, based on the review of the toxicological literature, data suitable for developing a numerical sediment quality guideline or benchmark for bismuth were not available, and an effects benchmark could not be calculated for bismuth in sediment. Therefore, no further action is anticipated at this time.

6 CONCLUSIONS

- Twelve sediment quality parameters had spatial trends consistent with a Mine-related effect in Lac de Gras and were identified as SOIs (i.e., total bismuth, total lead, total lithium, total molybdenum, total phosphorus, total potassium, total sodium, total silver, total strontium, total tin, total titanium, and total uranium). Three SOIs (i.e., total bismuth, total lead, and total uranium) had significant decreasing trends extending away from the Mine effluent diffuser along all three transects.
- Total bismuth, total lead, total uranium, total molybdenum, and total strontium had NF median concentrations in sediments that exceeded the upper bound of their respective normal ranges[1].
- Sediment quality monitoring results indicate that effluent discharge is likely the primary source of elevated concentrations of metals in bottom sediments[1], 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.
- Total lead, phosphorus and silver are the only SOI in 2019 with applicable SQGs; total lead and silver concentrations in Lac de Gras sediments did not exceed CCME or OMOEE guidelines. Total 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, and it is unlikely that bottom sediments in this lake would be a significant source of phosphorus to the water column[1].
- 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[1].
- Total molybdenum and total uranium triggered Action Level 1, which represents an early warning change.
- Total 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. 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, bismuth 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 total bismuth is anticipated.

The understanding of sediment quality in Lac de Gras and the Mine-related effects on sediments have not changed since the last comprehensive year.

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8 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:	**Report reviewed by:**
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ATTACHMENT A

SEDIMENT QUALITY DATA SCREENING

INTRODUCTION

Data screening is the initial phase of data handling when analyzing chemistry datasets, which are subject to occasional extreme values that are frequently incorrect, reflecting field or laboratory errors, data transcription or calculation errors, or extreme natural variability. This initial step is undertaken prior to data analysis and interpretation to verify that the data quality objectives established by the *Quality Assurance Project Plan Version 3.1* (Golder 2017b) and the *AEMP Design Plan Version 4.1* (Golder 2017a) have been met. The purpose of this step is to initially identify unusually large or small values (i.e., anomalous data), correct them if possible, and make a decision whether to retain or exclude remaining anomalous data from further analysis.

In previous Diavik Diamond Mines (2012) Inc. (DDMI) Aquatic Effects Monitoring Program (AEMP) reports, the judgment whether to retain an anomalous value in the analysis was made based on a visual inspection of the data using scatter-plots, and logical consistency with results for other variables. To prepare data for analyses presented in this report, a revised approach was used to identify anomalous data to address concerns noted by the Wek'èezhìı Land and Water Board (WLWB) and other reviewers regarding the handling of outliers in AEMP datasets. The revised data screening approach includes a numerical method to aid in the identification of anomalous values, thus removing the subjectivity of classifying values based on visual evaluation of data alone.

METHODS

Initial screening of the 2019 sediment mixing boundary (i.e., SNP-19) and AEMP dataset was completed before data analyses to identify unusually large (or small) values and decide whether to retain or exclude the data from further analysis. Data screening for anomalous data was conducted using a method based on Chebyshev's theorem (Amidan et al. 2005), combined with the visual examination of scatter plots and logic checks. This method allowed for detection of multiple anomalous values at one time and assumes that the data being screened contain a relatively small percentage of anomalous values (Amidan et al. 2005). Chebyshev's theorem states that at least $1\text{-}1/k^2$ proportion of the data of any distribution (i.e., no assumption of normality) lies within k standard deviations (SD) of the mean (Mann 2010). Setting $1\text{-}1/k^2 = 0.95$ and solving for k results in 4.47 SD, indicating that 95% of the data, regardless of distribution, will be within approximately 4.47 SD of the mean. In the case of a normal distribution, 95% of the data is expected to be within 2 SD, suggesting that the method based on Chebyshev's theorem is conservative (i.e., identifies values that are far removed from the mean). The method was applied by first identifying data that lie outside the 4.47 SD on a scatter plot of annual data, and then visually verifying the anomalous values based on potential spatial trends. No data were identified as anomalous based on visual evaluation alone.

In cases where the above screening method identified a value in the NF area or at the mixing zone boundary as anomalous, the identified value was conservatively retained in the dataset used for analysis if the SD distance from the mean was less than two times the 4.47 SD criterion discussed above. Hence, only very extreme values, which were greater than approximately 9 SDs from the mean were removed from further analysis of NF area data. Finally, in cases where the annual datasets contained a large proportion of non-detect data, only values that were greater than or equal to five times the DL were considered anomalous and were removed from the analysis.

RESULTS

All required samples were collected, and all requested analyses were performed within specified holding time limits. The relative percent differences (RPDs) for laboratory duplicate samples analyzed in 2019 met the data quality objective (DQOs) set by BV Labs for all sediment analytes. Concentrations for all laboratory blanks were below the DL; therefore, the results were considered acceptable. The measured concentrations represent the actual concentrations in lake sediments and no sign of a laboratory source of contamination was identified.

There were no anomalous values identified for the mixing zone boundary dataset nor for the AEMP dataset, therefore no data was removed.

ATTACHMENT B

SPEARMAN RANK CORRELATION RESULTS

Table B-1 Results of Spearman Rank Correlations Between Sediment Chemistry Substances of Interest, and Total Organic Carbon and Percent Fine Sediments, 2019

Variable	Sample Size	Correlation Coefficient (r_S)	
		Total Organic Carbon (%)	Fine Sediment (%)
Total Bismuth	34	-0.100	0.336
Total Lead	34	0.318	0.126
Total Lithium	34	-0.386	0.171
Total Molybdenum	34	0.180	0.011
Total Phosphorus	34	0.339	0.114
Total Potassium	34	-0.258	**0.453**
Total Silver	34	**0.600**	0.127
Total Sodium	34	0.002	**0.542**
Total Strontium	34	**0.415**	**0.562**
Total Tin	34	-0.136	0.388
Total Titanium	34	-0.565	0.341
Total Uranium	34	0.096	0.181

Notes: r_S= Spearman rank correlation coefficient. **Bolded** values indicate significant positive correlations between sediment chemistry variables and percent fines or TOC ($P<0.01$). Percent fine sediments is calculated as the sum of percent clay and silt.

Figure B-1 **Scatter Plot of Correlations Between Total Bismuth and Total Lead and supporting variables (Total Organic Carbon and Percent Fines), 2019**

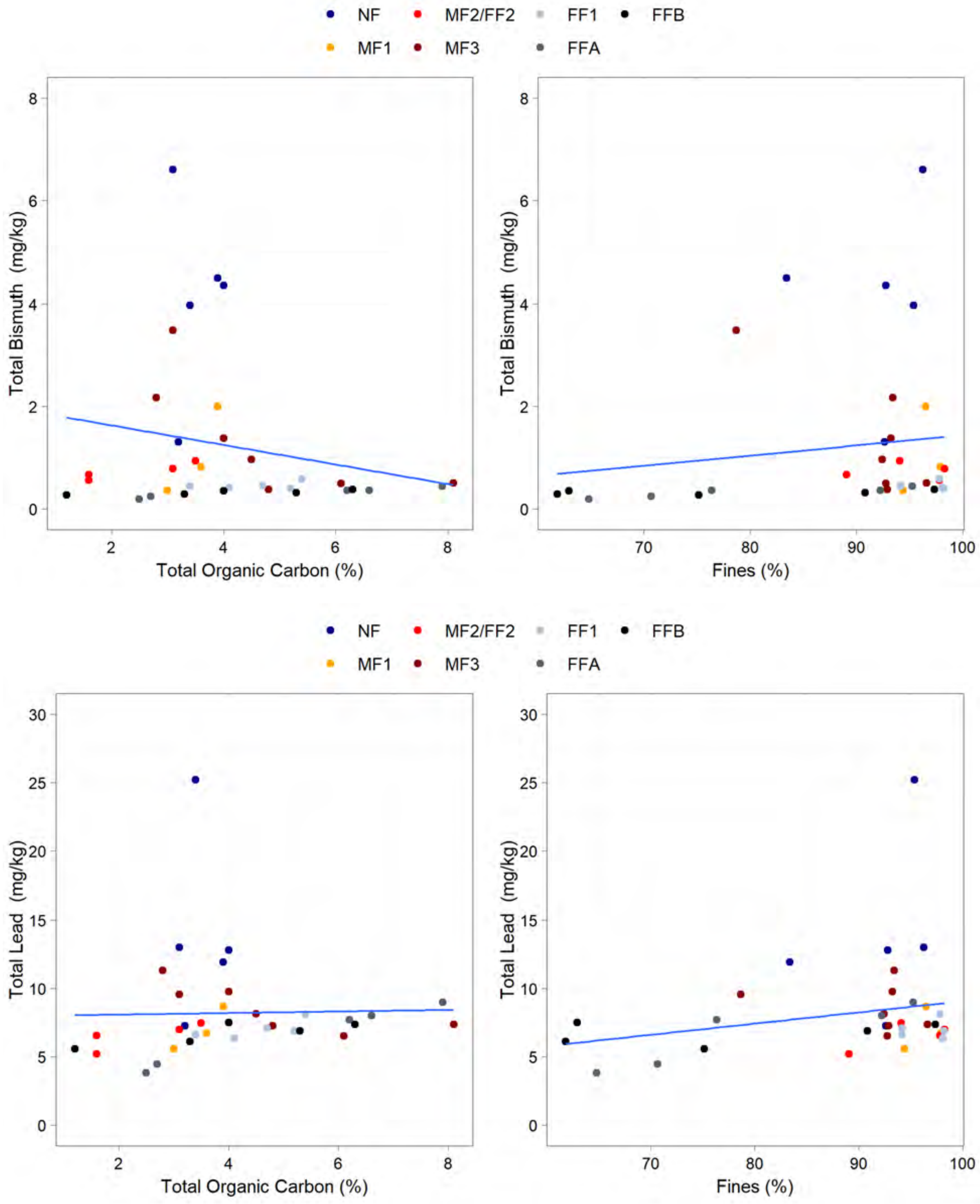


Figure B-2 **Scatter Plot of Correlations Between Total Lithium and Total Molybdenum and supporting variables (Total Organic Carbon and Percent Fines), 2019**

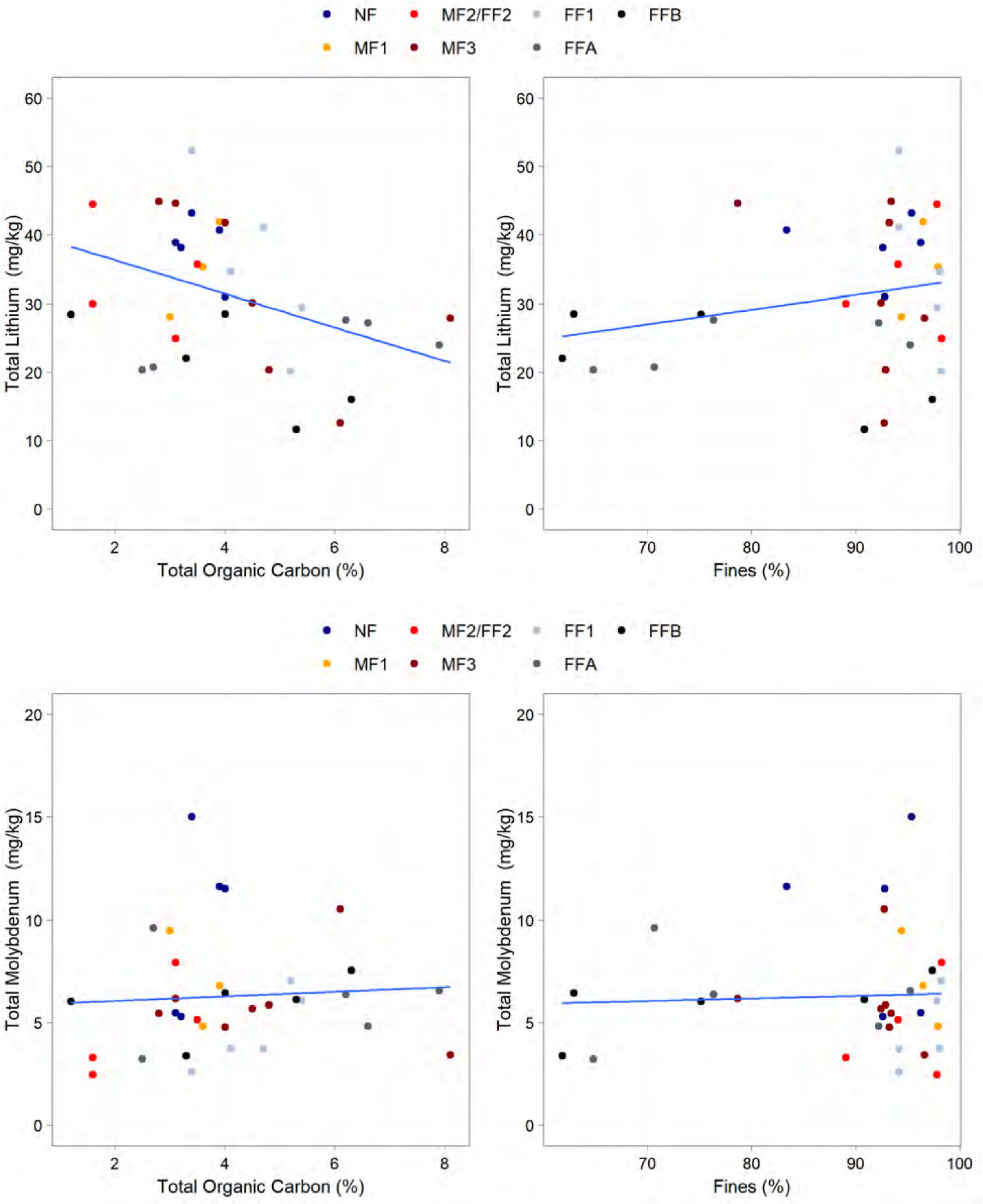


Figure B-3 **Scatter Plot of Correlations Between Total Phosphorus and Total Potassium and supporting variables (Total Organic Carbon and Percent Fines), 2019**

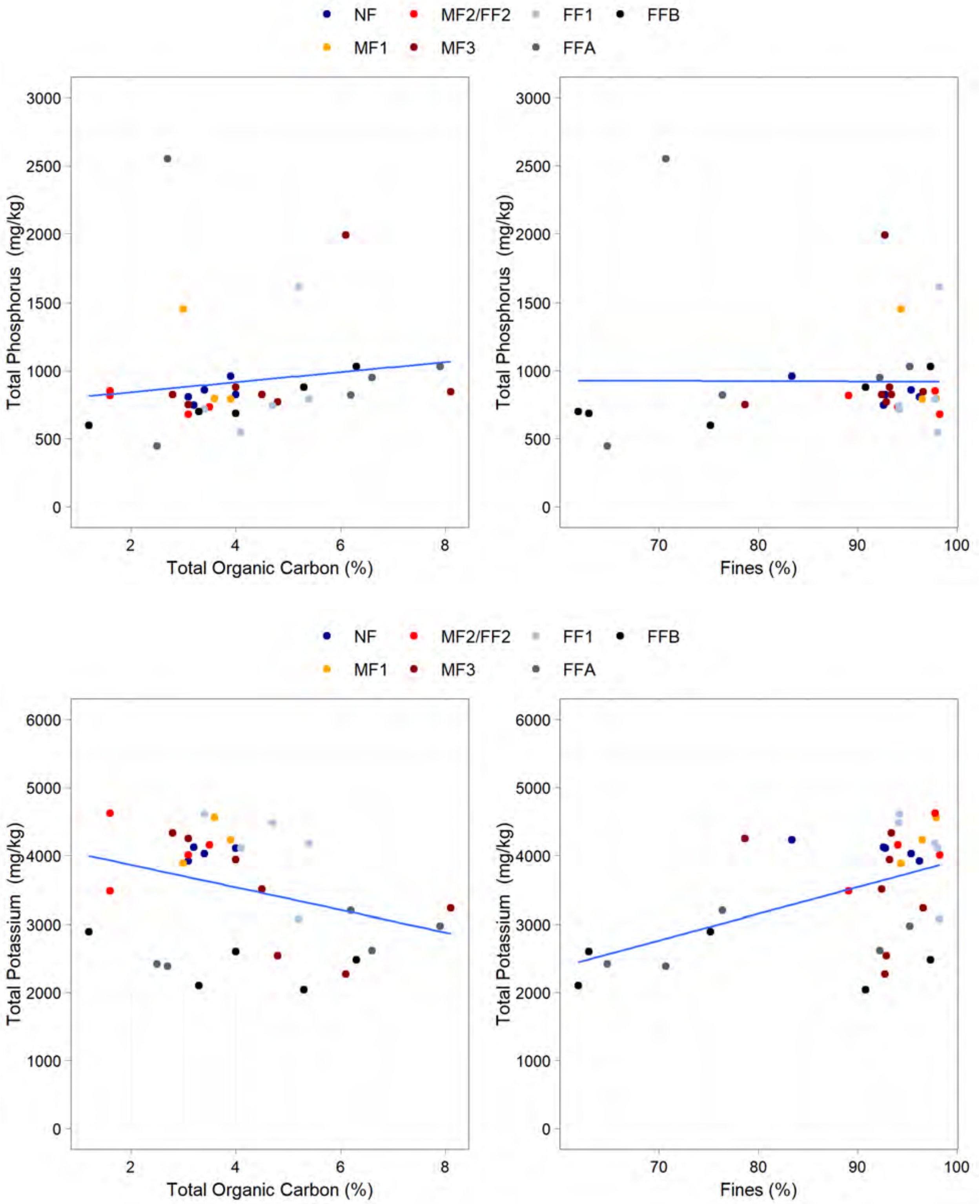


Figure B-4 Scatter Plot of Correlations Between Total Silver and Total Sodium and supporting variables (Total Organic Carbon and Percent Fines), 2019

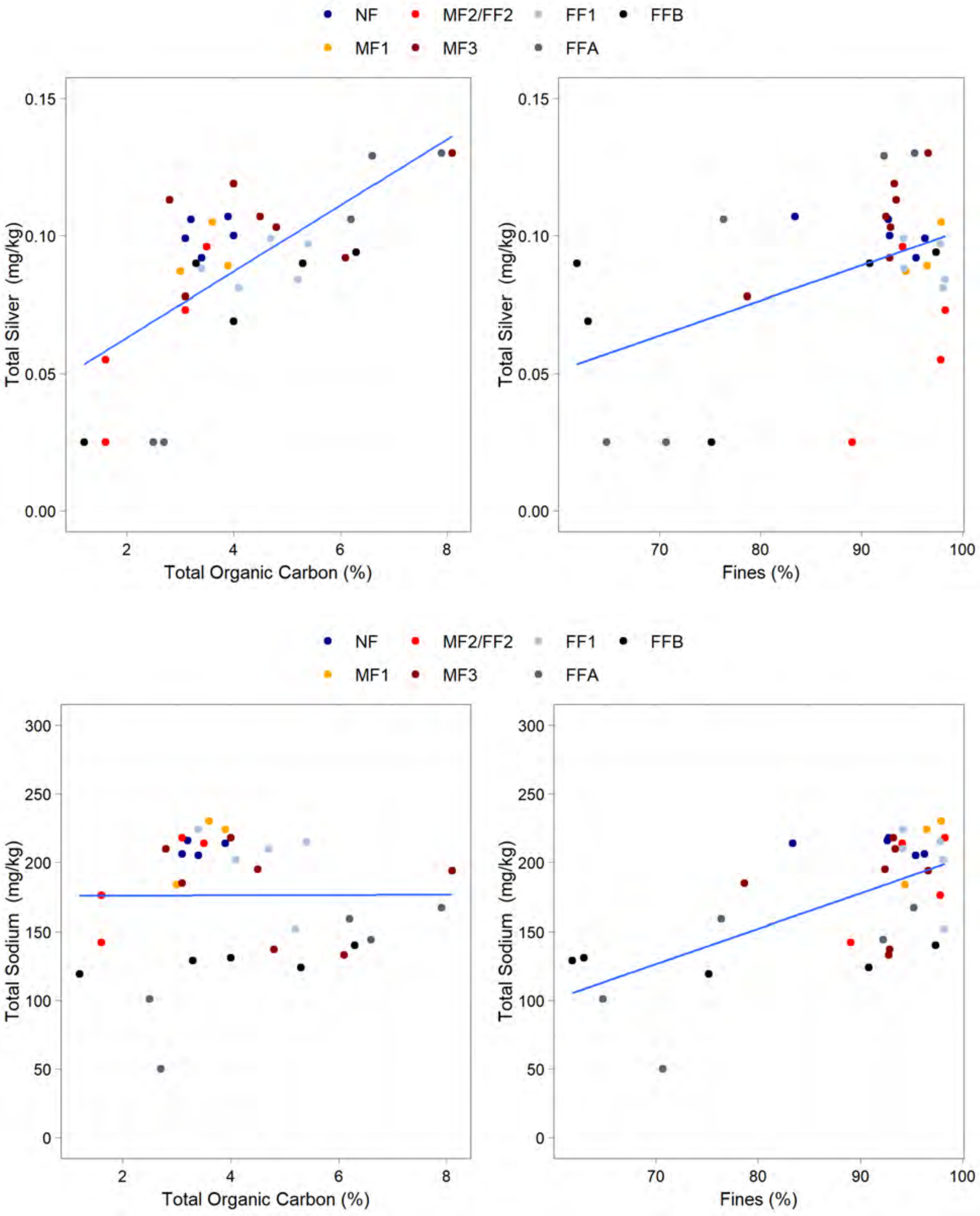


Figure B-5 **Scatter Plot of Correlations Between Total Strontium and Total Tin and supporting variables (Total Organic Carbon and Percent Fines), 2019**

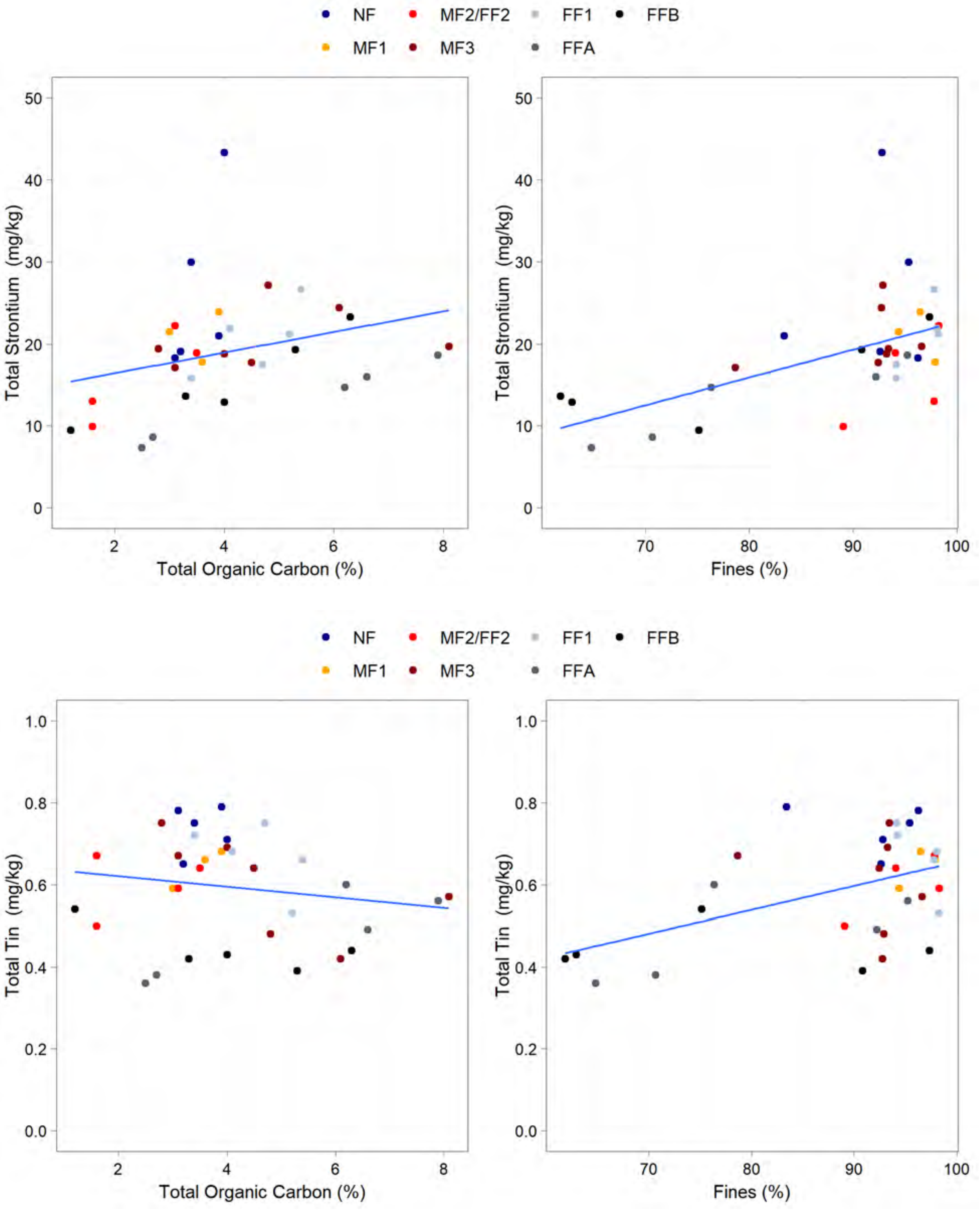
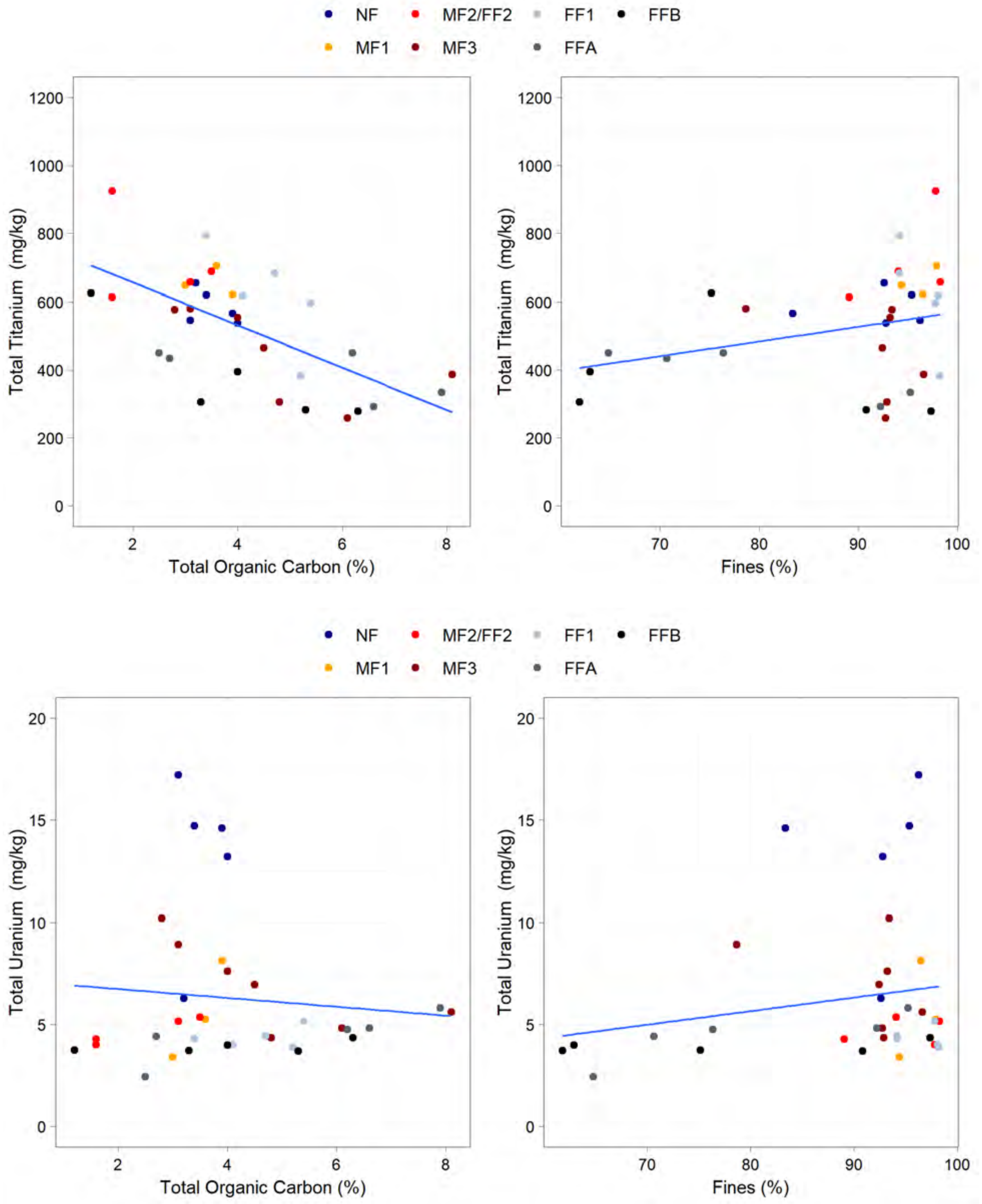


Figure B-6 Scatter Plot of Correlations Between Total Titanium and Total Uranium and supporting variables (Total Organic Carbon and Percent Fines), 2019



ATTACHMENT C

QUALITY ASSURANCE AND QUALITY CONTROL

INTRODUCTION

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. The *Quality Assurance Project Plan Version 3.1* (QAPP; Golder 2017b), outlines the QA/QC procedures employed to support the collection of scientifically-defensible and relevant data addressing the objectives of the AEMP (Golder 2017b). Quality assurance encompasses management and technical practices designed to generate consistent, high quality data. Quality control is an aspect of quality assurance and includes the techniques used to assess data quality and the corrective actions to be taken when data quality objectives (DQOs) are not met. This appendix describes QA/QC practices applied to the sediment quality component of the 2019 Aquatic Effects Monitoring Program (AEMP), evaluates the associated QC data, and describes the implications of QC results to the interpretation of AEMP study results.

QUALITY ASSURANCE

Field Staff Training and Operations

Diavik Diamond Mines (2012) Inc. (DDMI) field staff are trained to be proficient in standardized field sampling procedures, data recording, and equipment operations applicable to sediment quality sampling. Field work was completed according to specified instructions and standard operating procedures (SOPs) described in:

- ENVI-923-0119 AEMP Combined Open Water and Ice Cover
- ENVI-902-0119 Quality Assurance Quality Control
- ENVI-900-0119 Chain of Custody

These SOPs contain guidelines for field record-keeping and sample tracking, guidance for use and calibration of sampling equipment, relevant technical procedures, and sample labelling, shipping, and tracking protocols.

Laboratory

Sediment samples were sent for analyses to Bureau Veritas Laboratory (BV Labs, formerly Maxxam Analytics Inc.). BV Labs is a laboratory accredited by the Canadian Association for Laboratory Accreditation for specific analyses defined in their scope of accreditation. Under the accreditation program, performance assessments are conducted annually for laboratory procedures, analytical methods and internal quality control, and laboratories undergo site assessments every two years. BV Labs used state-of-the-art equipment and instrumentation for the preparation and analysis of the Diavik AEMP samples, and they incorporated a QA protocol in all testing procedures.

Office Operations

A data management system was set in place as an organized system of data control, analysis and filing. Relevant elements of this system were:

- pre-field meetings to discuss specific work instructions with field crews
- field crew check-in with task managers every 24 to 48 hours to report work completed during that period
- designating two crew members responsible for:
  - collecting all required samples
  - immediate download and storage of electronic data
  - completing chain-of-custody and analytical request forms
  - labelling and documentation
  - processing, where required, and delivering samples to analytical laboratory in a timely manner
- cross-checking chain-of-custody forms and analysis request forms by the task manager to verify that the correct analysis packages had been requested
- review of field sheets by the task manager for completeness and accuracy
- reviewing laboratory data immediately after receipt from the analytical laboratory
- creating backup files before data analysis
- completing appropriate logic checks for accuracy of calculations

QUALITY CONTROL

Quality control is a specific aspect of QA that includes techniques used to assess data quality, as well as any remedial measures that are undertaken when DQOs are not met. The techniques employed for QC of the sediment component of the 2019 AEMP consisted of both field- and laboratory-based methods.

The field component of the QC program involved the collection of field duplicate samples, which were used to assess within-station variation and sampling precision. These samples were analyzed for the full suite of sediment chemistry variables assessed in the AEMP.

The internal QC procedures of BV Labs were applied in the chemical analyses of the 2019 AEMP sediment samples. Each laboratory batch included specific laboratory QC samples (e.g., method blanks, laboratory duplicates, reference materials or spiked samples). Sediment sample results were evaluated relative to the QC samples that accompanied the corresponding batch of samples.

Results of field- and laboratory-based QC procedures employed in 2019 are discussed in the following subsections. All sediment variable concentrations are expressed on a dry weight (dw) basis, except for moisture content, which is expressed in percent (%).

Data Completeness

A total of 38 sediment samples were collected in 2019, representing 34 AEMP stations in Lac de Gras and 4 field duplicate samples. All of the 2019 AEMP sediment samples submitted to BV Labs were analyzed for the target analytes listed in Table 4.4-1 of the *AEMP Design Plan Version 4.1* (Golder 2017a).

Sample Holding Times

All sediment sample analyses were performed within the recommended sample holding times for each target analyte.

Detection Limits

BV Labs used analyte-specific detection limits (DLs) to report results for each analyte (i.e., the same DL was used for all samples for a particular analyte, unless some factor such as matrix interference necessitated the use of a greater DL). The DLs used by BV Labs in 2019 are listed in Table 2-2 of this Sediment Quality Report. These DLs were compared with those originally requested by DDMI (Golder 2017a) to identify differences in DLs, and whether those differences would affect data quality.

The laboratory DLs for several analytes were greater than recommended in the *AEMP Design Plan Version 4.1* (Golder 2017a). The DLs for four analytes were greater than those requested: moisture content (0.30 versus 0.10%); aluminum (100 versus 50 mg/kg dw), magnesium (100 versus 20 mg/kg dw), and potassium (100 versus 20 mg/kg dw). BV Labs were contacted to investigate the reasons for the adjusted DLs, at which time BV Labs indicated that they are working towards lowering DLs. Concentrations of these analytes were measured well beyond the DLs (i.e., greater than 5 times the DL) in AEMP sediment samples; therefore, data quality was not affected for these analytes.

The following analytes had improved DLs relative to previous years, and were within the DLs specified in the *AEMP Design Plan Version 4.1* (Golder 2017a): particle size (0.01% dw); arsenic (0.20 mg/kg dw), TOC (0.035% dw), beryllium (0.20 mg/kg dw), chromium (0.50 mg/kg dw), cobalt (0.10 mg/kg dw), lithium (0.50 mg/kg dw), nickel (0.50 mg/kg dw), and vanadium (1.0 mg/kg dw).

Laboratory Method Blanks

A method blank is a clean sample matrix that undergoes processing identical to that carried out on the AEMP samples (e.g., all the reagents used in the analytical procedure). Its purpose is to assess method contamination control, to determine whether any laboratory contamination might have entered into the analytical procedure. In 2019, BV Labs included method blanks in each batch for all applicable variables. The DQO for method blanks is that no target variables should be detected. Concentrations for all laboratory blanks were below the method DL; therefore, the 2019 AEMP sediment quality results were considered acceptable. The measured concentrations represent the actual concentrations in lake sediments and no sign of a laboratory source of contamination was identified.

Laboratory Duplicates

Laboratory duplicates or replicates consist of two or more independently subsampled portions of the same homogenized sample, separately prepared and processed by the identical method. Their purpose is to evaluate the precision of analysis on samples of unknown characteristics. BV Labs analyzed at least one laboratory replicate for each type of analysis performed. The DQO applied by BV Labs for the original sample and the laboratory replicate was that the RPD was less than or equal to 20% for moisture, 35% for particle size analysis and total nitrogen, and either 30% or 40% for metals, depending on the analyte. The RPD was calculated using the following formula:

RPD = (|difference in concentration between duplicate samples| / mean concentration) x 100.

In those cases where concentrations were near the DL (i.e., less than five times the DL), the RPD was not calculated, because the concentrations were not sufficiently elevated to permit a reliable determination. The RPDs for laboratory duplicate samples analyzed in 2019 met the DQOs set by BV Labs for all sediment analytes.

Laboratory Spiked Samples

A matrix spike is a sample to which a known amount of the analyte of interest has been added prior to undergoing sample processing. The results of these analyses are used to evaluate sample matrix interference. In 2019, BV Labs included at least one matrix spike in each sample batch. The DQO for analyses of metals in matrix spike samples was a percent recovery of 75% to 125%, which was met for all analytes.

A spiked blank is a blank matrix sample to which a known amount of the analyte of interest has been added prior to undergoing sample processing. The results of this analysis are used to evaluate method accuracy. In 2019, BV Labs included at least one spiked blank in each sample batch. The DQO for analyses of total nitrogen and metals in spiked blank samples was a percent recovery of 75% to 125%, which was met for all analytes.

Field Duplicates

Field duplicate samples consisted of two samples collected from the same location at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually and submitted separately to BV Labs for identical analyses. Field duplicate samples were used to check within-station variation and precision of field sampling. Differences between concentrations measured in field duplicate sediment samples were calculated as the RPD for each analyte, using the same formula as for laboratory duplicates. Before calculating the RPD, concentrations below the DL were replaced with values equal to 0.5 times the DL value. The RPD was calculated using the following formula:

RPD = (|difference in concentration between duplicate samples| / mean concentration) x 100.

The RPD was only calculated if concentrations in one or both samples were greater than or equal to five times the DL. The RPD value for a given variable was considered notable if it did not meet the DQO of less than or equal to 30%. Because in some cases this DQO was more stringent than used by BV Labs for internal QC of laboratory duplicate samples (i.e., 30% to 40%, depending on analyte), duplicate samples with an RPD greater than 60% were noted as requiring additional follow-up, per the QAPP (Golder 2017b). Laboratory duplicates consist of two independently analyzed portions of the same sample and would, therefore, be expected to have less variability than field duplicates, which consist of two completely separate grab samples collected from the lake bottom.

In 2019, field duplicate samples were collected from four of the 34 AEMP stations (i.e., NF2, MF2-1, MF3-1, and FF2-2 for metals, TOC and TOM [top 1 cm]; and NF2, MF1-3, MF3-1, and FF2-2 for particle-size and TOC [top 10 to 15 cm]), representing 12% of the total number of sediment samples submitted to the laboratory (Table C-1). Results for 17 sediment quality variables analyzed in 2019 (i.e., TOM, TOC, sand, clay, arsenic, bismuth, cadmium, copper, lead, lithium, manganese, molybdenum, nickel, strontium, tin, uranium, and zinc) exceeded the DQO of less than or equal to 30% RPD in at least one set of field duplicates. Of the 17 variables that had RPDs above 60%, nine variables (i.e., TOM, TOC, sand, clay, bismuth, cadmium, lead, manganese and molybdenum) had RPD values that were greater than 60% in one set of field duplicates (Table C-1). Manganese and cadmium had respective RPDs of up to 175% and 155%, which were from two different sets of duplicates, FF2-2 and NF2, respectively. Clay, sand, arsenic, bismuth, cadmium, manganese and uranium exceeded the DQO in two or more sets of field duplicates, with bismuth and manganese exceeding the DQO in all four sets; therefore bismuth and manganese showed a tendency of being more variable than other parameters.

Re-analysis of the sediment samples was requested and results were confirmed, with the exception of TOC at MF3-5 top 10 to 15 cm (updated from 0.064% to 4.7%) and the particle-size analysis for the MF3-1 duplicate (MF3-1-5, sand fraction, updated from 29.8% to 30.2 %; silt fraction, updated form 54.7% to 60.0%; and clay fraction, updated from 15.6% to 9.8%).

Overall, the inconsistent concentrations observed in the field duplicate samples do not imply a systematic error in sample collection or analysis, but rather that sediment chemistry has large variability naturally throughout Lac de Gras, as demonstrated by the relatively large RPDs.

Logic Checks

Logic checks done for the sediment quality component included the comparison of parameters that have close relationships (i.e., TOC and OM, TOC and TN), or differences in TOC between top 1-cm and top 10-cm samples. To assess the relationships, two different ratios were calculated (e.g. TOC/TN and TOM/TOC). These checks do not have established criteria for acceptance or refusal of the data. Rather, these ratios provide insights to data issues that might have been overlooked by other methods, which might include dilution errors, typographical errors and inconsistent results overall. The decision to request re-checks is based on the best professional judgment of the reviewer. Given the similarities of the study area, it is expected that these ratios will not fluctuate excessively, and therefore, results deviating from the overall pattern were looked into in detail. Based on these assessments, one inconsistent TOC result, for the sample collected at MF3-5 top 10 to 15 cm was identified and subsequently reviewed by BV Labs; the result was found to be erroneous and was updated from 0.064% to 4.7%.

Summary and Conclusion

Field duplicate samples were collected at four of the 34 stations (representing 12% of total samples). A total of 17 sediment quality variables (TOM, TOC, sand, clay, arsenic, bismuth, cadmium, copper, lead, lithium, manganese, molybdenum, nickel, strontium, tin, uranium, and zinc) had RPDs greater than 30% in one or more duplicate samples. Of these, nine variables (TOM, TOC, sand, clay, bismuth, cadmium, lead, manganese and molybdenum) had RPDs greater than 60%. Organic matter, TOC, manganese, silver, and tin exceeded the DQO (i.e., had an RPD greater than 30%) in one set of field duplicates. Lead tended to be more variable, with RPD values greater than 30% in three of four sets of field duplicates, but only one set had an RPD value greater than 60%.

Based on the results of the QA/QC analysis, the sediment quality data collected were deemed to be of acceptable quality for the purposes of the program.

Table C-1 Results for Sediment Quality Field Duplicate Samples, 2019

Variable	Unit	Detection Limit	NF2-4	NF2-5	RPD	MF2-1-4[a]	MF2-1-5[a]	RPD	MF3-1-4	MF3-1-5	RPD	FFA-2-4	FFA-2-5	RPD
			Duplicate 1[b]	Duplicate 2		Duplicate 1[b]	Duplicate 2		Duplicate 1[b]	Duplicate 2		Duplicate 1[b]	Duplicate 2	
Physical Properties														
Moisture	%	0.30	72	77	7%	68	68	0%	71	67	6%	73	64	13%
Total Organic Carbon[c]	%	0.005	3.1	3.0	3%	2.9	2.8	4%	2.3	1.8	24%	4.4	2.4	**59%**
Total Organic Carbon[d]	%	0.005	3.4	3.3	3%	1.6	1.8	12%	3.1	2.8	10%	1.6	3.6	**77%**
Organic Matter	%	0.035	5.8	5.7	2%	2.7	3.2	17%	5.3	4.9	8%	2.8	6.1	**74%**
Nutrients														
Total Nitrogen	%	0.20	<0.2	0.4	-	<0.2	<0.2	-	0.2	0.2	-	0.3	0.3	-
Total Phosphorus	mg/kg dw	10	857	898	5%	819	809	1%	750	744	1%	852	780	9%
Total Metals														
Aluminum	mg/kg dw	100	15,200	15,400	1%	14,200	13,700	4%	17,300	13,600	24%	18,700	15,600	18%
Antimony	mg/kg dw	0.1	0.11	<0.10	-	<0.10	<0.10	-	<0.10	<0.10	-	<0.10	<0.10	-
Arsenic	mg/kg dw	0.2	29.4	46.8	**46%**	21.7	26.1	18%	19.9	35.1	**55%**	19.9	22.2	11%
Barium	mg/kg dw	0.1	159	121	27%	88.6	90	2%	111	117	5%	126	135	7%
Beryllium	mg/kg dw	0.2	0.58	0.55	5%	0.54	0.48	12%	0.57	0.51	11%	0.64	0.54	17%
Bismuth	mg/kg dw	0.1	3.97	2.2	**57%**	0.67	0.92	**31%**	3.48	1.82	**63%**	0.56	1.02	**58%**
Boron	mg/kg dw	1.0	5.1	5.0	2%	4.4	4.3	2%	6.2	5.3	16%	5.7	4.6	21%
Cadmium	mg/kg dw	0.05	2.31	0.295	**155%**	0.104	0.147	**34%**	0.417	0.356	16%	0.109	0.397	**114%**
Calcium	mg/kg dw	100	2,100	2010	4%	1,530	1,520	1%	1,850	1,940	5%	2,070	2,080	0%
Chromium	mg/kg dw	0.5	49.3	53.3	8%	49.3	48.1	2%	46.9	49.9	6%	67.1	56.3	18%
Cobalt	mg/kg dw	0.1	27.3	31.3	14%	19.1	22.6	17%	23	28.2	20%	19.3	25.7	28%
Copper	mg/kg dw	0.5	55.7	41.1	**30%**	34.9	35.5	2%	34.7	38	9%	42.6	39.1	9%
Iron	mg/kg dw	100	30,300	38,500	24%	24,100	25,300	5%	25,600	29,400	14%	30,800	30,000	3%
Lead	mg/kg dw	0.1	25.2	8.51	**99%**	5.22	6.19	17%	9.55	8.52	11%	6.56	7.47	13%
Lithium	mg/kg dw	0.5	43.2	42.5	2%	30	28	7%	44.6	36	21%	44.5	29.6	**40%**
Magnesium	mg/kg dw	100	7,890	8,420	6%	7,360	7,100	4%	9,080	7,430	20%	9,940	8,890	11%
Manganese	mg/kg dw	0.2	19,300	10,400	**60%**	1,670	2,280	**31%**	8,660	12,000	**32%**	1,370	20,900	**175%**
Mercury	mg/kg dw	0.05	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-
Molybdenum	mg/kg dw	0.1	15	7.88	**62%**	3.29	4.3	27%	6.16	6.07	1%	2.46	8.25	**108%**
Nickel	mg/kg dw	0.5	77.5	50.1	**43%**	39.5	40.9	3%	73.5	65.8	11%	58.4	66.5	13%
Potassium	mg/kg dw	100	4,030	4,140	3%	3,480	3,470	0%	4,250	4,130	3%	4,620	4,190	10%
Selenium	mg/kg dw	0.5	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%
Silver	mg/kg dw	0.05	0.092	0.094	-	<0.05	0.055	-	0.078	0.073	-	0.055	0.086	-
Sodium	mg/kg dw	100	205	197	4%	142	144	1%	185	185	0%	176	226	25%
Strontium	mg/kg dw	0.1	29.9	21.2	**34%**	9.89	10.7	8%	17.1	19.8	15%	13	21.9	**51%**
Thallium	mg/kg dw	0.05	0.373	0.337	10%	0.246	0.265	7%	0.377	0.377	0%	0.26	0.309	17%
Tin	mg/kg dw	0.1	0.75	0.63	17%	0.5	0.53	6%	0.67	0.68	1%	0.67	0.58	14%
Titanium	mg/kg dw	1.0	619	599	3%	613	601	2%	579	578	0%	925	629	**38%**
Uranium	mg/kg dw	0.05	14.7	10.5	**33%**	4.29	4.96	14%	8.9	7.29	20%	4.02	6.36	**45%**
Vanadium	mg/kg dw	1.0	40.1	42.8	7%	39.7	39.6	0%	37.1	39.5	6%	52	46.3	12%
Zinc	mg/kg dw	1.0	101	70.2	**36%**	54.7	54.7	0%	69.5	66.6	4%	76	71.5	6%
Particle Size														
Sand	%	0.01	4.6	4.4	3%	2.1	2.0	4%	21.3	29.8	**33%**	2.2	4.7	**74%**
Silt	%	0.01	84.1	84.8	0.8%	76.1	66.6	13%	69.8	54.7	24%	85.6	71.5	18%
Clay	%	0.01	11.3	10.8	5%	21.9	31.4	**36%**	8.9	15.6	**55%**	12.2	23.8	**64%**

(a) Samples MF2-1-4 and MF2-1-5 (top 1 cm) were analyzed for organic matter, total organic carbon, metals and nutrients, whereas MF1-3-4 and MF1-3-5 (top 10-15cm) were analyzed for particle-size and total organic carbon.

(b) Duplicate 1 also referred to as “parent sample”.

(c) Total Organic Carbon from top 10 to 15 cm samples.

(d) Total Organic Carbon from top 1 cm samples.

Notes: - = not measured or relative percent difference (RPD) was not calculated, because the concentration in one or both of the duplicate samples was below the detection limit or less than five times the detection limit.

Bolded and underlined values indicate duplicate samples that had RPD values greater than 30%.

dw = dry weight; < = less than; NF = near-field; MF = mid-field; FF= far-field.

ATTACHMENT D

2019 SURVEILLANCE NETWORK PROGRAM (SNP) DATA FOR SELECTED SEDIMENT QUALITY VARIABLES

Table D-1 Metal Concentrations at the Mixing Zone, 2019 Surveillance Network Program

Variable	Unit	Detection Limit	SNP Station		
			1645-19A	1645-19B2	1645-19C
Aluminum	mg/kg dw	100	14,200	15,300	16,800
Antimony	mg/kg dw	0.1	0.14	0.10	<0.10
Arsenic	mg/kg dw	0.5	848	80	20
Barium	mg/kg dw	0.1	1,060	106	133
Beryllium	mg/kg dw	0.2	0.49	0.49	0.52
Bismuth	mg/kg dw	0.1	10	9.3	17
Cadmium	mg/kg dw	0.05	0.31	0.2	0.28
Calcium	mg/kg dw	100	2,150	2,010	2,280
Chromium	mg/kg dw	1	37	44	40
Cobalt	mg/kg dw	0.3	74	36	26
Copper	mg/kg dw	0.5	36	37	32
Iron	mg/kg dw	100	109,000	46,300	26,100
Lead	mg/kg dw	0.1	19	15	26
Lithium	mg/kg dw	5.0	44	46	59
Magnesium	mg/kg dw	100	5,750	6,590	6,600
Manganese	mg/kg dw	0.2	40,500	5,190	20,500
Mercury	mg/kg dw	0.05	<0.050	<0.050	<0.050
Molybdenum	mg/kg dw	0.1	26	4.8	5.4
Nickel	mg/kg dw	0.8	47	41	50
Phosphorus	mg/kg dw	10	2,220	981	1,180
Potassium	mg/kg dw	100	4,000	4,030	4,600
Selenium	mg/kg dw	0.5	<0.50	<0.50	<0.50
Silver	mg/kg dw	0.05	0.13	0.14	0.14
Sodium	mg/kg dw	100	212	200	252
Strontium	mg/kg dw	0.1	32	19	17
Thallium	mg/kg dw	0.05	0.35	0.33	0.41
Tin	mg/kg dw	0.1	0.93	0.93	1.4
Titanium	mg/kg dw	1.0	653	732	765
Uranium	mg/kg dw	0.05	28	26	44
Vanadium	mg/kg dw	2.0	30	35	31
Zinc	mg/kg dw	1.0	97	78	97

dw = dry weight; <= less than; SNP = Surveillance Network Program.

ATTACHMENT E

2019 BOX-PLOTS OF SEDIMENT QUALITY VARIABLES

Figure E-1 Clay content (%) Mixing Zone (SNP-19) and AEMP Stations, 2019

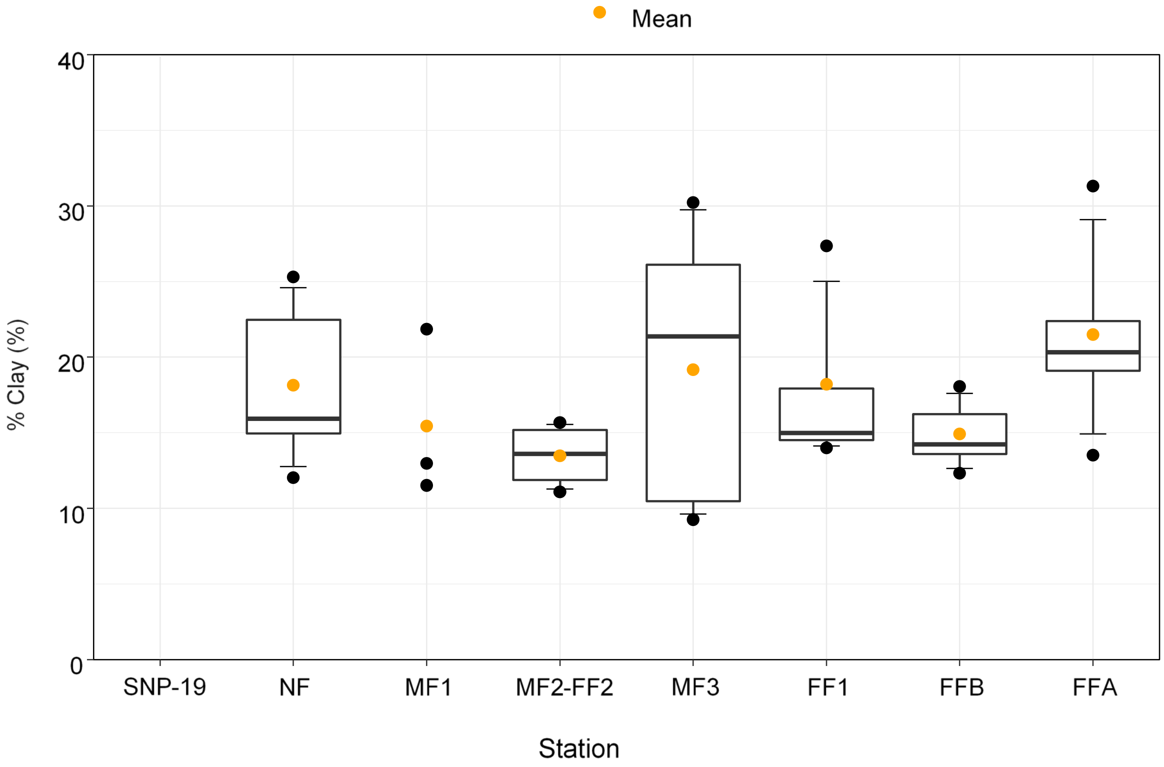


Figure E-2 Sand content (%) Mixing Zone (SNP-19) and AEMP Stations, 2019

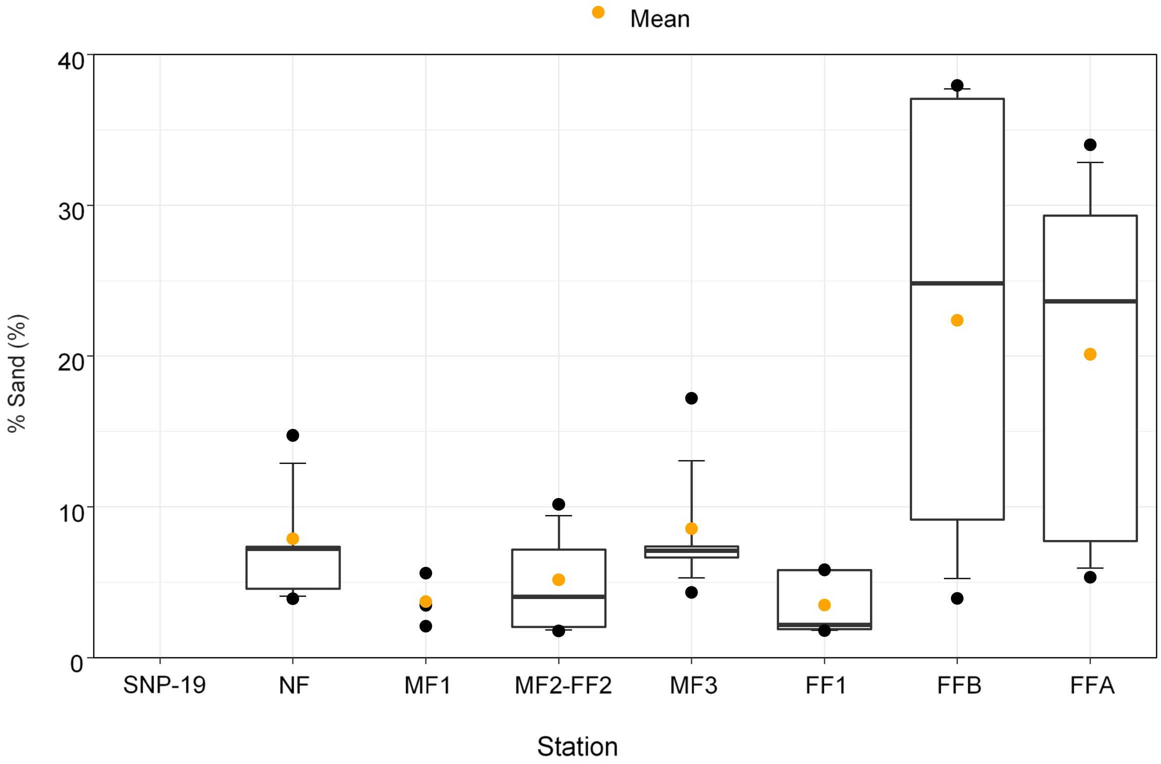


Figure E-3 **Silt content (%) Mixing Zone (SNP-19) and AEMP Stations, 2019**

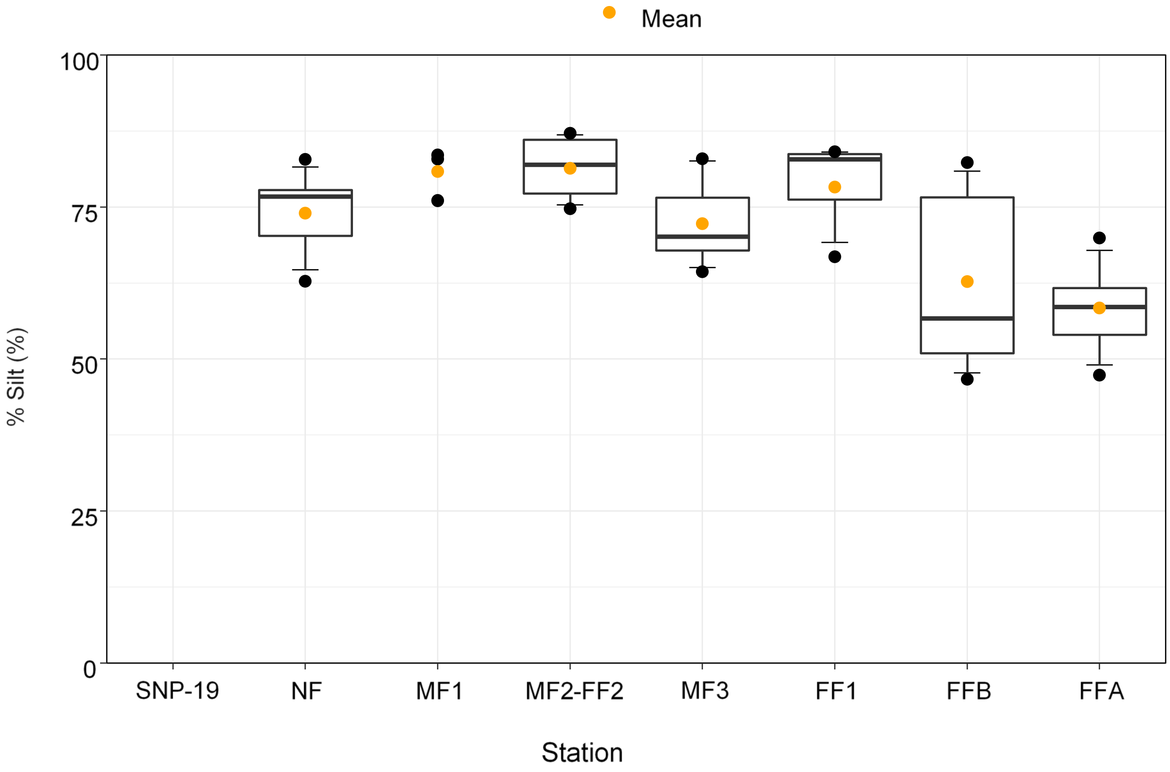


Figure E-4 **Fine Sediment content (%) Mixing Zone (SNP-19) and AEMP Stations, 2019**

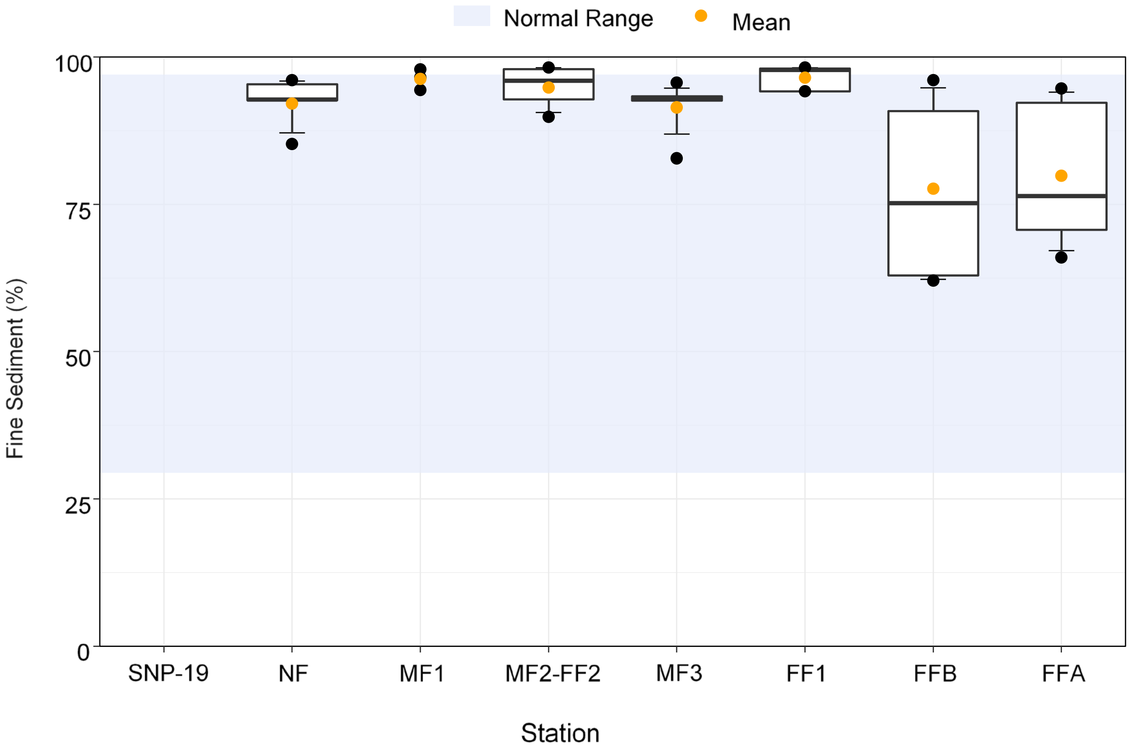


Figure E-5 **Organic Matter (%) Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

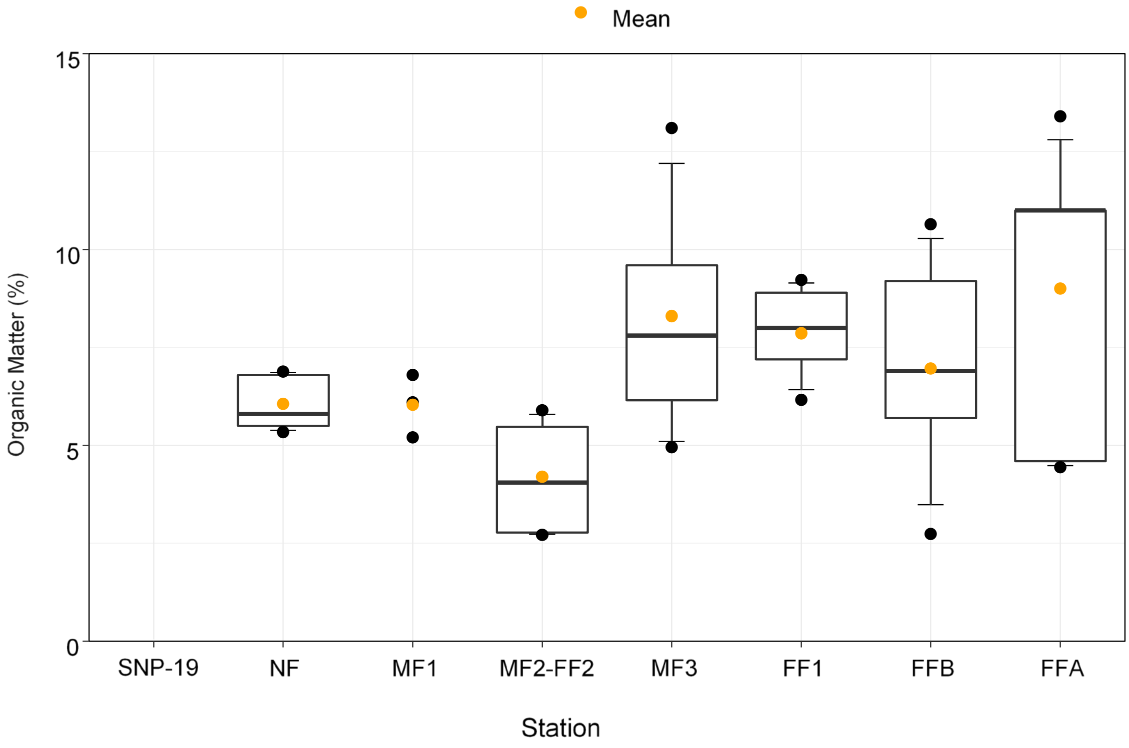


Figure E-6 Total Aluminum Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

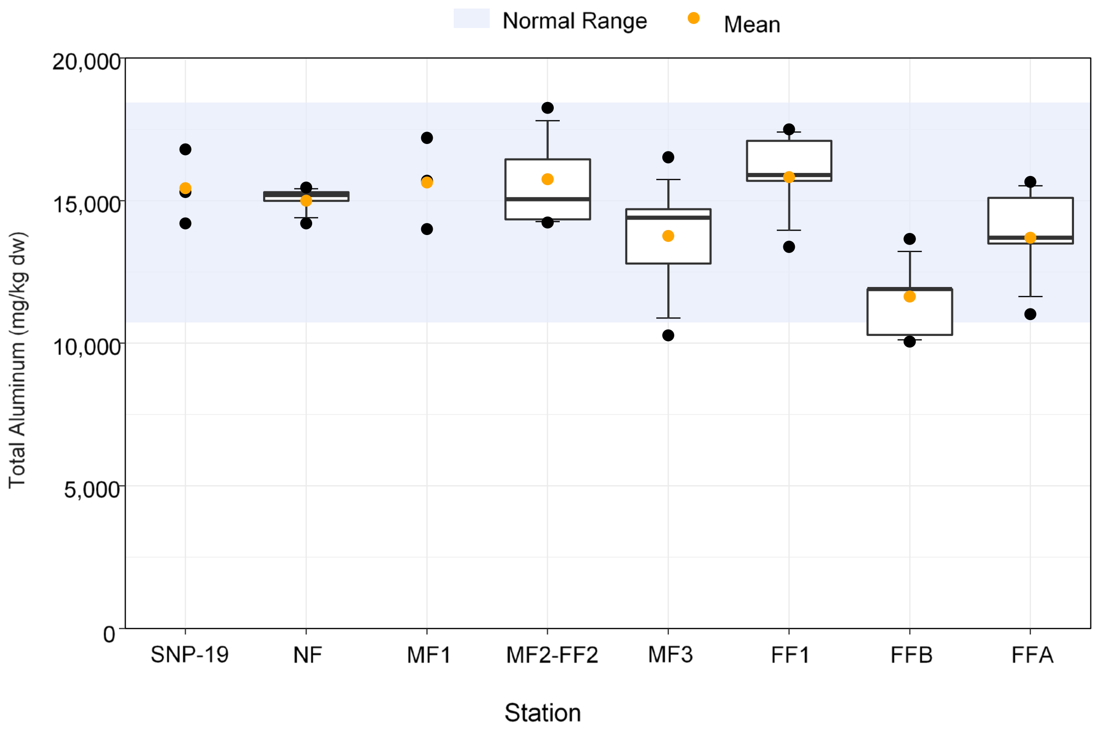


Figure E-7 Total Antimony Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

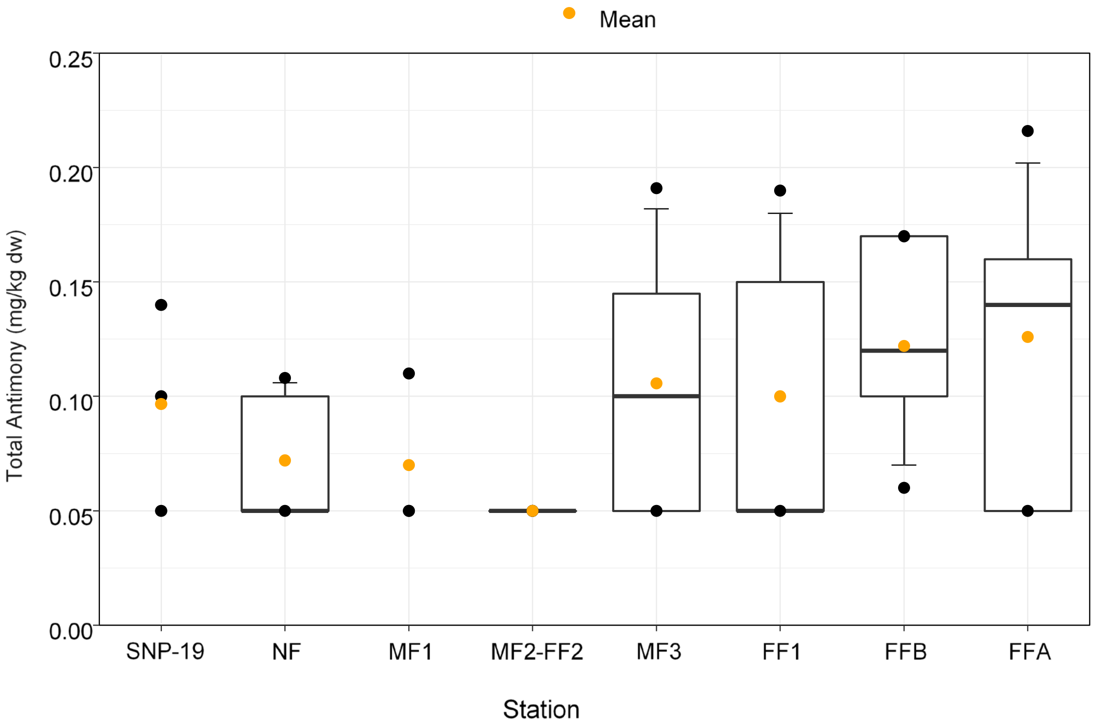


Figure E-8 Total Arsenic Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

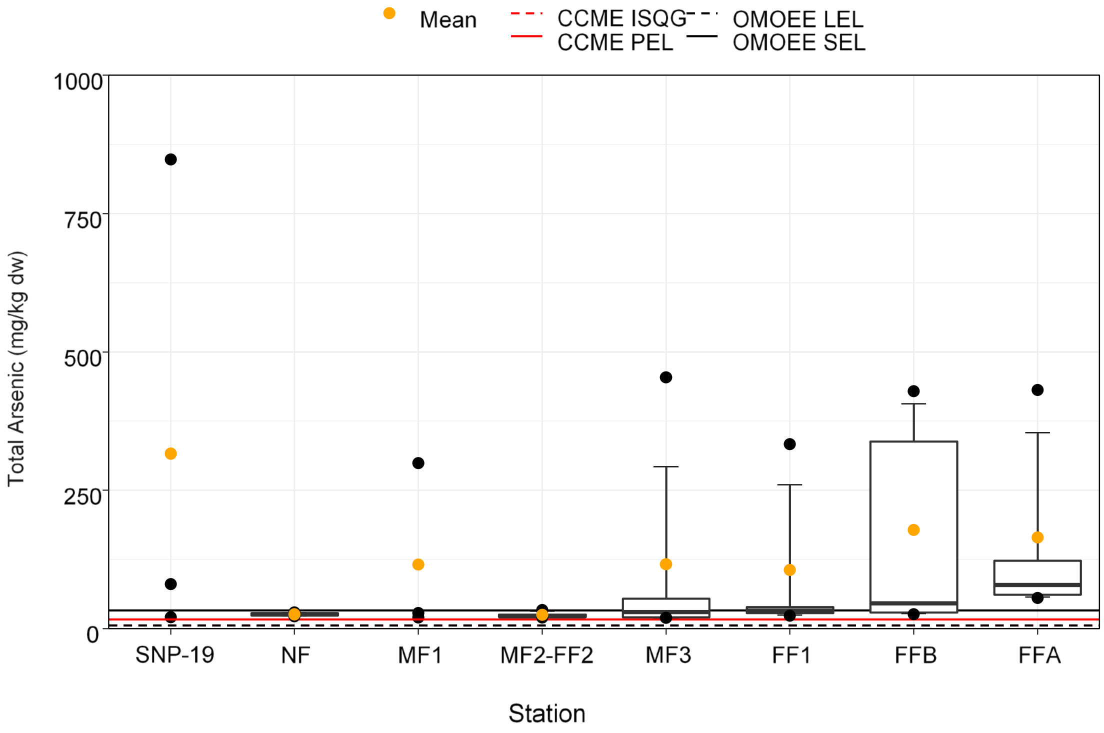


Figure E-9 Total Barium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

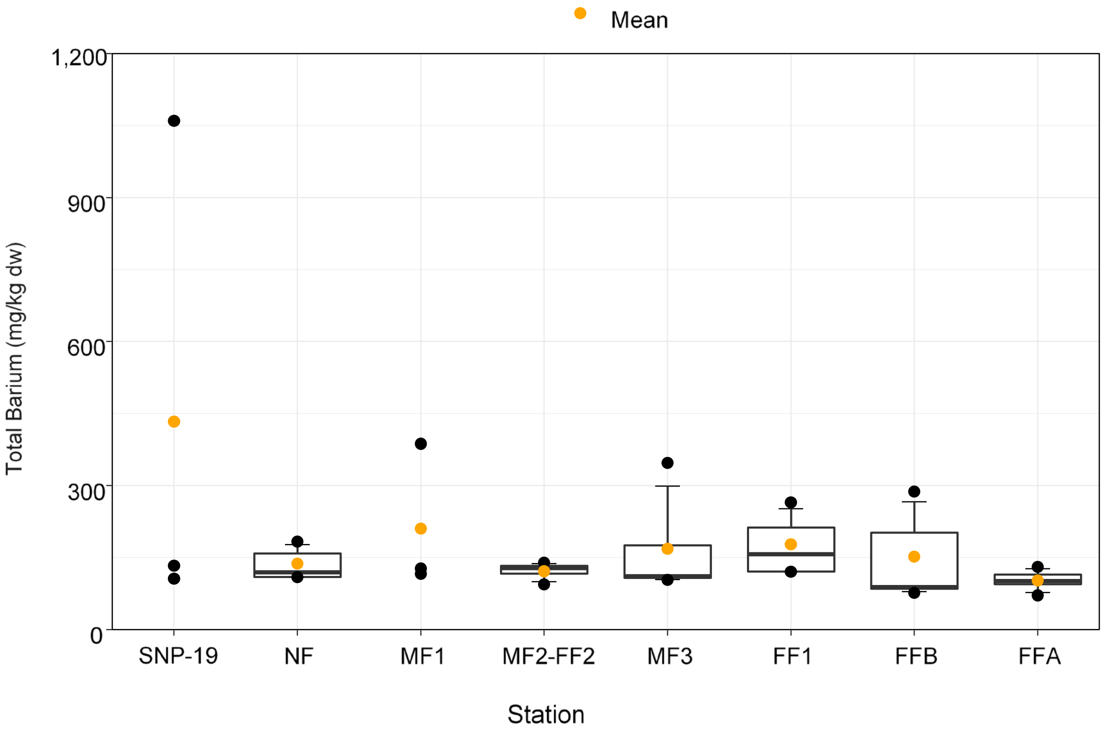


Figure E-10 Total Beryllium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

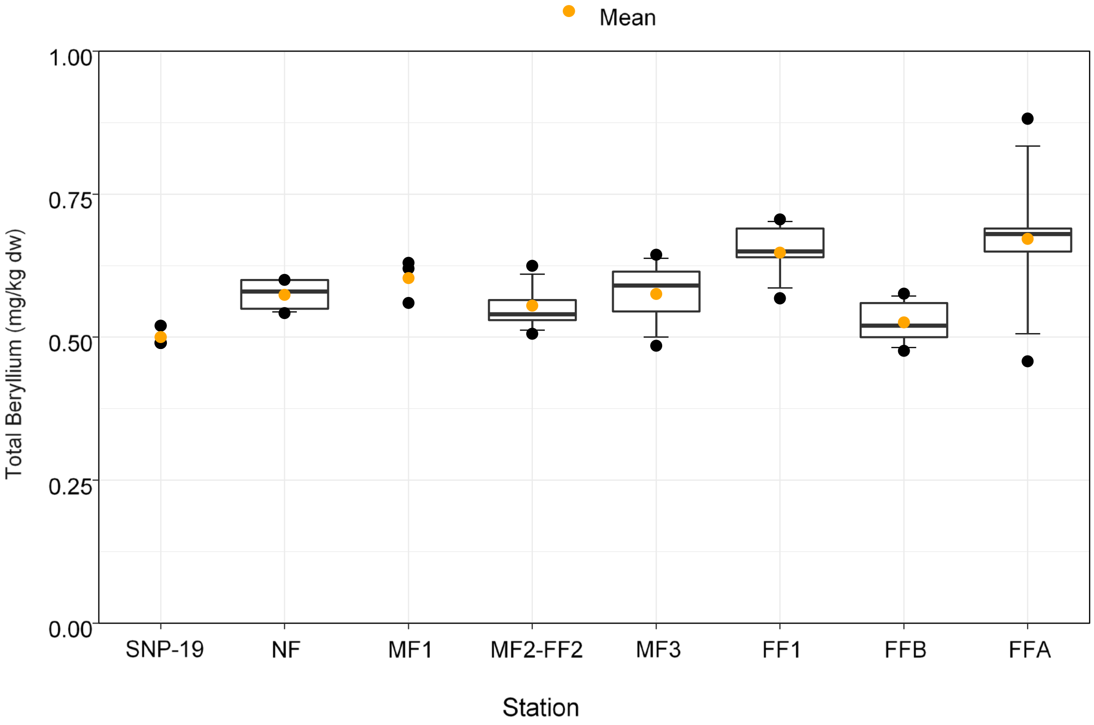


Figure E-11 Total Bismuth Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

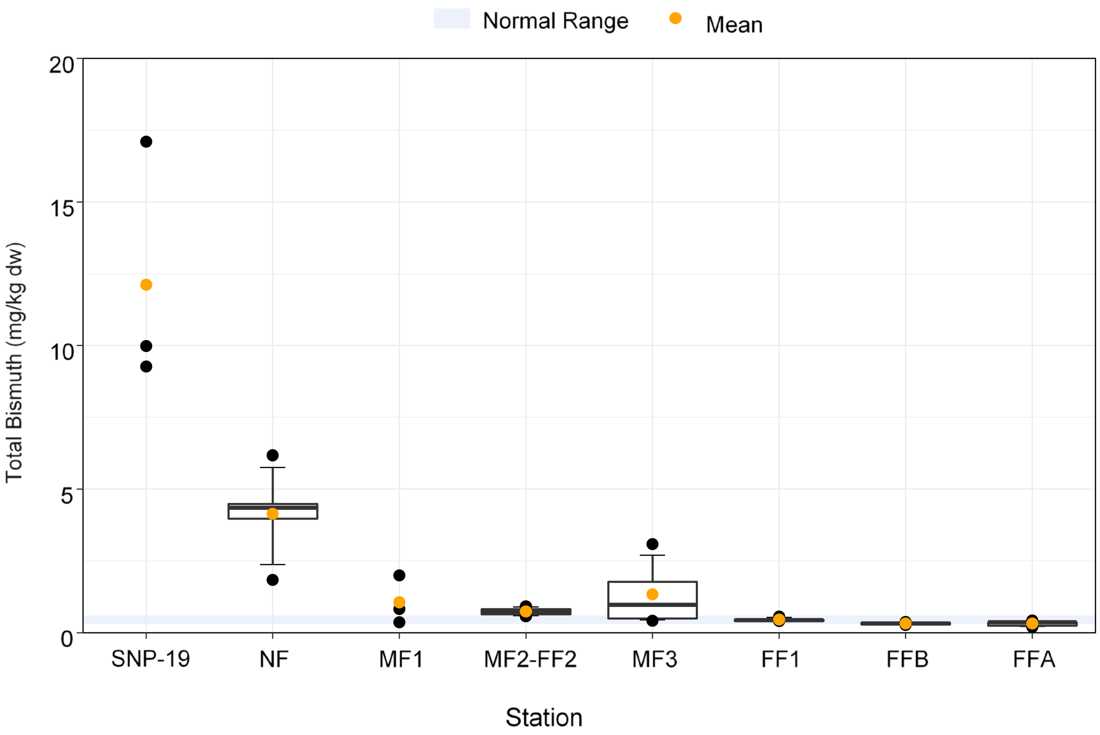


Figure E-12 Total Boron Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

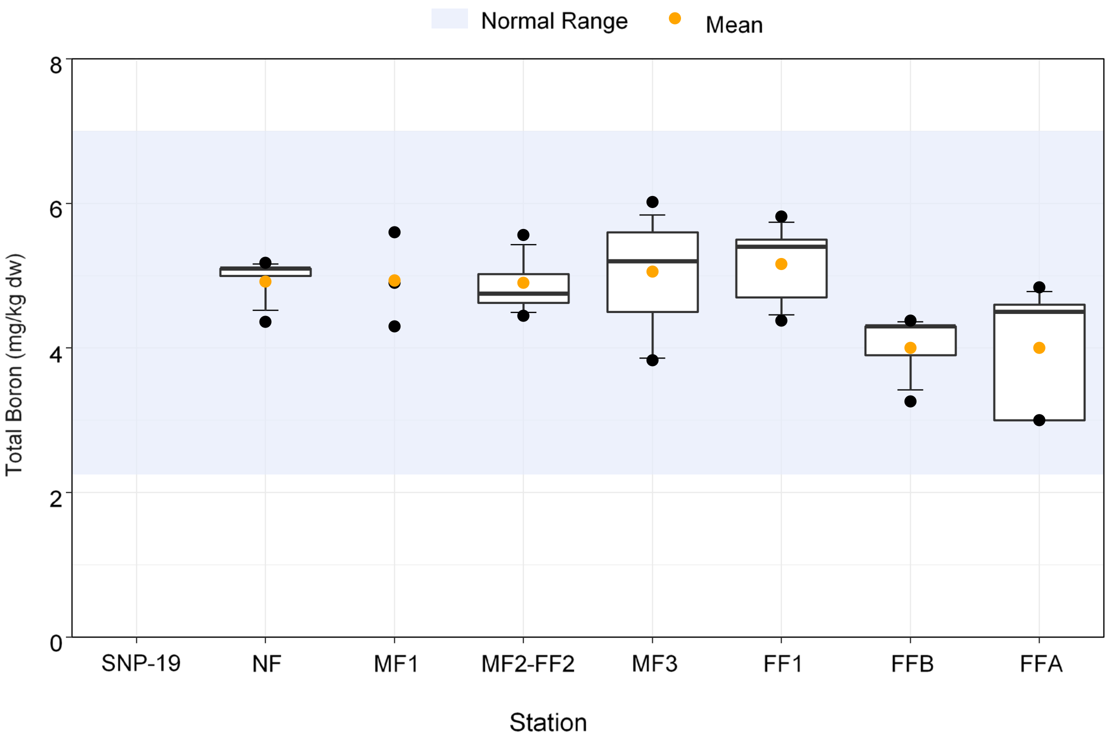


Figure E-13 Total Cadmium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

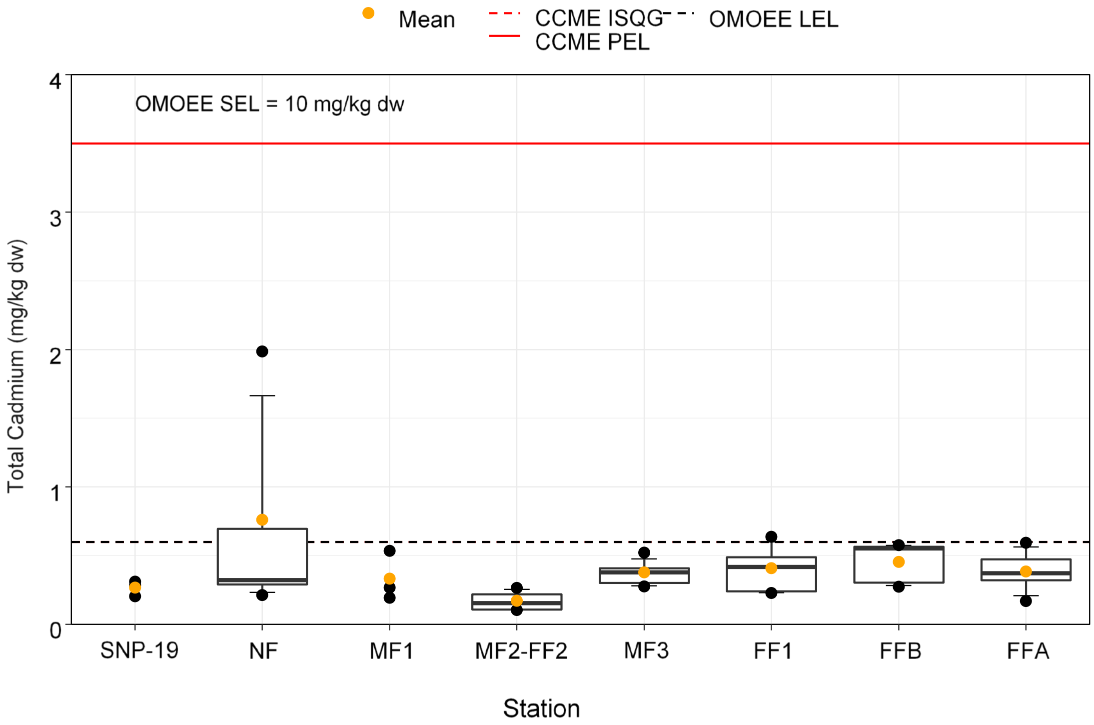


Figure E-14 Total Calcium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

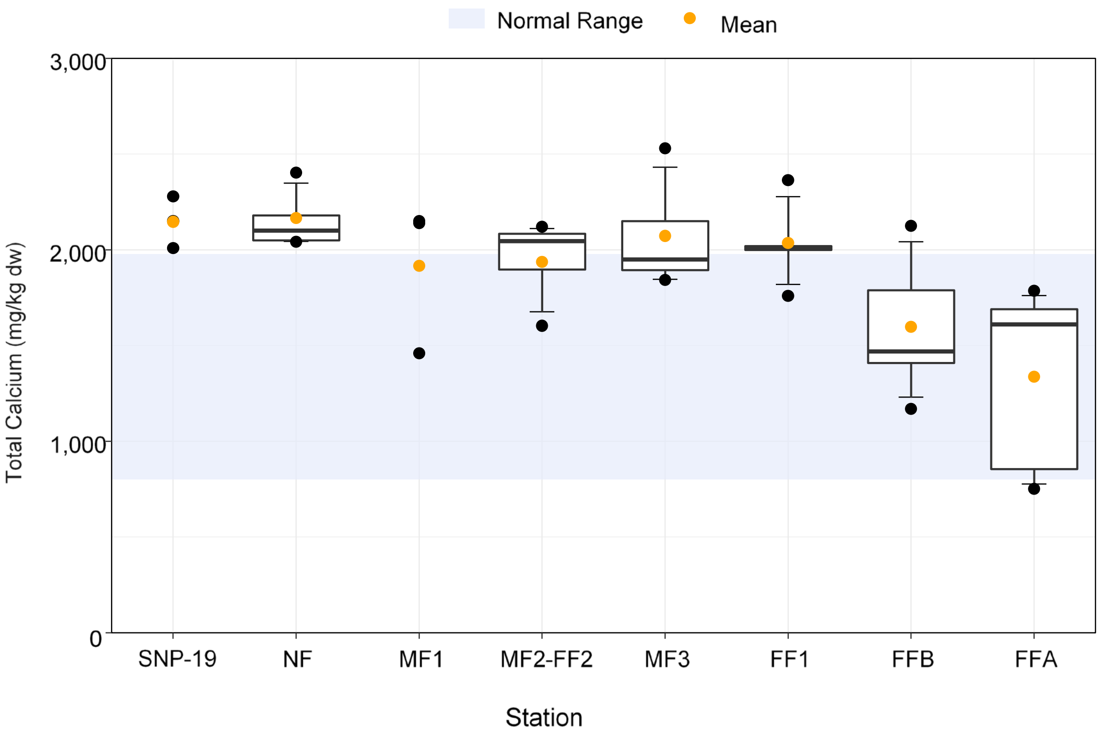


Figure E-15 Total Chormium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

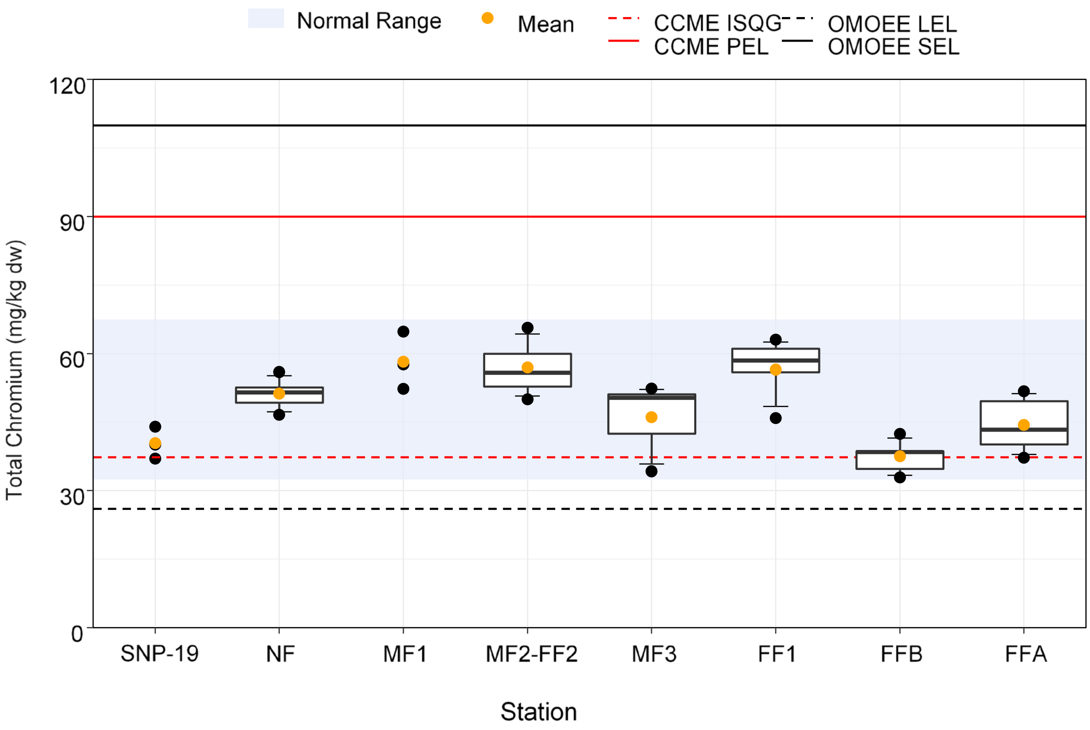


Figure E-16 **Total Cobalt Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

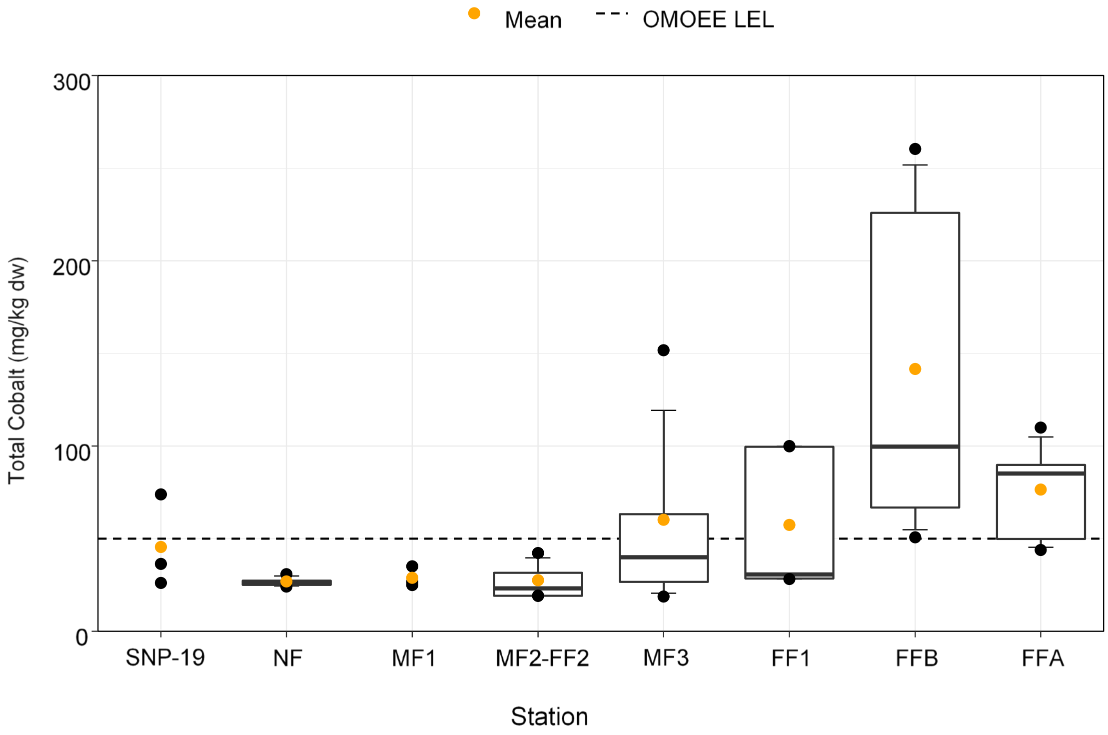


Figure E-17 Total Copper Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

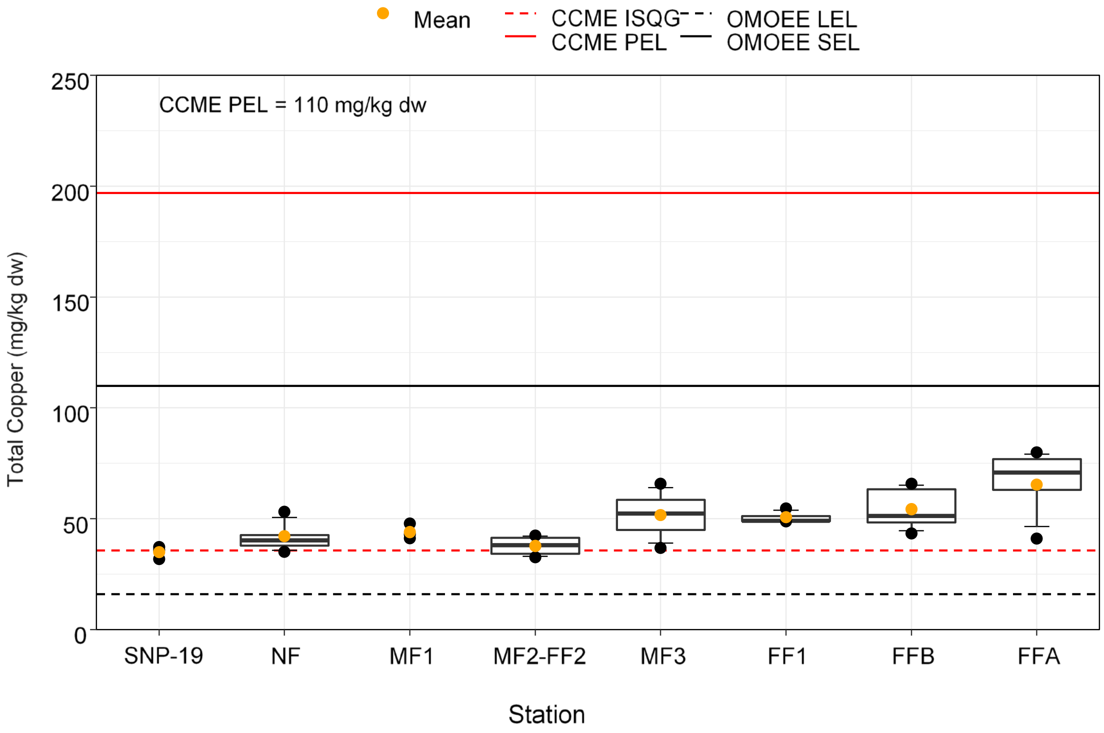


Figure E-18 Total Iron Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

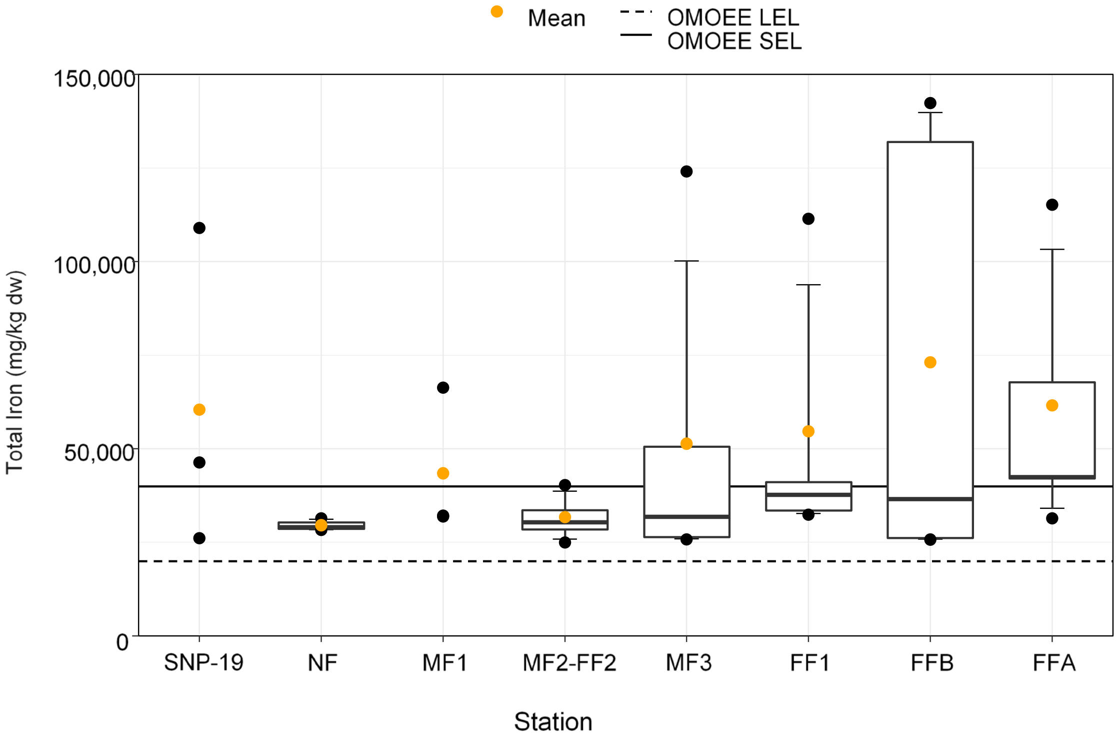


Figure E-19 Total Lead Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

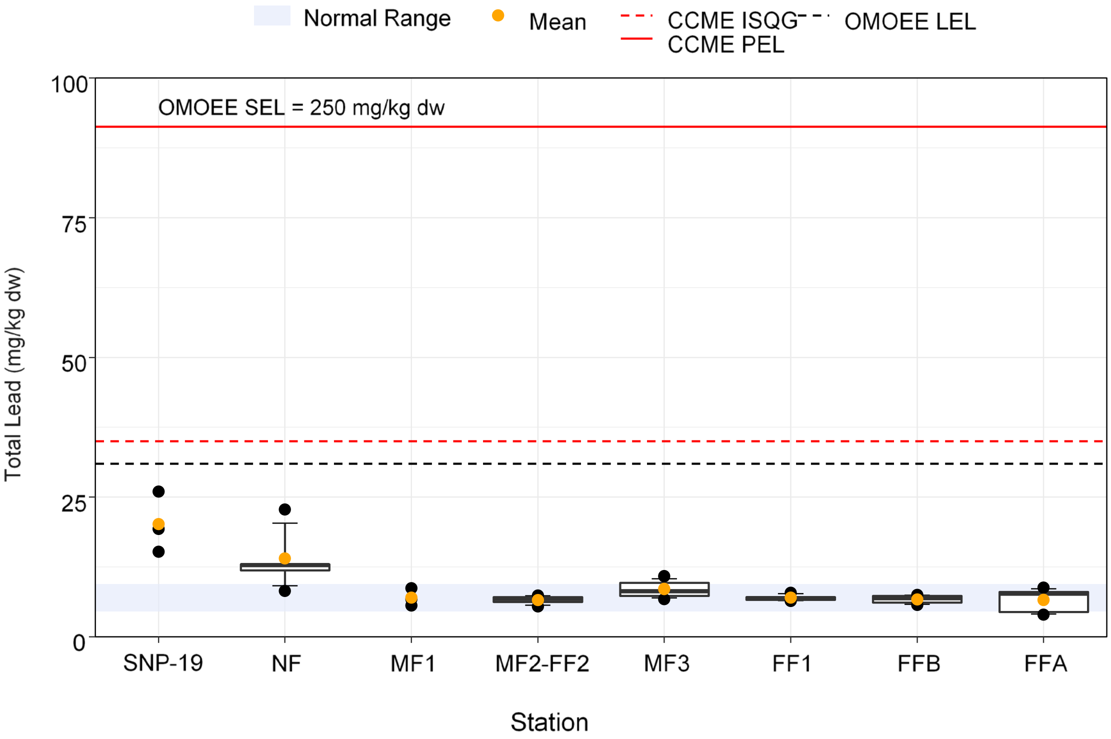


Figure E-20 Total Lithium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

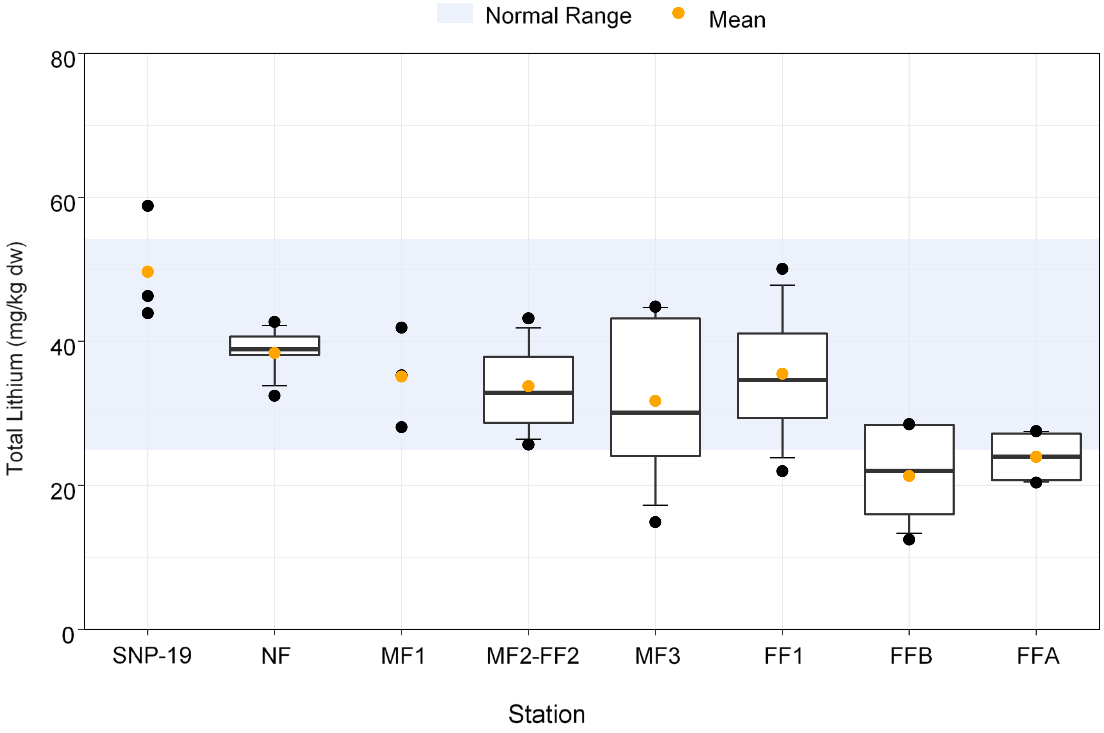


Figure E-21 **Total Magnesium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

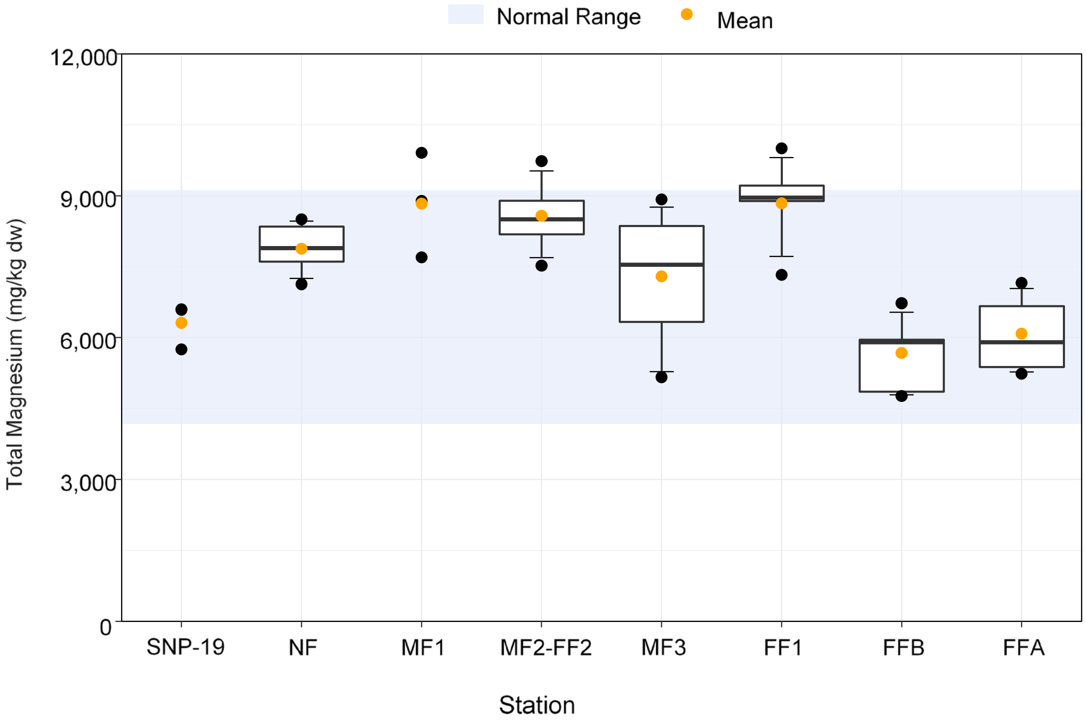


Figure E-22 **Total Manganese Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

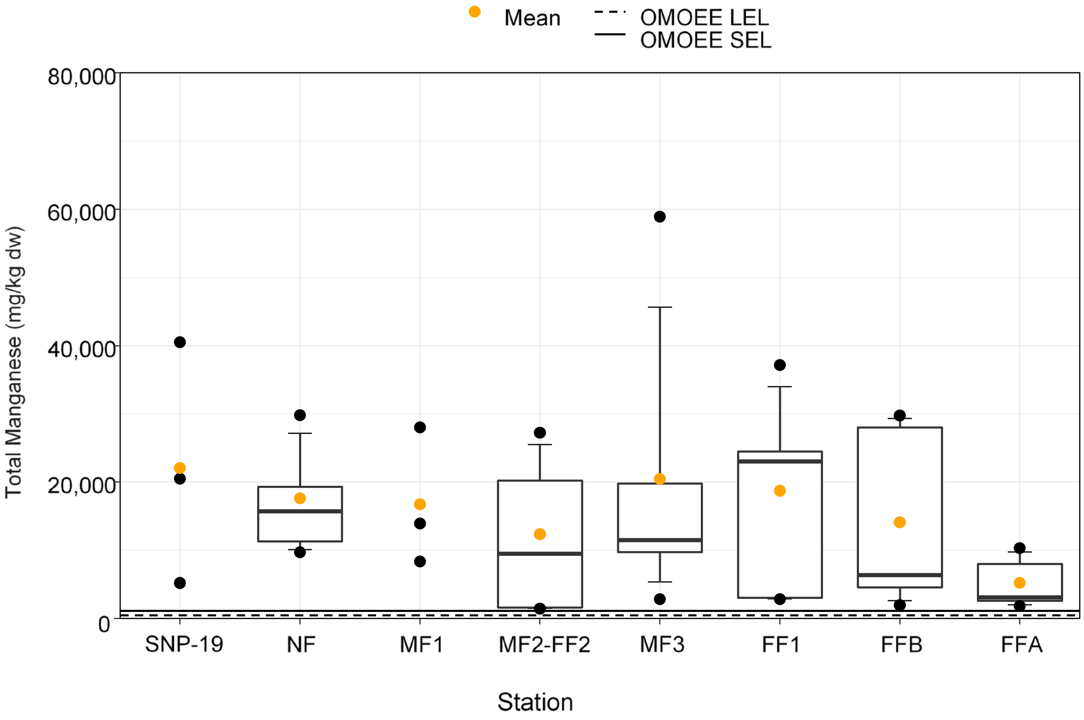


Figure E-23 Total Mercury Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

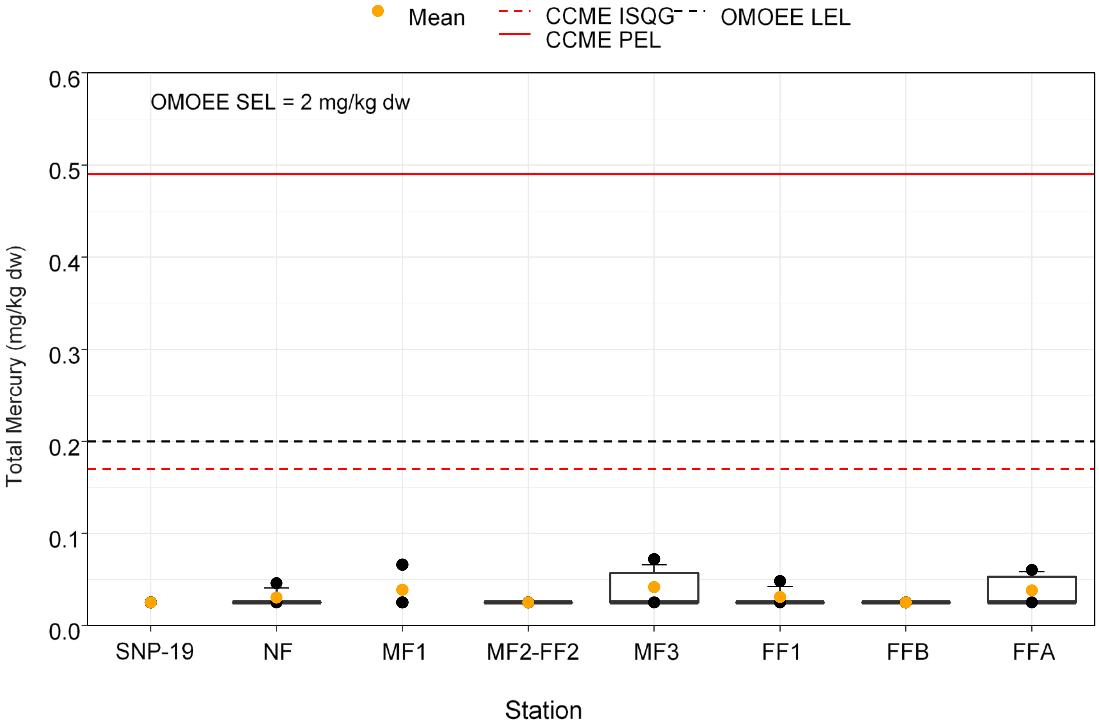


Figure E-24 **Total Molybdenum Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

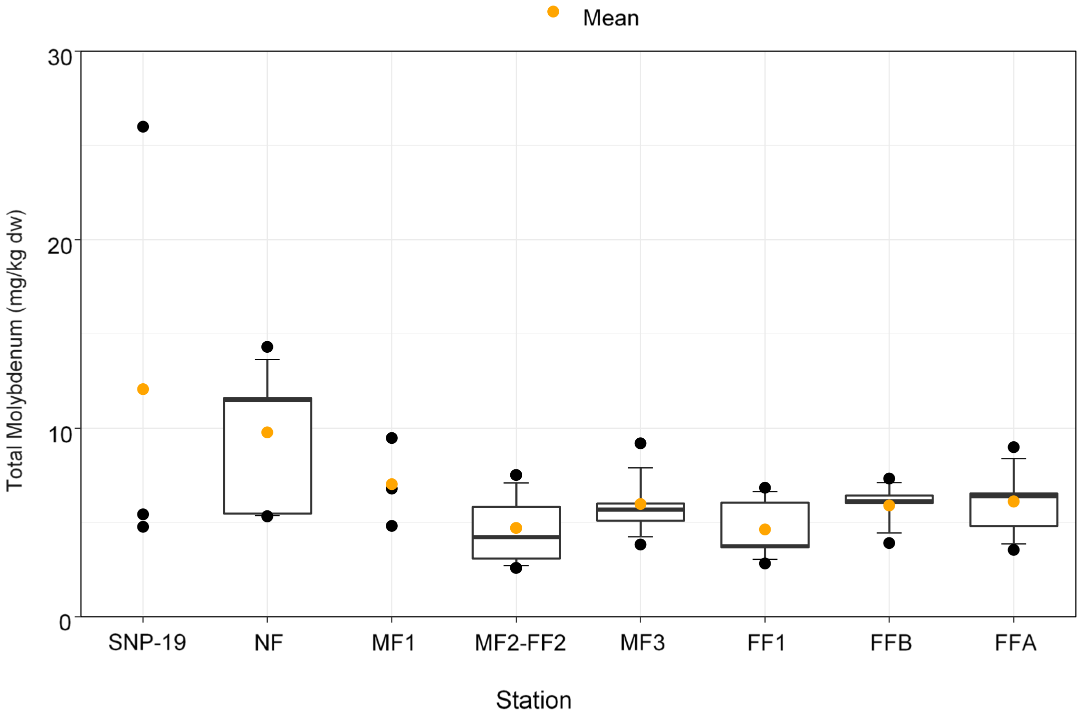


Figure E-25 **Total Nickel Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

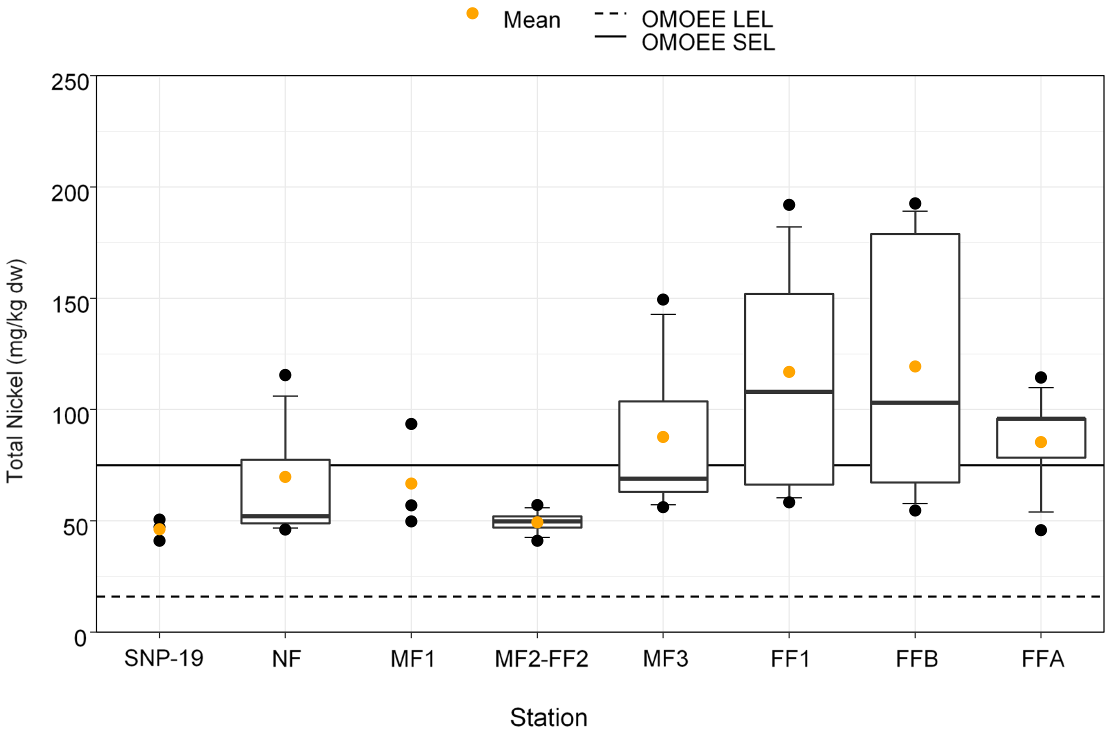


Figure E-26 Total Nitrogen Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

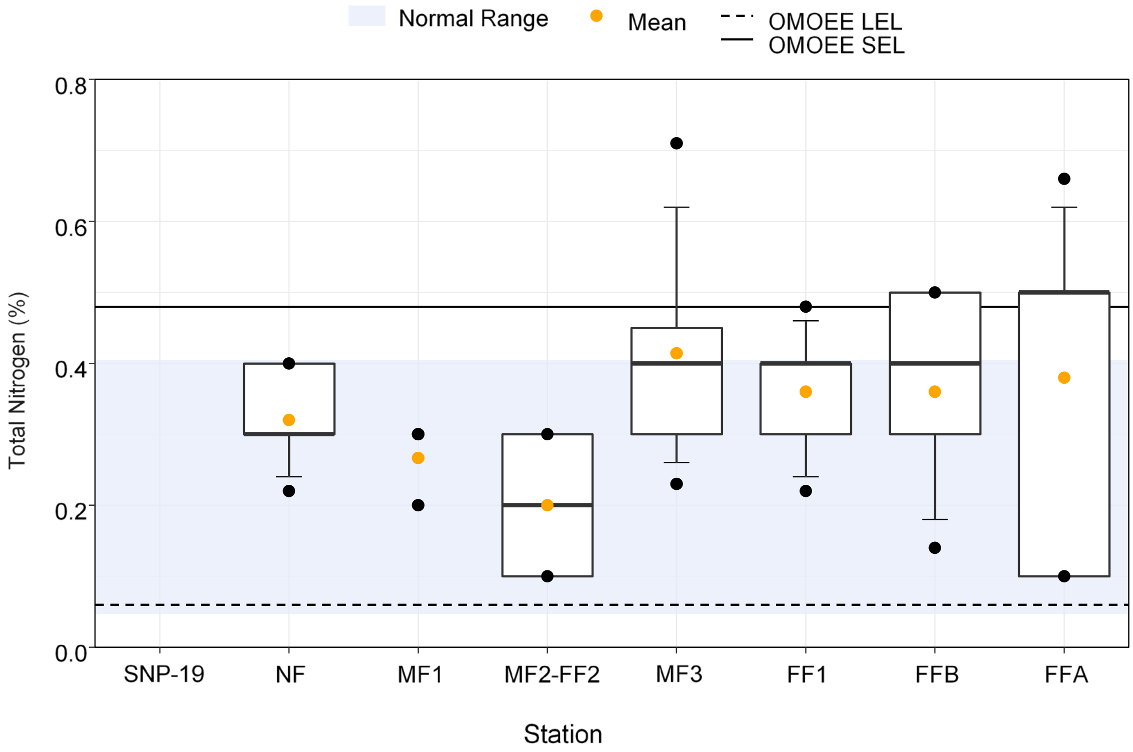


Figure E-27 **Total Organic Carbon Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

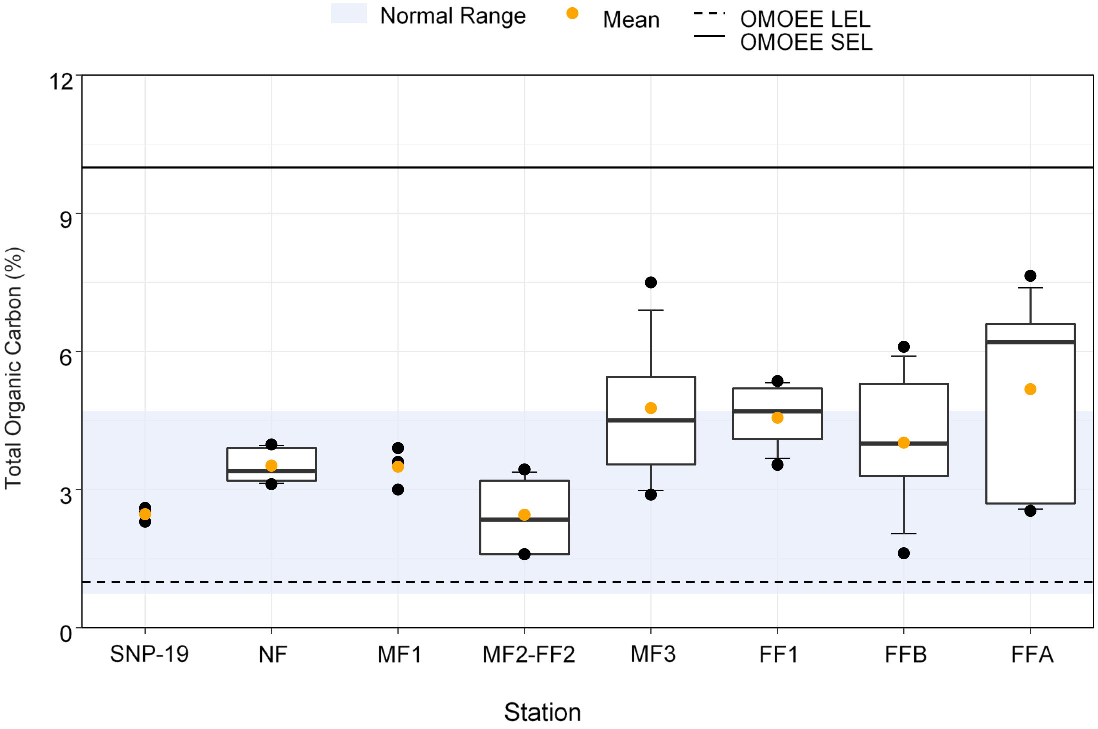


Figure E-28 Total Phosphorus Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

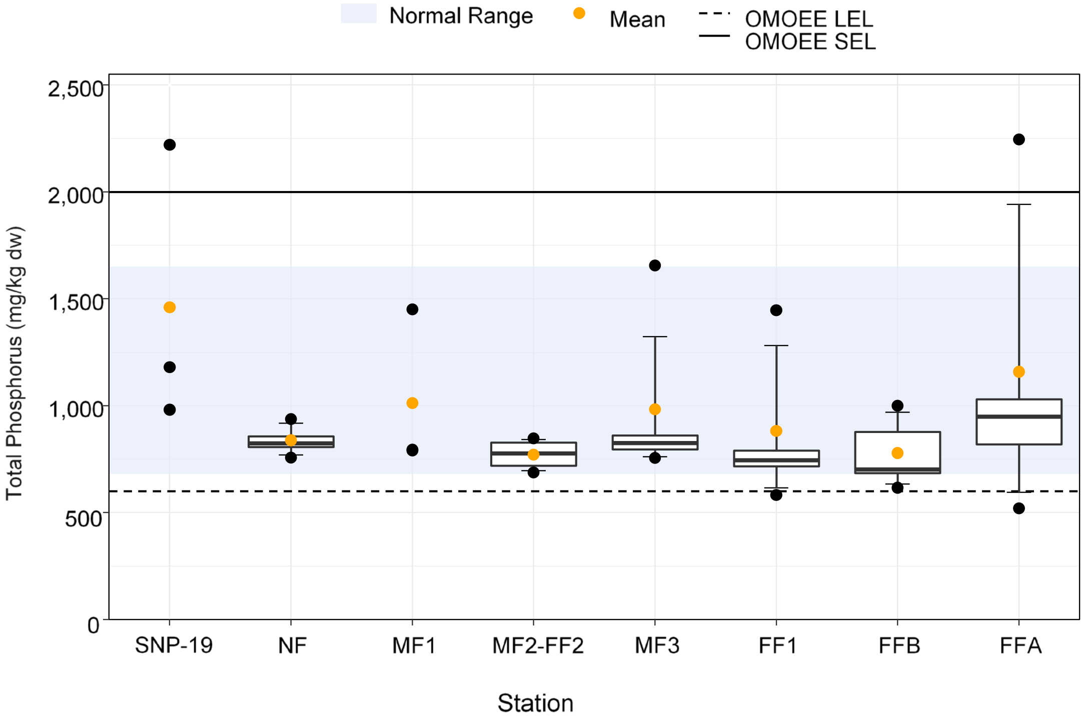


Figure E-29 Total Potassium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

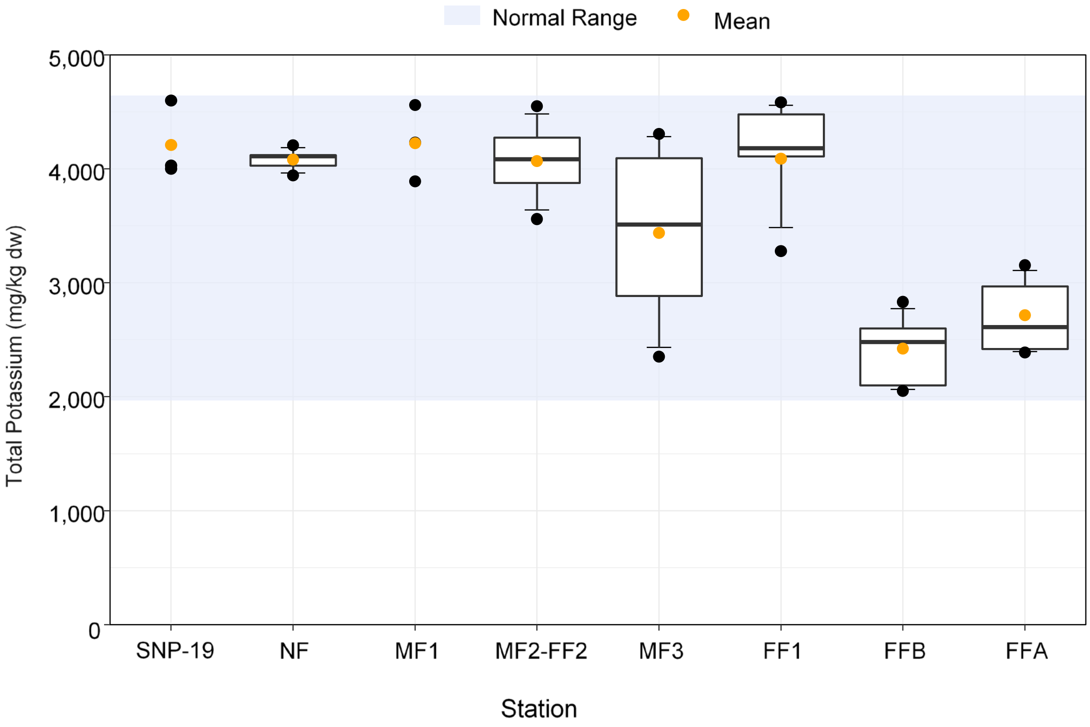


Figure E-30 **Total Selenium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

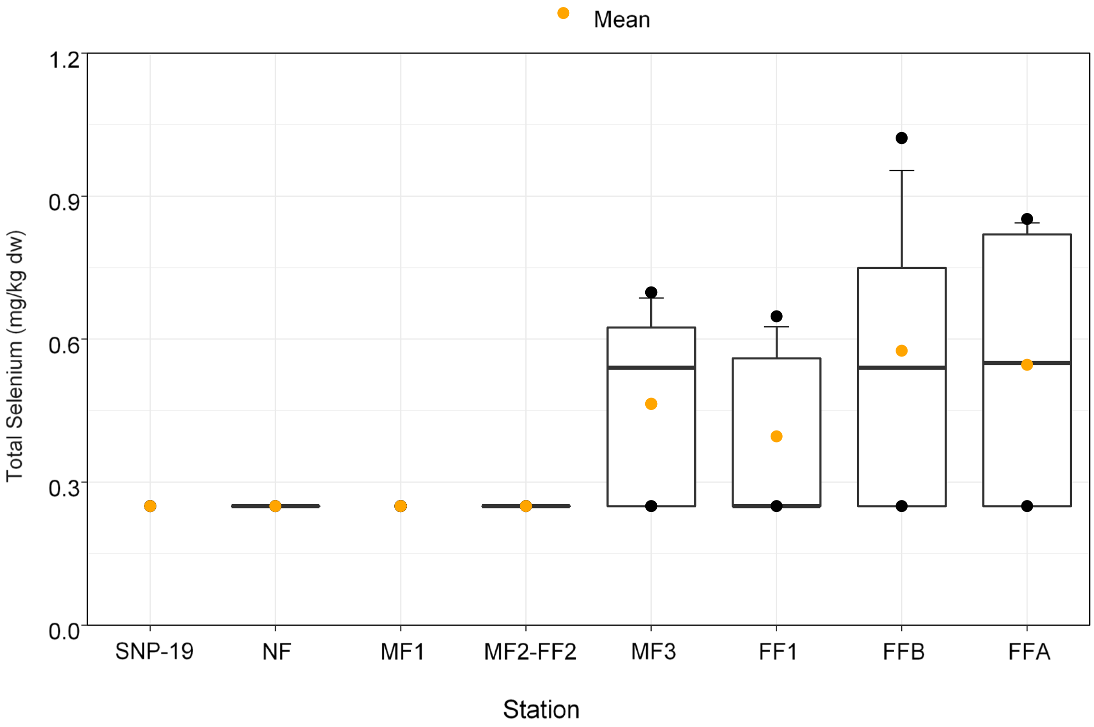


Figure E-31 Total Silver Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

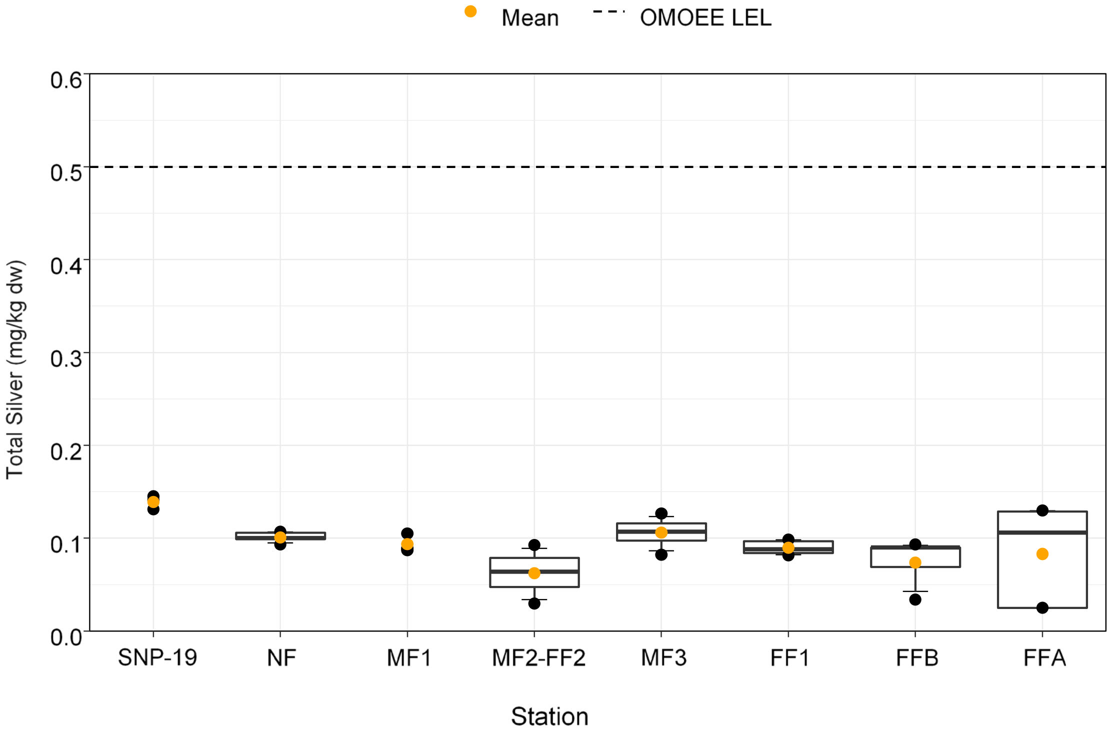


Figure E-32 Total Sodium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

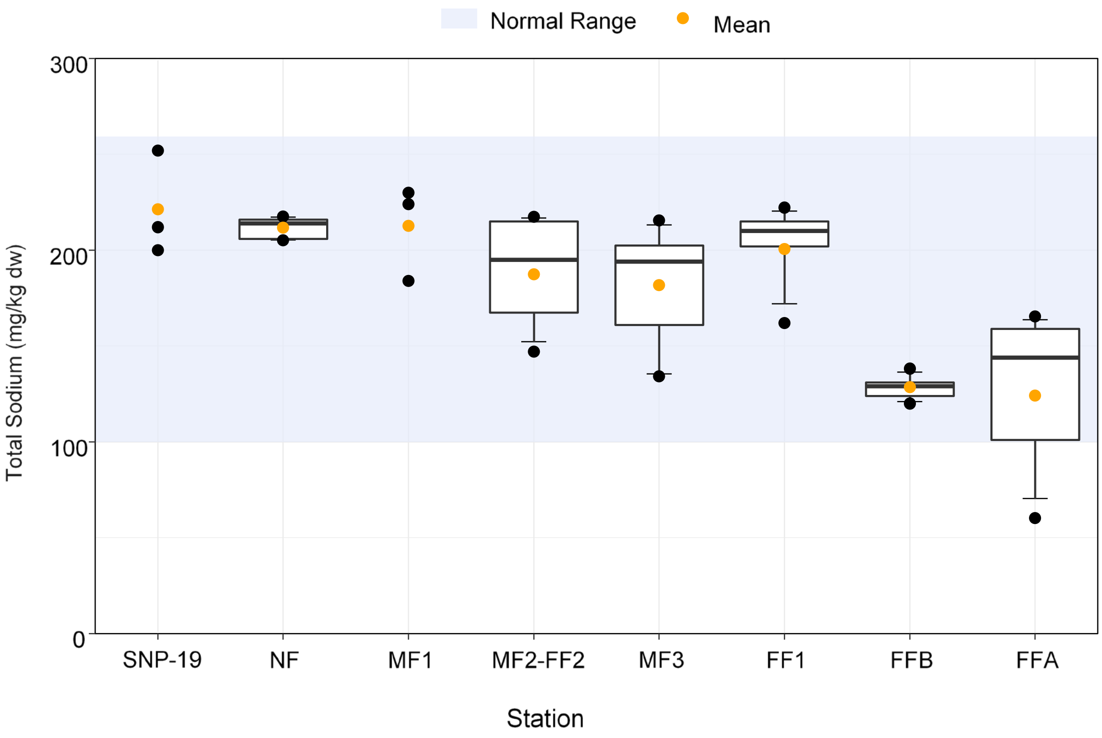


Figure E-33 Total Strontium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

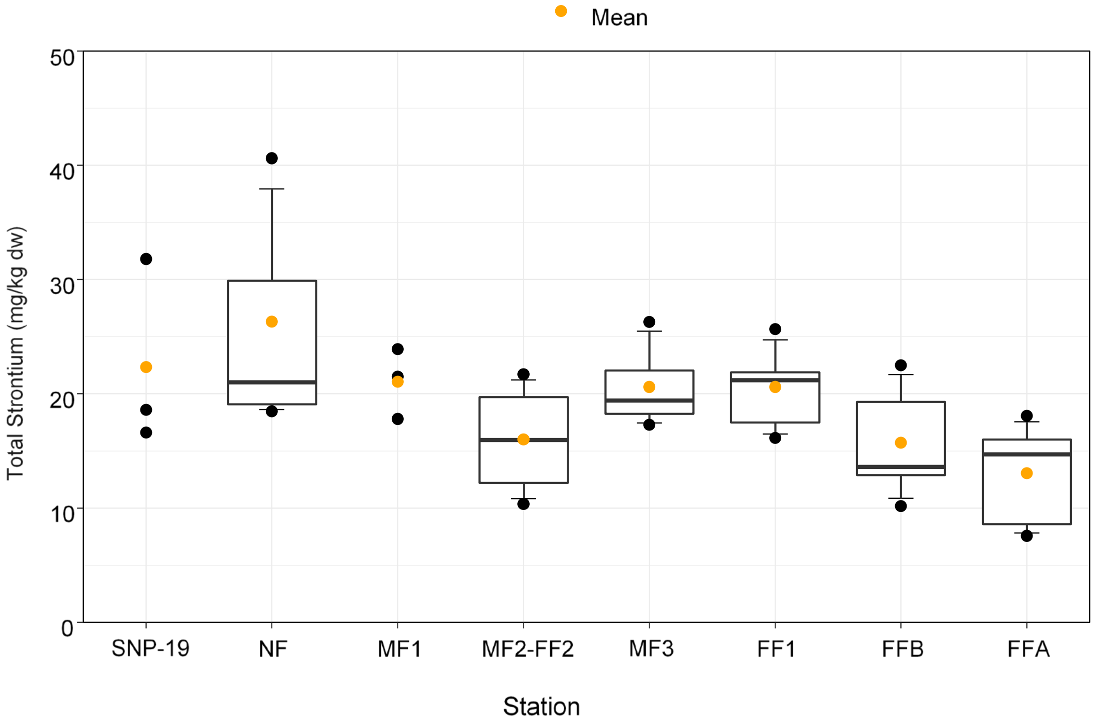


Figure E-34 Total Thallium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

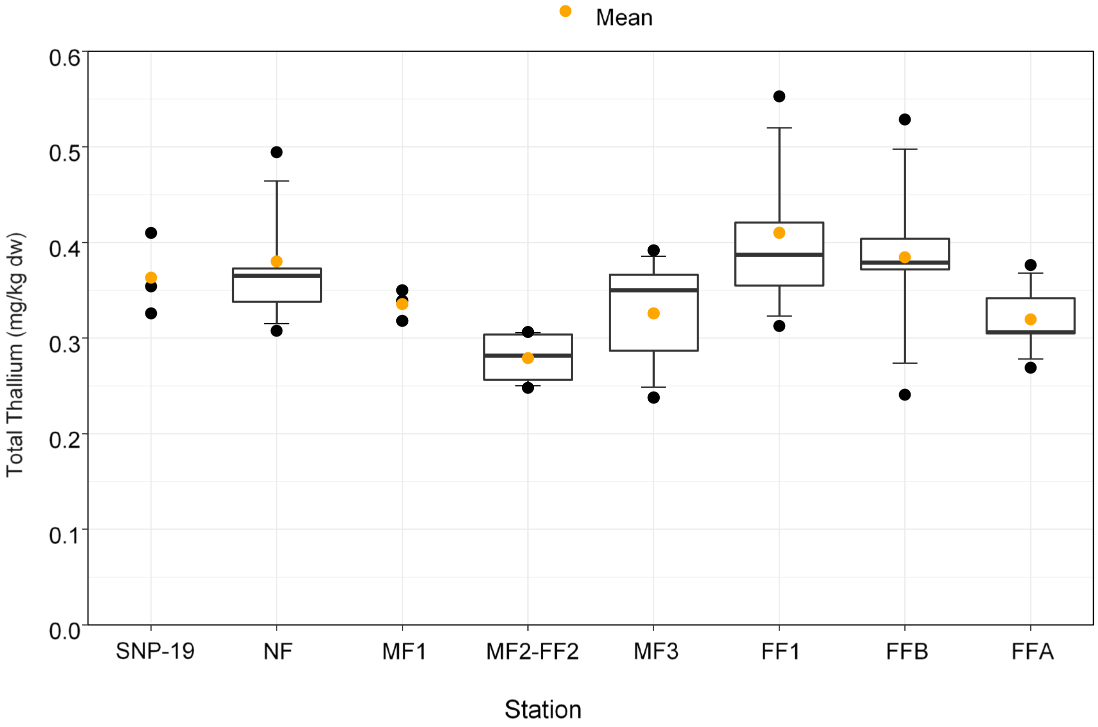


Figure E-35 Total Tin Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

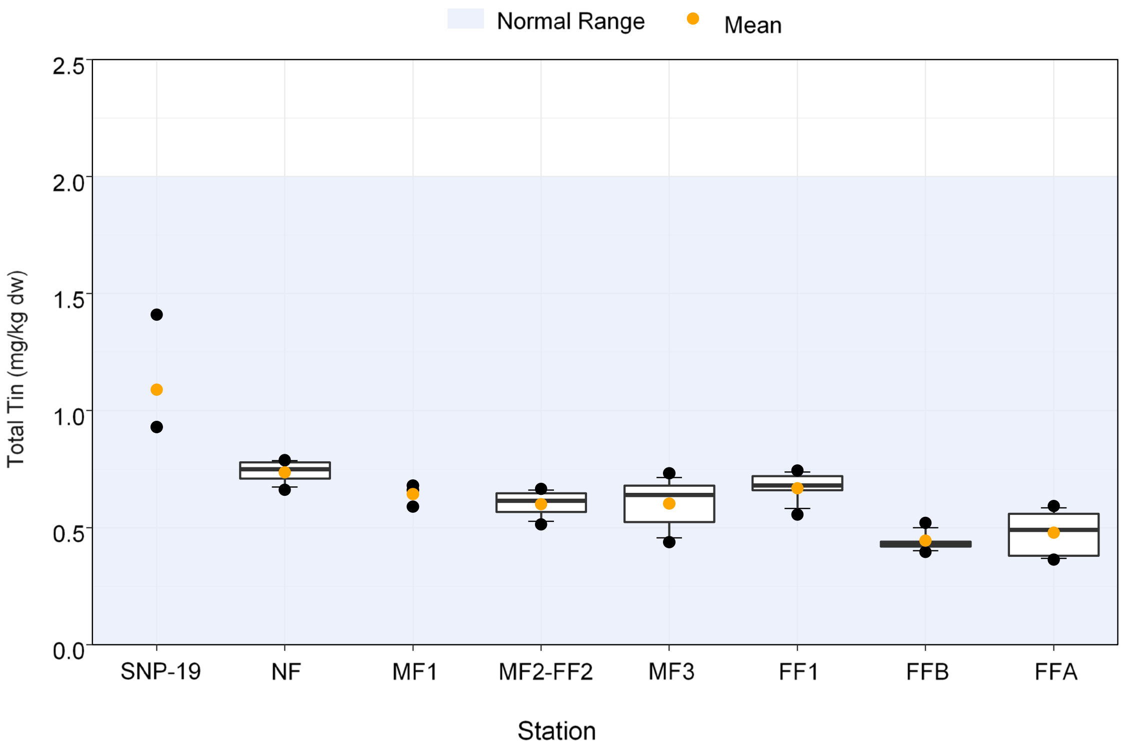


Figure E-36 **Total Titanium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

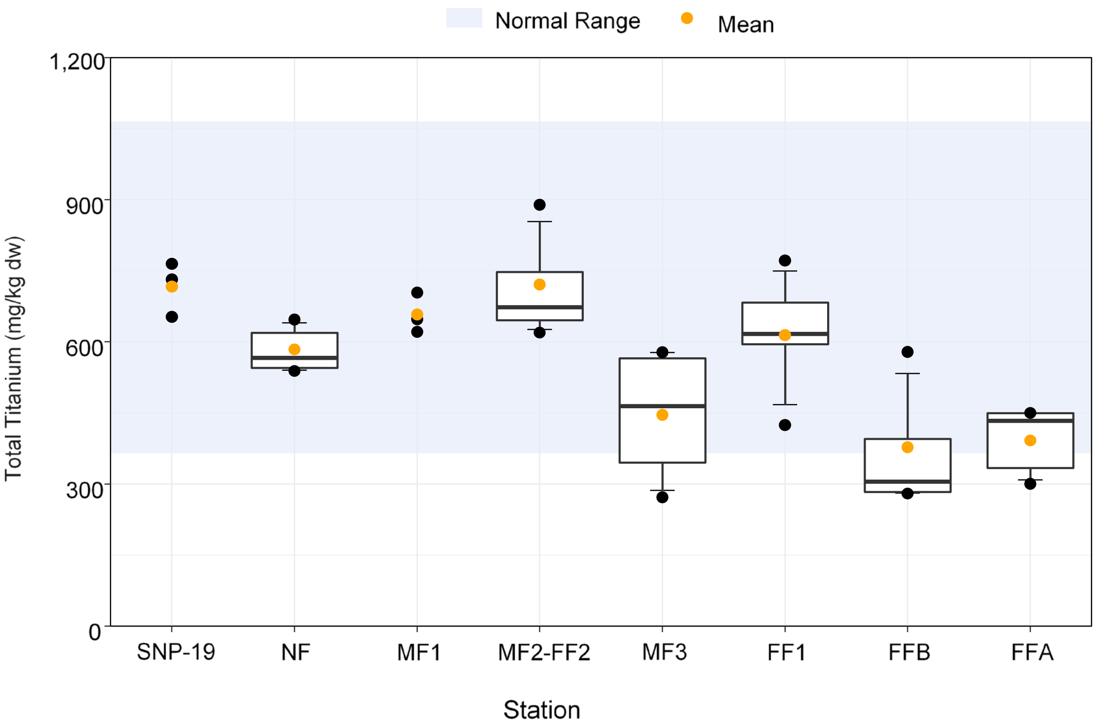


Figure E-37 Total Uranium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019

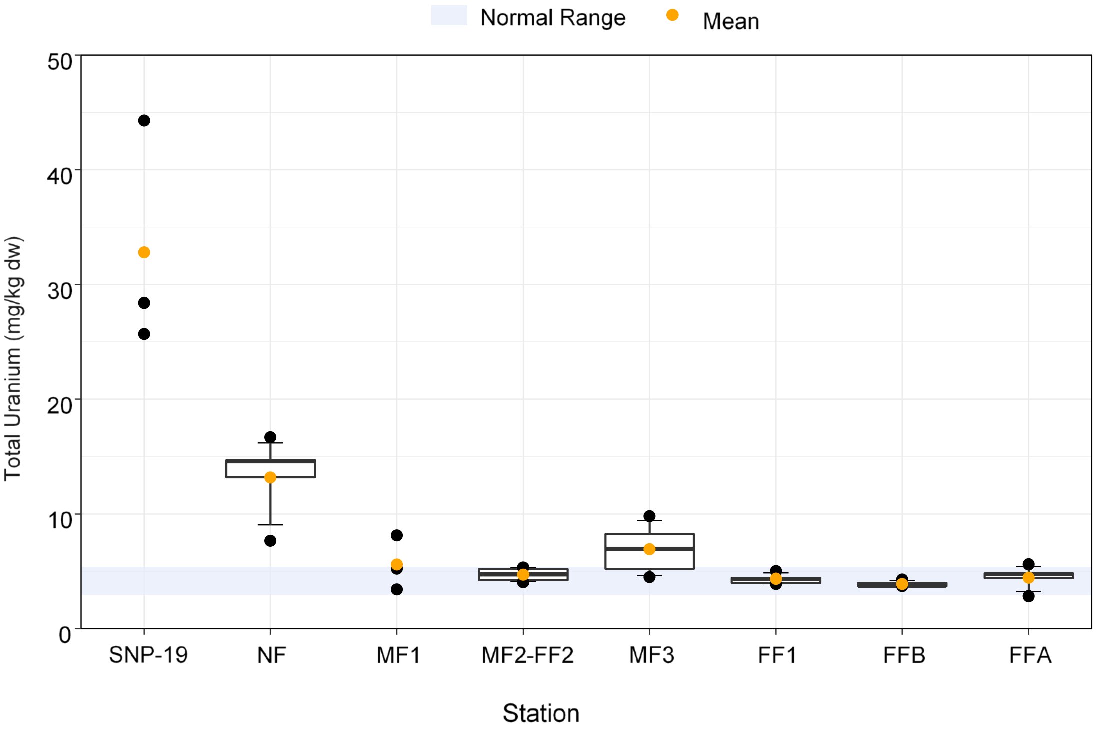


Figure E-38 **Total Vanadium Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**

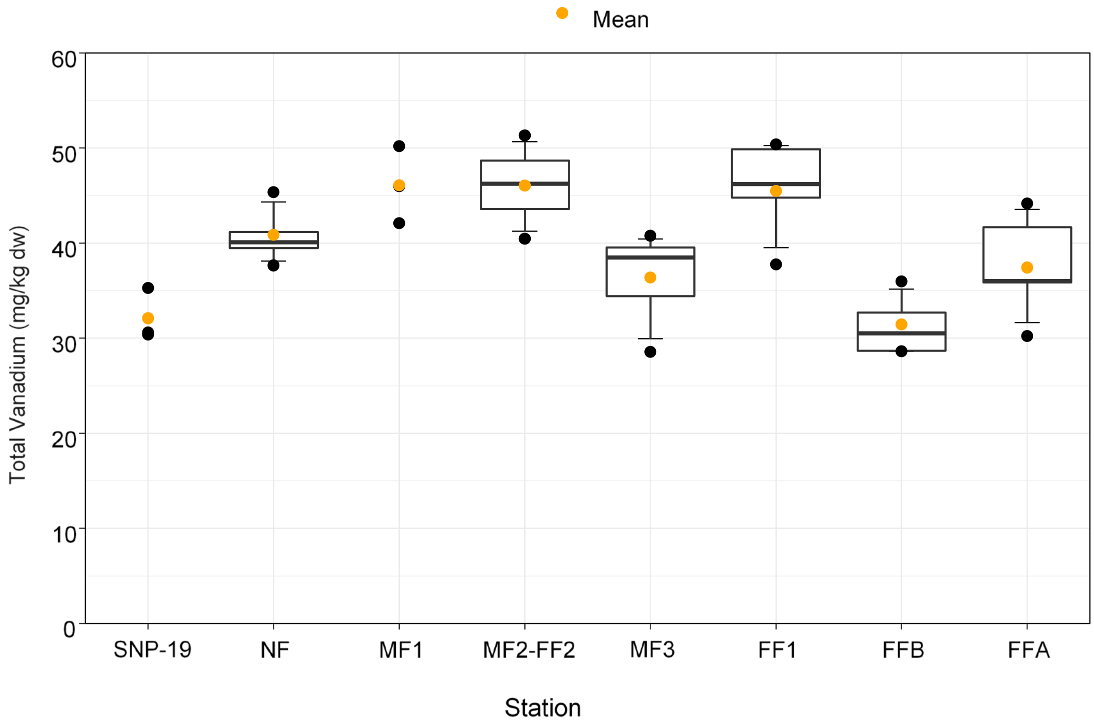
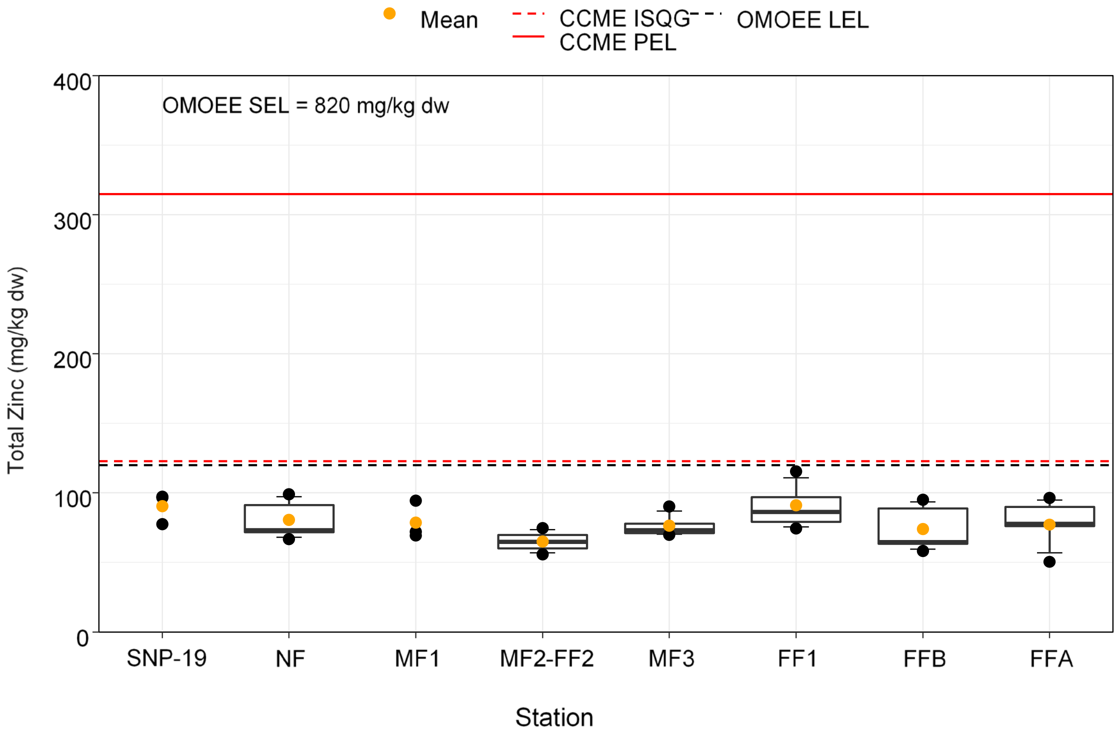


Figure E-39 **Total Zinc Concentrations at Mixing Zone (SNP-19) and AEMP Stations, 2019**



ATTACHMENT F

2019 AEMP SEDIMENT QUALITY DATA AND COMPARISONS TO SEDIMENT QUALITY GUIDELINES

Table F-1 Sediment Chemistry Results, 2019 (Part A)

Parameter	Unit	Detection Limit	OMOEE Guidelines(a)		CCME Guidelines(d)		NF1	NF2	NF3	NF4	NF5	MF1-1	MF1-3	MF1-5	MF2-1	MF2-3	FF2-2	FF2-5
			LEL(b)	SEL(c)	ISQG(e)	PEL(f)	2019-08-22	2019-08-23	2019-09-03	2019-08-23	2019-08-15	2019-08-22	2019-08-22	2019-08-21	2019-08-23	2019-08-20	2019-08-20	2019-08-20
Particle Size																		
Sand	%	0.01	-	-	-	-	17	4.6	7.2	7.4	3.7	3.5	2.1	5.6	11	5.9	2.2	1.7
Silt	%	0.01	-	-	-	-	61	84	78	77	70	84	76	83	74	78	86	87
Clay	%	0.01	-	-	-	-	22	11	15	16	26	13	22	12	15	16	12	11
Physical Properties																		
Moisture content	%	0.30	-	-	-	-	71	72	75	73	73	78	68	73	57	73	73	69
Total Organic Carbon(g)	%	0.005	1.0	10	-	-	*2.6*	*3.1*	*3.0*	*2.7*	*3.3*	*2.2*	*2.9*	*2.9*	1.0	*2.6*	*4.4*	0.57
Total Organic Carbon(h)	%	0.005	1.0	10	-	-	*3.9*	*3.4*	*4.0*	*3.2*	*3.1*	*3.9*	*3.6*	*3*	*1.6*	*3.5*	*1.6*	*3.1*
Organic matter	%	0.035	-	-	-	-	6.8	5.8	6.9	5.5	5.3	6.8	6.1	5.2	2.7	6.0	2.8	5.3
Nutrients																		
Total Nitrogen	%	0.20	0.055	0.48	-	-	*0.4*	*0.3*	*0.4*	*0.2*	*0.3*	*0.3*	*0.3*	*0.2*	<0.2(DL>L)	*0.3*	<0.2(DL>L)	*0.3*
Total Phosphorus	mg/kg dw	10	600	2,000	-	-	*958*	*857*	*824*	*745*	*807*	*790*	*795*	*1450*	*819*	*733*	*852*	*680*
Total Metals																		
Aluminum	mg/kg dw	100	-	-	-	-	15300	15200	15000	15500	14000	15700	17200	14000	14200	15700	18700	14400
Antimony	mg/kg dw	0.1	-	-	-	-	0.1	0.11	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	mg/kg dw	0.2	6.0	33	5.9	17	*25*	*29*	*28*	*24*	*22*	*28*	*20*	*299*	*22*	*35*	*20*	*23*
Barium	mg/kg dw	0.1	-	-	-	-	110	159	189	119	109	127	116	387	89	141	126	130
Beryllium	mg/kg dw	0.2	-	-	-	-	0.55	0.58	0.6	0.6	0.54	0.63	0.62	0.56	0.54	0.54	0.64	0.5
Bismuth	mg/kg dw	0.1	-	-	-	-	4.5	4.0	4.4	1.3	6.6	2.0	0.82	0.36	0.67	0.94	0.56	0.79
Boron	mg/kg dw	1.0	-	-	-	-	5.0	5.1	5.2	5.1	4.2	5.6	4.9	4.3	4.4	4.7	5.7	4.8
Cadmium	mg/kg dw	0.05	0.6	10	0.6	3.5	0.29	*2.3*	*0.7*	0.19	0.32	0.27	0.19	0.54	0.1	0.2	0.11	0.28
Calcium	mg/kg dw	100	-	-	-	-	2180	2100	2460	2040	2050	2150	2140	1460	1530	2020	2070	2130
Chromium	mg/kg dw	0.5	26	110	37	90	*52*	*49*	*53*	*57*	*46*	*58*	*65*	*52*	*49*	*58*	*67*	*54*
Cobalt	mg/kg dw	0.1	50	-	-	-	25	27	32	27	24	27	25	35	19	45	19	27
Copper	mg/kg dw	0.5	16	110	36	197	*38*	*56*	*43*	*40*	*34*	*43*	*41*	*48*	*35*	*41*	*43*	*32*
Iron	mg/kg dw	100	20,000	40,000	-	-	*29000*	*30300*	*28600*	*31700*	*28200*	*31900*	*32100*	*66300*	*24100*	*42000*	*30800*	*29900*
Lead	mg/kg dw	0.1	31	250	35	91	12	25	13	7.3	13	8.7	6.7	5.6	5.2	7.5	6.6	7.0
Lithium	mg/kg dw	0.5	-	-	-	-	41	43	31	38	39	42	35	28	30	36	45	25
Magnesium	mg/kg dw	100	-	-	-	-	7610	7890	8350	8540	7010	8890	9910	7700	7360	8460	9940	8550
Manganese	mg/kg dw	0.2	460	1,100	-	-	*9300*	*19300*	*32400*	*11300*	*15700*	*13900*	*8330*	*28000*	*1670*	*17300*	*1370*	*29000*
Mercury	mg/kg dw	0.05	0.2	2.0	0.17	0.49	0.051	<0.05	<0.05	<0.05	<0.05	0.066	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/kg dw	0.1	-	-	-	-	12	15	12	5.3	5.5	6.8	4.8	9.5	3.3	5.1	2.5	7.9
Nickel	mg/kg dw	0.5	16	75	-	-	*49*	*78*	*125*	*45*	*52*	*57*	*50*	*94*	*40*	*50*	*58*	*50*
Potassium	mg/kg dw	100	-	-	-	-	4230	4030	4110	4120	3920	4230	4560	3890	3480	4160	4620	4010
Selenium	mg/kg dw	0.5	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	mg/kg dw	0.05	0.5	-	-	-	0.11	0.092	0.1	0.11	0.099	0.089	0.11	0.087	<0.05	0.096	0.055	0.073
Sodium	mg/kg dw	100	-	-	-	-	214	205	218	216	206	224	230	184	142	214	176	218
Strontium	mg/kg dw	0.1	-	-	-	-	21	30	43	19	18	24	18	22	9.9	19	13	22
Thallium	mg/kg dw	0.05	-	-	-	-	0.34	0.37	0.53	0.3	0.37	0.35	0.32	0.34	0.25	0.31	0.26	0.3
Tin	mg/kg dw	0.1	-	-	-	-	0.79	0.75	0.71	0.65	0.78	0.68	0.66	0.59	0.5	0.64	0.67	0.59
Titanium	mg/kg dw	1.0	-	-	-	-	566	619	537	654	545	621	704	648	613	689	925	657
Uranium	mg/kg dw	0.05	-	-	-	-	15	15	13	6.3	17	8.1	5.2	3.4	4.3	5.4	4.0	5.2
Vanadium	mg/kg dw	1.0	-	-	-	-	40	40	41	46	37	46	50	42	40	48	52	45
Zinc	mg/kg dw	1.0	120	820	123	315	73	101	91	66	72	72	69	94	55	68	76	62

Table F-1 Sediment Chemistry Results, 2019 (Part B)

Parameter	Unit	Detection Limit	OMOEE Guidelines[a]		CCME Guidelines[d]		MF3-1	MF3-2	MF3-3	MF3-4	MF3-5	MF3-6	MF3-7	FF1-1	FF1-2	FF1-3	FF1-4	FF1-5
			LEL[b]	SEL[c]	ISQG[e]	PEL[f]	2019-09-03	2019-08-28	2019-08-28	2019-08-27	2019-08-27	2019-08-27	2019-08-26	2019-08-17	2019-08-19	2019-08-18	2019-08-21	2019-08-19
Particle Size																		
Sand	%	0.01	-	-	-	-	21	6.6	6.8	7.6	7.2	3.4	7.1	2.2	1.8	1.9	5.8	5.8
Silt	%	0.01	-	-	-	-	70	83	70	71	64	66	82	83	84	84	76	64
Clay	%	0.01	-	-	-	-	8.9	10	23	21	29	31	11	15	15	14	18	30
Physical Properties																		
Moisture content	%	0.30	-	-	-	-	71	76	70	71	79	84	81	77	82	81	75	77
Total Organic Carbon[g]	%	0.005	1.0	10	-	-	*2.3*	*3.0*	*5.9*	*2.7*	*4.7*	*5.4*	*4.1*	*3.4*	*3.9*	*3.3*	*3.3*	*3.8*
Total Organic Carbon[h]	%	0.005	1.0	10	-	-	*3.1*	*2.8*	*4.0*	*4.5*	*6.1*	*8.1*	*4.8*	*5.4*	*5.2*	*4.1*	*3.4*	*4.7*
Organic matter	%	0.035	-	-	-	-	5.3	4.8	7.0	7.8	11	14	8.2	9.3	8.9	7.2	5.9	8.0
Nutrients																		
Total Nitrogen	%	0.2	0.055	0.48	-	-	*0.2*	*0.3*	*0.3*	*0.4*	*0.5*	*0.8*	*0.4*	*0.5*	*0.4*	*0.3*	*0.2*	*0.4*
Total Phosphorus	mg/kg dw	10	600	2,000	-	-	*750*	*823*	*878*	*825*	*1990*	*845*	*769*	*790*	*1610*	548	*717*	*744*
Total Metals																		
Aluminum	mg/kg dw	100	-	-	-	-	17300	13900	14700	14700	9660	14400	11700	15700	12800	15900	17600	17100
Antimony	mg/kg dw	0.1	-	-	-	-	<0.1	<0.1	0.1	<0.1	0.2	0.12	0.17	0.15	0.2	<0.1	<0.1	<0.1
Arsenic	mg/kg dw	0.2	6.0	33	5.9	17	*20*	*22*	*30*	*31*	*616*	*19*	*77*	*39*	*407*	*28*	*22*	*33*
Barium	mg/kg dw	0.1	-	-	-	-	111	116	111	105	235	103	395	278	213	157	120	121
Beryllium	mg/kg dw	0.2	-	-	-	-	0.57	0.6	0.63	0.65	0.47	0.59	0.52	0.64	0.55	0.65	0.71	0.69
Bismuth	mg/kg dw	0.1	-	-	-	-	3.5	2.2	1.4	0.97	0.5	0.51	0.38	0.59	0.4	0.42	0.44	0.45
Boron	mg/kg dw	1.0	-	-	-	-	6.2	5.2	5.6	5.1	3.9	5.6	3.8	5.5	4.3	4.7	5.9	5.4
Cadmium	mg/kg dw	0.05	0.6	10	0.6	3.5	0.42	0.32	0.27	0.38	0.4	0.28	0.57	*0.67*	0.49	0.42	0.24	0.22
Calcium	mg/kg dw	100	-	-	-	-	1850	1950	2300	1940	1840	2630	2000	2450	1700	2000	2020	2010
Chromium	mg/kg dw	0.5	26	110	37	90	*47*	*52*	*53*	*50*	*33*	*50*	*38*	*56*	*43*	*59*	*64*	*61*
Cobalt	mg/kg dw	0.1	50	-	-	-	23	31	40	*51*	*76*	17	*184*	*100*	*100*	31	29	28
Copper	mg/kg dw	0.5	16	110	36	197	*35*	*42*	*48*	*56*	*52*	*62*	*68*	*55*	*51*	*49*	*49*	*49*
Iron	mg/kg dw	100	20,000	40,000	-	-	*25600*	*26100*	*31800*	*32800*	*148000*	*26800*	*68300*	*41100*	*129000*	*33500*	*32100*	*37700*
Lead	mg/kg dw	0.1	31	250	35	91	9.6	11	9.8	8.1	6.5	7.4	7.3	8.1	6.9	6.4	6.6	7.1
Lithium	mg/kg dw	0.5	-	-	-	-	45	45	42	30	13	28	20	29	20	35	52	41
Magnesium	mg/kg dw	100	-	-	-	-	9080	8550	8180	7540	5050	7240	5430	8890	6940	8960	10200	9220
Manganese	mg/kg dw	0.2	460	1,100	-	-	*8660*	*11500*	*11700*	*10800*	*27900*	337	*72200*	*40300*	*23000*	*24500*	*3020*	*2790*
Mercury	mg/kg dw	0.05	0.2	2.0	0.17	0.49	<0.05	<0.05	<0.05	<0.05	0.078	0.056	0.058	0.054	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/kg dw	0.1	-	-	-	-	6.2	5.4	4.8	5.7	11	3.4	5.9	6.1	7.0	3.7	2.6	3.7
Nickel	mg/kg dw	0.5	16	75	-	-	*74*	*68*	*59*	*69*	*134*	*55*	*156*	*202*	*152*	*108*	*56*	*66*
Potassium	mg/kg dw	100	-	-	-	-	4250	4330	3940	3510	2270	3230	2540	4180	3070	4110	4610	4480
Selenium	mg/kg dw	0.5	-	-	-	-	<0.5	<0.5	<0.5	0.54	0.71	0.58	0.67	0.56	0.67	<0.5	<0.5	<0.5
Silver	mg/kg dw	0.05	0.5	-	-	-	0.078	0.11	0.12	0.11	0.092	0.13	0.1	0.097	0.084	0.081	0.088	0.099
Sodium	mg/kg dw	100	-	-	-	-	185	210	218	195	133	194	137	215	152	202	224	210
Strontium	mg/kg dw	0.1	-	-	-	-	17	19	19	18	24	20	27	27	21	22	16	18
Thallium	mg/kg dw	0.05	-	-	-	-	0.38	0.35	0.31	0.36	0.26	0.23	0.4	0.59	0.39	0.42	0.36	0.3
Tin	mg/kg dw	0.1	-	-	-	-	0.67	0.75	0.69	0.64	0.42	0.57	0.48	0.66	0.53	0.68	0.72	0.75
Titanium	mg/kg dw	1.0	-	-	-	-	579	577	554	464	258	386	305	595	382	617	794	683
Uranium	mg/kg dw	0.05	-	-	-	-	8.9	10	7.6	7.0	4.8	5.6	4.4	5.2	3.9	4.0	4.3	4.4
Vanadium	mg/kg dw	1.0	-	-	-	-	37	39	41	40	27	39	32	45	36	46	51	50
Zinc	mg/kg dw	1.0	120	820	123	315	70	74	71	72	83	73	94	120	97	86	73	79

Table F-1 Sediment Chemistry Results, 2019 (Part C)

Parameter	Unit	Detection Limit	OMOEE Guidelines(a)		CCME Guidelines(d)		FFA-1	FFA-2	FFA-3	FFA-4	FFA-5	FFB-1	FFB-2	FFB-3	FFB-4	FFB-5
			LEL(b)	SEL(c)	2019-09-04	2019-09-05	2019-09-04	2019-09-04	2019-09-04	2019-08-26	2019-08-25	2019-08-26	2019-08-25	2019-08-25		
Particle Size																
Sand	%	0.01	-	-	29	24	7.8	35	4.7	38	2.6	9.2	37	25		
Silt	%	0.01	-	-	59	54	72	46	62	46	84	77	51	57		
Clay	%	0.01	-	-	12	22	20	19	34	16	14	14	12	19		
Physical Properties																
Moisture content	%	0.30	-	-	63	70	75	65	80	62	78	69	47	58		
Total Organic Carbon(g)	%	0.005	1.0	10	*2.0*	*3.2*	*3.3*	*2.1*	*6.0*	*3.6*	*5.2*	*3.3*	*1.4*	*1.1*		
Total Organic Carbon(h)	%	0.005	1.0	10	*2.7*	*6.2*	*6.6*	*2.5*	*7.9*	*3.3*	*6.3*	*5.3*	*4.0*	*1.2*		
Organic matter	%	0.035	-	-	4.6	11	11	4.4	14	5.7	11	9.2	6.9	2.0		
Nutrients																
Total Nitrogen	%	0.2	0.055	0.48	<0.2(DL>L)	*0.5*	*0.5*	<0.2(DL>L)	*0.7*	*0.3*	*0.5*	*0.5*	*0.4*	<0.2(DL>L)		
Total Phosphorus	mg/kg dw	10	600	2,000	*2550*	*820*	*948*	445	*1030*	*701*	*1030*	*878*	*685*	599		
Total Metals																
Aluminum	mg/kg dw	100	-	-	13700	15800	13500	10400	15100	10300	11900	10000	11900	14100		
Antimony	mg/kg dw	0.1	-	-	<0.1	0.14	0.16	<0.1	0.23	0.12	0.17	0.17	0.1	<0.1		
Arsenic	mg/kg dw	0.2	6.0	33	*508*	*79*	*54*	*61*	*123*	*46*	*338*	*452*	*30*	*25*		
Barium	mg/kg dw	0.1	-	-	134	101	95	65	115	75	309	202	85	89		
Beryllium	mg/kg dw	0.2	-	-	0.93	0.69	0.65	0.41	0.68	0.52	0.58	0.47	0.56	0.5		
Bismuth	mg/kg dw	0.1	-	-	0.25	0.36	0.36	0.19	0.44	0.29	0.38	0.32	0.35	0.27		
Boron	mg/kg dw	1.0	-	-	3.0	4.5	4.6	3.0	4.9	4.3	4.4	3.9	4.3	3.1		
Cadmium	mg/kg dw	0.05	0.6	10	0.47	0.32	*0.62*	0.13	0.37	0.27	0.57	0.58	0.55	0.31		
Calcium	mg/kg dw	100	-	-	725	1690	1610	855	1810	1470	1790	2210	1410	1110		
Chromium	mg/kg dw	0.5	26	110	*40*	*52*	*43*	*37*	*50*	*35*	*39*	*32*	*38*	*43*		
Cobalt	mg/kg dw	0.1	50	-	*115*	42	*90*	50	*85*	47	*226*	*269*	*100*	*67*		
Copper	mg/kg dw	0.5	16	110	*63*	*71*	*77*	*36*	*81*	*51*	*66*	*63*	*48*	*42*		
Iron	mg/kg dw	100	20,000	40,000	*127000*	*42400*	*42100*	*28700*	*67800*	*36500*	*132000*	*145000*	*26200*	*25600*		
Lead	mg/kg dw	0.1	31	250	4.5	7.7	8.0	3.8	9.0	6.1	7.4	6.9	7.5	5.6		
Lithium	mg/kg dw	0.5	-	-	21	28	27	20	24	22	16	12	29	28		
Magnesium	mg/kg dw	100	-	-	5380	7280	5900	5200	6670	4860	5960	4740	5900	6920		
Manganese	mg/kg dw	0.2	460	1,100	*10900*	*1600*	*7980*	*2600*	*3070*	*1300*	*30200*	*28000*	*6360*	*4570*		
Mercury	mg/kg dw	0.05	0.2	2.0	<0.05	<0.05	0.053	<0.05	0.062	<0.05	<0.05	<0.05	<0.05	<0.05		
Molybdenum	mg/kg dw	0.1	-	-	9.6	6.4	4.8	3.2	6.6	3.4	7.6	6.1	6.4	6.0		
Nickel	mg/kg dw	0.5	16	75	*96*	*79*	*119*	*38*	*96*	*52*	*179*	*196*	*103*	*67*		
Potassium	mg/kg dw	100	-	-	2380	3200	2610	2420	2970	2100	2480	2040	2600	2890		
Selenium	mg/kg dw	0.5	-	-	<0.5	0.55	0.86	<0.5	0.82	0.54	0.75	1.1	<0.5	<0.5		
Silver	mg/kg dw	0.05	0.5	-	<0.05	0.11	0.13	<0.05	0.13	0.09	0.094	0.09	0.069	<0.05		
Sodium	mg/kg dw	100	-	-	<100	159	144	101	167	129	140	124	131	119		
Strontium	mg/kg dw	0.1	-	-	8.6	15	16	7.3	19	14	23	19	13	9.5		
Thallium	mg/kg dw	0.05	-	-	0.34	0.31	0.39	0.26	0.31	0.21	0.38	0.37	0.56	0.4		
Tin	mg/kg dw	0.1	-	-	0.38	0.6	0.49	0.36	0.56	0.42	0.44	0.39	0.43	0.54		
Titanium	mg/kg dw	1.0	-	-	433	450	292	450	334	305	279	283	395	625		
Uranium	mg/kg dw	0.05	-	-	4.4	4.8	4.8	2.4	5.8	3.7	4.4	3.7	4.0	3.7		
Vanadium	mg/kg dw	1.0	-	-	36	45	36	29	42	29	33	29	31	37		
Zinc	mg/kg dw	1.0	120	820	76	90	78	44	98	57	97	89	65	64		

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

Table F-1 Sediment Chemistry Results, 2019 (Part D)

Notes: Total metals and nutrient analyses were conducted on top 1-cm core samples; particle size analyses were conducted on top 10 to 15 cm Ekman grab samples.

(a) = Ontario Ministry of Environment and Energy (OMOEE) *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (OMOEE 1993).

(b) = Lowest Effect Level.

(c) = Severe Effect Level.

(d) = Canadian Council of Ministers of the Environment (CCME), *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME 2002).

(f) = Probable effect level.

(g) = Total organic carbon results for core samples (top 1 cm).

(h) = Total organic carbon results for Ekman grab samples (top 10 to 15 cm).

Value	Values greater than or equal to the OMOEE LEL guidelines are italicized.
Value	Values greater than or equal to the OMOEE SEL guidelines are underlined.
Value	Values greater than or equal to the CCME ISQG guidelines are shaded.
Value	Values greater than or equal to the CCME PEL guidelines are red font.
Value	Anomalous value removed from statistical analyses (see Attachment A)

(DL>L) = analytical detection limit was higher than the OMOEE LEL; - = no guideline or data.; dw = dry weight; <= less than.

Sediment quality data shown in this table were rounded to reflect laboratory precision after comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Measured concentrations equal to the guideline values were not identified as exceedances.

Table F-2 Percentage and Number of Samples Exceeding Sediment Quality Guideline in Sampling Areas in Lac de Gras, 2019

Variable	Unit	Guideline		NF n = 5	MF1 n = 3	MF2-FF2 n = 4	MF3 n = 7	FF1 n = 5	FFB n = 5	FFA n = 5	MF and FF2 Areas n = 14	FF Areas n = 15
Total Organic Carbon (Cores)	% dw	OMOEE LEL	1	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		OMOEE SEL	10	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Total Organic Carbon (Grabs)	% dw	OMOEE LEL	1	100% n = 5	100% n = 3	50% n = 2	100% n = 7	100% n = 5	100% n = 5	10% n = 5	86% n = 12	100% n = 15
		OMOEE SEL	10	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Total Nitrogen	% dw	OMOEE LEL	0.055	100% n = 5	100% n = 3	50% n = 2	100% n = 7	100% n = 5	80% n = 4	60% n = 3	86% n = 14	80% n = 12
		OMOEE SEL	0.48	0% n = 0	0% n = 0	0% n = 0	29% n = 2	20% n = 1	40% n = 2	60% n = 3	14% n = 2	40% n = 6
Total Phosphorus	mg/kg dw	OMOEE LEL	600	100% n = 5	100% n = 3	100% n = 4	100% n = 7	80% n = 4	80% n = 4	80% n = 4	100% n = 14	80% n = 12
		OMOEE SEL	2,000	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	20% n = 1	0% n = 0	7% n = 1
Arsenic	mg/kg dw	OMOEE LEL	6	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		OMOEE SEL	33	0% n = 0	33% n = 1	25% n = 1	29% n = 2	40% n = 2	60% n = 3	100% n = 5	29% n = 4	67% n = 10
		CCME ISQG	5.9	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		CCME PEL	17	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
Cadmium	mg/kg dw	OMOEE LEL	0.6	40% n = 2	0% n = 0	0% n = 0	0% n = 0	20% n = 1	0% n = 0	20% n = 1	0% n = 0	13% n = 2
		OMOEE SEL	10	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	0.6	40% n = 2	0% n = 0	0% n = 0	0% n = 0	20% n = 1	0% n = 0	20% n = 1	0% n = 0	13% n = 2
		CCME PEL	3.5	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Chromium	mg/kg dw	OMOEE LEL	26	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		OMOEE SEL	110	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	37.3	100% n = 5	100% n = 3	100% n = 4	86% n = 6	100% n = 5	60% n = 3	80% n = 4	93% n = 13	80% n = 12
		CCME PEL	90	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Cobalt	mg/kg dw	OMOEE LEL	50	0% n = 0	0% n = 0	0% n = 0	43% n = 3	40% n = 2	80% n = 4	60% n = 4	21% n = 3	67% n = 10
Copper	mg/kg dw	OMOEE LEL	16	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		OMOEE SEL	110	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	35.7	80% n = 4	100% n = 3	50% n = 2	86% n = 6	100% n = 5	100% n = 5	80% n = 4	79% n = 11	93% n = 14
		CCME PEL	197	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0

Table F-2 Percentage and Number of Samples Exceeding Sediment Quality Guideline in Sampling Areas in Lac de Gras, 2019

Variable	Unit	Guideline		NF n = 5	MF1 n = 3	MF2-FF2 n = 4	MF3 n = 7	FF1 n = 5	FFB n = 5	FFA n = 5	MF and FF2 Areas n = 14	FF Areas n = 15
Iron	mg/kg dw	OMOEE LEL	20,000	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		OMOEE SEL	40,000	0% n = 0	33% n = 1	25% n = 1	29% n = 2	40% n = 2	40% n = 2	80% n = 4	29% n = 4	53% n = 8
Lead	mg/kg dw	OMOEE LEL	31	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		OMOEE SEL	250	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	35	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME PEL	91.3	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Manganese	mg/kg dw	OMOEE LEL	460	100% n = 5	100% n = 3	100% n = 4	86% n = 6	100% n = 5	100% n = 5	100% n = 5	93% n = 13	100% n = 15
		OMOEE SEL	1,100	100% n = 5	100% n = 3	100% n = 4	86% n = 6	100% n = 5	100% n = 5	100% n = 5	93% n = 13	100% n = 15
Mercury	mg/kg dw	OMOEE LEL	0.2	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		OMOEE SEL	2	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	0.17	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME PEL	0.486	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Nickel	mg/kg dw	OMOEE LEL	16	100% n = 5	100% n = 3	100% n = 4	100% n = 7	100% n = 5	100% n = 5	100% n = 5	100% n = 14	100% n = 15
		OMOEE SEL	75	40% n = 2	33% n = 1	0% n = 0	29% n = 2	60% n = 3	60% n = 3	80% n = 4	21% n = 3	67% n = 10
Silver	mg/kg dw	OMOEE LEL	0.5	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
Zinc	mg/kg dw	OMOEE LEL	120	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		OMOEE SEL	820	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME ISQG	123	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0
		CCME PEL	315	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0	0% n = 0

Note: Only the parent samples of duplicate samples were included in the screening.

n = number of samples; OMOEE = Ontario Ministry of the Environment and Energy; CCME = Canadian Council of Ministers of the Environment; LEL = lowest effect level; SEL = severe effect level; ISQG = Interim Sediment Quality Guideline; PEL = probable effect level; dw = dry weight; NF = near-field; MF = mid-field; FF = far-field.

APPENDIX IV

BENTHIC INVERTEBRATE REPORT

BENTHIC INVERTEBRATE REPORT
IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT
FOR THE DIAVIK DIAMOND MINE,
NORTHWEST TERRITORIES

Submitted to:

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Executive Summary

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2015L2-0001, according to the *AEMP Design Plan Version 4.1* approved by the Wek'èezhìı Land and Water Board (WLWB). This report presents the analyses of the benthic invertebrate community data collected during the 2019 AEMP field sampling. Objectives of the benthic invertebrate community survey were to assess effects of the Mine effluent on the benthic invertebrate community in Lac de Gras and, if present, estimate the type, magnitude, and spatial extent of the effects.

Benthic invertebrate samples were collected and analyzed from 34 stations located near-field (NF), mid-field (MF) and far-field (FF) areas in Lac de Gras during open-water conditions in 2019. 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. This conclusion is based on the following results:

- 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.
- 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.
- 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 mid-field (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; 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.
- 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.

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[1].

No Action Levels were triggered for the benthic invertebrate community, as observed effects were indicative of nutrient enrichment, and NF area means were not significantly lower that the 2007 to 2010 reference condition mean values for all variables compared. No response plans are required for the 2019 benthic invertebrate community component of the AEMP[2].

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[1] This is consistent with observations reported in previous AEMP years, as summarized in the 2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1 (Golder 2019a).

[2] This is inconsistent with observations reported in previous AEMP years, as summarized in the 2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1 (Golder 2019a). In 2016 an Action Level 1 was triggered for Pisidiidae density and evenness.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
AIC	Akaike’s information criterion
AICc	corrected for small sample size
ANOSIM	analysis of similarities
ANOVA	analysis of variance
BCI	Bray-Curtis index
CCME	Canadian Council of Ministers of the Environment
DDMI	Diavik Diamond Mines (2012) Inc.
DO	dissolved oxygen
FF	far-field
GPS	global positioning system
i.e.	that is
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
nMDS	non-metric multidimensional scaling
P	probability
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
SDI	Simpson’s Diversity Index
SIMPROF	similarity profile
TDS	total dissolved solids
TOC	total organic carbon
WLWB	Wek'èezhìı Land and Water Board
WOE	weight-of-evidence

Symbols and Units of Measure

°C	degree Celsius
±	plus or minus
%	percent
>	greater than
<	less than
=	equals
-	not applicable
cm	centimetre
L	litre
m	metre
m^2	square metre
mm	millimetre
mg/L	milligrams per Litre
µS/cm	microsiemens per centimetre
µm	micrometre
na	not applicable
no./m^2	number of organisms per square metre
ns	not significant
nt	not tested

1 INTRODUCTION

1.1 Background

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP), as required by Water Licence W2015L2-0001 (WLWB 2015). This report presents the analysis of benthic invertebrate community data collected during the 2019 field program, which was carried out by DDMI according to the *AEMP Design Plan Version 4.1* (Golder 2017a). Supporting environmental data (i.e., limnology profiles, water samples, and sediment quality samples) were collected concurrently and are presented in the Effluent and Water Chemistry Report (Appendix II) and the Sediment Quality Report (Appendix III).

1.2 Objectives

The overall objective of the AEMP is to monitor the Diavik Diamond Mine (Mine) effluent discharge and other stressors from the Mine, and to assess potential ecological effects. 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. Benthic invertebrate community data were analyzed to evaluate whether there were differences in variables among areas of Lac de Gras exposed to Mine-related inputs, and between the near-field (NF) area and reference conditions for Lac de Gras (as defined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019a]). In addition, analyses were done to evaluate whether declining gradients in variables existed along each of the three transects sampled in Lac de Gras.

1.3 Scope and Approach

The benthic invertebrate component of the AEMP is designed to monitor both spatial and temporal changes in the benthic invertebrate community. As described in *AEMP Design Plan Version 4.1* (Golder 2017a), the objective of the annual report for a comprehensive AEMP year (i.e., when benthic invertebrates are sampled) is to assess the spatial extent of Mine-related effects and evaluate whether Action Levels have been reached. A summary report of all AEMP data collected since the baseline period, up to and including 2016, was described in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019b). 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 2019b) is an important reference when considering ongoing monitoring results.

Effects on the benthic invertebrate community were assessed using statistical tests comparing benthic community variables between the NF area, which receives the greatest exposure to the Mine effluent, and the three least-exposed far-field (FF) areas (i.e., FF1, FFA, and FFB). In addition, spatial trends in benthic community variables and community structure along the gradient of effluent exposure in Lac de Gras were evaluated using gradient analysis, visual means and multivariate analysis.

Magnitudes of effects were assessed by comparing benthic invertebrate community variables in the NF area to the reference condition, as defined for Lac de Gras in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a). Values that were beyond the reference condition were considered to be exceeding the range of natural variability in Lac de Gras. The importance of effects observed on benthic invertebrate community variables were categorized according to the Action Level classifications defined in the *AEMP Design Plan Version 4.1* (Golder 2017a).

2 METHODS

2.1 Field Sampling

Benthic invertebrate community samples were collected by DDMI personnel according to DDMI Standard Operating Procedures (e.g., ENVR-003-0702, ENVI-133-0112, ENVI-134-0112; Golder 2017b). Benthic invertebrate community sampling dates, station locations, and water depths are summarized in Table 2-1.

Benthic invertebrate samples were collected and analyzed from 34 replicate stations in Lac de Gras during open-water conditions in 2019 (Figure 2-1). Specifically:

- five stations in the NF area
- three stations in the mid-field (MF) 1 area
- two stations in the MF2 area
- two stations in the FF2 area
- seven stations in the MF3 area
- five stations in each of the three FF areas (i.e., FF1, FFA, FFB)

The FF1, FFA and FFB areas are the least exposed FF areas sampled in Lac de Gras, as previous AEMP results have demonstrated a low level of effluent exposure in these areas in previous years (Golder 2017a). While the five stations within the NF area and within each FF area are subject to approximately the same level of effluent exposure, the MF areas (i.e., MF1, MF2-FF2[3] and MF3) represent a gradient of exposure between the NF and FF areas. Therefore, the MF areas, together with the NF area and corresponding FF area(s), are considered transects extending away from the Mine effluent diffuser, and are referred to as the MF1, MF2 and MF3 transects in this report.

Water depth has been demonstrated to influence the benthic community in Lac de Gras (Golder 1997); therefore, benthic invertebrate community station selection was constrained to depths as close to 20 m as possible to prevent confounding the study design.

Six subsamples, each consisting of a single Ekman grab with a sampling area of 0.023 m^2, were collected at each station. Each subsample was sieved through a 500 micrometre (µm) mesh Nitex screen, and material retained by the mesh was placed in a separate 1 L plastic bottle and preserved in 10% buffered formalin. Samples were shipped to J. Zloty, PhD (independent consultant), for enumeration and taxonomic identification of invertebrates.

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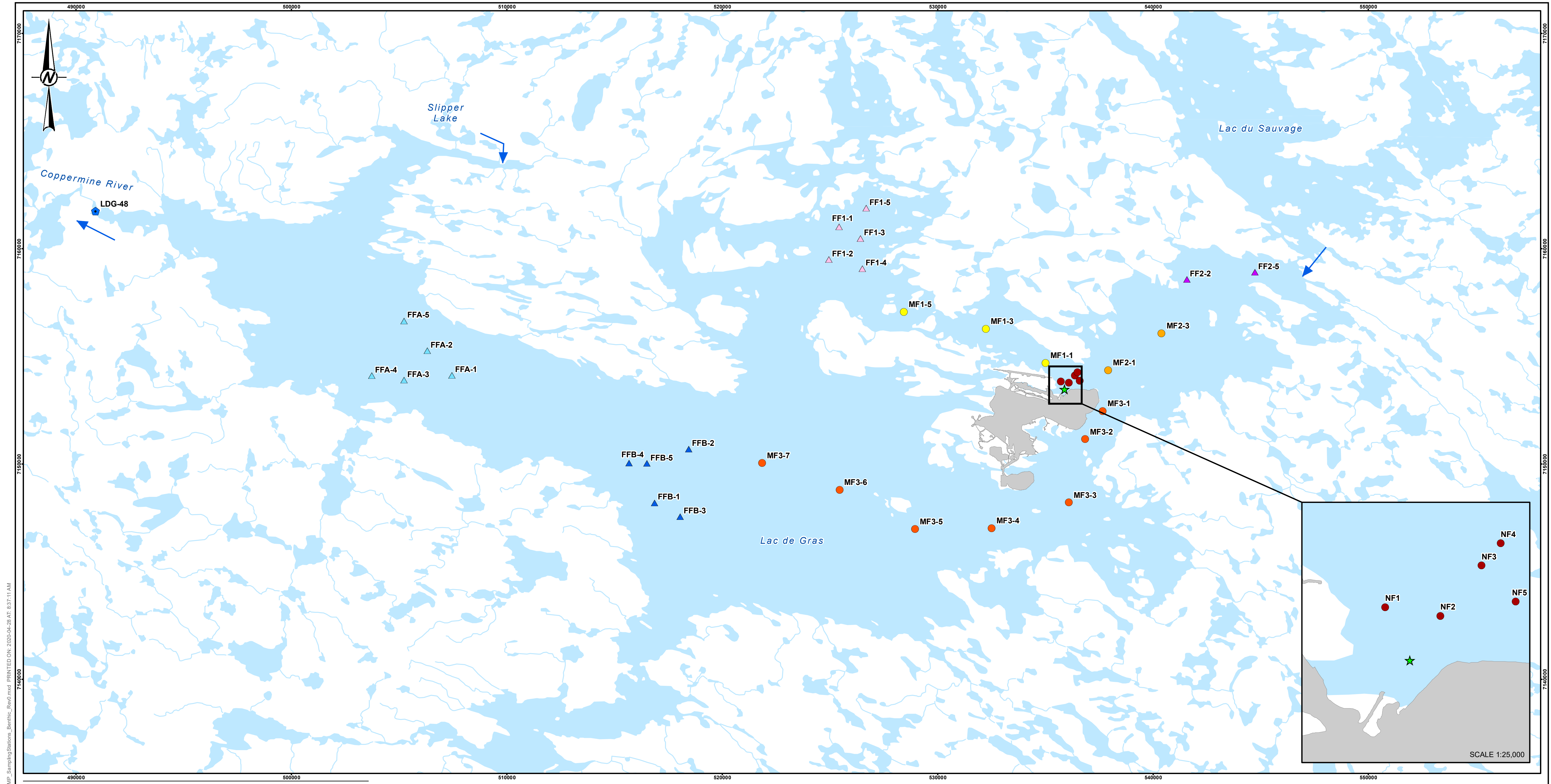
[3] The MF2 and FF2 areas were analyzed separately in the past, but the four stations in these areas are now considered together as the MF2 transect (Golder 2017a).



LEGEND

★ DIFFUSERS

STATION LOCATIONS

- △ FAR-FIELD 1
- ▲ FAR-FIELD 2
- △ FAR-FIELD A
- ▲ FAR-FIELD B
- ⬟ LAC DE GRAS OUTLET
- ● MID-FIELD 1
- ● MID-FIELD 2
- ● 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
LOCATIONS OF AEMP BENTHIC INVERTEBRATE SAMPLING STATIONS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
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Table 2-1 Benthic Invertebrate Station Locations and Sampling Dates, 2019

Area	Station	Sample Date	UTM Coordinates		Distance from Diffusers[a] (m)	Water Depth (m)
			Easting	Northing		
NF	NF1	22-Aug-19	535740	7153854	394	22.0
	NF2	23-Aug-19	536095	7153784	501	20.5
	NF3	03-Sep-19	536369	7154092	936	19.0
	NF4	23-Aug-19	536512	7154240	1,131	21.0
	NF5	15-Aug-19	536600	7153864	968	20.5
MF1	MF1-1	22-Aug-19	535008	7154699	1,452	20.0
	MF1-3	22-Aug-19	532236	7156276	4,650	19.0
	MF1-5	21-Aug-19	528432	7157066	8,535	18.0
MF2	MF2-1	23-Aug-19	538033	7154371	2,363	18.0
	MF2-3	20-Aug-19	540365	7156045	5,386	20.0
MF3	MF3-1	03-Sep-19	537645	7152432	2,730	19.0
	MF3-2	28-Aug-19	536816	7151126	4,215	20.0
	MF3-3	28-Aug-19	536094	7148215	7,245	20.0
	MF3-4	27-Aug-19	532545	7147011	11,023	20.0
	MF3-5	27-Aug-19	528956	7146972	14,578	18.0
	MF3-6	27-Aug-19	525427	7148765	18,532	18.0
	MF3-7	26-Aug-19	521859	7150039	22,330	21.5
FF2	FF2-2	20-Aug-19	541588	7158561	8,276	19.0
	FF2-5	20-Aug-19	544724	7158879	11,444	20.0
FF1	FF1-1	17-Aug-19	525430	7161043	13,571	21.9
	FF1-2	19-Aug-19	524932	7159476	12,915	19.0
	FF1-3	18-Aug-19	526407	7160492	12,788	18.7
	FF1-4	21-Aug-19	526493	7159058	11,399	20.0
	FF1-5	19-Aug-19	526683	7161824	12,823	18.0
FFA	FFA-1	04-Sep-19	506453	7154021	36,769	19.0
	FFA-2	05-Sep-19	506315	7155271	38,312	19.0
	FFA-3	04-Sep-19	505207	7153887	38,734	22.0
	FFA-4	04-Sep-19	503703	7154081	40,211	19.0
	FFA-5	04-Sep-19	505216	7156657	39,956	19.0
FFB	FFB-1	26-Aug-19	516831	7148207	26,355	20.5
	FFB-2	25-Aug-19	518473	7150712	24,991	18.3
	FFB-3	26-Aug-19	518048	7147557	25,245	21.9
	FFB-4	25-Aug-19	515687	7150036	27,591	19.0
	FFB-5	25-Aug-19	516533	7150032	26,761	19.5

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

UTM = Universal Transverse Mercator, NAD (North American Datum) 83, Zone 12V; NF = near-field; MF = mid-field; FF = far-field.

Supporting information recorded and variables measured at each station were:

- sampling date
- GPS coordinates, recorded as Universal Transverse Mercator
- water depth
- detailed water quality and vertical profiles of water temperature, dissolved oxygen (DO), pH and specific conductivity were measured as part of the water quality component; field measurements taken at the near-bottom depth are summarized herein, and water quality data are described in detail in the Effluent and Water Chemistry Report (Appendix II)
- detailed sediment quality was collected as part of the sediment quality component, where samples were collected and analyzed for total organic carbon (TOC) and particle size distribution (in samples from the top 10 to 15 cm of sediments), and total metals[4], total nitrogen, total phosphorus, and TOC (in samples from the top 1 cm of sediments); sediment quality data are described in detail in the Sediment Quality Report (Appendix III)

2.2 Sample Processing and Taxonomic Identification

Benthic invertebrate samples were analyzed as a single composite sample per station (i.e., six subsamples were pooled per station by the taxonomist). Previous benthic invertebrate studies in Lac de Gras, including a baseline study (Golder 1997), and the 2007 to 2011, 2013, 2014, 2015, 2016, 2017, and 2018 AEMP Annual Reports (Golder 2008, 2009, 2010, 2011, 2012, 2014, 2016a, 2016b, 2017b, 2018b, 2019b) demonstrated that six subsamples are typically sufficient to collect representative benthic community data from a station in Lac de Gras.

Benthic invertebrate samples were processed according to standard protocols based on Environment Canada (2002) and Gibbons et al. (1993). Samples were first washed through a 500 µm mesh sieve to remove the preservative and fine sediments remaining after field sieving. Organic material was separated from inorganic material using elutriation (i.e., separation of the lighter organic material from the heavier inorganic material in a water-filled pan). The inorganic material was checked for remaining shelled or cased invertebrates, which were removed and added to the organic material. The organic material was split into coarse and fine fractions using a set of nested sieves of 1 mm and 500 µm mesh size. Because samples were generally small, containing less than 300 organisms, laboratory subsampling was not necessary.

Invertebrates were identified to the lowest practical taxonomic level, typically genus, using recognized taxonomic keys (Brinkhurst 1986; Clifford 1991; Coffman and Ferrington 1996; Epler 2001; Maschwitz and Cook 2000; McAlpine et al. 1981; Merritt and Cummins 1996; Oliver and Roussel 1983; Pennak 1989; Soponis 1977; Wiederholm 1983). Organisms that could not be identified to the desired taxonomic level (e.g., immature or damaged specimens) were reported as a separate category at the lowest taxonomic level possible, typically family. Organisms that required detailed microscopic examination for identification (e.g., Chironomidae and Oligochaeta) were mounted on microscope slides using an appropriate mounting medium. The most common taxa were distinguishable based on gross morphology and required only a few

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

slide mounts (i.e., five to ten) for verification. All rare or less common taxa were slide-mounted for identification.

A reference collection was prepared that contains preserved representative specimens of each taxon identified from the AEMP samples. Invertebrates removed from the samples have been stored for potential future taxonomic analysis.

2.3 Data Analysis

2.3.1 Data Screening

Initial screening of the 2019 benthic invertebrate community data was completed prior to completing data analysis to identify anomalous data (i.e., unusually large or small values) and decide whether to retain or exclude anomalous data from further analysis. An explanation of the objectives and the methods taken to complete the initial screening is provided in the *Quality Assurance Project Plan Version 3.1* (Golder 2017c). Initial data screening identified *Stictochironomus* density at MF1-1 as potentially anomalous data in the 2019 benthic invertebrate community dataset.

2.3.2 Data Preparation and Variable Selection

To prepare the data for analysis, the following taxa were removed from the dataset:

- non-benthic invertebrates (i.e., Copepoda, Cladocera, and pupae)
- benthic meiofauna which were not quantitatively sampled (i.e., Nematoda) because they are not reliably enumerated using 500 µm mesh sampling gear
- terrestrial invertebrates.

In addition, the abundance of organisms per sample was converted to density (i.e., number of organisms per square metre [no./m^2]) based on the bottom area of the sampling device and the number of subsamples collected.

The following variables were included in the statistical analysis:

- total invertebrate density
- richness (total taxa per station at the lowest level of identification)
- dominance (percentage of the dominant taxon at a station)
- Simpson's diversity index (SDI)
- evenness index (evenness)
- Bray-Curtis index (BCI; a distance measure based on pair-wise comparisons of NF and FF stations; Golder 2017a)

- densities of common taxa[5]:
  - Pisidiidae or fingernail claims (24%)
  - *Procladius*, a genus of non-biting midges (32%)
  - *Heterotrissocladius*, a genus of non-biting midges (5%)
  - *Micropsectra*, a genus of non-biting midges (4%)
  - *Microtendipes*, a genus of non-biting midges (5%)
  - *Stictochironomus*, a genus of non-biting midges (13%)

Additional aspects of the benthic invertebrate community structure were examined visually, and included presence-absence by each invertebrate taxon and community composition by major taxonomic group.

2.3.3 Evaluation of Effects of Habitat Variation

Spearman rank correlations were performed between habitat variables (i.e., sediment TOC, percent fine sediments, water depth) and the biological variables selected for analysis. Only those habitat variables with sufficient ranges of variation to influence the benthic community were included in this analysis. Results of these correlations were used to evaluate whether habitat variation had the potential to influence the results of statistical comparisons among sampling areas. Correlations were performed using SYSTAT Version 13.1 (Systat 2019).

2.3.4 Statistical Analysis

2.3.4.1 Testing Assumptions of Analysis of Variance

Before statistical comparisons, the assumptions of parametric statistical tests were verified using the Kolmogorov-Smirnov test for normality and Levene's test for homogeneity of variances (Sokal and Rohlf 1995) on untransformed, log-transformed, and rank-transformed data for density variables. Data were transformed where significant normality or equality of variance violations were found, and the effectiveness of the transformations was verified. Issues with non-normality and heteroscedasticity were addressed if either Kolmogorov-Smirnov test or Levene's test had probability (*P*) value of less than 0.01. Analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019).

For community indices (i.e., dominance, SDI, evenness, BCI), the assumptions of parametric statistical tests were verified on untransformed data. The indices did not violate parametric test assumptions; therefore, ANOVA was used for statistical analysis. *Micropsectra* density and *Stictochironomus* density were log-transformed. *Microtendipes* density did not meet the assumptions of parametric tests even after transformation and was therefore compared among sampling areas using non-parametric tests.

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[5] The values presented in parentheses are the 2019 relative densities as percentages; the first four of these common taxa are consistent with those evaluated during previous AEMP benthic invertebrate community surveys. In 2019, densities of *Microtendipes* and *Stictochironomus* were added to the evaluation of common taxa, because they also met the 5% criterion applied to identify common taxa.

2.3.4.2 Near-Field Versus Far-Field Area Comparisons

The 2019 means of the NF, FF1, FFA, and FFB areas were initially compared to one another in an overall analysis of variance (ANOVA) (Sokal and Rohlf 1995). If a significant difference was observed, the NF area was compared with the FF areas within the overall ANOVA, as an *a priori* comparison (i.e., planned contrast). Multiple comparison techniques that were not planned prior to undertaking the analysis (i.e., *a posteriori*) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear contrasts by formulating meaningful comparisons among sampling areas prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the NF area of Lac de Gras.

At the study design stage, the probability of a Type I error (α) was set to the same level (i.e., 0.1) as a Type II error (β) probability, because the probability of missing important effects was deemed to be as important as the probability of finding an effect when none existed (Environment Canada 2012). This approach resulted in a power of 90% for the study as designed.

To investigate variability between the three FF areas, multiple comparisons were performed between pairwise combinations of the FFA, FFB, and FF1 areas, using Tukey's test (Sokal and Rohlf 1995). If any of the multiple comparisons were significant, the NF area mean was compared to either the smallest or the largest FF area mean, as applicable, using a one-tailed test to evaluate whether the NF mean was higher than the largest or lower than the smallest FF area mean. If the NF mean was within the range bounded by the largest and smallest FF means, no additional test was run. If multiple comparisons between FF areas were not significant, the NF area mean was compared to the average of the FF area means using a two-tailed test.

For *Microtendipes* density, the Kruskal-Wallis test was used to test for differences among sampling areas, because parametric assumptions were not met, and the NF area was compared to the largest FF area mean using the pairwise Wilcoxon rank sum test (Sokal and Rohlf 1995).

Statistical analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019).

The magnitude of the difference between the NF area mean and the largest or the smallest FF area mean was calculated as percent difference, regardless of significance determined during statistical testing:

$$Percent\ Difference\ (\%) = \frac{(NF\ mean - largest/smallest\ FF\ mean)}{largest/smallest\ FF\ mean} \times 100$$

2.3.5 Comparison to Reference Conditions

2.3.5.1 Normal Range

Benthic invertebrate community variables were in the NF area were compared 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. Normal ranges were calculated using data from three AEMP FF areas (i.e., FF1, FFA, and FFB) from 2007 to 2010 (with some exceptions). Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a) and are summarized in Table 2-2. *Microtendipes* density and *Stictochironomus* density were new variables added in 2019 and, therefore, normal ranges were not available for these taxa. Normal ranges were calculated in 2019 for these variables according to the methods outlined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

Table 2-2 Normal Ranges for Benthic Invertebrate Community Variables

Variable	Unit	Normal Range[(a)]	
		Lower Limit	Upper Limit
Total Density	no./m^2	110.4	998.4
Richness	number of taxa	4.3	15.0
Dominance	%	21.7	57.3
Simpson's Diversity Index	-	0.60	0.86
Evenness	-	0.23	0.76
Bray-Curtis Distance	-	0.45	0.81
Percent Chironomidae	%	46.9	91.3
Pisidiidae Density	no./m^2	0	206.1
Procladius Density	no./m^2	0	149.7
Heterotrissocladius Density	no./m^2	0	203.2
Micropsectra Density	no./m^2	0	171.6
Microtendipes Density[(b)]	no./m^2	0	47.0
Stictochironomus Density[(b)]	no./m^2	0	14.0

Note: Normal range values were calculated in 2019 for *Microtendipes* density and *Stictochironomus* density according to methods described in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

Source: *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

no./m^2 = number of organisms per square metre.

2.3.5.2 Statistical Comparison to Reference Condition

Benthic invertebrate data were also analyzed to assess differences between the 2019 NF area and the reference condition dataset. Since toxicological impairment is expected to result in declines in most variables relative to the reference condition, a one-tailed test was performed to determine if NF data were significantly lower than the mean of the reference condition dataset. This comparison was done to evaluate whether Action Levels for toxicological impairment have been triggered, and was run for variables that had 2019 NF area means that were lower than reference condition means (i.e., Dominance, Evenness, *Heterotrissocladius* density and *Micropsectra* density).

To complete these comparisons, data were analyzed using mixed effects models, where Type (NF versus reference) was the only fixed variable, and the random factor was a random intercept of Year nested in Area. Residual normality and homoscedasticity were evaluated using Kolmogorov-Smirnov test and Levene's tests, respectively. In addition, residuals were examined using quantile-quantile plots to visually assess normality, and scatter plots vs. fitted values and boxplots vs. categorical variables to assess heteroscedasticity. The analysis output included a *P*-value for the coefficient assessing whether NF data were significantly lower than the reference conditions. Analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019).

The magnitude of the difference in variables between NF area and the 2007 to 2010 Reference Condition mean was calculated by expressing the difference as a percentage of the 2007 to 2010 Reference Condition mean:

$$Magnitude\ of\ Difference\ (\%) = \frac{(NF\ \ mean - Reference\ Conditon\ mean)}{Reference\ Condition\ mean} \times 100$$

2.3.6 Gradient Analysis

Spatial gradients in benthic invertebrate community variables along the various transects were analyzed using linear regressions, per the *AEMP Design Plan Version 4.1* (Golder 2017a). The NF area data were included in the linear regression for each of the three transects (i.e., MF1, MF2, MF3), which consisted of the following stations:

- MF1 Transect: NF1 to NF5; MF1-1, MF1-3, MF1-5; FF1-1 to FF1-5 (13 stations)
- MF2 Transect: NF1 to NF5; MF2-1, MF2-3, FF2-2, FF2-5 (9 stations)
- MF3 Transect: NF1 to NF5; MF3-1 to MF3-7; FFA1 to FFA5; FFB1 to FFB5 (22 stations)

Linear regressions were completed using statistical environment R v. 3.6.1 (R Core Team 2019). All 34 stations were included in the analysis, assigned to transects as described above. Density variables were log-transformed prior to regression analyses and regression analyses were considered significant at $\alpha = 0.1$.

Due to the inherent variability in benthic invertebrate community datasets, variables often had non-linear patterns with distance from the diffusers. Therefore, the analysis method allowed for piecewise regression (also referred to as segmented or broken stick regression). The following approaches were used:

- Model 1: a linear multiplicative model, with main effects of distance from diffusers, gradient (MF1, MF3 transects), and their interactions
- Piecewise modelling to account for changes in spatial gradients, where individual transects are analyzed separately from one another:
  - Model 2: a linear multiplicative model with main effects of distance from diffusers, gradient (MF1 and MF2-FF2 transect) and their interaction
  - Model 3: a linear piecewise (broken stick) model with distance (MF3 only)

For each variable, Model 1 was used to test for the presence of a significant ($P<0.05$) breakpoint using the Davies test (Davies 1987, 2002). If a significant breakpoint was identified, Models 2 and 3 were used for that variable in that season. If no significant breakpoint was identified, Model 1 was used.

Following the initial fit of the model, the residuals (of either Model 1 or Model 2, as applicable) were examined for normality. Model 3 was not considered for transformations, since the addition of a breakpoint was expected to resolve non-linear patterns. For each response variable, the data underwent Box-Cox transformations (Box and Cox 1964). The Box-Cox transformations are a family of transformations that include the commonly used log and square root transformations. The Box-Cox transformation process tests a series of power values, usually between -2 and +2, and records the log-likelihood of the relationship between the response and the predictor variables under each transformation. The transformation that maximizes the log-likelihood is the one that will best normalize the data. Therefore, the data are transformed using a power value identified by the transformation process. For a power value of zero, the data are natural log transformed. The transformation rules can be described using the following definitions:

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

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

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

Following data transformation (if required), the selected models were fitted to the data. Statistical outliers were identified using studentized residuals with absolute values of 3.5 or greater, or due to consideration of leverage (where a single point could strongly influence the overall fit of the model). All values removed from analysis were retained for plots of model predictions, where they were presented using a different symbol from the rest of the data.

Following removal of outliers, breakpoint significance and data transformation was re-examined. Residuals from the refitted models were examined for normality and heteroscedasticity, and evidence of nonlinear patterns. If non-linearity was evident from residual examination, the analysis was terminated and data were presented qualitatively. If normality was evident, then three models were constructed to assess the effect of heteroscedasticity for each response variable in each season:

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

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

The constructed models were used to produce the following outputs:

- Estimates and significance of slopes (i.e., distance effects) for each gradient. In the case of MF3 data analyzed using piecewise regression, the significance of the first slope, extending from the NF to the breakpoint, was calculated.

- The r^2 or R^2 value of each model, to examine explained variability.
- Fitted prediction lines and 95% confidence intervals, back-transformed to original scale of the variable.

Analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019) and package “segmented” (Muggeo 2008).

2.3.7 Multivariate Analysis

Benthic invertebrate community structure was summarized using the non-parametric ordination method of non-metric multidimensional scaling (nMDS; Clarke 1993). The nMDS data were scaled in Primer, Version 7 for Windows (PRIMER E Ltd., Plymouth, UK; Clark and Gorley 2016). Species-level benthic invertebrate data were log (x+1) transformed, to improve the separation of the data among stations on the nMDS plots and to reduce weighting of the analysis by the most abundant taxa. A Bray-Curtis resemblance matrix was generated, and the nMDS procedure was applied to this matrix. Using rank order information, nMDS determined the relative positions of stations in two dimensions based on community composition. Goodness-of-fit was determined by examining the Shepard diagrams as well as the stress value, which was calculated from the deviations in the Shepard diagrams. Smaller stress values (i.e., less than 0.10) indicate a greater goodness-of-fit between the original data and the configuration produced by the ordination. Larger stress values (i.e., greater than 0.20) must be interpreted with caution, and a greater number of dimensions (i.e., typically three) may be needed to describe the dataset (Clarke 1993). Points that fall close together on the nMDS ordination plot represent stations with similar community composition. Points that are far apart from each other represent stations with dissimilar communities.

A similarity profile (SIMPROF) test was also carried out on the ordination data to identify meaningful clusters of important taxa (i.e., those taxa that behave in a coherent manner across areas) and to prevent over-interpretation of the nMDS plots (Clarke et al. 2014). These SIMPROF clusters were superimposed on the nMDS plots.

An overall one-way analysis of similarities (ANOSIM) test was carried out on the Bray-Curtis resemblance matrix to confirm interpretation of the separation of the points on the nMDS ordination plot. Multivariate statistics were performed using PRIMER, Version 7.0.11 (Clarke and Gorley 2016).

2.4 Action Level Evaluation

Benthic invertebrate community variables were assessed for a Mine-related effect according to Action Levels described in the Response Framework presented in *AEMP Study Design Version 4.1* (Golder 2017a). The goal of the Response Framework is to ensure that significant adverse effects never occur. A significant adverse effect, as it pertains to aquatic biota, was defined in the Environmental Assessment for the Mine as a change in fish population(s) that is greater than 20% (Government of Canada 1999). The effect must have a large probability of being permanent or long-term in nature and must occur throughout Lac de Gras.

The AEMP addresses two impact hypotheses for Lac de Gras: the toxicological impairment hypothesis and the nutrient enrichment hypothesis (Golder 2017a). Action Levels for the benthic invertebrate community address only the toxicological impairment hypothesis, whereas the nutrient enrichment hypothesis is assessed in the Eutrophication Indicators Report (Appendix XIII). Conditions required to trigger Action

Levels 1 to 3 for the benthic invertebrate community are presented in Table 2-3, and conditions for Action Level 4 would be defined if Action Level 3 were triggered.

According to the Action Level criteria defined in the *AEMP Design Plan Version 4.1* (Golder 2017a), evaluation of Action Level triggers for benthic invertebrates involves statistically comparing benthic invertebrate community variables between the NF area and the FF areas (and possibly the MF areas), and comparing NF area results to the normal range (Golder 2019a). As toxicological impairment would be expected to result in declines in most benthic invertebrate community variables relative to the reference condition, Action Level 1 would be triggered if the mean value in the NF area was significantly lower than the FF areas' mean value. Action Level 2 would be triggered if the effect observed in the NF area extends to the nearest MF stations (i.e., MF1-1, MF2-1, MF3-1), and Action Level 3 would be triggered if the NF area results were lower than the lower limit of the normal range defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

Consistent with previous comprehensive AEMP years, the NF area was compared statistically to the FF1, FFA and FFB areas. However, previous AEMP results have indicated the three former FF reference areas have been exposed to Mine effluent and can no longer be considered valid reference areas in a control-impact comparison. This was explained in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019b), which proposed an adjustment to the biological Action Level assessment for the updated AEMP Design Plan in the form of comparing the NF area results to the reference condition dataset. This change was approved by the WLWB in Directive 3Q (WLWB 2019), to be first applied during the analysis of the 2019 AEMP dataset. Therefore, the results of statistical comparisons of the NF area (and MF areas, if required) to the reference condition dataset (Section 2.3.5.2) were used to evaluate Action Levels 1 and 2 for benthic invertebrates.

Table 2-3 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 2019a).
c) Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
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.

2.5 Quality Assurance/Quality Control

The *Quality Assurance Project Plan Version 3.1* (Golder 2017c), or QAPP, outlined the quality assurance/quality control (QA/QC) procedures implemented to support the collection of scientifically-defensible and relevant benthic invertebrate community data required to meet the objectives of the *AEMP Design Plan Version 4.1* (Golder 2017a). The QAPP facilitates creation of a technically-sound and scientifically defensible report by standardizing field sampling, laboratory analysis, data entry, data analysis, and report preparation activities.

Results of the QC program are provided in Attachment A. Benthic invertebrate community sample processing included re-sorting by a second individual of 10% of the total number of samples collected to evaluate invertebrate removal efficiency, and preparation of a reference collection. Subsampling was not done in the laboratory because all samples were small enough to be sorted in their entirety. Re-sorted samples satisfied the data quality objective of at least 90% invertebrate removal.

2.6 Weight-of-Evidence Input

The results of the benthic invertebrate community survey are integrated through the weight-of-evidence (WOE) analysis to determine the strength of evidence supporting the two broad impact hypotheses for Lac de Gras (i.e., nutrient enrichment and toxicological impairment), as described in the *AEMP Design Plan Version 4.1* (Golder 2017a). The WOE is not intended to determine the ecological significance or level of concern associated with a given change. The WOE evaluation is provided in the Weight-of-Evidence Report (Appendix XV).

3 RESULTS

Benthic invertebrate community sampling was completed between 15 August and 5 September 2019. Details relating to QA/QC of the 2019 data are presented in Attachment A. The 2019 benthic invertebrate community raw abundance data are presented in Attachment B. One anomalous value, which was also identified as a statistical outlier, was identified during the 2019 data analysis (*Stictochironomus* density of 1,537 organisms/m^2 at MF1-1).

3.1 Field Water Quality

Field water quality measurements were taken at the benthic invertebrate community stations near the sediment/water interface. The pH was slightly acidic to neutral at the bottom depth of Lac de Gras (Table 3-1). Water temperature was similar among all sampling areas, with a mean of 10.2°C. The concentration of DO was similar at all stations with a mean of 11.1 mg/L, well above the Canadian Council of Ministers of the Environment (CCME) guideline for minimum DO for the protection of all life stages of aquatic life of 6.5 mg/L to 9.5 mg/L for coldwater systems (CCME 2002).

Specific conductivity was highest in the NF area and gradually decreased with distance from the diffuser. Field measured conductivity values were compared with laboratory-calculated specific conductivity measurements and were found to be similar and, therefore, field measured specific conductivity was included in Table 3-1.

Table 3-1 Water Depth, Water Quality and Sediment Quality Data for Benthic Invertebrate Community Stations, 2019

Area	Station	Sample Date	Water Depth (m)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH	Sediment Total Organic Carbon (%)	Sediment Particle Size			
									Sand (%)	Silt (%)	Clay (%)	Fines (silt + clay) (%)
NF	NF1	22-Aug-19	22.0	9.4	11.1	50.6	6.3	2.6	17	61	22	83
	NF2	23-Aug-19	20.5	9.9	11.1	36.2	6.6	3.1	5	84	11	95
	NF3	3-Sep-19	19.0	9.3	11.2	47.0	6.7	3.0	7	78	15	93
	NF4	23-Aug-19	21.0	9.8	11.1	35.6	6.6	2.7	7	77	16	93
	NF5	15-Aug-19	20.5	8.9	11.4	34.2	6.3	3.3	4	70	26	96
MF1	MF1-1	22-Aug-19	20.0	10.4	11.2	41.6	6.7	2.2	3	84	13	97
	MF1-3	22-Aug-19	19.0	10.4	11.2	40.7	6.6	2.9	2	76	22	98
	MF1-5	21-Aug-19	18.0	11.1	11.1	32.6	6.8	2.9	6	83	12	94
MF2 FF2	MF2-1	23-Aug-19	18.0	10.0	11.2	36.0	6.5	1.0	11	74	15	89
	MF2-3	20-Aug-19	20.0	9.8	11.3	39.0	6.7	2.6	6	78	16	94
	FF2-2	20-Aug-19	19.0	9.7	11.4	39.2	6.6	4.4	2	86	12	98
	FF2-5	20-Aug-19	20.0	9.7	11.4	38.6	6.4	0.6	2	87	11	98
MF3	MF3-1	3-Sep-19	19.0	9.4	11.2	40.7	6.4	2.3	21	70	9	79
	MF3-2	28-Aug-19	20.0	10.6	11.0	31.6	6.7	3.0	7	83	10	93
	MF3-3	28-Aug-19	20.0	10.4	11.0	30.6	6.6	5.9	7	70	23	93
	MF3-4	27-Aug-19	20.0	10.4	10.9	30.4	6.6	2.7	8	71	21	92
	MF3-5	27-Aug-19	18.0	10.5	11.0	28.0	6.6	0.1	7	64	29	93
	MF3-6	27-Aug-19	18.0	10.8	11.1	27.9	6.6	5.4	3	66	31	97
	MF3-7	26-Aug-19	21.5	10.4	11.0	28.0	6.7	4.1	7	82	11	93
FF1	FF1-1	17-Aug-19	21.9	11.0	11.0	31.4	6.3	3.4	2	83	15	98
	FF1-2	19-Aug-19	19.0	10.9	11.1	31.4	6.5	3.9	2	84	15	98
	FF1-3	18-Aug-19	18.7	10.8	11.1	31.3	6.4	3.3	2	84	14	98
	FF1-4	21-Aug-19	20.0	10.9	11.1	31.4	6.5	3.3	6	76	18	94
	FF1-5	19-Aug-19	18.0	11.0	11.1	31.2	6.7	3.8	6	64	30	94
FFA	FFA-1	4-Sep-19	19.0	9.7	11.1	33.0	6.7	2.0	29	59	12	71
	FFA-2	5-Sep-19	19.0	9.5	11.2	33.2	6.5	3.2	24	54	22	76
	FFA-3	4-Sep-19	22.0	9.7	11.1	33.0	6.7	3.3	8	72	20	92
	FFA-4	4-Sep-19	19.0	9.8	11.1	33.0	6.5	2.1	35	46	19	65
	FFA-5	4-Sep-19	19.0	9.6	11.2	33.1	6.5	6.0	5	62	34	95
FFB	FFB-1	26-Aug-19	20.5	10.5	11.0	27.9	6.6	3.6	38	46	16	62
	FFB-2	25-Aug-19	18.3	10.6	11.1	27.9	6.5	5.2	3	84	14	97
	FFB-3	26-Aug-19	21.9	10.6	11.1	27.9	6.5	3.3	9	77	14	91
	FFB-4	25-Aug-19	19.0	10.5	11.1	27.9	6.6	1.4	37	51	12	63
	FFB-5	25-Aug-19	19.5	10.5	11.0	27.9	6.6	1.1	25	57	19	75

Note: Near-bottom field water quality data are shown.

µS/cm = microsiemens per centimetre; NF = near-field; MF = mid-field; FF = far-field.

3.2 Effects of Habitat Variation

Consistent with previous years, water depth of the sampling locations was standardized to approximately 20 m, with only minor (i.e., <2 m) variation observed among sampling areas in mean water depth (Table 3-2). The variation in sediment TOC was also low among areas, with mean sediment TOC ranging from 2.1% to 3.5% (Table 3-2). Sediment quality data for 2019 are described in detail in the Sediment Quality Report (Appendix III).

Greater variability was observed in percent fine sediments, where mean values among sampling areas ranged from 78% to 95% (Table 3-2). The variability in percent fine sediments was sufficiently large to potentially influence the benthic invertebrate community, which may affect the ability to interpret Mine-related effects. Spearman rank correlation analysis on pooled data for all stations (n = 34) detected significant relationships of varying strength between percent fine sediments and seven of the 13 benthic invertebrate community variables (Table 3-3, Figures 3-1 and 3-2). Positive relationships were detected between total density, dominance, and densities of three chironomid genera (i.e., *Procladius*, *Microtendipes* and *Stictochironomus*) and fine sediment content. Evenness and SDI had weak negative relationship with percent fine sediments. These relationships, although mostly weak, are consistent with the expected relationship between benthic community variables and fine sediment content.

The results of the correlation analysis were not used to select covariates for inclusion in among-area comparisons. Most relationships with percent fine sediments were weak, and although the overall relationships based on data for all stations were significant, they were either absent within individual sampling areas or inconsistent among sampling areas.

Table 3-2 Summary of Habitat Variables in Benthic Invertebrate Community Sampling Areas, 2019

Area	Number of Stations	Water Depth (m)				TOC (%)				% Fine Sediments (silt + clay)			
		Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE
NF	5	19.0	22.0	20.6	0.5	2.6	3.3	2.9	0.1	83	96	92	2.3
MF1	3	18.0	20.0	19.0	0.6	2.2	2.9	2.7	0.2	94	98	96	1.0
MF2-FF2	4	18.0	20.0	19.3	0.5	0.6	4.4	2.1	0.9	89	98	95	2.1
MF3	7	18.0	22.0	19.7	0.2	0.1	6.0	3.0	0.2	79	97	91	2.2
FF1	5	18.0	21.9	19.5	0.7	3.3	3.9	3.5	0.1	94	98	97	0.9
FFA	5	19.0	22.0	19.6	0.6	2.0	6.0	3.3	0.7	65	95	80	6.0
FFB	5	18.3	21.9	19.8	0.6	1.1	5.2	2.9	0.8	62	97	78	7.2

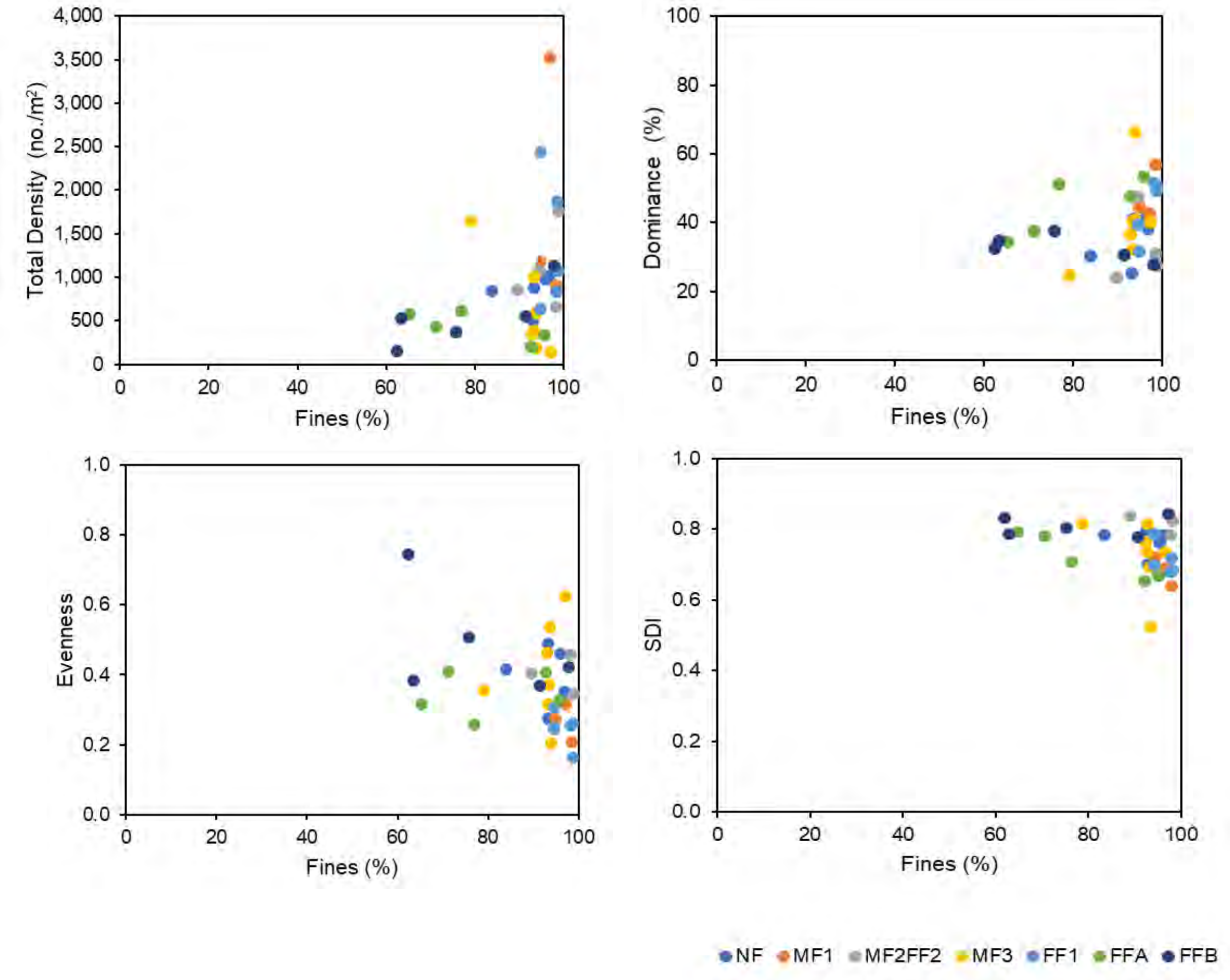
Notes: SE = standard error; TOC = total organic carbon; NF = near-field; MF = mid-field; FF = far-field.

Table 3-3 Spearman Rank Correlations between Biological Variables and Percent Fine Sediments, 2019

Variable	Percent Fine Sediments (silt + clay)
Total density	**0.494****
Richness	0.140
Dominance	**0.342***
Simpson’s diversity index	**-0.355***
Evenness index	**-0.347***
Bray-Curtis index	-0.031
Percent Chironomidae	0.280
Pisidiidae density	0.212
Procladius density	**0.616*****
Heterotrissocladius density	-0.210
Micropsectra density	0.267
Microtendipes density	**0.379***
Stictochironomus density	**0.345***

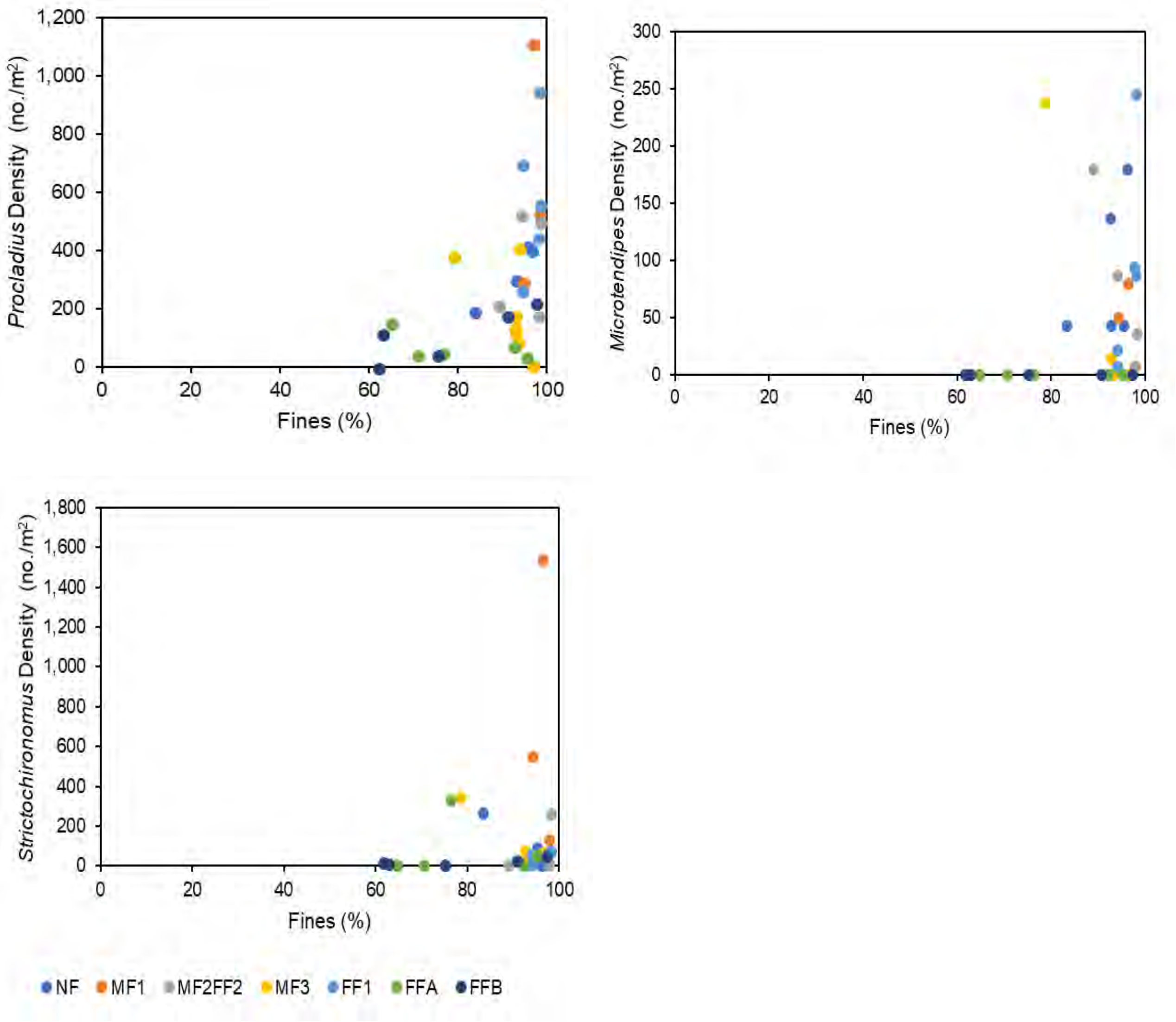
Note: **Bolded** values indicate significant Spearman correlations (n = 34); * = *P*<0.05; ** = *P*<0.01; *** = *P*<0.001.

Figure 3-1 **Percent Fine Sediments versus Total Density, Evenness, Dominance, and Simpson's Diversity Index in Lac de Gras, 2019**



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

Figure 3-2 **Percent Fine Sediments versus *Procladius* Density, *Microtendipes* Density, and *Stictochironomus* Density in Lac de Gras, 2019**



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

3.3 Exposure to Mine Effluent

Exposure of benthic invertebrate community sampling stations to the Mine effluent was evaluated using total dissolved solids (TDS) concentrations measured in lake water (see the Effluent and Water Chemistry Report [Appendix II]). Open-water TDS concentrations measured between 15 August and 5 September 2019 were beyond the upper limit of the normal range (i.e., 5.8 mg/L) at all stations (Table 3-4). Near-bottom specific conductivity measured at benthic invertebrate community stations demonstrated a very similar pattern to TDS (Table 3-4), indicating all sampled stations were exposed to Mine effluent.

Further details regarding distribution of Mine effluent in Lac de Gras are provided in the Effluent and Water Chemistry Report (Appendix II).

Table 3-4 Summary of Mine Effluent Exposure Indicator Variables at the Benthic Invertebrate Community Sampling Areas, 2019

Area	Station	Distance from Diffuser (m)	Specific Conductivity (µS/cm)	TDS, Calculated (mg/L)
NF	NF1	394	50.6	17.7
	NF2	501	36.2	18.3
	NF3	936	47.0	17.7
	NF4	1,131	35.6	17.0
	NF5	968	34.2	16.2
MF1	MF1-1	1,452	41.6	17.9
	MF1-3	4,650	40.7	16.8
	MF1-5	8,535	32.6	13.7
MF2	MF2-1	2,363	36.0	17.5
	MF2-3	5,386	39.0	16.5
FF2	FF2-2	8,276	39.2	16.8
	FF2-5	11,444	38.6	15.6
MF3	MF3-1	2,730	40.7	16.1
	MF3-2	4,215	31.6	14.6
	MF3-3	7,245	30.6	13.9
	MF3-4	11,023	30.4	14.7
	MF3-5	14,578	28.0	13.1
	MF3-6	18,532	27.9	12.9
	MF3-7	22,330	28.0	13.5
FF1	FF1-1	13,571	31.4	13.4
	FF1-2	12,915	31.4	13.2
	FF1-3	12,788	31.3	12.5
	FF1-4	11,399	31.4	13.2
	FF1-5	12,823	31.2	13.0
FFB	FFB-1	26,355	27.9	14.3
	FFB-2	24,991	27.9	13.1
	FFB-3	25,245	27.9	13.5
	FFB-4	27,591	27.9	12.9
	FFB-5	26,761	27.9	12.7
FFA	FFA-1	36,769	33.0	13.5
	FFA-2	38,312	33.2	13.1
	FFA-3	38,734	33.0	13.1
	FFA-4	40,211	33.0	13.4
	FFA-5	39,956	33.1	12.9

µS/cm = microsiemens per centimetre; NF = near-field; MF = mid-field; FF = far-field.

3.4 Community Composition

As in previous years, chironomid midges dominated the Lac de Gras benthic invertebrate community in 2019 (Figures 3-3 and 3-4; raw abundance data are provided in Attachment B). Chironomid relative densities were variable among stations and ranged from 16% (FFB-1) to 90% (NF-4). Mean chironomid density accounted for 73% of total density in the NF area, while the MF3 and FF1 areas generally had greater percentages of chironomids and the MF1, MF2-FF2, FFA and FFB areas had comparable percentages (i.e., within 5%) to the NF area.

Pisidiidae (i.e., fingernail clams) also contributed a large proportion of the total invertebrate density at the majority of stations, with the largest percentage observed at Station FFB-1 (58.3%). Mean Pisidiidae density accounted for greater than 18% of the total density in the NF, MF1, FFA and FFB areas.

A summary of presence/absence of benthic invertebrate taxa showed no clear distinction in community composition between the NF area, and the MF or FF areas (Table 3-4). All major groups that accounted for greater than 5% of the community by abundance were present at each station (i.e., Chironomidae, Oligochaeta and Pisidiidae). Invertebrates observed in some sampling areas, but missing from others included Notostraca (*Lepidurus*) in the FF1 and MF1 areas, Trichoptera (caddisflies) in the FF1 area, and the gastropod *Valvata sincera* in the MF3, FFB, and FF1 areas. Hydracarina were present at all areas except FFA, and were unevenly distributed, with specific taxa often present at only one or two stations sampled. One chironomid genus, *Stempellinella*, was restricted to the NF area. The greatest number of taxa (i.e., 26) was observed in the FF1 area, while the lowest number of taxa (i.e., 18) was observed in the MF1 area.

Figure 3-3 **Composition of the Benthic Invertebrate Community at Each Sampling Area in Lac de Gras, 2019**

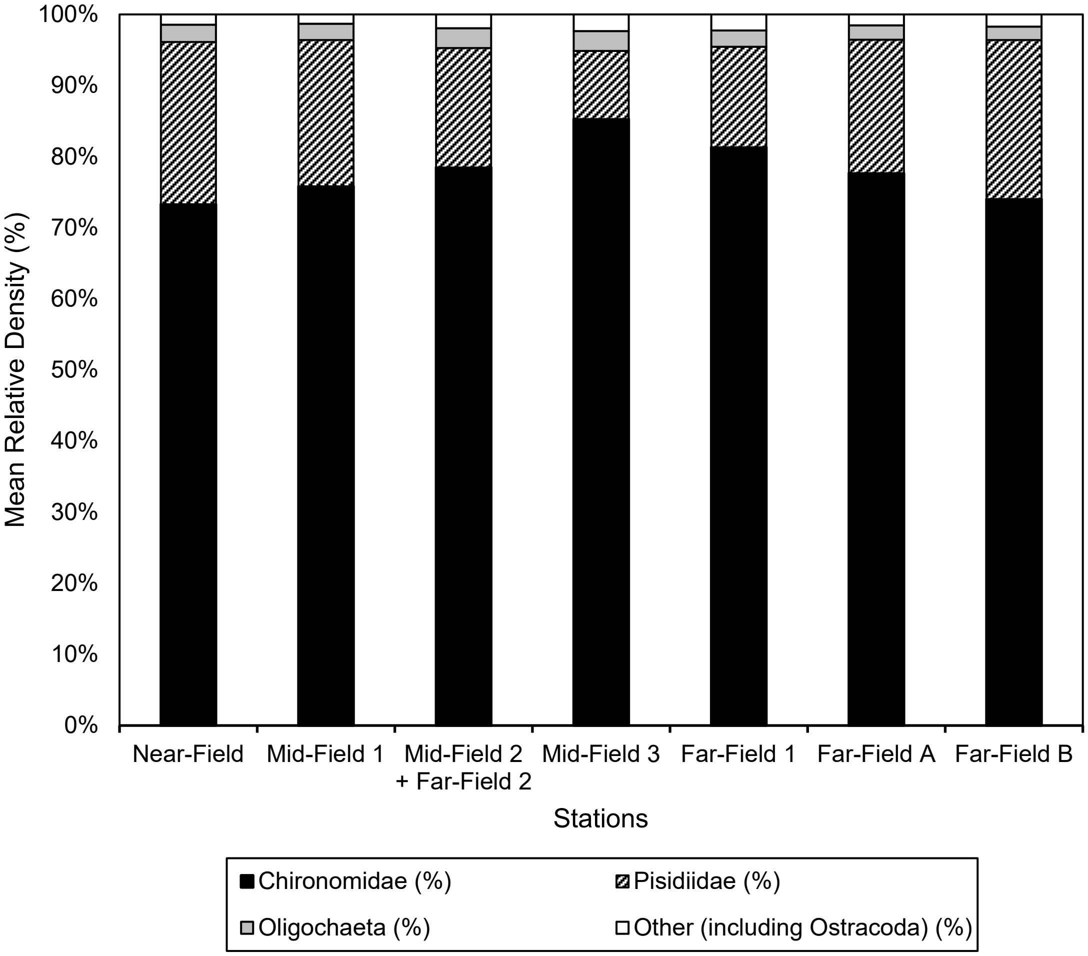
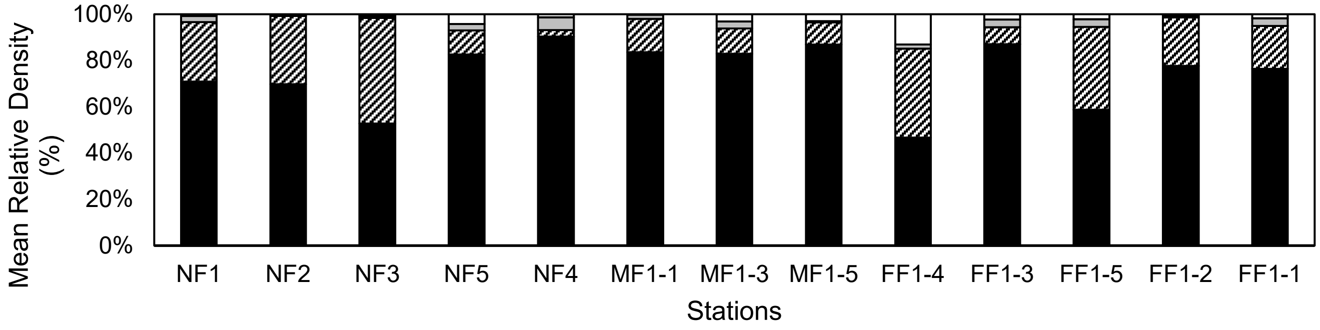
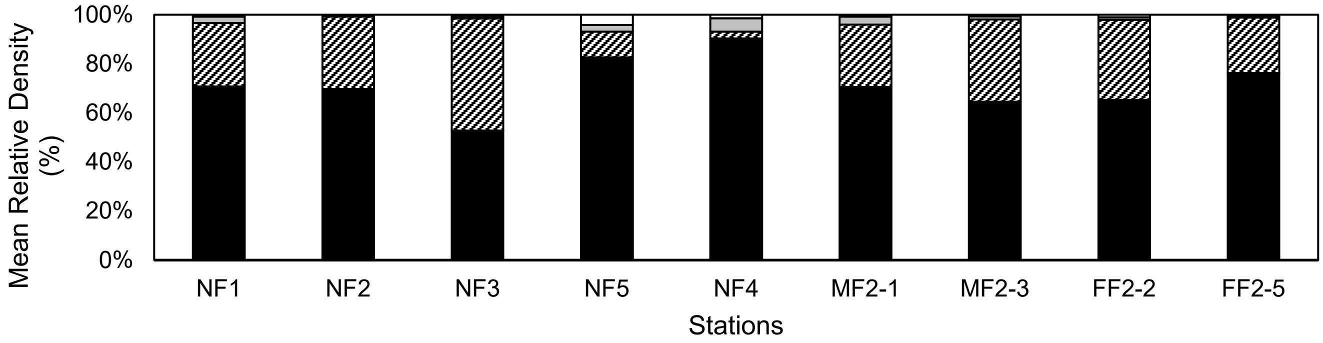


Figure 3-4 Composition of the Benthic Invertebrate Community along Each Sampling Transect in Lac de Gras, 2019

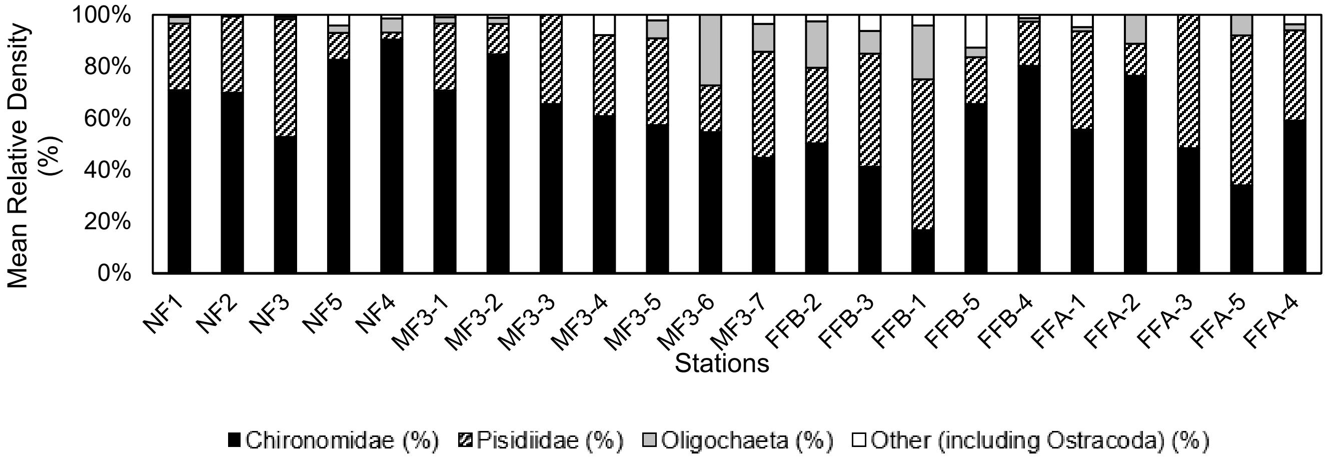
A) MF1 Transect



B) MF2 Transect



C) MF3 Transect



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

Table 3-5 Presence/Absence of Benthic Invertebrate Taxa by Area in Lac de Gras, 2019

				NF Area	MF Areas			FF Areas		
Major Group	**Family**	**Subfamily/Tribe**	**Genus/Species**	**NF**	**MF1**	**MF2-FF2**	**MF3**	**FF1**	**FFA**	**FFB**
				n=5	**n=3**	**(n=4)**	**(n=7)**	**(n=5)**	**(n=5)**	**(n=5)**
Hydrozoa	Hydridae	-	*Hydra*	X	-	-	-	X	X	-
Microturbellaria (i/d)	-	-	-	-	-	-	X	X	-	-
Oligochaeta	Lumbriculidae	-	-	X	X	X	X	X	X	X
	Naididae	Tubificinae	-	X	X	X	X	X	X	X
Gastropoda	Valvatidae	-	*Valvata sincera*	-	-	-	X	X	-	X
Pelecypoda	Pisidiidae	-	*Sphaerium*	X	X	X	X	X	X	X
		-	*Pisidium*	X	X	X	X	-	X	X
Hydracarina	Hygrobatidae	-	*Hygrobates*	-	-	X	-	X	-	-
	Lebertiidae	-	*Lebertia*	X	X	-	X	X	-	X
	Oxidae	-	*Oxus*	-	X	-	-	-	-	-
	Pionidae	-	*Piona*	-	-	X	-	-	-	-
	Unionicolidae	-	*Unionicola*	-	-	-	-	-	-	X
Notostraca	Triopsidae	-	*Lepidurus*	-	X	-	-	X	-	-
Ostracoda	-	-	-	X	X	X	X	X	X	-
Plecoptera	Capniidae	-	-	-	-	-	-	-	-	X
Trichoptera	Apataniidae	-	*Apatania*	-	-	-	-	X	-	-
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*	-	X	X	X	X	-	-
			Thienemannimyia group	-	X	-	X	X	X	X
			Procladius	X	X	X	X	X	X	X
		Chironomini	*Dicrotendipes*	-	-	-	-	X	-	-
			Microtendipes	X	X	X	X	X	-	-
			Sergentia	-	-	-	-	-	-	X
			Stictochironomus	X	X	X	X	X	X	X
		Tanytarsini	*Corynocera*	-	X	-	-	-	-	-
			Micropsectra	X	X	X	X	X	X	X
			Micropsectra / Tanytarsus	-	-	X	-	-	X	-
			Paratanytarsus	X	X	X	X	X	X	X
			Stempellinella	X	-	-	-	-	-	-
			Tanytarsus	X	X	X	X	X	X	X
		Orthocladiinae	*Abiskomyia*	-	-	-	X	-	X	X
			Cricotopus / Orthocladius	X	-	-	X	-	X	X
			Heterotrissocladius	X	-	X	X	X	X	X
			Paracladius	-	-	-	-	-	X	-
			Parakiefferiella	-	-	-	-	X	X	-
			Psectrocladius	-	-	X	-	-	X	-
			Zalutschia	X	-	X	-	X	-	-
		Diamesinae	*Potthastia longimanus* group	-	-	-	-	-	-	X
			Protanypus	X	-	X	X	X	X	X
		Prodiamesinae	*Monodiamesa*	X	X	X	X	X	X	X
	Empididae	-	*Chelifera / Metachela*	-	-	-	-	X	-	-
Total Taxa				**19**	**18**	**20**	**21**	**26**	**21**	**21**

X = present; - = not present; i/d = immature/damaged specimen; NF = near-field, MF = mid-field, FF = far-field.

3.5 Comparison to Normal Range

In 2019, some benthic invertebrate community variables exceeded the normal range in AEMP sampling areas. However, with the exception of densities of four common taxa, all variables had NF area means within the normal range (Table 3-6; Figures 3-5 to 3-11). Mean total density was above the normal range in the MF1, MF2-FF2 and FF1 areas (Figure 3-5), while total richness approached the upper boundary of the normal range in the MF2-FF2 and FF1 areas, but did not exceed it (Figure 3-6). Dominance, SDI and BCI were within normal range in all sampling areas (Figures 3-6 and 3-7). Mean evenness approached the lower limit of the normal range in the MF1 and FF1 areas in 2019 (Figure 3-7), and was within normal range at the remaining sampling areas. Mean percent Chironomidae approached the lower limit of the normal range in the FFB and FFA areas (Figure 3-8).

Mean densities of four common taxa exceeded the normal range (i.e., Pisidiidae, *Procladius*, *Microtendipes* and *Stictochironomus*), while the remaining taxa had mean densities within the normal range in all sampling areas (Figures 3-8 to 3-11). Mean Pisidiidae density was above the normal range in the NF, MF1, MF2-FF2 and FF1 areas (Figure 3-8). Mean *Procladius* and *Microtendipes* densities were above the upper limit of the normal range in the NF, MF1, MF2-FF2 and FF1 areas. Mean *Procladius* density was also above the upper limit of the normal range in the MF3 area. Mean *Stictochironomus* density was above the normal range in all areas sampled. No benthic invertebrate community variables had sampling area mean values below the normal range.

Table 3-6 Benthic Invertebrate Community Variables in the NF Area of Lac de Gras Compared to the Normal Range and the FF Area Mean, 2019

Variable	Unit	2019 NF Area		2019 FF Areas		Normal Range(a)		
		Mean ± SD	n	Mean ± SD	n	Lower Limit	2007-2010 Reference Condition Mean	Upper Limit
Total density	no./m^2	864 ± 202	5	806 ± 632	15	110	527	998
Richness	number of taxa	11 ± 2	5	12 ± 3	15	4.3	10	15
Dominance	%	*36* ± 7	5	41 ± 9	15	22	38	57
Simpson's diversity index	-	0.77 ± 0.04	5	0.75 ± 0.06	15	0.6	0.76	0.86
Evenness	-	*0.40* ± 0.09	5	0.36 ± 0.14	15	0.23	0.49	0.76
Bray-Curtis distance	-	0.68 ± 0.01	5	0.67 ± 0.09	15	0.45	0.62	0.81
Percent Chironomidae	%	73 ± 14		58 ± 20	15	47	71	91
Pisidiidae density	no./m^2	**210** ± 155	5	**223** ± 214	15	0	96	206
Procladius density	no./m^2	**289** ± 186	5	**255** ± 283	15	0	91	150
Heterotrissocladius density	no./m^2	*78* ± 31	5	38 ± 58	15	0	89	203
Micropsectra density	no./m^2	*60* ± 50	5	26 ± 34	15	0	91	172
Microtendipes density(b)	no./m^2	**89** ± 65	5	30 ± 67	15	0	5	47
Stictochironomus density(b)	no./m^2	**75** ± 112	5	**48** ± 83	15	0	17	14

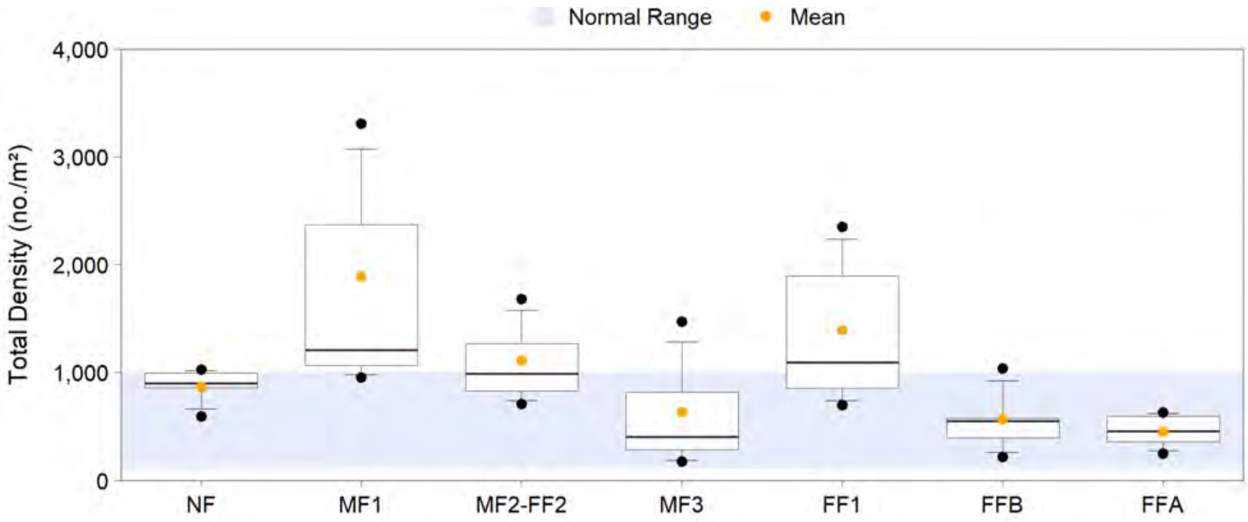
a) Normal ranges were obtained from the AEMP Reference Conditions Report Version 1.4 (Golder 2019a) except where noted. Some values were rounded to achieve consistent number of significant figures across table rows.

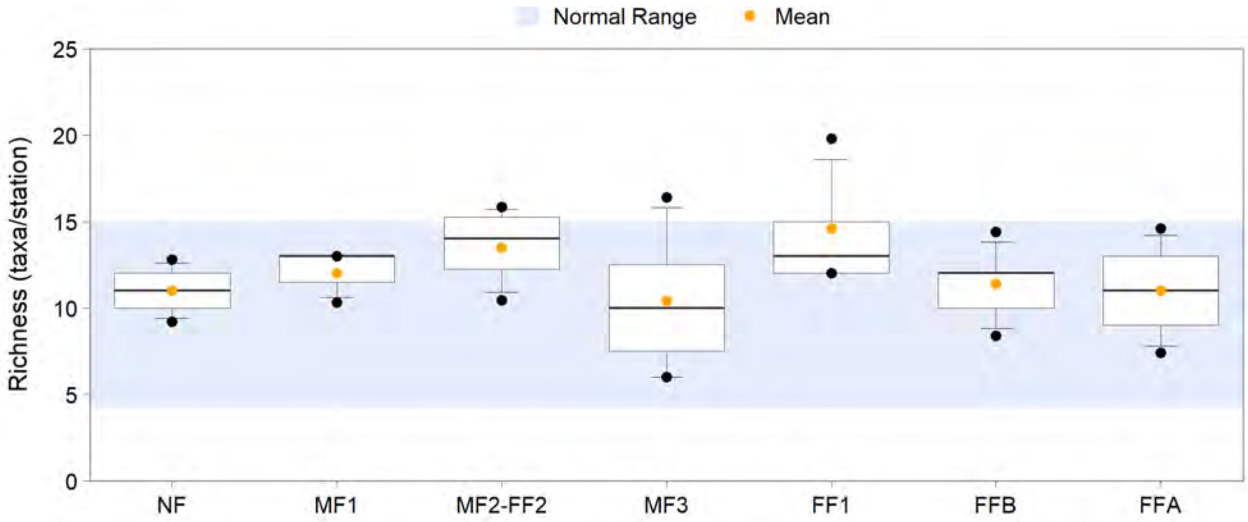
b) Normal range was calculated in 2019 according to the methods described in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

Note: **Bolding** identifies 2019 NF and FF area mean values above normal ranges. *Italicized* values are 2019 near-field area means that are lower than the Reference Condition mean, and therefore identify variables included in the Action Level evaluation (Dominance, Evenness, *Heterotrissocladius* density and *Micropsectra* density).

NF = near-field; FF = far-field; n = number of samples; SD = standard deviation; ± = plus or minus.

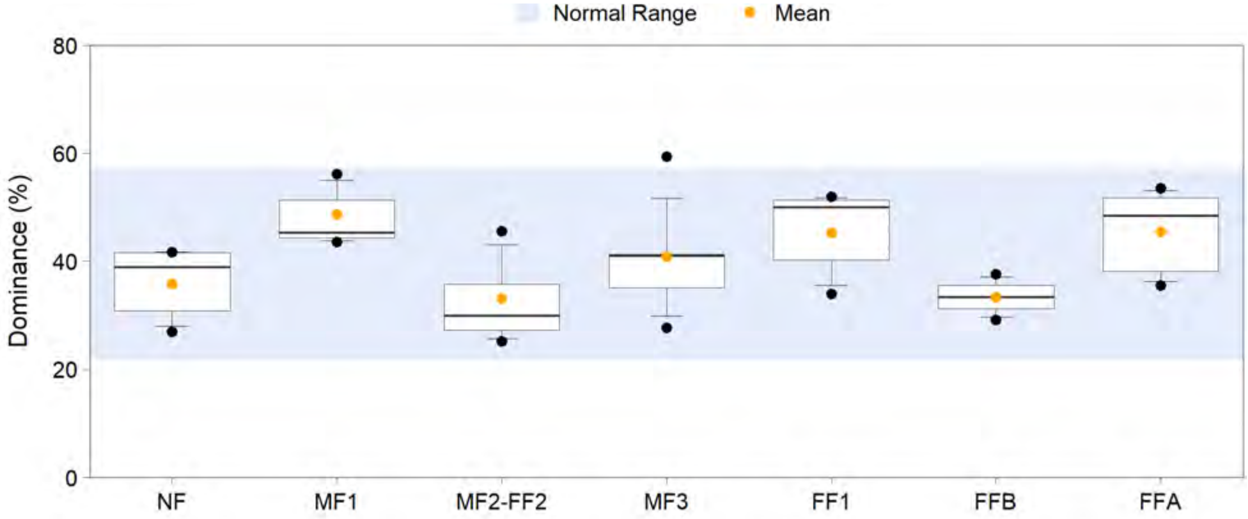
Figure 3-5 Total Invertebrate Density and Richness at Sampling Areas in Lac de Gras, 2019

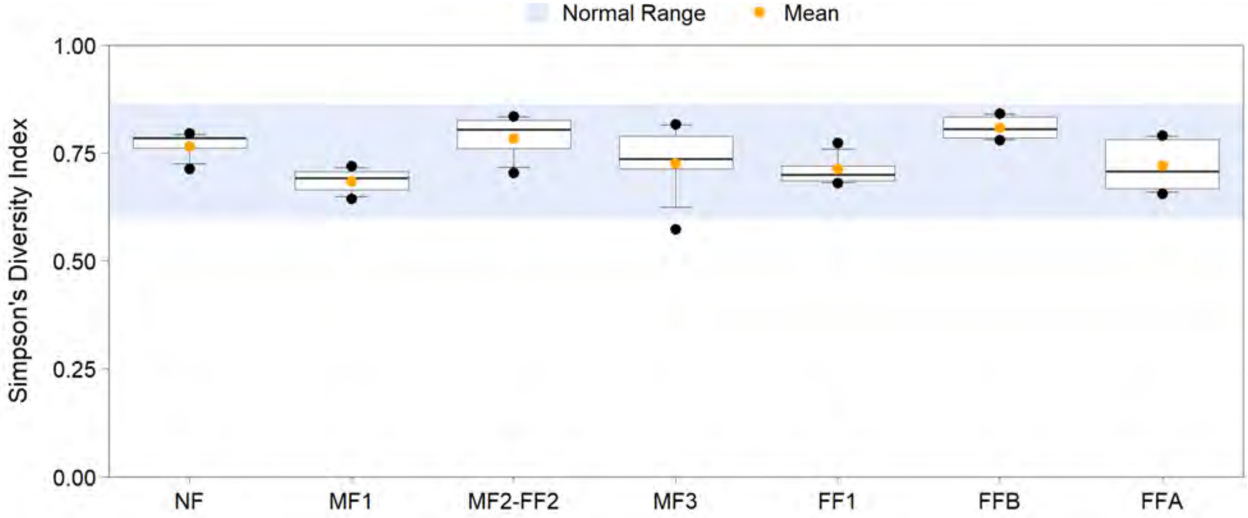




Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

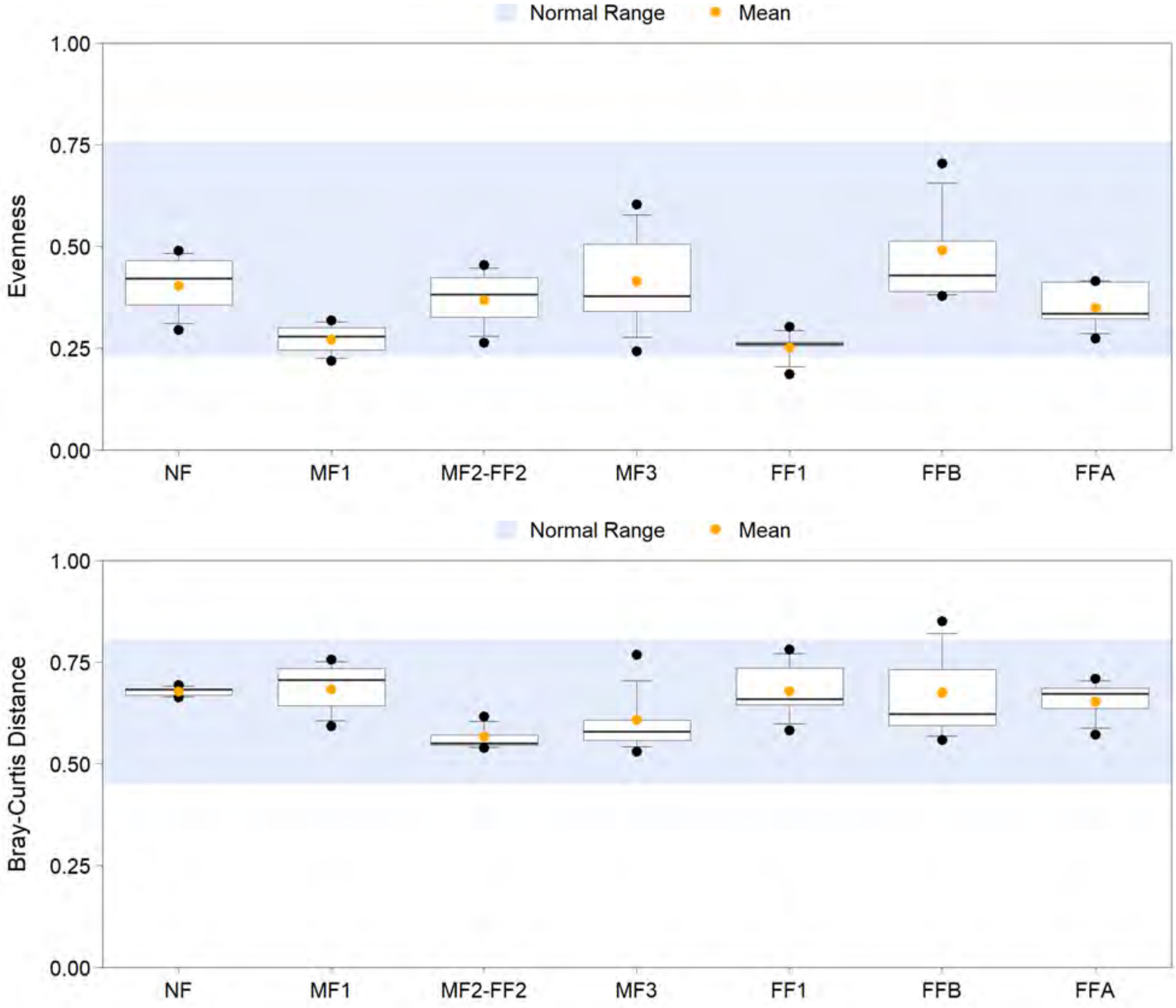
Figure 3-6 Dominance and Simpson's Diversity Index at Sampling Areas in Lac de Gras, 2019





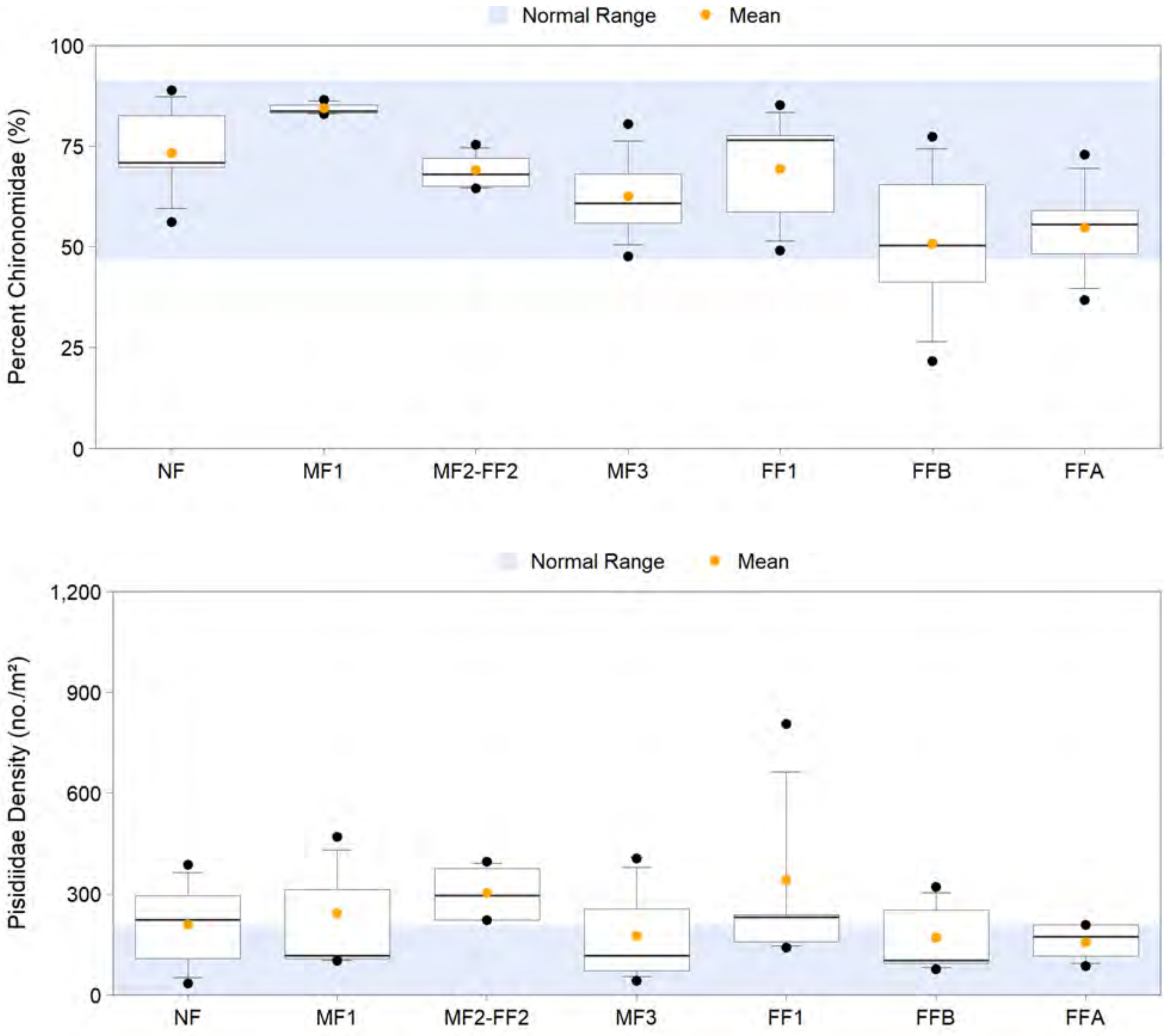
Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
NF = near-field; MF = mid-field; FF = far-field.

Figure 3-7 Evenness and Bray-Curtis Index at Sampling Areas in Lac de Gras, 2019



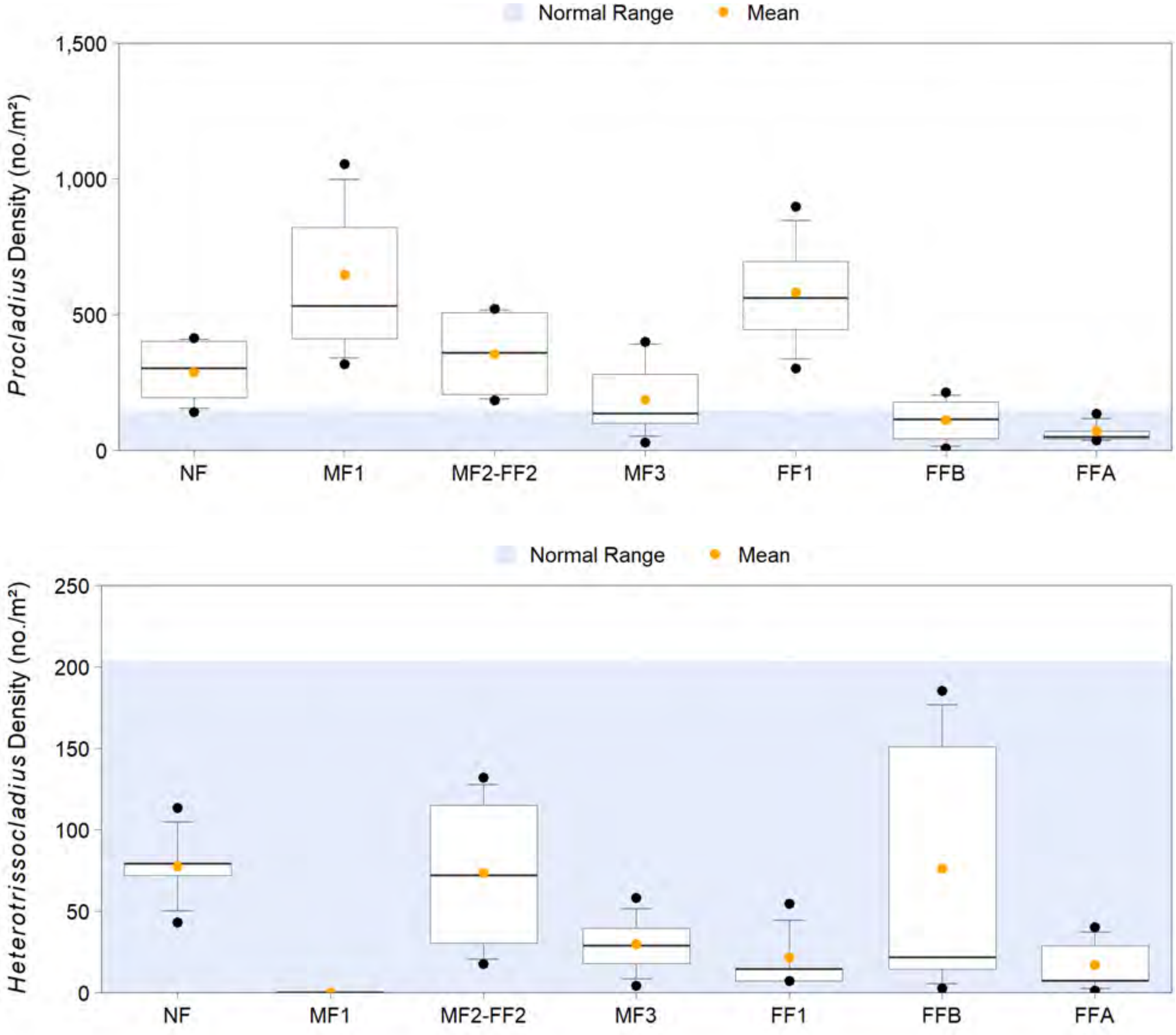
Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
NF = near-field; MF = mid-field; FF = far-field.

Figure 3-8 Percent Chironomidae and Density of Pisidiidae at Sampling Areas in Lac de Gras, 2019



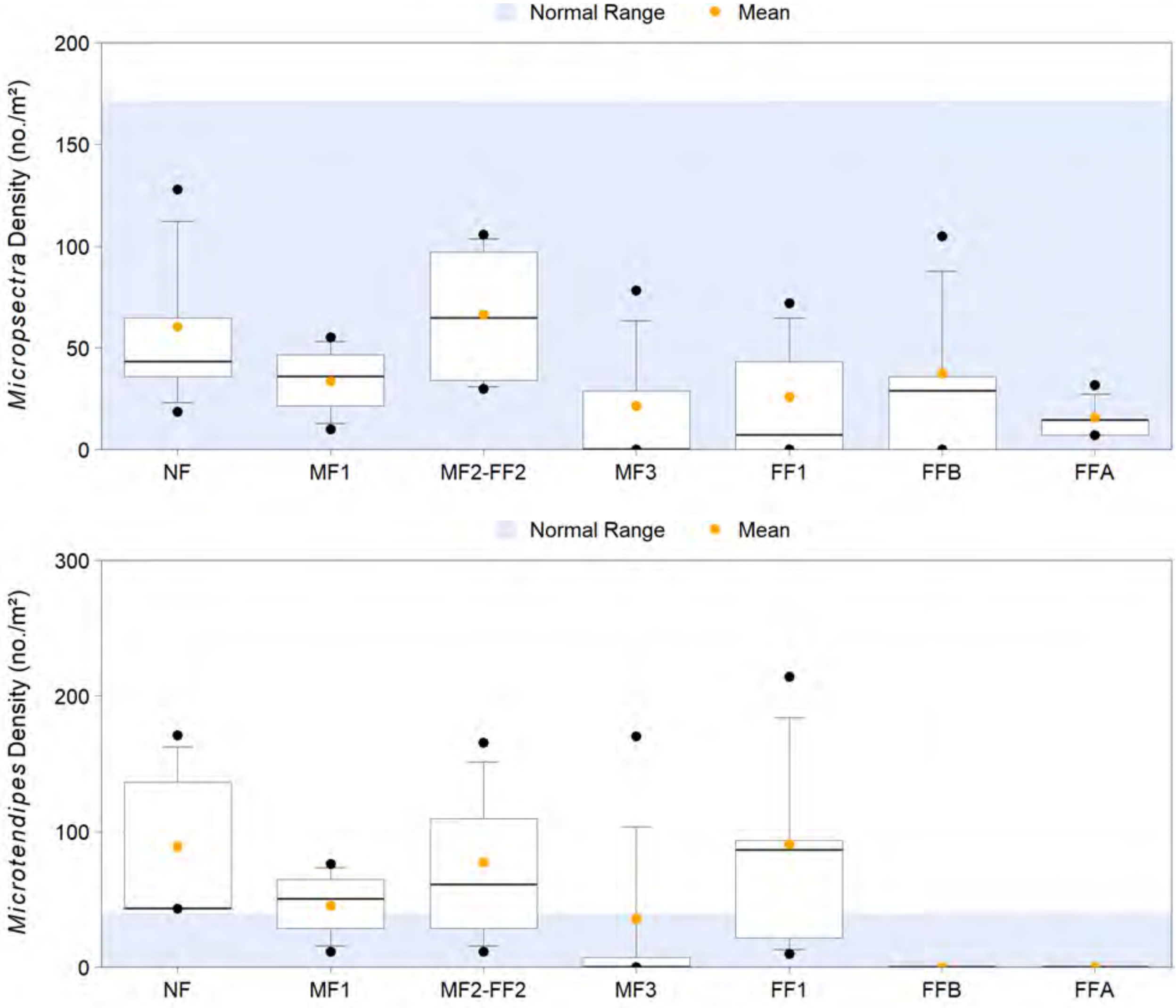
Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-9 Densities of *Procladius* and *Heterotrissocladius* at Sampling Areas in Lac de Gras, 2019



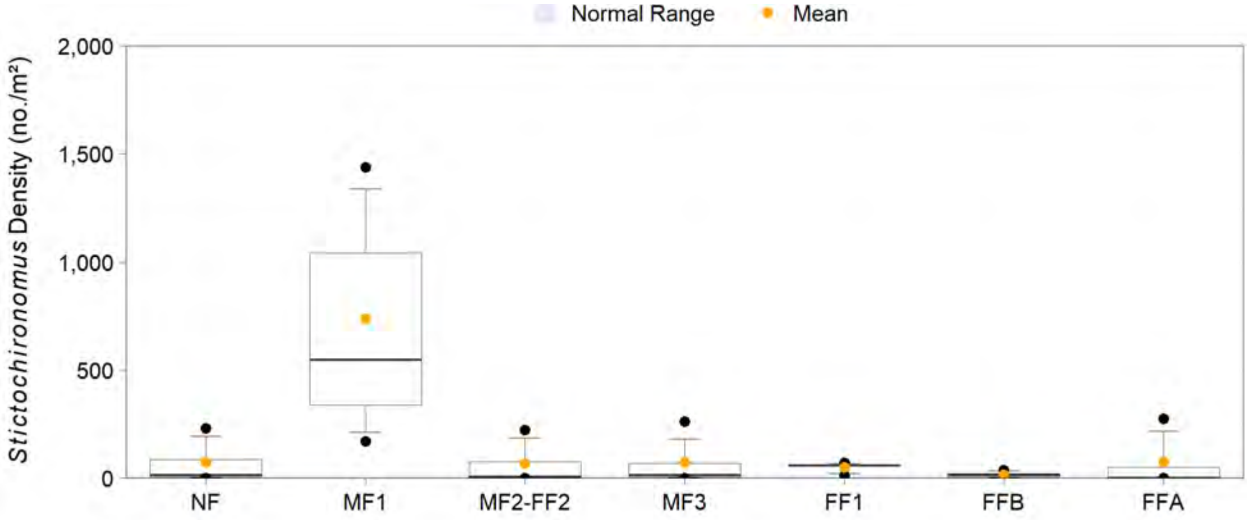
Note: Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-10 Density of *Micropsectra* 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 2019a). The normal range for *Microtendipes* density was calculated in 2019 according to the methods described by Golder (2019a).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

Figure 3-11 Density of *Stictochironomus* at Sampling Areas in Lac de Gras, 2019



Note: The normal range for *Stictochironomus* density was calculated in 2019 according to the methods described in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a), and falls very low on the x-axis, and, therefore, is visible only as a thin blue line.

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

3.6 Near-Field Versus Far-Field Area Comparisons and Comparison to Reference Condition

Two variables required transformation prior to testing (i.e., *Micropsectra* density and *Stictochironomus* density [both were log-transformed]). *Microtendipes* density did not meet parametric test assumptions, regardless of the transformations applied; therefore, non-parametric tests were used to investigate differences among the sampling areas in this variable. *Stictochironomus* density at MF1-1 (i.e.,1,537 organisms/m^2) was determined to be an anomalous value during the initial data screening and was also identified as an outlier during statistical analyses; statistical tests for *Stictochironomus* density were run without this station.

Overall significant differences were detected among sampling areas in six of the thirteen benthic invertebrate community variables in 2019 (Table 3-7); differences among areas were identified in total density, dominance, SDI, evenness, *Procladius* density and *Microtendipes* density. All six of these variables differed significantly among FF areas, and the NF area means fell in an intermediate position between the FF area means (Figures 3-5, 3-6, 3-7, 3-9 and 3-10). Therefore, further testing of effects was not required to evaluate significant differences relative to individual FF area means, because an effect would only occur if the NF mean was significantly higher or lower than the largest or smallest FF area mean, respectively. Overall, the results of statistical comparisons of the NF and FF areas do not provide evidence of Mine-related effects on the benthic invertebrate community. However, these tests did not provide information regarding potential spatial gradients in Lac de Gras, and would not detect an effect in the form of higher or lower mean values lake-wide, relative to reference conditions.

The 2019 NF area mean was also compared statistically to the reference condition dataset, to evaluate changes relative to biological conditions in Lac de Gras during the 2007 to 2010 reference period. This comparison focussed on decreases in means relative to the reference condition mean, to provide information for the Action Level assessment for the Toxicological Impairment Hypothesis. Variables with means below the reference condition mean were included in these comparisons, and the tests were run one-tailed to detect decreases relative to the reference condition mean. Based on results summarized in Table 3-6, these tests were run for dominance, evenness, *Heterotrissocladius* density, and *Micropsectra* density. No significant differences were detected for any of these variables between the 2019 NF area mean and the reference condition mean (Table 3-7).

Table 3-7 Results of Statistical Tests Comparing Sampling Areas in Lac de Gras, 2019

Variable	Statistical Test	Overall Comparison	NF vs. FF Area Comparison			FF Area Comparisons			NF vs. Reference Condition	
			NF vs FF1 + FFB + FFA			FF1 vs. FFA	FF1 vs FFB	FFA vs FFB	NF vs. 2007 to 2010[c,d]	
		P	***P***	**Area Used[a]**	**Magnitude (%)[b]**	***P***			***P***	**Magnitude (%)[b]**
Total density	ANOVA	**0.038**	nt	FF1	-38	**0.028**	**0.076**	ns	nt	64
			nt	FFA	90					
Richness	ANOVA	ns	-	-	-	-	-	-	nt	9
			-	-	-					
Dominance	ANOVA	**0.032**	nt	FFA	-21	ns	**0.059**	**0.053**	ns	-5
			nt	FFB	7					
Simpson's diversity index	ANOVA	**0.015**	nt	FFB	-5	ns	**0.013**	**0.021**	nt	1
			nt	FF1	7					
Evenness index	ANOVA	**0.006**	nt	FFB	-18	ns	**0.005**	ns	ns	-18
			nt	FF1	60					
Bray-Curtis index	ANOVA	ns	-	-	-	-	-	-	nt	10
			-	-	-					
Percent Chironomidae	ANOVA	ns	-	-	-	-	-	-	nt	3
			-	-	-					
Pisidiidae density	ANOVA	ns	-	-	-	-	-	-	nt	119
			-	-	-					
Procladius density	ANOVA	**<0.001**	nt	FF1	-50	**<0.001**	**<0.001**	ns	nt	218
			nt	FFA	310					
Heterotrissocladius density	ANOVA	ns	-	-	-	-	-	-	ns	-12
			-	-	-					
Micropsectra density	ANOVA$^{\text{Log}}$	ns	-	-	-	-	-	-	ns	-34
			-	-	-					
Microtendipes density	KW	**0.001**	nt	FF1	-2	**0.022**	**0.022**	nt	nt	1,680
			nt[e]	FFA/FFB[e]	-					
Stictochironomus density	ANOVA$^{\text{LOG}}$	ns	-	-	-	-	-	-	nt	341
			-	-	-					

a) The largest FF area mean (top cell) and smallest FF area mean (lower cell) are shown for variables that had significant overall comparison results.

b) Percent difference between sampling area means; i.e., NF mean compared to FF area mean, or NF mean compared to reference condition mean.

c) Reference condition data were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

d) NF mean vs reference condition mean was analyzed to evaluate Action Levels for the toxicological impairment hypothesis, only for variables with NF means below the reference condition mean (dominance, evenness, *Heterotrissocladius* density, and *Micropsectra* density).

e) NF mean vs smallest FF area mean was not tested, because *Microtendipes* was absent from both FFA and FFB areas in 2019.

Note: **Bolding** identifies statistically significant results ($P < 0.1$).

P = probability; NF = near-field; FF = far-field; ns = not significant; - = not applicable, because overall comparison was non-significant; nt = not tested; KW = Kruskal-Wallis test; ANOVA = analysis of variance (transformation is indicated by superscript).

3.7 Gradient Analysis

Statistically significant gradients were detected for eight of the thirteen benthic invertebrate variables assessed in 2019 (Table 3-8; Figures 3-12 to 3-18), including richness, evenness, percent Chironomidae, *Pisidiidae* density, *Procladius* density, *Heterotrissocladius* density, *Micropsectra* density and *Microtendipes* density.

Total density did not exhibit a significant gradient along any of the transects (Table 3-8), but tended to increase along the MF1 and MF2 transects with increasing distance from the diffusers (Figure 3-12), and tended to decrease along the MF3 transect. Although the normal range was not exceeded at most stations in the NF area, the mean approached the upper limit of the normal range.

The MF1 transect demonstrated a significant increasing trend in richness with distance from the diffusers (Table 3-8), and while the MF2 transect showed a similar increasing trend, it was not significantly different (Figure 3-12). For most transects, richness values largely remained within the normal range; all richness values in the NF and MF1 areas were within the normal range.

No significant gradients were detected in dominance, SDI or BCI during the 2019 gradient analysis. The majority of values for these benthic invertebrate community indices were within the normal range (Table 3-8; Figures 3-13 and 3-14).

A significant decreasing trend in evenness was observed along the MF1 transect with increasing distance from the diffuser (Table 3-8, Figure 3-14). With the exception of a single station from each of the MF1, MF3 and FF1 areas, evenness was within the normal range at all stations.

A significant increasing trend in Pisidiidae density was observed along the MF2 transect (Table 3-8), and numerous exceedances of the normal range were observed (Figure 3-15). The majority of exceedances occurred in the NF and MF2 areas.

With the exception of *Stictochironomus* density, significant gradients were observed in all Chironomidae variables (i.e., percent Chironomidae and density of each genus tested; Table 3-8; Figures 3-15 to 3-18). Percent Chironomidae declined along the MF3 transect, but nearly all stations within 20 km of the diffuser remained within the normal range. *Procladius*, *Microtendipes*, and *Stictochironomus* densities were above the normal range at a number of stations within 25 km of the diffuser. *Procladius*, *Heterotrissocladius*, and *Microtendipes* density exhibited significant decreasing trends with increasing distance from the diffuser along the MF3 transect. In contrast, *Micropsectra* density demonstrated the opposite trend along the MF2 transect.

Results of gradient analysis are consistent with low level Mine-related nutrient enrichment in Lac de Gras, as indicated by significant decreasing trends in a number of benthic invertebrate variables (mostly density variables) along the MF3 transect, which represents the longest effluent exposure gradient in Lac de Gras. Variables related to community structure (i.e., richness and community indices) showed fewer significant trends, consistent with a mild nutrient enrichment effect that results in increased densities of some invertebrates, without structural changes in the community.

Table 3-8 Gradient Analysis Results for Benthic Invertebrate Community Variables in Lac de Gras, 2019

Variable	Model	Box-Cox Transformation Power Value[a]	Gradient	Slope Direction[b]	Breakpoint (km)[c]	*P*-value	r^2 or R^2 [d]
Total density	Model 1	1	MF1	↑	-	0.677	0.30
		1	MF2	↑	-	0.133	0.30
		1	MF3	↓	-	0.063	0.30
Richness	Model 1	1	MF1	↑	-	**0.013**	0.15
		1	MF2	↑	-	0.202	0.15
		1	MF3	↑	-	0.987	0.15
Dominance	Model 1	-	MF1	↑	-	0.088	0.16
		-	MF2	↓	-	0.594	0.16
		-	MF3	↑	-	0.063	0.16
Simpson's diversity index	Model 1	-	MF1	↓	-	0.211	0.07
		-	MF2	↑	-	0.604	0.07
		-	MF3	↓	-	0.351	0.07
Evenness index	Model 1	-	MF1	↓	-	**0.004**	0.26
		-	MF2	↓	-	0.651	0.26
		-	MF3	↑	-	0.946	0.26
Bray-Curtis index	Model 1	-	MF1	↓	-	0.807	0.06
		-	MF2	↓	-	0.071	0.06
		-	MF3	↑	-	0.814	0.06
Percent Chironomidae	Model 1	-	MF1	↓	-	0.687	0.20
		-	MF2	↓	-	0.898	0.20
		-	MF3	↓	-	**0.011**	0.20
Pisidiidae density	Model 1	1	MF1	↑	-	0.469	0.13
		1	MF2	↑	-	**0.047**	0.13
		1	MF3	↑	-	0.941	0.13
Procladius density	Model 1	1	MF1	↑	-	0.211	0.55
		1	MF2	↑	-	0.461	0.55
		1	MF3	↓	-	**<0.001**	0.55
Heterotrissocladius density	Model 1	1	MF1	↓	-	0.242	0.21
		1	MF2	↓	-	0.504	0.21
		1	MF3	↓	-	**0.012**	0.21
Micropsectra density	Model 1	1	MF1	↓	-	0.051	0.35
		1	MF2	↑	-	**0.032**	0.35
		1	MF3	↓	-	0.467	0.35
Microtendipes Density	Model 3	1	MF1	↓	-	0.771	0.32
		1	MF2	↓	-	0.124	0.32
		1	MF3	↓	-	**0.005**	0.32
Stictochironomus Density	Model 1	1	MF1	↓	-	0.948	-0.02
		1	MF2	↑	-	0.778	-0.02
		1	MF3	↓	-	0.349	-0.02

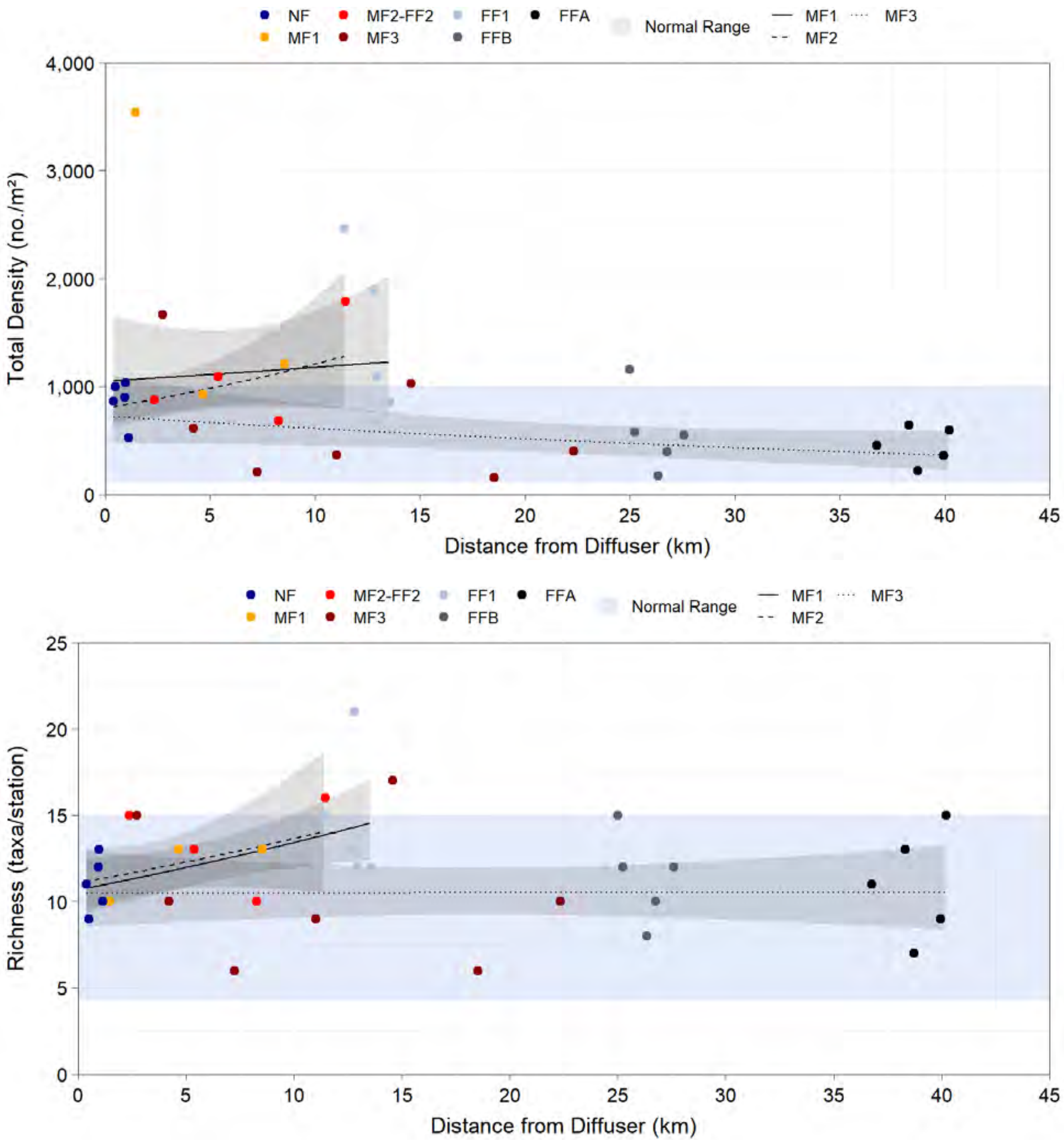
a) Models used and transformation rules are described in Section 2.3.6

b) A positive slope indicates and increasing trend with distance from the diffuser; a negative slope indicates a decreasing trend with distance from the diffuser.

c) The breakpoint is the location from the diffuser where the slopes of the linear regressions along the MF3 transect changed values.

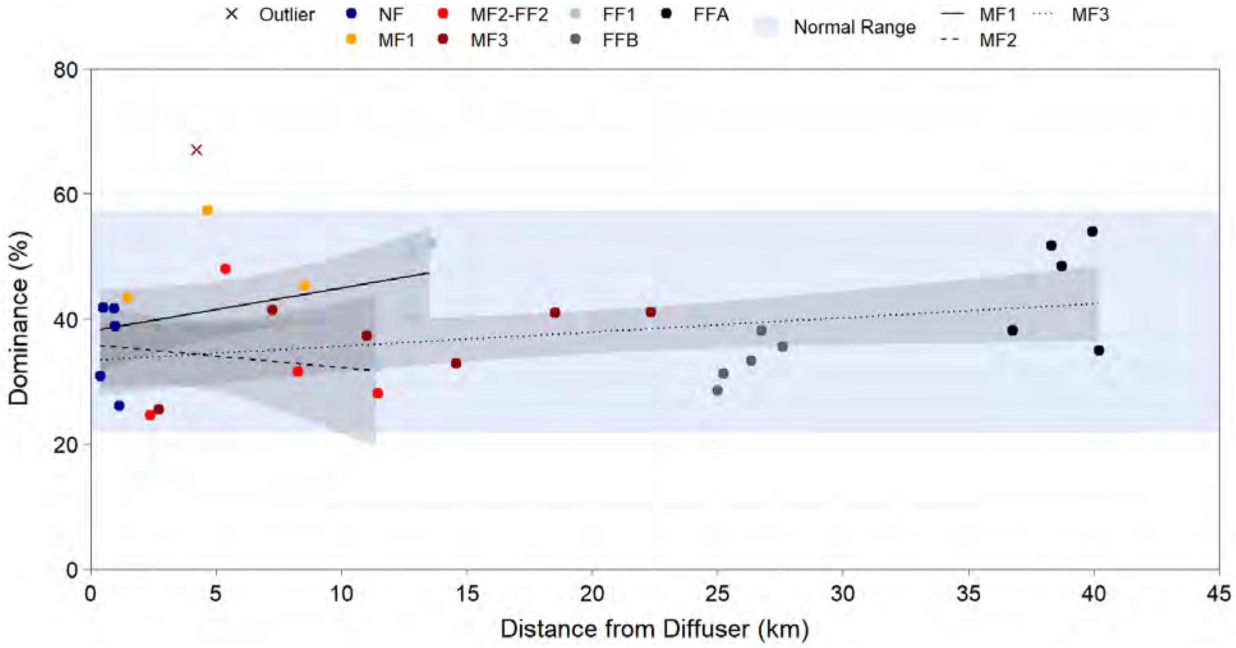
d) For the MF3 broken stick model, r2 is calculated because there is only one predictor, which is distance; for the other models R2, is used because there is more than one predictor, i.e., distance and gradient.
Notes: **Bold** indicates *P*-value significant at <0.05.
MF = mid-field; ↑ = increasing slope direction; ↓ = decreasing slope direction.

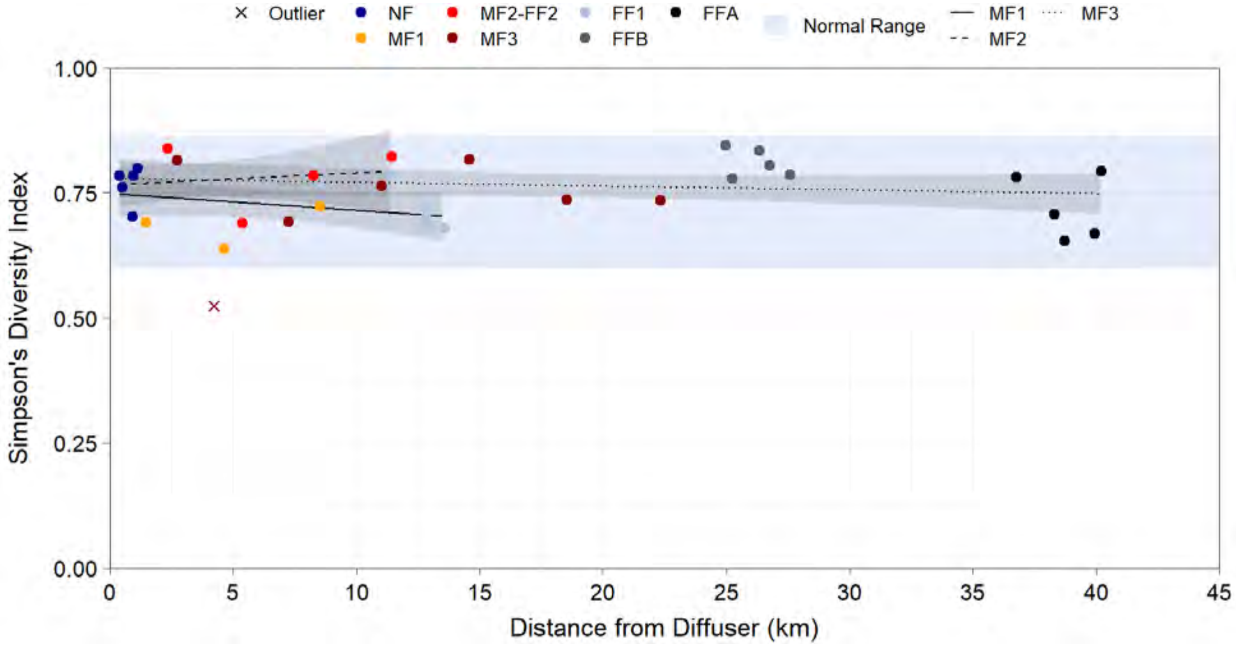
Figure 3-12 Total Invertebrate Density and Richness in Lac de Gras According to Distance from the Effluent Discharge, 2019.



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

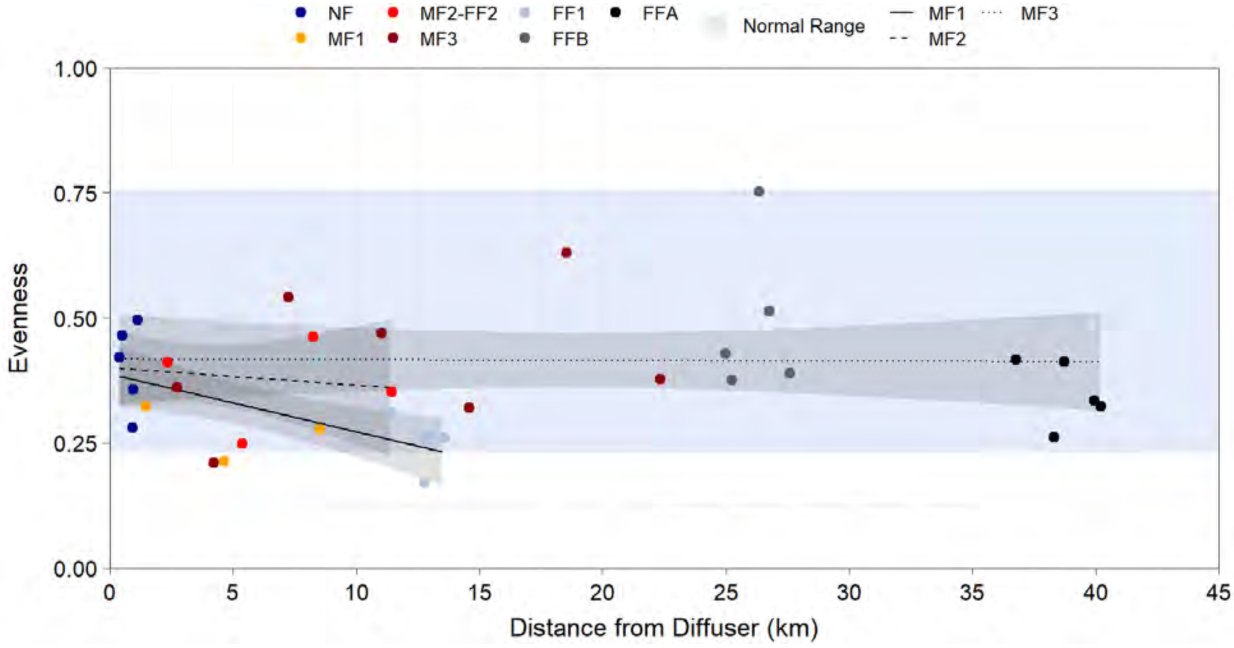
Figure 3-13 Dominance and Simpsons Diversity Index in Lac de Gras According to Distance from the Effluent Discharge, 2019.

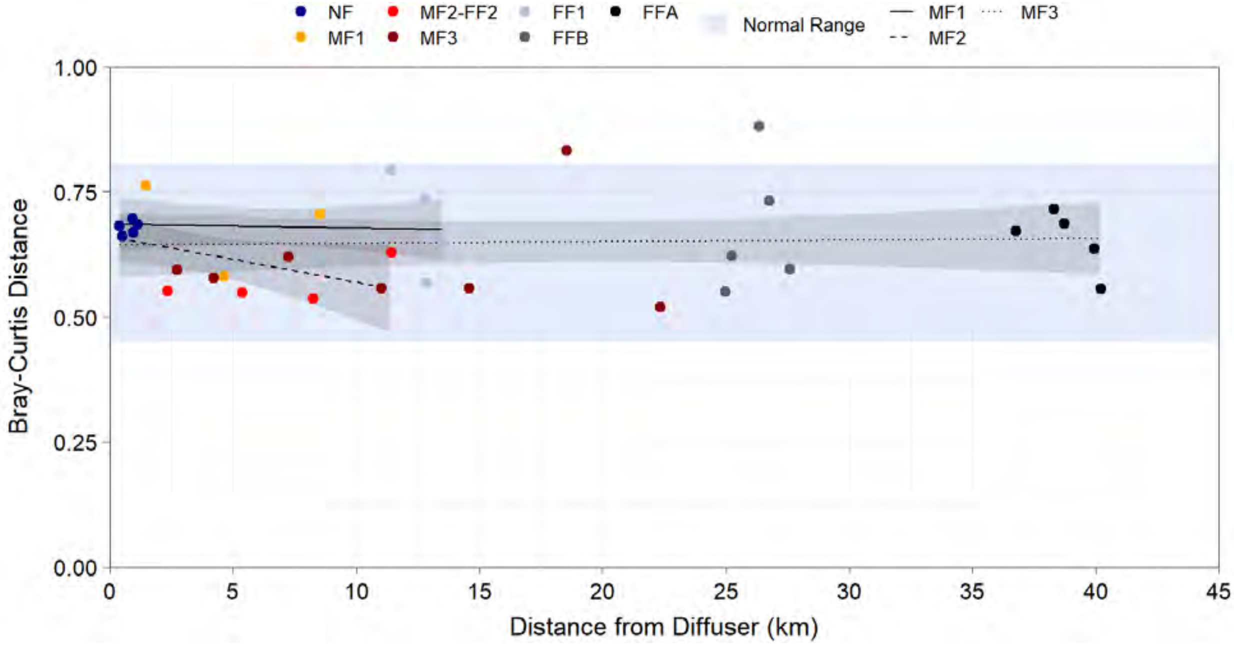




Note: Reference conditions were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
NF = near-field; MF = mid-field; FF = far-field.

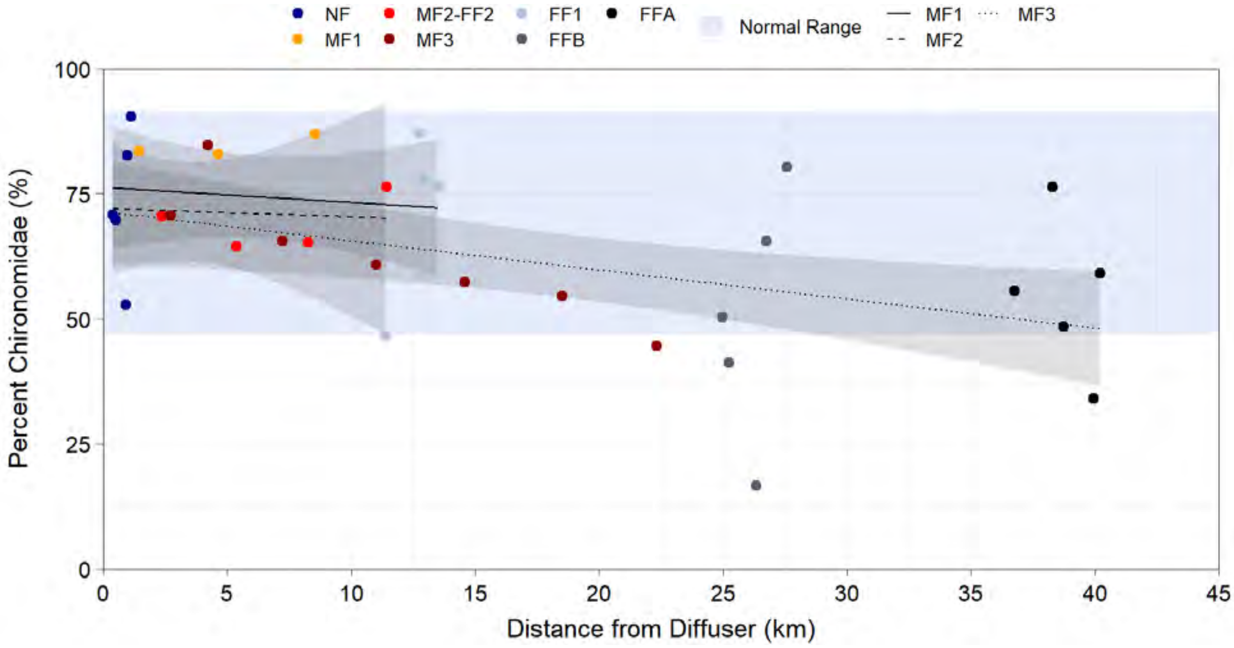
Figure 3-14 Evenness and Bray-Curtis Index in Lac de Gras According to Distance from the Effluent Discharge, 2019.

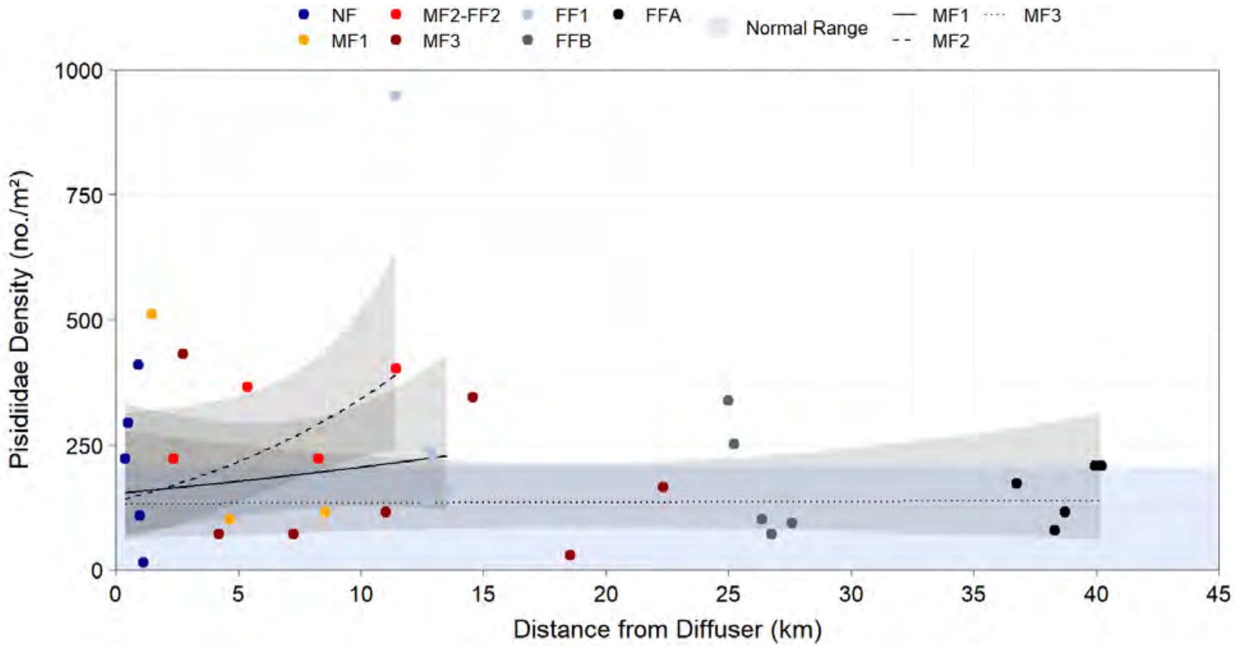




Note: Reference conditions were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
NF = near-field; MF = mid-field; FF = far-field.

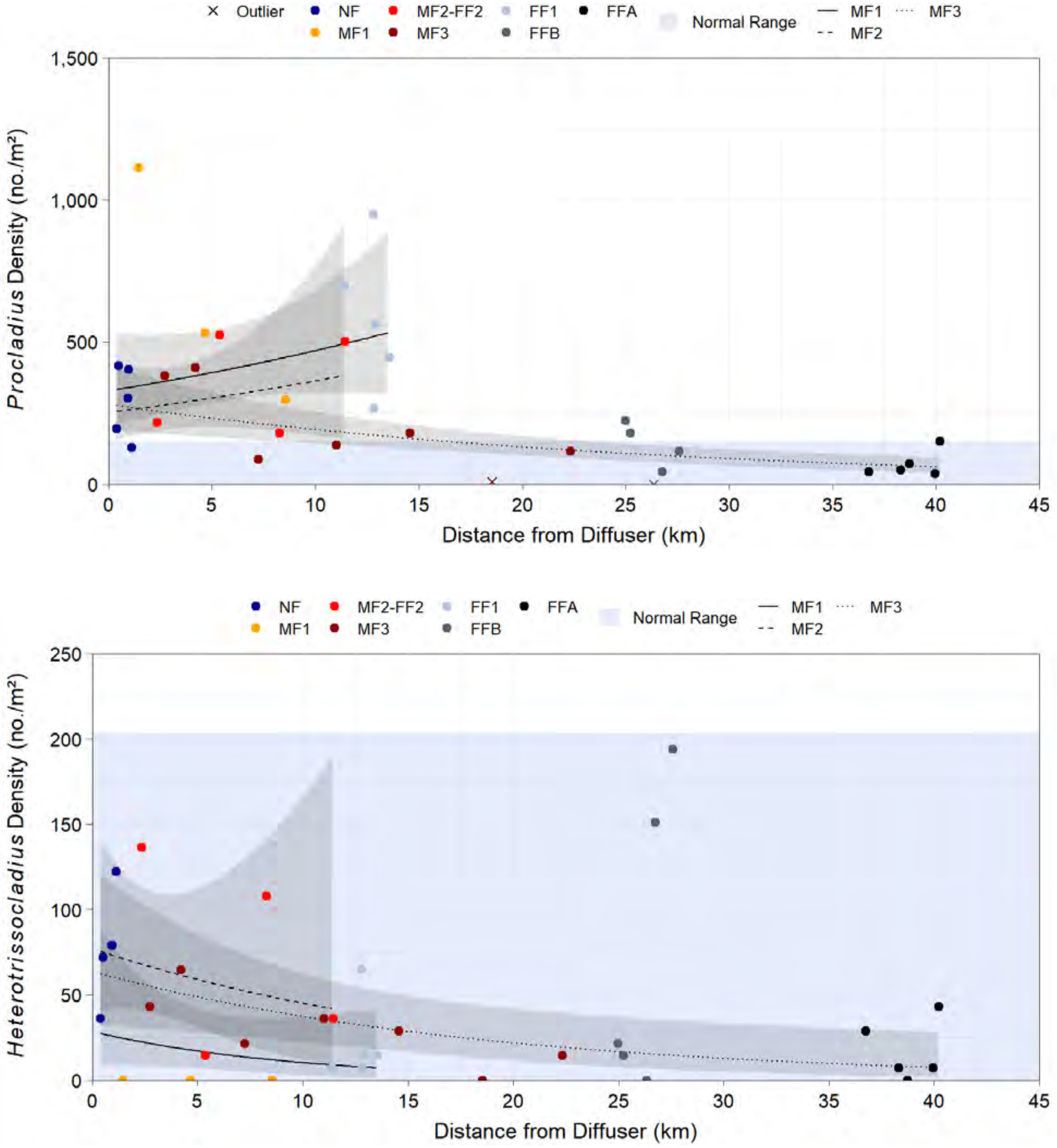
Figure 3-15 Percent Chironomidae and Pisidiidae Density in Lac de Gras According to Distance from the Effluent Discharge, 2019.





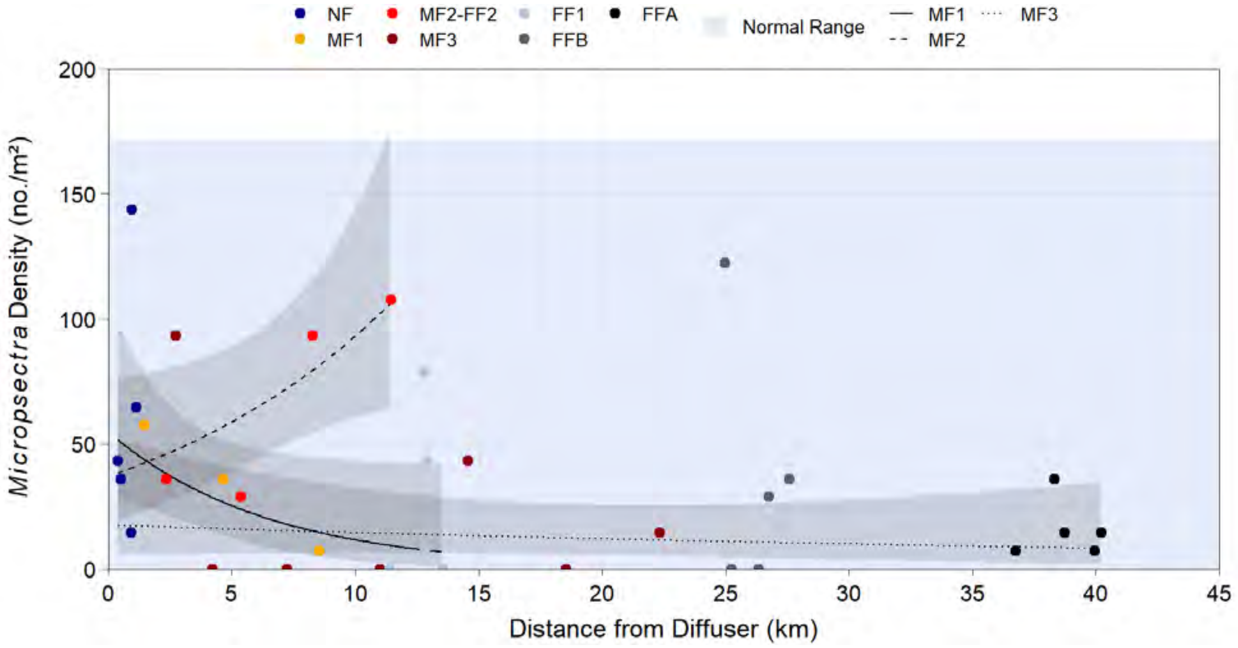
Note: Reference conditions were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

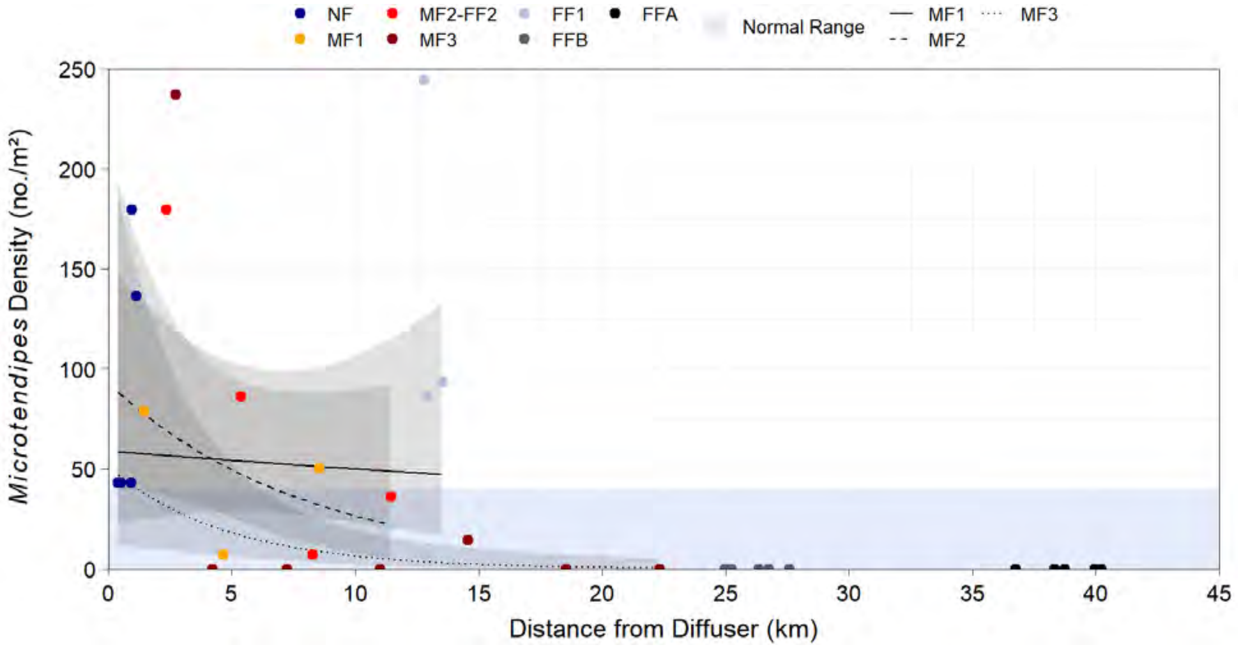
Figure 3-16 ***Procladius*** **Density and** ***Heterotrissocladius*** **Density in Lac de Gras According to Distance from the Effluent Discharge, 2019.**



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

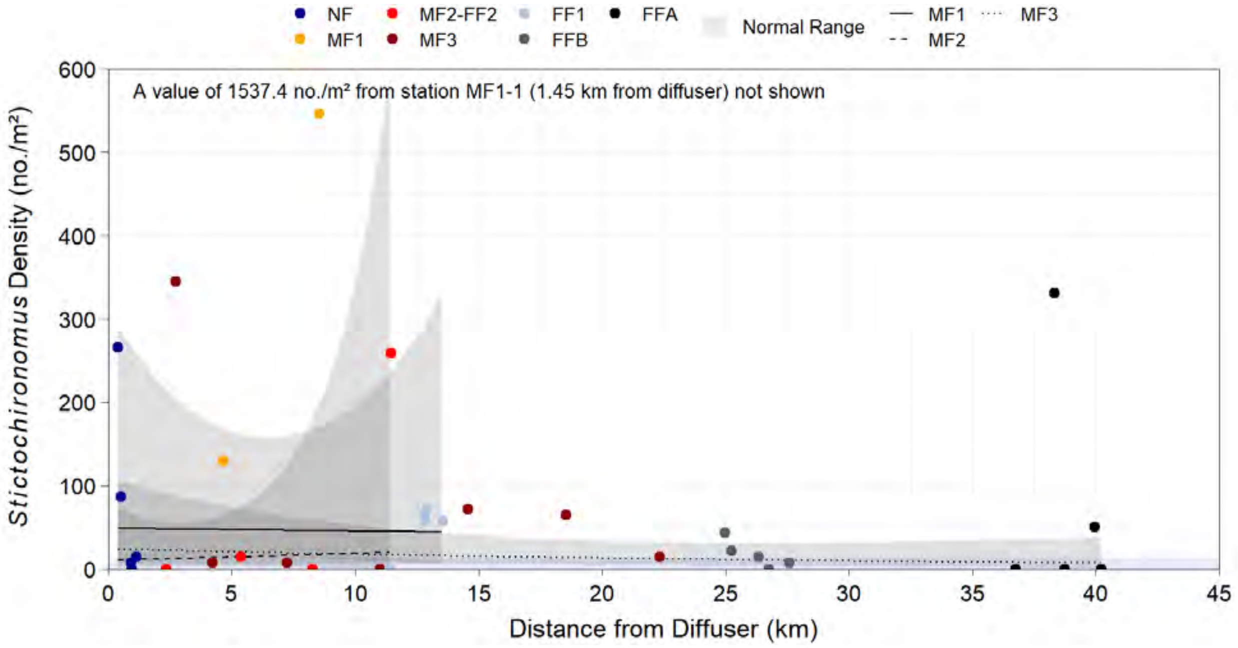
Figure 3-17 ***Micropsectra* Density and *Microtendipes* Density in Lac de Gras According to Distance from the Effluent Discharge, 2019.**





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

Figure 3-18 *Stictochironomus* Density in Lac de Gras According to Distance from the Effluent Discharge, 2019.



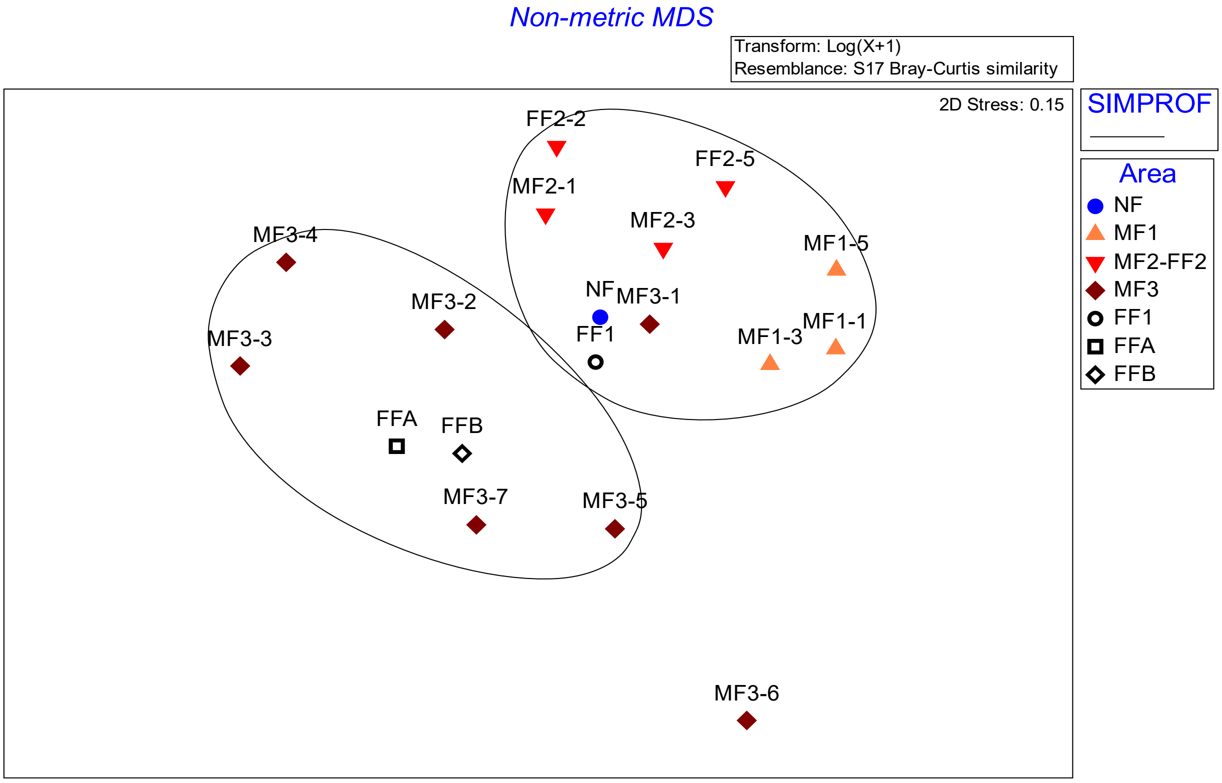
Note: Reference conditions were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
no./m² = number per square metre; NF = near-field; MF = mid-field; FF = far-field.

3.8 Multivariate Analysis

Ordination of the 2019 benthic invertebrate community data using nMDS produced a two-dimensional configuration with a stress value of 0.15, which indicates a good level of fit to the original dataset (Clarke 1993). The SIMPROF test (*P* <0.05) indicated meaningful clusters, and the global ANOSIM tests (R = 0.244, *P* = 0.001) indicated that statistical interpretation of the nMDS structure is valid. The ordination plot (Figure 3-19) shows good separation among the sampling areas, with the NF area and the closest MF areas (i.e., MF1 and MF2-FF2), as well as the FF1 area, clustering together. With the exception of the MF3-1 station (i.e., nearest to the effluent diffusers and the NF area) and the MF3-6 station (i.e., second farthest station in the MF3 transect from the effluent diffusers), the MF3 transect sampling stations generally clustered together with the FFA and FFB areas. Station MF3-6 was dissimilar from all other stations analyzed.

Overall, these results 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.

Figure 3-19 Non-metric Multidimensional Scaling of Benthic Invertebrate Density Data per Station for Lac de Gras, 2019



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

3.9 Action Level Evaluation

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[6]. 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.

3.10 Weight-of-Evidence Input

As described in Section 2.5, the results reported in the preceding sections also contribute to the WOE analysis presented in the Weight-of-Evidence Report (Appendix XV); the results of the WOE analysis relevant to benthic invertebrate community and related components are described in Section 3.1 of Appendix XV.

4 SUMMARY AND DISCUSSION

The 2019 AEMP benthic invertebrate community survey was completed between 15 August and 5 September 2019 in Lac de Gras, using methods consistent with the *AEMP Design Plan Version 4.1* (Golder 2017a) and *Quality Assurance Project Plan Version 3.1* (Golder 2017c). The benthic invertebrate community was sampled in the NF area, three FF areas and along three MF transects connecting the NF and FF areas.

As reported in the Sediment Quality Report (Appendix III), fine-grained sediment content was lower at some stations in the FFA and FFB areas compared to other areas. Correlation analyses indicated that percent fine sediment content of Lac de Gras was significantly correlated with some benthic invertebrate community variables. Relationships with percent fine sediments were in most cases weak and inconsistent among sampling areas. Although study results indicate that Mine-related changes in water quality are driving the overall spatial trends detected in the benthic invertebrate community in Lac de Gras, the physical characteristics of the sediments are also influencing biological communities, but do not appear to interfere with the ability to detect effects.

Mean densities of four common taxa (i.e., Pisidiidae, *Procladius*, *Microtendipes* and *Stictochironomus*) exceeded the normal range in the NF area, consistent with the Mine-related nutrient enrichment effect observed in effluent-exposed areas of Lac de Gras in previous tears. Mean Pisidiidae density was above the normal range in the NF, MF1, MF2-FF2 and FF1 areas. Mean *Procladius* and *Microtendipes* densities were above the upper limit of the normal range in the NF, MF1, MF2-FF2 and FF1 areas. Mean *Procladius* density was also above the upper limit of the normal range in the MF3 area. Mean *Stictochironomus* density was above the normal range in all areas sampled. All other variables had NF area means within the normal range, but mean total density was also above the normal range in the MF1, MF2 and FF1 areas.

Community composition at the major group level and percent Chironomidae showed gradual divergence from FFA and FFB area community structure with increasing effluent exposure, indicating a minor shift towards greater midge dominance. Overall significant differences among sampling areas were observed in total density, dominance, Simpson's diversity index, *Procladius* density and *Microtendipes* density. All of

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[6] This is inconsistent with observations reported in previous AEMP years, as summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1* (Golder 2019a). In 2016 an Action Level 1 was triggered for Pisidiidae density and evenness.

these variables were also significantly different among the three reference areas, which likely reflect differences in habitat features, such as the FF1 area being located closer to shore in a sheltered bay, whereas the FFA and FFB areas are located at mid-lake. In all cases where a significant difference was detected, the NF area mean was observed to fall in an intermediate position between the largest and smallest FF area means. These results did not provide clear evidence of Mine-related effects, but also did not provide information regarding potential spatial gradients in Lac de Gras, and would not detect an effect in the form of higher or lower mean values lake-wide, relative to reference conditions.

Statistically significant gradients were detected for eight of the thirteen benthic invertebrate variables assessed in 2019, including richness, evenness, percent Chironomidae, Pisidiidae density, *Procladius* density, *Heterotrissocladius* density, *Micropsectra* density and *Microtendipes* density. Results of gradient analysis are consistent with Mine-related nutrient enrichment in Lac de Gras, as indicated by mostly decreasing trends in benthic invertebrate variables (mostly density variables) along the MF3 transect, which represents the longest effluent exposure gradient in Lac de Gras. Variables related to community structure (i.e., richness and community indices) showed fewer significant trends, consistent with a low level nutrient enrichment effect that results in increased densities of some invertebrates, without structural changes in the community.

Multivariate analysis identified a distinct clustering of sampling areas, with the NF, MF1, MF2 and FF1 areas generally grouped together, and separated from the MF3 (excluding the most effluent-exposed station), FFA and FFB areas in terms of community structure. Overall, these results 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.

No Action Levels were triggered in 2019 for the benthic invertebrate community[7].

Overall, the 2019 benthic invertebrate community results are consistent with previously observed low level nutrient enrichment effect resulting from the Mine effluent discharge (Golder 2018a)[8], and with results of the Water Quality (Effluent and Water Chemistry Report [Appendix II]) and Eutrophication Indicators (Eutrophication Indicators Report [Appendix XIII]) components[8]. No changes in water quality were identified that would suggest toxicological impairment of aquatic life in Lac de Gras, and eutrophication indicators suggest that nutrient enrichment is occurring in Lac de Gras. The Sediment Quality Report (Appendix III) reported NF area median concentrations of total bismuth, total lead, total molybdenum, total strontium, and total uranium 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 Appendix III, concentrations of these metals are not anticipated to have detectable toxicological effects on the benthic invertebrate community.

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[7] This is inconsistent with observations reported in previous AEMP years, as summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1* (Golder 2019a). In 2016 an Action Level 1 was triggered for Pisidiidae density and evenness.

[8] This is consistent with observations reported in previous AEMP years, as summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1* (Golder 2019a).

5 RESPONSE FRAMEWORK

In 2019, the NF area mean values for the benthic invertebrate community variables were not significantly less than the reference condition mean, indicating that Action Level 1 was not triggered. The majority of benthic invertebrate variables had NF mean values that were greater than or equal to the 2007 to 2010 reference condition means, and all NF means were within or above the normal range.

6 CONCLUSIONS

This report presents the findings of the benthic invertebrate community survey completed during the 2019 comprehensive year AEMP field program. 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[9]. This conclusion is based on the following results:

- 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.
- 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.
- 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 mid-field (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; 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.
- 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.

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[9]. No Action Levels were triggered for the benthic invertebrate community based on the 2019 AEMP results[10].

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[9] This is consistent with observations reported in previous AEMP years, as summarized in the 2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1 (Golder 2019a).

[10] This is inconsistent with observations reported in previous AEMP years, as summarized in the 2014 to 2016 Aquatic Effects Re-evaluation Report Version1.1 (Golder 2019a). In 2016, an Action Level 1 was triggered for Pisidiidae density and evenness.

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8 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

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ATTACHMENT A

QUALITY ASSURANCE AND QUALITY CONTROL

Introduction

The quality assurance/quality control (QA/QC) program for the Diavik Diamond Mines 2012 Inc. (DDMI) Aquatic Effects Monitoring Program (AEMP) is described in the *Quality Assurance Project Plan* (QAPP) *Version 3.1* submitted to and approved by the Wek'èezhìı Land and Water Board (Golder 2017c). This attachment provides a summary of QA/QC information relevant to the 2019 AEMP benthic invertebrate survey.

Field and Laboratory Operations

Field operations during the 2019 benthic invertebrate program incorporated QA/QC functions required by the QAPP (Section 2.7 in Golder 2017c).

In the laboratory, benthic invertebrate samples were processed according to standard protocols consistent with those required for metal mining environmental effects monitoring (Environment Canada 2002). Benthic invertebrate sample processing included re-sorting 10% of the total number of samples collected to evaluate invertebrate removal efficiency, as well as preparation of a reference collection. Subsampling was not necessary in 2019 because all samples were small and entirely sorted. Therefore, subsampling quality control requirements described in the QAPP do not apply to the 2019 benthic invertebrate data set. The reference collection is maintained by the taxonomist (J. Zloty, Ph.D., Summerland, British Columbia) and is updated each year as new invertebrate taxa are identified from Lac de Gras.

Invertebrates were re-sorted in 4 of 34 samples collected during the 2019 field program. The data quality objective for benthic invertebrate sample sorting under the AEMP is a minimum sorting efficiency of 90%. If this level of sorting efficiency is not achieved, all samples must be re-sorted until such a level is attained. Invertebrate sorting efficiency ranged from 97.7% to 100% in re-sorted samples (Table A-1), which satisfies the data quality objective. Therefore, the quality of the 2019 benthic invertebrate data was considered acceptable.

Table A-1 Quality Control Data for Re-sorted Samples, 2019 AEMP

Sample	Total Missed	Total in Sample	Percent Missed	Sorting Efficiency (%)
NF4	1	118	0.8	99.2
MF1-5	2	141	1.4	98.6
MF3-5	0	47	0	100.0
FFB-2	2	86	2.3	97.7

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

Data Management and Analysis

Data were received from the taxonomist in electronic format (Excel spreadsheet) and were added to the project data management system. The raw data were reviewed upon receipt to identify any unusual invertebrate sample labels, or abundances identified as extreme values based on initial visual assessment of the raw abundance data. No unusual values were observed in the raw data file. However, anomalous data screening identified *Stictochironomus* density at MF1-1 (214 organisms per sample, or 1,537 organisms/m^2) as potentially anomalous data in the 2019 benthic invertebrate community dataset. This datapoint was verified with the taxonomist and was included in the data analysis.

During data analysis and manipulation, a backup worksheet was generated before each major operation to prevent loss of data and allow re-tracing of analysis steps. Accuracy of calculations was verified by running appropriate logic checks. Benthic invertebrate data and results of data analysis are stored in printed and electronic format with appropriate documentation, to allow the analysis to be reproduced, if necessary.

ATTACHMENT B

BENTHIC INVERTEBRATE DATA

Table B-1: Benthic Invertebrate Abundance (no./sample) Data for Ekman Grabs Collected in Lac de Gras as Part of the 2019 Aquatic Effects Monitoring Program, August and September 2019 (Part A)

Major Group	Family	Subfamily/Tribe	Genus/Species	NF					MF											
				NF					MF1			MF2		MF3						
				NF1	NF2	NF3	NF4	NF5	MF1-1	MF1-3	MF1-5	MF2-1	MF2-3	MF3-1	MF3-2	MF3-3	MF3-4	MF3-5	MF3-6	MF3-7
Hydrozoa	Hydridae	-	*Hydra*	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Microturbellaria (i/d)	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Nematoda	-	-	-	4	6	5	3	8	4	1	2	10	6	3	2	0	2	2	2	1
Oligochaeta	Lumbriculidae	-	-	2	0	1	1	2	1	4	1	3	2	2	1	0	0	5	1	1
	Naididae	Tubificinae	-	1	1	0	3	2	8	0	0	1	0	4	1	0	0	5	5	5
Gastropoda	Valvatidae	-	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Pelecypoda	Pisidiidae	-	(i/d)	1	14	4	2	3	2	2	3	2	7	0	0	0	1	0	4	0
		-	*Sphaerium*	0	0	1	0	1	69	12	5	20	40	59	10	10	14	47	0	23
		-	*Pisidium*	30	27	52	0	11	0	0	8	9	4	1	0	0	1	1	0	0
Hydracarina	-	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hygrobatidae	-	*Hygrobates*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Lebertiidae	-	*Lebertia*	0	0	0	1	4	0	1	3	0	0	1	1	0	4	1	0	0
	Oxidae	-	*Oxus*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Pionidae	-	*Piona*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Unionicolidae	-	*Unionicola*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notostraca	Triopsidae	-	*Lepidurus*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cladocera	Bosminidae	-	*Bosmina*	1	0	0	2	2	16	2	1	2	0	3	5	0	0	0	0	0
	Chydoridae	-	*Eurycercus*	0	0	0	0	0	1	0	1	2	0	2	0	1	1	8	1	1
	Daphniidae	-	*Daphnia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Holopediidae	-	*Holopedium gibberum*	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Copepoda - Calanoida	-	-	-	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Copepoda - Cyclopoida	Cyclopidae	-	-	3	1	1	0	2	20	5	2	2	1	6	3	0	3	1	0	1
Copepoda – Poecilostomatoida	Ergasilidae	-	*Ergasilus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda – Harpacticoida	-	-	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ostracoda	-	-	-	1	0	1	0	0	0	3	1	0	0	1	0	0	0	0	0	0
Plecoptera	Capniidae	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Apataniidae	-	*Apatania*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	-	(pupa)	5	0	0	0	5	0	1	3	4	4	0	1	0	0	1	0	0
		Tanypodinae	(i/d)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
			Ablabesmyia	0	0	0	0	0	0	0	4	0	1	0	0	0	0	2	0	0
			Thienemannimyia group	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
			Procladius	27	58	42	18	56	155	74	41	30	73	53	57	12	19	25	1	16
		Chironomini	*Dicrotendipes*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Microtendipes	6	6	6	19	25	11	1	7	25	12	33	0	0	0	2	0	0
			Sergentia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Stictochironomus	37	12	1	2	0	**214**	18	76	0	2	48	1	1	0	10	9	2

Table B-1: Benthic Invertebrate Abundance (no./sample) Data for Ekman Grabs Collected in Lac de Gras as Part of the 2019 Aquatic Effects Monitoring Program, August and September 2019 (Part A) (continued)

Major Group	Family	Subfamily/Tribe	Genus/Species	NF					MF											
				NF					MF1			MF2		MF3						
				NF1	NF2	NF3	NF4	NF5	MF1-1	MF1-3	MF1-5	MF2-1	MF2-3	MF3-1	MF3-2	MF3-3	MF3-4	MF3-5	MF3-6	MF3-7
Diptera (continued)	Chironomidae (continued)	Tanytarsini	*Corynocera*	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
			Micropsectra	6	5	2	9	20	8	5	1	5	3	13	0	0	0	6	0	2
			Micropsectra / Tanytarsus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
			Paratanytarsus	0	0	1	0	0	0	1	0	1	1	3	0	1	3	5	0	1
			Stempellinella	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
			Tanytarsus	3	3	2	0	5	8	3	13	2	3	4	1	0	2	0	2	0
		Orthocladiinae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Abiskomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	26	0	2
			Cricotopus / Orthocladius	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
			Heterotrissocladius	5	10	11	17	11	0	0	0	19	2	6	9	3	5	4	0	2
			Paracladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Parakiefferiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Psectrocladius	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
			Zalutschia	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
		Diamesinae	*Potthastia longimanus* group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Protanypus	0	0	0	1	0	0	0	0	1	0	2	1	2	1	0	0	0
		Prodiamesinae	*Monodiamesa*	1	3	0	0	0	16	2	4	1	0	1	3	0	0	0	0	0
	Empididae	-	*Chelifera / Metachela*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terrestrial	-	-	-	0	0	0	0	1	0	0	0	2	0	0	4	1	0	0	0	3
Total				**133**	**146**	**132**	**78**	**162**	**534**	**138**	**179**	**144**	**164**	**246**	**102**	**31**	**57**	**155**	**25**	**62**

a) Samples were collected using a standard Ekman grab with a bottom sampling area of 0.023 m². Each sample is a composite of six Ekman grabs.

Note: **Bold** and highlighted value was identified as an anomalous value during data screening.

NF = near-field; MF = mid-field; FF = far-field; - = not applicable; i/d = immature or damaged specimen identified to the lowest taxonomic level possible.

Table B-1: Benthic Invertebrate Abundance (no./sample) Data for Ekman Grabs Collected in Lac de Gras as Part of the 2019 Aquatic Effects Monitoring Program, August and September 2019 (Part B)

Major Group	Family	Subfamily/Tribe	Genus/Species	FF																
				FF2		FF1					FFA					FFB				
				FF2-2	FF2-5	FF1-1	FF1-2	FF1-3	FF1-4	FF1-5	FFA-1	FFA-2	FFA-3	FFA-4	FFA-5	FFB-1	FFB-2	FFB-3	FFB-4	FFB-5
Hydrozoa	Hydridae	-	*Hydra*	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0
Microturbellaria (i/d)	-	-	-	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0
Nematoda	-	-	-	4	1	11	2	15	5	5	10	2	4	3	2	0	11	6	8	22
Oligochaeta	Lumbriculidae	-	-	1	1	3	1	8	2	1	1	5	0	2	0	3	9	1	1	2
	Naididae	Tubificinae	-	0	0	1	0	1	4	2	0	5	0	0	4	2	20	6	0	0
Gastropoda	Valvatidae	-	*Valvata sincera*	0	0	0	1	0	12	1	0	0	0	0	0	0	4	4	0	1
Pelecypoda	Pisidiidae	-	(i/d)	1	2	1	1	0	21	0	0	0	0	0	0	4	1	0	0	3
		-	*Sphaerium*	30	53	21	31	19	111	33	24	7	15	29	27	2	46	10	13	5
		-	*Pisidium*	0	1	0	0	0	0	0	0	4	1	0	2	8	0	25	0	2
Hydracarina	-	-	(i/d)	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0
	Hygrobatidae	-	*Hygrobates*	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lebertiidae	-	*Lebertia*	0	0	1	0	1	4	0	0	0	0	0	0	0	0	1	1	6
	Oxidae	-	*Oxus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pionidae	-	*Piona*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Unionicolidae	-	*Unionicola*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Notostraca	Triopsidae	-	*Lepidurus*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera	Bosminidae	-	*Bosmina*	3	6	1	0	1	4	0	0	0	0	0	0	0	0	0	0	0
	Chydoridae	-	*Eurycercus*	0	1	0	0	6	1	8	1	7	0	0	5	2	1	7	3	0
	Daphniidae	-	*Daphnia*	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
	Holopediidae	-	*Holopedium gibberum*	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0
Copepoda - Calanoida	-	-	-	0	0	1	3	0	16	0	0	1	1	0	0	0	0	1	0	0
Copepoda - Cyclopoida	Cyclopidae	-	-	2	6	0	0	15	0	4	0	1	0	0	2	0	2	1	0	2
Copepoda – Poecilostomatoida	Ergasilidae	-	*Ergasilus*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda – Harpacticoida	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	-	-	-	0	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0
Plecoptera	Capniidae	-	-	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Trichoptera	Apataniidae	-	*Apatania*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	-	(pupa)	1	0	7	4	9	5	5	0	0	0	1	1	0	13	2	4	6
		Tanypodinae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Ablabesmyia	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
			Thienemannimyia group	0	0	0	0	2	0	0	1	0	0	1	0	0	2	0	0	0
			Procladius	25	70	62	78	132	97	37	6	7	10	21	5	0	31	25	16	6
		Chironomini	*Dicrotendipes*	0	0	0	1	3	0	1	0	0	0	0	0	0	0	0	0	0
			Microtendipes	1	5	13	12	34	3	1	0	0	0	0	0	0	0	0	0	0
			Sergentia	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
			Stictochironomus	0	36	8	10	9	0	8	0	46	0	0	7	2	6	3	1	0

Table B-1: Benthic Invertebrate Abundance (no./sample) Data for Ekman Grabs Collected in Lac de Gras as Part of the 2019 Aquatic Effects Monitoring Program, August and September 2019 (Part B) (continued)

Major Group	Family	Subfamily/Tribe	Genus/Species	FF																
				FF2		FF1					FFA					FFB				
				FF2-2	FF2-5	FF1-1	FF1-2	FF1-3	FF1-4	FF1-5	FFA-1	FFA-2	FFA-3	FFA-4	FFA-5	FFB-1	FFB-2	FFB-3	FFB-4	FFB-5
Diptera (continued)	Chironomidae (continued)	Tanytarsini	*Corynocera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Micropsectra	13	14	0	6	11	0	1	1	4	2	2	1	0	17	0	5	4
			Micropsectra / Tanytarsus	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
			Paratanytarsus	1	0	2	2	10	44	0	12	4	1	8	0	0	8	1	7	4
			Stempellinella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Tanytarsus	5	19	2	4	9	4	4	0	1	0	1	0	0	0	1	1	0
		Orthocladiinae	(i/d)	0	0	0	1	1	0	0	0	0	0	0	0	0	3	0	0	0
			Abiskomyia	0	0	0	0	0	0	0	0	3	1	0	0	0	7	0	1	0
			Cricotopus / Orthocladius	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
			Heterotrissocladius	15	5	2	2	9	1	1	4	1	0	6	1	0	3	2	27	21
			Paracladius	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
			Parakiefferiella	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0
			Psectrocladius	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
			Zalutschia	2	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
		Diamesinae	*Potthastia longimanus* group	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
			Protanypus	0	37	0	0	5	6	1	9	1	1	4	2	0	1	1	2	0
		Prodiamesinae	*Monodiamesa*	0	1	0	2	2	1	0	0	0	0	2	1	1	1	0	1	1
	Empididae	-	*Chelifera / Metachela*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Terrestrial	-	-	-	4	0	0	0	0	1	3	0	1	0	0	0	0	0	0	1	0
Total				**109**	**264**	**139**	**162**	**313**	**375**	**117**	**74**	**101**	**36**	**87**	**60**	**28**	**188**	**98**	**92**	**85**

a) Samples were collected using a standard Ekman grab with a bottom sampling area of 0.023 m². Each sample is a composite of six Ekman grabs.

Note: **Bold** and highlighted value was identified as an anomalous value during data screening.

NF = near-field; MF = mid-field; FF = far-field; - = not applicable; i/d = immature or damaged specimen identified to the lowest taxonomic level possible.

APPENDIX V

FISH REPORT

FISH REPORT
IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

Diavik Diamond Mines (2012) Inc.
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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-1918 Ver. 0
PO No. 3103966486

Executive Summary

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2015L2-0001, according to the *AEMP Design Plan Version 4.1* approved by the Wek'èezhìı Land and Water Board (WLWB). This report presents the analysis of small-bodied fish data collected during the 2019 field program according to the *AEMP Design Plan Version 4.1.* The objective of the small-bodied fish program was to evaluate the potential effects of the discharge of Mine effluent on the health of the Slimy Sculpin fish population in Lac de Gras.

Slimy Sculpin samples were collected from five areas in Lac de Gras from 28 August to 16 September 2019. Fish were processed, analyzed and data were interpreted for both fish health and fish tissue chemistry endpoints, as per the *AEMP Design Plan Version 4.1.* Slimy Sculpin exhibited similar reproductive success and prevalence of internal and external abnormalities among sampling areas. The prevalence of parasites (i.e., tapeworms) varied among areas but was not associated with proximity to the Mine. Relative to the far-field (FF) areas, significant differences were observed in the near-field (NF) area for male gonad weight and female total length, total weight and relative liver weight. Relative to reference conditions, significant differences were observed in the NF area for age-1+ total length, total weight, carcass weight, condition, relative liver weight, as well as male and female gonad weight. Differences in fish health endpoints were not consistent between the FF area and reference condition comparisons, with the exception of male gonad weight. This suggests a temporal interaction, where fish health endpoints in the FF area in 2019 appear to differ relative to reference conditions. Male fish in the NF area had larger gonads relative to the FF areas and reference conditions, suggesting greater male reproductive investment in the NF area.

Slimy Sculpin from the NF area had significantly greater concentrations of lead, molybdenum, silver, strontium, uranium, and vanadium relative to the FF areas. Molybdenum concentrations in fish tissue in the NF increased by a magnitude of 34% since 2013 and 24% since 2016, while tissue concentrations of lead, silver, strontium, uranium, and vanadium have remained relatively stable over time. Considering the marginal increase in molybdenum and relatively stable concentrations of lead, silver, strontium, uranium, and vanadium at NF over time, it is unlikely the response patterns in fish health were directly linked to concentrations of these metals in fish tissue.

The differences observed in length, weight and relative liver size of age-1+ fish between the NF and mid-field (MF) areas compared to reference conditions may be indicative of a toxicological response as defined under the Action Level assessment and triggered the Action Level 2 for fish health. Action Level 2 was previously triggered during the 2016 AEMP based on differences observed in Slimy Sculpin length, weight and relative liver size, which were further described in the *2014 to 2016 AEMP Response Plan Fish*. Factors contributing to these differences were evaluated in the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report*, 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. It is not anticipated that an additional Response Plan for the same Action Level 2 trigger will be required at this time. The direction and magnitude of effects on fish health were comparable to those reported in the 2016 AEMP.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
ALS	ALS Canada Ltd.
AICc	Akaike’s Information Criterion corrected
ANOVA	analysis of variance
ANCOVA	analysis of covariance
BC	British Columbia
CALA	Canadian Association for Laboratory Accreditation Inc.
CPUE	catch-per-unit-effort
DDMI	Diavik Diamond Mines (2012) Inc.
DL	detection limit
FF	far-field
Golder	Golder Associates Ltd.
GSI	gonadosomatic index
K	condition factor
KS	Kolmogorov-Smirnov
LSI	liversomatic index
MF	mid-field
Mine	Diavik Diamond Mine
NAD	North American Datum
NF	near-field
P	probability
PVC	polyvinylchloride
QA	quality assurance
QC	quality control
QA/QC	quality assurance/quality control
RPD	relative percent difference
SD	standard deviation
SR	studentized residuals
TP	Technical Procedure
UTM	Universal Transverse Mercator
WLWB	Wek'èezhìı Land and Water Board
WOE	weight-of-evidence
YOY	young-of-the-year

Symbols and Units of Measure

+	plus
±	plus or minus
%	percent
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
°	degrees
°C	degrees Celsius
µg/L	micrograms per litre
µS/cm	microsiemens per centimetre
cm	centimetre
g	gram
h	hour
Hz	hertz
m	metre
mg	milligram
mg/L	milligrams per litre
m/s	metres per second
mm	millimetre
mL	millilitre
ww	wet weight
V	volt

1 INTRODUCTION

1.1 Background

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP) for the Diavik Diamond Mine (Mine), as required by Water Licence W2015L2-0001, issued by the Wek'èezhìı Land and Water Board (WLWB) (WLWB 2015), and the Fisheries Act Authorization SC98001 issued by Fisheries and Oceans Canada. This report presents the analysis of small-bodied fish data collected during the 2019 field program, which was carried out by Golder Associates Ltd. (Golder) according to the *AEMP Design Plan Version 4.1* (Golder 2017a).

AEMP Design Plan Version 4.1 (Golder 2017a) is the currently approved version of the AEMP design; however, a number of changes outlined in the proposed *AEMP Design Plan Version 5.1* (Golder 2019a) and in WLWB Directives (28 August 2017, 24 January 2018, 25 March 2019, and 21 October 2019 Decision Packages) have been incorporated into the 2019 AEMP Annual Report, where relevant.

1.2 Objectives

The overall objective of the AEMP is to monitor the Mine water discharge and other stressors from the Mine and assess potential ecological risks. The objective of the small-bodied fish survey is to evaluate the potential effects of the Mine discharge on the health of the Lac de Gras Slimy Sculpin fish population using the following variables:

- catch-per-unit-effort, as an indicator of abundance
- length, weight, and age distributions
- size-at-age
- condition and relative liver and gonad weight

In addition, analysis of fish tissues for metal[1] concentrations were conducted on Slimy Sculpin collected as part of the fish health study. The Slimy Sculpin chemistry results were used as part of the interpretation of the fish health study, and as an early warning indicator of potential effects on tissue quality of Lake Trout.

1.3 Scope and Approach

The fish health and tissue chemistry component of the AEMP is designed to monitor both spatial and temporal changes in the health of small bodied fish. As described in the *AEMP Design Plan Version 4.1* (Golder 2017a), the objective of the annual report for a comprehensive AEMP year (i.e., when small-bodied fish are sampled) is to assess the spatial extent of Mine-related effects and evaluate whether any Action Levels have been reached. A summary report of all AEMP data collected since before mining began, up to and including 2016, was described 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*

---

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

2016 Aquatic Effects Re-evaluation Report Version 1.1 (Golder 2019c) is an important reference when considering ongoing monitoring results.

Effects on small-bodied fish were assessed using statistical tests comparing fish health and tissue chemistry variables between the near-field (NF) area, which receives the greatest exposure to the Mine effluent, and two far-field (FF) areas (i.e., FF1, and FFA) with the least exposure.

Magnitudes of effects were assessed by comparing small-bodied fish health variables in the NF area to the reference condition, as defined for Lac de Gras in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a). Values that were beyond the reference condition were considered to be exceeding the range of natural variability in Lac de Gras. The importance of effects observed on small-bodied fish health variables were categorized according to the Action Level classifications defined in the *AEMP Design Plan Version 4.1* (Golder 2017a).

2 METHODS

2.1 Species

Slimy Sculpin were approved as the sentinel fish species for the AEMP small-bodied fish survey in the *AEMP Design Plan Version 4.1* (Golder 2017a) and were therefore used in the 2019 AEMP fish program. This is consistent with past small-bodied fish surveys at Lac de Gras that used Slimy Sculpin as the study species (e.g., 2004 [Gray et al. 2005], 2007 [Golder 2008], 2010 [Golder 2011], 2013 [Golder 2014b], and 2016 [Golder 2017b]).

2.2 Timing

Field sampling was conducted from 28 August to 16 September 2019. The survey was conducted in late-summer to allow time for fish gonads to re-develop (i.e., recrudesce) following early spring spawning (Golder 2017a). This timing is similar to that of the 2007, 2013, and 2016 small-bodied fish surveys (Golder 2008, 2014b, 2017b).

2.3 Sampling Areas

Five areas of Lac de Gras were sampled for the fish survey, defined by their level of exposure to effluent and their distance from the treated effluent discharge (Table 2-1, Figure 2-1): one NF area, two mid-field (MF) areas (far-field 2 [FF2] and mid-field 3 [MF3]), and two FF areas (FF1 and FFA, herein collectively called the FF areas). Sampling area FF2 is considered a mid-field area due to presence of Mine effluent. The five sampling areas were in close proximity to Lac de Gras AEMP water quality, sediment, plankton and benthic invertebrate sampling areas. At least two stretches of shoreline were sampled in each area. Sampling areas in 2019 were similar to those sampled during the 2016 small-bodied fish survey (Golder 2017b). Within each of the five areas, the selection of sampling sites was based on:

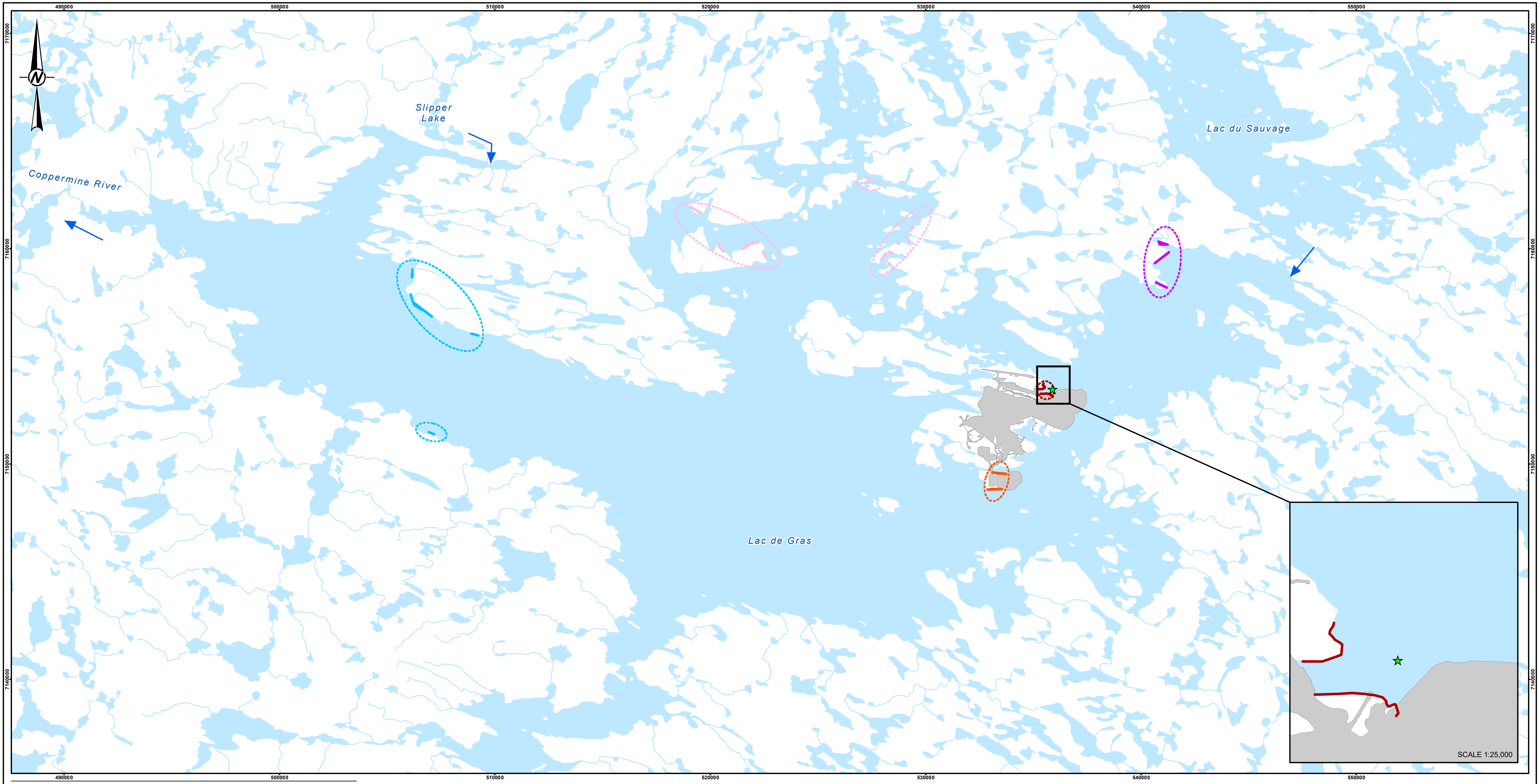
- presence of Slimy Sculpin habitat (i.e., shallow, less than 40 cm in depth, natural shoreline with small cobble substrate)
- Slimy Sculpin abundance (i.e., sites where Slimy Sculpin were not captured during the first sampling event were not sampled again)

- health and safety concerns (i.e., shoreline not suitable for wading, limited boat access to safe sites, relative exposure to wind and wave action)
- The total length of shoreline sampled was not pre-determined but depended on fish abundance. Sampling continued at shoreline sites in each area until the required number of fish were captured. Sites with higher fish abundance, therefore, received less sampling effort.

Table 2-1 Fish Sampling Sites, 2019

Sampling Area	Shoreline Site	Universal Transverse Mercator (UTM) coordinates (NAD 83, Zone 12W)				Length of Shoreline Sampled (m)
		Start		End		
		Easting	Northing	Easting	Northing	
NF	North-east of causeway	535276	7153434	535474	7153724	574
	South-east of causeway	535823	7153135	535355	7153278	530
FF2(a)	South on peninsula	540703	7158424	541192	7158188	979
	North-east of peninsula	540645	7159329	541300	7159843	1,002
	Eastern shore of large bay	540805	7160321	541240	7160190	633
MF3	Southern site	532881	7148813	533541	7148820	723
	North-east site	533733	7149533	533101	7149607	760
FF1	North-east of large island	519580	7161652	519071	7161954	720
	North-west on large island	520344	7160196	520603	7159862	453
	North-east on large island	521480	7159985	522621	7159549	1,486
	Northern site	527217	7163059	527406	7163085	206
	South-east shoreline site	528332	7159271	528304	7159330	93
	South-east bay site	528486	7159780	527925	7159483	734
	Eastern shoreline site	528701	7160249	528758	7160243	60
	Eastern bay site	529268	7160345	529448	7161021	607
	North-east island site	529670	7161440	529443	7161537	403
FFA	South site	507178	7151383	506923	7151484	296
	Eastern site	506174	7159045	506148	7158664	530
	South-east site	507082	7156839	506088	7157880	1,816
	South-east site	508896	7156052	509230	7155975	347

a) Sampling area FF2 is considered a mid-field area due to presence of Mine effluent.
NF = near-field; MF = mid-field; FF = far-field.



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LEGEND

★	DIFFUSERS
2019 FISH SAMPLING AREA TRANSECTS	
—	FAR-FIELD 1
—	FAR-FIELD 2
—	FAR-FIELD A
—	MID-FIELD 3
—	NEAR-FIELD
2019 GENERALIZED FISH SAMPLING AREAS	
◯	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

LOCATIONS OF AEMP SMALL-BODIED FISH SAMPLING AREAS, 2019

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

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

25mm

0

2.4 Sample Size

For the relative abundance survey, there were no set target sample sizes. For the lethal fish health survey, target sample size for males, females, and age-1+ fish (i.e., juveniles) was 20 to 30 fish of each group at each sampling area (Golder 2014a). The target sample size for tissue was a minimum of eight samples per area, where each tissue sample was a composite of fish of the same sex and size class (Golder 2017a). Fish captured and sacrificed during the surveys were used in the tissue analysis to reduce mortality. Only fish that were uninfected by tapeworms were targeted (see below). An additional 50 Slimy Sculpin from each sampling area were targeted for non-lethal assessment (i.e., length and weight measurements).

Slimy Sculpin in Lac de Gras were infected with cestode parasites, likely *Ligula intestinalis* (which is known to infect Slimy Sculpin in the region) and are negatively affected by such infections (Golder 2008, 2011). Inclusion of these fish in data analyses could increase the variability of the data; therefore, this source of variability was minimized by excluding fish infected with tapeworms during field sampling using a visual, external assessment. Uninfected fish were targeted for the lethal and non-lethal assessments, consistent with past surveys (Golder 2014b; Golder 2017b) and the *AEMP Design Plan Version 4.1* (Golder 2017a).

2.5 Field Sampling

2.5.1 Supporting Environmental Information

Supporting environmental variables provide information that allows for comparison of aquatic habitats between the NF/MF areas and the FF areas, and assists with the interpretation of biological results for fish. Of particular importance is the effect of temperature on fish spawning, growth, and other aspects of energy utilization. At the beginning of the day, air temperature (ºC) and wind direction (º) were recorded from the DDMI weather station. In addition, the following supporting environmental variables were documented at each sampling site during the 2019 small-bodied fish survey:

- habitat information (e.g., minimum and maximum water depth, substrate type, photographs of the area)
- *in situ* water quality variables (i.e., water temperature [ºC], pH, specific conductivity [microSiemens per centimetre (µS/cm)], dissolved oxygen [mg/L], and percent saturation of oxygen [%]) were collected daily at each sampling location throughout the fish survey
- weather conditions for each sampling effort (i.e., percent cloud cover and precipitation)
- seasonal water temperatures, recorded continuously throughout May-September

In situ water quality variables were measured using a YSI Professional Plus Multimeter. Seasonal water temperatures were recorded using temperature loggers (Onset HOBO Data Loggers Tidbit V2 Water Temperature Data Logger – UTBI-001). Two temperature data loggers were deployed at each sampling area to assess differences in seasonal water temperatures among the sampling areas. Temperature data loggers were set to measure water temperature every hour, and were installed on a mooring <2.0 m from the anchor (Photo 2-1; Table 2-2). Moorings were deployed in the spring and retrieved in the fall, so that the sampling period encompassed the temperature range of the principal period of growth for fish in the area (Coker et al. 2001). Note that the differences in depth of logger deployment may result in some discrepancies in temperature measurements among areas, as deeper loggers are more likely to record lower water temperatures.

Table 2-2 Temperature Logger Deployment Details, 2019

Area	Deployed[(a)]	Retrieved	Depth at installation (m)	Depth after ice melt (m)	Ice thickness (m)
NF	10-May	16-Sep	1.8	4.4	0.98
FF2	10-May	07-Sep	3.7	3.8[(b)]	1.44
FF1	04-May	07-Sep	-	5.8	-
FFA	08-May	08-Sep	1.9	<2.0[(c)]	1.19
MF3	10-May	07-Sep	1.8	>2.0[(c)]	1.14

a) Two loggers were set at each location.
b) Average based on logger depths of 4.7 and 2.8 m.
c) Depth was not recorded in the field and later estimated.
- = not recorded; NF = near-field; MF = mid-field; FF = far-field.

All temperature data loggers were recovered. Daily averages were calculated for each individual logger and then a daily average within each sampling area was calculated across the two loggers. Daily means for the dates of logger deployment and retrieval were not calculated because they included periods where the loggers were not installed. Differences in temperatures at each area were assessed by plotting the difference in mean daily temperature between NF, FF2, and MF3 and the pooled FF1-FFA mean daily temperature. Statistical tests were not performed due to the concern of bias, considering the differences in logger deployment depths.

Photo 2-1 Temperature logger setup, Spring 2016.

Note: The temperature logger was installed inside a PVC casing (black) and suspended on a cable between an anchor (red), and two buoys – one just above the temperature logger to prevent sinking, and another at the end of the cable to remain at water surface.

2.5.2 Fish Collection

Slimy Sculpin were captured by backpack electrofishing (Smith-Root 12B, Smith-Root Inc., Vancouver, WA, USA; Photo 2-2) by certified field staff, following methods detailed in the Golder Technical Procedure (TP) 8.1-3, Fish Inventory Methods (Golder, unpublished) and TP 8.16-0, Fish Health Assessment – Metals (Golder, unpublished). Large anode rings (18-inch diameter) were used during the sampling to mitigate the effects of low conductivity in Lac de Gras (less than 50 µS/cm during the 2019 fish survey) on electrofishing efficiency. For each electrofishing effort, the following information was collected:

- sampling date, start and end time
- Universal Transverse Mercator (UTM) coordinates for start and end locations of sampled shoreline sites
- general habitat description (Section 2.5.1)
- fishing effort, as electrofishing duration in seconds
- backpack electrofishing settings (voltage [V], frequency [Hz], and pulse width [m/s])
- number of each fish species captured and observed

Each electrofishing effort was assigned a unique number. Captured Slimy Sculpin were held in buckets filled with ambient temperature, well-oxygenated water until processed. Fishing effort was conducted according to the conditions detailed in the Fisheries and Oceans Canada Licence to Fish for Scientific Purposes (S-1920-3042-YK-A1) and Animal Use Protocol (FWI-ACC-2019-054).

Photo 2-2 Electrofishing at FF2 in Lac de Gras, September 2016

2.5.3 Fish Processing

2.5.3.1 Tapeworm Infection Screening

Tapeworm infection was identified visually during the non-lethal assessment by the presence of a distended abdomen (Photo 2-3). Fish with distended abdomens were assumed to carry an adult tapeworm and were released back to the lake following the non-lethal assessment of length and weight. A subset of fish that were captured and dissected were found to contain an adult tapeworm, despite no externally visible signs of infection.

Photo 2-3 External observations of Slimy Sculpin from Lac de Gras. The fish on the left showing signs of tapeworm infection (i.e., distended belly) relative to an uninfected fish on the right.

2.5.3.2 Relative Abundance Survey

To compare the relative abundance of Slimy Sculpin among sampling areas, 500 m sections of shoreline were fished over a standardized duration of time (e.g., 3 to 4 h). Captured fish were assigned an individual fish identification number, measured for total length (±1 mm) and body weight (±1 mg), and released at the area of capture. The relative abundance survey was completed on the initial visit to each sampling area, prior to commencing lethal and non-lethal sampling. Slimy Sculpin data collected during the relative abundance survey were incorporated into the non-lethal assessment (e.g., length and weight data), and some individuals captured during the relative abundance survey were retained for lethal sampling.

2.5.3.3 Non-lethal Assessment

Captured non-target species and Slimy Sculpin not retained for lethal assessment (including fish captured in the relative abundance survey, field mortalities and fish externally examined and believed to be infected with a tapeworm) were assigned an individual fish identification number, measured for total length (±1 mm) and body weight (±1 mg), assessed for external abnormalities and released at the area of capture. Fish were measured using a graduated measuring board; body weight was measured using an Ohaus Scout SPX-123 electronic scale (capacity 120 g, readability 1 mg).

2.5.3.4 Lethal Health Assessment

Slimy Sculpin captured for the lethal fish health assessment were assigned an individual fish identification number and were transported live in aerated buckets from the field to the Diavik laboratory for processing. Fish were measured for total length (±0.1 mm) using digital calipers; body weight was measured (±0.1 mg) using an Ohaus PA124 Pioneer Analytical Balance (capacity 120 g, readability 0.1 mg).

Both external and internal assessments were completed on lethally sampled Slimy Sculpin according to Golder TP 8.16-0 Fish Health Assessment – Metals (Golder unpublished). External observations of fish features (i.e., eyes, gills, pseudobranchs, thymus, skin, body form, fins, and opercula) were recorded. Detailed observations were made of any abnormal features of the fish, such as wounds, lesions, tumours, parasites, fin fraying, or gill parasites.

Following the external observations, Slimy Sculpin were sacrificed by a sharp blow to the back of the head. Fish were dissected on a cutting board wrapped with a clean sheet of plastic wrap that was changed between fish. Dissecting equipment was washed in a phosphate-free soap and rinsed with 10% nitric acid and then deionized [DI] water. New gloves and a new scalpel blade were used for each specimen.

The internal examination collected the following information (Photo 2-4):

- sex
- stage of maturity (recorded as per maturity stages outlined in Attachment A)
- life stage (adult/age-1+)
- abnormalities observed in liver, spleen, gall bladder, kidney, and gonads
- mesenteric fat covering the gastrointestinal tract (%)
- liver weight (±0.1 mg)
- total gonad weight (±0.1 mg)
- parasite presence and weight (±0.1 mg)
- carcass weight (±0.1 mg)
- stomach fullness estimate (%)

A subset of fish were found to contain adult tapeworms once they were dissected which had not been visible externally. Once the infection was identified, the fish were discarded; however, external examination and limited internal data were retained for those fish. Liver observations did not consider a fatty, cream-coloured liver as an abnormality during this fish program.

The gonads of each fish were placed in individually-labelled 2 mL cryovials and preserved in 10% buffered formalin. A total of 334 samples were sent for histopathological analysis to confirm the field-assessed sex and stage of development of the fish (Section 2.6.1).

Stomachs that were more than 75% full were placed in individually-labelled 5 mL cryovials, preserved in 10% buffered formalin, and sent for enumeration and taxonomic identification of contents (Section 2.6.2).

As Slimy Sculpin lack scales, sagittal otoliths were collected as the primary aging structure. Slimy Sculpin ages derived from otolith sections have been found to be unreliable (CRI 2014); therefore, the otoliths were not analyzed, but were archived for possible future use.

Following the internal examination, fish bodies (i.e., carcass without gonads, stomach or otoliths) were placed in individual pre-labelled plastic bags and frozen for shipment to the analytical laboratory for tissue chemistry analyses (Section 2.6.3).

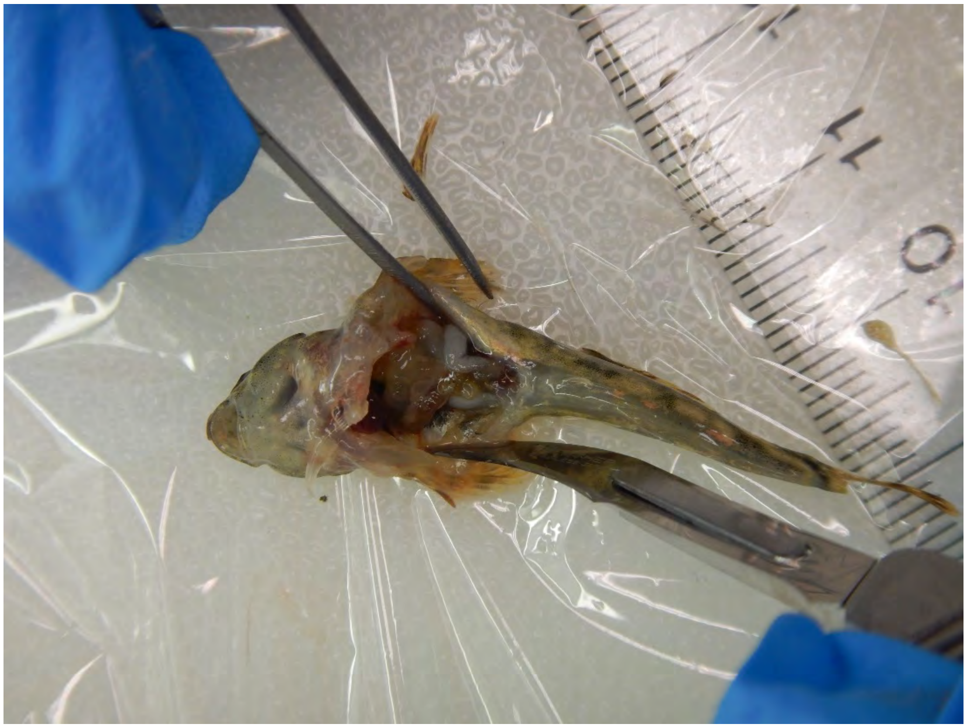


Photo 2-4 **Slimy Sculpin internal examination, September 2013**

2.6 Laboratory Analysis

2.6.1 Histology

Gonads were sent for histological analysis of sex and state of maturity to Aquatic Diagnostic Services, Atlantic Veterinary College, at the University of Prince Edward Island, Charlottetown, PEI, Canada. The tissue samples were mounted on slides, sectioned, and stained for microscopic analysis (Photo 2-5). The histology codes and associated definitions used for categorizing the stages of Slimy Sculpin gonad development are presented in Attachment A.

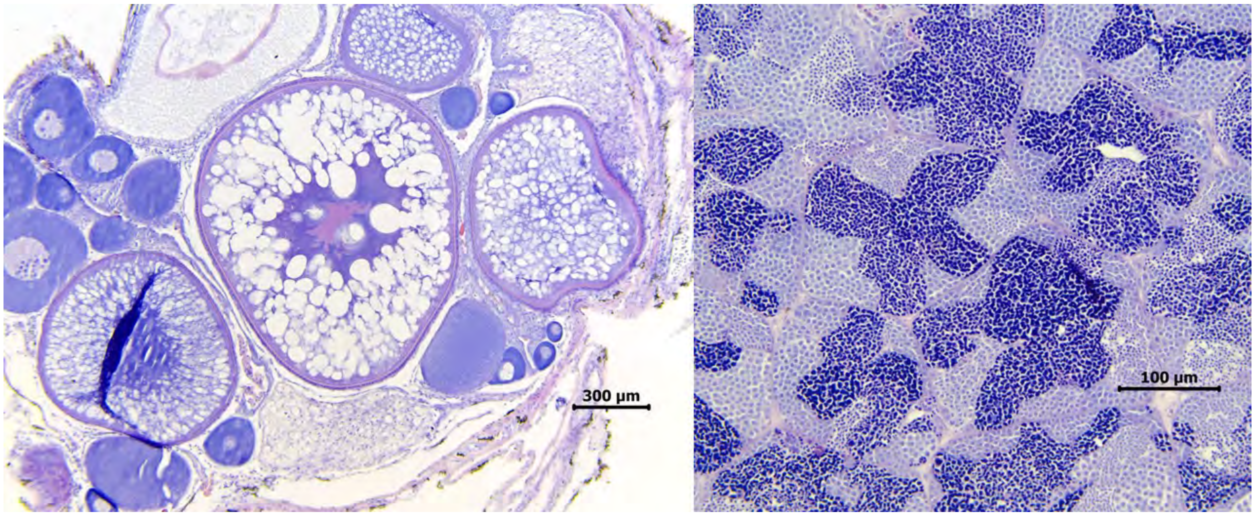


Photo 2-5 **Cross section of the ripe ovary of a Slimy Sculpin female (collected from FF2 in 2016, left) and ripe testes of a Slimy Sculpin male (collected from NF in 2016, right)**

2.6.2 Stomach Content

Slimy Sculpin stomach content enumeration and taxonomic identification were conducted by Dr. Jack Zloty (Summerland, BC). Organisms within the stomach were identified to genus using recognized taxonomic keys. Organisms that could not be identified to the desired taxonomic level (e.g., were partially digested or otherwise degraded) were reported as "other". The taxonomic composition within each individual stomach was determined as percentages of major invertebrate groups by abundance. Stomach content data were available for 143 of 434 lethally sampled fish. Of the 143 samples, 68 were from adult male fish, 34 were from female fish, and 41 were from age-1+ fish (Table 2-3).

Table 2-3 **Sample Sizes for Slimy Sculpin Stomach Contents**

Area	Sex	Sample Size
NF	Male	10
	Female	6
	Age-1+	5
FF2	Male	11
	Female	6
	Age-1+	7
MF3	Male	19
	Female	6
	Age-1+	6
FF1	Male	12
	Female	9
	Age-1+	8
FFA	Male	16
	Female	7
	Age-1+	15

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

2.6.3 Fish Tissue Chemistry

Fish tissue samples were submitted to ALS Canada Ltd. (ALS), Burnaby, BC for tissue chemistry analysis (i.e., moisture and metals). Fish bodies (i.e., carcass excluding gonads, stomachs or otoliths) were composited into a total of 40 samples (i.e., eight composite samples per sampling area). Each composite sample was made by combining three to seven fish of the same sex and size class, based on the field assessment of sex/maturity stage, into a total of four to five adult male and three to four adult female composite samples per area (Table 2-4). Attempts were made to include adult fish of the same sex only; however, one fish (i.e., DDMI19UMF3SLSC7071) included in composite DDMI2019MF3SLSCG1 was later defined as age-1+ by gonad histology, and three fish (i.e., DDMI19UFF2SLSC6109, DDMI19UFF2SLSC6131, DDMI19UFF2SLSC6189) in composites DDMI2019FF2SLSCD1, DDMI2019FF2SLSCD2 and DDMI2019FF2SLSCD1, respectively, were initially classified as male and reclassified as female based on gonad histology. Samples were composited to meet the minimum sample volume requirement of 5 g wet weight (g ww). Target detection limits (DLs) defined in the *AEMP Design Plan Version 4.1* (Golder 2017a) are provided in Table 2-5.

Split samples were collected to determine inter-laboratory variability of fish tissue chemistry. Five tissue chemistry split samples were sent by ALS to Flett Research Ltd., Winnipeg, Manitoba for mercury analysis quality control (QC) purposes, as outlined by the *Quality Assurance Project Plan Version 3.1* (Golder 2017c). Flett Research used the moisture content values provided by ALS to calculate mercury concentrations in fish tissue.

Table 2-4 Composite Samples Prepared to Meet Tissue Volume Requirements for Slimy Sculpin Tissue Samples from Lac de Gras, 2019

Area	Sex(a)	Composite Number	Number of Fish in Sample	Composite Weight (g)	Fish in Composite Sample		Split Samples
					Mean Weight (g)	Mean Length (mm)	
NF	Male	1	6	6.597	1.244	53.8	
		2	5	6.594	1.502	58.3	
		3	4	7.351	2.084	63.6	
		4	3	6.552	2.465	65.8	x
	Female	5	6	5.919	1.108	53.0	
		6	4	5.171	1.507	57.3	
		7	3	5.552	2.081	63.4	
		8	2	5.526	3.115	71.9	
FF2	Male	9	6(b)	5.849	1.152	51.8	x
		10	5(b)	6.288	1.453	56.7	
		11	4	6.409	1.812	60.9	
		12	4	7.628	2.163	64.0	
		13	3	6.460	2.474	66.7	
	Female	14	6	5.893	1.117	51.4	
		15	4	5.683	1.559	58.8	
		16	3	5.479	2.068	63.8	
MF3	Male	17	5	5.674	1.309	54.5	
		18	4	5.660	1.641	57.8	
		19	4	6.844	1.963	62.9	
		20	3	5.899	2.208	65.8	x
	Female	21	6(c)	4.655	0.910	48.4	
		22	5	5.433	1.233	53.4	
		23	4	5.505	1.549	59.3	
		24	2	5.030	2.807	72.0	
FF1	Male	25	5	5.328	1.208	52.7	
		26	4	5.033	1.448	55.2	
		27	4	6.561	1.828	60.6	
		28	3	6.420	2.422	65.5	
	Female	29	5	5.884	1.347	55.2	x
		30	4	5.751	1.632	59.4	
		31	4	7.234	2.032	63.8	
		32	3	6.506	2.456	68.4	
FFA	Male	33	7	6.559	1.080	52.5	x
		34	5	6.131	1.387	56.8	
		35	5	7.030	1.617	58.6	
		36	4	7.000	1.977	64.7	
	Female	37	6	5.683	1.097	52.9	
		38	5	5.549	1.283	56.5	
		39	4	6.470	1.825	62.1	
		40	3	5.973	2.343	66.2	

a) Sex as assessed by the field crew.

b) Composite sample included fish that were assessed as male in the field but were later defined female by gonad histology.

c) Composite sample included fish that were assessed as adult in the field but were later defined as age-1+ by gonad histology.

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

Table 2-5 Variables Analyzed and Method Detection Limits for Slimy Sculpin Tissue Samples from Lac de Gras, 2019

Variable	Detection Limit (mg/kg ww)	Variable	Detection Limit (mg/kg ww)
% Moisture Content	0.25	Mercury	0.0010
Aluminum	0.40	Molybdenum	0.0040
Antimony	0.0020	Nickel	0.040
Arsenic	0.0040	Phosphorus	2.0
Barium	0.010	Potassium	4.0
Beryllium	0.0020	Rubidium	0.010
Bismuth	0.0020	Selenium	0.010
Boron	0.20	Silver	0.0010
Cadmium	0.0010	Sodium	4.0
Calcium	4.0	Strontium	0.010
Cesium	0.0010	Tellurium	0.0040
Chromium	0.010	Thallium	0.00040
Cobalt	0.0040	Tin	0.020
Copper	0.020	Titanium	0.020
Iron	0.60	Uranium	0.00040
Lead	0.0040	Vanadium	0.020
Lithium	0.10	Zinc	0.10
Magnesium	0.40	Zirconium	0.040
Manganese	0.010		

2.7 Data Analysis

2.7.1 Catch-per-Unit-Effort

The number of fish captured was standardized as catch-per-unit-effort (CPUE), defined as the number of fish caught per 100 seconds of electrofishing effort; CPUE provides an estimate of relative abundance among sampling areas by standardizing the catch data according to the fishing effort.

2.7.2 Data Handling

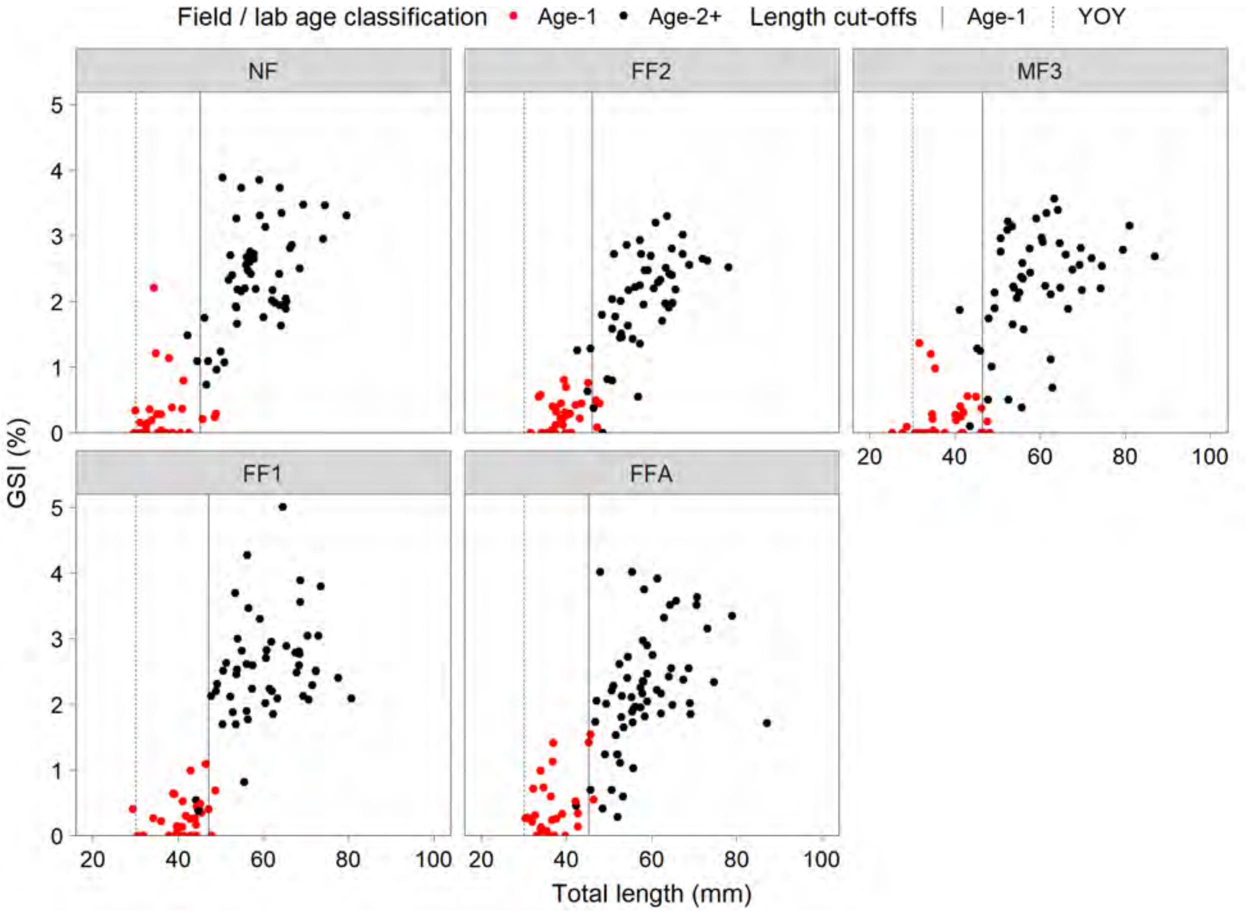
2.7.2.1 Fish Population Health

Slimy Sculpin were grouped according to maturity (i.e., age-1+ or adult) and sex, and then analyzed as separate groups. Maturity and sex determination were based on field observations and confirmed by lab histology data. In cases where field and lab maturity designations differed, final designations were based on a review of field photos and histology slides as well as fish size, gonad weight and gonadosomatic index (GSI).

Otolith age was not measured and surrogates for determining age were developed (i.e., young-of-the-year [YOY], age-1+ and age-2+), as detailed in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c). The separation of YOY, age-1+, and age-2+ fish was important because of the different energetic requirements associated with reproduction, which results in differences in the rate of growth and body weight gain. Fish less than 30 mm total length were considered YOY and were removed from most of the fish health analyses, with the exceptions of the length-frequency analysis (i.e., all fish without tapeworms were included), and the assessments of abnormalities and parasites. Previous studies suggested the general use of 1% GSI as a cut-off value between immature (i.e., age-1+) and mature (i.e., age-2+) fish (Environment Canada 2010). However, as suggested by the data distribution in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c), a GSI cut-off of 1% would retain many fish that were likely YOY (i.e., age-1+); therefore, a GSI value of 1.2% was used. Fish with no known GSI were not assigned an age. In addition, maturity curves, constructed to describe fish maturity (i.e., age-1+ or age-2+) as a function of total length, were used to calculate the size at maturity (i.e., the total length at which 50% of the Slimy Sculpin were expected to be mature). This size at maturity value was specific to each sampling area and was applied to scatter plots of fish GSI versus total length. Using these metrics, fish smaller than the size at maturity with a GSI value less than 1.2% were considered to be age-1+ fish. Slimy Sculpin that were larger than the area-specific size at maturity, or had GSI greater than 1.2%, were assigned to the age-2+ group and were, therefore, considered adults.

In the 2019 AEMP, maturity codes were used to further categorize fish maturity (Attachment A) and only fish with maturity codes of “unknown”, “immature”, or “early development” were included in the age-1+ group. Fish with gonads classified as “immature”, “resting”, “spent”, “reabsorbing”, and “unknown” were not included in fish health analyses for the age-2+ group. Fish infected with adult tapeworms were also excluded from analysis, except for the analysis of incidence of parasitism. The results of the age re-classifications are presented graphically in Figure 2-2.

Figure 2-2 **Age Re-classification by Station and Original Field-based Age Classification for Slimy Sculpin Captured in Lac de Gras, 2019**



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

2.7.2.2 Fish Tissue Chemistry

Prior to summarizing fish tissue chemistry data and performing statistical analyses, values below the DL were estimated; non-detect values were substituted with a value of 0.5 times the DL, as per the approved methods applied in the calculation of the normal range in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). For tissue chemistry data where at least 60% of samples were below DL in at least one sampling area, the data were not analyzed quantitatively (i.e., summary and inferential statistics were not calculated).

2.7.3 Data Screening

2.7.3.1 Fish Population Health

Data checks for anomalous data (i.e. unusually large or small values) and confirmation of sex and reproductive staging were performed as follows:

- Fish health data were plotted to visually examine the dataset for potential data entry errors or unusual data. Plots included total weight versus total length, carcass weight versus total length, gonad weight versus carcass weight, liver weight versus carcass weight, and total weight versus carcass weight.
- Anomalous data, as detected by the qualitative screening above, were removed from the data set only if they were determined to be the result of human error (i.e., sampling or measurement error). Errors were checked with field data sheets and field photos as part of the screening process prior to removal from the data set.
- Gonad histology results were visually screened for anomalous values (i.e., incorrect sex or reproductive stage) by plotting length, total weight, GSI, and gonad weight versus life stage, sex and reproductive stage. Anomalous values were selected for reassessment to confirm the accuracy of sex and/or reproductive stage assignments.
- Both fish health and fish tissue chemistry datasets underwent screening using a method based on Chebyshev's theorem to identify unusually large or small values, which were then assessed and excluded from further analysis if necessary. The screening was combined with visual examination of scatter plots and logic checks, and is reported in detail in Attachment B.
- The separation of adults and age-1+ fish was determined after consideration of field assessments, gonad size, histology results, and size at maturity (see Section 2.7.2.1). If there were inconsistencies between field assessments and histology results, gonad histology results were weighted more heavily with consideration of available data to assign the final gonad maturity categories and sex determination.

Statistical outliers were identified by the analysis of studentized residuals (SR; Section 2.7.5.5). The outlier screening approach is described in Attachment B and was approved as part of the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c) to handle outliers in the AEMP datasets. Observations that were more than 3.5 SR from the mean were considered to be statistical outliers. When identified, statistical outliers were removed from the analysis (Attachment B) and the models were refitted without these values.

2.7.3.2 Fish Tissue Chemistry

Initial screening of the 2019 fish tissue chemistry data was completed to identify unusually large values and decide whether to retain or exclude anomalous data from subsequent analyses. Data screening and outlier handling followed the same methods described for fish population health data. When outliers were identified, scatter plots were generated to allow a visual review of anomalous data and provide transparency (Attachment B).

2.7.4 Descriptive Statistics

Summary statistics (i.e., sample size, arithmetic mean, median, minimum, maximum, standard deviation [SD], and standard error) were calculated separately for each sampling area and each biological variable for age-1+, adult male, and adult female fish. Common fish indices describing relationships between body metrics (i.e., Fulton's condition factor [K], liversomatic index [LSI] and GSI) were calculated as follows:

Condition factor (age-1+) $$K = \left(\frac{total\ body\ weight}{total\ length^3}\right) \times 100{,}000$$

Condition factor (adults) $$K = \left(\frac{carcass\ weight}{total\ length^3}\right) \times 100{,}000$$

Liversomatic index $$LSI = \left(\frac{liver\ weight}{carcass\ weight}\right) \times 100$$

Gonadosomatic index $$GSI = \left(\frac{gonad\ weight}{carcass\ weight}\right) \times 100$$

Carcass (i.e., eviscerated) weight was used in the calculations of GSI and LSI to eliminate confounding effects of including organ weight in body weight. In addition to these indices, mean total weight adjusted to the total length, mean liver weight adjusted for carcass weight, and mean gonad weight adjusted for carcass weight were also provided as summary statistics. Since the ages of individual fish could not be determined with sufficient accuracy (CRI 2014), mean age as a variable of interest was not evaluated.

2.7.5 Statistical Analysis

2.7.5.1 Approach

The objectives of the statistical comparisons were to compare variables from the NF and MF areas (i.e., FF2 and MF3) to the FF areas (i.e., FFA and FF1). Statistical testing of differences among areas was conducted for the following variables:

- incidence of parasitism (i.e., adult tapeworms)
- length-frequency distribution
- size (i.e., total length, total weight, and carcass weight) by age and sex
- energy storage (i.e., condition, liver weight) by age and sex
- reproduction (i.e., gonad weight) by sex
- metals concentrations in tissue

A chi-square test was used to test for differences in the occurrence of adult tapeworm parasitism among areas. Differences among areas in total length, weight, and carcass weight were assessed by analysis of variance (ANOVA) or the non-parametric equivalent (the Kruskal-Wallis test). Differences among areas in total weight, liver weight, and gonad weight were adjusted for total length or carcass weight and were then assessed using analysis of covariance (ANCOVA). This size-adjusted ANCOVA approach allowed a more robust examination of among-area differences in condition factor, LSI and GSI, compared to analyzing the data as indices (Environment Canada 2012). Because infection by adult tapeworms can affect the size and health of fish, as well as energy storage and energy use, only fish not parasitized by adult tapeworms were used in statistical analyses. Statistical analyses were carried out separately for each sex and state of maturity (i.e., age-1+ fish, adult males, and adult females).

In previous reports, the proportion of age-1+ fish at each sampling area was used as a proxy of reproductive success (Golder 2014b). However, because only lethally-assessed fish were assigned an age in 2019 per the methods developed for the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c), and an assessment of proportion of age-1+ fish as previously completed relies on the assumption that lethal samples were randomly selected[2], this analysis was not completed in 2019. Therefore, differences in length-frequency distributions among sampling areas (i.e., including all fish) were assessed as a metric for reproductive success using the non-parametric, two-sample Kolmogorov-Smirnov (KS) test.

The effects of area on concentrations of metals in Slimy Sculpin were analyzed by ANOVA, ANCOVA, or the non-parametric Kruskal-Wallis test, if normality could not be achieved (see Section 2.7.5.2). Because mercury and selenium biomagnify (i.e., accumulate via food up three or more trophic levels to a greater degree at each trophic level), if the concentration of mercury or selenium was significantly correlated to fish size, comparisons among areas for these metals were conducted by ANCOVA. All calculations and statistical summaries were performed in the statistical environment R v. 3.6.1 (R Core Team 2019).

2.7.5.2 Testing Assumptions for Statistical Analysis

Both ANOVA and ANCOVA assume that the residuals of the statistical models are (1) normally distributed and (2) have homogeneity of variances. If a model has residuals that are not normally distributed, there is an increased chance of committing a Type I error (i.e., false positive) using parametric tests. To test residuals for normality, a KS test was carried out. Since many data sets with non-normal residuals are still suitable for analysis with ANOVA or ANCOVA (Sokal and Rohlf 2012), strong evidence of non-normality ($P<0.01$) was required to justify the use of non-parametric equivalents in place of these parametric tests. Similarly, Levene's test was used to test for violations of homogeneity of variances ($P<0.01$).

If model residuals were clearly non-normal and/or the assumption of homogeneity of variances was violated, the data were log-transformed in an attempt to meet these assumptions. If the transformed data still did not meet the assumptions, the non-parametric Kruskal-Wallis test was used.

2.7.5.3 Chi-Square Test

Differences in the incidence of adult tapeworms in Slimy Sculpin among areas were evaluated using the chi-square test (Sokal and Rohlf 2012). The chi-square test is used with frequency or proportional data, such as incidence of parasites (i.e., adult tapeworms). Fish assessed with non-lethal methods and fish sampled lethally (i.e., dissected) were included in the chi-squire test; the goal of which was to assess the overall incidence of tapeworm parasitism across all fish captured. Presence of adult tapeworm was determined based on a distended abdomen in non-lethally and externally assessed fish, and the visual

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[2] Lethal samples were not randomly selected; uninfected, larger fish were targeted for dissections for determination of sex and reproductive stage. This invalidated the approach of using the proportion of age-1+ fish as a measure of reproductive success.

confirmation of adult tapeworm in the abdomen area in lethally assessed fish. The magnitude of the differences between the NF, FF2, or MF area mean and the FF area mean was calculated as the absolute difference in the rate of parasitism in Slimy Sculpin. *P*-values for comparison between areas were adjusted using the Dunn-Šidák method for four comparisons.

2.7.5.4 Kolmogorov-Smirnov Test

Differences in length-frequency distributions between areas were evaluated using the non-parametric, two sample KS test (Sokal and Rohlf 2012). The KS test is best suited for testing differences in distributions (based on continuous data) because it measures differences in the entire distribution as opposed to tests based on ranks, such as the Kruskal-Wallis test. Fish infected by adult tapeworms (as determined from external or internal assessment) were excluded from this analysis because parasites can adversely affect growth. *P*-values for comparison between areas were adjusted using the Dunn-Šidák method for four comparisons.

2.7.5.5 Analysis of Variance

A one-way ANOVA was performed to estimate the effect of area on fish health and tissue chemistry variables. If a significant overall difference was found ($P<0.1$), an *a priori* comparison (planned contrasts) within the overall ANOVA was conducted to test the following four contrasts:

- NF area vs. combined FF1 and FFA areas
- FF2 area vs. combined FF1 and FFA areas
- MF3 area vs. combined FF1 and FFA areas
- FF1 area vs. FFA area

The planned contrasts presented here are not completely uncorrelated because the three NF/MF areas are compared individually to the FF areas. An orthogonal set of comparisons would have precluded the independent comparison of each of the three NF/MF areas to the FF areas, which is important because each NF/MF area represents a different level of exposure. To maintain the benefits of planned contrasts and avoid the shortfalls of multiple comparison tests (Day and Quinn 1989), the planned contrasts were conducted within the overall ANOVA; however, the Type I error *P*-value was adjusted to maintain the overall experiment-wise error probability of 0.1. The *P*-value was adjusted to 0.026 using the Dunn-Šidák method (Sokal and Rohlf 2012).

An analysis of residuals was conducted to detect outlier data that could strongly influence the results. Datum with |SR| values larger than 3.5 were considered outliers and removed from analysis and documented in Attachment B.

The magnitude of the difference in variables between NF/MF areas and the pooled FF areas was calculated by expressing the difference as a percentage of the pooled mean of the two FF areas:

$$Magnitude\ of\ Difference\ (\%) = \frac{(NF\ or\ MF\ mean - pooled\ FF\ mean)}{Pooled\ FF\ mean} \times 100$$

The magnitude of the difference between FF areas was calculated as a percent difference:

$$Percent\ Difference\ (\%) = \frac{(FF1\ mean - FFA\ mean)}{FFA\ mean} \times 100$$

Both calculations used the geometric mean (i.e., the mean calculated on the log-scale and then back-transformed to original units) if the preceding analyses were conducted on log-transformed data. If the preceding analyses were conducted using non-parametric tests, the differences were calculated using the median.

2.7.5.6 Kruskal-Wallis Test

For data that did not meet the assumptions of ANOVA, the non-parametric Kruskal-Wallis test was used to assess differences among areas. Differences were considered significant at $P<0.1$ for the overall test, while the P-value was adjusted by the Dunn-Šidák method to 0.026 for the contrasts (Sokal and Rohlf 2012). Magnitude of difference and percent difference were calculated as above. For tissue chemistry data where the percent of values less than DL was 60% or greater within at least one sampling area, the data were not analyzed quantitatively, and were only interpreted qualitatively based on normal range comparisons (see Section 2.7.6).

2.7.5.7 Analysis of Covariance

Analysis of covariance (ANCOVA) was used to compare fish health and tissue chemistry variables among areas while controlling for the effect of covariates such as body length or carcass weight. An overall area effect was considered statistically significant at $P<0.1$. One of the assumptions of ANCOVA is that the dependant variable is linearly related to the covariate; regression analyses were carried out to test this assumption.

To determine the best covariate for fish size in the analysis of mercury and selenium concentrations, separate regression analyses were performed against total length and weight. The model with the lowest Akaike's Information Criterion, corrected for small sample size (AICc), was considered the best supported model and was retained for further interpretation. The data were screened for outliers using SR. If significant outliers ($|SR| > 3.5$) were detected by this method, the ANCOVAs were refitted after the outliers had been omitted.

Another assumption of ANCOVA is that the slopes of the regressions for different areas are parallel. A test for homogeneity of slopes among areas was carried out. If the slopes were parallel ($P>0.05$ for test of the interaction term in the ANCOVA model) then ANCOVA was performed and adjusted means were calculated. The adjusted means are the mean values of the dependent variable, adjusted to the mean value of the independent variable. If a significant interaction existed (i.e., between sampling area and a covariate), ANCOVA could still proceed if the coefficient of determination (r^2) of the full regression model (i.e., including the interaction term) was greater than 0.8, and only slightly greater (≤ 0.02) than the r^2 of the reduced regression model (i.e., interaction term removed; Barrett et al. 2010). If the slopes were not parallel, then the ANCOVA could not proceed and the difference in predicted values was compared at minimum and maximum values of the covariate instead.

The planned comparisons among sampling areas were conducted in the same manner as the ANOVAs. The magnitude of the difference among areas for ANCOVAs was calculated with the adjusted means:

$$Magnitude\ of\ Difference\ (\%) = \frac{(NF\ or\ MF\ adjusted\ mean - pooled\ FF\ adjusted\ mean)}{Pooled\ FF\ adjusted\ mean} \times 100$$

The magnitude of the difference between FF areas for ANCOVAs was calculated as the percent difference of the adjusted means:

$$Magnitude\ of\ Difference\ (\%) = \frac{(FF1\ adjusted\ mean - FFA\ adjusted\ mean)}{FFA\ adjusted\ mean} \times 100$$

2.7.5.8 Power Analysis

A Type I error (α) is the probability of concluding there is a significant difference when none exists (i.e., a false positive). A Type II error (β) is the probability of concluding there is no significant difference when there is a true difference of some specified magnitude (i.e., a false negative). The power of a statistical test (1 - β) is the probability of detecting a true difference. Since both types of error were considered to have equal importance, for this study α and β were set to 0.1 (and hence a power level of 90%). Power analyses were conducted to assess the power of statistical tests under three effect sizes: 10%, 20% and 30% (i.e., a reduction of 10%, 20%, and 30% relative to the FF areas for biological variables, and an increase of 10%, 20%, and 30% for tissue chemistry variables). The results indicate whether the study was capable of detecting relatively small (e.g., 10%) differences among areas.

The power to detect statistically significant effects was estimated using simulation in R. The general approach was to simulate data based on the achieved sample size and variability in the observed data and re-run the models that were used for analysis using the simulated data. The data simulation and analysis were repeated 1,000 times, and the proportion of repetitions where among-area differences were significant ($P<0.1$) was interpreted as the power. Simulation-based power analyses are an established tool (e.g., Seavy et al. 2005, Morris et al. 2019) which allows for calculation of power under flexible scenarios of area-specific samples sizes and variability. This flexibility allows replicating the exact structure of the collected data and providing more realistic estimates of statistical power.

The power analysis simulated data represented each of the five sampling areas. The data for the NF/MF areas were simulated by applying various effect sizes to the mean FF1-FFA predicted value and using the SD of the original ANOVA or ANCOVA residuals for each area. For each simulated area, predicted values of the variable of interest were calculated using the ANOVA or ANCOVA models. For each observation in the simulated data set, the variable was drawn from a normal distribution where the mean was either the predicted value calculated using the ANOVA or ANCOVA equation (for FF1 and FFA areas) or the predicted value with an applied effect size (for NF/MF areas), and the standard deviation was the area-specific standard deviation of the original model residuals. In each iteration, an ANOVA or ANCOVA was re-run on the simulated data. An F-test was used to compare a model with an area effect to an intercept-only model, and a $P<0.1$ was interpreted as a significant effect of area. This simulation was repeated 1,000 times for each effect size, and the proportion of repetitions with $P<0.1$ was interpreted as the power to detect significant area differences.

For the Kruskal-Wallis tests, power was estimated in a similar manner. The only difference from the ANOVA power simulation was that the Kruskal-Wallis simulations used means and standard deviations of the raw data, rather than predicted means and residual standard deviations. Once the data were simulated, a Kruskal-Wallis test was performed and the P-value of the test was recorded. Of the performed 1,000 simulations, the proportion of tests with $P<0.1$ was used as the estimated power level.

2.7.6 Normal Range

Differences in fish health and tissue chemistry variables were evaluated by comparing results in the NF and MF areas to background values. Background values for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b) and were calculated using data from two AEMP FF areas (i.e., FF1 and FFA), incorporating data from 2007 and 2013. In both 2007 and 2013, sampling was performed in late summer and, therefore, corresponds with the sampling season for the 2019 data collections (see Section 2.2). The normal ranges for fish health and fish tissue are summarized in Table 2-6 and Table 2-7.

Comparisons of the 2019 data to the normal ranges were performed using boxplots. The 2019 data were summarized by sex/stage and area; the box was bound by the 25th and 75th quantiles, with a thick line showing the median value. The whiskers depicted the 10th and 90th quantiles and points were used to show the 5th and 95th quantiles. The mean of each sex/stage at each sampling area was shown as a point overlaying the boxplot. The normal ranges were shown as shaded areas on the plot.

Table 2-6 Normal Ranges for Fish Health Indicators

Variable	Unit	Age-1+		Adult male		Adult female	
		Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
Total length	mm	33	50	46	75	48	80
Weight	g	0.30	0.96	0.68	3.36	0.82	4.24
Carcass weight	g	0.24	0.77	0.57	2.83	0.70	3.61
Condition factor	-	0.65	0.89	0.53	0.81	0.59	0.77
LSI	%	0.94	3.57	1.17	3.72	2.03	5.68
GSI	%	-	-	0.23	2.69	0.98	3.09

Source: *AEMP Reference Conditions Report Version 1.4* (Golder 2019b)

Table 2-7 Normal Ranges for Fish Tissue Chemistry

Variable	Unit	Late summer normal range	
		Lower limit	Upper limit
Aluminum	mg/kg ww	14.8	30.0
Antimony	mg/kg ww	0.000	0.002
Arsenic	mg/kg ww	0.120	0.150
Barium	mg/kg ww	3.73	4.95
Beryllium	mg/kg ww	0.000	0.002
Bismuth	mg/kg ww	0.000	0.002
Boron	mg/kg ww	0.0	2.0
Cadmium	mg/kg ww	0.020	0.030
Calcium	mg/kg ww	7,503	10,575
Cesium	mg/kg ww	0.000	0.095
Chromium	mg/kg ww	0.65	2.00
Cobalt	mg/kg ww	0.125	0.300
Copper	mg/kg ww	0.930	1.113
Gallium	mg/kg ww	0.000	0.004
Iron	mg/kg ww	30	43
Lead	mg/kg ww	0.00	0.02
Lithium	mg/kg ww	0.031	0.056
Magnesium	mg/kg ww	349	426
Manganese	mg/kg ww	9.23	12.60
Mercury	mg/kg ww	0.033	0.085
Molybdenum	mg/kg ww	0.00	0.05
Nickel	mg/kg ww	0.913	1.420
Phosphorus	mg/kg ww	5,723	7,338
Potassium	mg/kg ww	3,260	3,365
Rhenium	mg/kg ww	0.000	0.002
Rubidium	mg/kg ww	5.82	6.83
Selenium	mg/kg ww	0.403	0.453
Silver	mg/kg ww	0.000	0.001
Sodium	mg/kg ww	1,083	1,198
Strontium	mg/kg ww	26.4	34.9
Tellurium	mg/kg ww	0.000	0.004
Thallium	mg/kg ww	0.004	0.005
Thorium	mg/kg ww	0.00000	0.00255
Tin	mg/kg ww	0.038	0.049
Titanium	mg/kg ww	0.0	0.4
Uranium	mg/kg ww	0.009	0.0167
Vanadium	mg/kg ww	0.20	0.20
Yittrium	mg/kg ww	0.000	0.003
Zinc	mg/kg ww	25.23	29.48
Zirconium	mg/kg ww	0.00	0.04

Source: *AEMP Reference Conditions Report Version 1.4 (Golder 2019b)*
ww = wet weight.

2.8 Quality Assurance/Quality Control

The field and laboratory quality assurance/quality control (QA/QC) procedures, as outlined by the *DDMI Quality Assurance Project Plan Version 3.1* (Golder 2017c), were implemented at each stage of the small-bodied fish survey. These QA/QC procedures were implemented to confirm that field sampling, data entry, data analysis, and report preparation produced technically sound and scientifically defensible results.

2.8.1 Field QA/QC Procedures

As part of practices for field operations for this program, the following QA/QC procedures were undertaken:

- Detailed specific work instructions outlining each field task were provided to the field personnel prior to the field programs.
- A pre-field meeting with the field crew and team lead was conducted to review the specific work instructions so that procedures were understood.
- Samples were collected by experienced personnel and were collected, labelled, preserved and shipped according to laboratory instructions and Golder TP 8.1-3, Fish Inventory Methods (Golder, unpublished information) and TP 8.16-0, Fish Health Assessment – Metals (Golder, unpublished information).
- Field equipment (i.e., electronic scales, water quality meter) were regularly calibrated according to manufacturer’s recommendations.
- Detailed field notes were recorded in pencil in waterproof field notebooks, on waterproof pre-printed field data sheets, or directly entered electronically into an excel spreadsheet.
- Field data (i.e., datasheets, notebook, and electronic spreadsheets) were checked at the end of the day for completeness and accuracy.

Samples were documented and tracked using chain-of-custody forms and receipt of samples by the analytical laboratory was confirmed. Field crews were responsible for managing sample shipping to the analytical laboratory. Prior to sample shipping, field crews confirmed the following:

- required samples were collected and accounted for
- chain-of-custody and analytical request forms were completed and correct
- proper bottle labelling and documentation procedures were followed

2.8.2 Quality Control Samples

The *Quality Assurance Project Plan Version 3.1* (Golder 2017c) required that 10% of the histology data be randomly selected and re-analyzed by an independent histologist. In addition, Golder performed multiple detailed screenings of the fish data, combined with examination of photographs received from the histology lab, to verify the quality of results.

Split samples were collected to determine inter-laboratory variability of mercury concentrations in fish tissue. Five tissue chemistry split samples were sent by ALS to Flett Research Ltd., Winnipeg, Manitoba.

Differences between concentrations measured in split tissue samples (i.e., ALS vs. Flett) were calculated as the relative percent difference (RPD) for each variable using the following formula:

RPD = (|difference in concentration between two of the split samples| / mean concentration) x 100

The RPD value for a given variable was considered notable if it was greater than 40% or if concentrations in one or both samples were greater than or equal to five times their respective DL. Inter-lab variability of split sample results was rated as:

- low, if less than 10% of the variables included in the duplicate sample analysis had notable RPD values
- moderate, if 10% to 30% of the variables included in the duplicate sample analysis had notable RPD values
- high, if greater than 30% of the variables included in the duplicate sample analysis had notable RPD values

2.8.3 Internal Laboratory QA/QC Procedures

Internal QA/QC procedures were undertaken by the laboratories performing analyses for the fish survey. ALS internal quality control samples included duplicates, laboratory blanks and reference materials that must be within ALS standard acceptable limits. ALS is an analytical laboratory accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA). Under CALA's accreditation program, performance evaluation assessments are conducted for laboratory procedures, methods, and internal QC. As a result, there was high confidence that the analytical data reported by ALS were reliable.

2.8.4 QA/QC of Field and Laboratory Data

Field-collected data, datasheets, and the field notebook were reviewed for completeness and unexpected values and trends. Upon receipt of stomach content data, a check was undertaken to determine if each sample submitted was analyzed and that the sum of percentages of taxon composition within each individual stomach was 100%.

Upon receipt of tissue chemistry data from ALS and Flett, standard checks were performed to screen for potential data quality issues as follows:

- confirm that each requested variable was analyzed
- comparison of method DLs to *AEMP Design Plan Version 4.1* (Golder 2017a)
- review of units
- review of any hold time exceedances
- comparison of split sample results (i.e., ALS vs. Flett)
- review of internal laboratory QA/QC results

Tissue chemistry laboratory results were summarized as mean and SD for each variable across samples. Samples were then standardized by subtracting the mean value from each data point and dividing by the SD. Samples for which the absolute standardized value for a variable was above 3.5 were sent for re-analysis as per Dohoo et al. (2009). If re-analysis confirmed the original analysis result, the original result was retained. Otherwise, a decision was made to keep the original result or the re-analyzed result based on which value was within range of the expected concentration. This decision process was documented for each revised laboratory result.

At least 10% of the data entered electronically were verified by a second person to identify transcription errors. Results of statistical data analyses were reviewed by an independent biologist with appropriate technical qualifications. Tables containing data summaries and statistical results were reviewed and values were verified by a second, independent individual.

2.9 Action Level Evaluation

The Action Levels for fish are presented in *AEMP Design Plan Version 4.1* (Golder 2017a), with consideration of the WLWB 25 March 2019 Decision Letter which directed DDMI to compare to the reference condition instead of the FF areas in the 2019 AEMP Annual Report. Small-bodied fish health data from 2019 were compared to these Action Levels to identify possible toxicological Mine effects on Slimy Sculpin at Lac de Gras. The detailed Action Levels are provided in the results (Section 3.5).

2.10 Weight-of-Evidence Input

The results of the fish health survey were integrated through the weight-of-evidence (WOE) analysis to determine the strength of evidence supporting the two broad impact hypotheses for Lac de Gras (i.e., nutrient enrichment and toxicological impairment) as described in the *AEMP Design Plan Version 4.1* (Golder 2017a). The WOE is not intended to determine the ecological significance or level of concern associated with a given change. The WOE analysis and methods as applied to fish health are described in Section 2 of the Weight-of-Evidence Report (Appendix XV).

3 RESULTS

3.1 Supporting Environmental Information

3.1.1 Field Measurements

In situ water quality measurements were collected during each fish sampling effort at the five sampling areas from 28 August to 16 September 2019. With the exception of greater specific conductivity at the NF area and lesser specific conductivity at the FF1 area, mean specific conductivity, temperature, dissolved oxygen, and pH were similar among areas (Table 3-1; Attachment C).

Table 3-1 Mean Water Quality Data Collected During the Fish Survey, Averaged Across Sampling Efforts by Area, 28 August to 16 September 2019

Area	Sample size	Depth (m)	Water temperature (°C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	Specific conductivity (µS/cm)	pH
NF	12	0.25	9.5	11.0	96.3	47.2	6.2
FF2	6	0.30	9.9	12.1	106.6	34.6	6.3
MF3	7	0.36	9.2	11.2	97.2	37.8	6.4
FF1	16	0.28	9.2	11.6	100.4	29.2	5.9
FFA	9	0.22	8.8	11.5	98.9	38.2	6.0

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

3.1.2 Seasonal Water Temperature

Water temperature profiles, as recorded by *in situ* data loggers between 4 May and 16 September 2019, followed expected seasonal trends in each area (Figure 3-1). Overall, water temperatures were similar between sampling areas. Water temperatures increased gradually from <1°C in early May to 6°C at the end of June. Despite a dip in temperature in early July, water temperatures increased quickly throughout the remainder of the month, reaching 14°C by the end of July. Water temperatures gradually declined to 10°C by early September.

Despite some variability in temperature logger deployment depths across the sampling areas (Section 2.5.1), water temperatures recorded by the loggers were similar to temperatures recorded by hand-held YSI units during fishing. No consistent bias was observed in the temperatures (i.e., areas where the temperature loggers were deployed at deeper sites did not consistently have colder temperatures; Figure 3-2). This suggests that it is valid to compare water temperatures across areas.

In late June and early July, NF temperature was up to 3.5°C lower than the mean FF1-FFA values, while MF temperatures were 1°C to 2°C cooler than the mean FF1-FFA values during the same period (Figure 3-2). Water temperatures at NF and MF spiked 3 to 4°C higher than the mean FF1-FFA values in late July.

Figure 3-1 Mean Daily Water Temperature in Lac de Gras, May 4 to September 16, 2019

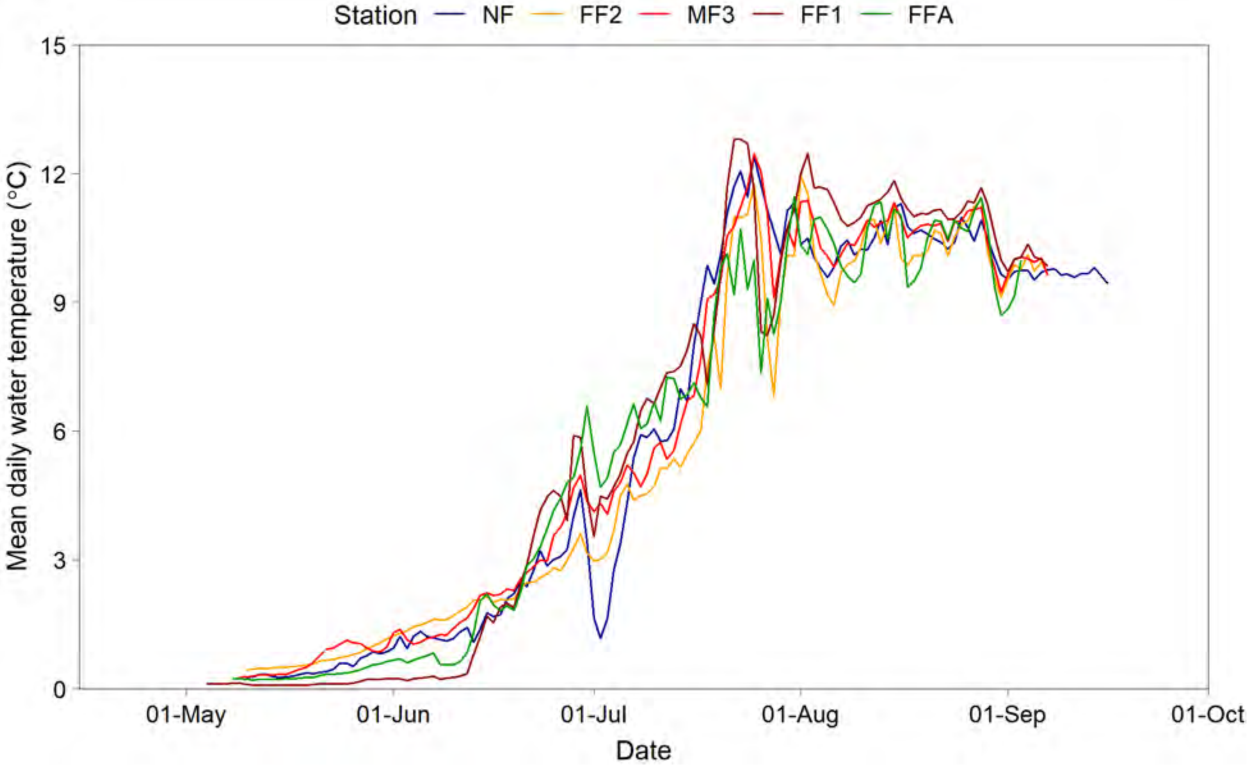
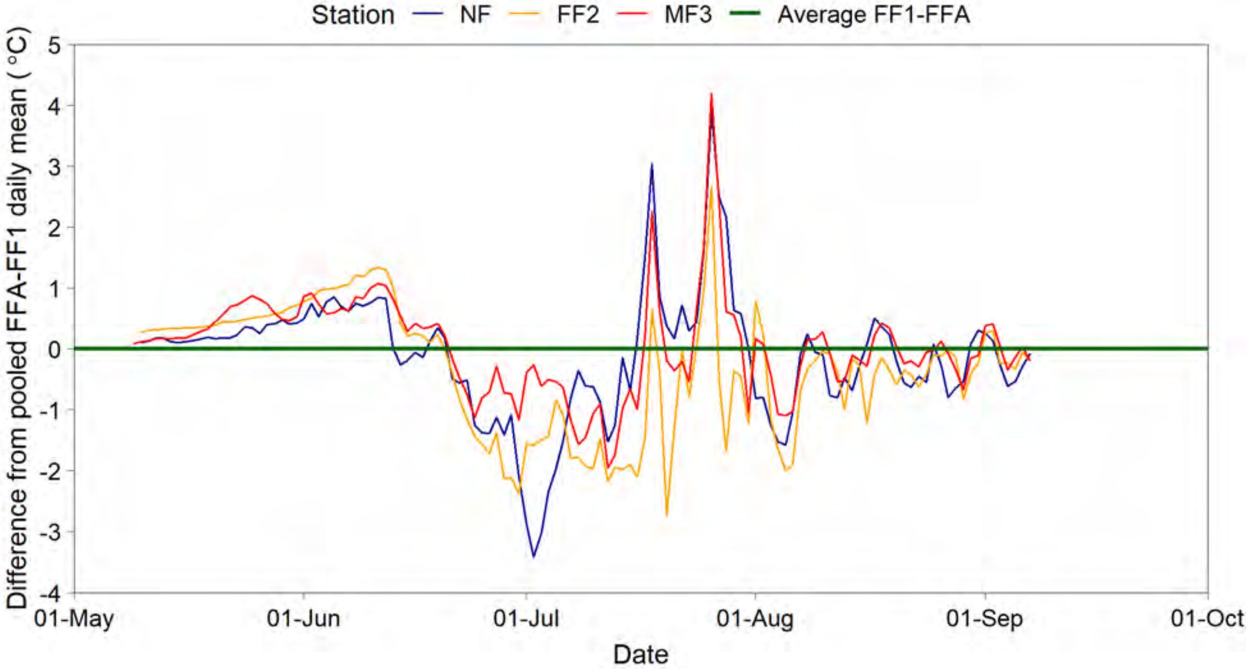


Figure 3-2 Difference between NF and MF Area Temperatures Relative to the FF Areas



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

3.2 Relative Abundance

A total of 110 Slimy Sculpin were captured during the relative abundance survey. Slimy Sculpin were of similar size among sampling areas, with mean total lengths ranging from 51.3 mm to 55.6 mm, and mean total weights ranging from 1.33 g to 1.91 g (Table 3-2). The relative abundance of Slimy Sculpin (standardized by CPUE) was similar among sampling areas, ranging from 0.020 fish/100 s effort at MF3 to 0.022 fish/100 s effort at FF2 (Table 3-3). Length-frequency distributions were also similar among sampling areas, with a range of sizes of fish captured in similar numbers, suggesting that sampling efficacy was not biased towards a specific size class (e.g., larger fish; Figure 3-3). The occurrence of parasites was also similar among sampling areas, with parasitized fish observed across a range of fish sizes, suggesting the rate of parasitism did not increase with fish size.

Table 3-2 Summary Statistics of Slimy Sculpin Captured during the Relative Abundance Survey in Lac de Gras, 2019

Station	N	N infected with adult tapeworms	Total length (mm)		Total weight (g)		Condition	
			Mean	SD	Mean	SD	Mean	SD
NF	22	8	53.0	10.4	1.33	0.68	0.80	0.10
FF2	30	19	55.6	14.8	1.91	1.42	0.87	0.12
MF3	16	8	53.7	16.0	1.62	1.40	0.81	0.07
FF1	23	9	51.3	13.5	1.39	1.08	0.87	0.10
FFA	19	15	55.4	8.9	1.52	0.68	0.83	0.11

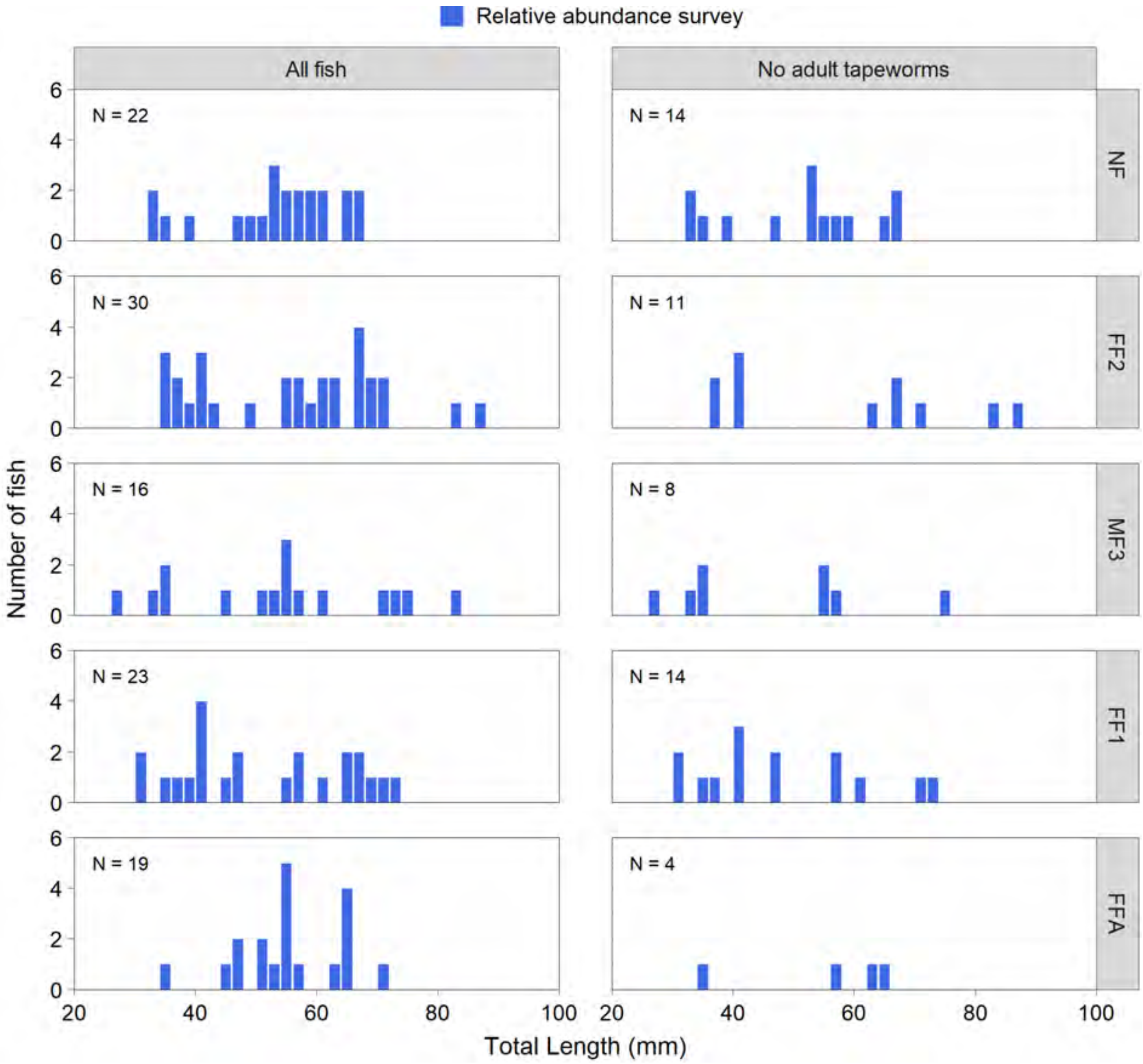
NF = near-field; MF = mid-field; FF = far-field.

Table 3-3 Catch per unit effort (CPUE) based on Relative Abundance Survey Data

Station	CPUE (N fish / 100 seconds of electrofishing)
NF	0.022
FF2	0.022
MF3	0.020
FF1	0.020
FFA	0.022

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

Figure 3-3 Length-Frequency Histograms for Slimy Sculpin Captured during the Relative Abundance Survey in Lac de Gras, 2019



N = sample size; NF = near-field; MF = mid-field; FF = far-field.

3.3 Fish Population Health

3.3.1 Fish Capture Data

In addition to Slimy Sculpin, several other species were captured during the fish health survey, including: Arctic Grayling (*Thymallus arcticus*), juvenile Burbot (*Lota lota*), Cisco (*Coregonus artedi*), Lake Chub (*Couesius plumbeus*), juvenile Lake Trout (*Salvelinus namaycush*), Ninespine Stickleback (*Pungitius pungitius*), and juvenile Round Whitefish (*Prosopium cylindraceum*; Table 3-4). Raw catch data, including fish lengths and weights, are provided in Attachment D. Overall, relative abundance of Slimy Sculpin (standardized by CPUE) was similar among sampling areas, with the greatest CPUE for Slimy Sculpin and all species combined observed at FF2, and the least CPUE at FF1.

When Slimy Sculpin fish were separated by sex / maturity (for lethally sampled fish only), the CPUE values for Age-1+ and adult male groups were generally similar within each sampling location (Table 3-5). CPUE values for adult female fish were generally smaller within each sampling location than either Age-1+ or adult male CPUE.

Table 3-4 Catch per Unit Effort (N Fish/100 Seconds of Electrofishing) for Fish Captured in Lac de Gras, 2019

Catch	Sampling effort (s)	Arctic Grayling		Burbot		Cisco		Lake Chub		Lake Trout		Ninespine Stickleback		Round Whitefish		Slimy Sculpin(a)		All species			
		N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE	Without Sculpin		With Sculpin	
																		N	CPUE	N	CPUE
NF	44,077	0	0	2	0.005	0	0	0	0	16	0.036	0	0	1	0.002	279	0.633	19	0.043	298	0.676
FF2	34,574	0	0	7	0.020	1	0.003	0	0	15	0.043	2	0.006	0	0	256	0.740	25	0.072	281	0.813
MF3	55,181	1	0.002	5	0.009	2	0.004	1	0.002	15	0.027	2	0.004	1	0.002	252	0.457	27	0.049	279	0.506
FF1	73,671	0	0	4	0.005	0	0	0	0	8	0.011	1	0.001	0	0	218	0.296	13	0.018	231	0.314
FFA	59,784	0	0	0	0	0	0	0	0	7	0.012	0	0	0	0	334	0.559	7	0.012	341	0.570

a) Total numbers include lethally and non-lethally sampled Slimy Sculpin, and both infected and non-infected fish, but do not include fish captured in the relative abundance survey.
N = sample size; CPUE = catch per unit effort; NF = near-field; MF = mid-field; FF = far-field; s = seconds.

Table 3-5 Catch per Unit Effort (N Fish/100 Seconds of Electrofishing) by Sex and Maturity for Slimy Sculpin in Lac de Gras, 2019

Catch	Sampling effort (s)	Sex / Maturity					
		Age-1+		Adult - male		Adult - female	
		N	CPUE	N	CPUE	N	CPUE
NF	44,077	29	0.066	30	0.068	21	0.048
FF2	34,574	35	0.101	32	0.093	17	0.049
MF3	55,181	34	0.062	33	0.060	17	0.031
FF1	73,671	36	0.049	29	0.039	21	0.029
FFA	59,784	32	0.054	38	0.064	23	0.038
Total	**267,287**	166	0.062	162	0.061	99	0.037

a) Total numbers include only lethally sampled Slimy Sculpin, and only non-infected fish, and do not include fish captured in the relative abundance survey.
N = sample size; CPUE = catch per unit effort; NF = near-field; MF = mid-field; FF = far-field; s = seconds.

3.3.2 Sample Size

A total of 1,339 Slimy Sculpin were captured during the combined relative abundance and fish health surveys in 2019 (Table 3-6). Of these fish, 645 were determined to be either infected with adult tapeworms or had an unknown infection status 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 total weight, examined for external abnormalities, and released back in the area from which they were captured. This included YOY fish from the NF (N=1) and MF3 (N = 4). Raw Slimy Sculpin survey data are provided in Attachment D.

Table 3-6 Total Number of Slimy Sculpin Sampled During the 2019 Fish Survey

Area	Fish Health Assessment							Total
	Lethal[a]					Non-lethal[c]		
	YOY	Age-1+	Male	Female	Excluded from analysis[b]	Uninfected fish	Infected fish	
NF	2	29	30	21	0	30	167	279
FF2	0	35	32	17	1	68	103	256
MF3	3	34	33	17	0	96	69	252
FF1	1	36	29	21	0	33	98	218
FFA	0	32	38	23	0	33	208	334
Total	**6**	**166**	**162**	**99**	**1**	**260**	**645**	**1,339**

a) Only uninfected fish were enumerated under the lethal assessment.
b) Adult fish whose sex or age could not be determined and that were not used for analysis.
c) Tapeworm presence as determined by either external (distended abdomen) or internal (tapeworm in body cavity) assessment.
NF = near-field; MF = mid-field; FF = far-field; YOY = young-of-the-year.

3.3.3 Assessment of Abnormalities

A total of 1,339 Slimy Sculpin were assessed externally during non-lethal and lethal assessments (Attachment E). Of the 1,339 fish to undergo an external assessment, 169 external abnormalities were observed (Table E1). These abnormalities consisted of mild skin aberrations (N = 7), mild thymus inflammation (N = 38), pale gills (N = 54), marginate gills (N = 3) or frayed gills (N = 2), fin erosion that was light (N = 33), moderate (N = 2) or severe (N = 2), and vent inflammation that was light (N = 21) or moderate (N = 2). The prevalence of external abnormalities was similar among sampling areas (Table E1).

Of the 1,339 fish captured, 434 fish were free of adult tapeworms and were dissected and assessed internally (i.e., all lethally assessed fish from Table 3-5). A total of 130 internal abnormalities were observed in lethally sampled fish (Table E2). These abnormalities consisted of livers that were discoloured (i.e., focal discolouration, N = 2; general discolouration, N = 2), or a combination of a granular appearance, enlarged size and/or focal discoloration (N = 5), and spleens that were enlarged (N = 4), granular (N = 1), nodular (N = 1) or a combination of focal discoloration and granular appearance (N = 2), kidneys that were mottled (N = 19), swollen (N = 21), or discolored (N = 2). A total of 222 livers were classified as cream-coloured; however, this was considered normal and was not reported as an abnormality (Table E-2). Similar abnormalities were observed at all sampling areas and, in general, the proportions of internal abnormalities observed at NF and MF were comparable to the FF areas.

3.3.4 Parasites

During the 2019 fish survey external examinations, one external parasite (i.e., leech) was observed on Slimy Sculpin. Parasitic tapeworms were observed in 538 Slimy Sculpin during the external assessment (Photo 2-3, Table 3-7), with an additional 97 infected fish identified during the internal assessment, for a total of 635. Parasite status was not determined in 10 non-lethal samples. The proportion of infected fish was largest at FFA (62%), and least at MF3 (27%); overall, 48% of fish were infected with tapeworms (Table 3-7). The proportion of Slimy Sculpin infected with adult tapeworms was not significantly greater at NF compared to the combined FF areas (Table 3-7, Table 3-8). However, the incidence of parasitism at both FF2 and MF3 was significantly different relative to the FF areas, with a difference in incidence of 17.6% and 28.0%, respectively (Table 3-8).

Table 3-7 Number of Slimy Sculpin, by Sampling Area Infected with Adult Tapeworms, in Lac de Gras, 2019

Group	NF	FF2	MF3	FF1	FFA	TOTAL
Uninfected	112	153	183	120	126	694
Infected[(a)]	167	93	69	98	208	635
Not assessed	0	10	0	0	0	10
Percent infected[(b)]	60%	38%	27%	45%	62%	48%

a) As determined by either external (distended abdomen) or internal (tapeworm in body cavity) assessment.

b) Values do not include fish with unknown parasite status.

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

Table 3-8 Proportion of Slimy Sculpin Infected with Adult Tapeworms from Lac de Gras, 2019

Variable	Statistical Test	Area	NF vs. FF		FF2 vs. FF		MF3 vs. FF		FF1 vs FFA	
		P	*P*	%	*P*	%	*P*	%	*P*	%
Proportion of Slimy Sculpin infected by adult tapeworms	Chi-square	**<0.001**	0.690	4.5	**<0.001**	-17.6	**<0.001**	-28.0	**<0.001**	-17.3

Notes: statistically significant (*P*<0.1) results are shown in bold. The percent magnitude of the difference between sampling areas are the absolute differences between the proportion of Slimy Sculpin infected with adult tapeworms. *P*-values for comparison between areas were adjusted using the Dunn-Šidák method for four comparisons.

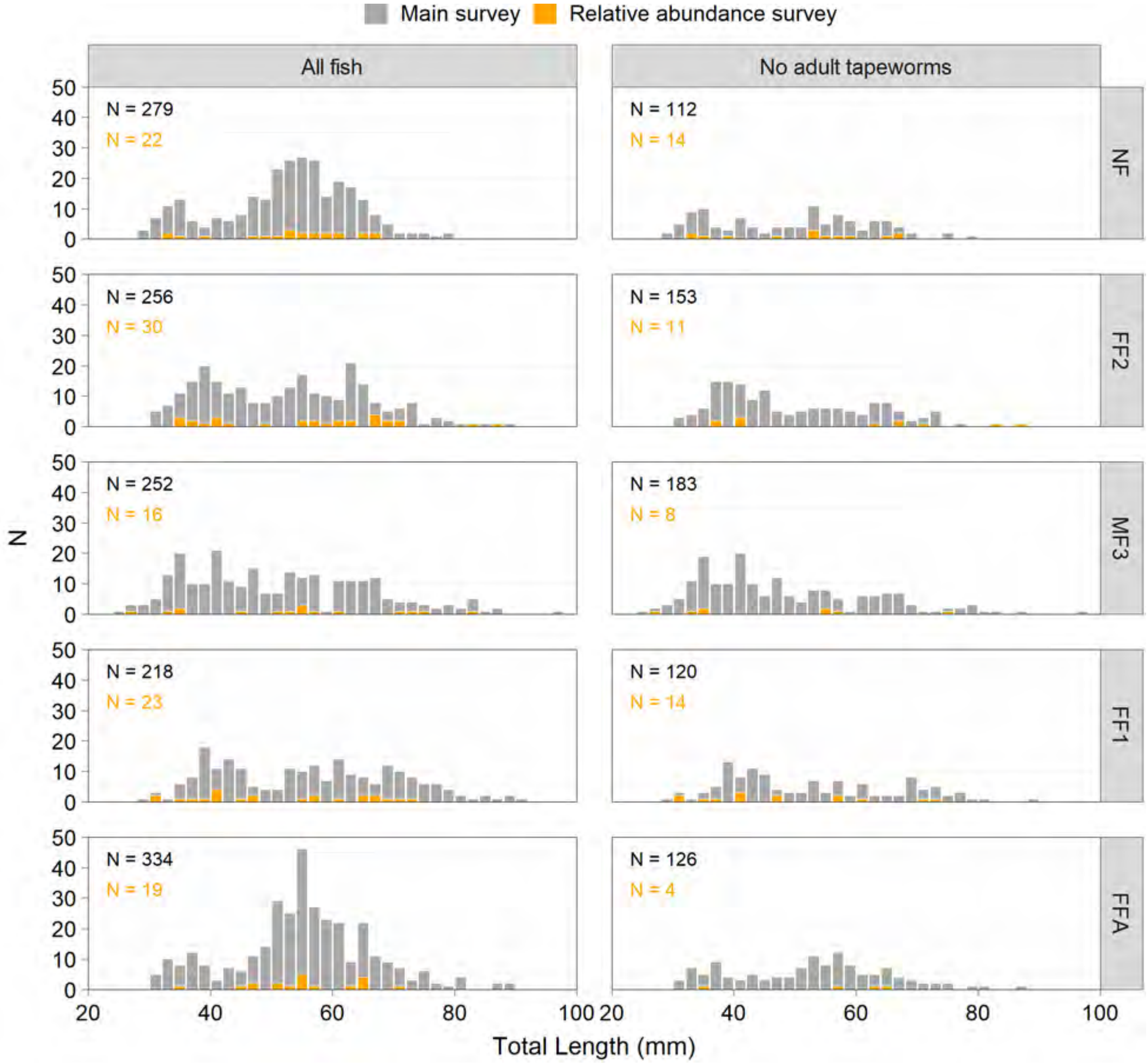
P = *P*-value or statistical probability; NF = near-field; MF = mid-field; FF = far-field.

3.3.5 Age

As described in Section 2.7.2.1, surrogates for age were developed as detailed in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c). A total of 24 fish had total lengths near their respective size at maturity value (ranging from 15.2 mm below the cut-off to 3.8 mm above the cut-off) and were categorized as age-1+ in the field/lab assessment. These fish were also assigned “immature” gonad maturity codes by the histopathologist. Therefore, while the size at maturity procedure detailed in Section 2.7.2.1 indicated these fish should be assigned to the “age-2+” category, the proximity of their lengths to the size at maturity value and the other lines of physical evidence (i.e., fish assessments and gonad histopathology) suggested they were actually age-1+ fish; these fish were, therefore, recategorized.

The 2019 length-frequency histograms did not have sufficiently distinct modes to confidently distinguish fish ages based on length (Figure 3-4); therefore, statistical comparisons of Slimy Sculpin age were not completed.

Figure 3-4 Length-Frequency Histograms by Parasite Incidence and Survey Type for Slimy Sculpin Captured in Lac de Gras, 2019



N = sample size; NF = near-field; MF = mid-field; FF = far-field.

3.3.6 Relative Reproductive Success

Relative reproductive success was assessed by observing the relative abundance of immature fish (i.e., YOY and age-1+) among sampling areas (Environment Canada 2012). A total of 11 YOY Slimy Sculpin were captured during the fish health survey, including 3 from NF, 7 from MF3, and 1 from FF1. The relatively small catch of YOY suggests that YOY were likely too small to be effectively captured electrofishing in the study area. Age-1+ fish were comparatively abundant (i.e., catch numbers ranged from 29 to 36) among the sampling areas (Table 3-6; Figure 2-2). Given the similar relative abundance of immature Slimy Sculpin among sampling areas, reproductive success was considered similar among the NF, MF and FF areas. Among each of the areas sampled, fish gonads appeared healthy and no abnormalities were observed.

3.3.7 Length-Frequency Analysis

The length-frequency distributions of Slimy Sculpin (i.e., uninfected fish only) among sampling areas were compared using two-sample KS tests (Table 3-9, Figure 3-4 and Figure 3-5), and there were no statistically significant differences. The length-frequency distributions indicated that FF1 had relatively few small (i.e., <40 mm) fish compared to the other areas, while FFA had relatively few intermediate-sized (i.e., 40-55 mm) fish and FF1 had relatively few large (i.e., 60-80 mm) fish compared to the other areas (Figure 3-5). At NF and MF3, there was a high proportion of small fish (<40 mm) compared to both FFA and FF1.

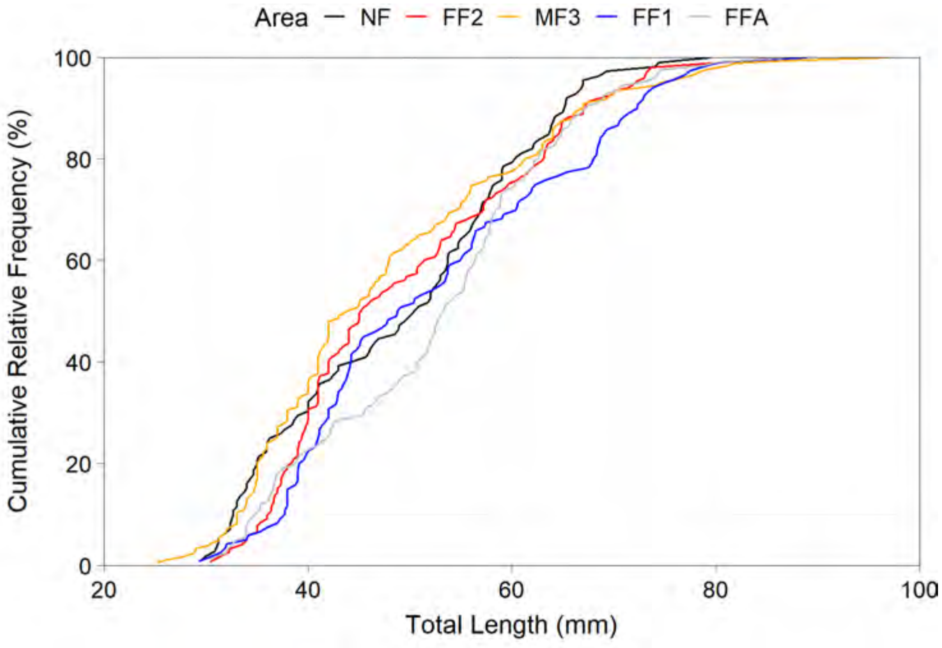
Table 3-9 Two-Sample Kolmogorov-Smirnov Test of Length-Frequency Distributions in Slimy Sculpin from Lac de Gras, 2019

Variable	Two-Sample Kolmogorov-Smirnov *P*-values						
	NF vs. FF		FF2 vs. FF		MF3 vs. FF		FF1 vs. FFA
	FF1	FFA	FF1	FFA	FF1	FFA	
Length	0.495	1.000	0.919	0.994	0.948	1.000	0.575

Notes: Statistically significant (*P*<0.1) results are shown in bold. *P*-values for comparison between areas were adjusted using the Dunn-Šidák method for seven comparisons.

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

Figure 3-5 Cumulative Length-Frequency Plots for Slimy Sculpin Captured in Lac de Gras, 2019



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

3.3.8 Size

Age-1+ Slimy Sculpin ranged in length from 30.3 to 48.9 mm, ranged in total weight from 0.212 to 0.931 g, and ranged in carcass weight from 0.132 to 0.795 g (Table 3-10). Age-1+ fish captured from the NF and MF areas were similar in total length, total weight and carcass weight to age-1+ fish captured from the FF areas (Table 3-11). Total length, total weight and carcass weight were significantly different between the FF areas, with fish captured from FF1 being longer and heavier than fish sampled from FFA. The statistical power to detect differences between the sampling areas for fixed effect sizes of 10%, 20% or 30% for length, total weight and carcass weight for age-1+ fish was good (i.e., power ranged from 0.950 to 1.000; Table 3-11).

Adult male Slimy Sculpin ranged in length from 45.5 to 87.0 mm, ranged in total weight from 0.687 to 6.183 g, and ranged in carcass weight from 0.535 to 4.885 g (Table 3-10). Male fish captured from the NF and MF areas were similar in length, total weight and carcass weight to male fish captured from the FF areas (Table 3-11). Total weight was significantly different between the FF areas, with fish captured from FF1 31% heavier than fish from FFA. The statistical power to detect differences between the sampling areas for fixed effect sizes of 10%, 20% or 30% for length, total weight and carcass weight for male fish was good (i.e., power ranged from 0.745 to 1.000; Table 3-11).

Adult female Slimy Sculpin ranged in length from 41.1 to 81.1 mm, ranged in total weight from 0.499 to 3.848 g, and ranged in carcass weight from 0.368 to 3.202 g (Table 3-10). Female fish captured from the NF and MF3 areas were significantly smaller than fish captured from the FF areas for total length (i.e., NF = -8%, MF3 = -12%) and total weight (i.e., NF = -23%, MF3 = -25%; Table 3-11), while only MF3 had significantly smaller carcass weight relative to the FF areas (i.e., -21%). There were no significant differences observed between the NF and FF areas for carcass weight, and there were no significant differences in adult female length or weight between the FF areas (i.e., FF1 and FFA). The statistical power to detect differences between the sampling areas for fixed effect sizes of 10%, 20% or 30% for length, total weight and carcass weight for adult female fish was good (i.e., power ranged from 0.815 to 1.000; Table 3-11).

Table 3-10 Summary Statistics of Raw Data of Slimy Sculpin from Lac de Gras, 2019

Stage/Sex	Variable	NF							FF2							MF3							FF1							FFA						
		N	Min	Mean	Median	Max	SD	SE	N	Min	Mean	Median	Max	SD	SE	N	Min	Mean	Median	Max	SD	SE	N	Min	Mean	Median	Max	SD	SE	N	Min	Mean	Median	Max	SD	SE
Age-1+	Total length (mm)	30	30.9	37.1	35.5	48.9	5.2	1.0	37	31.6	39.8	39.4	47.7	4.1	0.7	36	30.6	39.3	40.2	48.3	5.6	0.9	36	30.5	41.6	42.8	48.7	4.2	0.7	32	30.3	36.9	36.2	46.4	4.4	0.8
	Total weight (g)	30	0.239	0.414	0.344	0.904	0.173	0.032	37	0.262	0.494	0.435	0.907	0.159	0.026	36	0.212	0.491	0.463	0.863	0.195	0.032	36	0.254	0.568	0.577	0.931	0.167	0.028	32	0.233	0.394	0.339	0.702	0.144	0.026
	Carcass weight (g)	29	0.175	0.328	0.264	0.724	0.148	0.027	35	0.203	0.386	0.339	0.655	0.128	0.022	35	0.154	0.389	0.363	0.795	0.182	0.031	34	0.187	0.453	0.463	0.744	0.135	0.023	32	0.132	0.305	0.268	0.572	0.124	0.022
	Condition	30	0.60	0.80	0.80	1.00	0.10	0.01	37	0.70	0.80	0.80	1.00	0.10	0.01	36	0.70	0.80	0.80	1.10	0.10	0.01	36	0.70	0.80	0.80	0.90	0.10	0.01	32	0.60	0.80	0.70	0.90	0.10	0.02
	LSI (%)	28	1.60	2.70	2.60	4.60	0.80	0.10	33	0.60	2.50	2.60	3.90	0.80	0.10	34	1.80	2.90	2.80	6.80	0.90	0.20	34	1.10	2.60	2.60	5.10	0.90	0.20	31	1.10	2.70	2.60	5.40	1.00	0.20
Adult male	Total length (mm)	30	50.0	60.4	59.6	79.5	6.8	1.2	31	46.3	60.6	60.9	78.0	7.5	1.3	32	47.7	62.4	62.0	87.0	9.2	1.6	29	48.8	61.4	60.7	80.7	9.1	1.7	38	45.5	58.0	57.3	87.0	8.4	1.4
	Total weight (g)	30	0.822	1.866	1.633	4.292	0.777	0.142	31	0.806	1.943	1.889	3.823	0.781	0.140	32	0.687	2.172	1.869	6.183	1.138	0.201	29	0.859	2.146	1.903	5.338	1.117	0.207	38	0.722	1.613	1.392	5.243	0.896	0.145
	Carcass weight (g)	30	0.684	1.515	1.330	3.536	0.631	0.115	31	0.670	1.562	1.482	3.170	0.643	0.116	32	0.535	1.700	1.455	4.885	0.903	0.160	29	0.691	1.724	1.508	4.433	0.937	0.174	38	0.570	1.319	1.111	4.322	0.738	0.120
	Condition	30	0.50	0.70	0.70	0.70	0.10	0.01	31	0.60	0.70	0.70	0.80	0.10	0.01	32	0.50	0.60	0.60	0.80	0.10	0.01	29	0.50	0.70	0.70	0.80	0.10	0.02	38	0.50	0.60	0.60	0.80	0.10	0.01
	LSI (%)	30	1.30	2.40	2.30	4.40	0.70	0.10	31	1.20	2.90	3.00	5.80	0.90	0.20	32	1.60	3.00	3.00	5.30	0.90	0.20	29	1.50	3.90	2.90	15.30	2.90	0.50	38	0.70	2.30	2.10	5.20	1.10	0.20
	GSI (%)	30	1.00	2.00	1.90	3.10	0.50	0.10	31	0.30	1.60	1.80	2.70	0.60	0.10	32	0.30	1.80	1.90	2.70	0.60	0.10	29	0.50	1.90	1.90	2.50	0.40	0.10	38	0.20	1.50	1.60	3.00	0.60	0.10
Adult female	Total length (mm)	20	46.2	56.0	54.2	74.5	7.7	1.7	16	48.2	56.4	56.6	64.7	5.0	1.2	16	41.1	55.6	53.6	81.1	8.8	2.2	21	47.8	61.3	60.5	73.4	7.2	1.6	23	46.8	59.3	58.0	78.8	8.2	1.7
	Total weight (g)	20	0.728	1.465	1.175	3.440	0.731	0.163	16	0.817	1.455	1.362	2.200	0.375	0.094	16	0.499	1.409	1.234	3.848	0.732	0.183	21	0.881	1.899	1.701	3.355	0.701	0.153	23	0.785	1.686	1.359	3.830	0.798	0.166
	Carcass weight (g)	20	0.596	1.182	0.943	2.723	0.582	0.130	16	0.606	1.174	1.081	1.729	0.316	0.079	16	0.368	1.126	0.980	3.178	0.619	0.155	21	0.656	1.495	1.357	2.596	0.554	0.121	23	0.616	1.355	1.112	3.202	0.651	0.136
	Condition	20	0.50	0.60	0.60	0.70	0.10	0.01	16	0.50	0.60	0.60	0.80	0.10	0.02	16	0.50	0.60	0.60	0.80	0.10	0.02	21	0.50	0.60	0.60	0.70	0.10	0.01	23	0.50	0.60	0.60	0.80	0.10	0.02
	LSI (%)	20	1.40	3.00	2.70	5.00	1.00	0.20	16	1.90	3.10	2.90	5.40	1.00	0.20	16	1.70	3.10	2.90	5.00	0.80	0.20	21	2.20	4.50	4.50	7.40	1.30	0.30	23	1.80	3.20	2.80	6.80	1.20	0.30
	GSI (%)	19	0.60	1.90	2.00	3.00	0.70	0.20	16	1.10	1.80	2.00	2.60	0.50	0.10	16	0.60	1.90	1.80	2.70	0.60	0.20	21	1.40	2.30	2.20	3.90	0.70	0.10	23	0.80	2.20	2.30	3.30	0.70	0.20

NF = near-field; MF = mid-field; FF = far-field; N = sample size; Min = minimum; Max = maximum; SD = standard deviation; SE = standard error; LSI = liversomatic index; GSI = gonadosomatic index.

Table 3-11 Results of ANOVAs of Variables Measured in Slimy Sculpin from Lac de Gras, 2019

Sex/ Stage	Variable	Test	Overall *P*-value	NF/ MF vs FF						FF		Power to detect difference		
				NF		FF2		MF3		FF1 vs FFA				
				P	%$^{(a)}$	*P*	%$^{(a)}$	*P*	%$^{(a)}$	*P*	%$^{(b)}$	10%	20%	30%
Age-1+	Total length (mm)	ANOVA	**<0.001**	0.098	-6.0	0.998	0.7	0.996	-0.8	**<0.001**	13.0	1.000	1.000	1.000
	Total weight (g)	K-W	**<0.001**	0.106	-25.0	0.999	-6.4	0.988	-6.5	**<0.001**	70.1	0.950	0.997	0.998
	Carcass weight (g)	ANOVA$_{log}$	**<0.001**	0.196	-17.2	0.997	0.2	0.989	-5.4	**<0.001**	51.8	0.991	0.998	1.000
Adult male	Total length (mm)	ANOVA	0.145	0.956	1.8	0.984	1.4	0.459	4.3	0.154	7.2	0.992	1.000	1.000
	Total weight (g)	ANOVA$_{log}$	**0.083**	0.985	3.7	0.949	5.4	0.579	12.3	**0.059**	31.4	0.819	0.956	0.997
	Carcass weight (g)	ANOVA$_{log}$	0.191	0.974	4.7	0.970	4.8	0.824	8.8	0.118	28.1	0.745	0.923	0.996
Adult female	Total length (mm)	ANOVA	**0.007**	**0.046**	-8.2	0.105	-7.7	**0.006**	-11.5	0.846	3.3	0.960	1.000	1.000
	Total weight (g)	ANOVA$_{log}$	**0.034**	**0.076**	-22.8	0.252	-19.4	**0.058**	-25.3	0.655	15.9	0.755	0.808	0.927
	Carcass weight (g)	K-W	**0.047**	0.134	-24.8	0.504	-13.1	**0.088**	-20.7	0.604	22.1	0.783	0.815	0.918

a) Percent difference between NF, FF2 or MF area mean and the FF area means.

b) Percent difference between the FF area means.

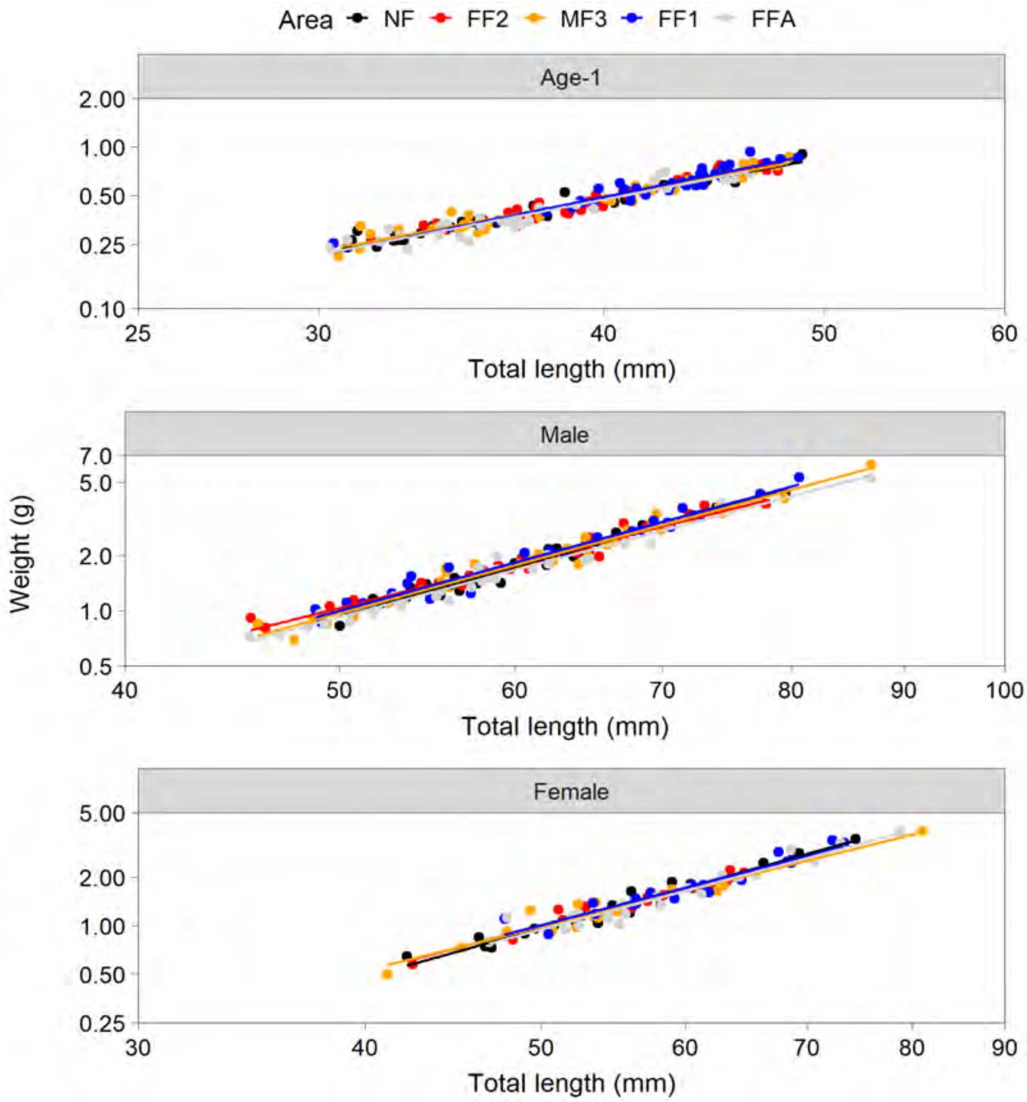
Note: Significant results (at the 0.1 level) are shown in bold.

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

3.3.9 Condition

Condition of age-1+ fish ranged from 0.6 to 1.1, and adult male and female condition both ranged from 0.5 to 0.8 (Table 3-10). No significant differences were observed in total body weight adjusted for length among sampling areas for age-1+ or adult female Slimy Sculpin (Figure 3-6; Table 3-12; Table 3-13). For male Slimy Sculpin, no significant differences were observed in total body weight adjusted for length between the NF and MF areas when compared to the FF areas; however significant differences were observed between the FF areas; condition of fish sampled from FF1 was 10% greater than FFA. The power to detect fixed effect sizes of 10%, 20% or 30% in condition for age-1+, male and female fish were good, and ranged from 0.985 to 1.000.

Figure 3-6 Log-Log Relationship between Weight and Total Length of Slimy Sculpin in Lac de Gras, 2019



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

Table 3-12 Least Squares Means (Model-Adjusted Means) and Standard Errors of Variables Analyzed by ANCOVA for Slimy Sculpin from Lac de Gras, 2019

Sex/ Stage	Variable	Mean covariate	NF			FF2			MF3			FF1			FFA		
			N	Mean(b)	SE(a)	N	Mean(b)	SE(a)	N	Mean(b)	SE(a)	N	Mean(b)	SE(a)	N	Mean(b)	SE(a)
Age-1+	Total body weight (g), adjusted for total length (mm) (c)	38.887	29	0.471	0.009	35	0.459	0.008	34	0.472	0.008	36	0.472	0.008	32	0.46	0.009
	Liver weight (g), adjusted for carcass weight (g) (c)	0.366	27	0.009	0.001	31	0.01	0.001	32	0.01	0.001	34	0.01	0.001	31	0.009	0.001
Adult male	Total body weight (g), adjusted for total length (mm) (c)	60.282	30	1.851	0.04	32	1.926	0.039	33	1.92	0.039	29	1.987	0.042	38	1.845	0.036
	Liver weight (g), adjusted for carcass weight (g) (c)	1.541	30	0.037	0.003	32	0.046	0.003	33	0.047	0.003	29	0.049	0.003	38	0.042	0.003
	Gonad weight (g), adjusted for carcass weight (g) (c)	1.541	30	0.039	0.001	32	0.034	0.001	33	0.037	0.001	29	0.036	0.001	38	0.033	0.001
Adult female	Total body weight (g), adjusted for total length (mm) (c)	57.494	21	1.611	0.046	17	1.563	0.051	17	1.564	0.054	21	1.58	0.047	23	1.534	0.044
	Liver weight (g), adjusted for carcass weight (g) (c)	1.258	21	0.041	0.003	17	0.04	0.003	17	0.04	0.003	21	0.059	0.003	23	0.04	0.003
	Gonad weight (g), adjusted for carcass weight (g)	1.263	20	0.034	0.002	17	0.031	0.002	17	0.032	0.002	21	0.037	0.002	23	0.036	0.002

a) SE values describe the standard error of the least squares mean value.
b) Least squares means and standard errors of log-transformed variables are presented on the log scale.
c) Both response variable and covariate were log-transformed.
NF = near-field; MF = mid-field; FF = far-field.

Table 3-13 Results of ANCOVA of Variables Measured in Slimy Sculpin from Lac de Gras, 2019

Sex/Stage	Variable	Interaction	Area(a)	Adjusted r^2		Covariate value	NF/MF vs FF						FF		Power to detect difference		
							NF		FF2		MF3		FF1 vs FFA				
				Full	Reduced		*P*(b)	%(c)	*P*(b)	%(c)	*P*(b)	%(c)	*P*(b)	%(d)	10%	20%	30%
Age-1+	Total body weight, adjusted for total length (mm) (e)	0.681	0.410	0.937	0.937	Mean	0.984	-0.1	0.937	0.3	0.953	1.2	0.785	3.4	0.999	1.000	1.000
	Liver weight (g) adjusted for carcass weight (g) (e)	0.260	0.281	0.548	0.544	Mean	1.000	2.0	0.999	0.3	0.889	13.4	0.998	1.9	0.805	0.981	1.000
Adult male	Total body weight, adjusted for total length (mm) (e)	0.314	**<0.001**	0.963	0.963	Mean	0.561	-0.7	0.999	3.1	1.000	1.2	**0.043**	10.0	1.000	1.000	1.000
	Liver weight (g) adjusted for carcass weight (g) (e)	0.097	**<0.001**	0.703	0.695	Mean	0.111	-15.6	1.000	5.4	0.991	6.5	0.348	37.6	0.983	1.000	1.000
	Gonad weight (g) adjusted for carcass weight (g) (e)	**0.003** (a)	**0.025**	0.800	0.784	Mean	**0.051**	12.1	0.986	-8.4	0.347	2.0	0.440	12.7	0.606	0.935	1.000
Adult female	Total body weight, adjusted for total length (mm) (e)	0.680	0.629	0.939	0.940	Mean	0.822	1.2	1.000	1.7	1.000	-1.7	0.921	4.9	0.985	1.000	1.000
	Liver weight (g) adjusted for carcass weight (g) (e)	0.166	**0.001**	0.784	0.778	Mean	**0.067**	-18.7	**0.070**	-17.4	**0.058**	-19.8	**<0.001**	41.1	0.963	0.980	0.995
	Gonad weight (g) adjusted for carcass weight (g)	0.492	0.267	0.835	0.836	Mean	0.795	-6.3	0.168	-15.5	0.357	-14.7	0.999	3.1	0.668	0.726	0.801

a) Regression slopes are considered practically similar (Barrett et al. 2009); ANCOVA proceeded.
b) probability of Type 1 Error, adjusted α of 0.026 (Dunn-Šidák method) for 4 comparisons.
c) percent difference between the NF, FF2 or MF area mean and FF area means, adjusted to mean covariate value.
d) Percent difference between the FF area means.
e) both response variable and covariate were log-transformed.
NF = near-field; MF = mid-field; FF = far-field.

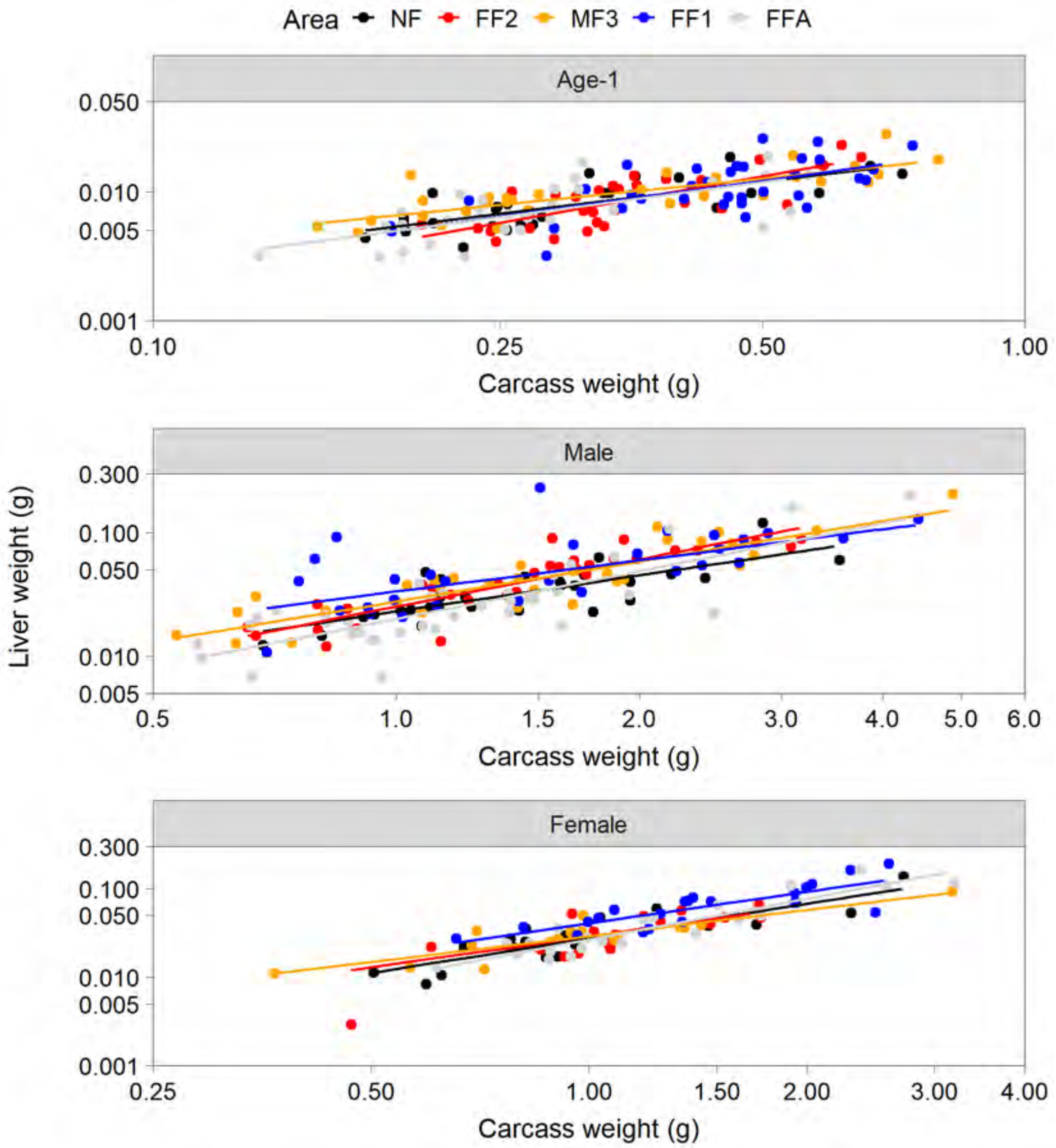
3.3.10 Relative Liver Size

The LSI for age-1+ fish ranged from 0.6 to 6.8 (Table 3-10). Liver weight adjusted for carcass weight was not significantly different among sampling areas for age-1+ fish (Figure 3-7; Table 3-12; Table 3-13). The statistical power to detect differences between areas for fixed effect sizes of 10%, 20% or 30% for age-1+ fish ranged from 0.805 to 1.000 (Table 3-13).

The LSI for male fish ranged from 0.7 to 15.3 (Table 3-10). While a statistical difference was detected among sampling areas for liver weight adjusted for carcass weight of male fish, no significant differences were observed among planned comparisons (Figure 3-7; Table 3-12; Table 3-13). The statistical power to detect differences between areas for fixed effect sizes of 10%, 20% or 30% for male fish ranged from 0.983 to 1.000 (Table 3-13).

The LSI for female fish ranged from 1.4 to 7.4 (Table 3-10). Liver weight adjusted for carcass weight was significantly different among sampling areas, with significantly smaller relative liver sizes for female fish sampled from NF (-19%), FF2(-17%), and MF3 (-20%) compared to the FF areas (Figure 3-7; Table 3-12; Table 3-13). Relative liver size was also significantly different between the FF areas, and was 41% greater at FF1 compared to FFA. The statistical power to detect differences between areas for fixed effect sizes of 10%, 20% or 30% for female fish was good, and ranged from 0.606 to 1.000 (Table 3-13).

Figure 3-7 **Relationship between Liver Weight and Carcass Weight of Slimy Sculpin in Lac de Gras, 2019**



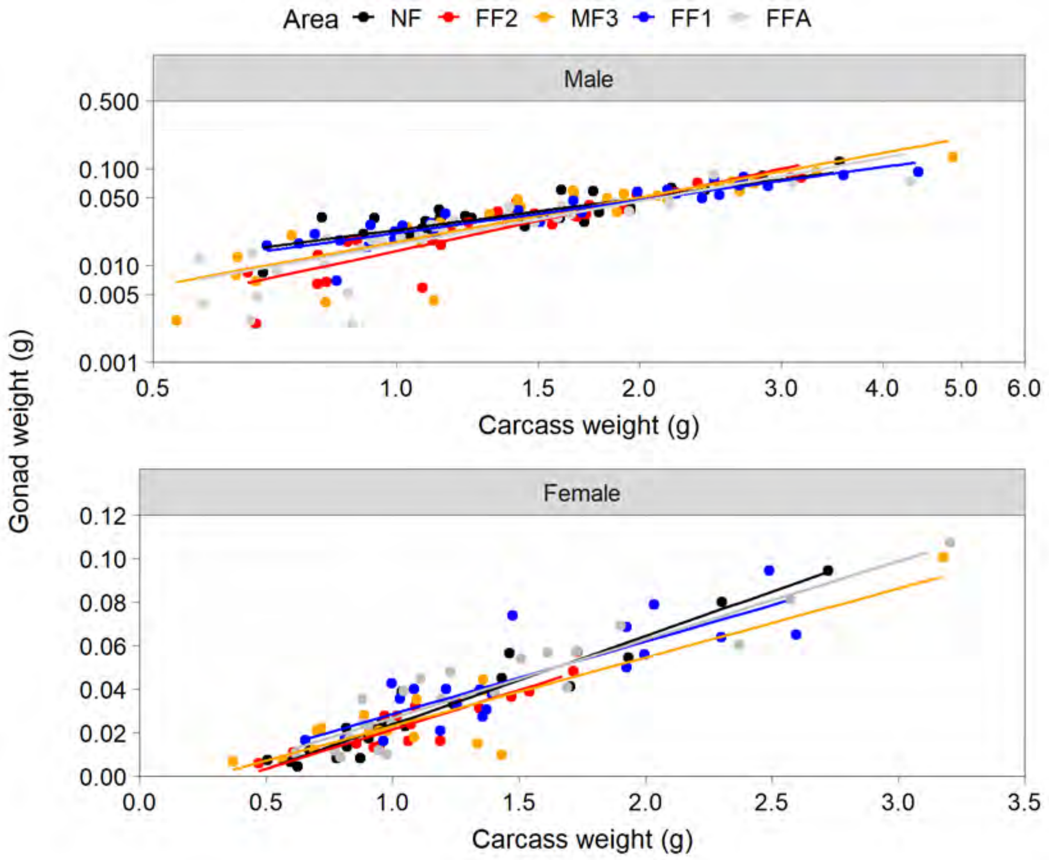
NF = near-field; MF = mid-field; FF = far-field.

3.3.11 Relative Gonad Size

The GSI for adult male fish ranged from 0.2 to 3.1 (Table 3-10), and gonad weight adjusted for carcass weight was 12% greater in male fish sampled from the NF when compared to the FF areas (Figure 3-8; Table 3-12; Table 3-13). No significant differences were observed among the MF and FF areas, and no significant differences were observed between the FF areas (i.e., FF1 and FFA). The statistical power to detect differences between areas for fixed effect sizes of 10%, 20% or 30% for male fish was good, and ranged from 0.606 to 1.000 (Table 3-13).

The GSI for adult female fish ranged from 0.6 to 3.9 (Table 3-10). No significant differences were observed in female gonad weight adjusted for carcass weight among sampling areas (Figure 3-8; Table 3-12; Table 3-13), and no significant differences were observed between the FF areas (i.e., FF1 and FFA). The statistical power to detect differences between areas for fixed effect sizes of 10%, 20% or 30% for female fish ranged from 0.668 to 0.801 (Table 3-13).

Figure 3-8 **Relationship between Gonad Weight and Carcass Weight of Slimy Sculpin in Lac de Gras, 2019**

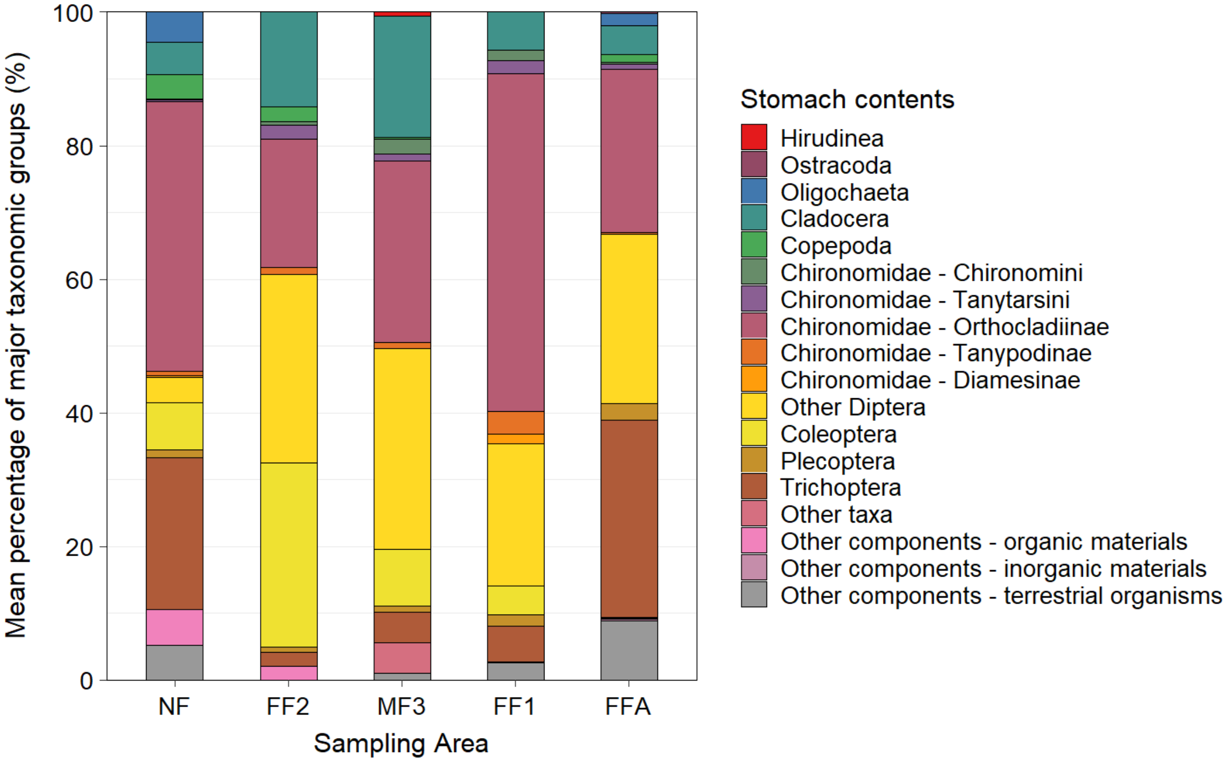


NF = near-field; MF = mid-field; FF = far-field.

3.3.12 Stomach Contents

A comparison of the major taxa present in Slimy Sculpin stomachs at the time of sampling is presented in Table 3-14 and Figure 3-9. Detailed stomach content results are presented in Attachment F. Chironomids (predominantly Orthocladiinae) were the dominant prey taxa observed in the stomachs of Slimy Sculpin at all sampling areas, while Diptera, Cladocera, Coleoptera and Trichoptera were also commonly present (Table 3-14; Attachment F). The number of taxa contained in individual fish stomachs ranged from 1 to 7, with the average number of taxa per area, sex and stage ranging from 2 to 4. Stomach contents were generally similar between the NF, MF and FF areas, with some variability observed in the relative abundance of Chironomidae, Coleoptera, Trichoptera and other Diptera. Hirudinea (i.e., leeches) were only observed in stomach contents at MF3, the same area where a single leech was observed during the external fish health assessment. No Ostracoda were observed in stomach contents of Slimy Sculpin in 2019.

Figure 3-9 Stomach Contents of Slimy Sculpin in Lac de Gras, 2019



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

Table 3-14 Stomach Contents of Slimy Sculpin Captured in Lac de Gras, 2019

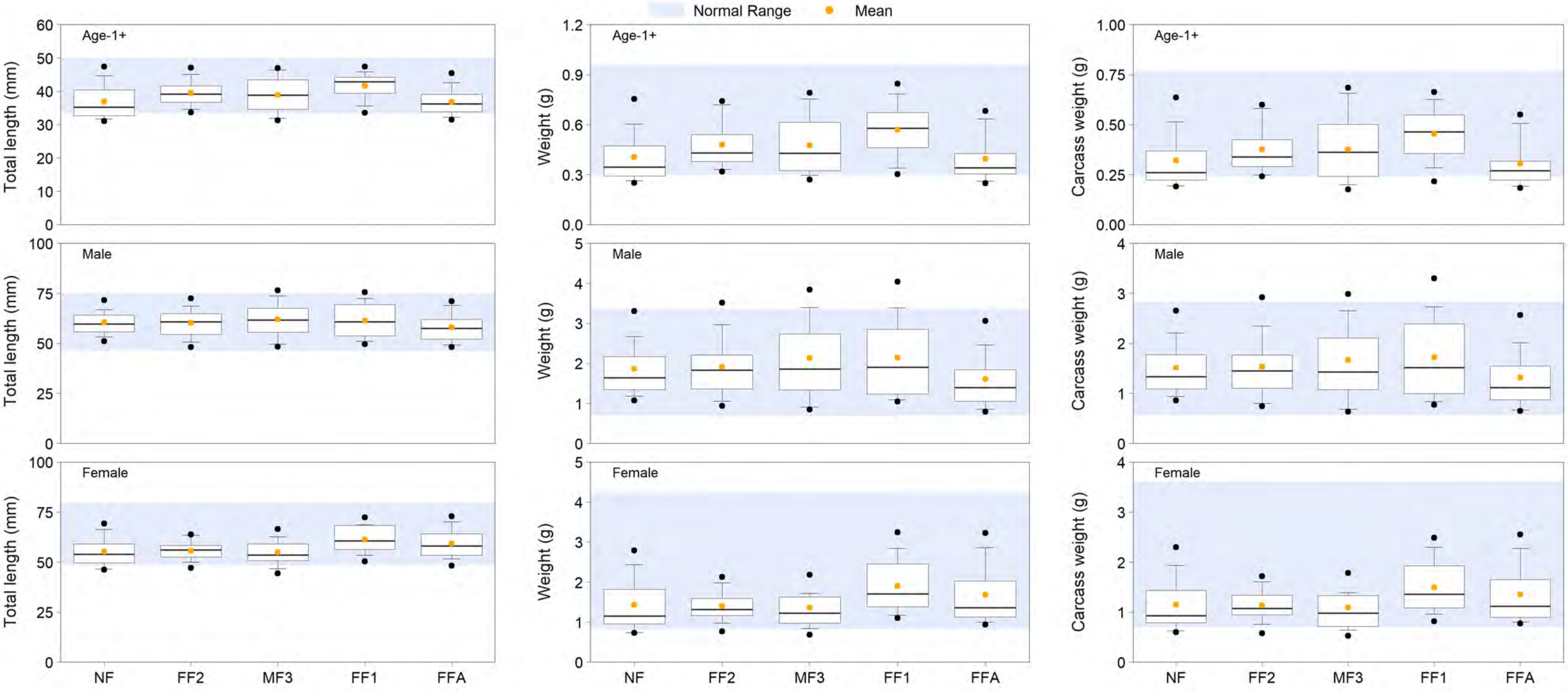
Stomach Contents	NF			FF2			MF3			FF1			FFA		
	Age-1+	**Male**	**Female**	**Age-1+**	**Male**	**Female**	**Age-1+**	**Male**	**Female**	**Age-1+**	**Male**	**Female**	**Age-1+**	**Male**	**Female**
Number of fish sampled	5	10	6	7	11	6	6	19	6	8	12	9	15	16	7
Aquatic Invertebrates															
Hirudinea (%)	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Ostracoda (%)	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0
Oligochaeta (%)	0	0	16	0	0	0	0	0	0	0	0	0	5	0	0
Cladocera (%)	1	8	3	4	13	28	23	20	8	0	12	2	5	6	0
Copepoda (%)	15	<1	0	1	0	8	2	0	0	0	0	0	3	0	0
Chironomidae - Chironomini (%)	0	1	0	0	0	2	0	2	6	0	4	0	0	0	1
Chironomidae - Tanytarsini (%)	0	1	0	1	4	0	2	1	2	1	3	2	1	0	3
Chironomidae - Orthocladiinae (%)	48	32	48	46	6	12	61	13	40	49	56	45	48	4	20
Chironomidae - Tanypodinae (%)	0	1	1	1	1	0	2	1	0	0	1	10	0	1	0
Chironomidae - Diamesinae (%)	0	1	0	0	0	0	0	0	0	4	1	1	0	0	0
Other Diptera (%)	2	7	0	27	35	17	11	46	0	17	16	32	13	24	55
Coleoptera (%)	12	2	12	11	34	35	0	9	16	12	0	3	0	0	0
Plecoptera (%)	4	1	0	0	2	0	0	2	0	0	0	6	0	6	0
Trichoptera (%)	10	39	7	0	5	0	0	7	2	18	1	0	20	47	10
Other taxa (%)	0	0	0	0	0	0	0	0	24	0	0	0	0	<1	0
Number of Taxa	**7**	**10**	**6**	**7**	**8**	**6**	**6**	**9**	**8**	**6**	**8**	**8**	**7**	**6**	**5**
Other Components															
Organic materials (%)	8	7	0	7	0	0	0	0	0	0	<1	0	0	0	1
Inorganic materials (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Terrestrial organisms (%)	0	2	15	0	0	0	0	2	0	0	6	0	7	11	10

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

3.3.13 Normal Range

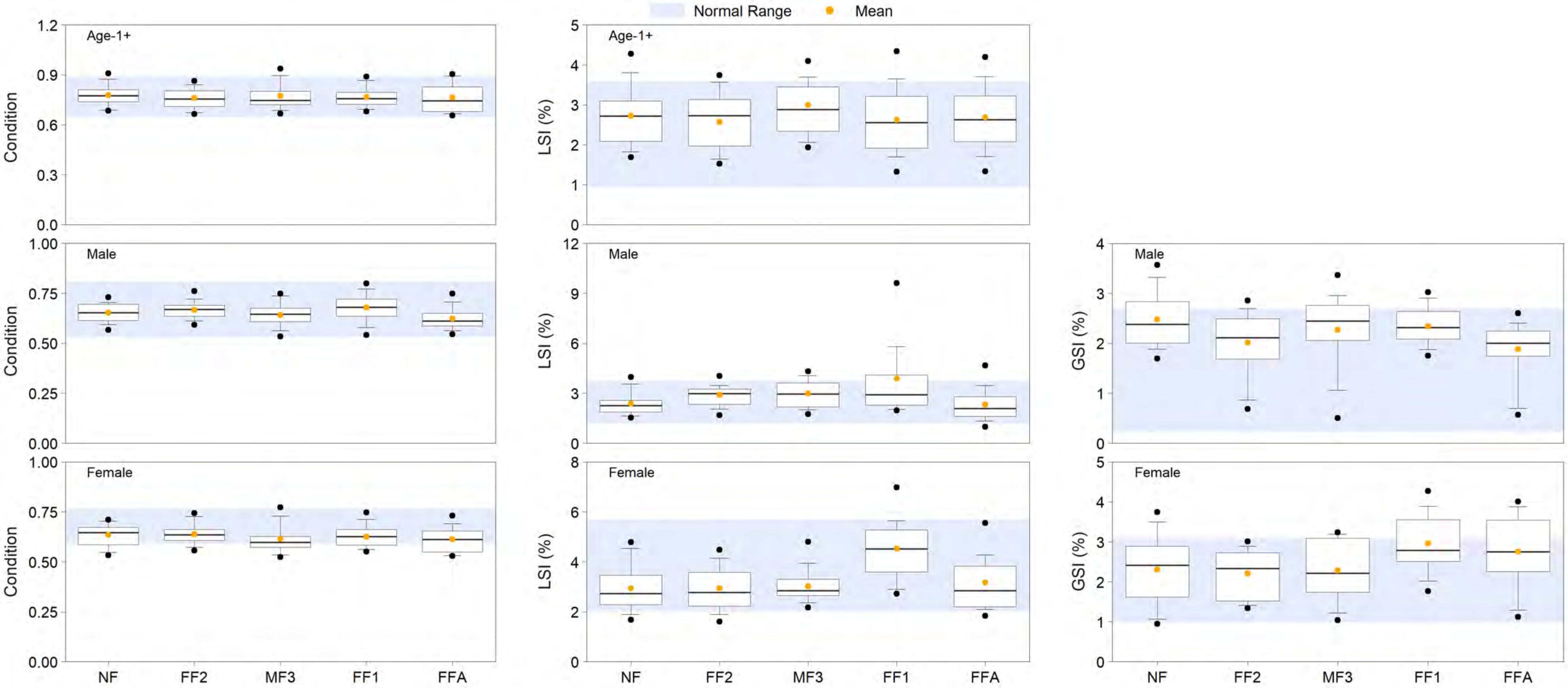
The mean values of fish health variables for age-1+, adult male and adult female Slimy Sculpin were within their respective normal ranges for total length, total weight, carcass weight, condition, LSI and GSI for each sampling area (Figure 3-10; Figure 3-11).

Figure 3-10 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 3-11 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.

3.3.14 Comparison to Reference Conditions

Fish health data collected from NF in 2019 was compared to reference conditions as defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). If significant differences were observed for the NF relative to reference conditions, comparisons were subsequently made for MF3.

For the NF area, age-1+ fish sampled in 2019 were significantly smaller when compared to reference conditions for total length (-14%), total weight (-37%) and carcass weight (-39%), with significantly larger condition (10% for maximum value of covariate) and relative liver weight (26%; Table 3-15). Adult male and female relative gonad weight was significantly greater when compared to reference conditions (44% and 111%, respectively). No other significant differences were observed between the NF and reference conditions.

For the MF3 area, age-1+ fish sampled in 2019 weighed significantly less when compared to reference conditions for carcass weight (-39%) and exhibited significantly greater relative liver weight (27%; Table 3-15). Adult male and female gonad weight was significantly greater when compared to reference conditions (35% for maximum value of covariate and 27%, respectively). No other significant differences were observed between the NF and reference conditions.

Table 3-15 Statistical Comparisons of Slimy Sculpin Sampled from NF and MF3 in 2019 to Reference Conditions

Sex/Stage	Variable	Test	NF			MF3		
			Interaction	***P*-value**	**%**	**Interaction**	***P*-value**	**%**
Age-1+	Total length (mm)	ANOVA	--	**0.073**	-14	-	0.105	-9
	Total weight (g)	ANOVA$_{log}$	--	**0.084**	-37	-	0.131	-25
	Carcass weight (g)	ANOVA$_{log}$	--	**0.043**	-39	-	**0.055**	-28
	Condition	ANCOVA$_{log}$	**0.018**	**0.072(a)**	10	0.052	0.496	-2
				0.117(b)	-8			
	Relative liver weight	ANCOVA$_{log}$	0.271	**0.011**	26	0.184	**0.001**	27
Male	Total length (mm)	ANOVA$_{log}$	--	0.749	2	-	-	-
	Total weight (g)	ANOVA$_{log}$	--	0.715	8	-	-	-
	Carcass weight (g)	ANOVA$_{log}$	--	0.879	3	-	-	-
	Condition	ANCOVA$_{log}$	0.144	0.548	2	-	-	-
	Relative liver weight	ANCOVA$_{log}$	0.220	0.966	0	-	-	-
	Relative gonad weight	ANCOVA$_{sqrt}$	1.000	**<0.001**	44	**0.041**	0.985(a)	5
			--	-	-		**0.005(b)**	35
Female	Total length (mm)	ANOVA$_{log}$	--	0.224	-8	-	-	-
	Total weight (g)	ANOVA$_{log}$	--	0.260	-22	-	-	-
	Carcass weight (g)	ANOVA$_{log}$	--	0.151	-26	-	-	-
	Condition	ANCOVA$_{log}$	0.806	0.917	0	-	-	-
	Relative liver weight	ANCOVA$_{log}$	0.386	0.171	-10	-	-	-
	Relative gonad weight	ANCOVA$_{log}$	**0.005**	0.368(a)	-18	0.481	**<0.001**	27
		ANCOVA$_{log}$		**0.002(b)**	111			

a) Interaction present, *P*-value based on a comparison of the response variable at the minimum value of the covariate.

b) Interaction present, *P*-value based on a comparison of the response variable at the maximum value of the covariate.

Note: Significant *P*-values are shown in bold.

NF = near-field; MF = mid-field; log = data were log transformed; sqrt = data were square root transformed; -- = not applicable; - = test not performed due to lack of significant different in NF area.

3.3.15 Quality Assurance/Quality Control Results

A total of 334 gonads were assessed for sex and maturity by a qualified histologist. Of these, 40 samples were re-analyzed as part of QA/QC by another independent biologist. No data quality issues were identified and data was determined to be of acceptable quality.

3.4 Fish Tissue Chemistry

3.4.1 Statistical Comparisons

A total of 40 composite fish tissue chemistry samples were analyzed for percent moisture content and metals (i.e., 8 samples per area; Attachment G). A summary of the data is presented in Table 3-16. More than 60% of bismuth, lithium, and zirconium concentrations were below DL in at least one sampling area; therefore, they were not considered further for statistical analyses but were interpreted qualitatively based on normal range plots (Section 3.4.2). Concentrations of antimony, beryllium, boron, and tellurium were all below DLs for all sampling areas and were, therefore, excluded from the statistical and qualitative analyses. Significant differences were observed among sampling areas for the remaining metals with the exception of chromium and nickel. Neither total length nor weight was a significant predictor of selenium concentrations in Slimy Sculpin among areas (i.e., the regression relationship was not significant; $P>0.2$); therefore, differences among areas in selenium concentration were tested by ANOVA. There was a significant linear relationship between mercury and total length and mercury and weight among areas ($P<0.001$ for both). The relationship with weight had a lower AICc value; therefore, ANCOVA with mercury was performed using weight as the covariate.

At NF, statistically significant differences were observed in Slimy Sculpin metals concentrations relative to the FF areas for cadmium, cesium, cobalt, lead, molybdenum, selenium, silver, strontium, uranium, and vanadium (Table 3-17). Lead, molybdenum, silver, strontium, uranium, and vanadium were detected in greater concentrations in the NF area than in the FF areas. The magnitudes of differences for metals with a greater concentration at NF ranged from 33.5% for vanadium to 356.4% for uranium. Cadmium, cesium, cobalt, and selenium were detected at lesser concentrations in Slimy Sculpin from the NF area than the FF areas.

At FF2, statistically significant differences were observed relative to the FF areas for Slimy Sculpin tissue concentrations of arsenic, barium, cadmium, cesium, cobalt, mercury, molybdenum, selenium, silver, strontium, uranium, thallium, and zinc (Table 3-17). Molybdenum was the only metal detected in greater concentrations in Slimy Sculpin from the FF2 area than in the FF areas, with a magnitude of difference of 30.4%. Arsenic, barium, cadmium, cesium, cobalt, mercury, selenium, silver, strontium, uranium, thallium, and zinc were detected in lesser concentrations in FF2 relative to the FF areas.

At MF3, statistically significant differences were observed relative to the FF areas for aluminum, barium, calcium, cesium, iron, lead, magnesium, phosphorus, selenium, strontium, thallium, titanium, uranium and vanadium (Table 3-17). Aluminum, barium, calcium, iron, lead, magnesium, phosphorus, strontium, thallium, titanium, uranium and vanadium were detected in greater concentrations in the MF3 area than in the FF areas. The magnitudes of differences for metals with a greater concentration at MF3 ranged from 7.7% for magnesium to 353.7% for uranium. Cesium and selenium were detected in lesser concentrations in Slimy Sculpin from the MF3 area relative to the FF areas. Uranium was the only metal with significantly greater concentrations measured in Slimy Sculpin from both NF and MF areas when compared to FF areas.

Table 3-16 Concentration of Metals in Slimy Sculpin Carcasses from Lac de Gras, 2019

Variable (mg/kg ww)	Detection limit	NF						FF2						MF3						FF1						FFA					
		>DL (%)	Min	Mean	Median	Max	SD	>DL (%)	Min	Mean	Median	Max	SD	>DL (%)	Min	Mean	Median	Max	SD	>DL (%)	Min	Mean	Median	Max	SD	>DL (%)	Min	Mean	Median	Max	SD
Sample size(a)	-	8						8						8						8						8					
Aluminum	0.4	100	2.4	6.3	6.3	12.2	2.95	100	3.2	5.3	4.7	8.5	1.91	100	3.1	9.1	10	12.3	3.14	87.5	1	4.6	3.8	10.1	3.06	100	2.2	5.3	5.5	8.8	2.61
Antimony	0.002	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0
Arsenic	0.004	100	0.035	0.052	0.055	0.062	0.0089	100	0.059	0.081	0.083	0.1	0.0142	100	0.04	0.055	0.056	0.074	0.0104	100	0.036	0.057	0.058	0.075	0.0123	100	0.046	0.064	0.063	0.09	0.0122
Barium	0.01	100	2.47	3.33	3.29	4.16	0.515	100	2.36	2.69	2.64	3.04	0.262	100	3.5	4.23	4.29	5.03	0.624	100	2.5	2.92	2.78	3.68	0.409	100	3.1	3.76	3.88	4.65	0.569
Beryllium	0.002	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0
Bismuth	0.002	62.5	0.001	0.003	0.002	0.007	0.0021	62.5	0.001	0.002	0.002	0.005	0.0014	87.5	0.001	0.005	0.003	0.011	0.0033	0	0.001	0.001	0.001	0.001	0	0	0.001	0.001	0.001	0.001	0
Boron	0.2	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0
Cadmium	0.001	100	0.006	0.013	0.012	0.026	0.0057	100	0.005	0.009	0.01	0.012	0.0019	100	0.012	0.019	0.019	0.024	0.004	100	0.007	0.012	0.009	0.022	0.0053	100	0.017	0.026	0.026	0.032	0.004
Calcium	4	100	8760	10755	10400	14000	1595.5	100	8440	9094	8985	10100	542.7	100	9760	11169	11150	12500	990.8	100	8030	9480	9455	11400	1142.5	100	7240	10138	10295	12400	1638.1
Cesium	0.001	100	0.021	0.025	0.026	0.033	0.0038	100	0.014	0.017	0.017	0.019	0.0019	100	0.027	0.037	0.035	0.065	0.0125	100	0.021	0.031	0.031	0.042	0.007	100	0.037	0.054	0.058	0.07	0.0106
Chromium	0.01	100	0.09	0.16	0.14	0.27	0.062	100	0.09	0.13	0.11	0.24	0.049	100	0.08	0.18	0.15	0.33	0.093	100	0.07	0.14	0.12	0.27	0.07	100	0.06	0.14	0.11	0.32	0.088
Cobalt	0.004	100	0.028	0.038	0.036	0.05	0.0084	100	0.033	0.05	0.049	0.073	0.0137	100	0.068	0.077	0.076	0.087	0.0077	100	0.025	0.032	0.034	0.036	0.0045	100	0.167	0.393	0.274	0.935	0.2791
Copper	0.02	100	0.55	0.63	0.65	0.68	0.048	100	0.54	0.62	0.62	0.7	0.054	100	0.64	0.67	0.65	0.74	0.038	100	0.58	0.63	0.63	0.7	0.041	100	0.62	0.68	0.67	0.76	0.045
Iron	0.6	100	13.2	23.5	23	36.8	6.66	100	21.3	25.8	24.5	36.4	5	100	21.3	31.4	33.6	40.3	6.8	100	14.4	28.5	26.9	44.5	9.92	100	12.9	19	17.1	28.4	5.43
Lead	0.004	100	0.008	0.014	0.013	0.019	0.0038	100	0.005	0.008	0.008	0.011	0.0021	100	0.013	0.021	0.022	0.032	0.0059	100	0.005	0.008	0.009	0.01	0.0017	100	0.006	0.008	0.008	0.01	0.0014
Lithium	0.02	62.5	0.01	0.02	0.02	0.03	0.009	37.5	0.01	0.02	0.01	0.06	0.019	87.5	0.01	0.03	0.03	0.06	0.013	12.5	0.01	0.01	0.01	0.02	0.005	75	0.01	0.02	0.02	0.03	0.007
Magnesium	0.4	100	375	416	421	460	31.63	100	355	379.9	382.5	400	15.96	100	390	424	417	466	25.02	100	374	387.2	392	398	11.03	100	358	400.1	396	444	24.76
Manganese	0.01	100	8.93	14.95	15.6	18.6	3.406	100	8.65	16.73	16.8	23.4	5.055	100	8.14	13.05	12.45	17.7	4.052	100	4.35	11.96	11.15	20.4	4.92	100	12	17.95	17.5	24.5	3.975
Mercury	0.001	100	0.01	0.016	0.014	0.025	0.0056	100	0.009	0.014	0.014	0.018	0.0028	100	0.012	0.017	0.017	0.022	0.0035	100	0.013	0.019	0.017	0.027	0.0053	100	0.011	0.018	0.017	0.024	0.0043
Molybdenum	0.004	100	0.034	0.051	0.053	0.065	0.0119	100	0.038	0.052	0.047	0.092	0.0172	100	0.033	0.039	0.039	0.056	0.0077	100	0.024	0.029	0.026	0.037	0.0051	100	0.032	0.041	0.036	0.073	0.0136
Nickel	0.04	100	0.6	2.46	1.81	5.55	1.789	100	2.2	3.79	3.09	6.89	1.738	100	0.9	2.76	2.45	5.42	1.579	100	1.92	4.32	3.73	7.83	2.127	100	1.09	2.96	2.99	4.97	1.49
Phosphorus	2	100	7210	8124	8105	9610	808.5	100	6760	7135	7090	7930	372.1	100	7520	8526	8610	9530	633.6	100	6910	7561	7495	8600	572.9	100	6100	7849	7855	9720	1031.7
Potassium	4	100	3170	3298	3245	3510	118.9	100	3020	3171	3155	3280	90.3	100	3150	3366	3310	3820	205.7	100	3040	3151	3105	3460	139.4	100	3000	3226	3225	3400	138.1
Rubidium	0.01	100	2.51	3.06	3.05	3.57	0.38	100	2.4	3	3.12	3.49	0.402	100	2.92	3.63	3.55	4.32	0.443	100	2.6	3.2	3.13	3.96	0.548	100	2.87	3.56	3.57	4.37	0.428
Selenium	0.01	100	0.25	0.29	0.29	0.32	0.027	100	0.16	0.21	0.21	0.23	0.025	100	0.23	0.29	0.29	0.32	0.027	100	0.26	0.28	0.27	0.31	0.021	100	0.42	0.48	0.46	0.58	0.064
Silver	0.001	100	0.002	0.002	0.002	0.003	0.0004	75	0	0.001	0.001	0.002	0.0004	100	0.001	0.002	0.002	0.002	0.0004	62.5	0	0.001	0.001	0.003	0.0009	87.5	0	0.002	0.002	0.002	0.0006
Sodium	4	100	1080	1194	1200	1270	65	100	1060	1120	1125	1180	43.1	100	1150	1224	1210	1300	63.5	100	1110	1164	1165	1210	29.2	100	1120	1180	1160	1290	65.5
Strontium	0.01	100	39.9	47.8	45.75	59.9	6.796	100	33.9	37.58	37.05	43	3.179	100	33.7	38.76	39.35	41.8	3.278	100	27.9	32.77	33.15	39.2	4.041	100	24.3	34.24	34.5	43.1	5.454
Tellurium	0.004	0	0.002	0.002	0.002	0.002	0	0	0.002	0.002	0.002	0.002	0	0	0.002	0.002	0.002	0.002	0	0	0.002	0.002	0.002	0.002	0	0	0.002	0.002	0.002	0.002	0
Thallium	0.0004	100	0.0048	0.0072	0.0068	0.0119	0.00209	100	0.0042	0.0045	0.0044	0.0054	0.00042	100	0.0062	0.0074	0.007	0.0093	0.00126	100	0.0036	0.0043	0.0042	0.0056	0.00065	100	0.0066	0.0076	0.0075	0.0095	0.00089
Tin	0.004	87.5	0.002	0.019	0.018	0.047	0.0159	100	0.016	0.048	0.049	0.081	0.0216	87.5	0.002	0.023	0.012	0.086	0.028	87.5	0.002	0.027	0.031	0.051	0.0181	100	0.011	0.035	0.039	0.056	0.0184
Titanium	0.05	100	0.11	0.33	0.29	0.71	0.181	100	0.18	0.38	0.29	1.04	0.279	100	0.16	0.56	0.57	0.9	0.223	100	0.09	0.21	0.2	0.41	0.104	100	0.05	0.19	0.19	0.36	0.104
Uranium	0.0004	100	0.0468	0.0847	0.0764	0.184	0.04274	100	0.0147	0.0209	0.0204	0.0265	0.00446	100	0.0347	0.0842	0.0746	0.136	0.03541	100	0.0088	0.0174	0.015	0.027	0.00652	100	0.013	0.0182	0.0173	0.0257	0.00467
Vanadium	0.02	100	0.05	0.05	0.05	0.07	0.008	100	0.04	0.05	0.05	0.08	0.012	100	0.04	0.07	0.07	0.14	0.032	100	0.03	0.05	0.04	0.07	0.014	100	0.02	0.04	0.03	0.05	0.007
Zinc	0.1	100	29.3	34.7	34.5	40.7	3.99	100	24.2	29.8	30.8	33	3.25	100	33	35.2	34.9	38.2	1.9	100	26	33.2	34.3	41.8	5.34	100	33.1	36.1	36.2	39.6	2.13
Zirconium	0.04	12.5	0.02	0.03	0.02	0.06	0.014	0	0.02	0.02	0.02	0.02	0	50	0.02	0.04	0.04	0.07	0.021	0	0.02	0.02	0.02	0.02	0	0	0.02	0.02	0.02	0.02	0

a) Refers to the number of composite whole-fish samples (excluding stomach, gonad, liver, and otoliths). The composition of each sample is summarized in Table 2-3.

NF = near-field; MF = mid-field; FF = far-field; mg/kg ww = milligrams per kilogram wet weight; > = less than; DL = detection limit; Min = minimum; Max = maximum; SD = standard deviation.

Table 3-17 Statistical Comparisons of Slimy Sculpin Tissue Metal Concentrations Among Sampling Areas of Lac de Gras, 2019

Variable	Statistical test	Area	NF/MF vs FF						FF		Power to detect difference		
			NF		FF2		MF3		FF1 vs FFA				
			P	%(a)	*P*	%(a)	*P*	%(a)	*P*	%(b)	10%	20%	30%
Aluminum	ANOVA	**0.021**	0.728	26.6	0.998	6.6	**0.006**	83.6	0.973	-13.9	0.59	0.832	0.848
Antimony	All data <DL												
Arsenic	ANOVA	**<0.001**	0.336	-14.3	**0.001**	33.1	0.760	-8.8	0.729	-10.1	0.972	0.991	0.998
Barium	ANOVA	**<0.001**	1.000	-0.4	**0.018**	-19.4	**0.001**	26.8	**0.006**	-22.4	1.000	1.000	1.000
Beryllium	All data <DL												
Bismuth	at least 1 area with >60% values <DL												
Boron	All data <DL												
Cadmium	ANOVA	**<0.001**	**0.001**	-39.3	**<0.001**	-50.8	0.997	2.7	**<0.001**	-54.3	1.000	1.000	1.000
Calcium	ANOVA	**0.011**	0.312	9.6	0.580	-7.3	**0.065**	13.9	0.760	-6.5	0.960	0.995	0.999
Cesium	ANOVA	**<0.001**	**<0.001**	-39.9	**<0.001**	-60.4	**0.020**	-21.3	**<0.001**	-43.4	1.000	1.000	1.000
Chromium	ANOVA	0.570	0.929	16.4	0.992	-9.0	0.545	31.7	1.000	3.8	0.281	0.330	0.402
Cobalt	ANOVA$_{log}$	**<0.001**	**<0.001**	-75.6	**<0.001**	-68.7	0.362	-50.6	**<0.001**	-88.5	1.000	1.000	1.000
Copper	ANOVA	**0.072**	0.699	-3.4	0.390	-4.8	0.913	2.3	0.202	-6.6	0.981	1.000	1.000
Iron	ANOVA	**0.012**	1.000	-1.1	0.938	8.7	**0.060**	32.4	**0.039**	50.2	0.920	0.923	0.949
Lead	ANOVA	**<0.001**	**<0.001**	67.5	0.995	-5.3	**<0.001**	145.2	0.970	10.4	1.000	1.000	1.000
Lithium	at least 1 area with >60% values <DL												
Magnesium	ANOVA	**0.002**	0.117	5.7	0.530	-3.5	**0.017**	7.7	0.713	-3.2	0.994	1.000	1.000
Manganese	ANOVA	**0.050**	1.000	-0.03	0.822	11.9	0.781	-12.7	**0.035**	-33.3	0.825	0.878	0.949
Mercury	ANCOVA(c)	**0.072**	0.164	-19.0	**0.032**	-24.7	0.796	-9.0	1.000	-3.0	0.815	0.899	0.942
Molybdenum	ANOVA	**0.001**	**0.002**	45.3	**0.070**	30.4	0.756	12.4	**0.053**	-29.9	0.927	0.958	0.971
Nickel	ANOVA	0.211	0.425	-32.5	0.999	4.1	0.694	-24.2	0.432	45.8	0.451	0.527	0.640
Phosphorus	ANOVA	**0.006**	0.564	5.4	0.270	-7.4	**0.049**	10.7	0.894	-3.7	0.993	1.000	1.000
Potassium	ANOVA	**0.053**	0.162	3.4	0.995	-0.5	0.169	3.5	0.627	-2.3	1.000	1.000	1.000
Rubidium	ANOVA	**0.020**	0.355	-9.5	0.211	-11.2	0.612	7.2	0.383	-10.1	0.928	0.997	1.000
Selenium	ANOVA$_{log}$	**<0.001**	**<0.001**	-24.3	**<0.001**	-46.2	**<0.001**	-24.5	**<0.001**	-41.7	1.000	1.000	1.000
Silver	ANOVA	**0.007**	**0.026**	50.9	0.631	-21.9	0.312	30.7	0.864	-16.1	0.670	0.753	0.809
Sodium	ANOVA	**0.011**	0.839	1.9	0.140	-4.4	0.140	4.4	0.963	-1.4	1.000	1.000	1.000
Strontium	ANOVA	**<0.001**	**<0.001**	42.7	0.206	12.1	**0.060**	15.7	0.956	-4.3	0.716	0.861	0.980
Tellurium	All data <DL												
Thallium	ANOVA	**<0.001**	0.499	9.6	**0.002**	-24.3	**0.003**	24.0	**<0.001**	-43.8	1.000	1.000	1.000
Tin	ANOVA	**0.005**	0.416	-39.0	0.123	55.5	0.166	-54.4	0.813	-24.3	0.908	0.920	0.939
Titanium	ANOVA	**<0.001**	0.227	63.1	0.615	43.5	**<0.001**	178.9	0.993	15.5	0.990	0.981	0.979
Uranium	ANOVA$_{log}$	**<0.001**	**<0.001**	356.4	0.671	20.0	**<0.001**	353.7	0.986	-7.7	1.000	1.000	1.000
Vanadium	ANOVA	**0.001**	**0.041**	33.5	0.230	23.7	**0.001**	55.1	0.216	32.4	0.984	0.990	0.990
Zinc	ANOVA	**0.010**	1.000	0	**0.012**	-14.2	0.995	1.5	0.369	-8.1	0.990	1.000	1.000
Zirconium	at least 1 area with >60% values <DL												

a) Percent difference between NF, FF2 or MF area mean and the FF area means.

b) Percent difference between the FF area means.

c) Carcass weight included as a covariate in the ANCOVA model

Note: Significant results (at the 0.1 level) are shown in bold.

NF = near-field; MF = mid-field; FF = far-field.; DL = detection limit; *P* = *P*-value; ANOVA = analysis of variance; ANOVA$_{log}$ = data log transformed prior to analysis.

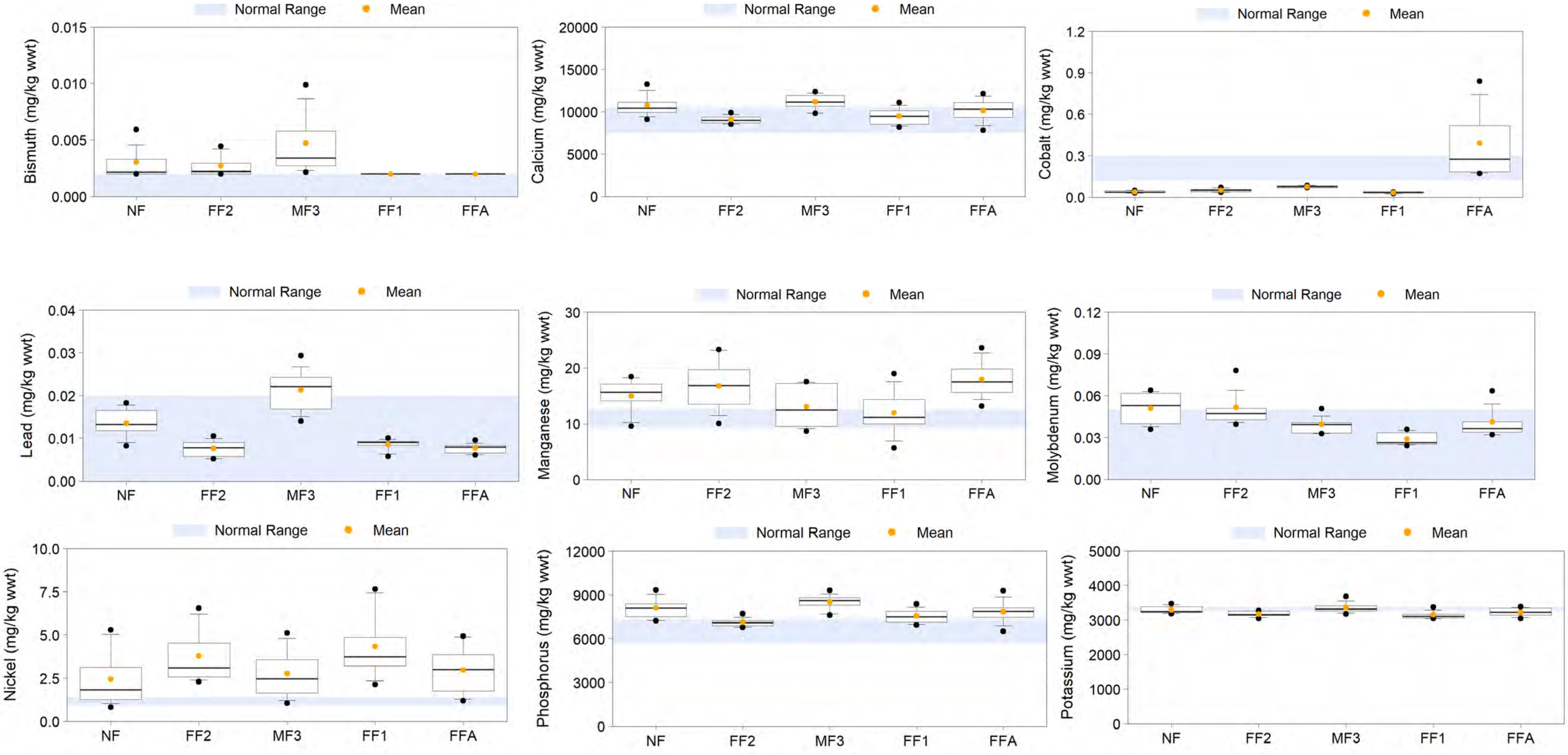
3.4.2 Normal Range

Numerous metals exceeded the upper limit of the normal range for at least one sampling area, including bismuth, calcium, cobalt, lead, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, thallium, titanium, uranium, zinc, and zirconium. Boxplots for metals in Slimy Sculpin exceeding normal ranges are provided in (Figure 3-12). Boxplots for all metals are provided in Attachment H. Metals with more than 60% of concentrations below DLs in at least one sampling area were not statistically analyzed, and included antimony, beryllium, bismuth, boron, lithium, tellurium, and zirconium. The normal ranges for these metals are presented for qualitative assessment only (Figure 3-13). For antimony, beryllium, boron, and tellurium, concentrations were below DLs in all areas. For bismuth, non-detect data were reported in all areas, ranging from 100% of the samples (areas FF1 and FFA) to 13% of the samples (MF3). For lithium, non-detects ranged from 13% of the samples (in MF3) to 88% of the samples (in FF1). Zirconium concentrations in Slimy Sculpin were above the DL in one sample at NF and four samples at MF3. Mean within-area concentrations exceeded the upper limit of normal range for the following metals (Figure 3-12):

- Bismuth: mean concentrations were above the normal range at NF, FF2, and MF3, whereas both FF area means were below DLs. The normal range plot is provided as a tool for qualitative evaluation.
- Calcium: mean concentrations exceeded the normal range at NF and MF3 areas, but not at FF2, FF1, or FFA.
- Cobalt: mean concentrations exceeded the normal range at FFA, but not in any of the other areas.
- Lead: mean concentrations exceeded the normal range at MF3, but not in any of the other areas.
- Manganese: mean concentrations exceeded the normal range at NF, FF2, MF3, and FFA, but not at FF1. The highest mean value was recorded at FFA.
- Molybdenum: mean concentrations exceeded the normal range at NF and FF2 areas.
- Nickel: mean concentrations exceeded the normal range at all areas. The greatest mean concentration was recorded at FF1 and the least mean concentration was recorded at NF.
- Phosphorus: mean concentrations exceeded the normal range at NF, MF3, FF1 and FFA sampling areas, but did not exceed at FF2.
- Potassium: mean concentrations exceeded the normal range at MF3 only.
- Selenium: mean concentrations exceeded the normal range at FFA only.
- Silver: mean concentrations exceeded the normal range at NF, MF3, FF1, and FFA, but not FF2.
- Sodium: mean concentrations exceeded the normal range at MF3 only.
- Strontium: mean concentrations exceeded the normal range at NF, FF2, and MF3, but not at the two FF areas. The greatest mean concentration was reported at NF.
- Thallium: mean concentrations exceeded the normal range at NF, MF3, and FFA, but not FF2 and FF1. The greatest mean concentration was recorded at FFA.
- Titanium: mean concentrations exceeded the normal range at MF3 only.

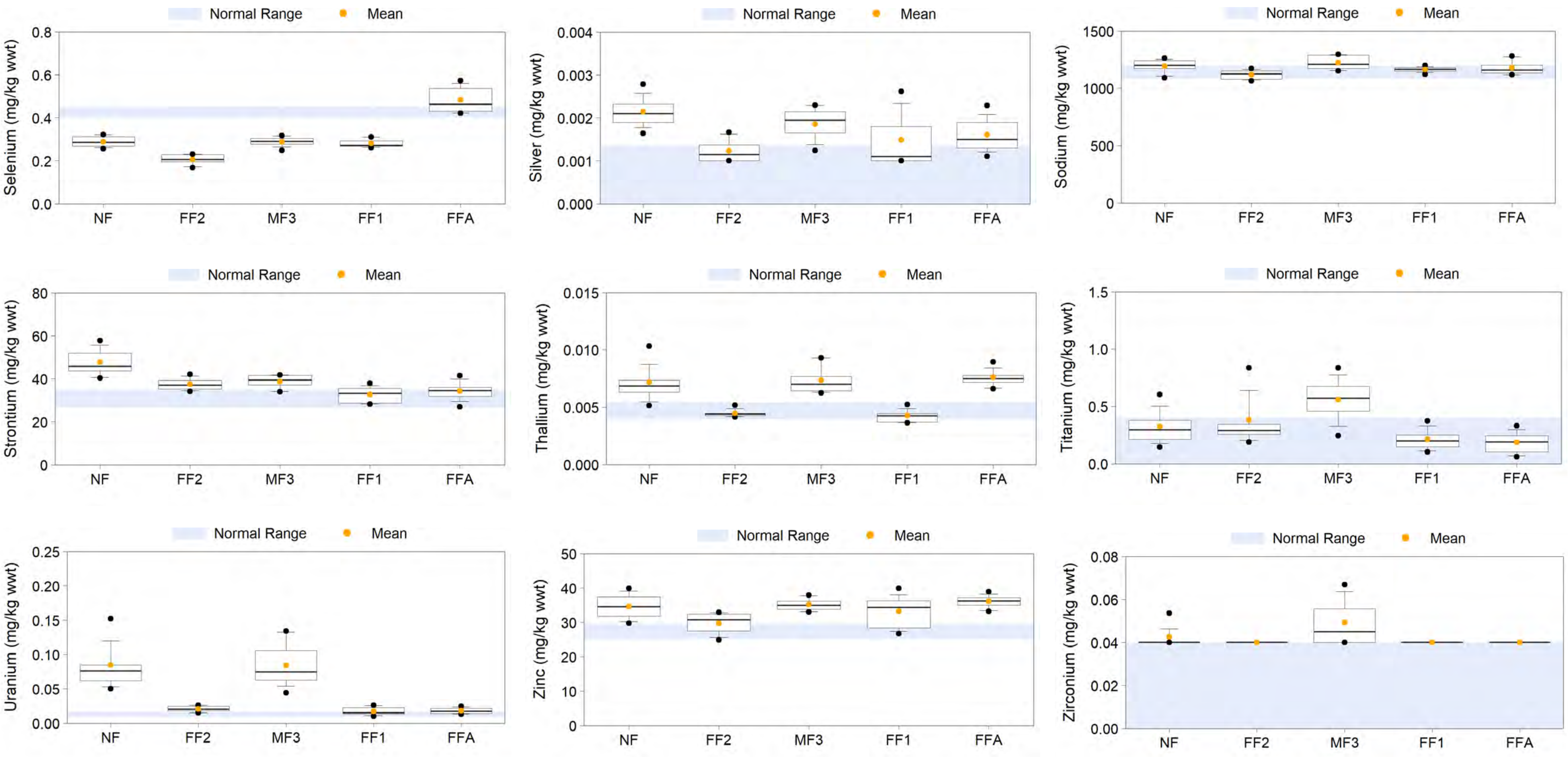
- Uranium: mean concentrations exceeded the normal range at all areas. The greatest mean concentration was recorded at NF, followed closely by MF3.
- Zinc: mean concentrations exceeded the normal range at all areas. The greatest mean concentration was recorded at FFA.
- Zirconium: mean concentrations exceeded the normal range at NF and MF3. The greatest mean value was recorded at MF3. Only one sample was above DL at NF (13% of data) and only four samples (50% of data) were above DL at MF3. All samples were below DL at FF2, FF1, and FFA.

Figure 3-12 Normal Range and Boxplots for Metals that Exceeded the Upper Limit of the Normal Range in Slimy Sculpin Tissue in Lac de Gras, 2019



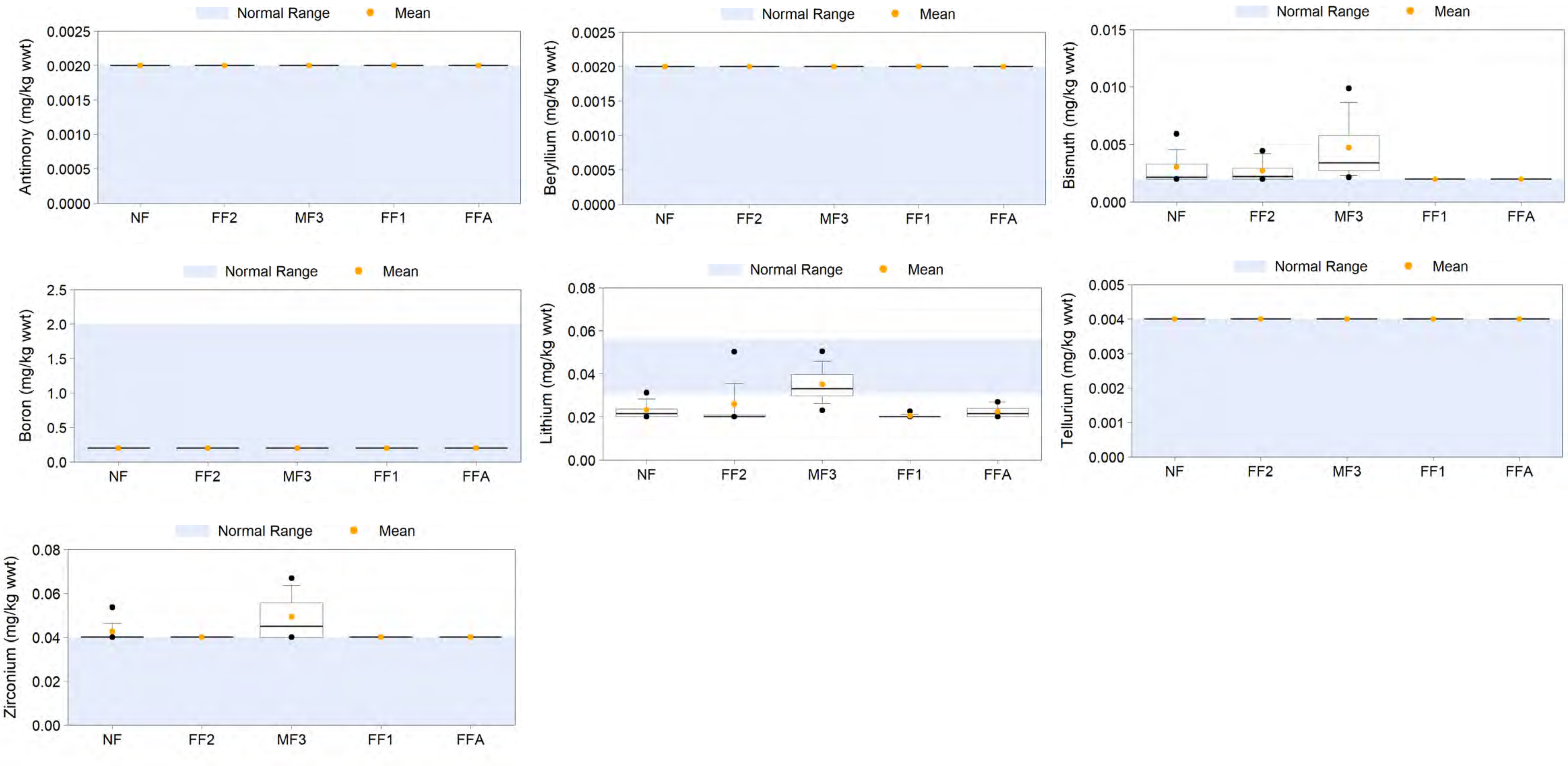
NF = near-field; MF = mid-field; FF = far-field.

Figure 3-12 Normal Range and Boxplots for Metals that Exceeded the Upper Limit of the Normal Range in Slimy Sculpin Tissue in Lac de Gras, 2019 (Continued).



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

Figure 3-13 **Normal Range and Boxplots for Metals with More than 60% of Concentrations below Detection Limits in Slimy Sculpin Tissue in Lac de Gras, 2019.**



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

3.4.3 Quality Assurance/Quality Control Results

3.4.3.1 Internal Laboratory QA/QC

Analytical quality control data from ALS were generally within acceptable limits for duplicates, laboratory blanks, control samples, and reference materials. Exceptions included sample heterogeneity in DDMI2019FF1COMPA4 for cadmium and DDMI2019NFCOMPI4 for titanium, with RPD between duplicates of 55% and 52%, respectively. A method blank exceeded the ALS data quality objective for aluminum, which raised the DL from 0.40 to 2.0, affecting DDMI2019FF1COMPA2. The ALS data quality objective was marginally exceeded for silver (by <10%) in a Multi-Element Scan for one batch of 20 samples; however, a deviation of this magnitude was considered acceptable under the method protocol. Overall, analytical data reported by ALS for Slimy Sculpin tissue chemistry were considered reliable.

3.4.3.2 QA/QC of Laboratory Data

All variables requested were analyzed and reported with the expected units. Hold times between sample collection and analysis were not exceeded for any variable. Samples submitted to ALS were analyzed with the requested DLs (Table 2-5), consistent with *AEMP Design Plan Version 4.1* (Golder 2017a). The DLs for moisture and titanium were marginally exceeded (0.5% and 0.050 mg/kg ww, respectively); however, measured concentrations in Slimy Sculpin exceeded DLs for all samples and results were not affected by the adjusted DLs. Sample results were re-checked for four variables in three samples, where the absolute standardized values of the individual tissue samples were greater than 3.5 (see Section 2.8.4). In three cases, the original result was confirmed, with a revised result reported in one case (Table 3-18).

Table 3-18 Fish Tissue Sample Re-Analysis Summary, Lac de Gras, 2019

Variable	Sample ID	Original result (mg/kg ww)	Re-analysis result (mg/kg ww)
Aluminum	DDMI2019FF2COMPC3	24.7	4.29
Potassium	DDMI2019MF3COMPG2	3820	No change
Bismuth, Vanadium	DDMI2019MF3COMPG3	0.0111, 0.144	No change

ID = identification; ww = wet weight.

3.4.3.3 Quality Control Samples Results

The RPDs in mercury samples between ALS and Flett were less than 40%, with split samples reporting values greater than five times their respective DLs (Table 3-19). Inter-lab variability was rated as low, with mean mercury concentrations measured by Flett 28% greater than those measured by ALS.

Table 3-19 Concentration of Mercury as Analyzed by ALS Environmental Laboratories and Flett Research Ltd. in Slimy Sculpin from Lac de Gras, 2019

Sample ID	Mercury (mg/kg ww)			RPD (%)	Moisture (%)
	ALS[(a)]	Flett[(b)]	Mean		
DDMI2019-FF1-COMP-A1	0.0244	0.0329	0.0287	30	72.6
DDMI2019-FF2-COMP-D1	0.0128	0.0173[(c)]	0.0150	30	73.4
DDMI2019-FFA-COMP-F1	0.0113	0.0134	0.0124	17	74.3
DDMI2019-MF3-COMP-H4	0.0161	0.0200[(c)]	0.0180	21	75.0
DDMI2019-NF-COMP-J4	0.0127	0.0154	0.0141	19	74.5

a) ALS detection limit = 0.0010 mg/kg ww.
b) Flett detection limit = 0.0013 mg/kg ww.
c) Average result between two duplicate analysis.
mg/kg ww = milligrams per kilogram wet weight; RPD = relative percent difference between ALS and Flett mercury concentrations.

3.5 Action Level Evaluation

The Action Levels for fish health address the toxicological impairment hypothesis; fish tissue chemistry data are considered supporting information and do not undergo an Action Level evaluation. The approved Action Levels from *AEMP Design Plan Version 4.1* (Golder 2017a), with consideration of the WLWB March 2019 Decision Letter, which directed DDMI to compare to the reference condition instead of the FF areas in the 2019 AEMP Annual Report, are provided in Table 3-20. Results from the 2019 Slimy Sculpin monitoring indicated statistically significant differences in the NF and MF areas when compared to reference conditions with respect to fish size, relative liver weight and relative gonad size (Table 3-15); however, statistically significant differences in fish size and relative liver weight were not observed when compared to the FF areas (Table 3-11 and Table 3-13). On the basis of the 2019 fish health study, the Action Level 2 for fish health is triggered, as detailed below.

Action Level 1: Differences in the NF Area

- Age-1+ fish in the NF area were significantly smaller (i.e., total length, total weight and carcass weight) with greater relative liver weight when compared to reference conditions

Action Level 2: Differences in the MF Areas

- Age-1+ fish in the MF area were significantly smaller (i.e., carcass weight) with greater relative liver weight when compared to reference conditions

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 2017d). Factors contributing to these differences were evaluated in the *2014* *to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017e), 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 (e.g., -29% for carcass weight compared to FF in 2016 versus -39% compared to reference conditions in 2019; 32% for liver weight compared to FF in 2016 versus 26% compared to reference conditions in 2019), 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.

Table 3-20 Action Levels for Fish Health Effects

Action Level	Fish Health	Extent	Action
1	Statistical difference from mean of reference dataset indicative of toxicological response[(a)]	NF	Confirm effect
2	Statistical difference from mean of reference dataset indicative of toxicological response	Nearest MF station	Investigate cause
3	A measurement endpoint beyond the reference condition range	NF	Examine ecological significance Set Action Level 4 Identify mitigation options
4	TBD[(b)]		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

a) Such a response could include a decrease in recruitment (fewer young fish), smaller gonads, reduced fecundity, changes to liver size, changes in condition, increased incidence of pathology, reduced growth, reduced survival.

b) To be determined if an Action Level 3 effect is reached.

> = greater than; NF = near-field; MF = mid-field; FF = far-field.

3.6 Weight-of-Evidence Input

As described in Section 2.10, the results reported herein contribute to the WOE analysis presented in the Weight-of-Evidence Report (Appendix XV). The results of the WOE analysis relevant to fish health and related components are described in Section 3.1 of the Weight-of-Evidence Report.

4 SUMMARY AND DISCUSSION

4.1 Fish Population Health

Slimy Sculpin sampled during the 2019 fish survey were considered healthy and in good physical condition. Fish exhibited similar relative abundance, reproductive success and prevalence of internal and external abnormalities among sampling areas. The prevalence of parasites (i.e., tapeworms) varied among areas but was not associated with proximity to the Mine (i.e., prevalence was similar between the NF and FF areas). Significant differences were observed for fish health endpoints at the NF area relative to the FF areas and reference conditions (Table 4-1). Relative to the FF areas, significant differences were observed for male gonad weight and female total length, total weight and relative liver weight. 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. Comparisons between the NF area relative to the FF areas and reference conditions were not consistent; only male gonad weight exhibited consistent differences in both comparisons, suggesting the presence of a temporal interaction between 2019 and reference conditions (i.e., fish health endpoints in the FF areas appeared to differ in 2019 relative to reference conditions), likely driven by interannual differences in regional environmental factors such as weather or temperature.

Relative to the FF areas, Slimy Sculpin adult females sampled from the NF area were smaller (i.e., total length and total weight) with smaller livers (Table 4-1). Differences were consistent with a toxicity or nutrient limitation response pattern (i.e., a decrease in growth and potential decrease in energy storage); however, the decrease in liver size was moderate (19%) and smaller than the magnitude typically associated with potential environmental risk (i.e., 25%; Environment Canada 2012). Similar differences were not observed in age-1+ fish and males, or in comparison to reference conditions. Male fish exhibited larger gonad size relative to the FF areas, consistent with comparisons to reference conditions, suggesting greater male reproductive investment in the NF area. Endpoint mean values were within normal ranges.

Relative to reference conditions, age-1+ Slimy Sculpin sampled from the NF area were smaller (i.e., total length, total weight and carcass weight) with greater energy storage (i.e., condition factor, and relative liver weight; Table 4-1). Smaller age-1+ Slimy Sculpin in the NF area may be indicative of a toxicological effect; however, the relative increase in condition was not consistent with a toxicity response pattern, which is typically characterized by an increase or decrease in liver weight, a decrease in condition factor and a decrease in gonad weight (Environment Canada 2012). It is also unlikely that nutrient limitation or enrichment contributed to these differences, as a decrease in growth accompanied with an increase in energy storage and reproductive investment was not consistent with either response pattern (i.e., decreases or increases in growth, energy storage, and reproductive investment, respectively; Environment Canada 2012). However, evidence of nutrient enrichment was observed by other AEMP components in 2019 and in previous years. Differences in size of age-1+ fish were more likely influenced by interannual variation in regional environmental factors between the 2019 fish survey and reference conditions (i.e., collected in 2007 and 2013), such as temperature and the timing of freshet and spawning, as similar differences were not observed in 2019 relative to the FF areas. Gonad weight in the NF area was significantly greater for male and female fish when compared to reference conditions, indicating greater reproductive investment in 2019. This was consistent with comparisons of male fish relative to fish sampled from the FF areas in 2019, suggesting greater male reproductive investment in the NF area.

Overall, Slimy Sculpin sampled from the NF and MF areas were in relatively good health. Significant differences were observed between the NF area and both the FF areas and reference conditions; however, differences were not all consistent between the FF areas and reference condition comparisons, suggesting the presence of a temporal interaction. The differences observed in length, weight and relative liver size of age-1+ 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 (Section 3.5), and triggered an Action Level 2 in 2019. The effects that were observed in 2016 were assessed again in the *2014 to 2016 AEMP Response Plan Fish* (Golder 2017d) and the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017e) documents, 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. No additional Response Plans are planned following the 2019 Action Level 2 trigger for fish health.

Table 4-1 Summary of Statistical Differences in Fish Health Endpoints, 2019

Variable	NF vs FF			NF vs Reference Condition		
	Age-1+	Male	Female	Age-1+	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.

4.2 Fish Tissue Chemistry

Slimy Sculpin from the NF area had significantly greater concentrations of lead, molybdenum, silver, strontium, uranium, and vanadium relative to the FF areas. Concentrations in the NF area exceeded normal ranges for molybdenum, silver, strontium, and uranium (Table 4-2). Similar differences were also observed in the MF areas for lead, molybdenum, strontium and uranium, which were significantly greater in either FF2 or MF3 and exceeded normal ranges.

Concentrations of molybdenum, strontium and uranium were significantly greater in water at the NF and MF areas when compared to reference conditions and triggered an Action Level 2 for water quality (Effluent and Water Chemistry Report [Appendix II]). No water quality Action Level triggers were 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 in the NF have increased by a magnitude of 34% since 2013 and 24% since 2016, from 0.038 mg/kg ww in 2013, to 0.041 mg/kg ww in 2016, and to 0.051 mg/kg in 2019, while tissue concentrations of lead, silver, strontium, uranium, and vanadium have remained relatively consistent (Table 4-2). Considering the marginal 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.

In 2019, weight-adjusted mercury concentrations did not differ significantly between NF, MF3 and the FF areas; however mercury concentrations were significantly less in FF2 when compared to FF. Selenium did not have a significant relationship with body size, and tissue concentrations in the NF/MF areas were significantly less than in the FF areas.

Table 4-2 Summary of Statistically Greater Concentrations of Fish Tissue Variables in the NF Area, 2019

Variable	NF vs FF	FF2 vs FF	MF3 vs FF
Lead	↑ (68%)	-	↑ (145%)*
Molybdenum	↑ (45%)*	↑ (30%)*	-
Silver	↑ (51%)*	-	-
Strontium	↑ (43%)*	-	↑ (16%)*
Uranium	↑ (356%)*	-	↑ (354%)*
Vanadium	↑ (34%)	-	↑ (55%)

* = exceeded normal range; NF = near-field; MF = mid-field; FF = far-field.

Table 4-3 Mean Concentrations of Elevated Metals in NF Fish Tissue Over Time, 2019

Variable	Units	2013	2016	2019
Lead	mg/kg ww	0.012 (117%)	0.005 (na)	0.014 (68%)
Molybdenum	mg/kg ww	0.038 (32%)	0.041 (60%)	0.051 (45%)
Silver	mg/kg ww	0.002 (28%)	0.001 (na)	0.002 (51%)
Strontium	mg/kg ww	46.4 (33%)	46.1 (21%)	47.8 (43%)
Uranium	mg/kg ww	0.108 (719%)	0.047 (410%)	0.085 (356%)
Vanadium	mg/kg ww	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 ww = milligrams per kilogram wet weight; na = magnitude not calculated.

5 RESPONSE FRAMEWORK

The 2019 results indicate that an Action Level 2 has been triggered (Section 3.5). An Action Level 2 is identified when a statistical difference between the NF, MF and FF areas is reported and is indicative of changes that could be a toxicological response (Table 3-20). Factors contributing to similar effects observed in 2016 were evaluated in the *2014 to 2016 AEMP Response Plan Fish* (Golder 2017d) and the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017e) documents, 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. Therefore, no additional Response Plans are planned to follow the 2019 Action Level 2 trigger for fish health.

6 CONCLUSIONS

This report presented the assessment of monitoring data collected for the fish health component of the 2019 AEMP, and concludes the following:

- Fish exhibited similar reproductive success and prevalence of internal and external abnormalities among sampling areas[3]. The prevalence of parasites, specifically tapeworms, varied among areas but was not associated with proximity to the Mine[4].
- Relative to the FF areas, significant differences were observed for male gonad weight[4] and female total length[3], total weight[4] and relative liver weight[4] in the NF area. Relative to reference conditions, significant differences were observed for age-1+ fish total length, total weight, carcass weight, condition, 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[3], silver[4], strontium[3] and uranium[3] 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 exhibits a marginal increase of 34%.

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

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

- The differences observed in length, weight and relative liver size of age-1+ 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 an Action Level 2 again in 2019[3]. Factors contributing to similar effects observed in 2016 were evaluated in the 2014 to 2016 *AEMP Response Plan Fish* (Golder 2017d) and the *2014 to 2016 AEMP Response Plan Fish – Supplemental Report* (Golder 2017e) documents, 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.

Overall, the conclusions from the 2019 AEMP are consistent with those reported in the 2016 AEMP, in that fish were overall healthy, with few abnormalities, and that significant decreases in total length, total weight, and carcass weight were observed in Age-1+ fish at NF and MF areas relative to reference conditions (in this report) and the FF areas (in 2016; Golder 2017b). The direction and magnitude of effects on fish health were overall similar to those estimated in the 2016 AEMP.

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8 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

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ATTACHMENT A

GONAD DEVELOPMENT CATEGORIES

Table A-1 Gonad Development Categories for Male Fish

Maturity Stage	Code			Definition
	Female	Male	Unknown Sex	
Unknown	10	20	00	External examination only or unable to determine stage (X0) or sex and stage (00) following internal examination.
Immature	11	21	01	Fish has never spawned and will not spawn in the coming season; testes/ovaries transparent, very small and close under the vertebral column, determination of sex may be difficult.
Early Stage Development	12	22	02	Fish is an adult and will spawn in the coming season and is in the earlier stages of gonad development; gonads are small but determination of sex is possible, ovaries are orange and granular in appearance while testes are semi-translucent and smooth.
Late Stage Development	13	23	03	Fish is an adult and will spawn in the coming season and is in the later stages of gonadal development, the gonads occupy a significant portion of the body cavity and determination of sex is possible, ovary is orange and individual eggs are visible, testes are milky white and have a granular appearance.
Ripe	14	24	04	Fish is an adult and will spawn imminently; Roe/milt extruded with very slight pressure on belly, eggs large and translucent, testes white.
Spent	15	25	05	Fish is an adult and spawned very recently, reabsorption of residual gonad tissue not yet completed.
Reabsorbing	16	26	06	Fish is an adult and completed spawning; reabsorption of gonad tissue is underway, eggs have become atretic (i.e., eggs are small, hard, and white).
Resting	17	27	07	Fish is an adult and has completed spawning but has not begun developing gonads for the coming season; gonads are small with prominent blood vessels.

ATTACHMENT B

FISH POPULATION HEALTH AND TISSUE CHEMISTRY DATA SCREENING

OUTLIER SCREENING METHODS

Data screening is the initial phase of data handling when data may be subject to occasional extreme values that are frequently incorrect, reflecting field or laboratory errors, data transcription or calculation errors, or extreme natural variability. This initial step is undertaken prior to data analysis and interpretation to verify that the data quality objectives established by the *Quality Assurance Project Plan Version 3.1* (Golder 2017c) and the study design have been met. The purpose of this step is to initially identify potential errors (referred to herein as erroneous data), correct them if possible, and make a decision whether to retain or exclude the data from subsequent analysis. Following erroneous data screening, anomalous data screening (i.e., checking for unusually large or small values) is undertaken.

In previous DDMI AEMP reports (Golder 2011, 2014b), the judgment whether to retain an anomalous value in the analysis was made based on a visual inspection of the data using scatter plots and logical consistency with results for other variables. To prepare data for analyses presented in this report, a revised approach was used to identify anomalous data to address concerns noted by the WLWB and other reviewers regarding the handling of outliers in AEMP datasets. The revised data screening approach included a numerical method to aid in the identification of outliers, thus removing the subjectivity of classifying values based on visual evaluation of data alone.

Initial screening of the 2019 fish datasets (i.e., fish health and tissue chemistry) was completed before data analyses to identify unusually large or small values and decide whether to retain or exclude anomalous data from further analysis. Data screening was conducted using a method based on Chebyshev’s theorem (Mann 2010), combined with visual examination of scatter plots and logic checks. This method allowed for detection of multiple outliers at one time and assumes that the data being screened contain a relatively small percentage of outliers (Amidan et al. 2005). Chebyshev’s theorem states that at least $1–1/k^2$ proportion of the data of any distribution (i.e., no assumption of normality) lies within k standard deviations (SD) of the mean (Mann 2010). Setting $1–1/k^2 = 0.95$ and solving for k results in 4.47 SD, indicating that 95% of the data, regardless of distribution, will be within about 4.47 SD of the mean. In the case of a normal distribution, 95% of the data is expected to be within 2 SD, suggesting that the method based on Chebyshev’s theorem is conservative (i.e., identifies values that are far removed from the mean). The method was applied by first identifying data that fell outside the ±4.47 SD band on a scatter-plot of annual data, and then visually verifying the anomalous values based on potential spatial trends.

In cases where the above screening method identified a suspect value in the NF area as anomalous, the identified value was conservatively retained in the dataset used for analysis if the SD distance from the mean was less than two times the 4.47 SD criterion discussed above. Hence, only very extreme values, which were greater than approximately 9 SDs from the mean, were removed from further analysis of NF area data following visual confirmation of screening results. Finally, in cases where the tissue chemistry dataset contained a large proportion of non-detect data (i.e., <DL), only values that were greater than or equal to five times the DL were considered anomalous and were removed from the analysis.

OUTLIER SCREENING RESULTS

During screening for erroneous data, a total of 16 values were identified as field or lab measurement errors. The QA/QC process included comparison of the electronic data records with field notes, laboratory notes, histology results, and pictures taken during sampling. The flagged values (Table B-1) included one value for carcass weight from MF3, seven values for total weight from NF, FF2, MF3, and FF1, five values of liver weight from NF, FF2, MF3, and FFA, and three values for gonad weight from FF2 and FF1. All 16 values were removed from the datasets as *a priori* erroneous data.

Table B-1 Erroneous Values of Fish Health Data

Station	Fish ID	Variable	Value	Reason for removal
MF3	7082	Carcass weight (g)	0.2341	Lab measurement error
FF1	8020	Total weight (g)	4.775	Field measurement error
FF2	6009	Total weight (g)	0.407	Field measurement error
FF2	6020	Total weight (g)	0.534	Field measurement error
FF2	6157	Total weight (g)	0.727	Field measurement error
NF	5168	Total weight (g)	1.597	Field measurement error
NF	5203	Total weight (g)	1.62	Field measurement error
MF3	7270	Total weight (g)	0.542	Field measurement error
FFA	9078	Liver weight (g)	0.078	Lab measurement error
NF	5070	Liver weight (g)	0.71	Lab measurement error
MF3	7044	Liver weight (g)	0.076	Lab measurement error
FF2	6197	Liver weight (g)	0.0012	Lab measurement error
FF2	6241	Liver weight (g)	0.086	Lab measurement error
FF1	8062	Gonad weight (g)	0.0001	Gonad dried prior to weighing
FF2	6137	Gonad weight (g)	0.0026	Decimal place error
FF1	8092	Gonad weight (g)	0.0002	Gonad dried prior to weighing

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

Data screening for anomalous values in the 2019 fish population health dataset identified four potentially anomalous values in fish that had a known sex and maturity status, representing less than 0.1% of the total dataset. Of the four potentially anomalous points, three were for LSI (2 male fish from FF1 and one Age-1+ fish from MF3), and one was a liver weight from one of the male fish with potentially anomalous LSI values. The three fish with the potentially anomalous liver weight and LSI values were re-examined, and data were deemed plausible and retained for subsequent analysis.

Data screening for anomalous values in the 2019 fish tissue chemistry dataset did not identify any anomalous values. Therefore, all fish tissue data were retained for analysis.

During statistical analysis of fish health variables, a total of two statistical outliers (based on SR) were identified (Table B-2). These values were removed from statistical analyses. No statistical outliers were identified in the ANCOVA analyses of relative weight, liver weight, or gonad weight.

Table B-2 Statistical Outliers in ANOVA of Fish Health Variables

Group	Variable	Fish ID	Area	Value	Studentized Residual
Male	Total length (mm)	9156	FFA	86.99	3.62
Female	Total length (mm)	7115	MF3	81.06	3.69

ID = identification; MF = mid-field; FF = far-field.

During statistical analysis of fish tissue chemistry variables, a total of 11 statistical outliers (based on SR) were identified (Table B-3). These values were removed from statistical analyses. No statistical outliers were identified in the ANCOVA analysis of mercury.

Table B-3 Statistical Outliers in ANOVA of Fish Tissue Chemistry Variables

Station	Variable	Composite Number	Value	Studentized Residual
NF	Cadmium (mg/kg wwt)	I4	0.0259	3.63
MF3	Cesium (mg/kg wwt)	G2	0.0649	4.44
MF3	Lead (mg/kg wwt)	G2	0.0318	3.87
FF2	Lithium (mg/kg wwt)	C3	0.065	5.78
FF2	Molybdenum (mg/kg wwt)	D5	0.0924	4.61
MF3	Potassium (mg/kg wwt)	G2	3820	4.05
NF	Thallium (mg/kg wwt)	I4	0.0119	5.78
MF3	Tin (mg/kg wwt)	H1	0.086	3.80
FF2	Titanium (mg/kg wwt)	C3	1.04	4.65
MF3	Vanadium (mg/kg wwt)	G3	0.144	6.48
FFA	Cobalt (mg/kg wwt)	F1	0.935	3.97

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

ATTACHMENT C

EFFORT AND ENVIRONMENTAL VARIABLES (RAW DATA)

These data are provided electronically as an Excel file.

ATTACHMENT D

FISH POPULATION HEALTH (RAW DATA)

These data are provided electronically as an Excel file.

ATTACHMENT E

ASSESSMENT OF ABNORMALITIES

Table E-1 External Abnormalities Observed in Slimy Sculpin from Lac de Gras, 2019

Abnormality		NF	MF3	FF1	FF2	FFA	Total
Body Deformity	Spinal Curvature	2	1	0	2	0	5
Eye Deformities		0	0	0	0	0	0
Skin Aberrations	Mild	4	0	3	0	0	7
Thymus Inflammation	Mild	7	4	8	3	16	38
Opercula		0	0	0	0	0	0
Gills	Pale	12	13	10	6	13	54
	Marginate	2	0	1	0	0	3
	Frayed	0	0	0	1	1	2
Pseudobranch Deformities		0	0	0	0	0	0
Fin Erosion	Light	2	6	4	8	13	33
	Moderate	0	0	0	0	2	2
	Severe	1	0	1	0	0	2
Vent Inflammation	Light	1	5	9	3	3	21
	Moderate	1	1	0	0	0	2

Note: All fish captured, with and without parasites, were assessed and included in the external abnormality counts.
NF = near-field; MF = mid-field; FF = far-field.

Table E-2 External and Internal Abnormalities Observed in Lethally Sampled Slimy Sculpin from Lac de Gras, 2019

Category	NF					MF3					FF1					FF2						FFA				
	Adult	Age-1+	Adult		Total	Adult	Age-1+	Adult		Total	Adult	Age-1+	Adult		Total	Adult	Age-1+	Adult			Total	Adult	Age-1+	Adult		Total
			M	F				M	F				M	F				M	F	U				M	F	
Number	52	30	30	22	82	51	36	34	17	87	53	34	32	21	87	51	34	33	17	1	85	62	31	39	23	93
Body Deformities	2	0	1	1	2	1	0	1	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0
Skin - Mild skin aberrations	2	1	1	1	3	0	0	0	0	0	2	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Thymus - Mild inflammation	3	1	2	1	4	2	2	0	2	4	3	4	3	0	7	1	1	1	0	0	2	3	6	3	0	9
Gills - Marginate	0	2	0	0	2	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Gills - Pale	2	7	2	0	9	3	9	1	2	12	5	5	2	3	10	2	3	2	0	0	5	6	5	5	1	11
Gills - Frayed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1
Fins - Light active erosion	1	1	0	1	2	3	3	2	1	6	2	1	1	1	3	2	5	2	0	0	7	4	7	1	3	11
Fins - Moderate active erosion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fins - Severe active erosion with hemorrhaging	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hindgut - Slight inflammation or reddening	0	1	0	0	1	4	0	3	1	4	4	4	2	2	8	2	1	2	0	0	3	1	0	0	1	1
Hindgut - Moderate inflammation or reddening	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
External parasites - Few observed parasites	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liver - Fatty Liver	27	12	17	10	39	26	25	20	6	51	36	10	22	14	82	29	11	18	11	0	40	29	17	14	15	46
Liver - Focal discoloration	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1	0	1	0	1
Liver - General discoloration	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	1
Liver - Other (e.g., enlarged, granular, and focal discoloration)	1	0	1	0	1	1	1	0	1	2	2	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Spleen - Granular	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spleen - Enlarged	2	0	0	2	2	0	0	0	0	0	1	0	1	0	1	1	0	1	0	0	1	0	0	0	0	0
Spleen - Nodular	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Spleen - Other (e.g., focal discoloration, and granular)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	2
Mesentaric Fat - < 50%	27	8	17	10	35	37	18	25	12	55	31	11	17	14	42	28	12	20	8	0	40	26	6	15	11	32
Mesentaric Fat - 50%	2	1	1	1	3	4	0	3	1	4	4	0	1	3	4	1	3	1	0	0	4	1	0	0	1	1
Mesentaric Fat - > 50%	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	2	0	0	0	0	0
Kidney - Mottled	2	3	2	0	5	3	4	2	1	7	0	0	0	0	0	0	1	0	0	0	1	3	3	2	1	6
Kidney - Swollen	1	0	0	1	1	8	4	6	2	12	5	2	3	2	7	0	0	0	0	0	0	1	0	1	0	1
Kidney - Other (e.g., focal discoloration)	0	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0

Note: Cream-coloured (fatty) livers are normal during the time of sampling and were not considered as abnormalities.
NF = near-field; MF = mid-field; FF = far-field; M = male; F = female; U = unknown; < = less than; > = greater than.

ATTACHMENT F

SLIMY SCULPIN STOMACH CONTENT (RAW DATA)

These data are provided electronically as an Excel file.

ATTACHMENT G

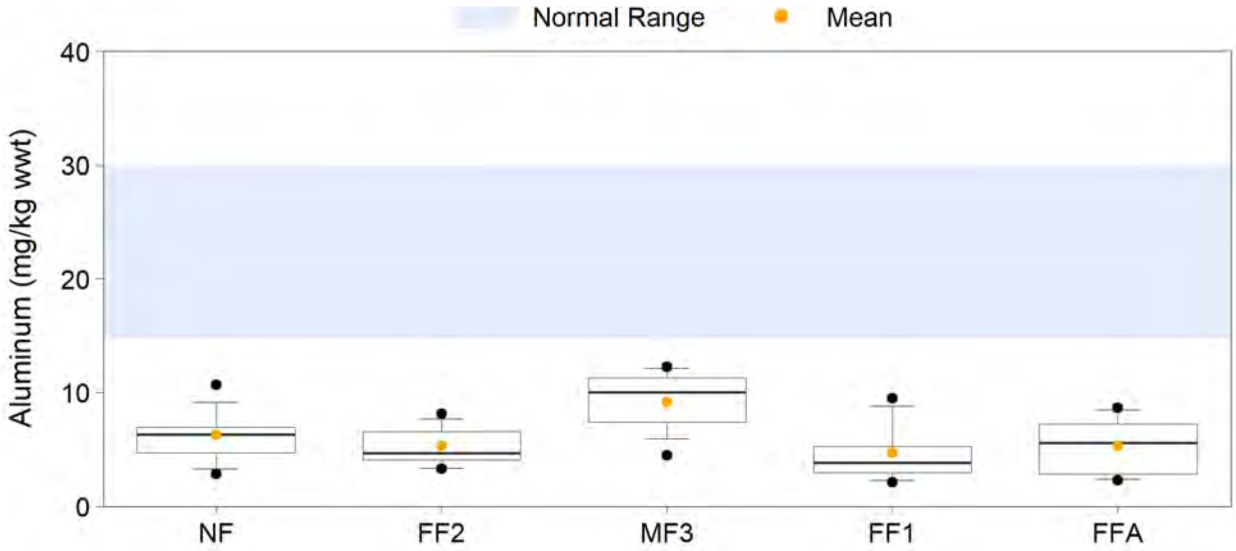
FISH TISSUE CHEMISTRY (RAW DATA)

These data are provided electronically as an Excel file.

ATTACHMENT H

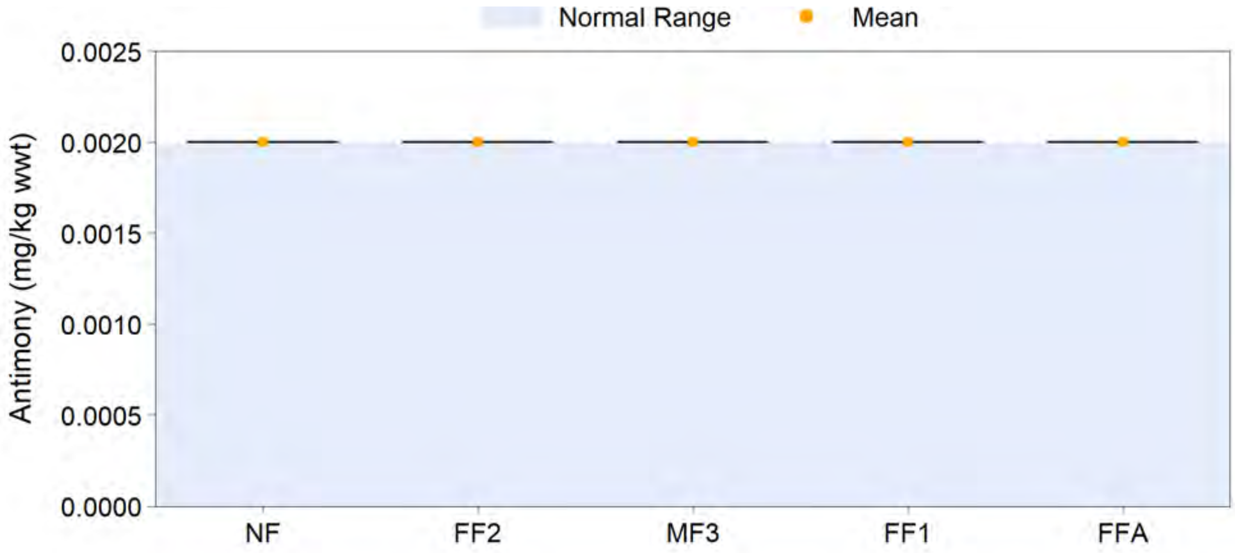
FISH TISSUE CHEMISTRY COMPARISONS TO NORMAL RANGE

Figure H-1 **Boxplots of Aluminum in Slimy Sculpin Tissue in Lac de Gras, 2019**



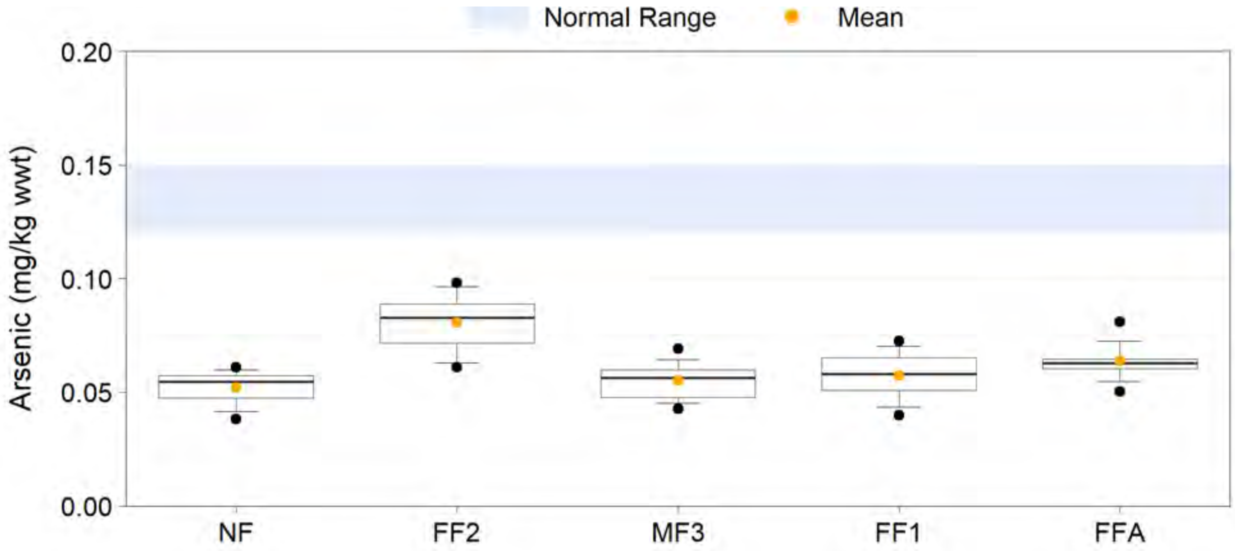
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-2 **Boxplots of Antimony in Slimy Sculpin Tissue in Lac de Gras, 2019**



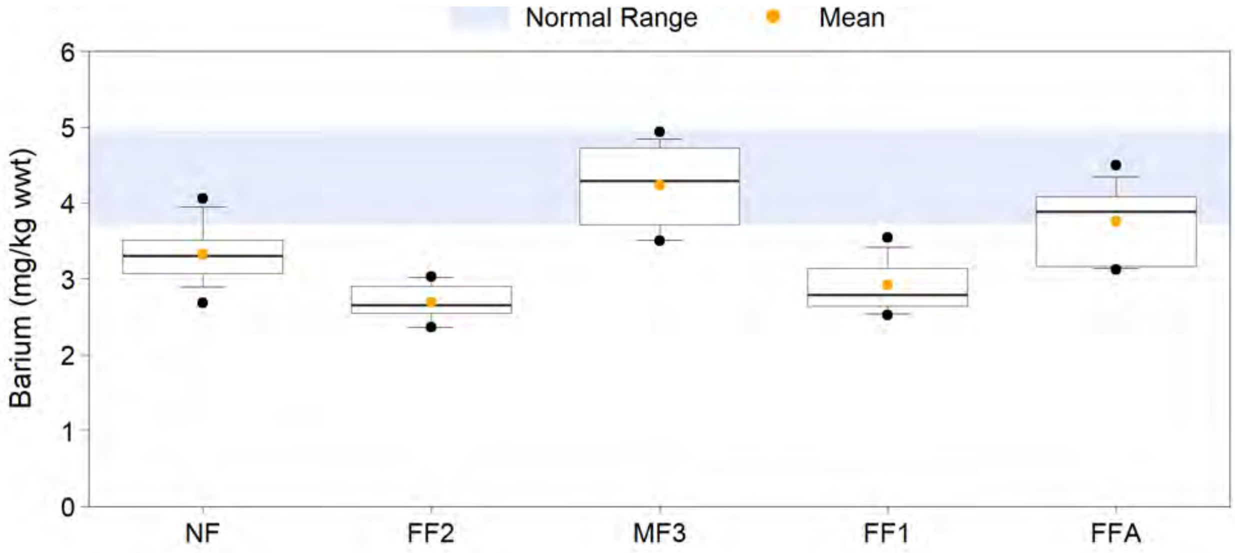
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-3 Boxplots of Arsenic in Slimy Sculpin Tissue in Lac de Gras, 2019



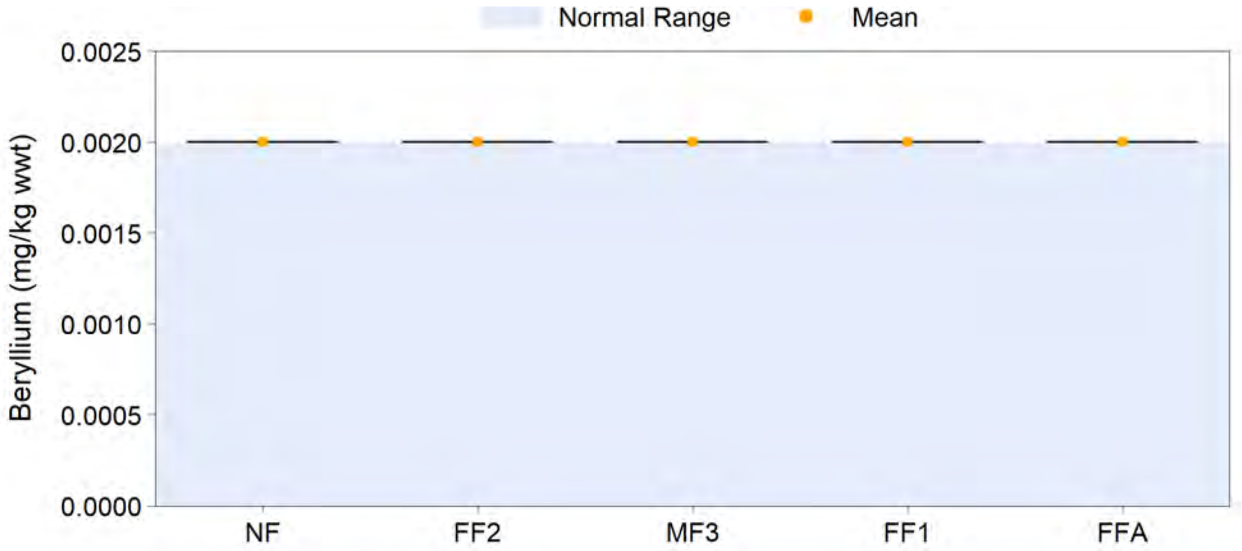
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-4 Boxplots of Barium in Slimy Sculpin Tissue in Lac de Gras, 2019



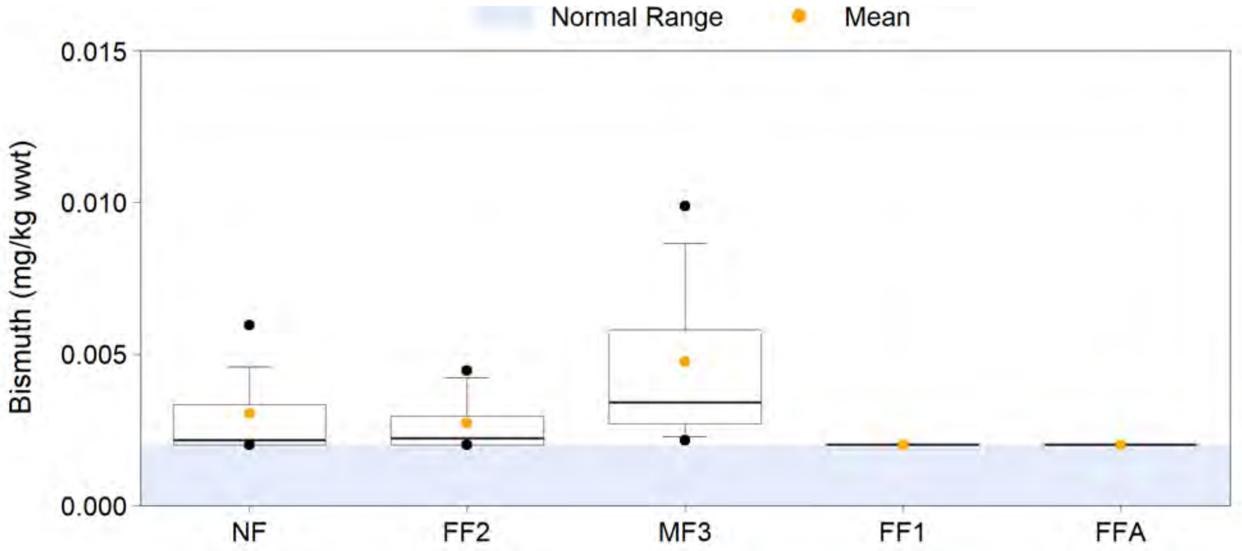
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-5 Boxplots of Beryllium in Slimy Sculpin Tissue in Lac de Gras, 2019



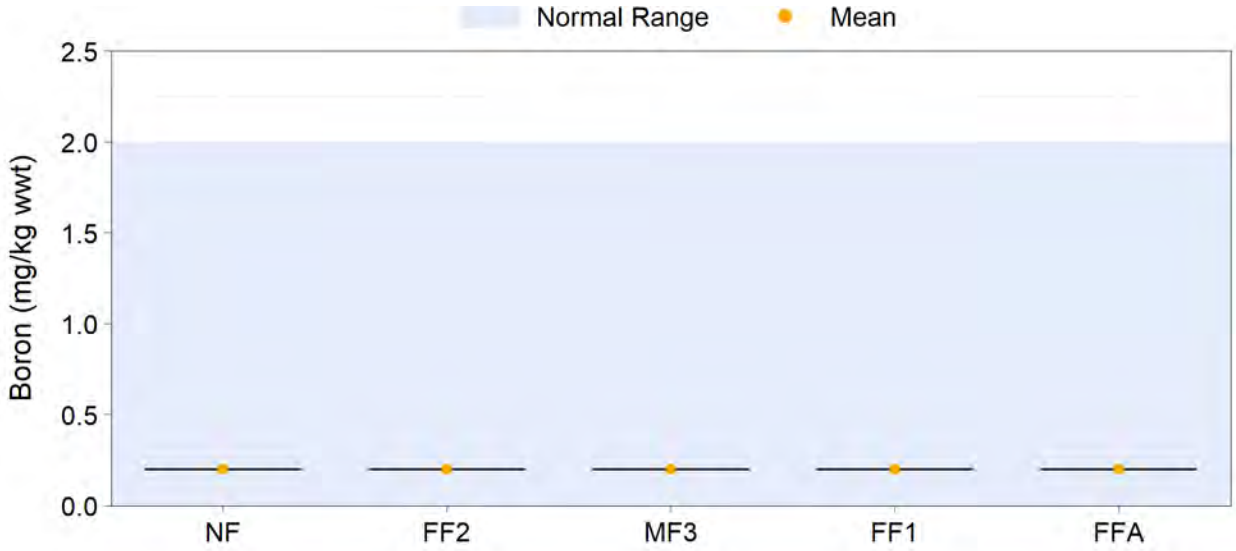
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-6 Boxplots of Bismuth in Slimy Sculpin Tissue in Lac de Gras, 2019



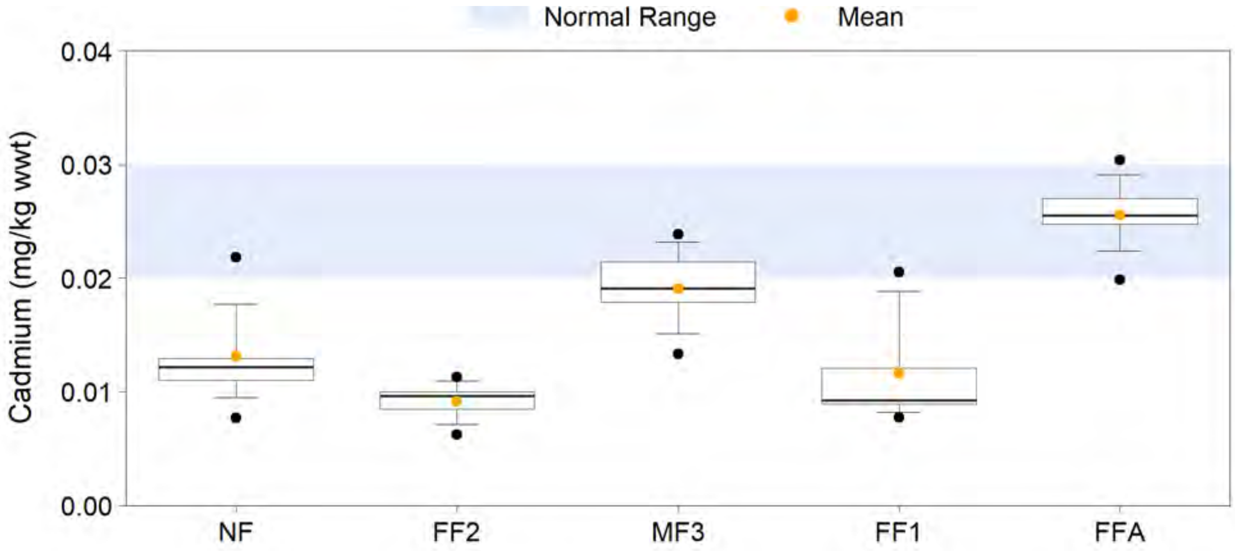
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-7 Boxplots of Boron in Slimy Sculpin Tissue in Lac de Gras, 2019



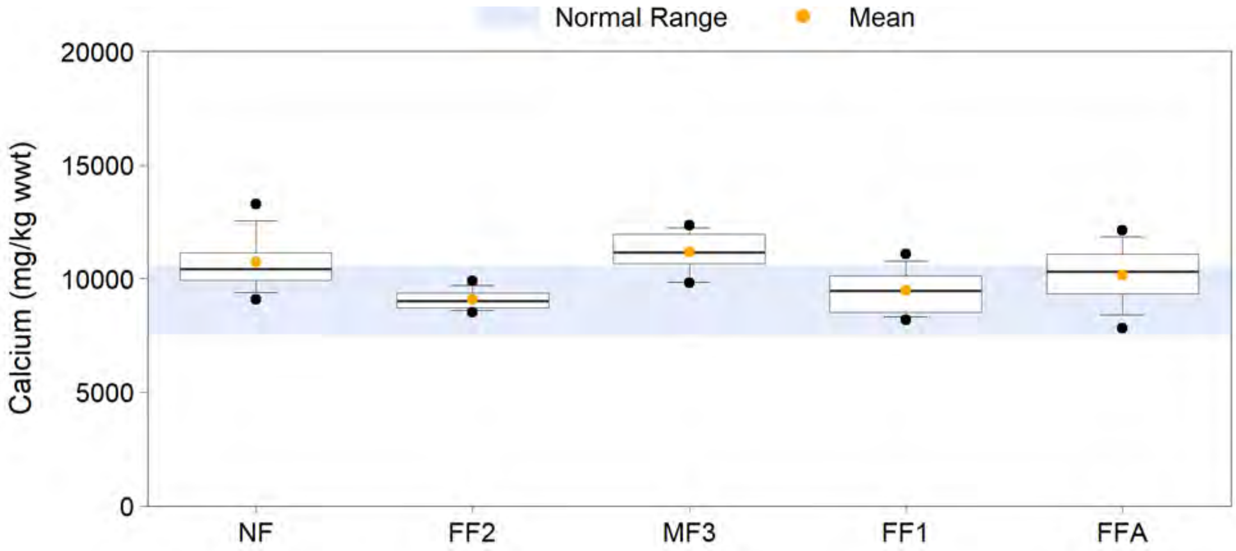
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-8 Boxplots of Cadmium in Slimy Sculpin Tissue in Lac de Gras, 2019



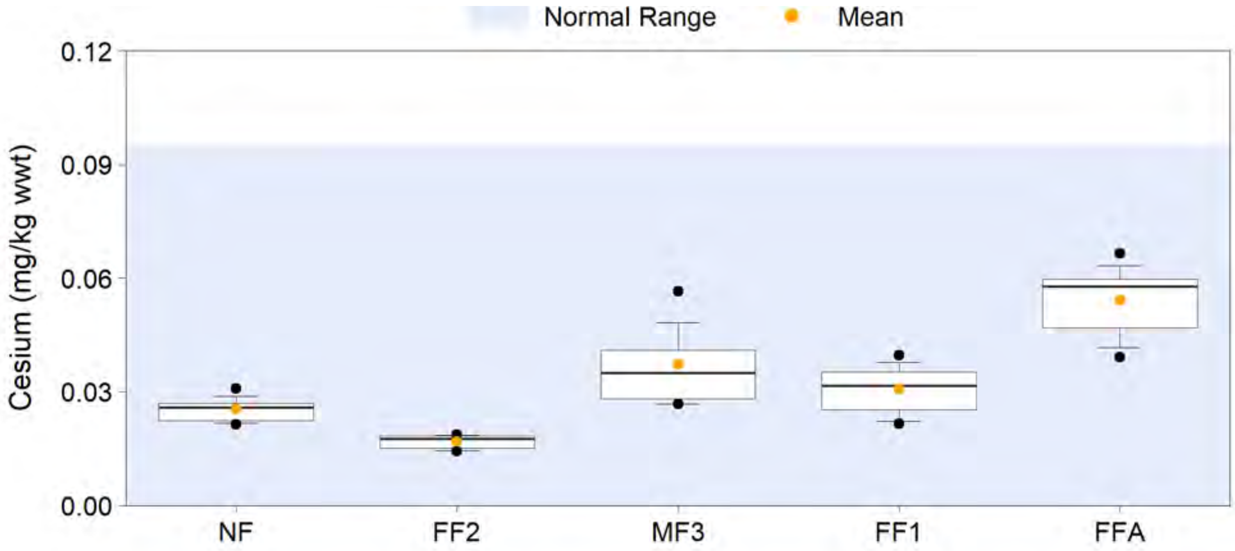
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-9 Boxplots of Calcium in Slimy Sculpin Tissue in Lac de Gras, 2019



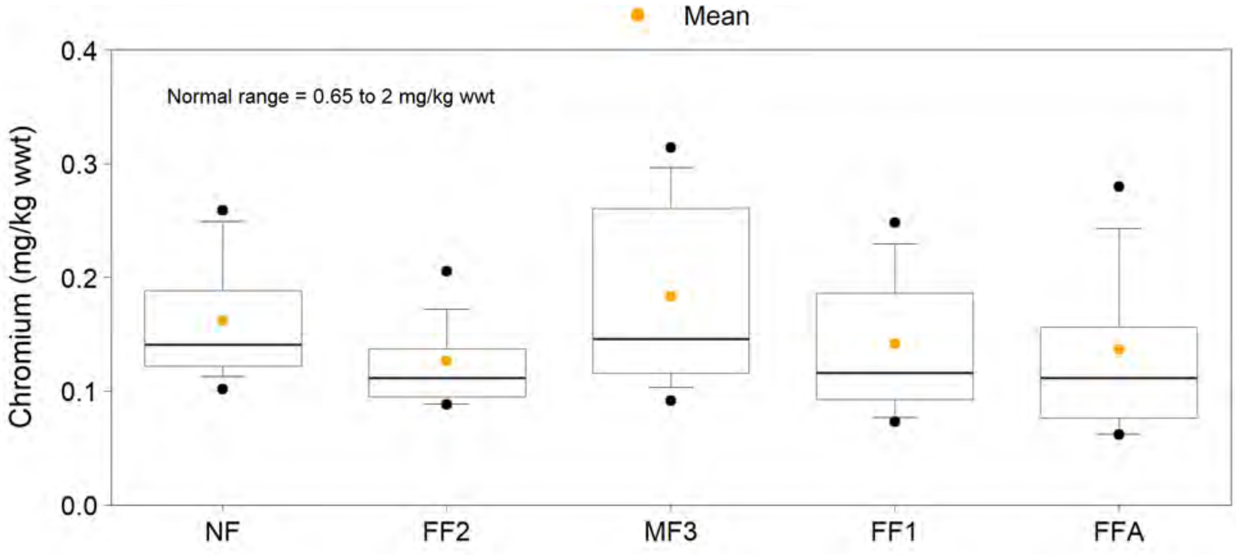
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-10 Boxplots of Cesium in Slimy Sculpin Tissue in Lac de Gras, 2019



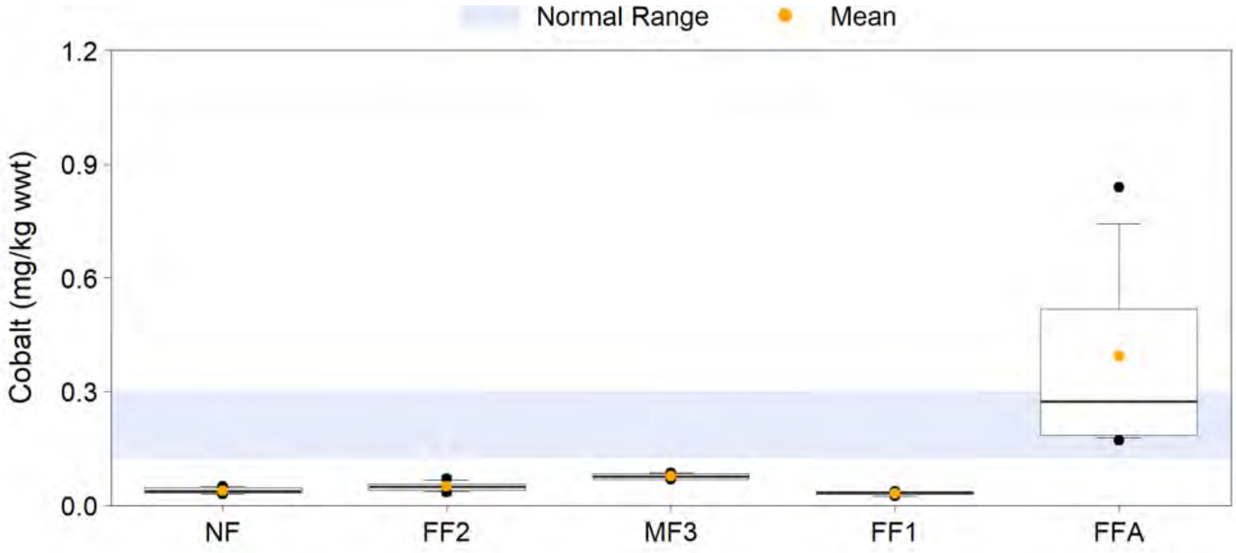
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-11 Boxplots of Chromium in Slimy Sculpin Tissue in Lac de Gras, 2019



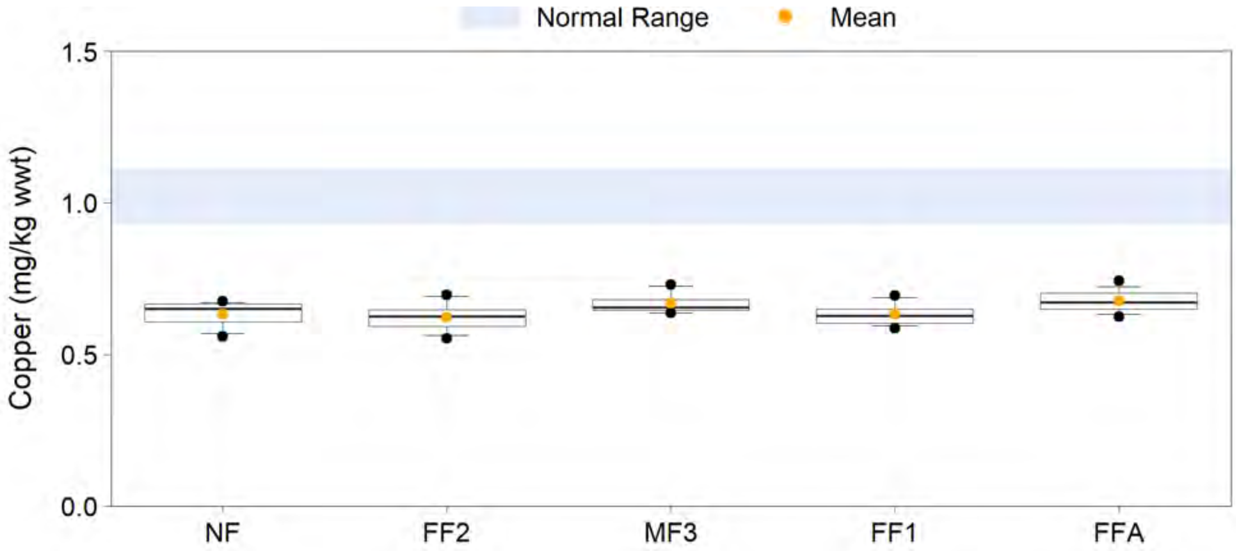
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-12 Boxplots of Cobalt in Slimy Sculpin Tissue in Lac de Gras, 2019



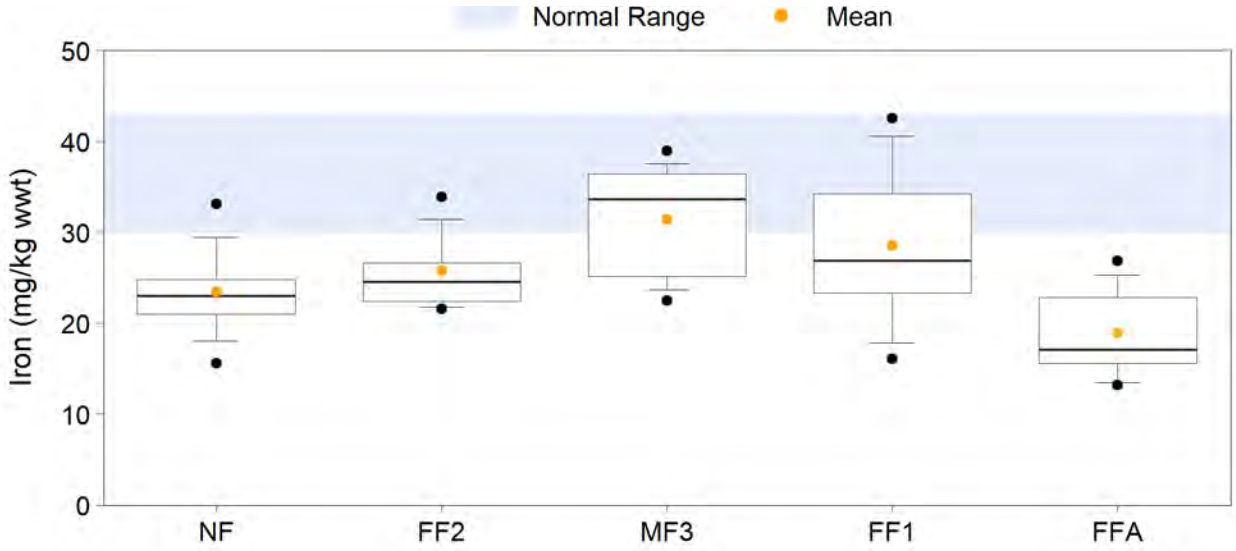
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-13 Boxplots of Copper in Slimy Sculpin Tissue in Lac de Gras, 2019



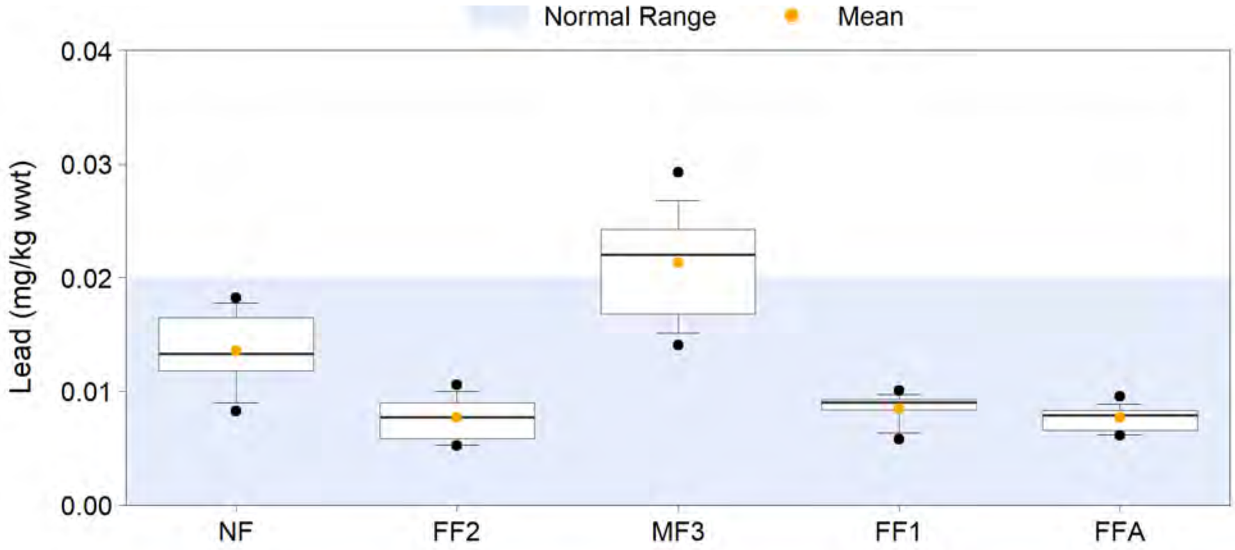
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-14 Boxplots of Iron in Slimy Sculpin Tissue in Lac de Gras, 2019



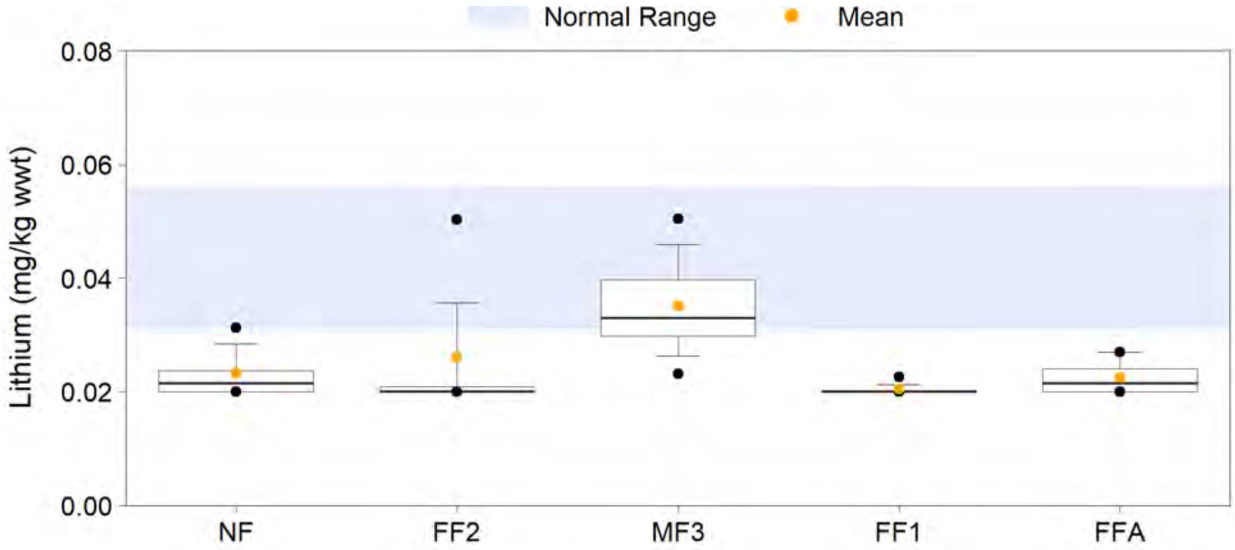
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-15 Boxplots of Lead in Slimy Sculpin Tissue in Lac de Gras, 2019



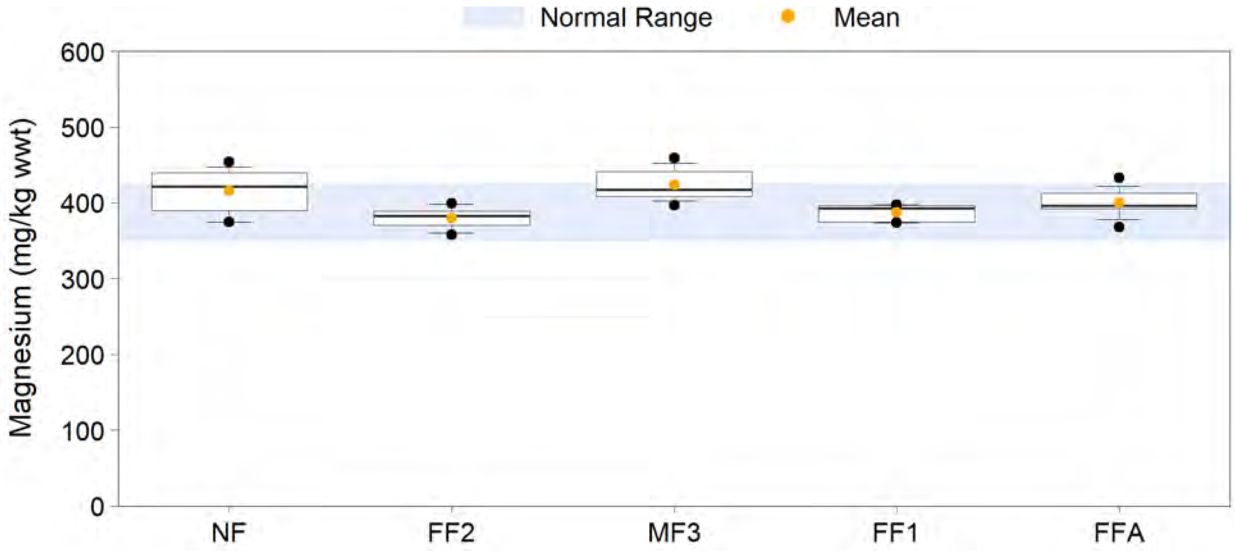
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-16 Boxplots of Lithium in Slimy Sculpin Tissue in Lac de Gras, 2019



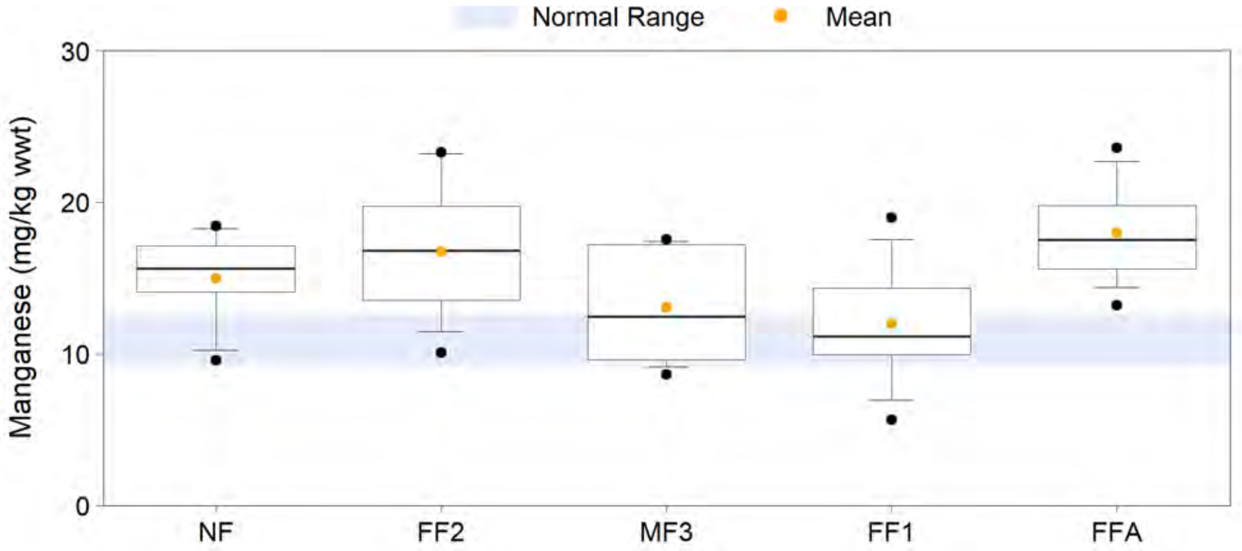
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-17 Boxplots of Magnesium in Slimy Sculpin Tissue in Lac de Gras, 2019



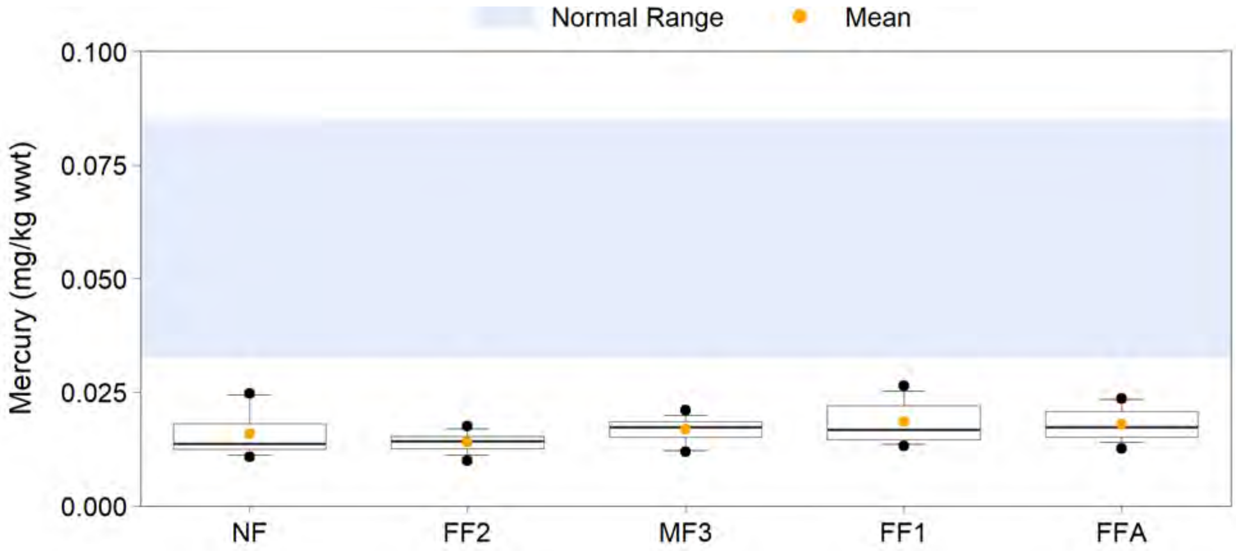
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-18 Boxplots of Manganese in Slimy Sculpin Tissue in Lac de Gras, 2019



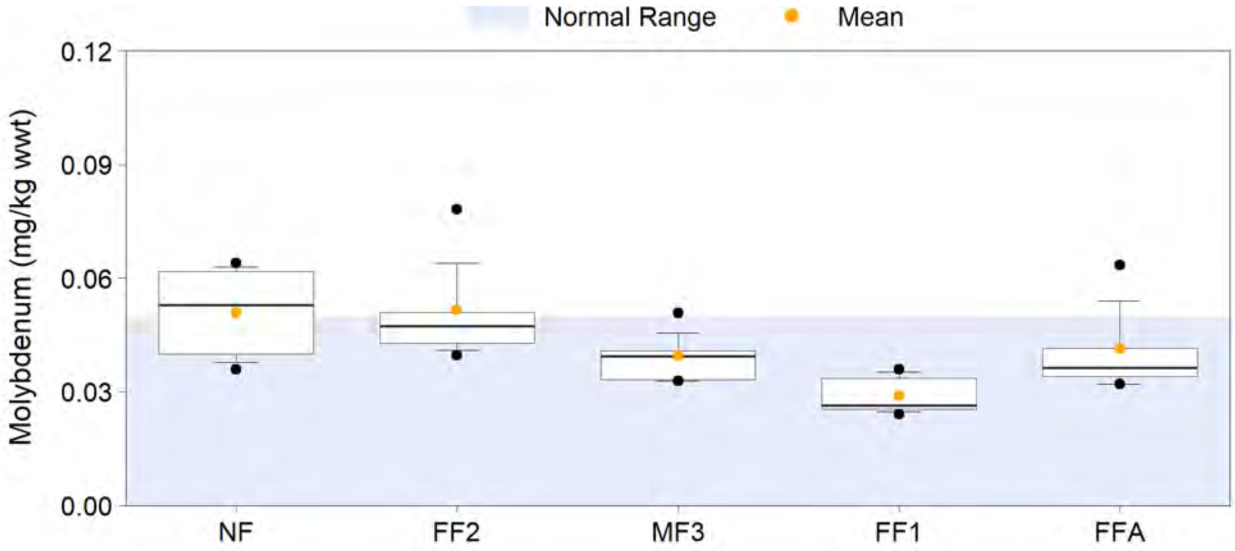
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-19 Boxplots of Mercury in Slimy Sculpin Tissue in Lac de Gras, 2019



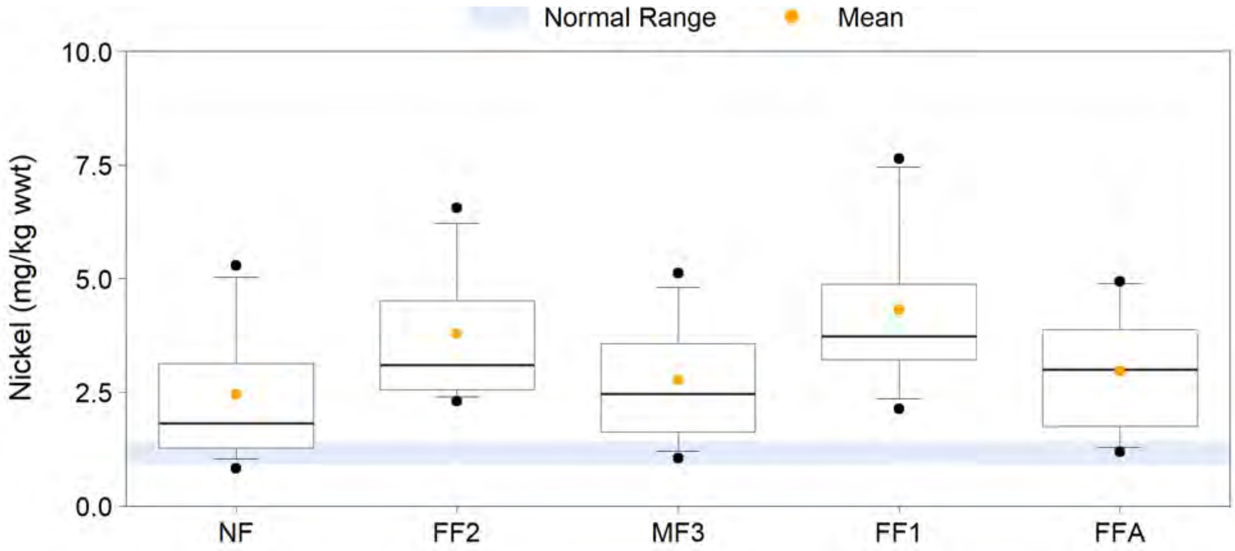
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-20 Boxplots of Molybdenum in Slimy Sculpin Tissue in Lac de Gras, 2019



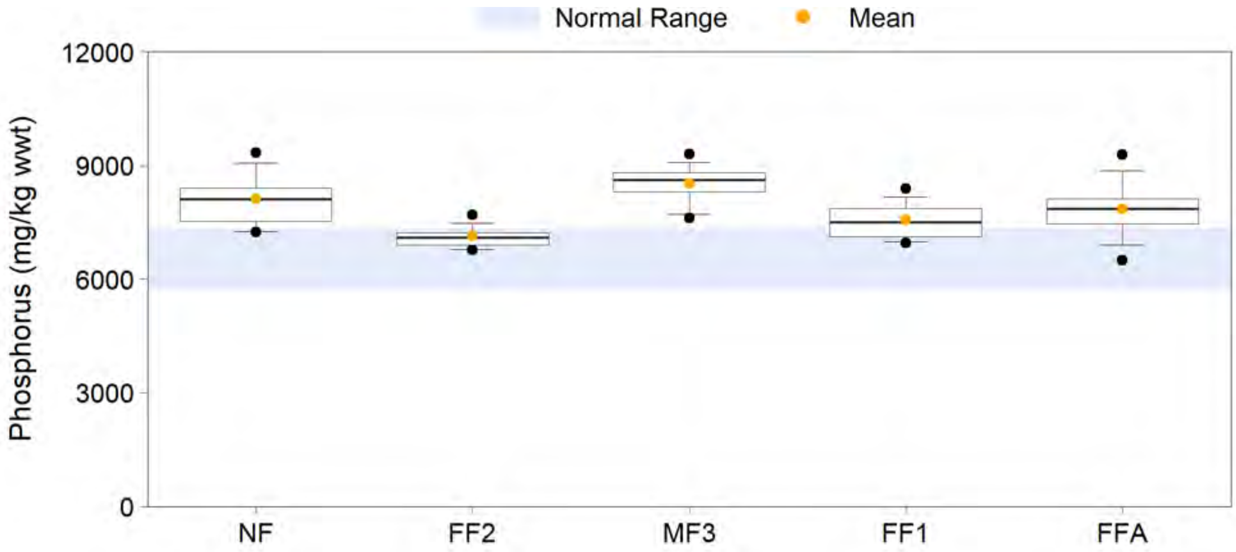
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-21 Boxplots of Nickel in Slimy Sculpin Tissue in Lac de Gras, 2019



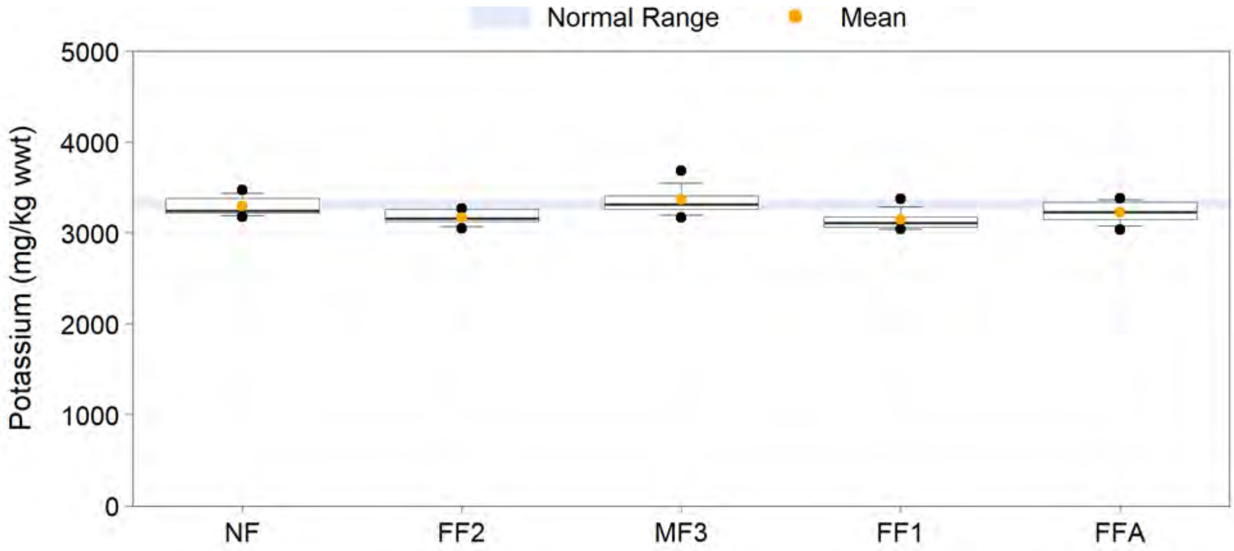
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-22 Boxplots of Phosphorus in Slimy Sculpin Tissue in Lac de Gras, 2019



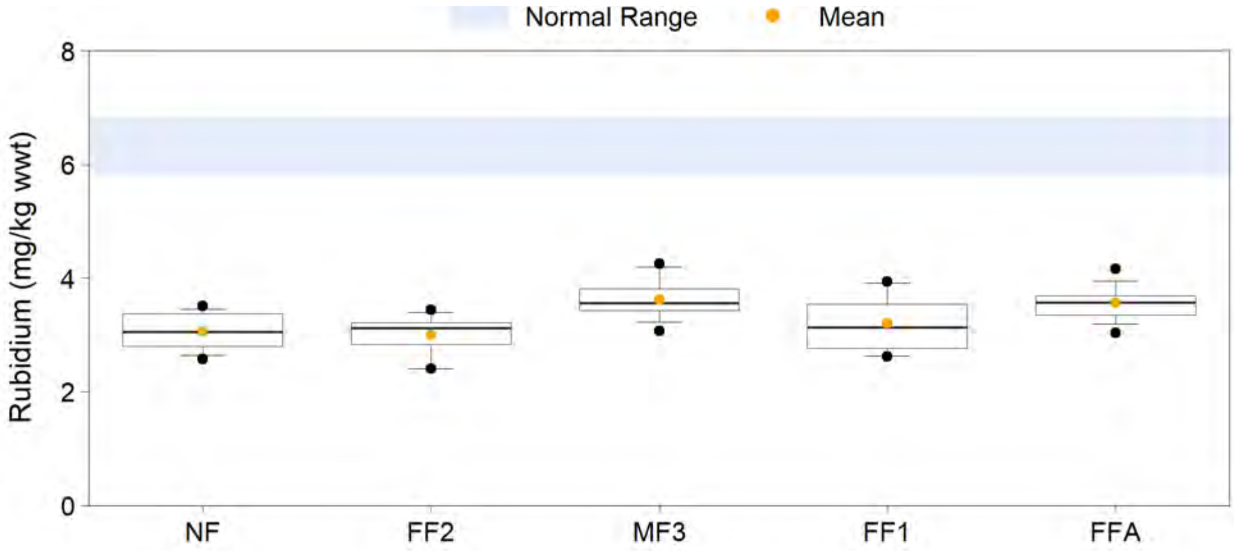
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-23 Boxplots of Potassium in Slimy Sculpin Tissue in Lac de Gras, 2019



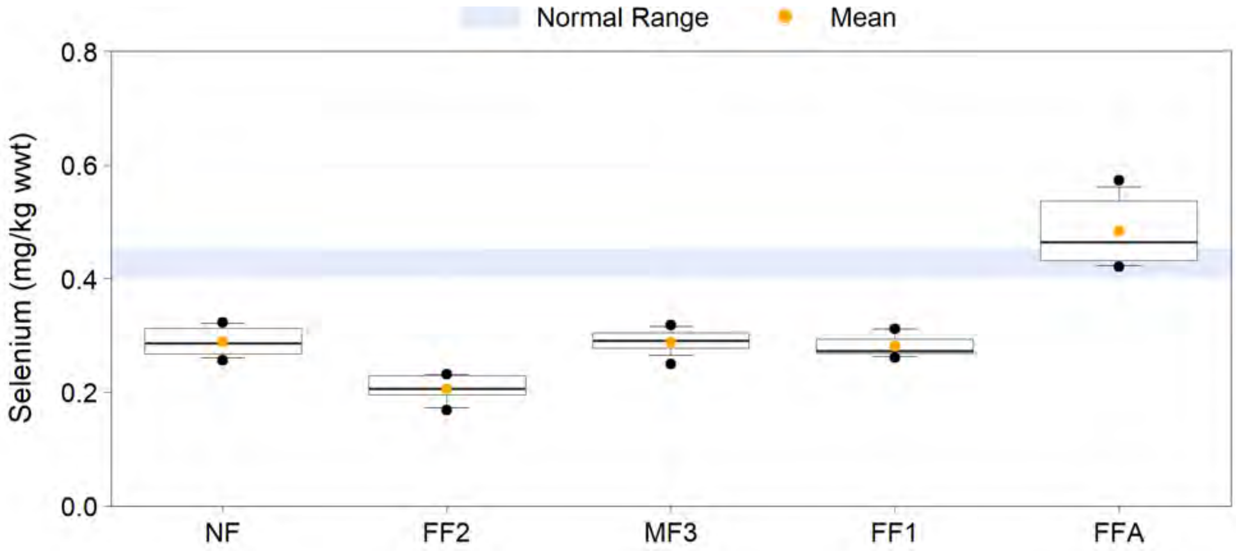
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-24 Boxplots of Rubidium in Slimy Sculpin Tissue in Lac de Gras, 2019



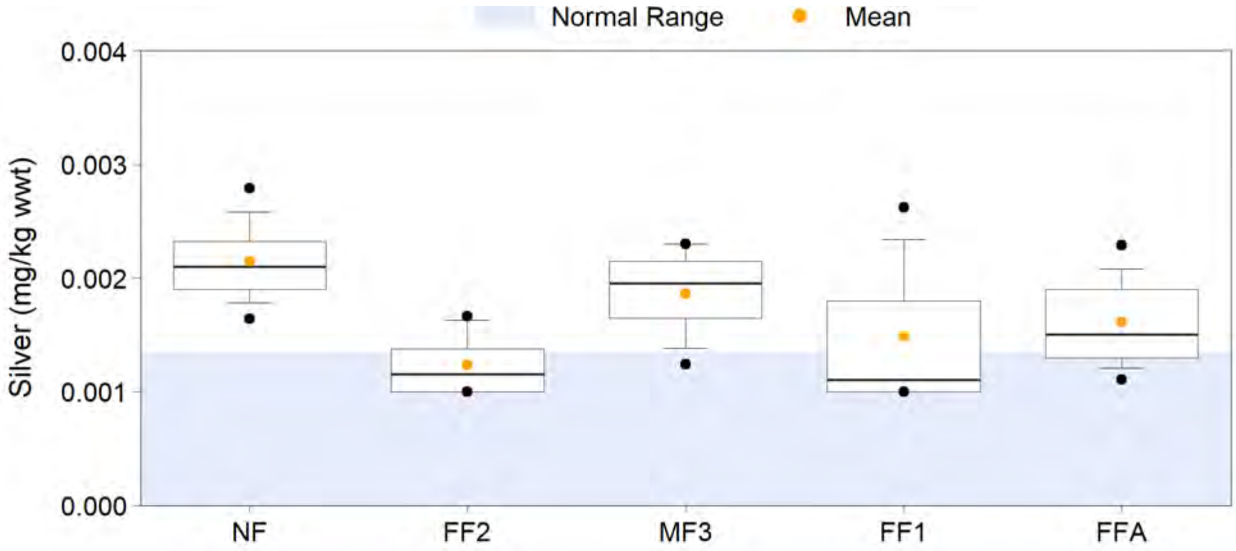
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-25 Boxplots of Selenium in Slimy Sculpin Tissue in Lac de Gras, 2019



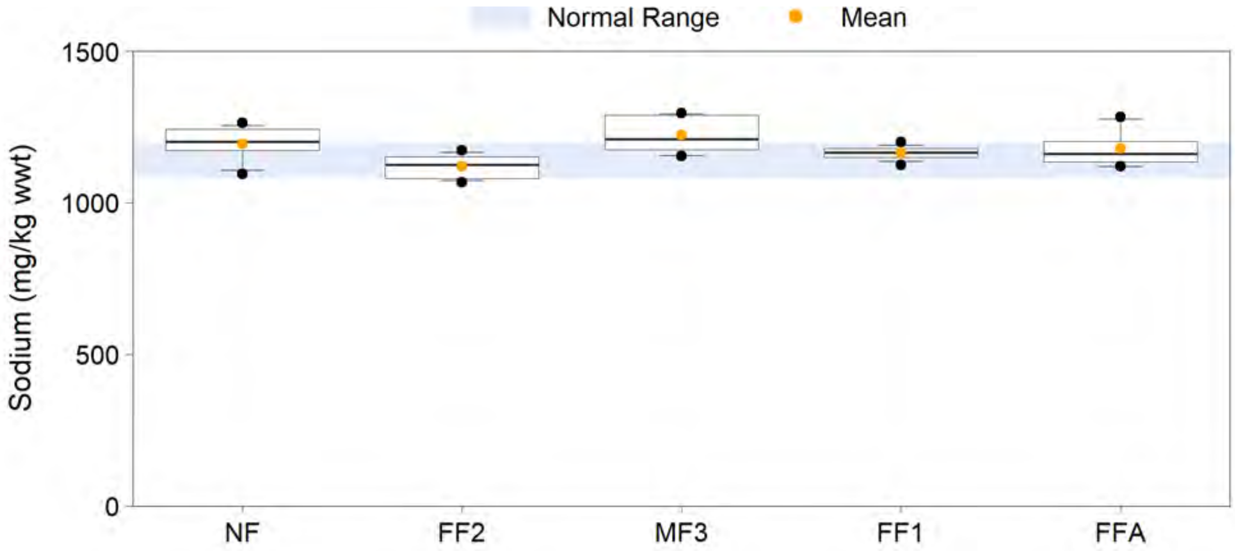
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-26 Boxplots of Silver in Slimy Sculpin Tissue in Lac de Gras, 2019



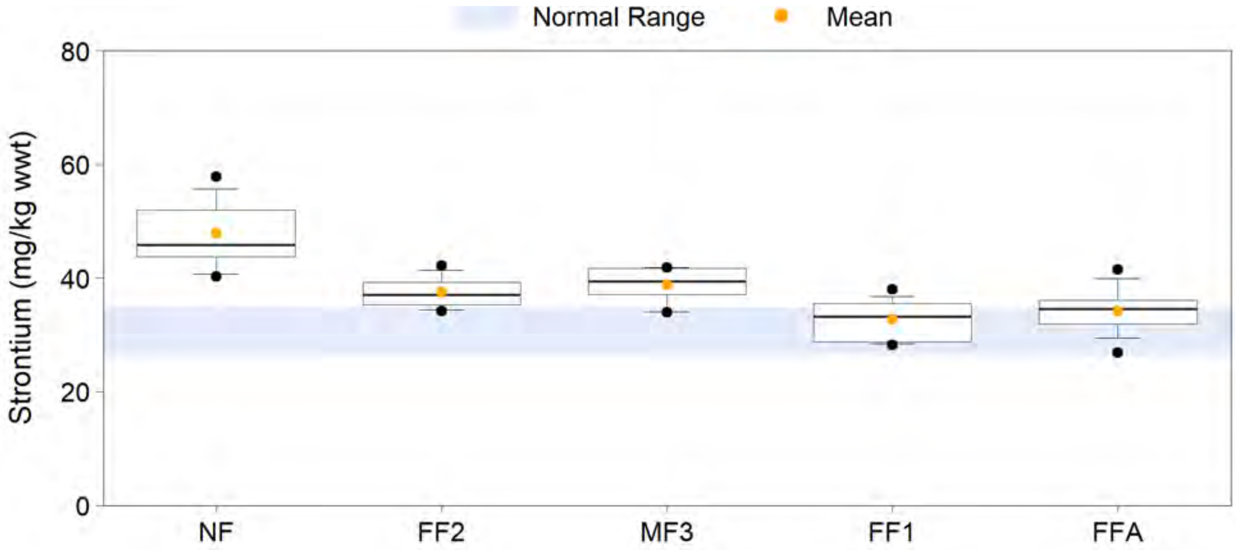
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-27 Boxplots of Sodium in Slimy Sculpin Tissue in Lac de Gras, 2019



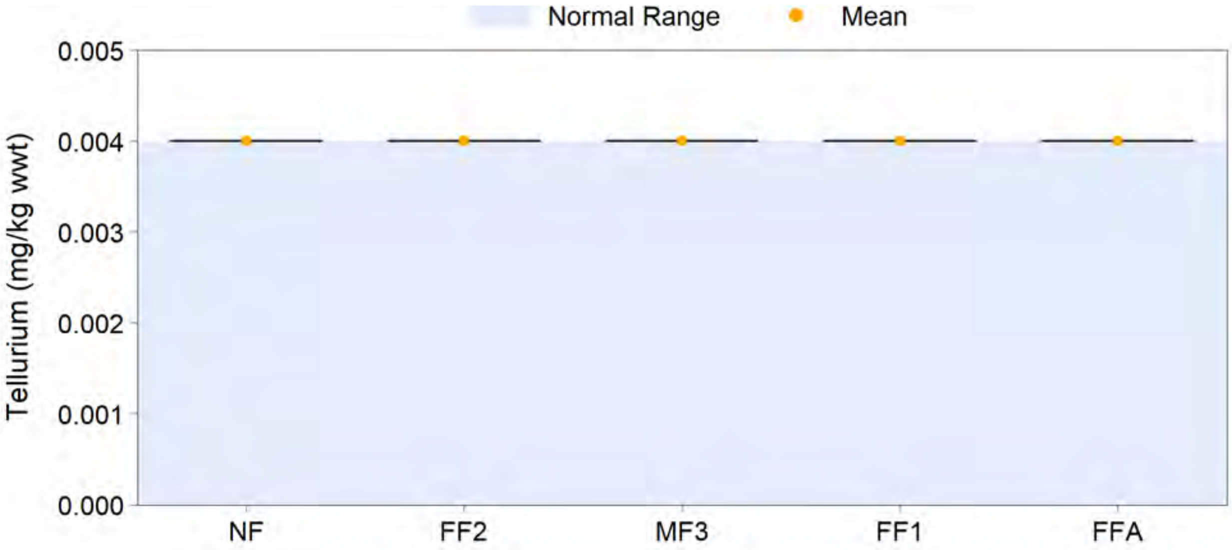
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-28 Boxplots of Strontium in Slimy Sculpin Tissue in Lac de Gras, 2019



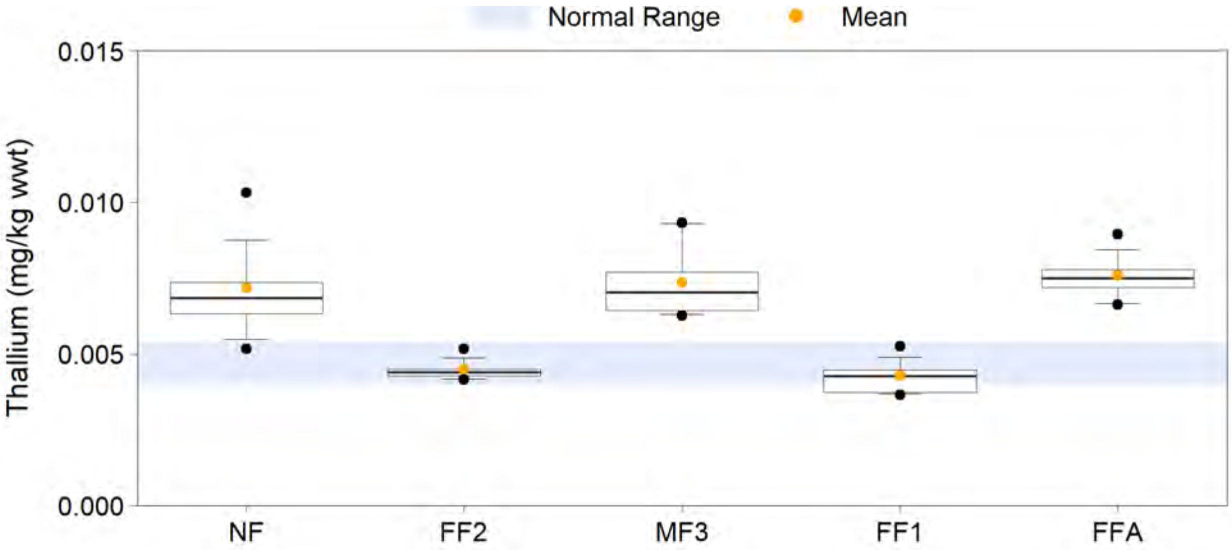
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-29 Boxplots of Tellurium in Slimy Sculpin Tissue in Lac de Gras, 2019



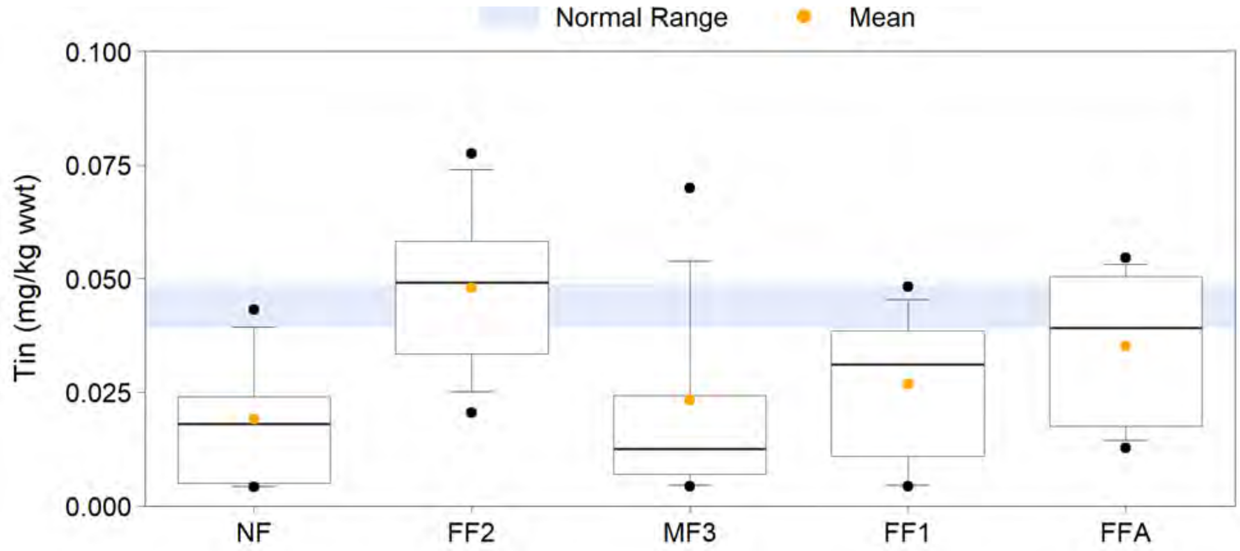
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-30 Boxplots of Thallium in Slimy Sculpin Tissue in Lac de Gras, 2019



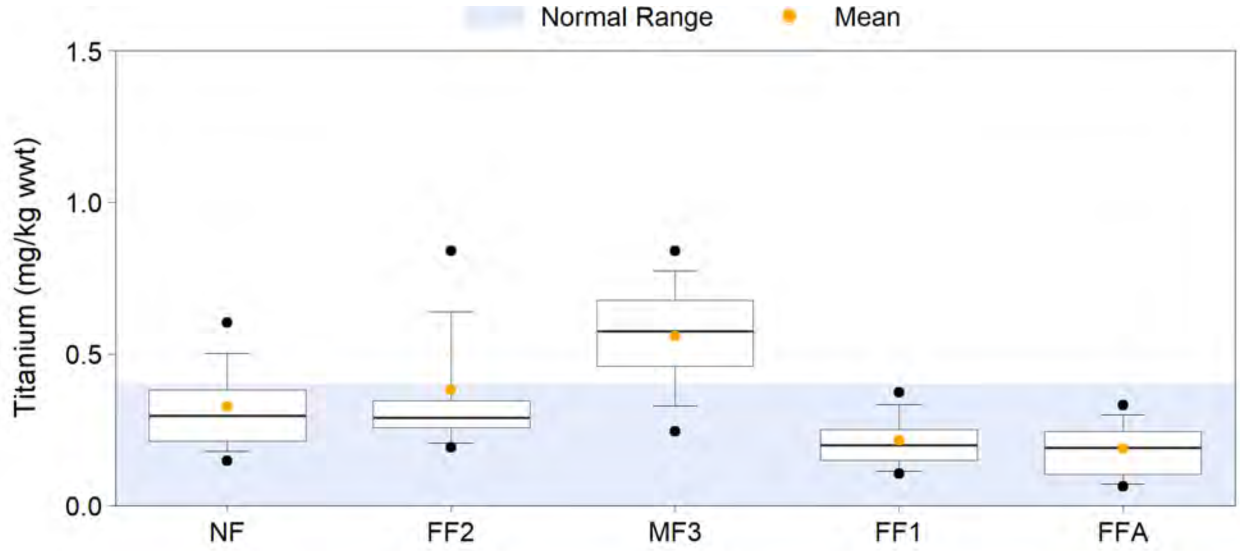
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-31 Boxplots of Tin in Slimy Sculpin Tissue in Lac de Gras, 2019



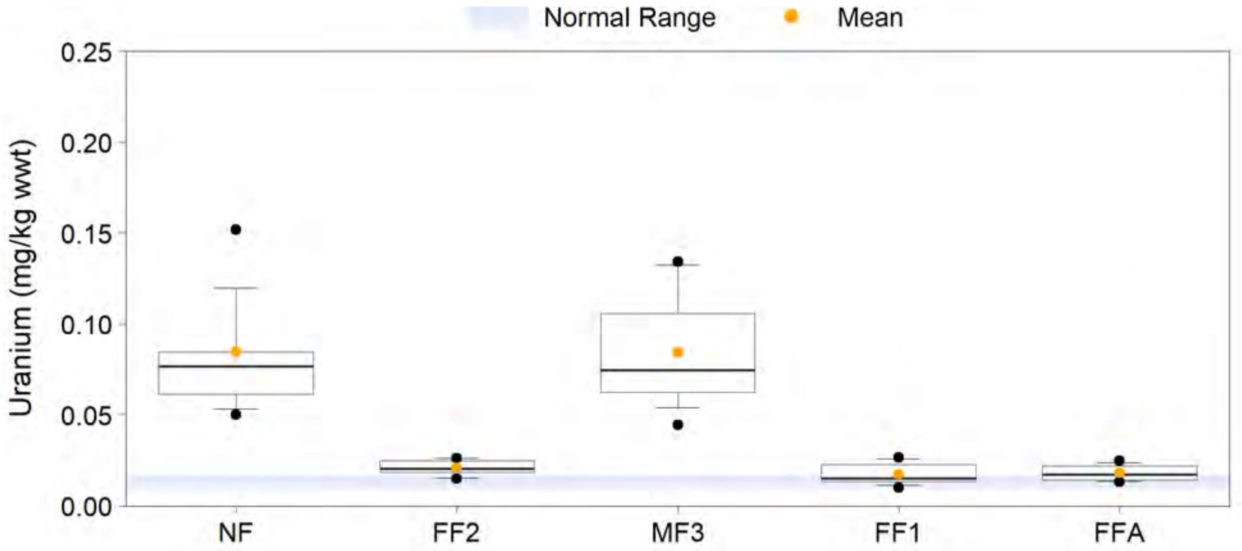
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-32 Boxplots of Titanium in Slimy Sculpin Tissue in Lac de Gras, 2019



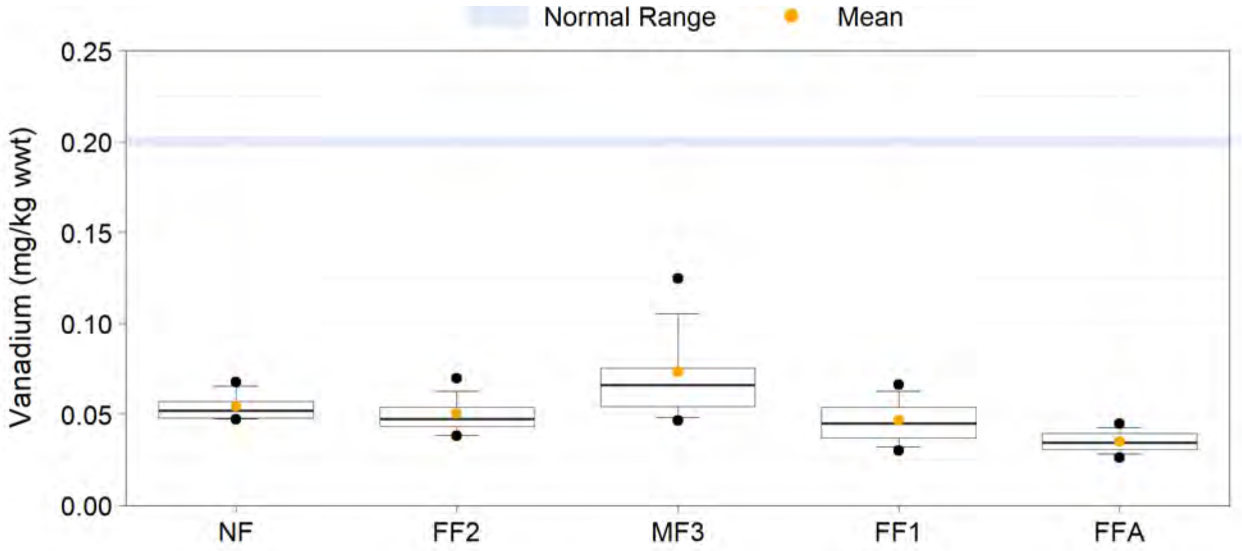
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-33 Boxplots of Uranium in Slimy Sculpin Tissue in Lac de Gras, 2019



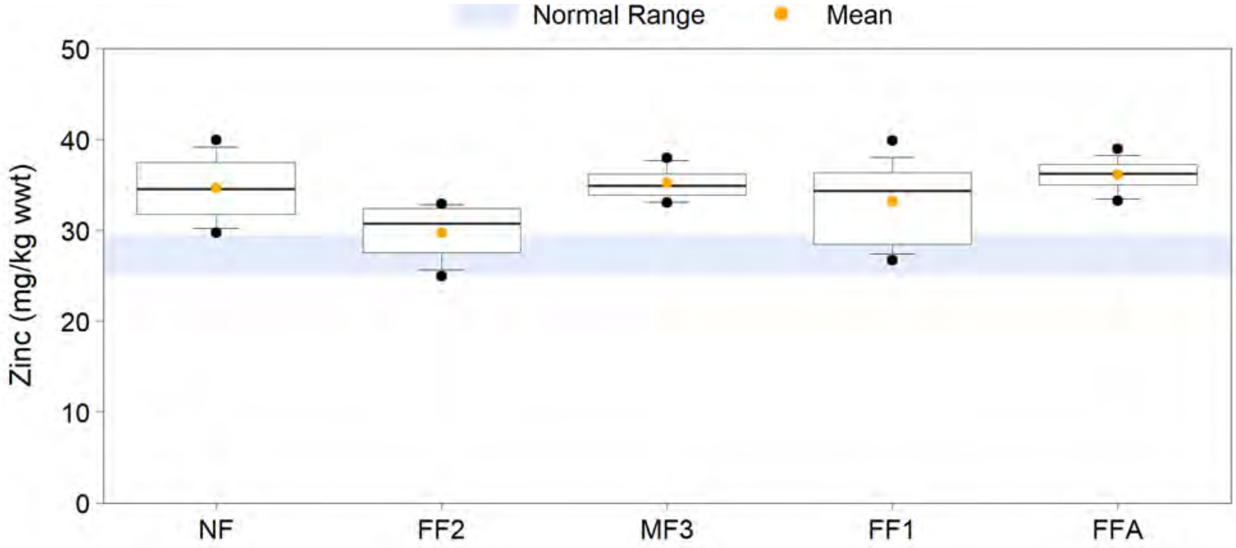
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-34 Boxplots of Vanadium in Slimy Sculpin Tissue in Lac de Gras, 2019



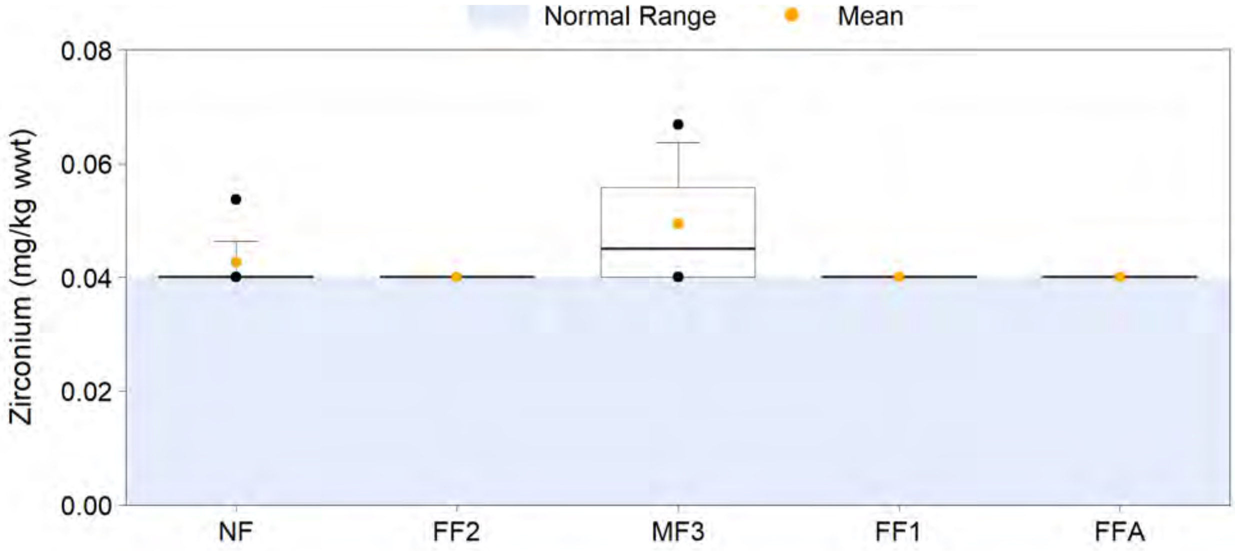
wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-35 Normal Range and Boxplots of Zinc in Slimy Sculpin Tissue in Lac de Gras, 2019



wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

Figure H-36 Normal Range and Boxplots of Zirconium in Slimy Sculpin Tissue in Lac de Gras, 2019



wwt = wet weight; NF = near-field; MF = mid-field; FF = far-field.

APPENDIX VI

PLUME DELINEATION SURVEY

No information was available for this appendix in 2019.

APPENDIX VII

DIKE MONITORING STUDY

No information was available for this appendix in 2019.

APPENDIX VIII

FISH SALVAGE PROGRAM

No information was available for this appendix in 2019.

APPENDIX IX

FISH HABITAT COMPENSATION MONITORING

No information was available for this appendix in 2019.

APPENDIX X

FISH PALATABILITY, FISH HEALTH, AND FISH TISSUE CHEMISTRY SURVEY

No information was available for this appendix in 2019.

APPENDIX XI

PLANKTON REPORT

PLANKTON REPORT
IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT
FOR THE DIAVIK DIAMOND MINE,
NORTHWEST TERRITORIES

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-1919 Ver. 0
PO No. 3103966486

Executive Summary

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of an Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2015L2-0001 (WLWB 2015) and according to the *AEMP Design Plan Version 4.1*, approved by the Wek'èezhìı Land and Water Board. This report presents the results of the 2019 plankton sampling program. Objectives of the plankton program were to monitor for potential ecological effects in phytoplankton and zooplankton community endpoints (i.e., abundance, biomass, and taxonomic composition) and assess the plankton community as indicators of potential toxicological effects from the Mine water discharge and other stressors from the Mine.

Plankton samples were collected and analysed from thirty-four stations in Lac de Gras and three stations in Lac du Sauvage during open-water season in 2019. Overall, the plankton community data suggest that a nutrient enrichment effect is occurring in Lac de Gras. The plankton community data do not indicate that a toxicological effect is occurring in Lac de Gras. The 2019 phytoplankton results are consistent with a nutrient enrichment effect, showing an increase in total phytoplankton biomass in the near-field (NF) area. The zooplankton data suggest that changes are occurring in the NF area of Lac de Gras. Zooplankton biomass, in the NF area was above the 2019 FF area mean and the reference condition mean (although not significantly), showing no indication of toxicological impairment.

The 2019 plankton data do not suggest that a toxicological effect is occurring in Lac de Gras. Action Levels for toxicological impairment were not triggered and results are consistent with nutrient enrichment, as demonstrated by increased zooplankton biomass in the NF area.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
AIC	Akaike’s information criterion
AICc	corrected for small sample size
ANOSIM	analysis of similarities
ANOVA	analysis of variance
DDMI	Diavik Diamond Mines (2012) Inc.
FF	far-field
i.e.	that is
MF	mid-field
Mine	Diavik Diamond Mine
NF	near-field
nMDS	non-metric multidimensional scaling
P	probability
QA/QC	quality assurance/quality control
QA	quality assurance
QC	quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
SD	standard deviation
SIMPROF	similarity profile
SOP	standard operating procedure
sp.	species
spp.	plural species
WLWB	Wek'èezhìı Land and Water Board
WOE	weight-of-evidence

Symbols and Units of Measure

±	plus or minus
%	percent
>	greater than
<	less than
µm	micrometre
cm	centimetre
cells/L	cells per litre
ind/L	individuals per litre
km	kilometre
m	metre
mg/m^3	milligrams per cubic metre
mL	millilitre

1 INTRODUCTION

1.1 Background

Diavik Diamond Mines (2012) Inc. (DDMI) has been monitoring plankton as indicators of changes in Lac de Gras water quality since 2007 (Golder 2011, 2016, 2018). In 2013, DDMI revised its Aquatic Effects Monitoring Program (AEMP) for the Diavik Diamond Mine (Mine), as required by Water Licence W2007L2-0003 (WLWB 2007). Among the revisions to the *AEMP Study Design Version 3.5* (Golder 2014) approved by the Wek'èezhìı Land and Water Board (WLWB) was the addition of plankton as a monitoring component. Plankton monitoring occurs annually, once during the open-water season (between 15 August and 15 September) which is consistent with other AEMP components (Golder 2017a). In 2019, DDMI completed the field component of its AEMP as required by Water Licence W2015L2-0001 (WLWB 2015). The assessment of the plankton data collected during the 2019 AEMP field program, which was carried out by DDMI according to the *AEMP Design Plan Version 4.1* (Golder 2017a), is presented herein.

1.2 Objectives

The objective of the plankton component of the AEMP is to monitor the potential ecological effects of the Mine on the phytoplankton and zooplankton communities in Lac de Gras, and to assess whether toxicological changes are occurring in the plankton community. Plankton data were analyzed to determine whether there were differences in plankton biomass, richness, and community composition between areas exposed to Mine-related inputs, far-field (FF) areas and reference conditions for Lac de Gras (as defined in the *AEMP Reference Conditions Report Version 1.4* [Golder 2019a]).

1.3 Scope and Approach

The plankton component of the AEMP is designed to monitor both spatial and temporal changes in phytoplankton and zooplankton biomass, richness, and community composition. As described in *AEMP Design Plan Version 4.1* (Golder 2017a), the objective of the annual report is to assess whether Mine-related toxicological changes are occurring in the plankton communities in the near-field (NF) and mid-field (MF) areas of Lac de Gras, and to evaluate whether any Action Levels have been triggered. Temporal analyses and an assessment of trends over time are completed at three-year intervals in re-evaluation reports; results of the most recent temporal trend assessment were provided in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019b).

The effects on the plankton communities are evaluated using statistical tests comparing plankton variables between the NF area and the three least-exposed FF areas (FF1, FFA, and FFB) and to reference conditions, as defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a). Values that were beyond the reference condition were different from what would be considered natural variation in Lac de Gras. The importance of effects observed on plankton variables was determined according to Action Level classification defined in the *AEMP Design Plan Version 4.1* (Golder 2017a). In addition, spatial trends in plankton community variables and community structure along the gradient of effluent exposure in Lac de Gras were evaluated using visual means and multivariate analysis.

2 METHODS

2.1 Field Sampling

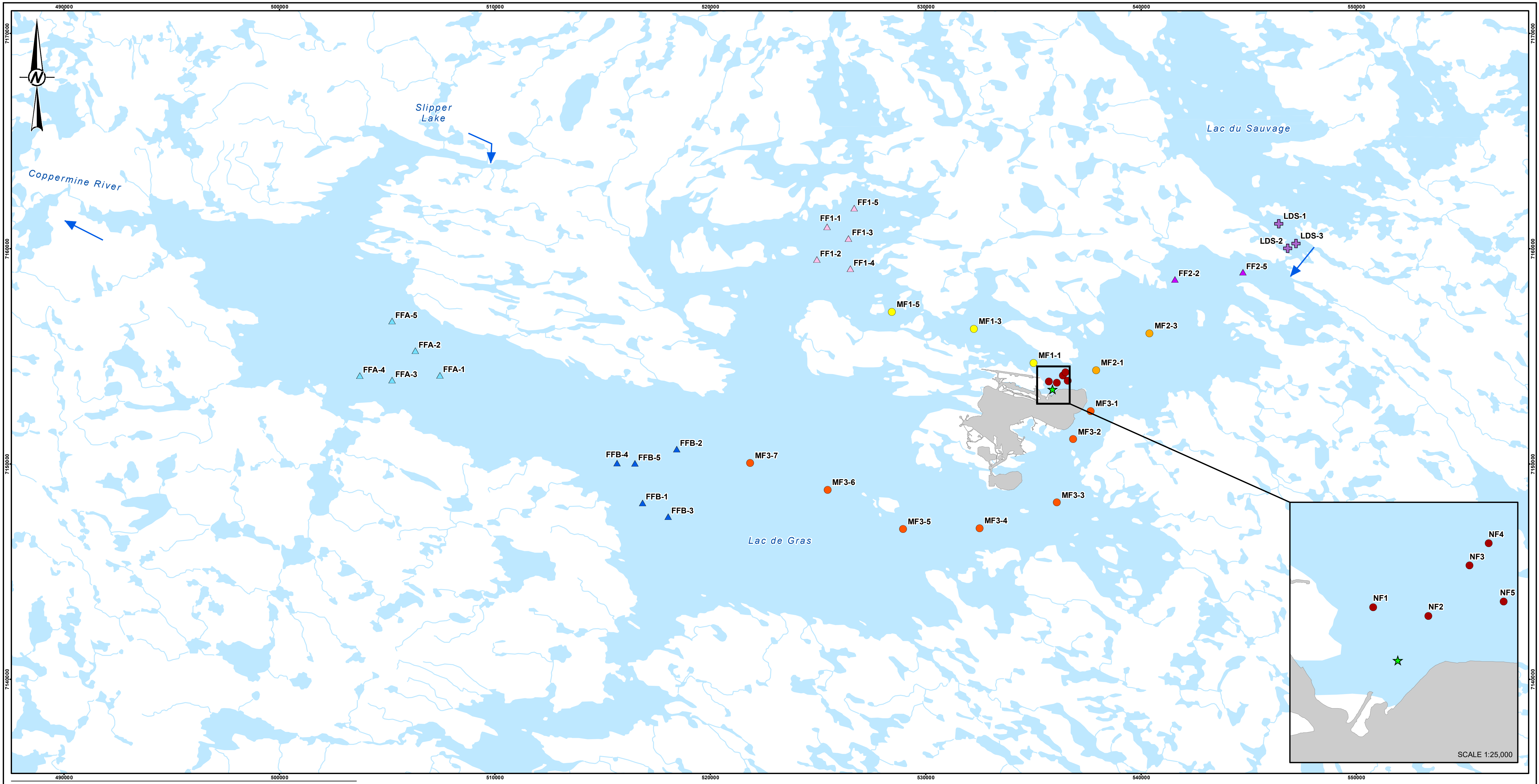
Plankton sampling was conducted by DDMI staff during the open-water season, from 15 August to 15 September 2019, in accordance with *AEMP Design Plan Version 4.1* (Golder 2017a) and the DDMI Standard Operating Procedure (SOP): ENVI-923-0119 AEMP Combined Open Water and Ice Cover". Water column profile measurements and samples for water chemistry were collected concurrently as part of the Effluent and Water Chemistry Report (Appendix II). No deviations from the SOP were reported during sample collection.

Thirty-four stations located in five general areas of Lac de Gras were sampled during the 2019 AEMP (Figure 2-1, Table 2-1). Sampling areas were selected based on exposure to the Mine effluent (Golder 2017a), and consisted of the NF area, three MF areas (i.e., MF1, MF2-FF2, and MF3) and three FF areas (i.e., FF1, FFA, FFB). The MF areas form transects extending away from the NF area in three directions towards the FF areas (i.e., FF1, FF2 and FFB-FFA); each transect includes the NF area stations. The MF1 transect runs northwest from the NF area, towards the FF1 area. The MF2 transect runs to the northeast, towards the Lac du Sauvage inlet. The FF2 area formerly encompassed five stations and was designated and analyzed as a separate FF area; however, the two remaining stations in this area are now considered together with MF2 stations as the MF2-FF2 transect. The MF3 transect is located south of the NF area, and extends towards the FFB and FFA areas.

Five stations were sampled in the NF area, three stations were sampled in the MF1 area, four stations were sampled in the MF2-FF2 area, seven stations were sampled in the MF3 area, and five stations were sampled in each of the FF1, FFA and FFB areas (Figure 2-1). In addition to stations in Lac de Gras, samples were collected at three stations in Lac du Sauvage (LDS-1 to LDS-3). Sampling locations, dates, and water depths are provided in Table 2-1.

A depth-integrated sampler, which collects water from the surface to a depth of 10 m, was used to collect phytoplankton samples. Twelve depth-integrated samples were combined from each station and the resulting composite sample was used to fill a sample bottle for phytoplankton taxonomy.

A 75 µm mesh Wisconsin plankton net with a 30 cm mouth diameter was used to collect duplicate zooplankton samples at each station. Each sample consisted of a composite of three vertical hauls from the entire water column, beginning at a depth of 1 m from the bottom.



LEGEND

★ DIFFUSERS

STATION LOCATIONS

△	FAR-FIELD 1
▲	FAR-FIELD 2
△	FAR-FIELD A
▲	FAR-FIELD B
✚	LAC DU SAUVAGE
●	MID-FIELD 1
●	MID-FIELD 2
●	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

LOCATIONS OF AEMP PLANKTON SAMPLING STATIONS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
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Table 2-1 Plankton Sampling Station Locations and Dates, 2019

Area	Station	Date	UTM Coordinates(a)		Distance from Diffuser(b) (m)	Water Depth (m)
			Easting (m)	Northing (m)		
NF	NF1	22-Aug-19	535740	7153854	394	22.3
	NF2	22-Aug-19	536095	7153784	501	20.6
	NF3	3-Sep-19	536369	7154092	936	18.6
	NF4	15-Aug-19	536512	7154240	1,131	21.1
	NF5	15-Aug-19	536600	7153864	968	20.6
MF1	MF1-1	22-Aug-19	535008	7154699	1,452	19.5
	MF1-3	22-Aug-19	532236	7156276	4,650	18.9
	MF1-5	21-Aug-19	528432	7157066	8,535	18.0
MF2 – FF2	MF2-1	23-Aug-19	538033	7154371	2,363	18.0
	MF2-3	20-Aug-19	540365	7156045	5,386	20.3
	FF2-2	20-Aug-19	541588	7158561	8,276	19.1
	FF2-5	20-Aug-19	544724	7158879	11,444	20.0
MF3	MF3-1	3-Sep-19	537645	7152432	2,730	19.7
	MF3-2	28-Aug-19	536816	7151126	4,215	22.6
	MF3-3	28-Aug-19	536094	7148215	7,245	20.6
	MF3-4	27-Aug-19	536094	7148215	11,023	20
	MF3-5	27-Aug-19	536094	7148215	14,578	18.6
	MF3-6	27-Aug-19	536094	7148215	18,532	18.0
	MF3-7	26-Aug-19	536094	7148215	22,330	21.5
FF1	FF1-1	17-Aug-19	525430	7161043	13,571	21.9
	FF1-2	19-Aug-19	524932	7159476	12,915	19.0
	FF1-3	18-Aug-19	526407	7160492	12,823	18.0
	FF1-4	21-Aug-19	526493	7159058	11,399	20.0
	FF1-5	19-Aug-19	526683	7161824	12,823	18.0
FFB	FFB-1	26-Aug-19	516831	7148207	26,355	20.8
	FFB-2	25-Aug-19	518473	7150712	24,991	18.0
	FFB-3	6-Sep-19	518048	7147557	25,245	22.0
	FFB-4	25-Aug-19	515687	7150036	27,591	19.2
	FFB-5	25-Aug-19	516533	7150032	26,761	20.3
FFA	FFA-1	6-Sep-19	506453	7154021	36,769	18.3
	FFA-2	5-Sep-19	506315	7155271	38,312	18.6
	FFA-3	4-Sep-19	505207	7153887	38,734	21.7
	FFA-4	4-Sep-19	503703	7154081	40,211	18.6
	FFA-5	4-Sep-19	505216	7156657	39,956	18.3
Lac du Sauvage	LDS-1	2-Sep-19	546398	7161179	-	18.5
	LDS-2	2-Sep-19	546807	7160027	-	18.9
	LDS-3	2-Sep-19	547191	7160256	-	10.5

a) UTM coordinates are reported as Zone 12, North American Datum (NAD) 83.

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

UTM = Universal Transverse Mercator coordinate system; NF = near-field; MF = mid-field; FF = far-field.

2.2 Sample Processing and Taxonomic Identification

2.2.1 Phytoplankton Community

A total of 37 composite phytoplankton samples from the NF, MF, FF and LSD areas in Lac de Gras and Lac du Sauvage were submitted to Advanced Eco-Solutions Inc. (Advanced Eco-Solutions), Newman Lake, Washington, USA, for analysis of taxonomic composition, abundance, and biomass. As a result of a field crew oversight, no duplicate samples were submitted to the taxonomist in 2019. Four laboratory Quality Control (QC; split) samples were analyzed by the taxonomist, representing approximately 10% of the total samples submitted. 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. Samples were analyzed according to methods provided by Advanced Eco-Solutions, as summarized below.

Phytoplankton samples were homogenized by gently shaking sample containers for 60 seconds. Aliquots of 25 mL were removed and poured into settling chambers and allowed to settle for a minimum of 4 hours. Quantitative counts were done on a Carl Zeiss Inverted phase-contrast microscope at a high power of 1,560× magnification followed by a low power scan at 625× magnification. The lower power scans were performed to confirm a uniform settling of the sample on the bottom of the plate and to evaluate the occurrence of rare species (Utermöhl 1958). A minimum of 250 and a maximum of 300 cells or counting units were enumerated in each sample for statistical accuracy (Lund et al. 1958). Taxonomic identifications were based primarily on Prescott (1978), Canter-Lund and Lund (1995), and Wehr and Sheath (2003). Phytoplankton taxa were identified to the genus level, and abundance was reported as cells per litre (cells/L).

Fresh weight biomass was calculated from recorded abundance and biovolume estimates based on geometric solids (Rott 1981). Biovolumes were estimated from the average dimensions of 10 to 15 individuals; the biovolumes of colonial taxa were based on the number of individuals within each colony. Assuming a specific gravity of one, the biovolume of each species was converted to biomass, reported in milligrams per cubic metre (mg/m^3).

2.2.2 Zooplankton Community

A total of 74 zooplankton samples, consisting of duplicates from the NF, MF, FF and Lac du Sauvage areas were submitted to Salki Consultants Inc. (Salki Consultants), Winnipeg, Manitoba, Canada, for analysis of taxonomic composition. Seven laboratory QC (split) samples were analyzed by the taxonomist in 2019, representing approximately 10% of the total samples submitted. Samples were analyzed for abundance and biomass of crustaceans and rotifers according to the methods provided by Salki Consultants Inc., as summarized below. Each sample underwent three levels of analysis, as follows:

- A 1/40 or 1/80 portion of each sample was examined under a compound microscope at 63× to 160× magnification. All specimens of crustaceans and rotifers were identified to the lowest taxonomic level (typically species) and assigned to size categories as indicated in the species list.

- A second sub-sample, representing 11% of the sample volume, was examined under a stereoscope at 12× magnification for large species (e.g., *Heterocope septentrionales*, *Holopedium gibberum*, *Daphnia middendorffiana*, and *Daphnia longiremis*) and rare species (e.g., *Eubosmina longispina*, *Diaptomus ashlandi*, *Epischura nevadensis, Chydorus sphaericus*, and *Cyclops capillatus*). These were enumerated and assigned to size classes.
- The entire sample was examined under the stereoscope to improve abundance estimates for the largest species (e.g., adult male and female *Heterocope septentrionales*, *Holopedium gibberum*, *Daphnia middendorffiana*, and *Daphnia longiremis*).

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

Biomass estimates for each taxon were obtained using mean adult sizes determined during the analysis of the 2007 zooplankton samples (Golder 2008) and from length-weight regression equations developed by Malley et al. (1989). Additional measurements were made on all newly encountered species. Zooplankton biomass was reported in units of mg/m^3.

2.3 Data Analysis

2.3.1 Data Screening

Initial screening of the 2019 plankton data was completed prior to data analyses to identify anomalous values and decide whether to retain or exclude anomalous data from further analysis. The anomalous data screening approach for AEMP component datasets was approved as part of the *2011 to 2013 Aquatic Effects Re-evaluation Report Version 3.2* (Golder 2016). The 2019 plankton community dataset did not contain any anomalous data (Attachment A); therefore, the plankton data was deemed acceptable to complete the plankton community analyses.

2.3.2 Plankton Community Analysis

The following methods were used to summarize the 2019 phytoplankton and zooplankton data:

- Abundance and biomass data were divided into the major ecological groups present in the 2016 samples. For phytoplankton they were divided into: diatoms, microflagellates, cyanobacteria, dinoflagellates, and chlorophytes and for zooplankton they were divided into: cladocerans, calanoids, cyclopoids, and rotifers.
- For zooplankton, mean abundance and biomass were calculated for each set of duplicate pairs.
- For phytoplankton, richness was calculated at the genus level for all ecological groups, while for zooplankton, richness was calculated at the lowest taxonomic level: species for cladocerans, cyclopoids, and calanoids; and genus for rotifers.

- The relative abundance and biomass (expressed as a percentage) of each major group was calculated for each sampling area and summary plots were created using R (R Core Team 2019).
- Descriptive statistics (i.e., sample size, minimum, maximum, median, mean and standard deviation) were calculated for total biomass, the biomass of each major ecological group, and taxonomic richness.
- Box-plots showing the mean, median, and range in the 2019 data from the NF, MF and FF areas of Lac de Gras for total biomass and the biomasses of the major ecological groups were prepared using R (R Core Team 2019).
- Phytoplankton and zooplankton biomass and taxonomic richness were plotted against distance from the discharge.
- Univariate and multivariate statistical analyses were used to evaluate potential Mine-related effects on the plankton communities in Lac de Gras. Variables included in the univariate analysis were total biomass, biomass of each major ecological group, and taxonomic richness. Entire communities were compared among sampling areas using non-metric multidimensional scaling (nMDS).
- A summary of the dominant taxa found in the NF area compared to the FF areas was presented. Dominant taxa in each area in Lac de Gras and Lac du Sauvage were identified as those with proportions greater than 10% of the total biomass in their respective area.

2.3.3 Normal Ranges

The magnitudes of effect on plankton communities were evaluated by comparing plankton variables (i.e., total biomass, richness, and the total biomass of each major ecological group) in the NF area to background values. Background values for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a) and are summarized in Table 2-2.

Table 2-2 Normal Ranges for Plankton

Variable	Unit	Normal Range	
		Lower Limit	Upper Limit
Phytoplankton			
Total phytoplankton taxonomic richness	No. of taxa	19	36
Total phytoplankton biomass	mg/m^3	19	385
Total microflagellate biomass	mg/m^3	13	72
Total diatom biomass	mg/m^3	0	13
Total chlorophyte biomass	mg/m^3	0	309
Total cyanobacteria biomass	mg/m^3	0	48
Total dinoflagellate biomass	mg/m^3	0	40
Zooplankton			
Total zooplankton taxonomic richness	No. of taxa	11	17
Total zooplankton biomass	mg/m^3	132	540
Total cladocera biomass	mg/m^3	8	127
Total calanoida biomass	mg/m^3	61	359
Total cyclopoida biomass	mg/m^3	13	105
Total rotifera biomass	mg/m^3	2	7

Source: *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

2.3.4 Statistical Analysis

2.3.4.1 Gradient Analysis

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 exposure. Normal ranges are also presented on these plots. Values from Lac du Sauvage were included on the plots for comparison purposes only; the normal range does not apply to the Lac du Sauvage stations.

Spatial gradients in phytoplankton and zooplankton community variables were also evaluated along each of the transects using linear regressions per *AEMP Design Plan Version 4.1* (Golder 2017a). The NF area data were included in the linear regression for each of the three transects (i.e., MF1, MF2-FF2, MF3). Linear regressions were completed using statistical environment R v. 3.6.1 (R Core Team 2019), regardless of statistical significances detected among sampling areas using analysis of variance (ANOVA). The transects included each of the stations as described in Section 2.1. All stations were included in the analysis. Phytoplankton and zooplankton community variables were generally log-transformed prior to regression analyses and regression analyses were considered significant at $\alpha = 0.1$.

Due to the inherent variability in the phytoplankton and zooplankton community datasets, variables often had non-linear patterns with distance from the effluent exposure. Therefore, the analysis method allowed for piecewise regression (also referred to as segmented or broken stick regression). The following approaches were used:

- Model 1: a linear multiplicative model with main effects of distance from the effluent exposure, gradient (MF1, MF2, MF3 transects), and their interactions
- Piecewise modelling to account for changes in spatial gradients where individual transects are analyzed separately from one another:
  - Model 2: a linear multiplicative model with main effects of distance from the effluent exposure, gradient (MF1 and MF2-FF2 transect) and their interaction
  - Model 3: a linear piecewise (broken stick) model with distance (MF3 only)

For each variable, Model 1 was used to test for the presence of significance ($P<0.05$) breakpoint using the Davies test (Davies 1987, 2002). If a significant breakpoint was identified, Models 2 and 3 were used for that variable. If no significant breakpoint was identified, Model 1 was used for that variable.

Following the initial fit of the model, the residuals (of either Model 1 or Model 2, as applicable) were examined for normality. Model 3 was not considered for transformations, since the addition of breakpoint was expected to resolve non-linear patterns. For each response variable, the data underwent Box-Cox transformations (Box and Cox 1964). The Box-Cox transformations are a family of transformations that include the commonly used log and square root transformations. The Box-Cox transformation process tests a series of power values, usually between -2 and +2, and records the log-likelihood of the relationship between the response and the predictor variables under each transformation. The transformation that maximizes the log-likelihood is the one that will best normalize the data. Therefore, the data are transformed using a power value identified by the transformation process. For a power value of zero, the data are natural log transformed. The transformation rules can be described using the following definitions:

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

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

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

Following data transformation (if required), the selected models were fitted to the data. Statistical outliers were identified using studentized residuals with absolute values of 3.5 or greater, or by considering leverage (where a single point could strongly influence the overall fit of the model). All values removed from analysis were retained for plots of model predictions, where they were presented using a different symbol from the rest of the data.

Following removal of outliers, breakpoint significance and data transformation was re-examined. Residuals from the refitted models were examined for normality and heteroscedasticity, and evidence of nonlinear patterns. If non-linearity was evident from residual examination, the analysis was terminated and data were presented qualitatively. If normality was evident, then three models were constructed to assess the effect of heteroscedasticity for each response variable in each season:

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

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

The constructed models were used to produce the following outputs:

- estimates and significance of slopes (i.e., distance effects) for each gradient
- the r^2 value of each model, to examine explained variability
- fitted prediction lines and 95% confidence intervals (back-transformed to original scale of the variable)

Analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019) and package "segmented" (Muggeo 2008).

2.3.4.2 Near-Field Versus Far-Field Area Comparisons

Before statistical comparisons, the duplicate zooplankton data were averaged to provide a single value for each combination of year, area, and station, and the assumptions of parametric statistical tests were verified using the Kolmogorov-Smirnov test for normality and Levene's test for homogeneity of variances (Sokal and Rohlf 1995) on untransformed, log-transformed, and rank-transformed data. Data were transformed where significant normality or equality of variances violations were found, and the effectiveness of the transformations was verified. Issues with non-normality and heteroscedasticity were addressed if either Kolmogorov-Smirnov test or Levene's test had probability (*P*) value of less than 0.01. In 2019, plankton community data were normal or normality was achieved with data transformations.

The 2019 means of the NF, FF1, FFA, and FFB areas were initially compared to one another in an overall ANOVA. If a significant difference was observed, the NF area was compared with the FF areas within the overall ANOVA, as an *a priori* comparison (i.e., planned contrast). Multiple comparison techniques that were not planned prior to undertaking the analysis (i.e., *a posteriori*) are frequently used with environmental assessment data; however, these techniques are not always appropriate for testing hypotheses (Hoke et al. 1990). The preferred approach is to analyze the data using planned, linear contrasts by formulating meaningful comparisons among sampling areas prior to conducting the study and outlining these in a study design. This preferred approach was used to help answer the question of whether effluent is having an effect in the NF area of Lac de Gras.

At the study design stage, the probability of a Type I error (α) was set to the same level (i.e., 0.1) as a Type II error (β) probability, because the probability of missing important effects was deemed to be as important as the probability of finding an effect when none existed (Environment Canada 2012). This approach resulted in a power of 90% for the study as designed.

To investigate variability between the three FF areas, multiple comparisons were performed between pairwise combinations of the FFA, FFB, and FF1 areas. To maintain the benefits of planned contrasts and avoid the shortfalls of multiple comparison tests (Day and Quinn 1989), the planned contrasts were conducted within the overall ANOVA; however, the Type I error *P*-value was adjusted to maintain the overall experiment-wise error probability of 0.1. If any of the multiple comparisons were significant, the NF area mean was compared to either the lowest or the highest FF area mean, as applicable, using a one-tailed test to evaluate whether the NF mean was greater than the largest or lower than the smallest FF area mean. If multiple comparisons between FF areas were not significant, the NF area mean was compared to the average of the FF area means using a two-sided test.

Statistical analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019).

The magnitude of the difference between the NF area mean and the largest or smallest FF area mean was calculated as percent difference, regardless of significance determined during statistical testing:

$$Percent\ Difference\ (\%) = \frac{(NF\ mean - largest/smallest\ FF\ mean)}{largest/smallest\ FF\ mean} \times 100$$

2.3.4.3 Comparison to Reference Conditions

Phytoplankton and zooplankton biomass and taxonomic richness were also used to assess differences between the 2019 NF area and reference conditions (Table 2-3). Since toxicological impairment is expected to result in declines in most plankton variables relative to the reference condition, a one-tailed test was performed to assess if the NF area mean was significantly less than the reference condition mean. The reference condition for phytoplankton was based on the 2013 normal range dataset adjusted to account for year-to-year variability (Golder 2019b); however, for the statistical analysis, the 2019 NF mean was compared to the mean of the reference conditions based on unadjusted 2013 data, because data for individual replicates (stations) could not be back-calculated from the adjusted upper and lower limits of the normal range.

Data were log(x+1) transformed to alleviate the heteroscedasticity associated with biomass and count data. Data were analyzed using mixed effects models, where Type (NF versus reference) is the only fixed variable, and the random factor was a random intercept of Year nested in Area. Residual normality and homoscedasticity were evaluated using the Kolmogorov-Smirnov and Levene’s tests, respectively. In addition, residuals were examined using quantile-quantile plots to visually assess normality, and scatter plots vs. fitted values and boxplots vs. categorical variables to assess heteroscedasticity. The analysis output included a *P*-value for the coefficient assessing whether NF data were significantly less than the reference conditions.

2.3.4.4 Multivariate Analysis

Phytoplankton and zooplankton community structure were summarized using the non-parametric ordination method of nMDS (Clarke 1993; Clark and Gorley 2016). The phytoplankton and zooplankton data were log(x+1) transformed to improve the separation of the data among stations on the nMDS plots and to reduce weighting of the analysis by the most abundant taxa. A Bray-Curtis resemblance matrix was generated and the nMDS procedure was applied to this matrix. Using rank order information, nMDS determined the relative positions of stations in two dimensions based on community composition. Goodness-of-fit was determined by examining the Shepard diagrams as well as the stress values, which were calculated from the deviations in the Shepard diagrams. Smaller stress values (i.e., less than 0.10) indicate less deviation and a greater goodness-of-fit (Clarke 1993). Points that fall close together on the nMDS ordination plot represent samples with similar community composition; points that are far apart from each other represent samples with dissimilar community composition. A similarity profile (SIMPROF) test was carried out on the ordination data to identify meaningful clusters of important taxa (i.e., those taxa that behave in a coherent manner across areas) and to prevent over-interpretation of the nMDS plot (Clarke et al. 2014). These SIMPROF clusters were superimposed on the nMDS plots.

A one-way analysis of similarities (ANOSIM) test was carried out on the Bray-Curtis resemblance matrix to determine whether the differences in community composition observed in the nMDS ordination plot were significant.

2.4 Action Level Evaluation

The importance of effects on phytoplankton and zooplankton was categorized according to the Action Levels in the Response Framework presented in the *AEMP Design Plan Version 4.1* (Golder 2017a). The main goal of the Response Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at predefined Action Levels, which are triggered well before significant adverse effects could occur. A significant adverse effect, as it pertains to aquatic biota, was defined in the Environmental Assessment for the Mine as a change in fish population(s) that is greater than 20% (Government of Canada 1999). The effect must have a high probability of being permanent or long-term in nature and must occur throughout Lac de Gras. The Significance Thresholds for all aquatic biota, including plankton are, therefore, related to effects that could result in a change in fish population(s) that is greater than 20%.

The AEMP addresses two broad impact hypotheses for Lac de Gras: the toxicological impairment hypothesis and the nutrient enrichment hypothesis (Golder 2017a). Action Levels for the plankton component address the toxicological impairment hypothesis, while the nutrient enrichment hypothesis is addressed in the Eutrophication Indicators Report (Appendix XIII). Conditions required to trigger Action Levels 1 to 3 for plankton are defined in Table 2-3. Conditions for Action Level 4 would be defined if Action Level 3 was triggered. Defining further Action Levels after initial effects are encountered is consistent with the draft guidelines for preparing a Response Framework in AEMPs (WLWB 2010; Racher et al. 2011).

Phytoplankton and zooplankton biomass and taxonomic richness are assessed annually, during both interim and comprehensive sampling years. This involves statistically comparing plankton biomass and richness in the NF area (and potentially MF areas) to the reference condition (Table 2-3). Since toxicological impairment is expected to result in declines in most plankton variables relative to the reference condition, Action Level 1 is triggered if the mean value in the NF area is significantly less than the mean of the reference condition dataset. Action Level 2 is triggered when the effect observed in the NF area expands to the nearest MF stations (i.e., MF1-1, MF2-1, MF3-1), and Action Level 3 is triggered when NF area results are less than the normal range.

Table 2-3 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 2019a).

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

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

2.5 Quality Assurance/Quality Control

The *Quality Assurance Project Plan Version 3.1* (Golder 2017b) outlines the quality assurance/quality control (QA/QC) procedures employed to support the collection of scientifically defensible and relevant data to meet the objectives of the AEMP. The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically-sound and scientifically defensible results. A description of the QA/QC program is provided in Attachment A.

There were data integrity issues with the phytoplankton data in 2019 (i.e., sample degradation from excess preservative) (Attachment A); therefore, interpretation of the 2019 phytoplankton data and comparisons to previous years' data and the reference conditions should be done with caution, especially for taxonomic richness. Efforts will be made during the 2020 field program to reduce the amount of preservative used in the samples (i.e., tea coloured) or dilute the concentrated preservative to a concentration of 1% prior to sample preservation. Data screening within the 2019 dataset did not identify anomalous values; therefore, within-year spatial analysis was deemed appropriate; however, among-year comparisons were performed with the caveat that the 2019 richness data may be suspect as a result of the sample degradation.

For the 2019 zooplankton community dataset, data screening did not identify anomalous values and the duplicate samples were within the expected range of natural variability; therefore, the zooplankton community dataset provided by the taxonomist was deemed acceptable and used to complete the zooplankton community analysis in 2019.

2.6 Weight-of-Evidence Input

The results of the plankton community survey are integrated through the weight-of-evidence (WOE) evaluation process, which determines the strength of evidence supporting the two broad impact hypotheses for Lac de Gras (i.e., toxicological impairment and nutrient enrichment), as described in the *AEMP Design Plan Version 4.1* (Golder 2017a). The WOE is not intended to determine the ecological significance or level of concern associated with a given change. The WOE analysis is described fully in the *Weight-of-Evidence Report* (Appendix XV). The methods as applied to the plankton community are described in Section 2 of the *Weight-of-Evidence Report* (Appendix XV).

3 RESULTS

The 2019 raw phytoplankton abundance and biomass data, as well as a list of phytoplankton taxa collected in Lac de Gras and Lac du Sauvage in 2019, and summary statistics for total phytoplankton biomass and the biomass of the major ecological groups are provided in Attachment B. The 2019 raw zooplankton abundance and biomass data, as well as a list of zooplankton taxa collected in Lac de Gras and Lac du Sauvage in 2019, and summary statistics for total phytoplankton biomass and the biomass of the major ecological groups are provided in Attachment C.

3.1 Phytoplankton Community

3.1.1 Phytoplankton Taxonomic Richness and Biomass

3.1.1.1 Near-Field Versus Far-Field Area Comparisons and Comparison to Reference Condition

In total, 27 taxa were identified in the phytoplankton samples in 2019 (Attachment B, Table B-4). Phytoplankton taxonomic richness was less than the lower bound of the normal range in all areas of Lac de Gras (Figure 3-1, Table 3-1). Although richness in the NF area was significantly less than the reference condition mean in 2019 (Tables 3-1 and 3-2), the NF area mean was greater than the FF area mean in 2019; but not significantly. However, these results should be interpreted with caution (Attachment A) because the 2019 taxonomic richness data are suspect, as a result of a preservation issue with the 2019 phytoplankton samples (Attachment A).

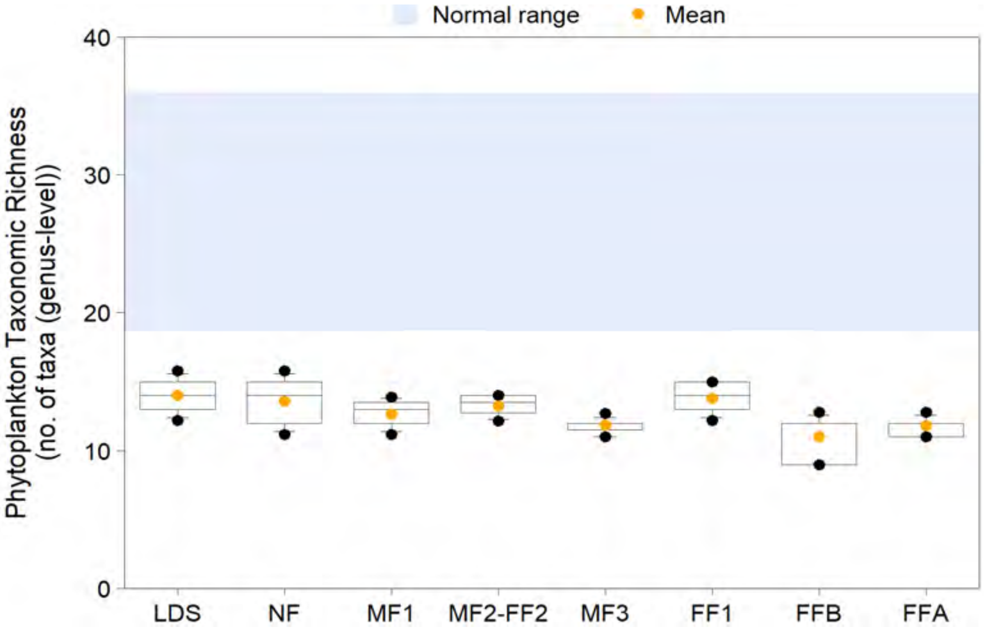
In 2019, mean phytoplankton biomass in all sampling areas was within the normal range (Table 3-1; Figure 3-2) and the NF area mean did not differ significantly from the 2019 FF area mean or the reference condition mean (Table 3-2). However, different responses were observed in the major ecological groups between the NF area and FF areas in 2019, and between the NF area and reference conditions (Table 3-2; Figure 3-2):

- Mean chlorophyte, cyanobacteria, and dinoflagellate biomass in the NF, MF, and FF areas was within the normal range, and the NF area did not significantly differ from the FF area means.
- Mean diatom biomass in the NF, MF1, and FFA areas was greater than the normal range, but the NF area mean did not significantly differ from the FF areas means.
- Mean microflagellate biomass in the NF, MF and FF areas was within the normal range, with the exception of four stations in the FFA area, two stations in the FFB area, and two stations in the FF1 area, which were beyond the upper bound of normal range. Mean biomass of this group was statistically less than the FF area mean.

- Chlorophyte biomass and Cyanobacteria biomass were statistically less in the NF area compared to the reference condition mean.

Phytoplankton taxonomic richness and total phytoplankton biomass at the stations in Lac du Sauvage (i.e., LDS-1 to LDS-3) were similar to richness and biomass observed in the FF areas of Lac de Gras in 2019 (Figures 3-1 and 3-2). Chlorophyte, cyanobacteria, and dinoflagellate biomass observed at the stations in Lac du Sauvage were similar to the biomass of these groups in the FF areas of Lac de Gras (Figure 3-2). Microflagellate biomass was less in Lac du Sauvage compared to the FF areas of Lac de Gras but was similar to biomass observed in the NF and MF areas of Lac de Gras, while diatom biomass was greater in Lac du Sauvage compared to all areas in Lac de Gras.

Figure 3-1 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.

Table 3-1 Phytoplankton Biomass and Taxonomic Richness in the NF Area of Lac de Gras in 2019 Compared to the Normal Range and the FF Area Mean

Variable	Unit	2019 NF		2019 FF Mean		Normal Range[(a)]			
		n	Mean ± SD	n	Mean ± SD	n	Lower Limit	2013 Mean	Upper Limit
Total phytoplankton taxonomic richness[(b)]	no. of taxa	5	**14** ± 2	15	12 ± 2	15	19	27	36
Total phytoplankton biomass	mg/m^3	5	151 ± 70	15	172 ± 46	15	19	200	385
Microflagellate biomass	mg/m^3	5	56 ± 8	15	69 ± 20	15	13	56	72
Diatom biomass	mg/m^3	5	**25** ± 52	15	7 ± 17	15	0	5	13
Chlorophyte biomass	mg/m^3	5	46 ± 19	15	82 ± 49	15	0	104	309
Cyanobacteria biomass	mg/m^3	5	2 ± 0	15	2 ± 0	15	0	28	48
Dinoflagellate biomass	mg/m^3	5	22 ± 17	15	13 ± 11	15	0	11	40

a) Normal ranges were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a); however, the mean is based on the 2013 data mean (Section 2.3.5.1.3).

b) Taxonomic richness is the number of taxa at the genus level.

Note: **Bolded** NF area means are outside the normal range.

n = number of samples; SD = standard deviation; ± = plus or minus; NF = near-field; FF = far-field.

Table 3-2 Statistical Comparisons of Phytoplankton Biomass and Taxonomic Richness in Lac de Gras, 2019

Variable	NF vs. FF Area Comparison							Comparison to Reference Condition Mean$^{(b,c)}$		
	Statistical Test	Overall Comparison	NF vs. FF Area Comparison		FF Area Comparisons			Statistical Test	NF vs. 2013	
			NF vs. FF1+FFB+FFA		FF1 vs. FFA	FF1 vs. FFB	FFB vs. FFA			
		P	*P*	Magnitude (%)$^{(a)}$	*P*	*P*	*P*		*P*	Magnitude (%)$^{(a)}$
Total phytoplankton taxonomic richness	ANOVA	**0.030**	nt	-	ns	**0.040**	ns	ANOVA^{ln}	**<0.001**	-50
Total phytoplankton biomass	ANOVA	ns	-	-	-	-	-	ANOVA^{ln}	ns	-25
Microflagellate biomass	ANOVA	**0.090**	**0.030**	-23	ns	ns	ns	nt	-	0
Diatom biomass	ANOVA^{log}	ns	-	-	-	-	-	nt	-	400
Chlorophyte biomass	ANOVA	ns	-	-	-	-	-	ANOVA^{ln}	**0.040**	-56
Cyanobacteria biomass	ANOVA	**0.001**	nt	-	**0.008**	ns	**0.003**	ANOVA^{rank}	**<0.001**	-94
Dinoflagellate biomass	ANOVA	**0.020**	nt	-	**0.051**	**0.013**	ns	nt	-	100

a) Percent difference between sampling area means (i.e., NF mean compared to pooled mean of the FF1, FFA, and FFB areas; and NF mean compared to reference condition mean).

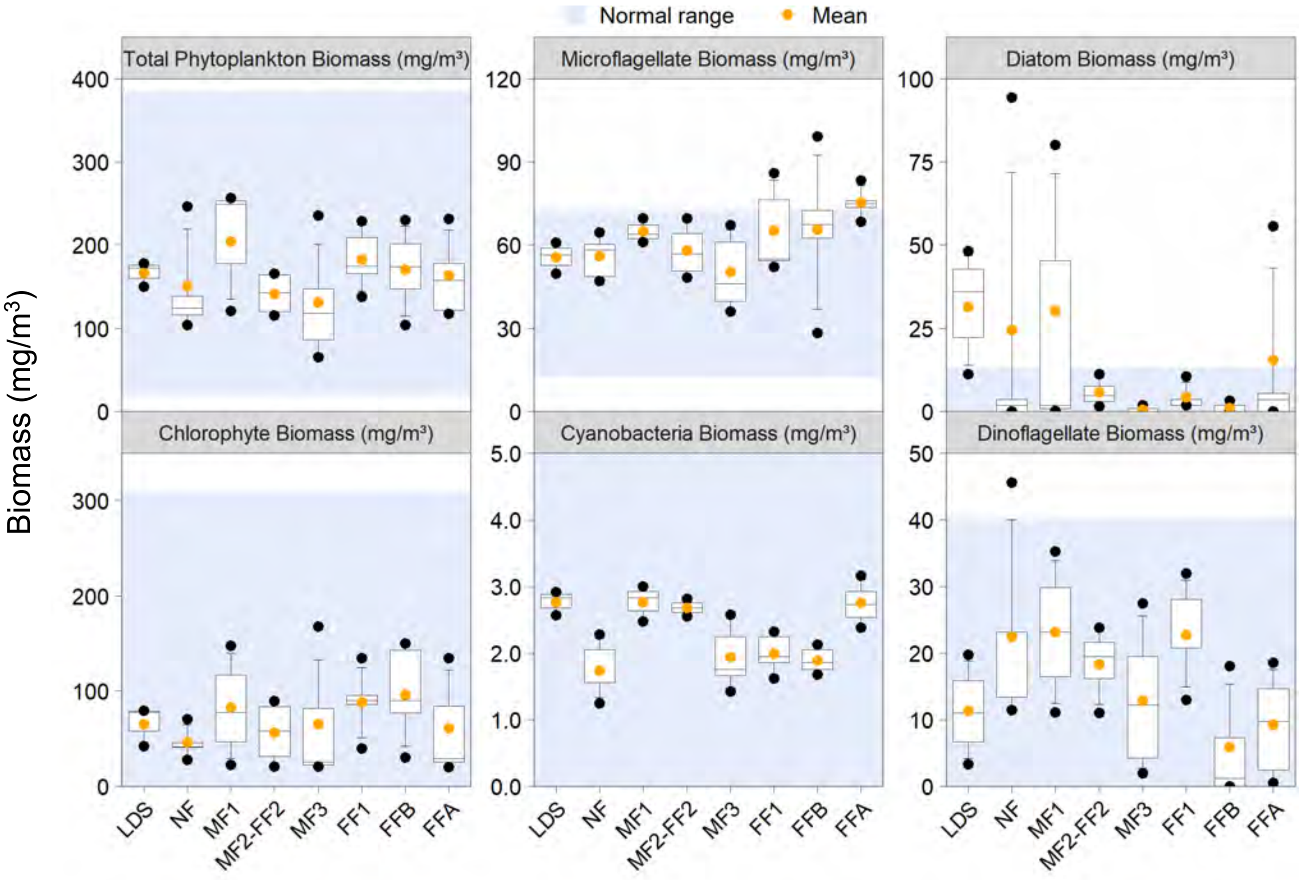
b) Reference area mean based on the 2013 data (Section 2.3.5.1.3).

c) One-tailed comparison to assess toxicological impairment in the NF area compared to the reference conditions.

Note: Some variables are not tested because the 2019 NF mean is within the range of FF means, or greater than or equal to the reference condition mean.

ANOVA = analysis of variance (transformation is indicated by superscript); NF = near-field; FF = far-field; *P* = probability; ns = not significant; na = not applicable; nt = not tested.

Figure 3-2 Phytoplankton Biomass of Major Ecological Groups 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.

3.1.2 Gradient Analysis

Gradient analysis of phytoplankton richness, biomass and the biomass of the major ecological groups indicate that generally, the phytoplankton variables do not show a response in relation to the effluent exposure and that stations close to the effluent diffusers are similar to the more distant stations in 2019 (Table 3-3; Figures 3-3, 3-4 and 3-5). The exceptions to this are microflagellate biomass along the MF3 transect and cyanobacteria biomass along the MF2 and MF3 transects, both of which increased with increasing distance from the diffusers (Figure 3-5).

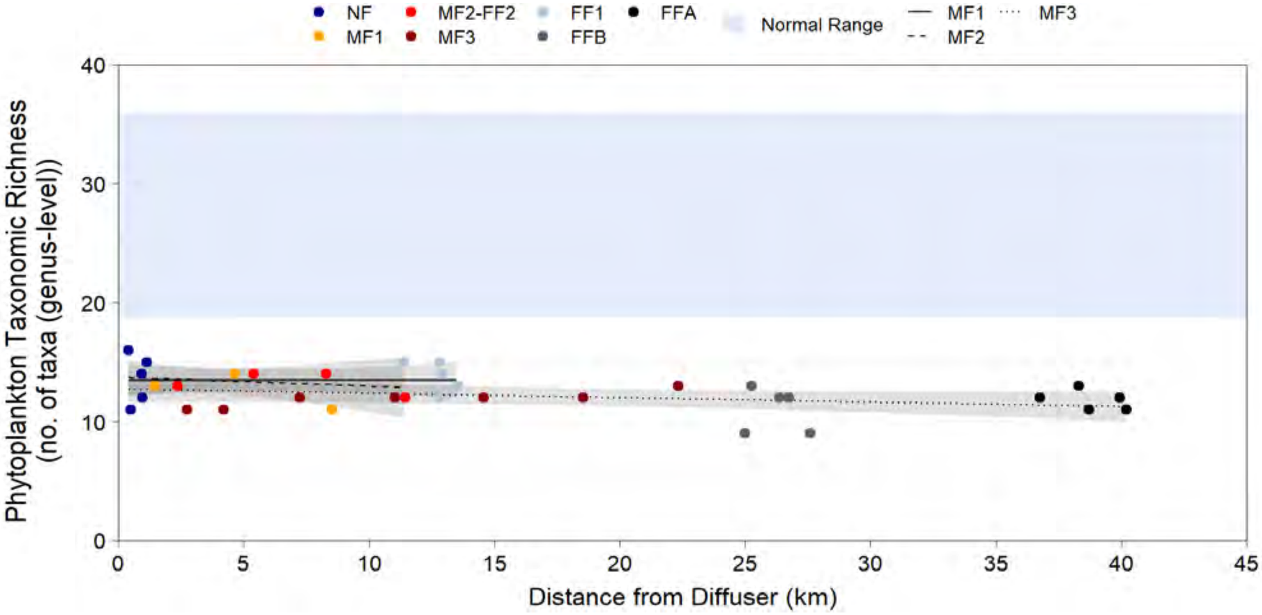
Table 3-3 Gradient Analysis for Phytoplankton Community Variables in Lac de Gras, 2019

Variable	Model	Transformation	Gradient	Slope Direction[a]	*P*-value	R^2
Total phytoplankton taxonomic richness	Model 1	-	MF1	↑	0.983	0.12
			MF2	↓	0.613	0.12
			MF3	↓	0.130	0.12
Total phytoplankton biomass	Model 1	Log	MF1	↑	0.691	-0.03
			MF2	↓	0.955	-0.03
			MF3	↑	0.165	-0.03
Microflagellate biomass	Model 1	-	MF1	↑	0.325	0.20
			MF2	↓	0.930	0.20
			MF3	↑	0.001	0.20
Diatom biomass	Model 1	Log	MF1	↑	0.155	0.10
			MF2	↑	0.202	0.10
			MF3	↑	0.665	0.10
Chlorophyte biomass	Model 1	Log	MF1	↑	0.418	-0.06
			MF2	↑	0.635	-0.06
			MF3	↑	0.380	-0.06
Cyanobacteria biomass	Model 1	-	MF1	↑	0.556	0.13
			MF2	↑	0.031	0.13
			MF3	↑	0.018	0.13
Dinoflagellate biomass	Model 1	Log	MF1	↑	0.597	0.18
			MF2	↓	0.706	0.18
			MF3	↓	0.111	0.18

a) Slope direction was represented by an upward arrow (↑) indicating an increasing trend with distance from the diffusers, or a downward arrow (↓) indicating a decreasing trend with distance from the diffusers.

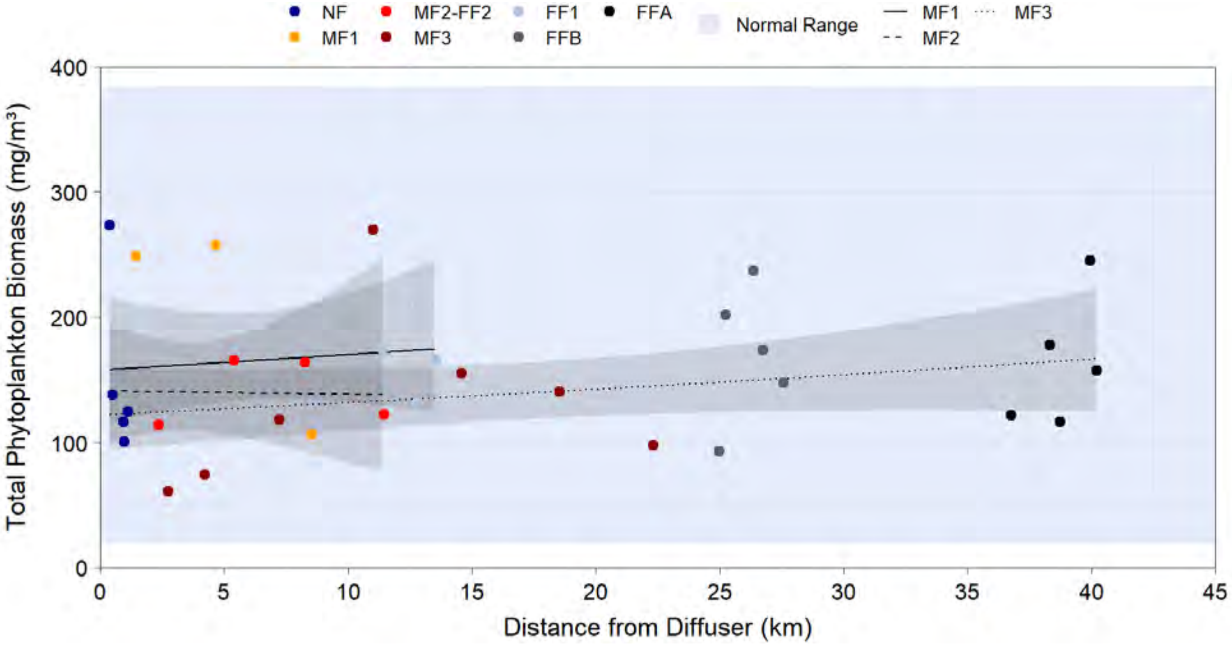
- = not applicable; MF = mid-field.

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



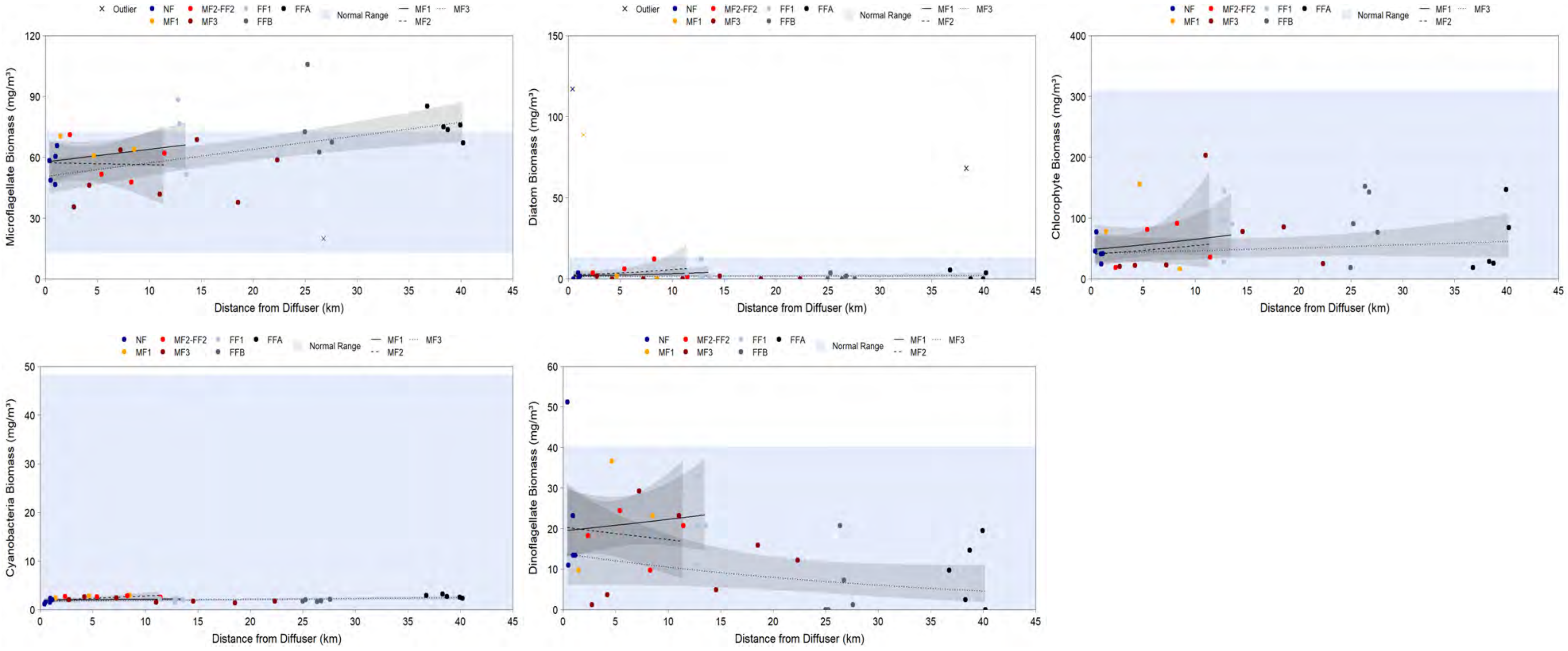
NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Figure 3-4 **Phytoplankton Biomass in Lac de Gras Relative to Distance from the Effluent Discharge, 2019**



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

Figure 3-5 Biomass of Major Phytoplankton Groups 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.

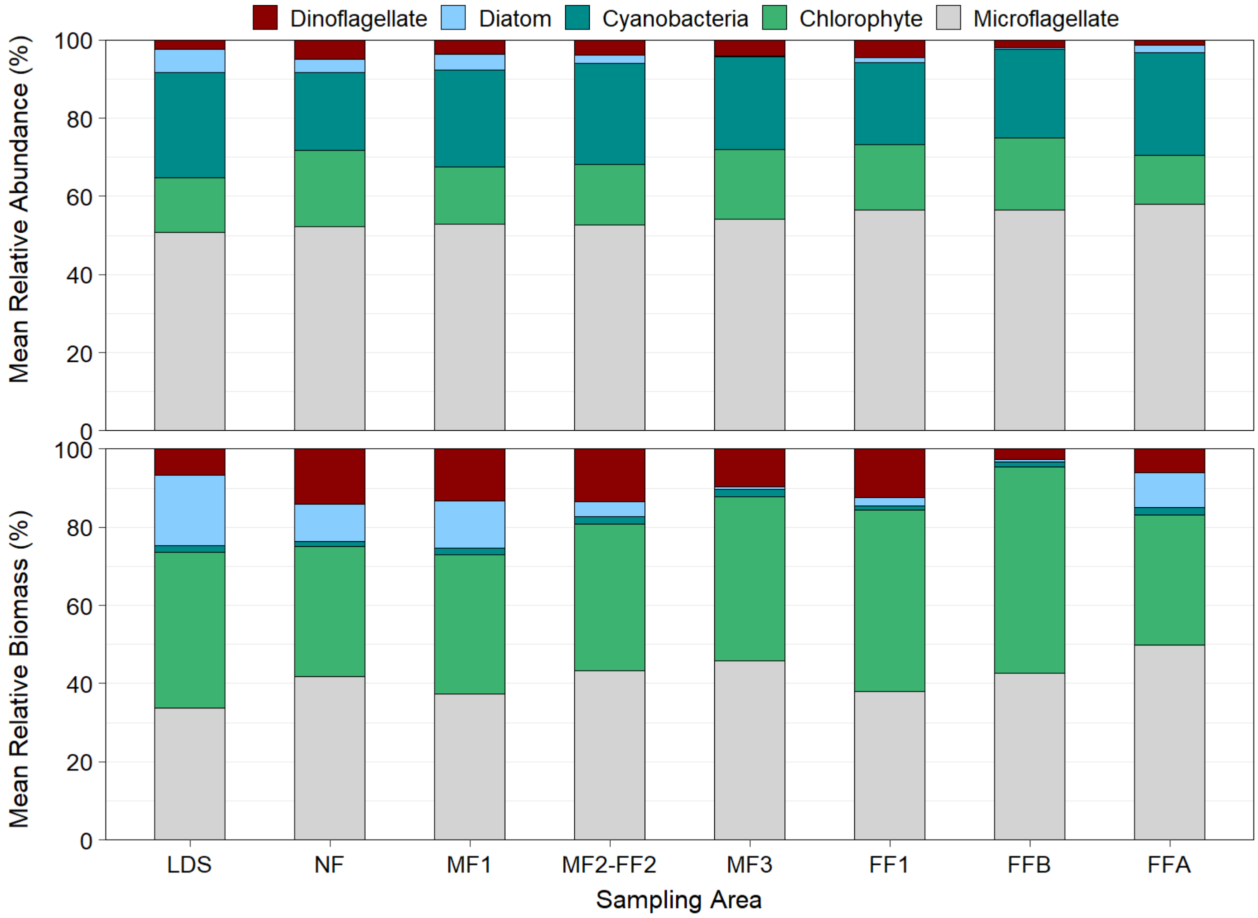
3.1.3 Phytoplankton Community Structure

Phytoplankton community composition in the NF area of Lac de Gras did not substantially differ from the FF areas, in terms of relative abundance or biomass in 2019 (Figure 3-6). The phytoplankton communities in all areas of Lac de Gras were dominated by microflagellates, based on abundance, with cyanobacteria and chlorophyte sub-dominance, and by chlorophytes and microflagellates, by biomass. Cyanobacteria biomass was low in all areas of Lac de Gras in 2019 (Figures 3-2 and 3-6). The NF and MF areas of Lac de Gras had greater proportions of diatoms and dinoflagellates in terms of abundance and biomass compared to the FF areas, with the exception of FF1, which had similar proportions of dinoflagellates as the NF and MF areas (Figure 3-6). Mean relative abundance of microflagellates was similar among areas and chlorophytes were greater in the NF area compared to the FF areas.

Despite accounting for a relatively large proportion of the total phytoplankton abundance, cyanobacteria accounted for a small proportion of the total biomass (i.e., less than 2.5% in the NF area and less than 3.5% in the FF areas), reflective of the small size of their cells. In contrast, dinoflagellates accounted for a relatively small proportion of the phytoplankton community in terms of abundance (i.e., 5% on average in the NF area and 3% on average in the FF areas), but contributed a relatively large proportion of total phytoplankton biomass (i.e., 14% on average in the NF area and 9% on average in the FF areas) because of the comparatively large size of their cells.

Phytoplankton community structure in Lac du Sauvage was generally similar to the communities in the NF and MF1 areas of Lac de Gras in terms of relative abundance (Figure 3-6). In terms of relative biomass, Lac du Sauvage had a greater proportion of diatoms than the areas in Lac de Gras. The Lac du Sauvage stations were dominated by microflagellates by abundance and co-dominated by microflagellates and chlorophytes by biomass in 2019.

Figure 3-6 Mean Relative Phytoplankton Abundance and Biomass in Lac de Gras, 2019



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

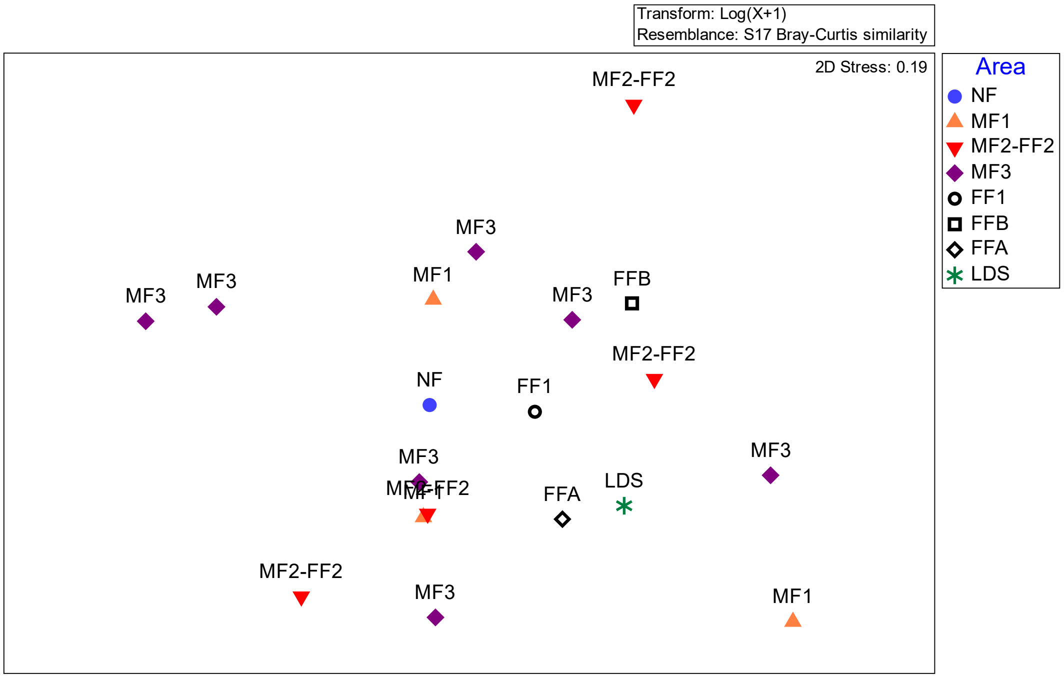
The two-dimensional nMDS plot demonstrates that there are no significant differences among stations or areas in terms of the phytoplankton community composition in 2019 (Figure 3-7). The nMDS configuration for phytoplankton biomass had a stress value of 0.19, indicating a reasonable level of fit to the original data. The global ANOSIM (R = 0.084, P = 0.99) test indicated that there are no differences among areas in the phytoplankton community data in 2019 and interpretation of differences in the nMDS structure is not recommended.

The ordination plot does not show clear separation in terms of phytoplankton community composition between Lac de Gras and Lac du Sauvage, or between the NF and FF areas (Figure 3-7). Stations along the MF transects (i.e., MF1-1, MF1-3 and MF2-1) are also grouped together with the NF and FF areas (Figure 3-7).

Dominant taxa in each area of Lac de Gras and Lac du Sauvage were identified as those with proportions greater than 10% of the total biomass in each area (Table 3-4). The three dominant taxa, based on biomass, in the NF area of Lac de Gras were the microflagellate, *Cryptomonas* sp. (17%), the diatom, *Tabellaria* sp. (15%), and the dinoflagellate, *Gymnodinium* sp. (13%). In the FF areas, the chlorophyte, *Euglena* sp. was the dominant taxon in the FF1 (33%) and FFB (43%) areas, while in the FFA area the microflagellate, *Cryptomonas* sp. (24%) and the chlorophyte, *Euglena* sp. (22%) co-dominated. The microflagellate, *Cryptomonas* sp. was either the first or second most dominant taxon in all sampling areas in Lac de Gras. The chlorophytes, *Euglena* sp. and *Tetraedron* sp. and the microflagellate, *Chroomonas* sp. were dominant taxa in all areas of Lac de Gras.

The dominant taxa observed in the samples collected from Lac du Sauvage were similar to those collected from all areas of Lac de Gras (Table 3-4) and included the chlorophyte, *Euglena* sp. (24%) followed by the microflagellate, *Cryptomonas* sp. (15%) and the diatom, *Tabellaria* sp. (15%).

Figure 3-7 Non-metric Multidimensional Scaling of Phytoplankton Biomass in Lac de Gras, 2019



NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; 2D = two dimensional plot; SIMPROF = similarity profile.

Table 3-4 Dominant Phytoplankton Taxa in Lac de Gras and Lac du Sauvage, 2019

Area	Ecological Group	Dominant Taxa[(a)]	Dominance Ranking	Biomass (mg/m^3)	Proportion of total sample
					(%)
NF	Microflagellate	*Cryptomonas* sp.	1	126	17
	Diatom	*Tabellaria* sp.	2	111	15
	Dinoflagellate	*Gymnodinium* sp.	3	98	13
MF1	Chlorophyte	*Euglena* sp.	1	183	30
	Microflagellate	*Cryptomonas* sp.	2	99	16
	Diatom	*Tabellaria* sp.	3	85	14
	Dinoflagellate	*Gymnodinium* sp.	4	63	10
MF2-FF2	Chlorophyte	*Euglena* sp.	1	122	22
	Microflagellate	*Cryptomonas* sp.	2	109	19
	Dinoflagellate	*Gymnodinium* sp.	3	63	11
	Microflagellate	*Chroomonas* sp.	4	54	10
MF3	Chlorophyte	*Euglena* sp.	1	305	33
	Microflagellate	*Cryptomonas* sp.	2	160	18
	Microflagellate	*Chroomonas* sp.	3	90.2	10
FF1	Chlorophyte	*Euglena* sp.	1	305	33
	Microflagellate	*Cryptomonas* sp.	2	136	15
	Dinoflagellate	*Gymnodinium* sp.	3	102	11
FFB	Chlorophyte	*Euglena* sp.	1	366	43
	Microflagellate	*Cryptomonas* sp.	2	138	16
FFA	Microflagellate	*Cryptomonas* sp.	1	200	24
	Chlorophyte	*Euglena* sp.	2	183	22
LDS	Chlorophyte	*Euglena* sp.	1	122	24
	Microflagellate	*Cryptomonas* sp.	2	82	16
	Diatom	*Tabellaria sp.*	3	77	15

a) Dominant taxa were identified as those present in proportions greater than 10% of total biomass.

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

3.2 Zooplankton Community

3.2.1 Zooplankton Taxonomic Richness and Biomass

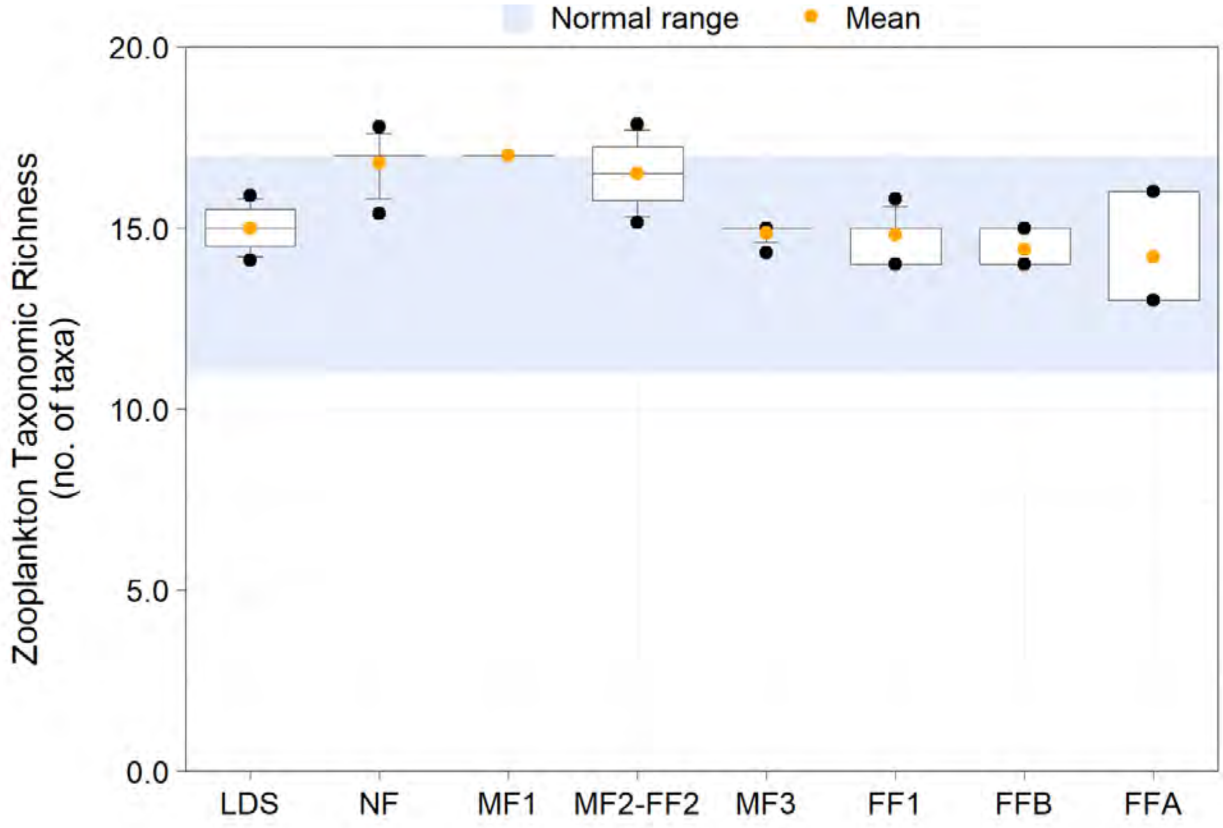
3.2.1.1 Near-Field Versus Far-Field Area Comparisons and Comparison to Reference Condition

In total, 25 zooplankton taxa were identified in the zooplankton samples in 2019 (Attachment C, Table C-4). Zooplankton taxonomic richness was greater at stations closer to the effluent diffusers than at the FF stations in 2019 (Figure 3-8; Table 3-5). In the NF area, richness at NF5 was greater than the normal range, while values for NF1, NF2 and NF3 were equal to the upper limit of the normal range, and NF4 richness was within the normal range. Stations in the MF1 and MF2-FF2 areas were at or beyond the upper limit of the normal range in 2019. Stations along the MF3 transect, and stations in the FF1 area were within the normal range. Although zooplankton taxonomic richness did not significantly differ from the reference condition mean (Tables 3-5 and 3-6), mean richness in the NF area was significantly greater than the FF area mean in 2019.

In 2019, mean zooplankton biomass, and the biomass of cladocerans, cyclopoid copepods, and rotifers were greater at stations closer to the effluent diffusers than in the FFA and FFB areas (Figure 3-9). For zooplankton biomass, stations in the NF, MF and FF1 areas were at or above the upper limit of the normal range, and biomass in the NF area was greater than the 2019 FF area mean and the reference condition mean (although not significantly), showing no indication of toxicological impairment (Tables 3-5 and 3-6). Mean cladoceran, cyclopoid copepod and rotifer biomass in the FF areas were at or above the upper bounds of the normal range (Figure 3-9). Mean cladoceran biomass in the NF area was not significantly different than the FF area mean or the reference condition mean, while mean cyclopoid copepod biomass and mean rotifer biomass were significantly greater in the NF area compared to the FF area mean in 2019, and were greater than the reference condition mean (Table 3-6). Mean calanoid copepod biomass was at or below the normal range in all areas in 2019 (Figure 3-9). Calanoid copepod biomass in the NF area was not statistically different from the FF area mean but was significantly less than the reference condition mean (Table 3-6).

Zooplankton taxonomic richness, total biomass and biomass of cladocerans and rotifers at the stations in Lac du Sauvage (i.e., LDS-1 to LDS-3) were similar to richness and biomass observed in the FF areas of Lac de Gras in 2019 (Figures 3-8 and 3-9). Calanoid copepod biomass was greater in Lac du Sauvage compared to all areas in Lac de Gras, while cyclopoid copepod biomass was lower in Lac du Sauvage compared to all areas in Lac de Gras (Figure 3-9).

Figure 3-8 **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.

Table 3-5 Zooplankton Biomass and Taxonomic Richness in the NF Area of Lac de Gras in 2019 Compared to the Normal Range and the FF Mean

Variable	Unit	2019 NF		2019 FF		Normal Range[(a)]			
		n	Mean ± SD	n	Mean ± SD	n	Lower Limit	2008-2010 Reference Area Mean	Upper Limit
Total zooplankton taxonomic richness	no. of taxa	5	17 ± 1	15	14 ± 1	103	11	14	17
Total zooplankton biomass	mg/m^3	5	**750** ± 207	15	423 ± 215	103	132	288	540
Cladocera biomass	mg/m^3	5	**332** ± 243	15	232 ± 154	100	8	50	127
Calanoida biomass	mg/m^3	5	**43** ± 23	15	36 ± 13	98	61	165	359
Cyclopoida biomass	mg/m^3	5	**358** ± 54	15	149 ± 64	101	13	55	105
Rotifera biomass	mg/m^3	5	**18** ± 3	15	7 ± 1	96	2	4	7

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

Note: **Bolded** NF area means are outside the normal range.

n = number of samples; SD = standard deviation; ± = plus or minus; NF = near-field; FF = far-field.

Table 3-6 Statistical Comparisons of Zooplankton Biomass and Taxonomic Richness in Lac de Gras, 2019

Variable	NF vs. FF Area Comparison							Comparison to Reference Condition Mean(b,c)		
	Statistical Test	Overall Comparison	NF vs. FF Area Comparison		FF Area Comparisons			Statistical Test	NF vs. 2013	
			NF vs. FF1+FFB+FFA		FF1 vs. FFA	FF1 vs. FFB	FFB vs. FFA			
		P	*P*	Magnitude (%)(a)	*P*	*P*	*P*		*P*	Magnitude (%)(a)
Total zooplankton taxonomic richness	ANOVA	**0.007**	**0.001**	16	ns	ns	ns	ANOVA	nt	21
Total zooplankton biomass	ANOVA^{log}	**<0.001**	ns	-	**<0.001**	**0.001**	ns	ANOVA^{log}	nt	160
Cladoceran biomass	ANOVA^{log}	**0.011**	nt	-	**0.012**	**0.024**	ns	ANOVA^{log}	nt	564
Calanoid copepod biomass	ANOVA	ns	-	-	ns	ns	ns	ANOVA	**<0.001**	-74
Cyclopoid copepod biomass	ANOVA	**<0.001**	**<0.001**	141	**0.002**	**0.002**	ns	ANOVA	nt	551
Rotifer biomass	ANOVA^{log}	**<0.001**	**<0.001**	170	ns	ns	ns	ANOVA^{log}	nt	350

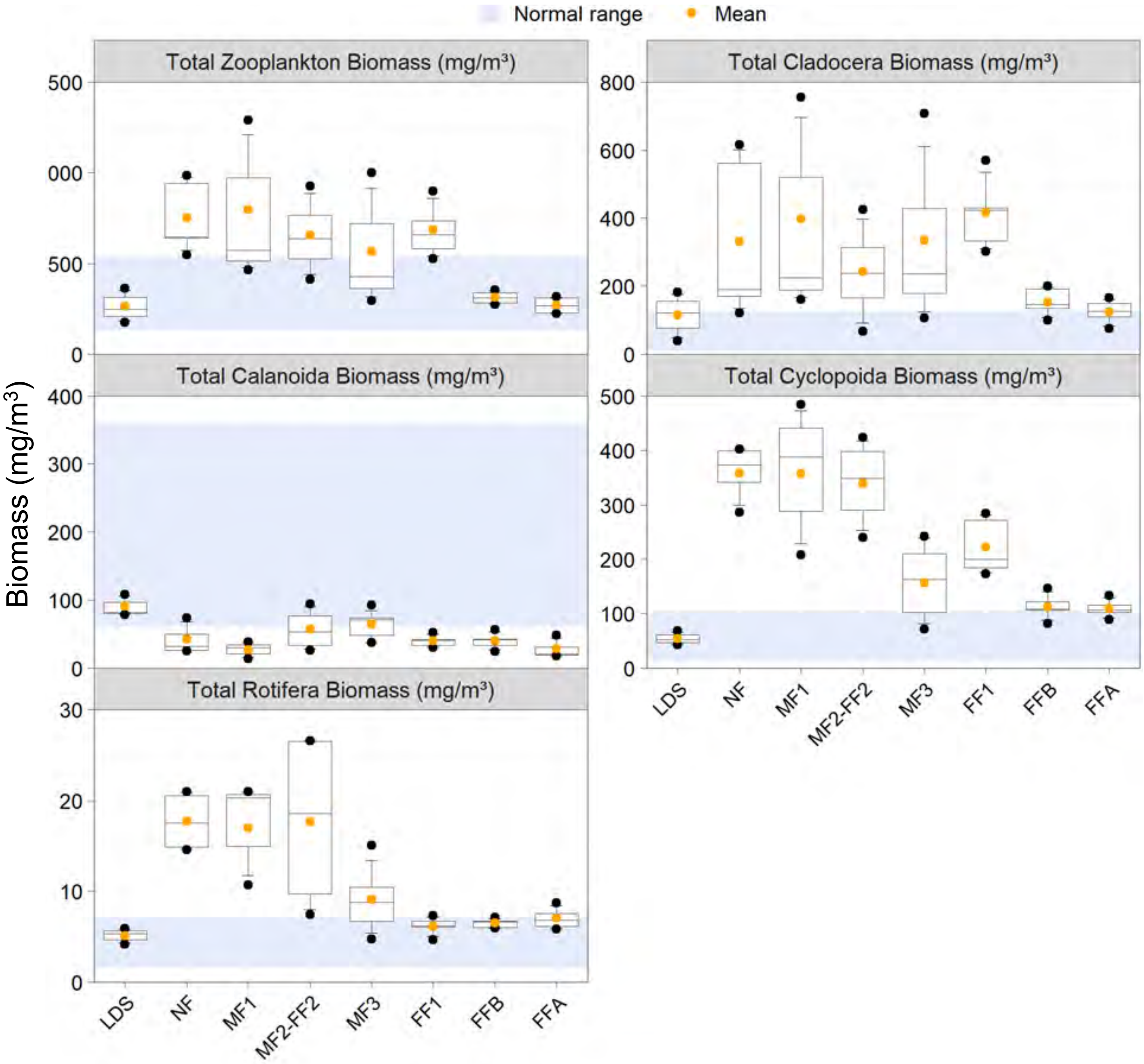
a) Percent difference between sampling area means (i.e., NF mean compared to pooled mean of the FF1, FFA, and FFB areas).

b) Obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).

c) One-tailed comparison to assess toxicological impairment in the NF compared to the reference conditions.

NF = near-field; FF = far-field; *P* = probability; ns = not significant; n/a = not applicable; REF = reference condition mean; ANOVA = analysis of variance (transformation is indicated by superscript).

Figure 3-9 **Zooplankton Biomass of Major Ecological Groups 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.

3.2.1.2 Gradient Analysis

Gradient analysis of zooplankton richness, biomass and the biomass of the major ecological groups indicate that the zooplankton variables at stations close to the effluent diffusers in 2019 were generally greater compared to more distant stations (Table 3-7; Figures 3-10, 3-11 and 3-12). Along the MF1 transect to the northwest of the Mine, taxonomic richness, cyclopoid copepod biomass and rotifer biomass significantly declined with increasing distance from the effluent diffusers (Table 3-7). Along the MF2 transect to the northeast of the Mine, towards the Lac du Sauvage inlet, only rotifer biomass decreased significantly with increasing distance. Along the MF3 transect southeast of the Mine, taxonomic richness, total biomass, cladoceran biomass, and calanoid copepod biomass significantly declined with increasing distance from the effluent diffusers. Cyclopoid copepod biomass significantly decreased with distance along the MF3 transect from the NF area to MF3-2, with a breakpoint at 3.94 km from the effluent diffusers, and continued to decline along the transect thereafter. Rotifer biomass significantly decreased along the MF3 transect until MF3-5, where a breakpoint occurred at 17.47 km from the effluent diffusers but increased thereafter.

Table 3-7 Trend Analysis for Zooplankton Community Variables in Lac de Gras, 2019

Variable	Model	Transformation	Gradient	Slope Direction (a)	Breakpoint (km)(b)	*P*-value	r^2 and R^2(c)
Total zooplankton taxonomic richness	Model 1	Log	MF1	↓	-	0.004	0.44
			MF2	↑	-	0.732	0.44
			MF3	↓	-	0.001	0.44
Total zooplankton biomass	Model 1	Log	MF1	↓	-	0.638	0.76
			MF2	↓	-	0.064	0.76
			MF3	↓	-	<0.001	0.76
Cladoceran biomass	Model 1	Log	MF1	↑	-	0.224	0.24
			MF2	↓	-	0.081	0.24
			MF3	↓	-	0.006	0.24
Cyclopoid biomass	Model 2	-	MF1	↓	-	0.002	0.39
	Model 2		MF2	↓	-	0.211	0.39
	Model 3		MF3 (1st slope)	↓	3.94	0.018	0.85
			MF3 (2nd slope)	↓		-	0.85
Calanoid biomass	Model 1	Log	MF1	↑	-	0.543	0.05
			MF2	↑	-	0.857	0.05
			MF3	↓	-	0.023	0.05
Rotifer biomass	Model 2	Log	MF1	↓	-	<0.001	0.74
	Model 2		MF2	↓	-	0.007	0.74
	Model 3		MF3 (1st slope)	↓	17.47	<0.001	0.85
			MF3 (2nd slope)	↑		-	0.85

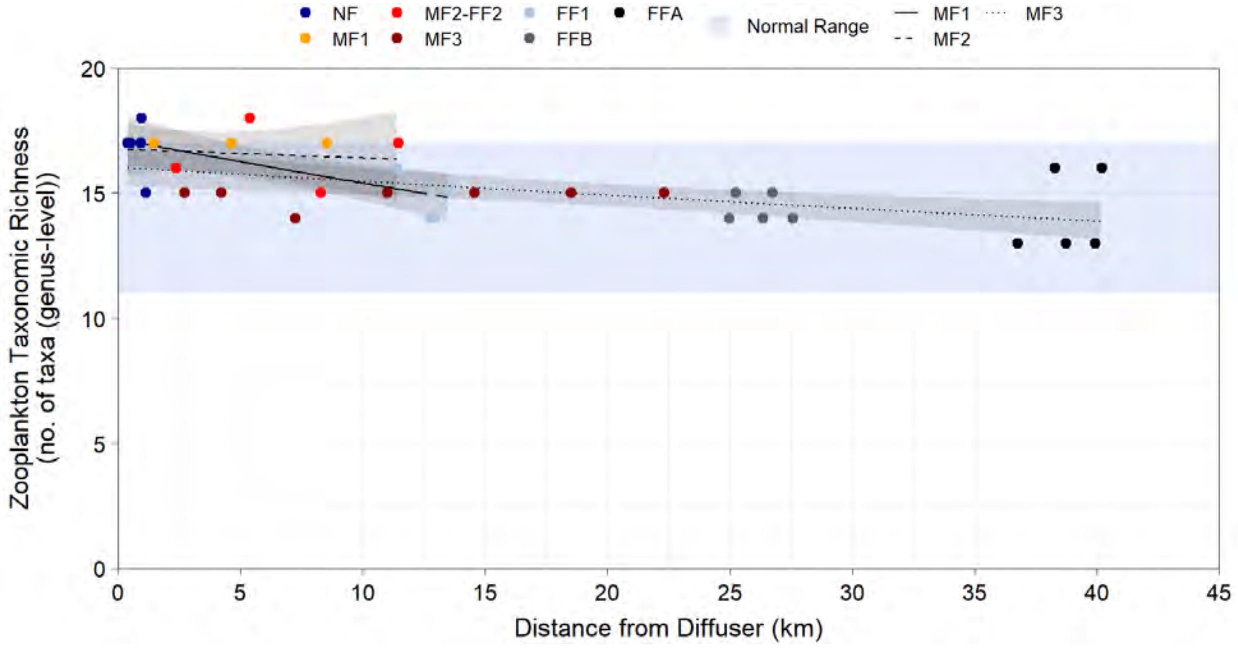
a) Slope direction was represented by an upward arrow (↑) indicating an increasing trend with distance from the effluent diffusers, or a downward arrow (↓) indicating a decreasing trend with distance from the effluent diffusers.

b) The breakpoint is the location from the effluent diffusers where the slopes of the linear regressions along the MF3 transect changed values.

c) For the MF3 broken stick model, r^2 is calculated because there is only one predictor, which is distance; for the other models, R^2 is used because there is more than one predictor, i.e., distance and gradient.

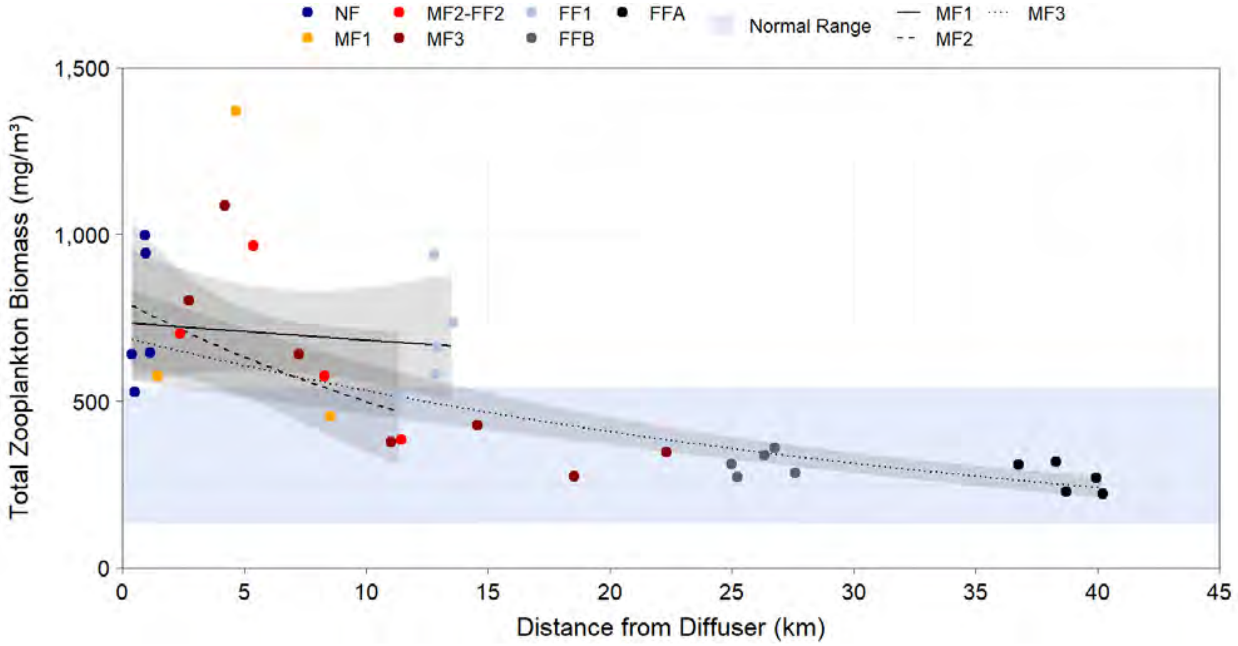
MF = mid-field.

Figure 3-10 Zooplankton Taxonomic Richness in Lac de Gras and Lac du Sauvage Relative to Distance from the Effluent Discharge, 2019



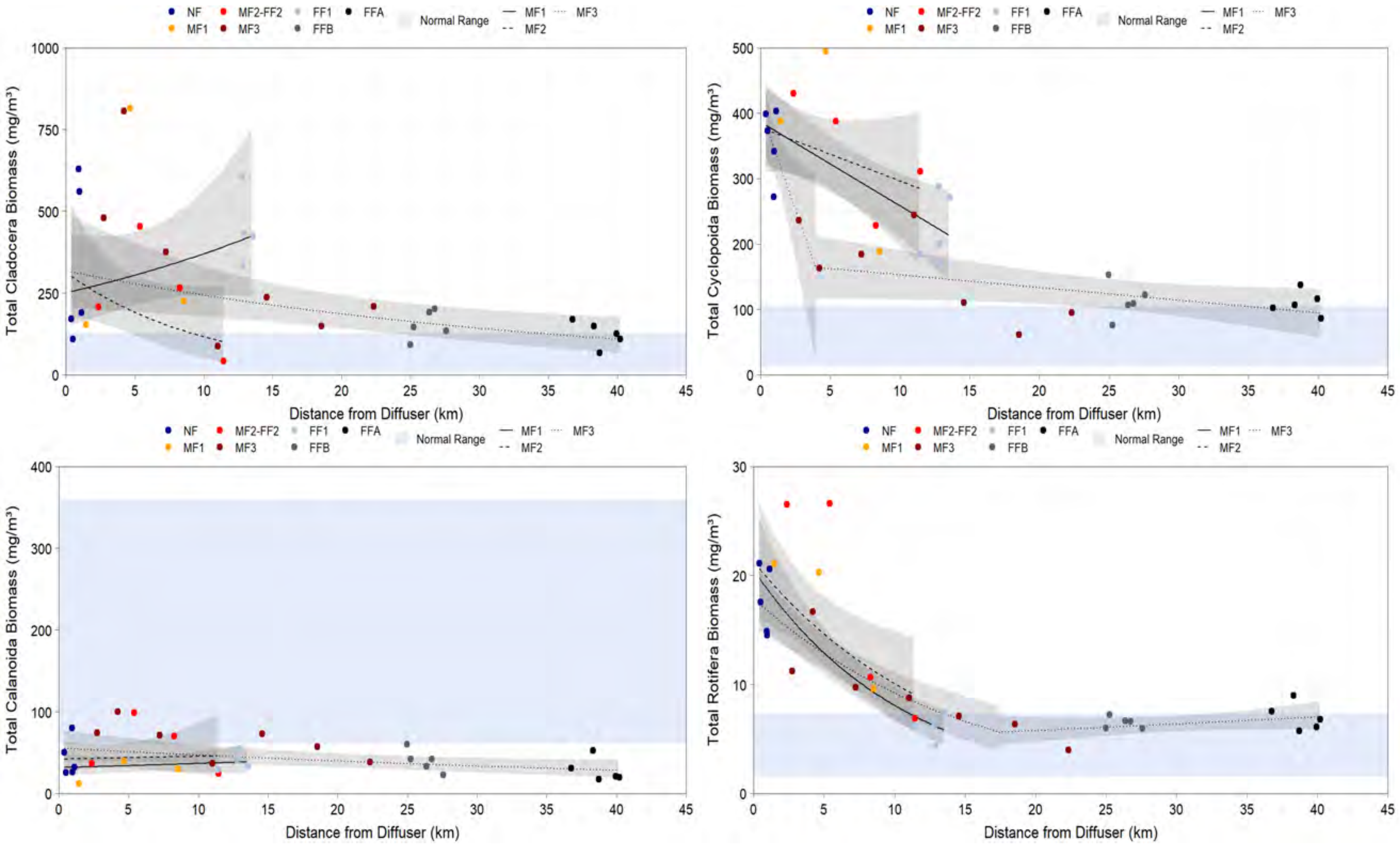
NF = near-field; MF = mid-field; FF = far-field.

Figure 3-11 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.

Figure 3-12 **Biomass of Major Zooplankton Groups 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.

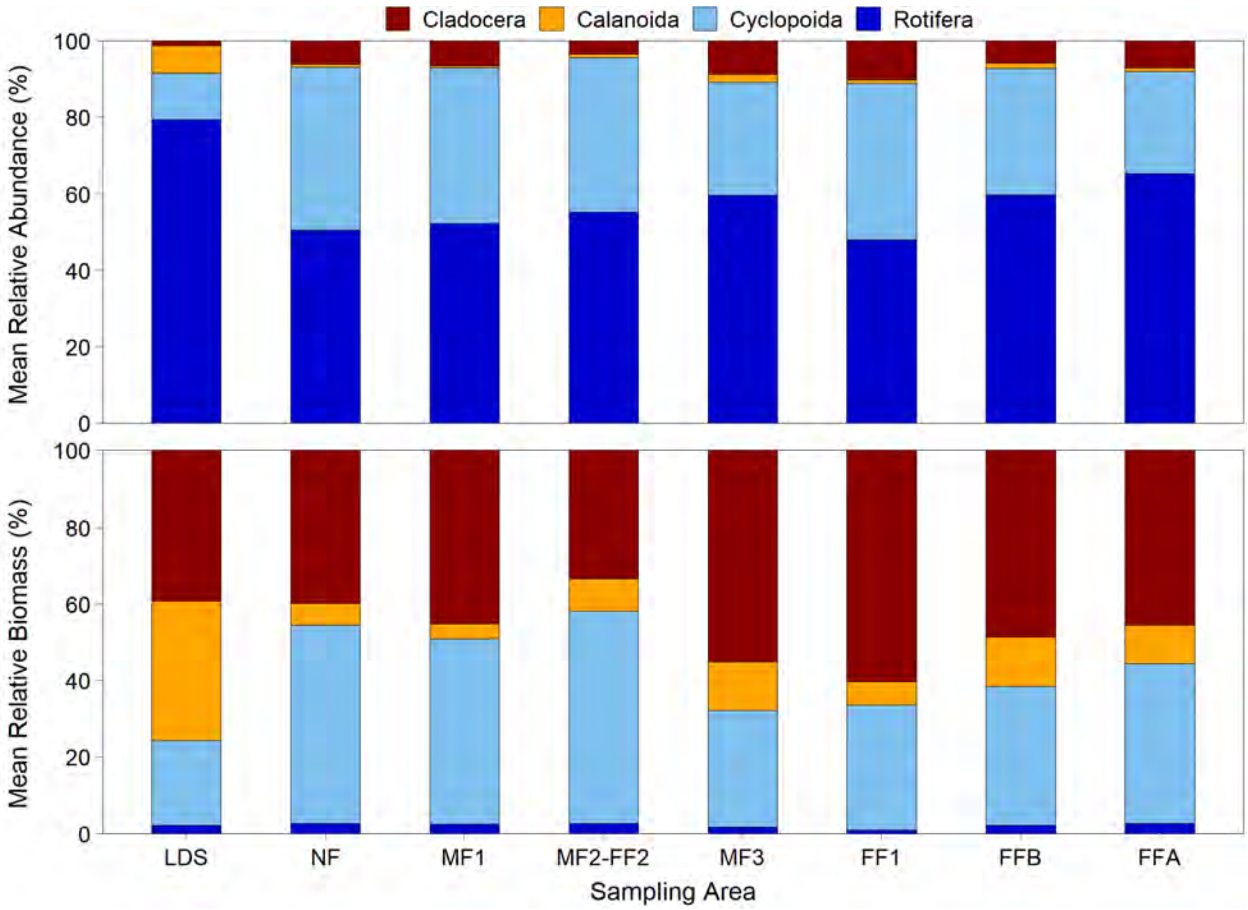
3.2.2 Zooplankton Community Structure

Zooplankton communities, based on abundance, in the NF and FF areas of Lac de Gras were co-dominated by rotifers and cyclopoid copepods in 2019 (Figure 3-13). In terms of mean relative biomass, the zooplankton community in the NF area was co-dominated by cladocerans and cyclopoid copepods, while the FF areas were dominated by cladocerans with cyclopoid copepod sub-dominance. There were fewer calanoid copepods in the NF and MF1 areas compared to the other areas, in terms of both abundance and biomass. Calanoid copepods were a minor component of the zooplankton community in all sampling areas in Lac de Gras 2019.

Despite accounting for a large proportion of total abundance, rotifers accounted for a small proportion of the total biomass (i.e., 3% in the NF area and less than 3% in the FF areas), reflective of their small body size (Figure 3-13). In contrast, cladocerans accounted for a small proportion of zooplankton community relative abundance in the NF area (i.e., 6% in the NF area and less than 10% in the FF areas), but contributed a large proportion of total zooplankton biomass (i.e., 40% in the NF area and approximately 50% in the FF areas), because of their relatively large body size.

In 2019, zooplankton community structure in the samples collected from Lac du Sauvage differed from samples collected from all areas of Lac de Gras in terms of relative abundance and relative biomass, and was dominated by rotifers by abundance, and co-dominated by cladocerans and calanoid copepods by biomass (Figure 3-13). The Lac du Sauvage stations had greater proportions of rotifers and calanoid copepods by abundance and a lower percentage of cyclopoid copepods and cladocerans compared to Lac de Gras. In terms of biomass, the Lac du Sauvage stations had similar proportions of cladocerans and rotifers, but greater proportions of calanoid copepods and lower proportions of cyclopoid copepods.

Figure 3-13 Mean Relative Zooplankton Abundance and Biomass in Lac de Gras, 2019



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

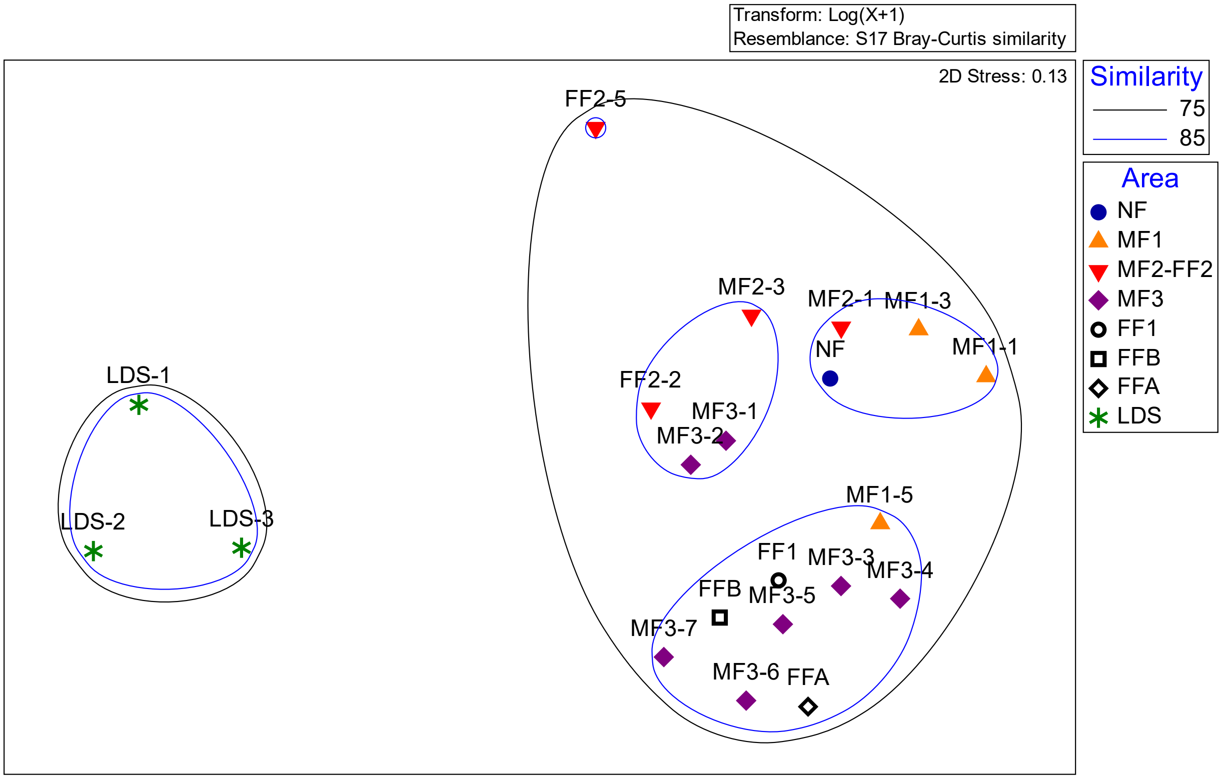
The two-dimensional nMDS plot demonstrates that there is a difference in zooplankton community composition between the NF area and FF areas and between Lac de Gras and Lac du Sauvage (Figure 3-14). The nMDS configuration for zooplankton biomass had a stress value of 0.13, indicating a reasonable level of fit to the original data. The SIMPROF test (*P*-value <0.05) indicated that the level of interpretation of the 75% and 85% clusters are acceptable and the global ANOSIM (*R* = 0.631, *P* = 0.001) test indicates that statistical interpretation of the nMDS structure is permitted.

The ordination plot shows separation in terms of zooplankton community composition between Lac de Gras and Lac du Sauvage (75% similarity clusters) and between the FF area stations and the NF area (85% similarity clusters). Stations along the MF transects closer to the NF area grouped together with the NF area (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 grouped together with the FF stations. The FF2-5 station, the station closest to the inlet to Lac de Gras from Lac du Sauvage, is separated out from the remainder of the Lac de Gras stations but is still within a 75% similarity ellipse with the remainder of the Lac de Gras stations.

Dominant taxa in each area of Lac de Gras and Lac du Sauvage were identified as those with proportions greater than 10% of the total biomass in each area. The three dominant taxa, based on biomass, in the NF area of Lac de Gras were the cyclopoid copepod, *Cyclops scutifer* (36%), and the cladocerans*, Daphnia longiremis* (27%) and *Eubosmina longispina* (14%) (Table 3-8). The same three dominant taxa were observed in the MF areas of Lac de Gras, with the addition of the cladoceran, *Holopedium gibberum* in MF2-FF2 area (13%) and MF3 area (22%). In the FF areas, the cladoceran*, D. longiremis* was the most dominant taxa (i.e., for the FF1 area: 27%; FFB area: 19%; and, FFA area: 20%). The cyclopoid copepod, *Cyclops bicuspidatus thomasi*, was a dominant taxa in the three FF areas, but not in the NF area.

The three dominant taxa in the samples collected from Lac du Sauvage were the cladoceran, *H. gibberum* (37%), the calanoid copepod, *Diaptomus sicilis* (22%), and the cyclopoid copepod, *C. bicuspidatus thomasi* (11%) (Table 3-8). Two of the five taxa identified as dominant taxa in the FF area of Lac de Gras were also identified as dominant taxa in the samples collected from Lac du Sauvage (i.e., the cladoceran, *H. gibberum* and the cyclopoid copepod, *C. bicuspidatus thomasi*).

Figure 3-14 Non-metric Multidimensional Scaling of Zooplankton Biomass in Lac de Gras, 2019



NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; 2D = two dimensional plot.

Table 3-8 Dominant Zooplankton Taxa in Lac de Gras and Lac du Sauvage, 2019

Area	Ecological Group	Dominant Taxa[(a)]	Dominance Ranking	Biomass	Proportion of total sample
				(mg/m^3)	(%)
NF	Cyclopoida	*Cyclops scutifer*	1	1,168	36
	Cladocera	*Daphnia longiremis*	2	867	27
	Cladocera	*Eubosmina longispina*	3	466	14
MF1	Cladocera	*Daphnia longiremis*	1	798	36
	Cyclopoida	*Cyclops scutifer*	2	769	35
	Cladocera	*Eubosmina longispina*	3	231	11
MF2 – FF2	Cyclopoida	*Cyclops scutifer*	1	966	42
	Cladocera	*Daphnia longiremis*	2	366	16
	Cladocera	*Eubosmina longispina*	3	304	13
	Cladocera	*Holopedium gibberum*	4	298	13
MF3	Cladocera	*Holopedium gibberum*	1	826	22
	Cladocera	*Eubosmina longispina*	2	779	21
	Cladocera	*Daphnia longiremis*	3	738	20
	Cyclopoida	*Cyclops scutifer*	4	625	17
FF1	Cladocera	*Daphnia longiremis*	1	889	27
	Cladocera	*Holopedium gibberum*	2	883	27
	Cyclopoida	*Cyclops scutifer*	3	572	18
	Cyclopoida	*Cyclops bicuspidatus thomasi*	4	383	12
FFB	Cladocera	*Daphnia longiremis*	1	277	19
	Cladocera	*Holopedium gibberum*	2	246	17
	Cladocera	*Eubosmina longispina*	3	238	17
	Cyclopoida	*Cyclops scutifer*	4	229	16
	Cyclopoida	*Cyclops bicuspidatus thomasi*	5	211	15
FFA	Cladocera	*Daphnia longiremis*	1	246	20
	Cyclopoida	*Cyclops bicuspidatus thomasi*	2	242	19
	Cladocera	*Eubosmina longispina*	3	223	18
	Cyclopoida	*Cyclops scutifer*	4	218	17
	Cladocera	*Holopedium gibberum*	5	152	12
LDS	Cladocera	*Holopedium gibberum*	1	295	37
	Calanoida	*Diaptomus sicilis*	2	22	22
	Cyclopoida	*Cyclops bicuspidatus thomasi*	3	88	11

a) Dominant taxa were identified as taxa present in proportions greater than 10% of total biomass.

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

3.3 Action Level Evaluation

The Action Levels for plankton effects address the toxicological impairment hypothesis. Action Level 1 is triggered when biomass or richness in the NF exposure area is significantly less than the reference condition mean (Table 2-3). In 2019, the NF area mean values for total phytoplankton and zooplankton biomass and zooplankton taxonomic richness were not significantly less than the reference condition mean (Tables 3-2 and 3-6).

Phytoplankton taxonomic richness in the NF area in 2019 was significantly less than the reference condition mean (Table 3-2), and less than the lower bound of the normal range, in all areas of Lac de Gras (Figure 3-1, Table 3-1). This could indicate an Action Level 3 trigger; however, the QC evaluation of the 2019 phytoplankton data (Attachment A) indicated that the data should be interpreted with caution and comparisons to previous years' data would be unreliable. A qualifier was added to the data as a result of a follow-up investigation with the taxonomist, preservation distributor, and field personnel. This investigation revealed that that unclear labelling and product description by the distributor led to the addition of preservative at a concentration five times more concentrated than used in previous years. This more concentrated preservative was added to the phytoplankton samples in 2019, which resulted in sample degradation and potentially fewer rare taxa in the samples (D. Brandt pers. comm. 04-Feb-2020; Attachment A). Therefore, the phytoplankton richness data were excluded from the Action Level evaluation in 2019.

Based on the 2019 phytoplankton biomass and zooplankton biomass and richness results, no Action Levels were triggered.

3.4 Weight-of-Evidence Input

The results described in the preceding sections also feed into the WOE approach described in the *Weight-of-Evidence Report* (Appendix XV). The results of the WOE approach relevant to plankton components are described in Section 3.1.5 of the *Weight-of-Evidence Report* (Appendix XV).

4 SUMMARY AND DISCUSSION

4.1 Phytoplankton Community

Phytoplankton taxonomic richness was less than the lower bound of the normal range in all areas of Lac de Gras in 2019, and the NF area was significantly less than the reference condition mean. The QC evaluation of the 2019 phytoplankton data (Attachment A) suggested that the richness data should be interpreted with caution and comparisons to previous years data are unreliable. As a result, phytoplankton richness was not included in the Action Level evaluation in 2019.

Mean phytoplankton biomass in the NF and FF areas was within the normal range, and the NF area mean did not differ significantly from the 2019 FF area mean or the reference condition mean. The gradient analysis demonstrated that phytoplankton richness, biomass, and the biomass of the major ecological groups have generally not shown a response in relation to effluent diffusers. Stations close to the effluent diffusers in 2019 were generally similar to the more distant stations, with the exception of microflagellates and cyanobacteria biomass, which increased significantly with increasing distance from the effluent diffusers.

Phytoplankton communities in all areas of Lac de Gras were dominated by microflagellates, based on abundance, with cyanobacteria and chlorophyte sub-dominance and by chlorophytes and microflagellates, based on biomass. Community composition in the NF area of Lac de Gras did not substantially differ from the FF areas in terms of relative abundance or biomass. The nMDS ordination results also indicated that the NF area community did not differ from the FF area communities.

Overall, the 2019 phytoplankton results did not provide clear evidence of toxicological impairment and the Action Level 1 for toxicological impairment was not triggered based on phytoplankton biomass. The 2019 phytoplankton biomass results were within the normal range in 2019, which is consistent with the chlorophyll *a* results presented in the 2019 Eutrophication Indicators Report (Appendix XIII).

4.2 Zooplankton Community

Zooplankton taxonomic richness was greater at stations closer to the effluent diffusers than the more distant stations in 2019, and mean richness in the NF area was significantly greater than the FF area mean but did not significantly differ from the reference condition mean. Mean zooplankton biomass and biomass of cladocerans, cyclopoid copepods, and rotifers were also greater at stations closer to the diffusers than the FFA and FFB areas. Biomass in the NF area was above the 2019 FF area mean, the normal range, and the reference condition mean, showing no indication of toxicological impairment.

The gradient analysis of zooplankton richness, biomass and the biomass of the major ecological groups indicated that the zooplankton variables have generally not shown a decrease close to the effluent diffusers; rather, richness and biomass generally declined with distance away from the diffusers, consistent with nutrient enrichment.

Zooplankton communities, based on abundance, in the NF and FF areas of Lac de Gras were co-dominated by rotifers and cyclopoid copepods in 2019. In terms of mean relative biomass, the zooplankton community in the NF area was co-dominated by cladocerans and cyclopoid copepods, while the FF areas were dominated by cladocerans with cyclopoid copepod sub-dominance. The nMDS ordination plot and ANOSIM results showed that community composition differed between the NF and FF areas of Lac de Gras in 2019.

The 2019 zooplankton community did not show a response consistent with toxicological impairment and Action Level 1 for toxicological impairment was not triggered. Rather, results were consistent with nutrient enrichment, as demonstrated by greater zooplankton biomass in the 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 indicate that nutrient enrichment is occurring in Lac de Gras, which further suggests that the spatial trends observed in the zooplankton community in 2019 are the result of nutrient enrichment.

5 RESPONSE FRAMEWORK

In 2019, 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.

Phytoplankton taxonomic richness, in all areas of Lac de Gras, was below the reference conditions mean and the normal range. However, the QC evaluation of the 2019 phytoplankton data (Attachment A) indicates that the 2019 data should be interpreted with caution, and for taxonomic richness, the 2019 comparison to previous years is unreliable, due to a sample preservation issue.

6 CONCLUSIONS

This report presents the analysis of the phytoplankton and zooplankton data collected during the 2019 AEMP field program. It addresses the objectives of the plankton comprehensive report, which are to evaluate the current year's plankton community data according to the AEMP Response Framework, to evaluate whether Mine-related toxicological changes are occurring in the plankton community in the NF area of Lac de Gras, and to assess the spatial extent of Mine-related effects.

Overall, the 2019 plankton data do not suggest that a toxicological effect is occurring in Lac de Gras. Rather, results continue to be consistent with nutrient enrichment[1], as demonstrated by greater zooplankton biomass in NF area compared to the FF areas, the reference condition mean, and the normal range. The NF area mean values for total phytoplankton and zooplankton biomass and zooplankton taxonomic richness were not significantly less than the reference condition mean[2], indicating that Action Level 1 was not triggered. The QC evaluation of the 2019 phytoplankton data suggested that the 2019 data should be interpreted with caution, and for phytoplankton taxonomic richness, that the 2019 comparison to previous years is unreliable. Efforts will be made during the 2020 field program to reduce the amount of preservative used in the samples (i.e., tea coloured) or dilute the concentrated preservative to a concentration of 1% prior to sample preservation.

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[1] 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 2019a) and subsequent AEMP annual reports (Golder 2018, 2019c).

[2] This is consistent with observations reported in the 2018 and 2019 AEMP, annual reports (Golder 2018, 2019c).

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8 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

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ATTACHMENT A

QUALITY ASSURANCE AND QUALITY CONTROL

QUALITY ASSURANCE AND QUALITY CONTROL

Introduction

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting, and are described for the Mine AEMP in the *Quality Assurance Project Plan Version 3.1* (Golder 2017). Quality assurance (QA) encompasses management and technical practices designed to generate data of appropriate quality. Quality control (QC) is an aspect of QA and includes the techniques used to assess data quality and the corrective actions to be taken when the data quality objectives are not met. This appendix describes QA/QC practices applied during the 2019 plankton component of the Aquatic Effects Monitoring Program (AEMP), evaluates QC data, and describes the implications of QC results to the interpretation of study results.

Quality Assurance

Field Staff Training and Operations

Diavik Diamond Mines (2012) Inc. (DDMI) field staff are trained to be proficient in standardized field sampling procedures, data recording, and equipment operations applicable to water quality sampling. Field work was completed according to specified instructions and Standard Operating Procedures (SOP). The procedures are described in:

- ENVI-923-0119 AEMP Combined Open Water and Ice Cover
- ENVI-902-0119 Quality Assurance/Quality Control
- ENVI-900-0119 Chain of Custody

These SOPs include guidelines for field record-keeping and sample tracking, guidance for use of sampling equipment, relevant technical procedures, and sample labelling, shipping and tracking protocols.

Office Operations

A data management system was in place to facilitate an organized system of data control, analysis, and filing. Relevant elements of this system are as follows:

- pre-field meetings to discuss specific work instructions with field crews
- field crew check-in with task managers every 24 to 48 hours to report work completed during that period
- designating two crew members responsible for:
  - collecting all required samples
  - immediate download and storage of electronic data
  - completing chain-of-custody and analytical request forms; labelling and documentation
  - processing, where required, and delivering samples to analytical laboratory in a timely manner

- cross-checking chain-of-custody forms and analysis request forms by the task manager to verify that the correct analysis packages had been requested
- review of field sheets by the task manager for completeness and accuracy
- reviewing taxonomy data immediately after receipt from the taxonomist
- creating backup files before data analysis
- completing appropriate logic checks for accuracy of calculations

Quality Control

Methods

Quality control is a specific aspect of QA that includes the techniques used to assess data quality. The field QC program consisted of the collection of duplicate samples to assess within-station variation and sampling precision. Duplicate samples consisted of two samples collected from the same station at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually and were submitted separately to the taxonomist for identical analyses. In 2019, duplicate zooplankton samples were collected from each station and submitted to Salki Consultants Inc. for analysis of taxonomic composition. Duplicate phytoplankton samples were not collected in 2019 as a result of a field crew oversight, which is a deviation from the *Quality Assurance Project Plan Version 3.1* (Golder 2017). The zooplankton and phytoplankton laboratory QC program consisted of four split samples which were analyzed by the same taxonomist to verify the taxonomist’s counting accuracy. The data were entered into electronic format by the taxonomist and were double-checked by the same taxonomist upon entry; errors were corrected as necessary before transferring the electronic files to DDMI.

Initial screening of the 2019 AEMP dataset was completed using a method based on Chebyshev’s theorem (Mann 2010) combined with the visual examination of scatter-plots (Golder 2017). If anomalies were identified during the screening process, the data were plotted with the corresponding 2007 to 2018 data for a range comparison. If the data were also outside the corresponding 2007 to 2018 range, laboratory re-analysis was requested. If laboratory re-analysis confirmed the results, the anomalous values were retained in the final data set, unless there was a technically defensible reason to exclude them.

The inherent variability associated with the plankton samples makes the establishment of a QC threshold value difficult. For the purposes of the plankton QC, samples were flagged and assessed further if there was a greater than 50% difference, calculated as the relative percent difference (RPD), in total abundance or total biomass between the original and duplicate samples. Similarly, samples were flagged and assessed further if there was a greater than 50% difference in total abundance or biomass between the taxonomist’s split samples.

The RPD was calculated using the following formula:

RPD = (|difference in abundance or biomass between duplicate samples| / mean abundance or biomass) x 100

In addition, the Bray-Curtis dissimilarity index, which is a measure of ecological distance between two communities, was used to assess the overall similarity between the taxonomist's split samples. The value of the Bray-Curtis dissimilarity index ranges from zero (identical communities) to one (very dissimilar communities) and is calculated using the following formula:

$$b = \frac{\sum_{k=1}^{n} \left| x_{ik} - x_{jk} \right|}{\sum_{k=1}^{n} \left(x_{ik} + x_{jk} \right)}$$

In this formula, *b* is the Bray-Curtis dissimilarity index, *n* is the number of taxa in the sample, x_{ik} and x_{jk} are abundance or biomass of taxon *(i)* in the original *(j)* and re-counted *(k)* samples, respectively. Bray-Curtis comparisons were performed on data grouped at the major ecological group level for the phytoplankton community (i.e., diatoms, chlorophytes, microflagellates, cyanobacteria, and dinoflagellates) and zooplankton community (i.e., cladocerans, cyclopoids, calanoids, and rotifers). Index values greater than 0.5 were flagged and follow-up discussions with the taxonomist were initiated.

Duplicate data were not automatically rejected because of an exceedance of the acceptance criterion; rather, they were evaluated on a case-by-case basis, because some level of within-station variability is expected for duplicate samples. If there were departures from the acceptance criterion, the samples were flagged, and a variety of follow-up assessments were performed. These assessments included plotting the data for visual identification of anomalous data. If there were values that were visually anomalous, the data were plotted with the corresponding 2007 to 2018 data for a range comparison. If the data were outside the corresponding 2007 to 2018 range, laboratory re-analysis was requested. If laboratory re-analysis confirmed the results, the anomalous values were retained in the final data set, unless there was a technically defensible reason to exclude them.

Results

Sample Integrity

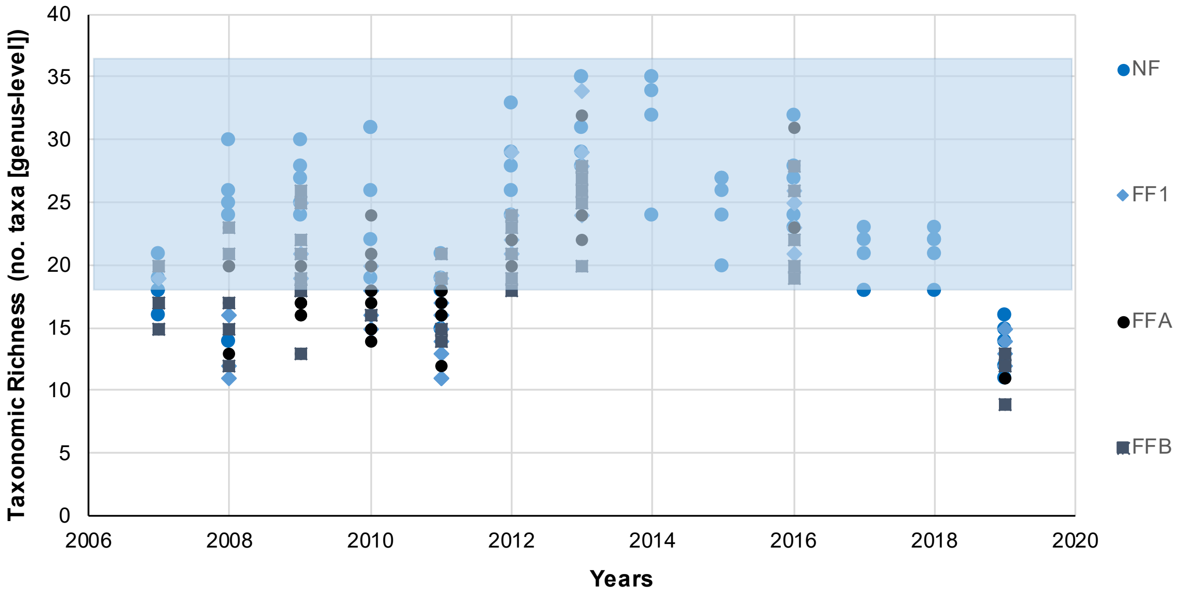
Based on a visual evaluation of the 2019 phytoplankton data, taxonomic richness in all areas of Lac de Gras was less than observed in recent years (i.e., 2012 to 2018) and below the reference condition (Figure A-1). However, phytoplankton biomass data were similar to those observed in recent years and were within the normal range (Figure A-2). As a result of the visual evaluation of the phytoplankton richness and biomass data, follow-up actions were performed to understand the differences from the historical dataset for the taxonomic richness data. Follow-up actions included discussion with the taxonomist and field personnel to evaluate the suitability of the 2019 phytoplankton results for use in the effects analysis and Action Level evaluation. Discussions with field personnel confirmed that the field methods did not deviate from the SOP and the taxonomist confirmed that the taxonomic methods were the same as those used in 2018 and those used by the previous taxonomist (i.e., 2013 to 2017). However, the taxonomist noted a problem with the 2019 phytoplankton sample integrity related to the amount of Lugols preservative added to the samples. Lugols is an acidic preservative and when used in the proper dilution (i.e., 1%) the result is inhibition of fungal and bacterial growth; however, the samples in 2019 exhibited excessive digestion and staining of the samples which resulted in an extended level of effort for the taxonomist to count and identify each sample (i.e., two to three times more than the previous year) (D. Brandt pers. comm. 4 Feb 2020). Further investigation into the issue found that unclear labelling and product description by the distributor led to the addition of preservative at a concentration five times more concentrated (i.e., 5.4%) than used in previous years.

The taxonomist also noted that the lower taxonomic richness in 2019 could have been the result of this preservation issue (i.e., the more concentrated preservative may have caused the degradation of the rare taxa in the sample prior to sample analysis), which would affect the number of taxa in a sample but may not affect the overall biomass of the dominant taxa.

The taxonomist also noted that comparing taxonomic richness among taxonomists is not ideal and comparisons should be based on abundance and/or biomass (D. Brandt pers. comm. 4 Feb 2020). It is possible that a number of the taxa observed by the previous taxonomist were skewed towards rare taxa (i.e., single individuals of a taxon observed in a sample were counted) as the total community biomass in 2019 was similar to biomass in previous years (Figure A-2), but taxonomic richness was lower. Rare taxa can be very transitory from year to year (D. Brandt pers. comm. 4 Feb 2020).

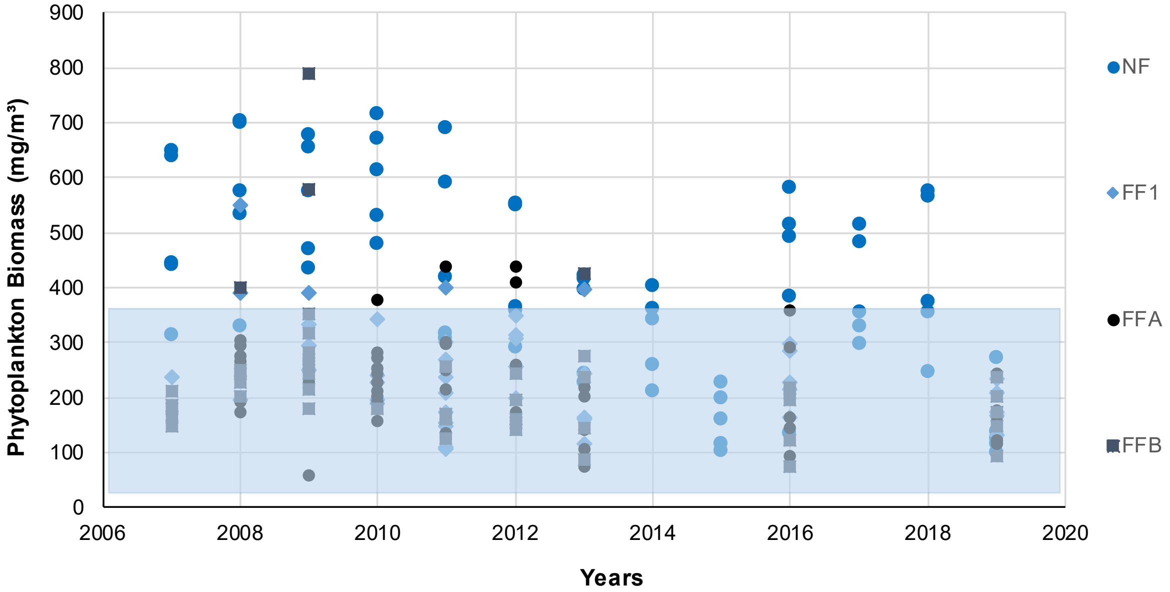
Overall, it was determined that there were sample integrity issues with the phytoplankton samples sent to the taxonomist in 2019 (i.e., sample disintegration from excess preservative) and that interpretation of the 2019 phytoplankton data and comparisons to previous years data and the reference condition should be done with caution, especially for taxonomic richness. Efforts will be made during the 2020 field program to reduce the amount of preservative used in the samples (i.e., tea coloured) or dilute the concentrated preservative to a concentration of 1% prior to sample preservation.

Figure A-1 Phytoplankton Taxonomic Richness in the NF and FF areas of Lac de Gras, 2019



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

Figure A-2 Phytoplankton Biomass in the NF and FF areas of Lac de Gras, 2019



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

Duplicate Samples

Phytoplankton field QC duplicate samples were not collected in 2019 as a result of a field crew oversight, which is a deviation from the *Quality Assurance Project Plan Version 3.1* (Golder 2017).

Comparison of duplicate zooplankton samples for total abundance and the abundances of the dominant groups indicated an overall similarity between duplicate samples based on the Bray-Curtis dissimilarity index (Table A-1).

A number of stations had RPDs that exceeded 50% for one or more of the dominant groups for zooplankton abundance: NF2, NF4, NF5, MF1-1, MF1-3, MF1-5, MF3-1, MF3-2, MF3-4, MF3-7, FF1-1, FF1-2, FF1-5, FFB-1, FFB-2, FFB-3, FFB-4, FFA-3, FFA-5, LDS-1, LDS-2, and LDS-3. However, only two samples had RPDs greater than 50% for total zooplankton abundance: FF1-2 and MF3-1. Despite these exceedances, the overall sample dissimilarity did not exceed the acceptance criterion (i.e., none of the samples had Bray-Curtis dissimilarity values greater than 0.5). Therefore, the duplicate zooplankton abundance samples were deemed acceptable for the purposes of this study.

Table A-1 Results for Field QC (Duplicate) Zooplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019

Area	Station	Major Taxonomic Group	Total Abundance (Ind/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
NF	NF1	Calanoida	0.8	1.2	39.1	0.13
		Cyclopoida	44.4	49.5	10.8	
		Cladocera	6.0	6.6	9.6	
		Rotifera	49.9	73.3	37.9	
		Total abundance	101.1	130.5	25.4	
	NF2	Calanoida	0.6	0.3	**71.8**	0.19
		Cyclopoida	61.8	40.8	41.0	
		Cladocera	4.5	3.7	20.0	
		Rotifera	59.0	41.7	34.3	
		Total abundance	125.9	86.5	37.1	
	NF3	Calanoida	1.1	0.8	32.7	0.03
		Cyclopoida	30.3	28.9	4.9	
		Cladocera	9.2	6.1	40.6	
		Rotifera	41.5	44.4	6.6	
		Total abundance	82.1	80.1	2.5	
	NF4	Calanoida	1.0	0.3	**100.2**	0.05
		Cyclopoida	52.0	56.7	8.6	
		Cladocera	3.5	4.4	23.3	
		Rotifera	56.5	63.4	11.5	
		Total abundance	113.0	124.8	9.9	
	NF5	Calanoida	0.7	0.7	1.4	0.06
		Cyclopoida	35.4	39.4	10.5	
		Cladocera	5.2	9.8	**60.3**	
		Rotifers	41.4	43.9	5.9	
		Total abundance	82.8	93.7	12.4	
MF1	MF1-1	Calanoida	0.4	0.1	**132.8**	0.05
		Cyclopoida	41.9	40.2	4.2	
		Cladocera	2.6	3.4	26.8	
		Rotifera	47.4	40.9	14.8	
		Total abundance	92.3	84.5	8.8	
	MF1-3	Calanoida	0.6	0.3	**77.6**	0.05
		Cyclopoida	38.5	38.2	0.8	
		Cladocera	11.8	7.7	41.7	
		Rotifers	53.4	49.0	8.6	
		Total abundance	104.3	95.1	9.1	
	MF1-5	Calanoida	0.3	0.6	**54.4**	0.16
		Cyclopoida	18.7	16.1	14.8	
		Cladocera	3.4	2.7	21.5	
		Rotifera	31.7	20.2	44.1	
		Total abundance	54.1	39.7	30.8	

Table A-1 Results for Field QC (Duplicate) Zooplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Abundance (Ind/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
MF2-FF2	MF2-1	Calanoida	0.7	0.7	5.9	0.05
		Cyclopoida	51.6	49.3	4.5	
		Cladocera	4.1	6.3	41.4	
		Rotifera	75.3	65.0	14.6	
		Total abundance	131.7	121.3	8.2	
	MF2-3	Calanoida	2.2	1.7	22.4	0.05
		Cyclopoida	31.3	26.2	17.8	
		Cladocera	7.0	6.0	16.0	
		Rotifera	83.0	96.5	15.0	
		Total abundance	123.5	130.4	5.4	
	FF2-2	Calanoida	1.3	0.8	47.0	0.05
		Cyclopoida	28.2	32.1	12.8	
		Cladocera	2.9	1.8	49.5	
		Rotifera	36.2	39.5	8.6	
		Total abundance	68.6	74.1	7.7	
	FF2-5	Calanoida	0.3	0.4	21.9	0.03
		Cyclopoida	33.8	30.6	9.9	
		Cladocera	0.5	0.7	36.5	
		Rotifera	23.2	24.3	4.5	
		Total abundance	57.9	56.1	3.2	
MF3	MF3-1	Calanoida	1.2	0.7	**56.4**	0.29
		Cyclopoida	24.3	14.7	49.2	
		Cladocera	7.2	3.8	**62.4**	
		Rotifera	52.7	27.6	**62.7**	
		Total abundance	85.4	46.7	**58.6**	
	MF3-2	Calanoida	0.9	1.6	**52.9**	0.11
		Cyclopoida	10.2	12.2	17.6	
		Cladocera	11.8	12.5	5.9	
		Rotifera	52.1	67.7	26.1	
		Total abundance	75.1	94.1	22.5	
	MF3-3	Calanoida	1.4	1.2	14.2	0.13
		Cyclopoida	14.4	10.0	36.5	
		Cladocera	6.4	5.7	11.9	
		Rotifera	43.8	33.7	26.0	
		Total abundance	66.1	50.6	26.5	
	MF3-4	Calanoida	0.5	0.5	0.4	0.08
		Cyclopoida	28.2	37.3	27.7	
		Cladocera	1.5	2.5	**51.7**	
		Rotifera	25.4	24.8	2.5	
		Total abundance	55.5	65.0	15.7	

Table A-1 Results for Field QC (Duplicate) Zooplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Abundance (Ind/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
MF3	MF3-5	Calanoida	1.5	1.0	33.3	0.05
		Cyclopoida	13.2	9.8	29.9	
		Cladocera	4.1	4.9	17.5	
		Rotifera	24.4	25.7	5.3	
		Total abundance	43.1	41.4	4.1	
	MF3-6	Calanoida	0.9	1.0	9.4	0.10
		Cyclopoida	10.7	8.3	24.8	
		Cladocera	1.6	1.8	13.3	
		Rotifera	27.0	22.0	20.7	
		Total abundance	40.2	33.0	19.5	
	MF3-7	Calanoida	1.3	0.3	**131.5**	0.05
		Cyclopoida	10.0	11.6	14.7	
		Cladocera	4.0	2.6	40.9	
		Rotifera	15.1	16.8	10.7	
		Total abundance	30.3	31.3	3.0	
FF1	FF1-1	Calanoida	0.4	0.7	47.9	0.21
		Cyclopoida	19.9	22.8	14.0	
		Cladocera	3.5	5.7	47.8	
		Rotifera	17.5	33.5	**62.6**	
		Total abundance	41.3	62.8	41.2	
	FF1-2	Calanoida	0.8	0.2	**109.1**	0.27
		Cyclopoida	16.7	7.9	**72.0**	
		Cladocera	4.8	4.4	8.0	
		Rotifera	22.6	13.3	**51.7**	
		Total abundance	45.0	25.9	**54.0**	
	FF1-3	Calanoida	0.7	0.5	24.5	0.06
		Cyclopoida	26.2	28.6	8.8	
		Cladocera	5.3	7.3	31.6	
		Rotifera	22.6	25.2	10.6	
		Total abundance	54.8	61.6	11.7	
	FF1-4	Calanoida	0.3	0.4	34.5	0.12
		Cyclopoida	16.6	13.4	21.2	
		Cladocera	3.5	3.8	9.2	
		Rotifera	22.8	17.0	29.1	
		Total abundance	43.1	34.6	21.9	
	FF1-5	Calanoida	0.2	0.5	**71.1**	0.10
		Cyclopoida	16.0	21.5	28.9	
		Cladocera	3.3	4.3	26.9	
		Rotifers	19.8	22.0	10.8	
		Total abundance	39.3	48.2	20.4	

Table A-1 Results for Field QC (Duplicate) Zooplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Abundance (Ind/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
FFB	FFB-1	Calanoida	0.3	0.6	**64.5**	0.13
		Cyclopoida	12.2	15.7	25.4	
		Cladocera	2.7	3.6	28.9	
		Rotifera	20.4	26.5	26.0	
		Total abundance	35.5	46.3	26.4	
	FFB-2	Calanoida	1.0	0.6	**52.9**	0.01
		Cyclopoida	14.4	15.0	3.8	
		Cladocera	1.4	1.3	5.9	
		Rotifers	21.2	21.7	2.5	
		Total abundance	38.0	38.6	1.5	
	FFB-3	Calanoida	0.9	0.6	34.6	0.02
		Cyclopoida	9.3	9.6	3.5	
		Cladocera	1.3	2.1	**50.3**	
		Rotifera	26.5	25.0	5.9	
		Total abundance	38.0	37.4	1.5	
	FFB-4	Calanoida	0.4	0.2	**72.3**	0.11
		Cyclopoida	17.8	12.2	37.2	
		Cladocera	4.9	2.3	**71.7**	
		Rotifera	20.0	20.1	0.6	
		Total abundance	43.0	34.8	21.1	
	FFB-5	Calanoida	0.5	0.4	34.5	0.05
		Cyclopoida	11.7	11.0	6.0	
		Cladocera	1.4	1.9	32.7	
		Rotifera	24.2	27.5	12.9	
		Total abundance	37.8	40.9	7.8	
FFA	FFA-1	Calanoida	0.7	0.4	48.7	0.14
		Cyclopoida	9.1	11.3	21.6	
		Cladocera	4.6	3.2	34.9	
		Rotifera	24.1	34.6	35.8	
		Total abundance	38.4	49.5	25.2	
	FFA-2	Calanoida	0.6	0.7	11.0	0.04
		Cyclopoida	10.2	7.4	30.8	
		Cladocera	3.4	2.3	38.1	
		Rotifera	33.1	36.0	8.4	
		Total abundance	47.3	46.4	1.8	
	FFA-3	Calanoida	0.1	0.2	**67.0**	0.08
		Cyclopoida	13.2	9.5	33.4	
		Cladocera	3.0	1.1	**90.1**	
		Rotifera	21.1	22.3	5.5	
		Total abundance	37.5	33.2	12.3	
	FFA-4	Calanoida	0.1	0.2	24.7	0.03
		Cyclopoida	9.6	11.6	19.1	
		Cladocera	2.6	2.8	5.7	
		Rotifera	26.9	26.2	2.8	
		Total abundance	39.3	40.7	3.7	

Table A-1 Results for Field QC (Duplicate) Zooplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Abundance (Ind/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
FFA (continued)	FFA-5	Calanoida	0.4	0.3	5.3	0.09
		Cyclopoida	17.1	10.0	**52.1**	
		Cladocera	3.4	2.8	19.5	
		Rotifera	22.4	24.6	9.6	
		Total abundance	43.2	37.8	13.4	
LDS	LDS-1	Calanoida	0.9	1.4	48.3	0.26
		Cyclopoida	2.2	1.8	22.7	
		Cladocera	0.2	0.1	46.4	
		Rotifera	19.1	10.2	**60.5**	
		Total abundance	22.3	13.5	49.3	
	LDS-2	Calanoida	1.6	0.8	**67.6**	0.05
		Cyclopoida	2.1	1.6	25.5	
		Cladocera	0.2	0.2	5.1	
		Rotifera	11.8	11.5	2.9	
		Total abundance	15.7	14.0	10.9	
	LDS-3	Calanoida	1.6	1.5	7.4	0.23
		Cyclopoida	2.2	3.0	32.2	
		Cladocera	0.3	0.4	34.0	
		Rotifera	11.6	20.1	**54.1**	
		Total abundance	15.6	25.0	46.4	

Note: **Bolded** values are RPD values greater than 50%.

QC = quality control; RPD = relative percent difference; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Comparison of duplicate zooplankton samples for total biomass and biomass of the dominant groups indicated an overall similarity between duplicate samples based on the Bray-Curtis dissimilarity index (Table A-2).

A number of stations had RPDs that exceeded 50% for one or more of the dominant groups for zooplankton biomass: NF3, NF4, NF5, MF1-1, MF1-3, MF2-1, MF3-1, MF3-2, MF3-3, FF1-1, FF1-2, FF1-4, FF1-5, FFB-1, FFB-2, FFB-3, FFB-4, FFB-5, FFA-2, FFA-3, LDS-1, and LDS-2. Five stations had exceedances based on total biomass: FF1-1, FF1-5, FFA-3, FFB-1, LDS-2. Despite these exceedances, the overall sample dissimilarity did not exceed the acceptance criterion (i.e., none of the samples had Bray-Curtis dissimilarity values greater than 0.5). Therefore, the duplicate zooplankton biomass samples were deemed acceptable for the purposes of this study.

Table A-2 Results for Field QC (Duplicate) Zooplankton Biomass Samples Collected from Lac de Gras and Lac du Sauvage, 2019

Area	Station	Major Taxonomic Group	Total Biomass (mg/m^3)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
NF	NF1	Calanoida	40.6	59.4	37.6	0.02
		Cyclopoida	404.3	393.6	2.7	
		Cladocera	176.6	164.4	7.2	
		Rotifera	17.2	25.1	37.4	
		Total biomass	638.6	642.4	0.6	
	NF2	Calanoida	29.2	22.1	28.0	0.14
		Cyclopoida	440.1	306.2	35.9	
		Cladocera	104.4	115.2	9.9	
		Rotifera	19.2	16.0	18.1	
		Total biomass	592.9	459.5	25.4	
	NF3	Calanoida	103.7	56.6	**58.8**	0.12
		Cyclopoida	316.2	228.6	32.2	
		Cladocera	685.2	572.3	17.9	
		Rotifera	12.8	17.0	28.5	
		Total biomass	1117.9	874.5	24.4	
	NF4	Calanoida	44.7	19.3	**79.6**	0.08
		Cyclopoida	368.8	438.1	17.2	
		Cladocera	175.2	204.6	15.5	
		Rotifera	20.1	21.1	4.9	
		Total biomass	608.8	683.0	11.5	
	NF5	Calanoida	21.7	30.3	33.1	0.21
		Cyclopoida	320.1	362.5	12.4	
		Cladocera	391.4	730.1	**60.4**	
		Rotifers	14.3	14.7	2.6	
		Total biomass	747.5	1137.6	41.4	
MF1	MF1-1	Calanoida	15.8	8.1	**65.0**	0.02
		Cyclopoida	394.1	381.7	3.2	
		Cladocera	154.4	151.7	1.8	
		Rotifera	22.3	19.8	11.9	
		Total biomass	586.6	561.2	4.4	
	MF1-3	Calanoida	57.6	21.7	**90.5**	0.22
		Cyclopoida	534.2	454.9	16.1	
		Cladocera	1056.3	572.8	**59.4**	
		Rotifers	18.0	22.6	22.7	
		Total biomass	1666.1	1072.0	43.4	
	MF1-5	Calanoida	33.8	26.1	25.8	0.06
		Cyclopoida	192.9	183.9	4.8	
		Cladocera	195.9	254.5	26.0	
		Rotifera	9.7	9.5	1.8	
		Total biomass	432.3	474.0	9.2	
MF2-FF2	MF2-1	Calanoida	39.7	33.9	15.7	0.20
		Cyclopoida	385.7	474.0	20.5	
		Cladocera	114.7	301.7	**89.8**	
		Rotifera	28.6	24.4	15.8	
		Total biomass	568.8	834.1	37.8	
	MF2-3	Calanoida	112.5	85.0	27.8	0.10
		Cyclopoida	368.5	406.5	9.8	
		Cladocera	382.6	523.7	31.1	
		Rotifera	23.5	29.6	22.9	
		Total biomass	887.1	1044.8	16.3	
	FF2-2	Calanoida	77.2	63.1	20.2	0.07
		Cyclopoida	189.8	266.4	33.6	
		Cladocera	284.5	248.4	13.5	
		Rotifera	10.0	11.3	12.5	
		Total biomass	561.6	589.2	4.8	

Table A-2 Results for Field QC (Duplicate) Zooplankton Biomass Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Biomass (mg/m^3)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
MF2-FF2 (continued)	FF2-5	Calanoida	21.9	26.6	19.7	0.03
		Cyclopoida	302.0	319.2	5.6	
		Cladocera	41.5	42.5	2.4	
		Rotifera	6.6	7.2	7.8	
		Total biomass	371.9	395.5	6.1	
MF3	MF3-1	Calanoida	84.1	64.5	26.4	0.14
		Cyclopoida	310.4	161.6	**63.0**	
		Cladocera	501.5	459.3	8.8	
		Rotifera	15.0	7.5	**66.8**	
		Total biomass	911.0	693.0	27.2	
	MF3-2	Calanoida	79.5	120.8	41.2	0.12
		Cyclopoida	118.7	207.5	**54.4**	
		Cladocera	749.0	862.4	14.1	
		Rotifera	12.7	20.7	48.3	
		Total biomass	959.9	1211.4	23.2	
	MF3-3	Calanoida	75.4	67.3	11.4	0.23
		Cyclopoida	148.7	220.0	38.7	
		Cladocera	515.1	237.6	**73.7**	
		Rotifera	12.2	7.2	**51.3**	
		Total biomass	751.4	532.1	34.2	
	MF3-4	Calanoida	40.7	32.9	21.1	0.08
		Cyclopoida	219.2	269.6	20.6	
		Cladocera	82.6	93.7	12.7	
		Rotifera	9.3	8.3	11.6	
		Total biomass	351.7	404.5	13.9	
	MF3-5	Calanoida	84.1	62.4	29.7	0.13
		Cyclopoida	121.0	99.7	19.3	
		Cladocera	181.4	291.6	46.6	
		Rotifera	5.9	8.3	33.7	
		Total biomass	392.4	462.0	16.3	
	MF3-6	Calanoida	62.4	52.2	17.7	0.06
		Cyclopoida	71.5	51.9	31.8	
		Cladocera	133.7	164.8	20.8	
		Rotifera	6.7	6.0	10.4	
		Total biomass	274.3	274.9	0.2	
	MF3-7	Calanoida	47.1	30.5	42.8	0.06
		Cyclopoida	87.3	103.5	17.0	
		Cladocera	195.9	220.8	11.9	
		Rotifera	3.5	4.5	23.5	
		Total biomass	333.8	359.2	7.3	

Table A-2 Results for Field QC (Duplicate) Zooplankton Biomass Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Biomass (mg/m^3)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
FF1	FF1-1	Calanoida	24.0	42.6	**55.7**	0.32
		Cyclopoida	261.5	281.1	7.2	
		Cladocera	213.5	633.7	**99.2**	
		Rotifera	4.5	10.5	**80.5**	
		Total biomass	503.5	967.9	**63.1**	
	FF1-2	Calanoida	90.6	18.9	**131.1**	0.12
		Cyclopoida	202.2	137.9	37.8	
		Cladocera	441.3	420.6	4.8	
		Rotifera	5.6	3.1	**56.1**	
		Total biomass	739.7	580.4	24.1	
	FF1-3	Calanoida	44.3	37.8	16.0	0.07
		Cyclopoida	317.5	257.6	20.8	
		Cladocera	543.7	666.2	20.2	
		Rotifera	5.9	7.6	25.9	
		Total biomass	911.4	969.1	6.1	
	FF1-4	Calanoida	25.9	32.3	22.2	0.09
		Cyclopoida	231.3	137.9	**50.6**	
		Cladocera	278.6	310.5	10.8	
		Rotifera	8.0	4.4	**59.5**	
		Total biomass	543.8	485.1	11.4	
	FF1-5	Calanoida	42.3	41.4	2.3	0.37
		Cyclopoida	152.2	248.1	47.9	
		Cladocera	166.5	500.9	**100.2**	
		Rotifers	5.1	7.1	33.7	
		Total biomass	366.1	797.4	**74.1**	
FFB	FFB-1	Calanoida	26.6	39.9	39.9	0.24
		Cyclopoida	100.9	112.9	11.3	
		Cladocera	124.6	258.3	**69.9**	
		Rotifera	6.1	7.3	17.5	
		Total biomass	258.1	418.3	47.4	
	FFB-2	Calanoida	57.9	62.5	7.7	0.17
		Cyclopoida	113.1	192.0	**51.7**	
		Cladocera	81.5	102.5	22.9	
		Rotifers	5.6	6.4	12.1	
		Total biomass	258.1	363.4	33.9	
	FFB-3	Calanoida	45.1	38.9	14.9	0.15
		Cyclopoida	89.2	62.6	35.1	
		Cladocera	104.5	188.0	**57.1**	
		Rotifera	7.2	7.3	2.3	
		Total biomass	246.0	296.8	18.7	
	FFB-4	Calanoida	22.9	22.2	3.1	0.29
		Cyclopoida	156.8	87.0	**57.3**	
		Cladocera	181.1	87.0	70.2	
		Rotifera	6.0	5.9	1.0	
		Total biomass	366.9	202.2	**57.9**	
	FFB-5	Calanoida	47.2	37.4	23.2	0.12
		Cyclopoida	146.5	71.2	**69.1**	
		Cladocera	186.6	217.3	15.2	
		Rotifera	6.6	6.6	0.7	
		Total biomass	386.9	332.5	15.1	

Table A-2 Results for Field QC (Duplicate) Zooplankton Biomass Samples Collected from Lac de Gras and Lac du Sauvage, 2019 (continued)

Area	Station	Major Taxonomic Group	Total Biomass (mg/m^3)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
FFA	FFA-1	Calanoida	25.2	36.5	36.6	0.10
		Cyclopoida	87.5	116.6	28.6	
		Cladocera	160.3	178.8	10.9	
		Rotifera	6.3	8.8	32.9	
		Total biomass	279.3	340.7	19.8	
	FFA-2	Calanoida	36.5	69.1	**61.7**	0.07
		Cyclopoida	115.8	97.6	17.0	
		Cladocera	161.7	137.9	15.9	
		Rotifera	8.2	9.8	16.8	
		Total biomass	322.2	314.3	2.5	
	FFA-3	Calanoida	13.1	21.4	48.3	0.31
		Cyclopoida	178.3	97.2	**58.9**	
		Cladocera	96.8	37.6	**88.2**	
		Rotifera	5.6	5.9	5.3	
		Total biomass	293.8	162.1	**57.8**	
	FFA-4	Calanoida	17.7	21.6	19.6	0.16
		Cyclopoida	69.7	102.3	37.8	
		Cladocera	93.6	126.3	29.8	
		Rotifera	6.5	7.1	8.3	
		Total biomass	187.5	257.3	31.4	
	FFA-5	Calanoida	25.2	16.4	42.5	0.11
		Cyclopoida	138.5	93.4	38.9	
		Cladocera	129.6	123.0	5.3	
		Rotifera	5.6	6.7	18.5	
		Total biomass	298.9	239.4	22.1	
LDS	LDS-1	Calanoida	66.1	91.5	32.1	0.08
		Cyclopoida	61.1	42.5	35.9	
		Cladocera	31.1	31.1	0.0	
		Rotifera	8.2	2.5	**105.4**	
		Total biomass	166.6	167.6	0.6	
	LDS-2	Calanoida	104.6	59.2	**55.4**	0.35
		Cyclopoida	34.6	48.5	33.5	
		Cladocera	41.8	202.6	**131.5**	
		Rotifera	3.7	4.3	16.4	
		Total biomass	184.7	314.7	**52.1**	
	LDS-3	Calanoida	122.4	100.5	19.6	0.05
		Cyclopoida	74.3	67.3	9.9	
		Cladocera	171.9	206.7	18.4	
		Rotifera	4.8	7.1	39.4	
		Total biomass	373.3	381.6	2.2	

Note: **Bolded** values are RPD values greater than 50%.

QC = quality control; RPD = relative percent difference; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Split Samples

The laboratory QC program consisted of four phytoplankton and seven zooplankton split samples in 2019.

The phytoplankton laboratory QC data indicated that the occurrence of dominant groups was consistent between the split samples (Tables A-3 and A-4). The phytoplankton split sample results did not exceed an RPD of 50% for total abundance or biomass, but did exceed an RPD of 50% for diatom abundance and biomass in the FF1-3 and LDS-2 samples, dinoflagellate abundance in the FFA-1 sample, and chlorophyte biomass in the MF3-6 and FFA-1 samples. Despite these exceedances, the overall sample dissimilarity did not exceed the acceptance criterion (i.e., none of the samples had Bray-Curtis dissimilarity values greater than 0.5). Therefore, based on the split phytoplankton abundance and biomass results, samples were deemed acceptable for the purposes of this study.

Table A-3 Results for Laboratory QC (Split) Phytoplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019

Area	Station	Major Taxonomic Group	Total Abundance (cells/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
MF3	MF3-6	Microflagellates	926,870	951,261	2.6	0.01
		Diatoms	0	0	0.0	
		Chlorophytes	390,261	365,870	6.5	
		Cyanobacteria	341,478	341,478	0.0	
		Dinoflagellates	73,174	48,783	40.0	
		Total abundance	1,731,783	1,707,391	1.4	
FF1	FF1-3	Microflagellates	1,585,435	1,585,435	0.0	0.02
		Diatoms	24,391	48,783	**66.7**	
		Chlorophytes	414,652	487,826	16.2	
		Cyanobacteria	463,435	487,826	5.1	
		Dinoflagellates	48,783	48,783	0.0	
		Total abundance	2,536,696	2,658,652	4.7	
FFA	FFA-1	Microflagellates	1,756,174	1,853,739	5.4	0.05
		Diatoms	73,174	121,957	50.0	
		Chlorophytes	243,913	195,130	22.2	
		Cyanobacteria	731,739	829,304	12.5	
		Dinoflagellates	24,391	48,783	**66.7**	
		Total abundance	2,829,391	3,048,913	7.5	
LDS	LDS-2	Microflagellates	1,292,739	1,317,130	1.9	0.05
		Diatoms	121,957	0	**200.0**	
		Chlorophytes	317,087	414,652	26.7	
		Cyanobacteria	731,739	853,696	15.4	
		Dinoflagellates	48,783	48,783	0.0	
		Total abundance	2,512,304	2,634,261	4.7	

Note: **Bolded** values are RPD values greater than 50%.

QC = quality control; RPD = relative percent difference; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Table A-4 **Results for Laboratory QC (Split) Phytoplankton Biomass Samples Collected from Lac de Gras and Lac du Sauvage, 2019**

Area	Station	Major Taxonomic Group	Total Biomass (mg/m^3)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
MF3	MF3-6	Microflagellates	37.8	40.6	7.2	0.26
		Diatoms	0.0	0.0	0.0	
		Chlorophytes	85.6	25.9	**107.0**	
		Cyanobacteria	1.4	1.4	0.0	
		Dinoflagellates	15.9	19.5	20.7	
		Total biomass	140.6	87.4	46.7	
FF1	FF1-3	Microflagellates	88.3	83.9	5.1	0.05
		Diatoms	1.8	3.7	**66.7**	
		Chlorophytes	27.8	34.6	21.8	
		Cyanobacteria	1.9	2.0	5.1	
		Dinoflagellates	11.0	14.6	28.6	
		Total biomass	130.8	138.8	5.9	
FFA	FFA-1	Microflagellates	85.1	84.4	0.9	0.004
		Diatoms	5.5	9.1	50.0	
		Chlorophytes	18.4	10.5	**54.9**	
		Cyanobacteria	2.9	3.3	12.5	
		Dinoflagellates	9.8	14.6	40.0	
		Total biomass	121.7	122.0	0.2	
LDS	LDS-2	Microflagellates	49.0	50.4	2.7	0.11
		Diatoms	36.0	0.0	**200.0**	
		Chlorophytes	79.9	81.1	1.5	
		Cyanobacteria	2.9	3.4	15.4	
		Dinoflagellates	11.0	19.5	**56.0**	
		Total biomass	178.8	154.4	14.6	

Note: **Bolded** values are RPD values greater than 50%.

QC = quality control; RPD = relative percent difference; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

The zooplankton laboratory QC data indicated that the occurrence of dominant groups was generally consistent between the split samples (Tables A-5 and A-6). The zooplankton split sample results did not exceed an RPD of 50% for total abundance or biomass in 2019, but did exceed an RPD of 50% for calanoid copepod abundance and biomass in the MF3-5A sample, cladoceran biomass in the MF3-6B sample, calanoid and cyclopoid copepod abundance, cladoceran abundance, and calanoid copepod biomass in the FFB-4A sample, and cladoceran abundance in the LDS-1B sample. Despite these exceedances, the overall sample dissimilarity did not exceed the acceptance criterion (i.e., none of the samples had Bray-Curtis dissimilarity values greater than 0.5). Therefore, based on the split zooplankton abundance and biomass results, the samples were deemed acceptable for the purposes of this study.

Table A-5 Results for Laboratory QC (Split) Zooplankton Abundance Samples Collected from Lac de Gras and Lac du Sauvage, 2019

Area	Station	Major Taxonomic Group	Total Abundance (Ind/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Split Sample		
MF3	MF3-1B	Calanoida	0.7	0.6	12.9	0.07
		Cyclopoida	14.7	15.2	3.3	
		Cladocera	3.8	5.0	29.2	
		Rotifera	27.6	32.8	17.5	
		Total abundance	46.7	53.7	13.9	
	MF3-5A	Calanoida	1.5	0.6	**89.6**	0.06
		Cyclopoida	13.2	10.5	23.1	
		Cladocera	4.1	2.5	48.5	
		Rotifera	24.4	27.3	11.3	
		Total abundance	43.1	40.8	5.5	
	MF3-6B	Calanoida	1.0	0.9	7.7	0.08
		Cyclopoida	8.3	8.6	2.8	
		Cladocera	1.8	1.4	22.8	
		Rotifera	22.0	27.3	21.6	
		Total abundance	33.0	38.2	14.4	
FF1	FF1-2B	Calanoida	0.2	0.4	47.2	0.11
		Cyclopoida	7.9	11.6	38.6	
		Cladocera	4.4	3.9	11.9	
		Rotifera	13.3	16.0	18.0	
		Total abundance	25.9	31.9	21.0	
FFB	FFB-4A	Calanoida	0.4	0.1	**127.6**	0.23
		Cyclopoida	17.8	4.7	**116.8**	
		Cladocera	4.9	2.5	**62.8**	
		Rotifera	20.0	19.9	0.6	
		Total abundance	43.0	27.2	45.2	
LDS	LDS-1B	Calanoida	1.4	1.1	24.5	0.03
		Cyclopoida	1.8	1.7	2.7	
		Cladocera	0.1	0.0	**103.7**	
		Rotifera	10.2	10.9	6.7	
		Total abundance	13.5	13.8	2.1	
	LDS-3B	Calanoida	1.5	1.4	3.5	0.17
		Cyclopoida	3.0	4.5	38.7	
		Cladocera	0.4	0.3	28.9	
		Rotifera	20.1	12.8	44.9	
		Total abundance	25.0	18.9	27.7	

Note: **Bolded** values are RPD values greater than 50%.

QC = quality control; RPD = relative percent difference; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Table A-6 Results for Laboratory QC (Split) Zooplankton Biomass Samples Collected from Lac de Gras and Lac du Sauvage, 2019

Area	Station	Major Taxonomic Group	Total Biomass (mg/m^3)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Split Sample		
MF3	MF3-1B	Calanoida	64.5	46.4	32.6	0.05
		Cyclopoida	161.6	143.1	12.2	
		Cladocera	459.3	428.4	7.0	
		Rotifera	7.5	8.2	9.9	
		Total biomass	693.0	626.2	10.1	
	MF3-5A	Calanoida	84.1	56.5	39.2	0.11
		Cyclopoida	121.0	207.9	**52.9**	
		Cladocera	181.4	142.7	23.9	
		Rotifera	5.9	8.5	35.8	
		Total biomass	392.4	415.6	5.7	
	MF3-6B	Calanoida	52.2	65.6	22.7	0.20
		Cyclopoida	51.9	56.5	8.5	
		Cladocera	164.8	71.0	**79.6**	
		Rotifera	6.0	9.7	46.9	
		Total biomass	274.9	202.8	30.2	
FF1	FF1-2B	Calanoida	18.9	27.4	36.8	0.11
		Cyclopoida	137.9	184.5	28.9	
		Cladocera	420.6	299.9	33.5	
		Rotifera	3.1	3.7	16.0	
		Total biomass	580.4	515.5	11.9	
FFB	FFB-4A	Calanoida	22.9	9.2	**85.1**	0.22
		Cyclopoida	156.8	95.4	48.7	
		Cladocera	181.1	126.5	35.5	
		Rotifera	6.0	5.6	7.7	
		Total biomass	366.9	236.7	43.1	
LDS	LDS-1B	Calanoida	91.5	71.0	25.2	0.13
		Cyclopoida	42.5	32.3	27.2	
		Cladocera	31.1	23.5	28.1	
		Rotifera	2.5	2.9	11.9	
		Total biomass	167.6	129.6	25.6	
	LDS-3B	Calanoida	100.5	99.9	0.6	0.04
		Cyclopoida	67.3	96.5	35.7	
		Cladocera	206.7	184.0	11.6	
		Rotifera	7.1	3.1	77.6	
		Total biomass	381.6	383.6	0.5	

Note: **Bolded** values are RPD values greater than 50%.

QC = quality control; RPD = relative percent difference; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

Summary

There were data integrity issues with the phytoplankton data in 2019 (i.e., sample degradation from excess preservative); therefore, interpretation of the 2019 phytoplankton data and comparisons to previous years data and the reference conditions should be done with caution, especially for taxonomic richness. Efforts will be made during the 2020 field program to reduce the amount of preservative used in the samples (i.e., tea coloured) or dilute the concentrated preservative to a concentration of 1% prior to sample preservation. Data screening within the 2019 dataset did not identify anomalous values; therefore, within-year spatial analysis was deemed appropriate; however, among-year comparisons were performed with the caveat that the 2019 data may be suspect as a result of the sample degradation.

For the 2019 zooplankton community dataset, data screening did not identify anomalous values and the duplicate samples were within the expected range of natural variability; therefore, the zooplankton community dataset was deemed acceptable and used to complete the zooplankton community analysis in 2019.

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ATTACHMENT B

2019 PHYTOPLANKTON COMMUNITY DATA

These data are provided electronically in an Excel file.

ATTACHMENT C

2019 ZOOPLANKTON COMMUNITY DATA

These data are provided electronically in an Excel file.

APPENDIX XII

SPECIAL EFFECTS STUDY - DUST DEPOSITION

SPECIAL EFFECTS STUDY – DUST DEPOSITION IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

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Executive Summary

A Special Effects Study (SES) was conducted in August 2019 to provide additional information to support the evaluation of potential for dust-related effects on water quality and aquatic life in the Aquatic Effects Monitoring Program (AEMP). 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 at selected stations within the area of greatest dust deposition
- to evaluate the fate of dust-related phosphorus in lake water
- to inform the next Design Plan update (i.e., version 6) with respect to the evaluation of dust-related effects in Lac de Gras.

The concentrations of major ions, nutrients, and total metals in effluent, lake-water (AEMP and SES stations) and dust as measured in 2019 were used in the geochemistry evaluation. The geochemistry evaluation was conducted by evaluating relationships between major ions and metals in water to differentiate between dust and effluent-based sources. Identifying geochemical signatures, or fingerprints, for dust and effluent in lake water may also help to evaluate the relative influence of dust on water quality.

The geochemistry evaluation determined that samples of effluent and dustfall (as determined from snow core data) have distinct geochemical signatures. Effluent samples had a calcium-chloride and calcium-sulphate composition. The major ion composition of the dustfall samples varied; calcium was generally the major cation, and major anions were bicarbonate, sulphate and chloride.

Element versus element relationships were investigated to identify parameters that could be used to develop unique molar ratios to geochemically fingerprint dustfall versus effluent. Unique relationships were identified between potassium and silicon, and magnesium and silicon. The relationships between molar ratios of potassium and silicon, and magnesium and silicon are well defined, and could be used to fingerprint the influence of dust versus effluent. Concentrations of major ions and sulphate correlated linearly in all datasets and demonstrated a difference in molar ratios between dustfall and effluent. The relationships between major ions and nutrients (including total phosphorus) were not well defined and cannot be used to fingerprint the influence of dustfall versus effluent.

The geochemical signature of lake water (represented by water quality samples collected as part of the SES and AEMP) was similar to that of effluent. Based on this evaluation, dustfall is likely to have a negligible influence on lake water quality, with some degree of uncertainty, as the concentrations are so low that they are effectively “masked” by effluent water quality.

As part of the SES, water quality data (including indicators of eutrophication) were collected at four stations in Lac de Gras within the dust zone of influence (ZOI). Stations were located closer to potentially high dust generating areas than the currently approved AEMP stations, and therefore, are expected to be more impacted by dust deposition than by effluent. Concentrations of major ions, metals and eutrophication indicators at these potentially high dust deposition stations were compared to those at nearby AEMP stations (i.e., MF3-1 to MF3-4) to evaluate whether dust deposition had an additional detectable effect on top of the effluent effect. These AEMP stations were selected because their distances from the diffuser were similar to that of the SS stations and, therefore, their relative effluent exposure would be similar.

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, beyond what was observed at MF stations. Concentrations of major ions and metals that could be associated with dust were similar at the SES and MF3 stations. Concentrations of eutrophication indicators, including total phosphorus, were also similar between the SES and MF3 stations. This finding is consistent with the geochemistry evaluation, which also found that the major ion, metal, and SRP content of the SES and AEMP samples overlapped, and that lake water chemistry was more similar to effluent than to dustfall.

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. The likely mineralogical source of phosphorus in dustfall is the phosphate mineral apatite, which has low solubility in the pH and redox conditions in lake water and is unlikely to dissolve. Apatite is stable in solid form above a pH of approximately 5. Given that the average pH of effluent is approximately 7.2, and the average pH of the AEMP water quality samples is 6.3, the potential for phosphorus release from apatite dissolution from dustfall should be limited in Lac de Gras.

The main conclusions of the SES are as follows:

- Effluent and dustfall samples have distinct geochemical signatures.
- The geochemical signature of lake water (i.e., the SES and AEMP samples) is similar to that of effluent. Dustfall is likely to have a negligible influence on lake water quality, with some degree of uncertainty, as the concentrations are so low that they are effectively “masked” by effluent water quality.
- 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.

Based on the results of the SES, the AEMP provides sufficient and appropriate data to evaluate the influence of Mine-related effects on the water quality of Lac de Gras, and additional sampling effort in Lac de Gras to further investigate dust-related effects is not warranted.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
ALS	ALS Laboratories
BV Labs	Bureau Veritas Laboratories (BV Labs; formerly Maxxam Analytics)
DDMI	Diavik Diamond Mines (2012) Inc.
DKN	dissolved Kjeldahl nitrogen
DL	detection limit
DQO	data quality objective
e.g.	for example
FF	far-field
GWB	Geochemist’s Workbench
i.e.	that is
LDG	Lac de Gras
Maxxam	Maxxam Analytics
MF	mid-field
Mine	Diavik Diamond Mine
n	sample size/count
NF	near-field
OW	open-water
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RPD	relative percent difference
SES	special effects study
SNP	surveillance network program
SS	special effects study sample
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TDS	total dissolved solids
TK	Traditional Knowledge
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
WLWB	Wek'èezhìı Land and Water Board
ZOI	zone of influence

Symbols and Units of Measure

%	percent
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
×	times
µS/cm	microsiemens per centimetre
m	metre
mg/L	milligrams per litre
µg/L	micrograms per litre
µg-N/L	micrograms nitrogen per litre
µg-P/L	micrograms phosphorus per litre

1 INTRODUCTION

As required by Water Licence W2015L2-0001 (WLWB 2015), issued by the Wek'èezhìı Land and Water Board (WLWB), Diavik Diamond Mines (2012) Inc. (DDMI) has been monitoring Lac de Gras (LDG) through the Aquatic Effects Monitoring Program (AEMP) since 2007. The technical components of the AEMP include dust, effluent and water quality, lake productivity (i.e., eutrophication indicators), sediment quality, plankton and benthic invertebrate communities, fish health and tissue chemistry, and the use of fisheries resources in Lac de Gras (i.e., Traditional Knowledge [TK]). The AEMP monitors effects resulting from all Mine-related pathways leading to potential effects on the aquatic ecosystem of Lac de Gras, including dust deposition, although the sampling design focusses on effluent discharge because the Mine water discharge represents the principal stressor of potential concern to Lac de Gras.

Although water quality and biological monitoring results to date have not shown a 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[1] that suggest mine-generated dust contributes an appreciable loading of total phosphorus (TP) to Lac de Gras (e.g., Attachment D in the *Eutrophication Indicators Report* [Appendix XIII]). These concerns led to the Wek'èezhìı Land and Water Board (WLWB) issuing Decisions #3A and #3D. The specific wording of the Decisions are as follows:

- 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, Diavik Diamond Mines (2012) Inc. (DDMI) conducted a Special Effects Study (SES) 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

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[1] As noted in Appendix XIII, phosphorus loading to Lac de Gras from dustfall was estimated using snow water chemistry data from the dust monitoring program, with consideration of background and anthropogenic TP deposition rates, and conservative assumptions were used including the lack of terrestrial attenuation. The dust sampling program was not designed to be as precise as the AEMP effluent assessment for measuring TP loading to Lac de Gras, and the estimate of TP loading from dust is considered to have low precision with an order of magnitude variance.

- 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
  - how to differentiate between the effects of dust deposition versus effluent on TP concentrations in Lac de Gras

A geochemistry evaluation was conducted to use relationships between major ions, metals[2], and nutrients in water to differentiate between dust and effluent based sources. Identifying geochemical signatures, or fingerprints, for dust and effluent in lake water is also useful to evaluate the relative influence of dust and effluent on lake water quality.

Water quality and biological data (including indicators of eutrophication) were collected at four stations in Lac de Gras within the dust zone of influence (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 by effluent. 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 has 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. A better understanding of release of phosphorus from dust particles in the water chemistry of Lac de Gras will aid the interpretation of the relative influence of TP loadings from dust on nutrient enrichment in the lake.

2 METHODS

2.1 Geochemistry Evaluation

The purpose of the geochemistry evaluation was to identify unique chemical trends that could be used to fingerprint the end-member composition of Mine-related dustfall versus effluent, and determine if these signatures can be used to distinguish the influence of Mine-related dustfall from the Mine effluent influence in water quality samples collected from Lac de Gras.

2.1.1 Data Sources

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. Sources of the five datasets are as follows:

- 2019 snow core chemistry – reported in *Dust Deposition Report* (Appendix I)
- 2019 effluent chemistry – reported in *Effluent and Water Chemistry Report* (Appendix II)
- 2019 AEMP water quality in Lac de Gras – reported in *Effluent and Water Chemistry Report* (Appendix II)

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[2] The term metal is used herein and includes non-metals (i.e., selenium) and metalloids (i.e., arsenic).

- 2019 AEMP phosphorus and nitrogen concentrations in Lac de Gras – reported in *Eutrophication Indicators Report* (Appendix XIII)
- 2019 SES major ions, metals, and nutrients in Lac de Gras – reported herein

Details on the field collection, laboratory analysis, and data quality evaluation for the first four datasets are provided in the respective technical appendices. A brief summary is provided below.

The SES included the collection of additional water quality samples located in Lac de Gras in areas in closer proximity to dust-generating Mine activities. The field collection and laboratory analysis of these samples are discussed in Section 2.2.

2.1.1.1 Snow Core Chemistry

The dust monitoring program analyzed snow water from snow core surveys to characterize the chemical characteristics of dust (see the *Dust Deposition Report* [Appendix I]). Snow water chemistry samples were collected at 16 monitoring, 3 control and 4 control-assessment stations. The monitoring stations were placed at varying distances around the Mine along five transects. Across stations, the distance from mining operations ranged from approximately 35 to 2,175 m for the monitoring stations, from 3,042 to 4,802 m for the control stations and from 7,614 to 30,711 m for the control-assessment stations (Figure 2-1). The control-assessment stations were added to the dust monitoring program in 2019 to assess the adequacy of the current control locations.

At each station, a snow corer was used to drill into the snow pack to retrieve a cylindrical snow core. A minimum of three cores at each station were extracted and composited to obtain the necessary 3 L of snow water required for the laboratory chemical analysis. Snow cores were double-bagged and melted at room temperature prior to processing and shipment to Bureau Veritas Laboratories (BV Labs; formerly Maxxam Analytics) where the chemical analysis was performed.

Snow water was analyzed for conventional parameters (i.e., pH, specific conductivity, alkalinity, hardness, total dissolved solids [TDS], total suspended solids [TSS], turbidity); major ions (i.e., bicarbonate, calcium, chloride, fluoride, magnesium, potassium, sodium, sulphate); nutrients (i.e., total ammonia, total nitrogen, nitrate, nitrite, nitrate+nitrite, total Kjeldahl nitrogen [TKN], total and dissolved phosphorus, soluble reactive phosphorus); and total and dissolved metals.

2.1.1.2 Effluent Chemistry

Effluent chemistry data for the Mine were obtained from the Surveillance Network Program (SNP) for the Mine and reported as part of the *Effluent and Water Chemistry Report* (Appendix II). Data were summarized for the period of effluent discharge from 1 November 2018 to 31 October 2019. Treated effluent from the NIWTP was sampled from both diffusers, which discharged continuously to Lac de Gras throughout the 2019 monitoring period. Sampling was completed approximately every six days at each discharge point. For the purposes of the SES, data from both diffusers were pooled and used in the geochemistry evaluation. The effluent chemistry dataset included conventional parameters (i.e., pH, specific conductivity, alkalinity, hardness, TDS, TSS, turbidity); major ions (i.e., bicarbonate, calcium, chloride, fluoride, magnesium, potassium, sodium, sulphate); nutrients (i.e., total ammonia, total nitrogen, nitrate, nitrite, nitrate+nitrite, TKN, total and dissolved phosphorus, soluble reactive phosphorus); and total and dissolved metals.

2.1.1.3 Water Quality in Lac de Gras

Water quality sampling at AEMP stations in 2019 occurred in the near-field (NF) area, three mid-field (MF) areas, and three far-field (FF) areas (Figure 2-1). Sampling stations in the MF areas follow transect lines that run from the NF area to the FF areas (FF1, FFA, and FFB). The MF1 transect is located northwest of the NF area towards the FF1 area. The MF2 transect is located to the northeast, towards the FF2 area near the Lac du Sauvage inlet. The MF3 transect is located south of the NF area, towards the FFB and FFA areas. Three stations were located within 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 within the larger MF3 area (i.e., MF3-1 to MF3-7). Five stations were sampled in each of the three FF areas.

Chemistry samples were collected over two monitoring seasons: ice-cover and open-water. Ice-cover season (i.e., late winter) sampling was completed from 22 April to 15 May 2019. Open-water sampling was completed from 15 August to 5 September 2019.

During the ice-cover season, stations in the NF and MF areas were sampled at three depths (i.e., top, middle, and bottom). Near-surface water samples (top) were collected at a depth of 2 m from the ice surface, and bottom samples were collected at a depth of 2 m above the lake bottom. Mid-depth samples were collected from the mid-point of the total water column depth. Stations in the FF areas (FF1, FFA, and FFB) were sampled at mid-depth only.

During the open-water season, the same discrete depths[3] were sampled for conventional parameters, major ions, and metals as part of the Effluent and Water Chemistry Report (Appendix II). However, depth-integrated samples were collected in duplicate at the NF and MF stations for analysis of nutrients, which were reported in the *Eutrophication Indicators Report* (Appendix XIII). Mid-depth samples were collected in the FF areas for the analysis of nutrients.

Water samples were shipped to BV Labs for analysis of conventional parameters, major ions, nutrients and total and dissolved metals. Split samples for ammonia was also analyzed by both BV Labs and ALS Laboratories (ALS). The AEMP water quality in Lac de Gras chemistry dataset considered in the SES geochemistry evaluation included conventional parameters (i.e., pH, specific conductivity, alkalinity, hardness, TDS, TSS, turbidity); nutrients (i.e., total ammonia, total nitrogen, nitrate, nitrite, nitrate+nitrite, TKN, total and dissolved phosphorus, soluble reactive phosphorus); major ions (i.e., bicarbonate, calcium, chloride, fluoride, magnesium, potassium, sodium, sulphate); and total and dissolved metals.

2.1.2 Geochemical Fingerprinting

The results of major ions, metals and nutrient analysis were used to evaluate the relative differences in concentrations of key parameters that could be associated with Mine-related dust versus effluent, to identify a geochemical "fingerprint" associated with Mine effluent versus Mine-related dust. The data used to complete this evaluation included the SES dataset (13 samples), the 2019 Diavik dustfall dataset (28 snow core samples), and the 2019 effluent quality dataset (28 samples). In addition, the data were also compared to the composition of samples from the 2019 AEMP dataset (146 samples) to confirm that the general water quality characteristics of the SES samples fell within the range of composition of the samples in the AEMP dataset.

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[3] Top depth is sampled 2 m below the water surface.

The general major ion chemistry of the samples in the five datasets was evaluated by plotting the data in a piper (i.e., trilinear) diagram. A piper diagram is a graphical representation of the water chemistry of a sample, where major cations (e.g., magnesium, calcium and sodium+potassium) and anions (e.g., sulphate, chloride and bicarbonate) are presented in separate ternary plots, which are then projected onto a diamond-plot. The piper diagram was prepared using the geochemical software Geochemist's Workbench (GWB).

Next, the key parameters were identified by categorizing variables more likely to be associated with Mine effluent (e.g., nutrients) versus those more likely to be associated with Mine-related dust (e.g., calcium, magnesium and silicon). Box plots were prepared to compare the range of concentrations of these variables in the samples in each dataset. Box plots graphically depict groups of data according to the minimum, first quartile, median, third quartile and maximum concentrations. The box is drawn around the first to third quartile, and a horizontal line is placed at the median. The minimum and maximum are presented as lines extending from upper and lower quartiles. These plots are useful in evaluating the general characteristics of each dataset.

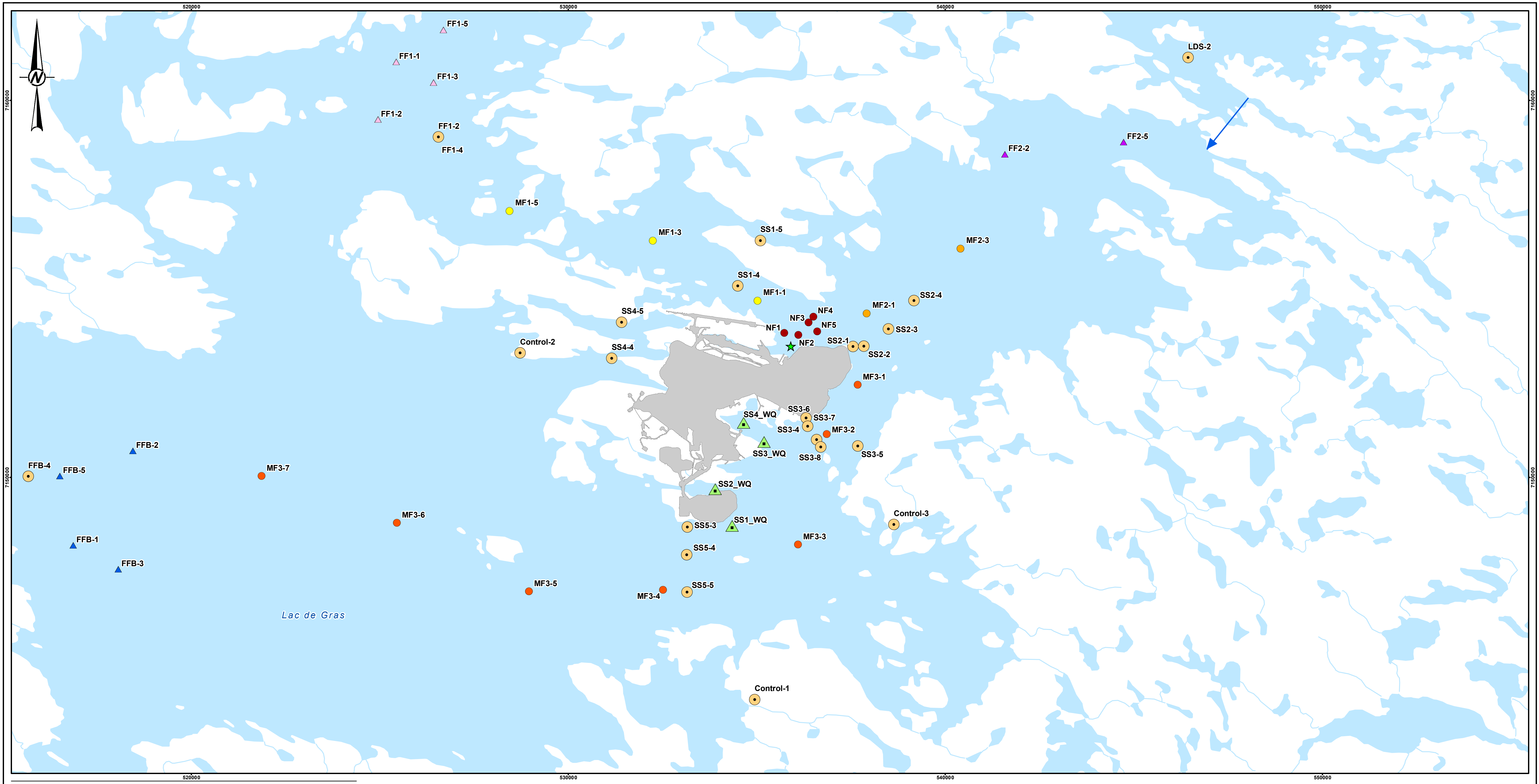
After identifying the key parameters that could be used as geochemical fingerprints, the data were imported into GWB to develop ternary diagrams. Ternary diagrams graphically depict the molar ratios of three variables. Ternary diagrams are used to perform a screening level, multivariate comparison of the relative concentrations of the key parameters, for the purpose of validating the selection of parameters that can be used to fingerprint Mine-related dust versus effluent. The multivariate approach was used to elucidate unique geochemical signatures that result as the provenance of the key parameters in dust versus effluent. The key parameters that occur in dust are expected to be derived from rock material that is abundant in aluminosilicate minerals, which contain abundant aluminum, magnesium, and silicon. Effluent, on the other hand, should be dominated by parameters associated with minewater, such as calcium, chloride and sulphate.

The final step was to use bivariate plots to identify relationships between two parameters that could be used to more simply distinguish the geochemical signature of effluent versus dustfall. Parameters were chosen to generate bivariate plots based on the relationships observed in the ternary diagrams.

2.2 SES Water Quality Sampling

2.2.1 Field Collection

Additional water quality sampling for the SES was conducted at four stations located adjacent to the Mine (Figure 2-1 and Table 2-1). The SES stations had the potential to be more influenced by dust deposition than the AEMP stations based on closer proximity to dust-generating Mine activities (e.g., A21 Dike and pit development) and predominant southeast wind direction. It was assumed that no other influence at those SES stations would confound the results. However, it is possible that the stations in a shallow bay (i.e., SS3 and SS4) may be slightly different because of the shallower water depth and a greater influence of natural flow/run-off compared to open-lake stations. Also, the rock spiff in that area is the main water intake for the Mine.



LEGEND

★	DIFFUSERS
▲	DUST SPECIAL EFFECTS STUDY SAMPLING STATION
⊙	SNOW CORE CHEMISTRY SAMPLING STATION

AEMP SAMPLING STATIONS

△	FAR-FIELD 1
▲	FAR-FIELD 2
▲	FAR-FIELD A
▲	FAR-FIELD B
●	MID-FIELD 1
●	MID-FIELD 2
●	MID-FIELD 3
●	NEAR-FIELD

➡	FLOW DIRECTION
—	WATERCOURSE
▨	DIAVIK FOOTPRINT
▨	WATERBODY

0 3 6

1:100,000 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
LOCATIONS OF DUST SPECIAL EFFECTS STUDY SAMPLING STATIONS, 2019

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

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Table 2-1 Locations of Dust Special Effects Study Stations in Lac de Gras, 2019

Station	UTM Coordinates		Water Depth (m)	Approximate Distance from Effluent Diffuser (m)
	Easting	Northing		
SS3	533890	7149688	19.5	5,847
SS4	534335	7148719	19.5	6,349
SS2	535190	7150948	15.7	7,600
SS1	534646	7151455	18.7	7,775

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

Sampling occurred during the open-water AEMP sampling program, with SES samples collected on 24 August 2019. Water samples were collected using the same equipment and the same methods as described in the *Effluent and Water Chemistry Report* (Appendix II), the *Plankton Report* (Appendix XI), and the *Eutrophication Indicators Report* (Appendix XIII):

- For analysis of major ions and metals: samples were collected at three depths (top, middle, bottom) as described in Appendix II (a total of 12 samples and one field duplicate).
- For analysis of nutrients and chlorophyll *a*: depth-integrated samples were collected in duplicate as described in Appendix XIII (a total of eight samples).
- For analysis of total phytoplankton biomass as biovolume: depth-integrated samples were collected as described in Appendix XI (a total of four samples).
- For analysis of zooplankton biomass as ash-free dry mass (AFDM): samples were collected in duplicate using a plankton net as described in Appendix XIII (a total of eight samples).

2.2.2 Laboratory Analysis

The water samples from the SES stations were analyzed for the same parameters as for AEMP water quality and eutrophication indicators. Details on the analytical laboratory and detection limits are provided in Appendix II (major ions and metals), Appendix XI (phytoplankton biomass), and Appendix XIII (nutrients, chlorophyll *a* and zooplankton biomass). Raw data are provided in Attachment A.

2.2.3 Data Quality Assessment

The SES samples were collected during the same open-water program as the AEMP samples. Therefore, the assessment of quality control samples such as travel, equipment, and field blanks as discussed in Appendix II and Appendix XIII also applies to the SES. The discussion of phytoplankton biomass data quality as presented in Appendix XII is also relevant here. Additional evaluation specific to the SES samples, specifically comparability of duplicates, is provided in Attachment B. Overall, the data quality assessment confirmed that the data were of acceptable quality, with the possible exception of the phytoplankton dataset, which was potentially affected by a sample preservation issue, as reflected in the taxonomic richness values (*Plankton Report*, Appendix XI).

2.2.4 Data Analysis

Data from the SES stations were compared qualitatively to nearby AEMP stations MF3-1 to MF3-4 (Figure 2-1), by comparing the mean and range of concentrations at each set of stations. These AEMP stations were selected because their distances from the diffuser were similar to that of the SES stations and, therefore, their relative effluent exposure would be similar. If dust had a greater influence on water quality than effluent at the SES stations due to greater potential for dust deposition, then concentrations of dust-related parameters would be greater at the SES stations than at these four AEMP stations.

Major ions and metals that were identified by the geochemistry evaluation to be associated with dust were selected for these comparisons. These parameters included total aluminum, bicarbonate, calcium, chloride, potassium, magnesium, total silicon, and sulphate. Total silicon was not detected in any of the water samples at a detection limit of 50 µg/L. Therefore, this parameter was not considered further. The average concentration from the three depths was used to represent the water column concentration of these parameters[4].

The eutrophication indicators selected for comparison were TP, SRP, TN, TKN, nitrate, total ammonia, SRSi, chlorophyll *a*, phytoplankton biomass, and zooplankton biomass. Nitrite was not detected in any SES sample; therefore, nitrite and nitrate+nitrite were not considered further. The dissolved fractions (i.e., TDN, DKN, and TDP) were not selected as the total fractions (i.e., TN, TKN, and TP) provided sufficient information. Also TDP was not detected in any SES sample. Eutrophication indicators were analyzed in duplicate; these duplicate results were averaged prior to use.

2.3 Phosphorus Mobilization

A general review of the mechanisms of phosphorus mobilization was performed by considering the likely mineralogical host of phosphorus in Mine-related dustfall, and the potential for mobilization of phosphorus from dust in the chemical conditions present in Lac de Gras. An Eh-pH diagram was constructed to demonstrate mineral solubility in various redox and pH conditions to evaluate the likelihood for phosphorus mobilization.

3 RESULTS

3.1 Geochemistry Evaluation

3.1.1 Major Ion and Metal Chemistry

Figure 3-1 compares the major ion chemistry of effluent, dustfall, and lake water. The Mine effluent had a sodium-chloride signature. This composition is distinct from the snow core data (dustfall), SES and AEMP water quality samples, particularly with respect to chloride content.

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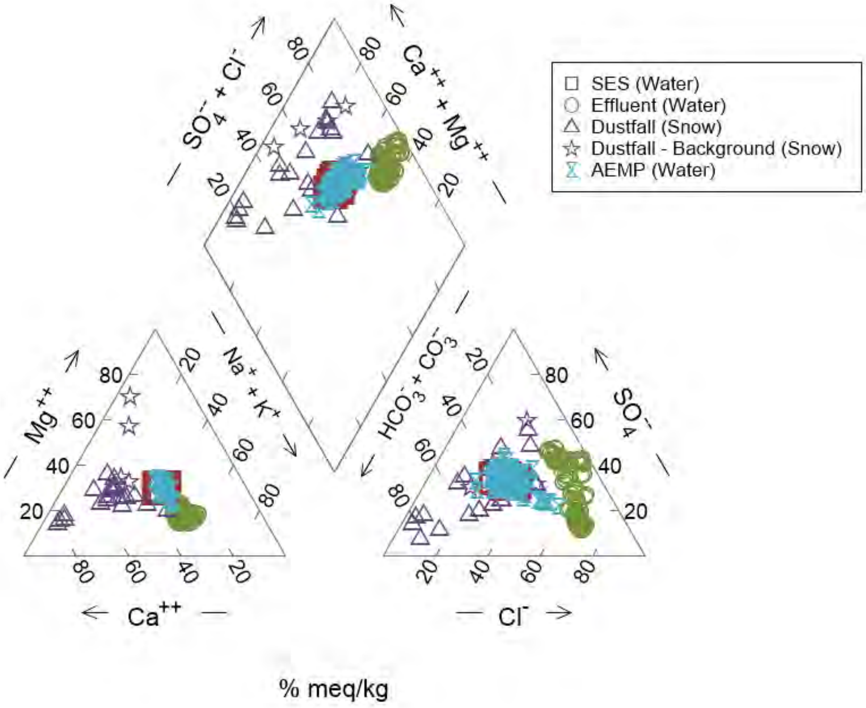
[4] The coefficient of variation (CV) among depths was low (≤11%) for all parameters except total aluminum. Total aluminum concentrations were more variable among depths at SS2, SS4, and MF3-3 (CV ranged from 31 to 77%), but consistent at the other stations (i.e., ≤13% at SS1, SS3, MF3-1, MF3-2, and MF3-4). The depth with the maximum total aluminum concentration was not consistent. Overall, it was assumed that the average concentration of all depths was an appropriate estimate of the water column concentration, but the range of concentrations across all depths are provided for information.

Figure 3-1: Major Ion Content of Effluent, Dustfall, SES and AEMP Samples, 2019



meq/kg = milliequivalents per kilogram.

Calcium was the dominant major cation in all SES water quality samples (n = 13). The major anion was sulphate in eight samples, and chloride in five samples. The composition of lake water varied spatially:

- **Calcium-chloride signature:** SS3 (all points) and SS1 (middle)
- **Calcium-sulphate signature:** SS2 (all points), SS4 (all points), SS1 (top and bottom)

The AEMP dataset followed a similar spatial trend with respect to the major anion signature; however, the major cations in the AEMP water quality samples included calcium, sodium and magnesium.

Calcium was the dominant major cation in most Mine-related dustfall samples (n = 24); the major anion was bicarbonate in 14 samples, chloride in seven samples, and sulphate in four samples. The major ion composition of Mine-related dustfall samples varied spatially:

- **Calcium-bicarbonate signature:** SS2-2-4, SS2-3, SS2-4, SS3-4, SS3-5, SS3-6, SS3-7, SS3-8, SS4-4, SS4-5, SS-3-4, and SSC-3
- **Calcium-chloride signature:** SS1-5, SS2-1-1, SS5-3-5, SS5-5, SSC-1-4, SSC-1-5 and SSC-2
- **Calcium-sulphate signature**: SS1-4, SS2-1-1B, SS5-4
- **Sodium-bicarbonate signature**: SS2-2-4

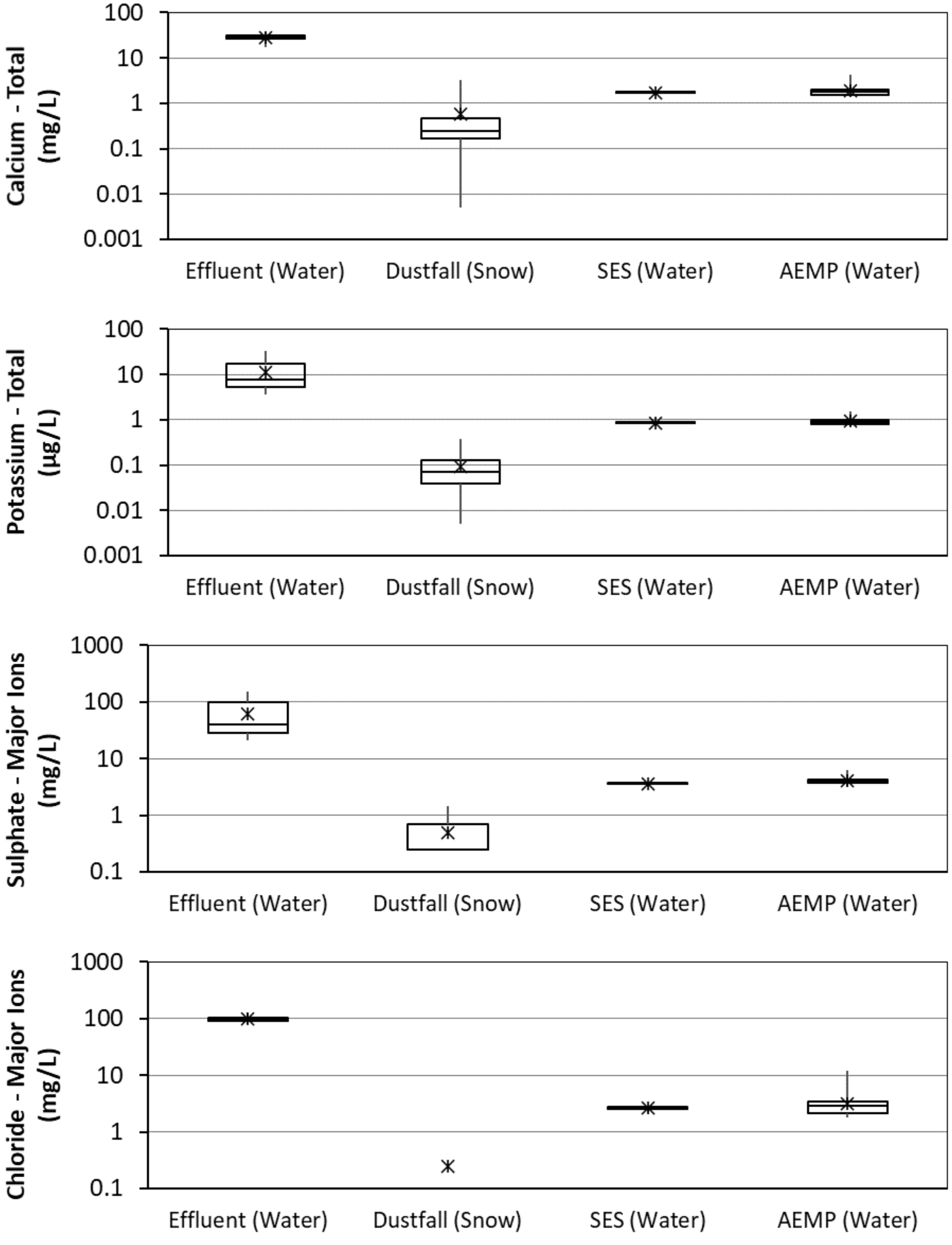
The major ion composition of the background dustfall samples varied, with major cations being both calcium and magnesium, and major anions were bicarbonate, sulphate and chloride.

As presented in Figure 3-1, there is some overlap in the major ion signature of dustfall, effluent, and lake water; however, anion signatures can be used to distinguish dustfall from effluent. Effluent samples were dominated by sulphate and chloride, whereas roughly half of the dustfall samples were dominated by bicarbonate, followed by chloride and sulphate. The SES and AEMP water quality samples formed tight clusters that nearly completely overlapped on the piper diagram, whereas dustfall samples showed a wider range of variation in major ion chemistry.

The relative concentrations of major ions were generally greater in effluent samples than dustfall samples (Figure 3-2); therefore, it is not possible to use a single parameter for quantification of the effect of dustfall on lake water quality. The rock material from which the dustfall is derived is abundant in aluminosilicate minerals, which contain abundant aluminum, magnesium, and silicon; the range of concentrations of these parameters in dustfall is presented in Figure 3-3. The correlation between concentrations of key parameters was used to identify unique relationships that could be used as a geochemical fingerprint for dustfall versus effluent. These relationships are presented in ternary diagrams, which graphically depict the molar ratios of three variables. Based on the relationships observed in the ternary diagrams, parameters were then chosen to generate bivariate plots to establish trends between parameters that can be used to determine a unique chemical signature for dustfall versus effluent.

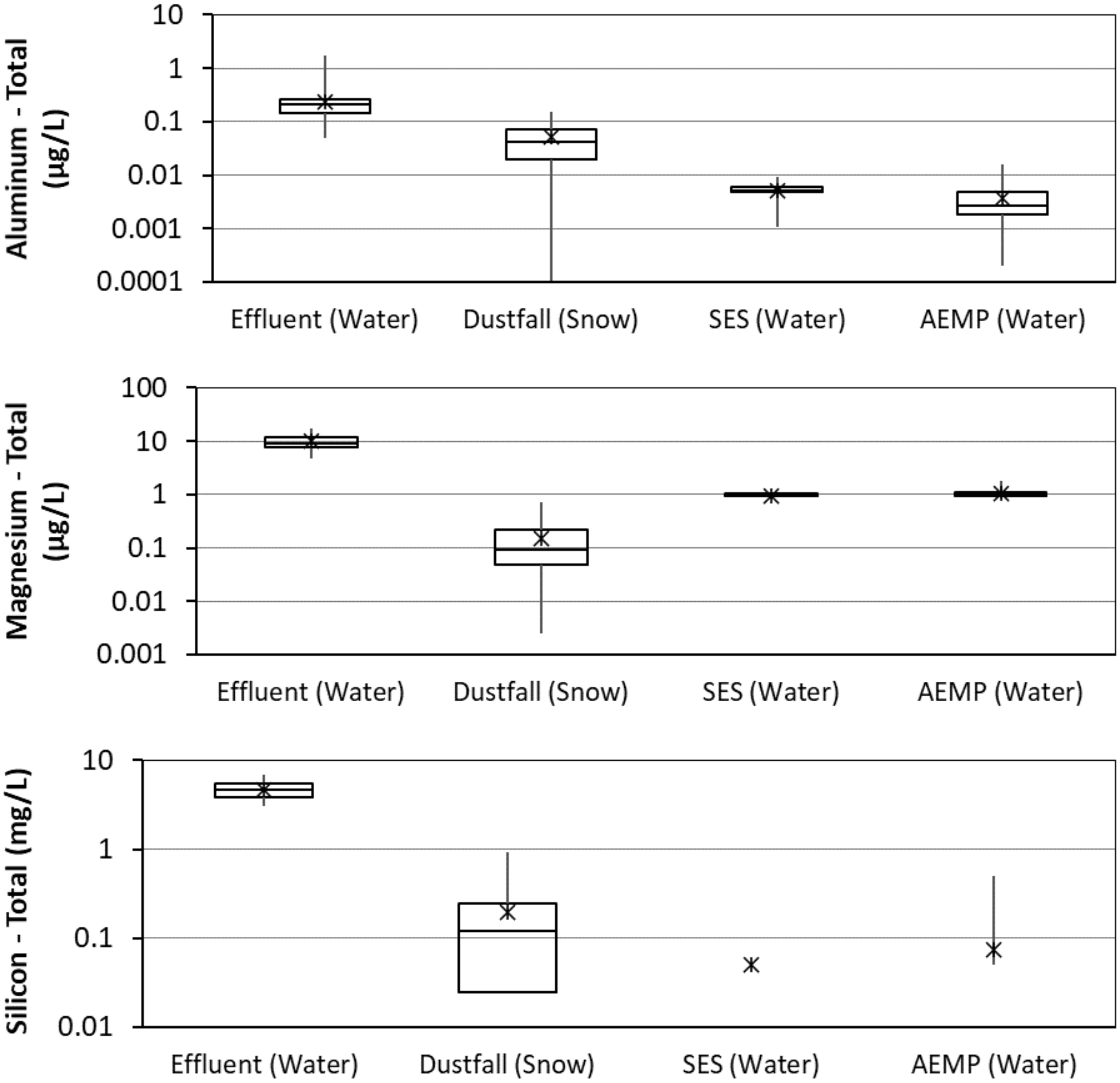
As presented in Figures 3-4 through 3-8, the major ion and metal composition of lake water/SES and effluent samples generally overlap, but dustfall samples have unique characteristics with respect to the aluminum, calcium, potassium, magnesium, silicon, and sulphate content. The similarity of major ion and metal composition of lake water/SES samples to that of effluent suggests that effluent is the dominant influence on lake water composition, as the dustfall signature is not distinguishable in lake water/SES sample composition.

Figure 3-2: Relative Concentrations of Selected Major Ions in Effluent, Dustfall, and Water Quality Samples, 2019



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

Figure 3-3: Relative Concentrations of Selected Parameters in Effluent, Dustfall, and Water Quality Samples, 2019



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

Figure 3-4: Ternary Diagram for Aluminum, Calcium and Sulphate, 2019

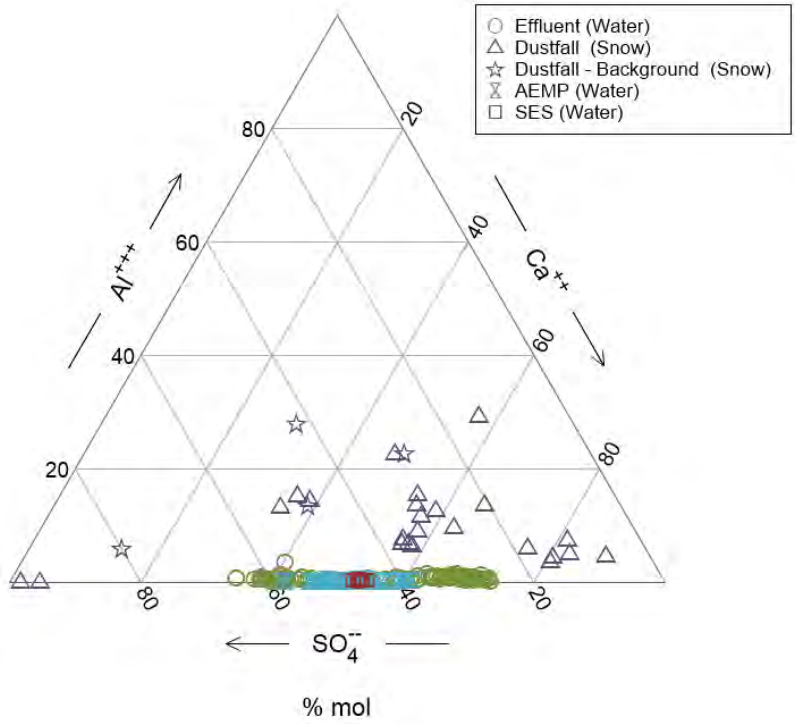


Figure 3-5: Ternary Diagram for Aluminum, Magnesium and Sulphate, 2019

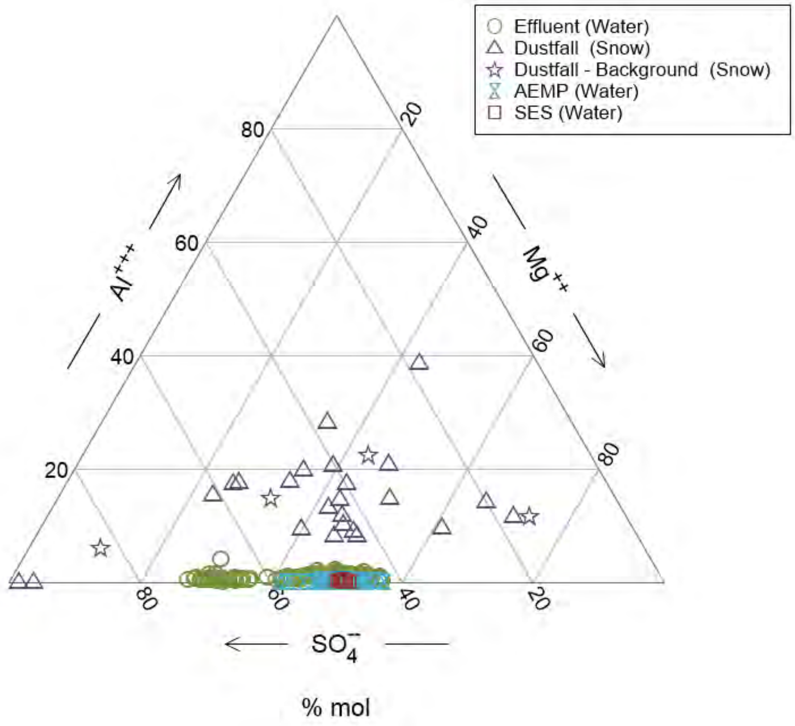
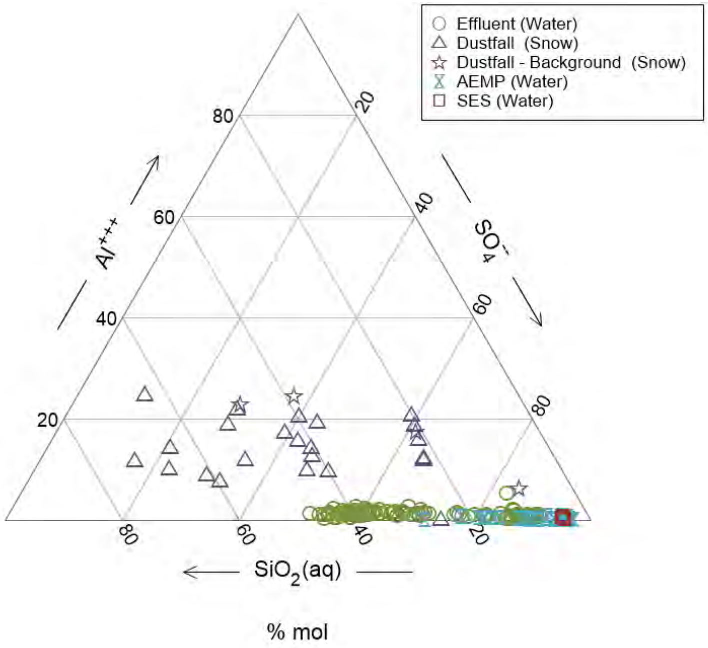
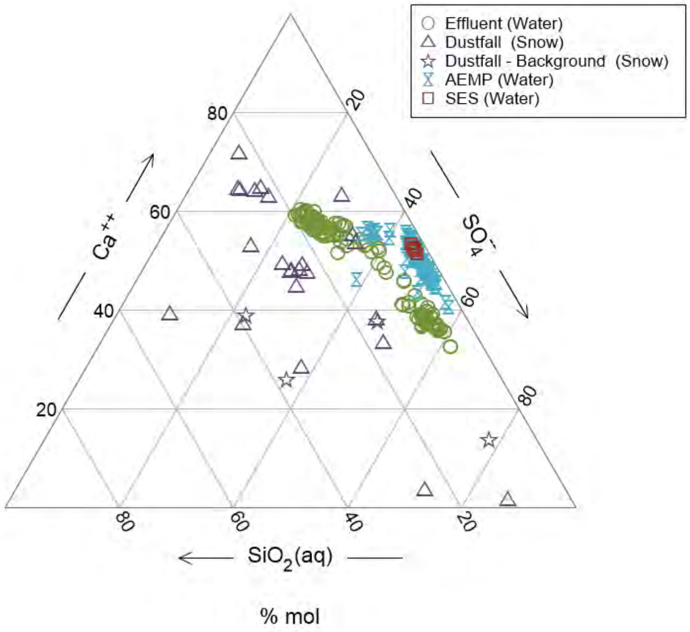


Figure 3-6: Ternary Diagram for Aluminum, Sulphate and Silicon, 2019



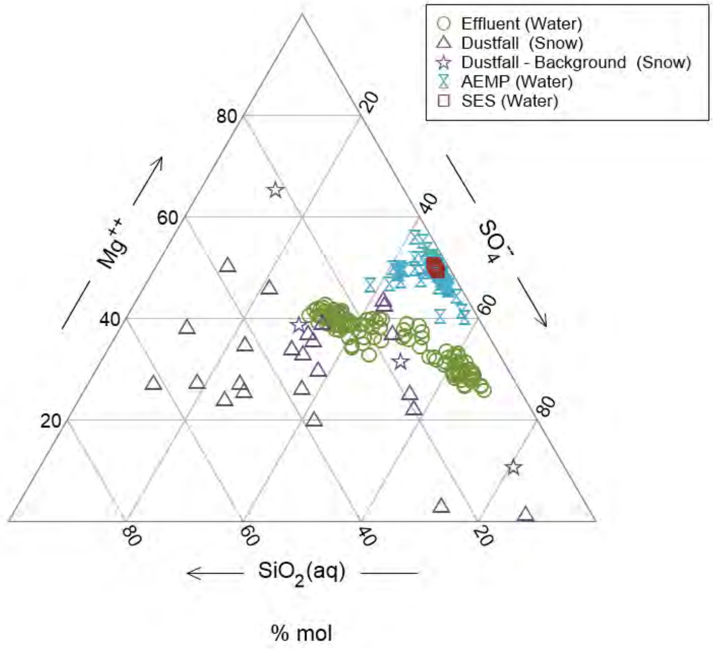
Note: SiO_2 (aq) represents Silicon - Total (mg/L)

Figure 3-7: Ternary Diagram for Calcium, Sulphate and Silicon, 2019



Note: SiO_2 (aq) represents Silicon - Total (mg/L)

Figure 3-8: Ternary Diagram for Magnesium, Sulphate and Silicon, 2019



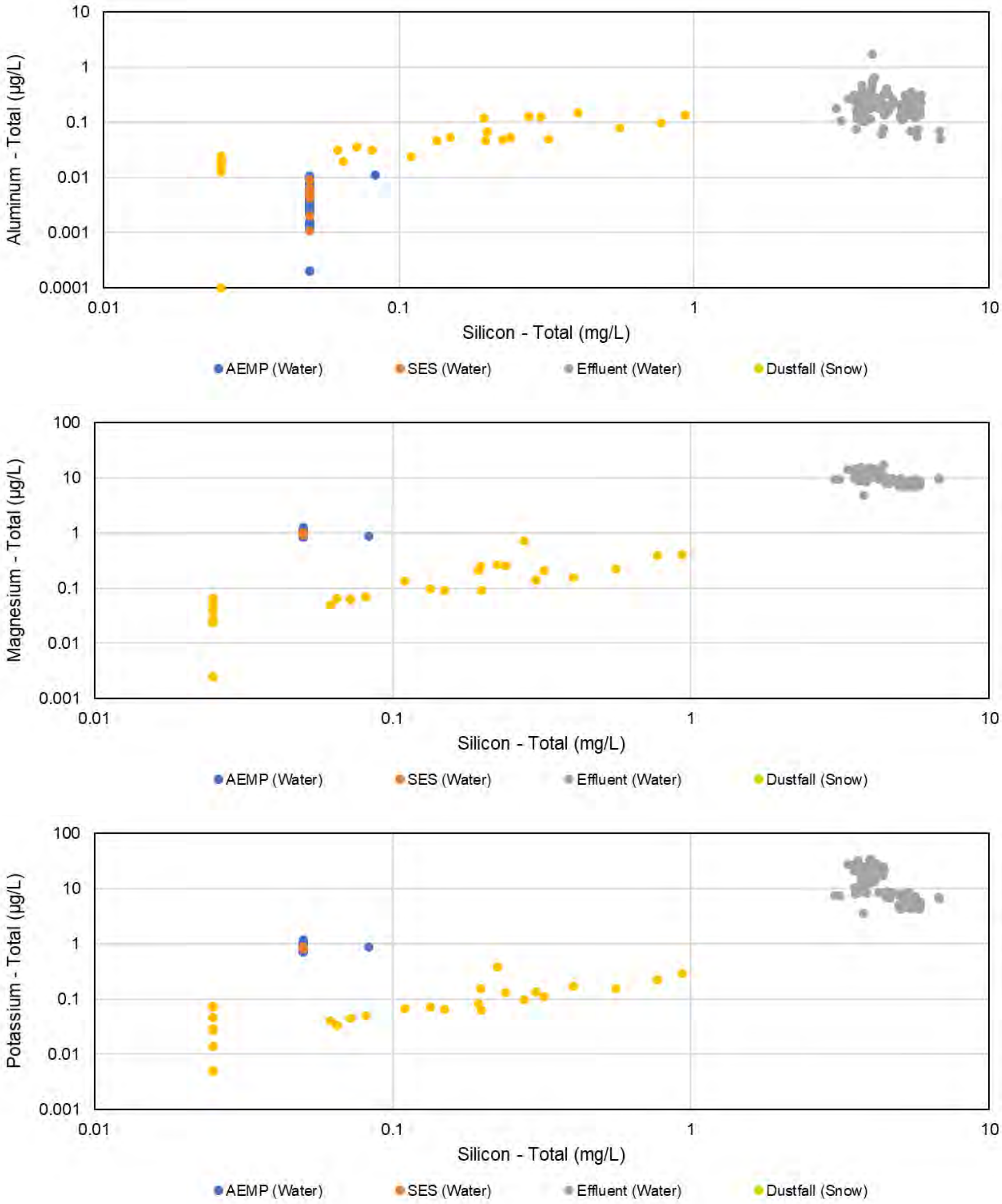
Note: SiO_2 (aq) represents Silicon - Total (mg/L)

The range of silicon in lake water samples is generally similar to those in effluent samples; however, dustfall is distinguished by silicon concentrations less than 1 mg/L in all samples, and effluent samples contained greater than 1 mg/L silicon (Figure 3-9). The average molar ratio of potassium to silicon was approximately 0.0004 in dustfall samples, 0.002 in effluent samples, and greater than 0.01 in lake water samples. Similarly, the average molar ratio of magnesium to silicon was approximately 0.0008 in dust samples, 0.002 in effluent samples and greater than 0.02 in lake water samples. 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.

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.

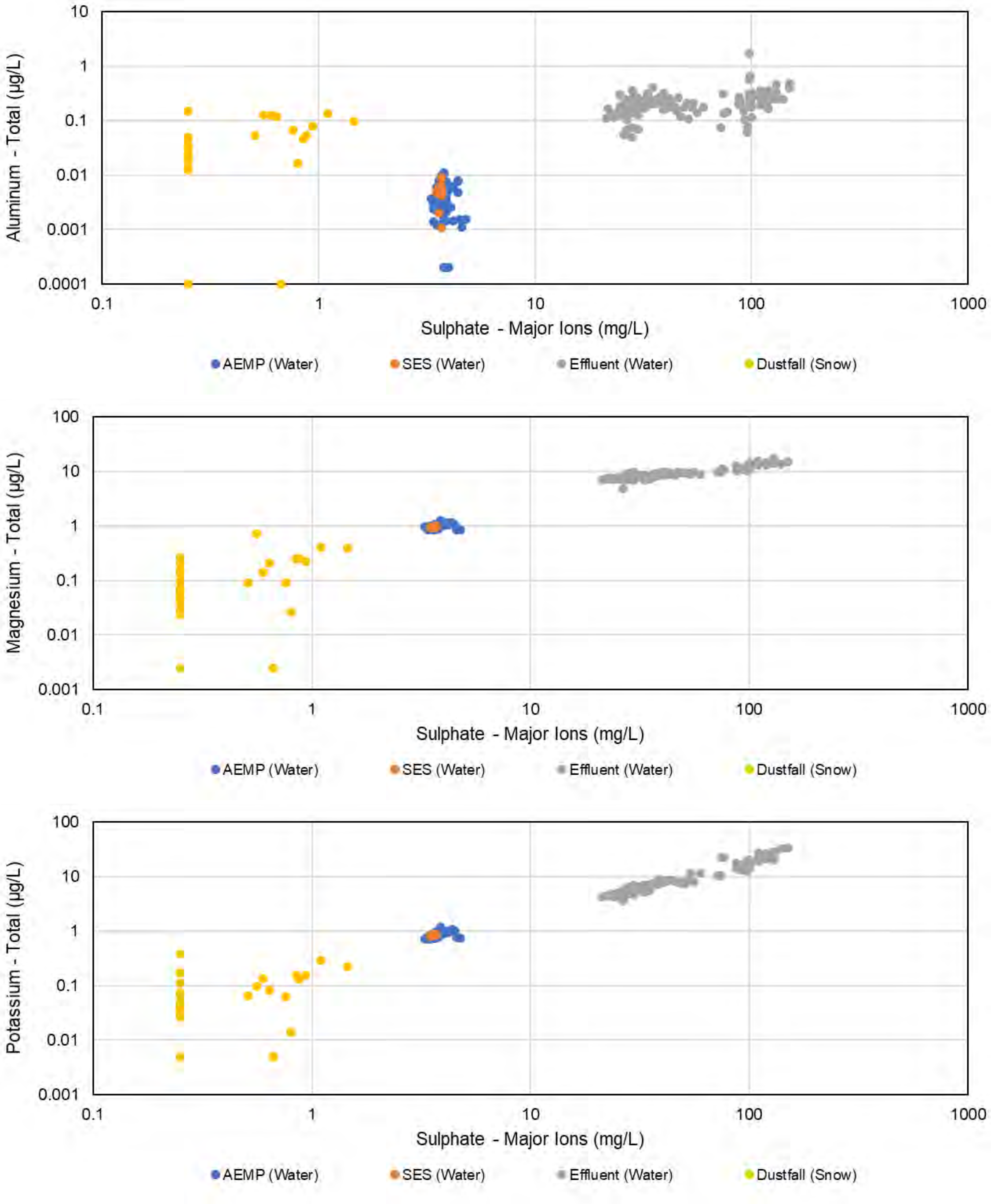
Similar to the relationships described for silicon, sulphate concentrations in dustfall samples were generally less than 1 mg/L, and lake water and effluent samples contained greater than 10 mg/L sulphate (Figure 3-10). Potassium, magnesium and aluminum correlated well with sulphate. Similar to silicon, 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.

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



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

Figure 3-10: Bivariate Plots of Sulphate versus Aluminum, Magnesium and Potassium, 2019

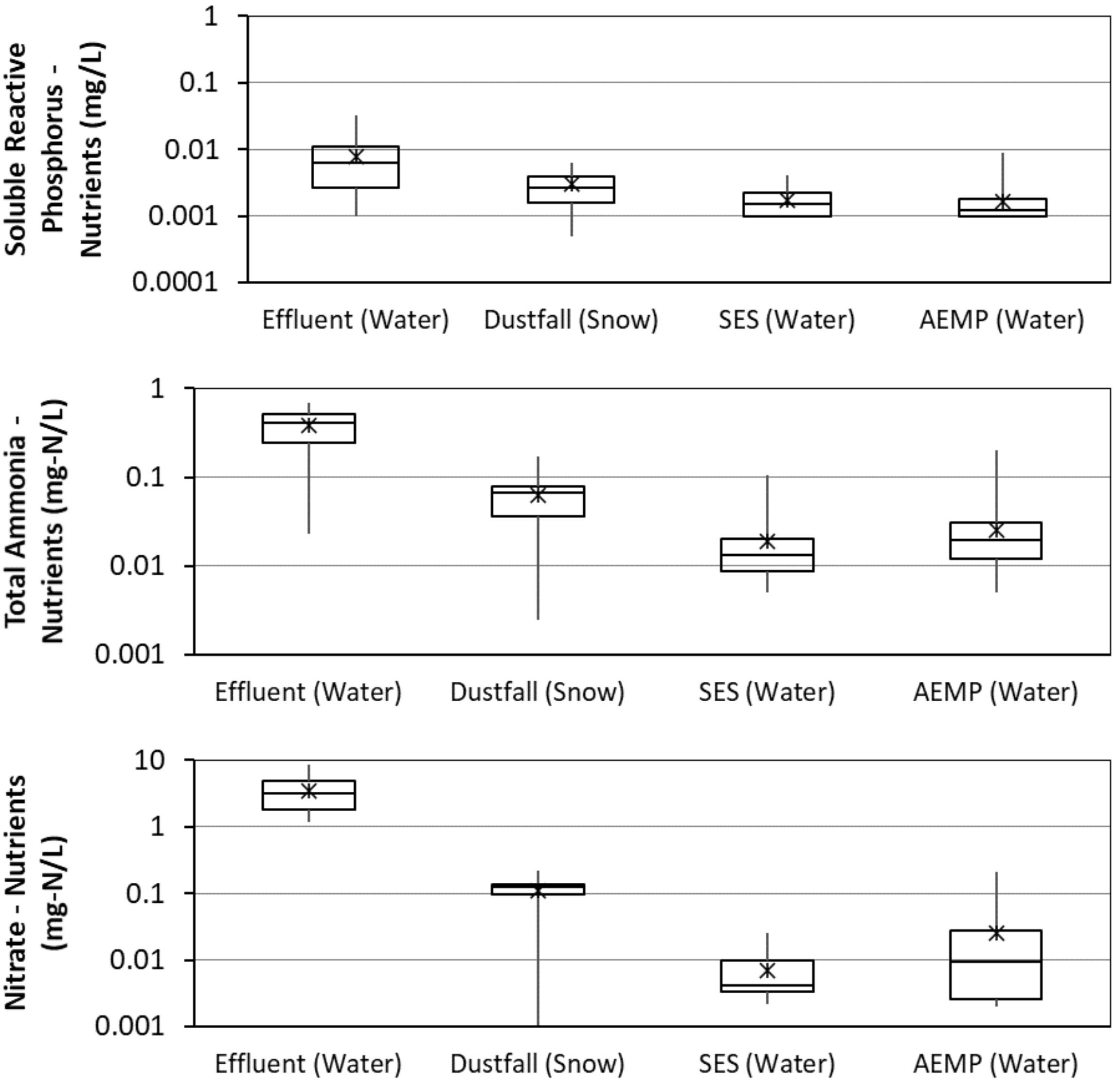


mg/L = milligrams per litre; µg/L = micrograms per litre.

3.1.2 Nutrients

Relative ranges of nutrient concentrations (i.e. ammonia, nitrate and soluble reactive phosphorus) are presented in Figure 3-11. The relative concentrations of the nutrients selected for evaluation were greater in the effluent than dustfall.

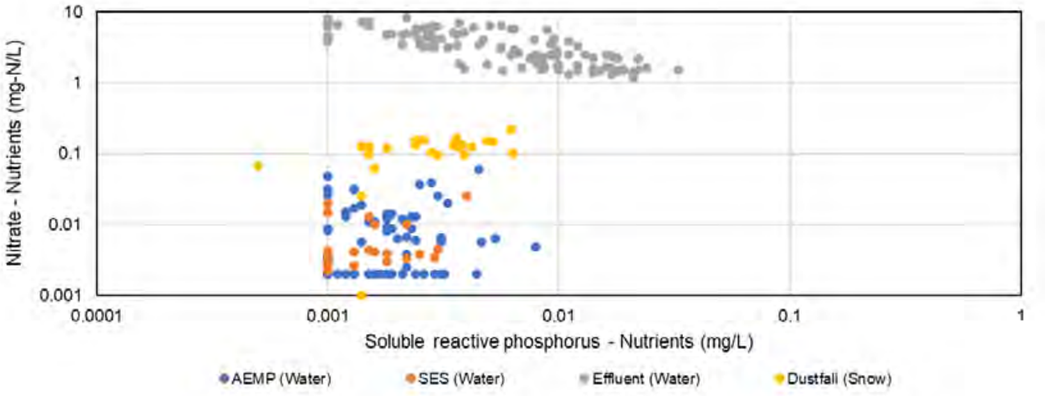
Figure 3-11: Relative Concentrations of Selected Nutrients in Effluent, Dustfall, and Water Quality Samples, 2019



mg/L = milligrams per litre; mg-N/L = milligrams Nitrogen per litre.

A direct comparison of nutrient concentrations in dustfall versus effluent was also performed. As presented in Figure 3-12, nitrate concentrations were highest in effluent, followed by dustfall, followed by lake water. The molar ratio of nitrate to reactive soluble phosphorus was highest in effluent samples, followed by dustfall and lake water.

Figure 3-12: Bivariate Plot of Soluble Reactive Phosphorus versus Nitrate, 2019



mg/L = milligrams per litre; mg-N/L = milligrams nitrogen per litre.

Although soluble reactive phosphorus concentrations are lower in dustfall than effluent, the relative proportion of soluble reactive phosphorus is unique in dustfall samples relative to effluent and lake water. As presented in Figures 3-13 and 3-14, dustfall samples generally can be distinguished by molar ratios of soluble reactive phosphorus relative to lake water and effluent.

Figure 3-15 presents bivariate plots comparing soluble reactive phosphorus concentrations to other key parameters, including aluminum, calcium and silicon. The range of concentrations of soluble reactive phosphorus were similar between dustfall, effluent and lake water. In general, the molar ratios of major ions (including aluminum, calcium and total silicon) to soluble reactive phosphorus were two orders of magnitude greater in effluent than dustfall for all parameters. Dustfall had greater major ion to total reactive phosphorous ratios than lake water. The relationships between soluble reactive phosphorus and aluminum, calcium and silicon were not strong enough to use for the purpose of geochemical fingerprinting.

Figure 3-13: Ternary Diagram for Aluminum, Calcium and Soluble Reactive Phosphorus, 2019

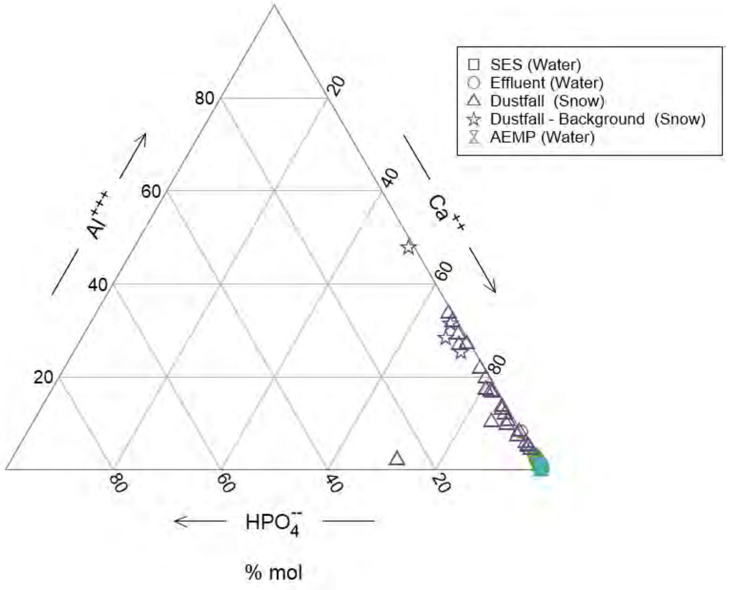
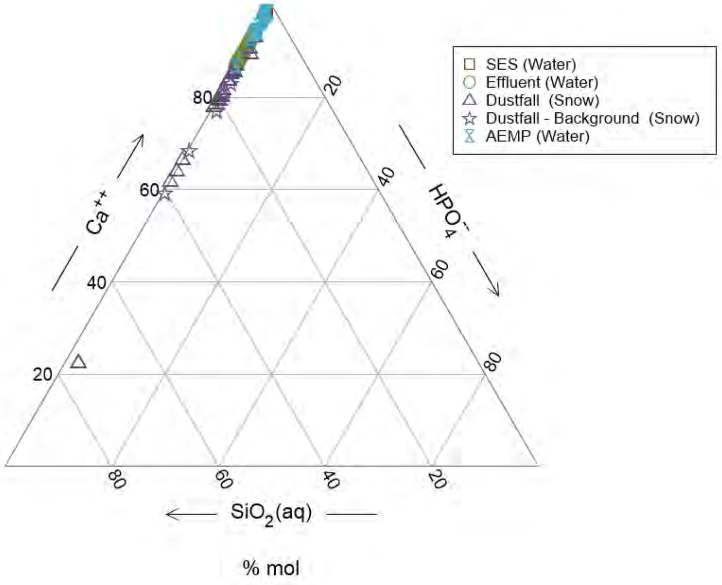
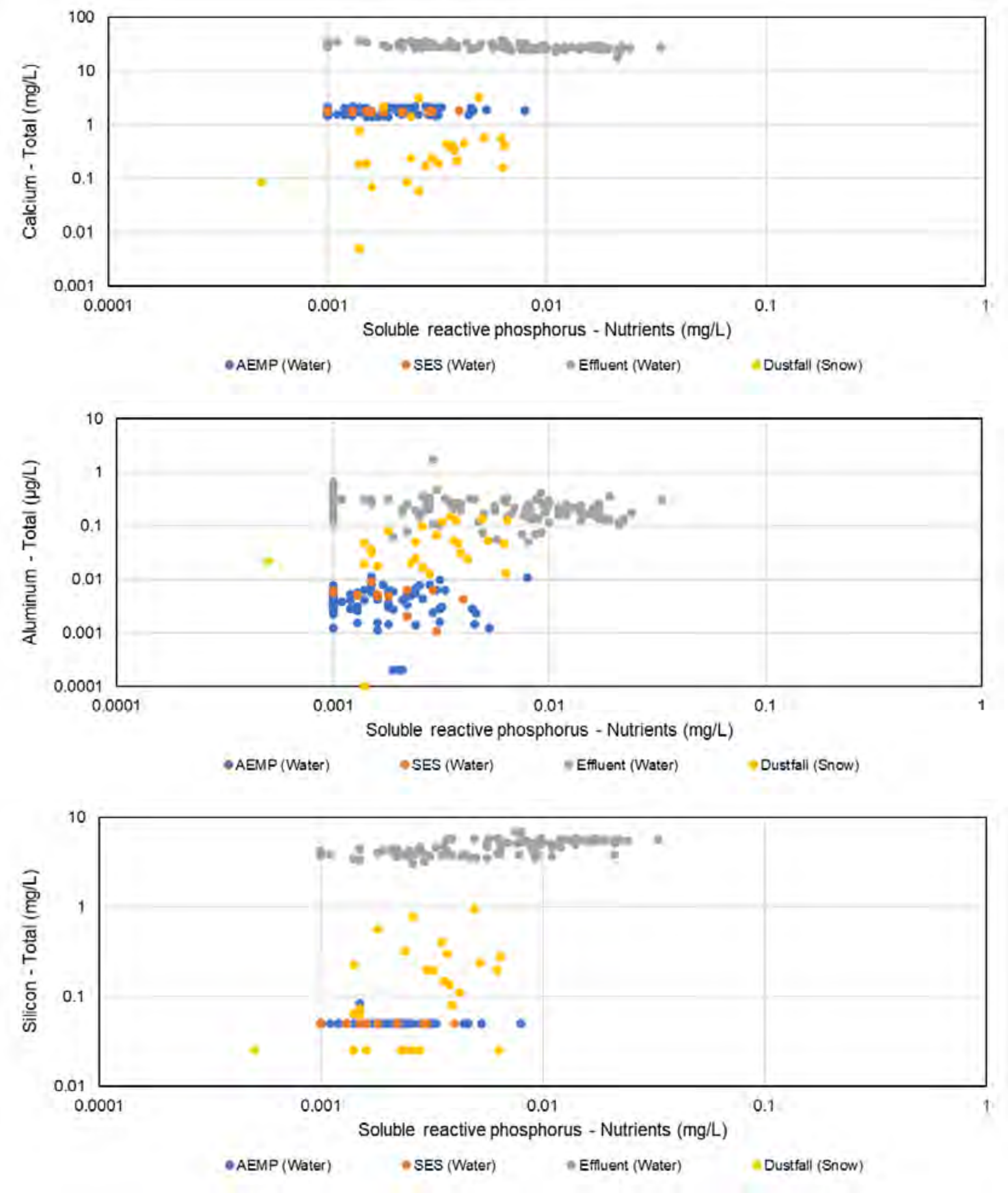


Figure 3-14: Ternary Diagram for Calcium, Soluble Reactive Phosphorus and Silicon, 2019



Note: SiO_2 (aq) represents Silicon - Total (mg/L).

Figure 3-15: Bivariate Plots of Soluble Reactive Phosphorus versus Calcium, Aluminum and Silicon, 2019



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

3.1.3 Discussion

Based on the results of the geochemical interpretation, molar ratios of major ion and metal concentrations including aluminum, calcium, potassium, magnesium, silicon, and sulphate content can be used to differentiate dustfall from effluent samples. In general, dustfall samples have lower relative concentrations of these parameters than effluent samples. Lake water concentrations are lower than those in effluent and snowfall.

The molar ratios of key parameters to silicon and sulphate, respectively, are unique in dustfall relative to effluent and lake water. This is expected, as dustfall originates from sources abundant in aluminosilicate minerals, relative to effluent, which is dominated by elements that originate from minewater. Specifically, the relationships between potassium and magnesium to silicon and sulphate, respectively, are well defined. The molar ratios of potassium and magnesium to silicon are one order of magnitude greater in effluent than dustfall, and two orders of magnitude greater in lake water than dustfall. Lake water has a closer geochemical signature to effluent than to dustfall, based on the preliminary investigation of the results.

A similar evaluation was performed using relative concentrations of nutrients, and molar ratios of major parameters to nutrients; however, the relationships between soluble reactive phosphorus and aluminum, calcium and silicon were not strong enough to use for the purpose of geochemical fingerprinting.

3.2 SES Versus AEMP Data Comparison

3.2.1 Major Ions and Metals

Concentrations of major ions and metals associated with dust were generally consistent within areas (Table 3-1, Figure 3-16). Mean concentrations were similar or lower at the SES stations compared to the AEMP stations, suggesting that the influence of dust did not noticeably affect water quality at the time of sampling (Table 3-1).

Table 3-1 Concentrations of Dust-Related Major Ions and Metals at the Dust Special Effects Study Stations versus the MF3-1 to MF3-4 Stations in Lac de Gras, 2019

Parameter	Units	SES		MF3[a]	
		Mean ± SD[b]	Range[c]	Mean ± SD[b]	Range[c]
Bicarbonate	mg/L	6.2 ± 0.2	5.7 to 6.5	6.4 ± 0.3	5.8 to 7.0
Calcium	mg/L	1.7 ± 0.03	1.7 to 1.9	1.7 ± 0.1	1.5 to 1.9
Chloride	mg/L	2.6 ± 0.2	2.1 to 2.9	2.5 ± 0.4	2.1 to 3.2
Magnesium	mg/L	0.96 ± 0.03	0.91 to 1.0	0.98 ± 0.08	0.87 to 1.1
Potassium	mg/L	0.88 ± 0.02	0.84 to 0.92	0.79 ± 0.05	0.71 to 0.90
Sulphate	mg/L	3.6 ± 0.07	3.5 to 3.7	3.7 ± 0.1	3.6 to 3.9
Total Aluminum	µg/L	5.0 ± 0.4	1.1 to 9.2	4.2 ± 0.9	3.3 to 7.6

(a) MF3 stations include MF3-1, MF3-2, MF3-3, and MF3-4.
(b) Mean ± standard deviation (SD) of four stations.
(c) Minimum and maximum values across all depths and stations.
mg/L = milligrams per litre; µg/L = micrograms per litre; SES = special effects study; MF = mid-field.

Figure 3-16: Mean Concentrations of Major Ions and Metals Associated with Dust at the Special Effect Study Stations and MF3-1 to MF3-4 Stations, 2019

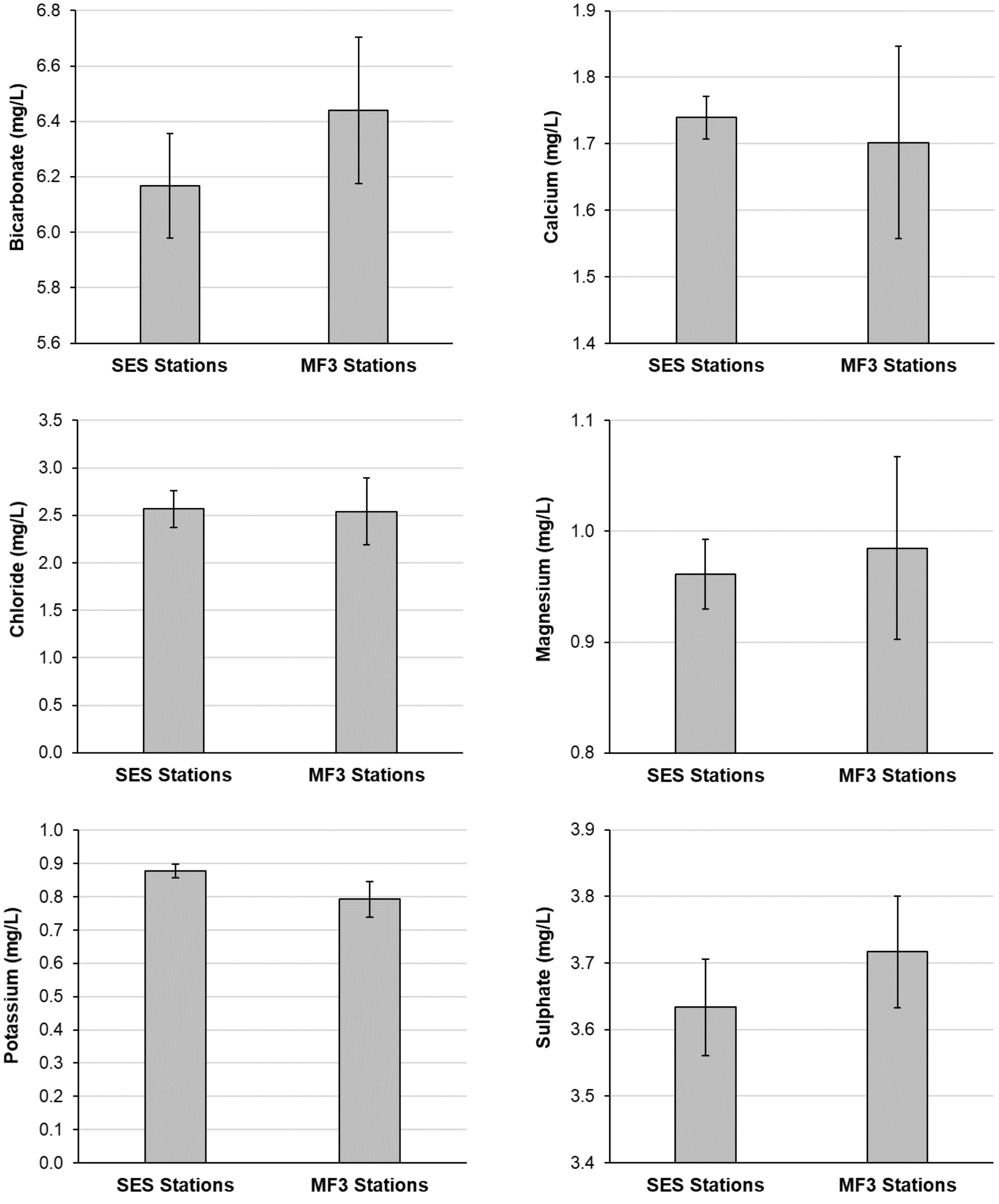
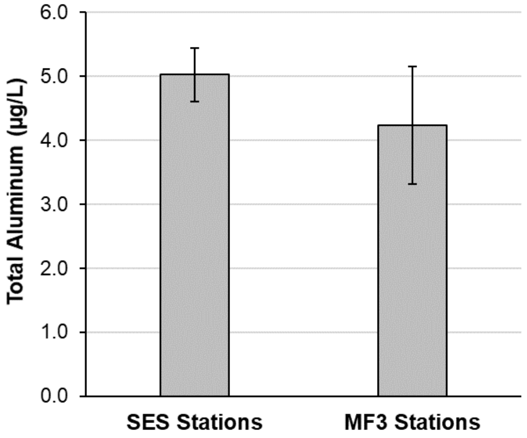


Figure 3-16: Mean Concentrations of Major Ions and Metals Associated with Dust at the Special Effect Study Stations and MF3-1 to MF3-4 Stations, 2019



Note: Error bars represent standard deviation.
mg/L = milligrams per litre; µg/L = micrograms per litre; SES = special effects study; MF = mid-field.

3.2.2 Nutrients

Concentrations of nutrients, particularly TP, SRP, and nitrate, were generally more variable within areas (Table 3-2, Figure 3-17). For TP and SRP, this variability is reflective of the low concentrations; most TP and SRP concentrations were either less than the detection limit or within five times the detection limit. Nitrate and total ammonia concentrations were also variable within areas. However, mean concentrations were not consistently greater at the SES stations compared to the AEMP stations, and the range in concentrations overlapped, suggesting that the influence of dust did not noticeably affect nutrient concentrations at the time of sampling (Table 3-2).

Table 3-2 Concentrations of Nutrients at the Dust Special Effects Study Stations versus the MF3-1 to MF3-4 Stations in Lac de Gras, 2019

Parameter	Units	SES		MF3[(a)]	
		Mean ± SD[(b)]	Range[(c)]	Mean ± SD[(b)]	Range[(c)]
Total Phosphorus	µg-P/L	1.8 ± 0.9	<2 to 2.9	1.6 ± 0.4	<2 to 2.1
Soluble Reactive Phosphorus	µg-P/L	1.1 ± 0.7	<1 to 2.2	1.7 ± 0.8	<1 to 2.4
Total Nitrogen	µg-N/L	205 ± 15	190 to 220	196 ± 18	175 to 215
Total Kjeldahl Nitrogen	µg-N/L	198 ± 10	190 to 210	189 ± 13	170 to 200
Nitrate	µg-N/L	7.0 ± 7.0	3.0 to 18	6.4 ± 5.7	1.9 to 15
Total Ammonia	µg-N/L	16.8 ± 8.8	9.0 to 29	10.1 ± 2.7	8.3 to 14
Soluble Reactive Silica	µg/L	53 ± 9	42 to 61	45 ± 3	41 to 49

(a) MF3 stations include MF3-1, MF3-2, MF3-3, and MF3-4.
(b) Mean ± standard deviation (SD) of four stations.
(c) Minimum and maximum values across all stations.
µg/L = micrograms per litre; µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre; SES = special effects study; MF = mid-field.

Figure 3-17: Mean Concentrations of Nutrients at the Special Effect Study Stations and MF3-1 to MF3-4 Stations, 2019

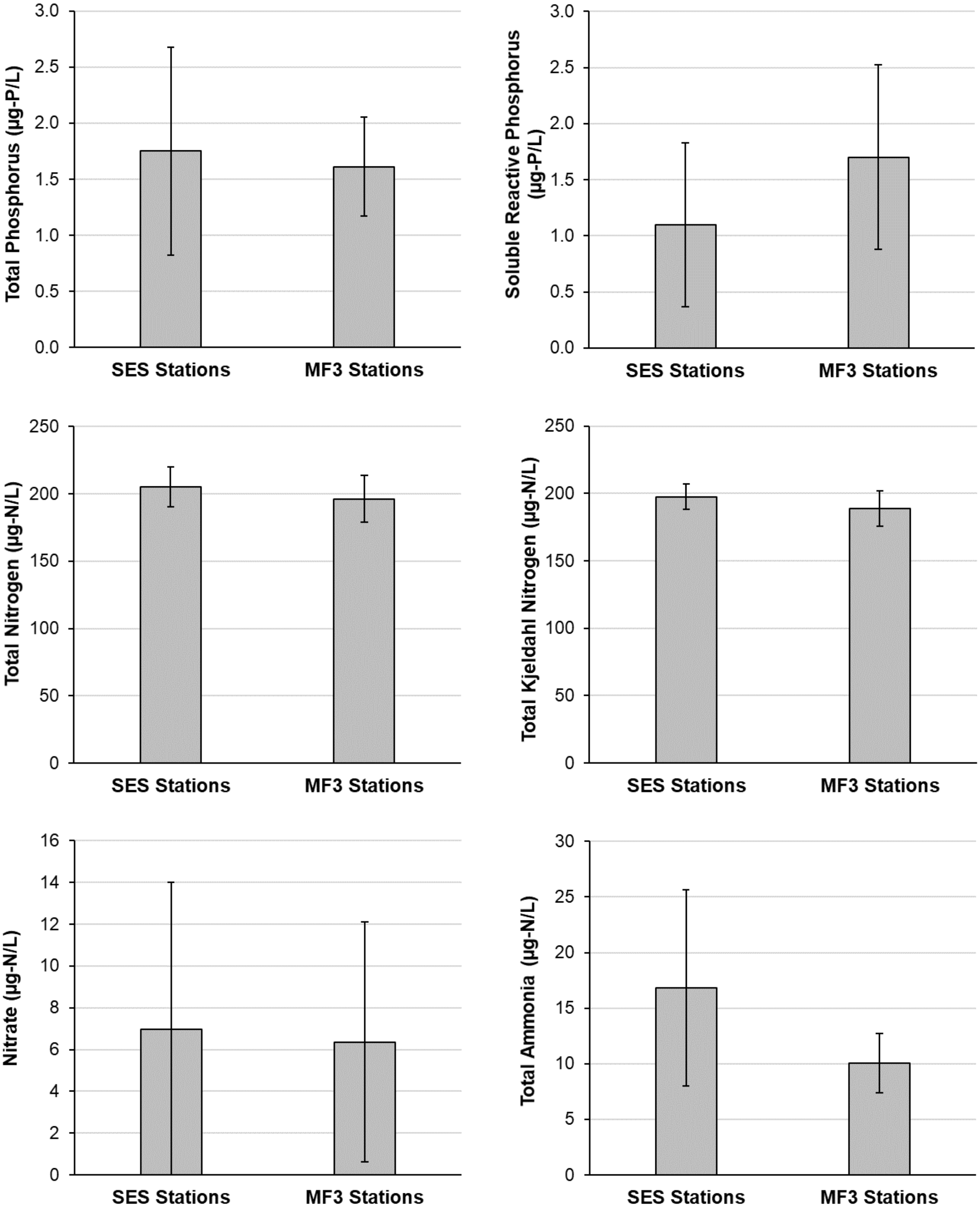
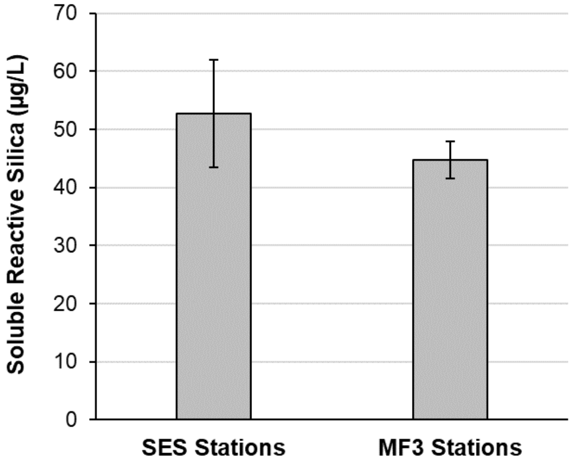


Figure 3-17: Mean Concentrations of Nutrients at the Special Effect Study Stations and MF3-1 to MF3-4 Stations, 2019



Note: Error bars represent standard deviation.
µg/L = micrograms per litre; µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre; SES = special effect study; MF = mid-field.

3.2.3 Chlorophyll *a*, Phytoplankton Biomass, Zooplankton Biomass

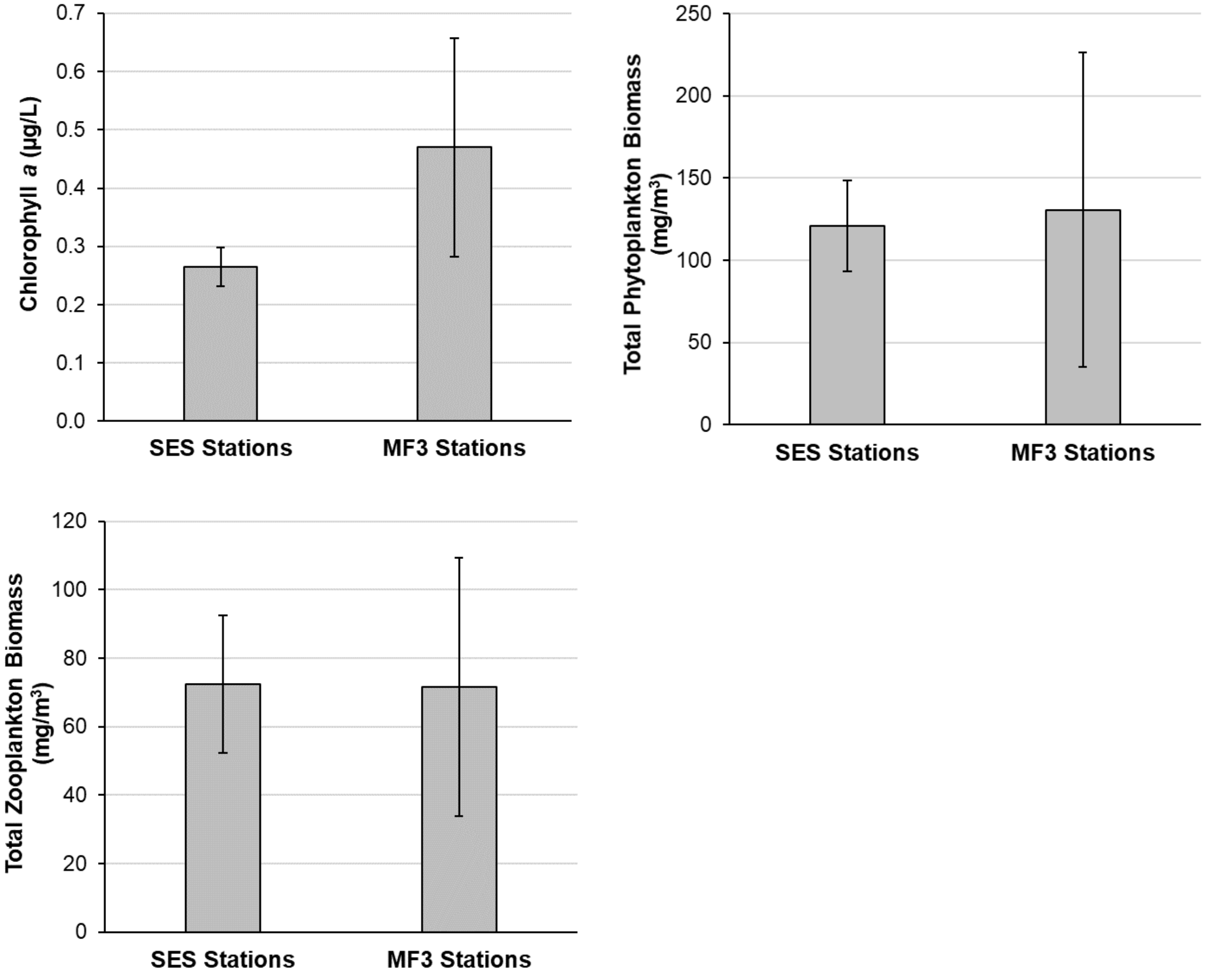
Mean chlorophyll *a* concentrations and plankton biomass were either lower at the SES stations (chlorophyll *a* and total phytoplankton biomass) or similar (total zooplankton biomass) to the MF3 stations (Table 3-3, Figure 3-18). These results and the degree of variability among stations (i.e., as indicated by the standard deviation) suggest that the influence of dust did not noticeably affect biological productivity at the time of sampling, consistent with the results obtained for nutrients.

Table 3-3 Concentrations of Chlorophyll *a*, Total Phytoplankton Biomass, and Total Zooplankton Biomass in the Dust Special Effects Study Stations versus the MF3-1 to MF3-4 Stations in Lac de Gras, 2019

Parameter	Units	SES		MF3[(a)]	
		Mean ± SD[(b)]	Range[(c)]	Mean ± SD[(b)]	Range[(c)]
Chlorophyll *a*	µg/L	0.27 ± 0.03	0.23 to 0.31	0.47 ± 0.19	0.35 to 0.75
Phytoplankton biomass (as biovolume)	mg/m^3	121 ± 27	88 to 144	131 ± 96	61 to 270
Zooplankton biomass (as AFDM)	mg/m^3	72 ± 20	50 to 97	72 ± 38	33 to 124

(a) MF3 stations include MF3-1, MF3-2, MF3-3, and MF3-4.
(b) Mean ± standard deviation (SD) of four stations.
(c) Minimum and maximum values across all stations.
µg/L = micrograms per litre; mg/m^3 = milligrams per cubic metre; SES = special effects study; MF = mid-field.

Figure 3-18: Mean Chlorophyll *a* Concentration, Total Phytoplankton Biomass, and Total Zooplankton Biomass at the Special Effect Study Stations and MF3-1 to MF3-4 Stations



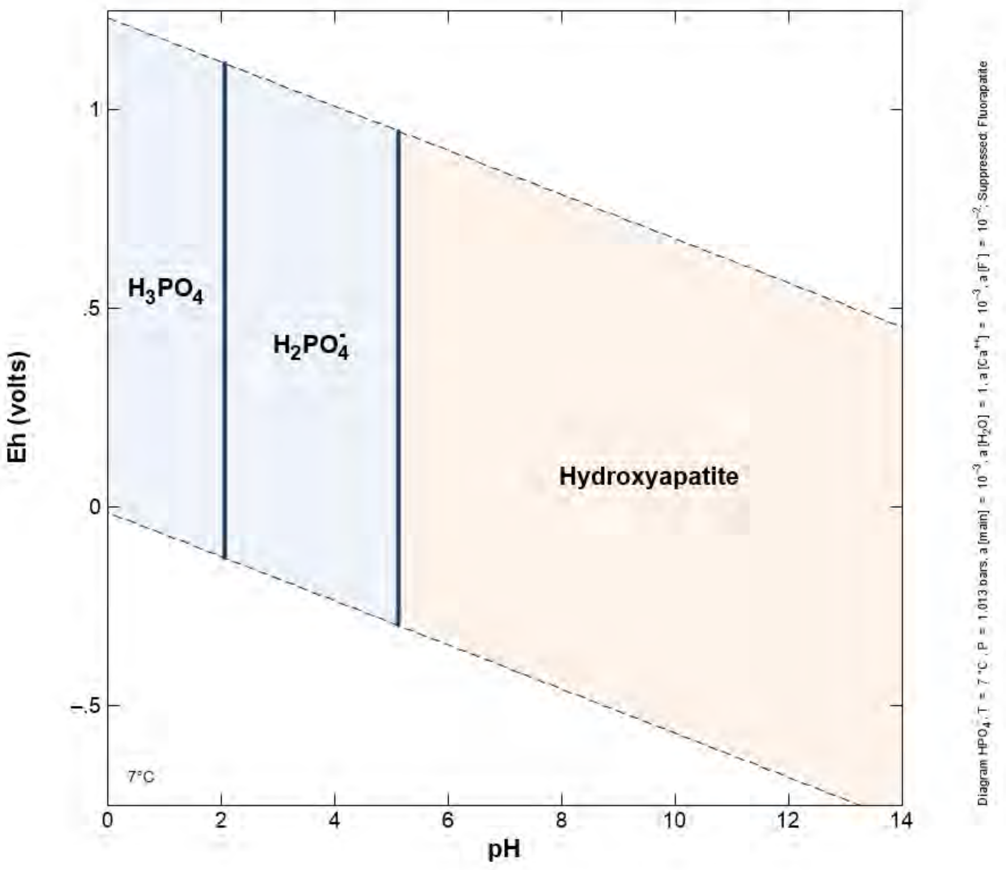
Note: Error bars represent standard deviation.
µg/L = micrograms per litre; mg/m^3 = milligrams per cubic metre; SES = special effects study; MF = mid-field.

3.3 Phosphorus Mobilization

The mineralogical host of phosphorus in dustfall is not known; however, the mineral apatite $[Ca_5(PO4)_3(F,Cl,OH)]$ is the typical host of phosphorus in granite and kimberlite. Figure 3-19 presents an Eh-pH diagram for apatite, which was constructed to demonstrate the solubility of apatite in various redox and pH conditions. The average concentrations of phosphorus, fluoride and calcium in lake water (derived from the AEMP and SES datasets) were used as the basis for the diagram.

Apatite is stable in solid form above a pH of approximately 5. Given that the average pH of effluent is approximately 7.2, and the average pH of the AEMP water quality samples is 6.3, the potential for phosphorus release from apatite dissolution from dustfall is expected to be limited in Lac de Gras.

Figure 3-19: Mineral Stability Diagram for Apatite



Note: Blue fields indicate aqueous species; orange field represents mineral species.

4 SUMMARY AND DISCUSSION

An evaluation of major ion chemistry identified unique chemical signatures between effluent and dustfall samples. Effluent samples had a calcium-chloride and calcium-sulphate composition. The major ion composition of the dustfall samples varied; calcium was generally the major cation, and major anions were bicarbonate, sulphate and chloride.

Element versus element relationships were investigated to identify parameters that could be used to develop unique molar ratios to geochemically fingerprint dustfall versus effluent. Unique relationships were identified between potassium and silicon, and magnesium and silicon. The relationships between molar ratios of potassium and silicon, and magnesium and silicon were well defined, and could be used to fingerprint the influence of dust versus effluent. Concentrations of major ions and sulphate correlated linearly in all datasets and demonstrated a difference in molar ratios between each source of water. The relationships between major ions and nutrients were not well defined.

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 with respect to molar ratios of key parameters. Dustfall is likely to have a negligible influence on lake water quality, with some degree of uncertainty, as the concentrations are so low that they are effectively “masked” by effluent water quality.

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 more impacted by dust deposition on top of the effect of the Mine effluent. Concentrations of major ions and metals that could be associated with dust were similar at the SES and MF3 stations. Concentrations of eutrophication indicators, including TP, were also similar between the two areas. This finding is consistent with the geochemistry evaluation, which also found that the major ion, metal, and SRP content of the SES and AEMP samples overlapped, and that lake water chemistry was more similar to effluent than to dustfall.

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. Instead of dissolving in the water, dust-associated phosphorus would settle to the sediment. This supports the observed lack of effects due to phosphorus-related dust on water quality in Lac de Gras, particularly in 2019.

5 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. Dustfall is likely to have a negligible influence on lake water quality, with some degree of uncertainty, as the concentrations are so low that they are effectively “masked” by effluent water quality.

- 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 present in lake water.

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

6 REFERENCES

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

7 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:	**Report reviewed by:**
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Kerrie Serben, M.Sc. Environmental Scientist	Zsolt Kovats, M.Sc. Associate, Senior Aquatic Ecologist

ATTACHMENT A

Raw Data From 2019 Special Effects Study

These data are also provided electronically in an Excel file.

ATTACHMENT B

Quality Assurance/Quality Control Review for the 2019 Special Effects Study

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance (QA) and quality control (QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting and are described in the *Quality Assurance Project Plan Version 3.1* (Golder 2017). Quality assurance encompasses management and technical practices designed to generate consistent, high quality data. Quality control is an aspect of QA and includes the techniques used to assess data quality and the corrective actions to be taken when the DQOs are not met.

The QA/QC practices applied during the 2019 Special Effects Study were the same as those applied during the 2019 water quality and eutrophication indicators components of the Aquatic Effects Monitoring Program (AEMP). Water samples collected for the SES were collected according to the same methods as the AEMP samples, and the data quality evaluation presented in Attachment B of the *Effluent and Water Chemistry Report* (Appendix II) and Attachment B of the *Eutrophication Indicators Report* (Appendix XIII) also apply to the SES. This appendix focuses on the QC assessment of SES field duplicate samples.

Duplicate Samples

Methods

Consistent with the eutrophication indicators component, duplicate samples were collected for analysis of nutrients, chlorophyll *a*, phytoplankton biomass, and zooplankton biomass. Duplicate samples from the top depth of station SS3 were also collected and analyzed for the full analytical suite of water quality.

Duplicate samples consisted of two samples collected from the same location at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually and submitted separately to the analytical laboratory for identical analyses. Duplicate samples were used to check within-station variation and the precision of field sampling and analytical methods. Differences between concentrations measured in duplicate water samples were calculated as the relative percent difference (RPD) for each variable. Before calculating the RPD, concentrations below the detection limit (DL) were replaced with 0.5 times the DL value. Substitution with half the DL is a common approach used to deal with censored data (US EPA 2000) and is consistent with the approved methods applied in the calculation of the normal range in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019). The RPD was calculated using the following formula:

$$\text{RPD} = \left(|\text{difference in concentration between duplicate samples}| \,/\, \text{mean concentration} \right) \times 100$$

The RPD value for a given variable was considered notable if:

- it was greater than 40%
- concentrations in one or both samples were greater than or equal to five times the DL

These criteria were approved as part of the *Quality Assurance Project Plan Version 3.1* (Golder 2017).

The number of variables which exceeded the assessment criteria was compared to the total number of variables analyzed to evaluate analytical precision. The analytical precision was rated as follows:

- high, if less than 10% of the total number of variables were notably different from one another
- moderate, if 10% to 30% of the total number of variables were notably different from one another
- low, if more than 30% of the total number of variables were notably different from one another

Results – Water Chemistry

Two depth-integrated samples were collected from each of the four SES stations for analysis of nutrients. In addition, two samples were collected from one SES station for analysis of conventional parameters, major ions, nutrients and total and dissolved metals. Therefore, there was a total of five duplicate pairs for nutrients, and one duplicate pair for the rest of the analytical suite.

Duplicate values generally met the data quality objective (DQO). Three results out of 147 (2%) had an RPD of more than 40% between duplicates, while having concentrations greater than five times the DL in at least one of the samples (Table C-1). The DQO exceedances occurred in the total ammonia – ALS data (n = 2) and in the dissolved molybdenum data (n = 1). Overall, because less than 10% of the duplicate pairs were notably different from one another, the analytical precision for the samples was rated as high.

Table C-1 Duplicate Sample Results in the Special Effects Study, 2019

Variable	Units	Season	Station or Sample	Sampling Date	DL	Result 1	Result 2	RPD (%)	>5×DL?	QC Fail?
Total Phosphorus	µg-P/L	OW	SS1	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS2	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS3	24 Aug 2019	2	2.2	3.6	48	N	N
	µg-P/L	OW	SS3-T	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS4	24 Aug 2019	2	<2	3.2	105	N	N
Total Dissolved Phosphorus	µg-P/L	OW	SS1	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS2	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS3	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS3-T	24 Aug 2019	2	<2	<2	0	N	N
	µg-P/L	OW	SS4	24 Aug 2019	2	<2	<2	0	N	N
Soluble Reactive Phosphorus	µg-P/L	OW	SS1	24 Aug 2019	1	1	<1	67	N	N
	µg-P/L	OW	SS2	24 Aug 2019	1	<1	<1	0	N	N
	µg-P/L	OW	SS3	24 Aug 2019	1	1.5	<1	100	N	N
	µg-P/L	OW	SS3-T	24 Aug 2019	1	1.6	<1	105	N	N
	µg-P/L	OW	SS4	24 Aug 2019	1	1.8	2.5	33	N	N
Total Nitrogen	µg-N/L	OW	SS1	24 Aug 2019	20	190	200	5	Y	N
	µg-N/L	OW	SS2	24 Aug 2019	20	200	240	18	Y	N
	µg-N/L	OW	SS3	24 Aug 2019	20	200	180	11	Y	N
	µg-N/L	OW	SS3-T	24 Aug 2019	20	180	180	0	Y	N
	µg-N/L	OW	SS4	24 Aug 2019	20	210	220	5	Y	N
Total Dissolved Nitrogen	µg-N/L	OW	SS1	24 Aug 2019	20	190	180	5	Y	N
	µg-N/L	OW	SS2	24 Aug 2019	20	200	210	5	Y	N
	µg-N/L	OW	SS3	24 Aug 2019	20	210	170	21	Y	N
	µg-N/L	OW	SS3-T	24 Aug 2019	20	200	200	0	Y	N
	µg-N/L	OW	SS4	24 Aug 2019	20	180	200	11	Y	N

Table C-1 Duplicate Sample Results in the Special Effects Study, 2019 (continued)

Variable	Units	Season	Station or Sample	Sampling Date	DL	Result 1	Result 2	RPD (%)	>5×DL?	QC Fail?
Total Kjeldahl Nitrogen	µg-N/L	OW	SS1	24 Aug 2019	20	190	190	0	Y	N
	µg-N/L	OW	SS2	24 Aug 2019	20	180	220	20	Y	N
	µg-N/L	OW	SS3	24 Aug 2019	20	200	180	11	Y	N
	µg-N/L	OW	SS3-T	24 Aug 2019	20	180	170	6	Y	N
	µg-N/L	OW	SS4	24 Aug 2019	20	210	210	0	Y	N
Dissolved Kjeldahl Nitrogen	µg-N/L	OW	SS1	24 Aug 2019	20	180	180	0	Y	N
	µg-N/L	OW	SS2	24 Aug 2019	20	180	190	5	Y	N
	µg-N/L	OW	SS3	24 Aug 2019	20	210	170	21	Y	N
	µg-N/L	OW	SS3-T	24 Aug 2019	20	190	200	5	Y	N
	µg-N/L	OW	SS4	24 Aug 2019	20	180	190	5	Y	N
Nitrate	µg-N/L	OW	SS1	24 Aug 2019	2	3.8	2.2	53	N	N
	µg-N/L	OW	SS2	24 Aug 2019	2	15	20	29	Y	N
	µg-N/L	OW	SS3	24 Aug 2019	2	4.3	2.7	46	N	N
	µg-N/L	OW	SS3-T	24 Aug 2019	2	4.1	4.2	2	N	N
	µg-N/L	OW	SS4	24 Aug 2019	2	3.9	3.8	3	N	N
Nitrate + Nitrite	µg-N/L	OW	SS1	24 Aug 2019	1	<1	<1	0	N	N
	µg-N/L	OW	SS2	24 Aug 2019	1	<1	<1	0	N	N
	µg-N/L	OW	SS3	24 Aug 2019	1	<1	<1	0	N	N
	µg-N/L	OW	SS3-T	24 Aug 2019	1	<1	<1	0	N	N
	µg-N/L	OW	SS4	24 Aug 2019	1	<1	<1	0	N	N
Nitrite	µg-N/L	OW	SS1	24 Aug 2019	2.2	3.8	<2.2	110	N	N
	µg-N/L	OW	SS2	24 Aug 2019	2.2	15	20	29	Y	N
	µg-N/L	OW	SS3	24 Aug 2019	2.2	4.3	2.7	46	N	N
	µg-N/L	OW	SS3-T	24 Aug 2019	2.2	4.1	4.2	2	N	N
	µg-N/L	OW	SS4	24 Aug 2019	2.2	3.9	3.8	3	N	N

Table C-1 Duplicate Sample Results in the Special Effects Study, 2019 (continued)

Variable	Units	Season	Station or Sample	Sampling Date	DL	Result 1	Result 2	RPD (%)	>5×DL?	QC Fail?
Total Ammonia – BV Labs	µg-N/L	OW	SS1	24 Aug 2019	5	11	7	44	N	N
	µg-N/L	OW	SS2	24 Aug 2019	5	11	13	17	N	N
	µg-N/L	OW	SS3	24 Aug 2019	5	25	9.7	88	N	N
	µg-N/L	OW	SS3-T	24 Aug 2019	5	<5	<5	0	N	N
	µg-N/L	OW	SS4	24 Aug 2019	5	30	28	7	Y	N
Total Ammonia - ALS	µg-N/L	OW	SS1	24 Aug 2019	5	18.3	16.8	9	N	N
	µg-N/L	OW	SS2	24 Aug 2019	5	29.8	13.4	76	N	Y
	µg-N/L	OW	SS3	24 Aug 2019	5	106	13.5	155	N	Y
	µg-N/L	OW	SS3-T	24 Aug 2019	5	14.2	20.7	37	N	N
	µg-N/L	OW	SS4	24 Aug 2019	5	13.3	15.8	17	N	N
Total Organic Carbon	µg/L	OW	SS1	24 Aug 2019	200	2,100	1,900	10	Y	N
	µg/L	OW	SS2	24 Aug 2019	200	2,200	2,200	0	Y	N
	µg/L	OW	SS3	24 Aug 2019	200	1,900	2,100	10	Y	N
	µg/L	OW	SS3-T	24 Aug 2019	200	2,300	2,300	0	Y	N
	µg/L	OW	SS4	24 Aug 2019	200	2,200	2,200	0	Y	N
pH	-	OW	SS3-T	24 Aug 2019	-	5.8	5.82	0	-	N
Specific conductivity	µS/cm	OW	SS3-T	24 Aug 2019	1	29.5	29.6	0	Y	N
Hardness, as $CaCO_3$	mg/L	OW	SS3-T	24 Aug 2019	0.5	8.3	8.31	0	Y	N
Total alkalinity, as $CaCO_3$	mg/L	OW	SS3-T	24 Aug 2019	0.5	4.99	5.18	4	Y	N
Total dissolved solids	mg/L	OW	SS3-T	24 Aug 2019	1	23.6	23.2	2	Y	N
Total dissolved solids (calculated)	mg/L	OW	SS3-T	24 Aug 2019	0.5	14.9	15.1	1	Y	N
Total suspended solids	mg/L	OW	SS3-T	24 Aug 2019	1	<1	<1	0	N	N
Turbidity	NTU	OW	SS3-T	24 Aug 2019	0.1	<0.1	0.21	123	N	N
Bicarbonate, as $CaCO_3$	mg/L	OW	SS3-T	24 Aug 2019	0.5	6.09	6.31	4	Y	N
Calcium	mg/L	OW	SS3-T	24 Aug 2019	0.01	1.75	1.77	1	Y	N
Carbonate, as $CaCO_3$	mg/L	OW	SS3-T	24 Aug 2019	0.5	<0.5	<0.5	0	N	N
Chloride	mg/L	OW	SS3-T	24 Aug 2019	0.5	2.8	2.9	4	Y	N

Table C-1 Duplicate Sample Results in the Special Effects Study, 2019 (continued)

Variable	Units	Season	Station or Sample	Sampling Date	DL	Result 1	Result 2	RPD (%)	>5×DL?	QC Fail?
Fluoride	mg/L	OW	SS3-T	24 Aug 2019	0.01	0.03	0.03	0	N	N
Hydroxide, as $CaCO_3$	mg/L	OW	SS3-T	24 Aug 2019	0.5	<0.5	<0.5	0	N	N
Magnesium	mg/L	OW	SS3-T	24 Aug 2019	0.005	0.957	0.946	1	Y	N
Potassium	mg/L	OW	SS3-T	24 Aug 2019	0.01	0.883	0.871	1	Y	N
Sodium	mg/L	OW	SS3-T	24 Aug 2019	0.01	1.84	1.8	2	Y	N
Sulphate	mg/L	OW	SS3-T	24 Aug 2019	0.5	3.6	3.7	3	Y	N
Silica	mg/L	OW	SS3-T	24 Aug 2019	0.01	0.048	0.049	2	N	N
Aluminum, Total	µg/L	OW	SS3-T	24 Aug 2019	0.2	5.3	5.63	6	Y	N
Antimony, Total	µg/L	OW	SS3-T	24 Aug 2019	0.02	0.025	0.026	4	N	N
Arsenic, Total	µg/L	OW	SS3-T	24 Aug 2019	0.02	0.201	0.236	16	Y	N
Barium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.02	2.22	2.22	0	Y	N
Beryllium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.01	<0.01	<0.01	0	N	N
Bismuth, Total	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	<0.005	0	N	N
Boron, Total	µg/L	OW	SS3-T	24 Aug 2019	5	5.3	5.3	0	N	N
Cadmium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	0.0095	117	N	N
Calcium, Total	µg/L	OW	SS3-T	24 Aug 2019	10	1,690	1,710	1	Y	N
Chromium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	<0.05	<0.05	0	N	N
Cobalt, Total	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	0.0059	81	N	N
Copper, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	0.543	0.582	7	Y	N
Iron, Total	µg/L	OW	SS3-T	24 Aug 2019	1	2.5	2.8	11	N	N
Lead, Total	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	0.0109	125	N	N
Lithium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.5	1.94	2.08	7	N	N
Magnesium, Total	µg/L	OW	SS3-T	24 Aug 2019	5	966	985	2	Y	N
Manganese, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	2.02	2.18	8	Y	N
Mercury, Total	µg/L	OW	SS3-T	24 Aug 2019	0.002	<0.002	<0.002	0	N	N
Molybdenum, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	0.345	0.391	13	Y	N
Nickel, Total	µg/L	OW	SS3-T	24 Aug 2019	0.02	0.789	0.988	22	Y	N

Table C-1 Duplicate Sample Results in the Special Effects Study, 2019 (continued)

Variable	Units	Season	Station or Sample	Sampling Date	DL	Result 1	Result 2	RPD (%)	>5×DL?	QC Fail?
Potassium, Total	µg/L	OW	SS3-T	24 Aug 2019	10	837	881	5	Y	N
Selenium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.04	<0.04	<0.04	0	N	N
Silicon, Total	µg/L	OW	SS3-T	24 Aug 2019	50	<50	<50	0	N	N
Silver, Total	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	<0.005	0	N	N
Sodium, Total	µg/L	OW	SS3-T	24 Aug 2019	10	1,780	1,850	4	Y	N
Strontium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	17.9	20.1	12	Y	N
Sulphur, Total	µg/L	OW	SS3-T	24 Aug 2019	500	1,410	1,320	7	N	N
Thallium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.002	<0.002	<0.002	0	N	N
Tin, Total	µg/L	OW	SS3-T	24 Aug 2019	0.01	<0.01	<0.01	0	N	N
Titanium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.5	<0.5	<0.5	0	N	N
Uranium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.002	0.0729	0.0817	11	Y	N
Vanadium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	<0.05	<0.05	0	N	N
Zinc, Total	µg/L	OW	SS3-T	24 Aug 2019	0.1	0.15	0.33	75	N	N
Zirconium, Total	µg/L	OW	SS3-T	24 Aug 2019	0.05	<0.05	<0.05	0	N	N
Aluminum, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.2	3.07	3.17	3	Y	N
Antimony, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.02	<0.02	<0.02	0	N	N
Arsenic, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.02	0.172	0.167	3	Y	N
Barium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.02	2.26	2.25	0	Y	N
Beryllium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.01	<0.01	<0.01	0	N	N
Bismuth, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	<0.005	0	N	N
Boron, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	5	<5	<5	0	N	N
Cadmium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	<0.005	0	N	N
Chromium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	<0.05	<0.05	0	N	N
Cobalt, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.005	0.0108	0.0097	11	N	N
Copper, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	0.535	0.518	3	Y	N
Iron, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	1	1.6	1.4	13	N	N
Lead, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	<0.005	0	N	N

Table C-1 Duplicate Sample Results in the Special Effects Study, 2019 (continued)

Variable	Units	Season	Station or Sample	Sampling Date	DL	Result 1	Result 2	RPD (%)	>5×DL?	QC Fail?
Lithium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.5	<0.5	<0.5	0	N	N
Manganese, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	0.49	0.489	0	Y	N
Mercury, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.002	<0.002	<0.002	0	N	N
Molybdenum, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	1.16	0.166	150	Y	Y
Nickel, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.02	0.842	0.83	1	Y	N
Selenium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.04	<0.04	<0.04	0	N	N
Silicon, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	50	<50	<50	0	N	N
Silver, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.005	<0.005	<0.005	0	N	N
Strontium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	19.4	19.3	1	Y	N
Sulphur, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	500	1,070	1,050	2	N	N
Thallium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.002	<0.002	<0.002	0	N	N
Tin, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.01	<0.01	<0.01	0	N	N
Titanium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.5	<5	<5	0	N	N
Uranium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.002	0.0782	0.0769	2	Y	N
Vanadium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	<0.05	<0.05	0	N	N
Zinc, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.1	0.27	0.25	8	N	N
Zirconium, Dissolved	µg/L	OW	SS3-T	24 Aug 2019	0.05	<0.05	<0.05	0	N	N

Note: “Y” in “QC Fail?” column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

a) Duplicate sample collected for QA/QC purposes but only analyzed for total ammonia.

b) Duplicate sample collected for QA/QC purposes (full analytical suite).

µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; NTU = nephelometric turbidity unit; DL = detection limit; > = greater than; × = times; QC = quality control; OW = open water; SS = special effects study station; T = top depth; N = no; Y = yes.

Results – Chlorophyll a and *Zooplankton Biomass*

Two depth-integrated samples were collected from each of the four SES stations for analysis of chlorophyll *a* and zooplankton biomass (as AFDM). Therefore, there was a total of four duplicate pairs for these eutrophication indicators. Phytoplankton field QC duplicate samples were not collected in 2019 as a result of a crew oversight during the field program (see the *Plankton Report* [Appendix XI]).

Two of the four pairs of chlorophyll *a* duplicate samples exceeded the DQO of greater than 40% RPD, while having concentrations greater than five times the DL in at least one of the samples (Table C-2). This yields a rating of low for analytical precision for the chlorophyll *a* samples. However, despite this low precision, data were still considered sufficient for use in the SES versus AEMP comparison, which evaluated whether concentrations are higher in the SES samples due to the influence of higher dust deposition rates. Because the magnitude of the concentrations in SES samples were similar to or less than those in the MF3 samples, the low precision in the data did not affect the overall findings of the comparison.

Table C-2 Summary of Duplicate Sample Results for Chlorophyll *a*, 2019

Season	Station	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
OW	SS1	0.04	0.28	0.25	11	Y	N
OW	SS2	0.04	0.37	0.24	43	Y	Y
OW	SS3	0.04	0.24	0.21	13	Y	N
OW	SS4	0.04	0.20	0.33	49	Y	Y

Note: “Y” in “QC Fail?” column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

µg/L = micrograms per litre; DL = detection limit; > = greater than; × = times; QC = quality control; OW = open-water; SS = special effects study station; N = no; Y = yes.

None of the zooplankton biomass duplicate samples exceeded the DQO of greater than 40% RPD (Table C-3). The greater than five times the DL criterion did not apply to zooplankton biomass because the DL is undefined. Since less than 10% of the duplicate pairs were notably different from one another, the analytical precision for the zooplankton biomass samples was rated as high.

Table C-3 Summary of Duplicate Sample Results for Zooplankton Biomass as Ash Free Dry Mass, 2019

Season	Station	Result 1 (mg/m^3)	Result 2 (mg/m^3)	Relative Percent Difference (%)	QC Fail?
OW	SS1	62.9	64.9	3.2	N
OW	SS2	96.0	97.8	1.9	N
OW	SS3	65.1	93.1	35.4	N
OW	SS4	51.1	48.6	5.0	N

Note: “Y” in “QC Fail?” column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%.

mg/m^3 = milligrams per cubic metre; DL = detection limit; QC = quality control; OW = open-water; SS = special effects study station; N = no; Y = yes; - = not applicable.

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APPENDIX XIII

EUTROPHICATION INDICATORS REPORT

EUTROPHICATION INDICATORS REPORT IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

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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

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Executive Summary

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of the Aquatic Effects Monitoring Program (AEMP) for the Diavik Diamond Mine (Mine) in Lac de Gras, Northwest Territories, as required by Water Licence W2015L2-0001 (WLWB 2015), according to the *AEMP Design Plan Version 4.1* (Golder 2017a), as approved by the Wek'èezhìı Land and Water Board (WLWB). This report presents the assessment of eutrophication indicators data collected during the 2019 AEMP. The objective of the eutrophication indicators monitoring component of the AEMP was to determine if Mine-related activities are having an effect on concentrations of nutrients, chlorophyll *a*, and phytoplankton and zooplankton biomass in Lac de Gras. Mine-related activities in 2019 that had the potential to affect Lac de Gras include effluent discharge and dust deposition from vehicular and heavy equipment operations within the Mine footprint. No dyke construction or dewatering activities occurred in 2019. Therefore, the data analysis for eutrophication indicators considers effects due to effluent discharge and dust deposition.

To evaluate whether effluent from the Mine is causing nutrient enrichment in Lac de Gras, indicators of eutrophication were measured in the near-field (NF), mid-field (MF), and far-field (FF) areas of the lake. Eutrophication indicators evaluated by the AEMP are total and dissolved phosphorus (TP and TDP), soluble reactive phosphorus (SRP), total and dissolved nitrogen (TN and TDN), total ammonia, nitrate, nitrite, nitrate + nitrite, total and dissolved Kjeldahl nitrogen (TKN and DKN), soluble reactive silica (SRSi), chlorophyll *a*, phytoplankton biomass as biovolume, and zooplankton biomass as ash-free dry mass (AFDM). Secchi depth is also included in the analysis and used, as appropriate, in the interpretation of results for phytoplankton biomass and chlorophyll *a*. The analysis of potential effects focused on evaluating spatial trends in Lac de Gras, with supporting information from Lac du Sauvage and the Slipper Lake outflow (i.e., to evaluate potential cumulative effects from the Diavik and Ekati mines).

The assessment of eutrophication indicators data concluded that the Mine is having a nutrient enrichment effect in Lac de Gras. Concentrations of TP, TN, and SRSi were greatest during the ice-cover season. Although greater in the NF area compared to the rest of the lake, phosphorus concentrations were less than the normal range in Lac de Gras, likely due to smaller TP loads from Mine effluent. The extent of effects on TP was 0% of Lac de Gras, based on no concentrations at any station greater than the normal range. Nitrogen concentrations were above the normal range in most of Lac de Gras, with significant decreasing concentrations with distance from the diffuser. Considering the elevated TN concentration at LDG-48 during the open-water season, the extent of effects on TN included the entire lake area. During the ice-cover season, TN concentration at LDG-48 was less than the upper bound of the normal range, and therefore, the extent of effects was less, at 85%. The 2019 monthly loads of nitrogen parameters to Lac de Gras, and concentrations in AEMP sampling areas, were similar or greater in 2019 compared to 2018. Significant decreasing trends in SRSi was also observed.

Total phytoplankton biomass and chlorophyll *a* concentrations were low in all AEMP sampling areas, which is consistent with the lower phosphorus concentrations. Chlorophyll *a* concentrations in Lac de Gras were within or below the normal range, with the exception of station NF3. Concentrations were greater in the NF area, and decreased with distance from the diffuser. Total phytoplankton biomass at all stations was within the normal range, and there were no significant trends in phytoplankton biomass with distance from the diffuser or between NF and FF areas. Total zooplankton biomass (as AFDM) was above the normal range in the NF area and significant decreasing trends with distance from the diffuser

were observed. The extent of effects on chlorophyll *a*, phytoplankton biomass and zooplankton biomass were 0.1%, 0% and greater than or equal to ≥29% of Lac de Gras, respectively.

The concentration of chlorophyll *a* exceeded the normal range at one NF station, and the affected area was 0.1% of the lake. Based on these results, no Action Level was triggered in 2019 by the eutrophication indicators results. Therefore, no further action is required based on the 2019 monitoring results.

The 2019 results are consistent with the Environmental Assessment prediction of greater concentrations of nutrients, particularly phosphorus from the minewater discharge, resulting in an increase in primary productivity. The biological response to the nutrients discharged from the Mine were proportional to measured phosphorus concentrations and did not reflect the elevated nitrogen concentrations throughout the lake. These results underline the importance of phosphorus limitation in Lac de Gras, which was also indicated by nutrient ratios summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report* (Golder 2019c).

Overall, the observations of the 2019 AEMP are consistent with those reported in previous AEMP years as summarized in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c) and subsequent AEMP annual reports (i.e., 2017, 2018). However, unlike in previous AEMP years were either an Action Level 1 or 2 was triggered, no Action Level was triggered in 2019.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
AFDM	ash-free dry mass
AIC	Akaike's information criterion
AICc	corrected for small sample size
ALS	ALS Laboratories
ANOVA	Analysis of Variance
BV Labs	Bureau Veritas Laboratories (BV Labs; formerly Maxxam Analytics)
CALA	Canadian Association of Laboratory Accreditation
DDMI	Diavik Diamond Mines (2012) Inc.
DKN	dissolved Kjeldahl nitrogen
DL	detection limit
EA	environmental assessment
e.g.	for example
et al.	and more than one additional author
EQC	Effluent Quality Criteria
FF	far-field
Golder	Golder Associates Ltd.
HSD	honestly significant difference
i.e.	that is
k	number of standard deviations
KW	Kruskal-Wallis
LDG	Lac de Gras
LDS	Lac du Sauvage
LLCF	Long Lake Containment Facility
Maxxam	Maxxam Analytics
MF	mid-field
Mine	Diavik Diamond Mine
n	sample size/count
NIWTP	North Inlet Water Treatment Plant
NF	near-field
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RPD	relative percent difference
SD	standard deviation
SES	Special Effects Study
SNP	surveillance network program
SOP	standard operating procedure
SRSi	soluble reactive silica

SRP	soluble reactive phosphorus
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TP	total phosphorus
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
WLWB	Wek'èezhìı Land and Water Board
WOE	weight-of-evidence
ZOI	zone of influence

Symbols and Units of Measure

%	percent
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
×	times
µm	micrometre
µS/cm	microsiemens per centimetre
cm	centimetre
kg	kilogram
km	kilometre
km^2	square kilometre
m	metre
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
mo	month
P	probability
yr	year
µg/L	micrograms per litre
µg-N/L	micrograms nitrogen per litre
µg-P/L	micrograms phosphorus per litre

1 INTRODUCTION

1.1 Background

As required by Water Licence W2015L2-0001 (WLWB 2015) issued by the Wek'èezhìı Land and Water Board (WLWB), Diavik Diamond Mines (2012) Inc. (DDMI) has been monitoring indicators of eutrophication in Lac de Gras (LDG) as a component of the Aquatic Effects Monitoring Program (AEMP) since 2007. Eutrophication indicators are a key component of the AEMP, because the Environmental Assessment (EA) predicted that the discharge of effluent from the Diavik Diamond Mine (Mine) would cause a change in trophic status (which is a classification of productivity) in up to 20% of Lac de Gras as a result of nutrient enrichment (Government of Canada 1999).

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 approved through the Wek'èezhìı Land and Water Board directives (25 March 2019 and 21 October 2019 Decision Packages related to the *2014 to 2016 Aquatic Effects Re-evaluation Report*, *AEMP Design Plan Version 5.0*, *2017 AEMP Annual Report*, and *2018 AEMP Annual Report*) have been incorporated into the 2019 Eutrophication Report. These updates include revisions to the list of eutrophication indicators, additional data analysis and presentation of spatial extent of effects, and additional discussion of potential Mine effects including dust, dewatering, and construction activities.

This report presents the assessment of eutrophication indicators data collected during the 2019 AEMP field program. The potential influence of other sources on lake productivity, such as Mine-related dust deposition to Lac de Gras, are also considered herein.

1.2 Objectives

The primary objective of the eutrophication indicators program is to determine if effluent discharged from the Mine is having an effect on concentrations of nutrients, chlorophyll *a*, and phytoplankton and zooplankton biomass in Lac de Gras.

1.3 Scope and Approach

The Eutrophication Indicators component is designed to monitor both spatial and temporal changes in nutrients, chlorophyll *a*, and phytoplankton and zooplankton biomass. Eutrophication indicators selected for this AEMP component are total and dissolved phosphorus (TP and TDP), soluble reactive phosphorus (SRP), total and dissolved nitrogen (TN and TDN), total ammonia, nitrate, nitrite, nitrate + nitrite, total and dissolved Kjeldahl nitrogen (TN and TDN), soluble reactive silica (SRSi), chlorophyll *a*, phytoplankton biomass as biovolume, and zooplankton biomass as ash free dry mass (AFDM). Secchi depth is also included in the analysis and used, as appropriate, in the interpretation of results for phytoplankton biomass and chlorophyll *a*. The spatial extent of effects is established by estimating the surface area of the lake that demonstrates concentrations or biomass greater than background values. Background values for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range, as described in Section 1.2 of the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). The magnitude of effects is assessed by comparing eutrophication indicator endpoints in the near-field (NF), mid-field (MF), and far-field (FF) areas to background values. Values above the normal range exceed what would be considered natural levels for Lac de Gras. The importance of effects observed on eutrophication endpoints is assessed according to the Action Level classification defined by Golder (2017a).

The AEMP measures and evaluates the effects of Mine-related activities on the aquatic environment of Lac de Gras. Mine-related activities in 2019 that had the potential to affect Lac de Gras include effluent discharge and dust deposition from vehicular and heavy equipment operations within the Mine footprint. No dyke construction or dewatering activities occurred in 2019. In addition to the AEMP data analysis, a *Special Effects Study – Dust Deposition* (Appendix XII) was conducted in 2019 to further investigate dust-related effects on water quality and aquatic life in Lac de Gras, including helping to differentiate between effluent- and dust-related effects. The results of this Special Effects Study (SES) are also considered in this section when interpreting how TP load from dust affected TP and chlorophyll *a* concentrations in Lac de Gras.

2 METHODS

2.1 Field Sampling

2.1.1 Effluent and Mixing Zone

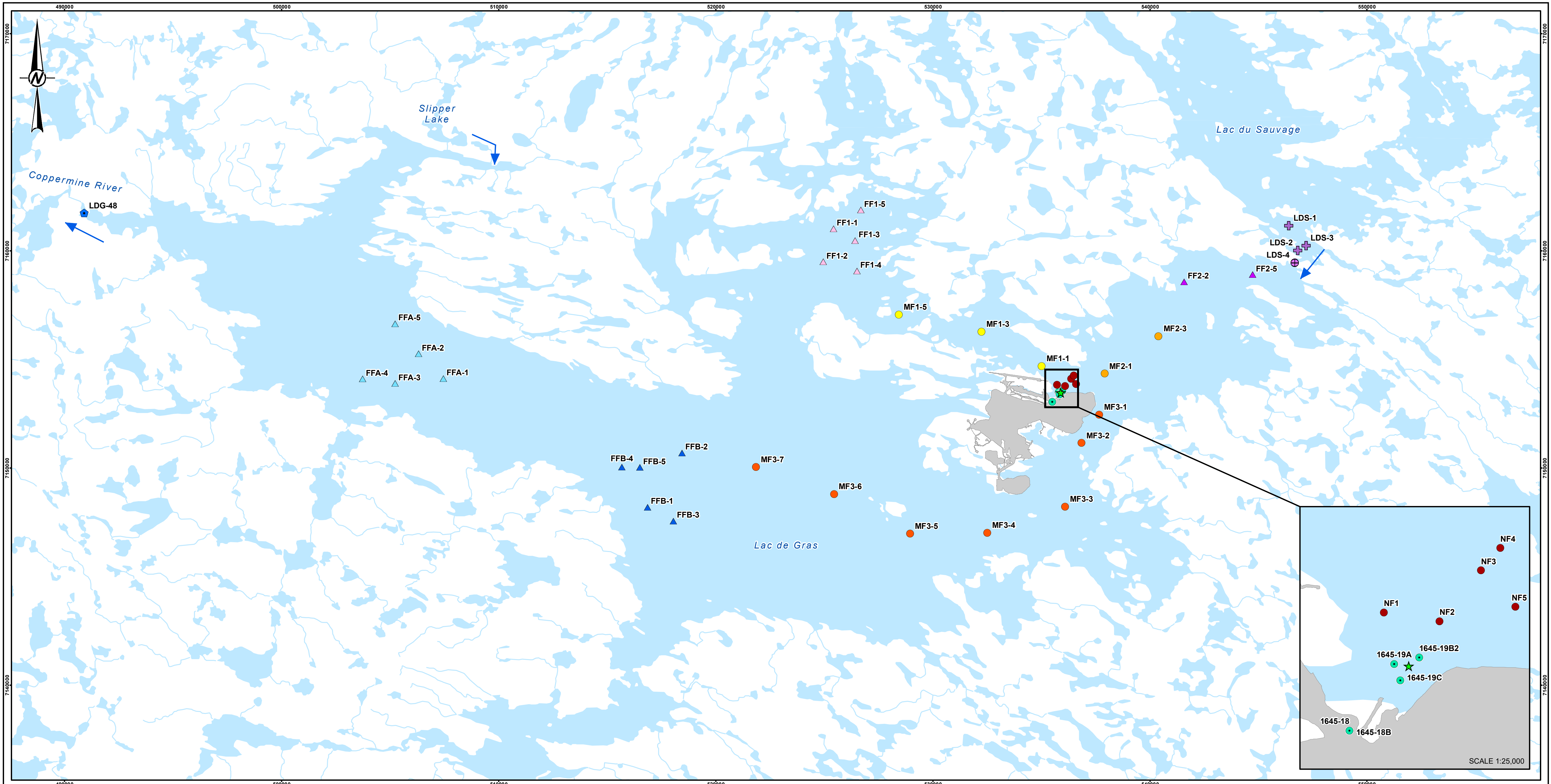
Treated effluent was sampled from the two diffusers that discharge water from the North Inlet Water Treatment Plant (NIWTP) to Lac de Gras, as part of the Mine's Surveillance Network Program (SNP). Station SNP 1645-18 is located at the original diffuser, which has discharged continuously to Lac de Gras since 2002, and Station SNP 1645-18B is located at the second diffuser, which became operational on 13 September 2009. In addition, water quality samples were collected at the mixing zone boundary in Lac de Gras at three stations (SNP 1645-19A, SNP 1645-19B2, and SNP 1645-19C), which are located along a semicircle, at 60 m from the effluent diffusers. These stations represent the edge of the mixing zone, which covers an area of approximately 0.01 km^2. Station SNP 1645-19B2 was established in 2009 to replace Station SNP 1645-19B, after the second diffuser became active in Lac de Gras.

Effluent samples were collected approximately every six days. At the mixing zone boundary, samples were collected monthly at each station at the lake water surface and at 5 m depth intervals. Samples were not collected during ice-off (June) and ice-on (November) at the mixing zone stations due to unsafe ice conditions which prevented access.

2.1.2 Lac de Gras

Thirty-four stations located in seven general areas of Lac de Gras were sampled by DDMI during the 2019 AEMP (Figure 2-1, Table 2-1). Sampling areas were selected based on exposure to the Mine effluent (Golder 2017a), and consisted of the NF area, three MF areas, and three FF areas. Sampling stations in the MF areas follow transect lines that run from the NF area to the FF areas (i.e., FF1, FFA, and FFB). The MF1 transect is located northwest of the NF area towards the FF1 area. The MF2 transect is located to the northeast, towards the FF2 area near the Lac du Sauvage (LDS) inlet. The MF3 transect is located south of the NF area, towards the FFB and FFA areas.

Nutrients were also sampled at the outlet of Lac de Gras to the Coppermine River (Station LDG-48), at the narrows between Lac de Gras and Lac du Sauvage (LDS-4), and at three stations in Lac du Sauvage (LDS-1 to LDS-3).



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

- → 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
LOCATIONS OF AEMP EUTROPHICATION INDICATORS SAMPLING STATIONS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
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Table 2-1 Eutrophication Indicators Sampling Station Locations, 2019

Area	Station	UTM Coordinates(a)		Distance from Diffuser(b) (m)	Water Depth (m)
		Easting (m)	Northing (m)		
NF	NF1	535740	7153854	394	22.3
	NF2	536095	7153784	501	20.6
	NF3	536369	7154092	936	18.6
	NF4	536512	7154240	1131	21.1
	NF5	536600	7153864	968	20.6
MF1	MF1-1	535008	7154699	1452	19.5
	MF1-3	532236	7156276	4650	18.9
	MF1-5	528432	7157066	8535	18.0
MF2– FF2	MF2-1	538033	7154371	2363	18.0
	MF2-3	540365	7156045	5386	20.3
	FF2-2	541588	7158561	8276	19.1
	FF2-5	544724	7158879	11444	20.0
MF3	MF3-1	537645	7152432	2730	19.7
	MF3-2	536816	7151126	4215	22.6
	MF3-3	536094	7148215	7245	20.6
	MF3-4	536094	7148215	11023	20
	MF3-5	536094	7148215	14578	18.6
	MF3-6	536094	7148215	18532	18.0
	MF3-7	536094	7148215	22330	21.5
FF1	FF1-1	525430	7161043	13571	21.9
	FF1-2	524932	7159476	12915	19.0
	FF1-3	526407	7160492	12823	18.0
	FF1-4	526493	7159058	11399	20.0
	FF1-5	526683	7161824	12823	18.0
FFB	FFB-1	516831	7148207	26355	20.8
	FFB-2	518473	7150712	24991	18.0
	FFB-3	518048	7147557	25245	22.0
	FFB-4	515687	7150036	27591	19.2
	FFB-5	516533	7150032	26761	20.3
FFA	FFA-1	506453	7154021	36769	18.3
	FFA-2	506315	7155271	38312	18.6
	FFA-3	505207	7153887	38734	21.7
	FFA-4	503703	7154081	40211	18.6
	FFA-5	505216	7156657	39956	18.3
Outlet of Lac de Gras	LDG-48	490900	7161750	55556	2.2
Outlet of Lac du Sauvage	LSD-4	546797	7159595	-	0.4
Lac du Sauvage	LDS-1	546398	7161179	-	18.5
	LDS-2	546807	7160027	-	18.9
	LDS-3	547191	7160256	-	10.5

a) UTM coordinates are reported as Zone 12, North American Datum (NAD) 83.

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

UTM = Universal Transverse Mercator coordinate system; - = not applicable; NF = near-field; MF = mid-field; FF = far-field; Lac du Sauvage.

The field sampling program included the collection of water samples for analysis of nutrients and chlorophyll *a*, phytoplankton and zooplankton samples for biomass analysis, and *in situ* water quality measurements. Sampling was conducted once during ice-cover season and once during the open-water season (Attachment A):

- ice-cover season sampling period: 22 April to 10 May 2019
- open-water season sampling period: 15 August to 5 September 2019

Nutrient samples were collected in both seasons, while chlorophyll *a*, phytoplankton, and zooplankton samples were collected only during the open-water season. The sampling protocol for nutrients differed between the ice-cover and open-water seasons, according to DDMI Standard Operating Procedure (SOP), ENVI-923-0119 AEMP “Combined Open Water and Ice Cover” and as described below. Water samples were handled according to DDMI SOPs, ENVI-902-0119 “Quality Assurance Quality Control” and ENVI-900-0119 “Chain of Custody”.

During the ice-cover season, duplicate samples were collected at three discrete 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 station, and at LDG-48. Because the effluent may not be vertically mixed under ice-cover and water chemistry may differ among depths, samples were collected at the three discrete depths during the ice-cover season. Surface samples were collected at a depth of 2 m from ice surface, and bottom samples were collected 2 m from the lake bottom. Mid-depth samples were collected at the middle of the total water column depth. No sample was collected at LDS-4 during the ice-cover season.

During the open-water season, duplicate depth-integrated water samples were collected at each NF, MF, FF, and LDS station for the analysis of nutrients and chlorophyll *a*. One sample was collected from mid-depth at LDG-48 and LDS-4 for the analysis of nutrients and chlorophyll *a*. Per Section 3.4.2 of the *AEMP Design Plan Version 4.1* (Golder 2017a), only water quality, nutrients, and chlorophyll *a* were sampled at LDG-48 and LDS-4. The depths of these stations are very shallow, limiting the possibility of quantitative plankton sampling using a plankton net.

Depth-integrated water samples were collected at deep stations for nutrient analysis to provide an estimate of the concentrations of nutrients to which phytoplankton are exposed. These samples were collected from the top 10 m of the water column using a depth-integrated sampler. A second depth-integrated sample was collected to produce duplicate samples for nutrients and chlorophyll a at each station. The phytoplankton biomass (as biovolume) data presented herein were taken from the *Plankton Report* (Appendix XI); however, samples were collected in the same manner as for chlorophyll *a* and nutrients, with the exception that twelve depth-integrated samples from each station were combined, and the resulting composite sample was used to fill a sample bottle for phytoplankton taxonomy.

Duplicate zooplankton samples were collected using a plankton net (30 cm mouth diameter, 75 µm mesh) for the determination of zooplankton biomass as AFDM. Each sample consisted of a composite of three vertical hauls through the entire water column.

2.2 Laboratory Analysis

Nutrient samples collected during the ice-cover and open-water seasons were sent to Bureau Veritas Laboratories (BV Labs; formerly Maxxam Analytics), Burnaby, British Columbia. As in recent years, filtering of the dissolved nutrients samples in 2019 was done at the BV Labs laboratory. Split samples for total ammonia analysis were also submitted to ALS Laboratories (ALS), Edmonton, Alberta, Canada. To be consistent with the dataset used in the *Effluent and Water Chemistry Report* (Appendix II), total ammonia data from both laboratories were used in the data analysis (i.e., ALS for ice-cover and BV Labs for open-water; see Section 2.4.1 in the *Effluent and Water Chemistry Report* [Appendix II]).

A list of the nutrients analyzed and the analyte-specific detection limits (DLs) reported in 2019 are provided in Table 2-2. Some samples were not analyzed using the DL shown in Table 2-2 due to insufficient sample volume or other problems with the original sample (e.g., interference by other analytes). Deviations from the target DLs and a discussion of potential effects on data quality are discussed in Attachment B. Raw nutrient data are provided in Attachment F.

Table 2-2 Detection Limits for Nutrient Analysis, 2019

Variable	Unit	Detection Limit
Nutrients		
Total phosphorus	µg-P/L	2
Total dissolved phosphorus	µg-P/L	2
Soluble reactive phosphorus	µg-P/L	1
Soluble reactive silica	µg/L	10
Total nitrogen	µg-N/L	20
Total dissolved nitrogen	µg-N/L	20
Total Kjeldahl nitrogen	µg-N/L	20
Dissolved Kjeldahl nitrogen	µg-N/L	20
Total ammonia	µg-N/L	5
Nitrate	µg-N/L	2
Nitrite	µg-N/L	1
Nitrate + nitrite	µg-N/L	2

µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre.

Depth-integrated chlorophyll *a* samples were sent to the Biogeochemical Analytical Service Laboratory at the University of Alberta, Edmonton, Alberta. Samples were analyzed for chlorophyll *a* at a DL of 0.04 µg/L. Composite phytoplankton samples were submitted to Advanced Eco-Solutions Inc. (Advanced Eco-Solutions), Newman Lake, Washington, United States, for analysis of abundance and biomass (for analytical methods, please see the *Plankton Report* [Appendix XI]). Zooplankton biomass (as AFDM) was measured by BV Labs, Burnaby, British Columbia.

2.3 Data Analysis

2.3.1 Data Screening

Initial screening of the 2019 nutrient, chlorophyll *a*, and zooplankton biomass (as AFDM) datasets was completed before data analyses to identify unusually large (or small) values and decide whether to retain or exclude anomalous data from further analysis. The anomalous data screening methods are described in the *Quality Assurance Project Plan Version 3.1* (Golder 2017b). Prior to data analyses and data screening, all duplicate data were averaged.

Data screening for anomalous values identified no anomalous values in the 2019 eutrophication indicators dataset.

2.3.2 Censored Data

For the purposes of the AEMP, censored data are concentrations reported below the analytical DL (referred to as non-detect values). Due to the location of Lac de Gras on the Canadian Shield, concentrations of many water quality variables are low and at or below the DL. A frequently used, simple approach to deal with censored data is the substitution of a surrogate value (e.g., the DL or some fraction of the DL) for non-detect data, which is considered generally acceptable in cases when a relatively small proportion of the data (e.g., <15%) are below the DL. Substitution with half the DL is a common approach used to deal with censored data (US EPA 2000) and is consistent with the approved methods applied in the calculation of the normal range in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).

2.3.3 Nutrients in Effluent and the Mixing Zone

The quantity of nutrients in effluent was evaluated graphically by plotting total monthly loads of nutrients using R version 3.6.1 (R Core Team 2019). The daily load from each diffuser was calculated by multiplying the effluent discharge rate by the nutrient concentration at each effluent diffuser station (i.e., SNP 1645-18 and SNP 1645-18B). The total daily load was calculated as the sum of loads from the two diffusers. Total monthly loads represent the sum of the total daily loads for a given month. The period of effluent discharge summarized in this report (i.e., the reporting period) was from 1 November 2018 to 31 October 2019.

Time series plots showing the concentrations of nutrients in effluent were generated for the reporting period. Results for individual grab samples were plotted separately for each effluent diffuser station (i.e., SNP 1645-18 and SNP 1645-18B).

Water was sampled at the mixing zone boundary monthly, at five depths (i.e., 2, 5, 10, 15, and 20 m) at each of the three mixing zone stations (i.e., SNP 1645-19A, SNP 1645-19B, SNP 1645-19C). Hence, up to 15 samples were collected each month. Results for the mixing zone were summarized by showing the 5th percentile, median, and 95th percentile concentrations for each month.

The quality of the effluent was assessed in the *Effluent and Water Chemistry Report* (Appendix II) by comparing water chemistry results at stations SNP 1645-18 and SNP 1645-18B with the Effluent Quality Criteria (EQC) defined in the Water Licence (WLWB 2015). Results for key nutrient variables are presented herein, specifically TP, TDP, SRP, TN, total ammonia, nitrate, and nitrite. Total phosphorus has an EQC specified in terms of load, rather than concentration. The Water Licence specifies that the load of TP must not exceed a maximum of 300 kg/mo, an average annual load of 1,000 kg/yr during the life of the Mine, and a maximum load of 2,000 kg/yr in any year during the life of the Mine.

2.3.4 Statistical Analysis

2.3.4.1 Approach

The main objective of the statistical analysis was to evaluate spatial trends in concentrations of eutrophication indicators along the three gradients sampled in Lac de Gras. A comparison among the NF exposure area and the three FF areas was also performed using an Analysis of Variance (ANOVA).

Recent updates to the *AEMP Design Plan Version 5.1* (Golder 2019a) have emphasized the gradient aspect of the AEMP sampling design, because the FF areas of Lac de Gras are exposed to a low level of Mine effluent. Consequently, a control-impact comparison of constituent concentrations in the NF area relative to the FF areas is no longer a valid approach to evaluating Mine effects. However, the NF vs FF comparisons have been retained in the 2019 AEMP to meet the data analysis requirements set out in *AEMP Design Plan Version 4.1* (Golder 2017a) and are considered as a supporting analysis to the spatial gradient analysis.

2.3.4.2 Gradient Analysis

Spatial gradients in eutrophication indicators along the three sampled transects (i.e., MF1, MF2, MF3) were analyzed using linear regression, per the *AEMP Design Plan Version 4.1* (Golder 2017a). The NF area data were included in the linear regression for each of the three transects. Linear regressions were completed using the statistical environment R v. 3.6.1 (R Core Team 2019). All 34 stations were included in the analysis. Regression analyses were considered significant at $\alpha = 0.1$.

Due to the spatial span of the MF3 transect, variables often had non-linear patterns with distance from the diffusers. Therefore, the analysis method allowed for piecewise regression (also referred to as segmented or broken-stick regression). The following approaches were used:

- Model 1: a linear multiplicative model, with main effects of distance from diffusers, gradient (MF1, MF2 and MF3 transects), and their interactions
- Piecewise modelling to account for changes in spatial gradients, where individual transects were analyzed separately from one another:
    - Model 2: a linear multiplicative model, with main effects of distance from diffusers, gradient (only MF1 and MF2 transect), and their interaction
    - Model 3: a linear piecewise (broken stick) model with distance (MF3 transect only)

For each variable in each season, Model 1 was used to test for the presence of a significant ($P<0.05$) breakpoint (i.e., where the slopes of the linear regressions changed) using the Davies test (Davies 1987, 2002). If a significant breakpoint was identified, Models 2 and 3 were used for that variable in that season. If no significant breakpoint was identified, Model 1 was used.

Following the initial fit of the model, the residuals (of either Model 1 or Model 2, as applicable) were examined for normality. Model 3 was not considered for transformations, since the addition of a breakpoint was expected to resolve non-linear patterns. For each response variable, the data underwent Box-Cox transformations (Box and Cox 1964). The Box-Cox transformations are a family of transformations that include the commonly used log and square root transformations. The Box-Cox transformation process tests a series of power values, usually between -2 and +2, and records the log-likelihood of the relationship between the response and the predictor variables under each transformation. The transformation that maximizes the log-likelihood is the one that will best normalize the data. Therefore, the data are transformed using a power value identified by the transformation process. For a power value (λ) of zero, the data are natural log transformed. The transformation rules can be described using the following definitions:

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

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

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

Following data transformation (if required), the selected models were fitted to the data. Statistical outliers were identified using studentized residuals with absolute values of 3.5 or greater, or due to consideration of leverage (where a single point could strongly influence the overall fit of the model). All values removed from the analysis were retained for plots of model predictions, where they were presented using a different symbol from the rest of the data.

Following removal of outliers, breakpoint significance and data transformation was re-examined. Residuals from the refitted models were examined for normality and heteroscedasticity, and evidence of nonlinear patterns. If non-linearity was evident from residual examination, the analysis was terminated and data were presented qualitatively. If normality was evident, then three models were constructed to assess the effect of heteroscedasticity for each response variable in each season:

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

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

The constructed models were used to produce the following outputs:

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

Analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019) and package “segmented” (Muggeo 2008).

Based on US EPA (2000) guidance, a screening value of greater than 15% censoring was used to flag datasets that may not be amenable to the linear regression analysis. The decision of whether to analyze the data using linear regression was based on review of the number of values less than the DL according to variable and season. Because of large numbers of values below the DL, linear regression analysis was not performed for:

- TP: ice-cover (82% <DL) and open-water (64% <DL)
- TDP: ice-cover (93% <DL) and open-water (95% <DL)
- SRP: ice-cover (64% <DL)
- nitrate: open-water (50% <DL)
- nitrite: ice-cover (60% <DL) and open-water (86% <DL)
- nitrate + nitrite: open-water (54% <DL)
- total ammonia: open-water (37% <DL)

Scatter-plots of concentrations according to distance from the effluent discharge have been included for variables which had large numbers of values that were less than the DL.

2.3.4.3 Near-Field Versus Far-Field Area Comparisons

The objective of the statistical comparisons for eutrophication indicators was to compare the NF area to the three FF areas (i.e., FF1, FFB, and FFA). Statistical testing was conducted using a combination of ANOVA and the Kruskal-Wallis (KW) test. The choice of test depended on the amount of censoring (i.e., values below the DL) within a dataset and the outcome of assumptions testing for ANOVA, as described in Section 2.3.4.3.1. Statistical methods used for each type of test are provided in the subsections below. Statistical analyses were performed using the statistical environment R v. 3.6.1 (R Core Team 2019).

2.3.4.3.1 Testing Assumptions for Analysis of Variance

Parametric tests such as ANOVA assume that the data fit a normal distribution, because the residuals (i.e., error terms of the variates) are assumed to fit a normal distribution. If a measurement variable is not normally distributed, there is an increased chance of a false positive result, or Type I error.

The goodness-of-fit of the data to the normal distribution was tested with the Kolmogorov-Smirnov test (Sokal and Rohlf 2012). Many datasets that are significantly non-normal will still be appropriate for an ANOVA; therefore, issues with non-normality were only addressed at a *P*-value less than 0.01. Another assumption of ANOVA is that group variances are equal (i.e., homogeneity of variances). When variances differ markedly, various data transformations will typically remedy the problem. As with normality, small to moderate deviations from the assumption of equal variances do not compromise the overall test of significance by ANOVA. Homogeneity of variances was tested using the Bartlett and Levene's tests. If the data were clearly non-normal and/or had large differences in-group variances, and if transformations did not remedy the problem, the data were analyzed using the non-parametric Kruskal-Wallis test.

2.3.4.3.2 Analysis of Variance

The mean values of the four areas (i.e., NF, FF1, FFB, and FFA) were compared in an overall ANOVA. Within the overall ANOVA, an *a priori* comparison (i.e., planned contrast) was conducted to test for differences of means among specific areas (e.g., NF vs. FF areas). The *P*-value used for these tests was 0.1.

In some cases, differences were observed among FF areas in Lac de Gras. To assess this variability, comparisons were also made among the three FF areas. Such comparisons are considered unplanned or *a posteriori* comparisons. The procedure used for these comparisons was Tukey's honestly significant difference (HSD) method. This test adopts a conservative approach by employing experiment-wise error rates for the Type I error (Day and Quinn 1989). Therefore, the *P*-value used for these tests was 0.1, the same *P*-value used for the planned contrasts.

Similar to the linear regression analysis, ANOVA was not conducted for certain variables because of large numbers of values below the DL (i.e., TP, TDP, and nitrite in both seasons; SRP in ice-cover and nitrate, nitrate + nitrite, and total ammonia in open-water).

2.3.5 Extent of Effects

The area of the lake with values greater than the normal range was estimated for TP, TN, chlorophyll *a*, and phytoplankton and zooplankton biomass, and this measure was used to estimate the extent of effects. The extent of effects calculated for 2019 was compared with those estimated in previous years to evaluate whether effects were expanding farther into the lake over time.

Directive 2B from the 25 March 2019 WLWB Decision regarding the 2017 AEMP directs DDMI to present the spatial extentppriopextent of effects of eutrophication indicators for both the ice-covered and open-water seasons in future AEMP Annual Reports. Therefore, the extent of effects was calculated for both seasons. In addition, the extent of effects was calculated for all three depths (i.e., top, middle, and bottom) for the ice-covered season.

To quantify the extent of effects along each transect, a linear interpolation method was used to estimate the distance between the station farthest from the diffuser with a value greater than the normal range and the adjacent station with a value below the normal range. In cases where concentrations did not decrease uniformly with distance from the diffuser, a conservative approach was taken by assuming that the effect extended to the farthest station with a concentration above the normal range, even if closer stations along the transect had concentrations below the normal range.

2.3.6 Normal Ranges

Magnitude of effects on indicators of eutrophication were evaluated by comparing nutrient concentrations, chlorophyll *a*, and phytoplankton and zooplankton biomass in the NF and MF areas to background values. Background values for Lac de Gras are those that fall within the range of natural variability, referred to as the normal range. Normal ranges were calculated using data from 2007 to 2010 (with some exceptions) and three AEMP FF areas (i.e., FF1, FFA, and FFB). The normal ranges used to evaluate potential effects for indicators of eutrophication were obtained from the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b) and are summarized in Table 2-3.

Table 2-3 Normal Ranges for Eutrophication Indicators

Variable	Unit	Normal Range			
		Ice Cover		Open-water	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit
Total phosphorus	µg-P/L	2.0	5.0	2.0	5.3
Total dissolved phosphorus	µg-P/L	1.1	3.2	0	3.5
Soluble reactive phosphorus	µg-P/L	0	1.5	0	1.0
Total nitrogen	µg-N/L	138	173	122	153
Total dissolved nitrogen	µg-N/L	130	166	105	133
Total ammonia	µg-N/L	11	17	0	6
Nitrate(a)	µg-N/L	0	15.2	0	2.0
Nitrite(a)	µg-N/L	0	2	0	2
Nitrate + nitrite	µg-N/L	5	10	0	1
Chlorophyll *a*	µg/L	-	-	0.31	0.82
Phytoplankton biomass	mg/m^3	-	-	19.1	384.7
Zooplankton biomass as AFDM	mg/m^3	-	-	16.4	40.5

Source: *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).

(a) Normal ranges for water chemistry (Table 4-1 in Golder 2019b) were used for nitrate and nitrate; normal ranges for these variables were not derived for Eutrophication Indicators (i.e., Table 4-2 in Golder 2019b).

AFDM = ash-free dry mass; µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre; - = not applicable.

2.3.7 Role of Nitrogen in Spatial Extent of Chlorophyll a

The 25 March 2019 WLWB Directive regarding the *2014 to 2016 Aquatic Effects Re-evaluation Report* required DDMI to include a spatial analysis of TN across the spatial extent of increased chlorophyll *a* in Lac de Gras. This directive was addressed in Section 5.3.5.3 of the *2014 to 2016 AEMP Re-evaluation*

Report Version 1.1 (Golder 2019c) using data available for all AEMP monitoring years up to 2016. The evaluation indicated that although moderate to strong relationships were detected between TN and chlorophyll *a* in 2007 to 2013, similarly strong relationships were found between TDS and chlorophyll *a*, and TDS and TN were also correlated. Given the strong P limitation expected in Lac de Gras based on the TN:TP ratio, it was considered unlikely that N would be the limiting nutrient; rather, the strong correlation between chlorophyll *a* concentration and TDS suggested a Mine-related nutrient enrichment effect related to an increase in micronutrients associated with TDS. To address this recommendation, relationships among these variables were evaluated in the 2019 open-water data set by calculating Pearson correlation coefficients.

2.3.8 Effects from Dust Deposition

Concerns have been raised regarding the potential for dust emissions from the Mine to affect water quality in Lac de Gras. To address these concerns, an analysis of effects at stations potentially affected by dust emissions was conducted. Based on the analysis conducted for the last re-evaluation, the zone of influence from dust deposition in Lac de Gras is estimated to be approximately 4.2 km from the geographic centre of the Mine (Mine centroid), or approximately 1.5 km from the boundary of the Mine footprint, extending radially from the source (Golder 2019c)[1]. These distances were estimated based on gradient analysis of dust deposition relative to distance from the Mine site and encompass the area of the lake where potential effects would be expected to be measurable (Golder 2019c). Beyond this estimated zone, dust deposition levels are similar to background levels. The AEMP sampling stations that fall within the expected zone of influence (ZOI) from dust deposition include the five stations in the NF area and stations MF1-1, MF2-1, MF3-1 and MF3-2.

To assess potential effects from dust emissions on nutrient enrichment in Lac de Gras, TP and chlorophyll *a* concentrations at stations within the estimated ZOI from dust deposition were evaluated visually, by comparing to results at other nearby stations outside the ZOI, and to reference conditions for Lac de Gras as defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). This comparison was only done on the open-water season data, because dust deposition to lake water under ice is prevented by ice cover during winter. If TP or chlorophyll *a* concentrations at the dust-affected MF stations (i.e., MF1-1, MF2-1, MF3-1 and MF3-2) are elevated beyond the expected range (i.e., the normal range) based on exposure to effluent alone, this may indicate a potential additional effect from dust deposition.

Chlorophyll *a* was included in this assessment because, as demonstrated by years of monitoring in Lac de Gras, concentrations of TP do not predict the actual biological response to nutrient enrichment (Golder 2016a, 2019c). Rather, the increase in the biomass of algae as measured by chlorophyll *a* has been a useful measure of the effects of nutrient enrichment.

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[1] Attachment D suggests a larger dust ZOI when the new control-assessment stations are considered. The dust ZOI will be re-evaluated as part of the analysis in the 2017 to 2019 Aquatic Effects Re-evaluation Report. For the 2019 AEMP analysis, stations in the NF and MF1-1, MF2-1, MF3-1, MF3-2 are still the most highly exposed stations to dust deposition of all of the AEMP stations, and therefore would show any deposition effects the most; therefore, these stations were the focus of the dust deposition analysis.

2.3.9 Action Level Evaluation

The severity of effects to an assessment endpoint was categorized according to the Action Level framework described for indicators of eutrophication in the *AEMP Design Plan Version 4.1* (Golder 2017a). The Action Level classifications were developed to meet the goals of the draft *Guidelines for Adaptive Management – A Response Framework for Aquatic Effects Monitoring* (WLWB 2010) and Racher et al. (2011). The main goal of the Response Framework is to ensure that significant adverse effects never occur. This is accomplished by requiring proponents to take actions at predefined Action Levels, which are triggered well before significant adverse effects could occur.

The Significance Threshold for the indicators of eutrophication is a concentration of chlorophyll *a* that exceeds the Effects Threshold by more than 20% in the FFA area of Lac de Gras (Table 2-4; Golder 2017a). In contrast to linking toxicological impairment responses to water chemistry (e.g., from elevated concentrations of metals), eutrophication responses are difficult to link to nutrient concentrations. As demonstrated by years of monitoring in Lac de Gras, concentrations of TP do not predict the actual biological response to nutrient enrichment. Rather, the increase in the biomass of algae as measured by chlorophyll *a* has been a useful measure of the effects of nutrient enrichment.

Elevated concentrations of nutrients were predicted in Lac de Gras (Government of Canada 1999). Specifically, up to 20% (i.e., 116 km^2) of the surface area of Lac de Gras was expected to exceed the EA Benchmark for phosphorus during peak operations during the open-water season, and up to 11% (i.e., 64 km^2) of the lake during the ice-cover season. Outside these areas, TP concentration was predicted to increase relative to baseline in parts of Lac de Gras, but concentrations would remain below the EA Benchmark. The “extent of effect” for the chlorophyll *a* Action Levels reflects this prediction (Table 2-4).

A box-and-whisker plot was generated for chlorophyll *a* to present the 2019 results relative to Action Level threshold values.

Table 2-4 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 2019b).

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.

Given that an Action Level 2 for chlorophyll *a* has been triggered in previous years (Golder 2016b,c, 2017c), an Effects Benchmark for chlorophyll *a* was developed as part of *AEMP Study Design Version 3.5* (Golder 2014). The chlorophyll *a* Effects Benchmark concentration of 4.5 µg/L is appropriate in terms of both the aesthetic quality and food web functionality in Lac de Gras. Aesthetic qualities are likely to be preserved at chlorophyll *a* concentrations up to 10 µg/L, while a benchmark of 4.5 µg/L maintains the trophic classification of the lake as oligotrophic (Golder 2017a).

2.3.10 Cumulative Effects

A spatial gradient approach was used to evaluate potential cumulative effects in Lac de Gras from the Ekati and Diavik Mines per *AEMP Design Plan Version 4.1* (Golder 2017a). Effects were assessed for eutrophication indicators along the gradient of exposure at stations in the MF3, FFB, and FFA areas and at Station LDG-48. Only variables that are consistently measured by both AEMP programs in Lac de Gras were included in the cumulative effects assessment. These variables included TP, SRP, TKN, nitrate, nitrite, and total ammonia.

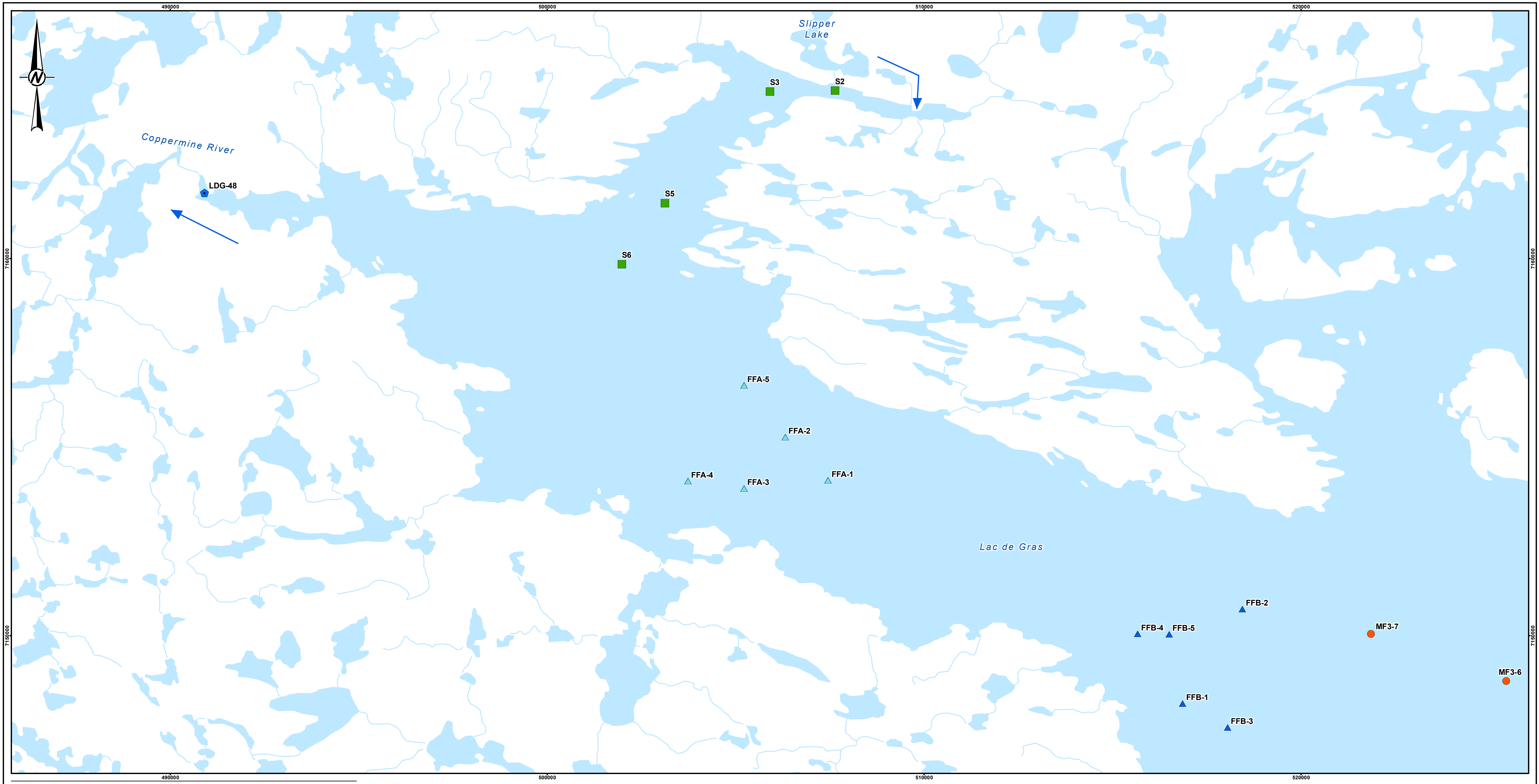
Effluent from Ekati mine is discharged to the Long Lake Containment Facility (LLCF) and flows through several small lakes, eventually to Slipper Bay, which is located at the northwest end of Lac de Gras (Figure 2-2). The effluent discharge from the Ekati mine could, therefore, influence water quality in the northwest portion of Lac de Gras. Given that the primary direction of water flow in Lac de Gras is from east to west, the concentration of a substance released via the Diavik effluent would be expected to decrease with distance from the effluent diffusers, with the lowest concentrations occurring at the far northwest end of Lac de Gras, at the mouth of the Coppermine River (LDG-48). The presence of a spatial trend with distance from the Diavik diffusers that is reversed in the western part of the lake (based on data from the FFA, FFB and MF3 areas) would suggest that effluent from Ekati mine is potentially influencing the variable in question. This interaction would signal a potential cumulative effect, since it is known that the DDMI effluent is influencing water quality in Lac de Gras beyond the FFA area.

The Diavik AEMP results were qualitatively compared to Ekati mine's AEMP data collected at the Slipper Bay monitoring stations in Lac de Gras (i.e., S2, S3, S5 and S6) to further evaluate the potential contribution of Ekati mine to cumulative effects in Lac de Gras (Figure 2-2). As the 2019 Ekati mine data were not publicly available at the time of preparation of this appendix, the 2018 Ekati mine data were used in the comparisons to Diavik data collected in 2019. There is some potential that environmental factors (e.g., freshet and summer precipitation contributions to the watershed), or differences in effluent release (i.e., timing, loading rates, chemistry) between years and mines, and placement of sampling stations could interfere with the ability to draw conclusions based on these comparisons. These factors were considered in the interpretation of results.

Graphs were prepared to visually evaluate potential cumulative effects in Lac de Gras from the Ekati and Diavik mines. From east to west in Lac de Gras, areas and stations included in the plots were MF3, FFB (mid-lake), FFA (closest to the Ekati mine discharge via Slipper Lake) and LDG-48 (outlet to the Coppermine River). These stations were plotted against distance from the Diavik Mine effluent diffusers. Ekati mine stations (i.e., S2, S3, S5 and S6; Figure 2-2) were plotted separately from the Diavik Mine distance axis as these stations are associated with the Ekati mine effluent source, and do not lie along the Diavik Mine effluent concentration gradient. For reference purposes, the approximate location of the S6 station, which is the Ekati station located farthest into the body of Lac de Gras, was indicated with an arrow denoting its location along the Diavik Mine distance axis, and relative to the Diavik AEMP stations.

Magnitude of effects was evaluated by comparing the results to the normal range for Lac de Gras, as defined in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b).

Results for all available depths were plotted. Sampling depths for the Diavik AEMP are described in Section 2.1. The Ekati mine samples were collected in duplicate during both ice-cover and open-water seasons. During ice-cover, samples were collected at mid-depth and near the bottom (~2 m above the sediment water interface). During open-water, samples were collected at mid-depth and at a shallow depth (1 m below water surface).



LEGEND

🟩 EKATI STATION LOCATION

DIAVIK STATION LOCATIONS

△ FAR-FIELD A

▲ FAR-FIELD B

⬟ LAC DE GRAS OUTLET

● MID-FIELD 3

→ FLOW DIRECTION

— WATERCOURSE

▭ WATERBODY

0 3 6

1:100,000 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
LOCATIONS OF DIAVIK MINE AEMP SAMPLING STATIONS RELATIVE TO EKATI MINE AEMP SAMPLING STATIONS

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

PATH: I:\CLIENTS\DIAVIK\19115664\Mapping\Products\Fish\AEMP_2019\Fig2-2_2019_AEMP_SamplingStations_Ekati_Diavik_Rev0.mxd PRINTED ON: 2020-04-28 AT: 8:35:41 AM

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2.4 Quality Assurance/Quality Control

The *Quality Assurance Project Plan Version 3.1* (Golder 2017b) outlines the quality assurance (QA) and quality control (QC) procedures employed to support the collection of scientifically defensible and relevant data required to meet the objectives of the *AEMP Design Plan Version 4.1* (Golder 2017a). The QAPP is designed so that field sampling, laboratory analysis, data entry, data analysis, and report preparation activities produce technically sound and scientifically defensible results. A description of the QA/QC practices applied to the eutrophication indicators component of the 2019 AEMP and an evaluation of the QC data are provided in Attachment B. Data collected during the 2019 AEMP were considered to be of acceptable quality, with the exception of total ammonia as discussed below, and TDN)and TKN in the FFA and LDG-48 samples.

Data quality issues with total ammonia continue to be a concern, with incidental occurrences in blank samples, and relatively high variability between duplicate samples. As discussed in the *Effluent and Water Chemistry Report* (Appendix II), some of these issues may be related to the low DL used for total ammonia (0.005 mg/L), which is at the absolute limit of instrument sensitivity. Therefore, concentrations measured close to the DL, which frequently occur in the eutrophication indicators dataset, are subject to large uncertainty.

As discussed in the *Effluent and Water Chemistry Report* (Appendix II), BV Labs identified a preservative contamination issue for total ammonia. As a result, the total ammonia data generated by BV Labs for the ice-cover season was invalidated, and the data generated by ALS was retained. During the open-water season, BV Labs analysed total ammonia in the unpreserved bottles, which generated acceptable data for all but four duplicate sets. These four duplicate sets included two field blanks, an equipment blank, and samples collected from station FF1-2. Although there were open-water total ammonia data from both BV Labs and ALS, an interlaboratory comparison study conducted by BV Labs suggested that the total ammonia data generated by BV Labs had fewer data quality issues and should, therefore, be used for the data analysis. This suggestion was accepted and the total ammonia data generated by BV Labs for the open-water season was used in the 2019 AEMP data analysis.

Concentrations of TDN and dissolved Kjeldahl nitrogen (DKN) that were greater than TN and TKN concentrations were observed for several samples collected on 8 and 10 May 2019. Samples from FFA and LDG-48 appeared to be the most affected (i.e., mean concentrations of TDN and DKN were greater than expected). For example, concentrations were greater in the FFA area compared to the FFB area. Concentrations of TDN and TKN at LDG-48 during the ice-cover season were also greater than normal range, which was not consistent with previous years (e.g., 2014, 2015, 2018), when concentrations were within normal range at LDG-48. Therefore, the 2019 TDN and DKN concentrations for FFA and LDG-48 may be biased high. This was considered when interpreting the 2019 monitoring results.

2.5 Weight-of-Evidence Input

The results of the indicators of eutrophication survey are integrated through the weight-of-evidence (WOE) analysis to determine the strength of evidence supporting the two impact hypotheses for Lac de Gras (i.e., Nutrient Enrichment and Toxicological Impairment), as described in the *AEMP Design Plan Version 4.1* (Golder 2017a). The WOE is not intended to determine the ecological significance or level of concern associated with a given change. The WOE analysis is described fully in the *Weight-of-Evidence*

Report (Appendix XV). The methods as applied to the indicators of eutrophication survey are described in Section 2 of the *Weight-of-Evidence Report* (Appendix XV).

3 RESULTS

3.1 Nutrients in Effluent and the Mixing Zone

From November to April, monthly loads of TP generally followed concentrations in effluent with larger loads between December and March when effluent concentrations were greatest (Figure 3-1). Starting in May, the magnitude of the monthly loads appeared to follow effluent volume (i.e., NITWP flow) more than effluent concentration. For example, TP load was greatest in May when flow rate started to increase, and TP load in August was similar to that of November and April despite smaller effluent concentrations. Concentrations at the mixing zone boundary followed effluent concentrations, with greater concentrations between December and March.

The monthly TP load did not exceed the 300 kg/mo loading criterion, with the greatest monthly load of TP (32 kg) occurring in May 2019. The annual TP load in 2019 (279 kg) was below the average annual loading criterion of 1,000 kg defined in the Water Licence (W2015L2 0001; WLWB 2015), and much lower than the maximum annual loading criterion of 2000 kg. The annual TP load in 2019 was also less than the annual TP load in 2018 (375 kg).

Monthly loads of TDP did not follow the same pattern as TP, in that monthly TDP loads were more similar during the ice-cover season and load did not decrease in October. However, lower TDP loads occurred in the open-water season compared to the ice-cover season, which followed the magnitude of TDP in effluent (i.e., concentrations in effluent were lower during the open-water season; Figure 3-2). Concentrations at the mixing zone boundary followed the pattern in effluent, with greater concentrations in December, February, and March.

For SRP, monthly loads and concentrations in effluent followed a similar pattern to TP, but concentrations and at the mixing zone boundary followed a similar pattern to TDP (Figure 3-3).

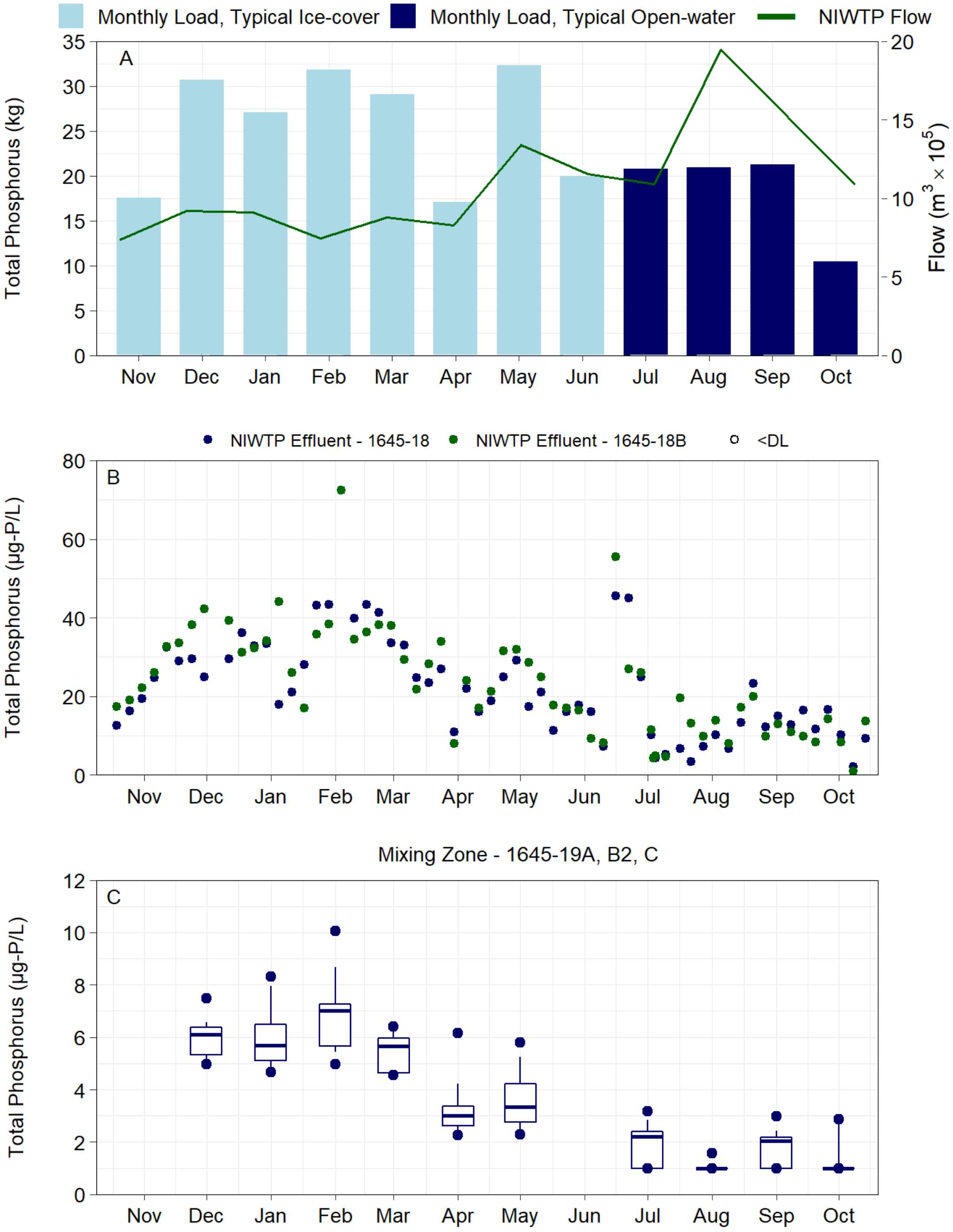
Total nitrogen concentrations and loads in effluent tracked closely together, and followed a similar trend to effluent volume (Figure 3-4 to Figure 3-7). Monthly TN loads were similar or greater in 2019 compared to 2018. Most of the TN was present as nitrate in the effluent (Figure 3-4 and Figure 3-5). Monthly loads and concentrations of TN and nitrate in effluent were smallest during the ice-cover season and steadily increased from February to September (Figure 3-4 and Figure 3-5). Median TN and nitrate concentrations at the mixing zone boundary were approximately equal between seasons, with the exception of a trend of increasing concentrations from April to May, and the lowest median concentrations in July (Figure 3-4 and Figure 3-5).

Monthly loads and concentrations of nitrite in effluent followed the same pattern as for TN and nitrate, with the exception of September (Figure 3-6). Concentrations in effluent declined from July to September, and monthly load in September reflected the lower concentrations in effluent. Nitrite concentrations at the mixing zone boundary followed the pattern in effluent, except in September when mixing zone boundary concentrations were greater.

Total ammonia monthly loads and concentrations in effluent did not follow the same pattern as the other nitrogen species. Loads generally followed effluent volume for most months (Figure 3-7). Concentrations in effluent were greatest in November and December, declined in January, increased until May, then sharply declined in July, peaking again in August. The smallest monthly load was in July, which corresponded to the smallest concentrations in effluent. Concentrations at the mixing zone boundary generally followed those in effluent, except in September when concentrations were greater than in August.

The decreases in concentrations of TN, nitrate, nitrite, and total ammonia between May and July at the mixing zone boundary (Figure 3-4 to Figure 3-7) reflects quick assimilation by algae and bacterial nitrification (Wetzel 2001) during the shift between the seasons.

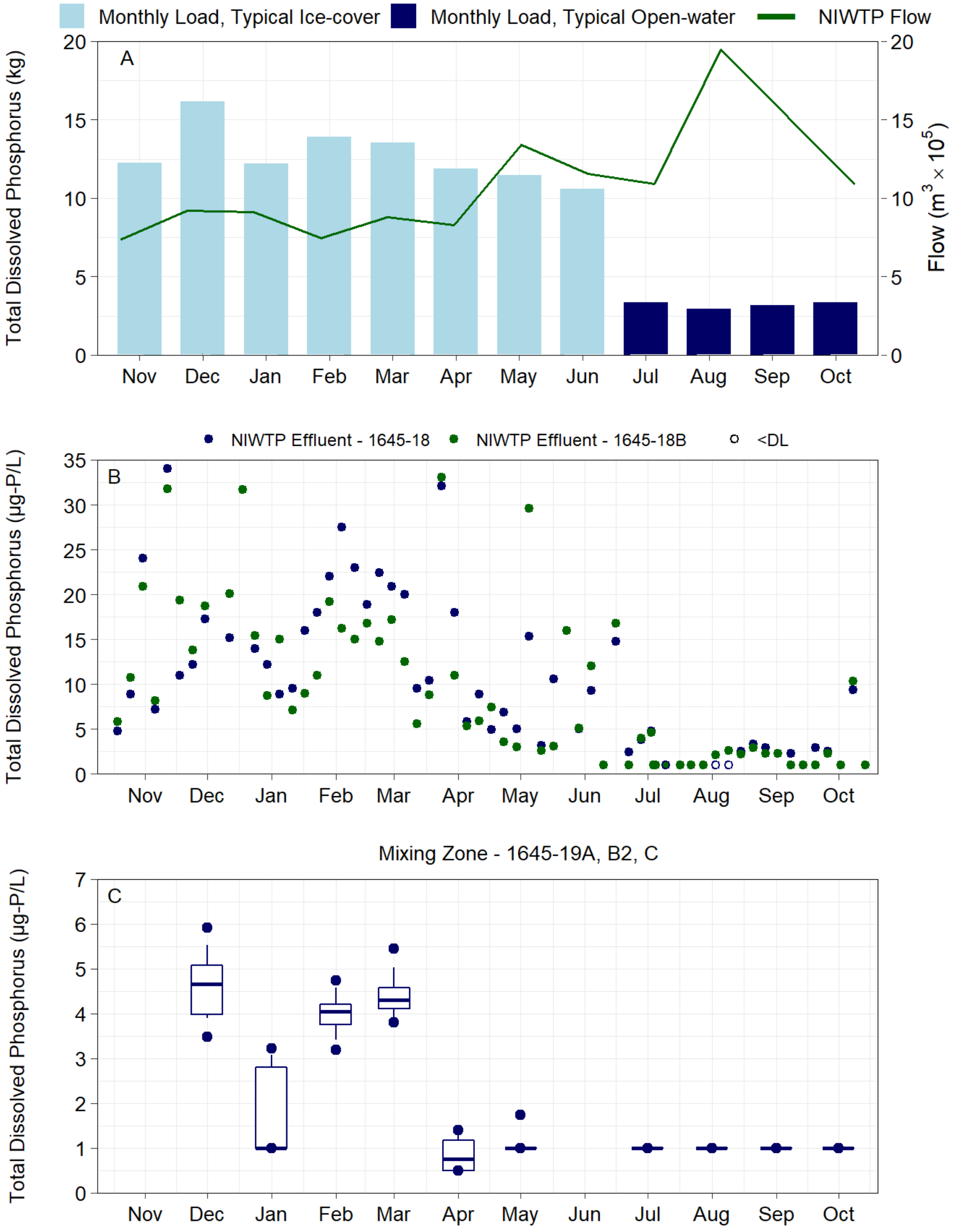
Figure 3-1 **Total Phosphorus: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019**



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.

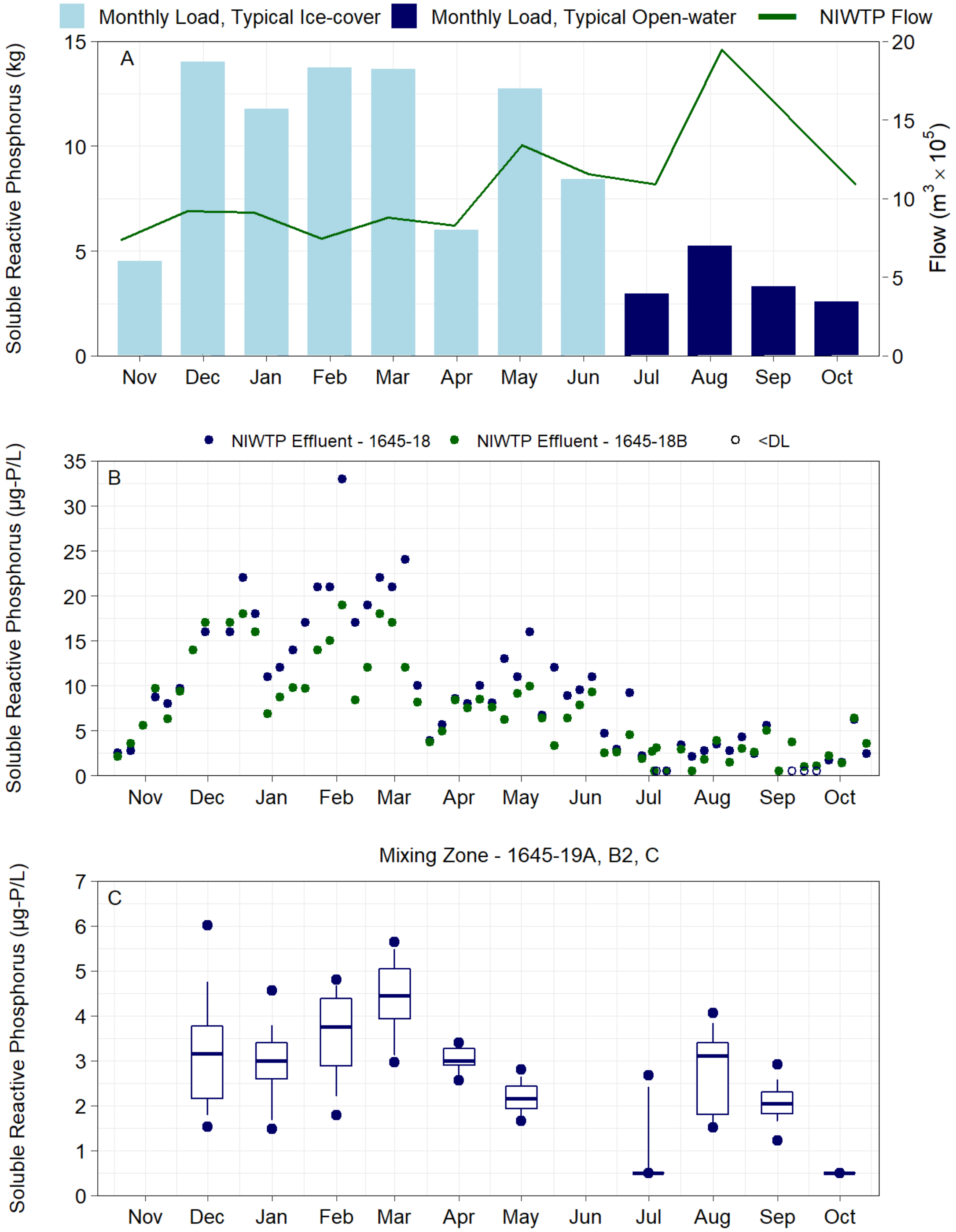
Figure 3-2 **Total Dissolved Phosphorus: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019**



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.

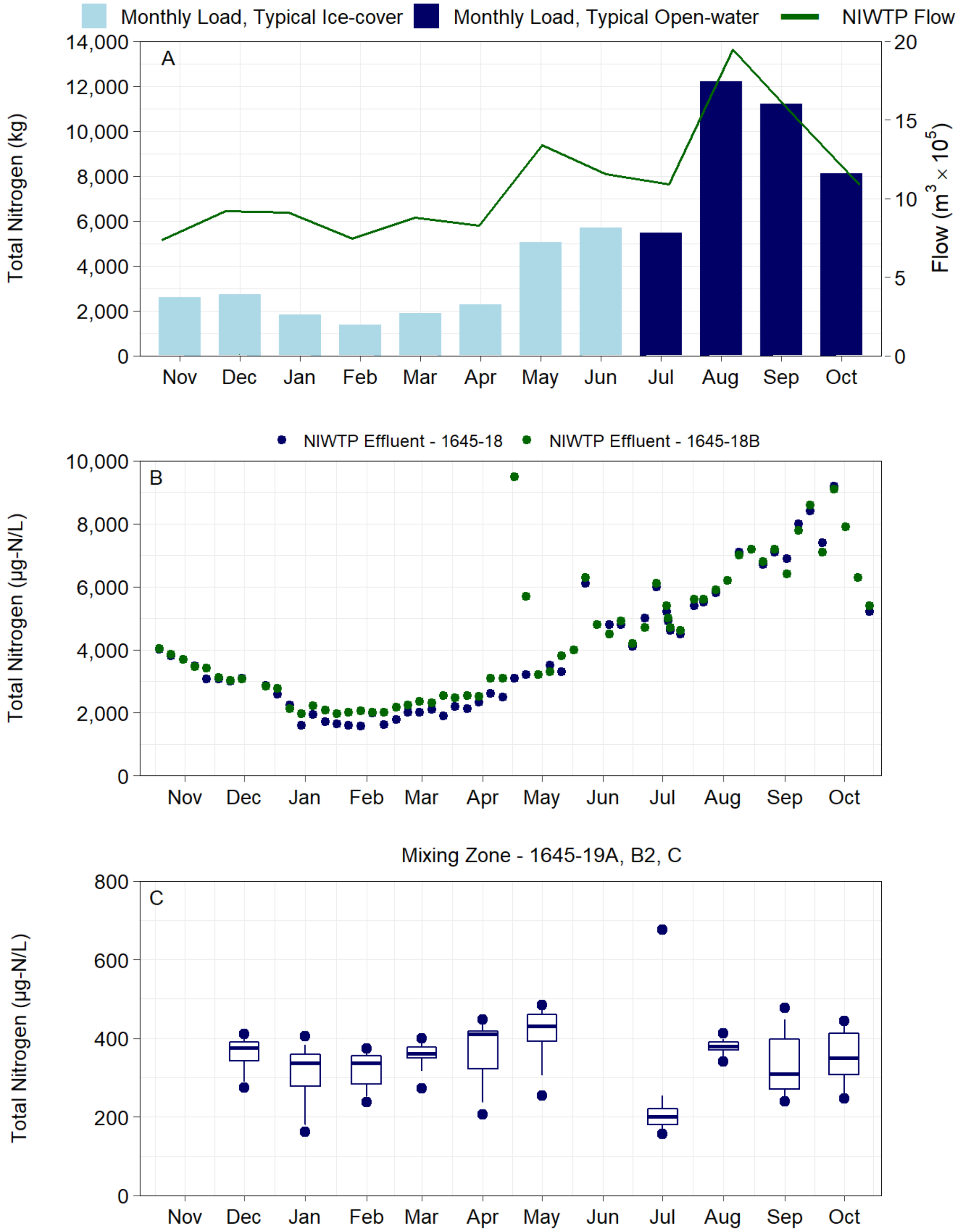
Figure 3-3 Soluble Reactive Phosphorus: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019



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

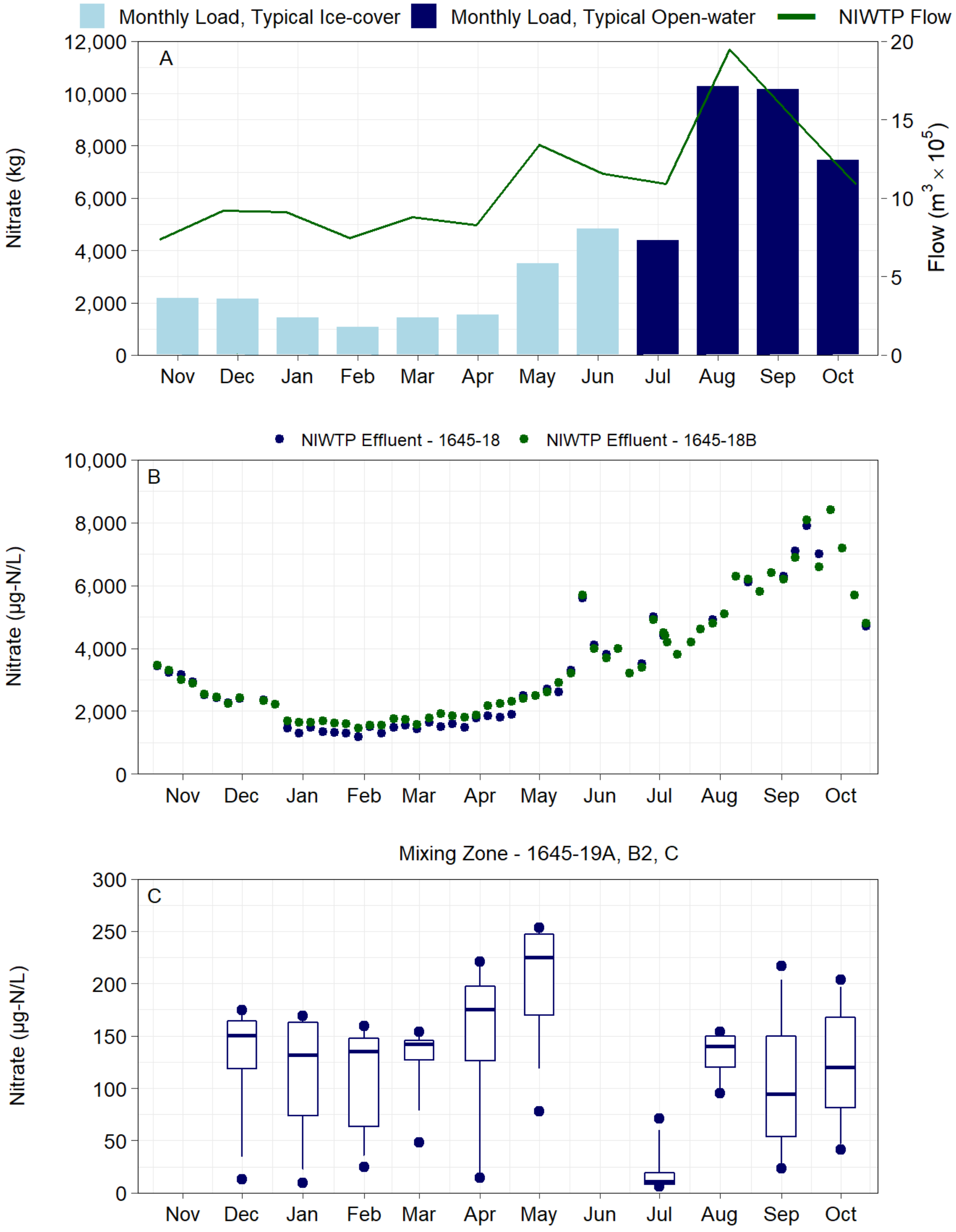
Figure 3-4 Total Nitrogen: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019



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.

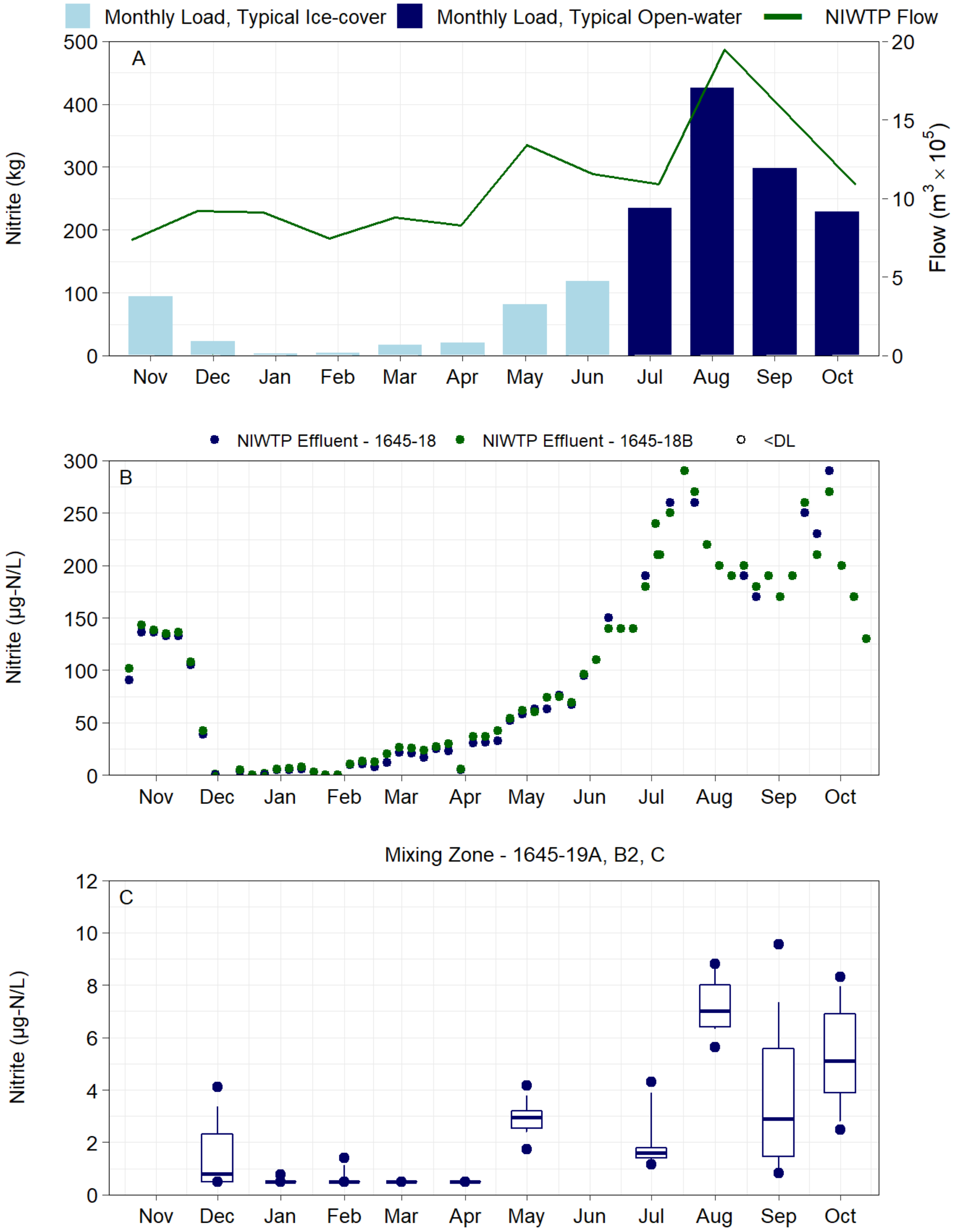
Figure 3-5 **Nitrate: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019**



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.

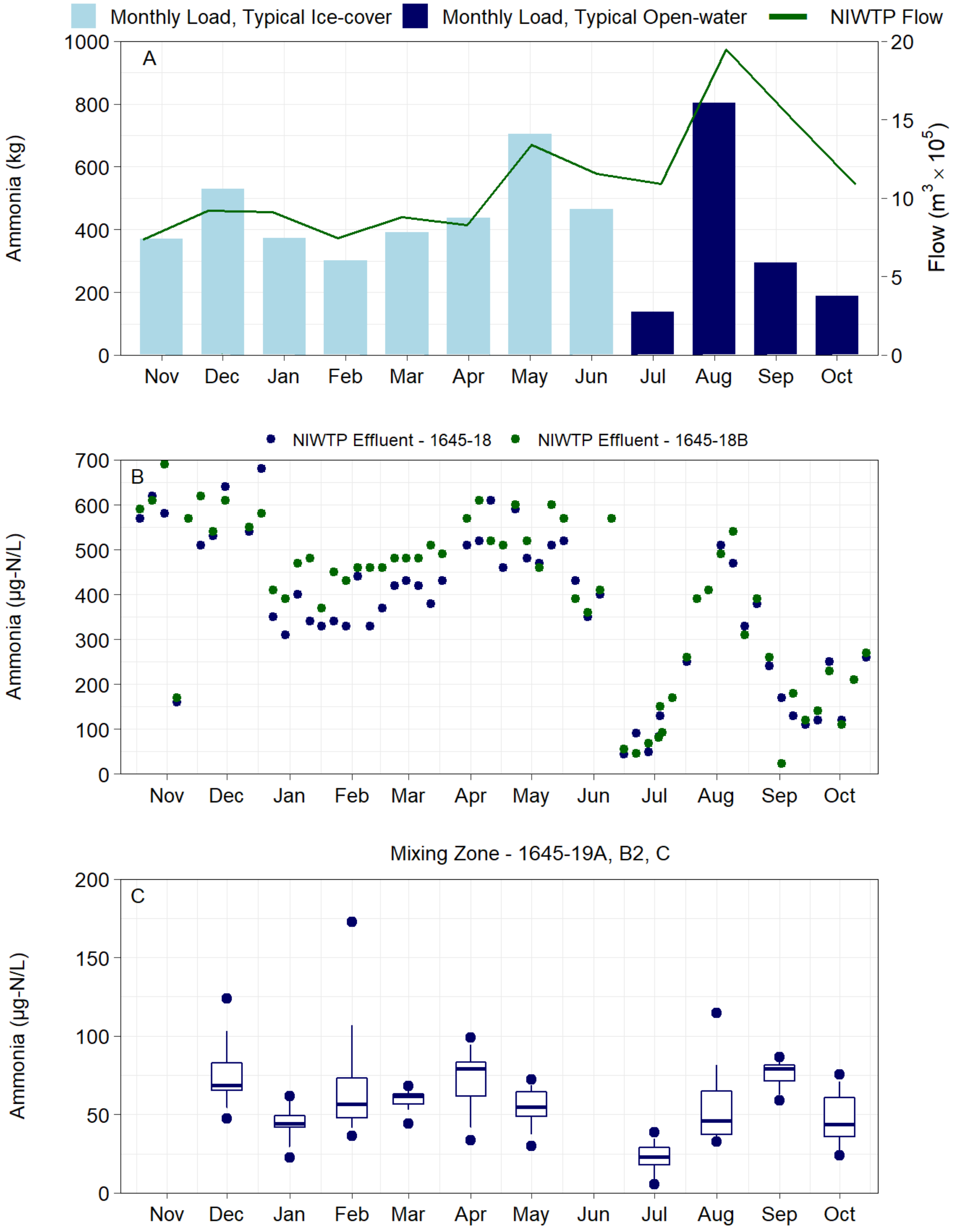
Figure 3-6 Nitrite: A) Monthly Loads in the Effluent, B) Concentrations in the Effluent, C) at the Mixing Zone Boundary, November 2018 to October 2019



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; <DL = less than detection limit.

Figure 3-7 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.

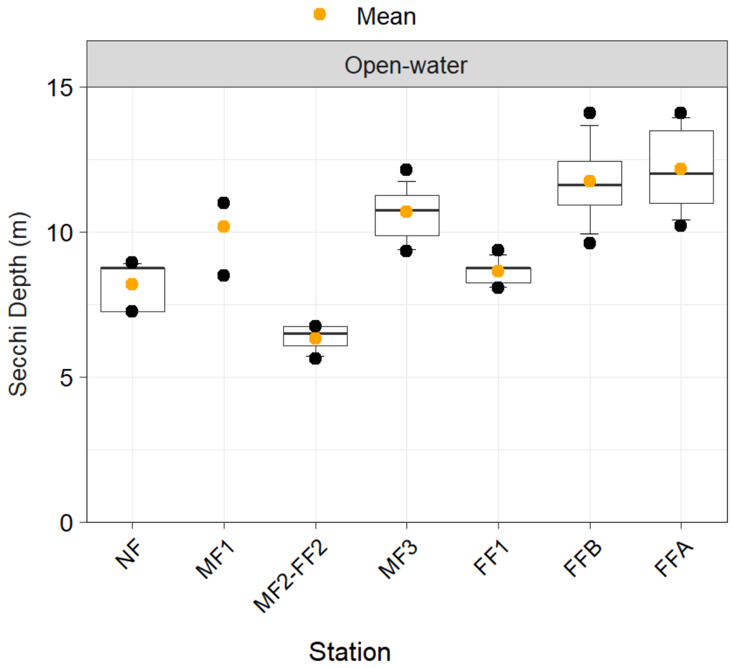
µg-N/L = micrograms nitrogen per litre; NIWTP = North Inlet Water Treatment Plant

3.2 Secchi Depth

The Secchi depth corresponds to the depth at which approximately 10% of surface light remains (Dodds and Whiles 2010). The euphotic zone extends to a depth where approximately 1% of surface light remains, often estimated as twice the Secchi depth (Dodds and Whiles 2010). In less productive (i.e., oligotrophic) waterbodies like Lac de Gras, with low amounts of suspended or dissolved material, light is transmitted to greater depths (Dodds and Whiles 2010). Secchi depth data are useful to estimate the extent of the euphotic zone where sufficient light is available for phytoplankton, and provide an indirect measure of algal biomass in the water column.

Secchi depth measurements indicated good light penetration throughout Lac de Gras. Secchi depth was between 5.5 and 14.5 m during the open-water season in 2019 (Figure 3-8). Mean Secchi depth was highest in the FFA area (12.2 m), and lowest in the MF2-FF2 area (6.3 m). Given the Secchi depths measured in Lac de Gras, a large proportion of the total volume of this lake is within the euphotic zone and can support phytoplankton growth.

Figure 3-8 Secchi Depth in Lac de Gras during the Open-Water Season, 2019



Notes: Station FFB-2 did not have the Secchi depth reported in 2019 and is not included in the plot. Secchi depth was not measured at LDS stations and at LDG-48. The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles.

LDS = Lac du Sauvage; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet.

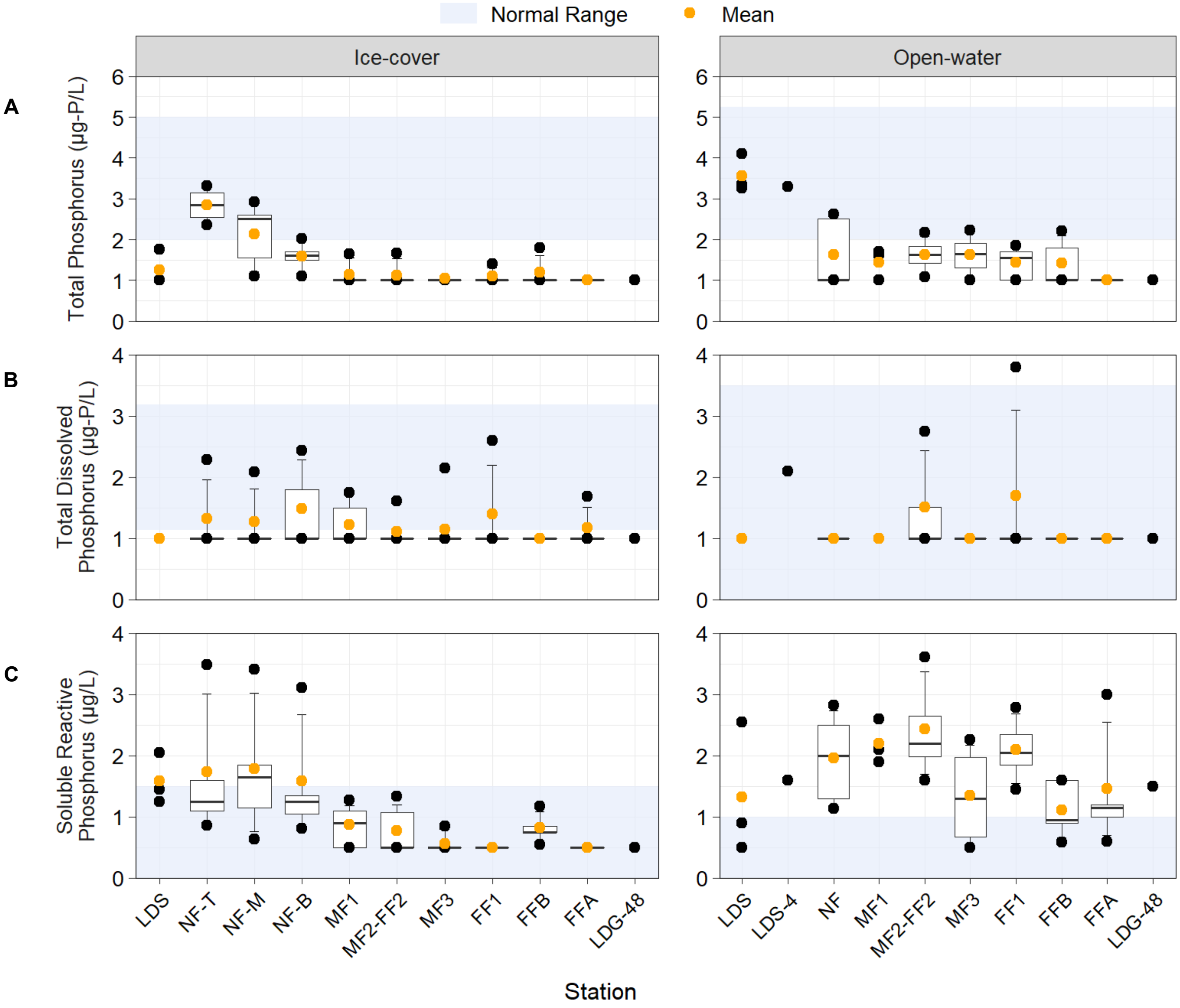
3.3 Nutrients in Lac de Gras

Concentrations of TP were within or below normal range at all stations during the ice-cover and open-water seasons (Figure 3-9A). During the ice-cover season, TP concentrations were generally greatest in the NF area, and generally below the DL of 2 µg-P/L in all other areas (Figure 3-9A). During the open-water season, TP concentrations were greatest in LDS (Lac du Sauvage) and LDS-4 (Lac du Sauvage outlet), and smallest at FFA and LDG-48 (outlet of Lac de Gras) (Figure 3-9A).

Similar to TP, TDP concentrations were infrequently detected during both the ice-cover and open-water seasons. During the ice-cover season, all detected concentrations were within or below normal range at all stations (Figure 3-9B). During the open-water season, all detected concentrations were within or below the normal range with the exception of FF1-5 (Figure 3-9B). Concentration of TDP at LDG-48 was below the DL of 2 µg-P/L for both the ice-cover and the open-water seasons (Figure 3-9B).

In contrast to TP and TDP, concentrations of SRP were more frequently detected due to its lower DL (1 µg/L for SRP compared to 2 µg/L for TP and TDP). However, concentrations were low (i.e., within five times the DL). During the ice-cover season, SRP concentrations at some NF stations exceeded the normal range, while all concentrations in the MF and FF areas were within normal range (Figure 3-9C).

Figure 3-9 **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. As noted in Section 2.4 and Attachment B, 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.

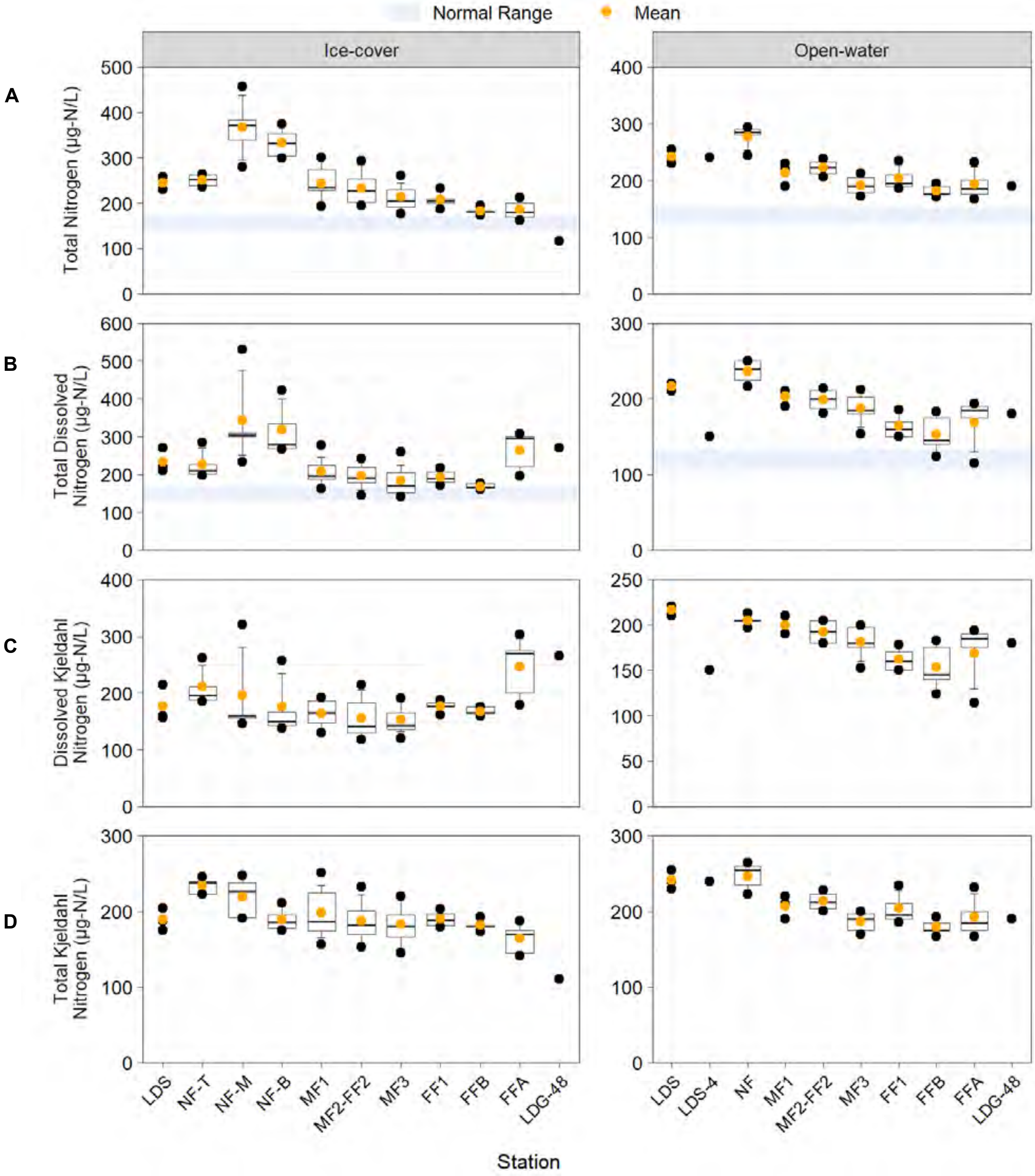
µg/L = micrograms per litre; µg-N/L = micrograms nitrogen per litre; µg-P/L = micrograms phosphorus per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth;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

Concentrations of TN and TDN in the NF area were greater during ice-cover than during open-water (Figure 3-10A,B). During the ice-cover season, TN and TDN concentrations were greater in the NF area at the middle and bottom depths compared to the top depths, reflecting the discharge of effluent to the bottom of the water column. Concentrations of TN and TDN were generally at or above normal range, with the greatest concentrations in the NF area and concentrations decreasing with distance from the diffuser. During the open-water season, TN and TDN concentrations were also greatest in the NF area, were generally above the normal range, and decreased with distance from the diffuser. Concentrations of TN and TDN in Lac du Sauvage were similar to those in the MF1 area during the ice-cover season. During the open-water season, concentrations of TN in Lac du Sauvage and its outlet were similar to those in the NF area, whereas TDN concentrations were more similar to the FF areas. Concentrations of TKN and DKN generally followed the same patterns as TN and TDN, respectively (Figure 3-10C,D).

As noted in Section 2.4 and Attachment B, the TDN and DKN results for FFA and LDG-48 during the ice-cover season are suspected to be biased high. Concentrations of TDN and DKN were greater than the corresponding TN and TKN concentrations for these two areas (Figure 3-10). Also, mean concentration in the FFA area was greater than in the FFB area. At LDG-48, TDN concentrations were greater than the normal range during the ice-cover season, which is not consistent with previous AEMP results (i.e., 2014, 2015, and 2018), when concentrations were lower at this station.

During the open-water season, TN, TDN, TKN, and DKN concentrations at LDG-48 were similar to mean concentrations in the FFA area (Figure 3-10).

Figure 3-10 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.

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.

Nitrate and nitrate + nitrite concentrations followed the same pattern as TN, with the greatest concentrations measured in the NF bottom and middle depths during ice-cover season (Figure 3-11A,C). Concentrations decreased with distance from the diffuser. Most concentrations were greater than the normal range. Concentrations of nitrate and nitrate + nitrite at LDG-48 were similar to those at FFB during the ice-cover season and not detected during the open-water season. Nitrate and nitrate + nitrite concentrations at LDS were similar to those in the MF areas during the ice-cover season, and were not detected during the open-water season.

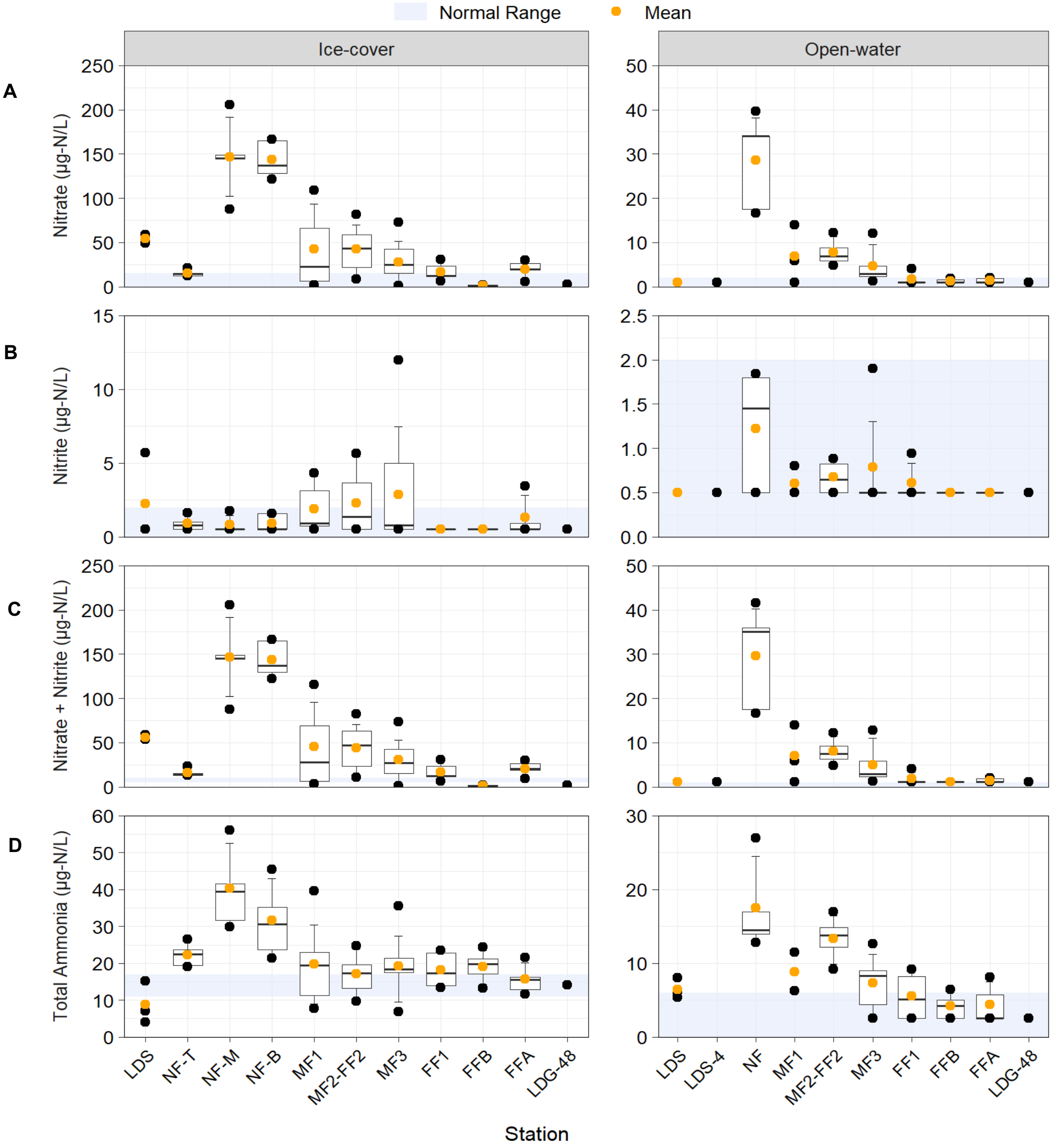
As with TN, TDN, and total ammonia, nitrate concentrations were substantially greater during the ice-cover season compared to the open-water season. This pattern is commonly observed, because concentrations decline as algae assimilate the dissolved nutrients for growth during the open-water season (Wetzel 2001).

Nitrite concentrations were much lower than nitrate concentrations, and did not follow the same pattern. Nitrite concentrations during the ice-cover season were similar among depths in the NF area, and generally lower than in the MF areas (Figure 3-11B). During the ice-cover season, more than half of the stations in the MF area had nitrite concentrations that were above the normal range, with a few FFA stations also above normal range. However, most nitrite concentrations were within five times the DL of 1 µg-N/L. During the open-water season, all nitrite concentrations were at or near the DL and within the normal range (Figure 3-11B). Nitrite was detected at one station in LDS (i.e., LDS-3M) during the ice-cover season but otherwise was not detected in either season. Nitrite was not detected at LDG-48 during either season.

Total ammonia concentrations followed the same pattern as nitrate (Figure 3-11D). Most total ammonia concentrations were greater than the normal range during the ice-cover season. During the open-water water season, most total ammonia concentrations in Lac de Gras were greater than the normal range in the NF and MF areas, but ammonia was not frequently detected in the FF areas (DL = 5 µg/L). In LDS, concentrations were below those in Lac de Gras during the ice-cover season, and similar to those in the MF1 and MF3 areas in the open-water season. Total ammonia concentrations at LDG-48 during the ice-cover season were similar to those in the MF and FF areas, and were among the smallest values reported in 2019 during the ice-cover season.

Concentrations of SRSi during the ice-cover season were greatest in the NF area at the middle and bottom depths, and were noticeably lower in the MF and FF areas, with the exception of greater concentrations at MF1-1 (Figure 3-12). Concentrations during the open-water season were lower in all areas and more variable, with greater concentrations in the NF and FF1 areas compared to the MF and other FF areas. Concentrations of SRSi in Lac du Sauvage were less than in the NF area but greater than the MF areas during the ice-cover season. During the open-water season, SRSi concentrations in Lac du Sauvage were noticeably greater than in Lac de Gras, with the exception of LDG-48, which had the highest measured SRSi in the open-water season. During the ice-cover season, SRSi concentration at LDG-48 was similar to the FFA area.

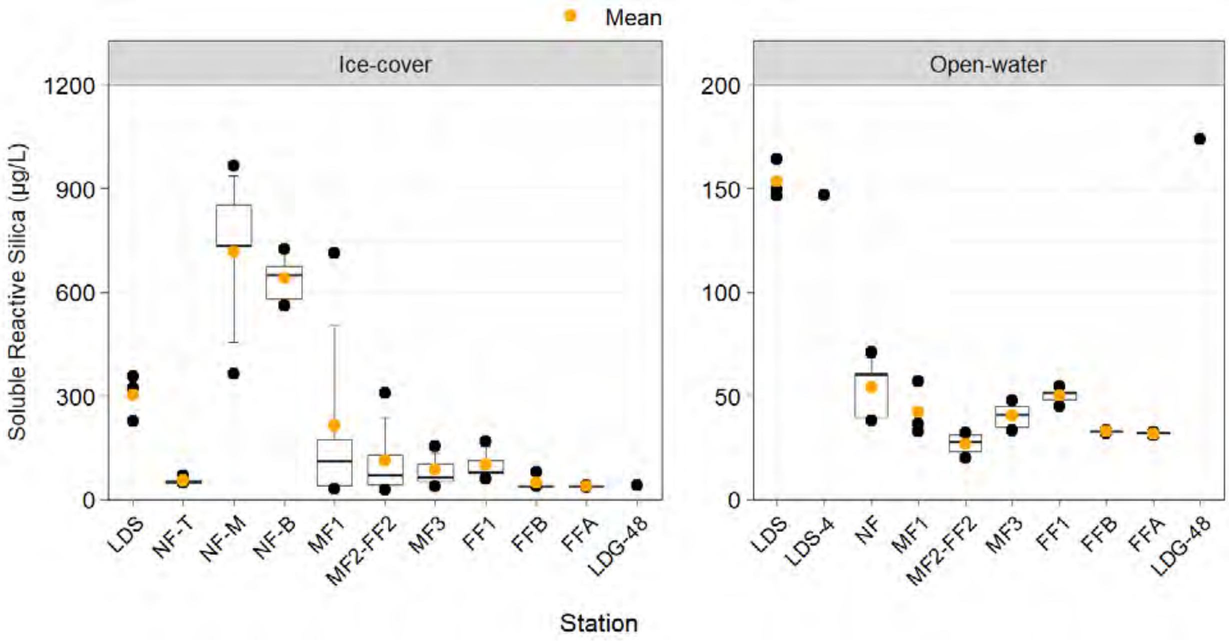
Figure 3-11 Concentrations of Nitrate (A), Nitrite (B), Nitrate + Nitrite (C) and Total Ammonia (D) in Lac de Gras during the Ice-Cover and Open-Water Season, 2019



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 3-12 **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.

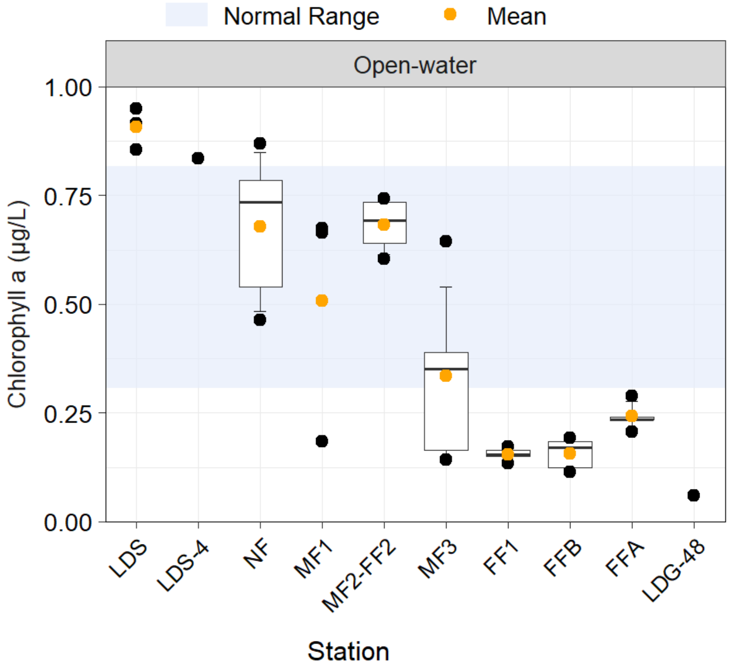
µg/L = micrograms per litre; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage Outlet (the Narrows); NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; T = top depth; M = middle depth; B = bottom depth.

3.4 Chlorophyll *a*, and Phytoplankton and Zooplankton Biomass

Chlorophyll *a* concentration was used as an indicator of phytoplankton standing crop (i.e., biomass) in Lac de Gras during the open-water season. Ice and snow reduce the amount of light entering the lake to a fraction of surface solar radiation; consequently, algal growth under ice-cover is limited by light and temperature, resulting in low chlorophyll *a* concentrations (Golder 2008). Therefore, chlorophyll *a* concentration is not measured at AEMP stations during the ice-cover season.

Chlorophyll *a* concentrations in Lac de Gras were within or below the normal range with the exception of station NF3 (Figure 3-13). Mean chlorophyll *a* concentrations at both the NF and MF areas were greater than concentrations in the FF areas and at station LDG-48. Concentrations in the MF2-FF2 area were greater than in the MF3 area. Chlorophyll *a* concentrations in Lac du Sauvage and the Lac du Sauvage outlet were above the normal range for lac de Gras, and likely influenced the concentrations in the MF2-FF2 area. The lowest chlorophyll *a* concentration was measured at LDG-48.

Figure 3-13 Chlorophyll *a* Concentrations in Lac de Gras during the Open-Water Season, 2019



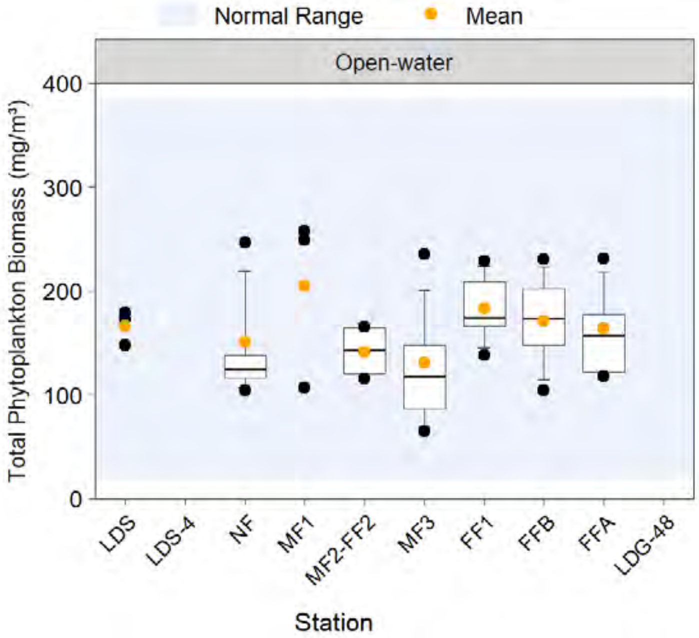
Notes: The black dots in the boxplots represent the 5th (on the bottom) and 95th (on the top) percentiles.

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.

Total phytoplankton biomass was within or below the normal range at all stations, and there were no apparent differences in biomass among sampling areas or between lakes (Figure 3-14). In 2019, nearly all biomass values were close to the lower boundary of the normal range. However, the QC evaluation of the phytoplankton data suggested that the 2019 data should be interpreted with caution (Appendix XI, Attachment A).

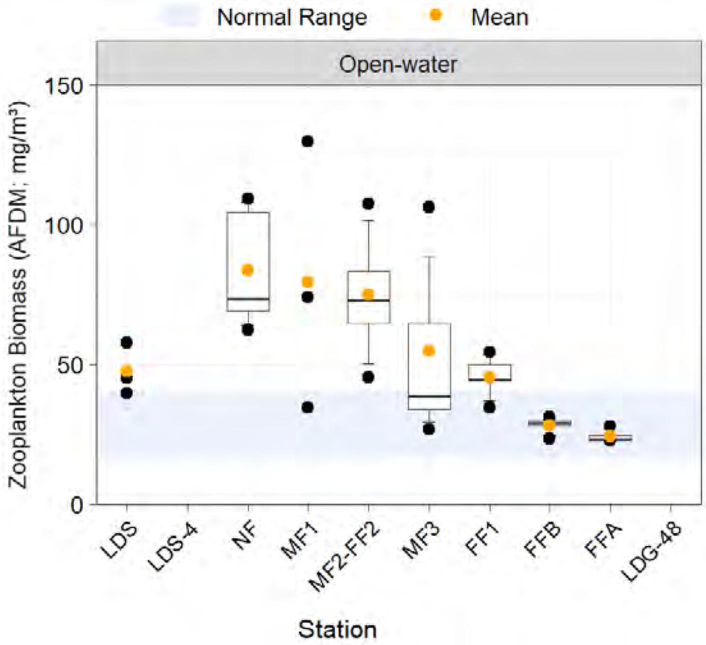
Mean zooplankton biomass (as AFDM) in the FFB and FFA areas was within the normal range, while mean zooplankton biomass in all other areas was above the normal range (Figure 3-15). Zooplankton biomass in the NF, MF1, and MF2-FF2 areas was greater than in Lac du Sauvage. Mean zooplankton biomass in Lac du Sauvage was similar to that in FF1 area. Mean zooplankton biomass was above the normal range in the NF, MF1, MF2-FF2, and FF1 areas, as well as in Lac du Sauvage.

Figure 3-14 Total Phytoplankton Biomass in Lac de Gras during the Open-Water Season, 2019



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 3-15 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.

3.5 Percent Change from Baseline and Previous Year

Per Directive 2D from the 25 March 2019 WLWB Decision regarding the 2017 AEMP, percent change values from the baseline median and the previous year (i.e., 2018) median value were calculated for each eutrophication indicator, by area (NF, MF1, MF2-FF2, MF3, and LDG-48) and season (ice-cover and open-water) (Attachment C Tables C-1 to C-16). The results indicate that median values of eutrophication indicators have generally increased in the NF area relative to baseline, consistent with EA predictions and interpretation of AEMP data during annual reporting. Further discussion of these results is provided in Attachment C.

3.6 Gradient Analysis

3.6.1 Secchi Depth

Secchi depth along the MF1 and MF2-FF2 transects appeared to decrease with increasing distance from the effluent discharge (Table 3-1), but the slope of the regression line for the MF1 transect was not significantly different from zero (Figure 3-16). The slope of the regression line for the MF2 transect was significantly different from zero. Secchi depth along the MF3 transect significantly increased with distance from the diffuser, which is consistent with reduced Secchi depth due to greater phytoplankton biomass (i.e., biovolume based on the taxonomy data) and chlorophyll *a* concentrations in the water column closer to the diffusers.

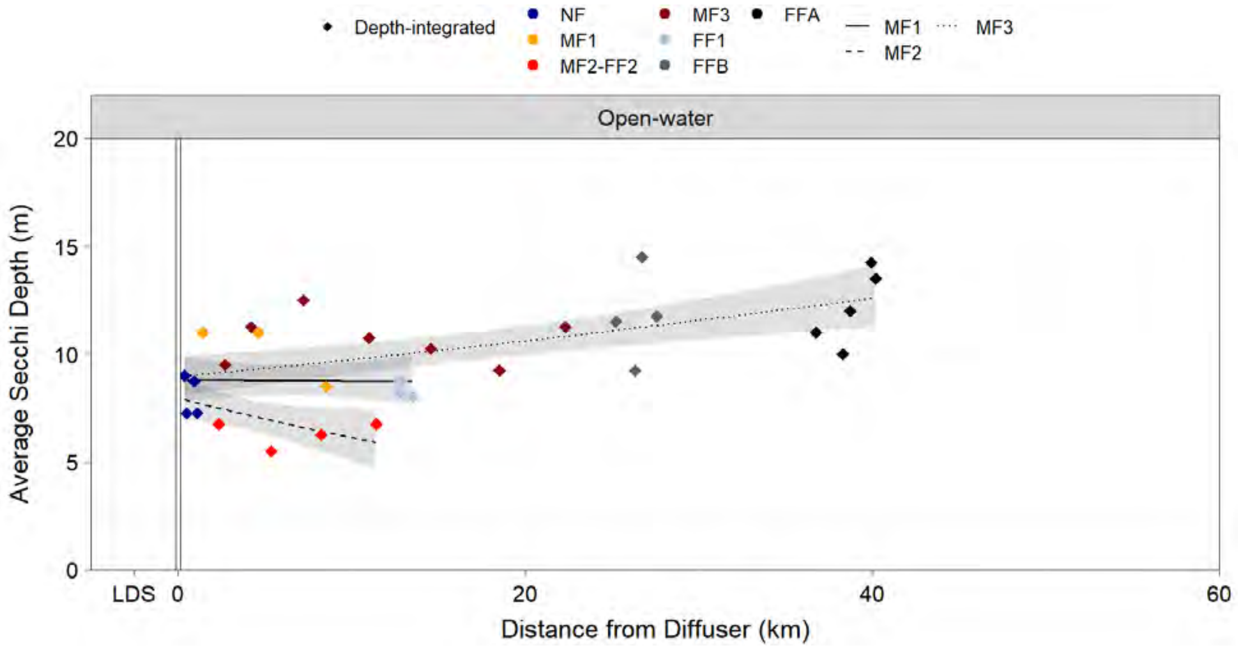
Table 3-1 Gradient Analysis Results for Secchi Depth during the Open-water Season, 2019

Variable	Model	Transformation[a]	Gradient	Slope[a]	*P*-value	R^2
Secchi Depth	Model 1	-	MF1	↓	0.924	0.58
			MF2	↓	0.045	
			MF3	↑	<0.001	

a) Slope direction was represented by an upward arrow (↑) indicating an increasing trend with distance from the effluent diffusers, or a downward arrow (↓) indicating a decreasing trend with distance from the effluent diffusers.

- = not applicable; MF = mid-field; *P* = probability; R^2 = coefficient of determination.

Figure 3-16 Secchi Depth in Lac de Gras According to Distance from the Effluent Discharge, 2019

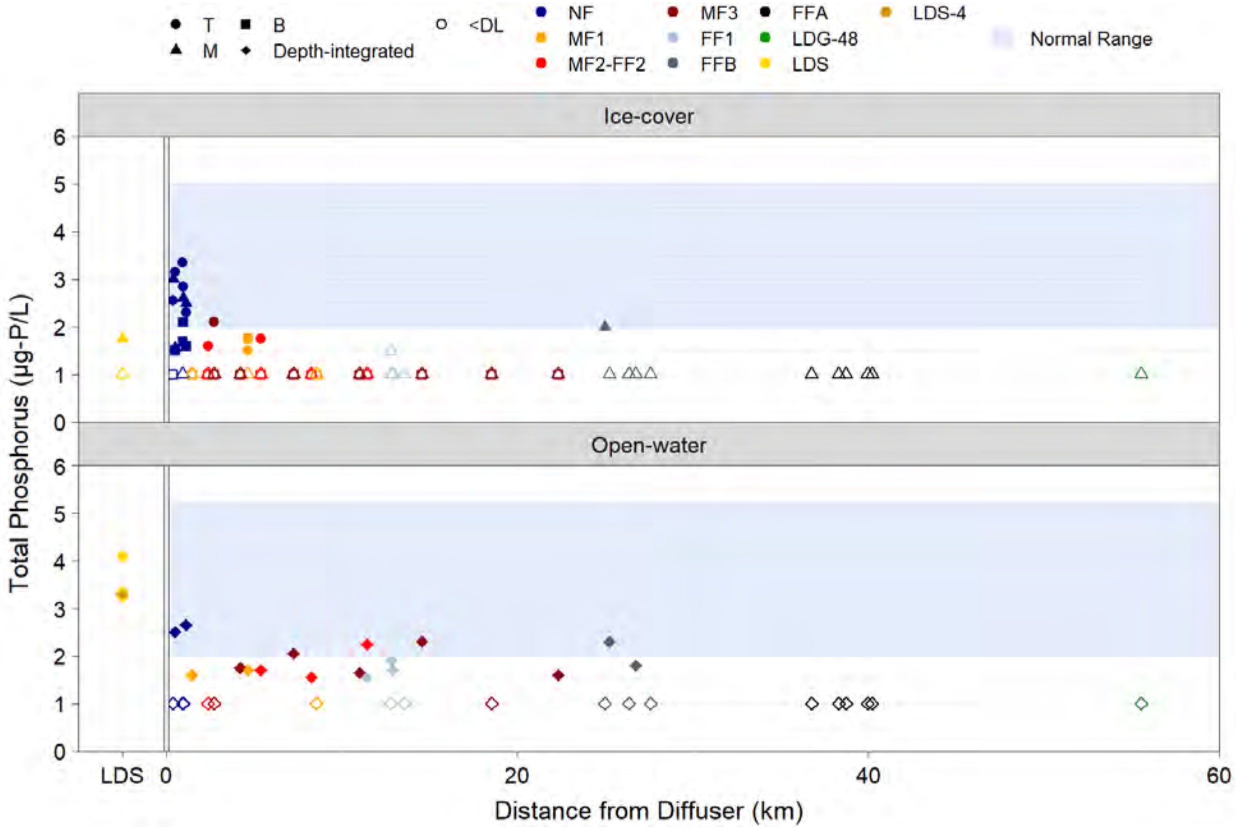


Note: Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage.

3.6.2 Nutrients

During the ice-cover and open-water seasons, TP concentrations were below the normal range at the majority of stations (Figure 3-17). Concentrations at all other stations were within the normal range. Spatial analysis was not done for TP because of the low detection frequency. During the ice-cover season, TP concentration was variable and elevated in the NF area and declined to near the DL at an approximately 5 km distance from the diffusers. During the open-water season, a spatial trend was not apparent, with the possible exception of a lack of detectable concentrations in the FFA area and at LDG-48, suggesting lower concentrations at stations farther from the diffusers.

Figure 3-17 Concentrations of Total Phosphorus in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



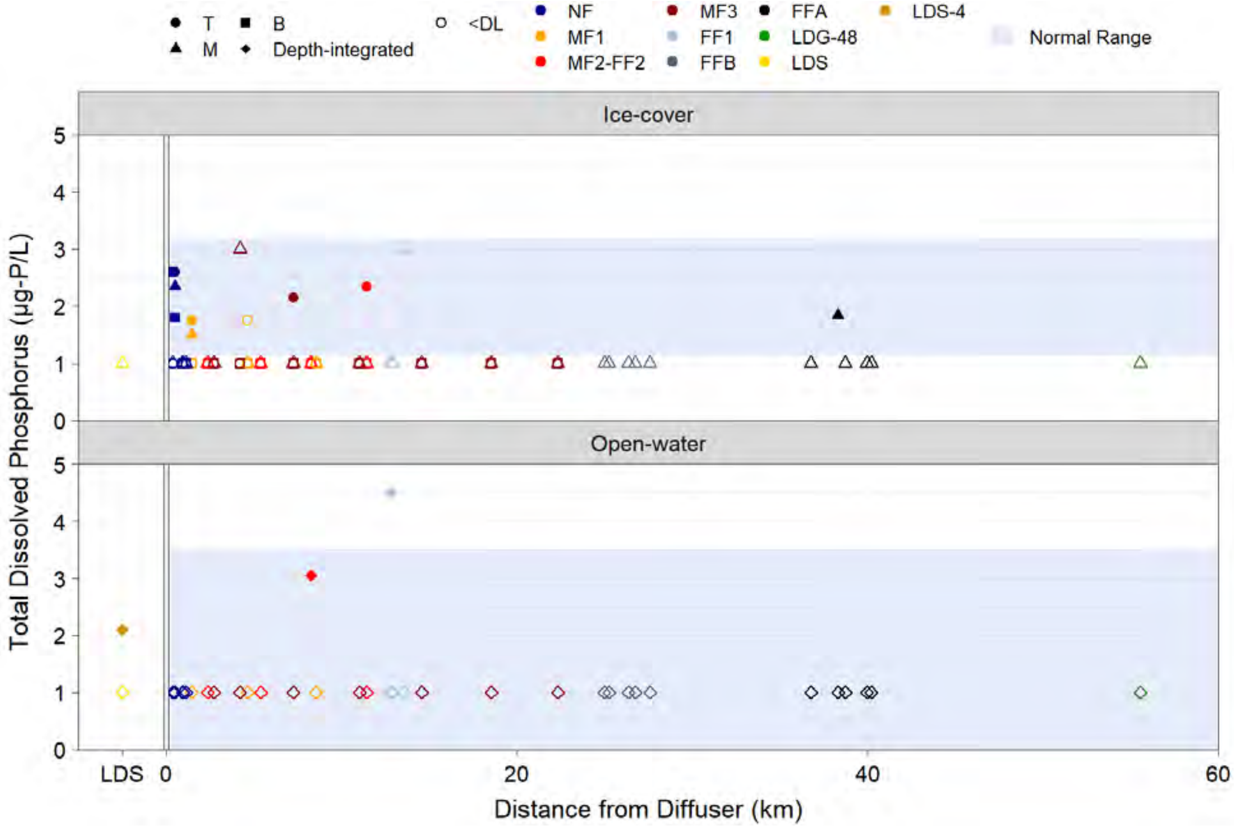
Note: Samples collected from Lac du Sauvage are presented to the right of the y-axis in a separate plot.

µg-P/L = micrograms phosphorus per litre; T = top depth; M = middle depth; B = bottom depth; <DL = less than detection limit; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage..

Concentrations of TDP during the ice-cover season were within or below the normal range at most of the stations (Figure 3-18). Spatial analysis was not done for TDP for the ice-cover season because of the low detection frequency. Visual evaluation of the data suggest a decline in concentrations with distance from the diffusers.

During the open-water season, TDP concentrations were within the normal range, with the exception of one station in the FF1 area (Figure 3-18). Spatial analysis was not done for TDP in open-water because of the low detection frequency. No spatial trend was apparent in TDP.

Figure 3-18 Concentrations of Total Dissolved Phosphorus in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



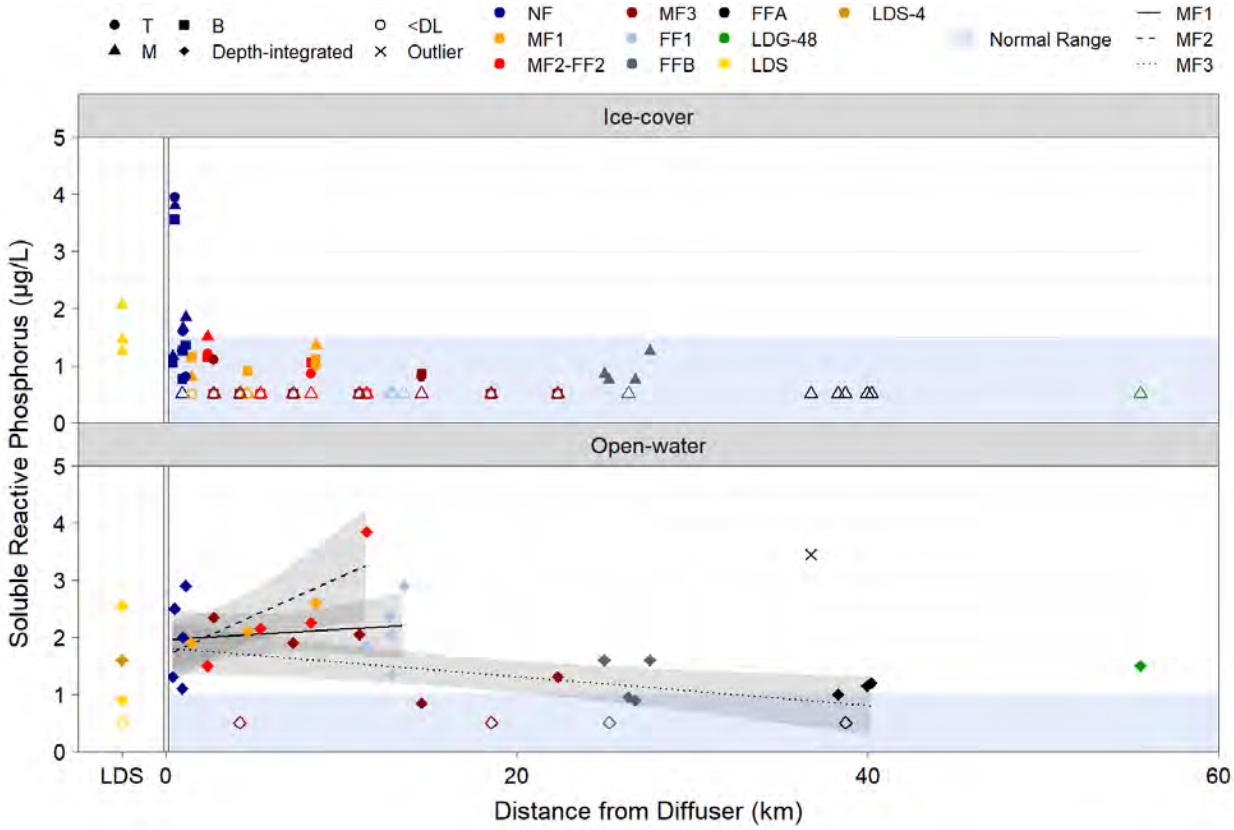
Note: Samples collected from Lac du Sauvage are presented to the right of the y-axis in a separate plot.

µg-P/L = micrograms phosphorus per litre; T = top depth; M = middle depth; B = bottom depth; <DL = less than detection limit; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage.

Concentrations of SRP during the ice-cover season were within the normal range at most of the stations, with the exception of in the NF area (Figure 3-19). Spatial analysis was not done for SRP in under-ice because of the low detection frequency. Visual evaluation of the data suggest a decreasing trend with distance from the diffusers.

During the open-water season, SRP concentrations were above the normal range with few exceptions (Figure 3-19). A significant increasing trend in SRP concentrations was detected along the MF2 transect and a significant decreasing trend was detected along the MF3 transect (Table 3-2).

Figure 3-19 Concentrations of Soluble Reactive Phosphorus in Lac de Gras and Lac du Sauvage According to Distance 4from the Effluent Discharge, 2019



Note: Soluble reactive phosphorus was analyzed by Maxxam as ortho-phosphorus. Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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

Table 3-2 Gradient Analysis Results for Nutrients, 2019

Variable	Season	Model	Transformation	Gradient	Slope(a)	Breakpoint (km)(b)	*P*-value	r^2 or R^2 (c)
Soluble Reactive Phosphorus	Open-water	Model 1	-	MF1	↑	-	0.567	0.36
		Model 1		MF2	↑	-	0.017	
		Model 1		MF3	↓	-	0.012	
Total Nitrogen	Ice-cover	Model 2	-	MF1	↓	-	<0.001	0.76
		Model 2		MF2	↓	-	0.001	
		Model 3		MF3 (1st slope)	↓	3.5	0.005	0.88
		Model 3		MF3 (2nd slope)	↓		-	
	Open-water	Model 2	Log	MF1	↓	-	0.001	0.48
		Model 2		MF2	↓	-	0.053	
		Model 3		MF3 (1st slope)	↓	5.3	0.01	0.82
		Model 3		MF3 (2nd slope)	↓		-	
Total Dissolved Nitrogen	Ice-cover	Model 2	-	MF1	↓	-	<0.001	0.63
		Model 2		MF2	↓	-	0.013	
		Model 3		MF3 (1st slope)	↓	24	<0.001	0.65
		Model 3		MF3 (2nd slope)	↑		-	
	Open-water	Model 2	Log	MF1	↓	-	<0.001	0.8
		Model 2		MF2	↓	-	0.001	
		Model 3		MF3 (1st slope)	↓	24	0.005	0.77
		Model 3		MF3 (2nd slope)	↑		-	
Total Kjeldahl Nitrogen	Ice-cover	Model 1	-	MF1	↓	-	<0.001	0.68
		Model 1		MF2	↓	-	0.003	
		Model 1		MF3	↓	-	<0.001	
	Open-water	Model 2	-	MF1	↓	-	0.009	0.31
		Model 2		MF2	↓	-	0.143	
		Model 3		MF3 (1st slope)	↓	5.1	<0.001	0.73
		Model 3		MF3 (2nd slope)	↓		-	
Dissolved Kjeldahl Nitrogen	Ice-cover	Model 1	-	MF1	↓	-	0.005	0.15
		Model 1		MF2	↓	-	0.632	
		Model 1		MF3	↑	-	0.166	
	Open-water	Model 2	-	MF1	↓	-	<0.001	0.61
		Model 2		MF2	↓	-	0.059	
		Model 3		MF3 (1st slope)	↓	25	<0.001	0.55
		Model 3		MF3 (2nd slope)	↑ (d)		-	
Nitrate	Ice-cover	Model 2	-	MF1	↓	-	<0.001	0.76
		Model 2		MF2	↓	-	0.001	
		Model 3		MF3 (1st slope)	↓	3.2	0.001	0.89
		Model 3		MF3 (2nd slope)	↓		-	

Table 3-2 Gradient Analysis Results for Nutrients, 2019 (continued)

Variable	Season	Model	Transformation	Gradient	Slope(a)	Breakpoint (km)(b)	*P*-value	r^2 or R^2 (c)
Nitrate + Nitrite	Ice-cover	Model 2	-	MF1	↓	-	<0.001	0.76
		Model 2		MF2	↓	-	0.001	
		Model 3		MF3 (1st slope)	↓	3.1	0.001	0.87
		Model 3		MF3 (2nd slope)	↓		-	
Total Ammonia	Ice-cover	Model 1	-	MF1	↓	-	<0.001	0.62
		Model 1		MF2	↓	-	0.001	
		Model 1		MF3	↓	-	<0.001	
Soluble Reactive Silica	Ice-cover	Model 2	-	MF1	↓	-	<0.001	0.61
		Model 2		MF2	↓	-	0.002	
		Model 3		MF3 (1st slope)	↓	2.9	0.131	0.96
		Model 3		MF3 (2nd slope)	↓		-	
	Open-water	Model 2	-	MF1	↑	-	0.879	0.27
		Model 2		MF2	↓	-	0.013	
		Model 3		MF3 (1st slope)	↓	21	0.002	0.77
		Model 3		MF3 (2nd slope)	↓		-	

a) Slope direction was represented by an upward arrow (↑) indicating an increasing trend with distance from the effluent diffusers, or a downward arrow (↓) indicating a decreasing trend with distance from the effluent diffusers.

b) The breakpoint is the location from the effluent discharge where the slopes of the linear regressions along the MF3 transect changed value.

c) For the MF3 broken stick model, r^2 is calculated because there is only one predictor, which is distance; for the other models, R^2 is calculated, because there is more than one predictor, i.e., distance and gradient.

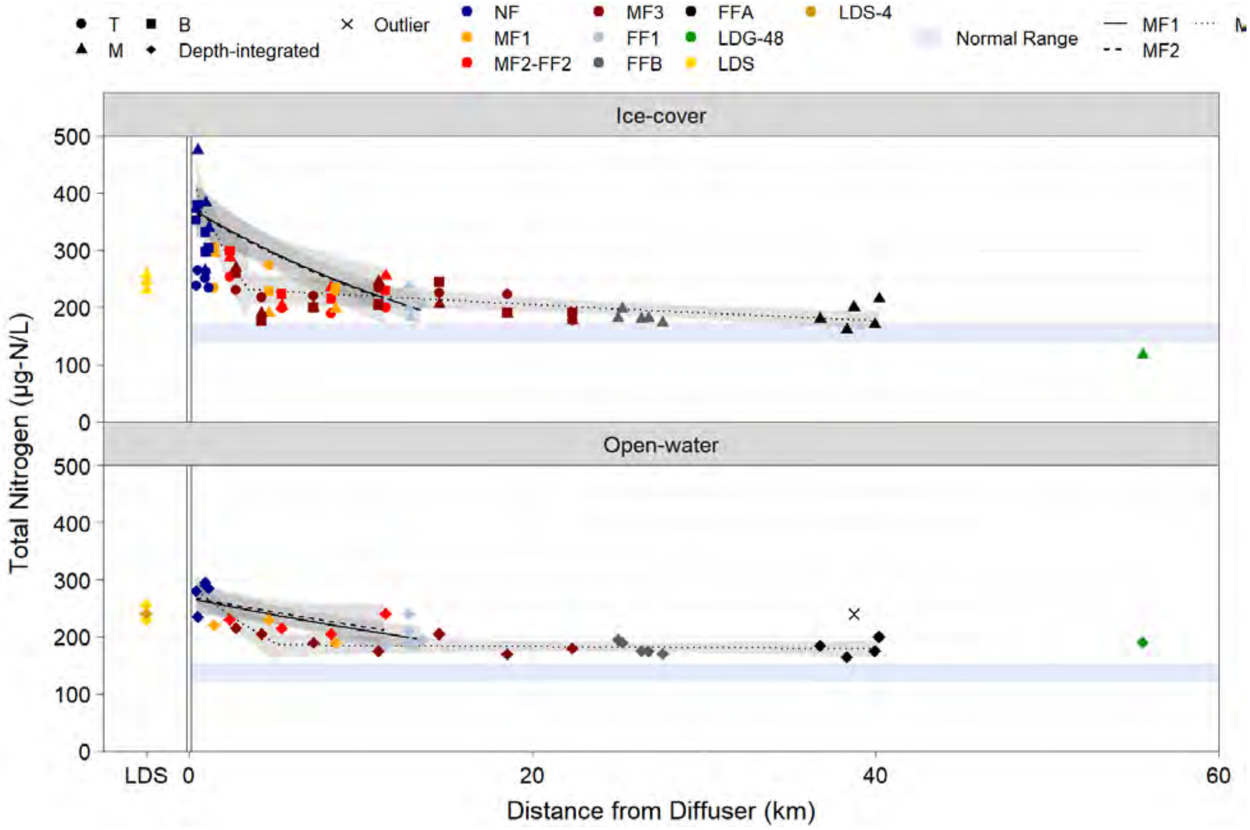
d) As noted in Section 2.4 and Attachment B, TDN concentrations during the ice-cover season in the FFA area and at LDG-48 were suspected to be biased high. This likely contributed to the positive slope observed along the MF3 transect after the breakpoint.

Note: Spatial analysis was not done for the following variables because of low detection frequency: total phosphorus (ice-cover and open-water), total dissolved phosphorus (ice-cover and open-water), soluble reactive phosphorus (ice-cover), nitrate (open-water), total nitrite (ice-cover and open-water), nitrate + nitrite (open-water), ammonia (open-water).

- = not applicable; MF = mid-field; FF = far-field; LDG = Lac de Gras; TDN = total dissolved nitrogen; *P* = probability; r^2 or R^2 = coefficient of determination.

Concentrations of TN were greater than the normal range during both ice-cover and open-water seasons with few exceptions (Figure 3-20). Significant decreasing trends in TN concentrations were observed along all transects during both seasons (Table 3-2). Significant decreasing trends in concentrations of TDN were observed along all transects during both seasons: however, slope direction reversed beyond the break-point along the MF3 transect in both seasons (Table 3-2, Figure 3-21).

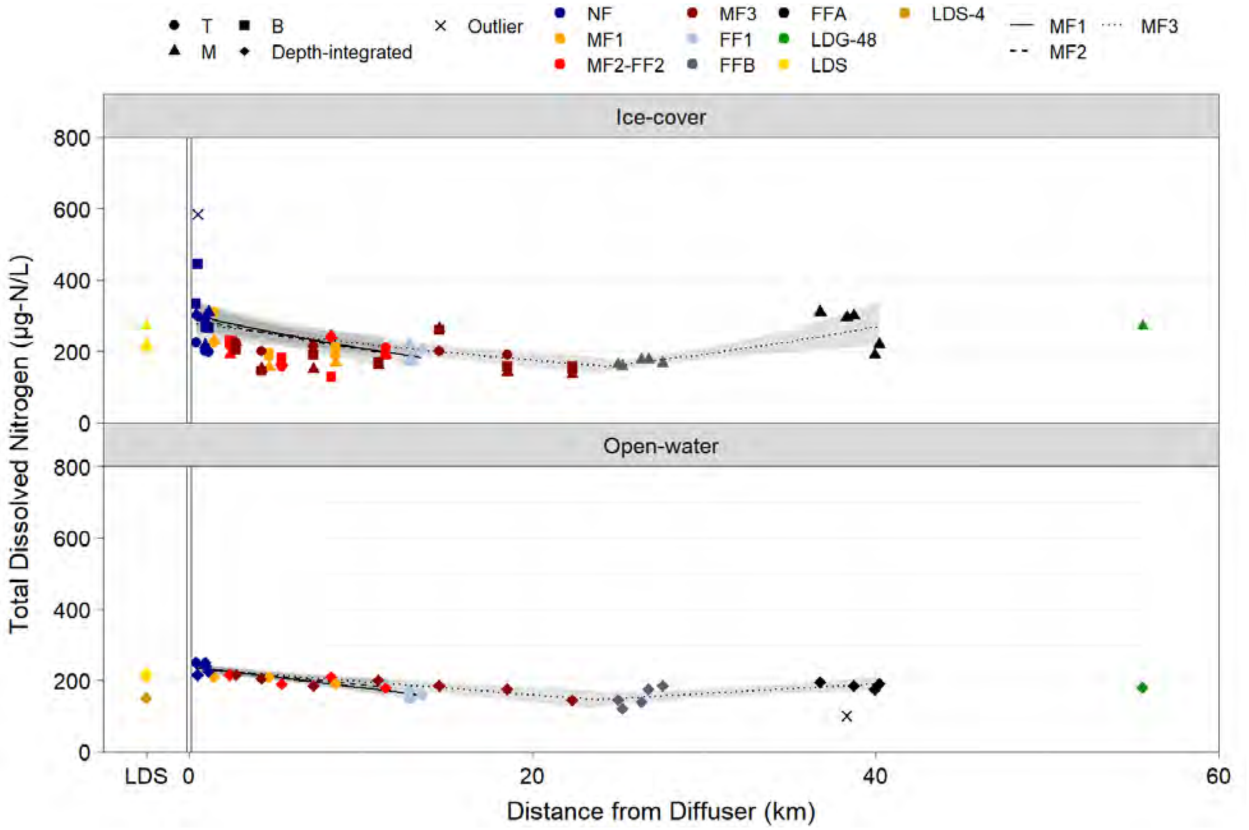
Figure 3-20 Concentrations of Total Nitrogen in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). As noted in Section 2.4 and Attachment B, TDN concentrations during the ice-cover season in the FFA area and at LDG-48 were suspected to be biased high.

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

Figure 3-21 **Concentrations of Total Dissolved Nitrogen in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019**



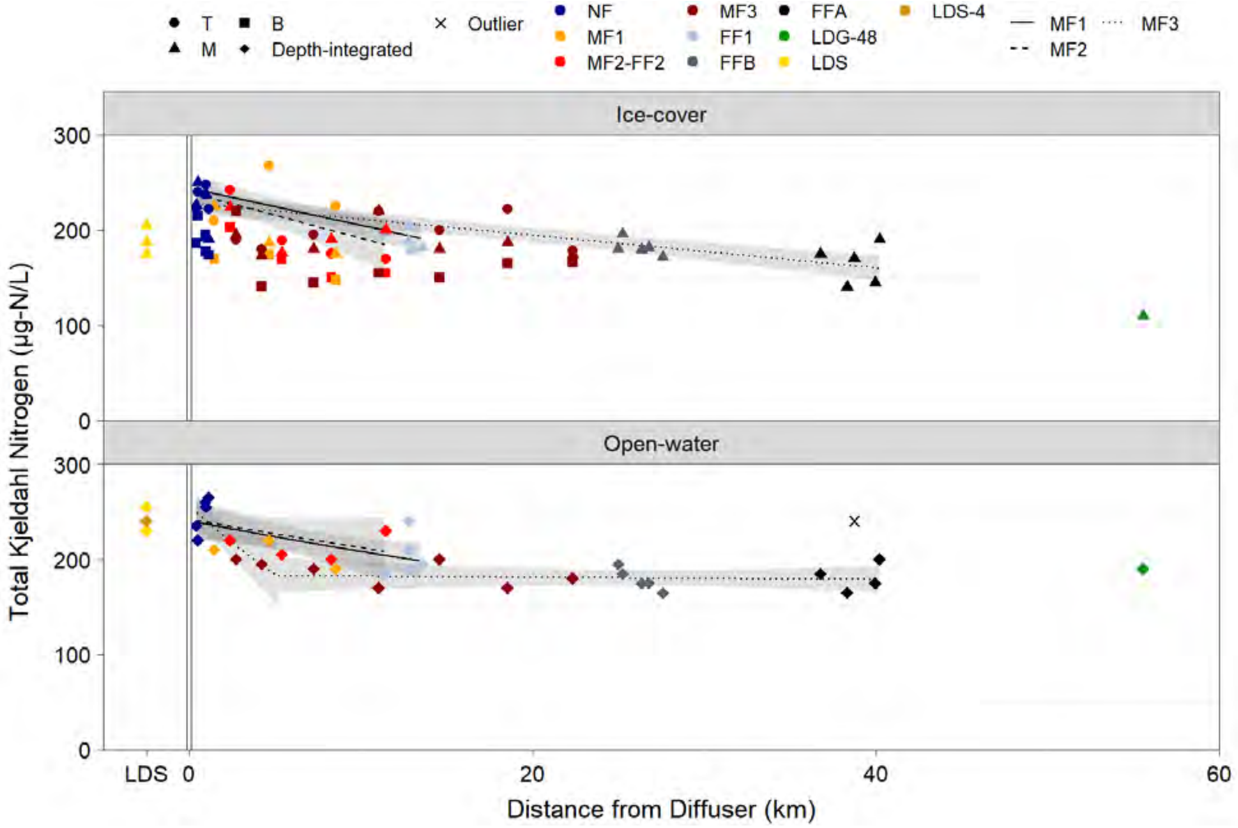
Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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

Spatial trends in TKN concentrations were similar to those in TN. Significant decreasing trends in concentrations of TKN were observed along all transects during the ice-cover season, and along the MF1 and MF3 transects during the open-water season (Table 3-2, Figure 3-22).

Significant decreasing trends in concentrations of DKN were observed only along the MF1 transect during the ice-cover season and along all transects during the open-water season (Table 3-2, Figure 3-23).

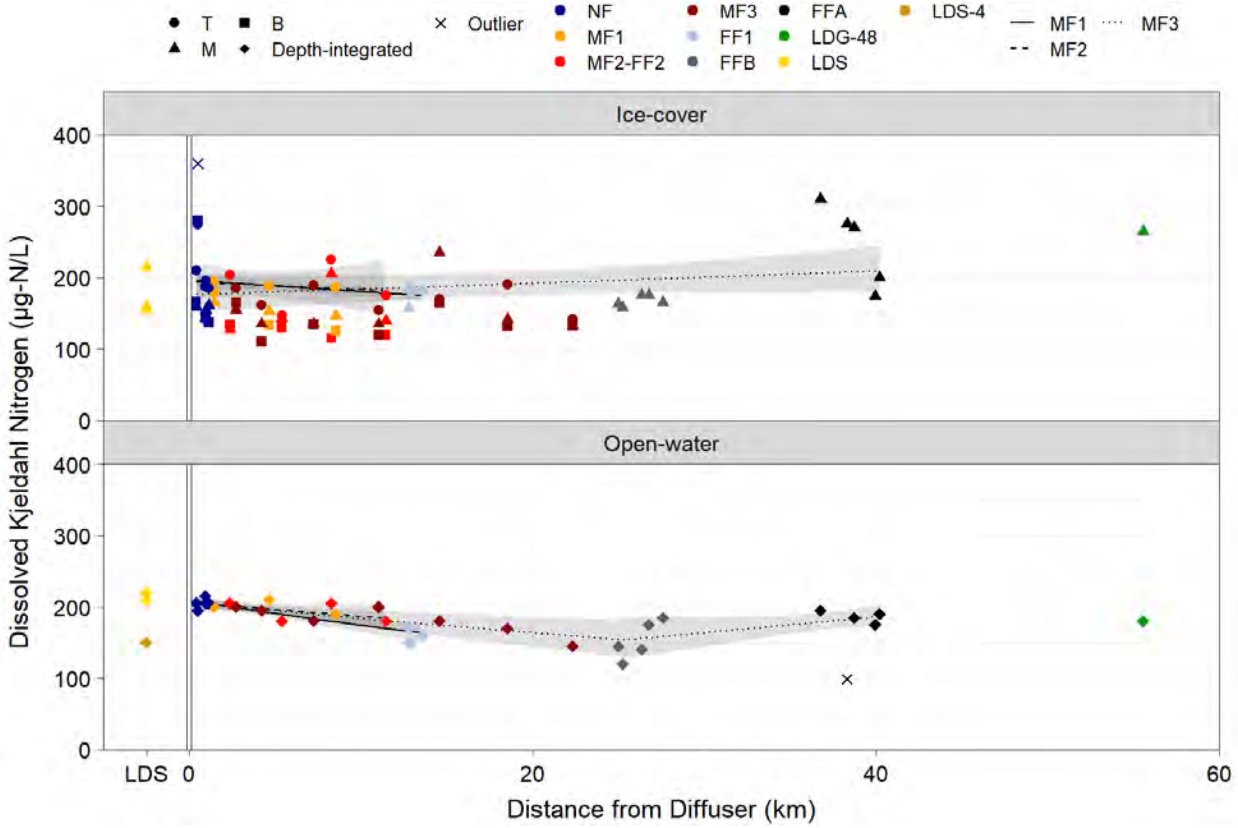
Figure 3-22 Concentrations of Total Kjeldahl Nitrogen in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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

Figure 3-23 Concentrations of Dissolved Kjeldahl Nitrogen in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019

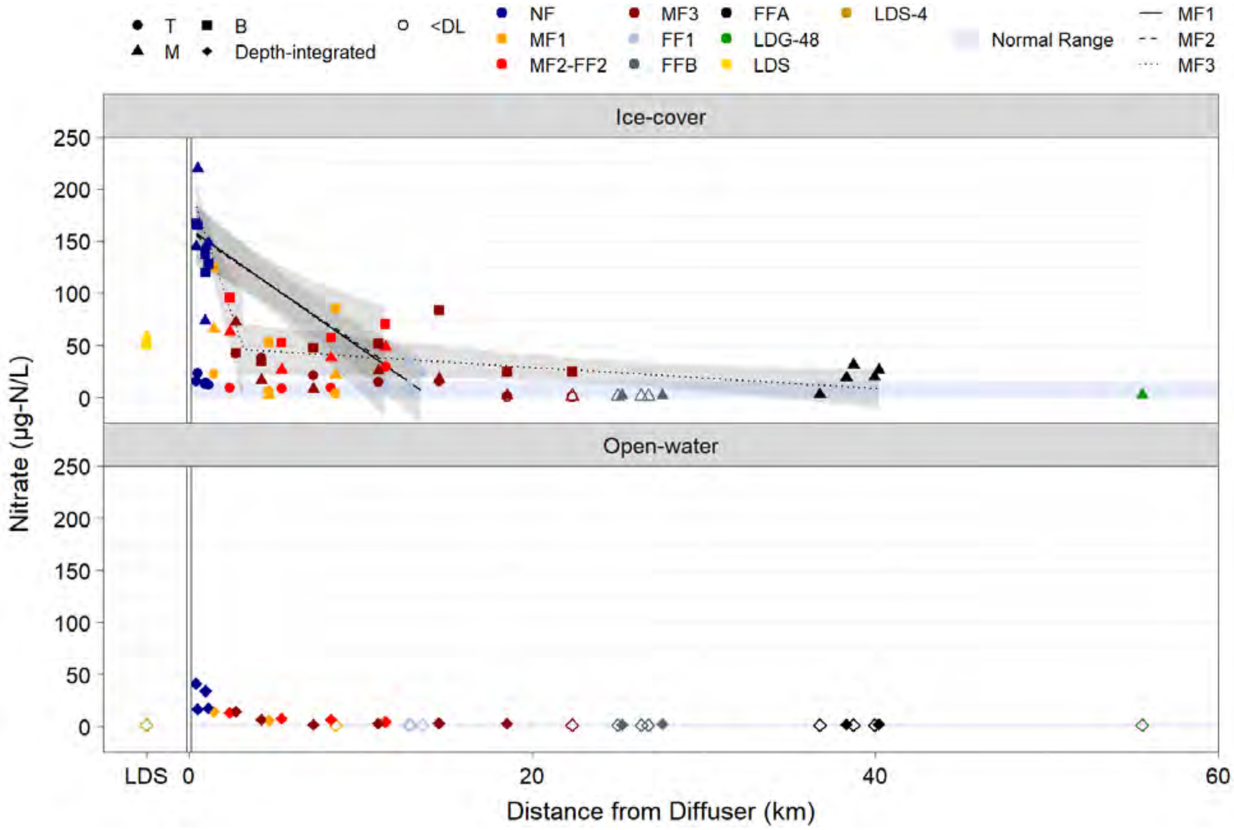


Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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

Concentrations of nitrate were greater than the normal range during the ice-cover season with some exceptions (Figure 3-24). Significant decreasing trends in nitrate concentrations during the ice-cover season were observed along all transects (Table 3-2). The concentration of nitrate at LDG-48 was lower than concentrations at most other stations in Lac de Gras during the ice-cover season. During the open-water season, nitrate concentrations were not detected frequently enough to allow linear regression analysis. Detected nitrate concentrations were generally above the normal range (Figure 3-24). Based on visual evaluation, a shallow decreasing concentration gradient was apparent along each MF transect.

Figure 3-24 Concentrations of Nitrate in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019

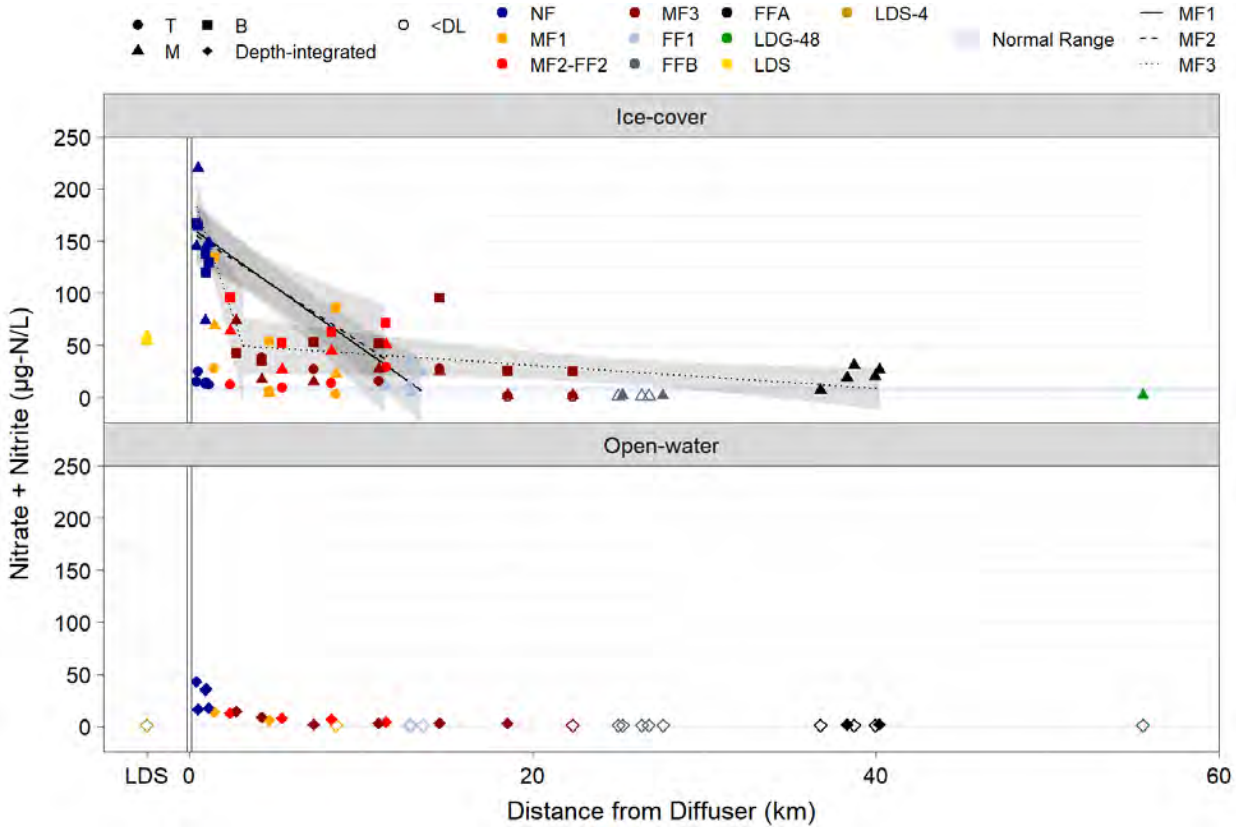


Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). The open-water data were not statistically analysed because of the high frequency of non-detects in the dataset.

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

The results for nitrate + nitrite were similar to that for nitrate in terms of the stations with concentrations that exceeded normal range and significant decreasing trends with distance from the diffusers along the all transects during the ice-cover season (Table 3-2, Figure 3-25). During the open-water season, nitrate + nitrite concentrations were not detected frequently enough to allow for linear regression analysis. Based on visual evaluation, a shallow decreasing concentration gradient was apparent along each MF transect.

Figure 3-25 Concentrations of Nitrate + Nitrite in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). The open-water data were not statistically analysed because of the high frequency of non-detects in the dataset.

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

Nitrite concentrations were more frequently detected in the NF area than in the MF areas, with many NF concentrations and some MF concentrations greater than normal range during the ice-cover season (Figure 3-26). However, nitrite concentrations were not detected frequently enough to allow for linear regression analysis in either season. Nitrite was detected less frequently during the open-water season, and detected concentrations were within normal range. Based on visual evaluation, obvious decreasing trends were not apparent along the MF transects.

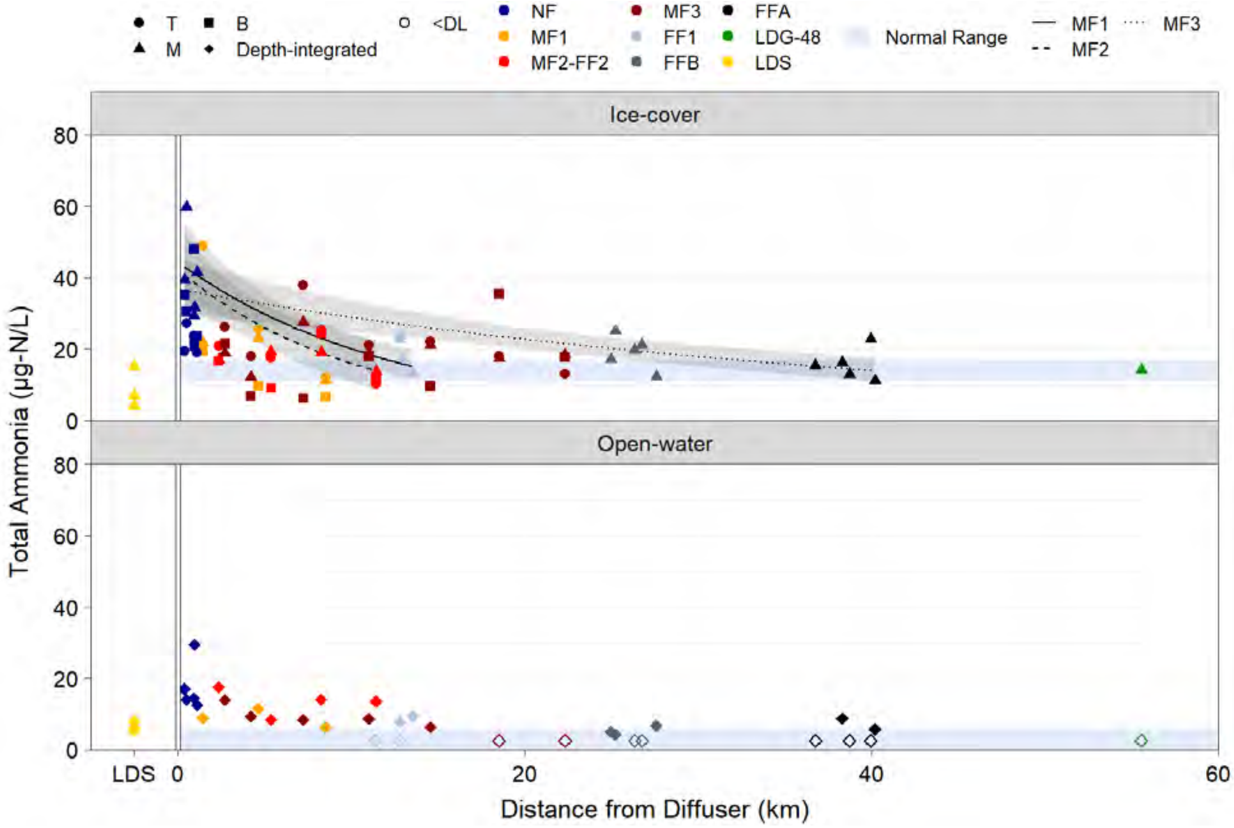
Figure 3-26 Concentrations of Nitrite in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019

Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). The open-water data were not statistically analysed because of the high frequency of non-detects in the dataset.

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

Total ammonia concentrations were generally greater than the normal range during the ice-cover season at most stations (Figure 3-27). A significant decreasing trend with distance from the diffuser was detected along all transects (Table 3-2). During the open-water season, total ammonia concentrations were not detected frequently enough to allow linear regression analysis (Figure 3-27), but based on visual evaluation, decreasing trends were apparent along all three transects.

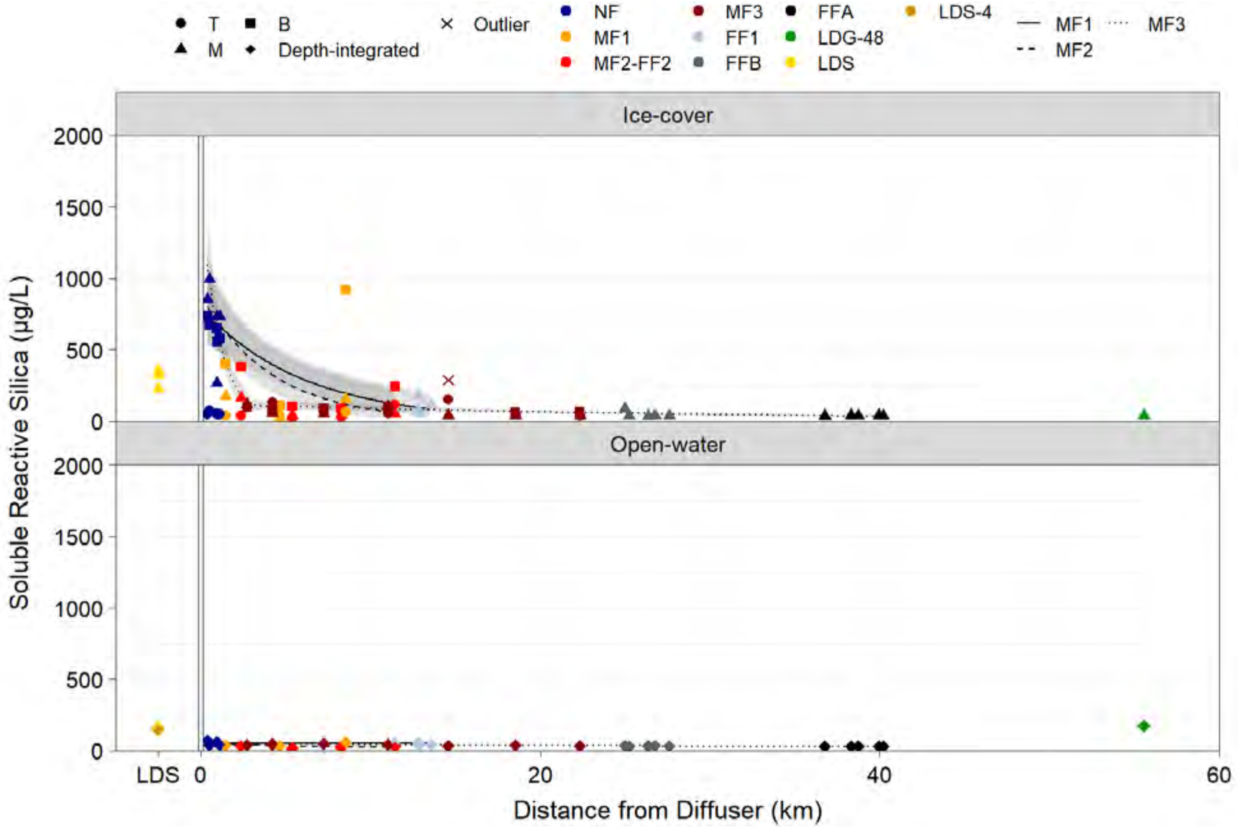
Figure 3-27 Concentrations of Total Ammonia in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). The open-water data were not statistically analysed because of the high frequency of non-detects in the dataset. µg-N/L = micrograms nitrogen per litre; NF = near-field; MF = mid-field; FF = far-field; T = top depth; M = middle depth; B = bottom depth; <DL = detection limit; LDG-48 = Lac de Gras outlet; LDS-4 = Lac du Sauvage Outlet (the Narrows).

Significant decreasing trends in concentrations of SRSi were observed along the MF1 and MF2-FF2 transects during the ice-cover season and along the MF2 and MF3 transects during the open-water season (Table 3-2, Figure 3-28). Concentrations of SRSi were much higher during ice-cover than open-water season (Figure 3-12 and Figure 3-28).

Figure 3-28 Concentrations of Soluble Reactive Silica in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable). The open-water data were not statistically analysed because of the high frequency of non-detects in the dataset.

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

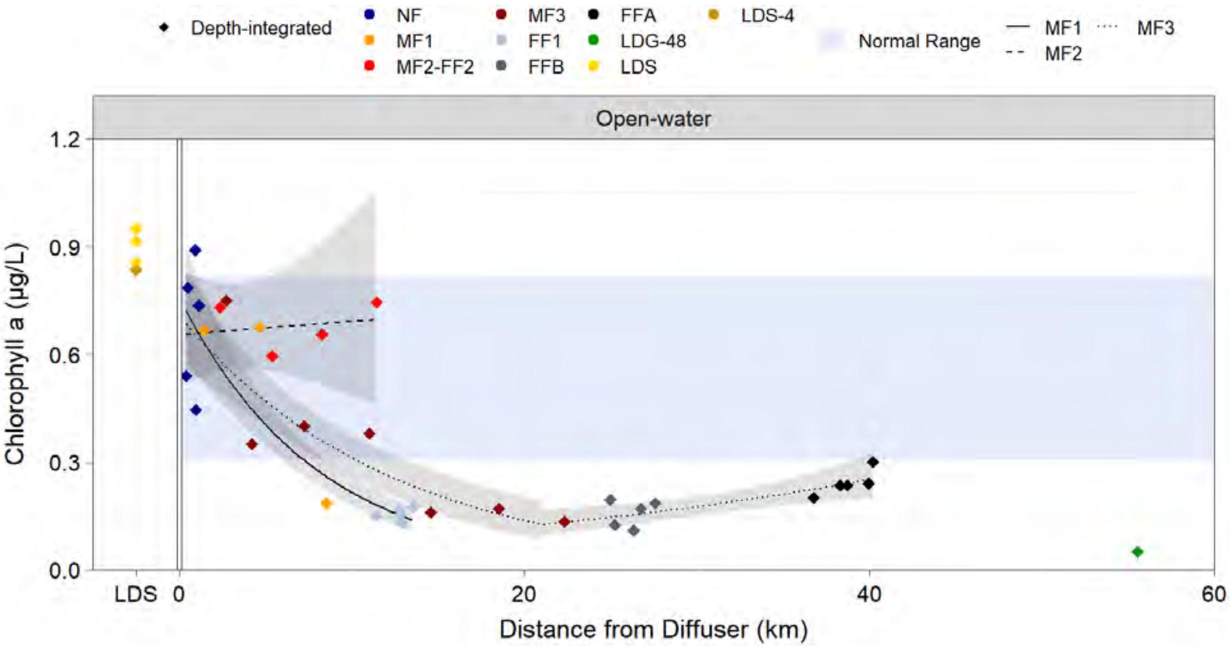
3.6.3 Chlorophyll a, and Phytoplankton and Zooplankton Biomass

There were strong, significant decreasing trends in chlorophyll *a* concentrations with distance from the diffuser along the MF1 and MF3 transects (Table 3-3, Figure 3-29). Along the MF3 transect, the trend direction reversed beyond the breakpoint of the broken stick regression, but the concentration was low again at the lake outlet.

Phytoplankton biomass was within the normal range at all stations (Figure 3-30). No significant trends in phytoplankton biomass with distance were detected in 2019 (Table 3-3).

Zooplankton biomass (as AFDM) was above the normal range in 2019 at all of the NF stations, and several MF stations (Figure 3-31). Significant decreasing trends in zooplankton biomass with distance from the diffuser were observed along the MF1 and MF3 transects in 2019 (Table 3-3).

Figure 3-29 Concentrations of Chlorophyll *a* in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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

Table 3-3 Gradient Analysis Results for Biological Variables during the Open-Water Season, 2019

Variable	Model	Transformation	Gradient	Slope(a)	Breakpoint (km)(b)	*P*-value	r^2 or R^2
Chlorophyll *a* (µg/L)	Model 2	Log	MF1	↓	-	<0.001	0.86
	Model 2		MF2	↑	-	0.812	
	Model 3		MF3 (1st slope)	↓	21	<0.001	
	Model 3		MF3 (2nd slope)	↑	21	-	
Phytoplankton Biomass (mg/m^3)	Model 1	Log	MF1	↑	-	0.691	0.03
	Model 1		MF2	↓	-	0.955	
	Model 1		MF3	↑	-	0.165	
Zooplankton Biomass as AFDM (mg/m^3)	Model 2	Log	MF1	↓	-	0.004	0.37
	Model 2		MF2	↓	-	0.163	
	Model 3		MF3 (1st slope)	↓	17	0.006	0.80
	Model 3		MF3 (2nd slope)	↓	17	-	

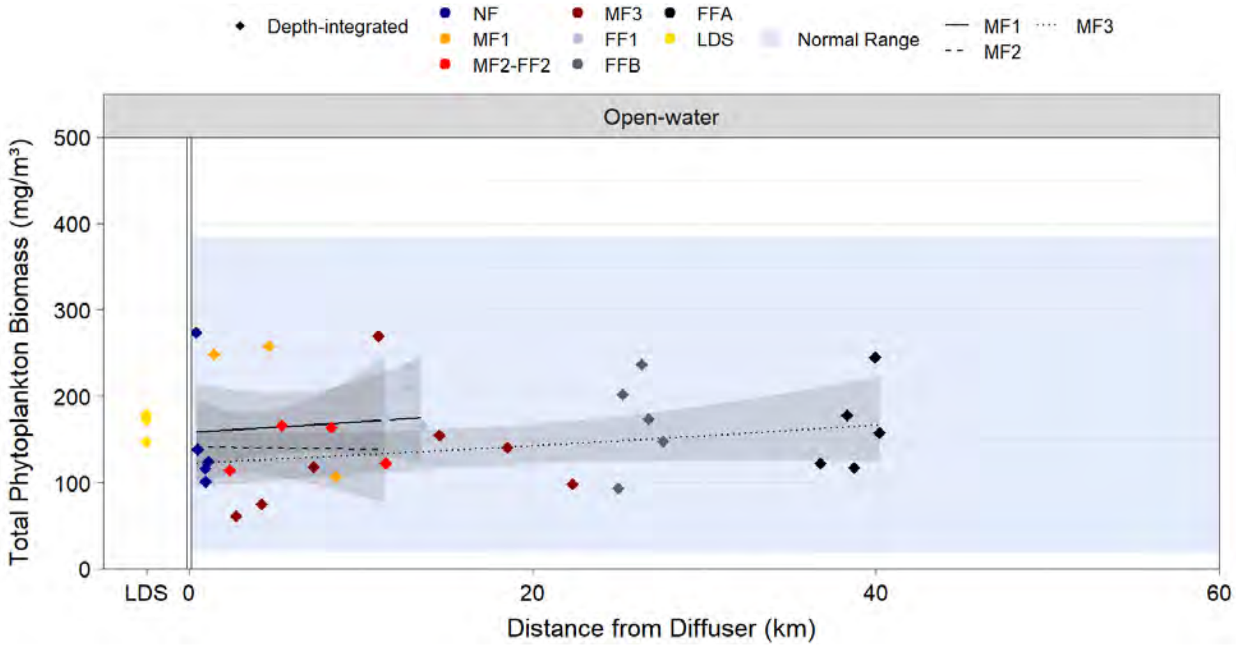
a) Slope direction was represented by an upward arrow (↑) indicating an increasing trend with distance from the effluent diffusers, or a downward arrow (↓) indicating a decreasing trend with distance from the effluent diffusers.

b) The breakpoint is the location from the effluent discharge where the slopes of the linear regressions along the MF3 transect changed value.

Note: The *P*-value relevant to the second slope is not reported by the statistical software because it cannot be estimated (Muggeo 2008).

µg/L = micrograms per litre; AFDM = ash-free dry mass; MF = mid-field; - = not applicable; < = less than; r^2 or R^2 = coefficient of determination.

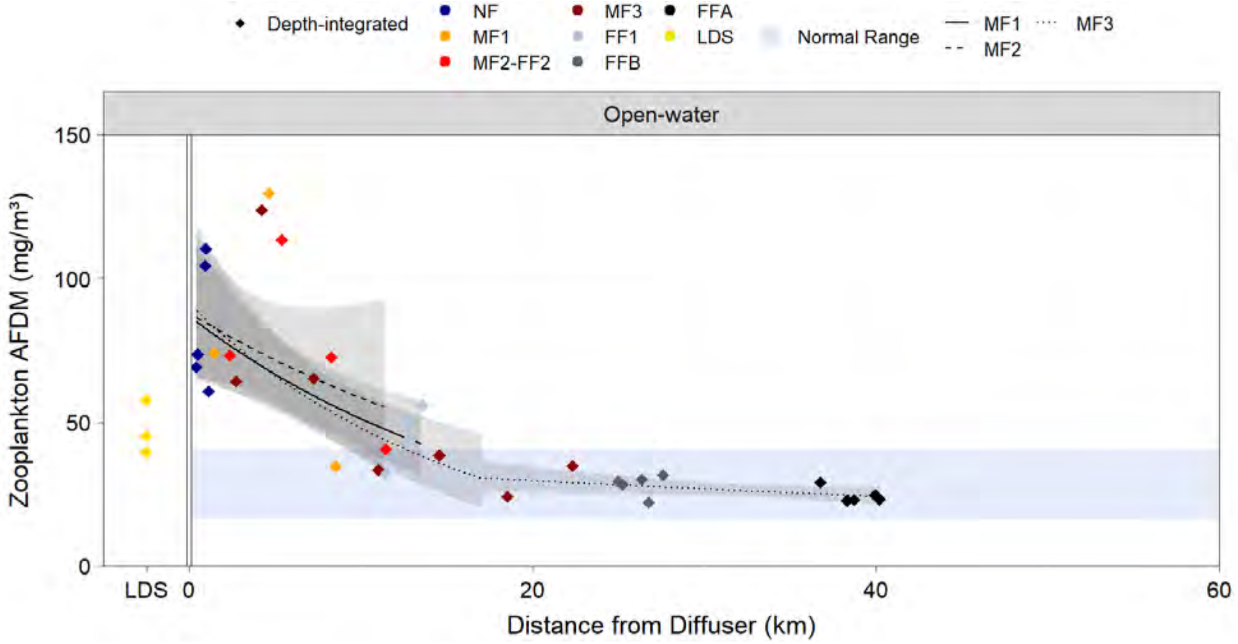
Figure 3-30 Total Phytoplankton Biomass in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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 Outlet (the Narrows).

Figure 3-31 Total Zooplankton Biomass in Lac de Gras and Lac du Sauvage According to Distance from the Effluent Discharge, 2019



Note: Samples collected from Lac du Sauvage are presented to the left of the y-axis in a separate panel and LDG-48 in presented to the right of the y-axis. Shaded bands around fitted prediction lines are 95% confidence intervals (back-transformed to original scale of the variable).

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 Outlet (the Narrows).

3.7 Near-Field Versus Far-Field Area Comparisons

The comparison between NF and FF areas was completed as supporting information towards the evaluation of Mine-related effects on eutrophication indicators. With the exception of total phytoplankton biomass, all eutrophication indicators had significant overall ANOVA results (Table 3-4). *Post-hoc* comparisons following the overall ANOVA detected significant differences among reference areas for most variables, and significantly greater concentrations in the NF area compared to the FF areas for TN (both seasons), TDN (open-water), TKN (both seasons), DKN (open-water), nitrate (ice-cover), nitrate + nitrite (ice-cover), total ammonia (ice-cover), SRSi (ice-cover), chlorophyll *a*, and total zooplankton biomass. These results are consistent with the spatial gradient analysis results (Section 3.8), and indicate nutrient enrichment in the area of the lake close to the effluent diffusers.

Table 3-4 Statistical Comparisons of Eutrophication Indicators Concentrations in Lac de Gras, 2019

Variable	Season	Statistical Test	Overall Comparison	NF vs FF Area Comparison		FF Area Comparisons		
				NF vs FF1+FFB+FFA$^{(a)}$		FF1 vs FFA	FF1 vs FFB	FFA vs FFB
			P	*P*	NF vs FF	*P*	*P*	*P*
Secchi Depth	OW	ANOVA	**0.001**	0.312	NF = FF	**0.004**	**0.016**	0.968
Soluble Reactive Phosphorus	OW	ANOVA	**0.016**	nt		**0.029**	**0.045**	0.975
Total Nitrogen	IC	ANOVA	**<0.001**	**<0.001**	NF > FF	0.236	0.163	0.995
	OW	ANOVA	**<0.001**	**<0.001**	NF > FF	0.837	0.336	0.799
Total Dissolved Nitrogen	IC	ANOVA	**0.001**	0.212	NF = FF	**0.023**	0.646	**0.003**
	OW	ANOVA	**<0.001**	**0.001**	NF > FF	0.255	0.741	**0.051**
Total Kjeldahl Nitrogen	IC	ANOVA	**<0.001**	**<0.001**	NF > FF	**0.026**	0.739	0.161
	OW	ANOVA	**0.001**	**<0.001**	NF > FF	0.814	0.231	0.681
Dissolved Kjeldahl Nitrogen	IC	ANOVA	**0.010**	nt		**0.017**	0.974	**0.008**
	OW	ANOVA	**0.001**	**0.052**	NF > FF	0.118	0.776	**0.024**
Nitrate	IC	ANOVA	**<0.001**	**<0.001**	NF > FF	0.936	**0.028**	**0.010**
Nitrate + Nitrite	IC	ANOVA	**<0.001**	**<0.001**	NF > FF	0.836	**0.018**	**0.004**
Total Ammonia	IC	ANOVA	**<0.001**	**<0.001**	NF > FF	0.827	0.990	0.662
Soluble Reactive Silica	IC	ANOVA	**<0.001**	**<0.001**	NF > FF	0.358	0.500	0.993
	OW	ANOVA$_R$	**<0.001**	0.285	NF = FF	**<0.001**	**0.002**	**0.099**
Chlorophyll *a*	OW	ANOVA	**<0.001**	**<0.001**	NF > FF	0.204	1.000	0.220
Total Phytoplankton Biomass	OW	ANOVA	ns	-		-	-	-
Total Zooplankton Biomass	OW	ANOVA	**<0.001**	**<0.001**	NF > FF	**0.046**	0.121	0.948

a) If a significant result was observed for the comparison of FF areas, the NF area was compared to the FF area with the highest concentration.

Note: **Bold** indicates *P*-value significant at <0.1 for overall comparison, NF vs. FF area comparisons, and parametric FF area comparisons, and at <0.15 for non-parametric FF area comparisons. *P* = probability; ns = not significant; nt = not tested, because the three FF areas differed from each other and the NF mean was within the range of the FF areas; - = not applicable, overall comparison is non-significant; NF = near-field; FF = far-field; KW = Kruskal-Wallis test; ANOVA = analysis of variance; ANOVA$_R$ = ANOVA after rank transformation.

3.8 Role of Nitrogen in Spatial Extent of Chlorophyll *a*

In 2019, the relationship between concentrations of chlorophyll *a* and TN was moderate (r = 0.462, P = 0.005, n = 35), and the relationship between TP and chlorophyll *a* was poor (r = 0.243, P = 0.159, n = 35), while a strong relationship between chlorophyll *a* concentrations and TDS was observed (r = 0.905, P<0.001, n = 35).

In Lac de Gras, the limiting nutrient is phosphorus, as determined based on nutrient ratios and TSI calculations (Golder 2019c). If chlorophyll *a* concentration (an indicator of algal biomass) is controlled by the limiting nutrient, a moderate to strong correlation between the two variables would be expected; however, the relationship between concentrations of chlorophyll *a* and TP was poor in 2019. This may be the result of the low TP concentrations in Lac de Gras (i.e., 0.5 to 7.2 µg/L) and a limited range in concentrations, as suggested by Shortreed and Stockner (1986) for lakes with low TP concentrations. Some studies have shown that Arctic lakes may be N-limited (Levine and Whalen 2001; Keatley et al. 2007; Symons et al. 2011); however, the lakes in these studies were often small and shallow (<2 km^2 and ~2 m, respectively), unlike Lac de Gras.

A poor relationship between chlorophyll *a* concentrations and TP, but a strong relationship with TDS, suggests phytoplankton may be responding to an increase in micronutrients associated with TDS. Chlorophyll *a* concentrations are influenced by a number of factors, including nutrient concentrations (often dependent on the limiting nutrient and micronutrients), and biological (e.g., herbivory), and physical (e.g., thermal stratification or lake morphometry) interactions (Mazumder 1994). Therefore, a strong linear relationship to a single variable may not be evident. The moderate relationship between TN and chlorophyll *a* concentrations may be the result of the strong correlation between TN and TDS, rather than a direct response of chlorophyll *a* to increased TN concentrations (Golder 2019c).

In 2019, TN concentrations were generally above the normal range across Lac de Gras, particularly in the open-water season (Section 3.3 and 3.6.2). Monthly TN loads were similar or greater in 2019 compared to 2018. In contrast, the TP load from effluent declined by nearly 100 kg, from 375 kg in 2018 (Golder 2019d), to 279 kg in 2019, which was reflected in lower concentrations of TP and TDP measured at the AEMP stations compared to 2018. While TN, nitrate and total ammonia were greater than the normal ranges in 2019 at most stations sampled, TP and TDP were within or below their normal ranges throughout the lake. Concentrations of SRP were low in absolute terms (<3 µg/L at most stations), and were within or greater than the normal range, depending on season. Consistent with the smaller phosphorus load from effluent and the lower TP and TDP concentrations throughout the lake, chlorophyll *a* concentrations also decreased in 2019 and were within the normal range, with the exception of one station in the NF area (NF3), which had a concentration only slightly above the normal range. In 2018, all stations in the NF, MF1 and MF2-FF2 areas were above the normal range, with most values between 1.0 and 1.5 µg/L (Golder 2019d). In 2019, chlorophyll a concentrations at most stations in these areas ranged from 0.5 to 0.75 µg/L, suggesting a 50% reduction. These results show that despite no change or an increase in Mine-related TN load and concentrations at AEMP stations from 2018 to 2019, primary productivity decreased notably in 2019, reflecting the lower TP load and concentrations in lake water.

These results are consistent with nitrogen not being the limiting nutrient in Lac de Gras, as also indicated by nutrient ratios, and also imply that the Mine-related enrichment effect may in part be related to an increase in micronutrients associated with TDS, in addition to phosphorus.

3.9 Effects of Dust Deposition

Phosphorus load to Lac de Gras from dustfall was estimated using snow water chemistry data collected as part of the *2019 Dust Deposition Report* (Appendix I), with consideration of background and anthropogenic TP deposition rates (Attachment D). The methods for calculating TP loads in dust are provided in Attachment D and are the same as those used in the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c). Analysis of multiple years of dustfall data from dust gauges during the open-water season and snow cores during the ice-cover season indicated that the amount of dust deposition was similar between the two seasons (i.e., no measurable seasonality in dust deposition was identified; Golder 2019c). Therefore, no further consideration was given to seasonal dust deposition, and analyses assumed that there were no seasonal differences in the source of TP in dust. Snow water chemistry data were used to extrapolate TP concentrations in dust throughout the year for this assessment. It was assumed that all atmospheric deposition of TP (i.e., background and anthropogenic) that fell within the Lac de Gras watershed either fell directly on Lac de Gras or were delivered to Lac de Gras with no terrestrial attenuation. The lack of terrestrial attenuation is a conservative assumption and is expected to result in an overestimation of the TP load from dustfall to Lac de Gras.

It should be noted that the dust sampling program was not designed to be as precise as the AEMP effluent assessment for measuring TP loading to Lac de Gras. As stated in Section 3.1, the total TP load from Mine effluent and dewatering discharge, based on TP concentrations in effluent discharge and measured discharge volume, was 0.28 t/yr in 2019. This load estimate is associated with a high degree of confidence because it is based on direct and precise measurements of TP concentrations in effluent and effluent volume. The estimate of the TP load from dust is considered to have low precision with an order of magnitude variance. Therefore, low confidence should be placed in the estimate of TP load from dust and it should not be directly compared to the TP load from effluent.

Previous monitoring years' results indicated that the rate of dust deposition is greatest within the Mine footprint and declines exponentially with distance and is indistinguishable from background at approximately 4.2 km from the Mine centroid or approximately 1.5 km from the boundary of the Mine footprint (Golder 2019c). Dustfall within the Mine footprint was assumed to be captured within the Mine water management system and thus incorporated within the estimate of TP load in effluent. Therefore, only dustfall to surfaces outside the Mine footprint was included in the estimate of the atmospheric TP load to Lac de Gras. The load of TP was calculated, which includes both particulate-bound as well as free (i.e., potentially bioavailable) phosphorus.

In 2019, four new reference stations (referred to as "control-assessment stations") were sampled that were farther away from the Mine than the control stations sampled in previous years, which were also sampled in 2019. Dust deposition rates to snow at the control stations in 2019 were greater than those at the control-assessment stations (Attachment D). This suggests that the control-assessment stations may provide more representative values of background dust deposition rates. Phosphorus load to Lac de Gras from dustfall was estimated using both the control station data (to allow comparison to previous years) and the control-assessment station data.

Using data for either the control stations or the control-assessment stations resulted in greater anthropogenic TP loads due to dust in 2019 than in 2018. However, 2018 and 2019 were both low dust deposition years at the control stations, when considering data from all years with available data (i.e., 2010 to 2019) (Attachment D).

When the background TP and dust deposition rates were calculated using the control-assessment station data, the anthropogenic TP load due to dust in 2019 (3.2 t/yr) was lower compared to using the control stations as background (4.6 t/yr). When considering the TP load from Mine effluent (0.28 t/y), the relative contribution of anthropogenic sources of TP to Lac de Gras (effluent and dust) is 48% when using the control-assessment stations, compared to 12% when using the control stations. This difference in the relative contribution is due to the order of magnitude difference between the estimates of the background rate of TP deposition (i.e., 89 µg/dm^2/yr using the control station data versus 8.9 µg/dm^2/yr using the control-assessment station data).

As stated above, the estimates of TP loads from dust are subject to uncertainty, in part because the loading estimates related to dust do not take into account retention of deposited phosphorus on land. Additionally, a large proportion of phosphorus from dust deposition (i.e., approximately 75%) that reaches the lake may not be bioavailable because it would be mostly in particulate form. As discussed in the *Special Effects Study – Dust Deposition* (Appendix XII), 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 under the pH and redox conditions in lake water and would not dissolve. Dust-associated phosphorus would settle to the sediment instead of being dissolved and becoming available for algae to uptake. Therefore, dust-associated phosphorus is unlikely to contribute dissolved phosphorus in amounts that would result in a measurable contribution to the nutrient enrichment observed in the lake.

Despite the apparently large contribution of TP from dust relative to other sources, the 2019 AEMP and SES results provided no evidence that dust deposition had an additional measurable effect on concentrations of TP or chlorophyll *a* in Lac de Gras, beyond the effect apparent from the Mine effluent discharge. Concentrations of TP in Lac de Gras during the open-water season, measured as part of the 2019 AEMP, were below the upper bound of the normal range at all stations in the ZOI from dust deposition (i.e., NF1 to NF5, MF1-1, MF2-1, MF3-1) (Figure 3-32). This result is consistent with the interpretation that the potential for mobilization of phosphorus from Mine-related dustfall is low.

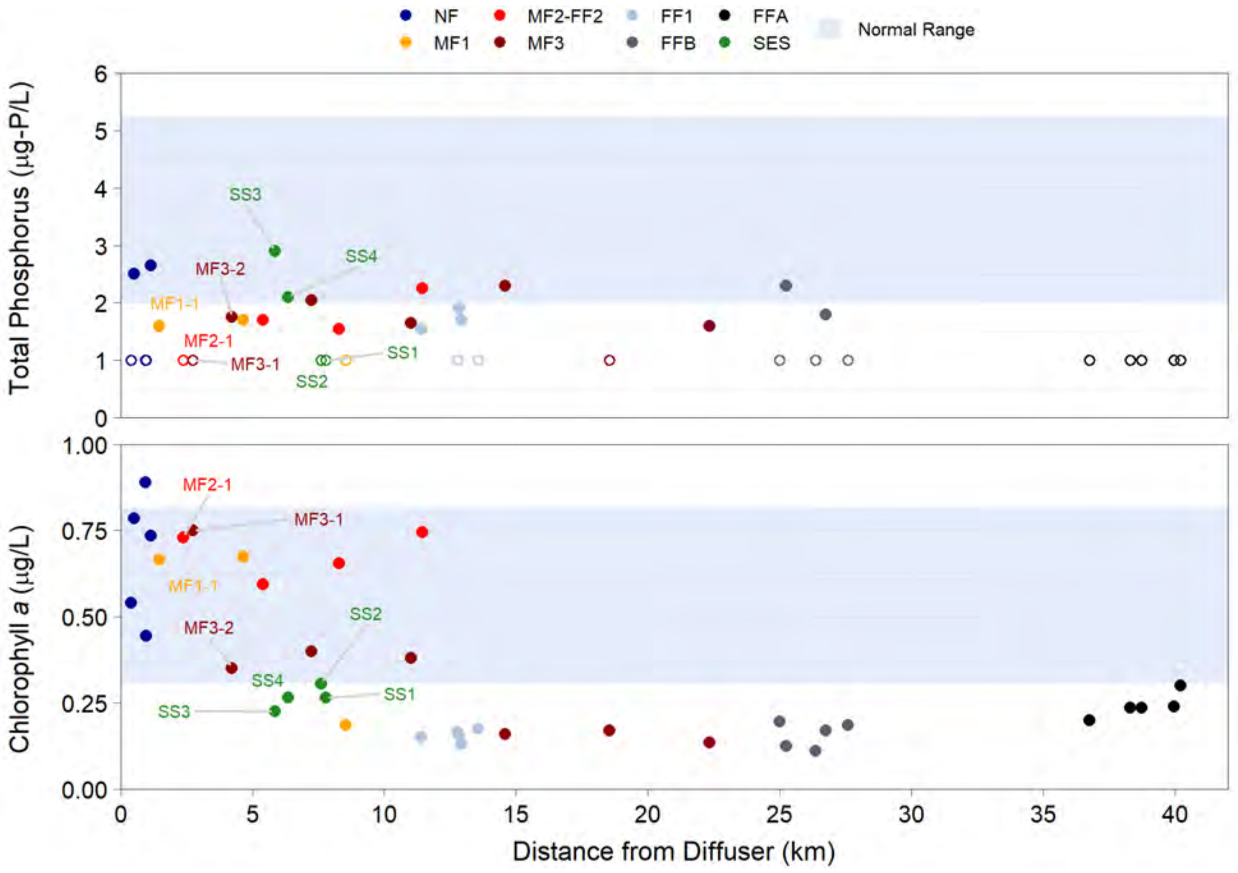
Chlorophyll *a* concentrations were generally below the upper bound of the normal range of 0.82 µg/L at all stations with the exception of station NF3, which had a chlorophyll *a* concentration of 0.89 µg/L (Figure 3-16). Chlorophyll *a* concentrations were greater in the NF area and at MF stations closest to the diffuser (i.e., MF1-1, MF1-2, MF2-1, and MF3-1) (Figure 3-32). Other stations within the dust ZOI (e.g., MF3-2) had lower concentrations, with an overall decreasing 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. Chlorophyll *a* concentrations along the MF2 transect increased between MF2 and FF2-5, but remained with normal range. This increase was likely reflecting water entering Lac de Gras from Lac du Sauvage, as the LDS stations had greater chlorophyll *a* concentrations than station FF2-5 (i.e., 0.84 µg/L at the LDS outlet and mean of 0.91 µg/L in LDS).

Extra TP and chlorophyll *a* sampling was completed at four additional stations in 2019 as part of the *Special Effects Study – Dust Deposition* (Appendix XII) to evaluate the influence of dust deposition on water quality in Lac de Gras. These stations were located within the dust ZOI but were closer to dust-generating Mine activities and, therefore, had the potential to be more influenced by dust deposition than the AEMP stations. Mean TP concentrations at these stations were similar to those measured in other areas of Lac de Gras (Figure 3-32), and were also below the upper bound of the normal range.

Chlorophyll *a* concentrations at these stations were less than those measured at nearby AEMP stations (i.e., MF3-1 to MF3-4), and were also at or below the lower bound of the normal range (Figure 3-32).

In summary, although the estimate of TP loading to Lac de Gras due to dust suggests that dust deposition could contribute to nutrient enrichment in the lake, this is not supported by the measured concentrations of TP and chlorophyll *a*. Instead, the smaller TP load from Mine effluent yielded lower concentrations of both TP and chlorophyll *a* in 2019, and a declining trend in chlorophyll *a* concentration was observed with distance from the diffusers. Stations sampled as part of the *Special Effects Study – Dust Deposition* (Appendix XII) in the potentially greater dust deposition areas did not have elevated concentrations of dust-related major ions, metals, nutrients including TP, or chlorophyll *a* or greater plankton biomass compared to nearby AEMP stations. These results suggest that Mine effluent, not dust deposition, is the most influential factor on TP concentration and associated effects on chlorophyll *a* in Lac de Gras.

Figure 3-32 Concentrations of Total Phosphorus and Chlorophyll *a* in Lac de Gras in Relation to Dust Deposition during the Open-water Season, 2019

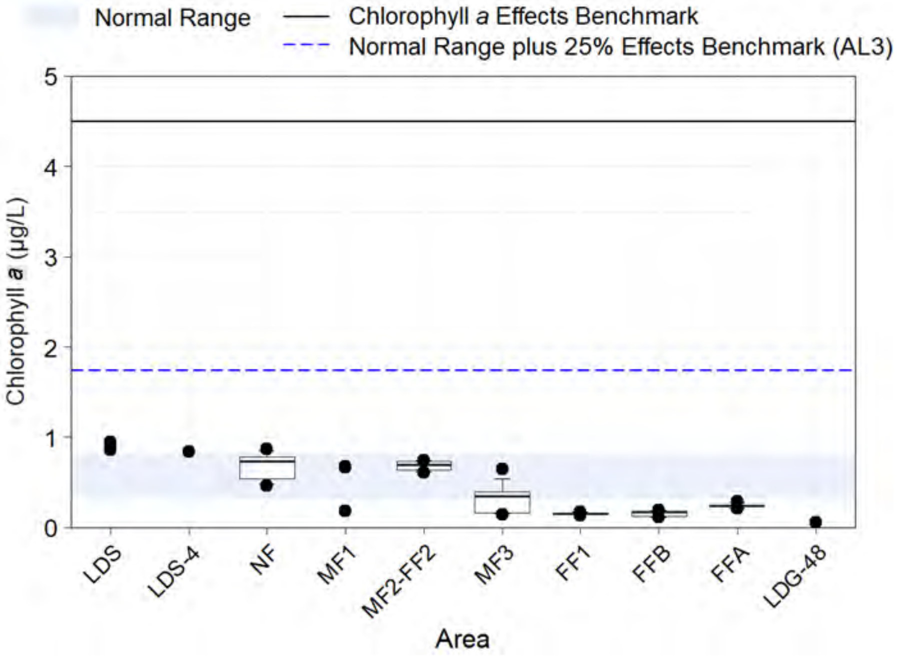


Note: MF stations in the zone of influence from dust deposition are labelled (i.e., MF1-1, MF2-1, MF3-1, MF3-2); all NF stations are within the zone of influence. Special Effects Study stations are also labelled (i.e., SS1, SS2, SS3, SS4).
µg-P/L = micrograms phosphorus per litre; µg/L = micrograms per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

3.10 Action Level Evaluation

The 2019 eutrophication indicators results indicate that Action Level 1 has not been triggered (i.e., the 95th percentile of MF values for chlorophyll *a* [0.75 µg/L] is less than the upper limit of the normal range [0.82 µg/L]) (Table 3-5). In the NF area, chlorophyll *a* concentration at one of the five stations (i.e., 0.89 µg/L in NF3) was greater than the upper limit of the normal range; however, the average chlorophyll *a* concentration in the NF area was 0.68 µg/L. The Lac du Sauvage stations had higher chlorophyll *a* concentrations than most Lac de Gras stations, and the concentration at LDG-48 was well below the lower limit of the normal range (Figure 3-33).

Figure 3-33 Concentrations of Chlorophyll *a* by Area in Lac de Gras, 2019



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.

Table 3-5 Action Levels Classification for Chlorophyll *a*, 2019

Action Level	Action Level Classification				2019 Assessment		Action Level Triggered?
	Magnitude of Effect	Extent of Effect	Description	Value (µg/L)	Value (µg/L)	Extent of Effects	
1	Top of normal range(a)	MF station	95th percentile of MF values greater than normal range(a)	0.82	0.75	NF area	N
2	Top of normal range(a)	20% of lake area or more	NF and MF values greater than normal range(a)	0.82	n/a	n/a	N
3	Normal range plus 25% of Effects Benchmark(b)	20% of lake area or more	NF and MF values greater than normal range plus 25% of Effects Benchmark(b)	1.74	n/a	n/a	N
4	Normal range plus 50% of Effects Threshold(c)	20% of lake area or more	NF and MF values greater than normal range plus 50% of Effects Threshold(c)	-(d)	-(d)	-(d)	N
5	Effects Threshold	20% of lake area or more	NF and MF values greater than Effects Threshold	-(d)	-(d)	-(d)	N
6	Effects Threshold + 20%	20% of lake area or more	NF and MF values greater than Effects Threshold +20%	-(d)	-(d)	-(d)	N
7	Effects Threshold + 20%	All MF stations	95th percentile of MF values greater than Effects Threshold +20%	-(d)	-(d)	-(d)	N
8	Effects Threshold + 20%	FFB	95th percentile of FFB values greater than Effects Threshold +20%	-(d)	-(d)	-(d)	N
9(e)	Effects Threshold + 20%	FFA	95th percentile of FFA values greater than Effects Threshold+20%	-(d)	-(d)	-(d)	N

a) The normal range for chlorophyll *a* was obtained from the *AEMP Reference Conditions Report, Version 1.4* (Golder 2019b).

b) Indicates 25% of the difference between the Effects Benchmark (i.e., 4.5 µg/L) 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) Undefined, because the Effects Threshold has not been established.

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.

n/a = not applicable; N = no; - = undefined, because the Effects Threshold has not been established; NF = near-field; MF = mid-field; FF = far-field.

3.11 Cumulative Effects

Potential cumulative effects of the Diavik and Ekati mines on concentrations of eutrophication indicators in Lac de Gras were investigated using a graphical (i.e., visual) approach. The following were considered to be supporting evidence for potential cumulative effects:

1. concentrations greater at the LDG outlet compared to one or both of the FFB or FFA areas
2. consistent increases in concentrations observed to extend from the FFB area through the FFA area, with further increases at LDG-48 at the lake outlet
3. concentrations at the Ekati stations decline from the station closest to the Slipper Lake outlet to station S6, indicating that the Slipper Lake outlet is a source to Lac de Gras
4. concentrations at FFB, FFA, LDG-48 and S6 greater than normal range

Concentrations of TP in the MF3, FFB, and FFA areas and at LDG-48 in 2019 were within or below normal range in both seasons (Figure 3-34). Concentrations in the FFB area and LDG-48 were also below the DL. Greater TP concentrations were measured at the Ekati stations in 2018, with a decreasing trend from the Slipper Lake outlet to station S6 during the open-water season. However, there is no indication that greater TP concentrations from Slipper Lake influenced the TP concentrations at FFB or LDG-48.

Similar results to TP were observed for SRP during the ice-cover season, with all concentrations within the normal range, and FFB and LDG-48 concentrations less than the DL (Figure 3-35). Greater SRP concentrations were measured during the open-water season with several results above the normal range, including the concentration at LDG-48 (Figure 3-35). The spatial gradient analysis discussed in Section 3.8.2 identified a significant decreasing trend in concentrations along the MF3 transect for SRP in the open-water season, and this trend extended from the FFB to the FFA area. Concentration of SRP at LDG-48 was the same as the average concentration of FFB, which may indicate an influence from Slipper Lake but this is unlikely, as SRP was detected at S6 in 2018 but not at the other Ekati stations. It is also possible that the Diavik effluent influenced SRP concentration at S6. However, SRP concentrations at FFB, LDG-48, and S6 were all very low (within two times the DL of 1 µg/L); therefore, this may reflect analytical uncertainty rather than a possible cumulative effect or a Diavik effect. The lack of a corroborating cumulative effect on TP supports this interpretation.

Concentrations of TKN at LDG-48 were less than (ice-cover) or similar to (open-water) average concentrations in the FFA aera (Figure 3-36). Concentrations decreased with distance from the diffuser in both seasons, which is consistent with the influence of Diavik effluent (Section 3.8.2). In the ice-cover season, this trend extended from the FFB to the FFA area, with a lower concentration at LDG-48, but in the open-water season, the slope of the decreasing trend was very shallow, and the average concentration in the FFB area was similar to that at LDG-48. Greater TKN concentrations were measured at the Ekati stations in 2018 (both seasons), with a decreasing trend from the Slipper Lake outlet to station S6. However, the average concentration at S6 during ice-cover was less than those observed in the FFB area and greater than at LDG-48, whereas TKN concentrations at the Ekati stations were less than the concentrations measured at Diavik stations in 2019. There is no normal range for TKN, but as nitrate and nitrite were not detected at the Ekati stations in 2018, the TKN concentrations can be assumed to be similar to the TN concentrations[2]. Concentrations of TKN at S6 in 2018 were within or below the normal range for TN. Therefore, there is no indication that TKN concentrations from Slipper Lake influenced the TKN concentrations at FFB or LDG-48.

During the ice-cover season, nitrate concentration at LDG-48 was less than the average concentrations in either the FFB or the FFA area; however the average concentration in the FFA area was greater than in FFB (Figure 3-37). However, the spatial gradient analysis did not identify a positive slope after the breakpoint along the MF3 transect (Section 3.8.2). Nitrate has increased in the Koala Watershed as a result of Ekati mine effluent (ERM 2019). Nitrate concentrations in samples collected at bottom depth decreased between S3 and S6 in 2018, but concentrations at mid-depth were noticeably lower and within five times the DL. Bottom depth nitrate concentrations at S6 in 2018 were within the range of concentrations observed at FFA in 2019, and greater than normal range. These Ekati results suggest a potential for Ekati mine effluent to influence nitrate concentrations in FFB. However, because nitrate concentrations at LDG-48 were lower than in the FFA or FFB areas, a cumulative effect on nitrate was not identified during the ice-cover season.

During the open-water season, nitrate concentrations were at or less than the DL in the FFB and FFA areas, and less than the DL at LDG-48 and the Ekati stations (Figure 3-37). Similar results were observed for nitrite during both seasons (Figure 3-38), and for total ammonia during the open-water season (Figure 3-39). These results do not provide evidence of a potential cumulative effect.

Total ammonia concentrations during the ice-cover season decreased with distance from the diffuser in both seasons (Section 3.8.2), and this trend extended from the FFB to the FFA area, with a lower concentration at LDG-48 (Figure 3-39). Average concentrations in the FFA area and at LDG-48 were within the normal range. In comparison, total ammonia concentrations at the Ekati stations were less than the normal range and were slightly greater at the S5 and S6 stations. However, total ammonia concentrations at S6 were less than those at FFA and LDG-48, suggesting no influence of Slipper Lake outflow on total ammonia concentrations in Lac de Gras in 2019.

Use of the 2018 AEMP data from Ekati to compare to the 2019 AEMP data from Diavik did not appear to impair the cumulative effects assessment, although it contributes to uncertainty in the assessment. A key observation was that there was no indication of an increase in nutrient concentrations at station LDG-48 relative to either the FFB or FFA area. Therefore, the magnitude of the nutrient concentrations at S6 only support the lack of Ekati influence on nutrient concentrations at LDG-48. There remains some potential that year-to-year variability in water quality and potentially, differences in discharge rate (i.e., effluent flow, loading rates and timing of discharge), could influence the interpretation of results.

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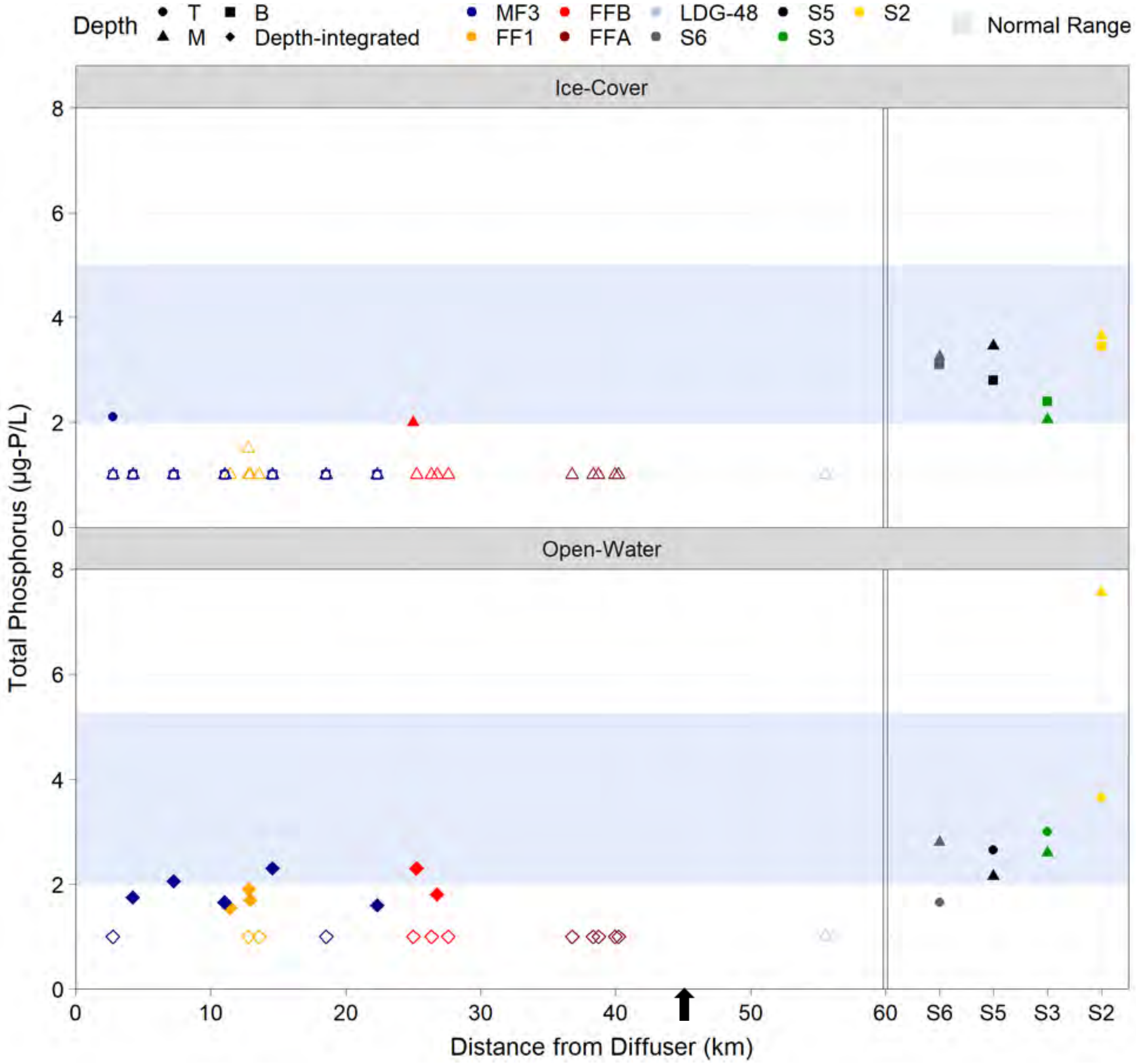
[2] TKN is calculated by the analytical laboratory as the TN minus nitrate+nitrite.

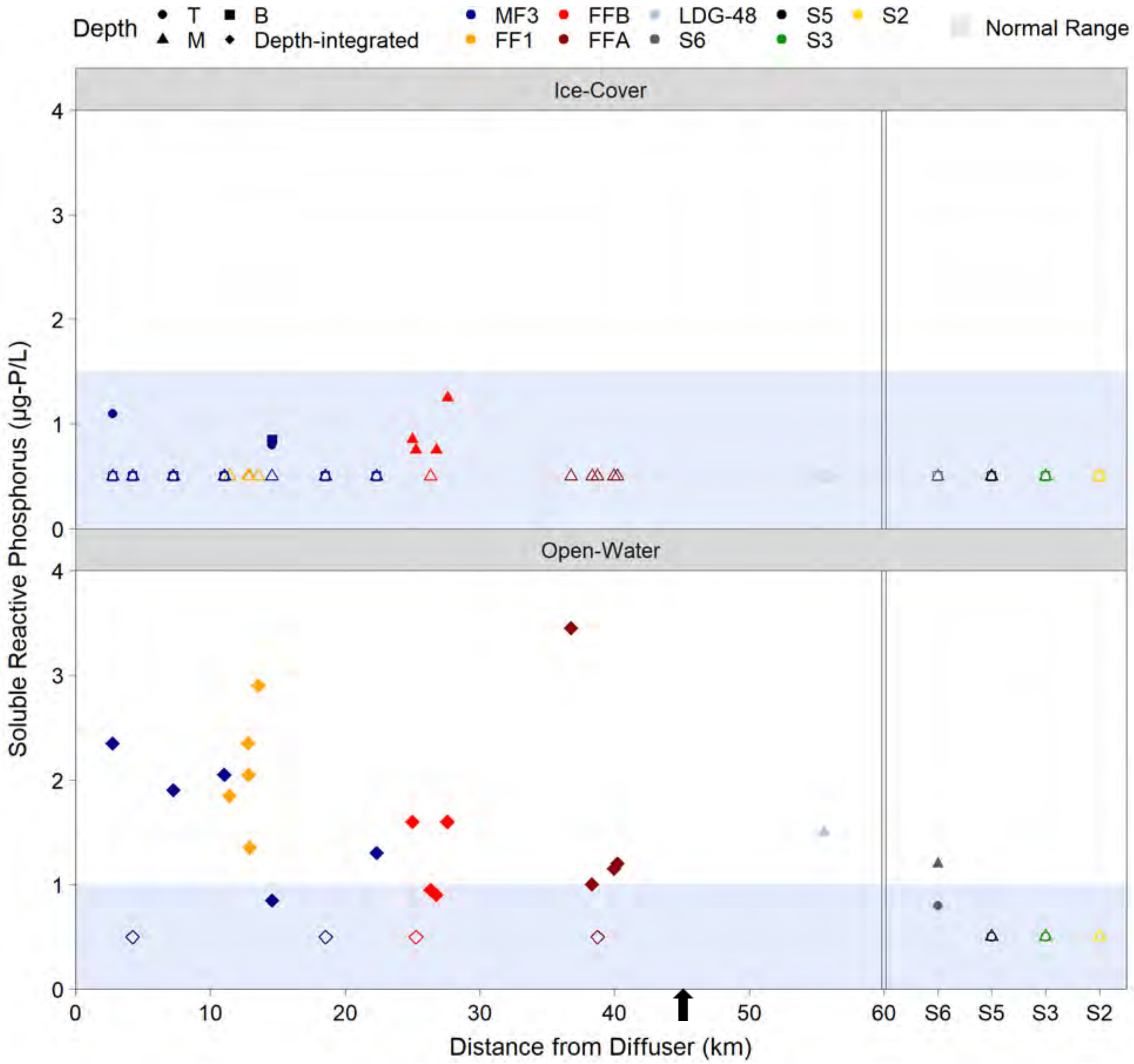
Figure 3-34 Spatial Variation in Total Phosphorus at Diavik (FFB, FFA, LDG-48) and Ekati Stations (S2, S3, S5, S6) at the Northwest End of Lac de Gras



Notes: Values represent concentrations in individual samples collected at the top, middle and bottom depths. Open symbols represent non-detect data. The most recent publicly available Ekati data from the 2018 AEMP are included on the plot for reference. The approximate location of S6 relative to the Diavik AEMP stations is indicated by an arrow (i.e., approximately 45 km from the Diavik diffuser).

µg-P/L = micrograms phosphorus per litre; T = top depth; M = middle depth; B = bottom depth; MF = mid-field; FF = far-field; LDG = Lac de Gras; S = station.

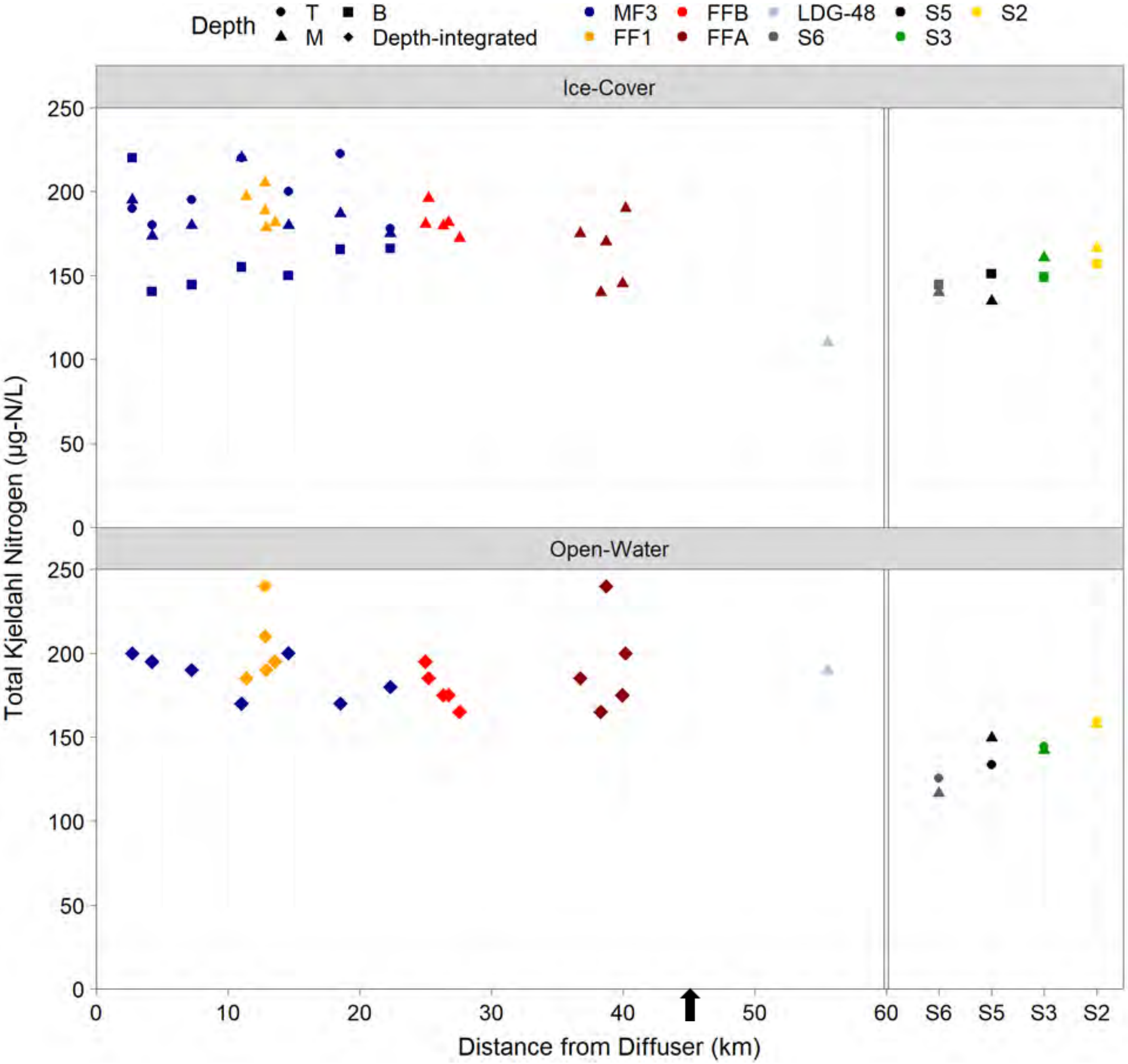
Figure 3-35 Spatial Variation in Soluble Reactive Phosphorus at Diavik (FFB, FFA, LDG-48) and Ekati Stations (S2, S3, S5, S6) at the Northwest End of Lac de Gras



Notes: Values represent concentrations in individual samples collected at the top, middle and bottom depths. Open symbols represent non-detect data. The most recent publicly available Ekati data from the 2018 AEMP are included on the plot for reference. The approximate location of S6 relative to the Diavik AEMP stations is indicated by an arrow (i.e., approximately 45 km from the Diavik diffuser).

µg-P/L = micrograms phosphorus per litre; T = top depth; M = middle depth; B = bottom depth; MF = mid-field; FF = far-field; LDG = Lac de Gras; S = station.

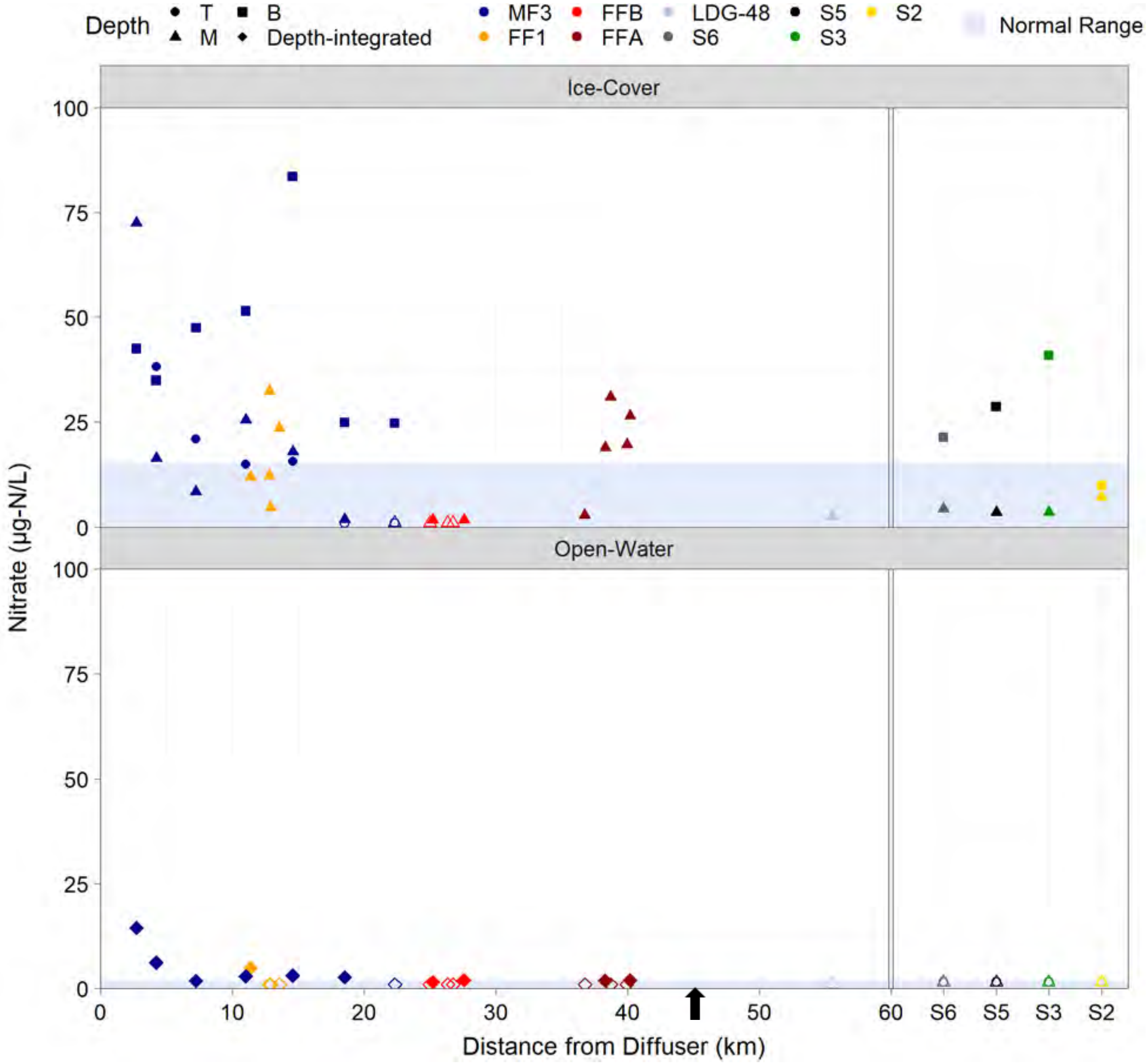
Figure 3-36 Spatial Variation in Total Kjeldahl Nitrogen at Diavik (FFB, FFA, LDG-48) and Ekati Stations (S2, S3, S5, S6) at the Northwest End of Lac de Gras



Notes: Values represent concentrations in individual samples collected at the top, middle and bottom depths. Open symbols represent non-detect data. The most recent publicly available Ekati data from the 2018 AEMP are included on the plot for reference. The approximate location of S6 relative to the Diavik AEMP stations is indicated by an arrow (i.e., approximately 45 km from the Diavik diffuser).

µg-N/L = micrograms nitrogen per litre T = top depth; M = middle depth; B = bottom depth; MF = mid-field; FF = far-field; LDG = Lac de Gras; S = station.

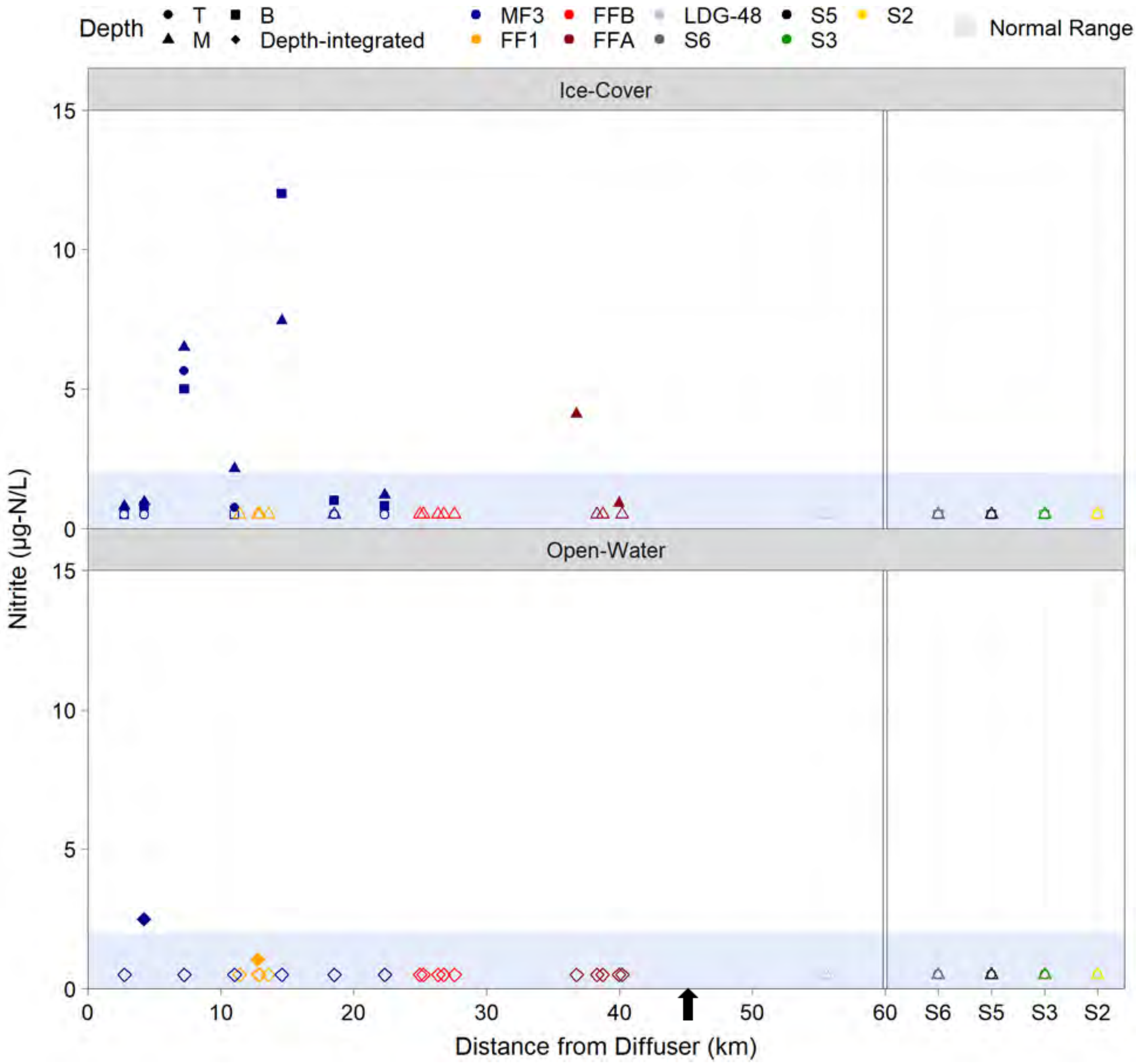
Figure 3-37 Spatial Variation in Nitrate at Diavik (FFB, FFA, LDG-48) and Ekati Stations (S2, S3, S5, S6) at the Northwest End of Lac de Gras



Notes: Values represent concentrations in individual samples collected at the top, middle and bottom depths. Open symbols represent non-detect data. The most recent publicly available Ekati data from the 2018 AEMP are included on the plot for reference. The approximate location of S6 relative to the Diavik AEMP stations is indicated by an arrow (i.e., approximately 45 km from the Diavik diffuser).

µg-N/L = micrograms nitrogen per litre; T = top depth; M = middle depth; B = bottom depth; MF = mid-field; FF = far-field; LDG = Lac de Gras; S = station.

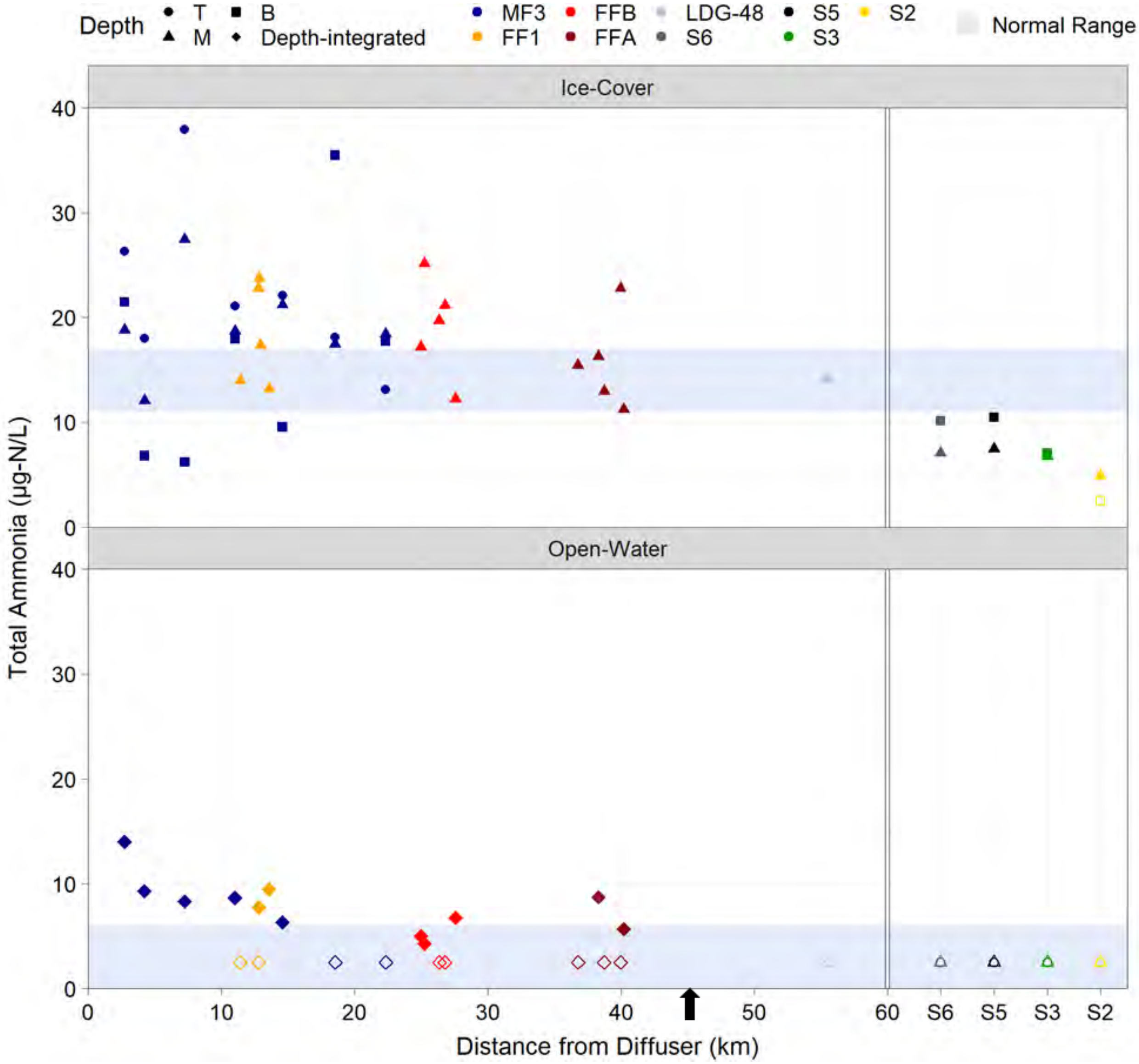
Figure 3-38 Spatial Variation in Nitrite at Diavik (FFB, FFA, LDG-48) and Ekati Stations (S2, S3, S5, S6) at the Northwest End of Lac de Gras



Notes: Values represent concentrations in individual samples collected at the top, middle and bottom depths. Open symbols represent non-detect data. The most recent publicly available Ekati data from the 2018 AEMP are included on the plot for reference. The approximate location of S6 relative to the Diavik AEMP stations is indicated by an arrow (i.e., approximately 45 km from the Diavik diffuser).

µg-N/L = micrograms nitrogen per litre; T = top depth; M = middle depth; B = bottom depth; MF = mid-field; FF = far-field; LDG = Lac de Gras; S = station.

Figure 3-39 Spatial Variation in Total Ammonia at Diavik (FFB, FFA, LDG-48) and Ekati Stations (S2, S3, S5, S6) at the Northwest End of Lac de Gras



Notes: Values represent concentrations in individual samples collected at the top, middle and bottom depths. Open symbols represent non-detect data. The most recent publicly available Ekati data from the 2018 AEMP are included on the plot for reference. The approximate location of S6 relative to the Diavik AEMP stations is indicated by an arrow (i.e., approximately 45 km from the Diavik diffuser).

µg-N/L = micrograms nitrogen per litre; T = top depth; M = middle depth; B = bottom depth; MF = mid-field; FF = far-field; LDG = Lac de Gras; S = station.

3.12 Weight-of-Evidence Input

As described in Section 2.5, the results reported in the preceding sections also contribute to the WOE analysis presented in the *Weight-of-Evidence Report* (Appendix XV). The results of the WOE analysis relevant to nutrients, chlorophyll *a*, phytoplankton biomass, and zooplankton biomass (AFDM) are described in Section 3.1 of the *Weight-of-Evidence Report* (Appendix XV).

4 Summary and Discussion

4.1 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. 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.

Concentrations of TP, TDP and SRP in effluent were generally greater during the ice-cover season, which generally resulted in greater monthly loads. However, monthly loads of TP and SRP were greater from December to March and in May compared to the other months, whereas TDP loads were similar throughout the ice-cover season. Monthly loads of TP and SRP were generally greater during the ice-cover season, likely due to larger effluent volumes, because effluent concentrations were lower during this season. Concentrations and loads of TDP were smaller in the open-water season. The smallest monthly load of TP occurred in October, reflecting smaller effluent concentrations and volumes. Patterns in phosphorus concentrations at the mixing zone boundary generally reflected patterns observed in the Mine effluent.

Seasonal differences were observed in loads and effluent concentrations of nitrogen species; TN, nitrate, and nitrite concentrations were lowest during the ice-cover season and highest in the open-water season. Concentrations and loads of TN, nitrate, and nitrite in effluent tracked closely together, and followed a similar trend to effluent volume. Most of the TN was present as nitrate in the effluent. Monthly loads and concentrations of TN and nitrate in effluent were smallest during the ice-cover season and steadily increased from February to September. Trends for nitrite were similar, except the relatively smaller monthly load in September reflected the lower effluent concentrations in this month. Patterns in TN, nitrate, and nitrite concentrations at the mixing zone boundary generally reflected patterns observed in the Mine effluent during the ice-cover season, but not during the open-water season. Concentrations decreased sharply between May and July. For TN and nitrate, concentrations at the mixing zone boundary were approximately equal between seasons, whereas nitrite concentrations were greater, following the trends in the effluent.

Total ammonia monthly loads and concentrations in effluent did not follow the same pattern as the other nitrogen species. Loads generally followed the pattern in effluent volume for most months. Concentrations in effluent were highest during the ice-cover season, with a sharp decline between May and July, followed by a peak in August. The smallest monthly load for total ammonia occurred in July, which corresponded with the smallest concentrations in effluent. Concentrations at the mixing zone boundary generally followed those in effluent. The sharp decreases in concentrations of TN, ammonia, and nitrate at the mixing zone boundary between May and July reflect quick assimilation by algae and bacterial nitrification (Wetzel 2001).

4.2 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 can 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 (Section 3.1 and Golder 2018). Although phosphorus concentrations at the mixing zone boundary were lower 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 low in 2019 compared to previous years, likely due to the lower phosphorus load from effluent. Concentrations were greater in the NF area, but all concentrations in the lake were below the normal range. 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. 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 much 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. The lower 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 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, 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 were likely due to lower TP loading from effluent. No effects on total phytoplankton biomass were observed in 2019. 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 greater than the normal range at all of the NF stations and several MF stations, with a decreasing trend with distance from the diffuser. The 2019 zooplankton community displayed a response consistent with nutrient enrichment, in agreement with the chlorophyll *a* results.

4.3 Extent of Effects

Per Directive 2B from the 25 March 2019 WLWB Decision regarding the 2017 AEMP , the spatial extent of effects of eutrophication indicators was estimated for both the ice-covered and open-water seasons, and all three depths (top, middle, and bottom) for the ice-covered season (Attachment E).

Concentrations of TP were below the normal range at all stations in both seasons, and at all depths (Figure 4-1). Therefore, the area of the lake affected was 0% (Table 4-1).

Concentrations of TN were greater in the NF area during the ice-cover season in the middle and bottom depths than in the top depths, or during the open-water season. All NF stations had TN concentrations greater than normal range. Concentrations were greater than normal range at all stations along the MF1, MF2, and MF3 transects, with the exception of two stations in the FFA area (i.e., FFA-2 and FFA-5) during the ice-cover season (Figure E-1). Concentrations of TN were also greater than the normal range at LDG-48 during the open-water season, but not during the ice-cover season (Figure E-1). Therefore, when LDG-48 was included in the calculation, the entire lake was affected (i.e., 573 km^2 or 100%) based on the open-water data calculation (Figure 4-2, Table 4-1), versus 484 km^2 or 85% of the lake being affected based on the ice-cover data calculation.

Chlorophyll *a* concentrations were within or below the normal range at all stations, with the exception of NF3. Therefore, the extent of lake affected was much smaller than in previous years, at 0.5 km^2 or 0.1% (Table 4-1, Figure 4-3). This result is consistent with the smaller extent of effects observed for TP, at least partly due to the lower TP load from Mine effluent. This result also supports the lack of effect of TN on chlorophyll *a*, and is consistent with the importance of phosphorus as the limiting nutrient in Lac de Gras. In addition, the low extent of effects on chlorophyll *a* in 2019 was measured despite estimated TP deposition rate from dust that was higher than in 2018, suggesting that TP deposition from dust is not an important factor influencing lake productivity.

Total phytoplankton biomass was less than normal range at all stations (Figure 4-4). Therefore, the area of the lake affected was 0% (Table 4-1). This smaller extent of effects is consistent with the results for TP and chlorophyll *a*.

Effects on zooplankton biomass (as AFDM) 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 (Figure 4-5). 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 in the currently approved design plan[3]. 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 (as AFDM) represents greater than or equal to 168 km^2, or greater than or equal to 29% of the lake area (Table 4-1). Because there is uncertainty in the extent of the effect to the northwest, comparisons to the affected areas calculated in recent years should be done 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%) (Table 4-1).

---

[3] Station FFD-1 was added to *AEMP Design Plan Version 5.1*, which will be located between FF1 and MF3-7.

Table 4-1 Spatial Extent of Effects on Concentrations of Total Phosphorus, Total Nitrogen and Chlorophyll *a*, and Phytoplankton and Zooplankton Biomass, 2007 to 2019

Year	Total Phosphorus		Total Nitrogen		Chlorophyll *a*		Phytoplankton Biomass		Zooplankton Biomass (AFDM)	
	Area (km^2)[a]	Lake Area (%)[b]	Area (km^2)[a]	Lake Area (%)[b]	Area (km^2)	Lake Area (%)[b]	Area (km^2)	Lake Area (%)[b]	Area (km^2)	Lake Area (%)[b]
2007	29	5.1	-[d]	-[d]	89	15.5	67	11.7	-[d]	-[d]
2008	112[c]	19.6	85	14.8	77	13.5	116	20	-[e]	-[e]
2009	54[c]	9.3	180	32	121	21	274	48	0	0
2010	24[c]	4.2	132[c]	23	89	15.5	217	38	52	9.1
2011	9.2[c]	1.6	213[c]	37	89	15.6	125	22	129	23
2012	3.6[c]	0.6	118	21	17.0	3.0	67	11.8	77	13.4
2013	81[c]	14.1	183[c]	32	129	23	59	10.4	355	62
2014	3.5[c,f]	0.6[f]	≥230[c,f]	≥40[f]	≥243[f]	≥42[f]	-[h]	-[h]	-[i]	-[i]
2015	<3.5[f,g,j]	<0.6[f,g,j]	≥243[c,f]	≥42[f]	59[f]	10.3[f]	-[h]	-[h]	<3.5[j]	<0.6[j]
2016	37[c]	6.5	≥485[k]	≥85[k]	250	44	75	13.0	2.9	0.5
2017	6.2	1.1	≥240[l]	≥42[l]	≥150[l]	≥26[l]	111	19.4	<3.5[j]	<0.6[j]
2018	2.6	0.5	≥234[l]	≥41[l]	≥84[l]	≥14.7[l]	96	16.8	≥74[l]	≥12.8[l]
2019[m]	0	0	573 (OW) 484 (IC)[n]	100 (OW) 85 (IC)[n]	0.5	0.1	0	0	≥168	≥29

a) Lake area reported is the greater of the area affected during the open-water or ice-cover season.

b) The lake area affected represents the percentage of lake area experiencing levels greater than the normal range, and was calculated relative to the total surface area of Lac de Gras (573 km^2).

c) Lake area reported is for the ice-cover season.

d) Data not available due to field subsampling errors (Golder 2016b).

e) Data not available due to differences in sample collection procedures (Golder 2016b).

f) Percent lake area affected could not be estimated with certainty, because the FF1, FFA, and FFB areas were not sampled in 2014 and 2015.

g) Data are reported for the open-water season.

h) Only NF area sampled in 2014 and 2015; therefore, extent of effects was not calculated.

i) Data not available due to the loss of the zooplankton samples.

j) The mean of the NF area stations was within the normal range. Since only one or two NF stations exceeded the normal range, the affected area was assumed to be less than the total area of the NF area (0.6% of lake area).

k) Due to an uncertain effect boundary at the end of the MF3-FFB-FFA transect, the extent of effects could have been greater than the area presented.

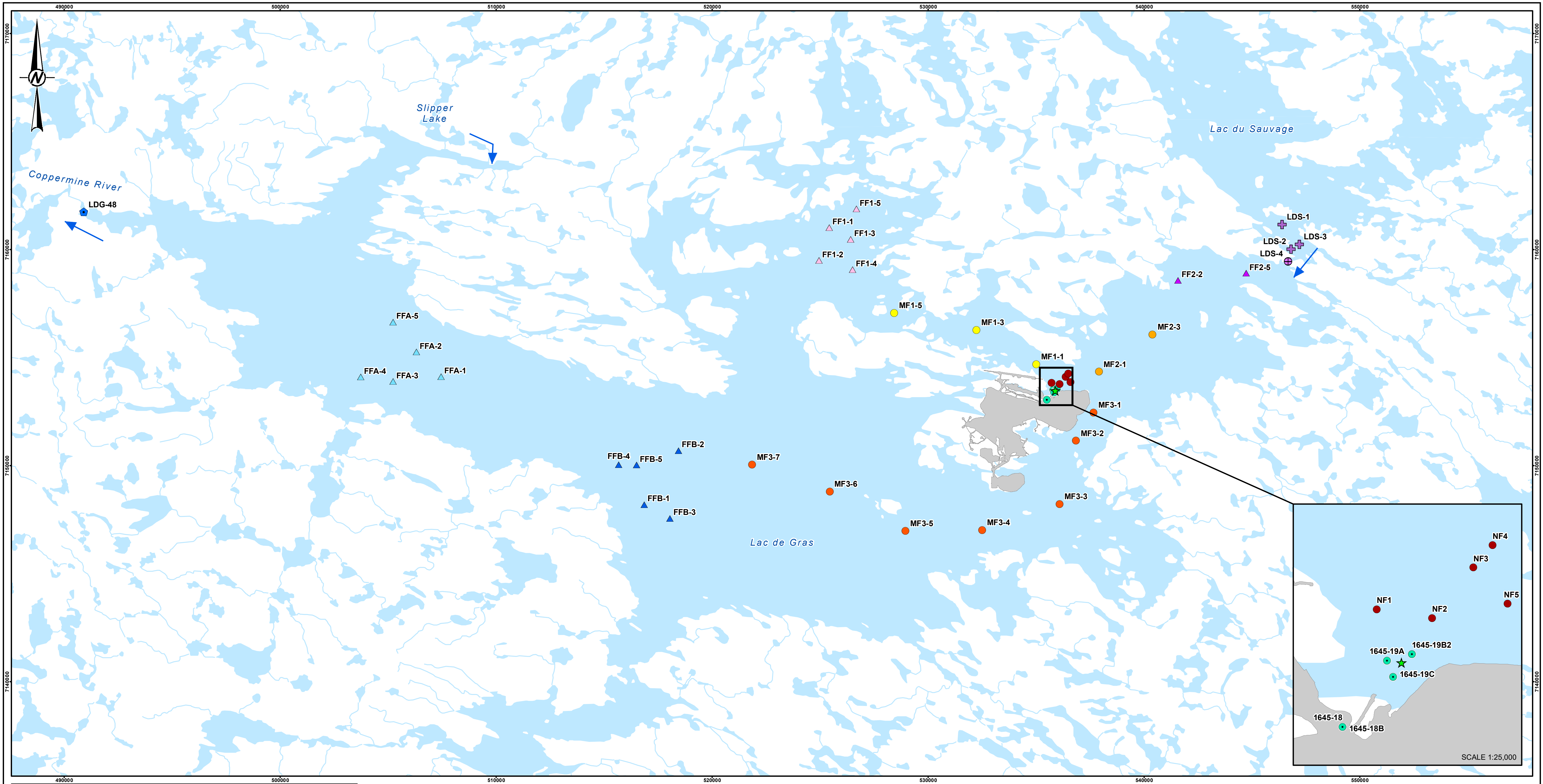
l) Percent lake area affected could not be estimated with certainty, because the extent of effects along the MF1 transect extended to at least MF1-5 and the FF1 area was not sampled in 2017 and 2018.

m) Area affected by nutrient concentrations greater than normal range was calculated for both open-water and ice-cover seasons and for all three depths (top, middle, bottom) for the ice-cover season.

n) There was no difference in area affected among depths.

< = less than; ≥ = greater than or equal to; - = not determined; NF = near-field; MF = mid-field; FF = far-field; AFDM = ash-free dry mass.

Note: To enhance readability, numbers greater than 20 km^2 or 20% in this table were rounded to whole numbers.



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

→	FLOW DIRECTION
—	WATERCOURSE
🟪	AFFECTED AREA[1]
⬜	DIAVIK FOOTPRINT
🟦	WATERBODY

0 5 10

1:175,000 KILOMETRES

NOTE(S)

1. NO AFFECTED AREA. ALL STATIONS HAD PHOSPHORUS RESULTS THAT WERE LESS THAN THE UPPER BOUND OF THE NORMAL RANGE.

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

RioTinto

PROJECT

DIAVIK DIAMOND MINES INC.

CONSULTANT

GOLDER

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

TITLE

TOTAL PHOSPHORUS AFFECTED AREA IN LAC DE GRAS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
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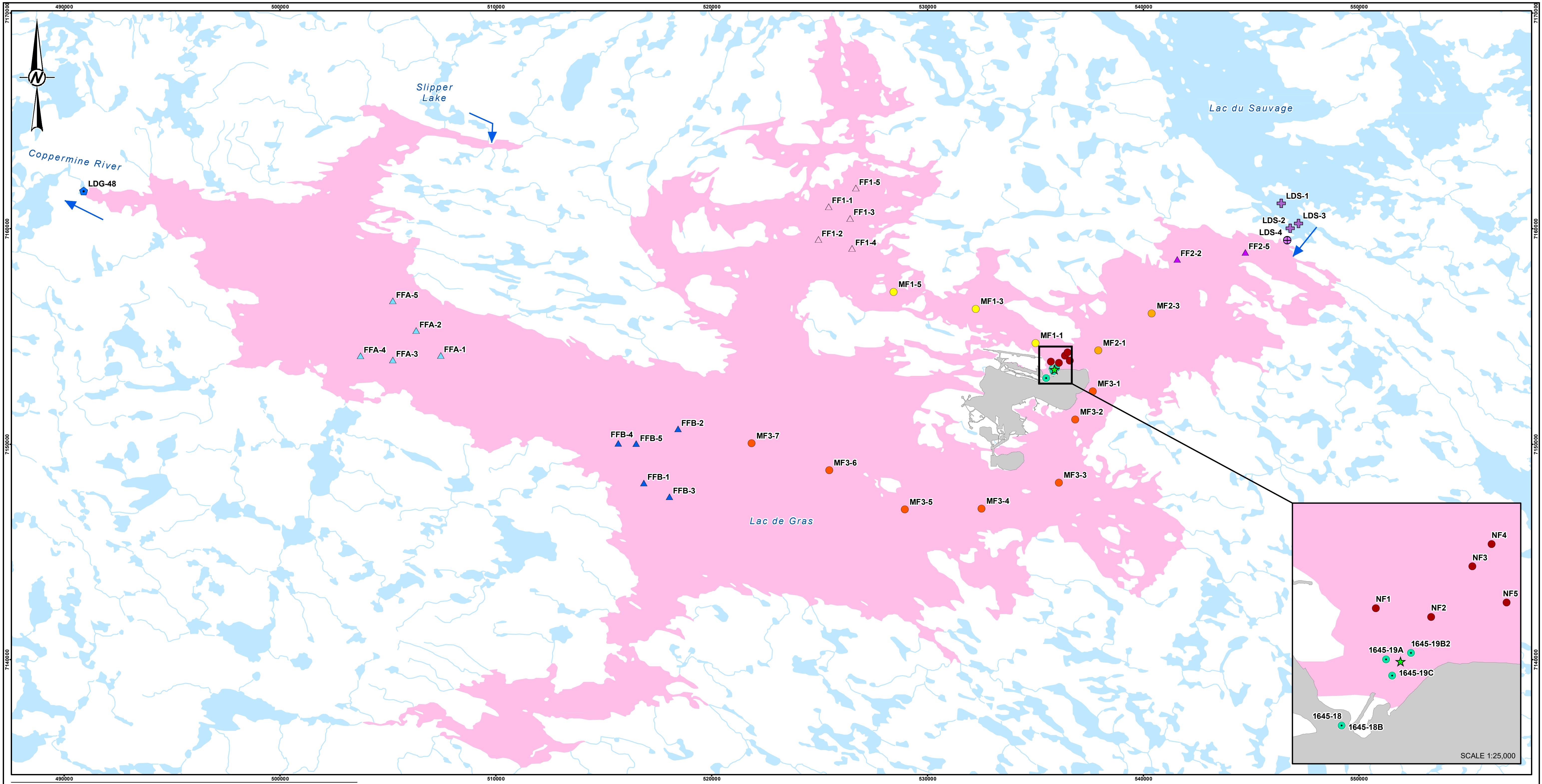

LEGEND

★	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

→	FLOW DIRECTION
—	WATERCOURSE
■	AFFECTED AREA[1]
■	DIAVIK FOOTPRINT
■	WATERBODY

0 5 10

1:175,000 KILOMETRES

NOTE(S)
1. TOTAL AREA OF THE LAKE AFFECTED IS BASED ON OPEN-WATER DATA.

REFERENCE(S)
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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

CONSULTANT
GOLDER

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

PROJECT
DIAVIK DIAMOND MINES INC.

TITLE
TOTAL NITROGEN AFFECTED AREA IN LAC DE GRAS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
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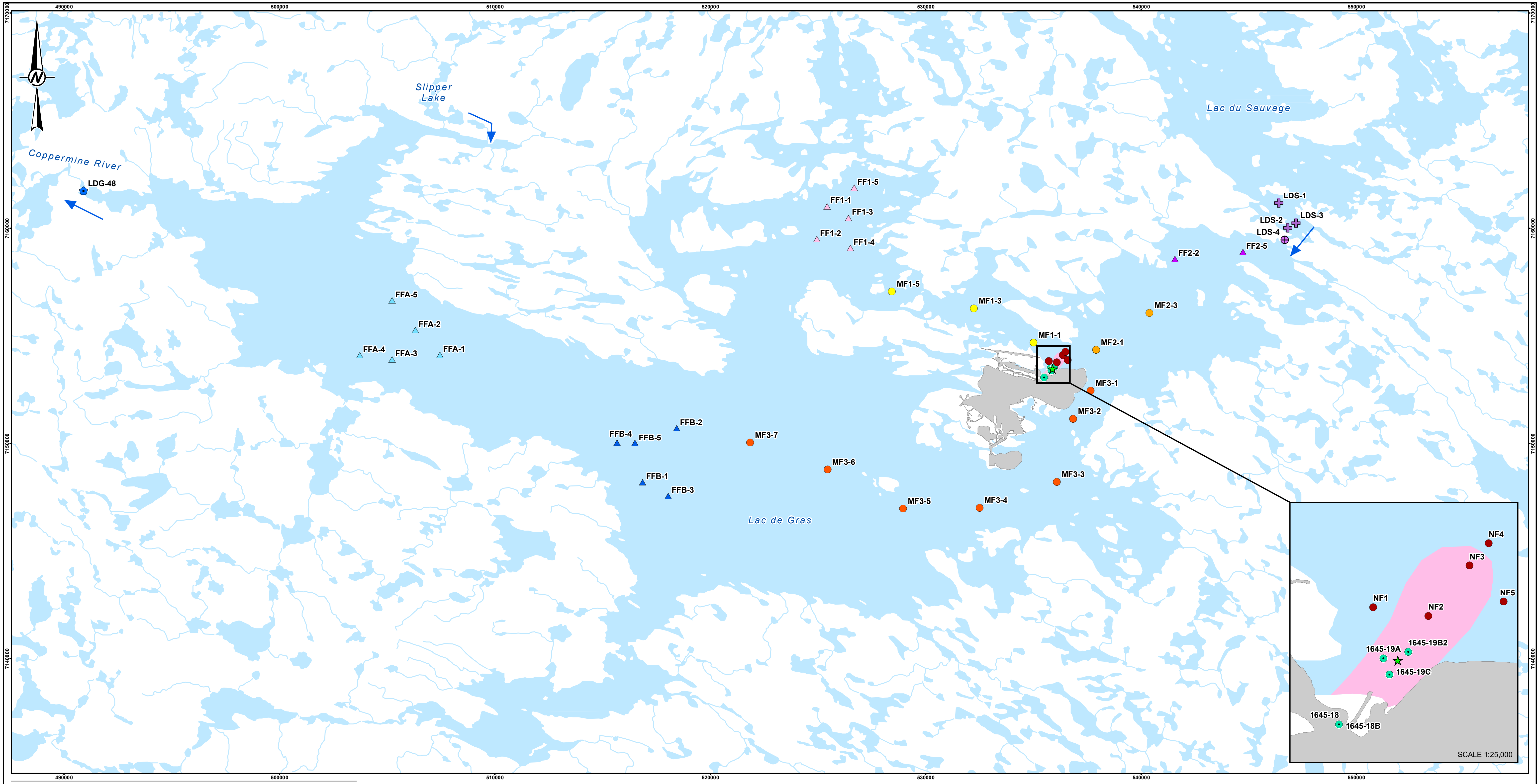

LEGEND

★ 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

→ FLOW DIRECTION

— WATERCOURSE

▨ AFFECTED AREA[1]

▨ DIAVIK FOOTPRINT

▨ WATERBODY

0 5 10

1:175,000 KILOMETRES

NOTE(S)

1. TOTAL AREA OF THE LAKE AFFECTED IS BASED ON OPEN-WATER DATA.

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

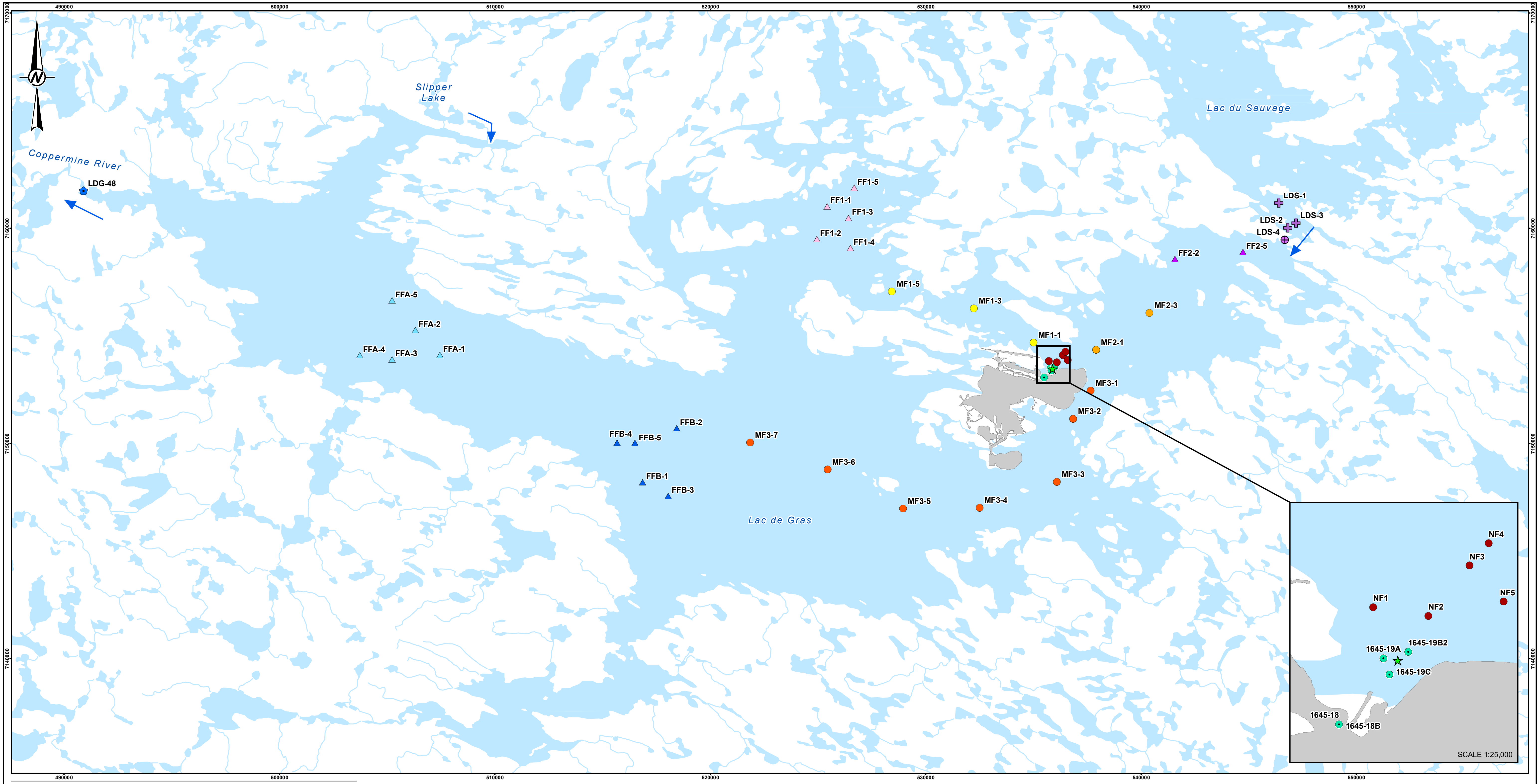
PROJECT
DIAVIK DIAMOND MINES INC.

CONSULTANT
GOLDER

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

TITLE
CHLOROPHYLL A AFFECTED AREA IN LAC DE GRAS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
19115664	8000	0	4-3



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

- → FLOW DIRECTION
- — WATERCOURSE
- ▨ AFFECTED AREA[1]
- ▨ DIAVIK FOOTPRINT
- ▨ WATERBODY

0 5 10
1:175,000 KILOMETRES

NOTE(S)
1. NO AFFECTED AREA. ALL STATIONS HAD PHYTOPLANKTON BIOMASS RESULTS THAT WERE LESS THAN THE UPPER BOUND OF THE NORMAL RANGE.

REFERENCE(S)
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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
RioTinto

PROJECT
DIAVIK DIAMOND MINES INC.

CONSULTANT
GOLDER

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

TITLE
TOTAL PHYTOPLANKTON BIOMASS AFFECTED AREA IN LAC DE GRAS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
19115664	8000	0	4-4

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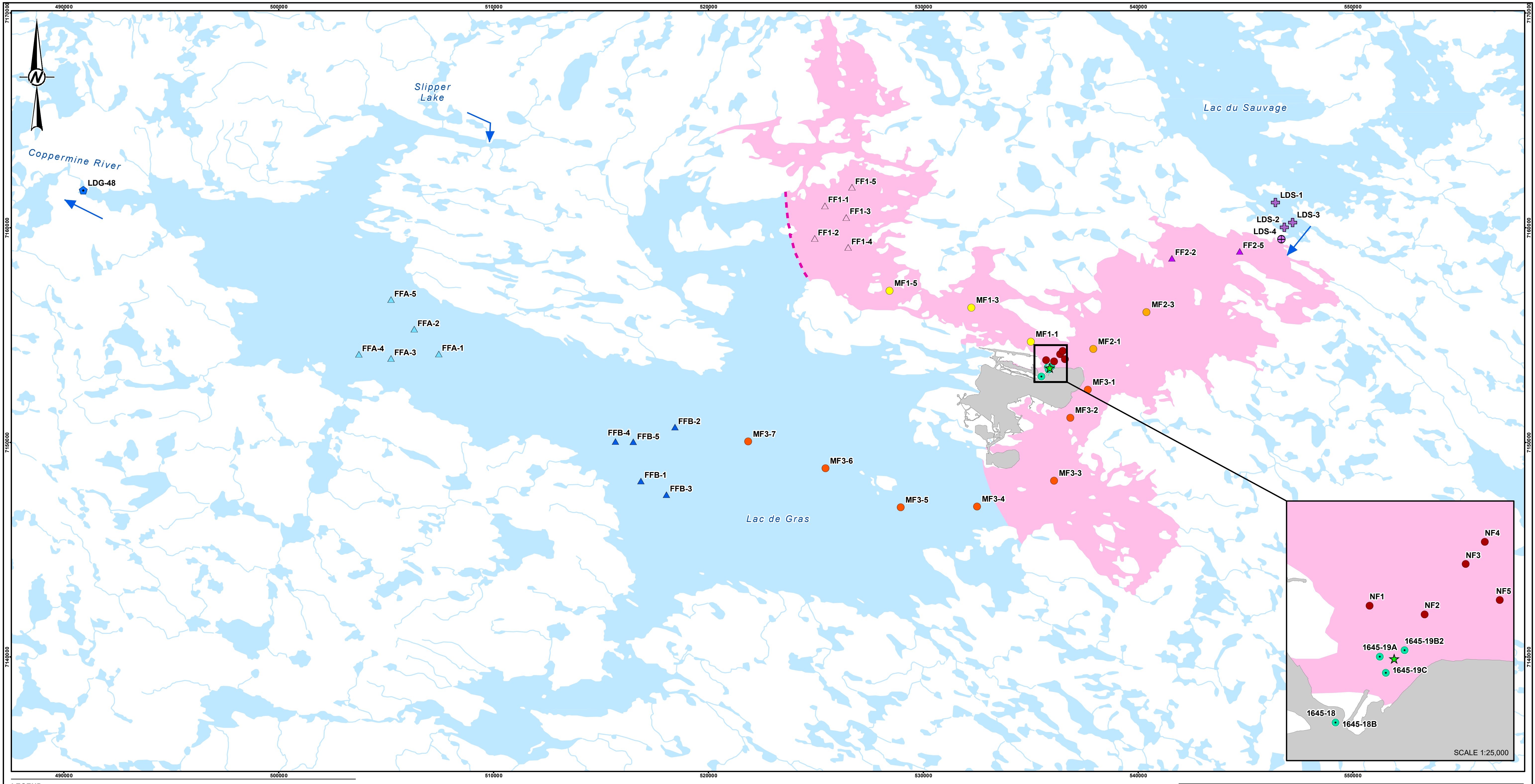

LEGEND

★ 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

→ FLOW DIRECTION

- - UNCERTAIN EFFECT BOUNDARY

— WATERCOURSE

🟪 AFFECTED AREA[1]

⬜ DIAVIK FOOTPRINT

🟦 WATERBODY

0 5 10

1:175,000 KILOMETRES

NOTE(S)

1. TOTAL AREA OF THE LAKE AFFECTED IS BASED ON OPEN-WATER DATA.

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

RioTinto

PROJECT

DIAVIK DIAMOND MINES INC.

CONSULTANT

GOLDER

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

TITLE

TOTAL ZOOPLANKTON BIOMASS (AS AFDM) AFFECTED AREA IN LAC DE GRAS, 2019

PROJECT NO.	PHASE	REV.	FIGURE
19115664	8000	0	4-5

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5 RESPONSE FRAMEWORK

No Action Levels were triggered for eutrophication indicators based on the 2019 chlorophyll *a* results (Section 3.10). Therefore, no action is required to follow-up on the 2019 monitoring results for this AEMP component.

6 CONCLUSIONS

This report presents the assessment of data collected by DDMI for the eutrophication indicators component of the 2019 AEMP. Results of the 2019 eutrophication assessment indicate the following:

- The Mine is having a nutrient enrichment effect in Lac de Gras[4], as evidenced by greater nutrient and chlorophyll *a* concentrations, and zooplankton biomass in the NF area, compared to the rest of the lake. The enrichment effect was not apparent on total phytoplankton biomass.
- TP and TDP concentrations were below the normal range throughout most of Lac de Gras, but SRP concentrations were within or above the normal range throughout the lake during the open-water season. The upper bound of the normal range for SRP is the same as the DL, therefore, any detected concentrations were also above the normal range. However, all phosphorus concentrations were within five times the DL, and therefore within the range of analytical uncertainty. The smaller phosphorus concentrations in lake water relative to previous years were at least partly due to the lower TP loads from Mine effluent in 2019.
- Nitrogen concentrations were greater than the normal range in most of Lac de Gras, with significant decreasing concentrations with distance from the diffusers. A significant decreasing trend in SRSi concentration was also observed.
- Total phytoplankton biomass and chlorophyll *a* concentrations were low, which was consistent with the lower phosphorus concentrations. A decreasing gradient was apparent in chlorophyll *a* concentration with distance from the diffusers, but not in total phytoplankton biomass.
- Cumulative effects of Diavik and Ekati effluent on eutrophication indicators in Lac de Gras were not observed for TP, TKN, nitrate, nitrite, or total ammonia based on a comparison of 2019 data from Diavik and 2018 data from Ekati.
- The spatial extent of effects on eutrophication indicators in 2019 varied from 0% to 100% of lake area depending on indicator[5]:
  - The extent of effect was 0% for TP, and 85% to 100% of the lake area for TN, depending on season.

---

[4] 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) and subsequent AEMP annual reports (i.e., 2017, 2018).

[5] 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) and subsequent AEMP annual reports (i.e., 2017, 2018); extent of effects for TP has been low and variable and <20%, for chlorophyll *a* has been variable and <45%, for TN has been greater than 40% since 2014, and for plankton has been variable.

  - The extent of effect was 0.1% for chlorophyll *a* concentration, 0% for phytoplankton biomass and ≥29% of the lake area for zooplankton biomass.

- Although the estimate of TP loading to Lac de Gras due to dust suggests that dust deposition could contribute to nutrient enrichment in the lake, this is not supported by the measured concentrations of TP and chlorophyll *a* at AEMP stations in the dust ZOI, or at stations sampled as part of the *Special Effects Study – Dust Deposition* (Appendix XII) in potentially greater dust deposition areas.

- Despite higher estimated TP deposition rates from dust in 2019 compared to 2018, effects on TP concentration and indicators of primary productivity in Lac de Gras were lower in 2019, consistent with the interpretation that effluent is the main source of Mine effects on Lac de Gras, with a negligible contribution from dust deposition. This conclusion is consistent with the results of the *Special Effects Study – Dust Deposition* (Appendix XII), which did not detect a dust-related chemical signature in lake water and suggested limited bioavailability of phosphorus in dust.

- The 2019 results are consistent with the EA prediction of greater concentrations of nutrients, particularly phosphorus from the minewater discharge, resulting in an increase in primary productivity. The biological response to the nutrients discharged from the Mine were proportional to measured phosphorus concentrations and did not reflect the elevated nitrogen concentrations throughout the lake. These results underline the importance of phosphorus limitation in Lac de Gras, which is also indicated by nutrient ratios summarized by Golder (2019c).

- The magnitude of the effect on eutrophication indicators was small in 2019, and results for chlorophyll *a* concentration did not trigger an Action Level[6]. This finding is different from previous AEMP reports, where at least Action Level 1 was triggered. These results imply rapid recovery of lake productivity to near background levels upon a reduction in effluent-related phosphorus load, even after nearly two decades of mining and effluent release to Lac de Gras.

Overall, the conclusions from the 2019 AEMP are consistent with those reported in previous AEMPs, in that the Mine is having a nutrient enrichment effect in Lac de Gras, inputs of phosphorus not nitrogen appear to be the main driver to increases in primary productivity, and the main source of Mine-related effects on eutrophication indicators is effluent not dust, with significant decreasing concentrations of most eutrophication indicators with distance from the diffuser and no evidence of a measurable influence of dust. Unlike previous AEMPs, no Action Level was triggered. Also, smaller effects on concentrations of phosphorus and chlorophyll *a*, and on phytoplankton biomass was at least partly due to the smaller TP load in effluent.

---

[6] 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) and subsequent AEMP annual reports (i.e., 2017, 2018); either an Action Level 1 or 2 was triggered in the 2007 to 2018 AEMPs.

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8 CLOSURE

We trust the information in this report meets your requirements at this time. If you have any questions relating to the information contained in this report, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

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ATTACHMENT A

AEMP SAMPLING SCHEDULE

Table A-1 2019 AEMP Sampling Schedule

Sites	Ice-cover														Open-water																
	April							May							August													September			
	22	23	24	25	26	28	30	1	4	5	6	8	9	10	15	17	18	19	20	21	22	23	25	26	27	28	31	2	3	4	5
NF1	N																				Np										
NF2														N								Np									
NF3		N																											Np		
NF4		N																				Np									
NF5		N													Np																
MF1-1														N							Np										
MF1-3						N															Np										
MF1-5						N														Np											
MF2-1				N																		Np									
MF2-3			N																Np												
FF2-2														N					Np												
FF2-5														N					Np												
MF3-1														N															Np		
MF3-2							N																			Np					
MF3-3													N													Np					
MF3-4													N												Np						
MF3-5													N												Np						
MF3-6								N																	Np						
MF3-7								N																Np							
FF1-1									N							Np															
FF1-2									N									Np													
FF1-3									N								Np														
FF1-4									N											Np											
FF1-5									N									Np													
FFA-1												N																		Np	
FFA-2												N																		p(b)	Np
FFA-3												N																		Np	
FFA-4												N																		Np	
FFA-5												N																		Np	
FFB-1											N													Np							
FFB-2											N												Np								
FFB-3											N													Np							
FFB-4										N													Np								
FFB-5										N													Np								
LDG-48(a)												N															Np(b)				
LDS-1					N																							Np			
LDS-2					N																							Np			
LDS-3														N														Np			
LDS-4(a)																															Np(b)

a) Discrete samples were collected at mid-depth.
b) Only chlorophyll *a* was sampled, not plankton. Notes:
If a quality control sample was collected at the same time as the Nutrient sample, then the “N” was colour-coded: Equipment Blank (EB), Field Blank (FB), Travel Blank (TB), and Field Duplicate (FD).
N = nutrient sample collected; p = chlorophyll *a* and plankton sample collected; NF = near-field; MF = mid-field; FF = far-field; LDG = lac de Gras; LDS = Lac du Sauvage.

ATTACHMENT B

QUALITY ASSURANCE AND QUALITY CONTROL

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting and are described in the *Quality Assurance Project Plan Version 3.1* (Golder 2017). Quality assurance encompasses management and technical practices designed to generate consistent, high quality data. Quality control is an aspect of quality assurance and includes the techniques used to assess data quality and the corrective actions to be taken when the data quality objectives are not met. This Attachment describes QA/QC practices applied during the 2019 eutrophication indicators component of the Aquatic Environment Monitoring Program (AEMP), evaluates quality control (QC) data, and describes the implications of QC results to the interpretation of study results.

Quality Assurance

Field Staff Training and Operations

Diavik Diamond Mines (2012) Inc. (DDMI) field staff are trained to be proficient in standardized field sampling procedures, data recording, and equipment operations applicable to water quality sampling. Field work was completed according to specified instructions and standard operating procedures (SOP). The procedures are described in:

- ENVI-923-0119 AEMP SOP Combined Open Water and Ice Cover
- ENVI-902-0119 SOP Quality Assurance Quality Control
- ENVI-900-0119 SOP Chain of Custody

These SOPs include guidelines for field record-keeping and sample tracking, guidance for use of sampling equipment, relevant technical procedures, and sample labelling, shipping and tracking protocols.

Laboratory

Nutrient samples were sent for analysis to Bureau Veritas Laboratories (BV Labs; formerly Maxxam Analytics), Burnaby, British Columbia or Calgary, Alberta, a laboratory accredited by the Canadian Association of Laboratory Accreditation (CALA). All open-water samples were analyzed by BV Labs in Burnaby; the ice-cover samples were divided between the two locations. Split samples for total ammonia analysis were also sent to ALS Laboratories (ALS) in Vancouver; ALS is also a CALA accredited laboratory. Under the accreditation program, performance assessments are completed annually for laboratory procedures, analytical methods, and internal quality control.

Quality assurance at the DDMI Environmental Laboratory encompasses all quality-related activities related to aquatic testing and analysis, and relevant technical support (ENVI-646-0117 Quality Manual Documentation Outline).

DDMI's quality assurance places an emphasis on four aspects:

- infrastructure (instruments, testing capabilities, calibrations, SOPs)

- control measures (internal/external)
- personnel (competence, ethics, and integrity)
- data management

Field and Office Operations

A quality assurance system was established as an organized system of data control, analysis and filing. Relevant elements of this system are as follows:

- pre-field meetings to discuss specific work instructions with field crews
- field crew check-in with task managers every 24 to 48 hours to report work completed during that period
- designating two crew members responsible for:
    - collecting all required samples
    - downloading and storing electronic data
    - completing chain-of-custody and analytical request forms; labelling and documentation
    - processing, where required, and delivering samples to analytical laboratory in a timely manner
- cross-checking chain-of-custody forms and analysis request forms by the task manager to verify that the correct analysis packages had been requested
- review of field sheets by the task manager for completeness and accuracy
- reviewing laboratory data immediately after receipt from the analytical laboratory
- creating backup files before data analysis
- completing appropriate logic checks and verifying accuracy of calculations

Quality Control

Methods

Quality control is a specific aspect of quality assurance that includes the techniques used to assess data quality. The field QC program consisted of the collection of field blanks, equipment blanks, travel blanks, and duplicate samples. The blanks are used to assess potential sample contamination in the field, and the duplicates are used to assess within-station variation and sampling precision. Field, travel, and equipment blank samples were submitted to BV Labs for nutrient analysis during both the open-water and ice-cover seasons. Split samples were submitted to ALS's Vancouver (BC) laboratories for total ammonia analysis. As discussed in the *Effluent and Water Chemistry Report* (Appendix II), total ammonia data from both BV Labs and ALS were used in the eutrophication indicators data analysis: the ALS ice-cover total ammonia data were used, and the BV Labs open-water data were used. The open-water chlorophyll *a* QC samples were submitted to the Biogeochemical Analytical Service Laboratory at the University of

Alberta, Edmonton, Alberta for analysis. The zooplankton biomass (as AFDM) QC samples were submitted to BV Labs. Duplicate samples were collected and submitted for analysis of nutrients, chlorophyll *a*, and zooplankton biomass (as AFDM).

Field, Travel, and Equipment Blanks

Blanks contained de-ionized water obtained from the laboratory. Field blanks consisted of samples prepared in the field. Equipment blanks were exposed to all aspects of sample collection and analysis, including the procedures used in the field, and contact with all sampling devices and other equipment. Travel blanks were transported with the crew during daily sampling procedures and remained unopened during field sampling. Blanks were submitted blind to the laboratory for the same analyses as the field samples. Equipment and travel blanks provide information regarding potential sample contamination from equipment or sample transport.

The field, travel, and equipment blanks were also used to detect potential contamination during collection, shipping, and analysis. Although concentrations should be below DLs in these blanks, their concentrations were considered notable if they were greater than five times the corresponding DL. This threshold is based on the Practical Quantitation Limit defined by the United States Environmental Protection Agency (US EPA 1994, 2007; BC MOE 2009), which takes into account the potential for data accuracy errors when variable concentrations approach or are below DLs.

Notable results observed in the field blanks were evaluated relative to analyte concentrations observed in the field samples to determine whether sample contamination was limited to the QC sample or was apparent in other samples as well. Where, based on this comparison, sample contamination was not an isolated occurrence, the field data were flagged and interpreted with this limitation in mind.

Duplicate Samples

Duplicate samples consisted of two samples collected from the same location at the same time, using the same sampling and sample handling procedures. They were labelled and preserved individually and submitted separately to the analytical laboratory for identical analyses. Duplicate samples were used to check within-station variation and the precision of field sampling and analytical methods. Differences between concentrations measured in duplicate water samples were calculated as the relative percent difference (RPD) for each variable. Before calculating the RPD, concentrations below the DL were replaced with 0.5 times the DL value. Substitution with half the DL is a common approach used to deal with censored data (US EPA 2000) and is consistent with the approved methods applied in the calculation of the normal range in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b). The RPD was calculated using the following formula:

RPD = (|difference in concentration between duplicate samples| / mean concentration) x 100

The RPD value for a given variable was considered notable if:

- it was greater than 40%
- concentrations in one or both samples were greater than or equal to five times the DL

These criteria were approved as part of the *Quality Assurance Project Plan Version 3.1* (Golder 2017).

The number of variables which exceeded the assessment criteria was compared to the total number of variables analyzed to evaluate analytical precision. The analytical precision was rated as follows:

- high, if less than 10% of the total number of variables were notably different from one another
- moderate, if 10% to 30% of the total number of variables were notably different from one another
- low, if more than 30% of the total number of variables were notably different from one another

Total Versus Dissolved Forms

The concentrations of total nitrogen (TN), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) consist of both particulate and dissolved forms of the analyte. Thus, total dissolved nitrogen (TDN), dissolved Kjeldahl nitrogen (DKN), and total dissolved phosphorus (TDP) should be equal to or less than the total concentrations. Typically, the RPD between the two forms should not exceed 20%. If the RPD was found to be greater than 20% and one or both of the samples were greater than or equal to five times the DL, these data were flagged, and the validity of the data was investigated.

Results

Detection Limits

In general, achieved DLs were the same as target DLs, with the exception of a few samples (Table B-1).

For TP and TDP, some field samples had elevated DLs above the target DL of 2 µg/L. However, as none of these samples (either duplicate) had detected concentrations, these elevated DLs did not affect the results interpretation. Both TP and TDP had a high frequency of non-detected values in the dataset and, therefore, could not be statistically analysed for spatial gradients (Section 3.6) or NF vs FF comparisons (Section 3.7). Both TP and TDP were assessed qualitatively using plots. The very high DL of 20 µg/L for MF1-1 would have confused the interpretation of the plots for TP and was, therefore, not included in any plot. The samples were plotted as half the DL, which is consistent with the approach to censored data.

For TDN, most samples (i.e., 189 samples, including QC samples) were analyzed at the target DL of 20 µg/L, but 62 samples were analyzed at a DL of 55 µg/L and 3 samples at 100 µg/L. As TN is the more useful variable, and there were data for multiple nutrient species to support the interpretation of results, these deviations from target DLs were considered unlikely to affect the overall conclusions of the assessment.

The target DL for SRSi is 5 µg/L, which was selected based on consultation with the analytical laboratory. However, most samples were analysed at a DL of 10 µg/L (229 samples, which include QC samples). A total of 23 samples were analysed at a DL of 50 µg/L. This year (2019) is the first year that this variable has been added to the analytical suite. Statistically significant differences were detected between NF and FF areas, and a significant declining trend in concentrations with distance from diffuser was identified (see Sections 3.3 and 3.6.2 of the main appendix). Therefore, it is unlikely that the raised DL impaired the results interpretation or that the overall conclusions of the assessment would be different with lower DLs.

For the other samples with raised DLs, the achieved DLs were sufficient to assess effects on eutrophication indicators in Lac de Gras.

Table B-1 Target and Achieved Detection Limits, 2019

Variable	Unit	Target DL	Achieved DL for Most Samples	Other DL	Sample	Sample Type	Season
Total Phosphorus	µg/L	2	2	4	FF1-3M	N	IC
				20	MF1-1T-3-5	TB	IC
				20	MF1-1M-5	N	IC
Total Dissolved Phosphorus	µg/L	2	2	5	MF1-3T-4	N	IC
				10	MF3-2M-5	N	IC
				10	FF1-1M-5	N	IC
Soluble Reactive Phosphorus	µg/L	1	1	n/a			
Total Nitrogen	µg/L	20	20	100	MF2-3-1-4	EB	OW
				200	MF2-1T-4	N	IC
Total Dissolved Nitrogen	µg/L	20	20	55	several		
				100	FF1-2-4	N	OW
				100	FF1-2-5	N	OW
				100	FF1-4-5	N	OW
Total Kjeldahl Nitrogen	µg/L	20	20	100	MF3-5M-5	N	IC
				100	MF2-3-1-4	EB	OW
				200	MF2-1T-4	N	IC
				200	MF1-1T-3-5	TB	IC
Dissolved Kjeldahl Nitrogen	µg/L	20	20	100	FF1-2-4	N	OW
				100	FF1-2-5	N	OW
				100	FF1-4-5	N	OW
				200	MF1-1T-3-5	TB	IC
				200	FF2-2B-4	N	IC
Nitrate	µg/L	2	2	n/a			
Nitrite	µg/L	1	1	n/a			
Nitrate + Nitrite	µg/L	2	2.2 (n = 160)	2 (n = 94)	several		
Total Ammonia	µg/L	5	5	10	MF2-3-5	N	OW
Soluble Reactive Silica	µg/L	5	10	50 (n = 23)	several		

Note: DL = detection limit; µg/L = micrograms per litre; MF = mid-field; FF = far-field; N = normal (field) sample; TB = travel blank; EB = equipment blank; IC = ice-cover; OW = open-water; n = sample size; n/a = not applicable.

Field, Travel, and Equipment Blanks

Twelve travel blanks, 12 equipment blanks, and 14 field blanks were collected during the 2019 AEMP eutrophication indicators component; 22 blank samples were collected during the ice-cover season (Table B-2) and 16 blank samples were collected during the open-water season (Table B-3). Of these 38 blanks, 20 were analyzed for all nutrient variables (ten blanks during ice-cover season and ten during open-water season), and 18 blanks were only analyzed for total ammonia (split samples at BV Labs and ALS).

BV Labs identified a sample preservative contamination issue in the total ammonia analysis, and re-analyzed total ammonia using water from unpreserved sample bottles for the open-water samples. However, two field blanks (i.e., MF1-5-2 and FFB-2-2) and one equipment blank (i.e., MF3-2-1) could not be re-analyzed. Therefore, the total ammonia results for these three blanks were not considered valid and are not included in Table B-3.

During the ice-cover season, concentrations that were more than five times the DL were observed in one sample for TKN (travel blank MF1-1T-3-5), two samples for TDN and DKN (equipment blanks NF2-B-1-4 and NF2-B-1-5), one sample for total ammonia (equipment blank FFB-4M-1-5), one sample for nitrite and nitrate+nitrite (travel blank MF1-1T-3-4), and one sample for nitrate and nitrate+nitrite (field blank MF3-1B-2-5). These notable results are discussed below:

- The travel blank MF1-1T-3-5 collected on 10 May 2019 had TN and TKN concentrations of 240 µg-N/L, which were similar to those concentrations measured in the field samples collected in MF1 area. However, the duplicate of this blank had much lower concentrations similar to other blanks (Table C-2). Concentrations of TN and TKN in the MF1 samples were within the range expected for this area. Therefore, it is assumed that the sample contamination was limited to the MF1-1T-3-5 travel blank.
- The equipment blanks NF2B-1-4 and NF2B-1-5 collected on 10 May 2019 had TDN and DKN concentrations between 110 and 130 µg/L. These concentrations are within the range of concentrations measured in field samples collected on the same day, but are generally lower than concentrations measured in the NF area on that day. Concentrations of TDN and DKN in the NF samples were within the range expected for this area (e.g., compared to 2018). Therefore, it is assumed that the sample contamination was limited to these equipment blanks.
- The travel blank MF1-1T-3-4 collected on 10 May 2019 had nitrite and nitrate+nitrite concentrations of 5.2 and 12 µg/L, respectively, which were slightly more than five times the DL. The duplicate of this blank had much lower concentration that was similar to other blanks (Table C-2). Therefore, it is assumed that contamination was limited to the MF1-1T-3-4 blank.
- The field blank MF3-1B-2-5 collected on 10 May 2019 had nitrate and nitrate+nitrite concentrations of 19 µg/L. The duplicate of this blank had a much lower concentration that was similar to other blanks (Table B-2). Therefore, it is assumed that contamination was limited to the MF3-1B-2-5 blank.
- The equipment blank FFB-4M-1-5 collected on 5 May 2019 had total ammonia concentration of 26.5 µg/L. The duplicate of this blank had much lower concentration that was similar to other blanks (Table B-2). Therefore, it is assumed that contamination was limited to the FFB-4M-1-5 blank.

Fewer exceedances of data quality objectives were observed in the open-water dataset (Table B-3). One field blank had measurable concentrations of total ammonia in a sample analysed by ALS. However, this does not affect the results interpretation, because the total ammonia open-water data provided by BV Labs were used in the data analysis.

Overall, the number of notable results was small and not indicative of a systemic contamination issue.

Nutrient Duplicate Samples

During the ice-cover season, 63 out of a total of 1,110 results (6%) had an RPD of more than 40% between duplicates, while having concentrations greater than five times the DL in at least one of the samples (Table B-2). Flagged samples varied among locations and analytes (i.e., TN, TDN, total ammonia, nitrate, nitrate-nitrite, TKN, DKN, and SRSi). Because less than 10% of the duplicate pairs were notably different from one another, the analytical precision for the ice-cover nutrient samples was rated as high.

Fewer DQO exceedances were observed during the open-water season. Out of a total of 547 results, 18 results (3%) had an RPD of more than 20% between duplicates, while having concentrations greater than five times the DL in at least one of the samples (Table B-3). Most notable results were identified as total ammonia analysed by ALS. This did not affect the quality of the data used in the eutrophication indicators assessment because the total ammonia data from BV Labs were used for the open-water data analysis. The other set of notable results was for TN and TKN in the sample from FFA-3; RPD was 50% for this sample. Flagged samples varied among locations and analytes (i.e., soluble reactive phosphorus, TN, TDN, total ammonia, total dissolved ammonia, total Kjeldahl nitrogen, and total dissolved Kjeldahl nitrogen). Because less than 10% of the duplicate pairs were notably different from one another, the analytical precision for the open-water nutrient samples was rated as high.

Table B-2 Concentrations of Nutrients in Field and Equipment Blanks During Ice-cover Season, 2019

Variable	Unit	DL	Ice-cover																					
			MF1-1T-3-4	**MF1-1T-3-5**	**LDS-2M-3-4**	**LDS-2M-3-5**	**MF3-4T-1-4**	**MF3-4T-1-5**	**FF2-2T-3-4**	**FF2-2T-3-5**	**MF1-3B-1-4**	**MF1-3B-1-5**	**FFB-4M-1-4**	**FFB-4M-1-5**	**MF3-3B-1-4**	**MF3-3B-1-5**	**NF2B-1-4**	**NF2B-1-5**	**FF1-3M-2-4**	**FF1-3M-2-5**	**FF1-4M-2-4**	**FF1-4M-2-5**	**MF3-1B-2-4**	**MF3-1B-2-5**
			Travel Blank	**Travel Blank**	**Travel Blank**	**Travel Blank**	**Travel Blank**	**Travel Blank**	**Travel Blank**	**Travel Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**
			10-May-19	10-May-19	26-Apr-19	26-Apr-19	9-May-19	9-May-19	10-May-19	10-May-19	28-Apr-19	28-Apr-19	5-May-19	5-May-19	09-May-19	09-May-19	10-May-19	10-May-19	04-May-19	04-May-19	4-May-19	4-May-19	10-May-19	10-May-19
Total Phosphorus	µg-P/L	2/20	<2	<20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<2	<2	<2	<2	<2	<2	n/a	n/a	<2	<2
Total Dissolved Phosphorus	µg-P/L	2	<2	<2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<2	2.7	<2	<2	<2	<2	n/a	n/a	<2	<2
Soluble Reactive Phosphorus	µg-P/L	1	<1	<1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<1	<1	2.4	3.5	<1	<1	n/a	n/a	<1	<1
Total Nitrogen	µg-N/L	20/200	36	240	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<20	<20	<20	<20	58	61	n/a	n/a	23	85
Total Dissolved Nitrogen	µg -N/L	20/55	<55	<55	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<55	<55	**130**	**120**	28	26	n/a	n/a	37	88
Total Ammonia - ALS	µg -N/L	5	5.2	<5	<5	<5	<5	7.8	<5	18.7	<5	6.4	<5	**26.5**	<5	<5	<5	6.0	<5	<5	<5	<5	11	8.5
Total Ammonia – BV Labs	µg -N/L	5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nitrate	µg -N/L	2	6.3	<2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.7	2.5	<2	<2	<2	<2	n/a	n/a	<2	**19**
Nitrite	µg -N/L	1	**5.2**	4.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.2	4.8	1.5	1.5	<1	<1	n/a	n/a	<1	<1
Nitrate + Nitrite	µg -N/L	2/2.2	**12**	4.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	6.9	7.2	<2.2	<2.2	<2	<2	n/a	n/a	<2.2	**19**
Total Kjeldahl Nitrogen	µg -N/L	20/100	24	**240**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<20	<20	<20	<20	58	61	n/a	n/a	23	66
Dissolved Kjeldahl Nitrogen	µg -N/L	20/200	34	<200	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<20	<20	**120**	**110**	28	26	n/a	n/a	37	69
Soluble Reactive Silica	µg/L	10	<10	<10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<10	<10	<10	<10	<10	<10	n/a	n/a	<10	<10

Notes: **Bolded** terms indicate QC flags for concentrations that were greater than five times the corresponding DL.

µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre; DL = detection limit; < = less than; LDS = Lac du Sauvage; NF = near-field; MF = mid-field; FF = far-field; n/a = not applicable.

Table B-3 Concentrations of Nutrients in Field and Equipment Blanks During Open-water Season, 2019

Variable	Unit	DL	Open-water															
			FFA-3-3-4	**FFA-3-3-5**	**MF3-1-3-4**	**MF3-1-3-5**	**MF2-3-1-4**	**MF2-3-1-5**	**MF3-2-1-4**	**MF3-2-1-5**	**FFB-2-2-4**	**FFB-2-2-5**	**MF1-5-2-4**	**MF1-5-2-5**	**MF3-7-2-4**	**MF3-7-2-5**	**NF1-2-4**	**NF1-2-5**
			Travel Blank	**Travel Blank**	**Travel Blank**	**Travel Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Equipment Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**	**Field Blank**
			04-Sep-19	04-Sep-19	03-Sep-19	03-Sep-19	20-Aug-19	20-Aug-19	28-Aug-19	28-Aug-19	25-Aug-19	25-Aug-19	21-Aug-19	21-Aug-19	26-Aug-19	26-Aug-19	22-Aug-19	22-Aug-19
Total Phosphorus	µg-P/L	2/20	<2	<2	<2	<2	<2	<2	n/a	n/a	n/a	n/a	n/a	n/a	<2	<2	<2	<2
Total Dissolved Phosphorus	µg-P/L	2	<2	<2	<2	<2	<2	<2	n/a	n/a	n/a	n/a	n/a	n/a	<2	<2	<2	<2
Soluble Reactive Phosphorus	µg-P/L	1	1.6	2.3	1.3	1.2	1.4	<1	n/a	n/a	n/a	n/a	n/a	n/a	<1	<1	2.2	1.5
Total Nitrogen	µg-N/L	20/100	60	52	51	47	<100	59	n/a	n/a	n/a	n/a	n/a	n/a	55	58	65	62
Total Dissolved Nitrogen	µg-N/L	20/55	22	21	<20	<20	<20	<20	n/a	n/a	n/a	n/a	n/a	n/a	<20	<20	<20	<20
Total Ammonia - ALS	µg-N/L	5	<5	11.6	<5	**37.8**	<5	13	13.3	13.4	17.4	14.4	<5	5.4	**79.4**	**129**	<5	12.1
Total Ammonia – BV Labs	µg-N/L	5	<5	<5	6.6	7.0	<5	<5	n/a	n/a	n/a	n/a	n/a	n/a	<5	<5	<5	<5
Total Dissolved Ammonia	µg-N/L	5	15	<5	18	19	<5	<5	n/a	n/a	n/a	n/a	n/a	n/a	<5	<5	5.8	<5
Nitrate	µg-N/L	2	<2	<2	<2	<2	<2	5.0	n/a	n/a	n/a	n/a	n/a	n/a	<2	<2	5.2	2.1
Nitrite	µg -N/L	1	<1	<1	<1	<1	<1	<1	n/a	n/a	n/a	n/a	n/a	n/a	<1	<1	<1	<1
Nitrate + Nitrite	µg-N/L	2/2.2	<2.2	<2.2	<2.2	<2.2	<2.2	5.0	n/a	n/a	n/a	n/a	n/a	n/a	<2.2	<2.2	5.2	<2.2
Total Kjeldahl Nitrogen	µg-N/L	20/100	60	52	51	47	<100	54	n/a	n/a	n/a	n/a	n/a	n/a	55	58	59	60
Dissolved Kjeldahl Nitrogen	µg-N/L	20/200	22	21	<20	<20	<20	<20	n/a	n/a	n/a	n/a	n/a	n/a	<20	<20	<20	<20
Soluble Reactive Silica	µg/L	10	n/a	n/a	<10	<10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<10	<10	<10	<10

Notes: **Bolded** terms indicate QC flags for concentrations that were greater than five times the corresponding DL.

µg-P/L = micrograms phosphorus per litre; µg-N/L = micrograms nitrogen per litre; DL = detection limit; < = less than; NF = near-field; MF = mid-field; FF = far-field; n/a = not applicable.

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Total Phosphorus (µg-P/L)	IC	NF1T	22-Apr-19	2	2.9	2.2	28	N	N
	IC	NF1M	22-Apr-19	2	5	1	133	N	N
	IC	NF1B	22-Apr-19	2	1	1	0	N	N
	IC	NF5T	23-Apr-19	2	3.2	2.5	25	N	N
	IC	NF5M	23-Apr-19	2	2.7	2.5	7.7	N	N
	IC	NF5B	23-Apr-19	2	2.2	2	9.5	N	N
	IC	MF1-5T	28-Apr-19	2	1	1	0	N	N
	IC	MF1-5M	28-Apr-19	2	1	1	0	N	N
	IC	MF1-5B	28-Apr-19	2	1	1	0	N	N
	IC	NF3T	23-Apr-19	2	3.8	2.9	27	N	N
	IC	NF3M	23-Apr-19	2	1	1	0	N	N
	IC	NF3B	23-Apr-19	2	2.4	1	82	N	N
	IC	MF2-1T	25-Apr-19	2	1	2.2	75	N	N
	IC	MF2-1M	25-Apr-19	2	1	1	0	N	N
	IC	MF2-1B	25-Apr-19	2	1	1	0	N	N
	IC	LDS-2M	26-Apr-19	2	1	2.5	86	N	N
	IC	LDS-1M	26-Apr-19	2	1	1	0	N	N
	IC	MF2-3T	24-Apr-19	2	1	2.5	86	N	N
	IC	MF2-3M	24-Apr-19	2	1	1	0	N	N
	IC	MF2-3B	24-Apr-19	2	1	1	0	N	N
	IC	MF1-3T	28-Apr-19	2	2	1	67	N	N
	IC	MF1-3M	28-Apr-19	2	1	1	0	N	N
	IC	MF1-3B	28-Apr-19	2	1	2.5	86	N	N
	IC	NF4T	23-Apr-19	2	2.2	2.4	8.7	N	N
	IC	NF4M	23-Apr-19	2	2.6	2.4	8	N	N
	IC	NF4B	23-Apr-19	2	1	2.2	75	N	N
	IC	MF3-2T	30-Apr-19	2	1	1	0	N	N
	IC	MF3-2M	30-Apr-19	2	1	1	0	N	N
	IC	MF3-2B	30-Apr-19	2	1	1	0	N	N
	IC	MF3-7T	01-May-19	2	1	1	0	N	N
	IC	MF3-7M	01-May-19	2	1	1	0	N	N
	IC	MF3-7B	01-May-19	2	1	1	0	N	N
	IC	MF3-6T	01-May-19	2	1	1	0	N	N
	IC	MF3-6M	01-May-19	2	1	1	0	N	N
	IC	MF3-6B	01-May-19	2	1	1	0	N	N
	IC	FF1-4M	04-May-19	2	1	1	0	N	N
	IC	FFB-3M	06-May-19	2	1	1	0	N	N
	IC	FF1-5M	04-May-19	2	1	1	0	N	N
	IC	FF1-1M	04-May-19	2	1	1	0	N	N
	IC	FFB-1M	06-May-19	2	1	1	0	N	N
	IC	FFB-2M	06-May-19	2	3	1	100	N	N
	IC	FF1-3M	04-May-19	4	1	1	0	N	N
	IC	FF1-2M	04-May-19	2	1	1	0	N	N
	IC	FFB-4M	05-May-19	2	1	1	0	N	N
	IC	FFA-5M	08-May-19	2	1	1	0	N	N
	IC	FFA-2M	08-May-19	2	1	1	0	N	N
	IC	FFA-3M	08-May-19	2	1	1	0	N	N
	IC	FFA-1M	08-May-19	2	1	1	0	N	N
	IC	NF2T	10-May-19	2	2.2	4.1	60	N	N
	IC	NF2M	10-May-19	2	2.1	1	71	N	N
	IC	NF2B	10-May-19	2	1	2	67	N	N
	IC	MF3-1T	10-May-19	2	1	3.2	105	N	N
	IC	MF3-1M	10-May-19	2	1	1	0	N	N
	IC	MF3-1B	10-May-19	2	1	1	0	N	N
	IC	FF2-5T	10-May-19	2	1	1	0	N	N
	IC	FF2-5M	10-May-19	2	1	1	0	N	N
	IC	FF2-5B	10-May-19	2	1	1	0	N	N
	IC	MF3-4T	09-May-19	2	1	1	0	N	N
	IC	MF3-4M	09-May-19	2	1	1	0	N	N
	IC	MF3-4B	09-May-19	2	1	1	0	N	N
	IC	LDS-3M	10-May-19	2	1	1	0	N	N
	IC	MF1-1T	10-May-19	2	1	1	0	N	N
	IC	MF1-1M	10-May-19	2/10	1	10	164	N	N
	IC	MF1-1B	10-May-19	2	1	1	0	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FFB-5M	05-May-19	2	1	1	0	N	N
	IC	FF2-2T	10-May-19	2	1	1	0	N	N
	IC	FF2-2M	10-May-19	2	1	1	0	N	N
	IC	FF2-2B	10-May-19	2	1	1	0	N	N
	IC	LDG48	08-May-19	2	1	1	0	N	N
	IC	FFA-4M	08-May-19	2	1	1	0	N	N
	IC	MF3-3T	09-May-19	2	1	1	0	N	N
	IC	MF3-3M	09-May-19	2	1	1	0	N	N
	IC	MF3-3B	09-May-19	2	1	1	0	N	N
	IC	MF3-5T	09-May-19	2	1	1	0	N	N
	IC	MF3-5M	09-May-19	2	1	1	0	N	N
	IC	MF3-5B	09-May-19	2	1	1	0	N	N
	IC	NF3B[a]	23-Apr-19	2	2.1	1	71	N	N
	IC	FFA-5M[a]	08-May-19	2	1	1	0	N	N
	IC	MF3-5T[a]	09-May-19	2	1	1	0	N	N
	IC	NF2B	10-May-19	2	1	1	0	N	N
	IC	MF3-3B	09-May-19	2	1	1	0	N	N
	IC	FF1-3M	04-May-19	2	1	2	0	N	N
	IC	MF3-1B	10-May-19	2	1	2	0	N	N
	IC	MF1-1T	10-May-19	20	1	20	164	N	N
Total Dissolved Phosphorus (µg-P/L)	IC	NF1T	22-Apr-19	2	1	1	0	N	N
	IC	NF1M	22-Apr-19	2	1	1	0	N	N
	IC	NF1B	22-Apr-19	2	4.2	1	123	N	N
	IC	NF5T	23-Apr-19	2	1	1	0	N	N
	IC	NF5M	23-Apr-19	2	1	1	0	N	N
	IC	NF5B	23-Apr-19	2	1	1	0	N	N
	IC	MF1-5T	28-Apr-19	2	1	1	0	N	N
	IC	MF1-5M	28-Apr-19	2	1	1	0	N	N
	IC	MF1-5B	28-Apr-19	2	1	1	0	N	N
	IC	NF3T	23-Apr-19	2	1	1	0	N	N
	IC	NF3M	23-Apr-19	2	1	1	0	N	N
	IC	NF3B	23-Apr-19	2	1	1	0	N	N
	IC	MF2-1T	25-Apr-19	2	1	1	0	N	N
	IC	MF2-1M	25-Apr-19	2	1	1	0	N	N
	IC	MF2-1B	25-Apr-19	2	1	1	0	N	N
	IC	LDS-2M	26-Apr-19	2	1	1	0	N	N
	IC	LDS-1M	26-Apr-19	2	1	1	0	N	N
	IC	MF2-3T	24-Apr-19	2	1	1	0	N	N
	IC	MF2-3M	24-Apr-19	2	1	1	0	N	N
	IC	MF2-3B	24-Apr-19	2	1	1	0	N	N
	IC	MF1-3T	28-Apr-19	2	1	1	0	N	N
	IC	MF1-3M	28-Apr-19	2	1	1	0	N	N
	IC	MF1-3B	28-Apr-19	2	1	1	0	N	N
	IC	NF4T	23-Apr-19	2	1	1	0	N	N
	IC	NF4M	23-Apr-19	2	1	1	0	N	N
	IC	NF4B	23-Apr-19	2	1	1	0	N	N
	IC	MF3-2T	30-Apr-19	2	1	1	0	N	N
	IC	MF3-2M	30-Apr-19	2/10	1	5	133	N	N
	IC	MF3-2B	30-Apr-19	2	1	1	0	N	N
	IC	MF3-7T	01-May-19	2	1	1	0	N	N
	IC	MF3-7M	01-May-19	2	1	1	0	N	N
	IC	MF3-7B	01-May-19	2	1	1	0	N	N
	IC	MF3-6T	01-May-19	2	1	1	0	N	N
	IC	MF3-6M	01-May-19	2	1	1	0	N	N
	IC	MF3-6B	01-May-19	2	1	1	0	N	N
	IC	FF1-4M	04-May-19	2	1	1	0	N	N
	IC	FFB-3M	06-May-19	2	1	1	0	N	N
	IC	FF1-5M	04-May-19	2	1	1	0	N	N
	IC	FF1-1M	04-May-19	2/10	1	5	133	N	N
	IC	FFB-1M	06-May-19	2	1	1	0	N	N
	IC	FFB-2M	06-May-19	2	1	1	0	N	N
	IC	FF1-3M	04-May-19	2	1	1	0	N	N
	IC	FF1-2M	04-May-19	2	1	1	0	N	N
	IC	FFB-4M	05-May-19	2	1	1	0	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FFA-5M	08-May-19	2	1	1	0	N	N
	IC	FFA-2M	08-May-19	2	2.7	1	92	N	N
	IC	FFA-3M	08-May-19	2	1	1	0	N	N
	IC	FFA-1M	08-May-19	2	1	1	0	N	N
	IC	NF2T	10-May-19	2	2.8	2.4	15	N	N
	IC	NF2M	10-May-19	2	2.6	2.1	21	N	N
	IC	NF2B	10-May-19	2	2.6	1	89	N	N
	IC	MF3-1T	10-May-19	2	1	1	0	N	N
	IC	MF3-1M	10-May-19	2	1	1	0	N	N
	IC	MF3-1B	10-May-19	2	1	1	0	N	N
	IC	FF2-5T	10-May-19	2	1	3.7	115	N	N
	IC	FF2-5M	10-May-19	2	1	1	0	N	N
	IC	FF2-5B	10-May-19	2	1	1	0	N	N
	IC	MF3-4T	09-May-19	2	1	1	0	N	N
	IC	MF3-4M	09-May-19	2	1	1	0	N	N
	IC	MF3-4B	09-May-19	2	1	1	0	N	N
	IC	LDS-3M	10-May-19	2	1	1	0	N	N
	IC	MF1-1T	10-May-19	2	1	2.5	86	N	N
	IC	MF1-1M	10-May-19	2	2	1	67	N	N
	IC	MF1-1B	10-May-19	2	1	1	0	N	N
	IC	FFB-5M	05-May-19	2	1	1	0	N	N
	IC	FF2-2T	10-May-19	2	1	1	0	N	N
	IC	FF2-2M	10-May-19	2	1	1	0	N	N
	IC	FF2-2B	10-May-19	2	1	1	0	N	N
	IC	LDG48	08-May-19	2	1	1	0	N	N
	IC	FFA-4M	08-May-19	2	1	1	0	N	N
	IC	MF3-3T	09-May-19	2	1	3.3	107	N	N
	IC	MF3-3M	09-May-19	2	1	1	0	N	N
	IC	MF3-3B	09-May-19	2	1	1	0	N	N
	IC	MF3-5T	09-May-19	2	1	1	0	N	N
	IC	MF3-5M	09-May-19	2	1	1	0	N	N
	IC	MF3-5B	09-May-19	2	1	1	0	N	N
	IC	NF3B[a]	23-Apr-19	2	1	1	0	N	N
	IC	FFA-5M[a]	08-May-19	2	1	1	0	N	N
	IC	MF3-5T[a]	09-May-19	2	1	1	0	N	N
	IC	NF3B	23-Apr-19	2	1	1	0	N	N
	IC	FFA-5M	08-May-19	2	1	1	0	N	N
	IC	MF3-5T	09-May-19	2	1	1	0	N	N
	IC	FF1-3M	04-May-19	2	1	1	0	N	N
	IC	NF2B	10-May-19	2	1	1	0	N	N
Soluble Reactive Phosphorus (µg-P/L)	IC	NF1T	22-Apr-19	1	1.2	1	18	N	N
	IC	NF1M	22-Apr-19	1	1.1	1.2	8.7	N	N
	IC	NF1B	22-Apr-19	1	1.1	1	9.5	N	N
	IC	NF5T	23-Apr-19	1	1.8	1.4	25	N	N
	IC	NF5M	23-Apr-19	1	1.7	1.6	6.1	N	N
	IC	NF5B	23-Apr-19	1	1.2	1.3	8	N	N
	IC	MF1-5T	28-Apr-19	1	1	1	0	N	N
	IC	MF1-5M	28-Apr-19	1	0.5	2.2	126	N	N
	IC	MF1-5B	28-Apr-19	1	1	1.2	18	N	N
	IC	NF3T	23-Apr-19	1	1.1	1.4	24	N	N
	IC	NF3M	23-Apr-19	1	0.5	0.5	0	N	N
	IC	NF3B	23-Apr-19	1	0.5	1	67	N	N
	IC	MF2-1T	25-Apr-19	1	1.3	1.1	17	N	N
	IC	MF2-1M	25-Apr-19	1	1.9	1.1	53	N	N
	IC	MF2-1B	25-Apr-19	1	1.1	1.2	8.7	N	N
	IC	LDS-2M	26-Apr-19	1	2.4	0.5	131	N	N
	IC	LDS-1M	26-Apr-19	1	2.3	1.8	24	N	N
	IC	MF2-3T	24-Apr-19	1	0.5	0.5	0	N	N
	IC	MF2-3M	24-Apr-19	1	0.5	0.5	0	N	N
	IC	MF2-3B	24-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-3T	28-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-3M	28-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-3B	28-Apr-19	1	1.3	0.5	89	N	N
	IC	NF4T	23-Apr-19	1	0.5	1.1	75	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	NF4M	23-Apr-19	1	1.9	1.8	5.4	N	N
	IC	NF4B	23-Apr-19	1	1.1	1.6	37	N	N
	IC	MF3-2T	30-Apr-19	1	0.5	0.5	0	N	N
	IC	MF3-2M	30-Apr-19	1	0.5	0.5	0	N	N
	IC	MF3-2B	30-Apr-19	1	0.5	0.5	0	N	N
	IC	MF3-7T	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-7M	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-7B	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-6T	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-6M	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-6B	01-May-19	1	0.5	0.5	0	N	N
	IC	FF1-4M	04-May-19	1	0.5	0.5	0	N	N
	IC	FFB-3M	06-May-19	1	1	0.5	67	N	N
	IC	FF1-5M	04-May-19	1	0.5	0.5	0	N	N
	IC	FF1-1M	04-May-19	1	0.5	0.5	0	N	N
	IC	FFB-1M	06-May-19	1	0.5	0.5	0	N	N
	IC	FFB-2M	06-May-19	1	1.2	0.5	82	N	N
	IC	FF1-3M	04-May-19	1	0.5	0.5	0	N	N
	IC	FF1-2M	04-May-19	1	0.5	0.5	0	N	N
	IC	FFB-4M	05-May-19	1	2	0.5	120	N	N
	IC	FFA-5M	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-2M	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-3M	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-1M	08-May-19	1	0.5	0.5	0	N	N
	IC	NF2T	10-May-19	1	4.6	3.3	33	N	N
	IC	NF2M	10-May-19	1	4.2	3.4	21	N	N
	IC	NF2B	10-May-19	1	3.1	4	25	N	N
	IC	MF3-1T	10-May-19	1	1.7	0.5	109	N	N
	IC	MF3-1M	10-May-19	1	0.5	0.5	0	N	N
	IC	MF3-1B	10-May-19	1	0.5	0.5	0	N	N
	IC	FF2-5T	10-May-19	1	0.5	0.5	0	N	N
	IC	FF2-5M	10-May-19	1	0.5	0.5	0	N	N
	IC	FF2-5B	10-May-19	1	0.5	0.5	0	N	N
	IC	MF3-4T	09-May-19	1	0.5	0.5	0	N	N
	IC	MF3-4M	09-May-19	1	0.5	0.5	0	N	N
	IC	MF3-4B	09-May-19	1	0.5	0.5	0	N	N
	IC	LDS-3M	10-May-19	1	1.3	1.2	8	N	N
	IC	MF1-1T	10-May-19	1	0.5	0.5	0	N	N
	IC	MF1-1M	10-May-19	1	0.5	1.1	75	N	N
	IC	MF1-1B	10-May-19	1	1.2	1.1	8.7	N	N
	IC	FFB-5M	05-May-19	1	0.5	1	67	N	N
	IC	FF2-2T	10-May-19	1	0.5	1.2	82	N	N
	IC	FF2-2M	10-May-19	1	0.5	0.5	0	N	N
	IC	FF2-2B	10-May-19	1	0.5	1.6	105	N	N
	IC	LDG48	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-4M	08-May-19	1	0.5	0.5	0	N	N
	IC	MF3-3T	09-May-19	1	0.5	0.5	0	N	N
	IC	MF3-3M	09-May-19	1	0.5	0.5	0	N	N
	IC	MF3-3B	09-May-19	1	0.5	0.5	0	N	N
	IC	MF3-5T	09-May-19	1	0.5	1.1	75	N	N
	IC	MF3-5M	09-May-19	1	0.5	0.5	0	N	N
	IC	MF3-5B	09-May-19	1	1.2	0.5	82	N	N
	IC	NF3B[a]	23-Apr-19	1	0.5	1.4	95	N	N
	IC	FFA-5M[a]	08-May-19	1	0.5	0.5	0	N	N
	IC	MF3-5T[a]	09-May-19	1	0.5	0.5	0	N	N
	IC	FF1-3M	04-May-19	1	0.5	0.5	0	N	N
	IC	NF2B	10-May-19	1	2.4	3.5	37	N	N
	IC	MF3-1B	10-May-19	1	0.5	0.5	0	N	N
	IC	MF1-1T	10-May-19	1	0.5	0.5	0	N	N
	IC	MF3-3B	09-May-19	1	0.5	0.5	0	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Total Nitrogen (µg-N/L)	IC	NF1T	22-Apr-19	20	233	244	4.6	Y	N
	IC	NF1M	22-Apr-19	20	398	345	14	Y	N
	IC	NF1B	22-Apr-19	20	349	357	2.3	Y	N
	IC	NF5T	23-Apr-19	20	245	279	13	Y	N
	IC	NF5M	23-Apr-19	20	337	429	24	Y	N
	IC	NF5B	23-Apr-19	20	291	304	4.4	Y	N
	IC	MF1-5T	28-Apr-19	20	224	234	4.4	Y	N
	IC	MF1-5M	28-Apr-19	20	195	200	2.5	Y	N
	IC	MF1-5B	28-Apr-19	20	233	235	0.9	Y	N
	IC	NF3T	23-Apr-19	20	259	244	6	Y	N
	IC	NF3M	23-Apr-19	20	266	264	0.8	Y	N
	IC	NF3B	23-Apr-19	20	309	355	14	Y	N
	IC	MF2-1T	25-Apr-19	200/20	290	217	29	Y	N
	IC	MF2-1M	25-Apr-19	20	314	261	18	Y	N
	IC	MF2-1B	25-Apr-19	20	325	273	17	Y	N
	IC	LDS-2M	26-Apr-19	20	255	262	2.7	Y	N
	IC	LDS-1M	26-Apr-19	20	248	243	2	Y	N
	IC	MF2-3T	24-Apr-19	20	192	205	6.5	Y	N
	IC	MF2-3M	24-Apr-19	20	203	202	0.5	Y	N
	IC	MF2-3B	24-Apr-19	20	210	236	12	Y	N
	IC	MF1-3T	28-Apr-19	20	289	260	11	Y	N
	IC	MF1-3M	28-Apr-19	20	194	187	3.7	Y	N
	IC	MF1-3B	28-Apr-19	20	220	237	7.4	Y	N
	IC	NF4T	23-Apr-19	20	230	240	4.3	Y	N
	IC	NF4M	23-Apr-19	20	362	316	14	Y	N
	IC	NF4B	23-Apr-19	20	304	303	0.3	Y	N
	IC	MF3-2T	30-Apr-19	20	216	220	1.8	Y	N
	IC	MF3-2M	30-Apr-19	20	184	196	6.3	Y	N
	IC	MF3-2B	30-Apr-19	20	172	180	4.5	Y	N
	IC	MF3-7T	01-May-19	20	184	172	6.7	Y	N
	IC	MF3-7M	01-May-19	20	180	173	4	Y	N
	IC	MF3-7B	01-May-19	20	192	191	0.5	Y	N
	IC	MF3-6T	01-May-19	20	197	248	23	Y	N
	IC	MF3-6M	01-May-19	20	184	192	4.3	Y	N
	IC	MF3-6B	01-May-19	20	186	197	5.7	Y	N
	IC	FF1-4M	04-May-19	20	219	198	10	Y	N
	IC	FFB-3M	06-May-19	20	169	226	29	Y	N
	IC	FF1-5M	04-May-19	20	234	242	3.4	Y	N
	IC	FF1-1M	04-May-19	20	201	209	3.9	Y	N
	IC	FFB-1M	06-May-19	20	181	178	1.7	Y	N
	IC	FFB-2M	06-May-19	20	185	176	5	Y	N
	IC	FF1-3M	04-May-19	20	193	208	7.5	Y	N
	IC	FF1-2M	04-May-19	20	190	176	7.7	Y	N
	IC	FFB-4M	05-May-19	20	186	160	15	Y	N
	IC	FFA-5M	08-May-19	20	190	150	24	Y	N
	IC	FFA-2M	08-May-19	20	170	150	13	Y	N
	IC	FFA-3M	08-May-19	20	200	200	0	Y	N
	IC	FFA-1M	08-May-19	20	180	180	0	Y	N
	IC	NF2T	10-May-19	20	260	270	3.8	Y	N
	IC	NF2M	10-May-19	20	480	470	2.1	Y	N
	IC	NF2B	10-May-19	20	370	390	5.3	Y	N
	IC	MF3-1T	10-May-19	20	140	320	78	Y	Y
	IC	MF3-1M	10-May-19	20	240	300	22	Y	N
	IC	MF3-1B	10-May-19	20	280	240	15	Y	N
	IC	FF2-5T	10-May-19	20	120	280	80	Y	Y
	IC	FF2-5M	10-May-19	20	250	260	3.9	Y	N
	IC	FF2-5B	10-May-19	20	220	240	8.7	Y	N
	IC	MF3-4T	09-May-19	20	210	260	21	Y	N
	IC	MF3-4M	09-May-19	20	250	240	4.1	Y	N
	IC	MF3-4B	09-May-19	20	200	210	4.9	Y	N
	IC	LDS-3M	10-May-19	20	180	280	44	Y	Y
	IC	MF1-1T	10-May-19	20	220	250	13	Y	N
	IC	MF1-1M	10-May-19	20	330	260	24	Y	N
	IC	MF1-1B	10-May-19	20	310	300	3.3	Y	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FFB-5M	05-May-19	20	189	174	8.3	Y	N
	IC	FF2-2T	10-May-19	20	210	170	21	Y	N
	IC	FF2-2M	10-May-19	20	280	190	38	Y	N
	IC	FF2-2B	10-May-19	20	210	220	4.7	Y	N
	IC	LDG48	08-May-19	20	83	150	58	Y	Y
	IC	FFA-4M	08-May-19	20	290	140	70	Y	Y
	IC	MF3-3T	09-May-19	20	240	200	18	Y	N
	IC	MF3-3M	09-May-19	20	170	230	30	Y	N
	IC	MF3-3B	09-May-19	20	170	230	30	Y	N
	IC	MF3-5T	09-May-19	20	240	210	13	Y	N
	IC	MF3-5M	09-May-19	20	230	180	24	Y	N
	IC	MF3-5B	09-May-19	20	250	240	4.1	Y	N
	IC	NF3B	23-Apr-19	20	339	346	2	Y	N
	IC	FFA-5M	08-May-19	20	170	180	5.7	Y	N
	IC	MF3-5T	09-May-19	20	220	250	13	Y	N
	IC	FF1-3M	04-May-19	20	58	61	5	N	N
	IC	NF2B	10-May-19	20	10	10	0	N	N
	IC	MF3-1B	10-May-19	20	23	85	115	N	N
	IC	MF1-1T	10-May-19	20	36	240	148	Y	Y
	IC	MF3-3B	09-May-19	20	10	10	0	N	N
Total Dissolved Nitrogen (µg-N/L)	IC	NF1T	22-Apr-19	20	252	199	24	Y	N
	IC	NF1M	22-Apr-19	20	308	301	2.3	Y	N
	IC	NF1B	22-Apr-19	20	346	321	7.5	Y	N
	IC	NF5T	23-Apr-19	20	206	213	3.3	Y	N
	IC	NF5M	23-Apr-19	20	299	301	0.7	Y	N
	IC	NF5B	23-Apr-19	20	272	265	2.6	Y	N
	IC	MF1-5T	28-Apr-19	20	185	193	4.2	Y	N
	IC	MF1-5M	28-Apr-19	20	173	165	4.7	Y	N
	IC	MF1-5B	28-Apr-19	20	209	215	2.8	Y	N
	IC	NF3T	23-Apr-19	20	195	207	6	Y	N
	IC	NF3M	23-Apr-19	20	223	211	5.5	Y	N
	IC	NF3B	23-Apr-19	20	280	279	0.4	Y	N
	IC	MF2-1T	25-Apr-19	20	250	181	32	Y	N
	IC	MF2-1M	25-Apr-19	20	190	193	1.6	Y	N
	IC	MF2-1B	25-Apr-19	20	234	226	3.5	Y	N
	IC	LDS-2M	26-Apr-19	20	208	214	2.8	Y	N
	IC	LDS-1M	26-Apr-19	20	231	207	11	Y	N
	IC	MF2-3T	24-Apr-19	20	155	160	3.2	Y	N
	IC	MF2-3M	24-Apr-19	20	170	169	0.6	Y	N
	IC	MF2-3B	24-Apr-19	20	183	181	1.1	Y	N
	IC	MF1-3T	28-Apr-19	20	204	188	8.2	Y	N
	IC	MF1-3M	28-Apr-19	20	151	163	7.6	Y	N
	IC	MF1-3B	28-Apr-19	20	191	185	3.2	Y	N
	IC	NF4T	23-Apr-19	20	197	198	0.5	Y	N
	IC	NF4M	23-Apr-19	20	309	311	0.6	Y	N
	IC	NF4B	23-Apr-19	20	269	264	1.9	Y	N
	IC	MF3-2T	30-Apr-19	20	198	202	2	Y	N
	IC	MF3-2M	30-Apr-19	20	156	148	5.3	Y	N
	IC	MF3-2B	30-Apr-19	20	142	150	5.5	Y	N
	IC	MF3-7T	01-May-19	20	146	138	5.6	Y	N
	IC	MF3-7M	01-May-19	20	129	140	8.2	Y	N
	IC	MF3-7B	01-May-19	20	163	154	5.7	Y	N
	IC	MF3-6T	01-May-19	20	191	190	0.5	Y	N
	IC	MF3-6M	01-May-19	20	142	143	0.7	Y	N
	IC	MF3-6B	01-May-19	20	157	158	0.6	Y	N
	IC	FF1-4M	04-May-19	20	185	192	3.7	Y	N
	IC	FFB-3M	06-May-19	20	165	153	7.5	Y	N
	IC	FF1-5M	04-May-19	20	220	222	0.9	Y	N
	IC	FF1-1M	04-May-19	20	212	200	5.8	Y	N
	IC	FFB-1M	06-May-19	20	177	175	1.1	Y	N
	IC	FFB-2M	06-May-19	20	171	156	9.2	Y	N
	IC	FF1-3M	04-May-19	20	166	173	4.1	Y	N
	IC	FF1-2M	04-May-19	20	183	177	3.3	Y	N
	IC	FFB-4M	05-May-19	20	169	163	3.6	Y	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FFA-5M	08-May-19	55	130	250	63	N	N
	IC	FFA-2M	08-May-19	55	290	300	3.4	Y	N
	IC	FFA-3M	08-May-19	55	280	320	13	Y	N
	IC	FFA-1M	08-May-19	55	300	320	6.5	Y	N
	IC	NF2T	10-May-19	55	310	290	6.7	Y	N
	IC	NF2M	10-May-19	55	670	500	29	Y	N
	IC	NF2B	10-May-19	55	430	460	6.7	Y	N
	IC	MF3-1T	10-May-19	20	250	200	22	Y	N
	IC	MF3-1M	10-May-19	20	220	230	4.4	Y	N
	IC	MF3-1B	10-May-19	20	210	200	4.9	Y	N
	IC	FF2-5T	10-May-19	55	190	230	19	N	N
	IC	FF2-5M	10-May-19	55	210	170	21	N	N
	IC	FF2-5B	10-May-19	55	200	180	11	N	N
	IC	MF3-4T	09-May-19	55	170	170	0	N	N
	IC	MF3-4M	09-May-19	55	180	140	25	N	N
	IC	MF3-4B	09-May-19	55	160	180	12	N	N
	IC	LDS-3M	10-May-19	20	280	260	7.4	Y	N
	IC	MF1-1T	10-May-19	55	210	240	13	N	N
	IC	MF1-1M	10-May-19	55	230	230	0	N	N
	IC	MF1-1B	10-May-19	55	350	270	26	Y	N
	IC	FFB-5M	05-May-19	20	182	170	6.8	Y	N
	IC	FF2-2T	10-May-19	55	210	270	25	N	N
	IC	FF2-2M	10-May-19	55	200	290	37	Y	N
	IC	FF2-2B	10-May-19	55	68	190	95	N	N
	IC	LDG48	08-May-19	55	260	280	7.4	Y	N
	IC	FFA-4M	08-May-19	55	290	150	64	Y	Y
	IC	MF3-3T	09-May-19	55	210	220	4.7	N	N
	IC	MF3-3M	09-May-19	55	150	150	0	N	N
	IC	MF3-3B	09-May-19	55	210	170	21	N	N
	IC	MF3-5T	09-May-19	55	190	210	10	N	N
	IC	MF3-5M	09-May-19	20	320	210	42	Y	Y
	IC	MF3-5B	09-May-19	55	250	270	7.7	N	N
	IC	NF3B	23-Apr-19	20	288	291	1	Y	N
	IC	FFA-5M	08-May-19	55	280	280	0	Y	N
	IC	MF3-5T	09-May-19	55	200	290	37	Y	N
	IC	FF1-3M	04-May-19	20	28	26	7.4	N	N
	IC	NF2B	10-May-19	55	130	120	8	N	N
	IC	MF3-1B	10-May-19	20	37	88	82	N	N
	IC	MF1-1T	10-May-19	55	27.5	27.5	0	N	N
	IC	MF3-3B	09-May-19	55	27.5	27.5	0	N	N
Total Ammonia (µg-N/L) - ALS	IC	FF1-1M	04-May-19	5	10	16.4	49	N	N
	IC	FF1-2M	04-May-19	5	25.5	9.2	94	Y	Y
	IC	FF1-3M	04-May-19	5	34.7	10.9	104	Y	Y
	IC	FF1-4M	04-May-19	5	17.3	10.6	48	N	N
	IC	FF1-5M	04-May-19	5	22	25.5	15	Y	N
	IC	FF2-2B	10-May-19	5	34.6	13.9	85	Y	Y
	IC	FF2-2M	10-May-19	5	19.2	19	1	N	N
	IC	FF2-2T	10-May-19	5	32.8	18	58	Y	Y
	IC	FF2-5B	10-May-19	5	15.3	8	63	N	N
	IC	FF2-5M	10-May-19	5	15.2	12.3	21	N	N
	IC	FF2-5T	10-May-19	5	14.3	6.1	80	N	N
	IC	FFA-1M	08-May-19	5	15.6	15.3	1.9	N	N
	IC	FFA-2M	08-May-19	5	20.3	12.2	50	N	N
	IC	FFA-3M	08-May-19	5	12.4	13.5	8.5	N	N
	IC	FFA-4M	08-May-19	5	8.9	13.5	41	N	N
	IC	FFA-5M	08-May-19	5	25.8	19.8	26	Y	N
	IC	FFA-5M	08-May-19	5	16	19	17	N	N
	IC	FFB-1M	06-May-19	5	19.3	20.1	4.1	N	N
	IC	FFB-2M	06-May-19	5	13.3	21	45	N	N
	IC	FFB-3M	06-May-19	5	16.1	34.2	72	Y	Y
	IC	FFB-4M	05-May-19	5	9.7	14.8	42	N	N
	IC	FFB-5M	05-May-19	5	24.4	17.9	31	N	N
	IC	LDG48	08-May-19	5	9.7	18.6	63	N	N
	IC	LDS-1M	26-Apr-19	5	11.5	2.5	129	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	LDS-2M	26-Apr-19	5	5.7	2.5	78	N	N
	IC	LDS-3M	10-May-19	5	16.9	13.5	22	N	N
	IC	MF1-1B	10-May-19	5	9.1	29.6	106	Y	Y
	IC	MF1-1M	10-May-19	5	22.9	20.8	9.6	N	N
	IC	MF1-1T	10-May-19	5	54.9	43.1	24	Y	N
	IC	MF1-3B	28-Apr-19	5	16.8	2.5	148	N	N
	IC	MF1-3M	28-Apr-19	5	26.3	19.7	29	Y	N
	IC	MF1-3T	28-Apr-19	5	23.4	28	18	Y	N
	IC	MF1-5B	28-Apr-19	5	8.2	5	49	N	N
	IC	MF1-5M	28-Apr-19	5	12.6	10	23	N	N
	IC	MF1-5T	28-Apr-19	5	11	13	17	N	N
	IC	MF2-1B	25-Apr-19	5	14	19.4	32	N	N
	IC	MF2-1M	25-Apr-19	5	20.8	13.2	45	N	N
	IC	MF2-1T	25-Apr-19	5	22.5	19.4	15	N	N
	IC	MF2-3B	24-Apr-19	5	2.5	15.7	145	N	N
	IC	MF2-3M	24-Apr-19	5	19.4	19.1	1.6	N	N
	IC	MF2-3M	24-Apr-19	5	16.2	16.3	0.6	N	N
	IC	MF2-3T	24-Apr-19	5	17.9	17.3	3.4	N	N
	IC	MF3-1B	10-May-19	5	21.3	21.6	1.4	N	N
	IC	MF3-1M	10-May-19	5	18.3	19.3	5.3	N	N
	IC	MF3-1T	10-May-19	5	30.4	22.2	31	Y	N
	IC	MF3-2B	30-Apr-19	5	8.1	5.5	38	N	N
	IC	MF3-2M	30-Apr-19	5	11.5	12.6	9.1	N	N
	IC	MF3-2T	30-Apr-19	5	11.4	24.6	73	N	N
	IC	MF3-3B	09-May-19	5	9.9	2.5	119	N	N
	IC	MF3-3M	09-May-19	5	29	25.9	11	Y	N
	IC	MF3-3T	09-May-19	5	33	42.8	26	Y	N
	IC	MF3-4B	09-May-19	5	16.7	19.2	14	N	N
	IC	MF3-4M	09-May-19	5	20.2	17.1	17	N	N
	IC	MF3-4T	09-May-19	5	20.9	21.2	1.4	N	N
	IC	MF3-5B	09-May-19	5	10.4	8.7	18	N	N
	IC	MF3-5M	09-May-19	5	23.7	18.7	24	N	N
	IC	MF3-5T	09-May-19	5	17.7	20	12	N	N
	IC	MF3-5T	09-May-19	5	18.7	25.5	31	Y	N
	IC	MF3-6B	01-May-19	5	41	29.9	31	Y	N
	IC	MF3-6M	01-May-19	5	15.5	19.4	22	N	N
	IC	MF3-6T	01-May-19	5	18	18.2	1.1	N	N
	IC	MF3-7B	01-May-19	5	20.9	14.5	36	N	N
	IC	MF3-7M	01-May-19	5	16.4	20.4	22	N	N
	IC	MF3-7T	01-May-19	5	11.3	14.9	28	N	N
	IC	NF1B	22-Apr-19	5	31.9	38.5	19	Y	N
	IC	NF1M	22-Apr-19	5	41.6	37.4	11	Y	N
	IC	NF1T	22-Apr-19	5	15.9	22.8	36	N	N
	IC	NF2B	10-May-19	5	28.3	32.8	15	Y	N
	IC	NF2M	10-May-19	5	61.3	58.2	5.2	Y	N
	IC	NF2T	10-May-19	5	27.4	26.9	1.8	Y	N
	IC	NF3B	23-Apr-19	5	47.3	48.8	3.1	Y	N
	IC	NF3B	23-Apr-19	5	32.3	65	67	Y	Y
	IC	NF3M	23-Apr-19	5	38	20.9	58	Y	Y
	IC	NF3T	23-Apr-19	5	24	23.4	2.5	N	N
	IC	NF4B	23-Apr-19	5	27.3	20	31	Y	N
	IC	NF4M	23-Apr-19	5	40.5	42.6	5.1	Y	N
	IC	NF4T	23-Apr-19	5	26.7	11.3	81	Y	Y
	IC	NF5B	23-Apr-19	5	21	20.5	2.4	N	N
	IC	NF5M	23-Apr-19	5	31.7	31.4	1	Y	N
	IC	NF5T	23-Apr-19	5	21.3	23.6	10	N	N
	IC	MF1-3B	28-Apr-19	5	5	6.4	25	N	N
	IC	LDS-2M	26-Apr-19	5	5	5	0	N	N
	IC	FF1-3M	04-May-19	5	5	5	0	N	N
	IC	FF1-4M	04-May-19	5	5	5	0	N	N
	IC	FFB-4M	05-May-19	5	5	26.5	137	Y	Y
	IC	MF3-1B	10-May-19	5	11.1	8.5	27	N	N
	IC	MF3-3B	09-May-19	5	5	5	0	N	N
	IC	MF3-4T	09-May-19	5	5	7.8	44	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	MF1-1T	10-May-19	5	5.2	5	3.9	N	N
	IC	FF2-2T	10-May-19	5	5	18.7	116	N	N
	IC	NF2B	10-May-19	5	5	6	18	N	N
Nitrate (µg-N/L)	IC	NF1T	22-Apr-19	2	16.7	14	18	Y	N
	IC	NF1M	22-Apr-19	2	149	140	6.2	Y	N
	IC	NF1B	22-Apr-19	2	170	164	3.6	Y	N
	IC	NF5T	23-Apr-19	2	14	14.6	4.2	Y	N
	IC	NF5M	23-Apr-19	2	144	146	1.4	Y	N
	IC	NF5B	23-Apr-19	2	120	120	0	Y	N
	IC	MF1-5T	28-Apr-19	2	4.3	2.7	46	N	N
	IC	MF1-5M	28-Apr-19	2	19.3	24.1	22	Y	N
	IC	MF1-5B	28-Apr-19	2	84.1	87	3.4	Y	N
	IC	NF3T	23-Apr-19	2	12	13	8	Y	N
	IC	NF3M	23-Apr-19	2	76.9	70.5	8.7	Y	N
	IC	NF3B	23-Apr-19	2	135	139	2.9	Y	N
	IC	MF2-1T	25-Apr-19	2	10.9	7.2	41	Y	Y
	IC	MF2-1M	25-Apr-19	2	65.5	60.7	7.6	Y	N
	IC	MF2-1B	25-Apr-19	2	94.2	97.5	3.4	Y	N
	IC	LDS-2M	26-Apr-19	2	57.5	50.3	13	Y	N
	IC	LDS-1M	26-Apr-19	2	48.3	69.1	35	Y	N
	IC	MF2-3T	24-Apr-19	2	8	8.5	6.1	N	N
	IC	MF2-3M	24-Apr-19	2	29.6	23.5	23	Y	N
	IC	MF2-3B	24-Apr-19	2	54.7	50.1	8.8	Y	N
	IC	MF1-3T	28-Apr-19	2	4.6	8.9	64	N	N
	IC	MF1-3M	28-Apr-19	2	1	2.3	79	N	N
	IC	MF1-3B	28-Apr-19	2	53.8	53.3	0.9	Y	N
	IC	NF4T	23-Apr-19	2	11.8	12.3	4.1	Y	N
	IC	NF4M	23-Apr-19	2	145	152	4.7	Y	N
	IC	NF4B	23-Apr-19	2	128	128	0	Y	N
	IC	MF3-2T	30-Apr-19	2	38.8	37.6	3.1	Y	N
	IC	MF3-2M	30-Apr-19	2	14.5	18.3	23	Y	N
	IC	MF3-2B	30-Apr-19	2	34.9	35	0.3	Y	N
	IC	MF3-7T	01-May-19	2	1	1	0	N	N
	IC	MF3-7M	01-May-19	2	1	1	0	N	N
	IC	MF3-7B	01-May-19	2	26.3	23.3	12	Y	N
	IC	MF3-6T	01-May-19	2	1	1	0	N	N
	IC	MF3-6M	01-May-19	2	1	2.6	89	N	N
	IC	MF3-6B	01-May-19	2	24.5	25.3	3.2	Y	N
	IC	FF1-4M	04-May-19	2	13.5	10.4	26	Y	N
	IC	FFB-3M	06-May-19	2	2.5	1	86	N	N
	IC	FF1-5M	04-May-19	2	32.3	32.6	0.9	Y	N
	IC	FF1-1M	04-May-19	2	21.7	25.5	16	Y	N
	IC	FFB-1M	06-May-19	2	1	1	0	N	N
	IC	FFB-2M	06-May-19	2	1	1	0	N	N
	IC	FF1-3M	04-May-19	2	13.1	11.3	15	Y	N
	IC	FF1-2M	04-May-19	2	4.8	4.5	6.5	N	N
	IC	FFB-4M	05-May-19	2	2.3	1	79	N	N
	IC	FFA-5M	08-May-19	2	34	5.3	146	Y	Y
	IC	FFA-2M	08-May-19	2	17	21	21	Y	N
	IC	FFA-3M	08-May-19	2	21	41	65	Y	Y
	IC	FFA-1M	08-May-19	2	2.8	2.7	3.6	N	N
	IC	NF2T	10-May-19	2	25	21	17	Y	N
	IC	NF2M	10-May-19	2	220	220	0	Y	N
	IC	NF2B	10-May-19	2	160	170	6.1	Y	N
	IC	MF3-1T	10-May-19	2	43	42	2.4	Y	N
	IC	MF3-1M	10-May-19	2	50	95	62	Y	Y
	IC	MF3-1B	10-May-19	2	42	43	2.4	Y	N
	IC	FF2-5T	10-May-19	2	23	36	44	Y	Y
	IC	FF2-5M	10-May-19	2	54	42	25	Y	N
	IC	FF2-5B	10-May-19	2	77	64	18	Y	N
	IC	MF3-4T	09-May-19	2	11	19	53	Y	Y
	IC	MF3-4M	09-May-19	2	26	25	3.9	Y	N
	IC	MF3-4B	09-May-19	2	52	51	1.9	Y	N
	IC	LDS-3M	10-May-19	2	40	59	38	Y	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	MF1-1T	10-May-19	2	23	22	4.4	Y	N
	IC	MF1-1M	10-May-19	2	66	66	0	Y	N
	IC	MF1-1B	10-May-19	2	130	120	8	Y	N
	IC	FFB-5M	05-May-19	2	1	1	0	N	N
	IC	FF2-2T	10-May-19	2	9.3	9.2	1.1	N	N
	IC	FF2-2M	10-May-19	2	41	35	16	Y	N
	IC	FF2-2B	10-May-19	2	61	54	12	Y	N
	IC	LDG48	08-May-19	2	3.1	2	43	N	N
	IC	FFA-4M	08-May-19	2	16	37	79	Y	Y
	IC	MF3-3T	09-May-19	2	21	21	0	Y	N
	IC	MF3-3M	09-May-19	2	6.7	10	40	N	N
	IC	MF3-3B	09-May-19	2	61	34	57	Y	Y
	IC	MF3-5T	09-May-19	2	25	6.2	121	Y	Y
	IC	MF3-5M	09-May-19	2	18	18	0	Y	N
	IC	MF3-5B	09-May-19	2	79	88	11	Y	N
	IC	NF3B	23-Apr-19	2	139	136	2.2	Y	N
	IC	FFA-5M	08-May-19	2	20	19	5.1	Y	N
	IC	MF3-5T	09-May-19	2	2.8	11	119	Y	Y
	IC	FF1-3M	04-May-19	2	1	1	0	N	N
	IC	NF2B	10-May-19	2	1	1	0	N	N
	IC	MF3-1B	10-May-19	2	1	19	180	Y	Y
	IC	MF1-1T	10-May-19	2	6.3	1	145	N	N
	IC	MF3-3B	09-May-19	2	2.7	2.5	7.7	N	N
Nitrite (µg-N/L)	IC	NF1T	22-Apr-19	1	0.5	0.5	0	N	N
	IC	NF1M	22-Apr-19	1	0.5	0.5	0	N	N
	IC	NF1B	22-Apr-19	1	0.5	0.5	0	N	N
	IC	NF5T	23-Apr-19	1	0.5	0.5	0	N	N
	IC	NF5M	23-Apr-19	1	0.5	0.5	0	N	N
	IC	NF5B	23-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-5T	28-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-5M	28-Apr-19	1	1	0.5	67	N	N
	IC	MF1-5B	28-Apr-19	1	1.2	0.5	82	N	N
	IC	NF3T	23-Apr-19	1	1.5	0.5	100	N	N
	IC	NF3M	23-Apr-19	1	0.5	0.5	0	N	N
	IC	NF3B	23-Apr-19	1	0.5	0.5	0	N	N
	IC	MF2-1T	25-Apr-19	1	1.5	5.1	109	Y	Y
	IC	MF2-1M	25-Apr-19	1	0.5	1.3	89	N	N
	IC	MF2-1B	25-Apr-19	1	0.5	0.5	0	N	N
	IC	LDS-2M	26-Apr-19	1	0.5	0.5	0	N	N
	IC	LDS-1M	26-Apr-19	1	0.5	0.5	0	N	N
	IC	MF2-3T	24-Apr-19	1	1.4	1.7	19	N	N
	IC	MF2-3M	24-Apr-19	1	0.5	0.5	0	N	N
	IC	MF2-3B	24-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-3T	28-Apr-19	1	0.5	0.5	0	N	N
	IC	MF1-3M	28-Apr-19	1	2.3	1.6	36	N	N
	IC	MF1-3B	28-Apr-19	1	1.3	0.5	89	N	N
	IC	NF4T	23-Apr-19	1	1.1	0.5	75	N	N
	IC	NF4M	23-Apr-19	1	0.5	0.5	0	N	N
	IC	NF4B	23-Apr-19	1	2.7	0.5	138	N	N
	IC	MF3-2T	30-Apr-19	1	0.5	0.5	0	N	N
	IC	MF3-2M	30-Apr-19	1	1.4	0.5	95	N	N
	IC	MF3-2B	30-Apr-19	1	1.1	0.5	75	N	N
	IC	MF3-7T	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-7M	01-May-19	1	1.9	0.5	117	N	N
	IC	MF3-7B	01-May-19	1	1.1	0.5	75	N	N
	IC	MF3-6T	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-6M	01-May-19	1	0.5	0.5	0	N	N
	IC	MF3-6B	01-May-19	1	0.5	1.5	100	N	N
	IC	FF1-4M	04-May-19	1	0.5	0.5	0	N	N
	IC	FFB-3M	06-May-19	1	0.5	0.5	0	N	N
	IC	FF1-5M	04-May-19	1	0.5	0.5	0	N	N
	IC	FF1-1M	04-May-19	1	0.5	0.5	0	N	N
	IC	FFB-1M	06-May-19	1	0.5	0.5	0	N	N
	IC	FFB-2M	06-May-19	1	0.5	0.5	0	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FF1-3M	04-May-19	1	0.5	0.5	0	N	N
	IC	FF1-2M	04-May-19	1	0.5	0.5	0	N	N
	IC	FFB-4M	05-May-19	1	0.5	0.5	0	N	N
	IC	FFA-5M	08-May-19	1	0.5	1.3	89	N	N
	IC	FFA-2M	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-3M	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-1M	08-May-19	1	4.2	4	4.9	N	N
	IC	NF2T	10-May-19	1	1.8	1.8	0	N	N
	IC	NF2M	10-May-19	1	1.7	2.4	34	N	N
	IC	NF2B	10-May-19	1	1.6	1.6	0	N	N
	IC	MF3-1T	10-May-19	1	0.5	0.5	0	N	N
	IC	MF3-1M	10-May-19	1	1.1	0.5	75	N	N
	IC	MF3-1B	10-May-19	1	0.5	0.5	0	N	N
	IC	FF2-5T	10-May-19	1	0.5	0.5	0	N	N
	IC	FF2-5M	10-May-19	1	1.6	3.4	72	N	N
	IC	FF2-5B	10-May-19	1	1.2	1.1	8.7	N	N
	IC	MF3-4T	09-May-19	1	0.5	1	67	N	N
	IC	MF3-4M	09-May-19	1	2.7	1.6	51	N	N
	IC	MF3-4B	09-May-19	1	0.5	0.5	0	N	N
	IC	LDS-3M	10-May-19	1	5.9	5.5	7	Y	N
	IC	MF1-1T	10-May-19	1	4.6	4.5	2.2	N	N
	IC	MF1-1M	10-May-19	1	3.2	3.1	3.2	N	N
	IC	MF1-1B	10-May-19	1	3.8	4.2	10	N	N
	IC	FFB-5M	05-May-19	1	0.5	0.5	0	N	N
	IC	FF2-2T	10-May-19	1	4.4	5	13	N	N
	IC	FF2-2M	10-May-19	1	5.5	5.5	0	Y	N
	IC	FF2-2B	10-May-19	1	6.9	4.7	38	Y	N
	IC	LDG48	08-May-19	1	0.5	0.5	0	N	N
	IC	FFA-4M	08-May-19	1	0.5	0.5	0	N	N
	IC	MF3-3T	09-May-19	1	5.9	5.4	8.8	Y	N
	IC	MF3-3M	09-May-19	1	6.4	6.6	3.1	Y	N
	IC	MF3-3B	09-May-19	1	5.7	4.3	28	Y	N
	IC	MF3-5T	09-May-19	1	13	11	17	Y	N
	IC	MF3-5M	09-May-19	1	3.9	11	95	Y	Y
	IC	MF3-5B	09-May-19	1	12	12	0	Y	N
	IC	NF3B[a]	23-Apr-19	1	0.5	0.5	0	N	N
	IC	MF3-5T[a]	09-May-19	1	11	13	17	Y	N
	IC	FFA-5M[a]	08-May-19	1	0.5	0.5	0	N	N
	IC	FF1-3M	04-May-19	1	0.5	0.5	0	N	N
	IC	NF2B	10-May-19	1	1.5	1.5	0	N	N
	IC	MF3-1B	10-May-19	1	0.5	0.5	0	N	N
	IC	MF1-1T	10-May-19	1	5.2	4	26	Y	N
	IC	MF3-3B	09-May-19	1	4.2	4.8	13	N	N
Nitrate + Nitrite (µg-N/L)	IC	NF1T	22-Apr-19	2	16.7	14	18	Y	N
	IC	NF1M	22-Apr-19	2	149	140	6.2	Y	N
	IC	NF1B	22-Apr-19	2	170	164	3.6	Y	N
	IC	NF5T	23-Apr-19	2	14	14.6	4.2	Y	N
	IC	NF5M	23-Apr-19	2	144	146	1.4	Y	N
	IC	NF5B	23-Apr-19	2	120	120	0	Y	N
	IC	MF1-5T	28-Apr-19	2	4.3	2.7	46	N	N
	IC	MF1-5M	28-Apr-19	2	20.3	24.1	17	Y	N
	IC	MF1-5B	28-Apr-19	2	85.3	87	2	Y	N
	IC	NF3T	23-Apr-19	2	13.5	13	3.8	Y	N
	IC	NF3M	23-Apr-19	2	76.9	70.5	8.7	Y	N
	IC	NF3B	23-Apr-19	2	135	139	2.9	Y	N
	IC	MF2-1T	25-Apr-19	2	12.4	12.3	0.8	Y	N
	IC	MF2-1M	25-Apr-19	2	65.5	62	5.5	Y	N
	IC	MF2-1B	25-Apr-19	2	94.2	97.5	3.4	Y	N
	IC	LDS-2M	26-Apr-19	2	57.5	50.3	13	Y	N
	IC	LDS-1M	26-Apr-19	2	48.3	69.1	35	Y	N
	IC	MF2-3T	24-Apr-19	2	9.4	10.2	8.2	Y	N
	IC	MF2-3M	24-Apr-19	2	29.6	23.5	23	Y	N
	IC	MF2-3B	24-Apr-19	2	54.7	50.1	8.8	Y	N
	IC	MF1-3T	28-Apr-19	2	4.6	8.9	64	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	MF1-3M	28-Apr-19	2	3.9	3.9	0	N	N
	IC	MF1-3B	28-Apr-19	2	55.1	53.3	3.3	Y	N
	IC	NF4T	23-Apr-19	2	12.9	12.3	4.8	Y	N
	IC	NF4M	23-Apr-19	2	145	152	4.7	Y	N
	IC	NF4B	23-Apr-19	2	131	128	2.3	Y	N
	IC	MF3-2T	30-Apr-19	2	38.8	37.6	3.1	Y	N
	IC	MF3-2M	30-Apr-19	2	15.9	18.3	14	Y	N
	IC	MF3-2B	30-Apr-19	2	36	35	2.8	Y	N
	IC	MF3-7T	01-May-19	2	1	1	0	N	N
	IC	MF3-7M	01-May-19	2	2.7	1	92	N	N
	IC	MF3-7B	01-May-19	2	27.4	23.3	16	Y	N
	IC	MF3-6T	01-May-19	2	1	1	0	N	N
	IC	MF3-6M	01-May-19	2	1	2.6	89	N	N
	IC	MF3-6B	01-May-19	2	24.5	26.8	9	Y	N
	IC	FF1-4M	04-May-19	2	13.5	10.4	26	Y	N
	IC	FFB-3M	06-May-19	2	2.5	1	86	N	N
	IC	FF1-5M	04-May-19	2	32.3	32.6	0.9	Y	N
	IC	FF1-1M	04-May-19	2	21.7	25.5	16	Y	N
	IC	FFB-1M	06-May-19	2	1	1	0	N	N
	IC	FFB-2M	06-May-19	2	1	1	0	N	N
	IC	FF1-3M	04-May-19	2	13.1	11.3	15	Y	N
	IC	FF1-2M	04-May-19	2	4.8	4.5	6.5	N	N
	IC	FFB-4M	05-May-19	2	2.3	1	79	N	N
	IC	FFA-5M	08-May-19	2.2	34	6.6	135	Y	Y
	IC	FFA-2M	08-May-19	2.2	17	21	21	Y	N
	IC	FFA-3M	08-May-19	2.2	21	41	65	Y	Y
	IC	FFA-1M	08-May-19	2.2	7	6.7	4.4	N	N
	IC	NF2T	10-May-19	2.2	27	23	16	Y	N
	IC	NF2M	10-May-19	2.2	220	220	0	Y	N
	IC	NF2B	10-May-19	2.2	160	170	6.1	Y	N
	IC	MF3-1T	10-May-19	2.2	43	42	2.4	Y	N
	IC	MF3-1M	10-May-19	2.2	52	95	59	Y	Y
	IC	MF3-1B	10-May-19	2.2	42	43	2.4	Y	N
	IC	FF2-5T	10-May-19	2.2	23	36	44	Y	Y
	IC	FF2-5M	10-May-19	2.2	56	45	22	Y	N
	IC	FF2-5B	10-May-19	2.2	78	65	18	Y	N
	IC	MF3-4T	09-May-19	2.2	11	20	58	Y	Y
	IC	MF3-4M	09-May-19	2.2	29	26	11	Y	N
	IC	MF3-4B	09-May-19	2.2	52	51	1.9	Y	N
	IC	LDS-3M	10-May-19	2.2	46	65	34	Y	N
	IC	MF1-1T	10-May-19	2.2	28	27	3.6	Y	N
	IC	MF1-1M	10-May-19	2.2	69	69	0	Y	N
	IC	MF1-1B	10-May-19	2.2	140	130	7.4	Y	N
	IC	FFB-5M	05-May-19	2	1	1	0	N	N
	IC	FF2-2T	10-May-19	2.2	14	14	0	Y	N
	IC	FF2-2M	10-May-19	2.2	47	41	14	Y	N
	IC	FF2-2B	10-May-19	2.2	68	58	16	Y	N
	IC	LDG48	08-May-19	2.2	3.1	1.1	95	N	N
	IC	FFA-4M	08-May-19	2.2	16	37	79	Y	Y
	IC	MF3-3T	09-May-19	2.2	27	27	0	Y	N
	IC	MF3-3M	09-May-19	2.2	13	17	27	Y	N
	IC	MF3-3B	09-May-19	2.2	67	39	53	Y	Y
	IC	MF3-5T	09-May-19	2.2	38	17	76	Y	Y
	IC	MF3-5M	09-May-19	2.2	22	29	28	Y	N
	IC	MF3-5B	09-May-19	2.2	91	100	9.4	Y	N
	IC	NF3B[a]	23-Apr-19	2	139	136	2.2	Y	N
	IC	FFA-5M[a]	08-May-19	2.2	20	19	5.1	Y	N
	IC	MF3-5T[a]	09-May-19	2.2	23	15	42	Y	Y
	IC	FF1-3M	04-May-19	2	1	1	0	N	N
	IC	NF2B	10-May-19	2.2	1.1	1.1	0	N	N
	IC	MF3-1B	10-May-19	2.2	1.1	19	178	Y	Y
	IC	MF1-1T	10-May-19	2.2	12	4	100	Y	Y
	IC	MF3-3B	09-May-19	2.2	6.9	7.2	4.3	N	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Total Kjeldahl Nitrogen (µg-N/L)	IC	NF1T	22-Apr-19	20	216	230	6.3	Y	N
	IC	NF1M	22-Apr-19	20	249	204	20	Y	N
	IC	NF1B	22-Apr-19	20	179	193	7.5	Y	N
	IC	NF5T	23-Apr-19	20	231	264	13	Y	N
	IC	NF5M	23-Apr-19	20	193	283	38	Y	N
	IC	NF5B	23-Apr-19	20	171	184	7.3	Y	N
	IC	MF1-5T	28-Apr-19	20	220	231	4.9	Y	N
	IC	MF1-5M	28-Apr-19	20	174	176	1.1	Y	N
	IC	MF1-5B	28-Apr-19	20	147	148	0.7	Y	N
	IC	NF3T	23-Apr-19	20	245	231	5.9	Y	N
	IC	NF3M	23-Apr-19	20	190	193	1.6	Y	N
	IC	NF3B	23-Apr-19	20	174	217	22	Y	N
	IC	MF2-1T	25-Apr-19	200/20	280	205	31	Y	N
	IC	MF2-1M	25-Apr-19	20	249	199	22	Y	N
	IC	MF2-1B	25-Apr-19	20	231	175	28	Y	N
	IC	LDS-2M	26-Apr-19	20	197	212	7.3	Y	N
	IC	LDS-1M	26-Apr-19	20	200	174	14	Y	N
	IC	MF2-3T	24-Apr-19	20	183	195	6.3	Y	N
	IC	MF2-3M	24-Apr-19	20	174	178	2.3	Y	N
	IC	MF2-3B	24-Apr-19	20	155	185	18	Y	N
	IC	MF1-3T	28-Apr-19	20	284	251	12	Y	N
	IC	MF1-3M	28-Apr-19	20	190	183	3.8	Y	N
	IC	MF1-3B	28-Apr-19	20	165	184	11	Y	N
	IC	NF4T	23-Apr-19	20	217	228	4.9	Y	N
	IC	NF4M	23-Apr-19	20	217	164	28	Y	N
	IC	NF4B	23-Apr-19	20	173	175	1.1	Y	N
	IC	MF3-2T	30-Apr-19	20	177	183	3.3	Y	N
	IC	MF3-2M	30-Apr-19	20	169	178	5.2	Y	N
	IC	MF3-2B	30-Apr-19	20	136	145	6.4	Y	N
	IC	MF3-7T	01-May-19	20	184	172	6.7	Y	N
	IC	MF3-7M	01-May-19	20	177	173	2.3	Y	N
	IC	MF3-7B	01-May-19	20	164	168	2.4	Y	N
	IC	MF3-6T	01-May-19	20	197	248	23	Y	N
	IC	MF3-6M	01-May-19	20	184	190	3.2	Y	N
	IC	MF3-6B	01-May-19	20	161	170	5.4	Y	N
	IC	FF1-4M	04-May-19	20	206	188	9.1	Y	N
	IC	FFB-3M	06-May-19	20	166	226	31	Y	N
	IC	FF1-5M	04-May-19	20	201	209	3.9	Y	N
	IC	FF1-1M	04-May-19	20	179	184	2.8	Y	N
	IC	FFB-1M	06-May-19	20	181	178	1.7	Y	N
	IC	FFB-2M	06-May-19	20	185	176	5	Y	N
	IC	FF1-3M	04-May-19	20	180	197	9	Y	N
	IC	FF1-2M	04-May-19	20	185	172	7.3	Y	N
	IC	FFB-4M	05-May-19	20	184	160	14	Y	N
	IC	FFA-5M	08-May-19	20	150	140	6.9	Y	N
	IC	FFA-2M	08-May-19	20	150	130	14	Y	N
	IC	FFA-3M	08-May-19	20	180	160	12	Y	N
	IC	FFA-1M	08-May-19	20	170	180	5.7	Y	N
	IC	NF2T	10-May-19	20	230	250	8.3	Y	N
	IC	NF2M	10-May-19	20	250	250	0	Y	N
	IC	NF2B	10-May-19	20	210	220	4.7	Y	N
	IC	MF3-1T	10-May-19	20	100	280	95	Y	Y
	IC	MF3-1M	10-May-19	20	190	200	5.1	Y	N
	IC	MF3-1B	10-May-19	20	240	200	18	Y	N
	IC	FF2-5T	10-May-19	20	100	240	82	Y	Y
	IC	FF2-5M	10-May-19	20	190	210	10	Y	N
	IC	FF2-5B	10-May-19	20	140	170	19	Y	N
	IC	MF3-4T	09-May-19	20	200	240	18	Y	N
	IC	MF3-4M	09-May-19	20	230	210	9.1	Y	N
	IC	MF3-4B	09-May-19	20	150	160	6.5	Y	N
	IC	LDS-3M	10-May-19	20	140	210	40	Y	N
	IC	MF1-1T	10-May-19	20	200	220	9.5	Y	N
	IC	MF1-1M	10-May-19	20	260	190	31	Y	N
	IC	MF1-1B	10-May-19	20	170	170	0	Y	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FFB-5M	05-May-19	20	189	174	8.3	Y	N
	IC	FF2-2T	10-May-19	20	200	150	29	Y	N
	IC	FF2-2M	10-May-19	20	230	150	42	Y	Y
	IC	FF2-2B	10-May-19	20	140	160	13	Y	N
	IC	LDG48	08-May-19	20	80	140	55	Y	Y
	IC	FFA-4M	08-May-19	20	280	100	95	Y	Y
	IC	MF3-3T	09-May-19	20	210	180	15	Y	N
	IC	MF3-3M	09-May-19	20	150	210	33	Y	N
	IC	MF3-3B	09-May-19	20	99	190	63	Y	Y
	IC	MF3-5T	09-May-19	20	200	200	0	Y	N
	IC	MF3-5M	09-May-19	20/100	200	160	22	Y	N
	IC	MF3-5B	09-May-19	20	150	150	0	Y	N
	IC	NF3B[a]	23-Apr-19	20	200	211	5.4	Y	N
	IC	FFA-5M[a]	08-May-19	20	150	160	6.5	Y	N
	IC	MF3-5T[a]	09-May-19	20	200	230	14	Y	N
	IC	FF1-3M	04-May-19	20	58	61	5	N	N
	IC	NF2B	10-May-19	20	10	10	0	N	N
	IC	MF3-1B	10-May-19	20	23	66	97	N	N
	IC	MF1-1T	10-May-19	20	24	240	164	N	N
	IC	MF3-3B	09-May-19	20	10	10	0	N	N
Dissolved Kjeldahl Nitrogen (µg-N/L)	IC	NF1T	22-Apr-19	20	236	185	24	Y	N
	IC	NF1M	22-Apr-19	20	159	160	0.6	Y	N
	IC	NF1B	22-Apr-19	20	176	157	11	Y	N
	IC	NF5T	23-Apr-19	20	192	199	3.6	Y	N
	IC	NF5M	23-Apr-19	20	155	155	0	Y	N
	IC	NF5B	23-Apr-19	20	152	146	4	Y	N
	IC	MF1-5T	28-Apr-19	20	181	191	5.4	Y	N
	IC	MF1-5M	28-Apr-19	20	153	141	8.2	Y	N
	IC	MF1-5B	28-Apr-19	20	124	128	3.2	Y	N
	IC	NF3T	23-Apr-19	20	181	194	6.9	Y	N
	IC	NF3M	23-Apr-19	20	146	141	3.5	Y	N
	IC	NF3B	23-Apr-19	20	145	141	2.8	Y	N
	IC	MF2-1T	25-Apr-19	20	238	169	34	Y	N
	IC	MF2-1M	25-Apr-19	20	124	131	5.5	Y	N
	IC	MF2-1B	25-Apr-19	20	140	129	8.2	Y	N
	IC	LDS-2M	26-Apr-19	20	150	163	8.3	Y	N
	IC	LDS-1M	26-Apr-19	20	182	137	28	Y	N
	IC	MF2-3T	24-Apr-19	20	146	150	2.7	Y	N
	IC	MF2-3M	24-Apr-19	20	140	145	3.5	Y	N
	IC	MF2-3B	24-Apr-19	20	129	131	1.5	Y	N
	IC	MF1-3T	28-Apr-19	20	199	179	11	Y	N
	IC	MF1-3M	28-Apr-19	20	147	159	7.8	Y	N
	IC	MF1-3B	28-Apr-19	20	136	132	3	Y	N
	IC	NF4T	23-Apr-19	20	184	186	1.1	Y	N
	IC	NF4M	23-Apr-19	20	163	159	2.5	Y	N
	IC	NF4B	23-Apr-19	20	138	136	1.5	Y	N
	IC	MF3-2T	30-Apr-19	20	159	164	3.1	Y	N
	IC	MF3-2M	30-Apr-19	20	140	130	7.4	Y	N
	IC	MF3-2B	30-Apr-19	20	106	115	8.1	Y	N
	IC	MF3-7T	01-May-19	20	146	138	5.6	Y	N
	IC	MF3-7M	01-May-19	20	126	140	11	Y	N
	IC	MF3-7B	01-May-19	20	136	130	4.5	Y	N
	IC	MF3-6T	01-May-19	20	191	190	0.5	Y	N
	IC	MF3-6M	01-May-19	20	142	141	0.7	Y	N
	IC	MF3-6B	01-May-19	20	133	131	1.5	Y	N
	IC	FF1-4M	04-May-19	20	172	182	5.6	Y	N
	IC	FFB-3M	06-May-19	20	163	153	6.3	Y	N
	IC	FF1-5M	04-May-19	20	188	189	0.5	Y	N
	IC	FF1-1M	04-May-19	20	190	175	8.2	Y	N
	IC	FFB-1M	06-May-19	20	177	175	1.1	Y	N
	IC	FFB-2M	06-May-19	20	171	156	9.2	Y	N
	IC	FF1-3M	04-May-19	20	153	162	5.7	Y	N
	IC	FF1-2M	04-May-19	20	178	173	2.8	Y	N
	IC	FFB-4M	05-May-19	20	167	163	2.4	Y	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	FFA-5M	08-May-19	20	98	250	87	Y	Y
	IC	FFA-2M	08-May-19	20	270	280	3.6	Y	N
	IC	FFA-3M	08-May-19	20	260	280	7.4	Y	N
	IC	FFA-1M	08-May-19	20	300	320	6.5	Y	N
	IC	NF2T	10-May-19	20	280	270	3.6	Y	N
	IC	NF2M	10-May-19	20	440	280	44	Y	Y
	IC	NF2B	10-May-19	20	270	290	7.1	Y	N
	IC	MF3-1T	10-May-19	20	210	160	27	Y	N
	IC	MF3-1M	10-May-19	20	170	140	19	Y	N
	IC	MF3-1B	10-May-19	20	170	160	6.1	Y	N
	IC	FF2-5T	10-May-19	20	160	190	17	Y	N
	IC	FF2-5M	10-May-19	20	150	130	14	Y	N
	IC	FF2-5B	10-May-19	20	120	120	0	Y	N
	IC	MF3-4T	09-May-19	20	160	150	6.5	Y	N
	IC	MF3-4M	09-May-19	20	150	120	22	Y	N
	IC	MF3-4B	09-May-19	20	110	130	17	Y	N
	IC	LDS-3M	10-May-19	20	230	200	14	Y	N
	IC	MF1-1T	10-May-19	20	180	210	15	Y	N
	IC	MF1-1M	10-May-19	20	160	170	6.1	Y	N
	IC	MF1-1B	10-May-19	20	220	140	44	Y	Y
	IC	FFB-5M	05-May-19	20	182	170	6.8	Y	N
	IC	FF2-2T	10-May-19	20	190	260	31	Y	N
	IC	FF2-2M	10-May-19	20	160	250	44	Y	Y
	IC	FF2-2B	10-May-19	200/20	100	130	26	Y	N
	IC	LDG48	08-May-19	20	250	280	11	Y	N
	IC	FFA-4M	08-May-19	20	280	120	80	Y	Y
	IC	MF3-3T	09-May-19	20	180	200	11	Y	N
	IC	MF3-3M	09-May-19	20	140	130	7.4	Y	N
	IC	MF3-3B	09-May-19	20	140	130	7.4	Y	N
	IC	MF3-5T	09-May-19	20	150	190	24	Y	N
	IC	MF3-5M	09-May-19	20	290	180	47	Y	Y
	IC	MF3-5B	09-May-19	20	160	170	6.1	Y	N
	IC	NF3B[a]	23-Apr-19	20	149	155	3.9	Y	N
	IC	FFA-5M[a]	08-May-19	20	260	260	0	Y	N
	IC	MF3-5T[a]	09-May-19	20	170	270	46	Y	Y
	IC	FF1-3M	04-May-19	20	28	26	7.4	N	N
	IC	NF2B	10-May-19	20	120	110	8.7	Y	N
	IC	MF3-1B	10-May-19	20	37	69	60	N	N
	IC	MF1-1T	10-May-19	20/200	34	100	99	N	N
	IC	MF3-3B	09-May-19	20	10	10	0	N	N
Soluble Reactive Silica (µg/L)	IC	NF1B	22-Apr-19	50	699	774	10	Y	N
	IC	NF1M	22-Apr-19	50	1050	657	46	Y	Y
	IC	NF1T	22-Apr-19	10	52	47	10	Y	N
	IC	NF2B	10-May-19	50	668	682	2.1	Y	N
	IC	NF2M	10-May-19	50	967	1020	5.3	Y	N
	IC	NF2T	10-May-19	10	72	75	4.1	Y	N
	IC	NF3B-4	23-Apr-19	50	650	650	0	Y	N
	IC	NF3B-5	23-Apr-19	50	611	652	6.5	Y	N
	IC	NF3M	23-Apr-19	10	281	257	8.9	Y	N
	IC	NF3T	23-Apr-19	10	48	48	0	N	N
	IC	NF4B	23-Apr-19	50	582	576	1.0	Y	N
	IC	NF4M	23-Apr-19	50	730	740	1.4	Y	N
	IC	NF4T	23-Apr-19	10	47	48	2.1	N	N
	IC	NF5B	23-Apr-19	50	550	565	2.7	Y	N
	IC	NF5M	23-Apr-19	50	721	750	3.9	Y	N
	IC	NF5T	23-Apr-19	10	53	55	3.7	Y	N
	IC	MF1-1B	10-May-19	10	426	377	12	Y	N
	IC	MF1-1M	10-May-19	10	174	174	0	Y	N
	IC	MF1-1T	10-May-19	10	40	38	5.1	N	N
	IC	MF1-3B	28-Apr-19	10	87	134	43	Y	Y
	IC	MF1-3M	28-Apr-19	10	26	26	0	N	N
	IC	MF1-3T	28-Apr-19	10	39	44	12	N	N
	IC	MF1-5B	28-Apr-19	50	922	918	0.4	Y	N
	IC	MF1-5M	28-Apr-19	10	152	156	2.6	Y	N

Table B-4 Summary of Duplicate Sample Results for Nutrient Variables, Ice-Cover Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	IC	MF1-5T	28-Apr-19	10	64	67	4.6	Y	N
	IC	MF2-1B	25-Apr-19	10	376	387	2.9	Y	N
	IC	MF2-1M	25-Apr-19	10	169	162	4.2	Y	N
	IC	MF2-1T	25-Apr-19	10	39	40	2.5	N	N
	IC	MF2-3B	24-Apr-19	10	129	79	48	Y	Y
	IC	MF2-3M	24-Apr-19	10	47	40	16	N	N
	IC	MF2-3T	24-Apr-19	10	26	26	0.0	N	N
	IC	FF2-2B	10-May-19	10	94	81	15	Y	N
	IC	FF2-2M	10-May-19	10	51	46	10	Y	N
	IC	FF2-2T	10-May-19	10	31	31	0	N	N
	IC	FF2-5B	10-May-19	10	303	188	46.8	Y	Y
	IC	FF2-5M	10-May-19	10	52	54	3.8	Y	N
	IC	FF2-5T	10-May-19	10	89	144	47	Y	Y
	IC	MF3-1B	10-May-19	10	99	96	3.1	Y	N
	IC	MF3-1M	10-May-19	10	113	120	6.0	Y	N
	IC	MF3-1T	10-May-19	10	105	91	14	Y	N
	IC	MF3-2B	30-Apr-19	10	79	77	2.6	Y	N
	IC	MF3-2M	30-Apr-19	10	55	57	3.6	Y	N
	IC	MF3-2T	30-Apr-19	10	132	135	2.2	Y	N
	IC	MF3-3B	09-May-19	10	82	87	5.9	Y	N
	IC	MF3-3M	09-May-19	10	51	54	5.7	Y	N
	IC	MF3-3T	09-May-19	10	62	61	1.6	Y	N
	IC	MF3-4B	09-May-19	10	102	103	1.0	Y	N
	IC	MF3-4M	09-May-19	10	51	160	103	Y	Y
	IC	MF3-4T	09-May-19	50	66	48	32	N	N
	IC	MF3-5B	09-May-19	10	299	279	6.9	Y	N
	IC	MF3-5M	09-May-19	10	44	42	4.7	N	N
	IC	MF3-5T-4	09-May-19	10	47	259	139	Y	Y
	IC	MF3-5T-5	09-May-19	10	45	46	2.2	N	N
	IC	MF3-6B	01-May-19	10	60	66	9.5	Y	N
	IC	MF3-6M	01-May-19	10	41	41	0	N	N
	IC	MF3-6T	01-May-19	10	51	49	4.0	Y	N
	IC	MF3-7B	01-May-19	10	65	66	1.5	Y	N
	IC	MF3-7M	01-May-19	10	40	38	5.1	N	N
	IC	MF3-7T	01-May-19	10	38	39	2.6	N	N
	IC	FF1-1M	04-May-19	10	104	119	13	Y	N
	IC	FF1-2M	04-May-19	10	55	55	0	Y	N
	IC	FF1-3M	04-May-19	10	75	72	4.1	Y	N
	IC	FF1-4M	04-May-19	10	85	75	13	Y	N
	IC	FF1-5M	04-May-19	10	177	185	4.4	Y	N
	IC	FFB-1M	06-May-19	10	38	37	2.7	N	N
	IC	FFB-2M	06-May-19	10	38	141	115	Y	Y
	IC	FFB-3M	06-May-19	10	39	39	0	N	N
	IC	FFB-4M	05-May-19	10	39	38	2.6	N	N
	IC	FFB-5M	05-May-19	10	39	38	2.6	N	N
	IC	FFA-1M	08-May-19	10	36	35	2.8	N	N
	IC	FFA-2M	08-May-19	10	42	39	7.4	N	N
	IC	FFA-3M	08-May-19	10	38	40	5.1	N	N
	IC	FFA-4M	08-May-19	10	41	37	10	N	N
	IC	FFA-5M-4	08-May-19	10	41	40	2.5	N	N
	IC	FFA-5M-5	08-May-19	10	41	42	2.4	N	N
	IC	LDG-48M	08-May-19	10	40	40	0	N	N
	IC	LDS-1M	26-Apr-19	10	337	377	11	Y	N
	IC	LDS-2M	26-Apr-19	10	333	313	6.2	Y	N
	IC	LDS-3M	10-May-19	10	240	212	12	Y	N

a) Duplicate sample collected for QA/QC purposes.

Note: "Y" in "QC Fail?" column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

µg/L = micrograms per litre; DL = detection limit; > = greater than; × = times; QC = quality control; IC = ice-cover; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; N = no; Y = yes.

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Total Phosphorus (µg-P/L)	OW	NF5	15-Aug-19	2	1	1	0	N	N
	OW	FF1-3	18-Aug-19	2	1	1	0	N	N
	OW	FF2-5	20-Aug-19	2	2	2.5	22	N	N
	OW	MF1-5	21-Aug-19	2	1	1	0	N	N
	OW	MF1-1	22-Aug-19	2	1	2.2	75	N	N
	OW	FF2-2	20-Aug-19	2	1	2.1	71	N	N
	OW	NF4	23-Aug-19	2	3.1	2.2	34	N	N
	OW	FFB-1	26-Aug-19	2	1	1	0	N	N
	OW	FFB-3	26-Aug-19	2	3.6	1	113	N	N
	OW	MF3-3	28-Aug-19	2	1	3.1	102	N	N
	OW	FFB-4	25-Aug-19	2	1	1	0	N	N
	OW	FFB-2	25-Aug-19	2	1	1	0	N	N
	OW	FFB-5	25-Aug-19	2	1	2.6	89	N	N
	OW	FF1-1	17-Aug-19	2	1	1	0	N	N
	OW	MF1-3	22-Aug-19	2	1	2.4	82	N	N
	OW	NF2	23-Aug-19	2	2.2	2.8	24	N	N
	OW	MF2-1	23-Aug-19	2	1	1	0	N	N
	OW	FFA-2	05-Sep-19	2	1	1	0	N	N
	OW	NF3	03-Sep-19	2	1	1	0	N	N
	OW	FFA-5	04-Sep-19	2	1	1	0	N	N
	OW	MF3-4	27-Aug-19	2	2.3	1	79	N	N
	OW	MF3-5	27-Aug-19	2	1	3.6	113	N	N
	OW	FFA-1	04-Sep-19	2	1	1	0	N	N
	OW	FFA-3	04-Sep-19	2	1	1	0	N	N
	OW	FFA-4	04-Sep-19	2	1	1	0	N	N
	OW	MF2-3	20-Aug-19	2	2.4	1	82	N	N
	OW	MF3-6	27-Aug-19	2	1	1	0	N	N
	OW	LDS-1	02-Sep-19	2	3.3	3.4	3	N	N
	OW	MF3-1	03-Sep-19	2	1	1	0	N	N
	OW	LDS-2	02-Sep-19	2	4	4.2	4.9	N	N
	OW	NF1	22-Aug-19	2	1	1	0	N	N
	OW	LDS-3	02-Sep-19	2	3.6	2.9	22	N	N
	OW	FF1-2	19-Aug-19	2	1	2.4	82	N	N
	OW	FF1-5	19-Aug-19	2	1	2.8	95	N	N
	OW	FF1-4	21-Aug-19	2	1	2.1	71	N	N
	OW	MF3-7	26-Aug-19	2	2.2	1	75	N	N
	OW	MF3-2	28-Aug-19	2	1	2.5	85.7	N	N
	OW	FFA-3	04-Sep-19	2	1	1	0	N	N
	OW	MF2-3	20-Aug-19	2	1	1	0	N	N
	OW	MF3-1	03-Sep-19	2	1	1	0	N	N
	OW	NF1	22-Aug-19	2	1	1	0	N	N
	OW	MF3-7	26-Aug-19	2	1	1	0	N	N
Total Dissolved Phosphorus (µg-P/L)	OW	NF5	15-Aug-19	2	1	1	0	N	N
	OW	FF1-3	18-Aug-19	2	1	1	0	N	N
	OW	FF2-5	20-Aug-19	2	1	1	0	N	N
	OW	MF1-5	21-Aug-19	2	1	1	0	N	N
	OW	MF1-1	22-Aug-19	2	1	1	0	N	N
	OW	FF2-2	20-Aug-19	2	5.1	1	134	N	N
	OW	NF4	23-Aug-19	2	1	1	0	N	N
	OW	FFB-1	26-Aug-19	2	1	1	0	N	N
	OW	FFB-3	26-Aug-19	2	1	1	0	N	N
	OW	MF3-3	28-Aug-19	2	1	1	0	N	N
	OW	FFB-4	25-Aug-19	2	1	1	0	N	N
	OW	FFB-2	25-Aug-19	2	1	1	0	N	N
	OW	FFB-5	25-Aug-19	2	1	1	0	N	N
	OW	FF1-1	17-Aug-19	2	1	1	0	N	N
	OW	MF1-3	22-Aug-19	2	1	1	0	N	N
	OW	NF2	23-Aug-19	2	1	1	0	N	N
	OW	MF2-1	23-Aug-19	2	1	1	0	N	N
	OW	FFA-2	05-Sep-19	2	1	1	0	N	N
	OW	NF3	03-Sep-19	2	1	1	0	N	N
	OW	FFA-5	04-Sep-19	2	1	1	0	N	N
	OW	MF3-4	27-Aug-19	2	1	1	0	N	N
	OW	MF3-5	27-Aug-19	2	1	1	0	N	N
	OW	FFA-1	04-Sep-19	2	1	1	0	N	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	OW	FFA-3	04-Sep-19	2	1	1	0	N	N
	OW	FFA-4	04-Sep-19	2	1	1	0	N	N
	OW	MF2-3	20-Aug-19	2	1	1	0	N	N
	OW	MF3-6	27-Aug-19	2	1	1	0	N	N
	OW	LDS-1	02-Sep-19	2	1	1	0	N	N
	OW	MF3-1	03-Sep-19	2	1	1	0	N	N
	OW	LDS-2	02-Sep-19	2	1	1	0	N	N
	OW	NF1	22-Aug-19	2	1	1	0	N	N
	OW	LDS-3	02-Sep-19	2	1	1	0	N	N
	OW	FF1-2	19-Aug-19	2	1	1	0	N	N
	OW	FF1-5	19-Aug-19	2	3.6	5.4	40	N	N
	OW	FF1-4	21-Aug-19	2	1	1	0	N	N
	OW	MF3-7	26-Aug-19	2	1	1	0	N	N
	OW	MF3-2	28-Aug-19	2	1	1	0	N	N
	OW	FFA-3	04-Sep-19	2	1	1	0	N	N
	OW	MF2-3	20-Aug-19	2	1	1	0	N	N
	OW	MF3-1	03-Sep-19	2	1	1	0	N	N
	OW	NF1	22-Aug-19	2	1	1	0	N	N
	OW	MF3-7	26-Aug-19	2	1	1	0	N	N
Soluble Reactive Phosphorus (µg-P/L)	OW	NF5	15-Aug-19	1	3.5	0.5	150	N	N
	OW	FF1-3	18-Aug-19	1	2.6	2.1	21	N	N
	OW	FF2-5	20-Aug-19	1	3.6	4.1	13	N	N
	OW	MF1-5	21-Aug-19	1	3.2	2	46	N	N
	OW	MF1-1	22-Aug-19	1	1.8	2	11	N	N
	OW	FF2-2	20-Aug-19	1	4	0.5	156	N	N
	OW	NF4	23-Aug-19	1	3	2.8	6.9	N	N
	OW	FFB-1	26-Aug-19	1	0.5	1.4	95	N	N
	OW	FFB-3	26-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-3	28-Aug-19	1	1.9	1.9	0	N	N
	OW	FFB-4	25-Aug-19	1	1.7	1.5	13	N	N
	OW	FFB-2	25-Aug-19	1	1.7	1.5	13	N	N
	OW	FFB-5	25-Aug-19	1	0.5	1.3	89	N	N
	OW	FF1-1	17-Aug-19	1	3	2.8	6.9	N	N
	OW	MF1-3	22-Aug-19	1	1.9	2.3	19	N	N
	OW	NF2	23-Aug-19	1	2.4	2.6	8	N	N
	OW	MF2-1	23-Aug-19	1	2.5	0.5	133	N	N
	OW	FFA-2	05-Sep-19	1	1.5	0.5	100	N	N
	OW	NF3	03-Sep-19	1	1	1.2	18	N	N
	OW	FFA-5	04-Sep-19	1	1.1	1.2	8.7	N	N
	OW	MF3-4	27-Aug-19	1	1.5	2.6	54	N	N
	OW	MF3-5	27-Aug-19	1	1.2	0.5	82	N	N
	OW	FFA-1	04-Sep-19	1	2.5	4.4	55	N	N
	OW	FFA-3	04-Sep-19	1	0.5	0.5	0	N	N
	OW	FFA-4	04-Sep-19	1	1.1	1.3	17	N	N
	OW	MF2-3	20-Aug-19	1	1.6	2.7	51	N	N
	OW	MF3-6	27-Aug-19	1	0.5	0.5	0	N	N
	OW	LDS-1	02-Sep-19	1	0.5	4.6	161	N	N
	OW	MF3-1	03-Sep-19	1	2.6	2.1	21	N	N
	OW	LDS-2	02-Sep-19	1	1.3	0.5	89	N	N
	OW	NF1	22-Aug-19	1	0.5	2.1	123	N	N
	OW	LDS-3	02-Sep-19	1	0.5	0.5	0	N	N
	OW	FF1-2	19-Aug-19	1	1.7	1	52	N	N
	OW	FF1-5	19-Aug-19	1	2.8	1.3	73	N	N
	OW	FF1-4	21-Aug-19	1	2.3	1.4	49	N	N
	OW	MF3-7	26-Aug-19	1	2.1	0.5	123	N	N
	OW	MF3-2	28-Aug-19	1	0.5	0.5	0	N	N
	OW	FFA-3	04-Sep-19	1	1.6	2.3	36	N	N
	OW	MF2-3	20-Aug-19	1	1.4	0.5	95	N	N
	OW	MF3-1	03-Sep-19	1	1.3	1.2	8	N	N
	OW	NF1	22-Aug-19	1	2.2	1.5	38	N	N
	OW	MF3-7	26-Aug-19	1	0.5	0.5	0	N	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Total Nitrogen (µg-N/L)	OW	NF5	15-Aug-19	20	280	300	6.9	Y	N
	OW	FF1-3	18-Aug-19	20	250	230	8.3	Y	N
	OW	FF2-5	20-Aug-19	20	230	250	8.3	Y	N
	OW	MF1-5	21-Aug-19	20	180	200	11	Y	N
	OW	MF1-1	22-Aug-19	20	200	240	18	Y	N
	OW	FF2-2	20-Aug-19	20	210	200	4.9	Y	N
	OW	NF4	23-Aug-19	20	300	270	11	Y	N
	OW	FFB-1	26-Aug-19	20	170	180	5.7	Y	N
	OW	FFB-3	26-Aug-19	20	190	190	0	Y	N
	OW	MF3-3	28-Aug-19	20	190	190	0	Y	N
	OW	FFB-4	25-Aug-19	20	180	160	12	Y	N
	OW	FFB-2	25-Aug-19	20	210	180	15	Y	N
	OW	FFB-5	25-Aug-19	20	170	180	5.7	Y	N
	OW	FF1-1	17-Aug-19	20	190	200	5.1	Y	N
	OW	MF1-3	22-Aug-19	20	240	220	8.7	Y	N
	OW	NF2	23-Aug-19	20	240	230	4.3	Y	N
	OW	MF2-1	23-Aug-19	20	230	230	0	Y	N
	OW	FFA-2	05-Sep-19	20	160	170	6.1	Y	N
	OW	NF3	03-Sep-19	20	310	280	10	Y	N
	OW	FFA-5	04-Sep-19	20	170	180	5.7	Y	N
	OW	MF3-4	27-Aug-19	20	170	180	5.7	Y	N
	OW	MF3-5	27-Aug-19	20	200	210	4.9	Y	N
	OW	FFA-1	04-Sep-19	20	190	180	5.4	Y	N
	OW	FFA-3	04-Sep-19	20	300	180	50	Y	Y
	OW	FFA-4	04-Sep-19	20	200	200	0	Y	N
	OW	MF2-3	20-Aug-19	20	200	230	14	Y	N
	OW	MF3-6	27-Aug-19	20	160	180	12	Y	N
	OW	LDS-1	02-Sep-19	20	210	250	17	Y	N
	OW	MF3-1	03-Sep-19	20	220	210	4.7	Y	N
	OW	LDS-2	02-Sep-19	20	260	250	3.9	Y	N
	OW	NF1	22-Aug-19	20	290	270	7.1	Y	N
	OW	LDS-3	02-Sep-19	20	230	250	8.3	Y	N
	OW	FF1-2	19-Aug-19	20	190	190	0	Y	N
	OW	FF1-5	19-Aug-19	20	230	190	19	Y	N
	OW	FF1-4	21-Aug-19	20	180	190	5.4	Y	N
	OW	MF3-7	26-Aug-19	20	190	170	11	Y	N
	OW	MF3-2	28-Aug-19	20	210	200	4.9	Y	N
	OW	FFA-3	04-Sep-19	20	60	52	14	N	N
	OW	MF2-3	20-Aug-19	100/20	50	59	17	N	N
	OW	MF3-1	03-Sep-19	20	51	47	8.2	N	N
	OW	NF1	22-Aug-19	20	65	62	4.7	N	N
	OW	MF3-7	26-Aug-19	20	55	58	5.3	N	N
Total Dissolved Nitrogen (µg-N/L)	OW	NF5	15-Aug-19	20	240	240	0	Y	N
	OW	FF1-3	18-Aug-19	20	150	150	0	Y	N
	OW	FF2-5	20-Aug-19	20	190	170	11	Y	N
	OW	MF1-5	21-Aug-19	20	210	170	21	Y	N
	OW	MF1-1	22-Aug-19	20	220	200	9.5	Y	N
	OW	FF2-2	20-Aug-19	20	230	190	19	Y	N
	OW	NF4	23-Aug-19	20	230	220	4.4	Y	N
	OW	FFB-1	26-Aug-19	20	120	160	29	Y	N
	OW	FFB-3	26-Aug-19	20	110	130	17	Y	N
	OW	MF3-3	28-Aug-19	20	200	170	16	Y	N
	OW	FFB-4	25-Aug-19	20	180	190	5.4	Y	N
	OW	FFB-2	25-Aug-19	20	130	160	21	Y	N
	OW	FFB-5	25-Aug-19	20	180	170	5.7	Y	N
	OW	FF1-1	17-Aug-19	20	150	170	13	Y	N
	OW	MF1-3	22-Aug-19	20	200	220	9.5	Y	N
	OW	NF2	23-Aug-19	20	230	200	14	Y	N
	OW	MF2-1	23-Aug-19	20	210	220	4.7	Y	N
	OW	FFA-2	05-Sep-19	20	100	100	0	N	N
	OW	NF3	03-Sep-19	20	240	260	8	Y	N
	OW	FFA-5	04-Sep-19	20	180	170	5.7	Y	N
	OW	MF3-4	27-Aug-19	20	190	210	10	Y	N
	OW	MF3-5	27-Aug-19	20	180	190	5.4	Y	N
	OW	FFA-1	04-Sep-19	20	190	200	5.1	Y	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	OW	FFA-3	04-Sep-19	20	200	170	16	Y	N
	OW	FFA-4	04-Sep-19	20	170	210	21	Y	N
	OW	MF2-3	20-Aug-19	20	190	190	0	Y	N
	OW	MF3-6	27-Aug-19	20	190	160	17	Y	N
	OW	LDS-1	02-Sep-19	20	230	210	9.1	Y	N
	OW	MF3-1	03-Sep-19	20	210	220	4.7	Y	N
	OW	LDS-2	02-Sep-19	20	220	200	9.5	Y	N
	OW	NF1	22-Aug-19	20	260	240	8	Y	N
	OW	LDS-3	02-Sep-19	20	220	220	0	Y	N
	OW	FF1-2	19-Aug-19	100	160	140	13	N	N
	OW	FF1-5	19-Aug-19	20	180	160	12	Y	N
	OW	FF1-4	21-Aug-19	20/100	180	200	11	Y	N
	OW	MF3-7	26-Aug-19	20	130	160	21	Y	N
	OW	MF3-2	28-Aug-19	20	210	200	4.9	Y	N
	OW	FFA-3	04-Sep-19	20	22	21	4.7	N	N
	OW	MF2-3	20-Aug-19	20	10	10	0	N	N
	OW	MF3-1	03-Sep-19	20	10	10	0	N	N
	OW	NF1	22-Aug-19	20	10	10	0	N	N
	OW	MF3-7	26-Aug-19	20	10	10	0	N	N
Total Ammonia (µg-N/L) - ALS	OW	FF1-1	17-Aug-19	5	18.5	2.5	152	N	N
	OW	FF1-2	19-Aug-19	5	39	20.1	64	Y	Y
	OW	FF1-3	18-Aug-19	5	19.6	16.8	15	N	N
	OW	FF1-4	21-Aug-19	5	7.8	8.5	8.6	N	N
	OW	FF1-5	19-Aug-19	5	9.6	20.8	74	N	N
	OW	FF2-2	20-Aug-19	5	13.7	39.3	97	Y	Y
	OW	FF2-5	20-Aug-19	5	19.2	18	6.5	N	N
	OW	FFA-1	04-Sep-19	5	7	30.8	126	Y	Y
	OW	FFA-2	05-Sep-19	5	44.2	12.6	111	Y	Y
	OW	FFA-3	04-Sep-19	5	7.1	11.8	50	N	N
	OW	FFA-3	04-Sep-19	5	2.5	11.6	129	N	N
	OW	FFA-4	04-Sep-19	5	92.1	22.4	122	Y	Y
	OW	FFA-5	04-Sep-19	5	29.3	20.1	37	Y	N
	OW	FFB-1	26-Aug-19	5	38.1	41.1	7.6	Y	N
	OW	FFB-2	25-Aug-19	5	39	14.1	94	Y	Y
	OW	FFB-2	25-Aug-19	5	17.4	14.4	19	N	N
	OW	FFB-3	26-Aug-19	5	33.2	38.8	16	Y	N
	OW	FFB-4	25-Aug-19	5	9.8	41.7	124	Y	Y
	OW	FFB-5	25-Aug-19	5	34.7	15.7	75	Y	Y
	OW	LDS-1	02-Sep-19	5	7	8.2	16	N	N
	OW	LDS-2	02-Sep-19	5	2.5	2.5	0	N	N
	OW	LDS-3	02-Sep-19	5	13.4	15.4	14	N	N
	OW	MF1-1	22-Aug-19	5	201	63.7	104	Y	Y
	OW	MF1-3	22-Aug-19	5	37.3	48.4	26	Y	N
	OW	MF1-5	21-Aug-19	5	26.2	10.6	85	Y	Y
	OW	MF1-5	21-Aug-19	5	2.5	5.4	73	N	N
	OW	MF2-1	23-Aug-19	5	76.1	34.6	75	Y	Y
	OW	MF2-3	20-Aug-19	5	5	2.5	67	N	N
	OW	MF2-3	20-Aug-19	10/5	2.5	13.1	136	N	N
	OW	MF3-1	03-Sep-19	5	35	52.1	39	Y	N
	OW	MF3-1	03-Sep-19	5	2.5	37.8	175	Y	Y
	OW	MF3-2	28-Aug-19	5	12.7	45.2	112	Y	Y
	OW	MF3-2	28-Aug-19	5	13.3	13.4	0.7	N	N
	OW	MF3-3	28-Aug-19	5	20.2	26.5	27	Y	N
	OW	MF3-4	27-Aug-19	5	11.7	2.5	130	N	N
	OW	MF3-5	27-Aug-19	5	21.4	6.2	110	N	N
	OW	MF3-6	27-Aug-19	5	86.7	15.4	140	Y	Y
	OW	MF3-7	26-Aug-19	5	10.3	19	59	N	N
	OW	MF3-7	26-Aug-19	5	79.4	129	48	Y	Y
	OW	NF1	22-Aug-19	5	12.5	13.2	5.4	N	N
	OW	NF1	22-Aug-19	5	2.5	12.1	132	N	N
	OW	NF2	23-Aug-19	5	63.8	19.5	106	Y	Y
	OW	NF3	03-Sep-19	5	24.5	15.1	48	N	N
	OW	NF4	23-Aug-19	5	66.1	52.9	22	Y	N
	OW	NF5	15-Aug-19	5	34.4	26.1	27	Y	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Total Ammonia (µg-N/L) – BV Labs	OW	NF5	15-Aug-19	5	32	27	17	Y	N
	OW	FF1-3	18-Aug-19	5	2.5	2.5	0	N	N
	OW	FF2-5	20-Aug-19	5	13	14	7.4	N	N
	OW	MF1-5	21-Aug-19	5	5.2	7.3	34	N	N
	OW	MF1-1	22-Aug-19	5	8.7	9	3.4	N	N
	OW	FF2-2	20-Aug-19	5	11	17	43	N	N
	OW	NF4	23-Aug-19	5	14	11	24	N	N
	OW	FFB-1	26-Aug-19	5	2.5	2.5	0	N	N
	OW	FFB-3	26-Aug-19	5	6	2.5	82	N	N
	OW	MF3-3	28-Aug-19	5	7.6	9	17	N	N
	OW	FFB-4	25-Aug-19	5	11	2.5	126	N	N
	OW	FFB-2	25-Aug-19	5	2.5	7.5	100	N	N
	OW	FFB-5	25-Aug-19	5	2.5	2.5	0	N	N
	OW	FF1-1	17-Aug-19	5	9.8	9.1	7.4	N	N
	OW	MF1-3	22-Aug-19	5	12	11	8.7	N	N
	OW	NF2	23-Aug-19	5	13	15	14	N	N
	OW	MF2-1	23-Aug-19	5	15	20	29	N	N
	OW	FFA-2	05-Sep-19	5	8.5	8.9	4.6	N	N
	OW	NF3	03-Sep-19	5	14	15	6.9	N	N
	OW	FFA-5	04-Sep-19	5	2.5	2.5	0	N	N
	OW	MF3-4	27-Aug-19	5	7.8	9.5	20	N	N
	OW	MF3-5	27-Aug-19	5	6.6	6	9.5	N	N
	OW	FFA-1	04-Sep-19	5	2.5	2.5	0	N	N
	OW	FFA-3	04-Sep-19	5	2.5	2.5	0	N	N
	OW	FFA-4	04-Sep-19	5	8.9	2.5	112	N	N
	OW	MF2-3	20-Aug-19	5	8.4	8.4	0	N	N
	OW	MF3-6	27-Aug-19	5	2.5	2.5	0	N	N
	OW	LDS-1	02-Sep-19	5	6.8	5.3	25	N	N
	OW	MF3-1	03-Sep-19	5	14	14	0	N	N
	OW	LDS-2	02-Sep-19	5	8.9	7.1	23	N	N
	OW	NF1	22-Aug-19	5	20	14	35	N	N
	OW	LDS-3	02-Sep-19	5	2.5	8.2	107	N	N
	OW	FF1-2	19-Aug-19	5	51	52	1.9	Y	N
	OW	FF1-5	19-Aug-19	5	13	2.5	136	N	N
	OW	FF1-4	21-Aug-19	5	2.5	2.5	0	N	N
	OW	MF3-7	26-Aug-19	5	2.5	2.5	0	N	N
	OW	MF3-2	28-Aug-19	5	6.6	12	58	N	N
	OW	MF1-5	21-Aug-19	5	62	47	28	Y	N
	OW	FFB-2	25-Aug-19	5	47	51	8.2	Y	N
	OW	FFA-3	04-Sep-19	5	2.5	2.5	0	N	N
	OW	MF2-3	20-Aug-19	5	2.5	2.5	0	N	N
	OW	MF3-1	03-Sep-19	5	6.6	7	5.9	N	N
	OW	NF1	22-Aug-19	5	2.5	2.5	0	N	N
	OW	MF3-7	26-Aug-19	5	2.5	2.5	0	N	N
	OW	MF3-2	28-Aug-19	5	53	51	3.8	Y	N
Nitrate (µg-N/L)	OW	NF5	15-Aug-19	2	32	36	12	Y	N
	OW	FF1-3	18-Aug-19	2	1	1	0	N	N
	OW	FF2-5	20-Aug-19	2	4.6	4.4	4.4	N	N
	OW	MF1-5	21-Aug-19	2	1	1	0	N	N
	OW	MF1-1	22-Aug-19	2	16	12	29	Y	N
	OW	FF2-2	20-Aug-19	2	4.2	8.6	69	N	N
	OW	NF4	23-Aug-19	2	17	18	5.7	Y	N
	OW	FFB-1	26-Aug-19	2	1	1	0	N	N
	OW	FFB-3	26-Aug-19	2	2.1	1	71	N	N
	OW	MF3-3	28-Aug-19	2	2.7	1	92	N	N
	OW	FFB-4	25-Aug-19	2	2	2.1	4.9	N	N
	OW	FFB-2	25-Aug-19	2	1	1	0	N	N
	OW	FFB-5	25-Aug-19	2	1	1	0	N	N
	OW	FF1-1	17-Aug-19	2	1	1	0	N	N
	OW	MF1-3	22-Aug-19	2	5.7	6	5.1	N	N
	OW	NF2	23-Aug-19	2	16	17	6.1	Y	N
	OW	MF2-1	23-Aug-19	2	13	13	0	Y	N
	OW	FFA-2	05-Sep-19	2	1	2.8	95	N	N
	OW	NF3	03-Sep-19	2	31	37	18	Y	N
	OW	FFA-5	04-Sep-19	2	1	1	0	N	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	OW	MF3-4	27-Aug-19	2	4.8	1	131	N	N
	OW	MF3-5	27-Aug-19	2	2.8	3.4	19	N	N
	OW	FFA-1	04-Sep-19	2	1	1	0	N	N
	OW	FFA-3	04-Sep-19	2	1	1	0	N	N
	OW	FFA-4	04-Sep-19	2	1	3	100	N	N
	OW	MF2-3	20-Aug-19	2	7.9	6.9	14	N	N
	OW	MF3-6	27-Aug-19	2	4.5	1	127	N	N
	OW	LDS-1	02-Sep-19	2	1	1	0	N	N
	OW	MF3-1	03-Sep-19	2	14	15	6.9	Y	N
	OW	LDS-2	02-Sep-19	2	1	1	0	N	N
	OW	NF1	22-Aug-19	2	43	39	9.8	Y	N
	OW	LDS-3	02-Sep-19	2	1	1	0	N	N
	OW	FF1-2	19-Aug-19	2	1	1	0	N	N
	OW	FF1-5	19-Aug-19	2	1	1	0	N	N
	OW	FF1-4	21-Aug-19	2	4.9	4.9	0	N	N
	OW	MF3-7	26-Aug-19	2	1	1	0	N	N
	OW	MF3-2	28-Aug-19	2	6.8	5.6	19.4	N	N
	OW	FFA-3	04-Sep-19	2	1	1	0	N	N
	OW	MF2-3	20-Aug-19	2	1	5	133	N	N
	OW	MF3-1	03-Sep-19	2	1	1	0	N	N
	OW	NF1	22-Aug-19	2	5.2	2.1	85	N	N
	OW	MF3-7	26-Aug-19	2	1	1	0	N	N
Nitrite (µg-N/L)	OW	NF5	15-Aug-19	1	2	1.6	22	N	N
	OW	FF1-3	18-Aug-19	1	0.5	1.6	105	N	N
	OW	FF2-5	20-Aug-19	1	0.5	0.5	0	N	N
	OW	MF1-5	21-Aug-19	1	1.1	0.5	75	N	N
	OW	MF1-1	22-Aug-19	1	0.5	0.5	0	N	N
	OW	FF2-2	20-Aug-19	1	0.5	1.1	75	N	N
	OW	NF4	23-Aug-19	1	0.5	0.5	0	N	N
	OW	FFB-1	26-Aug-19	1	0.5	0.5	0	N	N
	OW	FFB-3	26-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-3	28-Aug-19	1	0.5	0.5	0	N	N
	OW	FFB-4	25-Aug-19	1	0.5	0.5	0	N	N
	OW	FFB-2	25-Aug-19	1	0.5	0.5	0	N	N
	OW	FFB-5	25-Aug-19	1	0.5	0.5	0	N	N
	OW	FF1-1	17-Aug-19	1	0.5	0.5	0	N	N
	OW	MF1-3	22-Aug-19	1	0.5	0.5	0	N	N
	OW	NF2	23-Aug-19	1	0.5	0.5	0	N	N
	OW	MF2-1	23-Aug-19	1	0.5	0.5	0	N	N
	OW	FFA-2	05-Sep-19	1	0.5	0.5	0	N	N
	OW	NF3	03-Sep-19	1	0.5	2.4	131	N	N
	OW	FFA-5	04-Sep-19	1	0.5	0.5	0	N	N
	OW	MF3-4	27-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-5	27-Aug-19	1	0.5	0.5	0	N	N
	OW	FFA-1	04-Sep-19	1	0.5	0.5	0	N	N
	OW	FFA-3	04-Sep-19	1	0.5	0.5	0	N	N
	OW	FFA-4	04-Sep-19	1	0.5	0.5	0	N	N
	OW	MF2-3	20-Aug-19	1	1.3	0.5	89	N	N
	OW	MF3-6	27-Aug-19	1	0.5	0.5	0	N	N
	OW	LDS-1	02-Sep-19	1	0.5	0.5	0	N	N
	OW	MF3-1	03-Sep-19	1	0.5	0.5	0	N	N
	OW	LDS-2	02-Sep-19	1	0.5	0.5	0	N	N
	OW	NF1	22-Aug-19	1	2.1	1.6	27	N	N
	OW	LDS-3	02-Sep-19	1	0.5	0.5	0	N	N
	OW	FF1-2	19-Aug-19	1	0.5	0.5	0	N	N
	OW	FF1-5	19-Aug-19	1	0.5	0.5	0	N	N
	OW	FF1-4	21-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-7	26-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-2	28-Aug-19	1	2.6	2.4	8	N	N
	OW	FFA-3	04-Sep-19	1	0.5	0.5	0	N	N
	OW	MF2-3	20-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-1	03-Sep-19	1	0.5	0.5	0	N	N
	OW	NF1	22-Aug-19	1	0.5	0.5	0	N	N
	OW	MF3-7	26-Aug-19	1	0.5	0.5	0	N	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Nitrate + Nitrite (µg-N/L)	OW	NF5	15-Aug-19	2.2	34	38	11	Y	N
	OW	FF1-3	18-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FF2-5	20-Aug-19	2.2	4.6	4.4	4.4	N	N
	OW	MF1-5	21-Aug-19	2.2	1.1	1.1	0	N	N
	OW	MF1-1	22-Aug-19	2.2	16	12	29	Y	N
	OW	FF2-2	20-Aug-19	2.2	4.2	9.7	79	N	N
	OW	NF4	23-Aug-19	2.2	17	18	5.7	Y	N
	OW	FFB-1	26-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FFB-3	26-Aug-19	2.2	1.1	1.1	0	N	N
	OW	MF3-3	28-Aug-19	2.2	2.8	1.1	87	N	N
	OW	FFB-4	25-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FFB-2	25-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FFB-5	25-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FF1-1	17-Aug-19	2.2	1.1	1.1	0	N	N
	OW	MF1-3	22-Aug-19	2.2	5.7	6	5.1	N	N
	OW	NF2	23-Aug-19	2.2	16	17	6.1	Y	N
	OW	MF2-1	23-Aug-19	2.2	13	13	0	Y	N
	OW	FFA-2	05-Sep-19	2.2	1.1	2.8	87	N	N
	OW	NF3	03-Sep-19	2.2	31	39	23	Y	N
	OW	FFA-5	04-Sep-19	2.2	1.1	1.1	0	N	N
	OW	MF3-4	27-Aug-19	2.2	4.8	1.1	125	N	N
	OW	MF3-5	27-Aug-19	2.2	2.8	3.4	19	N	N
	OW	FFA-1	04-Sep-19	2.2	1.1	1.1	0	N	N
	OW	FFA-3	04-Sep-19	2.2	1.1	1.1	0	N	N
	OW	FFA-4	04-Sep-19	2.2	1.1	3	93	N	N
	OW	MF2-3	20-Aug-19	2.2	9.2	6.9	29	N	N
	OW	MF3-6	27-Aug-19	2.2	4.5	1.1	121	N	N
	OW	LDS-1	02-Sep-19	2.2	1.1	1.1	0	N	N
	OW	MF3-1	03-Sep-19	2.2	14	15	6.9	Y	N
	OW	LDS-2	02-Sep-19	2.2	1.1	1.1	0	N	N
	OW	NF1	22-Aug-19	2.2	45	41	9.3	Y	N
	OW	LDS-3	02-Sep-19	2.2	1.1	1.1	0	N	N
	OW	FF1-2	19-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FF1-5	19-Aug-19	2.2	1.1	1.1	0	N	N
	OW	FF1-4	21-Aug-19	2.2	4.9	4.9	0	N	N
	OW	MF3-7	26-Aug-19	2.2	1.1	1.1	0	N	N
	OW	MF3-2	28-Aug-19	2.2	9.5	8	17	N	N
	OW	FFA-3	04-Sep-19	2.2	1.1	1.1	0	N	N
	OW	MF2-3	20-Aug-19	2.2	1.1	5	128	N	N
	OW	MF3-1	03-Sep-19	2.2	1.1	1.1	0	N	N
	OW	NF1	22-Aug-19	2.2	5.2	1.1	130	N	N
	OW	MF3-7	26-Aug-19	2.2	1.1	1.1	0	N	N
Total Kjeldahl Nitrogen (µg-N/L)	OW	NF5	15-Aug-19	20	250	260	3.9	Y	N
	OW	FF1-3	18-Aug-19	20	250	230	8.3	Y	N
	OW	FF2-5	20-Aug-19	20	220	240	8.7	Y	N
	OW	MF1-5	21-Aug-19	20	180	200	11	Y	N
	OW	MF1-1	22-Aug-19	20	190	230	19	Y	N
	OW	FF2-2	20-Aug-19	20	210	190	10	Y	N
	OW	NF4	23-Aug-19	20	280	250	11	Y	N
	OW	FFB-1	26-Aug-19	20	170	180	5.7	Y	N
	OW	FFB-3	26-Aug-19	20	180	190	5.4	Y	N
	OW	MF3-3	28-Aug-19	20	190	190	0	Y	N
	OW	FFB-4	25-Aug-19	20	170	160	6.1	Y	N
	OW	FFB-2	25-Aug-19	20	210	180	15	Y	N
	OW	FFB-5	25-Aug-19	20	170	180	5.7	Y	N
	OW	FF1-1	17-Aug-19	20	190	200	5.1	Y	N
	OW	MF1-3	22-Aug-19	20	230	210	9.1	Y	N
	OW	NF2	23-Aug-19	20	220	220	0	Y	N
	OW	MF2-1	23-Aug-19	20	220	220	0	Y	N
	OW	FFA-2	05-Sep-19	20	160	170	6.1	Y	N
	OW	NF3	03-Sep-19	20	280	240	15	Y	N
	OW	FFA-5	04-Sep-19	20	170	180	5.7	Y	N
	OW	MF3-4	27-Aug-19	20	160	180	12	Y	N
	OW	MF3-5	27-Aug-19	20	200	200	0	Y	N
	OW	FFA-1	04-Sep-19	20	190	180	5.4	Y	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
	OW	FFA-3	04-Sep-19	20	300	180	50	Y	Y
	OW	FFA-4	04-Sep-19	20	200	200	0	Y	N
	OW	MF2-3	20-Aug-19	20	190	220	15	Y	N
	OW	MF3-6	27-Aug-19	20	160	180	12	Y	N
	OW	LDS-1	02-Sep-19	20	210	250	17	Y	N
	OW	MF3-1	03-Sep-19	20	210	190	10	Y	N
	OW	LDS-2	02-Sep-19	20	260	250	3.9	Y	N
	OW	NF1	22-Aug-19	20	240	230	4.3	Y	N
	OW	LDS-3	02-Sep-19	20	230	250	8.3	Y	N
	OW	FF1-2	19-Aug-19	20	190	190	0	Y	N
	OW	FF1-5	19-Aug-19	20	230	190	19	Y	N
	OW	FF1-4	21-Aug-19	20	180	190	5.4	Y	N
	OW	MF3-7	26-Aug-19	20	190	170	11	Y	N
	OW	MF3-2	28-Aug-19	20	200	190	5.1	Y	N
	OW	FFA-3	04-Sep-19	2.2	1.1	1.1	0	N	N
	OW	MF2-3	20-Aug-19	2.2	1.1	5	128	N	N
	OW	MF3-1	03-Sep-19	2.2	1.1	1.1	0	N	N
	OW	NF1	22-Aug-19	2.2	5.2	1.1	130	N	N
	OW	MF3-7	26-Aug-19	2.2	1.1	1.1	0	N	N
Dissolved Kjeldahl Nitrogen (µg-N/L)	OW	NF5	15-Aug-19	20	210	200	4.9	Y	N
	OW	FF1-3	18-Aug-19	20	150	150	0	Y	N
	OW	FF2-5	20-Aug-19	20	190	170	11	Y	N
	OW	MF1-5	21-Aug-19	20	210	170	21	Y	N
	OW	MF1-1	22-Aug-19	20	210	190	10	Y	N
	OW	FF2-2	20-Aug-19	20	230	180	24	Y	N
	OW	NF4	23-Aug-19	20	210	200	4.9	Y	N
	OW	FFB-1	26-Aug-19	20	120	160	29	Y	N
	OW	FFB-3	26-Aug-19	20	110	130	17	Y	N
	OW	MF3-3	28-Aug-19	20	190	170	11	Y	N
	OW	FFB-4	25-Aug-19	20	180	190	5.4	Y	N
	OW	FFB-2	25-Aug-19	20	130	160	21	Y	N
	OW	FFB-5	25-Aug-19	20	180	170	5.7	Y	N
	OW	FF1-1	17-Aug-19	20	150	170	13	Y	N
	OW	MF1-3	22-Aug-19	20	200	220	9.5	Y	N
	OW	NF2	23-Aug-19	20	210	180	15	Y	N
	OW	MF2-1	23-Aug-19	20	200	210	4.9	Y	N
	OW	FFA-2	05-Sep-19	20	100	98	2	N	N
	OW	NF3	03-Sep-19	20	210	220	4.7	Y	N
	OW	FFA-5	04-Sep-19	20	180	170	5.7	Y	N
	OW	MF3-4	27-Aug-19	20	190	210	10	Y	N
	OW	MF3-5	27-Aug-19	20	170	190	11	Y	N
	OW	FFA-1	04-Sep-19	20	190	200	5.1	Y	N
	OW	FFA-3	04-Sep-19	20	200	170	16	Y	N
	OW	FFA-4	04-Sep-19	20	170	210	21	Y	N
	OW	MF2-3	20-Aug-19	20	180	180	0	Y	N
	OW	MF3-6	27-Aug-19	20	180	160	12	Y	N
	OW	LDS-1	02-Sep-19	20	230	210	9.1	Y	N
	OW	MF3-1	03-Sep-19	20	190	210	10	Y	N
	OW	LDS-2	02-Sep-19	20	220	200	9.5	Y	N
	OW	NF1	22-Aug-19	20	210	200	4.9	Y	N
	OW	LDS-3	02-Sep-19	20	220	220	0	Y	N
	OW	FF1-2	19-Aug-19	100	160	140	13	N	N
	OW	FF1-5	19-Aug-19	20	180	160	12	Y	N
	OW	FF1-4	21-Aug-19	20/100	170	190	11	Y	N
	OW	MF3-7	26-Aug-19	20	130	160	21	Y	N
	OW	MF3-2	28-Aug-19	20	200	190	5.1	Y	N
	OW	FFA-3	04-Sep-19	20	22	21	4.7	N	N
	OW	MF2-3	20-Aug-19	20	10	10	0	N	N
	OW	MF3-1	03-Sep-19	20	10	10	0	N	N
	OW	NF1	22-Aug-19	20	10	10	0	N	N
	OW	MF3-7	26-Aug-19	20	10	10	0	N	N

Table B-5 Summary of Duplicate Sample Results for Nutrient Variables, Open-Water Season, 2019 (continued)

Variable	Season	Station	Sampling Date	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
Soluble Reactive Silica (µg/L)	OW	NF1	22-Aug-19	10	72	75	4.1	Y	N
	OW	NF2	23-Aug-19	10	36	39	8.0	N	N
	OW	NF3	03-Sep-19	10	59	61	3.3	Y	N
	OW	NF4	23-Aug-19	10	38	41	7.6	N	N
	OW	NF5	15-Aug-19	10	62	60	3.3	Y	N
	OW	MF1-1	22-Aug-19	10	36	37	2.7	N	N
	OW	MF1-3	22-Aug-19	10	33	33	0	N	N
	OW	MF1-5	21-Aug-19	10	58	56	3.5	Y	N
	OW	MF2-1	23-Aug-19	10	33	31	6.3	N	N
	OW	MF2-3	20-Aug-19	10	19	19	0	N	N
	OW	FF2-2	20-Aug-19	10	23	26	12.2	N	N
	OW	FF2-5	20-Aug-19	10	31	31	0	N	N
	OW	MF3-1	03-Sep-19	10	41	41	0	N	N
	OW	MF3-2	28-Aug-19	10	45	47	4.3	N	N
	OW	MF3-3	28-Aug-19	10	47	50	6.2	N	N
	OW	MF3-4	27-Aug-19	10	44	43	2.3	N	N
	OW	MF3-5	27-Aug-19	10	33	34	3.0	N	N
	OW	MF3-6	27-Aug-19	10	40	33	19	N	N
	OW	MF3-7	26-Aug-19	10	35	31	12	N	N
	OW	FF1-1	17-Aug-19	10	45	43	4.5	N	N
	OW	FF1-2	19-Aug-19	10	48	48	0	N	N
	OW	FF1-3	18-Aug-19	10	52	52	0	Y	N
	OW	FF1-4	21-Aug-19	10	52	51	1.9	Y	N
	OW	FF1-5	19-Aug-19	10	55	55	0	Y	N
	OW	FFB-1	26-Aug-19	10	35	32	9.0	N	N
	OW	FFB-2	25-Aug-19	10	36	30	18.2	N	N
	OW	FFB-3	26-Aug-19	10	32	33	3.1	N	N
	OW	FFB-4	25-Aug-19	10	31	33	6.3	N	N
	OW	FFB-5	25-Aug-19	10	33	33	0	N	N
	OW	FFA-1	04-Sep-19	10	31	30	3.3	N	N
	OW	FFA-2	05-Sep-19	10	32	32	0	N	N
	OW	FFA-3	04-Sep-19	10	32	33	3.1	N	N
	OW	FFA-4	04-Sep-19	10	32	31	3.2	N	N
	OW	FFA-5	04-Sep-19	10	32	32	0	N	N
	OW	LDS-1	02-Sep-19	10	147	146	0.7	Y	N
	OW	LDS-2	02-Sep-19	10	165	163	1.2	Y	N
	OW	LDS-3	02-Sep-19	10	149	150	0.7	Y	N

a) Duplicate sample collected for QA/QC purposes.

Note: “Y” in “QC Fail?” column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

µg/L = micrograms per litre; DL = detection limit; > = greater than; × = times; QC = quality control; IC = ice-cover; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; N = no; Y = yes.

Total Versus Dissolved Forms

The differences between TP and TDP concentrations were within the DQO (Table B-6). Based on this criterion, the TDP data for both seasons were considered acceptable.

The TDN samples were filtered in the laboratory to avoid issues with contamination during filtering, which was observed in 2018. Despite this, there were still several samples with greater dissolved nitrogen (TDN and DKN) than TN (Tables B-7 and B-8). All but one station had concentrations greater than five times the DL. The differences between TN and TDN and between TKN and DKN exceeded the DQO of 20% in 14 and 16 samples (out of 234 samples), or 6% and 6.8% of samples, respectively. The affected samples were collected during the ice-cover season on 8 and 10 May 2019. On these two collection dates, a total of 52 samples were collected, which makes up 27% and 31% of samples from those collection dates affected. This suggests a possible contamination issue for some but not all samples analysed in these batches.

On 8 and 10 May 2019, samples were collected from FF2-2, FF2-5, FFA-1 to FFA-3, FFA-5, MF3-1, LDG-48, LDS (only TDN samples collected), and NF2M (only TN samples collected). For most of these areas, the greater dissolved nitrogen concentrations did not affect the overall interpretation of results at those areas because only a few samples were affected (i.e., duplicate samples were collected at three depths for a total of six samples, but only one or two of those samples had dissolved concentrations more than 20% greater than total). Also, the concentrations at these stations and areas fall in the expected range given the trends with distance from the diffuser. Therefore, the observed DQO failure did not affect the results interpretation for the sampling areas of NF, MF3-1, FF2, and LDS.

The results for FFA and LDG-48, however, were affected, as discussed below:

- Several samples and stations from FFA had DQO failures, such that the mean concentrations of TDN and DKN during the ice-cover season for the FFA area may have been affected. Concentrations were greater in this area compared to FFB. However, FFA concentrations were also greater than FFB during the open-water season, when any difference between total and dissolved concentrations were smaller and within DQO.
- For TDN, one sample from LDS-48 was affected; for DKN, both samples were affected. Concentrations of TDN and DKN were greater than TN and TKN at LDG-48 during ice-cover season, and also greater than normal range. This was different from previous years (e.g., 2014, 2015, 2018), when concentrations were within normal range at LDG-48. Therefore, the 2019 concentrations may be suspect and should be interpreted with caution.
- In summary, the results for TDN and DKN in FFA and LDG-48 are likely biased high and should be used with caution. However, this should not affect the overall interpretation of results for the eutrophication indicator assessment, because the assessment mainly relies on the TN results (e.g., for extent of effects determination), and TDN and TKN are supporting variables to the overall nitrogen evaluation.

Table B-6 Comparison of Total and Dissolved Phosphorus Concentrations, 2019

Season	Sample Name	Sampling Date	DL (µg-P/L)	Total Phosphorus (µg-P/L)	Total Dissolved Phosphorus (µg-P/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
IC	FF2-5T-5	10-May-19	2	1.0	3.7	115	N	N
IC	FFA-2M-4	08-May-19	2	1.0	2.7	92	N	N
IC	MF1-1T-5	10-May-19	2	1.0	2.5	86	N	N
IC	MF3-3T-5	09-May-19	2	1.0	3.3	107	N	N
IC	NF1B-4	22-Apr-19	2	1.0	4.2	123	N	N
IC	NF2B-4	10-May-19	2	1.0	2.6	89	N	N
IC	NF2M-4	10-May-19	2	2.1	2.6	21	N	N
IC	NF2M-5	10-May-19	2	1.0	2.1	71	N	N
IC	NF2T-4	10-May-19	2	2.2	2.8	24	N	N
OW	FF2-2-4	20-Aug-19	2	1.0	5.1	134	N	N
OW	FF1-5-4	19-Aug-19	2	1.0	3.6	113	N	N
OW	FF1-5-5	19-Aug-19	2	2.8	5.4	63	N	N

Notes: Only cases where the total dissolved phosphorus was greater than total phosphorus are presented in this table.

Results were evaluated using the criterion of relative percent difference (RPD) greater than 20%, where concentrations in one or both of the duplicate samples are greater than or equal to five times the corresponding DL.

µg-P/L = micrograms phosphorus per litre; DL = detection limit; QC = quality control; IC = ice-cover; OW = open-water; NF = near-field; MF = mid-field; FF = far-field; N = no; Y = yes.

Table B-7 Comparison of Total and Dissolved Nitrogen Concentrations, 2019

Season	Station	Sampling Date	DL (µg-N/L)	Total Nitrogen (µg-N/L)	Total Dissolved Nitrogen (µg-N/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
IC	FF1-1M-4	04-May-19	20	201	212	5.3	Y	N
IC	FF1-2M-5	04-May-19	20	176	177	0.6	Y	N
IC	FF2-2M-5	10-May-19	20/55	190	290	42	Y	Y
IC	FF2-2T-5	10-May-19	20/55	170	270	45	Y	Y
IC	FF2-5T-4	10-May-19	20/55	120	190	45	Y	Y
IC	FFA-1M-4	08-May-19	20/55	180	300	50	Y	Y
IC	FFA-1M-5	08-May-19	20/55	180	320	56	Y	Y
IC	FFA-2M-4	08-May-19	20/55	170	290	52	Y	Y
IC	FFA-2M-5	08-May-19	20/55	150	300	67	Y	Y
IC	FFA-3M-4	08-May-19	20/55	200	280	33	Y	N
IC	FFA-3M-5	08-May-19	20/55	200	320	46	Y	Y
IC	FFA-4M-5	08-May-19	20/55	140	150	6.9	Y	N
IC	FFA-5M-4-5	08-May-19	20/55	150	250	50	Y	Y
IC	FFA-5M-5-4	08-May-19	20/55	170	280	49	Y	Y
IC	FFA-5M-5-5	08-May-19	20/55	180	280	44	Y	Y
IC	FFB-4M-5	05-May-19	20	160	163	1.9	Y	N
IC	LDG-48M-4	08-May-19	20/55	83	260	103	N	N

Table B-7 Comparison of Total and Dissolved Nitrogen Concentrations, 2019 (continued)

Season	Station	Sampling Date	DL (µg-N/L)	Total Nitrogen (µg-N/L)	Total Dissolved Nitrogen (µg-N/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
IC	LDG-48M-5	08-May-19	20/55	150	280	61	Y	Y
IC	LDS-3M-4	10-May-19	20	180	280	44	Y	Y
IC	MF1-1B-4	10-May-19	20/55	310	350	12	Y	N
IC	MF3-1T-4	10-May-19	20	140	250	56	Y	Y
IC	MF3-3B-4	09-May-19	20/55	170	210	21	Y	N
IC	MF3-3T-5	09-May-19	20/55	200	220	9.5	Y	N
IC	MF3-5B-5	09-May-19	20/55	240	270	12	Y	N
IC	MF3-5M-4	09-May-19	20	230	320	33	Y	N
IC	MF3-5M-5	09-May-19	20	180	210	15	Y	N
IC	MF3-5T-5-5	09-May-19	20/55	250	290	15	Y	N
IC	NF1T-4	22-Apr-19	20	233	252	7.8	Y	N
IC	NF2B-4	10-May-19	20/55	370	430	15	Y	N
IC	NF2B-5	10-May-19	20/55	390	460	17	Y	N
IC	NF2M-4	10-May-19	20/55	480	670	33	Y	N
IC	NF2M-5	10-May-19	20/55	470	500	6.2	Y	N
IC	NF2T-4	10-May-19	20/55	260	310	18	Y	N
IC	NF2T-5	10-May-19	20/55	270	290	7.1	Y	N
OW	FF1-4-5	21-Aug-19	20/100	190	200	5.1	Y	N
OW	FF2-2-4	20-Aug-19	20	210	230	9.1	Y	N
OW	FFA-1-5	04-Sep-19	20	180	200	11	Y	N
OW	FFA-4-5	04-Sep-19	20	200	210	4.9	Y	N
OW	FFA-5-4	04-Sep-19	20	170	180	5.7	Y	N
OW	FFB-4-5	25-Aug-19	20	160	190	17	Y	N
OW	FFB-5-4	25-Aug-19	20	170	180	5.7	Y	N
OW	LDS-1-4	02-Sep-19	20	210	230	9.1	Y	N
OW	MF1-1-4	22-Aug-19	20	200	220	9.5	Y	N
OW	MF1-5-4	21-Aug-19	20	180	210	15	Y	N
OW	MF3-1-5	03-Sep-19	20	210	220	4.7	Y	N
OW	MF3-3-4	28-Aug-19	20	190	200	5.1	Y	N
OW	MF3-4-4	27-Aug-19	20	170	190	11	Y	N
OW	MF3-4-5	27-Aug-19	20	180	210	15	Y	N
OW	MF3-6-4	27-Aug-19	20	160	190	17	Y	N

Notes: Only cases where the total dissolved nitrogen was greater than the total nitrogen are presented in this table. “Y” in “QC Fail?” column indicates a QC flag for relative percent difference (RPD) values that were greater than 20%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

µg-N/L = micrograms nitrogen per litre; DL = detection limit; QC = quality control; IC = ice-cover; OW = open-water; NF = near-field; MF = mid-field; FF = far-field; N = no; Y = yes; LDG = Lac de Gras; LDS = Lac du Sauvage.

Table B-8 Comparison of Total and Dissolved Kjeldahl Nitrogen Concentrations, 2019

Season	Sample	Sampling Date	DL (µg-N/L)	Total Kjeldahl Nitrogen (µg-N/L)	Dissolved Kjeldahl Nitrogen (µg-N/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
IC	NF1T-4	22-Apr-19	20	216	236	8.8	Y	N
IC	FF1-1M-4	04-May-19	20	179	190	6.0	Y	N
IC	FF1-2M-5	04-May-19	20	172	173	0.6	Y	N
IC	FFB-4M-5	05-May-19	20	160	163	1.9	Y	N
IC	FFA-5M-4-5	08-May-19	20	140	250	56.4	Y	Y
IC	FFA-5M-5-4	08-May-19	20	150	260	53.7	Y	Y
IC	FFA-5M-5-5	08-May-19	20	160	260	47.6	Y	Y
IC	FFA-2M-4	08-May-19	20	150	270	57.1	Y	Y
IC	FFA-2M-5	08-May-19	20	130	280	73.2	Y	Y
IC	FFA-3M-4	08-May-19	20	180	260	36.4	Y	N
IC	FFA-3M-5	08-May-19	20	160	280	54.5	Y	Y
IC	FFA-1M-4	08-May-19	20	170	300	55.3	Y	Y
IC	FFA-1M-5	08-May-19	20	180	320	56.0	Y	Y
IC	NF2T-4	10-May-19	20	230	280	19.6	Y	N
IC	NF2T-5	10-May-19	20	250	270	7.7	Y	N
IC	NF2M-4	10-May-19	20	250	440	55.1	Y	Y
IC	NF2M-5	10-May-19	20	250	280	11.3	Y	N
IC	NF2B-4	10-May-19	20	210	270	25.0	Y	N
IC	NF2B-5	10-May-19	20	220	290	27.5	Y	N
IC	MF3-1T-4	10-May-19	20	100	210	71.0	Y	Y
IC	FF2-5T-4	10-May-19	20	100	160	46.2	Y	Y
IC	LDS-3M-4	10-May-19	20	140	230	48.6	Y	Y
IC	MF1-1B-4	10-May-19	20	170	220	25.6	Y	N
IC	FF2-2T-5	10-May-19	20	150	260	53.7	Y	Y
IC	FF2-2M-5	10-May-19	20	150	250	50.0	Y	Y
IC	LDG-48M-4	08-May-19	20	80	250	103.0	Y	Y
IC	LDG-48M-5	08-May-19	20	140	280	66.7	Y	Y
IC	FFA-4M-5	08-May-19	20	100	120	18.2	Y	N
IC	MF3-3T-5	09-May-19	20	180	200	10.5	Y	N
IC	MF3-3B-4	09-May-19	20	99	140	34.3	Y	N
IC	MF3-5T-5-5	09-May-19	20	230	270	16.0	Y	N
IC	MF3-5M-4	09-May-19	20	200	290	36.7	Y	N
IC	MF3-5M-5	09-May-19	100	160	180	11.8	Y	N
IC	MF3-5B-4	09-May-19	20	150	160	6.5	Y	N
IC	MF3-5B-5	09-May-19	20	150	170	12.5	Y	N
OW	MF1-5-4	21-Aug-19	20	180	210	15.4	Y	N
OW	MF1-1-4	22-Aug-19	20	190	210	10.0	Y	N
OW	FF2-2-4	20-Aug-19	20	210	230	9.1	Y	N
OW	FFB-4-4	25-Aug-19	20	170	180	5.7	Y	N
OW	FFB-4-5	25-Aug-19	20	160	190	17.1	Y	N
OW	FFB-5-4	25-Aug-19	20	170	180	5.7	Y	N

Table B-8 Comparison of Total and Dissolved Kjeldahl Nitrogen Concentrations, 2019 (continued)

Season	Sample	Sampling Date	DL (µg-N/L)	Total Kjeldahl Nitrogen (µg-N/L)	Dissolved Kjeldahl Nitrogen (µg-N/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
OW	MF1-3-5	22-Aug-19	20	210	220	4.7	Y	N
OW	FFA-5-4	04-Sep-19	20	170	180	5.7	Y	N
OW	MF3-4-4	27-Aug-19	20	160	190	17.1	Y	N
OW	MF3-4-5	27-Aug-19	20	180	210	15.4	Y	N
OW	FFA-1-5	04-Sep-19	20	180	200	10.5	Y	N
OW	FFA-4-5	04-Sep-19	20	200	210	4.9	Y	N
OW	MF3-6-4	27-Aug-19	20	160	180	11.8	Y	N
OW	LDS-1-4	02-Sep-19	20	210	230	9.1	Y	N
OW	MF3-1-5	03-Sep-19	20	190	210	10.0	Y	N

Notes: Only cases where the total dissolved Kjeldahl nitrogen was greater than the total Kjeldahl nitrogen are presented in this table. "Y" in "QC Fail?" column indicates a QC flag for relative percent difference (RPD) values that were greater than 20%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

µg-N/L = micrograms nitrogen per litre; DL = detection limit; QC = quality control; IC = ice-cover; OW = open-water; NF = near-field; MF = mid-field; FF = far-field; N = no; Y = yes; LDG = Lac de Gras; LDS = Lac du Sauvage.

Chlorophyll a Duplicate Samples

Three of the 38 pairs of chlorophyll *a* duplicate samples exceeded the DQO of less than 40% RPD, while having concentrations greater than five times the DL in at least one of the samples (Table B-9). Overall, 8% of the duplicate pairs were notably different from one another; therefore, the analytical precision for the chlorophyll *a* samples was rated as high.

Table B-9 Summary of Duplicate Sample Results for Chlorophyll *a*, 2019

Season	Station	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
OW	NF2	0.04	0.77	0.8	3.8	Y	N
OW	NF3	0.04	0.9	0.9	2.2	Y	N
OW	NF4	0.04	0.7	0.8	9.5	Y	N
OW	NF5	0.04	0.46	0.4	6.7	Y	N
OW	MF1-1	0.04	0.66	0.7	1.5	Y	N
OW	MF1-3	0.04	0.66	0.7	4.4	Y	N
OW	MF1-5	0.04	0.21	0.2	27	Y	N
OW	MF2-1	0.04	0.74	0.7	2.7	Y	N
OW	MF2-3	0.04	0.55	0.6	15	Y	N
OW	FF2-2	0.04	0.72	0.6	20	Y	N
OW	FF2-5	0.04	0.81	0.7	17	Y	N
OW	MF3-1	0.04	0.68	0.8	19	Y	N
OW	MF3-2	0.04	0.38	0.3	17	Y	N
OW	MF3-3	0.04	0.45	0.4	25	Y	N

Table B-9 Summary of Duplicate Sample Results for Chlorophyll *a*, 2019 (continued)

Season	Station	DL (µg/L)	Result 1 (µg/L)	Result 2 (µg/L)	Relative Percent Difference (%)	>5 × DL?	QC Fail?
OW	MF3-4	0.04	0.39	0.4	5.3	Y	N
OW	MF3-5	0.04	0.15	0.2	13	N	N
OW	MF3-6	0.04	0.17	0.2	0.0	N	N
OW	MF3-7	0.04	0.14	0.1	7.4	N	N
OW	FF1-1	0.04	0.17	0.2	5.7	N	N
OW	FF1-2	0.04	0.13	0.1	0.0	N	N
OW	FF1-3	0.04	0.14	0.2	30	N	N
OW	FF1-4	0.04	0.20	0.1	67	N	N
OW	FF1-5	0.04	0.18	0.1	32	N	N
OW	FFA-1	0.04	0.16	0.2	40	Y	N
OW	FFA-2	0.04	0.19	0.3	39	Y	N
OW	FFA-3	0.04	0.29	0.2	47	Y	Y
OW	FFA-4	0.04	0.29	0.3	6.7	Y	N
OW	FFA-5	0.04	0.2	0.3	33	Y	N
OW	FFB-1	0.04	0.08	0.1	55	N	N
OW	FFB-2	0.04	0.2	0.2	5.1	N	N
OW	FFB-3	0.04	0.14	0.1	24	N	N
OW	FFB-4	0.04	0.2	0.2	16	N	N
OW	FFB-5	0.04	0.17	0.2	0.0	N	N
OW	LDG-48	0.04	<0.04	0.1	120	N	N
OW	LDS-1	0.04	1.1	0.7	40	Y	**Y**
OW	LDS-2	0.04	0.83	1.1	25	Y	N
OW	LDS-3	0.04	0.91	0.8	13	Y	N
OW	LDS-4	0.04	0.62	1.1	52	Y	**Y**

Note: "Y" in "QC Fail?" column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%, where concentrations in one or both of the duplicate samples were greater than or equal to five times the corresponding DL.

µg/L = micrograms per litre; DL = detection limit; > = greater than; × = times; QC = quality control; OW = open-water; NF = near-field; MF = mid-field; FF = far-field; LDG-48 = Lac de Gras outlet; LDS = Lac du Sauvage; LDS-4 = Lac du Sauvage outlet; N = no; Y = yes.

Zooplankton Biomass (as AFDM) Duplicate Samples

None of the zooplankton biomass duplicate samples exceeded the DQO of less than 40% RPD (Table B-10). The greater than five times the DL criterion did not apply to zooplankton biomass because the DL is undefined. Since less than 10% of the duplicate pairs were notably different from one another, the analytical precision for the zooplankton biomass samples was rated as high.

Table B-10 **Summary of Duplicate Sample Results for Zooplankton Biomass as Ash Free Dry Mass, 2019**

Season	Station	Result 1 (mg/m^3)	Result 2 (mg/m^3)	Relative Percent Difference (%)	QC Fail?
OW	NF1	71.7	66.6	7.3	N
OW	NF2	77.0	70.1	9.3	N
OW	NF3	93.6	115.3	21	N
OW	NF4	60.7	60.6	0.2	N
OW	NF5	120.8	99.7	19	N
OW	MF1-1	70.7	77.5	9.2	N
OW	MF1-3	130.4	128.8	1.3	N
OW	MF1-5	41.1	27.9	38	N
OW	MF2-1	72.8	73.6	1.1	N
OW	MF2-3	111.5	115.3	3.4	N
OW	FF2-2	70.3	74.9	6.3	N
OW	FF2-5	39.1	42.1	7.4	N
OW	MF3-1	63.2	65.3	3.2	N
OW	MF3-2	125.0	122.5	2.0	N
OW	MF3-3	69.0	61.2	12	N
OW	MF3-4	32.8	33.8	3.1	N
OW	MF3-5	37.3	39.6	5.8	N
OW	MF3-6	24.9	23.1	7.4	N
OW	MF3-7	34.1	35.3	3.5	N
OW	FF1-1	58.6	52.9	10	N
OW	FF1-2	42.1	46.2	9.2	N
OW	FF1-3	48.4	51.5	6.3	N
OW	FF1-4	27.4	36.8	29	N
OW	FF1-5	44.0	44.9	2.1	N
OW	FFA-1	30.3	27.6	9.4	N
OW	FFA-2	18.1	27.1	40	N
OW	FFA-3	23.8	22.2	6.7	N
OW	FFA-4	21.7	24.4	12	N
OW	FFA-5	22.5	26.7	17	N
OW	FFB-1	28.3	31.8	12	N
OW	FFB-2	27.7	30.8	10	N
OW	FFB-3	26.7	29.8	11	N
OW	FFB-4	31.7	31.5	0.5	N
OW	FFB-5	23.1	21.1	8.9	N
OW	LDS-1	40.6	38.5	5.3	N
OW	LDS-2	45.4	44.9	1.2	N
OW	LDS-3	54.0	61.5	13	N

Note: “Y” in “QC Fail?” column indicates a QC flag for relative percent difference (RPD) values that were greater than 40%.

mg/m^3 = milligrams per cubic metre; DL = detection limit; QC = quality control; OW = open-water; NF = near-field; MF = mid-field; FF = far-field; LDS = Lac du Sauvage; N = no; Y = yes; - = not applicable.

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ATTACHMENT C

PERCENT CHANGE FROM BASELINE AND PREVIOUS YEAR

Tables C-1 to C-16 provide percent change values for each eutrophication indicator from the baseline median and the previous year (i.e., 2018) median value, by area (NF, MF1, MF2-FF2, MF3, and LDG-48) and season (ice-cover and open-water) as required by Directive 2B from the WLWB review of the *2017 AEMP Annual Report*.

The results indicate that median values of eutrophication indicators have generally increased in the NF area relative to baseline, consistent with EA predictions and interpretation of AEMP data during annual reporting. Further discussion of these results is provided below.

In the NF area, the eutrophication indicator that has increased the most since baseline is nitrate during both the ice-cover and open-water seasons. During the ice-cover season, the greatest increase in nitrate relative to baseline was measured in the NF area in middle and bottom depth samples, reflecting the discharge of effluent to this area and the likely position of the effluent plume in the water column. Large percent changes from baseline in nitrate and other nitrogen species were observed across all three MF areas with decreasing concentrations with distance from diffuser, which is consistent with the results discussed in Sections 3.3 and 3.6.2.

During the open-water season, the increase in nitrate concentration relative to baseline was observed in the NF area, but less so in the MF areas, which is consistent with the results discussed in Sections 3.3 and 3.6.2. The percent change in total ammonia from baseline was greater in the MF areas, particularly MF1 and MF2-FF2 areas, compared to the NF area, which is consistent with the results in Section 3.3.

Percent change from the previous year (2018) in nitrogen variables was more variable, consisting of positive and negative values at varying magnitudes, and reflects the general finding of year-to-year variability. Nitrate had the greatest percent increase during the open-water season in the NF area.

The concentration of total and dissolved phosphorus either decreased or did not change in 2019 in nearly all sampling areas in Lac de Gras, both relative to baseline and the previous year, during both seasons. In contrast, soluble reactive phosphorus concentration increased relative to baseline and the previous year in the NF, MF1, FFB areas during the ice-cover season, and in all sampling areas during the open-water season.

Concentrations of chlorophyll *a* decreased in 2019 across Lac de Gras including at the outlet (i.e., LDG-48). Concentrations increased from baseline in the NF, MF1, and MF2-FF2 areas, but decreased in all other areas including LDG-48, which is consistent with the results in Section 3.3 and 3.6.3. The results for phytoplankton biomass were inconsistent among sampling areas, with apparent decreases or no changes relative to baseline and the previous year in all sampling areas with the exception of MF1, where biomass increased relative to baseline and the previous year. Zooplankton biomass increased from baseline in all areas except FFA and FFB and the changes from baseline were consistent with extent of effects as reported in Section 4.3. Zooplankton biomass in 2019 generally increased from the previous year.

Table C-1 Percent Change from Baseline and Previous Year Data in the NF Area for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median(a)	Previous Year Median(c)			Current Year Median			% Change from Baseline			% Change from Previous Year		
			Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom	Top	Mid	Bottom
Nutrients														
Total phosphorus	µg-P/L	3.6	3.9	4.4	4.2	2.9	2.5	1.6	-21%	-31%	-56%	-26%	-43%	-61%
Total dissolved phosphorus	µg-P/L	2.0	1.0	1.6	2.8	1.0	1.0	1.0	-50%	-50%	-50%	0%	-35%	-64%
Soluble reactive phosphorus (b)	µg-P/L	0.5	0.5	0.5	0.5	1.3	1.7	1.3	150%	230%	150%	150%	230%	150%
Total nitrogen	µg-N/L	152	252	364	338	252	372	332	66%	145%	119%	0%	2%	-2%
Total dissolved nitrogen	µg-N/L	143	200	323	296	210	305	280	47%	113%	95%	5%	-6%	-6%
Total Kjeldahl nitrogen	µg-N/L	-	212	180	197	238	227	186	-	-	-	12%	26%	-6%
Dissolved Kjeldahl nitrogen	µg-N/L	-	161	141	142	196	160	149	-	-	-	21%	13%	5%
Total ammonia	µg-N/L	14	35	42	33	22	40	31	60%	182%	118%	-35%	-5%	-6%
Nitrate	µg-N/L	3.4	26	159	146	14	145	137	321%	4165%	3929%	-45%	-9%	-6%
Nitrite (b)	µg-N/L	1.0	2.1	2.7	2.4	0.8	0.5	0.5	-20%	-50%	-50%	-62%	-81%	-79%
Nitrate + nitrite	µg-N/L	6.5	41	184	150	14	145	137	120%	2,131%	2,008%	-65%	-21%	-8%
Soluble reactive silica	µg/L	-	-	-	-	50	736	650	-	-	-	-	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.
(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

% Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median; - = no data or not applicable.

Table C-2 Percent Change from Baseline and Previous Year Data in the MF1 Area for Eutrophication Indicators During Ice-cover Season in 2019

Variable	Unit	Baseline Median[a]	Previous Year Median[c]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	3.7	1.0	-72%	-73%
Total dissolved phosphorus	µg-P/L	2.0	1.6	1.0	-50%	-35%
Soluble reactive phosphorus [b]	µg-P/L	0.5	0.5	0.9	80%	80%
Total nitrogen	µg-N/L	152	257	234	54%	-9%
Total dissolved nitrogen	µg-N/L	143	220	196	37%	-11%
Total Kjeldahl nitrogen	µg-N/L	-	179	187	-	4%
Dissolved Kjeldahl nitrogen	µg-N/L	-	173	165	-	-4%
Total ammonia	µg-N/L	14	18	19	38%	5%
Nitrate	µg-N/L	3.4	47	23	562%	-52%
Nitrite [b]	µg-N/L	1.0	0.5	0.9	-10%	80%
Nitrate + nitrite	µg-N/L	6.5	55	28	323%	-50%
Soluble reactive silica	µg/L	-	-	111	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-3 Percent Change from Baseline and Previous Year Data in the MF2-FF2 Area for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	3.6	1.0	-72%	-72%
Total dissolved phosphorus	µg-P/L	2.0	2.1	1.0	-50%	-53%
Soluble reactive phosphorus (b)	µg-P/L	0.5	0.5	0.5	0%	0%
Total nitrogen	µg-N/L	152	253	227	50%	-10%
Total dissolved nitrogen	µg-N/L	143	199	191	33%	-4%
Total Kjeldahl nitrogen	µg-N/L	-	189	183	-	-3%
Dissolved Kjeldahl nitrogen	µg-N/L	-	150	141	-	-6%
Total ammonia	µg-N/L	14	31	17	24%	-43%
Nitrate	µg-N/L	3.4	28	43	1,165%	55%
Nitrite (b)	µg-N/L	1.0	1.6	1.4	35%	-13%
Nitrate + nitrite	µg-N/L	6.5	38	47	627%	25%
Soluble reactive silica	µg/L	-	-	70	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-4 Percent Change from Baseline and Previous Year Data in the MF3 Area for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	3.2	1.0	-72%	-69%
Total dissolved phosphorus	µg-P/L	2.0	1.9	1.0	-50%	-46%
Soluble reactive phosphorus [(b)]	µg-P/L	0.5	0.5	0.5	0%	0%
Total nitrogen	µg-N/L	152	212	205	35%	-3%
Total dissolved nitrogen	µg-N/L	143	175	170	19%	-3%
Total Kjeldahl nitrogen	µg-N/L	-	175	180	-	3%
Dissolved Kjeldahl nitrogen	µg-N/L	-	149	142	-	-4%
Total ammonia	µg-N/L	14	49	18	31%	-62%
Nitrate	µg-N/L	3.4	17	25	629%	47%
Nitrite [(b)]	µg-N/L	1.0	0.5	0.8	-20%	60%
Nitrate + nitrite	µg-N/L	6.5	21	27	315%	27%
Soluble reactive silica	µg/L	-	-	66	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

\- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-5 Percent Change from Baseline and Previous Year Data in the FF1 Area for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	1.9	1.0	-72%	-47%
Total dissolved phosphorus	µg-P/L	2.0	1.0	1.0	-50%	0%
Soluble reactive phosphorus (b)	µg-P/L	0.5	0.5	0.5	0%	0%
Total nitrogen	µg-N/L	152	191	205	35%	8%
Total dissolved nitrogen	µg-N/L	143	233	189	32%	-19%
Total Kjeldahl nitrogen	µg-N/L	-	171	189	-	10%
Dissolved Kjeldahl nitrogen	µg-N/L	-	217	177	-	-18%
Total ammonia	µg-N/L	14	-	17	24%	-
Nitrate	µg-N/L	3.4	16	12	259%	-22%
Nitrite (b)	µg-N/L	1.0	1.0	0.5	-50%	-50%
Nitrate + nitrite	µg-N/L	6.5	16	12	88%	-22%
Soluble reactive silica	µg/L	-	-	80	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-6 Percent Change from Baseline and Previous Year Data in the FFA Area for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	1.75	1.0	-72%	-43%
Total dissolved phosphorus	µg-P/L	2.0	1.0	1.0	-50%	0%
Soluble reactive phosphorus [(b)]	µg-P/L	0.5	0.5	0.5	0%	0%
Total nitrogen	µg-N/L	152	162	180	19%	11%
Total dissolved nitrogen	µg-N/L	143	174	295	106%	70%
Total Kjeldahl nitrogen	µg-N/L	-	158	170	-	8%
Dissolved Kjeldahl nitrogen	µg-N/L	-	169	270	-	60%
Total ammonia	µg-N/L	14	-	15	10%	-
Nitrate	µg-N/L	3.4	5.1	20	478%	289%
Nitrite [(b)]	µg-N/L	1.0	1.0	0.5	-50%	-50%
Nitrate + nitrite	µg-N/L	6.5	5.1	20	212%	302%
Soluble reactive silica	µg/L	-	-	39	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

\- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-7 Percent Change from Baseline and Previous Year Data in the FFB Area for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	2.85	1.0	-72%	-65%
Total dissolved phosphorus	µg-P/L	2.0	1.7	1.0	-50%	-39%
Soluble reactive phosphorus [(b)]	µg-P/L	0.5	0.5	0.8	50%	50%
Total nitrogen	µg-N/L	152	154	181	19%	17%
Total dissolved nitrogen	µg-N/L	143	150	166	16%	11%
Total Kjeldahl nitrogen	µg-N/L	-	154	181	-	17%
Dissolved Kjeldahl nitrogen	µg-N/L	-	145	165	-	14%
Total ammonia	µg-N/L	14	-	20	41%	-
Nitrate	µg-N/L	3.4	5.0	1.0	-71%	-80%
Nitrite [(b)]	µg-N/L	1.0	1.0	0.5	-50%	-50%
Nitrate + nitrite	µg-N/L	6.5	5.0	1.0	-85%	-80%
Soluble reactive silica	µg/L	-	-	39	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-8 Percent Change from Baseline and Previous Year Data at LDG-48 for Eutrophication Indicators During the Ice-cover Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Nutrients						
Total phosphorus	µg-P/L	3.6	3.1	1.0	-72%	-68%
Total dissolved phosphorus	µg-P/L	2.0	2.8	1.0	-50%	-64%
Soluble reactive phosphorus (b)	µg-P/L	0.5	0.5	0.5	0%	0%
Total nitrogen	µg-N/L	152	259	117	-23%	-55%
Total dissolved nitrogen	µg-N/L	143	160	270	89%	69%
Total Kjeldahl nitrogen	µg-N/L	-	251	110	-	-56%
Dissolved Kjeldahl nitrogen	µg-N/L	-	152	265	-	75%
Total ammonia	µg-N/L	14	17	14	1%	-16%
Nitrate	µg-N/L	3.4	3.0	2.6	-25%	-15%
Nitrite (b)	µg-N/L	1.0	0.5	0.5	-50%	0%
Nitrate + nitrite	µg-N/L	6.5	8.5	2.1	-68%	-75%
Soluble reactive silica	µg/L	-	-	40	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-9 Percent Change from Baseline and Previous Year Data in the NF Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	1.09	0.74	56%	-32%
Phytoplankton biomass as biovolume	mg/m^3	163	375	124	-24%	-67%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	42	74	193%	76%
Nutrients						
Total phosphorus	µg-P/L	3.3	4.4	1.0	-70%	-77%
Total dissolved phosphorus	µg-P/L	1.0	3.6	1.0	0%	-72%
Soluble reactive phosphorus	µg-P/L	1.0	0.5	2.0	100%	300%
Total nitrogen	µg-N/L	138	229	285	106%	24%
Total dissolved nitrogen	µg-N/L	119	184	240	102%	30%
Total Kjeldahl nitrogen	µg-N/L	-	197	255	-	29%
Dissolved Kjeldahl nitrogen	µg-N/L	-	161	205	-	27%
Total ammonia[(b)]	µg-N/L	1.0	2.5	15	1,350%	480%
Nitrate[(b)]	µg-N/L	1.0	11	34	3,300%	204%
Nitrite[(b)]	µg-N/L	1.0	0.5	1.5	45%	190%
Nitrate + nitrite[(b)]	µg-N/L	0.5	11	35	6,900%	213%
Soluble reactive silica	µg/L	-	-	60	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-10 Percent Change from Baseline and Previous Year Data in the MF1 Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[a]	Previous Year Median[c]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	1.20	0.67	41%	-45%
Phytoplankton biomass as biovolume	mg/m^3	163	172	249	52%	45%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	53	74	195%	39%
Nutrients						
Total phosphorus	µg-P/L	3.3	3.3	1.6	-52%	-52%
Total dissolved phosphorus	µg-P/L	1.0	2.5	1.0	0%	-60%
Soluble reactive phosphorus	µg-P/L	1.0	1.8	2.1	110%	20%
Total nitrogen	µg-N/L	138	158	220	59%	40%
Total dissolved nitrogen	µg-N/L	119	164	210	76%	28%
Total Kjeldahl nitrogen	µg-N/L	-	156	210	-	35%
Dissolved Kjeldahl nitrogen	µg-N/L	-	164	200	-	22%
Total ammonia[b]	µg-N/L	1.0	2.5	8.9	785%	254%
Nitrate[b]	µg-N/L	1.0	1.0	5.9	485%	485%
Nitrite[b]	µg-N/L	1.0	0.5	0.5	-50%	0%
Nitrate + nitrite[b]	µg-N/L	0.5	1.0	5.9	1,070%	485%
Soluble reactive silica	µg/L	-	-	37	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-11 Percent Change from Baseline and Previous Year Data in the MF2-FF2 Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	1.17	0.69	47%	-41%
Phytoplankton biomass as biovolume	mg/m^3	163	460	140	-14%	-70%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	46	73	190%	59%
Nutrients						
Total phosphorus	µg-P/L	3.3	3.1	1.6	-51%	-47%
Total dissolved phosphorus	µg-P/L	1.0	1.0	1.0	0%	0%
Soluble reactive phosphorus	µg-P/L	1.0	0.5	2.2	120%	340%
Total nitrogen	µg-N/L	138	175	223	61%	27%
Total dissolved nitrogen	µg-N/L	119	153	200	68%	31%
Total Kjeldahl nitrogen	µg-N/L	-	172	213	-	24%
Dissolved Kjeldahl nitrogen	µg-N/L	-	151	193	-	27%
Total ammonia(b)	µg-N/L	1.0	10	14	1,275%	43%
Nitrate(b)	µg-N/L	1.0	3.4	6.9	590%	106%
Nitrite(b)	µg-N/L	1.0	0.5	0.7	-35%	30%
Nitrate + nitrite(b)	µg-N/L	0.5	3.4	7.5	1,400%	124%
Soluble reactive silica	µg/L	-	-	28	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline Median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-12 Percent Change from Baseline and Previous Year Data in the MF3 Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	0.55	0.35	-26%	-36%
Phytoplankton biomass as biovolume	mg/m^3	163	326	118	-28%	-64%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	34	38	53%	12%
Nutrients						
Total phosphorus	µg-P/L	3.3	2.5	1.7	-50%	-33%
Total dissolved phosphorus	µg-P/L	1.0	1.0	1.0	0%	0%
Soluble reactive phosphorus	µg-P/L	1.0	0.5	1.3	30%	160%
Total nitrogen	µg-N/L	138	179	190	37%	6%
Total dissolved nitrogen	µg-N/L	119	129	185	55%	43%
Total Kjeldahl nitrogen	µg-N/L	-	179	190	-	6%
Dissolved Kjeldahl nitrogen	µg-N/L	-	129	180	-	40%
Total ammonia[(b)]	µg-N/L	1.0	4.8	8.3	730%	75%
Nitrate[(b)]	µg-N/L	1.0	1.0	2.9	190%	190%
Nitrite[(b)]	µg-N/L	1.0	0.5	0.5	-50%	0%
Nitrate + nitrite[(b)]	µg-N/L	0.5	1.0	3.0	490%	195%
Soluble reactive silica	µg/L	-	-	41	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

\- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-13 Percent Change from Baseline and Previous Year Data in the FF1 Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	0.78	0.16	-67%	-80%
Phytoplankton biomass as biovolume	mg/m^3	163	228	174	7%	-24%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	32	44	77%	37%
Nutrients						
Total phosphorus	µg-P/L	3.3	3.5	1.6	-53%	-55%
Total dissolved phosphorus	µg-P/L	1.0	2.2	1.0	0%	-55%
Soluble reactive phosphorus	µg-P/L	1.0	0.5	2.1	105%	310%
Total nitrogen	µg-N/L	138	194	195	41%	1%
Total dissolved nitrogen	µg-N/L	119	162	160	34%	-1%
Total Kjeldahl nitrogen	µg-N/L	-	193	195	-	1%
Dissolved Kjeldahl nitrogen	µg-N/L	-	162	160	-	-1%
Total ammonia[(b)]	µg-N/L	1.0	42	7.8	675%	-82%
Nitrate[(b)]	µg-N/L	1.0	1.0	1.0	0%	0%
Nitrite[(b)]	µg-N/L	1.0	1.0	0.5	-50%	-50%
Nitrate + nitrite[(b)]	µg-N/L	0.5	1.0	1.1	120%	10%
Soluble reactive silica	µg/L	-	-	52	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-14 Percent Change from Baseline and Previous Year Data in the FFA Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	0.62	0.24	-50%	-62%
Phytoplankton biomass as biovolume	mg/m^3	163	164	158	-4%	-4%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	28	23	-8%	-18%
Nutrients						
Total phosphorus	µg-P/L	3.3	2.8	1.0	-70%	-64%
Total dissolved phosphorus	µg-P/L	1.0	1.8	1.0	0%	-43%
Soluble reactive phosphorus	µg-P/L	1.0	0.5	1.2	15%	130%
Total nitrogen	µg-N/L	138	226	185	34%	-18%
Total dissolved nitrogen	µg-N/L	119	144	185	55%	29%
Total Kjeldahl nitrogen	µg-N/L	-	226	185	-	-18%
Dissolved Kjeldahl nitrogen	µg-N/L	-	144	185	-	29%
Total ammonia(b)	µg-N/L	1.0	25	2.5	150%	-90%
Nitrate(b)	µg-N/L	1.0	1.0	1.0	0%	0%
Nitrite(b)	µg-N/L	1.0	1.0	0.5	-50%	-50%
Nitrate + nitrite(b)	µg-N/L	0.5	1.0	1.1	120%	10%
Soluble reactive silica	µg/L	-	-	32	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*(b) Baseline median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-15 Percent Change from Baseline and Previous Year Data in the FFB Area for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median[(c)]	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	0.71	0.17	-64%	-76%
Phytoplankton biomass as biovolume	mg/m^3	163	197	174	6%	-12%
Zooplankton biomass as ash-free dry mass	mg/m^3	25	24	29	16%	22%
Nutrients						
Total phosphorus	µg-P/L	3.3	1.0	1.0	-70%	0%
Total dissolved phosphorus	µg-P/L	1.0	1.0	1.0	0%	0%
Soluble reactive phosphorus	µg-P/L	1.0	1.5	1.0	-5%	-37%
Total nitrogen	µg-N/L	138	184	175	27%	-5%
Total dissolved nitrogen	µg-N/L	119	145	145	22%	0%
Total Kjeldahl nitrogen	µg-N/L	-	182	175	-	-4%
Dissolved Kjeldahl nitrogen	µg-N/L	-	145	145	-	0%
Total ammonia(b)	µg-N/L	1.0	60	4.3	325%	-93%
Nitrate(b)	µg-N/L	1.0	1.0	1.0	0%	0%
Nitrite(b)	µg-N/L	1.0	1.0	0.5	-50%	-50%
Nitrate + nitrite(b)	µg-N/L	0.5	1.0	1.1	120%	10%
Soluble reactive silica	µg/L	-	-	33	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*

(b) Baseline median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

- = not applicable; % Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median.

Table C-16 Percent Change from Baseline and Previous Year Data at LDG-48 for Eutrophication Indicators During the Open-water Season in 2019

Variable	Unit	Baseline Median[(a)]	Previous Year Median	Current Year Median	% Change from Baseline	% Change from Previous Year
Biomass Indicators						
Chlorophyll *a*	µg/L	0.47	0.27	0.06	-87%	-78%
Phytoplankton biomass as biovolume	mg/m^3	163	-	-	-	-
Zooplankton biomass as ash-free dry mass	mg/m^3	25	-	-	-	-
Nutrients						
Total phosphorus	µg-P/L	3.3	1.0	1.0	-70%	0%
Total dissolved phosphorus	µg-P/L	1.0	2.6	1.0	0%	-62%
Soluble reactive phosphorus	µg-P/L	1.0	0.5	1.5	50%	200%
Total nitrogen	µg-N/L	138	221	190	37%	-14%
Total dissolved nitrogen	µg-N/L	119	116	180	51%	55%
Total Kjeldahl nitrogen	µg-N/L	-	219	190	-	-13%
Dissolved Kjeldahl nitrogen	µg-N/L	-	114	180	-	58%
Total ammonia[(b)]	µg-N/L	1.0	2.5	2.5	150%	0%
Nitrate[(b)]	µg-N/L	1.0	2.2	1.0	0%	-55%
Nitrite[(b)]	µg-N/L	1.0	0.5	0.5	-50%	0%
Nitrate + nitrite[(b)]	µg-N/L	0.5	2.2	1.1	120%	-50%
Soluble reactive silica	µg/L	-	-	174	-	-

(a) Source: Golder (2019a). *AEMP Reference Conditions Report Version 1.4*.

(b) Baseline median was listed as less than the detection limit in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019b), so the value was substituted with one half the detection limit for the purposes of calculating percent change. Value presented is the substituted value.

(c) Previous year median values are from 2018.

Notes: Values below detection limit were substituted with one half the detection limit prior to median calculations. . Percentages presented in this table were calculated before rounding of data for consistent presentation; therefore, recalculation may not yield the exact percentages shown.

% Change from Baseline = (Current Year Median - Baseline Median) / Baseline Median; % Change from Previous Year = (Current Year Median - Previous Year Median) / Previous Year Median; - = no data or not applicable.

ATTACHMENT D

ASSESSMENT OF TOTAL PHOSPHORUS DEPOSITION TO LAC DE GRAS

ASSESSMENT OF TOTAL PHOSPHORUS DEPOSITION TO LAC DE GRAS

Introduction

Lac de Gras is an oligotrophic lake characterized by very low concentrations of nutrients, which includes phosphorus. Phosphorus is delivered naturally to Lac de Gras directly via atmospheric deposition and indirectly via runoff from the Lac de Gras watershed. In the region of the Diavik Mine, the background rate of atmospheric deposition of phosphorus is typically small and rock weathering rates are slow. As a result, the aquatic ecosystem in Lac de Gras is expected to be phosphorus-limited, consistent with the findings of the AEMP. Land and aquatic retention and recycling rates of phosphorus in the region are largely unknown.

The *AEMP Design Plan Version 4.1* (Golder 2017) requires annual analyses of phosphorus loads from the Diavik Diamond Mine (Mine) and from other sources to Lac de Gras. The methods used to compute TP loads to Lac de Gras from relevant sources and the discussion of the results of the analysis are presented herein.

Methods

In addition to natural sources, Mine effluent and atmospheric deposition of phosphorus contained in Mine-related fugitive dust can contribute additional anthropogenic phosphorus to Lac de Gras. In this document, the relative magnitudes of phosphorus delivered to Lac de Gras in 2019 from the following sources are estimated:

- natural (i.e., background) atmospheric deposition of TP directly to Lac de Gras
- natural (i.e., background) atmospheric deposition of TP to the Lac de Gras watershed delivered indirectly through runoff to Lac de Gras
- anthropogenic TP delivered directly to Lac de Gras via the Mine effluent
- anthropogenic TP delivered directly to Lac de Gras via atmospheric deposition of fugitive dust
- anthropogenic TP delivered indirectly to Lac de Gras via atmospheric deposition of fugitive dust to the Lac de Gras watershed

Estimation of the above quantities used the same approach as described previously in the *2018 AEMP Annual Report* (Golder 2019d) and the *2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.1* (Golder 2019c). The data used and methods implemented herein are summarized as follows:

- The 2019 dustfall monitoring program included three monitoring components: dustfall gauges, dustfall from snow surveys, and snow water chemistry from snow surveys (ERM 2020). Dustfall snow surveys were performed at 27 stations (i.e., 24 monitoring stations and 3 reference stations referred to as “control stations”), along five transects around the Mine, on land and on the ice. In 2019, four new reference stations located farther from the Project footprint, referred as “control-assessment stations”, were added to assess the suitability of the control stations sampled previously.

- Snow water chemistry was analyzed in snow core samples collected from 16 on-ice monitoring stations, 3 control stations, and the 4 new control-assessment stations. The TP concentrations (in µg/L) in snow data from the snow water chemistry samples were used in the analysis.
- Ancillary data collected with the snow cores enabled the conversion of concentration in snow water (in µg/L) to an areal deposition rate (in milligrams per square decimetre per year; mg/dm^2/yr). The formula used to perform the conversion was as follows:

  $$D = (C * V * 365)/(N * A * T)$$

  where:

  D = TP deposition rate (mg/dm^2/yr)

  C = concentration of TP in snow water (mg/L)

  V = snow water volume (L)

  N = number of snow cores

  A = area of snow core tube (0.2922 dm^2)

  T = number of exposure days
- The land-based snow sample exposure days were calculated as the days between the first snowfall date (28 September 2018) and the snow sample collection date at the land station. The over-water or "on-ice" snow sample exposure days were calculated as the days between the ice freeze-up date (28 October 2018) and the snow sample collection date at that ice station.
- In the 2017 and 2018 annual reports, the natural background TP deposition rate was calculated as the geometric mean of TP concentrations measured in snow samples collected at the control stations. In 2019, the distances of the four control-assessment stations ranged from 7.6 and 27.9 km from the Mine footprint, which are farther from the Mine than the control stations. Thus, the control-assessment stations were expected to have minimal exposure to dust from the Mine activities and are potentially more representative of background conditions. The geometric mean of TP concentrations measured in samples collected at the control-assessment stations were used to calculate natural background TP deposition. The "background" TP deposition from the control stations was also computed similarly to previous years, to provide context in the TP loading analysis by allowing a comparison to results from previous years.
- The surface area of Lac de Gras (573 km^2) and the Lac de Gras watershed area (3,542 km^2) were multiplied by the background rates of TP deposition to estimate the magnitude of the TP load from natural atmospheric deposition to Lac de Gras and the watershed.
- Observed rates of anthropogenic TP deposition in 2019 were calculated using TP concentrations measured in snow samples in the dust monitoring program. The relationship between the wintertime TP deposition and the wintertime dust deposition was robust in 2019 (r^2 = 0.93).
- The observed TP deposition data at the on-ice snow stations and the calculated TP deposition data at the on-land snow sampling stations and dustfall gauges were then spatially interpolated using kriging and integrated to estimate anthropogenic TP loads from fugitive Mine dust.
- The annual TP load from Mine effluent in 2019 was 279 kg.

- For the spatial interpolation of anthropogenic TP loading:
    - Spatial interpolation of the dust deposition data was carried out for a 105.7 km x 80 km domain centred on the Mine. The grid resolution inside the domain was set to 20 by 20 m but excluded the area of the domain occupied by the Mine footprint.
    - There were 23 valid TP observations from snow survey transects in 2019 (N_{obs} = 23). TP deposition rates as a function of distance from the Mine centroid were evaluated for 2019. Spatial trends in TP deposition as a function of distance from the centroid were fit using a first-order decay function, whose goodness-of-fit was evaluated using the coefficient of determination (r^2) from the least-squares regression. An r^2 larger than 0.5 indicates a robust fit of the dust deposition as a function of distance from the centroid.
    - A TP deposition zone of influence (ZOI) was identified by examining the distance from which the TP deposition would be reduced to the level of natural background.
    - Prior to spatial interpolation in ARCGIS, dust deposition rates at the edges of TP deposition ZOI were set equal to the background rates of TP deposition observed in 2019.
    - Prior to spatial interpolation, the observed and calculated areal deposition rates were log-transformed to better capture the steep gradients observed in dust deposition as a function of distance from the Mine boundary. Mass loads (in tonnes/year [t/yr]) were calculated by integrating the spatially interpolated areal loads (mg/dm^2/yr) across the domain, and then back-transforming the results. This procedure is described by the following equation where the “sum of dust deposition data” represents the sum of the areal loads interpolated for each 20 by 20 m grid cell within the domain.

$$Mass\ Loading\ \left(\frac{t}{yr}\right) = sum\ of\ dust\ deposition\ data\ \left(\frac{mg}{dm^2 \cdot yr}\right) \times \frac{100\ dm^2}{m^2} \times 20\ m \times 20\ m\ \times\ \frac{t}{10^9\ mg}$$

- The “zonal statistics table” tool in ARCGIS was used to calculate 2019 mass loads for three separate regions. These three regions correspond to: (1) the Mine footprint (excluded from analysis); (2) Lac de Gras; and, (3) the Lac de Gras watershed excluding Lac de Gras. Total loads to the Lac de Gras watershed can be obtained by summing deposition to Lac de Gras and the Lac de Gras watershed.

The following assumptions were implicit to the analysis of TP loading to Lac de Gras and its watershed:

- Chemical weathering of local rocks is a potential source of TP to Lac de Gras; however, this weathering is typically slow and was not considered due to a lack of relevant data.
- TP deposition, as derived from TP concentrations measured in snow, is assumed to represent all TP deposition over the winter period.
- TP concentrations in snow water are a reasonable surrogate for TP concentrations in dustfall throughout the year. This also assumes weak dustfall seasonality and constant TP fraction in the dust. Analysis of seasonal trends of dust deposition from multiple years of dustfall monitoring at the Mine has indicated that dust deposition is lowest in the fall and similar in magnitude in the other three seasons (Golder 2019c).

- There are no seasonal differences in the source of TP in dust (i.e., TP concentrations in dust are similar between the open-water and ice-cover seasons).
- The control stations are unaffected by atmospheric deposition of fugitive Mine dust (i.e., they are assumed to be representative of the regional background rate of TP deposition). In 2019 this assumption was tested by including four new control-assessment stations at greater distances from the Mine than the previously sampled control stations.
- Atmospheric deposition of natural TP is spatially homogeneous throughout the Lac de Gras watershed (i.e., the mean/median background values are assumed to be valid and spatially representative).
- All atmospheric deposition of TP in the Lac de Gras watershed reports to Lac de Gras. This explicitly ignores uptake of TP on land, its storage, and eventual release. In other words, steady-state is assumed where the mass of TP deposited to the landscape is assumed to be in equilibrium with the mass of TP being delivered to the lake via runoff during a single calendar year.

Results

TP Deposition Rates

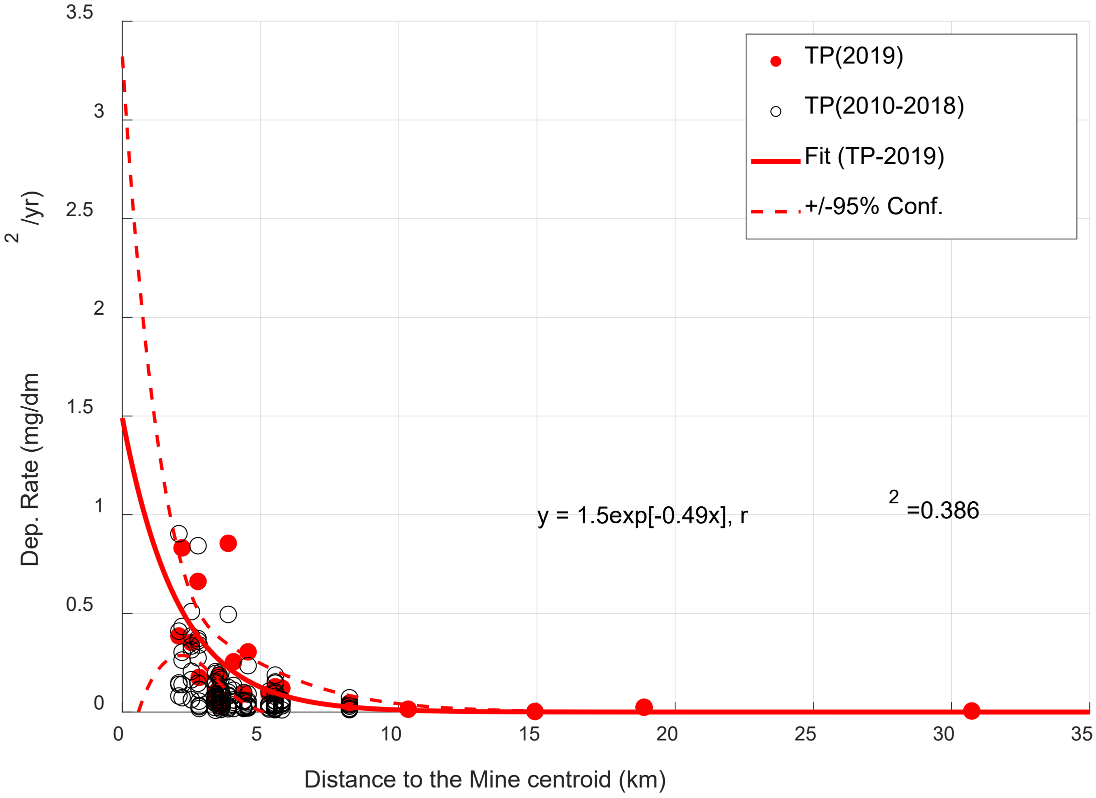
Figure D-1 shows TP deposition measured in 2019 as a function of distance from the Mine centroid. Also included in the figure are the data collected at the same locations from 2010 until 2018. Results of the fit to a first-order decay function for 2019 are plotted as a solid line on Figure D-1, with the 95% confidence interval limits plotted as dashed lines. The first order decay function did not result in a robust fit ($r^2 < 0.5$), which suggests there is spatial variability in dust deposition among the snow survey transects.

Table D-1 compares dust and TP deposition rates between the control stations and the new control-assessment stations in winter 2019. The geometric mean and 95% confidence interval for deposition at the control stations are included for all years (i.e., 2010 to 2019) along with geometric mean values of 2018 and 2019. The geometric mean deposition rate measured at the control-assessment stations is included in Table D-1 for 2019.

Using a 2-tailed Student's t-test, the dust deposition rates to snow at the control stations were significantly greater ($\alpha = 0.05$) than at the control-assessment stations. This was true for winter 2019 ($P<0.001$) and when the control station data were pooled for all years ($P = 0.041$). There were also significantly greater TP deposition rates at the control stations than at the control-assessment stations in winter 2019 ($P = 0.005$) compared to the control station data pooled for all years ($P = 0.015$).

Table D-1 shows that 2018 and 2019 have very low geometric mean dust deposition rates at the control stations (38 and 58 mg/dm^2/yr, respectively), compared to the mean and 95% CI for the pooled 2010 to 2019 data at these stations (147 and 96 to 224 mg/dm^2/yr, respectively). These results indicate that 2018 and 2019 were low dust deposition years at the control stations. Table D-1 also shows that 2018 and 2019 were high phosphorus deposition years at the control stations (0.068 and 0.089 mg/dm^2/yr, respectively), compared to the mean and 95% CI for the pooled 2010 to 2019 data (0.048 and 0.037 to 0.063 mg/dm^2/yr , respectively). These results indicate that in 2018 and 2019, the dust deposited to snow had high concentrations of phosphorus, because despite the lower dust deposition rates during these two years, TP deposition was greater than the estimated background rate based on the pooled 2010 to 2019 dataset.

Figure D-1 Total Phosphorus Deposition as a Function of Distance to the Diavik Mine Centroid



TP = total phosphorus; r^2 = coefficient of determination; mg/dm^2/yr = milligrams per square decimetre per year

Table D-1 Geometric Means and 95% Confidence Intervals for Dust and Total Phosphorus Deposition Rates in Snow from 2010 in 2019

Parameter	Dust Deposition (mg/dm^2/year)				TP Deposition (mg/dm^2/year)			
	2010 to 2019		2018	2019	2010 to 2019		2018	2019
Background from control stations	147	96 to 224[(a)]	38	58	0.048	0.037 to 0.063[(a)]	0.068	0.089
Background from control-assessment stations	-	-	-	23	-	-	-	0.0089

(a) 95% confidence interval of the geometric mean.

mg/dm^2/yr = milligrams per square decimetre per year; - = not available.

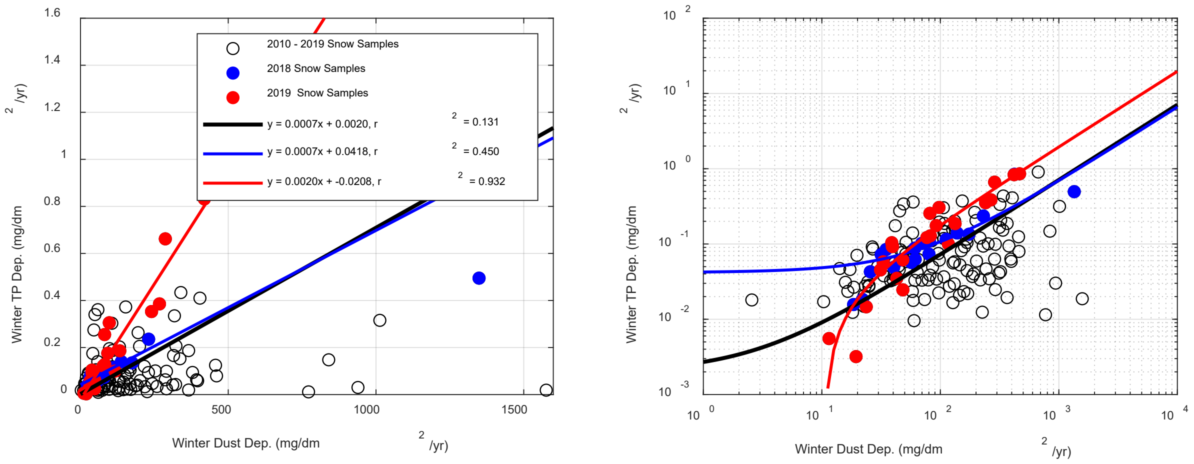
The determination of background versus Mine-related TP loading depends on spatial integration of TP deposition over a large area. Annual phosphorus deposition was estimated using the more numerous whole-year quarterly dust deposition data. This required employing Type-II linear regression of TP versus dust deposition from the snow sample data. The results of the 2019 regression are shown in Figure D-2.

In 2019, this relationship had a large slope (0.002 mg-P/mg dust) and a very robust fit (r^2 = 0.932). This confirms that dust generated by the Mine in 2019 had relatively large concentrations of phosphorus compared to background sources. The greater phosphorus concentration in 2019 might have been the result of higher phosphorus content in A21 Waste rock than the old A14/A418 Waste rock. In 2018, this relationship had a poor fit (r^2 = 0.450) due to two outliers, one a low-P dust sample and the other a high-P sample. The 2018 slope (0.0007) was comparable to the fit for all data from 2010 to 2019, but the fit for all years of data was very poor (r^2 = 0.131).

The low r^2 value for the pooled 2010 to 2019 wintertime TP and dust deposition rates implies other factors contribute to the observed variability in the phosphorus content of the dust. This may include variable TP content of dust being produced by the Mine (e.g., haul roads versus processed kimberlite), and seasonal and among-year variability at the locations where dust is being generated (e.g., due to site conditions, on-site activities, or meteorological conditions).

Additional analysis of the 2019 data will be included in the upcoming *2017 to 2019 Aquatic Effects Re-evaluation Report*. For the purposes of the 2019 AEMP report, the 2019 regression was used to compute atmospheric deposition of phosphorus to Lac de Gras watershed.

Figure D-2: Linear Regressions of Wintertime TP versus Dust Deposition Using Linear (left) and Logarithmic (right) axes



TP = total phosphorus; r^2 = coefficient of determination; mg/dm²/yr = milligrams per square decimetre per year.

TP Loads

Natural TP loads to Lac de Gras, and to the Lac de Gras watershed excluding Lac de Gras, were computed using the geometric mean deposition rates from the control stations (0.089 mg/dm^2/yr) and from the 2019 control-assessment stations (0.0089 mg/dm^2/yr). When using the background deposition from the control stations, the direct natural TP load to the lake is estimated at 5.1 t/yr and the natural TP load to the watershed excluding the lake is 31 t/y, for a total watershed load of 36 t/yr (Table D-2). This natural TP load is comparable to that estimated for 2018. When using the background deposition rates from control-assessment stations (0.0089 mg/dm^2/yr), the natural background load is estimated to be 3.7 t/yr.

The anthropogenic TP load from Mine effluent was 0.28 t/yr in 2019. Effluent is assumed to include any TP captured in runoff collected on-site that may be affected by the local deposition of fugitive dust within the Mine footprint.

Results of the spatial interpolation of TP deposition around the Mine footprint are illustrated in Figure D-3. The anthropogenic TP loads were calculated by subtracting the natural background load from the total TP load. As summarized in Table D-2, when using background deposition rate from the control-assessment stations, the anthropogenic TP loads to Lac de Gras and the watershed (excluding the Mine and lake) were 1.2 and 2.0 t/yr, respectively, for a total load (including Mine effluent) of 3.4 t in 2019. When using the background deposition rate from the control stations, the anthropogenic TP loads to Lac de Gras and the watershed (excluding the Mine and lake) were similar at 1.4 and 3.2 t/yr, respectively for a total (including Mine effluent) of 4.8 t in 2019.

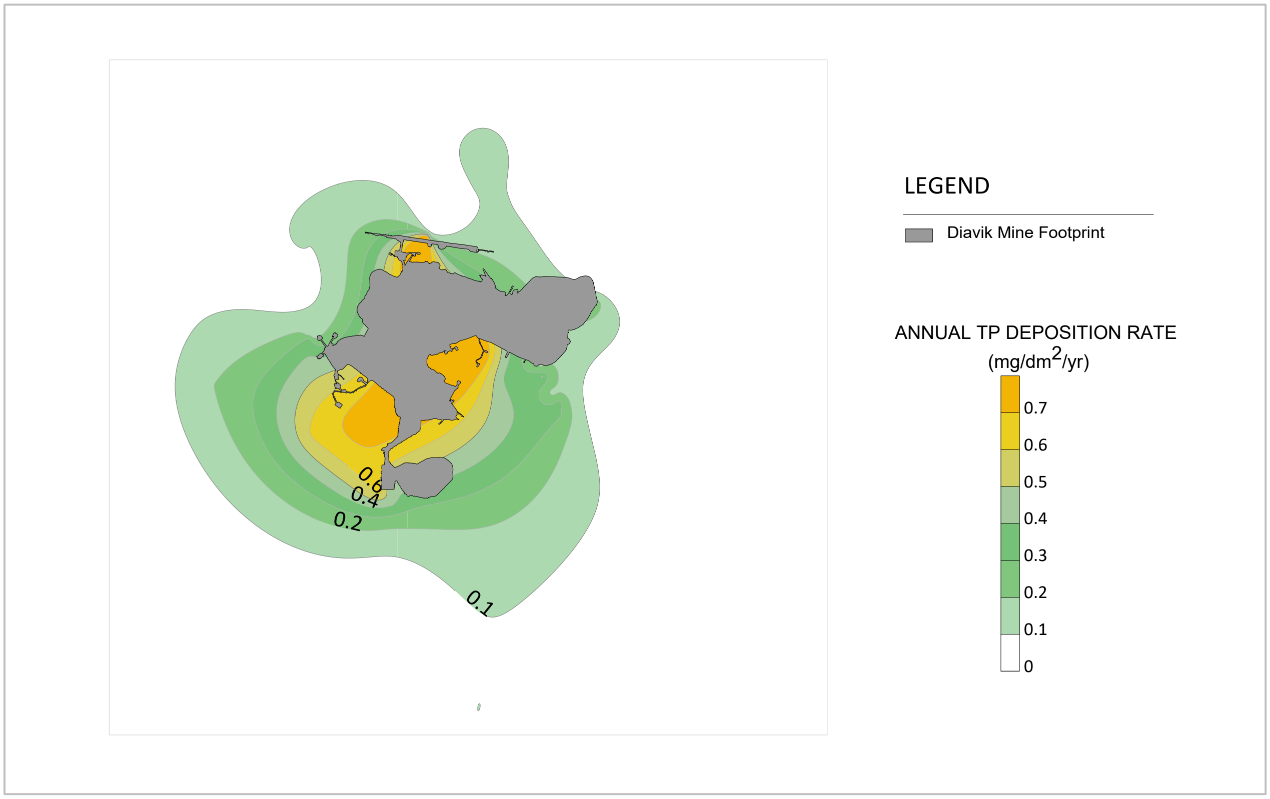
Using either the control or the control-assessment stations resulted in larger anthropogenic TP loads in 2019 than in 2018 (Table D-2). The contribution of anthropogenic sources of TP deposition to Lac de Gras in 2019 was 12%, which is greater than 2018 (i.e., 3.0%) when using control station data for the background deposition rate. When the background deposition rates are calculated using the control-assessment station data, the anthropogenic TP load in 2019 (3.4 t/yr) was smaller compared to using the control stations as background (4.8 t/yr). However, the relative contribution of anthropogenic sources of TP was greater (48% versus 12%). This is due to the order of magnitude difference between the estimates for the background rate of TP deposition when using control station data (0.089 mg/dm^2/yr) versus control-assessment station data (0.0089 mg/dm^2/yr).

Table D-2 Summary of Total Annual Phosphorus Loads to Lac de Gras

Total Phosphorus Source		Area (km²)	2018 (using background deposition rate from control stations)		2019 (using background deposition rate from control stations)		2019 (using background deposition rate from control-assessment stations)	
			TP Load (t/yr)	Percent contributing to the total TP load	TP Load (t/yr)	Percent contributing to the total TP load	TP Load (t/yr)	Percent contributing to the total TP load
Natural Background TP	Deposition to Lac de Gras	573	3.9	13%	5.1	12%	0.51	7.2%
	Deposition to Watershed excl. Lake	3,542	24	83%	31	76%	3.2	44%
	Watershed Subtotal[(a)]	**4,115**	**28**	**97%**	**36**	**88%**	**3.7**	**52%**
Anthropogenic TP	Diavik Mine Effluent	n/a	0.40	1.4%	0.28	0.67%	0.28	3.9%
	Deposition to Lac de Gras	573	0.41	1.4%	1.4	3.3%	1.2	16%
	Deposition to Watershed excl. Lake and Mine footprint	3,530	0.07	0.23%	3.2	7.7%	2.0	28%
	Watershed Subtotal[(a)]	**4,115**	**0.87**	**3.0%**	**4.8**	**12%**	**3.4**	**48%**
Total[(a)]		**4,115**	**29**	N/A	**41**	n/a	**7.1**	n/a

(a) Values do not sum up to subtotal or total due to rounding.
n/a = not applicable; TP = total phosphorus; t/yr = tonnes per year.

Figure D-3 Spatially Interpolated Total Phosphorus Deposition



mg/dm^2/yr = milligrams per square decimetre per year.

Summary and Discussion

The key findings from the 2019 assessment are as follows:

- Dust deposition rates to snow at the control stations were greater than at the control-assessment stations. In previous years, the control stations were assumed to be unaffected by atmospheric deposition of fugitive Mine dust (i.e., they were assumed to be representative of the regional background rate of TP deposition). The 2019 results indicate that this assumption may be invalid. Instead, the control-assessment stations may be more likely represent the regional background rate of TP deposition.
- The last two years (2018 and 2019) were low dust deposition years at the control stations, when considering data from all years (2010 to 2019).
- Dust generated by the Mine in 2019 was greater in phosphorus content compared to background sources. This is consistent with previous years.
- Using either control or control-assessment stations resulted in greater anthropogenic TP loads in 2019 than in 2018. This is because dust deposition rates and TP deposition rates were greater in 2019 compared to 2018.
- When using the control stations to estimate background TP and dust deposition rates (which were used in previous assessments), the anthropogenic TP loads for Lac de Gras and the watershed

(excluding the Mine and lake) were 1.4 and 3.2 t/yr, respectively, for a total (including Mine effluent) of 4.8 t in 2019.

- When using the control-assessment stations to estimate background TP and dust deposition rates, anthropogenic TP loads for Lac de Gras and the watershed (excluding the Mine and lake) were 1.2 and 2.0 t/yr, respectively, for a total (including Mine effluent) of 3.4 t in 2019.
- When the background TP and dust deposition rates are calculated using the control-assessment station data, the anthropogenic TP load in 2019 (3.4 t/yr) was less than when using the control stations as background (4.8 t/yr); however, the relative contribution of anthropogenic sources of TP become greater (48% versus 12%). This is due to the order of magnitude difference between the estimates of the background rate of TP deposition when using control station data (0.089 mg/dm^2/yr) versus control-assessment station data (0.0089 mg/dm^2/yr).

The dust sampling program was not designed to be as precise as the AEMP for measuring TP loads to Lac de Gras. The estimate of TP load from dust is considered to have low precision, with an order of magnitude uncertainty. Therefore, low confidence should be placed in the estimate of the TP load from dust and it should not be directly compared to the TP load from effluent, which is based on direct and precise measurements of effluent volume and TP concentrations. The effect on lake water quality and biological effects of nutrient inputs from all Mine-related sources are being monitored by the AEMP.

Effluent from the Mine enters Lac de Gras continuously as a point source. Wintertime atmospheric deposition of TP will report to the lake during spring break up, and then episodically during dry windy periods in the summer months. The phosphorus content of dust is variable, as is the proportion of total phosphorus that is soluble. As discussed in the *Special Effects Study – Dust Deposition* (Appendix XII), 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 under the pH and redox conditions in lake water. Extrapolating the dust deposition further, for example to evaluate the potential effects of the Mine-related TP loads from dust on biological productivity, is subject to further uncertainty.

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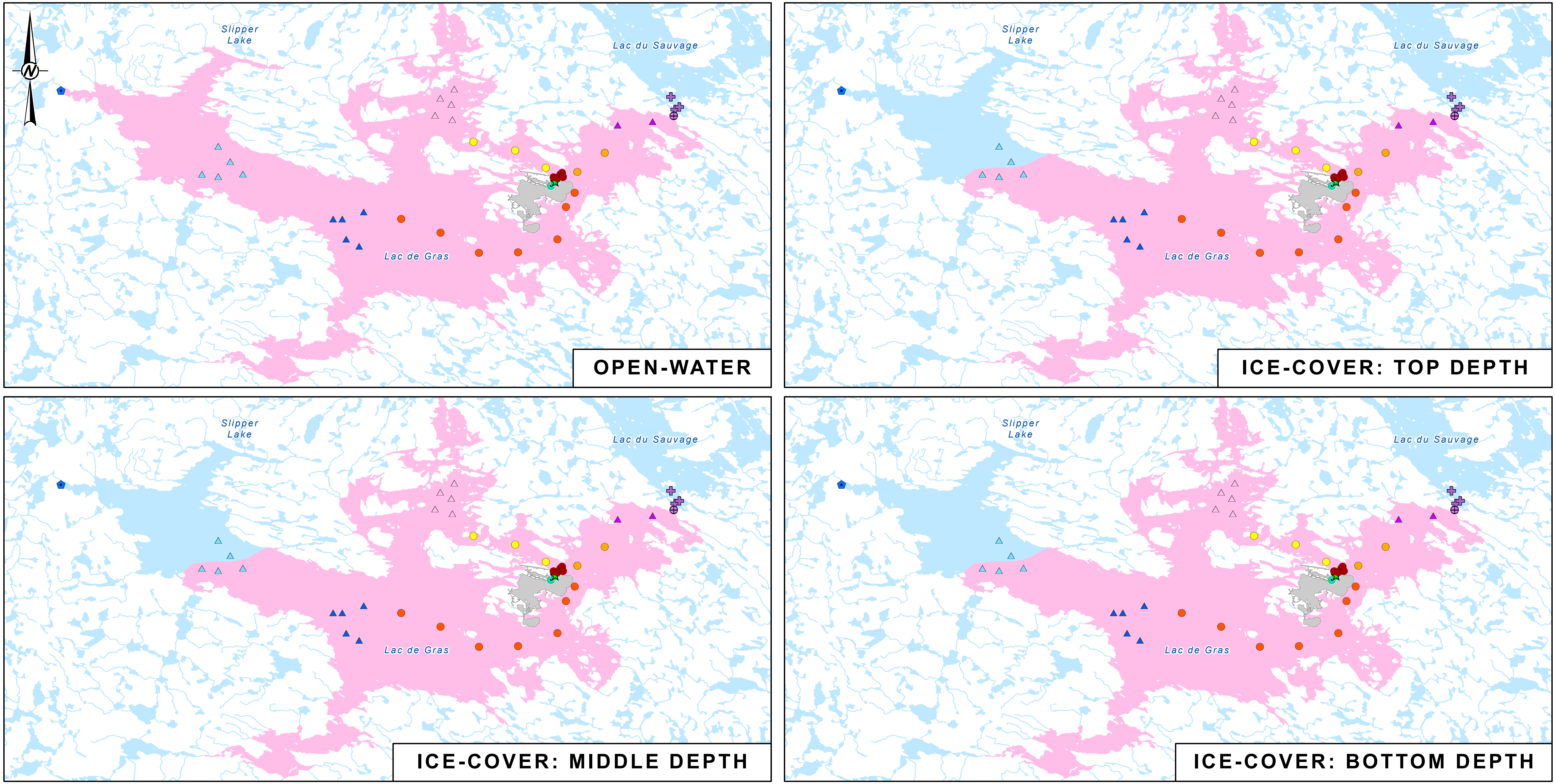
Golder. 2017. Diavik Diamond Mine Inc. – Aquatic Effects Monitoring Program Design Plan Version 4.1. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. June 2017.

Golder. 2019a. Eutrophication Indicators Report in Support of the 2018 AEMP Annual Report for the Diavik Diamond Mine, Northwest Territories. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. March 2019.

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

ATTACHMENT E

SUPPLEMENTAL EXTENT OF EFFECT FIGURES



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

—	WATERCOURSE
🟪	AFFECTED AREA
▨	DIAVIK FOOTPRINT
🟦	WATERBODY

0 10 20
1:350,000 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	KS
PREPARED	LMS
REVIEWED	LJ
APPROVED	ZK

TITLE
TOTAL NITROGEN AFFECTED AREA IN LAC DE GRAS BY SEASON AND DEPTH, 2019

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

PATH: I:\CLIENTS\DIAVIK\19115664\Mapping\Products\Fish\AEMP_2019\Euro_Appendix\FigE-1_2019_AEMP_AffectedAreas_Nitrogen_SeasonDepth_Rev0.mxd PRINTED ON: 2020-04-28 AT: 8:44:39 AM

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25mm
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ATTACHMENT F

EUTROPHICATION INDICATORS RAW DATA

These data are provided electronically as an Excel file.

APPENDIX XIV

TRADITIONAL KNOWLEDGE STUDY

No information was available for this appendix in 2019.

APPENDIX XV

WEIGHT-OF-EVIDENCE REPORT

WEIGHT-OF-EVIDENCE REPORT IN SUPPORT OF THE 2019 AEMP ANNUAL REPORT FOR THE DIAVIK DIAMOND MINE, NORTHWEST TERRITORIES

Submitted to:

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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-1921 Ver. 0
PO No. 3103966486

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Executive Summary

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP) in Lac de Gras, Northwest Territories, as required by Water Licence W2015L2-0001 (WLWB 2015), according to the *AEMP Design Plan Version 4.1* (Golder 2017a) approved by the Wek'èezhìı Land and Water Board (WLWB). This report presents the weight-of-evidence (WOE) integration of the AEMP findings based on data collected during the 2019 AEMP field program. The objectives of the WOE integration were to apply a standardized process to evaluate strength of evidence for potential toxicological impairment and nutrient enrichment effects, and to summarize the AEMP findings in a semi-quantitative manner that provides broad AEMP conclusions regarding the aquatic ecosystem of Lac de Gras.

The WOE analyses were conducted separately to address two broad impact hypotheses for Lac de Gras:

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

For each hypothesis, the WOE analysis integrated the results of endpoints for exposure and biological response (measured in the field) with *a priori* weighting factors, direction-weighting factors, and *a posteriori* weighting factors. Evidence of Impact (EOI) rankings were derived for lake productivity, the benthic invertebrate community, and fish population health. A higher rank represents greater strength of support for a particular hypothesis. The EOI ranking results for each hypothesis were then interpreted to develop conclusions regarding the types of effects that are most likely occurring in Lac de Gras.

The EOI rankings and key supporting findings of the 2019 AEMP, which formed the basis for the rankings, are described below.

Evidence of Toxicological Impairment

- Lake Productivity – EOI Rank 0 (Negligible):
  - There were significantly greater concentrations of some Substances of Interest (SOIs) in the water column of the near-field (NF) area relative to far-field (FF) areas, gradient analysis, and normal range. These findings were linked to effluent released from the Mine.
  - A minor shift in zooplankton community structure was documented in the NF area relative to the FF areas which could be consistent with the Toxicological Impairment hypothesis; however, this response was attributed to Nutrient Enrichment as it was in line with other responses in the Line of Evidence (LOE) group (i.e., chlorophyll *a* and zooplankton biomass). Based on the burden of evidence, the possibility of toxicity to lake productivity was concluded to be negligible.

- Benthic Invertebrate Community – EOI Rank 0 (Negligible):
  - Twelve parameters in 2019 were identified as SOIs in sediment (i.e., had a trend of decreasing concentration with distance from the Mine effluent diffusers, or an elevated concentration in the NF area compared to the FF areas), all of which showed either a significant difference between NF and FF areas or a significant decreasing trend for at least one transect resulting in a low-level rating, with exception for total phosphorus. Of these parameters, bismuth, lead, molybdenum, strontium and uranium also had median NF concentrations that were greater than their respective normal ranges. However, the concentrations of bismuth, lead, molybdenum, strontium and uranium were considered of low toxicological concern.
  - Significant differences were not observed in benthic invertebrate endpoints compared to the FF areas. However, significant gradients indicating increasing values with distance from the effluent discharge were detected along one mid-field (MF) area transect for richness, and densities of *Pisidiidae* and *Micropsectra*, but NF area means remained within the normal range. Increased effluent exposure in the NF area extending along the MF area transects resulted in a community shift towards increased midge dominance and changes within dominance patterns. No significant differences were observed in a direction indicating toxicological impairment between the NF area and the reference condition means for any benthic invertebrate variable. Overall, the possibility of toxicity affecting the benthic invertebrate community was concluded to be negligible.
- Fish Population Health – EOI Rank 2 (Moderate):
  - 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; and silver, strontium and uranium had tissue concentrations in the NF and MF areas that were greater than the normal range. However, there was uncertainty as to whether these elevated metals in fish tissues were related to effluent released from the Mine.
  - Fish were significantly smaller (i.e., smaller size at age) but had significantly greater energy stores (i.e., condition factor) in the NF area. The decreased growth could indicate toxicity, whereas increased energy storage is supportive of nutrient enrichment. Increased energy stores could be due to the observed increase in food supply (i.e., increases in chlorophyll *a*, zooplankton biomass, and total invertebrate density). In general, toxicity was not indicated by measurements taken for the plankton and benthic communities. Given these results for the lower trophic components, the discrepancy observed in the fish population health LOE was attributed to natural variability and/or could have been caused by other ecological or abiotic factors. Conservatively, the possibility of toxicity affecting fish population health was ranked as moderate.

Evidence of Nutrient Enrichment

- Lake Productivity – EOI Rank 3 (Strong):
  - The mean concentration of total nitrogen (TN) in the NF area exceeded the upper bound of the normal range and the affected area covered most of the lake.
  - Chlorophyll *a* concentrations in the NF area were significantly greater than the FF areas and there was a significant gradient along the MF1 and MF3 transects, but mean concentration in the NF was within the normal range. There were also indications of increased zooplankton biomass in addition

to nutrient-related shifts in plankton community structure in the NF area relative to the FF areas. Zooplankton total biomass (enumeration) showed a decreasing spatial gradient along the MF3 transect. Zooplankton biomass (ash-free dry mass [AFDM]) was statistically greater in the NF area relative to FF areas and there was a significant gradient along the MF1 and MF3 transects. Mean zooplankton biomass in the NF exceeded the upper limit of the normal range, and the area of the lake with biomass above the normal range was greater than 20%.

  - The strong linkage of elevated nutrient concentrations to the Mine combined with a clear indication of responses in primary and secondary productivity provided strong evidence for an enrichment effect on lake productivity.

- Benthic Invertebrate Community – EOI Rank 3 (Strong):
  - Chlorophyll *a* concentrations in the NF area were significantly greater than the FF areas and there was a significant gradient along the MF1 and MF3 transects, but mean concentration in the NF was within the normal range. The increase in chlorophyll *a* concentration represents increased food supply for benthic invertebrates, which has a clear linkage to the Mine as a result of corresponding increases in nutrients (i.e., nitrogen) in the NF area.
  - Significant differences were not observed in benthic invertebrate endpoints compared to the FF areas. However, significant gradients indicating decreasing values with distance from the effluent discharge were detected along one mid-field (MF) area transect for evenness, percent Chironomidae, and densities of *Procladius*, *Heterotrissocladius*, and *Microtendipes.* NF area means remained within the normal range, with the exception of *Procladius* and *Microtendipes*. These two midge genera had NF area mean densities above the normal range, which extended into the MF areas. The strong linkage of nutrient releases from the Mine to elevated food supply combined with a clear indication of increased biomass of the benthic community provide strong evidence for an enrichment effect on the benthic invertebrate community.
- Fish Population Health – EOI Rank 2 (Moderate):
  - Chlorophyll *a* concentrations in the NF area were significantly greater than the FF areas and there was a significant gradient along the MF1 and MF3 transects, but mean concentration in the NF was within the normal range. An increase in primary productivity could result in a corresponding increase in food supply for fish.
  - Among fish population health endpoints with an observed response, energy stores (i.e., condition factor) in the NF area was greater for age-1+ fish relative to reference conditions, but mean values were within normal range. This observation supports the Nutrient Enrichment hypothesis. However, there were inconsistencies in fish population health metrics (see Evidence for Toxicological Impairment). The observed inconsistencies were attributed to natural variability and/or could have been caused by other ecological or abiotic factors. The moderate ranking due to the possibility of nutrient enrichment was applied because of the observed chlorophyll *a* response as well as the increased fish condition factor.

The evidence for nutrient enrichment in Lac de Gras was stronger than the evidence for toxicological impairment. For 2019, there continued to be a relatively clear link between nutrient releases to Lac de Gras, increases in nutrient concentrations in the NF area, and greater lake productivity in the NF area. In addition, significant declining gradients in *Procladius, Heterotrissocladius,* and *Microtendipes* densities with distance from the effluent discharge, as well as a minor shift in community structure (i.e., relative abundance of dominant taxa) were consistent with the Nutrient Enrichment hypothesis.

In the case of fish population health, smaller size at age (i.e., decreased growth) in the NF area relative to the FF area or reference condition may be a result of toxicological impairment, whereas increased energy stores (i.e., condition factor) in NF area is supportive of the Nutrient Enrichment hypothesis. 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 natural variability caused by other ecological or abiotic factors. Consistent with previous AEMP years, overall, there is evidence in support of nutrient enrichment in Lac de Gras; the results of the assessment provide limited evidence in support of toxicological impairment in Lac de Gras.

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Acronyms and Abbreviations

AEMP	Aquatic Effects Monitoring Program
AFDM	ash-free dry mass
ANOSIM	analysis of similarities
CCME	Canadian Council of Ministers of the Environment
DDMI	Diavik Diamond Mines (2012) Inc.
ECCC	Environment and Climate Change Canada
ECHA	European Chemicals Agency
e.g.	for example
EOI	evidence of impact
ERA	ecological risk assessment
FF	far-field
Golder	Golder Associates Ltd.
GSI	gonadosomatic Index
i.e.	that is / there are
ISQG	interim sediment quality guideline
K	condition factor
LEL	lowest effect level
LOE	line of evidence
LSI	liversomatic index
MF	mid-field
Mine	Diavik Diamond Mine
N/A	not applicable
NF	near-field
nMDS	non-metric multidimensional scaling
OMOEE	Ontario Ministry of Environment and Energy
PEL	probable effect level
QA/QC	quality assurance/quality control
SEL	severe effect level
SOI	substance of interest
SDI	Simpson’s diversity index
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
US EPA	United States Environmental Protection Agency
VEC	valued ecosystem component
WLWB	Wek'èezhìı Land and Water Board
WOE	weight-of-evidence
WQ	water quality

Symbols and Units of Measure

+	plus
%	percent
>	greater than
≥	greater than or equal to
<	less than
mg/kg	milligrams per kilogram
mg/kg dw	milligrams per kilogram dry weight
mg/L	milligrams per litre
↑ or ↓	early warning / low level
↑↑ or ↓↓	moderate level
↑↑↑ or ↓↓↓	high level
=	equal to
-	no data

1 INTRODUCTION

1.1 Background

In 2019, Diavik Diamond Mines (2012) Inc. (DDMI) completed the field component of its Aquatic Effects Monitoring Program (AEMP) for the Diavik Diamond Mine (Mine), as required by Water Licence W2015L2 0001 (WLWB 2015). This report presents the weight-of-evidence (WOE) analysis of findings of the 2019 AEMP, which was carried out according to the *AEMP Design Plan Version 4.1* (Golder 2017a).

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 2019) and in Wek'èezhìı Land and Water Board (WLWB) directives (28 August 2017, January 2018, 25 March 2019, and 21 October 2019 Decision Packages) have been incorporated into the 2019 AEMP Annual Report, including clear identification of changes and updates throughout the Weight-of-Evidence Report as a result of the various directives. These are summarized in Section 1.3.

The goal of the AEMP is to monitor the Mine water discharge and other stressors from the Mine and assess potential risks such that appropriate actions can be taken to mitigate any possible adverse effects on the aquatic ecosystem of Lac de Gras. It focuses on Mine-related stressors (primarily metals[1] and nutrients) that are released to Lac de Gras. Related to these stressors, the AEMP has identified two broad impact hypotheses for Lac de Gras:

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

The WOE analysis is structured to distinguish between these two hypotheses. The products of the WOE analysis are estimates of the Evidence of Impact (EOI) in support of each hypothesis. The term “Impact” is used in this report in a generic sense to indicate a change (positive or negative) in Lac de Gras related to the Mine or Mine activities. It is not intended to reflect the ecological significance or level of concern associated with a given change, nor is it intended to indicate that “pollution” of Lac de Gras has occurred.

As described in the *AEMP Design Plan Version 4.1* (Golder 2017a), ecological significance and the severity of possible effects to an assessment endpoint are categorized in the AEMP according to Action Levels. These classifications were developed to meet the goals of the Response Framework for Aquatic Effects Monitoring that was drafted by the WLWB (Racher et al. 2011). The goal of the Response Framework is to ensure that significant adverse effects never occur. When Action Levels are triggered for a component of the AEMP, the findings of the WOE analysis serve to inform response planning and environmental stewardship. For example, if the plankton community structure were to shift to a degree that management responses and/or mitigation were concluded to be necessary based on the Response Framework, then the WOE findings would inform whether adaptive management should focus on the mitigation of nutrient releases or toxicant releases.

---

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

This report presents the WOE analysis of the findings of the 2019 AEMP. For 2019, the AEMP integrated the following field components: water quality (WQ); sediment quality; lake productivity (i.e., nutrients, chlorophyll *a*, and zooplankton biomass); plankton communities; benthic invertebrates; and fish population health. Details on WOE methodology are provided in Section 2. Section 3 provides results and discussion of the WOE analysis, while Section 4 provides conclusions.

1.2 Objectives

The WOE analysis applies a framework similar to an ecological risk assessment (ERA) for integrating the AEMP findings for various ecosystem components. An ERA process is designed to provide a systematic means for prioritizing environmental response pathways, for collecting appropriate data to evaluate those pathways, and for acknowledging uncertainties identified in each component of the assessment process. In particular, it combines measures of exposure (e.g., WQ or sediment chemistry) with either laboratory- or field-based biological responses (e.g., benthic invertebrate density or fish growth).

The objectives of the WOE analysis were two-fold:

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

1.3 Considerations

Changes or updates to the WOE analysis that were implemented in 2019 include the following:

- Calculation of normal ranges, which were calculated in a manner consistent with the approved methods in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
- Effect level ratings were expanded to align with the existing analytical approach for each component of the AEMP, as appropriate (e.g., consideration of gradient analysis, comparison to normal range).
- For fish, two endpoints (i.e., Population Structure [Survival] and Population Structure [Size]), which were included in 2013, were not assessed in 2016 or in 2019. Population Structure (Survival) was not assessed because specific ages could not be determined with accuracy; fish were only determined as adults or juveniles. Population Structure (Size) is assessed by testing differences between length frequency distributions among areas and as such there were no normal ranges for this test. Therefore, this measurement endpoint could not be assessed based on the effects level ratings in Section 2.3, which considers comparison to normal range. Size (i.e., growth) is also considered as part of the Growth (Size at Age) measurement endpoint, so inclusion of both was deemed to be duplication of similar endpoints.
- Relative abundance of Slimy Sculpin, standardized by catch-per-unit-effort (CPUE), was assessed using a non-lethal relative abundance survey; CUPE was added as a measurement endpoint to fish in 2019.

2 METHODS

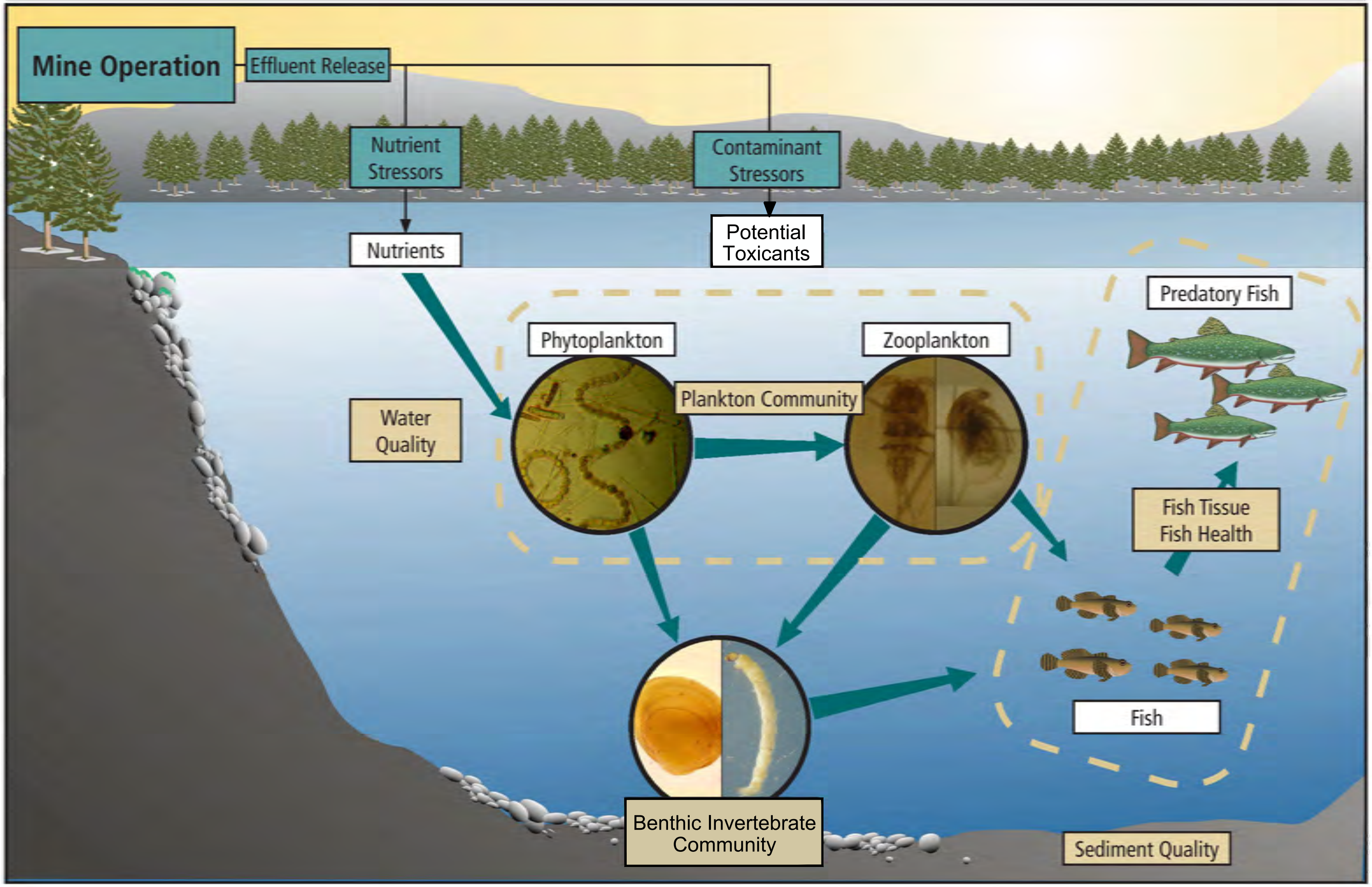
This section describes the conceptual model and endpoints that are included in the AEMP, and then develops the WOE framework that is applied for integrating the AEMP findings.

2.1 Conceptual Model

The general conceptual model for the Mine and Lac de Gras is presented in Figure 2-1. The primary exposure route for receptors of potential concern is via Mine effluent, which could lead to increases in Mine-related toxicological stressors (e.g., metals concentrations) or Mine-related enrichment stressors (e.g., nutrients) in Lac de Gras. Receptors of potential concern can consist of individual species, functional groups (e.g., trophic levels), or communities. For Lac de Gras, the broad ecosystem components that have common routes of exposure to Mine-related stressors are:

- phytoplankton (microscopic floating plants, mainly algae, that live suspended in the water column)
- zooplankton (animal component of plankton, including microscopic animals suspended or drifting in the water column)
- soft-bottom benthic invertebrate community (small animals found within or on the surface of the sediment bed)
- demersal fish (living in close proximity to bottom sediments; e.g., Slimy Sculpin, *Cottus cognatus*)
- pelagic fish (inhabiting upper layers of lake water; e.g., Lake Trout, *Salvelinus namaycush*)

The distinction between pelagic and demersal fish accounts for possible differences between exposure to potential stressors in sediments (and associated sediment porewater) versus surface waters. In years that the fish community is monitored, Slimy Sculpin are used as surrogates (i.e., sentinel species) for other members of the fish community found in Lac de Gras.



SCHEMATIC ONLY, NOT TO SCALE

CLIENT	RioTinto
CONSULTANT	GOLDER
YYYY-MM-DD	2020-04-28
DESIGNED	GZ
PREPARED	RFM
REVIEWED	GZ
APPROVED	ZK

PROJECT
DIAVIK DIAMOND MINES INC (2012)

TITLE
AEMP CONCEPTUAL MODEL

PROJECT NO.	CONTROL	REV.	FIGURE
19115664	8000-RF-0001	0	2-1

2.2 Assessment and Measurement Endpoints

The problem formulation for the AEMP identified multiple assessment and measurement endpoints that form the basis for evaluating potential changes, responses, or effects in Lac de Gras related to the Mine. Assessment endpoints are characteristics of the aquatic ecosystem that may be affected by the Mine, expressed explicitly as statements of the actual environmental values that are to be protected (Suter 1990; US EPA 1992; Warren-Hicks et al. 1989). Considerations in the selection of assessment endpoints include: ecological relevance, policy goals, future land use, societal values, susceptibility to substances of interest (SOIs), and the ability to define the endpoint in operational terms.

The assessment endpoints were used to select appropriate measurement endpoints, which are measurable responses to the stressor that are related to the valued characteristics chosen as the assessment endpoint (Suter 1990). Measurement endpoints may include measures of exposure (e.g., chemical concentrations in water and sediments) and measures of effects (e.g., plankton biomass and benthic invertebrate community structure). Measurement endpoints are operationally defined and can be assessed using appropriate field and laboratory studies.

Valued ecosystem components (VECs) for Lac de Gras and their corresponding assessment and measurement endpoints are described in Table 3.2-1 of the *AEMP Design Plan Version 4.1* (Golder 2017a. The VECs applicable to the WOE framework as well as additional components relative to the AEMP, are:

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

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

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

The strength of evidence for toxicological impairment or nutrient enrichment associated with observed changes was evaluated using an array of measurement endpoints specific to the WOE analysis. Measurement endpoints were selected to reflect the assessment endpoints formulated in the AEMP and to be directly linked to the Mine. For example, measures of WQ, comparing between near-field (NF) and far-field (FF) areas, provide an indication of exposure to potential toxicants or nutrients, and can be linked to effluent release. Similarly, increases or decreases in plankton biomass provide an indication of a biological response to increases in nutrients or potential toxicants. The various endpoints were integrated in the WOE framework to yield overall assessments for each ecosystem component under each impact hypothesis (toxicological impairment versus nutrient enrichment).

2.3 Weight-of-Evidence Framework

WOE analysis provides a systematic and transparent method for integrating the complexity of data generated in environmental assessment programs. The basis for decision-making within a WOE analysis is a combination of statistical analyses and scoring systems incorporated into a logic system. Best professional judgment is also a key component of any WOE analysis (Chapman et al. 2002) and was incorporated as appropriate. Key components that make up the design of the WOE framework for the DDMI AEMP are summarized in the following sections:

- Section 2.3.1: Description of the Line of Evidence (LOE) groups and measurement endpoints included in the WOE framework
- Section 2.3.2: Description of the process for evaluating the effect levels observed for the endpoints in each LOE group
- Section 2.3.3: Description of the process for determining the appropriate weighting of each endpoint towards the overall WOE conclusions

The following sections provide a more detailed explanation of the components of the framework.

2.3.1 Lines of Evidence and Measurement Endpoints

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

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

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

Within each LOE group there are LOE that encompass different stressor types, media, levels of biological organization, and data analysis methods:

- Exposure LOE: nutrient exposure, contaminant exposure, and primary productivity
- Biological Response LOE: biological productivity, benthic invertebrate community, and fish population health

Table 2-1 Endpoints and Lines of Evidence for Each Component - Toxicological Impairment Hypothesis, 2019

Ecosystem Component	Line of Evidence Group	Line of Evidence	Endpoints
Lake Productivity	Exposure	Contaminant Exposure	Water Chemistry
			Sediment Chemistry
	Biological Response	Biological Productivity	Chlorophyll *a*
			Phytoplankton Biomass
			Zooplankton Biomass
			Phytoplankton Community Structure
			Zooplankton Community Structure
Benthic Invertebrate Community	Exposure	Contaminant Exposure	Water Chemistry
			Sediment Chemistry
	Biological Response	Benthic Invertebrate Community	Total Invertebrate Density
			Dominant Taxa Density
			Percent Chironomidae
			Richness
			Simpson’s Diversity Index (SDI)
			Evenness
			Dominance
			Bray-Curtis Distance
			Relative Abundances of Dominant Taxa
Fish Community	Exposure	Contaminant Exposure	Water Chemistry
			Sediment Chemistry
			Fish Tissue Chemistry
	Biological Response	Fish Population Health	Growth – Size at Age
			Energy Stores – Condition (K)
			Energy Stores – Liver Somatic Index (LSI)
			Relative Reproductive Success – Age 1 Abundance
			Relative Reproductive Investment – Gonadosomatic Index (GSI)
			Tapeworm Parasitism – Occurrence
			Catch-per-unit-effort (CPUE)

Table 2-2 Endpoints and Lines of Evidence for Each Component - Nutrient Enrichment Hypothesis, 2019

Ecosystem Component	Line of Evidence Group	Line of Evidence	Endpoints
Lake Productivity	Exposure	Nutrient Exposure	Water Chemistry – Total Nitrogen (N) and Total Phosphorus (P)
	Biological Response	Biological Productivity	Chlorophyll *a*
			Phytoplankton Biomass
			Zooplankton Biomass
			Phytoplankton Community Structure
			Zooplankton Community Structure
Benthic Invertebrate Community	Exposure	Nutrient Exposure	Water Chemistry – Total N and Total P
			Sediment Chemistry – Total P and Total Organic Carbon (TOC)
		Primary Productivity	Chlorophyll *a*
	Biological Response	Benthic Invertebrate Community	Total Invertebrate Density
			Dominant Taxa Density
			Percent Chironomidae
			Richness
			Simpson’s Diversity Index
			Evenness
			Dominance
			Bray-Curtis Distance
			Relative Abundances of Dominant Taxa
Fish Community	Exposure	Nutrient Exposure	Water Chemistry – Total N and Total P
		Primary Productivity	Chlorophyll *a*
	Biological Response	Fish Population Health	Growth – Size at Age
			Energy Stores – Condition (K)
			Energy Stores – Liver Somatic Index (LSI)
			Relative Reproductive Success – Age 1 Abundance
			Relative Reproductive Investment – Gonadosomatic Index (GSI)
			Tapeworm Parasitism – Occurrence
			Fish Capture Data – Catch-per-unit-effort (CPUE)

For many of the LOE groups, multiple endpoints have been measured in Lac de Gras, providing a “battery” approach for assessing the degree of effect associated with each LOE. The evaluation of multiple endpoints for each LOE means that a wide variety of possible changes are considered in the overall analysis. The endpoint findings are discussed in further detail in separate reports:

- Effluent and Water Chemistry Report (Appendix II)
- Sediment Quality Report (Appendix III)
- Benthic Invertebrate Report (Appendix IV)

- Fish Report (Appendix V)
- Plankton Report (Appendix XI)
- Eutrophication Indicators Report (Appendix XIII)

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

In general terms, the endpoint results are *rated* according to a series of decision criteria, *weighted* to reflect the strength and relevance of the evidence they brought to the analysis, and then *integrated* to provide an overall assessment. This integration is accomplished using a WOE assessment framework based on McDonald et al. (2007), including guidance from Chapman and co-authors (Chapman 1990, 1996; Chapman et al. 1997, 2002; Chapman and McDonald 2005; Chapman and Anderson 2005; Chapman and Hollert 2006; Stevenson and Chapman 2016).

2.3.2 Rating the Magnitude of Observed Effects

2.3.2.1 Overview

The results for each of the endpoints within a LOE group were assessed relative to an appropriate reference or benchmark (typically NF vs. FF or reference condition comparisons), resulting in a rating for the endpoint. Rating schemes in WOE frameworks can vary from assessment to assessment. WOE frameworks used by Chapman and coauthors (e.g., Chapman et al. 2002; Chapman and McDonald 2005) use non-numerical rating systems in which endpoint results are assigned to one of a ranked series of categories (e.g., "↑", "↑↑", "↑↑↑"). Conversely, Menzie et al. (1996) proposed numerical ratings based on a set of attributes scored between 1 and 5 according to a series of causal criteria.

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

- Each endpoint is initially rated according to a non-numerical scheme (Chapman et al. 2002; Chapman and Anderson 2005). This approach emphasizes the semi-quantitative nature of rating each endpoint.
- These semi-quantitative ratings are then temporarily transformed into an arbitrary scale of numerical values to facilitate weighting and integration using simple mathematical functions (i.e., addition, multiplication). This approach is highly systematic as all cases use the same formulae. This approach is also highly transparent (especially with respect to the application of professional judgement) as stakeholders and reviewers can see the effect of each assumption and decision on the outcome of the WOE analysis.
- After weighting and integration, the numerical output of the WOE analysis is transformed back into a non-numerical set of categories termed EOI Rankings.

2.3.2.2 Effect Level Rating Criteria

During the original design of the AEMP, the effect ratings were agreed upon through a regulatory process with direct input from the WLWB and other reviewers (DDMI 2007; WLWB 2007). Since 2008, revised effect ratings have been applied to improve consistency in treatment of endpoints in the WOE analysis and address refinements that were recommended based on the experience with the WOE analysis in the 2007 AEMP. In addition, new effect ratings have been developed for new endpoints that are included in the revised AEMP.

Observed changes or differences in exposure and biological response endpoints are classified using a scale ranging from “negligible” to “high” to represent the degree of response in the particular endpoint. Typically, a finding of no difference between NF and FF areas, Reference Conditions, or Benchmarks indicated a rating of “negligible” effect (represented by “0” in the WOE table), whereas increasingly large and/or statistically significant differences received ratings of “early warning/low-level” (represented by “↑” or “↓”), “moderate-level” (represented by “↑↑” or “↓↓”) or “high-level” (represented by “↑↑↑” or “↓↓↓”). The following general categories have been adopted for distinguishing the strength of evidence provided by observed changes:

- **Negligible**: This rating applies either when there is no visual and/or statistical difference between the measurement endpoint result from the NF area relative to the FF areas; or the NF result is within the normal range; or, the NF result does not exceed an AEMP benchmark or guideline; or, effluent toxicity tests pass, demonstrating no toxic effects to aquatic test organisms.
- **Early Warning/Low-level**: This rating indicates that a change has occurred in the NF area but the potential for ecologically significant effects or harm is low. Some measurement endpoints are appropriate as early warnings on a project basis whereas others are not. For example, water and sediment chemistry alterations in the NF area would be expected to manifest prior to effects on benthos variables. An early warning/low-level rating identified for benthos would serve as an early warning of potential responses in the Lac de Gras ecosystem. For nutrients, this rating occurs only once concentrations are beyond the normal range to account for the complex nature of eutrophication responses.
- **Moderate-level**: An observed effect is classified as a moderate-level rating when a measured indicator is in excess of an early warning/low-level effect (e.g., for biota, both a statistical difference in the NF area relative to the FF areas, and NF area data beyond the normal range]. The spatial extent of observed effects is also considered to determine whether the change extends beyond the NF area. For nutrients, a moderate rating is applied once a change extends beyond the NF area.
- **High-level**: A high-level rating represents situations where moderate-level effects are extending beyond the NF area, meaning that the detected effect is being observed over a significant portion of Lac de Gras. The larger spatial area of changes is considered to pose a possibly larger overall impact on the ecosystem components of Lac de Gras.

These ratings for negligible, early warning/low-level, moderate-level, and high-level effects were converted to numerical equivalents (0, 0.5, 1, and 2, respectively) for the purposes of the integration process. This conversion was necessary so that integration could proceed using simple mathematical equations (i.e., weighted sums) rather than attempting to establish decision rules for each possible combination of semi-quantitative ratings.

2.3.2.2.1 Exposure Endpoints

The effect ratings applied in the WOE analysis for exposure endpoints are presented in Table 2-3. The exposure endpoints are similar to those used in previous AEMPs and effects ratings for each endpoint are rated by comparing NF to FF areas, normal ranges, reference conditions, and benchmarks.

For exposure endpoints, the studies of water and sediment chemistry generally employed an approach focused on concentrations of SOI. For sediment, this approach focused the analysis only on those substances with spatial trends consistent with a Mine-related effect in Lac de Gras (i.e., a trend of decreasing concentration with distance from the Mine effluent diffusers; or an elevated concentration in the NF area compared to the FF areas).

For water, only those WQ SOIs that met criteria 1 (i.e., effluent screening) and 2 (i.e., Action Level 1) of the SOI selection procedure, as described in Section 3.1 of the Effluent and Water Chemistry Report (Appendix II), were evaluated. Potential dust-affected WQ parameters (i.e., criteria 3 of the SOI selection) were not evaluated in the WOE because effluent is expected to be the main source of potential effects in Lac de Gras.

The effluent SOIs were then analyzed statistically to confirm whether observed increases were Mine-related. Because multiple SOIs were selected for each endpoint, the rating result for a particular endpoint was conservatively based on the worst-case result for all SOIs (i.e., chemistry results were aggregated and classified overall using the criteria in Table 2-3). The criteria for determining early warning/low level rating were refined to be consistent with the data analysis in support of Action Levels; the benchmarks for WQ are defined in Section 2.3.8 of the Effluent and Water Chemistry Report (Appendix II).

Comparison to guidelines for sediment quality results involved the use of Canadian Council of Ministers of the Environment (CCME) interim sediment quality guidelines (ISQGs) and probable effect level (PELs; CCME 2002) and/or Ontario Ministry of Environment and Energy lowest effect levels and severe effect levels (OMOEE 1993). The method for deriving the ISQGs and PELs is such that concentrations below the ISQG indicate that effects on benthic invertebrates are unlikely whereas, once the PEL is exceeded, effects on benthic invertebrates become likely (but not certain). Between the ISQG and the PEL, the likelihood of effects on benthic invertebrates is less certain. Thus, exceeding the ISQG is deemed to be an indicator of a potential low-level rather than moderate-level effect, but exceeding the PEL is retained as an indicator of a potential high-level effect. The midpoint of the ISQG and the PEL was used to represent the threshold for a potential moderate-level effect. For substances without ISQGs or PELs but having lowest effect levels and severe effect levels, a similar logic was also applied for guideline interpretation. Guidelines for sediment quality and screening results are provided in Table E-1 of the Sediment Quality Report (Appendix III).

Table 2-3 Effect Level Ratings Applied for Exposure Endpoints, 2019

LOE Group	Measurement Endpoint Analysis	No Response 0	Early Warning/Low ↑	Moderate ↑↑	High ↑↑↑
Water Quality (substances of potential toxicological concern)	**Comparison to FF Areas, Normal Range, Benchmarks, and Effluent Toxicity(a)**	Does not trigger criteria 1 and 2 of SOI selection procedure(b)	Statistically significant increase, NF vs FF areas **OR** Significant Gradient Analysis Results, **OR** Occurrence of effluent toxicity test failure	Low + 5th percentile of NF area >two times the FF area median **AND** 5th percentile of NF area >normal range **AND** 5th percentile of NF area greater than Effects Benchmark	Statistically significant increase, MF vs FF areas **AND** 75th percentile of MF area >normal range **AND** 75th percentile of MF area greater than Effects Benchmark
Water Quality (nutrients)	**Comparison to Normal Range(a)** Total phosphorus Total nitrogen	No difference	Statistically significant increase, NF vs FF areas **OR** Significant Gradient Analysis Results	Low + NF area mean>normal range **AND** Less than or equal to 20% of the lake area with concentrations greater than the normal range	Concentrations in more than 20% of the lake area greater than the normal range
Sediment Quality (substances of potential toxicological concern)	**Comparison to FF Areas, Normal Range, and Guidelines(a)**	No difference	Statistically significant increase, NF vs FF areas **OR** Significant Gradient Analysis Results	Low + NF >(ISQG+PEL)/2 (or other appropriate guideline)(c) **AND** NF area median >normal range	MF >(ISQG+PEL)/2 (or other appropriate guideline) **AND** MF area median >normal range **OR** NF >PEL **AND** NF area median >normal range
Sediment Quality (nutrient enrichment)	**Comparison to FF Areas, and Normal Range**	No spatial trends consistent with a Mine-related effect	Statistically significant increase, NF vs FF areas **OR** Significant Gradient Analysis Results	Low + NF area median >normal range	Moderate + MF area median >normal range
Sculpin Tissue Chemistry (substances of potential toxicological concern)	**Comparison to FF Areas and Normal Range(a)**	No difference	Statistically significant increase, NF vs FF areas **OR** NF vs Reference Conditions	Low + NF area mean >normal range	Moderate + MF area mean >normal range

a) Applied separately for each chemical parameter.

b) Only those water quality SOIs that met criteria 1 (effluent screening) and 2 (Action Level 1) of the SOI selection procedure were evaluated.

c) For example, the OMOEE (1993) [LEL+SEL]/2.

Note: Normal ranges for each LOE group and measurement endpoint are defined and provided in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019).

NF = near-field; MF = mid-field; FF = far-field; LEL = Lowest effect level; PEL = Probable effect level, SEL = severe effect level; SOI = substance of interest; ISQG = Interim sediment quality guideline; LOE = line of evidence; > = greater than; < = less than.

2.3.2.2.2 Biological Response Endpoints

The effect ratings applied in the WOE analysis for biological response endpoints are presented in Table 2-4.

Biological response endpoints generally used a similar rating system to the exposure indicator endpoints, involving comparison of NF area to FF areas, normal range and reference conditions. The exceptions were the rating system for the community structure endpoints, which are explained below.

For plankton community composition, a low-level effect corresponds to a divergence in community structure (at the species or genus level) between the NF area and the FF areas and between the NF area and reference conditions (Table 2-4), based on interpretation of the multivariate multidimensional scaling (MDS) plots. A moderate level effect corresponds to a shift in community structure, at the sub-dominant groups within each ecological grouping, between the NF and FF areas and between the NF and reference conditions, based on the community composition plots (i.e., stacked bars). Ecological groupings for phytoplankton are cyanobacteria, chlorophytes, microflagellates, dinoflagellates, and diatoms. For zooplankton, these groupings are: cladocerans, cyclopoids, calanoids, and rotifers. A high-level effect corresponds to a moderate rating for community structure and a change in the dominant group in more than 20% of the lake area.

For benthos, the community structure assessment is based on visual examination of relative density plots (stacked bar graphs) for major taxa, and non-metric multidimensional scaling (nMDS) results. A low-level rating is applied when there is a visual difference between NF and FF areas in major taxa, with progressive moderate- or high-level ratings applied as the differences extend further into the MF areas.

For Nutrient Enrichment, chlorophyll *a* acts as both an indicator of biological response (for lake productivity) and as an indicator of exposure (for secondary consumers such as benthos). For both cases, the effect ratings for chlorophyll *a* remain the same.

Table 2-4 Effect Level Ratings Applied for Biological Response Endpoints, 2019

LOE Group	Measurement Endpoint Analysis	No Response 0	Early Warning/Low ↑/↓	Moderate ↑↑/↓↓	High ↑↑↑/↓↓↓
Biological Productivity	**Comparison to FF Areas and Normal Range(a)** Chlorophyll *a*(b) Zooplankton Biomass (AFDM) Phytoplankton Biomass (enumeration) Zooplankton Biomass (enumeration)	No difference	Statistically significant change, NF vs FF areas **OR** NF vs Reference Conditions mean/median(c) **OR** Significant Gradient Analysis Results along the MF3 transect at a minimum	Low + NF area mean outside normal range	Moderate + values in more than 20% of the lake area either greater or lower than the normal range
	Community Structure(a) Phytoplankton Community Composition Zooplankton Community Composition	No difference	Divergent community structure, at the species or genus level, between the NF vs FF areas and compared to reference conditions	A shift in community structure, at the sub-dominant group level(d) level, between the NF and FF areas and compared to reference conditions	Moderate + a change in the dominant group in more than 20% of the lake area
Benthic Community	**Comparison to FF Areas(a)** Total Invertebrate Density Richness Dominance Simpson's Diversity Index Evenness Bray-Curtis Distance Percent Chironomidae Density of Dominant Invertebrates (multiple endpoints) (e)	No significant difference or gradient, and NF mean within normal range	Statistically significant difference: NF vs FF areas **OR** NF vs Reference Condition **OR** Significant Gradient Analysis result	Low + NF area mean outside the normal range	Moderate + values in more than 20% of the lake area outside the normal range
	Community Structure(a) Relative Abundance of Dominant Taxa(e)	Similar community structure among sampling areas	Divergent community structure at the major group level: NF vs FF areas **OR** NF vs Reference Condition	Divergent community structure at the major group level, extending into MF areas, between MF and FF areas **OR** between MF area and Reference Condition	Moderate + divergent community structure at the major group level, extending beyond 20% of the lake area
Fish Population Health	**Comparison to FF Areas, Reference Conditions, and Normal Range(a)** Energy Stores—K Energy Stores—LSI Relative Reproductive Success—Age 1 Abundance Relative Reproductive Investment—GSI Tapeworm Parasitism—Occurrence Fish Capture Data—CPUE	No difference	Statistically significant change, NF vs FF areas **OR** NF vs Reference Conditions	Low + NF area mean outside normal range	Moderate rating extending beyond NF

a) Applied separately for each measurement endpoint.
b) Chlorophyll *a* is interpreted both as an exposure and a biological response endpoint.
c) Statistical comparisons for chlorophyll *a* and zooplankton biomass (AFDM) assess the nutrient enrichment hypothesis, whereas statistical comparisons for phytoplankton biomass and zooplankton biomass (enumeration) assess the toxicological impairment hypothesis.
d) Ecological groupings for phytoplankton are cyanobacteria, chlorophytes, microflagellates, dinoflagellates, and diatoms, and for zooplankton are cladocerans, cyclopoids, calanoids, and rotifers.
e) Densities of dominant benthic invertebrate taxa include: Pisidiidae, *Procladius* sp., *Heterotrissocladius* sp., *Micropsectra* sp., *Microtendipes* sp., and *Stictochironomus* sp.
Note: Normal ranges for each LOE group and measurement endpoint are defined and provided in the *AEMP Reference Conditions Report Version 1.4* (Golder 2019a).
AFDM = ash-free dry mass; GSI = gonadosomatic index; K = condition factor; LSI = liversomatic index; CPUE = catch-per-unit-effort; SD = standard deviation; NF = near-field; MF = mid-field; FF = far-field; LOE = line of evidence; > = greater than; < = less than.

2.3.3 Weighting of Endpoints Prior to Integration

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

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

2.3.3.1 *A Priori* Weighting Factors

This first set of weights was established *a priori*, based on professional judgement regarding the strength and relevance of the evidence contributed by each endpoint. Each endpoint was assigned an overall *a priori* weighting based on the product of scores assigned to four *a priori* factors. Each factor was assigned a score ranging from 1 to 3 (i.e., 1 = poor; 2 = satisfactory; 3 = good). The *a priori* weighting factors for each endpoint were:

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

The scores assigned for each factor were originally established through internal discussions and review among senior professionals within Golder Associates Ltd. (Golder) specializing in risk assessment and environmental monitoring, and considering criteria established in previous Golder projects that applied a WOE process to similar monitoring data (e.g., McDonald et al. 2007). Reviewer comments have also contributed to the weighting of specific factors (e.g., comments received from review of the *2007 to 2010 AEMP Summary Report* [DDMI 2011]).

Similar *a priori* weightings for endpoints have been applied since 2008, the first year that the combined toxicological impairment and nutrient enrichment WOE process was applied. However, some new endpoints have also been included and *a priori* weightings for these endpoints were estimated considering similar endpoints in the AEMP.

The *a priori* weighting process is summarized in Table 2-5. The following generalizations are possible regarding the combined *a priori* weighting factors:

- Biological response variables (overall *a priori* weightings of 11.3 to 25) are weighted higher than chemical and nutrient exposure indicators (overall *a priori* weightings of 3.8 to 11.3). Overall, actual biological responses in Lac de Gras are deemed to provide a more direct indicator of potential effects in the aquatic ecosystem than indicators of exposure to nutrients or chemicals because the exposure indicators do not consider the dose-response relationship between exposure and response. Higher weighting for biological response measures is consistent with guidance from the literature that field-based effect studies should be weighted higher than laboratory and chemistry-based analyses (Chapman and Anderson 2005; Wenning et al. 2005; Environment Canada and Ontario Ministry of the Environment 2008).
- For indicators of chemical exposure, sediment chemistry endpoints (overall *a priori* weighting of 7.5) are weighted higher than water chemistry endpoints (overall *a priori* weighting 3.8), primarily because sediment chemistry integrates chemical emissions/exposures in Lac de Gras over time compared to water chemistry, which only provides a “snapshot” of water conditions, which may have considerable temporal variability.
- Indicators of nutrient exposure have higher *a priori* weighting than indicators of chemical exposure because, for an ultra-oligotrophic lake such as Lac de Gras, a response would be expected at any level of enrichment (i.e., the threshold for a biological response is low). Therefore, the potential link to biological responses is clearer for nutrient exposure relative to chemical exposure.
- Differences in the *a priori* weighting of biological response variables are primarily related to the degree of influence that confounding factors have on each endpoint.

Table 2-5 ***A Priori* Weighting Factors Applied to Individual Line of Evidence Endpoints Used in the Weight-of-Evidence Analysis**

LOE - Endpoints	Representativeness		Methodological Robustness		Clarity of Interpretation		Permanence of Effects		Overall Product of Factors
	Weight	Rationale	Weight	Rationale	Weight	Rationale	Weight	Rationale	
Exposure									
Water Quality – Toxicological Parameters	1.0	Samples of water collected at a set of representative stations may be an imperfect representation of spatial and temporal variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.5	Linkage of external chemical concentrations to ecological effects is generally considered weak and prone to multiple confounding factors.	1.0	Water quality varies seasonally depending on the source strength of contaminants from the Mine and the water balance of Lac de Gras.	3.8
Sediment Quality – Toxicological Parameters	2.0	Composite samples of sediment integrate chemical concentrations over time but are an imperfect representations of spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.0	Linkage of sediment concentrations to ecological effects is generally considered weak and prone to multiple confounding factors such as chemical bioavailability and organism sensitivity.	1.5	Mine-related contaminants, in particular metals, could persist in the biologically active zone of sediments for a long period of time. However, the bioavailability of sediment contaminants is likely to be limited.	7.5
Water Quality - Total Nitrogen	1.0	Grab samples of water are an imperfect representation of spatial and temporal variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.5	The linkage between water nitrogen concentrations and primary productivity is relatively well-established. However, for Lac de Gras, phosphorus, rather than nitrogen is expected to be the limiting nutrient; therefore, the influence of nitrogen on primary productivity is less clear.	1.5	Water quality varies seasonally depending on the source strength of contaminants from the Mine and the water balance of Lac de Gras. However, this variable is an indicator or eutrophication, which has a high degree of permanence.	5.6
Water Quality - Total Phosphorus	1.0	Grab samples of water are an imperfect representation of spatial and temporal variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	2.0	The linkage between water phosphorus concentrations and primary productivity is relatively well-established. However, the bioavailability of phosphorus in the water column may change seasonally in response to a variety of factors.	1.5	Water quality varies seasonally depending on the source strength of contaminants from the Mine and the water balance of Lac de Gras. However, this variable is an indicator or eutrophication, which has a high degree of permanence.	7.5
Sediment Total Organic Carbon	2.0	Composite samples of sediment integrate changes in organic carbon over time but are an imperfect representation of spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.0	Sediment organic carbon is an indicator of potential nutrient supply for deposit-feeding benthos. However, it provides a poor representation of nutrient supply for filter-feeding benthos. Many factors that are not related to enrichment (such as grain size and circulation patterns) may also influence organic carbon concentrations in a particular area.	1.5	An enrichment in sediment organic carbon could persist in the biologically active zone of sediments for a relatively long period of time. However, as the sediment organic carbon undergoes diagenesis, it may become a less energy dense or bioavailable supply of nutrients.	7.5
Sediment Total Phosphorus	2.0	Composite samples of sediment integrate changes in total phosphorus overtime but are imperfect representation of spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures, and data analysis techniques.	1.0	The linkage between sediment phosphorus concentrations and primary productivity is dependent on various factors. Bioavailability of phosphors in the sediment and transportation to water column may change seasonally in response to a variety of factors.	1.0	Enrichment of total phosphorus from water column through biotic and abiotic process is a key factor in the assessment of Me-related effects. Phosphorus may accumulate in the sediment and may result in sediment phosphorus to become an important source of phosphorus to the lake water.	5.0
Chlorophyll *a* - exposure	1.5	There is high natural variability in phytoplankton communities. Depending on the composition of the phytoplankton community, chlorophyll *a* may or may not be representative of total biomass However, biomass was monitored at multiple times and locations during the open-water season, reducing the influence of temporal and spatial variability.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis methods.	1.5	Chlorophyll *a* is an indicator of potential nutrient supply for filter-feeding benthos. However, it provides a poor representation of nutrient supply for deposit-feeding benthos and is only an indirect indicator of potential enrichment of the fish community	2.0	Although primary productivity is variable and ephemeral, it is an indicator or eutrophication, which has a high degree of permanence.	11.3

Table 2-5 ***A Priori*** **Weighting Factors Applied to Individual Line of Evidence Endpoints Used in the Weight-of-Evidence Analysis (continued)**

LOE - Endpoints	Representativeness		Methodological Robustness		Clarity of Interpretation		Permanence of Effects		Overall Product of Factors
	Weight	Rationale	Weight	Rationale	Weight	Rationale	Weight	Rationale	
Biological Responses									
Chlorophyll *a* - response	1.5	High natural variability in plankton communities. Although the plankton communities were monitored at multiple times and locations during the open water season, migration, aggregation, and predation can lead to patchy distributions that are difficult to characterize in field studies.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis methods.	2.0	Changes in community-level measures such as biomass provide a reasonable indicator of ecological effects, but they can also be related to natural processes, habitat differences, and other confounding factors. Community structure indices are subject to additional uncertainty because there is no one "ideal" community structure and differences in these endpoints are likely to occur naturally.	2.0	Although primary productivity and plankton biomass can be variable and ephemeral, they provide an indicator of eutrophication, which has a high degree of permanence.	15.0
Phytoplankton Biomass (enumeration)	1.5		2.5		2.0		2.0		15.0
Zooplankton Biomass (AFDM and Enumeration)	1.5		2.5		2.0		2.0		15.0
Phytoplankton Community Structure	1.5		2.5		1.5		2.0		11.3
Zooplankton Community Structure	1.5		2.5		1.5		2.0		11.3
Total Invertebrate Density	2.0	Moderate natural spatial variability and patchiness in zoobenthos communities mean that accurate characterization in field studies is challenging.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis techniques.	2.0	Total invertebrate density and richness provide a reasonable indicator of ecological effects, but they can also be related to natural processes, habitat differences, and other confounding factors. Benthic community indices, densities of dominant taxa, and relative abundance are subject to additional uncertainty because there is no one "ideal" community structure, and differences in these endpoints are likely to occur naturally.	2.0	Larval and resident invertebrates have low mobility; recolonization and regrowth of affected populations, or recovery to pre-enrichment conditions will take time. Recovery will be faster in areas dominated by aquatic insect larvae because of relatively high dispersal by adult life stages and therefore the permanence of effect weighting is lower for insects than for other taxa such as Pisidiidae.	20.0
Density of Pisidiidae	2.0		2.5		1.5		2.5		18.8
Density of Other Dominant Taxa	2.0		2.5		1.5		2.0		15.0
Benthic Richness	2.0		2.5		2.0		2.5		25.0
Simpson's Diversity Index	2.0		2.5		1.5		2.5		18.8
Other Benthic Community Indices(a)	2.0		2.5		1.5		2.0		15.0

Table 2-5 ***A Priori*** **Weighting Factors Applied to Individual Line of Evidence Endpoints Used in the Weight-of-Evidence Analysis (continued)**

LOE - Endpoints	**Representativeness**		**Methodological Robustness**		**Clarity of Interpretation**		**Permanence of Effects**		**Overall Product of Factors**
	Weight	**Rationale**	**Weight**	**Rationale**	**Weight**	**Rationale**	**Weight**	**Rationale**	
Fish Population Structure - survival	2.5	There is natural variability in forage fish communities - energy expenditure/stores, reproductive investment, can catchability can vary seasonally and inter-annually. However, fish populations represent a higher-level of organization in aquatic communities, meaning that effects to fish health are indicative of wider ecosystem impacts.	2.5	Methodologies are well established, with accepted QA/QC measures and data analysis methods.	1.5	Energy stores and reproductive investment measures in the field have clear relevance to ecological effects, and increased incidence of parasitism can be linked to a source of stress on fish health. The fish population structure and Age 1 abundance measurements are uncertain due to uncertainty in the ageing of slimy sculpin; therefore, apparent effects could be an artifact of the aging process rather than actual health effects. Clarity of interpretation for CPUE was treated similar to that of the Fish Reductive Success given that CPUE is a measure of fish relative abundance.	2.0	There is likely low resilience of fish populations to a high incidence of deformities. Impacts to population structure would take generations to recover. Energy expenditure/stores and reproductive investment affect long-term productivity and stability of populations. Performance of effects for CPUE was treated similar to that of the Fish Reductive Success given that CPUE is a measure of fish relative abundance.	18.8
Fish Population Structure - size	2.5		2.5		1.5		2.0		18.8
Growth – Size at Age	2.5		2.5		2.0		2.0		25.0
Energy Stores - K	2.5		2.5		2.0		2.0		25.0
Fish Energy Stores - LSI	2.5		2.5		2.0		2.0		25.0
Relative Reproductive Success - Age 1 abundance	2.5		2.5		1.5		2.0		18.8
Fish Reproductive Investment - GSI	2.5		2.5		2.0		2.0		25.0
Tapeworm Parasitism - Occurrence	2.5		2.5		2.0		2.0		25.0
Fish Capture Data – CPUE	2.5		2.5		1.5		2.0		18.8

a) = Evenness, dominance, Bray-Curtis distance, relative abundance of dominant taxa.

AFDM = ash-free dry mass; LSI = liversomatic index; K = condition factor; GSI = gonadosomatic index; CPUE = catch-per-unit-effort; QA/QC = quality assurance/quality control; LOE = line of evidence.

2.3.3.2 Direction-weighting Factors

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

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

As with the *a priori* factors, the direction-weighting factors were based on the professional judgement of Golder scientists experienced in ERA and environmental effects monitoring (McDonald et al. 2007), combined with consideration of reviewer comments (e.g., comments received from review of the *2007 to 2010 AEMP Summary Report* [DDMI 2011]). The following levels of support and numerical ratings were applied:

- **High (1.0)**: The direction of change or relationship only supports one of the hypotheses. There are no situations where the direction of change or relationship would be expected under the alternative hypothesis.
- **Moderate (0.75)**: The direction of change or relationship supports one of the hypotheses under most situations. However, it is possible that under certain conditions, the direction of change or relationship would be expected under the alternative hypothesis.
- **Neutral (0.5)**: The direction of change or relationship could support either hypothesis.
- **Low (0.25)**: The direction of change or relationship supports the alternative hypothesis under most situations.
- **None (0)**: The direction of change or relationship only supports the alternative hypothesis.

The support levels presume that nutrient enrichment or toxicological impairment are the only factors acting on endpoints in Lac de Gras (i.e., they answer the question: “If nutrient enrichment or toxicological impairment are the only factors acting on endpoints, what is the degree of support for each hypothesis under a given direction of endpoint change or relationship?”). The potential influences of confounding factors, natural variability, and uncertainty are represented in the *a priori* and *a posteriori* weighting factors. For a given change or relationship in an endpoint, the direction-weighting factors summed to 1 (e.g., if a given endpoint response provided 0.75 proportional support to the nutrient enrichment hypothesis, then the corresponding support for the Toxicological Impairment Hypothesis was 0.25). Direction-weighting factors were not applied for endpoints in exposure LOE groups because the direction of effect is implicit in the effect ratings for these endpoints. The direction-weighting factors that were applied to endpoint results where an effect was observed, depending on the direction of change or relationship, are presented in Table 2-6.

Table 2-6 Direction-Weighting Factors Applied to Endpoint Results

Line of Evidence	Endpoint	Direction of Change in Endpoint or Relationship of Endpoint with Effluent Exposure			
		Increase or Positive Relationship		Decrease or Inverse Relationship	
		Support for Nutrient Enrichment Hypothesis	Support for Toxicological Impairment Hypothesis	Support for Nutrient Enrichment Hypothesis	Support for Toxicological Impairment Hypothesis
Biological Productivity	Chlorophyll *a*	1	0	0	1
	Phytoplankton Biomass (Enumeration)	1	0	0	1
	Zooplankton Biomass (AFDM)	1	0	0	1
	Zooplankton Biomass (Enumeration)	1	0	0	1
	Phytoplankton Community Structure	1	0	0.5	0.5
	Zooplankton Community Structure	1	0	0.5	0.5
Benthic Invertebrates	Total Invertebrate Density	1	0	0	1
	Density of Pisidiidae and Other Dominant Taxa	0.75	0.25	0.25	0.75
	Percent Chironomidae	0.75	0.25	0.25	0.75
	Richness	1	0	0.5	0.5
	Benthic Community Indices(a)	0.5	0.5	0.5	0.5
Fish Population Health	Growth – Size at Age	1	0	0	1
	Energy Stores - K	1	0	0	1
	Energy Stores - LSI	0.75	0.25	0	1
	Relative Reproductive Success - Age 1 abundance	1	0	0.25	0.75
	Reproductive Investment - GSI	1	0	0	1
	Tapeworm Parasitism - Occurrence	0	1	1	0
	Fish Capture Data—CPUE	1	0	0	1

a) Simpson's diversity index, evenness, dominance, Bray-Curtis distance, relative abundance of dominant taxa.

AFDM = ash-free dry mass; LSI = liversomatic index; K = condition factor; GSI = gonadosomatic index; CPUE = catch-per-unit-effort; LOE = line of evidence.

The rationales for the various direction-weighting factors were as follows:

- An increase in biomass and total density indicators for plankton and benthos provides a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis. In the absence of other factors, this response would only be expected if nutrient enrichment were occurring. The converse is also true for biomass and density endpoints, where decreases provide a high level of support for the Toxicological Impairment Hypothesis.
- An increase in benthic invertebrate richness provides a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis. For decreases in benthic invertebrate richness, the cause can be equivocal (0.5 support for either hypothesis), indicating that either selective toxicity is occurring to certain species, or that certain species are benefiting from enrichment disproportionately relative to other species, lowering richness as fewer species dominate the system.
- Interpretation of shifts in phytoplankton or zooplankton community structure with respect to relative support for each hypothesis is improved by consideration of other endpoints in the LOE group and the direction of change in richness. The rationale for interpreting the direction of change in richness is similar to that for benthos; community structure shifts, combined with increases in richness provide a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis, whereas community structure shifts combined with decreases in richness are equivocal (0.5 support for either hypothesis).
- Family-specific or genus-specific indicators of biomass (e.g., density of Pisidiidae and other dominant taxa) follow a similar pattern to community-level biomass endpoints, except that the degree of support for each hypothesis is only moderate. For these endpoints, an increase or positive relationship normally supports the Nutrient Enrichment Hypothesis, whereas the converse normally supports the Toxicological Impairment Hypothesis (i.e., direction-weighting of 0.75). However, there are situations where these endpoints could potentially respond differently than expected when an ecosystem is influenced by enrichment or toxicity. For example, if toxicity acted selectively on a particular genus or family, this could give a competitive advantage to a tolerant genus or family that occupied a similar niche and, in this case, the density of this tolerant genus or family might be expected to increase. In these situations, *a posteriori* weighting (discussed in Section 2.3.3.3) can be useful.
- Multiple indicators of community structure for benthos (i.e., diversity, evenness, dominance, Bray Curtis distance, and relative abundances of dominant taxa) are typically equivocal with respect to supporting each impact hypothesis. These endpoints can indicate a change relative to the FF area; however, the cause of change in the biological community is less clear because there is no one "ideal" community structure, and differences in these endpoints are likely to occur naturally. A positive or negative change in these endpoints could support either impact hypothesis; their direction-weighting is neutral (0.5).
- Responses in the number of older/larger fish in a population (i.e., survival) are often equivocal. An increase could be due to lower survival of juveniles (i.e., toxic effect), which changes population proportions and competition for larger fish, or increased nutrient supply, which is better utilized by older/larger fish. The converse is also true, with decreases in the number of older/larger fish being related to lower overall survival (toxic effect), to enrichment that is disproportionally beneficial to smaller fish, or to neither.
- Increased growth, energy stores, and reproductive investment in fish are likely a reflection of greater abundance of resources (i.e., enrichment), whereas decreases in these endpoints may reflect toxicity and would not be expected to result from nutrient enrichment. Clear-cut direction weighting factors are

applied, with an increase indicating nutrient enrichment (1.0 or 100% support) and a decrease indicating toxicological impairment (1.0 or 100% support).

- Age-1 abundance is a less certain indicator of reproductive investment because decreased Age-1 abundance could be due to lower survival of juveniles (toxic effect, weighted at 0.75), or (less likely) an increased nutrient supply (enrichment effect, weighted at 0.25), better-utilized by older/larger fish, which in turn puts predatory pressure on smaller fish. An increase in Age-1 abundance provides a high level of support (1.0 or 100% support) for the Nutrient Enrichment Hypothesis.
- Increased liver size might indicate an increase in glycogen stores related to nutrient enrichment (weighting of 0.75), but in certain situations might indicate toxicological stress (i.e., abnormality; weighting of 0.25). Decreased liver size may also result from toxicological stress (1.0 or 100% support) but is unlikely to be caused by nutrient enrichment alone.
- An increase in occurrence of tapeworm parasitism is likely related to decreased resistance as a result of stress (i.e., toxicity). Conversely, decreased parasitism might be due to an increased resistance of fish due to less stress.
- An increase in CPUE in fish is likely a reflection of greater abundance of resources (i.e., enrichment), whereas a decrease in CUPE may reflect either toxicity or an effect of persistent harvesting pressure from the lethal fish surveys associated with the AEMP. A decrease in CPUE would not be expected to result from nutrient enrichment.

2.3.3.3 *A Posteriori* Weighting Factors

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

- **Coherence of Response**: This factor reflects consistency in response among the individual endpoints within an LOE group (i.e., similarity of findings from multiple exposure endpoints or biological response endpoints). Coherence of response was scaled from 0.25 to 0.75 for all LOE. The endpoint results within an LOE group were down-weighted if the constituent endpoints in the LOE group responded inconsistently.
- **Strength of Linkage**: This factor reflects correspondence between endpoint results and their causative agents. For exposure endpoints, this includes evidence that changes in chemical concentrations are related to Mine activities (e.g., spatial gradients). For biological response endpoints, this includes exposure-effect relationships in endpoints that showed effects, and especially in the endpoint with the highest weighted score. An endpoint was down-weighted if there was no evidence for a linkage between observed responses and causative agents. Strength of linkage was scaled from 0.25 to 0.75 for all LOE.

The values for strength of linkage and coherence of response were added to generate a combined *a posteriori* weighting factor. Combinations of “medium-medium” or “high-low”, therefore result in a combined *a posteriori* weighting factor of 1.0 (i.e., no change in the weight of the endpoint). Combinations of “low-low” result in a combined *a posteriori* weighting factor of 0.5 (i.e., halving the weight of the endpoint), whereas combinations of “high-high” result in a combined *a posteriori* weighting factor of 1.5 (i.e., increasing the weight of the endpoint).

The *a posteriori* weighting factors were applied once the AEMP results for 2019 were known; further discussion is provided in Section 3.2.

2.3.4 Integration of Observed Effects and Weighting Factors

2.3.4.1 Overview

Separate WOE ratings were estimated for each impact hypothesis. Within each WOE analysis, integrated WOE numerical scores for each of the ecosystem components were calculated as the sum of the highest scores (after weighting) for individual endpoints in each type of LOE group (exposure and biological response). The final WOE score was based on the addition of the final scores for the two LOE groups. The numerical scores for each ecosystem component were converted back to the EOI Ranking.

The numerical scores for each ecosystem component were converted back to a final, semi-quantitative EOI ranking. The EOI consists of four rankings:

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

The EOI rankings primarily provide an indication of strength of evidence with respect to the impact hypotheses associated with apparent effects on a particular ecosystem component. This strength of evidence serves to inform, along with other considerations such as ecological significance and feasibility of solutions/actions, response plans when Action Levels are triggered under the AEMP Response Framework.

A stronger EOI ranking is not necessarily intended to indicate that a higher or more intensive level of follow-up is needed. For example, a strong EOI for a given ecosystem component might support the conclusion that there is high confidence in the monitoring program for this component, meaning that an equal or lower level of effort could be considered for future monitoring. Conversely, a lower EOI due to uncertainty or less sensitive endpoints might provide an indication that this aspect of the monitoring program needs to be improved or expanded.

2.3.4.2 Calibration of EOI Rankings

Calibration of final numerical scores to the EOI Ranking scale was necessary to formulate EOI Rankings that were consistent with the level of effect ratings, and *a priori* weightings for endpoints. This calibration was achieved by “solving” for the numerical score for all hypothetical outcomes of the WOE framework using the average *a priori* weighting factors, while assuming that the direction of effect completely supported a particular hypothesis (i.e., direction-weighting of 1.0), and that the *a posteriori* weighting factors were neutral (i.e., values of 0.5 for both coherence of response and evidence of causality).

A summary of the calibration process is provided in Table 2-7. Solving for each possible combination of the two LOE categories generated a series of hypothetical numerical scores. Note that for some effect combinations, two hypothetical scores were possible because the contaminant exposure endpoints had different average *a priori* weighting than the nutrient exposure endpoints. The same calibration was applied for both impact hypotheses.

Table 2-7 Calibration of Final Weight-of-Evidence Ratings and Numerical Scores for Toxicological Impairment and Nutrient Enrichment Hypotheses, 2019

	Semi-Quantitative Effect Rating		Numerical WOE “Score”(a)	WOE Score Threshold	EOI Ranking	Description
	Biological Response LOE Groups	**Exposure LOE Groups**				
Possible Effect Rating Combinations	0	0	0	<10	**0**	**Negligible Evidence of Impact** This category includes scenarios where biological response endpoints indicate negligible effects and exposure endpoints are negligible to moderate, or where an early warning/low-level effect is apparent for biological response endpoints which is not attributable to exposure.
	↑/↓	0	9.6			
	0	↑	2.7-4.5			
	0	↑↑	5.3-9.0			
	↑/↓	↑	12.3-14.1	≥10	**1**	**Low Evidence of Impact** This category includes scenarios where: (a) moderate-level effects are observed in biological response endpoints that are not explained by exposure endpoints; (b) early warning/low-level effects in biological response endpoints are attributable to early warning/low-level or moderate-level effects for exposure endpoints; or, (c) where high-level effects are apparent for exposure endpoints but the effect levels for biological response endpoints are negligible.
	↑/↓	↑↑	14.9-18.6			
	↑↑/↓↓	0	19.2			
	0	↑↑↑	10.6-17.9			
	↑/↓	↑↑↑	17.6-20.2	≥20	**2**	**Moderate Evidence of Impact** This category includes scenarios where: (a) high-level effects for exposure endpoints coincide with early warning/low-level or moderate-level effect ratings for biological response endpoints; (b) moderate effects for biological response endpoints are attributable to early warning/low-level or moderate-level effect ratings for exposure endpoints; or, (c) high-level effects are apparent for biological response endpoints, even though exposure endpoint responses are rated as negligible.
	↑↑/↓↓	↑	21.9-23.7			
	↑↑/↓↓	↑↑	24.5-28.2			
	↑↑/↓↓	↑↑↑	29.8-37.1			
	↑↑↑/↓↓↓	0	38.4			
	↑↑↑/↓↓↓	↑	41.1-42.9	>40	**3**	**Strong Evidence of Impact** This category includes all scenarios where high-level effects are apparent for biological response endpoints and any effects greater than negligible are observed for exposure endpoints.
	↑↑↑/↓↓↓	↑↑	43.7-47.4			
	↑↑↑/↓↓↓	↑↑↑	49.0-56.3			

a) The average *a priori* weighting factor for the Contaminant Exposure LOE was 5.3, for Nutrient Exposure the LOE was 9.0, and for all Biological Response the LOE was 19.2. The direction-weighting factors and *a posteriori* weighting factors were set to 1.0 for the purpose of this calibration process.
LOE = line of evidence; WOE = weight-of-evidence; EOI = evidence of impact; > = greater than; ≥ = greater than or equal to; < = less than.

A range of these scores was identified for each semi-quantitative EOI rating:

- **EOI Rank 0 (Negligible Evidence of Impact)**: Numerical scores less than 10 were considered to represent an overall ranking of negligible for that particular ecosystem component.
- **EOI Rank 1 (Low Evidence of Impact)**: Numerical scores between 10 and 20 were considered to represent an overall ranking of low for that particular ecosystem component. This low EOI rank indicates that there are corresponding changes in exposure and resulting biological responses in the NF area, but that the potential for a wide-spread change in Lac de Gras is low.
- **EOI Rank 2 (Moderate Evidence of Impact)**: Numerical scores between 20 and 40 were considered to represent an overall WOE rating of moderate for the particular ecosystem component. This moderate EOI rank indicates that changes in exposure and biological response have occurred in Lac de Gras that exceed the early warning/low-level rating either in magnitude or spatial scale. The actual ecological significance of effects or changes depends on their magnitude. If changes are expected to be ecologically significant, this EOI rank would warrant increased concern, and this would be a consideration for Action Level response planning.
- **EOI Rank 3 (Strong Evidence of Impact)**: Numerical scores exceeding 40 were considered to represent an overall WOE rating of strong for the particular ecosystem component. This strong EOI rank indicates that a change has occurred in Lac de Gras that is: (i) equal to the magnitude of the moderate-level rating but great in spatial scale; or, (ii) exceeds the moderate-level rating. For this EOI rank, it can be concluded that there is a potential for a spatially wide-spread change in Lac de Gras. The actual ecological significance of effects or changes depends on their magnitude. If changes are expected to be ecologically significant, this EOI rank would warrant a high level of concern, and this would be a strong consideration for Action Level response planning.

3 RESULTS AND DISCUSSION

This section applies the effect rating scheme from Section 2.3.2 to classify the AEMP component findings, sets the *a posteriori* weighting for the WOE analysis, and then applies the WOE framework to characterize the degree of support for each impact hypothesis.

3.1 Effect Rating Results for Component Findings

The resulting effect level ratings for all endpoints were based on the analysis and findings of the component reports (see Appendices II, III, IV, V, XI, XIII). Summaries of the effect level results for WQ, sediment quality, fish tissue quality, eutrophication indicators, plankton, benthic invertebrates, and fish health are provided in the following subsections.

3.1.1 Water Quality

Table 3-1 lists the effects ratings for each of the WQ parameters that were identified as effluent SOIs in 2019. Sixteen effluent SOIs (i.e., total dissolved solids [calculated], turbidity [laboratory], calcium, chloride, magnesium, sodium, sulphate, ammonia, nitrate, aluminum, barium, chromium, copper, lead, manganese, molybdenum, silicon, strontium, and uranium) satisfied the requirement for an early warning/low-level rating, because concentrations in the NF area were significantly greater than both the normal range for Lac de Gras and two times the median of the FF areas; however, NF area concentrations were less than AEMP aquatic life Effects Benchmarks at all stations. Therefore, a moderate-level rating was not applied to any of the effluent SOIs.

Toxicity test results demonstrated no lethality to aquatic test organisms in all eight treated effluent samples submitted for lethal testing. No sublethal effects were demonstrated in the eight effluent samples submitted for sublethal testing.

Table 3-1 Effect Ratings for Water Quality Results, 2019

Measurement Endpoint Analysis	Parameter	Rating
Comparison to FF Areas, Gradient Analysis, Normal Range, and Benchmarks	Total dissolved solids, calculated	↑
	Turbidity	↑
	Calcium	↑
	Chloride	↑
	Magnesium	↑
	Sodium	↑
	Sulphate	↑
	Ammonia	↑
	Nitrate	↑
	Aluminum	↑
	Barium	↑
	Manganese	↑
	Molybdenum	↑
	Silicon	↑
	Strontium	↑
	Uranium	↑
	Remaining parameters	No Response

↑ = early warning/low-level rating; FF = far-field.

3.1.2 Sediment Quality

Table 3-2 lists the effect ratings for sediment quality parameters. Twelve parameters in 2019 were identified as SOIs in sediment (i.e., a trend of decreasing concentration with distance from the Mine effluent diffusers; or an elevated concentration in the NF area compared to the FF areas), all of which had either a significant difference between NF and FF areas or a significant decreasing trend for at least one transect resulting in a low-level rating, with exception for total phosphorus which was associated with no response rating. Five of these SOIs (bismuth, lead, molybdenum, strontium and uranium) also had median NF concentrations that were greater than their respective normal ranges, which is one of the requirements for classification as a moderate-level rating. Considerations regarding sediment quality guidelines were:

- Sediment quality guidelines for bismuth do not currently exist and information regarding bismuth toxicity in aquatic sediments has not been published. Results of the 2010 dike monitoring study (DDMI 2011), and the past six AEMP benthic invertebrate surveys (Golder 2008, 2009, 2010, 2011, 2014, 2016) detected no toxicity-related effect on the benthic or fish communities in areas of Lac de Gras with bismuth concentrations above the background range.

- In 2019, the median and maximum concentrations observed for lead in the NF area were 12.8 mg/kg dw and 25.2 mg/kg dw, respectively. These concentrations were below the OMOEE lowest effect level (LEL) for lead of 31 mg/kg dw and the CCME ISQG of 35 mg/kg dw. Therefore, sediment toxicity to aquatic biota in the NF area due to lead is not expected.
- CCME or OMOEE sediment quality guidelines do not exist for uranium. The primary route of exposure of aquatic organisms to uranium is likely from the water, rather than through food or sediment (ingestion of sediment is a possible route of exposure, though likely minimal) (CCME 2011). Sheppard et al. (2005) reported a predicted no-effect level for freshwater benthos of 100 mg/kg dw. More recently Goulet and Thompson (2018) predicted median lethal concentrations for uranium of juvenile and adult *Hyalella azteca* of 48 and 214 mg/kg respectively, a much smaller concentration than observed in other studies (Liber et al 2011). Goulet and Thompson (2018), however, had intentionally increased porewater concentrations by spiking sodium carbonate which made uranium available for uptake. Uranium, at a median concentration of 14.6 mg/kg dw (maximum of 17.2 mg/kg dw) in the NF area, and ranging up to 10.2 mg/kg dw at stations in the MF area, is thus unlikely to pose a toxicological risk to aquatic biota, particularly as uranium bioavailability is reduced by complexation with humic substances and inorganic ligands found in sediments (Lenhart et al. 2000; Markich 2002; Liber et al 2011; Trenfield et al. 2011a, b, 2012; Goulet and Thompson 2018).
- Molybdenum toxicity to *Hyalella azteca* was tested by Liber et al (2011), the authors were not able to detect any effects of molybdenum concentrations on either survival or growth of the amphipod tested even at concentration of up to 3,742 mg/kg. Median concentration in the NF area in 2019 was 11.5 mg/kg.
- CCME or OMOEE sediment quality guidelines do not exist for strontium. No studies on the toxicity of strontium in sediments have been identified; however, strontium does not generally pose concern in aquatic environments (Chowdhury and Blust 2012). The maximum observed sediment strontium concentration in NF area is 43 mg/kg; strontium does not have a strong affinity for sediment and is expected to be highly mobile and readily enter water (US EPA 1999; ECHA 2019). Environment and Climate Change Canada (ECCC) provides a toxicological based Federal Environmental Quality Guideline (FEQG) of 1.7 mg/L for strontium in water (ECCC 2019). The observed maximum NF strontium water concentration of 0.09 mg/L is well below the suggested FEQG and thus unlikely to pose a toxicological risk to aquatic life.
- Based on these considerations, in addition to the low biomagnification potential of the above SOIs, (Chapman 2008; Chowdhury and Blust 2012), bismuth, lead, strontium, and uranium do not meet the requirements for classification as a moderate effect level.

Table 3-2 Effect Ratings for Sediment Quality Results, 2019

Measurement Endpoint Analysis	Parameter	Rating
Comparison to FF Areas, Gradient Analysis, Normal Range, and Guidelines	Total Bismuth	↑
	Total Lead	↑
	Total Molybdenum	↑
	Total Uranium	↑
	Total Lithium	↑
	Normalized Total Potassium	↑
	Normalized Total Silver	↑
	Normalized Total Sodium	↑
	Normalized Total Strontium	↑
	Total Tin	↑
	Total Titanium	↑
	Total Phosphorus	No Response
	Remaining Parameters	No Response

↑ = early warning/low-level rating; FF = far-field.

3.1.3 Fish Tissue Chemistry

Effect ratings were determined for a total of six metals in Slimy Sculpin which had NF area mean tissue concentrations that were statistically greater than the FF area mean concentrations (Table 3-3). Lead and vanadium concentrations did not exceed normal ranges in the NF area and were assigned a low-level rating. Molybdenum concentrations exceeded the normal range in the NF area, but not the MF area and was assigned a moderate-level rating. Silver, strontium and uranium had tissue concentrations in the NF and MF areas that were greater than the normal range, resulting in a high-level rating.

Table 3-3 Effect Ratings for Fish Tissue Chemistry Results, 2019

Measurement Endpoint Analysis	Parameter	Rating
Comparison to FF Areas and Normal Range	Lead	↑
	Molybdenum	↑↑
	Silver	↑↑↑
	Strontium	↑↑↑
	Uranium	↑↑↑
	Vanadium	↑
	Remaining variables	No Response

↑ = early warning/low-level rating; ↑↑ = moderate-level rating; ↑↑↑ = high-level rating; FF = far-field.

3.1.4 Eutrophication Indicators

The effects ratings for eutrophication indicators are provided in Table 3-4. For total phosphorus (TP), statistical differences between NF and FF or spatial gradients were not analyzed because of the high frequency of non-detect values (i.e., 70% non-detect values in ice-cover, and 65% non-detect values in open-water). Measured TP concentrations were below the upper bound of the normal range across Lac de Gras. Therefore, a no response rating was determined for TP. The mean concentration of total nitrogen (TN) in the NF area exceeded the upper bound of the normal range and the affected area covered most of Lac de Gras, resulting in a high-level rating. Chlorophyll *a* concentrations in the NF area were significantly greater than the FF areas and there was a significant gradient along the MF1 and MF3 transects, but the mean concentration in the NF was within the normal range, resulting in a low-level rating. Phytoplankton biomass was not significantly different between NF and FF and no significant gradients were identified, resulting in a rating of no response. Zooplankton biomass (i.e., ash-free dry mass [AFDM]) was statistically greater in the NF area relative to FF areas and there was a significant gradient along the MF1 and MF3 transects. Mean zooplankton biomass in the NF exceeded the upper limit of the normal range, and the area of the lake with biomass above the normal range was greater than 20%, resulting in a high-level rating.

Table 3-4 Effect Ratings for Eutrophication Indicators, 2019

Measurement Endpoint Analysis	Measurement Endpoint	Rating	Type of Effect[(a)]
Statistical Analysis and Comparison to Normal Range	Total phosphorus	0	n/a[(a)]
	Total nitrogen	↑↑↑	n/a[(a)]
	Chlorophyll *a*	↑	Nutrient Enrichment
	Phytoplankton biomass	0	None
	Zooplankton biomass (AFDM)	↑↑↑	Nutrient Enrichment

a) Type of effect was only inferred for biological response endpoints (i.e., chlorophyll *a*, phytoplankton biomass, and zooplankton biomass).

Note: For biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the FF areas.

↑/↓ = early warning/low-level rating; ↑↑↑/↓↓↓= high-level rating; AFDM = ash-free dry mass; FF = far-field.

3.1.5 Plankton Community

The effects ratings for the plankton community are provided in Table 3-5. The rationale for the effect ratings assigned to the endpoints measured in 2019 was:

- Phytoplankton biomass (by enumeration): Mean total phytoplankton biomass was not significantly lower in the NF area relative to the 2019 FF area mean or the reference condition mean, and did not show spatial gradients along the NF-MF-FF transects. Mean biomass was also within the normal range, resulting in a no response rating in 2019.
- Phytoplankton community composition: Phytoplankton community composition based on the relative phytoplankton abundance/biomass plots, nMDS and analysis of similarities (ANOSIM) results resulted in a no response rating in 2019.
- Zooplankton biomass (by enumeration): Mean total zooplankton biomass was greater in the NF area relative to the 2019 FF area mean and the reference condition mean, and was above the upper

boundary of the normal range. Total biomass showed a decreasing spatial gradient along the MF3 transect, resulting in an early warning or low response rating in 2019 for nutrient enrichment.

- Zooplankton Community Composition: A low-level rating was applied to zooplankton community composition based on the relative zooplankton abundance/biomass plots and nMDS plots. In terms of mean relative biomass, the zooplankton community in the NF area had smaller proportions of cladocerans and calanoid copepods compared to the FF areas and greater proportions of cyclopoid copepods. The nMDS ordination plot shows separation in terms of zooplankton community composition between the NF area and the FF areas. Cyclopoid copepod biomass and rotifer biomass were significantly greater in the NF area compared to the FF areas in 2019 and cladoceran, rotifer and copepod biomass were all above the normal range. Decreasing biomasses of cladocerans (MF3), rotifers (MF1 and MF2) and copepods (MF1 and MF3) were observed on one or more transects in 2019, indicating nutrient enrichment. Calanoid copepod biomass was the only variable that showed significantly lower biomass in the NF area compared to the reference conditions mean.

The 2019 zooplankton results suggest that changes are occurring in the NF area of Lac de Gras compared to the FF areas and compared to reference conditions. These changes suggest nutrient enrichment is occurring.

Table 3-5 Effect Ratings for Plankton Results, 2019

Measurement Endpoint Analysis	Measurement Endpoint	Rating	Type of Effect
Comparison to FF Areas and Reference Conditions	Phytoplankton Biomass (based on enumeration)	0	No Response
	Phytoplankton Community Structure	0	No Response
	Zooplankton biomass (based on enumeration)	↑	Nutrient Enrichment
	Zooplankton Community Structure	↑/↓	Nutrient Enrichment or Toxicological Impairment

Note:. For biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the FF areas.

↑/↓ = early warning/low-level rating; ↑↑/↓↓ = moderate-level rating; FF = far-field.

3.1.6 Benthic Invertebrates

The effects ratings for the benthic invertebrate community are provided in Table 3-6. The rationale for the effect ratings assigned to the endpoints measured in 2019 was as follows:

- Total Invertebrate Density: Mean total density in the NF area was within the range of FF area means and remained within the normal range, resulting in a no response rating.
- Richness: Mean richness did not vary significantly among sampling areas, but exhibited a significant increasing gradient with distance from the diffusers along the MF1 gradient. Values in the NF area remained within the normal range, resulting in a low-level rating.
- Dominance: Mean dominance in the NF area was within the range of FF area means and remained within the normal range, resulting in a no response rating.

- Simpson's Diversity Index: Mean diversity in the NF area was within the range of FF area means and remained within the normal range, resulting in a no response rating.
- Evenness: Mean evenness in the NF area was within the range of FF area means and remained within the normal range. Index values declined significantly along the MF1 gradient with increasing distance from the diffusers, which resulted in a low-level rating.
- Bray-Curtis distance: Mean index value did not vary significantly among sampling areas, and remained within the normal range, resulting in a no response rating.
- Percent Chironomidae: Mean percentage did not vary significantly among sampling areas, but exhibited a significant decreasing gradient with distance from the diffusers along the MF3 gradient. Values in the NF area remained within the normal range, resulting in a low-level rating.
- Pisidiidae Density: Mean density did not vary significantly among sampling areas, but exhibited a significant increasing gradient with distance from the diffusers along the MF2 gradient. Values in the NF area remained within the normal range, resulting in a low-level rating.
- *Procladius* Density: Mean density in the NF area was within the range of FF area means, but exhibited a significant decreasing gradient with distance from the diffusers along the MF3 gradient. Mean density exceeded the upper limit of the normal range in the NF area, and this extended into the MF and some FF areas, resulting in a high-level rating.
- *Heterotrissocladius* Density: Mean density did not vary significantly among sampling areas, but exhibited a significant decreasing gradient with distance from the diffusers along the MF3 gradient. Values in the NF area remained within the normal range, resulting in a low-level rating.
- *Micropsectra* Density: Mean density did not vary significantly among sampling areas, but exhibited a significant increasing gradient with distance from the diffusers along the MF2 gradient. Values in the NF area remained within the normal range, resulting in a low-level rating.
- *Microtendipes* Density: Mean density in the NF area was within the range of FF area means, but exhibited a significant decreasing gradient with distance from the diffusers along the MF3 gradient. Mean density exceeded the upper limit of the normal range in the NF area, and this extended into the MF areas, resulting in a moderate-level rating.
- *Stictochironomus* Density: Mean density did not vary significantly among sampling areas, and remained within the normal range, resulting in a no response rating.
- Relative Abundances of Dominant Taxa: A low-level rating was applied to benthic invertebrate community composition (i.e., relative abundance of dominant taxa) based on relative abundance and nMDS plots. The community composition displayed greater relative densities of Chironomidae and decreased relative densities of Pisidiidae in the NF area. The nMDS showed separation of NF/MF1/MF2/FF1 area stations from the MF3/FFA/FFB area stations.

Generally, the direction of the effects ratings (i.e., the direction of change in the NF area relative to the FF areas) support the nutrient enrichment hypothesis. Increased densities and values were observed above the reference condition mean and beyond the normal range for the majority of benthic invertebrate variables. The distributions of dominant taxa show trends such as increasing densities, particularly among the NF, MF1, MF2-FF2 and FF1 areas, similar to the current effluent dispersion.

Statistically significant gradients were detected for eight of the thirteen benthic invertebrate variables assessed in 2019, including richness, evenness, percent Chironomidae, Pisidiidae density, *Procladius* density, *Heterotrissocladius* density, *Micropsectra* density and *Microtendipes* density. Results of gradient analysis are consistent with Mine-related nutrient enrichment in Lac de Gras, as indicated by mostly decreasing trends in benthic invertebrate variables (e.g., density variables) along the MF3 transect, which represents the longest effluent exposure gradient in Lac de Gras. Variables related to community structure (i.e., richness and community indices) showed fewer significant trends, consistent with a low-level nutrient enrichment effect that results in increased densities of some invertebrates, without structural changes in the community.

Multivariate analysis identified a distinct clustering of sampling areas, with the NF, MF1, MF2 and FF1 areas generally grouped together in terms of community structure, and separated from the MF3 (excluding the most effluent-exposed station), FFA and FFB areas. Overall, these results 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.

Table 3-6 Effect Ratings for Benthic Invertebrate Results, 2019

Measurement Endpoint Analysis	Measurement Endpoint	Rating	Type of Effect
Comparison to FF Areas, Gradient Analysis and Normal Range	Total Invertebrate Density	0	No Response
	Richness	↓	Nutrient Enrichment or Toxicological Impairment
	Dominance	0	No Response
	Simpson's Diversity Index	0	No Response
	Evenness	↑	Nutrient Enrichment or Toxicological Impairment
	Bray-Curtis Distance	0	No Response
	Percent Chironomidae	↑	Nutrient Enrichment or Toxicological Impairment
	Pisidiidae Density	↓	Toxicological Impairment
	Procladius Density	↑↑↑	Nutrient Enrichment
	Heterotrissocladius Density	↑	Nutrient Enrichment
	Micropsectra Density	↓	Toxicological Impairment
	Microtendipes Density	↑↑	Nutrient Enrichment
	Stictochironomus Density	0	No Response
Comparison to nMDS and Relative Density Plots[(a)]	Relative Abundance of Dominant Taxa[(a)]	↑/↓	Nutrient Enrichment or Toxicological Impairment

a) Based on visual evaluation.

Note: For biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the FF areas.

↑/↓ = early warning/low-level rating; ↑↑/↓↓ = moderate-level rating; ↑↑↑/↓↓↓ = high-level rating; FF = far-field.

3.1.7 Fish Population Health

The effects ratings determined for Slimy Sculpin fish health are provided in Table 3-7. Endpoint results for fish health were determined separately for adult (male and female) and juvenile (age-1) Slimy Sculpin, with an overall rating for each endpoint based on integration of the findings for these age and sex-classes. The rationales for the effects ratings were:

- Growth (Size at Age): Adult females and age-1+ Slimy Sculpin were significantly smaller in the NF area relative to either the FF area or reference conditions, but mean values were within normal range. No response was observed for adult males, resulting in an overall low-level effect rating for growth. This observation supports the toxicological impairment hypothesis.
- Energy Stores (K): Condition factor in the NF area was greater for age-1+ fish relative to reference conditions, but mean values were within normal range. No response was observed for adult female or adult male fish, resulting in a low-level effect rating for this endpoint. This observation supports the nutrient enrichment hypothesis.
- Energy Stores (LSI): LSI was lower in the NF area than the FF area for female fish, and greater for age-1+ fish, but mean values were within normal range. There was no response for male fish, resulting in an overall rating of no response.
- Reproductive Investment (Age-1+ Abundance): Age-1+ fish abundance was similar between the NF and FF areas, resulting in a rating of no response.
- Reproductive Investment (GSI): GSI in the NF area presented a contradictory response for female fish (i.e., lower than FF, but greater than reference condition) and was greater for male fish relative to reference conditions. Due to the lack of a consistent response within (i.e., females) and between sexes, the overall rating was no response.
- Tapeworm Parasitism (Occurrence): The occurrence of tapeworms in fish from the NF area was not significantly different from the FF area, resulting in an overall rating of no response.
- Fish Capture Data (CPUE): The relative abundance of Slimy Sculpin (standardized by CPUE) was assessed using a non-lethal relative abundance survey. The relative abundance was similar among sampling areas, ranging from 0.020 fish/100 s effort at MF3 to 0.022 fish/100 s effort at FF2, resulting in a rating of no response.

Table 3-7 Effect Ratings for Fish Health Results, 2019

Endpoint Analysis	Sub-endpoint	Rating				Type of Effect
		Female	**Male**	**Age 1+**	**Overall**	
Comparison of NF to FF Areas and Normal Range	Growth—Size at Age	↓	No response	↓	↓	Toxicological Impairment
	Energy Stores—K	No response	No response	↑	↑	Nutrient Enrichment
	Energy Stores—LSI	↓	No response	↑	No response	-
	Relative Reproductive Success—Age 1 Abundance	n/a	n/a	No response	No response	-
	Relative Reproductive Investment—GSI	↓/↑	↑	n/a	No response	-
	Tapeworm Parasitism—Occurrence	No response			No response	-
	Fish Capture Data—CPUE	No response			No response	-

↓ = early warning/low-level effect for biological metrics; n/a = analysis not conducted sex/age-class; K= condition; LSI = liversomatic index; GSI = gonadosomatic index; CPUE = catch-per-unit-effort; NF = near-field; FF = far-field.

3.2 *A Posteriori* Weighting

As described in Section 2.3.3, *a posteriori* weighting factors for strength of linkage and coherence of response were applied for each endpoint by examining the relationships among endpoints within and between LOE groups.

A summary of the *a posteriori* weighting factors applied for the WOE analyses are provided in Table 3-8. Up-weighting or down-weighting was only relevant for endpoints where non-negligible effects were observed, since a negligible effect was given a numerical score of 0, which would override the weighting factors. It was also only relevant for endpoints with a non-zero score following direction-weighting, since a zero score carried through the analysis regardless of the *a posteriori* weighting.

Table 3-8 ***A Posteriori* Weighting Factors Applied to Measurement Endpoints in the Weight-of-Evidence Analysis, 2019**

LOE	Measurement Endpoint	Strength of Linkage	Coherence of Response	Combined Factor
Toxicological Impairment Hypothesis				
Water Quality	Comparison to FF Areas, Gradient Analysis, Normal Range, and Benchmarks	0.75	0.75	1.5
Sediment Quality	Comparison to FF Areas, Gradient Analysis, Normal Range, and Guidelines	0.75	0.75	1.5
Sculpin Tissue Chemistry	Comparison to FF Areas, Reference Conditions, and Normal Range	0.5	0.25	0.75
Biological Productivity	Zooplankton Community Structure/Richness	0.75	0.25	1.25
Benthic Invertebrates	*Pisidiidae, Procladius*, *Heterotrissocladius*, *Micropsectra*, and *Microtendipes* Density	0.25	0.25	0.5
	Richness	0.25	0.25	0.5
	Evenness	0.25	0.25	0.5
	Percent Chironomidae	0.25	0.25	0.5
	Relative Abundances of Dominant Taxa	0.25	0.25	0.5
Fish Population Health	Growth—Size at Age	0.25	0.25	0.5
Nutrient Enrichment Hypothesis				
Water Quality	Comparison to Normal Range – TN[(a)]	0.75	0.5	1.25
Biological Productivity	Chlorophyll *a*[(b)]	0.75	0.5	1.25
	Zooplankton Biomass (AFDM)	0.75	0.5	1.25
	Zooplankton Biomass (enumeration)	0.75	0.5	1.25
	Zooplankton Community Structure/Richness	0.75	0.5	1.25
Benthic Invertebrates	*Pisidiidae, Procladius*, *Heterotrissocladius*, *Micropsectra*, and *Microtendipes* Density	0.75	0.75	1. 5
	Evenness	0.75	0.75	1. 5
	Percent Chironomidae	0.75	0.75	1.5
	Relative Abundances of Dominant Taxa	0.75	0.75	1. 5

a) Coherence of response for TN was down-weighed *a posteriori* to 0.25 for fish health.

b) Strength of linkage and coherence of response for chlorophyll *a* were maintained *a posteriori* at 0.5 when considered as nutrient exposure endpoints for fish health.

Notes: *A posteriori* weighting factors were not applied for the remaining endpoints because no effect was observed or they had a direction-weighting score of zero. Rationale for up-weighting or down-weighting is described in the text.
AFDM = ash-free dry mass; TN = total nitrogen; FF = far-field; LOE = line of evidence

For the Toxicological Impairment WOE analysis, the considerations that contributed to up-weighting or down-weighting of endpoint results were:

- Water chemistry endpoints: The analysis of effluent chemistry, mixing zone chemistry, and NF, MF, and FF area chemistry suggested a relatively strong link between SOI concentrations and effluent release from the Mine. In addition, a similar magnitude and extent of statistical differences was observed for most of the SOIs (see Effluent and Water Chemistry Report; Appendix II). Based on these findings, both coherence of response and strength of linkage were increased to 0.75 for water chemistry endpoints, resulting in an overall up-weighting in the Toxicological Impairment WOE analysis.
- Sediment chemistry endpoints: Comparison of WQ findings with sediment quality findings indicated correspondence of the low ratings for concentrations of molybdenum, strontium, and uranium in sediment. The multiple sediment metals at the low rating indicated a high coherence of response (weighting increased to 0.75) and the low rating for sediments was interpreted to be linked to Mine operation (weighting increased to 0.75).
- Fish tissue chemistry endpoints: NF and MF tissue concentrations of silver, strontium and uranium resulted in a high-level rating for tissue chemistry. Strontium and uranium were also elevated in sediment and water concentrations (low-level ratings for both components) while silver concentrations were only elevated in sediment (also low-level rating). NF molybdenum tissue concentrations resulted in a moderate-level rating whereas NF lead and vanadium tissue concentrations resulted in a low-level rating. Stable strontium in the environment is not generally considered a concern to aquatic organisms, which is likely the reason that there are no known national WQ criteria for the protection of aquatic life (Wood et al. 2012). Discussions in previous AEMP reports (e.g., Golder 2012) described how elevated metal concentrations (e.g., bismuth, lead, and uranium) in sediments of the NF area might be related to dike construction as opposed to an ongoing and progressive effluent-related effect in Lac de Gras. Although the strength of linkage for tissue chemistry is uncertain, the weighting factor was conservatively maintained at 0.5. Coherence of response was down-weighted to 0.25 because the ratings varied among metals (i.e., some metals such as lead and vanadium received a low-level rating in fish tissue, molybdenum received a moderate-level rating, whereas silver, strontium, and uranium received a high-level rating).
- Biological productivity endpoints: Based on consideration of plankton richness, phytoplankton community structure, chlorophyll *a*, and zooplankton biomass responses, biological productivity endpoint responses did not appear related to toxicological impairment. However, zooplankton community structure response supports the toxicological impairment hypothesis, and therefore, the strength of linkage was up-weighted to 0.75. Given that the direction of response for all other biological productivity endpoints supports the nutrient enrichment hypothesis, the coherence of response was down-weighted to 0.25.
- Benthic invertebrate endpoints: For the endpoints that demonstrated statistically significant gradients, few demonstrated responses consistent with a toxicity effect (e.g., greater rather than lower density in the NF area compared to FF areas). Some of the responses, however, demonstrated lower values (i.e., Pisidiidae and *Micropsectra* density, and richness) and an increase in percent Chironomidae in the NF area compared to the FF areas, which could be interpreted as supporting the toxicological impairment hypothesis. Toxicological effects are unlikely, however, given that sediment quality benchmarks were not exceeded for the SOIs (Sediment Quality Report; Appendix III). Based on these considerations, both strength of linkage and coherence of response for all benthic invertebrate

endpoints were reduced to 0.25 (i.e., down-weighted in the Toxicological Impairment WOE analysis) to reflect the lack of a causality with respect to contaminant releases from the Mine and lack of coherence with the type of responses that would be expected to result from toxicological impairment.

- Fish health endpoints: Water and sediment metals concentrations did not exceed concentrations that were considered of toxicological concern to fish (i.e., did not exceed water quality effects benchmarks or sediment quality guidelines), nor were fish tissue metals concentrations elevated to a degree that would suggest observed responses in the fish populations were related to metals exposure[2]. Therefore, strength of linkage was down-weighted to 0.25 in the Toxicological Impairment WOE analysis. For Growth (Size at Age), the direction of response may be interpreted as supporting the toxicological impairment hypothesis. For Energy Stores (K), the direction of response was indicative of a greater abundance of resources and, therefore, does not support the toxicological impairment hypothesis (and was not carried forward after *a priori* weighting under this scenario). There was no response in any other fish health endpoints; therefore, the coherence of response was reduced to 0.25. The decreased weighting for these fish health responses was also warranted based on the lack of any strong toxicological impairment responses in plankton or benthos. These considerations suggest that the inconsistent fish health responses for 2019 may be due to natural variability related to other ecological or abiotic factors.

For the Nutrient Enrichment WOE analysis, the considerations that contributed to up-weighting or down-weighting of endpoint results were:

- Nutrient exposure endpoints: The analyses of effluent chemistry, mixing zone chemistry, and NF, MF, and FF area chemistry suggested a relatively strong link between effluent release from the Mine, elevated TN concentrations, and an increase in biological productivity and invertebrate biomass; thus, the strength of linkage weighting factor was increased to 0.75. The coherence of response was maintained at 0.5 given the difference in observed responses for both TN (high-level rating) and TP (no response) in 2019. The increase in the strength of linkage weighting factor resulted in an overall up-weighting of TN in the Nutrient Enrichment WOE analysis for lake productivity and benthic invertebrate ecosystem components. Chlorophyll *a* was also used as an exposure endpoint for benthic invertebrates and fish. Benthic invertebrates showed a response that was generally consistent with enrichment; therefore, the up-weighting described above was also applied for chlorophyll *a* as an exposure endpoint. For fish health, the Growth (Size at Age) rating supported Toxicological Impairment, whereas the Energy Stores (K) rating was in support of the Nutrient Enrichment hypothesis. Applying the up-weighting for TN and chlorophyll *a* would have resulted in an unrepresentative EOI Ranking. Therefore, TN and chlorophyll *a* were maintained *a posteriori* when considered as nutrient exposure endpoints for fish health.
- Biological productivity endpoints: Significantly greater chlorophyll *a*, soluble reactive phosphorus (SRP) and TN concentrations in the NF area coincided with increased zooplankton biomass, indicating a relatively strong link between nutrient release in Mine effluent and responses in primary productivity. Because Lac de Gras is P-limited, the role of TN in the overall nutrient enrichment effect observed in the lake is believed to be small; this is also indicated by the correlation between low P and low

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[2] Considering the marginal 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 (See Section 4.2, Table 4-3 in the Fish Report, Appendix V),

productivity in 2019 being coincident with greater N concentrations in 2019 relative to previous years [Eutrophication Indicators, Appendix XIII]). The lack of response in phytoplankton biomass is interpreted to be due to high consumption by the zooplankton community, which is indicated with the high-level response observed in zooplankton biomass. The direction of response for the two measures of zooplankton biomass (i.e., AFDM and enumeration) were consistent although the strength of direction of responses differed; biomass by AFDM increase received a high-level rating, whereas biomass enumeration increase was associated with a low-level rating. Therefore, the strength of linkage for these endpoints was increased to 0.75 (i.e., up-weighted in the Nutrient Enrichment WOE analysis) but the coherence of response was maintained *a posteriori*. Overall, the zooplankton community structure changes are suggestive of nutrient enrichment; therefore, the strength of linkage was upweighted to 0.75.

- Benthic invertebrate endpoints: Where a response was observed for benthic invertebrate endpoints, the direction of response was generally consistent with nutrient enrichment contributed by the Mine effluent, with a shift in community structure proportional to effluent exposure. This pattern included greater *Procladius, Heterotrissocladius,* and *Microtendipes* densities, and altered community structure in the NF area. The lower density observed for Pisidiidae and *Micropsectra* in addition to the reduced richness and decrease in percent Chironomidae observed in the NF area compared to the FF areas could be interpreted as supporting the Toxicological Impairment hypothesis; however, based on the response of other benthic endpoints, it is considered more likely that these responses are a result of nutrient enrichment. Based on these considerations, the strength of linkage and coherence of response for all benthic invertebrate endpoints was increased to 0.75 (i.e., up-weighting in the Nutrient Enrichment WOE analysis).
- Fish population health endpoints: Only two endpoints, Growth (Size at Age) and Energy Stores (K), demonstrated a response for fish population health. The directions of response for the two measures of fish population health were inconsistent and, therefore, coherence of response was down-weighted to 0.25. The decrease in Growth (Size at Age) endpoint is not consistent with the Nutrient Enrichment hypothesis and, therefore, the strength of linkage was decreased to 0.25. In the case of Energy Stores (K), the observed increase is consistent with nutrient enrichment and the strength of linkage was increased to 0.75.

3.3 Weight-of-Evidence Results

The results of the WOE analyses are summarized in Table 3-9. The full analysis, including all endpoints, *a priori*, direction, and *a posteriori* weighting factors, combined scores and EOI Rankings, is provided in Attachment A, Table A-1 (Toxicological Impairment) and Table A-2 (Nutrient Enrichment).

Sources of uncertainty in the assessment of each ecosystem component are discussed in Section 3.4. Detailed discussion regarding the WOE outcome for each of the two impact hypotheses is provided below.

3.3.1 Toxicological Impairment

3.3.1.1 Lake Productivity

Based on statistical comparisons and/or gradient analysis results, early warning low-level effects were concluded for 16 SOIs: total dissolved solids (calculated), turbidity (laboratory), calcium, chloride, magnesium, sodium, sulphate, ammonia, nitrate, aluminum, barium, manganese, molybdenum, silicon, strontium, and uranium.

The endpoint responses for biological productivity did not indicate any toxicity-related decreases in chlorophyll *a* and zooplankton biomass. Rather, these endpoints exhibited changes that were consistent with enrichment, with a high degree of support (direction-weighting of 1.0) for the Nutrient Enrichment hypothesis. The observed minor shift in zooplankton community structure, however, was inconsistent with the other biological productivity endpoints and was associated with a direction weighting of 0.5 for both toxicological impairment and nutrient enrichment.

Combining the weighted scores for biological productivity and water chemistry resulted in a conservative EOI Rank of 0, which represents negligible evidence of toxicological impairment to lake productivity from Mine activities and effluent discharge.

3.3.1.2 Benthic Invertebrate Community

Twelve parameters in 2019 were identified as SOIs in sediment (i.e., based on a trend of decreasing concentration with distance from the Mine effluent diffusers, or an elevated concentration in the NF area compared to the FF areas), all of which had either a significant difference between NF and FF areas or a significant decreasing trend for at least one transect, resulting in a low-level rating, with the exception of total phosphorus, which was associated with a no response rating.

Of the SOIs in sediment, bismuth, lead, molybdenum, strontium and uranium also had median NF concentrations that were greater than their respective normal ranges. However, the concentrations of bismuth, lead, molybdenum, strontium and uranium were considered to be of low toxicological concern (Section 3.1.2). An overall rating of early warning/low-level was applied for eleven sediment parameters: bismuth, lead, lithium, molybdenum, potassium, silver, sodium, strontium, tin, titanium, and uranium.

Based on the direction-weighting factors, although the sixendpoint responses of richness, percent Chironomidae, evenness, Pisidiidae density, *Micropsectra* density, and relative abundances of dominant taxa could potentially support the Toxicological Impairment hypothesis, *Procladius*, *Heterotrissocladius,* and *Microtendipes* density responses did not. Therefore, the endpoint responses were down-weighted for the Toxicological Impairment WOE analysis. Based on the effect level designations for toxicological impairment, the benthic invertebrate community was rated as negligible. However, considering the overall pattern in response, the observed change was considered unlikely to be related to toxicity.

Combining the weighted scores for sediment quality and benthic invertebrates resulted in an EOI Rank of 0, which represents negligible evidence of toxicological impairment to the benthic invertebrate community from Mine activities and effluent discharge.

Table 3-9 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.

EOI = evidence of impact; LOE = line of evidence; 0 = Negligible; ↑/↓ = Early warning/low; ↑↑/↓↓ = Moderate; ↑↑↑/↓↓↓ = High; n/a = not applicable.

3.3.1.3 Fish Community

The exposure indicator with the highest weighting for fish health was Slimy Sculpin tissue chemistry. Six metals (i.e., lead, molybdenum, silver, strontium, uranium, and vanadium) had NF area mean concentrations that were significantly greater than the FF area mean concentrations. Of these, lead and vanadium concentrations did not exceed normal range in the NF area, resulting in a low-level rating. Molybdenum concentrations exceeded the normal range in the NF area but not the MF area and, therefore, was assigned a moderate-level rating. Silver, strontium, and uranium had tissue concentrations in the NF and MF areas that were greater than the normal range, resulting in a high-level rating. As discussed in Section 3.2, there was uncertainty as to whether these elevated metals in fish tissues were related to effluent release from the Mine, and the effect ratings varied among metals, so an overall down-weighting of 0.75 was applied in the WOE analysis.

The pattern of response in fish health endpoints measured for Slimy Sculpin included significantly smaller size at age (i.e., decreased growth) in the NF area relative to either FF area or reference conditions; size at age remained within normal range. In addition, condition factor (i.e., Energy Stores – K) in the NF area was greater for age-1+ fish relative to the reference conditions, but mean values were within normal range. No response was observed for adult female or adult male fish, resulting in a low-level effect rating for this endpoint.

Based on the results of fish health endpoints demonstrating statistical differences, it is unlikely that the observed differences are due to toxicological impairment. Although reduced growth could generally be anticipated as result of toxicological implement, it is only rated as an early warning/low-level. Strength of linkage was reduced to 0.25 for this endpoint because tissue metal concentrations did not indicate toxicological concern. Coherence of response was also reduced to 0.25 because of the inconsistent responses in the fish population health endpoints.

Combining the weighted scores for Slimy Sculpin tissue chemistry and fish health resulted in an EOI Rank of 2, which represents moderate evidence of toxicological impairment, to the fish community from Mine activities and effluent discharge. Because of an overall lack of evidence of potential toxicological impact in biological responses, the EOI Rank of 2 for fish community is interpreted to be conservative.

Even if an overall up-weighting of 1.5 was applied to the two fish health endpoints *a posteriori*, the EOI Rank would still remain at 2 (moderate). The lack of similar responses in previous years when elevated metals concentrations in fish tissue were also reported, and the lack of toxicological impairment responses in the plankton and benthic communities, suggest that the fish health responses for 2019 could also be due to natural variability related to other ecological or abiotic factors. Based on these considerations, the EOI Rank of 2 (i.e., moderate support for the Toxicological Impairment hypothesis) was interpreted to be conservative; further consideration will be given to the robustness of the *a priori* weighting factors in the next Aquatic Effects Re-evaluation Report.

3.3.2 Nutrient Enrichment

3.3.2.1 Lake Productivity

The AEMP findings indicated a generally consistent pattern of response between nutrient enrichment in the water column and enrichment responses in the plankton community of the NF and MF areas of Lac de Gras.

The mean concentration of TN in the NF area exceeded the upper bound of the normal range and the affected area covered most of the lake, resulting in an overall high-level rating. As discussed in Section 3.2, the *a posteriori* weighting factor for strength of linkage was up-weighted from 0.5 to 0.75 to reflect linkage to Mine activities (primarily the release of wastewater effluent), but the coherence of response was not adjusted given that a similar response was not observed for total phosphorus. Because Lac de Gras is P-limited, the role of TN in the overall nutrient enrichment effect observed in the lake is believed to be small; a conclusion that is also indicated by the correlation between low P and low productivity in 2019 being coincident with greater N concentrations in 2019 relative to previous years [Eutrophication Indicators, Appendix XIII]).

The endpoint responses for biological productivity indicated significantly greater chlorophyll *a* concentrations and zooplankton biomass (i.e., AFDM and enumeration). Each provided a high degree of support (i.e., direction-weighting of 1.0) for the Nutrient Enrichment hypothesis. The direction of response of these endpoints suggested that the shifts in plankton community structure were also linked to nutrient enrichment. Phytoplankton biomass had a no response rating likely due to the consequential increase in consumption of phytoplankton by the zooplankton community. The highest level of response (and resulting weighted score) was obtained for zooplankton biomass (AFDM), which had a NF area mean that was significantly greater than the FF area means, with a significant gradient along the MF1 and MF3 transects. Mean zooplankton biomass in NF exceeded the upper limit of the normal range, and the area of the lake with biomass above the normal range was greater than 20%, resulting in a high-level rating. The significantly greater chlorophyll *a* and zooplankton biomass in the NF area of Lac de Gras were consistent with increased TN in the NF area. Therefore, strength of linkage for these primary productivity endpoints was up-weighted to 0.75. Phytoplankton biomass exhibited no statistically significant difference in the NF area relative to the FF areas, resulting in a no response rating; however, given the observed increases in chlorophyll *a* and zooplankton biomass, and absence of toxicity-related changes in the phytoplankton community structure, the strength of linkage for chlorophyll *a* and zooplankton biomass was up-weighted to 0.75 and the coherence of response was maintained at 0.5.

Combining the weighted scores for nutrient enrichment exposure and biological productivity responses resulted in an EOI Rank of 3, which represents strong evidence that the response in lake productivity is due to nutrient enrichment related to Mine activities and effluent discharge.

3.3.2.2 Benthic Invertebrate Community

The 2019 AEMP findings indicated a consistent pattern of response between nutrient enrichment in the water column and enrichment responses in the benthic invertebrate community of the NF area of Lac de Gras.

There were significantly greater chlorophyll *a*, SRP and TN concentrations in the NF area and a significant TN gradient along the MF1 and MF3 transects. After *a posteriori* up-weighting, TN was the exposure endpoint that provided the greatest support for nutrient enrichment of the benthic invertebrate community; however, because Lac de Gras is phosphorus-limited, the role of TN in the overall nutrient enrichment effect observed in the lake is believed to be small. Increased zooplankton biomass is indicative of an increase in food supply, providing a strong linkage to the Mine as a result of corresponding increases in nutrients in the NF area and, therefore, strength of linkage was up-weighted to 0.75 for both chlorophyll *a* and TN.

Significant decreasing gradients in *Procladius, Heterotrissocladius,* and *Microtendipes* densities with distance from the diffusers, as well as a minor shift in community structure (i.e., relative abundances of dominant taxa) were consistent with the Nutrient Enrichment hypothesis. All endpoint responses (including decreases in richness, Pisidiidae density, percent Chironomidae, and changes in relative abundances of dominant taxa) were considered to be more likely related to nutrient enrichment; therefore, strength of linkage was increased to 0.75 (i.e., up-weighted in the Nutrient Enrichment WOE analysis) to reflect the similar responses suggesting enrichment, which appear linked to increased chlorophyll *a* concentrations. As discussed earlier, phytoplankton biomass had a no response rating likely due to the consequential increase in consumption of phytoplankton by the zooplankton community. Following weighting, the high-level response observed for *Procladius* density had the highest overall score.

Combining the weighted scores for nutrient enrichment exposure and benthic invertebrate responses resulted in an EOI Rank of 3, which represents strong evidence that the response in the benthic invertebrate community results from nutrient enrichment related to Mine activities and effluent discharge.

3.3.2.3 Fish Community

The high chlorophyll *a* concentrations in the NF and MF areas are indicative of enrichment-related increases in zooplankton and/or benthic invertebrate food supply for Slimy Sculpin and, as with the benthic invertebrate analysis, this change was rated as low-level for chlorophyll *a*. An increase in fish condition factor is consistent with the Nutrient Enrichment hypothesis whereas the decrease in growth is not.

Strength of linkage was increased to 0.75 for the condition factor endpoint because an increase in nutrient availability can result in an increase in food sources for fish and hence overall fish health and condition factor. Coherence of response was reduced to 0.25 because of the inconsistent responses in the fish population health endpoints.

Chlorophyll *a* was maintained *a posteriori* (both strength of linkage and coherence of response set at 0.5) when considered as a nutrient exposure endpoint for fish health.

Combining the weighted scores for Slimy Sculpin tissue chemistry and fish health resulted in an EOI Rank of 2, which represents moderate evidence of nutrient enrichment to the fish community from Mine activities and effluent discharge.

3.4 Uncertainty

The strength of evidence supporting the WOE analyses for each ecosystem component varies with the amount and quality of information available. Potential sources of uncertainty in the WOE analyses fall into four general classes:

- Difficulty in characterizing potential changes, responses, and effects (e.g., natural variability, potential confounding factors, presence of multiple stressors, uncertain persistence of any observed changes) can be described and estimated but cannot be eliminated. This type of uncertainty was characterized for each endpoint and LOE group in the WOE Framework in the *a priori* weighting factors for representativeness and persistence of effects. The *a posteriori* assessments of coherence and causality of endpoints also served to focus the WOE analyses on those endpoints that were most likely to reflect real and robust effects of the Mine, reducing the influence of this type of uncertainty on the WOE analyses.
- Uncertainty arising from simplification of the real world (e.g., the extrapolation of effects measured for certain benthic indicator species to the benthic community of Lac de Gras in general) can be reduced by increased realism in endpoints, but cannot be eliminated. This type of uncertainty was characterized for each endpoint in the WOE Framework in the *a priori* weighting factor, for clarity of interpretation. The use of multiple biological response endpoints for each LOE (e.g., for benthic invertebrate community there are endpoints addressing community structure, richness, diversity, total abundance, and species abundance), as well as the selection of study species that are robust indicators of response in a particular area (i.e., most benthic invertebrate species are relatively sedentary), reduced the influence of this type of uncertainty on the WOE analyses.
- Imperfect knowledge or error can be reduced or, in some cases, eliminated (e.g., through proper quality assurance/quality control [QA/QC] procedures). This type of uncertainty was characterized for each endpoint in the WOE Framework in the *a priori* weighting factor for methodological robustness. Appropriate QA/QC procedures were included for every endpoint, to reduce the influence of this type of uncertainty on the WOE analyses. QA/QC issues for specific endpoints are discussed in their respective reports (Appendices II, III, IV, V, XI, XIII).
- The ecological significance of observed effects and changes is uncertain because most of the effect levels do not identify what type of change would represent a significant degradation to Lac de Gras (this is the purpose of the Action Levels). The current effect levels focus on statistical significance and gradient analysis, which do not always coincide with ecological significance, especially for an ultra-oligotrophic system such as Lac de Gras where even a small magnitude change is likely to be detected for certain endpoints. This is especially important for nutrient enrichment effects, for which standardized approaches to estimating ecological significance are not in widespread use. Overall, the WOE analysis is intended to err on the side of conservatism, identifying EOI regardless of whether the apparent changes, responses, or effects are expected to have ecological significance.

Sources of uncertainty for the endpoints associated with individual ecosystem components are described in the individual reports for each component (Appendices II, III, IV, V, XI, XIII). For all endpoints, a significant source of uncertainty is natural spatial and temporal variability in Lac de Gras. Given the inherent variability of natural systems, it is never possible to eliminate the possibility of false negative results (i.e., failing to detect the effect of the Mine on a particular endpoint, when one actually exists), primarily for relatively subtle effects or false positive results (i.e., concluding that the Mine has had an effect on a particular endpoint, when the apparent change is due to natural variability or a confounding factor with natural causes).

As with previous years, this report describes a “point-in-time” analysis with inherent uncertainty. While the WOE findings may change from year to year, overall knowledge of the system and potential impacts to Lac de Gras will improve over time as patterns emerge that transcend year-to-year variability. The longer-term trend and pattern in AEMP findings will ideally guide future studies, refinements to the AEMP, and management actions as appropriate and necessary.

4 CONCLUSIONS

This report presents the WOE analysis for data collected during the 2019 AEMP field program. Specific endpoints for exposure and biological response were integrated to examine the EOI associated with two distinct types of potential stressors: toxicological impairment and nutrient enrichment.

4.1 Toxicological Impairment Findings

The AEMP findings for WQ, sediment quality, and fish tissue chemistry indicate that Mine effluent has resulted in increases in the concentrations of metals and other potentially toxic substances in the NF area. The observed concentrations in water exceeded the normal range and two times the median of the FF areas; however, none of the observed exposure concentrations in water or sediment exceeded Effects Benchmarks, guidelines (where available), or concentrations that would be expected 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. The pattern of response in fish health endpoints measured for Slimy Sculpin in the NF area included smaller body size and a larger 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 random fluctuations or other ecological or abiotic factors in Lac de Gras.

Based on the results of the Toxicological Impairment WOE analysis, EOI Rankings have been derived for lake productivity, benthic invertebrate community, and fish community in Lac de Gras. The EOI Rankings and key supporting endpoint results are summarized below:

- Lake Productivity: EOI Rank 0 (Negligible[3])
  - Exposure: Significantly greater concentrations of sixteen effluent SOIs in the water column of the NF area when compared to FF areas, consideration of gradient analysis, and normal range.
  - Biological Response: Minor shift in zooplankton community structure may be consistent with Toxicological Impairment hypothesis; however, this response is likely to be due to Nutrient Enrichment hypothesis and is in line with other responses in the LOE group (i.e., chlorophyll *a* and zooplankton biomass).

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

- Benthic Invertebrate Community: EOI Rank 0 (Negligible[3])
  - Exposure: Significantly greater concentrations of twelve parameters in NF area sediments relative to FF areas.
  - Biological Response: There was increased effluent exposure in the NF area, which extended along the MF1 and MF2 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 was also observed along the MF3 transect. No significant difference was 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[4])
  - 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 Stores (K) in NF area is supportive of Nutrient Enrichment hypothesis.

4.2 Nutrient Enrichment Findings

The endpoint results relevant to nutrient exposure support the interpretation that Mine discharges are resulting in changes to lake productivity and the benthic invertebrate community that are consistent with nutrient enrichment. For 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 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 responses were inconsistent; the increased primary productivity (i.e., zooplankton biomass) in the NF areas 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 natural variability caused by other ecological or abiotic factors.

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

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

supporting endpoint results and weighting considerations that formed the basis for the rankings are summarized below:

- Lake Productivity: EOI Rank 3 (Strong[4])
  - Exposure: Mean water column concentration of TN in the NF area exceeded the upper bound of the normal range and the extent of the affected area covered most of the lake. Because phosphorus is expected to be a limiting nutrient in Lac de Gras, the increase in TN is not expected to result in the eutrophication effects observed in the Lake. Given challenges in measuring TP (e.g., detection limits, lack of response due to timing of TP measurements and large TP uptake due to high consumption rate of plankton communities), spatial trends and gradients observed in SRP may be a more sensitive and reliable indicator of nutrient enrichment in comparison to TP and TN.
  - Biological Response: 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 were within the normal range.
- Benthic Invertebrate Community: EOI Rank 3 (Strong[4])
  - 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 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[3])
  - 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 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 stores (i.e., condition factor) in the NF area relative to reference conditions is supportive of the Nutrient Enrichment hypothesis.

4.3 Overall Conclusion

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 (i.e., TN, SRP) to Lac de Gras as a result of Mine effluent, greater nutrient concentrations in the NF area, and greater lake productivity in the NF area. There is also a consistent response of a higher invertebrate density and a mild community shift that can be linked to the observed enrichment.

The 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.

In the case of fish population health, decreased size at age (i.e., decreased growth) in the NF area relative to the FF area or reference conditions may be a result of toxicological impairment, while increased energy stores (i.e., condition factor) in NF area relative to reference conditions is supportive of the Nutrient Enrichment hypothesis. Increased primary and secondary productivity (i.e., chlorophyll *a* and zooplankton biomass, respectively) in the NF area suggests 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 natural variability caused by other ecological or abiotic factors, especially in light of the AEMP results for water quality, which indicate that no parameter is present in lake water at concentrations approaching water quality guidelines.

Consistent with previous AEMP years, overall, there is evidence in support of nutrient enrichment in Lac de Gras; the results of the assessment provide limited evidence in support of toxicological impairment in Lac de Gras.

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6 CLOSURE

We trust that the information in this report meets your requirements at this time. However, if you have any questions relating to the information contained in this report or require further information, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

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ATTACHMENT A

WEIGHT-OF-EVIDENCE ANALYSIS–QUANTITATIVE INTEGRATION OF ENDPOINTS, WEIGHTING FACTORS, COMBINED SCORES, AND EVIDENCE OF IMPACTS

Table A-1: Weight-of-Evidence Analysis for Toxicological Impairment Impacts, 2019

Ecosystem Component	LOE Group	LOE Endpoints	Effect Level Rating	Mathematical Representation	*A Priori* Weighting		Direction Weighting			*A Posteriori* Weighting				Final LOE Score	Total WOE Score
					A Priori Weighting Factor	Weighted LOE Score	Direction of Observed Effect or Correlation	Support for Toxicity Hypothesis	Weighted LOE Score	Strength of Linkage	Coherence of Response	Overall (Sum of Factors)	Weighted LOE Score		
Lake Productivity	Contaminant Exposure – Comparison to Benchmarks, FF, and Gradient Analysis	Water Quality	↑	0.5	3.8	1.9	n/a	n/a	n/a	0.75	0.75	1.50	2.8	2.8	5.6
	Biological Productivity - NF vs FF Areas and Normal Range (Biological Response)	Chlorophyll *a* (biological response)	↑	0.5	15.0	7.5	Increase	0	0					2.8	
		Zooplankton Biomass (AFDM)	↑↑↑	2	15.0	30.0	Increase	0	0						
		Phytoplankton Biomass (enumeration)	0	0	15.0	0									
		Zooplankton Biomass (enumeration)	↑	0.5	15.0	7.5	Increase	0	0						
		Phytoplankton Community Structure/Richness	0	0	11.3	0	n/a	0.50	0						
		Zooplankton Community Structure/Richness	↑/↓	0.5	11.3	5.6	n/a	0.50	2.8	0.75	0.25	1.00	2.8		
Benthic Invertebrates	Contaminant Exposure	Sediment Quality - Comparison to Guidelines and FF	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6	5.6	9.4
		Water Quality - Comparison to Benchmarks and FF	↑	0.5	3.8	1.9	n/a	n/a	n/a	0.75	0.75	1.50	2.8		
	Benthic Invertebrates - NF vs FF Areas, Condition Factor, and Gradient Analysis (Biological Response)	Total Invertebrate Density	0	0	20.0	0								3.8	
		Pisidiidae Density	↓	0.5	18.8	9.4	Decrease	0.75	7.0	0.25	0.25	0.50	3.5		
		Procladius Density	↑↑↑	2	15.0	30.0	Increase	0.25	7.5	0.25	0.25	0.50	3.8		
		Heterotrissocladius Density	↑	0.5	15.0	7.5	Increase	0.25	1.9	0.25	0.25	0.50	0.9		
		Micropsectra Density	↓	0.5	15.0	7.5	Decrease	0.75	5.6	0.25	0.25	0.50	2.8		
		Microtendipes Density	↑↑	1	15.0	15.0	Increase	0.25	3.8	0.25	0.25	0.50	1.9		
		Stictochironomus Density	0	0	15.0	0									
		Percent Chironomidae	↑	0.5	15.0	7.5	Increase	0.25	1.9	0.25	0.25	0.50	0.9		
		Richness	↓	0.5	25.0	12.5	Decrease	0.50	6.3	0.25	0.25	0.50	3.1		
		Simpson's Diversity Index	0	0	18.8	0									
		Evenness	↑	0.5	15.0	7.5	Increase	0.50	3.8	0.25	0.25	0.50	1.9		
		Dominance	0	0	15.0	0									
		Bray-Curtis	0	0	15.0	0									
		Relative Abundance of Dominant Taxa	↑/↓	0.5	15.0	7.5	n/a	0.50	3.8	0.25	0.25	0.50	1.9		
Fish Community	Fish Population Health - NF vs FF Areas, Reference Conditions, and Normal Range (Biological Response)	Growth - Size at Age	↓	0.5	25.0	12.5	Decrease	1.00	12.5	0.25	0.25	0.50	6.3	6.3	27.3
		Population Structure - Survival	n/s	0	18.8	0									
		Population Structure - Size	n/s	0	18.8	0									
		Pathology - Occurrence	0	0	25.0	0									
		Energy Stores - K	↑	0.5	25.0	12.5	Increase	0	0						
		Energy Stores - LSI	0	0	25.0	0									
		Relative Reproductive Success - Age 1 Abundance	0	0	18.8	0									
		Reproductive Investment - GSI	0	0	25.0	0									
		Tapeworm Parasitism - Occurrence	↑	0.5	25.0	12.5	Increase	1.00	12.5	0.25	0.25	0.50	6.3		
		Fish Capture Data - CPUE	0	0	18.8	0									
	Contaminant Exposure	Water Quality - Comparison to Benchmarks, FF, and Gradient Analysis	↑	0.5	3.8	1.9	n/a	n/a	n/a	0.75	0.75	1.50	2.8	21.1	
		Sediment Quality - Comparison to Guidelines, FF Areas, and Normal Range	↑	0.5	7.5	3.8	n/a	n/a	n/a	0.75	0.75	1.50	5.6		
		Sculpin Tissue Chemistry - Comparison to FF Area, Reference Conditions, and Normal Range	↑↑↑	2	14.1	28.1	n/a	n/a	n/a	0.50	0.25	0.75	21.1		

Note: For biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the FF areas.

↑/↓ = early warning/low-level rating; ↑↑/↓↓ = moderate-level rating; ↑↑↑/↓↓↓ = high-level rating; LOE = line of evidence; AFDM = ash-free dry mass; K = condition factor; LSI = liversomatic index; GSI = gonadosomatic index; CPUE = catch-per-unit-effort; NF= near-field; FF = far-field.

Weight- of-Evidence Score Color Coding

EOI Rank 3	🟥 >40.0
EOI Rank 2	🟧 >20.0
EOI Rank 1	🟨 >10.0
EOI Rank 0	🟩 <10

Table A-2: Weight-of-Evidence Analysis for Nutrient Enrichment Impacts, 2019

Ecosystem Component	LOE Group	LOE Endpoints	Effect Level Rating	Mathematical Representation	*A Priori* Weighting		Direction Weighting			*A Posteriori* Weighting				Final LOE Score	Total WOE Score
					Overall (Product of Factors)	Weighted Endpoint Score	Direction of Observed Effect or Correlation	Support for Nutrient Enrichment Hypothesis	Weighted Endpoint Score	Strength of Linkage	Coherence of Response	Overall (Sum of Factors)	Weighted Endpoint Score		
Lake Productivity	Nutrient Exposure - Comparison to FF Area, Normal Range, Guidelines, and Gradient Analysis	Water Chemistry Total N	↑↑↑	2	5.6	11.3	n/a	n/a	n/a	0.75	0.50	1.25	14.1	14.1	51.6
		Water Chemistry Total P	0	0	7.5	0	n/a	n/a	n/a						
	Biological Productivity - NF vs FF Areas and Normal Range (Biological Response)	Chlorophyll *a* (biological response)	↑	0.5	15.0	7.5	Increase	1.0	7.5	0.75	0.50	1.25	9.4	37.5	
		Zooplankton Biomass (AFDM)	↑↑↑	2	15.0	30.0	Increase	1.0	30.0	0.75	0.50	1.25	37.5		
		Phytoplankton Biomass (enumeration)	0	0	15.0	0									
		Zooplankton Biomass (enumeration)	↑	0.5	15.0	7.5	Increase	1.0	7.5	0.75	0.50	1.25	9.4		
		Phytoplankton Community Structure/Richness	0	0	11.3	0									
		Zooplankton Community Structure/Richness	↑/↓	0.5	11.3	5.6	n/a	0.5	2.8	0.75	0.50	1.25	3.5		
Benthic Invertebrates	Nutrient Exposure	Sediment - Total Organic Carbon P – Comparison to FF Areas, Normal Range and Gradient Analysis	0	0	7.5	0	n/a	n/a	n/a					14.1	47.8
		Sediment – Total P – Comparison to FF Areas, Normal Range and Gradient Analysis	0	0	5.0	0	n/a	n/a	n/a						
		Water Chemistry Total N - Comparison to FF Area, Normal Range, Guidelines, and Gradian Analysis	↑↑↑	2	5.6	11.3	n/a	n/a	n/a	0.75	0.50	1.25	14.1		
		Water Chemistry Total P - Comparison to FF Area, Normal Range, Guidelines, and Gradian Analysis	0	0	7.5	0	n/a	n/a	n/a						
	Primary Productivity (Exposure)	Chlorophyll *a* (enrichment exposure)	↑	0.5	11.3	5.6	n/a	n/a	n/a	0.75	0.50	1.25	7.0		
	Benthic Invertebrates – Comparison to FF Areas an, Normal Range, and Gradient Analysis (Biological Response)	Total Invertebrate Density	0	0	20.0	0								33.8	
		Pisidiidae Density	↓	0.5	18.8	9.4	Decrease	0.25	2.3	0.75	0.75	1.50	3.5		
		Procladius Density	↑↑↑	2	15.0	30.0	Increase	0.75	22.5	0.75	0.75	1.50	33.8		
		Heterotrissocladius Density	↑	0.5	15.0	7.5	Increase	0.75	5.6	0.75	0.75	1.50	8.4		
		Micropsectra Density	↓	0.5	15.0	7.5	Decrease	0.25	1.9	0.75	0.75	1.50	2.8		
		Microtendipes Density	↑↑	1	15.0	15.0	Increase	0.75	11.3	0.75	0.75	1.50	16.9		
		Stictochironomus Density	0	0	15.0	0									
		Percent *Chironomidae*	↑	0.5	15.0	7,5	Increase	0.75	5.6	0.75	0.75	1.5	8.4		
		Richness	↓	0.5	25.0	12.5	Decrease	0.50	6.3	0.75	0.75	1.50	9.4		
		Simpson's Diversity Index	0	0	18.8	0									
		Evenness	↑	0.5	15.0	7.5	Increase	0.50	3.8	0.75	0.75	1.50	5.6		
		Dominance	0	0	15.0	0									
		Bray-Curtis	0	0	15.0	0									
		Relative Abundance of Dominant Taxa	↑/↓	0.5	15.0	7.5	n/a	0.50	3.8	0.75	0.75	1.50	5.6		

Table A-2: Weight-of-Evidence Analysis for Nutrient Enrichment Impacts, 2019 (continued)

Ecosystem Component	LOE Group	LOE Endpoints	Effect Level Rating	Mathematical Representation	*A Priori* Weighting		Direction Weighting			*A Posteriori* Weighting				Final LOE Score	Total WOE Score
					Overall (Product of Factors)	Weighted Endpoint Score	Direction of Observed Effect or Correlation	Support for Nutrient Enrichment Hypothesis	Weighted Endpoint Score	Strength of Linkage	Coherence of Response	Overall (Sum of Factors)	Weighted Endpoint Score		
Fish Community	Fish Population Health - NF vs FF Areas, Reference Conditions, and Normal Range (Biological Response)	Growth - Size at Age	↓	0.5	25.0	12.5	Decrease	0	0					12.5	23.8
		Energy Stores - K	↑	0.5	25.0	12.5	Increase	1.0	12.5	0.75	0.25	1.00	12.5		
		Energy Stores - LSI	0	0	25.0	0									
		Relative Reproductive Success - Age 1 Abundance	0	0	18.8	0									
		Reproductive Investment - GSI	0	0	25.0	0									
		Tapeworm Parasitism - Occurrence	0	0	25.0	0									
		Fish Capture Data - CPUE	0	0	18.8	0									
	Nutrient Exposure	Water Chemistry Total N - Comparison to FF Area, Normal Range, Guidelines, and Gradian Analysis	↑↑↑	2	5.6	11.3	n/a	n/a	n/a	0.75	0.25	1.00	11.3	11.3	
		Water Chemistry Total P - Comparison to FF Area, Normal Range, Guidelines, and Gradian Analysis	0	0	7.5	0	n/a	n/a	n/a						
	Primary Productivity (Exposure)	Chlorophyll *a* (enrichment exposure)	↑	0.5	11.3	5.6	n/a	n/a	n/a	0.50	0.50	1.00	5.6		

Note: For biological metrics, the direction of the sign (↑ or ↓) indicates the direction of difference relative to the FF areas.
↑/↓ = early warning/low-level rating; ↑↑/↓↓ = moderate-level rating; ↑↑↑/↓↓↓ = high-level rating; LOE = line of evidence; AFDM = ash-free dry mass; K = condition factor; LSI = liversomatic index; GSI = gonadosomatic index; NF = near-field; FF = far-field.

Weight-of-Evidence Score Color Coding

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