Baffinland Iron Mines Corporation

APPENDIX A
WATER AND SEDIMENT QUALITY REVIEW AND CREMP STUDY DESIGN

Rev. 3

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
03/28/14	0	KP	KP	Issued in Final
05/30/14	1	KP	KP	Revised Study Design to Align with freshwater biota CREMP
06/25/14	2	KP	KP	Minor Updates to Sections 2.7.8 and 3.6.8
03/31/16	3	AV	JM	Updated to reflect CREMP study design modifications proposed by Minnow in 2016
05/1/19	4	AM	CM	Issued for Phase 2 Proposal

Index of Major Changes/Modifications in Revision 3

Item No.	Description of Change	Relevant Section
1	Updated background/introduction to include the ERP phase and discussed status current operations.	1.1
2	Updated CREMP water quality monitoring areas and stations to reflect Minnow's recommendations.	2.7.4
3	Clarified sampling frequency and schedule for the CREMP water quality sampling program.	2.7.5
4	Included 2014 sediment quality program in Table 3.1 and discussed final sediment quality stations established by Intrinsik in 2015.	3.1
5	Updated summary to reflect current status of the Lake Sedimentation Study in Sheardown Lake NW.	3.2.3
6	Updated the CREMP sediment quality study design to reflect the recommendations proposed by Minnow.	3.6
7	Updated the CREMP sediment quality study design to reflect the recommendations proposed by Minnow.	3.6.1

Item No.	Description of Change	Relevant Section
8	Updated sediment quality parameters in Table 3.5 to reflect the 2015 CREMP.	3.6.2
9	Updated sediment quality benchmarks in Table 3.6 to reflect the benchmarks established by Intrinsik in 2015. Discussed Minnow's recommendation of including reference areas in the derivation of lake sediment quality benchmarks.	3.6.3
10	Updated sediment quality monitoring areas and stations to reflect Minnow's recommendations.	3.6.4

PREFACE

This document was originally written by Knight Piésold Consulting in June 2014 for Baffinland Iron Mines Corporation (Baffinland). This document has since then been revised by Baffinland to reflect the recommendations proposed by Minnow Environmental Inc. in 2016 regarding modifications to the CREMP Study Design.

TABLE OF CONTENTS

PAGE

TABLES

FIGURES

~~APPENDICES~~ATTACHMENTS

1 – INTRODUCTION

1.1 BACKGROUND

Baffinland Iron Mines Corporation (Baffinland) conducted water and sediment quality baseline studies at the Mary River Project from 2005 to 2014. The water and sediment quality baseline data were utilized to support the preparation of the Final Environmental Impact Statement (FEIS) submitted to NIRB in February 2012 (Baffinland, 2012). The Project was approved by the NIRB on December 28, 2012 (with the issuance of Project Certificate No. 005; NIRB, 2012) and the NWB issued Type A Water Licence No. 2AM-MRY1325 to Baffinland on July 24, 2013 (NWB, 2013).

Due to poor market conditions in 2013 and the large amount of financial resources required to complete the construction of the railway to Steensby Port, Baffinland proposed an Early Revenue Phase (ERP) of the Project to the NIRB and NWB in 2013. The ERP proposal outlined a plan that involved mining 3.5 million tonnes per annum (Mt/a) of iron ore and transporting the ore year-round by truck to Milne Port using the Tote Road. The iron ore would be stockpiled at Milne Port and transported to market by ship during the open water season.

On May 28, 2014, NIRB issued to Baffinland an amendment to the Mary River Project Certificate No. 005 to reflect modifications to the Project associated with the ERP. Baffinland initiated construction of the mine in the summer of 2013 and began ERP mine operations in September 2014.

On September 2, 2015 the NWB issued the Type A Water Licence No: 2AM-MRY1325 Amendment No.1 to Baffinland. The Amended Licence incorporates entire scope of the Type "B" Water Licences (8BC-MRY1314 and 8BC-MRY1416), issued to the Mary River Project for construction and site preparation work; specific elements on the scope of Type "B" Licence No 2BE-MRY1421, issued to the Project for Exploration and Bulk Sample Programs and addressed many elements associated with ERP activities and facilities.

Baffinland has contemplated a 5-year operating plan for the ERP, after which time the full-scale railway project would also be brought on-line. However, the development of the railway will be subject to a commercial decision by Baffinland to proceed and will be heavily influenced by both market conditions and available financing.

Since the beginning of mine operations in September 2014, the attention of the AEMP monitoring programs has shifted from baseline data collection to the development and execution of monitoring programs. These programs include the development of the Aquatic Effects Monitoring Program (AEMP), which is a requirement of Baffinland`s amended Type A Water Licence.

This document presents a review of water and sediment quality baseline data up to 2013 and outlines the current study design for the water and sediment components of a key monitoring program referred to as the Core Receiving Environment Monitoring Program (CREMP). The CREMP is a component program of the AEMP.

In 2015, Minnow Environmental Inc. (Minnow) was contracted to assist Baffinland in completing the fieldwork and reporting requirements of several of the AEMP component studies, including the CREMP. After completing the CREMP in 2015, Minnow proposed several modifications to the program to provide greater efficiencies and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems). Modifications proposed by Minnow were documented in a memo addressed to Baffinland, dated March 17, 2016 (Minnow, 2016). This document~~-~~ has been revised to reflect ~~all of the~~the ~~proposed~~ modifications proposed by Minnow and accepted by Baffinland ~~regarding~~ for the CREMP sediment and water quality monitoring programs.

1.2 SCOPE OF REVIEW AND STUDY DESIGN

The scope of the baseline review and study design for water and sediment quality monitoring was to:

- Identify data quality issues
- Determine whether or not mineral exploration and bulk sampling activities conducted since 2004 have affected water or sediment quality in the ~~mine site area~~Mine Site Area
- Understand the seasonal, depth (for lakes) and inter-annual variability of water quality
- Understand natural enrichment of ~~the mine site area~~ waters and sediment near the Mine Site
- Determine the potential to pool data from multiple sample stations to increase the statistical power of the baseline water and sediment quality dataset
- Develop study designs for monitoring water and sediment quality in mine site streams and lakes, including an a priori power analysis[1]
- Determine if changes to the existing water and sediment quality monitoring program are required to meet monitoring objectives

Parameters of interest in the baseline review included water quality stressors of potential concern (SOPCs) identified on the basis of the existence of an established water quality guideline, as well as other factors such as Exposure Toxicity Modifying Factors (ETMF): pH, water hardness, dissolved organic carbon, etc., and indicator parameters (alkalinity, chloride, nitrate). Baseline water quality data was compared to Canadian Council of Ministers of the Environment (CCME) - Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-PAL). The focus was on total concentrations (versus dissolved) since CWQG-PAL guidelines are developed for total concentrations. The parameters of interest are displayed graphically in box plots. The box plots are used to portray natural ranges of selected parameters. Concentration data measured for the parameters of interest has been log transformed and further analyzed to investigate the possibility of aggregating data, bearing in mind:

- Seasonal variability (between spring, summer, fall and winter samples)
- Inter-annual variability (from 2006 through 2008 and 2011 through 2013)

To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework (see Section 2.7.8), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmark values

---

[1] Power analysis can be used to calculate the minimum sample size required so that one can be reasonably likely to detect an effect of a given size. A power analysis completed before data are collected is an *a priori* or prospective power analysis. *A priori* power analysis is used in estimating sufficient sample sizes to achieve adequate power.

were developed for the identified SOPCs that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; Intrinsik, 2015; see Section 5.3 of the AEMP). Draft benchmarks established by Intrisik in 2014 were applied in the power analysis of the baseline data reviews presented below.

1.3 PROJECT ACTIVITIES DURING BASELINE DATA COLLECTION

Baffinland ~~has been actively undertaking~~undertook mineral exploration, bulk sampling and feasibility level studies at the Project ~~site~~ since 2004. These activities have had the potential to affect the water and sediment in the Mine Site Area. A description of these activities follows.

Baffinland established a camp and initiated exploration drilling at Deposit No. 1 in 2004. Drilling programs were executed most years since 2004, and some exploration was undertaken at nearby Deposit Nos. 2 and 3. Historical drillhole locations are shown in relation to historical water quality sampling stations on Figure 1.1 (~~mine site area~~Mine Site Area including Mary Lake) and Figure 1.2 (~~mine site~~ Mine Site ~~c~~Core A~~a~~rea). Historic sediment quality sampling stations are shown on Figure 1.3.

In 2007, Baffinland's operations and facilities were expanded to carry out a bulk sampling program and to accommodate expanded geotechnical investigations and environmental baseline studies. The exploration camp at the Mine Site was enlarged, the Milne Inlet Tote Road (Tote Road) was upgraded, and small camps were established at Milne Port, Steensby Port and mid-way along the proposed railway alignment. With preparatory work completed in 2007, the bulk ore sample was mined in 2008. This included construction of a haul road to Deposit No. 1; mining of an 118,000 tonne bulk sample; crushing, screening and stockpiling of ore at the M~~m~~ine ~~s~~Site; haulage of ore over the T~~t~~ote R~~r~~oad; and stockpiling and ship loading the ore at Milne Port.

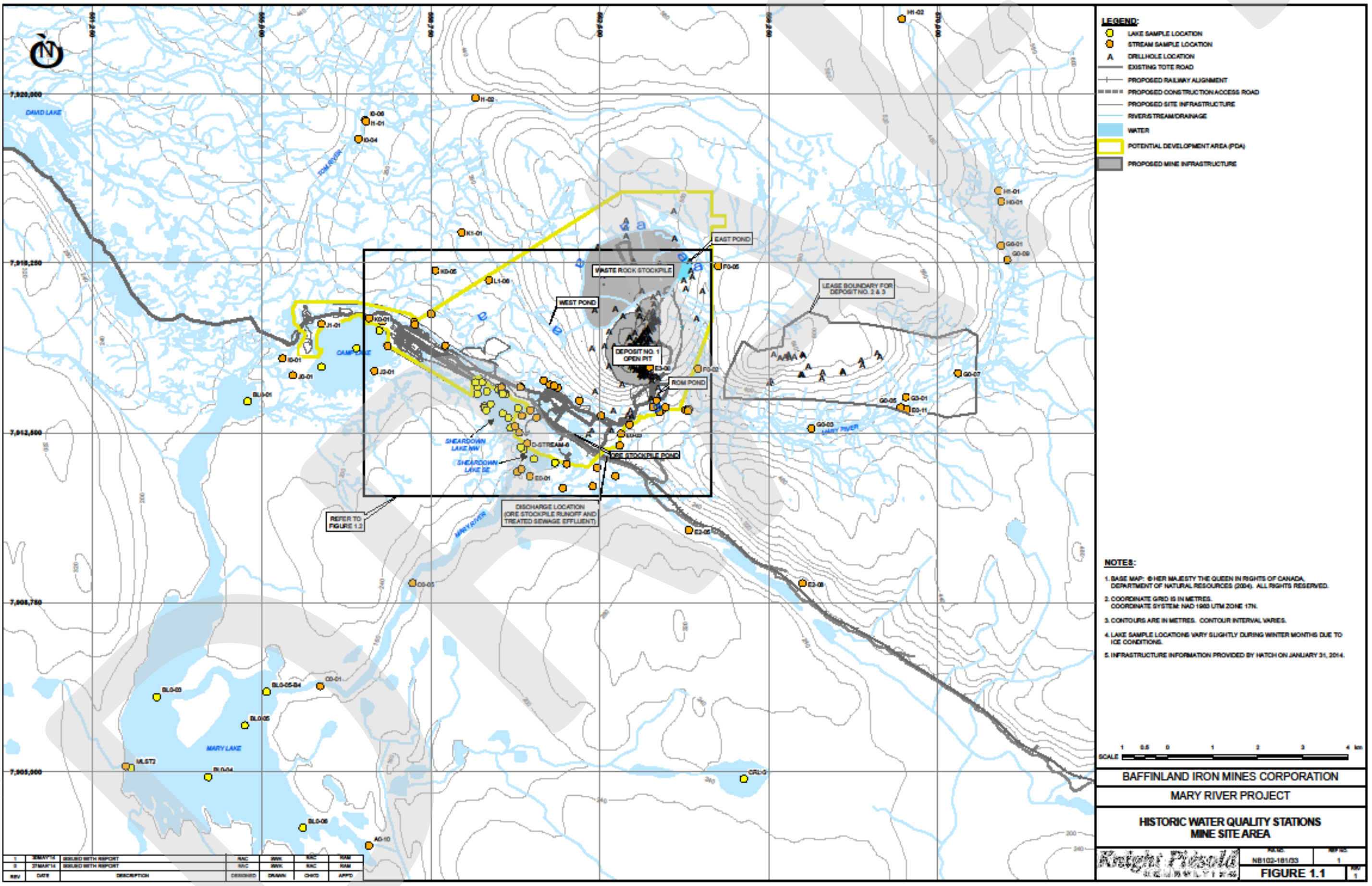
Between 2009 and the start of construction in the summer of 2013, site activities typically involved operating a summer camp to support ongoing exploration drilling at Deposits No. 1, 2 and 3; geotechnical investigations; and regional mineral exploration. A small contingent of care and maintenance staff maintained the camp and airstrip and monitored site conditions during the winter months.

The following historic activities have had the potential to affect local water and sediment quality:

- Exploration drilling on Deposits Nos. 1, 2 and 3 have involved the use of calcium chloride brine. Progressively sophisticated and effective measures were employed over the years to recycle and contain the brine. Monitoring of water quality in the Mary River downstream of Deposit No. 1 has confirmed that calcium chloride has reached the river.
- Treated sewage effluent has been discharged to Sheardown Lake during most open water seasons starting in 2009.
- The bulk sampling program in 2007 and 2008 involved various construction activities, the mining of the ore from the top of Deposit No. 1, as well as the crushing, stockpiling and transport of ore to Milne Port. The crushing activities resulted in the dispersion of dust in the vicinity of Sheardown Lake and its main tributary. Monitoring detected only minor changes to water and sediment quality potentially attributable to bulk sampling operations.

These activities were considered during the review of the baseline dataset.

Figure 1.1 Historic Water Quality Stations - Mine Site Area



NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

Figure 1.2 Historic Water Quality Stations - Immediate Mine Site Area

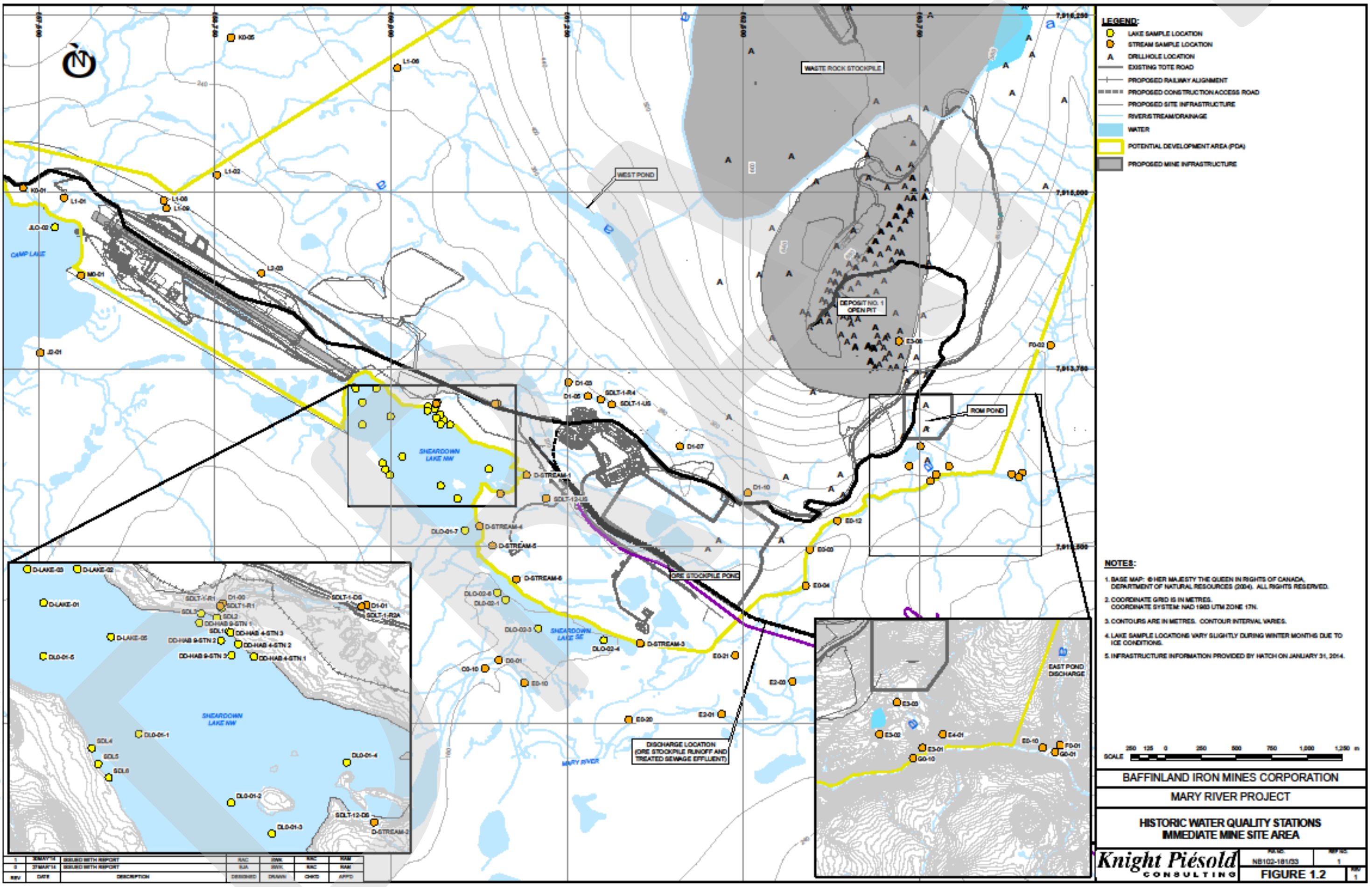
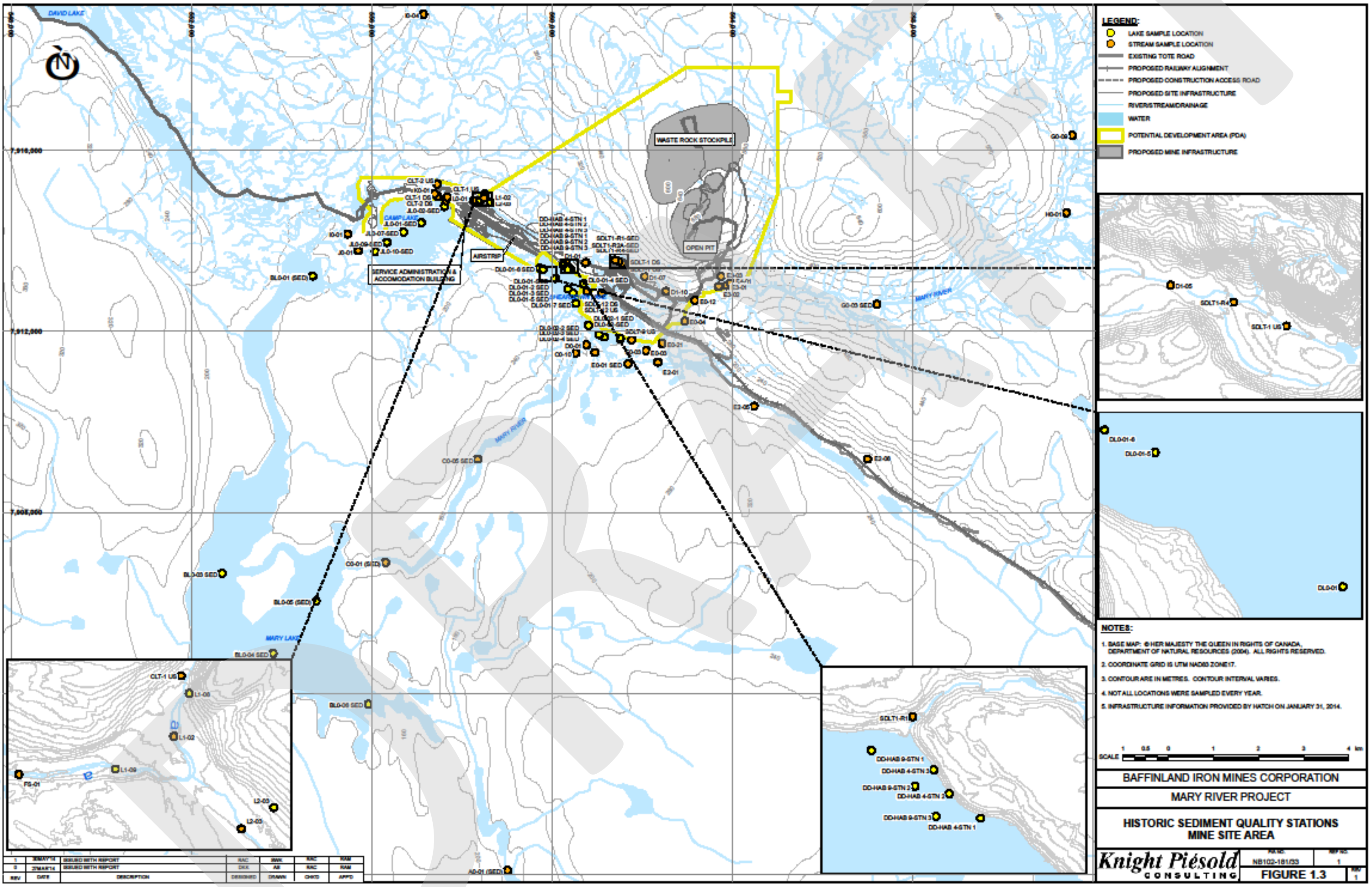


Figure 1.3 Historic Sediment Quality Stations - Mine Site Area


LEGEND:
LAKE SAMPLE LOCATION
STREAM SAMPLE LOCATION
EXISTING TOTE ROAD
PROPOSED RAILWAY ALIGNMENT
PROPOSED CONSTRUCTION ACCESS ROAD
PROPOSED SITE INFRASTRUCTURE
RIVER/STREAM/DRAINAGE
WATER
POTENTIAL DEVELOPMENT AREA (PDA)
PROPOSED MINE INFRASTRUCTURE
DAVID LAKE
CAMP LAKE
MARY RIVER
MARY LAKE
SHEARDOWN LAKE
WASTE ROCK STOCKPILE
OPEN PIT
AIRSTRIP
SERVICE ADMINISTRATION & ACCOMODATION BUILDING
CLT-2 US
K0-01
CLT-1 US
CLT-1 DS
CLT-2 DS
L0-01
L1-02
JL0-02-SED
JL0-01-SED
JL0-07-SED
JL0-09-SED
JL0-10-SED
I0-01
J0-01
I0-04
DD-HAB 4-STN 1
DD-HAB 4-STN 2
DD-HAB 4-STN 3
DD-HAB 9-STN 1
DD-HAB 9-STN 2
DD-HAB 9-STN 3
SDLT1-R1-SED
SDLT1-R2A-SED
SDLT1-R4-SED
SDLT-1 DS
D1-01
D1-07
D1-10
DL0-01-6 SED
DL0-01-4 SED
DL0-01-2 SED
DL0-01-3 SED
DL0-01-5 SED
DL0-01-7 SED
SDLT-12 DS
SDLT-12 US
DL0-02-1 SED
DL0-02-2 SED
DL0-02-3 SED
DL0-02-4 SED
SDLT-9 US
D0-01
C0-10
E0-01 SED
E0-03
E0-12
E0-04
E0-21
E2-01
E3-01
E3-02
E3-05
E2-05
E2-06
G0-09
H0-01
G0-03 SED
BL0-01 (SED)
C0-05 SED
C0-01 (SED)
BL0-03 SED
BL0-05 (SED)
BL0-04 SED
BL0-06 SED
A0-01 (SED)
7,916,000
7,912,000
7,908,000
CLT-1 US
L1-08
L1-02
L1-09
FS-01
L2-03
L2-05
D1-05
SDLT1-R4
SDLT-1 US
DL0-01-6
DL0-01-5
DL0-01
SDLT1-R1
DD-HAB 9-STN 1
DD-HAB 4-STN 3
DD-HAB 9-STN 2
DD-HAB 4-STN 2
DD-HAB 9-STN 3
DD-HAB 4-STN 1
NOTES:
1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOUR ARE IN METRES. CONTOUR INTERVAL VARIES.
4. NOT ALL LOCATIONS WERE SAMPLED EVERY YEAR.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
SCALE 1 0.5 0 1 2 3 4 km
BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT
HISTORIC SEDIMENT QUALITY STATIONS
MINE SITE AREA
Knight Piésold CONSULTING
NB102-181/33
1
FIGURE 1.3
1
ISSUED WITH REPORT
ISSUED WITH REPORT
REV DATE DESCRIPTION DESIGNED DRAWN CHK'D APP'D

2 – BASELINE WATER QUALITY REVIEW

2.1 SUMMARY OF BASELINE WATER QUALITY PROGRAM

The collection of baseline water quality data began in 2005 and was carried through to 2013. Work was completed each year; however, a very limited number of samples were collected during 2009 and 2010 when the global financial crisis reduced Baffinland's P~~p~~roject activities. As such, about 7 to 8 years of baseline data are available for the Project.

Results of the various studies are presented in a number of baseline reports prepared over the years (KP, 2007, 2008, 2010a, 2010b, 2011 and 2012; North/South Consultants Inc., 2008). Water quality data collected in 2012 and 2013 were not previously reported upon but are included within this review.

Sampling and analytical methods, and quality assurance/ quality control (QA/QC) procedures applied during the sampling period are described in the referenced baseline reports. Current sampling methods are described in Appendix A. To ensure consistency, the field work was undertaken by the same small group of individuals.

Historic water quality stations in the Mine Site Area are shown on Figures 1.1 and 1.2. Streams were typically sampled once in the spring (June), summer (July) and fall (late August/early September). The timing of spring sampling was dependent on the onset of freshet and fall sampling was carried out before the streams ran dry or froze (typically in the second half of September to early October). The stream sampling history is presented in Table 2.1.

Lake water quality/limnology was studied in 2006, 2007, 2008, 2011, 2012 and 2013, but not all lakes were studied in all years (Table 2.2). Open lake water quality samples were typically collected during the fall (late August or early September). Winter sampling was carried out in select years at the Mine Site lakes (Camp, David, Mary and Sheardown Lakes), with sampling carried out typically in late April. Sheardown Lake has been the most studied in the area, since the lake was the receiving water for treated sewage during the open season in 2009, 2011, 2012 and 2013.

Table 2-1 Timing of Stream Water Quality Sampling

Year	Winter	Spring	Summer	Fall
2005	No sampling	June 9 - 11	August 9 - 12	September 9 - 11
2006	No sampling	June 18 - 26	July 2 - 30; Aug 6 - 14	Aug 20 - Sept 20
2007	No sampling	June 13 - 24	July 1 - 28; August 5 - 12	Aug 19 - 31; Sept 2 - 30
2008	No sampling	June 9 - 24	July 1 - 21; August 1 - 11	Aug 18 - Sept 16
2009	No sampling	June 29	July 6 - 20	Aug 9 - 18; Sept 2 - 14
2010	No sampling	No sampling	No sampling	Aug 13; Sept 15
2011	No sampling	No sampling	July 21 - 26	Aug 28 - Sept 1
2012	No sampling	June 18 - 23	July 22 - 24	Aug 24 - 31
2013	No sampling	June 21 - 23	July 23 - 25	Aug 20 - Sept 3

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30.
2. DUE TO NO FLOW, NO SAMPLING OF STREAMS OCCURRED DURING THE WINTER.
3. DURING 2009 AND 2010 VERY LIMITED SAMPLING OCCURRED ONLY WITHIN MARY RIVER.

Table 2-2 Timing of Lake Water Quality Sampling

Year	Winter (Lakes)	Spring	Summer	Fall
2005	No sampling	No sampling	No Sampling	No sampling
2006	No sampling	No sampling	July 31 - Aug 2	Aug 31 - Sept 6
2007	May 6 - 8	No sampling	Aug 5 - Aug 14	Aug 13 - 20; Sept 13 - 20
2008	May 11	June 25	July 30 - 31; Aug 5 - 7	Sept 2 -14
2009	No sampling	No sampling		
2010	No sampling	No sampling		
2011	No sampling	No sampling	July 24 - 26	Sept 2 - 6
2012	April 27 - 28	No sampling	No sampling	Aug 21 - 26
2013	May 2 - 5	No sampling	July 25 - 28	Aug 24 - Sept 1

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30TH.
2. LAKE SAMPLING GENERALLY DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE, WITH THE EXCEPTION OF ONE SAMPLING EVENT IN 2008.
3. NO SAMPLING OCCURRED DURING 2009 AND 2010.

2.2 REVIEW OF WATER QUALITY DETECTION LIMITS

Method detection limits (MDLs; also referred to as Method Recording Limits - MRLs or Limits of Quantification - LOQs) have changed for a number of water quality parameters since baseline sampling was initiated in 2005. These changes are primarily due to improvements in laboratory instrumentation. The MDLs for key parameters are presented in Table 2.3.

Baffinland is interested in utilizing its existing baseline dataset to the maximum extent possible. The objective is to reduce the number of sampling events that would be required to detect a statistical change during P~~p~~roject monitoring. Power analyses can be used to calculate the minimum sample size needed to reasonably detect an effect of a given size. The statistical power needed to detect change during future monitoring is a function of the number of sampling events and the spread in the results.

A number of parameters, particularly metals, are present in the water quality dataset at low concentrations (below their MDLs). For several parameters, the dataset contained different detection limits over the sampling period due to improvements in analytical laboratory tools. As such, the dataset contains a high proportion of non-detects at various MDLs.

In the interest of utilizing as many results as possible to increase the statistical power of the dataset, the baseline dataset was plotted in relation to the MDL(s) for each metal parameter. An example plot for silver is presented as Figure 2.1. Plots of this type provide a visual representation of the various MDLs and their influence on the dataset.

From review of the statistics (i.e., number and percent detects), the following actions were taken:

- For those parameters in which at least 85% of the water quality dataset was below detect limits even at the lowest MDL, the lower MDL number was adopted and replaced the higher MDL non-detect results.
- For those parameters in which less than 85% of the water quality dataset was non-detect (or conversely, more than 15% of the dataset was measured at detectable concentrations), a replacement of the lower MDL was not undertaken. Instead, the non-detect results at the higher MDL(s) were removed from the dataset. While these deletions reduce the potential statistical power of the dataset, the higher MDL non-detect results will skew the baseline results if they are left in the dataset.

Table 2.3 summarizes the yearly detection limits for each of the parameters along with any MDL adjustments that were undertaken. The MDL assessment successfully removed the occurrence of most historically elevated MDLs. In instances where 15% of the data were detectable, and below an MDL, the non-detect values at the elevated MDL were removed. In some cases, more than one MDL remained below detectable concentrations. In these instances, the MDLs were kept as is. For this reason, it is still possible to locate multiple detection limits within the data. As discussed, these lower valued MDLs are not expected to interfere with data analysis.

TABLE 2.3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

WATER AND SEDIMENT QUALITY REVIEW AND PRELIMINARY CREMP STUDY DESIGN
REVIEW OF WATER QUALITY METHOD DETECTION LIMITS

Print Apr-01-14 11:25:12

Parameters	Units	Receiving Water Quality Objectives (2012)	Method Detection Limits							% Detects in the Dataset	MDL Changes to the Dataset
			2005	2006	2007	2008	2011	2012	2013		
General Parameters											
Alkalinity	mg/L CaCO3	-	2	5	5	5	5	5	5	Not reviewed	No changes
Br-	mg/L	-	0.3	0.05	0.05	0.05	0.25	0.25	0.25		
Cl-	mg/L	120	0.2	1	1	1	1	1	1		
Conductivity	uS/cm	-	1	5	5	5	5	5	5		
NH3+NH4	mg/L N	0.021-2313	0.1	0.02	0.02	0.02	0.02	0.02	0.02		
NO2-	mg/L N	0.06	0.06	0.005	0.005	0.005	0.1	0.005	0.005		
NO3-	mg/L N	13	0.05	0.1	0.1	0.1	0.1	0.1	0.1		
NO2+NO3	mg/L N	-	0.06	0.1	0.1	0.1	0.1	0.1	0.1		
Phenols	mg/L	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Chlorophyll-a	mg/m3	-					0.2				
Pheophytin-a	mg/m3	-					0.2				
SO4-	mg/L	-	0.5	1	1	1	1	3	3		
TKN	mg/L	-			0.1	0.1	0.1	0.1	0.1		
TOC	mg/L	-			0.5	0.5	0.5	0.5	0.5		
DOC	mg/L	-			0.5	0.5	0.5	0.5	0.5		
TSS	mg/L	-			2	2	2	2	2		
TDS	mg/L	-	30	5	5	5	1	1	1		
Hardness	mg/L CaCO3	-	0.5	1	1	0.5	0.5	0.5	0.5		
Phosphorus	Total	-	0.02	0.01	0.003	0.003	0.003	0.003	0.003		
Turbidity	NTU	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
Total and Dissolved Metals											
Aluminum	mg/L	0.94	0.004	0.005	0.001	0.001	0.003	0.003	0.003	93%	
Antimony	mg/L	-	0.0004	-	0.0001	0.0001	0.0001	0.0001	0.0001	0%	
Arsenic	mg/L	0.005	0.005	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	5%	Non-detects at 0.005 and 0.001 were revised to <0.0001
Barium	mg/L	-	0.01	0.01	0.00005	0.00005	0.00005	0.00005	0.00005	68%	
Beryllium	mg/L	-	0.005	-	0.0005	0.0005	0.0005	0.0001	0.00002	0%	
Bismuth	mg/L	-	0.0003	-	0.0005	0.0005	0.0005	0.0005	0.0005	0%	
Boron	mg/L	1.5	0.05	0.01	0.01	0.01	0.01	0.01	0.01	5%	
Cadmium	mg/L	0.000029	0.0001	0.0001	0.000017	0.000010	0.00001	0.00001	0.00001	8%	Non-detects at 0.0001 were revised to <0.00001
Calcium	mg/L	-	0.05	1	0.05	0.05	0.05	0.05	0.05		
Chromium	mg/L	0.0047	0.001	0.001	0.0005 0.001	0.0005	0.0005 0.001	0.0001	0.0001	16%	Non-detects from 2005 through 2011 were revised to <0.0001
(Hexavalent) Chromium	mg/L							0.001	0.001		
(Trivalent) Chromium	mg/L							0.005	0.005		
Cobalt	mg/L	-	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	12%	
Copper	mg/L	0.002	0.0008	0.001	0.0001 0.001	0.0001	0.0005	0.0005	0.0005	72%	Non-detects at 0.001 were removed from the dataset
Iron	mg/L	0.3	0.02	0.03	0.03	0.03	0.03	0.01	0.01	64%	
Lead	mg/L	0.001	0.0002	0.001	0.00005	0.00005	0.00005	0.00005	0.00005		Non-detects at 0.001 were removed from the dataset
Lithium	mg/L	-	-	-	0.005	0.005	0.005	0.0005	0.0005	4%	
Magnesium	mg/L	-	0.005	1	0.1	0.1	0.1	0.1	0.1	100%	
Manganese	mg/L	-	0.0007	0.01	0.00005 0.01	0.00005	0.00005	0.00005	0.00005	62%	Non-detects at 0.01 were removed from the dataset
Mercury	mg/L	0.000026	0.0001	0.00005	0.00005	0.00001	0.00001	0.00001	0.00001	1%	Non-detects at 0.0001 and 0.00005 were revised to <0.00001
Molybdenum	mg/L	0.073	0.0003	0.005	0.00005 0.005	0.00005	0.00005 0.005	0.00005	0.00005	55%	Non-detects at 0.005 were removed from the dataset
Nickel	mg/L	0.083	0.001	0.005	0.0005	0.0005	0.0005	0.0005	0.0005	42%	Non-detects at 0.001 and 0.005 were removed from the dataset
Potassium	mg/L	-	0.02	0.01	2	0.05	0.05	0.05	0.05	48%	
Selenium	mg/L	0.001	0.005	0.001	0.001	0.001	0.001			1%	Non-detects at <0.001 and <0.005 were revised to <0.0001
Silicon	mg/L	-	-	-	0.05	0.05	0.05	0.05	0.05	99%	
Silver	mg/L	0.0001	0.0001	0.0001	0.00001 0.00005 0.00001	0.00001	0.000001	0.000001	0.000001	3%	Non-detects at 0.001 and 0.00005 revised to <0.000001
Sodium	mg/L	-	0.05	0.05	2	0.05	0.0012	0.0012	0.0012	86%	
Strontium	mg/L	-	0.001	0.001	0.0001	0.0001	0.0001	0.0002	0.0002	100%	
Thallium	mg/L	0.0008	0.0002	-	0.0001	0.0001	0.0001	0.00001	0.00001	0%	
Tin	mg/L	-	0.001	0.01	0.0001	0.0001	0.0001	0.0001	0.0001	10%	
Titanium	mg/L	-	0.003	-	0.01	0.01	0.01	0.01	0.01	20%	
Uranium	mg/L	0.015	-	-	0.00001	0.00001	0.00001	0.00001	0.00001	98%	
Vanadium	mg/L	0.006	0.0009	0.001	0.001	0.001	0.001	0.001	0.001	8%	
Zinc	mg/L	0.03	0.001	0.01	0.001	0.001	0.003	0.003	0.003	22%	Non-detects at 0.01 were removed from the dataset

NOTES:

1. MDL VALUES MAY BE ELEVATED IN INDIVIDUAL SAMPLES DUE TO SAMPLE MATRICES. THE MDL VALUES ABOVE REPRESENT THE NORMAL VALUE.
2. MULTIPLE MDL VALUES ARE NOTED FOR SEVERAL PARAMETERS IN 2007 DUE TO TWO LABORATORIES DOING METALS ANALYSIS FOR COMPARISON PURPOSES.

0	28MAR'14	ISSUED WITH REPORT NB102-181/33-1	MAS	RAC	RAM
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

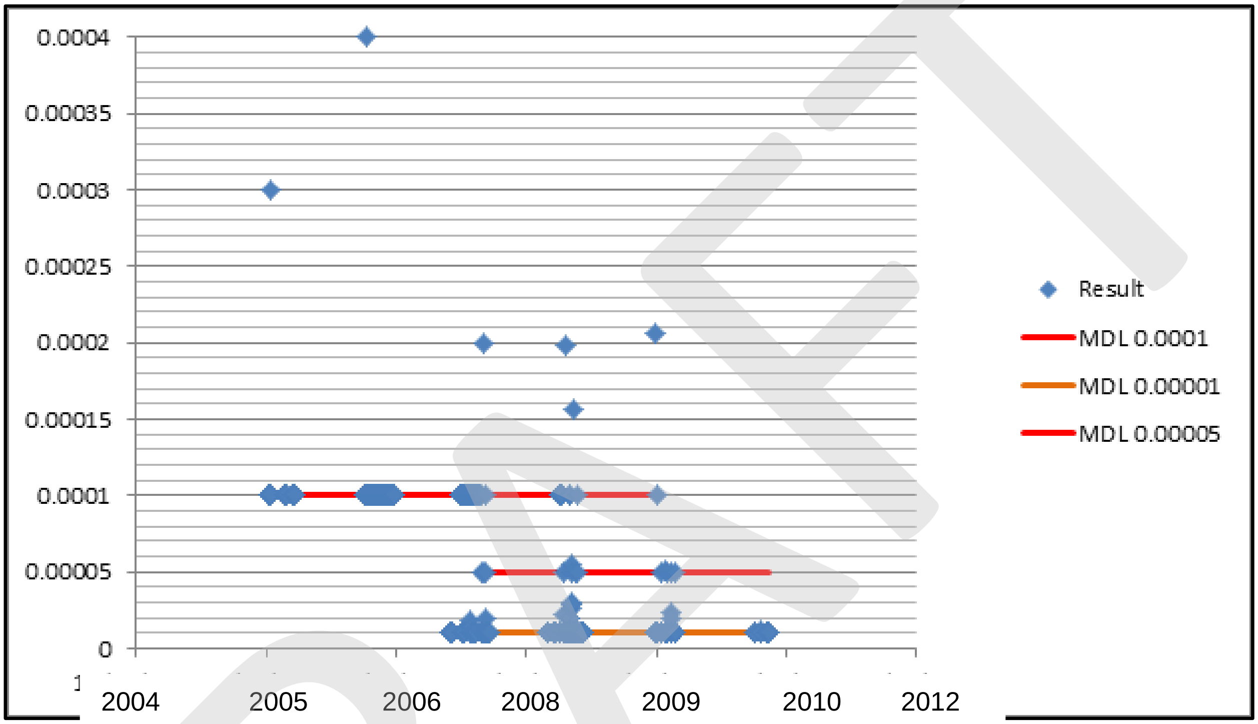


Figure 2.1 **Example MDL Evaluation Graph - Silver**

2.3 TREATMENT OF OUTLIERS

Once the non-detect results were modified or removed, the data were then plotted graphically and reviewed statistically in order to identify outliers. An outlier is an unusually extreme value for a variable, given the statistical model in use (Edwards, 1998). It is important to note that water quality data are among the environmental data that naturally produces extreme values. As such, outlier removal was only undertaken if there were a data entry error or if there was a quality assurance explanation that justified data removal.

2.4 WATER QUALITY PARAMETERS OF CONCERN

The parameters of concern are those metals predicted by water quality modeling to be of most concern during mine operation, and those that are currently enriched naturally. These parameters are the focus on the baseline review and include:

- Aluminum
- Arsenic
- Cadmium
- Chloride

- Chromium
- Copper
- Iron
- Nitrate
- Nickel

Aluminum, copper, iron and nickel were found to be naturally enriched in the Project Area, relative to the Water Quality Guidelines. Other parameters that have the potential to be elevated, but at a lower magnitude, due to M~~m~~ine Si~~si~~te releases include the following (these parameters were not a focus of the baseline review):

- Cobalt
- Lead
- Phosphorous
- Silver
- Thallium

Not surprisingly, several of the above parameters were found to be naturally elevated in the vicinity of the Mine Site. In several watercourses, the mean concentrations of the above parameters occasionally exceeded the generic criteria of the Canadian Environmental Quality Guidelines for the protection of freshwater aquatic life (CWQG-PAL). As such, interim site-specific water quality objectives (SSWQOs) were initially developed by Knight Piésold (2012b) during review of the FEIS.

These Interim SSWQOs and the generic CWQG-PAL criteria are referred to in the following discussions for the above parameters.

2.5 GRAPHICAL ANALYSIS OF WATER QUALITY DATA

A detailed review of water quality was undertaken using various graphical analysis tools to characterise the baseline water quality for waterbodies expected to be most influenced by mine operations. A detailed review of the Mine Site Area lake and stream water quality is presented in Appendix B and Appendix C, respectively. The raw data for pH, hardness, alkalinity and parameters of interest are displayed graphically in box plots and scatter plots in these two appendices. A summary of the key findings of the reviews presented in Appendices B and C is presented in the following sub-sections.

2.5.1 Lake Water Quality

Lake water quality sampling was completed in the vicinity of the Mine Site at Camp Lake, Sheardown Lake and Mary Lake between 2006 and 2008 and between 2011 and 2013 (Figures 1.1 and 1.2). Lake water quality samples were collected from both shallow depths (1 m below the ~~waterline~~surface) and deep depths (approximately 1 m above the lake bottom).

The lakes in the study area are typically ice covered between October and June. As such, most of the data was collected during the summer and fall, while the least amount of data were collected during the winter.

Table 2.4 summarizes the range and median values of the general water chemistry parameters selected for evaluation. The water chemistry is similar between the three (3) Mine Site lakes and is generally slightly alkaline and soft with alkalinity values similar to hardness values, suggesting that the hardness is predominantly carbonate hardness.

Table 2-4 Concentrations of Select General Chemistry Parameters in Mine Site Lakes

Parameter	Camp Lake	Sheardown L. NW	Sheardown L. SE	Mary Lake
In Situ pH (pH)	6.93 - 8.23 (7.88)	6.76 - 8.33 (7.94)	6.41 - 8.32 (7.85)	6.71 - 8.55 (7.68)
Alkalinity (mg/L $CaCO_3$)	50 - 74 (60)	47 - 72 (57)	43 - 82 (50)	25 - 126 (38)
Hardness (mg/L)	50 - 77 (59.6)	43 - 77.9 (60.5)	16 - 82 (51.75)	24.9 - 137 (39.5)
Chloride (mg/L)	<1 - 4 (1)	<1 - 4 (3)	<1 - 5 (3)	<1 - 14 (2)
Nitrate (mg/L)	<0.10	<0.10 - 0.18 (0.10)	<0.10	<0.10

NOTES:

1. MEDIAN CONCENTRATIONS IN BRACKETS.

A summary of the trends observed during the review of water quality within the individual lakes follows.

2.5.1.1 Camp Lake

The trends observed in the Camp Lake baseline data included:

- Distinct depth trends are not observed for Camp Lake, which suggests that the lake is completely mixed through much of the year. Review of data above suggests aggregation of deep and shallow stations may be appropriate.
- Geographic trends between discrete sampling stations were not observed for any parameters.
- With the exception of chloride and chromium, parameters did not show any distinct inter-annual trends/variability over the six year sampling history. Chloride and chromium concentrations in Camp Lake measured from 2011 through 2013 are elevated compared to earlier samples from 2005 to 2010.
- Parameters with MDL interference and/or that do not show seasonal trends include: cadmium, chloride, arsenic, iron and nitrate.
- Parameters that have maximum concentrations occurring in the summer: nitrate and aluminum. This is likely as a result of the spring runoff period caused by rapid melt of winter snowpack.
- Parameters that have maximum concentrations occurring in the winter: copper and nickel. Most of this concentration occurs in a dissolved form, not as particulate.
- Parameters that have maximum concentrations occurring in the fall: chromium.

2.5.1.2 Sheardown Lake

Summary of trends observed during review of Sheardown Lake NW baseline data:

- Deeper sampling stations show slightly elevated concentrations of aluminum. Distinct depth trends are not observed for other parameters within Sheardown Lake, which suggests that lake is completely mixed throughout the year, despite winter ice. As a result, aggregation of deep and shallow stations is appropriate for all parameters except aluminum.
- Detection limits decreased over the course of sampling and this decrease is particularly apparent in the copper and iron concentration data.
- Little variability was observed between geographically distinct sampling stations.

- Parameters below MDLs and/or do not show any seasonal trends: arsenic, cadmium, chloride, chromium, copper, nitrate and iron.
- Parameters with highest concentration occurring in the fall: aluminum.
- Parameters with highest concentrations occurring in the winter: nickel. The majority of the elevated nickel and copper total concentrations are in predominantly dissolved form.

Summary of trends observed during review of Sheardown Lake SE baseline data:

- Distinct depth trends are not observed for any parameters within Sheardown Lake SE. This suggests that the lake is completely mixed throughout the year, despite winter ice.
- Elevated concentrations observed at DL0-02-4 compared to other stations: copper, iron and nickel.
- Early data (2007, 2008) appears elevated when compared to more recent data: copper and nickel.
- Parameters below MDLs and/or do not show any seasonal trends: nitrate, arsenic, cadmium, chromium and copper.
- Parameters with highest concentration occurring in the summer and/or fall: aluminum and iron.
- Parameters with highest concentrations occurring in the winter: chloride and nickel.

2.5.1.3 Mary Lake

Summary of trends observed during review of Mary Lake baseline water quality data:

- Distinct depth trends were not observed for any parameters within Mary Lake, which suggests complete mixing of the lake. As a result, both deep and shallow station data have been utilized to inform baseline trends in water quality.
- Inlet sampling shows elevated concentrations for certain parameters: aluminum, chloride, copper, iron, hardness, chromium and nickel.
- Parameters that occur below MDL or do not show seasonal trends include: cadmium, copper, nitrate, and chromium.
- Parameters with the highest concentrations in the summer include: aluminum and iron.
- Parameters with the highest concentration during the fall include: arsenic.
- Parameters with the highest concentration during the winter: chloride, nickel and cadmium.
- The overall trends in the lake baseline water quality data include:
  - The only parameter with distinct depth trends is aluminum in Mary Lake. The rest of the data gathered at lake stations suggests aggregations of deep and shallow stations is appropriate.
  - Mary Lake inlet sampling was the only station that showed variability between geographically distinct sampling stations. In particular, slightly elevated concentrations for aluminum, chloride, copper, iron, hardness, chromium and nickel were observed (although elevated, these concentrations were below guidelines). Outlet sample locations show elevated concentrations of arsenic.
  - Aluminum was noted to have high summer concentrations at all stations, with the exception of Sheardown Lake NW where highest concentrations were recorded in the fall. This would be expected given the magnitude of the spring runoff that is caused by rapid melting of the winter snowpack.

- Arsenic, cadmium and nitrate (except for some slightly elevated fall concentrations) generally occurred below MDL and seasonal affects were difficult to discern.
- Chloride, iron and copper did not show conserved seasonality trends at most stations.
- Nickel was generally high during the winter, which was not necessarily expected. One possibility is that under-ice formation concentrates solutes at depth. However, this trend would be expected to occur for all parameters. Data indicates that nickel and copper were present predominately in their dissolved form during the winter, while other parameters were present predominately in particulate form.

2.5.2 Stream Water Quality

Since 2005, a variety of watercourses have been sampled as part of the baseline monitoring program. For the purposes of the CREMP, a subset of the baseline sampling stations was selected that were deemed applicable for future monitoring. As a result, only two river/tributary systems were examined: Mary River and the Camp Lake Tributary. In general, similar station-wide and seasonal trends were noted for each parameter within rivers/tributary systems on the property. No distinct inter-annual trends were noted. Comparison of the general chemistry of the two systems indicates the general composition is quite similar: water is characterised as circum-neutral/slightly alkaline pH and high alkalinity/low sensitivity to acidic inputs. Hardness ranges from "soft" to "moderately soft" and is almost entirely carbonate hardness.

Chemical concentration trends were analysed with the knowledge that the intense spring runoff period resulting from winter snowpack melting characterizes the arctic hydrologic cycle (Stewart and Lamoureux, 2011). Our data indicates highest trace metal concentrations occur during summer (and occasionally fall), and that spring concentrations are generally lowest. This indicates that the snowpack is acting as a fresh, diluting seasonal input.

Station-wide, nitrate, arsenic and cadmium general occur at detection limit. Chloride and nickel generally occur above MDL, but below guideline values. Chloride concentration increases through the seasons from the lowest recorded concentration in the spring to the highest recorded concentrations in the fall. In Mary River, the highest nickel concentrations occur in the summer; whereas, no seasonal trends are noted for nickel within the Camp Lake Tributary. Copper concentrations are consistently close to guideline value throughout the station, with highest concentrations occurring in the summer and fall.

Aluminum and iron show slightly different trends between stations within Mary River and the Camp Lake Tributary. Within Mary River, median total aluminium concentrations occur above CWQG-PAL guidelines, but below the SSWQO and are highest during the summer. Within the Camp Lake Tributary, median total aluminum concentrations are generally low and below the CWQG-PAL guideline and are highest during the spring. Total iron concentrations within Mary River are consistently close to the guideline, with maximum values exceeding guideline and highest concentrations occurring in the summer. Within the Camp Lake Tributary, iron concentrations are consistently below guidelines, with maximum values occurring during the spring.

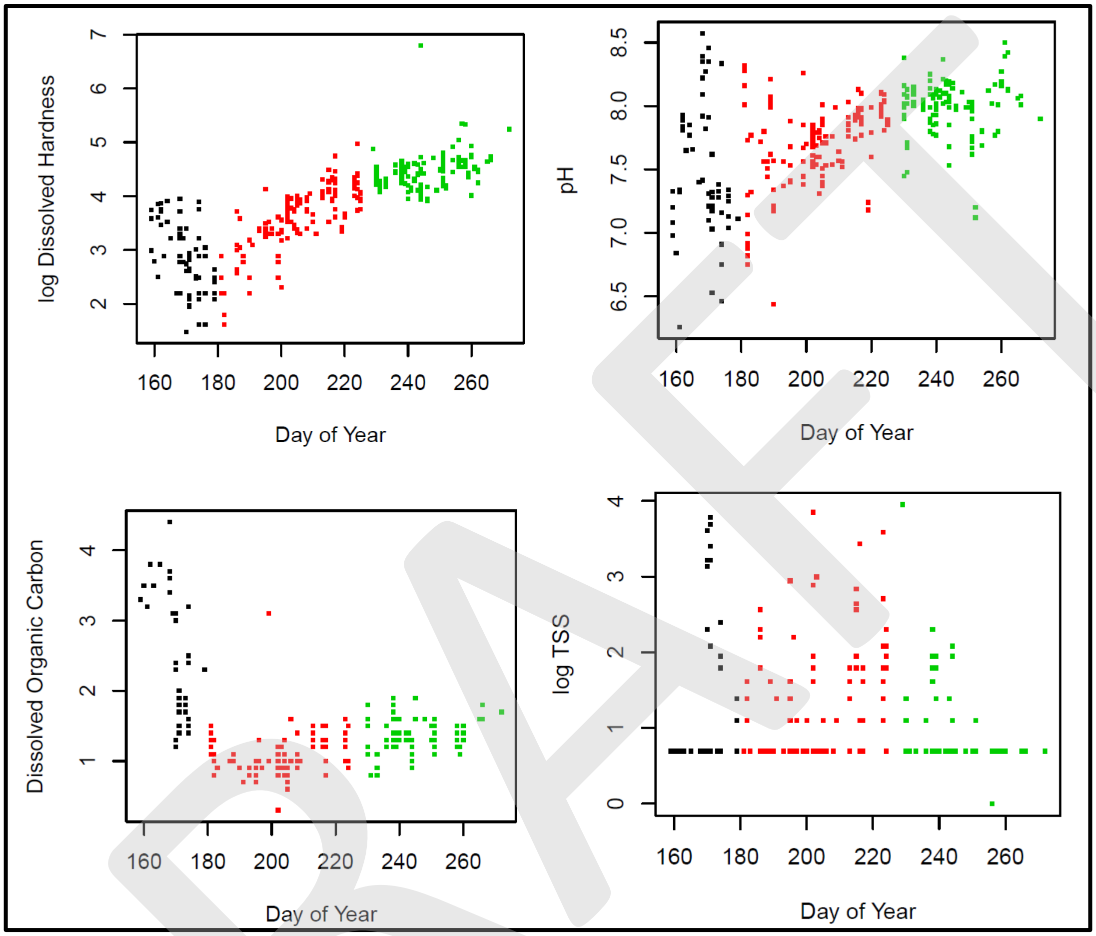
2.5.3 Site-Wide Overview of Water Quality Including Seasonal Trends

General site-wide trends were noted for the concentration of many parameters. Few inter-annual trends of significance were noted, with the exception of a general decline in detection limits. Site-wide and seasonal trends are parameter-specific and were fairly consistent for river stations. Seasonal trends for lake stations were less consistent. In general, all lakes are well mixed and did not show concentration differences with depth, with the exception of aluminum.

2.5.3.1 General Chemistry

Site-wide, general water chemistry is consistent across stations within rivers and lakes. Circum-neutral/slightly alkaline pH (7.3 through 7.8) is noted throughout the site. The water is characterized by high alkalinity, indicating low sensitive to acidic inputs and "soft" hardness and is composed almost entirely of carbonate hardness. Water within the Camp Lake tributary ranges from "moderately soft" to "soft". In general, metal concentrations within the three lakes (Camp Lake, Sheardown Lake and Mary Lake) are reduced and below guidelines, when compared to river samples from Mary River and the Camp Lake tributary, which exceed certain guidelines. High background metal concentrations are expected in an area with such a rich ore body.

Seasonal review of general chemistry shows the relationship between spring freshet and hardness, pH, TSS and DOC. TSS does not show very distinct trends. Both pH and hardness tend to be slightly lower during spring and increase during summer, to a maximum level recorded in the fall. DOC is at its peak during spring and decreases substantially during summer and fall (Figure 2.2). Geographic trends for pH are not noted within Mary River (Figure 2.3).



NOTES:

1. BLACK (SPRING); RED (SUMMER); GREEN (FALL).

Figure 2.2 Mary River - pH, TSS, DOC and Hardness

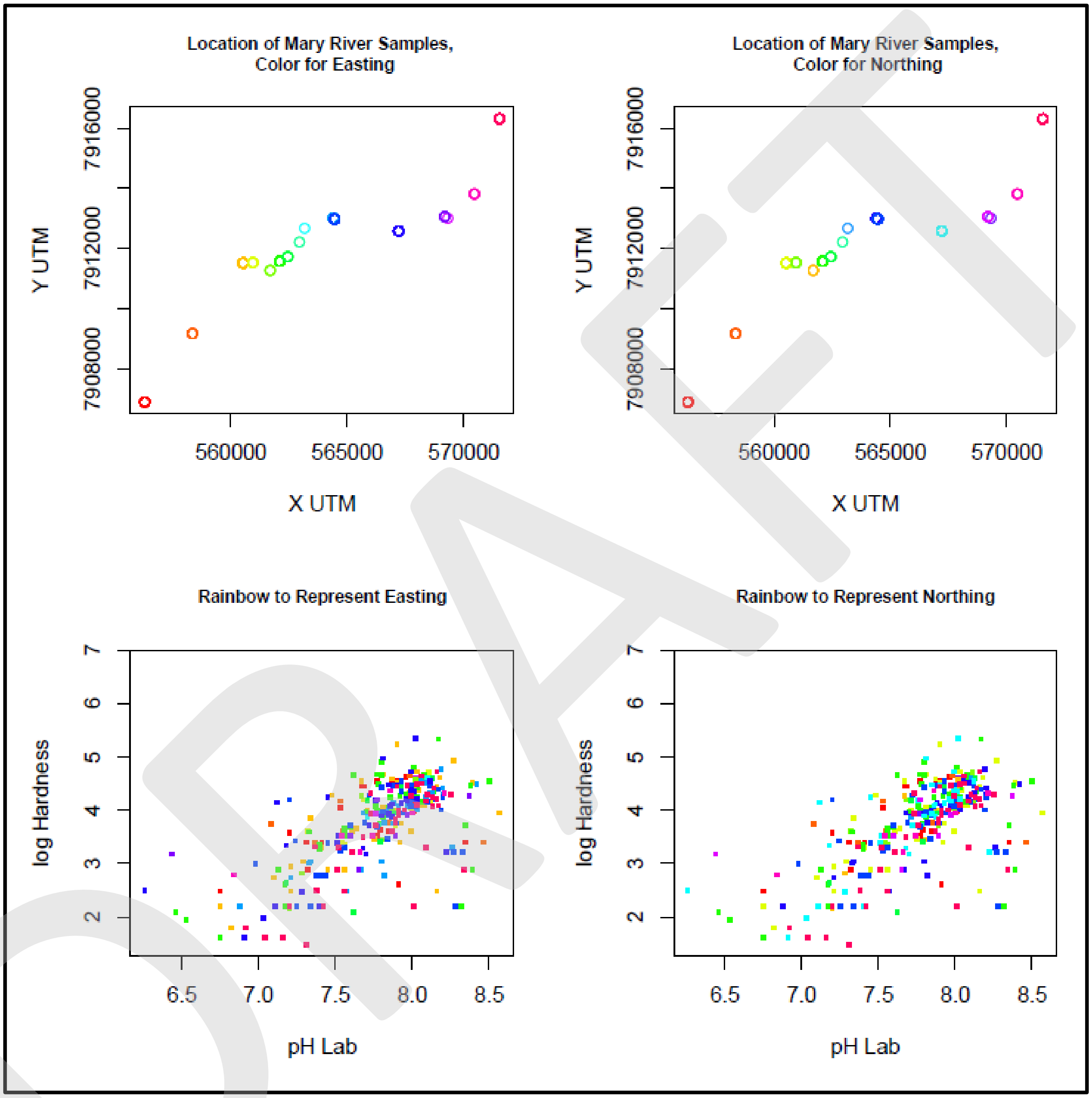


Figure 2.3 **Mary River - Geographic pH Trends**

2.5.3.2 Anions, Nutrients and Metals

Site-wide, nitrate, arsenic and cadmium occur at detection limit, with the exception of the Mary Lake outlet, which has slightly elevated arsenic concentrations. Due to detection limit interference, it is difficult to discern temporal and seasonal trends for these parameters.

Iron, aluminum, copper and chromium are observed to be elevated and often occur above guideline values within Mary River and Camp Lake tributary. Concentrations of these parameters are generally quite a bit lower in the identified lakes. Camp lake has high outlying iron concentrations; Mary Lake has elevated aluminum and chromium concentrations and Sheardown Lake SW has elevated aluminum and copper concentrations (Table B.9). Site-wide, iron concentrations are slightly enriched, but always occur below guidelines.

A more detailed discussion of seasonal trends site-wide for chloride, iron, nickel, copper and aluminum follows. Site-wide trends observed match closely to the trends observed for streams, but not lakes. This is simply a result of the magnitude difference between stream and lake concentrations. Lake concentrations are consistently depressed when compared to stream concentrations. Lake concentrations also have subtle differences in seasonality that can only be determined by looking at the lake in question. With the exception of chloride and nickel, site-wide the other elevated parameters are seen to increase during the summer months.

Exploration drilling on Deposits Nos. 1, 2 and 3 has involved the use of calcium chloride brine, as mentioned in Section 1.3. Progressively more sophisticated and effective measures were employed over the years to recycle and contain the brine. Monitoring of water quality in the Mary River in the E3 tributary, downstream of Deposit No. 1 in 2007/2008 confirmed that calcium and chloride were quite elevated downstream of this activity. Chloride concentrations reached maximum concentrations of approximately 3,000 mg/L. Detailed analysis of concentrations at E0-03 indicated that calcium and chloride concentrations were significantly reduced, but slightly elevated. Chloride concentrations reached a maximum of 73 mg/L within E0-03 and had seasonal peaks during the summer (Figure 2.4 and Figure 2.5). Despite use of the drilling salts during baseline, plots of the entire dataset indicate chloride concentrations are not distinctly elevated.

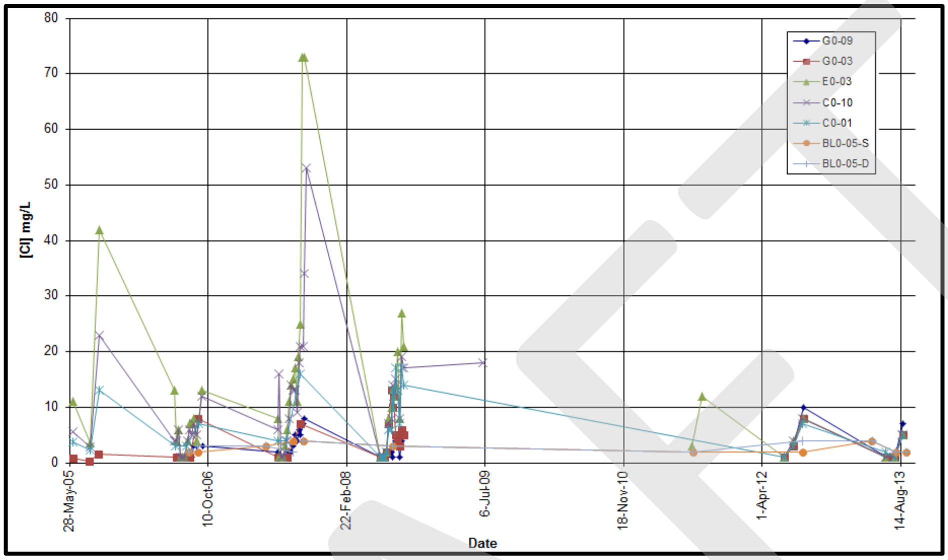
Figures 2.6 through 2.8 depict the changes in concentrations that occur during seasons in both the streams and lake in vicinity to the proposed ~~mine~~ Mine S~~s~~ite. Spring lake concentrations are never depicted and neither are winter stream concentrations. Figure 2.6 shows a small increase in chloride concentrations during the fall, with highest concentrations recorded at E0-03 and C0-01 and within the Camp Lake Tributary. In general, lake concentrations of chloride are below concentrations of chloride measured in the streams.

Iron concentrations are at their peak site-wide during the summer, although elevated concentrations were noted in the Camp Lake Tributary during the spring, as shown on Figure 2.7. Iron concentrations reduce slightly, but remain elevated during the fall. Stream water quality stations consistently depict concentrations in excess of lake water quality stations.

With the exception of one large outlying value for nickel, Figure 2.8 shows relatively conservative concentrations for nickel are observed throughout the site, during different seasons. Slightly lower nickel concentrations in the spring; however, a small sample size is also observed.

Copper concentrations increase slightly during the summer and remain slightly elevated during the fall, as depicted on Figure 2.9. Some particularly high copper values have been recorded in Camp Lake, which has maximum values that exceed those observed in Mary River.

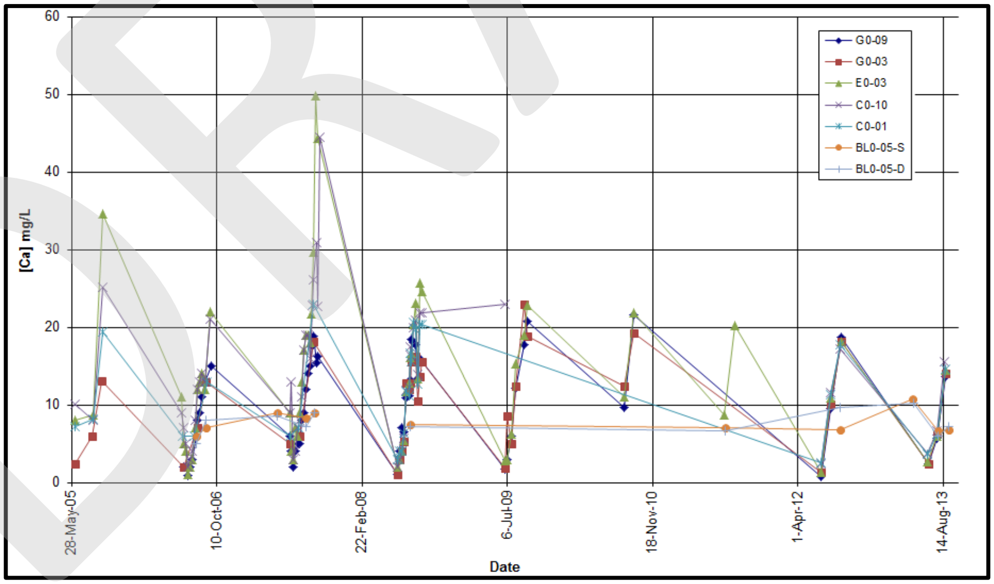
Stream aluminum concentrations are depressed in the spring, and elevated in the summer, as shown in Figure 2.10. Stream concentrations, particularly those recorded in Mary River are greater than the concentrations recorded in the lakes. Fall concentrations are elevated, when compared to fall and winter, but are less than those concentrations recorded in the summer.



NOTES:

1. G0-09 REPRESENTS BACKGROUND CONDITIONS.
2. E0-03 REPRESENTS A LOCATION DIRECTLY INFLUENCED BY DRILLING ACTIVITIES.
3. G0-03 REPRESENTS BACKGROUND IN 2005 AND 2006 (NO DRILLING AT DEPOSITS NO. 2 AND 3).

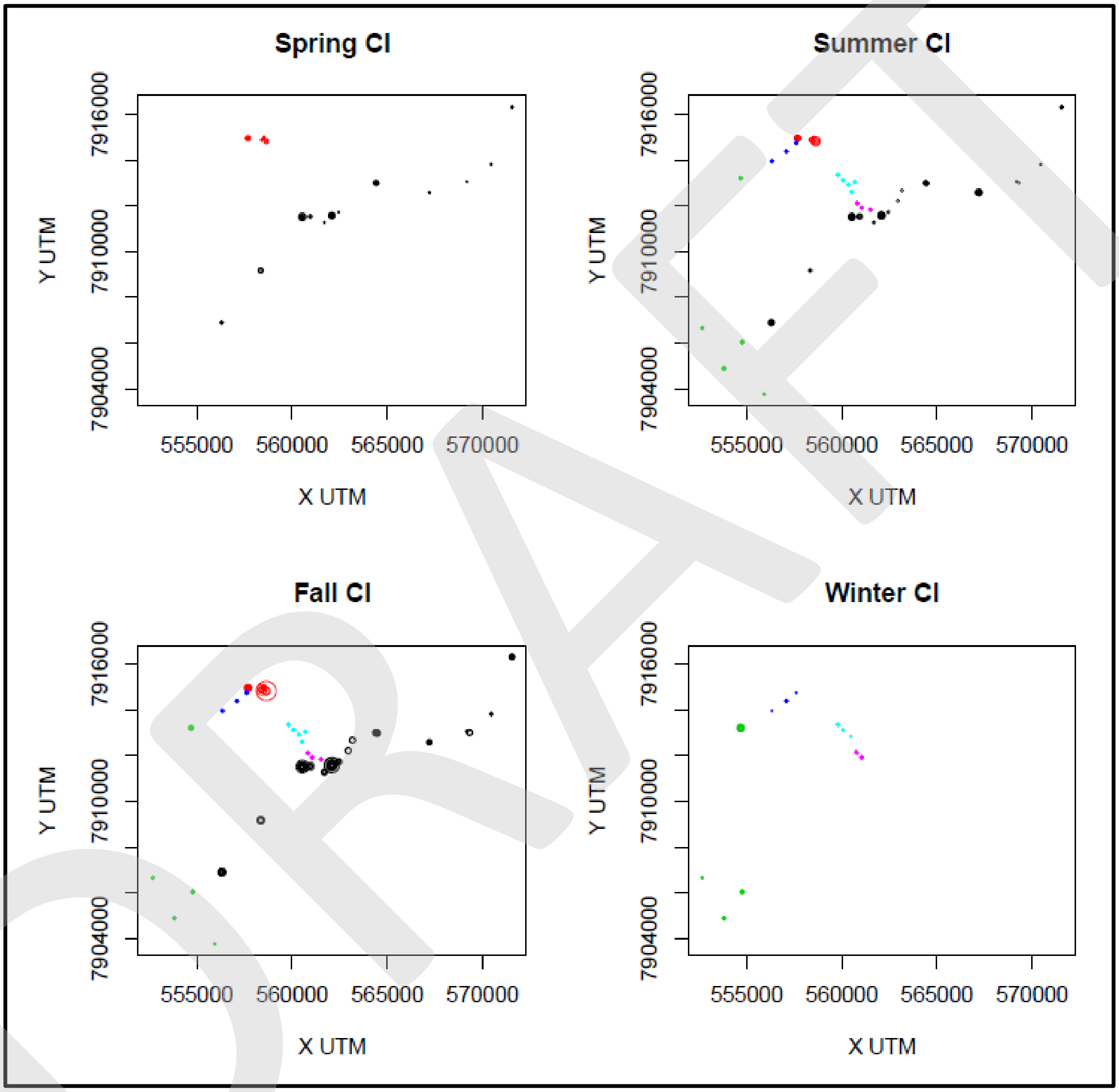
Figure 2.4 Chloride Concentrations in Mine Site Waters over the Study Period



NOTES:

1. G0-09 REPRESENTS BACKGROUND CONDITIONS.
2. E0-03 REPRESENTS A LOCATION DIRECTLY INFLUENCED BY DRILLING ACTIVITIES.
3. G0-03 REPRESENTS BACKGROUND IN 2005 AND 2006, AS THERE WAS NO DRILLING ON DEPOSITS NO. 2 AND 3.

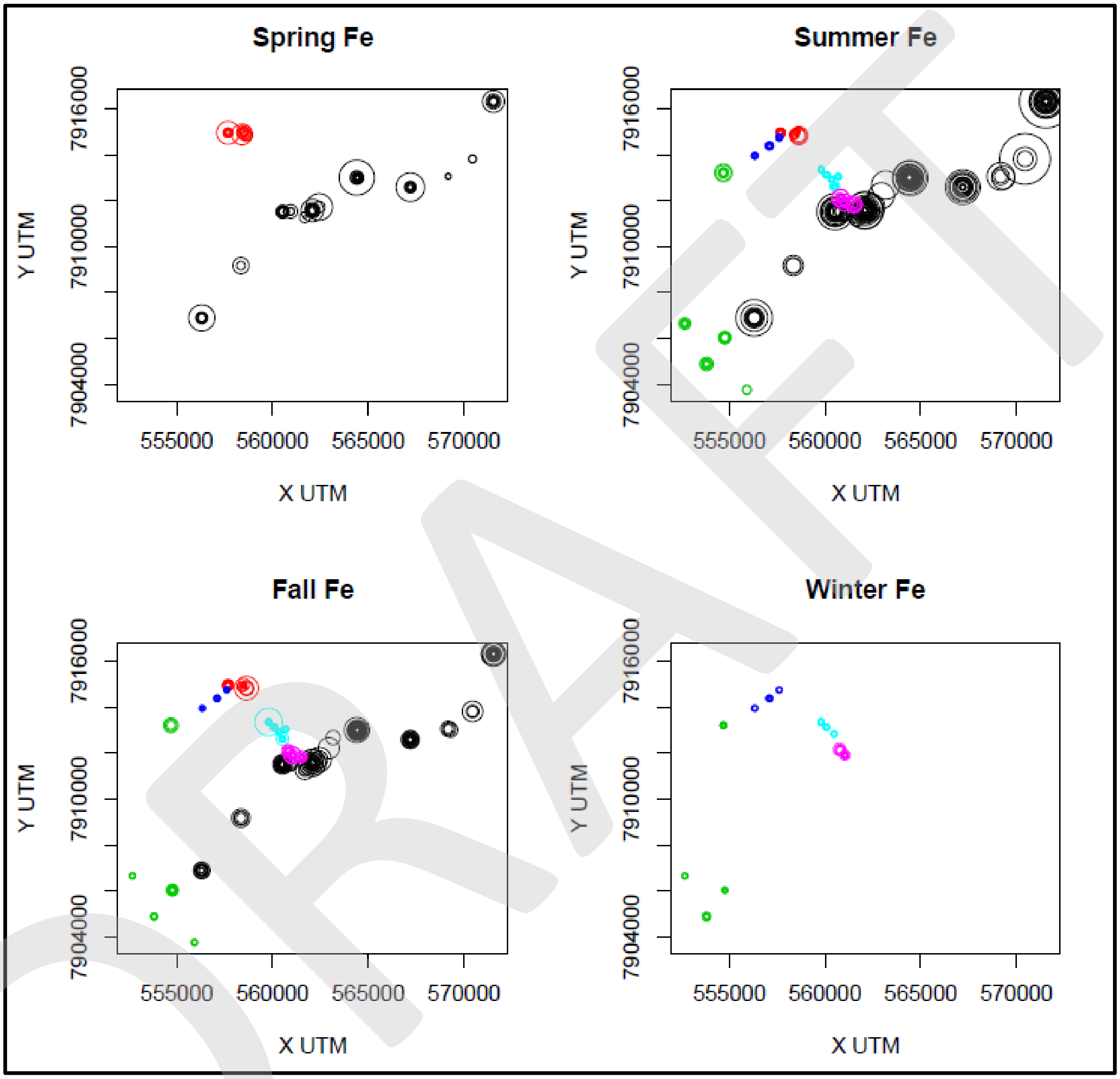
Figure 2.5 Calcium Concentrations in Mine Site Waters over the Study Period



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).
3. THE SITE WITH CLEARLY ELEVATED CONCENTRATIONS IS E0-03.

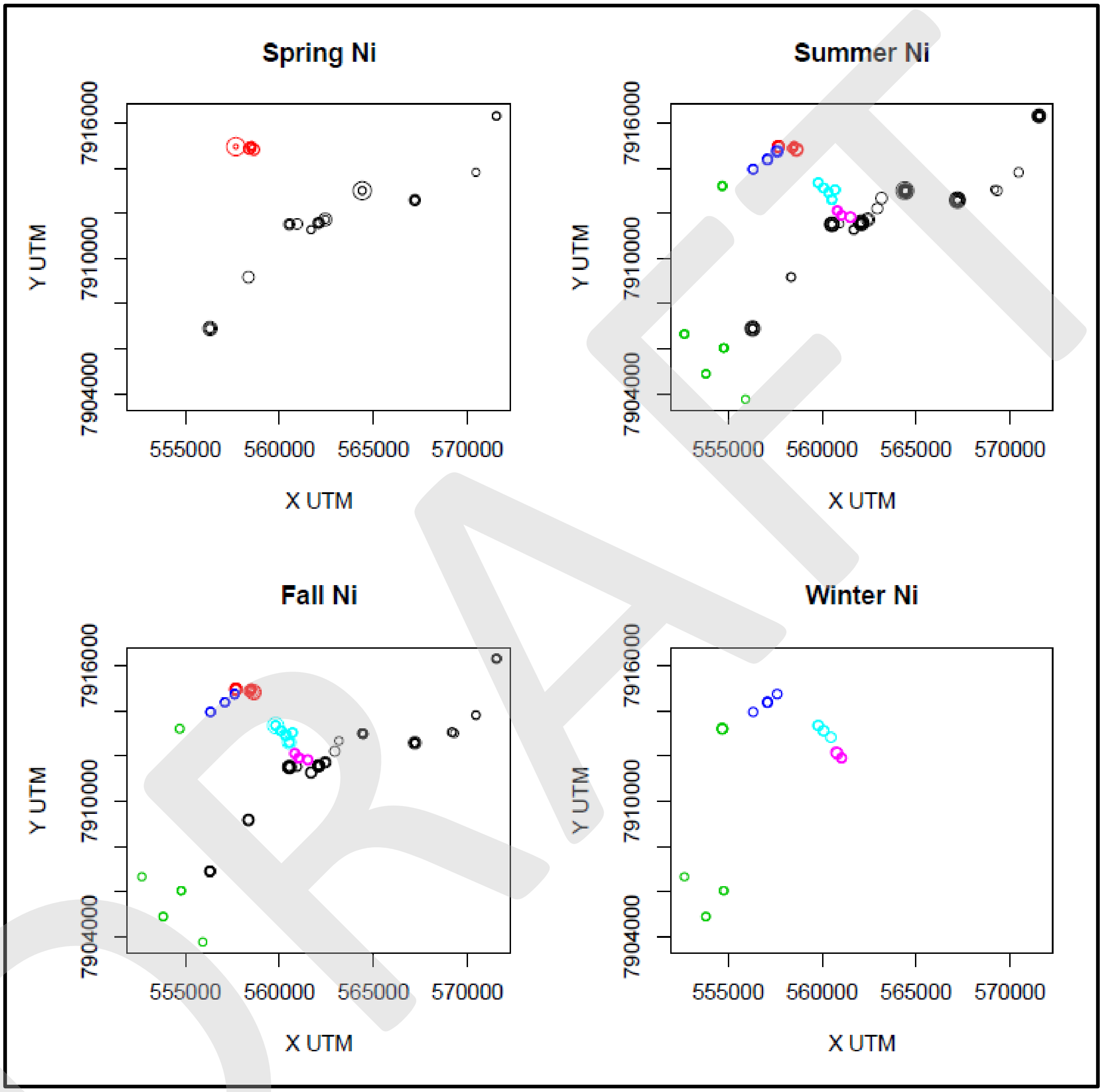
Figure 2.6 Site-Wide Seasonal Trends for Chloride



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

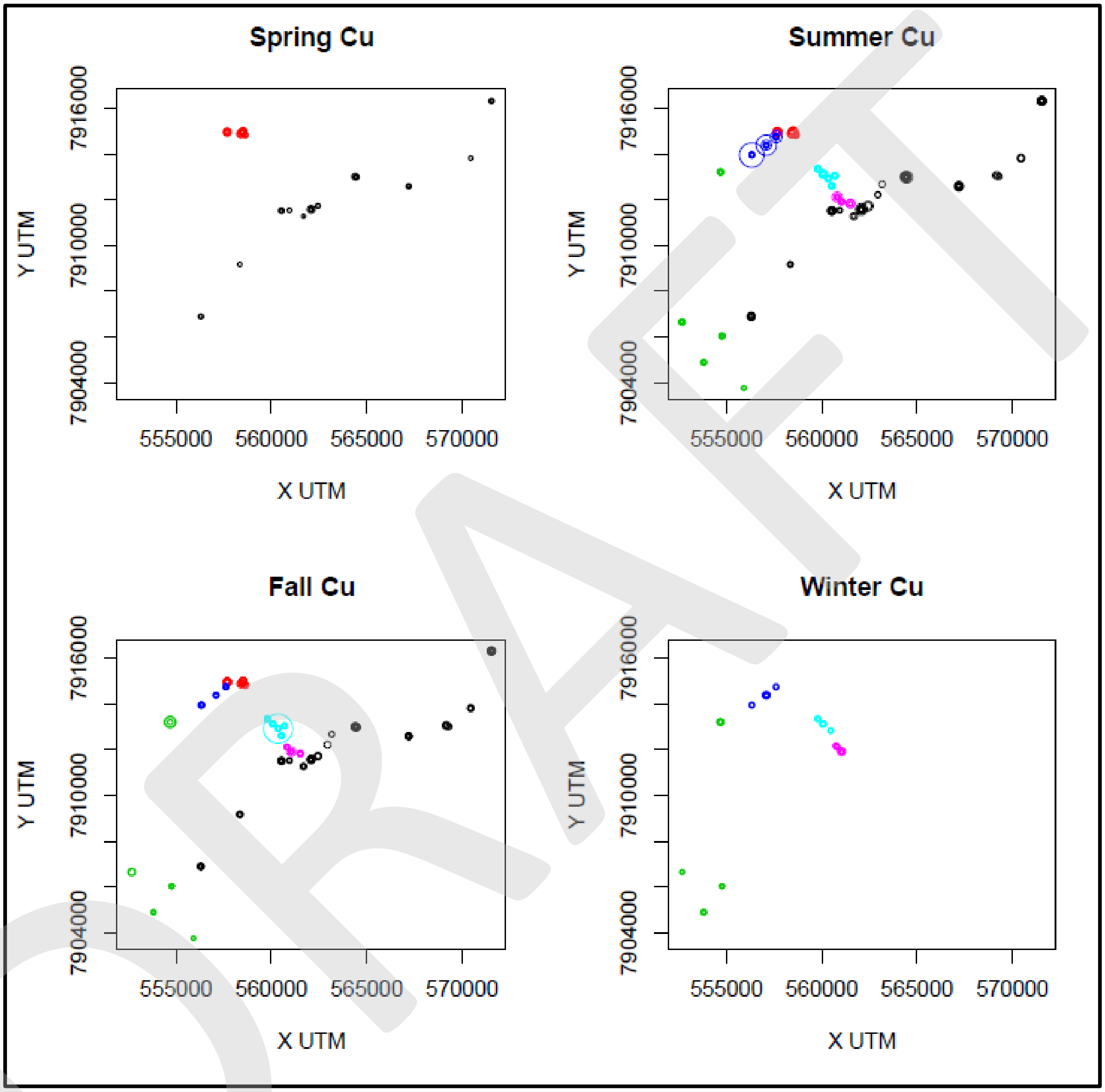
Figure 2.7 Site-Wide Seasonal Trends for Total Iron



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

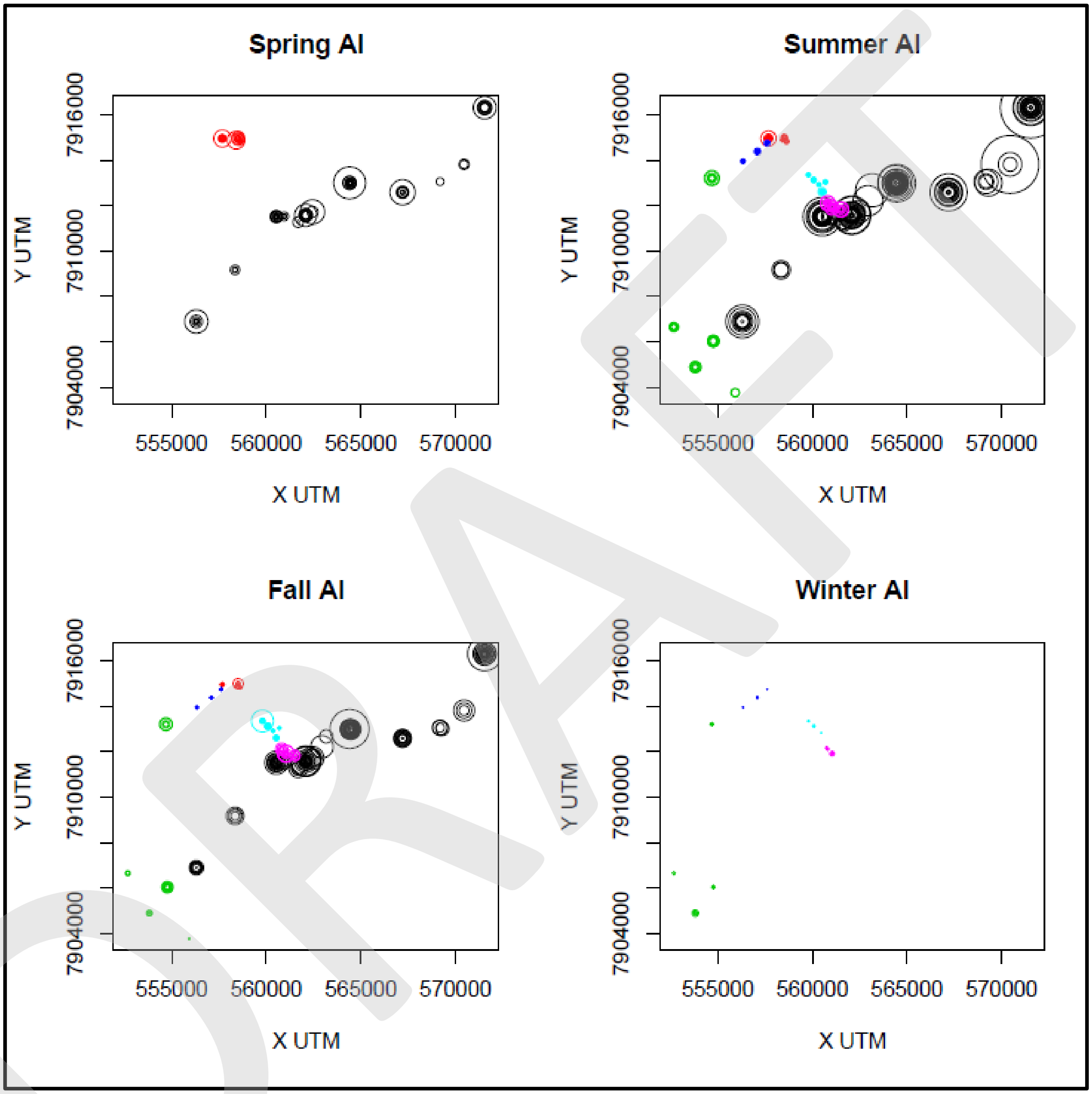
Figure 2.8 Site-Wide Seasonal Trends for Total Nickel



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

Figure 2.9 Site-Wide Seasonal Trends for Total Copper



NOTES:

1. AREA OF THE DOT IS EQUAL TO CONCENTRATION OF THE PARAMETER.
2. BLACK (MARY RIVER); RED (CAMP LAKE TRIBUTARY); GREEN (MARY LAKE); DARK BLUE (CAMP LAKE); LIGHT BLUE (SHEARDOWN LAKE NW); PINK (SHEARDOWN LAKE SE).

Figure 2.10 Site-Wide Seasonal Trends for Total Aluminum

2.5.3.3 Chromium

A discussion of chromium is appropriate since most of the sampling to date has been for total chromium yet the CWQG-PAL guidelines are for two chromium species (trivalent chromium - Cr III and hexavalent chromium - Cr VI). During review of the FEIS, naturally elevated concentrations of total chromium were identified within M~~m~~ine S~~s~~ite waterbodies, and as discussed in Section 2.4, an interim SSWQO of 0.0047 mg/L was established based on the 95th percentile of baseline concentration of total chromium in the Mary River upstream of the deposits.

In 2012 and 2013, analysis of chromium (III) and chromium (VI) was added to the program to understand the concentrations of these two chromium species. The generic criteria for chromium (III) and chromium (VI) is 0.0089 mg/L and 0.001 mg/L, respectively.

The majority of total chromium samples as well as chromium (III) and chromium (VI) samples were measured below MDLs. The MDLs for total chromium, chromium (III) and chromium (VI) are presented in Table 2.5.

Table 2-5 Water Quality Objectives for Chromium

Parameter	CWQG-PAL or SSWQO (mg/L)	MDL (mg/L)
Cr (total)	0.047	0.0001
Cr (III)	0.0089	0.005
Cr (VI)	0.001	0.001

The MDLs are higher for Cr (III) and Cr (VI) compared to total chromium. Total chromium was measured in 36% of samples within the Camp Lake Tributary and 38% of the samples in Mary River. There were no detectable concentrations of Cr (III) and Cr (VI) in Mary River for only 5% of Cr (III) and 2% of Cr (VI) samples were above MDLs.

Monitoring of chromium in water will likely need to focus on total chromium as a parameter of concern; however, the proportion of detectable concentrations of Cr (III) and Cr (VI) will also be monitored as an indicator of increasing concentrations over time.

2.5.3.4 Total Phosphorus and Total Kjeldahl Nitrogen

Total phosphorus was found to be elevated in the water in the streams and in the sediment in depositional areas of streams (Sheardown Lake tributary) and in the lakes (Camp, Mary and Sheardown Lakes). The distribution of total phosphorus within the Mary River system from the station furthest upstream of Deposit No. 1 (G0-09) to the station as far downstream as Mary Lake is presented in Table 2.5.

It can be seen from this table that the total phosphorus concentrations are elevated in the baseline condition throughout the Mary River system. According to Baffinland, limestone in the area is high in phosphorus up to a couple of percent by weight (Michael Zurowski, pers. comm.). This limestone outcrops to the west of

Sheardown Lake and the weathered material from this limestone is found in the overburden throughout the Mine Site Area. As such, it is possible that the concentrations of total phosphorus in the Mary River system is due to increased contact with local soils. Moss (2012) notes clay particles in soils also tend to bind tightly with phosphorus making the phosphorous resistant to simple leaching by water.

Concentrations of total phosphorus in lake sediment are high and regularly exceed the Ontario Sediment Quality Guideline`s Lower Effects Level (LEL) criterion for total phosphorus in depositional areas of the lake where metals also tend to accumulate. Sediment quality results are discussed in more detail in Appendix D, Section 3.

Monitoring of nutrients from sewage discharges to Sheardown Lake NW and the Mary River is anticipated to form a component of the AEMP. Table 2.6 suggests that total phosphorus concentrations in the Mine Site waters are elevated, and more importantly for monitoring, are highly variable, ranging widely from below the MDL of 0.003 mg/L (ultra-oligotrophic) to 0.035 to 0.100 mg/L (eutrophic) at each of the sampling stations in the Mary River, Mary Lake and Sheardown Lake.

Table 2-6 Total Phosphorus in the Mary River and Mary Lake

Sample Location	**Total Phosphorus Concentration (mg/L)**			**CCME Eutrophication Scale**	
	Min	**Mean**	**Max**	**Category**	**TP (mg/L)**
G0-09 (upstream)	<0.003	0.015	0.069	Ultra-oligotrophic	<0.004
G0-01	<0.003	0.010	0.032	Oligotrophic	0.004 to 0.010
E0-03	<0.003	0.014	0.060	Mesotrophic	0.010 to 0.020
Sheardown Lake NW	<0.003	0.006	0.090	Meso-eutrophic	0.020 to 0.035
C0-10	<0.003	0.014	0.060	Eutrophic	0.035 to 0.100
C0-01	<0.003	0.015	0.062	Hyper-eutrophic	>0.100
Mary Lake	<0.003	0.006	0.020		

NOTES:

1. NON-DETECT MEASUREMENTS AT OR ABOVE 0.01 MG/L WERE REMOVED BEFORE CALCULATING THE ABOVE STATISTICS.

Ongoing monitoring of total phosphorus is proposed as part of the CREMP; however, the high natural variability of total phosphorus do not allow for the measurement of statistically significant Project-related changes over time. An alternate indicator, ~~Chlorophyll~~ chlorophyll a, is proposed to monitor effects of nutrient additions to Mine Site waters as part of the freshwater biota CREMP developed by North/South Consultants Inc.

The total nitrogen (TN) and total phosphorous (TP) ratio can vary with a waterbody's trophic status (Downing & McCauley, 1992). As noted above, the Mary River and Mary Lake stations show these waterbodies are oligotrophic to mesotrophic. The majority of limnological literature identifies total phosphorus as the limiting nutrient in freshwater environments that can influence phytoplankton communities. The range of TN:TP ratios for the ~~mine~~ Mine A~~a~~rea waterbodies are provided in Table 2.7.

Table 2-7 Range of Total Nitrogen -: Total Phosphorus Ratios in Mine Site Lakes

Lake	TN:TP Ratio Calculation Method	Minimum TN:TP Ratio	Average TN:TP Ratio	Maximum TN:TP Ratio
Camp Lake	Mass	13	56	150
	Molar Weight	29	124	332
Sheardown Lake NW	Mass	20	65	177
	Molar Weight	44	144	391
Mary Lake	Mass	33	70	113
	Molar Weight	74	154	249

It is likely that, despite the periodically high total phosphorus concentrations measured in the Mine Site lakes, total phosphorus remains the limiting nutrient.

2.6 POWER ANALYSES

Parameter-specific and site-specific power analyses were completed to assess the sample size required to detect changes at individual stations. The analyses are presented in detail in Appendix C.

The parameters selected for power analysis included:

- Aluminum
- Arsenic
- Cadmium
- Copper
- Iron

These parameters were selected as they are expected to be the most affected parameters during mine operation. Stations were strategically selected to ensure sampling and subsequent statistical analyses would be able to provide information regarding the source of any contaminants that might be caused by mine development.

Power analyses were completed to determine the sample size required to detect changes in mean concentration with respect to the selected benchmarks, as per the AEMP Framework (Baffinland, 2013b). Also of interest was the ability to detect smaller statistically significant changes below the AEMP benchmark that would lead to low action adaptive management. Several “low-action” benchmarks were investigated for each parameter at each station.

Key sources of variation in the data were identified in the exploratory analysis:

- Spatial variability - from waterbody to waterbody and station to station, as for example from near field to far field
- Temporal variability - seasonal trends

- Within station variability - due to varying weather conditions such as rainfall effects on stream data (not shown here)

The following types of power analysis were completed, depending on the data available:

1) The power to detect a change in means was assessed for parameters with sufficient data above MDL (<15% of non-detected data). A before-after-control-impact (BACI) design was used to assess the power to detect differences in log mean concentration values (using the methods of Stroup, 1999)[2]. A BACI design is rigorous in the sense that it shows a change in the difference between impact (exposure) and control (reference) stations from before to after the commencement of a potential environmental impact. The following modifications to the complete BACI approach were taken, as dictated by the data available:
    i. Before-after (BA) design was used when control data was not available. Under this design, power analysis was carried out using a two sample t-test to compare means.
    ii. Control-impact (CI) design was assumed when very little baseline data was available. Under this design, power analysis for testing means was carried out using a paired t-test.
2) The power to detect a change in the proportion of values above MDL was assessed for parameters with a large proportion of values below MDL (>15% of non-detected data). For some parameters the baseline dataset is represented predominantly by values below MDL. This occurred for arsenic and cadmium at all stations.
    i. BA designs were assessed using a test for two independent proportions (Agresti, 1990).
    ii. McNemar's test (Agresti, 1990) was used to assess the power to detect a difference between the paired proportions at impact and control stations.

The outcome of the power analysis along with further details on the methodology used are provided in Appendix B and C.

2.7 WATER QUALITY CREMP STUDY DESIGN

The water quality CREMP will monitor water quality within ~~mine site~~ lakes and streams near the Mine Site with the objective of identifying P~~p~~roject-related effects to water quality from multiple sources. The water quality CREMP applies the assessment approach and response framework identified in the AEMP that is being applied to the various components of the aquatic environment (i.e., water, sediment, biota).

---

[2] Comparison of medians or log means are both supported methods to compare data sets. Median comparisons are more robust when distributions are non-normally distributed. Median or mean comparisons are equally robust when distributions are normally distributed. Log distribution of water quality data collected created a data set that was normally distributed. As a result, mean comparison was determined appropriate.

The water quality CREMP study design is consistent with the requirements for the Environmental EEM Program as specified under the Metal Mining Effluent Regulations (MMER). ~~The CREMP water quality stations overlap with those identified in the Draft EEM Cycle One Study Design (Baffinland, 2014; AEMP Appendix A).~~

2.7.1 Pathways of Effect and Key Questions

Key questions were developed for the CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. These questions and metrics focus upon key potential effects identified in the Final Environmental Impact Statement (FEIS) and the Early Revenue Phase (ERP) addendum, as well as metrics commonly applied for characterizing water quality.

The key pathways of potential effects of the Project on water quality include:

- Water quality changes related to ore body or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1)
- Water quality changes (primarily nutrients and total suspended solids [TSS]) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW)
- Water quality changes due to deposition of dust in lakes and streams (Mine Area in zone of dust deposition)
- Water quality changes due to non-point sources, such as site runoff and use of ~~Ammonium~~ ammonium nitrate fuel oil (ANFO) explosives (Mine Area)

The key question related to the pathways of effect is:

- What is the estimated mine-related change in contaminant concentrations in the exposed area?

The primary issue of concern with respect to water quality is related to the combined effects on metal and TSS concentration from mine effluent discharges and ore dust deposition on water quality in lake and streams. As such, the CREMP and the baseline monitoring focused on waterbodies that will receive mine effluent discharges, site runoff, and are closest to the sources of mine related dust. Camp Lake and its Tributary 1 (CLT-1), as well as the Mary River and Mary Lake, will receive mine effluent discharges. These waterbodies, along with Sheardown Lake, may also be affected by ore dust deposition and non-point sources of fugitive dust (i.e., road dust).

The discharge of treated sewage effluent also has the potential to cause eutrophication, with total phosphorus (TP) being a key limiting nutrient. As discussed in Section 2.5.3.4, however, TP concentrations are highly variable making it a poor indicator. While TP will continue to be monitored as part of the CREMP, ~~Chlorophyll~~ chlorophyll a will be monitored as a more reliable indicator of potential eutrophication, as part of the freshwater biota CREMP (North/South, 2014).

2.7.2 Indicators and Metrics

Water quality indicators identified for monitoring include various physical parameters, metals and nutrients. They were selected on the basis of the following:

- The potential to be naturally elevated in the environment

- The potential to become elevated in the environment as a result of current and future M~~m~~ine ~~s~~Site activities
- Discharge limit(s) ~~have been~~ established for the parameter ~~in~~ under the Type A Water Licence
- An established criterion exists for the protection of freshwater aquatic life
- Regulation under the MMER, or potential regulation as a result of the current re-evaluation of the regulations
- The parameter is an exposure toxicity modifying factor (ETMF) for other parameters of concern

The stressors of potential concern (SOPCs) and supporting parameters are listed in Table 2.8.

Table 2-8 Water Quality Parameters Selected for Monitoring

Contaminants of Potential Concern		Exploratory Data Analysis Only
Aluminum	Dissolved oxygen	Hardness
Arsenic	pH	Total Dissolved Solids
Cadmium	Total Suspended Solids	Turbidity
Chromium	Chloride	Alkalinity
Copper	Ammonia (NH3+NH4)	Calcium
Cobalt	Nitrite (NO2-)	Magnesium
Iron	Nitrate (NO3-)	Potassium
Lead	Phosphorus	Total Organic Carbon (TOC)
Nickel	Sulphate	Dissolved Organic Carbon (DOC)
Silver		
Thallium		
Vanadium		
Zinc		

2.7.3 Benchmarks

Since the Mine Site occurs within an area of metals enrichment, generic water quality guidelines established for all areas within Canada may naturally be exceeded near the Mine Site. Therefore, the selection of appropriate benchmarks must consider established water quality guidelines, such as those developed by the Canadian Council of Ministers of the Environment (CCME), as well as site-specific natural enrichment, and other factors (such as Exposure Toxicity Modifying Factors (ETMF) including pH, water hardness, dissolved organic carbon, etc.), in the selection or development of final benchmarks for monitoring data comparison (CCME, 1999, updated to 2014).

The assessment of surface water and sediment quality data over the life of the Project will be ongoing, and the recommended benchmarks of comparison throughout this process may change, as more data become available. For example, a site-specific water quality guideline established early on in the life of the mine may require updating in 10 years, based on new published literature which has become available, or site-specific toxicity tests conducted to further understand ETMF or resident species toxicity. The iterative, cyclical nature of modification of benchmarks under an AEMP is well established (MacDonald et al., 2009).

Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied in the CREMP (Intrinsik, 2014; Intrinsik, 2015; see Appendix C and D of the AEMP). These benchmarks were designed to assist in identifying temporal changes and mine related influences on the Mine Site Area lakes and streams to inform management decisions. Water quality benchmarks were identified for ~~mine site~~ Mine Site lakes and streams individually, considering the higher of the generic water quality objective (i.e., CCME or other jurisdiction) or the 97.5th percentile of baseline concentrations. For parameters that are mostly below MDL (less than 5% detected values), either the Water Quality Guideline was selected (if available), or three (3) ~~3~~times~~*~~ MDL was adopted as the benchmark, as follows:

- **Method A:** Water Quality Guideline was higher than 97.5%ile, and therefore was selected

- **Method B:** 97.5%ile was higher than the Water Quality Guideline, and therefore was selected
- **Method C:** Parameter has < 5% detected values, and either the Water Quality Guideline was selected (if available), or 3 * MDL was used to derive benchmark

If Method B was selected, additional assessment of the data was conducted to ensure the percentile calculations were not being driven by elevated detection limits, or other factors.

The selected benchmark development method and corresponding water quality benchmarks for the M~~m~~ine S~~s~~ite lakes are presented in Table 2.9. The benchmark method and benchmark values for stream water quality are presented in Table 2.10.

Table 2-9 Selected Water Quality Benchmark Approach and Values for Mine Site Lakes

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Metals [3]							
Aluminium	mg/L	0.1	0.026	0.137	0.179 (Shallow) 0.173 (Deep)	CL = 0.1 ML = 0.13; SDL shall/deep = 0.179/0.173	A (CL), B (ML/SDL)
Arsenic	mg/L	0.005	NC	0.00018	0.0001	0.005	A
Cadmium	mg/L	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	NC	0.000023	0.000017	0.0001 (CL) 0.00006 (ML) 0.00009 (SDL)	A
Chromium	mg/L	NGA	NC	0.001	0.000641	0.0003 (CL) (ML) = 0.0005[8] (SDL) = 0.000642[9]	B (ML/SDL), C (CL)
Chromium $^{+3}$	mg/L	0.0089	NC	0.005	NC	0.0089	A
Chromium $^{+6}$	mg/L	0.001	NC	0.001	NC	0.003 – 0.015 (CL)[5] 0.003 (ML/SDL)[5]	C
Cobalt	mg/L	0.004	NC	NC	0.0002	0.004	A
Copper	mg/L	0.002	0.0113	0.00239	0.00243	(CL) = 0.004[7] (ML) = 0.0024 (SDL) = 0.0024	B
Iron	mg/L	0.3	0.0421	0.173	0.211	0.3	A
Lead	mg/L	0.001	0.000334	0.00013	0.00026	0.001	A
Nickel	mg/L	0.025	0.000941	0.00080	0.000973	0.025	A
Silver	mg/L	0.0001	NC	NC	0.0000104	0.0001	A
Thallium	mg/L	0.0008	NC	NC	0.0001	0.0008	A
Vanadium	mg/L	0.006	NC	0.00146	0.001	0.006	A
Zinc	mg/L	0.030	0.0037	0.003	0.00391	0.030	A
Water Quality Parameters							
Chloride (Cl$^-$)	mg/L	120	4	13	5	120	A

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Ammonia (NH_3+NH_4)	mg N/L	0.855[4]	0.84	0.32	0.44	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.1[6]	0.1[6]	0.1[6]	0.060	A
Nitrate (NO_3)	mg N/L	13	NC	0.11	NC	13	A
Sulphate	mg/L	218	3	7	5	218	A

NOTES:

1. NGA = NO GUIDELINE AVAILABLE; NC = NOT CALCULATED; TBD = TO BE DETERMINED; GUIDELINE STILL UNDER DEVELOPMENT; CL = CAMP LAKE; ML = MARY LAKE; SDL = SHEARDOWN LAKE.
2. METHOD A = WATER QUALITY GUIDELINE FROM CCME/B.C. MOE; METHOD B = 97.5%ILE OF BASELINE; METHOD C = 3* MDL.
3. TOTAL METALS UNLESS OTHERWISE NOTED.
4. ASSUMES TEMPERATURE AT 10 DEGREES C, AND pH OF 8.
5. THE 2013 DETECTION LIMIT FOR Cr^{6+} INCREASED IN 2013 FROM 0.001 to 0.005, HENCE THIS AFFECTS THE 3* MDL CALCULATION FOR THE BENCHMARK IN CAMP LAKE. EFFORTS WILL BE MADE TO REDUCE THIS MDL IN 2014, AND COMPARISONS TO THE LOWER OF THE 2 BENCHMARKS WOULD THEN BE APPLIED IN CAMP LAKE. IF DETECTION LIMITS IMPROVE, METHOD A (SELECTION OF THE GUIDELINE) MAY BE IMPLEMENTED.
6. THESE VALUES ARE ELEVATED DETECTION LIMITS, AND HENCE, THE GUIDELINE HAS BEEN SELECTED AS THE BENCHMARK.
7. THE MAXIMUM VALUE OF 0.0113 MG/L COPPER WAS REMOVED TO CALCULATE THE 97.5TH PERCENTILE, AS THIS VALUE APPEARS TO BE AN OUTLIER.
8. AN ELEVATED DETECTION LIMIT OF 0.001 MG/L WAS REMOVED FROM THE DATASET AND CALCULATIONS, AND THE AEMP SELECTED WAS THE 97.5th PERCENTILE, WHICH IS 0.0005 mg/L.
9. SEVERAL DETECTED VALUES RANGING FROM 0.00079 - 0.00316 mg/L Cr HAVE BEEN REPORTED IN THE DATASET FOR SDL, AND HENCE, THESE VALUES WERE CONSIDERED TO REPRESENT BASELINE, AND WERE INCLUDED IN THE 97.5th PERCENTILE CALCULATION.

Table 2-10 Selected Water Quality Benchmark Approach and Values for Mine Site Streams

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
Metals[4]						
Aluminum	mg/L	0.1	0.179	0.97	CLT = 0.179 MR = 0.966	B
Arsenic	mg/L	0.005	0.00012	0.00013	0.005	A
Cadmium	mg/L	0.00008 (CLT) 0.00006 (MR)	NC	0.00002	CLT = 0.00008 MR = 0.00006	A
Chromium	mg/L	NGA	0.000856	0.0023	CLT = 0.000856 MR = 0.0023	B
Chromium $^{+3}$	mg/L	0.0089	NC	0.005	0.0089	A
Chromium $^{+6}$	mg/L	0.001	NC	NC	0.003[5]	C
Cobalt	mg/L	0.004	NC	0.0004	0.004	A
Copper	mg/L	0.002	0.00222	0.0024	CLT = 0.0022 MR = 0.0024	B

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
Iron	mg/L	0.3	0.326	0.874	CLT = 0.326 MR = 0.874	B
Lead	mg/L	0.001	0.000333	0.00076	0.001	A
Nickel	mg/L	0.025	0.00168	0.0018	0.025	A
Silver	mg/L	0.0001	NC	0.0001	0.0001	A
Thallium	mg/L	0.0008	0.0002	0.0002	0.0008	A
Vanadium	mg/L	0.006	NC	0.002	0.006	A
Zinc	mg/L	0.030	0.0035	0.01	0.030	A
Water Quality Parameters						
Chloride (Cl^-)	mg/L	120	23	21.55	120	A
Ammonia (NH_3+NH_4)	mg N/L	0.855[6]	0.60	0.60	0.855	A
Nitrite (NO_2^-)	mg N/L	0.060	0.095[7]	0.06	0.060	A
Nitrate (NO_3)	mg N/L	13	0.118	0.14	13	A
Sulphate	mg/L	218	6	8	218	A

NOTES:

1. NGA = NO GUIDELINE AVAILABLE; NC = NOT CALCULATED; TBD = TO BE DETERMINED; GUIDELINE STILL UNDER DEVELOPMENT; MR = MARY RIVER; CLT = CAMP LAKE TRIBUTARY.
2. METHOD A = WATER QUALITY GUIDELINE FROM CCME/B.C. MOE; METHOD B = 97.5%ILE OF BASELINE; METHOD C = 3* MDL.
3. ONE SAMPLE (OUTLIER) CONTAINING CHEMICAL CONCENTRATIONS ORDERS OF MAGNITUDE ABOVE OTHER VALUES WAS NOT INCLUDED IN THE CALCULATIONS FOR MARY RIVER.
4. TOTAL METALS UNLESS OTHERWISE NOTED.
5. EFFORTS WILL BE MADE TO REDUCE THIS MDL IN 2014, AND COMPARISONS TO THE HIGHER OF THE METHOD A OR C WOULD THEN BE APPLIED AS THE AEMP BENCHMARK.
6. ASSUMES TEMPERATURE AT 10 DEGREES C, AND pH OF 8.0.
7. 97.5th PERCENTILE IS BEING DRIVEN BY ELEVATED DETECTION LIMIT, THEREFORE, THE GUIDELINE WAS SELECTED.

In most cases, the recommended benchmarks are consistent between lakes and streams, with the vast majority of selected benchmarks being generic WQOs. Where natural concentrations varied, and exceeded available water quality guidelines, or < 5% of values was detected, recommended benchmarks varied.

As discussed in the baseline review in Section 2.5 and Appendices B (lakes) and C (streams), some parameters have been shown to exhibit some changes in concentrations with season. For those parameters, Step 1 of the assessment framework (see Section 2.7.8) will include an evaluation of seasonality trends relative to the benchmark and baseline. Benchmarks may need to be re-visited for these compounds, and SSWQO can be considered.

Several water quality guidelines established by the CCME are currently under revision (i.e., lead and iron) or have been released in draft form for comments (silver). Once finalized, these revised benchmarks can be evaluated, using the benchmark selection process outlined, and benchmarks updated accordingly.

2.7.4 Monitoring Area and Sampling Stations

The monitoring area for water quality includes Mine Site Area lakes, specifically Camp Lake, Mary Lake, and Sheardown Lake NW and SE; selected tributaries of each lake; and the Mary River (Figure 2.11). Reference Lake 3, was selected in 2015 as the CREMP reference lake and will be sampled concurrently with ~~mine~~ Mine Area lakes in the summer and fall[3].

After completing the CREMP in 2015, Minnow proposed several modifications to the ~~program~~ CREMP to provide greater efficiencies and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems).

Within their list of recommendations, Minnow noted that no consistent spatial differences in water quality/chemistry were evident in any of the study lakes in 2015, nor during any of the baseline studies, suggesting that study lakes are generally well mixed with relatively uniform water chemistry throughout the year. (Minnow, 2016). Because of this, Minnow recommended three modifications to the CREMP lake water quality sampling program:

1. Reduce the number of water quality monitoring stations to three (3) in each of Camp, Sheardown NW and SE lakes and four (4) in Mary Lake (~~Item~~ Minnow Recommendation 7; Minnow, 2016);

Lake	Station ID	Depth (m)	Description
Reference Lake 3	REF03-01	15.1	East end of southeast basin
	REF03-02	30.4	Centre of southeast basin
	REF03-03	37.5	Centre of northwest basin
Camp Lake	JLO-02	12.3	Littoral station near primary lake inlet (CLT1, CLT2)
	JLO-07	32.7	Deep basin, near centre of lake
	JLO-09	14.3	Near lake outlet
Sheardown Lake NW	DD-Hab9-Stn1	10.3	Near inlet from SDLT1
	DLO-01-2	17.5	Deep location, near centre of northwest basin
	DLO-01-7	11.4	Near lake outlet
Sheardown Lake SE	DLO-02-6	7.1	Near inlet from Sheardown Lake NW
	DLO-02-3	13.7	Deep location, near centre of southeast basin
	DLO-02-4	8.05	Near inlet from SDLT9
Mary Lake	BLO-1A	14.65	Deepest location at the north basin

---

[3] Reference Lake 3 is located approximately 60 km south of the ~~mine~~Mine Site, and therefore no winter sampling is proposed during the winter months due to difficult accessibility and associated safety concerns for ~~mine~~ field personnel.

Lake	Station ID	Depth (m)	Description
	BLO-5	21	Near inlet from Mary River
	BLO-9	30	Deepest location at the south basin
	BLO-6	6.8	Near lake outlet

2. Collect a single water quality sample at mid-depth instead of collecting two samples, surface and bottom, at each lake water quality monitoring station (~~Item~~ Minnow Recommendation 9; Minnow, 2016) and;
3. Focus water quality *in-situ* profiling to a few select stations located at the main (i.e. deepest) basin of the study lakes with the goal of identifying the occurrence of anoxic conditions to guide sampling approach (~~Item~~ Recommendation 8; Minnow 2016).[4]

Lake water quality stations selected by Minnow for *in-situ* profiling are listed below.

- Camp Lake Station - JL0-07
- Sheardown Lake NW Station – DL0-01-2
- Sheardown Lake SE Station – DL0-02-3
- Mary Lake (North Basin) Station – BL0-1A
- Mary Lake (South Basin) Station – BL0-9
- Reference Lake 3 (NW Basin) Station – REF03-3

In addition to the recommendations pertaining to the lake water sampling program, Minnow also recommended the following modifications to the CREMP lotic (stream) water quality sampling program:

1. The addition of three stream water quality monitoring stations to the program, including one station in each of lower Tom River, Sheardown Lake Tributary 9 and Sheardown Lake Tributary 12 (Minnow Recommendations 2, 3; Minnow, 2016).
2. Discontinue water quality monitoring at stations L1-09 (Camp Lake Tributary 1) and D1-05 (Sheardown Lake Tributary 1) (Minnow Recommendations 1, 4; Minnow, 2016).
3. Discontinue water quality monitoring at stations G0-09A, G0-09B and C0-01 on the Mary River (Minnow Recommendations 5, 6; Minnow, 2016).

Following further discussions with Minnow, regulators and stakeholders, Baffinland decided not to remove water quality stations L1-09 and D1-05 from the CREMP (Minnow Recommendation 1,4). Maintaining L1-09 and D1-05 in the CREMP will allow the program to better assess potential effects of Project roads (i.e. Tote Road) on nearby water bodies.

---

[4] Anoxic conditions have not been observed at any of the study lakes since baseline studies began in 2005.

Upon further review of the Mary River GO-09 series reference stations, relatively high variability in concentrations of non-conservative parameters (e.g., aluminum, iron) related to natural turbidity differences was shown among the three GO-09 stations. Therefore, the three GO-09 stations, including GO-09A & B, will be maintained in the CREMP to better capture the influence of natural turbidity on parameter concentrations in the Mary River system.

In order to implement the mid-depth lake water sampling methodology proposed by Minnow (Minnow Recommendation 9; Minnow, 2016) and, in tandem, ensure lake water chemistry gradients in Mine Area lakes are adequately documented and monitored if present (i.e. weak lake stratification during winter periods), an in-field lake water sampling framework has been developed to guide the sampling approach. In summary, in cases where lake stratification is determined to be present, a surface and bottom water sampling approach will be undertaken. If lake stratification is determined to be absent, a mid-depth sampling approach will be conducted.

This revision of the AEMP (Rev. 2) has been updated to reflect all Minnow's recommendations listed above with exception of Minnow Recommendation 1 and 4 (removal of L1-09 and D1-05) and the removal of GO-09A & B, proposed in Minnow Recommendation 5. ~~This document has been revised reflect all of the recommendations listed above. Additional details regarding water quality sampling methodology for lakes and streams is presented in Appendix A.~~

Figure 2.11 Recommended CREMP Water Quality and Phytoplankton Monitoring Stations following the 2015 Program

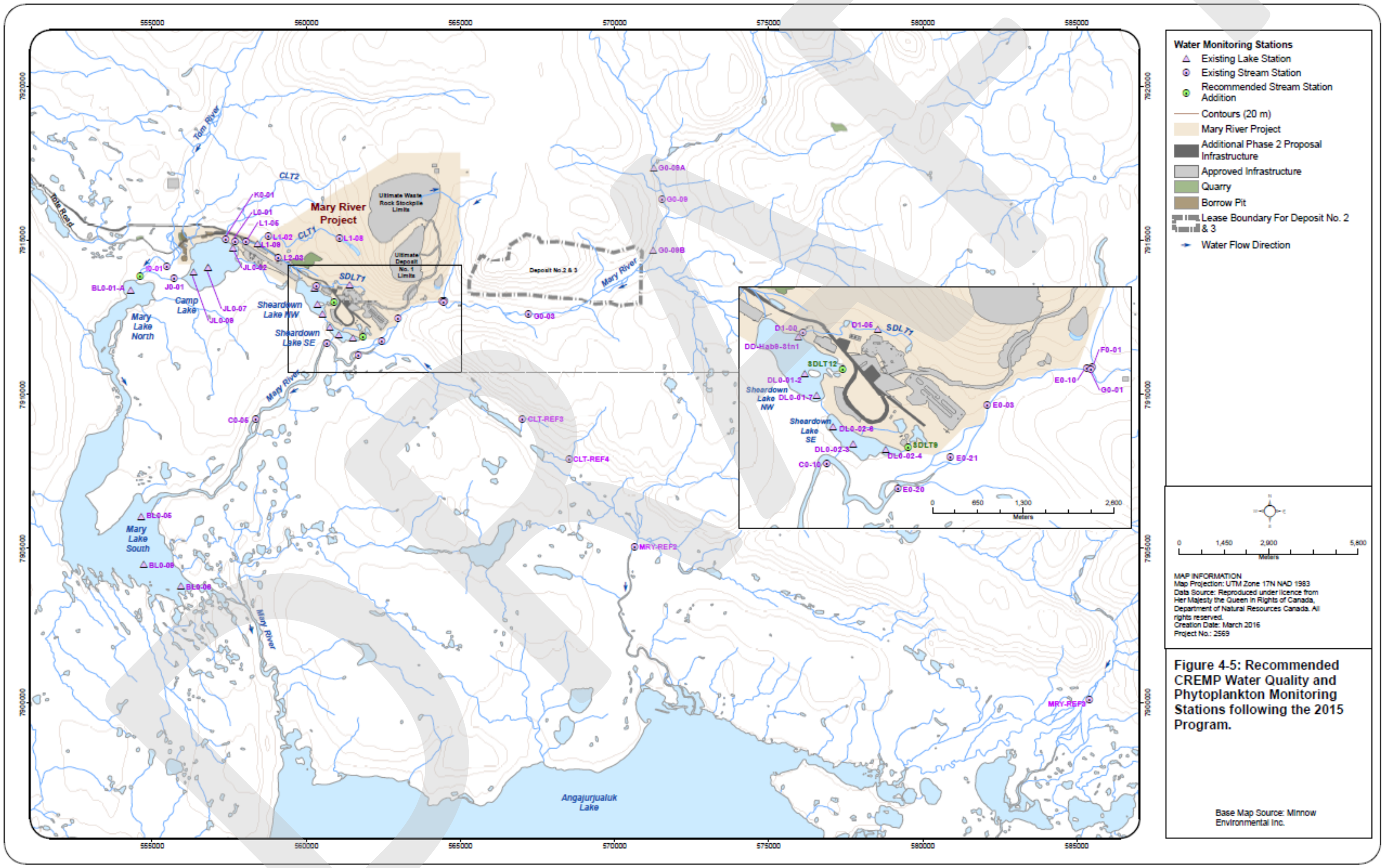


Table 2-11 Water Quality CREMP Station Details

Station ID	Easting	Northing	Winter	Spring	Summer	Fall	Description/Rationale
	NAD83, Zone 17N						
Mary Lake (North Basin)							
BL0-01-A	554300	7913378	1		1	1	North basin receiving water from Camp Lake
Mary Lake (South Basin)							
BL0-05	554632	7906031	1		1	1	Mary Lake, southern basin near outlet of Mary River
BL0-06	555924	7903760	1		1	1	
BL0-09	554715	7904479	1		1	1	Main basin between BL0-05 & BL0-06
Mary River (D/S of SDL)							
C0-05[1]	558352	7909170		1	1	1	Mainstem, d/s of mine
C0-10	560669	7911633		1	1	1	Mainstem, d/s Sheardown Lake outflow
SDL-Trib 1							
D1-00	560329	7913512		1	1	1	Tributary D1
D1-05	561397	7913558		1	1	1	
Sheardown Lake NW							
DD-Hab 9-Stn1	560259	7913455	1		1	1	Nearshore monitoring location
DL0-01-2	560353	7912924	1		1	1	Long-term lake monitoring
DL0-01-7	560525	7912609	1		1	1	
Sheardown Lake SE							
DL0-02-3	561046	7911915	1		1	1	Long-term lake monitoring
DL0-02-4	561511	7911832	1		1	1	
DL0-02-6	560756	7912167	1		1	1	
Mary River (US of SDL)							
E0-03	562974	7912472		1	1	1	Mainstem, u/s of Deposit 1
E0-10	564405	7913004		1	1	1	Mainstem, u/s of Deposits No. 2 and 3, d/s of F0-01
E0-20	561688	7911272		1	1	1	Mainstem u/s of trib E2 and d/s of ore/sewage discharge
E0-21	562444	7911724		1	1	1	
F0-01	564483	7913015		1	1	1	Mainstem tributary from east pond
G0-01	564459	7912984		1	1	1	Mainstem, u/s of F0-01
G0-03	567204	7912587		1	1	1	Upstream, potential reference station within anticipated dust plume
G0-09	571546	7916317		1	1	1	Upstream, reference station beyond anticipated dust plume
G0-09-A	571264	7917344		1	1	1	Upstream, reference station beyond anticipated dust plume
G0-09-B	571248	7914682		1	1	1	Upstream, potential reference station beyond anticipated dust plume
Tom River							
TR-01	TBD	TBD		1	1	1	Downstream of I0-01 and J0-01
SDL-Trib 9							
SDLT-09	TBD	TBD		1	1	1	Downstream of Emulsion Plant
SDL-Trib 12							
SDLT-12	TBD	TBD		1	1	1	Downstream of Crusher Pad

Station ID	Easting	Northing	Winter	Spring	Summer	Fall	Description/Rationale
	NAD83, Zone 17N						
Camp Lake							
JL0-02	557615	7914750	1		1	1	Littoral station near CLT1, CLT2 inlet
JL0-07	556800	7914094	1		1	1	Deep basin, near centre of lake
JL0-09	556335	7913955	1		1	1	Near lake outlet
Camp Lake Tributaries							
I0-01	555470	7914139		1	1	1	Tom River, below Tote Road
J0-01	555701	7913773		1	1	1	Outlet of Camp Lake
K0-01	557390	7915030		1	1	1	Drains to north region of Camp Lake
Camp Lake Tributary 1 (CLT-1)							
L0-01	557681	7914959		1	1	1	Mainstem tributary of CLT-1
L1-02	558765	7915121		1	1	1	Northern tributary of CLT-1,upstream of L0-01
L1-05	558040	7914935		1	1	1	
L1-08	561076	7915068		1	1	1	
L1-09	558407	7914885		1	1	1	Receives outflow from West Pond
L2-03	559081	7914425		1	1	1	Southern tributary of CLT-1
Camp Lake Tributary Reference Areas							
CLT-REF3 (E2-08)	567004	7909174		1	1	1	Reference stream outside dust plume
CLT-REF4 (CV-006-1)	568533	7907874		1	1	1	
Mary River Reference Areas							
MRY-REF3 (S2-020)	585407	7900061		1	1	1	Reference river outside dust plume
MRY-REF2 (S2-010)	570650	7905045		1	1	1	
Reference Lake 3							
REF03-01	575642	7852666			1	1	East end of southeast basin
REF03-02	574836	7852744			1	1	Centre of southeast basin
REF03-03	574158	7853237			1	1	Centre of northeast basin
TOTAL			**13**	**26**	**42**	**42**	

Table 2-12 CREMP Study Stations/Areas and Corresponding Reference Stations/Areas Used for Comparison

		Representative Water Quality Station[4]			Reference Area used for each Study Component[1, 2, 3]				
Study Area	**Water Body**	**Station Identifier**	**Easting**	**Northing**	**Water Quality**	**Sediment Quality**	**Phytoplankton**	**Benthic Invertebrates**	**Fish**
Reference Areas	Lotic Reference	CLT-REF3	567004	7909174	Y	-	Y	-	-
		CLT-REF4	568533	7907874	Y	-	Y	Y	-
		MRY-REF3	585407	7900061	Y	-	Y	-	-
		MRY-REF2	570650	7905045	Y	-	Y	-	-
	Mary River Reference	G0-09	571546	7916317	Y	-	Y	-	-
		G0-09-A	571264	7917344	Y	-	Y	-	-
		G0-09-B	571248	7914682	Y	-	Y	-	-
	Reference Lake 3	REF-03-W1	575642	7852666	Y	Y	Y	Y	Y
		REF-03-W2	574836	7852744	Y		Y		
		REF-03-W3	574158	7853237	Y		Y		
Camp Lake	Camp Lake Tributaries	I0-01	555470	7914139	Lotic Reference Average	Not Applicable	Lotic Reference Average	Not Applicable	Not Applicable
		J0-01	555701	7913773					
		K0-01	557390	7915030				CLT-REF4	
		L0-01	557681	7914959					
		L1-02	558765	7915121					
		L1-05	558040	7914935					
		L1-08	561076	7915068					
		L1-09	558407	7914885					
		L2-03	559081	7914425					
	Camp Lake	JL0-02	557615	7914750	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3
		JL0-07	556800	7914094					
		JL0-09	556335	7913955					
Sheardown Lake System	Tributary 1	D1-00	560329	7913512	Lotic Ref. Average	Not Applicable	Lotic Ref. Average	CLT-REF4	Not Applicable
		D1-05	561397	7913558					
	Tributary 9	SDLT-09	TBD	TBD	Not Applicable	Not Applicable	Not Applicable	CLT-REF4	Not Applicable
	Tributary 12	SDLT-12	TBD	TBD					
	Sheardown Lake NW	DD-Hab 9-Stn1	560259	7913455	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3
		DL0-01-2	560353	7912924					
		DL0-01-7	560525	7912609					

Study Area	**Water Body**	**Representative Water Quality Station[4]**			**Reference Area used for each Study Component[1, 2, 3]**				
		Station Identifier	**Easting**	**Northing**	**Water Quality**	**Sediment Quality**	**Phytoplankton**	**Benthic Invertebrates**	**Fish**
S. L. System	Sheardown Lake SE	DL0-02-3	561046	7911915	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3
		DL0-02-4	561511	7911832					
		DL0-02-6	560756	7912167					
Mary River and Mary Lake System	Mary River	G0-03	567204	7912587	Mary River GO-09 Average	Not Applicable	Mary River Reference Average (GO-09)	Mary River Reference Average (GO-09)	Not Applicable
		G0-01	564459	7912984					
		F0-01	564483	7913015					
		E0-21	562444	7911724					
		E0-20	561688	7911272					
		E0-10	564405	7913004					
		E0-03	562974	7912472					
		C0-10	560669	7911633					
		C0-05	558352	7909170					
		C0-01	556305	7906894					
	Mary River Lake (North Basin)	BL0-01-A	554300	7913378	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3	Not Applicable
	Mary River Lake (South Basin)	BL0-05	554632	7906031	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3	Reference Lake 3
		BL0-06	555924	7903760					
		BL0-09	554715	7904479					

NOTES:

1. LOTIC REFERENCE AVERAGE (LOTIC REF. AVG.) BASED ON MEAN OF REFERENCE STATIONS CLT-REF3, CLT-REF4, MRY-REF2 and MRY-REF3 STATION DATA.
2. STATION GO-09 AVERAGE (GO-09 AVG.) BASED ON MEAN OF UPPER MARY RIVER GO-09, GO-09A and GO-09B STATION DATA.
3. NOT APPLICABLE INDICATES NO SAMPLING COMPLETED FOR SPECIFIED STUDY COMPONENT AT THE STUDY AREA INDICATED.
4. STATION IDENTIFIERS AND COORDINATES PRESENTED ARE APPLICABLE ONLY TO WATER QUALITY MONITORING COMPONENT. DIFFERENT STATIONS MAY HAVE BEEN USED FOR THE REMAINING STUDY COMPONENTS.

2.7.5 Sampling Frequency and Schedule

Environment Canada (2012) specifies that four (4) samples collected over a 12-month period, not less than one (1) month apart, from the same exposure and reference locations is the minimum amount of sampling required to detect differences in median values between exposure and reference stations. Due to the short open water season (3-4 months) experienced at the Mary River Project, three sampling events will be conducted for streams and lakes under the CREMP.

Stream water quality will be monitored during the spring (June), summer (July) and fall (August), whereas, lake water quality monitoring will take place during the winter (~~late ~~April), summer (July) and fall (August). This sampling frequency should be adequate to detect early warning flag concentrations and determine significance for most water quality parameters. The sampling frequency and schedule will be re-evaluated after the first three (3) years of mine operation.

2.7.6 Quality Assurance/Quality Control

A strict QA/QC program is in place to ensure that high quality and representative data are obtained in a manner that is scientifically defensible, repeatable and well documented. This program aims to ensure that the highest level of QA/QC standard methods and protocols are used for the collection of all environmental media samples. Quality assurance is obtained at the project management level through organization and planning, and the enforcement of both external and internal quality control measures. The following lists summarize the QA/QC procedures and practices being followed:

- Internal Quality Control:
    - Staffing the P~~p~~roject with experienced and properly trained individuals
    - Ensuring that representative, meaningful data are collected through planning and efficient research
    - Using standard protocols for sample collection, preservation, and documentation
    - Calibrating and maintaining all field equipment
    - Collecting duplicate, blank, filter and travel blank samples for submission for analysis (approximately 10% of overall samples)
    - External Quality Control:
    - Employing fully accredited analytical laboratories for the analysis of all samples
    - Determining analytical precision and accuracy through the interpretation of the analysis reports for the blind duplicate, blank, filter and travel blank samples

The field sampling protocols being applied to the water (and sediment) quality programs are presented in Appendix A and are consistent with the Project's Sampling Program - Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-00001, Rev. 2).~~.~~

The quality of the data obtained for a project is assessed via their adherence to the pre-set data quality objectives (DQOs). DQOs provide a means of assessing whether the data in question are precise, accurate, representative, and complete. The results from QA/QC samples are reviewed to determine if sample contamination occurred. These data are further used to determine if the contamination occurred during collection, handling, storage, or shipping. Upon receipt from the laboratory, the data are uploaded into EQWin® along with copies of field notes, photos, Sample Receipt Confirmations, Microsoft Excel data, and Certificates of Analysis.

2.7.7 Study Design and Data Analysis

The purpose of effluent characterization and water quality monitoring is to answer the question:

"What is the estimated mine-related change in contaminant concentrations in the exposed area?"

To answer this question, the study has been designed to test the following three hypotheses:

- Null hypothesis: Change over time is the same for exposure and reference stations. Alternate hypothesis: Data from exposure stations is statistically different from data measured at reference stations.
- Null hypothesis: Difference between exposure and reference stations is due to natural environmental variation. Alternate hypothesis: Difference in exposure and reference station is due to mine effects.
- Null hypothesis: Magnitude of concentrations at the reference station does not exceed the benchmark. Alternate hypothesis: Magnitude of concentrations at the reference station exceeds the benchmark.

Environment Canada (2012) does not explicitly define the program design required to monitor effects to water quality. Environment Canada does specify that:

- Comparisons between reference and exposure stations should identify parameters for which there are differences. This approach is consistent with a Control-Impact (CI) approach to design.
- If logistically possible, samples of effluent and water for reference and exposure stations be collected on the same day or in as close succession as possible. This implies paired sampling.
- If there is adequate pre-mining data in the exposure area, then this data may be used a basis for comparison to determine post-mining effects. This provision suggests comparison of concentrations before and after disturbance (BA design).

With federal EEM monitoring guidance in mind, and following guidance from INAC (2009) and peer-reviewed scientific journal articles (Green, 1979; Underwood, 1992; Smith, 2002), the selected program design framework is a BACI design. The BACI design addresses each of the three points above. A BACI design compares changes over time at exposure and control stations, while considering natural variation that may occur over this same time period. With this Project, the historical pre-mining data has already been collected for exposure and reference stations. Post-mining data at the exposure stations and reference stations would then be collected during mine operations. The BACI design will be used to detect changes in mean concentration with respect to the selected benchmarks, as per the assessment framework (Section 2.7.8).

A BACI design is good for assessing large short term changes and is a natural starting point for long term monitoring. The use of other analyses will be considered as well (e.g. use of 97th percentile of background and regression analysis) to define trends in the short terms. A BACI design compares the baseline mean to the post-mining mean, which ignores time trends in the post-mining data. While this is reasonable for the initial mining period, long term temporal trends require adjustments to the statistical analyses that consider the rate of change over time.

2.7.8 Assessment Framework

Monitoring data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2.12 and described below.

2.7.8.1 Step 1: Initial Data Analysis

Initial data analysis will involve following specific data management and monitoring protocols in the handling and initial comparison of data. These protocols are in accordance with the conceptual sampling approach defined in Figure 2.12.

Data Input and Storage

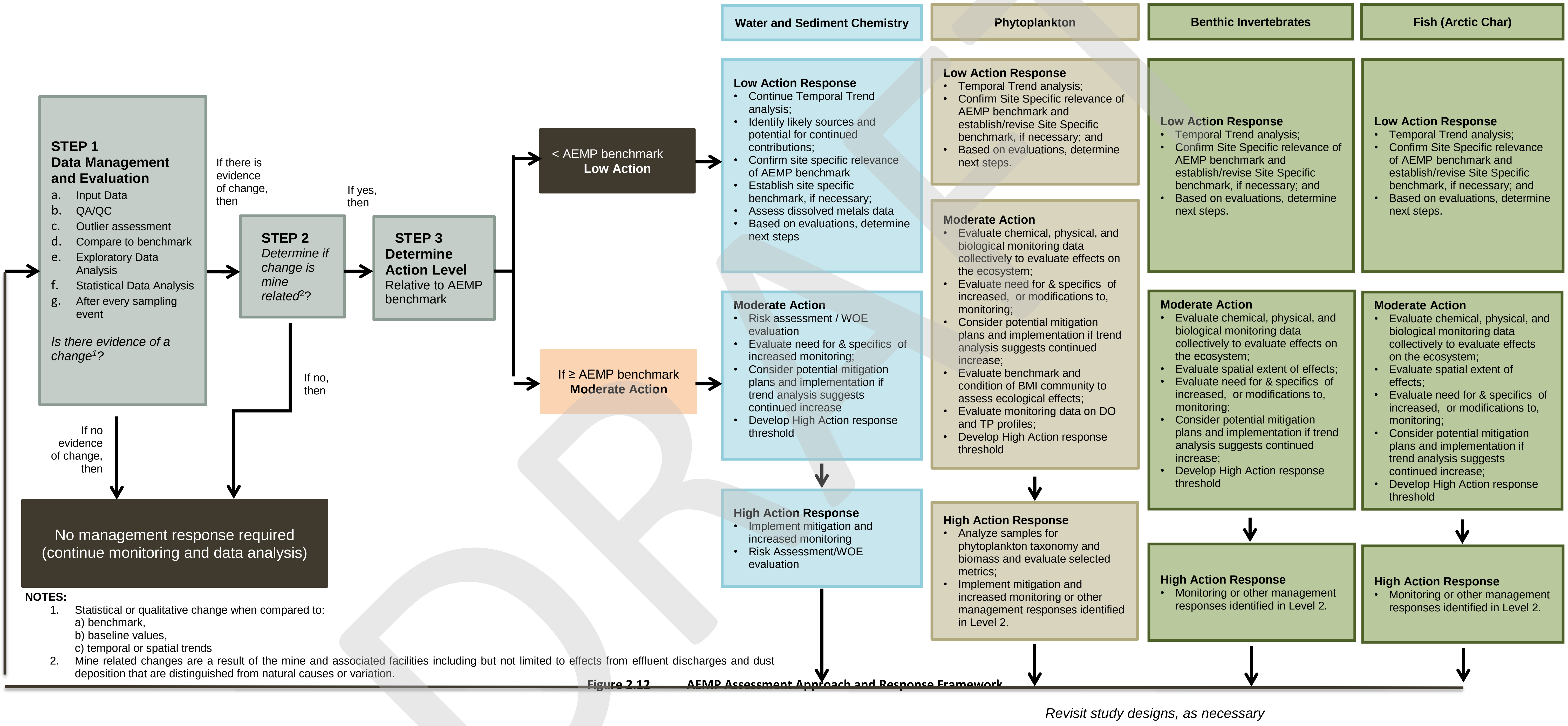
Following data collection, and upon receipt of the laboratory reports, data will be entered into the Project EQWin® database. The EQWin® Software was developed for collecting, analyzing, storing and interpreting sample data from environmental monitoring programs. All environmental data will be stored in EQWin® to expedite quality assurance/quality control and all subsequent analyses.

Initial Data Analysis including Outlier Assessment

The initial data analysis will include the following:

- Completion of summary statistics for parameters sampled (average, median, maximum, minimum, quartiles)
- Flagging of values greater than the defined benchmark values
- Flagging of values at or exceeding the mid-point between the baseline mean and the benchmark
- Evaluating temporal changes in the data by season

The initial data analysis will include an outlier assessment after data entry and the completion of quality assurance and quality control steps. An outlier assessment is completed after each round of sampling to ensure data anomalies are identified early. If necessary, the laboratory can be contacted to re-analyze samples. Any identified outliers will be investigated to ensure no data integrity issue exists. For example, duplicate and blank samples will be assessed along with any holding time exceedances. If no evidence exists to discard data, then the data will remain in the dataset but be flagged for future consideration.



Water and Sediment Chemistry

Phytoplankton

Benthic Invertebrates

Fish (Arctic Char)

STEP 1
Data Management and Evaluation
a. Input Data
b. QA/QC
c. Outlier assessment
d. Compare to benchmark
e. Exploratory Data Analysis
f. Statistical Data Analysis
g. After every sampling event

Is there evidence of a change¹?

If there is evidence of change, then

STEP 2
Determine if change is mine related²?

If yes, then

STEP 3
Determine Action Level
Relative to AEMP benchmark

< AEMP benchmark
Low Action

If ≥ AEMP benchmark
Moderate Action

If no, then

If no evidence of change, then

No management response required (continue monitoring and data analysis)

Low Action Response
- Continue Temporal Trend analysis;
- Identify likely sources and potential for continued contributions;
- Confirm site specific relevance of AEMP benchmark
- Establish site specific benchmark, if necessary;
- Assess dissolved metals data
- Based on evaluations, determine next steps

Moderate Action
- Risk assessment / WOE evaluation
- Evaluate need for & specifics of increased monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase
- Develop High Action response threshold

High Action Response
- Implement mitigation and increased monitoring
- Risk Assessment/WOE evaluation

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Evaluate benchmark and condition of BMI community to assess ecological effects;
- Evaluate monitoring data on DO and TP profiles;
- Develop High Action response threshold

High Action Response
- Analyze samples for phytoplankton taxonomy and biomass and evaluate selected metrics;
- Implement mitigation and increased monitoring or other management responses identified in Level 2.

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate spatial extent of effects;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Develop High Action response threshold

High Action Response
- Monitoring or other management responses identified in Level 2.

Low Action Response
- Temporal Trend analysis;
- Confirm Site Specific relevance of AEMP benchmark and establish/revise Site Specific benchmark, if necessary; and
- Based on evaluations, determine next steps.

Moderate Action
- Evaluate chemical, physical, and biological monitoring data collectively to evaluate effects on the ecosystem;
- Evaluate spatial extent of effects;
- Evaluate need for & specifics of increased, or modifications to, monitoring;
- Consider potential mitigation plans and implementation if trend analysis suggests continued increase;
- Develop High Action response threshold

High Action Response
- Monitoring or other management responses identified in Level 2.

Revisit study designs, as necessary

NOTES:
1. Statistical or qualitative change when compared to:
   a) benchmark,
   b) baseline values,
   c) temporal or spatial trends
2. Mine related changes are a result of the mine and associated facilities including but not limited to effects from effluent discharges and dust deposition that are distinguished from natural causes or variation.

Figure 2.12 AEMP Assessment Approach and Response Framework

2.7.8.2 Step 2: Determine if Change is Mine Related

Step 2 involves determining if the changes in water quality parameters of concern are due to the Project or due to natural variability or other causes. This question will be addressed using exploratory data analysis (EDA) and subsequently using statistical data analysis (SDA), as described below.

Prior to conducting EDA and SDA, Project activities with the potential to alter water quality will be reviewed to identify potential Project-related causes or sources. This could include evaluating effluent quality, discharge regime/rates, and loading, dust deposition, and other point/non-point sources as required. Also, any evidence of potential natural causes (i.e., a major erosional event such as a slumping riverbank) will be investigated. Sampling data sheets and site personnel will be a source of this information.

Exploratory Data Analysis

Exploratory data analysis (EDA) will be completed to visualize overall data trends. This could include evaluating spatial patterns in water quality results for the Mine Area as a whole, including Mine Area lakes and streams, to evaluate if changes are widespread or specific to certain waterbodies, or proximate to mine-related sources, and to identify the spatial extent and pattern of observed changes.

Other exploratory data analyses could include comparisons of data from Mine Area streams to data from reference streams and comparisons of Mine Area Lakes to reference lake(s). This will further assist with determining whether the observed changes were due to natural variability or the Project.

Graphical analyses may be used to confirm assumptions required for statistical testing (normality, sample size, independence). Results of the EDA can be used in tandem with the Statistical Data Analysis (SDA) to evaluate the observed statistical trends and further assess whether the changes noted are mine related.

Statistical Data Analysis

Primary SDA consistent with the statistical methodology used for power analysis (BACI design) will be completed on total metals to determine the magnitude of change during post-mining. This step in the analysis tests the primary hypothesis for the effects of mine-related change and will be applied to the parameters of interest.

If the Step 2 analysis concludes that the changes in water quality parameters of concern are, or are likely, due to the Project, the assessment will proceed to Step 3. If it is concluded the observed differences relative to baseline conditions are not due to the Project, no management response will be required.

2.7.8.3 Step 3: Determine Action Level

Once EDA and primary SDA has indicated with some certainly that the measured change is P~~p~~roject-related, Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark.

If the benchmark is not exceeded, a **low action response** would be undertaken and would include:

- Evaluate temporal trends

- Identify likely loading source(s) and potential for continued loading contributions
- Confirm the site-specific relevance of benchmark and establish a site-specific benchmark, if necessary
- Further evaluate data (for example, for water quality, review dissolved metals data and/or supporting variables)
- Based on evaluations, determine next steps

If the benchmark is exceeded and it is concluded to be Project-related, a **moderate action level response** would be undertaken and could include, in addition to analyses identified for a low action response, the following:

- Consider a weight-of-evidence (WOE) evaluation and/or risk assessment, considering other monitoring results collectively with water quality to evaluate effects on the ecosystem
- Evaluate the need for and specifics of increased monitoring
- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP
- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

A quantitative trigger for the **high action level response** has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed increases in water quality parameters of concern on the lakes as a whole, as well as the monitoring results from the freshwater biota CREMP. Also, the benchmark may need to be revised in consideration of ongoing monitoring results. The precise relationships between water quality, sediment quality and lower trophic level changes and the collective effects on fish is difficult to predict and therefore actions undertaken under Step 3 will attempt to explore these relationships to advise on overall effects to the ecosystem. Results would be discussed with regulatory agencies and the next steps would be identified. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) could include:

- Implementation of increased monitoring to further assess the potential for effects and/or define magnitude and spatial extent if warranted
- Implementation of mitigation measures or other management actions that may be identified under the moderate action level response

3 – SEDIMENT QUALITY REVIEW

3.1 SUMMARY OF SEDIMENT SAMPLING PROGRAM

The collection of baseline sediment quality samples for the Project was carried out between 2005 and 2008 and between 2011 and 2014. Because ERP ~~mine~~ operations started in September, 2014, sediment quality data collected after the 2014 CREMP field program were not included in this review.

Sampling of sediment in streams and lakes around the Mine Site ~~is~~ was typically conducted once in the fall (late August/early ~~–~~September) in conjunction ~~with and at the same stations as~~with the water quality and benthic invertebrate sampling. Table 3.1 summarizes the sediment quality baseline program by year and location around the Mine Site. The sediment sampling locations around the Mine Site up until 2013 are shown on Figure 1.3.

Table 3-1 Number of Sediment Samples by Year and Location

Grouping	2005	2006	2007	2008	2011	2012	2013	2014[1]
Camp Lake	0	0	6	0	0	3	3	9
Camp Lake Tributary	3	0	4	0	3	7	5	1
Mary River Downstream	2	1	5	0	10	4	3	0
Mary Lake	0	2	5	0	0	1	1	10
Sheardown Lake NW	0	0	7	12	3	4	6	8
Sheardown Lake SE	0	0	5	0	0	1	1	5
Sheardown Lake Tributary	2	0	5	3	4	3	1	2
Mary River Upstream	1	1	1	0	0	0	1	0

NOTES:

1. FIVE (5) SAMPLES WERE TAKEN AT REFERENCE LAKE 1 AND 2. ONE (1) SEDIMENT SAMPLE WAS TAKEN AT REFERENCE LAKE 3.

Current ~~S~~sampling and analytical methods, and quality assurance/quality control (QA/QC) procedures applied ~~during the sampling period~~for the sediment quality program are described in ~~the sampling protocol included as~~ Appendix A and are consistent with the Project's Sampling Program - Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-00001, Rev. 2).~~.~~ Contrary to current protocols which uses a core sampler to collect sediment samples in ~~,~~lakes, sediment sampling in the initial years of baseline studies was carried out using of a Petite Ponar dredge sampler to collect a maximum sample collection thickness of 5 cm. This depth is appropriate for monitoring studies where historical contamination is not a priority (Environment Canada, 2012). During the NIRB review, Baffinland agreed to a recommendation from Environment Canada that the upper 1 to 2 cm of sediment be collected as part of Project monitoring. Most infaunal organisms and the most recently introduced sediment (including any contaminants of concern) are found in the upper 2 cm of the sediment. Arctic lakes experience low sedimentation rates and therefore collection of a thinner sample on surface using a sediment core sampler should provide better resolution of changes in sediment quality. Collection of thinner (2 cm) sediment samples was implemented by Baffinland starting in 2012.

Laboratory analysis of the sediment samples includes physical tests, as well as tests for nutrients, carbon and metal concentrations (Table 3.2). Specific metal parameters have been identified as parameters of interest due to their potentially toxic effects when present at defined concentrations. These are the parameters for which sediment quality criteria have been established in order to protect aquatic life.

Table 3-2 Summary of Baseline Sediment Quality Analytical Parameters

Parameter Category	Analytes
Physical Tests	Moisture, Particle Size (% Sand, % Silt, % Clay)
Nutrients	Ammonia, Nitrate, Nitrite, Total Kjeldahl Nitrogen (TKN)
Carbon	Total Organic Carbon (TOC)
Metals	Aluminium, Antimony, **Arsenic**, Barium, Beryllium, Boron, Cadmium, Calcium, **Chromium**, Cobalt, **Copper**, Gold, **Iron**, Lead, Magnesium, **Manganese**, Mercury, Molybdenum, **Nickel**, Potassium, Selenium, Sodium, Strontium, Thallium, Vanadium, Zinc

NOTES:

1. THE PARAMETERS OF INTEREST ARE INDICATED IN BOLD FONT.

Baseline analytical sediment quality data were compared to relevant guidelines for the Project that include:

- Canadian Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life (CSQG-PAL) established by the CCME (CCME, 2001)
- MOE Ontario Provincial Sediment Quality Guidelines (PSQG) (Fletcher et al., 2008)

The CSQG established Interim Sediment Quality Guidelines (ISQGs) for select parameters. These guidelines correspond to the concentration thresholds below which adverse biological effects are not expected. The Probable Effect Level (PEL) corresponds to the concentration above which adverse biological effects are frequently found (CCME, 2001).

The PSQG established a Lowest Effect Level (LEL) threshold for parameters that correspond to concentrations that can be tolerated by the majority of sediment dwelling organisms. The Severe Effect Level (SEL) corresponds with concentrations expected to be detrimental to the majority of sediment dwelling organisms (Fletcher et al., 2008).

The laboratory detection limits for many metals improved over the duration of the testing program (i.e., between 2005 and 2015). All laboratory results and their respective detection limits for each year are presented in Section 3.3.

During 2014 and 2015, Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied to the CREMP. In 2015, Intrinsik established area-specific benchmarks for sediment quality at mine exposed lakes, with the exception of Sheardown Lake NW. The current sediment quality benchmarks are further discussed in Section 3.6.3. The specifics of the benchmark selection process for both sediment and surface water are outlined in Appendix C and D of the AEMP document.

3.1.1 ~~r~~Related S~~s~~tudies

Other studies that have been undertaken that provide information on sediment quality, include:

- Substrate mapping associated with aquatic biota studies
- Monitoring of water and sediment quality and benthic invertebrates in Sheardown Lake and its tributary. This work was related to dust emissions associated with an ore crushing operation in 2008 during a bulk sampling program.
- Measurements of baseline sedimentation rates in Sheardown Lake

Each of these studies is described in the following sub-sections.

~~3.1.2.0~~3.1.1.1 Substrate Mapping

Bathymetry and substrate mapping along with historic sediment monitoring stations of Camp Lake, Sheardown Lake and Mary Lake are shown in Figures 3.1, 3.2 and 3.3, respectively. Substrate was described by North/South (2012) as either:

- Cobble/boulder
- Gravel/pebble
- Sand
- Fine sand/silt/clay

Substrate mapping provides a coarse representation of the substrate. Substrate conditions within each of the study lakes (Mary Lake, Camp Lake and Sheardown Lake), described by North/South (2012):

In **Camp Lake** the shoreline, littoral/euphotic, and profundal zones occupy approximately 16 ha (8%), 117 ha (37%), and 78 ha (55%), respectively. Camp Lake has a maximum depth of 35.1 m and a mean depth of 13.0 m. In general, depth extends to 10 m within approximately 100 to 200 m of the shoreline with a relatively uniform depth (10 to 20 m) throughout the majority of the lake (Figure 3.1). The shoreline in Camp Lake consists primarily of gravel/pebble (or smaller-sized substrate, particularly in the southwest), with small, isolated areas of cobble/boulder shoreline in the east, southeast, and northwest sections of the lake. Sand is the dominant substrate in Camp Lake and is found throughout the near shore and offshore areas. Small patches of finer substrates are dispersed primarily in deeper, offshore areas, while patches of cobble/boulder substrate are found primarily in shallower, near shore areas (i.e., shoreline zone). Gravel/ pebble sized substrates are dispersed throughout the lake.

Within the northwest basin of Sheardown Lake, referred to as **Sheardown Lake NW** ~~Within the northwest basin of Sheardown Lake~~, the shoreline, littoral/euphotic, and profundal zones occupy approximately 8 ha (12%), 28 ha (42%), and 32 ha (46%), respectively. Sheardown Lake NW is characterized by maximum and mean depths of 30.1 m and 12.1 m, respectively. This basin typically reaches depths of greater than 10 m at distances of less than 50 m from shore (Figure 3.2). The exception to this is a broad, shallow area in the southeast section of this basin. The shoreline in Sheardown Lake NW is primarily sand or gravel/pebble with a few areas of cobble/boulder. Substrate in the northwest basin consists primarily of sand or gravel/pebble with some cobble/boulder areas (usually in the littoral zone) and a few, small patches of fine substrates (typically in the profundal zone).

The southeast basin of Sheardown Lake, referred to as **Sheardown Lake SE**~~, The southeast basin of Sheardown Lake~~ is shallower than the northeast basin with maximum and mean depths of 26.7 m and 7.4 m, respectively. The shoreline, littoral/euphotic, and profundal zones occupy approximately 5 ha (19%), 16 ha (65%), and 4 ha (15%), respectively. Relatively large areas of this basin are less than 10 m in depth (Figure 3.2). This characteristic, combined with high water clarity, results in the lake being dominated by the littoral/euphotic zone.

The southeast basin has a similar proportion of sand to the northwest basin, but lacks finer substrates. An area of relatively dense aquatic macrophyte growth was observed in the southern extent of this basin. This macrophyte growth likely consists of non-vascular plants, such as macroalgae (e.g., *Chara* sp).

Figure 3.1 **Camp Lake – Substrate and Bathymetry**

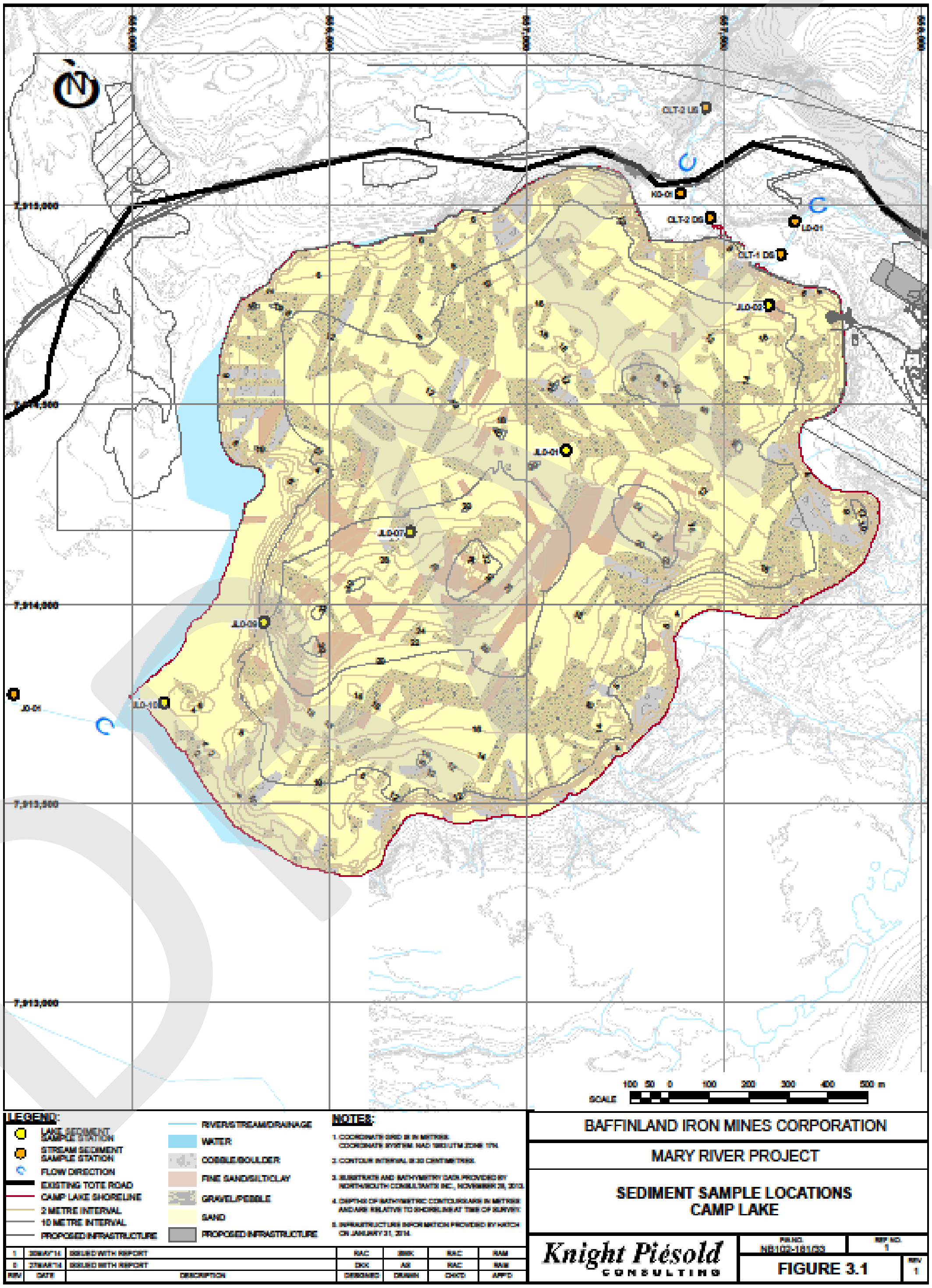


Figure 3.2 Sheardown Lake –Substrate and Bathymetry

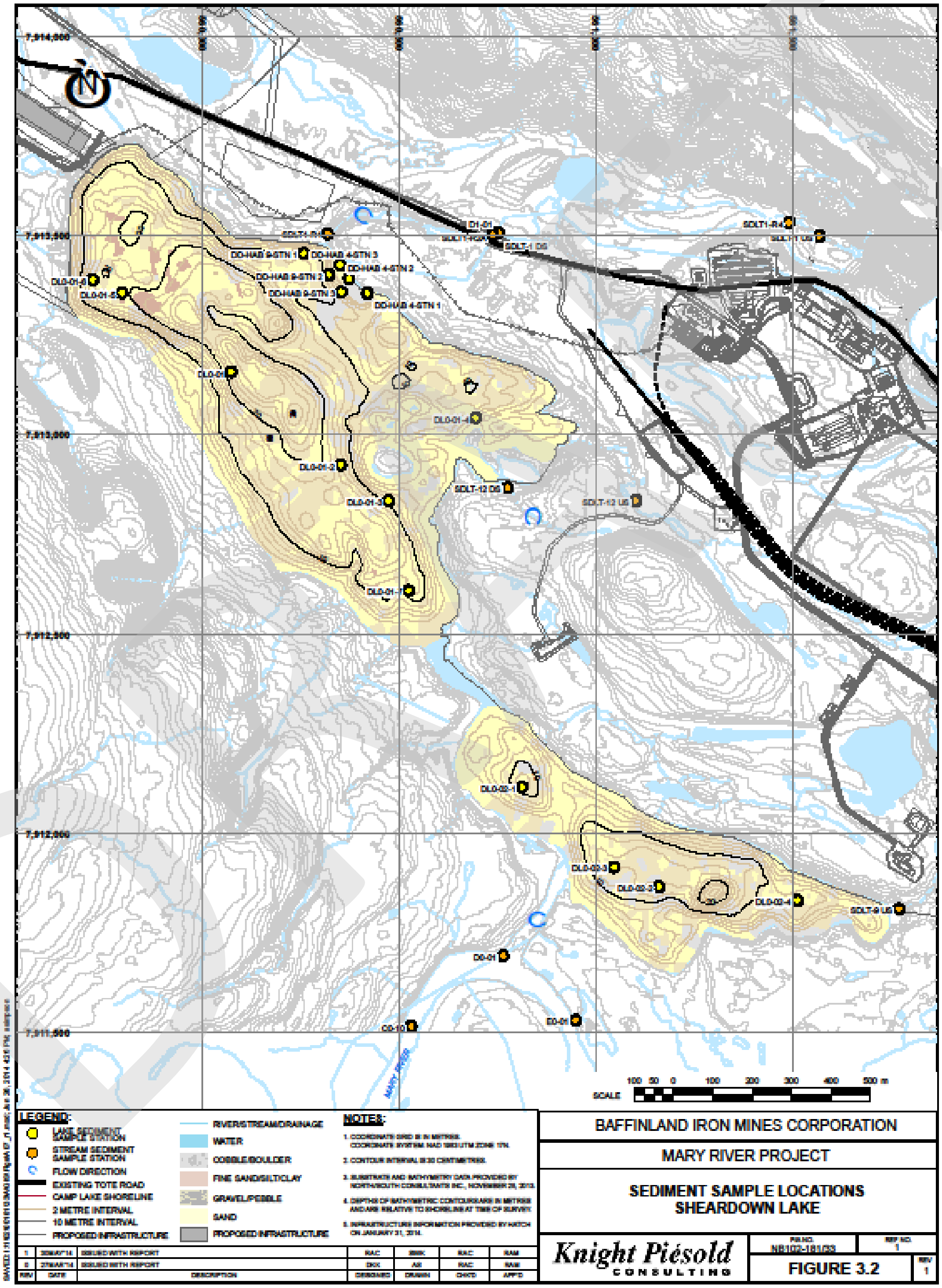
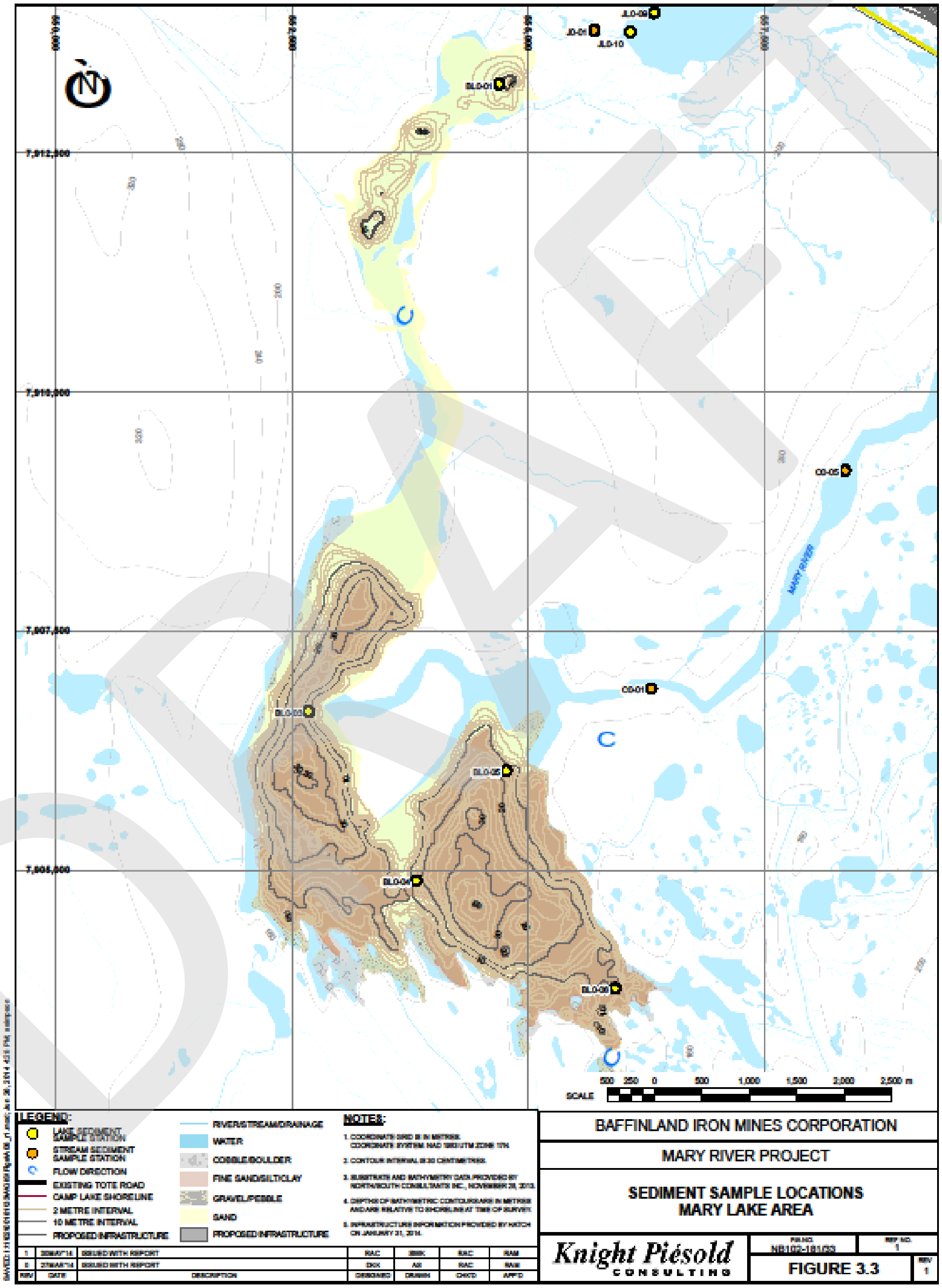


Figure 3.3 Mary Lake – Substrate and Bathymetry



Mary Lake ~~Similar to Camp Lake, Mary Lake~~ is relatively deep, similar to Camp Lake, with a maximum depth of 41.1 m in the large south basin. The mean depth of 12.0 m is shallower than Camp Lake and more similar to ~~the NW basin of~~ Sheardown Lake NW. The shoreline, littoral/euphotic, and profundal zones occupy approximately 493 ha (36%), 365 ha (26%), and 522 ha (38%), respectively. Expansive, shallow, near shore areas at the north end of the south basin (in proximity to the Mary River inlet and outlet) contribute to the comparatively shallow mean depth (Figure 3.3). Near shore substrate in Mary Lake, like the other lakes that have been surveyed for sediment quality, consists primarily of sand with patches of finer substrates and cobble/boulder. The substrata type in the shallower north arm is sand, while relatively fine sand mixed with silt/clay predominates throughout the deeper south basin.

~~3.1.3~~3.1.2 Aquatic Effects Monitoring of Dust from Bulk Sample Ore Crushing

A single season study was completed in 2008 that sampled sediment (as well as water quality and lower trophic level components) to monitor dust emissions from ore crushing during the bulk sampling program (North/South, 2010). As part of the bulk sampling program, crushing and screening of ore occurred during the winter and spring of 2008 near Sheardown Lake NW and Tributary SDLT-1 (Tributary 1, which is a main tributary supporting the lake). The study evaluated the water and sediment quality as well as periphyton, drifting invertebrates and benthic invertebrates within SDLT-1. The near shore environment at the mouth of SDLT-1, and control stations, were also evaluated.

Collectively, the results of the chemical and biological samples obtained did not indicate a definitive effect of dust deposition on the benthic invertebrate density or composition. Water quality monitoring results indicate that aluminum and lead may have been measurably increased in spring near the mouth of the tributary to Sheardown Lake NW, but other effects on sediment quality and lower trophic level biota were not definitive (North/South, 2010). North/South noted that the assessment was hampered by a lack of data collected in the immediately affected area prior to dust deposition and by other confounding factors such as substrate differences that limited direct comparisons.

~~3.1.4~~3.1.3 AEMP Target Study on Lake Sedimentation Rates (Sheardown Lake NW)

This study began in the open-water season of 2013 to measure sedimentation in Sheardown Lake NW and is currently ongoing. The study was designed to monitor the effects of dust generated by mine operations on sedimentation rates in lakes near the Mine Site with a specific focus on Sheardown Lake NW. The study involves deploying sediment traps at three stations in the lake, with five replicates at each station. This configuration is utilized to ensure adequate sediment is obtained for laboratory analysis and to provide sufficient information to evaluate variability at each station. The stations are selected to generate measurements of sedimentation rates at a deep station (where sedimentation is typically greatest) and at two shallower locations. The data from the study will be used to monitor potential influence of sedimentation on Arctic charr populations related to smothering of incubating eggs in spawning beds. This ongoing study along with the Dustfall Monitoring Program (Appendix G of AEMP) will provide supporting information for the interpretation of results generated from CREMP sediment quality monitoring. Details on the Land Sedimentation Program are further discussed in Appendix F of the AEMP document.

3.2 REVIEW OF SEDIMENT QUALITY DETECTION LIMITS

The yearly laboratory MDLs for sediment quality parameters of interest are presented in Table 3.3 and compared to the CSQG limits and PSQG criteria. In general, the detection limits were well below the relevant quality guidelines concentrations, and MDLs did not change meaningfully over the sampling period (up to and including 2014).

As with the water quality, power analysis can be utilized to calculate the minimum sample size required to be reasonably sure that an effect of a given size can be detected. The ability to detect change during future monitoring is a function of the number of sampling events and the spread in results. Baffinland is interested in utilizing its existing baseline dataset to the maximum extent possible. This approach should reduce the number of monitoring events that will be required to detect a given change.

Table 3-3 Summary of Sediment Quality Laboratory Detection Limits

Parameter	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
Units	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**	**µg/g**
CSQG-PAL ISQG	5.9	0.6	37.3	35.7	--	0.17	--	--	35	123
CSQG-PEL	17	3.5	90	197	--	0.486	--	--	91.3	315
PSQG-LEL	6	0.6	26	16	20,000	0.2	460	16	31	120
PSQG-SEL	33	10	110	110	40,000	2	1100	75	250	820
Method Detection Limits (by year)										
2005	0.03	0.006	0.5	0.1	0.5	0.1	0.05	1	0.7	0.1
2006	1.0	0.5	1	1	1	0.1	1	1	1	1
2007	1	0.5	1	1	1	0.1	1	1	1	1
2008	1	0.5	1	0.1	1	0.1	1	1	1	1
2011	1	0.5	1	1	5	0.1	1	1	1	2
2012	1	0.5	1	1	5	0.1	1	1	1	2
2013	1	0.5	1	1	5	0.1	1	1	1	2
2014	1	0.5	1	1	5	0.1	1	1	1	2

3.3 SEDIMENT QUALITY STRESSORS OF POTENTIAL CONCERN

The FEIS for the Project (Baffinland, 2012) identified the following stressors of potential concern for sediment quality given the average geochemical composition of the iron ore:

- Arsenic
- Cadmium

- Iron
- Nickel

The following metals have been noted to be naturally elevated in the sediment in the streams and lakes within the Mine Site Area (see Section 3.5 and Table 3.4):

- Arsenic
- Cadmium
- Chromium
- Copper
- Iron
- Manganese
- Nickel

It is expected that the metals found to be naturally elevated in the sediment is due to the mineralization associated with the ore body. As such, it is possible that these same metals will accumulate in sediment during the Project. On that basis, the metals listed immediately above are the identified sediment quality stressors of potential concern.

Lead and zinc were noted at one location in Sheardown Lake during sediment quality monitoring in~~in recent (~~ 2012 and 2013~~) sediment testing~~. These two metals are not consistently elevated in sediment within the Mine Site streams and lakes and are, therefore, not carried forward as sediment quality stressors of potential concern. Lead and zinc will still be tested for in sediment as part of the ongoing CREMP sediment quality monitoring program.

3.4 REVIEW OF SEDIMENT QUALITY BASELINE

A detailed review of the baseline data using various graphical analysis tools is presented in ~~Appendix~~ Attachment D. The sediment quality baseline review presented in ~~Appendix~~ Attachment D and summarized below (Section 3.5) was written by ~~Knight Piesold~~KP in early 2014 and does not include sediment quality data collected ~~during the 2014~~following ~~or 2015 CREMP field program.~~2013.

3.4.1 Metals Accumulation in Sediment and Total Organic Carbon and Fines

Metals concentrations in sediment are positively correlated with both finer grained particles as well as higher organic carbon content (Horowitz, 1991). Smaller particles have more binding sites and a higher affinity for metals than coarser grained material. Organic carbon within sediment decreases the dissolved oxygen and creates a more anoxic environment. Depending on pH, an anoxic environment may influence metal solubility and speciation. Within depositional areas of the lake that are characterized by higher concentrations of TOC and/or greater proportions of fine grained sediment, concentrations of several metals regularly exceeded the CSQG-PAL ISQGs or the PSQG-LEL. This includes chromium, copper, iron, manganese, nickel and phosphorus, and sometimes arsenic. Iron in some instances exceeded the PSQG-SEL. Most metals correlated well; in samples where one of the metals was elevated, all others were also elevated, except arsenic and manganese.

At the Mine Site, depositional environments were predominantly found within the lakes. The main exception to this is the stations within the main tributary of Sheardown Lake (Tributary 1). Streams at the Mine Site are mostly high gradient, high energy depositional environments that are not likely to have substantial amounts of fine grained sediment or sediment with high organic carbon content. The accumulation of metals in the depositional environments of the lakes is observed when reviewing mean concentrations of key metals as presented in Table 3.4 (numbers have been rounded). Stream versus lake sediment sample groupings are shaded different colours.

Table 3-4 Mean Concentrations of Key Metals in Sediment at the Mine Site

Sample ID		As µg/g	Cd µg/g	Cr µg/g	Cu µg/g	Fe µg/g	Mn µg/g	Ni µg/g	Pb µg/g	Zn µg/g
CCME	ISQG	5.9	0.6	37.3	35.7				35	123
	PEL	17	3.5	90	197				91.3	315
Ontario Sediment Quality Guidelines	LEL	6	0.6	26	16	20,000	460	16	31	120
	SEL	33	10	110	110	40,000	1,100	75	250	820
	n									
Upstream of Deposits	4	0.9	0.4	12.8	1.9	9,446	41	5	1.6	5.9
Downstream of Deposits	22	<1	<0.5	22.9	4.5	11,795	83	13	2.4	8.5
Drainages Off the Deposits	10	<1	<0.5	28.3	12.8	9,688	135	21	2.9	15.1
Mary River Tributary E2	7	1.0	0.4	18.5	3.8	9,507	64	12	2.5	7.0
Mary River Downstream of Mary Lake	2	0.7	0.3	74.5	7.0	6,050	90	29	1.5	7.8
Sheardown Lake Tributaries	18	1.4	0.65	45.2	27.0	13,524	235	39	12.1	47.6
Camp Lake Tributaries	12	0.9	0.4	27.0	12.3	8,501	95	22	3.7	13.3
Tom River	4	<1	<0.5	14.5	2.3	6,993	48	7	1.5	5.8
Mary Lake	9	2.5	<0.5	54.6	21.7	27,469	1,099	40	13.4	51.6
Camp Lake	12	2.7	<0.5	60.2	33.2	27,748	700	52	14.7	48.8
Sheardown Lake NW	32	3.1	<0.5	59.6	36.8	30,687	1,149	54	14.6	56.6
Sheardown Lake SE	7	1.5	0.6	68.0	23.4	27,462	397	57	13.3	46.3

Table 3.4 shows that the metal concentrations in depositional environments tended to be consistently higher in the same metals. In most of the ~~mine site~~Mine Site lakes, the mean concentrations of chromium, copper, iron, manganese and nickel exceeded the referenced guidelines.

Metals concentrations in depositional lake samples are relatively consistent between samples, between sample stations within a given lake, and between each of the three (3) ~~m~~Mine ~~s~~Site lakes (Camp, Mary, Sheardown). The Sheardown Lake Tributary 1 sample location (D1-05) also exhibited the same substrate characteristics and elevated metals concentrations.

Conversely, metals concentrations in lake sediment and most stream sediment stations which were low in fines and/or TOC contained relatively low concentrations of metals. These locations also had a high degree of variability in metals concentrations between sampling events and between nearby sampling stations.

In terms of long-term monitoring, it is recommended that sediment sampling stations in depositional environments be the focus of monitoring along with the application of the Assessment Approach and Response Framework (Figure 2.12):

- Detection of a change~~[5]~~
- Establishing if the change is mine related
- Comparison to benchmark
- Undertaking a low or moderate action depending on the result compared to the benchmark

The high level of variability within sediment samples characterized by low TOC and/or low fines (high proportion of sand) do not allow for the detection of statistically significant changes as the variability between samples is likely to be greater than any ~~p~~Project-related changes and collection of a sufficient number of samples to obtain statistical power is likely not possible.

As such, further evaluation of the sediment quality database was undertaken to understand the relationship between TOC, the proportion of fines, and metals concentrations.

Figure 3.4 shows the entire sediment quality dataset (up until 2013) plotted as percent clay vs percent sand with the circle size representing the proportion of silt. Figure 3.5 shows the same information in another way, plotting the proportion of clay/clay+silt versus the percent sand. The figures show the 3-way relationship between sand, silt and clay and the negative association between sand and clay.

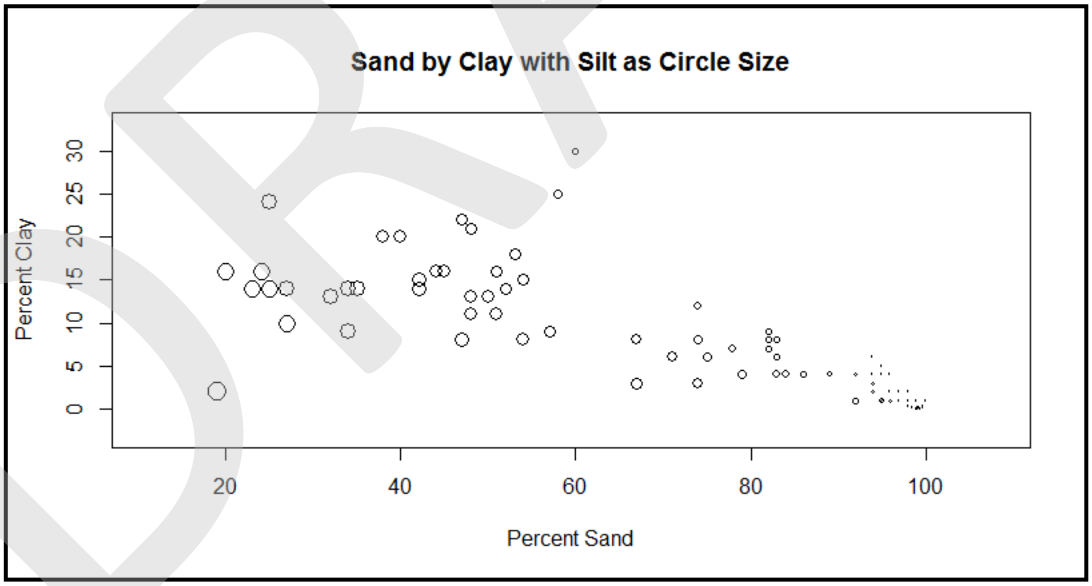


Figure 3.4 Clay by Sand with Silt as Circle Size

---

1. ~~A change in this instance may be a statistical or qualitative change when compared to: a benchmark, baseline values, or temporal or spatial trends~~

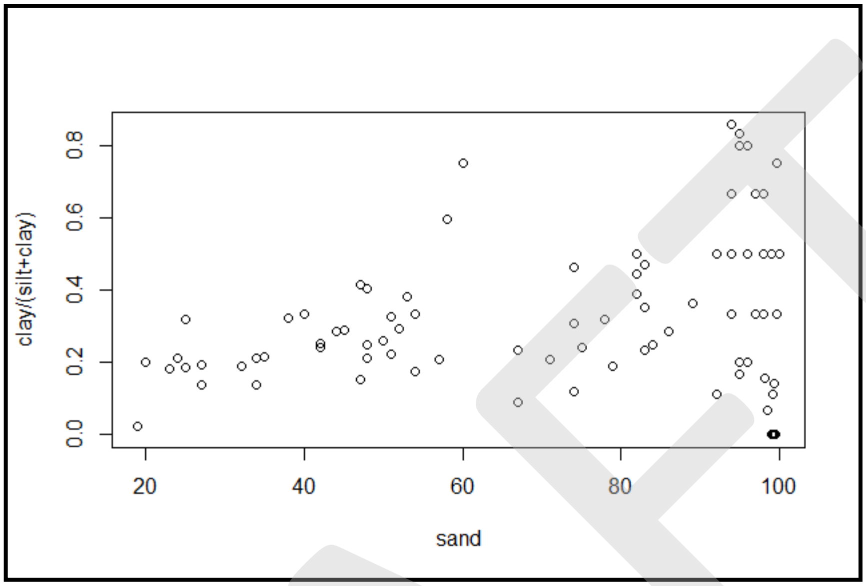


Figure 3.5 Dependent Relationship between Sand, Silt and Clay in Sediment

Colored scatter plots (Figure 3.6) show the relationship between TOC (or log TOC) and sand for lakes, streams and tributaries. Lakes are plotted using circles, streams and tributaries with triangles. Colors are used to identify the specific water bodies. Note that the x axis limits for streams and tributaries were adjusted because all the stream data is clumped at high proportions of sand (minimum of 82%). The figure shows that as expected the majority of lake sediment samples contain elevated TOC and higher proportions of fines (a lower proportion of sand), and conversely, the majority of stream samples are low in TOC and low in fines (predominantly sand).

A further evaluation was undertaken to identify cut offs in TOC and percent sand that could be applied to identify sediment samples in the baseline data. These same cut offs would be applied to sediment samples collected for monitoring.

3.4.2 Cut Point Analysis

Percent sand and TOC are generally related to metals concentrations. Deposition seems to be limited in sediment samples with a lot of sand and very little TOC. The focus of monitoring as part of the CREMP will be on identifying mine-related changes in metals concentrations. Variability due to TOC and particle size introduces extraneous noise. As such, it is generally better to control confounding factors in the study design rather than adjust for them during the data analysis. The data was reviewed to determine appropriate TOC and particle size cut-offs in order to identify sensitive depositional environments and minimize variability related to TOC and particle size. It was clear from the graphical analyses presented in ~~Appendix~~ Attachment D that establishing cut-offs in the vicinity of 80 to 90% sand (10 to 20% fines) and around 0.5% to 1% TOC would remove the non-depositional samples with high variability and comparatively low metals accumulation. Analyses were completed for four key parameters: arsenic, cadmium, iron and nickel.

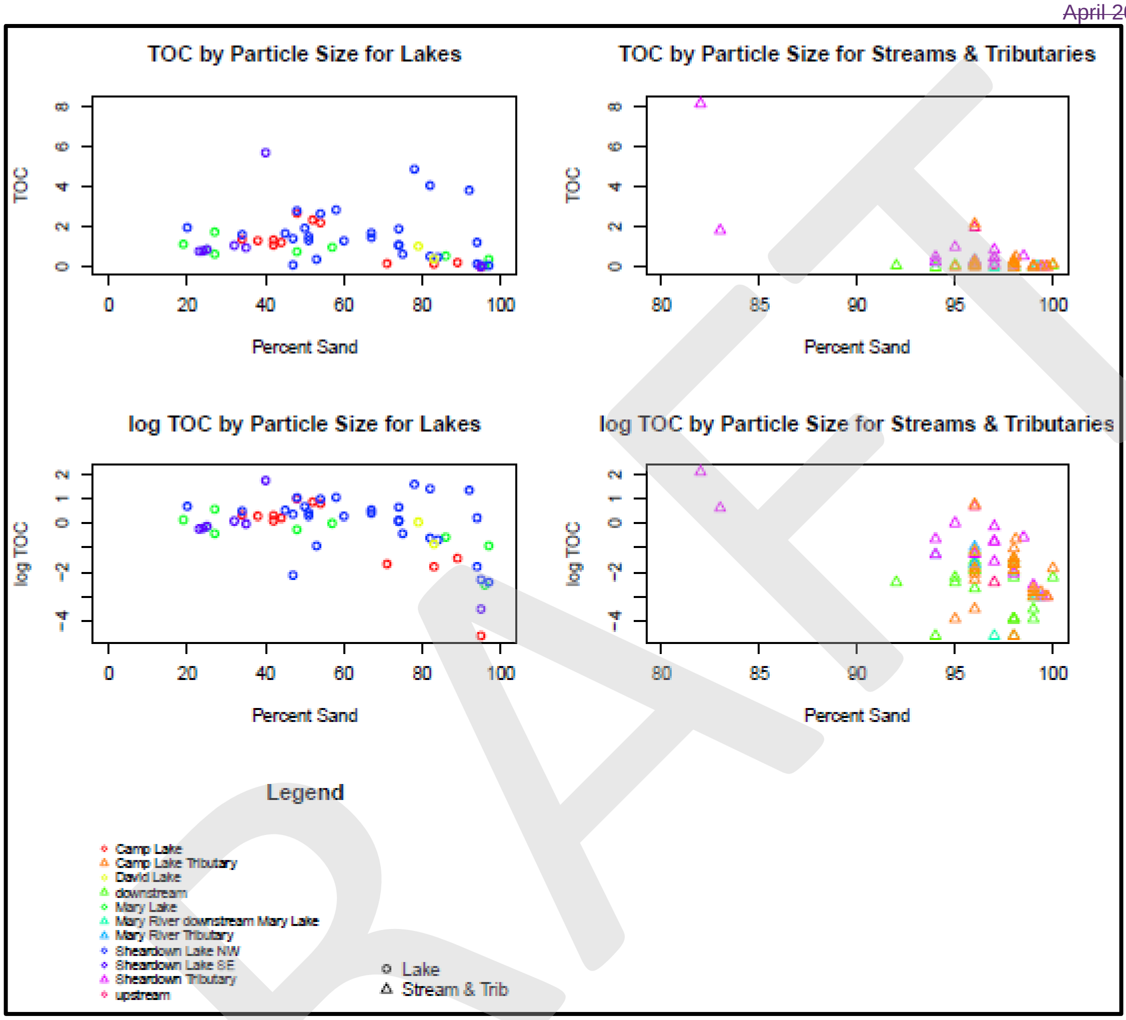


Figure 3.6 Sediment TOC versus Particle Size for Lakes and Streams

Analyses presented in ~~Appendix~~ Attachment D helped to identify cut points in the vicinity of inflection points on the curves. These cut points were used in subsequent linear regression analyses to explore the linear relationship above and below the cut off points.

A subset of the data was defined that excluded all samples with greater than 90% sand as well as samples with less than 0.6% TOC and greater than 80% sand (indicated in orange in Figure 3.7). Alternatively, a cut off could be established such as the sloped black line in Figure 3.7. It may be useful to carry out future research with additional data to develop such a rule.

The selection criterion reduces variability associated with TOC and particle size. For post-mining data, using only samples which meet the criterion is expected to be a conservative approach since samples with more than 80% sand and low TOC tend to have the smallest parameter concentration.

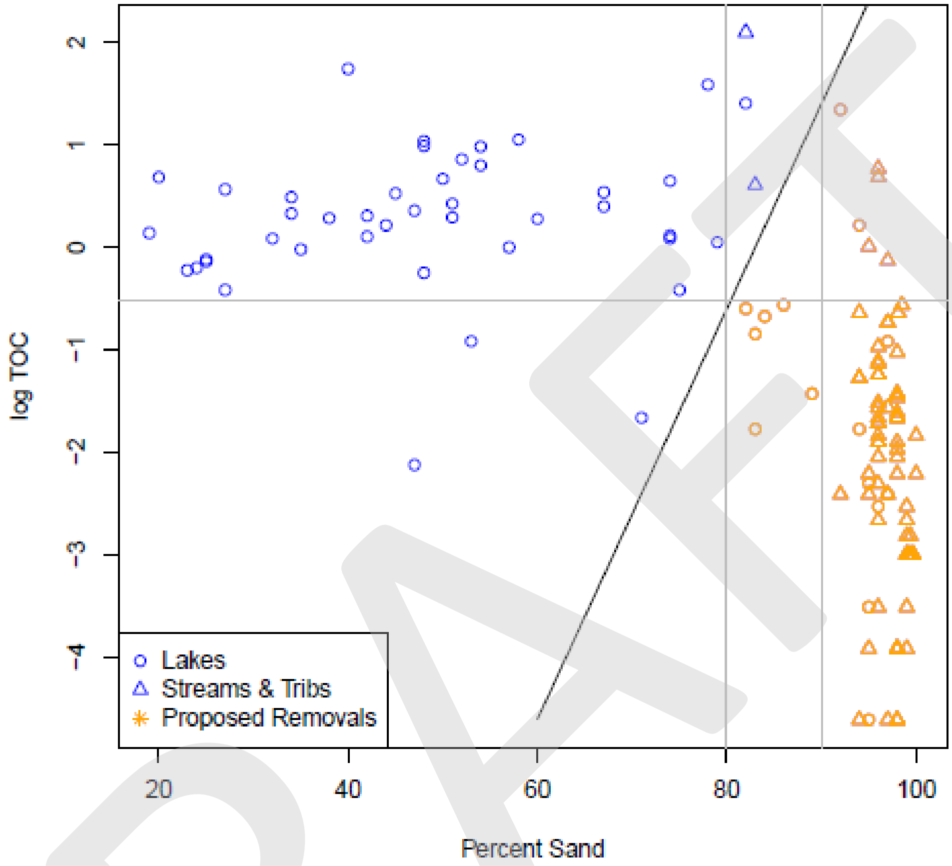


Figure 3.7 **Results of Cut Point Analysis for Sediment**

Environment Canada (2012) recommends that normalized metal concentrations be used to account for the effects of particle size and organic carbon. This method was considered, but it was found that the best way to minimize the relationship to organic carbon and fines involved creating data cut-offs. Additionally, normalized metals concentrations do not reflect the actual toxicity exposure in the environment.

Cut-off points have been identified for TOC and % sand based on metals accumulation in sediment in the baseline lake sediment samples. Baseline sediment samples with a TOC ≥0.6% and a minimum of 20% fines (or less than 80% sand) have been used for the development of the benchmarks and to calculate mean baseline concentrations (for “before” comparisons). Sediment samples with TOC <0.6% or with >80% sand (<20% fines) have not been included in the calculation of benchmarks, baseline means, and a priori power analyses. The same cut-off points will be applied to future ~~CREMP monitoring~~sediment quality samples collected under the CREMP, with samples not meeting these cut-off points being excluded from exploratory and statistical analysis. ~~during monitoring.~~

3.4.3 Overview of Lake Sediment Results

Lakes are depositional environments that receive sediment inputs from airborne dust and surface runoff from adjacent shorelines as well as material transported into the lakes from upland areas due to seasonal stream inflows. Concentrations of metals in sediment are greatly influenced by the presence of organic carbon and/or fine sediment particle size in the substrate as described above. Substrate in depositional areas of the lake characterized by higher organic carbon content and/or higher fine sediment particle sizes are well suited for long-term monitoring since:

- These areas tend to accumulate metals due to the substrate characteristics and are therefore expected to be the most consistent with respect to elevated metals as well as the most sensitive to change (increasing accumulation of metals)
- The baseline data between lakes was similar

Each of the ~~mine area~~Mine Area lakes (Camp, Mary, Sheardown) showed considerable similarities in metals concentrations in sediment as well as the observed trends regarding metals accumulation at stations with high TOC and higher fines substrates. The variability in substrates that are predominantly sand and their limited TOC concentrations were also evident.

3.4.4 Overview of Stream Sediment Results

Concentrations of metals in sediments were generally highly variable within the streams, which tend to be higher energy environments with limited depositional areas. As such, these environments provide limited amounts of sediment quality data. Two sampling stations on Sheardown Lake ~~(~~Tributary 1 (D1-10 and D1-05) are depositional areas that show slightly higher fine sediments and elevated concentrations of cadmium, chromium, copper, iron, nickel, lead and zinc. These concentrations were above the applicable sediment quality guidelines.

Based on the sediment quality review for samples collected up until 2013, presented in Attachment D, KP recommended that~~S~~ select near-field stream sediment sampling stations ~~will continue~~should ~~to~~ be monitored as described below:

- Sediment stations within Sheardown Tributary 1 that meet the TOC and % sand cut-offs will be monitored following the lake sediment monitoring program
- All other retained stream sediment stations will be monitored for comparison against previous results. These stations will be evaluated, but the higher energy, non-depositional environment may not be useful for a statistical comparison against CSQG-PAL and AEMP benchmarks. The results may support conclusions of lake samples or may trigger action using a different protocol.

During the 2015 CREMP field season, Minnow reaffirmed KP's previous observations regarding the general absence of depositional areas within streams and rivers monitored under the CREMP and subsequently concluded that the absence of any substantial accumulation of fine sediments within the streams and rivers precluded any meaningful assessment of mine-related influences on sediment quality within, along, and/or between watercourses. Based on this observation, Minnow recommended the discontinuation of the CREMP sediment quality program for lotic environments (Minnow Recommendation 10; Minnow, 2016). Minnow's recommendation has been adopted and incorporated into the current sediment quality design for CREMP described below.

~~3.6~~3.5 SEDIMENT QUALITY CREMP STUDY DESIGN

Sediments are frequently part of environmental monitoring programs due to their importance in aquatic ecosystems. Sediments originate from particulates and precipitates that are generated from chemical and biological processes within aquatic systems. The determination of total metal concentrations in sediments is not required as part of the EEM program; however, mines are encouraged to determine total metal concentrations in sediments when completing benthic invertebrate community surveys (Environment Canada, 2012). For EEM monitoring programs where benthic invertebrate sampling is conducted in erosional habitat (e.g., streams), sediment sampling may not be possible and would not be reported. The spring freshet ~~near the~~that occurs at the ~~mine~~ Project typically flushes fine grained sediment downstream into depositional areas (e.g., lakes). Because of this and the very limited depositional habitat suitable for the collection of fine sediments in streams and rivers in and around the Mine Site, the CREMP sediment monitoring program had been revised, as per Minnow's recommendation (Minnow Recommendation 10; Minnow, 2016), to focus~~es~~ solely on ~~the four (4) m~~Mine ~~area~~ Area lakes (Camp, Sheardown ~~NW and NE~~, Mary Lake). In addition, Reference Lake 3 was selected in 2015 as the CREMP reference lake and will be sampled concurrently with ~~mine~~ Mine ~~area~~ Area lakes in the summer and fall during future studies[6]. Further details on the CREMP sediment quality monitoring program is discussed in Section 3.6.4 and Section 3.6.5.

~~3.6.3~~3.5.1 Pathways of Effect and Key Questions

Key questions were developed for the CREMP to guide the review of baseline data adequacy and, ultimately, design of the monitoring program. These questions and metrics focus upon key potential effects identified in the Final Environmental Impact Statement (FEIS) and the Early Revenue Phase (ERP) addendum, as well as metrics commonly applied for characterizing ~~water~~ sediment quality.

The key pathways of potential effects of the Project on sediment quality include:

- Sediment quality changes related to discharge of ore or stockpile runoff to freshwater systems (immediate receiving environments: Mary River and Camp Lake Tributary 1)
- Sediment quality changes (primarily nutrients and TSS) related to discharge of treated sewage effluent (immediate receiving environments: Mary River and Sheardown Lake NW)
- Sediment quality changes due to direct deposition of dust in lakes and streams (Mine Area in zone of dust deposition)
- Sediment quality changes due to dust deposition on land and subsequent runoff into lakes and streams (Mine Area in zone of dust deposition)

The key question related to the pathways of effect is:

~~2. change in this instance may be a statistical or qualitative change when compared to: a benchmark, baseline values, or temporal or spatial trends~~

~~late April.~~

- What is the estimated mine-related change in contaminant concentrations in the exposed area?

The primary issues of concern with respect to sediment quality is the effect of ore dust containing elevated metals being deposited on, or running off into ~~m~~Mine A~~a~~rea lakes. In addition, another concern to consider is metal loads from ~~Mine~~ mine effluent influencing sediment metal concentrations over time, although limited effluent is released in the current ~~phase of the mine~~ERP of the Project. In the review of baseline sediment data presented in Attachment~~Appendix~~ D, ~~Knight Piésold~~KP noted that the high-energy streams in the Mine Site area do not readily accumulate metals, and metals concentrations tend to be highly variable, in comparison to depositional lake sediment stations typically characterized by high organic carbon content and a higher proportion of fines (~~Knight Piésold~~KP, 2014a).

~~Moreover, a~~After conducting the 2015 CREMP sediment quality program, Minnow recommended that the ~~stream~~ sediment sampling in future CREMP studies be discontinued on the basis that very limited depositional habitat suitable for the collection of fine sediments was present in streams and rivers in and around the Mine Site (Minnow Recommendation 10; Minnow, 2016). As such, CREMP sediment quality monitoring ~~will~~ program has been revised to ~~focus s~~solely focus on the Mine Area lakes ~~four (4) mine area lakes~~ closest to mine operations and the sources of ore dust: Sheardown Lake ~~NW and SE~~, Camp Lake and Mary Lake. Sediment quality monitoring will also be conducted at Reference Lake 3 to assist in identifying ~~any~~ sediment quality changes related to mine operations.

~~3.6.4~~3.5.2 Parameters and Metrics

Sediment quality parameters identified for monitoring include various physical parameters and metals. They were selected on the basis of the following:

- The potential to be naturally elevated in the environment
- The potential to become elevated in the environment as a result of future ~~mine site~~Mine Site activities
- An established criterion exists for the protection of freshwater aquatic life
- Regulation under the MMER, or potential regulation as a result of the current re-evaluation of the regulations
- The parameter affects the attenuation of metals (i.e., particle size and total organic carbon)

The contaminants of potential concern and supporting parameters are listed in Table 3.5. Those SOPCs with local enrichment are noted in the table.

Table 3-5 Sediment Quality Parameters Selected for Monitoring[7]

Contaminants of Potential Concern	Exploratory Data Analysis Only
Arsenic	Moisture content
Cadmium	Particle Size
Chromium *	Total Organic Carbon (TOC)
Copper *	

---

[7] Nitrite, nitrate, phosphorus and Total Kjeldahl Nitrogen (TKN) had been monitored during CREMP sediment monitoring programs up to but not including the 2015 CREMP ~~program.~~field season.

Iron *	
Lead	
Manganese *	
Mercury	
Nickel *	
Phosphorus *	
Zinc	

~~3.6.5~~3.5.3 Benchmarks

Since the Mine Site occurs within an area of metals enrichment, generic sediment quality guidelines established for all areas within Canada may naturally be exceeded near the Mine Site. Therefore, the selection of appropriate benchmarks must consider established sediment quality guidelines, such as those developed by the Canadian Council of Ministers of the Environment (CCME) and the Ontario Ministry of the Environment (MOE), as well as site-specific natural enrichment in the selection or development of final benchmarks for monitoring data comparison (CCME, 2007).

Intrinsik Environmental Sciences Inc. was retained by Baffinland to develop water and sediment quality benchmarks to be applied in the CREMP (Intrinsik, 2014; Intrinsik, 2015; see Appendix C and D of the AEMP). The sediment quality data utilized in benchmark development met the TOC and % sand cut-off points described in Section 3.4~~5~~.2. The development of sediment quality benchmarks followed the same process identified for the water quality benchmarks (Section 2.7.3), considering the higher of the generic sediment quality objective (i.e., CCME or other jurisdiction) or the 97.5th percentile of baseline concentrations. For parameters that are mostly below MDL (less than 5% detected values), either the generic sediment quality guideline was selected (if available), or 3 ~~*~~ times the MDL was adopted as the benchmark, as follows:

- **Method A**: Sediment Quality Guideline was higher than 97.5th percent~~%~~ile, and therefore was selected
- **Method B**: 97.5th percent~~%~~ile was higher than the Sediment Quality Guideline, and therefore was selected
- **Method C**: Parameter has < 5% detected values, and either the Sediment Quality Guideline was selected (if available), or 3 ~~*~~ times the MDL was used to derive benchmark

If Method B was selected, additional assessment of the data was conducted to ensure the percentile calculations were not being driven by elevated detection limits, or other factors.

In 2015, Intrinsik established area-specific sediment quality benchmarks for all ~~mine area~~Mine Area lakes with the exception of Sheardown Lake NW. (Table 3.6).

In the case of mercury, lead and zinc, the selected benchmark was either a CCME or an Ontario sediment quality guideline, as area-wide data were less than or equal to this value. ~~–~~Lake sediment characterization during future CREMP studies may result in changes to this decision. In the case of arsenic, chromium, copper, iron, manganese, nickel and phosphorus, the established AEMP benchmark is the 97.5th percentile of baseline (including 2014). ~~The use of the area-wide percentiles as benchmarks appears to be reasonable, based on comparisons to both the existing guidelines, and characterization data for the lakes.~~

For cadmium, the available data ~~are~~ was largely non-detect, at an MDL of 0.5 mg/kg. The ISQG is 0.6 mg/kg, and due to the close proximity of the MDL to the ISQG, the 3 times MDL approach was applied to determine an AEMP benchmark for cadmium.

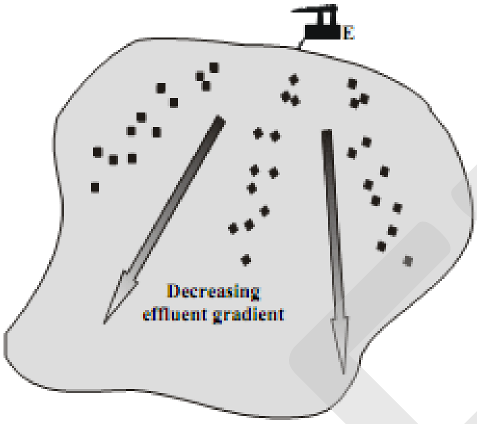
~~During the 2015 CREMP~~During the 2015 CREMP field season, it was observed that average arsenic, copper and iron concentrations in Reference Lake 3, were elevated above the AEMP sediment quality benchmarks established by Intrinsik in 2015 (Intrinsik, 2015). In turn, this suggests that the AEMP sediment benchmarks established for these metals may be overly conservative. Because reference lake information had not been available at the time of AEMP benchmark development, Minnow ~~recommends~~ has recommended (Minnow Recommendation 14; Minnow, 2016) that reference sediment quality data be factored into the derivation of AEMP benchmarks for arsenic, copper and iron in the future to improve the applicability of these benchmarks as a tool for evaluating potential mine effects for the ~~Mary River Project~~ CREMP.

As noted in Section 2.7.3 in regard to water quality benchmarks, the assessment of sediment quality data over the life of the Project will be on-going, and the recommended benchmarks of comparison throughout this process may change, as more data becomes available. For example, a site-specific sediment quality guideline established early on in the life of the mine may require updating in 10 years, based on new published literature which has become available, or site-specific toxicity tests conducted to further understand ETMF or resident species toxicity. The iterative, cyclical nature of modification of benchmarks under an AEMP is well established (MacDonald et al., 2009).

~~3.6.6~~3.5.4 Monitoring Area and Sampling Stations

The monitoring area for sediment quality under the CREMP focuses on the ~~includes mine area~~Mine Area lakes (~~, including~~ Camp, ~~Lake,~~ Sheardown ~~Lake NW and SE and~~and Mary Lake) ~~as well as~~and Reference Lake 3.

Environment Canada (2012) recommends a Control-Impact (CI) or Gradient Sample design for detection of effects in the lake environment benthic invertebrate community (Figure 3.8). A gradient sample design has been defined for the CREMP lake sediment stations that is integrated with benthic invertebrate sampling and utilizes several historic sediment sampling locations that meet the cut-off criteria (Section 3.5.2).



c) Radial gradient design for lake or coastal situations

Figure 3.8 Gradient Sampling Design to Lake Sediment Monitoring

The current sediment sampling locations for the ~~mine exposed lakes~~Mine Area lakes ~~(Sheardown Lake, NW and SE, Camp Lake and Mary Lake)~~ are shown in Figure 3.9. Sediment sampling locations for Reference Lake 3 are shown in Figure 3.10. Within each mine exposed study lake, stations are positioned to allow for the evaluation of any spatial differences in sediment chemistry in order to determine potential gradients in metal concentrations associated with mine sources (i.e. mine exposed tributaries).

Prior to 2016, the sediment quality monitoring program did not sample sediment at each lake benthic macroinvertebrate (BMI) station. Therefore, in effort to harmonize the sediment quality and ~~benthic macroinvertabrate~~BMI monitoring programs and refocus the lake benthic macroinvertebrate program solely on littoral (shallow) habitats, Minnow proposed the following recommendations in 2016:

1. Harmonize lake sediment quality and BMI monitoring by ~~E~~establishing ~~-~~five (5) sediment quality/~~BMI~~ BMI stations ~~located~~ within~~in~~ the littoral (shallow) habitat at each mine exposed study lake and Reference Lake 3 (Minnow Recommendations 15, 16; Minnow, 2016).~~.~~
2. Continue sediment quality monitoring at three (3) existing sediment quality stations located in profundal (deep) habitat at Reference Lake 3 and each mine exposed study lake, with the exception of Sheardown Lake SE where limited profundal habitat is present (Minnow Recommendation 17; Minnow, 2016).

The five (5) l~~L~~ittoral sediment sampling stations are situated at the same locations as the littoral BMI stations at each mine-exposed lake and Reference Lake 3. Utilizing the same littoral stations for both sediment quality and ~~benthic macroinvertebrate community~~ BMI ~~sampling~~ monitoring will provide supporting information for interpretation and analysis of BMI results (e.g., metals concentrations) and allow the CREMP to establish potential linkages between sediment metal concentrations and effects on ~~benthic macroinvertebrates.~~ BMI communities.

To the extent possible, the five (5) littoral sediment quality/BMI stations in each lake ~~proposed by Minnow~~ were established at existing (historic) BMI stations. However, in some cases, new stations were established to ensure sufficient coverage of the lake, and to ensure that substrate properties are comparable among and within lakes.

In contrast, all profundal sediment quality stations recommended by Minnow (Minnow Recommendation 17; Minnow, 2016) were selected from existing sediment stations. Because the majority of southeast basin of Sheardown Lake, referred to as Sheardown Lake SE, ~~Sheardown Lake~~ is less than 12 meters deep and represents primarily littoral habitat, sediment quality monitoring at Sheardown Lake SE will focus solely ~~only~~ on littoral habitat. ~~of this lake.~~.

During the 2015 CREMP field season, Minnow reaffirmed KP's previous observations regarding the general absence of depositional areas within streams and rivers monitored under the CREMP and subsequently concluded that the absence of any substantial accumulation of fine sediments within the streams and rivers precluded any meaningful assessment of mine-related influences on sediment quality within, along, and/or between watercourses. Based on this observation, Minnow recommended the discontinuation of the CREMP sediment quality program for lotic environments (Minnow Recommendation 10; Minnow, 2016).

~~Moreover, in addition to modifications to the lake sediment quality program, Minnow also recommended that the CREMP sediment monitoring program focus solely on depositional lake environments and that CREMP sediment monitoring stations in streams and rivers be discontinued in future CREMP studies. This recommendation was based on the observation that the majority of streams and rivers in the Mary River Project local study area (LSA) contain very limited depositional habitat suitable for the collection of fine sediments. As observed during the 2015 CREMP and baseline studies (KP, 2015), the general absence of any substantial accumulation of fine sediments within these watercourses preclude any meaningful assessment of potential mine-related influences on sediment quality within, along and/or between watercourses. As a result, all sediment quality stations in streams and rivers near the Mine Site have been removed from future CREMP studies.~~

This document has been revised reflect all of the recommendations listed above. Additional details regarding sediment quality sampling methodology is presented in ~~Appendix~~ Attachment A.

An updated list of the CREMP sediment monitoring stations is presented in Table 3.7.

~~3.6.8~~3.5.5 Sampling Frequency and Schedule

Sediment quality monitoring will be conducted once each monitoring year in the fall (August) to coincide with benthic invertebrate sampling to be conducted as part of the freshwater biota CREMP (Appendix D of AEMP).

As outlined in Schedule 5, Part 2 of the MMER, biological monitoring studies are to be conducted on a three (3) year cycle until two consecutive biological monitoring studies indicate no effect on fish populations, on fish tissue and on the benthic invertebrate community. In the long-term, sediment sampling under the CREMP will be conducted every three years, coinciding with biological monitoring studies. However, to be cautious initially, Baffinland will conduct sediment sampling annually for the first three (3) years of mining. After monitoring three operating (mining) years, the sampling frequency will be re-assessed with the expectation of conducting the monitoring program on a three (3) year cycle provided annual sampling up to that time supports this change. Sedimentation rates at Sheardown Lake NW are predicted to be less than 1mm per year; therefore, a three (3) year frequency should be sufficient to track changes in sediment metal concentrations over time.

~~3.6.9~~3.5.6 Quality Assurance/Quality Control

The same QA/QC program described in Section 2.6.6 will be applied to sediment quality monitoring. The field sampling protocols being applied to the sediment (and water) quality programs are presented in ~~Appendix~~ Attachment A.

Table 3-6 Development of Area-Specific Aquatic Effects Sediment Benchmarks, based on Area-Specific Baseline Calculations and Relevant Sediment Quality Guidelines (mg/kg; dw; Intrinsik, 2015)

Jurisdiction, Type of Guideline and Statistical Metric		Hg	As	Cd	Cr	Cu	Fe	Mn	Ni	P*	Pb	Zn
CCME (2014)	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario (OMOE, 2008)	**LEL**	0.2	6	0.6	26	16	20,000	460	16	600	31	120
	SEL	2	33	10	110	110	40,000	1100	75	2,000	250	820
97.5th Percentiles of Lake Areas and Lake Specific Benchmarks by Area												
Mary Lake (2007 – 2014) and Camp lake (2007 – 2014) (N=31)		<0.1	5.3	<0.5	98	50	52,400	4,370	72	1580	25	135
Proposed AEMP Benchmark – Mary Lake and Camp Lake		0.17^{A}	5.9^{A}	1.5^{C}	98^{B}	50^{B}	52,400^{B}	4,370^{B}	72^{B}	1,580^{B}	35^{A}	135^{B}
Sheardown Lake SE (2007 – 2014) (N=11)		<0.1	2	1	79	56	34,400	657	66	1278	18	63
Proposed AEMP Benchmark – Sheardown Lake SE		0.17^{A}	5.9^{A}	1.5^{C}	79^{B}	56^{B}	34,400^{B}	657^{B}	66^{B}	1278^{B}	35^{A}	123^{A}
Sheardown Lake NW (2007-2014, excluding 2008) (N=25)		<0.1	6.4	<0.5	96	62	53,000	4,300	84	1,100	24	107
Interim AEMP Benchmark – Sheardown Lake NW		0.17^{A}	6.2^{B}	1.5^{C}	97^{B}	58^{B}	52,200^{B}	4,530^{B}	77^{B}	1958^{B}	35^{A}	123^{A}

NOTES:

*='N' FOR PHOSPHORUS IS LOWER THAN OTHER ELEMENTS / PARAMETERS ~~for phosphorus is lower than other elements / parameters~~

A = GUIDELINE IS BASED ON SEDIMENT QUALITY GUIDELINE (CCME OR ONTARIO) ~~guideline is based on sediment quality guideline (CCME or Ontario)~~

B = GUIDELINE IS BASED ON 97.5th PERCENTILE OF BASELINE DATA ~~guideline is based on 97.5% percentile of baseline data~~

C = GUIDELINE IS BASED ON 3 TIMES MDL~~guideline is based on 3 times MDL~~

WHERE MERCURY AND CADMIUM WERE NOT DETECTED IN ANY SAMPLES IN A GIVEN AREA; THE DETECTION LIMIT IS USED TO REPRESENT THE 97.5th PERCENTILE. ~~Where mercury and cadmium were not detected in any samples in a given area; the detection limit is used to represent the 97.5% percentile~~

~~5.~~

Figure 3.9 ~~Recommended~~ CREMP Sediment Quality and BMI~~enthic~~ Monitoring Stations ~~following the 2015 Program~~

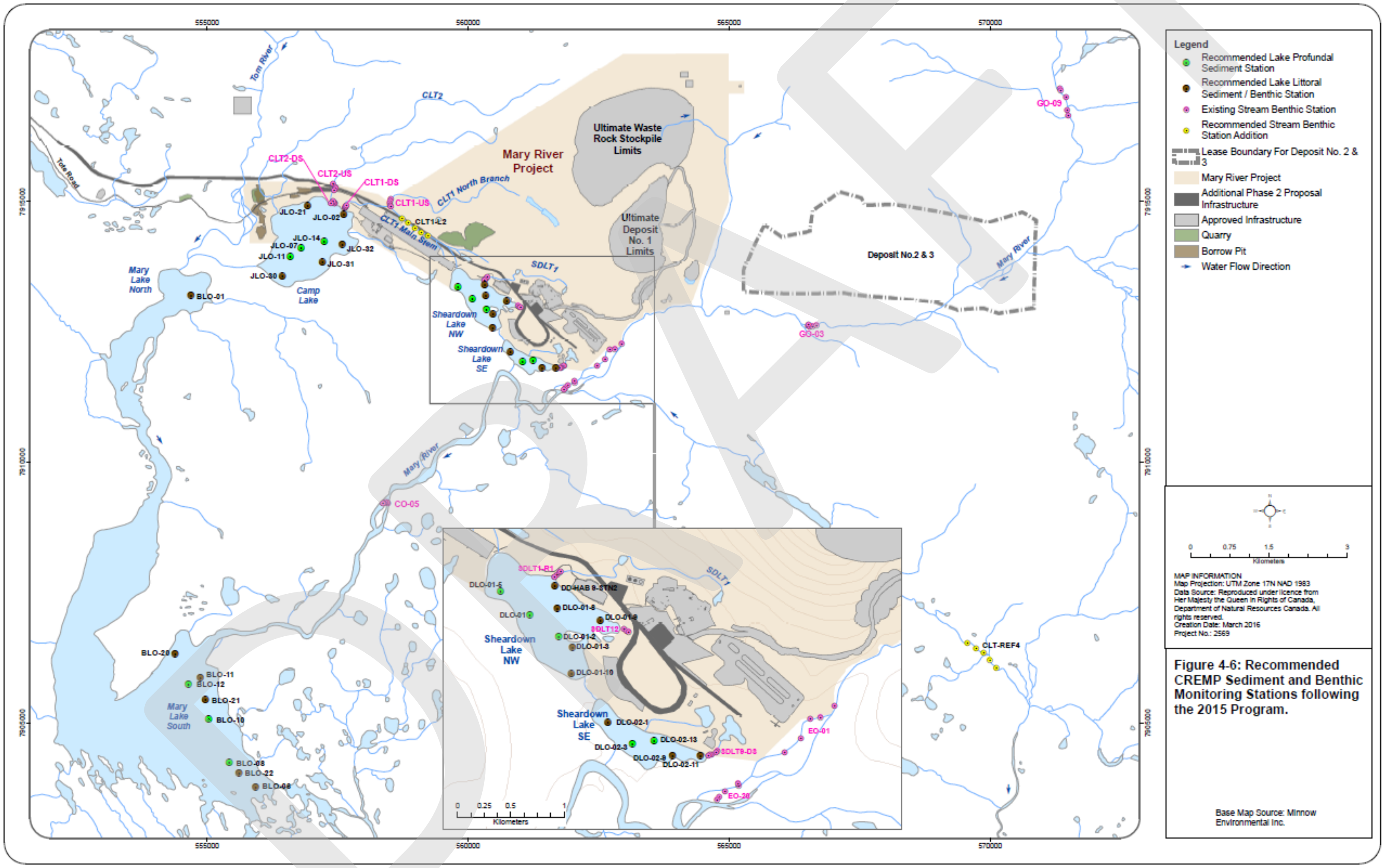


Figure 3.10 ~~Recommended~~ CREMP Monitoring Stations for Reference Lake 3 ~~Monitoring Stations following the 2015 Program~~

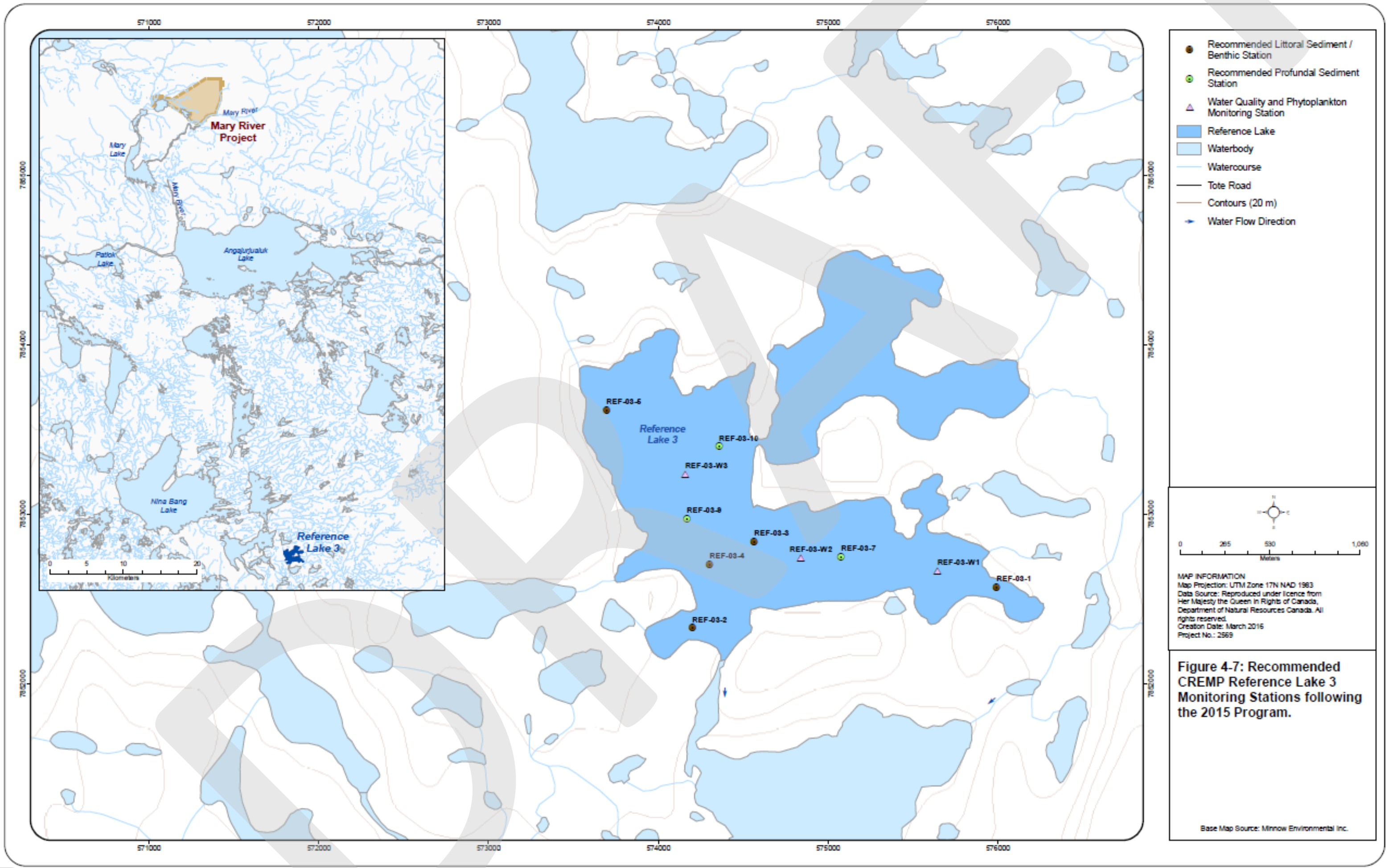


Table 3-7 CREMP Sediment Quality and BMI ~~CREMP~~ Monitoring Stations ~~Details~~

Station ID	Easting	Northing	Sediment Quality	Benthic Macroinvertebrates	Description/Rationale
	NAD 83, Zone 17N				
Mary Lake (North Basin)					
BL0-01	554690	7913194	X	X	North basin receiving water from Camp Lake
Mary Lake (South Basin)					
BL0-06	555924	7903760	X	X	Main basin near outlet of Mary River
BL0-08	555420	7904237	X		Main basin between BL0-05 and BL0-06
BL0-10	555038	7905069	X		Main basin between BL0-05 and BL0-06
BL0-11	554987	7905976		X	Main basin near outlet of Mary River
BL0-12	554641	7905752	X		Main basin near outlet of Mary River
TBD[1]	TBD	TBD	X	X	Main basin near outlet of Mary River
TBD[1]	TBD	TBD	X	X	Main basin nearshore between BL0-12 and BL0-10
TBD[1]	TBD	TBD	X	X	Main basin near south shore
Mary River (D/S of SDL)					
C0-05	558352	7909170		X	Mainstem - downstream of Mine Site
SDL-Tributaries					
SDLT-1-R1	560320	7913504		X	Tributary SDLT-1
SDLT-9-DS	561770	7911810		X	Tributary SDLT-9
SDLT-12	560776	7912867		X	Tributary SDLT-12
Sheardown Lake NW					
DD-Hab 9-Stn 2	560323	7913402	X	X	Nearshore station
DL0-01	560079	7913128	X		Mid-lake position
DL0-01-2	560353	7912924	X		Mid-lake position
DL0-01-3	560474	7912833	X	X	Southeastern region
DL0-01-5	559798	7913356	X		Near treated wastewater discharge location
DL0-01-8	560329	7913197	X	X	Mid-lake position
DL0-01-9	560750	7913077	X	X	Eastern region, near SDLT-9 inflow stream
DL0-01-10	560580	7912537	X	X	Near outlet channel to Southeast Basin
Sheardown Lake SE					
DL0-02-1	560813	7912116	X	X	Near inlet channel from Northwest Basin
DL0-02-3	561046	7911915	X	X	Mid-lake position
DL0-02-9	561414	7911804	X	X	Eastern region
DL0-02-11	561688	7911801	X	X	Eastern region near SDLT-9 stream inflow
DL0-02-13	561237	7911943	X	X	Mid-lake position
Mary River (US of SDL)					
E0-20	561688	7911272		X	Near EEM near field exposure area
E0-01	562942	7912274		X	Downstream of Deposit 1 near sewage outfall
G0-03	566516	7912618		X	Upstream of Deposit 1
G0-09	571341	7917169		X	Mary River Reference Area - Upstream of Deposit 1, 2 and 3
Camp Lake					
JL0-02	557614	7914750	X	X	On gradient transect between CLT-1 and lake outlet.
JL0-07	556800	7914094	X		

Station ID	Easting	Northing	Sediment Quality	Benthic Macroinvertebrates	Description/Rationale
	NAD 83, Zone 17N				
JLO-11	556598	7913935	X		
JLO-14	557235	7914222	X		Mid-lake position
JLO-16	556329	7914456	X	X	Near northwest shoreline
JLO-21	556935	7914913	X	X	Along the northwest shoreline
TBD[1]	TBD	TBD	X	X	Near northwest shoreline
~~Camp Lake cont'd~~					
TBD[1]	TBD	TBD	X	X	Near southwest shoreline
TBD[1]	TBD	TBD	X	X	Near southeast shoreline
Camp Lake Tributaries					
CLT-1--DS	557645	7914878		X	Lower reach of CLT-1 near lake outlet
CLT-1--US	558504	7915022		X	Upstream of CLT-1 near natural fish barrier
CLT-2--DS	557466	7914969		X	Lower reach of CLT-2 near lake outlet
CLT-2-US	557441~~TBD~~	7915291~~TBD~~		X	Upper reach of CLT-2
CLT1-L2[2*]	TBD	TBD		X	CLT1 Upper Main Stem, DS of QMR2
Reference Tributary					
CLT-REF4[2*]	TBD	TBD		X	Camp Lake Tributary Reference Area 4
Reference Lake					
REF-03-1	575992	7852572	X	X	Nearshore southeast shoreline
REF-03-2	574200	7852330	X	X	Nearshore south shoreline
REF-03-3	574564	7852840	X	X	Nearshore north shoreline
REF-03-4	574301	7852705	X	X	Mid-lake position
REF-03-5	573694	7853613	X	X	Nearshore northwest shoreline
REF-03-7	575076	7852750	X		East Mid-lake position
REF-03-9	574168	7852975	X		Mid-lake position
REF-03-10	574358	7853400	X		Northwest shoreline
TOTAL			**38**	**41**	

NOTES:

1. NEW LAKE LITTORAL SEDIMENT QUALITY/BMI STATIONS – STATION IDS AND EXACT LOCATION TO BE DETERMINED IN THE FIELD

~~1.~~2. STATION LOCATIONS PROPOSED BASED ON AVAILABLE SUBSTRATE AND WATER DEPTH DATA, SUBJECT TO CHANGE FOLLOWING IN-SITU FIELD CONFIRMATION OF CONDITIONS.

~~3.6.11~~3.5.7 Study Design and Data Analysis

The purpose of sediment quality monitoring is to answer the same question posed in regard to water quality:

"What is the estimated mine-related change in contaminant concentrations in the exposed area?"

To answer this question, the study has been designed to test the following three hypotheses:

- Null hypothesis: Change over time is the same for exposure and reference stations. Alternate hypothesis: Data from exposure stations is statistically different from data measured at reference stations.
- Null hypothesis: Difference between exposure and reference stations is due to natural environmental variation. Alternate hypothesis: Difference in exposure and reference station is due to mine effects.

- Null hypothesis: Magnitude of concentrations at the exposure station does not exceed the benchmark. Alternate hypothesis: Magnitude of concentrations at the exposure station exceeds the benchmark.

The sediment quality CREMP monitoring program will focus solely on sediment in lakes, since the depositional characteristics found within the lakes is the final sink for natural and P~~p~~roject-related contributions to sediment load.

Environment Canada (2012) recommends a Control-Impact (CI) or Gradient Sample design for detection of effects in the lake environment benthic invertebrate community (Figure 3.8). Stations are generally situated on a gradient type approach within each lake while the analysis is conducted using a CI approach. A gradient sample design has been defined for the CREMP lake sediment stations that is integrated with benthic invertebrate sampling and utilizes several historic sediment sampling locations that meet the cut-off criteria (Section 3.5.2). Within each mine exposed study lake and Reference Lake 3, stations are positioned to allow for the evaluation of any spatial differences in sediment chemistry in order to determine potential gradients in metal concentrations associated with mine sources (i.e. mine-~~-~~exposed tributaries).

~~As mentioned before, ~~Reference ~~3 ~~Lake 3 was established as the reference lake for the CREMP in 2015. Being located outside of the M~~m~~ine A~~a~~rea, Reference Lake 3 is expected to be unaffected by local mineralization to the extent that the ~~m~~Mine S~~s~~ite lakes are. Therefore, a control-impact approach to monitoring change in the M~~m~~ine S~~s~~ite lakes may require use of various statistical approaches to assist with the detection of Project-related changes to sediment quality.

Additionally, a before-after comparison of monitoring data to baseline data will be conducted to detect Project-related changes to sediment quality.

In addition, the gradient design selected for lake sediment quality will allow for an assessment of the spatial extent of mine impacts. Since effluent discharges are fixed and dust deposition can be expected to occur in a gradient, it is expected that concentrations will decrease as the distance from the mine increases. In the absence of appropriate control data, it may be necessary to use the exposure data alone to assess mine effects. Mining effects could be observed in several ways:

- Before-After: concentrations increase over time at a given station
- Gradient effect: concentrations increase with increasing proximity to the mine
- Gradient effect changes over time: concentrations are stable across the gradient during baseline but increase with increasing proximity to the mine after mining commences. That is, concentrations increase over time at stations close to the mine but remain relatively stable at far field stations (i.e., the slope of the gradient effect increases over time).

In addition, because there is a relationship between sediment SOPCs, increases in multiple parameters can be used in a weight of evidence to identify ~~p~~Project-related changes.

~~3.6.12~~3.5.8 Assessment Framework

Monitoring data will be assessed during each year of monitoring and would follow the assessment framework as outlined in Figure 2.12 and described below. The assessment framework for sediment quality monitoring closely mirrors that described for water quality in Section 2.6.8, with minor differences.

~~3.6.12.1~~3.5.8.1 Step 1: Initial Data Analysis

Initial data analysis will involve following specific data management and monitoring protocols in the handling and initial comparison of data.

Data Input and Storage

Following data collection, and upon receipt of the laboratory reports, data will be entered into the Project EQWin® database.

Initial Data Analysis including Outlier Assessment

The initial data analysis will include a number of possible steps, such as the following:

- Completion of summary statistics (average, median, maximum, minimum, quartiles)
- Flagging of sediment samples that do not meet the TOC and % sand cut-off values
- Flagging of values greater than the defined benchmark values
- Flagging of values at or exceeding the mid-point between the baseline mean and the benchmark
- Evaluating temporal changes in the data by season

The initial data analysis will include an outlier assessment after data entry and the completion of quality assurance and quality control steps. An outlier assessment is completed after each round of sampling to ensure data anomalies are identified early. If necessary, the laboratory can be contacted to re-analyze samples. Any identified outliers will be investigated to ensure no data integrity issue exists. For example, duplicate samples will be assessed along with any holding time exceedances. If no evidence exists to discard data, then the data will remain in the dataset but be flagged for future consideration.

~~3.6.12.2~~3.5.8.2 Step 2: Determine if Change is Mine Related

Step 2 involves determining if the changes in sediment quality parameters of concern are due to the Project or due to natural variability or other causes. This question will be addressed using exploratory data analysis (EDA) and subsequently using statistical data analysis (SDA), as described below.

Prior to conducting EDA and SDA, Project activities with the potential to alter sediment quality will be reviewed to identify potential Project-related causes or sources. This could include evaluating effluent quality, discharge regime/rates, and loading, dust deposition, and other point/non-point sources as required. Also, any evidence of potential natural causes (i.e., a major erosional event such as a slumping riverbank) will be investigated. Sampling data sheets and site personnel will be a source of this information.

Exploratory Data Analysis

Exploratory data analysis (EDA) will be completed to visualize overall data trends. This could include evaluating spatial patterns in sediment quality results for M~~m~~ine A~~a~~rea lakes to evaluate if changes are widespread or specific to certain waterbodies, or proximate to mine-related sources, and to identify the spatial extent and pattern of observed changes.

Data from Mine Area lakes will be compared to data from Reference Lake 3. This will further assist with determining whether the observed changes were due to natural variability or the Project.

These graphical analyses will also confirm assumptions required for statistical testing (normality, sample size, independence). Results of the EDA will be used in tandem with the SDA to confirm the observed statistical trends and can be used to evaluate the potential for biologically relevant change.

Statistical Data Analysis

Primary SDA will be completed using methodology consistent with the before-after design used for the power analysis. This will be used to assess the potential magnitude of change during post-mining. This step in the analysis tests the primary hypothesis for the effects of mine-related change and can be applied to the parameters of interest.

If the Step 2 analysis concludes that the changes in sediment quality parameters of concern are, or are likely, due to the Project, the assessment will proceed to Step 3. If it is concluded the observed differences relative to baseline conditions are not due to the Project, no management response will be required.

~~3.6.12.3~~3.5.8.3 Step 3: Determine Action Level

Once EDA and primary SDA has indicated with some certainly that the measured change is P~~p~~roject-related, Step 3 involves determination of the action level associated with the observed monitoring results through comparisons to the benchmark.

If the benchmark is not exceeded, a **low action response** would be undertaken and would include:

- Evaluate temporal trends
- Identify likely source(s) and potential for continued contributions
- Confirm the site-specific relevance of benchmark and establish a site-specific benchmark, if necessary
- Based on evaluations, determine next steps

If the benchmark is exceeded and it is concluded to be due to, or likely due to, the Project, a **moderate action level response** would be undertaken and would include, in addition to analyses identified in for a low action response, the following:

- Consider a weight-of-evidence (WOE) evaluation and/or risk assessment, considering other monitoring results collectively with sediment quality to evaluate effects on the ecosystem
- Evaluate the need for and specifics of increased monitoring
- Evaluate the need for additional monitoring (e.g., confirmation monitoring) and/or modifications to the CREMP
- Consider results of the trend analysis (i.e., trend analysis indicates an upward trend) and evaluation of potential pathways of effect (i.e., causes of observed changes) to determine if management/mitigation is required
- Identify next steps based on the above analyses. Next steps may include those identified for the high action level response.

A quantitative trigger for the **high action level response** has not been identified as the need for additional study and/or mitigation will depend on the ultimate effects of the observed increases in sediment quality parameters of concern on the lakes as a whole, as well as the monitoring results from the freshwater biota CREMP. Also, the benchmark may need to be revised in consideration of ongoing monitoring results. The precise relationships between water quality, sediment quality and lower trophic level changes and the collective effects on fish is difficult to predict and therefore actions undertaken under ~~Level~~ Step 2 will attempt to explore these relationships to advise on overall effects to the ecosystem. Results would be discussed with regulatory agencies and the next steps would be identified. Additional actions that may be implemented in a subsequent phase (i.e., high action level response) include:

- Implementation of increased monitoring to confirm effects and/or define magnitude and spatial extent of effects if warranted
- Implementation of mitigation measures or other management actions that may be identified under the moderate action level response

4 – REFERENCES

Agresti, A, 1990. *Categorical Data Analysis*. Wiley Series, New York.

Baffinland Iron Mines Corporation, 2012. *Mary River Project - Final Environmental Impact Statement.* February.

Baffinland Iron Mines Corporation, 2013a. *Mary River Project - Aquatic Effects Monitoring Program Framework.* February.

Baffinland Iron Mines Corporation, 2013b. *Mary River Project - Updated Aquatic Effects Monitoring Program Framework.* December.

Baffinland Iron Mines Corporation, 2014. *Mary River Project - Aquatic Effects Monitoring Plan.* In-progress.

Canadian Council of Ministers of the Environment, 2002. *Canadian sediment quality guidelines for the protection of aquatic life: Introduction*. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. *Canadian water quality guidelines for the protection of freshwater aquatic life*. Canadian Environmental Quality Guidelines Summary Table on-line, http://st-ts.ccme.ca/. Updated in 2014.

Downing, J.A. and E. McCauley, 1992. The Nitrogen : Phosphorus Relationship in Lakes, in: *Limnol. Oceanogr.* 37(5), pages 936-945. The American Society of Limnology and Oceanography, Inc.

Edwards, D., 1998. Data Quality Control/Quality Assurance, in: *Data and Information Management in the Ecological Sciences: A Resource Guide*. Michener, W.K., Porter, J.H. and Stafford, S.G. (eds.), LTER Network Office, Univ. of New Mexico, Albuquerque, NM, USA.

Environment Canada, 2012. *Metal Mining Technical Guidance for Environmental Effects Monitoring*. Available online at: https://www.ec.gc.ca/esee-eem/AEC7C481-D66F-4B9B-BA08-A5DC960CDE5E/COM-1434---Tec-Guide-for-Metal-Mining-Env-Effects-Monitoring_En_02[1].pdf

Fletcher R., P. Welsh and T. Fletcher, 2008. *Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach.* Queen`s Printer for Ontario. PIBS 6658e. May 2008.

Green, R., 1979. *Sampling Design and Statistical Methods for Environmental Biologists. In 'Proceedings of the 29th Congress of the Australian Society of Limnology, Jabiru, NT, 1990*'. (Ed. R. V. Hyne.) pp. 105-23. (Office of the Supervising Scientist Alligator Rivers Region, Australian Government Publishing Service: Canberra.).

Horowitz, Arthur J., 1991. *A Primer on Sediment-Trace Element Chemistry, 2nd Edition*. United States Geological Survey, Open File Report 91-76.

Indian and Northern Affairs Canada, 2009. *Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the Northwest Territories. Volume 6: Recommended Procedures for Evaluating, Compiling, Analyzing, Interpreting, and Reporting Data and Information Collected under the Aquatic Effects Monitoring Programs*. Available online at:

http://mvlwb.com/sites/default/files/documents/INAC%20-%20AEMP%20Guidelines%20-%20Volume%206%20-%202009.pdf

Indian and Northern Affairs Canada, 2009. *Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in NWT: Overview Report*. Available online at: http://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-NWT/STAGING/texte-text/aemp_1313792165251_eng.pdf

Intrinsik Environmental Sciences Inc., 2014. *Development of Water and Sediment Quality Benchmarks for Application in Aquatic Effects Monitoring at the Mary River Project.* Intrinsik Project No. 30-30300.

Intrinsik Environmental Sciences Inc., 2015. *Establishment of Final Sediment Quality Aquatic Effects Monitoring Program Benchmarks.* Intrinsik Project No. 30-30300.

Knight Piésold Ltd., 2013. *2013 Lake Surface Water and Sediment Quality Sampling Protocol*. North Bay, Ontario. Ref. No. NB102-181/33-2, Rev. A. July 31.

Knight Piésold Ltd., 2012a. *Compendium to Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/30-6, Rev. 0. January 30.

Knight Piésold Ltd., 2012b. Memorandum to Oliver Curran, Baffinland Iron Mines Corporation. Re: *Response to Environment Canada IR EC-23 on Site-Specific Water Quality Objectives*. April 27. North Bay, Ontario. Ref. No. NB12-00183.

Knight Piésold Ltd., 2011. *Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/30-5, Rev. 0. December 22.

Knight Piésold Ltd., 2010a. *Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/25-2, Rev. 0. October 29.

Knight Piésold Ltd., 2010b. *Compendium to Surface Water and Sediment Quality Baseline Report*. North Bay, Ontario. Ref. No. NB102-00181/25-16, Rev. 0. December 31.

Knight Piésold Ltd., 2008. *2007 Baseline Water Quality Summary Report.* Ref. No. NB102-00181/7-5, Rev. A. June 6.

Knight Piésold Ltd., 2007. *2005/2006 Baseline Water Quality Summary Report.* Vancouver, BC. Vancouver, BC. Ref. No. NB102-00181/4-5, Rev. A. March 13.

Minnow Environmental Inc., 2016. *Mary River Project CREMP Recommendations for Future Monitoring*. March 17.

Nunavut Impact Review Board, 2012. *NIRB Project Certificate No. 005*. In the matter of the Nunavut Land Claims Agreement, Nunavut Land Claims Agreement Act, S.C. 1993, c. 29, Article 12, Part 5 and in the matter of an application by Baffinland Iron Mines Corporation for the development of the Mary River Project Proposal in the Qikiqtani Region of Nunavut: NIRB Project Certificate No. 005.

Nunavut Water Board, 2013. Type A Water Licence No. 2AM-MRY1325. Issued on June 12, 2013.

North/South Consultants Inc., 2014. *Baffinland Iron Mines Corporation - Mary River Project - Core Receiving Environment Monitoring Program: Freshwater Biota*. Internal Draft, dated May 2014.

North/South Consultants Inc., 2012. *Baffinland Iron Mines Corporation - Mary River Project - Freshwater Aquatic Biota and Habitat Baseline Synthesis Report 2005-2011*. January 2012.

North/South Consultants Inc., 2010. Technical Memorandum Describing the Results of Monitoring for Effects of Dust Deposition from the Bulk Sampling Program: 2008. August 31, 2010.

North/South Consultants Inc., 2008. *Freshwater Aquatic Environment Baseline Report: Lake Limnology and Lower Trophic Levels: 2007*.

R Development Core Team, 2012. *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Smith, E., 2002. BACI Design. *Encyclopedia of Environmetrtics*. John Wiley and Sons. 1(141-148).

Stewart, K.A. and Lamoureux, S.F., 2011. Seasonal hydrochemical conditions and limnological response in adjacent High Arctic lakes: Cape Bounty, Melville Island, Nunavut. *Arctic* 64: 169-182.

Stroup, W.W., 1999. *Mixed Model Procedures to Assess Power, Precision, and Sample Size in the Design of Experiments*. Department of Biometry, University of Nebraska.

Underwood, A.J., and C.H. Peterson, 1992. Beyond BACI: experimental designs for detecting human environmental impacts in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology*. 161: 145-178.

ATTACHMENT A

WATER AND SEDIMENT QUALITY SAMPLING PROTOCOL

(Pages A-1 to A-24)

Baffinland Iron Mines Corporation

ATTACHMENT A
CREMP WATER AND SEDIMENT QUALITY SAMPLING PROTOCOL

Rev. 3

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
03/28/14	0	KP	KP	Issued in Final
03/31/16	1	AV	JM	Updated to reflect CREMP Study Design modifications proposed by Minnow in 2016
05/01/19	1	AV	CM	Further CREMP Design Revision following 2017 Freshwater Workshop and Phase 2 Proposal

Index of Major Changes/Modifications in Revision 1

Item No.	Description of Change	Relevant Section
1	Included Baffinland's Sampling Program – Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-0001) and discussed Minnow's recommendations for future CREMP monitoring.	1.0
2	Updated Table 2.1 to reflect the bottle types required in the 2015 CREMP field program.	2.2.2
3	Updated sampling handling and shipping protocols to reflect current operations.	2.2.5
4	Updated all lake sampling methodology sections to reflect recommendations proposed by Minnow.	2.3
5	Included modifications recommended by Minnow regarding water quality sampling methodology and protocols.	2.4
6	Discussed Minnow's recommendations to discontinue stream and sampling stations from future CREMP sediment sampling programs. Removed sections discussing stream and river sediment sampling methodology and protocols.	3.1, 3.3
7	Updated list of water and sediment quality analytes/parameters to reflect the parameters analyzed in the 2015 CREMP field program.	Appendix A
8	Replaced Exova COC with an ALS COC example.	Appendix C
9	Added Baffinland's Sampling Program – Quality Assurance and Quality Control Plan (BAF-PH1-830-P16-0001) as Appendix D.	Appendix D

PREFACE

This document was originally written by Knight Piésold Consulting (KP) in March 2014 for Baffinland Iron Mines Corporation (Baffinland). This document had been revised by Baffinland to reflect the recommendations proposed by Minnow Environmental Inc. (Minnow) in 2016 regarding modifications to the CREMP Study Design.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

Appendix A – Surface Water and Sediment Quality Parameter List
Appendix B – Field Record Sheet
Appendix C – Example of Chain of Custody

ABBREVIATIONS

AEMP	Aquatic Environment Monitoring Program
Baffinland	Baffinland Iron Mines Corporation
DO	Dissolved oxygen
EC	Environment Canada
FEIS	Final Environmental Impact Statement
KP	Knight Piésold Ltd
Mary River Project	The Project
NSC	North South Consultants
UTM	Universal Transverse Mercator

1 – INTRODUCTION

This document is intended to provide a detailed description of the water and sediment quality sampling methodologies used under the CREMP and should be used in conjunction with Baffinland's Sampling Program – Quality Assurance and Quality Control Plan (QA/QC Plan; BAF-PH1-830-P16-0001, Rev. 2). Where methodology protocols differ between this document and the QA/QC Plan, methodology protocols outlined in this document will be followed.

CREMP water quality stations are monitored three (3) times per year. Stream water quality will be monitored during the spring (June), summer (July) and fall (August), whereas, lake water quality will take place during the winter (April), summer (July) and fall (August). Lake sediment quality sampling is done concurrently with the water sampling program in the fall (August).

In 2015, Minnow Environmental Inc. (Minnow) was contracted to assist Baffinland in completing the fieldwork and reporting requirements of several of the AEMP component studies, including the CREMP. After completing the CREMP in 2015, Minnow proposed several modifications to the CREMP to provide greater efficiencies and improve the program's ability to achieve its objectives (i.e. to evaluate short and long term effects of the Project on aquatic ecosystems).

The sampling methodologies within this protocol have been revised to reflect Minnow's recommendations and have taken into account comments and feedback received from regulators and stakeholders up until and during the 2017 Freshwater Workshop, chaired by Baffinland in Iqaluit, Nunavut on November 8 & 9, 2017.

In general, this document includes details regarding:

- Sampling and equipment
- Field measurements and observations
- Quality assurance/quality control (QA/QC)
- Sample tracking and shipping

2 – WATER QUALITY

2.1 GENERAL

Stream and lake water quality data for baseline studies and the CREMP have been collected for the Mary River Project (the Project) during every year since 2005, with the exception of 2009 and 2010. The analytical suite of parameters includes nutrients, total and dissolved metals, and major ions. A detailed list of water quality parameters is outlined in Table 2-1 below.

Table 2-1 – CREMP Water Quality Parameters

Water Quality Parameter/Type		
Physical Tests (Water)	**Metals (Total & Dissolved)**	**Metals (Total & Dissolved) cont'd**
Conductivity	Aluminum (Al)	Strontium (Sr)
Hardness (as $CaCO_3$)	Antimony (Sb)	Thallium (Tl)
pH	Arsenic (As)	Tin (Sn)
Total Suspended Solids	Barium (Ba)	Titanium (Ti)
Total Dissolved Solids	Beryllium (Be)	Uranium (U)
Turbidity	Bismuth (Bi)	Vanadium (V)
Anions and Nutrients (Water)	Boron (B)	Zinc (Zn)
Alkalinity, Total (as $CaCO_3$)	Cadmium (Cd)	
Ammonia, Total (as N)	Calcium (Ca)	
Bromide (Br)	Chromium (Cr)	
Chloride (Cl)	Cobalt (Co)	
Nitrate and Nitrite as N	Copper (Cu)	
Nitrate (as N)	Iron (Fe)	
Nitrite (as N)	Lead (Pb)	
Total Kjeldahl Nitrogen	Lithium (Li)	
Total Phosphorus	Magnesium (Mg)	
Sulfate (SO_4)	Manganese (Mn)	
Organic / Inorganic Carbon (Water)	Mercury (Hg)	
Dissolved Organic Carbon	Molybdenum (Mo)	
Total Organic Carbon	Nickel (Ni)	
Aggregate Organics	Potassium (K)	
Phenols (4AAP)	Selenium (Se)	
Plant Pigments	Silicon (Si)	
Chlorophyll a	Silver (Ag)	

Phaeophytin a	Sodium (Na)	

2.2 STREAM WATER SAMPLING METHODOLOGY

2.2.1 Sampling Strategy

Consistent sampling methods have been applied throughout the stream water sampling programs, including the baseline studies completed by KP and recent iterations of the CREMP completed by Minnow and Baffinland. To date, stream water samples have been collected from flowing sections of streams (unless otherwise noted) and obtained by either wading into the stream or by collecting the sample from the bank. No significant changes have been made to the sampling methods and/or procedures for stream water quality programs under CREMP in this revision of the document. The following sub-sections discuss the sampling methods and procedures used by the CREMP for monitoring stream water quality.

2.2.2 Sampling Procedure

Stream water quality will be monitored during three sampling events each year: spring (June), summer (July) and fall (August).

At each stream water quality monitoring station during each sampling event, a new pair of nitrile gloves will be worn by personnel.

The general sampling procedure that will be undertaken at each stream water quality monitoring station during each sampling event is outlined below.

1. Water samples will be collected from flowing sections of the streams (unless otherwise noted) and will be obtained by either wading into the stream or by collecting the sample from the bank.
2. Water samples will be collected for the parameters outlined in Table 2-1, using a typical bottle set as outlined in Table 2-2.
3. Water samples will be collected by facing in an upstream direction, with bottles being placed beneath the surface (when possible) to minimize the amount of floating surface particulates/detritus collected in the sample.
4. Bottles that do not contain preservative (pre-charged by the accredited third party laboratory) will be rinsed three (3) times before being filled. Sample bottles that contain preservative (pre-charged by the accredited third party laboratory) will not be rinsed or immersed in the stream but instead will be filled by transferring stream water from a clean bottle/jug into the bottle containing the preservative. Bottles that do not contain preservative (pre-charged by the accredited third party laboratory) and will be used to collect filtered water samples will be rinsed with filtered water three (3) times before being filled. Upon filling the sample bottles at a given stream water quality monitoring station, any preservatives (e.g. HNO_3) required will be added to appropriate bottles (e.g. HNO_3 for dissolved metals bottle).

Table 2-2 – CREMP Water Quality Sample Bottle Set Summary

Sample Bottle Description	Quantity	Preservative	Analytical Parameter
125 mL HDPE	1	HNO_3	Total Metals/Hardness
125 mL HDPE	1	HNO_3 (after filtering)	Dissolved Metals
120 mL Square Glass	1	HCl	Total Mercury
120 mL Square Glass	1	HCl (after filtering)	Dissolved Mercury
250 mL Round Glass	1	H_2SO_4	Nutrients
1 L Rectangular HDPE	1	None	General Chemistry
1 L Amber Glass	1	None	Chlorophyll-a/Pheophytin-a

5. Prior to the addition of preservative, water samples for dissolved metals will be field filtered using Acrodisc® 32 mm Syringe Filters with 0.45 µm Supor® membrane filter (or a comparable filtration system with a 0.45 µm filter). The syringes and filters are sealed in sterile packaging and should not be rinsed prior to use. The following steps outline the basic filtration technique to be conducted in the field under the CREMP:

   a. Attach the filter to the syringe prior to pulling the plunger out of the syringe.
   Note: Pulling the plunger activates the filter media.

   b. Pull the plunger from the syringe, fill the syringe with sample water and then replace the plunger. Dispense the first 10 mL of water to the ground (not as sample).

   c. Filter the remaining sample directly into the appropriate bottle. Repeat the process until the sample bottle is full.

2.2.3 Repeat the initial two (2) steps if more than one (1) filter is necessary fill the required sample bottle(s).Field Measurements and Observations

At each stream water quality monitoring station during each sampling event, the following field observations and information will be recorded in the field notes.

- Station ID and UTM coordinates
- Date and time for water samples collected.
- The collection of any QA/QC water samples (e.g., duplicates, field blanks, etc.)
- Ambient weather conditions (e.g., wind speed, direction, wave action, current, air temperature)
- Description of the landscape (e.g., hilly, mountains, marsh, etc.)
- Vegetation present
- Stream substrate (e.g., sand, cobble, boulder, bedrock)
- Stream flow description (e.g., strong-turbulent, slow-calm)
- Deviations from the standard operating procedures (e.g. filtration of sample water at the Mine Site ALS Lab for dissolved metals samples instead of in the field)

- The width of the stream at the sampling location (using a range finder if greater than 5 metres or a tape measure if less than 5 metres)

Photos will also be taken upstream, downstream and across the stream water quality monitoring station during each sampling event.

In-situ water quality measurements will be taken during the sample collection process, provided the multi-parameter probe (e.g. YSI 6820, ProDSS or YSI 600Q sonde) can be positioned downstream of the sample collection site. During each sampling event, the following *in-situ* water quality parameters will be recorded in the field notes:

- Water temperature (°C)
- Dissolved oxygen (mg/L and %)
- pH (pH units)
- Conductivity (µS/cm) and/or specific conductance (µS/cm) (both when possible)

Multi-parameter probes (e.g., YSI 6820, ProDSS or YSI 600Q sonde) used in the stream water quality monitoring programs will be calibrated to the specifications outlined in the manufacturer's equipment manuals and protocols.

2.2.4 QA/QC

QA/QC protocols aim to ensure the collection of reliable and accurate data. Using standard methods, as outlined in this document, provides control of sample collection, handling and shipping. Collection of duplicate samples ensures the accredited laboratory results meet defined standards of quality in addition to the internal laboratory QA/QC protocols required for analytical accreditation. QA/QC samples, including duplicates, field blanks, equipment blanks and travel blanks, will, as a total, make up ten (10) percent of the total number of samples collected in a given sampling event (e.g. fall).

2.2.5 Chain of Custody and Sample Shipment

An essential part of QA/QC protocols is maintaining a record of the collected samples and the corresponding list of analytical parameters reported for those samples. A chain of custody (COC) form will be completed digitally and saved on the main Environmental server for all samples collected. The completed COC will be sent electronically to the accredited third party laboratory conducting the analysis. A hard copy of the completed COC will also be sent with the cooler containing the samples.

The current on-site, accredited laboratory is operated by ALS Canada Ltd. and is located at the Mine Site (Mine Site ALS Lab). Periodically, a select set of water quality parameters may be analyzed (i.e. turbidity, TSS, pH) or processed (i.e. filtering of chlorophyll a samples) onsite at the Mine Site ALS Lab to ensure parameters (analytes) are analyzed within the required holding times. The off-site laboratory, ALS Environmental, located in Waterloo, ON and run by ALS Canada Ltd. (Waterloo ALS Lab) performs the majority of analyses required.

Samples will be packaged in coolers with ice packs to ensure the temperature of the samples remain near 4 °C during transportation to the Waterloo ALS Lab.

Samples will be shipped from the Mine Site to the Mirabel airport and then expedited to the Waterloo ALS Lab by courier. All samples shipped from the Mine Site will be considered priority cargo to ensure samples are analyzed within the necessary parameter holding times.

2.3 LAKE WATER SAMPLING METHODOLOGY

2.3.1 Sampling Strategy

Consistent sampling methods have been applied throughout the lake water sampling programs, including the baseline studies completed by KP and recent iterations of the CREMP completed by Minnow and Baffinland. Historically and up until Revision 2 of the AEMP, a top and bottom sampling approach has been undertaken for the monitored lakes under the CREMP, involving the collection of one (1) discrete water sample at 1 metre below water surface/ice and one (1) discrete water sample at 1 metre above the lake bottom at each lake water quality monitoring station.

During the 2015 CREMP field season, Minnow reaffirmed observations made by KP during previous studies (e.g. baseline) that lakes monitored under the CREMP were generally well-mixed and that no consistent spatial differences in water quality/chemistry were evident. As result of this observation, Minnow noted that sampling at two (2) isolated depths at each lake water quality monitoring station under the CREMP was redundant and proposed that future CREMP studies adopt a mid-depth sampling approach where a single water sample would be collected at mid-depth at each lake water quality monitoring station (Minnow Recommendation 9; Minnow, 2016).

In order to implement the mid-depth water sampling approach proposed by Minnow (Minnow Recommendation 9; Minnow, 2016) and, in tandem, ensure significant lake water chemistry gradients in monitored lakes are adequately documented and monitored if present (i.e. weak lake stratification), an in-field lake water sampling framework has been developed to direct the sampling approach and is detailed below. In summary, in cases where thermal lake stratification is determined to be present, a top and bottom water sampling approach will be undertaken. If thermal lake stratification is determined to be absent, a mid-depth water sampling approach will be conducted.

For purposes of the CREMP lake water quality monitoring program, the presence of thermal lake stratification will be defined as when a minimum change of 0.5 °C per metre depth is detected in the water column. This definition for detecting thermal lake stratification and the presence of thermoclines in water bodies is significantly more conservative than the conventional definition accepted by the scientific community of a minimum change of 1 °C per metre depth (Wetzel, 2001). As such, the conservative definition for thermal lake stratification adopted by the CREMP is believed to be sufficient for detecting even weak forms of thermal lake stratification and identifying scenarios where a top and bottom water sampling approach may be warranted.

1. Consistent with Minnow's recommendation (Minnow Recommendation 8; Minnow, 2016), the presence or absence of thermal lake stratification in each lake/basin monitored under the CREMP will be determined by conducting *in-situ* water column profiles at the following water quality monitoring stations:

   a. Camp Lake Station - JL0-07
   b. Sheardown Lake NW Station – DL0-01-2
   c. Sheardown Lake SE Station – DL0-02-3
   d. Mary Lake (North Basin) Station – BL0-01A
   e. Mary Lake (South Basin) Station – BL0-09
   f. Reference Lake 3 (NW Basin) Station – REF03-3

   Stations listed above are located in the deepest portions of each lake/basin and therefore are the optimal locations for determining whether the water column of a lake/basin is well-mixed and uniform or thermally stratified.

2. During each lake water quality sampling event under the CREMP (i.e. winter, summer, fall), stations identified above for each lake/basin will be visited first to determine the appropriate sampling approach for each respective lake/basin.

3. At each of the stations listed above, *in-situ* water column profiles will be conducted by lowering a multi-parameter probe (e.g., YSI 6820, ProDSS or YSI 600Q sonde) at 1 metre increments, starting at 1 metre below the water surface (or bottom of the ice during the winter sampling event) and continuing until 1 metre above the lake bottom. At each one (1) metre increment, the multi-parameter probe will be given time to stabilize prior to recording the water quality data. For each *in-situ* water column profile, data for the following water quality parameters will be recorded in the field notes.

   - Water temperature (°C)
   - Dissolved oxygen (mg/L and %)
   - pH (pH units)
   - Conductivity (µS/cm) and/or specific conductance (µS/cm) (both when possible)

4. Upon completing the i*n-situ* water profile, an in-field review of the profile data will be conducted to determine if thermal lake stratification (a minimum change of 0.5 °C per metre depth) is present. If a thermal lake stratification is determined to present, a top and bottom water sampling approach will be conducted for all water quality stations associated with that lake/basin, with exception water quality stations that have a total depth less than the depth of the determined epilimnion (Figure 2-1). Lake water quality stations that have a total depth less than the depth of the epilimnion will be sampled at mid-depth.

   Example: A change of 0.6 °C is detected between a depth of 10 and 11 metres depth. The depth of the epliminion (top layer) will be considered 9 metres (1 metre above the depth in which change was observed). A top and bottom water sampling approach will be undertaken at water quality stations in that same lake/basin that have a depth greater than 9 metres. A mid-depth water sampling approach will be taken at water quality stations in that same lake/basin that have a depth less than 9 metres.

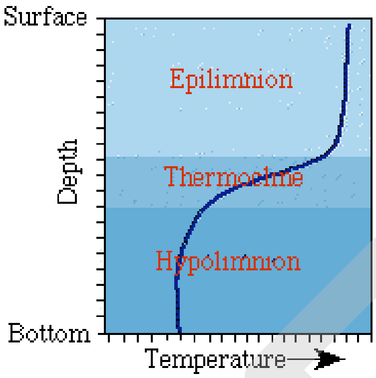


Figure 2-1 – Typical Thermal Lake Stratification

2.3.2 Sampling Procedure

During the winter sampling event, lake water quality monitoring stations will be accessed by snowmobile. Lake water columns will be accessed by drilling holes in the ice using an ice auger.

During the summer and fall sampling events, lake water quality stations will be accessed by small boats. Boats will be anchored at the stations for the duration of the water sampling event and data collection.

At each lake water quality monitoring station during each sampling event, a new pair of nitrile gloves will be worn by personnel.

The general sampling procedure that will be undertaken at each lake water quality monitoring station during each sampling event is outlined below.

1. Upon arriving at a lake/basin, the appropriate water sampling approach (top and bottom or mid-depth) will be determined by following the steps outlined in Section 2.3.1.
2. After the appropriate water sampling approach is determined, the total depth at the lake water quality monitoring station will be measured using a portable fish finder, a weighted measuring tape or the pressure sensor on the multi-parameter probe. Windy conditions during sampling events may result in variable depth measurements, as such, the depth range, the estimated wind speed, and the estimated wind direction will be recorded in the field notes as supplementary information.
3. After determining the total depth at the lake water quality monitoring station, a Kemmerer sampler (refer to Figure 2-2) equipped with a graduated line will be utilized to obtain water samples at the target depths (top and bottom or mid-depth). Prior to taking a water sample at a discrete depth, the Kemmerer sampler will be rinsed one time at the target depth.
4. To collect a water sample with a Kemmerer sampler, the sampler will be set in the open position and lowered to the target depth. Once at the target depth, the messenger weight will be released, sliding down the line and triggering the sampler to close. The Kemmerer sampler will be retrieved and the retained water will be dispensed into the appropriate sample bottles and/or field filter plungers (refer

to Section 2.2.2). Sample bottle sets will be consistent with those used for the stream water quality monitoring programs, outlined in Table 2-2.

5. Sample bottles that contain no preservative will be rinsed three (3) times with sample water before being filled. Sample bottles that contain preservative (pre-charged by the accredited third party laboratory) will not be rinsed before being filled. Some samples (e.g. dissolved metals) will require field filtration. The field filtration process used for the lake water quality monitoring programs will be consistent with the method used in the stream water quality monitoring programs, discussed in detail in Section 2.2.2. Bottles that do not contain preservative (pre-charged by the accredited third party laboratory) and will be used to collect filtered water samples will be rinsed with filtered water three (3) times before being filled.
6. Following the collection of water samples at a given station, the secchi depth for the station and *in-situ* water quality parameters for the depths at which water samples were collected will be recorded as outlined in Section 2.3.3.

Figure 2-2 – A Typical Acrylic Kemmerer Sampler

2.3.3 Field Measurements and Observations

At each lake water quality monitoring station, the following field observations and information will be recorded in the field notes.

- Station ID and UTM coordinates
- Sampling approach, including how many water samples were collected and at which depths

- Date and time for samples collected.
- The collection of any QA/QC samples (e.g., duplicates, field blanks, etc.)
- Ambient weather conditions (e.g., wind speed, direction, wave action, current, air temperature)
- General site description and observations (e.g. depth of water, depth of ice, etc.)
- Deviations from the standard operating procedures (e.g. filtration of sample water at the Mine Site ALS Lab for dissolved metals samples instead of in the field)

Following the collection of water samples at a given lake water quality monitoring station, *in-situ* water quality parameters, using a calibrated multi-parameter probe, will be measured and recorded for the depths at which water samples were collected. Data for the following *in-situ* water quality parameters will be recorded in the field notes:

- ○ Water temperature (°C)
- ○ Dissolved oxygen (mg/L and %)
- ○ pH (pH units)
- ○ Conductivity (µS/cm) and/or specific conductance (µS/cm) (both when possible)

Multi-parameter probes (e.g., YSI 6820, ProDSS or YSI 600Q sonde) used in the lake water quality monitoring programs will be calibrated to the specifications outlined in the manufacturer's equipment manuals and protocols.

Following the collection of *in-situ* water quality data at a given lake water quality monitoring station, the station's secchi depth will be measured and recorded during the summer and fall sampling events. Secchi depths will be determined by attaching a graduated line to the secchi disk and lowering the disk over the shaded side of the boat. To determine a station's secchi depth, two (2) depths will be recorded: the depth at which the disk disappears while lowering the disk and the depth at which it reappears while raising the disk. The secchi depth will be calculated from the average of these two (2) depths and recorded in the field notes.

2.3.4 QA/QC

Consistent with the stream water quality sampling programs under the CREMP, QA/QC samples, including duplicates, field blanks, equipment blanks and travel blanks, will, as a total, make up ten (10) percent of the total number of samples collected in a given sampling event (e.g. fall).

2.3.5 Chain of Custody and Sample Shipment

Information regarding COCs and sample shipping methods are discussed in Section 2.2.5.

3 – SEDIMENT QUALITY

3.1 GENERAL

Stream sediment quality data has been collected for the Project every year since 2005, with the exception of 2009 and 2010. Lake sediment quality data has been collected for the Project every year since 2006, with the exception of 2009 and 2010. Parameters analysed included nutrients, metals, major ions and particle size. A detailed list of current parameters is provided below in Table 3-1.

Sediment Quality Parameter/Type		
Physical Tests	**Metals cont'd**	**Metals cont'd**
% Moisture	Bismuth (Bi)	Potassium (K)
Particle Size	Boron (B)	Phosphorus (P)
% Sand (2.0mm - 0.05mm)	Cadmium (Cd)	Selenium (Se)
% Silt (0.05mm - 2um)	Calcium (Ca)	Silver (Ag)
% Clay (<2um)	Chromium (Cr)	Sodium (Na)
Texture	Cobalt (Co)	Strontium (Sr)
Organic / Inorganic Carbon	Copper (Cu)	Sulfur (S)
Fraction Organic Carbon	Iron (Fe)	Thallium (Tl)
Total Organic Carbon	Lead (Pb)	Tin (Sn)
Metals (Total)	Lithium (Li)	Titanium (Ti)
Aluminum (Al)	Magnesium (Mg)	Uranium (U)
Antimony (Sb)	Manganese (Mn)	Vanadium (V)
Arsenic (As)	Mercury (Hg)	Zinc (Zn)
Barium (Ba)	Molybdenum (Mo)	Zirconium (Zr)
Beryllium (Be)	Nickel (Ni)	

Sediment quality monitoring is typically conducted as part of the benthic macroinvertebrate (BMI) community surveys for mining projects. These sampling programs typically focus on total organic carbon content, metals and particle size distribution (EC, 2012). The purpose of sediment monitoring is to identify any changes in sediment quality from baseline data that may be attributed to mine operations and that may pose a risk to BMI communities. As such, sediment samples will be continued to be collected concurrently with BMI samples.

Following the 2015 CREMP field program, Minnow recommended that stream sediment sampling be discontinued in future CREMP studies due to the very limited amount of depositional habitat suitable for the collection of sediment in the streams and rivers located in the Mary River Project local study area (Minnow Recommendation 10; Minnow, 2016). As observed during the baseline studies and the 2015 CREMP field program, the general absence of any substantial accumulation of fine sediments within the studied watercourses preclude any meaningful assessment of potential mine-related influences on sediment quality within, along and/or between watercourses. Because of this, historic sediment sampling sites within streams and rivers have been removed from the CREMP and will not be continued in future studies.

3.2 LAKE SEDIMENT SAMPLING METHODOLOGY

3.2.1 Sampling Strategy

Historically, lake sediment samples have been collected using various methods at the Project. Sediment sampling conducted prior to 2012 utilized a Petite Ponar grab sampler (231 cm^2) or an Ekman dredge sampler (523 cm^2) with the sediment fraction collected for analysis being limited to the top five (5) centimetres (cm).

During review of the FEIS (Baffinland, 2012), Baffinland agreed to a recommendation made by Environment and Climate Change Canada (ECCC) that involved changing the sediment sampling approach to a method that utilized a sediment core sampler in order to collect only the uppermost one (1) to two (2) centimetres of lake sediment. The rationale for this approach was that most infaunal organisms and the most recently introduced sediment (including contaminants of concern) would be expected to be found in the upper two (2) cm of lake sediment. Arctic lakes experience low sedimentation rates and, therefore, collection of a thinner sample using a sediment core sampler provides better resolution of changes in sediment quality.

Starting in 2012, collection of thinner (1 cm to 2 cm) lake sediment samples was implemented by Baffinland and will be continued in future studies under the CREMP. The following subsections provide additional detail on the sampling methodology and protocols adopted by the CREMP for the annual lake sediment quality sampling program.

3.2.2 Sampling Procedure

Lake sediment quality monitoring stations under the CRMEP will be sampled once a year in the fall (August), during the same period as the fall lake water quality sampling event and annual lake BMI surveys. Lake sediment quality monitoring stations will be accessed by small boats. Boats will be anchored at the stations for the duration of the sampling event and data collection.

The general sampling procedure that will be undertaken at each lake sediment quality monitoring station is outlined below.

1. Upon arriving at a lake sediment quality monitoring station, a clear polycarbonate core tube will be loaded into sediment gravity core sampler (refer to Figure 3-1) and secured using a set of stainless steel hose clamps
2. The core sampler, attached to a line (e.g. rope), will be positioned perpendicular to the water surface and released. The penetration depth of the core tube will be affected by the depth of water, the angle of corer deployment and substrate type.
3. Once the core sampler is embedded in the substrate, the stainless steel messenger will be sent down the core sampler’s attached line to release the ball-type seal.
   Note: The seal creates a vacuum in the core tube, retaining the sampled sediment.
4. Upon the activation of the ball-type seal, the core sampler will be retrieved vertically and at a constant speed to the surface.

5. Upon retrieval, the bottom of the core tube will be plugged using an extruding plug prior to breaking the water surface in order to prevent sample loss.
6. Following placement of the core tube plugs, the hose clamps on the corer will be loosened to release the tube.
7. The visual characteristics of the core sample will be recorded in the field notes (e.g., colour, apparent horizons, evidence of redox reactions, aquatic vegetation, etc.).
8. Prior to decanting, the overlying water within the tube will be described in the field notes (e.g., clarity). The decanting process should be undertaken carefully to ensure that no sediment sample is lost in the process.
9. After decanting the overlying water, a suitable extruding apparatus, such as a PVC tube cut longer than core tube and with a slightly smaller outside diameter, will be used to force the extruding plug and sediment through the tube. Care will be taken not to extrude the sediment at this stage in the process, since the first two (2) cm are the target sample for analysis.
10. The top two (2) centimeters of sediment will be scooped out using a clean stainless steel spoon and placed in a clean stainless steel bowl for homogenization.
11. After the top two (2) cm are retained, the remaining, unused sediments within the core tube will be placed into a bucket and only discarded once sampling is complete at that particular station.
12. The core tube will be rinsed at surface and reloaded into the sampler in preparation for the next sample.
13. A minimum of three core samples will be required per lake sediment quality monitoring station.
14. Samples within a station will be close to one another, but far enough apart to ensure that sampling disturbance from one (1) core does not affect another. Sampling from both sides of the boat and around the bow typically provides suitable spatial distribution within the station.
15. Once a sufficient amount of sediment has been collected within the stainless steel bowl, the sample will be homogenized. Prior to homogenization, excess water will be decanted once the water has settled (to prevent loss of fines) and any large inorganic material (e.g., cobble) or debris will be removed.
16. Sediment within the stainless steel will be thoroughly mixed using a newly gloved hand or stainless steel spoon until the sample has a homogeneous appearance.
17. Sediment sample containers will be filled with the homogenized sediment by alternating aliquots between each of the containers. Once the containers are full, each sample will be transferred to an ice-packed cooler. Samples will be kept cool and in the dark until they can be shipped to the Waterloo ALS Lab.

3.2.3 Field Measurements and Observations

At each lake sediment quality monitoring station, the following information will be recorded during the collection of sediment samples.

- Site ID and UTM coordinates, including the location of any duplicate samples collected
- Sampling date and time of samples collected
- The collection of any duplicate samples
- Ambient weather conditions (e.g., wind speed, direction, wave action, current, air temperature)
- Sediment collection device
- General site description and observations
- Sample properties (e.g., colour, texture, consistency, odour, presence of biota, estimate of quantity of recovered sediment)
- Overlying water properties (e.g. clarity)
- Deviations from the standard operating procedures

Following the collection of sediment samples at a given lake sediment quality monitoring station, *in-situ* water quality parameters, using a calibrated multi-parameter probe, will be measured near the water–sediment interface (within 1 metre of the lake bottom). Data for the following *in-situ* water quality parameters will be recorded in the field notes:

    - Water temperature (°C)
    - Dissolved oxygen (mg/L and %)
    - pH (pH units)
    - Conductivity (µS/cm) and/or specific conductance (µS/cm) (both when possible)

Multi-parameter probes (e.g., YSI 6820, ProDSS or YSI 600Q sonde) used in the sediment quality water quality monitoring programs will be calibrated to the specifications outlined in the manufacturer's equipment manuals and protocols.

3.2.4 QA/QC

All sampling equipment will be thoroughly cleaned between sampling stations and rinsed with ambient water prior to sampling. Duplicate samples will, as a total, make up ten (10) percent of the total number of samples collected in a given year.

4 – REFERENCES

Baffinland Iron Mines Corporation (Baffinland), 2012. *Mary River Project - Final Environmental Impact Statement*. February, 2012.

Environment Canada (EC), 2012. *Environmental Effects Monitoring Technical Guidance Document*. National Environmental Effects Monitoring Office. 2012.

Minnow Environmental Inc. (Minnow), 2016. *Mary River Project CREMP Recommendations for Future Monitoring*. Issued March 17, 2016.

Wetzel, Robert G., 2001. *Limnology – Lake and River Ecosystems. Academic Press*. 2001.

ATTACHMENT B

DETAILED REVIEW OF BASELINE LAKE WATER QUALITY

(Pages B-1 to B-98)

ATTACHMENT B

DETAILED REVIEW OF BASELINE LAKE WATER QUALITY

(Pages B-1 to B-98)

ISO 9001 - FS 64925
ISO 14001 - EMS 550121
OHSAS 18001 - OHS 550122

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DETAILED REVIEW OF BASELINE LAKE WATER QUALITY
NB102-181/33-1B

Rev	Description	Date
1	Issued in Final	May 30, 2014

Knight Piésold Ltd.
1650 Main Street West
North Bay,Ontario Canada P1B8G5
Telephone: (705) 476-2165
Facsimile: (705) 474-8095
www.knightpiesold.com

Knight Piésold
CONSULTING

TABLE OF CONTENTS

PAGE

TABLES

FIGURES

B – LAKE WATER QUALITY REVIEW

B.1 OVERVIEW

A detailed review of lake water quality within the mine site area was undertaken to facilitate the development of the Core Receiving Environment Monitoring Program (CREMP) for water and sediment quality. As stated in Section 1.2 of the main report, the objectives of the baseline review were as follows:

- Identify data quality issues
- Determine whether or not mineral exploration and bulk sampling activities conducted since 2004 have affected water quality in the mine site area
- Understand the seasonal, depth (for lakes) and inter-annual variability of water quality
- Understand natural enrichment of the mine site area waters
- Determine the potential to pool data from multiple sample stations to increase the statistical power of the baseline water quality dataset
- Develop study designs for monitoring water quality in mine site streams and lakes
- Determine if changes to the existing water quality monitoring program are required to meet monitoring objectives

The focus of this review of lake water quality is the mine site area lakes: Camp Lake, Sheardown Lake NW, Sheardown Lake SE and Mary Lake.

Parameters of interest in the baseline review included water quality stressors of potential concern (SOPCs) identified on the basis of the existence of an established water quality guideline, as well as other factors such as Exposure Toxicity Modifying Factors (ETMF): pH, water hardness, dissolved organic carbon, etc., and indicator parameters (alkalinity, chloride, nitrate). Baseline water quality data was compared to Canadian Council of Ministers of the Environment (CCME) – Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-PAL). The focus was on total concentrations (versus dissolved) since CWQG-PAL guidelines are developed for total concentrations. The parameters of interest are displayed graphically in box plots. The box plots are used to portray natural ranges of selected parameters. Concentration data measured for the parameters of interest has been log transformed and further analyzed to investigate the possibility of aggregating data, bearing in mind:

- Seasonal variability (between summer, fall and winter samples)
- Inter-annual variability (from 2006 through 2008 and 2011 through 2013)

To assist in the development of study designs, parameter and station-specific a priori power analyses were completed in order to determine the power of the proposed sampling program to detect statistical changes. As per the Assessment Approach and Response Framework in the CREMP (see Figure 2.12 in the main report), management action is triggered if the mean concentrations of any parameter at selected stations reach benchmark values. Benchmark values were developed for the identified SOPCs that consider aquatic toxicology, natural enrichment in the Project area, or low concentrations below MDLs (Intrinsik, 2014; see Section 2.7.3 of the main report). Draft benchmarks were applied in the power analysis of the baseline presented in this detailed review.

The resultant study design for the monitoring of Project-related effects to water quality is presented in Section 2.7 of the main report.

B.2 BASELINE SUMMARY

B.2.1 Camp Lake

A total of 51 lake samples were collected over the baseline sampling period. Most sampling was completed during July and August. Late winter sampling (May) was carried out in 2007, 2008 and 2013. Three stations were monitored (Figures B.1 and B.2):

- JL0-01-S and JL0-01-D - Shallow and deep; centre and deepest part of the lake
- JL0-02-S and JL0-02-D - Near two main tributaries likely to be influenced by the Project
- JL0-09-S and JL0-09-D - Near the outlet of Camp Lake

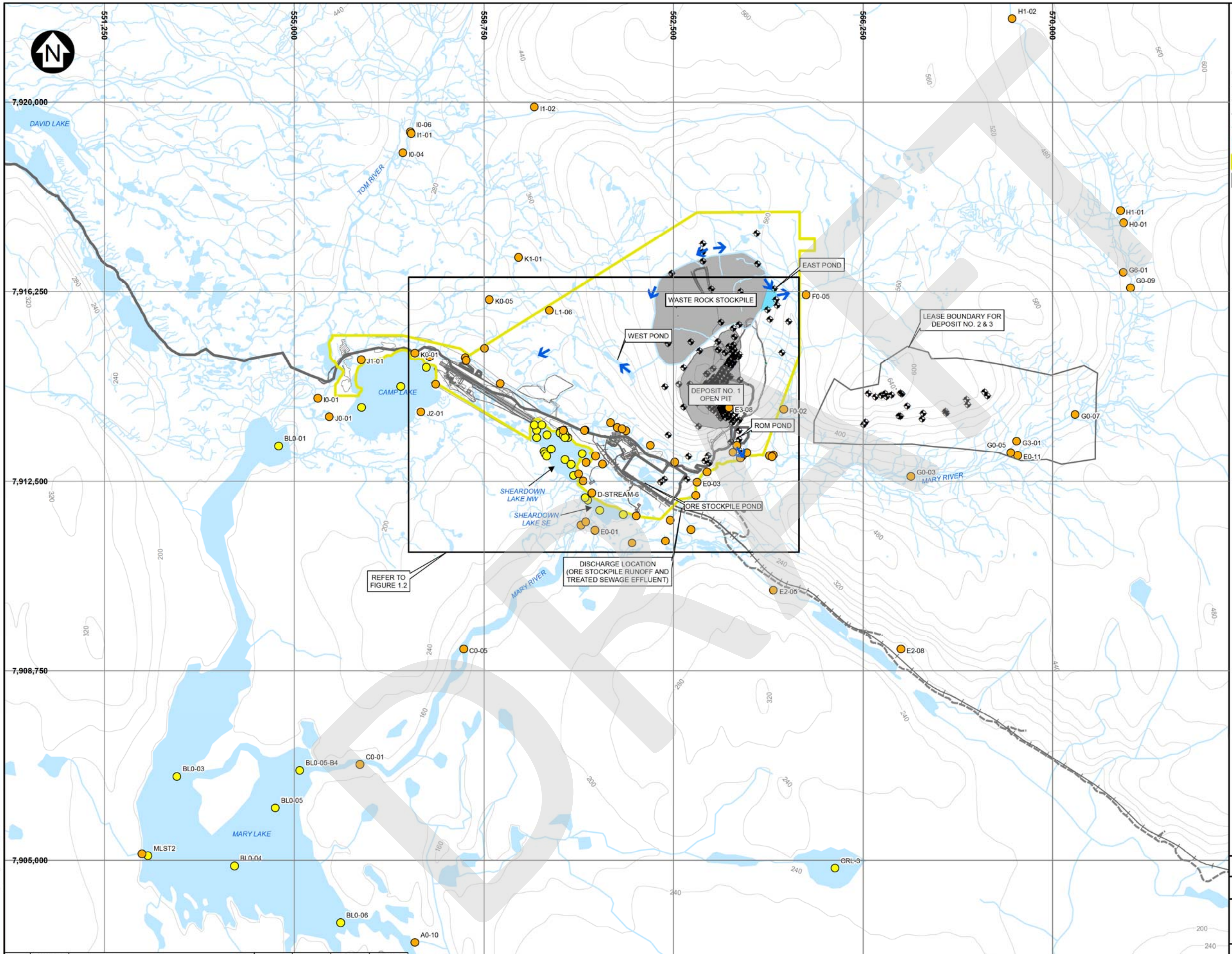
A summary of the data collected during each season are included in Table B.1. A graphical representation of the sampling events is provided in Figure B.3.

Table B.1 Camp Lake Sample Size

Year	Summer	Fall	Winter
2006	2	2	0
2007	6	6	6
2008	6	0	2
2011	4	0	0
2012	0	6	0
2013	5	6	2
Site	**Summer**	**Fall**	**Winter**
JL0-01-S	4	3	1
JL0-01-D	5	4	3
JL0-02-S	3	3	1
JL0-02-D	4	4	1
JL0-09-S	4	3	3
JL0-09-D	3	3	1

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30.
2. LAKE SAMPLING DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE.
3. NO SAMPLING OCCURRED DURING 2009 AND 2010.



LEGEND:
- ● LAKE SAMPLE LOCATION
- ● STREAM SAMPLE LOCATION
- ◆ DRILLHOLE LOCATION
- ━ EXISTING TOTE ROAD
- ┼ PROPOSED RAILWAY ALIGNMENT
- ╌ PROPOSED CONSTRUCTION ACCESS ROAD
- ─ PROPOSED SITE INFRASTRUCTURE
- ─ RIVER/STREAM/DRAINAGE
- ■ WATER
- ☐ POTENTIAL DEVELOPMENT AREA (PDA)
- ■ PROPOSED MINE INFRASTRUCTURE

NOTES:
1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 1 0.5 0 1 2 3 4 km

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM

SAVED: I:\1\02\00181\33\A\GIS\Figs\B40_r1.mxd; May 30, 2014 1:11 PM; skozmick

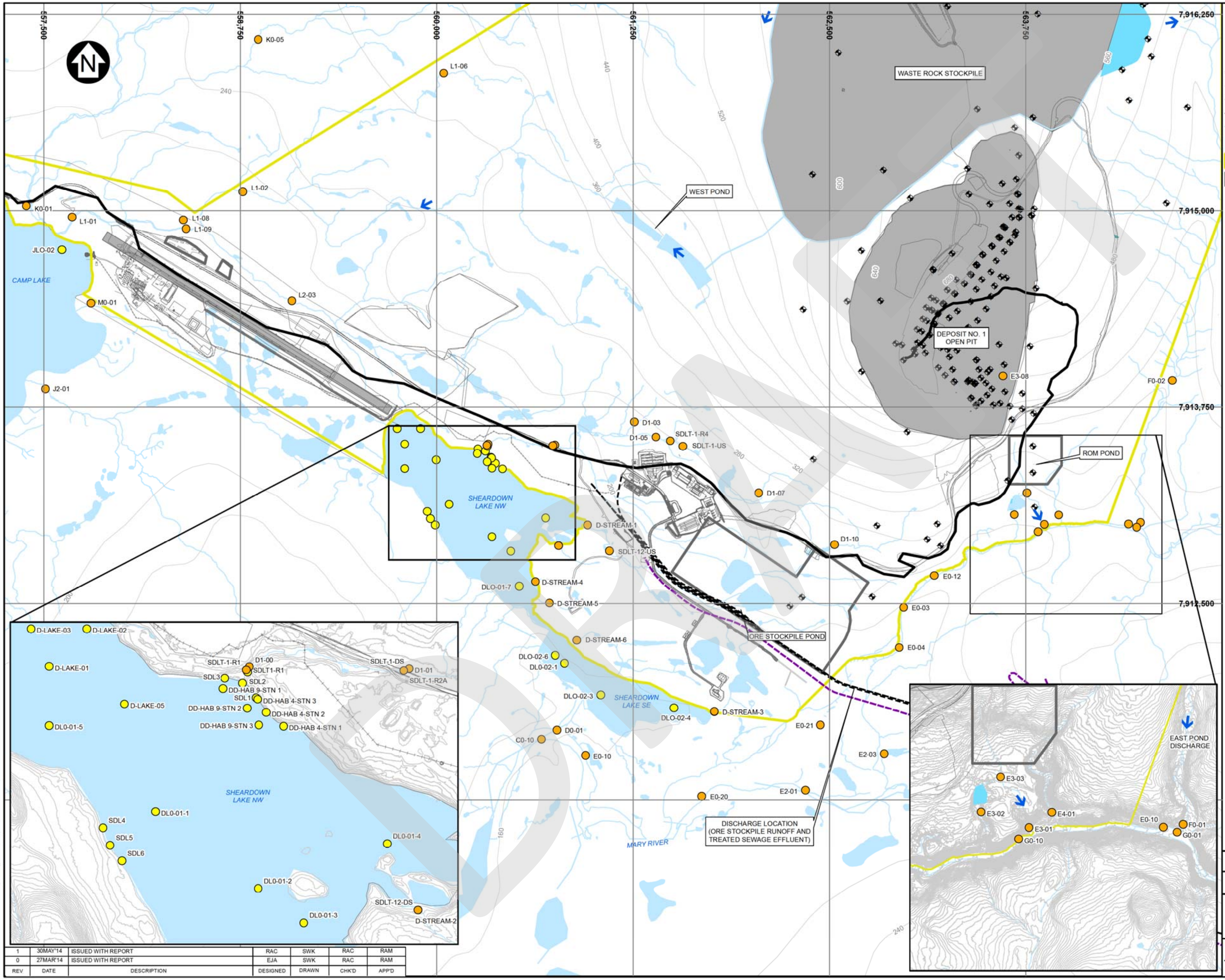
BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

HISTORIC WATER QUALITY STATIONS
MINE SITE AREA

Knight Piésold
CONSULTING

P/A NO. NB102-181/33
REF NO. 1
FIGURE B.1
REV 1



1	30MAY'14	ISSUED WITH REPORT	RAC	SWK	RAC	RAM
0	27MAR'14	ISSUED WITH REPORT	EJA	SWK	RAC	RAM
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

SAVED: I:\1\02\00181\33\A\GIS\Figs\B41_r1.mxd; May 30, 2014 1:19 PM; skozmick

LEGEND:

- 🟡 LAKE SAMPLE LOCATION
- 🟠 STREAM SAMPLE LOCATION
- ◆ DRILLHOLE LOCATION
- ▬ EXISTING TOTE ROAD
- ─┼─ PROPOSED RAILWAY ALIGNMENT
- ‑ ‑ ‑ PROPOSED CONSTRUCTION ACCESS ROAD
- ── PROPOSED SITE INFRASTRUCTURE
- ── RIVER/STREAM/DRAINAGE
- 🟦 WATER
- 🟨 POTENTIAL DEVELOPMENT AREA (PDA)
- ⬛ PROPOSED MINE INFRASTRUCTURE

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. LAKE SAMPLE LOCATIONS VARY SLIGHTLY DURING WINTER MONTHS DUE TO ICE CONDITIONS.
5. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.

SCALE 250 125 0 250 500 750 1,000 1,250 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

**HISTORIC WATER QUALITY STATIONS
IMMEDIATE MINE SITE AREA**

Knight Piésold
CONSULTING

P/A NO.	REF NO.	
NB102-181/33	1	
FIGURE B.2		REV 1

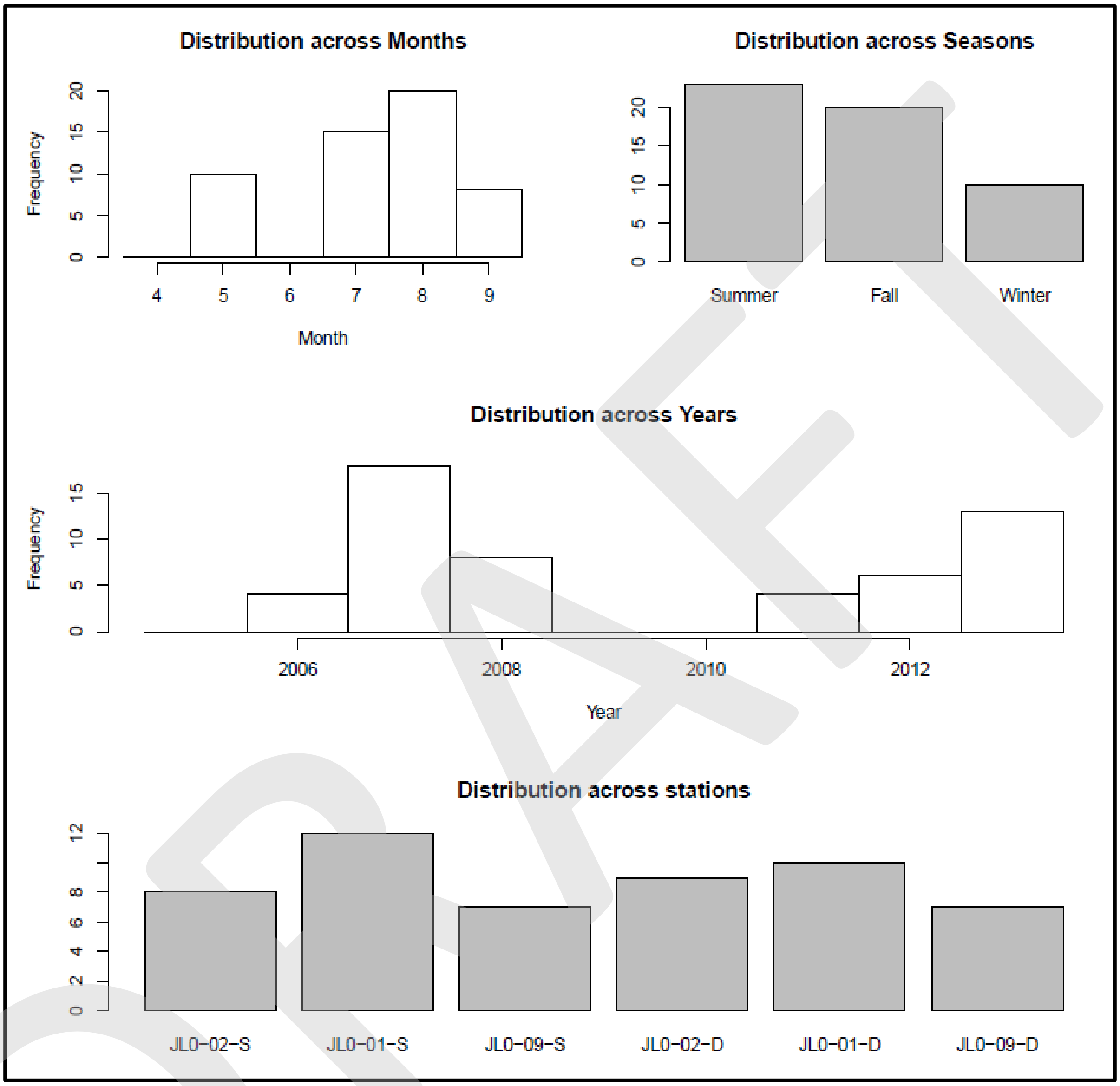


Figure B.3 Camp Lake - Graphical Summary of Sampling Events

The following summarizes the data review observations for the of the physical parameter data depicted in Figures B.4 and B.5.

pH (Figure B.4)

- Camp Lake is slightly alkaline, with total median pH of ~8.
- Measured median *In situ* pH at the deep stations (~7.6) was slightly lower compared to shallow samples (> 7.8).
- The lowest pH value was measured at the deep sample site JL0-01-D, located near the deepest portion of the lake.

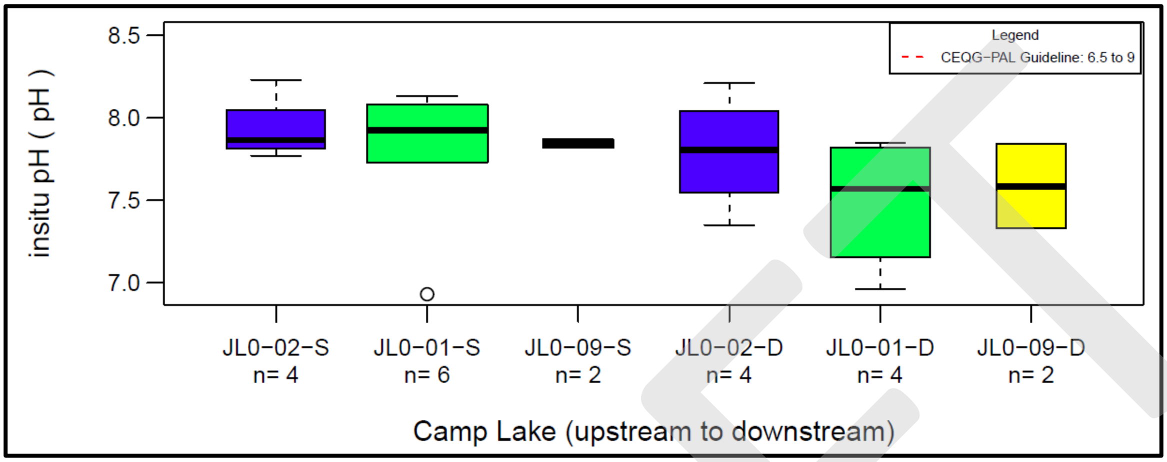


Figure B.4 **Camp Lake – pH**

Hardness (Figure B.5)

- Median hardness at stations within Camp Lake ranged from ~56 and 62 mg/L, classifying the lake water as "soft". One station, JL0-02-D had a median hardness concentration that classifies the lake water as "medium hardness".
- Hardness did not change meaningfully with depth, and portrayed trends very similar to alkalinity.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

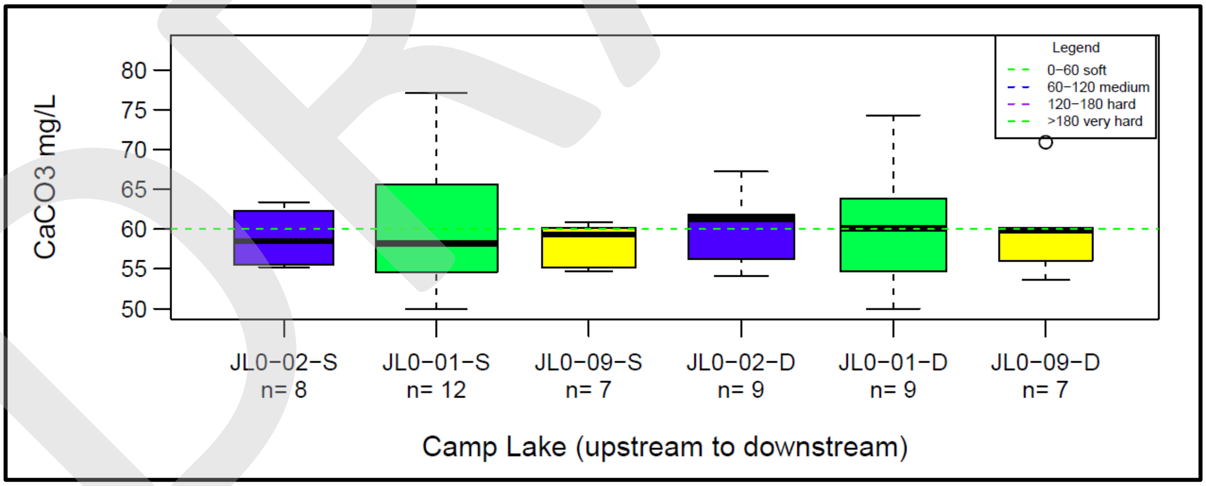
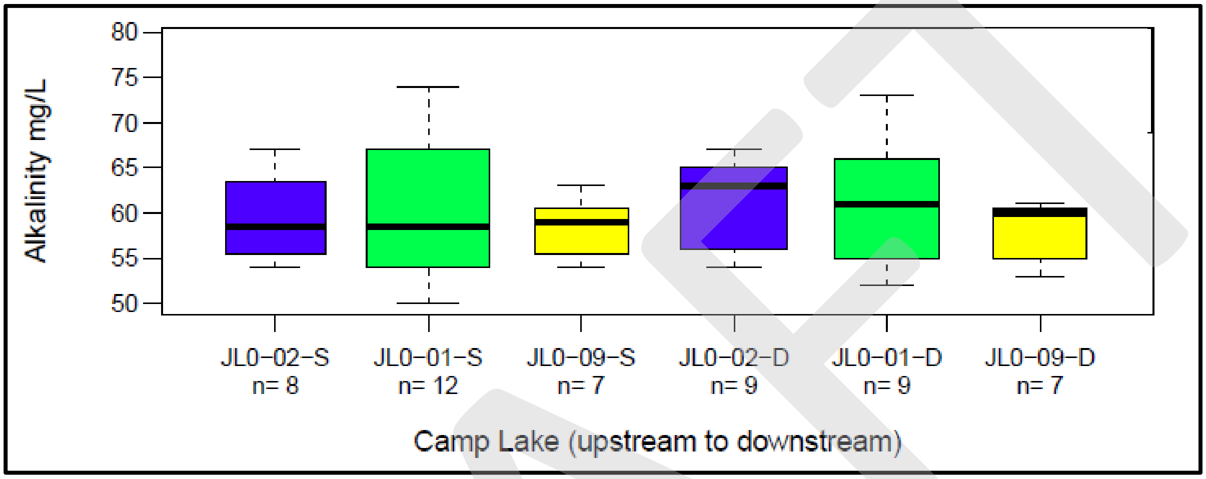


Figure B.5 **Camp Lake – Hardness**

Alkalinity (Figure B.6)

- Camp Lake sites have uniformly high median alkalinity values that range from 58 to 65 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.
- Discrete sites, regardless of depth, show similar measured alkalinity.



NOTES:

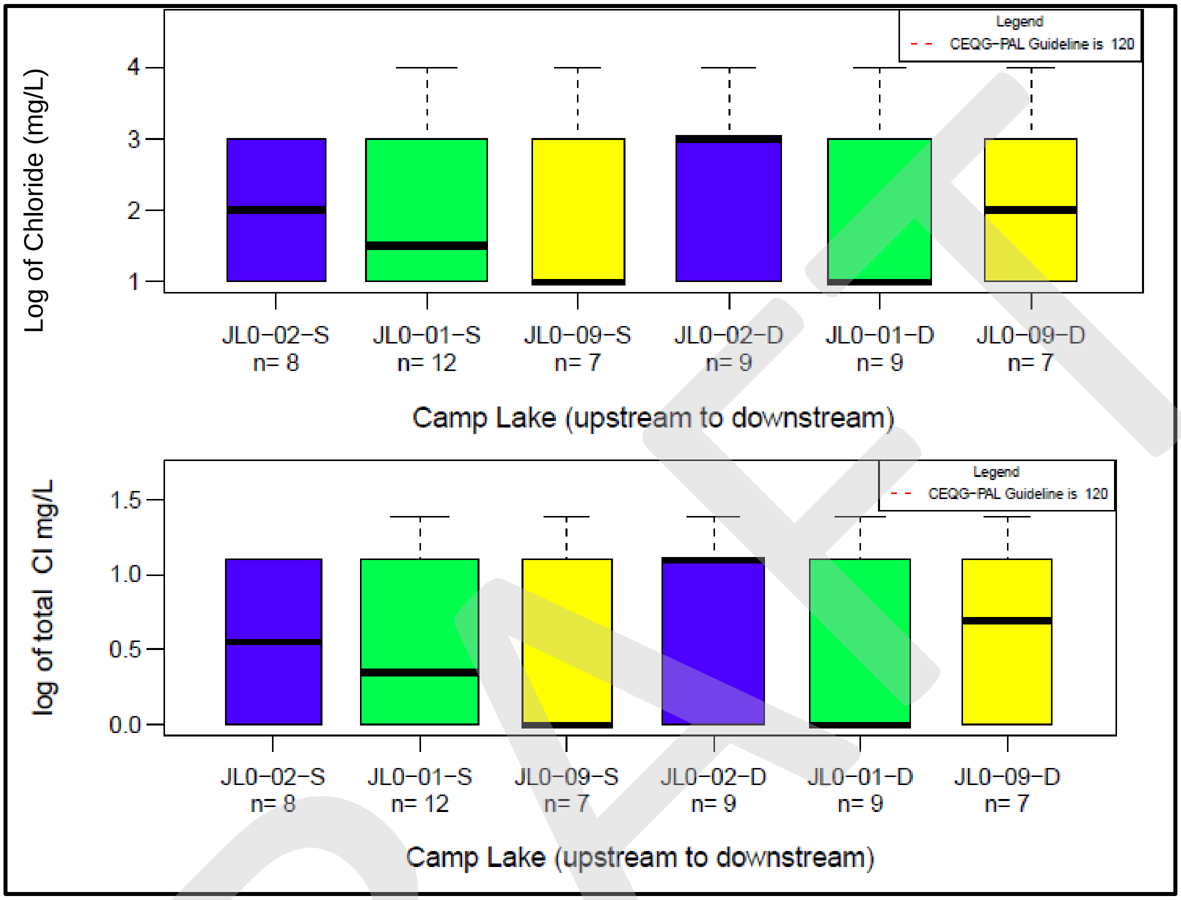
1. ALKALINITY VALUES BELOW 10 mg/L ARE HIGHLY SENSITIVE TO ACIDIC INPUTS; ALKALINITY VALUES BETWEEN 10 – 20 mg/L ARE MODERATELY SENSITIVE TO ACIDIC INPUTS AND ALKALINITY VALUES ABOVE 20 mg/L HAVE LOW SENSITIVITY TO ACIDIC INPUTS.

Figure B.6 Camp Lake – Alkalinity

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.7 and B.8)

The total sample size for chloride concentration samples collected ranges from seven to twelve, depending on the geographically distinct sampling site. Chloride concentrations are very low and range from maximum values of 4 mg/L to detection limit values of 1 mg/L (Figure B.7). These concentrations are far below the CWQG limit of 120 mg/L. All sites within Camp Lake have median values that range from 1 mg/L to 3 mg/L. No clear trends with respect to sample location are noted (Figure B.7). Raw data and log transformed data have identical distributions and therefore, chloride distributions remain unaffected by the lognormal data transformation.

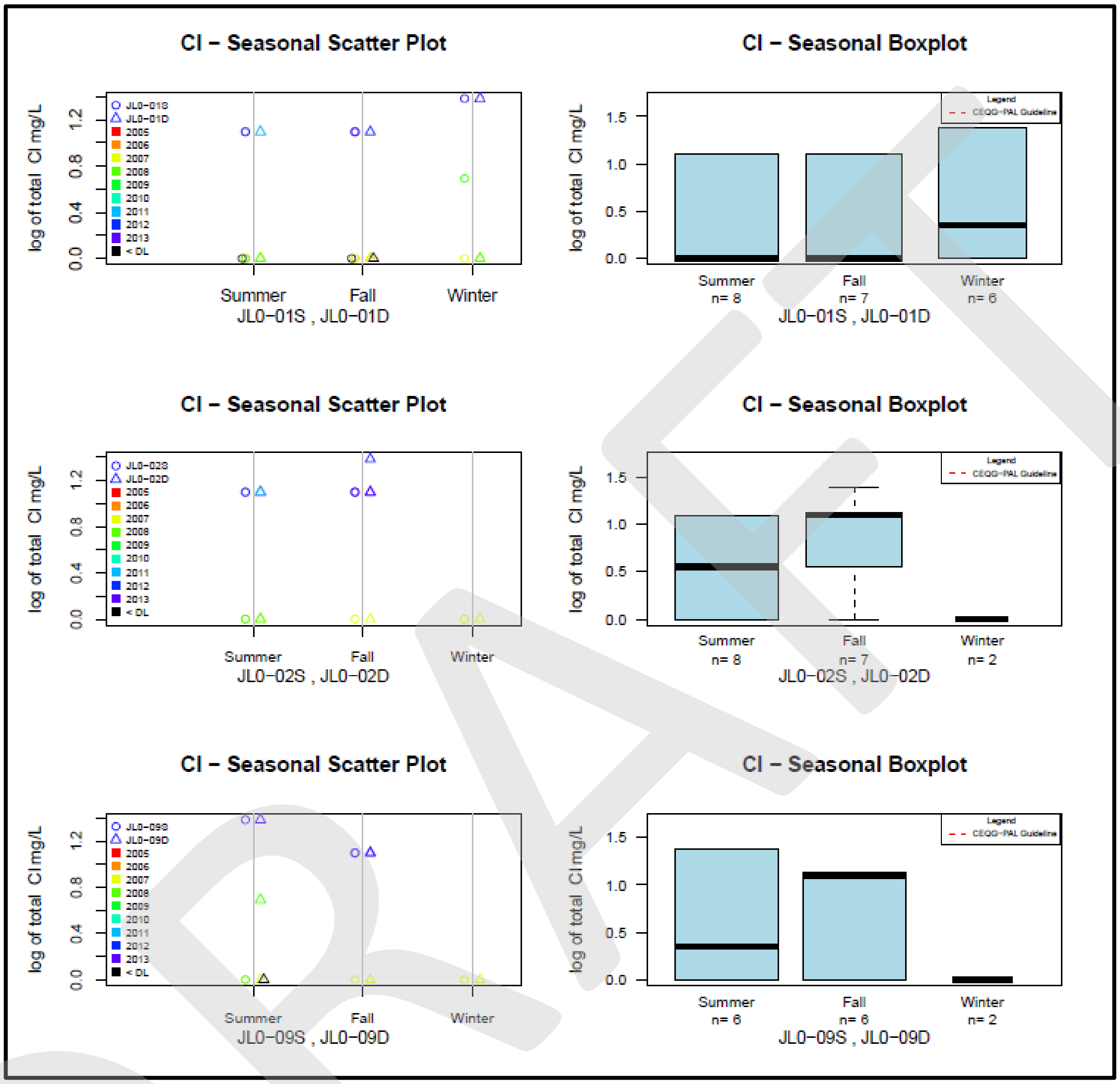


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.7 Camp Lake – Chloride Concentrations in Water

Seasonal scatterplots and boxplots (Figure B.8) show that deep and shallow samples taken during the same year often had similar concentration values, which does not support the assumption that chloride concentration changes with depth.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.8 Camp Lake – Variability of Chloride in Water

The absence of greater chloride concentrations at deep sites may be explained by the very low chloride concentrations or the lack of winter under ice samples, and does not necessarily indicate the absence of stratification. The seasonal scatterplots indicate that 2011 through 2013 chloride concentrations are elevated compared to 2005 to 2010 concentrations. No distinct seasonal trends are noted.

Nitrate

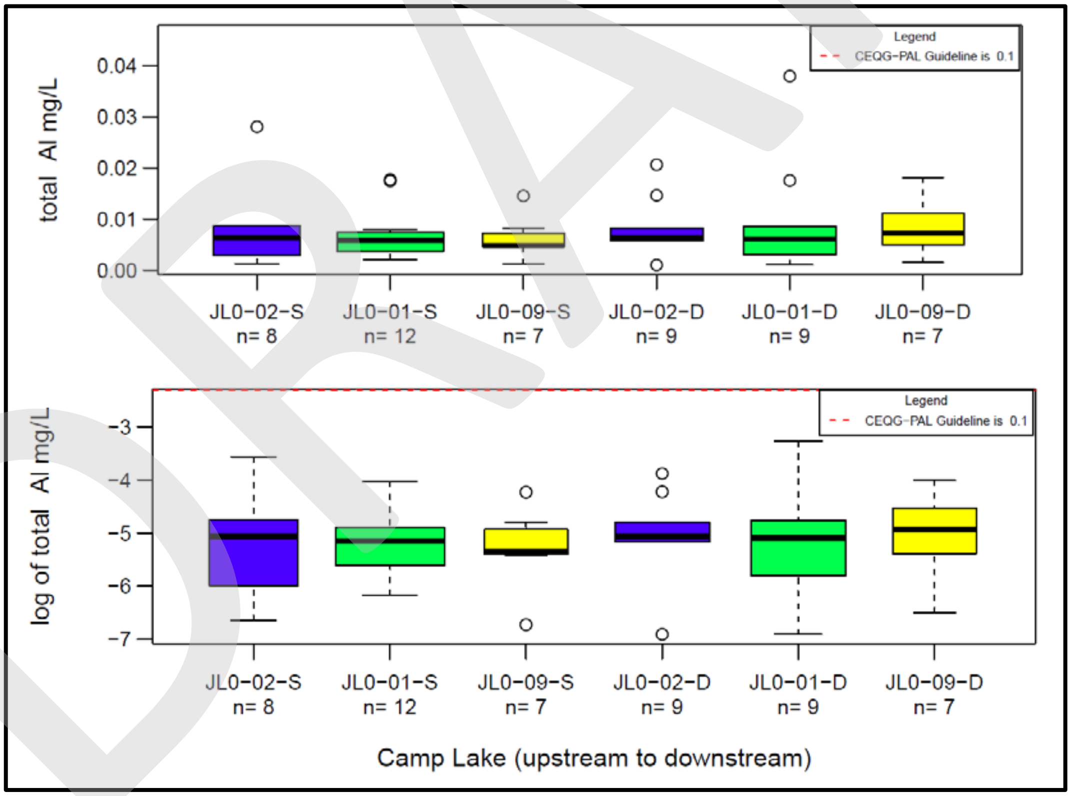
Fifty-two (52) nitrate concentration samples were collected at Camp Lake. All samples collected were at detection limit (0.10 mg/L) and occur well below the CWQG-PAL guideline (3 mg/L). Due to detection limit interference, no depth, seasonal or inter-annual variability is discernable and graphical depiction is not warranted.

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. Total metals concentrations for the parameters of interest have been presented on the basis that applicable guidelines are focused on total metals.

Total Aluminum (Figures B.9 and B.10)

Total aluminum values are uniformly above detection limits, but below the CWQG-PAL guideline across all sites in Camp Lake. Similar to nitrate and chloride, seasonal scatterplots and boxplots for aluminum show concentrations measured at deep and shallow samples taken during the same year have similar values (Figures B.9 and B.10).

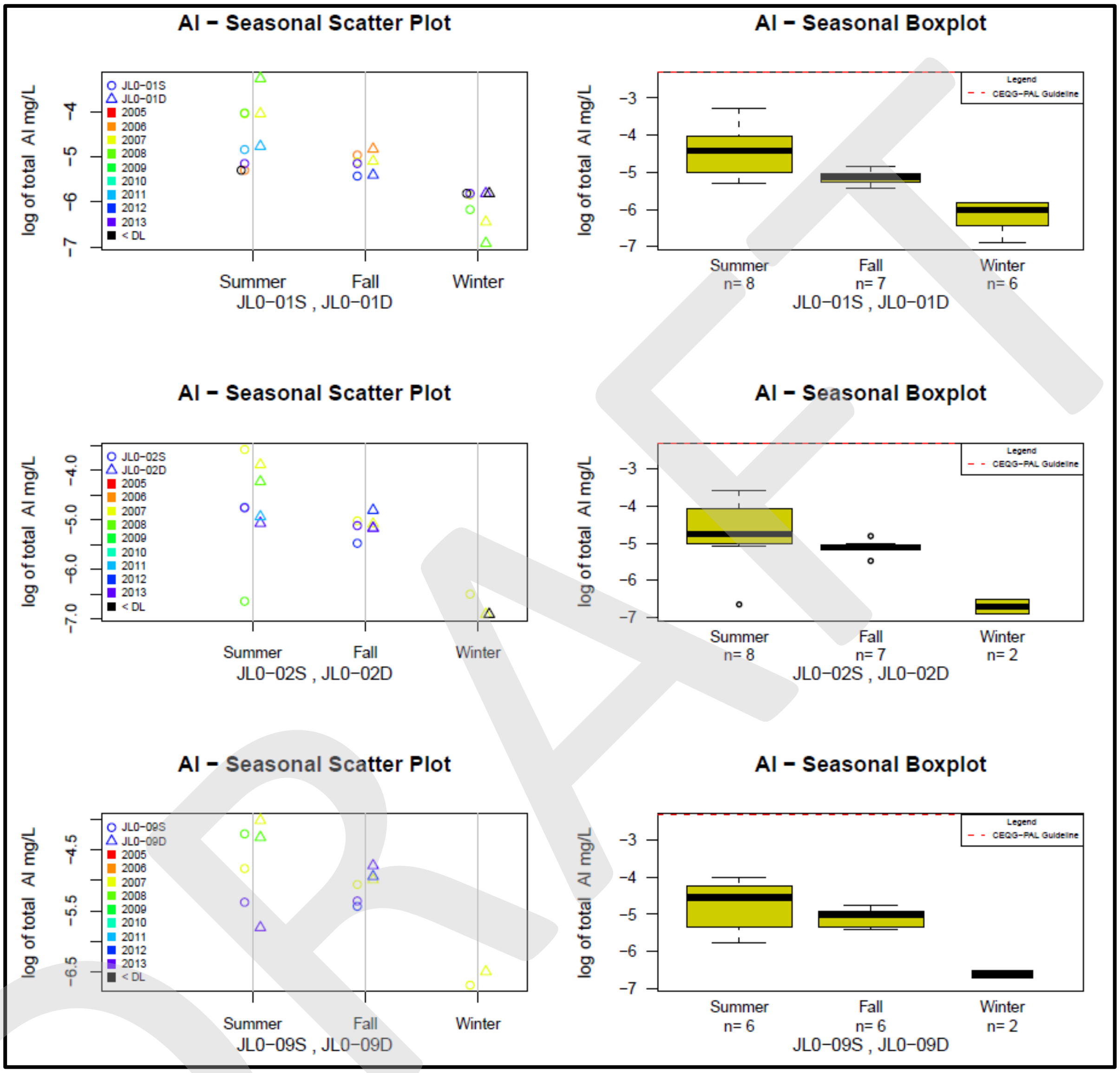
Seasonal plots show higher median values of aluminum measured during the summer, lower aluminum concentrations measured in the fall and the lowest aluminum concentrations measured in the winter. Due to the log scale of these graphs, the actual magnitude variation is small. This seasonal trend may be explained by a combination of natural and anthropogenic factors. Elevated summer concentrations may occur as result of increase summer water temperature, increased aluminum mobilization from rocks, soils and sediments by running water during summer and fall seasons or as a result of drilling activities that have occurred in vicinity to Camp Lake during the summer.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.9 Camp Lake – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

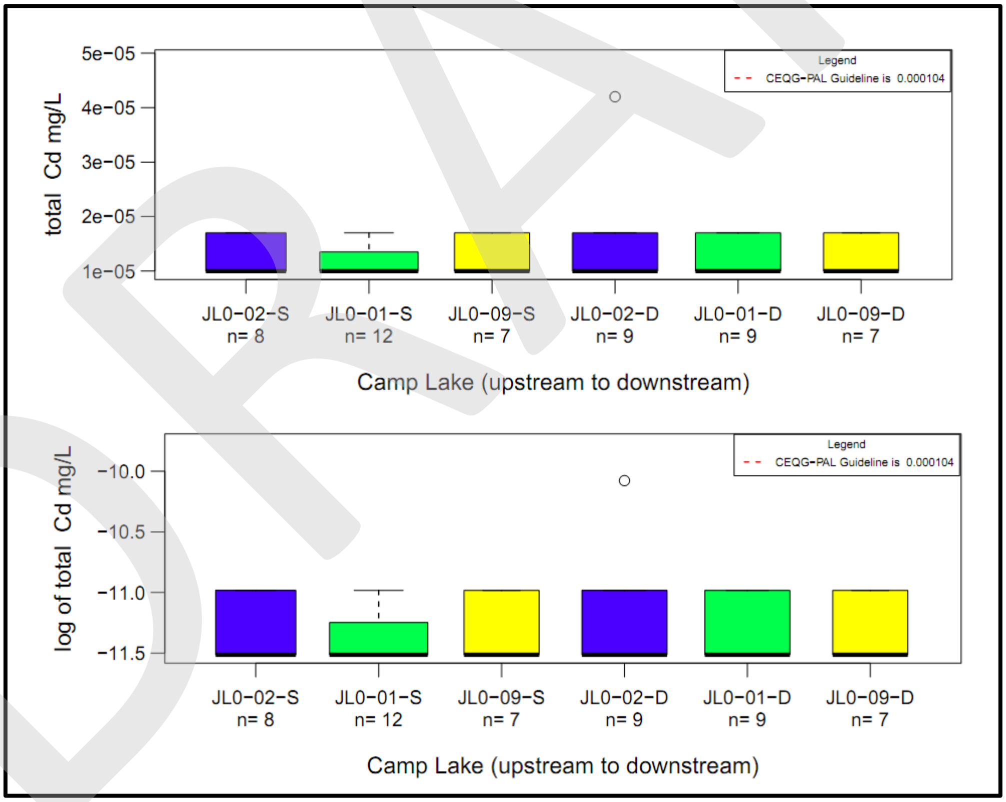
Figure B.10 Camp Lake – Variability of Total Aluminum in Water

Total Arsenic

Total arsenic concentrations were measured at the detection limit (0.0001 mg/L), consistently at all sampling locations within Camp Lake, throughout all seasons and during all years of sampling. As a result, graphical representation of data is not deemed necessary. The detection limit value is well below the appilcable CWQG-PAL guideline limit (0.005 mg/L).

Total Cadmium (Figures B.11 and B.12)

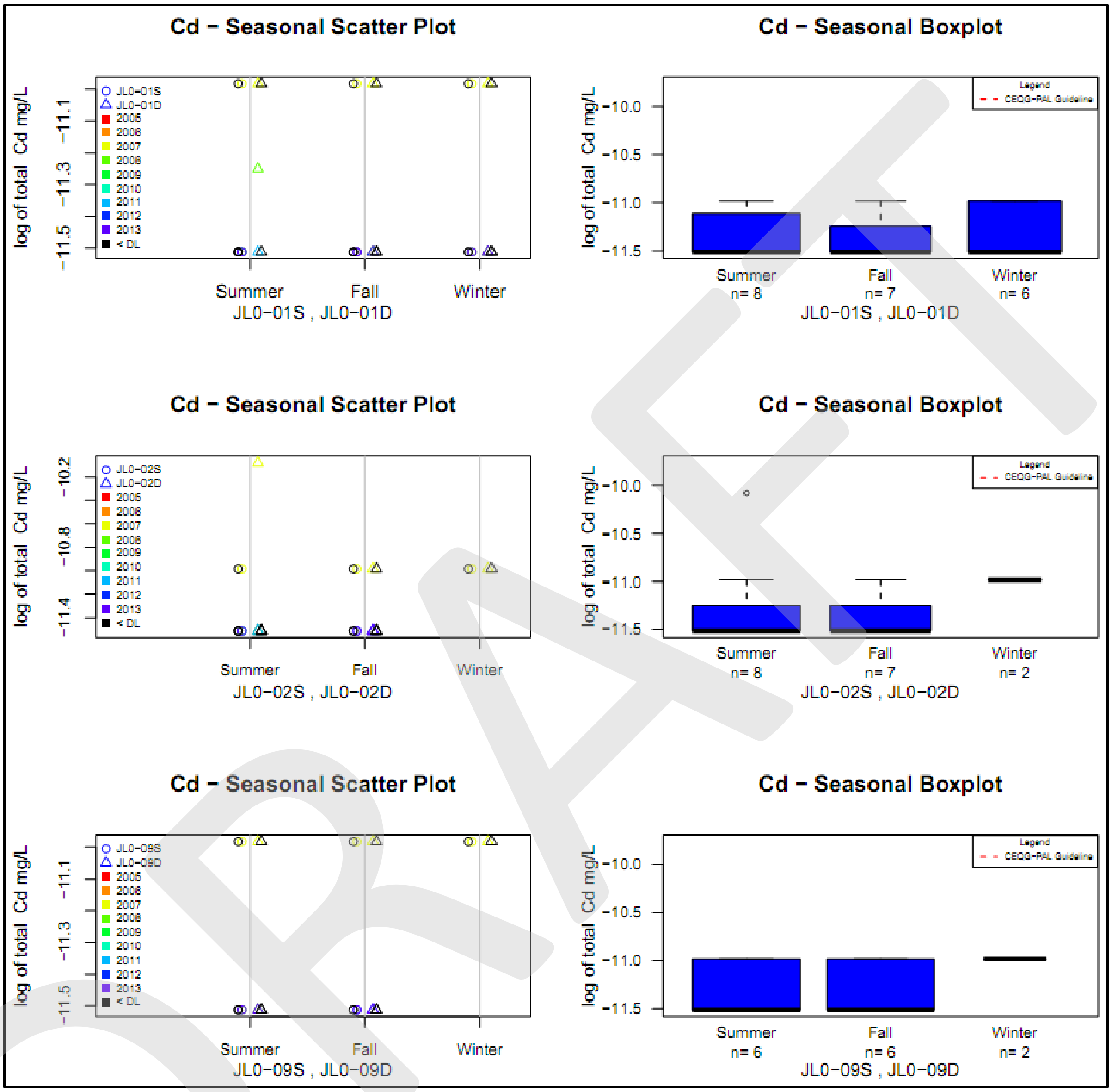
A total of 52 samples with measured cadmium concentrations were collected at Camp Lake, with seven to 12 samples collected at each of the sampling locations in Camp Lake (Figure B.11). Most total cadmium concentrations ranged from detection limit (0.00001 mg/L) to 0.00017 mg/L. One outlying value with a concentration of 0.00004 mg/L recorded in the summer, reported above the CWQG-PAL guideline (0.00018 mg/L, calculated using a median hardness of 50 mg/L $CaCO_3$). Seasonal scatter plots indicate that all measured cadmium concentrations are at a detection limit, with the exception of two data points. Seasonal box plots are obscured by artifact detection limits and do not show a consistent seasonal trend amoung the three sites sampled (Figure B.12). Definitive conclusions regarding depth and seasonal variability are obscured by artificially high detection limits.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.11 Camp Lake – Total Cadmium Concentrations in Water



NOTES:

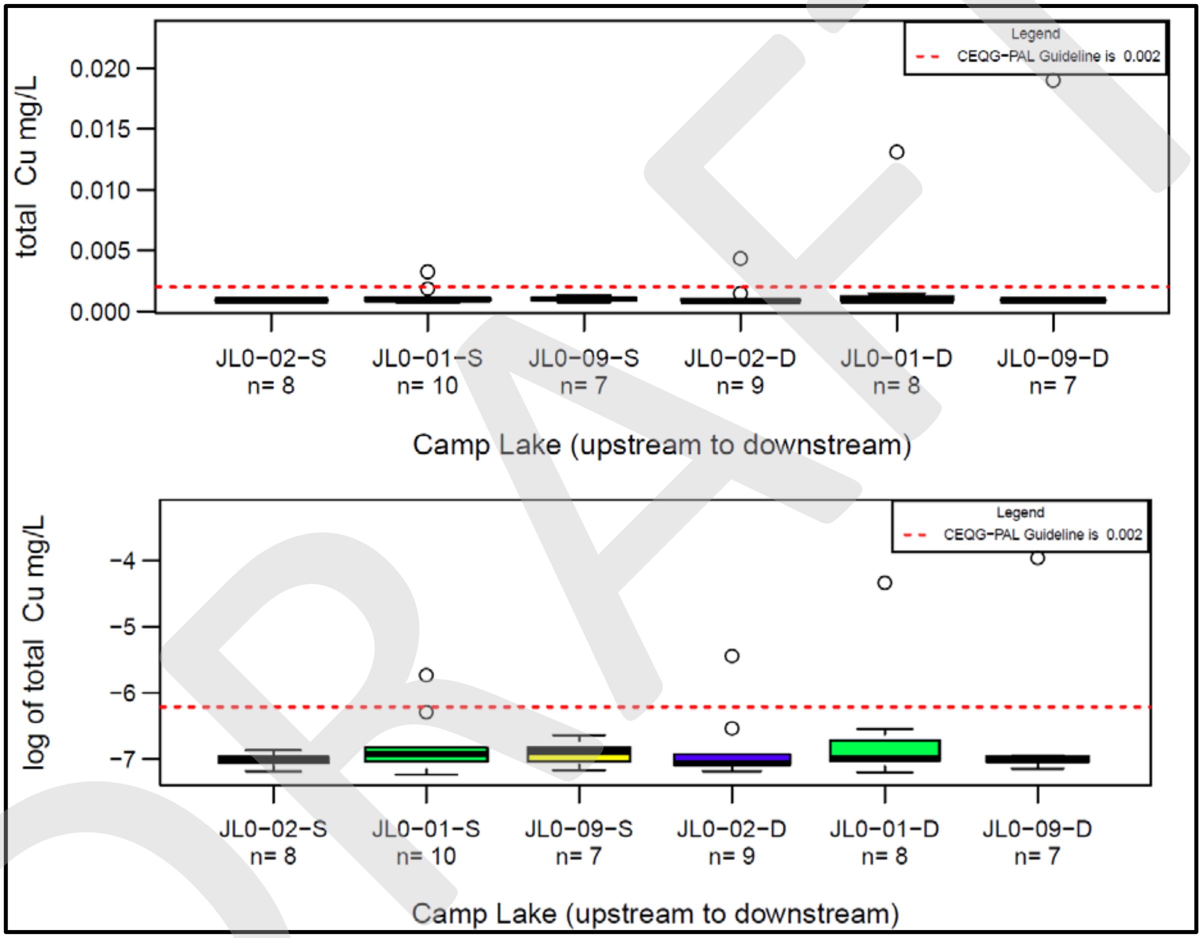
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.12 Camp Lake – Variability of Total Cadmium in Water

Total Copper (Figures B.13 and B.14)

The total sample size for copper samples in Camp Lake is 49, with between seven through ten samples collected at each sampling location. Median values for total copper at all sites occur below 0.002 mg/L (Figure B.13). Log values indicate a distribution of samples with low concentrations, below the guideline limit, that are not obscured by detection limits. Outlying values occur for several sites, to a maximum concentration of approximately 0.018 mg/L. Four outlying values exceed the CWQG-PAL guideline (0.002 mg/L).

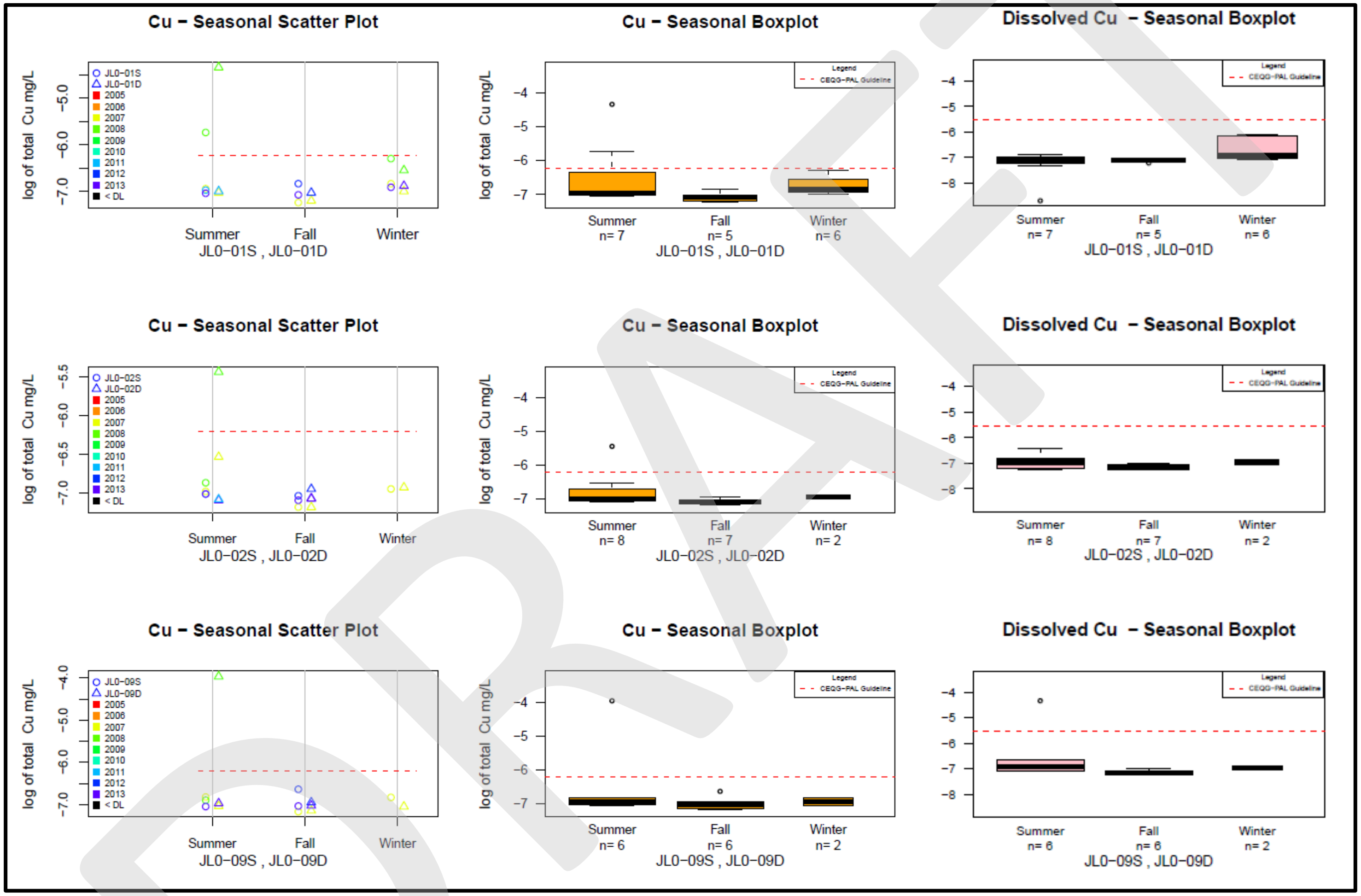
The seasonal copper scatterplot indicates that, with the exception of deep samples taken in 2008, shallow and deep concentrations are quite similar and do not show a consistent trend with depth (Figure B.14). In contrast to other parameters, seasonal trends indicates slightly higher concentrations are measured in summer and winter, when compared to fall. Further investigation into this seasonal trend revealed that winter total concentrations are almost entirely composed of the dissolved fraction, and not the particulate fraction (Figure B.14).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.13 Camp Lake –Total Copper Concentrations in Water



NOTES:

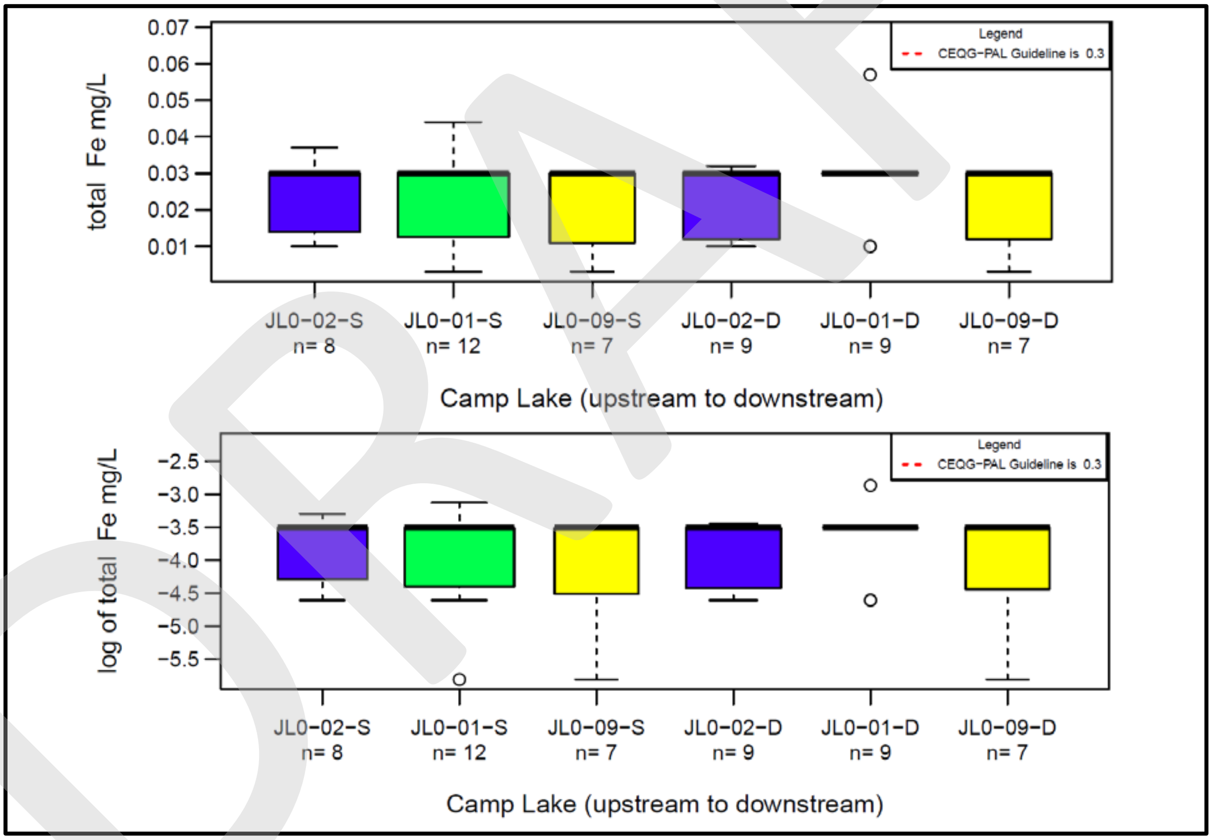
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.14 Camp Lake – Variability of Copper in Water

Total Iron (Figures B.15 and B.16)

Fifty-two (52) samples of total iron were taken within Camp Lake, with between 7 to 12 samples taken at each site within Camp Lake (Figure B.15). Median total iron concentrations at all sites was 0.03 mg/L, below the most stringent water quality guideline, CWQG-PAL at 0.3 mg/L (or the Interim SSWQO of 0.77 mg/L; see Section 2.4 of the main report). Raw and lognormal data show very similar trends, indicating that transformation may not be required for statistical tests and that graphical representation of outliers is not affected. Seasonal scatterplots of iron concentrations indicate that artificially elevated detection limits may be influencing the data and no distinct seasonal trends are noted.

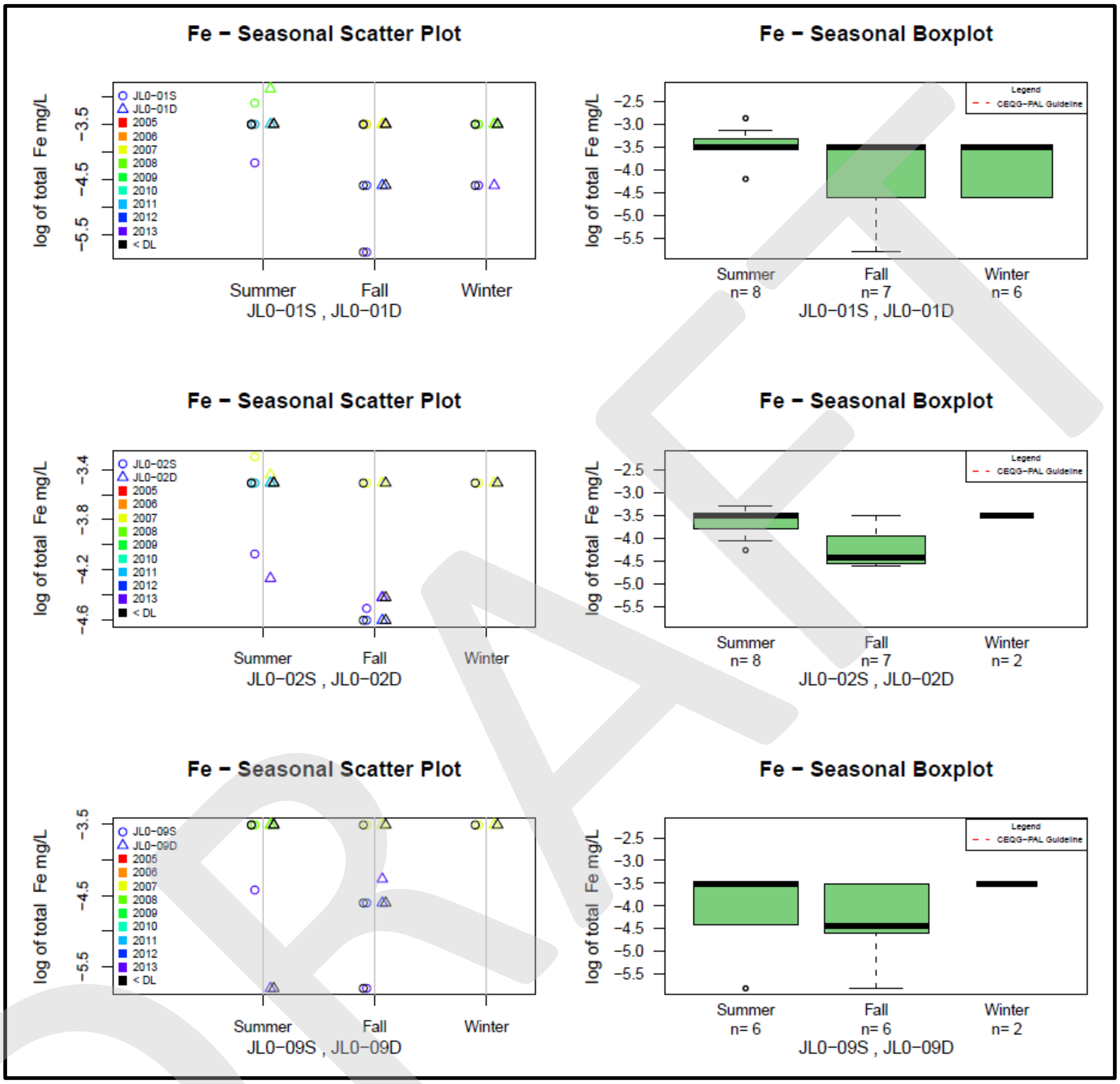
Due to interaction with detection limits during early years of sampling, definitive seasonal or depth trends are difficult to define (Figure B.16). Of note are the slightly lower iron concentrations during fall sampling events.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.15 Camp Lake – Total Iron Concentrations in Water



NOTES:

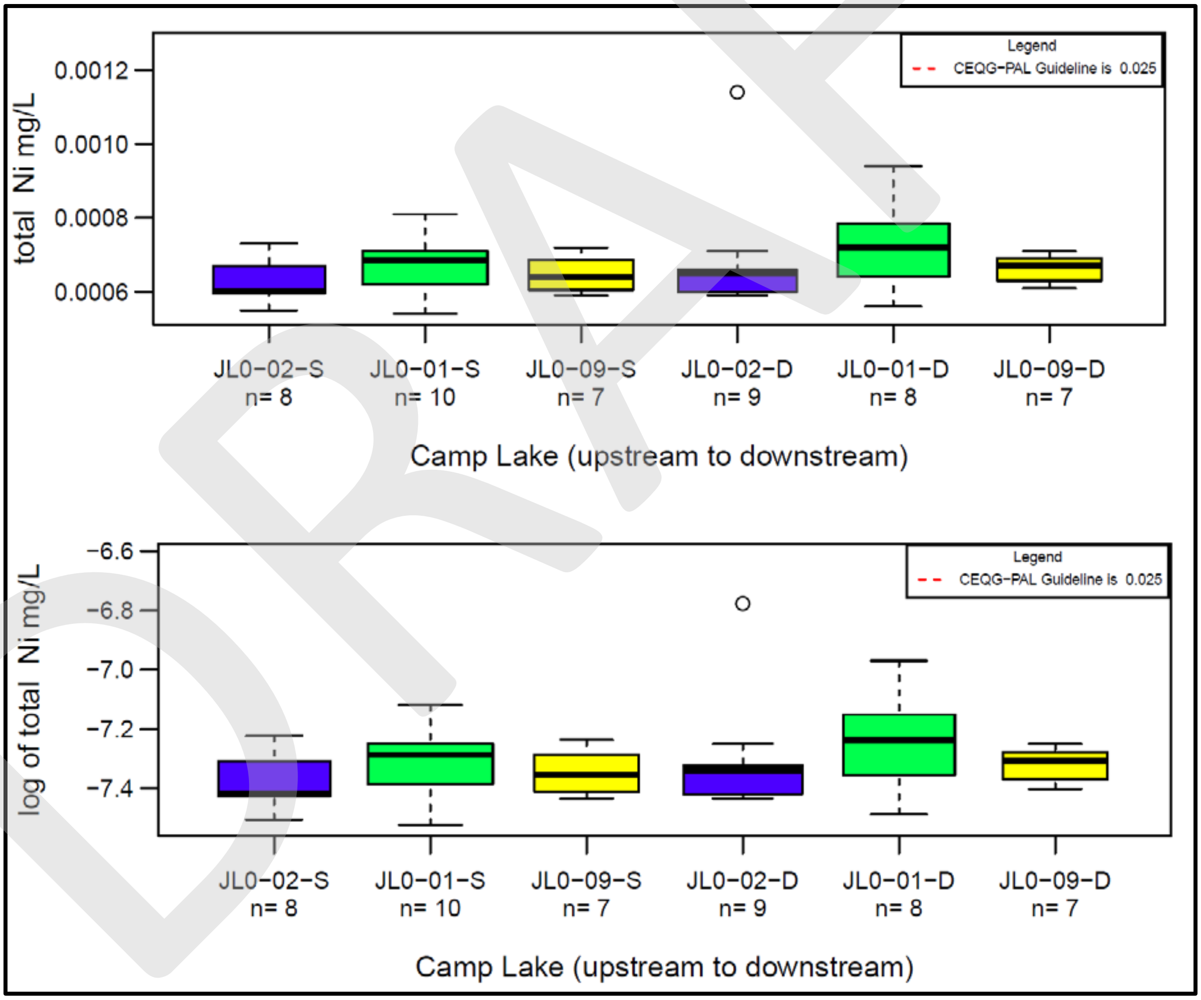
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.16 Camp Lake – Variability of Total Iron in Water

Total Nickel (Figures B.17 and B.18)

Forty-nine (49) nickel samples were collected at Camp Lake, with between seven to ten samples collected at each discrete sampling location. Median total nickel concentrations at each site are low and range from 0.0006 mg/L to 0.00075 mg/L (Figure B.17). All values are well below the CWQG-PAL guideline calculated to be 0.025 mg/L based on 50 mg/L $CaCO_3$ hardness.

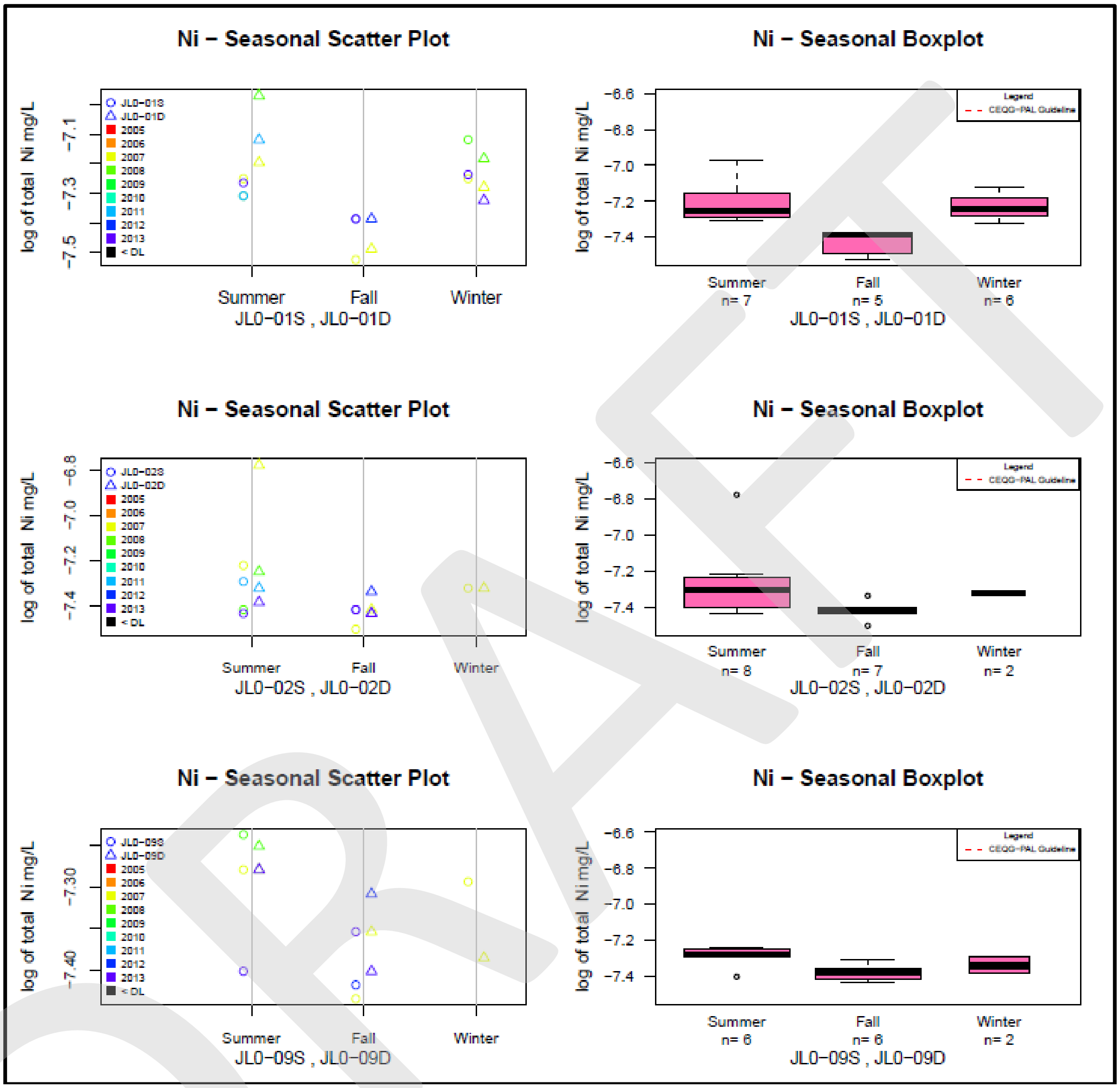
No distinct temporal trends over the course of yearly sampling are noted, although variation in site location is greater than variation as a result of depth (Figure B.18). JL0-01 has a very low magnitude elevation of nickel concentrations when compared to other sites. Seasonal trends are noted that are similar to those observed for copper, with very similar median summer and winter concentrations and lower fall sampling concentrations. Similar to copper, investigation into total versus dissolved concentration reveal that almost all total nickel is present in the dissolved form during the winter months, although summer and fall have more particulate data.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.17 Camp Lake – Total Nickel Concentrations in Water



NOTES:

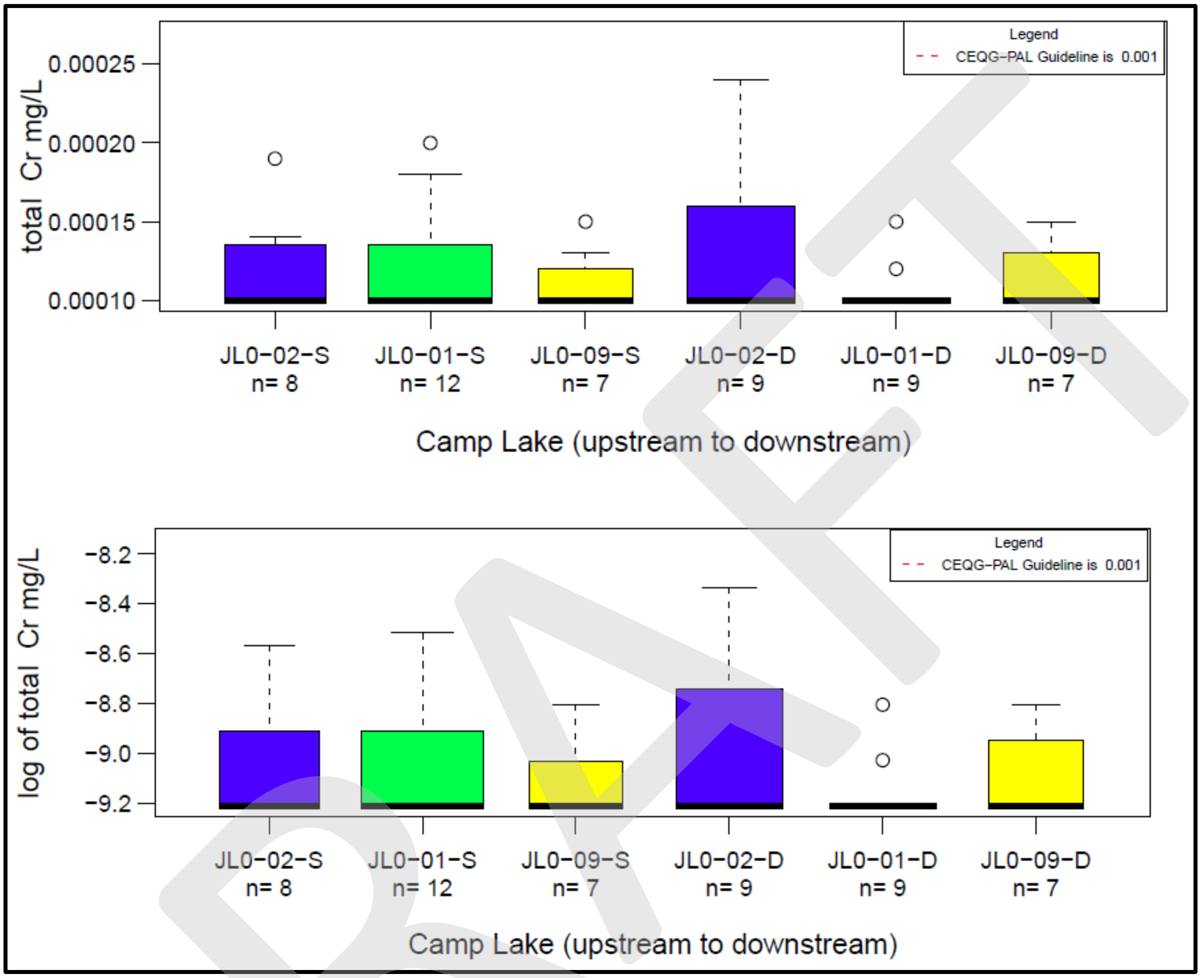
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.18 Camp Lake – Variability of Total Nickel in Water

Total Chromium (Figures B.19 and B.20)

Fifty-two (52) chromium samples were collected at Camp Lake, with between seven to twelve samples collected at each discrete sampling location. Median total chromium concentrations at each site are low and range from 0.0001 mg/L to 0.00024 mg/L (Figure B.19). All values are well below the CWQG-PAL guideline (0.001 mg/L).

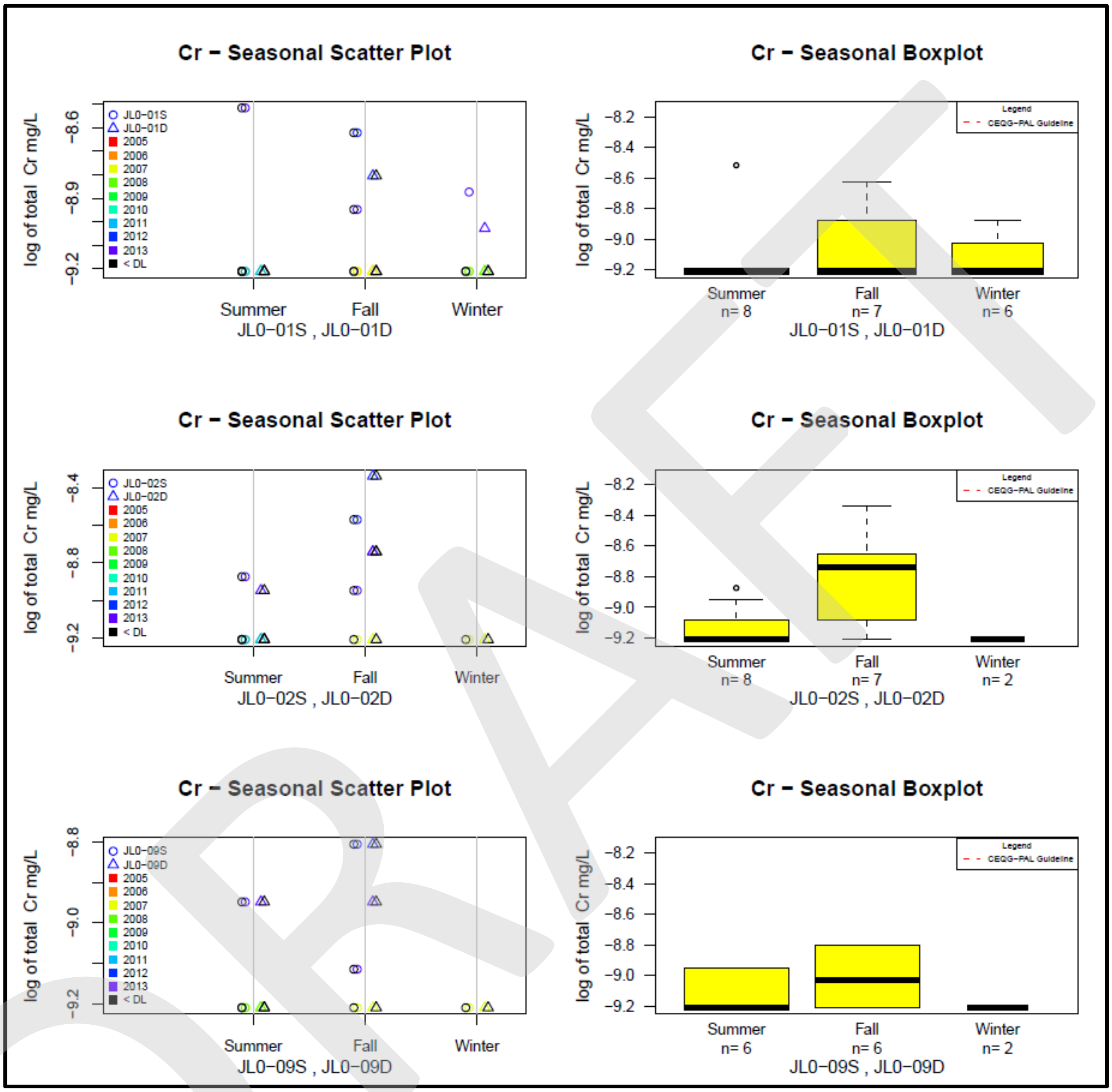
Samples from 2012 and 2013 are slightly elevated when compared to previous sampling years (Figure B.20). Slightly greater concentrations during the fall are noted for chromium



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.19 Camp Lake – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.20 Camp Lake – Variability of Total Chromium in Water

Summary of Camp Lake Water Quality

Summary of trends observed during review of Camp Lake baseline data:

- Distinct depth trends are not observed for Camp Lake, which suggests that the lake is completely mixed through much of the year. Review of data above suggests aggregation of deep and shallow sites may be appropriate.
- Geographic trends between discrete sampling sites were not observed for any parameters.

- With the exception of chloride and chromium, parameters did not show any distinct inter-annual trends/variability over the six year sampling history. Chloride and chromium concentrations in Camp Lake measured from 2011 through 2013 are elevated compared to earlier samples from 2005 to 2010.
- Parameters with MDL interference and/or that do not show seasonal trends include: cadmium, chloride, arsenic, iron and nitrate.
- Parameters that have maximum concentrations occurring in the summer: nitrate and aluminum. This is likely as a result of the spring runoff period caused by rapid melt of winter snowpack.
- Parameters that have maximum concentrations occurring in the winter: copper and nickel. Most of this concentration occurs in a dissolved form, not as particulate.
- Parameters that have maximum concentrations occurring in the fall: chromium.

B.2.2 Sheardown Lake

Sheardown Lake is separated into two basins, referred to as the northwest basin and southeast basin. Sheardown Lake NW has been the receiving water for treated sewage from the exploration camp. In addition, stockpiling and crushing of ore occurred in 2008 near the lake and the primary tributary to the lake. As such, the concentrations within the lake may have already been affected by construction and mining activities. Findings from both lakes will be discussed in the subsequent sections.

B.2.2.1 Sheardown Lake NW

A total of 92 lake samples were collected from the northwest basin of Sheardown Lake from 10 sampling stations over the sampling period. Most sampling was completed during the open water season, from July through September (summer and fall). Late winter sampling (May) was carried out only in 2007, 2008, 2012 and 2013. Ten stations are reported in detail (Figures B.1 and B.2):

- DL0-01-1-S and DL0-01-1-D - Shallow and deep; located in the centre of Sheardown Lake NW.
- DL0-01-2-S and DL0-01-2-D - Shallow and deep; located in the south centre of Sheardown Lake NW.
- DL0-01-4-S and DL0-01-4-D - Shallow and deep; located on the northeast bay within Sheardown Lake NW.
- DL0-01-5-S and DL0-01-5-D - Shallow and deep; located near the northwest shore within Sheardown Lake NW.
- DL0-01-7-S and DL0-01-7-D - Shallow and deep; located near the southern outlet of Sheardown Lake NW.

D-Lake-01, -02, -03, -04 and -05 were also established, but each has only one sampling point. A summary of the data collected during each season, with respect to year and site are included in Table B.2. A graphical representation of the sampling events within Sheardown Lake for the ten station reported in detail is provided in Figure B.21.

Table B.2 Sheardown Lake NW Sample Size

Year	Summer	Fall	Winter
2006	2	2	0
2007	10	10	4
2008	11	10	2
2011	6	6	0
2012	0	6	2
2013	13	8	6
Site	**Summer**	**Fall**	**Winter**
DL0-01-1-S	5	6	2
DL0-01-1-D	5	6	2
DL0-01-2-S	3	3	0
DL0-01-2-D	3	3	0
DL0-01-4-S	5	2	0
DL0-01-4-D	2	3	0
DL0-01-5-S	4	5	2
DL0-01-5-D	4	5	2
DL0-01-7-S	4	5	0
DL0-01-7-D	7	4	0

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30.
2. LAKE SAMPLING DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE.
3. DURING WINTER 2013, SAMPLES WERE COLLECTED WITHIN SHEARDOWN LAKE AT D-LAKE-05.

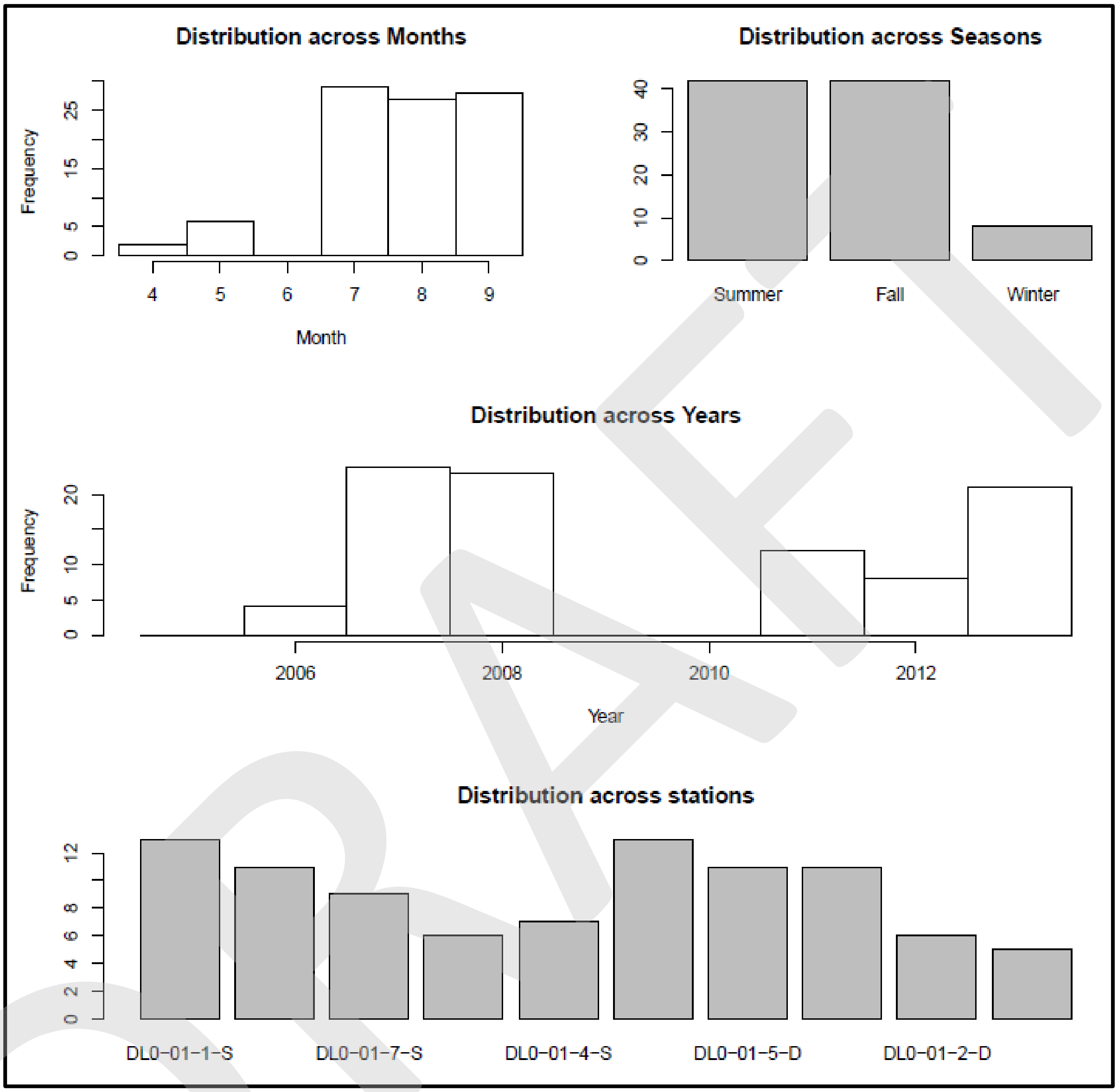


Figure B.21 Sheardown Lake NW – Graphical Summary of Sampling Events

The following summarizes the data review observations for Sheardown Lake NW.

pH (Figure B.22)

- Sheardown Lake NW is slightly alkaline with a median in-situ pH of ~7.6.
- A slight influence of depth on pH is observed with a measured median *in situ* pH at the deep stations is slightly lower compared to shallow stations.

Alkalinity (Figure B.22)

- Sheardown Lake sites are fairly uniform with median alkalinity values that range from 50 to 60 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.

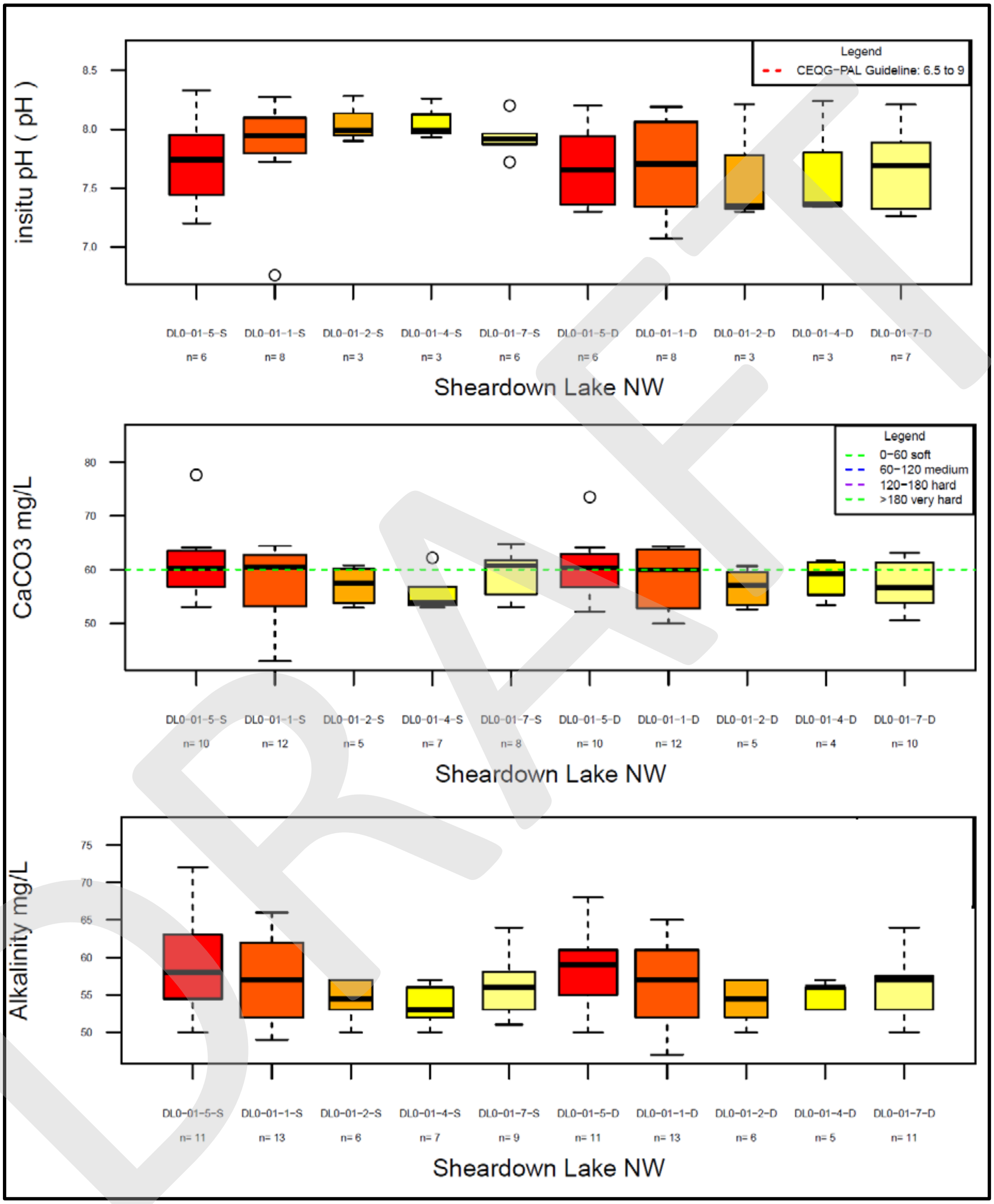


Figure B.22 Sheardown Lake NW – *In situ* pH, Alkalinity and Hardness

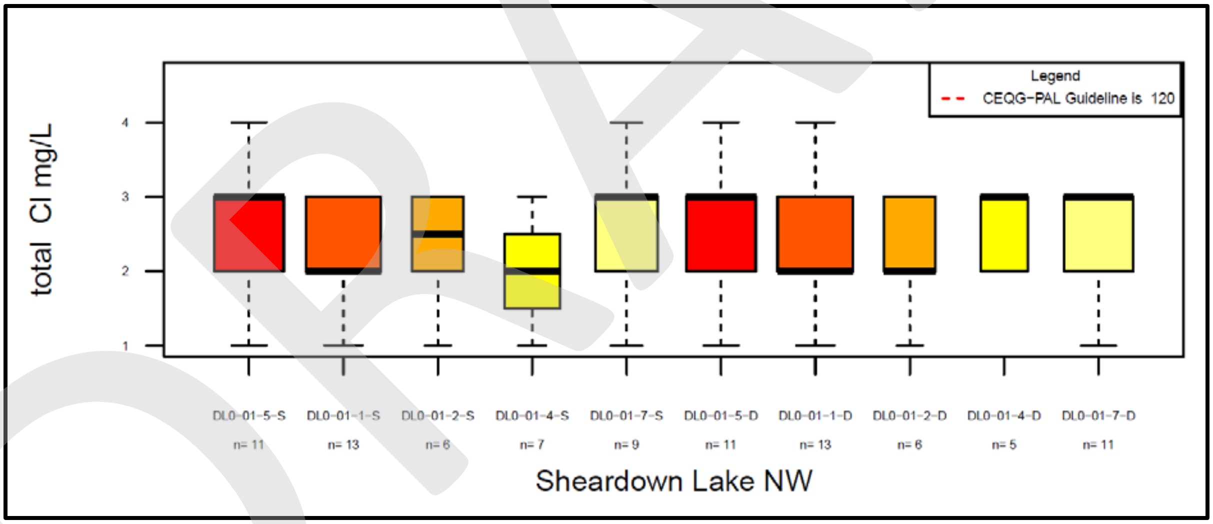
Hardness (Figure B.22)

- Median hardness ranged from 54 and 61 mg/L, putting Sheardown Lake NW right on the border of water that is considered “soft” or “medium” hardness.
- Hardness did not change meaningfully with depth, and showed more variation with station than with depth.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.23 and B.24)

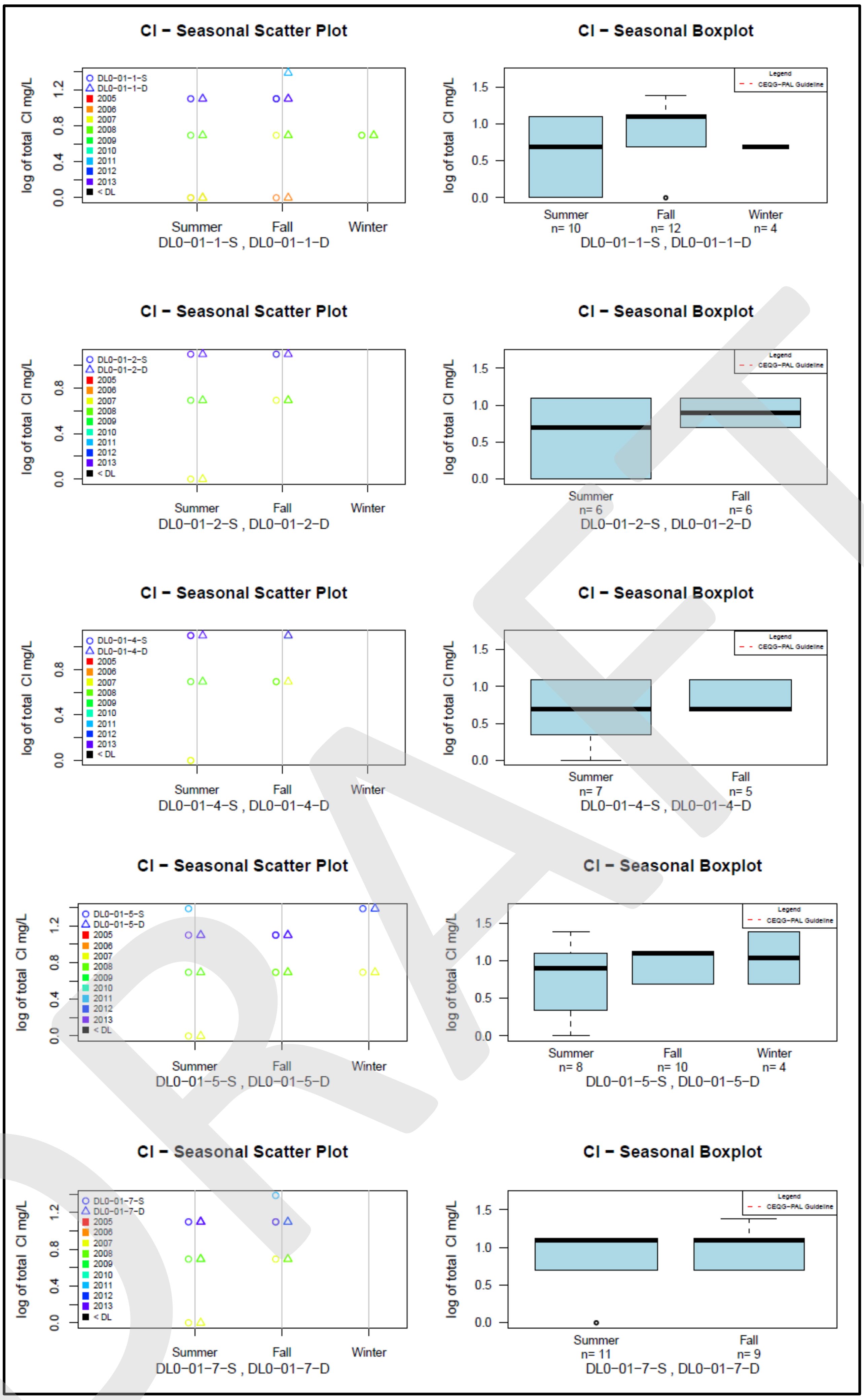
Ninety-two (92) chloride concentration samples were collected at Sheardown Lake NW. Chloride concentrations in Sheardown Lake NW are very low and have maximum values of 4 mg/L, well below the CWQG-PAL limit of 120 mg/L (Figure B.23). All sites within Sheardown Lake NW have very similar median chloride concentrations that range between 2 to 3 mg/L. Comparison of raw data and log values reveals the occurrence of low concentration outlying data, at a MDL. Seasonal scatterplots indicate that detection limit interference is occurring for chloride concentrations and that distinct trends with depth are not apparent (Figure B.24).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.23 Sheardown Lake NW – Chloride Concentrations in Water



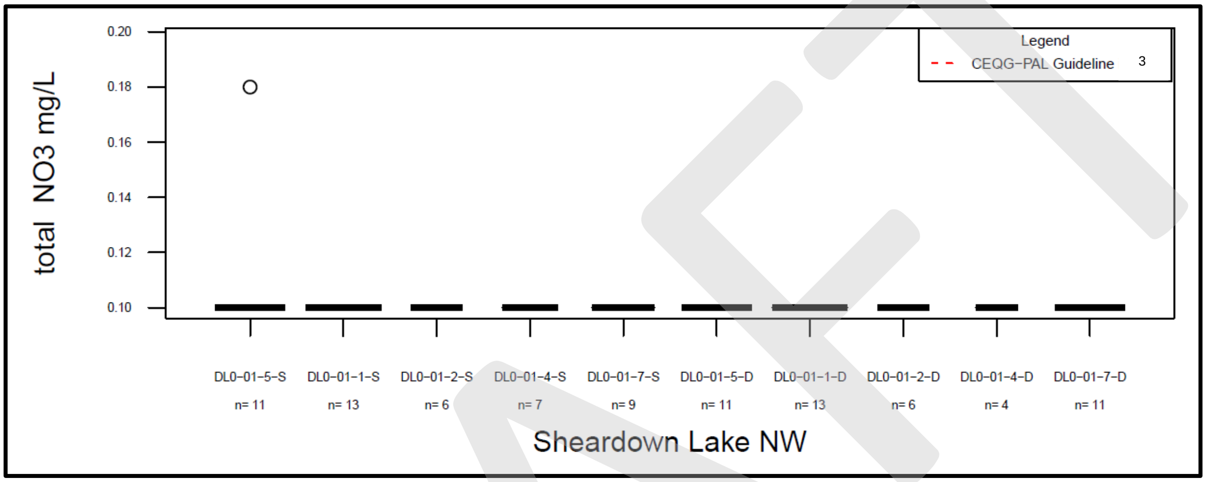
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.24 Sheardown Lake NW – Variability of Chloride in Water

Nitrate (Figure B.25)

Eighty-seven (87) nitrate concentration samples were collected from Sheardown Lake over the course of eight years. All nitrate concentrations were measured at the detection limit (0.10 mg/L), except for one outlying concentration equal to 0.18 mg/L (Figure B.25). As a result, no seasonal, inter-annual or depth variation can be determined.



NOTES:

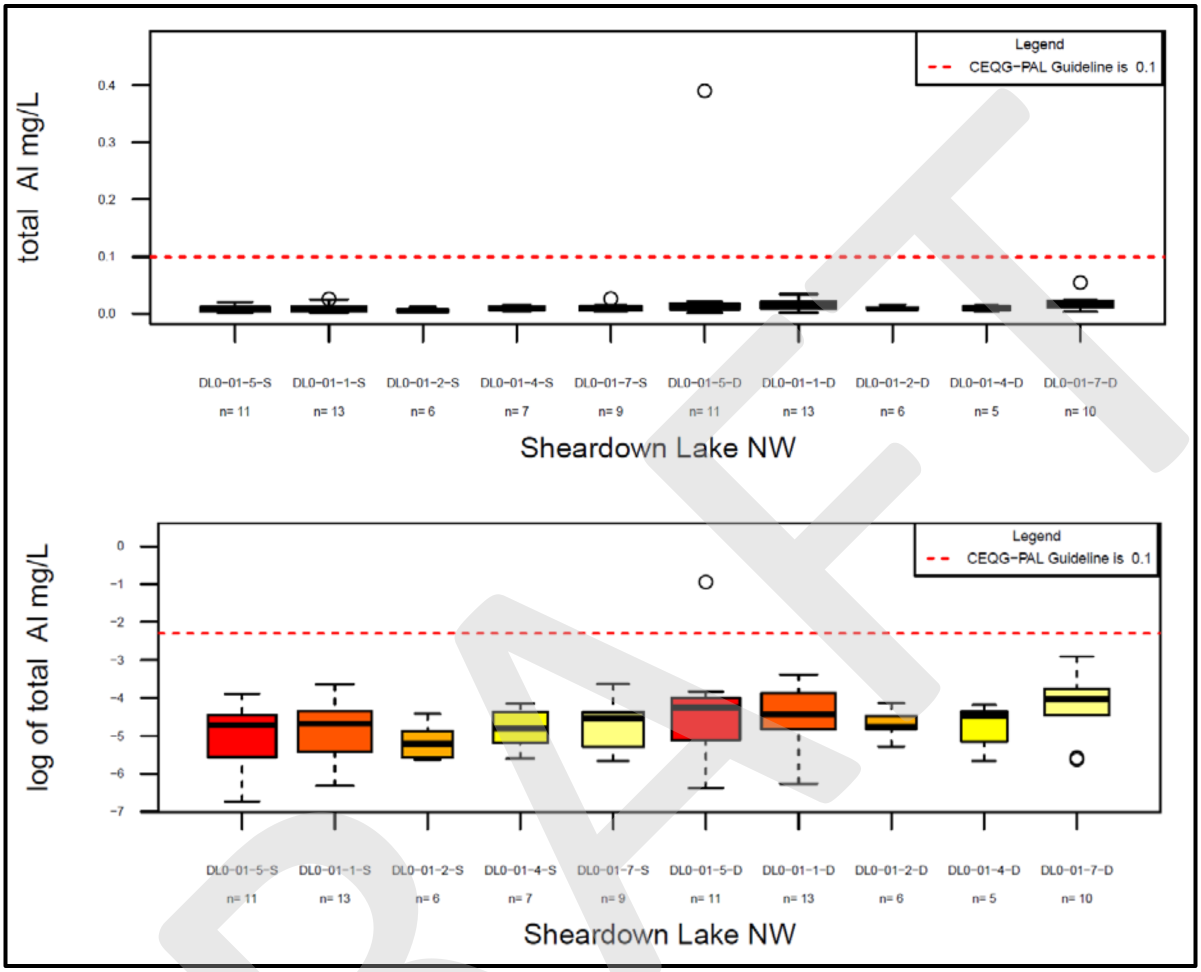
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.25 Sheardown Lake NW – Nitrate Concentrations in Water

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations to match the relevant applicable guidelines.

Total Aluminum (Figures B.26 and B.27)

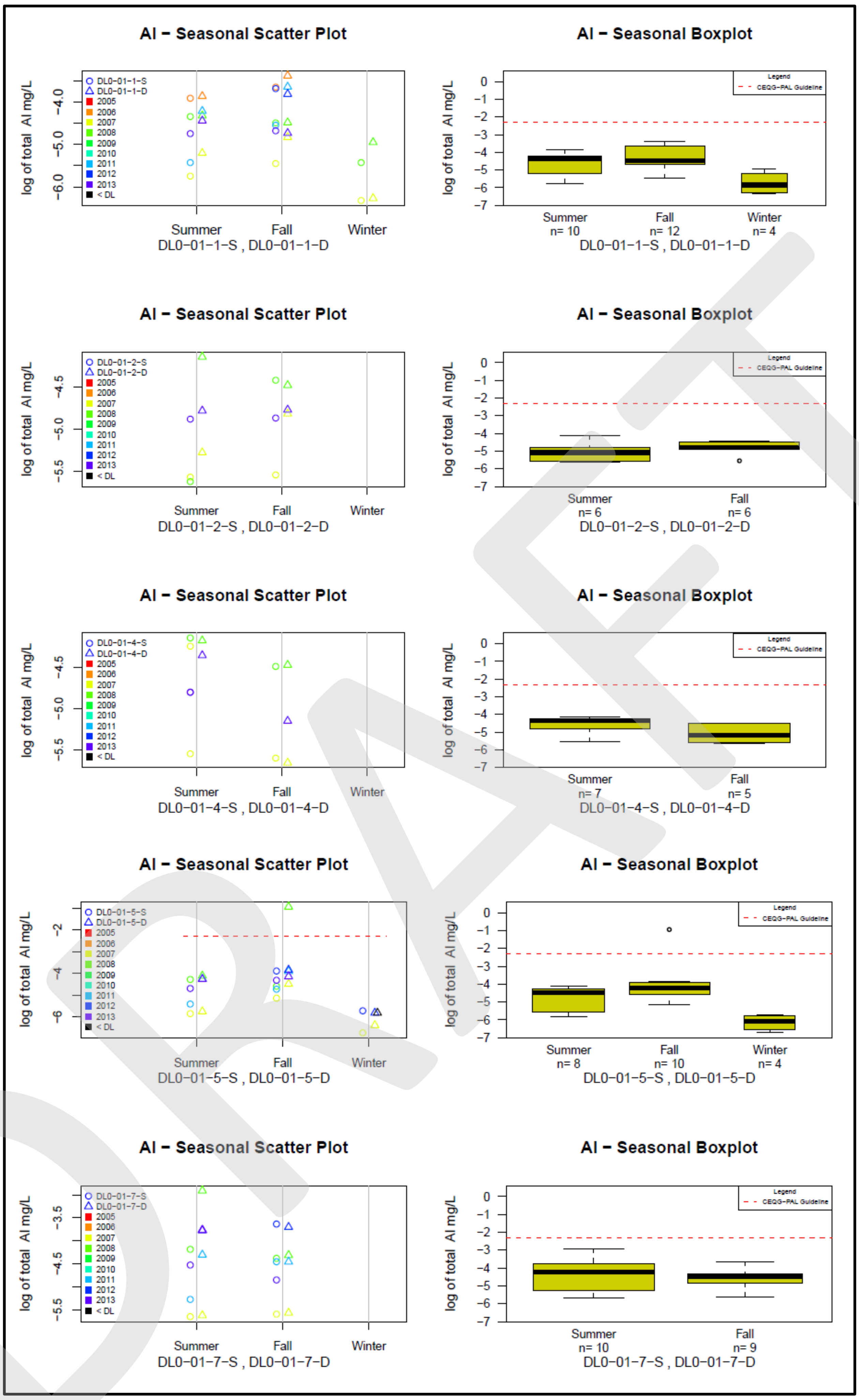
Ninety-one (91) total aluminum concentration samples were collected from Sheardown Lake NW over the course of eight years. Total aluminum concentrations consistently report above MDLs, and are consistently below the CWQG-PAL guideline, with the exception of one sample (Figure B.26). All stations within Sheardown Lake have similar median aluminum concentrations that are less than 0.05 mg/L. Deeper sampling stations show slightly elevated concentrations when compared to shallow stations. Comparison of raw data and log values reveals fewer outliers within the log transformed data, as expected. Seasonal scatterplots indicate that summer and fall concentrations of aluminum remain fairly elevated, while winter concentrations are reduced in comparison (Figure B.27).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.26 Sheardown Lake NW – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.27 Sheardown Lake NW – Variability of Total Aluminum in Water

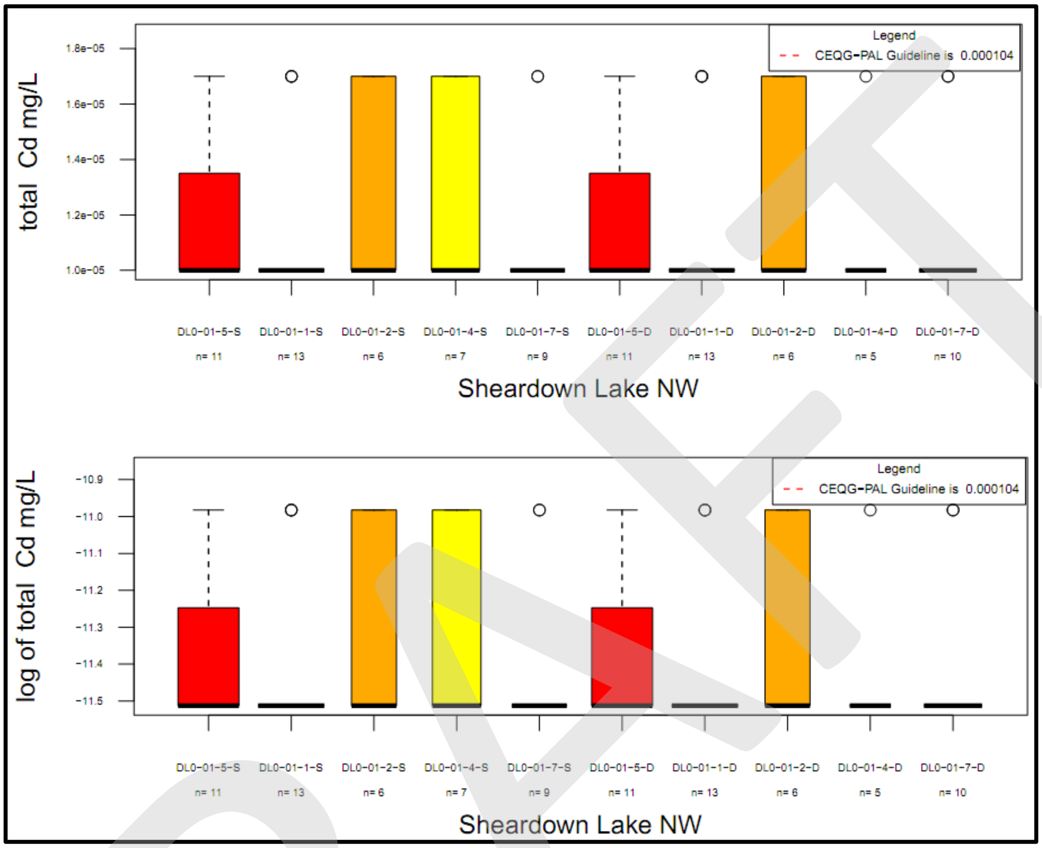
Total Arsenic

All (ninety-one) measured total arsenic levels report at detection limit and are therefore not not portrayed via graphical representation. The detection limit (0.00010 mg/L) is far below the CWQG-PAL guideline limit (0.005 mg/L).

Total Cadmium (Figures B.28 and B.29)

Ninety-one (91) total cadmium concentration samples were collected from Sheardown Lake over the course of eight years. Cadmium concentrations consistently report at or below MDLs, and are consistently below the CWQG-PAL guideline (Figure B.28). Although total boxplots of all data seem to indicate a range of values at each sampling point, this is as a result of two different detection limits. Seasonal scatterplots reveal that earlier data from 2007 had a detection limit of 0.000017 mg/L and later data from 2009 onwards had a detection limit of 0.00001 mg/L.

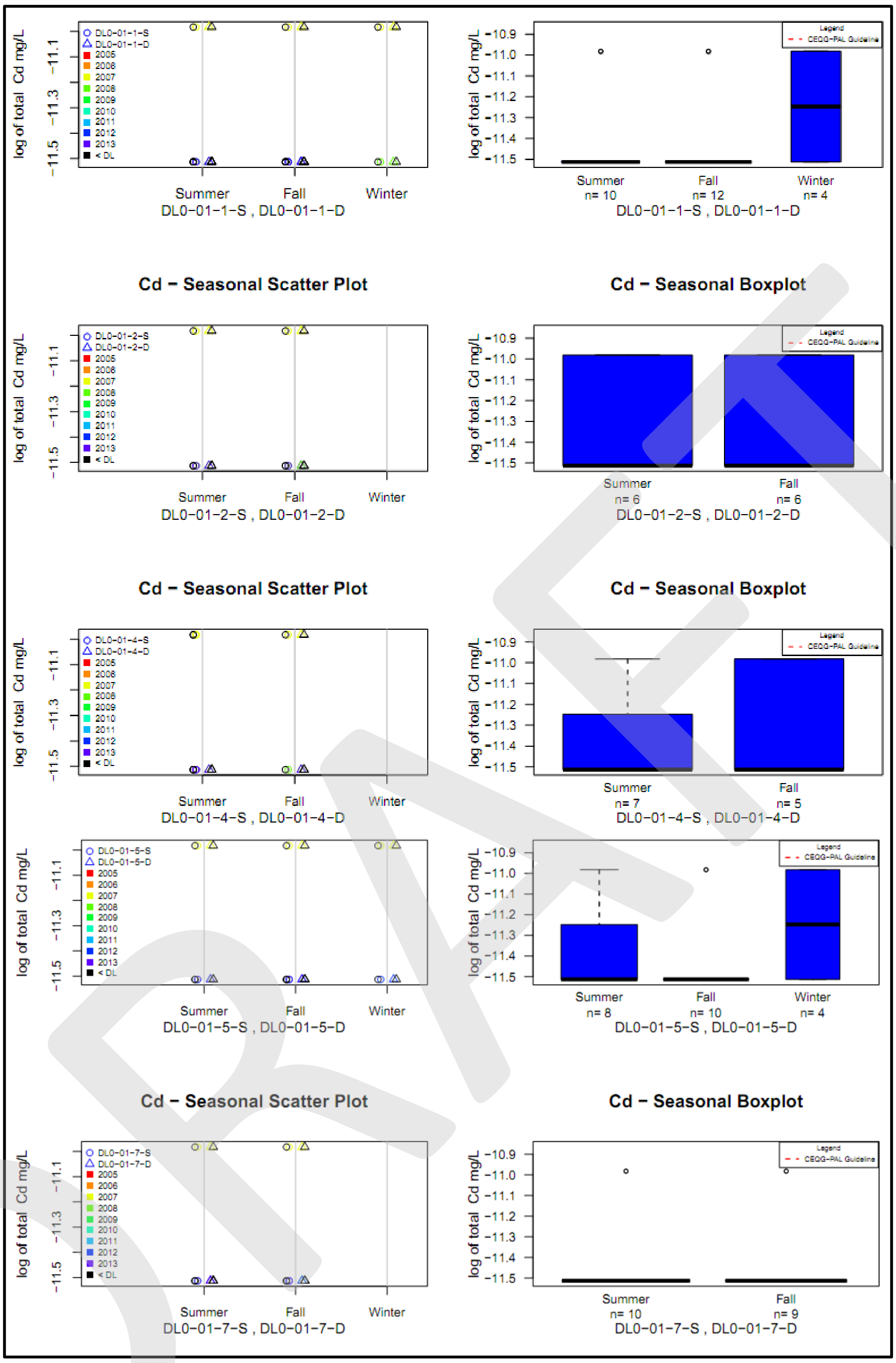
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations, as a result of MDL interference (Figure B.29). Similarly, seasonal differences are not noted as a result of MDL interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.28 Sheardown Lake NW – Total Cadmium Concentrations in Water



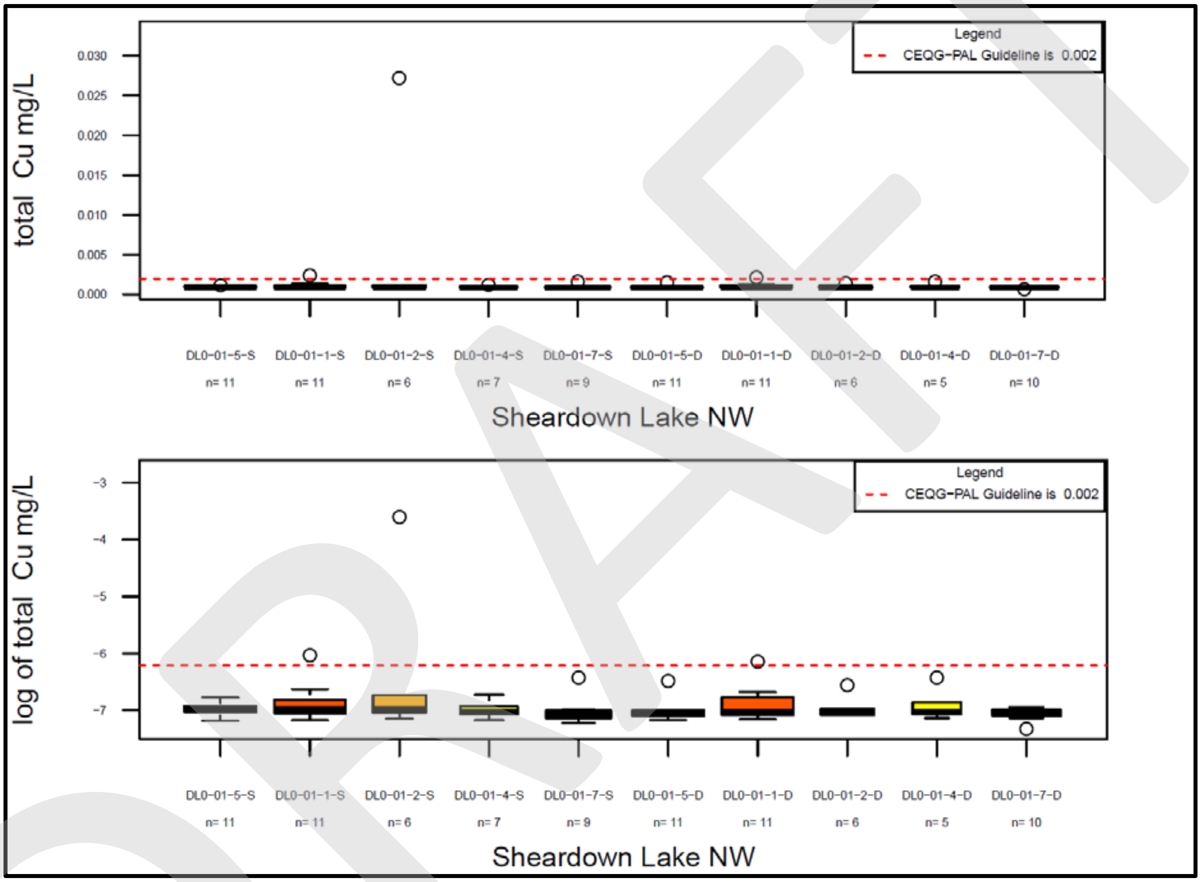
NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.29 Sheardown Lake NW – Variability of Total Cadmium in Water

Total Copper (Figures B.30 and B.31)

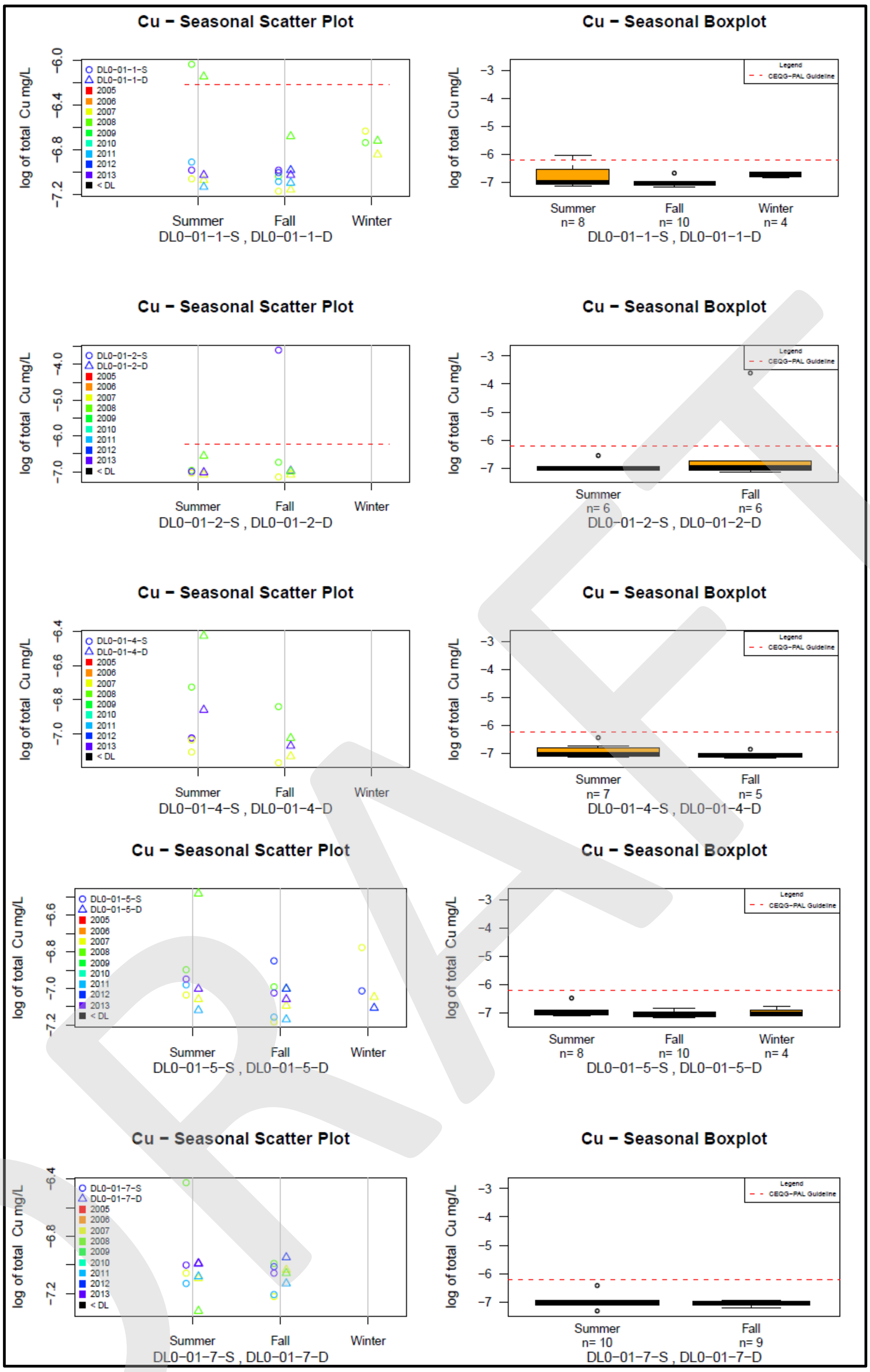
Eighty-seven (87) total copper concentration samples were collected from Sheardown Lake NW over the course of eight years. Total copper concentrations are slightly elevated, but usually below the CWQG-PAL guideline (Figure B.30). Seasonal scatterplots that combine data from deep and shallow sampling stations show little difference in values between the two stations (Figure B.31). No distinct seasonal differences are observed.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.30 Sheardown Lake NW – Total Copper Concentrations in Water



NOTES:

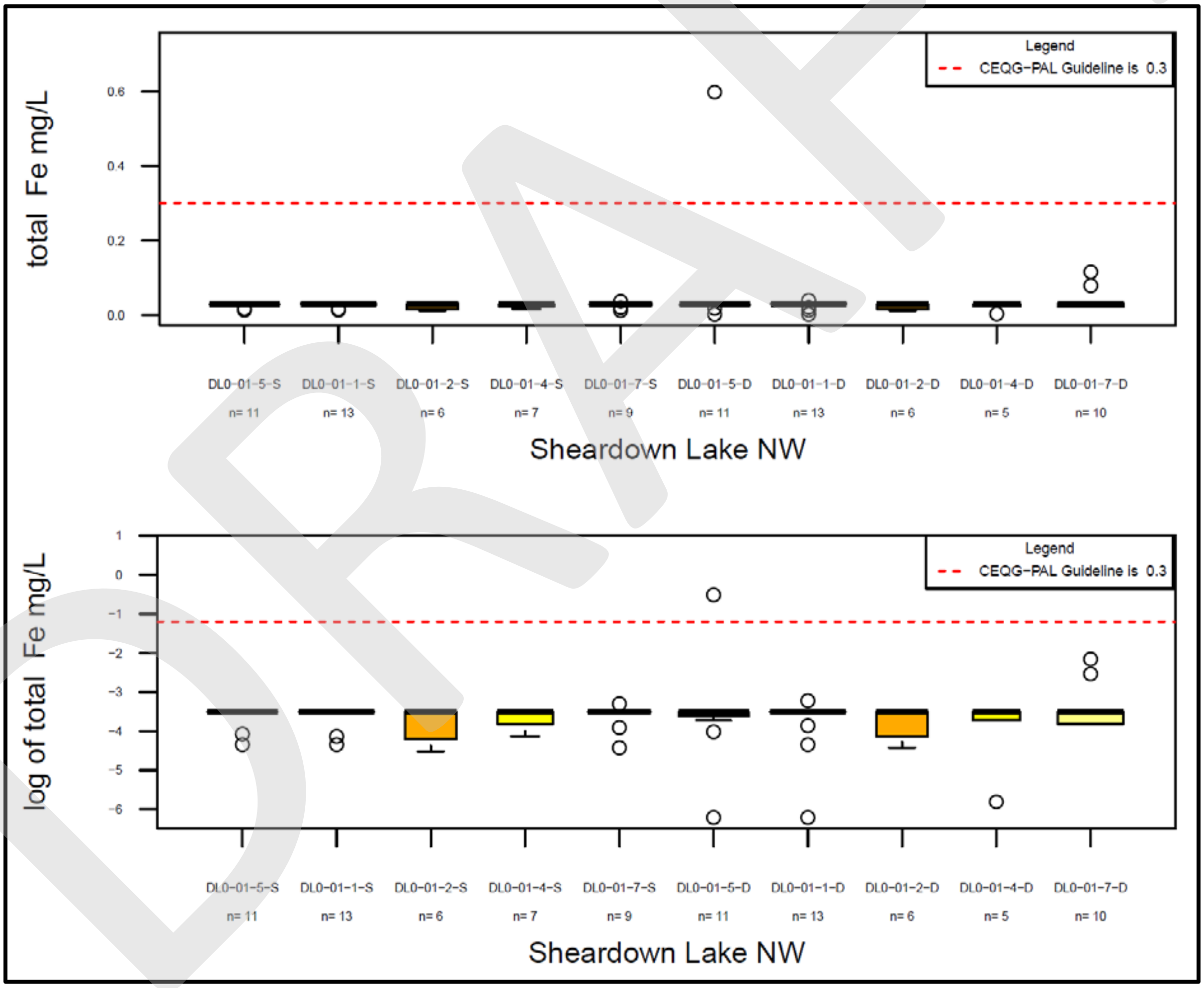
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.31 Sheardown Lake NW – Variability of Total Copper in Water

Total Iron (Figures B.32 and B.33)

Ninety-one (91) total iron concentration samples were collected from Sheardown Lake NW over the course of eight years. Total iron concentrations consistently report at or below MDLs, with the exception of one outlier (Figure B.32). Only one outlying data point, from DL0-01-5-D, reports above the CWQG-PAL guideline (0.002 mg/L). Seasonal scatterplots indicate samples prior to 2010 reported at or below the MDL. During 2013, detection limits were lowered and total iron concentrations consistently occurred below the 2010 MDL.

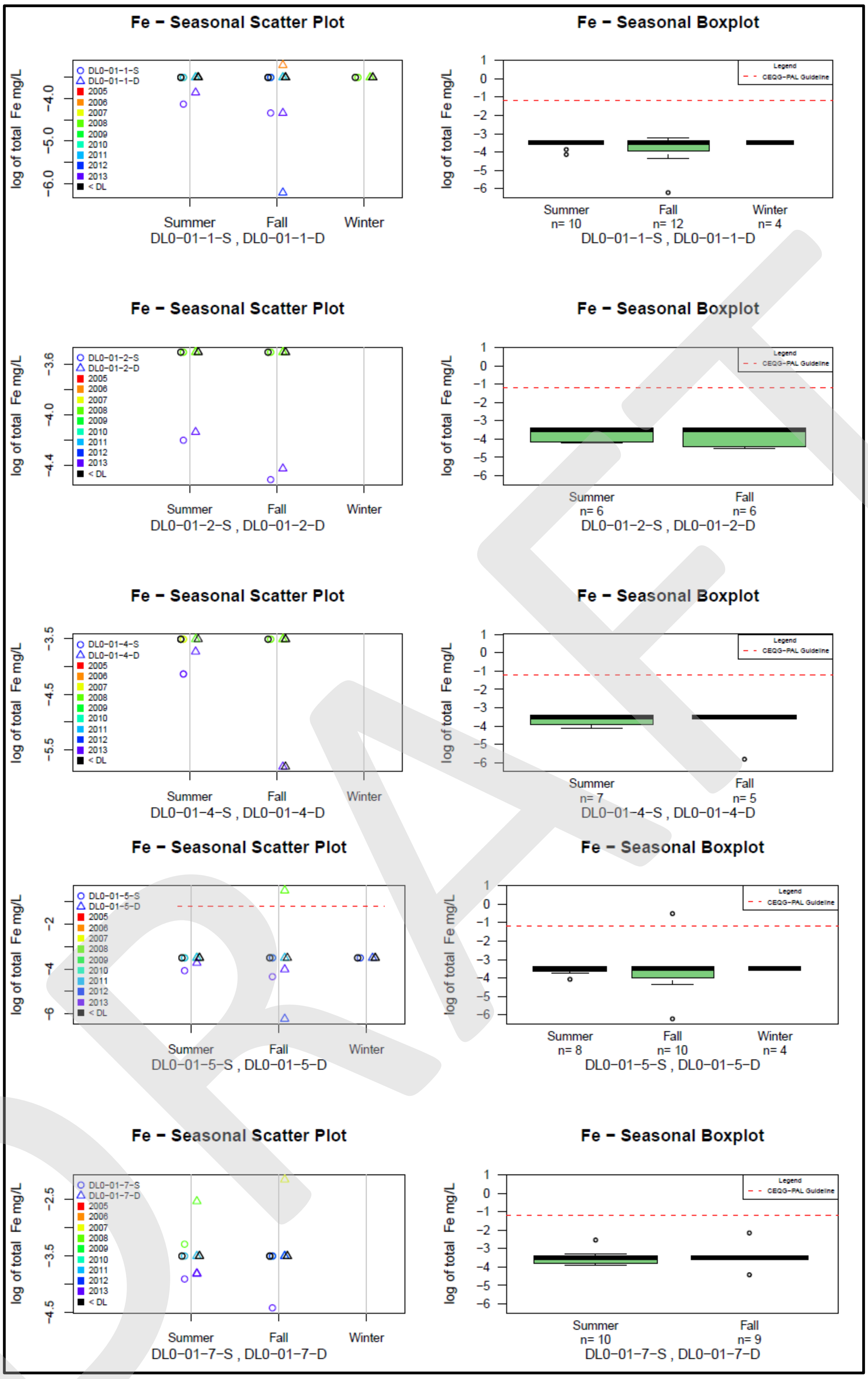
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations (Figure B.33). Seasonal differences are not noted as a result of MDL interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.32 Sheardown Lake NW – Total Iron Concentrations in Water



NOTES:

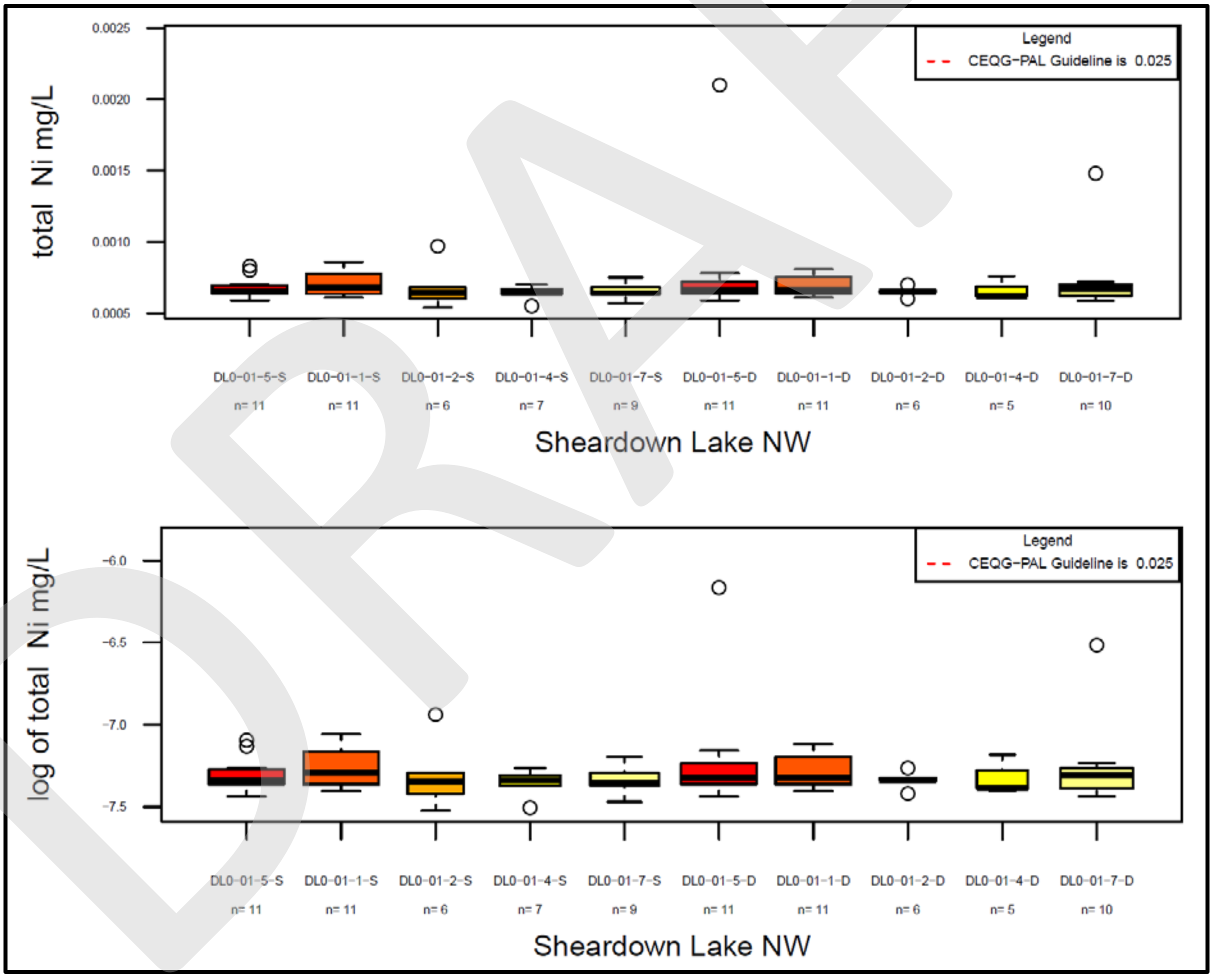
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.33 Sheardown Lake NW – Variability of Total Iron in Water

Total Nickel (Figures B.34 and B.35)

Eighty-seven (87) total nickel concentration samples were collected from Sheardown Lake NW over the course of eight years. Nickel concentrations consistently report above MDLs, but below the CWQG-PAL guideline (0.025 mg/L) (Figure B.34). Median total nickel concentrations are consistent throughout the geographically distinct sampling stations, and occur around 0.0007 mg/L; however, certain stations have a greater distribution of values. DL0-01-1-S and DL0-01-1-D show the greatest range of values, but also have the largest sample size.

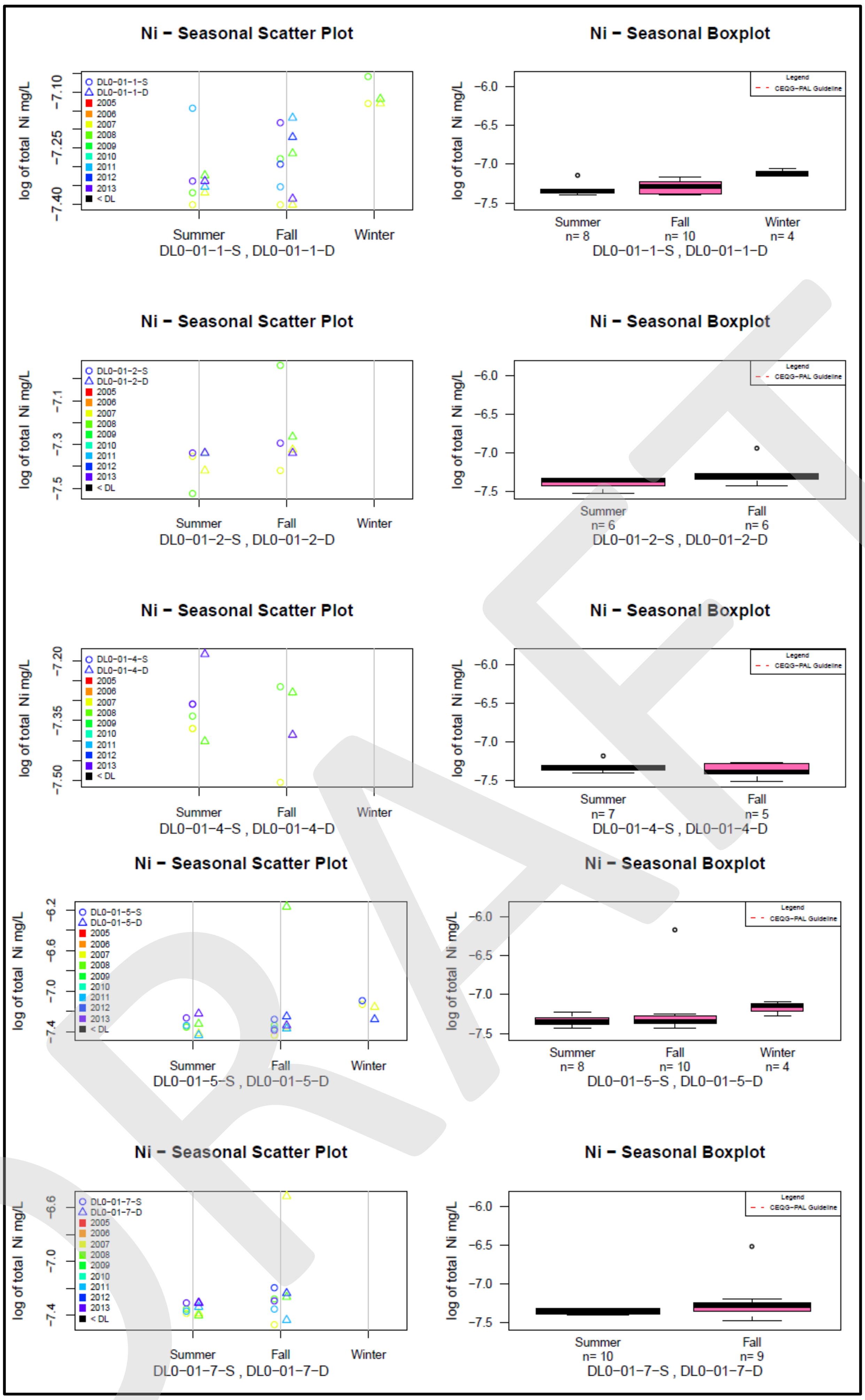
Seasonal scatterplots show that outlying data points tend to originate from sampling in 2008/2009 (Figure B.35). Seasonal boxplots show that the winter dataset for Sheardown lake nickel samples is limited. Historical summer and fall data have similar median values. The limited data collected for winter indicates winter samples have slightly higher concentrations; however, additional sampling is required to determine if this is a true trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.34 Sheardown Lake NW – Total Nickel Concentrations in Water



NOTES:

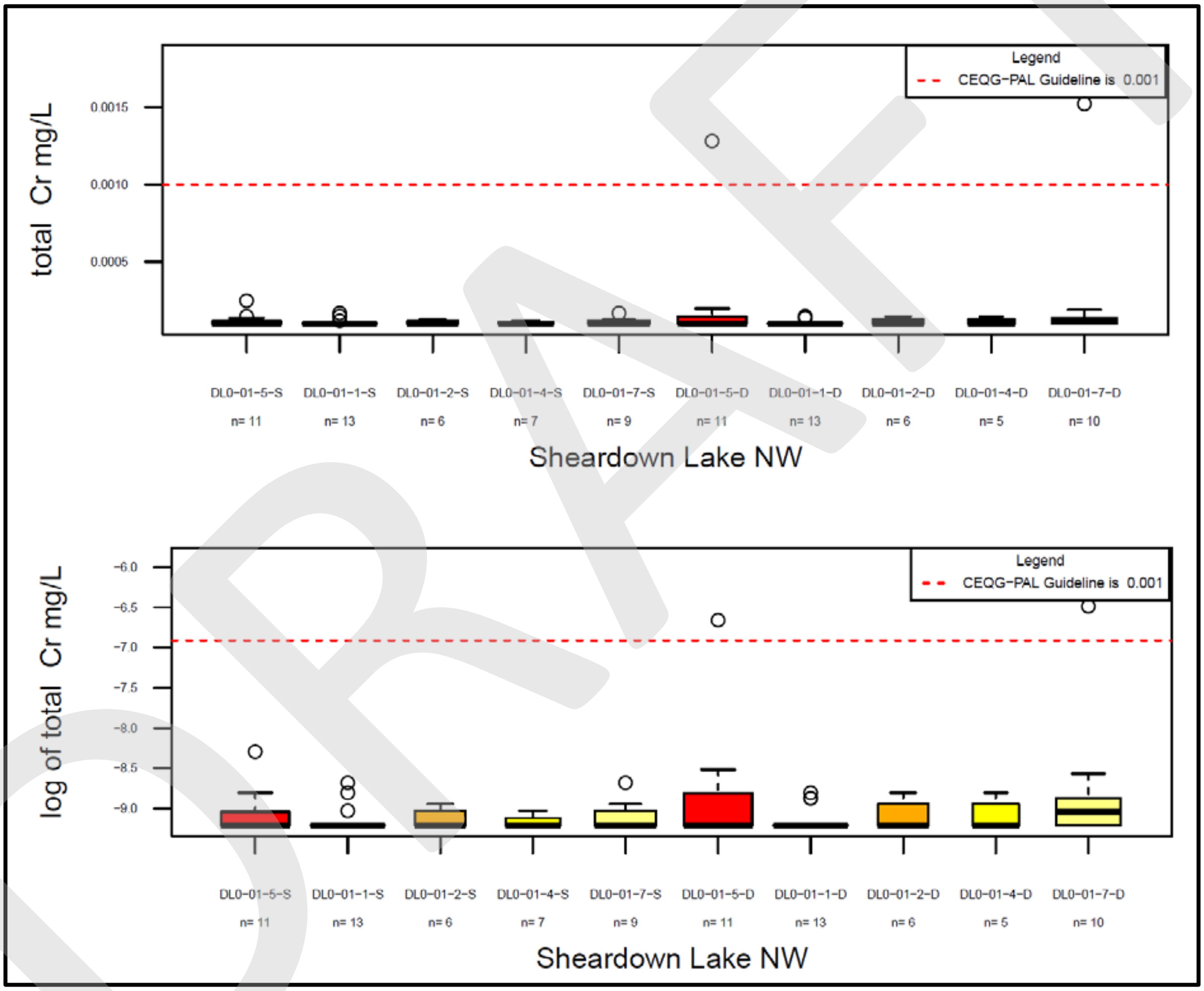
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.35 Sheardown Lake NW – Variability of Total Nickel in Water

Total Chromium (Figure B.36 and Figure B.37)

Ninety-one (91) total chromium concentration samples were collected from Sheardown Lake NW over the course of eight years. Chromium concentrations are low, with the exception of one outlier sampled at DL0-05-D (Figure B.36). Deep sites showed slightly elevated concentrations when compared with shallow samples.

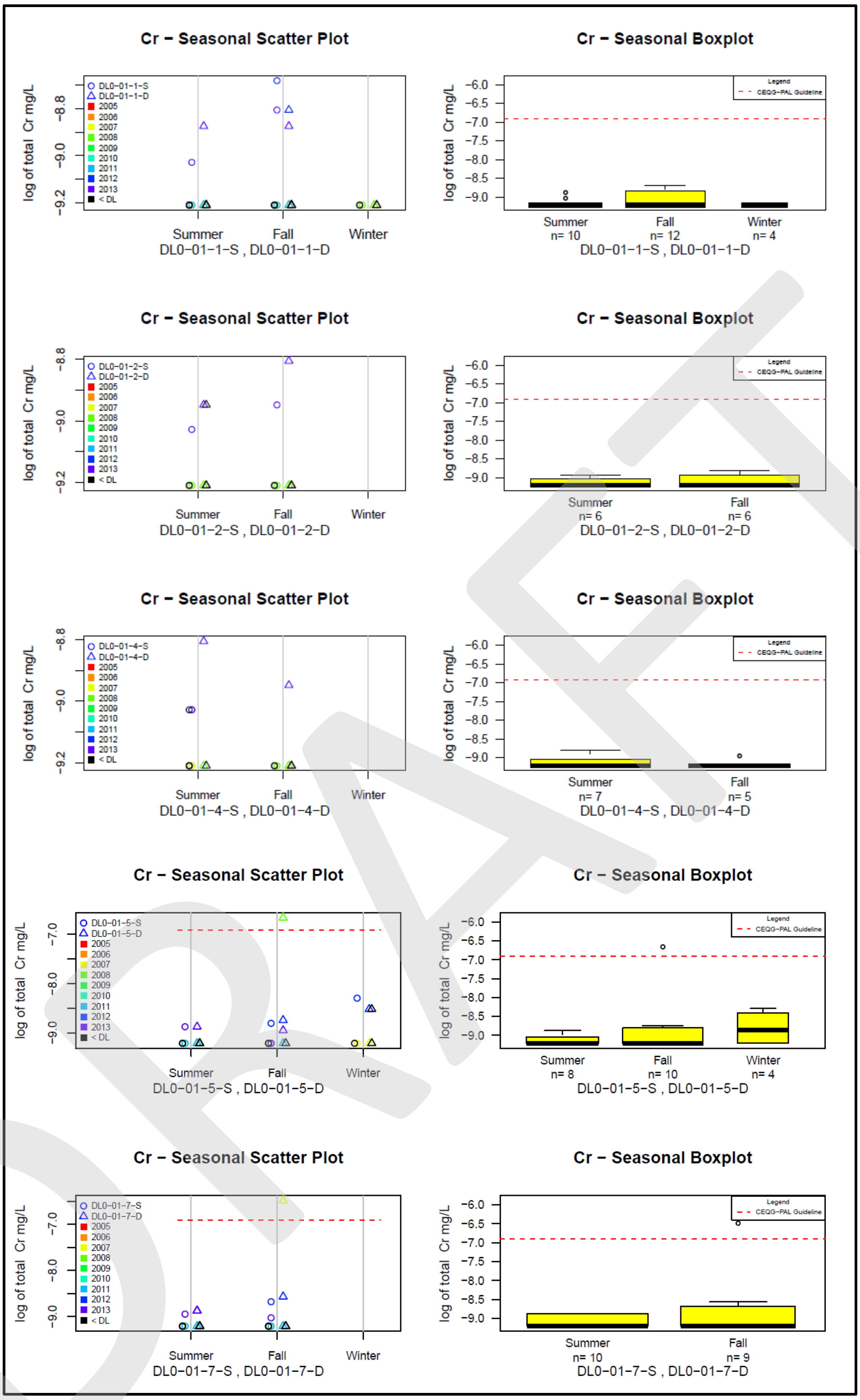
Seasonal scatterplots show 2012 and 2013 data is generally elevated when compared to older data (Figure B.37). Seasonal boxplots do not show a consistent seasonal trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.36 Sheardown Lake NW – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.37 Sheardown Lake NW – Variability of Total Chromium in Water

Summary of Sheardown Lake NW Water Quality

Summary of trends observed during review of Sheardown Lake NW baseline data:

- Deeper sampling stations show slightly elevated concentrations of aluminum. Distinct depth trends are not observed for other parameters within Sheardown Lake, which suggests that lake is completely mixed throughout the year, despite winter ice. As a result, aggregation of deep and shallow stations is appropriate for all parameters except aluminum.
- Detection limits decreased over the course of sampling and their decrease is particularly apparent in the copper and iron concentration data.
- Little variability was observed between geographically distinct sampling stations.
- Parameters below MDLs and/or do not show any seasonal trends: arsenic, cadmium, chloride, chromium, copper, nitrate and iron.
- Parameters with highest concentration occurring in the fall: aluminum.
- Parameters with highest concentrations occurring in the winter: nickel. The majority of the elevated nickel and copper total concentrations are as a result of dissolved metals.

B.2.2.2 Sheardown Lake SE

A total of forty-six (46) lake samples were collected from the southeast basin of Sheardown Lake from 8 sampling stations over the sampling period (Figures B.1 and B.2):

- DL0-02-1-S and DL0-02-1-D - Shallow and deep; located in west portion of Sheardown Lake SE.
- DL0-02-3-S and DL0-02-3-D - Shallow and deep; located in the centre of Sheardown Lake SE.
- DL0-02-4-S and DL0-02-4-D - Shallow and deep; located on the eastern lobe of Sheardown Lake SE.
- DL0-02-6-S and DL0-02-6-D - Shallow and deep; located in the most westerly portion of Sheardown Lake SE.

Most sampling was completed during the open water season, from July through September (summer and fall). Late winter sampling (May) was carried out only in 2007, 2008, 2012 and 2013. Six stations are reported in detail. Only one sample was taken at DL0-06-S and DL0-02-6-D, and therefore, these sites are excluded from graphical representation.

A summary of the data collected during each season, with respect to year and site are included in Table B.3. A graphical representation of the sampling events within Sheardown Lake for the six stations reported in detail is provided in Figure B.38.

Table B.3 Sheardown Lake SE Sample Size

Year	Summer	Fall	Winter
2006	1	1	0
2007	6	6	4
2008	8	6	2
2011	2	0	0
2012	0	2	2
2013	2	2	2
Site	**Summer**	**Fall**	**Winter**
DL0-02-1-S	3	2	1
DL0-02-1-D	5	3	1
DL0-02-3-S	3	4	3
DL0-02-3-D	3	4	3
DL0-02-4-S	3	2	0
DL0-02-4-D	2	2	0
DL0-02-6-S	0	0	1
DL0-02-6-D	0	0	1

NOTES:

1. WINTER SAMPLING OCCURRED DURING APRIL AND MAY; SPRING SAMPLING OCCURRED DURING JUNE; SUMMER SAMPLING OCCURRED FROM JULY TO AUGUST 17; FALL SAMPLING OCCURRED FROM AUGUST 18 THROUGH SEPTEMBER 30TH.
2. LAKE SAMPLING DID NOT OCCUR DURING SPRING, DUE TO SAFETY CONCERNS OF SAMPLING OVER MELTING ICE.
3. DURING WINTER 2013, SAMPLES WERE COLLECTED WITHIN SHEARDOWN LAKE AT D-LAKE-05.

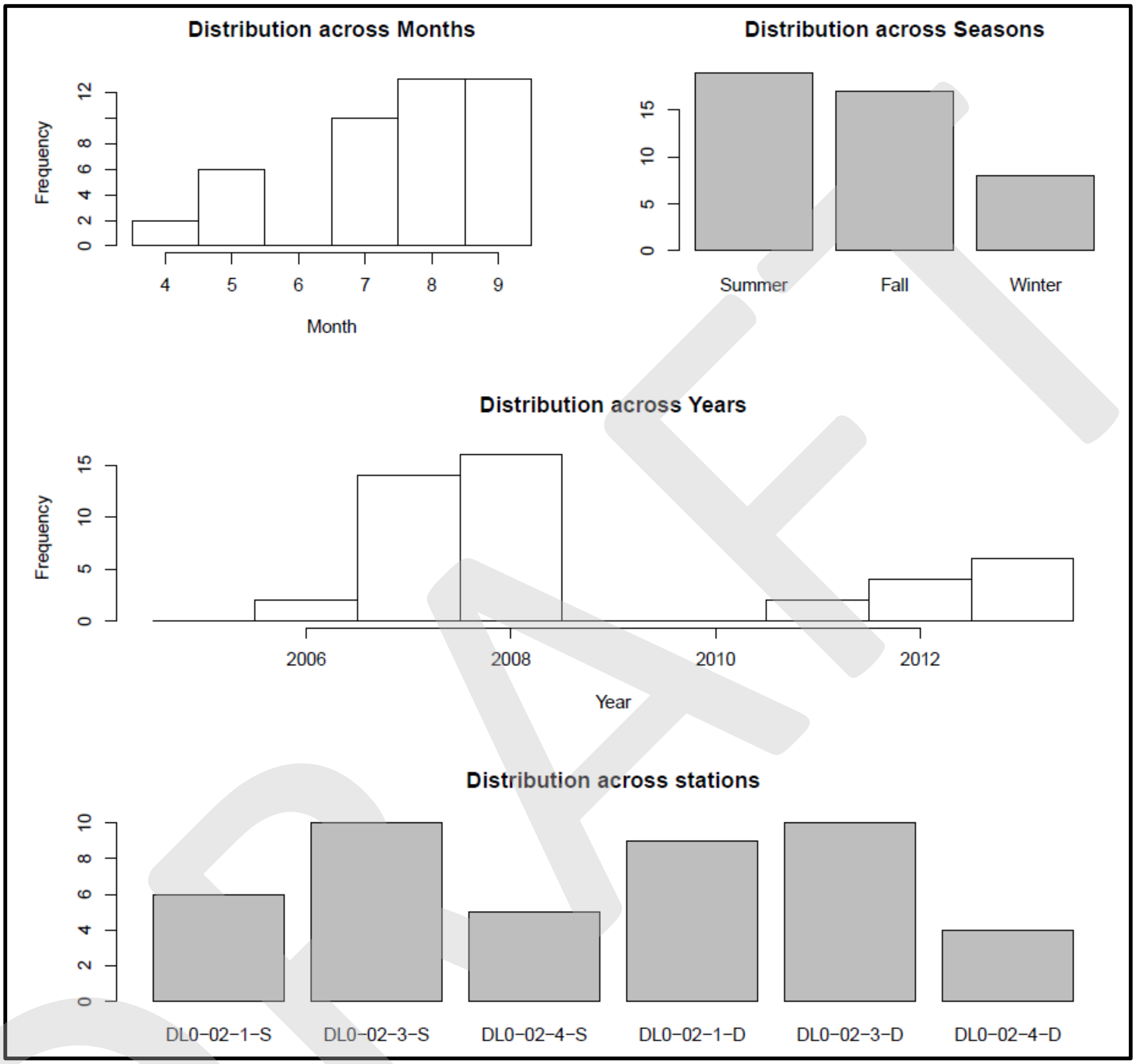


Figure B.38 Sheardown Lake SE – Graphical Summary of Sampling Events

The following summarizes the data review observations for Sheardown Lake NW.

pH (Figure B.39)

- Sheardown Lake NW is slightly alkaline with a median in-situ pH of 7.57 (range from 6.41 to 8.32).
- A slight influence of depth on pH is observed with a measured median in-situ pH at the deep stations of ~7.5, slightly lower compared to shallow samples (> 7.9).

Alkalinity (Figure B.39)

- Sheardown Lake sites are fairly uniform with median alkalinity values that range from 53 to 57 mg/L $CaCO_3$, classifying the lake water as having low sensitivity to acidic inputs.

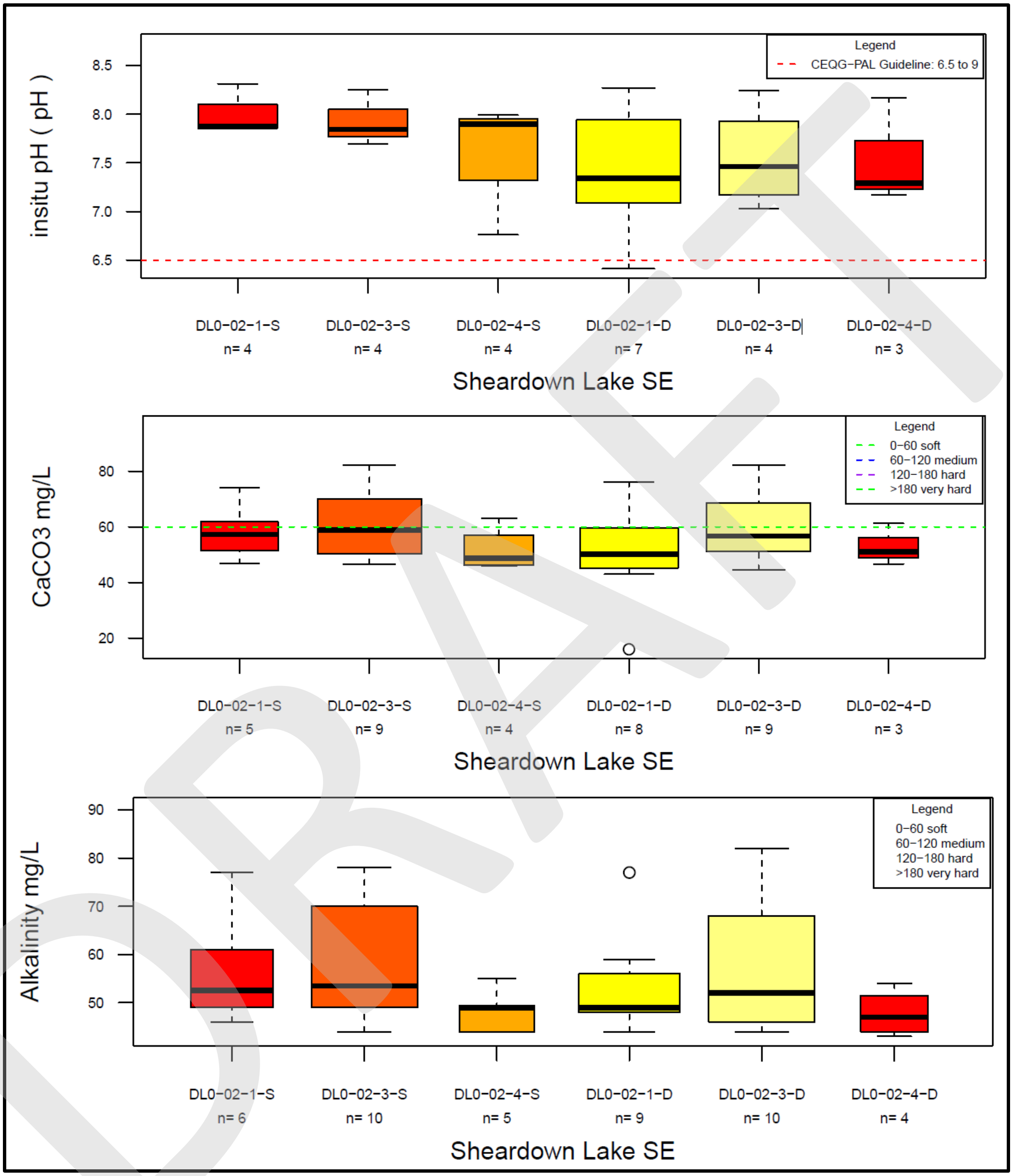


Figure B.39 Sheardown Lake SE – *In situ* pH, Alkalinity and Hardness

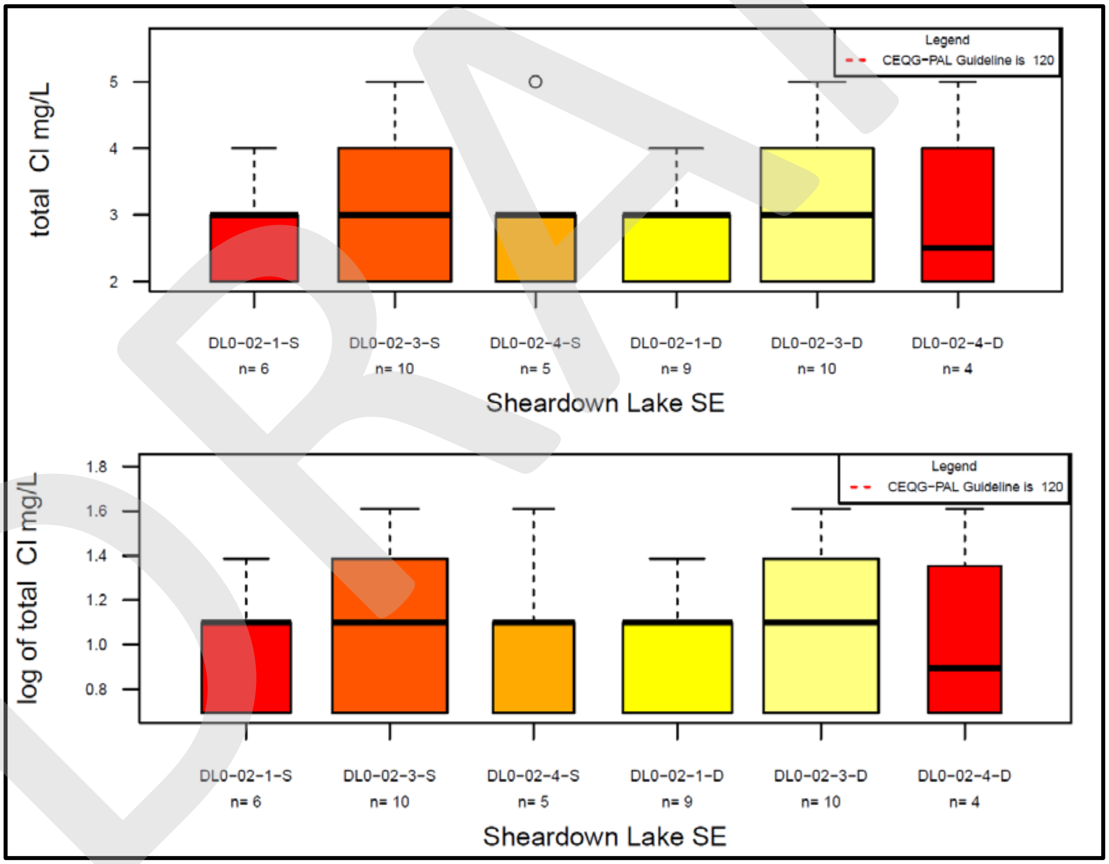
Hardness (Figure B.39)

- Median hardness ranged from 54 and 61 mg/L, classifying the lake water as “soft”.
- Hardness did not change meaningfully with depth, and portrayed trends very similar to alkalinity.
- The close range between hardness and alkalinity suggest that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.40 and B.41)

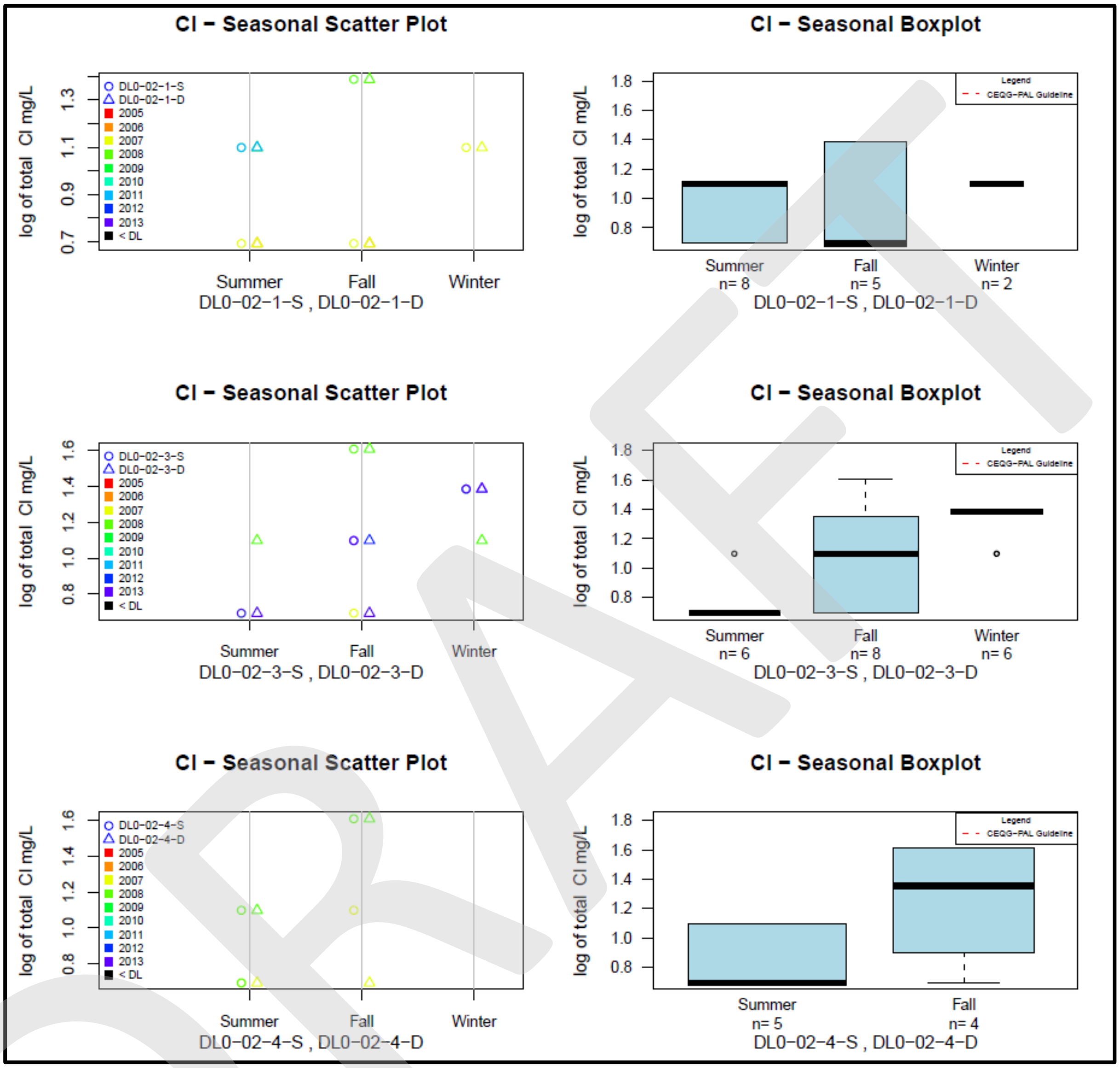
Forty-four (44) chloride concentration samples were collected at Sheardown Lake SE. Chloride concentrations in Sheardown Lake SE are very low and have maximum values of 5 mg/L, well below the CWQG-PAL limit of 120 mg/L (Figure B.40). All sites within Sheardown Lake SE have very similar median chloride concentrations that range between 0.9 mg/L to 1.1 mg/L. Log transformation does not reveal any outlying values in the data. Seasonal scatterplots indicate possible elevations of chloride concentrations in the winter. Additional baseline sampling will help to reveal this trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.40 Sheardown Lake SE – Chloride Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.41 Sheardown Lake SE – Variability of Chloride in Water

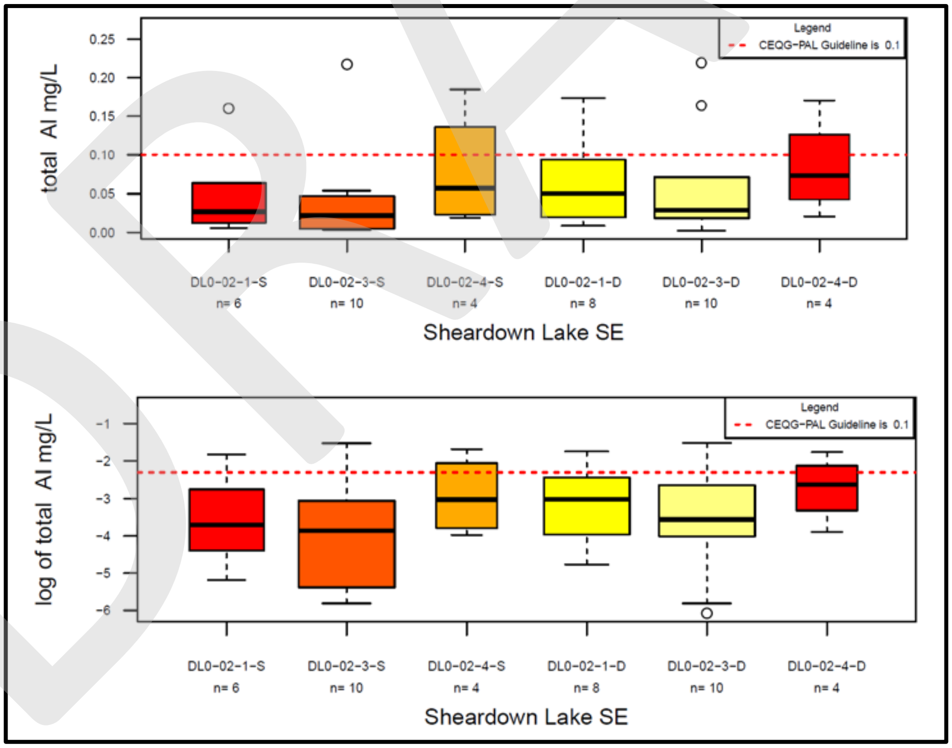
Nitrate

Forty-four (44) nitrate concentration samples were collected from Sheardown Lake SE over the course of eight years. All nitrate concentrations were measured at the detection limit (0.10 mg/L). As a result, no seasonal, inter-annual or depth variation can be determined and further graphical analyses are not warranted.

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations to reflect the applicable guidelines.

Total Aluminum (Figures B.42 and B.43)

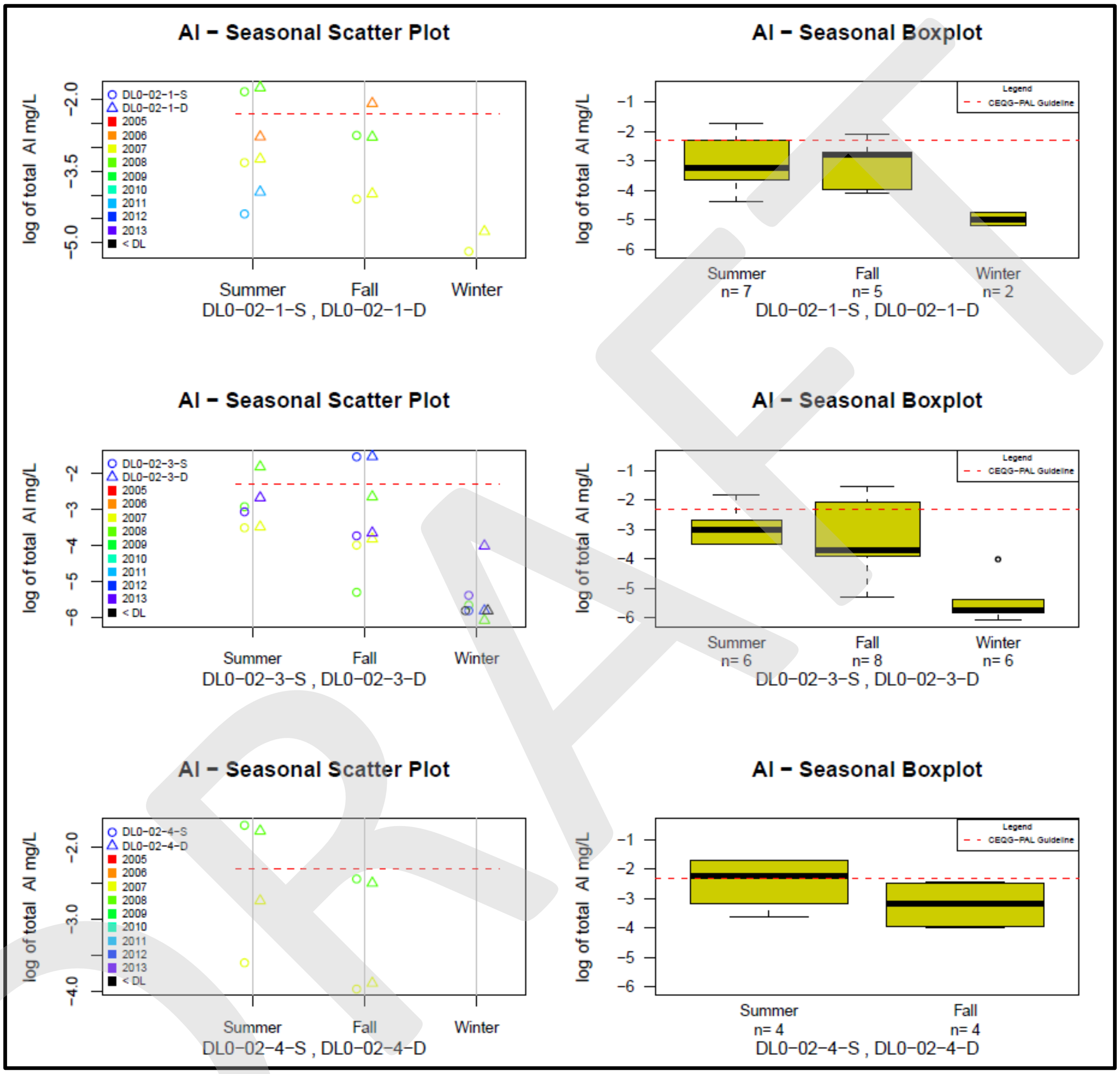
Forty-two (42) total aluminum concentration samples were collected from Sheardown Lake SE over the course of eight years. Total aluminum concentrations consistently report above MDLs and have 75th percentile values that exceed the CWQG-PAL guidelines of 0.1 mg/L (Figure B.42). All stations within Sheardown Lake have median aluminum concentrations that range from 0.02 mg/L to 0.06 mg/L. Deeper sampling stations show slightly elevated concentrations when compared to shallow stations. Comparison of raw data and log values reveals fewer outliers within the log transformed data, as expected. Similar to Sheardown NW, Sheardown SE data shows summer and fall concentrations of aluminum remain fairly elevated, while winter concentrations are reduced in comparison (Figure B.43).



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.42 Sheardown Lake SE – Total Aluminum Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.43 Sheardown Lake SE – Variability of Total Aluminum in Water

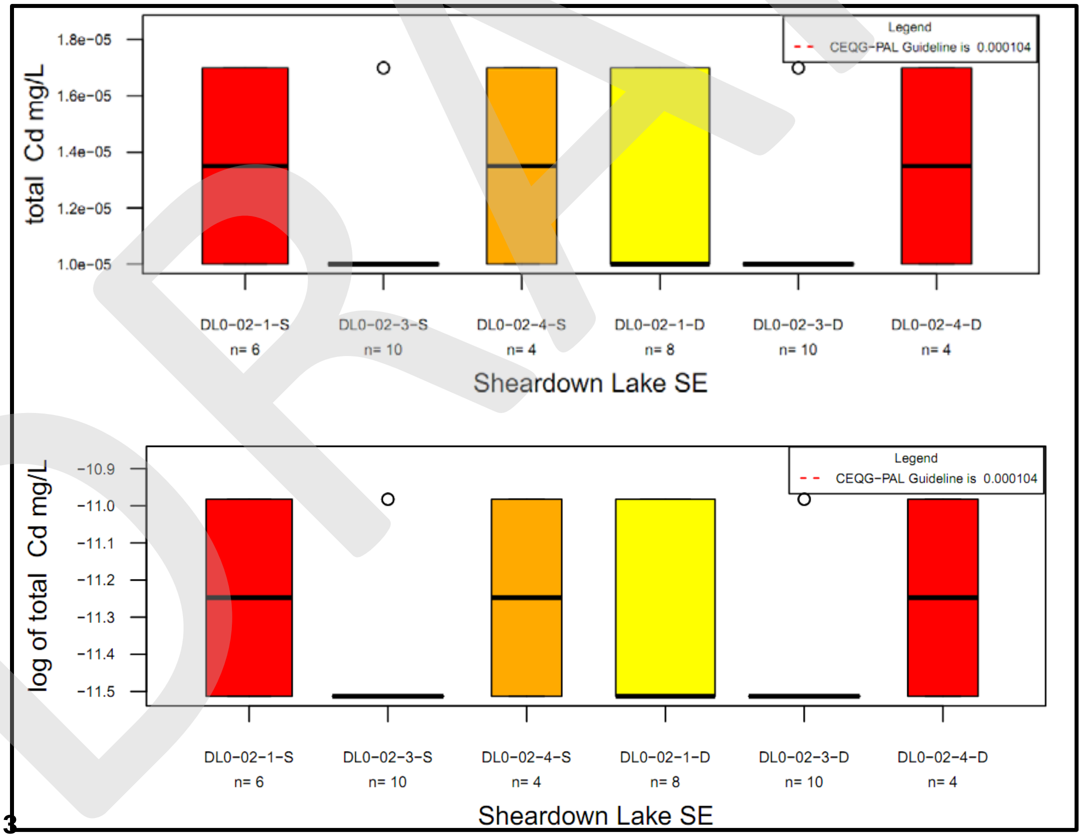
Total Arsenic

With the exception of one sample, the remaing (forty-one) measured total arsenic levels report at detection limit and are therefore not not portrayed via graphical representation. The detection limit (0.00010 mg/L) and the one outlying value (0.00011 mg/L) are far below the CWQG-PAL guideline limit (0.005 mg/L).

Total Cadmium (Figures B.44 and B.45)

Forty-two (42) total cadmium concentration samples were collected from six sites in Sheardown Lake SE over the course of eight years. Cadmium concentrations consistently report at or below MDLs, and are consistently below the CWQG-PAL guideline (Figure B.44). Although total boxplots of all data seem to indicate a range of values at each sampling point, this is as a result of two different detection limits. Seasonal scatterplots reveal that earlier data from 2007 had a detection limit of 0.000017 mg/L and later data from 2009 onwards had a detection limit of 0.00001 mg/L.

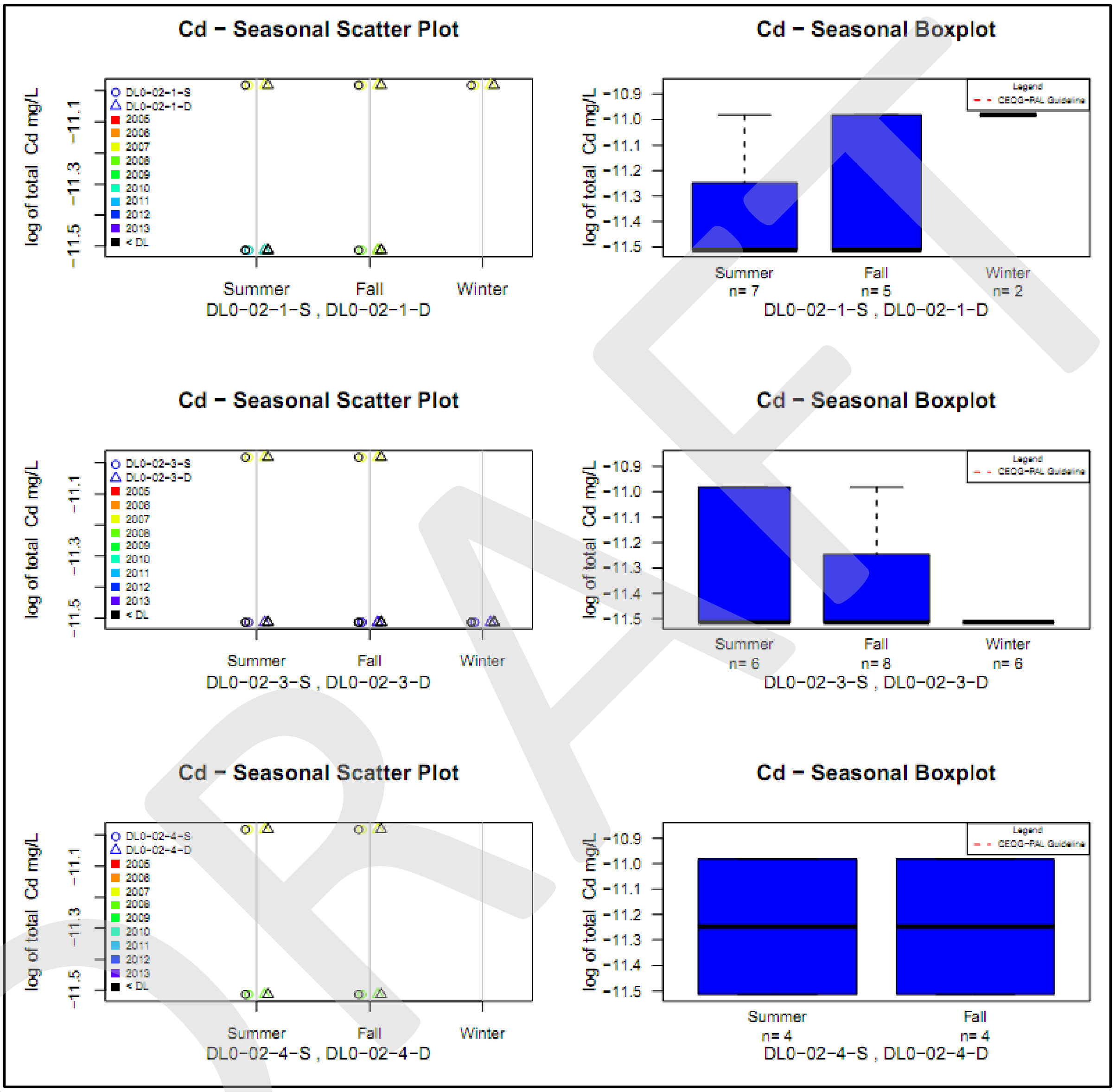
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations, as a result of MDL interference (Figure B.45). Similarly, seasonal differences are not noted as a result of MDL interference.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.44 Sheardown Lake SE – Total Cadmium Concentrations in Water



NOTES:

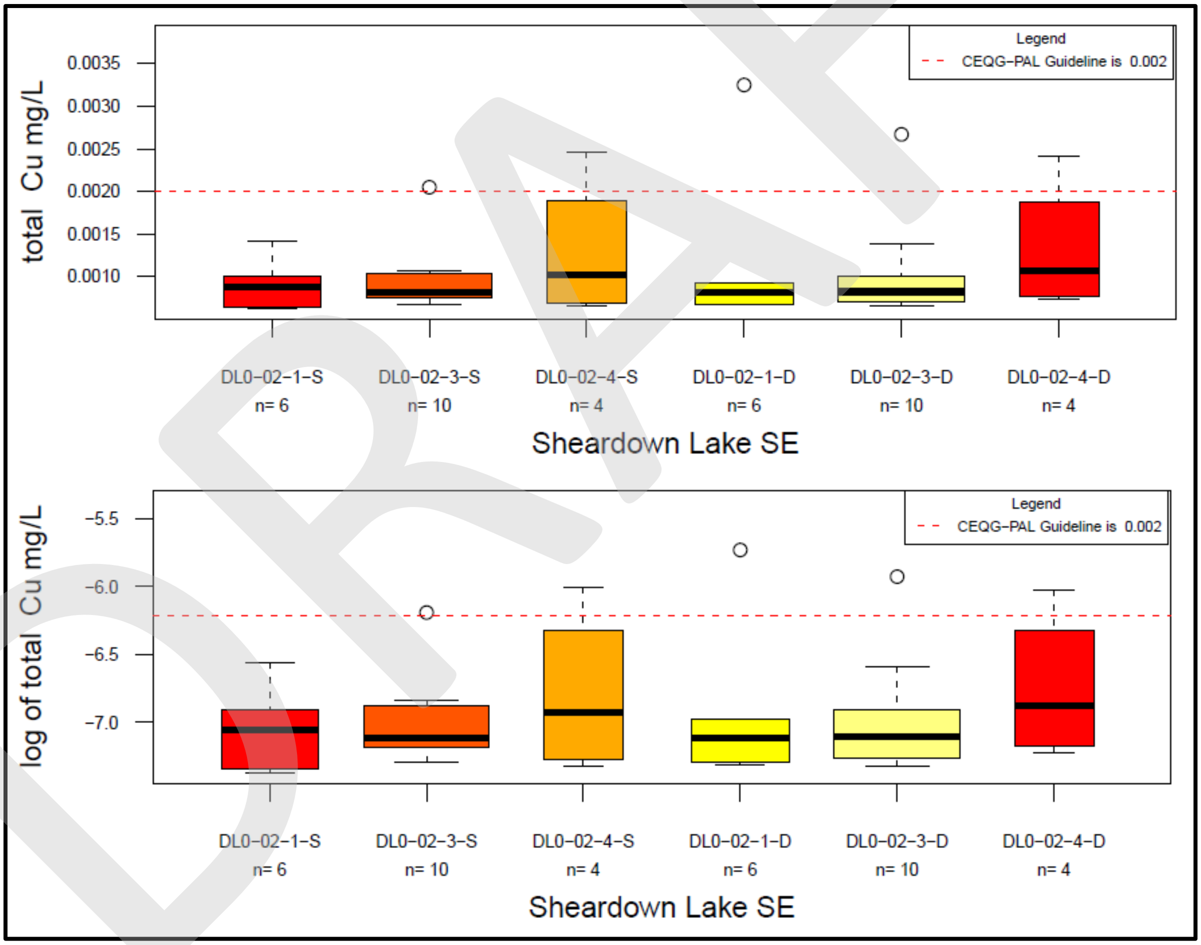
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.45 Sheardown Lake SE – Variability of Total Cadmium in Water

Total Copper (Figures B.46 and B.47)

Forty (40) total copper concentration samples were collected from six stations in Sheardown Lake SE over the course of eight years. Total copper concentrations consistently report above MDLs, and, with the exception of a few outliers, below the CWQG-PAL guideline (Figure B.46). Outliers at two deep and one shallow station just exceed the CWQG-PAL guideline of 0.002 mg/L, with a maximum outlying value of 0.0032 mg/L. Concentrations at DL0-02-4 are elevated compared to the other sites, which indicates inputs from D-Stream-3 might be higher in total copper concentrations than inputs from Sheardown NW. Log transformation of the data does not remove outliers observed in data.

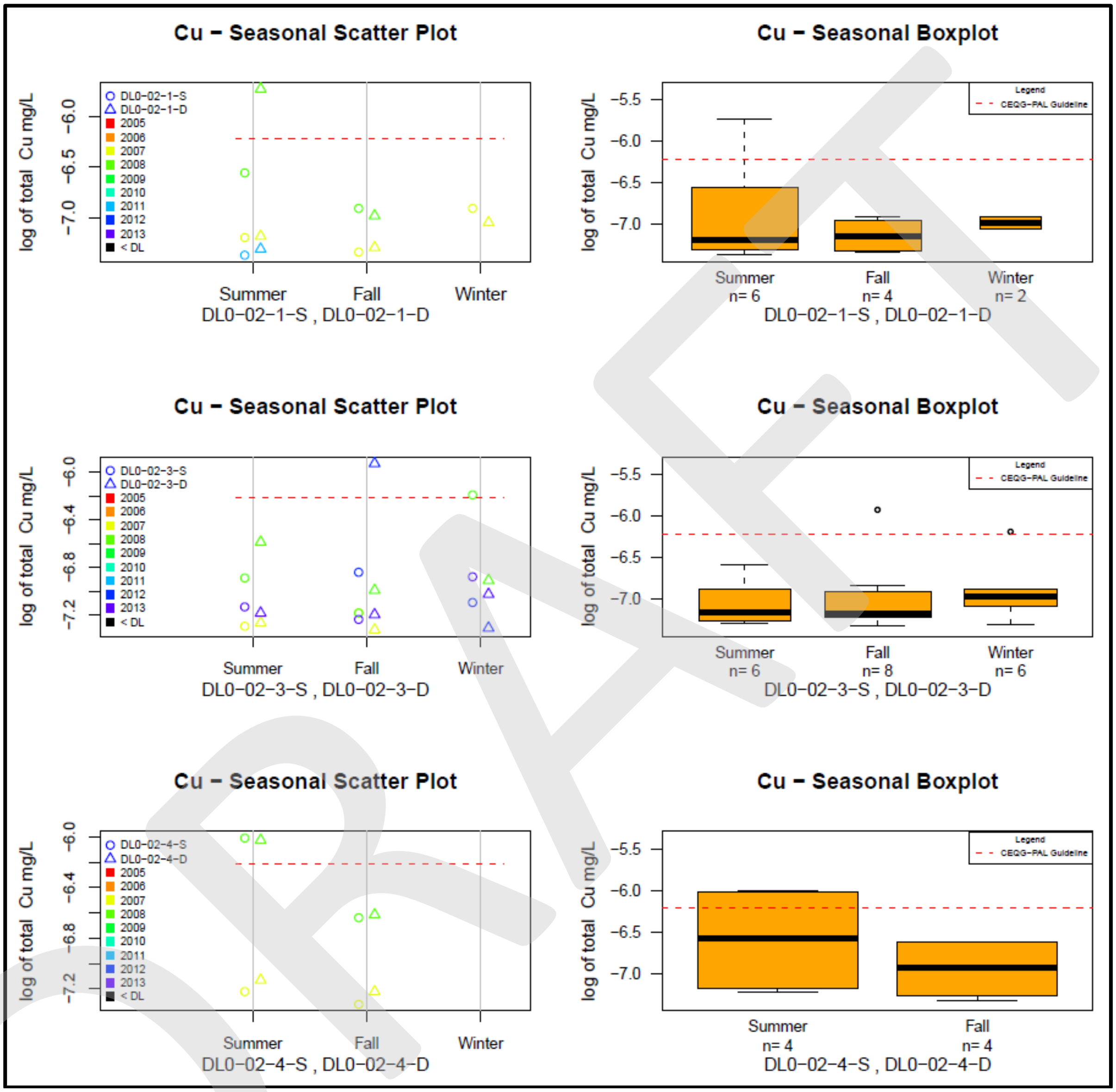
Seasonal scatterplots that combine data from deep and shallow sampling stations do not show a consistent trend across stations (Figure B.47). Data from 2008 appears to be slightly elevated when compared to later data. With the data available, distinct seasonal trends are not observed.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.46 Sheardown Lake SE – Total Copper Concentrations in Water



NOTES:

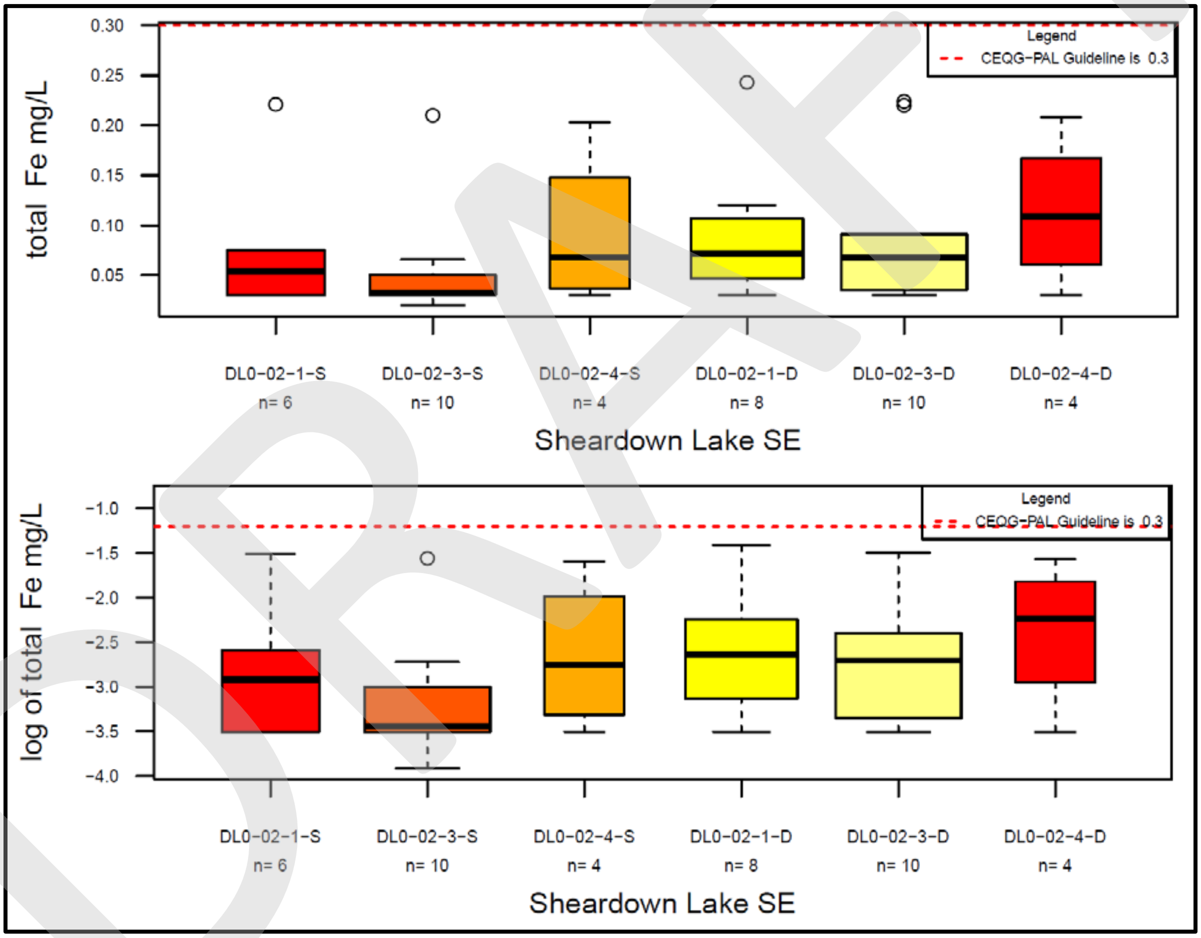
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.47 Sheardown Lake SE – Variability of Total Copper in Water

Total Iron (Figures B.48 and B.49)

Forty-two (42) total iron concentration samples were collected from Sheardown Lake SE at six stations over the course of eight years. The majority of total iron concentrations report above MDLs, band all samples report below the CWQG-PAL guideline of 0.3 mg/L (Figure B.48). Similar to copper, station DL0-02-4 has slightly elevated total iron concentrations when compared to the other stations in Sheardown Lake SE.

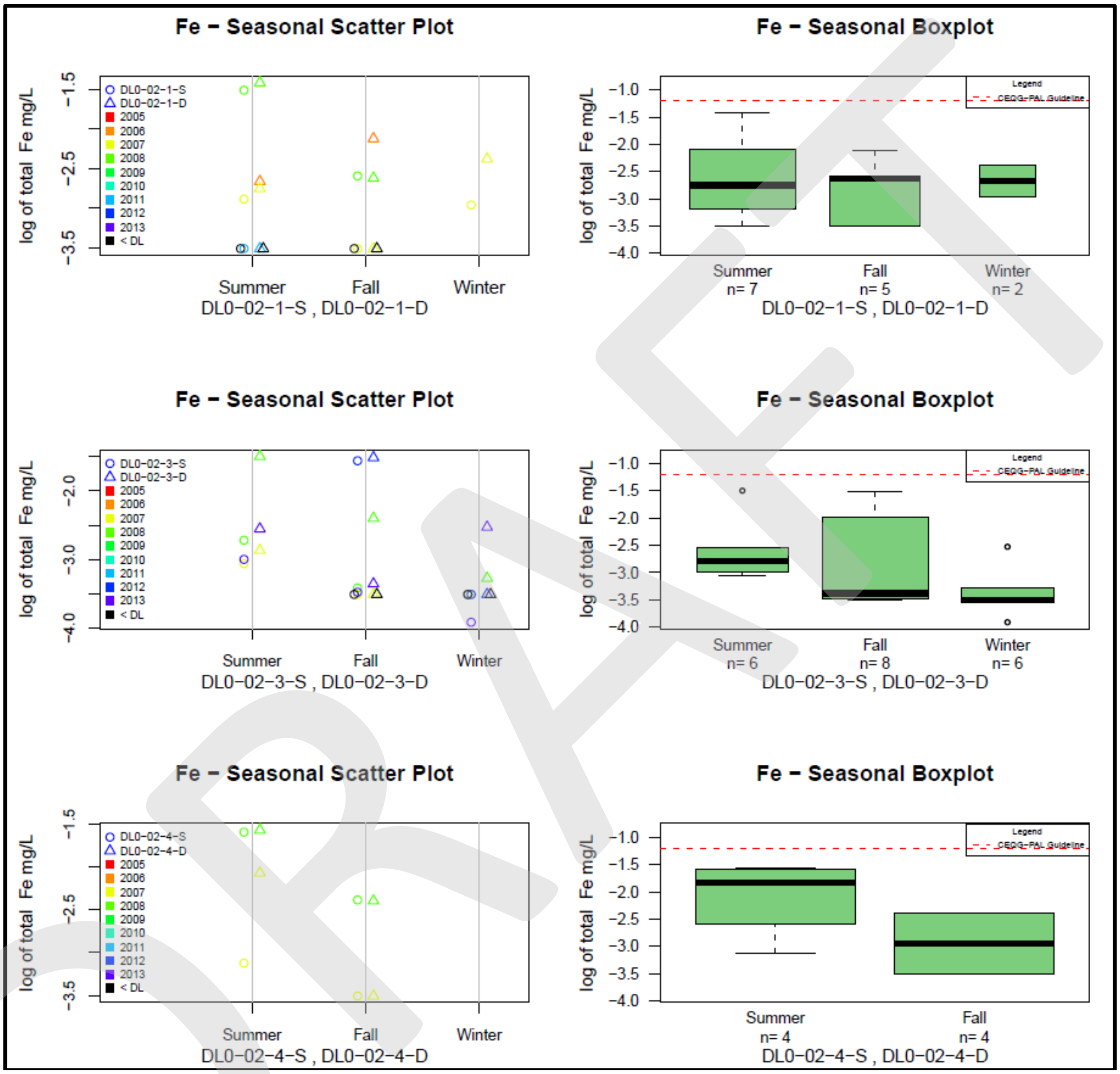
Seasonal scatterplots that combine data from deep and shallow sampling stations show no difference in values between the two stations (Figure B.49). Slightly elevated summer concentrations are noted; however, more samples are required to understand magnitude of seasonal trend.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.48 Sheardown Lake SE – Total Iron Concentrations in Water



NOTES:

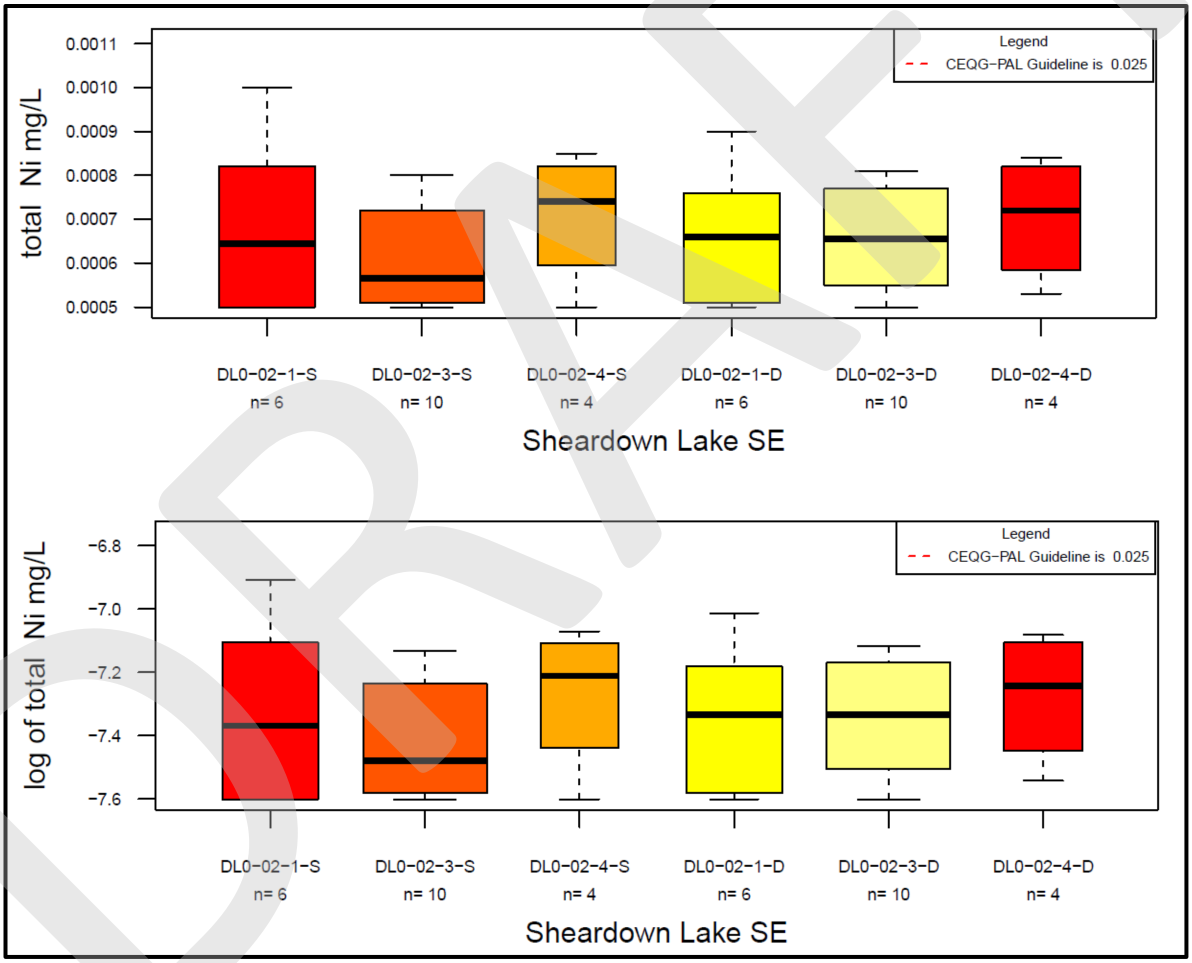
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.49 Sheardown Lake SE – Variability of Total Iron in Water

Total Nickel (Figures B.50 and B.51)

Forty (40) total nickel concentration samples were collected from Sheardown Lake SE at six sample stations over the course of eight years. Nickel concentrations consistently report above MDLs, but well below the CWQG-PAL guideline (0.025 mg/L) (Figure B.50). Median total nickel concentrations are consistent throughout the geographically distinct sampling stations and range from 0.00055 mg/L through 0.00075 mg/L. Similar to other iron, nickel concentrations are slightly elevated at the DL0-02-4 station.

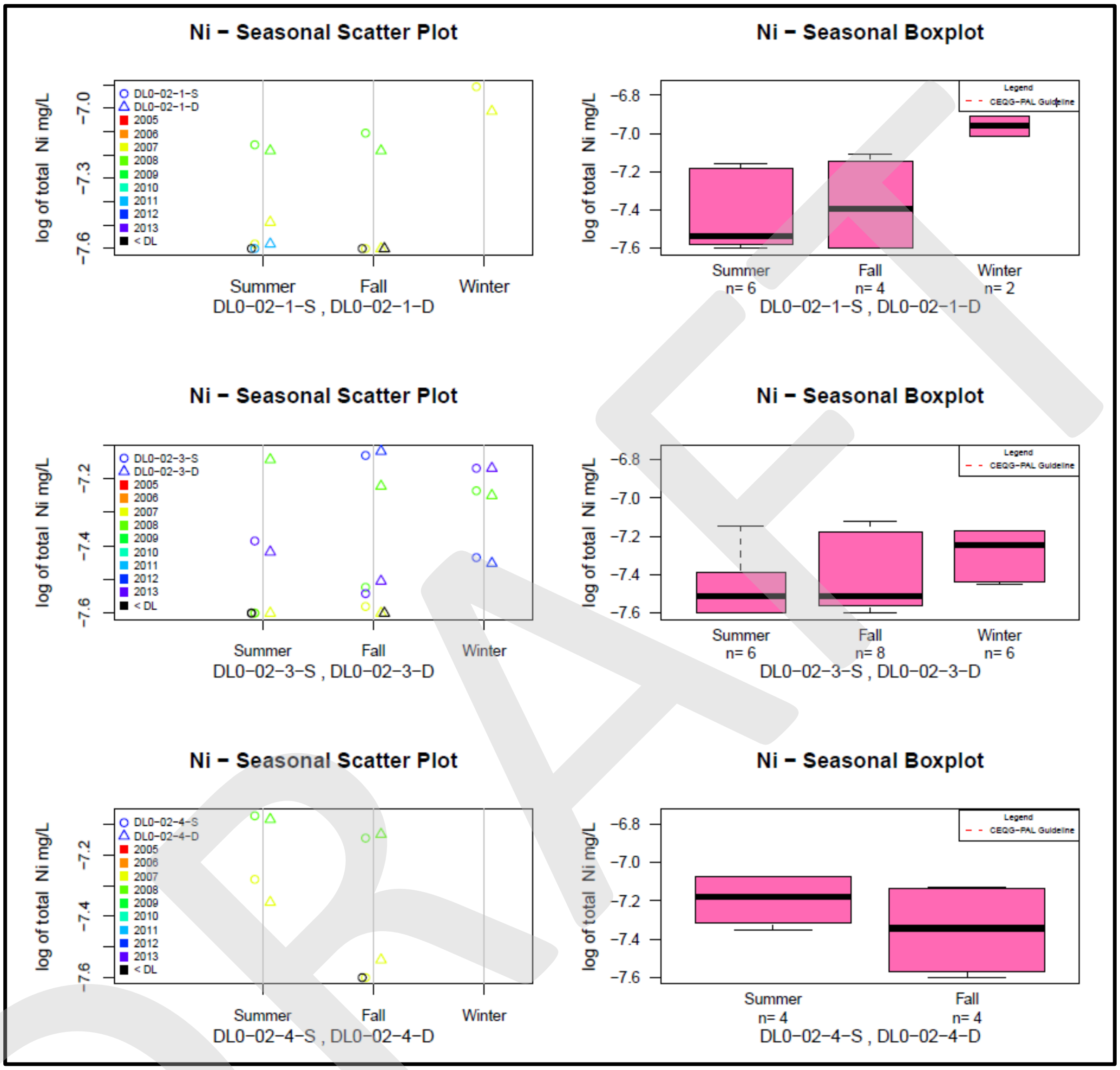
Seasonal scatterplots show that elevated concentrations are derived from early sampling (2007 and 2008), especially at DL0-02-1 and DL0-02-4 (Figure B.51). Although the winter dataset is limited, the current data indicates concentration peaks for nickel occur during the winter.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.50 Sheardown Lake SE – Total Nickel Concentrations in Water



NOTES:

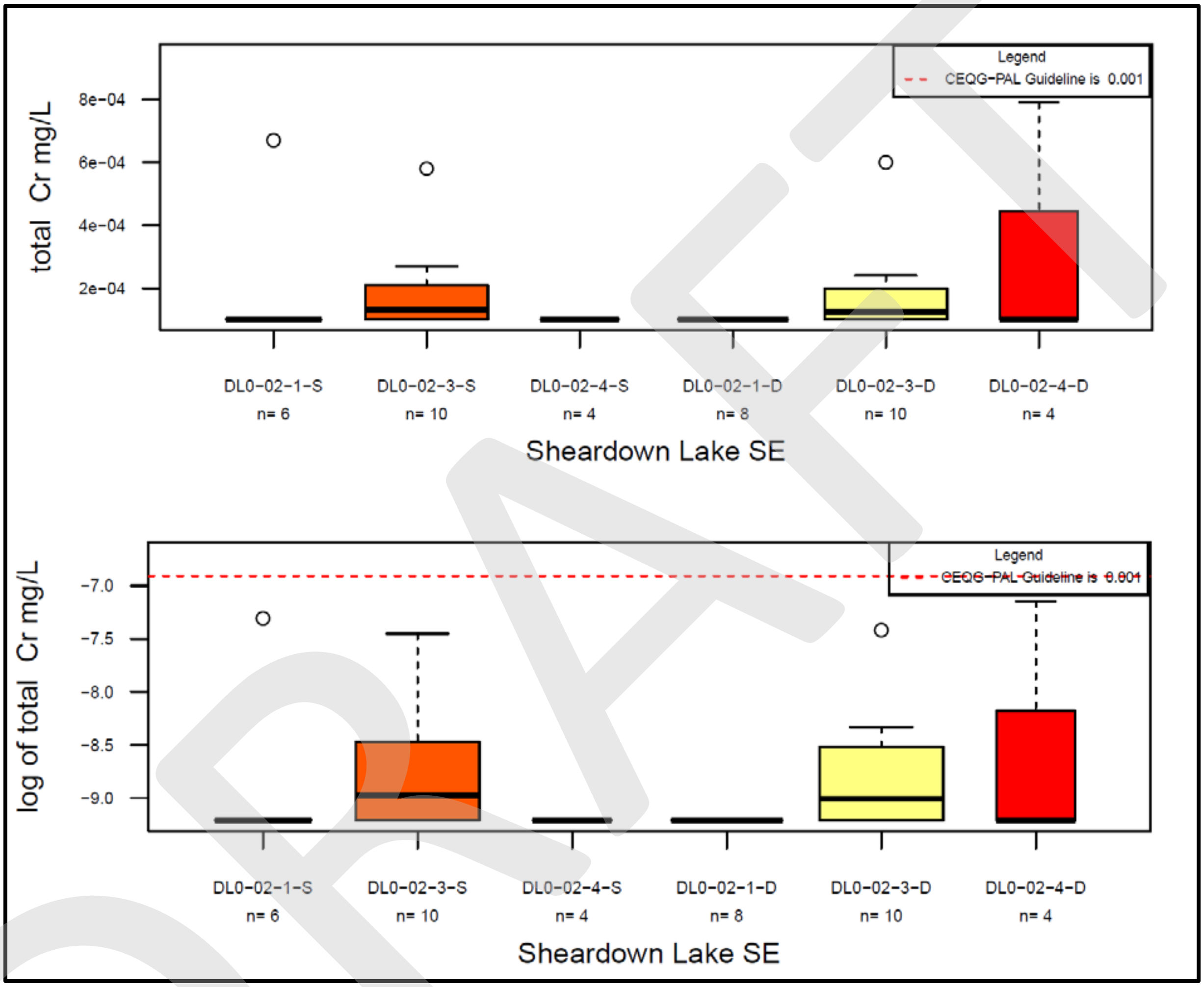
1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.51 Sheardown Lake SE– Variability of Total Nickel in Water

Total Chromium (Figures B.52 and B.53)

Forty-two (42) total chromium concentration samples were collected from Sheardown Lake SE at six sample stations over the course of eight years. Chromium concentrations are generally low, but concentrations are certain sites approach the CWQG-PAL guideline (0.001 mg/L) (Figure B.52). Samples from DL0-02-3/D and DL0-02-4-D are slightly elevated compared to the other stations with Sheardown Lake SE, but the trend is so muted, it is not considered important.

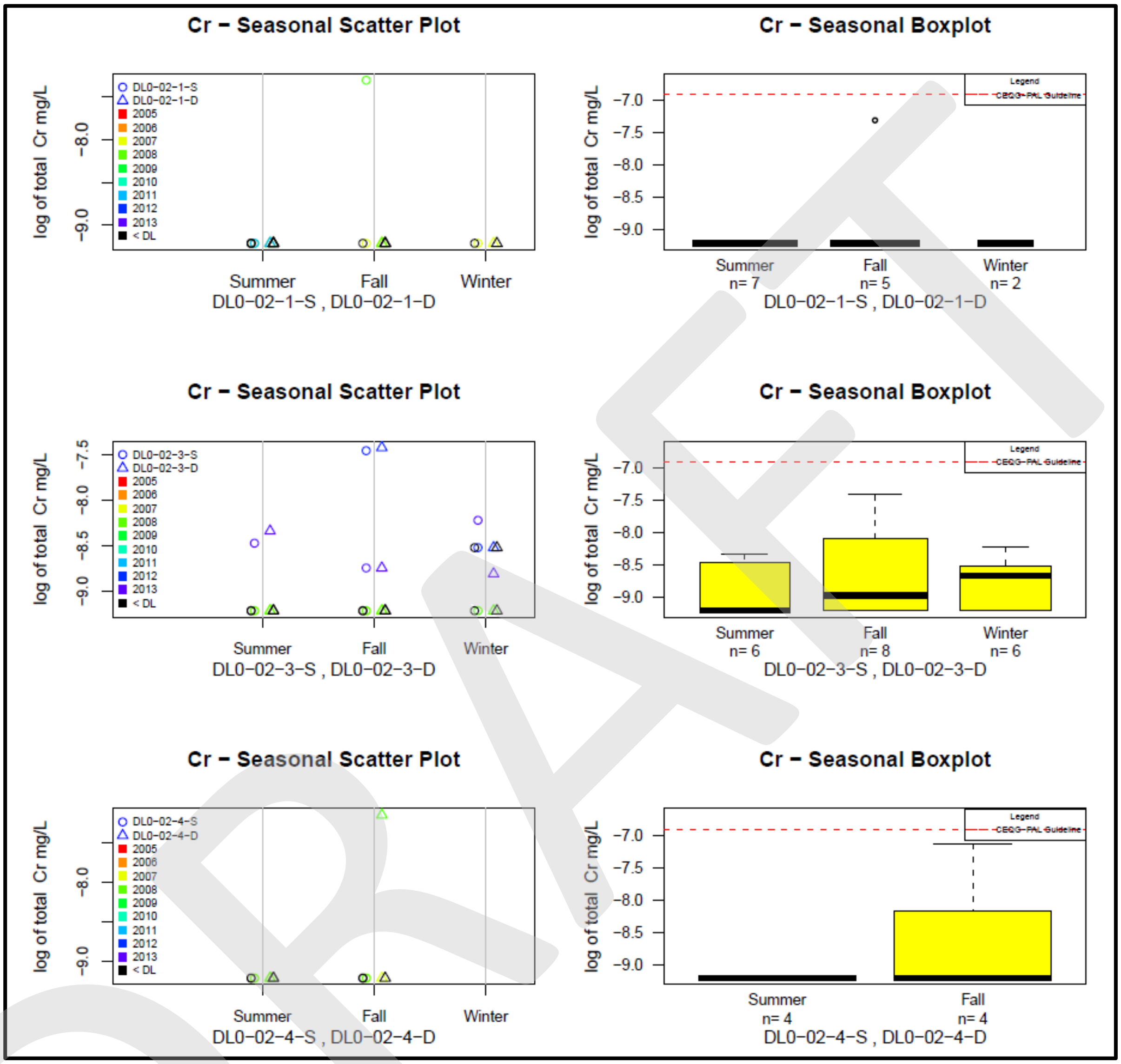
Seasonal scatterplots show that elevated concentrations at DL0-02-3-D are derived from recent sampling, during 2012 and 2013 (Figure B.53). No consistent seasonal trend was noted between sites.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.52 Sheardown Lake SE – Total Chromium Concentrations in Water



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.53 Sheardown Lake SE– Variability of Total Chromium in Water

Summary of Sheardown Lake SE Water Quality

Summary of trends observed during review of Sheardown Lake SE baseline data:

- Distinct depth trends are not observed for any parameters within Sheardown Lake SE, which suggests that lake is completely mixed throughout the year, despite winter ice.
- Elevated concentrations observed at DL0-02-4 compared to other sites: copper, iron and nickel.
- Early data (2007, 2008) appears elevated when compared to more recent data: copper and nickel.

- Parameters below MDLs and/or do not show any seasonal trends: nitrate, arsenic, cadmium, chromium and copper.
- Parameters with highest concentration occurring in the summer and/or fall: aluminum and iron.
- Parameters with highest concentrations occurring in the winter: chloride and nickel.

B.2.3 Mary Lake

A total of eighty-five (85) lake samples were collected at twelve stations over the eight-year sampling history at Mary Lake (Figures B.1 and B.2):

- BL0-01-D and S - Within a small basin at the north end of the northern arm of Mary Lake to which Camp Lake drains.
- BL0-03-D and S - Located at the centre of Mary Lake.
- BL0-04-D and S - Located in the centre of the main basin of Mary Lake.
- BL0-05-D and S - Located within the main basin of Mary Lake near the mouth of the Mary River.
- BL0-05-B4-D and S - Located at the inlet of Mary Lake.
- BL0-06-D and S - Located within the southern portion of Mary Lake.

Most samples were collected in 2007 and no samples were collected during 2009 and 2010. Most samples occurred in the summer, and the least number of samples were collected in the winter.

A summary of the data collected during each season, with respect to year and site are presented in Table B.4 and a graphical representation of the sampling events is provided in Figure B.54. Note that for the purposes of graphical analysis, data from BL0-05-B4 has been pooled with data from BL0-05.

Table B.4 Mary Lake Sample Size

Year	Summer	Fall	Winter
2006	8	4	0
2007	10	14	8
2008	10	0	4
2011	4	0	0
2012	0	2	0
2013	10	6	5
Site	**Summer**	**Fall**	**Winter**
BL0-01-S	4	3	2
BL0-01-D	4	2	4
BL0-03-S	4	2	1
BL0-03-D	4	2	1
BL0-04-S	4	2	2
BL0-04-D	4	2	2
BL0-05-S	5	5	2
BL0-05-D	5	5	2
BL0-05-B4-S	1	0	0
BL0-05-B4-D	1	0	0
BL0-06-S	3	2	0
BL0-06-D	3	2	0

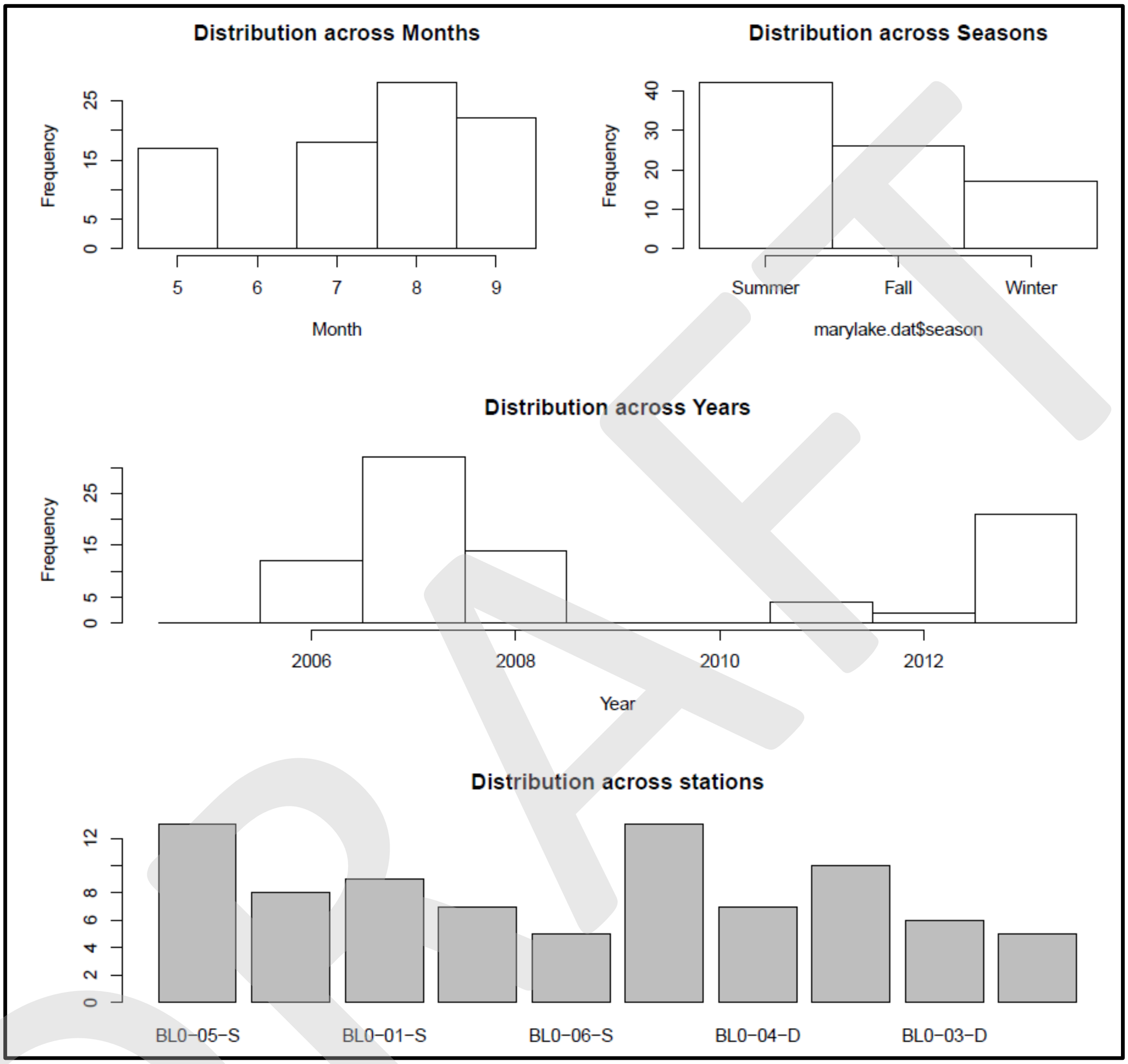


Figure B.54 Mary Lake – Graphical Summary of Sampling Events

The following summarizes the data review observations of the physical parameter data for Mary Lake.

pH (Figure B.55)

- The median pH from all samples collected in Mary Lake is ~7.5. Median values for pH at station within Mary Lake range from 6.6 to 8.3.

Alkalinity (Figure B.55)

- Mary Lake stations generally have alkalinity values that are below 40 mg/L $CaCO_3$; however, BL0-01-S/D show elevated median alkalinity values equal to approximately 70 mg/L $CaCO_3$.
- Differences between deep and shallow stations are not noted.

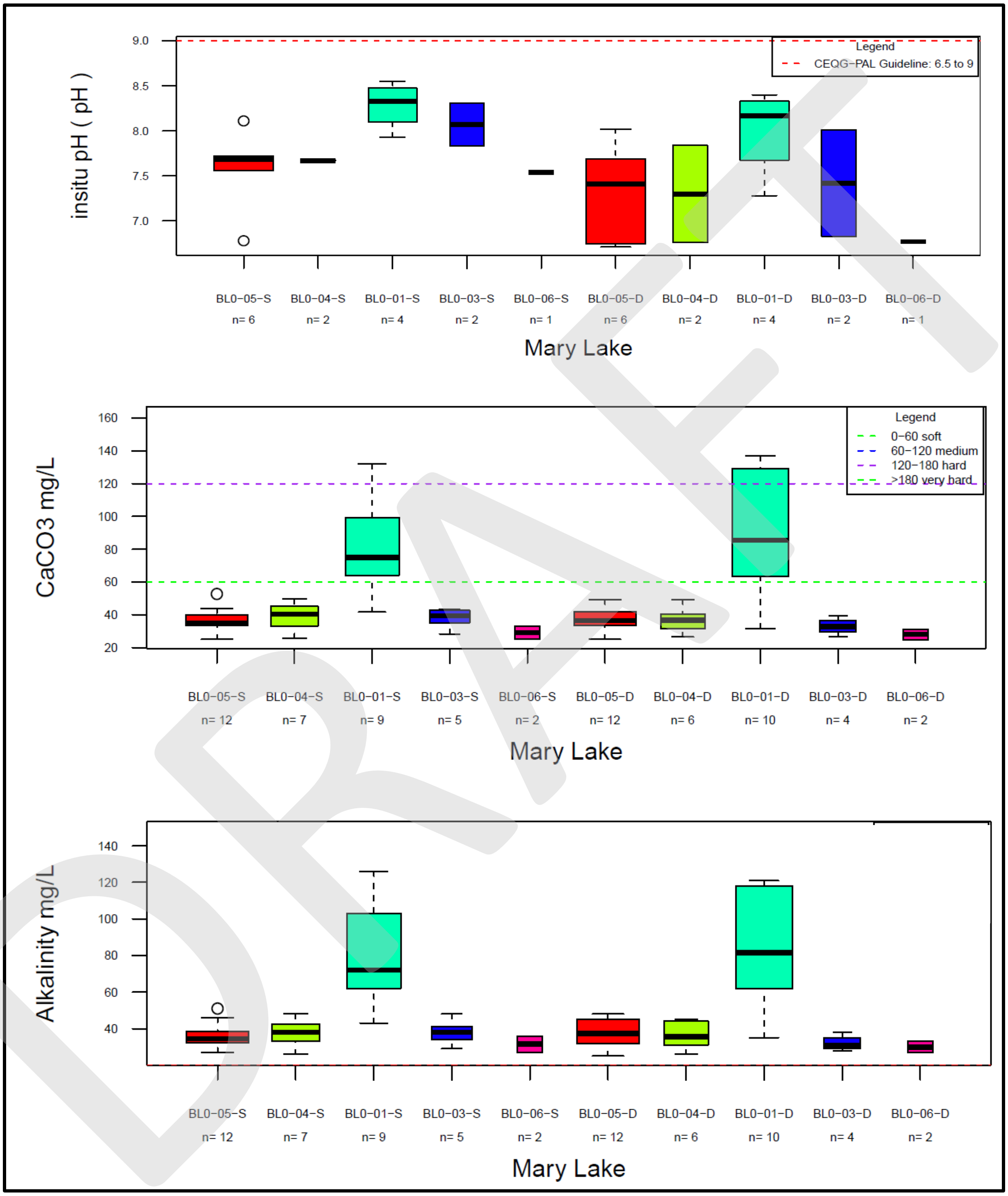


Figure B.55 Mary Lake – In-situ pH, Alkalinity and Hardness

Hardness (Figure B.55)

- Mary Lake stations have “soft water” and generally have alkalinity values that are below 40 mg/L hardness measured as $CaCO_3$, with the exception of BL0-01-S/D which has elevated median alkalinity values equal to ~80 mg/L $CaCO_3$.
- Differences between deep and shallow stations are not noted.
- Hardness portrayed trends very similar to alkalinity and suggests that the hardness is almost entirely carbonate hardness with little to no non-carbonate contributions to hardness.

The following sections summarize the results for the non-metallic inorganic parameters of interest: chloride and nitrate.

Chloride (Figures B.56 and B.57)

Sixty-nine (69) chloride concentration samples were collected from Mary Lake over the course of eight years. Chloride concentrations are consistently low, and each geographically distinct site in Mary Lake has a median than ranges from 2 to 2.5 mg/L (Figure B.56). This is well below the CWQG-PAL limit of 120 mg/L. A comparison of total data and seasonal scatterplots reveals that deep and shallow stations located at the same location vary little in reported concentrations. BL0-01-S and BL0-01-D show the greatest variability and have the largest sample size. These stations have outlying values recorded around 11 mg/L to 14 mg/L. The BL0 sampling stations are located in a small basin at the north end of the north arm of the lake, which receives flows from Camp Lake as well as the Tom River (Figure B.1).

Seasonal boxplots show lower chloride concentrations occur in the summer and higher concentrations occur in the winter (Figure B.57).

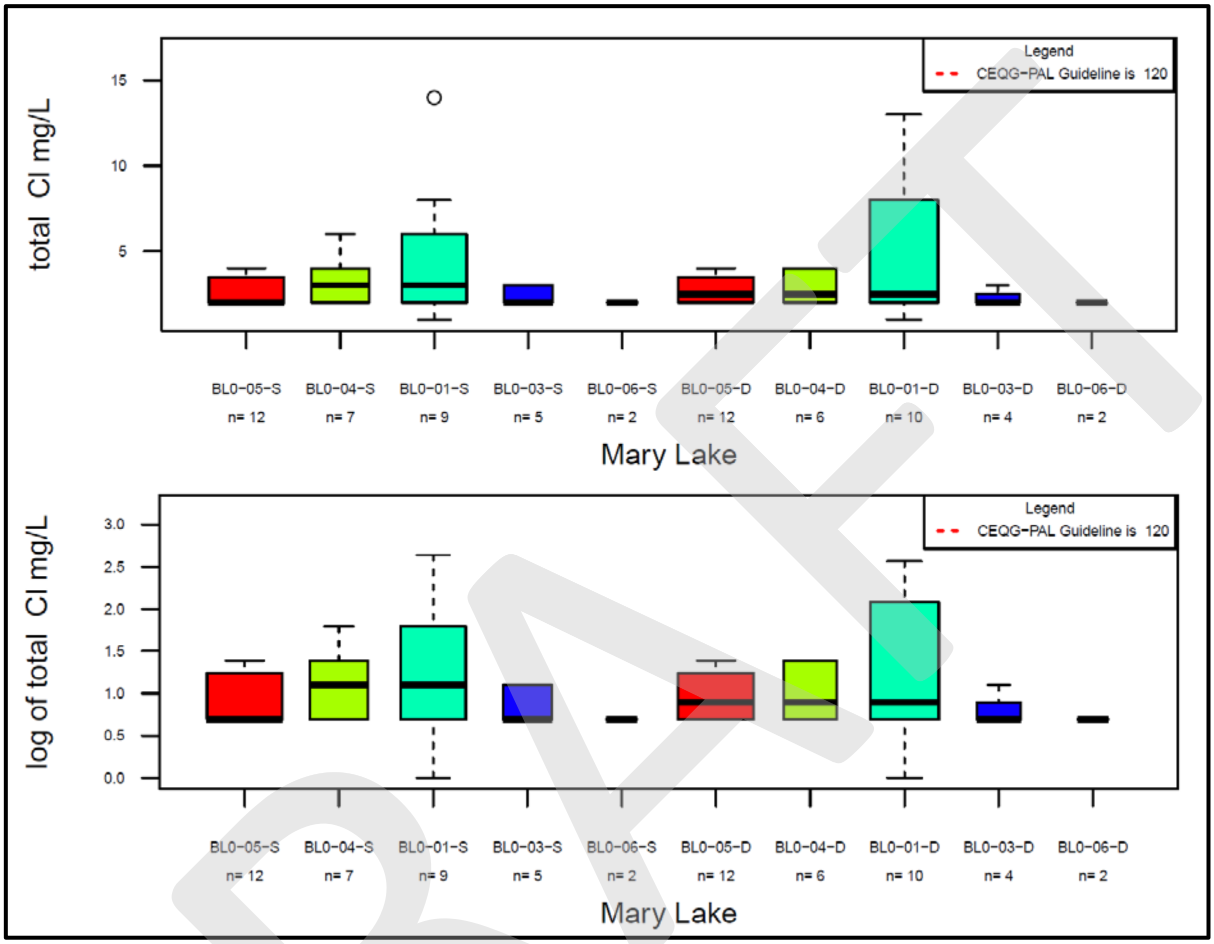
Nitrate

Sixty-nine (69) nitrate concentration samples were collected from Mary Lake over the course of eight years. All nitrate concentrations were measured at the detection limit (0.10), which is well below the CWQG-PAL limit (3 mg/L). As a result, no seasonal, inter-annual or depth variation can be determined and further graphical analyses are not warranted.

The following sections summarize the results for the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron, and nickel. All metals are discussed as total concentrations instead of dissolved concentrations, to reflect both the total dissolved and particulate metal loading.

Total Aluminum (Figure B.58 and Figure B.59)

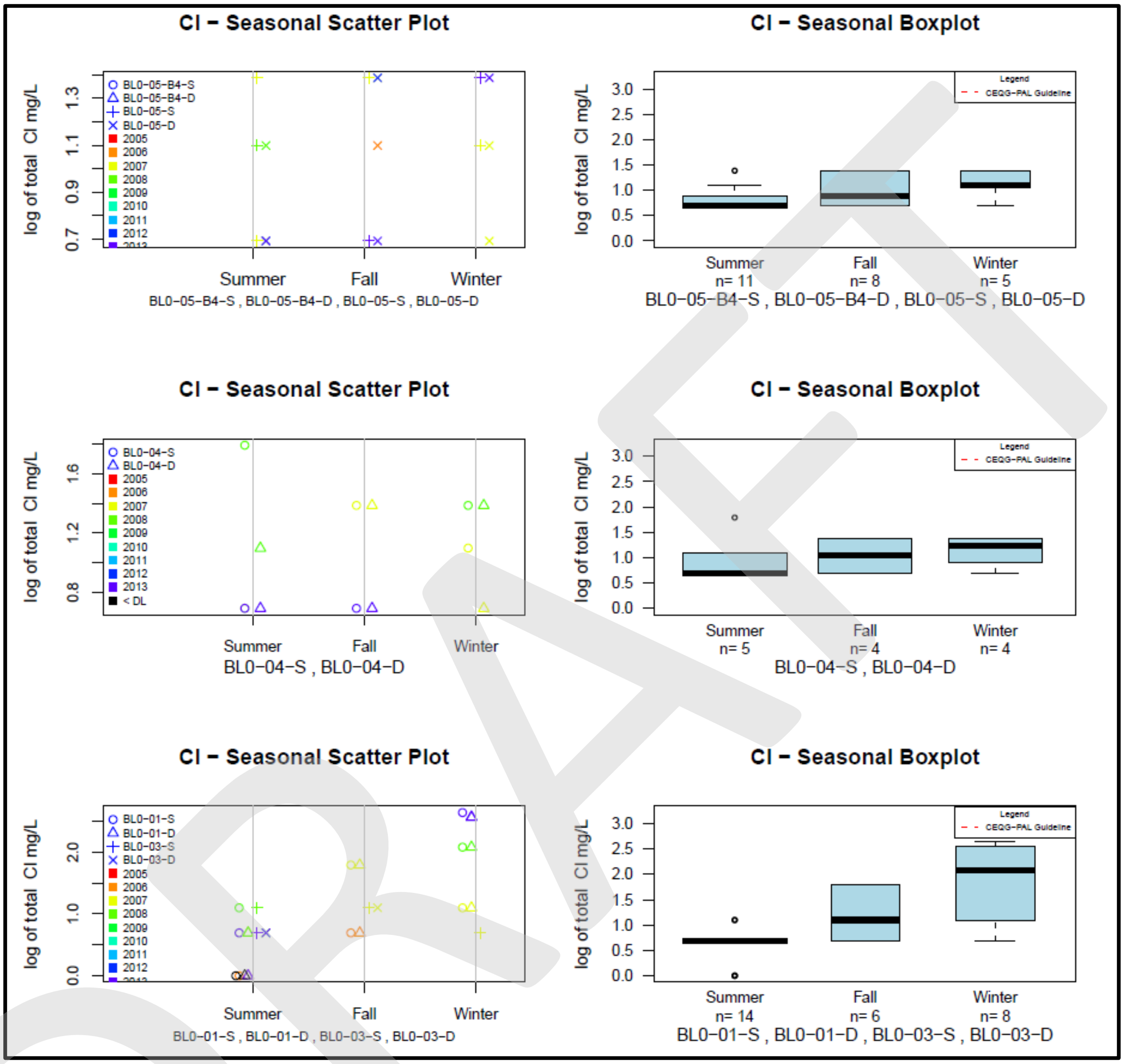
Sixty-nine (69) total aluminum concentration samples were collected from Mary Lake over the course of eight years. Total aluminum concentrations tend to occur above detection limits, and are elevated to concentrations above, or close to the CWQG-PAL limit (0.10 mg/L). Maximum aluminum concentrations exceed the CWQG-PAL limit at all sites except BL0-03-D/S and BL0-6S/D (Figure B.58). Median total aluminum concentrations at each geographically distinct sampling station in Mary Lake range from 0.03 mg/L to 0.06 mg/L. Sampling stations close to inlets, such as BL0-01 and BL0-05, show slightly higher aluminum concentrations when compared to other stations, indicating that upstream aluminum inputs may be occurring from waters flowing into the lake at these locations (the Mary River and Camp Lake). Elevated total aluminum concentrations measured in various watercourses across the mine site area.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.56 Mary Lake – Chloride Concentrations in Water

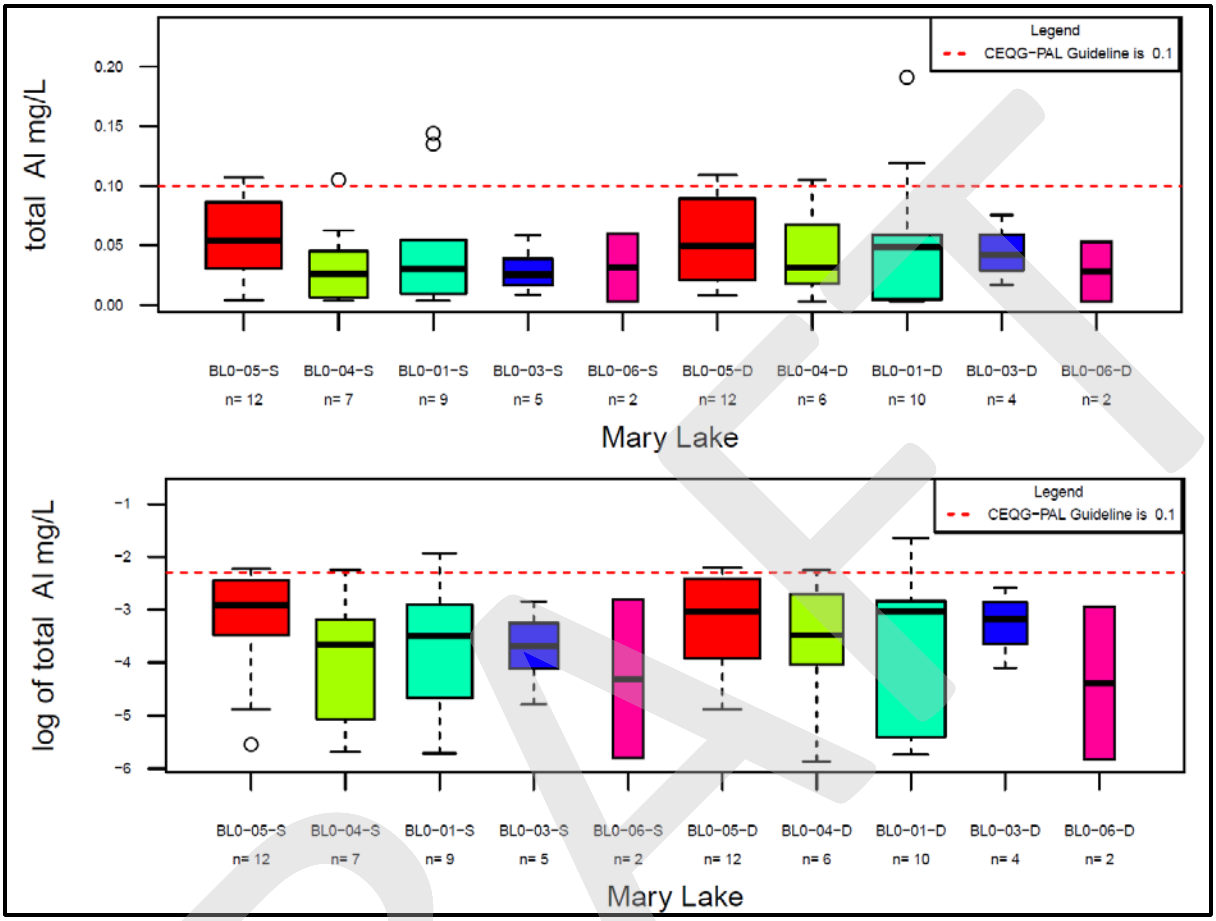


NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.

Figure B.57 Mary Lake – Variability of Chloride in Water

Seasonal scatterplots indicate shallow and deep sampling locations have similar data, and may be aggregated (Figure B.59). Distinct temporal trends over the eight-year sampling history are not noted.



NOTES:

1. CONCENTRATIONS MEASURED AT OR BELOW DETECTION LIMIT ARE PRESENTED AT DETECTION LIMIT.
2. THE CWQG-PAL GUIDELINE LIMIT IS BASED ON THE TOTAL MEDIAN HARDNESS.

Figure B.58 Mary Lake – Total Aluminum Concentrations in Water