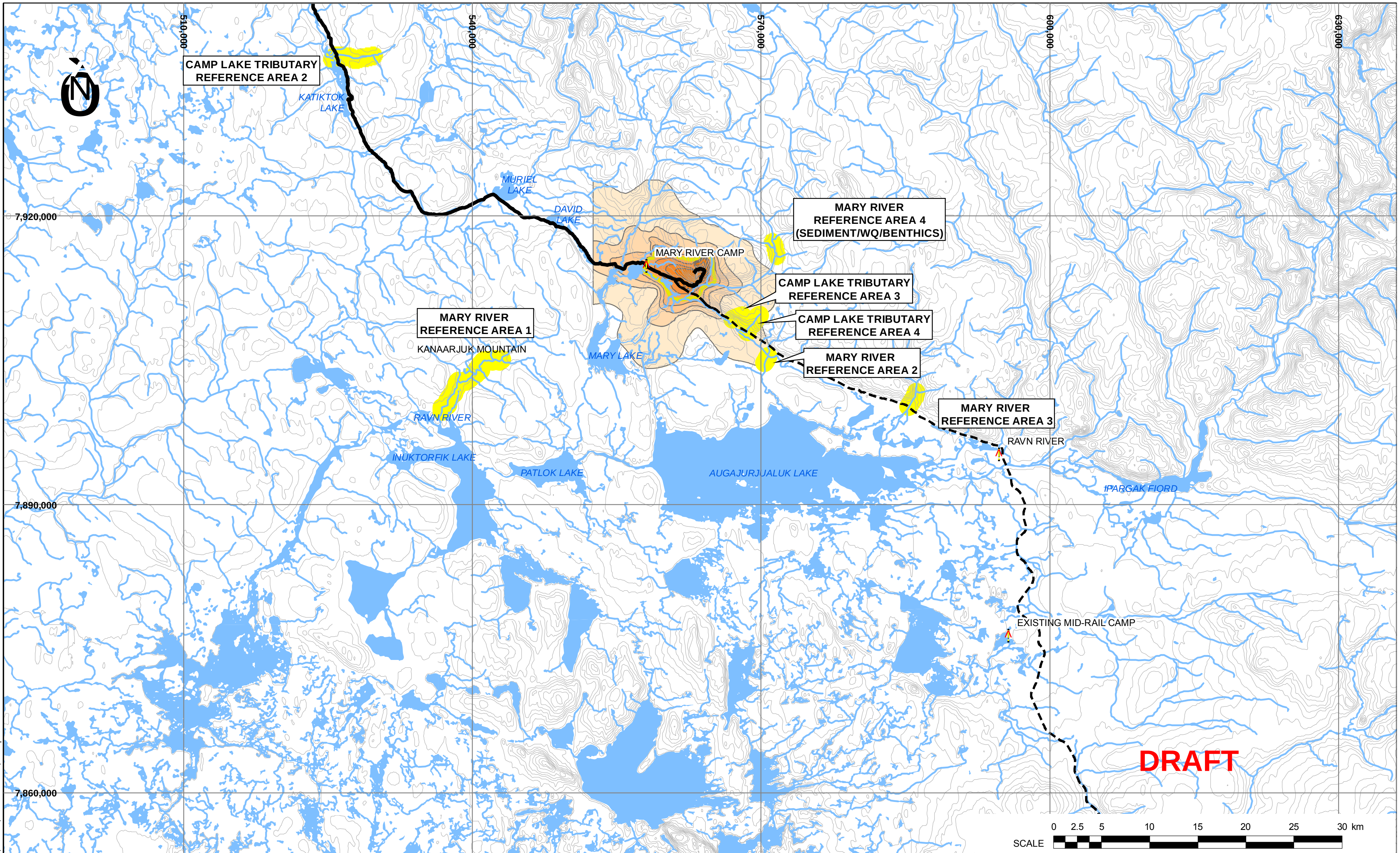


SAVED: I:\102\00181\34\A\GIS\Figs\A13_rA.mxd; Jun 26, 2014 1:32 PM; asimpson

LEGEND:

- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- PHOTO/VIDEO RECORD (2012-2013)
- WATER

Annual TSP Dep. ($g/m^2/yr$)

- 2 - 7.5
- 7.5 - 15
- 15 - 30
- 30 - 55
- 55 - 120
- 120 - 240
- 240 - 480
- > 480

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA DEPARTMENT OF NATURAL RESOURCES (2009). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 20 METRES.
4. TOTAL SUSPENDED PARTICULATE CONTOURS PROVIDED BY RWDI AIR INC. (2011). PRESENTED IN THE FINAL ENVIRONMENT IMPACT ASSESSMENT.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
A	20MAY'14	ISSUED WITH REPORT	DKK	SWK	PS	RAC

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CANDIDATE REFERENCE AREAS FOR EEM PROGRAM

Knight Piésold CONSULTING

P/A NO. NB102-181/34 | REF NO. 5

FIGURE 2.4 | REV A

Baseline environmental data has been collected at the exposure and reference areas by North/South Consultants Inc. (NSC) and Knight Piésold Ltd. (KP) on behalf of Baffinland. The 2013 study area site characterization program involved:

- Identifying the in-situ habitat conditions
- In-situ and laboratory water quality sampling
- Sediment quality sampling
- Benthic invertebrate community sampling
- Fish community and population sampling

The exposure area habitat information was used to evaluate suitability of the candidate reference study areas and to position the proposed field replicate stations. Characterizing more than one reference site for each exposure area increases the ability to evaluate natural variability, ecological relevance and confounding factors, and improves the ability to evaluate the adequacy of the chosen reference site(s) (EC, 2012).

Table 2.1 Freshwater EEM Study Design Exposure and Candidate Reference Areas

Study Area ID	Latitude (Deg. Min. Sec.)	Longitude (Deg. Min. Sec.)
Camp Lake Tributary Near Field Exposure Area	71 19' 46" N	79 21' 46" W
Camp Lake Tributary Far Field Exposure Area	71 19' 46" N	79 22' 46" W
Camp Lake Tributary Reference Area 2	71 31' 51" N	80 15' 42" W
Camp Lake Tributary Reference Area 3	71 15' 56" N	79 06' 27" W
Camp Lake Tributary Reference Area 4	71 15' 28" N	79 04' 23" W
Mary River Near Field Exposure Area (Surface water & Fish at outfall)	71 17' 50" N	79° 15' 57" W
Mary River Near Field Exposure Area (Sediment & Benthos)	71 17' 42" N	79 16' 47" W
Mary River Far Field Exposure Area	71 16' 42" N	79 22' 11" W
Mary River Reference Area 1	71 12' 47" N	79 56' 17" W
Mary River Reference Area 2	71 13' 21" N	79 02' 46" W
Mary River Reference Area 3	71 10' 26" N	78 39' 31" W
Mary River Reference Area 4	71 20 43" N	79 00 04" W

NOTES:
1. AREA COORDINATES REPRESENT THE UPSTREAM EXTENT OF EACH STUDY AREA.

The habitat at each area was documented, including a description of the riparian vegetation, substrate composition and general stream morphology characteristics. A photographic record of each area is provided in Appendix A to support the habitat descriptions. Point velocity and depth measurements were taken at each replicate station and are also provided in Appendix A summary tables.

Substrate samples were collected for particle size distribution analysis and total organic carbon (TOC) content at each of the five replicate stations in each study area to characterize the habitat and as a supporting measure for the benthic invertebrate community survey data. The replicate stations were located in wadeable, erosional habitat, therefore depositional organic sediment was not available for sampling or utilized for total metals analysis. Summary figures and tables of the substrate laboratory results are provided in Appendix B.

Surface water quality samples and measurements were taken at existing monitoring stations where available. The in-situ and laboratory results are provided in Appendix C.

The benthic invertebrate community was sampled using a Hess sampler with 500 micron mesh as recommended by the technical guidance document (EC, 2012). Three grab samples were collected at each replicate station and retained in separate containers for discrete analysis for evaluation of within station variability. The benthic invertebrate community data for each replicate station, descriptions of the effects endpoints and supporting endpoint summary tables are provided in Appendix D. Discussion of the benthic community results and comparisons between exposure and candidate reference area are provided in the following sections. These results describe the community assemblages and support rationale for the selection of suitable reference areas.

Fish community and population sampling was conducted utilizing a Smith-Root backpack electrofishing unit. The collection of 100 juvenile Arctic char (*Salvelinus alpinus*) older than young-of-year (YOY) was attempted at all study areas. Subsamples of the captured fish (n=10) were retained for age verification to characterize the Arctic char population. The fish data (fork length and round weight) measured in the field and age verification data from the subsampled individuals are provided in Appendix E. Ninespine stickleback (*Pungitius pungitius*) are the only other fish species present in the mine area freshwater streams. The ninespine stickleback collected during the fall 2013 program were enumerated, but insufficient numbers were collected to perform statistical comparisons of the reference and exposure areas. Discussion of study area population composition, including age verification results are provided in the following sections.

2.4 CAMP LAKE TRIBUTARY EXPOSURE AREAS AND REFERENCE AREAS

The Camp Lake Tributary exposure area is located on the west side of Deposit No. 1 and contains the near field study area upstream of the existing Tote Road, and the far field study area located downstream of the Tote Road stream crossing as shown on Figure 2.1.

Three candidate reference areas were characterized to evaluate their suitability as EEM reference areas for the exposure area. The reference areas included one area along the Tote Road between the mine site and Milne Port, and two locations near the rail alignment, north of Angajurjualuk Lake. The locations of these reference areas are shown on Figure 2.4. Originally, a fourth candidate reference area (CLT-REF1) was selected, but this area was deemed unsuitable following a ground-truthing site visit in the summer 2013.

2.4.1 Historical Site Characterization

Prior to the 2013 fall (late August) site characterization program, various baseline aquatic data collection programs have been conducted in the exposure and some of the reference streams. A summary of the study areas, corresponding historical studies and reference to the 2013 photographs included in Appendix A are provided in Table 2.2.

Table 2.2 Camp Lake Tributary Study Areas: Historical Characterization Summary

EEM Study Area ID	CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Historical ID	L1-09	L0-01	CV-078, N1-060	CV-004-1 E2-08	CV-006-1
Study Type	**Historical Study Years**				
Water Quality	2011-2013	2005-2007, 2011-2013	2005, 2006, 2011, 2012	2005, 2012	2008
Substrate/Sediment Quality	2007, 2011-2012	2007, 2011-2012	N/A	2012	N/A
Benthic Invertebrates	2007	2007	N/A	2008	N/A
Fish Community	2007, 2010	2007, 2010	2009, 2010	2008	2008
Appendix A Photographs	1 to 4	5 to 8	9 to 12	13 to 16	17 to 20

The land immediately adjacent to these streams is typically flat, and the streams have steep vertical banks. Riparian vegetation includes grasses, mosses, and wildflowers. The streams have varying amount of undercut banks and all have boulders that provide in-stream cover.

2.4.2 Water Quality

The 2013 surface water quality data from the exposure areas (CLT-NF and CLT-FF) shows this stream is “moderately soft” with no Canadian Water Quality Guideline exceedances of criteria for the protection of freshwater aquatic life (CWQG-PAL) (CCME, 2007) as provided in Appendix C (Table C.1). The exposure areas were highly oxygenated, which is an important measure to support aquatic life. A discussion of the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron and nickel are provided in the water and sediment quality review and preliminary study design report contained within the AEMP document (Baffinland, 2014).

The candidate reference areas varied in hardness with CLT-REF2 shown to have hard water and CLT-REF3 and CLT-REF4 shown to have soft water (Appendix C, Table C.1). Analytical results from reference area CLT-REF2 show a total ammonia concentration (0.83 mg/L) of from the July 2013 sample that is above the CWQG-PAL criteria. This was the only criteria exceedance documented at CLT-REF2. The laboratory results from CLT-REF3 and CLT-REF4 reference areas both show concentrations of total aluminum above the CWQG-PAL criteria (Appendix C, Table C.1). Total aluminum was the only CWQG-PAL criteria exceedance from these reference areas. All reference areas were highly oxygenated and comparable to the exposure areas.

2.4.3 Benthic Invertebrate Community Effect Endpoints

Benthic invertebrate community effect endpoints comparing the exposure and reference areas are summarized in Table 2.3. These endpoints show area CLT-REF3 was the only reference area not significantly different from CLT-NF for all effect endpoint calculations, and is the recommended reference area for use in the cycle one EEM biological monitoring study. Reference area CLT-REF4 should also be utilized in the cycle one study since family richness was the only significant difference and the use of multiple reference areas captures the natural variability of these streams, providing a less narrow comparison to a single reference area. Benthic invertebrate sample processing methods and details of the endpoint calculations are provided in Appendix D.

Table 2.3 Camp Lake Tributary Study Areas: Benthic Invertebrate Community Summary

Endpoint	Descriptor	Study Area			
		CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Total Invertebrate Density(TID)	Different from CLT-NF (p<0.10)	N[2]	Y[2]	N[2]	N[2]
Taxa Richness	Different from CLT -NF (p<0.10)	N	N	N	Y
Simpson's Evenness Index (E)	Different from CLT -NF (p<0.10)	N[2]	Y[2]	N[2]	N[2]
Bray-Curtis Similarity Index	Different from CLT -NF (p<0.10)	-	Y	N	N

NOTES:
1. TUKEY TEST RESULTS FOR POST-HOC COMPARISON PRESENTED UNLESS OTHERWISE NOTED.
2. VARIANCE NOT HOMOGENEOUS, GAMES-HOWELL TEST RESULTS PRESENTED.
3. SEE APPENDIX D FOR CAMP LAKE TRIBUTARY STUDY AREA ENDPOINT CALCULATIONS.

Baffinland has identified the Bray-Curtis Similarity Index as one of the benthic invertebrate community effect endpoints, in accordance with EC (2012), as shown in Table 2.3. It has been acknowledged in a study commissioned by EC that this current procedure results in a highly inflated type I error rate (Borcard and Legendre, 2013). Prior to submitting the final Cycle One Study Design, Baffinland plans to seek further guidance from EC on this issue, and give due consideration to using the replacement tests identified by Borcard and Legendre (2013).

2.4.4 Supporting Benthic Invertebrate Community Measures

Reference sites must share natural habitat features with the exposure sites and represent the environmental variability of the study region. Supporting measures for the benthic invertebrate community survey were recorded to support recommendations of the appropriate reference areas. These include hydrology, stream morphology and substrate characterization.

The hydrological and morphological characteristics of the Camp Lake Tributary study areas include channel wetted width, total water depth and point velocity measurements. The wetted width was measured at each of the five replicate stations. Total water depth and point velocity measurements were recorded at ten locations per replicate station, near to where the benthic invertebrate community sampling occurred. Reference areas CLT-REF3 and CLT-REF4 are the most similar to exposure area CLT-NF, whereas CLT-REF2 is much wider and has nearly twice the mean water velocity (Table 2.4). Detailed field measurement are provided in Appendix A including the total water depths, wetted widths and water velocities in each study area.

Substrate characterization included particle size distribution analysis and determination of total organic carbon (TOC) content. Reference area CLT-REF3 had particle size fractions similar to those measured at exposure area CLT-NF. Both areas were dominated by gravel and coarse sand. Reference area CLT-REF4 was also dominated by these size classes, but had higher gravel content.

Table 2.4 Camp Lake Tributary Study Areas: Stream Characterization Summary

Measure	Units	Study Area				
		CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Mean Wetted Width	m	5.8	4.9	15.4	4.6	2.6
Mean Total Depth	m	0.16	0.14	0.20	0.17	0.13
Mean Velocity	m/s	0.28	0.38	0.51	0.20	0.37

Reference area CLT-REF2 was dominated by gravel and silt, and is not a suitable representation of exposure area habitat. TOC content at CLT-REF3 and CLT-REF4 were most similar to the TOC content of the exposure area CLT-NF. The particle size distributions and TOC results for the Camp Lake Tributary study areas are shown in Table 2.5. Detailed field measurements, laboratory results and graphs are provided in Appendix B to assist with interpretation of the supporting measures.

Table 2.5 Camp Lake Tributary Study Areas: Substrate Characterization Summary

Mean Particle Size Fraction (%)	Size (mm)	Study Area				
		CLT-NF	CLT-FF	CLT-REF2	CLT-REF3	CLT-REF4
Gravel	16.0 - 2.0	58	57	73	54	79
Coarse Sand	2.0 - 0.2	33	35	4	38	12
Fine Sand	0.2 - 0.062	0	4	2	4	5
Silt	0.062 - 0.0039	0	1	11	0	1
Clay	< 0.0039	5	5	8	4	5
Mean TOC (%)	-	0.15	0.20	0.21	0.12	0.17

2.4.5 Fish Community and Population

Backpack electrofishing during the fall 2013 program captured arctic char at all Camp Lake Tributary study areas. The fish appeared healthy, with no visible abnormalities. A summary of the fish collection results and mean measurements from the study area populations are shown in Table 2.6. Detailed collection data are presented in Appendix E.

Table 2.6 Camp Lake Tributary Study Areas: Fish Sampling Data Summary

Measure	Study Area			
	CLT-NF	CLT-REF2	CLT-REF3	CLT-REF4
Number or Arctic char collected	120	30	116	117
Number of Ninespine stickleback collected	0	0	0	1
Arctic char catch-per-unit-effort (CPUE)	8.57	1.22	9.11	5.25
Mean Arctic char fork length (mm)	148	127	90	117
Mean Arctic char round weight (g)	32	23	10	21
Mean Arctic char age (yrs), (n=10/study area)	3	4	4	4
Mean Fulton's Condition (weight at length)	1.17	1.18	1.37	1.33

The collection of 100 individuals from each area is required under the EEM program to conduct comparisons between study areas. Due to the limited capture success at reference area CLT-REF2 (n=30), only reference areas CLT-REF3 and CLT-REF4 were compared to the exposure area. Ninespine stickleback were only captured from reference area CLT-REF4 (n=1) and no further data are discussed regarding this species.

The arctic char catch-per-unit-effort (CPUE) results are shown in Table 2.5, with the highest capture rate in reference area CLT-REF3. The CLT-REF4 area had approximately half the CLT-REF3 capture success, and was lower than the CPUE recorded at the exposure area CLT-NF.

The fork lengths of the first 100 individuals from the CLT-NF, CLT-REF3 and CLT-REF4 study areas are graphically shown in Appendix E (Figure E.1). Arctic char in the exposure area were the largest and consequently the heaviest of the three study area populations. Ten individuals were retained for age verification from each study area, and ages ranged from 1 to 7 years old.

Descriptive statistics of the fork length and round weight measurements are presented in Appendix E (Table E.1). Statistical comparisons of the CLT-REF3 and CLT-REF4 length and weight data to the CLT-NF data are presented in Appendix E (Table E.2). Tests of normality show the length and weight data for all Camp Lake Tributary study areas are not normally distributed. Transforming the data did not resolve this condition. An ANOVA comparison shows length and weight data of the study areas are significantly different.

The fish population data shows both reference areas CLT-REF3 and CLT-REF4 were significantly different from the CLT-NF study area.

2.4.6 Camp Lake Tributary Exposure and Reference Area Summary

Reference areas CLT-REF3 and CLT-REF4 are the most suitable study areas for use in the EEM cycle one biological monitoring study. These areas are representative of the benthic invertebrate community seen in the near field exposure area CLT-NF, with similar water quality, substrate, hydrology and stream morphology measures.

Comparison of the fish community and population data shows CLT-REF3 and CLT-REF4 have different fish age distributions and are statistically different from CLT-NF. Additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

2.5 MARY RIVER EXPOSURE AREAS AND REFERENCE AREAS

The Mary River is located southeast of the mine site and flows in a southwest direction reporting to Mary Lake approximately 12.8 km downstream. The exposure area will receive effluent inputs from three discrete MMER final discharge points listed below in descending order, upstream to downstream as follows (Figure 1.1):

- East waste rock pond discharge (MS-10)
- Run of mine (ROM) pond discharge (MS-08)
- Ore stockpile runoff (MS-07)

The Mary River aquatic habitat between these effluent discharge points is a high energy environment dominated by a boulder substrate and steep sloping banks. The Mary River near field (MRY-NF) exposure area has two stream sections proposed for the cycle one EEM biological monitoring study as shown on Figure 2.2. During study design development, the challenges of standard biological sampling in the immediate vicinity of the final discharge points were discussed with Environment Canada. Following a site visit by Environment Canada staff, it was agreed that the benthic invertebrate and substrate sampling would take place in wadeable river habitat downstream of the dangerous, high velocity conditions. It was also decided that receiving water quality sampling will remain near the discharge locations as per the CREMP as well as the fish sampling EEM component that will take place upstream of the benthic study area, as close to the final discharge point as safely possible.

The upstream extent of the Mary River far field (MRY-FF) exposure area is located approximately 3,900 m downstream of the Sheardown Lake outlet channel confluence as shown on Figure 2.3. Existing CREMP stations are located within this study area as shown on Figure 2.3. Baseline surface water quality monitoring at station C0-05 was conducted in 2007, 2008 and 2011. Sediment quality sampling at station C0-05 was conducted in 2007 and 2011. A fish community survey had not historically been conducted at this location on the river however the barrier-free conditions between MRY-FF and MRY-NF permits fish migration through these exposure areas.

Four reference areas geographically outside of the range of anticipated mining influences were selected for comparison to the Mary River exposure areas (Figure 2.4). One of these areas (MRY-REF4) was included following a recommendation by Environment Canada to locate a study area on the Mary River. The only available areas upstream of the final discharge points and predicted dust plume are located upstream of the Mary River fish barrier (waterfall). Study area MRY-REF4 is a candidate reference area for the benthic invertebrate community EEM component. It has been shown that the Mary River is fishless upstream of the waterfall (NSC, 2008). As such, study area MRY-REF4 would not satisfy the requirements of the fish population effects endpoints.

Four candidate reference areas were visited during the 2013 site characterization program. These streams are between 11 km and 27 km away from the MRY-NF exposure area. Three of these candidate areas are in separate drainage basins from MRY-NF. These areas include drainage basins located north of Inuktorfik Lake and two areas near the rail alignment north of Angajurjualuk Lake. The fourth candidate reference area is located on the Mary River, upstream of the Mary River waterfall (Figure 2.4).

2.5.1 Historical Site Characterization

Prior to the 2013 fall (late August) site characterization program, various baseline aquatic data collection programs have been conducted in the exposure and in some of the reference streams. A summary of the study areas, corresponding historical studies and reference to the 2013 photographs included in Appendix A are provided in Table 2.7.

The land immediately adjacent to these streams is typically flat, with steep banks on one or both sides away from the main channel. The in-streams banks are vertical with riparian vegetation including grasses, mosses, and wildflowers. The streams have varying amount of undercut banks and all have boulders that provide in-stream cover.

Table 2.7 Mary River Study Areas: Historical Characterization Summary

EEM Study Area ID	MRY-NF	MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Historical ID	E0-20 & E0-21	C0-05	N/A	BR 011-1, S2-010	BR-025-1, S2-020	G0-09
Study Type	**Historical Study Years**					
Water Quality	2011 & 2012	2007, 2008, 2011	-	2006 & 2011	2006 & 2011	2006, 2007, 2012
Substrate/Sediment Quality	2011	2007 & 2011	-	-	-	2006, 2007, 2009, 2010 & 2012
Benthic Invertebrates	2007	-	-	-	-	2007
Fish Community	2006 & 2008	-	-	2008	2008	2006 & 2008
Appendix A Photographs	21 to 24	25 to 28	29 to 32	33 to 36	37 to 40	41 to 44

2.5.2 Water Quality

The 2013 surface water quality data from the exposure areas (MRY-NF and MRY-FF) shows these areas are “soft” (MRY-NF) and “moderately hard” (MRY-FF) with concentrations of aluminum, copper and iron measured above the CWQG-PAL criteria at the MRY-NF study areas (Appendix C, Table C.1). A discussion of the metal parameters of interest: aluminum, arsenic, cadmium, copper, iron and nickel are provided in the water and sediment quality review and preliminary study design report contained within the AEMP document (Baffinland, 2014).

The candidate reference areas were all shown to have “soft” water with the exception of MRY-REF1 that had “moderately hard” water. Laboratory results from reference areas MRY-REF3 and MRY-REF4 show concentrations of aluminum and iron above the CWQG-PAL criteria, with aluminum as the only exceedance reported from MRY-REF2. There were no CWQG-PAL criteria exceedances reported from MRY-REF1.

2.5.3 Benthic Invertebrate Community Effect Endpoints

Benthic invertebrate community effect endpoints comparing the exposure and reference areas are summarized in Table 2.8. These endpoints show three of the four reference areas are not significantly different from MRY-NF for all effect endpoint calculations. Benthic invertebrate sample processing methods and details of the endpoint calculations are provided in Appendix D.

As mentioned in Section 2.4.3, prior to submitting the final Cycle One Study Design, Baffinland plans to seek further guidance from EC on the use of the Bray-Curtis Similarity Index, and give due consideration to using the replacement tests identified by Borcard and Legendre (2013).

Table 2.8 Mary River Study Areas: Benthic Invertebrate Community Summary

Endpoint	Descriptor	Study Area				
		MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Total Invertebrate Density (TID)	Different from MRY-NF ($p<0.10$)	N	N	N	Y	N
Taxa Richness	Different from MRY-NF ($p<0.10$)	N	N	N	N[2]	N
Simpson's Evenness Index (E)	Different from MRY-NF ($p<0.10$)	N	N	N	N[2]	N
Bray-Curtis Similarity Index	Different from MRY-NF ($p<0.10$)	-	N	N	Y	N

NOTES:
1. TUKEY TEST RESULTS FOR POST-HOC COMPARISON PRESENTED UNLESS OTHERWISE NOTED.
2. VARIANCE NOT HOMOGENEOUS, GAMES-HOWELL TEST RESULTS PRESENTED.
3. SEE APPENDIX D FOR MARY RIVER STUDY AREA ENDPOINT CALCULATIONS.

2.5.4 Supporting Benthic Invertebrate Community Measures

Reference sites must share natural habitat features with the exposure sites and represent the environmental variability of the study region. Supporting measures for the benthic invertebrate community survey were recorded to support recommendations of the appropriate reference areas. These include hydrology, stream morphology and substrate characterization.

The hydrological and morphological characteristics of the Mary River study areas include channel wetted width, total water depth and point velocity measurements. The wetted width was measured at each of the five replicate stations. Total water depth and point velocity measurements were recorded at ten locations per replicate station, near to where the benthic invertebrate community sampling occurred. Reference area MRY-REF1 and MRY-REF3 were the most similar to exposure area MRY-NF but are unlike the exposure area for other comparison criteria. The MRY-REF2 and MRY-REF4 study areas are shallower than the exposure area with higher and lower average point velocities respectively than the MRY-NF study area. Detailed field measurement are provided in Appendix A including the total water depths, wetted widths and water velocities in each study area.

Table 2.9 Mary River Study Areas: Stream Characterization Summary

Measure	Units	Study Area					
		MRY-NF	MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Mean Wetted Width	m	36	56	37	42	38	26
Mean Total Depth	m	0.30	0.25	0.35	0.20	0.23	0.25
Mean Velocity	m/s	0.40	0.30	0.31	0.46	0.39	0.22

Substrate characterization included particle size distribution analysis and determination of total organic carbon (TOC) content. Reference areas MRY-REF2 and MRY-REF3 had particle size fractions similar to those measured at exposure area MRY-NF. These areas were dominated by gravel and coarse sand. Reference area MRY-REF4 had nearly equal fractions of gravel and coarse sand, whereas MRY-REF1 had the highest percent coarse sand fraction. TOC content at MRY-REF2 and MRY-REF4 were nearly equal to the TOC concentration at MRY-NF as shown in Table 2.10. Detailed field measurements, laboratory results and graphs are provided in Appendix B to assist with interpretation of the supporting measures.

Table 2.10 Mary River Study Areas: Substrate Characterization Summary

Mean Particle Size Fraction (%)	Size (mm)	Study Area					
		MRY-NF	MRY-FF	MRY-REF1	MRY-REF2	MRY-REF3	MRY-REF4
Gravel	16.0 - 2.0	61	46	28	63	64	42
Coarse Sand	2.0 - 0.2	31	41	64	30	29	49
Fine Sand	0.2 - 0.062	3	6	4	3	2	4
Silt	0.062 - 0.0039	0	1	1	1	0	0
Clay	< 0.0039	4	6	3	3	4	4
Mean Total Organic Carbon (%)	-	0.10	0.16	0.07	0.11	0.21	0.11

2.5.5 Fish Community and Population

Backpack electrofishing during the fall 2013 program captured arctic char at all Mary River study areas. The fish appeared healthy, with no visible abnormalities. A summary of the fish collection results and mean measurements from the study area populations are shown in Table 2.11. Detailed collection data are presented in Appendix E.

Table 2.11 Mary River Study Areas: Fish Sampling Data Summary

Measure	Study Area			
	MRY-NF	MRY-REF1	MRY-REF2	MRY-REF3
Number or Arctic char collected	108	26	22	114
Number of Ninespine stickleback collected	0	26	0	0
Arctic char catch-per-unit-effort (CPUE)	1.56	0.61	0.71	2.01
Mean Arctic char fork length (mm)	126	121	100	104
Mean Arctic char round weight (g)	23	25	11	15
Mean Arctic char age (yrs), (n=10/study area)	4	4	3	3
Mean Fulton's Condition (weight at length)	1.43	1.29	1.18	1.23

The collection of 100 individuals from each area is required under the EEM program to conduct comparisons between study areas. Due to the limited capture success at reference area MRY-REF1 and MRY-REF2, only reference area MRY-REF3 compared to the exposure area. During the field studies at MRY-REF2, weather conditions limited the fishing effort, given more time it is likely that sufficient numbers of arctic char could have been collected. Ninespine stickleback were only captured from reference area MRY-REF1 (n=26) and no further data are discussed regarding this species.

The arctic char catch-per-unit-effort (CPUE) results are shown in Table 2.11, with the highest capture rate in reference area MRY-REF3. The remaining two reference areas showed less than half the CPUE recorded at the MRY-NF study area, however MRY-REF2 received half the fishing effort that was spent at the exposure area.

The fork lengths of the first 100 individuals from the MRY-NF and MRY-REF3 study areas are graphically shown in Appendix E (Figure E.4). Arctic char in the exposure area were the largest and consequently the heaviest of the Mary River study area populations. Ten individuals were retained for age verification from each study area, and ages ranged from 1 to 7 years old.

Descriptive statistics of the fork length and round weight measurements are presented in Appendix E (Table E.1). Statistical comparisons of the MRY-REF3 length and weight data to the MRY-NF data are presented in Appendix E (Table E.3). Tests of normality show the length and weight data for the Mary River study areas are not normally distributed. Transforming the data did not resolve this condition. An ANOVA comparison shows length and weight data of the study areas are significantly different.

The fish population data shows reference area MRY-REF3 was significantly different from the MRY-NF study area.

2.5.6 Mary River Reference Area Summary

Reference areas MRY-REF2 and MRY-REF4 are the most suitable study areas for use in the EEM cycle one biological monitoring study. These areas are representative of the benthic invertebrate community seen in the near field exposure area MRY-NF, with similar water quality, substrate, hydrology and stream morphology measures.

Comparison of the fish community and population data shows MRY-REF3 has different fish age distributions and is statistically different from MRY-NF. It is possible with additional sampling, MRY-REF2 could provide sufficient numbers of arctic char for a comparison using the endpoints. Additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

3 STUDY DESIGN METHODOLOGY

3.1 EFFLUENT PLUME DELINEATION STUDY

Site characterization will include an effluent plume delineation study to confirm the estimated effluent concentration and the manner in which mine effluent will mix with the receiving environment. The effluent plume delineation study will follow guidance provided in the *Revised Technical Guidance on How to Conduct Effluent Plume Delineation Studies* document available from Environment Canada (2003) as well as information provided in the technical guidance document for EEM (EC, 2012).

Effluent discharge has been estimated for the MMER final discharge points. The estimated 10-year low flow conditions of the receivers are presented in Table 3.1.

The three final discharge points to the Mary River will have a total estimated effluent discharge of 3,340,600 m^3/yr. The estimated 10-year low flow conditions of Mary River at the furthest downstream discharge point (E0-21) are 56,793,000 m^3/yr. The effluent concentration is estimated to be 6%, with little dilution between E0-21 and the outlet to Mary Lake.

Camp Lake Tributary will receive effluent from the West Pond (MS-08). Effluent concentrations have been estimated at station L1-09, which is located upstream of the L1 and L0 stream confluence (Table 6.2). The estimated 10-year low flow conditions of Camp Lake Tributary, at station L0-01, which is upstream of the outlet to Camp Lake, is 410,110 m^3/yr. The estimated effluent concentration in Camp Lake Tributary, before reporting to Camp Lake is 46%.

Based on these calculations, effluent concentrations in the Mary River and Camp Lake Tributary are estimated to be greater than 1% within 250 m of the final discharge points.

Table 3.1 Estimated Mine Effluent and Baseline Receiving Water Flows

Effluent Source	Receiving Water	Station ID	Baseline Receiver Discharge at Station (m^3/yr)	Estimated Effluent Discharge (m^3/yr)
East Pond (MS-09)	Mary River	E0-10	53,166,000	3,133,000
ROM Pond (MS-07)	Mary River	E0-12	N/A	97,600
Ore Stockpile Runoff (MS-06)	Mary River	E0-21	56,793,000	110,000
		Mary River Total	**56,793,000**	**3,340,600**
West Pond (MS-08)	Camp Lake Tributary (upstream of Camp Lake)	L0-01	410,100	354,100[1]
		Camp Lake Tributary Total	**410,100**	**354,100[1]**

NOTE:

1. DISCHARGE DATA PROVIDED IN THE FINAL ENVIRONMENTAL IMPACT ASSESSMENT (BAFFINLAND, 2012).

The predicted water quality of the mine effluent to be discharged into the Camp Lake Tributary and Mary River was presented in the FEIS. The predicted effluent quality from ore stockpiles was derived from lysimeter monitoring results of the bulk sample ore stockpile, whereas source terms for runoff from the waste rock stockpile was derived from geochemical testing of representative waste rock materials. Subsequently, mean ore stockpile source terms for the Mary River and the west waste rock pile source terms for Camp Lake Tributary were determined as shown in Table 3.2.

Table 3.2 Predicted Water Quality from Discharge Sources

Parameter	Unit	CWQG-PAL	West Pond	East Pond	Ore Stockpile
			Mean	Mean	95th Percentile
pH	pH	6.5 to 9.0	6.9	6.9	6.65
Arsenic	mg/L	0.005	0.006	0.003	0.002
Copper	mg/L	0.002 to 0.004[4]	0.007	0.004	0.007
Lead	mg/L	0.001 to 0.007[4]	0.0005	0.0002	0.001
Nickel	mg/L	0.025 to 0.150[4]	0.005	0.002	0.17
Zinc	mg/L	0.030	0.031	0.015	0.041

NOTES:

1. MODIFIED FROM FEIS (BAFFINLAND, 2012).
2. EFFLUENT QUALITY UNDER 10-YEAR DRY CONDITIONS PRESENTED
3. RECEIVING WATER QUALITY OBJECTIVES OBTAINED FROM THE CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT (CCME) CANADIAN WATER QUALITY GUIDELINES FOR THE PROTECTION OF FRESHWATER AQUATIC LIFE (CWQG-PAL).
4. CWQG-PAL GUIDELINE VALUE IS HARDNESS DEPENDENT.
5. ADDITIONAL PARAMETERS ARE PROVIDED IN THE FEIS TABLE 7-3.16 AND 7-3.20.

3.2 WATER QUALITY MONITORING

Sampling and analysis of water quality will be undertaken as part of the cycle one EEM biological monitoring study to compare the current water quality of the reference locations to that of the exposure locations. Water quality samples will be taken concurrently with sediment and benthic sampling unless otherwise noted. Field staff will follow the methods outlined in the water and sediment quality sampling protocol (KP, 2014).

The samples will be obtained by sub-surface grabs at least 15 cm below the surface directly into pre-labelled laboratory sample containers. All samples will be preserved according to protocol and stored at 4°C in a chilled cooler until delivered for laboratory analysis. Sample identification, date, time and other pertinent project information will be recorded in a field logbook, on the sample container and on the Chain of Custody forms.

All water samples will be submitted to the selected analytical laboratory for the following analyses as prescribed by the MMER and the technical guidance document: total metals (Ag, Al, As, Ba, B, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Ni, Na, Pb, Sb, Se, Si, Ti, Te, U, V, Zn, Ra 226), CN-, hardness, dissolved anions (Cl-, F-, SO2-4, NO2-, NO3-), total suspended solids, alkalinity, NH3, total P, total organic carbon and pH.

Detection limits for the above parameters will be at or below the site specific receiving water quality criteria based on the CCME guidelines for the protection of freshwater aquatic life. Field measurements of standard water quality parameters; pH, conductivity, dissolved oxygen (DO), water temperature and stream discharge will also be recorded at each study area using portable instruments, calibrated daily with standards of known value (where applicable).

For QA/QC purposes a laboratory prepared trip blank will accompany water samples during sampling and transport. Field blanks for 10% of the samples will also be performed. In addition, three discrete water quality samples will be collected at each study area as recommended in the technical guidance document (EC, 2012). Laboratory blanks, duplicates, spikes and reference standards will be employed according to standard operating procedures. Chain of custody forms will accompany all samples for identification, tracking and transporting purposes. The level of QA/QC employed will provide confidence in the data collected.

3.3 SUPPORTING BENTHIC INVERTEBRATE COMMUNITY MEASURES

Supporting measures for the benthic invertebrate community survey will be recorded to support the appropriateness of the selected reference areas. These measures include hydrology, stream morphology and substrate characterization.

The wetted width of the channel at time of sampling will be measured at each replicate station. Water depth and point velocities at a minimum of ten locations will be recorded near to the benthic invertebrate community sampling locations at each replicate station. Substrate samples will be collected using a core-style sampler to obtain representative samples of the top 5 cm to characterize the particle size distribution and total organic carbon content at each replicate station.

3.4 BENTHIC INVERTEBRATE COMMUNITY SURVEY

A benthic invertebrate community survey will be conducted as part of the cycle one EEM biological study as required by the MMER. The results of this survey will compare the benthic invertebrate communities between the exposure and reference areas. It is proposed that the benthic invertebrate survey take place in the late summer or early fall (late July to late August), as previous studies have indicated that this is an appropriate season to ensure the collection of the widest diversity of invertebrates.

For the benthic survey, the values of and will both be set at 0.1. This will result in a power of 0.9. To achieve this, the sample size will be set at five. Five replicate stations will be located within each of the exposure and reference sampling areas. The replicate stations will be positioned near to the 2013 site characterization program stations (Table A.1, Appendix A).

Three replicate field sub-samples will be collected at each of the five replicate stations (transects). The replicate field sub-samples will be collected and preserved as composite samples. These field sub-samples will be placed randomly within the replicate station so that all members of the benthic community within the area have an equal chance of being collected. Replicates are needed to ensure that a larger surface area at each station is collected, resulting in a larger proportion of the benthic community represented in the results.

Benthic samples will be collected from similar habitats at each of the monitoring areas, and area characterized as wadeable, erosional areas. The substrate type, stream width/depth, flow dynamics and vegetation will be evaluated prior to sample collection at all replicate stations. The benthic samples will be collected using a Hess sampler with a 500 micron mesh at all the stations.

The surficial area sampled will be recorded for each sample collected. Each benthic sample will be collected, stored separately and preserved with 10% buffered formalin solution. The habitat at each station will be described in detail while in the field, and a field collection record will be completed for each station. Chain of custody forms will accompany all samples for identification, tracking and transporting purposes.

3.4.1 Sample Processing

Benthic samples will be analyzed by a taxonomist. All samples will be sorted with the use of a stereo microscope (10X). A second independent taxonomist will verify the original analyses.

Samples will be washed through a 500 micron sieve and sorted entirely, except in the following instances: those samples with large amounts of organic matter (i.e., detritus, filamentous algae) and samples with high densities of major taxa. In these cases, samples will be first washed through a large mesh size sieve (3.36 mm), to remove all coarse detritus, leaves, and rocks. Large organisms such as fourth instar stoneflies and mayflies retained in the sieve will be removed from the associated debris. The remaining sample fraction will be sub-sampled quantitatively, if necessary.

3.4.2 Taxonomy

All invertebrates will be identified to the lowest practical level, usually family level. Additional identification of oligochaetes, stoneflies, mayflies, dragonflies, amphipods, adult beetles and bugs may be identified to species.

Chironimids and oligochaetes will be mounted on glass slides in a clearing media prior to identification. In samples with large numbers of oligochaetes and chironomids, a random sample of no less than 20% of the selected individuals from each group will be removed from the sample for identification, up to a maximum of 100 individuals.

Following identification and enumeration, a list of individuals collected for each sample will be included in the final interpretive report. The list will be in a standard spreadsheet format.

3.4.3 Data Evaluation

All data will be entered into an electronic database with controlled access. Screening studies will be employed to check for transcription errors or suspicious data points. An individual not responsible for entering the data will confirm that the data entered represents the original. Missing data will be distinguished from absence of particular taxa by using non-zero value codes, with definitions built into each file.

The variation among stations within the study area and analytical variation (among laboratory replicates) will be calculated as estimates of the components of variation in the data set and compared to the expected values.

The benthic community will be investigated to determine if mine discharge is having an effect on the receiving system, as defined by Environment Canada (2012). An effect will be deemed to have occurred in the benthic community when a significant statistical difference between the exposure and reference areas is found for one or more of the key descriptors. The critical effect size of +/- 2 standard deviations will be used to identify higher risk to the aquatic environment as per the EEM technical guidance document (EC, 2012).

Using the standard community indices within an Analysis of Variance (ANOVA) model for control/impact designs, the benthic community at the exposure areas will be compared to their representative reference area(s) to determine effect and provide supporting data (Table 3.3).

Table 3.3 Benthic Invertebrate Community Survey Effect Indicators and Endpoints

Effect Indicator	Effect Endpoints
Total benthic invertebrate density (TID)	Number of animals per unit area
Evenness index	Simpson's evenness
Taxa (family) richness	Number of taxa
Similarity index	Bray-Curtis index

NOTE:

1. MODIFIED FROM METAL MINING TECHNICAL GUIDANCE DOCUMENT TABLE 3-1 (EC, 2012).

As mentioned in Sections 2.4.3 and 2.5.3, prior to submitting the final Cycle One Study Design, Baffinland plans to seek further guidance from EC on the use of the Bray-Curtis Similarity Index, and give due consideration to using the replacement tests identified by Borcard and Legendre (2013).

3.4.4 QA/QC

A composite of three field sub-samples from each replicate station will be collected for benthic invertebrate analyses, to compensate for the within station, spatial variability encountered with benthic organisms. Appropriate QA/QC measures related to processing and identification, as outlined in the EEM technical guidance document will be followed (EC, 2012). These measures will incorporate the proper steps related to re-sorting, sub-sampling and maintenance of a voucher collection, as needed. A subset of the voucher collection will be taxonomically analysed by a second invertebrate taxonomist.

3.5 FISH COMMUNITY, POPULATION AND USABILITY SURVEY

3.5.1 Fish Community

Sufficient historical data have been collected to properly characterize the freshwater fish community in the study areas. Only two fish species are present in the exposure areas; Arctic char and ninespine stickleback. A fish population survey will be conducted as discussed below; any new fish species collected during this study will be documented in the final interpretive report.

3.5.2 Fish Population

A fish population survey of the exposure and reference areas will be conducted as required under the MMER. This is required as the effluent concentration is estimated to be above 1% at a distance of 250 metres from the final discharge points. This study will attempt to collect sufficient numbers (n=100) of the proposed sentinel species (Arctic char). The absence of ninespine stickleback in suitable numbers in the exposure and proposed reference areas precludes their use as a second sentinel species. Environment Canada officials will be notified of insufficient collection numbers during the study, and an agreed upon course of action will be followed to complete the study.

Non-destructive capture methods will be employed for all fish population sampling. Backpack electrofishing will be utilized as the primary means of sampling. A non-lethal survey will pose less of an impact on the fish population than a lethal survey.

Sections of aquatic habitat within the vicinity of each sample area will be fished. The operator of the electrofishing unit will start at a downstream location (relative to the area) and fish in an upstream direction towards natural or placed barriers where possible (e.g., waterfall, natural dam or block net). In this manner, all fish resident in the section of stream being sampled can be captured for measurement. A summary table of the specific sampling dates, collection method, fish species and corresponding numbers collected as well as a calculated CPUE will be included in the final interpretive report.

The fish community survey will follow the non-lethal fish sampling requirements as outlined in the technical guidance document (EC, 2012). Attempts will be made to capture at least 100 Arctic char older than young of the year (+YOY). Any YOY individuals collected will be measured and the proportion of fish that are YOY will be estimated from the first 100 fish collected.

Fish lengths will be measured to the nearest millimetre on a fish board. Weighs of the measured fish will be determined using a digital scale to the nearest 0.01 g. All fish captured will be released alive except for a sub-sample to be retained for aging purposes. Table 3.4 and Table 3.5 outline the fish survey measurements and effect indicators proposed for this study.

Table 3.4 Fish Survey Measurements, Expected Precision and Summary Statistics

Measurement Requirement	Expected Precision	Reporting of Summary Statistics
Length (fork and total)	+/- 1 mm	Mean, median, SD, standard error, minimum and maximum values for sampling areas
Total body weight (fresh)	+/- 1.0%	Mean, median, SD, standard error, minimum and maximum values for sampling areas
Age	+/- 1 year	Mean, median, SD, standard error, minimum and maximum values for sampling areas
Abnormalities	N/A	Presence of any lesions, tumours, parasites, or other abnormalities.
Sex	N/A	N/A

NOTE:
1. MODIFIED FROM THE TECHNICAL GUIDANCE DOCUMENT TABLE 3-1 (EC, 2012).

Table 3.5 Fish Population Effect Indicators and Endpoints

Effect Indicator	Non-lethal Effect and Supporting Endpoints
Survival	Length-frequency distribution Age-frequency distribution (if possible)
Growth	Length of YOY (age 0) at end of growth period Weight of YOY (age 0) at end of growth period Size of YOY+ (age 1+) Size at age (if possible)
Reproduction	Relative abundance of YOY (% composition of YOY) YOY survival
Condition	Body weight at length

NOTE:
1. MODIFIED FROM THE TECHNICAL GUIDANCE DOCUMENT TABLE 3-3 (EC, 2012).

Aging using fin rays will be undertaken. Aging structures will be removed from a minimum of 10% of the test populations sampled and from all incidental mortalities. The ratio of male/female specimens retained for age verification will be attempted, though sex determination of small, immature fish may not be conclusive.

Data will be tested for normality and homogeneity of variance prior to specific hypothesis testing. Transformations of the original data will be performed to normalize or homogenize the variances, where needed. An ANOVA model will be used to test for population differences related to the areas sampled (Reference versus Exposure), for length, weight, and condition factor provided the populations are normally distributed, of equal variance and independent of one another. An ANCOVA model will test for interactions for size-at-age and condition factor (length versus weight by area).

3.5.3 Fish Usability

Effluent quality has been estimated using humidity cell testing results of the ore, local precipitation volumes as well as contact time that precipitation will have with the ore and waste rock stockpiles. The effluent quality is not expected to contain mercury concentrations   0.01 µg/L, therefore a fish usability study is not proposed in this study design. Should effluent characterization results report concentrations of mercury   0.01 µg/L a fish usability study will be undertaken as required by the MMER.

4 SUMMARY AND SCHEDULE

The 2013 site characterization program confirmed in-situ conditions at the exposure areas and candidate reference areas. The most suitable reference areas to evaluate the benthic invertebrate community effect endpoints are as follows:

- Camp Lake Tributary Near Field (CLT-NF) : Camp Lake Tributary Reference Area 3 (CLT-REF3)
- Mary River Near Field (MRY-NF) : Mary River Reference Area 4 (MRY-REF4)

The statistical comparisons of the fish population data between the exposure and refernce areas for both receivers show significant difference within and between all groups. As such, additional data analysis may be performed following discussions with Environment Canada to determine an acceptable reference area for the fish component of the EEM cycle one biological monitoring study.

The anticipated timeline that includes milestones associated with the MMER requirements is provided below, and is subject to change based on regulatory approvals and the start of mining.

Mid-September 2014	Start of mining
June 2015	Mine is subject to MMERs once effluent discharge rate reaches 50 m^3/day
September 2015	Submission of Identifying Information & Final Discharge Points (within 60 days after date mine is subject to MMERs)
December 2015	Submission Cycle One Study Design (12 months from initial date when Mine was subject to MMERs)
	Environment Canada review of Cycle One Study Design (6 months)
August-Sept 2016	Conduct Cycle One Biological Monitoring Study (conducted no sooner than 6 months after Cycle One SD submission date)
November 2017	Submission of Cycle One Interpretive Report (within 30 months from initial date when Mine was subject to MMERs)

5 REFERENCES

Baffinland Iron Mines Corporation. 2014. Aquatic Effects Monitoring Program (in-progress).

Borcard, D and P. Legendre. 2013. Review of the pros and cons of available indices applicable to the Environmental Effects Monitoring (EEM) to evaluate changes in benthic invertebrate community structure in response to effluent exposure. Final Report. Project No. K2A80-12-0010. Dated March 15, 2013.

Canadian Council of Ministers of the Environment (CCME). (2007). *Canadian water quality guidelines for the protection of aquatic life: Summary table*. Updated December 2007. In: Canadian environmental quality guidelines, 1999. Winnipeg, MB.

Environment Canada. 2003. *Revised technical guidance on how to conduct effluent plume delineation studies.* National EEM Office, National Water Research Institute and Environment Canada. March 2003.

Environment Canada. 2012. *Metal Mining Technical Guidance for Environmental Effects Monitoring*. The National Environmental Effects Monitoring Office.

Fisheries Act. R.S.C. 1985. c. F-14, June 29, 2012.

Games, P.A., Keselman, H.J., & Rogan, J.C., 1983. *A review of simultaneous pairwise multiple comparisons*. Statistica Neerlandica 37: 53–58.

Knight Piésold Ltd. 2014. *Water and Sediment Quality Review and CREMP Study Design*. Ref.No.NB102-181/33-1, Rev. 2, dated June 26. 2014.

Krebs, C. J. 2001. Ecology. San Francisco, California, Benjamin Cummings.

Minister of Justice. 2014. Consolidation Metal Mining Effluent Regulations. SOR/2002-222. Current to January 23, 2014.

North/South Consultants Inc. 2008. *Mary River Project Freshwater Aquatic Environment Baseline Draft Report: Fish and Fish Habitat*. Winnipeg, MB.

Nunavut Water Board. 2013. *Water Licence No: 2AM-MRY1325*. Motion Number 2013-10-P4-05. June 10, 2013.

Ricker, W.E., 1975. *Computation and interpretation of biological statistics of fish populations*. Ca. Bull. Fish. Aquat. Sci. 191. 382 p.

Wilson, Anne. 2014. Head, Water Quality, Expert Support and Contaminated Sites, Environment Canada. Personal Communication on April 3, 2014.

APPENDIX A

STUDY AREA CHARACTERIZATION DATA

. / 104 (! 53 (!

TABLE A.1

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
2013 STUDY AREAS: REPLICATE STATION LOCATION SUMMARY

Print Jun/26/14 11:25:00

Study Area ID	Replicate Station ID	UTM Easting	UTM Northing	Latitude	Longitude	Latitude-Degrees	Latitude-Minutes	Latitude-Seconds	Longitude-Degrees	Longitude-Minutes	Longitude-Seconds
CLT-NF	CLT-NF-1	558493	7914937	71.32949	-79.3627138	71	19	46.14645	-79	21	45.76973
	CLT-NF-2	558516	7914899	71.32914	-79.3620992	71	19	44.9003	-79	21	43.55694
	CLT-NF-3	558511	7914871	71.32889	-79.3622603	71	19	44.00128	-79	21	44.13689
	CLT-NF-4	558479	7914872	71.32891	-79.3631547	71	19	44.06153	-79	21	47.35698
	CLT-NF-5	558422	7914879	71.32898	-79.3647441	71	19	44.33718	-79	21	53.07857
CLT-FF	CLT-FF-1	557896	7914927	71.32954	-79.3794235	71	19	46.34319	-79	22	45.9247
	CLT-FF-2	557863	7914945	71.32971	-79.3803333	71	19	46.95251	-79	22	49.19981
	CLT-FF-3	557831	7914975	71.32999	-79.3812061	71	19	47.94811	-79	22	52.34189
	CLT-FF-4	557776	7915001	71.33023	-79.3827254	71	19	48.83451	-79	22	57.81143
	CLT-FF-5	557705	7914980	71.33006	-79.3847275	71	19	48.21825	-79	23	5.019129
CLT-REF2	CLT-REF2-1	526096	7936773	71.53094	-80.261927	71	31	51.36724	-80	15	42.93705
	CLT-REF2-2	526051	7936769	71.5309	-80.2632009	71	31	51.25588	-80	15	47.52339
	CLT-REF2-3	526009	7936767	71.53089	-80.2643894	71	31	51.20786	-80	15	51.8018
	CLT-REF2-4	525970	7936787	71.53107	-80.2654854	71	31	51.86865	-80	15	55.74755
	CLT-REF2-5	525917	7936785	71.53106	-80.266985	71	31	51.82489	-80	16	1.145894
CLT-REF3	CLT-REF3-1	567828	7908060	71.26541	-79.107605	71	15	55.48167	-79	6	27.37784
	CLT-REF3-2	567792	7908083	71.26563	-79.1085886	71	15	56.26002	-79	6	30.91898
	CLT-REF3-3	567784	7908119	71.26595	-79.1087803	71	15	57.42946	-79	6	31.60896
	CLT-REF3-4	567754	7908137	71.26612	-79.109601	71	15	58.04043	-79	6	34.56369
	CLT-REF3-5	567732	7908119	71.26597	-79.1102301	71	15	57.48195	-79	6	36.82838
CLT-REF4	CLT-REF4-1	569095	7907235	71.25766	-79.0730137	71	15	27.57547	-79	4	22.84922
	CLT-REF4-2	569090	7907203	71.25737	-79.0731814	71	15	26.54832	-79	4	23.45315
	CLT-REF4-3	569066	7907186	71.25723	-79.0738654	71	15	26.02461	-79	4	25.91531
	CLT-REF4-4	569055	7907155	71.25695	-79.0741994	71	15	25.03588	-79	4	27.11793
	CLT-REF4-5	569034	7907136	71.25679	-79.0748015	71	15	24.44455	-79	4	29.28542
MRY-NF	MRY-NF-1	561572	7911165	71.29491	-79.2795794	71	17	41.68817	-79	16	46.48597
	MRY-NF-2	561498	7911053	71.29393	-79.2817348	71	17	38.14268	-79	16	54.24531
	MRY-NF-3	561346	7910945	71.293	-79.2860648	71	17	34.79759	-79	17	9.833226
	MRY-NF-4	561012	7911183	71.29522	-79.2952038	71	17	42.78106	-79	17	42.73356
	MRY-NF-5	560944	7911420	71.29736	-79.2969164	71	17	50.48928	-79	17	48.8989
MR-FF	MRY-FF-1	558400	7909217	71.27824	-79.3696302	71	16	41.67648	-79	22	10.66857
	MRY-FF-2	558253	7908669	71.27337	-79.374143	71	16	24.12339	-79	22	26.91465
	MRY-FF-3	558082	7908529	71.27215	-79.3790179	71	16	19.75458	-79	22	44.46431
	MRY-FF-4	558031	7908390	71.27092	-79.3805443	71	16	15.31393	-79	22	49.95946
	MRY-FF-5	557921	7908227	71.26949	-79.383734	71	16	10.14982	-79	23	1.442342
MRY-REF1	MRY-REF1-1	538165	7901502	71.21313	-79.9381601	71	12	47.25956	-79	56	17.37647
	MRY-REF1-2	538066	7901337	71.21166	-79.9409943	71	12	41.99067	-79	56	27.57936
	MRY-REF1-3	537916	7901249	71.2109	-79.9452091	71	12	39.2353	-79	56	42.75266
	MRY-REF1-4	537754	7901067	71.20929	-79.9498027	71	12	33.45272	-79	56	59.2896
	MRY-REF1-5	537598	7900717	71.20618	-79.9543094	71	12	22.24464	-79	57	15.51376
MRY-REF2	MRY-REF2-1	570185	7903339	71.22243	-79.0461442	71	13	20.76502	-79	2	46.11894
	MRY-REF2-2	570159	7903134	71.22061	-79.0470515	71	13	14.17908	-79	2	49.3855
	MRY-REF2-3	570198	7902946	71.21891	-79.0461356	71	13	8.07375	-79	2	46.08823
	MRY-REF2-4	570199	7902749	71.21714	-79.0462848	71	13	1.71772	-79	2	46.62513
	MRY-REF2-5	570288	7902506	71.21494	-79.0440281	71	12	53.78594	-79	2	38.50122
MRY-REF3	MRY-REF3-1	584306	7898429	71.17394	-78.6587003	71	10	26.19909	-78	39	31.32108
	MRY-REF3-2	584254	7898260	71.17245	-78.6603242	71	10	20.8137	-78	39	37.16713
	MRY-REF3-3	584189	7898080	71.17086	-78.6623202	71	10	15.08973	-78	39	44.35286
	MRY-REF3-4	584018	7897936	71.16963	-78.6672174	71	10	10.65884	-78	40	1.982762
	MRY-REF3-5	583948	7897837	71.16876	-78.6692648	71	10	7.553149	-78	40	9.353098
MRY-REF4	MRY-REF4-1	571350	7917079	71.34521	-79.0011024	71	20	42.76226	-79	0	3.968775
	MRY-REF4-2	571393	7917037	71.34482	-78.9999376	71	20	41.3615	-78	59	59.77538
	MRY-REF4-3	571452	7916972	71.34422	-78.9983463	71	20	39.20169	-78	59	54.04653
	MRY-REF4-4	571482	7916886	71.34344	-78.9975862	71	20	36.39546	-78	59	51.31044
	MRY-REF4-5	571491	7916771	71.34241	-78.997441	71	20	32.67622	-78	59	50.78743

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix A - Site Char\Individual Files\[EEM_Appendix A_Table A1 to A3.xlsx]TABLE_A.1

NOTES:

1. UTM COORDINATES WERE COLLECTED USING A HANDHELD GPS ONSITE IN ZONE 17 W, NAD83 DATUM.

Knight Piésold CONSULTING

TABLE A.2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER STUDY AREAS: STREAM MEASUREMENTS

Print Jun/26/14 11:26:31

STUDY AREA		CLT-NF-1	CLT-NF-2	CLT-NF-3	CLT-NF-4	CLT-NF-5
CHARACTERIZATION DATE		20-Aug-13				
MEASUREMENT	UNIT					
Distance to U/S Replicate Station	m	-	48	28	32	58
TOTAL DISTANCE	m	166				
Wetted Width	m	5.5	6.3	4.7	5.85	6.5
MEAN WETTED WIDTH	m	5.8				
TD1	m	0.10	0.10	0.14	0.15	0.12
VEL1	m/sec	0.48	0.08	0.19	0.06	0.10
TD2	m	0.08	0.08	0.20	0.26	0.15
VEL2	m/sec	0.22	0.21	0.46	0.14	0.10
TD3	m	0.10	0.06	0.20	0.26	0.20
VEL3	m/sec	0.12	0.06	0.20	0.38	0.40
TD4	m	0.16	0.10	0.18	0.30	0.26
VEL4	m/sec	0.26	0.20	0.41	0.40	0.30
TD5	m	0.11	0.09	0.20	0.18	0.28
VEL5	m/sec	0.35	0.29	0.11	0.25	0.29
TD6	m	0.10	0.06	0.22	0.09	0.16
VEL6	m/sec	0.56	0.21	0.22	0.46	0.45
TD7	m	0.11	0.18	0.18	0.16	0.17
VEL7	m/sec	0.05	0.12	0.30	0.45	0.85
TD8	m	0.10	0.15	0.06	0.30	0.14
VEL8	m/sec	0.23	-0.02	0.16	0.36	0.34
TD9	m	0.14	0.20	0.14	0.20	0.12
VEL9	m/sec	0.60	0.17	0.41	0.16	0.34
TD10	m	0.12	0.10	0.26	0.14	0.19
VEL10	m/sec	0.41	0.18	0.28	0.35	0.05
MEAN TOTAL DEPTH	m	0.11	0.11	0.18	0.20	0.18
MEAN VELOCITY	m/sec	0.33	0.15	0.27	0.30	0.32
MINIMUM DEPTH	m	0.06				
MAXIMUM DEPTH	m	0.30				
MEAN TOTAL DEPTH	m	0.16				
MINIMUM VELOCITY	m/sec	-0.02				
MAXIMUM VELOCITY	m/sec	0.85				
MEAN VELOCITY	m/sec	0.28				

STUDY AREA		CLT-FF-1	CLT-FF-2	CLT-FF-3	CLT-FF-4	CLT-FF-5
CHARACTERIZATION DATE		29-Aug-13				
MEASUREMENT	UNIT					
Distance to U/S Replicate Station	m	-	40	45	62	75
TOTAL DISTANCE	m	222				
Wetted Width	m	5.15	3.38	4.9	5.95	5.1
MEAN WETTED WIDTH	m	4.9				
TD1	m	0.12	0.12	0.12	0.13	0.06
VEL1	m/sec	0.31	0.47	0.19	0.27	0.25
TD2	m	0.16	0.07	0.11	0.14	0.06
VEL2	m/sec	0.51	0.61	0.46	0.4	0.07
TD3	m	0.18	0.08	0.18	0.18	0.1
VEL3	m/sec	0.28	0.39	0.21	0.17	0.34
TD4	m	0.14	0.13	0.21	0.22	0.11
VEL4	m/sec	0.74	0.32	0.5	0.48	0.34
TD5	m	0.22	0.18	0.18	0.18	0.1
VEL5	m/sec	0.5	0.53	0.45	0.54	0.41
TD6	m	0.14	0.1	0.22	0.13	0.08
VEL6	m/sec	0.46	0.59	0.33	0.31	0.43
TD7	m	0.17	0.18	0.15	0.1	0.13
VEL7	m/sec	0.68	0.54	0.3	0.13	0.5
TD8	m	0.14	0.14	0.24	0.08	0.13
VEL8	m/sec	0.21	0.62	0.32	0.18	0.49
TD9	m	0.13	0.18	0.13	0.06	0.14
VEL9	m/sec	0.61	0.43	0.39	0.15	0.15
TD10	m	0.1	0.16	0.12	0.08	0.19
VEL10	m/sec	0.39	0.47	0.07	0.13	0.35
MEAN TOTAL DEPTH	m	0.15	0.13	0.17	0.13	0.11
MEAN VELOCITY	m/sec	0.47	0.50	0.32	0.28	0.33
MINIMUM DEPTH	m	0.06				
MAXIMUM DEPTH	m	0.24				
MEAN TOTAL DEPTH	m	0.14				
MINIMUM VELOCITY	m/sec	0.07				
MAXIMUM VELOCITY	m/sec	0.74				
MEAN VELOCITY	m/sec	0.38				

STUDY AREA		CLT-REF2-1	CLT-REF2-2	CLT-REF2-3	CLT-REF2-4	CLT-REF2-5
CHARACTERIZATION DATE		24-Aug-13				
MEASUREMENT	UNIT					
Distance to U/S Replicate Station	m	-	47	48	43	56
TOTAL DISTANCE	m	194				
Wetted Width	m	22.6	17.4	10.8	13.45	12.95
MEAN WETTED WIDTH	m	15.4				
TD1	m	0.22	0.26	0.13	0.3	0.26
VEL1	m/sec	0.38	0.28	0.8	0.59	0.85
TD2	m	0.31	0.3	0.15	0.22	0.29
VEL2	m/sec	0.49	0.69	0.65	0.59	0.2
TD3	m	0.27	0.2	0.2	0.24	0.24
VEL3	m/sec	0.45	0.54	0.28	0.55	0.84
TD4	m	0.34	0.24	0.22	0.2	0.16
VEL4	m/sec	0.77	0.64	0.59	0.61	0.72
TD5	m	0.07	0.16	0.2	0.12	0.1
VEL5	m/sec	0.11	0.66	0.58	0.4	0.38
TD6	m	0.1	0.13	0.16	0.18	0.14
VEL6	m/sec	0.41	0.24	0.47	0.53	0.34
TD7	m	0.16	0.08	0.21	0.16	0.12
VEL7	m/sec	0.55	0.17	0.47	0.51	0.32
TD8	m	0.12	0.14	0.2	0.14	0.2
VEL8	m/sec	0.56	0.32	0.78	0.66	0.41
TD9	m	0.1	0.36	0.24	0.11	0.16
VEL9	m/sec	0.57	0.46	0.77	0.22	0.55
TD10	m	0.3	0.44	0.28	0.14	0.25
VEL10	m/sec	0.31	0.53	1	0.39	0.42
MEAN TOTAL DEPTH	m	0.20	0.23	0.20	0.18	0.19
MEAN VELOCITY	m/sec	0.46	0.45	0.64	0.51	0.50
MINIMUM DEPTH	m	0.07				
MAXIMUM DEPTH	m	0.44				
MEAN TOTAL DEPTH	m	0.20				
MINIMUM VELOCITY	m/sec	0.11				
MAXIMUM VELOCITY	m/sec	1.00				
MEAN VELOCITY	m/sec	0.51				

STUDY AREA		CLT-REF3-1	CLT-REF3-2	CLT-REF3-3	CLT-REF3-4	CLT-REF3-5
CHARACTERIZATION DATE		22-Aug-13				
MEASUREMENT	UNIT					
Distance to U/S Replicate Station	m	-	46	38	38	30
TOTAL DISTANCE	m	152				
Wetted Width	m	4.3	3.3	5.65	5.7	4.15
MEAN WETTED WIDTH	m	4.6				
TD1	m	0.07	0.24	0.16	0.23	0.17
VEL1	m/sec	0.47	0.16	0.25	0.2	0.05
TD2	m	0.09	0.2	0.15	0.17	0.22
VEL2	m/sec	0.11	0.23	0.08	0.16	0.03
TD3	m	0.18	0.13	0.17	0.18	0.22
VEL3	m/sec	0.08	0.12	0.09	0.14	0.03
TD4	m	0.1	0.15	0.12	0.18	0.25
VEL4	m/sec	0.19	0.42	0.12	0.24	0.04
TD5	m	0.08	0.24	0.05	0.18	0.24
VEL5	m/sec	0.41	0.23	0.03	0.07	0.08
TD6	m	0.06	0.12	0.13	0.21	0.24
VEL6	m/sec	0.28	0.43	0.16	0.27	0.16
TD7	m	0.08	0.2	0.2	0.18	0.17
VEL7	m/sec	0.36	0.47	0.23	0.11	0.18
TD8	m	0.1	0.2	0.24	0.14	0.19
VEL8	m/sec	0.48	0.34	0.16	0.13	0.2
TD9	m	0.12	0.17	0.2	0.18	0.16
VEL9	m/sec	0.12	0.12	0.02	0.14	0.06
TD10	m	0.22	0.13	0.12	0.21	0.2
VEL10	m/sec	0.36	0.54	0.06	0.31	0.12
MEAN TOTAL DEPTH	m	0.11	0.18	0.15	0.19	0.21
MEAN VELOCITY	m/sec	0.29	0.31	0.12	0.18	0.10
MINIMUM DEPTH	m	0.05				
MAXIMUM DEPTH	m	0.25				
MEAN TOTAL DEPTH	m	0.17				
MINIMUM VELOCITY	m/sec	0.02				
MAXIMUM VELOCITY	m/sec	0.54				
MEAN VELOCITY	m/sec	0.20				

STUDY AREA		CLT-REF4-1	CLT-REF4-2	CLT-REF4-3	CLT-REF4-4	CLT-REF4-5
CHARACTERIZATION DATE		22-Aug-13				
MEASUREMENT	UNIT					
Distance to U/S Replicate Station	m	-	33	40	40	29
TOTAL DISTANCE	m	142				
Wetted Width	m	2.25	3.6	2.2	2.7	2
MEAN WETTED WIDTH	m	2.6				
TD1	m	0.18	0.16	0.06	0.16	0.16
VEL1	m/sec	0.3	0.16	0.13	0.44	0.38
TD2	m	0.13	0.2	0.08	0.18	0.14
VEL2	m/sec	0.14	0.48	0.39	0.52	0.5
TD3	m	0.17	0.17	0.08	0.24	0.18
VEL3	m/sec	0.2	0.35	0.52	0.44	0.48
TD4	m	0.11	0.17	0.1	0.2	0.15
VEL4	m/sec	0.05	0.31	0.25	0.17	0.26
TD5	m	0.17	0.18	0.14	0.12	0.08
VEL5	m/sec	0.5	0.4	0.56	0.3	0.42
TD6	m	0.18	0.13	0.14	0.14	0.07
VEL6	m/sec	0.41	0.25	0.5	0.31	0.22
TD7	m	0.08	0.07	0.14	0.08	0.08
VEL7	m/sec	0.02	0.2	0.54	0.37	0.52
TD8	m	0.12	0.06	0.06	0.13	0.14
VEL8	m/sec	0.35	0.42	0.57	0.49	0.56
TD9	m	0.09	0.16	0.17	0.16	0.15
VEL9	m/sec	0.2	0.68	0.33	0.49	0.6
TD10	m	0.1	0.12	0.1	0.19	0.12
VEL10	m/sec	0.3	0.58	0.17	0.4	0.44
MEAN TOTAL DEPTH	m	0.13	0.14	0.11	0.16	0.13
MEAN VELOCITY	m/sec	0.25	0.38	0.40	0.39	0.44
MINIMUM DEPTH	m	0.06				
MAXIMUM DEPTH	m	0.24				
MEAN TOTAL DEPTH	m	0.13				
MINIMUM VELOCITY	m/sec	0.02				
MAXIMUM VELOCITY	m/sec	0.68				
MEAN VELOCITY	m/sec	0.37				

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix A - Site Char\Individual Files\[EEM_Appendix A_Table A1 to A3.xlsx]TABLE_A.2

NOTES:
1. TOTAL DEPTH AND VELOCITY MEASUREMENTS TAKEN USING A MRCH MCBIRNEY FLO-MATE WITH TOP-SETTING WADING ROD.
2. MEASUREMENTS TAKEN AT BENTHIC INVERTEBRATE REPLICATE STATIONS, NEAR THE FIELD SUB-SAMPLE LOCATIONS.

Knight Piésold
CONSULTING

TABLE A.3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

DRAFT EEM CYCLE ONE STUDY DESIGN
MARY RIVER STUDY AREA STREAM MEASUREMENTS

Print Jun/26/14 11:27:31

STUDY AREA		MRY-NF-1	MRY-NF-2	MRY-NF-3	MRY-NF-4	MRY-NF-5	MRY-FF-1	MRY-FF-2	MRY-FF-3	MRY-FF-4	MRY-FF-5	MRY-REF1-1	MRY-REF1-2	MRY-REF1-3	MRY-REF1-4	MRY-REF1-5
CHARACTERIZATION DATE		23-Aug-13	23-Aug-13	23-Aug-13	23-Aug-13	23-Aug-13	28-Aug-13	28-Aug-13	28-Aug-13	28-Aug-13	28-Aug-13	27-Aug-13	27-Aug-13	27-Aug-13	27-Aug-13	27-Aug-13
MEASUREMENT	UNIT															
Distance to U/S Replicate Station	m	-	170	195	440	275	-	564	215	145	196	-	210	167	262	410
TOTAL DISTANCE	m			1080					1120					1049		
Wetted Width	m	33	32	46	38	30	98	47	52	37	46	44	38	30	35	37
AVERAGE WIDTH	m			36					56					37		
TD1	m	0.32	0.22	0.20	0.20	0.27	0.19	0.32	0.26	0.28	0.33	0.20	0.48	0.46	0.40	0.50
VEL1	m/sec	0.66	0.22	0.18	0.39	0.55	0.23	0.26	0.25	0.50	0.36	0.29	0.07	0.26	0.21	0.47
TD2	m	0.25	0.28	0.32	0.26	0.35	0.26	0.24	0.46	0.26	0.29	0.22	0.31	0.54	0.46	0.54
VEL2	m/sec	0.55	0.36	0.39	0.38	0.50	0.22	0.25	0.38	0.40	0.50	0.40	0.02	0.18	0.18	0.57
TD3	m	0.16	0.36	0.32	0.30	0.33	0.18	0.28	0.39	0.19	0.16	0.26	0.32	0.44	0.49	0.56
VEL3	m/sec	0.14	0.29	0.32	0.39	0.56	0.34	0.23	0.58	0.36	0.36	0.33	0.33	0.38	0.39	0.42
TD4	m	0.16	0.37	0.43	0.29	0.31	0.20	0.40	0.34	0.18	0.16	0.30	0.30	0.32	0.40	0.44
VEL4	m/sec	0.08	0.38	0.50	0.45	0.46	0.22	0.29	0.50	0.43	0.29	0.37	0.29	0.10	0.36	0.21
TD5	m	0.22	0.30	0.29	0.30	0.36	0.27	0.40	0.29	0.20	0.19	0.24	0.28	0.25	0.46	0.42
VEL5	m/sec	0.18	0.36	0.48	0.42	0.50	0.40	0.36	0.40	0.25	0.28	0.49	0.30	0.36	0.39	0.20
TD6	m	0.28	0.36	0.26	0.39	0.29	0.32	0.36	0.30	0.26	0.14	0.25	0.20	0.29	0.57	0.50
VEL6	m/sec	0.23	0.50	0.38	0.56	0.58	0.34	0.32	0.37	0.26	0.26	0.59	0.42	0.18	0.25	0.26
TD7	m	0.37	0.49	0.22	0.41	0.27	0.34	0.31	0.28	0.22	0.24	0.34	0.26	0.32	0.48	0.36
VEL7	m/sec	0.40	0.51	0.23	0.36	0.51	0.22	0.39	0.38	0.15	0.28	0.33	0.31	0.39	0.30	0.27
TD8	m	0.42	0.47	0.25	0.36	0.27	0.30	0.10	0.26	0.10	0.22	0.16	0.30	0.28	0.46	0.36
VEL8	m/sec	0.49	0.46	0.35	0.52	0.65	0.03	0.17	0.42	0.19	0.34	0.48	0.32	0.30	0.40	0.26
TD9	m	0.36	0.26	0.19	0.36	0.30	0.14	0.22	0.24	0.14	0.28	0.20	0.22	0.34	0.36	0.28
VEL9	m/sec	0.23	0.18	0.29	0.45	0.58	0.14	0.34	0.31	0.08	0.08	0.27	0.09	0.31	0.26	0.24
TD10	m	0.26	0.17	0.33	0.32	0.31	0.19	0.16	0.20	0.17	0.22	0.28	0.28	0.42	0.34	0.29
TD10	m/sec	0.23	0.29	0.38	0.34	0.47	0.19	0.24	0.26	0.20	0.53	0.30	0.38	0.32	0.29	0.17
MEAN TOTAL DEPTH	m	**0.28**	**0.33**	**0.28**	**0.32**	**0.31**	**0.24**	**0.28**	**0.30**	**0.20**	**0.22**	**0.25**	**0.30**	**0.37**	**0.44**	**0.43**
MEAN VELOCITY	m/sec	**0.32**	**0.36**	**0.35**	**0.43**	**0.54**	**0.23**	**0.29**	**0.39**	**0.28**	**0.33**	**0.39**	**0.25**	**0.28**	**0.30**	**0.31**
MINIMUM DEPTH	m			**0.16**					**0.10**					**0.16**		
MAXIMUM DEPTH	m			**0.49**					**0.46**					**0.57**		
MEAN TOTAL DEPTH	m			**0.30**					**0.25**					**0.35**		
MINIMUM VELOCITY	m/sec			**0.08**					**0.03**					**0.02**		
MAXIMUM VELOCITY	m/sec			**0.65**					**0.58**					**0.59**		
MEAN VELOCITY	m/sec			**0.40**					**0.30**					**0.31**		

STUDY AREA		MRY-REF2-1	MRY-REF2-2	MRY-REF2-3	MRY-REF2-4	MRY-REF2-5	MRY-REF3-1	MRY-REF3-2	MRY-REF3-3	MRY-REF3-4	MRY-REF3-5	MRY-REF4-1	MRY-REF4-2	MRY-REF4-3	MRY-REF4-4	MRY-REF4-5
CHARACTERIZATION DATE		25-Aug-13	25-Aug-13	25-Aug-13	25-Aug-13	25-Aug-13	26-Aug-13	26-Aug-13	26-Aug-13	26-Aug-13	26-Aug-13	30-Aug-13	30-Aug-13	30-Aug-13	30-Aug-13	30-Aug-13
MEASUREMENT	UNIT															
Distance to U/S Replicate Station	m	-	220	224	226	258	-	188	200	220	125	-	60	88	93	115
TOTAL DISTANCE	m			928					733					356		
Wetted Width	m	31	35	52	43	50	46	34	45	26	40	22	25	27	30	24
AVERAGE WIDTH	m			42					38					26		
TD1	m	0.36	0.16	0.19	0.16	0.10	0.31	0.26	0.21	0.25	0.19	0.44	0.32	0.18	0.28	0.22
VEL1	m/sec	0.49	0.31	0.60	0.45	0.36	0.18	0.25	0.40	0.76	0.33	0.15	0.23	0.15	0.54	0.09
TD2	m	0.24	0.14	0.22	0.22	0.10	0.34	0.18	0.10	0.25	0.14	0.36	0.30	0.10	0.24	0.29
VEL2	m/sec	0.35	0.40	0.90	0.37	0.25	0.30	0.77	0.13	0.70	0.16	0.20	0.24	0.21	0.06	0.10
TD3	m	0.30	0.13	0.22	0.24	0.16	0.32	0.34	0.16	0.28	0.21	0.38	0.42	0.24	0.19	0.20
VEL3	m/sec	0.65	0.18	0.95	0.64	0.18	0.37	1.06	0.67	0.51	0.34	0.20	0.23	0.30	0.24	0.20
TD4	m	0.24	0.13	0.24	0.26	0.18	0.36	0.30	0.14	0.21	0.20	0.36	0.30	0.11	0.18	0.24
VEL4	m/sec	0.40	0.22	0.64	0.61	0.45	0.12	0.46	0.38	0.58	0.08	0.36	0.09	0.15	0.45	0.13
TD5	m	0.32	0.21	0.28	0.30	0.20	0.33	0.32	0.15	0.20	0.22	0.40	0.28	0.18	0.14	0.24
VEL5	m/sec	0.32	0.23	0.78	0.70	0.56	0.40	0.50	0.33	0.70	0.30	0.49	0.10	0.36	0.33	0.26
TD6	m	0.24	0.22	0.14	0.27	0.22	0.24	0.23	0.12	0.20	0.26	0.33	0.25	0.14	0.14	0.24
VEL6	m/sec	0.21	0.51	0.57	0.61	0.51	0.34	0.20	0.13	0.66	0.44	0.22	0.11	0.22	0.21	0.10
TD7	m	0.14	0.22	0.18	0.14	0.16	0.32	0.20	0.19	0.22	0.35	0.28	0.28	0.11	0.22	0.24
VEL7	m/sec	0.15	0.42	0.55	0.32	0.39	0.45	0.24	0.26	0.30	0.52	0.22	0.20	0.16	0.17	0.20
TD8	m	0.20	0.18	0.14	0.24	0.13	0.20	0.16	0.25	0.16	0.34	0.22	0.34	0.08	0.12	0.22
VEL8	m/sec	0.43	0.32	0.32	0.49	0.53	0.53	0.44	0.40	0.45	0.36	0.14	0.21	0.10	0.31	0.07
TD9	m	0.14	0.18	0.12	0.22	0.14	0.20	0.14	0.28	0.26	0.13	0.11	0.36	0.20	0.23	0.33
VEL9	m/sec	0.50	0.34	0.24	0.70	0.45	0.26	0.32	0.47	0.26	0.17	0.06	0.24	0.33	0.45	0.21
TD10	m	0.12	0.26	0.14	0.27	0.23	0.16	0.15	0.24	0.26	0.30	0.16	0.36	0.30	0.17	0.29
TD10	m/sec	0.65	0.41	0.36	0.61	0.66	0.40	0.27	0.24	0.32	0.10	0.20	0.12	0.38	0.21	0.16
MEAN TOTAL DEPTH	m	**0.23**	**0.18**	**0.19**	**0.23**	**0.16**	**0.28**	**0.23**	**0.18**	**0.23**	**0.23**	**0.30**	**0.32**	**0.16**	**0.19**	**0.25**
MEAN VELOCITY	m/sec	**0.42**	**0.33**	**0.59**	**0.55**	**0.43**	**0.34**	**0.45**	**0.34**	**0.52**	**0.28**	**0.22**	**0.18**	**0.24**	**0.30**	**0.15**
MINIMUM DEPTH	m			**0.10**					**0.10**					**0.08**		
MAXIMUM DEPTH	m			**0.36**					**0.36**					**0.44**		
MEAN TOTAL DEPTH	m			**0.20**					**0.23**					**0.25**		
MINIMUM VELOCITY	m/sec			**0.15**					**0.08**					**0.06**		
MAXIMUM VELOCITY	m/sec			**0.95**					**1.06**					**0.49**		
MEAN VELOCITY	m/sec			**0.46**					**0.39**					**0.22**		

\\NB4\Project$\1\02\00181\34\A\Report\Report 5 Rev B - EEM Study Design\Appendix A - Site Char\Individual Files\[EEM_Appendix A_Table A1 to A3.xlsx]TABLE_A.3

NOTES:

1. TOTAL DEPTH AND VELOCITY MEASUREMENTS TAKEN USING A MRCH MCBIRNEY FLO-MATE WITH TOP-SETTING WADING ROD.
2. MEASUREMENTS TAKEN AT BENTHIC INVERTEBRATE REPLICATE STATIONS, NEAR THE FIELD SUB-SAMPLE LOCATIONS.

PHOTO 1 – CLT-NF-1 facing upstream towards waterfall barrier.

PHOTO 2 – CLT-NF-3 facing downstream.

PHOTO 3 – CLT-NF-4 and CLT-NF-5 facing upstream.

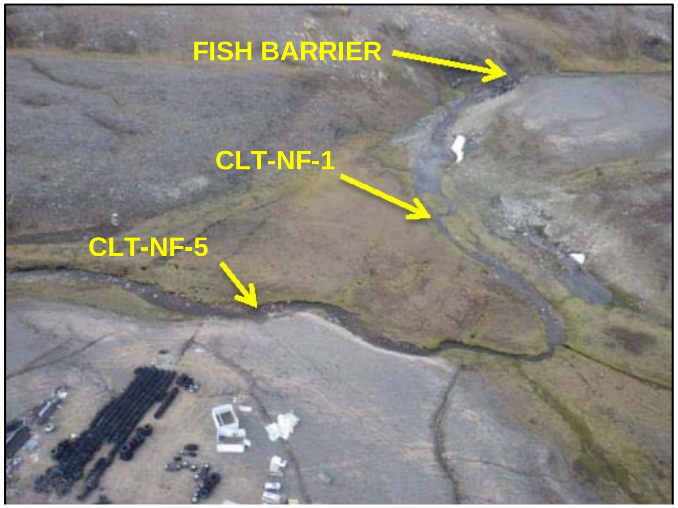


PHOTO 4 – CLT-NF aerial view including fish barrier upstream.

PHOTO 5 – CLT-FF-1 facing upstream to Tote Road culverts.

PHOTO 6 – CLT-FF-1 facing downstream.

PHOTO 7 – CLT-FF-4 facing downstream.

PHOTO 8 – CLT-FF-5 facing downstream towards Camp Lake.

PHOTO 9 – CLT-REF2-1 facing downstream.

PHOTO 10 – CLT-REF2-1 facing upstream.

PHOTO 11 – CLT-REF2-3 facing downstream.

PHOTO 12 – CLT-REF2-5 facing downstream towards Tote Road.

PHOTO 13 – CLT-REF3-1 facing downstream.

PHOTO 14 – CLT-REF3-2 facing downstream.

PHOTO 15 – CLT-REF3-4 facing downstream.

PHOTO 16 – CLT-REF3 aerial view of study area.

PHOTO 17 – CLT-REF4-1 facing upstream.

PHOTO 18 – CLT-REF4-3 facing downstream.

PHOTO 19 – CLT-REF4-5 facing upstream.

PHOTO 20 – CLT-REF4 aerial view of study area.

PHOTO 21 – MRY-NF-1 facing upstream, Deposit No.1 on horizon.

PHOTO 22 – MRY-NF-4 facing upstream.

PHOTO 23 – MRY-NF sediment characterization and BIC study area.

PHOTO 24 – MRY-NF fish community and water quality study area.


PHOTO 25 – MRY-FF-2 facing upstream.


PHOTO 26 – MRY-FF-4 facing upstream.


PHOTO 27 – MRY-FF-5 facing upstream from right bank.


PHOTO 28 – MRY-FF aerial view of study area facing upstream.

PHOTO 29 – MRY-REF1-1 facing upstream.

PHOTO 30 – MRY-REF1-3 facing downstream.

PHOTO 31 – MRY-REF1-5 facing upstream.

PHOTO 32 – MRY-REF1 aerial view facing upstream.

PHOTO 33 – MRY-REF2-1 facing downstream.

PHOTO 34 – MRY-REF2-2 facing upstream.

PHOTO 35 – MRY-REF2-5 facing downstream.

PHOTO 36 – MRY-REF2-1 to REF2-4 aerial view of study area.

PHOTO 37 – MRY-REF3-1 facing downstream.

PHOTO 38 – MRY-REF3-2 facing upstream.

PHOTO 39 – MRY-REF3-5 facing downstream.

PHOTO 40 – MRY-REF3 aerial view of study area facing upstream.

PHOTO 41 – MRY-REF4-1 facing upstream.

PHOTO 42 – MRY-REF4-2 facing left bank.

PHOTO 43 – MRY-REF4-3 facing downstream.

PHOTO 44 – MRY-REF4-5 facing downstream.

APPENDIX B

SEDIMENT QUALITY DATA

. / 104) ! 53) !%

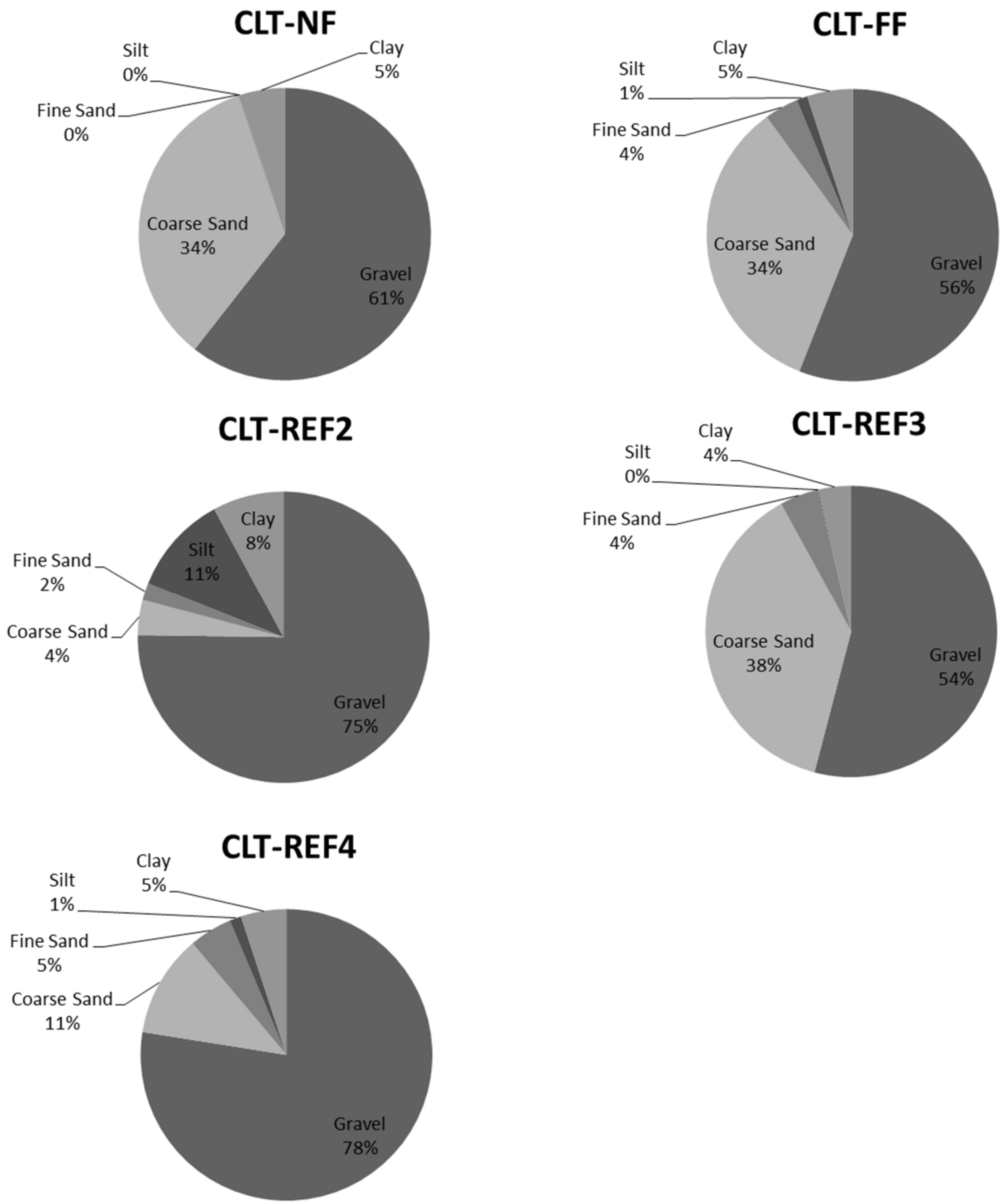


Figure B.1 Camp Lake Tributary Study Areas: Particle Size Distribution and TOC Summary

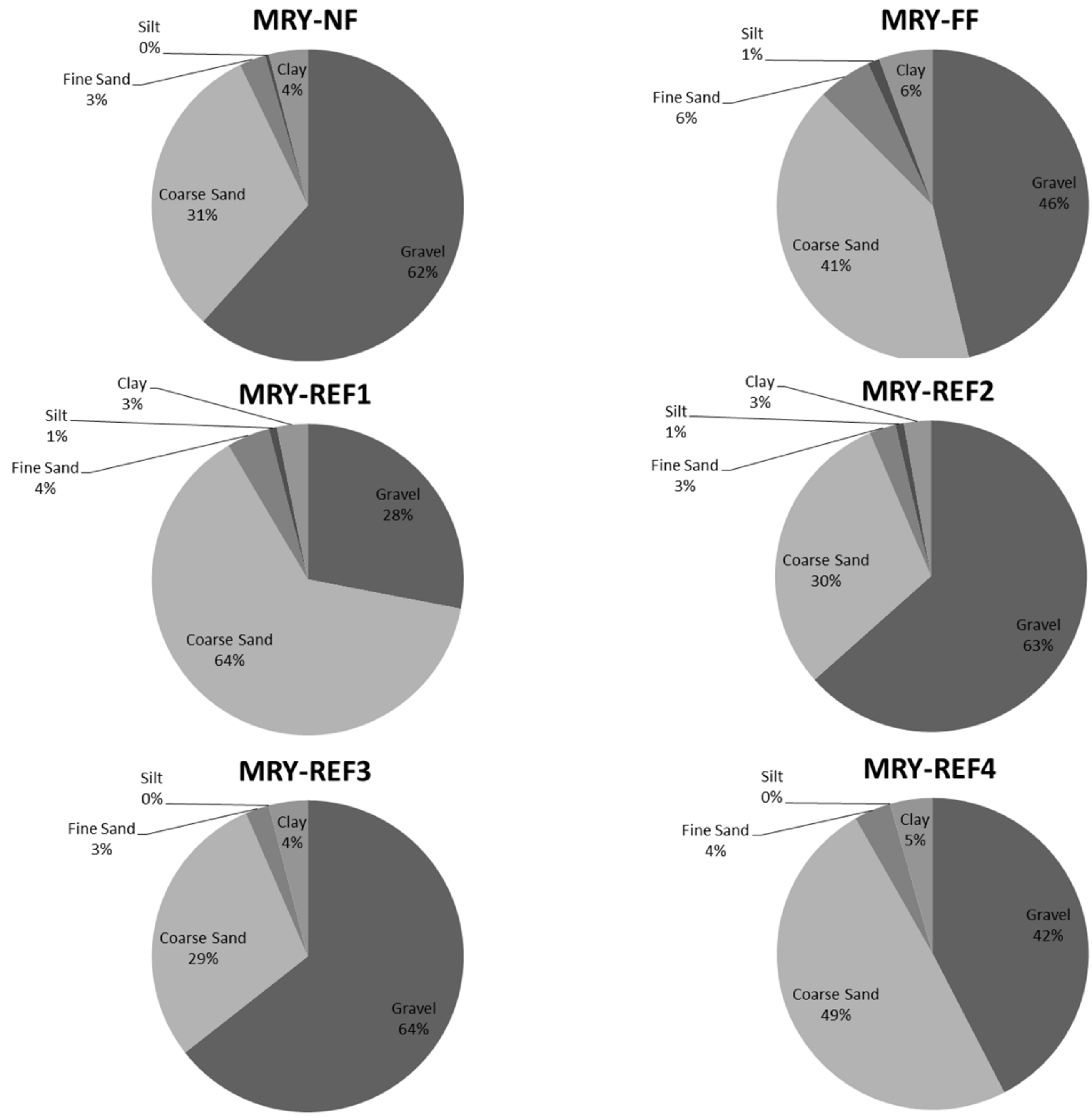


Figure B.2 Mary River Study Areas: Particle Size Distribution and TOC Summary

Appendix B

Water and Sediment Quality CREMP

Baffinland

April, 2016

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT

WATER AND SEDIMENT QUALITY REVIEW AND CREMP STUDY DESIGN
NB102-181/33-1

REVISION 3

Prepared By: Andrew Vermeer
Department: Environment
Title: Environmental Coordinator
Date: April 8, 2016

Approved By: Jim Millard
Department: Environment
Title: Environmental Manager
Date: April 8, 2016

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

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
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

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). This document has been revised to reflect all of the proposed modifications by Minnow regarding 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
- Understand the seasonal, depth (for lakes) and inter-annual variability of water quality
- Understand natural enrichment of the mine site area waters and sediment
- 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 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] 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.

1.3 PROJECT ACTIVITIES DURING BASELINE DATA COLLECTION

Baffinland has been actively undertaking 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 including Mary Lake) and Figure 1.2 (mine site core area). 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 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 mine site; haulage of ore over the tote road; 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 No. 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

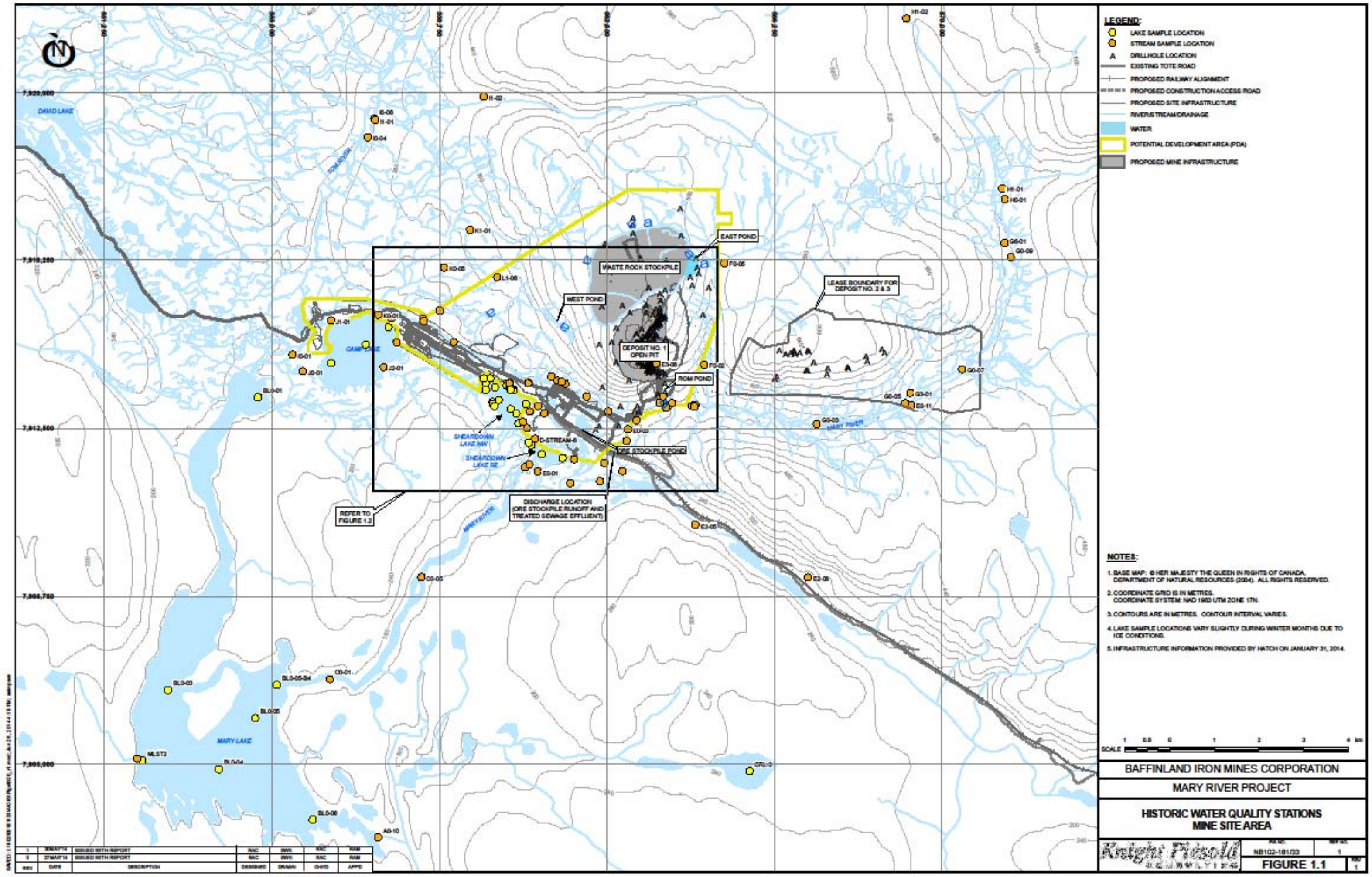


Figure 1.2 Historic Water Quality Stations - Immediate Mine Site Area

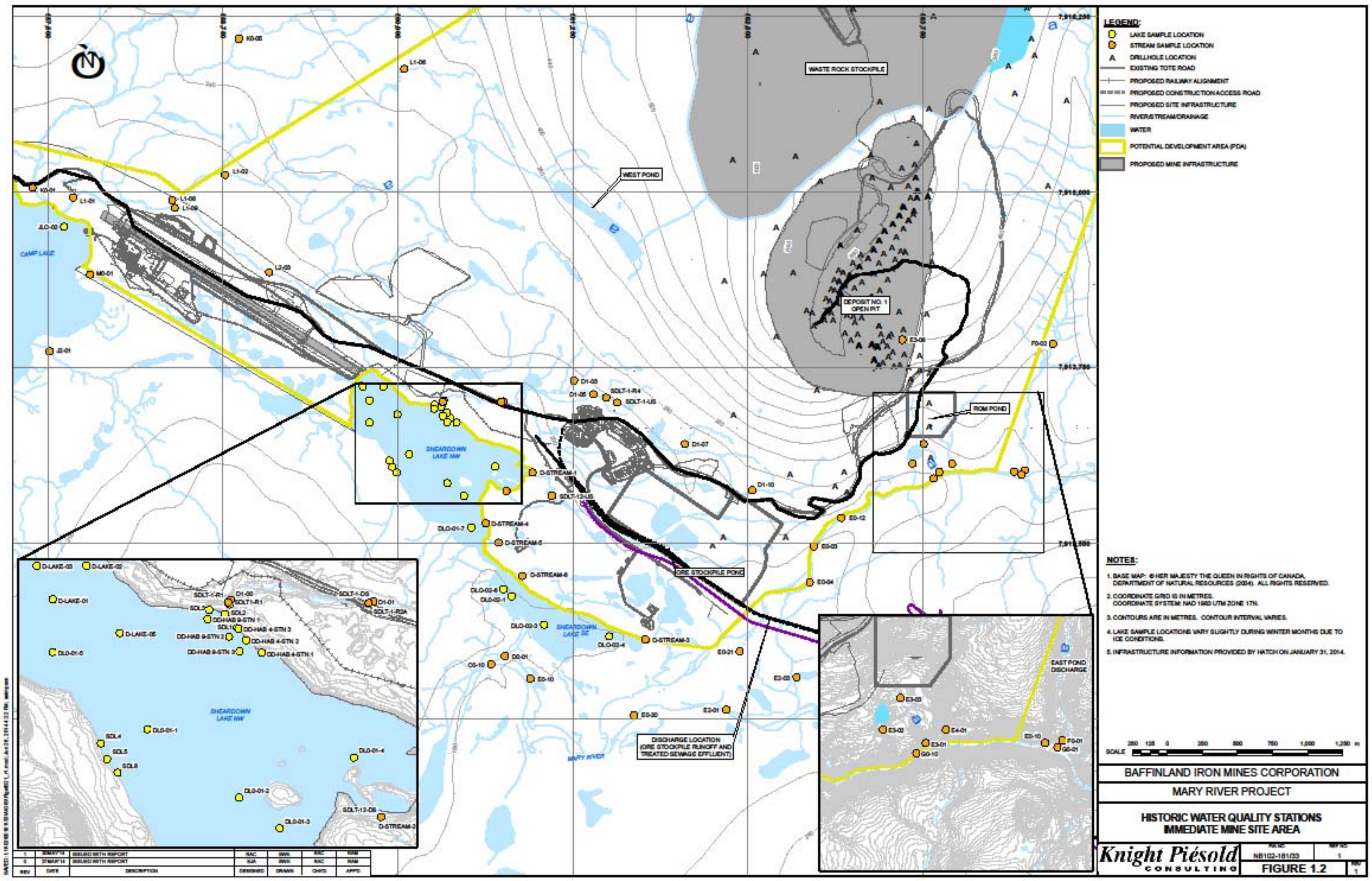
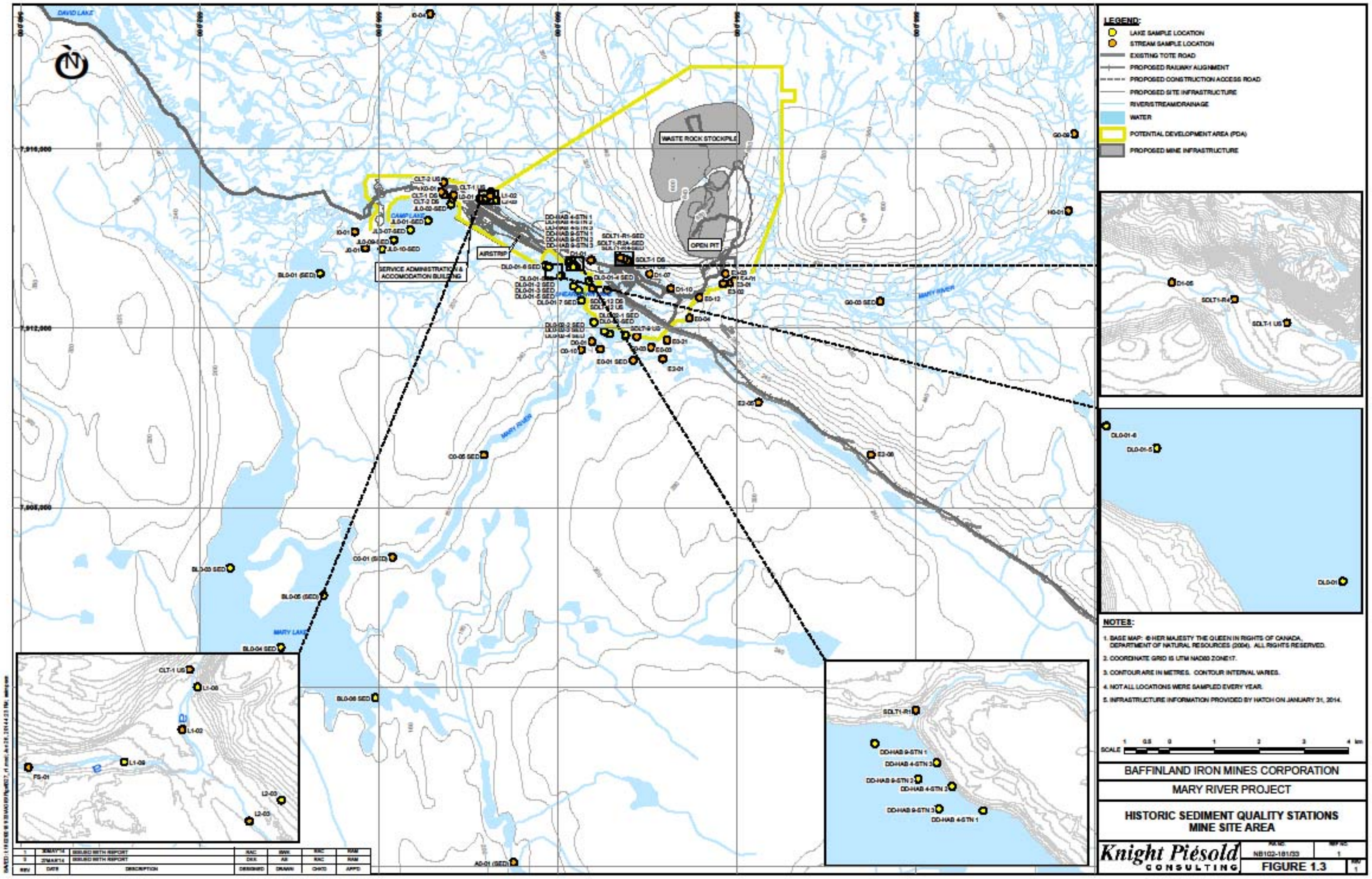


Figure 1.3 Historic Sediment Quality Stations - Mine Site Area



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 project 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 project 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 Review of Water Quality Method Detection Limits

Baffinland

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	0.0006	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.

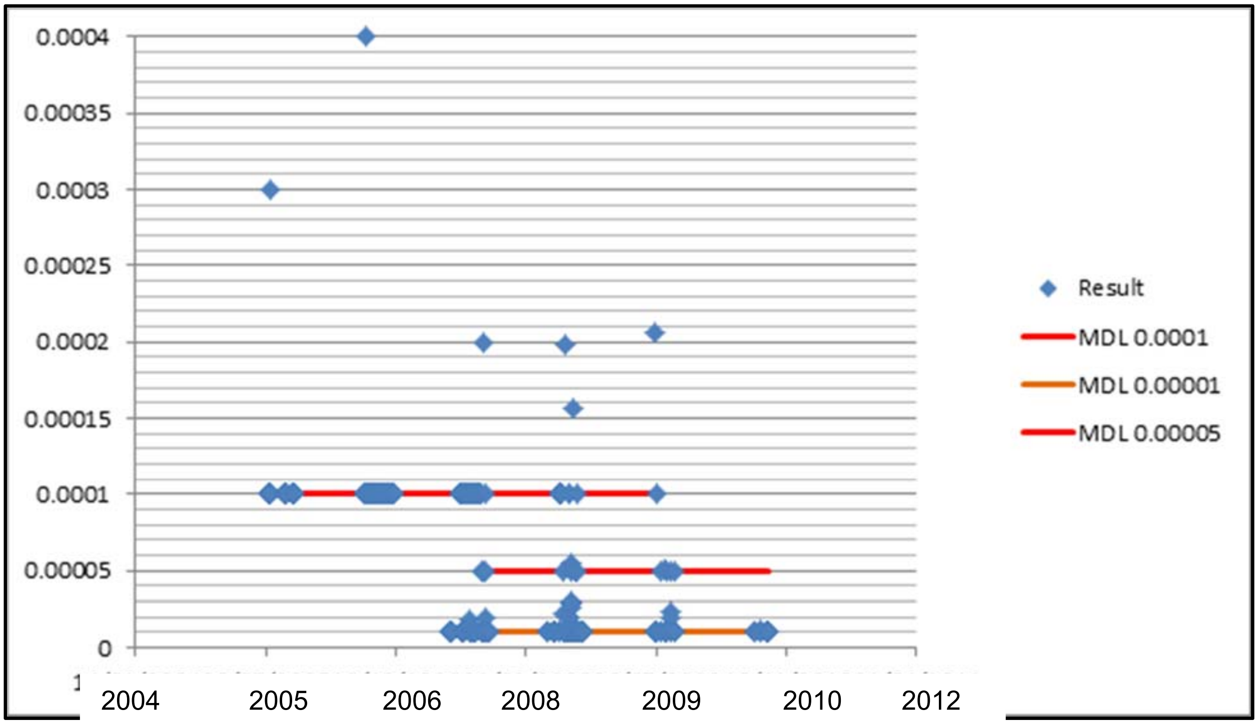


Figure 2.1 Example MDL Evaluation Graph - Silver

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 mine site 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) 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 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.

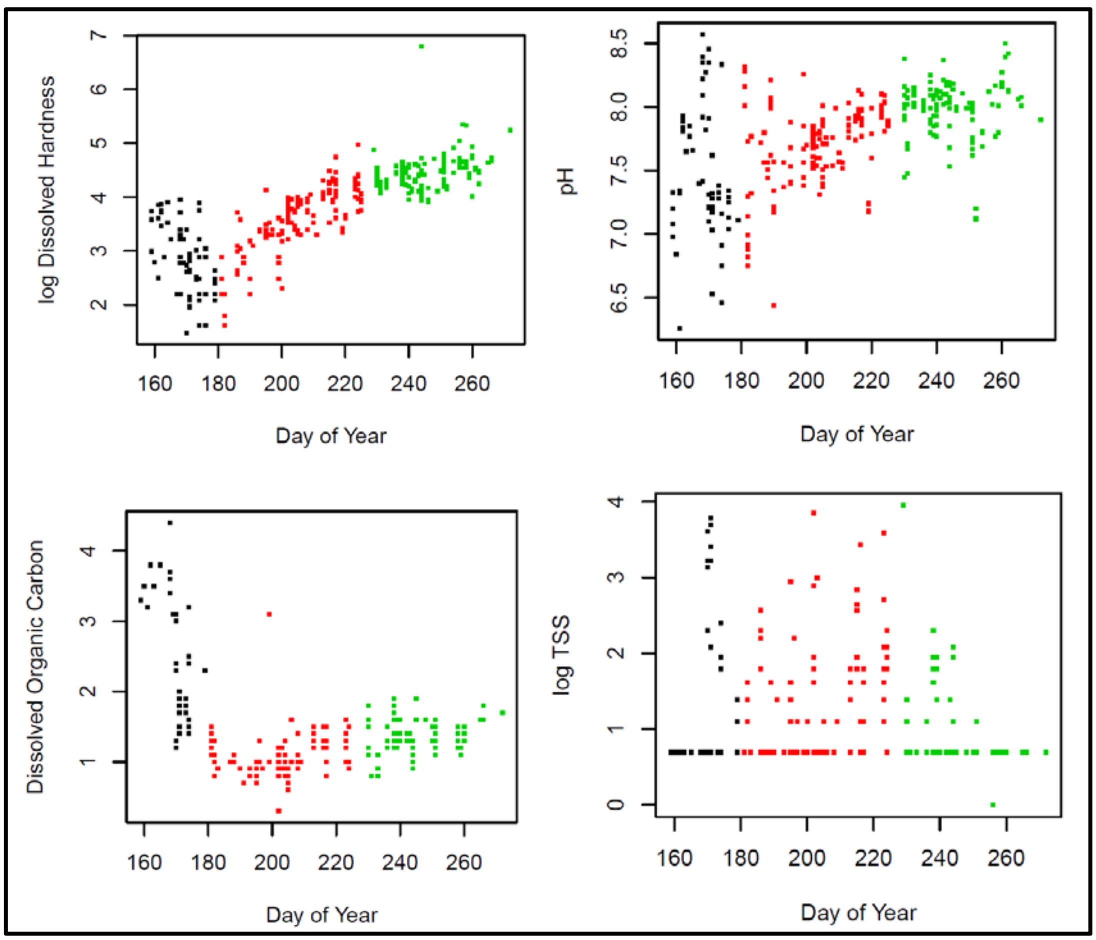
2.5.3 Site-Wide Overview of Water Quality Including Seasonal Trends

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

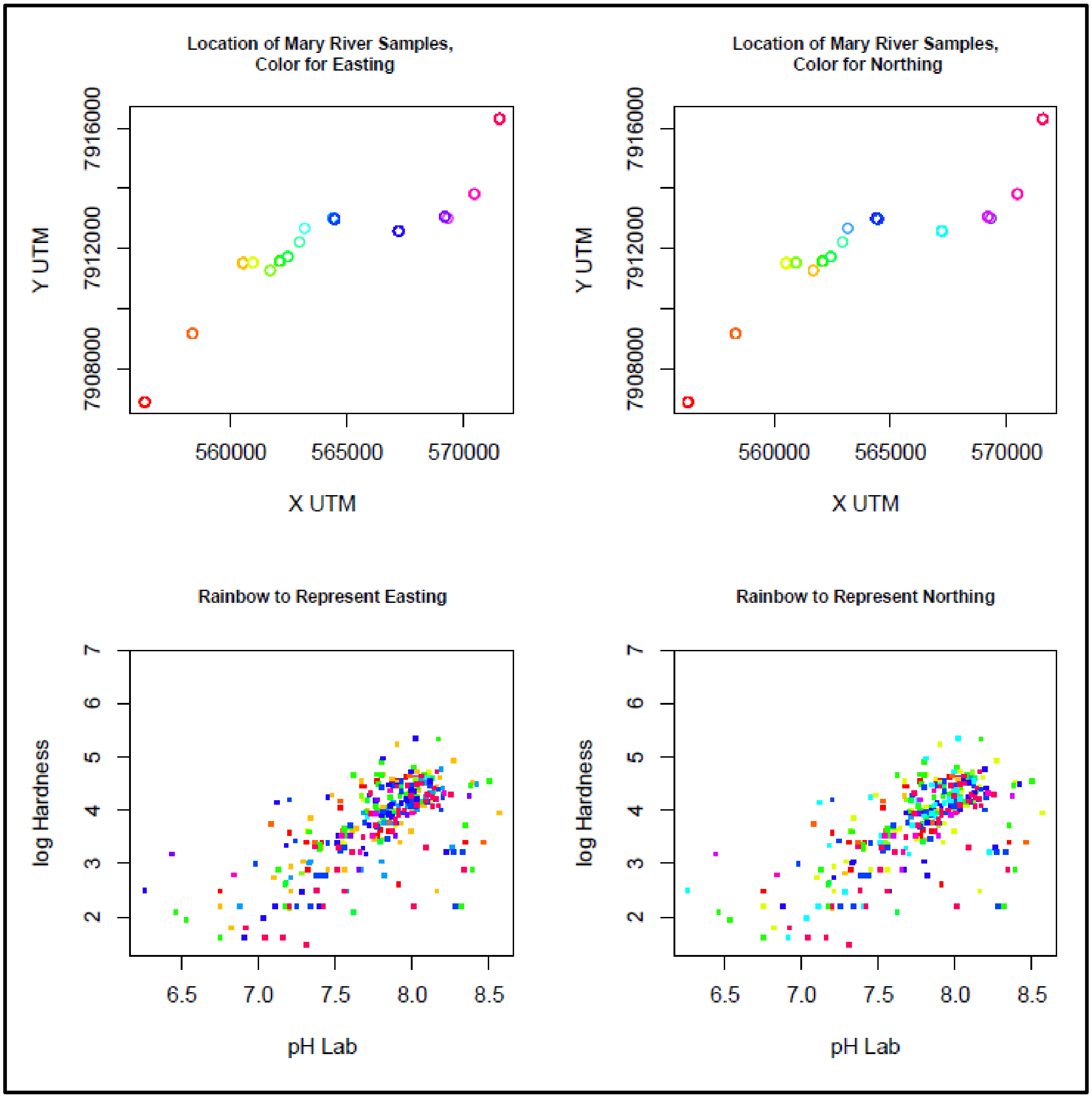


Figure 2.3 Mary River - Geographic pH Trends

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 No. 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.

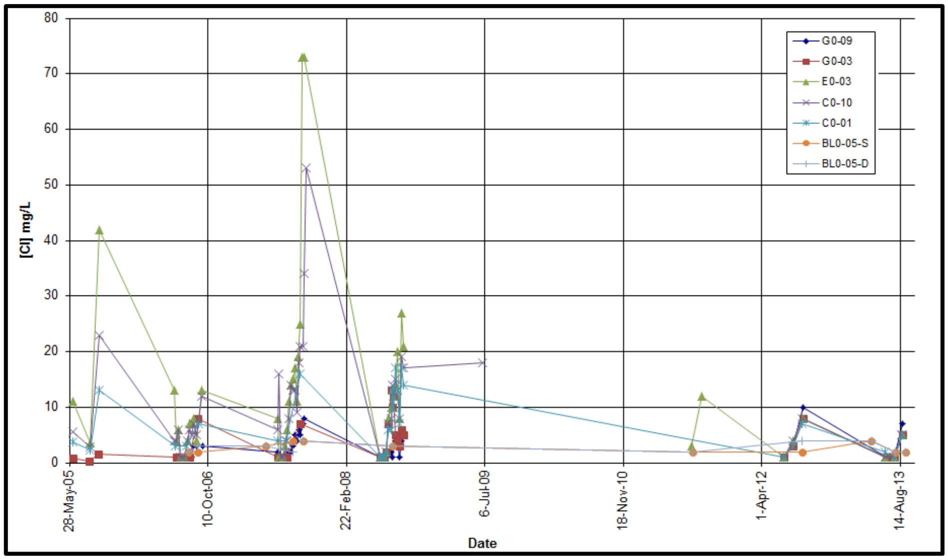
Figures 2.6 through 2.8 depict the changes in concentrations that occur during seasons in both the streams and lake in vicinity to the proposed mine site. Spring lake concentrations are never depicted and neither are winter stream concentrations. Figure 2.6 shows a small increase in chloride concentrations 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.

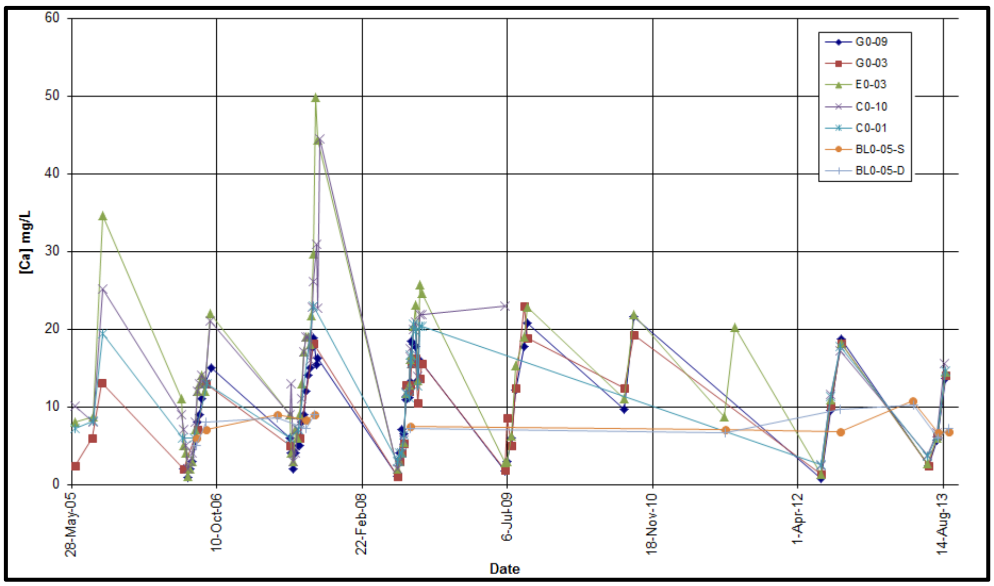
Stream aluminum concentrations are depressed in the spring, and elevated in the summer, as shown in Figure 2.10. Stream concentrations, particularly those recorded in Mary River are greater than the concentrations recorded in the lakes. Fall concentrations are elevated, when compared to fall and winter,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

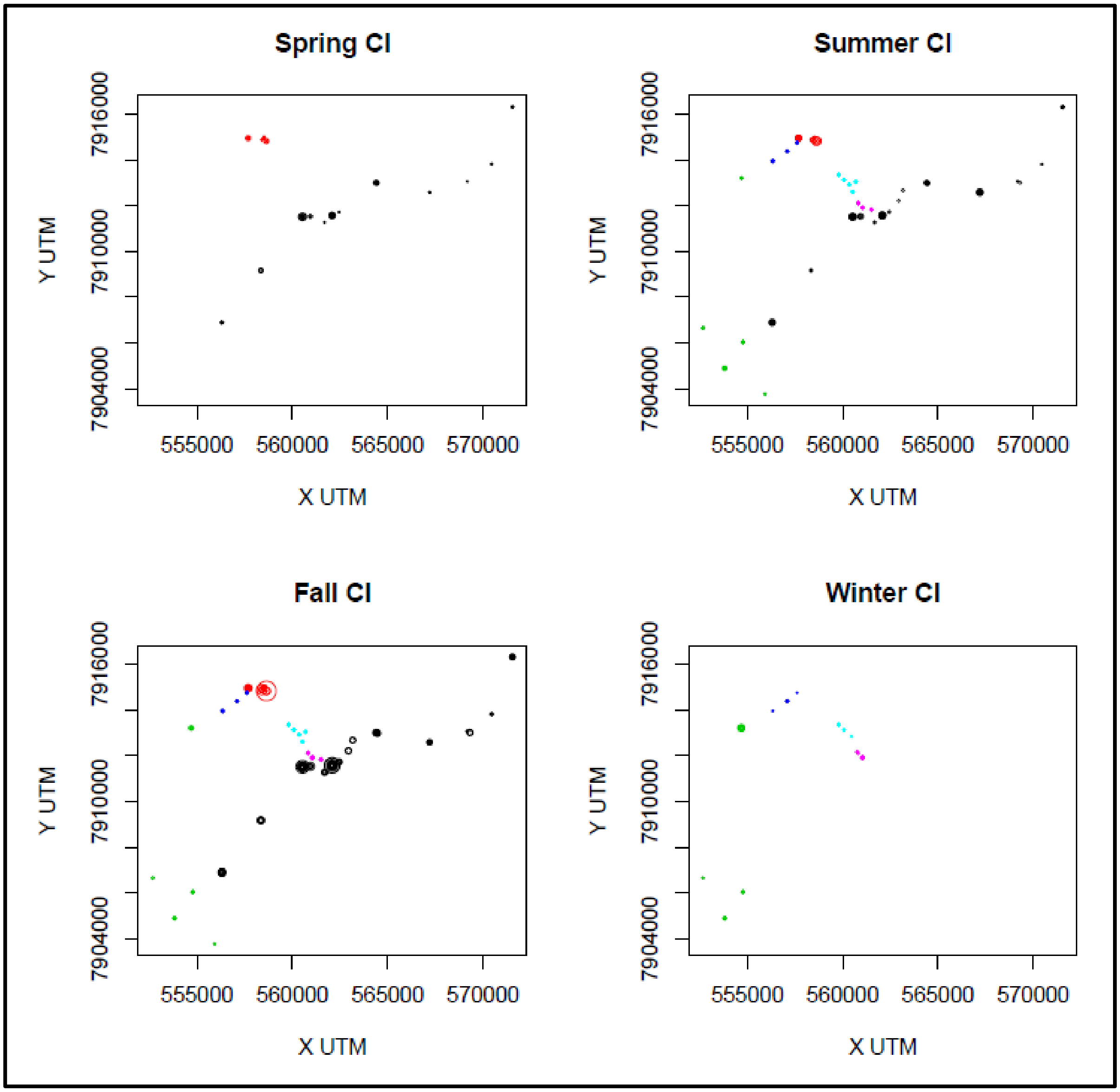
Figure 2.4 Chloride Concentrations in Mine Site Waters over the Study Period



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.

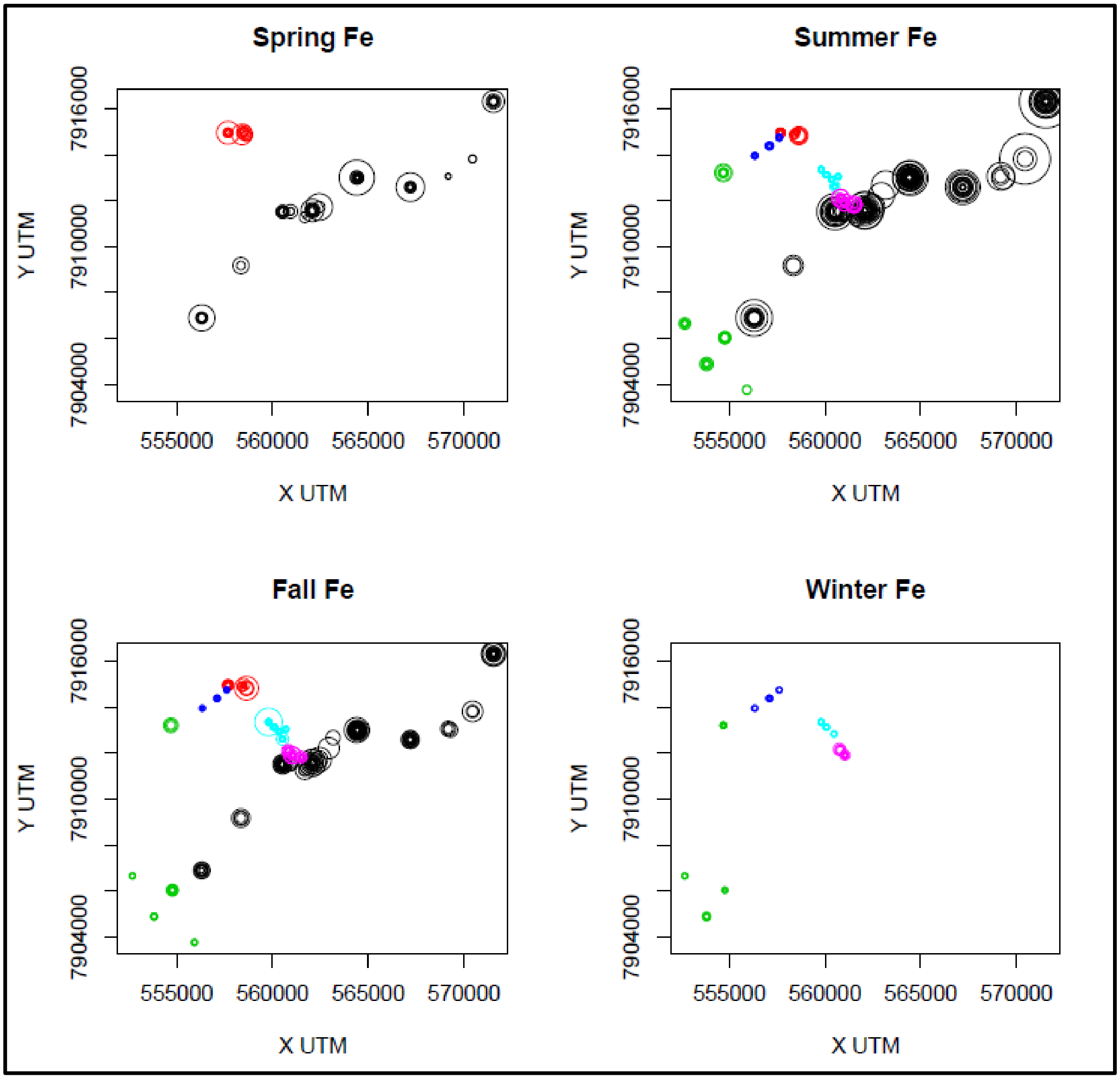
Figure 2.5 Calcium Concentrations in Mine Site Waters over the Study Period



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.

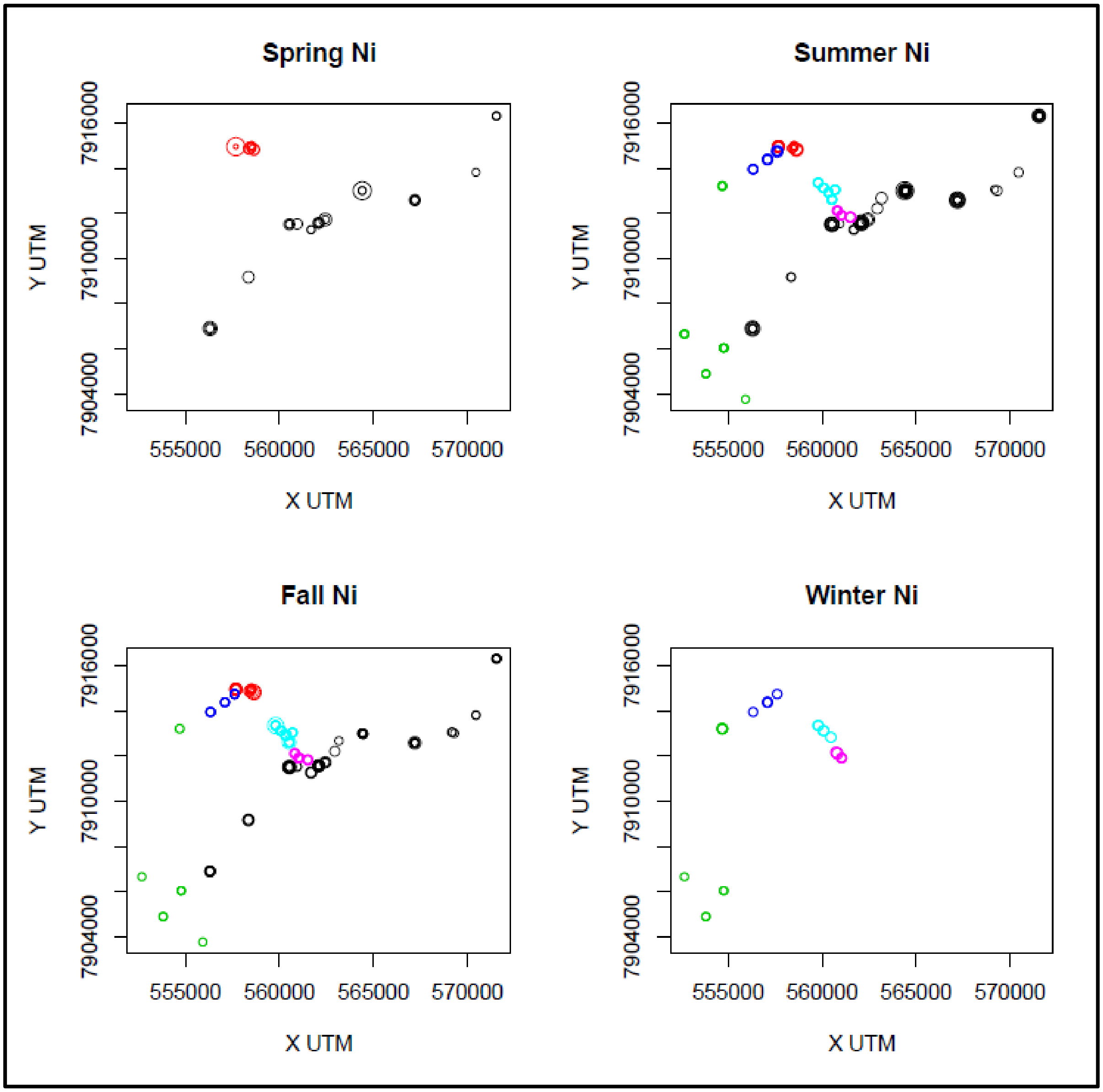
Figure 2.6 Site-Wide Seasonal Trends for Chloride



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).

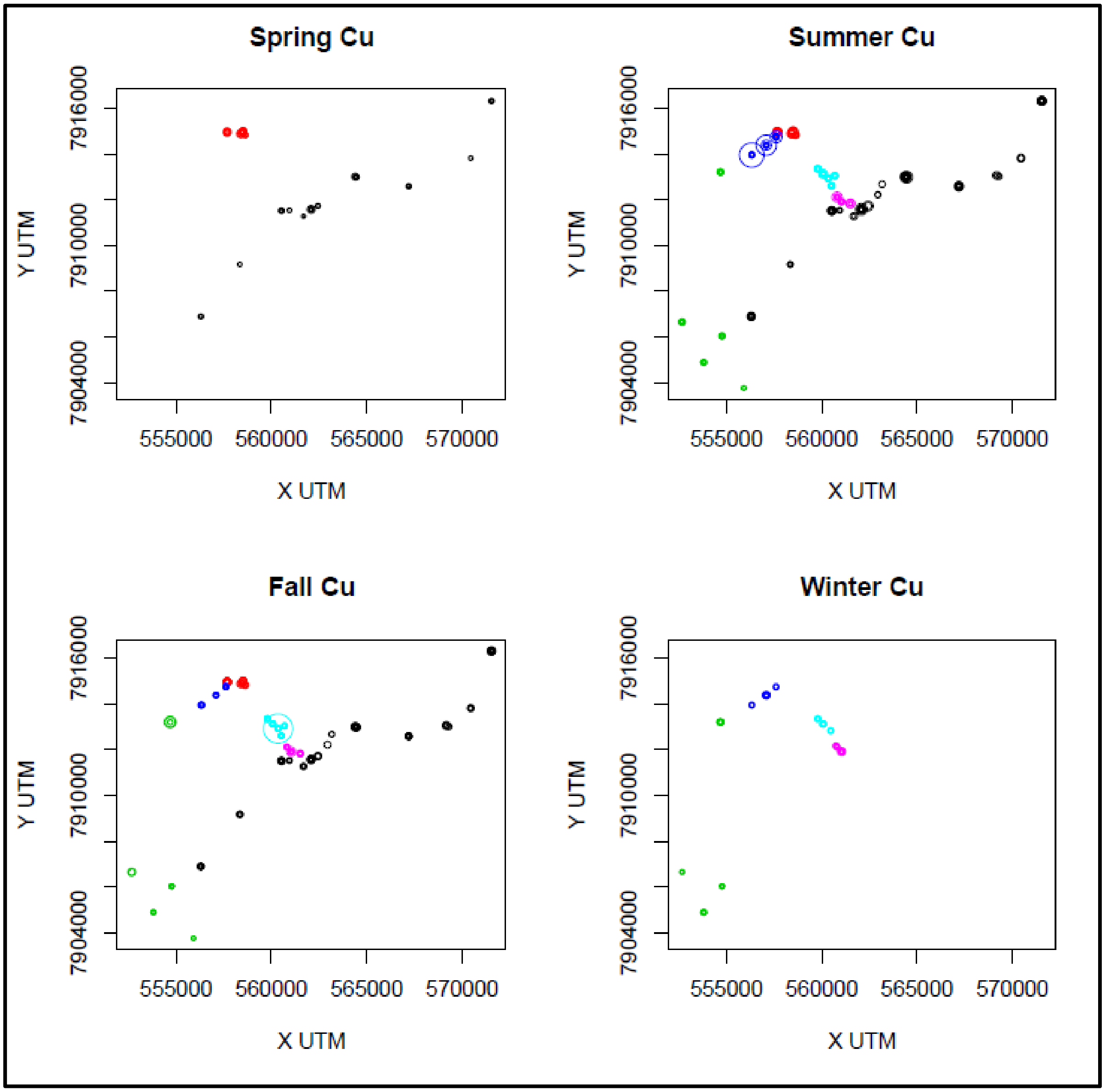
Figure 2.7 Site-Wide Seasonal Trends for Total Iron



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).

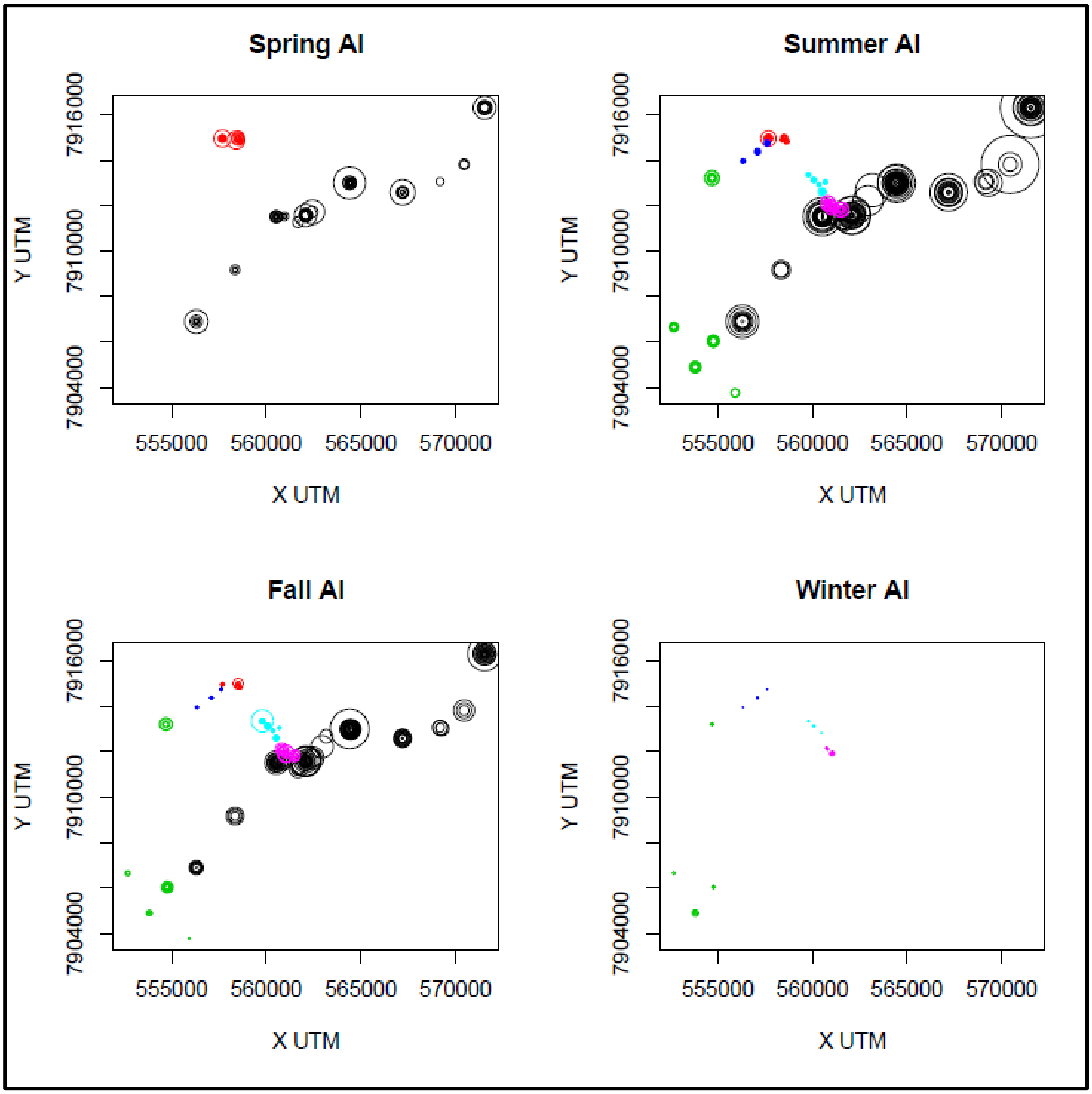
Figure 2.8 Site-Wide Seasonal Trends for Total Nickel



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 mine site 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 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 area 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 with the objective of identifying project-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).

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.

---

[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 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 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 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 mine site activities
- Discharge limit(s) have been established for the parameter in 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 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 3 * 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 mine site 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

Parameter	Units	Water Quality Guideline	Camp Lake	Mary Lake	Sheardown Lake	Selected Benchmark	Benchmark Method
Water Quality Parameters							
Chloride (Cl^-)	mg/L	120	4	13	5	120	A
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
Iron	mg/L	0.3	0.326	0.874	CLT = 0.326 MR = 0.874	B

Parameter	Units	Water Quality Guideline	Camp Lake Tributary	Mary River[3]	Selected Benchmark	Benchmark Method
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 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). In addition, Reference Lake 3 was selected in 2015 as the CREMP reference lake and will be sampled concurrently with mine area lakes in the summer and fall[3].

After completing the CREMP in 2015, Minnow proposed several modifications to the program (presented in Appendix I of the AEMP) 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 7; Minnow, 2016);
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 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 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.

[3] Reference Lake 3 is located approximately 60 km south of the mine, and therefore no winter sampling is proposed during the winter months due to difficult accessibility and associated safety concerns for mine personnel.
[4] Anoxic conditions have not been observed at any of the study lakes since baseline studies began in 2005.

2. Discontinue water quality monitoring at stations L1-09 (Camp Lake Tributary 1) and D1-05 (Sheardown Lake Tributary 1).
3. Discontinue water quality monitoring at stations G0-09A, G0-09B and C0-01 on the Mary River.

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.

An updated list of the CREMP water quality monitoring stations is presented in Table 2.11.

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

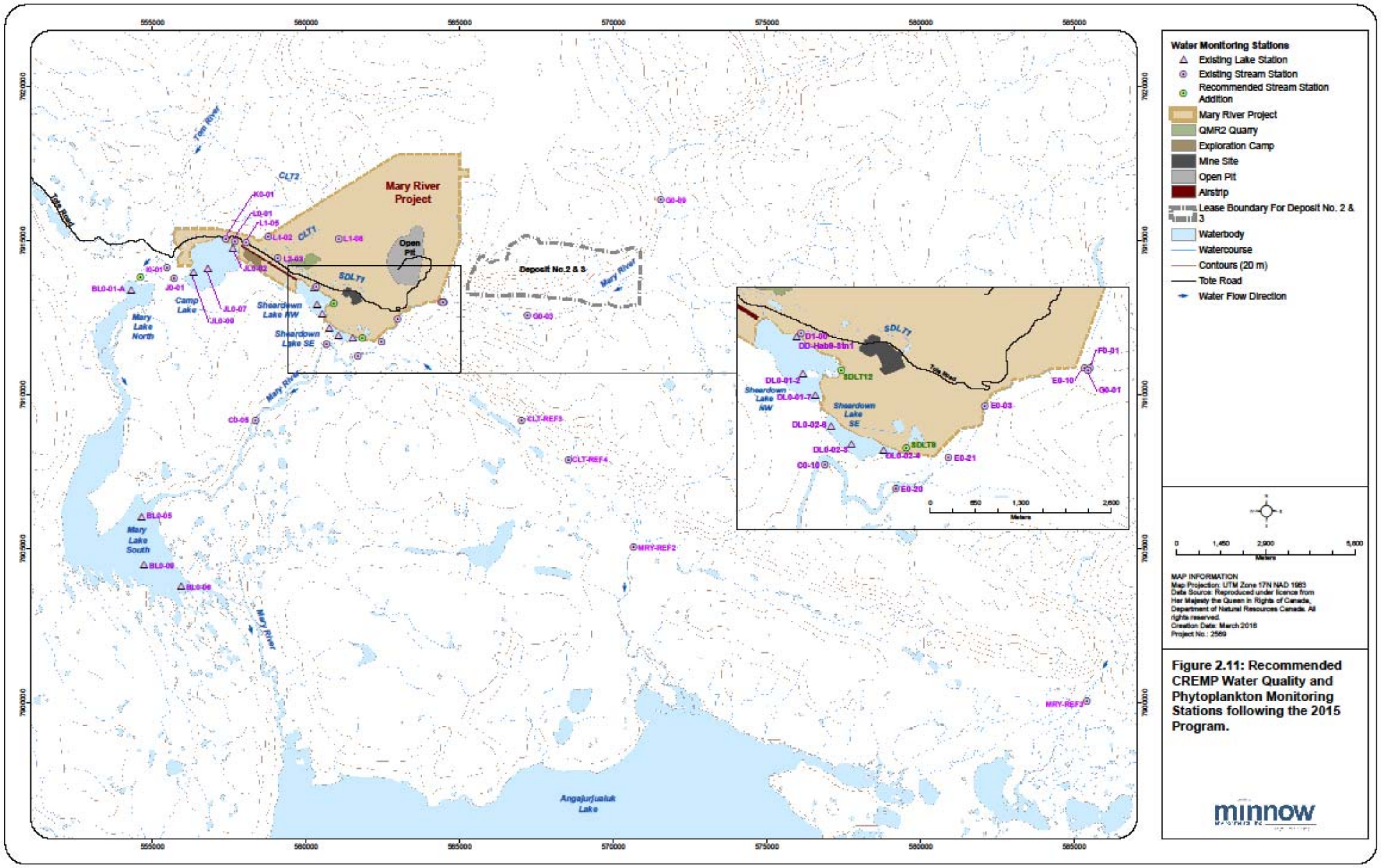


Table 2.11 Water Quality CREMP Station Details

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 Ca Lake
Mary Lake (South Basin)							
BL0-05	554632	7906031	1		1	1	Mary Lake, southern basin near ou of Mary River
BL0-06	555924	7903760	1		1	1	
BL0-09	554715	7904479	1		1	1	Main basin between BL0-05 & BL0-
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 La outflow
SDL-Trib 1							
D1-00	560329	7913512		1	1	1	Tributary D1
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 an 3, d/s of F0-01
E0-20[1]	561688	7911272		1	1	1	Mainstem u/s of trib E2 and d/s of ore/sewage discharge
E0-21[1]	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 statio within anticipated dust plume
G0-09[1]	571546	7916317		1	1	1	Upstream, potential reference statio 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
Camp Lake							
JL0-02	557615	7914750	1		1	1	Littoral station near CLT1, CLT2 inle
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	
L2-03	559081	7914425		1	1	1	Southern tributary of CLT-1
Camp Lake Tributary Reference Areas							
CLT-REF3 (E2-08)[1]	567004	7909174		1	1	1	Reference stream outside dust plume
CLT-REF4 (CV-006-1)[1]	568533	7907874		1	1	1	
Mary River Reference Areas							
MRY-REF3 (S2-020)[1]	585407	7900061		1	1	1	Reference river outside dust plume
MRY-REF2 (S2-010)[1]	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**	

NOTES:

1. STATIONS INCLUDED IN THE EEM PROGRAM.

2.7.5 Sampling Frequency and Schedule

Environment Canada (2012) specifies that four samples collected over a 12-month period, not less than one 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, summer and fall, whereas, lake water quality monitoring will take place during the winter (late April), summer and fall. 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 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:
  - o Staffing the project with experienced and properly trained individuals

- o Ensuring that representative, meaningful data are collected through planning and efficient research
- o Using standard protocols for sample collection, preservation, and documentation
- o Calibrating and maintaining all field equipment
- o Collecting duplicate, blank, filter and travel blank samples for submission for analysis (approximately 10% of overall samples)
- o External Quality Control:
- o Employing fully accredited analytical laboratories for the analysis of all samples
- o 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.

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.

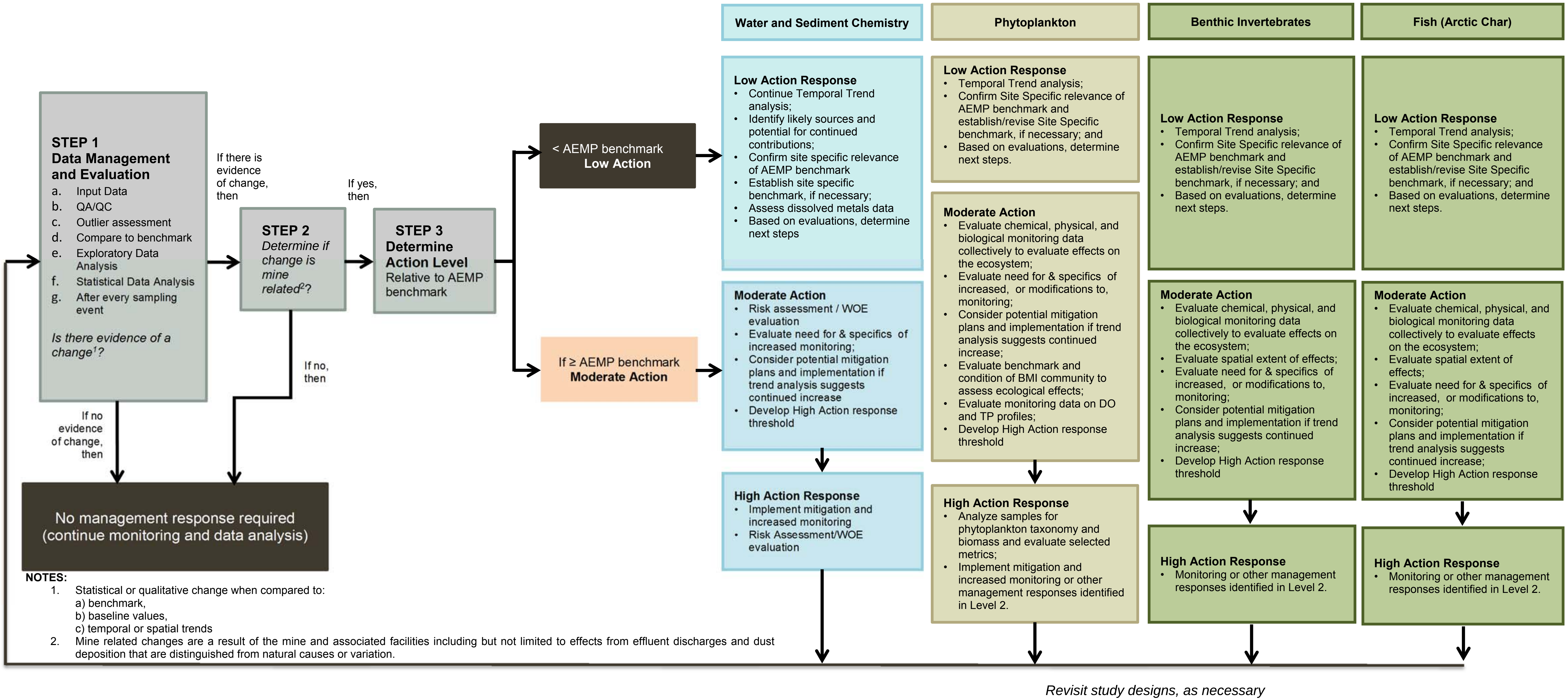


Figure 2.12 AEMP Assessment Approach and Response Framework

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 project-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 typically conducted once in the fall (late August/early September) in conjunction with and at the same stations as 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

[1] Five (5) sediment samples were taken at Reference Lake 1 and 2. One (1) sediment sample was taken at Reference Lake 3.

Sampling and analytical methods, and quality assurance/quality control (QA/QC) procedures applied during the sampling period are described in the sampling protocol included as Appendix A. Contrary to current protocols, 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. related studies

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.

3.1.1 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):

Camp Lake In this 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.

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).

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

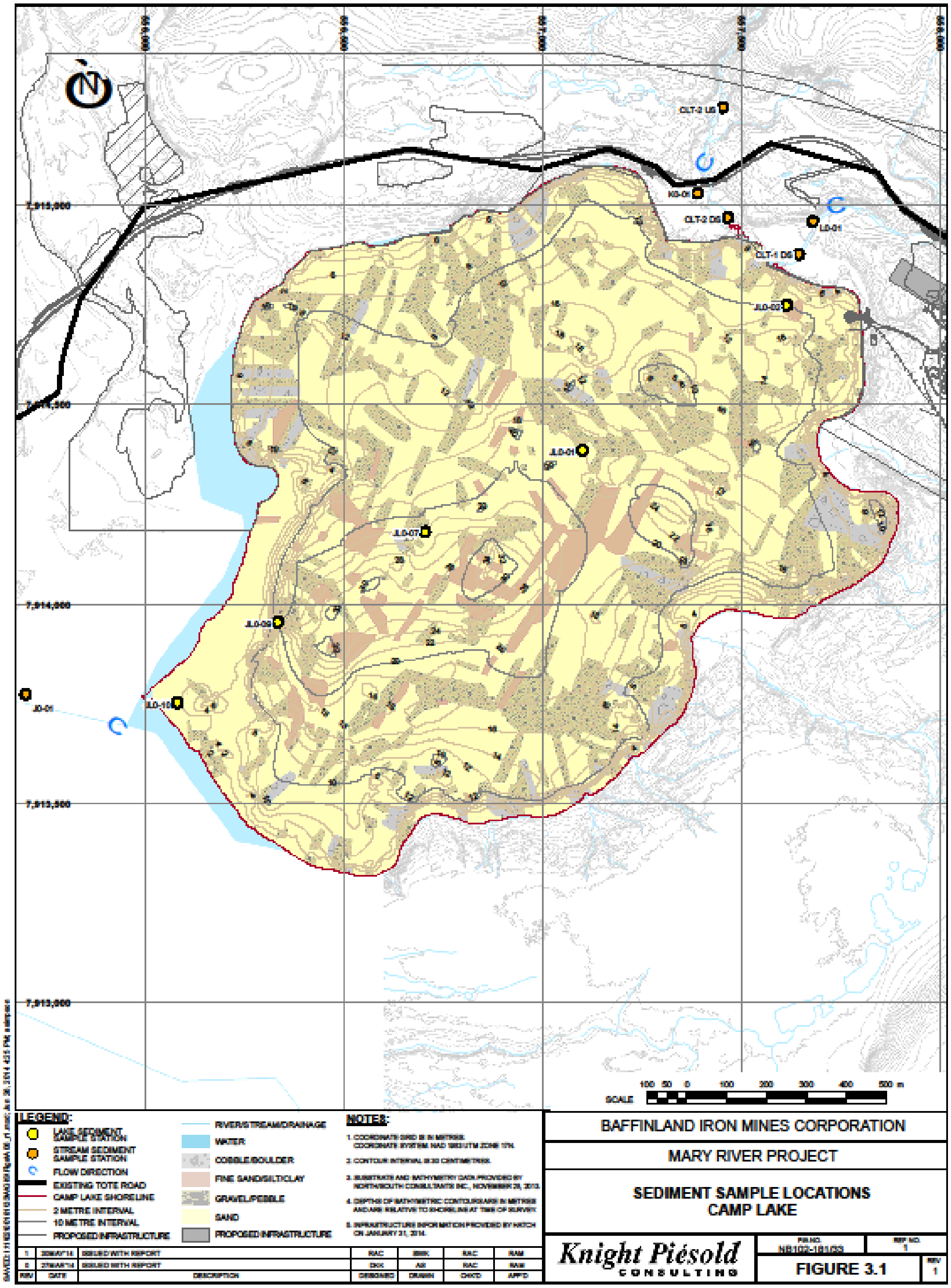


Figure 3.2 Sheardown Lake –Substrate and Bathymetry

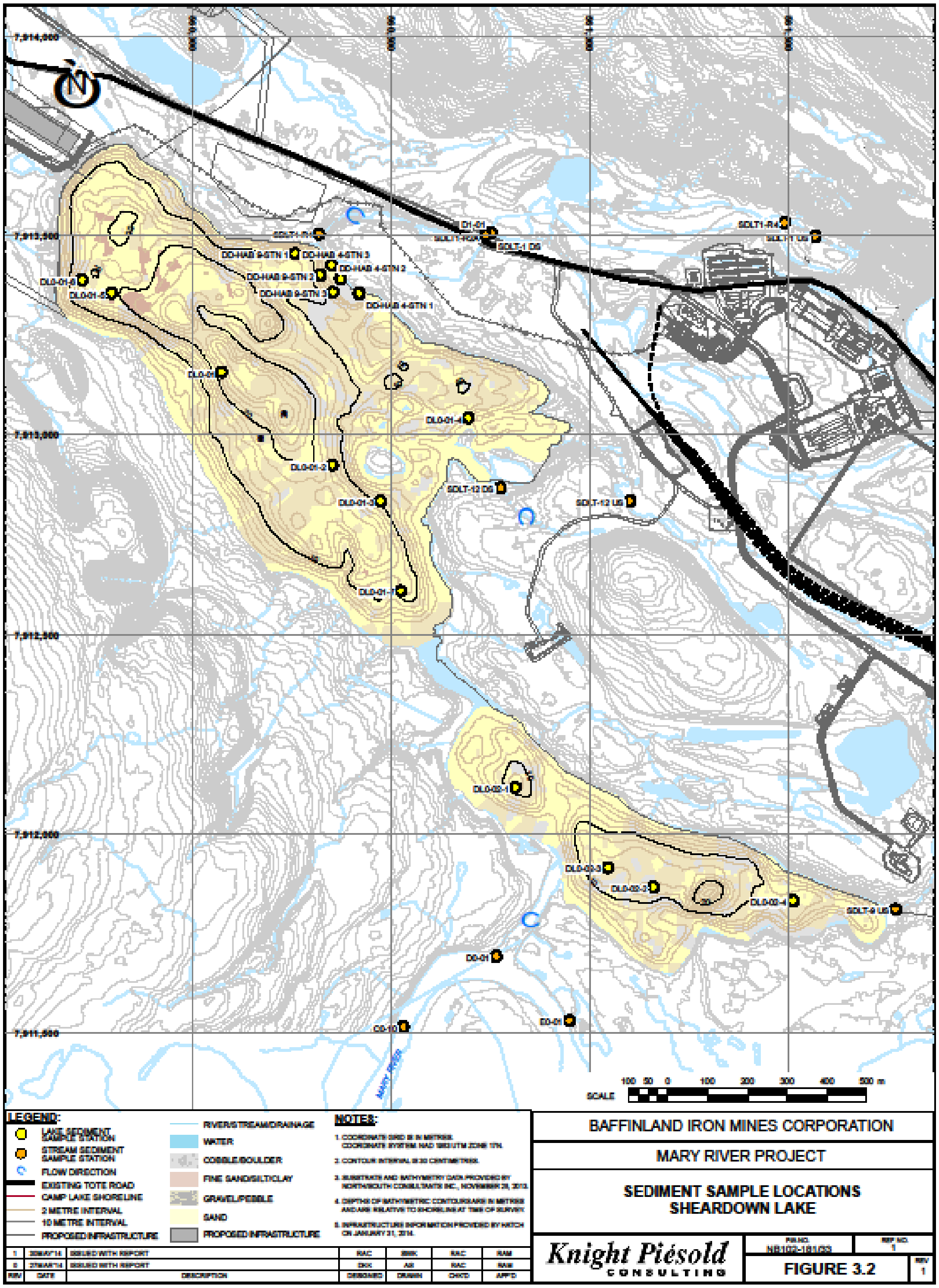
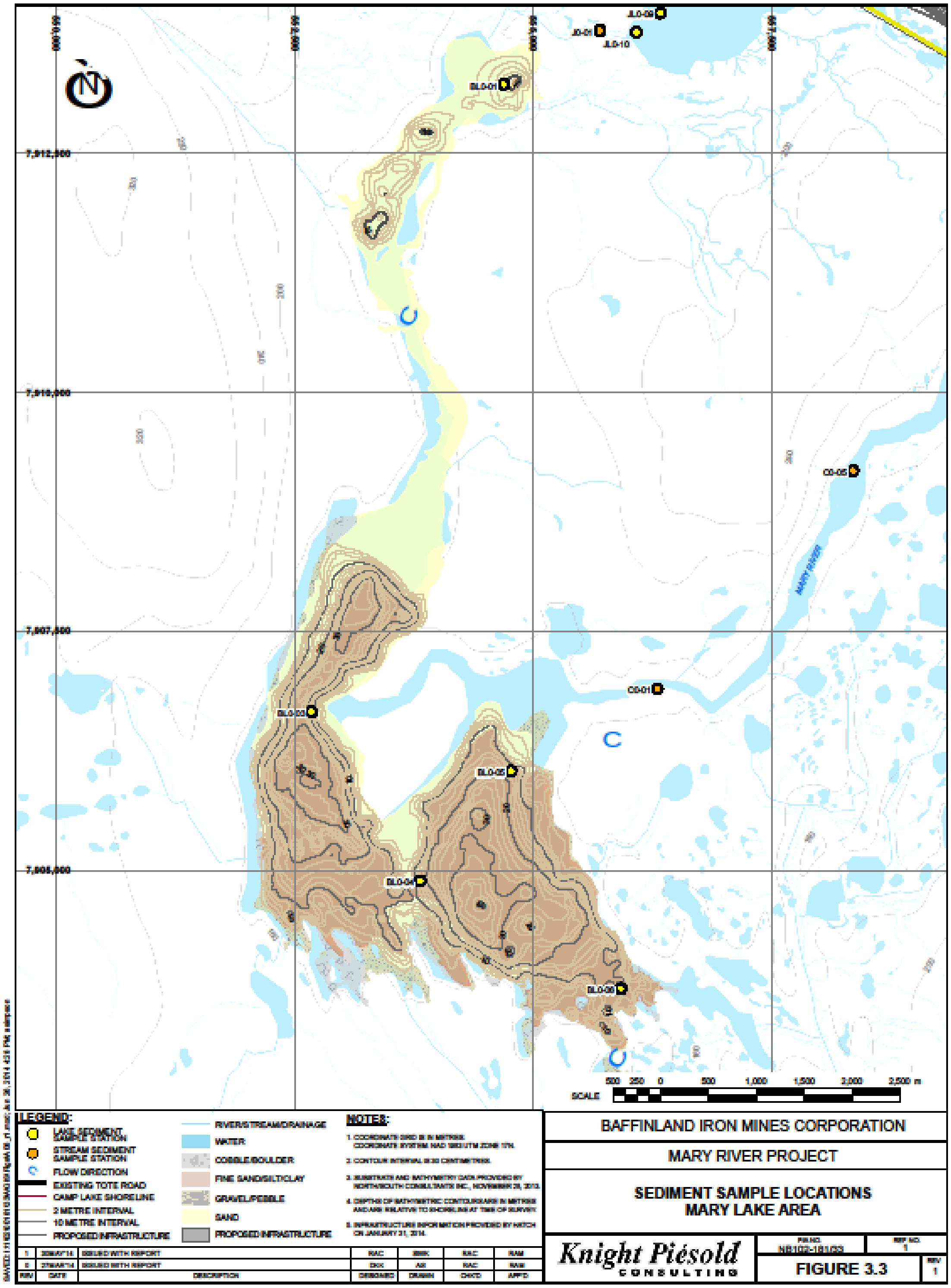


Figure 3.3 Mary Lake – Substrate and Bathymetry



Mary Lake Similar to Camp Lake, Mary Lake is relatively deep 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. 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.

3.1.2 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.

3.1.3 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.

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 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 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 D. The sediment quality baseline review presented in Appendix D and summarized below (Section 3.5) was written by Knight Piesold in early 2014 and does not include sediment quality data collected during the 2014 or 2015 CREMP field program.

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 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 mine 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

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

- 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 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 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.

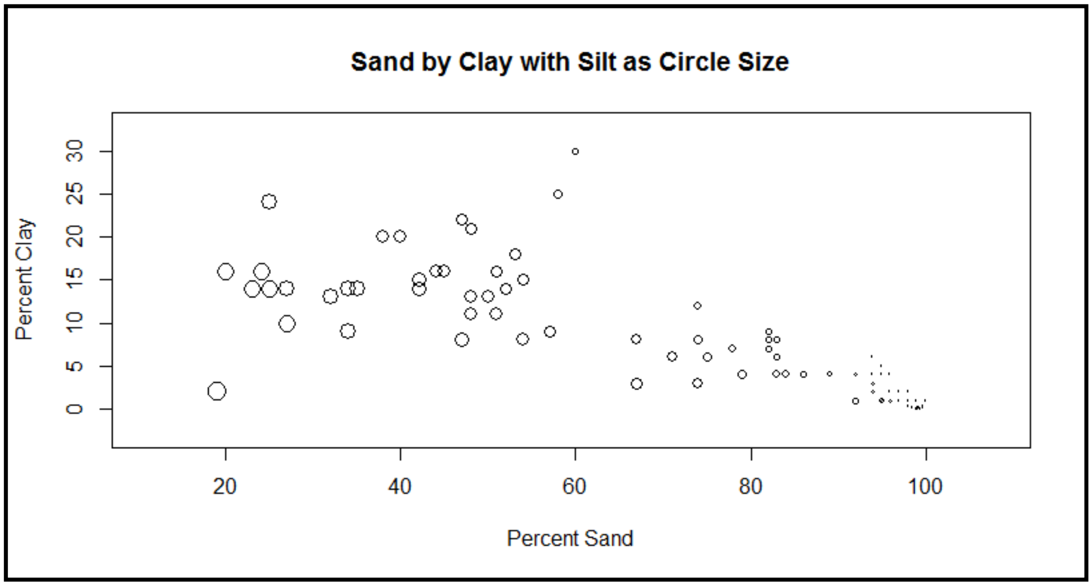


Figure 3.4 Clay by Sand with Silt as Circle Size

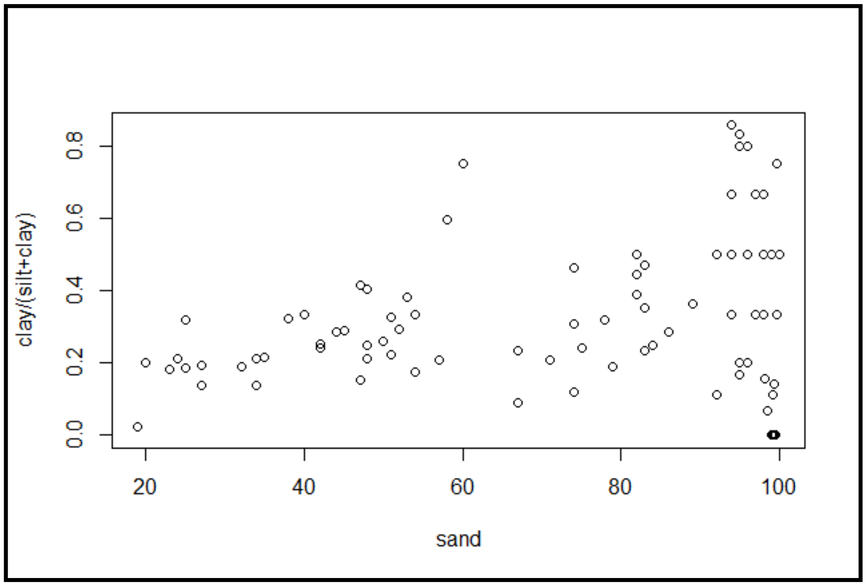


Figure 3.5 Dependent Relationship between Sand, Silt and Clay in Sediment

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 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.

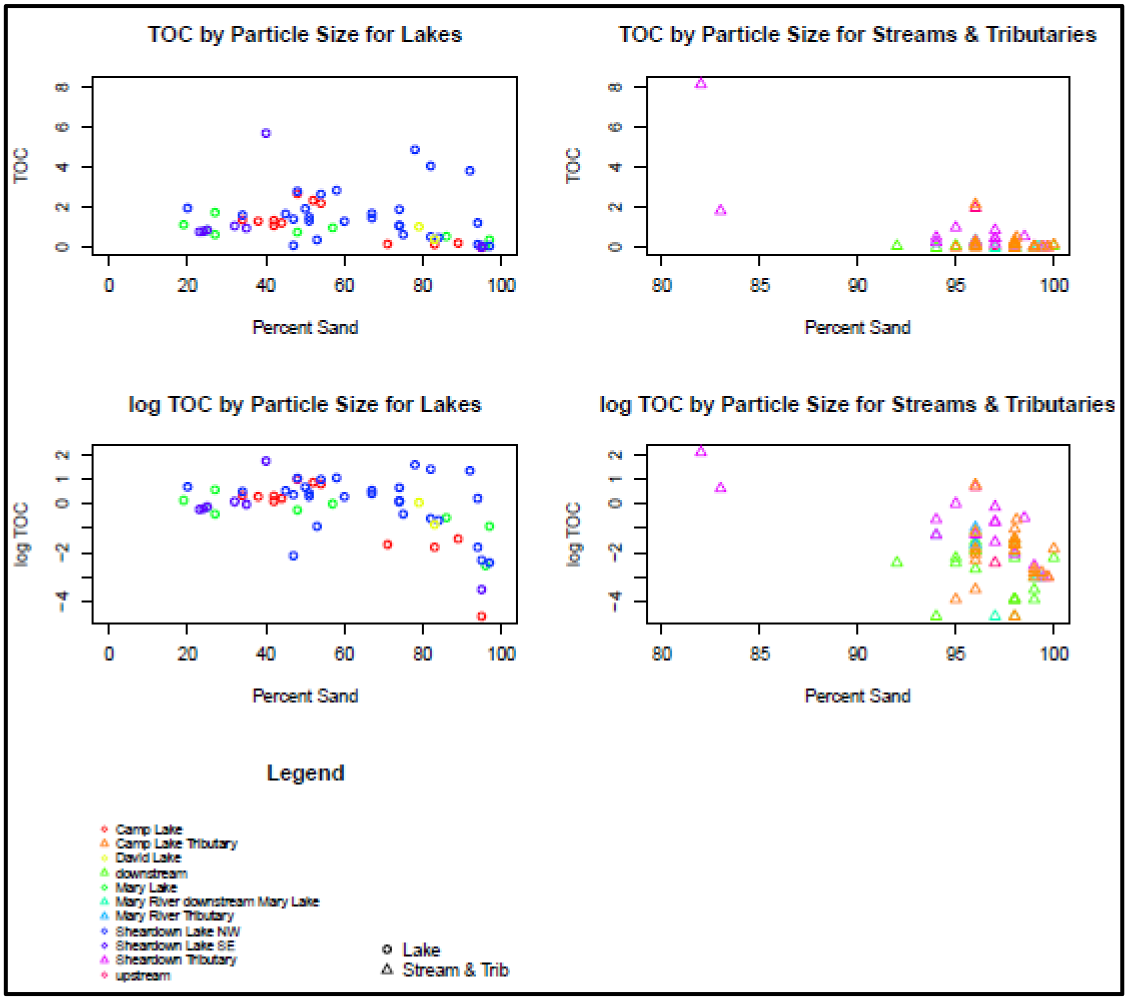


Figure 3.6 Sediment TOC versus Particle Size for Lakes and Streams

Analyses presented in Appendix 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.

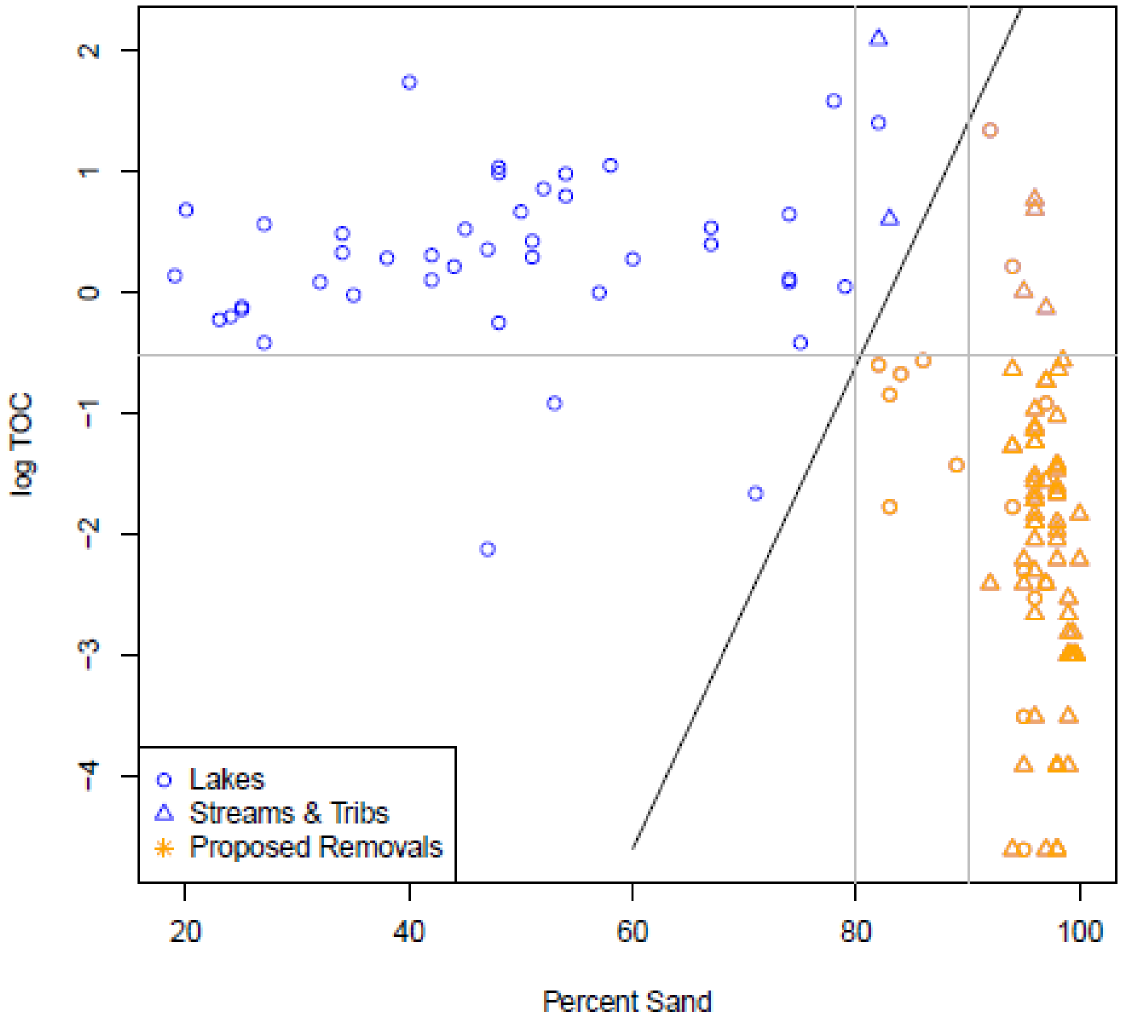


Figure 3.7 Results of Cut Point Analysis for Sediment

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 CREMP monitoring samples, 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 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.

Select near-field stream sediment sampling stations will continue 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.

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 mine 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 focuses solely on the four (4) mine 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 area lakes in the summer and fall[6]. Further details on the CREMP sediment quality monitoring program is discussed in Section 3.6.4 and Section 3.6.5.

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 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:

- 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 mine area lakes. In addition, another concern to consider is metal loads from Mine effluent influencing sediment metal concentrations over time, although limited effluent is released in the current phase of the mine. In the review of baseline sediment data presented in Appendix D, Knight Piésold 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, 2014a).

Moreover, 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. As such, CREMP sediment quality monitoring will focus solely on the 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

[6] The lack of accessibility to Reference Lake 3 during the winter months prevents the lake from being sampled concurrently with mine area lakes in late April.

3 to assist in identifying any sediment quality changes related to mine operations. 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 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 *	
Iron *	
Lead	
Manganese *	
Mercury	
Nickel *	
Phosphorus *	
Zinc	

3.5.2 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 3.5.2. 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

[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.

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 * MDL was adopted as the benchmark, as follows:

- **Method A**: Sediment Quality Guideline was higher than 97.5%ile, and therefore was selected
- **Method B**: 97.5%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 * 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 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 data are 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, 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 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 become 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).

3.5.3 Monitoring Area and Sampling Stations

The monitoring area for sediment quality includes mine area lakes, including Camp Lake, Sheardown Lake NW and SE and Mary Lake as well as 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).

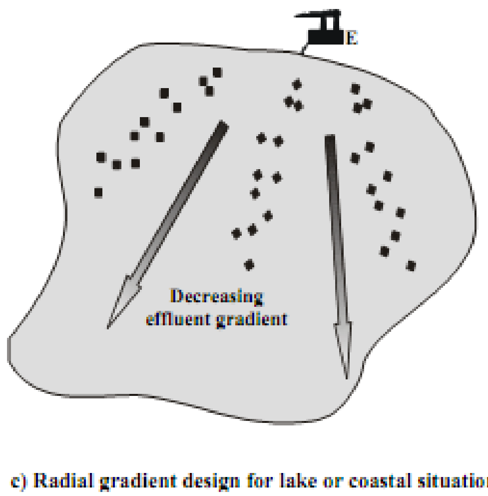


Figure 3.8 Gradient Sampling Design to Lake Sediment Monitoring

The current sediment sampling locations for the mine exposed 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 monitoring programs and refocus the lake benthic macroinvertebrate program solely on littoral (shallow) habitats, Minnow proposed the following recommendations in 2016:

1. Establish five (5) sediment quality/BMI stations located in littoral (shallow) habitat at each mine exposed study lake and Reference Lake 3.
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.

Littoral sediment sampling stations are situated at the same locations as the littoral BMI stations. Utilizing the same littoral stations for both sediment quality and benthic macroinvertebrate community sampling 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.

To the extent possible, littoral sediment quality/BMI stations 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 were selected from existing sediment stations. Because the majority of Sheardown Lake is less than 12 meters deep and represents primarily littoral habitat, sediment quality will focus only on littoral habitat of this lake..

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 A.

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

3.5.4 Sampling Frequency and Schedule

Sediment quality monitoring will be conducted once each monitoring year in the fall 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 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 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 year cycle provided annual sampling up to that time supports this change. Sedimentation rates at Sheardown Lake are predicted to be less than 1mm per year; therefore, a three year frequency should be sufficient to track changes in sediment metal concentrations over time.

3.5.5 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 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		0.17A	5.9A	1.5C	98B	50B	52,400B	4,370B	72B	1,580B	35A	135B
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		0.17A	5.9A	1.5C	79B	56B	34,400B	657B	66B	1278B	35A	123A
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		0.17A	6.2B	1.5C	97B	58B	52,200B	4,530B	77B	1958B	35A	123A

NOTES:

*=N for phosphorus is lower than other elements / parameters

A = guideline is based on sediment quality guideline (CCME or Ontario)

B = guideline is based on 97.5% percentile of baseline data

C = 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 97.5% percentile s.