Appendix F
Lake Sedimentation Monitoring Program

Mary River Project

June 2014

Aquatic Effects Monitoring Program:

Lake Sedimentation Monitoring Program

North/South Consultants Inc.
Aquatic Environment Specialists

Mary River Project

Aquatic Effects Monitoring Program:
Lake Sedimentation Monitoring Program

June, 2014

Prepared by

North/South Consultants Inc.

For

Baffinland Iron Mines Corporation

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LIST OF ABBREVIATIONS

AEMP	Aquatic Effects Monitoring Program
BIM	Baffinland Iron Mines Corporation
BMI	Benthic macroinvertebrate(s)
DFO	Department of Fisheries and Oceans
ERP	Early Revenue Phase
FEIS	Final Environmental Impact Statements
NSC	North/South Consultants Inc.
QA/QC	Quality assurance/quality control
TSS	Total suspended solids
UTM	Universal Transverse Mercator

1.0 INTRODUCTION AND BACKGROUND

The Mary River Project is expected to result in increased sediment deposition in Mine Area waterbodies, including lakes, due to dust deposition and potentially due to introduction of suspended solids from various activities (e.g., wastewater discharges). Dust will be directly deposited on watercourses during the open-water season and on snow and ice during the winter. Dust will be indirectly introduced from runoff within the watersheds which will likely be greatest during the snowmelt/freshet period.

Potential effects of dust on aquatic ecosystems include effects on water quality (i.e., total suspended solids [TSS], metals, nutrients, water clarity) when suspended in the water column and effects once deposited on the lake bottom or streambed. Sedimentation of dust in lakes and streams may affect aquatic biota through changes in sediment quality (e., metals, nutrients, particle size, organic matter), through changes in habitat quality (i.e., changes in substrate composition), direct effects on benthic macroinvertebrates (BMI; i.e., smothering), and direct effects on fish eggs (i.e., smothering of eggs).

Baffinland Iron Mines Corporation (BIM) proposed a targeted study, which was subsequently recommended by the Department of Fisheries and Oceans (DFO), to measure rates of sediment deposition in Mine Area lakes. The following describes the general background, approach, and methods for this targeted study to monitor sediment deposition in Mine Area lakes during Project operation as part of the Aquatic Effects Monitoring Program (AEMP).

2.0 PATHWAYS OF EFFECT AND KEY QUESTIONS

The Project may affect sediment deposition in Mine Area lakes through airborne dust deposition and through introduction of suspended materials (i.e., TSS) to lakes via tributary streams and/or aqueous point or non-point sources. Potential pathways of effect on freshwater biota in lakes include:

- Increased sediment deposition in lakes may adversely affect BMI communities which may in turn affect Arctic Char populations;
- Increased sediment deposition in lakes may alter Arctic Char (*Salvelinus alpinus*) habitat, notably Arctic Char spawning habitat, through changes in substrate composition; and
- Increased sediment deposition in lakes during the Arctic Char egg incubation period (i.e., over winter) may adversely affect egg survival and hatching success.

The key question related to the pathways of effect is:

- What are the combined effects of point and non-point sources of suspended materials on sedimentation rates in Mine Area lakes?

The primary issue of concern in relation to Mine Area lakes is the potential effect of the Project on sediment deposition on Arctic Char eggs.

3.0 PARAMETERS

The key parameter that will be monitored under this special study is total sediment deposition, measured as total dry weight of sediment deposited in a known area over a known duration (i.e., $mg/cm^2/day$). Measurements will also allow for determination of the total mass of sediment deposited over the sampling period. Results of a baseline sampling program conducted over the open-water season of 2013 in Sheardown Lake NW indicate that sufficient volumes of sediment for laboratory analysis of total dry weight of sediment can be obtained during this period (North/South Consultants Inc. [NSC] 2014). Sediment deposition monitoring over the ice-cover season is ongoing and it is unknown whether sufficient volumes of sediments can be obtained from the lake over this period for reliable laboratory analysis. ~~Results of the winter sedimentation program will be reviewed when available and details of this study may be modified in accordance.~~

Sediment dry bulk density information, will be collected in order to estimate the amount of sediment accumulation for separate ice-cover and open-water periods, using sediment traps of differing dimensions to those used for the collection of sedimentation rate data. Dry bulk density (DBD) sediment traps (constructed of a single 75 cm long, 15.2 cm inside diameter acrylonitrile-butadiene-styrene (ABS) pipe (i.e., 182 cm surface area)) will be capped at the bottom end. Each sediment trap unit will be secured to a float-anchor system designed to maintain the trap in an upright position on the lake bottom for the duration of the deployment period. The mouth of the DBD sediment trap is designed to sit approximately 1.5 m above the substrate, mirroring the same distance above bottom that the mouth of sediment traps used to monitor sedimentation rate were situated.

4.0 MONITORING AREA AND SAMPLING SITES

In the Mine Area, Arctic Char spawning habitat is restricted to lakes, as rivers and streams freeze solid in winter, and lakes provide the sole overwintering habitat for Arctic Char. The results of air quality modeling presented in the Final Environmental Impact Statement (FEIS) and the Addendum to the FEIS for the Early Revenue Phase (ERP), indicate that Sheardown Lake will experience the largest increases in sediment deposition of the Mine Area lakes. The lake sediment deposition special study is therefore focused on monitoring in Sheardown Lake NW. However, monitoring at additional Mine Area lakes may be undertaken in the future upon review of initial monitoring results collected during the ERP and/or during full production if increased effects (e.g., greater rates of dust deposition) are measured.

Increases in sedimentation rates may affect BMIs (through smothering and changes in substrate characteristics), Arctic Char habitat (notably spawning areas which are typically hard substrates), and/or Arctic Char eggs (through deposition on incubating eggs). Therefore the sampling sites will include a suspected Arctic Char spawning area, a shallow, soft substrate area, and a deep-water location. Collectively this information will provide information on sedimentation rates in different habitat types in the lake. Sites sampled during baseline studies will be retained for operation monitoring. A brief description of these sites is provided below.

Specific spawning sites have not been identified within Sheardown Lake NW and the FEIS conservatively assumed that areas of hard substrate at water depths ranging from 2-12 m in the lakes could potentially provide spawning habitat. One area in Sheardown Lake NW best matched these criteria and was selected for sediment trap deployment in 2013 to represent potential Arctic Char spawning habitat (Figure 1). A second sampling site was selected at a similar depth range (2-12 m), but with a soft substrate for comparison. A third sampling site was selected near the deepest point in the lake as these areas are typically the ultimate depositional areas in lakes and because sampling the profundal zone (i.e., depth > 12 m) would provide a measure of a dominant aquatic habitat type.

5.0 SAMPLING FREQUENCY AND SCHEDULE

Sediment traps will be deployed year-round in Sheardown Lake NW but will be retrieved and emptied in late summer/fall prior to freeze up and again in spring following ice breakup on the lake. This will provide a means for quantifying annual deposition rates in the lake as well as rates associated with the open-water and ice-cover seasons.

Baseline studies are on-going and will continue into fall 2014. Monitoring during Project operation will commence this fall and will continue for three years, following which a review of the program and results will be undertaken to advise on monitoring during full production.

6.0 FIELD AND LABORATORY METHODS

Sedimentation rates will be measured through deployment of sediment traps with an aspect ratio of > 5:1 as recommended for cylindrical sediment traps (Mudroch and MacKnight 1994). Traps will be anchored such that the trap is suspended off the bottom and secured with a buoy.

Five replicate traps (i.e., subsamples) will be deployed within close proximity at each of the three sites. The number of replicates may be modified pending the results of the ongoing baseline studies and initial results of monitoring during operation. Total water depth, substrate, date, time, and universal transverse mercator units (UTMs) will be recorded at each site. In addition to the study traps, bulk density traps are deployed to provide accurate reference data.

Traps will be retrieved and emptied in late summer/fall and in spring following breakup. Trap contents will be transferred to sample bottles, kept cool and in the dark and transported to an analytical laboratory for analysis.

Samples will be analysed by filtering samples, which includes sediments and water, through a pre-weighed 0.70 µm glass fibre filter, rinsing the filter apparatus and container three times, and drying the filter at 105 ^{o}C for two hours. Samples are then allowed to cool for one hour and weighed.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) measures will include verifications that sediments are not disturbed (i.e., resupended) during sediment deployment and retrieval and inclusion of sample replicates to measure variability.

8.0 STUDY DESIGN AND DATA ANALYSIS

As the objective of this study is to monitor rates of sediment deposition in Mine Area lakes as it may affect BMIs, habitat, and Arctic Char eggs, the study is designed to provide measures of sediment deposition on a seasonal (i.e., open-water vs. ice-cover season) basis. Rates will be measured through deployment of sediment traps in Sheardown Lake NW year-round, but with retrieval of samples at the end of the open-water and ice-cover seasons to provide measures for both periods. This will facilitate examination of sedimentation rates during the Arctic Char incubation period as well as during the growing season in Sheardown Lake NW.

Measured sedimentation rates will be compared to effects predictions presented in the FEIS and the Addendum to the FEIS for the ERP, as well as to the effects threshold applied in the impact assessment (i.e., 1 mm of deposition on fish eggs). Sedimentation rates exceeding 1 mm during the egg incubation period have been identified as exerting adverse effects on fish eggs (e.g., Fudge and Bodaly 1984). The FEIS and Addendum to the FEIS indicated that sedimentation is not expected to exceed this threshold in Mine Area lakes.

The study is designed to compare results directly to the threshold rather than to demonstrate statistically significant differences. Therefore, true replicates for each habitat type are not included in the design of the monitoring program. Rather, replicates will be included to provide a measure of variability at each site (i.e., subsamples) and to provide additional contingency in the event that traps cannot be located and/or quantities of sediments collected in the traps are so low that sample compositing is required. As previously indicated, results of open-water season sampling completed in 2013 indicate that sufficient sediment volumes will likely be obtainable in the open-water season, however, it is unknown whether this can be attained for winter.

Results of the targeted study may also be compared to baseline data collected in 2013 and 2014 from Sheardown Lake NW to provide a means of identifying Project-related effects on this parameter.

This document was prepared, and the special study was designed, with baseline information available at the time of preparation of this report. It is noted that not all results of additional baseline sampling initiated in 2013 were available at the time of preparation of this report; upon receipt and analysis of these additional data, recommendations for modification to the special study may be made. Results of the baseline program completed in the open-water season of 2013 are presented in NSC (2014).

9.0 REFERENCES

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Mudroch, A., and S.D. MacKnight (Eds). 1994. Handbook of techniques for aquatic sediment sampling. Second Edition, Lewis Publishers. 235 p.

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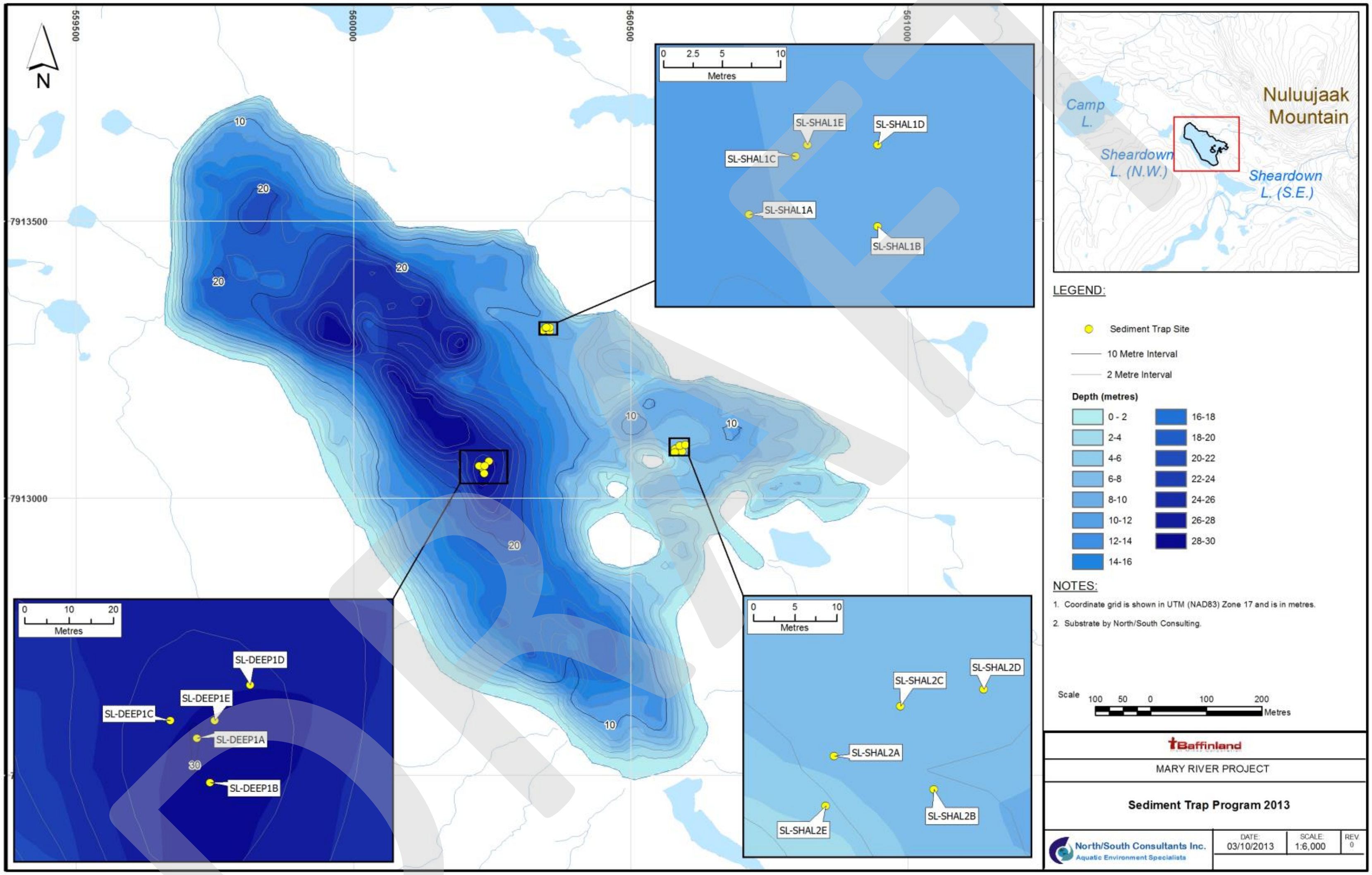

Figure 1. Sediment trap sampling sites in Sheardown Lake NW, 2013.

Appendix G

Initial Stream Diversion Barrier Study Design

Knight Piésold CONSULTING

www.knightpiesold.com

MEMORANDUM

To:	Mr. Oliver Curran	Date:	June 25, 2014
Copy To:		File No.:	NB102-181/34-A.01
From:	Dale Klodnicki	Cont. No.:	NB14-00160
Re:	Initial Stream Diversion Barrier Study - Rev. 0 Mary River Project - Aquatic Effects Monitoring Program		

1 – INTRODUCTION

A stream diversion barrier study was identified as a follow-up program in the Final Environmental Impact Statement (FEIS) for the Mary River Project (Baffinland, 2012). The primary objectives of the study are to monitor the effects of both increases and reductions in streamflow at several mine site streams and to further understand how Project-related reductions in streamflow may result in the creation of fish barriers that have the potential to occur at low flows. The monitoring program may identify the need for mitigation measures to address Project-related fish stranding.

The stream diversion barrier study is a “targeted study”, which forms part of Baffinland’s Aquatic Effects Monitoring Program (AEMP). This memorandum describes the initial study that was focussed on obtaining a better understanding for existing flow conditions and, in particular, the frequency and duration of the occurrence of fish barriers and fish stranding that was identified in five (5) mine site streams (North/South Consultants Inc. - NSC, 2008; Knight Piésold Ltd. - KP, 2012).

Since the stream diversion barrier study was identified in the FEIS, Baffinland has developed plans that are now in the final stages of approval to initiate an Early Revenue Phase (ERP) of the Project (Baffinland, 2013). The ERP will involve mining 3.5 million tonnes per annum (Mt/a) of iron ore. The iron ore will be transported year-round by truck to Milne Port and then to market by ship during the open water season. 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. This development schedule is subject to a commercial decision by Baffinland to proceed and will be influenced by both market conditions and available financing.

The reduced production rate associated with the ERP will result in a considerably smaller mining footprint (open pit and waste rock stockpile) than was originally envisioned. As such, Project-related stream diversions will be negligible. The absence of diversions provides Baffinland with an opportunity to better understand existing flow conditions as it relates to fish passage. This initial study is exploratory in nature with the following objectives (which contribute to the primary objectives stated above):

- Develop an understanding of low-flow conditions that may result in barriers to fish passage within two tributaries of Camp Lake and three tributaries of Sheardown Lake (Figure 1).
- Document fish presence throughout the stream length under various flow conditions. It is important to document upstream access during spring freshet, since high water velocities in the spring can prevent fish passage. It is also important to document the downstream passage of fish in the fall, when they are returning to overwintering habitat in the lakes.

Stream gauging stations are seasonally operated on three of the five targeted streams (Figure 1). The conditions observed throughout each season and between years can be related to the calculated flows in the streams. An understanding of the relationship between flow conditions and the presence of fish barriers and fish presence, understanding that streams are dynamic systems that change over time.

2 – PROJECT EFFECTS AND PROPOSED MONITORING

2.1 GENERAL

The Project footprint (including water management features) will reduce flows in five mine site streams. The resulting flow reduction will result in a loss of fish habitat that was assessed to be minor (low magnitude) in the FEIS. The flow reductions also have the potential to affect the ability of Arctic Char (primarily juveniles) to access small tributaries in the mine site area, particularly in the spring as fish move into the streams and in fall when fish return to the lakes to overwinter. The creation of barriers (or increased frequency or changed timing of existing barriers) due to reduced flows could impede fish passage upstream or downstream in the tributaries. Although considered unlikely, mortalities are possible in the event fish became stranded in the streams in fall.

The development of the open pit, a waste rock stockpile, and associated water management facilities (ditches, berms and settling ponds) will divert and redirect runoff away from certain watercourses during the operational phase of the Mary River Project (Baffinland, 2012). Five tributary streams are anticipated to be affected by diversions in the Mine Area (Figure 1).

2.2 CAMP LAKE TRIBUTARY 1 (CLT-1)

CLT-1 provides approximately 5.7 km of probable or confirmed fish-bearing habitat within the main channel and its smaller tributaries. This habitat is generally shallow (typically < 0.5 m deep), with predominantly cobble substrates (NSC, 2012; see Figure 2). Habitat in the upper reaches of the tributaries typically consists of a shallow series of cascades and riffles, with intermittent flow that provides only small amounts of habitat for aquatic life. The L1 branch of CLT-1 extends from the north-eastern shore of Camp Lake for approximately 1,400 m before reaching an impassable barrier (waterfall). It consists predominantly of riffle/pool habitat with cobble substrata. Undercut banks, deep pools and boulders provide ample cover in this stream. The utilization of the L1 branch of CLT-1 by Arctic Char is high. During surveys by Knight Piésold and NSC, one area on the L1 branch of CLT-1 between the lake and the falls was identified as a potential fish barrier under low flow conditions (Figures 1 and 2). Baffinland has continued to operate a seasonal stream gauge on the L1 branch of CLT-1 since 2006 (Figure 1).

A secondary channel (L2, referred to in NSC (2012) as Tributary 1b), continues an additional 1.25 km from downstream of the impassable falls into a series of broad and shallow ponds. This channel runs parallel to the airstrip along the base of the mountain. This channel is a low gradient area where several large, shallow (0.5 m) pools with cobble bottoms where limited in-stream cover is present. Limited sampling in the L2 stream suggests a much lower level of fish utilization compared with the L1 branch.

The west pond will collect runoff from the west half of the waste rock stockpile area and discharge it to the L1 stream of the Camp Lake Tributary 1 (CLT-1). This will result in an overall increase in flows in the L1 stream of CLT-1 that will be not be typical of the natural hydrograph. The L2 branch (CLT-1 L2 stream) will not receive flows from the west pond and will experience a flow reduction.

Flow regimes in CLT-1 for the FEIS predicted (Page 225 in Volume 7; Baffinland, 2012):

- An 8% reduction in flows during July
- A 25 to 39% increase in flows during June, August and September during operation and closure
- A 7 to 22% increase in flows throughout the open water period during post-closure

These predictions considered the total flow of CLT-1, including the L1 and L2 streams. A section of CLT-1 L1 was identified as a potential barrier under low flow conditions. Increased flow in CLT-1 L1 has the potential to create a barrier to upstream movement during the spring.

A detailed survey of L2 stream was not conducted. Anticipated effects from flow diversion are different between these streams. The L2 stream of CLT-1 flows parallel to the airstrip, and experiences a net reduction in flow as a result of west pond discharges being directed solely into the L1 stream. The L2 stream is identified as Arctic Char habitat, though it is lower quality habitat compared with the main channel of CLT-1 (L1 stream).

Monitoring within CLT-1 will initially include the potential barrier location on the L1 branch under low flow conditions and support a better understanding of the flow conditions and fish utilization of the L2 branch under different flow conditions (i.e., in spring and fall).

2.3 CAMP LAKE TRIBUTARY 2 (CLT-2)

CLT-2 is characterized by moderate to steep gradient, coarse bed material and a channel that tends to be braided (multiple channels, split by unvegetated islands and bars). Falls are located approximately 600 m from the mouth of the tributary (Figures 1 and 2). This tributary is heavily utilized by Arctic Char. During surveys by Knight Piésold and NSC, one area between the mouth and the falls on CLT-2 was identified as a potential fish barrier under low flow conditions (KP, 2011 and 2012; NSC, 2012).

Diversion of runoff from the west waste rock stockpile area and open pit will also alter discharge to CLT-2. The reduction in mean monthly flows is predicted to be 15 to 32% throughout the open-water period during operation, closure and post-closure (Page 225 in Volume 7; Baffinland, 2012). This reduction is predicted for the fish barrier location. Due to the apparent absence of any substantial inflows between the fish barrier and Camp Lake, the 15 to 32% reduction in flows is expected to be a fairly accurate estimate at its confluence with Camp Lake. No significant depth reduction was predicted within the fish-bearing section between Camp Lake and the upstream barrier that would impede fish access to habitat in CLT-2.

Since no barriers are expected under baseline flow conditions, limited “baseline” monitoring of CLT-2 will be undertaken during this initial study to validate predictions made in the FEIS. The stream will be visited opportunistically in the spring and fall during low flow years. More detailed monitoring of the fish-bearing section of CLT-2 will be undertaken once the Project has advanced to full-scale mining and the potential flow reductions identified in the FEIS have been realized.

2.4 SHEARDOWN LAKE TRIBUTARY 1 (SLDT-1)

Only four tributaries of Sheardown Lake support fish, and, of these, only one is of substantial size (SLDT-1). Three of the four fish-bearing tributaries (SDLT 1, SLDT 9, and SLDT 12) will be affected by a combination of open pit mining, ore stockpile placement and the associated water management practices during the Project’s operations and closure phases (Page 226 in Volume 7; Baffinland, 2012).

SDLT-1 (Tributary 1) and its main branch (Tributary 1b) flow into the northwest basin of Sheardown Lake and provide approximately 3 km of fish-bearing stream channel before reaching parts of the tributary that would not be passable to fish (Figure 3). Much of the stream is riffle or riffle/pool habitat over a predominantly cobble substrate and it is shallow (<0.1 m deep). The stream depth increases in the mid-section (up to 0.5 m) and both riffles and pools are present. Further upstream, the tributary forms a series of broad shallow pools. Stream habitat upstream of these pools is limited, consisting of a shallow (<0.1 m) stream with a cobble/boulder substrate and little cover. Cover in Tributary 1 varies with position, but is provided by boulders, undercut banks, and deep pools. SDLT-1 is the largest tributary of Sheardown Lake, providing important open water habitat for juvenile Arctic Char. Two potential barriers were identified within SDLT-1 (Figure 3).

The SDLT-1 stream contains stream gauge station H11 (established in 2011). Discharge hydrographs and rating curves have been developed for this stream.

During the operating and closure phases of the Project, SDLT-1 will experience flow reductions in the range of 21 to 35%. Post-closure, SDLT-1 will continue to experience a reduction in flows of 6 to 20% throughout the open-water period due to diversion of water around the open pit.

Monitoring within SDLT-1 will include the identified potential barrier locations within the lower reach near the outlet to the northwest lake basin and the other reach near the mine access road upstream. The proposed monitoring program will improve the mine's understanding of the flow and fish utilization conditions under different flow regimes (i.e., in the spring and fall).

2.5 SHEARDOWN LAKE TRIBUTARY 9 (SDLT-9)

SDLT-9 is characterized by cascade/pool habitat over cobble with varying amounts of boulder, gravel and/or sand (NSC, 2012). SDLT-9 drains a small fish-bearing lake with sufficient depth for overwintering, but an impassable barrier prevents upstream access from Sheardown Lake. Use of Tributary 9 habitat downstream of the barrier can also be limited due to lack of connectivity to Sheardown Lake under low flow conditions.

During operation of the railway project, SDLT-9 will experience an estimated 29% reduction in open-water season flows during operation and closure. Ore stockpiles will be removed at closure, so SDLT-9 flows will only be impacted during operations and closure. No Project-related reduction in flows is anticipated in SDLT-9 during the ERP, since there are no ERP facilities within this catchment.

SDLT-9 will be monitored during this initial program to understand the frequency and duration of fish barriers between Sheardown Lake and the small lake during low flow conditions (Figure 3). The presence and/or absence of fish will also be noted during low flow conditions.

2.6 SHEARDOWN LAKE TRIBUTARY 12 (SDLT-12)

SDLT-12 is similar to SDLT-9 and characterized by cascade/pool habitat over cobble with varying amounts of boulder, gravel and/or sand. Fish use of SDLT-12 is limited by an impassable waterfall and low flows during much of the open-water season.

SDLT-12 will experience an estimated 15% reduction in open-water season flows during operation and closure. Ore stockpiles will be removed at closure, so SDLT-12 flows will only be impacted during operations and closure. No Project-related reduction in flows is anticipated in SDLT-12 during the ERP, since there are no ERP facilities within this catchment.

SDLT-12 will be monitored during this initial program to understand the frequency and duration of fish barriers between Sheardown Lake and the permanent fish barrier (waterfall) during low flow conditions. The presence and/or absence of fish will also be noted during low flow conditions.

3 – MONITORING PROGRAM METHODOLOGY

The five streams of interest will be monitored in spring and fall during the initial years of operation. Low and high flow periods will be targeted where possible. Results of this initial monitoring will be reviewed to determine whether mitigation and/or ongoing monitoring is required. In spring, all five streams will be visually assessed to monitor for potential barriers and obstructions to upstream fish passage.

Surveys will document conditions within the monitoring streams between the upstream fish barriers and their outlets into Camp Lake and Sheardown Lake. The survey will utilize a field sheet (Appendix A) to document in situ conditions, including:

- A visual inspection along the targeted stream reaches
- Measurements of total water depth and point velocities at locations that may pose barriers to fish passage
- Instantaneous flow measurements within the SDLT-9 and SDLT-12 tributaries (not currently gauged)
- Photographing the potential natural barriers (facing upstream, downstream and the left and right banks). A minimum of 4 photos will be taken at each location.
- Documenting the presence and location of fish during the stream inspections

A target of two (2) spring surveys and three (3) fall surveys has been set. The number of surveys completed will be subject to on-site resource availability.

Other monitoring programs will contribute data relevant to this study. For example, Baffinland`s hydrology monitoring program includes stream gauges on three streams monitored under this program, and the freshwater biota monitoring will be undertaken as part of the Core Receiving Environment Monitoring Program (CREMP). Monitoring data from both these programs will be used in the analysis of data from this initial stream diversion monitoring study.

4 – ANALYSIS OF MONITORING RESULTS

The proposed Initial Stream Diversion Study will be completed annually over the next three years (2014, 2015 and 2016) followed by a review at the end of 2016. At the end of the three-year initial program, a report will be produced that summarizes the monitoring data and presents an analysis of results, including:

- Hydrographs from the existing stream gauging stations - The hydrograph results for the three years will be compared to historical hydrology records to better understand how flows varied throughout the year and how the flow rates compared to historical norms.
- The flow and water depths will also be compared to the values presented in support of the FEIS (KP, 2011 and 2012).
- Presentation of fish barrier identification information - This information will be summarized in tabular format and will most likely be organized by fish barrier or transect location. Comments will be provided on how the presence of specific fish barriers relate to flow conditions. This may help identify when specific sections of the streams become barriers to fish passage.
- Fish stranding information - A discussion on the frequency, timing and duration of current fish stranding. Comments will be provided on whether these events are likely to result in fish mortalities.

The 3-year initial stream diversion study monitoring report will be presented with the AEMP Annual Monitoring Report in the first half of 2017. The report will also include recommendations on potential mitigation measures and future monitoring.

Continuation of the monitoring program will depend upon the schedule and size of the Project. The Approved Project (18 Mt/a) will result in meaningful reductions in streamflow and monitoring will be required to identify Project-related fish barriers and fish stranding. If the ERP were to continue beyond 2017 and the 3-year study has met the stated objectives, then this targeted study may be discontinued until such time as the Approved Project proceeds. If possible, monitoring for the Approved Project will start one year prior to the start of larger scale mining.

5 – POTENTIAL MITIGATION MEASURES

A number of mitigation measures have been identified in the FEIS (Baffinland, 2012) and the Updated AEMP Framework (Baffinland, 2013), including:

- Monitoring and salvage fisheries
- Channel improvements
- Exclusion of Arctic Char from streams

Since the ERP will result in minimal to no changes in flows, implementation of mitigation measures will not be required within the initial three year study period. These mitigation options will be carried forward for consideration when the Project has reached full scale and the Project-related changes in flow can be expected to occur.

6 – REFERENCES

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North/South Consultants Inc., 2012. *Freshwater Aquatic Biota and Habitat Baseline Synthesis Report 2005-2011*. January 2012.

Signed: for

Dale Klodnicki, C.E.T. - Environmental Technologist

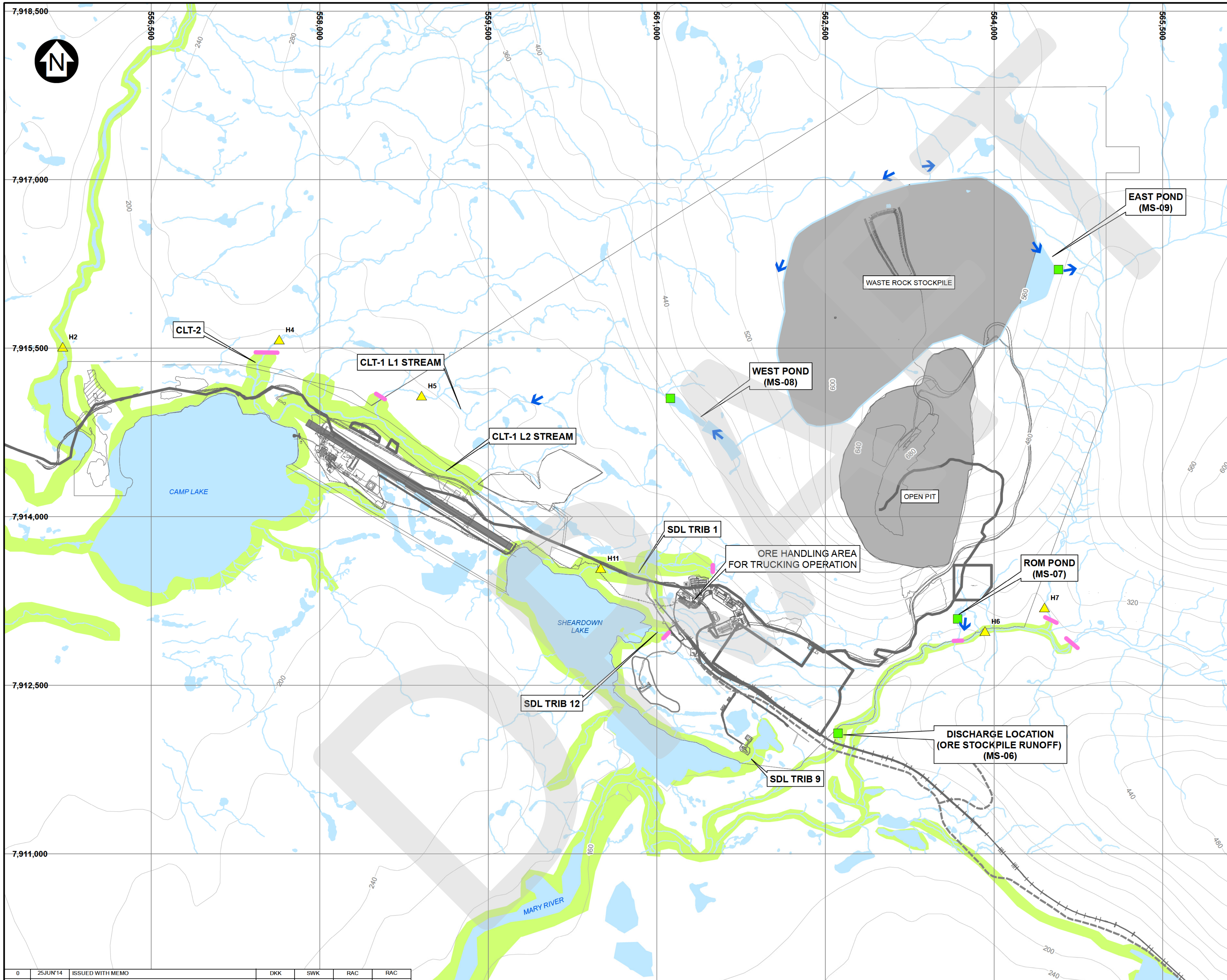
Reviewed and Approved:

Richard Cook, B.Sc. - Senior Scientist

Attachments:

Figure 1 Rev 0	Diversion Study Area Streams
Figure 2 Rev 0	Camp Lake Tributaries Subject to Monitoring
Figure 3 Rev 0	Sheardown Lake Tributaries Subject to Monitoring
Appendix A	Stream Diversion Field Data Sheet

/dkk



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SAVED: I:\102\00181\34\A\GIS\Figs\B50_r0.mxd; Jun 25, 2014 2:50 PM; skozmick

LEGEND:

- FINAL DISCHARGE POINT
- STREAM FLOW GAUGING STATION
- FISH BARRIER
- EXISTING TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- PROPOSED SITE INFRASTRUCTURE
- RIVER/STREAM/DRAINAGE
- WATER
- CONFIRMED ARCTIC CHAR HABITAT

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS UTM NAD83 ZONE17.
3. CONTOURS ARE IN METRES. CONTOUR INTERVAL VARIES.
4. INFRASTRUCTURE INFORMATION PROVIDED BY HATCH ON JANUARY 31, 2014.
5. ARCTIC CHAR HABITAT (PRESENCE) FROM NSC, 2012 MARY RIVER PROJECT FRESHWATER AQUATIC BASELINE SYNTHESIS. REPORT: 2005-2011.

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

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

DIVERSION STUDY AREA STREAMS

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 1 REV 0

LEGEND:

- STREAM FLOW GAUGING STATION
- FISH BARRIER
- PREVIOUS TRANSECT LINE (KNIGHT PIESOLD, 2011)
- MILNE INLET TOTE ROAD
- CONTOUR

NOTES:

1. TOPOGRAPHY AND ORTHOPHOTOS PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS IN METRES.
   COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 10 METRES.

SCALE 100 50 0 100 200 300 400 500 m

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

CAMP LAKE TRIBUTARIES SUBJECT TO MONITORING

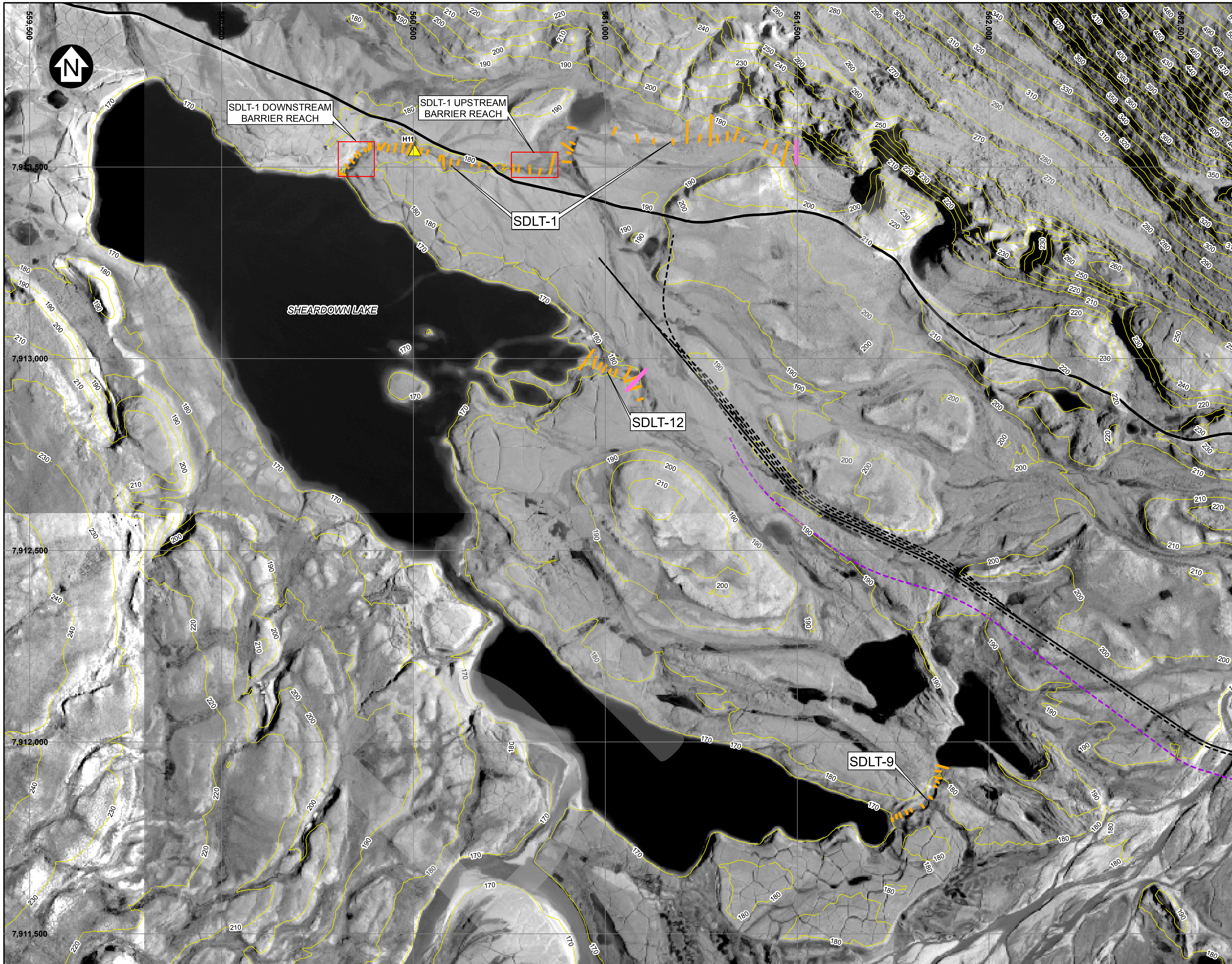
Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC

SAVED: I:\1\02\00181\34\A\GIS\Figs\B51_r0.mxd; Jun 25, 2014 2:05 PM; skozmick



LEGEND:

- STREAM FLOW GAUGING STATION
- FISH BARRIER
- PREVIOUS TRANSECT LINE (KNIGHT PIESOLD, 2011)
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- PROPOSED CONSTRUCTION ACCESS ROAD
- CONTOUR

NOTES:

1. TOPOGRAPHY AND ORTHOPHOTOS PROVIDED BY EAGLE MAPPING (2005).
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
3. CONTOUR INTERVAL IS 10 METRES.
4. RAILWAY ALIGNMENT PROVIDED BY CANARAIL CONSULTANTS INC. (AUGUST, 2010).

SCALE 100 50 0 100 200 300 400 500 m

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	25JUN'14	ISSUED WITH MEMO	DKK	SWK	RAC	RAC

SAVED: I:\102\00181\34\A\GIS\Figs\BS2_r0.mxd; Jun 25, 2014 2:44 PM; skozmick

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

SHEARDOWN LAKE TRIBUTARIES SUBJECT TO MONITORING

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/34	NB14-00160

FIGURE 3 REV 0

Knight Piésold CONSULTING

APPENDIX A

STREAM DIVERSION FIELD DATA SHEET

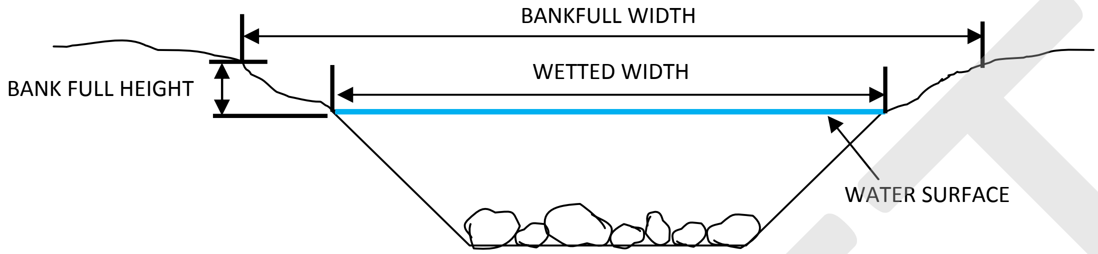
(Page A-1)

Knight Piésold CONSULTING

STREAM DIVERSION FIELD DATA SHEET

PROJECT NO: NB102-181/34	**WATER BODY:**	**DATE(ddmmmyyyy):**
FIELD CREW:	**START TIME:**	**END TIME:**
WEATHER:		

CHANNEL CHARACTERISTICS



Station ID:	**UTM Easting (m):**	**UTM Northing (m):**
Wetted Width (m):	**Bank Full Width (m):**	**Bank Full Height (m):**

Photos (check): ☐ Upstream ☐ Right Bank ☐ Downstream ☐ Left Bank

Depth/Point Velocity measurements across the stream

Total Depth (m):	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s
Total Depth (m)	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s

Fish Presence (circle US/DS) : US / DS >10 individuals US / DS <10 individuals US / DS No Fish Observed

Comments:

Station ID:	**UTM Easting (m):**	**UTM Northing (m):**
Wetted Width (m):	**Bank Full Width (m):**	**Bank Full Height (m):**

Photos (check): ☐ Upstream ☐ Right Bank ☐ Downstream ☐ Left Bank

Depth/Point Velocity measurements across the stream

Total Depth (m):	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s
Total Depth (m)	m	m	m	m	m	m
Velocity (m/s):	m/s	m/s	m/s	m/s	m/s	m/s

Fish Presence (circle US/DS) : US / DS >10 individuals US / DS <10 individuals US / DS No Fish Observed

Comments:

Incidental Fish Observations

UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals
UTM Easting (m)	**UTM Northing (m)**	**Fish:** ☐ >10 individuals ☐ <10 individuals

Appendix H
CREMP Lake Water Quality Power Analysis Memorandum (Minnow)

Technical Memorandum

Date:	April 11, 2018
To:	Andrew Vermeer, Christopher Murray, and William Bowden
From:	Paul LePage, Minnow Environmental Inc.
RE:	**Statistical Approach for Determining Water Quality Monitoring Sample Sizes at Lakes Sampled Under the CREMP**

Introduction

Following the completion of the first Core Receiving Environment Monitoring Program (CREMP) study conducted after start-up of the Mary River Project mine operations, it was recommended that the number of water chemistry monitoring stations be reduced to three in each of Camp, Sheardown NW, and Sheardown SE lakes, and to four in Mary Lake (Minnow 2016). The rationale for this recommendation was that no consistent spatial differences in water chemistry were evident at any of the CREMP mine-exposed or reference lakes after commercial mine start-up in 2015, nor during pre-mining baseline studies. In addition, *in situ* water quality profile data indicated that all CREMP study lakes were generally well mixed, and as a result, spatially within each lake, water chemistry has been relatively uniform from the lake inlet to the outlet. Due to the limited spatial variability in water chemistry among stations within each lake, the sampling of five or more water quality monitoring stations within the lakes sampled for the CREMP was thus considered redundant (Minnow 2016).

During the Baffinland Iron Mines Corporation (Baffinland) Freshwater Workshop held in Iqaluit, Nunavut, on November 8th and 9th, 2017, Minnow proposed a two-way analysis-of-variance (ANOVA) model to evaluate lake-specific significant changes in water chemistry between baseline and mine operational periods (i.e., before-after analysis). Included as part of this approach was the use of power analysis to determine an appropriate number of sampling stations that would be required from each study lake in each year to be able to assess for significant changes in water chemistry between baseline and individual years of mine operation. This technical memorandum outlines the recommended before-after statistical approach that can be used to determine changes in water chemistry at lakes potentially influenced by the Mary River Project mine operations, as well as background information, methods, and results of power analysis conducted using data subject to the proposed before-after statistical approach.

Proposed Statistical Model to Evaluate Mine-Related Changes in Water Quality

The study design for the CREMP outlined a water chemistry sampling approach that included the collection of samples from at least five stations per mine-exposed lake during each of three seasons each year (i.e., 15 samples per year per lake). No statistical approach to evaluating temporal changes in water chemistry was indicated in the CREMP study design (KP 2014a), although a mixed linear effects model was suggested as a potential approach to compare annual parameter concentrations from years of mine operation (e.g., 2015 and onwards) to concentrations during the mine baseline period (2006 to 2013 data; KP 2014b). The general approach to the temporal analysis of lake water chemistry data proposed by KP (2014b) focused on station-specific changes over time. However, for the reasons stated above, data collected following commercial mine start-up have since indicated that a lake-specific analysis is appropriate for evaluating temporal changes in water chemistry (Minnow 2016). The transition from a station-specific to a lake-specific approach for assessing changes in water chemistry requires fewer number of lake water quality monitoring stations without losing the ability of the CREMP to detect mine-related influences on lake water chemistry over time. This premise provides the basis for the recommended statistical approach described below for evaluating mine-related changes in water quality at CREMP study lakes over time.

The recommended approach to assess changes in water quality between mine-operational and baseline periods provided herein and proposed by Minnow (2016) is a two-way ANOVA hypothesis test with factors Year and Season conducted separately for each mine-exposed lake. Parameters considered for the analysis should include those that have been shown to exceed water quality guidelines or AEMP benchmarks, and/or parameters that have shown higher mean concentrations over time based on visual evaluation of plotted data, at each individual lake. For this hypothesis test, if the interaction between Year and Season is not statistically significant (i.e., the difference in parameter concentration among years is consistent among winter, summer and fall seasons) then an appropriate ANOVA model will be used to assess an among-year difference in parameter concentration. In the event that the latter ANOVA hypothesis test indicates a significant among-year difference in parameter concentration, then *post-hoc* contrasts will be conducted to test the following hypotheses for a temporal change:

- Linear trend;
- Step Change after year 1: (mean in year 1 = mean for years 2,3,4);
- Step Change after year 2: (mean in years 1 and 2 = mean for years 3 and 4); and,
- Step Change after year 3: (mean in years 1, 2, 3 = mean for year 4).

These four contrasts will be conducted to assess temporal change, and if any of these models indicate a significant difference, the model with the best fit (i.e., lowest p-value) will be used to describe the type of temporal change as defined above. A significant interaction shown between Year and Season will indicate no consistent temporal change in parameter concentrations among seasons, necessitating that the data be evaluated separately by season using the same general sequence for the determination as provided above. Representative outputs using this approach are provided for Camp Lake total aluminum and total uranium concentration data in Annex 1.

Determination of Appropriate Station Number for the Recommended Before-After Analysis

In experimental design, power analysis is an important set of procedures and formulas that allows the determination of suitable sample sizes required to detect an effect of a given size with a given degree of confidence (given an assumed true difference between groups). Power analysis of lake water chemistry data was conducted as part of the Baffinland baseline studies to assist with the determination of appropriate sample sizes (i.e., number of stations) during development of the Mary River Project mine site CREMP (Baffinland 2014; KP 2014a,b). This original power analysis was used to estimate the number of samples required to statistically demonstrate a significant change in parameter concentrations between the baseline period (i.e., prior to the initiation of commercial mine operation) and following mine start-up at individual stations in each of the four mine-exposed lakes located adjacent to the Mary River Project mine site (i.e., Camp, Sheardown NW, Sheardown SE, and Mary lakes). Briefly, this analysis indicated that as few as five water chemistry samples would be sufficient to determine a significant change in concentrations of five potential mine indicator metals (aluminum, arsenic, cadmium, copper and iron) at each individual station following mine start-up compared to the baseline period (KP 2014b).

As indicated in the original review of baseline water quality data by KP (2014b), once data from the commercial mine operation period becomes available, alternative statistical models to test for differences in parameter concentrations between baseline and mine-operational periods becomes warranted and can trigger the requirement to review experimental sample sizes. The approach recommended herein to evaluate water chemistry changes at CREMP study lakes (i.e., two-way ANOVA) assesses for changes at a lake-specific level, rather than at a station-specific level from which the original study design was based. Therefore, an updated power analysis must now be used to determine a suitable number of samples (i.e., stations) required from each CREMP study lake to allow detection of changes in concentrations of mine-related parameters compared to the baseline period based on the recommended ANOVA model. For the power analysis, the ANOVA hypothesis test is used to determine if there is a significant difference in mine-related parameter concentrations among years, or stated differently, whether mean parameter concentrations in each year are equal:

e.g., H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$ where μ_i = the mean parameter concentration in year i

Two types of statistical errors can result during a hypothesis test as a result of chance. A Type I error, defined as α, occurs when the ANOVA hypothesis test (i.e., H_0 above) indicates a difference among samples (in this case, annual parameter concentrations) when in fact there is truly no difference among years. A Type II error, defined as β, occurs when the hypothesis test indicates no difference among years when there is truly a difference between at least two years of data. In environmental monitoring, α and β are typically set equal to each other (e.g., Environment Canada, 2012) to set the risk to industry (Type I error: concluding there is an effect when in fact there isn't) equal to the risk to the environment (Type II error: concluding there is no effect when in fact there is). To conduct a power analysis to determine the number of samples required to detect a change, the following parameters must be defined:

- The magnitude of the change that we wish to define as being significant (referred to as the critical effect size);
- The variability expected in the data;
- Probability of Type I error (α); and,
- Probability of Type II error (β).

Critical effect sizes (CES) have not be formally defined in the literature for assessing differences in water quality parameter concentrations. However, in biological studies, CES have been defined as a two standard deviation (±2 SD) change between mine-exposed and reference areas (Environment Canada, 2012). By definition, ninety-five percent (95%) of data values fall within ±2 SD of the mean for normally distributed data. In other words, a magnitude change of ±2 SD is equivalent to the mean of one group falling outside of the range of 95% of the data for another group. This magnitude of change could be considered relevant for assessing a temporal change in water quality and was used as the CES (or magnitude of effect) for power analysis of Camp Lake water chemistry data conducted herein[1]. Because the CES of ±2 SD is defined based on the observed variability in the data, no measure of variability was required in this power analysis. Consistent with Environment Canada (2012) recommendations for environmental monitoring, Type I (α) and II (β) errors were set equally to 0.1 for the power analysis.

The statistical comparison of the Year term in a two-way ANOVA is equivalent (with the exception of a loss of two degrees of freedom for the Season term) to the use of a one-way ANOVA on Year after adjusting for differences in season. Therefore, the power analysis conducted herein applied to the data as described in the description of power analysis provided above. Data collected at

[1] The CREMP study design water quality baseline analysis used halfway between the station baseline mean and the AEMP benchmark as the CES for power analysis of the baseline data (KP 2014b). Although this same definition for CES can be applied to the approach recommended in this technical memorandum, application of a ±2 SD of the mean baseline to define CES allows analysis of those parameters to which AEMP benchmarks have not been developed.

Camp Lake from operational and baseline periods were used to estimate the sample size required to detect a ±2 SD (within year and season pooled SD; Table 1) change among years in selected parameter concentrations using ANOVA with α and β set equally at 0.1. Based on this analysis, a minimum sample size of 7 samples per year was determined to be sufficient for lake-specific detection of a ±2 SD change in parameter concentrations over time. However, in order to have an equal number of samples collected at each lake per season, and to accommodate the loss of two degrees of freedom for the Season term in the two-way ANOVA, a sample size of 9 samples per year (water samples collected at three stations on three separate occasions, winter, summer and fall, per year) is proposed for Camp, Sheardown NW and Sheardown SE lakes. At Mary Lake, a sample size of 9 samples per year is proposed for the south basin (water samples collected at three stations on three separate occasions, winter, summer and fall, per year), with an additional 3 samples collected each year collected over the same three seasonal sampling events at the north basin.

Table 1: Estimates of the Magnitude of a 2 SD Change for Select Parameters Using the Camp Lake Baseline Data

Parameter	Units	2 Standard Deviations (SD)
Chloride	mg/L	1.5
Sulphate	mg/L	1
Total Aluminum	µg/L	5.3
Total Copper	µg/L	1.8
Total Iron	µg/L	-
Total Manganese	µg/L	0.5
Total Molybdenum	µg/L	0.049
Total Nickel	µg/L	0.39
Total Potassium	mg/L	0.12
Total Sodium	mg/L	0.2
Total Strontium	µg/L	2.1
Total Uranium	µg/L	0.16
Dissolved Aluminum	mg/L	-
Dissolved Manganese	mg/L	0.0008

Notes: "-" = estimate could not be made due to the high proportion of values below the detection limit. Estimates of the SD were conducted using the Kaplan-Meier method (Helsel 2012) to accommodate values below the laboratory reportable detection limit.

Conclusion

Using the statistical approach provided herein for determining the occurrence of significant changes in water chemistry over time in the CREMP study lakes and subsequent power analysis, the collection of water samples from three stations per mine-exposed lake, three times per calendar year (winter, summer and fall), is sufficient to statistically evaluate annual changes in lake water chemistry with high statistical power. This analysis corroborated the Minnow (2016) proposal that reducing the number of CREMP water chemistry monitoring stations to three in each of Camp, Sheardown NW and Sheardown SE lakes, and to four in Mary Lake, would not compromise the ability of the CREMP to track mine-related influences on water quality of these lakes.

References

Baffinland (Baffinland Iron Mines Corporation). 2014. Mary River Project Aquatic Effects Monitoring Plan. Document No. BAF-PH1-830-P16-0039. Rev 0. June 27, 2014.

Environment Canada. 2012. Metal Mining Technical Guidance for Environmental Effects Monitoring. ISBN 978-1-100-20496-3.

Helsel, D.R., 2012. Statistics for Censored Environmental Data using Minitab and R, 2nd Edition. John Wiley and Sons, New York. 344 p.

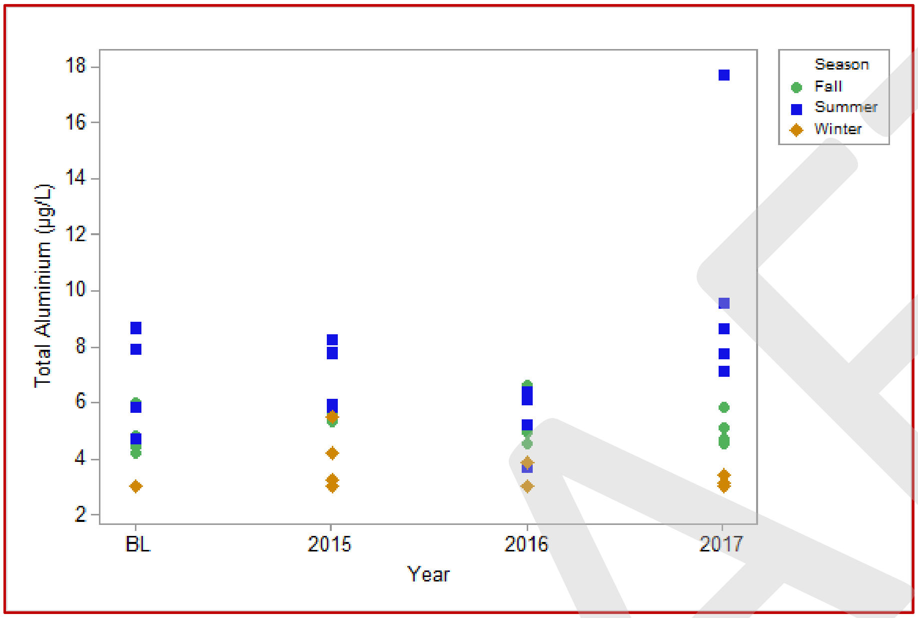
KP (Knight Piesold Ltd.) 2014a. Baffinland Iron Mines Corporation – Mary River Project – Water and Sediment Quality Review and CREMP Study Design. KP Ref. No. NB102-181/33-1 Rev 2. June 25, 2014.

KP (Knight Piesold Ltd.) 2014b. Baffinland Iron Mines Corporation – Mary River Project – Detailed Review of Baseline Lake Water Quality. KP Ref. No. NB102-181/33-1B. May 30, 2014.

Minnow (Minnow Environmental Inc.). 2016. Mary River Project CREMP Recommendations for Future Monitoring. Letter report to Jim Millard, Baffinland Iron Mines Corp. March 17, 2016.

Annex 1

Example 1: Camp Lake total aluminum concentration two-way ANOVA. Step 1: The interaction term between year and season was shown to be significant (p-value of 0.021 was less than a 0.1 level of significance) indicating that aluminum concentrations from at least one season differed among mine baseline (BL) and mine-operational years.



Year x Season p-value = 0.021

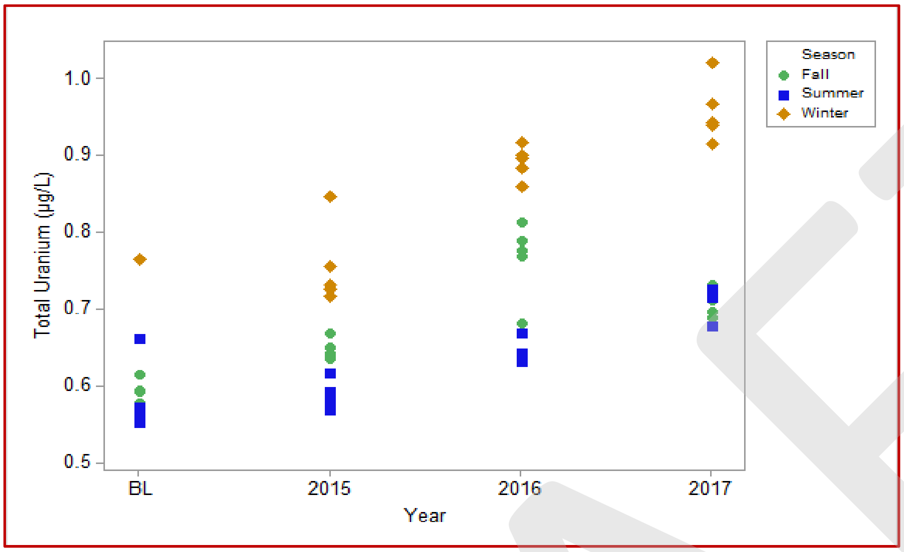
Step 2: Subsequent ANOVA of Camp Lake total aluminum concentrations over individual seasons indicated that aluminum concentrations did not differ significantly over time during fall and winter sampling seasons, but did differ significantly among study periods in summer (using a 0.1 p-value level of significance).

Season	P-value (YEAR)
Summer	**0.053**
Fall	0.320
Winter	0.378

Step 3: *Post hoc* analysis of the Camp Lake total aluminum concentrations during summer indicated a significant step change (increase) occurred after 2016. Notably, no significant change in summer aluminum concentrations was indicated over baseline, 2015, and 2016 periods.

Hypothesis *Post Hoc* Contrasts	Summer P-value
Linear	0.408
Step after BL	0.698
Step after 2015	0.585
Step after 2016	**0.004**

Example 2: Camp Lake total uranium concentration two-way ANOVA. Step 1: The interaction term between year and season was shown to be significant (p-value of 0.021 was less than a 0.1 level of significance) indicating that aluminum concentrations from at least one season differed among mine baseline (BL) and mine-operational years.



Year x Season
p-value < 0.001

Step 2: Subsequent ANOVA of Camp Lake total uranium concentrations over individual seasons indicated that uranium concentrations differed significantly over time for all summer, fall, and winter sampling seasons (using a 0.1 p-value level of significance).

Season	P-value (YEAR)
Summer	**< 0.001**
Fall	**< 0.001**
Winter	**< 0.001**

Step 3: *Post hoc* analysis of the Camp Lake total uranium concentrations for the winter data indicated a significant change (increase) has occurred since the baseline period. The model with the best fit (i.e., lowest p-value) indicated that a significant step change after 2015 most appropriately described the type of temporal change for uranium over time during winter sampling. Camp Lake uranium concentrations temporal post hoc analysis results for summer and fall seasons also indicated a significant step change after 2015 (values not shown here).

Hypothesis *Post Hoc* Contrasts	Winter P-value
Linear	**0.042**
Step after BL	**0.081**
Step after 2015	**< 0.001**
Step after 2016	**0.007**