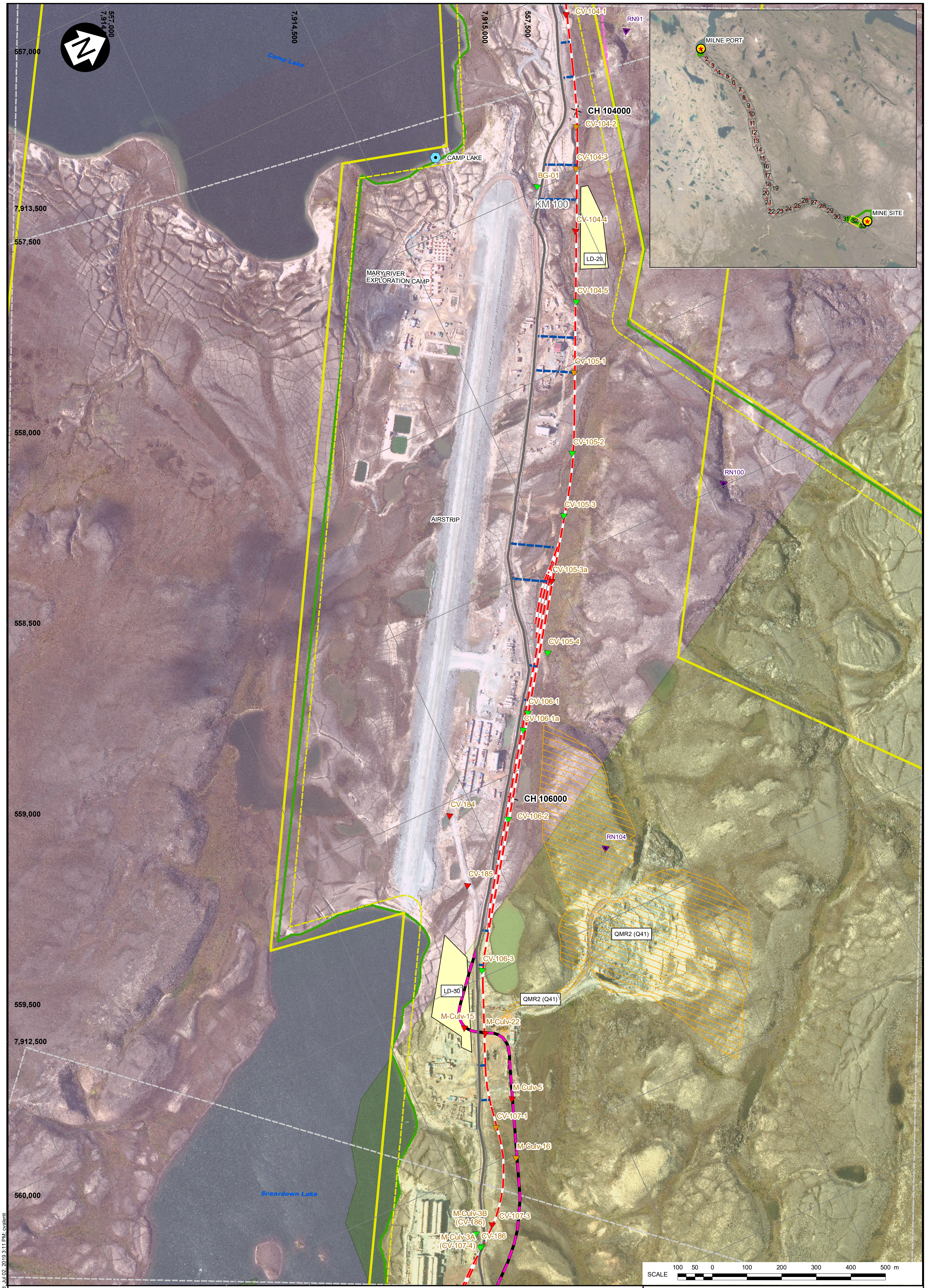

LEGEND:

TOTE ROAD km POST
NORTH RAIL CHANAGE (m)
QUARRY AREA
LAYDOWN AREA

FISH HABITAT ASSESSMENT
FISH BEARING
POTENTIAL
NONE

MILNE INLET TOTE ROAD
TOTE ROAD REALIGNMENT
PROPOSED NORTH RAILWAY
STREAM DIVERSION
PROPOSED ACCESS ROAD
TEMPORARY HAUL ROAD
EXPLOSIVES FACILITIES
RAPTOR NEST
COMMUNICATION TOWERS
SPOILS DEPOSIT LOCATIONS

BRIDGE LOCATIONS
APPROVED WATER SOURCE
PROPOSED CONSTRUCTION WATER SOURCE
POTENTIAL DEVELOPMENT AREA (MINE, PORT)
POTENTIAL DEVELOPMENT AREA (TOTE ROAD, NORTH RAIL)
COMMERCIAL LEASE BOUNDARY
UNDISTURBED BUFFER FROM COMMERCIAL LEASE BOUNDARY
PROPOSED ADDITIONAL COMMERCIAL LEASE AREA (IOL)
PROPOSED CROWN LAND LEASE

EXISTING BORROW AREA RECLAMATION PRIORITY
(FROM EBA TETRATECH, 2014)
A+ VERY HIGH PRIORITY
A HIGH PRIORITY
B MODERATE PRIORITY
C LOW PRIORITY; STABLE (NOT SHOWN ON THIS FIGURE)

FLOW DIRECTION
REFERENCE SHEET EXTENT
IOL SURFACE AND SUBSURFACE
IOL SURFACE ONLY

NOTES:
1. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. DETAILED WATER AND ORTHO IMAGERY BASED ON OCTOBER 2018 SATELLITE IMAGERY PROVIDED BY BAFFINLAND.
3. FIGURE CREATED BY KNIGHT PIESOLD LTD.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	02JUL'19	ISSUED WITH MEMO	RAC	AS/CJV	OG

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

NORTH RAILWAY
DETAILED CONSTRUCTION PHASE LAYOUT
(SHEET 32 OF 33)

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/53	NB19-00516

FIGURE 35 REV 0

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SCALE 100 50 0 100 200 300 400 500 m

LEGEND:

- TOTE ROAD km POST
- NORTH RAIL CHANAGE (m)
- QUARRY AREA
- LAYDOWN AREA

FISH HABITAT ASSESSMENT

- FISH BEARING
- POTENTIAL
- NONE

- MILNE INLET TOTE ROAD
- TOTE ROAD REALIGNMENT
- PROPOSED NORTH RAILWAY
- STREAM DIVERSION
- PROPOSED ACCESS ROAD
- TEMPORARY HAUL ROAD
- EXPLOSIVES FACILITIES
- RAPTOR NEST
- COMMUNICATION TOWERS
- SPOILS DEPOSIT LOCATIONS

- BRIDGE LOCATIONS
- APPROVED WATER SOURCE
- PROPOSED CONSTRUCTION WATER SOURCE
- POTENTIAL DEVELOPMENT AREA (MINE, PORT)
- POTENTIAL DEVELOPMENT AREA (TOTE ROAD, NORTH RAIL)
- COMMERCIAL LEASE BOUNDARY
- UNDISTURBED BUFFER FROM COMMERCIAL LEASE BOUNDARY
- PROPOSED ADDITIONAL COMMERCIAL LEASE AREA (IOL)
- PROPOSED CROWN LAND LEASE

EXISTING BORROW AREA RECLAMATION PRIORITY
(FROM EBA TETRATECH, 2014)

- A+ VERY HIGH PRIORITY
- A HIGH PRIORITY
- B MODERATE PRIORITY
- C LOW PRIORITY; STABLE (NOT SHOWN ON THIS FIGURE)

- FLOW DIRECTION
- REFERENCE SHEET EXTENT
- IOL SURFACE AND SUBSURFACE
- IOL SURFACE ONLY

NOTES:

1. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
2. DETAILED WATER AND ORTHO IMAGERY BASED ON OCTOBER 2018 SATELLITE IMAGERY PROVIDED BY BAFFINLAND.
3. FIGURE CREATED BY KNIGHT PIESOLD LTD.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	02JUL'19	ISSUED WITH MEMO	RAC	AS/CJV	OG

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

NORTH RAILWAY
DETAILED CONSTRUCTION PHASE LAYOUT
(SHEET 33 OF 33)

Knight Piésold CONSULTING

P/A NO.	REF NO.
NB102-181/53	NB19-00516

FIGURE 36 REV 0

ATTACHMENT 4: FISH PASSAGE RISK ASSESSMENT OF WATER CROSSINGS AND STREAM DIVERSIONS

Knight Piésold CONSULTING

June 18, 2019

Mr. Lou Kamermans
Director, Corporate Sustainability
Baffinland Iron Mines Corporation
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Oakville, Ontario
Canada, L6H 0C3

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Dear Lou,

RE: Fish Passage Risk Assessment of Water Crossings and Stream Diversions – Proposed North Railway – Mary River Project – Phase 2 Proposal

1.0 INTRODUCTION

In support of an amendment to Baffinland Iron Mines Corporation's (Baffinland's) Addendum to its Final Environmental Impact Statement (FEIS) for the Phase 2 Proposal of the Mary River Project (Baffinland, 2018), Knight Piésold Ltd. (KP) conducted a hydrologic and hydraulic assessment to determine water depths and velocities at fish-bearing culvert crossings along the proposed North Railway.

A similar assessment was completed by KP previously (KP, 2017). The design of the North Railway has advanced since that time, necessitating a new assessment. This assessment follows similar methods to the previous work with the following key differences:

1. Fish passage is assessed under mean monthly July and August flow conditions, rather than mean annual discharge.
2. The rail alignment was revised, resulting in different crossing conditions at some locations.
3. Culvert engineering has been advanced, resulting in revised culvert sizing at some locations, as well as specified culvert gradients (assumed gradients were used in the previous assessment).
4. Fish habitat designations were revised/updated to reflect the results of a field survey conducted in 2018 and changes to the Project design (North/South Consultants Inc. 2019a,b).

Installation of culverts presents a potential risk to fish passage and access to upstream habitat. During previous assessment, 11 sites were identified as higher risk and plate arch culverts will be installed to minimise instream footprint and potential impact to fish habitat. Bridges will cross the four largest rivers. This letter presents an assessment of the 93 char-bearing streams where corrugated steel pipe (CSP) crossings are proposed, to determine where highest effort should be placed to avoid impacts to fish habitat. The assessment considers fish presence, water velocities and depth within the culvert, culvert length, culvert embeddedness and outlet drop. Mitigation and monitoring is proposed to avoid potential impacts, as presented in Section 2.

The previous assessment also included a hydrologic and geomorphic assessment of proposed stream diversions. These were locations where a rock cut would intersect a stream, necessitating the upstream portion of that stream to be redirected to an adjacent stream. The previous assessment included potential geomorphic changes that could arise due to increased flow into the streams that receive diverted flows. The new railway design eliminated many of the previous rock cuts and incorporates a greater embankment thickness. As such, a total of 10 diversions are now proposed at locations different from the 27 diversions assessed previously. The updated hydrologic and geomorphic assessment is presented in Section 3.

Details of the assessment are presented in the following sections.

2.0 FISH PASSAGE AT CULVERT CROSSINGS

2.1 FISH USE

Streams and rivers within the study area dry up or freeze solid during winter, hence fish must overwinter in lakes, or possibly large pools within large rivers, where they exist. Based on literature and fisheries data collected at the Project site, North/South Consultants Inc. (NSC) note that juvenile and young-of-year char move upstream into the smaller tributaries to access rearing and foraging habitat in spring. Spring movements typically begin as streams begin to flow and water temperatures reach approximately 5-7°C. Typically, the number of Arctic char moving upstream will increase until water temperatures reach about 15°C. Although the general pattern is upstream movement during spring, juveniles may also return to lakes, likely in response to changes in flow or reductions in water temperature. Juvenile Arctic Char are thought to move into these tributaries for early access to warmer water and foraging habitat and to avoid predators. Figure 1 presents daily catch rates for Arctic char captured in hoop nets set in Sheardown Lake Tributary 1 in the spring of 2008 (NSC, pers. comm.). Two hoop nets were set near the mouth of the stream with the objective of evaluating the timing of fish movements and stream utilization. One faced upstream (US Catch) and one downstream (DS Catch) to look at direction of fish movements.

During fall, juvenile Arctic char typically initiate return movements to overwintering habitat as water temperature decreases to about 7°C. Peak fall movements occur as temperatures in tributaries decrease from 7° to 2°C after which few fish remain in the streams (Figure 2; NSC, pers. comm.).

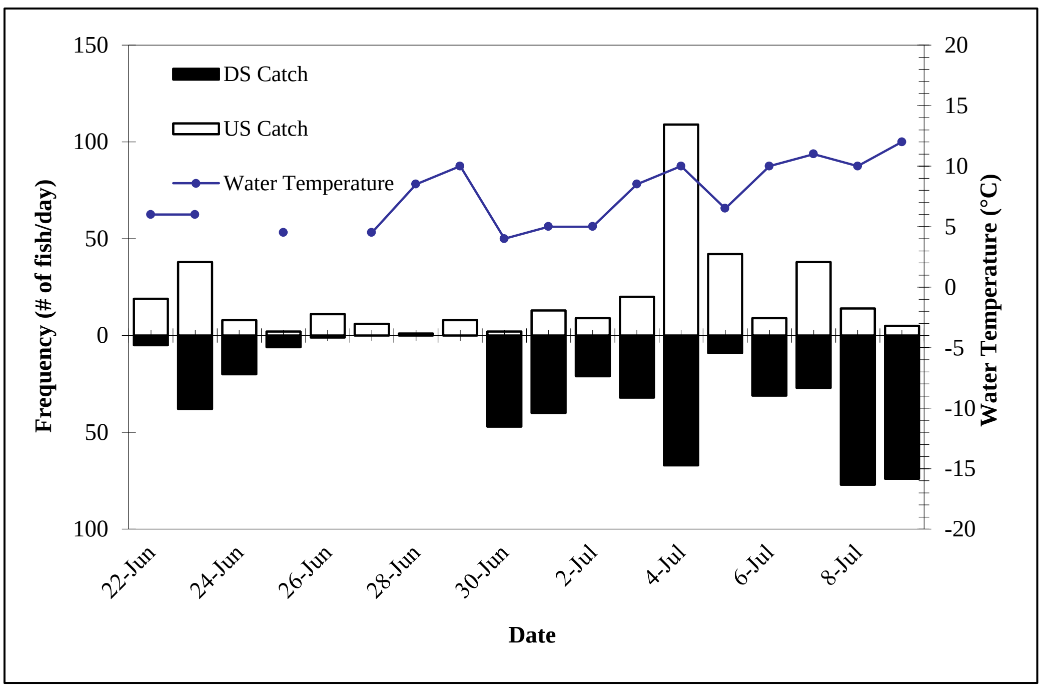

Figure 1 Hoop Net Catch Rates of Arctic Char, Sheardown Lake Tributary 1, Spring 2008

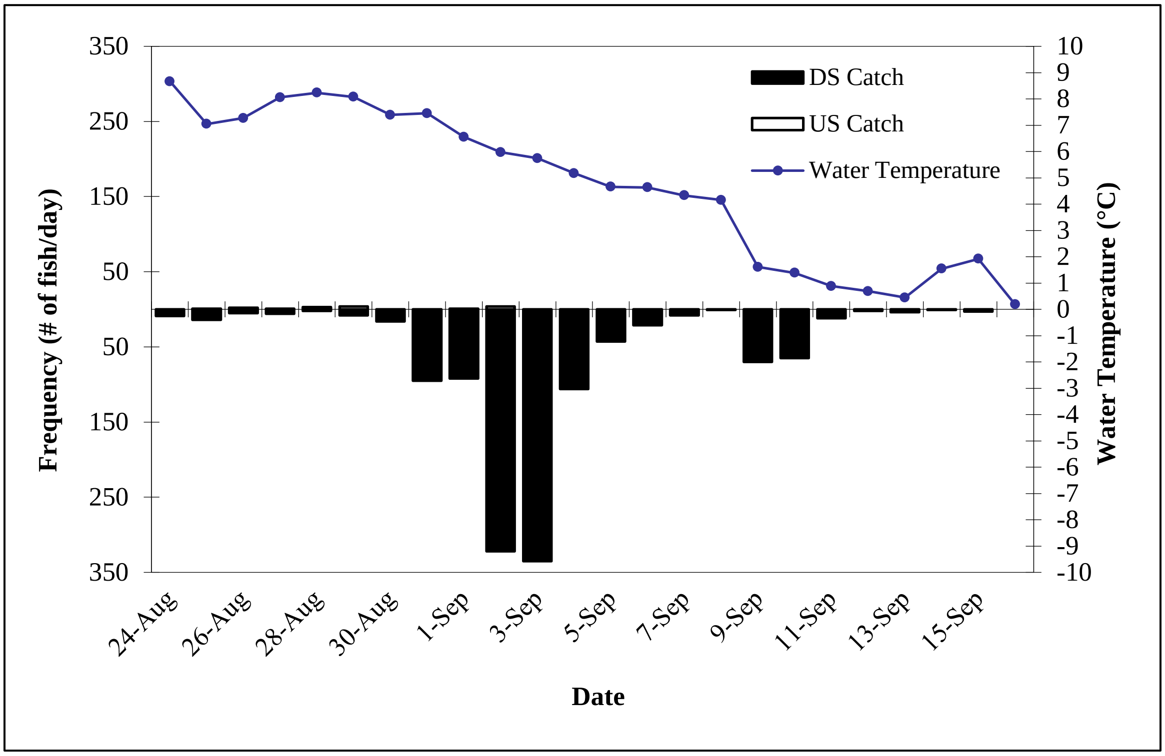

Figure 2 Hoop Net Catch Rates of Arctic Char, Sheardown Lake Tributary 1, Fall 2007

2.2 HYDROLOGIC ESTIMATES

A hydrologic analysis has been completed to determine mean monthly flows during July and August at the confirmed and potentially fish-bearing rail alignment crossings.

A hydrology baseline analysis for the Mary River Project was completed previously (KP, 2012). The analysis used the Project streamflow data collected over the period of 2006 to 2011, which included data from up to 16 stations on smaller river/creek systems and from four stations on larger systems. The 16 stations on smaller river/creek systems were managed by KP and operated during the open water season. The four stations on larger systems were operated year-round by the Water Survey of Canada (WSC). Since 2012, Baffinland has continued to operate six of the baseline hydrometric stations. The hydrology at three stations (H01, H05, and H06) was reviewed and updated based on data available to the end of 2016 (KP, 2017). The revised estimates resulted in a decrease of approximately 5% in mean annual discharge compared to those from the previous analysis. The updated mean monthly unit runoff (discharge per km^2) is presented in Table 1.

The northern railway water crossing catchment areas vary from approximately 0.003 km^2 to 540 km^2 and extend from the Mine Site north to the Milne Inlet Port. Runoff from the crossing catchments is expected to vary with physiographic factors including size, aspect, latitude, and lake content. However, given the hydrology, climate and physiography datasets available for the catchments upstream of the railway crossings, it was not possible to develop a model that considered all these factors. Consequently, monthly unit runoff at H6, which has the highest unit runoff was selected to predict watershed runoff. The high unit runoff results in relatively high culvert flow velocities and, as such, is considered conservative for the fish passage assessment.

Table 1 Estimated Long-Term Mean Streamflow

Station	Mean Unit Runoff (l/s/km^2)							
	Jan - May	Jun	Jul	Aug	Sept	Oct	Nov - Dec	MAUR
H1	0	33.5	32.2	14.3	6.6	0.4	0	7.3
H5	0	38.6	29.6	18.8	7.1	0.2	0	7.9
H6	0	41.4	56.6	20.2	8.3	0.2	0	10.6

NOTES:

1. MAUR – MEAN ANNUAL UNIT RUNOFF.

2.3 CULVERT DEPTH AND VELOCITIES

The water depth and velocity within the proposed culverts (as per Hatch, 2019) at each crossing was determined using Manning's equation for open channel flow. A Microsoft Excel model was developed, which uses the Goal Seek tool within a VBA Macro to determine the resulting depth and velocity in all the culverts from given flows, pipe diameters and pipe slopes. The goal seek tool is an iterative function that determines the culvert water depth that would occur during the given flow at the 93 known or potential char-bearing CSP culvert installations in streams along the North Railway, at the Milne Port and Mine Sites and at realigned sections of the Tote Road. Flow was estimated in 93 CSP culvert crossings using the July and August mean monthly unit discharge estimates for H6 (56.6 l/s/km^2 and 20.2 l/s/km^2, respectively) and the updated catchment areas. The model determines cross section average velocity and maximum depth at each crossing.

The current version of this analysis is based on the 2019 rail alignment with crossing details (watershed areas, and number, diameter and slope of culvert slope) provided by Hatch (2019).

Key assumptions in this hydraulics analysis include:

- The culverts are circular corrugated steel pipe. One culvert at each fish bearing crossing is embedded with bed material at 20% of the diameter.
- Depths and velocities are associated with the hydraulic normal depth (i.e. there is no backwatering from downstream).
- The invert of unembedded culverts is assumed to be at the same elevation as the top of the bed in the embedded culvert.
- Where the channel is split into multiple channels (e.g. at fans), flow is assumed to be uniformly distributed amongst the channels.
- A Manning's n of 0.025 for CSP culverts.
- A Manning's n of 0.08 for the embedded culverts. This value is based on estimates derived from Jarrett (1984) for typical slopes and hydraulic radius in the culverts and hydraulic model calibration conducted previously for the project (KP, 2011).

All results presented in the following sections are modelled cross-section average velocity and maximum water depth results for the embedded culvert.

2.4 OBSERVED CONDITIONS AND MODEL VALIDATION

North/South Consultants (NSC) conducted an aquatic habitat field program along the proposed North Rail alignment during the open-water season of 2018 (NSC, 2019). The field surveys were intended to provide empirical assessments of the presence/absence of fish, to identify fish barriers, and to document aquatic habitat in the vicinity of the proposed rail alignment and Tote Road realignment footprints in freshwater systems. Where fish presence was established or where a site was deemed to potentially provide fish habitat, measurements of physical habitat characteristics were collected at 20 m intervals along the creek for 100 m upstream and downstream of the crossing location. At each 20 m interval, measurements of bankfull width and water depth and velocity at three points across the channel (25%, 50% and 75% of wetted width) were collected.

Two different sampling periods occurred, one in the summer (June 28 to July 11) and one during the fall (August 23 to September 3). Flow conditions at active gauging stations during the data collection period were compared to long-term conditions and were generally similar to long-term average conditions (NSC, 2019). Consequently, the measured data are considered generally comparable to the July and August flows modelled in this assessment.

Because it is assumed that the embedded culvert has a similar gradient and bed material roughness to the adjacent channel, it would be expected that the culvert would have similar hydraulic characteristics to the adjacent channel. The ranges and mean values of the measurement conditions were compared to the calculated values for the culvert depths and velocities. Measured and modelled velocities and depths are shown in Tables 2 and 3.

Knight Piésold CONSULTING

TABLE 2

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT - PHASE 2 PROPOSAL

FISH PASSAGE RISK ASSESSMENT OF WATER CROSSINGS AND STREAM DIVERSIONS - PROPOSED NORTH RAILWAY
COMPARISON OF MEASURED AND MODELLED VELOCITIES

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Crossing Name	Catchment Areas (km²)	No. Barrels	Culvert Diameter (mm)	Length (m)	Slope (%)	Mean Monthly Flow (L/s)		Measured and Modelled Velocity (m/s)					
								NSC Summer Field Visit measurements		Embedded Culvert (modelled)	NSC Fall Field Visit measurements		Embedded Culvert (moddelled)
						July Flow	August Flow	Mean	Range	July Velocity	Mean	Range	August Velocity
CV-13-4	10.87	5	1800	24	1	615.3	219.6	0.23	0.00-0.60	0.41	0.33	0.07-0.77	0.29
CV-50-5	3.89	4	1800	30	5	220.2	78.6	0.49	0.06-1.25	0.53	0.36	0.00-0.84	0.38
CV-56-1	2.73	2	1500	24	1	154.6	55.2	0.12	0.02-0.26	0.37	0.11	0.00-0.62	0.25
CV-89-1	3.88	4	1500	30	1	219.6	78.4	0.13	0.05-0.26	0.32	0.16	0.01-0.41	0.23
CV-96-1	16.43	4	1800	36	1	929.8	331.8	0.21	0.05-0.54	0.50	0.22	0.02-0.53	0.36

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NOTES:

1. JULY AND AUGUST VELOCITY RESULTS REPRESENT THE RANGE OF RESULTS FROM MEAN MONTHLY FLOWS DURING THOSE MONTHS IN EMBEDDED CULVERTS. ALL VELOCITIES ARE CROSS SECTION AVERAGE VALUES.
2. NSC FIELD MEASUREMENTS SOURCED FROM NSC REPORT NORTH RAILWAY HABITAT SURVEY: 2018, DATED APRIL, 2019

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REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold CONSULTING

TABLE 3

BAFFINLAND IRON MINES CORPORATION
MARY RIVER PROJECT - PHASE 2 PROPOSAL

FISH PASSAGE RISK ASSESSMENT OF WATER CROSSINGS AND STREAM DIVERSIONS - PROPOSED NORTH RAILWAY
COMPARISON OF MEASURED AND MODELLED DEPTHS

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Crossing Name	Catchment Areas (km²)	No. Barrels	Culvert Diameter (mm)	Length (m)	Slope (%)	Mean Monthly Flow (L/s)		Measured and Modelled Water Depth (m)					
								NSC Summer Field Visit measurements		Embedded Culvert (modelled)	NSC Fall Field Visit measurements		Embedded Culvert (moddelled)
						July Flow	August Flow	Mean	Range	July Depth	Mean	Range	August Depth
CV-13-4	10.87	5	1800	24	1	615.3	219.6	0.16	0.09-0.28	0.18	0.14	0.02-0.40	0.11
CV-50-5	3.89	4	1800	30	5	220.2	78.6	0.14	0.04-0.38	0.08	0.13	0.06-0.25	0.05
CV-56-1	2.73	2	1500	24	1	154.6	55.2	0.29	0.10-0.98	0.15	0.36	0.05-1.00	0.09
CV-89-1	3.88	4	1500	30	1	219.6	78.4	0.12	0.04-0.30	0.13	0.11	0.02-0.28	0.08
CV-96-1	16.43	4	1800	36	1	929.8	331.8	0.26	0.05-0.54	0.25	0.23	0.02-0.61	0.15

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NOTES:

1. JULY AND AUGUST DEPTH RESULTS REPRESENT THE RANGE OF RESULTS FROM THE MEAN MONTHLY FLOWS DURING THOSE MONTHS. ALL DEPTHS ARE CROSS SECTION MAXIMUM VALUES.
2. NSC FIELD MEASUREMENTS SOURCED FROM NSC REPORT NORTH RAILWAY HABITAT SURVEY: 2018, DATED APRIL, 2019

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REV	DATE	DESCRIPTION	PREP'D	RVW'D

In general, the culverts have higher average velocities and lower total depth than the mean velocities and depths at each crossing. However, they are generally within the range of velocities and depths found along the creek in the 100 m upstream and downstream observed by NSC at each crossing. Photos of the stream conditions, reproduced from NSC (2019) are shown in Appendix A.

The measured conditions were not used to calibrate the culvert hydraulics model and there are many reasons why the measured and modelled conditions would not match (e.g. different flow conditions, field measurements at the stream crossings are point measurements of depths and velocities). However, the comparison is considered to show reasonable agreement between measured velocities in the natural channel and modelled conditions in the embedded culverts.

The measured data also show the variability in depth and velocity within a reach, which will be maintained in the embedded culverts. Katopodis and Gervais (2016) note that fish have the ability to detect and utilize zones of lower velocity and that studies of fish movement through culverts have shown that small fish can take advantage of the low velocity regions within the culvert.

2.5 FISH PASSAGE VELOCITY THRESHOLDS

The predicted culvert velocities were used as an indicator of potential fish migration barriers. NSC determined velocity thresholds as a function of culvert length for 88 mm and 256 mm length Arctic Char (i.e., the mean and maximum lengths of char, respectively, captured during field programs conducted in affected drainages from 2006-2018), using the equations provided in Katopodis and Gervais (2016). The velocity thresholds are shown in Appendix B.

Mean culvert velocity under July and August flow conditions was compared to the 75% passage thresholds (i.e. 50% to 75% of fish are expected to be able swim faster than the average culvert velocity). As noted above, average velocity may not reflect the velocity in the area within the culvert used by fish to move up the culvert. Additionally, modelled flows may not represent conditions when fish are moving upstream. The number of crossings exceeding the velocity thresholds for the two flow conditions and fish sizes are presented in Table 4. Results are presented in Appendix C and identify crossings that exceed the threshold criteria for the given mean flow conditions.

Table 4 Embedded Culverts with Modelled Average Flow Velocities Exceeding Thresholds

Category	July Velocity Thresholds (75% Passage)		August Velocity Thresholds (75% Passage)	
	88 mm Char	256 mm Char	88 mm Char	256 mm Char
Exceed	46	3	22	1
Do Not Exceed	47	90	71	92
% Exceeding	50%	3%	23%	1%

As noted above, fish passage is not necessarily restricted if the average flow velocity exceeds the flow velocity thresholds, as the flow within a channel (even a culvert) can vary considerably across the culvert section. Fish have the ability to detect and utilize zones of lower velocity, and small fish can take advantage of the low velocity boundary layer along the culvert wall to achieve passage where hydraulic conditions permit (Light et al., 2013; Peterson et al., 2013; Powers et al., 1997). Measured flow velocity ranges presented in Tables 2 and 3 and the average velocity of these same measurements underscore this, and the concept of a low velocity "sweet spot" is shown on Figure 3. Katopodis and Gervais (2016) note that misrepresentation of swimming performance can occur when passage success is reported based on average velocity when in fact fish are using zones of lower velocity. The size of the fish relative to low velocity zone is a factor in the ability to exploit these areas during passage. Hence, the average velocities presented in Appendix C should not be strictly interpreted as the flow velocity that the juvenile and young-of-year arctic char in the subject streams will need to pass.

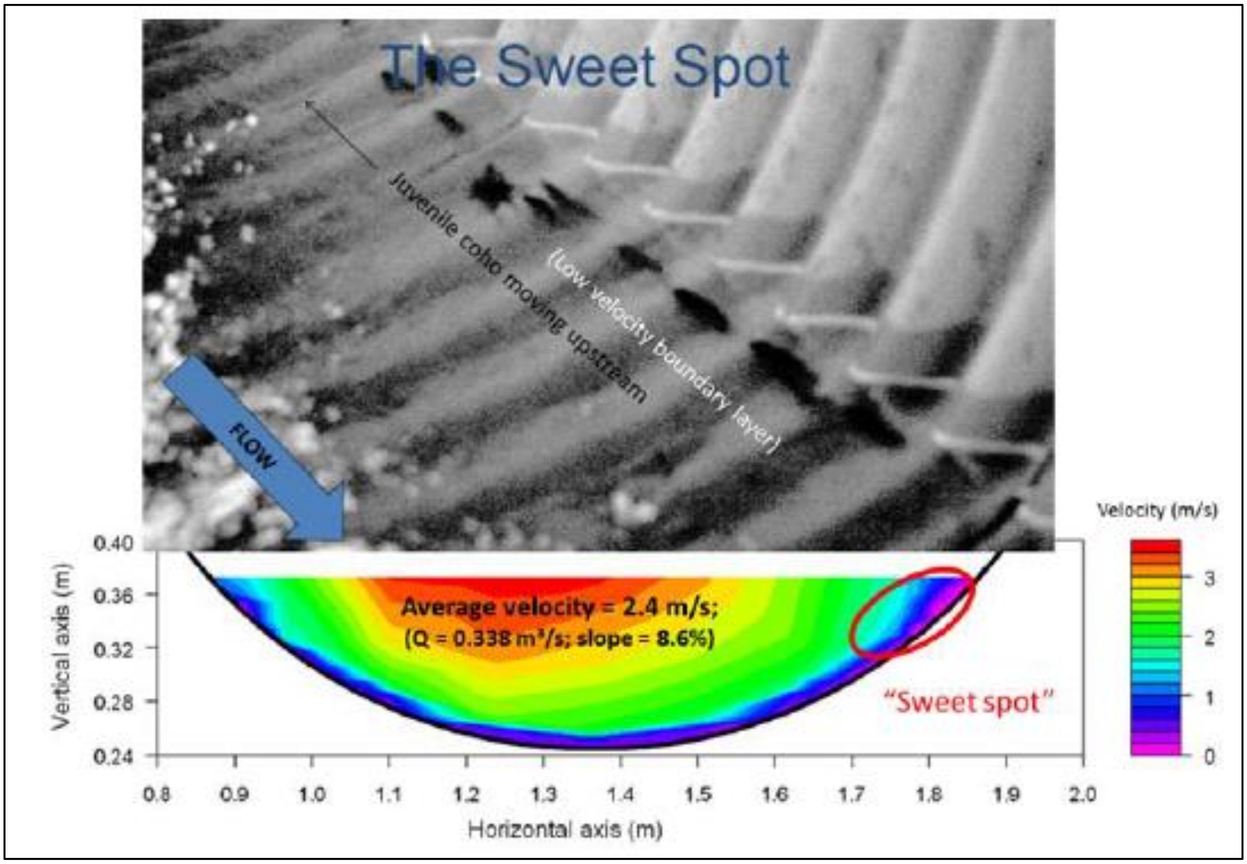

Figure 3: Low Velocity "Sweet Spot" in Culverts Used by Smaller Fish (from Katopodis and Gervais, 2016)

2.6 FISH PASSAGE RISK ASSESSMENT

A fish passage risk assessment has been conducted to support discussion making and selection of which crossings require additional mitigation and monitoring. The assessment is based on methods presented in the BC Ministry of Environment guide, Field Assessment for Determining Fish Passage Status Of Closed Bottom Structures (BC MoE, 2011), which presents a fish barrier scoring based on culvert embeddedness, outlet drop, stream width ratio, culvert slope and culvert length. We have modified the assessment to align with the available datasets and primary passage considerations at this Project. The assessment is described below.

Embeddedness

At least one culvert at each fish-bearing crossing will be embedded. Culverts will be embedded approximately 20% of pipe diameter and continuously through the culvert. Consequently, the embeddedness score for all fish-bearing crossings is 0.

Outlet Drop

The embedded culvert at each fish-bearing crossing will be designed to match the adjacent channel grade without an outlet drop. Consequently, the outlet drop score for all fish-bearing crossings is 0.

Velocity

A score is assigned to each crossings based on the velocity thresholds for 88 mm char (See Appendix B) and July flow velocities. Scores are assigned as follows:

- <5% Passage, score = 4
- <25% Passage, score = 3
- <50% Passage, score = 2
- <75% Passage, score = 1
- >95% Passage, score = 0

Water Depth

A score of 1 is assigned to crossings that where the August water depth in the culvert is predicted to be less than 0.15 m. If water depth is greater than 0.15 m a score of 0 is assigned.

Culvert Length

If culvert length is less than 30 m, a score of 0 is assigned. If culvert length is greater than 30 m but less than 60 m, a score of 1 is assigned. Culverts longer than 60 m receive a score of 2.

Risk Rating

The minimum and maximum possible scores are 0 and 7, respectively. If the cumulative score of the five metrics is ≤ 1, the risk of fish migration impacts is considered low. If the cumulative score of the five metrics is ≥4, the risk of impediments to fish passage is considered high. A high risk rating usually occurs when the velocity score is ≥2, combined with a culvert length of >30 m).

Twenty-nine of the 93 fish-bearing crossings were rated as high risk. Results at all crossings are presented in Appendix C

2.7 CONCLUSIONS

There are 93 stream crossing sites where CSP culverts will be installed in known or potential char habitat. Based on calculated culvert cross-section average velocities, 88 mm class Arctic char may have reduced fish passage at approximately 50% of the crossings in July and 23% in August. The 256 mm class Arctic char likely have minimal fish passage impacts in nearly all the culverts (thresholds exceeded in 4% and 1% of the culverts in July and August, respectively). KP notes that this overstates the potential to restrict fish passage, since small fish typically identify lower velocities by which they can pass.

Using a risk assessment method, based on the BC MoE's procedure, 46 crossings are predicted to be at moderate risk and 31 crossings are at high risk of affecting fish passage.

To avoid impacting fish passage, it is recommended that Baffinland:

1. Install at least one culvert at each fish bearing crossing as an embedded culvert, such that slope, bed material and discharge per unit width are sufficiently comparable to upstream and downstream conditions. A Qualified Professional (QP) with sufficient experience and training should supervise design and installation.
2. At the highest risk crossings, site-specific assessment (e.g. assess baseline depths, velocities and discharge, channel morphology and fish use) will be conducted. If required, site-specific design and construction (e.g. embedded box or arch culverts, or fish passage culverts) will be used to mitigate risk.
3. A monitoring program will be developed to monitor conditions at the highest risk crossings.

3.0 PHYSICAL EFFECTS OF FLOW DIVERSION

In areas where the rail alignment is cut into the terrain, it is not feasible to pass streams across the rail alignment. In these locations, the watercourse will be diverted along the rail alignment to an adjacent watercourse. Clearly, diversion will cause streamflow to be reduced downstream of the diversion and increased in the receiving watercourse.

3.1 POTENTIAL GEOMORPHIC RESPONSE TO FLOW CHANGES

The North Railway alignment passes through terrain dominated by its glacial history; including till, moraines, glaciofluvial and glaciolacustrine deposits. Bedrock outcrops ranging from granitic gneiss to sedimentary rocks are present (Hatch, 2016). For the most part, the rail route follows glacial valleys that have been infilled with granular material that varies in texture from silty sand to sandy gravel with cobbles and some boulders. The lacustrine sediments are finer grained silt and fine sand prevalent. The rail route travels through a region of continuous permafrost, where ice and frozen soil are significant in formation of post-glacial landforms and terrain stability. The active permafrost layer is expected to be thin in the lake sediments (less than 0.5 m) whereas the higher, well-drained terraces probably support an active layer of 1.5 m or more (Tetratech EBA Inc., 2015).

This assessment focuses on the effect of increased flow in the receiving stream, with potential effects including:

- *Exceedance of channel capacity and flooding.* If flow increases are modest, flooding may be infrequent. Where flow increases are larger, the channel banks may be overtopped each year during freshet (nival runoff) or during rainfall driven runoff events. Given the lack of vegetation and shallow frozen soils, rainfall runoff is rapid, causing sudden pronounced and relatively large increases in flow. If the channel is within a well-defined valley, the flooded extent may be modest, but in flat terrain flooding may be extensive or follow low terrain (e.g. ice wedges) into other drainages.
- *Changes in permafrost and frozen soil*. Flooding and higher water levels may affect permafrost and frozen soil conditions proximal to the channel, causing subsidence or slope instability.
- *Fluvial geomorphic change*. Increased flows may cause channel bed scour or bank erosion. Additionally, overbank flows may erode surficial soils. These eroded materials would be deposited downstream where the watercourse meets the diverted channel, larger river or lake.

In order to realize these potential effects, the magnitude of flow change must be sufficient and the channel morphology sensitive to flow changes. The likelihood of these potential effects occurring is discussed in the following section.

3.2 EFFECTS SCREENING

Each of the 10 diversion locations, where flow is diverted from one stream to another, were assessed based on available desktop information, and were screened with consideration of the following:

- *Change in flow.* If the predicted increase in flow in the receiving stream is less 10% (i.e. less than 10% change in contributing catchment area), it is unlikely that measurable changes in channel morphology or flood conditions would be detected. These diversions were rated as low risk.
- *Channel morphology.* For catchments less than 0.5 km^2, mean annual discharge and 2-year peak flow were estimated to be less than 5 l/s and 0.4 m^3/s respectively. In these locations, the channels are small and channel morphology is dominated by ice, frozen soil and non-fluvial processes. If the combined catchment area (baseline plus diverted catchments) is less than 0.5 km^2, it is unlikely that measurable changes in channel morphology or flood conditions would be detected. These diversions were rated as low risk.

Where diversions cause a greater than 10% increase in flow and the combined catchment area (baseline plus diverted catchments) is greater than 0.5 km^2, it is considered that there is potential to cause the effects discussed in Section 3.1, namely, more frequent overbank flooding, and potential changes in permafrost, frozen soil conditions and fluvial morphology.

Catchment area, mean annual discharge (MAD) and 2-year peak flow (Q2) and length of stream channel with affected flows were estimated for each diverted and receiving stream. Of the 10 diversions, 9 are considered low risk. The remaining diversion is considered medium risk as summarized in Table 5. The stream at crossing CV47-1b will receive increased flows, but the channel meets the CV47-1c channel approximately 100 m downstream of the crossing, at which point flows become unchanged from baseline.

Table 5 Summary of Diversions with Medium Risk of Geomorphic Change

Diverted Stream	Receiving Stream	% flow increase from Baseline	Fish Bearing at crossing?
CV47-1c			No
	CV47-1b	50%	Yes

Site specific assessments should be undertaken at this diversion during detailed engineering design of the railway. The assessments should consider fish use and length of impacted channel, and potential mitigation options can be identified and incorporated into the final design.

3.3 MITIGATION

For diversions considered low risk, mitigation will include monitoring for a short period of time post-construction (i.e., 1 to 2 years) to verify that the diversions are not having any unexpected effects as described in Section 4.1. Adaptive management can be used to address any unexpected effects.

Where diversions are considered moderate risk of causing measurable change to channel morphology and sediment transport, design mitigation measures can be used to address the identified risks. Options for mitigation may include:

- Channel widening
- Regrading
- Construction of habitat features (in fish bearing streams)

- Channel stabilization

Monitoring and adaptive management will also be conducted.

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5.0 CLOSURE

Please do not hesitate to contact the undersigned with any questions.

Yours truly,
Knight Piésold Ltd.

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Approval that this document adheres to the Knight Piésold Quality System:

Attachments:

Appendix A	NSC Freshwater Habitat Survey photos
Appendix B	Fish Swim Velocity Thresholds
Appendix C	Fish Passage Risk Assessment
Appendix D	Flow Diversions

Copy To: Megan Cooley, North/South Consultants Inc.

/tp

APPENDIX A

NSC Freshwater Habitat Survey photos

(Pages A-1 to A-6)

Phase 2 Milne Rail Corridor Aquatic Habitat Assessment

Location

Crossing ID: CV-13-4 **Dates Surveyed:** 30 June & 24 August, 2018 **UTM Coordinates:** 17 W 512415 7966799

Photographs

A **B** **C**

Figure 6. Summer (top) and fall (bottom) views of CV-13-4 at the rail crossing; (A) looking upstream; (B) looking downstream; and (C) looking across.

Phase 2 Milne Rail Corridor Aquatic Habitat Assessment

Location

Crossing ID: CV-50-5 & CV-50-6 **Dates Surveyed:** 8 July & 27 August, 2018 **UTM Coordinates:** 17 W 526924 7934630 & 17 W 526926 7934620

Photographs

A **B** **C**

Figure 5. Summer (top) and fall (bottom) views of CV-50-6 at the rail crossing; (A) looking upstream; (B) looking downstream; and (C) looking across.

Phase 2 Milne Rail Corridor Aquatic Habitat Assessment

Location

Crossing ID: CV-56-1 **Dates Surveyed:** 8 July & 27 August, 2018 **UTM Coordinates:** 17 W 528085 7929337

Photographs

A **B** **C**

Figure 7. Summer (top) and fall (bottom) views of CV-56-1 at the rail crossing; (A) looking upstream; (B) looking downstream; and (C) looking across.