

**Eqe Bay Exploration Program
Type 'B' Water Licence Application**

**Attachment 9
Culvert Design Memo**

MEMORANDUM

To:	Mr. Thomas Iannelli	Date:	May 2, 2018
Copy To:	Jon Hey, JT Gibbens, Megan Lord-Hoyle	File No.:	NB102-00181/46-A.01
From:	Deena Duff	Cont. No.:	NB18-00241
Re:	Ege Bay Exploration Program - Access Road Culvert Design		

1 – BACKGROUND

Baffinland Iron Mines Corporation (Baffinland) is planning to establish an exploration camp and associated infrastructure at its Ege Bay Prospect in 2018. The prospect location is shown on Figure 1.

Access from the exploration camp to the exploration area will initially be by helicopter. In subsequent years, Baffinland are considering construction of an access road connecting the exploration camp to the exploration area to reduce dependence on helicopters to move drills, workers and consumables. The proposed routing of the access road is shown on Figures 2 and 3.

In order to construct an access road, culverts will be required at two locations in order to maintain natural drainage paths (Figures 2 and 3). Based upon a desktop review of the two crossing locations, both are expected to include fish habitat. Additional descriptions of the streams and associated catchments are provided in Section 2 of this memorandum, while design details are provided in Sections 3 and 4.

2 – CULVERT LOCATIONS

2.1 GENERAL

Two streams along the proposed access road that have meaningfully sized catchments and are assumed fish habitat will require culvert installations. Neither location has been visited by Knight Piésold Ltd. personnel, and therefore, culvert installations will need to be field fit based on the design recommendation presented herein and observations made in the future.

Additionally, numerous minor drainages exist across the proposed access road alignment that will also require culverts to maintain drainage across the access road. These drainages are small and/or there are multiple drainages within a catchment, are largely ephemeral, and are not fish habitat. Culverts at these locations are best field fit based on local conditions. As such, sizing of these culverts has been excluded from this analysis.

2.2 EAST CATCHMENT

The first set of culverts are proposed to be installed in an unnamed stream on the east side of Lake EB-1, at the low end of the East Catchment. Detailed habitat mapping has not been conducted to describe the streambed and streambank material, streambank vegetation or meander characteristics. However, based on the knowledge of the area and experience with other similar locations on Baffin Island, the stream likely supports juvenile Arctic char. The estimated catchment area upstream of this culvert location is 8.85 km².

2.3 WEST CATCHMENT

The second set of culverts are proposed to be installed on the stream that discharges from Lake EB-2 to the marine environment at Harbour Bay (Figure 2). The upper portion of this stream may support juvenile rearing by land-locked Arctic char during the open water period. Fish use at the proposed crossing location is expected to be low given that it is 2.5 km by stream distance upstream from tidewater and 0.5 km below the Lake EB-2 outlet. It is unlikely that the proposed crossing is accessible by sea-run Arctic char due to insufficient flows and habitat connectivity to support fish passage. The estimated catchment area upstream of this culvert location is 10.71 km².

3 – DESIGN CRITERIA AND METHODOLOGY

Given that specific guidelines related to the design of culverts do not exist in Nunavut, reference is made to Ontario's Lakes and Rivers Improvement Act (LRIA; Ontario Ministry of Natural Resources, 2004) and the Ontario Ministry of Transportation's Drainage Manual requirements (Drainage Manual; Ontario Ministry of Transportation, 1997).

Initially, given the road's anticipated low usage over a short duration (approximately 5 years), the 1 in 10-year storm was identified as an appropriate design return period event, based on LRIA and the Drainage Manual. However, following initial analyses, the number and size of culverts was determined for each location, and the resulting total span of the culvert openings was greater than 6.0 m. For spans greater than 6.0 m, the design storm event increases to the 1 in 25-year event, according to LRIA and the Drainage Manual.

A peak flows analysis was previously completed by Knight Piésold Ltd. (2016) in support of the Mary River Project. As part of the analysis, peak flow equations were developed for various return period storm events. The peak flow resulting from the 1 in 25-year storm event, in m³/s, is calculated from the following equation:

$$Q_{10} = 1.70 \times A^{0.82}$$

where Q = peak instantaneous flow in m³/s, and A = drainage area in km².

Based on the above equation, the design flows for the east and west catchment culverts are 10.2 m³/s and 11.9 m³/s, respectively.

The hydraulic capacity of individual culverts was determined by water flowing under inlet control with a ratio of the maximum upstream water level (above the invert of the culvert) to culvert diameter of 1 (H/D = 1). That is for a culvert diameter equal to 1 m, the maximum upstream water level was restricted to 1 m above the bottom of the culvert at peak flow. For an entrance projecting from fill condition, the entrance loss coefficient (K_e) was assigned a value of 1.0, the coefficient of discharge (C) a value of 0.546, and the loss coefficient (a) a value of 0.60. Multiple culverts are required at both crossings to satisfy the peak flow requirements.

It should be noted, however, that sizing of the culverts in arctic environments simply on the basis of design flows may not be adequate given the risk of partial culvert blockage due to ice formation over the winter. Accordingly, consideration should be given to increasing culvert sizes to account for a partial blockage due to ice.

4 – CULVERT SIZING AND INSTALLATION DETAILS

All culverts will be corrugated steel culverts, with the culvert base projecting 0.5 m beyond the road fill slope at each end. A minimum of 0.5 m of road fill material will be placed over each culvert. Two culvert sizes are proposed, with every other culvert being the larger sized one. This will provide some contingency for capacity lost due to embedment of the culverts. The preliminary size and number of culverts required for each location are listed as follows:

- East Catchment - Five (5) 1 m diameter and five (5) 1.2 m diameter
- West Catchment - Six (6) 1 m diameter and five (5) 1.2 m diameter

Site-specific conditions have not been documented at either culvert location, and as such, the culverts must be field fit based upon the typical culvert details shown on Drawing 431, previously issued with the Mary River Project's Bulk Sampling Program - Road Upgrade Technical Specifications (Knight Piésold Ltd., 2007a). This report was stamped by a Professional Engineer licensed to practice in the Northwest Territories and Nunavut.

Although Drawing 431 includes an overflow swale for each crossing, the number and size of culverts provided above assumes that all of the design flow drains through the culverts, thereby negating the need for a swale. Depending on the drainage dimensions and site-specific conditions for each location, it may not be possible to install the required number of culverts in the space available. An overflow swale may be installed in place of some of the culverts if the existing drainage can not accommodate all of the specified number of culverts. The details of the swale will need to be determined based on site conditions and Baffinland's ability to maintain the swales.

Scheduling of culvert installations will be dependent on foundation requirements and coordination with environmental or archaeological requirements of the construction program.

All culverts will be installed as shown on the drawings, according to the supplier's recommendations and Technical Specifications (Knight Piésold Ltd., 2007a), and in compliance with all applicable regulatory requirements. In addition, culverts will be installed in accordance with direction provided by Fisheries and Oceans Canada (DFO). Typically, DFO will issue a Letter of Advice for such activities, rather than an authorization under the *Fisheries Act*. A minimum of one (1) culvert per crossing location will be embedded a maximum 10% of the diameter into the bed of the crossing to provide flow for fish passage during low flow conditions. Additional details are provided in the Bulk Sampling Program Road Upgrade Design Summary Report (Knight Piésold Ltd., 2007b).

Following construction, ongoing inspection, monitoring and maintenance of the road and culverts will be required to ensure integrity over the course of operations. In the spring, maintenance will likely include steaming out of the culverts in order to remove any ice buildup.

5 – ENVIRONMENTAL PROTECTION

Environmental protection measures will be incorporated into all aspects of the construction to ensure that the environment and receiving waters are protected from contaminated runoff and increased sediment loadings. Construction methods and mitigation measures are described in Appendix B in relation to Section 35 of the Nunavut Water Board's Supplemental Information Guidelines (SIG) for Water Works (Nunavut Water Board, 2010).

6 – REFERENCES

Knight Piésold Ltd., 2007a. *Baffinland Iron Mines Corporation - Mary River Project - Bulk Sampling Program Road Upgrade Technical Specifications*. August 1. Ref. No. NB102-00181/10-2, Rev. 0.

Knight Piésold Ltd., 2007b. *Baffinland Iron Mines Corporation - Mary River Project - Bulk Sampling Program Road Upgrade Design Summary*. July 13. Ref. No. NB102-00181/10-1, Rev. 0.

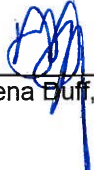
Knight Piésold Ltd., 2016. Letter to: Matt Weaver, Baffinland Iron Mines Corporation. Re: *Updated Design Peak Flow Assessment*. December 13. Ref. No. VA16-01950 (NB102-181/39). Prepared for Baffinland Iron Mines Corporation.

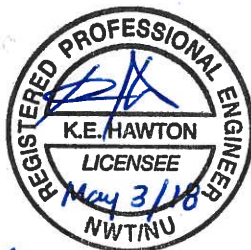
Nunavut Water Board, 2010. *Draft Miscellaneous Supplemental Information Guideline (SIG) for General Water Works (including Crossings, Trainings, Flood Control, Diversions, and Flow Alterations) (M1)*. February.

Ontario Ministry of Natural Resources, 2004. *Lakes & Rivers Improvement Act (LRIA) Technical Guidelines - Criteria and Standards for Approval*. June.

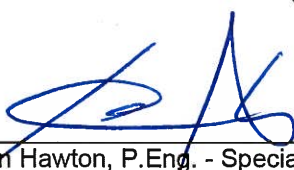
Ontario Ministry of Transportation, 1997. *Drainage Management Manual*. October.

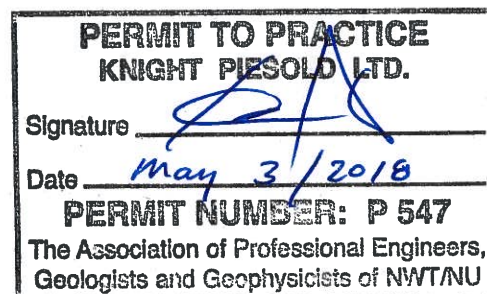
Prepared:


Deena Buff, P.Eng. - Senior Engineer



Reviewed:


Kevin Hawton, P.Eng. - Specialist Engineer | Associate

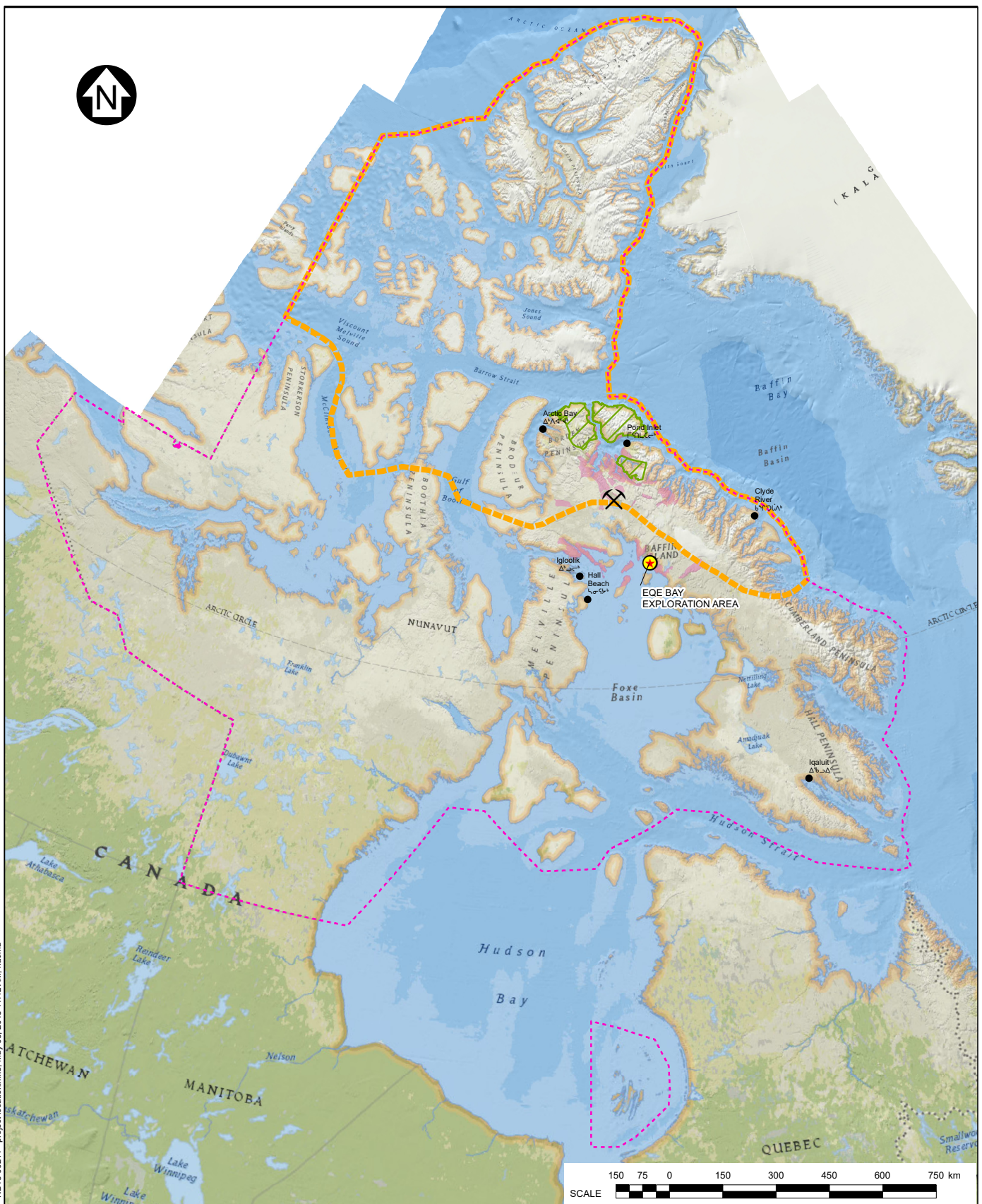


Approval that this document adheres to Knight Piésold Quality Systems: 

Attachments:

Figure 1 Rev 0	Project Location Map
Figure 2 Rev 0	Proposed Exploration Area Layout with Catchment Boundaries for Culverts
Figure 3 Rev 0	Proposed Access Road Layout
Appendix A	Drawing 431, Rev 1 - Large Crossings - Typical Sections and Details
Appendix B	Water Works SIG Section 35

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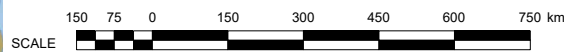


LEGEND

- COMMUNITY
- ✂ MARY RIVER PROJECT
- ★ EQE BAY EXPLORATION AREA
- NUNAVUT SETTLEMENT AREA
- NORTH BAFFIN PLANNING REGION
- SIRMILIK NATIONAL PARK
- IOL SURFACE AND SUBSURFACE INCLUDING MINERALS
- IOL SURFACE ONLY EXCLUDING MINERALS

NOTES

1. BASE MAP: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.
2. NORTH BAFFIN PLANNING REGION: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.
3. NORTH BAFFIN PLANNING BOUNDARY FROM NUNAVUT PLANNING COMMISSION (2017).
4. QIKIQTANI REGION BOUNDARY FROM STATISTICS CANADA, 2011 CENSUS DATA.
5. MARY RIVER PROJECT: © ESRI DATA AND MAPS (ONLINE) (2016). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.



EQE BAY EXPLORATION PROGRAM

PROJECT LOCATION MAP
ARCTIC CIRCLE EXPLORATION AREA

Knight Piésold
CONSULTING

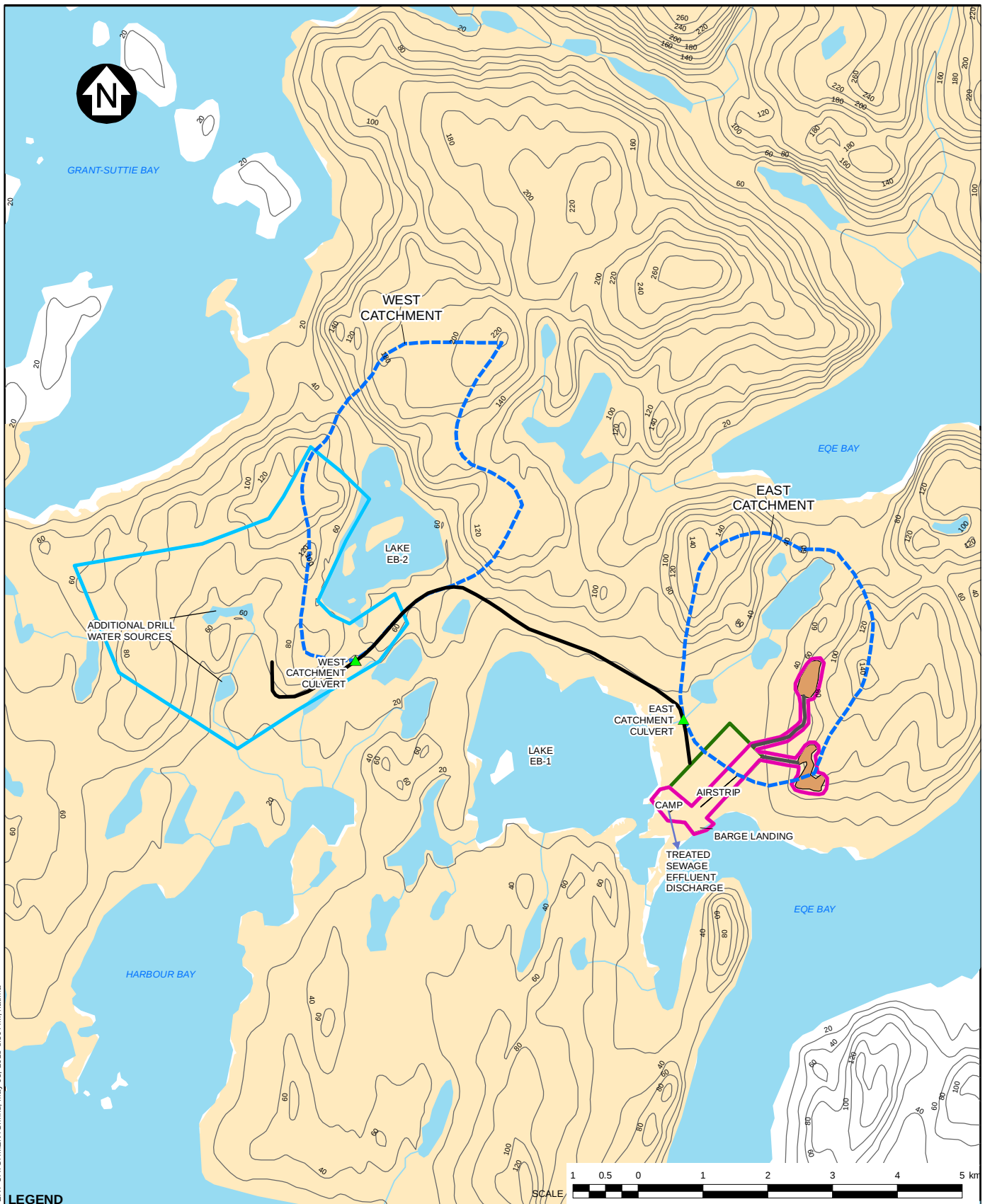
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NB102-181/46

REF NO.
NB18-00241

FIGURE 1

REV
0

0	02MAY18	ISSUED WITH MEMO	AV	RF	RAC
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED



LEGEND

- ▲ CULVERTS
- CONTOURS
- PROPOSED ACCESS ROAD/TRAIL
- QUARRY ACCESS ROAD
- WATER
- POTENTIAL QUARRY
- POTENTIAL DEVELOPMENT AREA
- INITIAL EXPLORATION AREA
- CAMP LAND USE FOOTPRINT
- CATCHMENT BOUNDARIES FOR CULVERTS
- NTI EXPLORATION AGREEMENT SUB-AREA

NOTES:

- COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
- CONTOUR INTERVAL IS 20 METRES.
- LOCATIONS AND SIZING OF PROJECT FACILITIES IS APPROXIMATE ONLY.

SCALE 1 0.5 0 1 2 3 4 5 km



EQE BAY EXPLORATION PROGRAM

**PROPOSED EXPLORATION AREA LAYOUT
WITH CATCHMENT BOUNDARIES FOR CULVERTS**

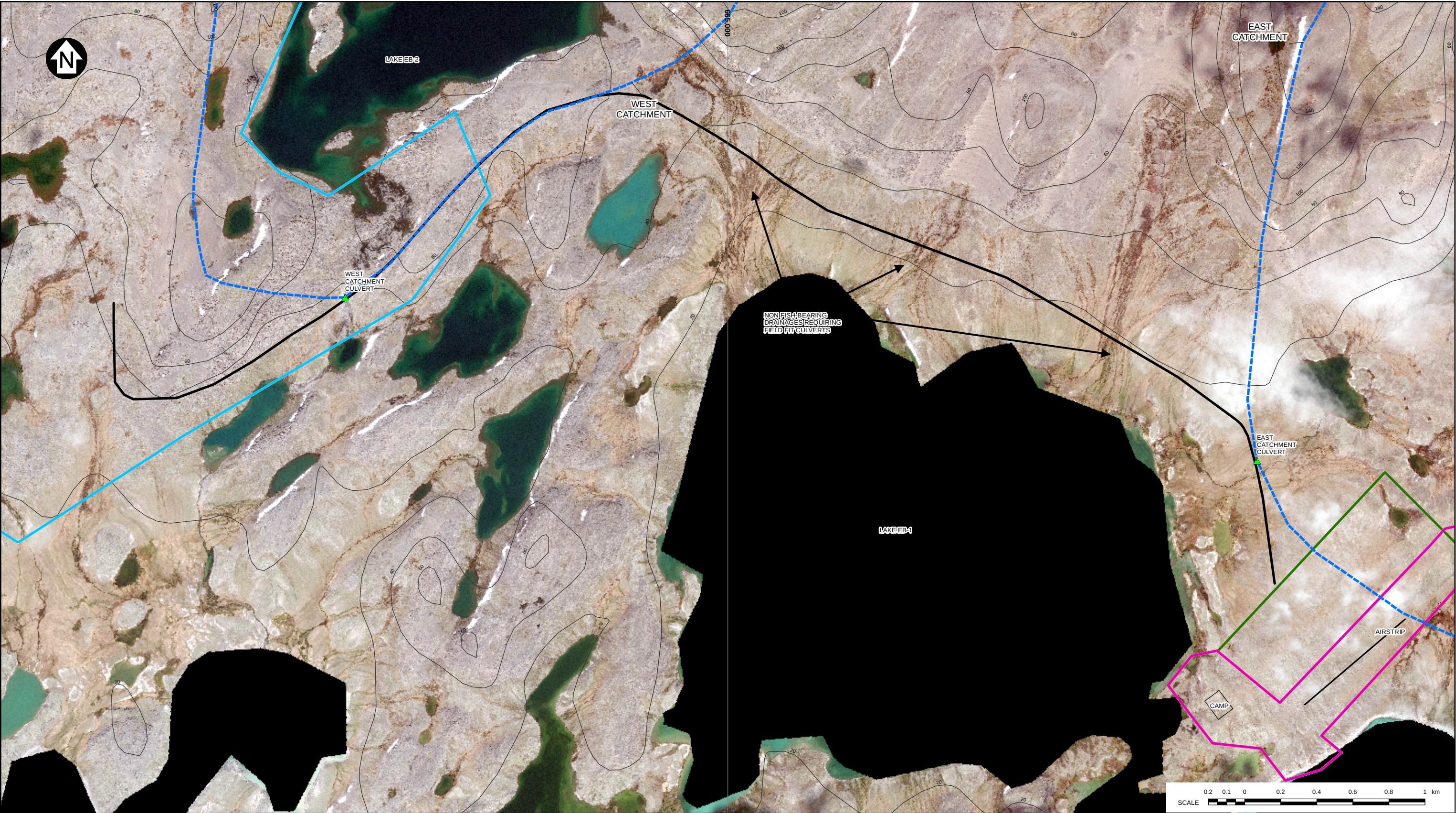
**Knight Piésold
CONSULTING**

PIA NO. NB102-181/46 REF NO. NB18-00241

FIGURE 2

REV 0

REV	DATE	DESCRIPTION	RAC DESIGNED	RF DRAWN	RAC REVIEWED
0	02MAY18	ISSUED WITH MEMO			



LEGEND:

- CULVERTS
- CATCHMENT BOUNDARIES FOR CULVERTS
- OVERLAND TRAVELWAY
- CAMP LAND USE FOOTPRINT
- POTENTIAL QUARRY
- POTENTIAL DEVELOPMENT AREA
- INITIAL EXPLORATION AREA

NOTES:

- COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N.
- CONTOUR INTERVAL IS 20 METRES.
- LOCATIONS AND SIZING OF PROJECT FACILITIES IS APPROXIMATE ONLY.

0	02MAY18	ISSUED WITH MEMO	RAC	RF	DMMD
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED

EQE BAY EXPLORATION PROGRAM

PROPOSED ACCESS ROAD LAYOUT

PIA NO. NB102-181/46	REF NO. NB18-00241
FIGURE 3	
REV 0	

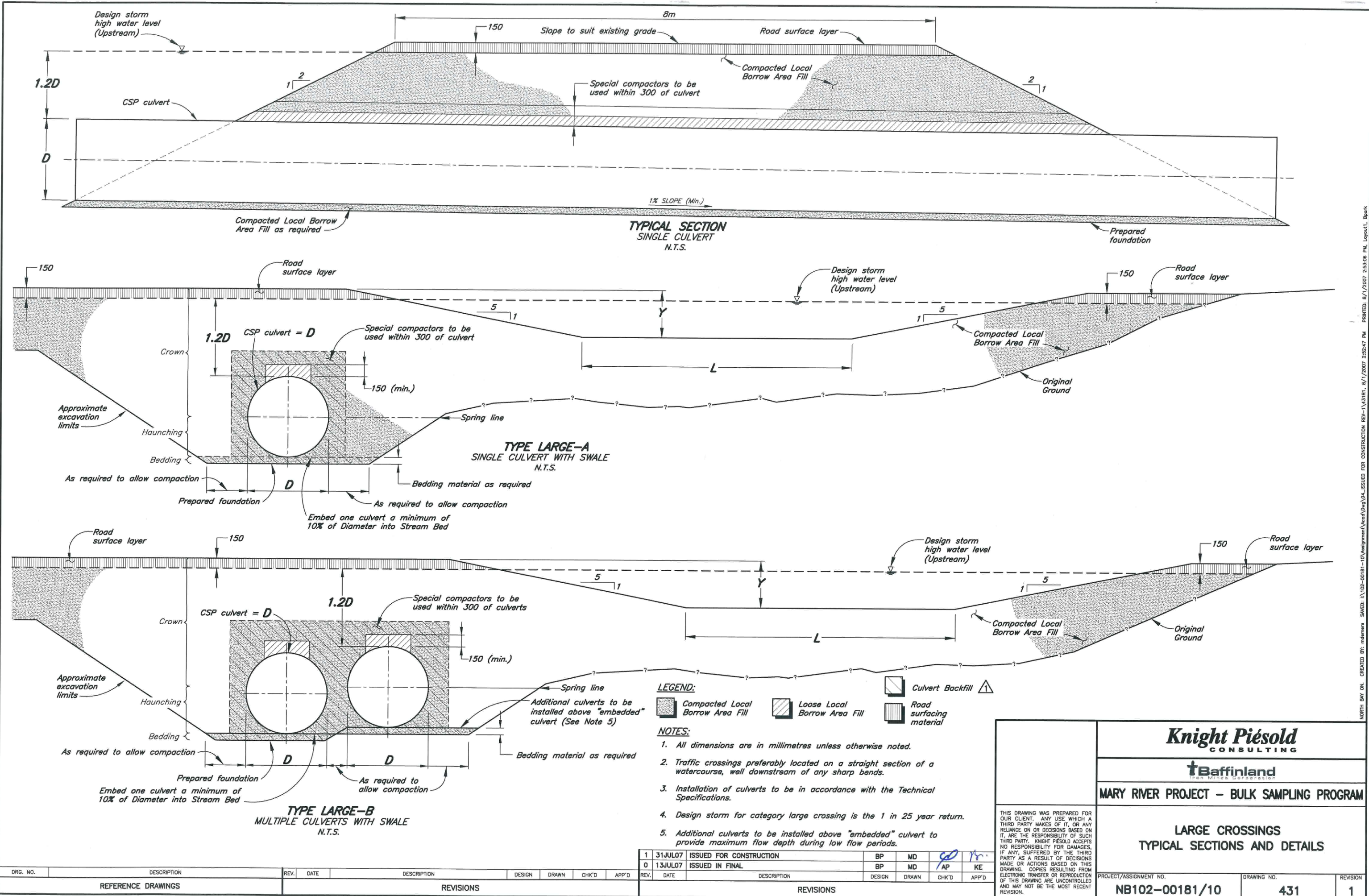
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APPENDIX A

DRAWING 431, REV 1 - LARGE CROSSINGS - TYPICAL SECTIONS AND DETAILS

(Page A-1)

IMAGE FILE(S): Baffinland logo-bkg corp-b-w



NORTH BAY ON. CREATED BY: mdeemers. SAVED: I:\102-00181-10\Assignment\Drawings\NB102-00181-10-Layout1.dwg. PRINTED: 8/1/2007 2:53:06 PM. Layout1, Bpork

APPENDIX B

WATER WORKS SIG SECTION 35

(Pages B-1 to B1-7)

Appendix B – Water Works SIG Information

<i>Watercourse Crossings</i>	23	Provide a description of any watercourse crossings including pipelines, bridges, culverts or roads and its purpose.	Two watercourse crossings are located on the proposed access road between the exploration camp and exploration area. This overland access to the exploration area will reduce helicopter use, which will reduce fuel consumption and noise emissions.
	24	Indicate whether a temporary detour road is required to construct the watercourse crossing.	A detour road is not required
	25	Provide a plan of any watercourse crossing showing cross section and elevations.	The location of the culvert crossings is shown on Figure 2 of the Memo. Site-specific cross-sections and elevations are not currently available.
<i>Watercourse Trainings</i>	26	Provide a description of any watercourse trainings including channel and bank alterations, culverts, spurs, erosion control, and artificial accretion, and its purpose.	No alterations to the channels or the banks of the watercourses is proposed
<i>Flood Control</i>	27	Provide a description of any flood control structures and its purpose.	Not applicable
<i>Diversions</i>	28	Provide a description of any diversions including ditches and dikes, and its purpose.	Temporary diversion channels may be required to isolate the worksites if the streams are flowing (see Section 35I).
<i>Alterations in flow</i>	29	Provide a description of any activities or structures that could alter the flow of a watercourse including dams, spillways, berms, cofferdams, and dikes, and its purpose.	Not applicable
	30	Indicate whether the natural storage capacity or water level of any lake or pond will be altered.	Not applicable
	31	If the alteration involves a dam, provide a plan showing the length, height, cross section and elevations of the dam and the location and preliminary designs of spillways, canals, sluice pipes, and any other outlet work.	Not applicable
<i>Dewatering</i>	32	Provide a description of dewatering programs, if planned, including estimated quantities, qualities, dewatering flow rates, methods and schedule of withdrawal, end use or discharge location.	Not applicable

<i>Identification</i>	33	Indicate whether there are any signs identifying past or present water intake, storage, distribution systems and/or waterworks structures presently in the project area.	Not applicable
<i>Modifications</i>	34	Indicate whether any changes are planned for the water intake, storage, distribution systems and/or waterworks structures. If applicable, see item 35 of this section.	Not applicable
<i>Proposed Water works</i>	35	For each proposed water work component provide design plans. Design plans shall consider the following:	
	a	Name of the water body(s) affected	Two unnamed streams
	b	Site photos, site map, or air photos of the location	Figure 2
	c	Description of the existing condition of the site	Section 2
	d	Indicate whether any structures will be placed in water on a temporary, seasonal or permanent basis and provide a description of when and how the structure will be removed	Culverts installed on a permanent basis, until such time that the Closure and Reclamation Plan is implemented
	e	The design flood flow in cubic metres per second and its return period for the type of structure proposed	Design flood is 1 in 25-year storm: $Q_{25} = 1.70 \times A^{0.82}$ where Q = peak instantaneous flow in m ³ /s, and A = drainage area in km ² East catchment culvert design flow = 10.2 m ³ /s West catchment culvert design flow = 11.9 m ³ /s
	f	An explanation of the rationale for the selected design flow flood and its return period	The Ontario Ministry of Transportation's Drainage Management Manual (1997) recommends applying the 1 in 25-year storm for local roads with spans greater than 6 m
	g	Design drawings in plan and profile, drawn to scale, including all relevant dimensions	Drawing No. 431 provides a culvert typical; culverts will be field fit
	h	Details of design parameters including seismic design criteria if applicable	Section 3; seismic criteria not applicable

<i>Proposed Water works</i>	i	In water work timing restriction for fisheries	The Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO, 2013) outlines timing constraints to protect fish and fish habitat during instream construction projects. The Project area is within Nunavut Fish Timing Zone 1, and the general range of spawning times for Arctic char, the species of concern, is noted as Fall. The in-water work timing restrictions (i.e., when work should be avoided) for fall spawning species in Zone 1 is September 1 to June 30. The two watercourse crossings at Ege Bay can be expected to dry up and/or freeze to the bottom each winter, starting in the second half of September for the smallest watercourses. During this period of time, it is KP's experience that fish are not present during this time. Further to this, watercourses that freeze solid during the winter do not provide over-wintering habitat for fish. The installation of water crossings during the winter months is within the Nunavut restricted activity timing window, however prior approvals to work during this period was granted to Baffinland under the <i>Fisheries Act</i> authorization for the Tote Road. Due to the lack of fish and suitable habitat within the water crossings at this time, this period of time is preferred as a mitigation strategy.
	j	Start and completion dates for construction	July 1 to August 31; possibly October 1 to May 30 (pending approval from DFO to work outside the Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO, 2013).
	k	Construction schedule and sequence taking into account any timing restrictions	Culvert installations at single stream crossings are expected to be completed in one day

<i>Proposed Water works</i>	l	Construction methods	The main steps for culvert installation include: isolate the work area and establish flow bypass using pumps or a pipe, install remaining sediment and erosion control measures, salvage fish if present, trench and place fill for culvert foundations, compact materials, place culverts, backfill around culverts, lay down road surface, add erosion protection riprap and rock materials, remove isolation berms and flow bypass, line ditches with clean rockfill, and stabilize the remainder of the construction site. Temporary diversion channels may be required to isolate the worksites if the streams are flowing: the diversion channels will be designed by a professional engineer to accommodate peak flows. Best practices in the construction of diversion channels will be followed, and include (DFO, 1998): • Excavation from the downstream end toward the upstream point of diversion, where a “plug” of earth is left to prevent the entry of streamflow into the diversion before channelization is complete • Placement of a cofferdam immediately below the upstream point of diversion to reroute the flow of water into the diversion • Placement of another cofferdam immediately above the downstream point of diversion to isolate the work area and prevent sediment-laden water from escaping into the stream • A fish salvage program will be required prior to re-routing the stream into the diversion channel. A fish collection permit will be required for salvage operations and the salvage must be completed by qualified professionals. Fish will be re-located in areas upstream or downstream of the work site in suitable habitat. If pumping is required in the isolated stream channel between the cofferdams prior to fish salvage, water intakes will be screened to prevent fish entrainment, and pumps and intake screens will be sized to prevent impingement of fish.
	m	Equipment to be used	Excavator, dump truck, soil compactor, pumps, erosion control materials, spill kits
	n	A description of the source, type, and composition of material used in construction	Crushed and sorted clean rockfill sourced from local borrow or quarry sites
	o	The quantity of material to be either placed into or removed from the watercourse	The road top width is 5 m. Assuming a crossing width of 10 m and height of 2 m the approximate fill requirements for the stream crossings are 100 m ³ pre-installation.

<i>Proposed Water works</i>	p	Sedimentation and erosion control measures	The proponent will adopt the mitigation measures to avoid causing harm to fish and fish habitat described in DFO (2016) that are relevant to the Arctic marine environment and installation of culverts at stream crossings. Mitigation will include a combination of sediment and erosion control measures (check dams, rip-rap, silt fences, etc.) to address and manage sedimentation concerns during construction. The following measures will be implemented at fish-bearing watercourses to minimize and mitigate erosion and sedimentation issues: • Sediment and erosion control measures will be implemented prior to the start of construction and maintained until all disturbed ground has been permanently stabilized • Work in watercourses will be conducted in isolation of surface waters, if flow is present • Slopes will be stabilized with rock material, geotextiles, or mulch • Regular inspection and maintenance of sediment and erosion control measures and structures will occur during the construction period • Repairs to erosion and sediment control measures and structures will be completed if damage occurs • Non-biodegradable sediment and erosion control materials will be removed once site is stabilized • Any stockpiled materials shall be stored and stabilized 30 m away from the High-Water Mark of any waterbody, unless for immediate use • Fill material placed below the high water mark within the floodplain will be either erosion resistant or protected from erosion and only clean fill will be used • Whenever possible, machinery will be operated on land above the high water mark, in a manner that minimizes disturbance to the banks and bed of the waterbody Additional Mitigation Measures for Installing Culverts in Winter: • Confirm that the larger streams are completely frozen • Remove snow and ice from the bed of the water course to ensure that the culvert is properly placed • Remove any loose or spilled sediment from the channel upon completion of the work • Put sediment and erosion control measures in place for when the thaw occurs
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<i>Proposed Water works</i>	q	Construction monitoring plans	Environmental monitoring of construction activities will consist of water quality monitoring and periodic environmental inspections. For all crossings where fish may be present an environmental monitor will be present to monitor construction activities and document turbidity levels upstream and downstream of the crossing under construction.
	r	Construction quality assurance and quality control measures	Stream crossings will be constructed according to the design drawing specifications for materials, fill, culvert sizing, and erosion protection. Inspections and construction progress will be documented as evidence that correct procedures were followed.
	s	Assessment of impacts to fish and fish habitat	Culvert installations are proposed on two streams that potentially support juvenile rearing by arctic char during the summer months. No spawning or overwintering habitat is present in streams. The potential impacts include habitat loss, mobilization of suspended sediment, and obstruction of upstream fish passage. Construction of road culverts is expected to have a negligible effect on Arctic char with implementation of appropriate engineering design, mitigation, and monitoring measures.
	t	Bank stabilization measures (including the size range of material if applicable)	Bank stabilization measures will include rock material, geotextiles, or mulch depending on the local site conditions
	u	Operation and maintenance plans including instrumentation, monitoring and inspection requirements	Culverts will be inspected on a weekly basis during the open water season and any required maintenance or repairs will be completed as soon as possible
	v	Contingency plans	Not applicable
	w	Re-vegetation plans	Not applicable
	x	Proposed post construction monitoring	Photos will be taken of the site before, during and after construction. Photos will be taken from the same reference point for easy comparison.
	y	Abandonment and restoration plans	See Closure and Reclamation Plan

<i>Proposed Water works</i>	36	Final plans and drawings for construction must be stamped by a Professional Engineer licensed to practice in Nunavut	See memo and Drawing 431
	37	If geotextile is used or a similar material to prevent the transport of sediment into a watercourse, provide the technical specifications for the proposed material as well as the location, extent and placement method for the material	The use of geotextile is not proposed
	38	If rip rap is used or a similar material for erosion protection, provide information regarding the minimum and maximum sizes of the material and the gradation between those limits. Indicate the quantity to be used and its source.	The use of riprap is not proposed