Knight Piésold CONSULTING

ATTACHMENT 6.3

NORTH RAILWAY GEOTECHNICAL EMBANKMENT REPORT

Baffinland Iron Mines Corporation
Mary River Expansion Study - Stage II

2

Preliminary Geotechnical Recommendation for Railway Embankment (Between Milne Inlet and Mine Site)

			Matt Buykx	J. Cleland	J. Cleland	M. Weaver
2017-01-10	2	Approved for Use	M. Buykx	J. Cleland	J. Cleland	M. Weaver
2016-11-28	1	Approved for Use	G. Liang	S. Hinchberger	J. Cleland	M. Weaver
2016-08-19	0	Approved for Use	G. Liang	K.S. Ho	J. Cleland	M. Weaver
Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**	**Approved By**
HATCH						**Client**

Table of Contents

List of Tables

List of Figures

Appendix

Appendix A

2016 Site Investigation Plan Photos

1. Introduction

Baffinland Iron Mines (BIM) currently operates the Mary River iron ore mine in Nunavut, Canada. BIM plans to increase the production rate of the mine from currently 4.2 million tonnes per annum (Mtpa) to 12Mtpa, shipping the output through Milne Port. This will be achieved by upgrading the mine fleet, constructing a 105 km long rail line from the mine site to the port, building a new crushing and screening facility at the port, construction of larger ore stockpiles and building a second ore dock and ship loader.

This report summarizes preliminary geotechnical recommendations for railway embankment design based on site reconnaissance and the existing geotechnical investigation data, as part of the Pre Feasibility Study of the Baffinland Expansion 12Mtpa Mine Option Project. The purpose is to support the estimation of earthworks quantities. The embankment structures developed in this report are preliminary based on experience.

It should be noted that thermal analysis and stability analysis will be required to optimize the preliminary design and to confirm their performance. Detailed geotechnical recommendations and construction considerations are not discussed in this report.

2. Scope of Work

The geotechnical work summarized in this report was developed to support the pre feasibility study for the railway embankment between Milne Inlet and the Mine Site. The total length is about 105 km. Appendix A contains drawings showing the proposed rail alignment and the anticipated terrain and soil conditions (surficial geology), compiled using the geologic maps listed in Section 3 of this report.

Figure 2-1 shows the approximate Chainage (Cha) along the Tote Road. In general, the proposed railway alignment follows the existing Tote road except for the main deviation between Cha 60+000 and 82+000 (see Figure 2-1). At the time this report was prepared, the alignment was being optimized and changes. Consequently, the Tote Road chainages are used herein for discussion purposes.

The alignment with chainage will be updated and finalized during the feasibility stage based on site specific geotechnical investigation data and additional design. .

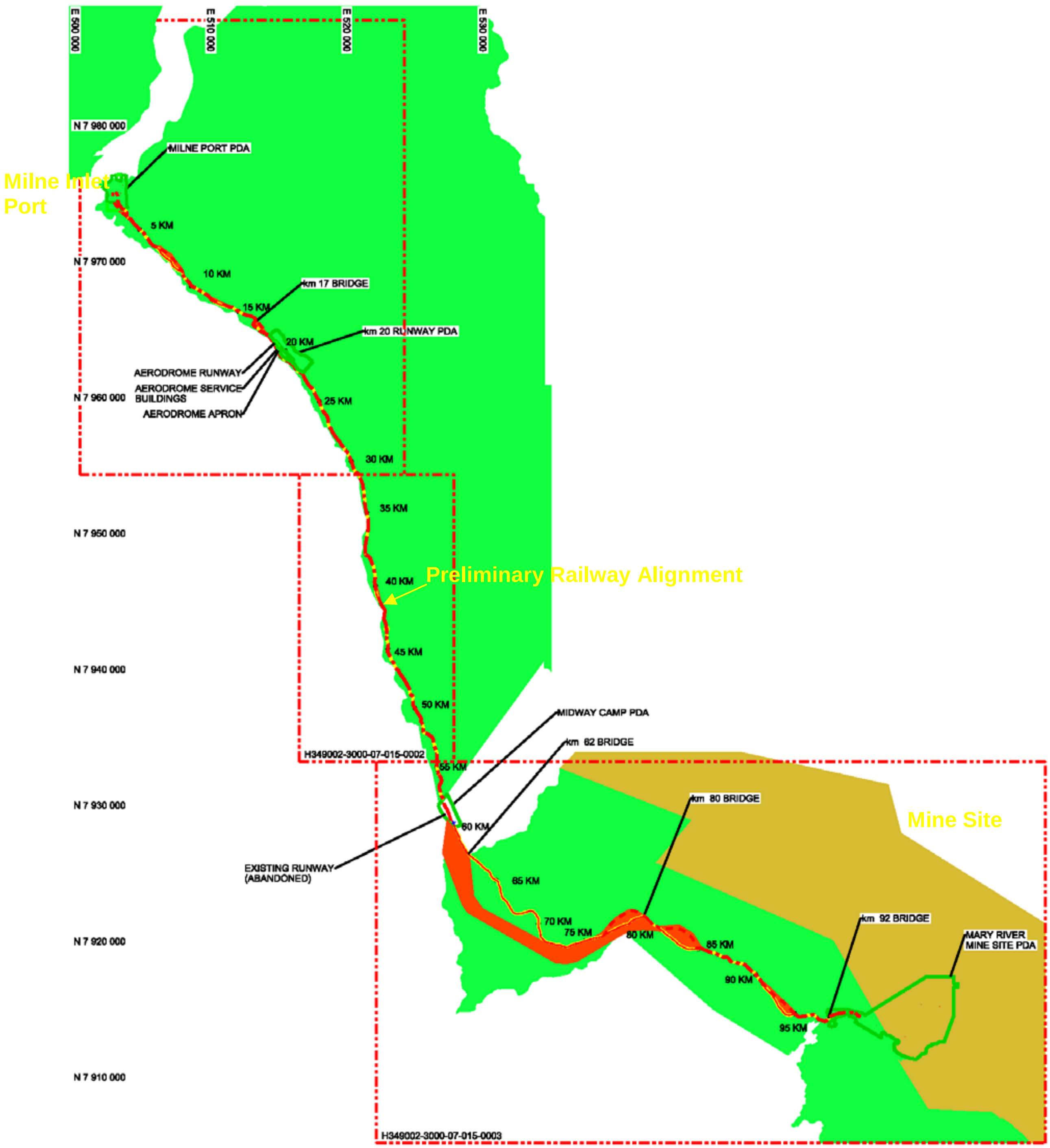


Figure 2-1: Chainage along Tote Road Alignment (Used for reference of the proposed rail line, the sketch was developed based on Hatch Drawing H349002-3000-07-015-0001)

3. Reference Document

A site specific geological investigation has not been undertaken at this time for the proposed rail line between Milne Inlet and Mine site. The preliminary geotechnical recommendation for the railway embankment provided in this report are based on the following information and investigations:

- AMEC Earth & Environmental, 2010. Geotechnical, Geochemical and Quarry Sourcing Investigation (Draft). Project No. TC101510. Dec. 2010.
- Knight Piesold Consulting Ltd. (KP) report “Mine Site Infrastructure, Pit Overburden and Waste Dumps – 2006 Site Investigation Summary Report”, (Ref. No. NB102-00181/3-2), February 28, 2007.
- Knight Piesold Consulting Ltd. (KP) report “Mine Site Infrastructure, Pit Overburden and Waste Dumps – 2007 Site Investigations and Foundations Recommendations Summary Report”, (Ref. No. NB102-00181/8-2), December 14, 2007.
- Knight Piesold Consulting Ltd. (KP) boreholes (PMT-001, PMBC-002, PMPL-002, PMTF-001, PMSD-001 and BS-001) advanced at Milne Inlet in May 2007.
- EBA Engineering Consultants Ltd. (EBA) memo “Foundation Recommendations, Mary River Mine Site Infrastructure”, (File: E14101009.003), September 9, 2010.
- Hatch Ltd. H337697-0000-15-124-0004.Geotechnical Data Report –Infrastructure. April 5, 2012.
- Hatch Ltd. H349000-1000-15-122-0001. Geotechnical Design Criteria. Aug 08, 2013.
- Little, E.C., Holme, P.J., and Kerr, D.E., 2013. Surficial Geology Icebound Lakes (Southwest) Baffin Island, Nunavut, Geological Survey of Canada Map 74 (preliminary), scale 1:100,000.
- Dyke, A.S. 2000, Surficial Geology Phillips Creek, Baffin Island, Nunavut, Geological Survey of Canada, Map 1961A, scale 1:250,000.
- Jackson, G.D., Morgan, W.C. and Davidson, A., 1975. Geology Icebound Lake District of Franklin, Geological Survey of Canada Map 1451A, scale 1:250,000
- Blackadar, R.G. and Davison, W.L., 1968, Geology Phillips Creek District of Franklin, Baffin Island, Geological Survey of Canada Map 1239A, scale 1:253,440.

4. Regional Geology

The proposed railway alignment in preliminary design stage generally follows the existing Tote road. Regional geologic mapping is available for the entire route of Tote Road (i.e. Scott and de Kemp, 1998), which can be used for railway preliminary design. Summarizing:

- The first 10± km of the Tote Road from Milne Inlet passes through either Precambrian terrain or glacial fluvial sand and gravel terraces. The Precambrian terrain is situated between 100 to 500 m west of the road (approximate), which mainly traverses the sand and gravel terraces.
- The middle 73 km of the road travels across relatively flat lying Paleozoic rocks (Limestone and Dolomitic Limestone Units). The Limestone and Dolostone units have been eroded by glaciations forming Mesa landforms, which locally rise 50 to 100m above the Tote Road level. The Limestone units are locally exposed at the Mesa ridges and elsewhere are typically overlain by glacial till or moraine. The till is generally fine grained comprising predominantly silt and sand whereas the moraine is sandy with embedded relic glacial ice; The thickness varies from a few meters to over 10 m.
- The final 14 km of the road to the Mary River mine site traverses a series of glacial lacustrine (sand and silty sand) and glacial fluvial plains, terraces and eskers, which are situated along the boundary between the Precambrian terrain to the north and Limestone units to the south.

The detailed regional geology was described in AMEC 2010 geotechnical Investigation Report (AMEC TC101510, 2010).

5. Site Geotechnical Summary

Based on the existing geotechnical investigation data along the Tote Road, alternating deposits of cohesionless soils consisting of sand, sand and gravel, gravel, cobbles and boulders were generally encountered. Bedrock was encountered at three of the bridge locations at depths varying between about 6 m and 14 m below existing ground surface. Typically gneiss bedrock was encountered near Milne Inlet and gneiss, schist and carbonate bedrock were encountered near Mary River Site.

Layers of cobbles and boulders were encountered at Milne Inlet and along the Tote Road. Based on the limited geotechnical investigations, cobbles and boulders were noted to be present within the majority of the cohesionless deposits at various depths with variable thickness.

The entire Tote Road site is underlain by permafrost and the estimated annual depth of thaw ranges from 2 m to 5 m and varies significantly.

6. Railway Embankment Recommendation

6.1 Ground Ice Definition

Ground ice refers to all kinds of ice formed in permafrost. The Unified Soil Classification System designates the ground frozen soil as “ice”, where the ground ice thickness is greater than 25 mm (1 inch).

“Massive ground ice”, however, is a comprehensive term, which refers to large masses of ground ice, including ice wedges, buried ice, and predominantly horizontal beds of segregated ice (Glossary of permafrost 1988). In the literature (Roujanski et. al. 2010), ice beds with a thickness in excess of 0.3 m are referred to as “massive ice” or “ground ice”. Whereas, layers of ice less than 0.3 m in thickness are termed “ice lenses”.

It should be noted that comments cannot be made regarding the presence of ground ice for areas where boreholes do not exist along the Tote road or the proposed railway. Generally, however, the following assumptions have been made to support the development of a pre-feasibility level rail route and preliminary embankment designs.

- All embankments should be constructed using compacted rock fill overlain by crusher run granular sub-ballast and ballast layers
- Based on the performance of the Tote Road, it has been decided that embankments will not be designed to maintain the ground in a frozen state. Thaw-freeze ground movements, if any, will be accommodated by maintenance and re-ballasting.
- To the extent possible, the rail alignment should avoid cuts in soil permafrost. However, if such cuts are required, then the subgrade should be insulated to avoid extending the thaw depth significantly below the historic maximum thaw depth (i.e. do not thaw previously unthawed permafrost). The insulation requirements for this purpose have been estimated for the current study phase.
- Based on site reconnaissance, there are numerous bedrock outcrops in the Precambrian terrain. Although frozen, the Precambrian rock is not expected to be susceptible to large thaw-induced settlement. As such, cuts are permissible in Precambrian terrain in order to produce rock fill for construction and to found the embankments on bedrock.
- In the Paleozoic terrain (i.e. Cha 10+000 to 83+000), there are several limestone beds, which are either exposed or covered by a thin veneer of till. Thick massive limestone beds are visible as large mesa structures; whereas, the thinner beds are present as more subtle ridges or ledges in the terrain (i.e. where the nose of these beds are exposed or within a meter of the ground surface). Because the limestone beds are relatively flat (i.e. sub-horizontal), there is an opportunity to route the railway along the smaller mesa structures or ledges to de-risk the railway. Where this can be done, it is considered feasible to make cuts into the ledges to found the embankments on limestone bedrock and produce rock fill for embankment construction.

6.2 Thaw Period

The thaw period corresponds to the period in which the foundation is not frozen. In this design, it is assumed that the railway foundation (generally along tote road) is frozen for eight months of the year. Therefore, the thaw period is assumed to be four months during each year.

Table 6–1: Preliminary Railway Embankment Recommendation

Embankment Section	Ground Frost/Thaw Susceptibility	Ground Ice Content	Classification	Thaw Settlement Estimate (mm)	Typical Section
Section I	Granitic Rock; Non Susceptible	None expected	Bedrock	Insignificant	Figure 6-1
Section II	Limestone Rock; Non Susceptible	None expected	Bedrock	Insignificant	Figure 6-2
Section III (700 mm)	Non Susceptible	Non to low	Segregated ice is not visible by eye[1]	<20	Figure 6-3
	Potentially Susceptible	Low to Mediate	Segregated ice is visible by eye, less than 25mm (1") in thickness[1]	20-100	
	Moderately Susceptible	Mediate to High	Ice greater than 25mm (1") thickness[1]	100-300	
Section III (1500 mm)	Highly Susceptible	Very High	Ice greater than 0.3m [2]	>300	Figure 6-3

Notes:[1]- Classification is based on Unified Soil Classification System of Frozen Soils; [2]- Based on Roujanski et. al. (2010).

6.3 Typical Railway Embankment Section

The geometry and configuration of the preliminary railway embankment depends on the condition of the foundation soil or rock considering ground frost and thaw susceptibility along the railway routine. The recommended types of embankment sections are summarized in Table 6–1 and discussed below.

6.3.1 Railway Embankment-Section I – Cuts in Precambrian Rock

Figure 6-1 shows the typical Cross Section I of the railway embankment. Embankment Section I can be utilized where the railway is re-routed through the Precambrian terrain in order to found the embankments on rock. This is expected to be feasible between approximately Cha 0+000 and 10+000, 82+000 and 85+000 and 95+000 and 105+000. Section I consists of:

- A layer of sub-ballast material (i.e. crusher run granular material) to level the blasted bedrock. The thickness is expected to vary because the blasting is expected to produce an irregular surface. The minimum leveling layer thickness is 150mm.
- A ballast layer (Type 25) placed on top of the Type 26 leveling material. The detail design of ballast and sub-ballast layer should follow the standard railway drawing.
- The bedrock is expected to be massive; and as, such slopes of 8V:1H should be feasible with benches at 5m vertical intervals.
- There should be a 2000 mm off-set between the edge of the railway embankment and the toe of the rock slope to collect debris. Ideally, this zone should be sloped toward culverts to allow cross-drainage.

- Embankment Section 1 is recommended for the railway on bedrock in the Precambrian terrains.

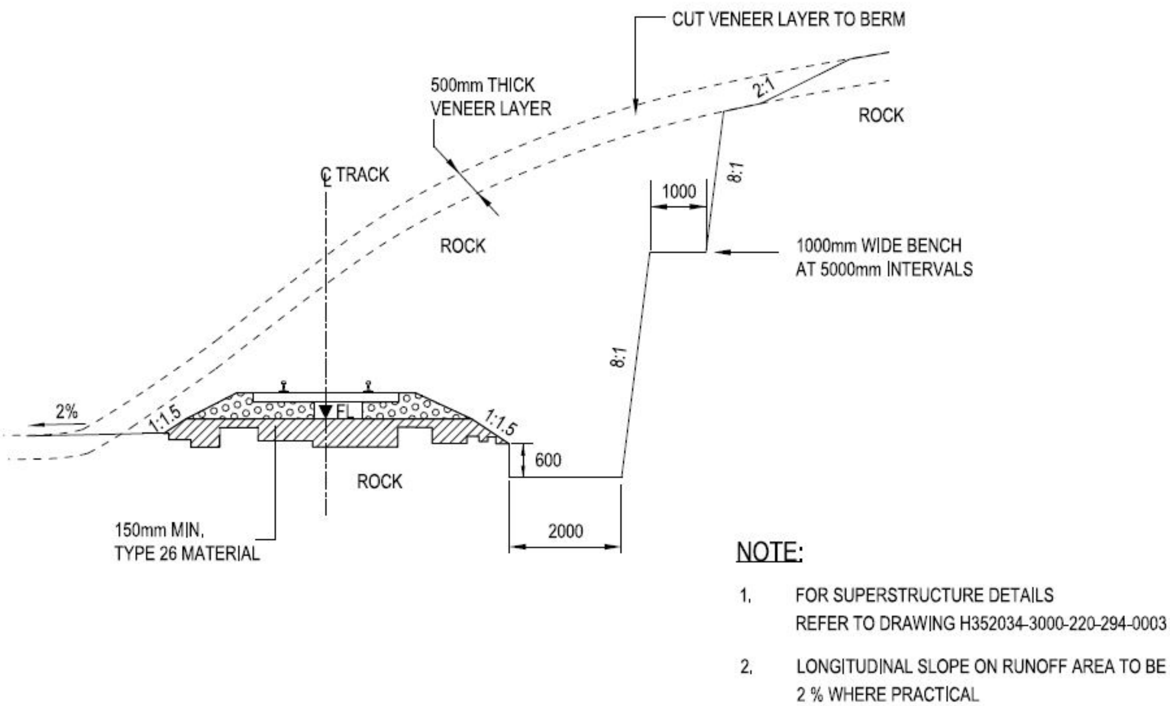


Figure 6-1: Typical Cross Section of Railway Embankment – Section I

6.3.2 Railway Embankment-Section II – Cuts in Limestone

Section II is proposed for the railway deviation between Cha 60+000 and 75+000 where the alignment can be situated to follow shallow or outcropping limestone beds, which show as small mesas or ledges in the terrain.

As shown in Figure 6-2, this type of embankment section consists of:

- A layer of sub-ballast material (i.e. crusher run granular material) to level the blasted bedrock. The thickness is expected to vary because blasting is expected to produce an irregular surface. The minimum leveling layer thickness is 150mm.
- Ballast material (Type 25) placed on top of the Type 26 leveling material. The detail design of ballast and sub-ballast layer should follow the standard railway drawing.
- The bedrock is expected to be bedded and the depth of cut should be predominantly less than 5m. In most areas, the rock should remain stable if cut at 8H:1V.
- There should be a 2000 mm off-set between the edge of the railway embankment and the toe of the rock slope to collect debris. Ideally, this zone should be sloped toward culverts to allow cross-drainage.
- The soil veneer is expected to be less than a meter thick; but locally it could be thicker. The soil will need to be stripped and stored in quarries or used to construct diversion berms to route run-off toward creek and stream beds.

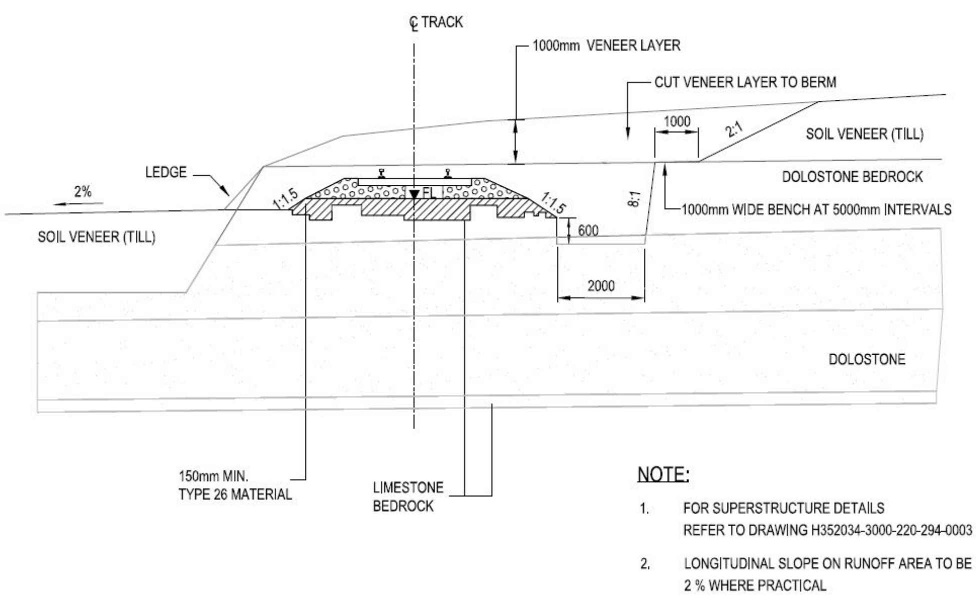


Figure 6-2: Typical Cross Section of Railway Embankment – Section II

6.3.3 *Railway Embankment Section III – Embankments on Permafrost Soil*

Section III is proposed for the railway on undisturbed (uncut) permafrost soil. As shown in Figure 6-3, this type of embankment consists of:

- A layer of compacted run-of-quarry rockfill (Type 12) founded directly on the undisturbed permafrost. A non-woven geotextile should be placed over the permafrost soil where the railway traverses ice-rich and fine-grained soils.
- A minimum 150mm thick sub-ballast layer (Type 26) on the Type 12 fill. The Type 26 material should be used to choke the rock fill embankment prior to placing the sub-ballast layer. Choking refers to using bulldozers, tired trucks and vibratory rollers to force the finer Type 26 material into the open pore space of the Type 12 rock fill until a stable base is achieved.
- The combined minimum thickness of the Type 12 and Type 26 materials should be 700mm for embankments on non-, potentially- and moderately - thaw susceptible permafrost. It should be increased to 1500mm on ice-rich soils or highly thaw-susceptible soils. Due to the sloping and undulating terrain, it is expected that the minimum thickness will occur only rarely at high-points in the sub-grade along the rail alignment. These high points should be assessed during detailed design.
- A ballast layer (Type 25) placed on top of the Type 26 leveling material. The detail design of ballast should follow the standard railway drawing.
- Type 12 fill is expected to comprise either run-of-quarry granitic blast rock or limestone blast rock. A side slope gradient of 1.5H:1V is considered suitable for estimating the fill quantities.
- The Type 25 and Type 26 materials should be placed with a 2H:1V side-slope gradient.
- A ditch or diversion berm can be used to manage run-off. The attached figure shows a ditch.

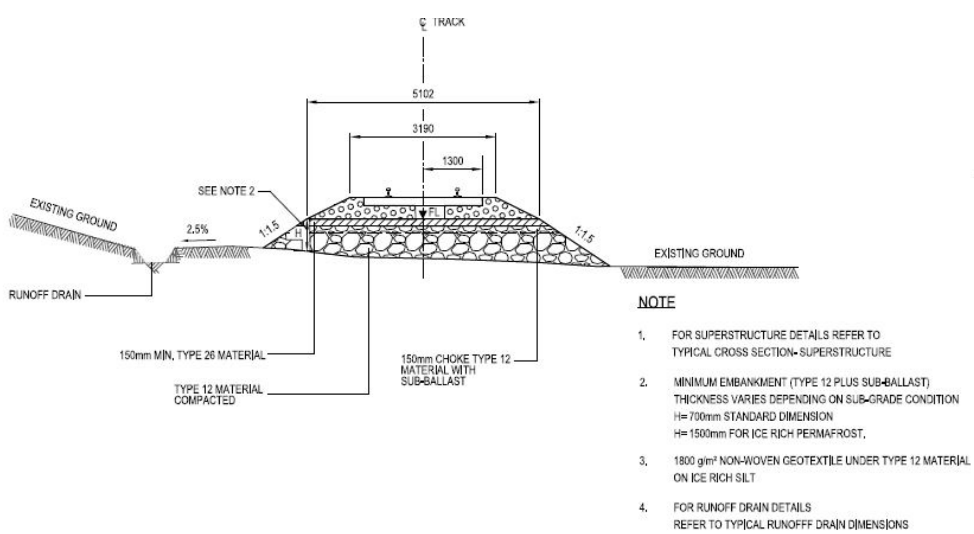


Figure 6-3: Typical Cross Section Railway Embankment on Soil – Section III

6.3.4 Embankment Section IV – Cuts in Permafrost Soil

Lastly, Section IV is proposed for cuts in permafrost soil. Such cuts should be avoided to the extent possible; However, based on the behaviour of cuts made for the Tote Road, occasional cuts in permafrost soil can be managed using the cross-section illustrated in Figure 6-4. Boreholes should be advanced at cut locations to determine if ground ice is present and thermal modelling should be used for design and to assess the risk.

This type of embankment consists of:

- A 1500mm layer of compacted run-of-quarry rock fill (Type 12) underlain by a zone of insulation materials. For estimating quantities, the insulation can be assumed to comprise either an additional 1500mm thick layer of Type 12 fill underlain by non-geotextile (1000 g/m^2) or 100mm thick rigid expanded polystyrene insulation board covered by non-woven geotextile (1000 g/m^2).
- A minimum 150mm thick sub-ballast layer (Type 26) on the Type 12 fill. The Type 26 material should be used to choke the rock fill embankment prior to placing the sub-ballast layer. Choking refers to using bulldozers, tired trucks and vibratory rollers to force the finer Type 26 material into the open pore space of the Type 12 rock fill until a stable base is achieved.
- A ballast layer (Type 25) placed on top of the Type 26 leveling material. The detail design of ballast should follow the standard railway drawing.
- Type 12 fill is expected to comprise either run-of-quarry granitic blast rock or limestone blast rock. A side slope gradient of 1.5H:1V is considered suitable for estimating the fill quantities.
- The Type 25 and Type 26 materials should be placed with a 2H:1V side-slope gradient.
- The cut side-slopes should be covered with a 500mm thick layer of Type 12 material to retain the soil as it thaws.

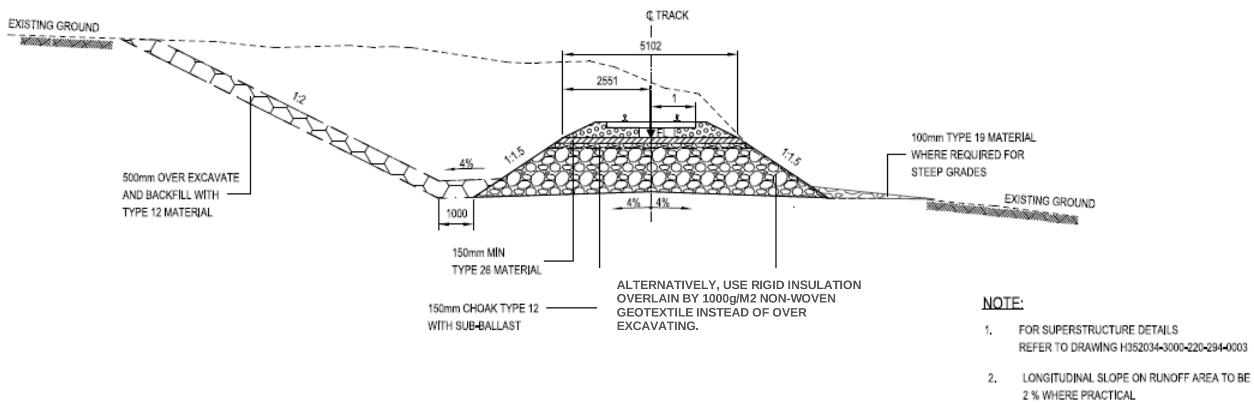


Figure 6-4: Typical Cross Section Railway Embankment in Soil Cut – Section IV

6.3.5 Use of Insulation Block

The thickness of railway embankment can be reduced with the installation of rigid type high strength polystyrene blocks or panels. The insulation would be most effective if placed as close to the surface of the embankment (i.e. under the sub-ballast) as possible, but the depth of cover above the insulation has to be thick enough to prevent crushing of the insulation. Thermal analysis has to be carried out to determine the optimum location and layout of the insulation within the embankment and the thickness of insulation to be adopted. Stability analysis will then be performed to ensure that the stability of the embankment will not be affected by the installation of insulation. If insulation is designed and installed at the right place, the thickness as well as thaw settlement of the embankment could be reduced.

7. Embankment Design along Railway Alignment

7.1 Subgrade Properties

As part of the Tote Road upgrade project in 2007/2008, Knight Piesold identified four categories of thaw susceptibility to delineate the subgrade conditions along the Tote Road. It is assumed that the subgrade conditions for the proposed railway will be similar to that of the Tote Road, except where the alignment is moved away from the Tote road to situate the railway on rock or meet railway grade requirements. The subgrade properties along the railway should be updated based on the site specific geotechnical investigation program.

The following foundation categories were described by Knight Piesold (ref. Road Upgrade Design Summary NB-102-0018/10-1) and are used herein:

7.1.1 Type 1 - Non Susceptible

This foundation condition is expected to require minimal road or rail embankment. Approximately 27.5 km of the road alignment was identified with this foundation condition.

7.1.2 Type 2 - Potentially Susceptible

Based on the existing geotechnical data, approximately 37.5 km of the road alignment was identified with this foundation condition.

7.1.3 Type 3 - Moderately Susceptible

Based on the existing geotechnical data, approximately 12.5 km of the road alignment was identified with this foundation condition.

7.1.4 Type 4: Highly Susceptible

Based on the existing geotechnical data, approximately 27.5 km of the road alignment was identified with this foundation condition.

For design purposes, Embankment Section III (700 mm) can be used on the Type 1, 2 and 3 subgrades. It is assumed that thaw-induced settlements will be small and can managed by re-ballasting the rail to accommodate the settlement.

Embankment Section III (1500 mm) can be used on Type 4 soils. The objective is to provide sufficient fill thickness to insulate the ground and avoid thawing to depths greater than that historically experienced by the soil.

7.2 Recommendations

Table 7–1 summarizes the recommended embankment types to be applied along the railway alignment during the pre-feasibility study. As noted above the Tote Road chainage has been used for reference purposes The recommended embankments are listed in the right-hand side column of Table 7–1. This column also includes recommendations to re-align the railway in order to found the embankments on bedrock.

The following summarizes the likely length of each embankment type if the railway were to follow the Tote road alignment:

- 75± km of railway will be constructed on non thaw-susceptible and potentially and moderately thaw-susceptible ground; Embankment Section III can be used. The minimum thickness of the combined Zone 12 and 26 materials should be 700 mm.
- 30± km railway will be founded on highly thaw-susceptible ground. Embankment Section III can be used; The minimum combined thickness of the Zone 12 and 26 materials should be increased to 1500mm.

Taking into account the deviation between Ch 60+000 and 82+000 and the re-alignments recommended in Table 7–1, the following approximate embankment types are expected:

- 20± km of Embankment Section I between Ch 0+000 and Ch 8+000, Ch 83+00 and Ch 85+000 and Ch 95+000 to Ch 105+000.
- 8± km of rail Embankment Section II between Ch66+000 and Ch74+000.
- 52± km of Embankment Section III (700 mm) – various locations.
- 25± km of Embankment Section III (1500 mm) – various locations.

It should be noted that the preceding quantities are approximate. The quantities should be re-estimated after re-aligning the railway and after each time the alignment is revised or optimized based on site specific geotechnical data using the CAD model.

Table 7–1: Summary of Type Railway Embankment along the Alignment

Starting Cha (km)	End Cha (km)	Frost/Thaw Susceptibility (km)[1]	Distance (km)	Recommended Embankment Section
0.0	10.0	Non Susceptible	10	Apply Section III (700mm) on soil; or apply Section I on Precambrian terrain
10.0	12.5	Potentially Susceptible	2.5	Apply Section III (700mm)
12.5	15.0	Highly Susceptible	2.5	Apply Section III (1500mm)
15.0	17.5	Potentially Susceptible	2.5	Apply Section III (700mm)
17.5	22.5	Non Susceptible	5	Apply Section III (700mm)
22.5	30.0	Potentially Susceptible	7.5	Apply Section III (700mm)
30.0	42.5	Highly Susceptible	12.5	Apply Section III (1500mm)
42.5	52.5	Potentially Susceptible	10	Apply Section III (700mm)
52.5	55.0	Moderately Susceptible	2.5	Apply Section III (700mm)
55.0	57.5	Highly Susceptible	2.5	Apply Section III (1500mm)
57.5	60.0	Moderately Susceptible	2.5	Apply Section III (700mm)
62.5	72.5	Highly Susceptible	10.0	Apply Section III (1500mm); Or realign onto Limestone Ledges and Apply Section II
72.5	80.00	Moderately Susceptible	7.5	Apply Section III (700mm)
80.0	95.0	Potentially Susceptible	15	Apply Section III (700mm); or Re-align onto Precambrian Terrain and apply Section I
95.0	105.0	Non Susceptible	10	Apply Section III (700mm); or

Starting Cha (km)	End Cha (km)	Frost/Thaw Susceptibility (km)[1]	Distance (km)	Recommended Embankment Section
				Re-align onto Precambrian Terrain and apply Section I

Note: [1-] The road foundation classifications are approximate. Foundations Classifications were based on report by Knight Piesold.

7.3 Properties of Embankment Fill Materials

The following Expansion Study – Stage II material gradations are recommended for the railway embankment fill. 2

Table 7–2: Type 12 Fill - Run of Quarry

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
1000	100
600	95 - 100
300	50 - 100
150	0 - 80
19	0 - 30
4.75	0 - 10

Table 7–3: Type 25 Fill – Ballast

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
37.5	100
25.4	70 – 100
19	50 – 80
12.7	10 - 40
9.5	0 – 15
4.75	<1

Table 7–4: Type 26 Fill – Sub-ballast

Nominal Sieve Size (mm)	Percentage Finer Than (By Weight)
50	100
13.2	60 – 80
4.75	20 – 45
1.18	0 – 15
0.075	0– 5

7.4 Drainage Consideration

Proper drainage design should be addressed in civil design along the railway alignment to prevent blocking of run-off resulting in ponding adjacent to the embankment fill.

8. References

1) Corps of Engineers, U.S. Army. Description and Classification of Frozen Soils. August 1966.

2) United States Department of the Interior, 1977, Design of Surface Mine Haulage Roads - A Manual.

3) Natural Resources Canada, 1995, Quantity-Distance Principles, first printing.

4) Tannant and Regensburg, 2001, Guidelines for Mine Haul road Design, University of Alberta.

5) Andersland, B.A., Ladani, B., 2004, “Frozen Ground Engineering”, Second Edition, ASCE, John Wiley and Sons, Inc.

6) International Permafrost Association, 2005, “Glossary of Permafrost”, The Arctic Institute of North America, The University of Calgary.

7) Canadian Geotechnical Society, 2006, “Canadian Foundation Engineering Manual”, Forth Edition.

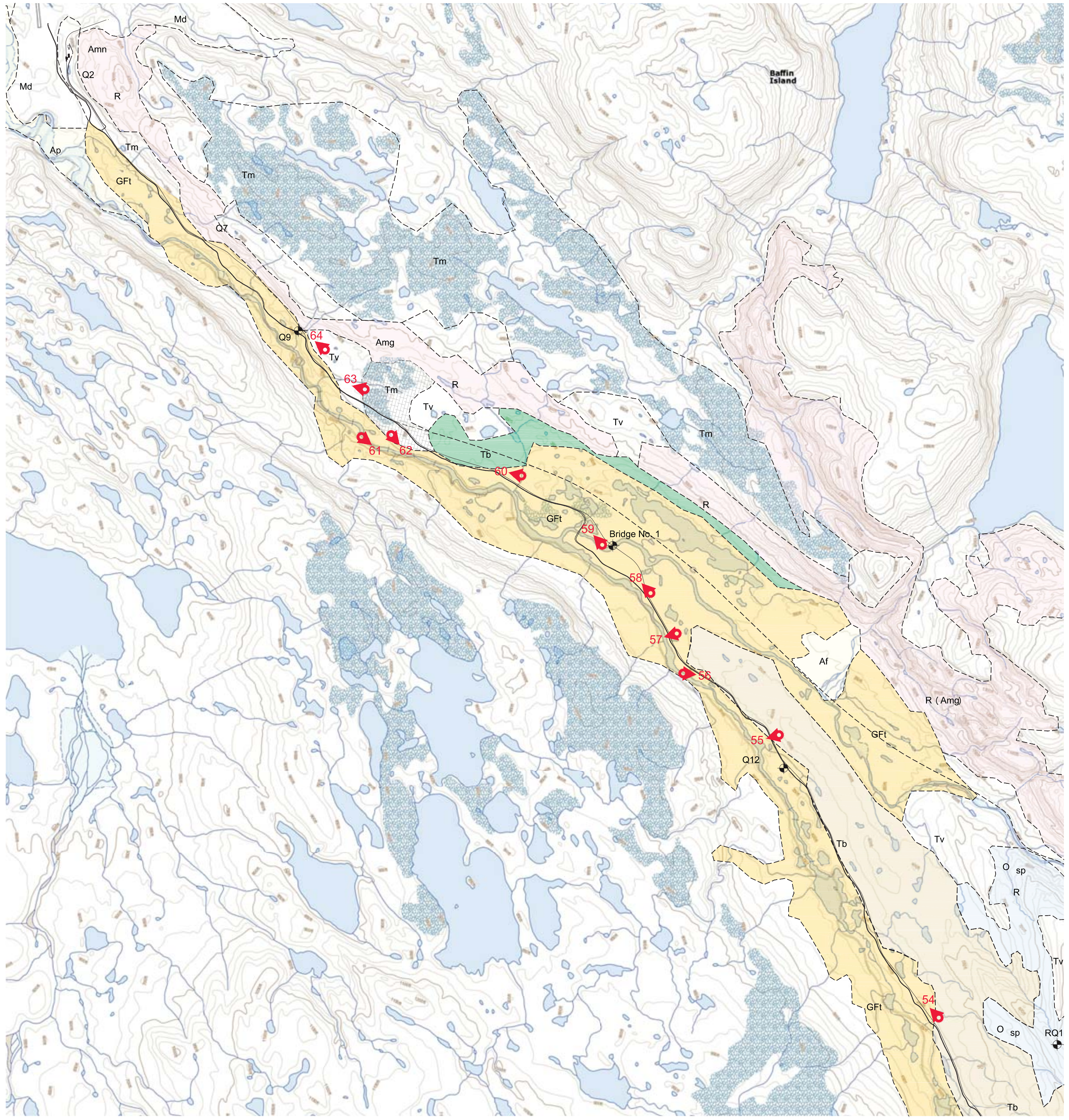
8) Das, Braja, 2007, “Principles of Foundation Engineering”, Sixth Edition, Thomson.

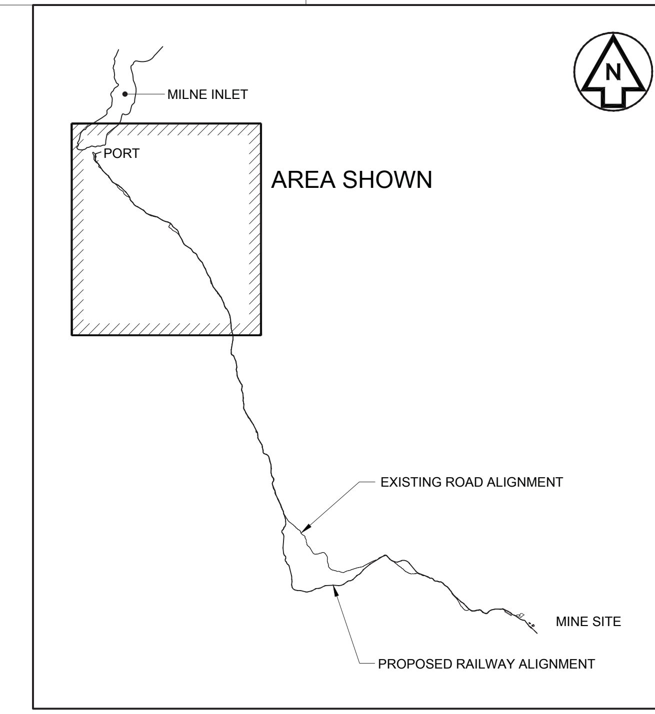
9) Roujanski V.E., Jones K.W., Haley J., Hawton K., Fitzpatrick C., 2010, “Some Permafrost-Related Terrain Features and Associated Design Considerations along the Proposed Southern Rail Alignment, Mary River Project, Baffin Island, Nunavut”.

Appendix A

2016 Site Investigation Plan Photos

DWG. No. H352034-1100-229-272-0001





KEY PLAN

0 10 20 30 40 50 kilometres

SCALE 1:500 000

LEGEND

55 PHOTOGRAPH LOCATION AND DIRECTION

UNIT	DESCRIPTION
R (Amg)	UNDIFFERENTIATED GNEISS AND GRANITIC ROCKS
R (Oba)	BAILLARGE FORMATION: DOLOMITIC LIMESTONE, IN PART SHALY; MINOR DOLOMITE
R (Osp)	SHIP POINT FORMATION: DOLOMITE, IN PART SILTY AND SHALY; DOLOMITIC INTRAFORMATIONAL CONGLOMERATE
R,GF	VENEERED ROCK: UNDULATING ROCK COVERED BY A DISCONTINUOUS VENEER OF GLACIAL FLUVIAL SAND AND GRAVEL. NUMEROUS OUTCROPS
Ap	ALLUVIAL PLANES: ACTIVE BRAIDED FLOODPLAINS; INCLUDES ACTIVE PROGLACIAL OUTWASH
Co	COLLUVIUM
Lb	DEEPWATER PROGLACIAL DEPOSITS: SILT AND CLAYEY SILT BLANKET, WITH FINE
SAND	WITH ICE RAFTED STONES
Mt	DELTAIC SEDIMENTS: CLAY SILT, SAND AND GRAVEL
Mr	BEACH SEDIMENTS: SAND
GFt,p,f	GLACIOFLUVIAL OUTWASH: TERRACES (t), PLANES (p) AND FANS (f)
GFc	GLACIOFLUVIAL ICE CONTACT DEPOSIT: ESKER
GL	GLACIOFLUVIAL DEPOSIT: CONTAINS MIXED TILL, SAND, AND SILT.
Tb	TILL BLANKET: 2-10m THICK FORMING AN UNDULATING BLACKET WITH DRUMLINS AND BIBBED MORAINES IN PLACES
Tv	TILL VENEE: 0.5-2m THICK; DISCONTINUOUSR
Tm	GLACIAL END MORAINE: 5-60m HIGH, COMPOSED OF OR MANTLED BY TILL, EXTENSIVELY KETTLED IN PLACES; PLARE GEATURES MAINLY CORED BY DEBRIS-RICH RELICT GLACIER ICE

0 1 2 3 4 5 KILOMETRES

SCALE 1:50 000 (B1 SHEET)

HATCH

Baffinland

DRAWING No.	DRAWING TITLE
REFERENCE DRAWINGS	

NAME

SIGNATURE

ENG REG NUMBER

REVISION DATE

ORIGINAL DATE

REG. PROFESSIONAL

No.	DESCRIPTION	BY	CHK'D	DATE
REVISIONS				

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	N. DONNELLY	NR	
DESIGNER	U. KHAN	NR	
CHECKER			
DESIGN COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

BAFFINLAND EXPANSION 12 MTPA MINE OPTION
PRE FEASIBILITY STUDY

2016 SITE INVESTIGATION PLAN
1 OF 4

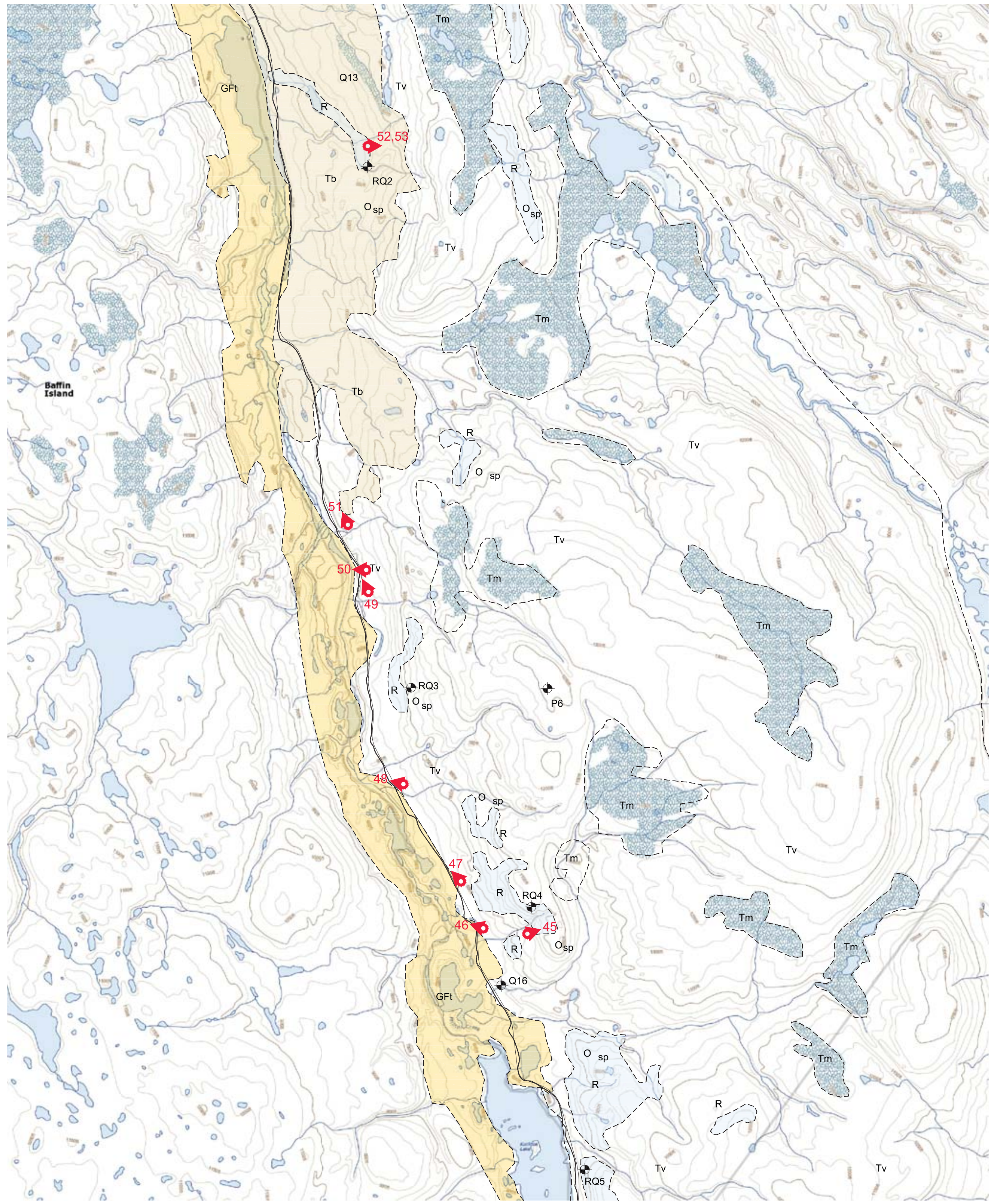
SCALE AS SHOWN OR AS NOTED

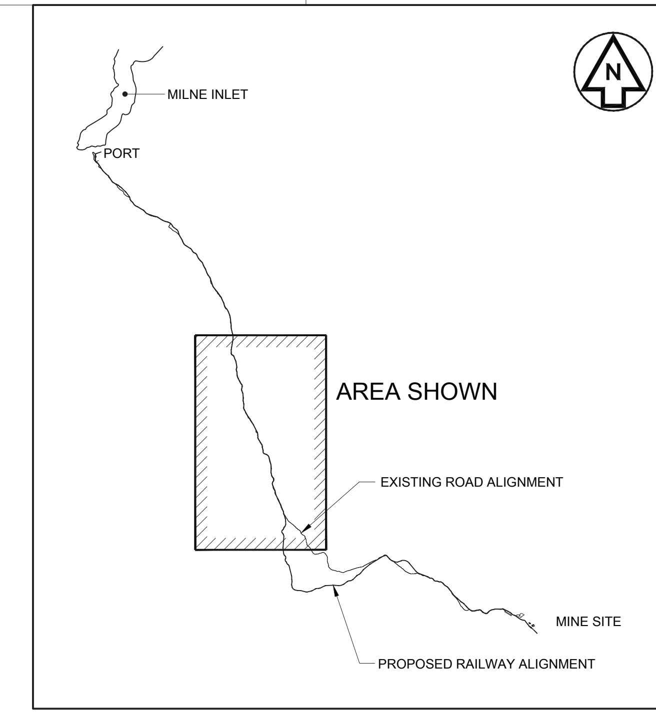
DWG. No. Geotech Photo Locations

REV A

SHEET SIZE: D

DWG. No.
H352034-1100-229-272-0002





KEY PLAN

0 10 20 30 40 50 kilometres

SCALE 1:500 000

LEGEND

55 PHOTOGRAPH LOCATION AND DIRECTION

UNIT	DESCRIPTION
R (Amg)	UNDIFFERENTIATED GNEISS AND GRANITIC ROCKS
R (Oba)	BAILLARGE FORMATION: DOLOMITIC LIMESTONE, IN PART SHALY; MINOR DOLOMITE
R (Osp)	SHIP POINT FORMATION: DOLOMITE, IN PART SILTY AND SHALY; DOLOMITIC INTRAFORMATIONAL CONGLOMERATE
R,GF	VENEERED ROCK: UNDULATING ROCK COVERED BY A DISCONTINUOUS VENEER OF GLACIAL FLUVIAL SAND AND GRAVEL. NUMEROUS OUTCROPS
Ap	ALLUVIAL PLANES: ACTIVE BRAIDED FLOODPLAINS; INCLUDES ACTIVE PROGLACIAL OUTWASH
Co	COLLUVIUM
Lb	DEEPWATER PROGLACIAL DEPOSITS: SILT AND CLAYEY SILT BLANKET, WITH FINE
SAND	WITH ICE RAFTED STONES
Mt	DELTAIC SEDIMENTS: CLAY SILT, SAND AND GRAVEL
Mr	BEACH SEDIMENTS: SAND
GFt,p,f	GLACIOFLUVIAL OUTWASH: TERRACES (t), PLANES (p) AND FANS (f)
GFc	GLACIOFLUVIAL ICE CONTACT DEPOSIT: ESKER
GL	GLACIOFLUVIAL DEPOSIT: CONTAINS MIXED TILL, SAND, AND SILT.
Tb	TILL BLANKET: 2-10m THICK FORMING AN UNDULATING BLACKET WITH DRUMLINS AND BIBBED MORAINES IN PLACES
Tv	TILL VENEE: 0.5-2m THICK; DISCONTINUOUSR
Tm	GLACIAL END MORAINE: 5-60m HIGH, COMPOSED OF OR MANTLED BY TILL, EXTENSIVELY KETTLED IN PLACES; PLARE GEATURES MAINLY CORED BY DEBRIS-RICH RELICT GLACIER ICE

0 1 2 3 4 5 KILOMETRES

SCALE 1:50 000 (B1 SHEET)

DRAWING No.	DRAWING TITLE
REFERENCE DRAWINGS	

NAME

SIGNATURE

ENG REG NUMBER

REVISION DATE

ORIGINAL DATE

REG. PROFESSIONAL

No.	DESCRIPTION	BY	CHK'D	DATE
REVISIONS				

HATCH

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	N. DONNELLY	NR	
DESIGNER	U. KHAN	NR	
CHECKER			
DESIGN COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

Baffinland

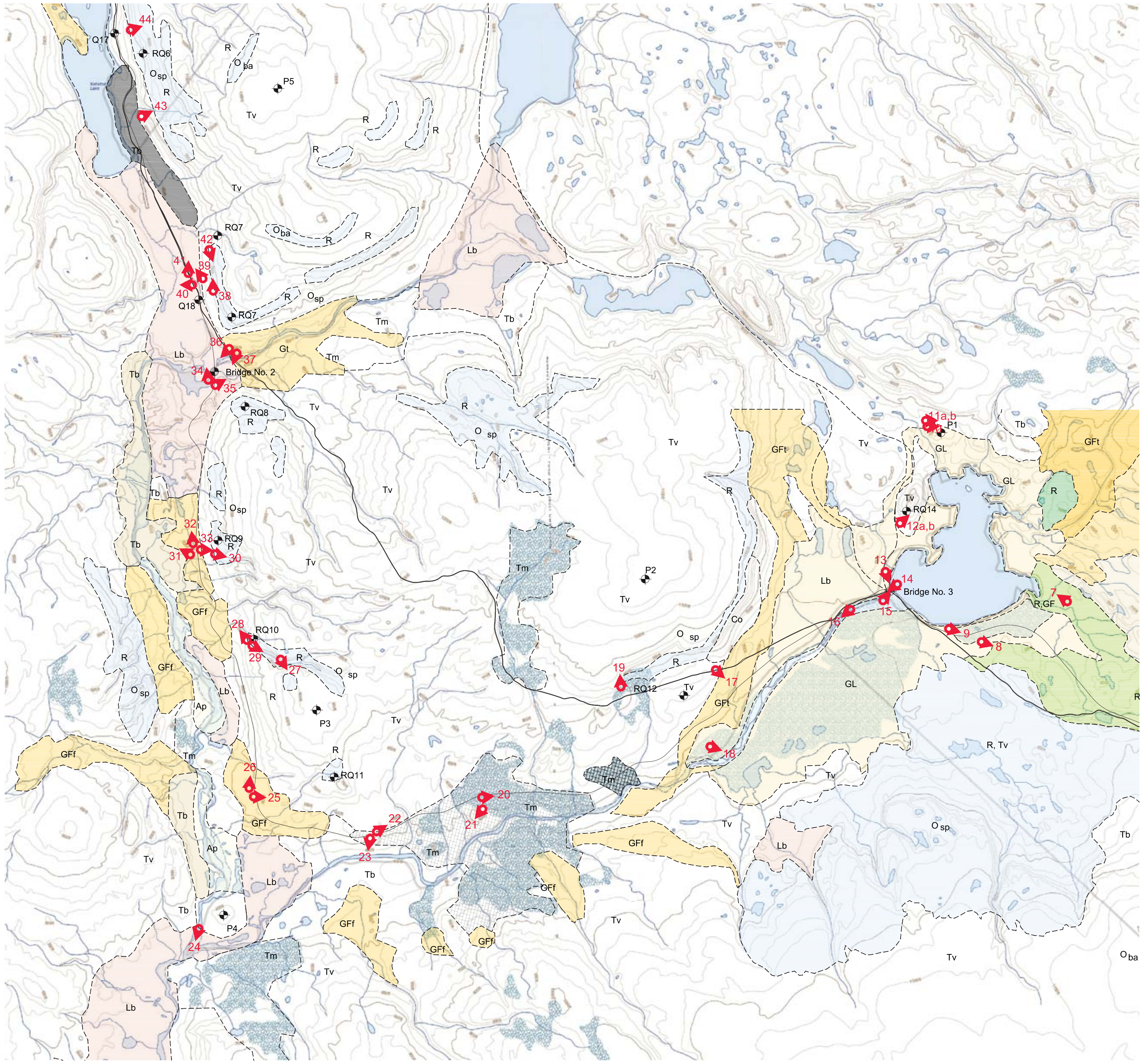
BAFFINLAND EXPANSION 12 MTPA MINE OPTION
PRE FEASIBILITY STUDY

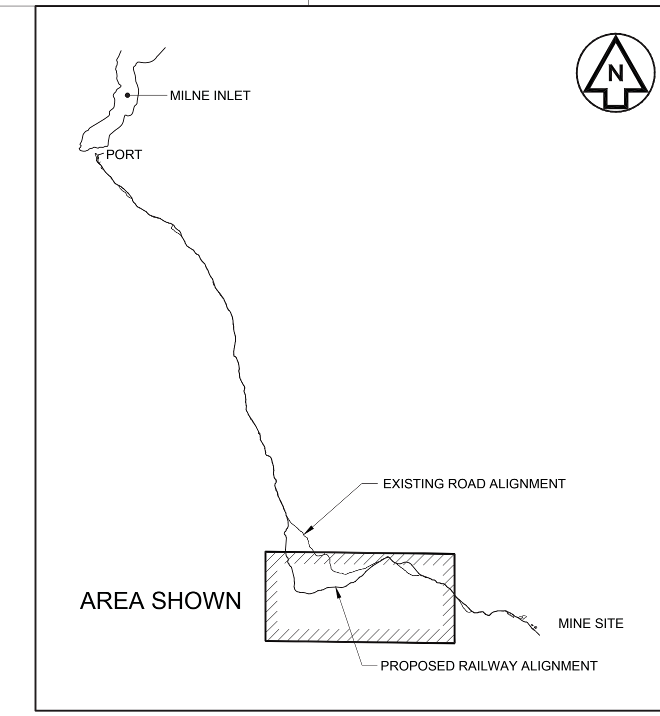
2016 SITE INVESTIGATION PLAN
2 OF 4

SCALE	DWG. No.	REV
AS SHOWN OR AS NOTED	Geotech Photo Locations	A

SHEET SIZE: D

DWG. No.
H352034-1100-229-272-0003





KEY PLAN

0 10 20 30 40 50 kilometres

SCALE 1:500 000

LEGEND

55 PHOTOGRAPH LOCATION AND DIRECTION

UNIT	DESCRIPTION
R (Amg)	UNDIFFERENTIATED GNEISS AND GRANITIC ROCKS
R (Oba)	BAILLARGE FORMATION: DOLOMITIC LIMESTONE, IN PART SHALY; MINOR DOLOMITE
R (Osp)	SHIP POINT FORMATION: DOLOMITE, IN PART SILTY AND SHALY; DOLOMITIC INTRAFORMATIONAL CONGLOMERATE
R,GF	VENEERED ROCK: UNDULATING ROCK COVERED BY A DISCONTINUOUS VENEER OF GLACIAL FLUVIAL SAND AND GRAVEL. NUMEROUS OUTCROPS
Ap	ALLUVIAL PLANES: ACTIVE BRAIDED FLOODPLAINS; INCLUDES ACTIVE PROGLACIAL OUTWASH
Co	COLLUVIUM
Lb	DEEPWATER PROGLACIAL DEPOSITS: SILT AND CLAYEY SILT BLANKET, WITH FINE
SAND	WITH ICE RAFTED STONES
Mt	DELTAIC SEDIMENTS: CLAY SILT, SAND AND GRAVEL
Mr	BEACH SEDIMENTS: SAND
GFt,p,f	GLACIOFLUVIAL OUTWASH: TERRACES (t), PLANES (p) AND FANS (f)
GFc	GLACIOFLUVIAL ICE CONTACT DEPOSIT: ESKER
GL	GLACIOFLUVIAL DEPOSIT: CONTAINS MIXED TILL, SAND, AND SILT.
Tb	TILL BLANKET: 2-10m THICK FORMING AN UNDULATING BLACKET WITH DRUMLINS AND BIBBED MORAINES IN PLACES
Tv	TILL VENEE: 0.5-2m THICK; DISCONTINUOUSR
Tm	GLACIAL END MORAINE: 5-60m HIGH, COMPOSED OF OR MANTLED BY TILL, EXTENSIVELY KETTLED IN PLACES; PLARE GEATURES MAINLY CORED BY DEBRIS-RICH RELICT GLACIER ICE

0 1 2 3 4 5 KILOMETRES

SCALE 1:50 000 (B1 SHEET)

HATCH

Baffinland

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	N. DONNELLY	NR	
DESIGNER	U. KHAN	NR	
CHECKER			
DESIGN COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

DRAWING No.	DRAWING TITLE
REFERENCE DRAWINGS	

NAME

SIGNATURE

ENG REG NUMBER

REVISION DATE

ORIGINAL DATE

REG. PROFESSIONAL

No.	DESCRIPTION	BY	CHK'D	DATE
REVISIONS				

BAFFINLAND EXPANSION 12 MTPA MINE OPTION
PRE FEASIBILITY STUDY

2016 SITE INVESTIGATION PLAN
3 OF 4

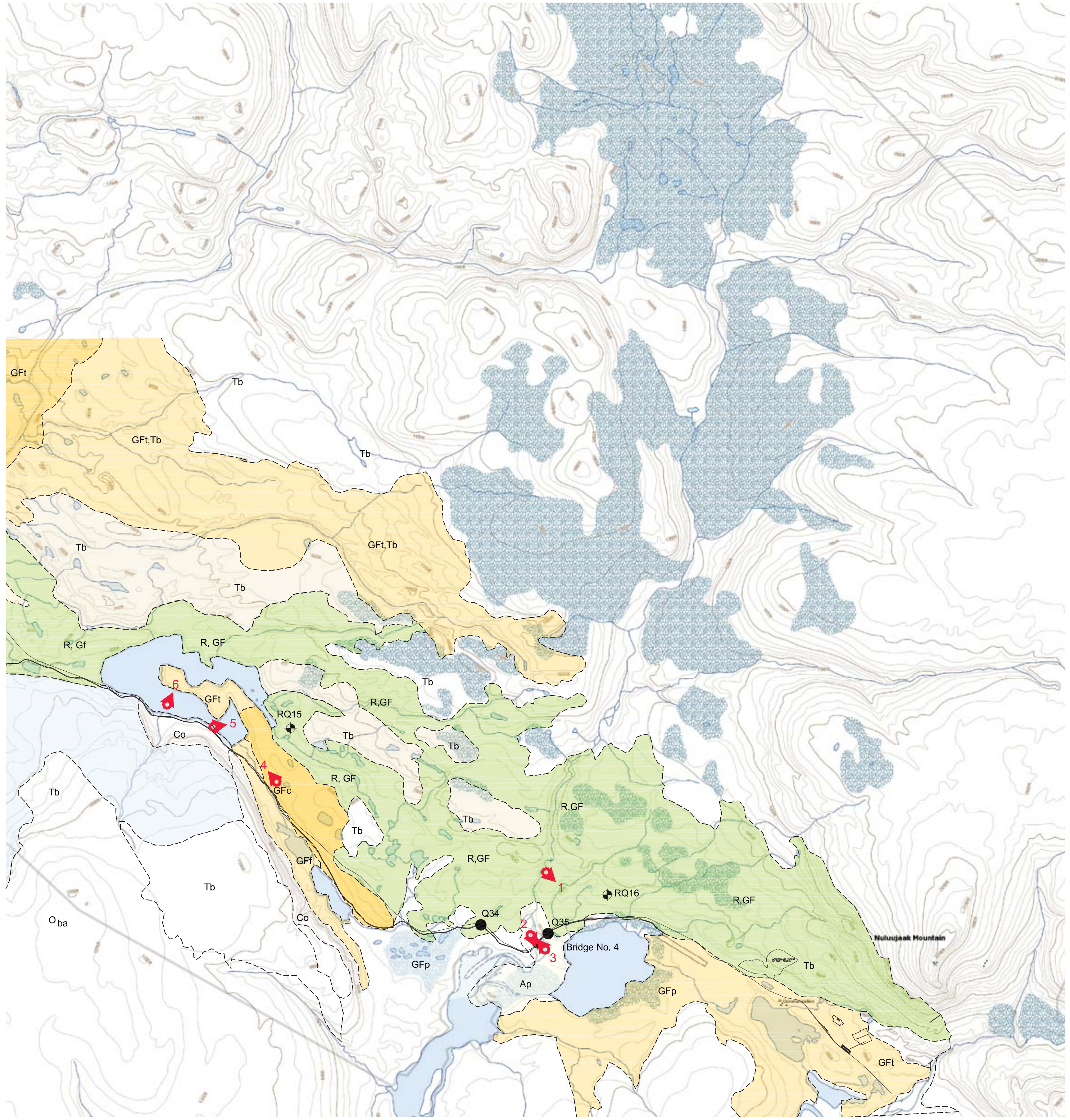
SCALE AS SHOWN OR AS NOTED

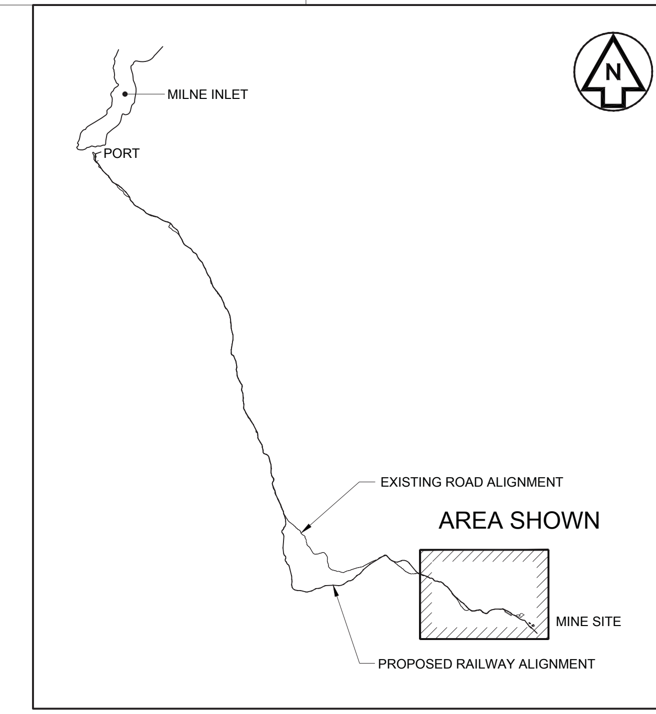
DWG. No. Geotech Photo Locations

REV A

SHEET SIZE: D

DWG. No.
H352034-1100-229-272-0004





KEY PLAN

0 10 20 30 40 50 kilometres

SCALE 1:500 000

LEGEND

55 PHOTOGRAPH LOCATION AND DIRECTION

UNIT	DESCRIPTION
R (Amg)	UNDIFFERENTIATED GNEISS AND GRANITIC ROCKS
R (Oba)	BAILLARGE FORMATION: DOLOMITIC LIMESTONE, IN PART SHALY; MINOR DOLOMITE
R (Osp)	SHIP POINT FORMATION: DOLOMITE, IN PART SILTY AND SHALY; DOLOMITIC INTRAFORMATIONAL CONGLOMERATE
R,GF	VENEERED ROCK: UNDULATING ROCK COVERED BY A DISCONTINUOUS VENEER OF GLACIAL FLUVIAL SAND AND GRAVEL. NUMEROUS OUTCROPS
Ap	ALLUVIAL PLANES: ACTIVE BRAIDED FLOODPLAINS; INCLUDES ACTIVE PROGLACIAL OUTWASH
Co	COLLUVIUM
Lb	DEEPWATER PROGLACIAL DEPOSITS: SILT AND CLAYEY SILT BLANKET, WITH FINE
SAND	WITH ICE RAFTED STONES
Mt	DELTAIC SEDIMENTS: CLAY SILT, SAND AND GRAVEL
Mr	BEACH SEDIMENTS: SAND
GFt,p,f	GLACIOFLUVIAL OUTWASH: TERRACES (t), PLANES (p) AND FANS (f)
GFc	GLACIOFLUVIAL ICE CONTACT DEPOSIT: ESKER
GL	GLACIOFLUVIAL DEPOSIT: CONTAINS MIXED TILL, SAND, AND SILT.
Tb	TILL BLANKET: 2-10m THICK FORMING AN UNDULATING BLACKET WITH DRUMLINS AND BIBBED MORAINES IN PLACES
Tv	TILL VENEE: 0.5-2m THICK; DISCONTINUOUSR
Tm	GLACIAL END MORAINE: 5-60m HIGH, COMPOSED OF OR MANTLED BY TILL, EXTENSIVELY KETTLED IN PLACES; PLARE GEATURES MAINLY CORED BY DEBRIS-RICH RELICT GLACIER ICE

0 1 2 3 4 5 KILOMETRES

SCALE 1:50 000 (B1 SHEET)

HATCH

Baffinland

DRAWING No.	DRAWING TITLE
REFERENCE DRAWINGS	

NAME
SIGNATURE
ENG REG NUMBER
REVISION DATE
ORIGINAL DATE
REG. PROFESSIONAL

No.	DESCRIPTION	BY	CHK'D	DATE
REVISIONS				

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	N. DONNELLY	NR	
DESIGNER	U. KHAN	NR	
CHECKER			
DESIGN COORD.			
RESP. ENG.			
LEAD DISC. ENG.			
ENG. MANAGER			
PROJ. MANAGER			

DRAWING APPROVAL STATUS:

BAFFINLAND EXPANSION 12 MTPA MINE OPTION
PRE FEASIBILITY STUDY

2016 SITE INVESTIGATION PLAN
4 OF 4

SCALE	DWG. No.	REV
AS SHOWN OR AS NOTED	Geotech Photo Locations	A

SHEET SIZE: D