ATTACHMENT 12

MINE AND PORT SITE GEOTECHNICAL REPORTS

ATTACHMENT 12.1

MINE SITE FACTUAL GEOTECHNICAL REPORT

Baffinland Iron Mines Corporation
Mary River Expansion Project

2018 Mine Site Geotechnical Investigation Report

HATCH PARALLEL REVIEW – Internal and Client

HATCH	***Signature***	***Date***
Port Area Lead		
Rail Area Lead		
PEng Reviewer (NAPEG)		
Construction		
Other		
Other		
BIM	***Signature***	***Date***
Port Area Manager		
Mine / Rail Area Manager		
Environmental		
Permitting		
Operations		
Other		
Other		
Review Grade *(check applicable box below)*		
C1	**C2**	**C3**
Proceed to next submission & status	*Proceed with exceptions as noted to next submission & status*	*Do not proceed.* *Revise as noted & resubmit*
Client Rep.		***Date:***

			Yang, Michael Digitally signed by Yang, Michael Date: 2018.09.13 13:47:48-04'00'			
2018-09-13	A	Internal/Client Review	M. Yang	K. Ho	W. Hoyle	
Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**	**Approved By Client**

DISCLAIMER

This Report has been prepared by Hatch Ltd. (“Hatch”) for the sole and exclusive benefit of Baffinland Iron Mines Corporation (the “Client”) for the sole purpose of assisting the Client to identify potential options to increase production from the Mary River mine, and may not be provided to, used or relied upon by any other party without the prior written consent of Hatch.

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This report is meant to be read, and sections should not be read or relied upon out of context. While it is believed that the information contained herein is reliable under the conditions and subject to the limitations set forth herein, this Report is based in part on information not within the control of Hatch and Hatch therefore cannot and does not guarantee the accuracy of such information based in whole or in part on information not within the control of Hatch. The comments in it reflect Hatch’s professional judgment in light of the information available to it at the time of preparation.

This report contains the expression of the professional opinion of Hatch exercising reasonable care, skill and judgment and based upon information available at the time of preparation. Hatch has conducted this investigation in accordance with the methodology outlined herein. It is important to note that the methods of evaluation employed, while aimed at minimizing the risk of unidentified problems, cannot guarantee their absence. The quality of the information, conclusions and estimates contained herein is consistent with the intended level of accuracy as set out in this report, as well as the circumstances and constraints under which this report was prepared.

Client’s Signature:

Name:

Title:

Date:

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

Baffinland Iron Mines LP (BIM) currently operates the Mary River iron ore mine in Nunavut, Canada. BIM plans to increase the production to 12Mtpa, shipping the output through Milne Port. This will be achieved by upgrading the mine fleet, constructing a 110 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 for ship loading.

In order to support the increased mine fleet, construction equipment and subsequent fuel consumption, an additional Tank Farm and Truck workshop is planned for the Mary River mine site. Hatch Ltd. (Hatch) was retained by BIM to conduct geotechnical drilling investigations for the design of a new truck workshop and tank farm at the Mine Site. The drilling program included one phase executed from June 15 to June 28, 2018.

This report summarizes the result of the geotechnical investigation for the truck workshop, tank farm, and associated infrastructure. The site program, borehole log reports, photographs and laboratory testing results are detailed in the following sections.

1.1 Previous Investigations

Geotechnical investigation programs have previously been conducted at the Mary River mine site, Steensby Inlet port structure, and the Milne Inlet port site, the Tote Road, as well as offshore investigations at Milne Port.

These previous programs were conducted in 2006, 2007, and 2008 by Knight Piésold Consulting Ltd. (Knight Piésold), in 2010 by AMEC Earth and Environmental (AMEC), and in 2011, and 2013-2014 and by Hatch. Relevant information from these investigations has been included in this report.

1.2 Local Topology and Geology

The site of the proposed truck workshop and tank farm is located within the Mary River Mine Site. The proposed truck workshop is to be located southeast of the Mine Site Complex (MSC) and the proposed tank farm is to be located northwest of the MSC and the existing tank farm. The geology of this area generally includes glacio-fluvial sand underlain by glacial till followed by a sandstone or granite bedrock.

2. Geotechnical Investigation

2.1 General

The drilling supervision, field core logging and sampling for the 2018 investigation program was carried out by Hatch. Boart Longyear Ltd. (Boart Longyear) was selected as the drilling contractor. The Hatch field personnel and the drilling contractor mobilized to site on June 15, 2018. The field investigation was completed on June 28, 2018.

2.2 Borehole Locations

A summary of the as-drilled borehole locations for the Truck Workshop and Tank Farm is shown in Table 2-1. All coordinates are located within Zone 17 of the Universal Transverse Mercator (UTM) Grid. The horizontal datum for this project is the North American Datum 1983 (NAD 83). The as-drilled borehole location plan is provided in Appendix A.

The prefix BH represents Borehole, while 18 refers to 2018, the year of the investigation. The two letters following the dash symbol (-) categorizes the borehole location as Truck Workshop (TW) or Tank Farm (TF).

Table 2-1: Truck Workshop and Tank Farm Borehole Locations

Borehole Number	Easting (m)	Northing (m)	Depth (m)	Ground elevation (masl)
BH18-TW-01	561,477	7,913,189	25.9	195.17
BH18-TW-02	561,532	7,913,229	25.9	N/A
BH18-TF-01	561,154	7,913,396	25.9	188.22
BH18-TF-02	560,988	7,913,441	25.9	186.42
BH18-TF-03	561,094	7,913,477	25.9	187.82
BH18-TF-04	561,002	7,913,499	25.9	187.16
BH18-TF-05	561,203	7,913,478	24.4	188.10
BH18-TF-7N	561,064	7,913,438	12.4	187.00*
BH18-TF-8N	561,166	7,913,449	12.2	189.00*

**Approximate elevations sourced from topographical maps*

2.3 Drilling and Sampling Methodology

The geotechnical boreholes were developed using a BL100 Mini Sonic Drilling rig manufactured and operated by Boart Longyear, shown in Figure 1. The boreholes were advanced by vibration of the drill string at a high frequency in addition to rotary motion, and pressure by the drilling head (vibracore). Casing, size H, was advanced with the vibracore to keep the hole open between runs. Sonic drilling does not require water at shallow depths in the overburden.

When using vibracore drilling in overburden, a 3 m drilling rod was advanced 1.5 m into the ground for each run. The bottom 1.5 m was collected into a 4 inch split PVC pipe as shown in Figure 2. Soil collected above the bottom 1.5 m, if encountered, was disposed to ensure the collected sample was not contaminated by surface soil caved-in accumulated at the bottom of the drilled hole. Soil sample were photographed in the PVC split. Once the material in the split was photographed and sampled, the splits were secured using caps and aluminum tape, and stored in a shipping container at the Milne Port site.

Where encountered, bedrock was cored using a HQ-3 triple tube wireline core barrel, which required the use of water and casing. In addition, rock coring required the installation of a high-speed rotary head on the drilling rig every time there was a switch from sonic drilling in soil to rock coring.

Figure 2-1: Boart Longyear Mini Sonic Drilling Rig

Figure 2-2: Sample Collected in a PVC Split using a Mini Sonic Drilling Rig

The Hatch field supervisor documented the materials encountered, and determined in situ testing and sampling requirements. When ice was encountered in the borehole, it was documented and classified according to ASTM D4083. The description of soils as detailed in the geotechnical borehole reports are based on field visual classification and confirmatory laboratory testing in accordance with the explanatory notes included with these reports.

The detailed geotechnical borehole drilling reports are contained in the attached Appendix B and should be referenced for a complete description of soil materials and the in situ testing and sampling performed. Appendix B also contains a set of explanatory notes detailing terminology used in the borehole reports. Additional observations such as testing and sampling procedures, percent recovery, water loss/gain, and mechanical heating of samples were recorded, along with time of observation. Photographs of samples collected during the drilling investigation are contained in Appendix C.

2.4 Safety Management Plan

Safety management was a key consideration during the planning process for the geotechnical investigations. A safety management plan was prepared by Hatch and reviewed by BIM and Boart Longyear. A Job Hazard Analysis (JHA), identifying the hazards associated with the work and the controls that were to be used, was developed by Hatch and BIM and reviewed by Boart Longyear. This JHA was reviewed on a periodic basis and when work conditions changed and updated accordingly. A notification procedure was prepared by BIM specifically for the drilling activities in remote areas. A copy of both the final JHA and the notification procedure is presented in Appendix G.

2.5 Laboratory Testing

2.5.1 Soil Testing

All samples were shipped to the Hatch geotechnical laboratory in Niagara Falls, Ontario. Representative samples were selected for testing including moisture content and particle size distribution in accordance with the standard listed in Table 2-2. Full laboratory test results are presented in Appendix D and laboratory results are summarized in Appendix F.

Table 2-2: Standards Used for the Current Geotechnical Investigation

Name	Standard
Standard Test methods for Laboratory Determination of Water Content of Soil and Rock by Mass	ASTM D2216
Standard Test Methods for Particle-Size Distribution of Soils using Sieve Analysis	ASTM D6913
Standard Test Method for Particle Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis	ASTM D7928

3. Results of Field Investigations

3.1 Mine Site Boreholes

A total of 9 boreholes were drilled at the Mine Site to support design of the proposed truck workshop and tank farm. Fence diagrams have been made for select boreholes and are presented in Appendix E.

3.1.1 Truck Workshop Area

The subsurface beneath the footprint of truck workshop has been mapped as layers of sand and gravel (typically till), sand, and ice, along with some cobbles and silt. The boreholes for this area are summarized in Table 3-1.

Table 3-1: Summary of Boreholes in Truck Workshop Areas

Borehole ID (Infrastructure)	Depth Material was Encountered (m)						
	Fill	Sand with Cobbles	Ice with Soil	Topsoil	Sand and Gravel	Sand	Silt and Sand
BH18-TW-01	0 – 2.6	2.6 – 15.2	15.2 – 15.8		15.8 – 25.2	25.2 – 25.9*	
BH18-TW-02				0 – 0.1	0.1 – 13.3	13.3 – 18.3 20.9 – 25.9*	18.3 – 20.9

* Indicates termination depth

3.1.1.1 Sand and Gravel / Sand with Cobbles

Both boreholes contain a layer of this material directly below the uppermost layer of either fill or topsoil. BH18-TW-01 also contained a second layer of this material that was separated from the first layer by a layer of ice. In general, the soil material was made up of a mix of sand and gravel, containing sections of cobbles, and trace silt. It was brown to grey in colour, sub-rounded to sub-angular, and is likely a layer of till.

3.1.1.2 Sand

Both boreholes contained sand as the lowermost layer, ranging from 0.7 m to 5 m. BH18-TW-02 also contains a second layer of sand overlying the first layer, separated by a layer of silt and sand. In general the material encountered was poorly graded sand, and was brown to grey in colour.

3.1.1.3 Ice with Soil

Ice with soil was encountered as an inferred layer in BH18-TW-01 in the truck workshop area where 0.6 m was encountered at 15.2 m depth.

3.1.2 Tank Farm Area

Additional tanks are proposed for the Mine Site, northwest of the existing tank farm. Seven boreholes were developed for the tank farm. The results of the boreholes are summarized in Table 3-2.

Table 3-2: Summary of Boreholes in Tank Area

Borehole ID (Infrastructure)	Depth Material was Encountered (m)					
	Topsoil	Sand and Gravel to Gravelly Sand	Ice to Ice with Soil	Sand	Sandy Silt to Silty Clay	Cobbles
BH18-TF-01		0.0 – 4.9 11.1 – 16.2	4.9 – 6.0 9.1 – 10.6	6.0 – 9.1 10.6 – 11.1 16.2 – 25.9*		
BH18-TF-02		0.0 – 5.4 12.1 – 18.3 19.8 – 22.9	5.4 – 7.2 11.7 – 12.1	7.2 – 11.7 18.3 – 19.50 22.9 – 25.9*		19.5 – 19.8
BH18-TF-03	1.4 – 1.5	0.0 – 1.4 1.5 – 13.2 13.7 – 16.2		13.2 – 13.7 16.2 – 25.9*		
BH18-TF-04		0.0 – 5.7 7.8 – 9.1	5.7 – 6.2 7.4 – 7.8	6.2 – 7.4 9.1 – 9.6 15.2 – 25.9*	9.6 – 15.2	
BH18-TF-05	0.0 – 0.1	1.4 – 5.0		5.0 – 9.1 12.2 – 24.4*	9.1 – 12.2	0.1 – 1.4
BH18-TF-7N		0.0 – 6.1 7.6 – 12.4*	6.6 – 7.6	6.1 – 6.6		
BH18-TF-8N	0.5 – 4.6	0.0 – 0.5 5.8 – 12.2*	4.6 – 5.8			

* Denotes termination depth

3.1.2.1 Sand and Gravel to Gravelly Sand

In most boreholes the uppermost soil encountered was sand and gravel to gravelly sand. This material tends to contain trace to some cobbles with increased depth. This material is likely a fill within the first 2 m and a till throughout the rest of the borehole.

3.1.2.2 Ice or Ice and Soil

A layer or two of ice or ice and soil was encountered in five out of seven boreholes. The ice layers range from 0.4 m to 1.8 m in thickness and contain clear, hard ice.

3.1.2.3 Sand

Sand was encountered in the lowermost soil of five out of seven boreholes as well as between layers of ice or ice and soil. The sand tends to be poorly graded and contains traces of silt and gravel.

3.2 Laboratory Testing

Select soil samples collected during the investigations were tested to confirm the field classification of the soil. These test results have been included in the borehole reports contained in Appendix B. For full test results please see Appendix D and Appendix E for the grain size and moisture content results, respectively.

4. Recommendations

4.1 Tank Farm Pad

The design and dimensions of the Tank Farm Pad and Fuel Tanks are sourced from Tank Farm drawings provided in transmittal H353004-TR-02071-CA01 and River Mine Site Fuel Storage Facility Project Memo (H353004-10000-240-210-0001, Rev. 0) respectively.

Due to the similarities between the subsurface conditions and pad designs between the existing Milne Port Tank Farm and proposed Mine Tank Farm, the Milne Port Tank Farm Pad Geotechnical Design memo (H349000-2000-15-220-001, Rev. A) recommendations will be applied to the Mine Tank Farm Pad Design. The subsurface of the existing Milne Port Tank Farm Pad consists of mostly sand containing varying amounts of gravel and silt. This soil is comparable to subsurface conditions beneath the proposed Mine Tank Farm Pad footprint, consisting of sand and gravel (till) overlaying thin layers of clear hard ice, followed by sand.

The following are the results and recommendations regarding the proposed granular fill pad:

- A combination of the equations and parameters found in the Milne Port Tank Farm Pad Geotechnical Design Memo (H349000-2000-15-220-0001, Rev. A), Geotechnical Design Basis report (H353004-00000-229-210-0001, Rev. 0) and Mary River Mine Site Fuel Storage Facility Project Memo (H353004-10000-240-210-0001, Rev. 0) was used in the proposed Mine Tank Farm Pad foundation bearing capacity calculations. The maximum surcharge on top of native material is less than 250 kPa with the height of fuel tank equal to 18.15 m. The calculations showed that the allowable bearing capacity is higher than the surcharge, using a maximum thickness of 2.16 m for the granular pad. Changes to the dimensions of the proposed fuel tanks or tank farm pads should be accompanied by bearing capacity calculations using the updated values.
- The transient thermal analysis conducted on the existing Milne Port Tank Farm pad resulted in recommendations of increasing the total pad thickness to 2.0 m from 1.95 m, and the extension of the edges of the granular pad a minimum of 2 m beyond the edge of the tanks to reduce the risk of differential settlement. The presence of thin ice layer underneath the proposed Mine Tank Farm Pad highlights the importance of minimizing the disturbance of the subsurface, therefore the recommendations for the existing Milne Port Tank Farm Pad presented above will be applied to the Mine Tank Farm Pad. The cross section of the pad in Figure 4-1 summarizes the recommendations for the proposed Mine Tank Farm Pad.

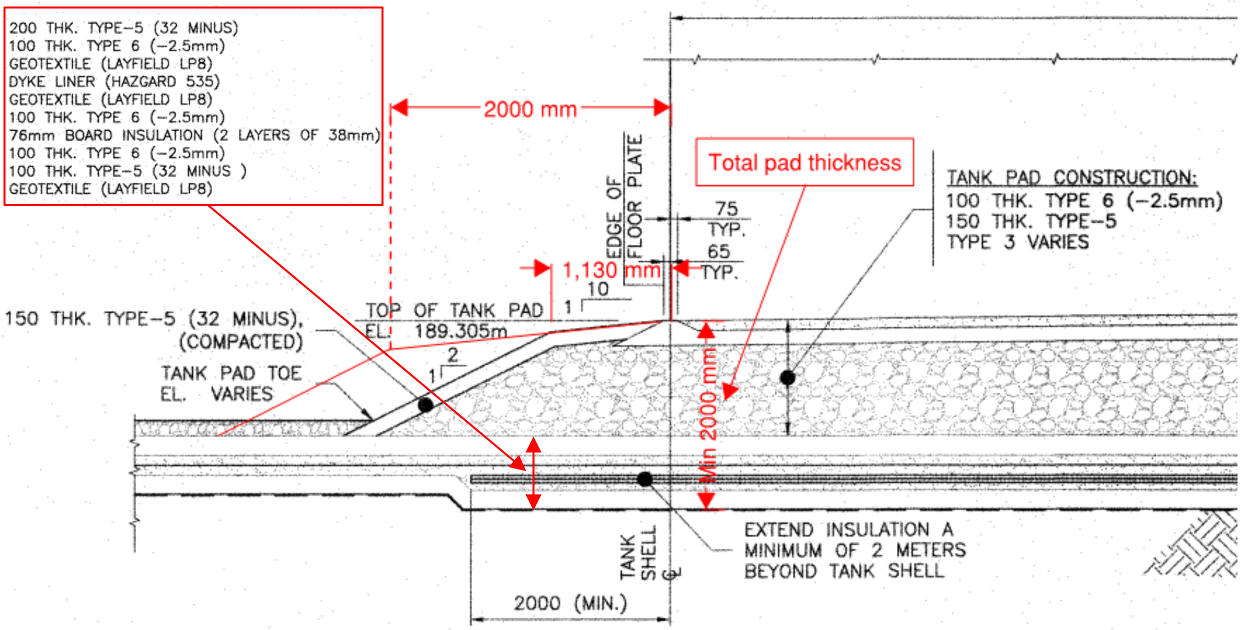

Figure 4-1: Recommendations for Tank Farm Pad at Mary River Mine Site (recommendations are highlighted in red)

- The Milne Port Tank Farm Pad memo recommended the removal of the insulation layer near the bottom of the pad. However the presence of hard ice beneath the proposed Mine Tank Farm Pad increases the risk of differential settlement, and the specified 76 mm board insulation should be kept in place. Any changes to the insulation should be verified for subsurface disturbance using a transient thermal analysis modelling program.
- The specifications for the granular fill materials and fill placement shall conform to the Hatch standards titled “Quarried Fill Materials Requirements” (H353004-00000-280-078-0002, Rev. 0) and “Placement of Fill” (H353004-00000-221-078-0001, Rev. 0), respectively.

4.2 Truck Workshop

The design and dimensions of the proposed Mine Truck Workshop Pad are sourced from Truck Workshop drawings titled “MINE TRUCK WORKSHOP PAD EARTHWORKS CROSS SECTIONS” and “MINE TRUCK WORKSHOP PAD LAYOUT PLAN” with document numbers H353004-10000-221-273-0001-0001 and H353004-10000-221-272-0005-0001, respectively. As all design and loading information was not available during the preparation of this report, assumptions were made based on the Geotechnical Criteria for Building Foundations specification (H353004-00000-229-078-0001). Any assumptions made are stated below.

The following are the results and recommendations regarding the proposed granular fill pad:

- The design of the granular pad beneath the slab on grade for the truck workshop follows the recommendations outlined in Geotechnical Criteria for Building Foundations specification document, additional details can be found in the aforementioned specification.
- Based on the Geotechnical Criteria for Building Foundations specification, a modulus of 30 MPa and 20MPa should be utilised for the Mine Site and Milne Port site, respectively. This is based on a maximum effective base width of 2.0 m.
- While the earthworks cross sections drawing does not indicate the use of footings for the truck workshop foundation, the Geotechnical Criteria for Building Foundations specification provides ultimate and allowable bearing capacity figures for square and rectangular footings with footing widths from 1 m to 4 m and a strip footing with footing widths from 1 m to 3 m, all over 400 mm of granular engineered fill. Any designs with footing widths, or required bearing capacities outside of the plotted range requires additional calculation or modelling.
- The insulation and compacted granular fill beneath the concrete slab on grade follows the insulation requirements defined in the Geotechnical Criteria for Building Foundations specification. The requirement states 100 mm thick rigid underneath the concrete, and 150 mm thick insulation below the engineered fill pad. It should be noted the insulation requirements covers for standard temperatures encountered in buildings (10°C to 23°C). Thermal modelling is recommended if the truck workshop will experience elevated temperatures to determine the risk for subsurface disturbance.
- The specifications for the granular fill materials and fill placement shall conform to the Hatch standards titled “Quarried Fill Materials Requirements” (H353004-00000-280-078-0002, Rev. 0) and “Placement of Fill” (H353004-00000-221-078-0001, Rev. 0) respectively.

5. References

1. ASTM – Standard Practice for Description of Frozen Soils (Visual-Manual Procedure) Designation D4083-89 *Approved June 1 2016.*
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3. Little, EC., Holme, P.J., and Kerr, D.E. 2013: Surficial Geology, Icebound Lakes (southwest), Baffin Island, Nunavut, Geological Survey of Canada, Canadian Geoscience Map 74 (preliminary), scale 1:100 000 doi:19.1985/292183.
4. Dyke, A.S. 2000: Surficial Geology, Phillips Creek, Baffin Island, Nunavut; Geological Survey of Canada, Map 1961A, scale 1:250 000.
5. AMEC Earth & Environmental, 2010: Geotechnical, Geochemical and Quarry Sourcing Investigation (Draft). Project No. TC101510. Dec. 2010.
6. 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.
7. 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.
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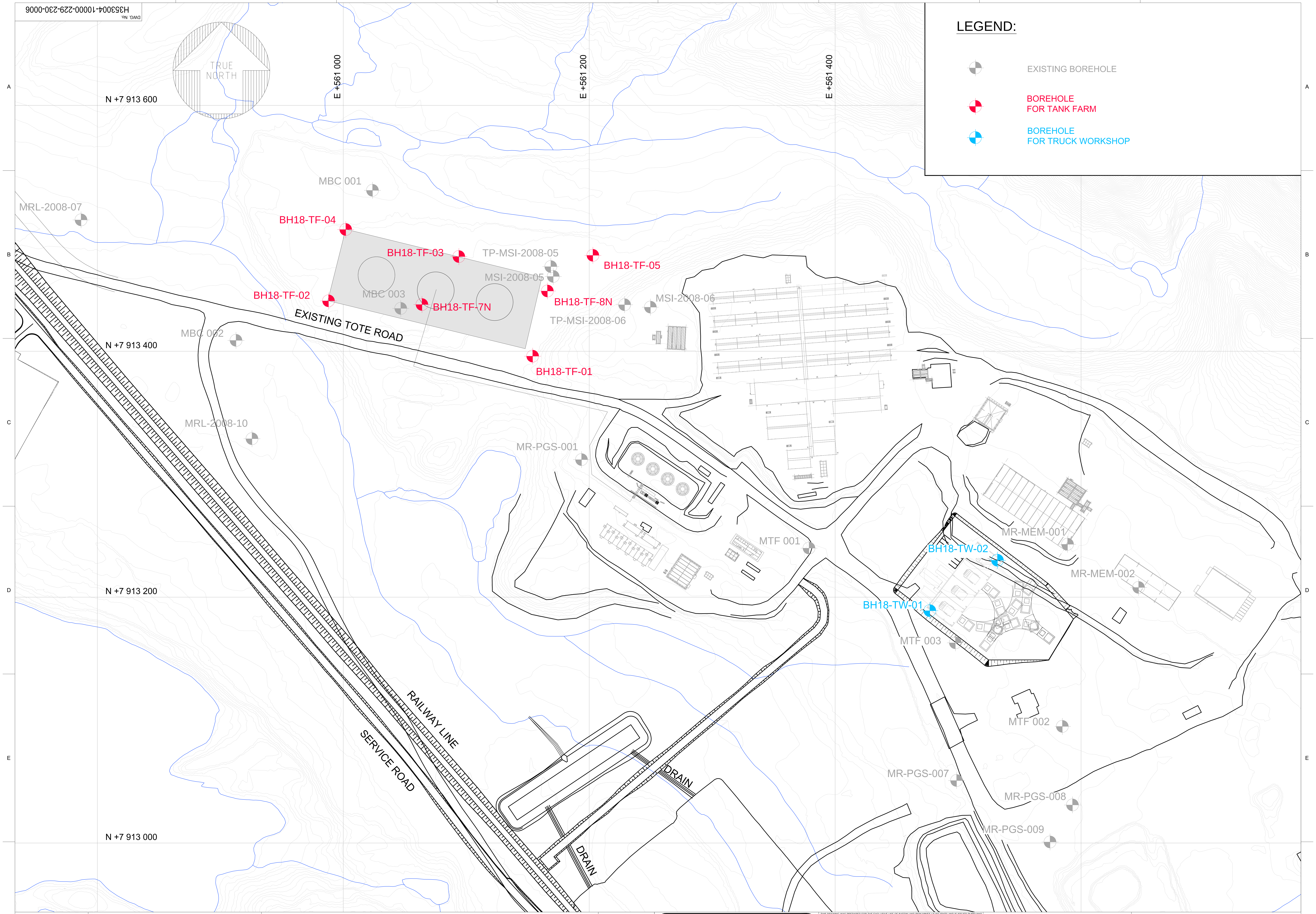
Appendix A

Borehole Location Plan



LEGEND:

◐	EXISTING BOREHOLE
🟥	BOREHOLE FOR TANK FARM
🟦	BOREHOLE FOR TRUCK WORKSHOP

NOT FOR CONSTRUCTION

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Baffinland

BAFFINLAND IRON MINES LP
MARY RIVER EXPANSION PROJECT

MINE SITE
BOREHOLE
LAYOUT

SCALE 1:2500 OR AS NOTED

DWG. No. H353004-10000-229-230-0006

REV A

SHEET SIZE: E

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Appendix B

Borehole Reports

HATCH™

List of Abbreviations and Terms Used in the Borehole Reports

(Sheet 1)

General

Elevations
Elevations are referenced to datum indicated.

Depth
All depths are given in meters (feet) measured from the ground surface unless otherwise noted.

Sample Recovery
Indicates the length retained in millimeters (inches) in a split spoon sampler or percentage recovery of sample retained in the core barrel sampler.

Sample Number
Samples are numbered consecutively in the order in which they were obtained or attempted in the borehole.

Sample Type
The first letter describes the sampling method and the second, the shipping container.

Sampling Method
A – Split Tube
B – Thin Wall Tube
C – Piston Sampler
D – Core Barrel
E – Auger
F – Wash
G – Shovel Grab Sample
K – Slotted Sampler

Shipping Container
O – Tube
P – Water Content Tin
Q – Jar
S – Plastic Bag
U – Not Recovered
X – Plastic & PVC Sleeve (Sonic)
Y – Core Box
Z – Discarded

Abbreviations
N/A – Not applicable
N/E – Not encountered
N/O – Not observed

Soil

Soil Description, Label and Symbol
Soil description under the “Description” column conforms generally, but not rigorously, to the Unified Soils Classification System. For a given soil unit, defined by depth boundaries, the descriptive text constitutes the definitive soil unit description and takes precedence over both the brief label and the symbol used to graphically represent the soil unit.

Grain Size

Clay		<0.002 mm
Silt	0.002 –	0.075 mm
Sand	0.075 –	4.75 mm
Fine	0.075 –	0.42 mm
Medium	0.42 –	2.00 mm
Course	2.00 –	4.75 mm
Gravel	4.75 –	75 mm
Fine	4.75 –	19.00 mm
Coarse	19.00 –	75.00mm
Cobbles	75 –	300 mm
Boulder		>300 mm

Relative Quantities

Term	***Example***	***(%)***
Trace	Trace sand	1 – 10
Some	Some sand	10 – 20
With (adjective)	With Sand (Sandy)	20 – 35
And	And sand	>35
Noun	Sand	>50

Standard Penetration Test (SPT)
The test is carried out in accordance with ASTM D-1586 and the ‘N’ value corresponds to the sum of the number of blows required by a 63.5-kg (140-lb) hammer, dropped 760 mm (30 in.), to drive a 50-mm (2-in.) diameter split tube sampler the second and third 150 mm (6 in.) of penetration.

Density (Granular Soils)

	N(SPT)
Very loose	0 – 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very dense	>50

Consistency (Cohesive Soils)

	N(SPT)
Very soft	<2
Soft	2 – 4
Firm	4 – 8
Stiff	8 – 15
Very stiff	15 – 30
Hard	>30

Plasticity/Compressibility

		Liquid Limit (%)
Low plasticity clays	Low compressibility silts	<30
Medium plasticity clays	Medium compressibility silts	30 – 50
High plasticity clays	High compressibility silts	>50

Dilatancy
None - No visible change, during shaking or squeezing
Slow - Water appears slowly on surface of specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid - Water appears quickly on the surface of specimen during shaking and disappears quickly upon squeezing.

Sensitivity

Insensitive	<2
Low	2 – 4
Medium	4 – 8
High	8 – 16
Quick	>16

HATCH™

List of Abbreviations and Terms Used in the Borehole Reports

(Sheet 2)

Rock

Core Recovery
Sum of lengths of rock core recovered from a core run, divided by the length of the core run and expressed as a percentage.

RQD (Rock Quality Designation)
Sum of lengths of hard, sound pieces of rock core equal to or greater than 100 mm from a core run, divided by the length of the core run and expressed as a percentage. Measured along centerline of core. Core fractured by drilling is considered intact. RQD normally quoted for N-size core.

RQD (%) Rock Quality

90 - 100	Excellent
75 - 90	Good
50 - 75	Fair
25 - 50	Poor
0 - 25	Very Poor

Grain Size

Term	*Grain Size*
Very coarse-grained	>60 mm
Coarse-grained	2 mm - 60 mm
Medium-grained	60 µm - 2 mm
Fine-grained	2 µm - 60 µm
Very fine-grained	< 2 µm

Bedding

Term	*Bed Thickness*	
Very thickly bedded	>2 m	>6.50 ft
Thickly bedded	600 mm - 2 m	2.00 - 6.50 ft
Medium bedded	200 mm - 600 mm	0.65 - 2.00 ft
Thinly bedded	60 mm - 200 mm	0.20 - 0.65 ft
Very thinly bedded	20 mm - 60 mm	0.06 - 0.20 ft
Laminated	6 mm - 20 mm	0.02 - 0.06 ft
Thinly laminated	<6 mm	<0.02 ft

Discontinuity Frequency
Expressed as the number of discontinuities per meter or discontinuities per foot. Excludes drill-induced fractures and fragmented zones.

Discontinuity Spacing

Term	*Average Spacing*	
Extremely widely spaced	>6 m	>20.00 ft
Very widely spaced	2 m - 6 m	6.50 - 20.00 ft
Widely spaced	600 mm - 2 m	2.00 - 6.50 ft
Moderately spaced	200 mm - 600 mm	0.65 - 2.00 ft
Closely spaced	60 mm - 200 mm	0.20 - 0.65 ft
Very closely spaced	20 mm - 60 mm	0.06 - 0.20 ft
Extremely closely spaced	<20 mm	<0.06 ft

Note: Excludes drill-induced fractures and fragmented rock.

Broken Zone
Zone of full diameter core of very low RQD which may include some drill-induced fractures.

Fragmented Zone
Zone where core is less than full diameter and RQD = 0.

Strength

Term	*Description*	*Unconfined Compressive Strength*	
		(MPa)	*(psi)*
Extremely weak rock	Indented by thumbnail	0.25 – 1.0	36 – 145
Very weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0 – 5.0	145 – 725
Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0 – 25	725 – 3625
Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer to facture it	25 – 50	3625 –7250
Strong rock	Specimen requires more than one blow of geological hammer to fracture it	50 – 100	7250 – 14500
Very strong rock	Specimen requires many blows of geological hammer to fracture it	100 – 250	14500 – 36250
Extremely strong rock	Specimen can only be chipped with geological hammer	>250	>36250

Weathering

Term	*Description*
Fresh	No Visible sign of rock material weathering
Faintly weathered	Discoloration on major discontinuity surfaces.
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker than in its fresh condition.
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

BASIS FOR SOIL DESCRIPTION

(Based on AS1726-1993 - Geotechnical Site Investigations, with modifications)

GRAPHIC SYMBOLS FOR SOILS

GRAVEL -
- poorly graded - ▩
- well graded - ▩

SAND -
- poorly graded - ▒
- well graded - ▒

SILT -
- of low plasticity - ▥
- of high plasticity - ▥

CLAY -
- of low plasticity - ▨
- of high plasticity - ▨

ICE - ■

COBBLES AND BOULDERS - ○

ORGANIC/ PEATY SOIL - ▩

FILL/ MADE GROUND - ▦

Composite soil types are presented using combined symbols, eg. **Gravelly Sandy CLAY** ▨

GROUNDWATER OBSERVATIONS

Permanent Water Level	▼	Inflow into Pit or Borehole	►	Slow Inflow/ Seepage into Pit or Borehole	≈
Temporary Water Level	▽	Outflow/ Water Loss in Borehole	◄		

SAMPLE TYPES

Disturbed bag sample	▧	Auger Flight Cuttings	▧	Thin walled "undisturbed" push tube sample eg. U60, U100 etc	■
Bulk Disturbed (>20kg)	☒	Standard Penetration Test (SPT), with Disturbed Split-Spoon Sample	◪		
Hollow Stem Auger Core	▯	SPT (no recovery)	▱	Sample attempted with no recovery	☒

BASIS FOR ROCK DESCRIPTION

(Based on AS1726-1993 - Geotechnical Site Investigations, with modifications)

GRAPHIC SYMBOLS FOR SOILS

GRAVEL -
- poorly graded - ▨
- well graded - ▨

SAND -
- poorly graded - ▨
- well graded - ▨

SILT -
- of low plasticity - ▥
- of high plasticity - ▥

CLAY -
- of low plasticity - ▨
- of high plasticity - ▨

FINE GRAINED TAILINGS - □

COBBLES AND BOULDERS - ▨

ORGANIC/ PEATY SOIL - ▨

FILL/ MADE GROUND - ▩

Composite soil types are presented using combined symbols, eg. **Gravelly Sandy CLAY** ▨

GRAPHIC SYMBOLS FOR ROCKS

SEDIMENTARY

- SHALE ▤
- CLAYSTONE ▤
- SILTSTONE ▤
- SANDSTONE ▨
- CONGLOMERATE ▨
- BRECCIA ▨
- CORE LOSS ⊠

CARBONATE

- LIMESTONE ▦
- Calcareous CLAYSTONE ▨
- Calcareous SILTSTONE ▦
- CALCARENITE ▦
- CALCIRUDITE ▦
- CALCRETE ▩

EVAPORITES

- GYPSUM ▨

IGNEOUS

- COARSE GRAINED ▨
- MEDIUM GRAINED ▨
- FINE GRAINED ▨
- DOLERITE ▨

METAMORPHIC

- COARSE GRAINED ▨
- MEDIUM GRAINED ▨
- FINE GRAINED ▨

Additional rock graphics may be added for specific projects.

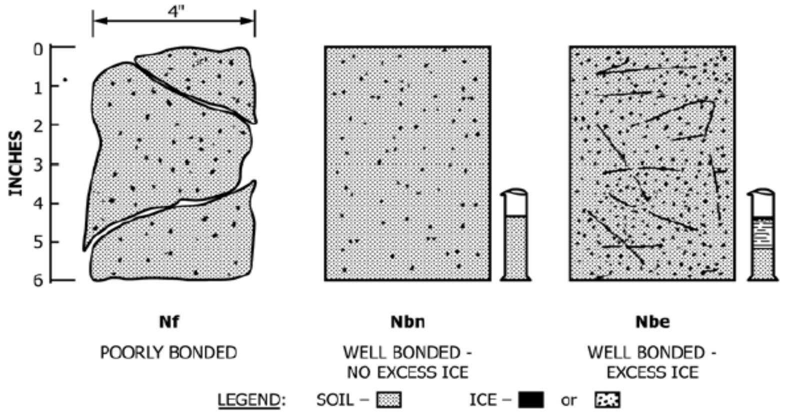
GROUNDWATER OBSERVATIONS

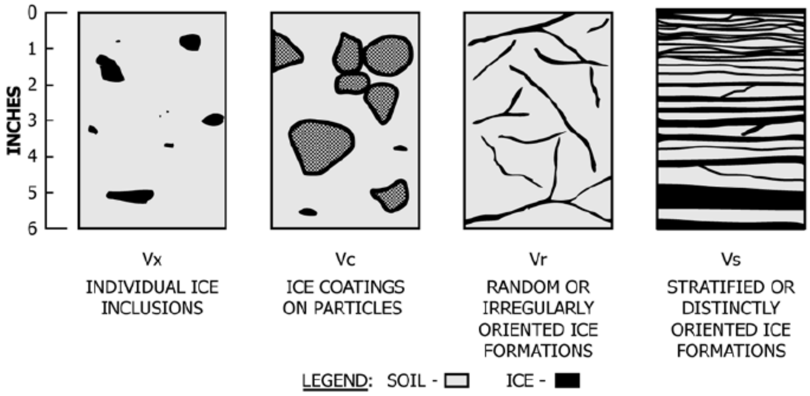
- Permanent Water Level ▼
- Temporary Water Level ▽
- Inflow into Pit or Borehole ►
- Outflow/ Water Loss in Borehole ◄
- Slow Inflow/ Seepage into Pit or Borehole ≈

SAMPLE TYPES

- Disturbed bag sample ▧
- Bulk Disturbed (>20kg) ⊠
- Hollow Stem Auger Core ▯
- Auger Flight Cuttings ▧
- Standard Penetration Test (SPT), with Disturbed Split-Spoon Sample ◪
- SPT (no recovery) ▯
- Thin walled "undisturbed" push tube sample eg. U60, U100 etc ▮
- Sample attempted with no recovery ⊠

Symbol	Description
Nf	Poorly bonded with no visible excess ice
Nbn	Well bonded with no visible excess ice
Nbe	Well bonded with excess cie
Vx	Individual ice inclusions
Vc	Ice coatings on particles
Vr	Random or Irregularly oriented ice formations
Vs	Stratified or distrinctly oriented ice formations





BOREHOLE REPORT

BH18-TF-01

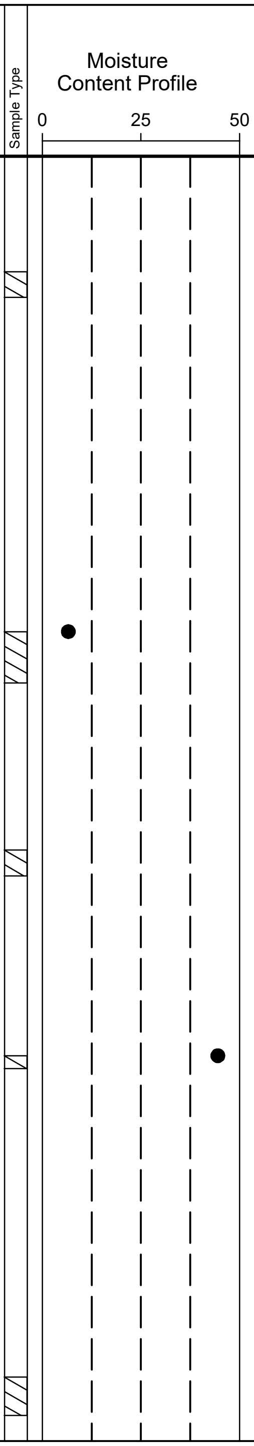
Sheet 1 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Southeast Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,154.0 m
Northing: 7,913,396.0 m
Surface Elevation: 188.00 m
Bottom Elevation: 162.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/25/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Elevation (m)	Depth (m)	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content
188.0	0.0	FILL: Sand and gravel, some boulders to cobbles, well graded, medium grained, light brown.	Non - frozen	
186.2	1.8	TILL: Silty gravelly sand to silty sandy gravel, fine to medium grained, dark grey, dense to very dense.	Nbn inferred	
		3.30 m - 3.50 m: Cobble to potential boulders.		7
183.1	4.9	ICE and SOIL: Clear to grey, granular, hard, 20% - 30% soil.	I+S	
182.0	6.0	SAND: Poorly graded, medium to fine grained, grey to light brown. 6.10 m - 7.60 m: High moisture content.	Nbn - Vx	45
		8.05 m - 8.30 m: Boulder inferred 8.40 m - 9.10 m: Becoming gravelly, sub-angular to sub-rounded, 30 mm - 50 mm.	Vs - clear hard ice	
178.9	9.1	ICE: clear, granular, becoming strong at 9.90 m.	ICE	



Notes:

HATCH BOREHOLE REPORT

BH18-TF-01

Sheet 2 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Southeast Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

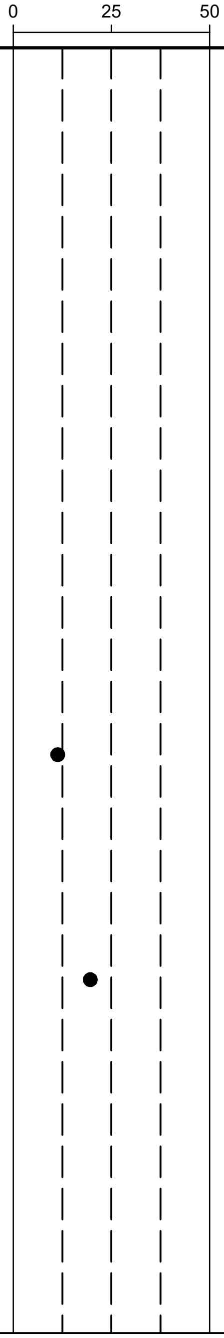
Easting: 561,154.0 m
Northing: 7,913,396.0 m
Surface Elevation: 188.00 m
Bottom Elevation: 162.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/25/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Elevation (m)	Depth (m)
177.0	11.0
176.0	12.0
175.0	13.0
174.0	14.0
173.0	15.0
172.0	16.0
171.0	17.0
170.0	18.0
169.0	19.0
168.0	20.0

Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content
ICE and SOIL: Sand, medium to fine grained, brown, hard, clear ice, granular.	I+S	
TILL: Sand, some gravel, light brown, wet / moist sand.	Nbn assumed	
TILL: Sand and gravel to sandy silty gravel, trace to some cobbles, grey, medium to fine grained, dense, sub-angular to sub-rounded gravel. 11.10 m - 11.90 m: Boulder with sand, some gravel in between.	Nbn assumed	
NO RECOVERY		
TILL: Sand and gravel to sandy silty gravel, trace to some cobbles. 13.0 m - 13.40 m: Core disturbance. 13.85 m - 14.00 m: Sandstone boulder. 14.60 m - 14.80 m: Becoming wet.		11
SAND, trace SILT: Organic sand band 3 mm thick, sand continues below.	Nbn	
SAND and SILT: Statified, layers of light greenish grey siltstone, yellowish grey, fine sand.	Nbn Vs Nbn Vs	20
SAND: Poorly graded, medium to fine grained, light grey to yellowish grey, dense to very dense, with very dense layers, similar consistency to sandstone. 18.75 m - 18.85 m: Statified silt and sand layers bounded by organic sand. 19.80 m - 20.60 m: Very hard band of	Nbn	

Moisture Content Profile



Notes:

BOREHOLE REPORT

BH18-TF-01

Sheet 3 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Southeast Corner of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 561,154.0 m

Northing: 7,913,396.0 m

Surface Elevation: 188.00 m

Bottom Elevation: 162.10 m

Total Depth: 25.9 m

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 6/25/2018

Logged By: MY

Driller: Brent McAndrew

Hole Diameter (mm): 100

Date Reviewed:

Reviewed By:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	**Soil Description** TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						sand, possible sandstone. SAND: Poorly graded, medium to fine grained, light grey to yellowish grey, dense to very dense, with very dense layers, similar consistency to sandstone. *(Continued)*	Nbn *(Continued)*										
	167.0	21.0															
						20.70 m: Organic smelling sand, grey, 2 mm.											
	166.0	22.0															
						22.30 m - 22.60 m: Wet.											
	165.0	23.0															
						23.40 m - 23.90 m: Compact moist sand.	Nbn		▨								
	164.0	24.0															
	163.0	25.0															
						25.50 m: Becoming dense and dry.											
	162.0	26.0				To Target Depth. **Drillhole BH18-TF-01 terminated at 25.9m.**											
	161.0	27.0															
	160.0	28.0															
	159.0	29.0															
	158.0	30.0															

Notes:

HATCH

BOREHOLE REPORT

BH18-TF-02

Sheet 1 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Southwest Corner of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 560,988.0 m

Northing: 7,913,441.0 m

Surface Elevation: 186.00 m

Bottom Elevation: 160.10 m

Total Depth: 25.9 m

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 6/24/2018

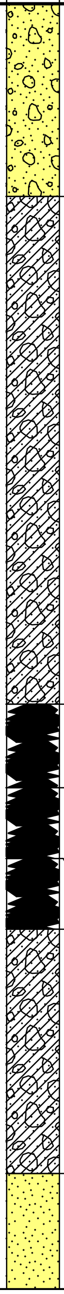
Logged By: MY

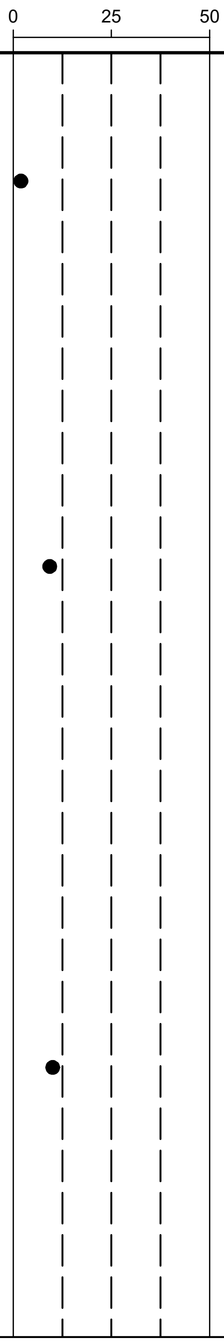
Driller: Brent McAndrew

Hole Diameter (mm): 100

Date Reviewed:

Reviewed By:





Water	Elevation (m)	Depth (m)	Method	Casing	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
					SAND and GRAVEL: Medium grained, light brown.	Non - frozen									
	185.0	1.0						▨	2						
					TILL: Silty gravelly sand to sand and gravel, fine grained, grey to light brown, dense to very dense, 1.50 m - 1.65 m: Boulder. 1.80 m - 2.30 m: Boulder.	Nbn Inferred									
	184.0	2.0													
	183.0	3.0			3.00 m - 3.15 m: Cobble. 3.20 m - 3.80 m: Boulder.										
	182.0	4.0						▨	9						
	181.0	5.0			5.10 m: Becoming moist.			▨							
					ICE and SOIL / ICE: Grey, hard, granular, clear ice lenses.	ICE		▨							
	180.0	6.0			ICE and SOIL: Stratified with sand, fine grained, grey to brown, 1 mm - 5 mm thick hard ice.	Vs		▨							
					ICE: Clear to grey, hard, granular to clear.	Ice									
	179.0	7.0			TILL: Silty gravelly sand.	Vs Nbn									
	178.0	8.0						▨	10						
	177.0	9.0			SAND: Poorly graded, medium to fine grained, brown. 9.40 m - 9.60 m: Wet.										
	176.0	10.0													

Notes:

HATCH

BOREHOLE REPORT

BH18-TF-02

Sheet 2 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Southwest Corner of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 560,988.0 m

Northing: 7,913,441.0 m

Surface Elevation: 186.00 m

Bottom Elevation: 160.10 m

Total Depth: 25.9 m

Logged By: MY

Reviewed By:

Contractor: Boart Longyear

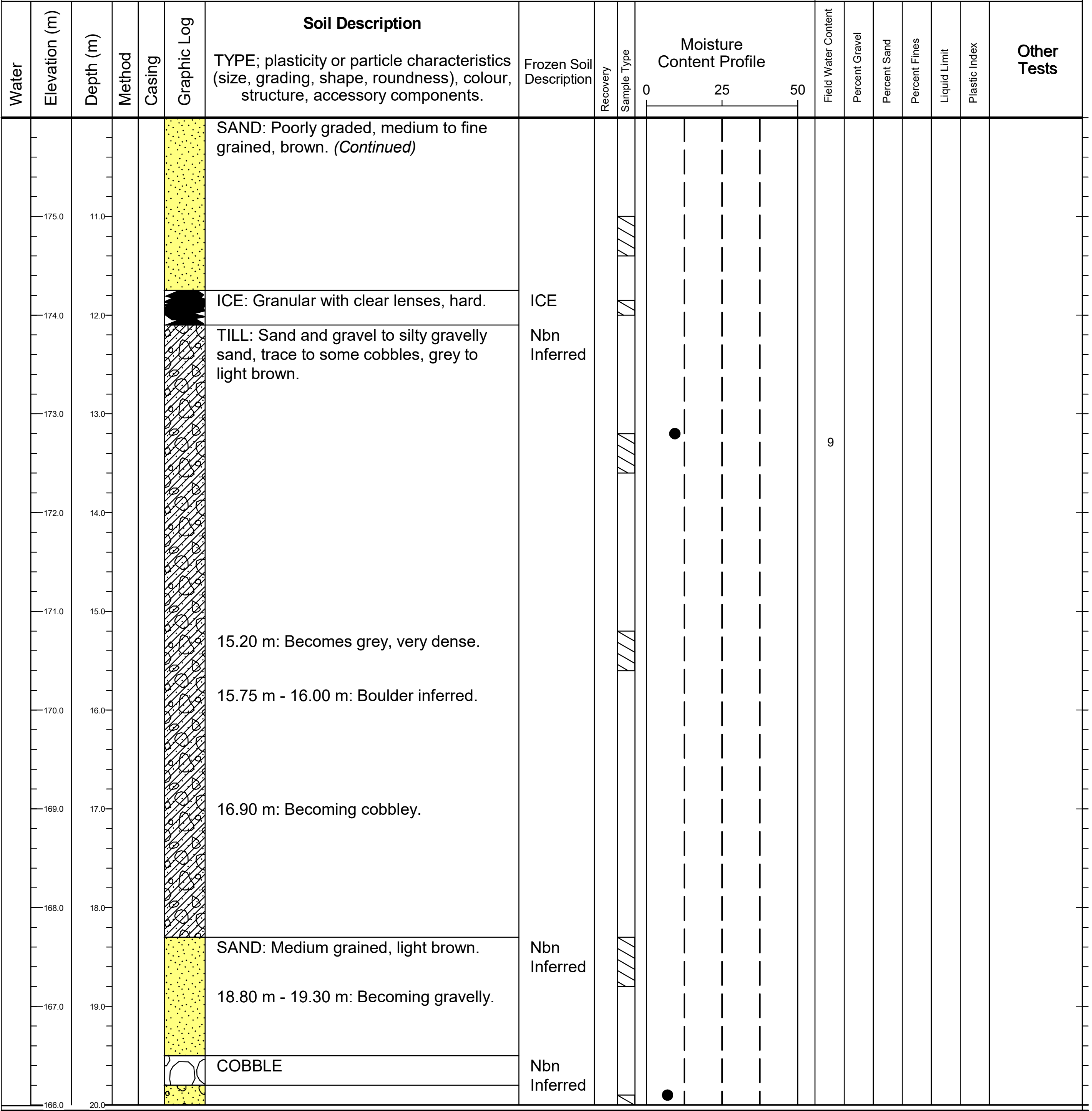
Driller: Brent McAndrew

Rig Type/ Mounting: MiniSonic Rig

Hole Diameter (mm): 100

Date Logged: 6/24/2018

Date Reviewed:



Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
SAND: Poorly graded, medium to fine grained, brown. *(Continued)*								
ICE: Granular with clear lenses, hard.	ICE							
TILL: Sand and gravel to silty gravelly sand, trace to some cobbles, grey to light brown. 15.20 m: Becomes grey, very dense. 15.75 m - 16.00 m: Boulder inferred. 16.90 m: Becoming cobbley.	Nbn Inferred	9						
SAND: Medium grained, light brown. 18.80 m - 19.30 m: Becoming gravelly.	Nbn Inferred							
COBBLE	Nbn Inferred							

Notes:

HATCH

BOREHOLE REPORT

BH18-TF-02

Sheet 3 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Southwest Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:
Easting: 560,988.0 m
Northing: 7,913,441.0 m
Surface Elevation: 186.00 m
Bottom Elevation: 160.10 m
Total Depth: 25.9 m
Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/24/2018
Logged By: MY
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:
Reviewed By:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	**Soil Description** TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	165.0 164.0	21.0 22.0				SILTY GRAVELLY SAND: Light reddish brown, dense. *(Continued)* 20.70 m - 20.90 m: Inferred boulder. 20.90 m - 21.03 m: Grey, loose sand. Boulder from 21.30 m - 21.65 m, and 22.40 m - 22.60 m (Inferred).	Nbn Inferred *(Continued)*		▨		7						
	163.0 162.0 161.0	23.0 24.0 25.0				SAND: Poorly graded, medium grained, light grey to yellowish brown.	Nbn										
	160.0 159.0 158.0 157.0 156.0	26.0 27.0 28.0 29.0 30.0				To Target Depth. **Drillhole BH18-TF-02 terminated at 25.9m.**											

Notes:

HATCH BOREHOLE REPORT

BH18-TF-03

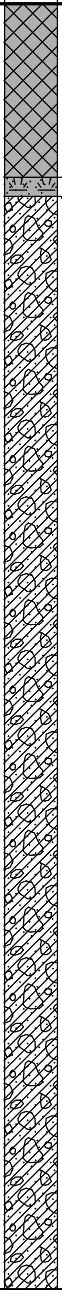
Sheet 1 of 3

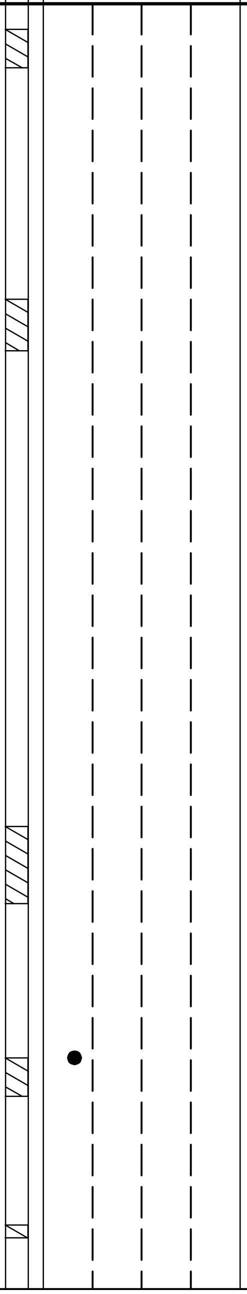
Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Center North Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,094.0 m
Northing: 7,913,477.0 m
Surface Elevation: 188.00 m
Bottom Elevation: 162.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Driller: Brent McAndrew
Rig Type/ Mounting: MiniSonic Rig
Hole Diameter (mm): 100
Date Logged: 6/21/2018
Date Reviewed:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile (0 25 50)	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						SAND and GRAVEL (FILL): Grey to red grains, sub-rounded to angular.	Non - frozen										
	187.0	1.0															
						Possible Reworked Topsoil											
						TILL: Sand and gravel to gravelly sand and silt, trace cobbles, medium to coarse grained, greyish brown.	Nf assumed										
	186.0	2.0				2.00 m: Moist, and loose to dry, and dense											
	185.0	3.0															
	184.0	4.0															
						4.60 m - 4.95 m: Possible rock powder or finer sand / silt. 4.95 m - 5.15 m: Inferred boulder.	Nbn Inferred										
	183.0	5.0															
	182.0	6.0				5.90 m - 6.05 m: Inferred boulder. 6.10 m: Becomes dense to very dense.											
	181.0	7.0															
	180.0	8.0								●	8						
						8.60 m - 9.05 m: Boulder.											
	179.0	9.0				9.10 m - 9.80 m: Wet, possible ice and soil, less than 20% ice.	I+S possible										
						9.80 m - 10.50 m: Boulder, brownish											
	178.0	10.0															





Notes:

BOREHOLE REPORT

BH18-TF-03

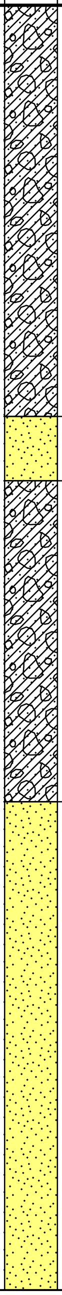
Sheet 2 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Center North Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,094.0 m
Northing: 7,913,477.0 m
Surface Elevation: 188.00 m
Bottom Elevation: 162.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

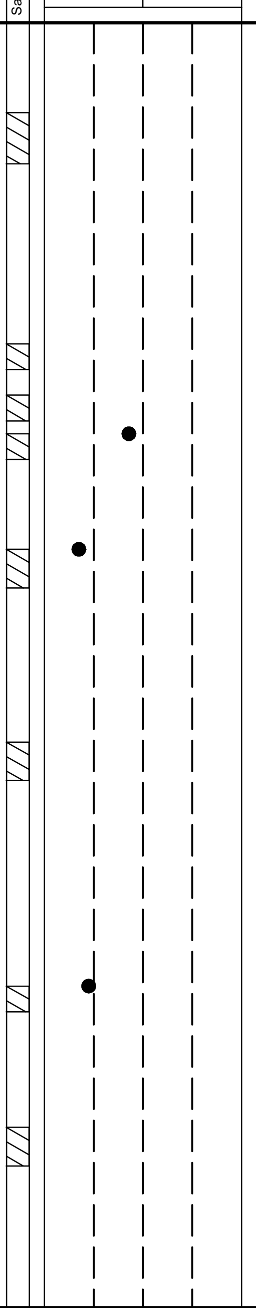
Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/21/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Elevation (m)	Depth (m)
177.0	11.0
176.0	12.0
175.0	13.0
174.0	14.0
173.0	15.0
172.0	16.0
171.0	17.0
170.0	18.0
169.0	19.0
168.0	20.0



Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content
grey sand and gravel after. TILL: Sand and gravel to gravelly sand and silt, trace cobbles, medium to coarse grained, greyish brown. *(Continued)*	Nf assumed *(Continued)* Nf Vc	
SAND: Poorly graded, medium to fine grained, light brown.	Nbn	21
TILL: Sand and gravel, trace cobbles, coarse grained, light brownish grey to light grey.	Vv	9
14.40 m - 14.90 m: Boulder, grey.		
15.20 m - 15.70 m: Moist to wet.	Vc	
SAND to SILTY SAND, some GRAVEL: Poorly graded, yellowish brown to light grey, medium to fine grained.	Nbn inferred	11
17.80 m - 18.00 m: Very hard sand pieces, weathered sandstone or compacted sand, some clevage.	Nbn inferred	

Moisture Content Profile



Water | Method | Casing | Percent Gravel | Percent Sand | Percent Fines | Liquid Limit | Plastic Index | Other Tests

Notes:

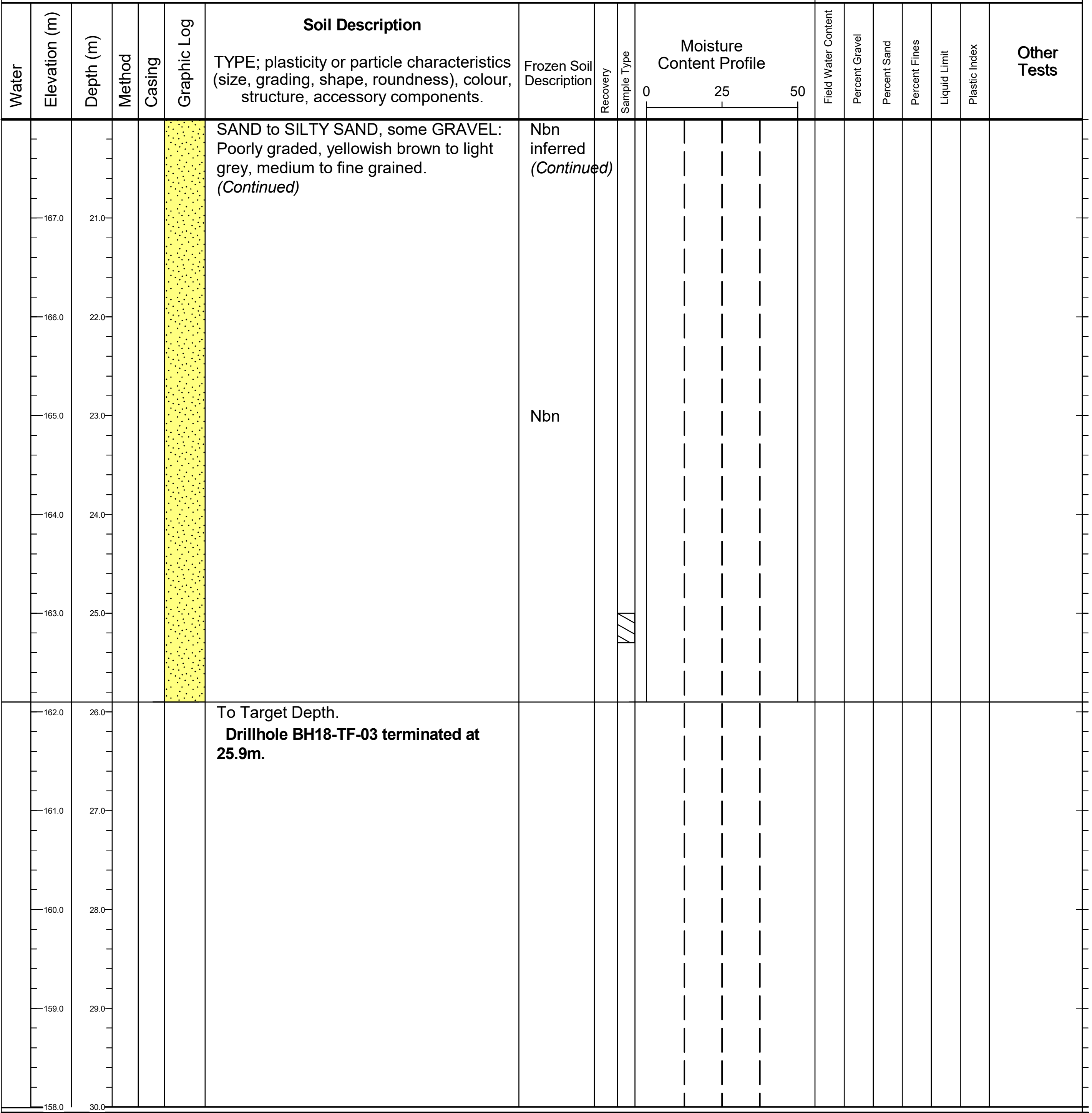
BOREHOLE REPORT

BH18-TF-03

Sheet 3 of 3

Client:	Baffinland Iron Mine	**Project No.:**	H353004
Project:	Mary River Expansion Study	**Datum:**	NAD83
Location:	Center North Corner of Tank Farm	**Platform:**	
Contractor: Boart Longyear	**Rig Type/ Mounting:** MiniSonic Rig	**Date Logged:** 6/21/2018	
Driller: Brent McAndrew	**Hole Diameter (mm):** 100	**Date Reviewed:**	

Easting:	561,094.0 m
Northing:	7,913,477.0 m
Surface Elevation:	188.00 m
Bottom Elevation:	162.10 m
Total Depth:	25.9 m
Logged By:	MY
Reviewed By:	



Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description
SAND to SILTY SAND, some GRAVEL: Poorly graded, yellowish brown to light grey, medium to fine grained. *(Continued)*	Nbn inferred *(Continued)* Nbn
To Target Depth. **Drillhole BH18-TF-03 terminated at 25.9m.**	

Notes:

HATCH

BOREHOLE REPORT

BH18-TF-04

Sheet 1 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Northwest Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

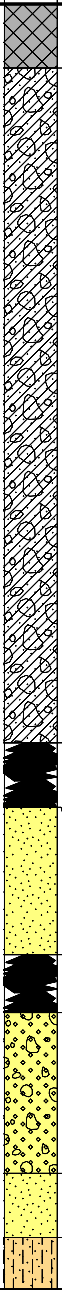
Easting: 561,002.0 m
Northing: 7,913,499.0 m
Surface Elevation: 187.00 m
Bottom Elevation: 161.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/23/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

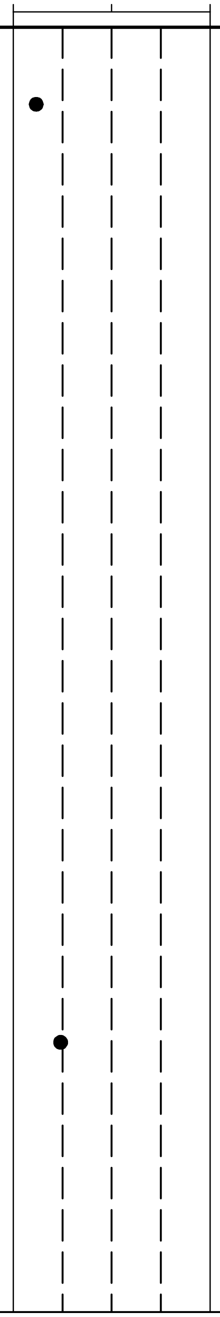
Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content
GRAVELLY SAND (FILL): Brown.	Non - frozen	
TILL: Sand and gravel, some silt, medium to coarse grained, reddish brown. 1.05 m - 1.20 m: Cobble / boulder. 1.70 m - 2.10 m: Boulder. 2.70 m - 3.00 m: Very dense. 3.00 m - 3.85 m: Boulder, red, white, and black banding. 4.60 m: Becoming moist.	Non - frozen Nbn inferred Nf Vs possible	6
ICE with SOIL: Layers of grey ice, soil matrix, circular grains very hard, 1 mm - 5 mm pellets of ice.	I+S	
SAND: Grey, medium to coarse grained, sub-angular to sub-rounded, pellet styled ice to clear lenses, 1 mm - 2 mm, approx. 40% ice.	Vs	
ICE and SOIL: Grey to clear ice, sand grains, 1mm, red to grey, subrounded.	I+S	
SAND and GRAVEL: Coarse grained, red to black.	Nbn Vs Vc	12
SAND: Poorly graded, medium to fine grained, light brownish grey.	Nbn	
SANDY SILT, trace GRAVEL: Fine grained, orangy brown.	Nbn	

Elevation (m)	Depth (m)
186.0	1.0
185.0	2.0
184.0	3.0
183.0	4.0
182.0	5.0
181.0	6.0
180.0	7.0
179.0	8.0
178.0	9.0
177.0	10.0

Water | Elevation (m) | Depth (m) | Method | Casing | Graphic Log | Recovery | Sample Type | Percent Gravel | Percent Sand | Percent Fines | Liquid Limit | Plastic Index | Other Tests



Moisture Content Profile



Notes:

HATCH BOREHOLE REPORT

BH18-TF-04

Sheet 2 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Northwest Corner of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 561,002.0 m

Northing: 7,913,499.0 m

Surface Elevation: 187.00 m

Bottom Elevation: 161.10 m

Total Depth: 25.9 m

Logged By: MY

Reviewed By:

Contractor: Boart Longyear

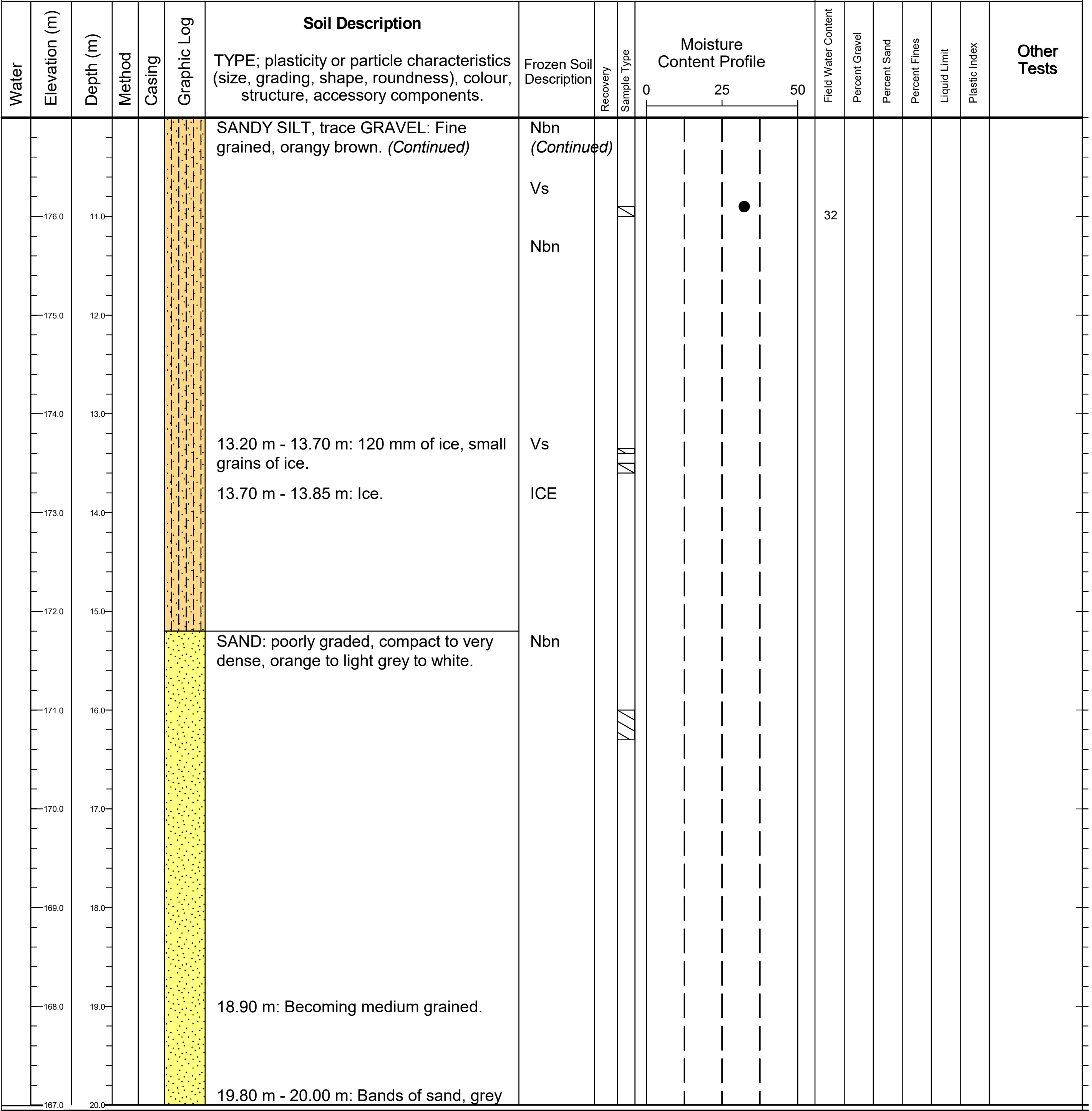
Driller: Brent McAndrew

Rig Type/ Mounting: MiniSonic Rig

Hole Diameter (mm): 100

Date Logged: 6/23/2018

Date Reviewed:



Elevation (m)	Depth (m)	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content
		SANDY SILT, trace GRAVEL: Fine grained, orangy brown. *(Continued)*	Nbn *(Continued)*	
			Vs	
176.0	11.0			32
			Nbn	
175.0	12.0			
174.0	13.0			
		13.20 m - 13.70 m: 120 mm of ice, small grains of ice.	Vs	
		13.70 m - 13.85 m: Ice.	ICE	
173.0	14.0			
172.0	15.0			
		SAND: poorly graded, compact to very dense, orange to light grey to white.	Nbn	
171.0	16.0			
170.0	17.0			
169.0	18.0			
		18.90 m: Becoming medium grained.		
168.0	19.0			
		19.80 m - 20.00 m: Bands of sand, grey		
167.0	20.0			

Notes:

BOREHOLE REPORT

BH18-TF-04

Sheet 3 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Northwest Corner of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 561,002.0 m

Northing: 7,913,499.0 m

Surface Elevation: 187.00 m

Bottom Elevation: 161.10 m

Total Depth: 25.9 m

Logged By: MY

Reviewed By:

Contractor: Boart Longyear

Driller: Brent McAndrew

Rig Type/ Mounting: MiniSonic Rig

Hole Diameter (mm): 100

Date Logged: 6/23/2018

Date Reviewed:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	**Soil Description** TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	**Other Tests**
						organics, very dense sand. SAND: poorly graded, compact to very dense, orange to light grey to white. *(Continued)*	Nbn *(Continued)*										
	166.0	21.0															
	165.0	22.0				22.00 m: Sand, grey, hard.											
	164.0	23.0															
	163.0	24.0															
	162.0	25.0				25.00 m: Becoming silty.			▨	●	12						
	161.0	26.0				To Target Depth. **Drillhole BH18-TF-04 terminated at 25.9m.**											
	160.0	27.0															
	159.0	28.0															
	158.0	29.0															
	157.0	30.0															

Notes:

HATCH BOREHOLE REPORT

BH18-TF-05

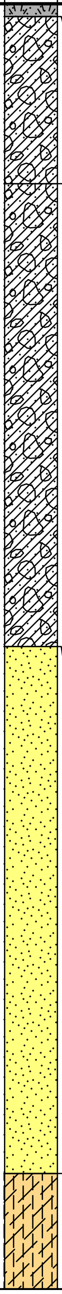
Sheet 1 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Outside Northeast Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,203.0 m
Northing: 7,913,478.0 m
Surface Elevation: 188.00 m
Bottom Elevation: 163.60 m
Total Depth: 24.4 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/18/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Water | Elevation (m) | Depth (m) | Method | Casing | Graphic Log | Soil Description: TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components. | Frozen Soil Description | Recovery | Sample Type | Moisture Content Profile 0 25 50 | Field Water Content | Percent Gravel | Percent Sand | Percent Fines | Liquid Limit | Plastic Index | Other Tests



Elevation (m)	Depth (m)	Soil Description	Frozen Soil Description
		ORGANIC TOPSOIL	Non - frozen
		Possible TILL: Mainly boulder fragments and cobbles with rock dust, grey, sub-rounded, 6 cm - 9 cm cobbles.	
187.0	1.0		
		TILL: Sand and gravel, trace to some cobbles, medium to coarse grained, grey to light brown.	Possible Nf
186.0	2.0		
185.0	3.0		
			Nf
184.0	4.0		
183.0	5.0	5.00 m: Slow transition from till to sand.	
		SAND, trace COBBLES: Poorly graded, light brown, cobbles at 5.20 m, 5.40 m, and 6.00 m.	
182.0	6.0		
		6.10 m - 6.70 m: Trace gravel.	
			Nbn / Nf
181.0	7.0		
			Nbn
180.0	8.0		
179.0	9.0		
		SILTY CLAY: Poorly graded, yellowish brown, black layers.	Nbn / Vs
178.0	10.0		

Notes:

BOREHOLE REPORT

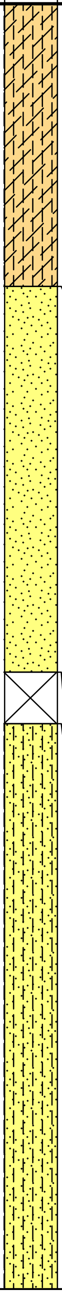
BH18-TF-05

Sheet 2 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Outside Northeast Corner of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,203.0 m
Northing: 7,913,478.0 m
Surface Elevation: 188.00 m
Bottom Elevation: 163.60 m
Total Depth: 24.4 m

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/18/2018
Logged By: MY
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:
Reviewed By:



Water	Elevation (m)	Depth (m)	Method	Casing	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
					SILTY CLAY: Poorly graded, yellowish brown, black layers. *(Continued)*	Nbn / Vs *(Continued)*										
	177.0	11.0														
	176.0	12.0			12.05 m: Dark stratified layer.	Nbn										
					SAND: Poorly graded, medium grained, light brown.	Nbn										
	175.0	13.0														
					13.60 m: Thin silt band (possible clay), darker grey.											
	174.0	14.0														
					14.75 m - 14.80 m: Dark organics in sand, black / dark grey.											
	173.0	15.0			15.00 m: Starting to change to silty sand then silt.											
					NO RECOVERY	Nbn										
	172.0	16.0			SAND with SILT: Poorly graded, medium to fine grained, grey to dark grey, possible sandstone pieces approx every 20 cm, hard frozen sand embedded in sand with silt.											
	171.0	17.0														
	170.0	18.0														
					18.60 m: Grey organic layer, 6 cm thick, very dense compacted.											
	169.0	19.0														
	168.0	20.0														

Notes:

HATCH BOREHOLE REPORT

BH18-TF-05

Sheet 3 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Outside Northeast Corner of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 561,203.0 m

Northing: 7,913,478.0 m

Surface Elevation: 188.00 m

Bottom Elevation: 163.60 m

Total Depth: 24.4 m

Logged By: MY

Reviewed By:

Contractor: Boart Longyear

Driller: Brent McAndrew

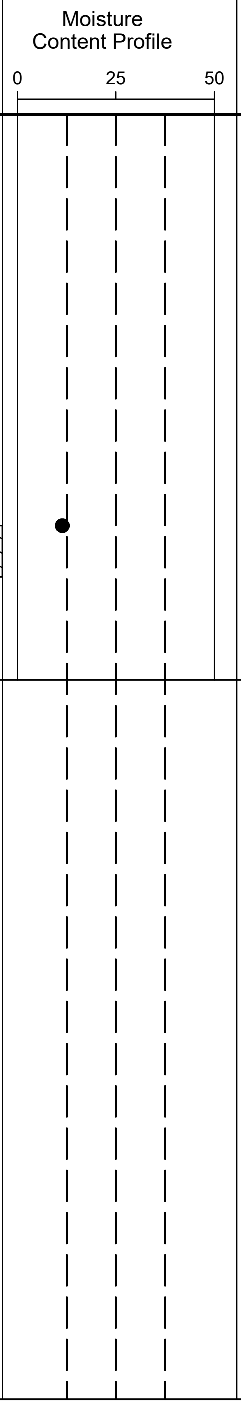
Rig Type/ Mounting: MiniSonic Rig

Hole Diameter (mm): 100

Date Logged: 6/18/2018

Date Reviewed:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	167.0 166.0 165.0 164.0	21.0 22.0 23.0 24.0			▨	SAND with SILT: Poorly graded, medium to fine grained, grey to dark grey, possible sandstone pieces approx every 20 cm, hard frozen sand embedded in sand with silt. *(Continued)*	Nbn *(Continued)*		▨	●	11						
	163.0 162.0 161.0 160.0 159.0 158.0	25.0 26.0 27.0 28.0 29.0 30.0				To Target Depth. **Drillhole BH18-TF-05 terminated at 24.4m.**											



Notes:

HATCH

BOREHOLE REPORT

BH18-TF-7N

Sheet 1 of 2

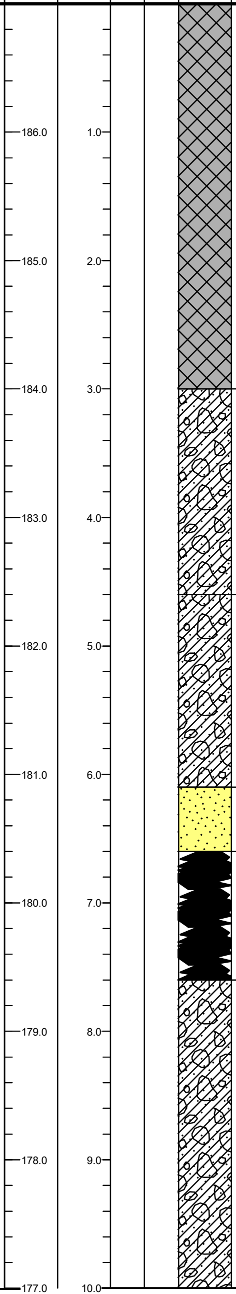
Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: South of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:

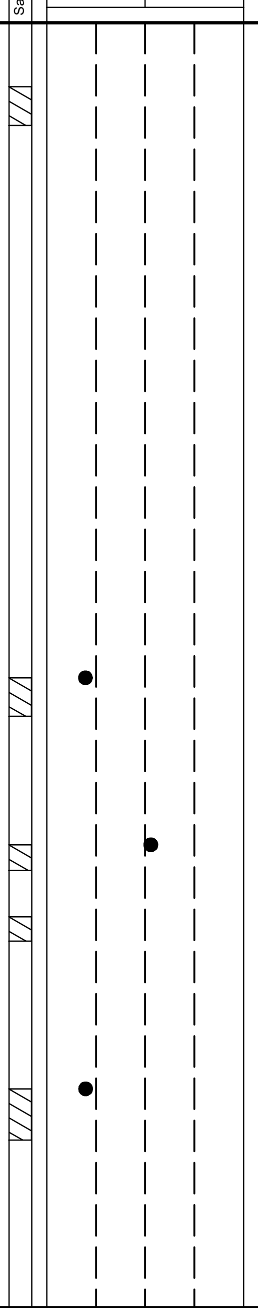
Easting: 561,064.0 m
Northing: 7,913,438.0 m
Surface Elevation: 187.00 m
Bottom Elevation: 174.55 m
Total Depth: 12.5 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/26/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Field Water Content
SAND and GRAVEL, trace COBBLES (FILL): Light grey, loose. 0.30 m: Dark sandy layer, 30 mm thick, possible organic over fill 1.50 m - 3.00 m: Boulder fragments and dust, gravel pieces in between.	Non - frozen	
TILL: Sand and gravel, trace cobbles, medium to fine grained, grey to brownish grey, dense to very dense.	Nbn inferred	
TILL: Sand and gravel to gravelly silty sand, reddish brown, moist to wet, sub-rounded to sub-angular, elongated to 'round'.	Nbn possible Vs	10
SAND, trace to some SILT: Poorly graded, stratified, brown.	Nbn possible	26
ICE: clear, granular, strong with clear grains, 1 mm - 5 mm.	ICE	
TILL: Sand and gravel to silty gravelly sand, trace to some cobbles, coarse grained, grey to light brown, moist. 7.90 m: Dry, medium to fine sand below.	Nbn	10

Columns: Water | Elevation (m) | Depth (m) | Method | Casing | Graphic Log | Recovery | Sample Type | Moisture Content Profile | Percent Gravel | Percent Sand | Percent Fines | Liquid Limit | Plastic Index | Other Tests





Notes:

HATCH

BOREHOLE REPORT

BH18-TF-7N

Sheet 2 of 2

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: South of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 561,064.0 m

Northing: 7,913,438.0 m

Surface Elevation: 187.00 m

Bottom Elevation: 174.55 m

Total Depth: 12.5 m

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 6/26/2018

Logged By: MY

Driller: Brent McAndrew

Hole Diameter (mm): 100

Date Reviewed:

Reviewed By:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	**Soil Description** TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	**Other Tests**
	176.0 175.0	11.0 12.0				TILL: Sand and gravel to silty gravelly sand, trace to some cobbles, coarse grained, grey to light brown, moist. *(Continued)* 10.45 m: Boulder, dark grey with white gneissic banding. 11.90 m - 12.20 m: Boulder and pieces, moist to wet.	Nbn *(Continued)*		▨								
	174.0 173.0 172.0 171.0 170.0 169.0 168.0 167.0	13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0				To Target Depth. **Drillhole BH18-TF-7N terminated at 12.5m.**											

Notes:

HATCH BOREHOLE REPORT

BH18-TF-8N

Sheet 1 of 2

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: East End of Tank Farm
Project No.: H353004
Datum: NAD83
Platform:
Easting: 561,166.0 m
Northing: 7,913,449.0 m
Surface Elevation: 189.00 m
Bottom Elevation: 176.80 m
Total Depth: 12.2 m
Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/26/2018
Logged By: MY
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:
Reviewed By:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile (0 25 50)	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						FILL: Grey, angular, crushed.	Non - frozen										
						TILL: Sand and gravel to gravelly silty sand, trace cobbles, well graded, medium to fine grained, grey.											
	188.0	1.0							▨	●	4						
							Nbn / Nf										
	187.0	2.0															
	186.0	3.0							▨								
	185.0	4.0															
						ICE and SOIL: Sand, fine to coarse grained, grey with red grains, 30% - 40% soil, granular, clear, hard ice, 1 mm - 5 mm grains.	I+S										
	184.0	5.0							▨								
						TILL: Gravelly sand to silty sand, some gravel, trace to some cobbles, medium to fine sand, yellowish grey, sub-rounded to sub-angular.	Nf / Nbn										
	183.0	6.0															
	182.0	7.0							▨	●	6						
						7.60 m - 7.80 m: Moist to wet.											
	181.0	8.0															
	180.0	9.0															
	179.0	10.0															

Notes:

BOREHOLE REPORT

BH18-TF-8N

Sheet 2 of 2

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: East End of Tank Farm

Project No.: H353004

Datum: NAD83

Platform:

Easting: 561,166.0 m

Northing: 7,913,449.0 m

Surface Elevation: 189.00 m

Bottom Elevation: 176.80 m

Total Depth: 12.2 m

Logged By: MY

Reviewed By:

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

Date Logged: 6/26/2018

Driller: Brent McAndrew

Hole Diameter (mm): 100

Date Reviewed:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	**Soil Description** TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
	178.0 177.0	11.0 12.0			▨	TILL: Gravelly sand to silty sand, some gravel, trace to some cobbles, medium to fine sand, yellowish grey, sub-rounded to sub-angular. *(Continued)* 10.50 m - 10.70 m: Moist. 11.20 m - 11.80 m: Moist.	Nf / Nbn *(Continued)* Nbn / Nf		▨								
	176.0 175.0 174.0 173.0 172.0 171.0 170.0 169.0	13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0				To Target Depth. **Drillhole BH18-TF-8N terminated at 12.2m.**											

Notes:

HATCH BOREHOLE REPORT

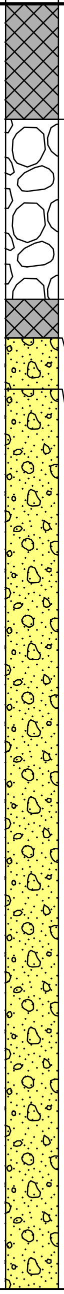
BH18-TW-01

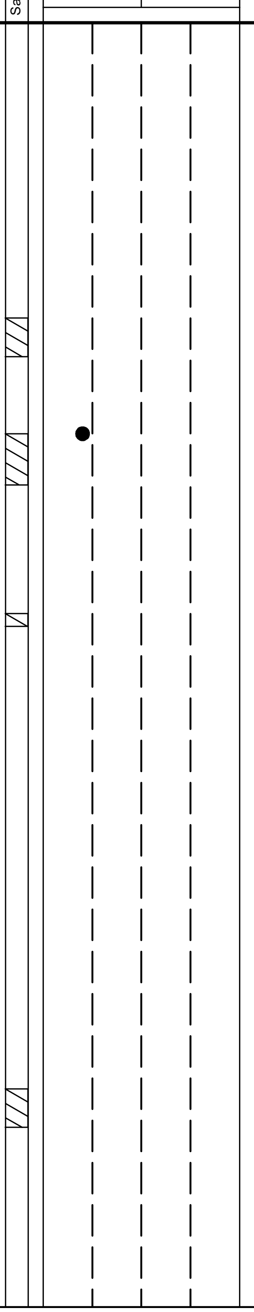
Sheet 1 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Southwest of Truck Workshop
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,477.0 m
Northing: 7,913,189.0 m
Surface Elevation: 195.00 m
Bottom Elevation: 169.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/16/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:





Water	Elevation (m)	Depth (m)	Method	Casing	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
					SANDY GRAVEL, some COBBLES (FILL): Brown, sub-rounded to sub-angular gravel and cobbles.	Non - frozen									
	194.0	1.0			BOULDER: Inferred rock dust.										
	193.0	2.0			SAND, some GRAVEL: Possible fill, light brown, sub-rounded. SAND and GRAVEL: Black, grey to red gravel, sub-rounded to sub-angular.										
	192.0	3.0			SAND with COBBLES, some SILT, some GRAVEL: Fine grained, greyish brown.				10						
	191.0	4.0			4.60 m - 4.70 m: Grey, melt water (snow).										
	190.0	5.0			5.00 m - 5.20 m, 5.60 m, 6.00m: Cobbles.										
	189.0	6.0			6.70 m, 6.90 m, 6.70m: Cobbles.										
	188.0	7.0			7.60 m - 8.30 m: Boulder.										
	187.0	8.0			8.00 m - 8.30 m: Crushed dust.										
	186.0	9.0			9.10 m: Boulder, dust, pulverized, water mixed in.										
	185.0	10.0													

Notes:

HATCH

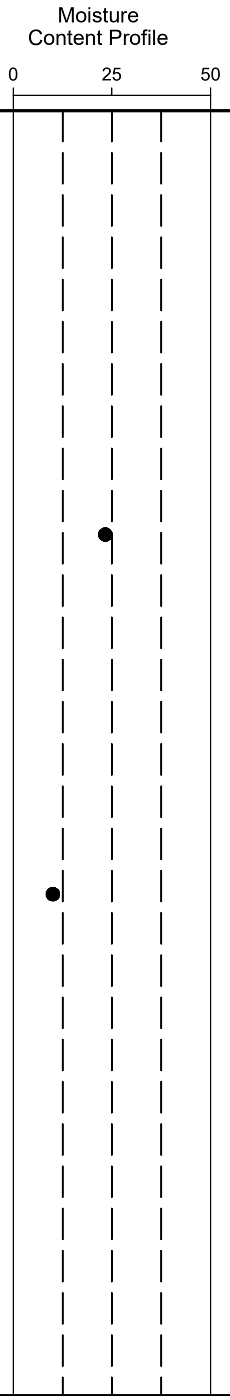
BOREHOLE REPORT

BH18-TW-01

Sheet 2 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Southwest of Truck Workshop
Project No.: H353004
Datum: NAD83
Platform:
Easting: 561,477.0 m
Northing: 7,913,189.0 m
Surface Elevation: 195.00 m
Bottom Elevation: 169.10 m
Total Depth: 25.9 m
Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/16/2018
Logged By: MY
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:
Reviewed By:

Water	Elevation (m)	Depth (m)	Method	Casing	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
					SAND with COBBLES, some SILT, some GRAVEL: Fine grained, greyish brown. *(Continued)*										
	184.0	11.0			COBBLES and BOULDERS: Grey, sub-angular. Cobbles at 10.70 m, 10.90 m, and 11.00 m. 11.45 m - 12.20 m: Inferred boulder.										
	183.0	12.0													
	182.0	13.0													
					SAND: Poorly graded, medium to coarse grained, light brown, sub-angular grains.	Nbn			23						
	181.0	14.0			SAND with GRAVEL, some COBBLES, trace SILT: Well graded, grey, organic smell.	Nf inferred									
					COBBLES: Pulverized, grey, yellow, sulphur smelling layer at 14.50 m, sub-rounded. 14.60 m - 14.70 m: Inferred boulder.	Vs									
	180.0	15.0													
					SAND and GRAVEL, some COBBLES: Greyish brown, red cobbles, sub-angular to sub-rounded.										
	179.0	16.0			ICE with SOIL (inferred). Ice at 15.85 m.				10						
					SILTY GRAVELLY SAND, some COBBLES: Medium to coarse grained sand, grey, sub-rounded.	Nf inferred									
	178.0	17.0													
					17.70 m: Becoming reddish brown.										
	177.0	18.0													
					SAND and GRAVEL, trace COBBLES: Fine to coarse grained, brownish grey, sub-rounded to sub-angular sand. 18.50 m: Becoming dry.										
	176.0	19.0													
					19.60 m, 19.80 m - 19.90m: Cobbles.										
	175.0	20.0													



Notes:

BOREHOLE REPORT

BH18-TW-01

Sheet 3 of 3

Client: Baffinland Iron Mine

Project: Mary River Expansion Study

Location: Southwest of Truck Workshop

Project No.: H353004

Datum: NAD83

Platform:

Contractor: Boart Longyear

Rig Type/ Mounting: MiniSonic Rig

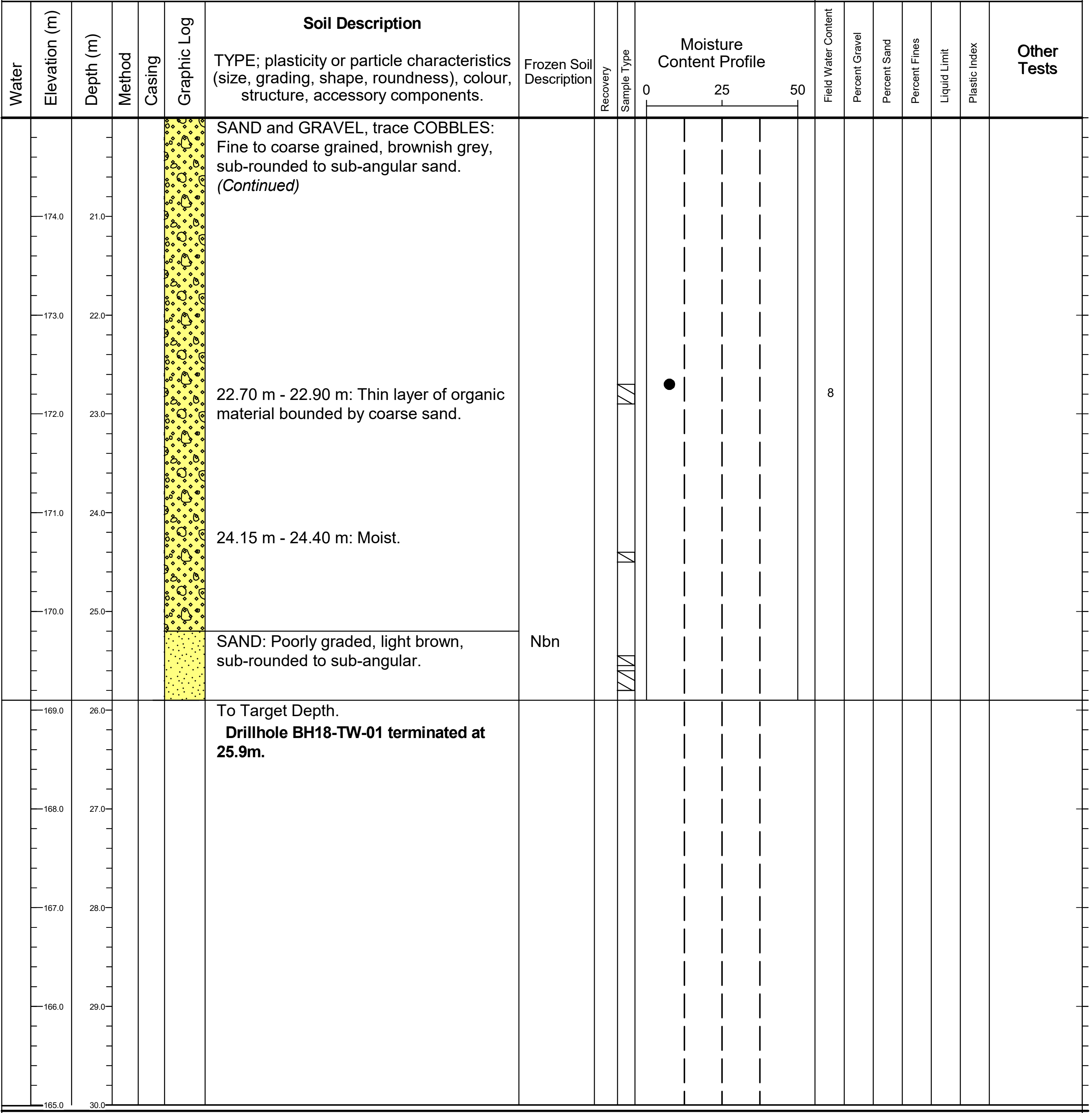
Date Logged: 6/16/2018

Driller: Brent McAndrew

Hole Diameter (mm): 100

Date Reviewed:

Easting:	561,477.0 m
Northing:	7,913,189.0 m
Surface Elevation:	195.00 m
Bottom Elevation:	169.10 m
Total Depth:	25.9 m
Logged By:	MY
Reviewed By:	



SAND and GRAVEL, trace COBBLES: Fine to coarse grained, brownish grey, sub-rounded to sub-angular sand. *(Continued)*

22.70 m - 22.90 m: Thin layer of organic material bounded by coarse sand.

24.15 m - 24.40 m: Moist.

SAND: Poorly graded, light brown, sub-rounded to sub-angular.

To Target Depth.

Drillhole BH18-TW-01 terminated at 25.9m.

Notes:

HATCH BOREHOLE REPORT

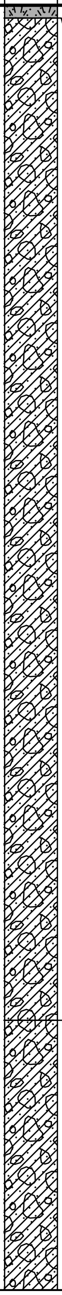
BH18-TW-02

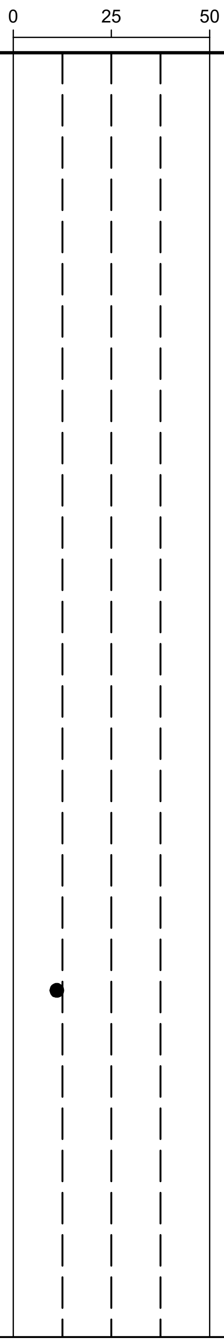
Sheet 1 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Northeast of Truck Workshop
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,532.0 m
Northing: 7,913,229.0 m
Surface Elevation: 200.00 m
Bottom Elevation: 174.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/20/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:





Elevation (m)	Depth (m)	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Sample Type	Field Water Content
		TOPSOIL: Organic	Non - frozen		
		TILL: Sand with gravel, light brown transition to grey. 0.70 m: Some cobbles (0.30 m, 0.60 m), 80 mm - 130 mm, grey to red gravel and sand.			
199.0	1.0				
			Possible Nf / Nbn		
198.0	2.0	2.00 m: Cobble.		▨	
197.0	3.0				
		3.45 m - 3.60 m: Compacted / very dense. 3.85 m: Becoming wet (surface run-off down the hole).	Nf / Nbn		
196.0	4.0				
		4.60 m, 5.00 m: Cobbles (100 mm), sub-angular to sub-rounded.	Nf / Nbn inferred		
195.0	5.0				
194.0	6.0	6.10 m: Some cobbles to becoming cobbley.			
193.0	7.0				
		7.30 m: Trace silt, moist to wet.		▨	11
		7.60 m - 7.90 m: Boulder.			
192.0	8.0	TILL: Sand and gravel, trace cobbles, medium to coarse grained, brownish grey, sub-angular to sub-rounded.			
191.0	9.0	9.10 m - 10.30 m: Possible traces silt.		▨	
190.0	10.0				

Water | Method | Casing | Graphic Log | Recovery | Percent Gravel | Percent Sand | Percent Fines | Liquid Limit | Plastic Index | Other Tests

Notes:

BOREHOLE REPORT

BH18-TW-02

Sheet 2 of 3

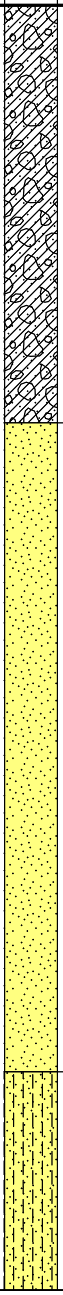
Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Northeast of Truck Workshop
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,532.0 m
Northing: 7,913,229.0 m
Surface Elevation: 200.00 m
Bottom Elevation: 174.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

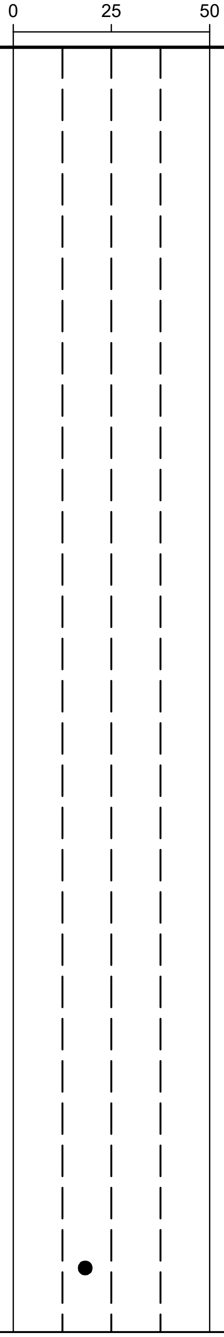
Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/20/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Water	Elevation (m)	Depth (m)	Method	Casing	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
					TILL: Sand and gravel, trace cobbles, medium to coarse grained, brownish grey, sub-angular to sub-rounded. *(Continued)*	Nbn / Nf									
	189.0	11.0													
	188.0	12.0													
					12.20 m: Poorly graded, wet to melted.	Nbn									
	187.0	13.0													
					SAND: Poorly graded, medium to fine grained, yellowish brown to light grey / white.										
	186.0	14.0													
	185.0	15.0													
	184.0	16.0													
	183.0	17.0													
						Vs									
	182.0	18.0													
					SILT and SAND to SILT, trace SAND: Poorly graded, light brown.	Nbn									
	181.0	19.0													
									18						
	180.0	20.0													

Graphic Log



Moisture Content Profile



Notes:

HATCH BOREHOLE REPORT

BH18-TW-02

Sheet 3 of 3

Client: Baffinland Iron Mine
Project: Mary River Expansion Study
Location: Northeast of Truck Workshop
Project No.: H353004
Datum: NAD83
Platform:

Easting: 561,532.0 m
Northing: 7,913,229.0 m
Surface Elevation: 200.00 m
Bottom Elevation: 174.10 m
Total Depth: 25.9 m
Logged By: MY
Reviewed By:

Contractor: Boart Longyear
Rig Type/ Mounting: MiniSonic Rig
Date Logged: 6/20/2018
Driller: Brent McAndrew
Hole Diameter (mm): 100
Date Reviewed:

Water	Elevation (m)	Depth (m)	Method	Casing	Graphic Log	Soil Description TYPE; plasticity or particle characteristics (size, grading, shape, roundness), colour, structure, accessory components.	Frozen Soil Description	Recovery	Sample Type	Moisture Content Profile 0 25 50	Field Water Content	Percent Gravel	Percent Sand	Percent Fines	Liquid Limit	Plastic Index	Other Tests
						SILT and SAND to SILT, trace SAND: Poorly graded, light brown. *(Continued)*	Nbn *(Continued)*										
	179.0	21.0				SAND: Poorly graded, medium grained, greenish brown, dark band at 21.20 m.											
	178.0	22.0							▨								
	177.0	23.0															
	176.0	24.0															
	175.0	25.0							▨								
	174.0	26.0				To Target Depth. **Drillhole BH18-TW-02 terminated at 25.9m.**											
	173.0	27.0															
	172.0	28.0															
	171.0	29.0															
	170.0	30.0															

Notes:

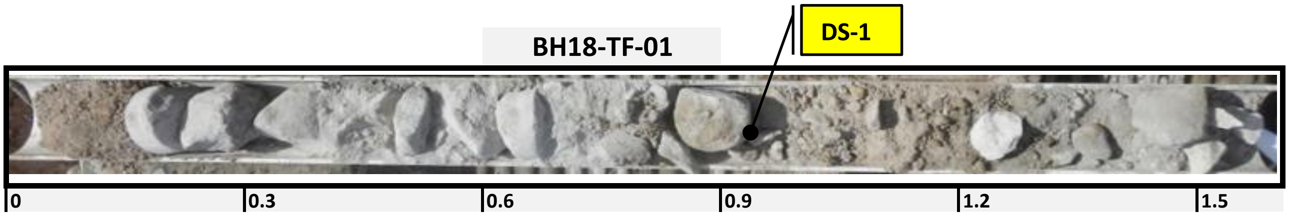
Appendix C

Sample Photographs

Sample Photographs

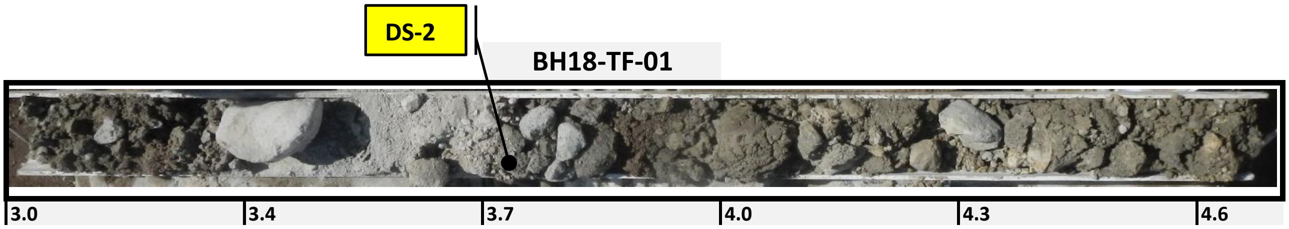
Borehole Name:	BH18-TF-01	Mary River Expansion Study Stage 2
Location:	17 W 561154 7913396	2018 Geotechnical Investigation
Completion Date:	June 25, 2018	Baffinland Iron Mines

BH18-TF-01



BH18-TF-01

BH18-TF-01



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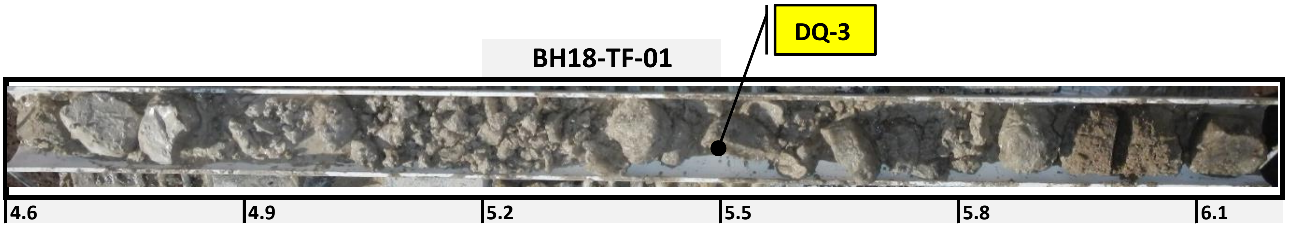
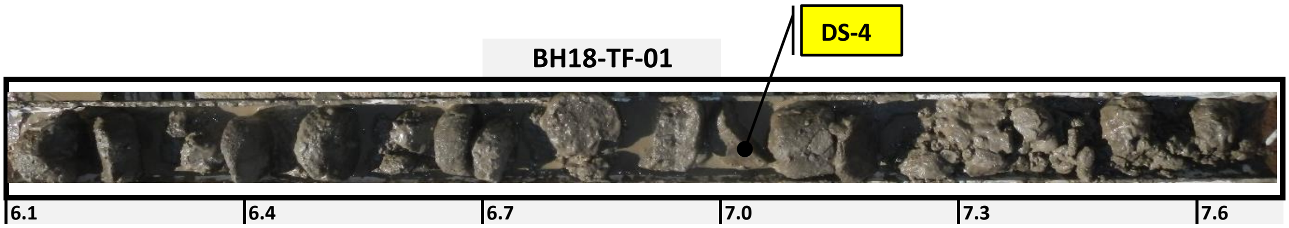


BH18-TF-01



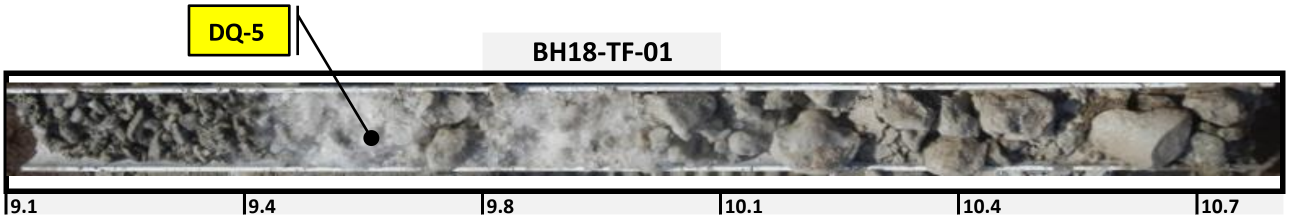
BH18-TF-01

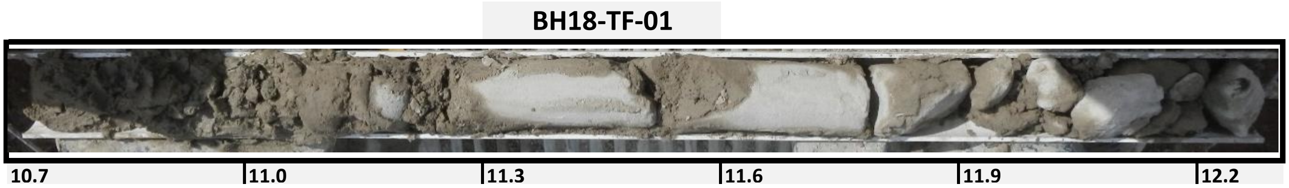
Sample Photographs

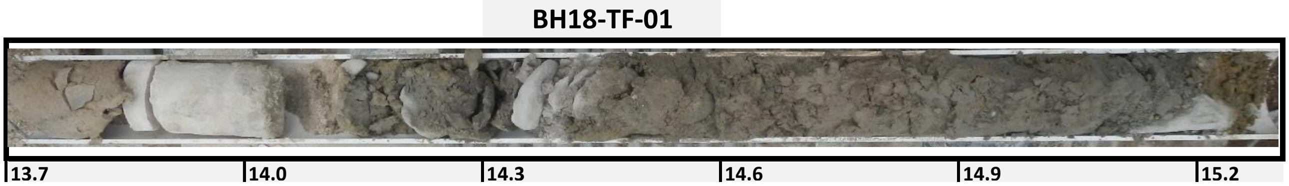
Borehole Name: BH18-TF-01
Location: 17 W 561154 7913396
Completion Date: June 25, 2018

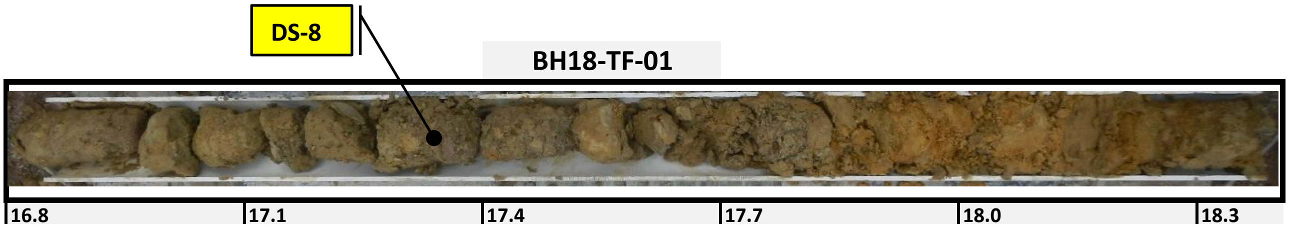
Mary River Expansion Study Stage 2

Baffinland Iron Mines









Sample Photographs

Borehole Name: BH18-TF-01
Location: 17 W 561154 7913396
Completion Date: June 25, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines

BH18-TF-01

BH18-TF-01

BH18-TF-01

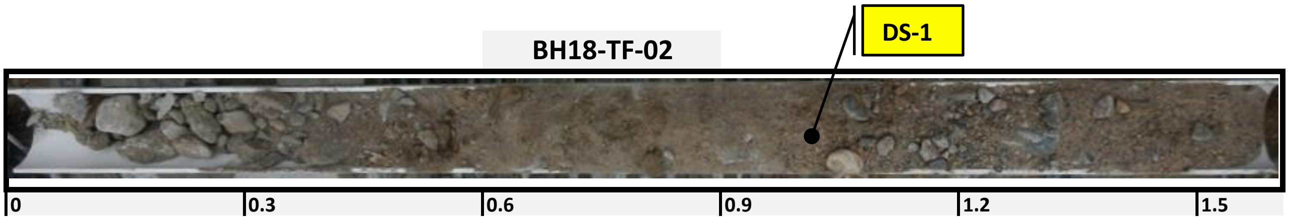
BH18-TF-01

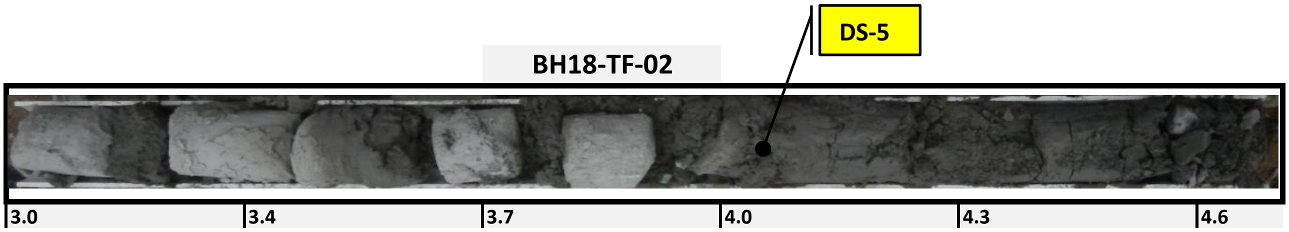
BH18-TF-01

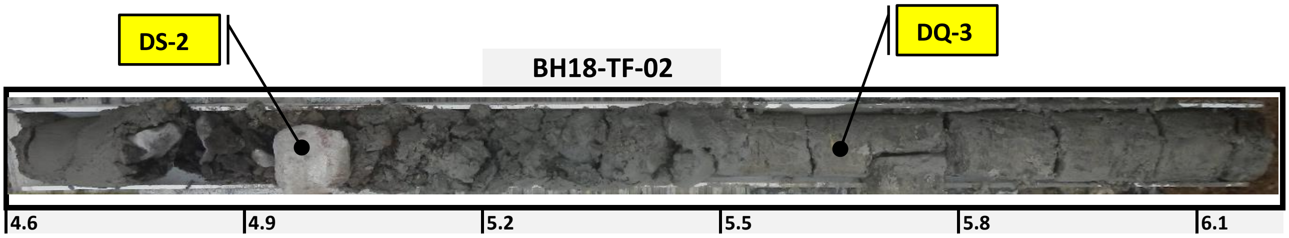
Sample Photographs

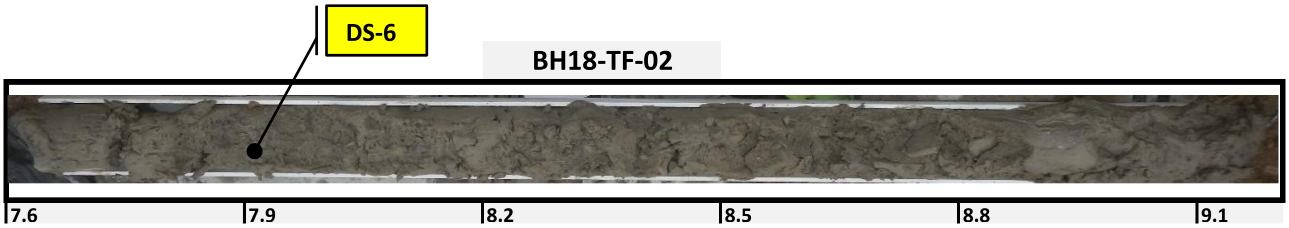
Borehole Name: BH18-TF-02
Location: 17 W 560988 7913441
Completion Date: June 24, 2018

Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines









Sample Photographs

Borehole Name:	BH18-TF-02	Mary River Expansion Study Stage 2
Location:	17 W 560988 7913441	
Completion Date:	June 24, 2018	Baffinland Iron Mines

BH18-TF-02

BH18-TF-02

BH18-TF-02

BH18-TF-02

BH18-TF-02

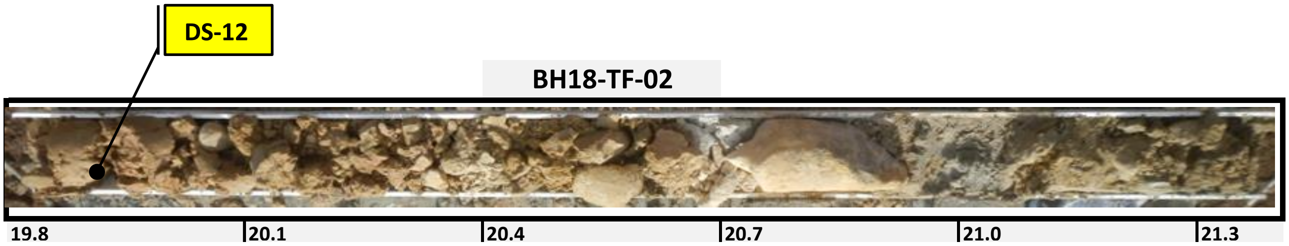
BH18-TF-02

Sample Photographs

Borehole Name:	BH18-TF-02	Mary River Expansion Study Stage 2
Location:	17 W 560988 7913441	
Completion Date:	June 24, 2018	Baffinland Iron Mines

BH18-TF-02

BH18-TF-02



BH18-TF-02

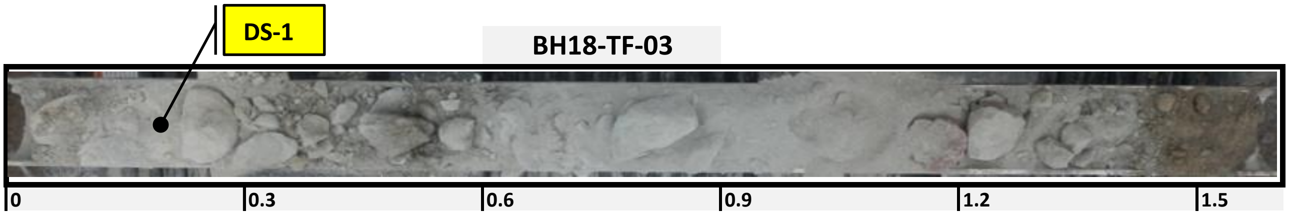
BH18-TF-02

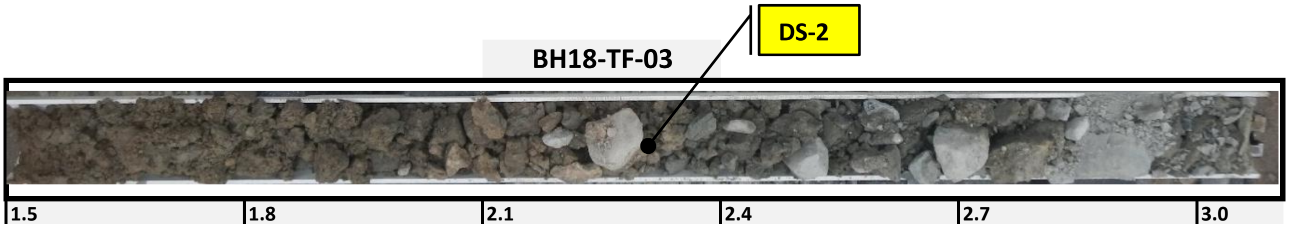
BH18-TF-02

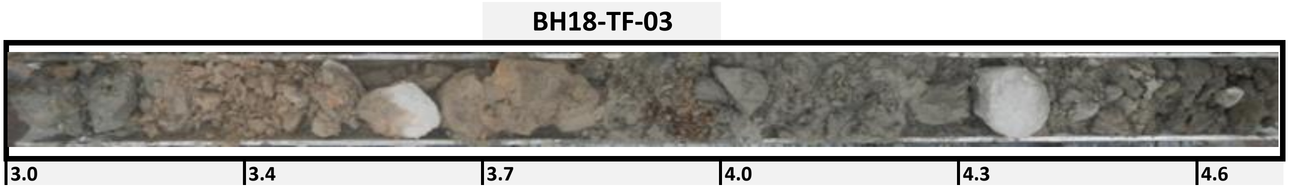
Sample Photographs

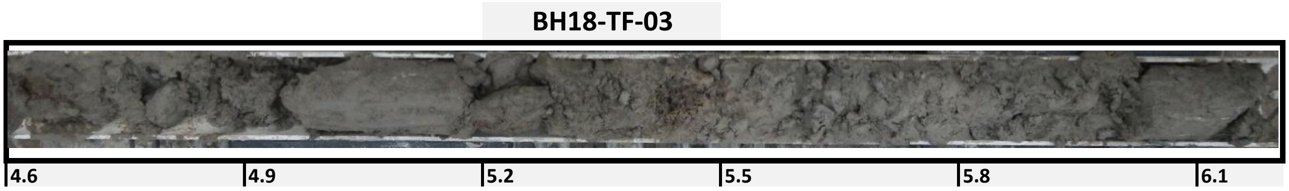
Borehole Name: BH18-TF-03
Location: 17 W 561094 7913477
Completion Date: June 22, 2018

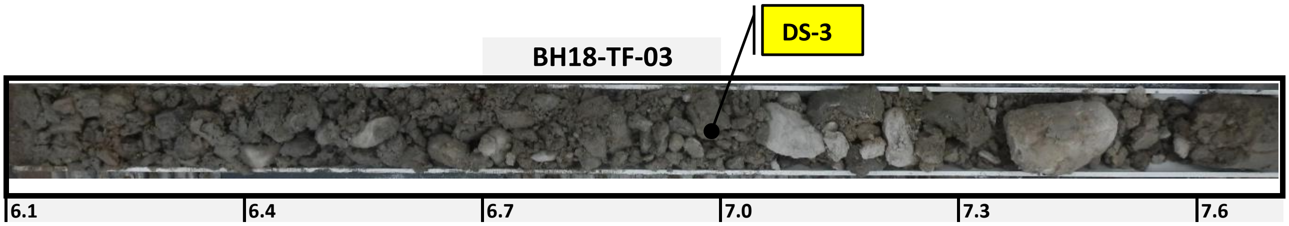
Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines

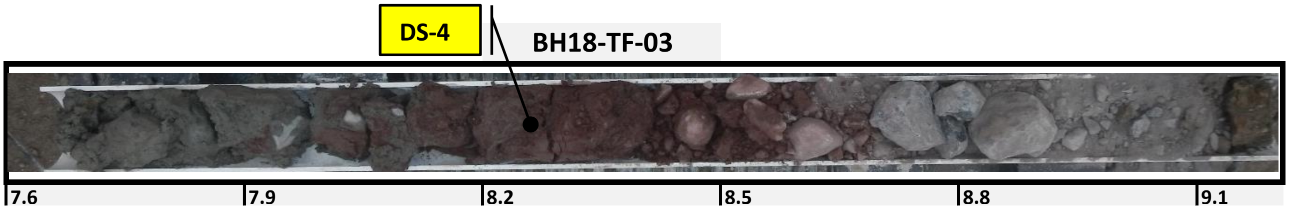






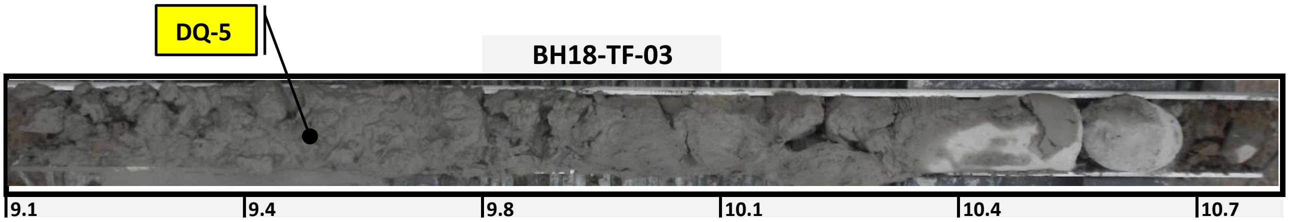


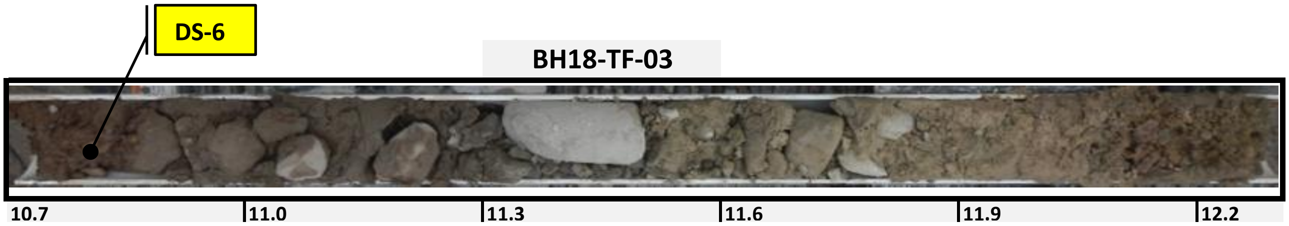


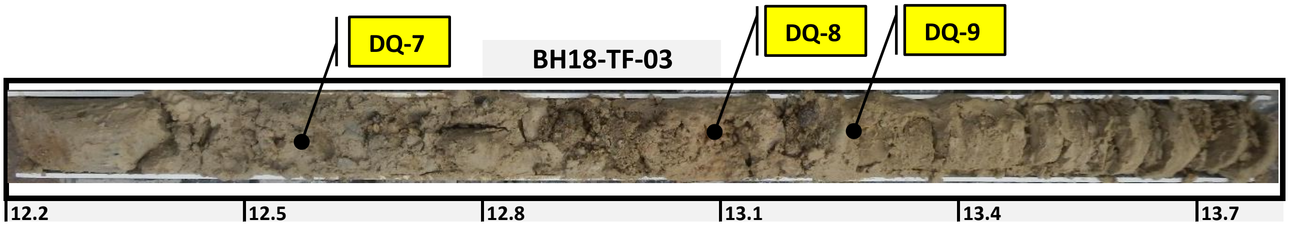


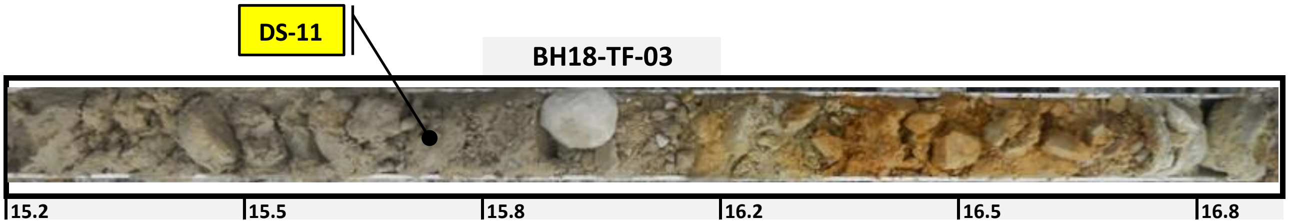
Sample Photographs

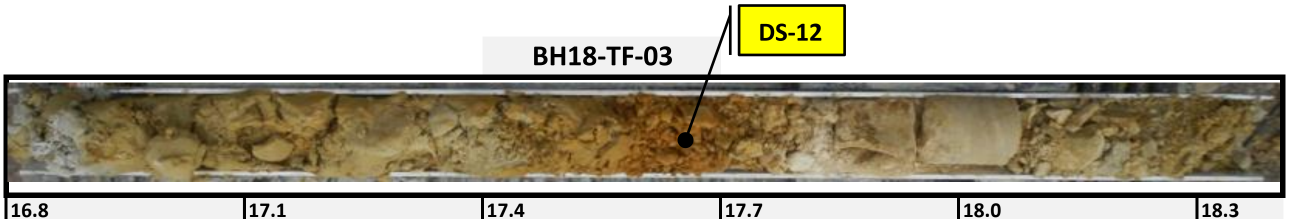
Borehole Name:	BH18-TF-03	Mary River Expansion Study Stage 2
Location:	17 W 561094 7913477	
Completion Date:	June 22, 2018	Baffinland Iron Mines









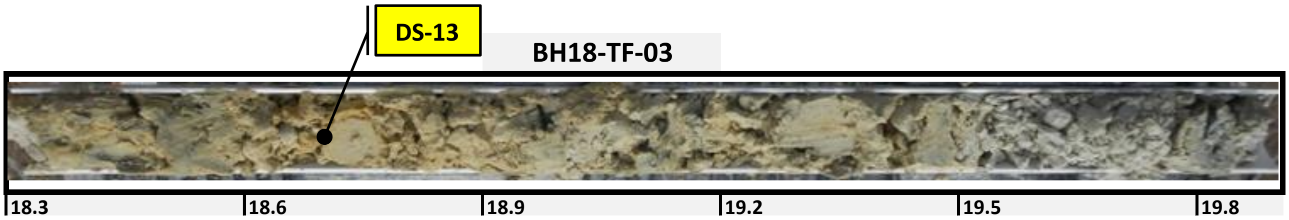


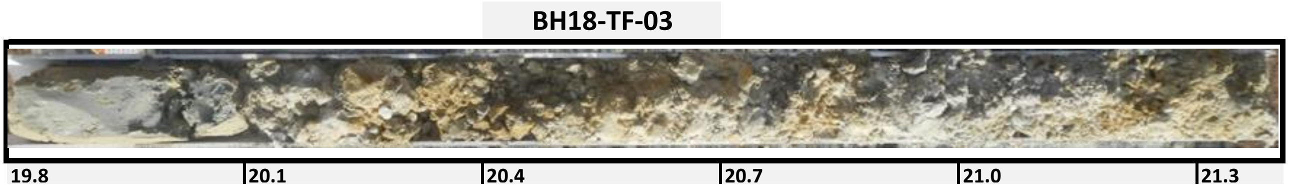
Sample Photographs

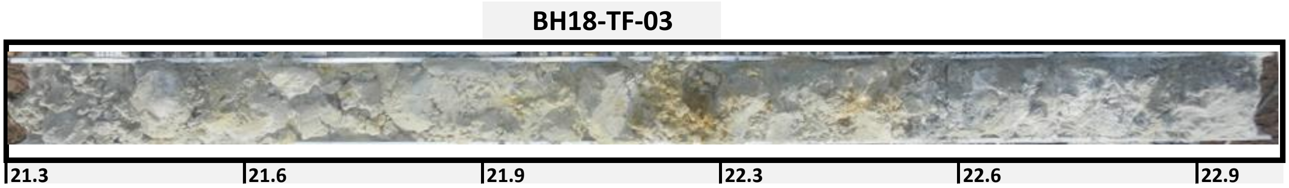
Borehole Name: BH18-TF-03
Location: 17 W 561094 7913477
Completion Date: June 22, 2018

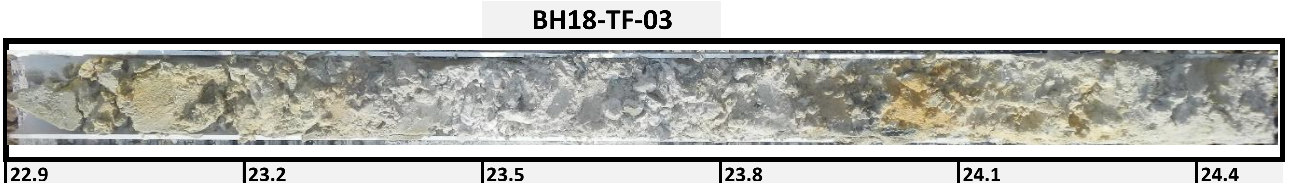
Mary River Expansion Study Stage 2

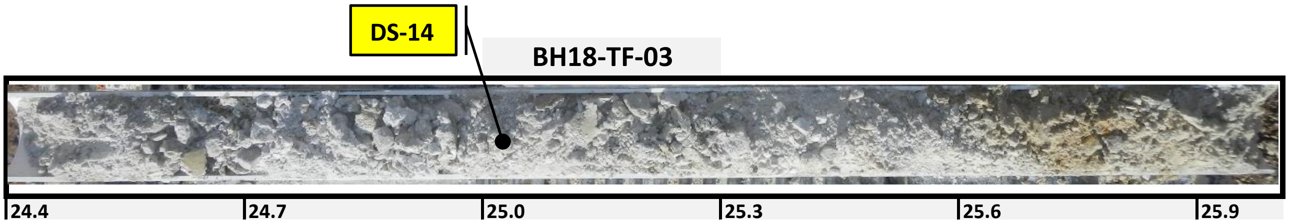
Baffinland Iron Mines









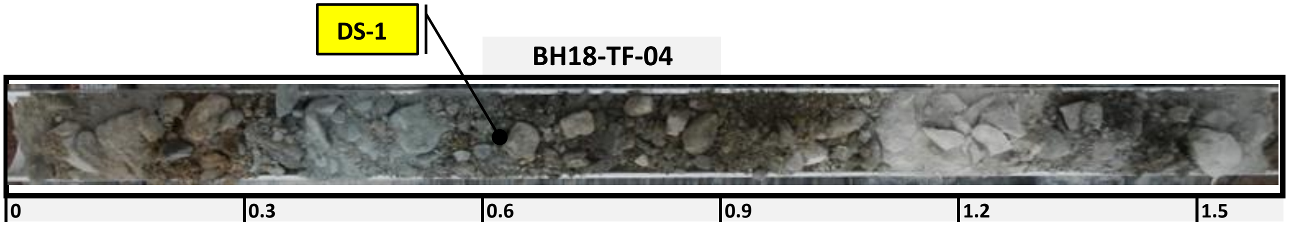


Sample Photographs

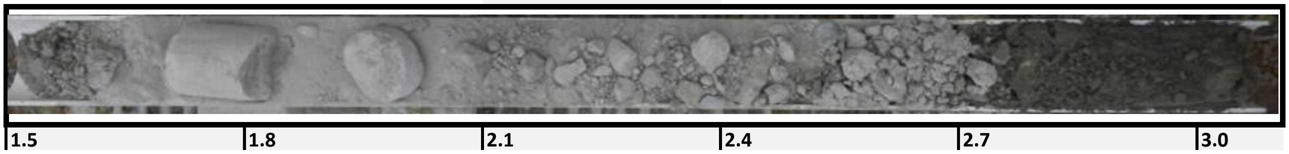
Borehole Name: BH18-TF-04
Location: 17 W 561002 7913499
Completion Date: June 24, 2018

Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines

BH18-TF-04



BH18-TF-04



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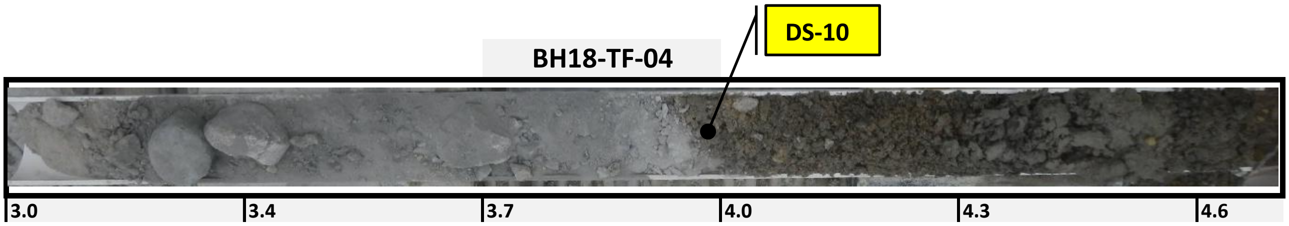

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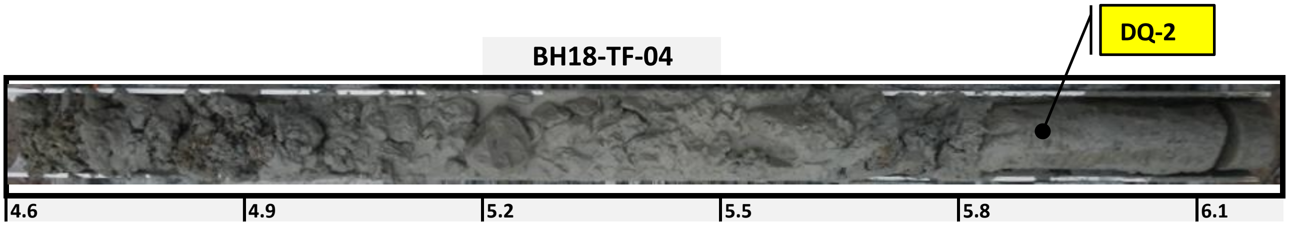
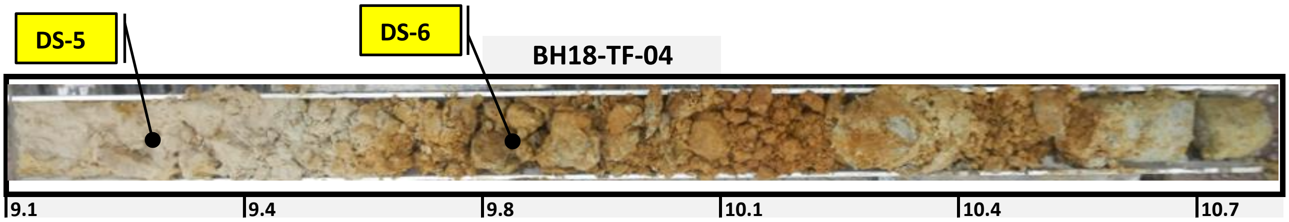


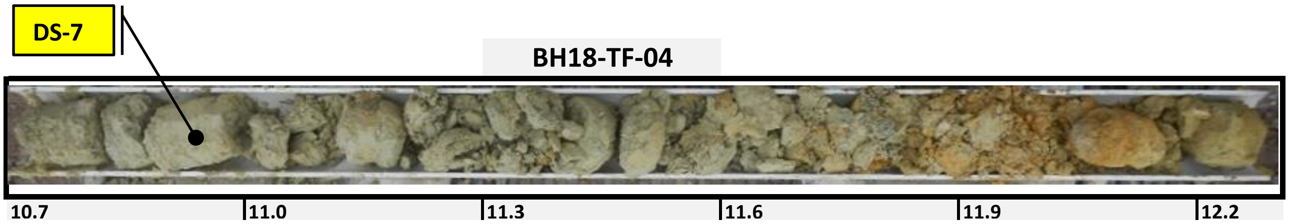
BH18-TF-04

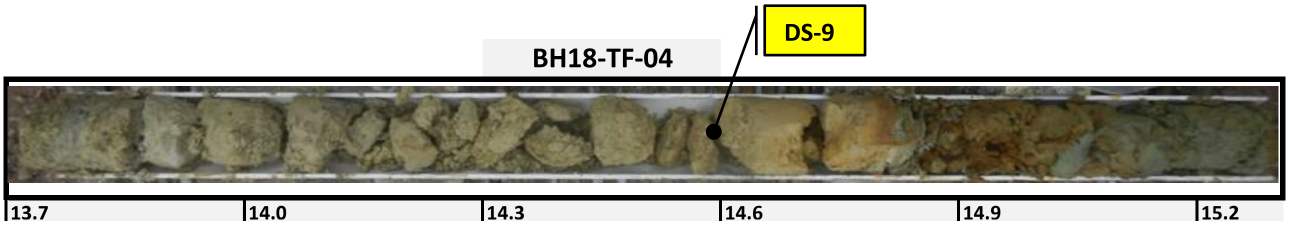
BH18-TF-04

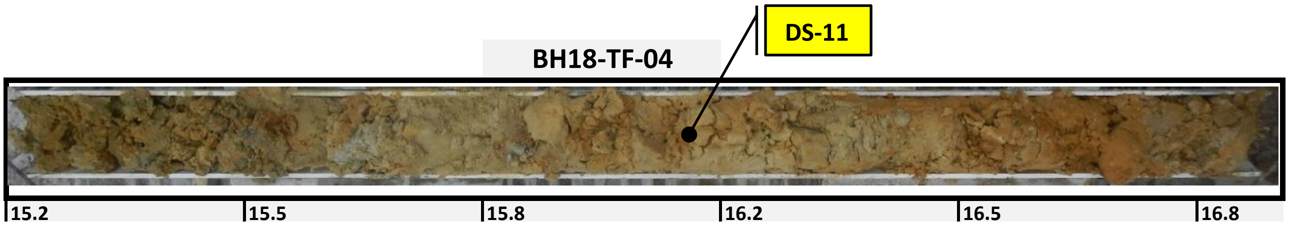
Sample Photographs

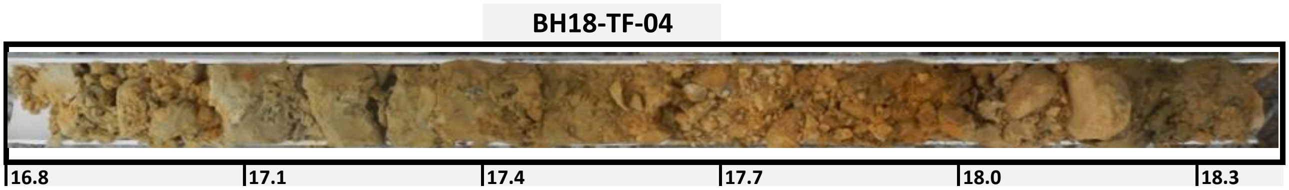
Borehole Name:	BH18-TF-04	Mary River Expansion Study Stage 2
Location:	17 W 561002 7913499	
Completion Date:	June 24, 2018	Baffinland Iron Mines











Sample Photographs

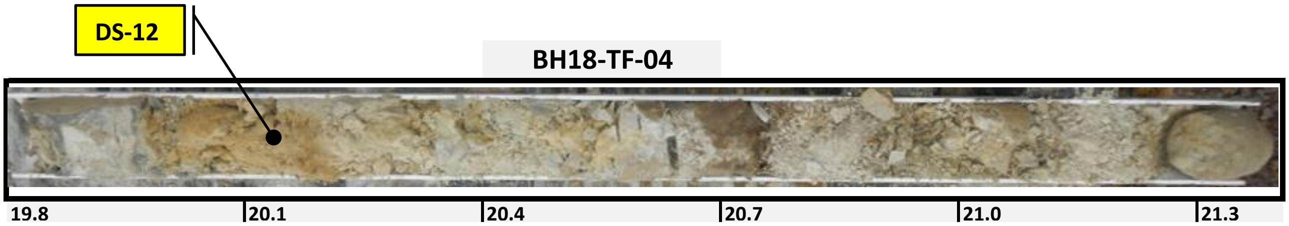
Borehole Name: BH18-TF-04
Location: 17 W 561002 7913499
Completion Date: June 24, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines

BH18-TF-04

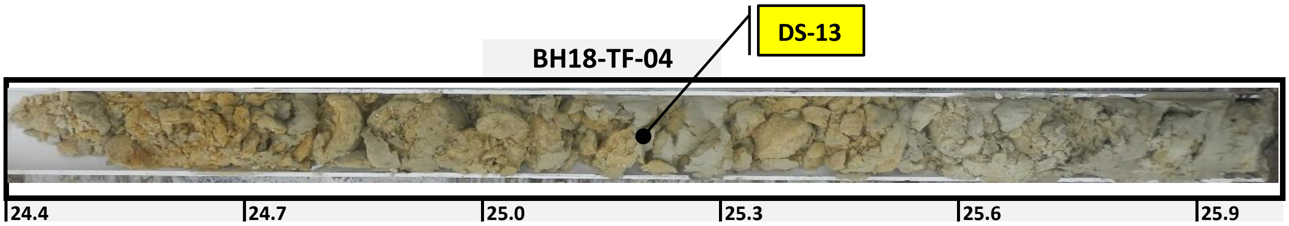
BH18-TF-04



BH18-TF-04

BH18-TF-04

BH18-TF-04



Sample Photographs

Borehole Name: BH18-TF-05
Location: 17 W 561203 7913478
Completion Date: June 20, 2018

Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines

BH18-TF-05

BH18-TF-05

BH18-TF-05

BH18-TF-05

BH18-TF-05

BH18-TF-05

Sample Photographs

Borehole Name: BH18-TF-05

Location: 17 W 561203 7913478

Completion Date: June 20, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines

BH18-TF-05

BH18-TF-05

BH18-TF-05

BH18-TF-05

BH18-TF-05

BH18-TF-05

Sample Photographs

Borehole Name: BH18-TF-05
Location: 17 W 561203 7913478
Completion Date: June 20, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines

BH18-TF-05

BH18-TF-05

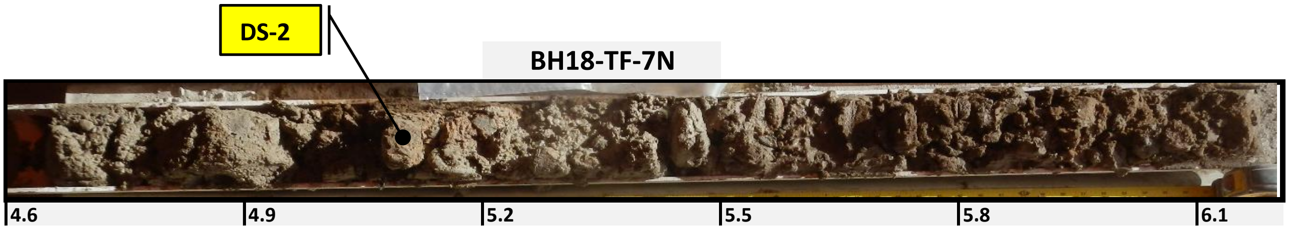
BH18-TF-05

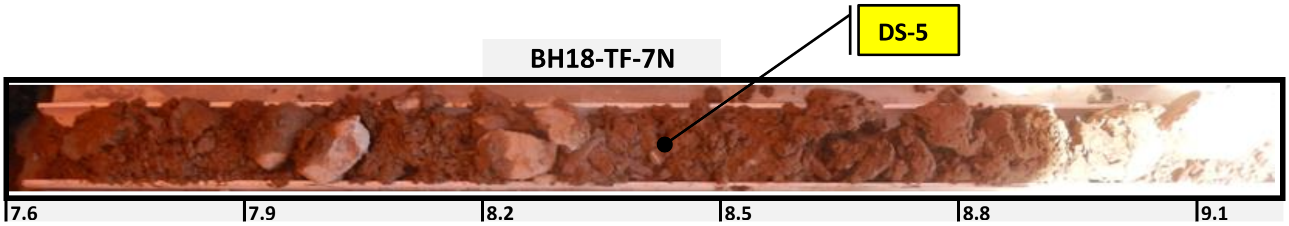
BH18-TF-05

Sample Photographs

Borehole Name: BH18-TF-7N
Location: 17 W 561064 7913438
Completion Date: June 26, 2018

Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines





Sample Photographs

Borehole Name:	BH18-TF-7N	Mary River Expansion Study Stage 2
Location:	17 W 561064 7913438	
Completion Date:	June 26, 2018	Baffinland Iron Mines

BH18-TF-7N

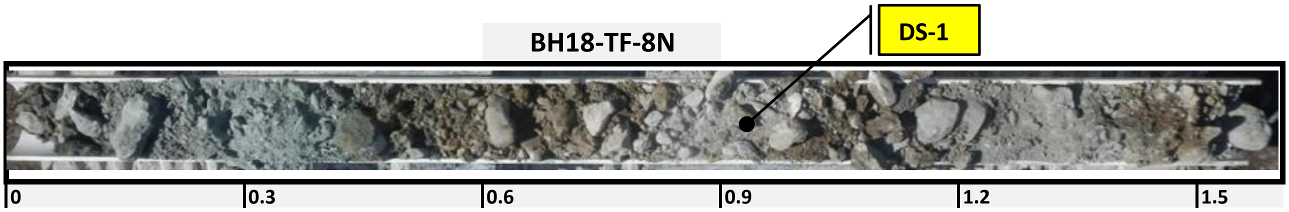
BH18-TF-7N

Sample Photographs

Borehole Name: BH18-TF-8N
Location: 17 W 561166 7913449
Completion Date: June 27, 2018

Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines

BH18-TF-8N



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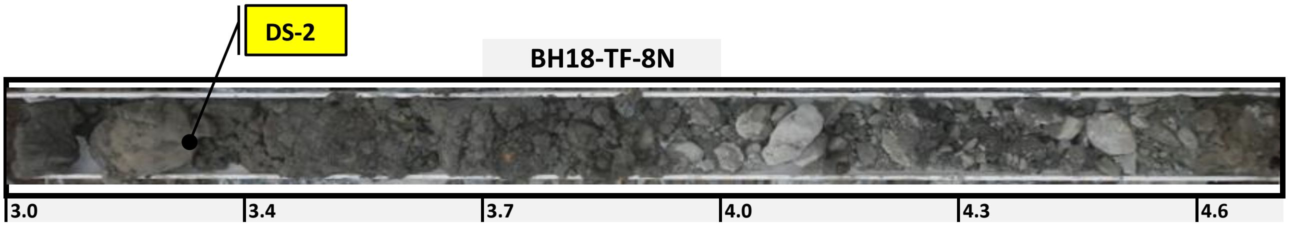
BH18-TF-8N



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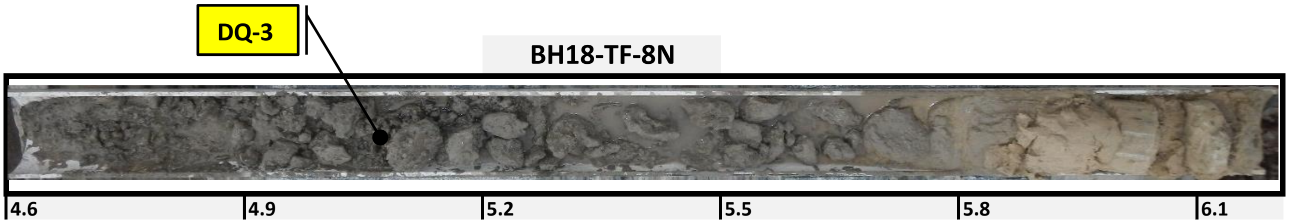

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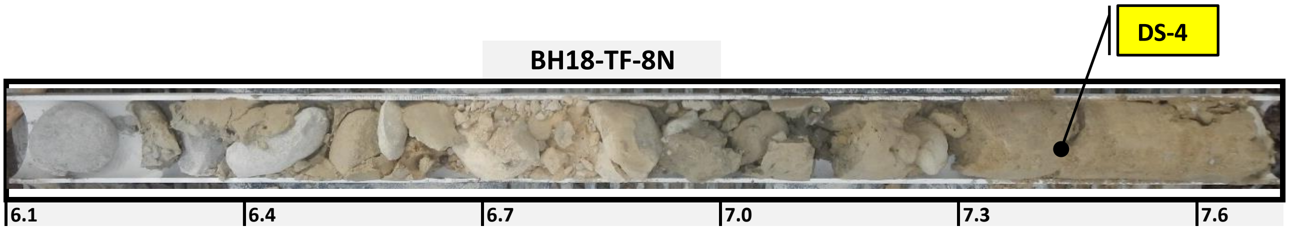


BH18-TF-8N

Sample Photographs

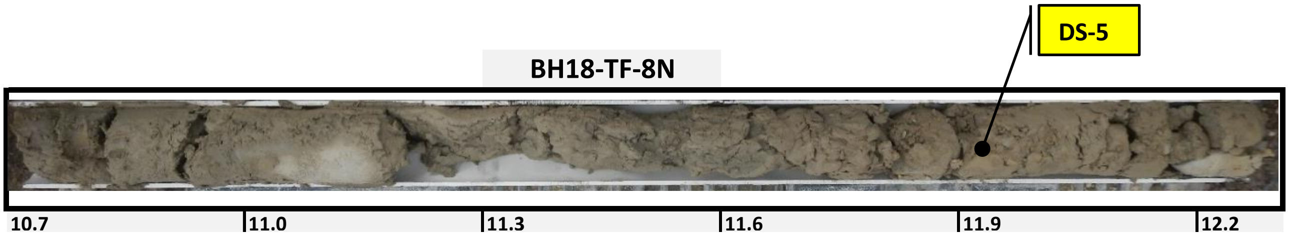
Borehole Name: BH18-TF-8N
Location: 17 W 561166 7913449
Completion Date: June 27, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines

BH18-TF-8N

BH18-TF-8N

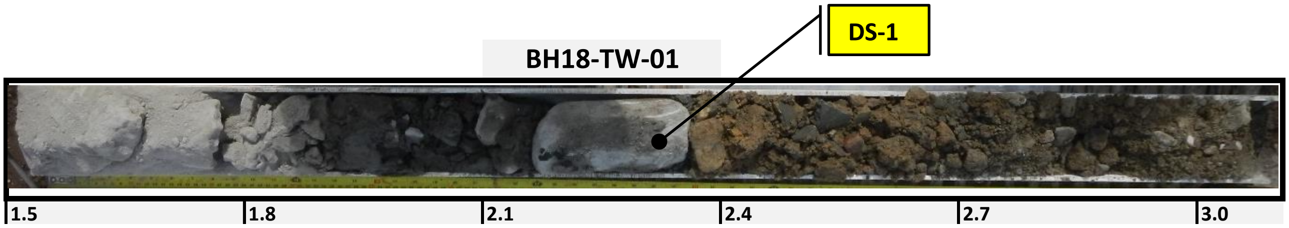


Sample Photographs

Borehole Name:	BH18-TW-01	Mary River Expansion Study Stage 2
Location:	17 W 561477 7913189	2018 Geotechnical Investigation
Completion Date:	June 17, 2018	Baffinland Iron Mines

BH18-TW-01

BH18-TW-01



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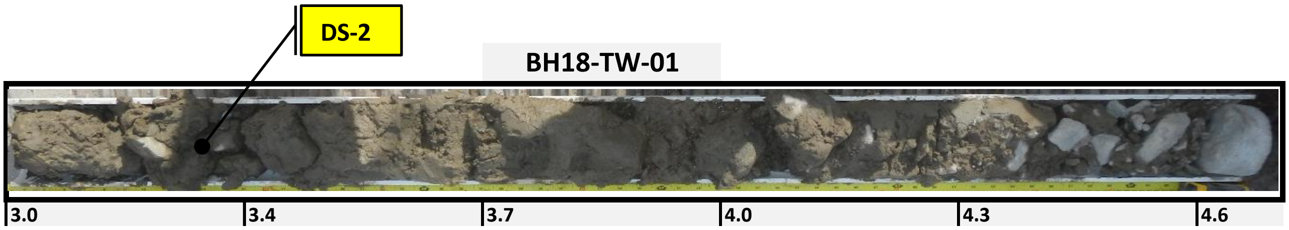

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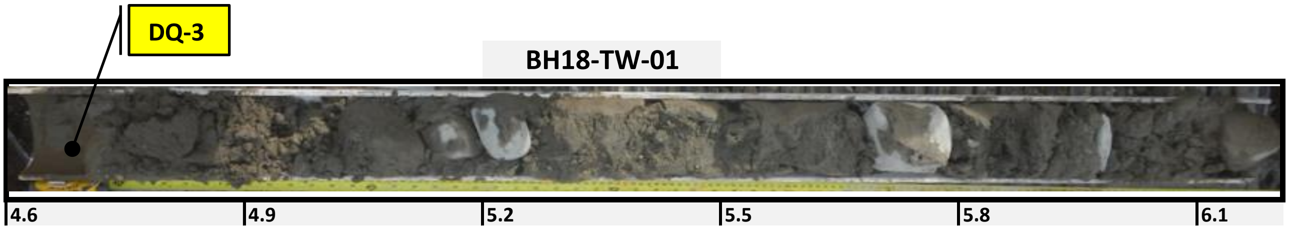

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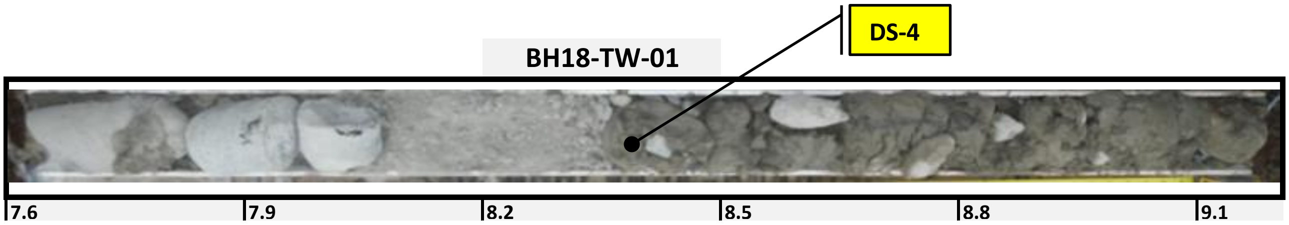
BH18-TW-01



Sample Photographs

Borehole Name: BH18-TW-01
Location: 17 W 561477 7913189
Completion Date: June 17, 2018

Mary River Expansion Study Stage 2

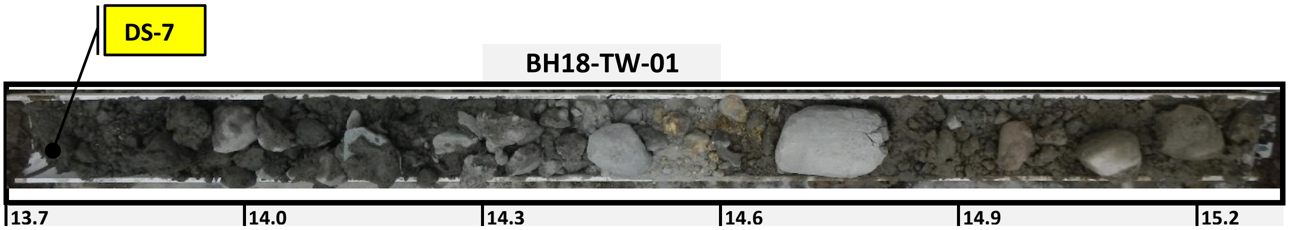
Baffinland Iron Mines

BH18-TW-01

BH18-TW-01

BH18-TW-01

BH18-TW-01



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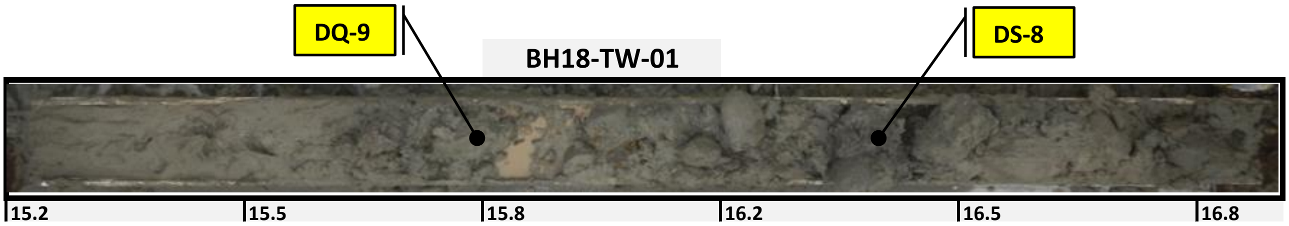


BH18-TW-01

Sample Photographs

Borehole Name: BH18-TW-01
Location: 17 W 561477 7913189
Completion Date: June 17, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines

BH18-TW-01

BH18-TW-01

BH18-TW-01

BH18-TW-01

BH18-TW-01

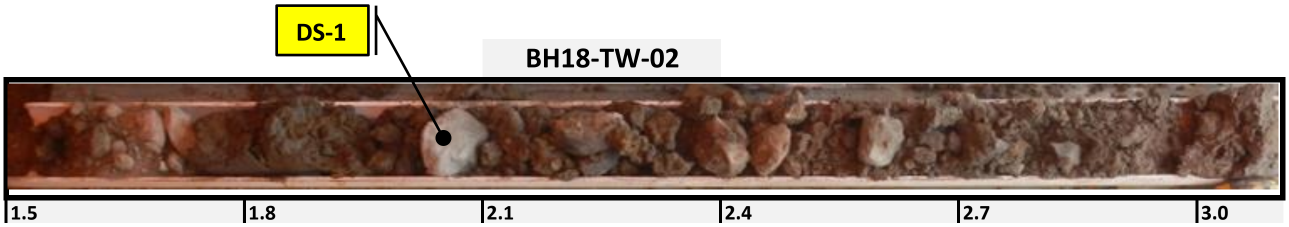
Sample Photographs

Borehole Name: BH18-TW-02
Location: 17 W 561532 7913229
Completion Date: June 17, 2018

Mary River Expansion Study Stage 2
2018 Geotechnical Investigation
Baffinland Iron Mines

BH18-TW-02

BH18-TW-02



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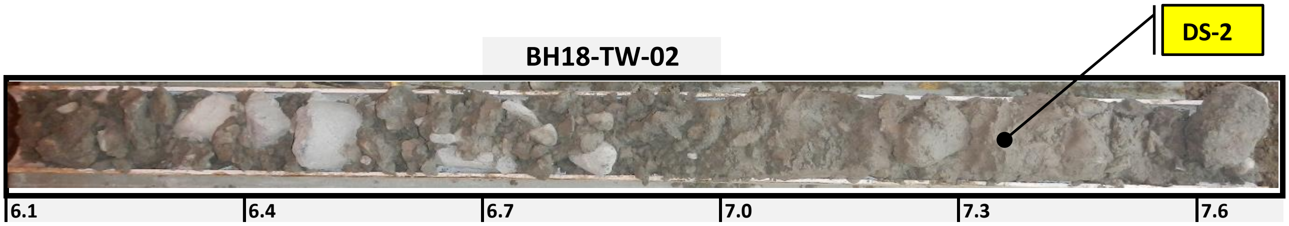
BH18-TW-02

BH18-TW-02



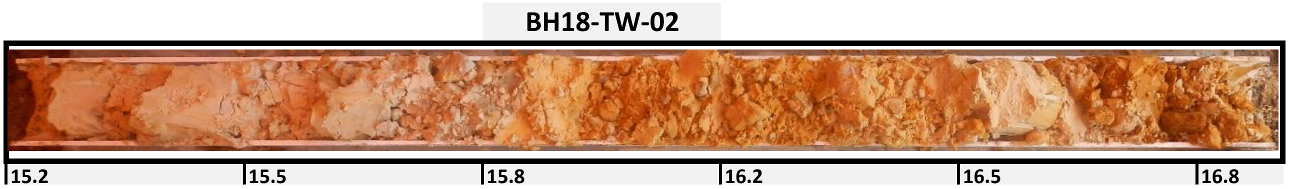
BH18-TW-02

Sample Photographs

Borehole Name: BH18-TW-02
Location: 17 W 561532 7913229
Completion Date: June 17, 2018

Mary River Expansion Study Stage 2

Baffinland Iron Mines



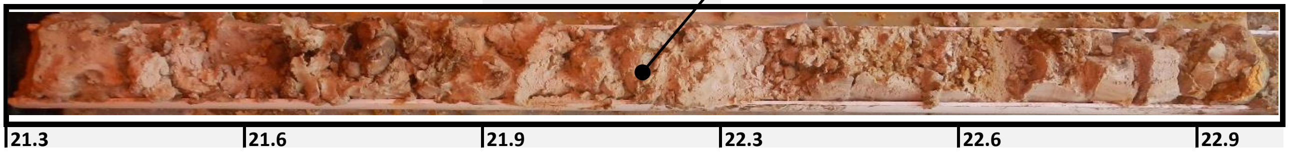
Sample Photographs

Borehole Name:	BH18-TW-02	Mary River Expansion Study Stage 2
Location:	17 W 561532 7913229	
Completion Date:	June 17, 2018	Baffinland Iron Mines

BH18-TW-02

BH18-TW-02

BH18-TW-02

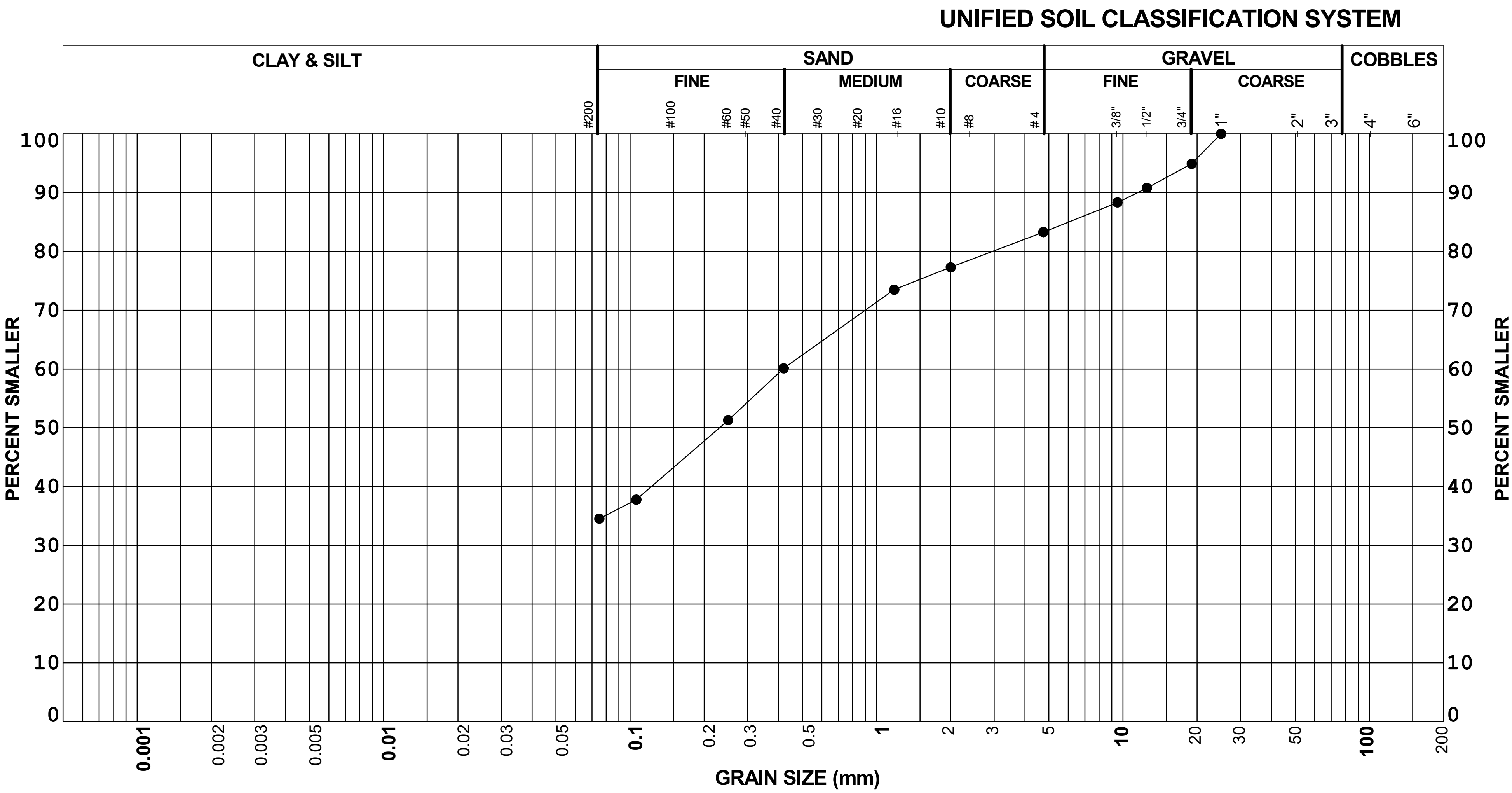


BH18-TW-02

BH18-TW-02

Appendix D

Laboratory Test Reports



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-01	DS-2	3.70	17	48	35		

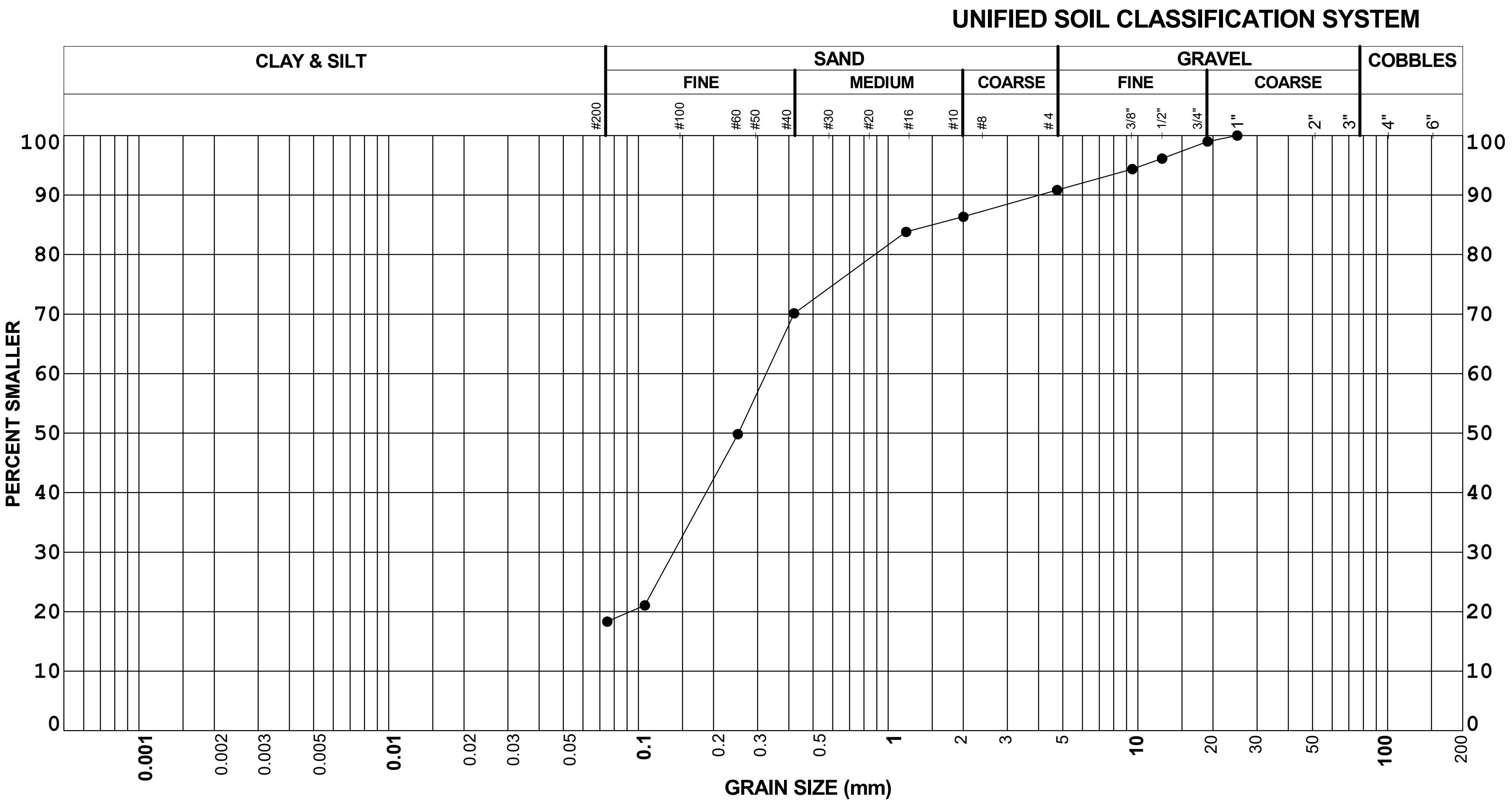
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-01	DS-4	7.00	9	73	18		

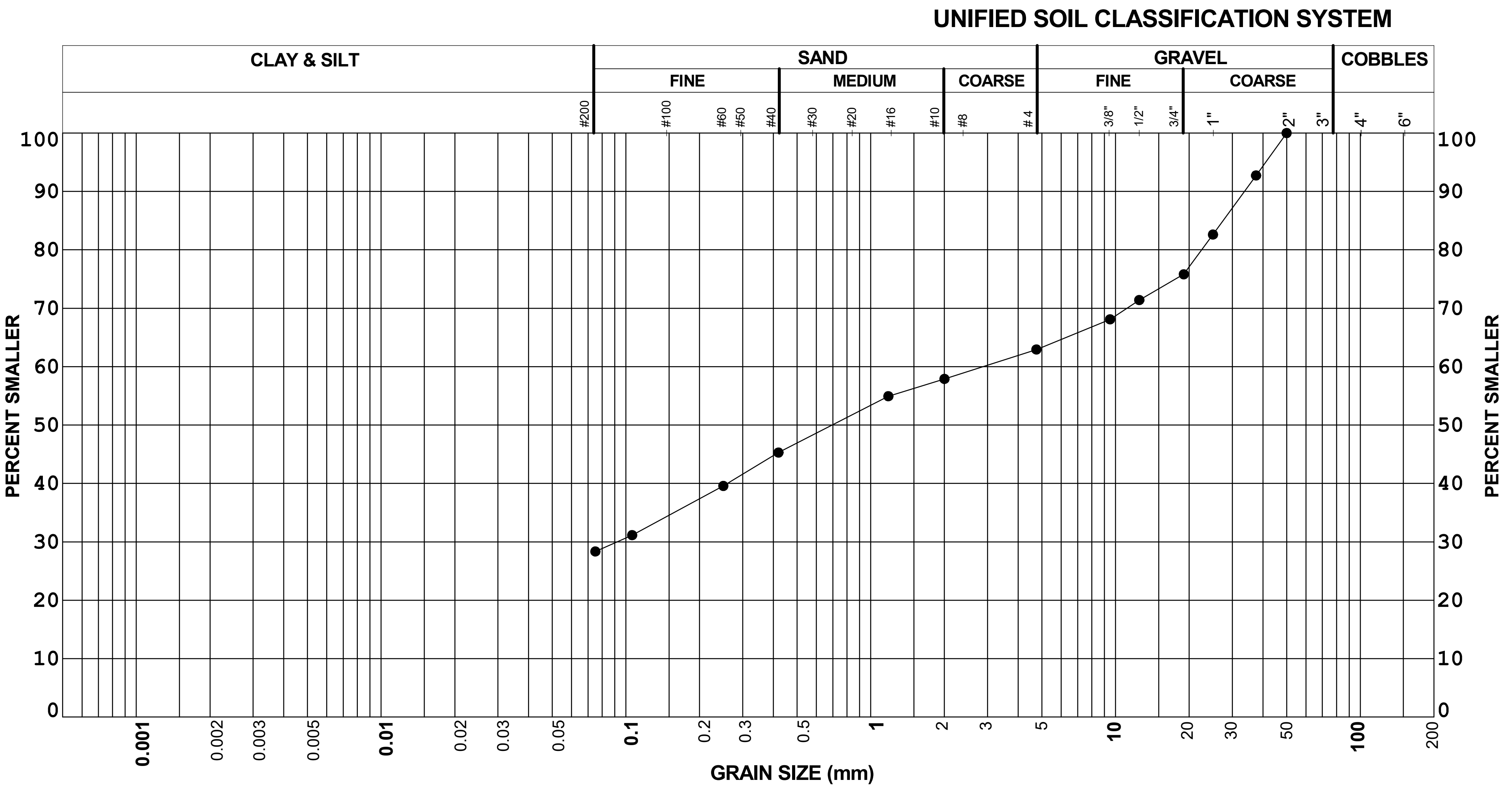
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



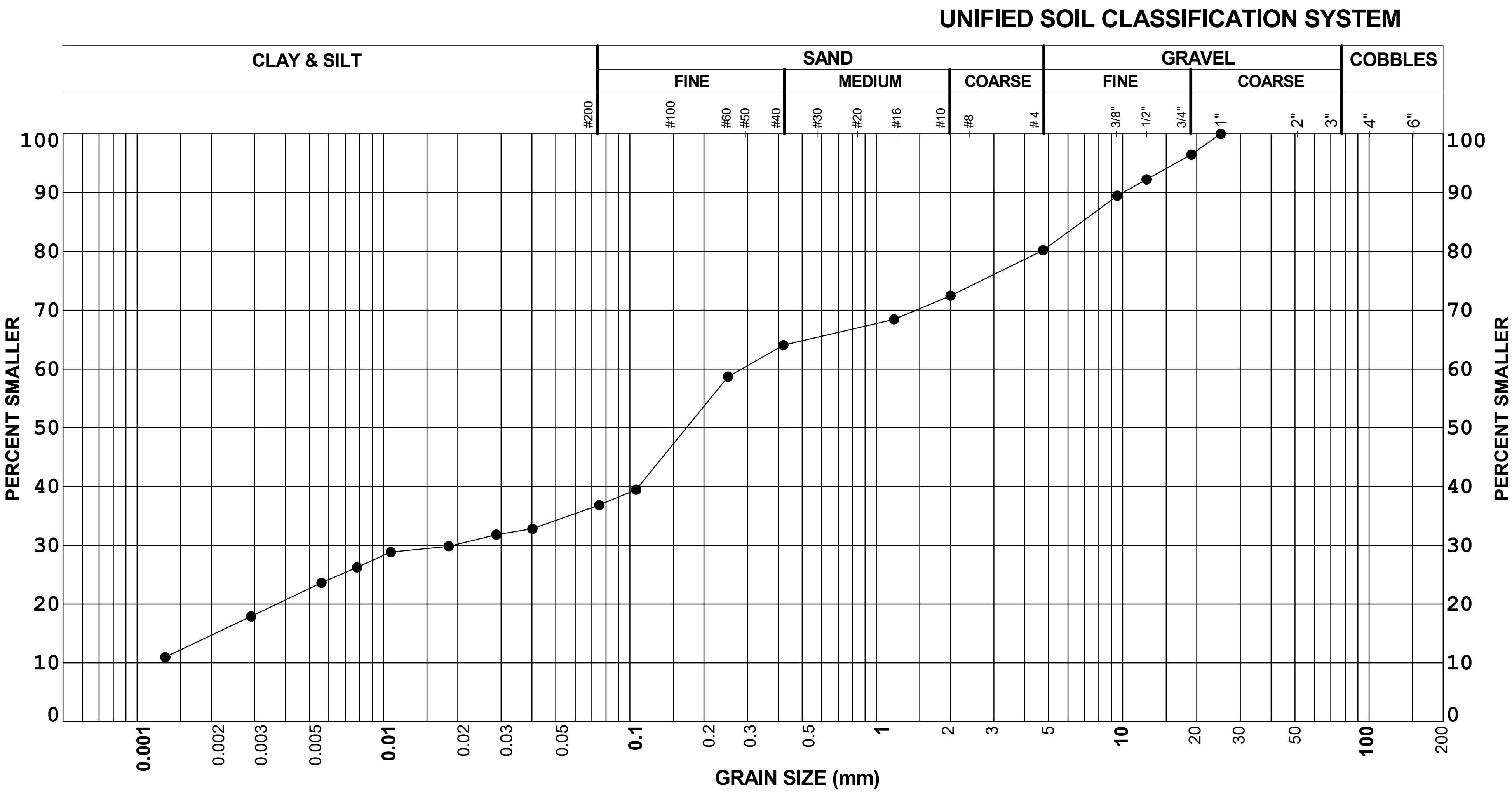
	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-01	DS-7	15.50	37	35	28		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-01	DS-8	17.25	20	43	37		

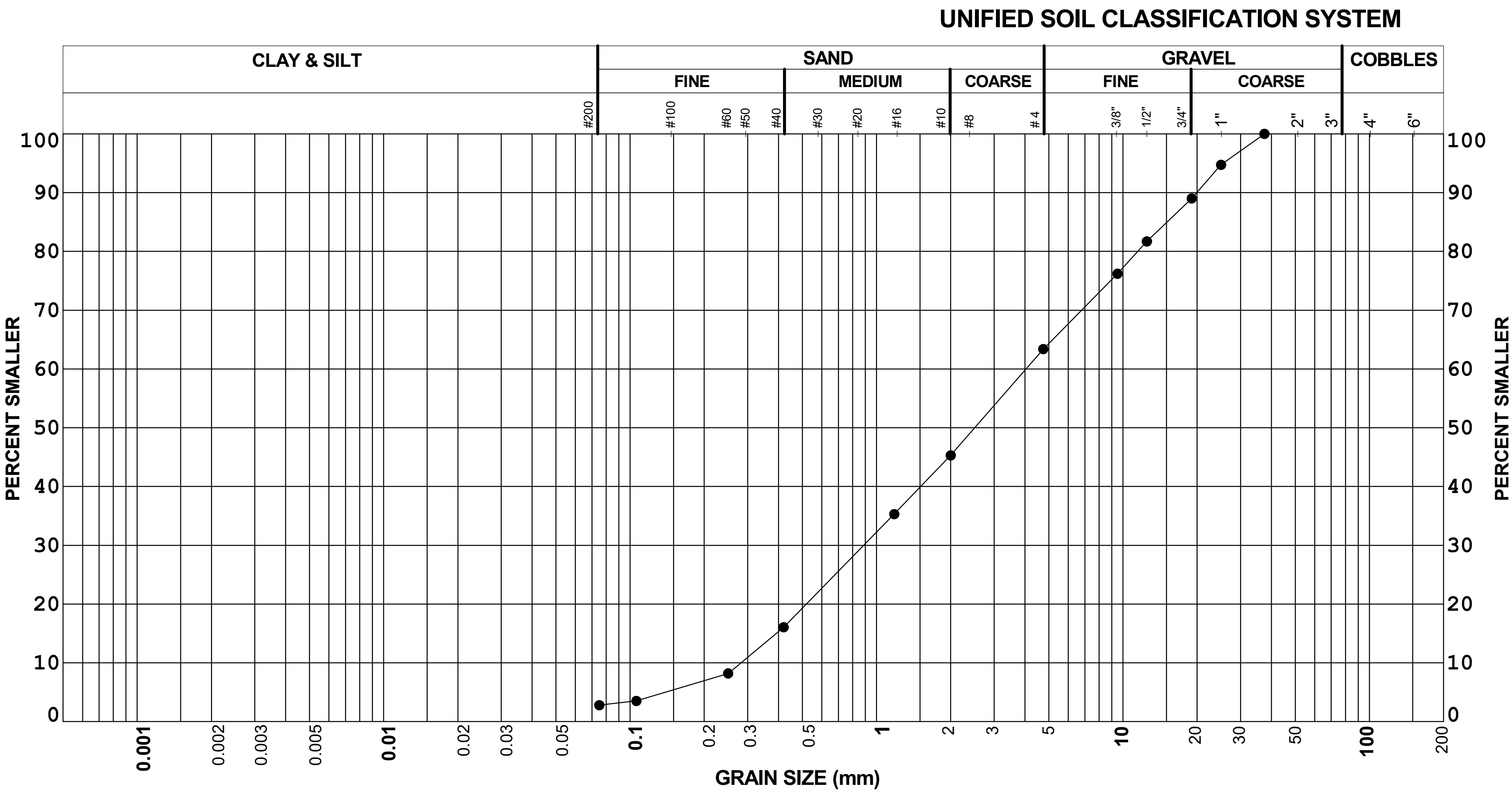
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-02	DS-1	1.00	37	60	3		

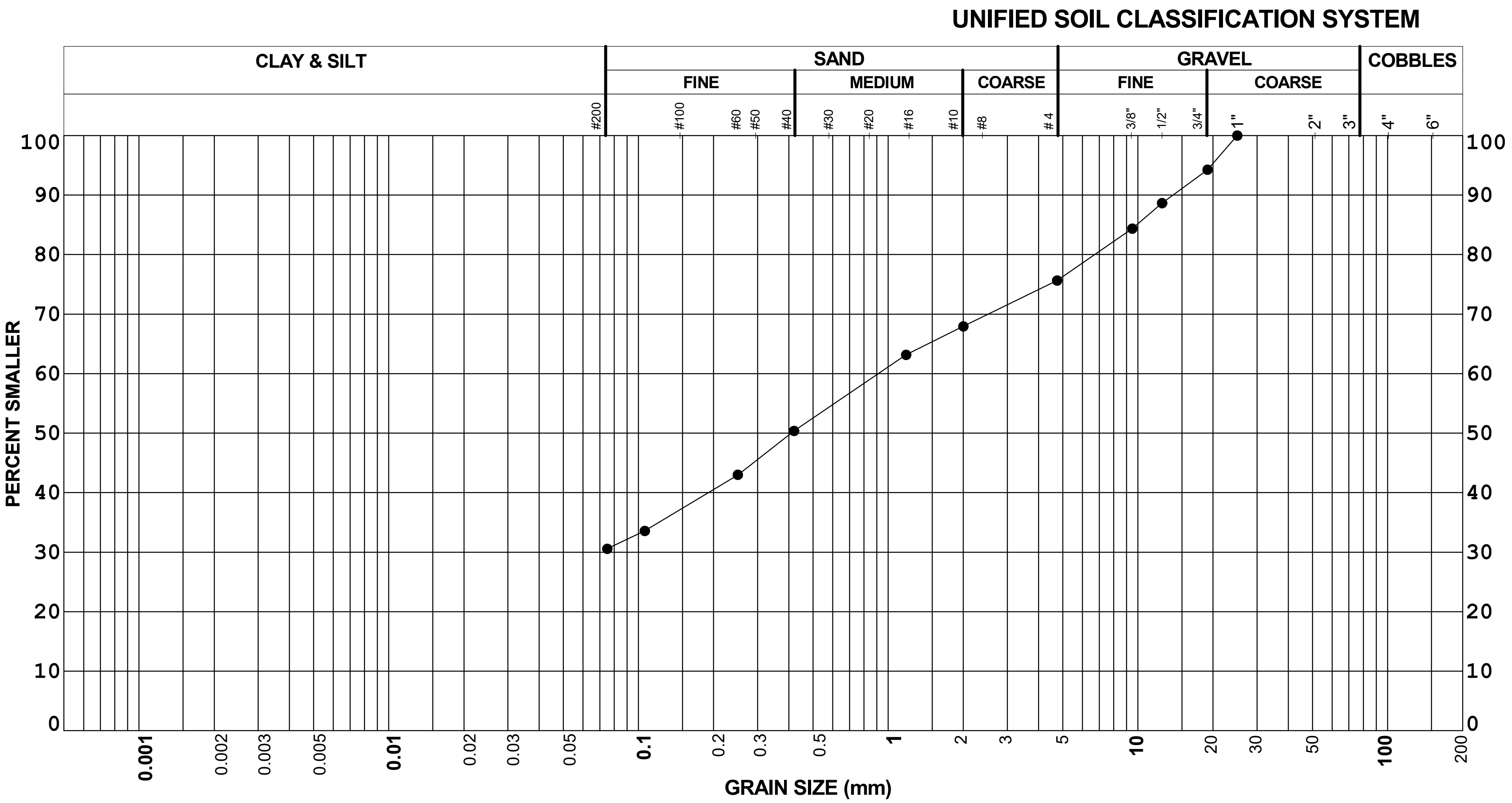
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



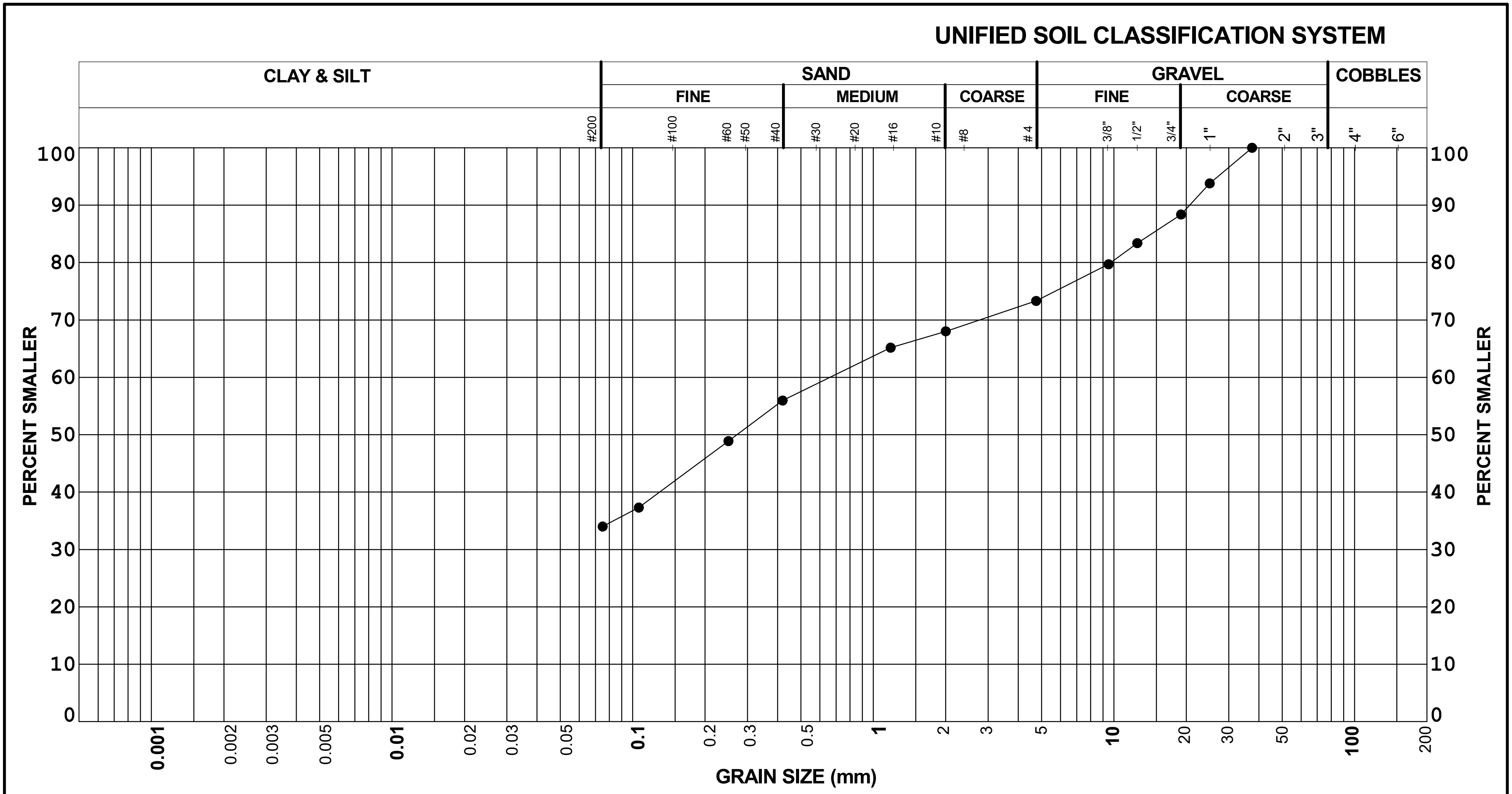
	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-02	DS-5	4.00	24	45	31		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-02	DS-6	7.90	27	39	34		

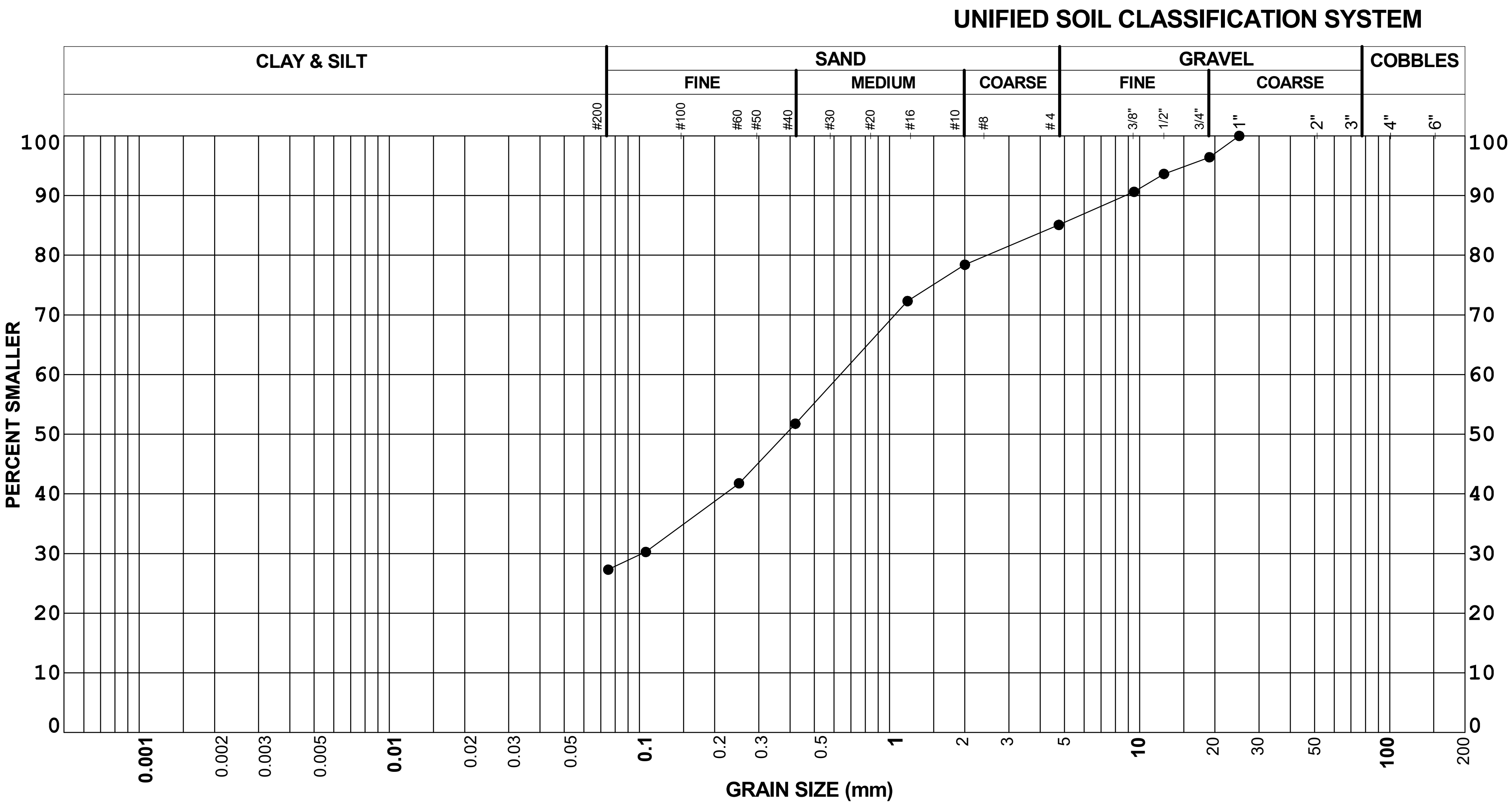
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



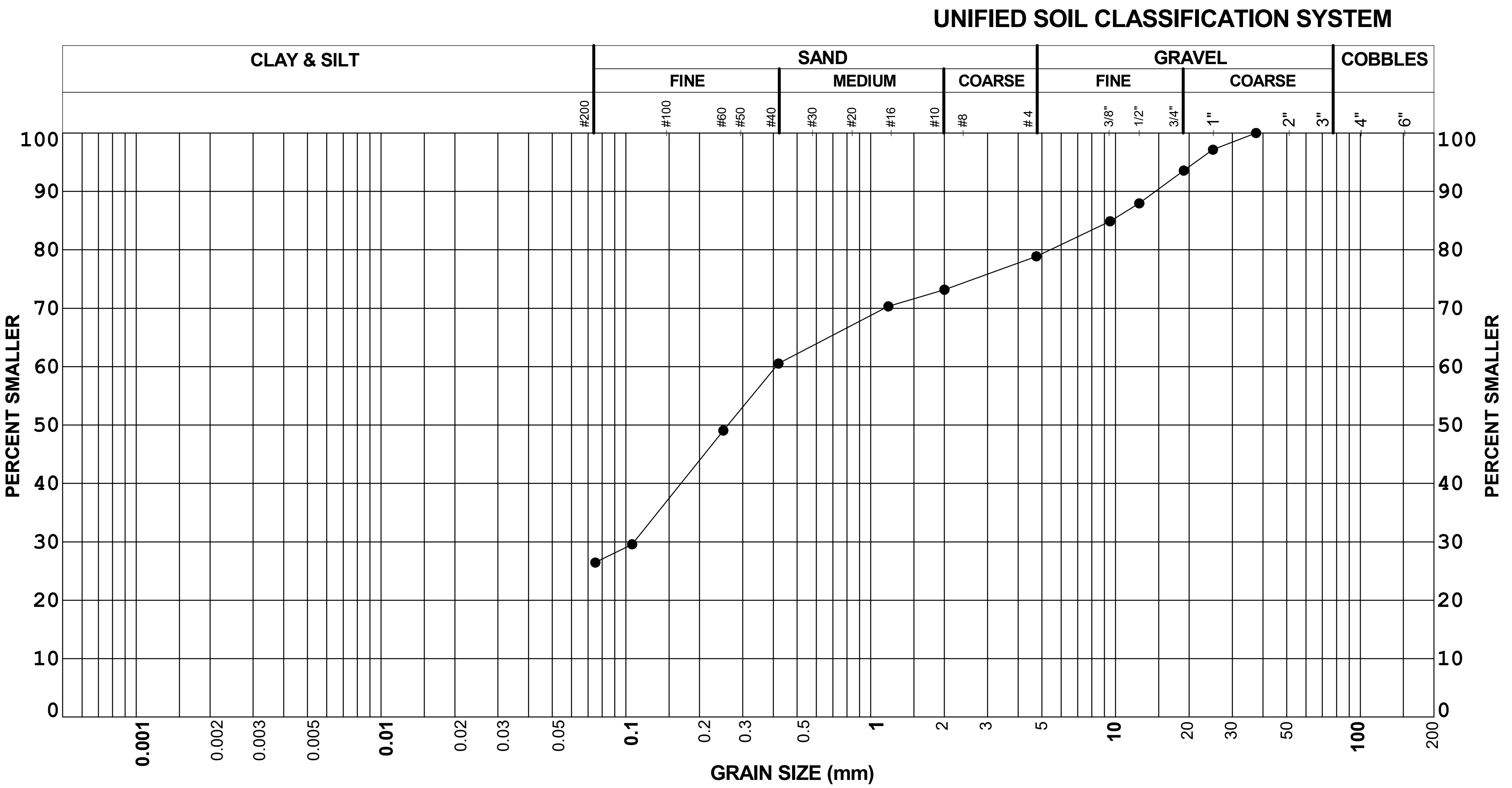
BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-02	DS-9	13.20	15	58	27		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



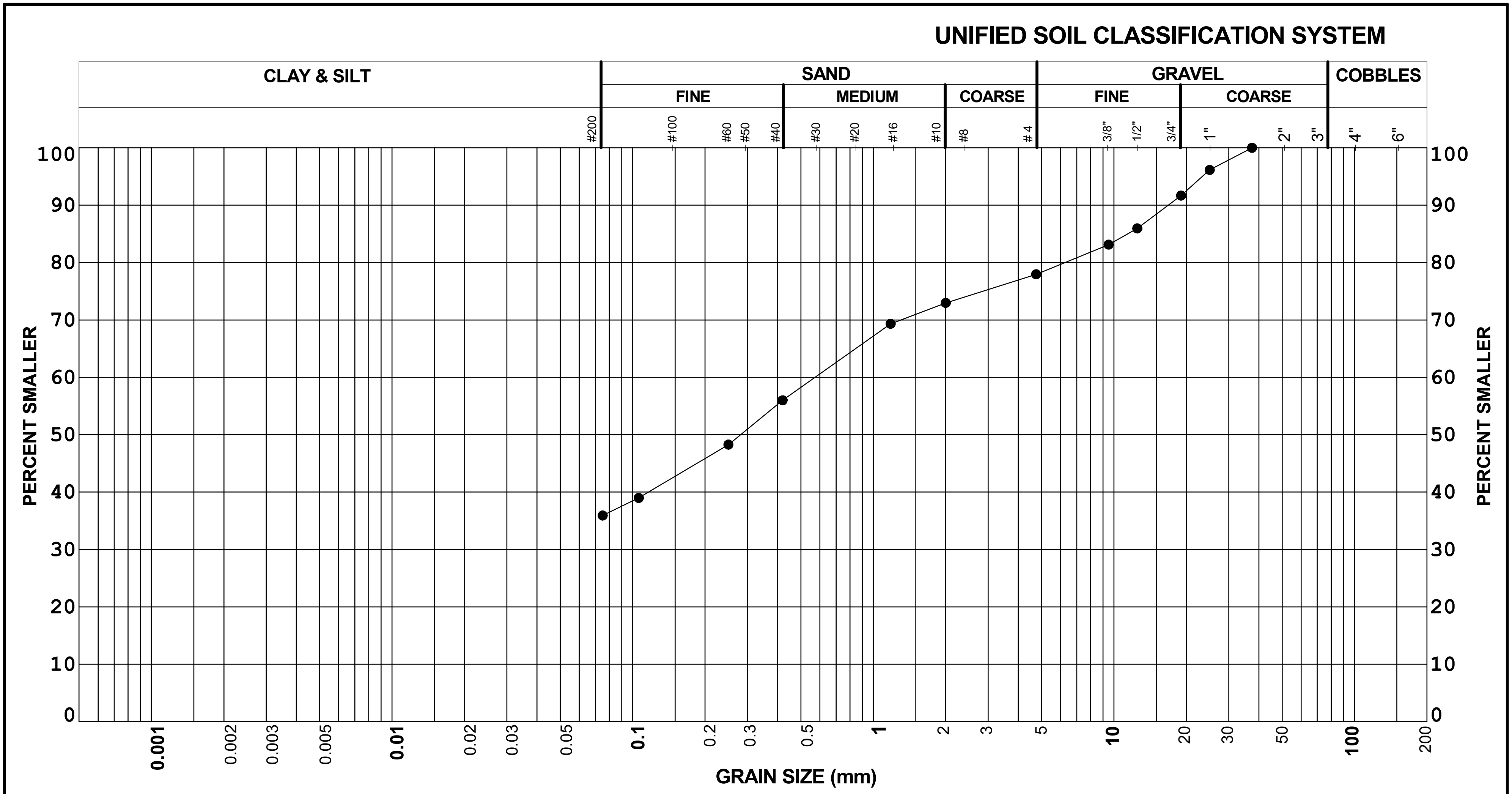
BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-02	DS-12	19.90	21	53	26		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-03	DS-4	8.20	22	42	36		

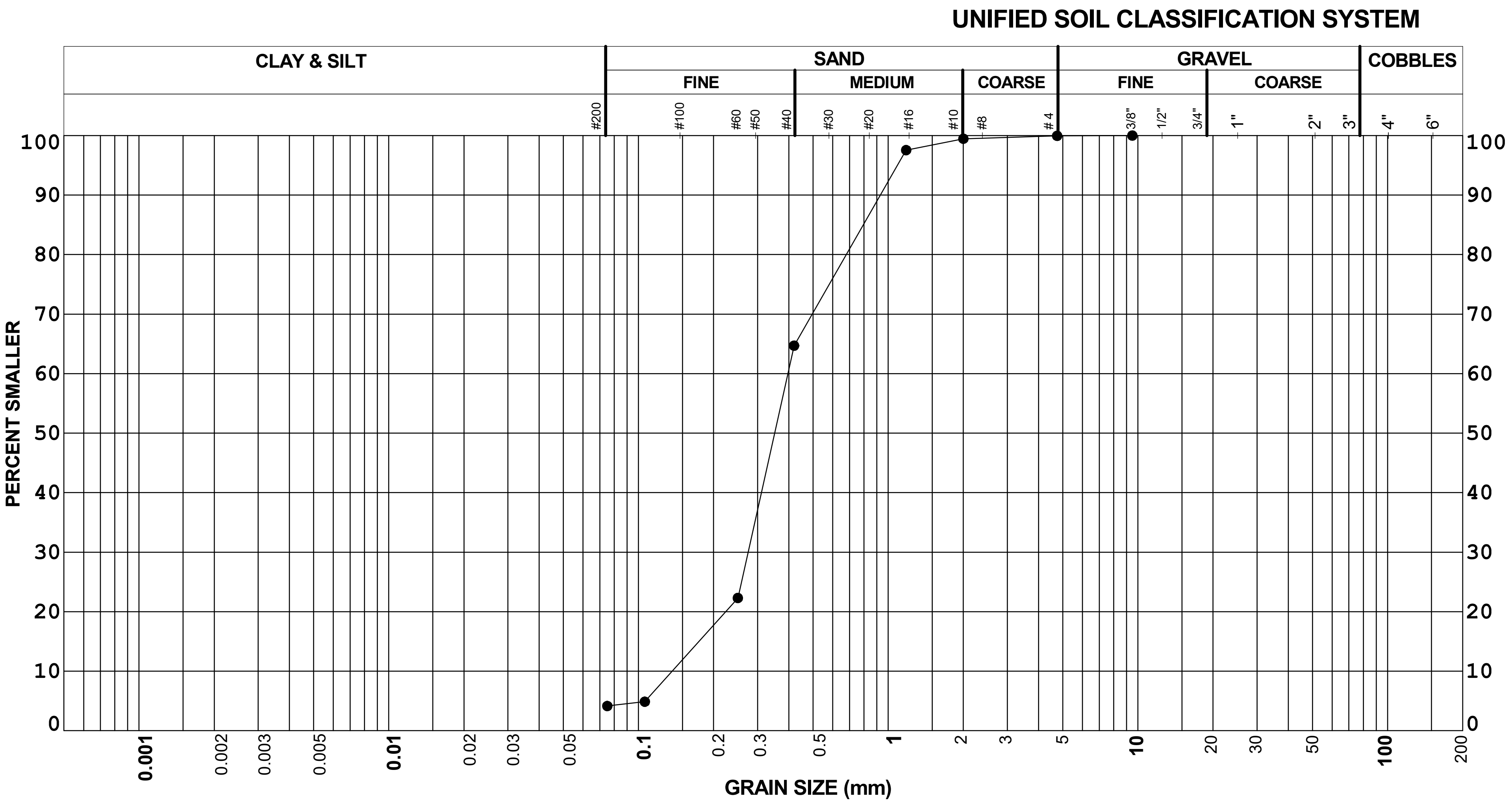
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-03	DQ-9	13.20	0	96	4		

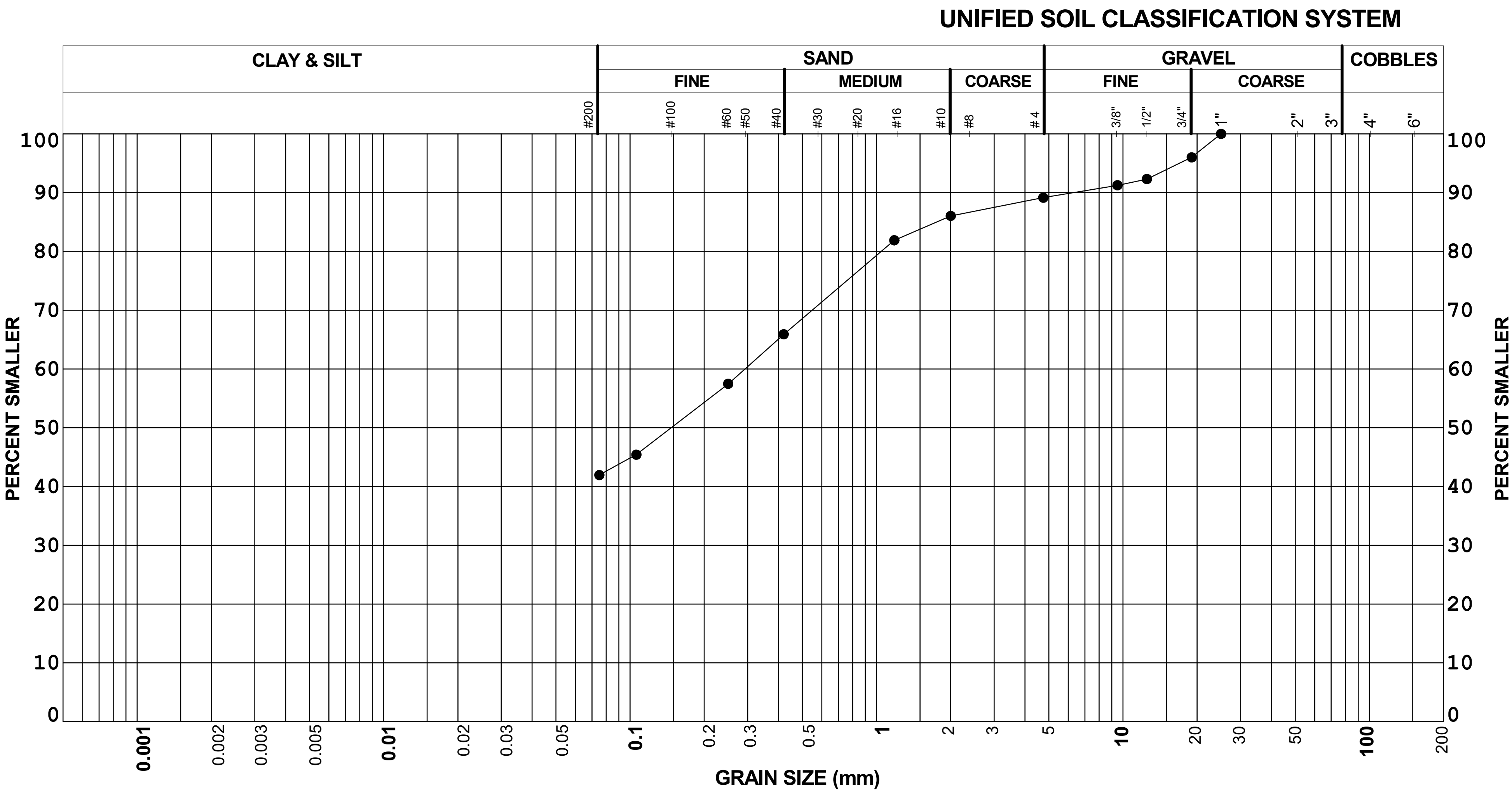
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-03	DS-10	14.10	11	47	42		

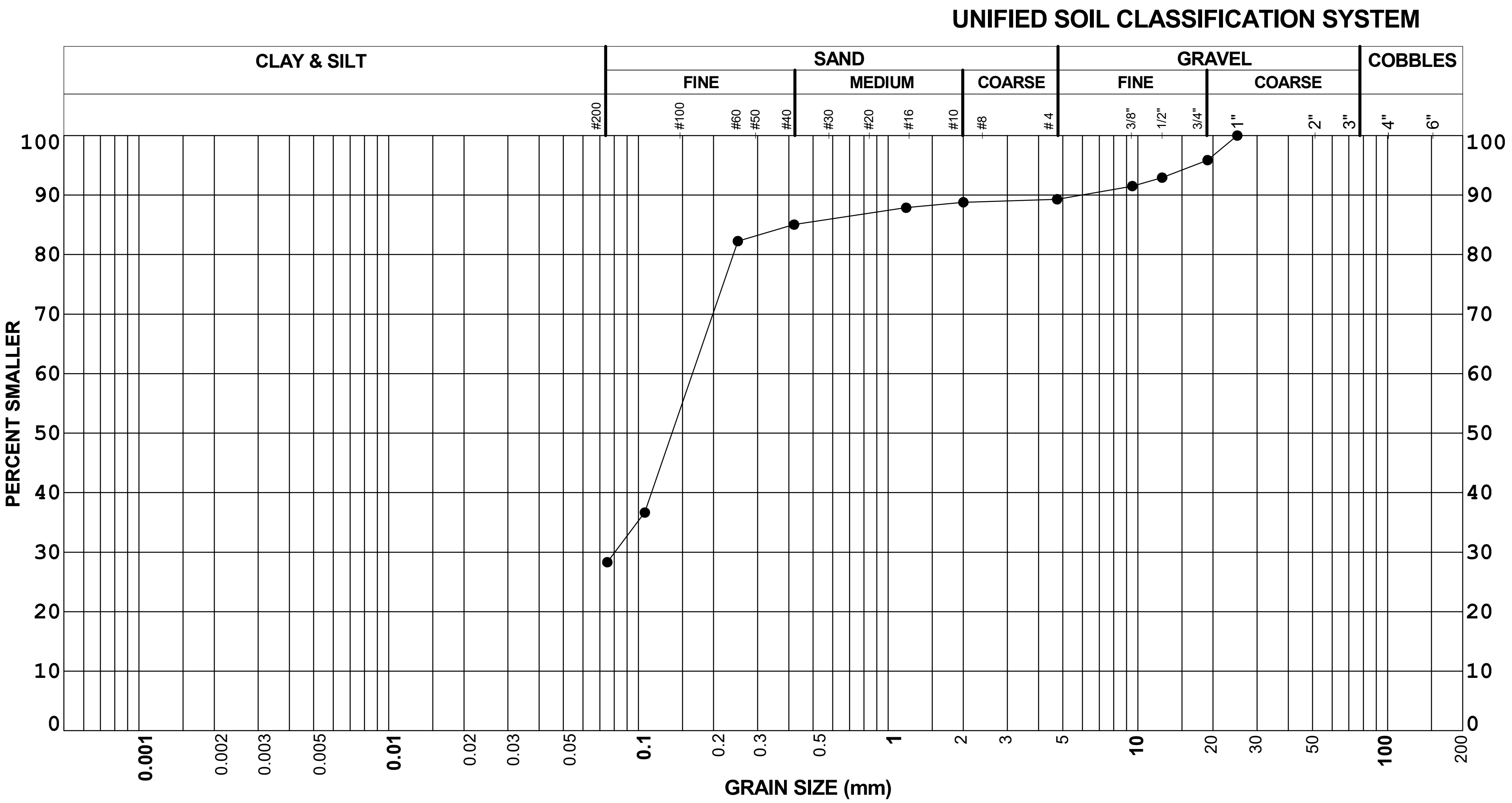
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-03	DS-12	17.50	11	61	28		

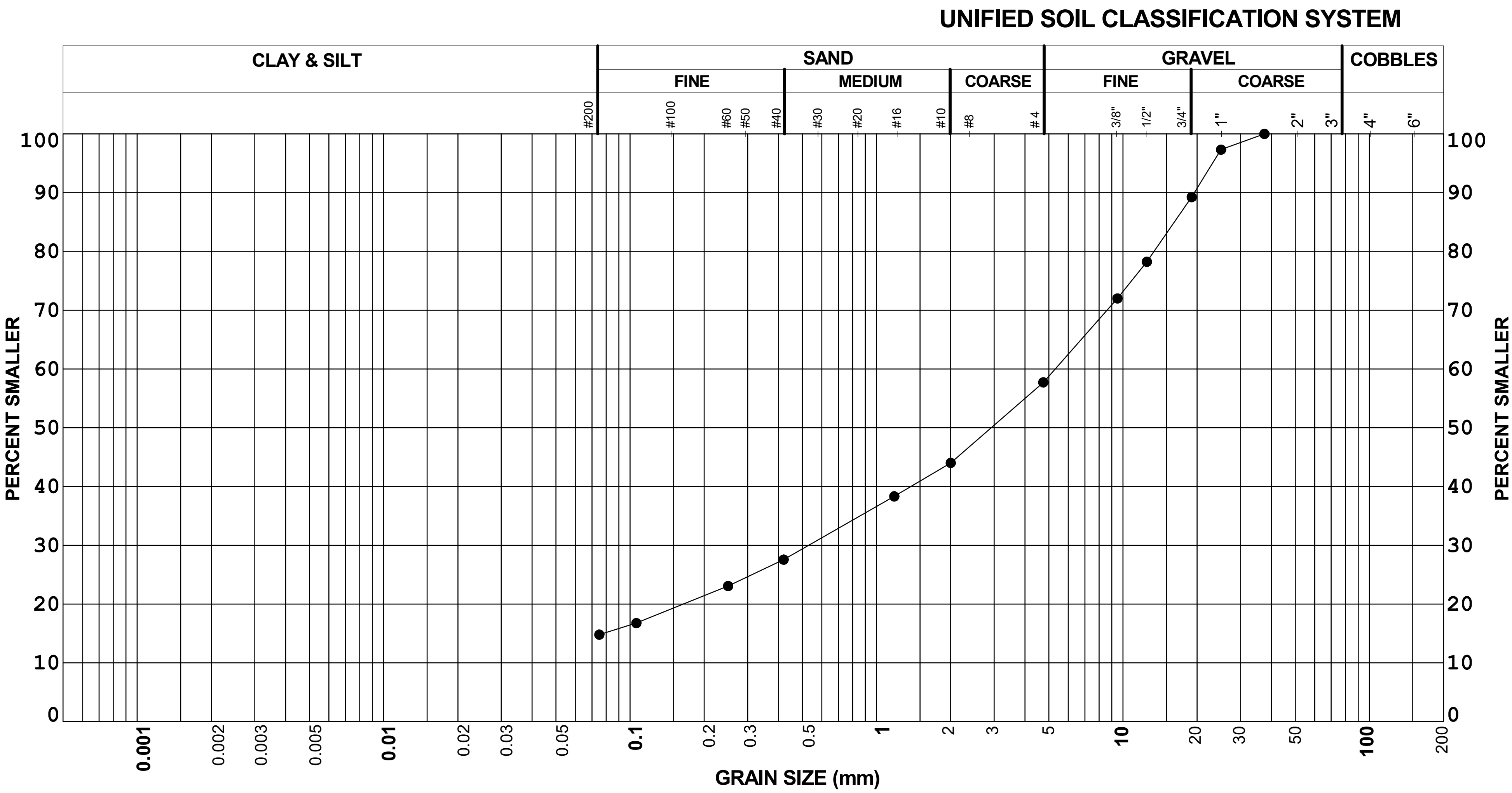
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



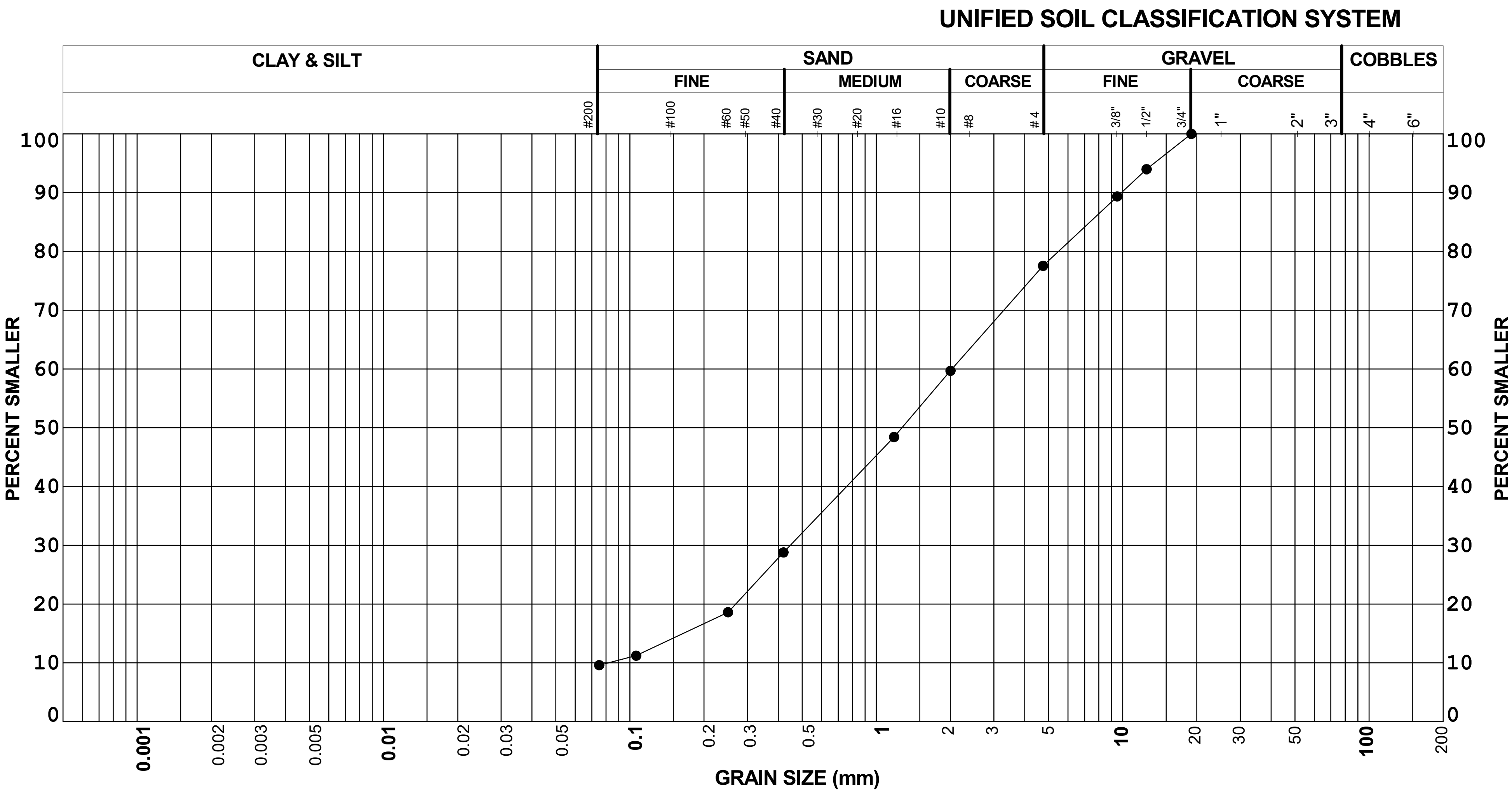
	BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
●	BH18-TF-04	DS-1	0.60	42	43	15		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-04	DS-4	7.90	22	68	10		

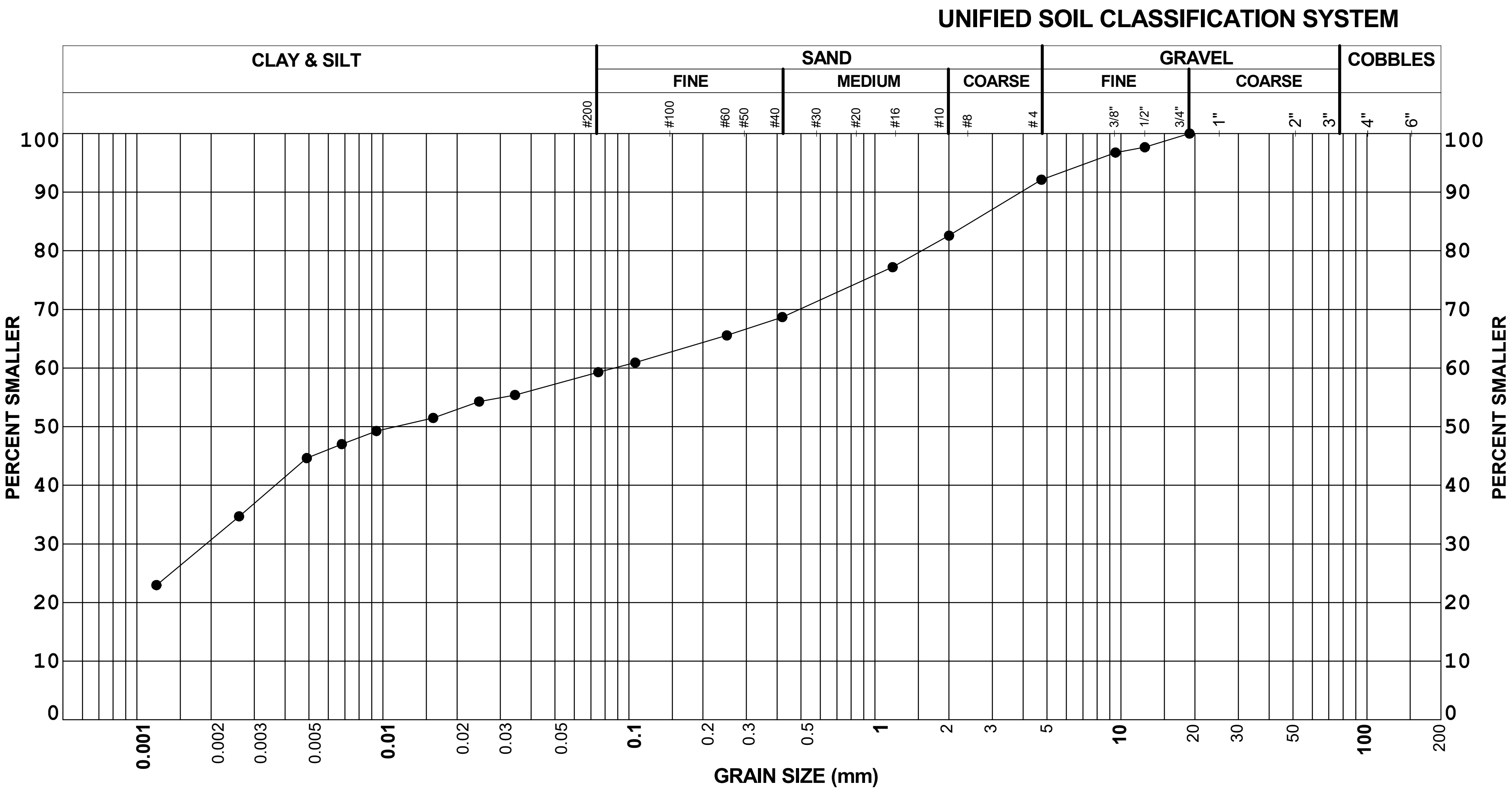
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-04	DS-7	10.90	8	33	59		

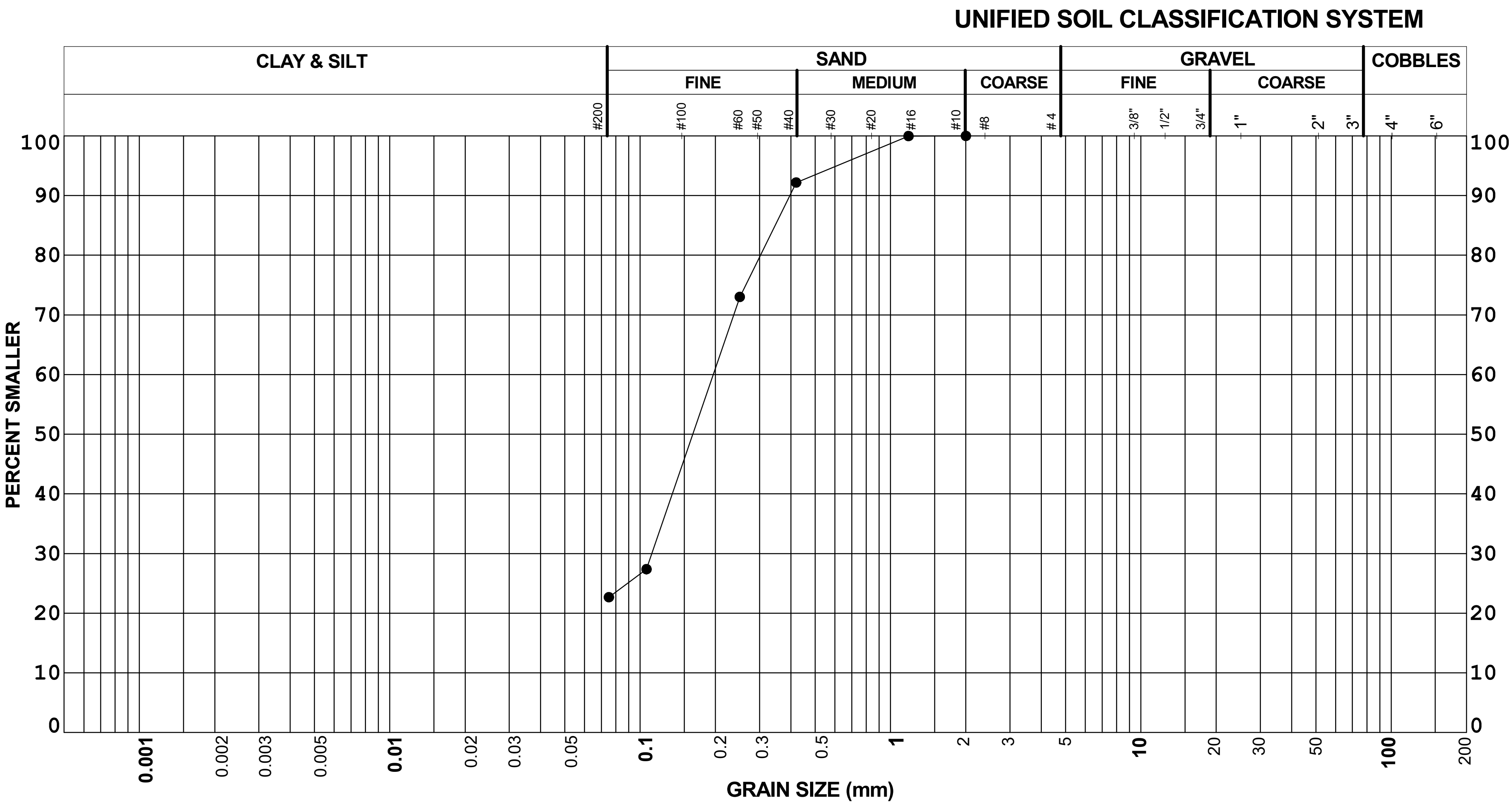
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-04	DS-13	25.00	0	77	23		

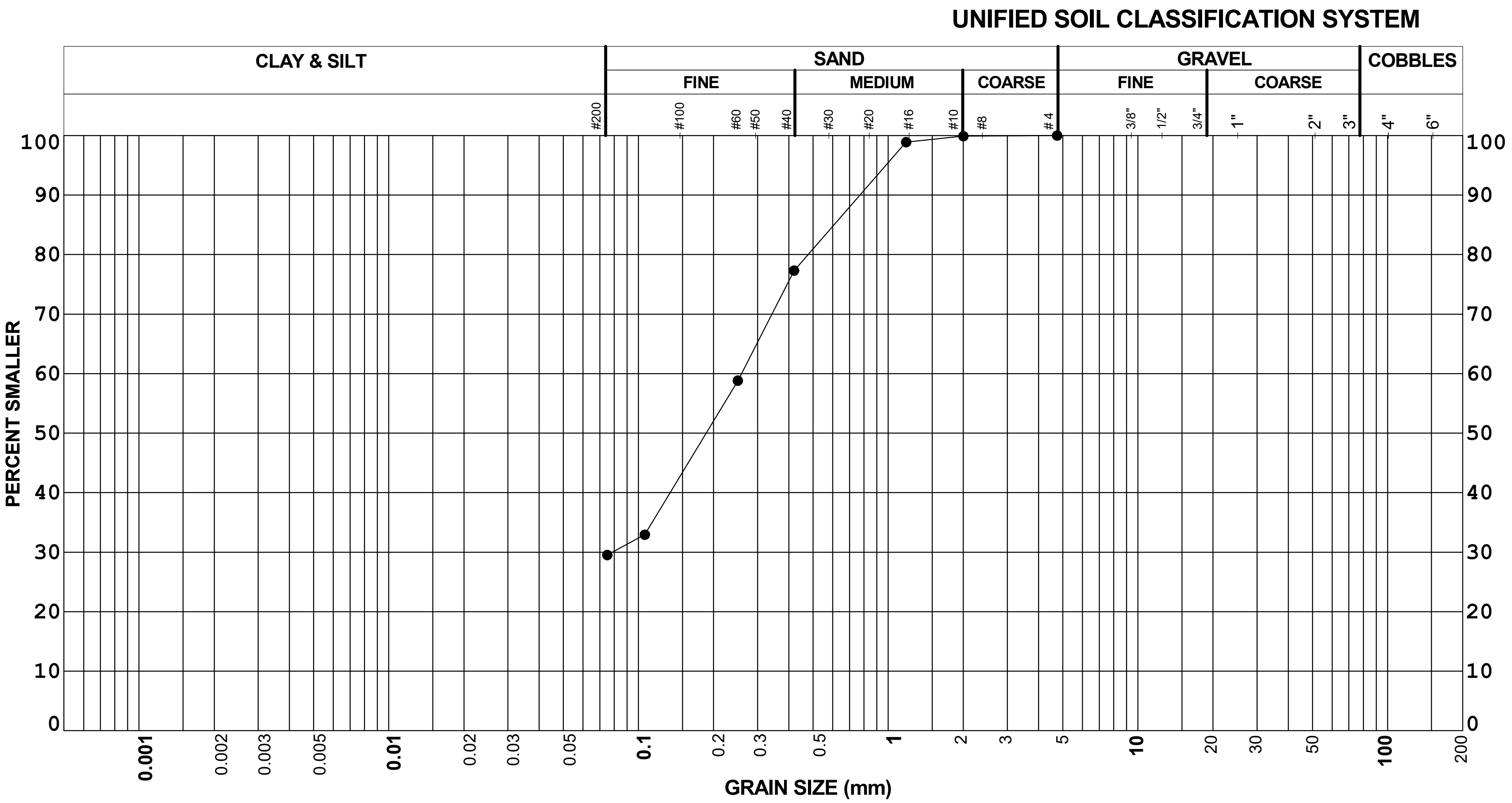
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



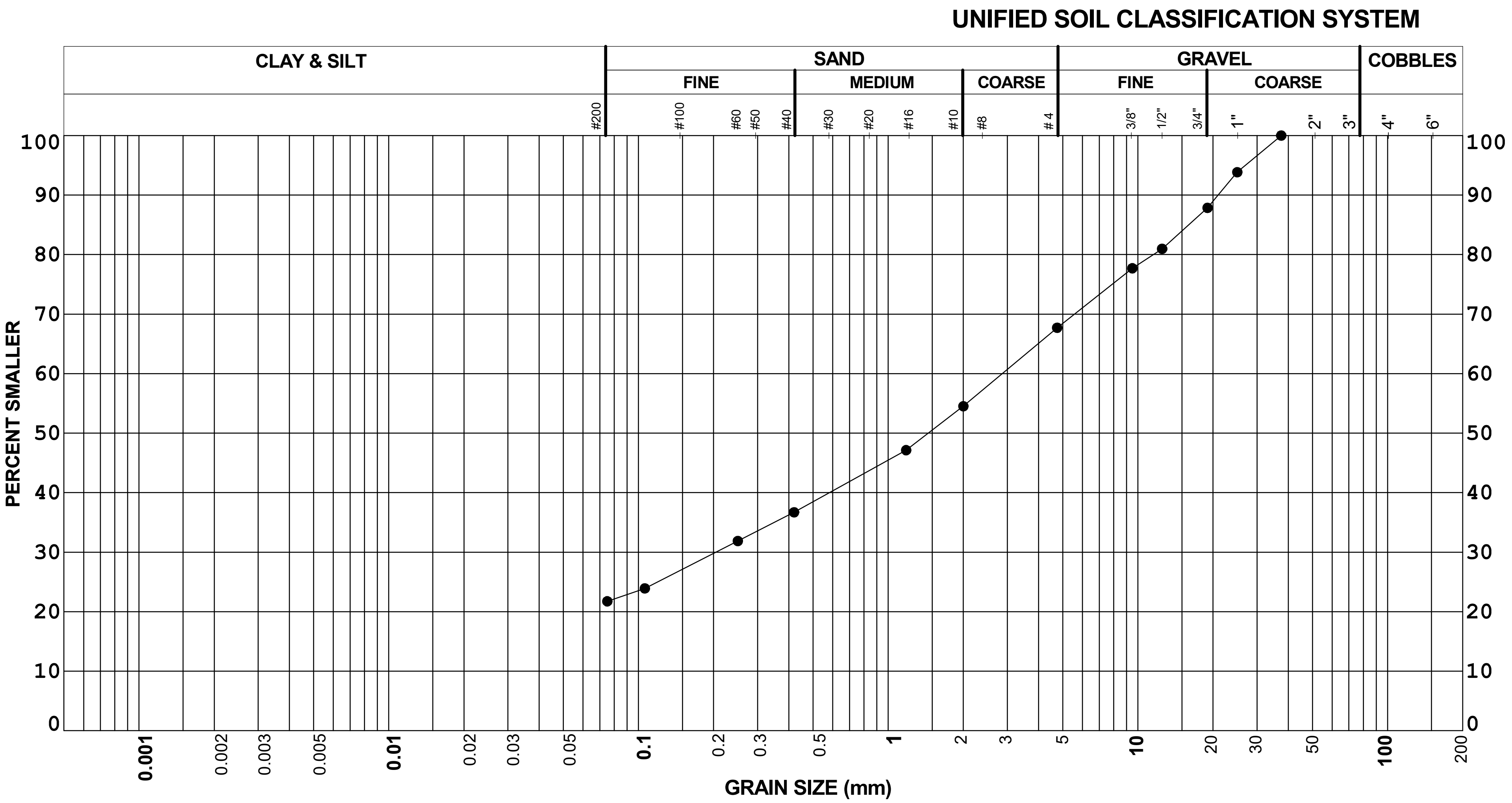
BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-05	DS-13	23.20	0	70	30		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-7N	DS-2	5.10	32	46	22		

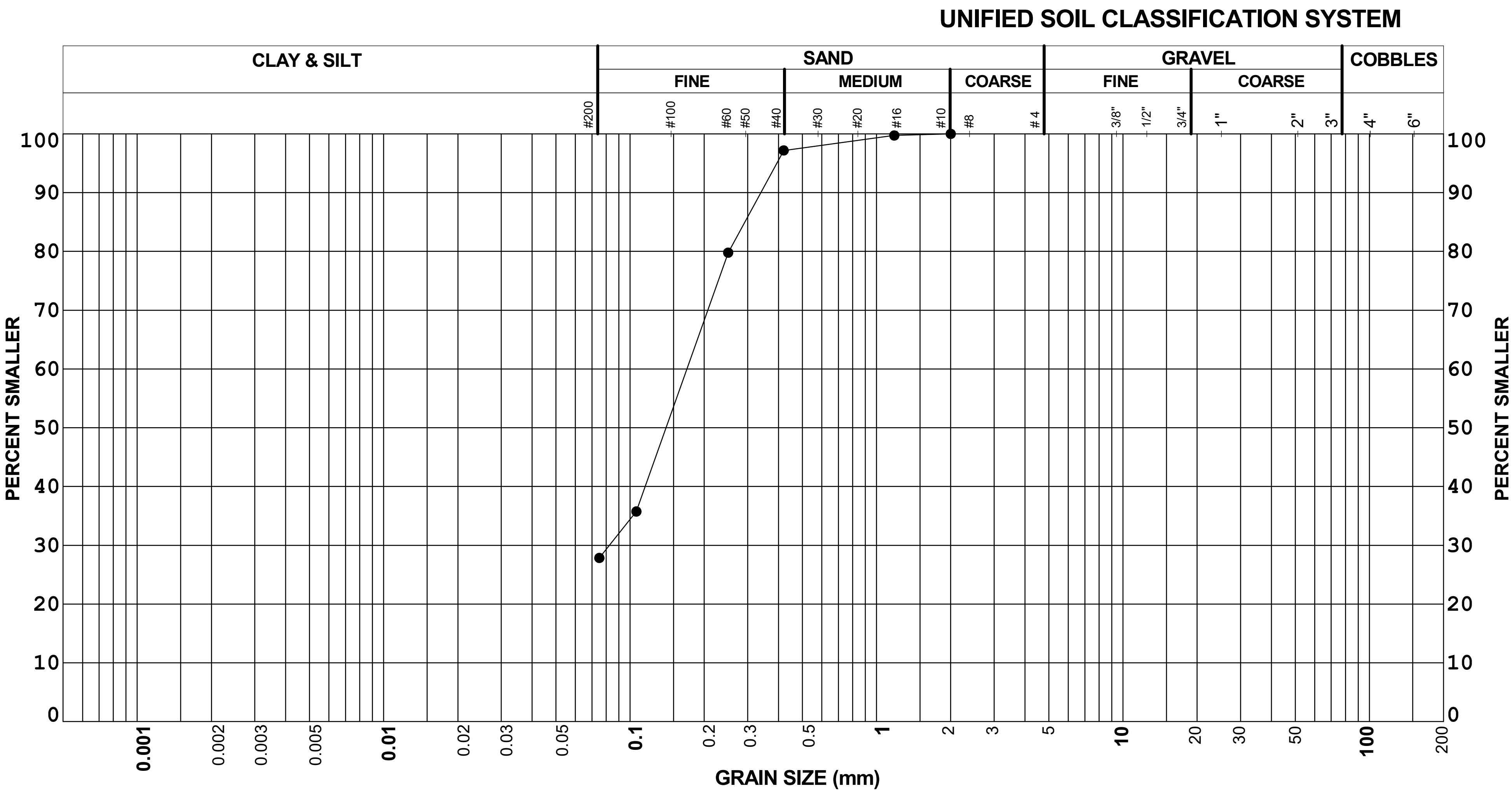
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-7N	DS-3	6.40	0	72	28		

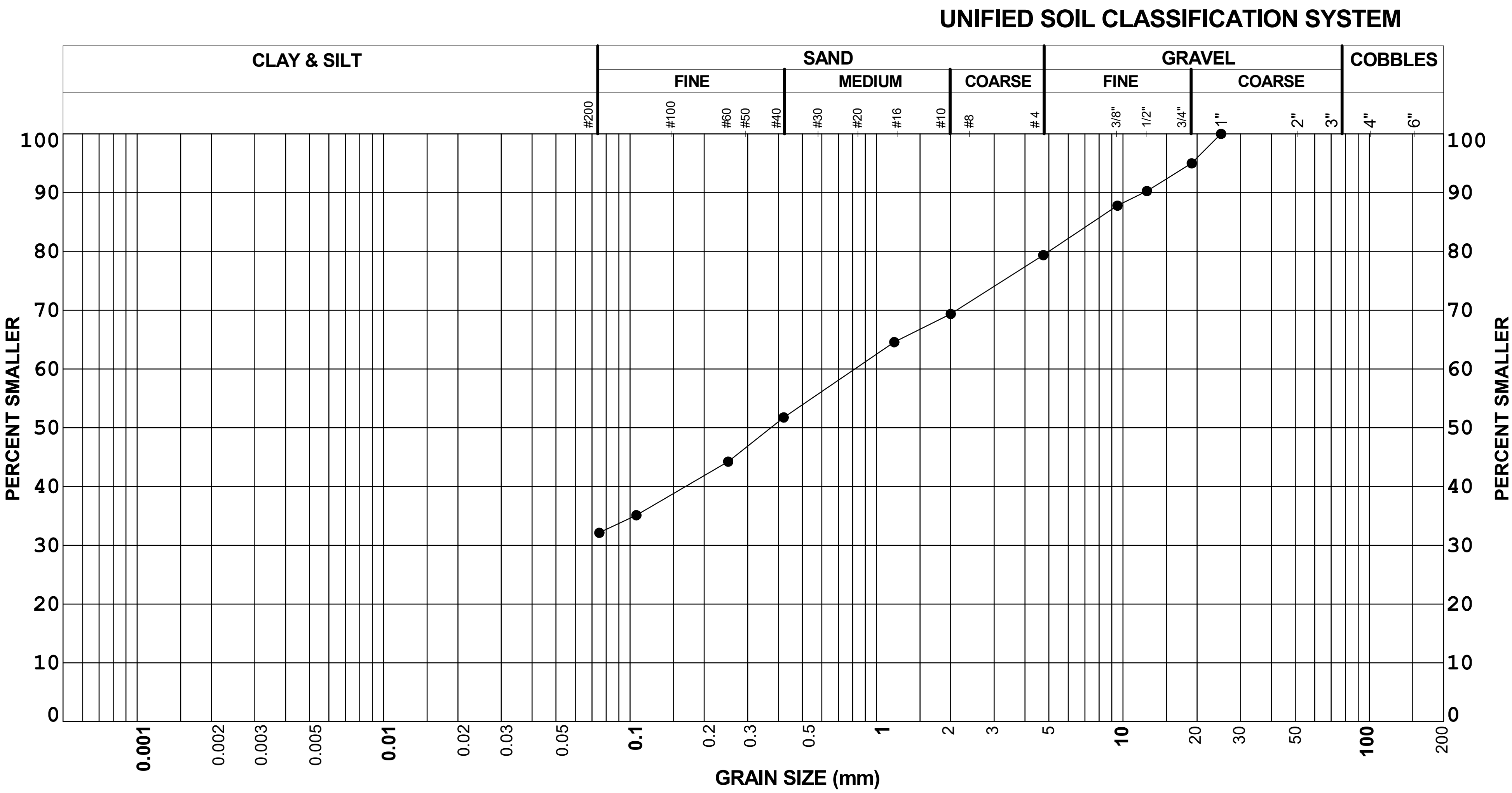
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-7N	DS-5	8.30	21	47	32		

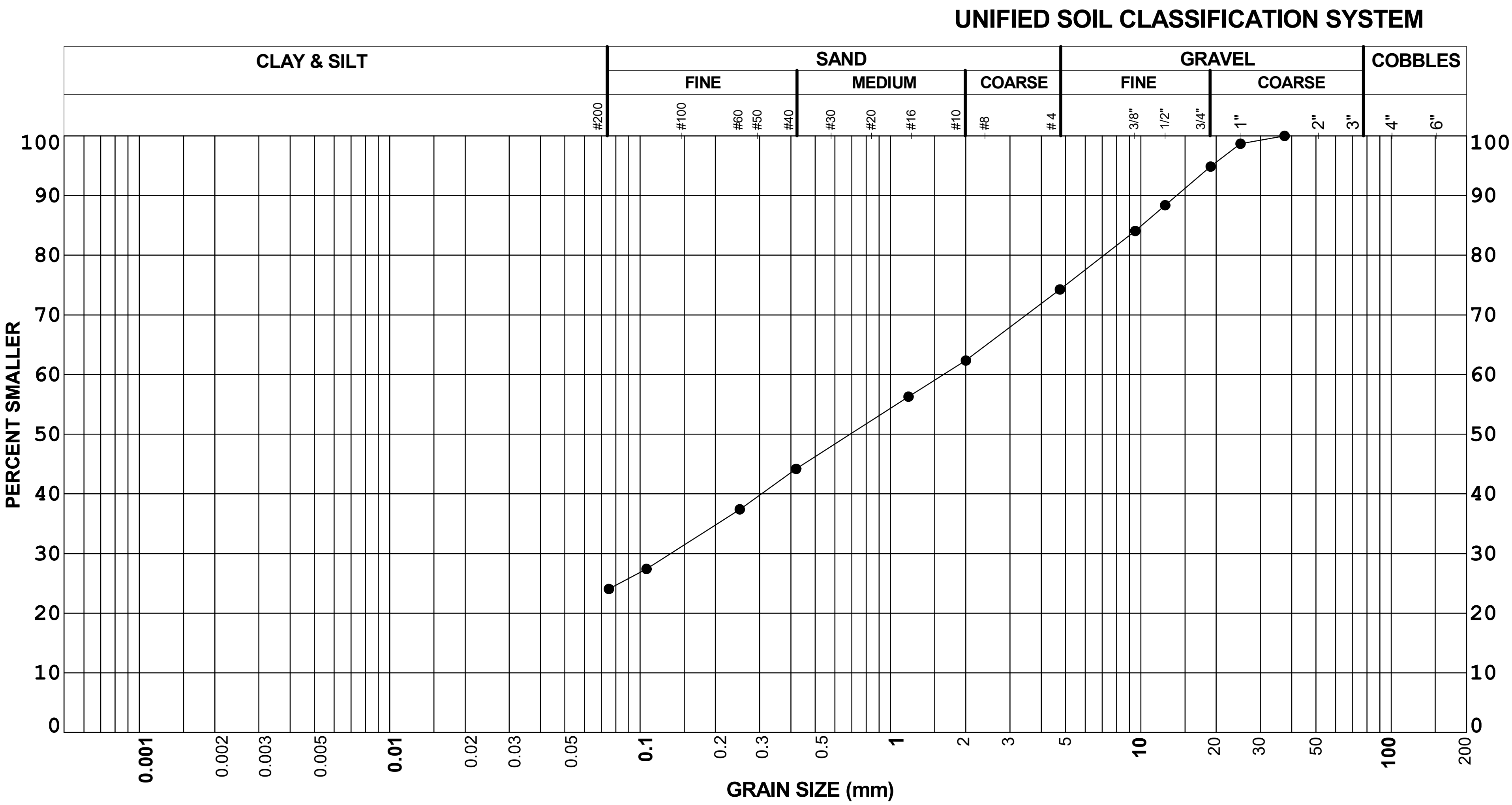
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-8N	DS-1	0.90	26	50	24		

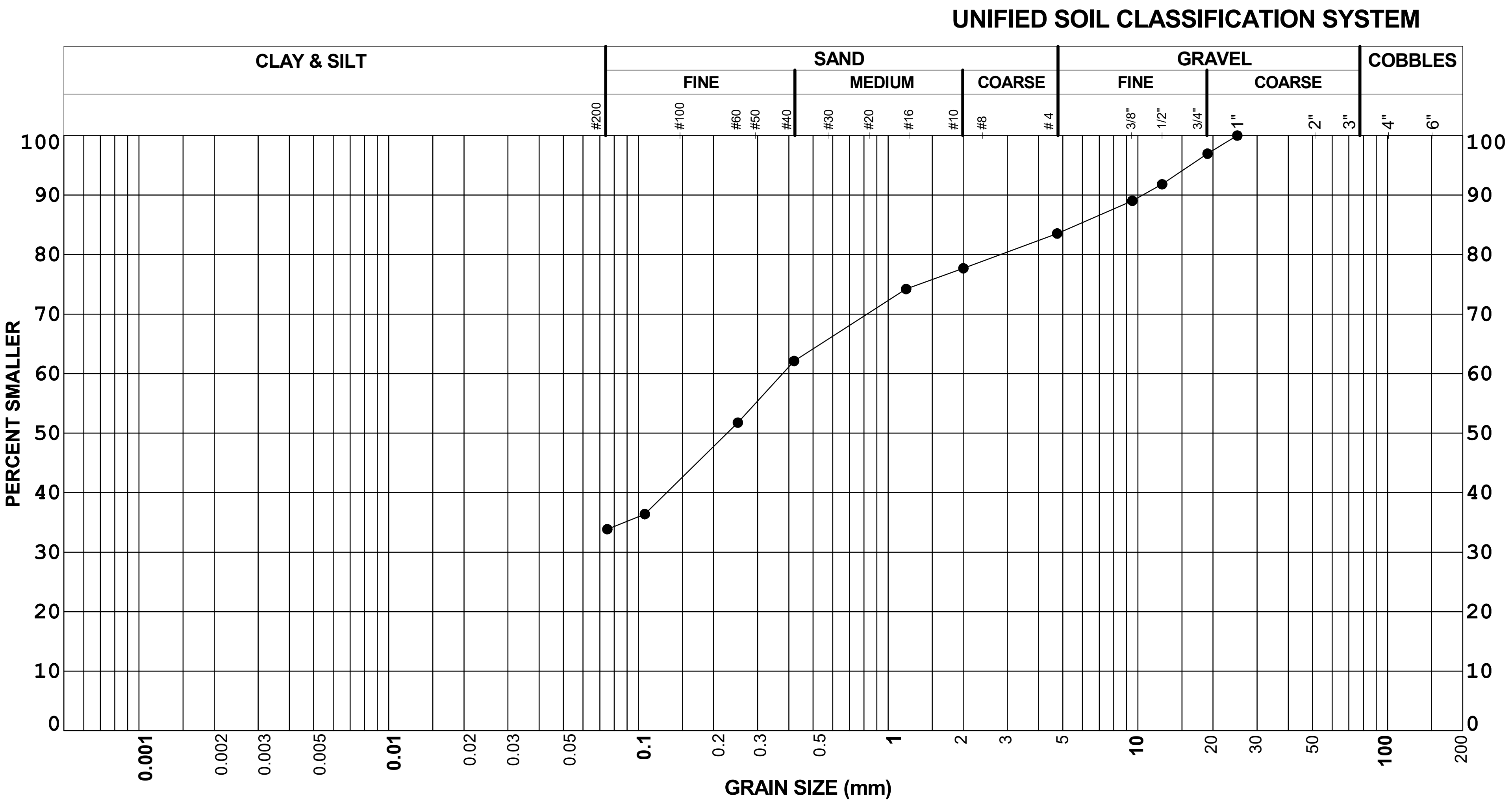
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TF-8N	DS-4	7.35	16	50	34		

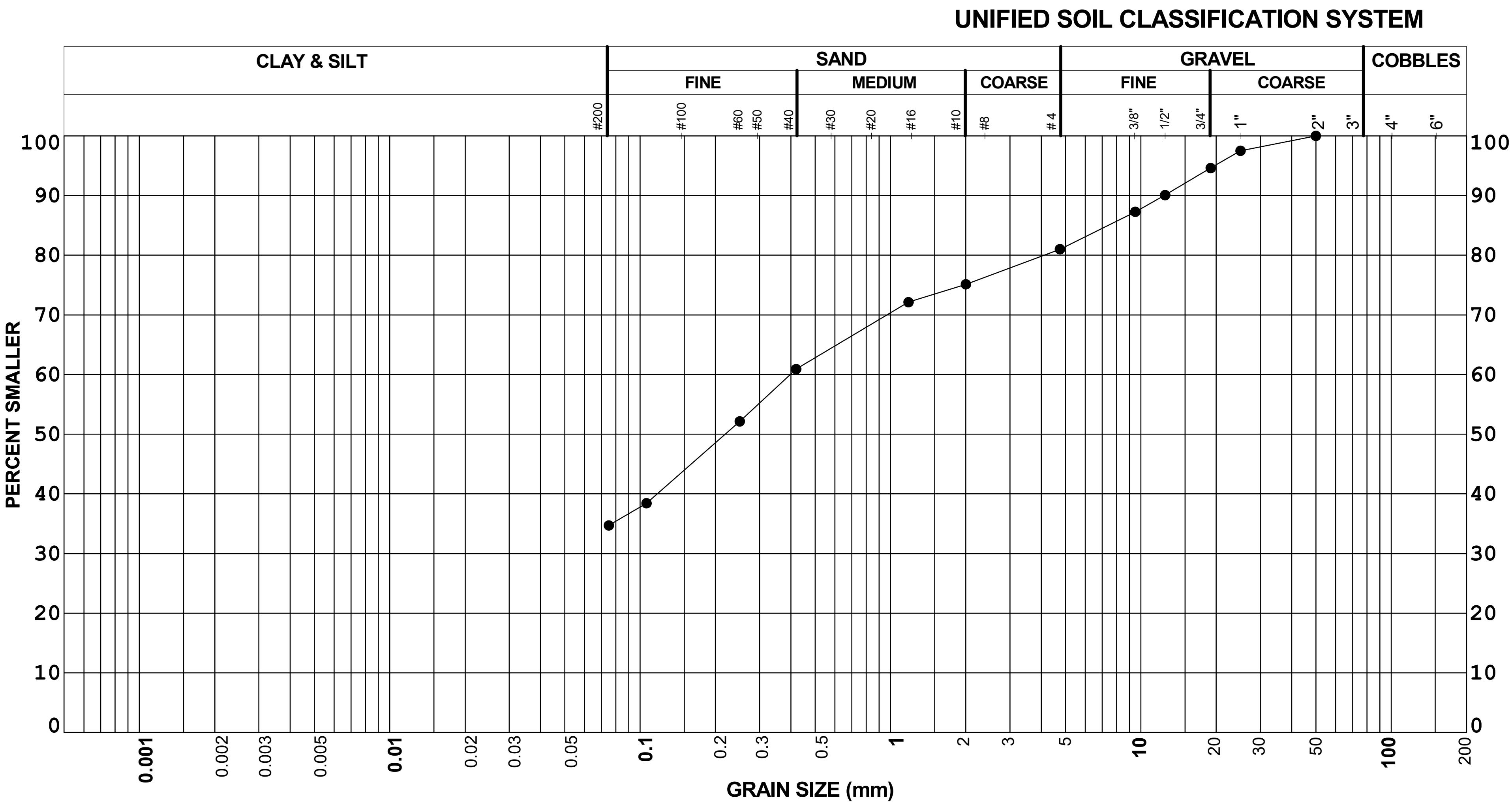
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TW-01	DS-2	3.20	19	46	35		

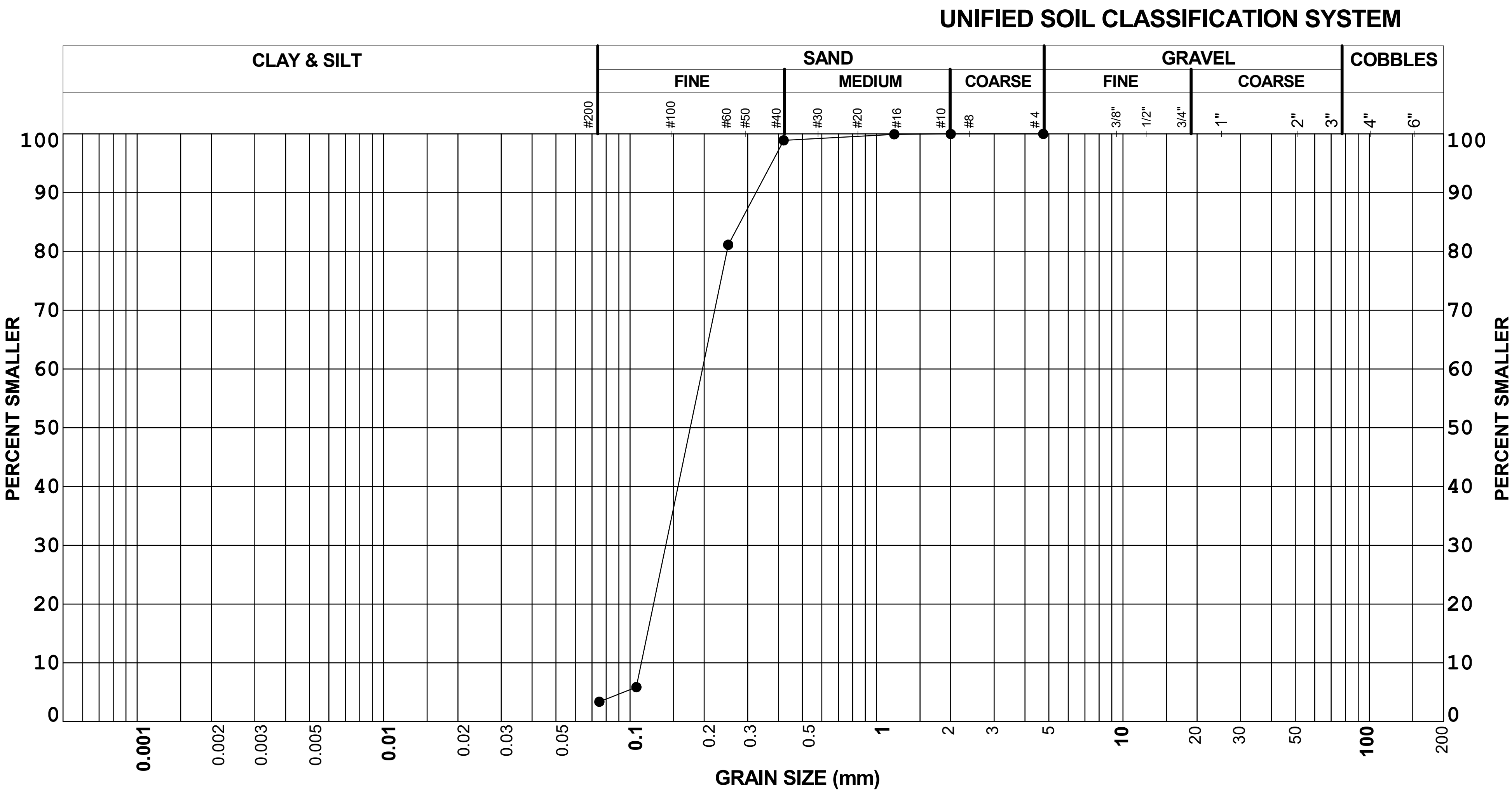
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TW-01	DS-6	13.30	0	97	3		

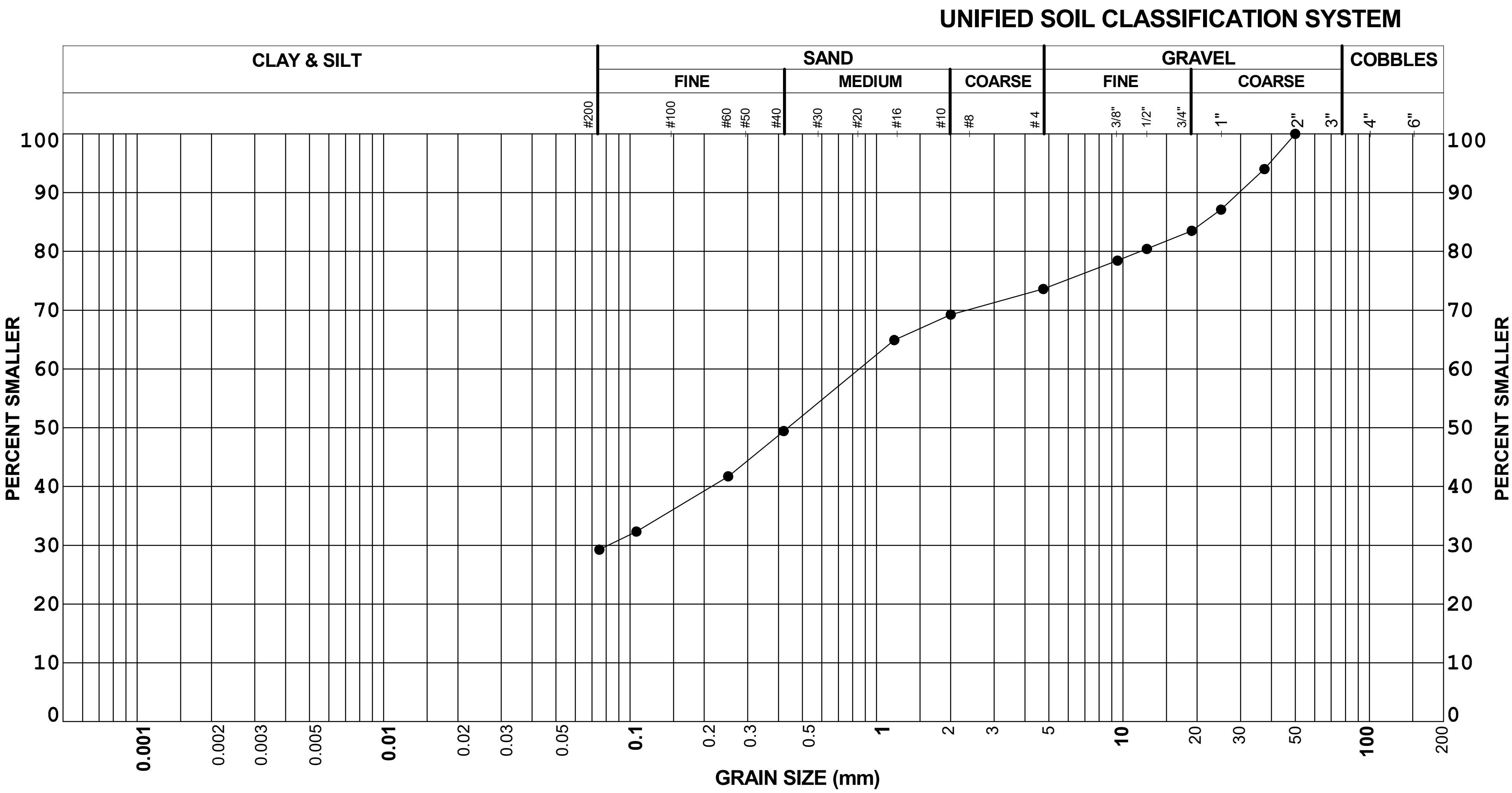
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



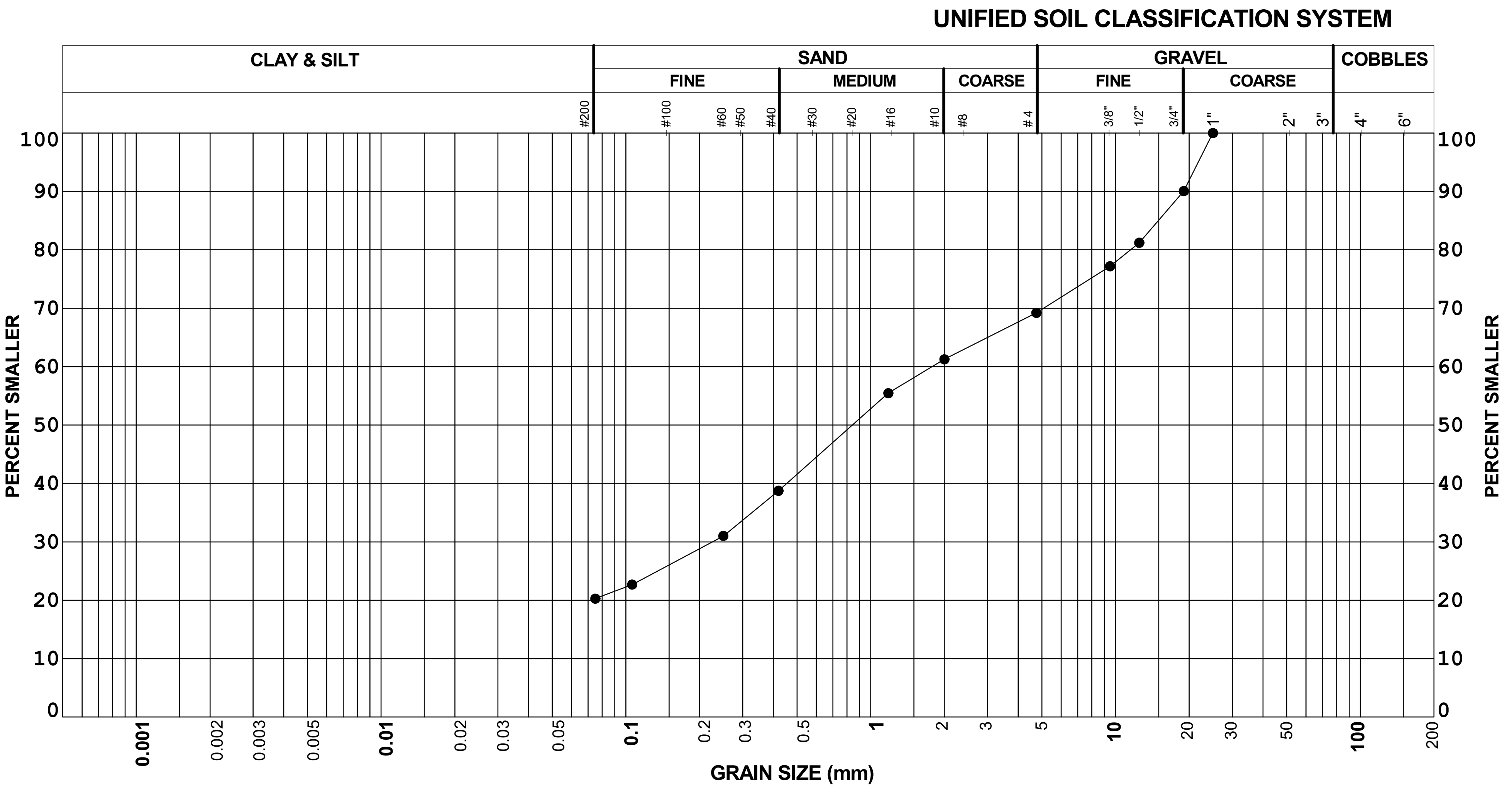
BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TW-01	DS-8	16.10	26	45	29		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TW-01	DS-11	22.70	31	49	20		

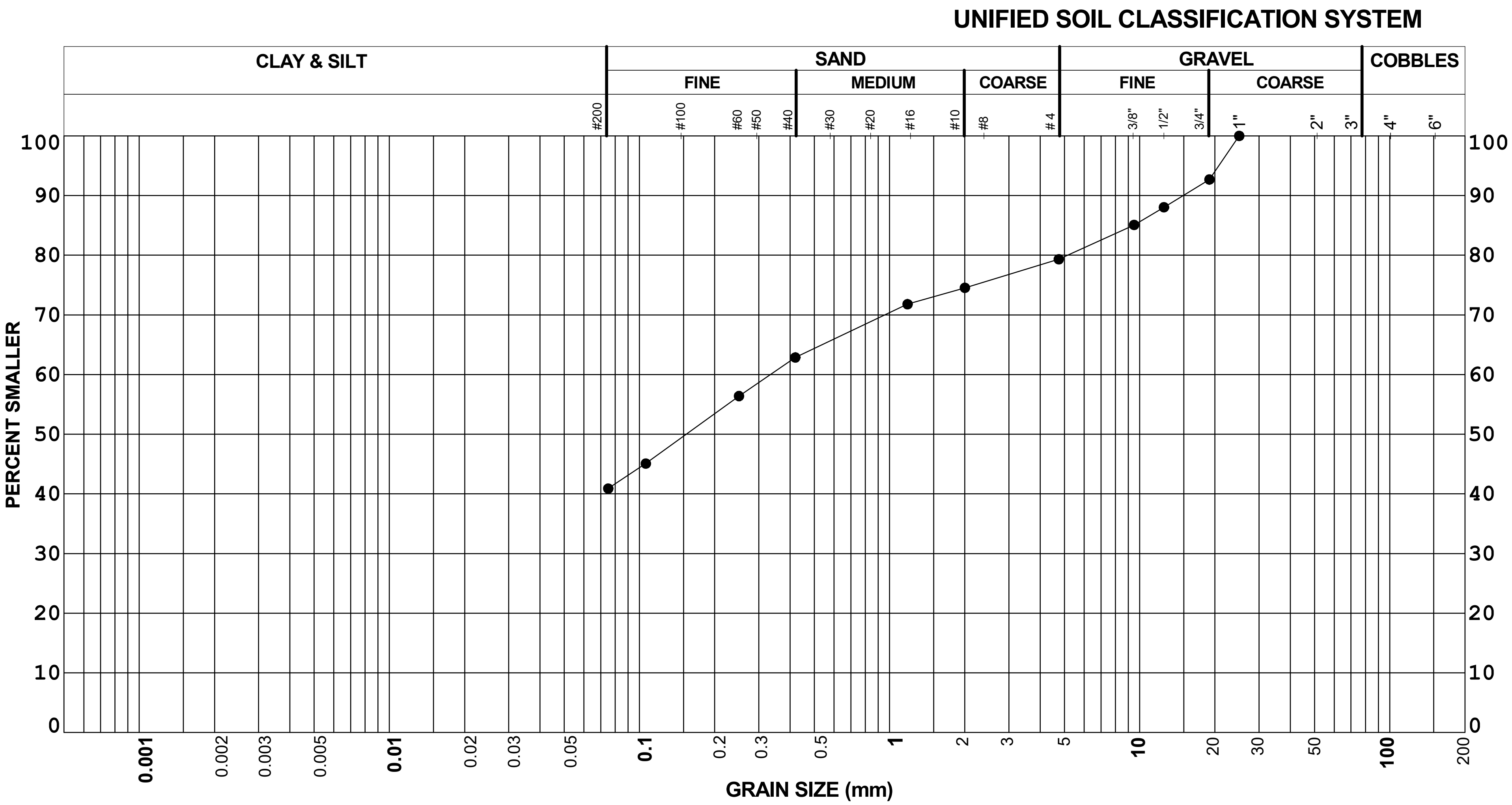
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TW-02	DS-2	7.30	21	38	41		

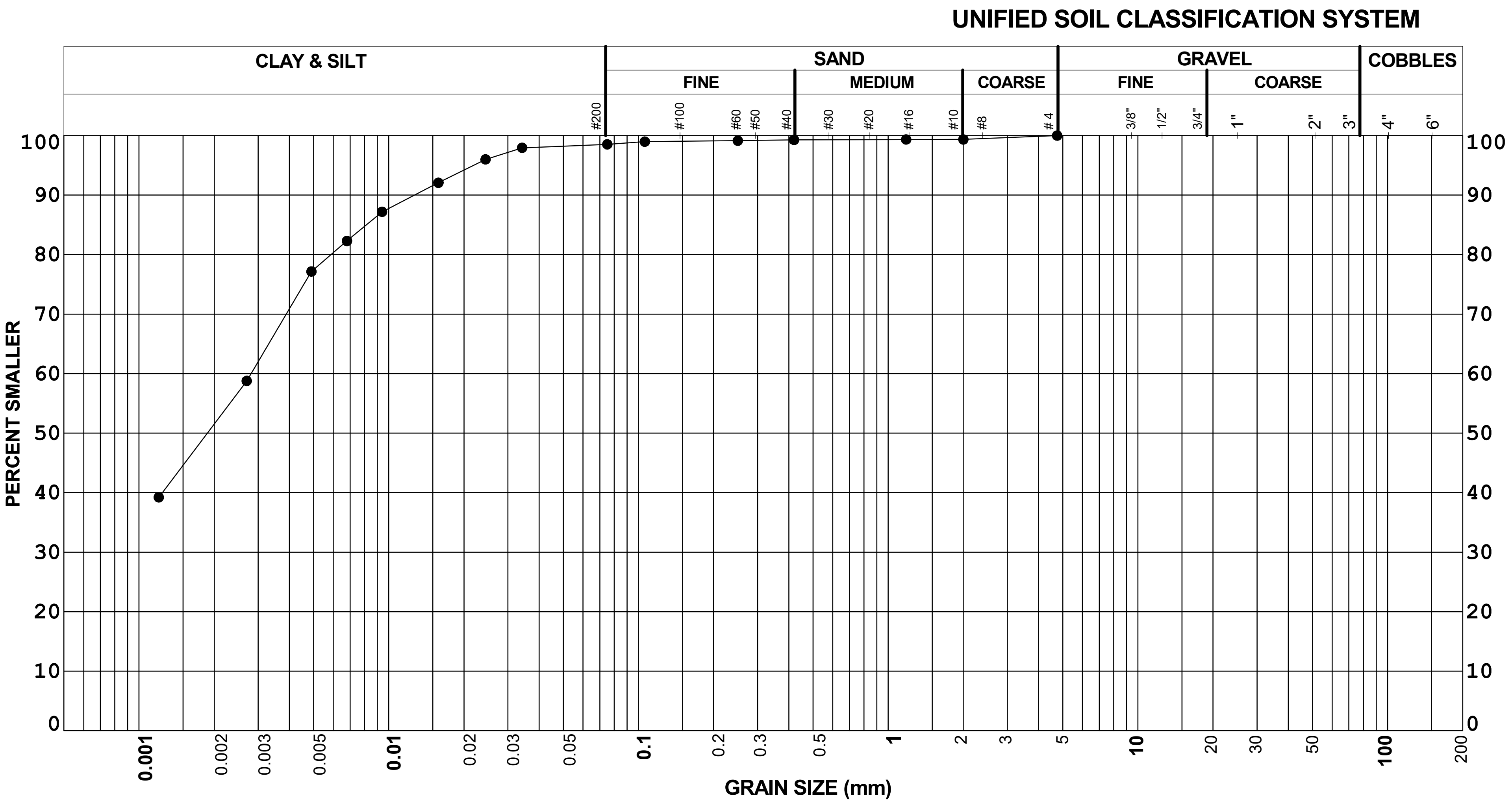
REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project



BOREHOLE	SAMPLE	DEPTH	GRAVEL (%)	SAND (%)	FINES (%)	LL (%)	PI (%)
● BH18-TW-02	DS-10	19.50	0	1	99		

REMARKS:

GRAIN SIZE DISTRIBUTION

Baffinland Iron Mine

HATCH

Project

Pore Water Extraction and Determination of Soluble Salt Content of Soils by Refractometer

ASTM D4542-15

HATCH
Geotechnical Laboratory

Date:	August 15. 2018	Baffinland Iron Mines
Project Number:	H/353004	2275 Upper Middle Rd, Oakville Ontario.
Project:	**Mary River Expansion Project**	**Attention: M. Yang**

Sample	**As Listed Below**
Source	**Proposed New Truck Shop and Tank Farm Locations, Boreholes noted in table.**

Borehole	**Sample**	**Depth m**	**Salinity PPT**	**Notes**
NA	NA	NA	0.0	Distilled Water
BH18-TF-1	DQ3	5.4 - 5.6	0.0	Water with silt
BH18-TF-1	DQ5	9.5 - 9.8	0.0	Water with silt
BH18-TF-2	DQ3	5.6 - 6.0	0.0	Water with silt
BH18-TF-2	DS4	6.1 - 6.5	0.0	Water with silt
BH18-TF-2	DQ8	11.85 - 12.0	0.0	Water with silt
NA	NA	NA	0.0	Distilled Water
BH18-TF-4	DQ2	5.9 - 6.0	0.0	Water with silt
BH18-TF-4	DS4	7.9 - 8.15	0.0	Soil (silt)
BH18-TF-4	DQ8	13.5 - 13.6	2.0	Soil (silt and sand)
BH18-TF-7N	DS3	6.4 - 6.6	0.0	Soil (silt and sand)
BH18-TF-7N	DQ4	6.95 - 7.15	0.0	Water with silt
BH18-TF-8N	DQ3	5.0 - 5.4	0.0	Water with silt
BH18-TW-2	DQ9	18.2 - 18.3	0.0	Water with silt
NA	NA	NA	0.0	Distilled Water

Comments: Tested with EXTECH Model RF20 Refractometer with automatic temperature compensation.

Reported by: R. Serluca. Lab Manager, Aug. 15, 2018

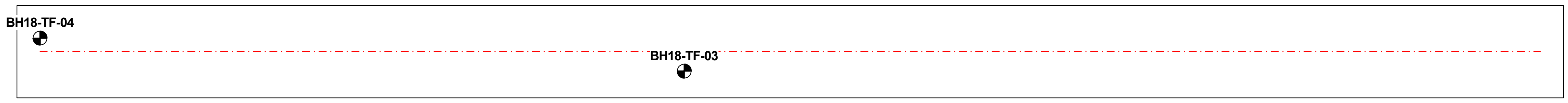
Name, Title, Date

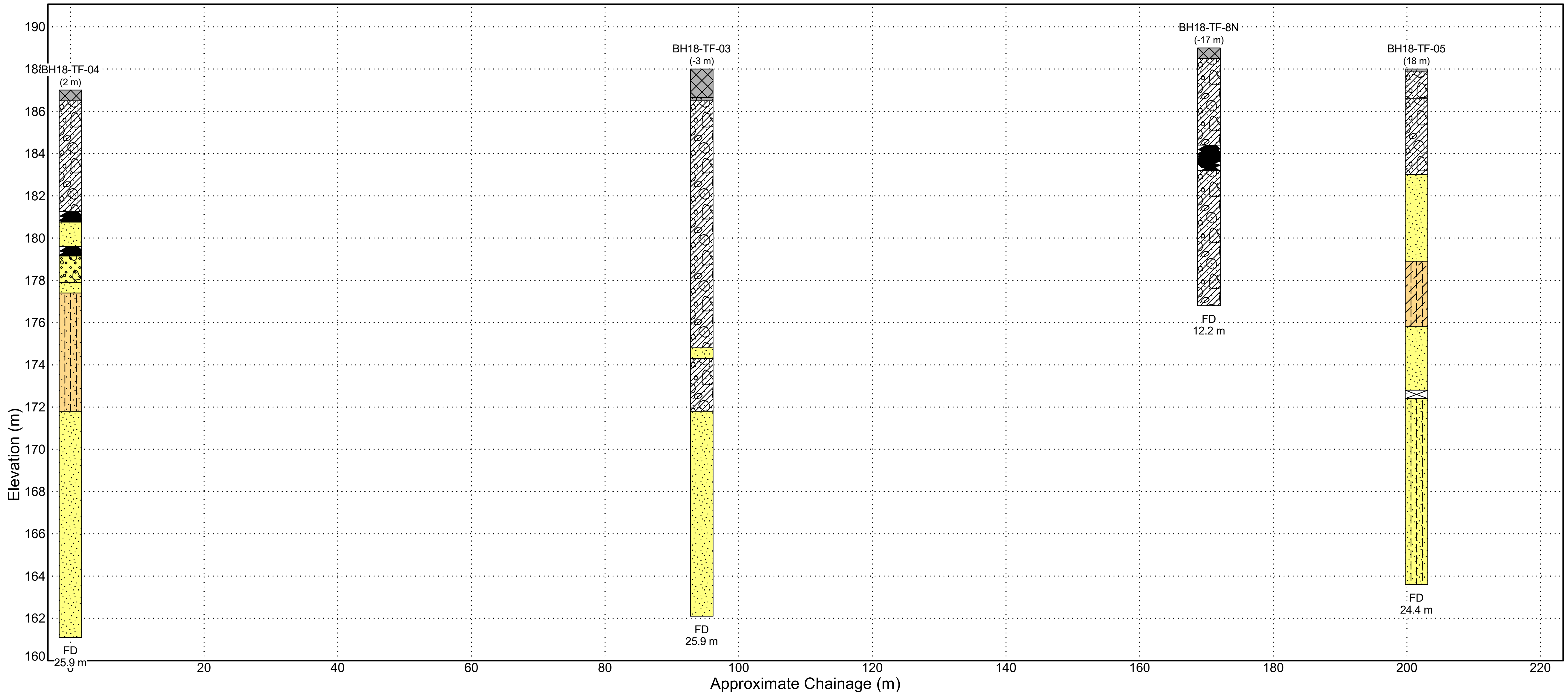
Reviewed by: M. Yang. EIT Aug.16 ,2018

Name, Title, Date

Appendix E

Fence Diagrams





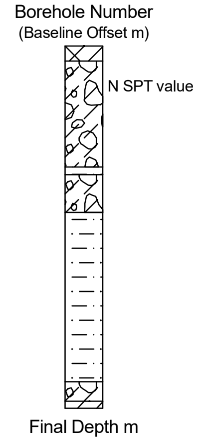
MAP KEY

◕ BH03 INVESTIGATION ON SECTION

◕ TP03 INVESTIGATION OFF SECTION

▲ ▲ SECTION LINES

POST LEGEND

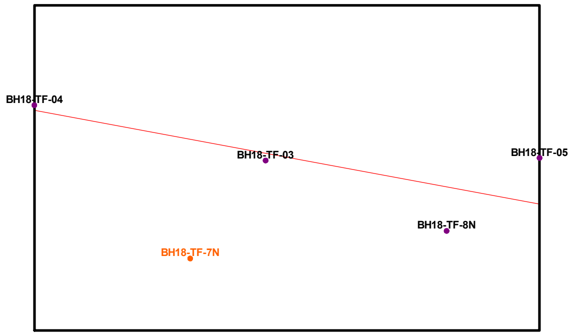


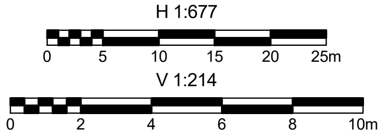
STRATAGRAPHIC BOUNDARIES

MATERIAL GRAPHICS

▩	FILL (made ground)	▨	Well-graded Gravelly SAND
▩	Topsoil	▨	Sandy SILT
▨	Glacial TILL	▨	Low Plasticity Silty CLAY to Clayey SILT
▨	Poorly-graded SAND	☒	Core Loss
■	Ice	▨	Silty SAND

SITE MAP

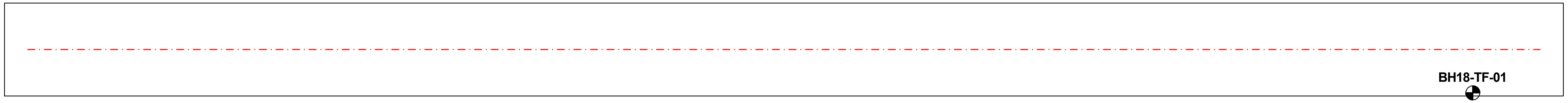


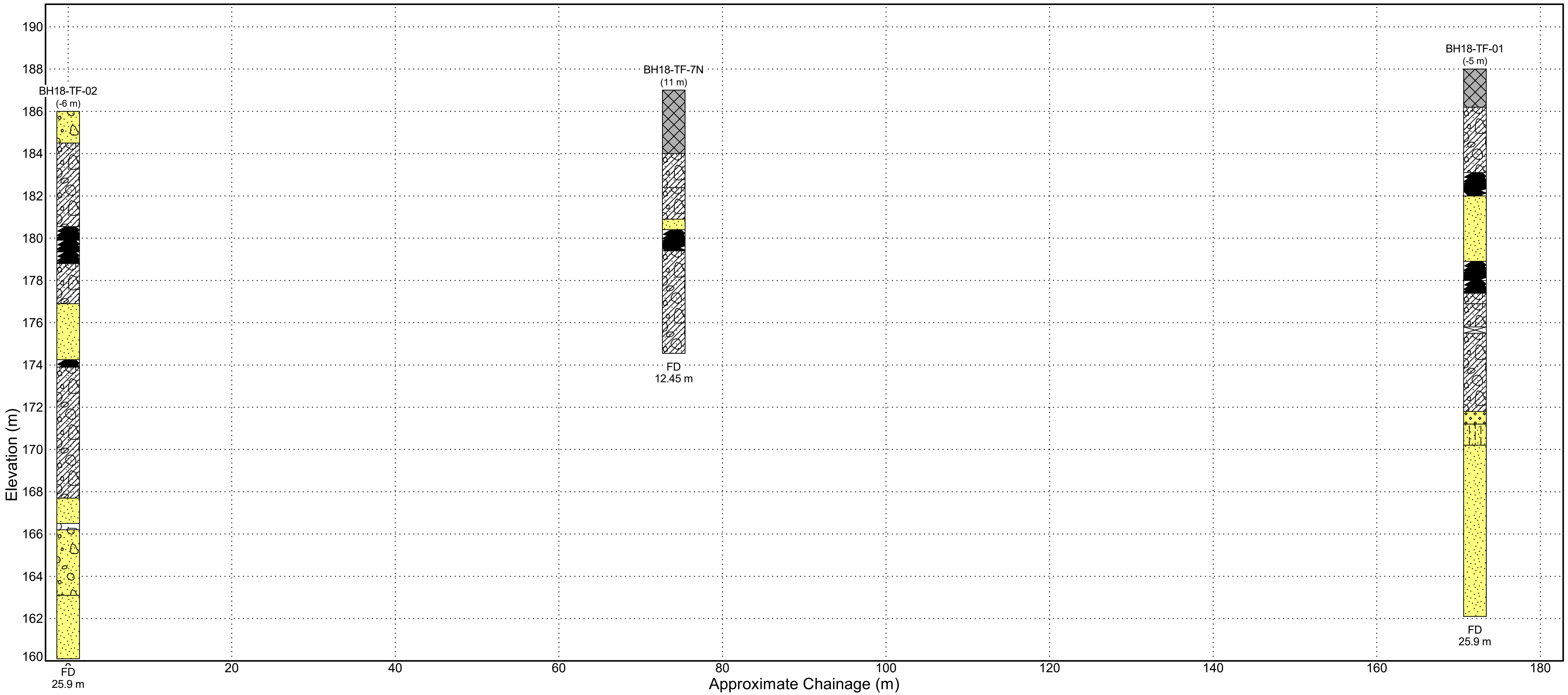


Coord.System: "NAD83" Zone 17 Height Datum: NAD83

HATCH

CLIENT Baffinland Iron Mine		PROJECT Mary River Expansion Study	
DRAWN CL	DATE 8/24/2018	TITLE TANK FARM NORTH SIDE	
CHECKED	DATE		
SCALE H 1:677 V 1:214 VE=3X		PROJECT No H353004	FIGURE No E3





MAP KEY

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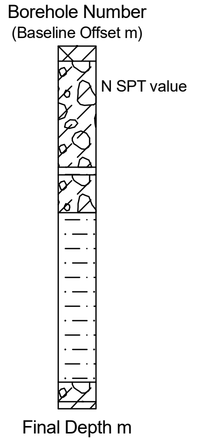
- ● TP03 INVESTIGATION OFF SECTION
- ▲ ▲ SECTION LINES

POST LEGEND

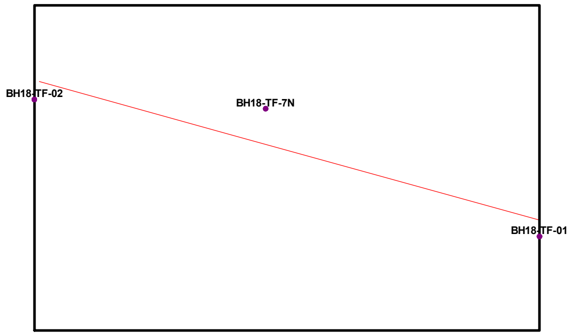


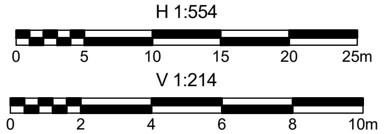
STRATAGRAPHIC BOUNDARIES

MATERIAL GRAPHICS

▨ FILL (made ground)	▨ Well-graded SAND
▨ Glacial TILL	▨ Silty SAND
■ Ice	▨ Poorly-graded Gravelly SAND
▨ Poorly-graded SAND	▨ BOULDERS
☒ Core Loss	

SITE MAP

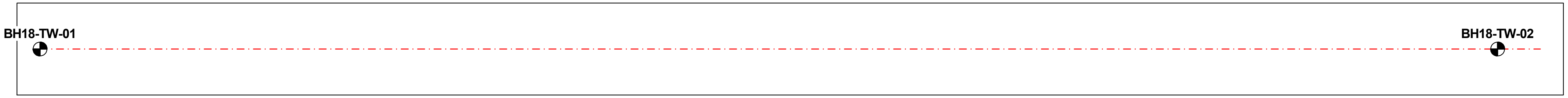


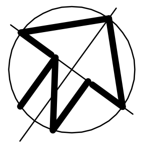


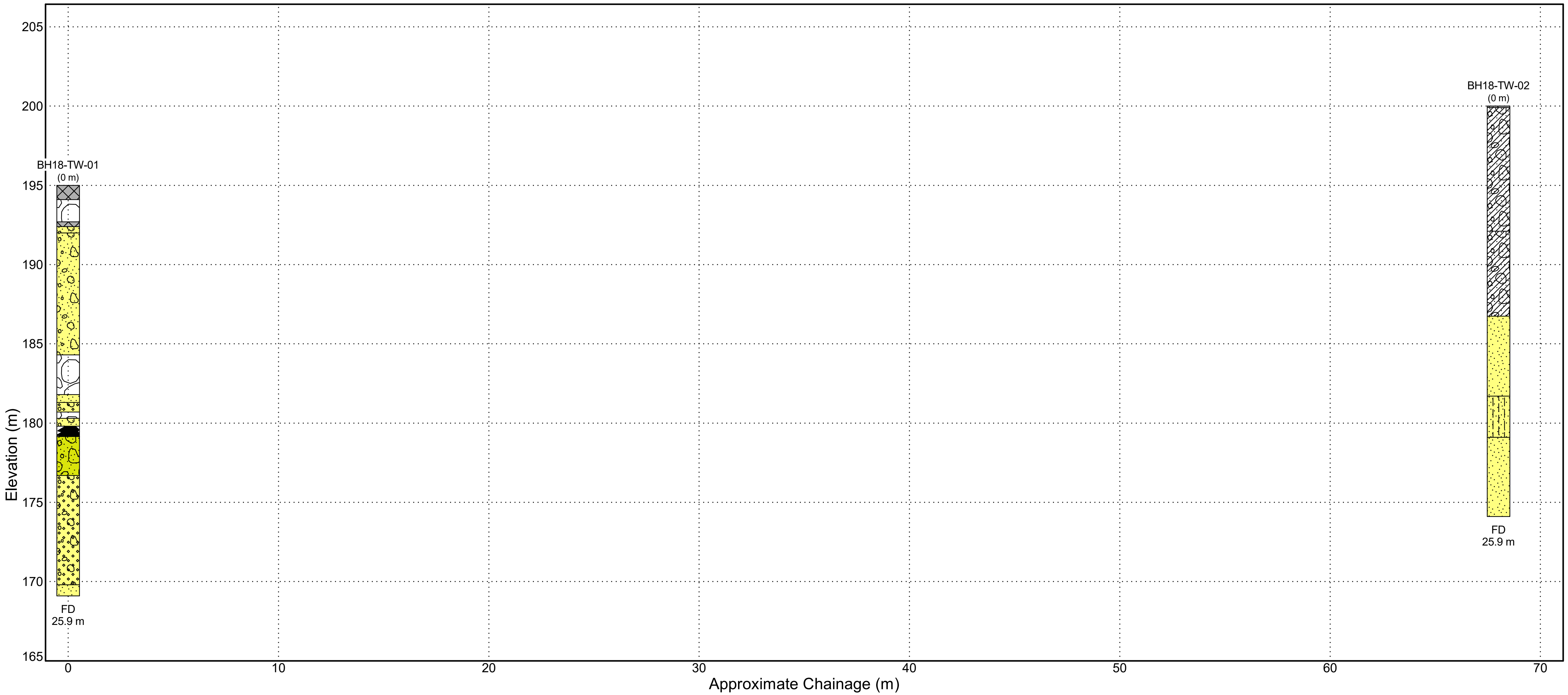
Coord.System: "NAD83" Zone 17 Height Datum: NAD83

HATCH

CLIENT Baffinland Iron Mine		PROJECT Mary River Expansion Study	
DRAWN CL	DATE 8/24/2018	TITLE TANK FARM SOUTH SIDE	
CHECKED	DATE		
SCALE H 1:554 V 1:214 VE=3X		PROJECT No H353004	FIGURE No E2



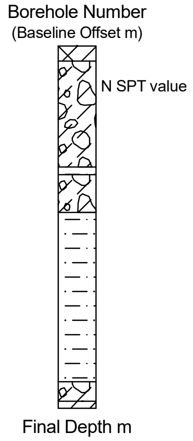




MAP KEY

◕	BH03	INVESTIGATION ON SECTION
◕	TP03	INVESTIGATION OFF SECTION
▲ ▲		SECTION LINES

POST LEGEND

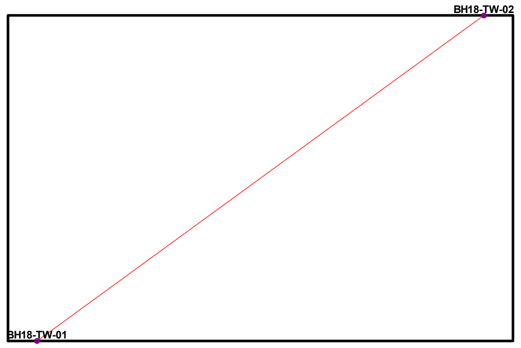


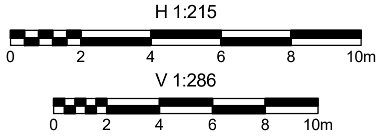
STRATAGRAPHIC BOUNDARIES

MATERIAL GRAPHICS

- ▨ FILL (made ground)
- ▢ BOULDERS
- ▨ Poorly-graded Gravelly SAND
- ▨ Poorly-graded SAND
- ▨ Well-graded Gravelly SAND
- ■ Ice
- ▨ Poorly-graded Sandy GRAVEL
- ▨ Topsoil
- ▨ Glacial TILL
- ▨ Silty SAND

SITE MAP





Coord.System: "NAD83" Zone 17 Height Datum: NAD83

HATCH

CLIENT Baffinland Iron Mine

PROJECT Mary River Expansion Study

DRAWN CL

DATE 8/24/2018

CHECKED

DATE

TITLE

TRUCK WORKSHOP

SCALE H 1:215 V 1:286 VE=1X

PROJECT No H353004

FIGURE No E1

Appendix F

Summary of Laboratory Results

Borehole No.	Sample No.	Depth	Moisture Content	Gravel (%)	Sand (%)	Fines (%)
BH18-TF-01	DS-1	0.9				
	DS-2	3.7	7	17	48	35
	DQ-3	5.4				
	DS-4	7.0	45	9	73	18
	DQ-5	9.5				
	DS-6	12.9				
	DS-7	15.5	11	37	35	28
	DS-8	17.3	20	20	43	37
	DS-9	19.1				
	DS-10	23.5				
BH18-TF-02	DS-1	1.0	2	37	60	3
	DS-5	4.0	9	24	45	31
	DS-2	4.9				
	DQ-3	5.6				
	DS-4	6.1				
	DS-6	7.9	10	27	39	34
	DS-7	11.0				
	DQ-8	11.9				
	DS-9	13.2	9	15	58	27
	DS-10	15.2				
	DS-11	18.3				
	DS-12	19.9	7	21	53	26
BH18-TF-03	DS-1	0.2				
	DS-2	2.3				
	DS-3	6.4				
	DS-4	8.2	8	22	42	36
	DQ-5	9.5				
	DS-6	10.7				
	DQ-7	12.5				
	DQ-8	12.9				
	DQ-9	13.2	21	0	96	4
	DS-10	14.1	9	11	47	42
	DS-11	15.6				
	DS-12	17.5	11	11	61	28
	DS-13	18.6				
	DS-14	25.0				
BH18-TF-04	DS-1	0.6	6	42	43	15
	DS-10	3.9				
	DQ-2	5.9				
	DS-4	7.9	12	22	68	10
	DS-5	9.2				
	DS-6	9.8				
	DS-7	10.9	32	8	33	59
	DS-9	14.6				
	DQ-8	13.5				
	DS-11	16.0				
	DS-12	20.1				
	DS-13	25.0	12	0	77	23
BH18-TF-05	DS-13	23.2	11	0	70	30

Borehole No.	Sample No.	Depth	Moisture Content	Gravel (%)	Sand (%)	Fines (%)
BH18-TF-7N	DS-1	0.5				
	DS-2	5.1	10	32	46	22
	DS-3	6.4	26	0	72	28
	DQ-4	7.0				
	DS-5	8.3	10	21	47	32
	DS-6	10.8				
BH18-TF-8N	DS-1	0.9	4	26	50	24
	DS-2	3.3				
	DQ-3	5.0				
	DS-4	7.4	6	16	50	34
	DS-5	11.9				
BH18-TW-01	DS-1	2.3				
	DS-2	3.2	10	19	46	35
	DQ-3	4.6				
	DS-4	8.3				
	DS-5	13.2				
	DQ-6	13.3	23	0	97	3
	DS-7	13.7				
	DQ-9	15.8				
	DS-8	16.1	10	26	45	29
	DS-9	18.9				
	DS-10	22.7	8	31	49	20
	DQ-12	24.4				
	DQ-13	25.5				
	DS-14	25.6				
BH18-TW-02	DS-1	2.1				
	DS-2	7.3	11	21	38	41
	DS-3	8.2				
	DS-4	9.5				
	DS-5	11.4				
	DQ-6	12.4				
	DQ-7	13.5				
	DS-8	17.4				
	DQ-9	18.2				
	DS-10	19.5	18	0	1	99
	DS-11	22.0				
	DS-12	25.3				

Appendix G

Geotechnical Investigation Safety Plan

1. Introduction

A geotechnical field investigation is underway to gather subsurface data for the 12 Mtpa mine expansion prefeasibility study, which includes an offshore (on ice) investigation for the proposed Ore Dock No. 2. This job hazard analysis (JHA) presents an assessment of the hazards and control measures to reduce the likelihood or consequence of the hazards in order to carry out the offshore investigation program. There are a total of 10 proposed boreholes for the dock area including 5 sonic boreholes and 5 Piezocone (CPTu) test holes.

Job Hazard Analysis Form

PROJECT/TASK: ZG003 Geotechnical Marine Drilling Milne Inlet		**Department: Projects Boart Longyear**				**JOB No.:ZG003**			
SUPERVISOR: Emile Beauchamp		**LOCATION: Future Ore Dock Milne Inlet**				**DATE: March 12 ,2017**			
JOB STEP Break the job into steps. Listing work which may be hazardous.	**HAZARDS** List the hazard or type of harm identified with each step.	**Inherent**			**CONTROL MEASURE** List the necessary control measures to be followed to eliminate/reduce the identified hazards.	**Residual**			**ACTION** Person who will ensure this happens
		Consequence	**Likelihood**	**Risk Ranking**		**Consequence**	**Likelihood**	**Risk Ranking**	
1. Pre-job JHA Review.	Missing critical items on the JHA that can lead to an incident	3	2	5	Conduct a pre-job JHA review with Safety and critical team members All workers will have the opportunity to identify changes needed Any changes will be added to this document	1	1	2	Marlon Coakley/Warren Hoyle
2. Workers to complete FLRA card in the field at location prior to starting work.	Additional hazards in the area that may not have been identified on the JHA and daily changes that may pose additional danger to the health and safety of workers, the environment and property	3	3	6	Look at immediate work area for hazards that may exist, not identified on the JHA. Have other workers in the group sign off on the FLHA	1	1	2	All workers
3. Load Weights – The number and types of vehicles and equipment and their maximum gross weights	Not knowing load calculations will run the risk of breaking through the ice.	5	3	8	All equipment and material shall have posted GVW or gross equipment weight or maximum pull back loads available for use with load-ice thickness tables and shall follow the Ice Safety Plan. Refer to Attachment B for minimum ice thickness required for the drilling operations and Attachment C for further guidelines regarding Ice Safety	4	2	6	Warren Hoyle

4. General Site	Ice Conditions – Slip falls Ice Conditions – Adequate load bearing capacity Inadequate lighting Interaction with a Polar Bear Cold Whiteout conditions Emergency Procedures	3	2	5	Construct a working platform for outside of drill shack to store drill steel and allow the use of salt Use of traction aids on work boots will be required for work on ice surfaces. Apply salt to drill shack decks Engineered Assessment of minimum ice thickness as referenced in Attachment B for ice thickness required for the drilling operations and Attachment C for further guidelines regarding Ice Safety Place delineators in the snow marking access from the drilling location to the shoreline Existing Baffinland procedure “Safely Working On Fresh And Salt Water Ice” shall be followed Polar Bear Monitor will be available at all times Employees will have appropriate PPE including clothing available for safely working in -40 C and windy conditions Worksite location is approximately 300 meters from the shoreline. No work will be conducted in whiteout conditions and a safety shelter will be available immediately adjacent to the work area Site emergency procedures will be provided and reviewed at site	2	1	3	All Crew

5. Working around water and sea ice	Water may appear to be completely frozen over, but not enough to support persons Falling in water Equipment breaking through ice Workers unaware of potential dangerous conditions	5 5 4 3	1 1 2 1	6 6 6 4	Ice thickness to be assessed before walking on ice as per BIM Policy. Initial ice profiling will be conducted with an ice auger Floatation suit will be used for the initial ice profiling using an ice auger. Survival Bag (sleeping bag) will be available to reduce the risk of hyperthermia Follow the BIM Working On Ice Procedure (BAF-PH1-320-PRO-005, Rev 0, March 1, 2016) All workers will be required to complete the Alberta Working Safely on Ice Procedure online training	2	1	3	Marlon Coakley/Warren Hoyle
6. Drill testing for ice thickness	Water may appear to be completely frozen over, but not enough to support persons. Large ice cracks or crevices Falling in water Strains/Sprains Slipping on ice Drilling ice with power auger Changes in ice conditions	3	4	7	Traction aids will be used for any ice work Ice thickness to be assessed before walking on ice Floatation suits will be worn by workers while ice auguring, the worker is to be tethered to a primary rescue worker at a distance of 30m Snow must be removed at the hole location so ice can be examined for quality as described in the Ice field guide. Hand shovelling may be necessary If crevices/ cracks greater than 50% of the ice thickness are present, repairs must be made if there is risk of falling through ice into deep water	2	2	4	Warren Hoyle / Marlon Coakley

					Ice thickness for a person to walk on must be a minimum 13 cm. **STOP** all work if this condition is not met and return to shore. Be aware when using power ice auger that auger bit could bind or jam, have secure footing and grip on auger The ice auger hole spacing will be 20 m along the centreline access and the grid established in the designated work area. Secondary test holes will be augured at 10 m spacing within 250 m of the shoreline, if required based on the variable ice thickness Complete daily inspections of ice surfaces and record on ice log inspection sheet				
7. Access from Land to Sea Ice Snow removal equipment, drill rig and access vehicles are to be used for borehole access	Long distances to walk Exposure to cold White Out conditions Risk of falling under sea ice along the shoreline	4	1	5	Proper warm winter wear to be used Sat phones and digital radio use. Rig mats to be used to bridge over the fractured ice transition area if the transition between sea ice and shoreline needs leveling Buddy system is important to verify presence of frost bite or other cold related concerns **Vehicle operators and passengers are not to wear seat belts when working on ice**	1	1	2	All workers

8. Refueling of equipment	Fuel spills Regulatory or social impacts Spills into water bodies	3	2	5	Use of duck ponds with any refueling Have sufficient spill cleanup supplies on hand to respond to potential spills Maximize space between refueling vehicle	3	1	4	All workers
9. Extreme weather exposure when working outdoors or driving to and from the Borehole Location	Stranded work crew in white out conditions Cold emergencies or cold injuries Mechanical equipment failure	4	2	6	BIM has a procedure that is designed for white out conditions – it would be announced on the radio An emergency shelter to be used when in the Marine Drilling areas Emergency Shelter: Heated wooden shack (7' 8" by 7' 8") set on platform with skis Crews to radio from Hatch leads Buddy system to watch out for fellow workers who may not realize they are developing frost bite Workers to dress in arctic gear and layered clothing Proper PPE required Equipment check list Review Tidal charts on a daily basis Workers to take warm up breaks to stay warm and alert At toolbox review weather forecast with crew and prepare accordingly	2	1	3	All workers

10. Chemical handling- No unusual chemicals other than equipment needs are anticipated to be used.	Spills, leaks Chemical splash Chemical exposure	2	2	4	All products to be stored in secondary containment MSDS to supplied to BIM for review MSDS books to be accessible at the work front MSDS training and WHMIS training completed before arriving to site PPE will be followed as per MSDS recommendations as will first aid and environmental responses Spills response training and supplies to be kept with the equipment	1	1	2	Boart Longyear
11. Waste management and Wildlife Encounters	Risk of wildlife encounters due to improper waste controls Regulatory non compliance	3	2	5	Crews will collect waste daily and transport it back to camp Crews will follow BIM waste management guidelines No placing or storing of food in the back of pickup trucks Secure all small tools and PPE as foxes may carry away small articles from the site	2	2	4	All workers
12. Ecological and Cultural sensitive areas	Risk of causing damage to archeological areas Destroying vegetation Sensitive wildlife and marine life areas Regulatory and reputation damage	3	3	6	Crews have been instructed that there will be **NO** entry to the area east of the sealift ramp Crews are not to build or alter any inukshuk's or other rock formations on the tundra Permits will be required for the work	2	2	4	All personnel

13. Assemble Drill on skid platform skid and construct four walls and roofs	General hazards associated with drill assembly Inadequate communication between Boart Longyear and Site Services / mobile equipment operators	2	2	4	FLRA to be complete by Boart Longyear supervisor prior to executing work Boart Longyear Drilling operations SOPs to be followed including Boart Longyear Procedure 4001	1	1	2	Warren Hoyle / Marlon Coakley
14. Auguring holes in ice for sonic drilling and CPT work	Large ice cracks or crevices Falling in water Strains/Sprains Slipping on ice Drilling ice with power auger Changes in ice conditions	3	3	6	Wear traction aids for any ice work PFDs to be worn by workers while ice auguring during the sonic drilling and CPT operations Snow must be removed at the hole location so ice can be examined for quality. Hand shovelling may be necessary Be aware when using power ice auger that auger bit could bind or jam, have secure footing and grip on auger Complete daily inspections of ice surfaces and record on ice log inspection sheet All holes must be marked using an orange spray paint Any hole in ice over 30 cm in diameter must have a physical barrier around the hole	3	2	5	
15. Working around rotating equipment	Entanglement injuries	3	2	5	All equipment guards to be in place and in good working condition No loose clothing or drawstrings that can get pulled into rotating equipment Long hair must be contained to prevent entanglement into rotating equipment	2	1	3	All workers

					If any maintenance is required then energy isolation procedures to be followed				
16. Isolation of energy sources	Potential energy release that causes injury	3	2	5	All crews will follow the BIM Zero Energy State (ZES) procedure Crews to be given the BIM ZES training on site and fully understand the BIM requirements	1	1	2	Boart Longyear Crews BIM H&S
17. Working on equipment	Slip and trip hazards around railings, stairs and uneven ground.	2	2	4	Rails are installed around deck and to be properly maintained in good condition Stairs to be used on equipment A head cage will be used to reduce chance of contact with the rotating head Estops to be in good working order and easily accessible FLRA to be completed daily to review hazards All crews will follow the BIM Zero Energy State (ZES) procedure	1	1	2	Boart Longyear crew
18. Ice monitoring during drilling activities	Excessive deflection in ice	4	3	7	Hatch geotechs crew will monitor ice conditions during drilling including cracks around the work area, monitor freeboard in drilled holes for signs of ice deflection	2	2	4	All crew

19. Spotter activities	Equipment could come in contact with Spotter	4	2	6	Spotter to maintain eye contact with driver Spotter to review FLRA Agreed hand signals to be used with drivers in conjunction with BIM spotter procedure Agreed hand signals will be documented on the FLRA Drivers to immediately stop if the Spotter is out of eye contact	1	1	2	Boart Longyear crew
20. Manual lifting	Pinch point, back injuries, muscle and joint sprains and strains	2	3	5	Work in pairs, FLRA reviews Work with a buddy on heavy or awkward lifts Use proper lifting techniques 100 pound pipes to be handled by two workers	1	1	2	All crew
21. Working with pressure systems	Pressurized water and hydraulic fluids are used on drill and support equipment	3	2	5	Pre operational inspection Follow all safe work procedures. ZES when maintenance is required.	1	1	2	Boart Longyear crew
22. Falling objects	Potential exists for falling of drill rod and casing falling from overhead	3	2	5	Rigging and slinging training required when working with suspended loads and overhead hazards Perform FLRA	1	1	2	Boart Longyear Hatch Geotec EHS techs
23. High noise and vibration areas on the rigs	Hearing damage	2	2	4	Hearing protection is required by use of ear plugs or muffs.	2	1	3	Boart Longyear Hatch Geotec EHS techs

24. Housekeeping	Potential exists for poor housekeeping causing slip/trips and other hazards	3	2	5	Daily site assessments and toolbox meetings by drillers and site supervisors BIM EHS techs to perform daily inspections	2	2	4	All Crew
25. Fatigue	Potential exists for crew fatigue	2	2	4	Fit for duty confirmation required for all employees, daily FLRA reviews Micro breaks to stretch Proper rest during off shift period	1	1	2	All Crew
26. Working at night or 24 hour darkness	Higher risk of injury due to poor visibility	3	3	6	Hi-vis work gear to be used Use of flashlight and headlamp Workers to stay within 10 meters (30 feet) of the worksites at any time Use of wobble lights and light tower Emergency shelter	1	1	2	All Crew
27. Hot work - welding	Fire risk Burn injuries Welders Flash	2	2	4	Hot work training Use of hot work permits and JHA for any Hot Work Fire Watch required Proper PPE Welding training required	1	1	2	Boart Longyear crew

28. Rescue Plan	Rough terrain Further injuries to casualty during transit. Snow storm, white out conditions. Darkness	3	3	6	The track unit will be used to pull the survival shack (survival shack is 7’ 8” x 7’ 8” square) on platform with skis. When an incident has occurred, the Geotechnical Engineer must call a Code 1. Provide first aid treatment to the injured person until MRT arrives on site MRT will be dispatched to the location. MRT will transport the casualty. Visibility (whiteout conditions) will hinder rescue time, rescuers will have to wait out the storm, or until the whiteout conditions have subsided.	2	2	4	Marlon Coakley/ Warren Hoyle
29. Cleanup and Demob	Unfrozen open holes Complacency	3	3	6	All drill holes must be filled in with water and snow upon completion of drilling operations A Hatch site representative will confirm safe conditions upon demob All debris must be removed from ice surface and disposed off site per waste management plan BIM safety and environment representatives to attend a post project closeout inspection to document the completion of the clean-up	2	2	4	Boart Longyear

Comments:

Score	*CONSEQUENCE*		
	People	Plant	Environment
5 – Very High/ Catastrophic	Multiple Fatalities.	Greater than $10 Million Loss	Catastrophe, destruction of sensitive environment, worldwide attention. Likely EPA prosecution. More than 30 days delay.
4 – High/ Major	Fatality or Permanent Disabilities.	$1 Million to $10 Million Loss	Disaster, high levels of media attention, high cost of clean-up. Offsite environmental harm; more than 10 days delay.
3 – Moderate	Major Injuries – Incapacitations or requiring time of work.	$100 Thousand to $1 Million Loss	Major spills, onsite release, substantial environmental nuisance, more than 1day delay. (Leads to additional resources call out i.e. SES).
2 – Low/ Minor	Significant Injuries – Medical Treatments, non-permanent injury.	$10 Thousand to $100 Thousand Loss	Significant spills. (Leads to a call out of Site Emergency Response Group).
1 – Very Low/ Insignificant	Minor Injuries – First Aid Treatments (cuts/bruises).	Less than $10 Thousand Loss	Low environmental impact. Minor Spills less than 80 Litres.

Score	*LIKELIHOOD*
5 – Almost Certain	The event is expected to occur in most circumstances. Likely to occur frequently - More than 1 per year.
4 – Likely/ Probable	The event will probably occur in most circumstances. Likely to occur several times – 1 per year.
3 – Moderate/ Occasional	The event should occur at some time. Likely to occur at some time – 1 per 5 years.
2 – Remote/ Unlikely	The event could occur at some time. Unlikely but possible. 1 per 10 years.
1 – Rare/ Very Unlikely	The event may occur only in exceptional circumstances. Assumed it may not be experienced. 1 per 100 years.

Job Hazard Analysis Attendees: Darryl Finlay, Marlon Coakley, Warren Hoyle, Usman Khan, Alex Boissonneault

	Name	Signature	Date
Written by:	Marlon Coakley	Marlon Coak	Mar 20/2017
Reviewed by:	Warren Hoyle (Hatch)	Warren Hoyle	March 30, 2017
	Darryl Finlay (BIM Safety Coordinator)		March 20, 2017

Risk Rating = Consequence + Likelihood

Consequence	Risk Rating				
5	6	7	8	9	10
4	5	6	7	8	9
3	4	5	6	7	8
2	3	4	5	6	7

Risk Rating - Definitions

Risk Rating	Definitions	*Action Required*
8 - 10	Intolerable	Task not to start till the risk is eliminated or reduced. Bring to the immediate attention of management. Formal assessment required. MUST reduce the risk as a matter of priority.
7	High	Bring to the immediate attention of management. Task not to start till the risk is eliminated or reduced. Further Assessment required. MUST reduce the risk as a matter of priority.
6	Significant Risk	Bring to the attention of supervision. Review risks and ensure that they are reduced to as low as reasonably practicable. To be dealt with as soon as possible, preferably before the task commences. Introduce some form of hardware to control risk.
5	Moderate Risk	Needs to be controlled but not necessarily immediately, an action plan to control the risk should be drawn up. Review effectiveness of controls. Ensure responsibilities for

			🟨	🟨	🟦
1	**2**	**3**	**4**	**5**	**6**
	1	2	3	4	5
	Likelihood				

		control are specified.
2-4	Low Risk	If practical reduce the risk. Ensure personnel are competent to do the task. Manage by routing procedure. Monitor for change

A JHA considers a variety of activities/tasks involved in a job scope and analyses the key hazards (sources of harm) and their consequences (types of harm) eg. Sources of harm – lifting a heavy pipe - manual handling. Types of harm – Back strain.

Main Points – On how to write a JHA.

1. Define the task – what is to be done.
2. Review previous JHA if any – have we done it before?
3. Identify the steps – what is to be done.
4. Identify the hazards of each step.
5. Identify who or what could be harmed.
6. Give the task a risk rating – Consequence + Frequency
7. Develop solutions to eliminate or control hazards in each step.
8. Review the risk rating after the control system has been implemented.
9. If risk rating unacceptable review the solutions till risk rating acceptable.
10. Agree who will implement the control system.
11. Document the JHA and discuss with the relevant personnel.

Hierarchy of Hazard Management – Control Measures

These steps outline what should be planned for when deciding what control measures are to be put in place. Whenever possible the highest step should be used first and then progress down the list.

1. Eliminate the hazard.
2. Substitution.
3. Reducing the frequency of a hazardous task.
4. Enclosing the hazard.
5. Additional procedures.
6. Additional supervision.
7. Additional training.
8. Instructions / information.
9. Some personal protective equipment.

Attachment A – BIM Working on Ice Procedure

Baffinland Iron Mines Corporation

Working on Ice Procedure

BAF-PH1-320-PRO-0055

Rev 0

Prepared By: Shawn Parry
Department: Road Maintenance
Title: Manager
Date: February 9, 2017
Signature:

Approved By: Sylvain Proulx
Title: Chief Operating Officer
Date: February 9, 2017
Signature:

DOCUMENT REVISION RECORD

Issue Date MM/DD/YY	Revision	Prepared By	Approved By	Issue Purpose
01/19/17	1	S.P.	B.G.	use

TABLE OF CONTENTS

1 PURPOSE AND SCOPE

Baffinland Iron Mines Corporation is committed to taking the necessary steps to ensure that work performed on ice of lakes, rivers, streams or the ocean is conducted in a safe, efficient and environmentally compliant manner.

This procedure is not intended to provide instructions for large scale ice operations such as ice road construction and operation. For large scale ice operations, refer to "Best Practice for Building and Working Safely on Ice Covers in Alberta (Work Safe Alberta)".

2 DEFINITIONS

2.1 BAFFINLAND CLASSIFICATIONS FOR WORKING ON ICE

Class A Job – The ice is between 15 centimetres and 38 centimetres thick and the load weight, including people on the ice will be 4,536 kilograms or less.

Class B Job – The ice is more than 38 centimetres thick and the load weight, including people, is greater than 4,536 kilograms but less than 63,000 kilograms.

Class C Job – The job requirements cannot be met by either Class A or B guidelines.

See section 4, Protocols for a discussion of Class A, B and C requirements.

3 RESPONSIBILITIES

The following roles have specific accountabilities that must be met to ensure that any work on ice is conducted in a safe and environmentally responsible manner.

3.1 CHIEF OPERATING OFFICER OR GENERAL MANAGER, OPERATIONS

The Chief Operating Officer or General Manager, Operations must review and approve any Class C job for working on ice.

3.2 DEPARTMENT MANAGER/SUPERINTENDENT

The Department Manager and Superintendent are responsible to ensure their department supervisors are aware of and comply with this procedure. The manager and superintendent are also responsible to validate the terms and conditions of the JHA are implemented.

3.3 DEPARTMENT SUPERVISOR

The Supervisor is responsible for supervising the work/tasks in accordance with this procedure and the terms and conditions of the JHA. Specifically, the supervisor is responsible for:

- Notify the department manager and superintendent of the requirement to work on ice and send each a copy of the completed JHA.
- Ensure a geographically specific JHA is completed and implemented, prior to starting work.
- Notify the MRT Trainer and have them participate in the JHA.
- Ensuring that workers have reviewed and understand the JHA, prior to starting work.
- Supervise the work and act as the main point of contact for workers working on ice.

3.4 WORKER

The worker, is responsible for the following:

- Review, sign and comply with the terms and conditions of the JHA.
- Promptly reporting to their supervisor, any safety concerns or incidents that occur while working on ice.

3.5 SAFETY SUPERINTENDENT OR COORDINATOR

The Safety Superintendent or Coordinator will facilitate the working on ice JHA process.

3.6 MINE RESCUE TEAM TRAINER OR DELEGATE

The Mine Rescue Team Trainer or delegate is responsible to work with the supervisor to develop the rescue plan component of the JHA.

4 PROTOCOL

4.1 CLASS A JOB

The following table provides requirements for performing work on ice under Class A conditions. The JHA must meet the following conditions;

Equipment Example	Weight (kilograms)	Minimum Ice Thickness (centimetres)	Ice Integrity
1 or 2 people and their tools and equipment	Up to 272	15	Solid ice that is free of cracks, water and slush
Snowmobile and rider	Up to 363	20	Solid ice that is free of cracks, water and slush
2 snowmobiles and riders	Up to 726	25	Solid ice that is free of cracks, water and slush
Pickup truck or other mobile equipment, cargo and driver/passengers	Up to 4536	38	Solid ice that is free of cracks, water and slush

4.2 CLASS B JOB

The ice is greater than 38 centimetres thick and the load weight, including people, is greater than 4536 kilograms but less than 63, 000 kilograms.

Ice Thickness Calculation	Weight and Ice Thickness	Ice Integrity
The Golds formula found in Section 5 must be applied to calculate the safe ice thickness. The calculation, including safe ice thickness must be documented in or attached to the working on ice JHA.	The combined weight of the load, including equipment and people is greater than 4536 kilograms but less than 63, 000 kilograms and the ice is 38 centimetres thick or greater	Solid ice that is free of cracks, water and slush

4.3 CLASS C JOB

The job requirements cannot be met by either Class A or B guidelines. The assistance of a professional engineer recognized as an authority on ice covers, must be consulted and their guidance documented in or attached to, the JHA.

5 GOLDS ICE WEIGHT BEARING CAPACITY FORMULA

GOLD'S FORMULA
All guidelines currently in use in Canada are based on a technical paper published by Dr. Lorne Gold in 1971 entitled "Use of Ice Covers for Transportation". Gold's Formula is;

$P = A \times h^2$
Where:

- P is the allowable load in kilograms
- A is a parameter that depends on the strength of the ice
- h is the effective thickness of good quality ice (cm)

Gold suggested a range of A-values for lake ice that corresponds to a range of safe ice thicknesses for a given load or a range of acceptable loads for a given ice thickness. Baffinland has adopted Golds "Tolerable Risk" value for ice quality, therefore the A value in Golds formula will be four (4) when calculating ice thickness for a Baffinland Class B job.

Gold's formula **A** value of 4 is most commonly used for normal operations with moving vehicles. When equipment will be working in the same spot (stationary) for more than 2 hours, the value for **A** in Golds formula, must be reduced to two (2).

Two examples using the Golds Formula for a Class B job:

What is the weight capacity of good quality ice that is 60 cm thick?
Capacity (in Kgs) = A x h^2
Capacity (in Kgs) = 4 x (60x60)
Capacity (in Kgs) = 4 x 3600
Capacity = 14400 Kgs

The weight bearing capacity of good quality ice that is 60 cm thick is up to 14400 kilograms.

What is the weight bearing capacity of good quality ice that is 60 cm thick and the load will be stationary for 2 hours or more?
Capacity (in Kgs) = A x h^2
Capacity (in Kgs) = 2 x (60x60)
Capacity (in Kgs) = 2 x 3600
Capacity = 7200 Kgs

7, 200 kgs is the weight bearing capacity of good quality ice that is 60 cm thick and the load will be stationary for 2 hours or more.

5.1 Working on Ice frozen to the bottom (River, Lake – etc.)

When Ice thickness measurements determine the ice has frozen to the bottom in the area of travel and work, the ice may be considered as safe provided the ice quality is routinely monitored and remains solid and free of slush and water.

6 Working on Ice JHA and Work Planning Meeting

Working on ice may be divided into two parts;

1. initial measurement of ice thickness
2. working on the ice

Both parts require a JHA.

A work planning meeting must be held prior to any work on ice. This meeting will be based on review of the completed JHA. All individuals participating in the work must present and review their work instructions, roles and responsibilities. The following points will be covered in the JHA and will be covered as part of the topics of discussion during the "planning meeting":

- A description of the work to be done – with sufficient detail for individuals to understand their role
- Potential hazards associated with the work
- Personal safety equipment
- Specific safety procedures for working on ice
- Rescue procedures and necessary equipment
- Individual job tasks
- Communications and hand signals to be used
- Load (i.e. equipment, personnel) weight and distribution on ice during work
- Ice assessment – thickness and condition

JHA safety and emergency response considerations;

- Measuring ice thickness should always be a two person operation.
- Initial ice measurement must be done with a PFD and the lead tester on a tether to the second person who is a safe distance behind.
- Self-recovery is not the primary means of rescue, it's the second person and the tether.
- The MRT will provide a backup rescue plan.

7 MEASURING AND RECORDING ICE THICKNESS

The task of ice thickness measurements may be the subject of a separate JHA or may be included in the working on ice JHA.

Ice thickness is the primary measurement required to determine the safe working load that can be put on the ice (allowable load bearing capacity). Manual measurements are made by cutting a hole in the ice cover with an auger, a saw or an ice chisel and then directly measuring the ice thickness. Measurements are made in a prescribed spacing or pattern to provide sufficient coverage and verify the thickness of the ice cover.

It must be mentioned that in all cases of manual ice thickness measurements it is the absolute minimum thickness measured in all holes that must be used. Not an average or any other measurement.

It is imperative that a systematic procedure be implemented to document all ice thickness measurements. Measurement locations should be taken either with a Global Positioning System (GPS) receiver or marked with stakes, or other reliable system so that these locations can be tracked in future measurements or identified for repairs. This information is a key element in the monitoring control plan.

These records are vital to reconcile any ice failures that may occur. These records must be maintained in a log that is specific to recording ice thickness. See Appendix #1 - Ice Thickness Measurement Log

Suitable equipment and personal protective equipment (PPE) must be prescribed for the work. Initial testing should be conducted by at least two trained crew members travelling separately over the ice. The work could be carried out by travelling:

- On foot, by snowmobile or by amphibious vehicle.

- While testing, the crew should also be checking the ice for cracks and noting the snow load.

- If vehicles are used, two separate vehicles must be used at all times and must be separated at safe distance unless ice conditions are known.

7.1 TEST HOLE SPACING

Rivers

If GPR is used, test holes are only required for calibration and for mapping of thin areas. Recommend 30 meters between test holes along alternate edges. Look for thin areas caused by river current.

Lakes

If GPR is used, test holes are only required for calibration. If within 250 metres of shore: 30 meters between test holes along centre line. If more than 250 metres from shore: 250 metres between test holes along centre line

Note – these recommendations indicate normal test hole spacing. Good judgement based on field experience must be used when varying from these recommendations. In thin ice areas the suggested spacing should be reduced to determine their extent and severity.

8 REFERENCES AND RECORDS

- Baffinland Job Hazard Analysis Procedure BAF-PH1-810-PRO-0016r1
- Baffinland Iron Mines Corporation– Emergency Response Plan (BAF-PH1-830-P16-0007)
- Best Practice for Building and Working Safely on Ice Covers in Alberta (Work Safe Alberta)
- NWT Transportations Guide to Ice Road Construction

Appendix #1
Ice Thickness Measurement Log

Date:		Location:
Completed by:		Signature:
Weather Conditions, including temperature:		
Test Hole #	Ice Thickness	Notes on test hole – clear solid ice cracking, water – etc.
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
Names of other participants		Signature of other participants

Attachment B – On Ice Platform for Geotechnical Drilling

On-Ice Platforms for Geotechnical Drilling at Steensby Island

2013-04-09	0	Approved for Use	V. Tatone	D. Wolek	S. Perry	D. Matthews
DATE	**REV.**	**STATUS**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**	**APPROVED BY**

Safety • Quality • Sustainability • Innovation

Table of Contents

List of Appendices

1. Purpose

1.1 This Procedure identifies minimum safe work practices for the set-up and maintenance of on-ice platforms to be used to support geotechnical drill rigs for near shore work at Steensby Island.

NOTE: This Procedure does not replace safe work procedures for working on ice.

2. Scope

2.1 This Procedure applies to all locations where on-ice platforms are required for near shore work at Steensby Island.

3. Roles and Responsibilities

3.1 Construction Manager

3.1.1 The Construction Manager shall be accountable for ensuring full implementation and compliance with the requirements of this Procedure.

3.2 Contractor’s Line Managers

3.2.1 Contractor’s Line Managers shall have the following accountabilities:

- Conduct risk assessments for tasks associated with this Procedure and ensure the implementation of controls
- Ensure equipment is used and processes are applied in accordance with this Procedure

3.3 Site Health and Safety Manager

3.3.1 The Site Health and Safety Manager shall have the following accountabilities:

- Audit and monitor compliance with this Procedure
- Identify remedial corrective actions required to meet this Procedure

3.4 Supervisors

3.4.1 Supervisors shall have the following accountabilities:

- Ensure the application of this Procedure
- Responsibility for details of construction of the platforms
- Ensure that a JHA/FLRA is developed for tasks associated with this Procedure

- Ensure that employees review and sign the JHA/FLRA prior to task commencement
- Responsibility for removal of the ice platforms

3.5 Employees

3.5.1 All employees shall have the following accountabilities:

- Ensure they follow this Procedure
- Ensure that JHA/FLRA developed for tasks associated with this Procedure are followed

4. Definitions

4.1 Solid Ice

4.1.1 Stable sheet of solid ice, thickness adequate to safely support the operation. The solid ice may be subject to movement due to tides.

4.2 Sea Ice

4.2.1 Sea ice is any form of ice that is found at sea and has originated from the freezing of sea water.

4.3 Rafted Ice or Raft Ice

4.3.1 Ice in cakes or sheets overlapping or piled on one another. This is a body of near shore ice segments fused together and formed during fall freeze-up. The surface of suitable rafted ice should be reasonably flat and elevation at or near high tide. This rafted ice is a stable entity. Rafted ice that moves with the tides shall be regarded as unstable.

4.4 Ice Platform

4.4.1 A platform constructed on the rafted ice by flooding with salt water and including embedded rig mats.

4.5 Rig Mat

4.5.1 A portable platform used to support equipment used in construction and resource based activity including drill rigs.

4.6 Drill Rig

4.6.1 A track mounted drill rig used for geotechnical investigations.

5. Procedure

5.1 Specific Requirements for Ice Platforms

5.1.1 The rafted ice must be stable and fused to act as a homogeneous mass. Appropriate ice profiling and/or direct measurement of ice thickness is required.

5.1.2 Do not attempt to construct an ice platform in locations where sea ice is pushed up onto the rafted ice to a height exceeding 2 m.

5.1.3 The solid ice adjacent to the ice platform must be stable during tidal influence and capable of safely supporting the gravity loads imposed by the operation, including at the edge of the ice sheet. Appropriate ice profiling and/or direct measurement of ice thickness is required.

5.1.4 The zone of discontinuity between the solid and rafted ice must not be open water at any time and must be sufficiently narrow so that the rig mats will safely support the movement of equipment and personnel across this zone. No work is to be performed over this zone of discontinuity. Appropriate ice profiling and/or direct measurement of ice thickness is required.

5.1.5 The ice platform shall be constructed by alternate overlapping layers of rig mats and flooding with salt water until a suitable work space is created over the rafted ice. Profile the ice with an ice profiler or measure ice thickness using a mechanical ice auger prior to any flooding.

5.1.6 The rig mats shall be constructed of steel frames and timber cross beams. The rig mats shall be strong enough to bridge across the zone of discontinuity. Note that the attached sketch is conceptual only. The number of rig mats must be determined on site. It is anticipated that the number of available rig mats will not be more than six.

5.1.7 The rig mats shall be adequately connected by mechanical means to be determined at site.

5.1.8 The platform must be sufficiently long and wide to permit a clearance of at least two metres on each side of the equipment and supplies.

5.1.9 The platforms must be removed by means established by the supervisor.

6. References

Nunavut General Safety Regulations, R.R.N.W.T. 1990.

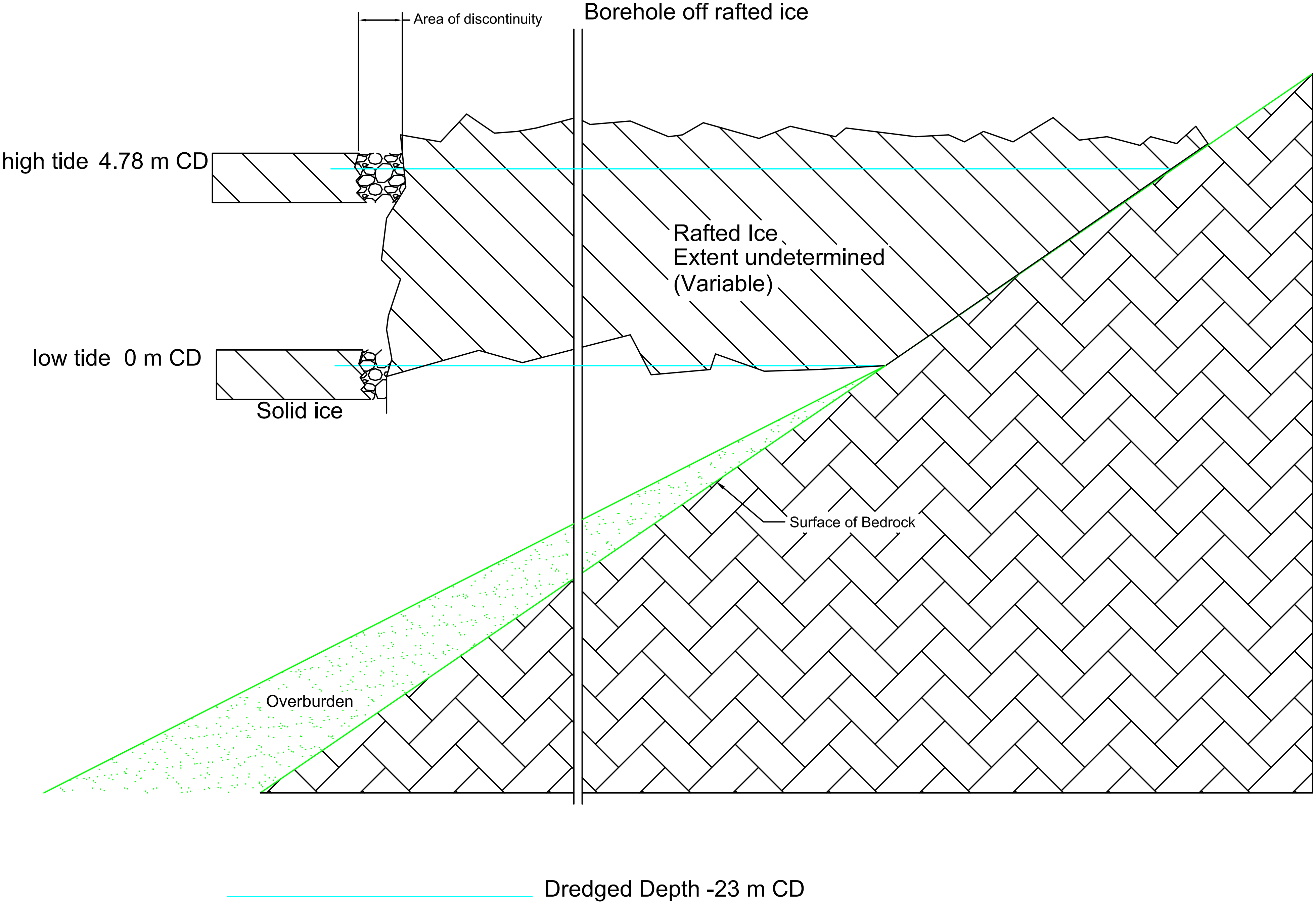
Nunavut Mine Health and Safety Regulations, R-125-95.

Safe Work Procedure – Working on Ice (HS-SWP-092).

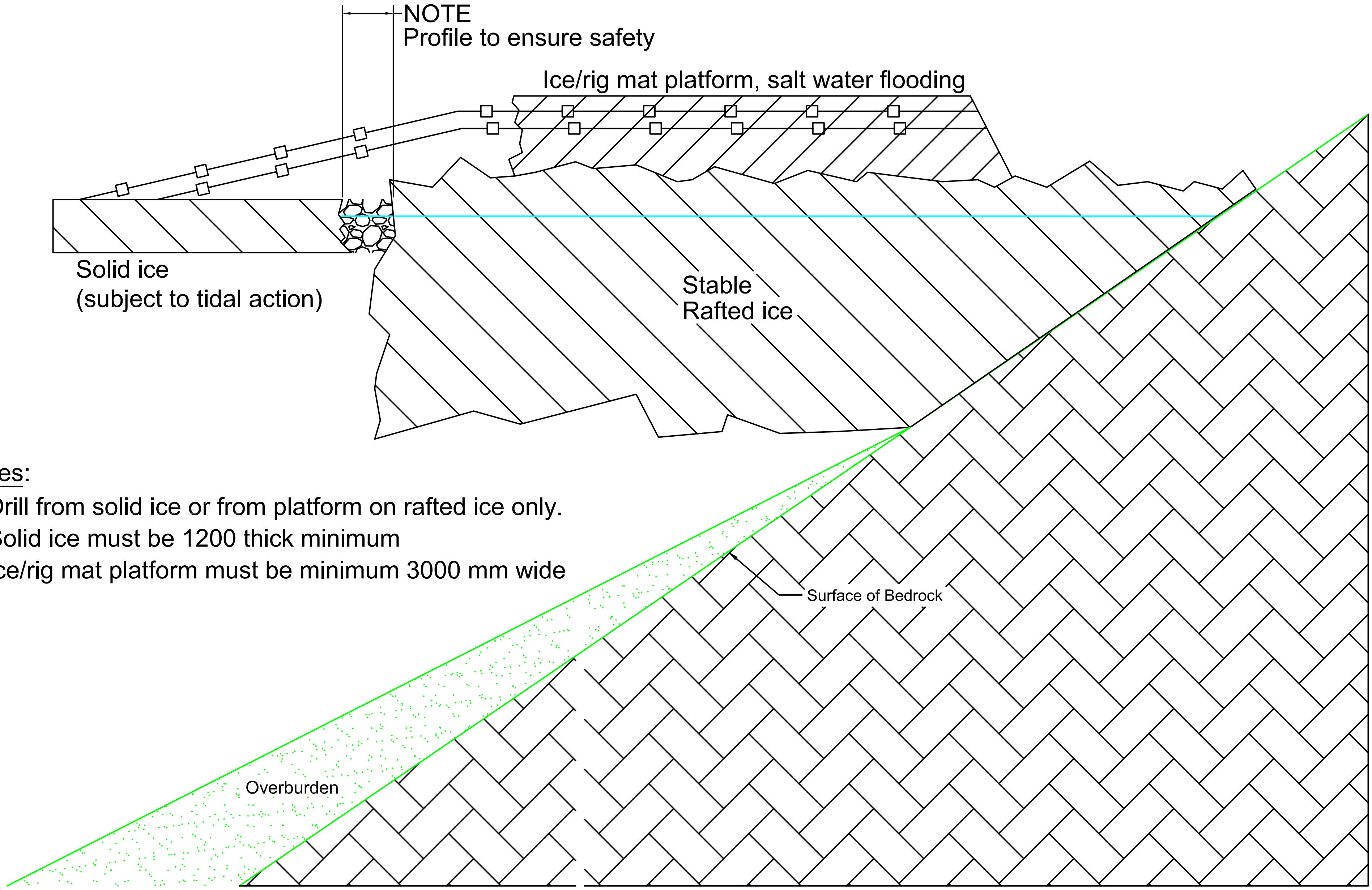
END OF SECTION

Appendix A

Illustrations



ORE DOCK
NEARSHORE CROSS SECTION



Notes:

1. Drill from solid ice or from platform on rafted ice only.
2. Solid ice must be 1200 thick minimum
3. Ice/rig mat platform must be minimum 3000 mm wide

ORE DOCK
ICE PLATFORM CONCEPT

Appendix B

Consideration of Bearing Capacity of Ice for Geotechnical Drilling Program

Project Memo

December 14, 2011

TO: K. Skebo FROM: B. Gill

cc: S. Hinchberger
R. MacCrimmon

Baffinland Iron Mines Corporation
Mary River Project

Consideration of Bearing Capacity of Ice for Geotechnical Drilling Program

1. Introduction

The purpose of this note is to consider the ice features that may affect the execution of a planned geotechnical drilling program in a safe and effective manner. The program will be conducted during April and May in the proposed mine and marine facilities areas of the Baffinland project on northern Baffin Island. This note addresses primarily the bearing capacity of the ice cover for supporting the drilling program vehicles and equipment.

1.1 Air Temperatures and Ice Thickness

The air temperatures over the period from 1971 to 2000 for Hall Beach to the southwest and Pond Inlet to the northeast for April and May are as follows:

Table 1-1: Air Temperatures

	Hall Beach		Pond Inlet	
	April	**May**	**April**	**May**
Daily Average	-20.4	-9.0	-22.1	-9.9
Daily Maximum	-15.2	-4.8	-17.7	-5.8
Daily Minimum	-25.6	-13.2	-26.5	-13.9

Thus it is seen that the air temperature is well below freezing for the period and ice will continue to grow. Ice thickness data for Hall Beach show that in most years, the thickness reaches to 2 m or greater by May. The minimum thickness for May over 50 years is approximately 1.5 m. This is a significant thickness that is capable of supporting very heavy loads.

1.2 The Bearing Capacity of Ice

The guidelines in Canada for determining safe working loads for operations on ice are based on work by Dr. L. Gold of the National Research Council (see for example, “A Field Guide to Ice Construction Safety” by NWT Department of Transportation, November, 2007 and “Best Practice for Building and Working Safely on Ice Covers in Alberta by Work Safe Alberta, Government of Alberta, October, 2009). Dr. Gold published his paper “Use of Ice Covers for Transportation” in 1971. His formula, which says that the safe working load is a function of the ice thickness squared, is $P = Ah^2$ where A is a parameter that is related to the ice strength and h is the ice thickness. The value of A may vary depending on the degree of risk one is willing to take and the offsetting precautionary and response measures that are implemented in a given case. For the current case in which the ice thickness is large, the ice is static, and the equipment loads are relatively modest in relation to the ice bearing capacity, one could assume a low risk factor, and the subsequent calculated minimum ice thickness for the planned equipment weight would be relatively high, but still well below the thickness in April and May. In the Alberta and NWT documents referred to above, the former document uses a range of values for 'A' from 3.5 to 7 and suggests hazard control measures appropriate to each level, whereas the latter document uses a single value of 4 for 'A'. Both of these documents are concerned with freshwater lake and river ice.

Using a value of 4 for 'A' and an ice thickness of 200 cm results in an allowable load of 160 tonnes or more than 12 times the weight of a Cat 950 loader. The ratio would be presumably even greater in the case of a drill rig. In the same manner, the minimum (freshwater) ice thickness that a stationary or slowly moving 950 loader weighing about 13,000 kg would require is 57 cm.

The allowable load in the case of sea ice would be less than that for an equivalent thickness of freshwater ice because of the lower strength (under the same temperature conditions) that results from brine inclusions in the sea ice. A reasonable understanding of this derating can be obtained by comparing the flexural strengths of the two types of ice. For a salinity of 8 ppt (parts per thousand) for arctic sea ice at an average ice temperature of -20 deg C, the resulting flexural strength is about 65 percent of the strength of freshwater ice at the same temperature. The minimum sea ice thickness for a 950 loader would then be about 70 cm. This is 35 percent of the expected ice thickness at the project site during the drilling period.

The rate of movement of the equipment is not expected to be a significant factor, unlike in the case of transport vehicles moving at speed on ice covers over relatively shallow water. The speeds in the present case will not be sufficient to cause any dynamic effects that could lead to a magnification in deflection of the ice cover. According to field studies reported in the above-referenced Alberta Government document, a vehicle would have to travel at 50 km/h over ice 1 m thick in 15 m of water to cause such effects.

1.3 Potential Hazard Control

As noted, the large ice thickness in relation to the minimums required to safely carry the loads and the static nature of the ice cover in the present case mean that this is a low-risk operation in terms of potential ice bearing problems. An appropriate hazard control procedure would entail prior ice measurements to confirm the anticipated thickness in the working areas, measurements thereafter if any uncertainties exist with respect to ice thickness, monitoring the ice quality (e.g. cracks, effects of warming, water on the ice, etc), and checking for deflection of the ice cover as time of equipment in one location increases (this can be done by observing the water level in boreholes).

An overall ice safety plan should be implemented, including orientation and instruction for employees and contractors and routine daily observations to ensure rules of working on an ice cover are followed.

BG:vl

Internal Memo

H352034

March 18, 2017

To: Warren Hoyle From: Usman Khan

cc: Marlon Coakley
Alex Boissonneault
Sean Hinchberger
Tyler Bruce
Sven Heiner

Baffinland Iron Mines
Mary River Expansion Study Stage 2

Minimum Ice Thickness for Offshore Drilling at Milne Port 2017

1. Introduction

Hatch Ltd. (Hatch) was retained by Baffinland Iron Mines to conduct an offshore, on-ice, geotechnical drilling investigation at the Milne Port Site. This investigation is scheduled for the period of mid to late March 2017. In order to mitigate risk relating to ice breakthrough, the investigation team reviewed ice strength evaluation completed for a similar offshore investigation at the Steensby site in 2011.

2. Allowable Ice Loading

2.1 Moving Loads

The 2011 evaluation of ice thickness utilized Gold's formula to calculate the allowable weight for a variable ice thickness. Gold's formula is based on literature that utilizes data collected from ice breakthroughs and forms an empirical relationship to predict the allowable bearing capacity of ice.

$$P = Ah^2$$

P = Allowable load in kilograms

A = Constant which depends on the quality of the ice, the geometry of the load and the factor of safety appropriate

h = Effective thickness of the ice in centimeters

Further literature review suggests using a value of 4 as a conservative estimate for freshwater ice. Government of Alberta and Northwest territories both recommend using a factor of 4.

It is noted that a factor of 4 is used for freshwater ice and does not account for the reduction of flexural strength in sea ice due to the presence of brine. A reduction factor of 0.65 is applied per Hatch project memo entitled, “On-Ice Platforms for Geotechnical Drilling at Steensby Island” (Document # H349000-HS-SWP-165).

Table 2-1: Maximum Allowable Load On Sea Ice

Ice Thickness (cm)	Load (kg)	Load (lb)		Ice Thickness (cm)	Load (kg)	Load (lb)
5	60	150		105	28,660	63,200
10	260	580		110	31,460	69,360
15	580	1,290		115	34,380	75,810
20	1,040	2,300		120	37,440	82,550
25	1,620	3,590		125	40,620	89,570
30	2,340	5,160		130	43,940	96,880
35	3,180	7,030		135	47,380	104,470
40	4,160	9,180		140	50,960	112,350
45	5,260	11,610		145	54,660	120,520
50	6,500	14,340		150	58,500	128,980
55	7,860	17,340		155	62,460	137,720
60	9,360	20,640		160	66,560	146,740
65	10,980	24,220		165	70,780	156,060
70	12,740	28,090		170	75,140	165,660
75	14,620	32,250		175	79,620	175,550
80	16,640	36,690		180	84,240	185,720
85	18,780	41,420		185	88,980	196,180
90	21,060	46,430		190	93,860	206,930
95	23,460	51,740		195	98,860	217,970
100	26,000	57,330		200	104,000	229,290

2.2 Static Loads

Gold's formula is adequate for calculating the allowable bearing capacity for moving loads on ice but it does not propose a relationship between allowable loads and ice thickness for static loads. To ensure ice safety for a static load operation, a literature review was completed. It was concluded that the deflection in ice must be monitored throughout the drilling operation and loading must be removed in case of excessive deflections. Ice cover should not exceed the freeboard elevation to ensure safety of the drilling crew.

3. Monitoring During Drilling Activities

A hole will be augured through ice within 5 m of the point of maximum load. The depth of water in the hole will be monitored throughout the duration of the drilling investigation at each borehole location. Drilling will be terminated if sea water is observed flowing through the top of the augured hole. Ref 3 provides further details regarding the bearing capacity of ice covers under static loads.

4. References

1. W, Gold. L. (n.d.). Field study on the load bearing capacity of ice covers. National Research Council Canada, 61(5), 3-7. Retrieved March 18, 2017, from http://nparc.cisti-icist.nrc-cnrc.gc.ca/eng/view/object/?id=e7d278d9-808a-4959-b9f7-27320d757afd
2. KINGERYW, . D., KLICKD, . W., DYKINSJ., E. Sea ice engineering summary report-Project ICEWAY. U.S. Naval Civ. Eng. Lab.Port Hueneme, Calif., Tech. Rep. R-189.
3. Frederking, R. M. W., and L. W. Gold. "The Bearing Capacity of Ice Covers under Static Loads." Canadian Journal of Civil Engineering 3.2 (1976): 288-93. Web Accessed March 18, 2017.

UK:UK
Attachment(s)/Enclosure

ATTACHMENT 12.2

PORT SITE GEOTECHNICAL RECOMMENDATIONS

Baffinland Iron Mines Corporation
Mary River Expansion Study - Stage II

Preliminary Geotechnical Recommendation for Infrastructures at Milne Inlet

2017-01-10	1	Approved for Use	M. Buykx	J. Cleland	J. Cleland	M. Weaver
2016-09-01	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

1. Introduction

Baffinland Iron Mines Corporation (BIM) currently operates the Mary River iron ore mine in Nunavut, Canada. BIM plans to increase the production rate of the mine from current 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 different types of foundation of infrastructures at Milne Inlet (the Site) based on the existing geotechnical investigation data, as part of the Mary River Expansion Study – Stage II. It should be noted that the site layout is not finalized; the structural loadings and the site specific geotechnical investigation data are not available at this time. The recommendations for foundation design provided in this report are preliminary. Detailed geotechnical engineering assessment (i.e. geotechnical investigation, temperature measurements, thermal analysis, bearing capacity and settlement analyses of foundations) will be required to confirm their performance and optimize the preliminary design in the next design stages. Detailed geotechnical recommendations and construction considerations are not discussed in this report.

2. Scope of Work

The geotechnical assessment summarized in this report was developed to support the pre feasibility study for the foundation design of infrastructures at Milne Inlet and for the Railway Bridges. Figure 2-1 shows the preliminary layout of the proposed infrastructures at this design stage. Table 2–1 summarizes the preliminary infrastructure list.

Table 2–1: Summary of Preliminary Infrastructures List at Milne Inlet and Railroad Bridges [1]

No.	Proposed Infrastructures
1	Rail car rotary tipper building
2	Ship loaders
3	Elevated conveyors
4	Bridges foundations for railroad
5	Conveyor transfer towers and drive houses
6	Ground level yard conveyor and stacker/reclaimer
7	Crushing and screening buildings
8	Rail workshop

Note ([1]) - the infrastructure lists are preliminary, which will be updated based on the final layout design.

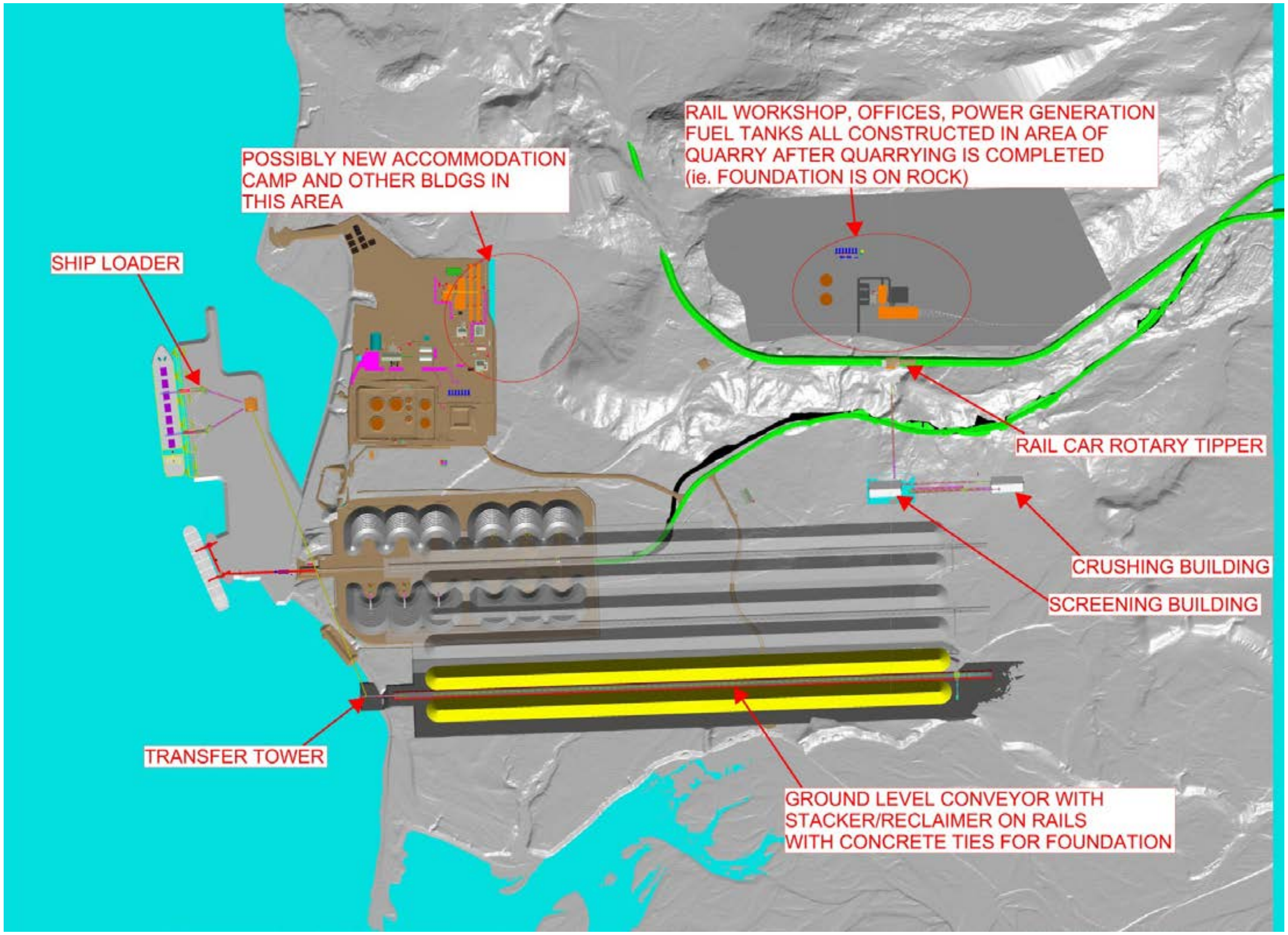


Figure 2-1: Preliminary Layout of Infrastructures at Milne Inlet (For Reference Only)

3. Reference Document

The preliminary geotechnical recommendation for the infrastructure foundation design at Milne Inlet provided in this report are based on the following information and investigation:

- 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.
- Knight Piesold, July 2007, Bulk Sampling Program Road Upgrade Design Summary (REF. NO. NB102-00181/10-1).
- Knight Piesold, 2008, “Mine site infrastructure, pit overburden and waste dumps – 2008 site investigations summary report” (ref NB102-181/24-1), May 4, 2010.
- Knight Piesold, Feb 2009, Bulk Sampling Program Milne Inlet Tote Road Construction Summary, (REF. NO. NB102-181/13-2).
- Thurber, 2011, “2011 Onshore Geotechnical Investigations Summary of Results”, (ref. 19-1605-126), Nov 10, 2011.
- Thurber 2011 report “Initial Geotechnical Recommendations Mary River Mine Site Facilities” (ref 19-1605-126), Nov 7, 2011.
- EBA Engineering Consultants Ltd. (EBA) memo “Foundation Recommendations, Mary River Mine Site Infrastructure”, (File: E14101009.003), September 9, 2010.
- EBA 2008, Mary Rive- Pile Foundations Revision C, E14101009.001.
- Hatch Ltd. H337697-0000-15-124-0004.Geotechnical Data Report –Infrastructure. April 5, 2012.
- Hatch 2013, Geotechnical Design Criteria, H349000-1000-15-122-0001, Rev 0.

4. Regional Geology

Regional geologic mapping is available for the project site from Milne Inlet follow the route of Tote Road (Scott and de Kemp, 1998), which can be used for preliminary design:

- Approximately the first 20 km of the Tote Road from Milne Inlet passes through Precambrian terrane.
- The middle 73 km of the road travels across relatively flat lying Paleozoic rocks.
- The final 14 km of the road to the Mary River mine site passes through Precambrian terrane near the boundary with the Paleozoic units.

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

5. Geotechnical Data Summary

5.1 Subsoil Conditions

In general, the overburden soils encountered at Milne Port consist of glacial alluvial deposits of cohesionless soils consisting of sand, sand and gravel, and gravel, containing frequent cobbles and boulders. A thin layer of organics at the ground surface is encountered in some locations. The glacial alluvial deposits are found at the ground surface to a depth of 42 m. An average of 9% passing 0.075 mm size (silt and clay content) was recorded in particle size tests from this area. Bedrock has not been encountered at the Site within the low lying area located at the base of the rock ridge.

Vegetation is sparse and consists primarily of a variety of mosses and grasses in areas where surface moisture is present during the thaw season. No shrubs or trees exist in the area and no peat deposits have been observed. Top soil and existing roots shall be removed to a minimum of 150 mm, if required.

The Site is underlain by permafrost, except below large bodies of water where water depths exceed 3 or 4 m. No sub-surface (ground) ice has been observed at the Milne Port site based on the previous geotechnical investigation campaigns. However significant ground ice was found in a deep excavation near the new ore dock and ground ice has been found in the vicinity of the existing Water Building; settlement due to thawing of ground ice is believed to be occurring under the Water Building and the Sewage Treatment Plant.

5.2 Foundation Type and Bearing Capacity

The anticipated foundation option for the infrastructures of Milne Inlet could be summarized in Table 5–1.

Table 5–1: Summary of Preliminary Infrastructures and Foundation Options

No.	Proposed Infrastructures	Potential Foundation Option
1	Rail car rotary tipper building	Shallow foundation (on rock); or Adfreeze pile (on permafrost)
2	Ship loaders	Adfreeze pile
3	Elevated conveyors	Adfreeze pile or shallow foundation
4	Bridges foundations for railroad	Adfreeze pile
5	Conveyor transfer towers and drive houses	Adfreeze pile
6	Ground level yard conveyor and stacker/reclaimer	Rockfill Embankment with shallow foundation
7	Crushing and screening buildings	Shallow foundation
8	Rail workshop	Shallow foundation (possibly on rock)

It should be noted that the above proposed foundation options should be reviewed based on ground investigation results during the next design phase.

5.2.1 Shallow Footings

The following types of shallow foundations are considered applicable for infrastructures at Milne Inlet for pre feasibility design stage.

- Square footing (Footing Length (L)/width (B) =1, with B=1 m to 4 m).
- Rectangular footing (L/B=3, with B =1 m to 4 m).
- Strip Footing (L/B>10, with B=1 m to 3 m).

5.2.2 Bearing Capacity

The allowable bearing capacity of different types of shallow foundation are estimated based on the following assumption.

- The existing subgrade soil is assumed non ice-rich permafrost in this preliminary design stage. It should be noted that, for footing placed on ice-rich soil, the serviceability of the foundation should be checked for secondary creep.
- The proposed shallow foundations at Milne port will be constructed on an engineered fill (granular pad) with a minimum thickness of 400 mm of Non Frost Susceptible (NFS) material. There will be no embedment considered for the foundations at this stage.
- An internal friction angle of 32° and a cohesion of zero are assumed for the soil shear strength parameters. Soil bulk density is assumed 20 kN/m^3.
- The engineered fill is placed and compacted to meet required specifications. Surface drainage is maintained to prevent formation of ice lenses.
- Bearing capacity is estimated based on the generalized foundation equation described in the Canadian Foundation Engineering Manual, 4th Edition.

- A factor of safety of 2.5 applied to the ultimate bearing capacity.

The estimated bearing capacities for different types of shallow foundation are shown in the design charts listed as follows:

- Bearing capacity for square footing: Figure 5-1.
- Bearing capacity for rectangular footing: Figure 5-2.
- Bearing capacity for strip footing: Figure 5-3.

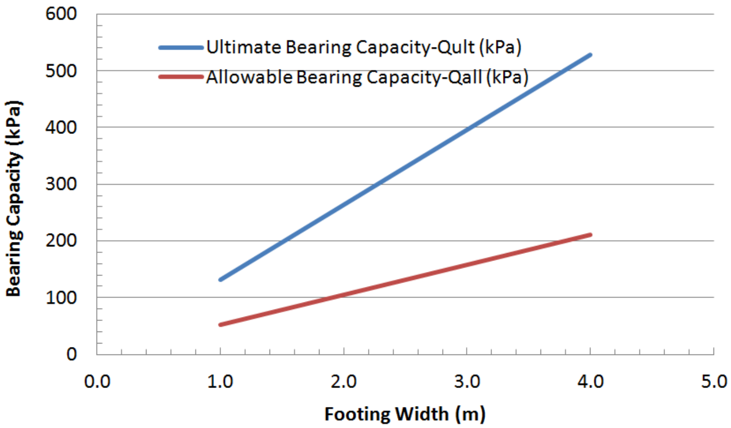


Figure 5-1: Bearing Capacity for Square Footing on 400 mm Granular Engineered Fill (L/B=1 with B =1 m to 4 m)

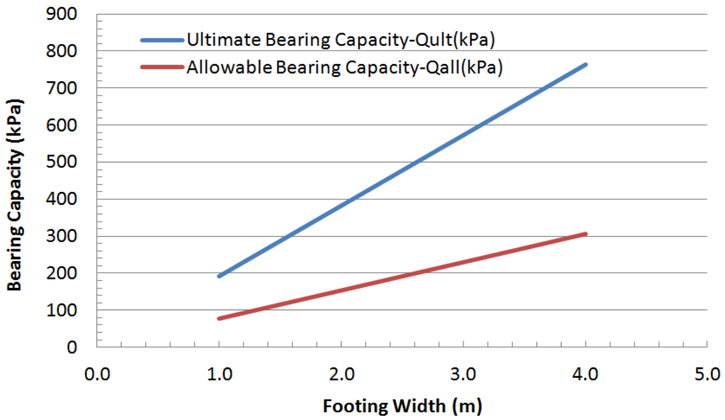


Figure 5-2: Bearing Capacity for Rectangular Footing on 400 mm Granular Engineered Fill (L/B=3 with B =1 m to 4 m)

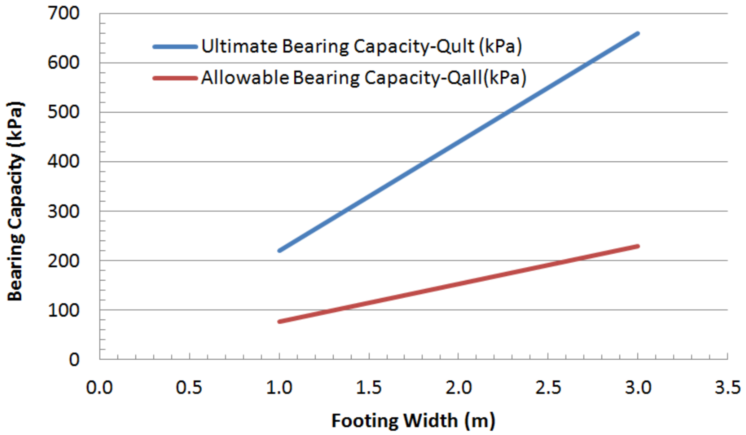


Figure 5-3: Bearing Capacity for Strip Footing on 400 mm Granular Engineered Fill (L/B>10 with B =1 m to 3 m)

5.2.3 *Modulus of Subgrade Reaction*

5.2.3.1 *Building Foundations*

Considering the soil conditions at Milne Inlet sites, the modulus of subgrade reaction recommended by Knight Piesold (2007) are considered suitable. Table 5–2 provides the modulus of subgrade reaction for foundations with different widths.

Table 5–2: The Modulus of Subgrade Reaction

Foundation Width (m)	Modulus of Subgrade Reaction (MPa/m)
1.0	66.0
1.5	44.0
2.0	33.0
2.5	26.0
3.0	22.0
3.5	19.0
4.0	16.5

5.2.3.2 *Slab on Grade*

The building slab at Milne port site will accept loads from heavy loaders, bulldozers, or haul trucks. No stockpile loads are anticipated on slabs. Therefore the maximum effective width of slabs below the trucks are assumed less than 2 m. A modulus of subgrade reaction for slabs on grades can be selected similar to building foundations with a width of 2 m.

Based on the latest field observation, significant ground ice was found in a deep excavation near the new ore dock and ground ice has been found in the vicinity of the existing Water Building, foundation settlement due to thawing of ground ice should be limited by design measures. As such, thermal insulation is recommended for the Milne port buildings. The modulus of subgrade reaction of 20 MPa/m is recommended for preliminary design.

5.2.4 Sliding Friction Angles

All the foundations will be founded on granular pad, not on native soils. Consequently the following friction angles and coefficients can be used for sliding of the foundations on granular pad, based on Canadian Foundation Engineering Manual (2006):

- 30° (friction coefficient: 0.58) for cast-in-place concrete.
- 24° (friction coefficient: 0.45) for precast concrete.

5.2.5 Thermal Insulation Design Consideration

Based on the test pits advanced during the 2010 investigation of borrow areas close to Milne Inlet, AMEC reported that the thickness of the active zone is anticipated to be between 2 m and 2.5 m. Thurber also indicated that, based on the results of geotechnical investigations carried out in 2006, 2007, 2008 and 2011 in the entire Mary River site, the depth of annual thaw ranges from 0.5 m in poorly drained areas to about 3 m in well drained areas.

For preliminary thermal insulation design at Milne Inlet Site, the following assumptions are applied:

- The temperatures of the heated structures are assumed constant throughout the year. The internal temperature is in a range of at +5°C (lower bound) to +22°C (upper bound).
- The ground temperature below 15m deep from the existing ground surface is -10°C (assumption based on the data from the thermistors installed at the Mine site)

The preliminary thermal insulation recommendations are summarized as follows:

- For the structures with an internal temperature of +5°C, an insulation layer of 125 mm thick is recommended to be placed below the granular fill and the native ground will remain frozen.
- For the structures with an internal temperature of +22°C, the following two insulation configurations are recommended:
    - 250 mm thick insulation layer to be placed below the granular fill.
    - The granular fill will be sandwiched between two insulation layers each with a thickness of 125 mm.

Hatch recommends that thermal analysis shall be carried out for the detail design to confirm the preliminary thermal design and to optimize the thermal insulation configuration, based on the site specific geotechnical investigation data and designed building internal temperatures.

5.3 Embankment Berm for Rail Stacker and Reclaimer Machine

Rail stacker and reclaimer machines are proposed to handle iron ore stockpile at Milne Inlet. Embankment berms for stacker and reclaimer machines are normally subjected to large static and dynamic machine loadings. The stability of these berms and acceptable deformation of machine foundations under working loads are of paramount importance to ensure a safe and cost effective mining operation.

The preliminary geotechnical recommendations for the embankment berm at Milne Inlet are summarized as the following:

- The embankment berm consists of a 200 cm thick compacted rock-fill (Type 8) material underlain a stiff geotextile on the existing ground. The side slope is 1.5H:1V. The maximum height of embankment depends on the design grade at the project site.
- The allowable capacity of the proposed compacted rock-fill embankment is 200 kPa.

It should be noted that the detailed geotechnical engineering assessment shall be carried out to confirm the preliminary design when the design loading and the site specific geotechnical data are available. The geotechnical engineering assessment consists of the following but not limited to:

- Bearing capacity.
- Embankment stability (local and global) under machine loadings.
- Design of geosynthetic reinforcements.
- Foundation deformation under machine loadings.

5.4 Deep Foundations

5.4.1 Adfreeze Piles

Pile foundations in permafrost soil can normally be selected from adfreeze or rock-socketed piles depending on the characteristics of the site and bedrock depth. Since the bedrock depth at the Milne Port site and Railway bridge locations has not been established, for preliminary design stage, only the adfreeze pile option will be studied. In addition, it is assumed that steel pipe piles with nominal diameters ranging from 4” to 12” could be utilized in this project.

5.4.2 Pile Capacity

The capacity of the adfreeze piles can be calculated using the following equation:

$P_a + W = \tau a\ .\pi.d.L$ (for compression) [5-1]

and,

$P_a - W = \tau_a.\pi.d.L$ (for tension) [5-2]

where:

P_a= allowable pile capacity (kN)

W= weight of pile (kN)

d= pile diameter (m)

L= pile embedment length (m) in permafrost (i.e. ignore embedment in active layer)

Also, based on the equation presented in literature for secondary creep, τ_a (kPa) which is the adfreeze shaft stress can be determined using the following:

$$\tau_a = \left[\frac{\frac{\dot{u}_a}{a}.(n-1)}{3^{(n+1)/2}.B}\right]^{\frac{1}{n}} \qquad [5\text{-}3]$$

where:

$\dot{u}_a$= allowable settlement rate (mm/year)

a = pile radius (mm)

B = creep parameter (kPa-n/year)

n = creep parameter (unitless)

It is assumed that the allowable settlement rate is 2 mm/year in the calculations. The creep parameter (n) is also assumed to be equal to 3. Furthermore, with the assumptions of non-saline porewater/ice and an average ground temperature of -5 C, the creep parameter (B) is estimated at 10^{-8} kPa^{-3}/year.

The pile capacity calculation is carried out for pipe piles with diameters of 4”, 6”, 8”, 10” and 12” with embedment lengths ranging between 2 m and 20 m. It is of note that the embedment length corresponds to the length within the permafrost layer (ignoring the length of the pile within the active layer). The allowable pile axial capacities (geotechnical) under compression and uplift (tension) are plotted in Figure 5–4. It should be noted that the weights of the piles (W) have to be be taken into consideration in calculation of the allowable pile capacities in both compression and tension.

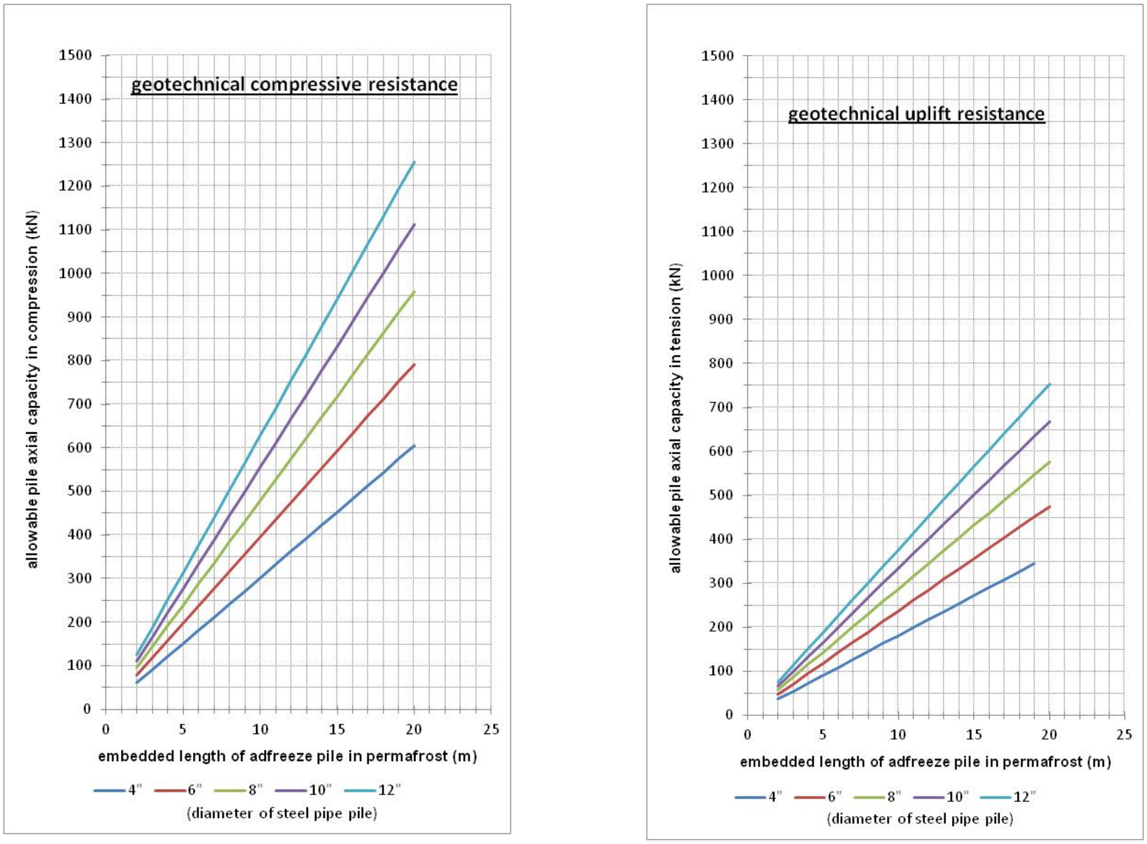


Figure 5–4: Plots of Geotechnical Axial Resistance with Embedded Length of Adfreeze Piles

In order to avoid frost heave, the length of the pile in the active layer should be wrapped with polyethylene film to break the adfreeze bond in the active layer.

It should be noted that Figure 5–4 presents the preliminary geotechnical capacities of adfreeze pile. The structural capacity of the steel pipe pile should be checked by a structural engineer.

6. References

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

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

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

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