# Baffinland Iron Mines Corporation
# Mary River Expansion Project

# Geotechnical Recommendations for Stacker/Reclaimer Berm Foundation

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| | | | Yang, Michael Digitally signed by Yang, Michael Date: 2019.03.07 10:31:01 -05'00' | Digitally signed by Kai-Sing Ho Date: 2019.03.07 10:46:13 -05'00' | Ghiabi, Hani | |
| 2019-03-01 | 0 | Approved for Use | M Yang | K S Ho | H Ghiabi | F Pittman |
| Date | Rev. | Status | Prepared By | Checked By | Approved By | Approved By |
| HATCH | | | | | | Client |

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Dated: [***insert current date***]

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# 1. Introduction

Hatch has been retained by Baffinland Iron Mines Ltd. (BIM) to assist on the design of a Bulk Material Handling (BMH) system at the Milne Inlet Port for the Mary River Expansion Project.

The BMH system consists of a rail car tippler located at the terminus of the mine-to-port railway, an indexer to push the rail car in the tippler, a loadout tunnel connecting with the tippler, a raw ore stockpile with embedded loadout tunnel, crushing and screening plants, and conveyor systems to transfer materials from the tippler through the crushing and screening plants to a longitudinal bucket-wheel Stacker/Reclaimer.

The Stacker/Reclaimer and the associated conveyor system will be operated on the rail tracks found on a Stacker/Reclaimer berm.

This memo provides geotechnical recommendations for the Stacker/Reclaimer berm foundation, evaluate the berm stability, the thermal regime in foundations, and the settlement. The analyses are based on the preliminary berm configuration shown in the drawings in Appendix B (Drawing H353004-CM001-400-465-0045) provided by Thyssenkrupp Industrial Solutions (tkIS) and the data from the geotechnical investigation program (H353004-40000-229-230-0009).

The requirements of the project include keeping the elevation of the rail track of the Stacker/Reclaimer, excluding any option to raise the berm or change the longitudinal grade of the berm, and the width and slope of the berm.

# 1. Geotechnical Site Information

The geotechnical site investigation plan and borehole profiles are illustrated in Appendix A1.

## 1.1 General

Six boreholes (BH 16-M001, BH 16-M004. BH 16-M005, BH 16-M006, BH 16-M014, BH 16-M015) were drilled along the longitudinal alignment of the berm from north (near shoreline) to south. The overall site is relatively flat over the footprint of the berm.

The subsurface conditions encountered at the site are highlighted as follows:

- Near the south end of the berm, the deposit consists of a sandy layer with a thickness of 6 m to 9 m, overlying a silt deposit extending to the borehole termination depths of about 15.2 m (BH 16-M006, BH 16-M014 and BH 16 -M015).
- In the middle of the berm, the sandy deposit dominates the encountered overburden (BH 16-M004 and BH 16-M005). A 1.5 m silt layer was encountered in BH 16-M004 from a depth of 10.6 m to 12.1 m.
- Near the north end of the berm, a sandy deposit (sand to sand and gravel) was encountered in BH 16-M001 down to the termination of the borehole (at about 15 m depth). No silt layer was found in this borehole.

- No bedrock was encountered during the investigation.

## 1.2 Subsurface Interpretation

Appendix A1 shows the site overall layout and a geological profile along the berm. Sketch 1 in Appendix A1 shows the interpreted soil profile below the berm.

Near the south end of the berm, the subsurface soil profile consists of a sandy layer, overlying a silty deposit, and an inferred till layer. The till layer, assumed at 65 m depth, was extrapolated from the till encountered in BH 17-008 and BH 17-M010 (see Sketch 2 in Appendix A1). The 65 m depth was adopted as the base case for settlement calculations; a sensitivity study was performed to evaluate the impact of the till layer on the results.

Near the north end of the berm, the subsurface soil profile consists of a sandy deposit (sand to sand and gravel) overlying an inferred till layer. The till layer depth was assumed to be same as at the south end.

There appears to be some localized water ponding along the berm alignment.

The following summarizes the key soil properties:

- The sandy deposit contains sand, with a varying amount of gravel and silt as per the assessment of the geotechnical investigation data (Hatch, 2017, H352034-1000-229-230-0002, Rev.2) at the Milne Inlet Site. This layer contains an ice content typically ranging from 10% to 20% by weight. This deposit can be classified as low to medium frost susceptible.
- The silty layer contains predominantly silt, with trace to some sand, trace gravel, trace organics and is thought to be a delta deposit. The silt is general frozen and well bonded and contains thin ice lenses with a typical ice content ranging from 20% to 40% by weight. This deposit can be classified as medium to high frost susceptible.
- Till: A possible till layer has been inferred at 65m depth as per the findings of BH 17-M010 and BH 16-M008 (see Sketch 2 in Appendix A1). The till is well graded and has a relatively low ice content of generally less than 10%. This deposit can be classified as low to medium frost susceptible.
- Ground ice was not encountered in the boreholes shown in the profile in Appendix A1. However, based on experience at other project locations, the presence of occasional ground ice is common for the Milne Inlet Port area, particularly within or close to the depth of the active zone.

There will be a SPMT (Self Propelled Modular Transporter) service road, which comprises approximately 600 mm thick crusher-run rockfill constructed from the station 1+800 to 1+100 prior to the Stacker/Reclaimer berm.

# 2. Climate Conditions

The site is in a continuous permafrost zone with a mean annual air temperature of about -12°C, based on the response document drafted by RWDI to Crown-Indigenous Relations and Northern Affairs Canada inquiry (RWDI, 2019). The global warming effect was taken into account according to the Intergovernmental Panel on Climate Change (IPCC) long term climate change studies (IPCC, 2014). A temperature adjustment was applied considering to global warming for the period spanning from 2010 to 2039, summarized in the Hatch Geotechnical Design Basis (H353004-00000-229-210-0001).

# 3. Structure

As per the preliminary design drawings provided (drawing no. A05212A04, dated on 09/12/2017, drawing no. 4832571, Rev.4, dated on 07/12/2017), the Stacker/Reclaimer berm is about 2.7 m high from the base to the top of berm, i.e., 3 m high from the berm base to the top of rail, and about 22 m wide at the crest with a side slope of 1.5H:1V. The Stacker/Reclaimer berm will be constructed using by compacted Type 8 rockfill. The preliminary design drawings have been updated by Hatch to be issued for construction (H353004-40000-221-272-0004-0001). The preliminary drawings are referenced for better illustration of the Stacker/Reclaimer berm details (See Appendix B).

The rail track over the berm is about 1.5 km long in the longitudinal direction. There are two large live ore stockpiles (about 20 m high, 30 m wide at the crest and 90 m wide at the base) on either side of the berm. The ore will be transferred to the ship-loader during the shipping season window in summer and will be stockpiled during the rest of the year.

## 3.1 Rail Surcharge Loads

The surcharge pressures on the berm are summarized as below:

- Rail surcharge pressure in **Long-term Operation** conditions (load case II) = 228 kPa (unfactored)
- Rail surcharge pressure in **Maintenance** conditions (load case III) = 280 kPa (unfactored).

The rail surcharge was calculated using the following formula as per the load data from the tkIS drawing No.4934009, dated 25 September 2017. The calculated surcharge load pressures were reviewed and confirmed by tkIS as per the email from Mr. Laurent, dated 21 February 2018. The surcharge pressure from the conveyor is 200 kPa as per the drawing provided by tkIS (BSCY-S-560, dated on 2017-11-27).

$$Surcharge\ Load = \frac{Max\ Wheel\ Load\ for\ load\ case}{Area} = \frac{F_1+F_2}{S \times L} * Load\ Coeffieicnt$$

Where:

$\boldsymbol{F_1}$ and $\boldsymbol{F_2}$ are the maximum wheel loads (kN);

**S** is the average spacing between the point loads;

**L** is the width of the track loading zone (m);

Rail Surcharge in Operational Cases (Load II)

$$Surcharge\ due\ to\ Load\ II = \frac{350kN + 350kN}{\frac{1}{2} * (1.2 + 1.5)m * 2.5m} * 1.1 \cong 228\ kPa$$

Rail Surcharge in Maintenance Case (Load III)

$$Surcharge\ due\ to\ Load\ III = \frac{450kN + 450kN}{\frac{1}{2} * (1.2 + 1.5)m * 2.5m} * 1.1 \cong 280\ kPa$$

# 4. Stability Analyses

## 4.1 Design Criteria

The preliminary design criteria for the slope stability of the Stacker/Reclaimer berm is summarized in Table 4-1 corresponding to loading cases. The design criteria (see Table 4-1) adopted a factor of safety of 1.4 and 1.3 for the Long-term Operation Case (Static Loading Case) and High Ground Water Level Case (Summer Seasons) cases respectively, due to the narrow timeframe which each of the two cases will occur. The side slopes of Stacker/Reclaimer Berm will be covered by iron ore during the stacking seasons, with full side slope exposure and loading from the Stacker/Reclaimer occurring infrequently during the ship loading seasons (~ 2 months). High ground water levels can only occur during the months with above zero temperatures, which ranges from June to August and June to September for the 2010 average Milne Port temperatures and estimated 2039 Milne Port temperatures, respectively.

Table 4-2 summarized the geotechnical parameters used in the analysis, sourced from the Geotechnical Design Basis (H353004-00000-229-210-0001). For pseudo-static analysis, a value of 2/3 of peak ground acceleration (PGA) 0.028 g was used. The PGA of 0.042 g was used for the design, consisting with that adopted for the design of the ore dock (BESIX, 2017), as per the 475-year return period.

**Table 4-1: Preliminary Design Criteria for Stacker/Reclaimer Berm**

| Loading Case | Minimum Factor of Safety |
|---|---|
| Long-term Operation Case (Static Loading Case) | 1.4 |
| Short-term Maintenance Case (Static Loading Case) | 1.3 |
| Pseudo-static Condition (Earthquake Case) | 1.1 |
| High Ground Water Level Case (Summer Seasons) | 1.3 |

**Table 4-2: Material Properties in Slope Stability Analysis**

| Material | Cohesion, c (kpa) | Internal Friction Angle, Φ,(Degree) | Unit Weight, γ, (kN/$m^3$) |
|---|---|---|---|
| Type 5 Rockfill | 0 | 40 | 22 |
| Type 8 or 12 Rockfill | 0 | 40 | 20 |
| Ballast | 0 | 40 | 20 |
| Sub-ballast | 0 | 40 | 22 |
| Native Sand | 0 | 32 | 18 |

## 4.2 Results

The factor of safety for slope stability analyses were calculated using Geo-Studio software 2016. A series of limit equilibrium analyses were performed using the Morgenstern-Price method of slices.

Table 4-3 presents the calculated factor of safeties for both original berm configurations.

1. The original berm configuration, as shown in Figure 4-1, doesn't satisfy the stability requirement, i.e., insufficient factor of safety as per the slope stability criteria in Table 4-3.
2. To keep the berm geometry unchanged, two rockfill trenches beneath the two sides of the Stacker/Reclaimer berm are being proposed. The rockfill trenches will run parallel to the Stacker/Reclaimer Berm for its entire length. The geometry of the trenches includes a top width of 15 m, a depth of 1.5 m, and side slopes of 1.5H:1V. The trench will be composed of 300 mm top layer of compacted Type 5 Rockfill, followed by 1200 mm of compacted Type 8 Rockfill. Details of the Rockfill Trench can be found in Figure 4-2. The additional Rockfill Trench improves the slope stability and satisfy the stability requirement as shown in Table 4-3.

At centre, the rockfill berm consists of minimum 100 mm road topping (compacted Type 5, 32 mm minus) overlying compacted Type 8 rockfill (150 mm minus, jaw run). Below the track is the ballast and sub-ballast overlying a “Combigrid” Type 40/40 Q1 151 GRK3 or similarly approved geo-composite on top of compacted Type 8 rockfill to form the berm. At the contact between the Type 8 rockfill and native soil material, an optional Combigrid” Type 40/40 Q1 151 GRK3 or similarly approved geo-composite is required as per the direction of the BIM’s site representative/Field Engineer or his/her designate, where fine-grained or soft deposit is encountered at ground.

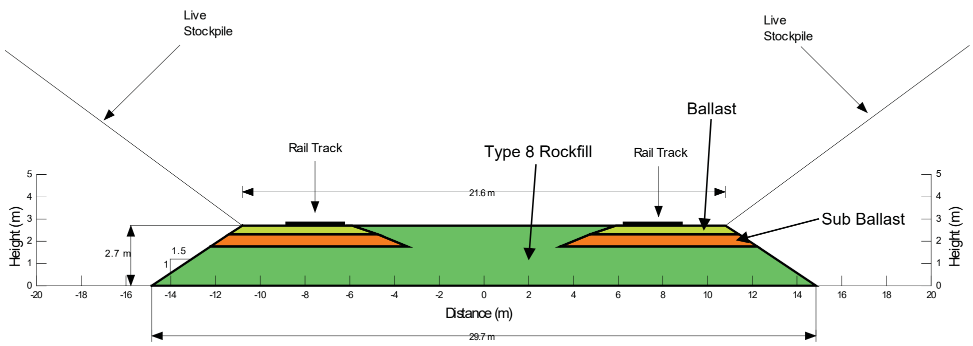


**Figure 4-1: Sketch of Stacker/Reclaimer Berm Configuration (Original)**

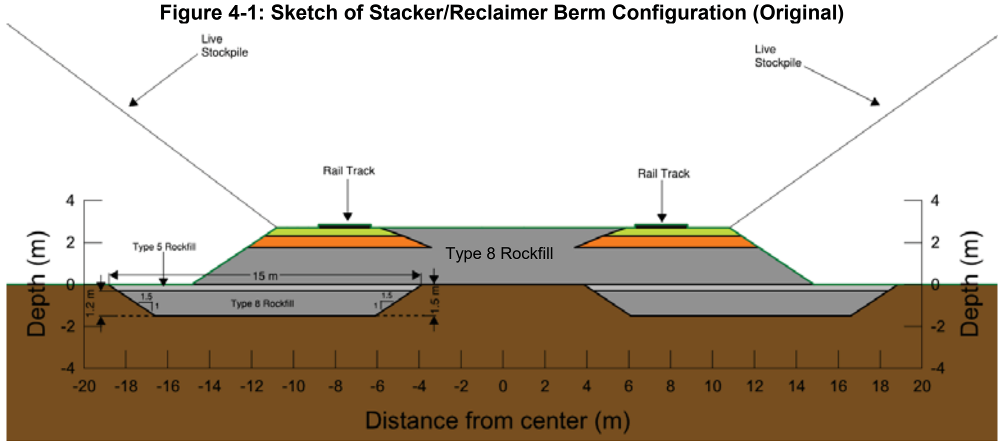


**Figure 4-2: Sketch of Stacker/Reclaimer Berm Configuration with Rockfill Trench**

**Table 4-3: Summary of the Results of Slope Stability Analyses**

| Berm Configuration | Loading Case | Calculated Factor of Safety / Figure | Minimum Factor of Safety | Note |
|---|---|---|---|---|
| Original Berm Configuration | Long-term Operation Case | 1.2 Figure C1B | 1.4 | Not Acceptable |
| | Short-term Maintenance Case | 1.2 Figure C2B | 1.3 | Not Acceptable |
| Original Berm Configuration with Rockfill Trench | Long-term Operation Case | 1.4 Figure C3 | 1.4 | Acceptable |
| | Short-term Maintenance Case | 1.3 Figure C4 | 1.3 | Acceptable |
| | Pseudo-static Condition (Earthquake Case) | 1.1 Figure C5 | 1.1 | Acceptable |
| | High Ground Water Case (Summer Season round) | 1.3 Figure C6 | 1.3 | Acceptable |

# 5. Ultimate Bearing Capacity

The ultimate bearing capacity of the rail track is estimated based on the following assumptions:

- The rail track is 2.5 m width.
- The friction angle of the compacted rockfill berm is 40 degrees.
- The groundwater is at the rockfill berm surface.

The factored geotechnical resistance below the rail track is 430 kPa using Geotechnical Resistance Factor of 0.5 for ultimate limit state design.

# 6. Thermal Analyses

The thermal analyses were performed to investigate the temperature regime in the foundation. Appendix A3 summarizes the methodologies and details of the thermal analyses. Figure D1 and D4 presents the thermal model results.

The temperature of the soil below rockfill pad is shown in Appendix D. The following summarizes the results:

- The active zone below the Stacker/Reclaimer rail track is generally located within the non-frost susceptible Rockfill Trench.

- The active zone beneath the center of the Stacker/Reclaimer Berm reaches a maximum depth of approximately 0.5 m over the 20-year operation life. This depth is much shallower than the natural depth of the active zone (~ 1.5 m) without the Stacker/Reclaimer Berm.
- The active zone crosses beneath the Rockfill trenches into the Native Sand horizontally at the start of the side slopes of the Stacker/Reclaimer Berm.
- It is noted that the airstrip at the Mary River site and the fuel tank at Milne Inlet site have a 2 m to 2.2 m thick granular pad and no freeze heave or thaw settlement actions were observed for these structures.
- As a result, the thaw settlement risk is considered low for the underlying permafrost. The salinity measurements for the samples near ground surface are 3 ppt and 5 ppt as per the BH 17-M010 and BH 17-M012 at 0.9 m and 4 m deep, corresponding to a freezing point of about -0.2°C and -0.3°C, respectively (note: assuming the freezing point decreases by 0.28 degrees Celsius for every 5 ppt increase in salinity). In addition, the native soil below the berm mainly consists of coarse-grain deposit (silty sand, sand, sand and gravel, and sandy gravel) with relatively low susceptibility to thaw settlement.
- The native soil (sand to sand and gravel) under/outside the side slope and trenches of the rockfill berm may experience the freeze and thaw action. However, the freeze and thaw actions are local and is not expected to cause a global stability issue to impact the rail-track on the rockfill berm.

# 7. Settlement Analyses

The loads of lump ore stockpiles and the berm will produce compression of the foundations and cause settlement including long-term creep. Deformation analyses were conducted to assess the settlement impact to the rail track. Appendix A4 summarizes the methodologies and the key parameters. The settlement analyses were conducted using the modified berm configuration.

Table 7-1 summarizes the cases analyzed in this study.

1. Two cross sections were selected for the typical subsurface soil deposits below the berm, as shown in the Sketch 1 in Appendix A1.
    a. The South Section represents the soil profile at the south portion of the berm, consisting of a sandy layer, an underlying silty deposit, and an inferred till layer. The soil profile is likely representative from Station 1+000 to 1+280. Figure E1-1 in Appendix E shows the typical soil configuration in the finite element model.

b. The North Section represents the soil profile at the north portion of the berm consisting of a sandy deposit overlying an inferred till layer. The soil profile is likely representative from Station 1+850 to 2+270. Figure E1-2 in Appendix E shows the configuration in the finite element model.

2. The base-case depth of the underlying till was 65 m, as extrapolated from the boreholes advanced well outside of the footprint of the berm.

## 7.1 Settlement Results

Table 7-1 summarizes the results of the settlement analyses. The base-case settlement is considered as the best estimated settlement for the berm in the current design stage. It should be noted that the calculated settlement is the best-estimated settlement without applying a safety factor. Considering the uncertainty of the till layer depth and the complexity of the permafrost creep, the possible settlement or differential settlement may range from -50% to +100% of the best-estimated value.

The following summarizes the main findings of the settlement analyses:

1. The calculated total settlements are 270 mm and 80 mm at the South Section and the North Section (near the shoreline) respectively, as shown in Figure E2-1. As shown, the south section of the berm has a larger settlement due to the presence of silt permafrost. The settlement components for the lump ore stockpiles and the berm & surcharge are summarized in Table 7-1.

2. The differential settlement along the berm will occur where either the load or the foundation soil properties vary. In general, the estimated differential settlement is approximately 0.5% near the south end of the lump stockpile, as per a preliminary assessment, as shown in Table 7-3. It is noted that large differential settlement may also occur locally along the berm if large load/soil variation is encountered.

3. The creep settlement takes place after construction in a slow rate, as shown in Figure E3-1 in Appendix E.

4. The lump stockpile contributes significantly to the settlement of the berm due to their high loading pressure and large footprints resulting in deep stress influence zones.

5. The instantaneous/elastic compression of the rockfill berm is small (less than 10 mm), as per the comparison of the settlement at the berm top and the berm base in Figure E2-2.

**Table 7-1: Summary for Settlement Analyses**

| Case | Cross Section | Bottom Boundary | Settlement Contour Figure | Total long-term Settlement of Rail Track, mm (over 20 year design life) |
|---|---|---|---|---|
| Case A1 (Base-case) | South Section | Base-case (Till Depth 65 m) | Figure E1-1 | 270 |
| Case A2 (Base-case) | North Section | Same as above | Figure E1-2 | 80 |

**Table 7-2: Summary for Settlement Components for Base-Case**

| Case | Cross Section | Settlement Component Due to Berm +Surcharge | Settlement Component Due to Lump Stockpile | Total Settlement of Rail Track, mm (over 20 year design life) |
|---|---|---|---|---|
| Case A1 (Base-case) | South Section | 80 mm | 190 mm | 270 mm |
| Case A2 (Base-case) | North Section | 30 mm | 50 mm | 80 mm |

**Table 7-3: Summary for Preliminary Differential Settlement Assessment****

| Soil Profile Case | Geometry | Total Settlement of Rail Track, mm | Differential Settlement, mm | Differential Settlement Ratio** (Order of Magnitude Estimate) |
|---|---|---|---|---|
| Case A1 (Base-case) | Section 1 (S1) South Section Berm only | 80 | 190 between S1 and S2 | 0.5% in average (=190 mm / 40 m*) *Assuming S1-S2 distance is about 40 m at the end of the lump stockpile |
| Case A1 | Section 2 (S2) South Section Berm+Stockpile | 270 | | |

Note: * *The soil layer was interpreted and inferred as per the currently available information. The soil profile between boreholes may be different from the assumed and ground ice may be present. The borehole locations were shown in Appendix A1.

## 7.2 Assumptions and Limitations

The following presents the assumptions and limitations for the settlement analyses:

(1) The creep parameters for permafrost were estimated from literature test data on soil with a similar soil type, ice content, loading range, and temperature range. Site-specific laboratory/field creep tests are required to verify and confirm these design parameters and to remove uncertainty associated with using the literature values.

(2) The primary limitation is the lack of subsurface drilling to confirm or identify the depth of the till layer. As a result, the calculated settlements have a high degree of uncertainty. The depth to the till layer was extrapolated from the boreholes advanced well outside of the footprint of the berm.

(3) The soil profile between the boreholes was inferred as per the borehole data. Although not encountered, ground ice may exist in-between borehole locations.

(4) The live lump ore stockpiles were assumed to be constant static loads in the analyses.

# 8. Recommendations

## 8.1 General

The Stacker/Reclaimer berm should be minimum 2.7 m in thickness below the rail track. The berm should have a minimum 21.6 m wide crest with a side slope of 1.5H:1V or flatter. The construction material shall consist of compacted crusher-run rockfill and granular fill.

## 8.2 Rockfill Trench

The top width of the Rockfill Trench was calculated such that the full thickness of the 1.5 trench lies underneath the Stacker/Reclaimer rail tracks to stabilize the slope of the berm and to minimize differential settlement. The width of the trench should be adjusted to maintain this thickness if the spacing between the Stacker/Reclaimer rail trackers are to be changed. The geometry of the trenches include a top width of 15 m, a depth of 1.5 m, and side slopes of 1.5H:1V. The trench should be composed of 300 mm top layer of compacted Type 5 Rockfill, followed by 1200 mm of compacted Type 8 Rockfill. The rockfill should be compacted by at least 5 passes of a 10-ton (or larger) vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h).

## 8.3 Construction Schedule

It should be noted that the subgrade soils are classified as low to high frost susceptible indicating that the subgrade is sensitive to frost heave and thaw settlement characteristics.

It is recommended to construct the berm and rockfill trench during the thaw season. In this way, the thaw depth below ground surface is at maximum during construction and the thermal regime can stabilize for the following winter-thaw season cycle prior to placing the rail track. This approach will minimize the risk of thaw settlement after the rail-track has been installed. Prior to the placement of the rockfill, any topsoil, soft materials, detrimental materials, frozen soil, ice and water ponding should be removed. The subgrade soil of the berm and trench should be proof rolled by a 10-ton (or larger) roller. The rockfill should be placed and compacted in accordance with the latest revision of the project specification (ref. H353004-00000-221-078-001, Standard Specification, Placement of Fill). The rockfill should be compacted by at least 5 passes of a 10-ton (or larger) vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h). Adequate drainage should be provided to divert surface run-off away from the berm footprint and prevent water ponding on the subgrade.

If the rockfill materials have to be placed in winter season, the Stacker Reclaimer Berm must be constructed with compacted rockfill (Type 8) to at least 1.5 m high above the existing grade (i.e. minimum thickness of the rockfill berm is 1.5 m) prior to the coming thaw season. If sub-excavation is to be conducted during the berm construction, the 1.5 m height for the compacted rockfill will be measured from the top of the sub-excavated surface. This approach is to minimize thawing and preserve the frozen ground condition of the subgrade and to minimize the risk of thaw settlement. The rockfill should be unfrozen and free from any detrimental materials, ice and snow. The rockfill should be placed and compacted in accordance with the latest revision of the project specification (ref. H353004-00000-221-078-001, Standard Specification, Placement of Fill). The rockfill should be compacted by at least 5 passes of a 10-ton (or larger) vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h). The proposed method of compaction should be proven to achieve satisfactory compaction of this type of rockfill in winter season. Adequate drainage should be provided to divert surface run-off away from the berm footprint and prevent water ponding on the subgrade during thaw seasons.

For the portions of the berm that are constructed in winter but cannot achieve the 1.5 m minimum thickness requirement before the coming thaw season, the rockfill of these portions of the berm should be removed to expose the subgrade and to proof roll the subgrade following the same procedures as for the thaw season as recommended above.

It should be noted that construction of berm during the winter season may result in excessive settlement. Consequently, additional remedial work may be necessary in the following thaw seasons to keep the settlement under control or under acceptable levels. If the final grade requires fill over 1.5 m thickness, the Contractor may also choose to carry out the work in the winter to build the minimum 1.5 m fills and come back in the following summer to continue the fill construction to the final grade levels.

The berm construction work should be supervised by an BIM’s site representative/Field Engineer or his/her designate. The settlement of the berm should be monitored during construction and operation. The degree of remedial work arising from settlement during construction can be determined during from this monitoring program. Any issue of settlements should be remediated by complete or partial removal of the affected fills, proof rolling of the native subgrade, and backfilling with compacted rockfill. Due to the potential settlement of the Stacker/Reclaimer Berm constructed in cold region, maintenance schedule should be established to re-level and/or re-align the railway track in regular interval.

It should be noted that deviation from the proposed construction scheduling and recommendations outlined in this Section carries risk of excessive settlement and consequences outside of what is presented in this report.

## 8.4 Field Test Stockpile

It is recommended to place a 25 m high test stockpile (approximate volume = 3,500 $m^3$) as soon as practical, ideally near the south end of the berm which is expected to have larger settlement due to the presence of high-ice-content silt deposit. A settlement monitoring program should be implemented to monitor the settlement of the foundation below the stockpile and the settlement adjacent to the stockpile. The data will provide a good indication of the berm settlement and also serve as a base of calibration for the creep parameters.

## 8.5 Subgrade Preparation

The subgrade should be proof-rolled and inspected prior to placing fill materials. The identified soft areas shall be further compacted, and/or, be excavated and replaced with compacted granular fill or rockfill as approved by BIM’s site representative/Field Engineer or his/her designate. BIM’s site representative/Field Engineer or his/her designate shall inspect and approve the subgrade.

The rockfill should not be frozen and should be free from snow, detrimental and frost susceptible materials. The rockfill should not be placed in water or on ice. Dewatering is required where ponding water is encountered. Over-excavation is required to remove ground ice if encountered.

## 8.6 Berm Construction

The berm construction materials should be free draining and non-frost susceptible to prevent the formation of ice lenses, which may cause frost action and significant damage to the footing and/or structure.

The rockfill materials should be Type 8 rockfills, satisfying the requirement of the project specifications and the construction notes in the drawings. Any ice or snow shall be removed during construction.

It is critical to achieve a satisfied compaction for the performance of the berm. The rockfill materials, fill placement and compaction for the construction of the Stacker/Reclaimer berm should strictly follow the project specifications (ref. H353004-00000-221-078-001, Standard Specification, Placement of Fill). The rockfill should be compacted by at least 5 passes of a 10-ton (or larger) vibratory roller with vibrations in the range of 1200 to 1500 vpm and the roller speed of about 2 mph (3.2 km/h).

The berm placement and compaction should be supervised by BIM’s site representative/Field Engineer or his/her designate and the construction QA/QC program should be carried out.

## 8.7 Maintenance / Monitoring Program

A monitoring program should be implemented during the construction of the Stacker/Reclaimer Berm to remediate areas with excess settlement. Remediation will consist of complete or partial removal of the affected fills, proof rolling of the native subgrade, and backfilling with compacted rockfill. This monitoring program, along with a maintenance program, should conducted during the lifetime of the Stacker/Reclaimer to address the long-term total and differential settlement of the Stacker/Reclaimer berm. The rail track may need to be re-leveled and/or re-aligned periodically by railway technologies/ machines, where the settlement exceeds the tolerance in the design life. The unfavorite differential settlement is likely to occur near the ends of the lump ore stockpiles. The reclaiming and stockpiling operation may be used to adjust the layout of the stockpile to smooth out the differential settlement if needed.

A monitoring program is recommended to survey the track settlement on a regular basis and provide information for the maintenance program.

Salt should not be used for the snow removal purpose over the berm, as it may increase the salinity of the underlying permafrost and cause thaw settlement.

## 8.8 Drainage

Proper drainage is an important component to ensure a satisfactory performance of the structure. Water that is ponding or seeping into the soils around the berm may cause permafrost degradation resulting in instabilities and excessive settlement.

(1) External drainage crossing the berm from the stockyard should not be intercepted or diverted by the berm or stockpiles. Water should be intercepted well before reaching the berm. Water may be passed under the berm using culverts, but this should also be avoided where possible. If required, ditches should be constructed a minimum 6 m from the berm. All ditches should be protected from erosion. Water should never be left to pond on or at the toe of the berm or inside the rockfill trench.

(2) A proper drainage system should be provided on the berm crest to avoid any ponding water or ice accumulation near the rail track during warm and cold seasons correspondingly. Any concentrated water flow in the drainage system shall be lined to avoid negative thermal impact to the foundation. If sump and pump drainage system is to be used, the sump shall be lined.

## 8.9 Operation of Reclaiming and Stacking

The following is recommended to be considered for the operation of reclaiming and stacking.

(1) Inspect the berm during every thaw season, particularly in the first two thaw seasons for settlement and side slope slumping.

(2) Maintain the two lump ore stockpiles symmetric to the berm during operation, as much as possible, to minimize the potential differential settlement at the cross-section direction.

(3) The stockpile operation may be optimized to mitigate the expected large differential settlement near the end of stockpile by flattening the stockpile longitudinal slope or shifting the locations of the stockpile end annually.

(4) Snow should be removed timely from the berm between the two lump stockpiles to avoid impacting the operation.

(5) Reclaiming operation for the lump stockpile should be carried out in a way to improve the drainage of run-off water collected from the berm.

(6) During thaw seasons, the sloughing along the live stockpile slope may occur and should be considered in the maintenance program.

# 9. References

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8. IPCC, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change., 2014. Climate Change 2014: Synthesis Report. IPCC, Geneva, Switzerland: Cambridge University Press.
9. RWDI, 181234 CIRNAC IR 14., 2019.

# Appendix A1
# Borehole Plan and Soil Profiles