Appendix V3-2F

Boston Tailings Management Area Preliminary Design, Hope Bay Project

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Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.004
December 2016

Boston Tailings Management Area Preliminary Design, Hope Bay Project

Hope Bay, Nunavut, Canada

December 2016

Prepared for

TMAC Resources Inc.
PO Box 4
Suite 1010 – 95 Wellington Street, West
Toronto, ON M5J 2N7
Canada

Tel: +1 604 998 4175
Web: www.tmacresources.com

Prepared by

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2
Canada

Tel: +1 604 681 4196
Web: www.srk.com

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1 Introduction

1.1 Background

1.1.1 General

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet (Figure 1). The Project comprises three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston (Figure 2).

The Project consists of two phases: Phase 1 (Doris deposit) with an estimated ore reserve of 2.5 million tonnes (Mt), and Phase 2 (all remaining deposits), which includes an additional ore reserve of approximately 18.7 Mt. The total ore reserve for the combined Phases is 21.2 Mt, which is approximately equal to the total amount of tailings that will be produced. Of this, approximately 18 Mt of tailings will be contained within the Doris Tailings Impoundment Area (TIA) (SRK 2016a), with the remaining tailings being deposited in the Boston Tailings Management Area (TMA).

Ore processing at Boston is limited to production of concentrate which is trucked to the Doris mill for final processing and gold extraction. Therefore, only floatation tailings are produced at Boston. Theses tailings will be dewatered through the use of a filter press, and trucked to the TMA where it will be placed in thin compacted lifts. The Boston ore reserve is 5.1 Mt, and this is the design capacity of the Boston TMA, not considering the fact that concentrate of about 10% of this total will be hauled to Doris.

Environmental containment for the Boston TMA is limited to a series of contact water ponds to collect surface runoff from the facility. At closure, the TMA will be covered with a low infiltration cover consisting of a geosynthetic liner with a protective quarry rock cover.

This report is documenting the preliminary design of TMAC's proposed Boston TMA.

1.2 Scope of Work

SRK Consulting (Canada) Inc. was retained by TMAC to carry out the preliminary design of the Boston TMA for the Phase 2 Hope Bay Project. The design and related information provided in this report has been prepared in accordance with industry best practice, which includes, but is not limited to, the Canadian Dam Safety Guidelines as documented by the Canadian Dam Association (CDA) (CDA 2007, 2013), the Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014), various Mining Association of Canada guidelines (MAC 2011a, b, c) and publications and bulletins published by the International Commission of Large Dams (ICOLD).

In addition, in response to the 2014 Mt. Polley tailings dam failure in British Columbia, and the 2015 Samarco tailings dam failure in Brazil, the design takes into consideration the key recommendations as outlined in the subsequent Independent Expert Engineering Investigation and Review Panel Report (IEEIRP 2015), as well as the recent BC Dam Safety Regulations (B.C. Reg. 40/2016).

1.3 Report Structure

A brief description of the TMA concept is described in Section 2 while the TMF design criteria are presented in Section 3. Details of the TMA design and detailed descriptions of the supporting analyses are provided in Section 4. Section 5 lists the TMA construction details, including construction material take-off quantities. The TMA operational plan which includes the deposition plan is described in Section 6, while TMA closure is described in Section 7 and includes a brief discussion on monitoring and maintenance.

2 Tailings Management System Concept

2.1 Tailings Storage Requirements

Phase 1 (Doris deposit) of the Hope Bay Project, currently licenced, has an estimated ore reserve of 2.5 million tonnes (Mt), and Phase 2 (all remaining deposits) includes an additional ore reserve of approximately 18.7 Mt. The total ore reserve for the combined Phases is 21.2 Mt, which is approximately equal to the total amount of tailings that will be produced. Of this, approximately 18 Mt of tailings will be contained within the Doris TIA (SRK 2016a), with the remaining tailings being deposited in the Boston TMA.

Ore processing at Boston is limited to production of concentrate which is trucked to the Doris mill for final processing and gold extraction. Therefore, only flotation tailings are produced at Boston. These tailings will be dewatered through the use of a filter press, and trucked to the TMA where it will be placed in thin compacted lifts. The Boston ore reserve is 5.1 Mt, and this has been adopted as the design capacity of the Boston TMA. This conservatively does not consider the fact that the concentrate which is about 10% of this total will be hauled to Doris.

2.2 Selection of Preferred Tailings Management System

A comprehensive tailings disposal alternatives assessment was completed for the Boston deposit in the form of a multiple accounts analysis (MAA). It was prepared in accordance with the Environment Canada guideline for disposal of mine waste (EC 2011). The alternatives assessment took into consideration technical, operational, environmental, socio-economic, and project economic factors. It also considered tailings disposal technologies, containment dam technologies, and tailings disposal sites (SRK 2016b).

The analysis concluded that the most favorable methodology is to place filtered tailings into a free-standing dry stack facility located about 1 kilometer east of the Boston processing facility, directly south of the proposed new Boston Airstrip (Figure 3). A portion of the contact water pond berms required to retain the run-off contact water will double as the access road to the proposed new airstrip.

The dewatered filtered tailings will be trucked to the dry-stack facility, where it will be spread in thin lifts (0.3 m thick) and compacted. The facility is continuously built up in this fashion to reach a maximum height of about 26 m, with 5 m high intermediate benches (Figures 4 and 5). The inter-bench slope will be 3H:1V, with an overall slope of about 3.9H:1V. The footprint occupied by the tailings facility is about 19.8 hectares, but the location offers further expansion capacity to the north.

Contact water from the tailings management area (TMA) will be retained by a series of contact water berms (Figure 6). At closure the TMA will receive a low permeability cover to mitigate against long term water quality concerns associated with neutral metal leaching of the tailings (Figure 7).

3 Tailings Management Area Design Criteria

3.1 Hazard Classification

The design, construction, operation and monitoring of dams in Canada have to be completed in accordance with appropriate territorial, provincial, and federal regulations and industry best practices. The foremost guidance documents in this regard are the Canadian Dam Safety Guidelines (CDA 2007, 2013) and the Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014) published by the CDA.

The Boston TMA is however not a dam, and in absence of an appropriate hazard classification system, the CDA guidelines were applied.

A key component of the guidelines is classifying the dams into hazard categories (dam class) that establish appropriate geotechnical and hydro-technical design criteria. Table 1 is a reproduction of the recommended dam classifications as presented in the CDA guidelines. This classification is based on the incremental consequence of a dam failure (as opposed to total consequence). The incremental consequences of failure are defined as the total damage from an event with dam failure, less the damage that would have resulted from the same event (e.g., a large earthquake or a large flood event) had the dam not failed.

Table 1: Dam Hazard Classification as per CDA (2013)

Dam Class	Population at Risk[1]	Incremental Losses		
		Loss of Life[2]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary Only	Unspecified	No significant loss of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities
Very High	Permanent	100 or fewer	Significant loss or deterioration of critical fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g. highway, industrial facility, storage facilities for dangerous substances)
Extreme	Permanent	More than 100	Major loss of critical fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g. hospital, major industrial complex, major storage facilities for dangerous substances)

[1] Definitions for population at risk:

None – There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseen misadventure.

Temporary – People are only temporarily in the dam-breach inundation zone (e.g. seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent – The population at risk is ordinarily located in the dam-breach inundation zone (e.g. as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

[2] Implication of loss of life:

Unspecified – The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Determination of the appropriate hazard rating is often subjective and is dependent on site-specific circumstances that may require an agreement between the proponent, regulators, and stakeholders. During the dam classification process, each of the four hazard rating components (i.e., population at risk, loss of life, environmental and cultural values, and infrastructure and economics) is considered individually and the overall dam hazard rating is defined by the component with the highest (i.e., most severe) rating. It is important to note that the hazard rating refers to the downstream consequences in the inundation zone of a dam breach; however, in the context of the TMA this was applied as the likely zone of run-out in the event of a slope failure.

The "*Population at Risk*" has been generously selected as "*Temporary Only*" due to very infrequent need for personnel to monitor the contact water pond berms in the likely failure debris run-out zone. The "*Loss of Life*" has again conservatively been selected as "Unspecified" to reflect that there will be short and infrequent periods of time where persons will be present in the likely run-out zone.

The "*Environment and Cultural*" impacts associated with a breach of the TMA will be associated with a finite quantity of tailings immediately downstream of the failure zone. This run-out will likely be captured by the contact water pond berms and therefore tailings run-out reaching the Aimaokatalok Lake is not expected. If the contact water ponds were to be completely full at the time of the breach, it is conceivable that this contact water may overtop the ponds entering Aimaokatalok Lake. Although Aimaokatalok Lake is considered significant habitat, restoration of that habitat under this scenario would be highly possible.

"*Economic*" consequences of a breach of any of the three structures could be significant in terms of direct costs to the proponent, including reputational loss, but would be very minimal in terms of losses to infrastructure or services that might affect other parties.

Based on these factors, the TMA hazard classification are summarized in Table 2.

Table 2: Boston TMA Hazard Classification

Population at Risk	Loss of Life	Environmental and Cultural Values	Infrastructure and Economics	Overall Hazard Classification
SIGNIFICANT	SIGNIFICANT	SIGNIFICANT	LOW	SIGNIFICANT

3.2 Design Life

Ore production at Boston will be for 11 years, with the concentrate processing facility operating for 10 years. The dry-stack will therefore have an active design life of 10 years, followed by a one year closure period during which the closure cover will be constructed, and the contact water ponds breached. Post-closure monitoring is assumed to span another 10 years. The closed TMA will however remain in perpetuity. Thermal analysis of the TMA considers climate change up to the year 2100 (SRK 2016c).

3.3 Tailings Physical Properties

Physical properties of the tailings were determined based on three separate geotechnical test campaigns carried out between 2003 and 2009 (SRK 2016d) and are summarised in Table 3.

Table 3: Summarized Tailings Geotechnical Properties

Parameter	Value
Specific gravity	2.85
% Fines (<0.075 mm)	65%
% Silt	52%
% Clay	13%

Parameter	Value
Void ratio (e) for filtered tailings	0.6
Deposited dry density (Tonnes/m^3) for filtered tailings	1.8
Internal angle of friction (degrees)	40
Cohesion (kPa)	0
Gravimetric moisture content (%)	20.5
Hydraulic conductivity (m/s)	1.3x10^{-7}

3.1 Tailings Geochemical Properties

Detailed geochemical characterization of the Boston flotation tailings (SRK 2016d) confirms that the tailings are not potentially acid generating but have the potential for neutral metal leaching. Collection and treatment of contact water may therefore be required, contingent on the water quality predictions for the leachate (SRK 2016e).

3.2 Tailings Storage Requirement

The total quantity of ore milled at Boston is in the order of 5.1 Million tons. Assuming an average density of 1.8 t/m^3 for the filtered tailings, this translates to about 2.8 million m^3. The Boston processing facility will however only produce concentrate, which will translate to about 10% of the total ore fed through the facility. Therefore, the tailings produced and sent to the TMA will be limited to about 4.5 Mt (2.5 Mm^3). For planning purposes this 10% reduction has not been considered. Complete Boston tailings storage requirements are summarized in Table 4.

Table 4: Tailings Storage Requirements

Component	Value	Source
Tailings storage requirement	2.8 Mm^3 (5.1 Mt)	Quantity based on TMAC mine plan; volume conversion based on dry density listed below in this table
Tailings production	800 tpd for first year; 1,600 tpd for remaining mine life	Supplied by TMAC.
Tailings production period	10 years	Supplied by TMAC.
Ice entrainment allowance	None	Tailings will be placed unsaturated with no excess water.
Run-off and contact water allowance	Not required	Additional storage capacity not required as contact water will be contained temporarily and pumped back to the processing facility.
Deposited tailings dry density	1.8 t/m^3	SRK (2016d)

3.3 Stability Criteria

The minimum factors of safety (FOS) that are applicable to, and required to be achieved for the TMA, are defined by the Canadian Dam Safety Guidelines applied specifically to tailings dams (CDA 2014), and are reproduced in Table 5.

Table 5: Minimum Required Factors of Safety in Accordance with CDA (2014)

Stability Condition	Minimum Factor of Safety
Static Assessment	
During, or at end of construction	Greater than 1.3 depending on risks assessed during construction
Long-term (steady-state seepage, normal reservoir level)	1.5
Seismic Assessment	
Pseudo-static	1.0
Post-earthquake	1.2

Note: This table is summarized from Tables 3-4 and 3-5 in CDA (2014)

3.4 Design Earthquake

Assuming a hazard classification of significant, the CDA (2014) specifies the design earthquake with AEP of between 1/100 and 1/1,000 years for the construction and operations stage. For long-term scenarios, i.e. post-closure, the design seismic event must be increased to 1:2,475 year event. A detailed analysis of the site-specific seismic factors was completed for the Project (SRK 2016f), with a resultant Peak Ground Acceleration (PGA) value of 0.018 g for the 1/2,475 years event.

The CDA guidelines (CDA 2014) specify that for long-term scenarios, i.e. operations and post-closure, the seismic event for a dam with the hazard classification of significant must be increased to halfway between the 1:100 and 1:1,000 year event. The PGA associated with this condition is 0.011 g. Since the facility will remain in perpetuity, the seismic coefficients considered in the stability analysis were increased to the more conservative value of 0.036 g, corresponding to the seismic event with a return period of 1:2,475 years (Appendix A).

3.5 Inflow Design Flood (Contact Water Ponds)

For dams with a significant hazard classification, the Inflow Design Flood (IDF) is defined to be an event half way between the 1/100 and 1/1,000 years rainfall (CDA 2014). The TMA however does not require containment of water and therefore this IDF does not apply.

Contact water running off from the TMA is collected in three contact water ponds with a combined IDF of the 1:100 year return period, 24 hour duration storm event (55 mm) plus the maximum daily snowmelt of 18 mm, for a total of 73 mm (SRK 2016g). The 1:100 year storm event includes allowances for climate change predicted to the year 2040 (SRK 2016c).

Based on the dry stack and contact water berms layout, three ponds will be formed. The volume to be stored in each of the ponds was determined by modelling the sub-catchments within the facility footprint and then determining the final water elevation using Global Mapper and Muck3D software respectively. The storage capacity of each pond is summarised in Table 7. It is important to note that storage capacity in the North-west pond is less than the required storage; however, water will overflow into the South-west pond which has ample excess storage capacity.

3.6 Design Freeboard (Contact Water Ponds)

A detailed freeboard analysis was not completed at this time for the Boston TMA; however, the normal freeboard (wind setup + wave action) for the Doris TIA was found to be in the order of 1.1 m (SRK 2016a) accounting for a pond surface much larger than the Boston Contact Water Ponds.

A conservative freeboard of 1.3 m was assumed for the contact water berms, to prevent overflow by wind setup and wave action, with no additional hydraulic freeboard allowed for, as the ponds will be operated normally dry. This freeboard extends from the top of the geomembrane to the crest of the berm (Figure 7). The top elevation of the geomembrane in each of the containment berms was determined based on the maximum elevation of the water resulting in each of the ponds from the combined IDF.

3.7 Summary of TMA Design Criteria

A complete summary of the TMA design criteria is listed below (Table 6), and is consistent with Best Management Practices, including the Canadian Dam Association (CDA 2013, 2014) guidelines.

Table 6. Summary of TMA Design Criteria

Component	Criteria
Hazard Classification	SIGNIFICANT
Design Life • Active deposition period • Assumed Post-closure monitoring period • Long-term design basis	 • 10 years • 10 years • Up to year 2100
Tailings Production Rate	800 tonnes per day for first year; 1,600 tonnes per day for remaining mine life
Tailing Moisture Content	20.5% (by weight)
Tailings Dry Density	1.8 t/m^3
Tailings Storage Requirement • By mass • By volume	 • 5.1 Mt • 2.8 Mm^3
Tailings Deposition Method	Load, haul, dump, place, and compact filtered tailings
Maximum Design Earthquake	1:2,475 seismic event; PGA of 0.018 g

Component	Criteria
Contact Water Pond(s) Inflow Design Flood	1:100 year return period, 24 hour duration storm event (55 mm) plus maximum daily snowmelt of 18 mm, for a total of 73 mm
Contact Water Pond(s) Storage Requirement	North-east Pond – 9,957 m^3 North-west Pond – 1,984 m^3 South-west Pond – 8,762 m^3 Total – 20,703 m^3
Contact Water Pond(s) Freeboard	1.3 m normal
Stability Factors of Safety (Static)	1.3 during construction 1.5 during operation and closure
Stability Factors of Safety (Pseudo-Static)	1.0 during earthquake 1.2 post earthquake

4 TMA Design

4.1 Foundation Conditions

Numerous geotechnical investigations have been performed at the Project site. A surficial geology and permafrost investigation was carried out at Boston in 1996 (EBA 1996). The investigation included air photo interpretation followed by ground truthing and completion of six onshore drill holes, followed up by laboratory testing of select geotechnical samples. The investigation found the proposed Boston area is characterized mostly by marine deposits of silty-clay with trace sand. Small pockets of glaciofluvial deposits of coarse sand and some gravel are also present.

Project-wide overburden consists of permafrost soils which are mainly marine clays, silty clay, and clayey silt, with pockets of moraine till underlying these deposits. The marine silts and clays contain ground ice ranging from 10 to 30% by volume on average, but occasionally as high as 50%. The till typically contains low to moderate ice contents ranging from 5 to 25%. Overburden soil pore water is typically saline due to past inundation of the land by seawater following deglaciation of the Project area. Salinity measurements in the EBA (1996) investigation ranged from 3 to 48 parts per thousand, which depresses the freezing point and contributes to higher unfrozen water content at below freezing temperatures.

Permafrost at the Project area extends to depths of about 565 m, with an average geothermal gradient of 0.021°C/m. Active layer depth in overburden soil averages 0.9 m, with a range from 0.5 to 1.4 m (SRK 2016f).

Isopach maps developed from seismic surveys and exploration and geotechnical drill holes indicate that depth of overburden under the infrastructure is expected to range from 0 to 10 m, with most areas having less than 6 m of overburden. General foundation conditions, material properties for geotechnical analysis, and development of the overburden isopach surface are described in more detail in SRK (2016f).

4.2 Dry Stack Components

4.2.1 Layout

The dry stack facility will occupy a flat area just east of the Aimaokatalok Lake extension, south of the proposed new Boston airstrip. This area is separated from the mining infrastructure (SRK 2016h) by the extension of the Aimokatalok Lake and the outflow creek from Stickleback Lake (Figure 3).

The footprint of the dry stack facility is in the shape of an irregular heptagon, with a footprint of about 19.8 hectares (about 410 m in east-west direction and 530 m in north-south direction) and a final height of 26 m. The final height of the facility is governed by the proximity to the airstrip to avoid encroachment into the airstrip exclusion zone (SRK 2016i).

The facility will be constructed in thin lifts of 0.3 m, spread and compacted successively over the life of the mine and 5 m high intermediate benches with side slopes of 3H:1V. Setback benches of 5 m will result in an overall slope configuration of about 3.9H:1V. The top off any given lift will be graded at 2% toward the perimeter of the facility, to promote run-off towards the three contact water ponds.

Access to the facility will be gained via the Madrid-Boston all weather road, then following the Airstrip access road which doubles as the contact water pond berms in select locations (Figure 4). An access ramp with a nominal grade of about 8% will provide continuous access to the rising dry stack.

4.2.2 Underdrain

In temperate and very wet climates, it is best practice to construct underdrainage for dry stack facilities to preclude buildup of a phreatic surface thereby reducing the risk of static liquefaction and slope instability.

The Boston dry stack is founded on permafrost soils, and complete freeze-back of the tailings is expected within the first winter season following deposition (Appendix B). Correspondingly, an underdrain will also freeze and remain frozen indefinitely once the tailings thickness exceeds the active zone depth. It is therefore not practical or necessary to construct an underdrain for the Boston dry stack facility.

4.2.3 Seepage Collection

The dry stack foundation is frozen, and the tailings will freeze back soon after placement (Appendix B), save for the active layer. Therefore there is no concern related to potential deep groundwater seepage. Shallow groundwater seepage emerging from the active layer will be collected in the contact water ponds. Post-closure seepage through the active layer will be limited to what may infiltrate through the low permeability cover (Appendix C). This volume of flow is considered negligible, and water and load balance modeling (SRK 2016e) confirms that there would be no environmental impact associated with this flow. As a result no post-closure seepage collection is planned or required.

4.2.4 Operational Erosion Protection

As far as practical progressive reclamation of the dry-stack facility will be completed; however, at any given time there will be exposed tailings that might be susceptible to overland runoff erosion. Should this occur all eroded sediments will end up in the contact water ponds, with no risk of an uncontrolled environmental discharge. The volume of sediment trapped in the contact water ponds will be monitored and if it compromises the pond design capacity, the sediment will be removed, or the contact water ponds capacity will be increased.

An alternate mitigation strategy that may be adopted will be top clad the dry-stack facility with geosynthetic erosion protection material which offers short to medium term protection.

4.3 Contact Water Ponds

The catchment area, which includes the dry stack facility that drains towards the three contact water ponds is about 28.0 ha. Water retention of these contact water ponds are provided by a geosynthetic high density polyethelyne (HDPE) liner tied into permafrost, i.e. a frozen foundation dam design.

4.3.1 Design Criteria

The contact water ponds are designed as event ponds, and have the following design criteria:

- Ponds will be normally empty (i.e. the pond will be kept in a dry state);
- Maximum residence time for ponded water is one week;
- Design life will be 20 years;
- Effects of climate change during the 2011 to 2040 time frame will be considered;
- Ponds will have the capacity to contain at a minimum the contact water from the 1:100 year, 24-hour duration storm event (55 mm), and the maximum daily snowmelt (18 mm);
- The inflow design flood assumes a runoff factor of 1, i.e. no allowance for attenuation, infiltration or evaporation;
- Operational freeboard of 1.3 m;
- The berms that make up the ponds will be used as an access road; and
- The berms will be constructed of locally available, geochemically suitable quarried rock.

4.3.2 Design

The contact water pond design uses the permafrost and naturally low permeability of the foundation materials to contain the contact water on the bottom of the pond, and a geomembrane acts as the impermeable layer within the berm (Figure 7). This design hinges on the contact between the geomembrane and permafrost soil remaining frozen.

The key design features of the contact water berm are listed below:

- 8 m wide crest;
- Side slopes of 2H:1V (26.5°);
- Maximum geomembrane slopes of 2H:1V (26.5°);
- 2.5 m minimum thickness to ensure the contact between the geomembrane and permafrost soils remains frozen;
- Minimum of 1 m cover between the top of the geomembrane and the driving surface;

- HDPE liner sandwiched between two layers of non-woven geotextile, except at the liner tie-in; and
- Two 0.3 m thick layers of bedding material surrounding the HDPE liner.

Thermal modelling was completed to demonstrate that the contact water ponds would perform as expected. This analysis is provided in Appendix B.

4.4 Monitoring Instrumentation

Ground temperature cables to verify the foundation thermal response will be installed below the containment berms, as well as along specific cross-sections of the contact water pond containment berms.

Deformation of the crest and slopes of the dry stack tailings will be monitored during construction and into the initial post-closure period to provide an early indication of possible instability. Monitoring will be performed through a network of survey prisms placed at appropriate intervals along the interbench berms and the crest of the facility. The prisms will be installed in large boulders imbedded within the final ROQ cover.

4.5 Dry Stack Stability Analysis

4.5.1 Foundation and Slope Stability Analysis

A comprehensive stability analysis was carried out to confirm whether the dry stack meets the appropriate design requirements as stipulated in Section 3.3. Complete details of the analysis are presented in Appendix A and the results are summarized in Table 7. The analysis considered staged construction of the facility according to the five bench heights, and the ultimate long-term stability was assessed at the end of construction, i.e. the full height of the facility.

Table 7: Dry Stack Minimum Factor of Safety

<table>
<tr><th></th><th colspan="2">Short Term (Undrained Condition)</th><th colspan="2">Long Term (Drained Condition)</th><th colspan="2">During Earthquake (Pseudo-Static)</th></tr>
<tr><th>Construction Stage</th><th>Computed FoS</th><th>Required Minimum FoS (CDA 2013)</th><th>Computed FoS</th><th>Required Minimum FoS (CDA 2013)</th><th>Computed FoS</th><th>Required Minimum FoS (CDA 2013)</th></tr>
<tr><td>1st Stage (Height: 6m)</td><td>1.4</td><td rowspan="5">1.3</td><td>1.8</td><td rowspan="5">1.5</td><td>1.2</td><td rowspan="5">1.0</td></tr>
<tr><td>2nd Stage (Height: 5m)</td><td>1.4</td><td>1.9</td><td>1.2</td></tr>
<tr><td>3rd Stage (Height: 5m)</td><td>1.4</td><td>1.9</td><td>1.2</td></tr>
<tr><td>4th Stage (Height: 5m)</td><td>1.4</td><td>1.9</td><td>1.2</td></tr>
<tr><td>5th Stage (Height: 5m)</td><td>1.4</td><td>1.9</td><td>1.2</td></tr>
</table>

The dry stack meets all the required minimum slope stability FOS as prescribed by CDA (2014).

Given the low seismicity of the Project area and the results of the pseudo-static analysis, deformation of the dry stack during the design earthquake is expected to be negligible. As a result, further numerical analysis of the dry stack facility post-earthquake was not deemed necessary.

4.5.2 Liquefaction Analysis

Liquefaction is a process by which all strength is temporarily lost from a saturated soil, and the soil behaves as a fluid. Liquefaction is normally associated with loose sandy soils, as suggested by the process commonly being referred to as “quicksand”. The mechanics of the process is due to a sudden increase in pore pressure, which cannot dissipate fast enough and results in the effective stress becoming near-zero (Holtz and Kovacs 1981). In the context of the Boston TMA, liquefaction could theoretically affect the foundation and the tailings deposit; however, it is extremely unlikely to occur for the reasons described below.

In the case of the foundation, the soils are mostly comprised of marine-type silty clay deposits, with traces of sand. As such, these soils are not susceptible to liquefaction. In addition, the foundation soils are frozen and will remain frozen for the foreseeable future. In the worst-case scenario of the foundation becoming unfrozen, any thawing would be progressing slowly from the outside of the facility toward the middle and thus would allow timely dissipation of any excess porewater pressures. The dry stack facility will be built gradually with an average rate of rise of about 3 m/year (Appendix A). The tailings will be laid out in thin lifts and compacted, thus eliminating the loose state required for liquefaction. In addition, the tailings deposited in previous years will freeze over the subsequent winter, eliminating any possibility of pore pressure fluctuations except for the top 2.5 m representing the active layer thickness in exposed tailings (see Section 4.8).

4.6 Settlement Analysis

Settlement of the dry stack facility is limited to foundation settlement as a result of thaw settlement and consolidation settlement of the tailings itself. The foundation will however remain frozen (Appendix B), preventing thaw settlement, and tailings placement in thin compacted layers precludes post construction consolidation settlement. Therefore the dry stack facility will experience negligible settlement.

4.7 Deformation Analysis

The stability analysis presented in Appendix A was done using an elasto-plastic deformation and consolidation analysis, which concluded that the maximum vertical deformation would occur at the top surface of the dry stack facility at the end of mine life to the tune of 6.3 cm.

4.8 Thermal Analysis

Tailings are expected to freeze completely during the first winter season following placement, therefore a tailings freeze-back model was not completed. Seasonal thaw of the upper-most layers of tailings will create an active layer of variable thickness, which was assessed in a detailed thermal model (Appendix B) which includes consideration for climate change.

Active layer thickness of exposed tailings located outside of areas of active material placement is estimate to average 2.5 m. Once the closure cover is constructed, active layer thickness is predicted to be between 2.7 m and 3.2 m depending on tailings saturation.

4.9 Seepage Analysis

Seepage through the tailings in the TMA is considered negligible due to the high placed density and the fact that tailings will freeze back and remain frozen for the foreseeable future (other than the active layer).

Although no seepage is expected through the geomembrane, a worst case scenario was analysed to provide an upper bound in case seepage does materialize (Appendix D). The analysis concludes a potential upper bound leakage rate of 0.64 m^3/day from the TMA after closure. This leakage is only possible for about 60 days per year, from the time the top 1 m of cover thawed (assumed early August) to the time when the surface starts to freeze back (typically early October).

5 Construction

5.1 Construction Materials

The dry stack facility will be built entirely of filtered tailings.

Construction material for the closure cover and contact water ponds consist of bedding, transition and run of quarry (ROQ) material. The granular fill will be produced on site from one of many local approved quarries. Complete geological, mineralogical and geochemical details on these quarry sites are documented in (SRK 2016j).

Other materials that will be used to construct these facilities include HDPE liner and geotextile. Complete details of all these materials are provided in the Technical Specifications (SRK 2011).

5.2 Construction Equipment

Typical earth moving equipment will be used for the construction of the dry stack, the cover and the contact water ponds. Tailings deposition will be completed with a dedicated fleet consisting of a front end loader, one or two articulated dump trucks (30 or 40 tonne), one bulldozer and one smooth drum 10 tonne compactor.

Construction of the contact water ponds and the closure cover will be completed using a contractor fleet of loaders, articulated haul trucks, bulldozers, and compactors. Hydraulic excavators may be used for special tasks as required. Drilling and blasting, if required, will be done using conventional tracked blast hole drills.

5.3 Construction Quality Control and Quality Assurance

Complete details of the Quality Assurance and Quality Control (QA/QC) procedures to be followed for the construction activities are provided in the Technical Specifications (SRK 2011). Quality Control will be the responsibility of the Contractor, and/or the equipment and materials manufacturer. The Engineer of Record, which will be a Registered Professional Engineer in the Nunavut Territory, will carry out Quality Assurance. Complete documentation of all QA/QC data will be provided in the relevant As-Built Reports.

5.4 Construction Schedule

Construction of the dry stack will be done year-round. The dry stack tailings material will be placed directly on the tundra, with no removal of vegetation or excavation of overburden prior to tailings placement. To ensure the permafrost foundations remain frozen, the first lift of filtered tailings should, if practical, be placed in the winter when the ground is frozen. If tailings placement must start when the ground is thawed, a layer of ROQ may be required for trafficability.

The closure cover should ideally be constructed during the warmer seasons to facilitate geomembrane seaming and welding. The gravel bedding layer protecting the integrity of the geomembrane must be constructed immediately after geomembrane installation is complete. The final ROQ cover can be placed any time of the year.

Construction of the containment berms of the contact water ponds must be done in the winter to eliminate potential issues caused by thawing of the soft overburden soils as well as to ensure that a thermal blanket is completed to protect the permafrost in the foundation.

5.5 Material Quantities

Includes materials for the construction of the closure cover and the contact water containment berms.

Material quantities for the construction of the TMA are summarized in Table 8. All fill and excavation volumes represent neat volumes, i.e. "in place", with no allowance for swelling and compaction. The liner quantities are neat quantities, with no allowance for seams and waste.

Table 8: Summary of Material Quantities

Material	Quantity
Closure Cover	
Liner Bedding Material(m^3)	60,850
Geomembrane (m^2)	202,800
Geotextile (m^2)	202,800
ROQ Fill (m^3)	142,000
Contact Water Pond Containment Berms	
Liner Bedding Material (m^3)	10,300
Geomembrane (m^2)	18,100
Geotextile (m^2)	36,200
ROQ Fill (m^3)	43,200
Transition Fill (m^3)	25,300
Key Trench Excavation (m^3)	1,000

6 Tailings Management System Operations

6.1 Operations, Maintenance and Surveillance (OMS) Manual

A standalone Operations, Maintenance and Surveillance (OMS) Manual exist for the Doris TIA (TMAC 2016). This OMS Manual is compliant with Part G of the mine's current Water Licence, the Mining Association of Canada's (MAC) guideline (MAC 2011), as well as the Canadian Dam Association's Dam Safety Guideline (CDA 2014). Prior to Phase 2 tailings deposition, this OMS Manual will need to be updated, and will include a module that pertains specifically to the Boston TMA

6.2 Dry Stack Tailings Deposition Plan

The tailings produced by the Boston process plant will be filtered to a water content amenable to handling by typical earth moving equipment (loaders, trucks, bulldozers) and stockpiled in the mill building. When sufficient tailings accumulated to provide several truckloads, a loader will load the tailings into 40 tonne trucks which will then transport the tailings to the dry stack facility. Tailings will be end-dumped by the dump trucks and spread to a thin lift (0.3 to 0.5 m) by a bulldozer dedicated to this operation. Once spread, the tailings will be compacted to achieve the target density. For the purposes of this preliminary design, a target density of 1.8 t/m^3 was selected; however, this may change in the more advanced phases of the design based on specific testing.

The facility is built up in this fashion to reach a maximum height of about 26 m, with 5 m high intermediate benches (Figure 5). The inter-bench slope will be 3H:1V, with the overall slope of about 3.9H:1V.

If for any reason the filtered tailings cannot achieve the specified minimum density, those tailings will be recycled to the mill and temporarily stored in dedicated tanks until adequate filtration can be resumed. Alternatively, if weather conditions allow, the non-compliant tailings will be spread in a lift as thin as possible and allowed to dry before final compaction is completed.

The footprint occupied by the tailings facility is about 19.8 hectares, but the location offers the possibility of expanding this area to the north if required in the future.

6.3 Contact Water Management

Contact water from the tailings area will be retained by a series of containment berms, surrounding the facility on three sides. The east portion of the berm will double as the access road to the proposed airstrip. The north side is open as the topography is rising in this area and a containment berm is not necessary (Figure 6).

Contact water will be collected in the PCP and pumped to back to the mill or to the water treatment plant for treatment and discharge. The ponds were sized to retain the IDF of 1/100 year rainfall plus the maximum daily snowmelt. The ponds will be emptied within one week of the storm event and operated normally empty.

6.4 Dust Management

A comprehensive assessment of possible dust management practices for the tailings surface is presented in Appendix D. The tailings stacking plan will be developed to, as far as practical, minimize the area of exposed inactive tailings surface that might be prone to dusting. Beyond such mitigation by design, the primary dust control measure of the TMA will be the use of environmentally suitable chemical dust suppressants. The application of these suppressants will be reviewed on an ongoing basis to ensure that any areas that may be at risk will be adequately covered. Generally annual application of chemical suppressants will be applied; however, it is recognized that more frequent applications may be required depending on the stacking sequence.

7 TMA Closure and Reclamation

7.1 Closure Concept

At closure, a low permeability cover will be constructed to reduce the amount of seepage expected. The geomembrane will be placed in direct contact with the tailings and will be protected by a granular cover consisting of 0.3 m of crushed rock and 0.7 m of ROQ. Construction of the cover will be done in stages or at the end of the active deposition.

The contact water containment berms will be breached and the liner will be cut to prevent collecting any water. Several breaches may be required and will be done at the topographic lows. The balance of the berms will be left in place, as removal of the ROQ fill will could result in localised permafrost degradation.

7.2 Closure Components

7.2.1 Landform Design

The tailings facility will be built in 5 m high benches. The inter-bench slope of 3H:1V and bench width of 5 m results in an overall slope of 3.9H:1V. This slope configuration will be created during active deposition, and no resloping is anticipated to be required at closure.

7.2.2 Cover System

Water quality for combined run-off and seepage from the TMA will meet the discharge criteria (SRK 2016e). Although the thermal model indicates the majority of the tailings will be perennially frozen, the seepage resulting from the active layer will exceed the water quality guidelines for closure. To mitigate this issue, a low permeability cover will be required to reduce seepage to essentially zero. This is achieved by constructing a very low permeability cover including a geomembrane. The geomembrane is assumed to be HDPE for the scope of this report, but a detailed assessment will have to be completed at a later stage of the design to confirm the most suitable geomembrane alternative. The geomembrane will be laid directly onto the tailings surface and covered by a protective non-woven geotextile and a 0.3 m thick crushed gravel layer. The final erosion protection layer of the cover will be constructed of ROQ.

7.2.3 Water Management

Conveyance Channels

The top surface of the tailings deposit will be graded to shed water and the final cover will assume the same configuration. This water will be collected and conveyed off the top of the dry stack by appropriately designed conveyance channels. A detailed hydraulic and geotechnical design of these channels will be completed at later stages in the project planning. As the final cover layer is ROQ which is not prone to erosion, no intermediate channels are required.

Contact Water Ponds

The contact water ponds are required to temporarily detain the contact run-off water from the dry stack. Once the closure cover is constructed, there will no longer be any contact water; therefore, the contact water ponds will be decommissioned.

Discharge Criteria

Water quality from the tailings pore water will not meet CCME guidelines; therefore, the very low permeability cover will be constructed to eliminate as much as possible any seepage from the tailings.

7.3 Monitoring and Maintenance

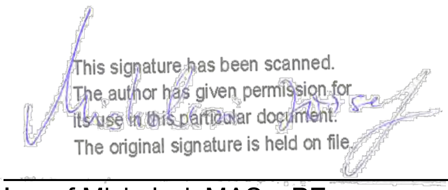
7.3.1 Monitoring

Throughout the operational phase of the Project, the contact water berms and the dry stack will be subject to rigorous monitoring to evaluate their performance. This will include thermal, settlement and other general deformation monitoring. In addition, thermal monitoring of the tailings profile will be carried out to confirm tailings freeze-back assumptions. All of the above will be subject to annual inspections by a qualified professional engineer as part of routine annual inspections. The frequency of these inspections may be reduced as time progresses in accordance with the inspection engineer’s recommendations.

7.3.2 Maintenance

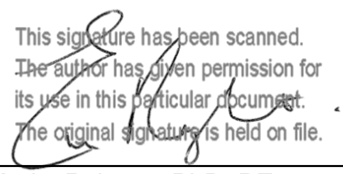
The geomembrane encapsulated in the closure cover will require maintenance and repairs in perpetuity. Periodic geotechnical inspections will be completed to inform of necessary maintenance work. Replacement of the geomembrane at appropriate time intervals (based on the manufacturer‘s warranty) will be included in the long-term maintenance requirements.

This final report, “Boston Tailings Management Area
Preliminary Design, Hope Bay Project”, was prepared by SRK Consulting (Canada) Inc.



Iozsef Miskolczi, MASc, PEng
Senior Consultant

and reviewed by



Maritz Rykaart, PhD, PEng
Principal Consultant

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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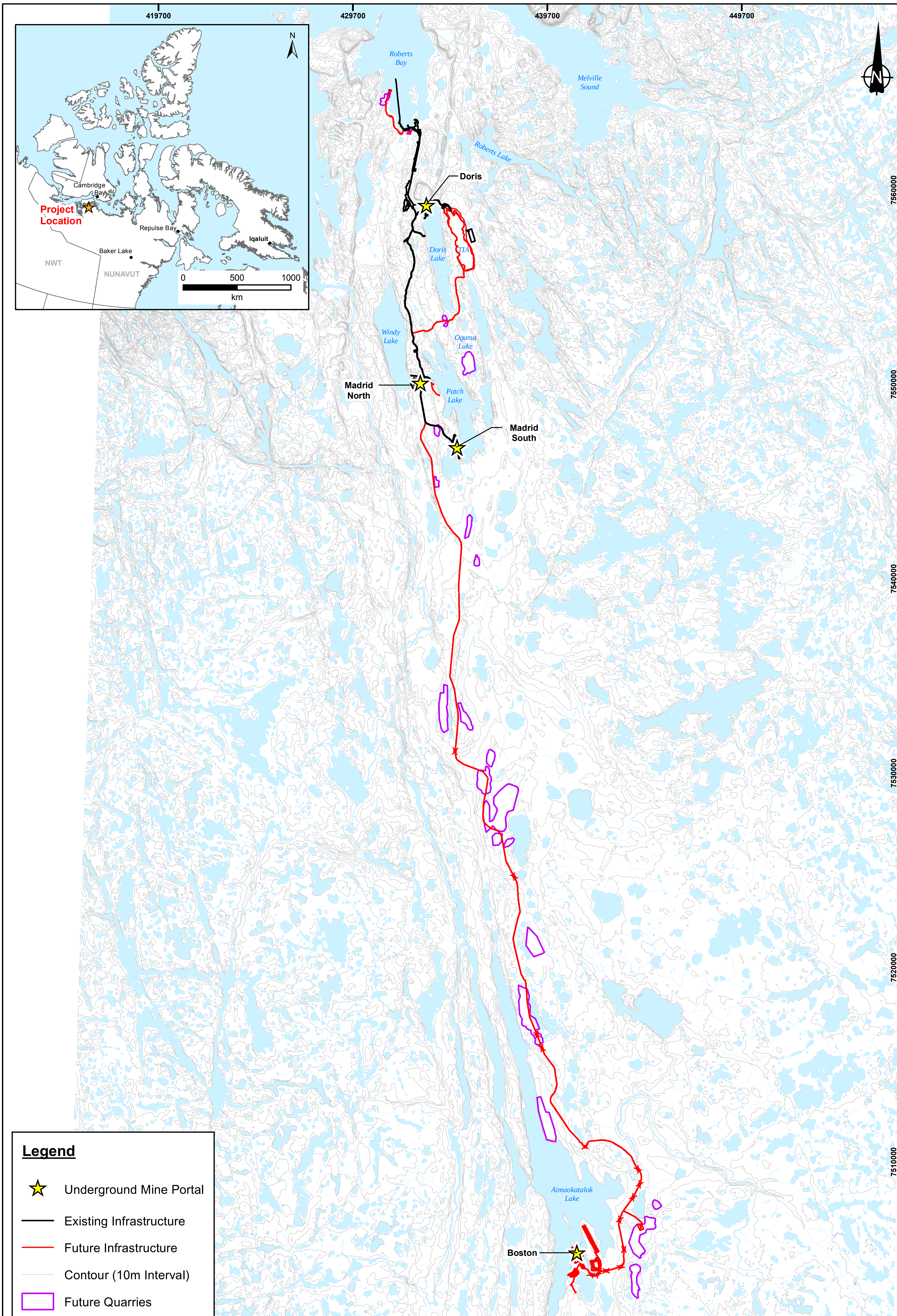
Figures

srk consulting	TMAC RESOURCES	Boston TMA Preliminary Design
		Site Location Plan
SRK JOB NO.: 1CT022.004.600.20	HOPE BAY PROJECT	DATE: Nov. 2016
FILE NAME: 1CT022.004T600.20-FIGURE 1 - Drystack.dwg		APPROVED: IM
		FIGURE: 1



0 2 4 6 8 10
Kilometres

Notes:
1. Coordinate System: NAD 1983 UTM Zone 13N
2. Base Topo Data: CanVec, Natural Resources Canada

srk consulting

Project No: 1CT022.004.200.10

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TMAC RESOURCES

HOPE BAY PROJECT

Boston TMA Preliminary Design

Site Location Map

Date:	Approved:	Figure:
Nov. 2016	MMM	2

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