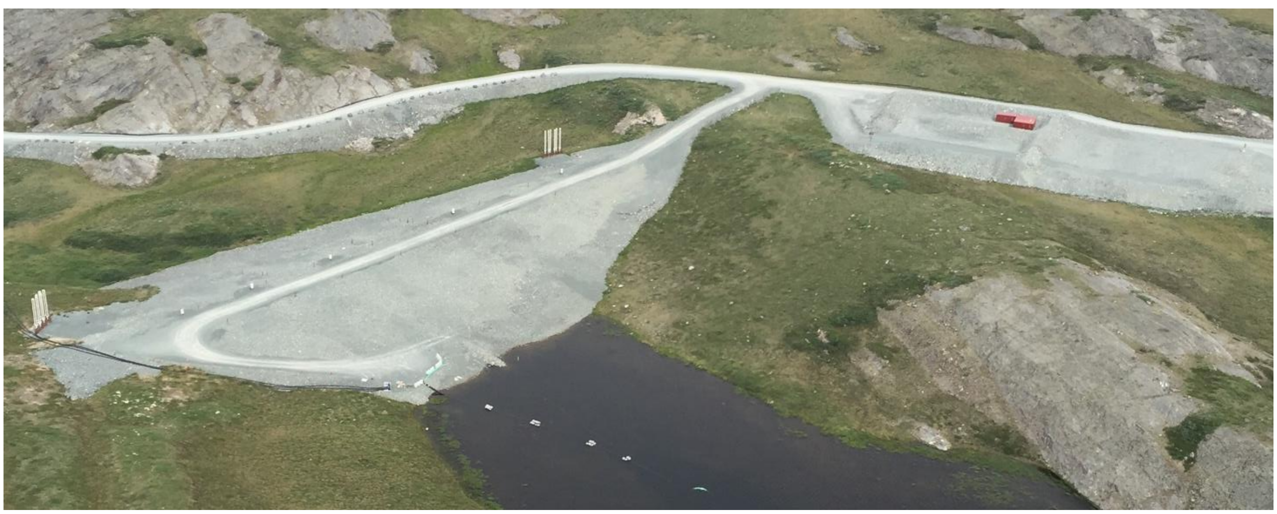
2016 Annual Geotechnical Inspection Tailings Impoundment Area Doris Project, Hope Bay, Nunavut Final Report

Prepared for

TMAC Resources Inc.



Prepared by

SRK Consulting (Canada) Inc.
1CT022.009.600
March 2017

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Executive Summary

The Doris Project (Project) is a mining and milling undertaking of TMAC Resources Inc. At the time of the annual geotechnical inspection described in this report, site operations were conducted under a Type “A” Nunavut Water Board License 2AM-DOH1323 dated August 16, 2013, which entitled TMAC to use water and dispose of waste associated with their operations. TMAC contracted SRK Consulting (Canada) Inc. to conduct the annual geotechnical inspection for the Tailings Impoundment Area (TIA) in accordance with stipulated License conditions. This inspection was carried out between July 12 and 15, 2016.

Under the existing license, at the time of inspection, the TIA consists of two water retaining dams, the North Dam and the South Dam. These dams provide containment for subaqueous deposition of tailings and other Project contact water. The North Dam was constructed during the winters of 2011 and 2012. The South Dam has not been constructed as a result of the Project being placed under Care and Maintenance between 2012 and 2014. Therefore, there has been no tailings deposition. Since 2012, contact water from the Doris North Pollution Control Pond (PCP) has been pumped to the TIA in accordance with the Project’s Interim Water Management Plan (SRK 2012c). The water level in the TIA has also been maintained through seasonal (summer) discharge to Doris Creek.

Table A below, provides a summary of the inspection components and the primary recommendations stemming from the site inspection, and subsequent review of the monitoring data. The North Dam is functioning as designed, and there are no concerns about the ongoing functioning of the structure. There are however smaller maintenance issues that require attention, and suggestions for improvement of the performance monitoring system. All of these items are considered important and require attention prior to the 2017 annual geotechnical inspection

Table A: Summary of Recommendations

Inspection Item	2015 Recommendations	2016 Recommendations
Third Party Dam Safety Review	• Not applicable.	• At this time, SRK is satisfied that the hazard classification for the North Dam of Low is appropriate, and therefore there is no need to conduct an independent third party Dam Safety Review.
Operations, Maintenance and Surveillance (OMS) Manual	• Not applicable.	• Ensure that all staff are made aware of the OMS Manual, and are familiar with its contents. • Review and provide any necessary training in accordance with the OMS Manual.
Compliance with Monitoring Requirements	• Perform monitoring of the North Dam at the frequency described in the North Dam Monitoring Standard Operating Procedures (SOPs). • Update the North Dam Monitoring SOPs to clarify datalogger download frequency.	• Perform monitoring of the North Dam at the frequency described in the updated North Dam Monitoring SOPs (SRK 2017). • Should conditions on site result is a requirement to change the monitoring frequency, the Engineer-of-Record must be contacted, and must formally approve such changes.
Ground Temperature Cables (GTCs)	• No action required.	• The datalogger supplier as stated in the Monitoring SOP recommends recalibration after it has been in operation for five years. That period has now been reached and therefore the dataloggers should be

Inspection Item	2015 Recommendations	2016 Recommendations
		submitted for recalibration. The internal batteries on the dataloggers must also be replaced. • A monitoring well near ND-VTS-130-DS should be drilled and instrumented with a piezometer to allow for continuous monitoring of water level. The well should extend to at a minimum the same depth as the lowest bead in ND-VTS-130-DS. During drilling, samples must be collected to allow for salinity testing of the foundation materials. The well should also allow for sampling of water quality at periodic intervals.
Thermosyphons	• Bring Arctic Foundations Inc. to site to inspect thermosyphon North 2, determine why it is not working, and carry out the necessary repairs. • While Arctic Foundations Inc. is on-site, have them inspect all thermosyphons, and carry out any maintenance they recommend.	• AFI, or another qualified contractor need to be contracted to visit site to inspect thermosyphon North 2 and determine why it is not working, and conduct any necessary repairs. • While AFI, or another suitable contractor FYI is on-site, have them also inspect all other thermosyphons, and carry out any additional maintenance they recommend. • Repair the erosion damage around the thermosyphon foundation base to remediate the progressive erosion damage. Care must be taken to not damage the instrumentation installed at the base of each thermosiphon.
CR1000 Datalogger Battery Voltage	• The CR1000 datalogger batteries should be tested and recharged, or replaced annually.	• The CR1000 datalogger batteries should be tested and recharged, or replaced annually.
Inclinometers	• No action required.	• No action required.
Survey Monitoring Points	• Backfill the erosion around ND−DSP−100. • Conduct surveys, in accordance with the frequency prescribed in the North Dam Monitoring SOPs. • Update North Dam Monitoring SOPs to clarify monitoring frequency during the winter months.	• Backfill the erosion around ND−DSP−100.
Walkover Surveys	• No action required.	• Conduct surveys, in accordance with the frequency prescribed in the updated North Dam Monitoring SOP
Physical Inspection of North Dam	• Update North Dam monitoring SOPs to include tracking and monitoring of depressions, including regular surveys when snow is not on the ground.	• Sample and test ponded or apparent toe seepage once tailings deposition commences to confirm the source of the water.
TSF Water Level and Shoreline Erosion	• Implement measures to maintain the water level in the TIA at 28.3 masl to prevent onset of permafrost degradation.	• As far as practical implement measures to maintain the water level in the TIA as low as possible to prevent onset of permafrost degradation.

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1 Introduction

1.1 General

Doris Mine, one of the mining areas of the Hope Bay Project (Project) is located within the Hope Bay Greenstone Belt, in the Kitikmeot Region of Nunavut, approximately 170 km southwest of Cambridge Bay (Figure 1).

The Project, which is being developed by TMAC Resources Inc., is licensed to conduct mining, milling and associated activities. Construction of the Project started in 2007, and underground development started in 2010. In addition to supporting construction activities, the site is used to carry out regional exploration. In February 2012, the Project was placed into Care and Maintenance, and therefore much of the licensed infrastructure components have not been constructed, including some items associated with the Tailings Impoundment Area (TIA). The Doris Mine was taken out of Care and Maintenance in 2015 and is currently proceeding with construction and underground mine development with the goal of starting commercial production in early 2017.

To fulfill regulatory requirements for an annual geotechnical inspection, TMAC requested that SRK Consulting (Canada) Inc. conduct the 2016 geotechnical site inspection for the TIA. This report provides a summary of the conditions observed, a review of monitoring data and recommendations to ensure ongoing successful performance of the system. This is the sixth inspection of the TIA. SRK has been performing annual inspections of the TIA since it was constructed in 2011 (SRK 2012a, 2013a, 2014a, 2014b, 2016a).

The objectives of the inspection were to visually assess the geotechnical performance of the TIA containment structures, which currently consists only of the North Dam and associated elements, and to identify any deficiencies or concerns. In conjunction with the visual inspection, monitoring data collected throughout the year was reviewed and analyzed to evaluate performance.

Mr. Maritz Rykaart, PhD, PEng, the Engineer-of-Record, and a Principal Consultant with SRK, conducted the on-site geotechnical inspection from July 12 to 15, 2016. Weather conditions during the inspection were cool and overcast. The detailed inspection of the North Dam was carried out on foot, followed by an aerial survey of the TIA using a low altitude helicopter flyover. Mr. Nick Hugo, Senior Mining Engineer with TMAC, accompanied Maritz during the walkover inspection. Photos detailing the inspection conditions are included in Figures 5 through 8.

1.2 Inspection Requirements

The Doris project, including the TIA, is licensed by the Nunavut Water Board (NWB). At the time of the inspection, site operations were conducted under the Type “A” License 2AM DOH1323, dated August 16, 2013, which entitled TMAC to use water and dispose of waste associated with their operations. The following inspection requirements, relevant to the TIA, are stated in Part J, items 18 and 19 of the license.

The Licensee shall ensure that a geotechnical inspection is carried out annually between July and September by a Geotechnical Engineer. The inspection shall be conducted in accordance with the Canadian Dam Safety Guidelines where applicable, and take into account all major earthworks, including the following:

- *North and South Dams*
- *Geotechnical instrumentation and associated monitoring data*
- *Tailings Impoundment Area shoreline and erosion strip survey monitoring results*

The Licensee shall submit to the Board, within sixty (60) days of completion of the geotechnical inspection, the Geotechnical Engineer's inspection report. The report shall include a cover letter from the Licensee outlining an implementation plan addressing each of the Geotechnical Engineer's recommendations.

It should be noted that additional inspection requirements for other components of the Project are listed within the water license; these conditions are addressed in separate geotechnical inspection reports for the Project which are submitted to the NWB under different covers.

1.3 Report Structure

Section 2 of this report describes the general site conditions and history associated with the TIA. Section 3 discusses the North Dam instrumentation and associated monitoring data, as well as physical inspection conditions observed during the annual geotechnical inspection. An overall summary of recommendations is provided in Section 4.

All elements of the TIA discussed in this report are presented in the enclosed figures, which include site photographs. Details of the North Dam instrumentation monitoring are presented in the appendices.

2 Site Conditions

2.1 Tailings Impoundment Area Infrastructure

Tailings for the Project will be deposited subaqueously in the TIA, which was listed on Schedule 2 of the Metal Mining Effluent Regulations (MMER) specifically for use as a tailings facility. The TIA is located south-east of the Doris mill and mine location (Figure 2). Under the existing licence (at the time of inspection), environmental containment for the TIA is provided through the construction of two water retaining frozen core dams: the North Dam, and the South Dam. In addition, supporting components will include:

- Tailings deposition infrastructure;
- Process water reclaim infrastructure;
- Fresh water make-up infrastructure;
- Operational discharge (decant) infrastructure; and
- Shoreline erosion protection infrastructure.

The dams have been designed to maintain the core and the underlying saline permafrost foundation at sufficiently cold temperatures, and over a wide enough area to create an impermeable barrier. Under normal operating conditions the dam core temperature should be −2˚C or colder, and during upset conditions the core should be −1°C or colder. The saline permafrost layer under the dams should be colder than −8°C under normal or upset conditions. The dams have been designed with a 25-year design life in mind, taking into account global warming and upset conditions (SRK 2007).

At the time of the inspection, only the North Dam has been constructed, and no tailings have been deposited in the TIA. Construction of the North Dam started in February 2011 and was completed in April 2012. Complete as-built details are provided in SRK (2012b).

2.2 North Dam Design

SRK is the Engineer-of-Record for the North Dam. The as-built North Dam general arrangement and typical dam cross-sections are presented in Figures 3 and 4.

The North Dam is located roughly 200 m downstream of the northern end of the TIA, within a relatively narrow valley and is aligned essentially perpendicular to the valley. The valley bottom is about elevation 26 m and consists of a narrow marshy area that drains from the TIA towards Doris Lake (Figure 3).

The North Dam is approximately 200 m long and 10 m high, with upstream and downstream slopes of 6H:1V and 4H:1V, respectively. The dam consists of a key trench, frozen core, geosynthetic clay liner (GCL), thermosyphons, transition layer and rockfill shell. A typical cross-section is presented in Figure 4.

The North Dam is founded half on sand overburden and half on ice-rich marine clayey silt, as can be seen in Figure 4. All peat that was encountered at the base of the key trench excavation was removed prior to frozen core material placement. Sloped thermosyphons were installed at the base of the key trench to enhance foundation cooling.

The dam core consists of a frozen mass of fine crushed rock that was placed in a near saturated state. On the upstream side of the core, a geosynthetic clay liner (GCL) was installed to provide a secondary water retaining capability should cracks develop in the core due to thermal degradation, creep deformation or differential settlement. The core and GCL extend 1.8 m above the design full supply level (FSL) to provide freeboard.

The core is surrounded by a transition layer consisting of 0.15 m minus crushed rock that acts as a filter, should the dam thaw. A minimum 1.5 m thick outer shell of run-of-quarry rock acts as a thermal protection layer for the frozen core and provides a buttress against creep deformation.

2.3 North Dam Instrumentation

Permanent instrumentation for the North Dam consists of:

- 11 vertical ground temperature cables (also known as thermistors);
- 13 horizontal ground temperature cables;
- 18 surficial survey monitoring points, located throughout the downstream face;
- 14 crest survey monitoring points, located along the upstream and downstream crests of the dam;
- 3 deep settlement points;
- 6 inclinometers, located within the downstream face; and
- 12 thermistors, measuring thermosyphon contact temperatures.

Figure 3 illustrates the North Dam instrumentation with the exception of the ground temperature cables and thermistors.

2.4 Site History

A summary of the TIA permitting, construction, and operations is provided in Table 1.

Table 1: Summary of TIA Development and History

Period	Comments
2003	Doris North Project preliminary economic assessment is completed (SRK 2002a).
2002 - 2005	Geotechnical and geophysical investigations of dam foundations, TIA perimeter and permafrost conditions (SRK 2002b, 2003 and 2005a, 2005b and 2005c).
2005	Environmental Assessment for the Doris North Project is completed.
2006	A Project Certificate is issued for the Doris North Project.
2006	Application for addition of TIA to Schedule 2 of the Metal Mining Effluent Regulations (MMER) was submitted.
2008	TIA MMER Schedule 2 listing obtained.
Winter 2011 and Winter 2012	North Dam constructed (SRK 2012b).
Winter 2012	Project placed into Care and Maintenance.
2012 - 2015	Project development delayed with only limited surface exploration activities continuing. Water within the TIA is managed in accordance with the Interim Water Management Plan (SRK 2012c). No tailings are deposited, but water from the Pollution Control Pond is pumped to the TIA. TIA water is discharged to Doris Creek.
2015 - 2016	TMAC submits and application to amend the Water Licence and Project Certificate which amongst other things will result in a change to sub-aerial tailings deposition, change of the South Dam design to a frozen foundation dam, and construction of an Interim Dike. As these approvals had not been obtained at the time of the inspection, this report does not consider these items. The Interim Dike field investigation was carried out (SRK 2016b).

2.5 Dam Classification

When designed, both the North and South dams were classified as “Low Hazard” according to the Dam Safety Guidelines (CDA 1999) (SRK 2007). As part of the 2014 annual geotechnical inspection, SRK reassessed the hazard classification of the North Dam considering the most recent Dam Safety Guidelines (CDA 2013), as well as the CDA Technical Bulletin on Application of Dam Safety Guidelines to Mining Dams (CDA 2014). As part of the 2016 inspection, SRK again revisited the hazard classification taking into consideration its current use.

There are no temporary or permanent communities within the likely inundation area downstream of the dam. The only mining infrastructure within the likely inundation area is the Doris Creek Bridge, more than 600 m downstream of the North Dam. Currently, there are no tailings within the TIA and the water quality within the TIA meets discharge criteria. SRK is therefore satisfied that based on the definitions of hazard categories as described in Table 2, the hazard category for the North Dam of “Low” remains appropriate.

Table 2: Dam Classification (as defined in 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 or deterioration 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 affection 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 unforeseeable 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] Implications for 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.

3 North Dam Physical Inspection and Monitoring

3.1 Third Party Dam Safety Review

In accordance with the Dam Safety Guidelines (CDA 2013, 2014), including the CDA Technical Bulletin on Dam Safety Reviews (CDA 2016), independent third party Dam Safety Reviews should be conducted in accordance with a frequency informed by the hazard classification of the structures. This frequency typically range between 5 and 10 years. A dam with a Low hazard classification does not require a Dam Safety Review; however, the hazard classification needs to be reviewed periodically to ensure that conditions remain valid. If not, the reclassification and a subsequent Dam Safety Review will be required.

Recommendations:

- At this time SRK is satisfied that the hazard classification for the North Dam of Low is appropriate, and therefore there is no need to conduct an independent third party Dam Safety Review.

3.2 Tailings Operating, Maintenance and Surveillance Manual

A comprehensive Tailings OMS Manual was prepared in 2016 (TMAC 2016). At the time of the 2016 geotechnical inspection, this OMS Manual had not been approved by the Regulators. The OMS Manual was written under the assumption that the proposed Water Licence Amendment that was under review would be approved, and therefore reflect a slightly modified tailings management approach as was evaluated during the 2016 inspection. As a result, the 2016 geotechnical inspection did not include a review of the OMS Manual procedures.

Recommendation:

- Once approved, TMAC should ensure all staff are properly informed and trained about the contents of the Tailings OMS Manual.

3.3 Compliance with Monitoring Requirements

The North Dam monitoring frequency requirements were first outlined in the North Dam As-built Report (SRK 2012b) and subsequent North Dam Monitoring Standard Operating Procedures (Monitoring SOP) (SRK 2013b). An update of this Monitoring SOP was completed in 2017 (SRK 2017). The monitoring frequency requirements and actual monitoring frequency are summarized in Table 3.

During the 2012 to 2013 monitoring year, SRK provided leeway on monitoring frequency as the Project was under care and maintenance, with only skeleton seasonal staff on-site during the winter months. In early 2014, the status of the Project changed from care and maintenance to active exploration with increased staff. Subsequently SRK recommended the North Dam monitoring be performed in accordance with the North Dam Monitoring SOP (SRK 2013b). Since 2014, inclinometer surveys and thermosyphon monitoring have generally been in compliance with the Monitoring SOP. Datalogger downloads have been compliant in the summer months. Weekly walkover surveys have been compliant until August 2015, after which inspections were conducted on a less frequent basis. Survey monitoring is not in compliance, as four surveys were performed in 2015, and only three surveys were performed in 2016, prior to the end of August when the inspection was conducted.

The reasons for not meeting the monitoring demands was due to a perception by site staff that the North Dam was not of great concern as a delay in the mill commissioning resulted in a delay in start of tailings deposition, and water levels in the TIA were maintained as low as practical. SRK understands these reasons; however, decisions on reducing monitoring frequency can only be made after an informed discussion with SRK in their capacity as Engineer-of-Record.

Table 3: North Dam Monitoring Requirements for the 2015 to 2016 Monitoring Year(1)

Element	Item	Method	Res-ponsibility	Required Frequency	Conformance with SOP (SRK 2013b)(2)	Comments
Thermal	Ground Temperature Cables	Datalogger	TMAC	Daily (automated)	Yes	• Record four times daily
	Thermo-syphons	Datalogger	TMAC	Daily (automated)	Yes	• Record four times daily
	Dataloggers	Manual	TMAC	Monthly Minimum twice per year	Yes	• No downloads between Oct. 2014 and May 2015 • Data not retrieved in 2014 and 2013, due to card reader error retrieved July 12, 2015
De-formation	Crest Settlement	Manual	TMAC	Monthly	No	• Four surveys in 2015 • Three surveys in 2016 (prior to September)
	Downstream Surface Settlement	Manual	TMAC	Monthly	No	
	Downstream Deep Settlement	Manual	TMAC	Monthly	No	
	Inclinometers	Manual	TMAC	Monthly	No	• Surveys missed in January, May and June 2016
Water Balance	Water Level	Datalogger (if installed)	TMAC	Daily (automated)	Yes	• Recorded daily during open water season
	Dataloggers (if installed)	Manual	TMAC	Monthly	No	• Downloaded annually
	Seepage Rate	Manual	TMAC	As Required	Yes	• Surface water runoff observed downstream of North Dam of unknown origin

Element	Item	Method	Res-ponsibility	Required Frequency	Conformance with SOP (SRK 2013b)(2)	Comments
Visual	Walkover Survey	Manual	TMAC	Weekly (below FSL) Daily (at or above FSL)	No	• Eight surveys conducted between September 2015 and August 2016.
	Annual Geotechnical Inspection	Manual	Independent Qualified Licensed Geotechnical Engineer	Annually	Yes	• August 2015 (SRK 2016a) • July 2016 (this report)

Source: Adapted from SRK 2013b

Note(s):
(1) Data cut-off for inclusion in this report was August 31, 2016, data received by SRK after this date will be included in the 2017 geotechnical inspection report.
(2) This column lists if the monitoring frequency is compliant with the monitoring frequency requirements since the last annual geotechnical inspection (August 2015).
(3) Details of monitoring dates and data quality are provided in the beginning of the relevant appendices.

Recommendations:

- Perform monitoring of the North Dam at the frequency described in the updated North Dam Monitoring SOP (SRK 2017).
- Should conditions on site result in a requirement to change the monitoring frequency, the Engineer-of-Record must be contacted, and must formally approve such changes.

3.4 Ground Temperature Cables

To monitor the long term temperature of the frozen core and the dam foundation, a total of twenty-four ground temperature cables (GTCs) were installed during the North Dam construction (SRK 2012b). Of the twenty-four installed GTCs, twenty-two are still functional. Since September 2012, GTC data for the North Dam is recorded every six hours by two Campbell Scientific CR1000 dataloggers. Data is downloaded from the dataloggers by TMAC personnel using compact flash memory cards.

The frequency of datalogger downloads and the recorded temperature data is presented in Appendix A. Card download errors have occurred since the 2015 inspection; however, in each case the data was ultimately recovered to replace any missing data.

The status of all North Dam GTCs is summarized in Table 4. There has only been change in the status of GTC ND-VTS-085-US and ND-VTS-085-DS since the 2015 inspection.

Table 4: Ground Temperature Cable Status

GTC ID	Status	Comments
ND-VTS-040-KT	Active	
ND-HTS-040-31.5	Active	
ND-HTS-040-33.5	Active	Cable disconnected from datalogger October 10, 2013 to May 13, 2014
		Connection to datalogger more permanently repaired July 2014
ND-VTS-060-US	Inactive	Irreparably damaged between April 27 and August 8, 2012
ND-VTS-060-DS	Active	
ND-VTS-060-KT	Active	Spliced during construction
ND-HTS-060-28.8	Active	Bead 7 - No readings February 11, 2012 to December 8, 2013
		Bead 7 - No readings since April 21, 2014
		Bead 7 - Readings between November 1, 2014 and April 19, 2015
		Bead 9 - No readings October 10, 2013 to May 20, 2015
ND-HTS-060-31.0	Active	
ND-HTS-060-33.5	Active	
ND-VTS-085-US	Active	Erratic data logging at most beads (excluding Beads 3, 6 and 9) between June and December 2016
ND-VTS-085-DS	Active	Erratic data logging at most beads (excluding Beads 3, 6 and 9) between June and December 2016
ND-VTS-085-KT	Active	Erratic data logging at most beads (excluding Beads 3, 6 and 9) between June and December 2016
ND-HTS-085-25.3	Active	
ND-HTS-085-29.4	Active	
ND-HTS-085-33.5	Inactive	Irreparably damaged during construction
ND-VTS-130-US	Active	
ND-VTS-130-DS	Active	
ND-VTS-130-KT	Active	
ND-HTS-130-28.8	Active	
ND-HTS-130-31.0	Active	
ND-HTS-130-33.5	Active	
ND-VTS-175-KT	Active	Spliced during construction.
		Incorrectly connected to datalogger as ND-HTS-175-33.5 from August 9, 2012 to June 16, 2014.
		Beads 9, 10 and 11 - No readings August 9, 2012 to June 16, 2014.
ND-HTS-175-32.5	Active	
ND-HTS-175-33.5	Active	Spliced during construction.
		Incorrectly connected to datalogger as ND-HTS-175-KT, from August 9, 2012 to June 16, 2014.

Source: J:\01_SITES\Hope.Bay\!Project_Data (Not Job Specific)\06_NorthDamMonitoringData\[SiteMonitoringSummary.xlsx]ThermisorStatus

The North Dam GTCs were installed to ensure the dam core and foundation remain below the design temperatures of −2˚C and −8˚C, respectively. In addition, ground temperature data along with thermosyphon monitoring data can be used to determine if the thermosyphons are functioning correctly. Observations related to a review of the data presented in Appendix A are summarized in Table 4.

Table 5: Summary of Key Ground Temperature Cable Observations

Zone	Horizontal GTCs	Vertical GTCs	Observation
Maximum Design Temperature	−2˚C	−8˚C	
Station 0+040	Meets	Meets	• Performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling
Station 0+060	Meets	Meets	• Performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling
Station 0+085	Meets	Meets	• Generally performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling • A temperature spike, followed by a period of elevated readings starting June 2016 for each vertical GTC. In each case the spike is observed at all beads with the exception of Beads 3, 6 and 9. Temperatures at all beads returned to normal by December 2016. This pattern is anomalous and suggest a system problem as opposed to actual foundation warming
Station 0+130	Meets	Meets	• Generally performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling • Short term temperature spikes are noticed for all but the uppermost 2 beads of ND−VTS−130−DS every year. In 2013 the spikes was the largest and most prolonged ranging between June and November. In 2014 it was markedly smaller and was only observed in August and September. The 2015 spike was even smaller, and lasted from August to September. The 2016 spike increased again and lasted from August to The end of the Reporting Period (Figure A.16) (The spike ends in October, based on 2017 AGI period data) • The reason for these temperature spikes are not clear. Previously it was hypothesised that the spikes could be due to groundwater flowing through a high saline pocket. This could not be verified as salinity testing was not performed when the GTC was installed. This hypothesis however no longer seems appropriate. • Based on the nature of the spikes, it is believed that they are more likely associated with surface runoff and direct percolation through the dam shell collecting below the downstream face of the dam at the low spot where the GTC is located. The presence of toe seepage at this location every year supports this observation. Such water would result in subsurface warming spikes; however why the uppermost beads are not affected remain a mystery.
Station 0+175	Meets	Meets	• Performing as expected with substantive safety buffer and slight trend suggesting ongoing cooling

Recommendations

- The temperature spikes in the three vertical GTCs at station 0+85, and the low temperature spikes in ND-VTS-130-US, are likely due to a system error. The datalogger supplier, as stated in the Monitoring SOP recommends recalibration after it has been in operation for five years. That period has now been reached and therefore the dataloggers should be submitted for recalibration. The internal batteries on the dataloggers must also be replaced.
- A monitoring well in the vicinity of ND-VTS-130-DS should be drilled and instrumented with a piezometer to allow for continuous monitoring of water level. The well should extend to, at a minimum, the same depth as the lowest bead in ND-VTS-130-DS. During drilling, samples must be collected to allow for salinity testing of the foundation materials. The well should also allow for sampling of water quality at periodic intervals.

3.5 Thermosyphons

The thermosyphon radiator steel foundations are in good condition. The thermosyphons themselves do not show any physical damage; however, there is rust and peeling paint at the weld between the evaporator pipe and the twin radiators on most of the thermosyphons. The granular fill surrounding the thermosyphon pilings are progressively eroding and gullies are increasing in size. Preventative repairs to avoid complete exposure of the foundations are recommended.

Thermosyphon monitoring for the North Dam has been automated. Single bead thermistors connected to the datalogger system are attached to each thermosyphon evaporator pipe below the ground surface, and insulation has been placed around the thermistor beads to ensure the evaporator pipe temperature, and not the ambient air temperature is measured (SRK 2012b). Dataloggers record the contact surface temperature of each thermosyphon pipe and the air temperature every six hours, and is downloaded by TMAC site personnel.

To monitor the performance of the thermosyphons, thermosyphon evaporator pipe contact temperatures and air temperatures are plotted against time. During the winter months, when the thermosyphons are working, the thermosyphon pipe temperature should be roughly 5˚C warmer than the air temperature. If the thermosyphon pipe temperature during the winter months is approximately the same as the air temperature, it indicates that the thermosyphon is not working correctly.

Thermistor data indicates all of the south and north thermosyphons are functioning with the exception of North 2 (Appendix D). Since 2012, the measured pipe temperature of North 2 was only slightly higher than the measured air temperature, which indicates a malfunction. Ground temperature readings in the vicinity of the North 2 thermosyphon pipe support the conclusion that the North 2 thermosyphon is not working correctly.

During the 2014 North Dam annual geotechnical inspection, thermosyphon North 2 was inspected in detail to determine the cause of the elevated temperature readings. No damage or reason for the malfunction was observed (SRK 2014b). Therefore, SRK recommended that Arctic Foundations Inc. (AFI) be contacted to investigate further and repair the thermosyphon. AFI provided TMAC with a cost estimate and scope of work dated June 25, 2015, to perform this work and carry out maintenance on all thermosyphons. The thermosyphon repair did not occur prior to the 2016 annual geotechnical inspection.

Recommendations:

- AFI, or another qualified contractor needs to be contracted to visit the site to inspect thermosyphon North 2 and determine why it is not working, and conduct any necessary repairs. Note this repair must occur in the winter otherwise the appropriate testing cannot be done.
- While AFI, or another suitable contractor is on-site, have them also inspect all other thermosyphons, and carry out any additional maintenance they recommend.
- Repair the erosion damage around the thermosyphon foundation base to remediate the progressive erosion damage. Care must be taken to not damage the instrumentation installed at the base of each thermosiphon.

3.6 CR1000 External Datalogger Battery Voltage

Each CR1000 data logger is powered by an external lead acid battery. Battery voltage is an important indicator of datalogger performance. If the battery voltage is too low, the recorded readings could be incorrect or readings may not be recorded at all. The dataloggers record the minimum battery voltage four times daily. A graph of battery voltage versus time is provided in Appendix E**Error! Reference source not found.**.

The batteries have been recharged on two occasions since the North Dam was commissioned, June 27, 2014 and October 20, 2015 (prior to August 31, 2016). At no time has the voltage dropped low enough to cause any concerns with data integrity. The batteries should continue to be monitored to ensure they maintain their charge through the winter months.

Recommendations:

- The CR1000 datalogger batteries should be tested and recharged, or replaced annually.

3.7 Inclinometers

Six inclinometers were installed within the downstream face of the North Dam. These inclinometers are used along with the survey monitoring points to monitor deformation within the dam and dam foundation. Inclinometer readings are taken by TMAC site personnel. As discussed in Section 3.1, inclinometer readings were collected intermittently prior to May 2014. Readings were taken at monthly intervals from May 2014 until October 2014, and since February 2015. Readings were not collected October 2014 to February 2014 because the datalogger was offsite for calibration.

Inclinometer measurements are provided in Appendix B. Data quality for the surveys has generally been good. The inclinometer profiles show only small displacements (less than 20 mm) in the portion of the inclinometer above the natural ground surface. There is no real trend emerging, suggesting there is not any real movement of concern.

Recommendations:

- No action required.

3.8 Survey Monitoring Points

A series of 14 crest survey monitoring points, 3 deep survey monitoring points, and 18 surficial survey points were installed in the North Dam upon completion. These survey monitoring points were installed to monitor any surface movement of the downstream face and deep settlement of the downstream foundation of the dam.

Survey monitoring of the North Dam has only occurred nine times since the survey monitoring points were installed, twice in 2012, once in 2013, twice in 2014, four times in 2015 and three times in 2016 (prior to the September cut-off), which is below the recommended monthly monitoring.

Overall, the measured horizontal and vertical displacement for the crest survey (SMP) and the deep survey (DSP) monitoring points is less than 0.1 m, which is considered to be close to the survey accuracy. As expected, the surficial survey points have larger measured displacement with horizontal and vertical displacement in the range of 0.2 m for most points. Generally, these measured displacements have not changed since the 2013 survey, indicating most of the movement was from settlement directly following construction. At this time the displacements are not of concern.

There is significant erosion around the deep settlement monitoring point ND−DSP−100. This was noted during all inspections since 2013 (SRK 2014a, 2014b, 2016a), yet the recommended remedial action has not been carried out. This needs to be repaired as the instrument’s integrity will be compromised.

Recommendations:

- Backfill the erosion around ND−DSP−100.

3.9 Walkover Surveys

Walkover surveys have been less frequent since August 2015, prior to when inspections were generally performed on a weekly basis (since June 2014). The walkover survey reports and tracks all changes to the dam surface, visible damage to dataloggers and thermosyphons, and signs of erosion. Since the dam is not at the full supply level, the walkover surveys are required weekly.

To date, the primary observations of note from the walkover surveys include:

- Surface depressions;

- Rust on the thermosyphons (Section 3.5);
- Erosion near the thermosyphons (Section 3.5); and
- Ponded or flowing water at the downstream toe of the dam (Section 3.10).

The surface depressions are located on the upstream and downstream faces of the dam. Six of these depressions were observed and given a unique identifying name during the 2014 SRK inspection. Since the 2014 SRK inspection, walkover surveys have identified and named up to an additional five depressions on the upstream side of the dam, and an additional 16 depressions on the downstream side of the dam.

The walkover survey reports, including photos, are provided in Appendix F. No changes in the depression sizes were noted in the past year.

Recommendations:

- Conduct surveys, in accordance with the frequency prescribed in the updated North Dam Monitoring SOP.

3.10 Physical Inspection of North Dam

During the 2013 inspection, two depressions (D2 and D3 (Appendix H)) were identified on the downstream face of the dam, and four additional depressions (D1, U1, U2 and U3 (Appendix H)) were identified in 2014 (SRK 2014b). A recommendation was made to regularly survey these depressions; however, these depressions have only been surveyed once in September 2013. Although there is no actual survey data, it appears as if these depressions have not increased in size over the year past year. SRK hypothesizes that these depressions are caused by fines migrating into the coarse rock fill of the dam, rather than being early indicators of foundation settlement. This conclusion seems to be supported by the survey monitoring, inclinometer and thermal data.

Sixteen additional depressions on the downstream side of the dam, and five additional depressions on the upstream side of the dam have been identified by TMAC site personnel since the 2014 annual geotechnical inspection. Based on inspection of the areas, SRK is of the opinion these are simply areas of poorly graded rock, rather than depressions. In all cases, the crests of the depressions have been outlined with spray paint, and photos are regularly taken to track the growth. The approximate location of these depressions, a table tracking the growth and development of the depressions are provided in Appendix H. For additional details and photos, refer to SRK (2016a).

Going forward, only significant depressions need to be identified and monitored (significant depressions identified to-date are D1, D2, D3, U1, U2 and U3). Additionally, regular surveys should be performed on the toe and crest of the significant depressions, as the current monitoring method is too subjective to be of value. The updated Monitoring SOP (SRK 2017) provides guidance on what is considered a significant depression and frequency of surveys.

Similar to the observations made since 2013 (SRK 2014a and 2014b), there is evidence of surface water flow along the downstream toe of the North Dam. It is unlikely this seepage is from the dam, but more likely from within the active layer of the north abutment which naturally flows along the downstream toe of the dam.

Available seepage and water quality data (SRK, 2012d, 2013c, and 2014c) were examined to see if the source of the water at the toe of the dam could be identified. The results of this examination were inconclusive because the water within the TIA did not have any chemical signatures which could be used to differentiate it from rainwater runoff. Field electrical conductivity values measured at the toe of the North Dam were 139 µS/cm and 223 µS/cm in 2012 and 2013, respectively (SRK 2013c and 2014c), while electrical conductivities within the TIA and former Tail Lake have measured between 84.6 µS/cm and 343 µS/cm. Seepage testing to evaluate the source of the water observed at the toe of the North Dam should be performed again once tailings are deposited within the TIA, as it is assumed that deposition of tailings will give the TIA water chemical signatures that will distinguish it from rainwater.

Recommendations:

- Sample and test ponded or apparent toe seepage once tailings deposition commences to confirm the source of the water.

3.11 TIA Water Level and Shoreline Erosion

Daily water levels in the TIA have been measured with a series of dataloggers, since 2011. Prior to 2015, the dataloggers have not been georeferenced and instead water levels were measured against an arbitrary benchmark of 100 masl. These arbitrary readings were then georeferenced in comparison to staff gauge readings. On July 15, 2015, ERM installed a new datalogger at a depth of approximately 5 m below the TIA water level of 29.08 m. TMAC site personnel have also measured the pond water levels through the open water season with a staff gauge set up near the upstream toe of the North Dam. Pond water level since 2011 is provided in Appendix G.

The normal water level in the pond is 28.3 m. Since there is no natural outflow, the water level of the pond is being managed though active pumping. At the time of the site inspection, the water level was 29.19 m, which is 0.89 m above the original lake water level. Therefore, a large section of shoreline has been flooded which has resulted in vegetation stress. At this time, there are no signs of shoreline erosion.

Water levels above the natural pond water level will ultimately lead to thaw of permafrost and erosion of the overburden soils. Erosion of the overburden soils will increase the total suspended solids in the pond, which is an expected consequence of the Project. However, steps should be taken to minimize this as much as possible.

Recommendations:

- Implement measures to maintain the TIA pond level as low as practical to prevent onset of permafrost degradation.

4 Recommendations and Conclusions

The North Dam is functioning as designed. Any of the issues observed in the physical inspection and any anomalies observed in the monitoring data can be explained and are not of concern. Table 6 presents a summary of the recommendations listed throughout this report.

Table 6: Summary of Recommendations

Inspection Item	2015 Recommendations	2016 Recommendations
Third Party Dam Safety Review	• Not applicable.	• At this time SRK is satisfied the hazard classification for the North Dam of Low is appropriate, and therefore there is no need to conduct an independent third party Dam Safety Review.
Operations, Maintenance and Surveillance (OMS) Manual	• Not applicable.	• Ensure that all staff are made aware of the OMS Manual, and are familiar with its contents. • Review and provide any necessary training in accordance with the OMS Manual.
Compliance with Monitoring Requirements	• Perform monitoring of the North Dam at the frequency described in the North Dam Monitoring Standard Operating Procedures (SOPs). • Update the North Dam Monitoring SOPs to clarify datalogger download frequency.	• Perform monitoring of the North Dam at the frequency described in the updated Monitoring SOPs (SRK 2017). • Should conditions on site result is a requirement to change the monitoring frequency, the Engineer-of-Record must be contacted, and must formally approve such changes.
Ground Temperature Cables (GTCs)	• No action required.	• The datalogger supplier as stated in the Monitoring SOP recommends recalibration after it has been in operation for five years. That period has now been reached and therefore the dataloggers should be submitted for recalibration. The internal batteries on the dataloggers must also be replaced. • A monitoring well in the vicinity of ND-VTS-130-DS should be drilled and instrumented with a piezometer to allow for continuous monitoring of water level. The well should extend to at a minimum the same depth as the lowest bead in ND-VTS-130-DS. During drilling, samples must be collected to allow for salinity testing of the foundation materials. The well should also allow for sampling of water quality at periodic intervals.
Thermosyphons	• Bring AFI to site to inspect thermosyphon North 2, determine why it is not working, and carry out the necessary repairs.	• AFI or another qualified contractor needs to be contracted to visit site to inspect thermosyphon North 2 and determine why it is not working, and conduct any necessary repairs.

	• While AFI is on-site, have them inspect all thermosyphons, and carry out any maintenance they recommend.	• While AFI, or another suitable contractor is on-site, have them also inspect all other thermosyphons, and carry out any additional maintenance they recommend. • Repair the erosion damage around the thermosyphon foundation base to remediate the progressive erosion damage. Care must be taken to not damage the instrumentation installed at the base of each thermosiphon.
CR1000 Datalogger Battery Voltage	• The CR1000 datalogger batteries should be tested and recharged, or replaced annually.	• The CR1000 datalogger batteries should be tested and recharged, or replaced annually.
Inclinometers	• No action required.	• No action required.
Survey Monitoring Points	• Backfill the erosion around ND−DSP−100. • Conduct surveys, in accordance with the frequency prescribed in the Monitoring SOPs. • Update Monitoring SOPs to clarify monitoring frequency during the winter months.	• Backfill the erosion around ND−DSP−100.
Walkover Surveys	• No action required.	• Conduct surveys, in accordance with the frequency prescribed in the updated North Dam Monitoring SOP (SRK 2017)
Physical Inspection of North Dam	• Update Monitoring SOPs to include tracking and monitoring of depressions, including regular surveys when snow is not on the ground.	• Sample and test ponded or apparent toe seepage once tailings deposition commences to confirm the source of the water.
TSF Water Level and Shoreline Erosion	• Implement measures to maintain the water level in the TIA at 28.3 masl to prevent onset of permafrost degradation.	• As far as practical implement measures to maintain the water level in the TIA as low as possible to prevent onset of permafrost degradation.

This final report, 2016 Annual Geotechnical Inspection, Tailings Impoundment Area, Doris Mine, Hope Bay, Nunavut, was prepared by

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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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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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