Design of the Tailings Containment Area Doris North Project, Hope Bay, Nunavut, Canada

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1 Introduction

This report presents the design of the tailings containment area (TCA) for the Doris North Project owned by Miramar Hope Bay Limited (MHBL). The document provides the TCA design, operating plan and related water management, as well as a conceptual closure plan for the facility.

This report has been prepared as part of the Water Licence Application to the Nunavut Water Board (NWB). The following documents form part of the designs presented in this report, and should therefore be read in conjunction with this document:

- SRK Consulting (2006a). *Design of the Surface Infrastructure Components*, Doris North Project, Hope Bay, Nunavut, Canada. Report submitted to MHBL, October.
- SRK Consulting (2006b). *Technical Specifications for Tailings Containment Area and Surface Infrastructure Components*, Doris North Project, Hope Bay, Nunavut, Canada. Report submitted to MHBL, October.
- SRK Consulting (2006c). *Water Quality Model*, Doris North Project, Hope Bay, Nunavut, Canada. Report submitted to MHBL, October.

The drawings referenced in this report form part of a set of drawings completed for the TCA and surface infrastructure designs for the Doris North Project, and are bound as a separate volume:

- SRK Consulting (2006d). *Engineering Drawings for Tailings Containment Area and Surface Infrastructure Components*, Doris North Project, Hope Bay, Nunavut, Canada. Drawings submitted to MHBL, October.

2 Project Area Description

2.1 Location and Access

The Doris North Project is located approximately 400 km east of Kugluktuk and 160 km southwest of Cambridge Bay in the West Kitikmeot Region of the Territory of Nunavut. The project location is shown on Dwg. G-01.

Access to the site is by air (float planes in the summer, and an ice airstrip in the winter); with an annual barge sealift re-supply in Roberts Bay during the open water season.

2.2 Regional Geology

The Doris North Project is in the faulted Bathurst Block, forming the northeast portion of the Slave Structural Province, a geological sub-province of the Canadian Shield. The region is underlain by the late Archean Hope Bay Greenstone belt, which is seven to 20 km wide and over 80 km long in a north-south direction. The belt is mainly comprised of mafic metavolcanic (mainly meta-basalts) and meta-sedimentary rocks that are bound by Archean granite intrusives and gneisses. The greenstone package has been deformed during multiple events, and is transected by major north-south trending shear zones that appear to exert a significant control on the occurrence of mineralization, particularly where major flexures are apparent and coincident with antiforms.

2.3 Sesimicity

A site specific seismic hazard assessment was done by the Geological Survey of Canada, according to the procedures documented in Adams and Halchuck (2003). Peak ground accelerations and velocities for various annual probabilities of exceedence were determined and are listed in Table 1.

Table 1: Probabilistic seismic ground motion analysis at the Doris North Project site

Annual Probability of Exceedence	Return Period (Years)	Peak Ground Acceleration (g)	Peak Ground Velocity (cm/sec)
0.01	100	0.014	0.033
0.005	200	0.018	0.039
0.0021	475	0.023	0.049
0.0010	1,000	0.028	0.060
0.0004*	2,475	0.059	-

*The 1:2,475 return period data is not site specific to the Doris North Project area, but are for Kugluktuk.

The Doris North Project falls within the “stable” zone of Canada. This region has too few earthquakes to define reliable seismic source zones. However, international experience suggests that large earthquakes can occur anywhere in Canada, although the probability is very low.

Within this “stable” zone, the project area falls in acceleration zone 1 (Za = 1) and experiences zonal accelerations of 0.05 g. The velocity zone in which the area falls is zone 0 (Zv = 0) which corresponds to zonal velocities of 0.05 m/s. These zonal classifications are the lowest zones classified on the seismic hazard maps of Canada (Adams and Halchuck 2003).

2.4 Climate

Baseline climate data for the project was collected at the Boston and Windy camps during exploration (August 1993 thru 2003, with some interruptions). This site specific data combined with data from three longer-term regional weather stations operated by Environment Canada (Lupin, Cambridge Bay, and Kugluktuk) were used to develop annual climate profiles for the Doris North site.

The Doris North site has a low arctic ecoclimate with a mean annual temperature of -12.1^{o}C with winter (October to May) and summer (June to September) mean daily temperature ranges of -50^{o}C to +11^{o}C and -14^{o}C to +30^{o}C, respectively; and mean precipitation ranges from 94 mm to 207 mm, with only about 40% falling as rain. Annual lake evaporation (typically occurring between June and September) is about 220 mm.

Wind speed data reported for the Boston area (Rescan 2001) indicates predominant wind directions ranging from northwest to northeast, with wind speed in the order of 5 to 7.5 m/s. Calm conditions (wind speed below 1 m/s) occur about 6 to 9% of the time.

2.5 Permafrost

The Doris North site is underlain by continuous permafrost that has been estimated to extend to depths in the order of 550 m (SRK 2005a). This permafrost depth is based on a 200 m deep drill hole (SRK-50, see Dwg. G-04) where the mean surface temperature is about -6.3 °C and the geothermal gradient is 11.4 °C.km^{-1}. The geothermal gradient in the upper 100 m appears to be isothermal or slightly negative. For comparison, the deep ground temperature profile measured at the Boston Camp, 60 km south of the site, also suggested a similar permafrost depth, about 560 m (EBA 1996; Golder 2001). The mean annual surface temperature is however colder at -10 °C and the geothermal gradient is higher at 18 °C.km^{-1}. The difference in the ground temperature profiles at these two sites can be attributed to different surface conditions and the thermal conductivity of the ground at depth. The geothermal gradient measured at the Doris North site is probably representative of the conditions at the TCA.

Temperature data collected around Tail Lake indicates that the active layer in the marine clay/silt soils appears to be about 0.5 m, while the sand deposit has an active zone no greater than 2 m. The depth of zero annual amplitude varies between 11 and 17 m. The ground temperatures at the depth of zero annual amplitude are generally in the range of -9 to -7 °C.

2.6 Hydrology

The Doris North Project is located primarily in the Doris Lake outflow drainage basin. Tail Lake basin, part of the Doris basin, is the Projects TCA. Peak flows typically occur in June during snowmelt. A second smaller peak may occur from rainfall in late August or early September. The streams in the study area are usually frozen with negligible flow from November until May. The mean flow from June to October for Tail, Doris and Little Roberts Lake outflows are about 0.03, 0.85, and 1.73 m^3/s, respectively (AMEC 2003a).

2.7 Hydrogeology

The permafrost underlying the Project site is generally impervious to groundwater movements. Groundwater movement will only occur in the shallow active layer (0.5 m to 2 m) during its seasonal thaw period. There is no hydraulic connection between the taliks beneath Tail and Doris Lakes, as has been demonstrated though a series of deep drill holes (SRK 2005b).

3 Design Criteria and Assumptions

3.1 Design Basis

3.1.1 Tailings Characteristics

MBHL is proposing to extract about 458,000 tonnes of ore from the underground Doris North mine. The ore will be processed at a rate of 668 tonnes per day to yield 306,830 ounces of gold over a 24-month operating period.

A site plan of the surface facilities is shown on Dwg. G-02. Ore will be trucked to a surface stockpile, crushed and conveyed to an ore stockpile and then fed to a single ball mill. Mineral processing of the gold bearing ore will comprise free gold recovery by gravity separation, followed by concentration of the sulphide minerals by conventional flotation technology. The flotation concentrate will be cyanide leached for gold recovery. The cyanide leached tailings will be detoxified to reduce total and free cyanide concentrations, using Caro's Acid. The detoxified cyanide leach effluent would be combined with the flotation tailings and pumped to the TCA.

Since tailings will not be used to structurally or hydraulically enhance the dam design, the tailings properties do not play a role in the dam design; however, for completeness Appendix A contains a detailed description of the physical tailings properties for the Doris North Project. A complete discussion of the tailings settlement characteristics and tailings geochemistry is presented in SRK (2006c).

3.1.2 Tailings Geochemistry and Supernatant Quality

The Doris North tailings will have low acid generating potential. Static acid base accounting (ABA) testing gave a total neutralization potential ratio of 8.8 and a carbonate neutralization potential of 10.6. The total Sulphur concentration was 0.34 wt% S with non detectable Sulphate sulphur. The net neutralization potential was +82.7 kg $CaCO_3$/tonne equivalent and a carbonate net neutralization potential of +101.9 kg $CaCO_3$/tonne equivalent.

The tailings solution will meet MMER discharge criteria, is not acutely toxic and will have a supernatant total suspended solids concentration of < 5 mg/L after 24 hours of settling time.

Once extracted from the underground workings, the ore is exposed to atmospheric conditions and the sulphide minerals are exposed to oxidizing conditions. The estimated solute release from the tailings, represent oxidation reactions that occur during the handling and processing of the ore. In addition, any readily available water soluble solutes associated with the ore rock will also be dissolved during processing and report to the tailings water.

Subsequent to deposition, the tailings will at all times be covered by a water depth in excess of 4 m. The water cover will prevent any oxygen entry to the tailings and therefore, the sulphide minerals contained in the tailings will be prevented from oxidizing. Consequently no additional solute release from the tailings will occur after the tailings have been deposited in the TCA. Furthermore the tailings will be fully submerged and water will be decanted from the surface of the TCA, such that no hydraulic gradients will develop that could cause the pore water to be displaced from the tailings. It is therefore expected that the tailings porewater will be "locked" interstitially in the tailings indefinitely. Solute release from the tailings once they have been deposited in the TCA is therefore considered to be negligible.

3.2 Design Criteria

The design criteria at the TCA and the associated ancillary facilities follow the guidelines provided in the Canadian Dam Safety Guidelines (Canadian Dam Association (CDA) 1999).

3.2.1 Dam Classification

The dam classification system recommended in the CDA (1999) guidelines is shown in Table 2.

Table 2: CDA dam classification in terms of consequences of failure

Consequence Category	Potential Incremental Consequences of Failure[a]	
	Life Safety[b]	Socioeconomic, Financial & Environmental[c]
Very High	Large number of fatalities	Extreme damages
High	Some fatalities	Large damages
<u>Low</u>	No fatalities anticipated	<u>Moderate damages</u>
Very Low	<u>No fatalities</u>	Minor damages beyond owner's property

a) Incremental to the impacts which would occur under the same natural conditions (flood, earthquake or other event) but without the failure of the dam. The consequence (i.e. loss of life or economic loses) with the higher rating determines which category is assigned to the structure. In the case of tailings dams, consequence categories should be assigned for each stage in the life cycle of the dam.

b) The criteria which define the Consequence Categories should be established between the Owner and the regulatory authorities, consistent with societal expectations. Where regulatory authorities do not exist, or do not provide guidance, the criteria should be set by the Owner to be consistent with societal expectations. The criteria may be based on levels of risk which are acceptable or tolerable to society.

c) The Owner may wish to establish separate corporate financial criteria which reflect their ability to absorb or otherwise manage the direct financial loss to their business and their ability to pay for damages to others.

There will be two dams associated with the TCA. The potential incremental consequences of failure of any of these two dams with regard to life safety factors are classified as "no fatalities", corresponding to a consequence category of "very low". This selection is based upon the remote nature of the site, the low seismic hazard, the climate, the type of dam, and the foundation conditions.

The potential incremental consequence of failure with regard to socioeconomic, financial and environmental factors is classified as "moderate damages", corresponding to a "low" consequence category. Selection of this classification is primarily based upon the financial impacts associated with a dam failure. The socioeconomic and environmental impacts associated with a dam failure at the TCA are very low due to the lack of downstream human habitation and the relatively low level of potential contamination. Based on these factors, the TCA dams are classified as “low” in terms of consequences of failure. However, for all practical purposes, there are no significant differences between design criteria based on a “low” versus a “very low” consequence rating.

3.2.2 Design Earthquake

The CDA (1999) guidelines indicate that the minimum criterion for the design earthquake for a dam in the “low” consequence category would be an earthquake with an annual exceedence probability of 0.01 to 0.001. These probabilities represent return periods of 100 and 1,000 years, respectively. The Geological Survey of Canada indicated that the 1,000 year event has a peak ground acceleration (PGA) of 0.028 g. However, the National Building Code of Canada, suggest that it would be prudent for designers to evaluate the performance of structures during an earthquake with a 2,475-year return period. Although no estimates are available for the Doris North site for that return period, a peak ground acceleration of 0.06 g was estimated for a 2,475-year return period earthquake based on Kugluktuk data.

3.2.3 Design Flood

The CDA guidelines indicates that the minimum criterion for the inflow design flood (IDF) for a dam which coincides with the “low” consequence category would be a flood with an annual exceedence probability of 0.01 (100-year return period) to 0.001 (1,000-year return period). Due to the relatively large catchment of the TCA (440 ha), as well as the real possibility that the spillway may never be put in service, the spillway will be designed to pass a 24-hour, 500-year return period flood (annual exceedance probability of 0.05).

As an added margin of safety, the spillway flood capacity calculation assumes no attenuation of the flood peak within the TCA catchment, and 100% of the design precipitation event will pass over the spillway, without accounting for infiltration or evaporation.

3.2.4 Stability

Slope Stability

The current stability requirements for earth and rock fill dams, advocated by the International Committee on Large Dams (ICOLD) and the CDA (1999), were adopted for the design of the TCA dams. The minimum acceptable factors of safety are 1.5 under static loading conditions and 1.1 under earthquake loading conditions.

Thermal Stability

The TCA dams have been designed as frozen core dams. The dams have been designed to maintain “critical sections” of the core and the underlying saline permafrost foundation. The critical section of the core is defined as the part of the core that is colder than -2^{o}C during impoundment under normal operating conditions, or colder than -1^{o}C during impoundment under upset conditions. The critical section of the saline permafrost foundation is defined as the portion of the saline permafrost layer that is colder than -8^{o}C under normal or upset conditions.

Creep Deformation

Strains will develop within the dam embankments and underlying permafrost foundation in response to long-term creep deformations. The Doris North dams have been designed to maintain the long-term integrity of the frozen core and permafrost foundation by limiting the long-term shear strains in these two areas to less than 2 and 10 percent, respectively. Localized zones of collapse or cracking away from the frozen core are tolerated, as this should not jeopardize the overall stability of the embankment.

4 Site Selection

4.1 Site Selection Approach

Site selection to identify the most appropriate location for the TCA has been a continuously evolving process since 2002. Complete details of the site selection process have been documented in a Comprehensive Tailings Alternatives Assessment Report (SRK 2006e).

Final site selection was done using the Multiple Accounts Analysis (MAA) methodology. This methodology allows for an unbiased quantitative assessment of all alternatives taking into account technical, economic, environmental and socioeconomic considerations of the project in question.

4.2 Identified Sites

A total of 22 tailings management alternatives, at 15 sites were selected for the Doris North Project. These sites are listed in Table 3. After completing a reconnaissance-level inspection at each of these sites, the relevant information pertaining to specific site selection criteria was documented. The evaluated criteria, which were grouped according to four master categories, are listed in Table 4. Comprehensive tables containing this information are provided in SRK (2006e).

Table 3: TCA sites considered for the Doris North Project

Disposal Method	Location	Site Number
Sub-aqueous slurry	Sub-marine disposal in Roberts Bay	#1
Sub-aerial slurry	Unnamed Lake southwest of Little Roberts Lake	#2
Sub-aerial slurry	Unnamed Lake west of Doris Creek	#3
Sub-aerial slurry	Unnamed Lake east of Windy Creek	#4
Sub-aerial slurry	Saddle west of Doris Mesa	#5
Sub-aerial slurry	Unnamed Lake west of Doris Lake	#6
Sub-aerial filtered tailings	Quarry #2	#7
Sub-aerial filtered tailings	Open Pit	#8
Sub-aerial filtered tailings	Underground Mine Backfill	#9
Sub-aqueous slurry	Doris Lake	#10
Sub-aqueous or sub-aerial slurry	Tail Lake	#11A & B
Sub-aqueous or sub-aerial slurry	Partial Tail Lake	#11C & D
Sub-aqueous or sub-aerial slurry	Twin Lakes	#12A & B
Sub-aqueous or sub-aerial slurry	South Windy Lake	#13A & B
Sub-aqueous slurry	Spyder Lake (Boston Site)	#14
Sub-aqueous or sub-aerial slurry	Stickleback Lake (Boston Site)	#15A & B

Table 4: Master categories and criteria used to evaluate TCA sites

Technical/Operational	Economic	Environmental	Socioeconomic
• Distance from mill site • Dam details • Dams and ancillary facilities footprint size • Size and volume of impacted lakes • Total permanent habitat loss (lakes and land) • Construction quarry volume requirements • Potential for increased tailings capacity • Ability to recycle tailings supernatant water • Technical, operational, and environmental uncertainty and flexibility • Precedent • Catchment boundaries • Technical feasibility and risks • Operational, closure and regulatory risks/uncertainties • Post closure land-use	• Capital costs • Operational costs • Closure costs • Post closure costs • Fish compensation and monitoring costs • Total costs • Economic risks • Construction risks	• ARD, ML potential • Topographical issues • Geotechnical and seismic issues • Hydrology issues • Geohydrology issues • Atmospheric issues • Water quality issues • Global warming • Arctic Char • Lake Trout • Lake Whitefish • Ninespine Stickleback • Fish habitat compensation and monitoring effort • Caribou • Wolverine • Grizzly bear • Upland birds • Waterfowl • Raptors	• Archaeological sites • Employment opportunities • Training opportunities • Regional economics • Community services • Maintenance of traditional lifestyle • Spiritual well being • Perceived community response • Landowner opinion • Overall perceived socioeconomic consequences and relative preferences

4.3 Results

A Pre-Screening Assessment (i.e. Fatal Flaw Analysis) eliminated 14 of the tailings management alternatives, leaving only nine sites upon which the MAA was carried out. The results of the base case evaluation are presented in Table 5. In addition, a large suite of sensitivity analysis runs were completed to test the bias in the assessment procedure. The details of these are presented in SRK (2006e). The final outcome of the site selection evaluation was that sub-aqueous disposal of tailings in Tail Lake would be the most appropriate tailings disposal alternative for the Doris North Project.

Table 5: Quantitative results of the base case MAA

Alternative	Score					Rank
	Envi-ronment	Socio-eco-nomic	Ope-rational	Eco-nomic	Total	
Site #2 – Unnamed lake southwest of Little Roberts Lake	0.55	0.30	0.33	0.60	1.78	4
Site #3 – Unnamed lake west of Doris Creek	0.52	0.30	0.33	0.50	1.65	6
Site #4 – Unnamed lake east of Doris Creek	0.45	0.30	0.30	0.30	1.35	8
Site #5 – Saddle west of Doris mesa	0.50	0.50	0.27	0.30	1.57	7
Site #6 – Unnamed lake west of Doris Lake	0.43	0.30	0.30	0.30	1.33	9
Site #10 – Doris Lake	0.53	0.15	0.70	0.70	2.08	2
Site #11A – Tail Lake	0.62	0.80	0.73	0.80	2.95	1
Site #12A – Twin Lakes	0.62	0.30	0.37	0.70	1.98	3
Site #13A – South Windy Lake	0.57	0.30	0.33	0.50	1.70	5

5 Dam Design

5.1 Overview of Tailings Containment Area

Operation of the TCA is based on sub-aqueous disposal of tailings, requiring a minimum water cover of 3 m at any given time. Furthermore, tailings is to be deposited within the deepest sections of the TCA, and only water will be in contact with the two containment dams at any given time. Based on this mode of operation, the North and South Dams have been designed as lined, frozen core water retaining structures.

The TCA is located south-east of the mill and mine location, as indicated on Dwg. G-02, and will consist of the following components:

- Two earthen containment structures (North and South Dams);
- Spillway (at the North Dam);
- Tailings deposition infrastructure;
- Process water reclaim infrastructure;
- Fresh water make-up infrastructure;
- Operational discharge (decant) infrastructure; and
- Shoreline erosion protection infrastructure.

5.2 Storage Characteristics

Tail Lake, with its normal water level of about elevation 28.3 meters above mean sea level (mamsl), occupies about 83 ha of an isolated basin south-east of the mill site. The lake is generally shallow, but does have a few pockets as deep as 6 m, as confirmed by bathymetric survey (Golder 2006).

Topographic and bathymetric data was used to develop elevation-capacity curves (stage curves) for the TCA. These are illustrated on Dwg. T-01. The drawing shows the storage capacity of the entire TCA assuming that the stored volume of tailings and/or water is struck level, i.e. a horizontal slope over the entire TCA.

The maximum operating elevation for the containment dams is 33.5 m, which corresponds to the invert elevation of the TCA spillway. The storage capacity of the entire TCA at elevation 33.5 m is about 7.4 million m^3, compared to a tailings volume requirement of about 400,000 m^3. There is an additional 1.8 m of normal freeboard, to an elevation 35.3 m at the North Dam, and an additional 2.3 m of normal freeboard, to an elevation of 35.8 m, at the South Dam. The maximum effective storage or containment elevation for the facility, i.e. emergency situation, is thus at elevation 35.3 m. However, since the dams rely on a frozen core, each dam has an additional 2.2 m of freeboard, which acts as thermal insulation above the frozen core (and GCL termination). Therefore the North Dam crest elevation is at 37.5 m, and the South Dam crest elevation is at 38.0 m. The normal freeboard for each dam as described here exceeds that which is required due to wave run-up, as is documented in Appendix E.

Tailings will be deposited sub-aqueously (summer and winter), starting at the deepest pockets within the TCA. Tailings will not be deposited on the lake ice during freeze-up, and tailings will under no circumstances be deposited such that it would come into contact with any of the two dams. Although the intent is to move the tailings deposition point frequently so as to deposit tailings as level (i.e. horizontal) as practical, it is understood that there will be some minor undulations which may have to be levelled by some other means. These will however not compromise the minimum water cover requirements for the TCA as is demonstrated in Appendix C.

The TCA has been designed to operate as a zero discharge facility during the two years of operation, if necessary. In addition, under the most conservative water balance assumptions, the TCA would take over five years to reach the FSL of 33.5 m.

In actual fact, the TCA water management plan stipulates that the maximum water level in the TCA would be about 29.4 m, and that within five years after start of tailings deposition, the natural inflow to the TCA would be equal to the amount of annual allowable discharge. Under this scenario, the dams will never reach FSL.

Notwithstanding any of these conditions, the dams have been designed with a 25-year design life in mind, which provides a substantial safety factor. The 25-year design takes into account global warming and upset conditions.

5.3 Foundation Conditions

5.3.1 Geotechnical Investigations

Eight geotechnical drilling programs and a geophysical survey have been undertaken at the Doris North site since 2002, many of which specifically targeted geotechnical and thermal information at the TCA. Details of these programs are presented on Dwg. G-04, and can be summarized as follows:

- The winter 2002 investigation comprised nine drill holes along three section lines across Tail Lake (SRK 2003a).
- The fall 2002 program consisted of five drill holes at the North Dam location (SRK 2003a).
- The winter 2003 program included a single drill hole along the eastern Tail Lake shoreline, as well as 4 drill holes at the South Dam and 3 drill holes at the North Dam (SRK 2003a).
- The summer 2003 program involved further drilling at the North (1 hole) and South Dam (2 holes), as well as three deep holes around the Tail Lake perimeter to investigate potential talik development. Three shallow auger holes and six shallow test pits was also completed at the North Dam (SRK 2003a).

- The summer 2004 program consisted of drilling one hole at the North Dam spillway, and three along the perimeter of Tail Lake (SRK 2005a).
- Two geotechnical bulk samples were collected along the North Dam alignment during the 2004 winter season. This program also included the installation of a 200 m long thermistor string located in the vicinity of the mill, between the mine and the Doris Lake shoreline (SRK 2005c).
- The winter 2005 investigation included 5 drill holes at or adjacent to the North Dam alignment and spillway, and three additional drill holes along the shoreline of Tail Lake (SRK 2005d).
- The winter 2006 program comprised two drill holes at the South Dam as well as a geophysical survey along both dam alignments. The geophysical survey also covered the entire TCA perimeter at the FSL elevation of 33.5 m (SRK 2006f, also included as Appendix D).

Many of these subsurface investigations included the installation of thermistors as illustrated in Dwg. G-04. Ten strings were installed along the North Dam alignment, four at the South Dam and ten around the perimeter of Tail Lake.

5.3.2 North Dam

The North Dam will be situated about 200 m downstream of the northern extremity of Tail Lake. The dam alignment, shown in more detail in Dwg. T-02, is within a relatively narrow valley and is essentially perpendicular to the valley. The valley bottom is about elevation 26 m and consists of a narrow marshy area that drains flow from Tail Lake. This surface flow discharges into Doris Lake.

Ground temperature measurements along the dam alignment confirm the presence of cold permafrost with mean annual ground temperatures ranging between -9°C and -7°C. No talik is present under the Tail Lake outflow channel.

The interpreted stratigraphy at the North Dam is shown in Dwg. T-03, and is characterised by two distinct zones. About two thirds of the dam longitudinal section, is dominated by an ice saturated sand deposit that is approximately 10 to 15 m thick. The sand deposit is overlain by a silt and clay layer that is less than 3 m thick. The remaining one-third portion is dominated by marine clayey silt that is up to 15 m thick. The fine-grained materials are ice-saturated and contain excess ground ice. The overburden soils are up to 20 m thick in the base of the valley and thin out at the dam abutments. Bedrock is generally competent basalt.

Pore water salinity measured from selected fine-grained soil samples typically ranged from 30 parts per thousand (ppt) to 50 ppt. The pore water salinity of the sand deposit is typically 4 ppt or less and is considered non-saline.

5.3.3 South Dam

The South Dam will be situated about 400 m south of Tail Lake, on the watershed with Ogama Lake. The proposed dam alignment is along a flat valley section that remains above elevation 33 m (Dwg. T-05).

Ground temperature and pore water salinity measurements at the South Dam alignment is consistent with those observed at the North Dam.

The inferred stratigraphy along the South Dam alignment is illustrated in Dwg. T-06. Soil conditions typically consist of marine silt and clay overlying gravel. The marine deposit, which is up to 20 m thick at the base of the valley is ice-saturated and contains excess ground ice. The gravel layer is up to 15 m thick. The overburden soils thin out at the dam abutments. Bedrock consists of basalt and agrillite and is typically competent.

5.3.4 Spillway

The spillway will be situated immediately north of the North Dam alignment. Permafrost overburden along the spillway alignment is generally less than 3 m thick, and consists of predominantly sand, although there are some ice-rich silt and clay pockets. Bedrock consists of basalt and is typically competent.

5.4 Dam Design

5.4.1 North Dam

Based on the proposed operating methodology, tailings will be deposited in the deepest sections of the TCA, stating at an elevation of about 22 m and ending at about 24.3 m, as compared to the normal water level in Tail Lake at elevation 28.3 m. Only water will be in contact with the North Dam. The North Dam has therefore been designed as a water retaining structure utilizing a central frozen core backed by a geosynthetic clay liner (GCL) as shown on Dwg. T-03. The frozen core and GCL are required to an elevation of 35.3 m to provide engineering and environmental containment under extreme operating conditions. The dam will be constructed in a single construction season because of the ice core requirements.

The core material would be composed of on-site processed, i.e. crushed quarry rock. The frozen core would be keyed and frozen into the central key-trench utilizing thermosyphon evaporators (Dwg. T-02 and T-07). A transition layer consisting of larger crushed quarry rock will be placed against the frozen core to protect it from the outer run of quarry shell.

Although the frozen core is intended to prevent seepage, the GCL will provide secondary water retaining capability in case the core develops cracks due to thermal expansion and contraction, as well as creep deformation and settlement. The core (and GCL) would extend 1.8 m above the FSL and the outer shell will be at least 2.2 m thick to provide insulation to the frozen core.

The upstream and downstream slopes of the dam will be 6 to 1 (horizontal to vertical) and 4 to 1 respectively. These slopes have been designed to ensure physical and thermal stability against creep deformation induced by the deep ice-rich saline foundation soils.

5.4.2 South Dam

The design of the South Dam is essentially identical to the North Dam, with the exception of additional allowance for creep deformation, due to the deeper foundation soils present. Dwg. T-05 illustrates the South Dam cross-section. The frozen core (and GCL) is required to an elevation of 35.8 m, and the final crest height will be at 38 m. Both the upstream and downstream dam slopes will be 6 to 1 (horizontal to vertical).

The intended operating water level in the TCA will be at elevation 29.4 m, which is below the lowest part of the South Dam at 33.0 m. Furthermore, even the most conservative water balance predictions suggest that it would take at least 4 years before the TCA water level reaches 33 m (Dwg. T-01). The construction of the South Dam should therefore be delayed until such time that the latest water balance predictions, under the most conservative assumptions suggest the water level in the TCA would reach elevation 33 m within two years. This would allow more than enough time to mobilize equipment and supplies to construct the dam.

5.5 Thermal Analysis

5.5.1 General

Thermal analysis were performed for the North and South dams because they are primary water retaining structures, and the retained water will transport additional heat towards the dams, which could significantly influence the thermal stability of the frozen cores.

A summary of the thermal analysis are provided here. Appendix B provides complete details of the thermal modeling, which has been carried out by EBA Engineering Consultants Ltd. (EBA). To prevent misinterpretation of information, many of the summaries below is paraphrased from the EBA report.

5.5.2 Method of Analysis

Thermal analysis was carried out using a proprietary finite element computer program, GEOTHERM, developed by EBA. The model was calibrated for site specific conditions, using thermistor data collected at both dam alignments.

Thermal analysis was carried out for dam cross sections near the deepest sections of each of the North and South Dam alignments. These selected soil profiles are considered the worst foundation conditions along each proposed dam alignment from a creep-deformation perspective.

Thermal analysis was carried out to model every step from dam construction through subsequent TCA impoundment. It was assumed that both the North and South Dams would be constructed the same season. The thermal analysis conservatively assumed that the water level in the TCA would be at elevations 31 m and 33.5 m by the first and second freshets (assumed to be June 1), respectively, following construction of the dams. Furthermore, it was assumed that from that point forward the dam would remain at FSL for the remainder of the 25-year design life.

The Doris North dams have been designed assuming global warming over their 25-year design life as the normal environmental condition. The effects of two extreme warm years immediately following dam construction have also been evaluated as an upset condition.

5.5.3 Results from Thermal Analysis

Complete figures demonstrating the ground temperature distributions during the month of December in Years 1, 2, 5, 10 and 25, respectively following construction are presented in Appendix B, for both the North and South Dams. December is the time of the year when temperatures below the frozen core are the warmest.

North Dam

The results show that upstream of the frozen core, the permafrost foundation is progressively getting warmer over the years in response to the continued warming influence of the TCA water level. Assuming the marine clay and silt layer fully thaw at -3°C, much of the marine clay and silt upstream of the core is predicted to thaw after 25 years of full impoundment. Downstream of the frozen core, the permafrost foundation is predicted to progressively warm due to the long-term effects of snow drifting and the modelled climate warming trend. The degree of permafrost warming below the downstream shell is not expected to be as great as below the upstream shell.

Beneath the frozen core, permafrost temperatures are predicted to progressively cool with time over the first ten years or so due to the thermal influence of the thermosyphons, but then become warmer because of long-term climate warming. The results show that the frozen core is well frozen (temperatures mainly below -5°C), as is the permafrost foundation beneath the core (temperatures colder than -8°C).

An upset condition was evaluated by assuming extreme warm years for the first two years following initial impoundment. These events have a greater influence on the dam embankment temperatures (e.g. the active layer penetration) than on the permafrost foundation temperatures, and as a result the thermal stability design criteria for the dams can still be maintained.

South Dam

The long-term geothermal response of the South Dam embankment and its permafrost foundation is similar to that described for the North Dam above.

5.6 Creep Deformation Analysis

5.6.1 General

Strains will develop within the dam embankments and underlying permafrost foundations in response to long-term creep deformations. A summary of the deformation analysis is provided here. Appendix B provides complete details of the deformation assessment.

5.6.2 Method of Analysis

The commercial, two-dimensional, explicit finite difference stress analysis program FLAC, developed by HCItasca, was used to carry out a two-dimensional plane-strain analysis. The analysis was carried out using the same dam section and foundation conditions used in the thermal evaluation.

5.6.3 Results from Creep Deformation Analysis

Complete figures demonstrating the results of the deformation analysis are presented in Appendix B, for both the North and South Dams.

Substantial settlement of both dam cores is predicted; however, it should be noted that the predicted creep deformations are considered to be very conservative. Based on these results, the design approach was to initially over-build the crest of the frozen core of the dams to accommodate some, but not all, of the predicted settlement over the 25-year design life.

North Dam

Appendix B contains figures that show the predicted horizontal and vertical displacements, ten years after construction of the North Dam. Predicted deformations are largely away from the frozen core, whilst the core itself is expected to behave rigidly.

The predicted maximum shear strain and shear strain rate, ten years after construction, show that the frozen core and permafrost foundation are expected to remain ductile, and brittle rupture is not expected. The most likely mechanisms of slope failure are deep-seated, rotational slips located upstream and downstream of the frozen core.

Ten years after construction, the frozen core and underlying permafrost foundation soils will have strengths that far exceed the predicted shear stresses on the dam.

South Dam

Deformation trends at the South Dam are similar to those at the North Dam. Although the dam is thinner and is designed to retain a lower head of water than the North Dam, even greater creep deformations are predicted at the South Dam because the creep-susceptible marine clay and silt foundation is much thicker at this dam alignment than it is at the North Dam alignment.

Conclusion

The creep deformation analyses indicate relatively high movement and strains in the foundation upstream and downstream of the frozen core, and relatively small movements and strains in the dam core and underlying foundation soils. The strains are predicted to occur very slowly and in a ductile manner. With monitoring of the actual dam displacements, potential stability concerns can be identified and mitigation measures can be put in place. Therefore acceptable dam performance is anticipated.

5.7 Stability Analysis

5.7.1 General

Limit equilibrium analysis were carried out to determine the factor of safety against slope failure during construction and operation of the North and South Dams. Again, complete details are presented in Appendix B.

5.7.2 Method of Analysis

The commercially available two-dimensional, limit equilibrium software, SLOPE/W, developed by Geo-Slope International Ltd. was used to conduct the stability analysis. The stability analysis were carried out for the dam sections near their maximum thickness, i.e. the same geometry and soil profiles used in the thermal and creep deformation analysis. Two cases were evaluated: one assuming full impoundment (i.e. water level at 33.5 m), and another assuming no water against the dam. A deep-seated slip surface and failure along the GCL were evaluated.

5.7.3 Results from Stability Analysis

Minimum factors of safety were determined from cases where there was no water impounded against the dam. This is because in total stress analyses, the weight of the water acts as a resisting load against slope failures beneath the upstream slope.

The minimum factors of safety calculated are for deep-seated, circular slip failures from the opposite slope (e.g., from the downstream dam slope for the upstream slip surface), through the marine silt/clay layer and daylighting beyond the slope toe. The calculated factors of safety satisfy dam safety requirements.

5.7.4 Liquefaction Potential

The peak horizontal ground acceleration for the area is very low at 0.06 g and, as a consequence, liquefaction of the thawed marine silt and clay due to earthquake loading is not expected to be a concern.

5.8 Dam Settlement Analysis

Thaw settlements were estimated based on the predicted thaw penetration into the typical cross section described in the thermal evaluation. In the extreme condition where the dams continuously retain water at its FSL over a 25-year period, up to 6 m of the frozen saline fine-grained soils is predicted to thaw below the upstream shell; however, below the core, the permafrost is predicted to remain well-frozen. Thaw settlements are therefore not expected to affect the integrity of the frozen core.

Deformation is predicted to occur due to permafrost creep and thaw and, to a lesser extent, consolidation of the marine clay and silt foundation soils. Given the variability in soil conditions along each dam alignment, there is a potential for differential movements across the dam embankment. This is particularly true at the North Dam, where most of the dam is sited on non-saline, ice-poor frozen sand and displacements are expected to be relatively small, compared to the remaining portion of the dam, which is sited on saline clays and silts, over which larger displacements are predicted.

Predicted deformations are considered conservative and are expected to develop slowly. The monitoring data should be regularly reviewed to verify that the dams are behaving as predicted. Remediation measures, such as flattening slopes or installing thermosyphons, should be implemented should differential dam movements be seen to pose a risk of rupture of the frozen core and/or permafrost foundation.

5.9 Seepage Control

The control of seepage at the TCA is dependant on the integrity of its two containment dams, and the extent of the talik beneath the TCA.

Extensive thermistor data along the North and South Dam alignments confirm that there are no talik zones present, even under the Tail Lake outflow. A series of shallow thermistors (up to 12 m depth) around the TCA perimeter between elevations 28 m and 33.5 m, show no indication of an extended Tail Lake talik. Furthermore, deep thermistor data (up to 50 m deep) along the Tail Lake watershed, including two locations between Tail and Doris Lakes, confirm that there is no talik between these lakes for at least 50 m depth, with the permafrost temperature at that depth still cold at -8^{o}C. Finally, a 200 m deep drill hole (SRK-50), only 100 m from the Doris Lake shoreline, confirm -4^{o}C permafrost even at that depth. Therefore, to the extent that the frozen cores of the various dams are thermally contiguous, with the natural permafrost, the seepage losses should be non-existent. SRK (2005b) presents a detailed discussion of the hydrogeological conditions at the site.

Conventional seepage analysis is not well suited to estimate seepage through frozen core dams. However, for water balance purposes only, it was assumed that seepage from the TCA will be about 0.9 L/s (Appendix F). This amount of seepage may be attributable to slight imperfections in the seepage control system as a result of, for example, minor construction flaws or imperfect freezing at select locations.

This allowance for seepage is deemed very conservative considering the expected maximum TCA operating level water is expected to be at elevation 29.4 m, which implies a maximum hydraulic head at the North Dam of 3.4 m, and zero hydraulic head at the South Dam. Even at the FSL, the maximum hydraulic heads at the North and South Dams respectively are 7.5 m and 0.5 m.

The toe areas at both dams will be monitored. To the extent that any seepage is observed, and depending on the amount and water quality of such seepage, consideration will be given to collecting this seepage in sumps and pumping it back to the TCA.

6 Water Balance

6.1 General

The water balance formed the basis for determining the dam design height, and water quality predictions for the operational, closure and post-closure periods. The detailed description of the overall water balance is provided in Appendix F. This section provides a brief overview of the TCA water balance. Primary assumptions that were adopted for the water balance include the following:

- The TCA will be completely isolated with respect to surface and groundwater from the adjoining Doris and Ogama Lake catchments by two water retaining structures; the North and South Dam respectively.
- Tailings deposition will be sub-aqueous and will be managed such that the final tailings surface will be relatively horizontal.
- Tail Lake will not be pumped out prior to constructing the dams or starting deposition. The volume of Tail Lake at its normal elevation of 28.3 m is about 2.2 million m^3.
- Annual discharge (decant) release from the TCA are planned; however, the TCA is designed to accommodate full containment (tailings and all natural runoff) for the two-year mine life, plus an additional period after mining ceases.
- The water balance is calculated in monthly time steps. The calculations use a year that starts in March and ends in February.
- The impact of varying climate and hydrology on the water balance has been evaluated.

6.2 Water Balance Calculation

The key input assumptions on which the water balance is based are repeated below:

- *Total precipitation:* The water balance is conducted using average climatic year data; however, it is recognized that extreme events can affect the outcome. The water balance sensitivity analysis therefore includes an evaluation of extreme wet and dry years. The average annual precipitation (rainfall and snow water equivalent) is about 207 mm.
- *Potential lake evaporation:* The average lake evaporation has been determined to be about 220 mm per year. The sensitivity analysis evaluated evaporation to ±20% of this value.
- *Water yield:* For the purpose of the water balance, the base case water yield was conservatively assumed to be 180 mm, and the effect of lower water yields (111 mm) were evaluated through sensitivity analysis.
- *Seepage:* Seepage from the TCA can be via three primary routes; North Dam, South Dam and deep recharge through the lake basin. In reality, the North and South Dams will be frozen core dams, which should not have any seepage. Average condition theoretical

seepage calculations are described in the water balance calculation and have been used in the TCA water balance. It was however assumed that all seepage from the North and South Dams would be intercepted and pumped back to the TCA. The average deep seepage rate is so low that it has been omitted from any water balance calculations.

- *Tailings slurry feed:* The average steady state tailings production rate will be about 668 tonnes per day. The specific gravity of the tailings solids will be 2.7. The tailings slurry will be discharged at about 36.1% solids, and will have a submerged in-place tailings void ratio of 1.2. This will result in a daily slurry feed of 1,727 m^3 (544 m^3/day solids and 1,183 m^3/day water).
- *Reclaim water:* The TCA is relatively shallow; a reduced water volume created by the freezing conditions (ice) may prevent water recovery for reclaim. Consequently, 100% recirculation water (1,183 m^3/day) is assumed for four months of the year only (June through September). During the remainder of the year fresh water make-up will be from Doris Lake.
- *Sewage sludge:* The sewage treatment plant outflow will be pumped to the TCA as part of the tailings feed stream. We assumed a 175-man camp, for a total sewage treatment plant load of about 68.6 m^3/day.
- *Underground mine discharge:* Although the Doris North Project would in all likelihood not experience any mine water inflow (SRK 2005b), a conservative assumption has been made that a mine inflow of 235m^3/day would occur for the life of the Project. This water would be captured in the mine and pumped to the TCA.
- *Discharge (decant) rate:* It was assumed that while the TCA is actively managed, annual discharge from the TCA will occur directly into Doris Creek. The allowable rate of discharge would be limited to maintain receiving water quality objectives in Doris Creek (SRK 2006c). The rate of discharge will be determined based on actual water quality in the TCA and Doris Creek, and the flows in Doris Creek.

6.3 Water Balance Results

The primary purpose of the water balance was to determine an appropriate height for the containment dams, such that there would be sufficient storage capacity in the TCA. Based on the water balance it was determined that an optimal design FSL for the TCA would be 33.5 m. Under the most conservative water balance assumptions, the TCA can operate as a zero discharge facility for just under 5½ years before reaching the FSL. Using more realistic water balance assumptions the TCA can operate as a zero discharge facility for at least 7½ years.

The water balance also illustrates that, by allowing an annual discharge the time to reach FSL in the TCA is dramatically increased. Allowing as little as 100,000 m^3/year of discharge increases the time to FSL under the base case to just under 9½ years, which is a 27% increase in storage time. If the annual discharge is 500,000 m^3/year, the FSL in the TCA will likely not be reached, since the decant rate will exceed the annual inflow.

7 Design of the Water Management Facilities

This section deals with the design of the facilities required to perform the tailings disposal and manage the supernatant within the TCA.

7.1 Tailings Deposition Infrastructure

Tailings is delivered to the TCA via a 4,630 m long single 127 mm diameter pre-insulated pipeline (Dwg. T-11 and T-12). Tailings pumps are installed at the mill and have duty point of 20 L/s at 263 m of total dynamic head. The pipeline is designed to convey 20 L/s of tailings with a solids concentration of 36.1 % by weight. Design tailings relative density is 1.3 tonne/m^3. The flow velocity in the pipe of 1.65 m/s must be maintained to prevent solids settling.

The pipeline follows the secondary road ensuring accessibility to the pipeline for monitoring and maintenance. The pipeline will be placed directly onto the road surface, towards one side with no physical separation between the pipeline and the traffic. The only section of the pipeline that will have spill containment is a 150 m long section where the pipeline crosses Doris Creek. Along this section, a double wall pipeline will be used.

The pipeline has been designed to have a minimum longitudinal grade of at least 1% at any location in order to ensure gravity draining of the pipeline towards five low points where emergency dump catch basins are located. Stoppage of the pipeline whilst full of slurry will lead to solids settling and/or line freezing. Therefore, during stoppage the pipeline will be drained into the emergency dump catch basins. Valves located immediately above each emergency dump catch basin will be manually opened to allow gravity drainage of the tailings line. Evacuated tailings will be collected and temporarily stored in the emergency dump catch basins. The emergency dump catch basins are HDPE lined to ensure containment, and have been sized to allow two sequential fillings plus an additional 0.5 m of freeboard (Dwg. T-13). Emergency dump catch basins outside of the TCA catchment is sized to allow containment of the reclaim water as well.

Tailings will be deposited sub-aqueously into the TCA using a floating line in the summer and a line through the ice-pack in the winter. Tailings will initially be deposited in the deepest sections of the TCA and the deposition points will be moved regularly to ensure that tailings are equally spread with minimal highs and lows. A total of five tailings deposition pipes are provided to allow for flexibility in tailings deposition and facilitate even deposition of tailings solids. Only one deposition pipe will be operational at a time.

7.2 Process Water Reclaim Infrastructure

Maximum recycle of water is the objective; however, since the TCA is shallow, and up to 2 m of ice every winter will further reduce capacity, there is a possibility that reclaim water may only be recovered from the TCA during the open water summer months. The reclaim pipeline has subsequently been designed to operate year round, for only four months of the year, or any other time period as applicable.

A reclaim barge on the TCA will house a vertical turbine reclaim pump with a design duty point of 14 L/s at 63 m of total dynamic head. The reclaim pipeline will be a pre-insulated and heat traced 102 mm diameter HDPE line. The pipeline will be about 1,800 m long. The pipeline will follow the secondary access road to the mill, and will be placed on the road shoulder immediately adjacent to the tailings delivery line.

The reclaim line will also have drain valves at the emergency dump catch basins. Where the emergency dump catch basins are outside of the TCA catchment, the reclaim line will drain into the emergency dump catch basins. However, where the emergency dump catch basins are within the TCA catchment, the reclaim line will be drained out directly onto the tundra downstream of the secondary road.

7.3 Fresh Water Make-Up Infrastructure

Since there is a real possibility that reclaim water may not be obtained from the TCA year round, a contingency fresh water make-up system is provided to draw water from Doris Lake. A pump will be installed on the float plane dock laydown area. The pump will have a duty point of 14 L/s at 45 m of total dynamic head. The intake pipe will be placed on the lake bottom and will terminate at a depth of 5 m. The intake pipe will be a 25 m long, 102 mm diameter pre-insulated and heat traced HDPE line. The intake pipe will be held in place with a cover of quarry fill. The pipe inlet will have an approved fish screen.

The fresh water make-up pipeline will be placed directly onto the float plane dock access road shoulder, with no physical separation from road traffic.

7.4 Operational Discharge (Decant) Infrastructure

The discharge system will comprise the installation of a control system that will accurately control and measure the discharge flow rate over a flow range spanning 50 L/s to 275 L/s. A programmable logic controller (PLC) will be used to both control the discharge rate as well as log instantaneous flow rates and cumulative discharge volumes. The flow would be controlled with an actuated flow control valve, with excess flow recycled back to the TCA. The PLC will actuate the flow control valve to discharge TCA water at a fixed ratio, equal to the target discharge rate (TDR), relative to the flow in Doris Creek.

The pump intake in the TCA (for the operational period) will be mounted on a floating barge (same system as the reclaim pump) well away from the tailings discharge point to minimise suspended solids in the intake. Silt curtains will be installed around the pump intake to minimise intake of suspended solids.

A vertical turbine pump will be located on the barge with a duty point of 275 L/s at 29 m total dynamic head. The pipeline up to the pump house pad will be about 500 m long and will be a 16" HDPE pipe (not insulated or heat traced, since discharge will only be done during the summer months). In the pump house a throttling valve will be used to regulate the actual discharge flow down to 50 L/sec if required. The excess will be drained back to the TCA.

From the pump house, a 900 m long gravity pipeline will convey the discharge to the decant point. This pipeline will be a 14" HDPE line (not insulated or heat traced). The pipeline will be placed directly onto the shoulder of the secondary and decant access roads, immediately adjacent the tailings discharge and reclaim pipelines.

The discharge to Doris Creek will be located sufficiently downstream from the flow monitoring location to ensure that the discharge will not interfere with flow measurements in Doris Creek, but sufficiently upstream of the waterfall to ensure complete mixing with Doris Creek water. The outlet would be placed such that the discharge flow would not lead to erosion or degradation of the creek bed.

7.5 Spillway

An operational spillway has been designed for the TCA at the North Dam, at elevation 33.5 m. This side-spillway will be 18 m wide, about 190 m long along its centerline, with an average gradient of about 0.8% (Dwg. T-08). The design flood of 3.3 m^3/s will pass through the spillway with a maximum flow depth of about 0.2 m at a sub-critical flow velocity of about 1.1 m/s.

The most conservative water balance estimates for the TCA, suggest that the FSL of 33.5 m will only be reached about five years after construction of the North and South Dams. Furthermore, since the anticipated maximum operating water level in the TCA is at an elevation of 29.4 m, there is a very real possibility that the spillway may never actually be required.

Therefore, construction of the spillway should be delayed, until such time as the most conservative water balance calculation suggests that the FSL level will be reached within two calendar years. This will allow more than enough time to mobilize equipment and materials with which to construct the spillway. Details regarding the predicted timing of spillway construction are presented on Dwg. T-01.

7.6 Shoreline Erosion Protection

The proposed water management strategy for the TCA will result in a maximum water level of 29.4 m, with a total flooded footprint of about 13 ha. Prior to tailings deposition, about 20% of this surface area will be pro-actively mitigated. Areas to be pro-actively mitigated are indicated on Dwg. T-14 and are areas that are subject to the greatest fetch distances.

Pro-active erosion protection will consist of laying a geotextile directly onto the tundra and covering it with a 0.5 m thick layer of run of quarry material as illustrated in Dwg. T-14. If during operation, and prior to final closure, there is any physical evidence of shoreline erosion, repairs should be carried out as per the details presented in Dwg. T-14.

At final closure, i.e. as soon as the water level is lowered to 28.3 m, the entire flooded perimeter of the TCA shoreline should be inspected and in areas where visible erosion is seen to occur, shoreline erosion protection must be put in place.

A comprehensive evaluation of the shoreline erosion processes, risks and mitigation measures are documented in SRK (2005e), which is also included as an appendix to SRK (2006c).

8 TCA Construction

8.1 Construction Materials

8.1.1 Dams, Spillway and Shoreline Erosion Protection

Construction fill material for the dams, spillway and shoreline erosion protection consists of core, transition and run of quarry material. This granular fill will be produced on site from one of four local quarries. Complete geological, mineralogical and geochemical details on these quarry sites are documented in MHBL (2003), AMEC (2003b), and SRK (2006g). The grain size distribution envelopes for all the construction fill is presented in Dwg. G-05.

Other materials that will be used to construct the dams, spillway and shoreline erosion protection measures include; GCL, thermosyphons and geotextile. Complete details of all these materials are provided in the Technical Specifications (SRK 2006b); however, for completeness a brief summary is presented below:

- *Core material:* the dam frozen core will be constructed with this well graded processed crushed rock with a maximum particle size of 20 mm. Since each lift of this material will have to be frozen prior to the placement of the next lift, it is important that this material contains sufficient fines to provide water retaining capabilities for the duration of the freezing process.
- *Transition material:* The transition material will be used immediately adjacent to the core material on the dam, and will act as a filter layer between the core and the outer shell. This material will be well graded, screened crushed rock with a maximum particle size of 150 mm.
- *Run of quarry material:* This material will be used to construct the outer shell of the dams, as well as armouring for the spillway and for the shoreline erosion protection. It will consist of run of quarry rock and have a maximum size of 500 mm. Fabrication of this material will be dependent on the condition of the rock and the blasting procedure at the quarry.
- *Impervious membrane (GCL):* Secondary containment for the dams will be provided by the GCL. The GCL will consist of a pre-manufactured three layer assembly of sodium bentonite enclosed between two geotextiles (one woven and one non-woven).
- *Thermosyphons:* The dam core and foundation will be kept frozen for the 25-year design life of the dams with the assistance of passive looped horizontal thermosyphons. A thermosyphon is a hollow pipe filled with pressurized carbon dioxide (CO_2) that evaporates and condensates depending on the ambient air and ground temperatures. They essentially consist of two main components; the evaporator and the condenser/radiator. The evaporator is the portion of the thermosyphon that is buried in the ground where the heat is extracted from the ground, i.e. where cooling occurs. The radiator is the component that is installed

above grade and is generally installed in a vertical position. The section joining the radiator and the evaporator is called the riser. The radiator is covered with protruded fins that increase the heat exchange between the thermosyphon and the ambient air. Thermosyphons become active only when the ambient air is colder than the evaporators (buried portion). The heat extraction simply ceases over the period where the ambient air temperature is warmer than the ground temperature.

- *Geotextile:* Non-woven geotextile is used as a filter layer beneath the run of quarry fill for shoreline erosion protection. The geotextile acts as a filter layer should erosion occur.

8.1.2 Pipelines and Emergency Dump Catch Basins

Complete details of the construction materials required for the pipeline installations and the emergency dump catch basins are provided in the Technical Specifications (SRK 2006b); however, for completeness, the main items are summarized here:

- *Tailings deposition pipe:* This pipeline will consist of six different pipe classes, all having a nominal diameter of 127 mm. The first segment of the pipeline will be an HDPE lined steel pipe, whilst the remaining five segments will be HDPE pipe with different pressure ratings. All pipe segments will have insulation. The steel pipe will be site welded, whilst the HDPE pipes will be fusion welded on site. All joints to valves and/or bends will be flanged.
- *Reclaim and fresh water make-up pipes:* These pipes will have different pressure ratings, but will both be 102 mm diameter pre-insulated and heat traced HDPE lines. The pipes will be fusion welded on site with flanged couplings at bends and valves.
- *Discharge pipes:* The discharge pipe from the barge to the pump house will be a 16” HDPE line, and the gravity pipeline from the pump house to the decant point will be a 14” HDPE line. Both pipes will be fusion welded on site with flanged couplings at bends and valves.
- *HDPE liner:* Primary containment in the emergency dump catch basins will be provided by a 57 mil HDPE liner sandwiched between two non-woven geotextiles.
- *Floating barge:* A floating barge will be required to house the reclaim and discharge pumps on the TCA. Access to the floating barge will be via floating walkway.

8.2 Construction Equipment

Construction of the dams can be achieved, in most part, using conventional earthworks equipment. Trucks, loaders, graders, excavators, smooth roller compactors and track-mounted bulldozers would not require special modifications other than to be capable of operating continuously in extremely cold weather.

Conventional rock quarry development equipment will be used to produce the construction fill material. This includes track-mounted air drills, crushers and screening equipment.

The placement of the core material will require some special attention. Since the material has to be placed with a high moisture content to ensure ice saturation, a mobile heating plant, capable of heating the crushed rock and a mobile mixer capable of controlling the proper dosage of water would be required.

Placement of the GCL and the geotextile poses no special problems, whilst the seaming of the HDPE liners and fusion welding of the HDPE pipelines will require heating tents over the joint areas to ensure proper bonding.

8.3 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 2006b). 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.

8.4 Construction Quantities

Construction quantities have not been generated as part of this report. Quantities will form part of Schedule 1 to the Technical Specifications (SRK 2006b).

8.5 Construction Procedure

8.5.1 Dams

Most of the dam construction activities must occur during the winter months. Placement of the dam material will require an ambient air temperature of at least -10 °C. A summary of the construction steps are provided below:

- Strip the organic cover within the footprint of the dam key-trench.
- Excavate the key trench and prepare the abutments. The key-trench must be at least 2 m deep, or until competent bedrock or ice saturated permafrost is encountered. Key-trench excavation is likely to require drill and blast excavation techniques, combined with conventional mechanical excavation. Final cleaning of the key-trench will be done with compressed air. The excavated material will be stockpiled in a suitable area for potential future use. The abutments will be cleared and stripped to assure a good bond between the core of the dam and the overburden and bedrock. Blasting in the bedrock may be required at the abutments to key in the core.
- Six looped thermosyphons will be installed along the base of the key-trench. Three loops will be located on either side of the dam alignment, extending from the lowest point in the key-trench. Each pair of looped pipes would cover opposing halves over the entire length of

the dams, spaced at 1.5 m intervals. One set of twin-branched vertical radiators will be connected to each loop, such that there will be three banks of radiators on either side of the dam.

- The GCL will be placed on the thermosyphon loops and the construction of the core will start. Care will be taken to advance the GCL with the construction of the core material.
- The core material must be placed at sufficiently high moisture content that complete ice saturation can be achieved, and that the layers can be compacted to at least 90% of its maximum dry density. Care must be taken to ensure that the compacted layer is ice-free at the time of placement. Lift thickness and compaction details will be determined on site based on site specific trials as stipulated in the Technical Specifications (SRK 2006b). Subsequent lifts may only be constructed once the previous lift has completely frozen and the surface is cleared of snow, ice and loose material.
- The transition and shell materials can be placed using material directly from stockpiles, with no special pre-conditioning. The lift thickness and compaction methods will again be determined on site based on material specific compaction trials.
- Monitoring instrumentation will be installed as part of the bulk earthworks. These instrument clusters will have to be protected from damage at all times, and must be continuously tested to ensure that they are operational. Special hand compacting equipment may be required to work in close vicinity to these instrument clusters.

It should be reiterated that although complete design details have been provided for the South Dam, the actual construction of the South Dam should be delayed until water balance predictions suggest that the dam construction is required. Once construction of the South Dam is commissioned, the procedures will be identical to what has been described above.

8.5.2 Spillway

As has been described previously, there is a real possibility that the spillway may never be put to use, and certainly, for at least 5½ years, the spillway will not be required. Therefore, although this report and all supporting documents provide complete detailed design information for the spillway, the spillway should not be constructed at the outset. Spillway construction should be delayed until such time that water balance prediction suggest that it would become necessary.

Irrespective, of when the spillway will be constructed, the construction should be carried out as follows:

- Clear, strip and stockpile the overburden soils to expose the bedrock along the spillway alignment.
- Drill and blast the bedrock to the required line and level for the spillway invert.
- Over-excavate and fill areas of the spillway that is not bedrock controlled, and clad with erosion resistant armouring.

- Over-excavate and fill exposed overburden cut slopes of the spillway to prevent permafrost degradation.

8.5.3 Pipelines

The installation of all pipelines must be done according the manufacturers specification and the Technical Specifications (SRK 2006b). Specialist contractors must be used to carry out pipe welds as well as seaming of the emergency dump catch basin liner.

8.5.4 Shoreline Erosion Protection

Placement of the shoreline erosion protection should be done as follows:

- Stake out the areas that require shoreline erosion protection and clear the snow from those areas.
- Place the geotextile directly onto the tundra, taking care to allow at least a 0.5 m overlap between layers.
- End dump and spread the run of quarry material, such that the finished surface is about 0.5 m thick, and has a smooth top surface that mimics the natural ground topography. The upslope perimeter of the erosion protection material must be shaped such that no natural runoff would be ponded behind the erosion protection layer.

9 TCA Operation

9.1 Dams

The dams have been designed to be fully operational for at least a 25-year design life, provided all the appropriate monitoring and maintenance are carried out (see next sections of this report). Since there are no active elements to the dams, there are no special operational procedures associated with the dams.

9.2 Spillway

If the TCA operates the way it is intended, the spillway will hopefully never have to be constructed. However, if it is constructed it has been designed as a passive spillway with no special operational requirements other than ensuring that the opening is not blocked as result of an ice jam. There is however, more that sufficient storage capacity in the TCA that even if an ice jam does occur, and zero outflow is allowed for the design flood, then the water level in the TCA will still be below the normal freeboard height of the North Dam, i.e. there will still be 100% containment with no risk to the dam integrity.

9.3 Tailings Deposition

Tailings deposition will be a continuous operation. The tailings slurry will be pumped from the mill to the TCA and deposition into the TCA will be via one of five discharge points along the eastern boundary of the TCA. A pre-planned deposition plan will be followed to ensure that the tailings surface remain as horizontal as practical, with manual changeover of the tailings deposition point as required.

When the TCA water surface starts to freeze, the discharge lines will be pushed through the ice such that tailings under no circumstances are deposited on the ice.

If for any reason tailings production stops, the tailings discharge line will be kept operational by recirculating reclaim water. This will prevent the need to dump the tailings line content into the emergency dump catch basins. If the tailings line must be decommissioned for any reason, the line will be flushed with reclaim water followed by fresh water. Once the pipe is filled with fresh water only, the line can be dumped, but the emergency dump catch basins can be bypassed.

When tailings deposition stops and the emergency dump catch basins are used to dump either tailings slurry or reclaim water, the emergency dump catch basins must be emptied out as soon as possible, preferably before the spill freezes. If the spill does freeze, a heating tent must be placed over the emergency dump catch basin, and the spill must be thawed and either pumped out or mechanically loaded onto a dump truck for disposal back to the TCA. Even though the emergency dump catch basins have been designed with sufficient capacity to contain at least two dumps plus an additional freeboard volume, cleanup should commence immediately after every spill.

9.4 Reclaim and Fresh Water Make-Up

The intent is to recover all reclaim water from the TCA. Therefore, for as long as there is sufficient water depth and the TCA supernatant at the reclaim pump inlet is sufficiently clear of suspended solids the reclaim pumps will remain active. If at any point the amount of reclaim from the TCA is no longer sufficient, the rest of the make-up water will be pumped from the fresh water make-up line in Doris Lake.

Whenever either one of these lines are decommissioned, they will be completely flushed with fresh water before being drained. Once flushed with fresh water the reclaim line does not have to be drained into the emergency dump catch basins, but can be diverted directly onto the tundra.

If for any reason tailings deposition stops, the reclaim line pumping will continue such that the reclaim water can be recirculated through the tailings discharge line. This will prevent unnecessary dumping into the emergency dump catch basins.

9.5 Discharge (Water Management Strategy)

The discharge (primary water management) strategy has been developed based on the results of a detailed water quality model for the TCA as documented in SRK (2006c). This section summarises the basic principles of the water management strategy. The primary objective of the TCA water management strategy will be to meet CCME guidelines for parameters of concern to protect freshwater aquatic life in Doris Creek, with the possible exception of nitrite. The key management and control components of the proposed discharge strategy will comprise:

- Real-time monitoring of flows in Doris Creek.
- Monitoring of water quality in Doris Creek and the TCA on a frequent basis.
- Managing the decant intake in the TCA to minimise suspended solids release.
- Use of the water quality results to determine allowable discharge rates.
- Controlling the discharge flow rate on a real-time basis.

The discharge strategy will be implemented as follows:

- Prior to commencement of milling, a low detection environmental laboratory will be set-up and analytical procedures developed, documented and verified. Sampling protocols will also be documented and verified.
- Two weeks prior to commencement of operations (assuming a spring start-up), water quality in the TCA and Doris Creek will be monitored every second day to establish baseline conditions.

- Real-time monitoring of the flows in Doris Creek will commence as soon as practical during the open water season. The pressure transducer would be connected to a programmable logic controller (PLC) that would record flows in Doris Creek and be used to control the discharge flow rate.
- During periods of active discharge, the flow level in Doris Creek will be monitored visually on a daily basis and checked against the real time monitoring results. For this purpose, a staff gauge will be installed at the location where the pressure transducer is located. The area will also be inspected on a daily basis for ice and any debris and cleared as required to ensure accurate monitoring of flows.
- Commencing with the start of tailings deposition, the TCA will be monitored for an additional two weeks every second day. As the dynamics of the system, i.e. rate of change in water quality, becomes better understood, the frequency of monitoring could be reduced.
- Before any discharge would commence, the TCA water would be submitted for toxicity testing and metals analysis. Only if the water meets MMER criteria will discharge from the TCA commence. The flow ratio would be calculated for each sampling event and adjusted as necessary. The discharge flow would be controlled by the automated flow control system which would use the real time flow monitoring in Doris Creek to control the discharge flow rate. Flow rates would automatically be logged by the flow control system.
- In subsequent years, it is anticipated that at the start of the open water season the analytical turnaround time will likely prevent discharge for the first few days. The downstream together with the upstream and TCA water quality monitoring results will be used to verify the performance of the discharge system at regular intervals and to make flow control adjustments as appropriate.
- As part of the control strategy, the actual water quality in the TCA will regularly be compared with the predicted water quality to assess the accuracy of the model. If necessary, the model may be recalibrated to the actual water quality observed in the TCA. The model would then be rerun to assess potential implications on the discharge strategy and to determine future operational requirements.

9.6 Operations Manuals

MHBL will prepare an Operation, Maintenance and Surveillance (OMS) Manual and an Emergency Preparedness Plan (EPP) prior to the start of operations at the TCA. These will be prepared in general accordance with the Dam Safety Guidelines published by the Canadian Dam Association (1999). The intent of the OMS Manual will be to provide mine personnel with descriptions of the equipment, tailings disposal, water management, equipment operation and monitoring procedures for the TCA.

The purpose of the EPP is to identify and evaluate potential emergencies in order to determine adequate preventive or remedial actions. The EPP will contain a notification process in case of an emergency situation and will incorporate preventive measures for situations or conditions that could be repaired or reduce the potential damage. The EPP will describe the actions to be taken in an emergency and will identify the various parties responsible for the actions and the agencies to be notified.

Copies of these plans will be issued to all parties that have responsibilities under the plan or that may be affected by the emergency situation. The EPP will be revised on annual basis to ensure that the site conditions still apply to the plan and that the contact information of the various parties is still valid.

10 TCA Maintenance

10.1 Dams

Dam maintenance will be determined each year after completion of the Dam Safety Inspection; however, it is likely that the following maintenance items would have to be completed every year:

- Some of the dam monitoring instrumentation may get damaged, either through natural wear and tear or perhaps as a result of animal damage, vandalism or accidents. Any damaged instrumentation will have to be repaired or replaced. Some of the instrumentation would also have to be recalibrated annually.
- Thermal modeling for the dams has shown that although the dam core and its foundation will remain well frozen, the upstream and downstream foundations will gradually thaw, and lead to settlement of those sections of the dam. Based on the findings of the Dam Safety Inspection, areas that have undergone settlement may have to be repaired by adding more fill.
- Snow drifts on the downstream toe of the dam will result in an insulating effect on the downstream toe, which may lead to more rapid thaw of the downstream foundation. If the snow is continuously cleared from this area, the dam may perform much better than the thermal modeling suggests, and therefore regular clearing of snow in this area is recommended.
- Every year the thermosyphons must be inspected and tested, and if necessary new CO_2 gas must be installed. Any damaged radiator fins must also be repaired or replaced.

10.2 Spillway

Spillway maintenance is limited to the following:

- During the freshet, regular inspections must be conducted to ensure that there is not an ice jam in the spillway entrance. If an ice jam is detected it must be cleared using appropriate equipment.
- The spillway invert must be inspected every year and any areas where there may be some subsidence must be in-filled and re-armoured.
- Immediately after a significant flood has passed through the spillway, the spillway must be inspected and any areas where the erosion protection material has been exposed, new material must be put in place.
- The overburden cut slopes must be inspected for signs of permafrost thaw. If such signs are detected, those areas must be repaired by whatever means are appropriate.

10.3 Pipelines

Routine pipeline maintenance tasks are as follows:

- *Pipeline:* At least once every six months all pipelines must be completely flushed with fresh water. Once every year, every pipeline must be pressure tested with fresh water to determine if there are any leaks.
- *Drain outlets:* The drain outlet pipes should be monitored during pipe drainage. Should a drop off in the flow rate be detected the pipe should be flushed out. This should be carried out using hydraulic cleaning equipment.
- *Pumps:* Maintenance of the pumps, seals, controls, instrumentation and electrics is to be carried in accordance with manufacturer's specifications.
- *Valves:* Maintenance of the isolating and check valves should be performed in accordance with manufacturer's specifications.
- *Flow- and hourmeters:* All flow and hourmeters must be annually serviced and recalibrated according to manufacturer's specifications.

10.4 Shoreline Erosion Protection

Maintenance tasks associated with the shoreline erosion protection works are as follows:

- Every year immediately before freeze-up the entire TCA shoreline must be inspected and areas where shoreline erosion is detected must be marked such that those areas can be clad when the ground is frozen.
- At any time during the summer months, if areas are detected along the TCA shoreline that is undergoing active shoreline erosion, silt curtains must be deployed such that any suspended matter will be contained. Physical erosion protection works will be carried out in those areas as soon possible.
- The six monitoring transects must be inspected, surveyed and routine maintenance must be carried out on the instrumentation to ensure that the instruments are in working order.
- If at any point during the life of the TCA, the suspended sediment concentration in the TCA exceeds the MMER value of 15 mg/L at the point of discharge, a silt curtain will be installed around the discharge uptake. At such time, water quality monitoring will be done both upstream and downstream of the silt curtain to ensure the success and integrity of the curtain.
- If the TSS concentration downstream of the silt curtain (if required) exceeds the MMER value before the TCA reaches FSL, or would not meet CCME Guideline values at the designated monitoring point downstream of the waterfall in Doris Creek during discharge, no water will be discharged.

11 TCA Monitoring

11.1 Dams

11.1.1 Routine Visual Inspections

Mine operations staff must carry out daily visual inspections of both dams, taking note of any signs of settlement, unaccounted for drops in water levels, signs of seepage, or any signs of damage or vandalism to instrument clusters. Records of these daily inspections must be documented in a site dairy, to be completed by the person carrying out the inspection. This inspection should also trigger actions such as snow clearing of the downstream dam abutments.

11.1.2 Annual Dam Safety Inspection

Annually, a suitably qualified Professional Engineer registered in the Nunavut Territory must undertake a personal physical inspection of the dams. This inspection must be carried out in the summer and must culminate in a detailed Dam Safety Inspection Report. The report must include findings and recommendations on the dam performance taking into account the personal inspection observations, interviews with mine operations staff responsible for the dams, as well as a review and analysis of all detailed monitoring data for the dams. This report must be delivered in a timely manner so that, if required, mitigation measures can be carried out to address any areas of concerns regarding the dams.

11.1.3 Instrumentation

Detailed monitoring instrumentation has been included in the dam design, as indicated in Dwg. T-09 and T-10. This equipment is used to monitor the thermal and deformation regime of the dams, and include the following:

- *Survey monitoring points:* 28 locations on the North Dam, along 7 transects, and 22 locations on the South Dam, along 6 transects. These monitoring points will consist of vertical settlement plates installed along the up- and downstream dam slopes to monitor the toe settlements, as well as along the dam crests to monitor core settlement. These stations must be manually read at least once a month.
- *Vertical thermistors:* 12 locations on the North Dam, along 4 transects, and 9 locations on the South Dam, along 3 transects. These thermistors will monitor the temperature of the foundation up- and downstream of the core. Manual reading of these strings will be required at least once a month. A continuous data logger recording daily values will be required along the most critical transect.
- *Horizontal thermistors:* 4 transects on the North Dam and 3 transects on the South Dam. These thermistors will monitor the temperature across the entire base of the core. Manual

reading of these strings will be required at least once a month. A continuous data logger recording daily values will be required along the most critical transect.

Other instrumentation, not directly linked to the dam, but that would provide necessary data to allow evaluation of the dam performance will include:

- *Weather station:* Detailed climatic data will be continuously recorded with a site specific weather station, which is already part of the monitoring program for the Doris North site.
- *Water level monitor:* The water level in the TCA will be continuously monitored by means of at least two submerged pressure transducers.
- *Bathymetric surveys:* Annually, a bathymetric survey will be completed to confirm the status of the deposited tailings surface.

11.2 Spillway

There will be no formal instrumentation in the spillway. Visual inspections of the facility will be undertaken as part of the daily operational inspections by the mine operations staff, and the facility will also be part of the annual Dam Safety Inspection.

11.3 Pipelines

Mine operations staff must carry out daily visual inspections of all pipelines, pump stations and emergency dump catch basins. The following information must be recorded in dedicated site logbooks, using a consistent format:

- *Pump stations:* Document which pumps are operational, how many hours each pump has operated and note the discharge and suction pressures of operational pumps. Carry out checks for leaks and spillages, and confirm oil levels for all pumps, and seals on water pumps for the tailings pumps. Take note of any alarms and messages.
- *Pipelines:* Record which pipelines are operational, and for how long they have been operating. Record the flowmeter data and the operating pressures along the pipelines. Check pipelines for any leaks and blockages and take note of any hazards along the pipeline route. Check the system for any alarms and messages (such as mal-function of the electric heat tracing cable inside the pipeline during freezing temperatures). Also record where actual tailings deposition has taken place in the previous 24-hour period.
- *Emergency dump catch basins:* Record the status of each emergency dump catch basin, and trigger any maintenance works such as snow clearing or emptying of a spill.

11.4 Water Quality

Detailed water quality monitoring will be required for to ensure adequate operation of the discharge strategy. Complete details of this monitoring are provided in SRK (2006c); however, for completeness these requirements are summarized as follows:

- *TCA:* The intake to the discharge pipeline will be located on a floating barge within the northern part of the TCA, about 1.5 m below the water surface. Three water samples will be obtained from the barge at depths of 1 m, 1.5 m and at 2 m to represent the intake water quality. The monitoring will initially be undertaken every second day, but may be reduced to weekly or less should the data indicate that the rate of change in water quality is small. Similarly, if the samples taken at different depths are shown to vary little, then sampling may be reduced to duplicate samples at the pipe intake depth.
- *End of pipe discharge:* The frequency of sampling and analysis is specified in the MMER to be weekly, at least initially, for regulated parameters. However, there is provision to reduce the frequency of analysis for some parameters based on the results obtained. These results will be correlated with the intake water quality results for further confirmation that the intake monitoring results reasonably reflect actual discharge water quality.
- *Doris Creek upstream of weir:* The upstream water quality samples for Doris Creek will be obtained upstream of the flow monitoring weir, as dictated by site conditions. Sampling will initially be undertaken every second day to coincide with the intake monitoring samples. As for the intake sampling, the frequency may be reduced to weekly should the data indicate that the rate of change in water quality is small.
- *Doris Creek downstream of waterfall:* Doris Creek downstream of the waterfall will be monitored only during periods of active discharge. The sample location will be established approximately 30 to 50 m downstream of the waterfall, as dictated by site conditions, to ensure that complete mixing of the TCA discharge and Doris Creek had occurred. Sampling will initially be undertaken every second day. As the discharge control strategy is refined and proven to meet discharge objectives, the frequency of sampling may be reduced.
- *Embankment seepage:* If evident, toe seepage at the North and South Dams will be sampled and monitored on a weekly basis. If flows become significant, the seepage will be collected and pumped back to the TCA.
- *Mill effluent:* Mill tailings discharge water will be monitored at a location after all of the effluent streams have been combined into a single flow. Initially the water quality will be sampled daily and composited over a two day period. Depending on the variability in the tailings effluent water quality, the composite period may be increased and the frequency of analysis reduced.

11.5 Shoreline Erosion Protection

Mine operations staff must carry out daily visual inspections along the entire TCA shoreline taking note of, and recording any signs of shoreline erosion. In addition, the following permanent instrumentation (as illustrated in Dwg. T-14) will be installed around the TCA perimeter (note that some of this instrumentation has already been put in place):

- *Thermistors:* 6 vertical thermistors have been installed along 6 important transects of the TCA perimeter, between elevations 28.3 m and 33.5 m. These thermistors will monitor the temperature profile in the overburden soils as the water level rises, giving advance warning of thaw. This data must be collected manually at least once a month.

- *Survey transects:* 6 detailed strip surveys along the same six transects where the thermistors are installed will be monitored such that the extent of shoreline erosion can be determined. Each strip will be 50 m wide. Strip surveys should be redone annually, including a bathymetry survey of the underwater section of the strip down to the original TCA water level of 28.3 m (this should continue for five years after the FSL is reached or till there is no discernable profile difference in any two consecutive years). This will provide information of the slope morphology as time progresses, as well as allow for calculation of a sediment balance.

The annual Dam Safety Inspection Report must include a detailed section that discusses and addresses the status of any shoreline erosion processes, and must recommend if necessary any remedial action that must be carried out.

12 TCA Closure Methodology

12.1 General

The TCA closure plan is described as part of the Doris North Project Abandonment and Closure Plan (MHBL 2006). A summary of some of the underlying closure principles as it relates to the closure of the TCA is provided here. The main closure components relating to the TCA include:

- Continued active water management until such time as the water quality in the TCA returns to acceptable discharge standards;
- Establish a suitable water cover over the tailings; and
- Breach the North Dam to allow the TCA catchment to revert back to its pre-deposition hydrologic cycle.
- The South Dam will remain in place.

12.2 Water Management

Active water management of the TCA will continue, either through active discharge via the discharge pump system, or through natural discharge via the spillway. Once the water quality in the TCA has returned to background water quality, containment of the TCA is no longer required, and the North Dam can be breached.

12.3 Water Cover

The final TCA closure require a permanent water cover of at least 3 m above the highest tailings elevation in the impoundment. Research has shown that a minimum stagnant water cover of 0.3 m is sufficient to prevent oxidization of tailings. Tailings can however be re-suspended due to wave action induced by environmental factors, and therefore the rule of thumb is to design a water cover of at least 1 m thick. Based on the orientation of the TCA, the predominant wind direction, maximum wind speeds, and the particle size of the tailings, the actual minimum water cover depth for the TCA has been calculated to be at least 2 m thick. A 3 m thick water cover was subsequently selected as the design criteria, which constitutes a factor of safety of 1.5, which seems reasonable to account for uncertainty. Complete details of the minimum water cover thickness design calculations are presented in Appendix C.

The maximum tailings surface in the TCA is expected to be below 24.3 m, which implies that the minimum final water elevation in the TCA must be at 27.3 m to ensure compliance with the design criteria. In actual fact, since the water level in the TCA will return to its pre-deposition elevation of 28.3 m once the North Dam is breached, the water cover will be at least 4 m thick offering an overall factor of safety of 2.

12.4 North Dam Breach

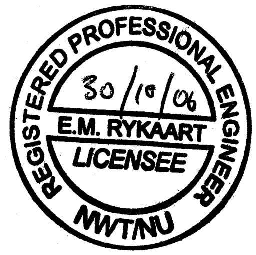
Prior to breaching the North Dam, any water in the TCA above elevation 28.3 m will be pumped via the discharge system into Doris Creek. Discharge of the excess water will be done using the same basic criteria as that used during the active discharge phase. Depending on the volume of water that has to be discharged, this draw-down period could be more than one discharge season.

Once the water level in the TCA is at 28.3 m, the North Dam will be breached by cutting a slot through the North Dam, down to the original pre-construction elevation. The slot will measure about 20 m wide, with 4H:1V side slopes on either side. The cut slopes will be covered with a 2.5 m thick layer of run of quarry material to ensure physical and thermal stability.

Tail Lake outflow will be re-established along the base of the slot cut, and suitable bedding material will be put in place to ensure erosional stability of the channel.

This report, "**Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada"**, was prepared by SRK Consulting (Canada) Inc.

Prepared by



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