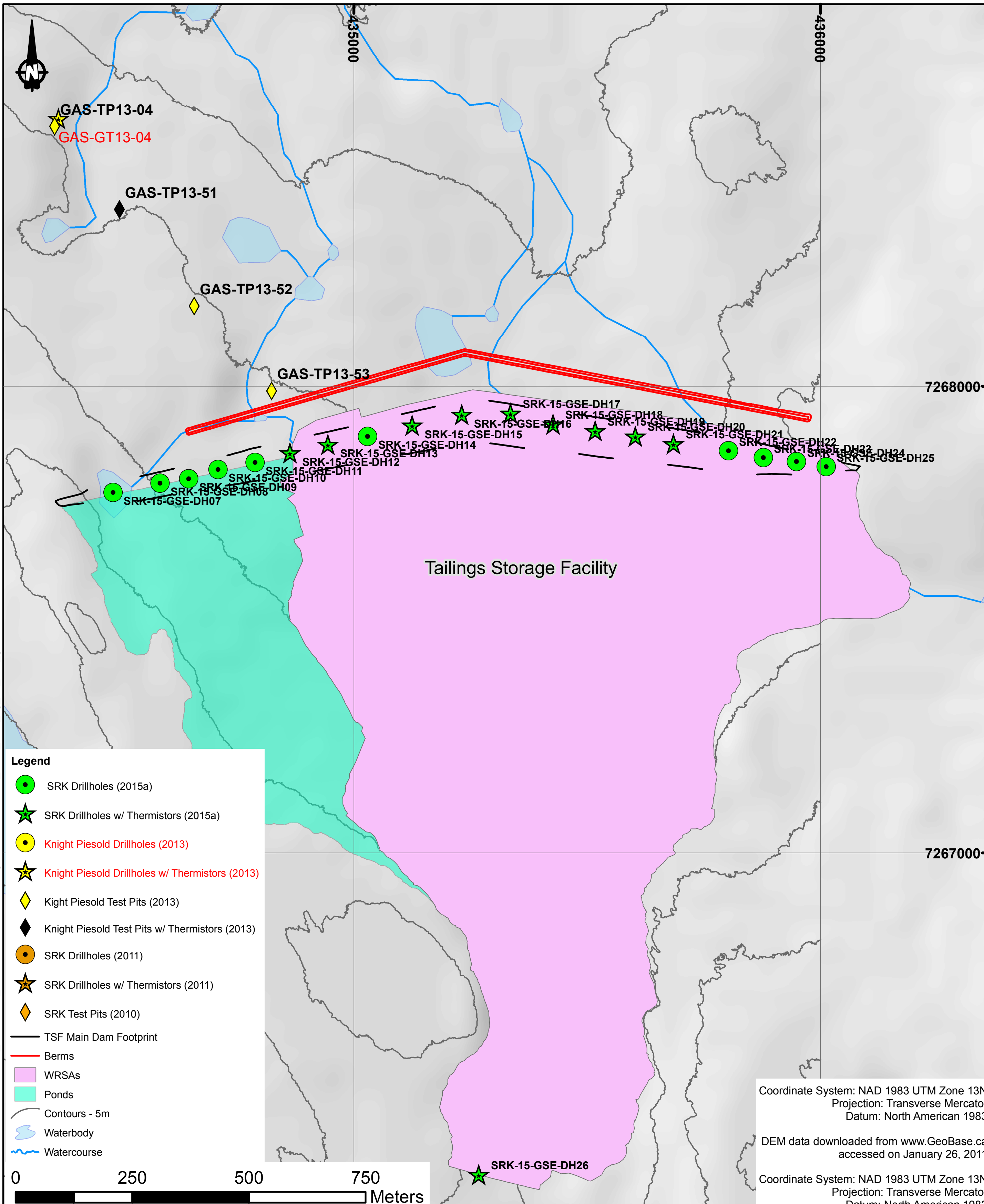

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GEOTECHNICAL DESIGN PARAMETERS

Overburden Investigations - Goose TSF

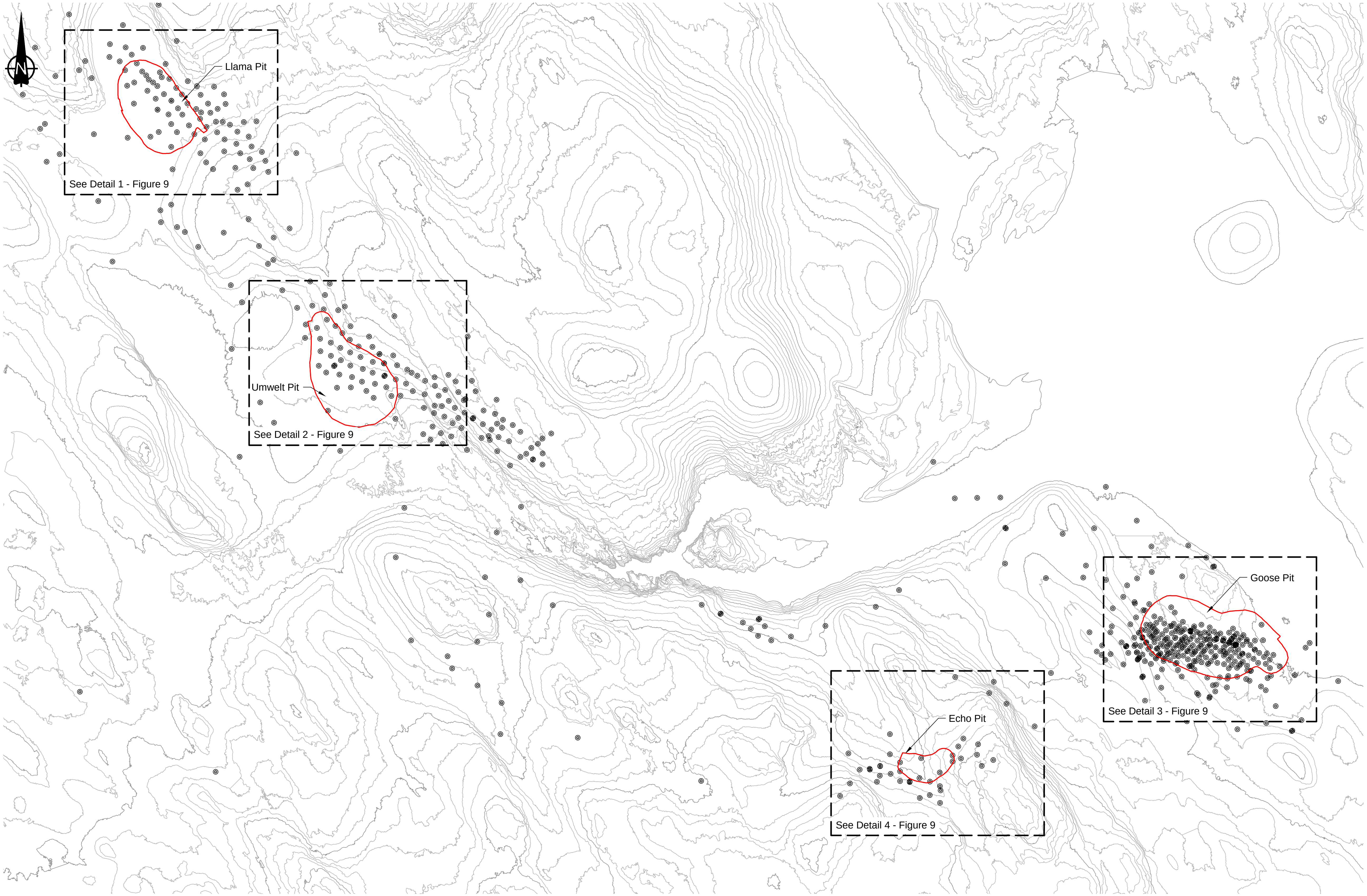
Job No: 1CS020.008

Filename: 1CS020.008_back_river_fig_07_ovb_goose

Back River

Date:	Approved:	Figure:
November 2015	EH	7

Path: \\VAN-SVR0\Projects\01_SITES\Back River\1CS020.008_Back River\1CS020.008_FEIS\040_AutoCAD\GIS\1.MXD Figures\1CS020.008_back_river_fig_07_ovb_goose.mxd



LEGEND

- Drillhole Location
- Pit Outline
- 1m Contours

NOTES

1. All drillhole locations and depths to overburden provided by Sabina.
2. Isopachs based on all drilling completed up to April, 2015
3. Pit outlines based on current FS mine plan provided by Sabina.
4. Topographic contour data provided by Sabina and is based on 2012 aerial photography. Contour intervals are 2.0m.
5. The coordinate system is UTM NAD83 Zone 13.

0 100 200 300 400 500
Scale in Metres

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GEOTECHNICAL DESIGN PARAMETERS

GOOSE PROPERTY
PIT LOCATIONS

SRK JOB NO.: 1CS020.008	BACK RIVER	DATE: November 2015	APPROVED: EH
FILE NAME: 1CS020.008-OB.dwg		FIGURE: 8	

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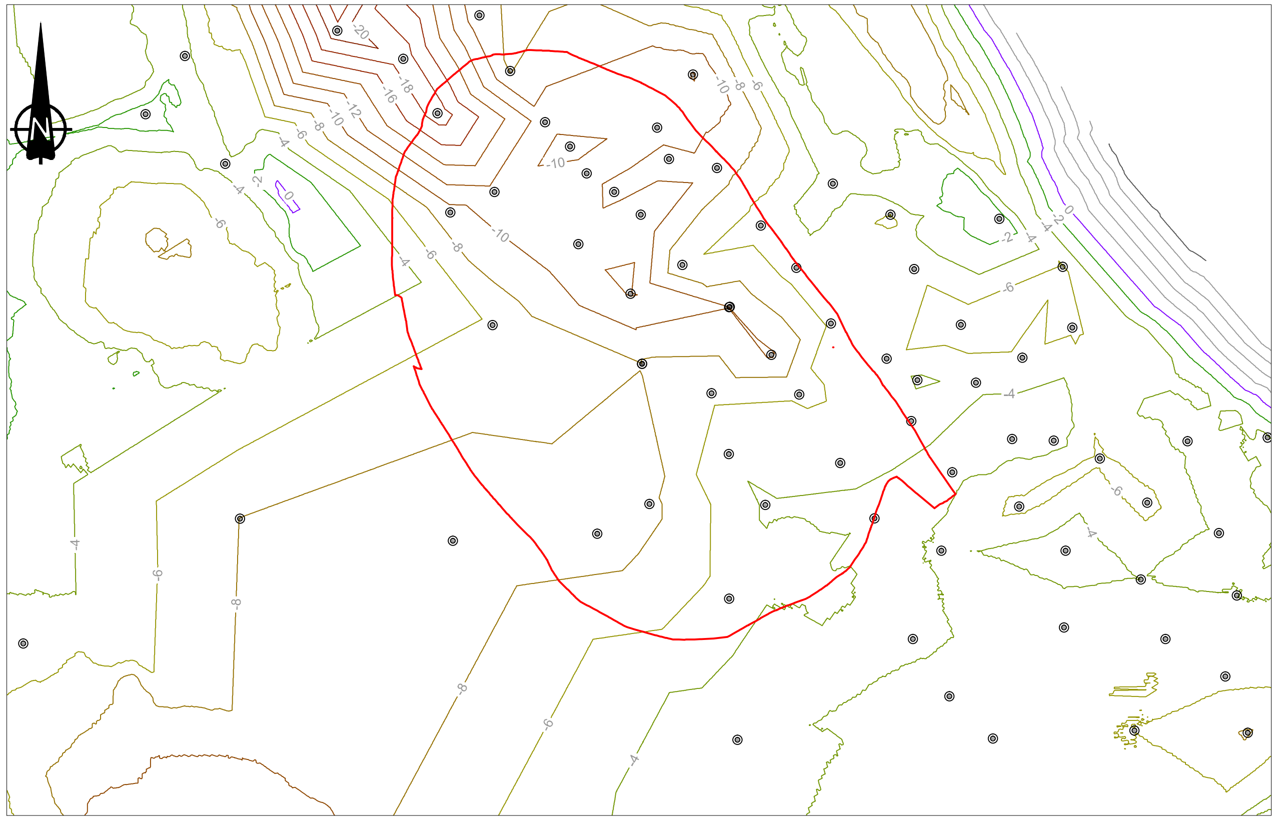
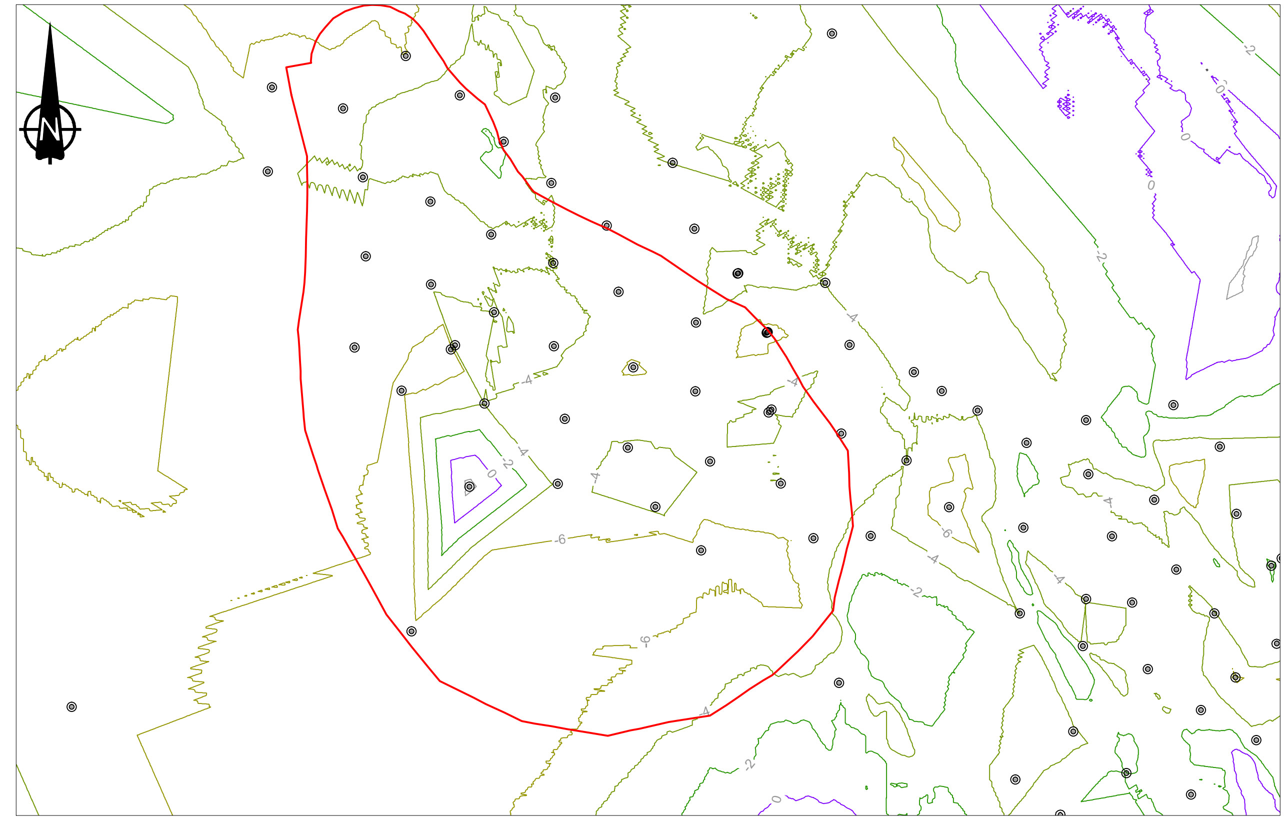
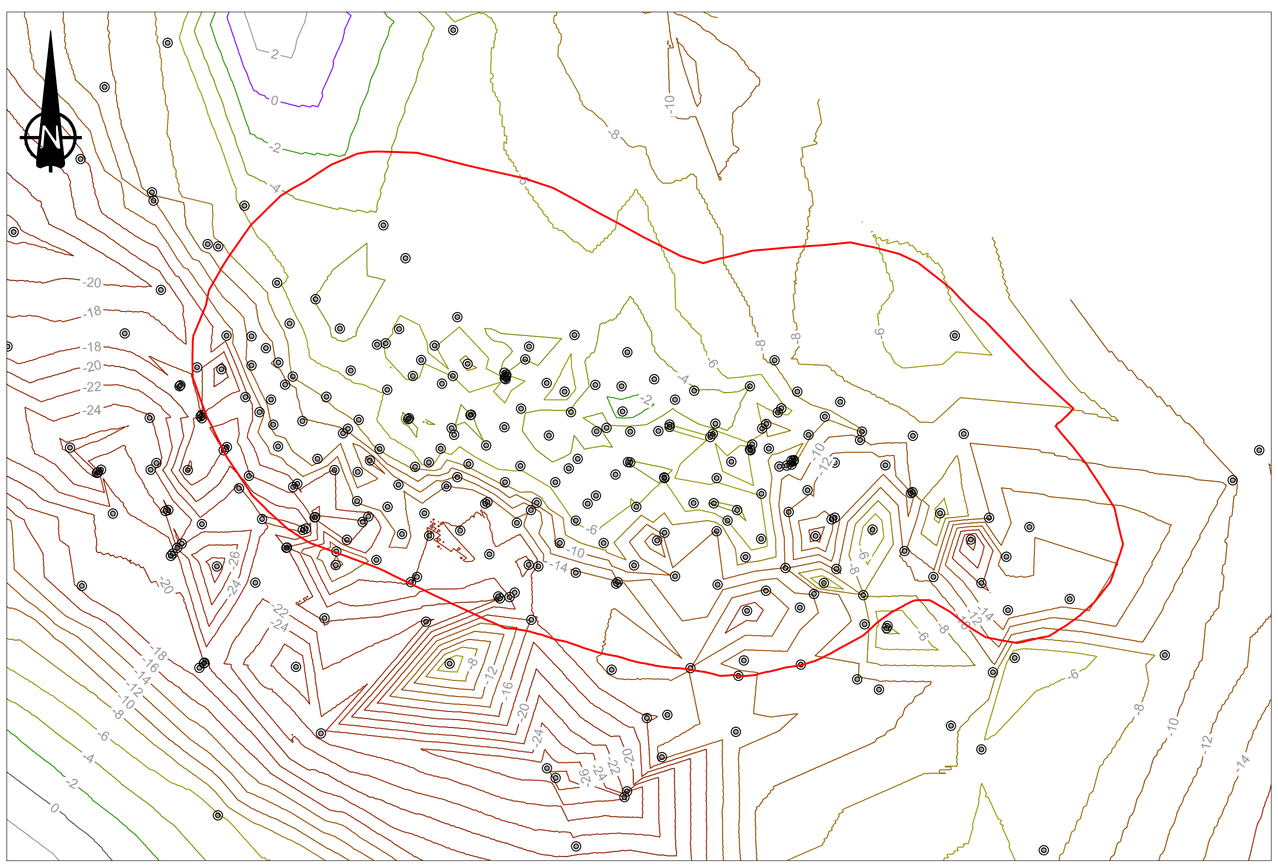
Detail 1 - Llama Pit



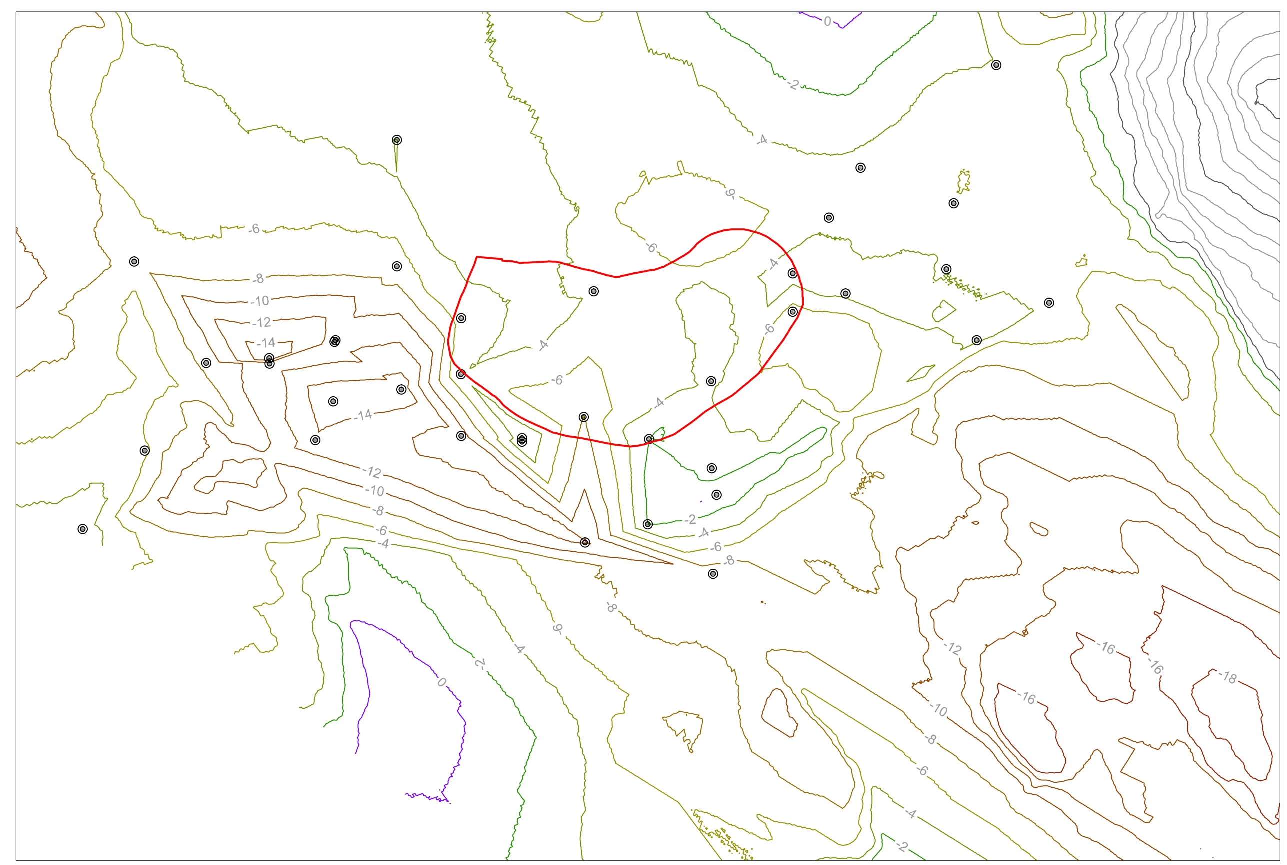
Detail 2 - Unwelt Pit



Detail 3 - Goose Pit



Detail 4 - Echo Pit



LEGEND

- Drillhole Location
- Pit Outline

OVERBURDEN THICKNESS (m)

- 45 to 25
- 25 to 15
- 15 to 10
- 10 to 8
- 8 to 6
- 6 to 4
- 4 to 3
- 3 to 2
- 2 to 1
- 1 to 0

NOTES

1. All drillhole locations and depths to overburden provided by Sabina.
2. Isopachs based on all drilling completed up to April, 2015.
3. Pit outlines based on current FS mine plan provided by Sabina.
4. Overburden isopach created using AutoCAD Civil3D 2014.
5. The coordinate system is UTM NAD83 Zone 13.

0 30 60 90 120 150
Scale in Metres

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SRK JOB NO.: 1CS020.008
FILE NAME: 1CS020.008-OB.dwg

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BACK RIVER

GEOTECHNICAL DESIGN PARAMETERS

GOOSE PROPERTY
OVERBURDEN ISOPACHS

DATE: November 2015 | APPROVED: EH | FIGURE: 9

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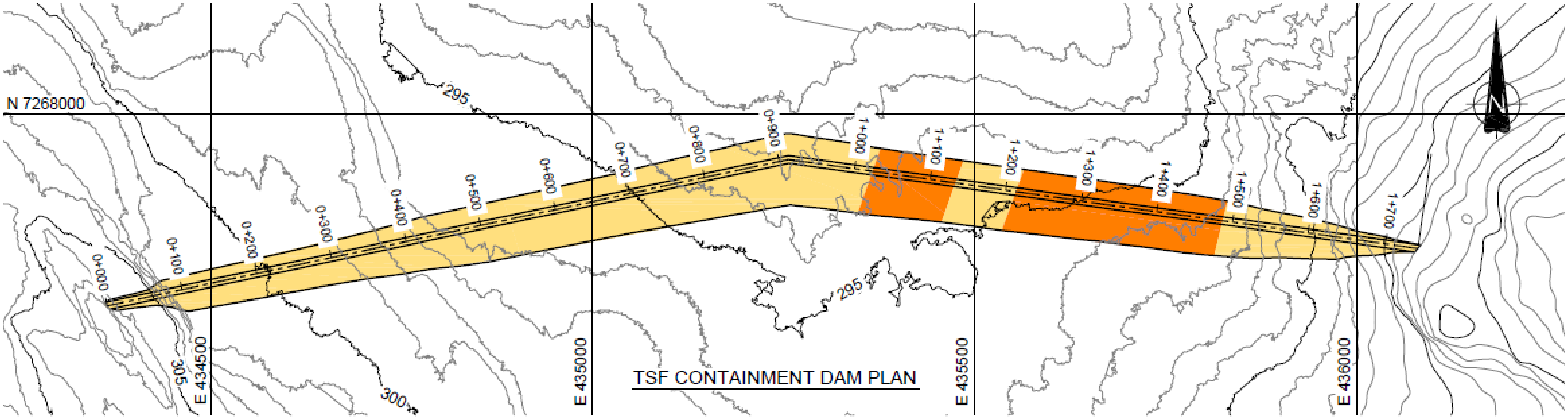
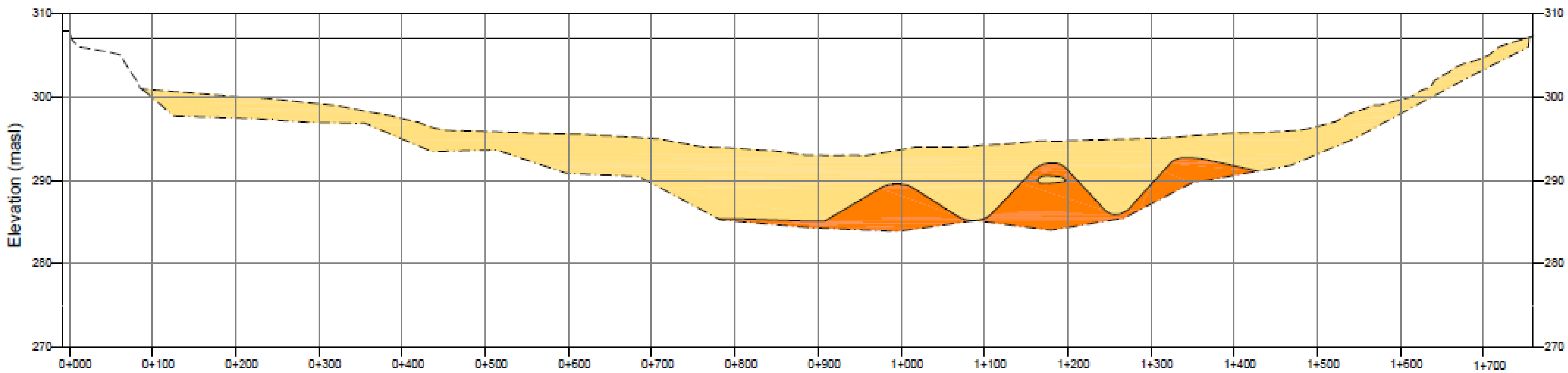


TSF CONTAINMENT DAM PLAN



CENTRELINE TSF DAM PROFILE

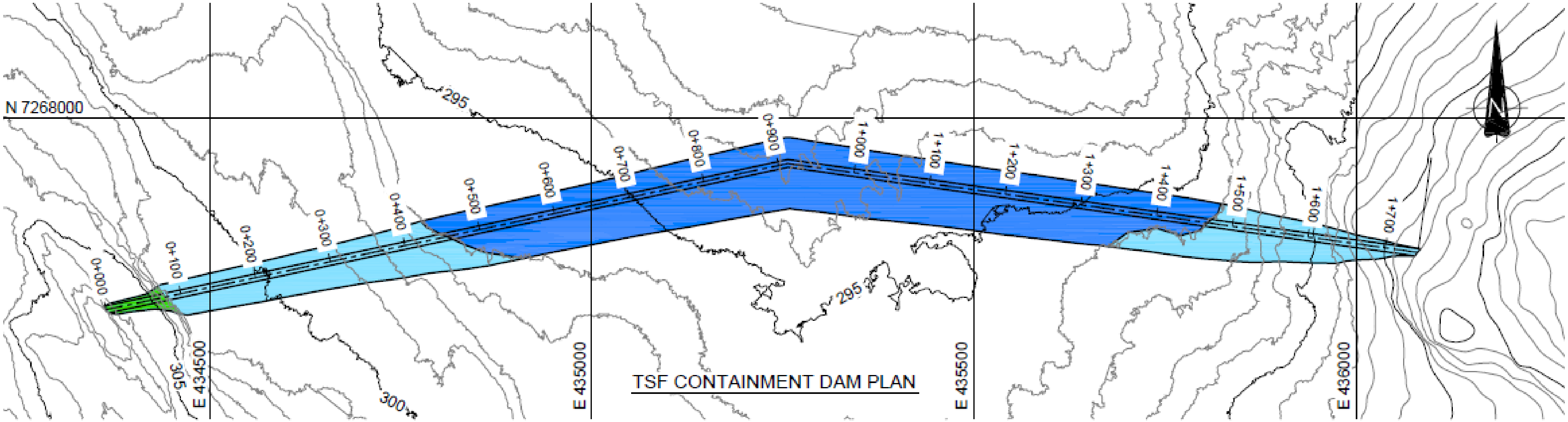
10x Exaggeration

LEGEND

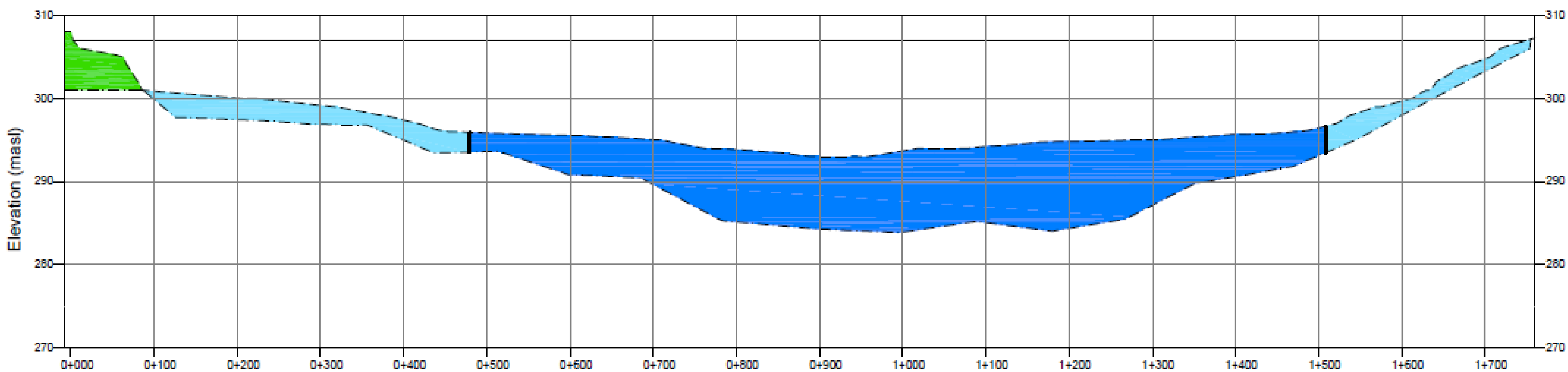
- Ground Surface
- Bedrock Surface
- Silt
- Sand

Source: Tailings Management System Preliminary Design Report, Back River Property, Nunavut, Canada (SRK 2015)

srk consulting	Sabina Gold & Silver Corp.	GEOTECHNICAL DESIGN PARAMETERS
		TSF Foundation Overburden Distribution
Job No: 1CS020.008 Filename: Fig10-12_TSFFoundationZones+Temps_20151103	Back River	Date: November 2015 / Approved: EH / Figure: **10**



TSF CONTAINMENT DAM PLAN



CENTRELINE TSF DAM PROFILE

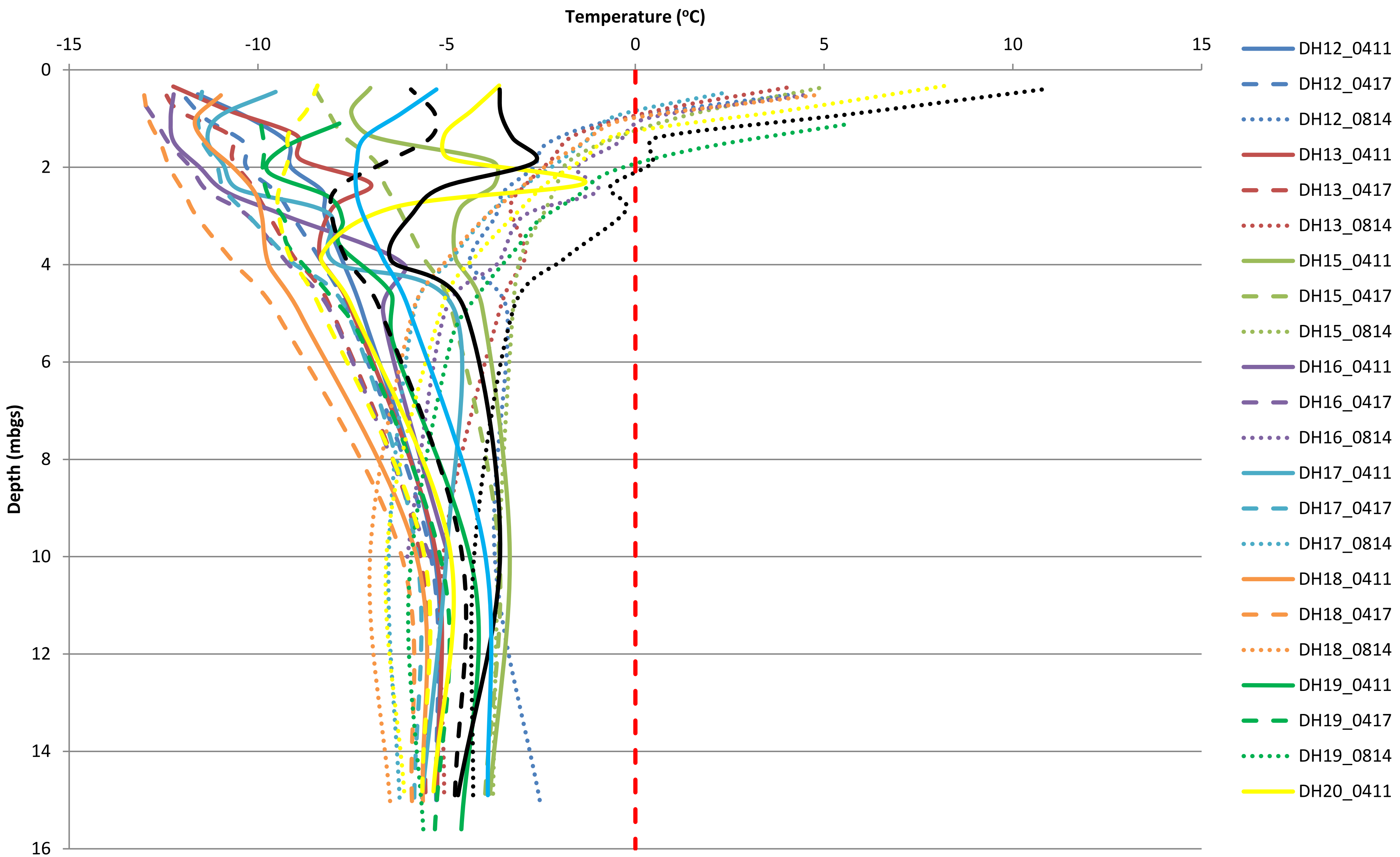
10x Exaggeration

LEGEND

- Ground Surface
- Bedrock Surface
- 10% - 30% Excess Ice Content and Massive Ice
- 0% - 5% Excess Ice Content
- Bedrock Outcrop

Source: Tailings Management System Preliminary Design Report, Back River Property, Nunavut, Canada (SRK 2015)

srk consulting	Sabina GOLD & SILVER CORP.	GEOTECHNICAL DESIGN PARAMETERS
		TSF Foundation Permafrost Distribution
Job No: 1CS020.008 Filename: Fig10-12_TSFFoundationZones+Temps_20151103	Back River	Date: November 2015 / Approved: EH / Figure: **11**



Source: ThermistorReadings_2015OBProgram_1CS020.009_rev1_eh_ts

srk consulting

Sabina GOLD & SILVER CORP.

GEOTECHNICAL DESIGN PARAMETERS

TSF Ground Temperature Measurements

Job No: 1CS020.008

Filename: Fig10-12_TSFFoundationZones+Temps_20151103

Back River

Date: November 2015

Approved: EH

Figure: 12

Appendix A
Goose and MLA Seismic Hazard Analyses

2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: , September 22, 2014

Site Coordinates: 65.5421 North 106.4266 West

User File Reference: Goose Property

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
0.095	0.057	0.026	0.008	0.036

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.011	0.035	0.055
Sa(0.5)	0.007	0.022	0.034
Sa(1.0)	0.003	0.011	0.016
Sa(2.0)	0.001	0.003	0.005
PGA	0.003	0.011	0.019

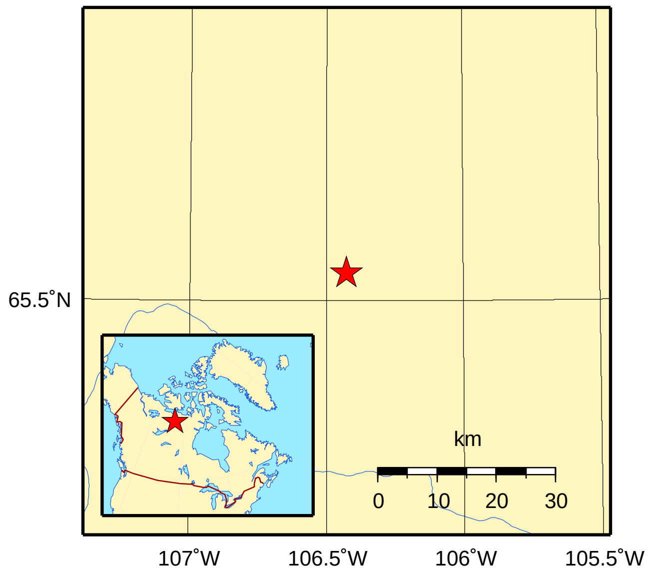
References

National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543 (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information



Aussi disponible en français

2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: , September 22, 2014

Site Coordinates: 66.65 North 107.6873 West

User File Reference: Marine Laydown Area

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
0.095	0.057	0.026	0.008	0.036

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.011	0.035	0.055
Sa(0.5)	0.007	0.022	0.034
Sa(1.0)	0.003	0.011	0.016
Sa(2.0)	0.001	0.003	0.005
PGA	0.003	0.011	0.019

References

National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

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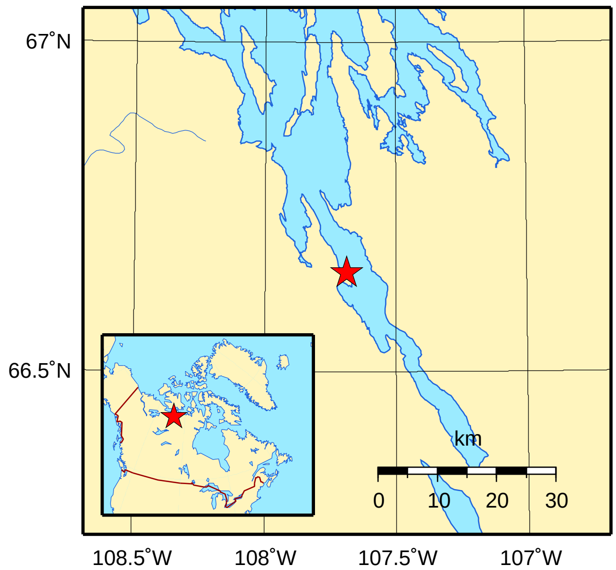
Aussi disponible en français



Appendix B
Thermal Modelling to Support Granular Pad Design Technical Memo

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4700 Business Park Blvd
Anchorage, Alaska 99503

T: +1 907 677 3520
F: +1 907 677 3620

anchorage@srk.com
www.srk.com

Memo

To:	Project File	**Client:**	Sabina Gold & Silver Corp.
From:	Christopher W. Stevens, PhD	**Project No:**	1CS020.008
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	October 14, 2015
Subject:	Thermal Modelling to Support Run-of-Quarry Pad Design – Final		

1 Introduction

The Back River Project (the Project) is a proposed gold project located south of Bathurst Inlet in the West Kitikmeot region of Nunavut. The Back River Property (the Property) is located in the continuous permafrost region of Canada, and the overburden soils consist of silts and sands, which in some areas are ice rich. These soils, if thawed, may not have sufficient bearing capacity to support important surface infrastructure such as roads or building foundations. Therefore, these structures must be founded on bedrock with the excavation of the overburden soils, or alternately the overburden soils must be kept frozen.

For the Project, infrastructure is proposed at two areas; the Marine Laydown Area (MLA) and the Goose Property. This memo presents thermal modelling carried out to determine the minimum run-of-quarry (ROQ) (or geochemically suitable run-of-mine (ROM) waste rock) pad thickness required to ensure that the underlying overburden soils remain frozen. This includes consideration of heated buildings and a depressed freezing point as a result of entrained pore water salinity.

The thermal modelling was performed for an operating design life of 20 years with no allowance for climate change. The majority of structures will have a functional design life of 15 years with select roads and the airstrip being operational for up to 20 years. At Closure these pads will remain; however, since they no longer have to functionally perform as a structural foundation, thaw settlement and consolidation is acceptable.

2 Climate and Permafrost

The proposed Property is located within a zone of continuous permafrost in the West Kitikmeot Region of Nunavut (approximately 66°N and 106 to 107°W). The base of the permafrost is estimated to range from 490 to 570 meters below ground surface (mbgs) using the 0°C isotherm, with a reported geothermal gradient of 0.013 to 0.014°C/m (Rescan 2014a). Ground temperature measurements indicate taliks are present beneath the larger lakes (e.g. Llama Lake).

Property and regional climate parameters were reviewed to support selection of the model input parameters provided in Section 3.2.

2.1 Air Temperature

Rescan (2014b) presents the available baseline meteorological data collected from the two Property areas; Goose Meteorological Station, and Bathurst Inlet Station located south of the MLA. In addition, data from the George Meteorological Station, located about 50 km north of Goose Property, provides additional site specific data.

Mean annual air temperatures (MAATs) for the period of record were calculated to be -10.6°C at the Goose Station, -9.9°C at the George Station, and -8.7°C at the Bathurst Inlet Station. The completeness of air temperature record is variable for each of these stations.

Regional air temperatures were reviewed and analyzed to establish MAAT for a recent 10 and 30-year period. Local air temperature data was correlated with two nearby meteorological stations operated by Environment Canada: Lupin A Station (ID: 23026HN) and Lupin LC Station (ID: 230N002). These sites are located approximately 220 km to the west of the Goose Meteorological Station.

Table 1 presents the linear regression established between each of the meteorological stations. The average residual error from measured and modelled values was 0.25°C for the Goose Meteorological Station and 0.28°C for the George Meteorological Station.

Table 2 shows measured and modelled MAAT for the extended periods of time. The modelled MAAT for the period of 2003-2012 (recent 10-year period) is -10.9°C and -10.5°C for the Goose and George stations, respectively.

Table 1: Correlation of Monthly Air Temperature between Meteorological Stations

Correlated Sites	Linear Regression Equation	R^2[1]
Lupin CS and Lupin A Stations	MATLupin_CS = 1.0205*(MATLupinA) - 0.0316	0.9908
Lupin CS and Goose Stations	MATGoose = 1.0291*(MATLupin_CS) + 0.3267	0.9924
Goose and George Stations	MATGeorge = 0.9881*(MATGoose) - 0.2481	0.9986

1. R-squared (R^2) indicates the correlation coefficient of the regression line.

Table 2: Measured and Modelled MAAT for Goose, George, and Bathurst Inlet Meteorological Stations

Site	Period	MAAT(1)	Amp.(2)	FDDa(3)	TDDa(4)
Goose Station					
Measured[5]	2004-2013	-10.6	21.6	-4,790	972
Modelled	2003-2012 (10 year period)	-10.9	21.7	-4,892	945
Modelled	1983-2012 (30 year period)	-11.1	22.2	-4,972	965
George Station					
Measured[5]	2006-2013	-9.9	21.0	-4,561	965
Modelled	2003-2012 (10 year period)	-10.5	21.4	-4,729	929
Modelled	1983-2012 (30 year period)	-11.0	21.9	-4,919	931
Bathurst Inlet Station					
Measured[6]	2007-2013	-8.7	22.0	-4,304	1,148
Modelled	1996-2005 (10 year period)	-	-	-	-
Modelled	1983-2005 (24 year period)	-9.7	20.9	-4,483	982

1. Mean Annual Air Temperature (°C) = MAAT.
2. Amplitude of air temperature wave (°C) = Amp.
3. Air Freezing Degree Days (°C · d) = FDDa.
4. Air Thawing Degree Days (°C · d) = TDDa.
5. MAAT calculated from measurements recorded over consecutive 12 month period.
6. MAAT calculated from available monthly temperatures recorded over multiple years.
7. Hyphen (-) indicates value cannot be calculated from the available data.

2.2 Mean Annual Ground Surface Temperature

Thermistor cables (*aka* ground temperature cables) have been installed for purposes of collecting baseline ground temperature data collected between 1997 and 2015. A summary of the instrumented sites installed between 1997 and 2013 are provided by Rescan (2014a).

Mean annual ground surface temperatures (MAGSTs) were assessed for sites where temperatures have been recorded at the appropriate depth and frequency to produce representative measurements. For purposes of this memo, MAGST is calculated for depths ranging from 0.25 to 0.75 mbgs due to the availability of data and lack of a common standardized depth among each site. It is recognized that MAGSTs are typically calculated from temperatures measured at a depth of 0.02 to 0.05 mbgs.

Table 3 shows the calculated MAGST for five (5) sites based on available data. The MAGST is calculated to range from -6.4°C to -7.0°C, with an average of -6.7°C for the period of May 26, 2013 to May 6, 2014. Interannual variability in MAGST can be expected in response to differences in annual air temperature, snow conditions, and other environmental factors.

Active layer thickness (ALT) has been measured from ground measurements to range from 1.3 m to 4.1 m, with an average of 2.1 m (Table 3). The ALT can also be expected to vary across terrain with variable organic ground cover, soil type, moisture content, and other microclimatic conditions which impact heat transfer in the ground. Interannual variability in ALT may be strongly attributed to differences in thawing-season air temperature and duration.

Near surface ground temperature (NSGT) calculated near or below the depth of annual temperature variation in the ground (i.e. depth of zero annual amplitude) is shown in Table 3. The NSGT have been reported for measurements at a depth less than 30 mbgs due to availability of near surface data. The range in NSGT was -4.7°C to -7.5°C, with an average of -6.3°C. Ground temperature measurements are not available for the MLA.

Table 3: Summary of Shallow Ground Temperatures for Sites Located within the Goose and George Properties

Thermistor Cable	Soil Type[1]	ALT (m)[1,2]	MAGST (°C)[3]	NSGT (°C)[1,4]
GAS-GT13-01	Organic, fine sand	1.3	-6.8	-6.3
GAS-GT13-02	Fine to coarse sand	2.0	-7.0	-5.7
TIA-GT13-10	Peat and silty sand	-	-	-7.3
TIA-GT13-15	Peat and cobble, bedrock at 0.3 m bgs	4.1	-6.8	-5.6
TIA-GT13-16	well-graded sand	2.3	-6.7	-6.5
08-GSE-009	NA	1.3	-6.4	-6.4
11-GL-10	NA	1.5	-	-6.5
13-GRL-115	NA	-	-	-4.7
13-GRL-124	NA			-7.5
13-GRL-129	NA	-	-	-6.5
13-GRL-130	NA	-	-	-6.8
13-GRL-133	NA	-	-	-6.9
13-GSE-279	NA	-	-	-6.0
13-GSE-314	NA	-	-	-4.8
	Average	**2.1**	**-6.7**	**-6.3**
	Min	**1.3**	**-7.0**	**-7.5**
	Max	**4.1**	**-6.4**	**-4.7**

1. Information from Rescan (2014a), values modified following collection of additional data and review of data.
2. Active Layer Thickness (m) = ALT.
3. Mean Annual Ground Surface Temperature (MAGST) for sensors between 0.25 and 0.75 mbgs.
4. Near surface Ground Temperature (°C) (NSGT), average based on sensors at a depth less than 30 mbgs.
5. NA Indicates information is not available and hyphen (-) indicates value cannot be estimated from the available data.

3 Thermal Modelling

3.1 Approach

Thaw depth estimates were based on analytical and numerical models. Numerical simulation of conductive heat transfer under transient conditions was completed using the finite element model SVHeat version 6 developed by SoilVision Systems Ltd. and FlexPDE Version 6.12 developed by PDE Solutions Inc. (SoilVision Systems 2004). SVHeat one-dimensional (1D) model simulations were used to estimate thaw depth for areas not impacted by heated buildings (Section 4.1). Thaw depths beneath non-insulated buildings were based on a steady-state thermal model (Section 4.2). Further details of the steady state model can be found in Andersland and Ladanyi (2004). Thaw depths beneath insulated buildings were estimated using SVHeat two-dimensional (2D) model simulations (Section 4.3).

Multiple foundation temperatures (0°C, -1°C, and -2°C) were analyzed to gauge the sensitivity of the results to changes in ROQ pad and/or insulation thickness. For design purposes, foundations were considered to be valid if the temperature within the base of the thermal pads remained colder than 0°C. Any subsidence that occurs would be considered manageable during normal operations.

3.2 Input Parameters

The material properties used in the thermal modelling are summarized in Table 4. Properties for the ROQ pads were estimated at 60% saturation using the method proposed by Johansen (1975) and reduced to 30% saturation following Kersten (1949). The thermal properties for ridged polystyrene insulation were obtained from Andersland and Ladanyi (2004). The thermal properties for natural overburden sand with gravel were based on average soil properties (SRK 2015a), and average porewater salinity (SRK 2015b) measured from samples collected at the Property. Soil samples collected from the location of the proposed Tailings Storage Facility were excluded from this average due to differences in material properties. The freezing point depression and unfrozen water content were estimated for sand with a porewater salinity of 23 parts per thousand (ppt) in accordance with Banin and Anderson (1974). The thermal properties for peat represent measured values presented by Romanovsky and Osterkamp (2000).

Table 4: Material Thermal Properties

Material	Degree of Saturation (%)	Porosity	Thermal conductivity (kJ m^{-1} day^{-1} $°C^{-1}$)		Volumetric Heat Capacity (kJ m^{-3} $°C^{-1}$)	
			Unfrozen	Frozen	Unfrozen	Frozen
Run of quarry material	30	0.30	104	117	1,697	1,509
Polystyrene Insulation	0	-	3	3	38	38
Peat	100	0.65	48	138	2,600	2,200
Overburden Sand with Gravel (23 ppt. salinity)[1]	70	0.30	159	185	2,214	1,768

1. Parts Per Thousand = ppt.

Table 5 summarizes the model inputs. The thermal modelling was based on an average ground temperatures of -6.5°C which is consistent with measured temperatures at the Property. Air temperatures were represented by average conditions for the more recent 10-year period, 2003 to 2012.

Table 5: Model Input Parameters

Model Parameter	Value
Mean annual air temperature	-10.7°C
Mean annual ground temperature	-6.5°C
Air temperature amplitude	21.5°C
Air thawing degree days	937°C
Air freezing degree days	-4,811°C
Seasonal thawing period	102 days
Thawing N-factor	1.0
Freezing N-factor	0.7
Geothermal gradient	0.014°C/m

4 Model Results

4.1 Thaw Penetration Depth

A transient 1D model was constructed in SVHeat to estimate thaw penetration depth for ROQ pads for areas not thermally impacted by heated buildings and other surface infrastructure. The model was based on the input parameters outlined Table 5 and a sinusoidal surface ground temperature (with a mean annual temperature of -6.5°C). All model runs consisted of 10 cm peat underlain by sand with gravel which extended to 10 m below the base of the ROQ pad (Figure 1).

Figure 1 summarizes the depth of the 0°C, -1°C, and -2°C isotherm for different ROQ pad thicknesses. The depths are relative to the base of the pad. The model estimates a minimum pad thickness of 1.9 m would be required to maintain the 0°C isotherm at the base of the pad assuming a thawing index of 1. A minimum pad thickness of 2.35 m and 2.85 m were estimated to maintain the -1°C and -2°C isotherms at the base of the pad, respectively. For general design purposes, it is estimated that a minimum pad thickness of 1.9 m would be required.

The modified Berggren equation was used to confirm SVHeat thaw depths for the 0°C isotherm. The Berggren model represents a more simplified analytical model and assumes uniform ROQ material. The thaw depth based on this model ranges from 1.8 m to 2.5 m using a minimum and maximum surface thawing index of 1.0 to 1.5. Comparable estimates produced with SVHeat range from 1.9 m to 3.3 m for the same range of thawing indices.

The model simulations are relatively simplistic as they do not account for lateral heat flow. Heat transported by surface water and near surface groundwater is also not accounted for in the model and would be expected to alter thermal conditions within and beneath the pad. However, at this level of design, the simplistic 1D model simulations are deemed appropriate.

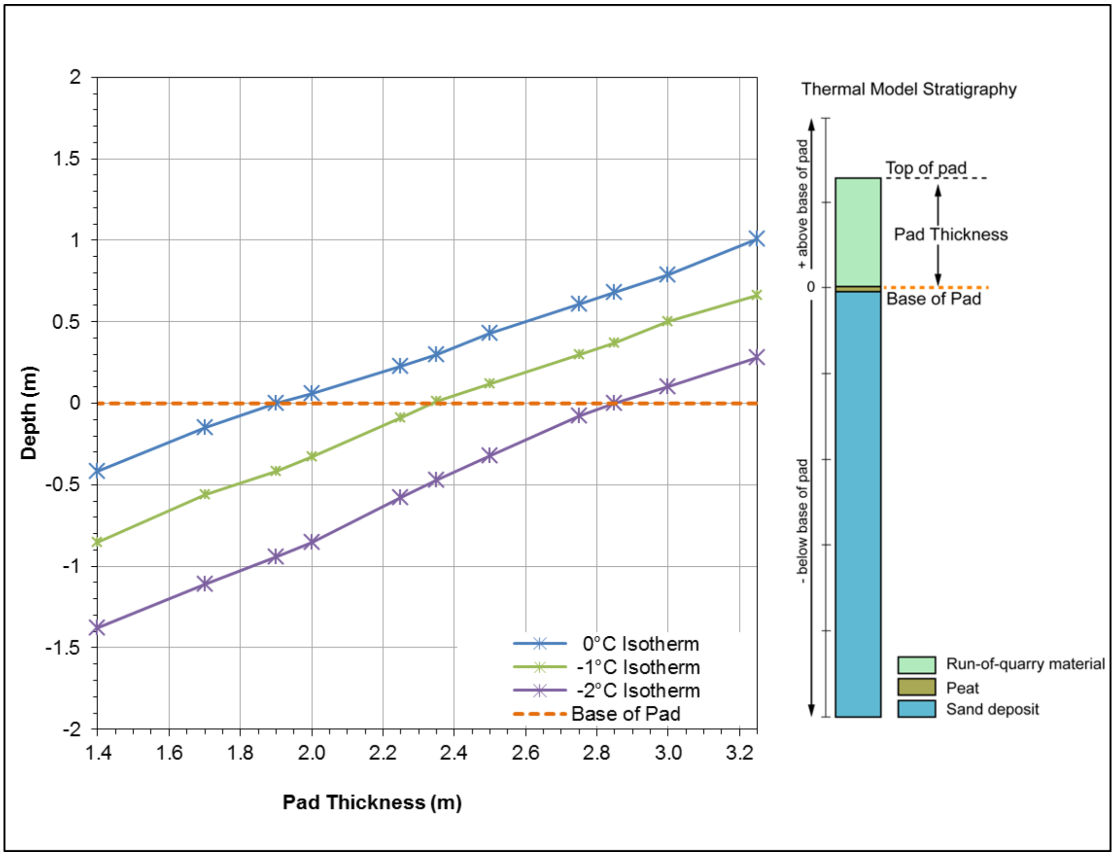

Figure 1: Depth of 0°C, -1°C, and -2°C isotherm for different ROQ pad thickness. Depth measurements are relative to the base of the pad.

4.2 Heated Buildings with Non-Insulated Foundation

The following section estimates thaw depth for heated buildings with non-insulated foundations constructed over a ROQ pad surface. Thaw depth calculations presented in this section were based on a steady-state heat strip method. Analyses were completed for building widths ranging from 0 to 100 m and for interior temperatures from 5 to 30°C. The steady-state model assumes average interior temperature throughout the entire year and average ground temperatures. Buildings are assumed to be rectangular with the plotted widths equal to the smallest dimension.

The steady-state thaw depth for a heated building with no foundation insulation to maintain 0°C, -1°C, and -2°C isotherms within the ROQ pad is shown in Figure 2, Figure 3, and Figure 4, respectively. The steady-state thaw depths are in general agreement with SVHeat numerical model simulations. The results show a linear relationship between the required pad thickness (thaw depth) and the minimum building dimension for buildings less than 20 m wide. As the building width increases, this relationship becomes non-linear with resultant increase in the required pad thickness. This analysis indicates that an insulated foundation is likely required for most heated buildings to maintain a foundation temperature below 0°C.

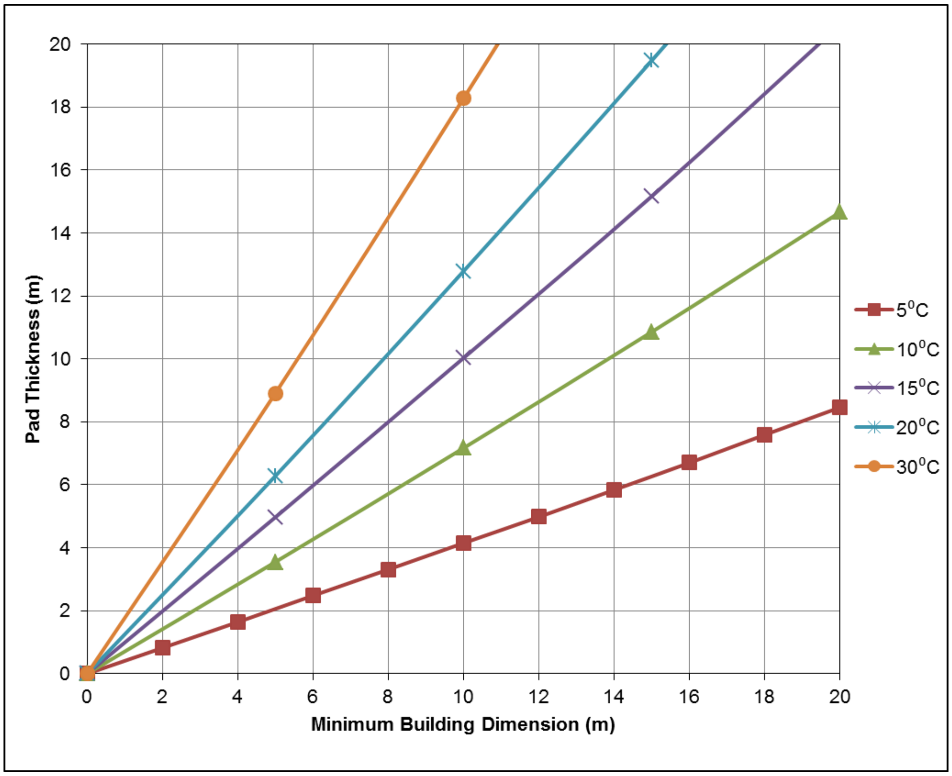

Figure 2: Required ROQ thickness for heated buildings with non-insulated foundations to maintain 0°C isotherm within the pad.

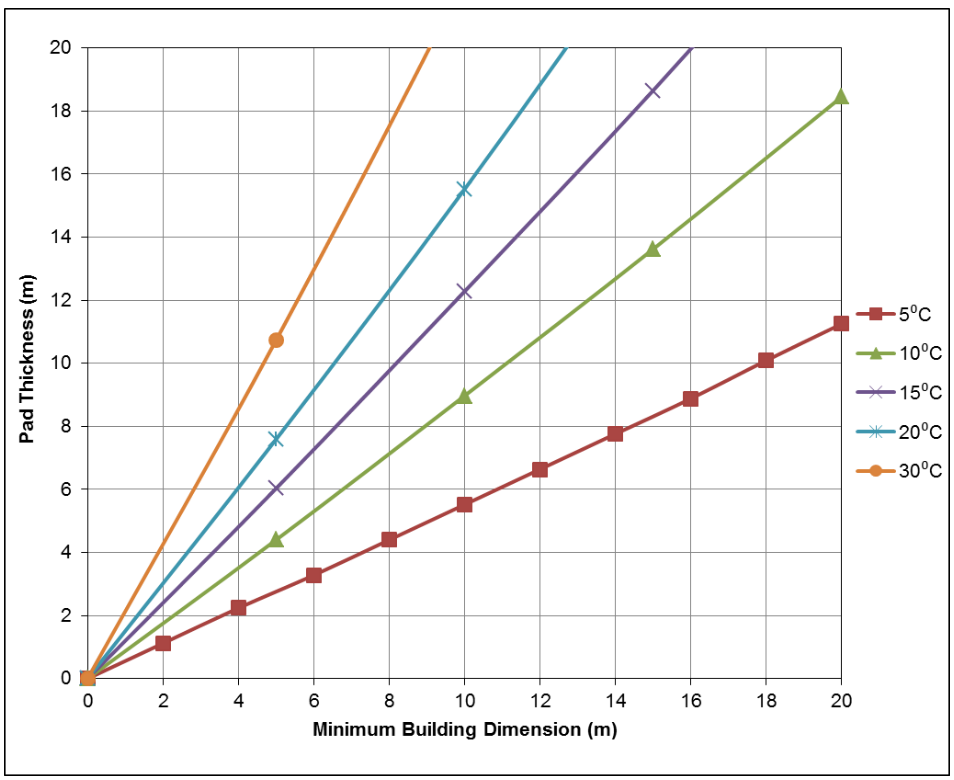

Figure 3: Required ROQ pad thickness for heated buildings with non-insulated foundations to maintain -1°C isotherm within the pad.

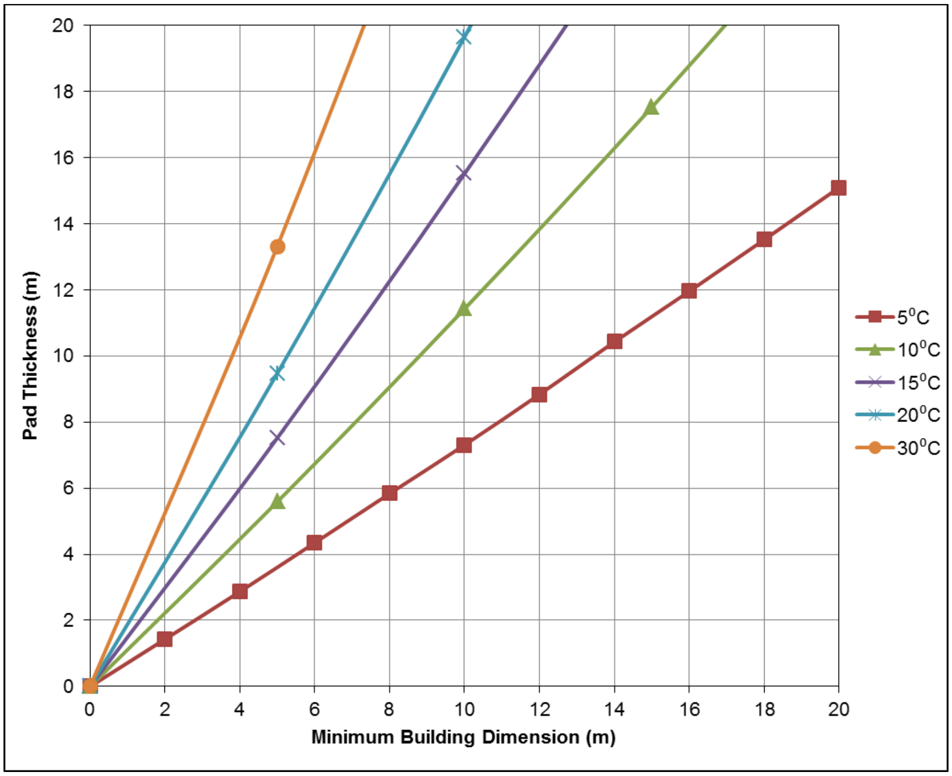

Figure 4: Required ROQ thickness for heated buildings with non-insulated foundations to maintain -2°C isotherm within the pad.

4.3 Heated Buildings with Insulated Foundations

The thaw depth for heated buildings with insulated foundations was analyzed using 2D SVHeat models. The transient models were based on the following:

- Polystyrene board insulation applied on top of the ROQ pad with a width equal to the building;
- Insulation thicknesses simulated over the range of 0 m to 0.5 m thick;
- Minimum building dimension of 20 m;
- Internal building heat at 5°C, 10°C, 15°C, 20°C, 30°C; and
- A sinusoidal surface ground temperature surrounding the building (mean annual temperature of -6.5°C and an amplitude of 21.5).

The results of the analysis are provided in Figure 5 through Figure 7. The figures show combinations of ROQ pad and insulation thicknesses required to maintain the 0°C, -1°C, and -2°C isotherms within the pad material for different interior building temperatures.

The model results indicate that increasing the insulation thickness from 0.1 m to 0.2 m for a building heated to 30°C and assuming a thawing point of 0°C will reduce the required pad thickness from 17.2 m to 13.1 m (i.e. 100 mm insulation is equivalent to 4.1 m of ROQ pad). A further increase in insulation thickness from 0.2 m to 0.3 m will reduce the ROQ pad thickness by an additional 2.9 m from 13.1 m to 10.2 m.

The following example is provided to estimate the ROQ pad and insulation thickness requirements for a heated building with a minimum dimension other than 20 m.

<u>Example</u>: 10 m wide building heated to a constant internal temperature of 5°C and a thaw temperature of 0°C.

<u>Step 1</u>: Select a desired insulation thickness (0.1 m).

<u>Step 2</u>: From Figure 5 (thaw temperature of 0°C), a 0.1 m insulation layer for a 20 m wide building is estimated to require a ROQ pad thickness of 3.0 m.

<u>Step 3</u>: From Figure 2, a 10 m wide building requires approximately 50% of the ROQ pad thickness compared to a 20 m wide building (4.2 m vs. 8.5 m).

<u>Step 4</u>: Therefore, for a 0.1 m insulation layer, approximately 1.5 m of ROQ pad is required (50% of 3.0 m).

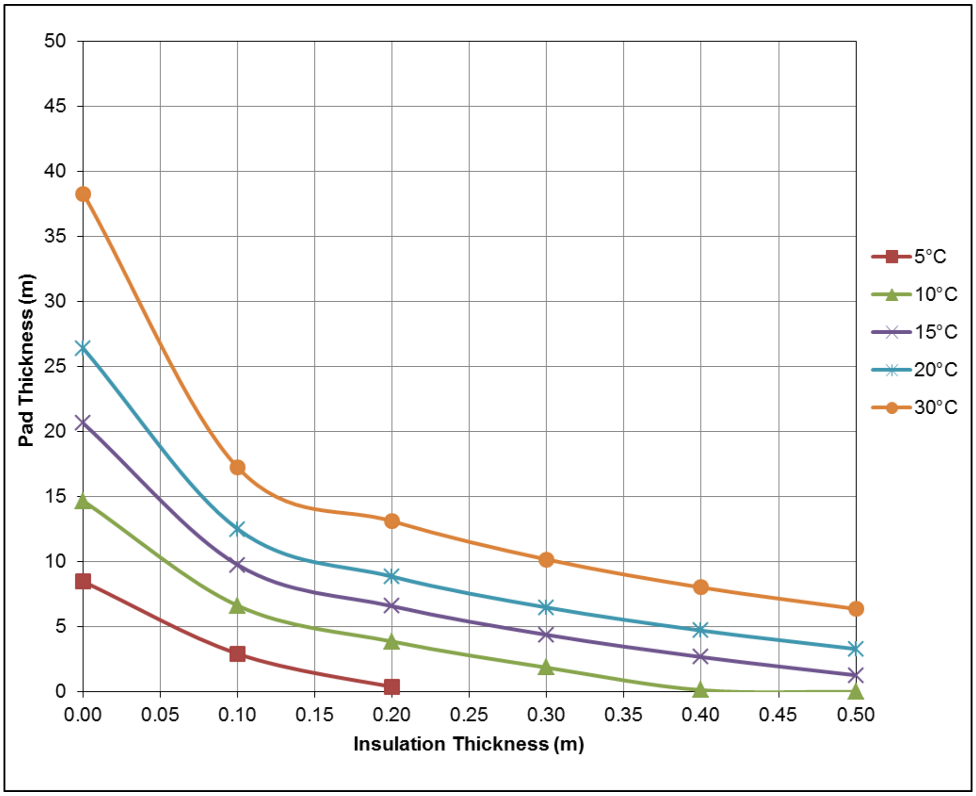

Figure 5: Minimum pad thickness required for heated building insulated foundation to maintain 0°C isotherm within pad for a minimum building width of 20 m.

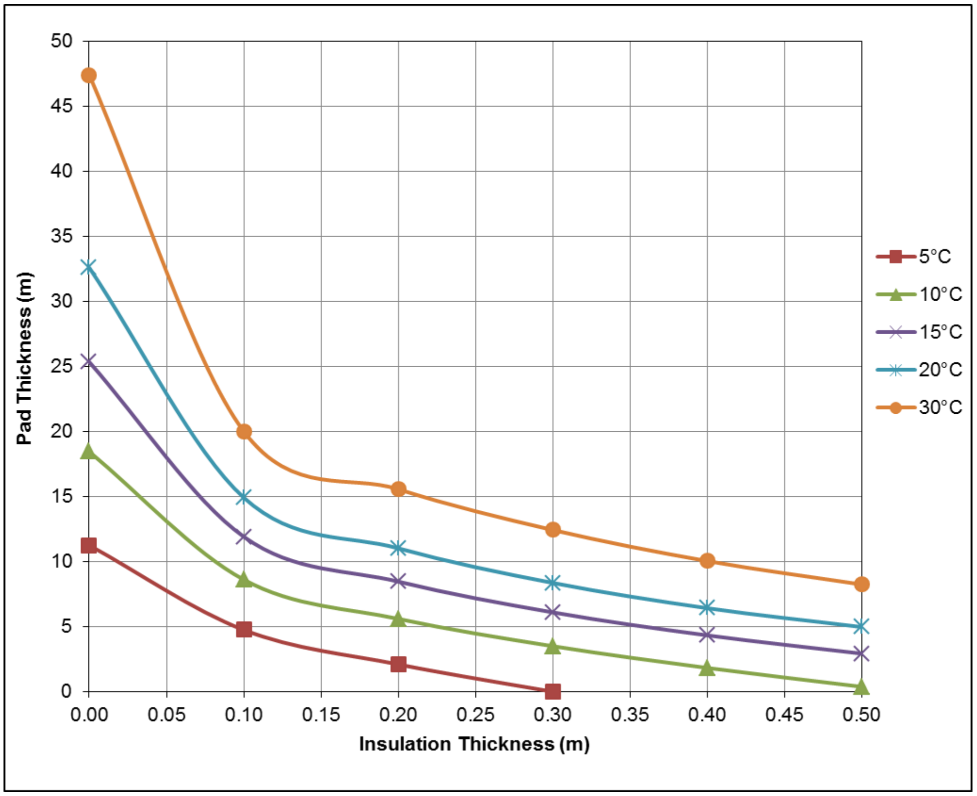

Figure 6: Minimum pad thickness required for heated building with insulated foundation to maintain -1°C isotherm within pad for a minimum building width of 20 m.

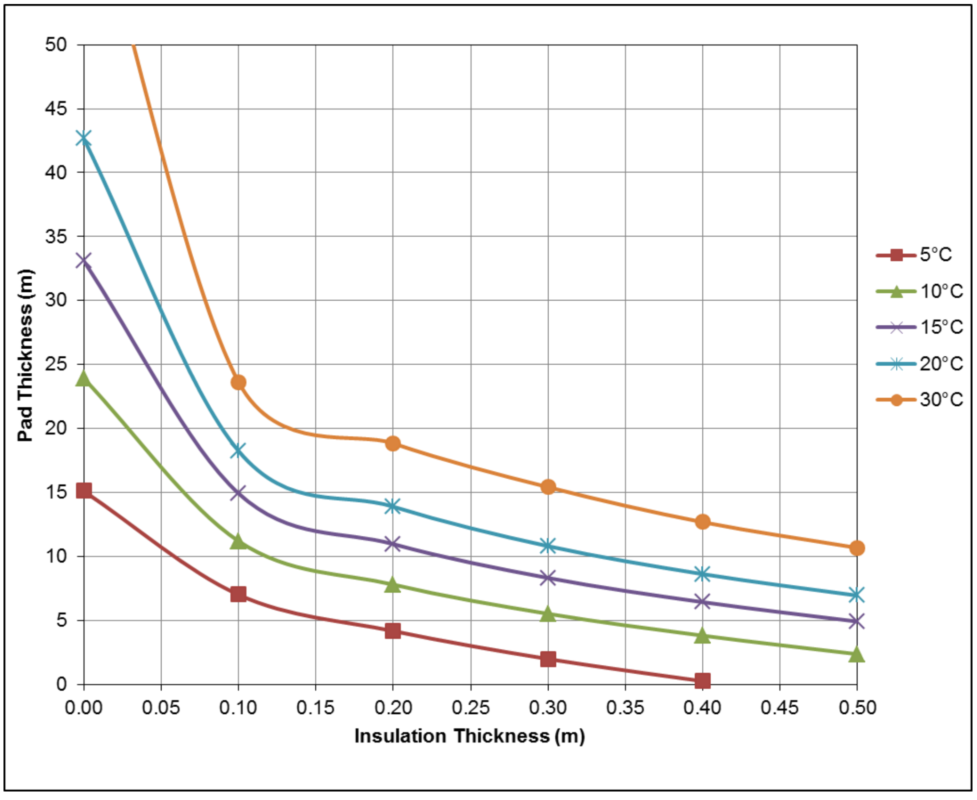

Figure 7: Minimum pad thickness required for heated building with insulated foundation to maintain -2°C isotherm in pad for a minimum building width of 20 m.

5 Conclusions

A ROQ (or geochemically suitable waste rock) pad design thickness of at least 1.90 m is required to maintain the 0°C isotherm at the base of the pad for areas not thermally impacted by heated buildings and other surface infrastructure. A minimum pad thickness of 2.35 m and 2.85 m are estimated to maintain the -1°C and -2°C isotherms at the base of the pad, respectively under the same conditions. For typical design purposes, the 0°C isotherm should be maintained within the pad to limit any potential subsidence to a manageable level.

A greater pad thickness as well as possible foundation insulation would be required to maintain thaw penetration within the pad for areas thermally influenced by heated buildings. For large heated buildings, it is likely that additional preventative measures are required to prevent permafrost degradation. These may include:

- Raising of the buildings off the ground surface on footings or piles to allow circulation of cold air;
- Placement of thermosyphons beneath the buildings; or
- Placement of metal pipe ducts in the pads beneath the buildings to provide air circulation.

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