REPORT

Meliadine Extension - 2020 Thermal Assessment

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1.0 INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) retained Golder Associates Ltd. (Golder) through Nuqsana Golder to carry out thermal modelling as part of the Meliadine Extension to predict the depth to the base of permafrost in the study area, to assess the extent of lake taliks and to determine whether the proposed open pits and underground developments will remain within the permafrost limits. This thermal assessment is also aimed to improve and update understanding of existing permafrost conditions compared to what was evaluated in the 2014 Permafrost Baseline Study (Golder 2014a), as well as to support future updates of the hydrogeological model that was included in the 2014 Freshwater Environment FEIS (Golder 2014b).

Two-dimensional (2D) thermal models were prepared from cross-sections throughout the study area and calibrated with thermistor data from the site and projected permafrost depths.

Following the completion of the 2D thermal models, results were used to create a three-dimensional (3D) block model for each of the three main project areas which include:

- Tiriganiaq, F Zone, Pump, and Wesmeg deposits (Main Area)
- Discovery Area
- Tiriganiaq-Wolf Area

The 3D ground temperature blocks are intended to provide an overall view of the permafrost conditions within the project areas and can be used to further cut supplemental cross-sections at different locations to evaluate permafrost conditions in areas that were not covered by the 2D thermal model cross-sections.

This report describes the methodology adopted for this thermal assessment, presents the model results and provides comments on how the predicted permafrost conditions differ from the 2014 Permafrost Baseline Study and potential implications to the hydrogeological model included in the 2014 FEIS.

2.0 SITE CONDITIONS

2.1 Regional Permafrost Conditions

The Meliadine Extension is in the zone of continuous permafrost. Permafrost refers to subsurface soil or rock where temperatures remain at or below 0°C for at least two consecutive years. The base of the permafrost is expected to be an undulating surface and the actual depth to permafrost is variable.

The land surface of the Meliadine site is underlain by permafrost except under lakes where water is too deep to freeze to the bottom during winter. Taliks (areas of unfrozen ground) are expected beneath a water body where the water depth is greater than the ice thickness. Closed talik formations show a depression in the permafrost below relatively shallower and smaller lakes. Open talik formations that penetrate through the permafrost and connect the lake waterbody with the sub-permafrost regime are expected for relatively deeper and larger lakes in the Project area.

Published data regarding permafrost indicates that the ground ice content in the region is expected to be between 0% and 10% (dry permafrost) based on (Golder 2014).

2.2 Subsurface Geology

The local overburden is between 2 and 18 m thick and typically consists of silt, sand, and gravel deposits of various thicknesses overlying till with cobbles and boulders. A thin layer of organics covers much of the area. Bedrock in the project area consists of a stratigraphic sequence of clastic sediments, oxide iron formation, siltstones, graphitic argillite, and mafic volcanic flows (Snowden 2008; Golder 2009). Bedrock types consisting of metavolcanics, gabbro, greywacke, iron formation, siltstone, and argillite were encountered during geotechnical field investigations (Golder 2010a,b, 2012).

2.3 Site Climatic Conditions

Table 1 presents a summary of the site climate data for air temperature and precipitation (Agnico Eagle 2021). The values presented in the Agnico Eagle Playbook (2021) are based on data available from Environment and Climate Change Canada (ECCC) for Rankin Inlet, approximately 25 km south of the Meliadine site. ECCC has hourly records for Rankin Inlet from 1981 to present, of which the period January 1981 to January 2020 was used to create a 39-year database.

Table 1: Mean Climate Characteristics – Existing Conditions based on MEL/Rankin Weather Station

Month	Average Maximum Temperature (°C)	Average Minimum Temperature (°C)	Monthly Precipitation	
			Total Precipitation (mm)	Number of Days
January	-26.7	-33.9	17	26
February	-26.4	-33.7	15	24
March	-20.7	-29.2	23	26
April	-11.4	-20.4	32	21
May	-2.3	-8.9	30	22
June	8.1	0.6	33	15

Table 1: Mean Climate Characteristics – Existing Conditions based on MEL/Rankin Weather Station

Month	Average Maximum Temperature (°C)	Average Minimum Temperature (°C)	Monthly Precipitation	
			Total Precipitation (mm)	Number of Days
July	15.1	6.3	46	15
August	13.2	6.3	61	18
September	6.4	1.4	50	21
October	-1.8	-7.2	57	27
November	-13.0	-20.8	40	26
December	-21.7	-29.2	25	27
Annual	**-6.7**	**-14.0**	**429**	**270**

The thermal modelling exercise described in this document was prepared to allow for assessment of existing permafrost conditions; therefore, it does not incorporate climate change in the long-term. Climate change during the operational stage of the Meliadine Extension is anticipated to be minimal and to have no impact on permafrost conditions.

2.4 Lake Elevation and Temperature

Bathymetry surveys of critical lakes included in this study were provided by Agnico Eagle and used to develop temperature boundary conditions as described in Section 4.3. Average ice thicknesses used for modelling were based on the SD-6 Thermal Regime Baseline Studies Report (Golder 2014), summarized in Table 2. No ice thickness data were available for Lake D4 at the Tiriganiaq-Wolf Area, but it is assumed that this lake freezes to the lakebed based on the lake bathymetry (i.e., lake is less than 1.5 m deep) and the range of ice thickness available for other lakes (as summarized in Table 2).

Table 2: Average Ice Thickness

Area	Lake	Average Ice Thickness (m)	Maximum Lake Depth[(a)] (m)
Main	B4	1.2	2.0
	B5	1.6	3.0
	B7	1.8	4.5
	A6	1.6	4.0
	A8	1.7	4.0
Discovery	CH6	1.7	8.0

(a) Based on bathymetry survey provided by Agnico Eagle using 0.5 m contours.

3.0 SITE PERMAFROST CONDITIONS

The following sections present a summary of site permafrost conditions estimated directly from available thermistor data.

3.1 Site Thermistors

3.1.1 Locations

The location of active thermistors installed at depths greater than 40 m within the vicinity of the area of interest is shown in Appendix A and Table 3.

Table 3: Thermistor Summary

Location	Thermistor	Collar Coordinates					Depth Below Ground Surface (m)
		Northing (m)	Easting (m)	Elevation	Inclination (°)	Azimuth (°)	
Tiriganiaq	GT09-19	6,989,458	537,899	63	51	123	152
	GT07-11	6,989,910	538,507	69	90	0	44
	GT07-10	6,988,805	538,506	69	90	0	44
F Zone	GT09-07	6,986,260	542,429	60	60	74	130
	GT09-08	6,986,317	542,494	60	71	48	139
Discovery	DS09GT-03	6,981,625	554,379	72	67	54	129
	DS09GT-04	6,981,611	554,453	74	71	45	128
	DC-16[(a)]	6,981,980	554,770	67	70	179	475
	DC-19[(a)]	6,982,025	554,220	67	66	179	260
	DC-21[(a)]	6,981,071	554,846	70	60	140	572

(a) Thermistors installed in 2020 and were still in the process of temperature stabilization at the time of this study.

3.1.2 Thermistor Data Summary

Table 4 presents a summary of the permafrost temperature conditions estimated from deep thermistors in the Project area and used as reference for calibration of thermal models as described in Section 4.2. In the Discovery area, three new thermistors were installed in 2020. Of the three thermistors, DC-16 and DC-19, installed in May 2020, did not have enough data to determine zero annual amplitude. Temperatures along the thermistor string DC-21, which was also installed at the Discovery Area in 2020, were still stabilizing and were therefore not used as reference in this modelling exercise except as a conceptual check of modelling predictions.

Table 4: Summary of Permafrost Temperature Conditions in Site Thermistors

Thermistor ID	Zero Annual Amplitude		Temperature Gradient (°C/m)
	Approximate Depth (m)	Approximate Temp (°C)	
GT09-07	40	-5.9	0.015
GT09-08	40	-6.2	0.010
GT09-19	28	-3.5	0.011
DS09GT-03	20	-7.0	0.018
DS09GT-04	18	-6.7	0.015
DC-16[(a)]	-	-	0.020
DC-19[(a)]	-	-	0.016

(a) Thermistors installed in 2020 and were still in the process of temperature stabilization at the time of this study.

4.0 THERMAL MODEL

To assess permafrost conditions in the project area and the extent of talik formations beneath the various lakes on the Meliadine site, steady-state 2D thermal modelling was carried out using the finite element software TEMP/W of GeoStudio 2020 (Version 10.2.1), developed by GEO-SLOPE International Ltd. (GEO-SLOPE 2020).

Certain lakes were designated as critical for hydrogeologic study and underground development. These lakes were chosen based on their size and depth (likelihood to support potential open talik) and proximity to mine infrastructure. Table 5 summarizes the critical lakes evaluated by location. Relative to the 2014 FEIS, this list of lakes that may influence the understanding of groundwater flow conditions is expanded and reflects the current mine development plans, particularly in the Tiriganiaq-Wolf and Discovery areas. In the 2014 FEIS the lakes considered to have open talik were: Meliadine, B7, A8 and D7. From those, Meliadine lake and lake D7 were not included in this study because they are away from target areas defined for modelling. Meliadine lake is to the north of the Tiriganiaq TSF area, and lake D7 is in-between the Main and the Tiriganiaq-Wolf areas.

Table 5: Critical Lakes Included in the Thermal Models

Location	Critical Lake[a]
Main Area	A6
	A8
	B4
	B5
	B7
Discovery Area	CH6
Tiriganiaq-Wolf Area	D4

Note – lake locations shown on Figure A1.

The thermal models predicted permafrost limits based on the 0°C isoline. However, water salinity will cause depression of the freezing point and allows water to flow in sub-zero temperatures. Cryopeg thickness will be presented separately as part of the documentation of the baseline hydrogeological conditions and groundwater modelling report in combination with measured groundwater salinity in the Project area.

The 2D thermal models were prepared for 18 cross-sections aligned with underground developments, instrumentation, critical lakes, and areas of interest. Section locations are presented in Appendix A and were distributed as follows:

- seven main sections in the Main Area
- five supplemental sections in the Main Area (SS1 to SS5)
- three sections in the Discovery Area
- three sections in the Tiriganiaq-Wolf Area

The supplemental sections SS1 to SS5 were added during the modelling process to add resolution to the three-dimensional (3D) block model that was developed from the 2D data.

Table 6 presents the 2D model cross-section locations and critical lakes they intersect. Section locations are presented in Appendix A.

Table 6: 2D Cross-Sections

Area	Section Name	Critical Lakes
Main	A	A8
	C	B4, B5, B7
	D	A8
	E	A6
	F	A8
	I	B5, B7
	I-2	B5, B7
	SS1	B7
	SS2	B5, B7
	SS3	B4, A8
	SS4	A6
	SS5	B7
Discovery	G	CH6
	H	N/A
	J	CH6
Tiriganiaq-Wolf	L	D4
	M	D4
	N	D4

The 3D block was prepared based on results obtained from the 2D sections as control reference temperatures. The 3D model was completed using the software Datamine Studio RM (v1.4.175.0), developed by Datamine Corporate Ltd.

4.1 Model Limitations

This study consisted of steady-state 2D models prepared for several cross-sections defined within the project area. The models constitute a simplification of the field reality and carry limitations that shall be taken into consideration during interpretation of model results. The most important model limitations are as follows:

- The 2D nature of the thermal models can only capture heat transfer along the cross-sections and does not incorporate the dynamics of 3D heat transfer coming from adjacent areas. This limitation has greater effects on model results for cross-sections that include large stretches crossing lakes, or sections crossing shallow and narrow lakes, where the 3D nature of heat transfer from adjacent ground would greatly limit the effect of the lake on permafrost conditions. This limitation was partially overcome by using wide cross-sections, positioning cross-sections that are perpendicular to each other, and adjusting the mean temperature of shallow lakes.
- Similarly, temperatures profiles measured by the reference thermistors used for model calibration are a result of three-dimensional heat transfer, while in the 2D models the predicted temperature profiles are a result of two-dimensional heat transfer. This limitation was partially overcome by using engineering judgment when interpreting the model results and relocating projections of reference thermistors onto the model cross-sections to have the model better represent the thermistor data.
- Results of steady-state models show a condition where an equilibrium is attained among all the model input parameters and boundary conditions, including material thermal properties, ground surface and lake temperatures and upward heat flux from the earth. The permafrost has formed over many millennia and its conditions adjust continuously to changes in surface conditions such as ground and lake temperatures as well as spatial and temporal variations in the extent and depth of lakes. Therefore, model results can differ from real field conditions. This limitation was partially overcome by calibrating the models against site thermistors data, but field information is limited compared to the size of the area modelled.
- The 3D blocks were prepared using information from the 2D thermal models as reference. The model interpolates temperature in-between cross-sections along with additional control temperatures around lakes. Therefore, the spatial distribution of the cross-sections affects the model accuracy, with interpolation between cross-sections that are separated by large distances being less accurate than interpolation between cross-sections that are nearby. This limitation was partially overcome by modelling supplemental cross-sections in specific areas to reduce spatial gaps in the 3D temperature block.

4.2 Model Approach and Calibration Process

Steady-state thermal modelling was performed initially along cross-sections that intersected thermistor locations. The locations of cross-sections are presented in Appendix A and were defined in such a way that allowed for models to be partially calibrated based on data from existing site thermistors. Locations of the different cross-sections were also defined to provide an estimate of current permafrost conditions along the alignment of the proposed pits and underground mining and in areas where the existence of open or closed talik is uncertain. Section I-2 and supplemental sections SS1 through SS5 were added to further define critical lakes and provide additional data for the 3D block model.

The calibration process consisted of adjusting model input parameters until predicted temperature profiles were in good agreement with measured temperatures along reference thermistors located near each of the cross-sections. The following model input parameters were adjusted during the calibration process.

- mean ground surface temperature as presented in Table 8.
- mean lake temperatures as presented in Table 8.
- material thermal properties (i.e., thermal conductivity and volumetric heat capacity) as presented in Table 9.
- thermal gradients at depth, based on site thermistors as presented in Table 4.

The models were considered calibrated when the same, or slightly different, sets of input parameters could be applied to the different cross-sections that resulted in predicted temperature trends and profiles that were in reasonable agreement with the thermistors data used as reference in each individual section. It should be noted that some thermistors were not aligned with the cross-sections. Thermistor locations were projected onto cross-sections to have the model represent the conditions with which the thermistor data was recorded. In some cases, this resulted in thermistors being projected perpendicularly onto cross-sections, and in other cases thermistors were realigned in model cross-sections as if the dip direction was parallel to the section orientation. These decisions were made on an instrument-by-instrument basis to have the models best represent the data being recorded.

Not all sections were calibrated as information from reference thermistor strings was not available for all areas. Table 7 lists the sections that have been calibrated and the thermistors used as reference for calibration of each section.

Table 7: Model Sections Calibrated Using Reference Thermistors

Thermistor Section	GT09-07	GT09-08	GT09-19	GT07-11	GT07-10	DS09GT-03	DS09GT-04	DC-16	DC-19	DC-21
A	X	X								
E	X	X								
G						X	X	X	X	
H						X	X			
I			X	X	X					
I-2			X	X						
J										X

In general, 2D model parameters were chosen to have the best possible agreement with the relevant thermistor data, while remaining relatively consistent across the entire study area. Section I-2 was the primary calibration section due to its proximity to thermistor GT09-19, which is the only deep thermistor on site in close proximity to a critical lake (B7) in the Main Area. This section was used to calibrate the ground surface and lake interaction and determine appropriate ground surface and lakebed temperature boundary conditions. Section H, in the Discovery Area, did not cross any lakes and was used to calibrate the ground surface temperature and thermal gradients used as a heat flux boundary conditions at the base of the model geometry.

Three sets of input parameter scenarios were developed during the calibration process, with Scenario 3 being selected as the final calibrated set of model inputs. The scenarios were:

- Scenario 1: developed based on initial calibration which had reasonable agreement between model results and calibration thermistors. This scenario was reviewed to check for consistency of the model results with site observations and projections of permafrost depths, and further adjustments were deemed necessary.
- Scenario 2: included an additional set of lake temperature boundary conditions based on lake depth to improve lakebed temperature resolution. Scenarios 1 and 2 showed agreement between 2D model results and calibration thermistors, however, were found to overestimate the permafrost thickness when compared to thermistor projections and observations from underground development.
- Scenario 3: further developed with adjustments in thermal gradients to maintain agreement between the calibration thermistors and model results, as well as predicted and projected permafrost thicknesses in consideration of observations from underground development.

Section 4.3 presents the boundary conditions used in each calibration scenario. Certain sections and thermistors were unable to achieve good agreement during calibration including sections I, E, and J. This was assessed to be a result of section geometry in relation to reference thermistors or 3D effects of lake and ground interactions and did not indicate a problem with the input parameters.

4.3 Boundary Conditions

Throughout the calibration process, three scenarios were developed with different input parameters. Boundary conditions for each calibration scenario are summarized in Table 8 below. Scenario 3 was selected as the final set of model inputs.

Table 8: Boundary Conditions

Scenario	Ground Temperature (°C)	Shallow Lake Conditions		Intermediate Lake Conditions		Deep Lake Conditions		Geothermal Gradient (°C/m)
		Depth (m)	Temperature (°C)	Depth (m)	Temperature (°C)	Depth (m)	Temperature (°C)	
1	-7.5 to -7.0	<1	1.0	-	-	>1	3.0	0.01 to 0.013
2	-7.3 to -7.0	<1	-0.5	< Average Ice Thickness[(a)]	0.0	> Average Ice Thickness[(a)]	3.0	0.01 to 0.013
3 (Final)	**-7.9**	**<1**	**-2.0**	**< Average Ice Thickness**[(a)]	**0.0**	**> Average Ice Thickness**[(a)]	**2.0**	**0.018 to 0.02**

(a) Average ice thickness data was measured in late winter for freshwater lakes in the Meliadine Extension area (Golder 2014).

4.4 Material Properties

It is expected that the thermal properties of the bedrock will have a more significant effect on the thermal conditions of permafrost depth than the overburden soils because of the shallow layer of overburden (i.e., between 2 and 18 m below ground surface) compared to the bedrock. As such, overburden has been omitted from the 2D models. In the model geometry, bedrock extends from surface elevation of about 70 m above sea level to an elevation of 500 m below sea level at the base of the model geometry.

The thermal properties adopted for the bedrock in the end of the calibration phase are summarized in Table 9.

Table 9: Thermal Properties of Bedrock used in the models.

Material	Volumetric Water Content (%)	Thermal Conductivity (W/m°C)		Volumetric Heat Capacity (MJ/m³°C)	
		Frozen	Unfrozen	Frozen	Unfrozen
Bedrock	1.0	3.0	3.0	2.0	2.0

The thermal models were simplified using a constant thermal conductivity without considering phase change. This assumption is considered reasonable as the bedrock in general is expected to have very low water content and the latent heat due to phase change is not significant. Also, variations in the bedrock thermal properties associated with different rock types were not incorporated in the models due to the large scale of model geometry and wide spatial distribution of model cross-sections within the project site.

4.5 Three-Dimensional Block Models

3D block models were produced from the results of the 2D thermal modelling using Datamine Studio software. Separate models were produced for the Main Area, Discovery Area, and Tiriganiaq-Wolf Area. The procedure used is summarized below.

- A block model volume was defined to encompass the 2D thermal sections.
- Blocks of size 25 m Easting, 25 m Northing, and 10 m elevation were created below topography down to a elevation of 500 m below sea level (i.e., base of the 2D thermal model cross-sections).
- Temperature was estimated in each block using the temperature values from the 2D thermal sections, with the following controls applied:
  - Inverse power of distance squared estimation methodology; 2D section temperature values closer to the block centroid carry more weight than those further away.
  - A flattened elliptical search volume was used to provide stronger horizontal continuity than vertical continuity (anisotropy). The maximum search distance horizontally was 750 m for the Main Area and 300 m for Discovery and Tiriganiaq-Wolf Areas. The maximum search distance vertically was 20 m in all areas. This anisotropy was necessary to prevent over-smoothing in the vertical dimension.
  - Horizontal distance to lake boundaries (both inside and outside of the lakes) influenced the estimate. Not all lakes were used, only those that were intersected by the 2D thermal sections. This was necessary to prevent smoothing of temperature values across lake boundaries, which, when close to the topographic surface, could result in increased temperature values outside lake boundaries and decreased temperatures inside lake boundaries.
  - Data points from at least two sections were needed to contribute to a block estimate.

The 3D block models were validated using the following steps.

- Slices through the 3D block model at the location of the 2D sections were examined to ensure the 3D model was honouring the 2D sections.
- Stepping through the 3D model in all three orthogonal directions to ensure between section relationships made sense.
- Examination of surface conditions in the lakes to ensure open talik was correctly represented.

A view of the 2D thermal sections and the controlling lake boundaries of the Main Area is provided in Figure 1.

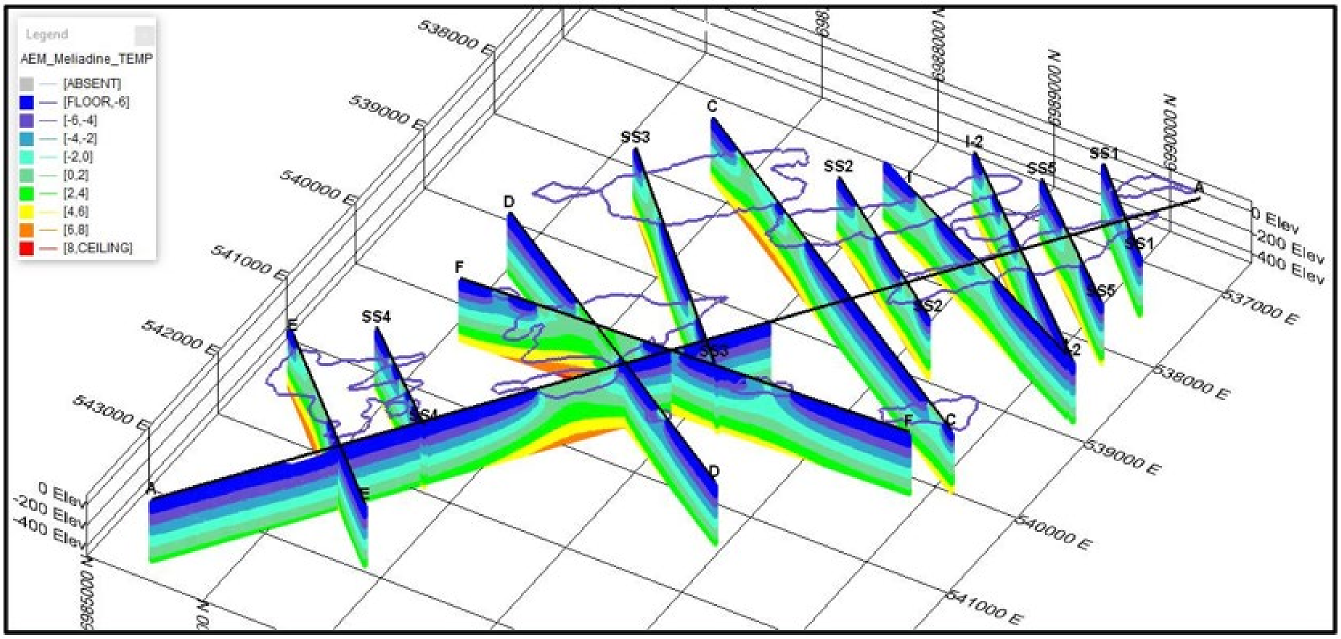

Figure 1: Main Area: 2D Thermal Sections and Lake Boundaries used as Input to Create the 3D Block Model

5.0 MODEL RESULTS

5.1 Two-Dimensional Thermal Models

Graphs showing model results are presented in Appendix B.

Figures B1 through B18 present the 2D thermal model results showing the 0°C isotherm that defines permafrost limits (i.e., limit of frozen and unfrozen ground) and predicted temperature contours for each section. The results of computed temperature profiles compared to measured temperatures from reference thermistors are also shown for sections that crossed reference thermistors. Certain sections and thermistors were unable to achieve good agreement during calibration including sections I, E, and J. This was assessed to be a result of section orientation in relation to reference thermistors and 3D effects of lake and ground interactions that could not be captured in 2D. Overall, correlations between measured and predicted temperature profiles were considered satisfactory and the predicted trends are considered realistic and consistent with the level of information available for model calibration at this stage.

The maximum depth of permafrost (defined by the 0°C isotherm) was 430 m at the Discovery Area north of CH6 Lake. The maximum depth of permafrost predicted in the Main Area was about 400 m in areas away from lakes. At the Tiriganiaq-Wolf Area, a maximum permafrost depth of some 280 m was predicted by the models, but as the model cross-sections within the Tiriganiaq-Wolf deposit were in general shorter than in the other areas, permafrost depth in areas away from Lake D4 is anticipated to be around 400 m as predicted for the other areas and projected based on more recent data from deep thermistors installed in the Discovery Area.

The permafrost limits shown by the 0°C isolines in Figures B-1 to B-18 represent the limit of frozen and unfrozen ground. This should not be confused with the cryopeg limits, which includes portions of frozen ground where water can still flow due to depression of the freezing point associated with water salinity. Cryopeg thickness will be presented separately as part of the documentation of the baseline hydrogeological conditions and groundwater modelling report in combination with measured groundwater salinity in the Project area.

Table 10 summarizes the talik characteristics predicted for each of the critical lakes by 2D section.

Table 10: Critical Lake Talik Formation

Location	Cross-section	Open or Closed Talik						
		Lake B4	Lake B5	Lake B7	Lake A8	Lake A6	Lake CH6	Lake D4
Main Area	A	-	-	-	**Open**	-	-	-
	C	**Open**	**Open**	-	-	-	-	-
	D	-	-	-	**Open**	-	-	-
	E	-	-	-	-	**Open**	-	-
	F	-	-	-	**Open**	-	-	-
	I	-	**Open**	Closed	-	-	-	-
	I-2	-	Closed	Closed	-	-	-	-

Table 10: Critical Lake Talik Formation

Location	Cross-section	Open or Closed Talik						
		Lake B4	Lake B5	Lake B7	Lake A8	Lake A6	Lake CH6	Lake D4
	SS1	-	-	Closed	-	-	-	-
	SS2	-	**Open**	Closed	-	-	-	-
	SS3	**Open**	-	-	Closed	-	-	-
	SS4	-	-	-	-	Closed	-	-
	SS5	-	-	**Open**	-	-	-	-
Discovery Area	G	-	-	-	-	-	**Open**	-
	J	-	-	-	-	-	**Open**	-
Tiriganiaq-Wolf Area	L	-	-	-	-	-	-	Closed
	M	-	-	-	-	-	-	**Open**
	N	-	-	-	-	-	-	Closed

Notes: Section H did not cross any lakes and is not presented in the table. Section B was deemed unrealistic due to 2D model limitations and was removed. The portion of Section A crossing Lake B7 was deemed unrealistic due to 2D model limitations and this section was truncated to remove potentially erroneous results.

Thermal models showed open taliks present for portions of each of the critical lakes in the Main Area. Sections I, I-2, SS1 and SS2 through showed closed taliks through the narrow parts of elongate lakes B5 and B7.

Sections G and J through Lake CH6 both showed open taliks. Section H did not cross any lakes.

Section M was the only section at the Tiriganiaq-Wolf deposit to show an open talik through lake D4. Sections L and N cross shallower and/or narrower parts of the lake, which may contribute to the prediction of closed talik on those sections. On the basis of the more conservative Section M, Lake D4 is assumed to have open talik, but temperature data from thermistor strings would be required to confirm the presence of open talik. Currently, there are no thermistors installed in the Tiriganiaq-Wolf Area.

5.2 Three-Dimensional Block Models

The 3D model can be used to examine the temperature profile of any 2D section (horizontal, vertical, or inclined) through the model volume and to produce iso-surfaces for any given temperature. For example, 0-degree iso-surfaces for the Main Area, Discovery Area, and Tiriganiaq-Wolf Area are shown in Figure 2, Figure 3 and Figure 4, respectively.

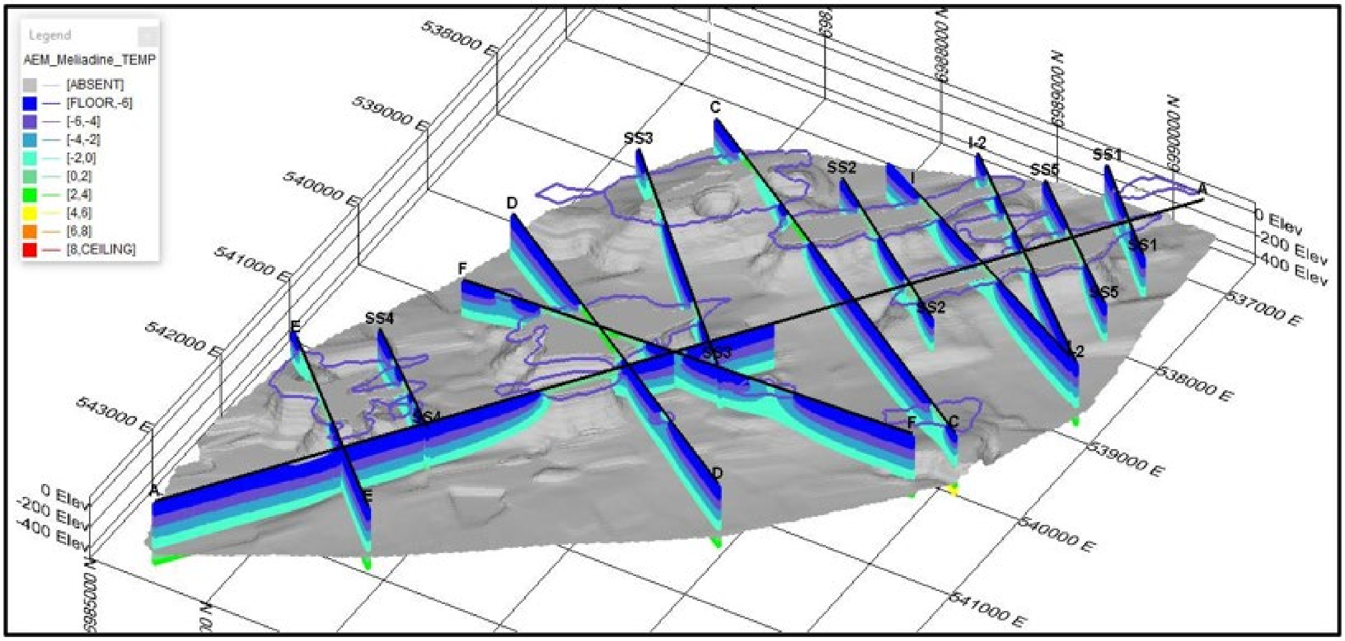

Figure 2: Main Area: 0-degree Iso-surface Produced from the 3D Block Model

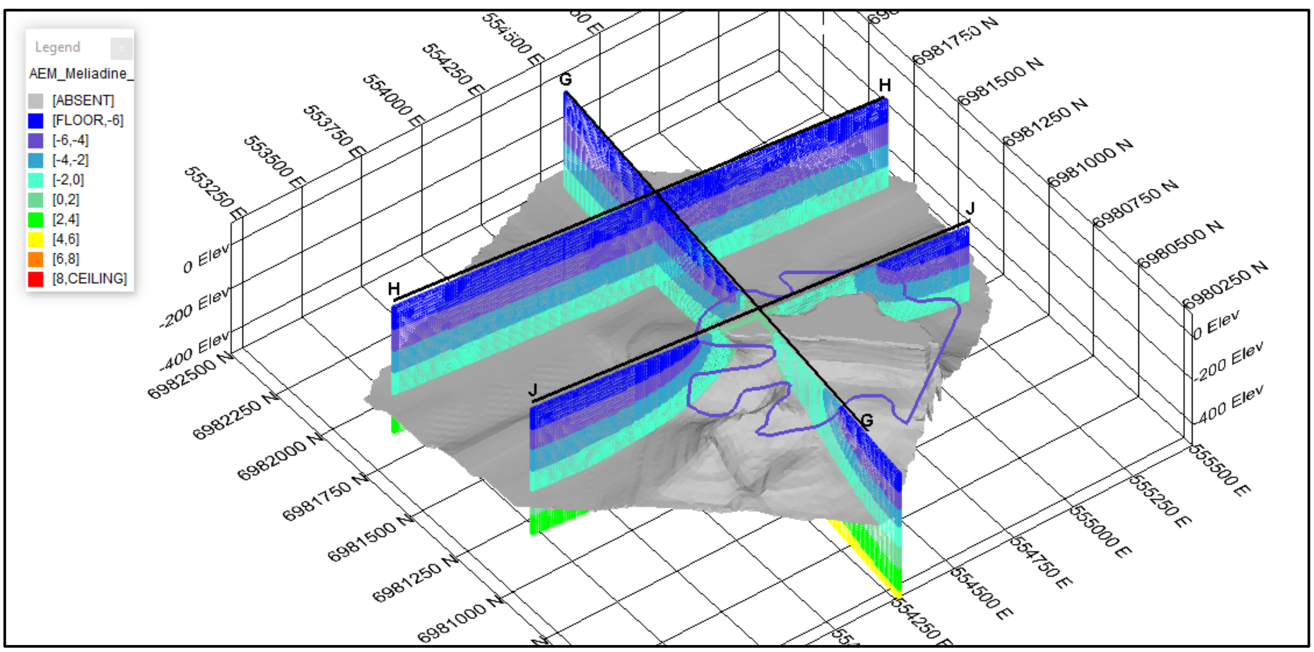

Figure 3: Discovery Area: 0-degree Iso-surface Produced from the 3D Block Model

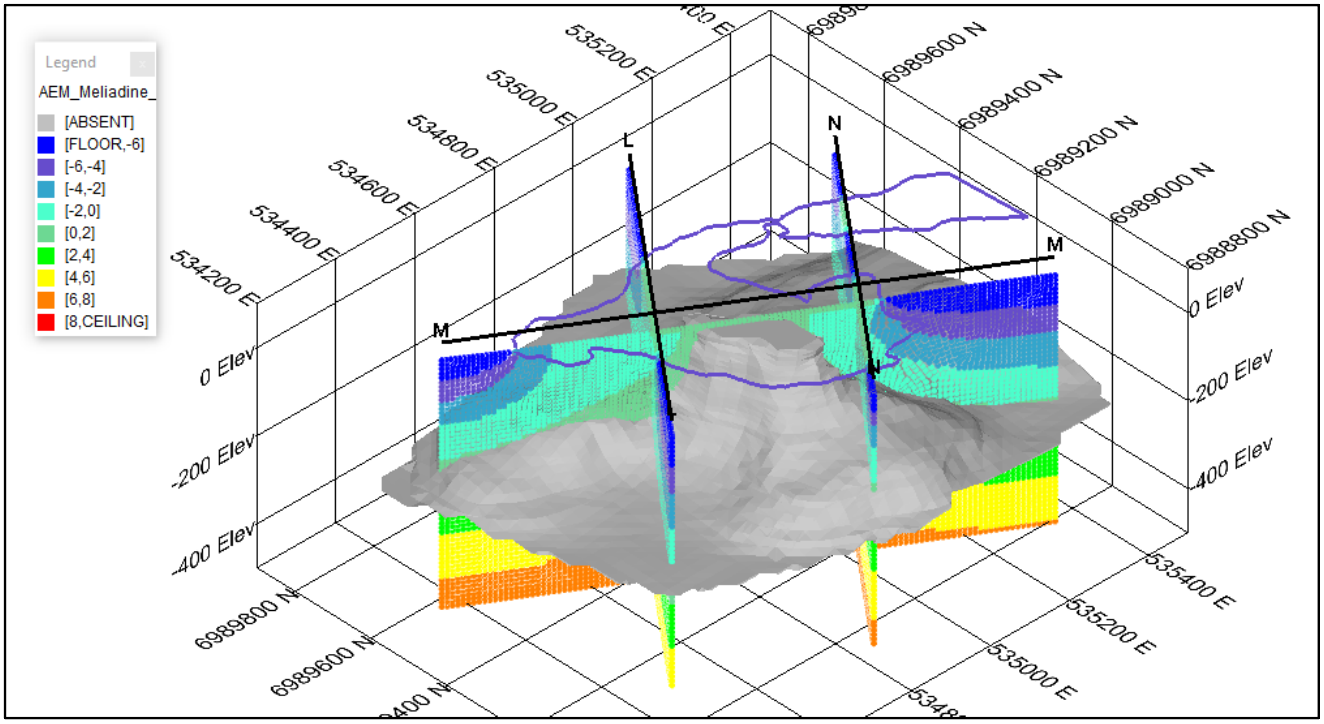

Figure 4: Tiriganiaq-Wolf Area: 0-degree Iso-surface Produced from the 3D Block Model

The 3D model was prepared by stitching together the 2D models with professional judgement on interpolation between sections. The representation of temperature is more accurate where the 2D sections are close together and where sections of different orientations contribute to the temperature estimates and diminishes with increasing distance between two cross-sections, or in deeper portions of lakes where no information was available from the 2D model cross-sections.

6.0 SUMMARY

Golder has carried out numerical modelling of the Meliadine site area to assess talik characteristics beneath critical lakes in the study area where permafrost conditions will have greater impact on operation activities and water management. Based on the latest thermistor data available, the permafrost characteristics in the project area are summarized below:

- Preliminary data from the string DC-16, installed in the Discovery Area north of CH6 Lake, indicate permafrost depth of about 400 metres below ground surface.
- The estimated depth of zero amplitude from the temperature profiles ranges from 18 to 40 m.
- The temperatures at the depths of zero amplitude are in the range of -5.9 to -7°C in thermistors away from lakes and -3.5°C at thermistor GT09-19 next to lake B7.
- Geothermal gradients were estimated to be between 0.018 and 0.020°C/m based on deep thermistors installed in the Discovery Area in 2020.

The results of numerical modelling indicate open taliks are present beneath portions of each of the identified lakes:

- Lake B4
- Lake B5
- Lake B7
- Lake A6
- Lake A8
- Lake CH6
- Lake D4

These results expand the list of lakes with potential open talik compared to what was estimated in the 2014 Freshwater Environment FEIS, where only the Meliadine lake, and lakes A8, B7 and D7 were considered large enough to support open talik. From the critical lakes listed in the 2014 FEIS, Meliadine lake and lake D7 were not included in the models because those lakes are away from the Tiriganiaq-Wolf deposit and the Tiriganiaq area. The 2014 Permafrost Baseline Study utilized analytical analysis to estimate that taliks extending through the permafrost would exist beneath circular lakes having a minimum radius of approximately 290 to 330 m, and beneath elongated lakes having a minimum half width of approximately 160 to 195 m. The updated modelling in this assessment utilized additional thermistor data and 2D thermal analysis to refine permafrost estimates and to consider the effects of lake terrace geometries.

It should be noted that the models were calibrated based on limited information from existing deep thermistor strings, which makes it difficult to point which areas with predicted open talik carry more certainty. However, based on the size and geometry of lakes and trends from nearby strings, it is probable that open talik predicted under Lakes A6, A8 and CH6 carry more certainty than open talik conditions predicted under lakes B5 and B7.

Thermal modelling results indicated the base of permafrost was between 285 and 430 m depth, with the interpreted depth dependent on the proximity of the location to nearby lakes. Shallower depths are from locations closer to lakes with and without open talik. The permafrost depth range predicted in the models is shallower than assessed in the 2014 Permafrost Baseline Study, in which the depth of permafrost in the project area was estimated to be between 360 m and 495 m.

Based on permafrost depth limits and talik conditions predicted in this study, as well as locations and depths of open pits and underground structures included in the CAD file provided by AEM, open pits in FZone and Discovery, which vary in depth between 70 and 140 mbgs, will all be within permafrost. The Wesmeg-North pit is planned to be about 130 m deep and is under a portion of Lake B5 where the models predict the existence of open talik, suggesting this pit would operate in unfrozen ground. The Wesmeg05 pit is planned to be about 120 m deep and is partially under the north side of Lake A8, where the models also predict the existence of open talik. Therefore, this pit could operate in partially unfrozen ground. The Pump04 pit is planned to be under the south side of lake A8 where the models predicted the existence of open talik. Therefore, the pit could operate in partially unfrozen ground.

The underground developments in FZone and Discovery shown in the CAD file provided by AEM both extend below the model-predicted permafrost limit of 430 m, with FZone underground developments reaching depth of about 560 mbg and Discovery underground operations reaching about 460 m in depth. Portions of underground developments below the permafrost limit and within the cryopeg limits could be subject to influx of groundwater.

The hydrogeological modelling included in the 2014 Freshwater Environment FEIS assumed depth of permafrost of 450 m, and that the permafrost zone where groundwater may be partially or wholly unfrozen due to the freezing point depression was at a depth of approximately 350 m. The hydrogeological model will be updated based on the results presented in this study and model updates will be presented in forthcoming Hydrogeological Modelling Reports.

The thermal modelling results should be reviewed as new data is collected from deep thermistors strings that have been recently installed in strategic locations. In addition, one historical thermistor in the FEIS (M98-195) is no longer monitored and was not considered in the assessment. Comparison of the historical measurements from M98-195 to the temperatures predicted by the 2D thermal modelling suggests the maximum permafrost depths in the Tiriganiaq area away from major lakes may be deeper than predicted by the thermal model. Overall, this would likely make the thermal model predictions conservative with respect to groundwater flow, with potentially more of the underground developments being located in frozen bedrock than is predicted by the thermal model at present.

7.0 CLOSURE

The reader is referred to the Study Limitations section, which follows the text and forms an integral part of this report.

We trust that this report meets your present requirements. If you have any questions or requirements, please contact the undersigned.

Golder Associates Ltd.

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Mine Waste West Division

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FJ/ZS/GW/ca/dh/et/it

https://golderassociates.sharepoint.com/sites/120710/project files/6 deliverables/working/20136436-815-r-rev2 -thermal assessment/20136436-815-r-rev2-2200-thermal assessment_05nov_21.docx

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STUDY LIMITATIONS

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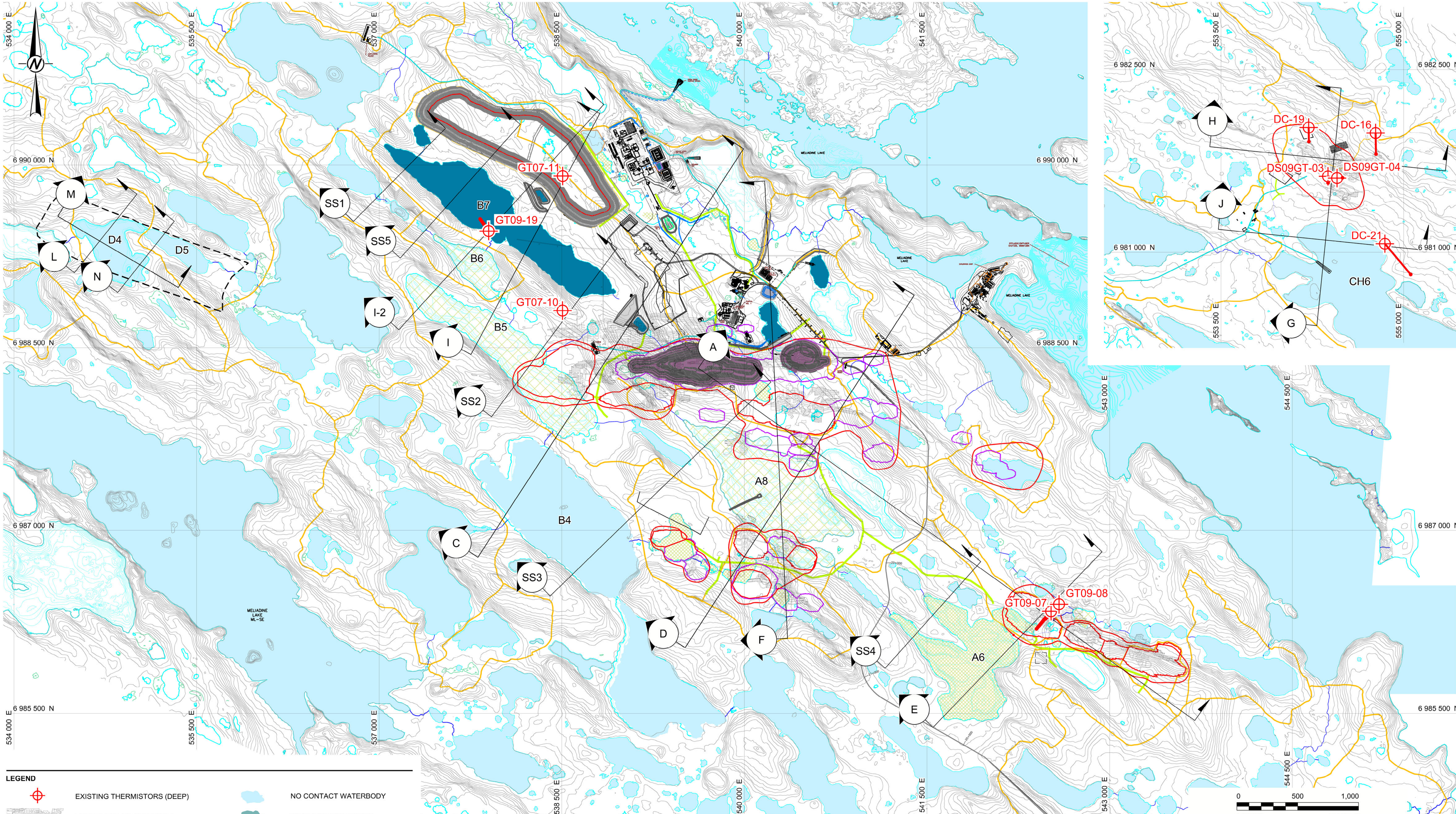
APPENDIX A

Location of Thermal Model Cross-Sections in the Meliadine Extension Site



LEGEND

- EXISTING THERMISTORS (DEEP)
- UNDERGROUND WORKINGS
- CATCHMENT BOUNDARY
- PLOM 2020 PIT DESIGN LIMIT
- PERMITTING BOUNDARY
- ORE BODY
- HAUL ROAD
- TIRIGANIAQ-NORTH EXTENTS
- NO CONTACT WATERBODY
- CONTACT WATERBODY
- WATER COLLECTION POND
- DRAINED LAKE AREA

REFERENCE

1. BASE MAP OBTAINED FROM AGNICO EAGLE CAD
   FILE: OPTION E_PLOM2020_final_V4.dwg, DATE RECEIVED: 2020-03-20
2. 2020 EXPLORATION BOREHOLES PROVIDED BY AEM EXCEL
   FILE Discovery_CONV_DISCO_2020_collar, DATE RECEIVED: 2020-04-07

NOTES

1. INSTALLATION OF A NEW DEEP THERMISTOR WILL ALSO BE REQUIRED FOLLOWING SELECTION OF THE WESTBAY WELL LOCATION.
2. INSTALLATION OF NEW SHALLOW THERMISTORS BETWEEN THE LAKE CH6 AND MELIADINE LAKE IS ALSO RECOMMENDED.

CLIENT
AGNICO EAGLE

PROJECT
MELIADINE EXTENSION

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-11-04
DESIGNED	ZM
PREPARED	AF
REVIEWED	FJ
APPROVED	JL

TITLE
THERMAL MODEL CROSS SECTION LOCATIONS

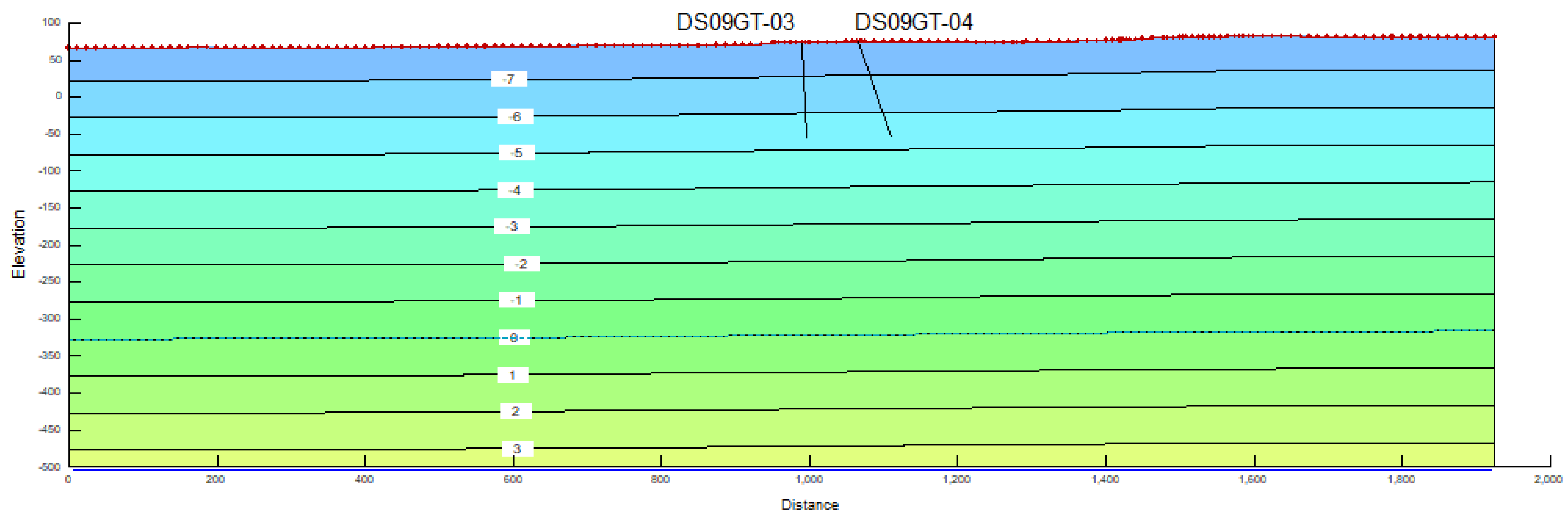
PROJECT NO.	PHASE/TASK	REV.	FIGURE
20136436	2400/2405	0	A-1

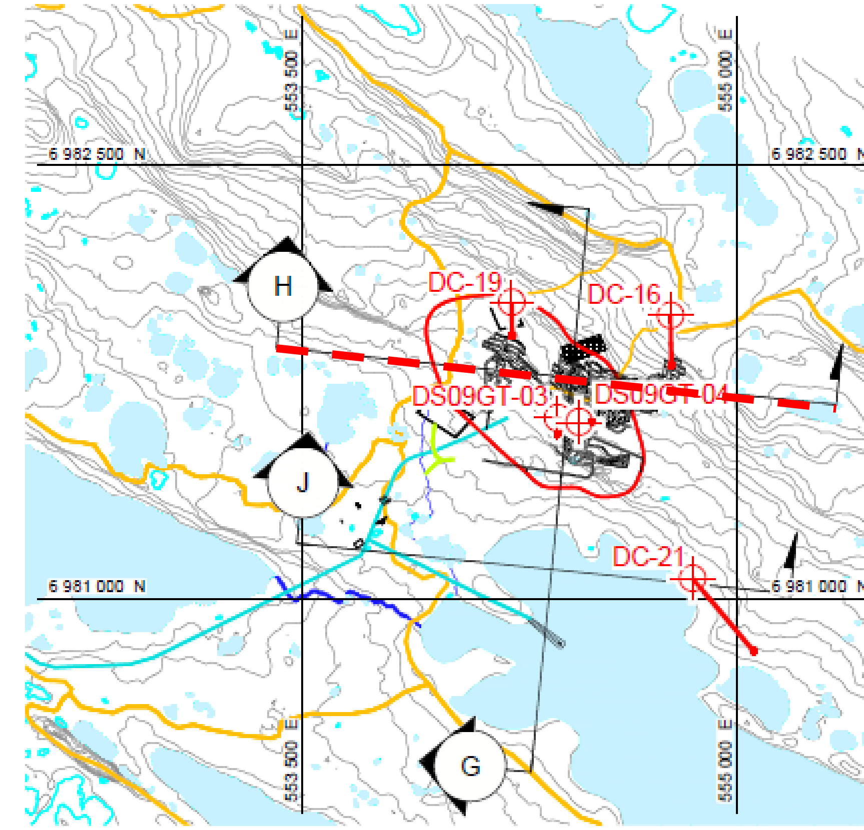
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25 mm

APPENDIX B

2D Thermal Model Results

Color	Name	Parameters
(red)	Ground Temp -7.9	-7.9 °C
(blue)	Lower Heat Flux 60	6e-05 kJ/sec/m²





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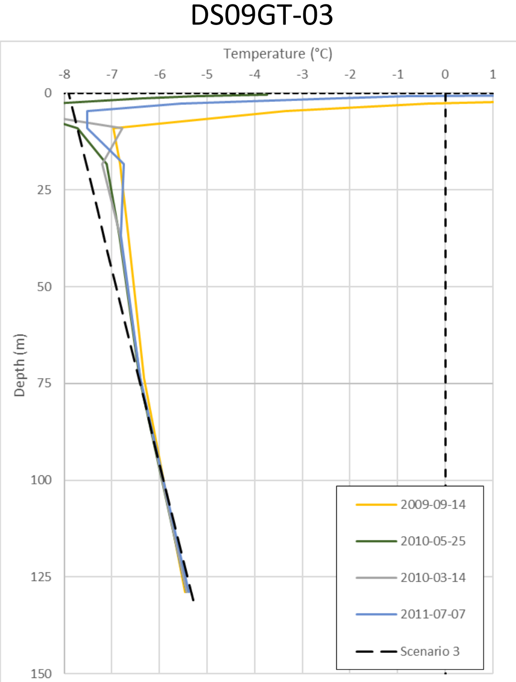

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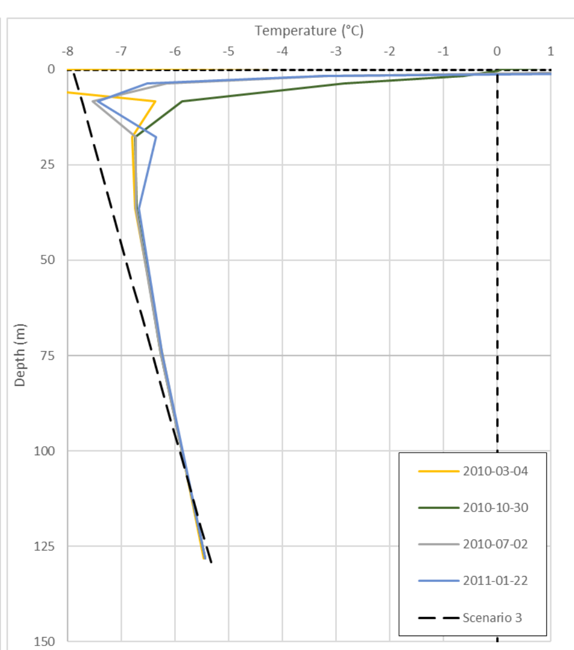

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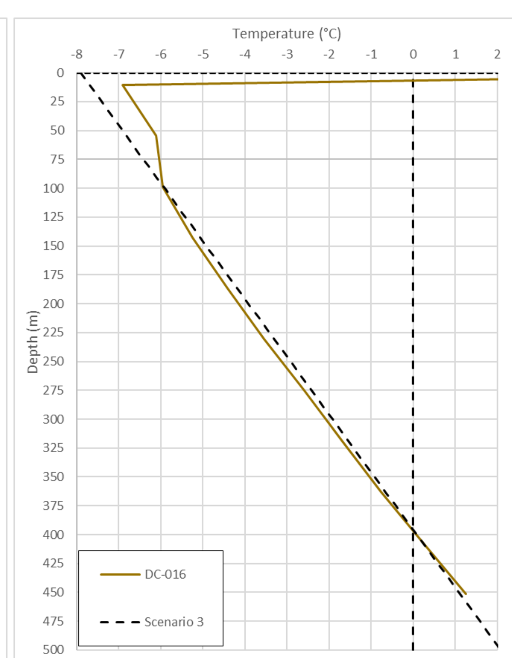

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GOLDER MEMBER OF WSP

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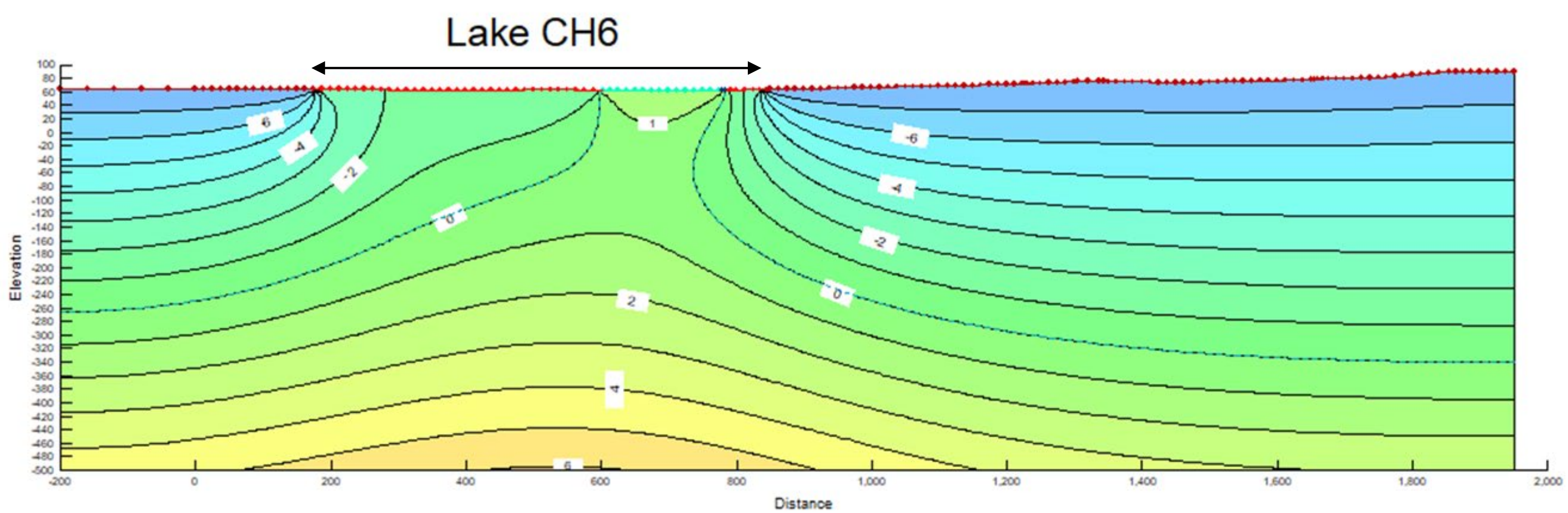
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

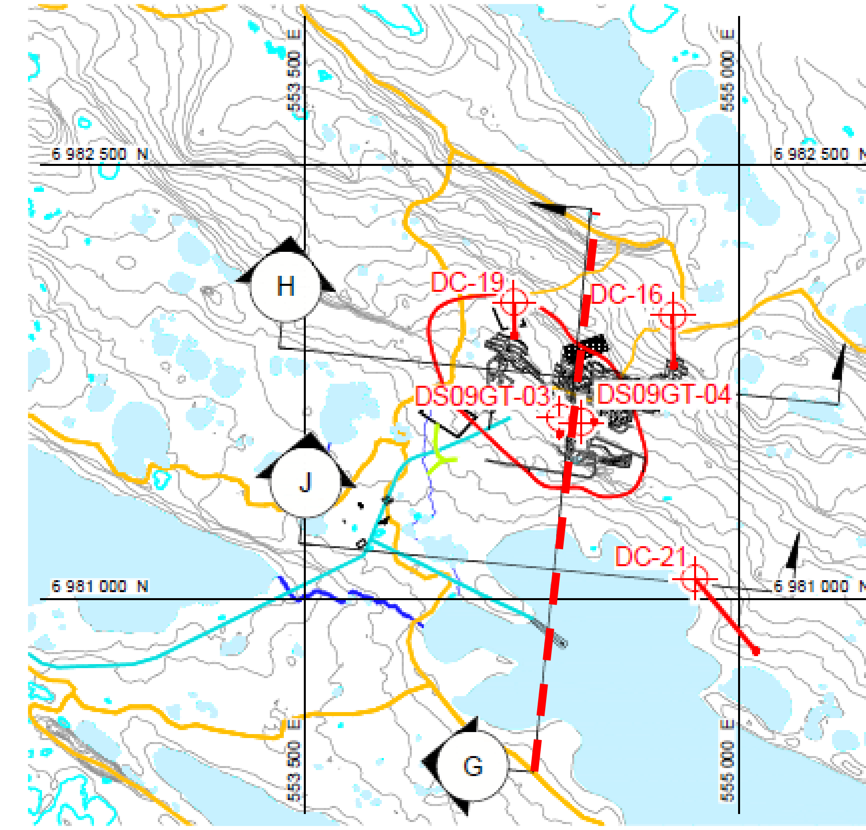
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION H
DISCOVERY AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-1

Color	Name	Parameters
(dark red)	Ground Temp -7.9	-7.9 °C
(light cyan)	Lower Heat Flux G and J 54	5.4e-05 kJ/sec/m²
(aqua)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C





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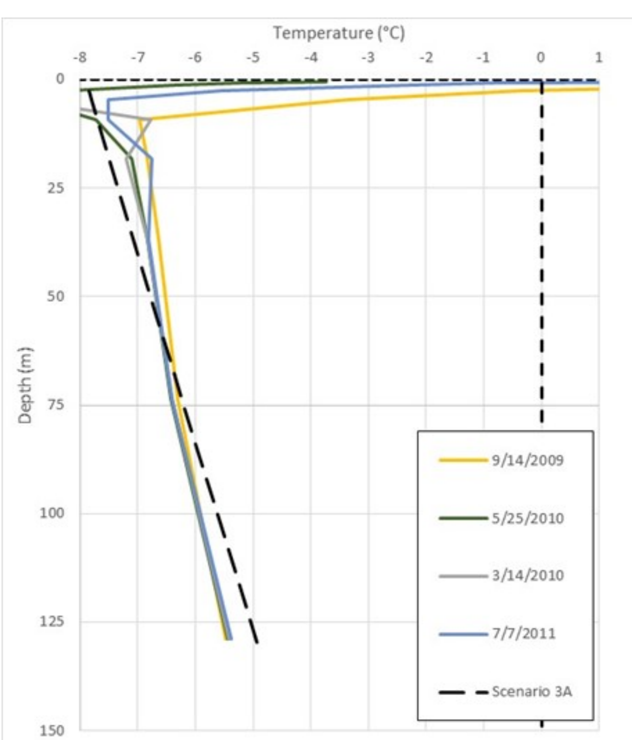

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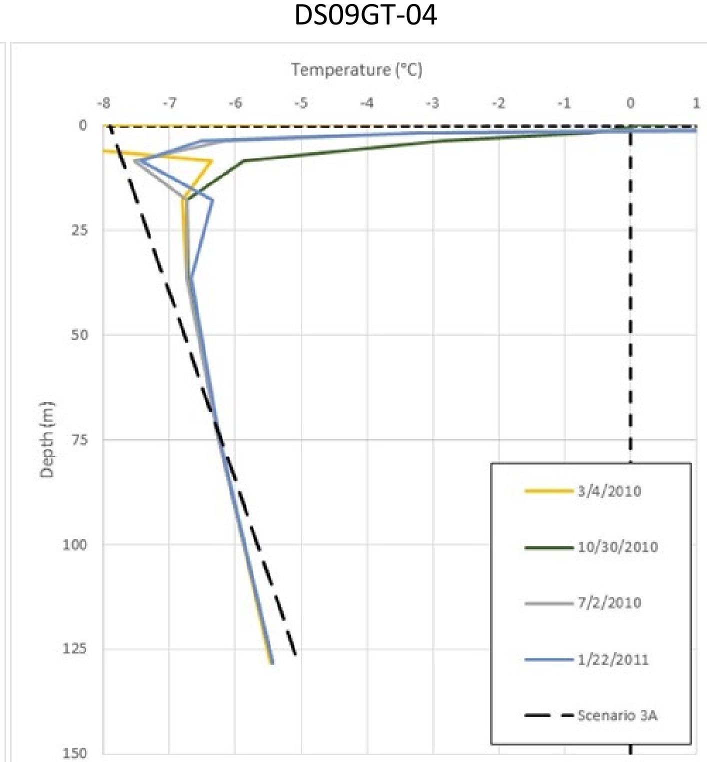

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MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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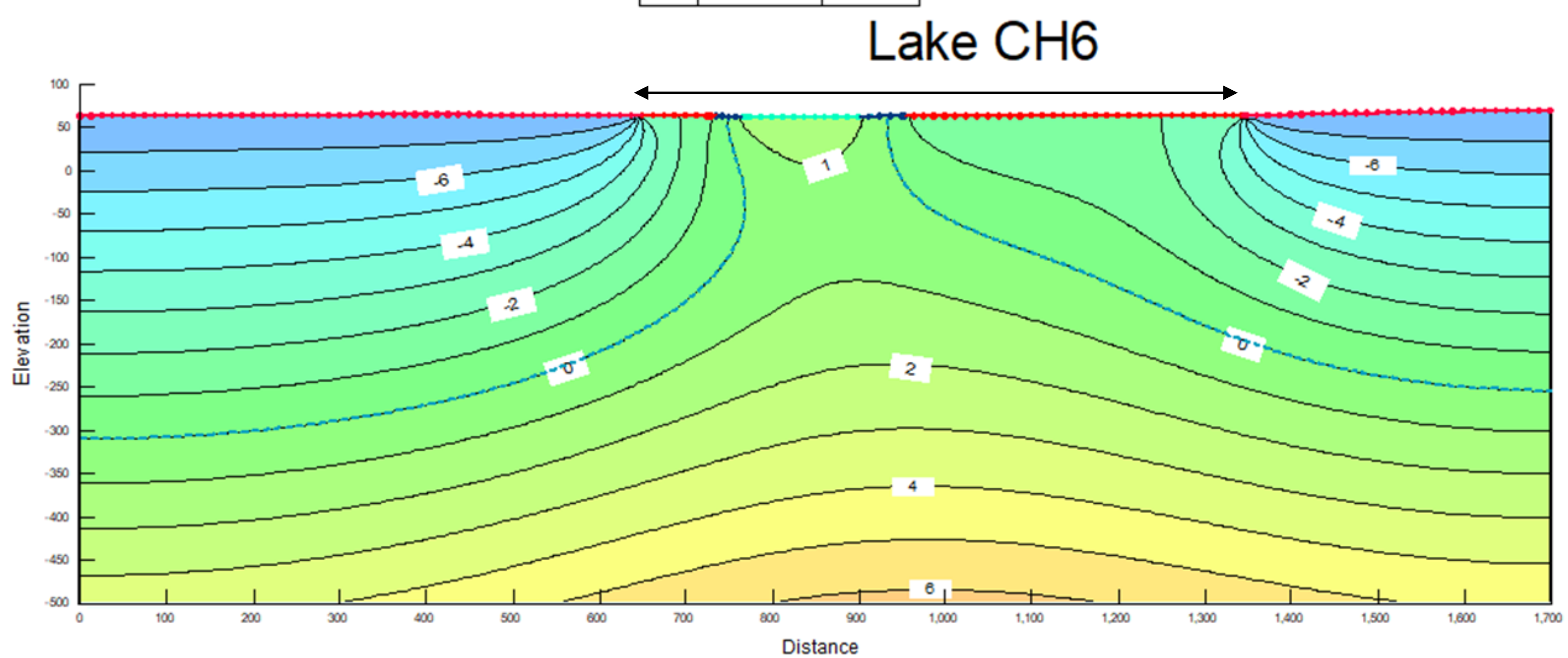
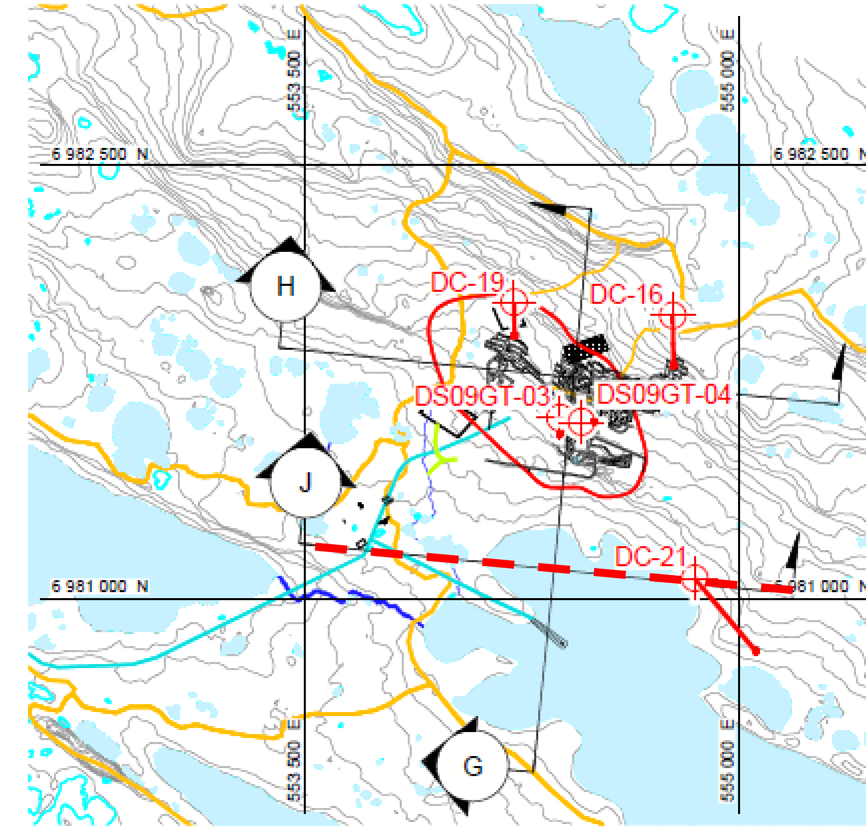
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION G
DISCOVERY AREA

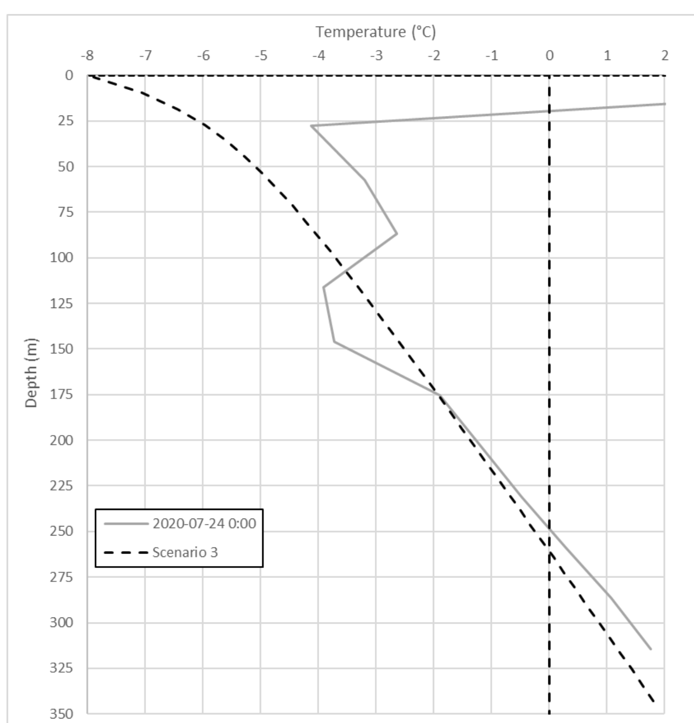
PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-2

Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(white)	Lower Heat Flux G and J 54	5.4e-05 kJ/sec/m²
(teal)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C





DC-21



Note: Certain sections could not achieve good calibration due to section orientation relative to reference thermistors or effects of 3D interaction between lakes and ground

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MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION J
DISCOVERY AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-3

Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
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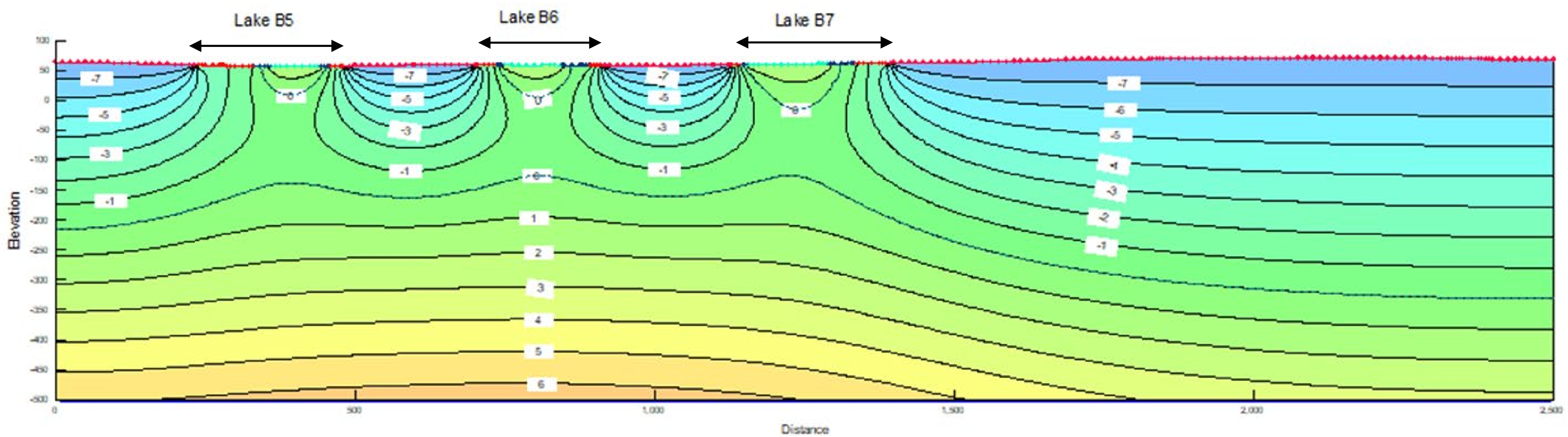
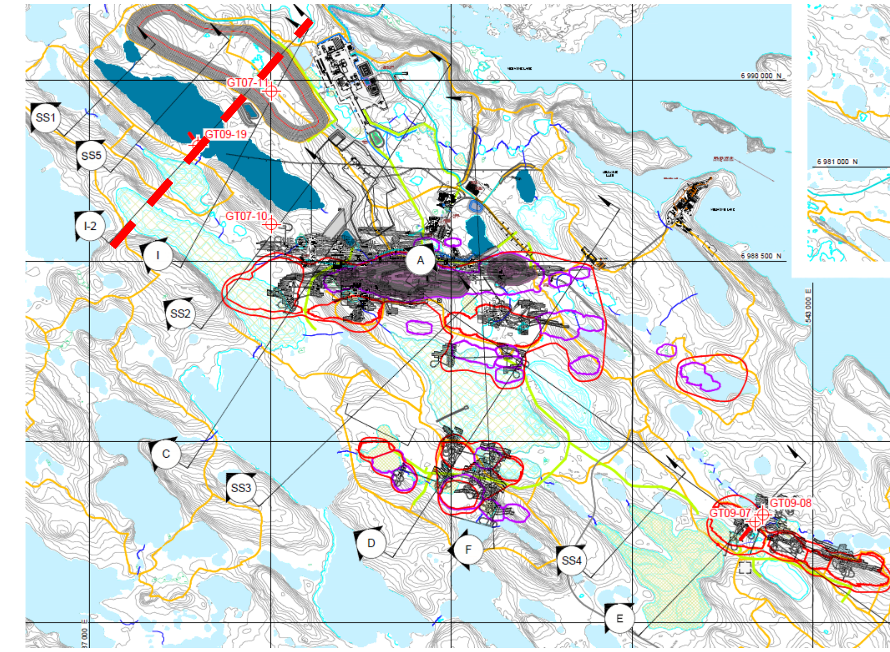
(red)	Terrace <1m	-2 °C





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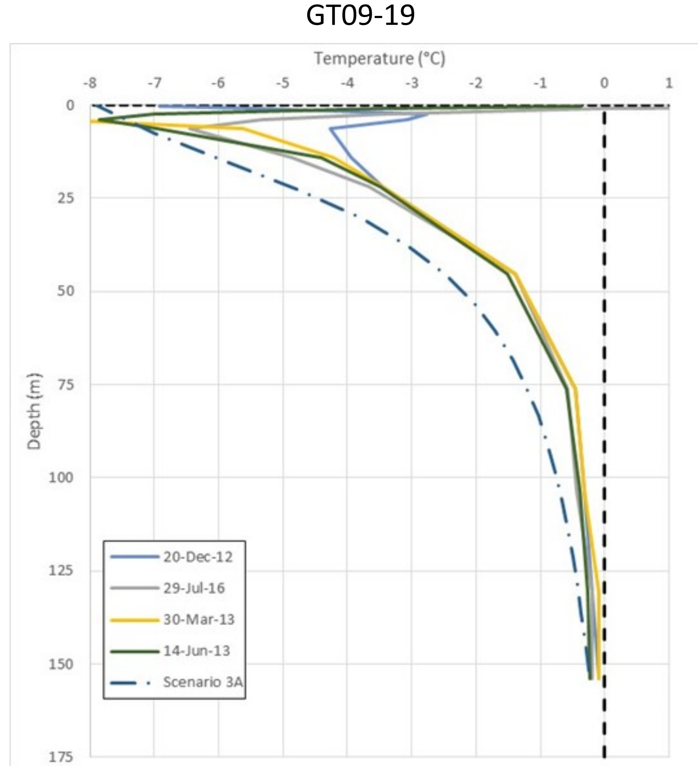

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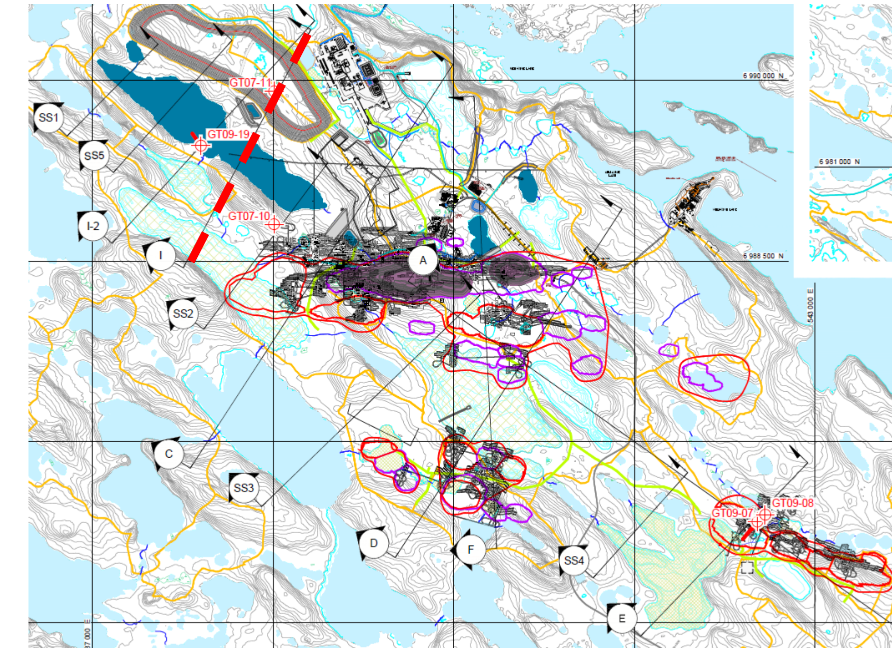
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION I-2
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-4



Color	Name	Parameters
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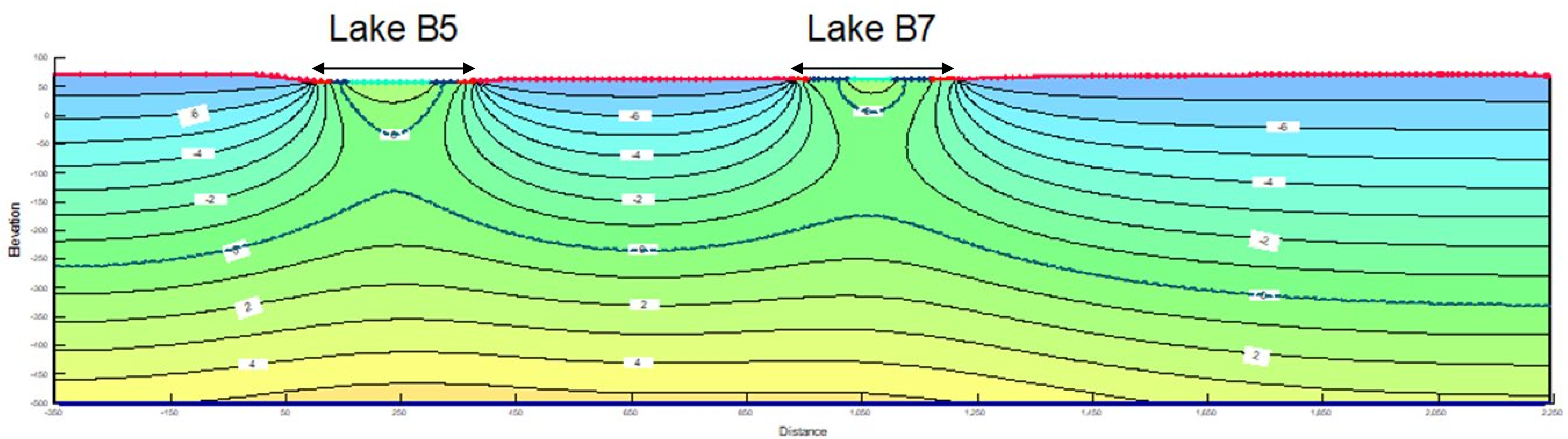
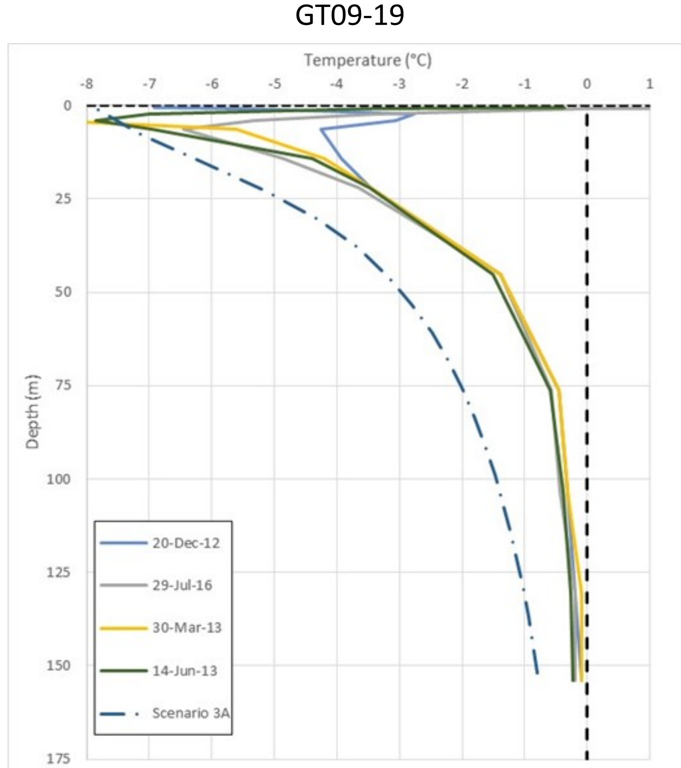
	Terrace - Ice	0 °C
	Terrace <1m	-2 °C



GT09-19



Note: Certain sections could not achieve good calibration due to section orientation relative to reference thermistors or effects of 3D interaction between lakes and ground

CLIENT AGNICO EAGLE MINES LTD.		PROJECT MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS	
CONSULTANT GOLDER MEMBER OF WSP	YYYY-MM-DD 2021-11-05 PREPARED ZPS DESIGNED ZPS REVIEWED FJ APPROVED JL	TITLE SECTION I MAIN AREA	
PROJECT NO. 20136436	Phase 2000	REV. 1	FIGURE B-5

Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
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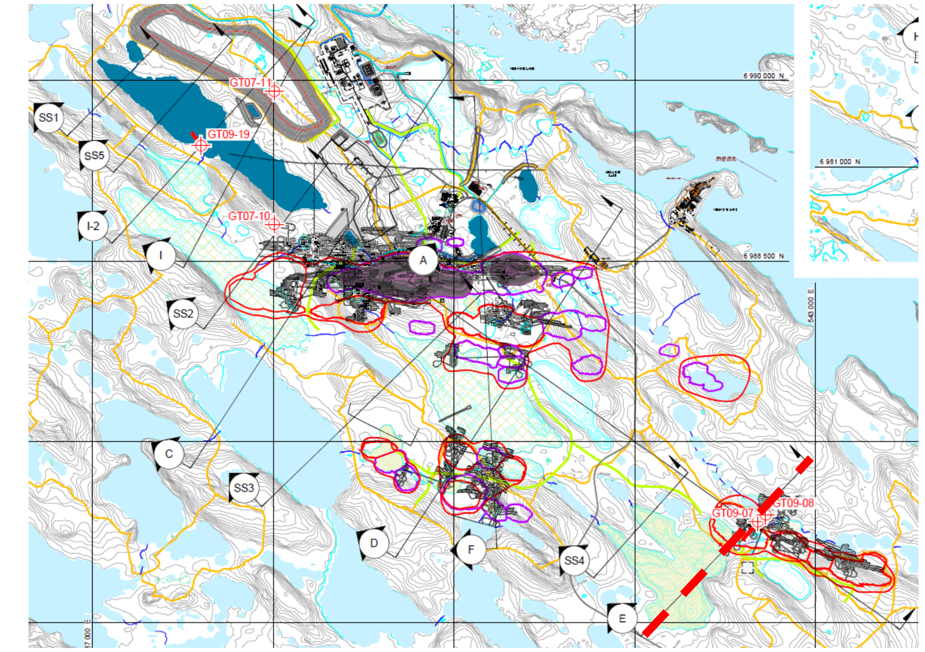
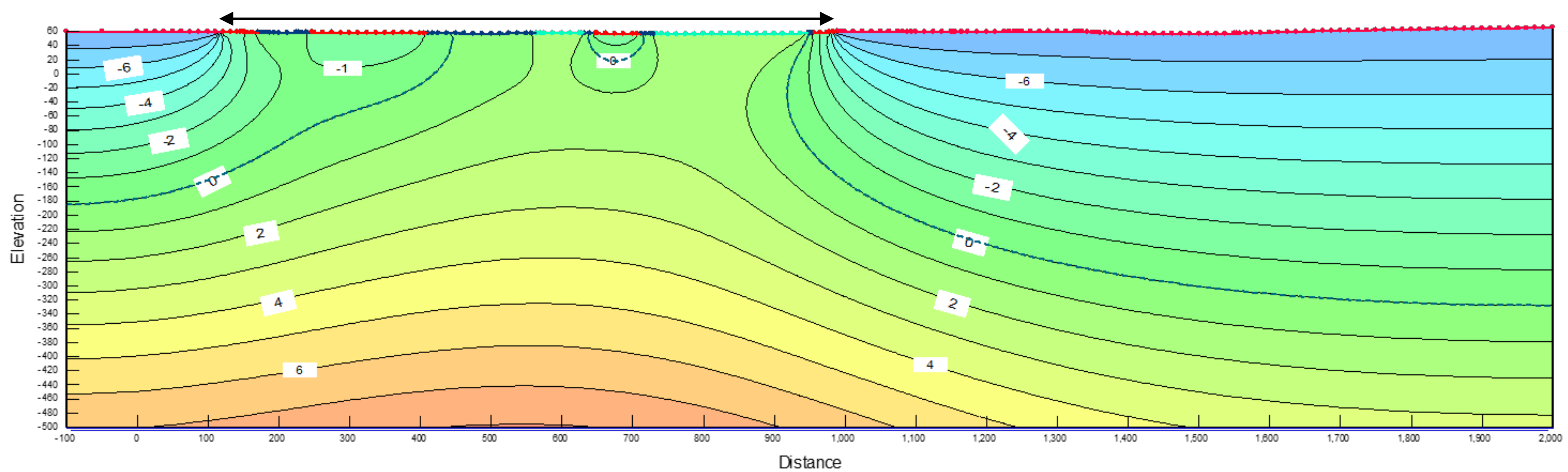
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C



Lake A6



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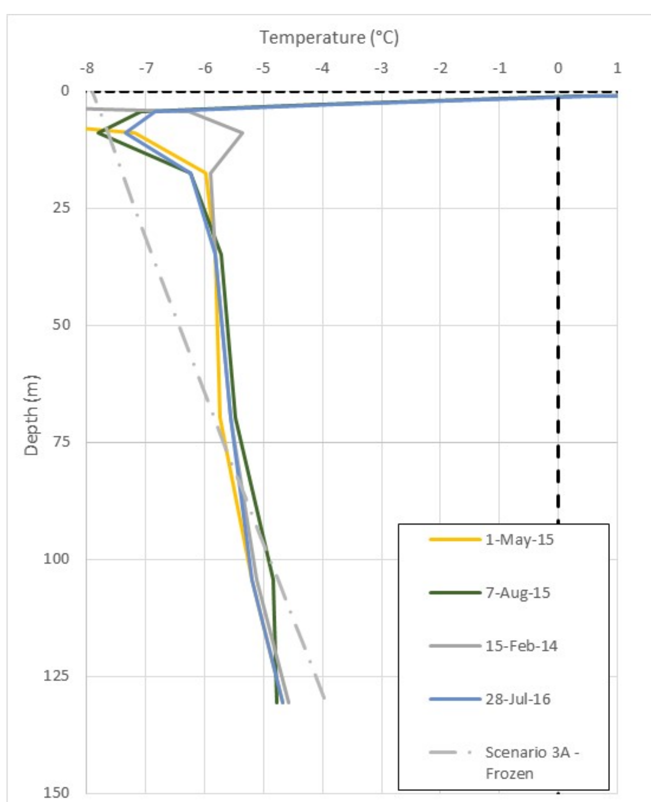
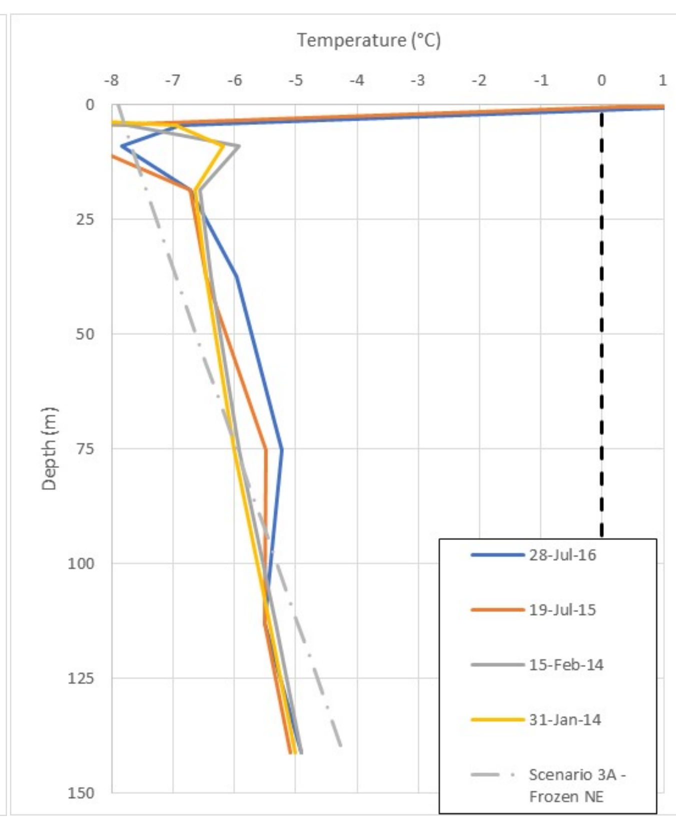


GT09-08



Note: Certain sections could not achieve good calibration due to section orientation relative to reference thermistors or effects of 3D interaction between lakes and ground

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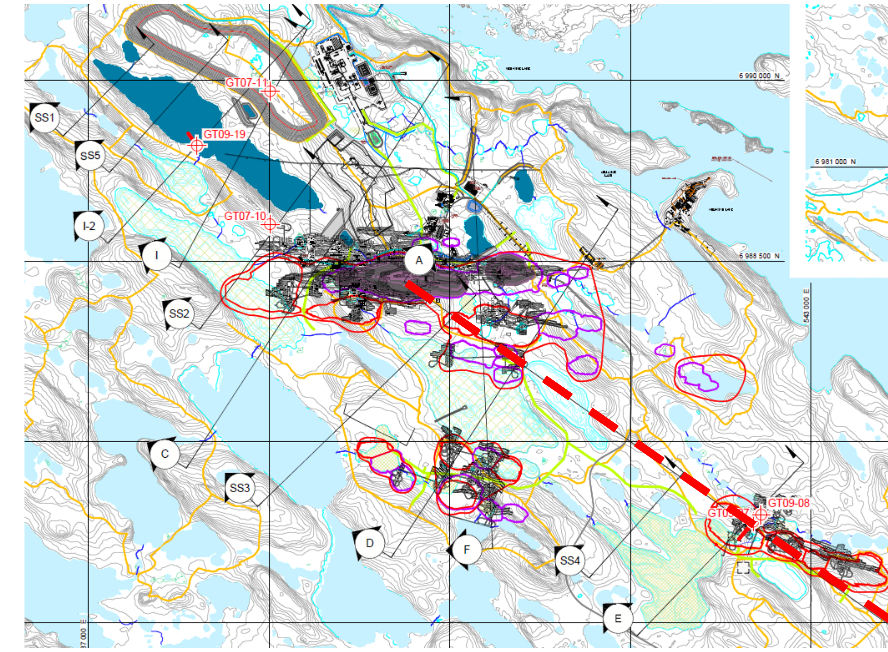
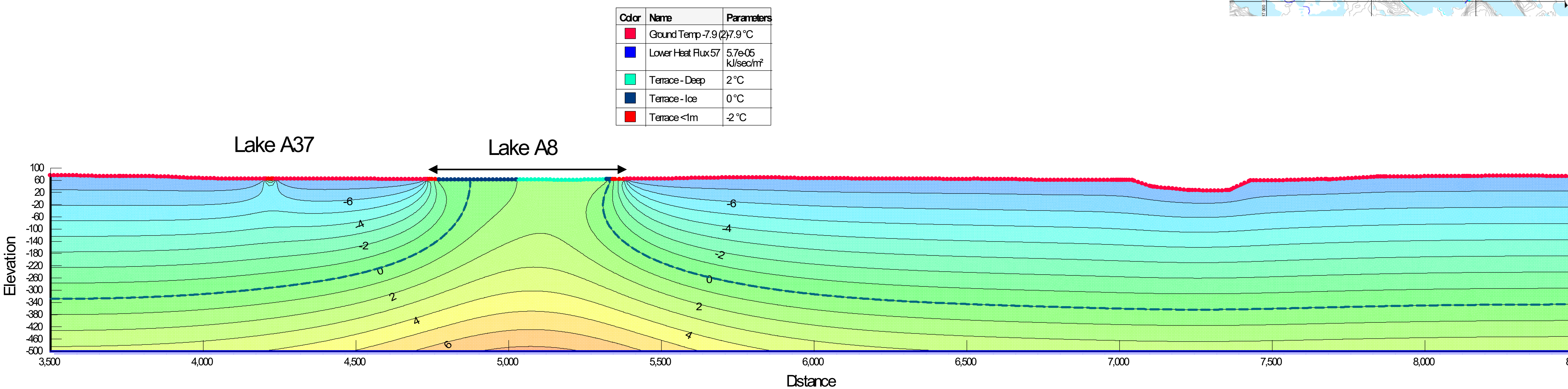
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION E
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-6





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PROJECT

MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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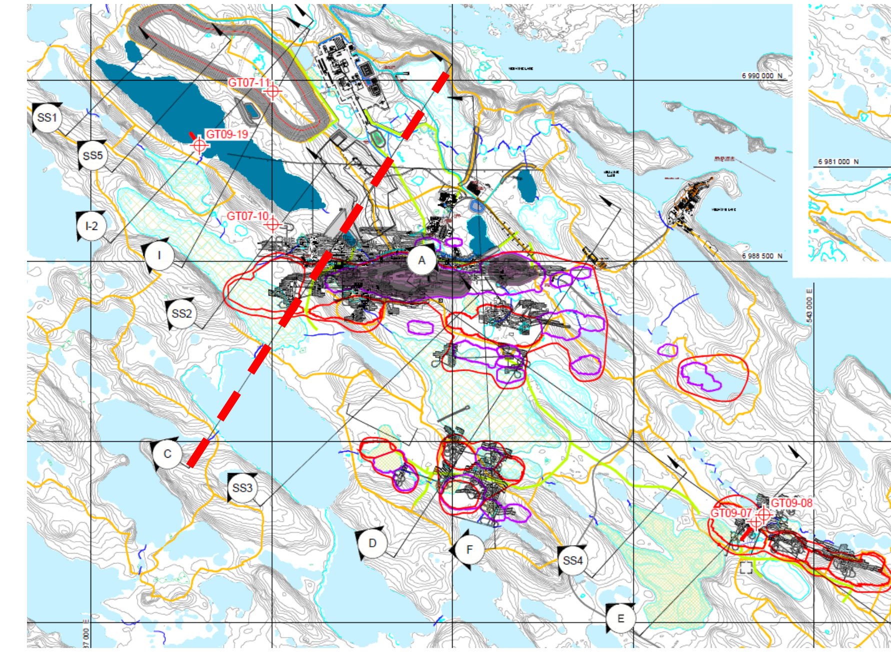
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE

SECTION A
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-7



Color	Name	Parameters
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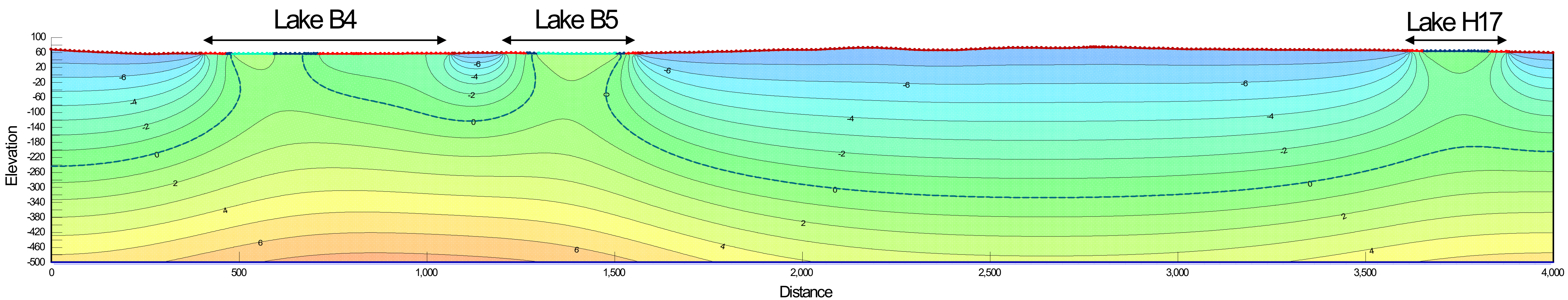
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
(aqua)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C



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MEMBER OF WSP

YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

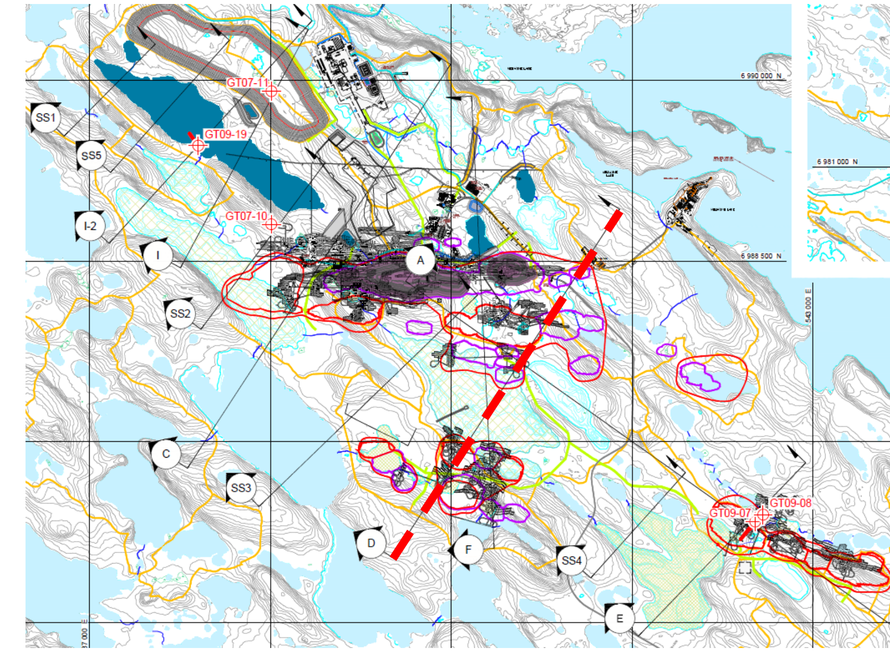
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION C
MAIN AREA

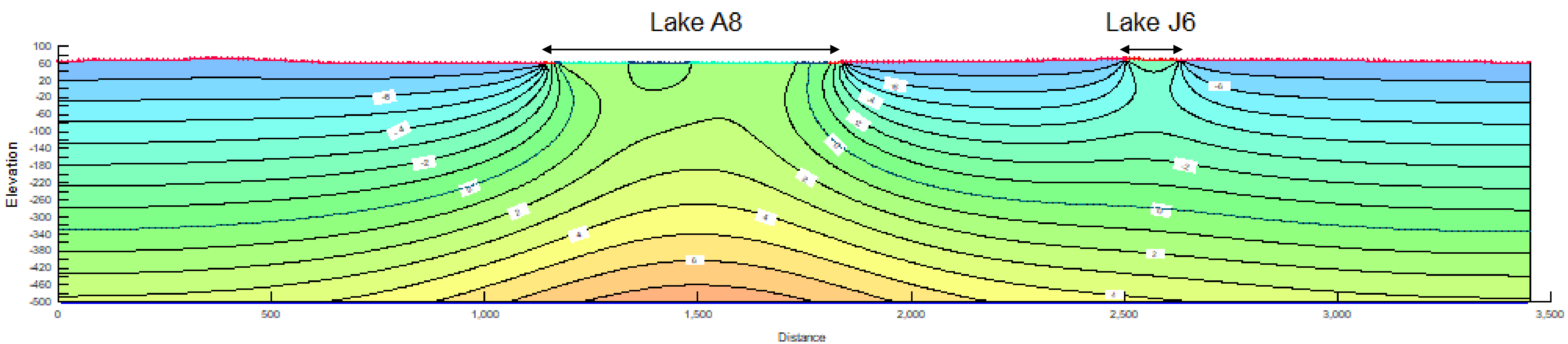
PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm



Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
(aqua)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace < 1m	-2 °C



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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT

GOLDER
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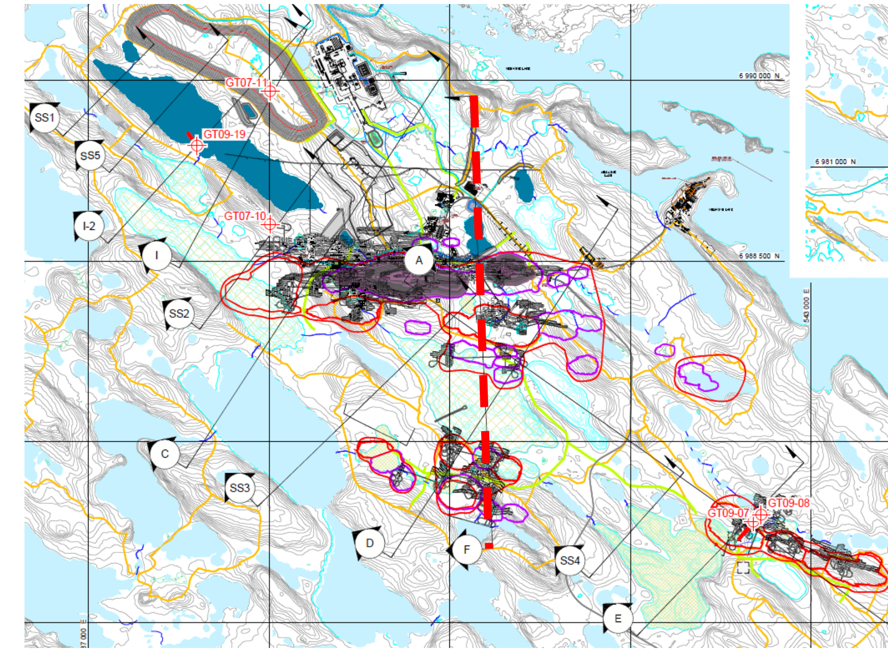
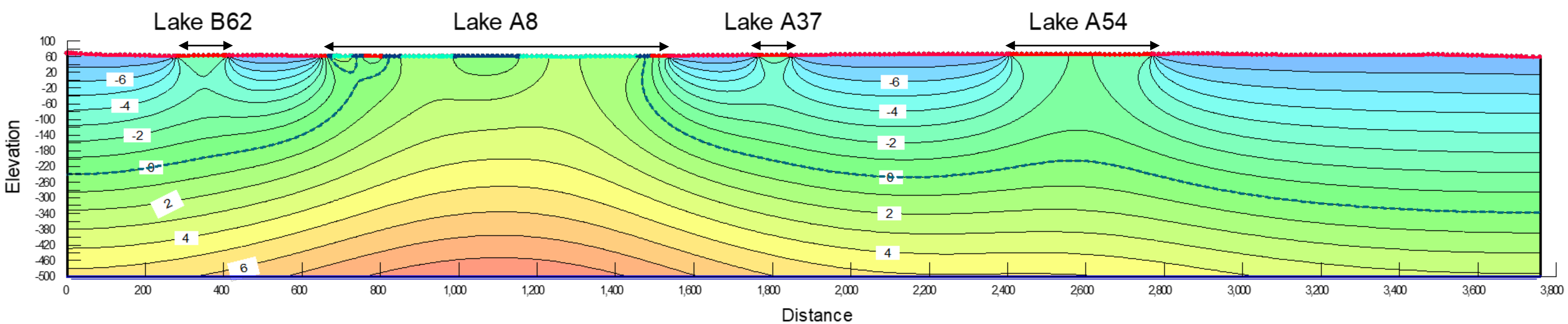
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION D
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-9



Color	Name	Parameters
	Ground Temp -7.9 (2)	-7.9 °C
	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
	Terrace - Deep	2 °C
	Terrace - Ice	0 °C
	Terrace <1m	-2 °C



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AGNICO EAGLE MINES LTD.

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT

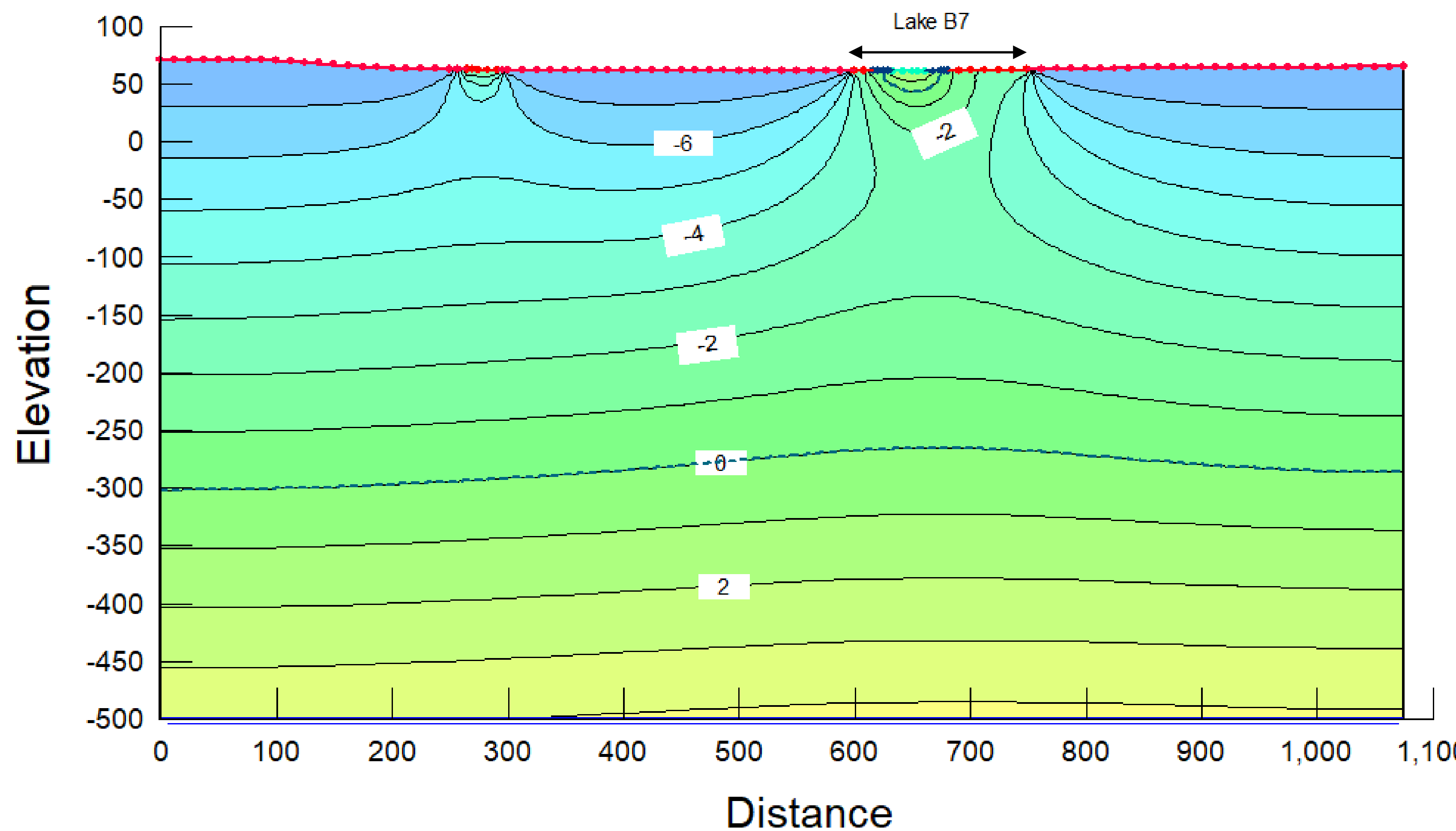
GOLDER MEMBER OF WSP

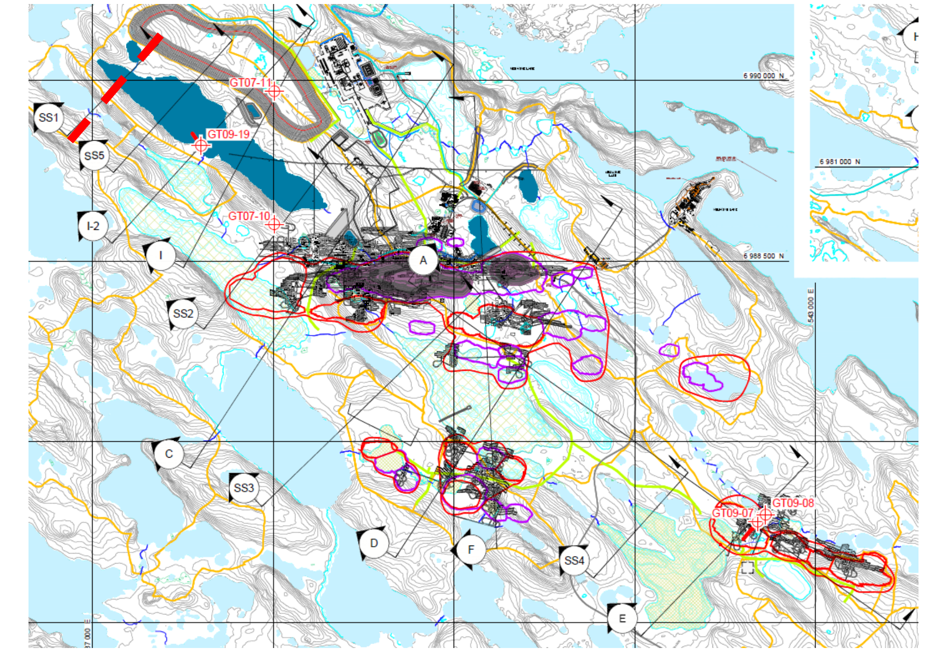
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION F
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-10

Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
(cyan)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C





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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT

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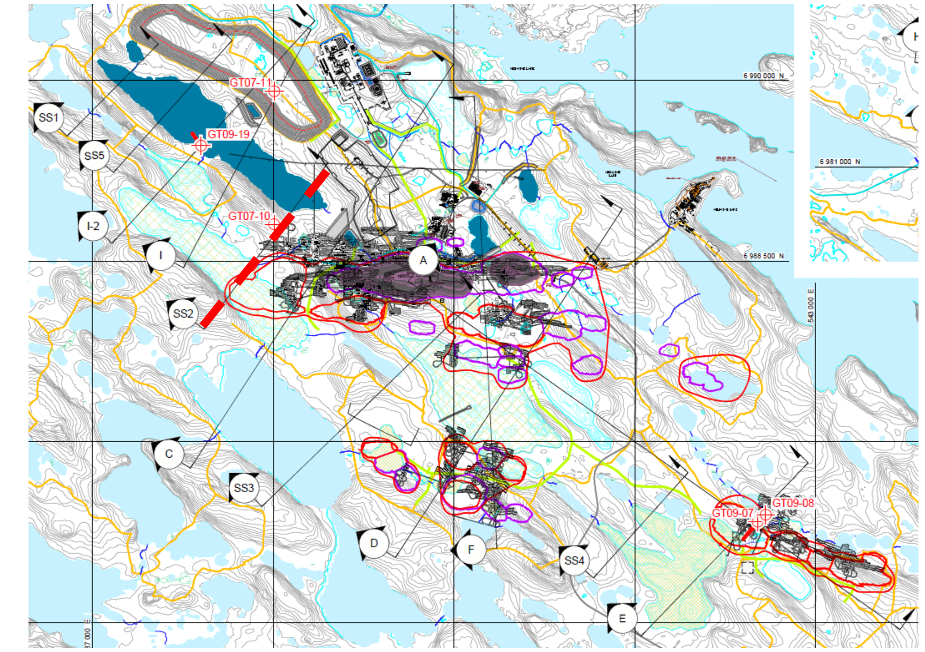
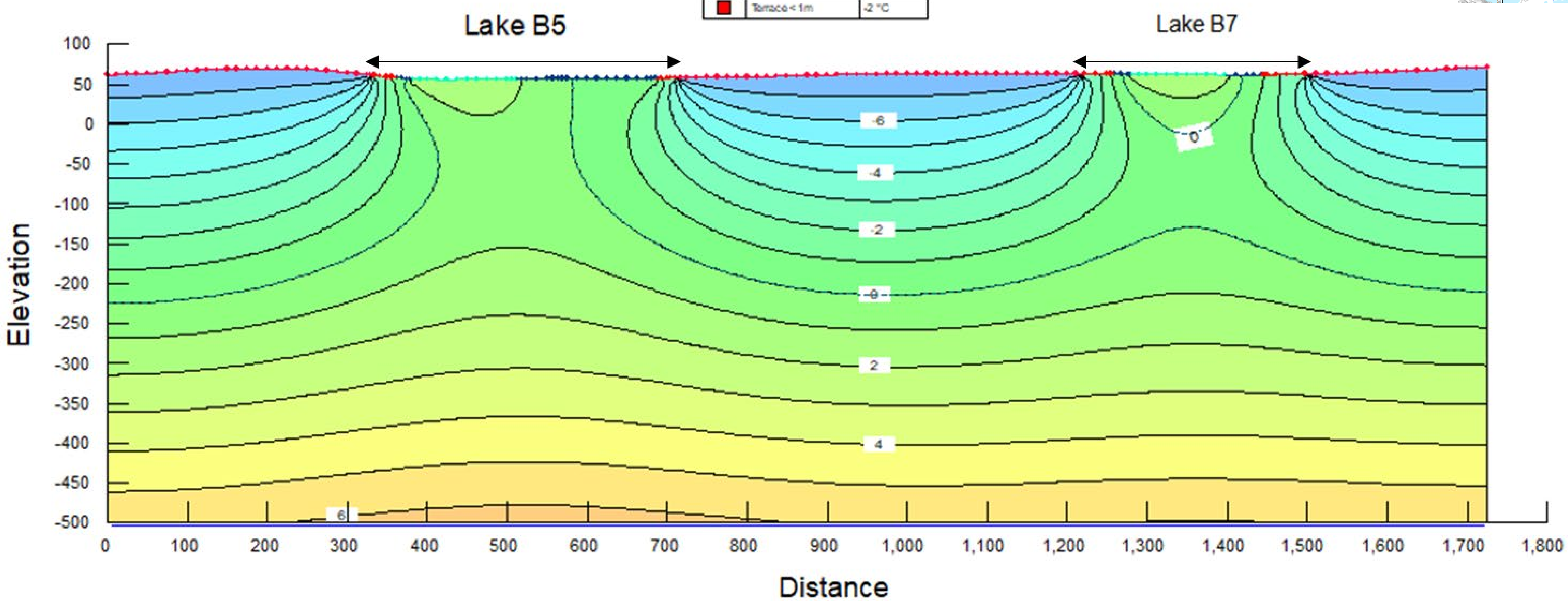
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION SS1
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-11



Color	Name	Parameters
	Ground Temp -7.9 (2)	-7.9 °C
	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
	Terrace - Deep	2 °C
	Terrace - Ice	0 °C
	Terrace < 1m	-2 °C



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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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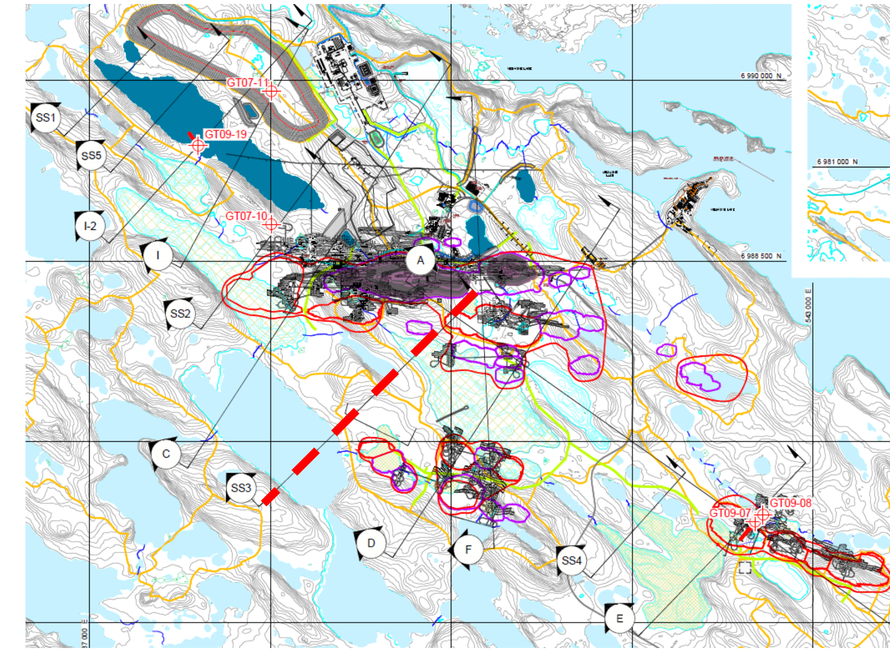
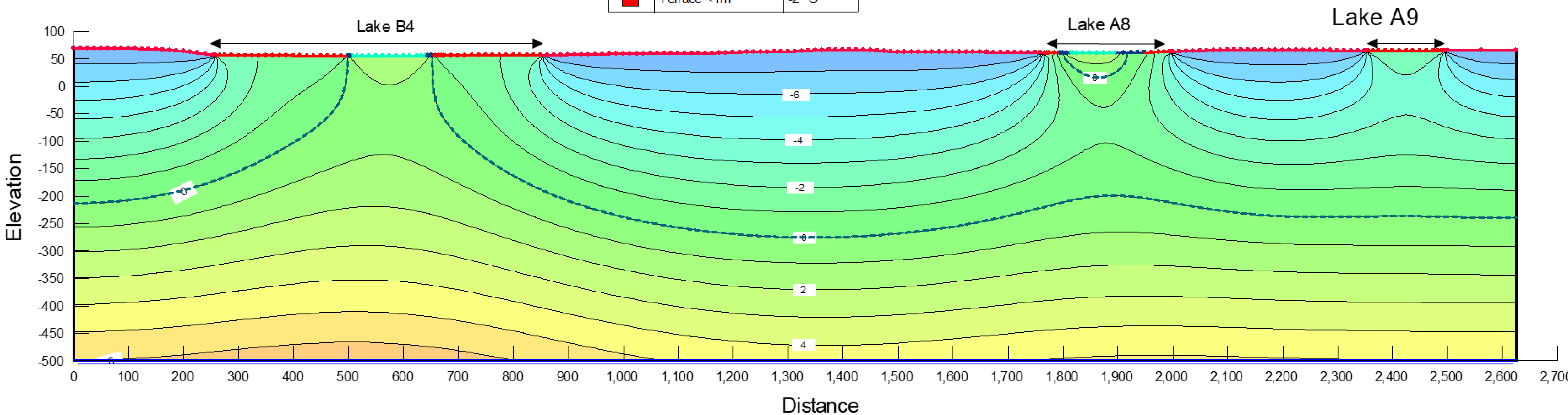
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION SS2
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-12



Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
(aqua)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C



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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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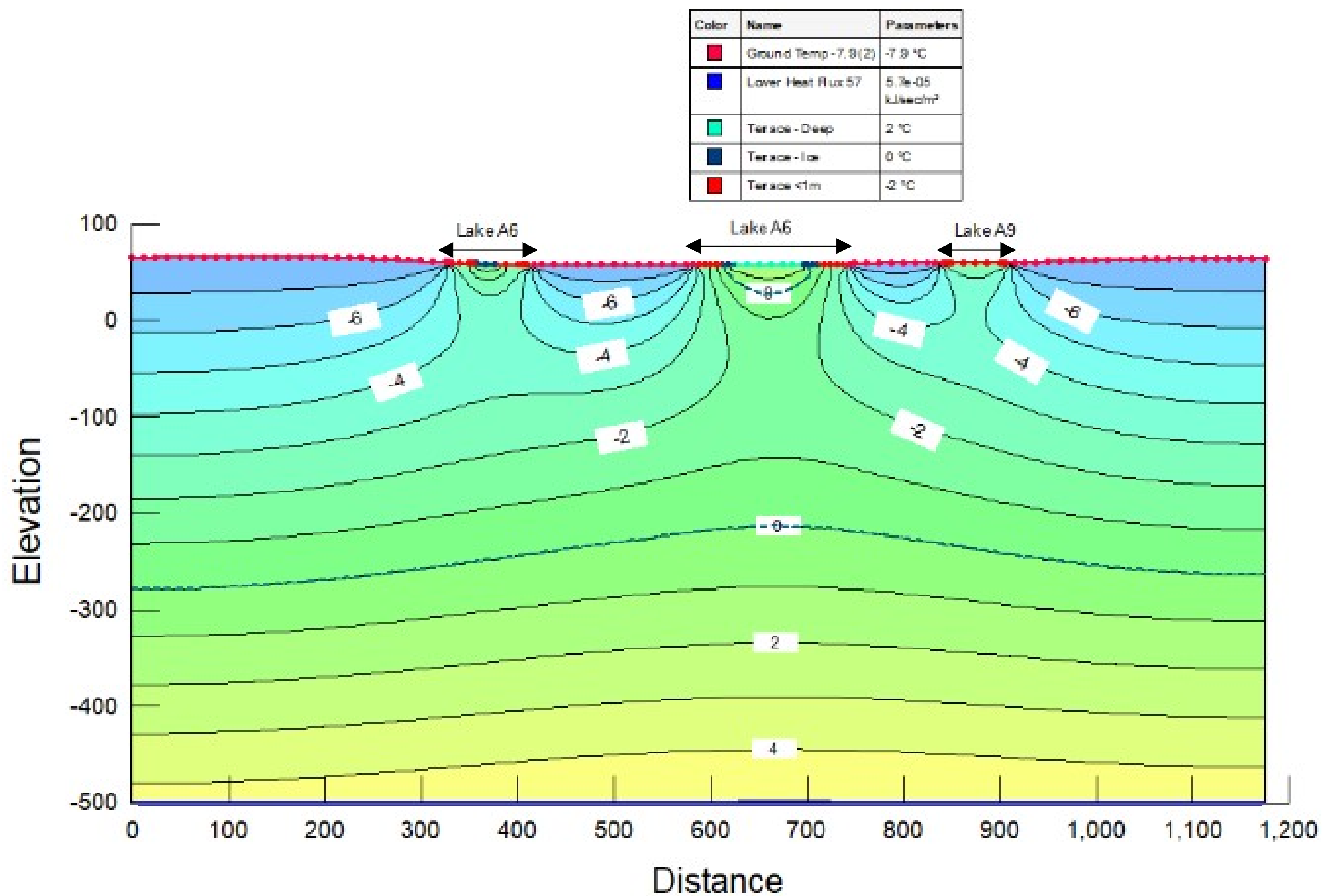
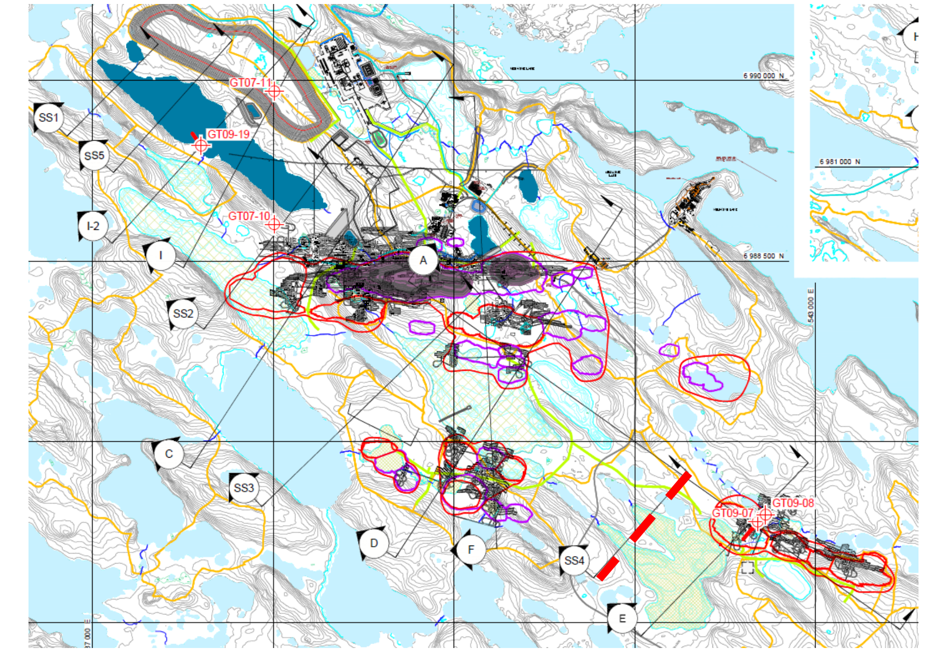
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION SS3
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-13





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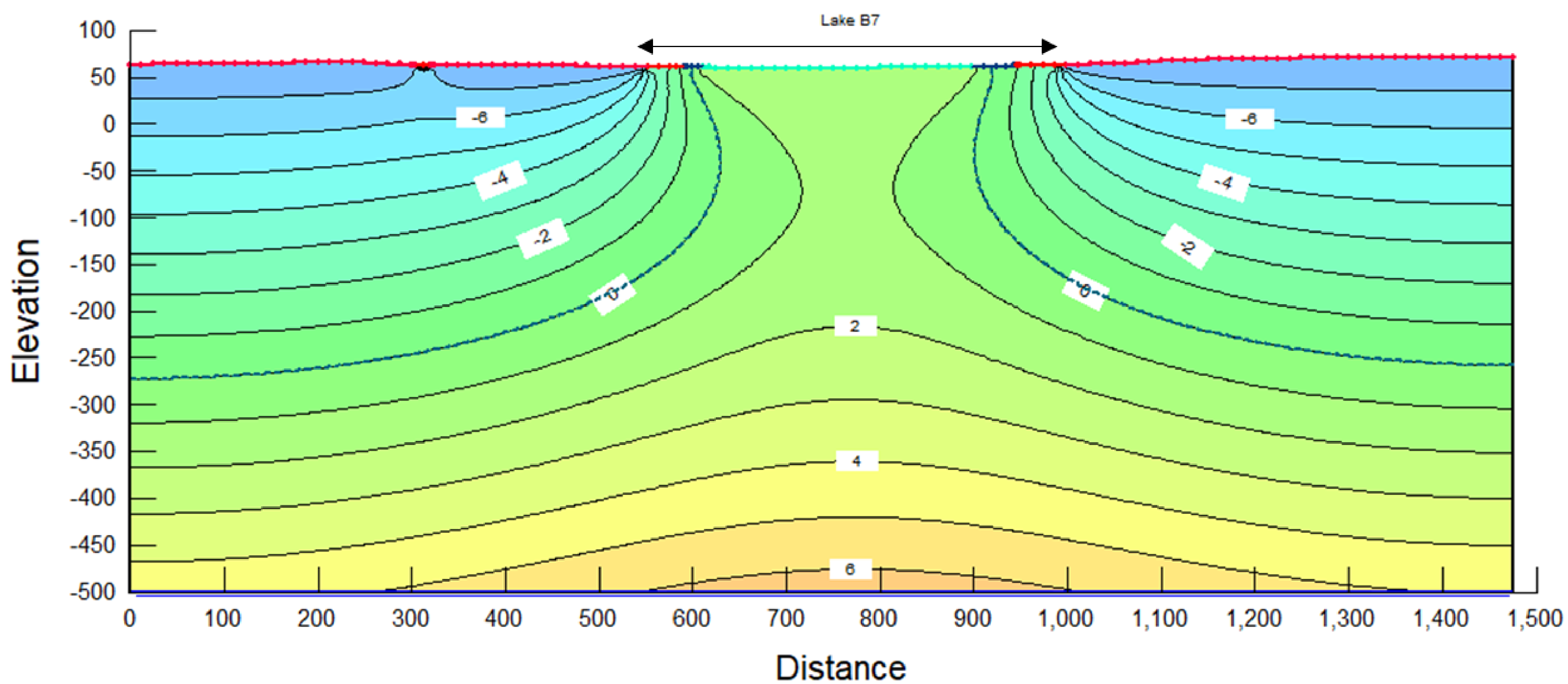
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

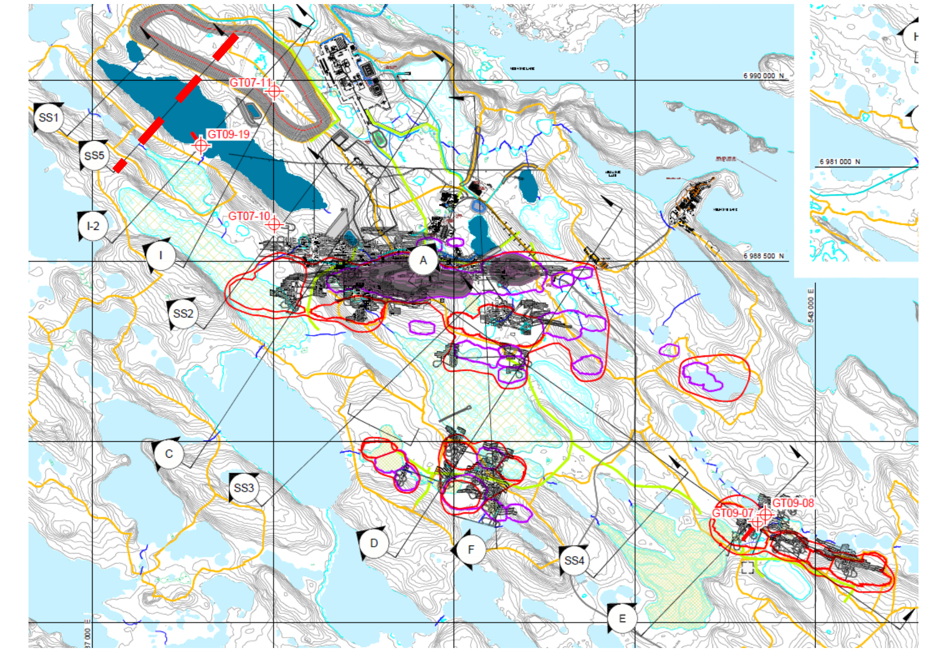
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION SS4
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-14

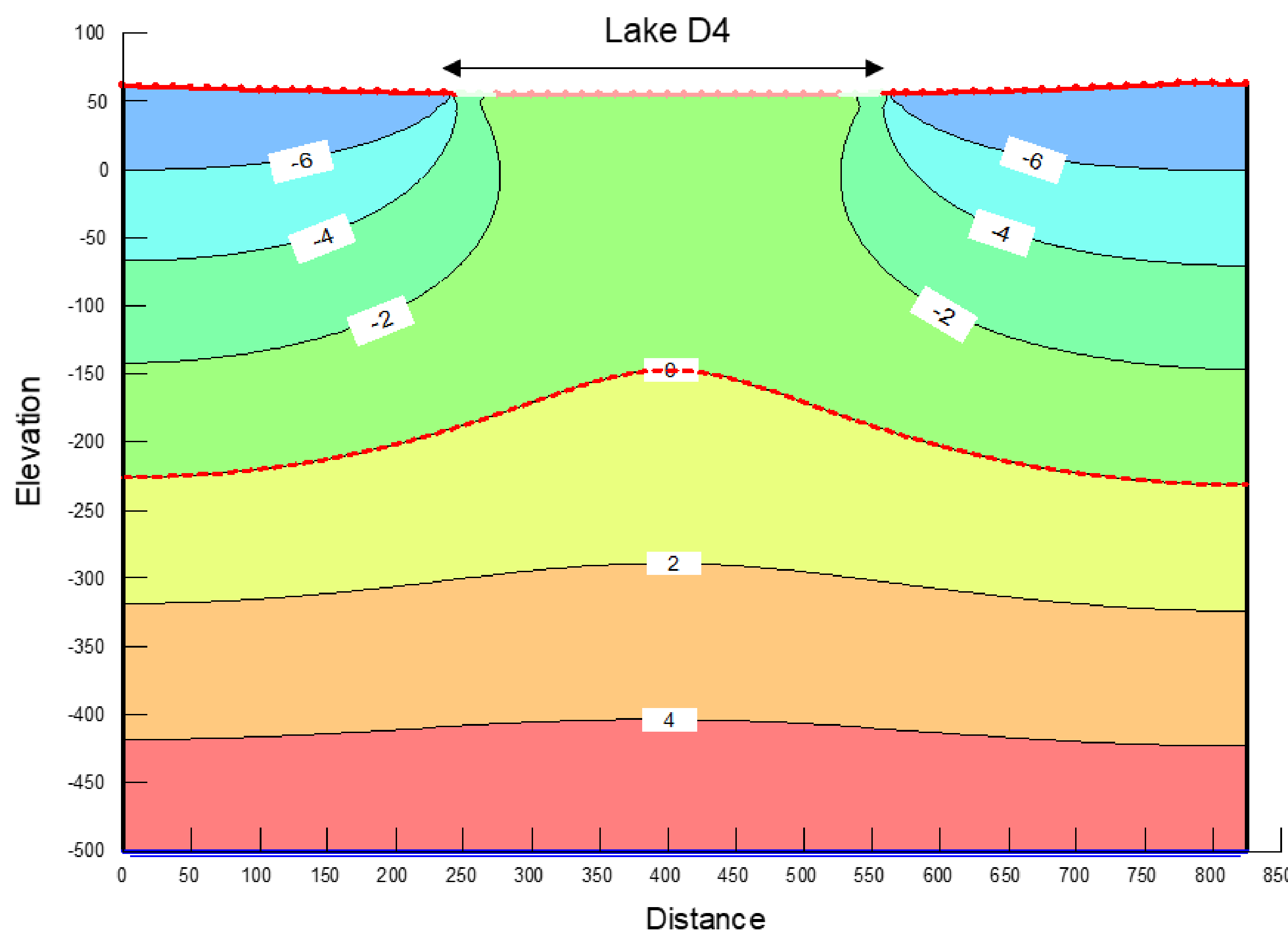
Color	Name	Parameters
(red)	Ground Temp -7.9 (2)	-7.9 °C
(blue)	Lower Heat Flux 57	5.7e-05 kJ/sec/m²
(aqua)	Terrace - Deep	2 °C
(dark blue)	Terrace - Ice	0 °C
(red)	Terrace <1m	-2 °C

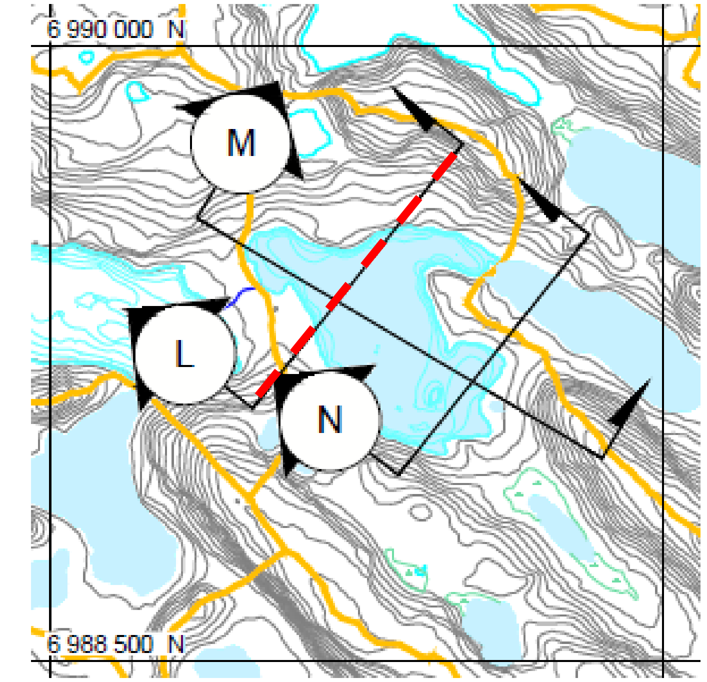




CLIENT	AGNICO EAGLE MINES LTD.
PROJECT	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL
TITLE	SECTION SS5 MAIN AREA
PROJECT NO.	20136436
Phase	2000
REV.	1
FIGURE	B-15

Color	Name	Parameters
(light green)	2- Lake <1m	-2 °C
(pink)	2- Lake <Ice	0 °C
(blue)	Geothermal Gradient	5.7e-05 kJ/sec/m²
(red)	Ground -7.9	-7.9 °C





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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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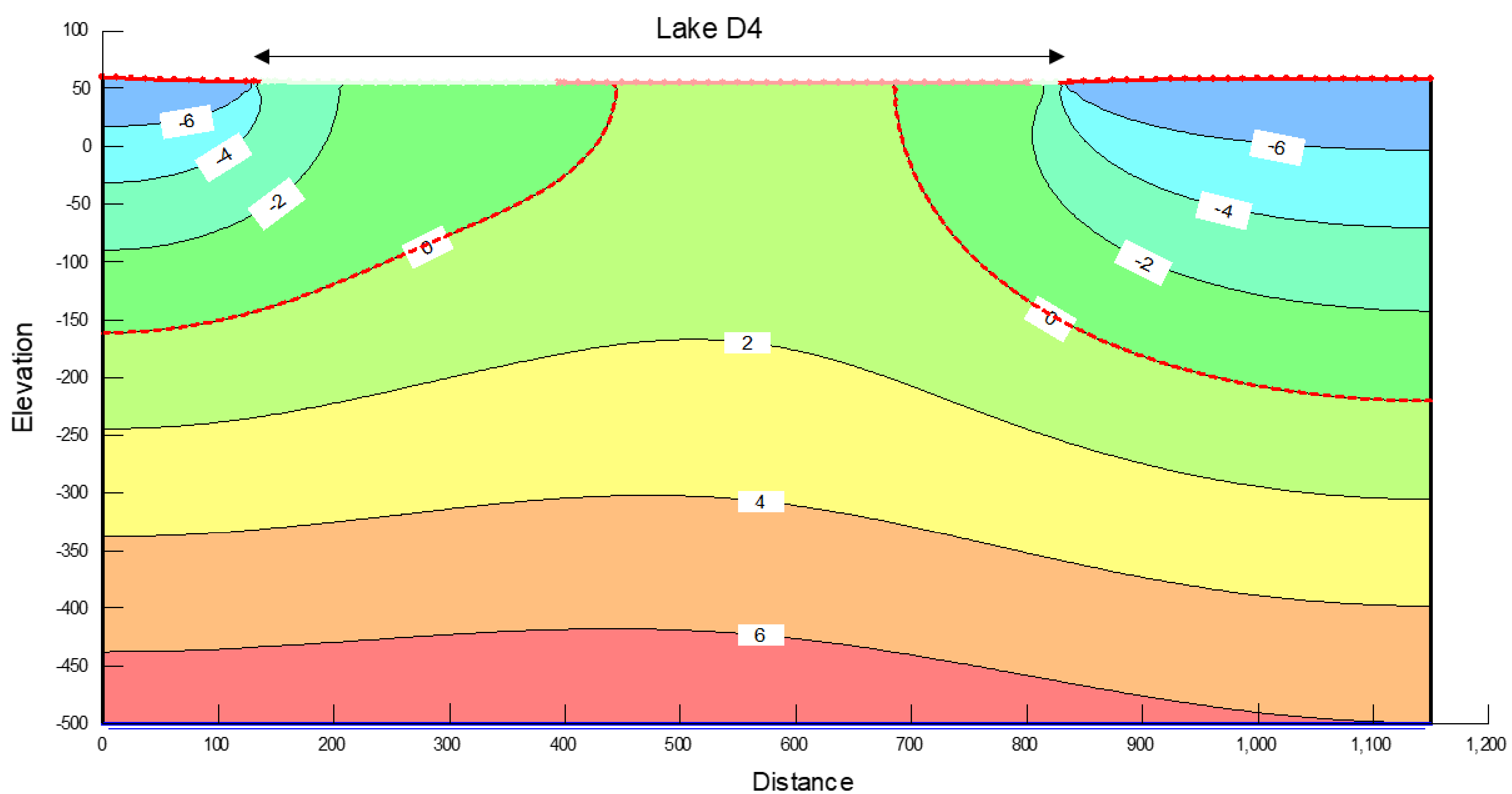
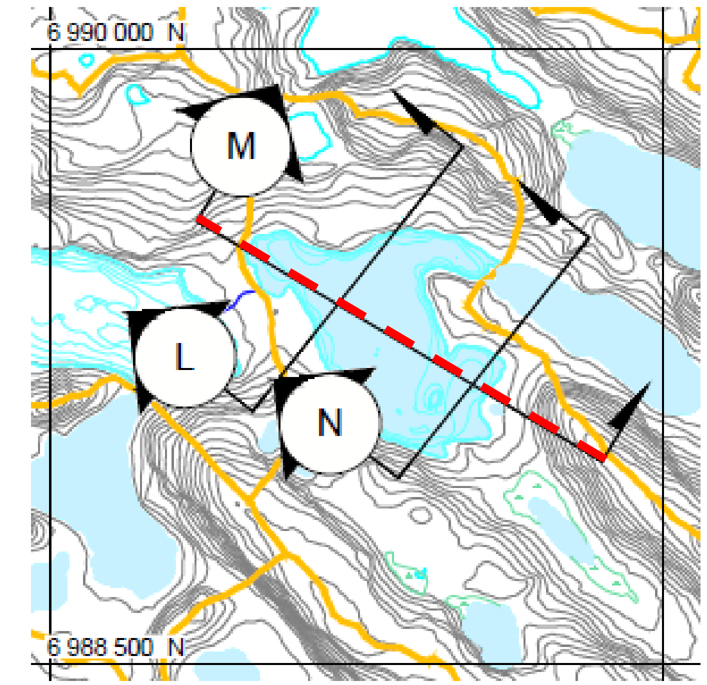
YYYY-MM-DD	2021-11-05
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION L
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-16

Color	Name	Parameters
(light green)	2- Lake <1m	-2 °C
(pink)	2- Lake <Ice	0 °C
(blue)	Geothermal Gradient	5.7e-05 kJ/sec/m²
(red)	Ground -7.9	-7.9 °C





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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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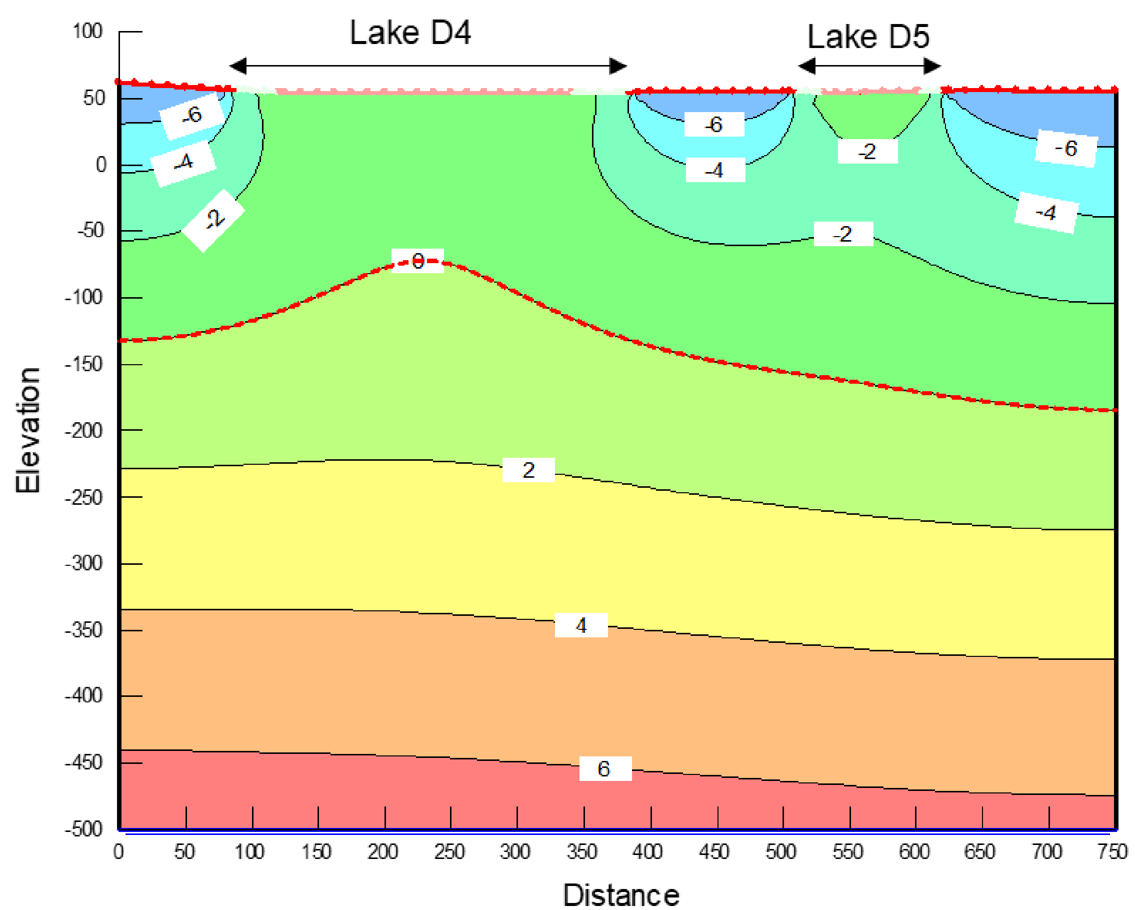
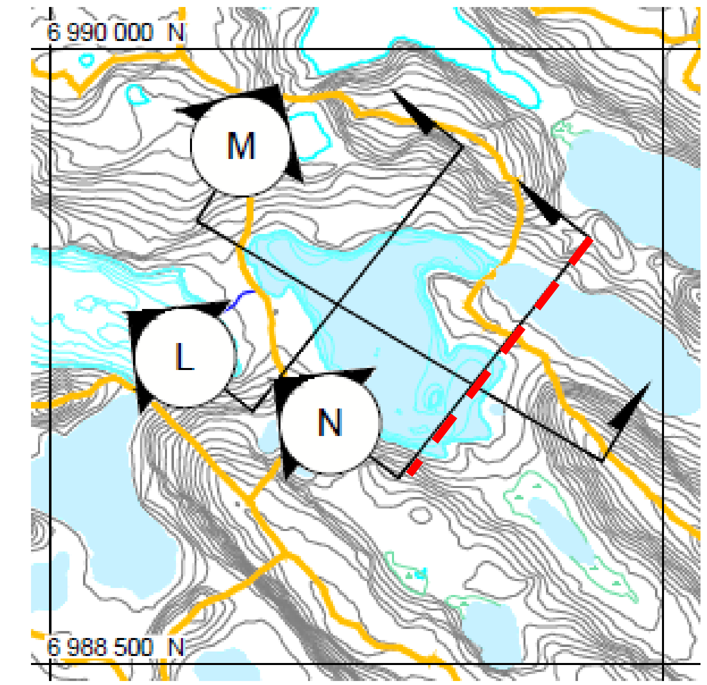
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION M
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-17

Color	Name	Parameters
(light green)	2- Lake <1m	-2 °C
(pink)	2- Lake <Ice	0 °C
(blue)	Geothermal Gradient	5.7e-05 kJ/sec/m²
(red)	Ground -7.9	-7.9 °C





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MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	JL

TITLE
SECTION N
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
20136436	2000	1	B-18

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