REPORT

Meliadine Extension - 2022 Thermal Assessment

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1.0 INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) retained Golder Associates Ltd. (Golder) to carry out thermal modelling as part of the Meliadine Extension aimed 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 an update of the 2020 thermal modelling exercise (Golder 2021) and incorporates new data from deep thermistors strings installed within the main project area in 2021.

Two-dimensional (2D) thermal models were prepared using cross-sections distributed throughout the study area, with some cross-sections being calibrated against available data from deep thermistors strings, including strings that breach the permafrost and provide direct information about permafrost depths.

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

- Tiriganiaq, F-Zone, Pump, and Wesmeg/Wesmeg North 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 the thermal assessment, lists updates made to the 2020 assessment, presents the model results and provides comments on how the predicted permafrost conditions compare to the 2020 assessment (Golder 2021) and the 2014 Permafrost Baseline Study (Golder 2014a).

The results of this thermal assessment update will also be used to update the hydrogeological model for the Project.

2.0 SITE CONDITIONS

2.1 Regional Permafrost Conditions

The Meliadine site 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). Bedrock types consisting of greywacke and diorite were encountered in the 2021 geotechnical site investigation (Tetra Tech 2021).

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 Okane (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
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 project 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 3.4. 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.

2.5 Site Permafrost Conditions

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

2.5.1 Locations of Thermistors

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	M98-195	6,988,660	539,968	69	80	180	437
	GT09-19	6,989,458	537,899	63	51	325	152
	GT07-11	6,989,910	538,507	69	90	0	44
	GT07-10	6,988,805	538,506	69	90	0	44
	GT21-44	6,987,062	540,307	62	64	199	478
	GT21-46	6,987,915	539,750	64	67	181	370
	GT21-71	6,988,590	538,259	58	64	231	376
	GT21-75	6,988,948	539,779	70	79	188	493
F-Zone	GT09-07	6,986,260	542,429	60	60	204	130
	GT09-08	6,986,317	542,494	60	71	207	139
	GT21-59	6,986,412	542,045	62	67	156	402
Discovery	DS09GT-03	6,981,625	554,379	72	67	180	129
	DS09GT-04	6,981,611	554,453	74	71	87	128
	DC-16	6,981,980	554,770	67	70	179	475
	DC-19	6,982,025	554,220	67	66	179	260
	DC-21	6,981,071	554,846	70	60	140	572

2.5.2 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 3.3.

Table 4: Summary of Permafrost Temperature Conditions in Site Thermistors

Thermistor ID	Zero Annual Amplitude[a]		Temperature Gradient (°C/m)	Permafrost Depth (m)
	Approximate Depth (m)	Approximate Temp (°C)		
GT09-07	40	-5.9	0.015	260[b]
GT09-08	40	-6.2	0.010	N/A[c]
GT09-19	28	-3.5	0.011	200
DS09GT-03	20	-7.0	0.018	430[b]
DS09GT-04	18	-6.7	0.015	485[b]
DCS-016	-	-	0.020	400
DCS-019	36	-6.2	0.016	420[b]
DSC-021	28	-4.7	0.025	245
GT21-44	-	-	0.016	115 to 300
GT21-46	-	-	0.015	370
GT21-59	-	-	0.019	310
GT21-71	-	-	0.011 (unstable)	250
GT21-75	-	-	0.016	480
M98-195	22	-7.5	0.018	480[b]

a) No zero annual amplitude reported for unstable thermistors or those with less than one year of data recorded.

b) Thermistor does not breach the bottom of permafrost. The permafrost depth has been extrapolated using the measured data and temperature gradient.

c) Extrapolation from thermal gradient not realistic.

3.0 THERMAL MODEL

3.1 General

Steady-state two-dimensional thermal modelling was carried out using the finite element software TEMP/W of GeoStudio 2021 (Version 11.2.0), developed by GEO-SLOPE International Ltd. (GEO-SLOPE 2021).

The model cross-sections were distributed to cross certain lakes that are 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, the 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 Tailings Storage Facility (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
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.

2D thermal models were prepared for 21 cross-sections aligned with underground developments, instrumentation, critical lakes, and areas of interest. Most sections remained as defined in the 2020 thermal assessment (Golder 2021), but some supplemental sections were added or adjusted to provide better alignment with the deep thermistor strings installed in 2021. Section locations are presented in Appendix A and were distributed across the project area as follows:

- Thirteen (13) sections in the Main Area
  - Compared to the 2020 study, Sections S22-A and S22-B were added, Section SS2 was adjusted (became SS2-2), and Section I was removed. The other sections remained the same as defined previously.
- Four (4) sections in the Discovery Area
  - Compared to the 2020 study, Section J-2 was added.
- Four (4) sections in the Tiriganiaq-Wolf Area
  - Compared to the 2020 study, Section O was added.

Table 6 presents the 2D model cross-sections locations and critical lakes they intersect. Sections' locations are also 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-2	B5, B7
	SS1	B7
	SS2-2	B5, B7
	SS3	B4, A8
	SS4	A6
	SS5	B7
	S22-A	A8
	S22-B	A6
Discovery	G	CH6
	H	N/A
	J	N/A
	J-2	CH6
Tiriganiaq-Wolf	L	D4
	M	D4
	N	D4
	O	D4

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

3.2 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:

- 2D thermal models can only capture heat transfer along the cross-sections and do 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 and variation in bedrock lithology. 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 2D models considered a single, general type of bedrock lithology across the site. Different bedrock lithologies and fracture conditions can affect the rock thermal properties, heat flow patterns and, consequently, variations in ground temperature. This limitation was partially overcome by relying on the results of calibrated sections, with the calibrated model input parameters offsetting possible variations in bedrock lithology.

- 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 cross-sections in specific areas to reduce spatial gaps in the 3D temperature block.

3.3 Model Approach and Calibration Process

The calibration process consisted of adjusting model input parameters until predicted temperature profiles were in agreement with measured temperature patterns 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 a general set, or slightly adjusted sets, of input parameters could be applied to the different areas that resulted in predicted temperature trends and profiles in 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 and thermistor locations were projected onto cross-sections. 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

Area	Section	Reference Thermistor Strings
Main	S22-A	GT21-46, GT21-75 and M98-198
	S22-B	GT21-59
	SS2-2	GT21-71
	SS3	GT21-46
	D	GT21-44
	E	GT09-07 and GT09-08
	F	GT21-44
	I-2	GT0-19
Discovery	G	DSC-16, DSC-19, DS09-GT03 and DS09-GT04
	H	DSC-16, DSC-19, DS09-GT03 and DS09-GT04
	J	DSC-021
	J-2	DSC-021

In general, 2D model input parameters were chosen that resulted in the best possible agreement with the relevant thermistor data, while remaining relatively consistent across the entire study area. Section S22-A, in the Main Area, was the primary calibration section for predicting regional permafrost conditions due being directly aligned with string GT21-75 and used projected temperature profile from the legacy M98-195 string, both are deep (i.e., >400 m in depth) strings located relatively farther away from lakes. These sections were used to calibrate the ground surface and basal thermal gradient (heat flux) model boundaries. In addition, Section S22-A is also aligned with the deep string GT21-46, which dips below a shallow portion of Lake A8 and was used to calibrate lake temperature in that area. Sections S22-B, SS2-2, SS3, D, E and I2 were further used to calibrate lakebed temperatures for different lake depths.

In the Discovery Area, Section H did not cross any lakes and was used to calibrate the ground surface temperature and thermal gradients used as a heat flux boundary condition at the base of the model geometry. Calibration of Section H used a combination of intermediate and deep strings as presented in Table 7. Lake bottom temperatures in the Discovery area were as calibrated from the Main area and used string DSC-021 as reference.

Section 3.4 presents the boundary conditions obtained from the model calibration phase. Certain sections and thermistors were unable to achieve good agreement during calibration including sections E (Main area), and J (Discovery area). 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.

3.4 Boundary Conditions

Throughout the calibration process, different sets of model inputs were tried, and the best-fit calibrated model inputs are summarized in Table 8.

Table 8: Calibrated model input parameters.

Area	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)	
Main	-7.9	<1	-2.0	< Average Ice Thickness[a]	0.0	> Average Ice Thickness[a]	2.0	0.016 to 0.017
Discovery	-7.9							0.018

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

3.5 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

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.

3.6 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 an 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.
  - In certain areas where information from two or more intersecting sections contradicted each other, two forms of action were taken, based on our professional judgement:
    - Less weight was given to those sections that were less representative of the expected temperature profiles for the area. Specifically, section A (main area) was given less weight in all instances of intersection with other sections and section O (Tiriganiaq-Wolf area) was given less weight in the vicinity of section N.
    - Components of sections were removed where contradiction with expected temperature profile could not be resolved through using lesser weights. Specifically, section F (main area) south of 6,987,400 was omitted, section G (main area) north of 6,981,340 was omitted and section M (Tiriganiaq-Wolf area) between 534,485 and 535,035 easting was omitted.
  - 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.

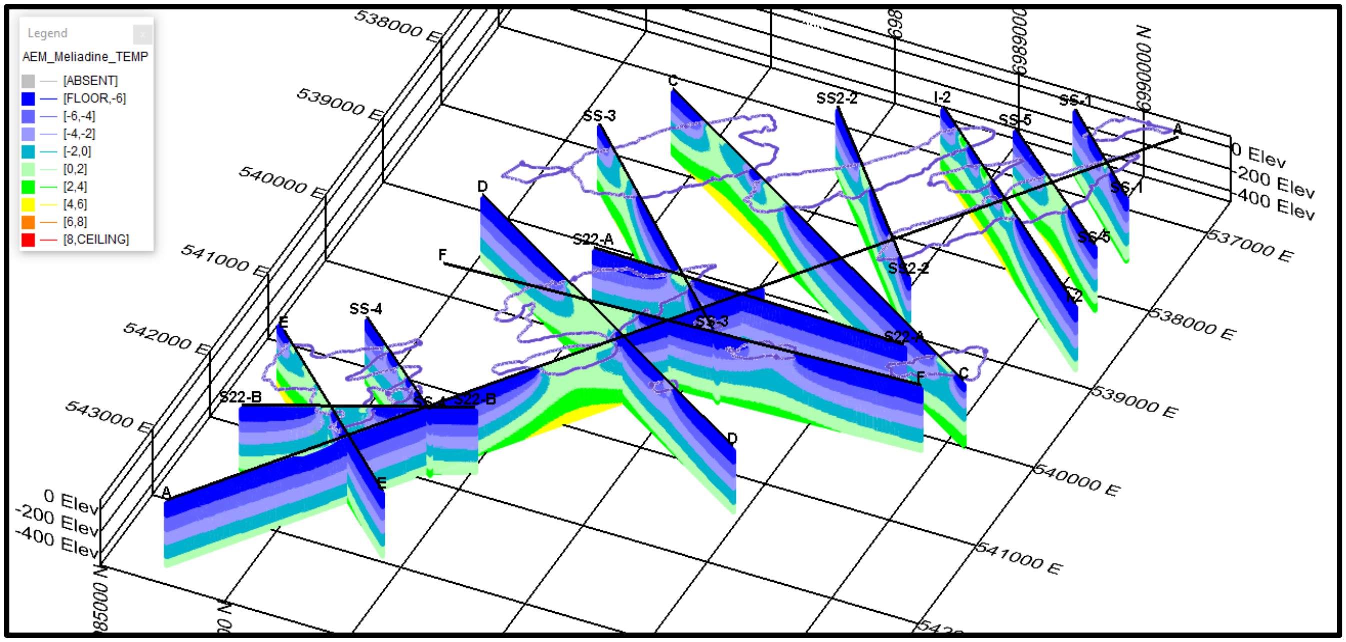

Figure 1: Main Area: 2D Thermal Sections and Lake Boundaries used as Input to Create the 3D Block Model

4.0 MODEL RESULTS

4.1 Two-Dimensional Thermal Models

Graphs showing model results are presented in Appendix B.

Figures B1 through B21 present the 2D thermal model results showing the 0°C isotherm that defines permafrost limits (i.e., limit of frozen and unfrozen ground without consideration of cryopeg), 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 thermistors used for model calibration. Certain sections and thermistors were unable to achieve good agreement during calibration including sections E (Main area) and J and J-2 (Discovery). 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 information available for model calibration.

The maximum depth of permafrost (defined by the 0°C isotherm) was about 430 m in the Discovery Area north of CH6 Lake, which is within a similar range of what is measured by string DSC-016. The maximum depth of permafrost predicted in the Main area was about 490 m in areas farther away from lakes, which is consistent with measurements from string GT21-75 and estimated permafrost depth based on legacy data from the deep string M98-195. At the Tiriganiaq-Wolf Area, a maximum permafrost depth of some 320 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 490 m as predicted and measured by deep strings in the Main area.

The permafrost limits shown by the 0°C isolines in Figures B-1 to B-21 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 existing 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: Predicted 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	S22-A		-	-	Closed	-	-	-
	S22-B	-	-	-	-	Closed	-	-
	A	-	-	-	Open	-	-	-
	C	Open	Open	-	-	-	-	-
	D	-	-	-	Open	-	-	-
	E	-	-	-	-	Open	-	-
	F	-	-	-	Open	-	-	-
	I-2	-	Closed	Closed	-	-	-	-
	SS1	-	-	Closed	-	-	-	-
	SS2-2	-	Closed	Closed	-	-	-	-
	SS3	Open	-	-	Closed	-	-	-
	SS4	-	-	-	-	Closed	-	-
	SS5	-	-	Open	-	-	-	-
Discovery Area [(a)]	G	-	-	-	-	-	Open	-
	J	-	-	-	-	-	Open	-
	J-2						Open	
Tiriganiaq-Wolf Area	L	-	-	-	-	-	-	Closed
	M	-	-	-	-	-	-	Open[(b)]
	N	-	-	-	-	-	-	Closed
	O							Closed

a) Section H did not cross any lakes and is not presented in the table. 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.

b) Open talik predicted by Section A has likely been affected by 2D model limitations.

Thermal models showed open taliks present for portions of each of the critical lakes in the Main area, although the interpreted extent of taliks beneath the lakes is reduced compared to the 2020 thermal assessment (Golder 2021) because of colder ground conditions being predicted in this thermal assessment update. Sections I-2, SS1 and SS2-2 showed closed taliks through the narrow parts of elongate lakes B5 and B7.

In the Discovery area, Sections G, J and J-2 through Lake CH6 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, but this section runs through the longest axis of the lake and results were probably affected by limitations associated with the 2D nature of the model geometry. Sections L and N cross shallower and/or narrower parts of the lake that contribute to closed talik, but the new Section O crosses a deeper portion of the lake and still showed closed talik conditions. Lake D4 is, in general, a shallow lake with maximum depth less than 1.5 m and, based on this and results from cross-sections L, N and O, it was interpreted that closed talik condition prevails beneath Lake D4. As such, the open talik portion in cross-section M was removed from the 3D block to reflect the assumption of closed talik under D4. Currently, there are no thermistors installed in the Tiriganiaq-Wolf Area to allow for a better assessment of talik conditions in that area.

4.2 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. The data grey areas within the lakes represent open talik (as defined by the 0-degree iso-surface).

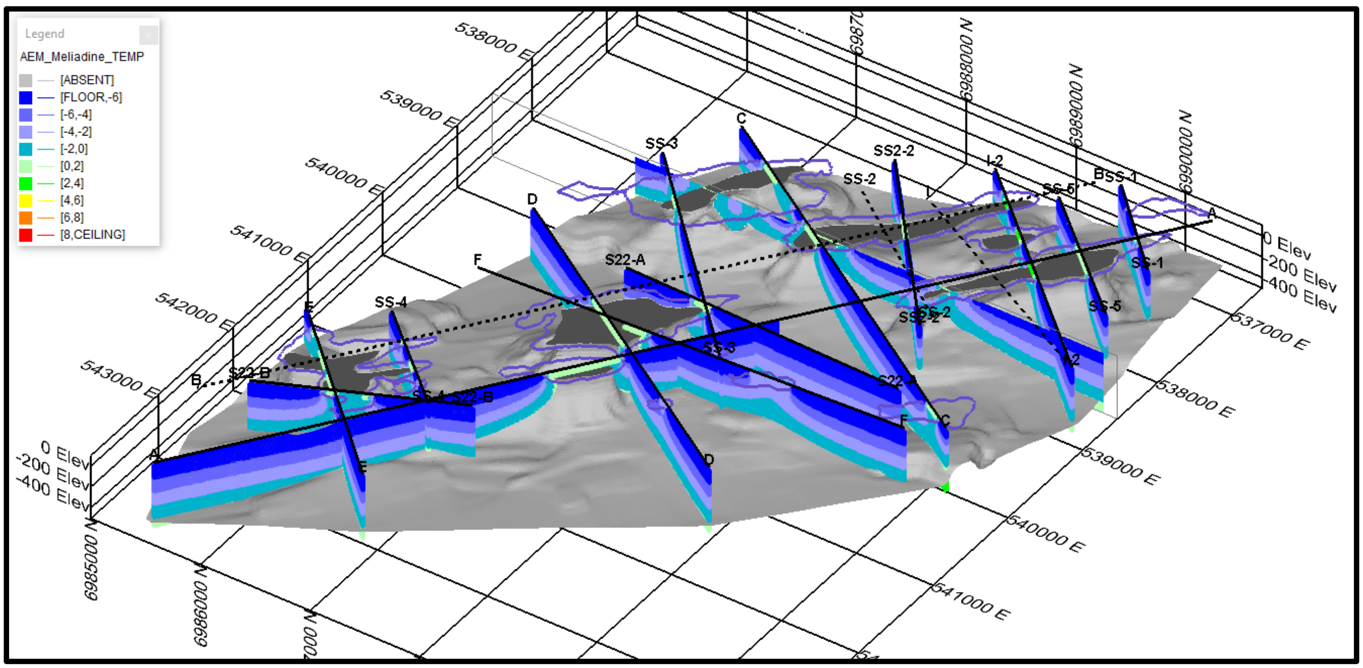

Figure 2: Main Area: 0-degree Iso-surface produced from the 3D Block Model

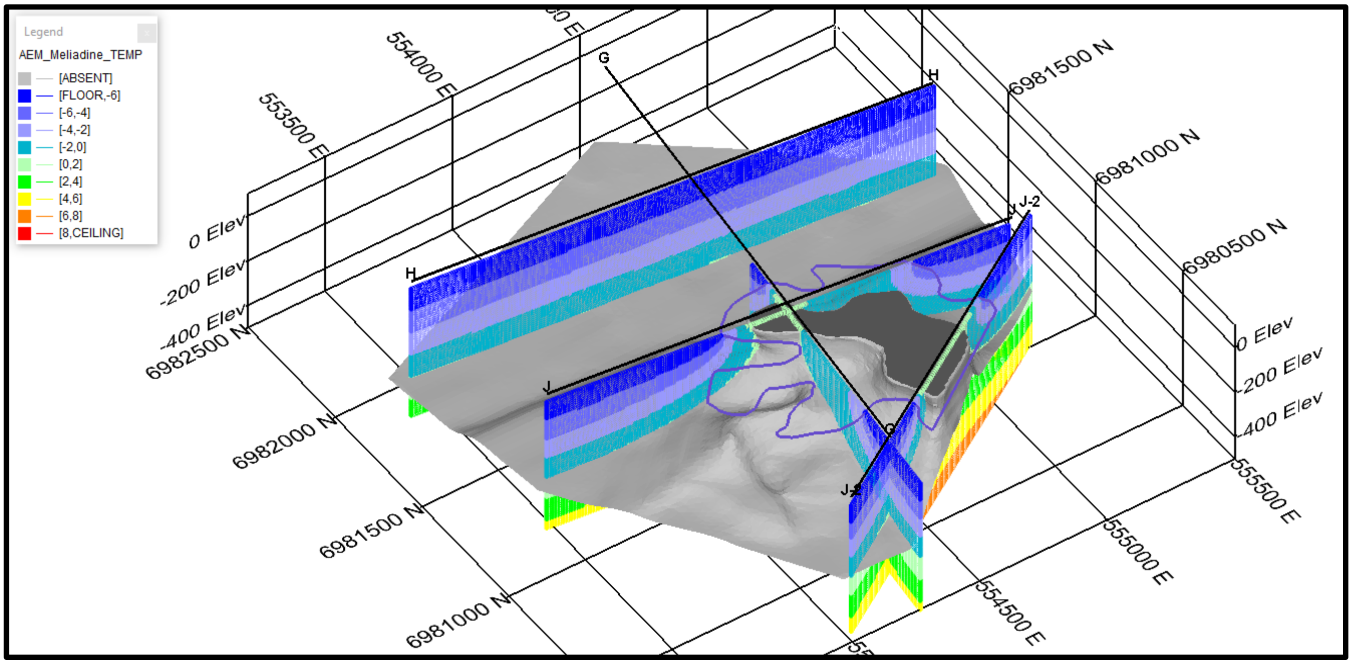

Figure 3: Discovery Area: 0-degree Iso-surface produced from the 3D Block Model

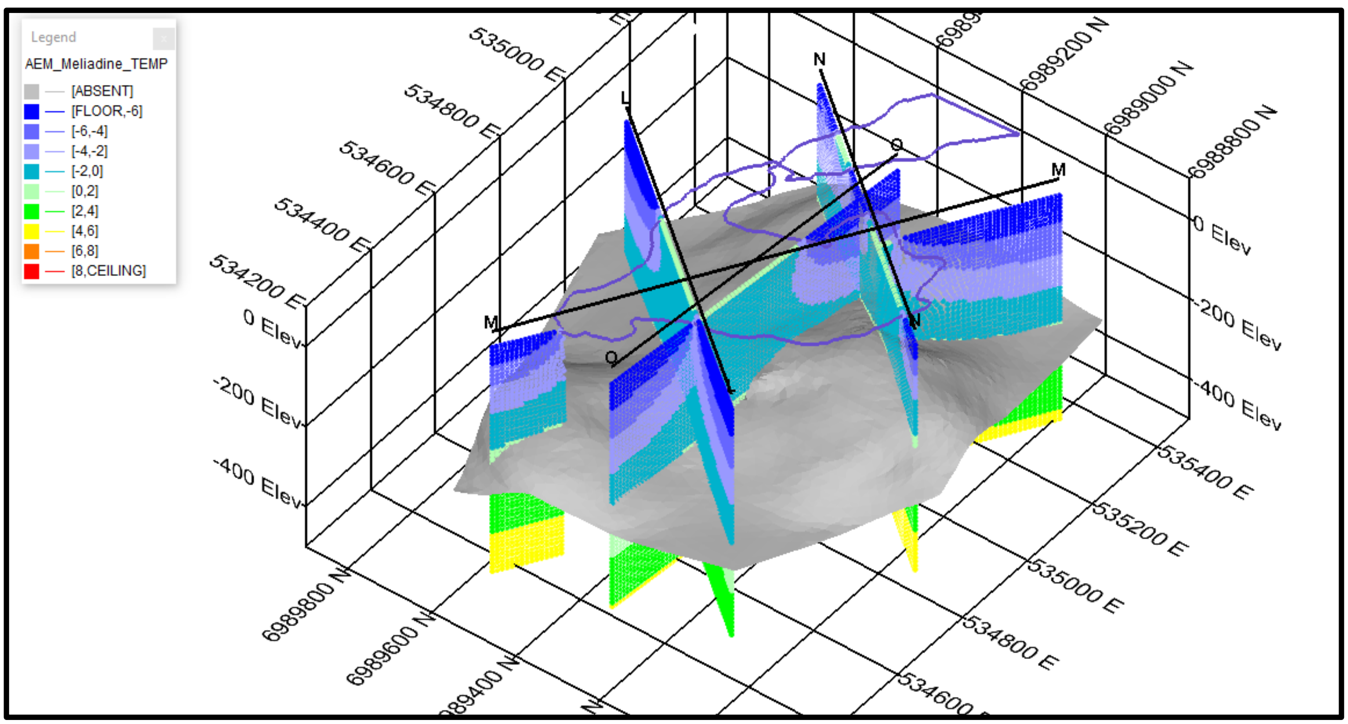

Figure 4: Tiriganiaq-Wolf Area: 0-degree Iso-surface produced from the 3D Block Model

The 3D model was prepared using the 2D model cross-sections, with professional judgement used on the controls for the estimation of temperature between those 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. The accuracy diminishes with increasing distance from a cross-section, or in deeper portions of lakes where no information was available from the 2D model cross-sections.

The 3D models results are provided to Agnico Eagle as a companion to this report, so Agnico can make use of the results as needed.

5.0 SUMMARY

Golder has performed thermal numerical modelling of the Meliadine Extension 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. The modelling exercise described in this document is an update of the 2020 thermal assessment (Golder 2021) and was carried out to incorporate new data from deep thermistor strings installed in 2021 in the Main area (i.e., GT21-44, GT21-46, GT21-59, GT21-71 and GT21-75), as well as legacy data from string M98-195. The models also included more recent data from strings DSC-016, DSC-019 and DSC-021 installed in the Discovery area.

Permafrost depth and the presence of closed or open talik conditions beneath lakes are interpreted based on the 0-degree isotherm. However, due to very high groundwater salinity with Total Dissolved Solids (TDS) concentrations as high as 55,000 mg/L (Golder 2022), depression in the water freezing point could cause some lakes to be potentially connected to the regional groundwater flow system through the cryopeg. Results from the 3D block model can be used to draw thermal iso-surfaces equivalent to the estimated depressed water freezing point to assess the impact of cryopeg on groundwater flow in critical areas.

Based on the latest thermistor data available, the permafrost characteristics in the project area are summarized below:

- Data from string DSC-016, installed in the Discovery area to the north of CH6 Lake, indicate permafrost depth of about 400 metres below ground surface.
- Data from the new string GT21-75, installed in the Main area to the north of Lake A8, indicates permafrost depth of approximately 480 m below ground surface.
- Legacy data from string M98-195, also installed to the north of Lake A8, indicates permafrost depth greater than 437 m, with an estimated depth of 480 m based on thermal gradients along this string.
- 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 calculated to be between 0.015 and 0.020 °C/m from deep thermistor strings installed in the Discovery area in 2020, and in the Main area in 2021. Thermal gradients are generally higher in the Discovery area, and this is reflected in less deep permafrost limits measured in the Discovery area (about 400 m in depth) compared to the Main area (approximately 480 m in depth).

The results of numerical modelling indicate open taliks are present beneath portions of each of the identified lakes, although the extent of taliks beneath the lakes is reduced compared to the 2020 thermal assessment (Golder 2021). The following critical lakes are predicted to present open-talik conditions:

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

In the Tiriganiaq-Wolf deposit, although open talik condition is predicted by Section M of the 2D thermal model, it is interpreted that closed talik (based on the 0-degree isoline) probably prevails in that area. This interpretation is because Lake D4 is relatively shallow (i.e., less than 1.5 m deep), and the other three cross-sections (L, N and O), showed closed talik.

The model results expand the list of lakes with potential open talik compared to what was estimated in the 2014 Freshwater Environment FEIS (Golder 2014b), 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.

Updated thermal modelling results for the Main area indicated the base of permafrost (i.e., $0^{o}C$ isotherm) is between 320 and 490 m below ground surface, with the interpreted depth dependent on the proximity of the location to nearby lakes. This represents an increase of about 60 m in permafrost depth compared to what was predicted in the 2020 thermal assessment. The permafrost depth range predicted in the models is also consistent with what has been measured by string GT21-75 and estimated based on legacy data from string M98-195, both located in the Main area to the north of Lake A8. The predicted permafrost depth range is also in agreement with 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.

For the Discovery area, the predicted maximum permafrost depth of 400 m is similar to what had been predicted in the 2020 thermal assessment.

As discussed above, after reviewing of model results and lake depth in the Tiriganiaq-Wolf area, closed talik is interpreted below Lake D4 even though the 2D cross-section M still shows open talik. This is different than what was interpreted in the 2020 thermal assessment.

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 Agnico Eagle (Agnico Eagle 2020), open pits in F Zone 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 Wesmeg03 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 limits of 490 m (FZone) and 400 m (Discovery), with FZone underground developments reaching depth of about 560 m and Discovery underground operations reaching a depth of about 460 m. 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.

6.0 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.

ORIGINAL SIGNED

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Senior Geotechnical Engineer

ORIGINAL SIGNED

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Senior Consultant

FJ/GW/pls/jlb

https://golderassociates.sharepoint.com/sites/158318/project files/6 deliverables/00_working/22513890-938-r 2022 thermal assessment_rev0/22513890-938-r 2022 thermal assessment_revb.docx

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STUDY LIMITATIONS

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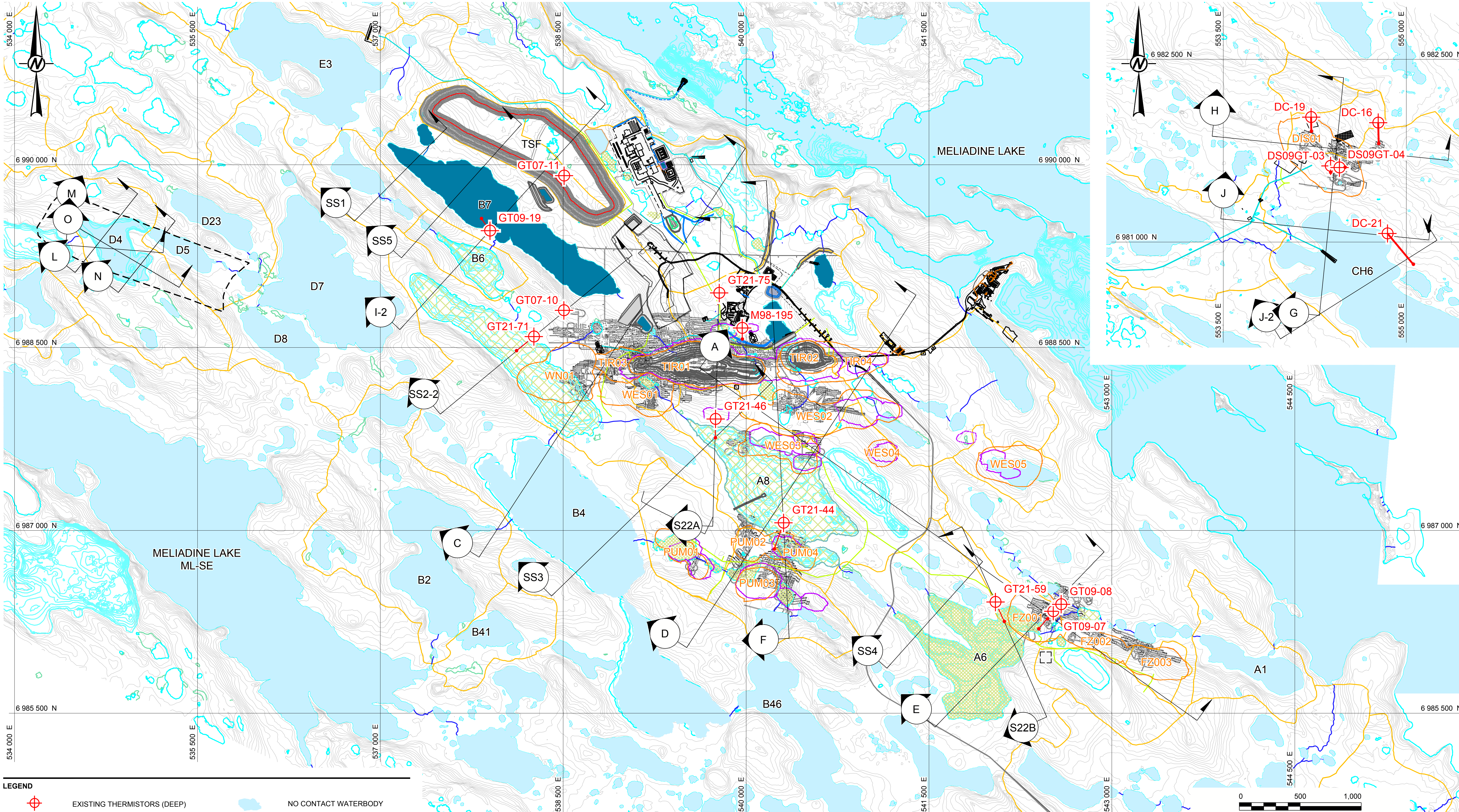
APPENDIX A

Location of Thermal Model Cross-Sections in the Meliadine Project 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
- OPEN PITS

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

NOT FOR CONSTRUCTION

DRAFT

CLIENT
AGNICO EAGLE

PROJECT
MELIADINE EXTENSION

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-06-23
DESIGNED	ZS
PREPARED	AF
REVIEWED	
APPROVED	

TITLE
THERMAL MODEL CROSS SECTION LOCATIONS

PROJECT NO.	PHASE/TASK/DOC.	REV.	FIGURE
22513890	1000/1002/938	B	01B

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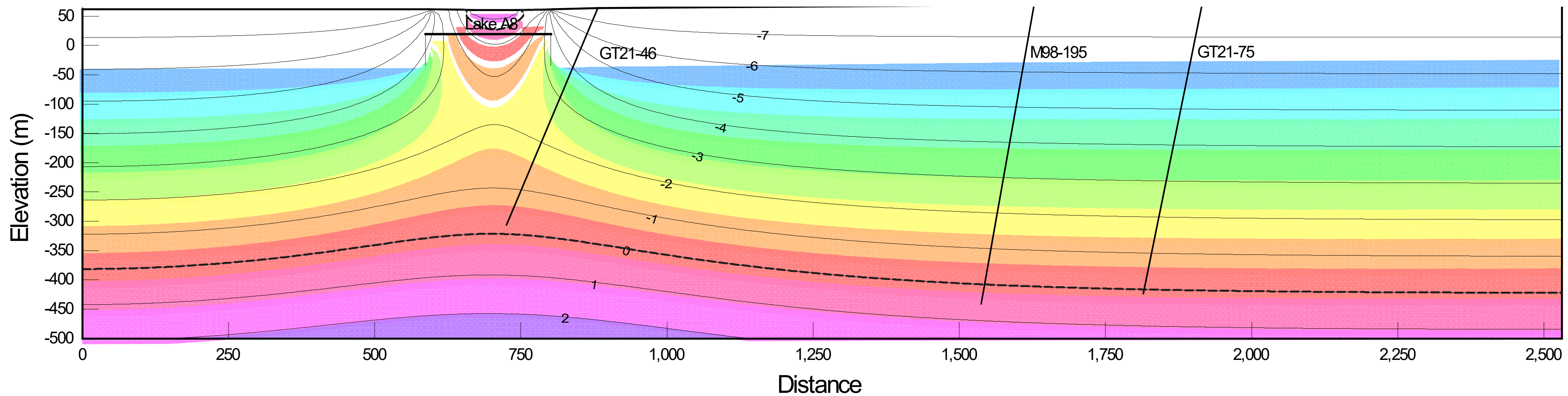
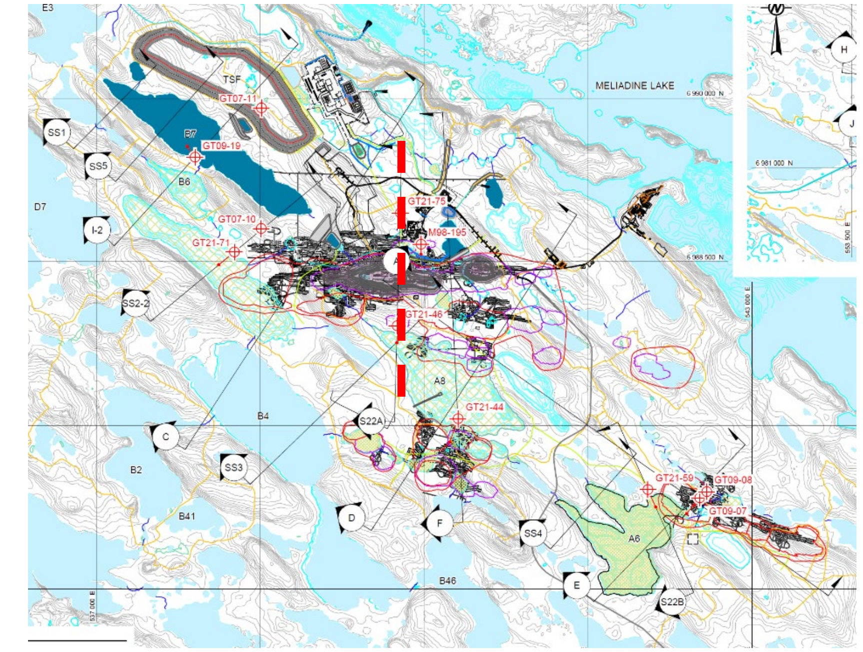
APPENDIX B

2D Thermal Model Results





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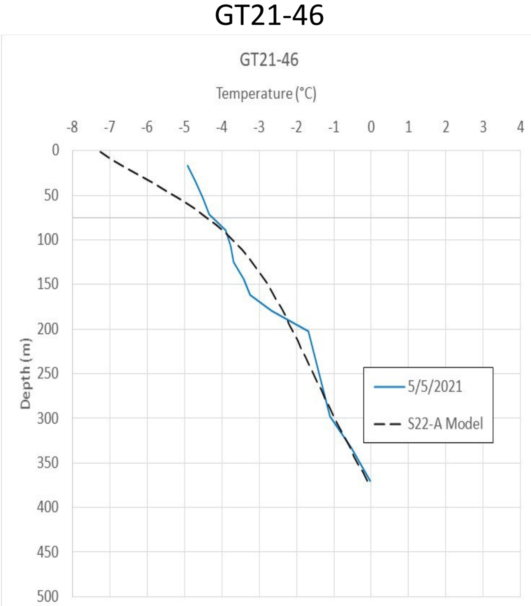

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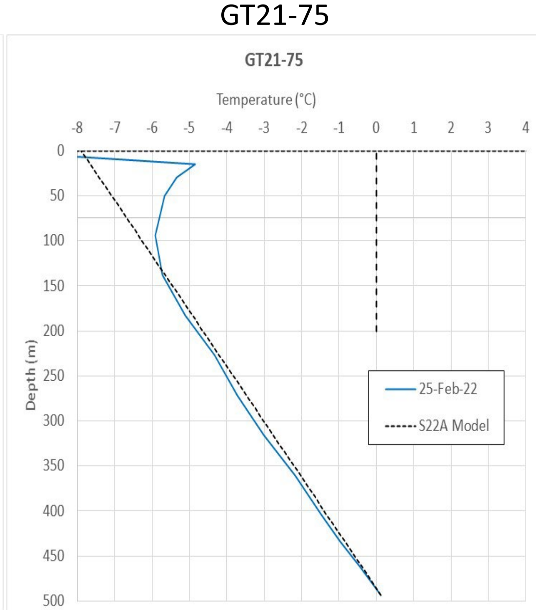

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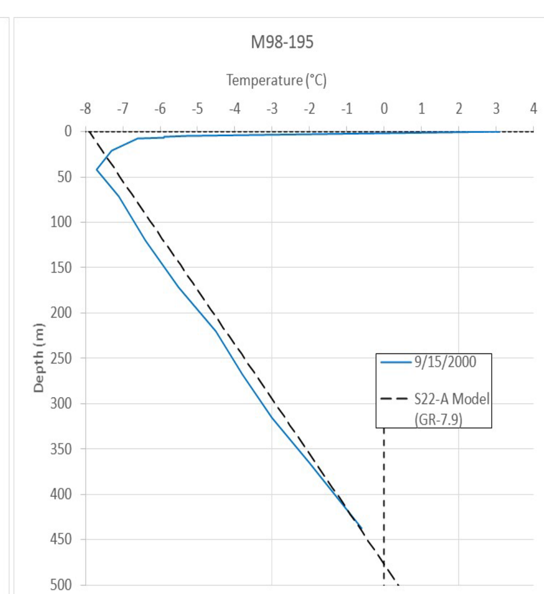

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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT
GOLDER
MEMBER OF WSP

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PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION S22-A
MAIN AREA

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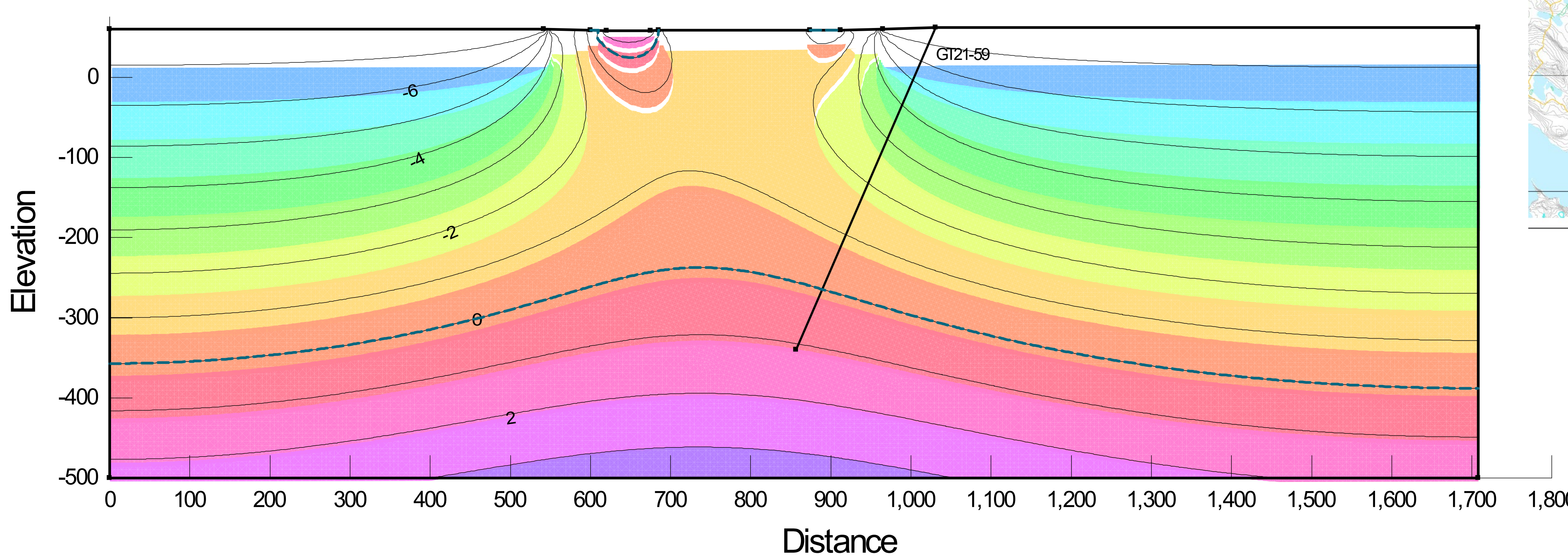

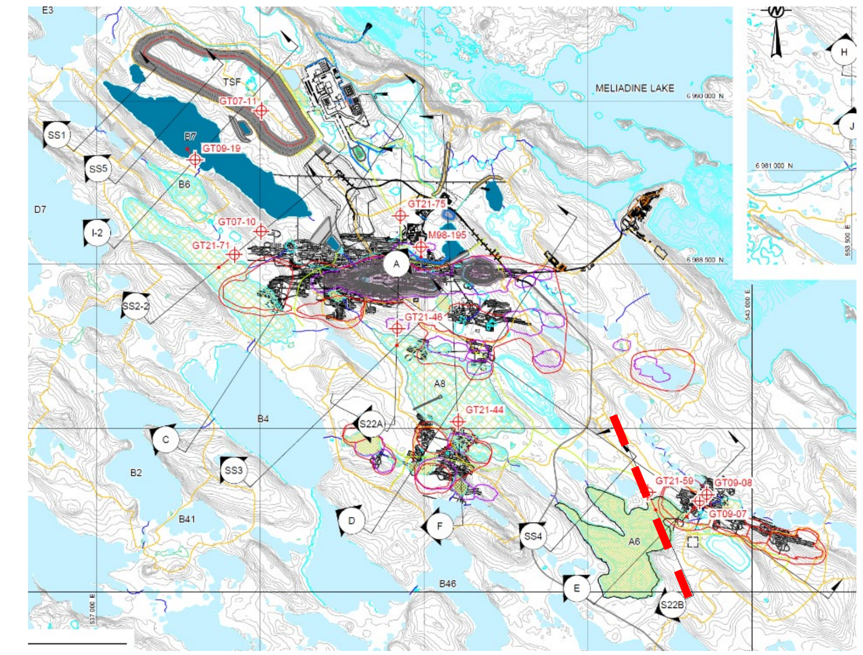

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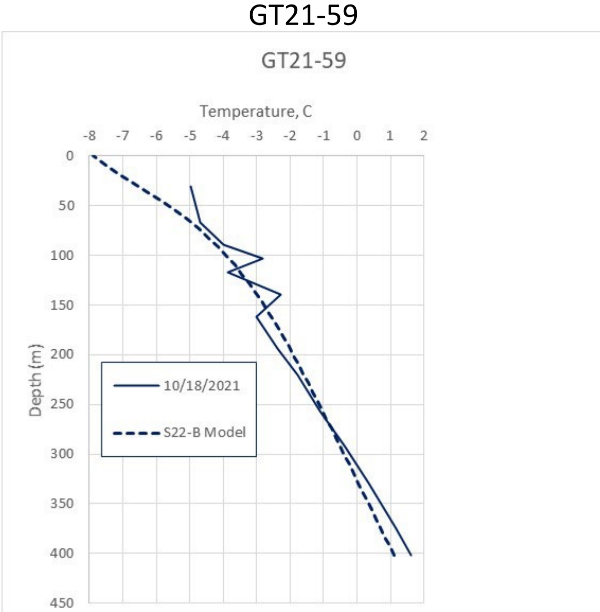

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PROJECT	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS
CONSULTANT	GOLDER MEMBER OF WSP
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PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-
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PROJECT NO.	22513890
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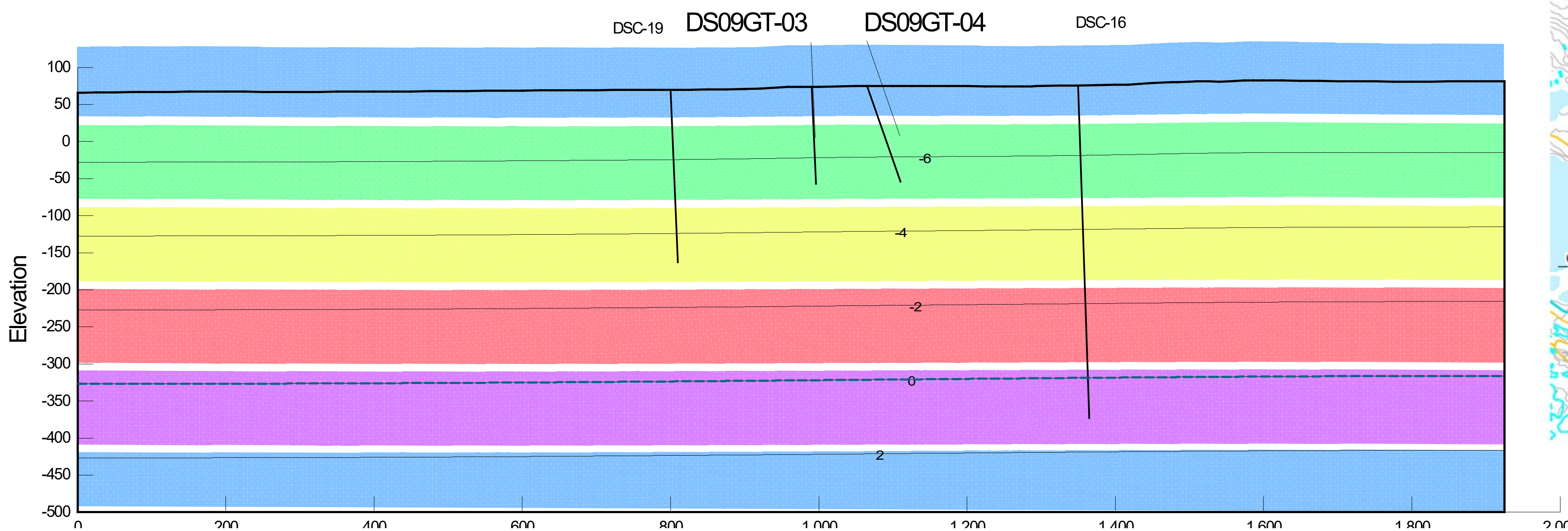

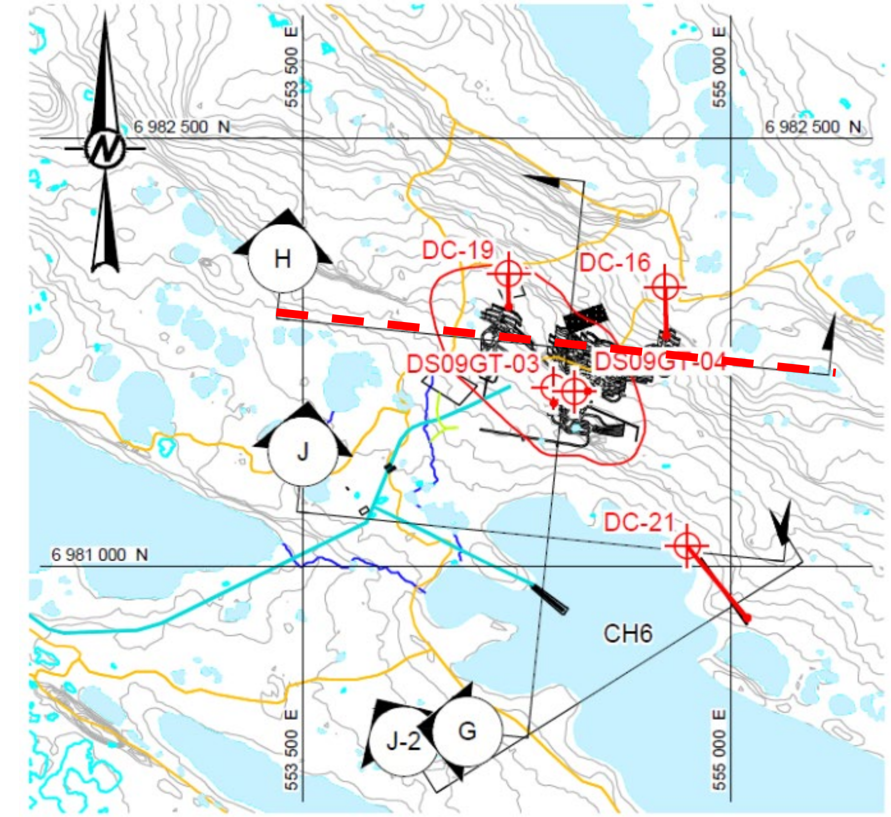

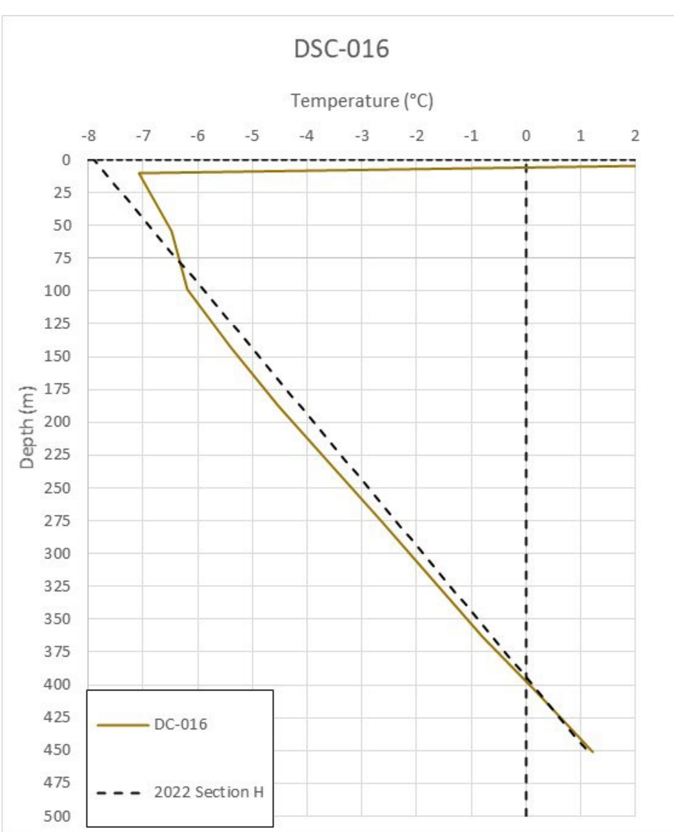

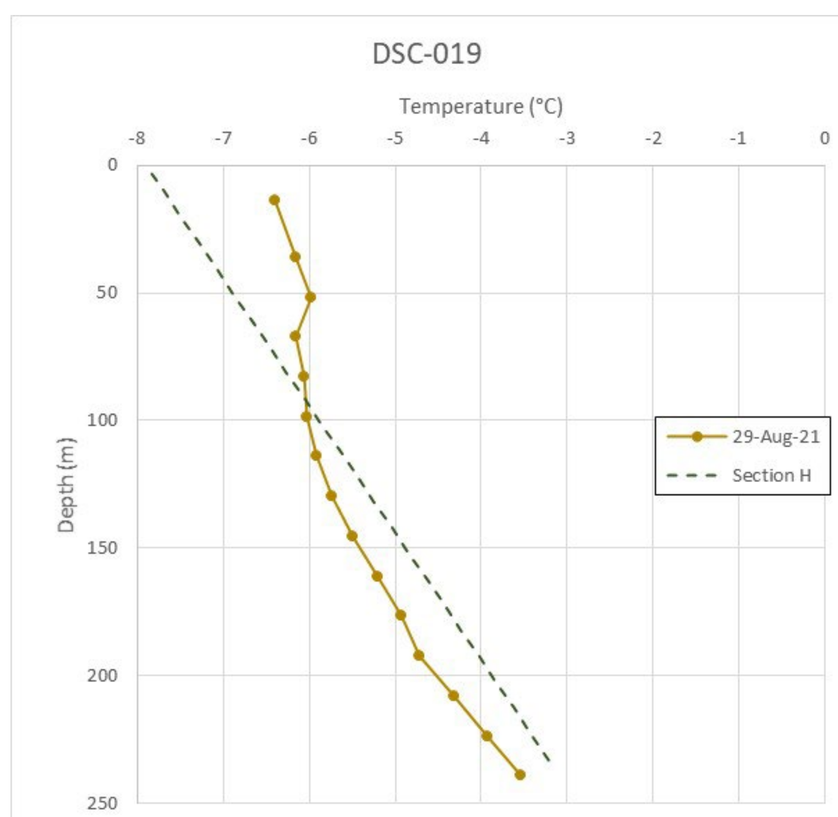

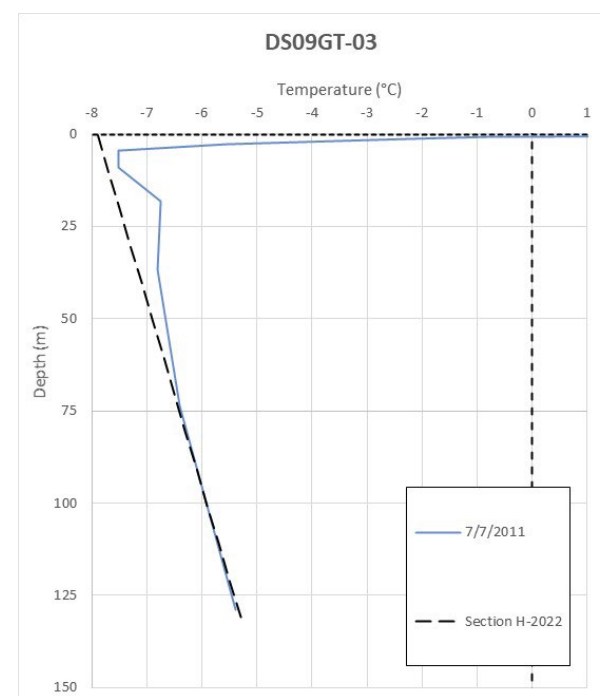

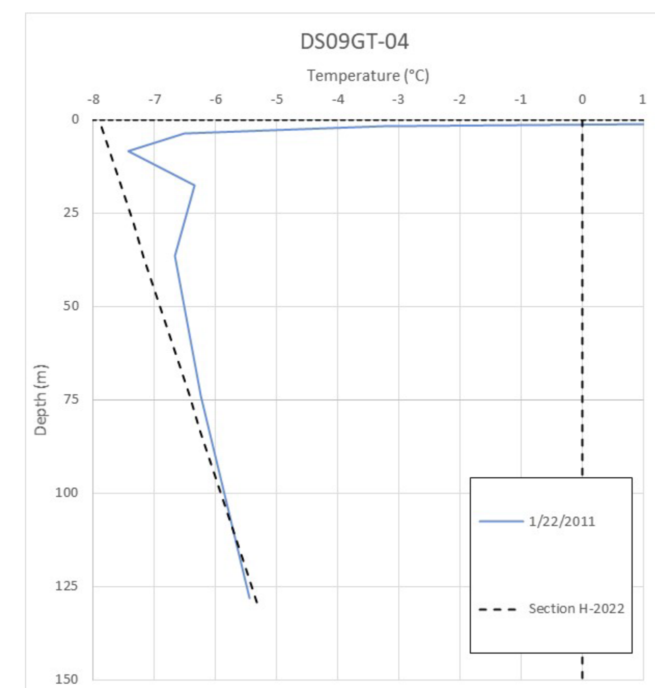

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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION H
DISCOVERY AREA

PROJECT NO.	Phase	REV.	FIGURE
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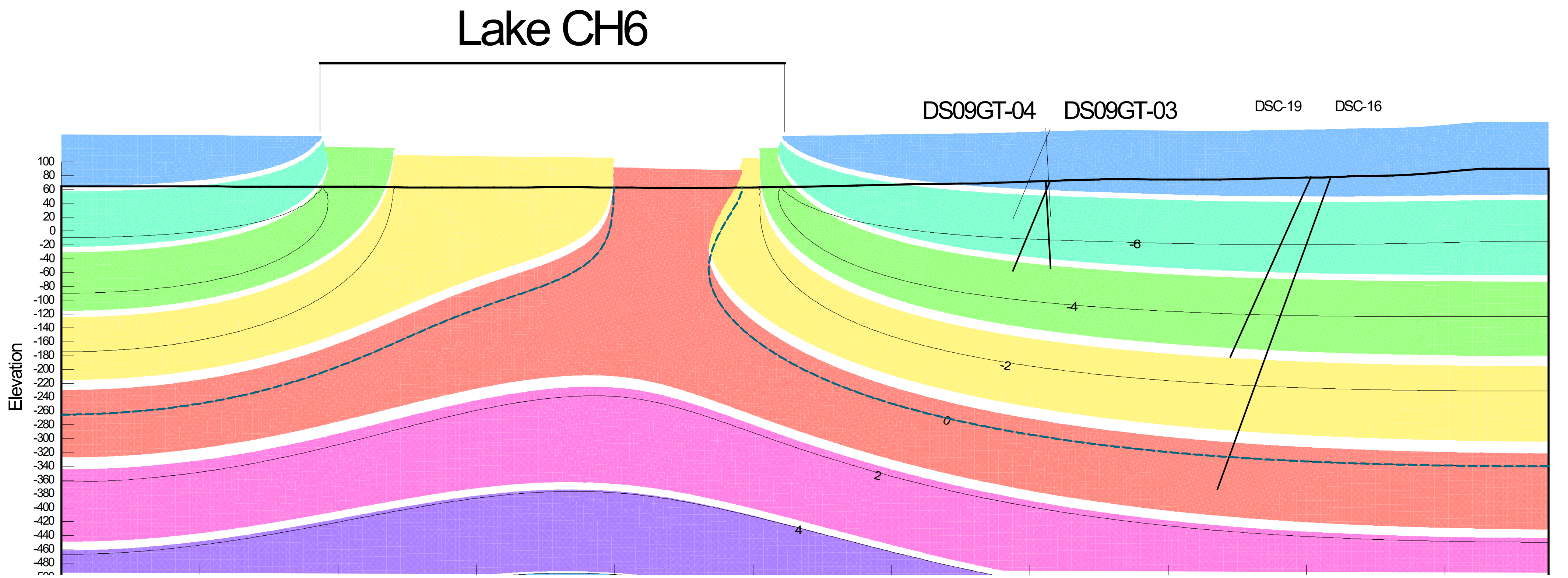

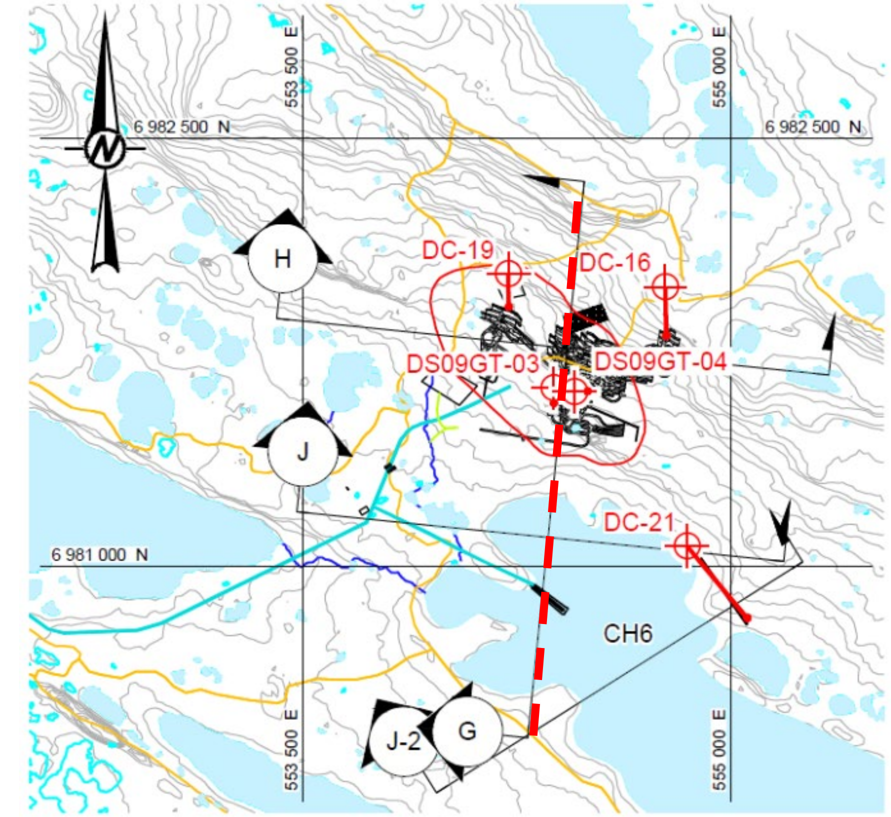

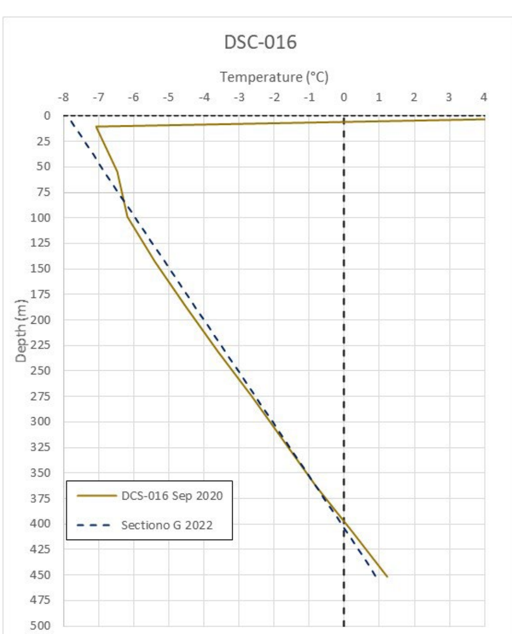

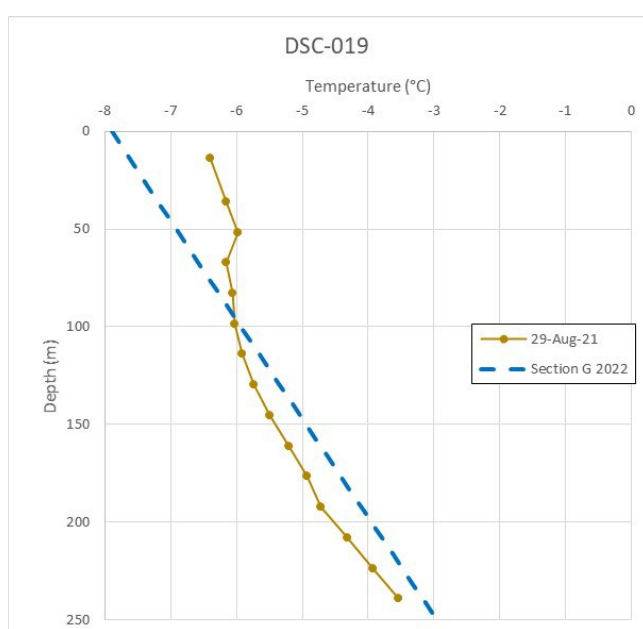

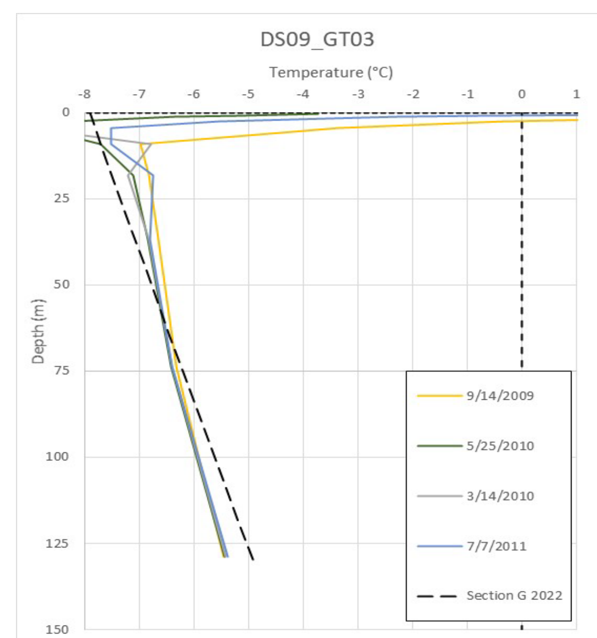

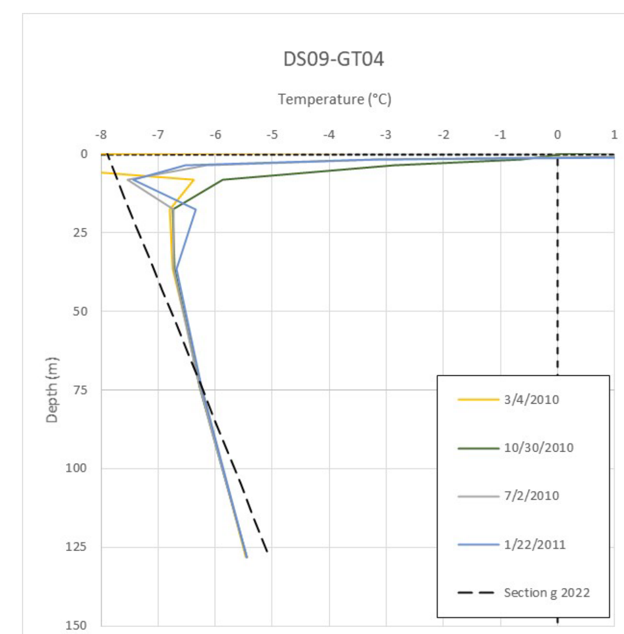

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MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

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YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION G
DISCOVERY AREA

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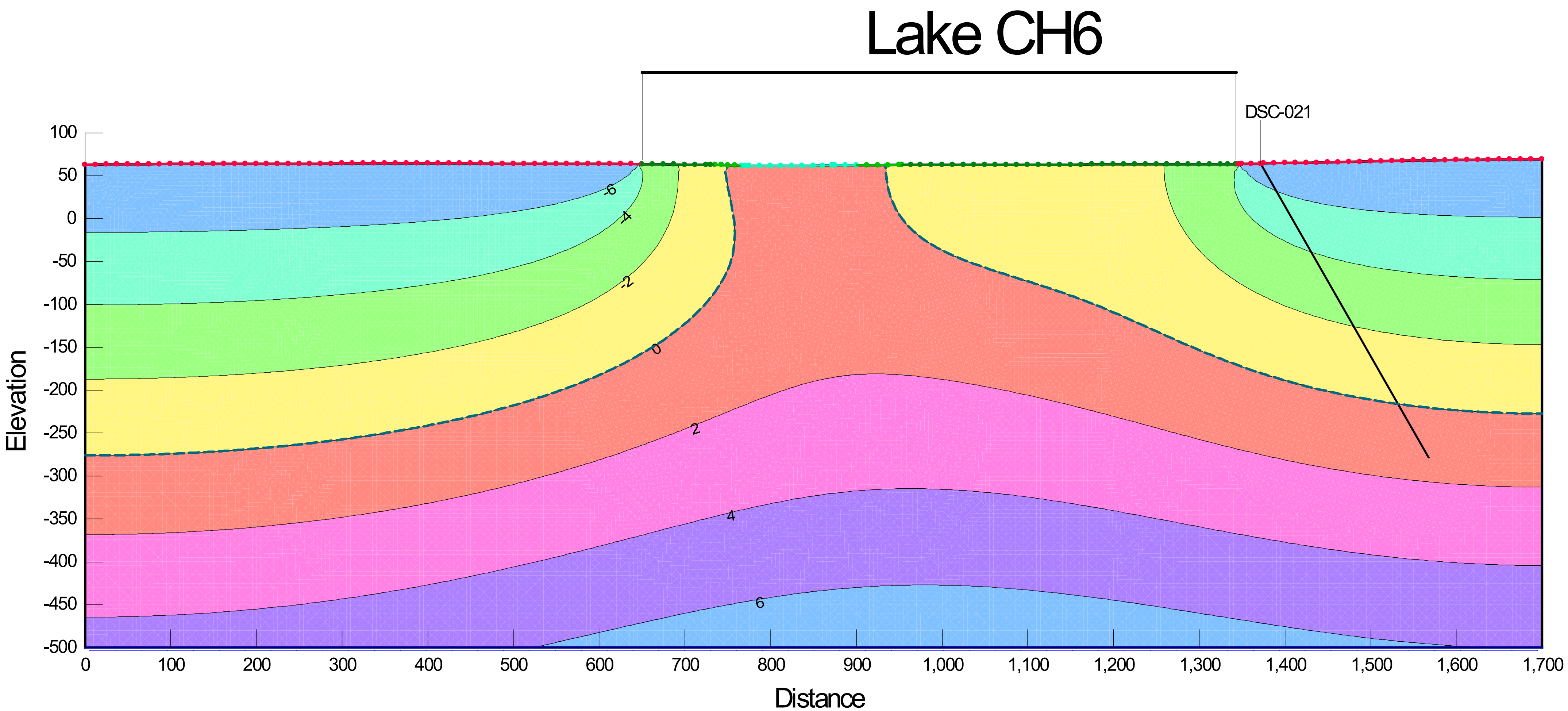

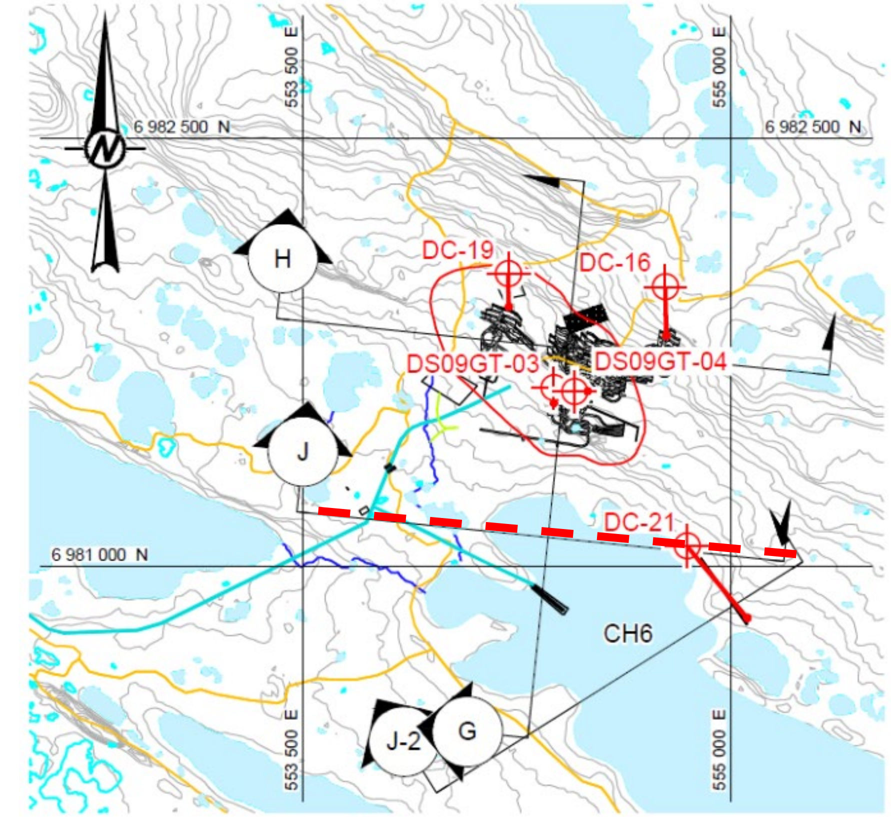

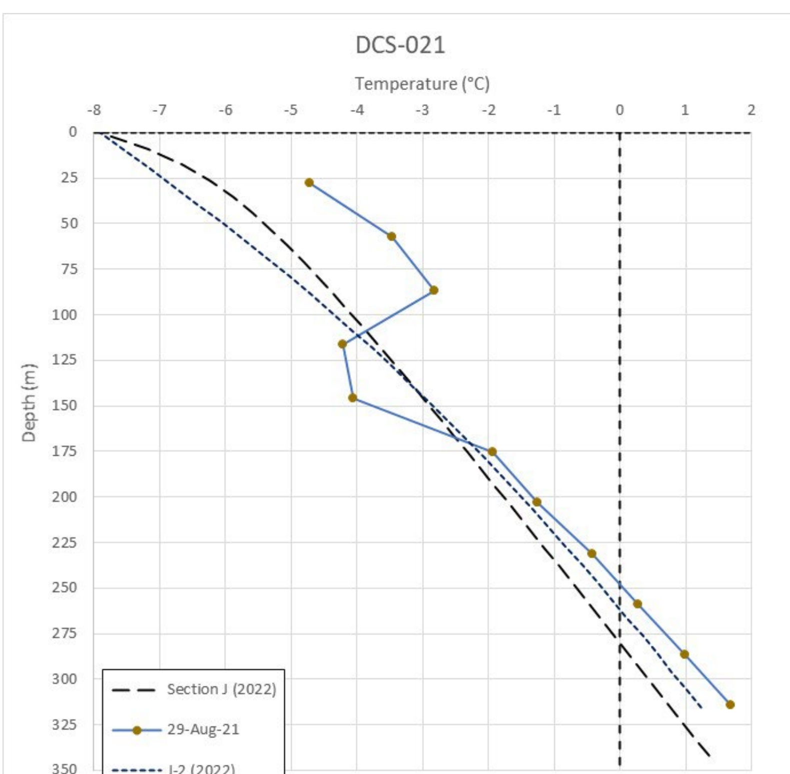

CLIENT	AGNICO EAGLE MINES LTD.	PROJECT	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS
CONSULTANT	YYYY-MM-DD: 2022-06-XX	TITLE	SECTION J DISCOVERY AREA
GOLDER MEMBER OF WSP	PREPARED: ZPS		
	DESIGNED: ZPS		
	REVIEWED: FJ	PROJECT NO. 22513890	Phase 1000
	APPROVED: -	REV. 0	FIGURE B-5

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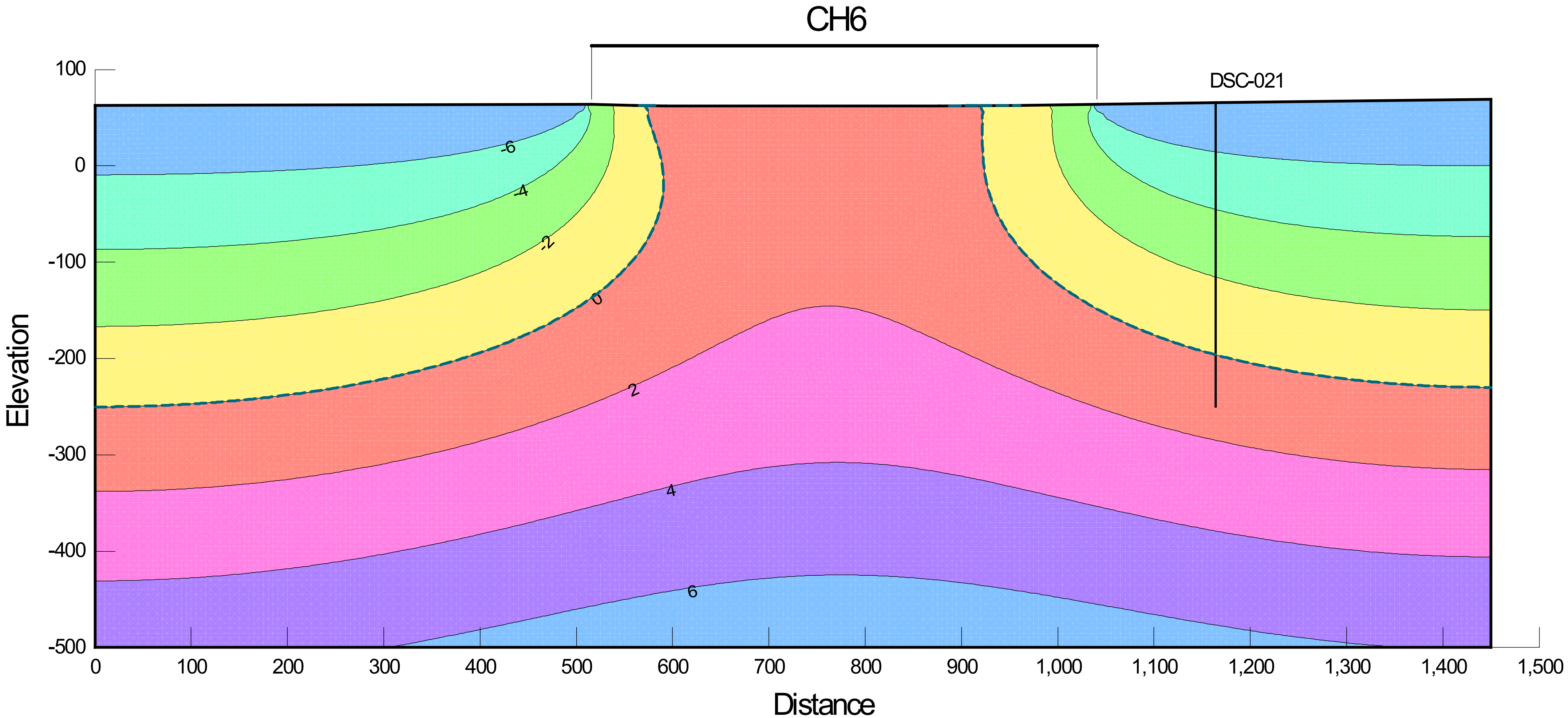

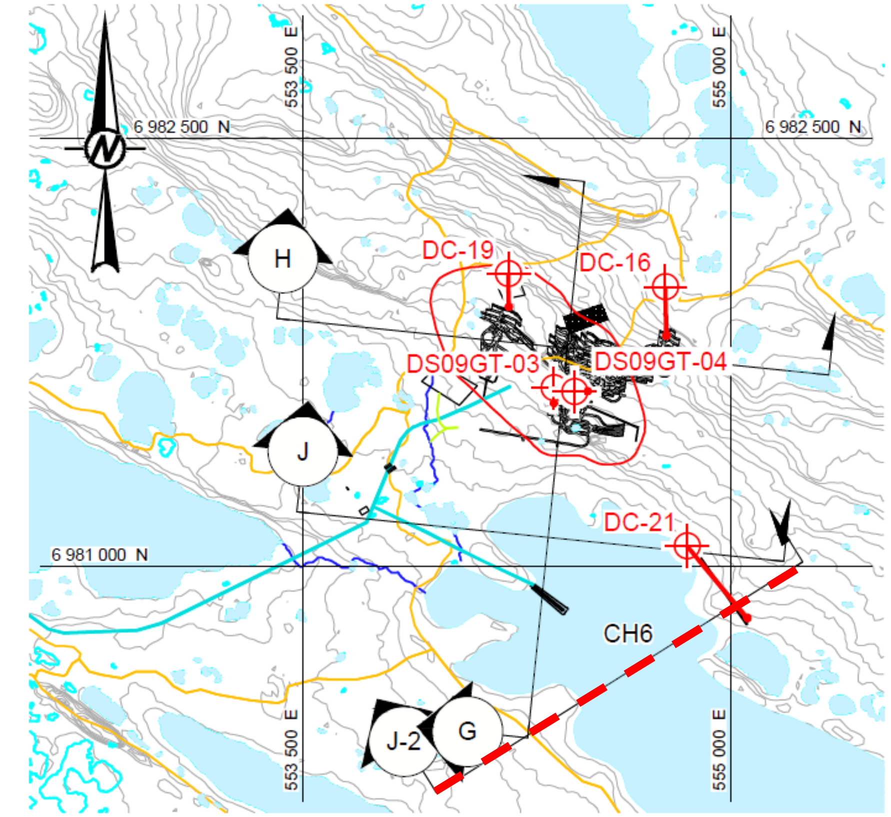

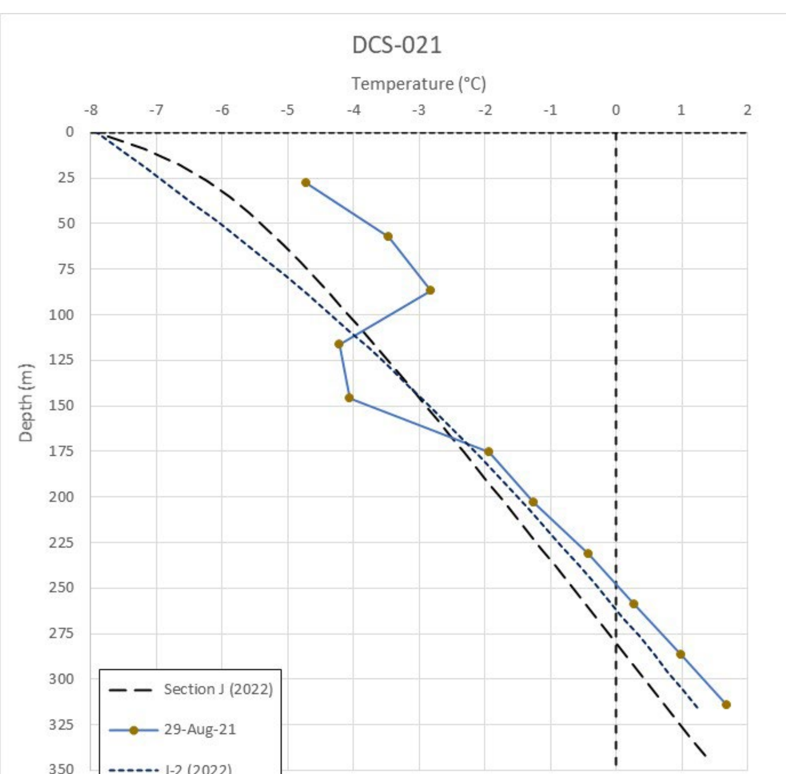

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MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT

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YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION J-2
DISCOVERY AREA

PROJECT NO.	Phase	REV.	FIGURE
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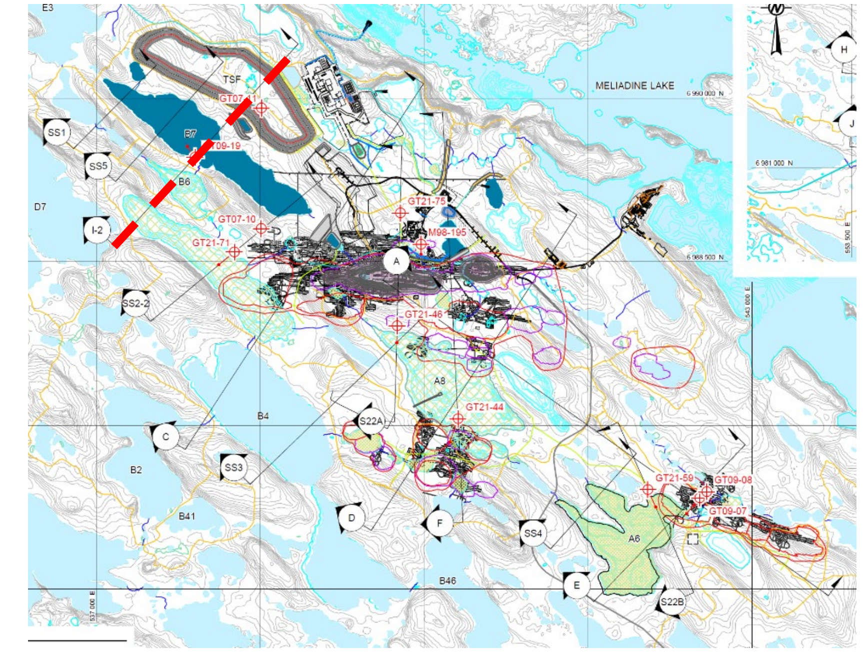
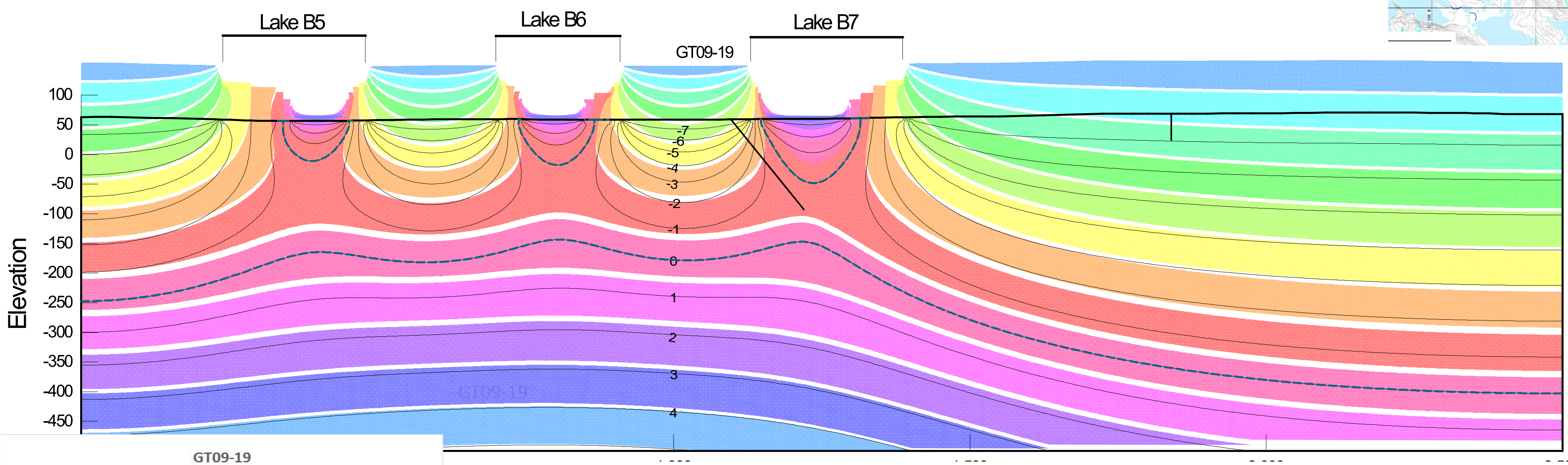
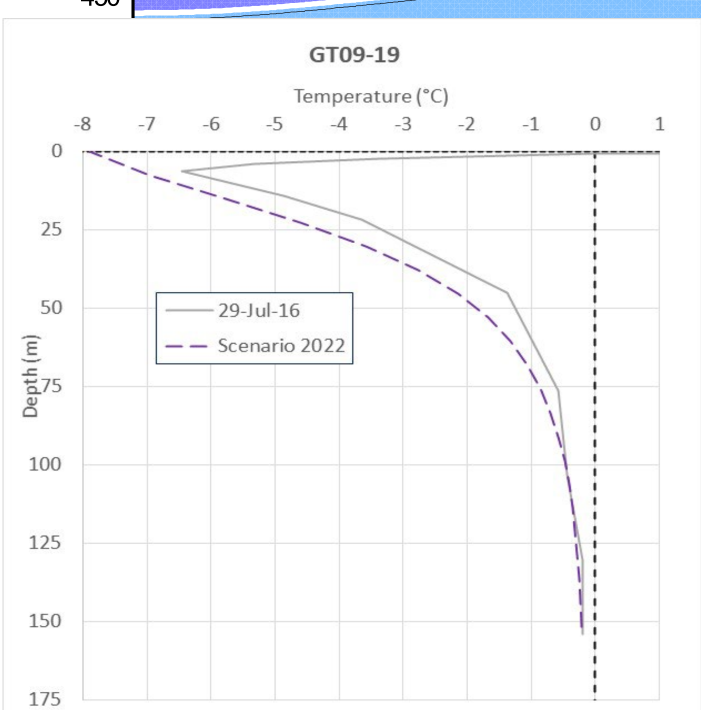






CLIENT
AGNICO EAGLE MINES LTD.

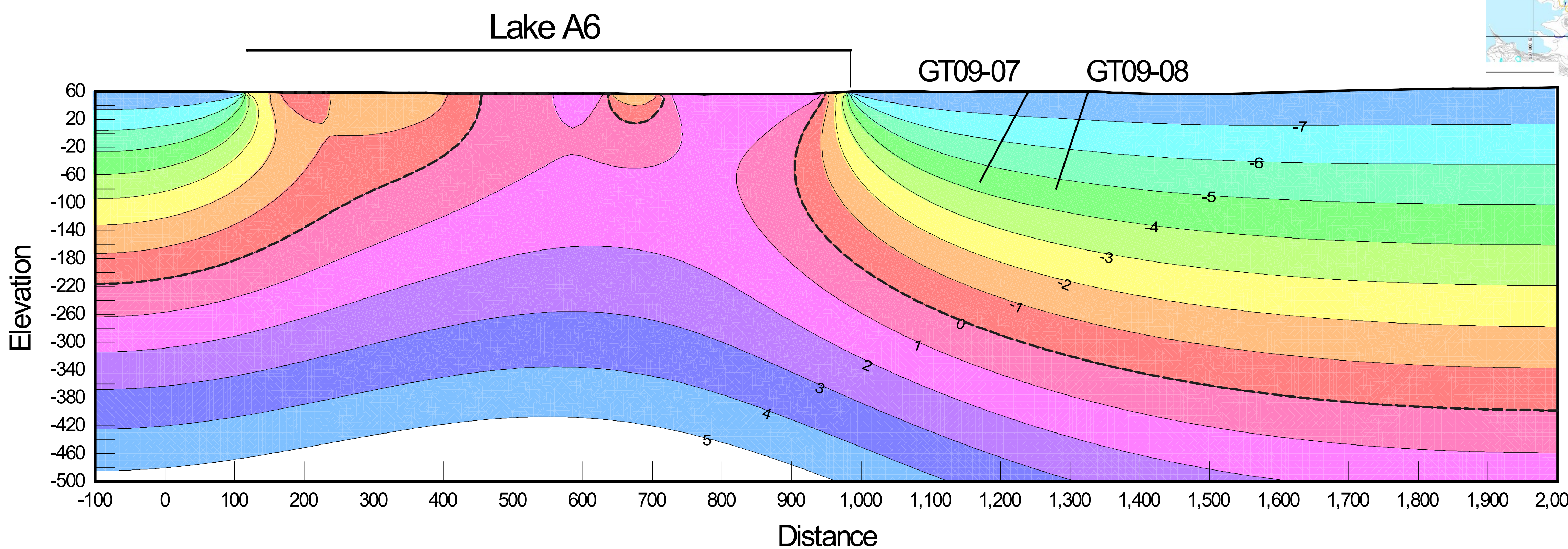
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

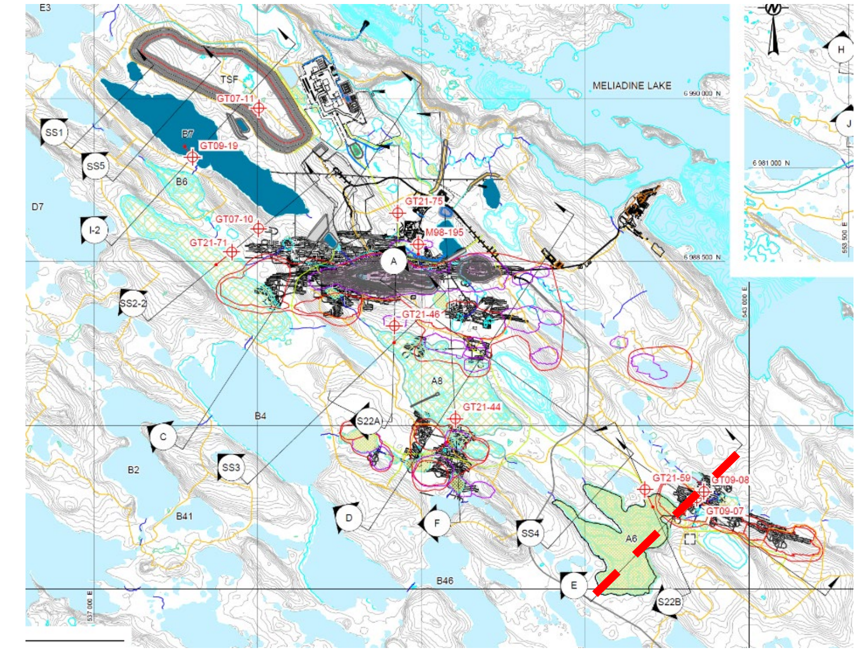
CONSULTANT
GOLDER
MEMBER OF WSP

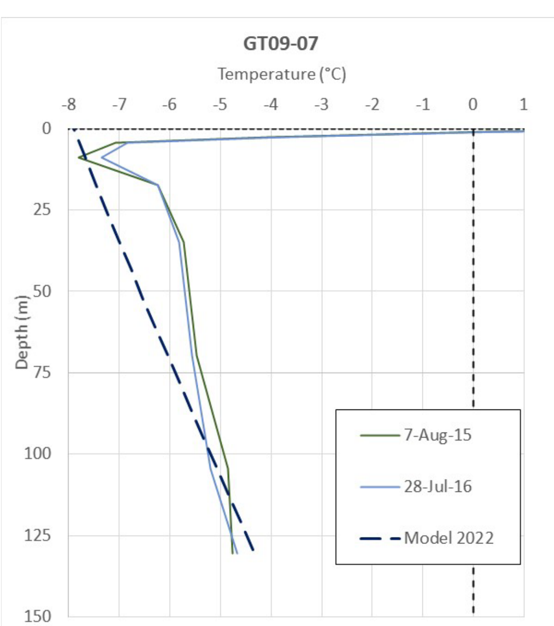
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

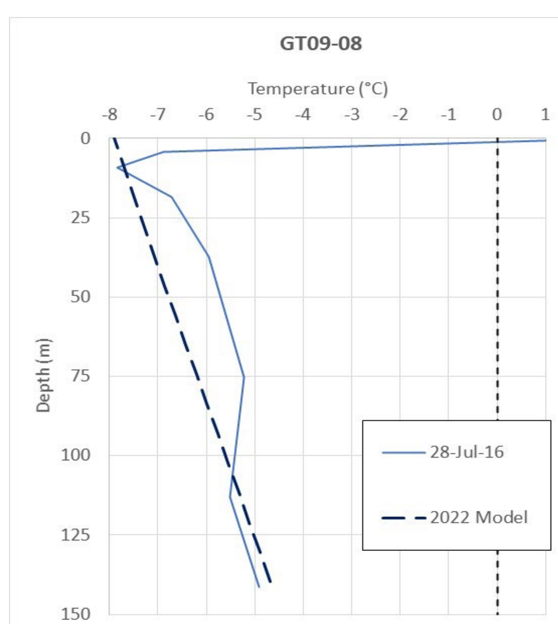
TITLE
SECTION I-2
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-7









CLIENT
AGNICO EAGLE MINES LTD.

CONSULTANT

GOLDER
MEMBER OF WSP

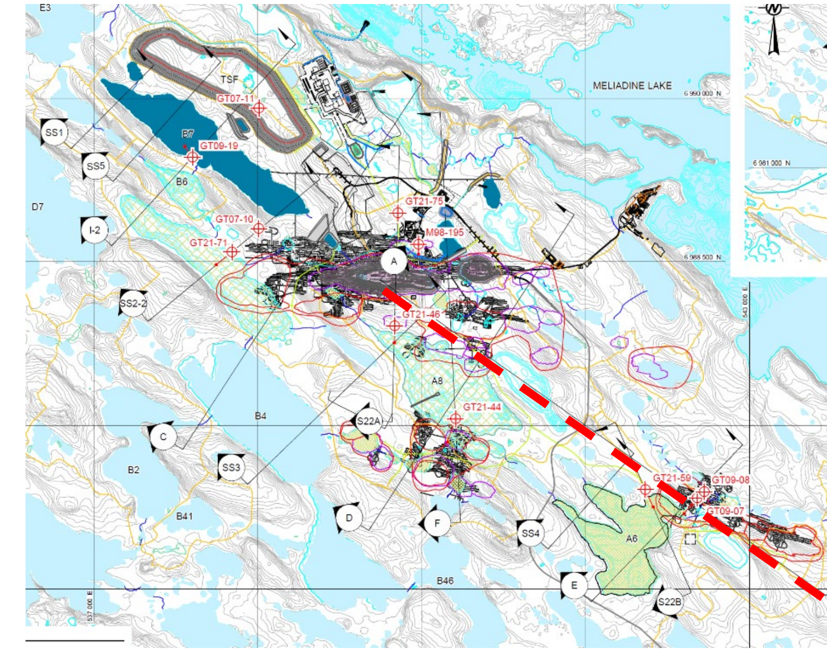
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

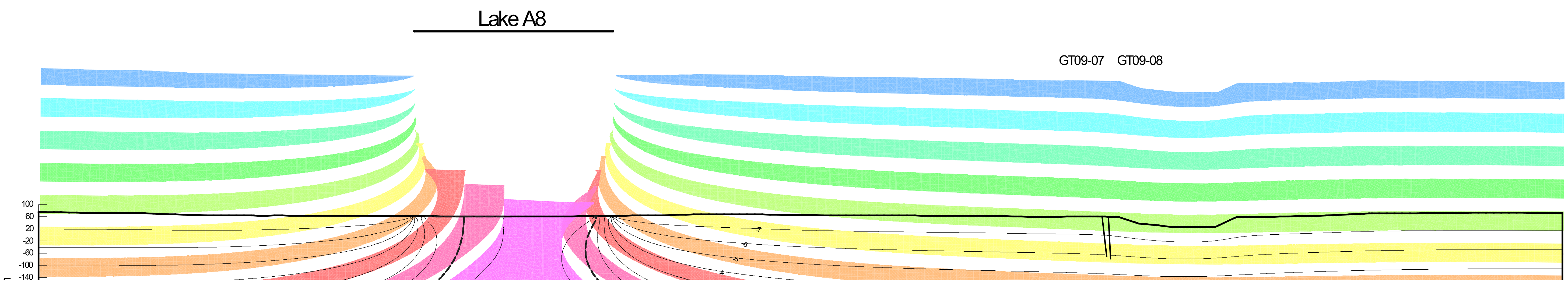
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION E
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-8

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





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AGNICO EAGLE MINES LTD.

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT

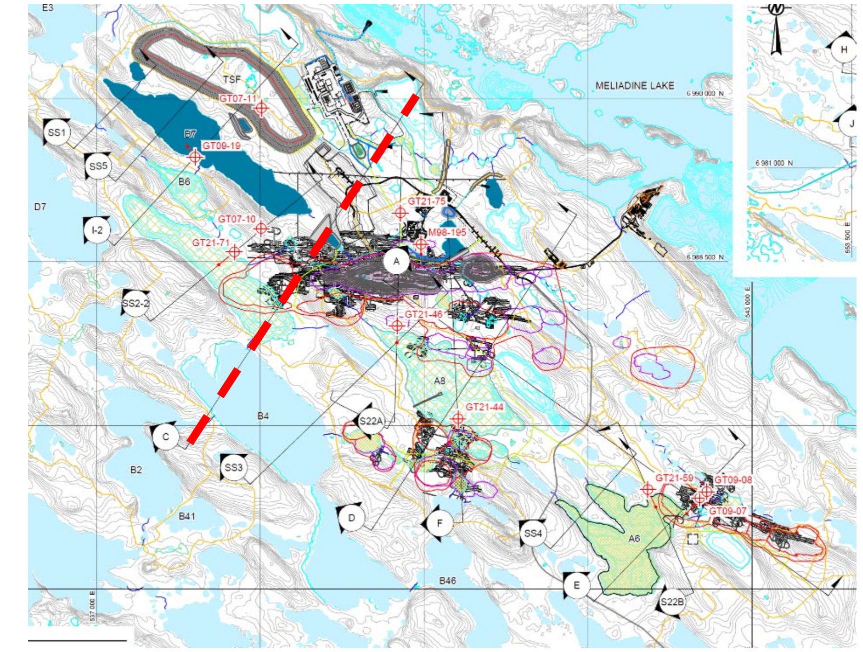
GOLDER
MEMBER OF WSP

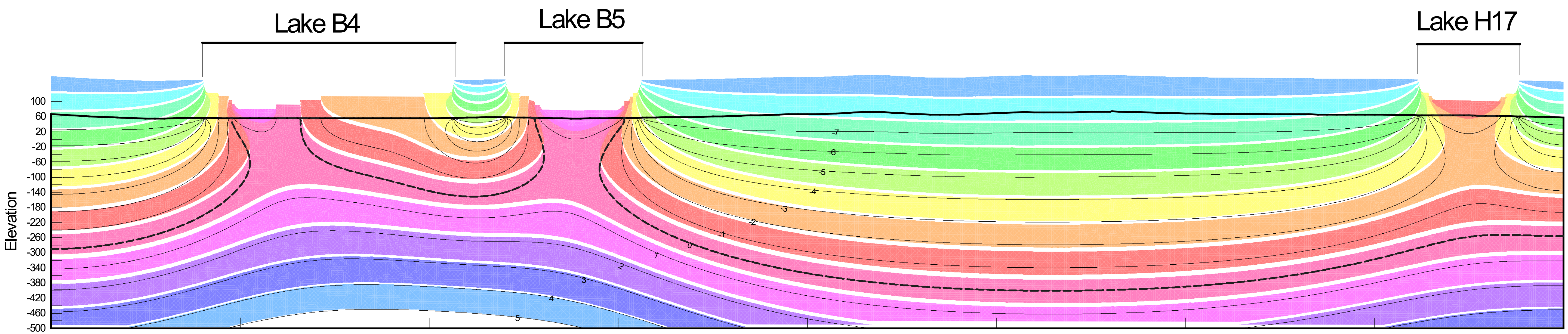
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION A
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-9

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





CLIENT
AGNICO EAGLE MINES LTD.

CONSULTANT

GOLDER
MEMBER OF WSP

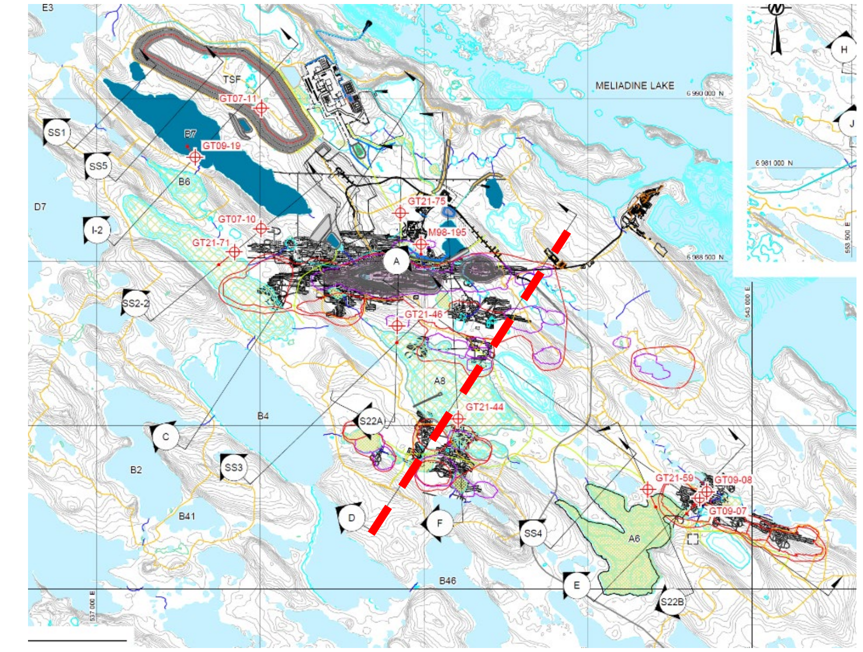
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

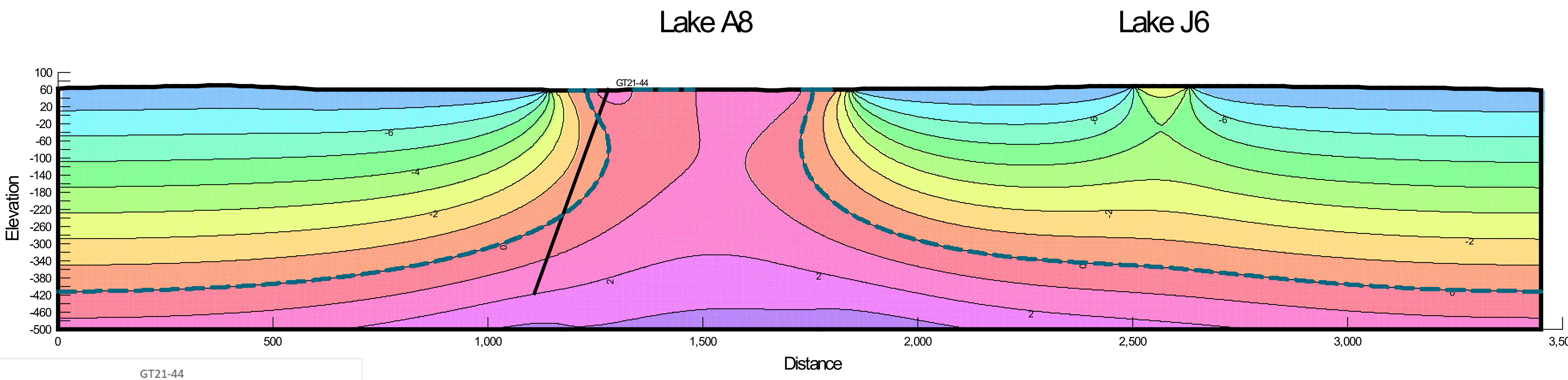
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

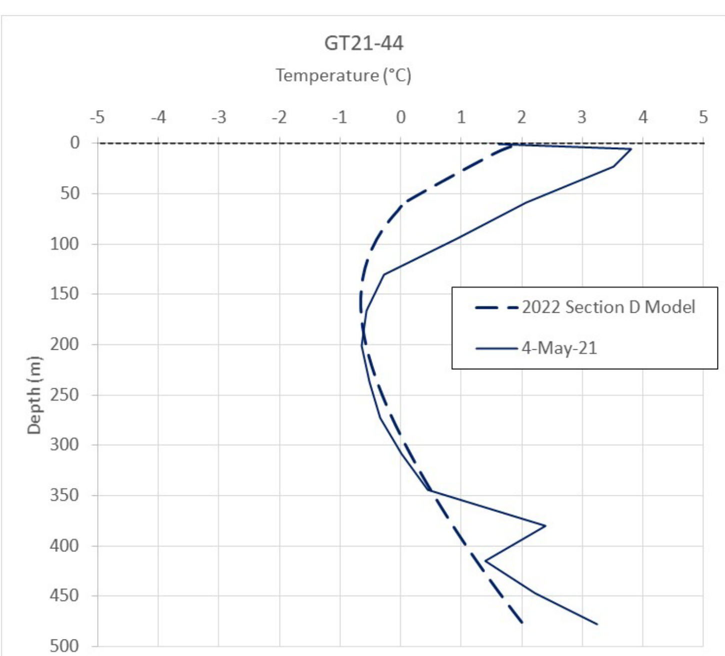
TITLE
SECTION C
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-10

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

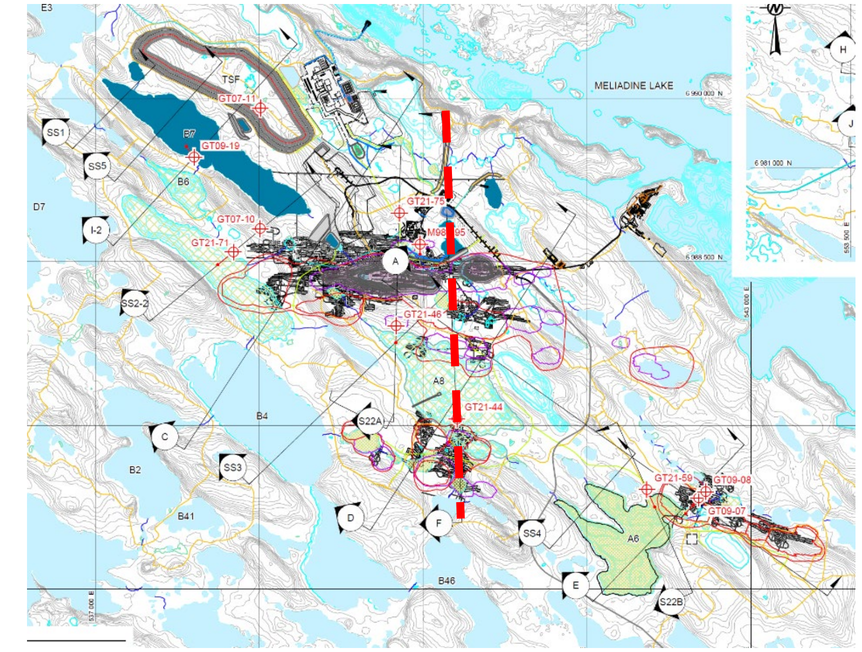


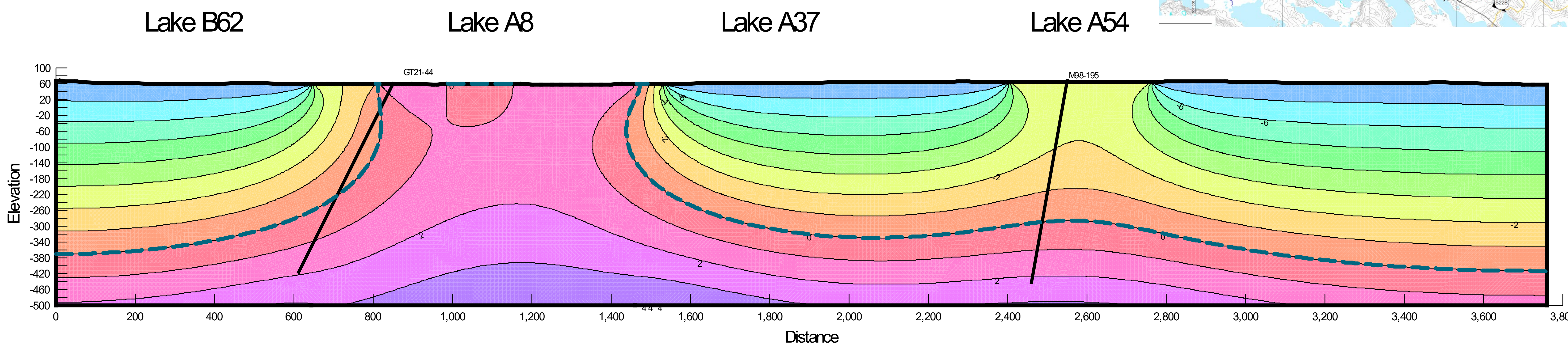


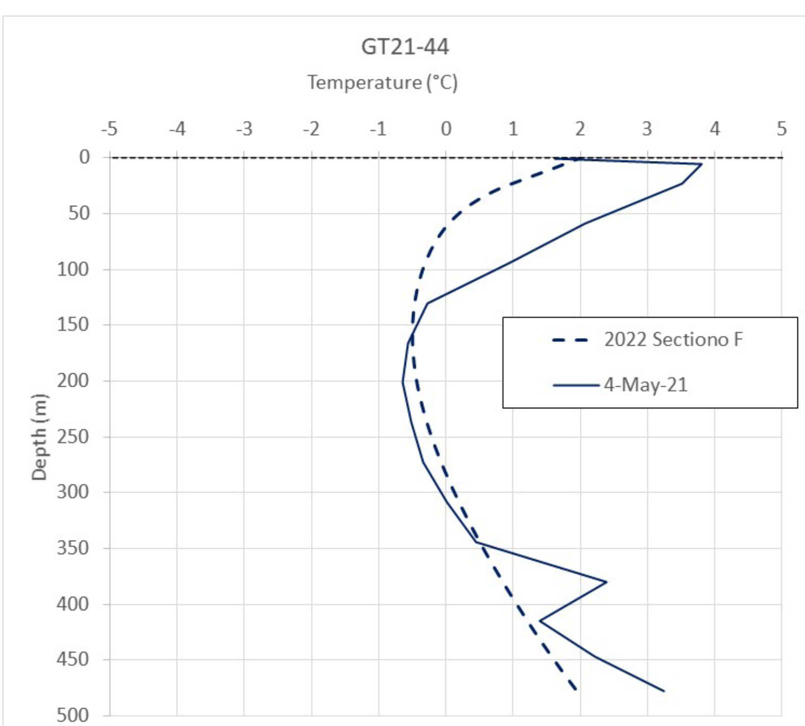


CLIENT	AGNICO EAGLE MINES LTD.	PROJECT	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS
CONSULTANT	YYYY-MM-DD: 2022-06-XX PREPARED: ZPS DESIGNED: ZPS REVIEWED: FJ APPROVED: -	TITLE	SECTION D MAIN AREA
GOLDER MEMBER OF WSP		PROJECT NO. 22513890	Phase 1000 · REV. 0 · FIGURE B-11

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







CLIENT	PROJECT
AGNICO EAGLE MINES LTD.	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS

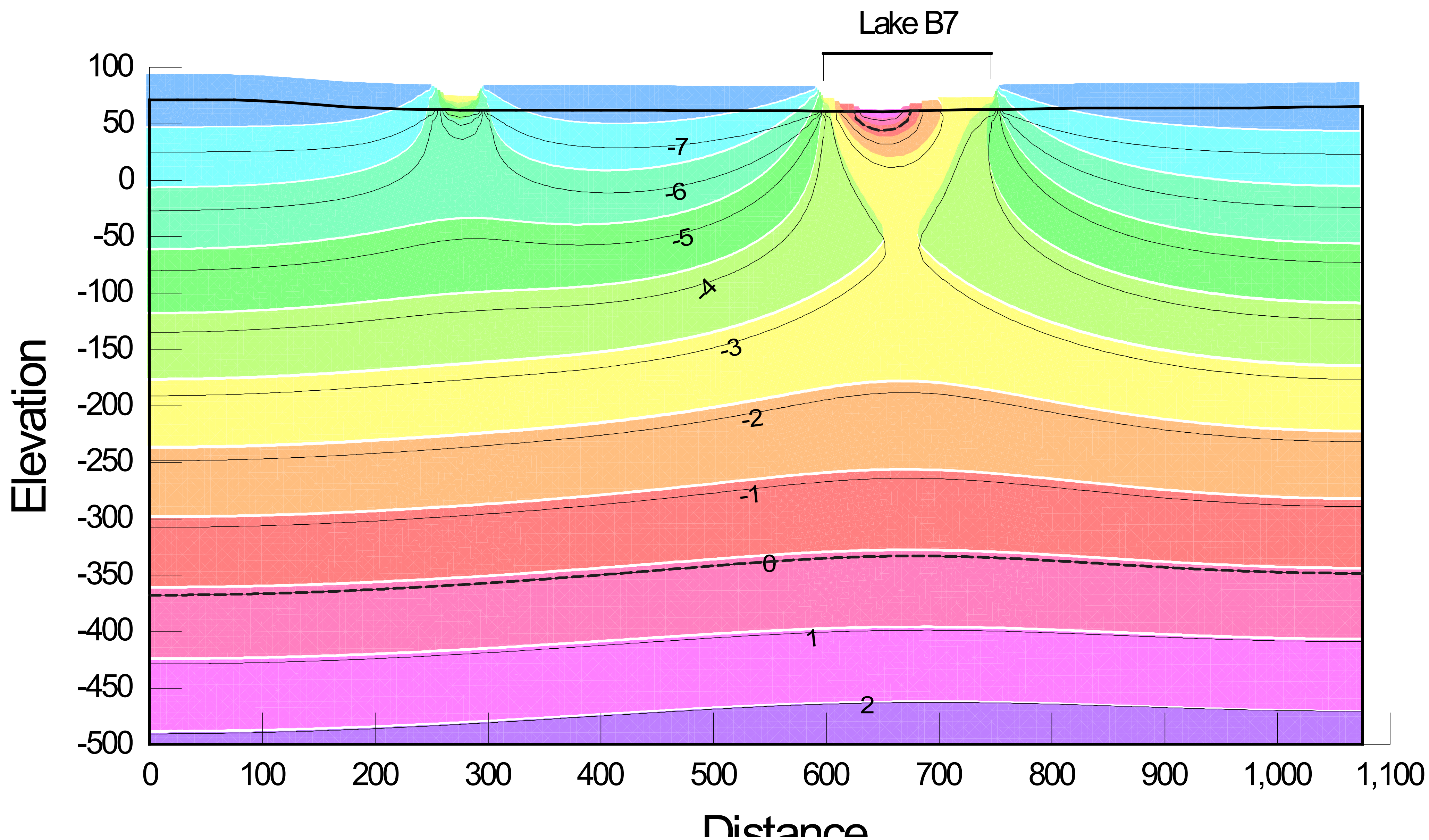
CONSULTANT: GOLDER MEMBER OF WSP

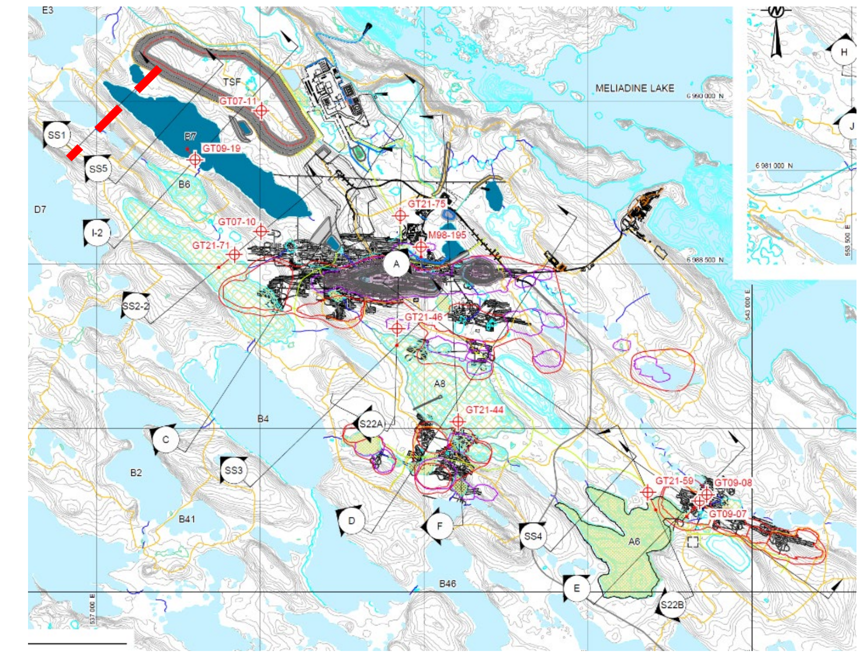
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION F
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-12

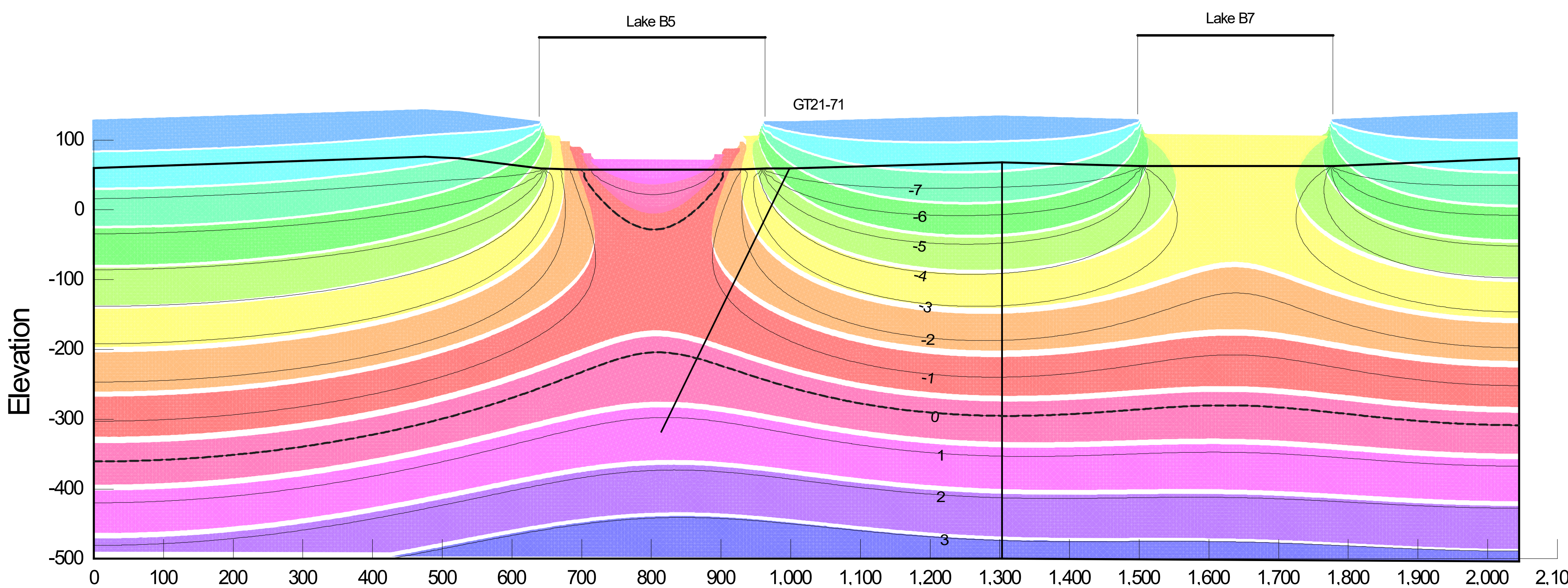
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

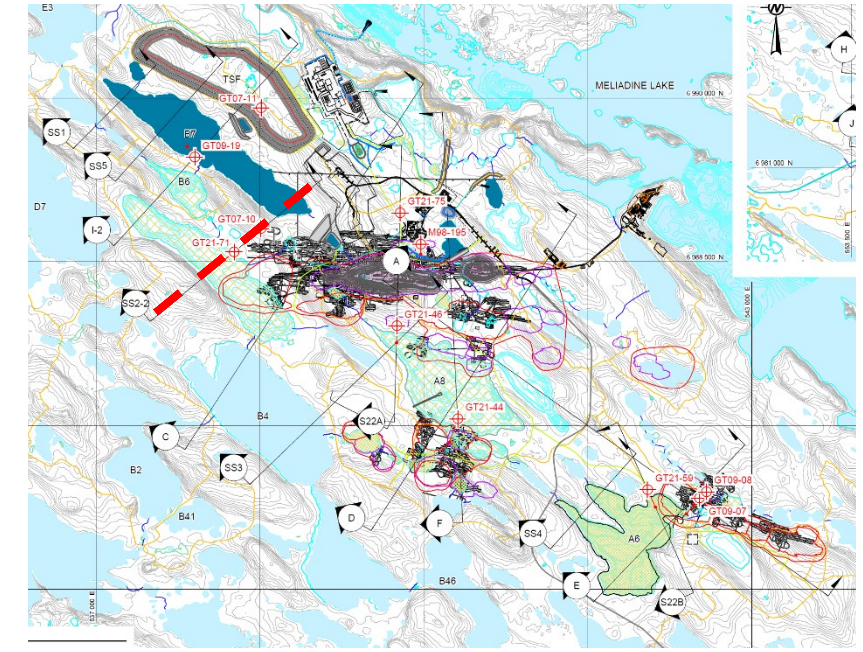


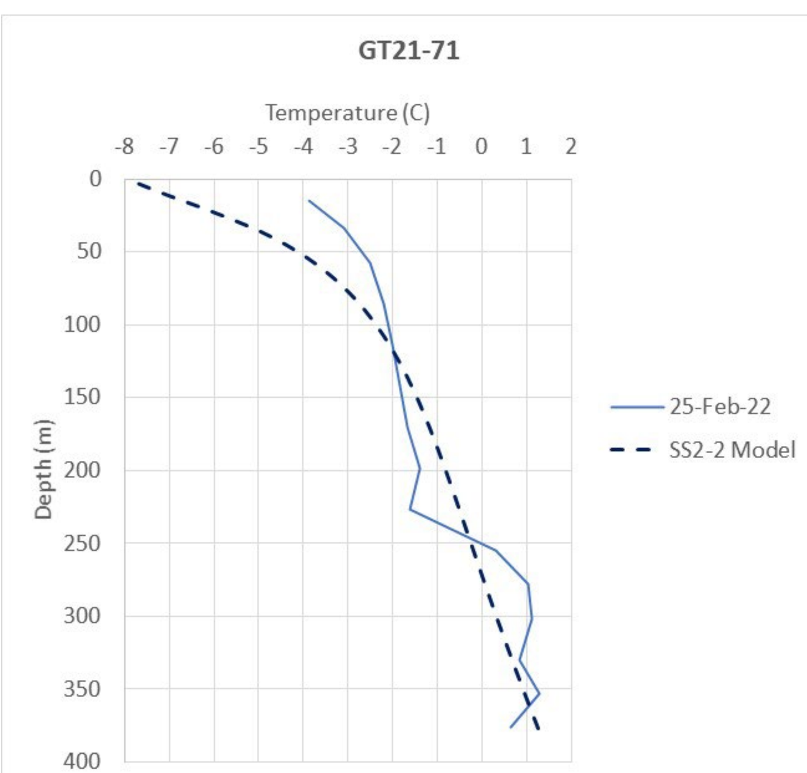


CLIENT AGNICO EAGLE MINES LTD.	PROJECT MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS
CONSULTANT GOLDER MEMBER OF WSP YYYY-MM-DD 2022-06-XX PREPARED ZPS DESIGNED ZPS REVIEWED FJ APPROVED -	TITLE SECTION SS1 MAIN AREA
	PROJECT NO. 22513890 · Phase 1000 · REV. 0 · FIGURE B-13

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







CLIENT
AGNICO EAGLE MINES LTD.

CONSULTANT

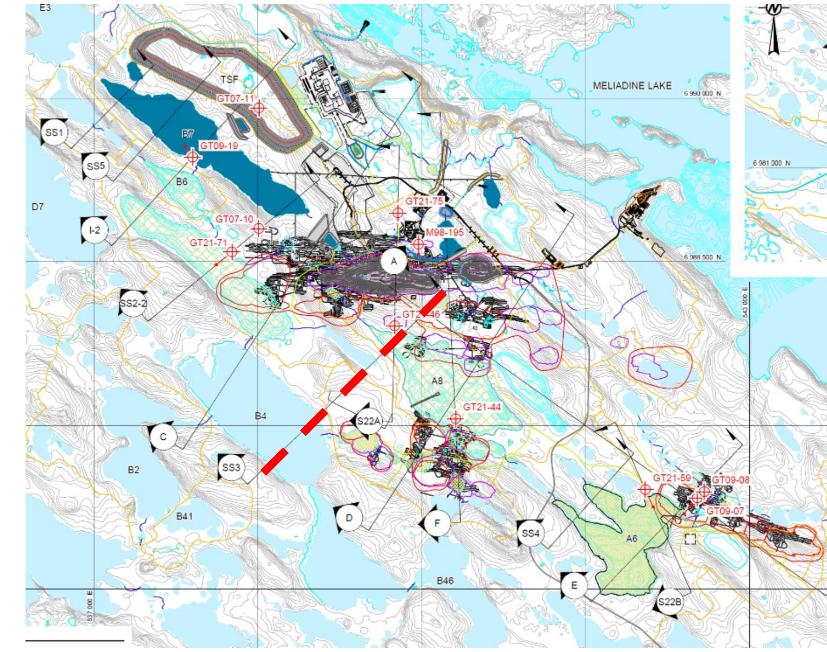
GOLDER
MEMBER OF WSP

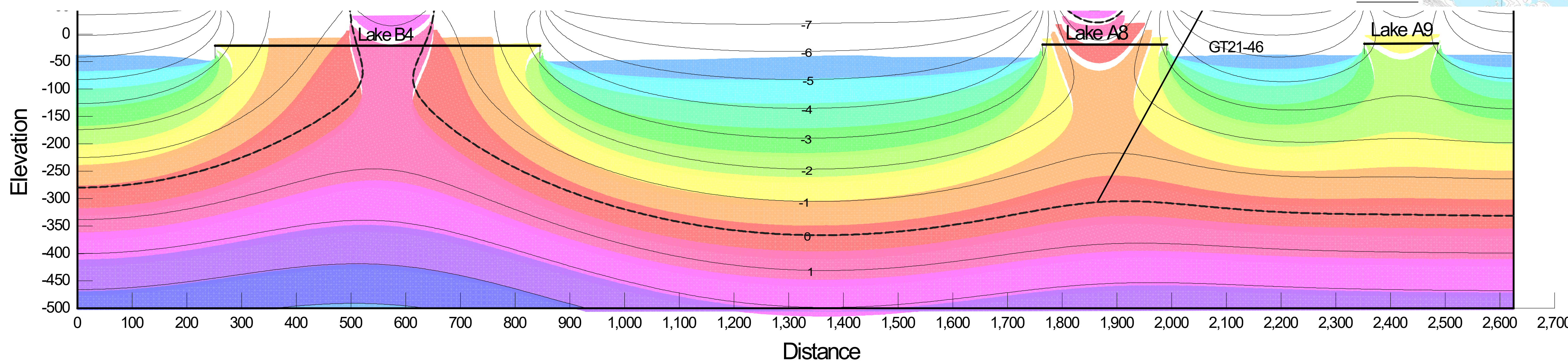
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

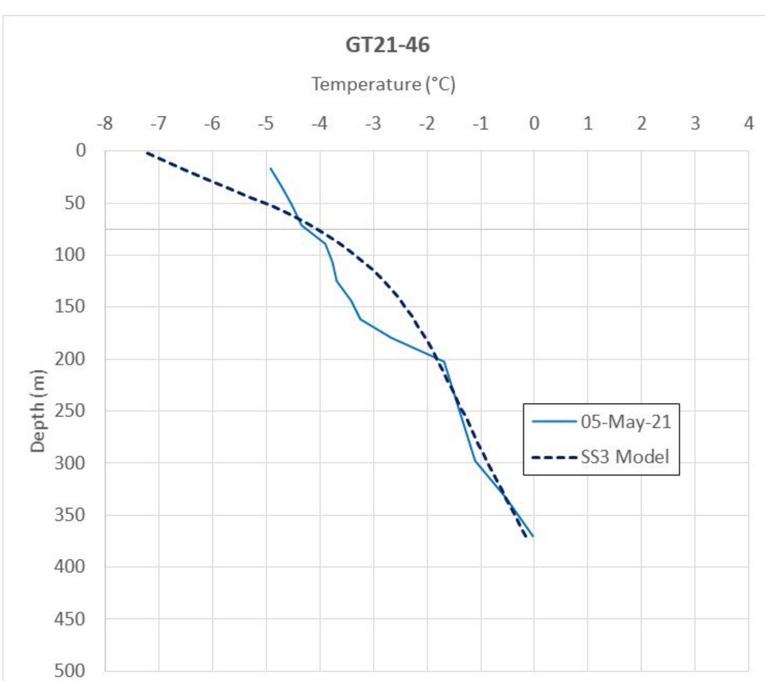
PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION SS2-2
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-14

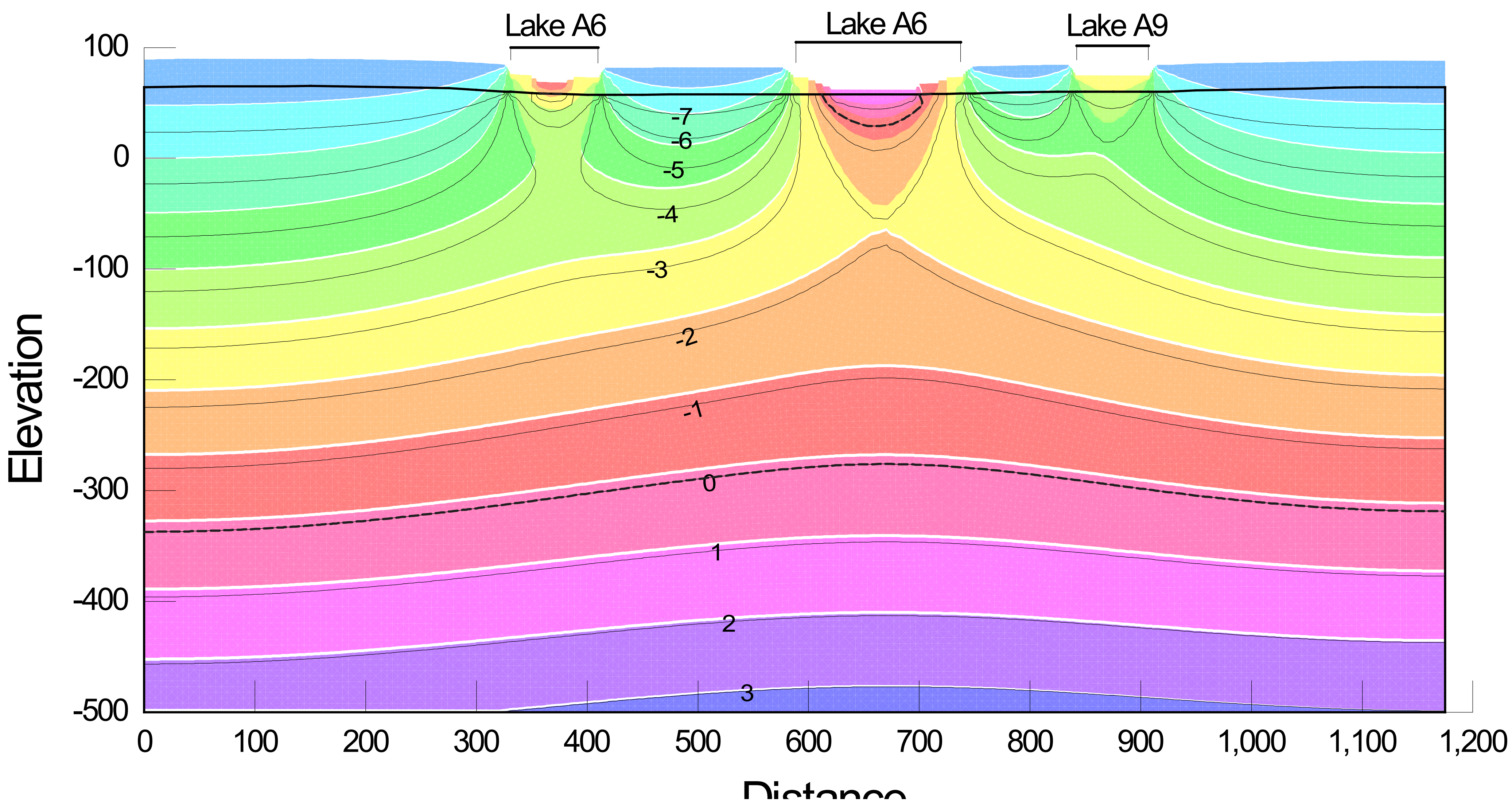


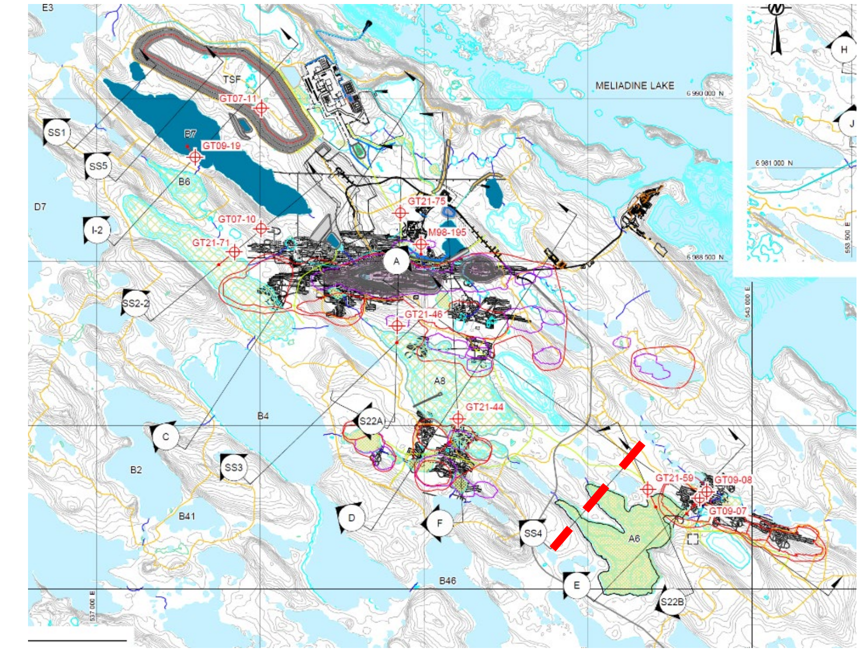




CLIENT	AGNICO EAGLE MINES LTD.
PROJECT	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-
TITLE	SECTION SS3 MAIN AREA
PROJECT NO.	22513890
Phase	1000
REV.	0
FIGURE	B-15

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





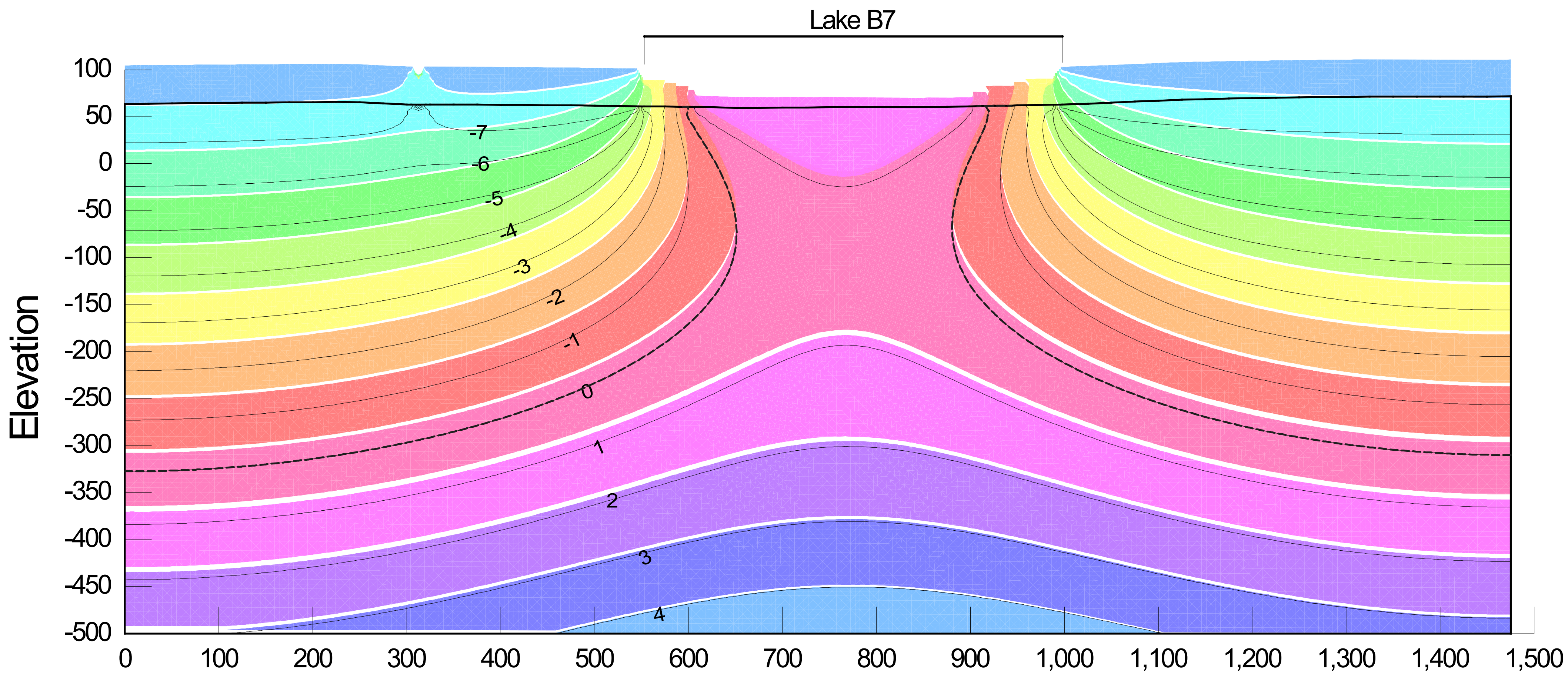
CLIENT	PROJECT
AGNICO EAGLE MINES LTD.	MELIADINE EXTENSION 2D THERMAL MODELLING RESULTS

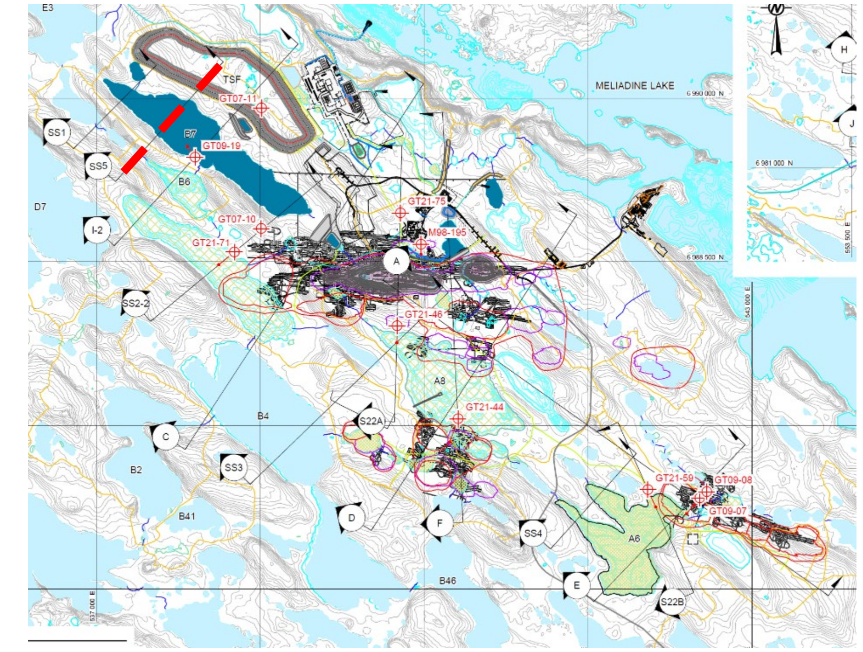
CONSULTANT		
GOLDER MEMBER OF WSP	YYYY-MM-DD	2022-06-XX
	PREPARED	ZPS
	DESIGNED	ZPS
	REVIEWED	FJ
	APPROVED	-

TITLE
SECTION SS4
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-16

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





CLIENT
AGNICO EAGLE MINES LTD.

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

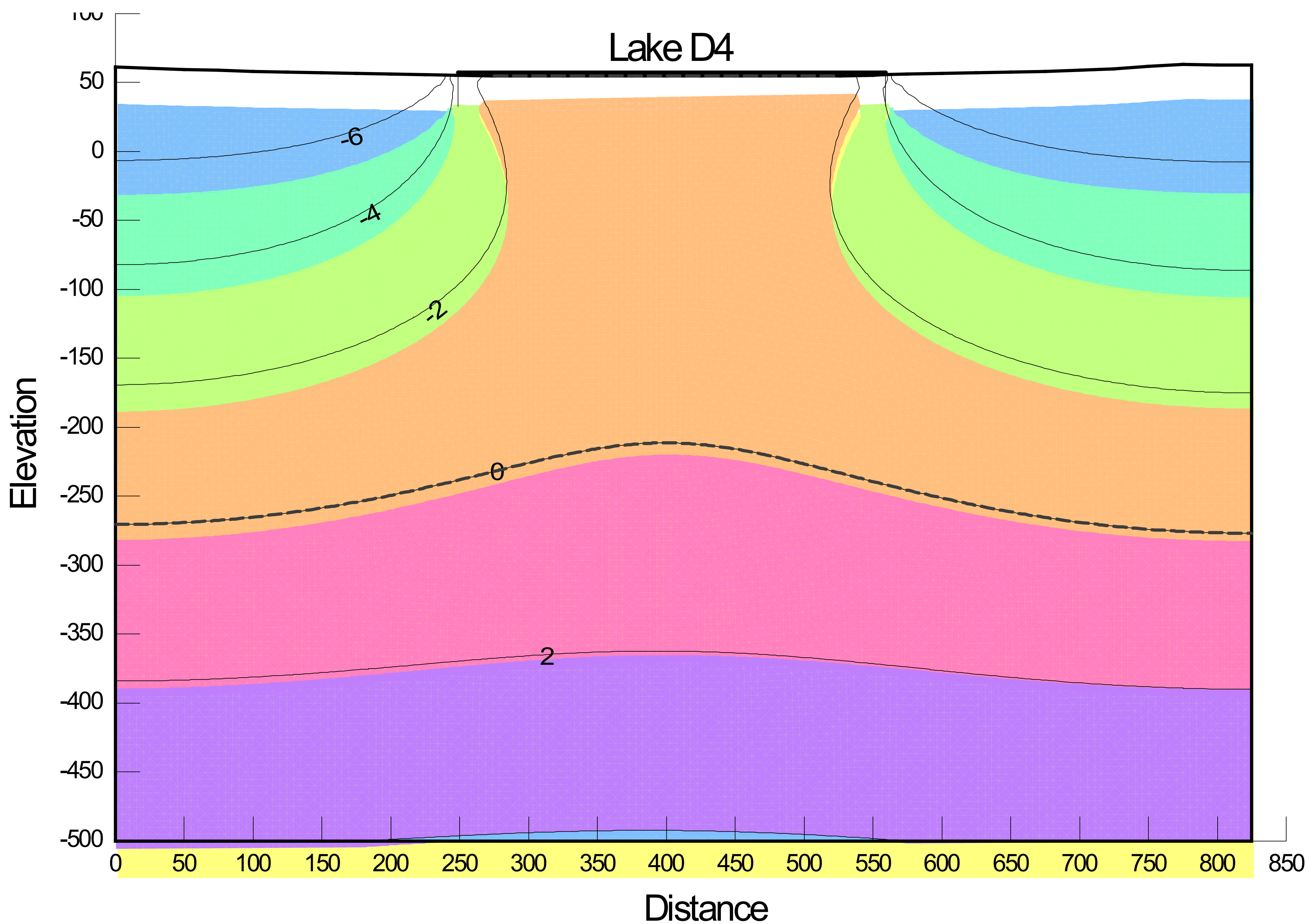
CONSULTANT

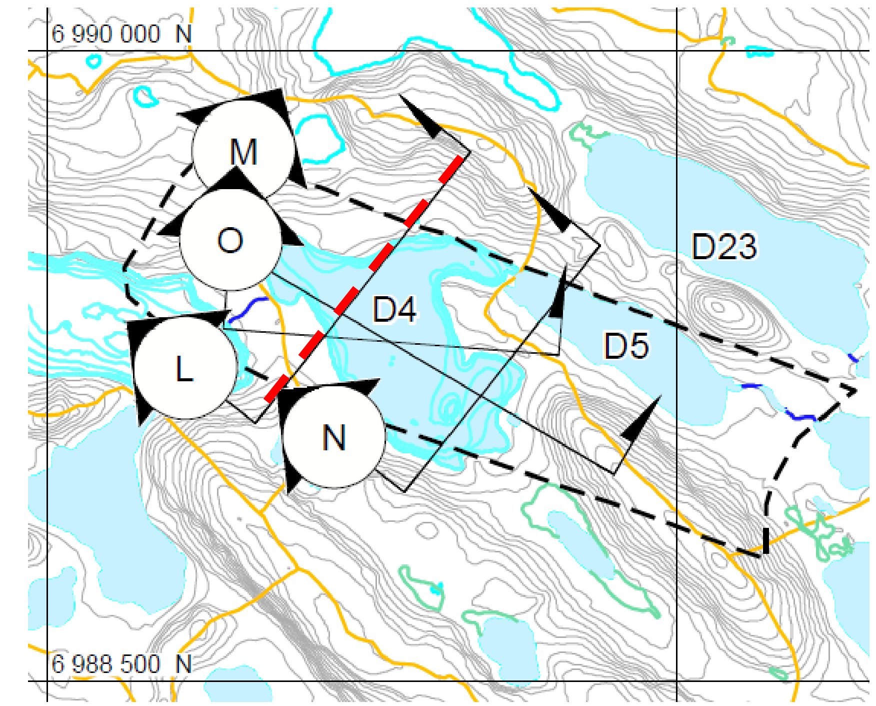
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION SS5
MAIN AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-17





CLIENT
AGNICO EAGLE MINES LTD.

CONSULTANT

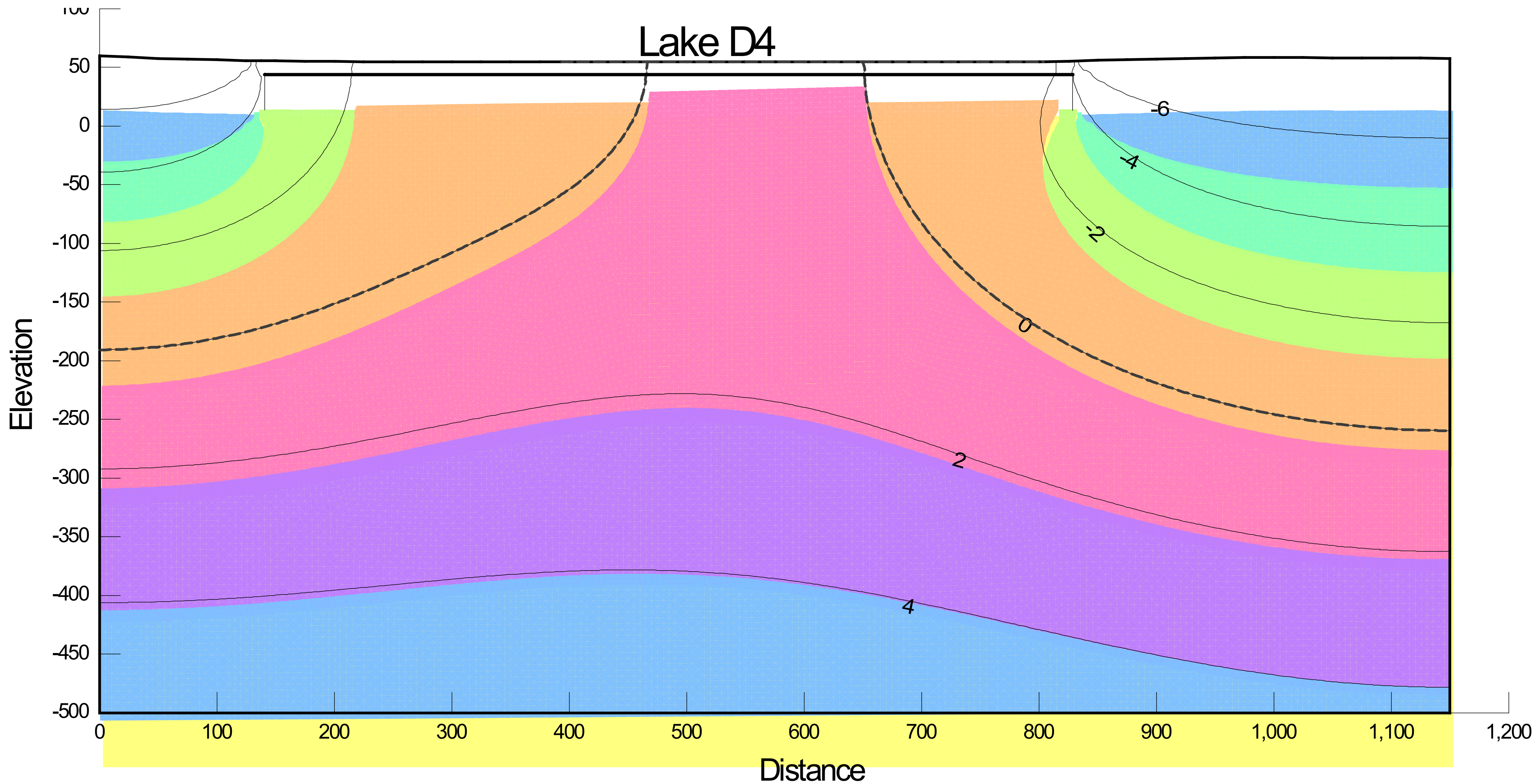
GOLDER
MEMBER OF WSP

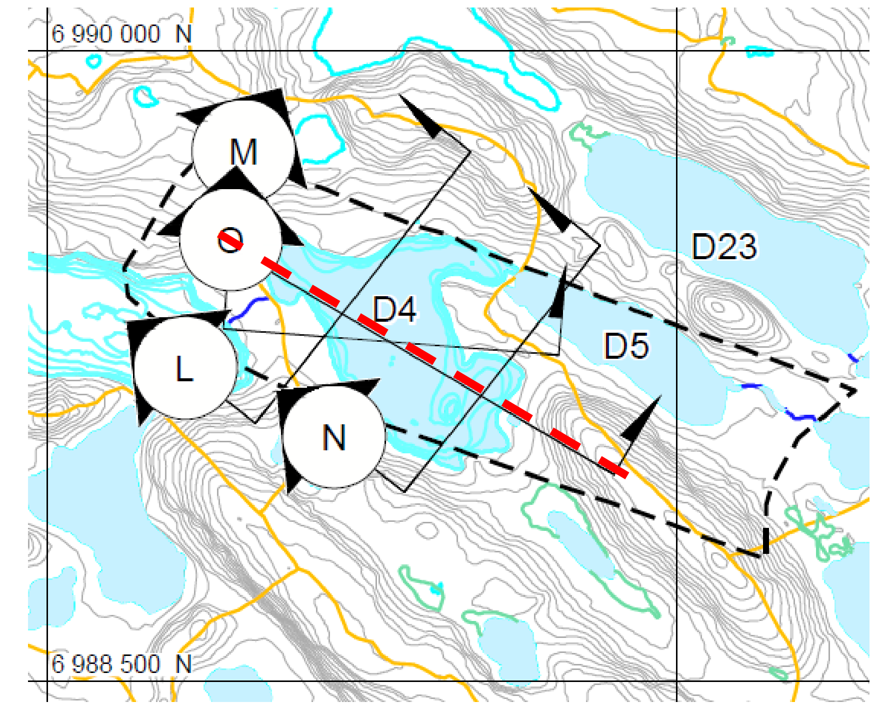
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

TITLE
SECTION L
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-18





CLIENT
AGNICO EAGLE MINES LTD.

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT
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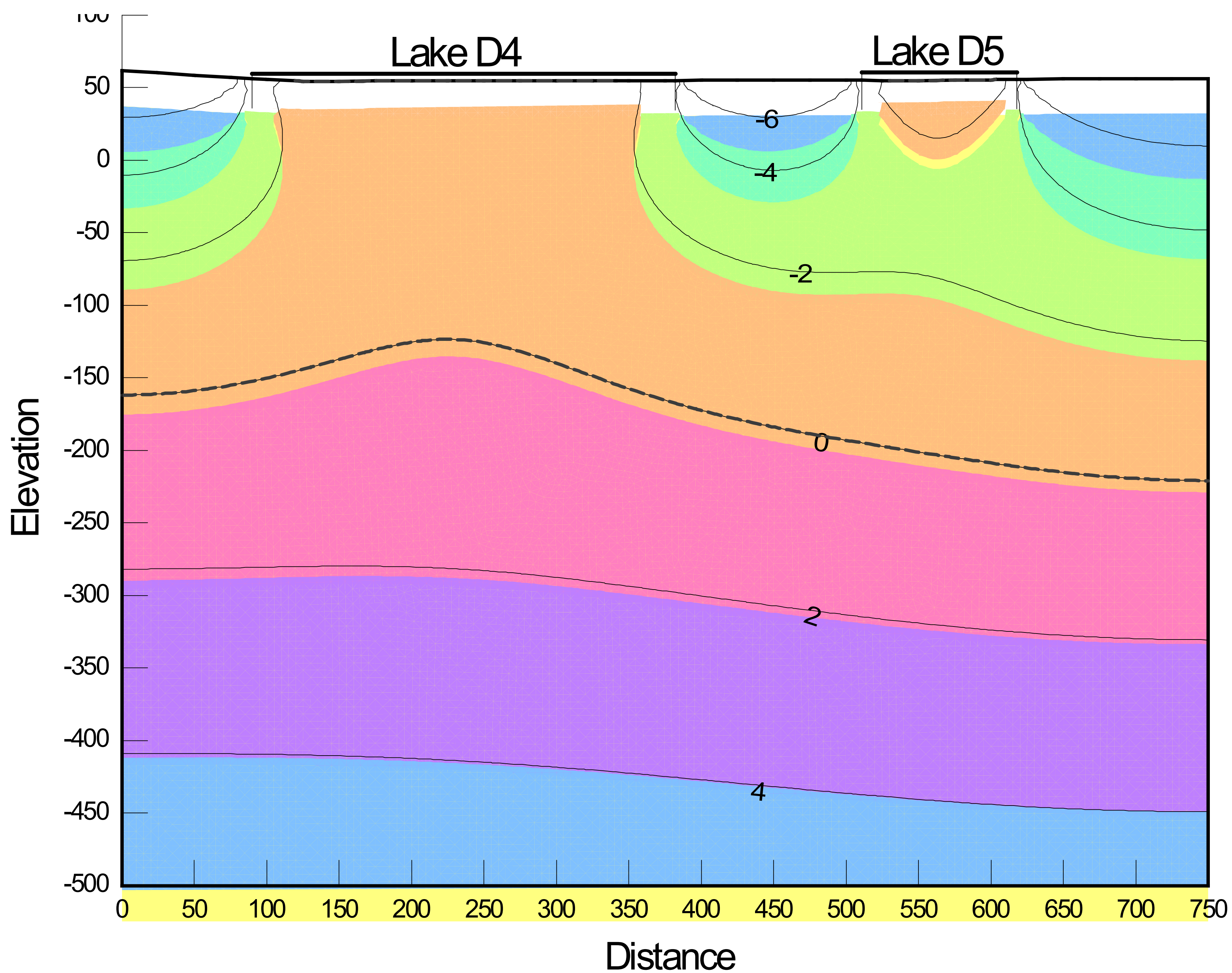
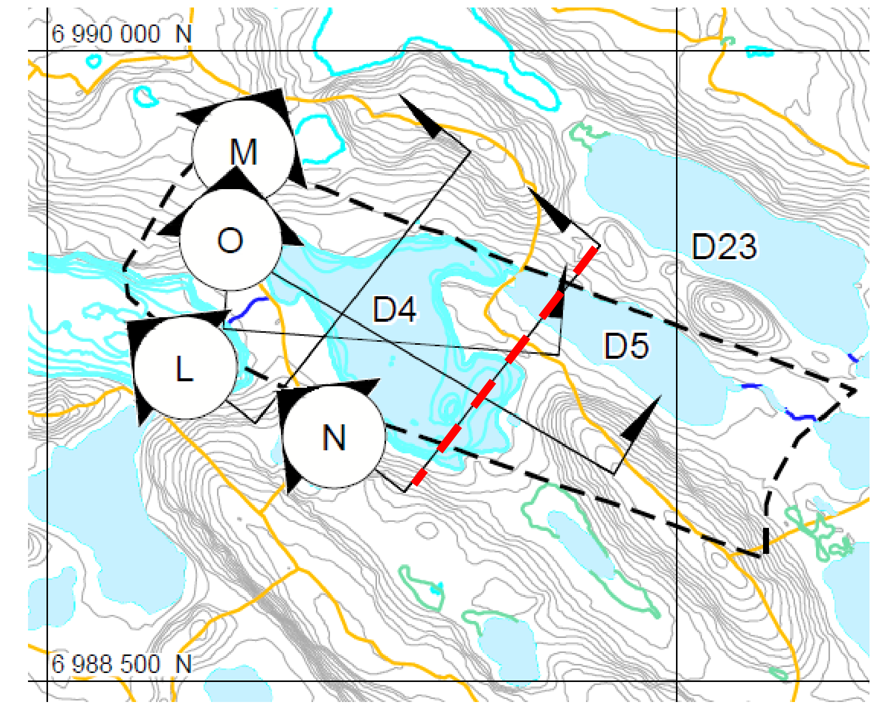
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION M
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-19





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AGNICO EAGLE MINES LTD.

PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT

GOLDER
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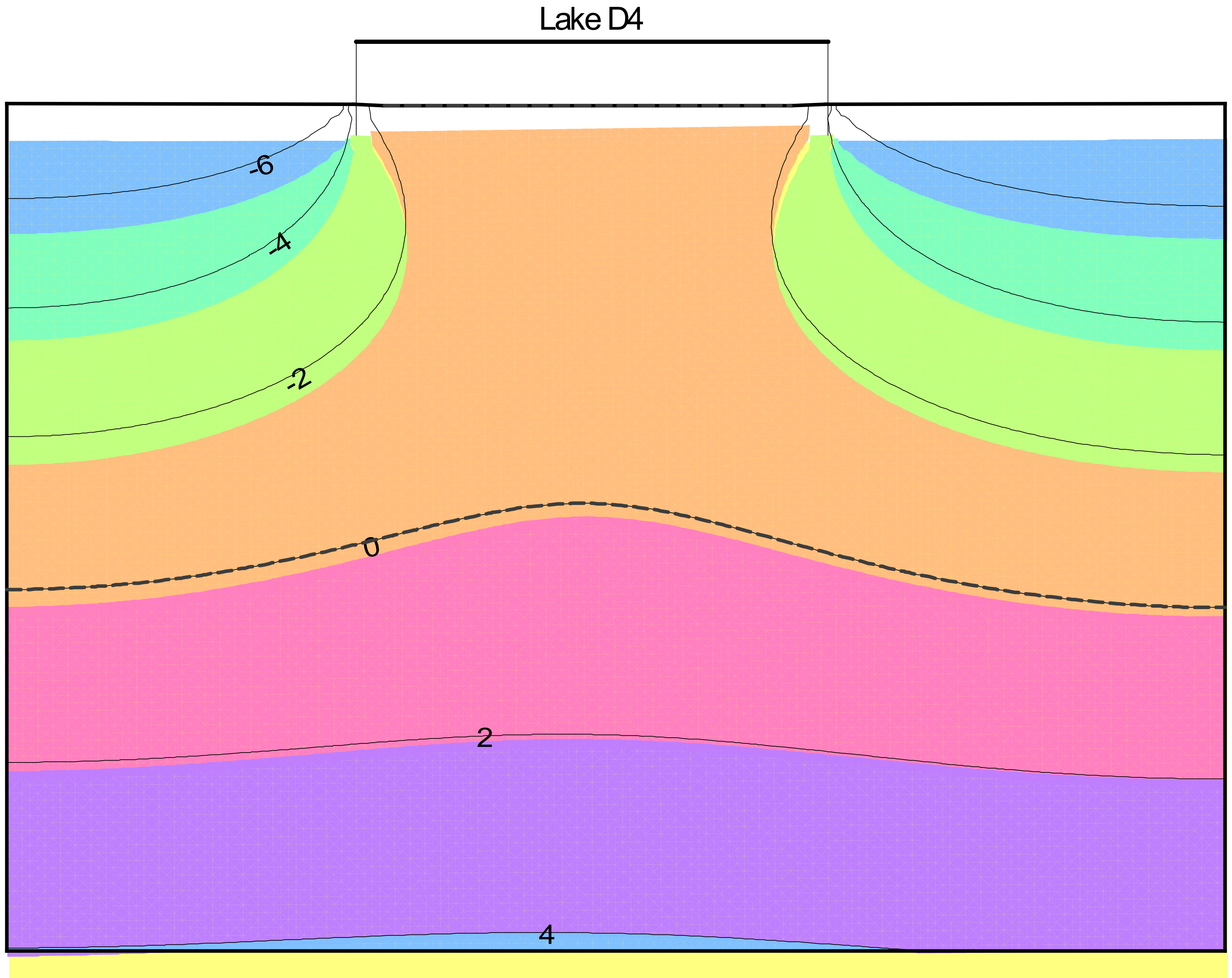
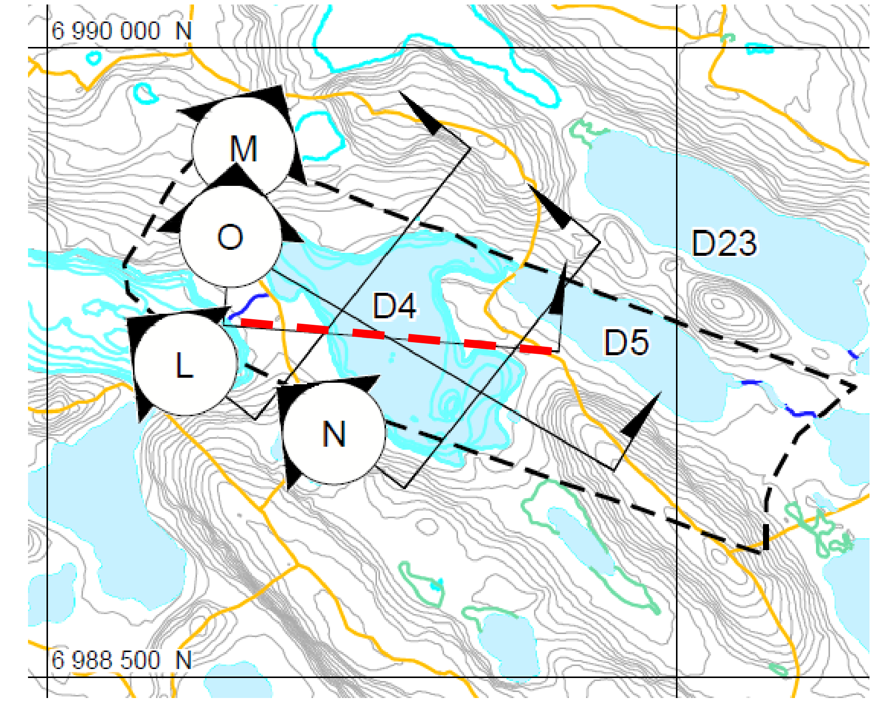
YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION N
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-20





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PROJECT
MELIADINE EXTENSION
2D THERMAL MODELLING RESULTS

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-06-XX
PREPARED	ZPS
DESIGNED	ZPS
REVIEWED	FJ
APPROVED	-

TITLE
SECTION O
TIRIGANIAQ-NORTH AREA

PROJECT NO.	Phase	REV.	FIGURE
22513890	1000	0	B-21

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