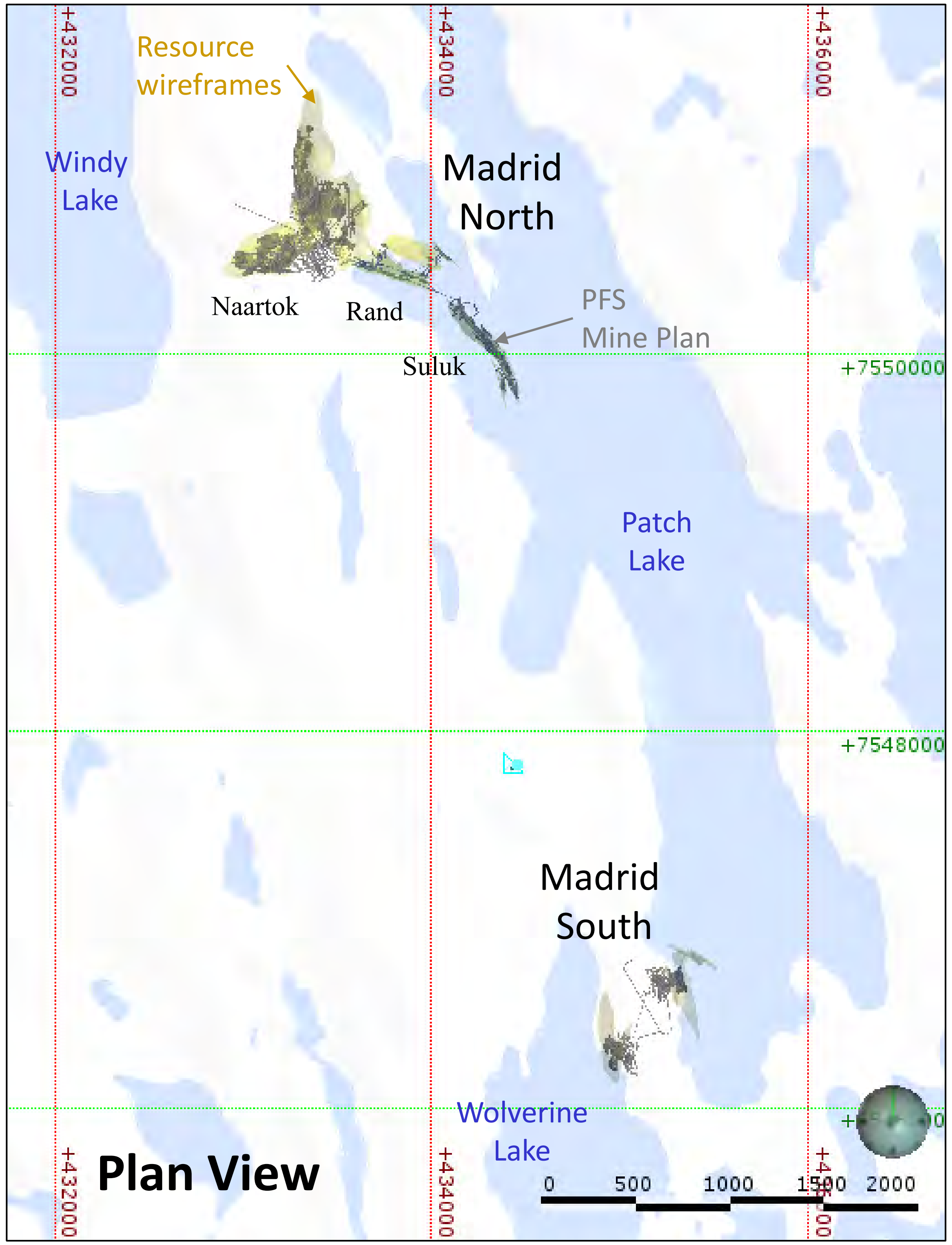
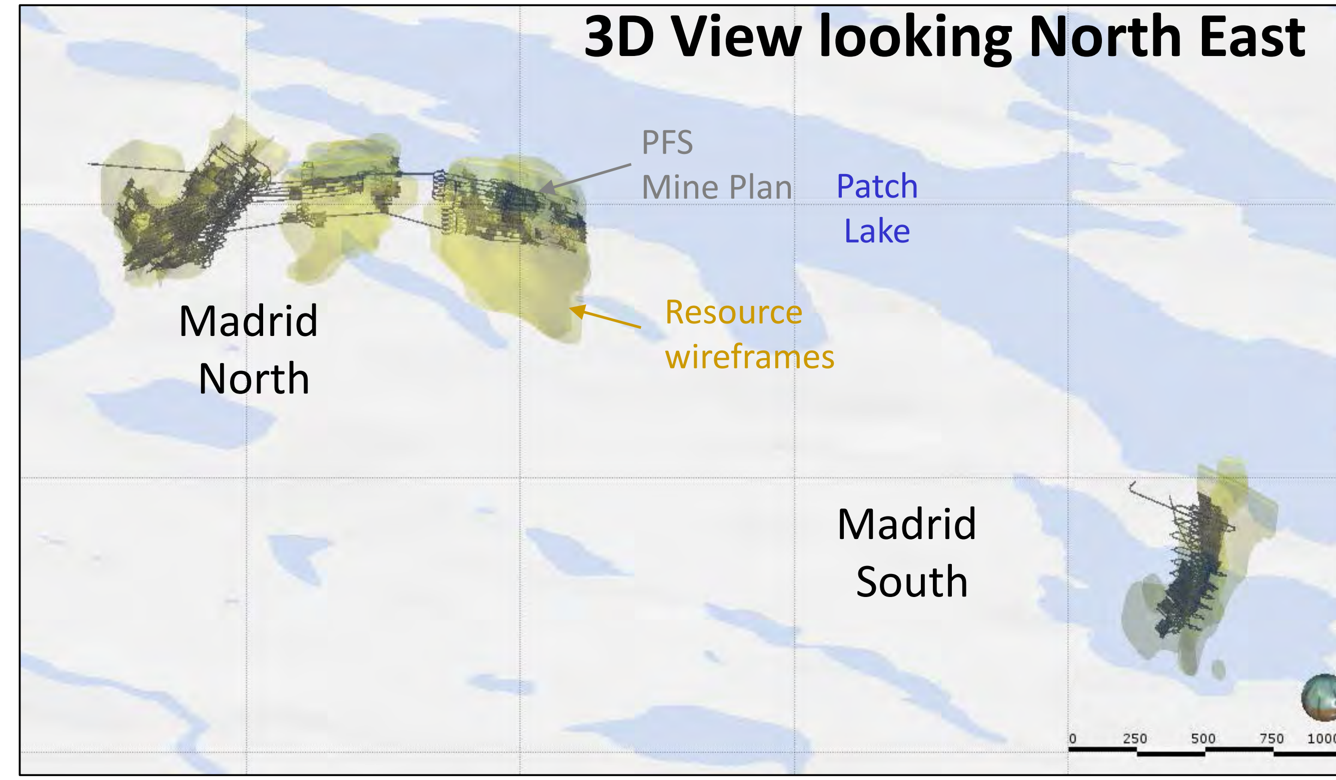
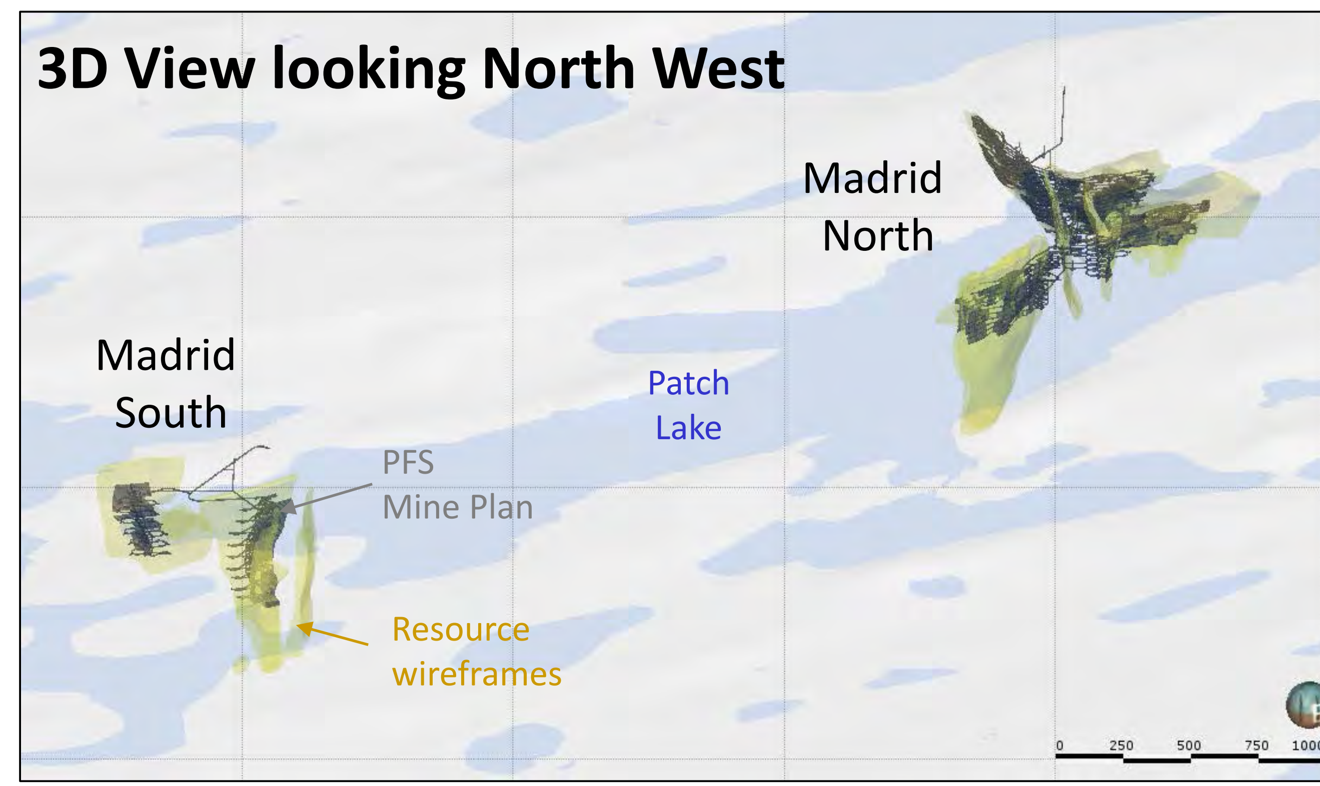
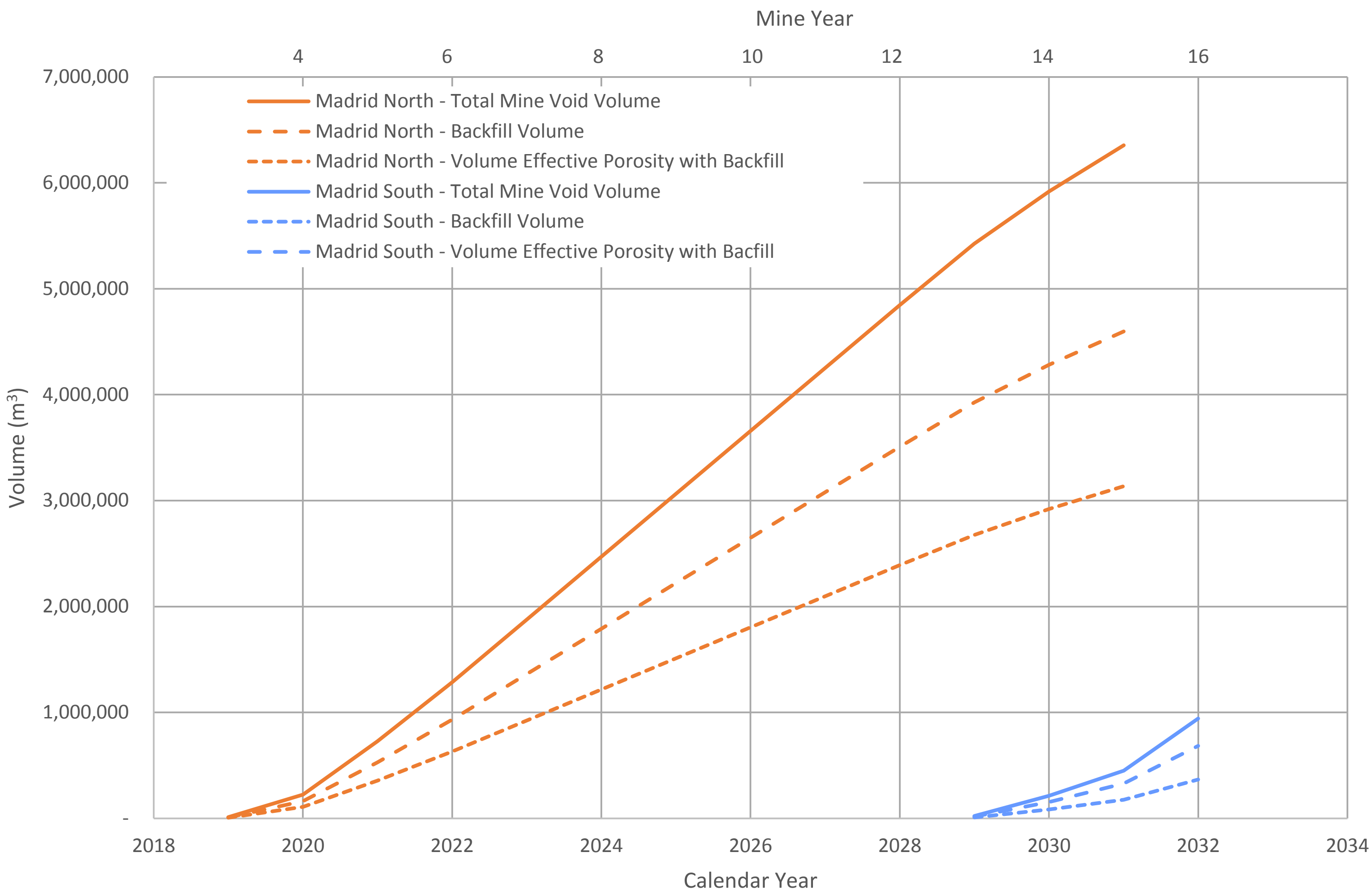






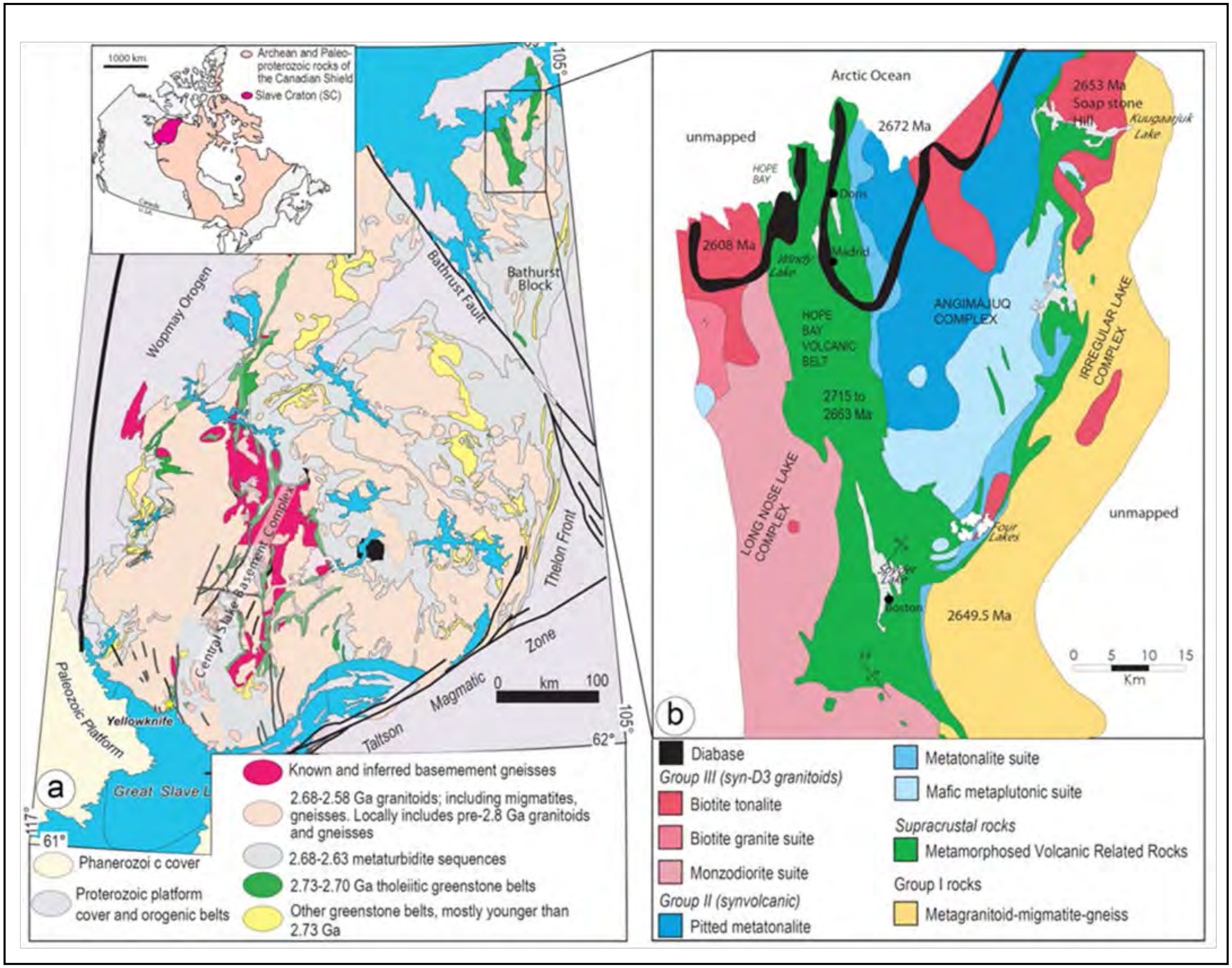
Note:
Prefeasibility mine plan shown, which will be updated as mining progresses.

srk consulting	MAC RESOURCES	Hydrogeological Modeling
Job No: 1CT022.004	Hope Bay Project	**Madrid South and Madrid North Mine Views**
Filename: App D_FigureD1-D2_Appx_Sensitivity.pptx		Date: Dec 2016 / Approved: GF / Figure: 3



Note:
The assumed in-place density and porosity of backfill is respectively 1.6 t/m^3 and 30%.

srk consulting	MAC RESOURCES	Hydrogeological Modeling
		Mine Void Volumes Over Time
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 4



Note:

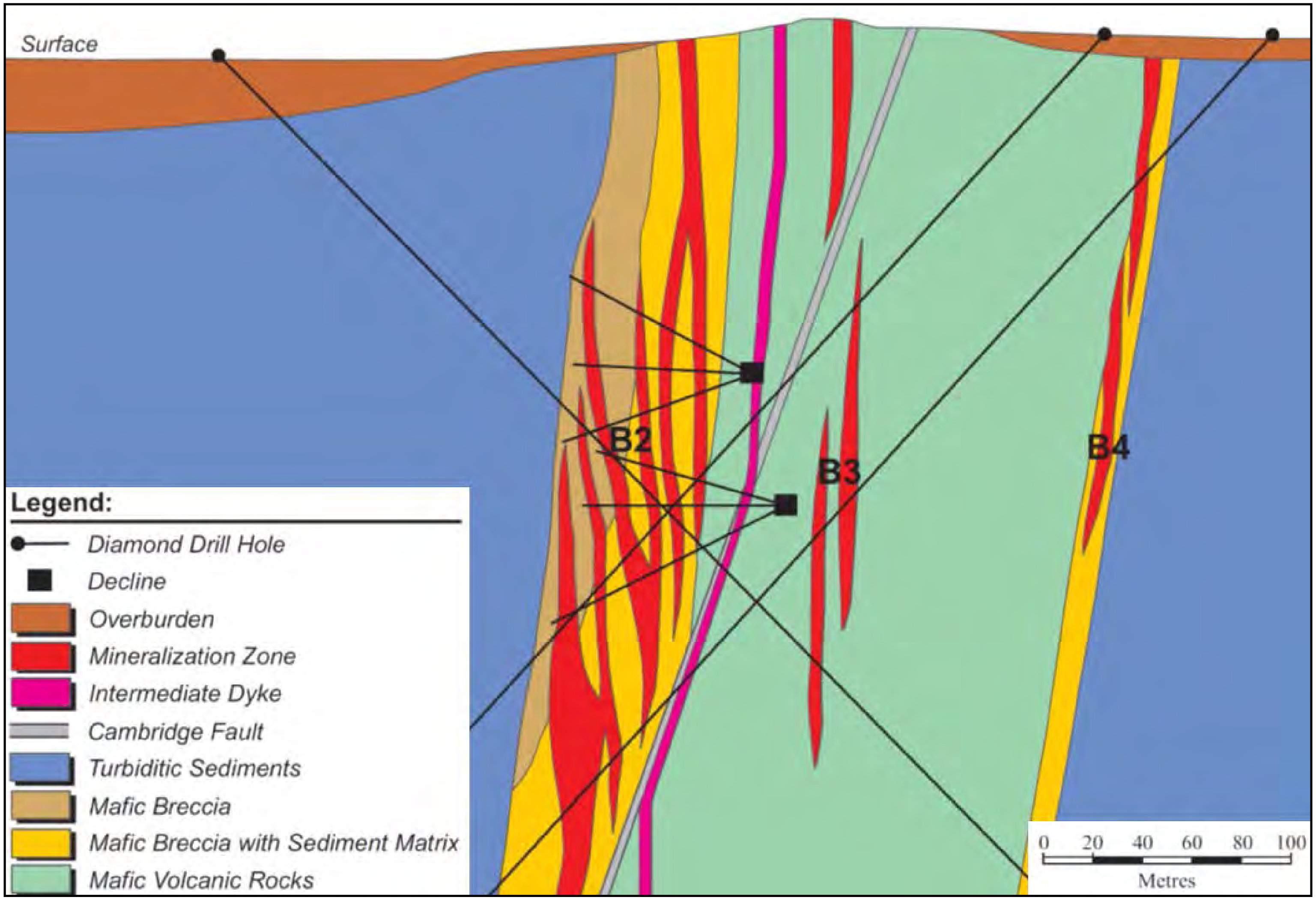
a) Regional geology of the Slave Structural Province (Craton).

b) Simplified geology of the Hope Bay Volcanic Belt (greenstone belt), from Mvondo et al. (2012).

srk consulting

TMAC RESOURCES

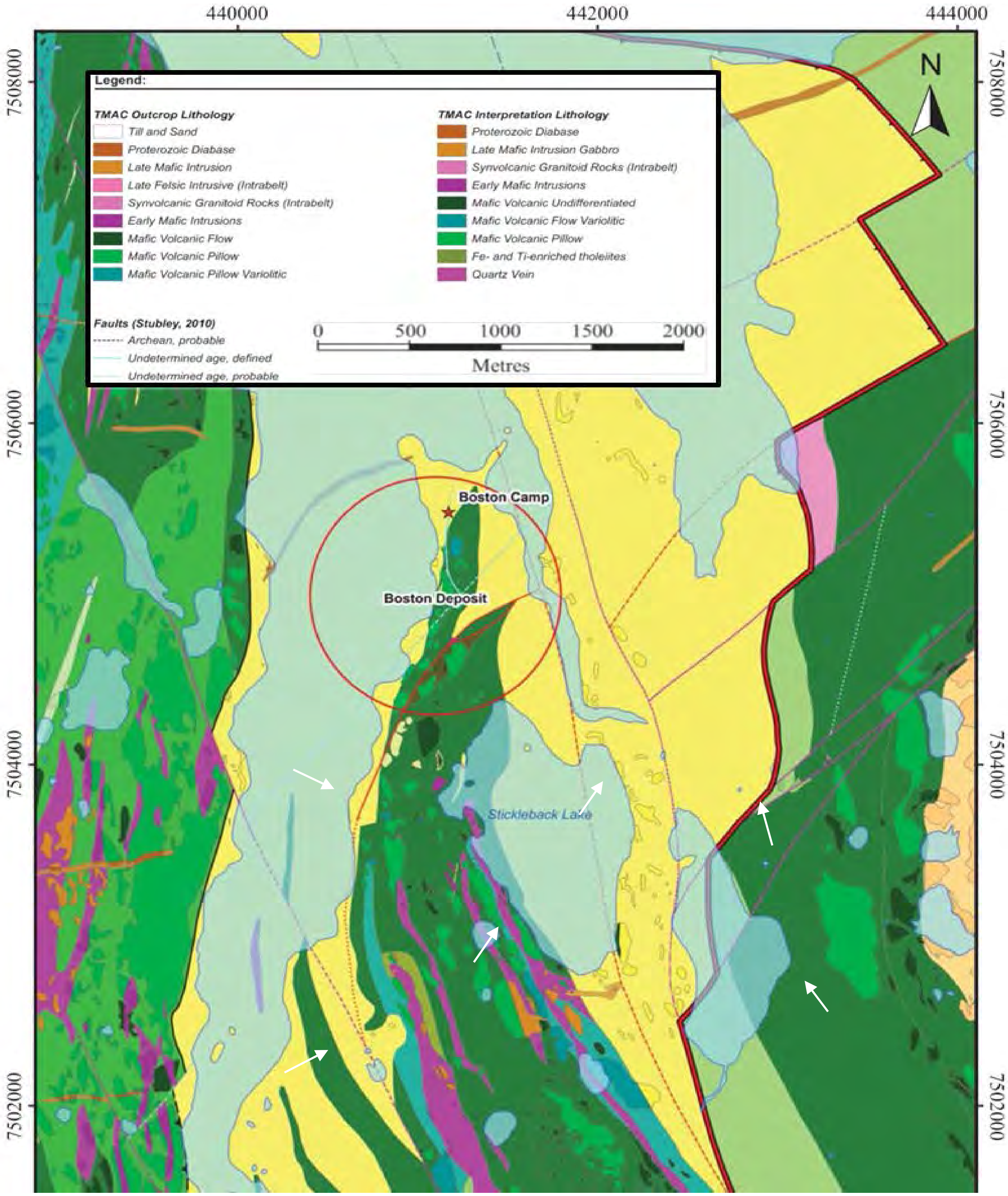
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Hydrogeological Modeling Regional Geology
		Date: Dec 2016 — Approved: GF — Figure: 5



Source: Roscoe Postle Associates Inc., 2015

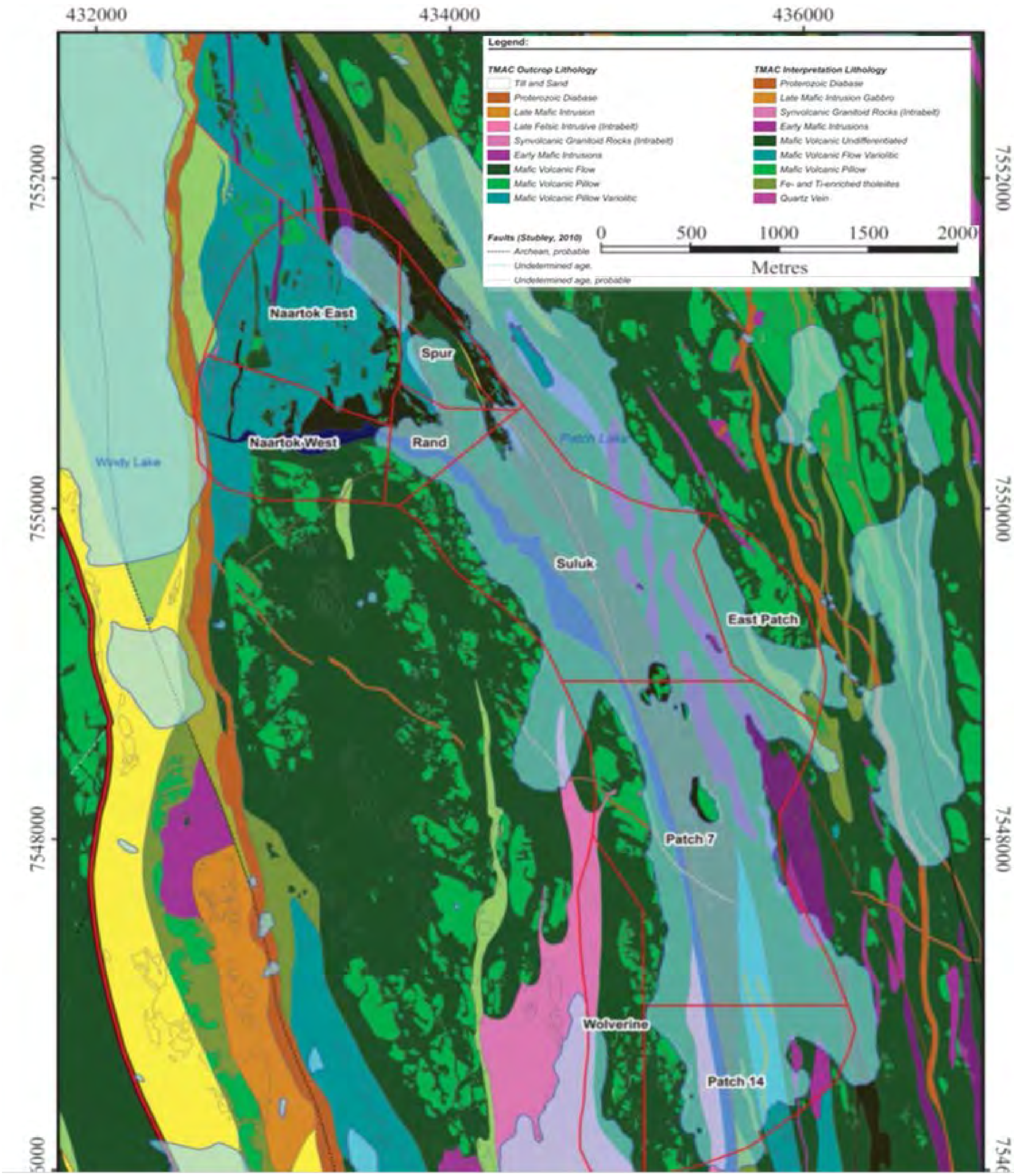
srk consulting	MAC RESOURCES	Hydrogeological Modeling
		Schematic Cross West-East Section of the Boston Mineralization
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 6

Quaternary surficial sediments are shown in yellow.
Roscoe Postle Associates Inc., 2015



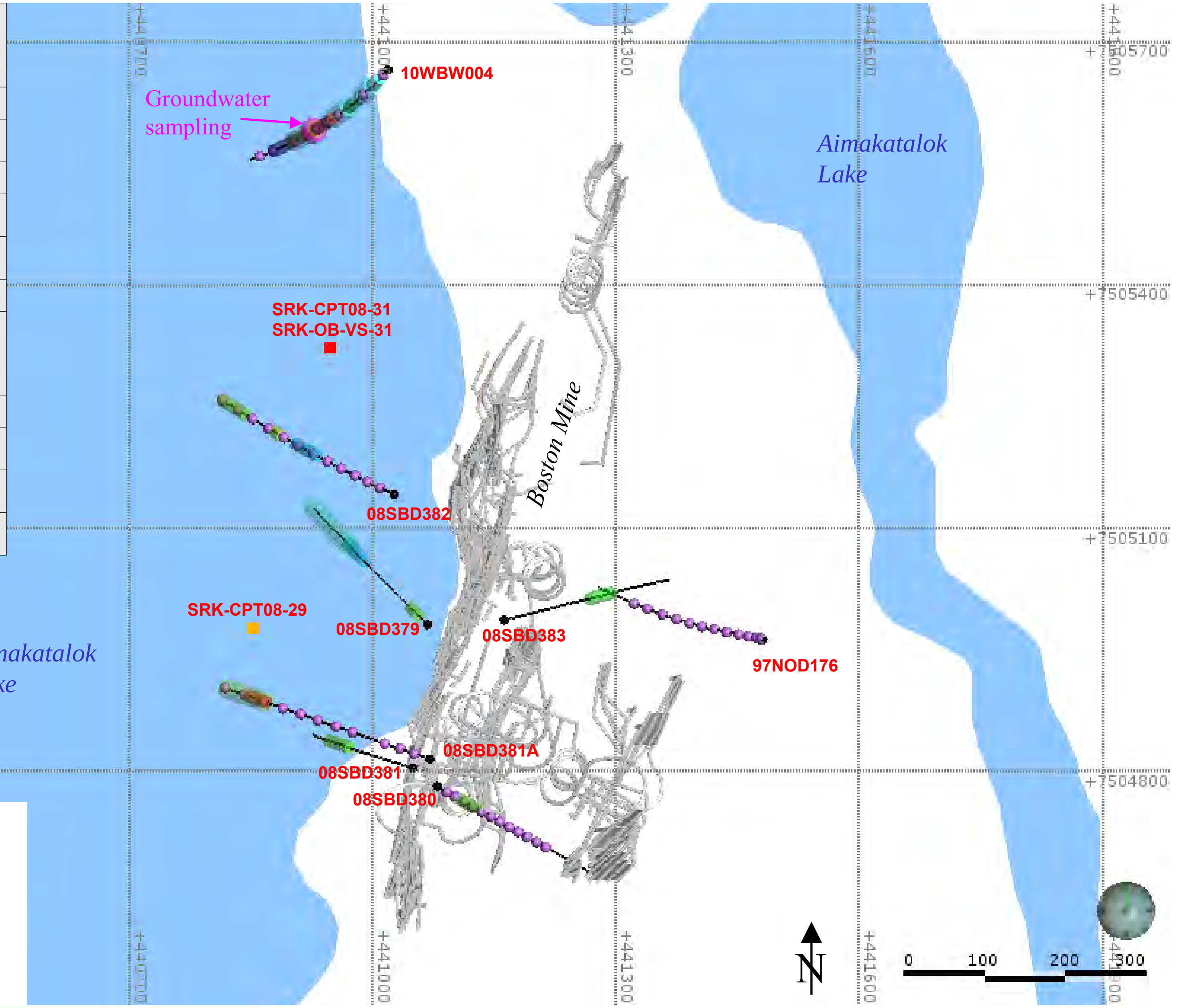
srk consulting	TMAC RESOURCES	Hydrogeological Modeling
		Detailed Geology Map of the Boston Area
Job No: 1CT022.004	Hope Bay Project	Date: Dec 2016
Filename: Figures_8x11_Portrait_r2.pptx		Approved: GF
		Figure: 7

Quaternary surficial sediments are shown in yellow.
Roscoe Postle Associates Inc., 2015



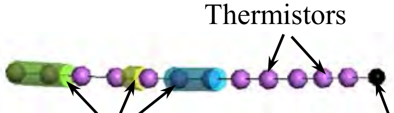
srk consulting	TMAC RESOURCES	Hydrogeological Modeling
		Detailed Geology Map of the Madrid Area
Job No: 1CT022.004 Filename: Figures_8x11_Portrait_r2.pptx	Hope Bay Project	Date: Dec 2016 · Approved: GF · Figure: 8

Hole ID	Length (m)	Dip (deg)	Data Type
08SBD379	332	52	K tests (3)
08SBD380	401	56	K tests (1) Thermistors (12)
08SBD381	244	58	K tests (1)
08SBD381A	401	48	K tests (2) Thermistors (12)
08SBD382	404	53	K tests (3) Thermistors (12)
08SBD383	356	54	K tests (1)
10WBW004	470	65	Westbay well K tests (9) Thermistors GW Samples (2/20)
97NOD176	367	54	Thermistors (14)
SRK-CPT08-29	6.1	90	CPT pressure dissipation Test
SRK-CPT08-31	12.8	90	CPT pressure dissipation Test
SRK-OB-VS-31	12.8	90	Lab. Consolidation test



Note:
K, Hydraulic Conductivity
GW, Groundwater
CPT, Cone Penetration Testing
(2), # of test, or sensor
(2/20), # final sample / Total # of samples

Prefeasibility mine plan shown, which will be updated as mining progresses.



srk consulting

Job No: 1CT022.004
Filename: Figures_8x11_Landscape_r1.pptx

MAC RESOURCES

Hope Bay Project

Hydrogeological Modeling

Location Map of the Hydrogeological Data at Boston

Date:	Approved:	Figure:
Dec 2016	GF	9

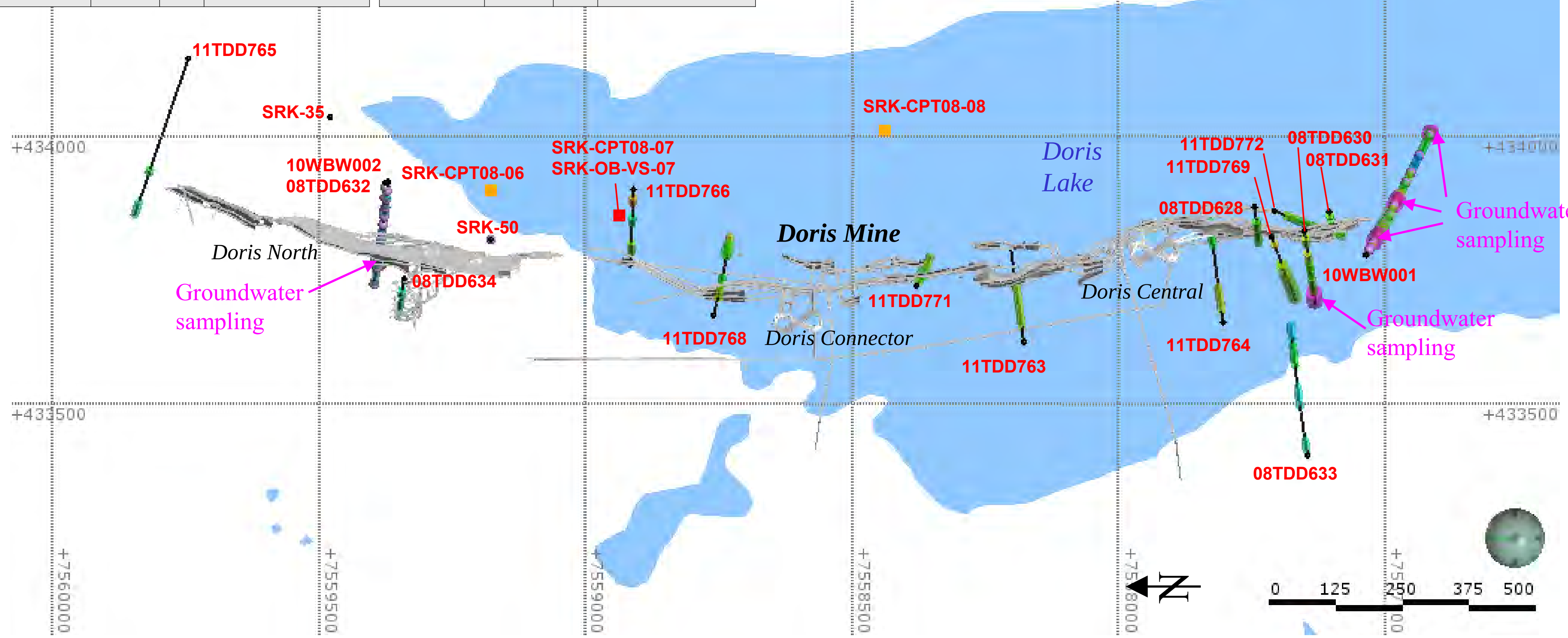
Hole ID	Hole Length (m)	Dip (deg)	Data Type
08TDD628	141	61	K tests (1)
08TDD630	317	63	K tests (5) GW sample (1/1)
08TDD631	122	82	K tests (2)
08TDD632	401	61	K tests (4) Thermistors (12)
08TDD633	401	52	K tests (4)
08TDD634	140	59	K tests (1)
10WBW001	564	62	Westbay well K tests (17) Thermistors (12) GW samples (20/40)

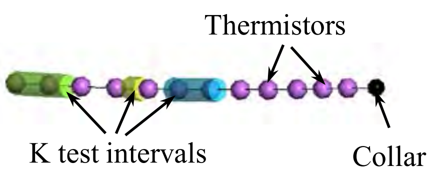
Hole ID	Hole Length (m)	Dip (deg)	Data Type
10WBW002	602	75	Westbay well K tests (5) Thermistors (8) GW Samples (0/15)
11TDD763	285	52	K tests (1)
11TDD764	341	56	K tests (2)
11TDD765	437	44	K tests (2)
11TDD766	297	60	K tests (3)
11TDD768	299	60	K tests (6)
11TDD769	310	65	K tests (6)
11TDD771	294	78	K tests (6)

Hole ID	Hole Length (m)	Dip (deg)	Data Type
11TDD772	330	65	K tests (5)
SRK-35	10	90	Thermistors (6)
SRK-50	200	90	Thermistors (13)
SRK-CPT08-06	12	90	CPT pressure dissipation Test
SRK-CPT08-07	7.8	90	CPT pressure dissipation Test
SRK-CPT08-08	20.6	90	CPT pressure dissipation Test
SRK-OB-VS-07	7.8	90	Lab. Consolidation test

Note:
K, Hydraulic Conductivity
GW, Groundwater
CPT, Cone Penetration Testing
(2), # of test, or sensor
(2/20), # final sample / Total # of samples

Prefeasibility mine plan shown, which will be updated as mining progresses.





srk consulting

Job No: 1CT022.004
Filename: Figures_8x11_Landscape_r1.pptx

TMAC RESOURCES

Hope Bay Project

Hydrogeological Modeling

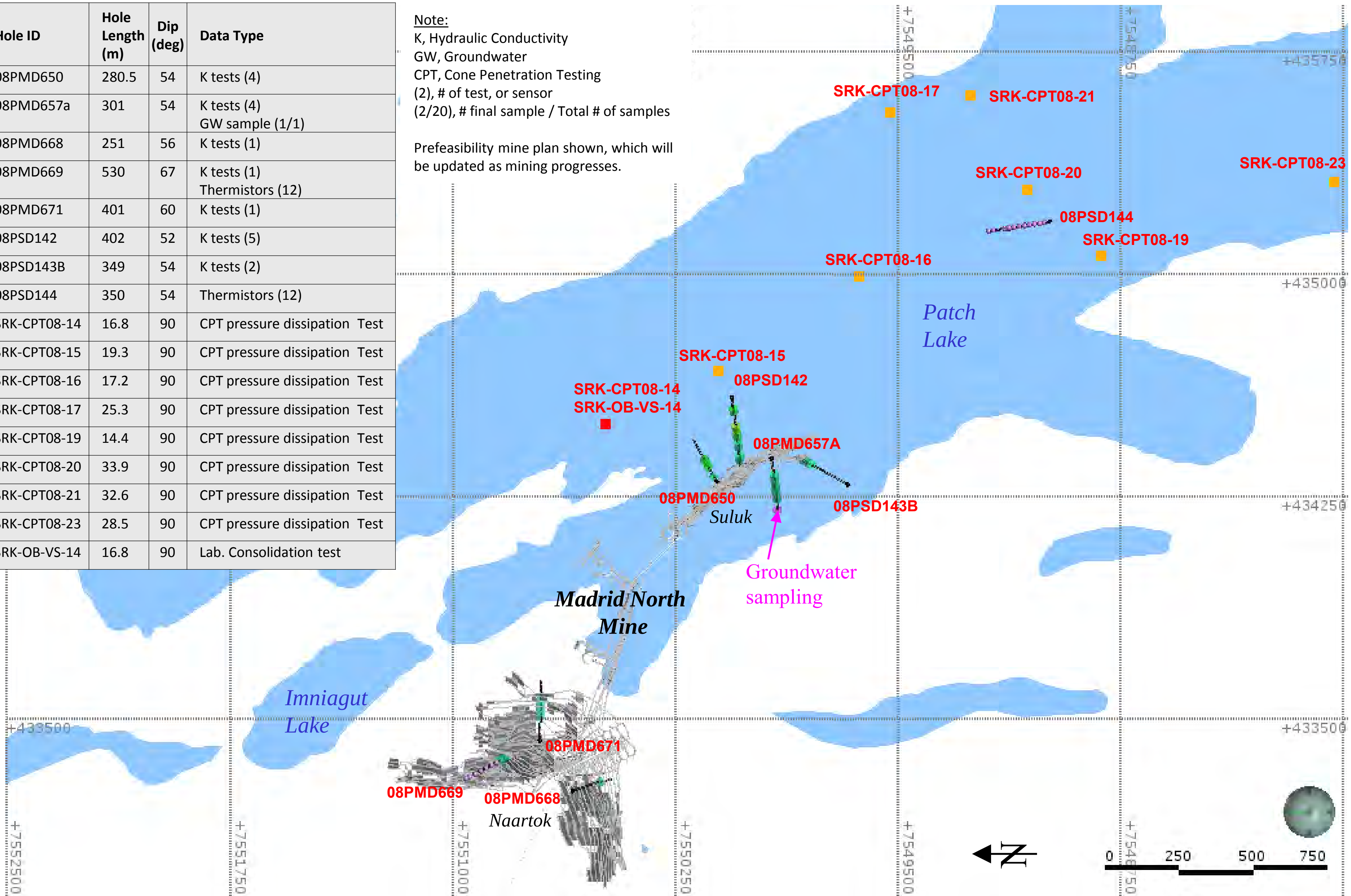
Location Map of the Hydrogeological Data at Doris

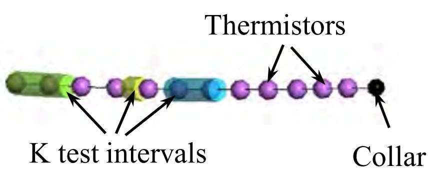
Date:	Approved:	Figure:
Dec 2016	GF	10

Hole ID	Hole Length (m)	Dip (deg)	Data Type
08PMD650	280.5	54	K tests (4)
08PMD657a	301	54	K tests (4) GW sample (1/1)
08PMD668	251	56	K tests (1)
08PMD669	530	67	K tests (1) Thermistors (12)
08PMD671	401	60	K tests (1)
08PSD142	402	52	K tests (5)
08PSD143B	349	54	K tests (2)
08PSD144	350	54	Thermistors (12)
SRK-CPT08-14	16.8	90	CPT pressure dissipation Test
SRK-CPT08-15	19.3	90	CPT pressure dissipation Test
SRK-CPT08-16	17.2	90	CPT pressure dissipation Test
SRK-CPT08-17	25.3	90	CPT pressure dissipation Test
SRK-CPT08-19	14.4	90	CPT pressure dissipation Test
SRK-CPT08-20	33.9	90	CPT pressure dissipation Test
SRK-CPT08-21	32.6	90	CPT pressure dissipation Test
SRK-CPT08-23	28.5	90	CPT pressure dissipation Test
SRK-OB-VS-14	16.8	90	Lab. Consolidation test

Note:
K, Hydraulic Conductivity
GW, Groundwater
CPT, Cone Penetration Testing
(2), # of test, or sensor
(2/20), # final sample / Total # of samples

Prefeasibility mine plan shown, which will be updated as mining progresses.





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MAC RESOURCES

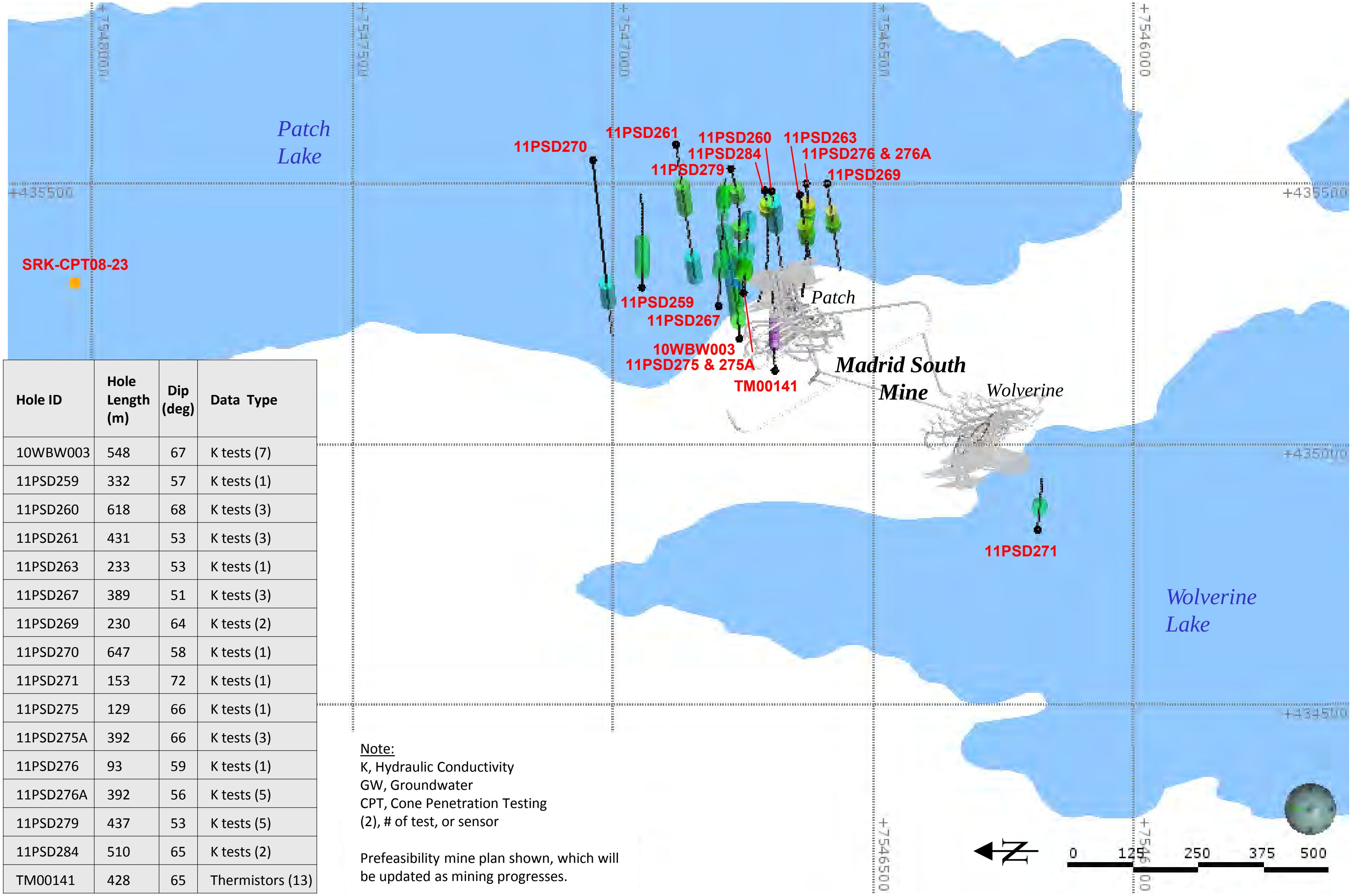
Job No: 1CT022.004
Filename: Figures_8x11_Landscape_r1.pptx

Hope Bay Project

Hydrogeological Modeling

Location Map of the Hydrogeological Data at Madrid North

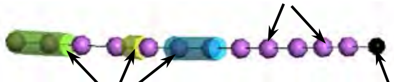
Date: Dec 2016 | Approved: GF | Figure: 11



Hole ID	Hole Length (m)	Dip (deg)	Data Type
10WBW003	548	67	K tests (7)
11PSD259	332	57	K tests (1)
11PSD260	618	68	K tests (3)
11PSD261	431	53	K tests (3)
11PSD263	233	53	K tests (1)
11PSD267	389	51	K tests (3)
11PSD269	230	64	K tests (2)
11PSD270	647	58	K tests (1)
11PSD271	153	72	K tests (1)
11PSD275	129	66	K tests (1)
11PSD275A	392	66	K tests (3)
11PSD276	93	59	K tests (1)
11PSD276A	392	56	K tests (5)
11PSD279	437	53	K tests (5)
11PSD284	510	65	K tests (2)
TM00141	428	65	Thermistors (13)

Note:
K, Hydraulic Conductivity
GW, Groundwater
CPT, Cone Penetration Testing
(2), # of test, or sensor

Prefeasibility mine plan shown, which will be updated as mining progresses.



srk consulting

MAC RESOURCES

Hydrogeological Modeling

Location Map of the Hydrogeological Data at Madrid South

Job No: 1CT022.004

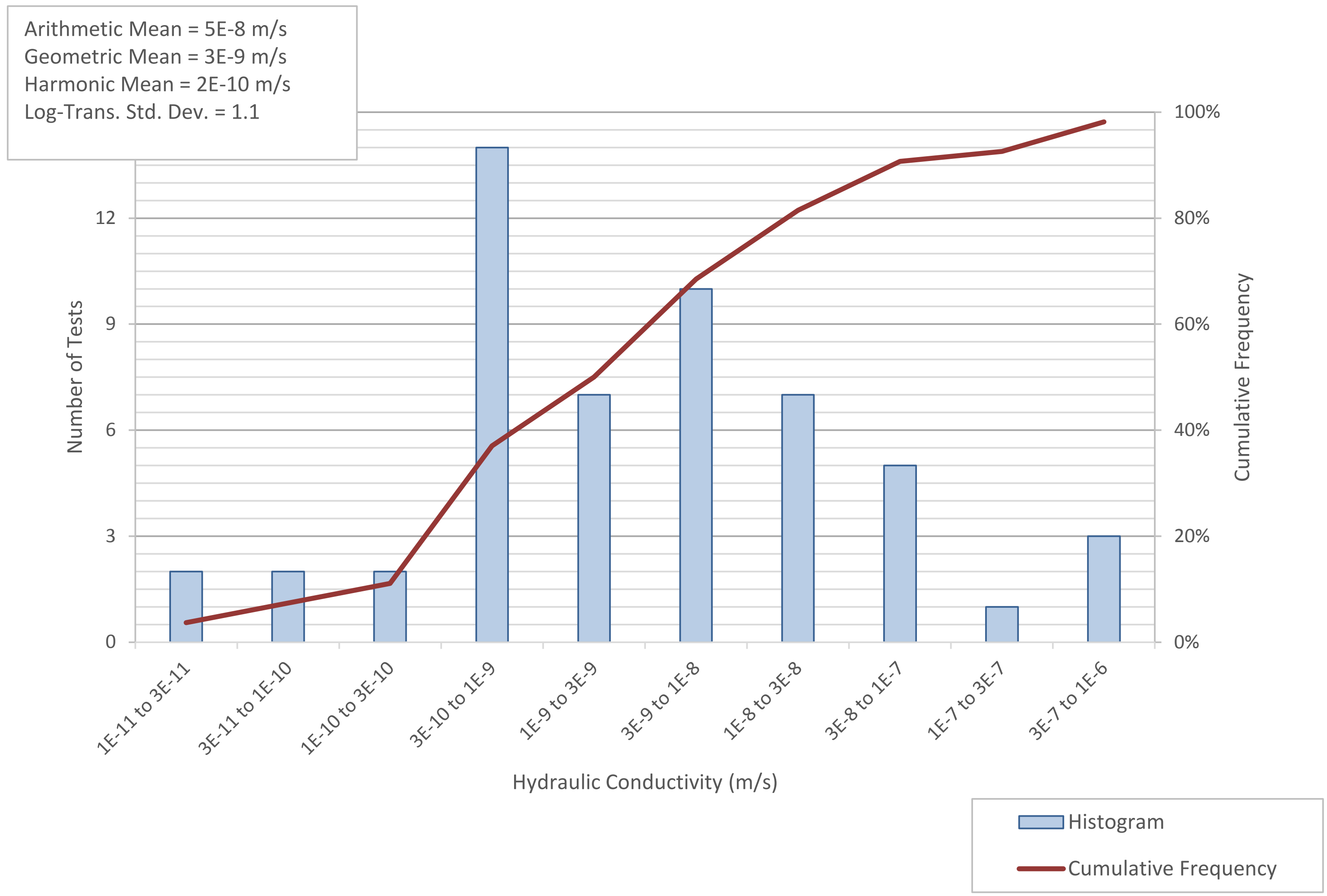
Filename: Figures_8x11_Landscape_r1.pptx

Hope Bay Project

Date: Dec 2016

Approved: GF

Figure: 12



Source: Boston_Madrid_K_Statistical Summary.xlsx

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MAC RESOURCES

Hydrogeological Modeling

Statistical Summary of the K Measurements

Job No: 1CT022.004

Filename: Figures_8x11_Landscape_r1.pptx

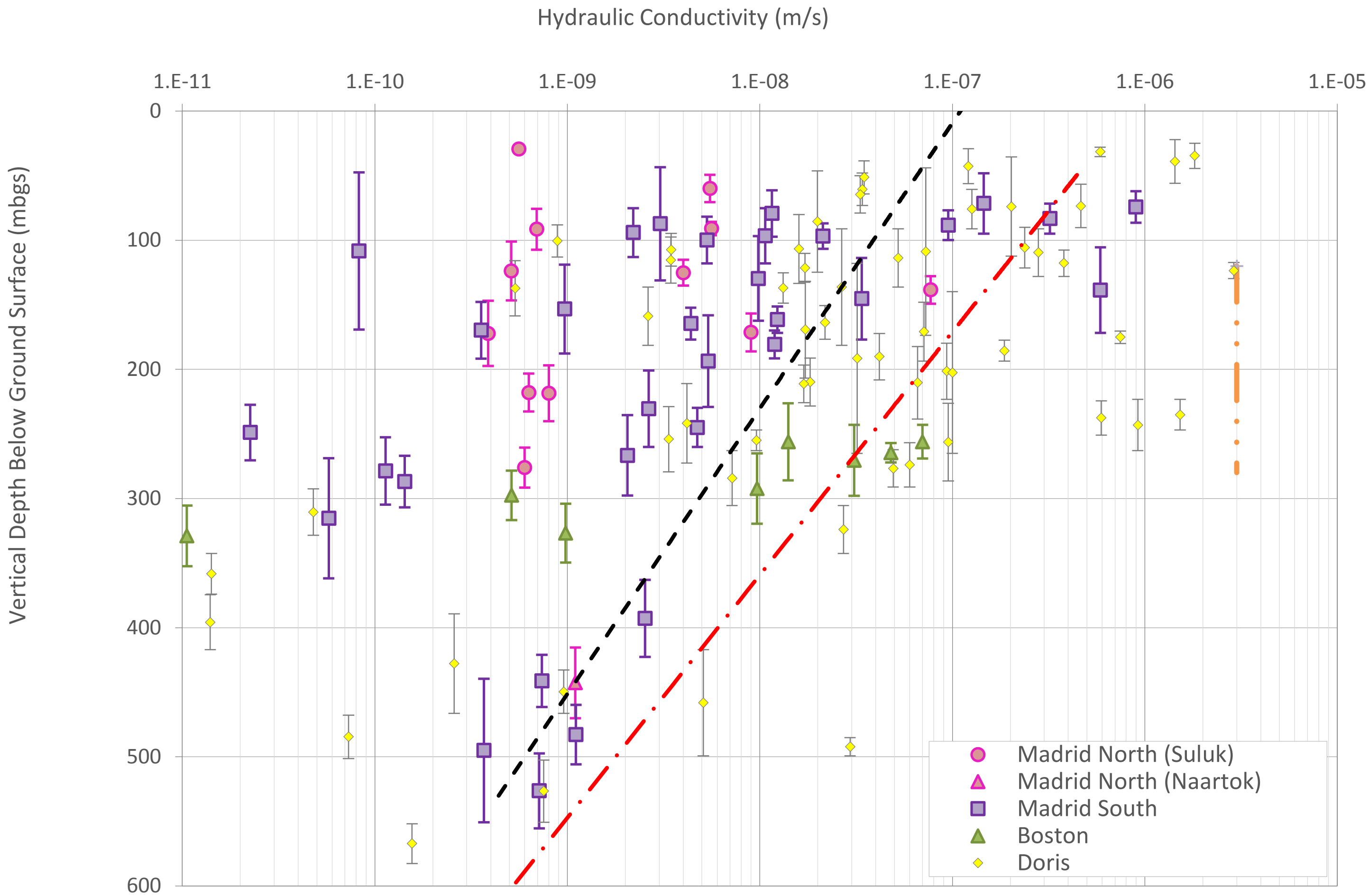
Hope Bay Project

Date: Dec 2016

Approved: GF

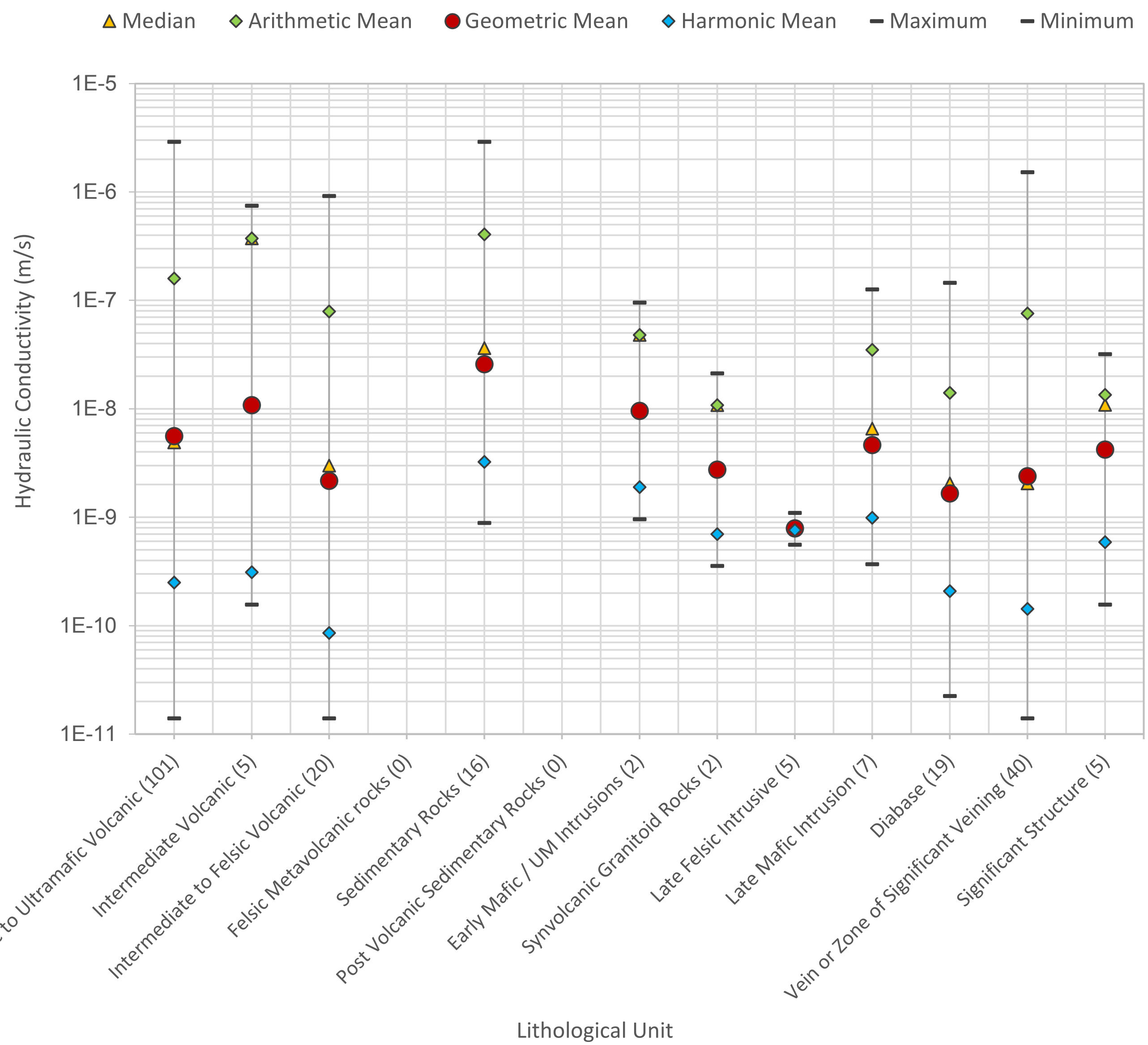
Figure: 13

Note: The black dashed line is a function of K with depth based on a moving geometric mean. The red dashed line is a function of K based on a moving arithmetic mean. The orange dashed line represents the highest K values of the Hope Bay project, reported for at Doris North.



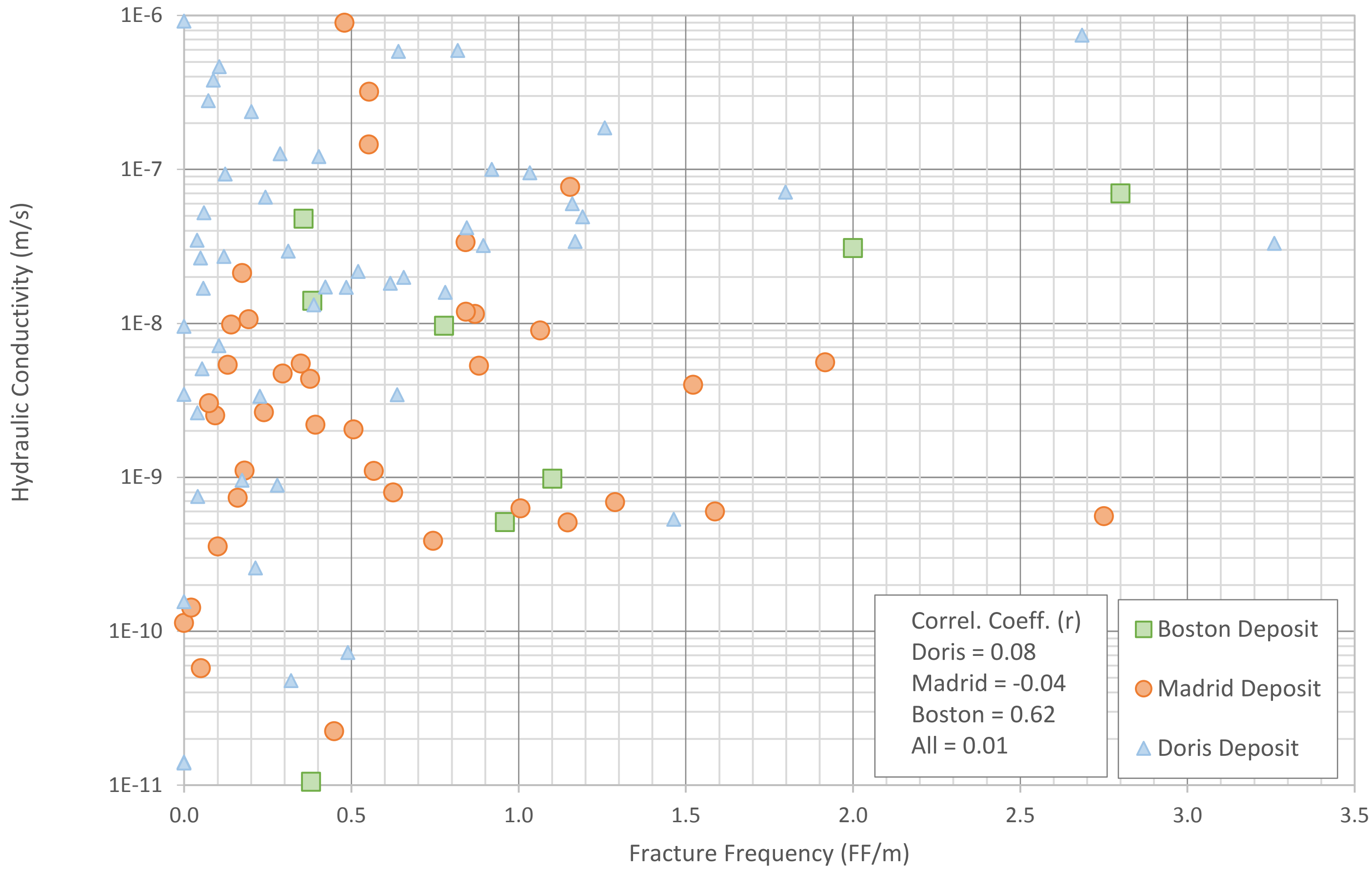
Source: !HB_Master_PackerDataSummary.rev16.gf.xlsx

srk consulting	MAC RESOURCES	Hydrogeological Modeling
		K vs Depth
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 · Approved: GF · Figure: 14



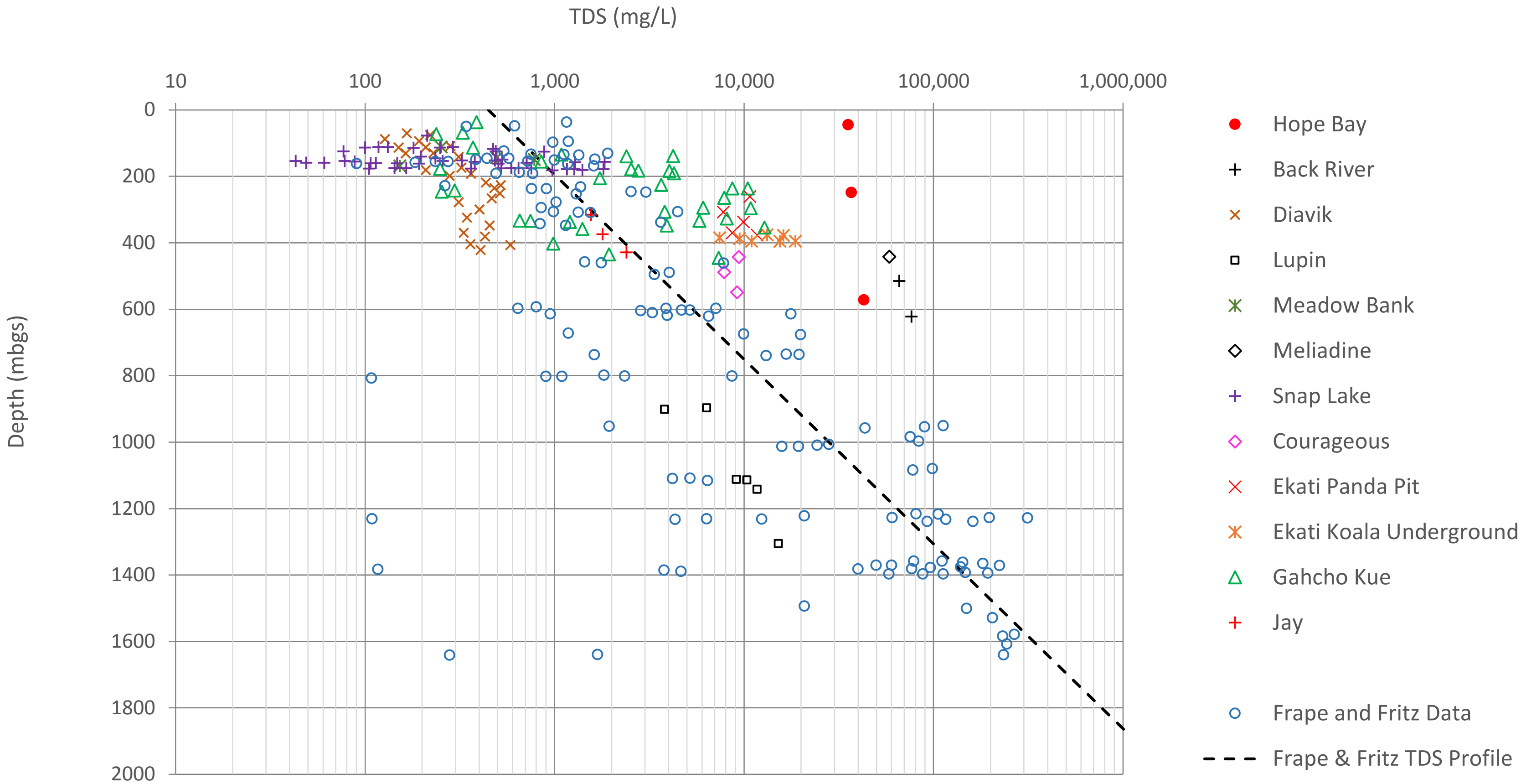
Source: KvsLithoFF_Rev02.xlsx

srk consulting	MAC RESOURCES	Hydrogeological Modeling K vs Geological Units
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 15



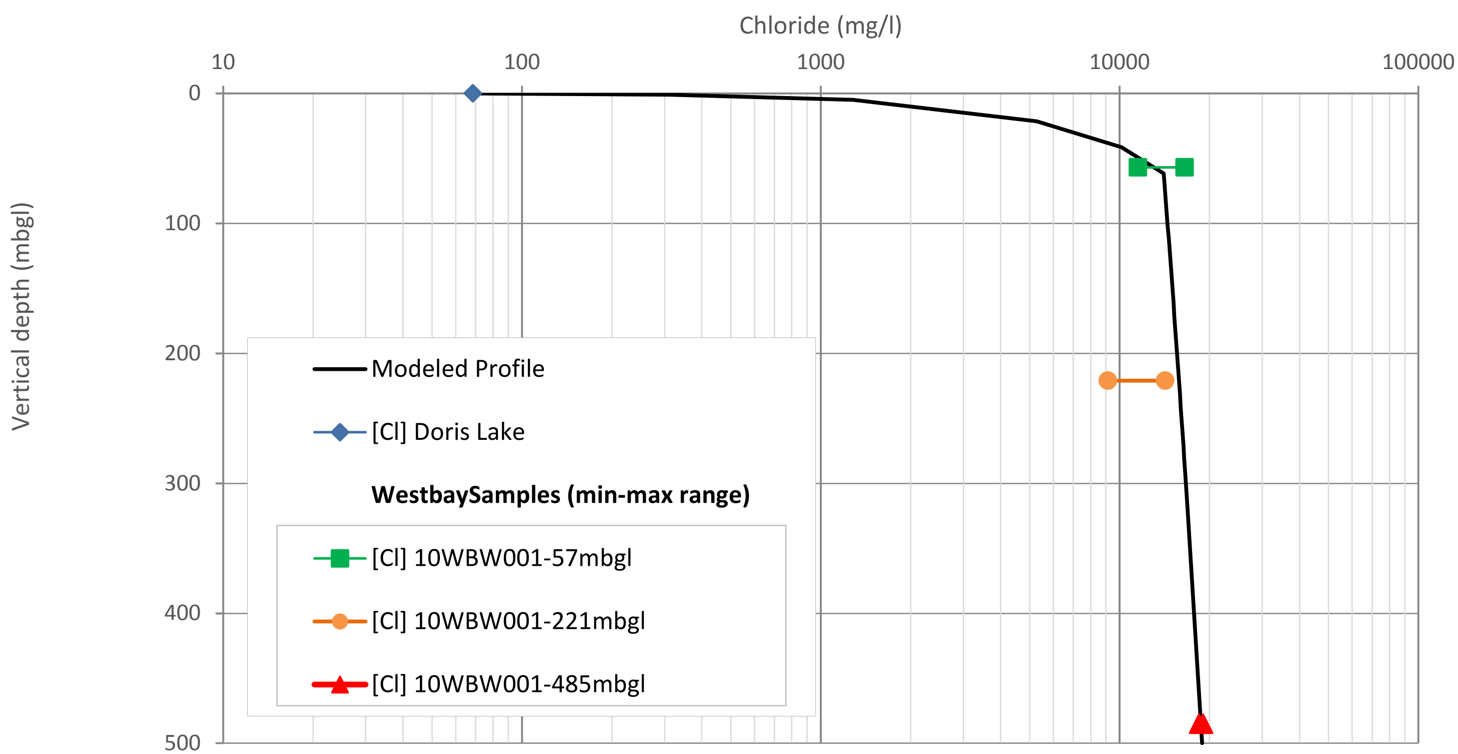
Source: KvsLithoFF_Rev02.xlsx

srk consulting	TMAC RESOURCES	Hydrogeological Modeling
		Correlation K vs Fracture Frequency
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 16

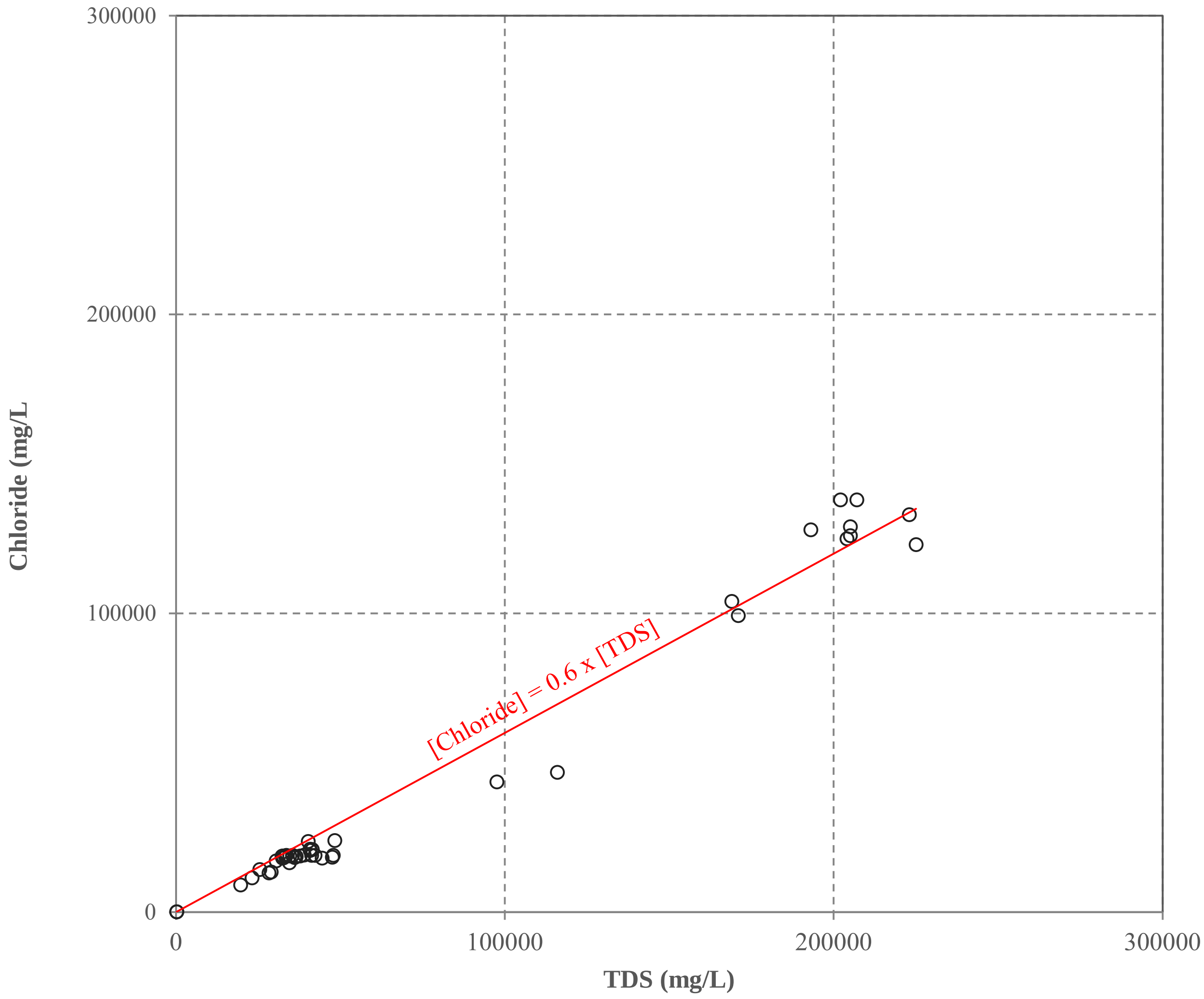


Source: Compilation of TDS data Versus Depth_20151130.GF.xlsx

srk consulting	MAC RESOURCES	Hydrogeological Modeling
		TDS Concentrations with Depth in Canada's North
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 17



srk consulting	MAC RESOURCES	Hydrogeological Modeling
		Observed Profile of Chloride Concentration with Depth
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 18



srk consulting

MAC RESOURCES

Hydrogeological Modeling

TDS versus Chloride

Job No: 1CT022.004

Filename: Figures_8x11_Landscape_r1.pptx

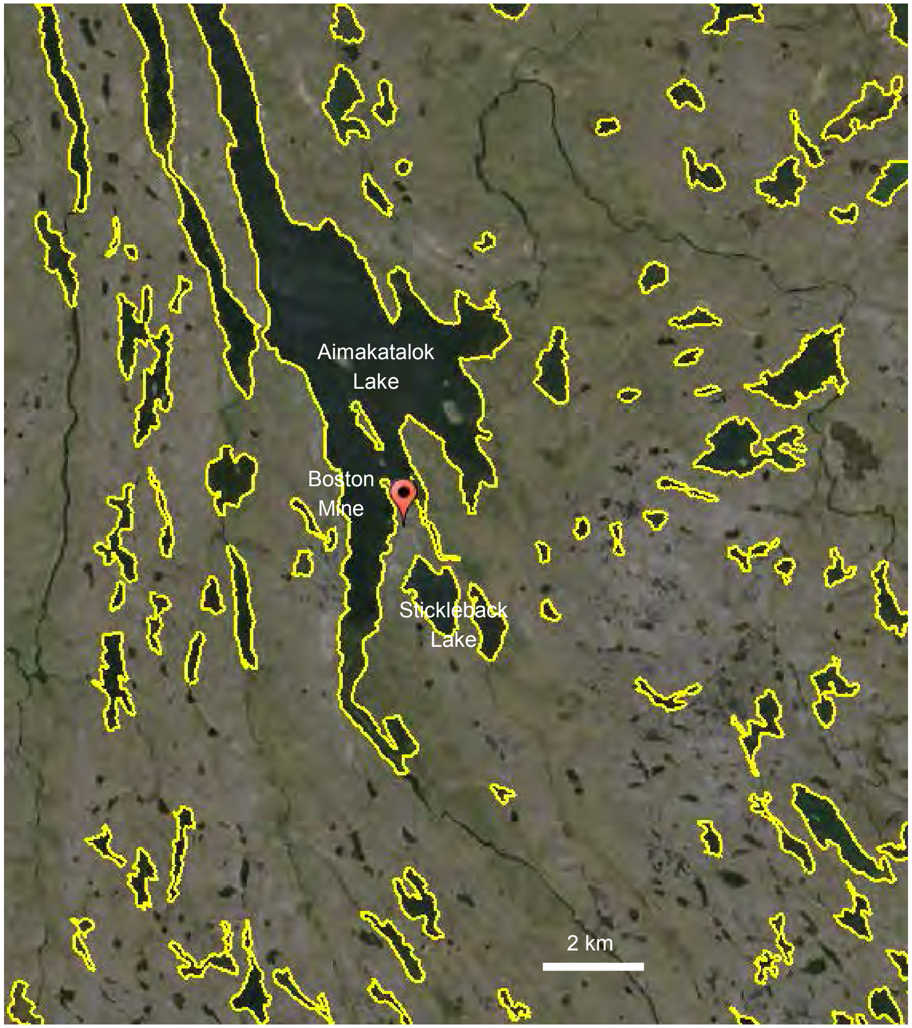
Hope Bay Project

Date: Dec 2016

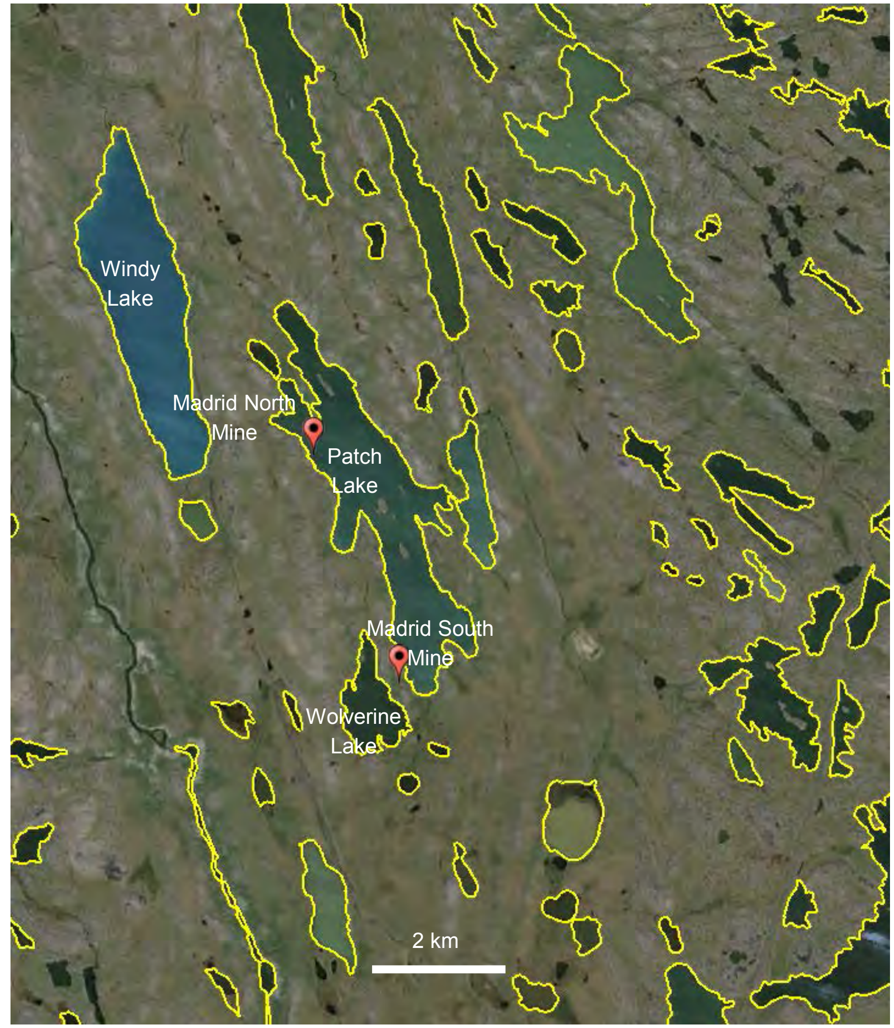
Approved: GF

Figure: 19

Boston Area

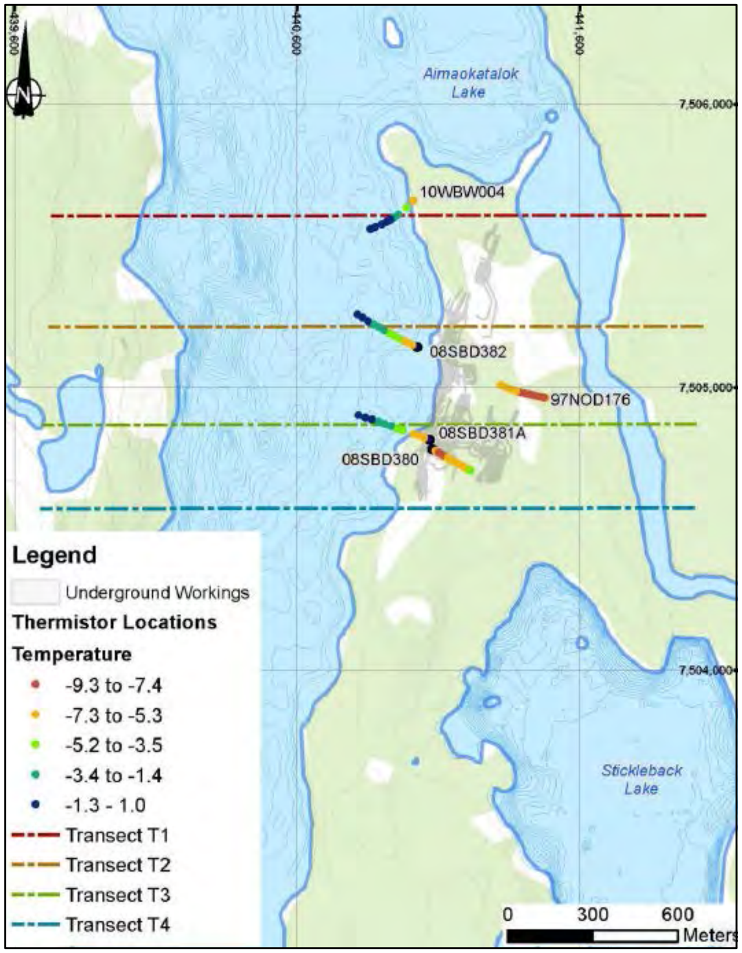


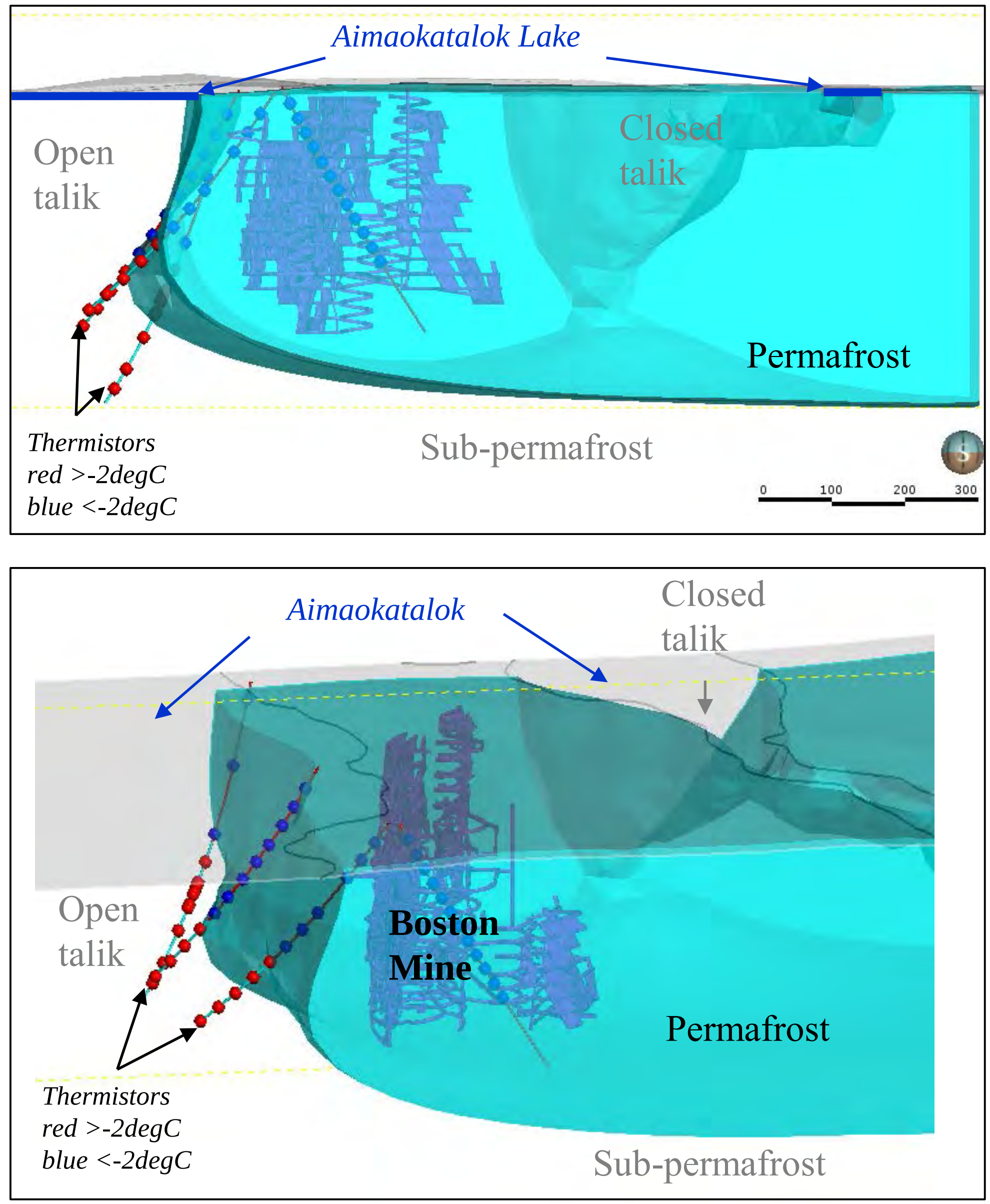
Madrid Area



Lakes with yellow contours are estimated to be potential open taliks

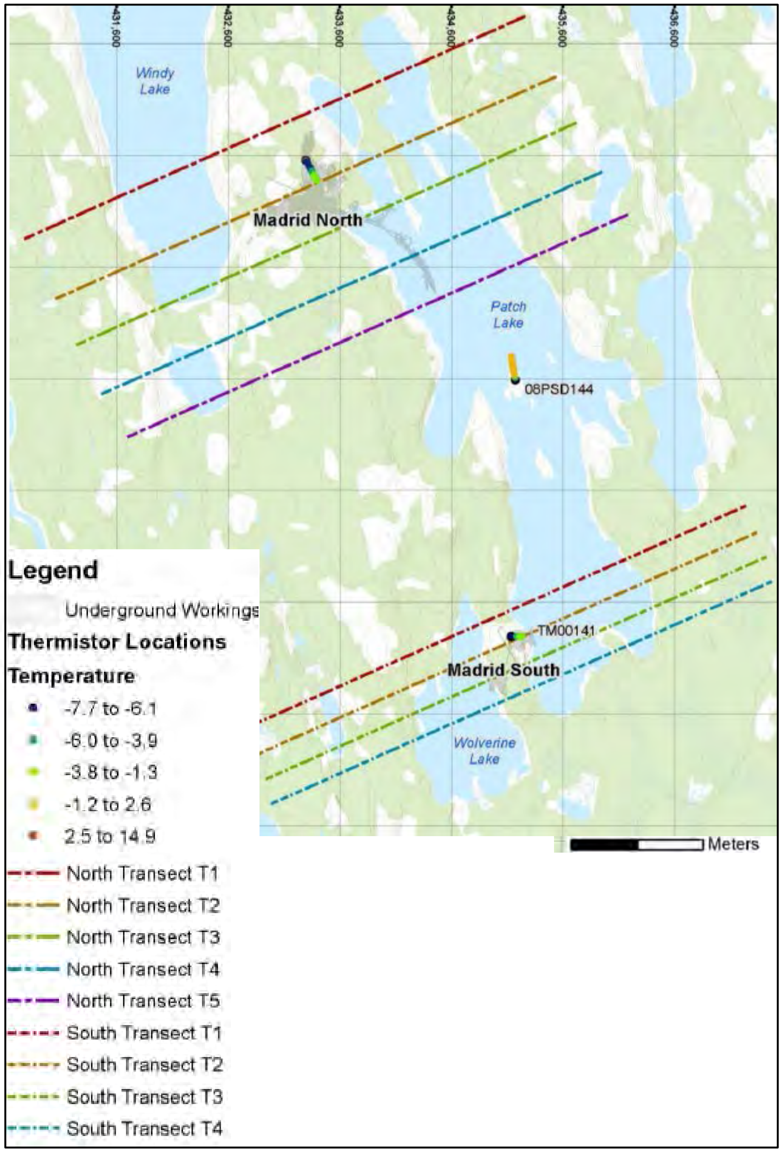
srk consulting	TMAC RESOURCES	Hydrogeological Modeling
		Potential Through Taliks at Boston and Madrid
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 | Approved: GF | Figure: 20

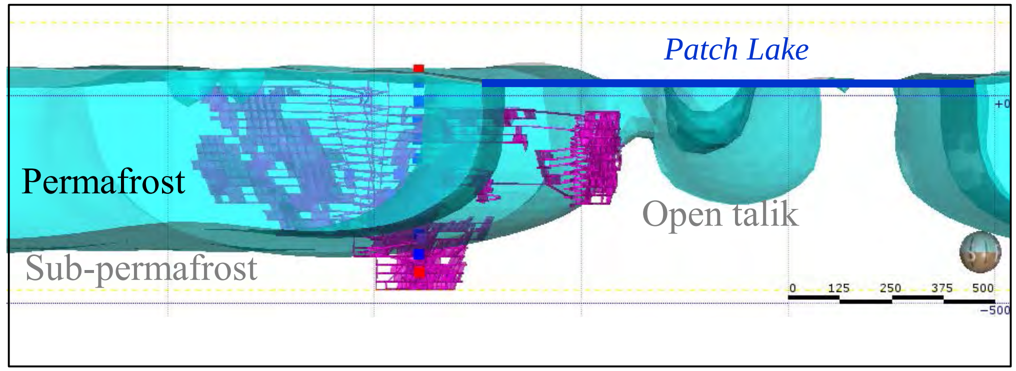


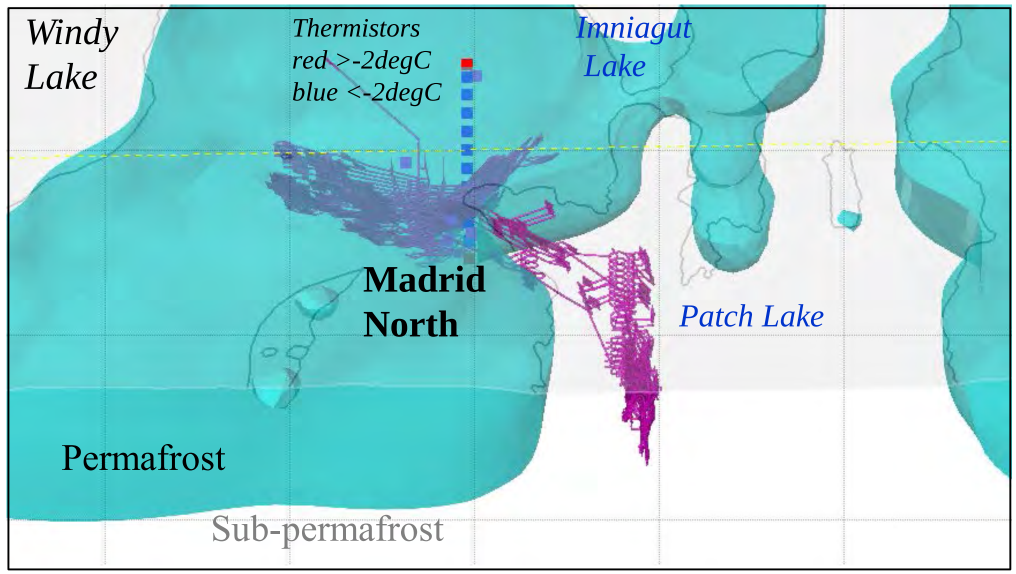


Note:
Prefeasibility mine plan shown, which will be updated as mining progresses.

srk consulting	TMAC RESOURCES	Hydrogeological Modeling
		3D Sections Showing the Permafrost and the Boston Mine (Looking North)
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 | Approved: GF | Figure: 21

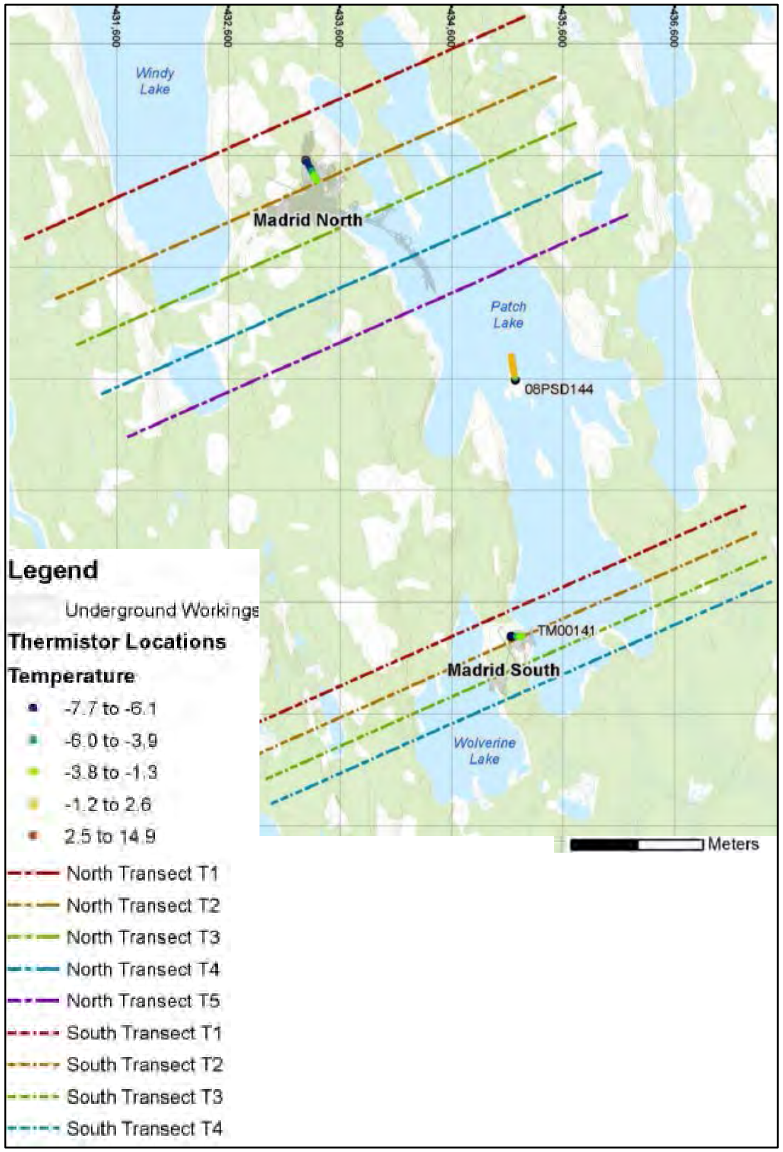


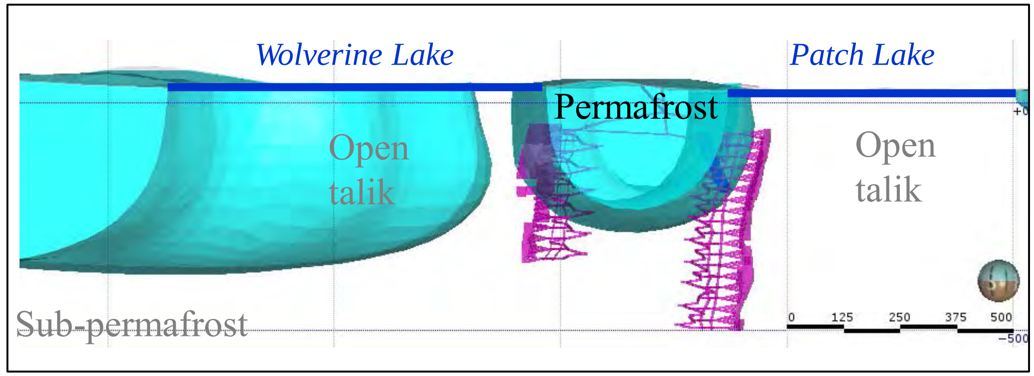


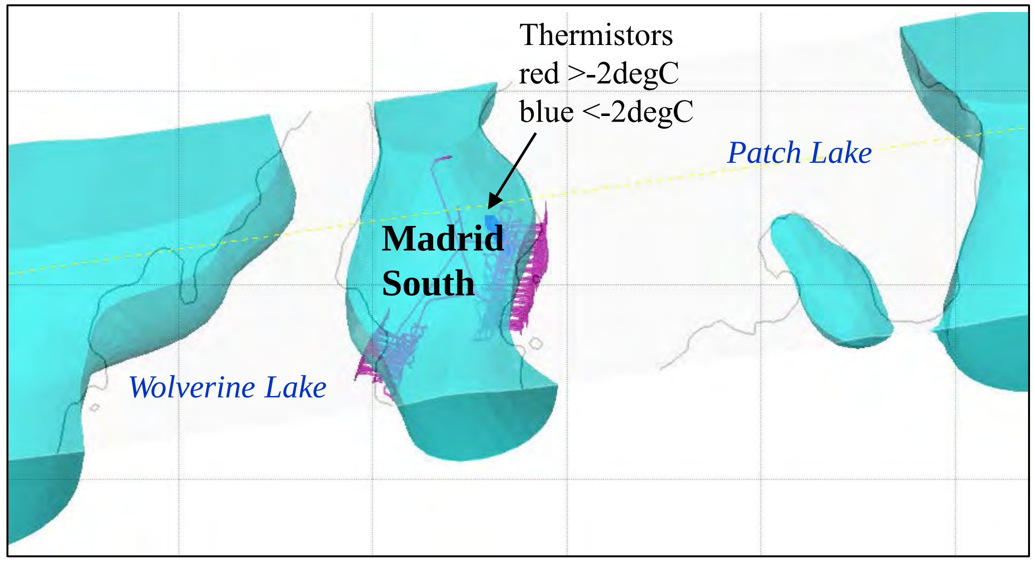


Note:
Prefeasibility mine plan shown, which will be updated as mining progresses.

srk consulting	TMAC RESOURCES	Hydrogeological Modeling
		3D Sections Showing the Permafrost and the Madrid North Mine (Looking North)
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 · Approved: GF · Figure: 22

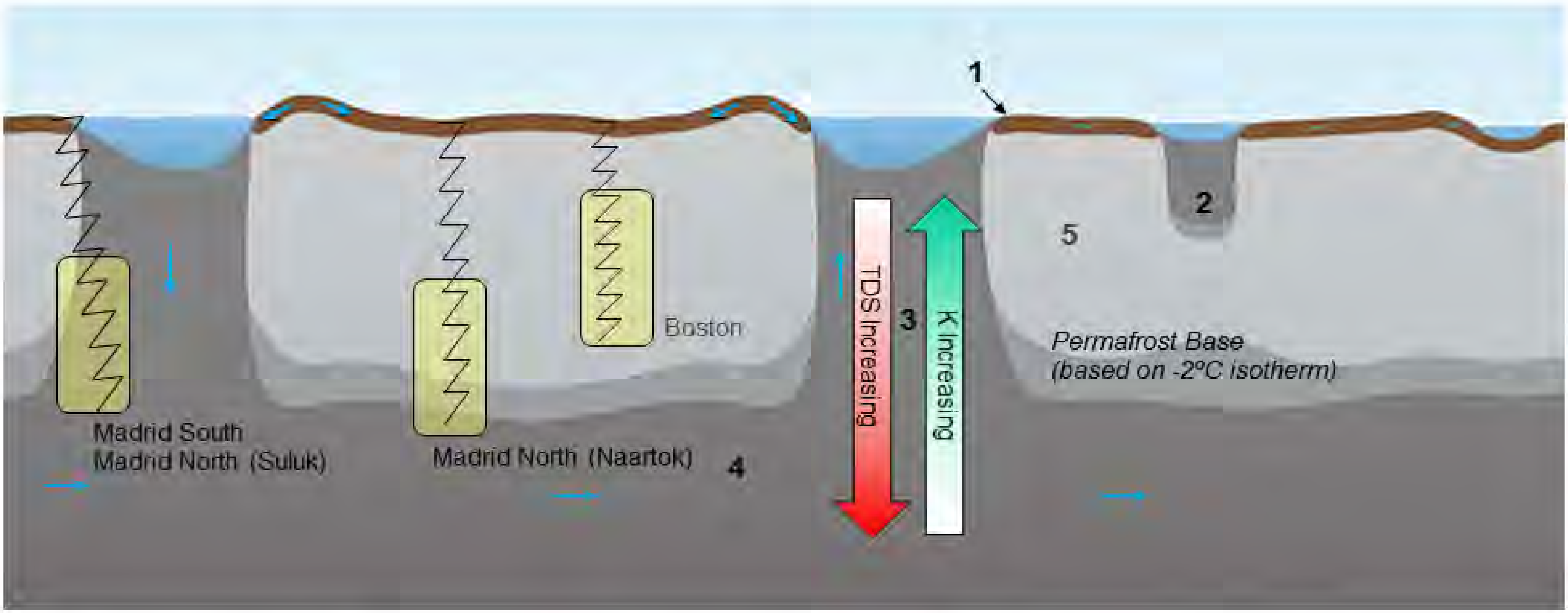






Note:
Prefeasibility mine plan shown, which will be updated as mining progresses.

srk consulting	TMAC RESOURCES	Hydrogeological Modeling 3D Sections Showing the Permafrost and the Madrid South Mine (Looking North)
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 · Approved: GF · Figure: 23



PERMAFROST COMPONENTS:

1 – Active layer.
2 – Closed talik caused by mid-size lake, pond or stream.
3 – Open talik caused by large lake or river.
4 – Sub-permafrost.
5 – Permafrost.

GROUNDWATER FLOW REGIMES

1 – Seasonally flowing
2 – Flowing, not connected to sub-permafrost.
3 – Flowing, connected to sub-permafrost.
4 – Flowing, connected to open taliks.
5 – No flow.

LEGEND

Decline
Underground
Groundwater Flow Direction

srk consulting

TMAC RESOURCES

Hydrogeological Modeling

Conceptual Groundwater System

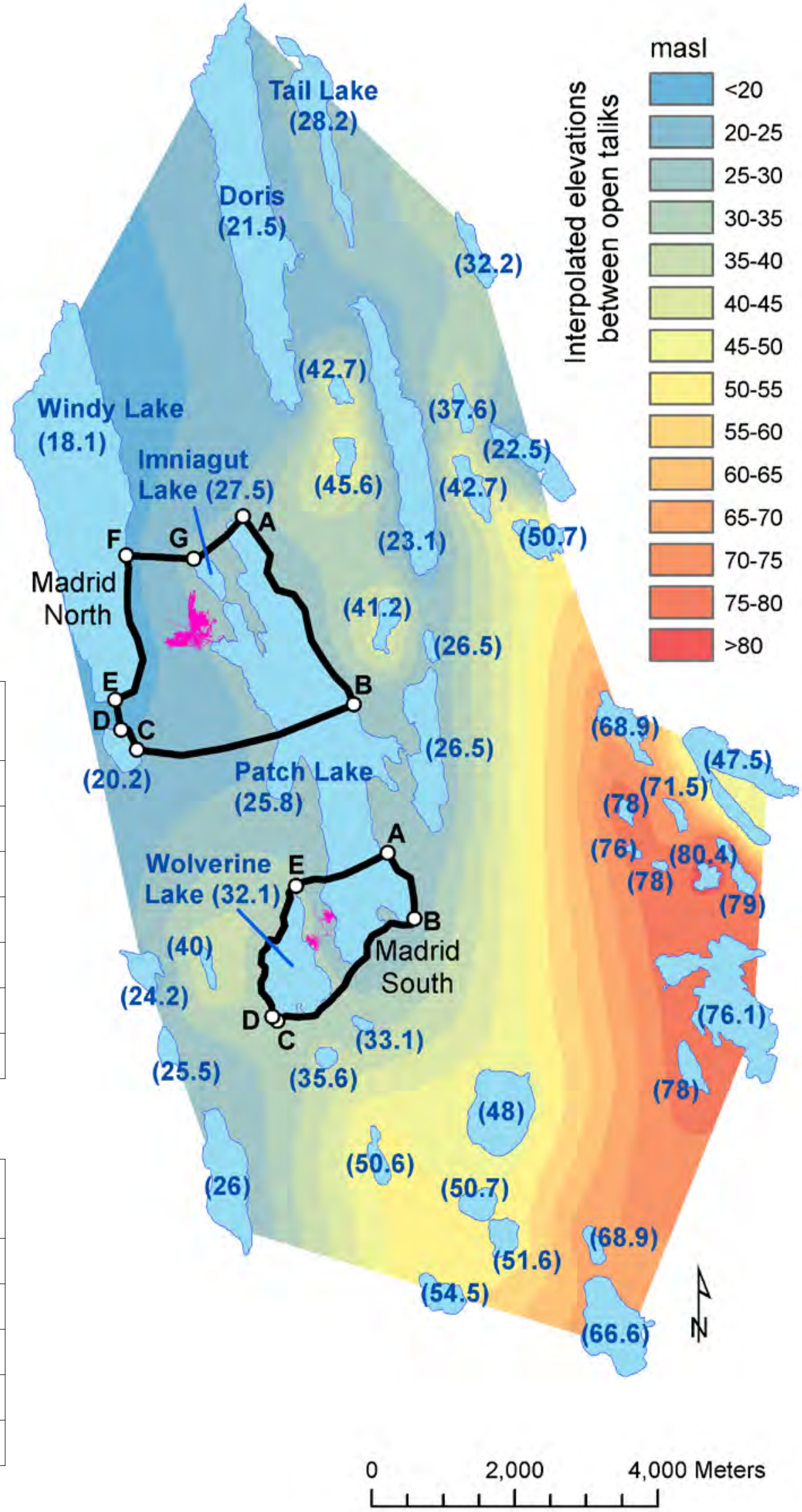
Job No: 1CT022.004
Filename: Figures_8x11_Landscape_r1.pptx

Hope Bay Project

Date: Dec 2016 | Approved: GF | Figure: 24

Model Domain
Potential Open talik
Underground Mine
(#) Lake Elevation in masl

Note:
Prefeasibility mine plan shown,
which will be updated as mining progresses.



Madrid North

Edge	BC Type	Head (masl)	Distance (m)
AB	Trsf	43	1000
BC	Trsf	25.8	1 to 850
CD	Trsf	20.2	1
DE	No Flow	-	-
EF	Trsf	18.1	1
FG	No Flow	-	-
GA	Trsf	18.1	1900

Madrid North

Edge	BC Type	Head (masl)	Distance (m)
AB	Trsf	76	4000
BC	Trsf	49	2100
CD	Trsf	26	1500
DE	Trsf	40	800
EA	Trsf	25.8	1 to 1700

Trsf = fluid-transfer boundary condition
H_{ref} = Reference water level
d_{ref} = Distance from the model to the reference water level

srk consulting

MAC RESOURCES

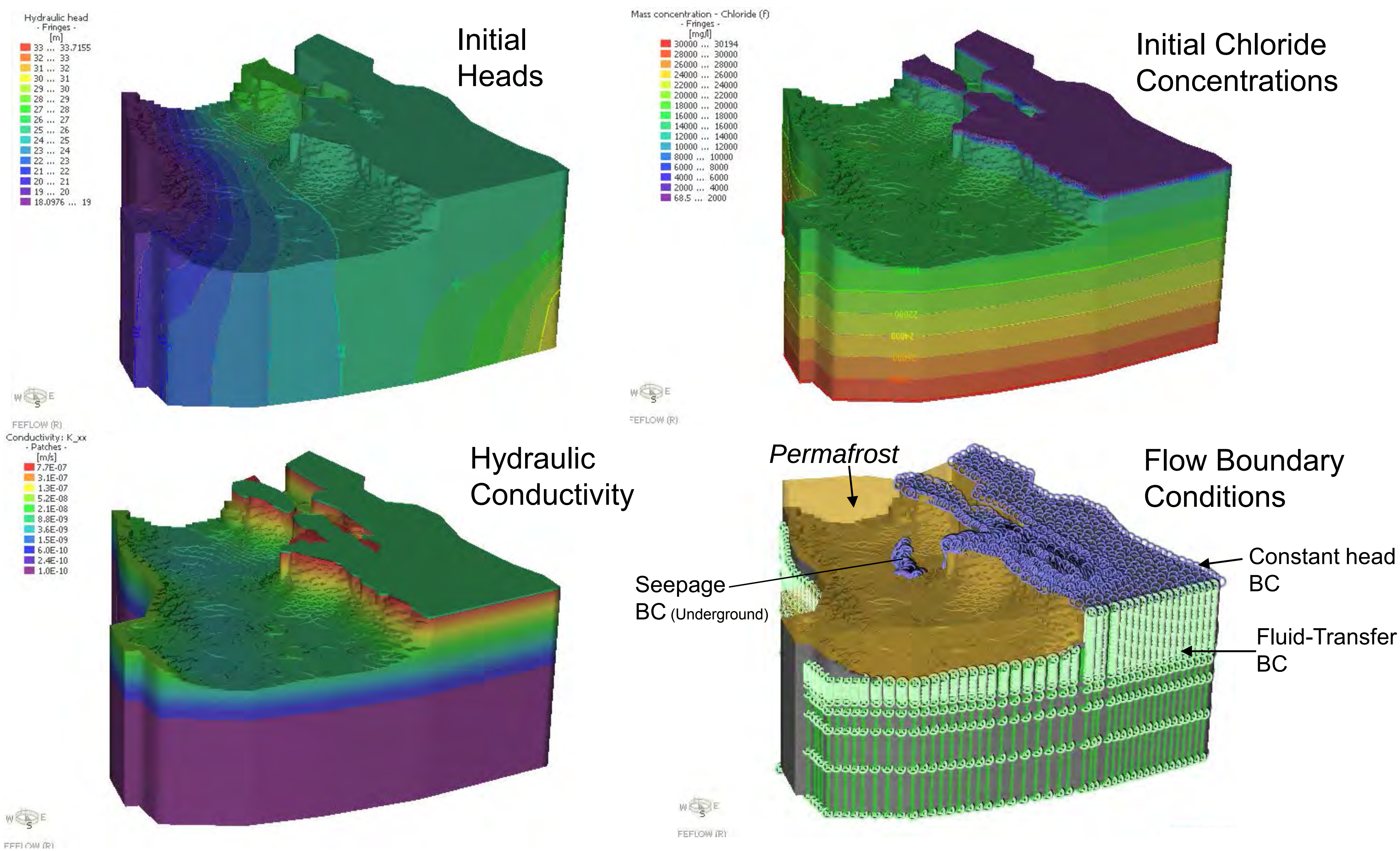
Hydrogeological Modeling

Model Domains and Boundary Conditions

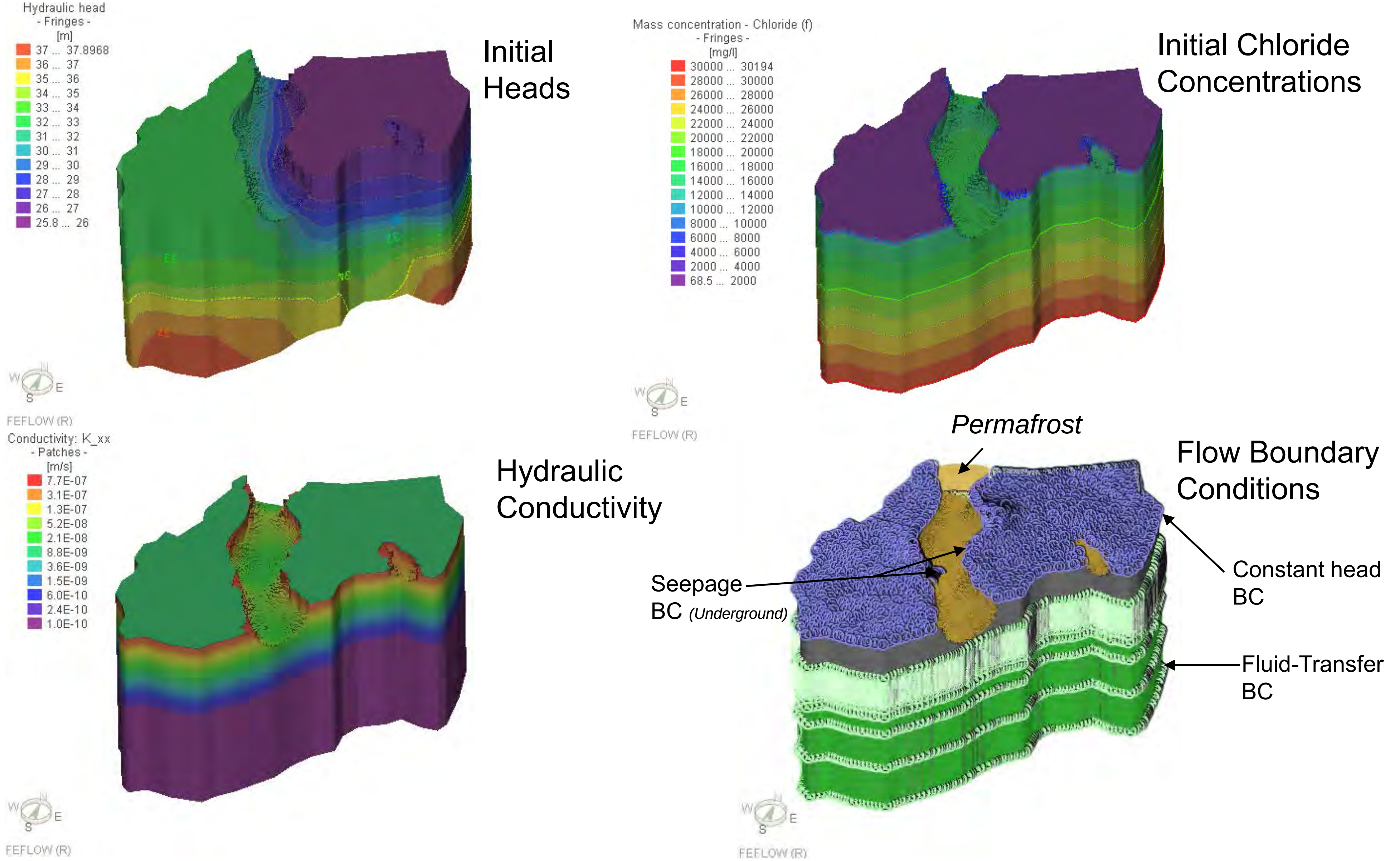
Job No: 1CT022.004
Filename: Figures_8x11_Portrait_r2.pptx

Hope Bay Project

Date: Dec 2016 | Approved: GF | Figure: 25



		Hydrogeological Modeling
		3D Views of the Madrid North Numerical Model
Job No: 1CT022.004 Filename: Fig_3D_Model_Snapshots.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 26



srk consulting	TMAC RESOURCES	Hydrogeological Modeling
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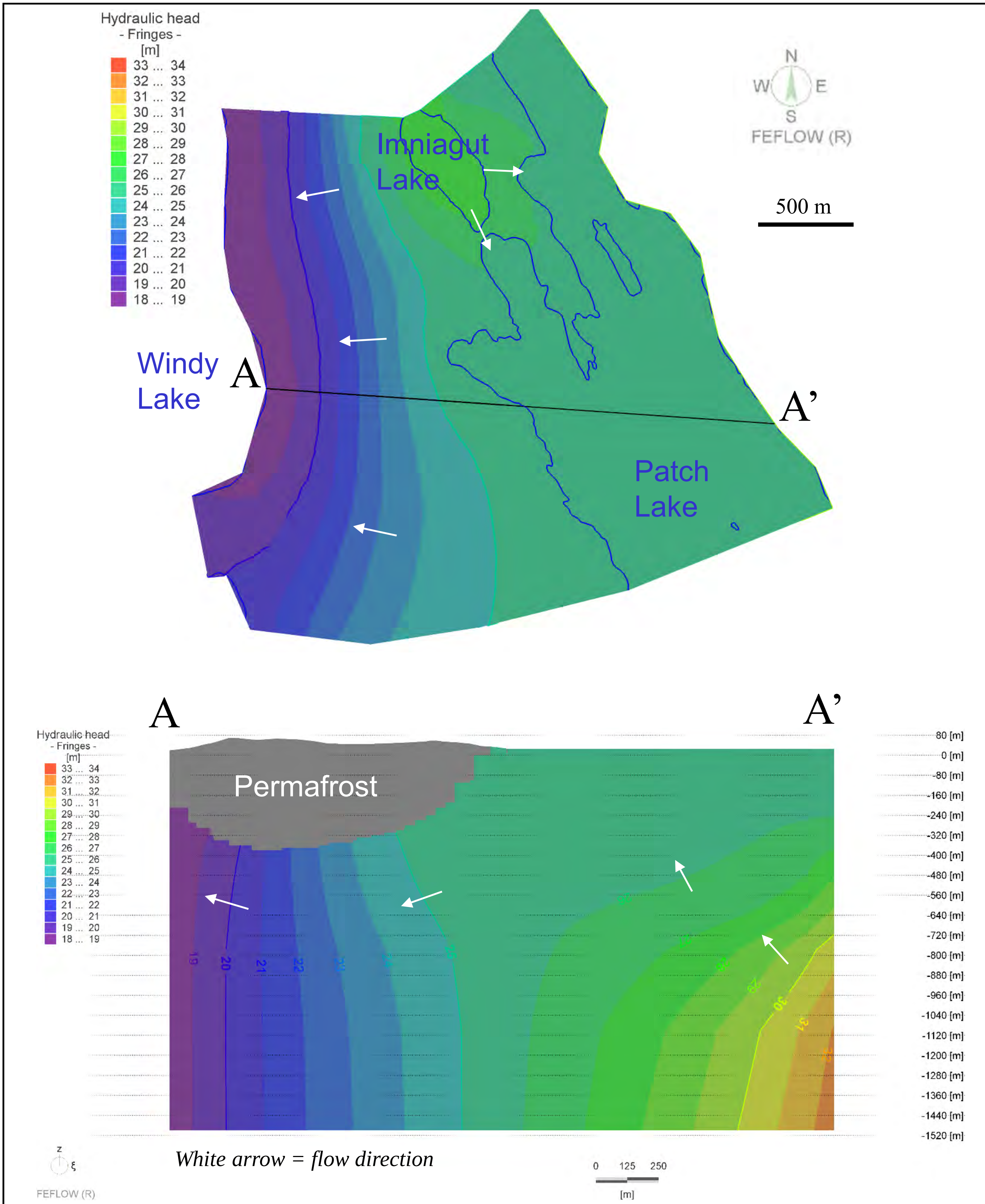
Job No: 1CT022.004 Filename: Fig_3D_Model_Snapshots.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 27



srk consulting

MAC RESOURCES

Hydrogeological Modeling

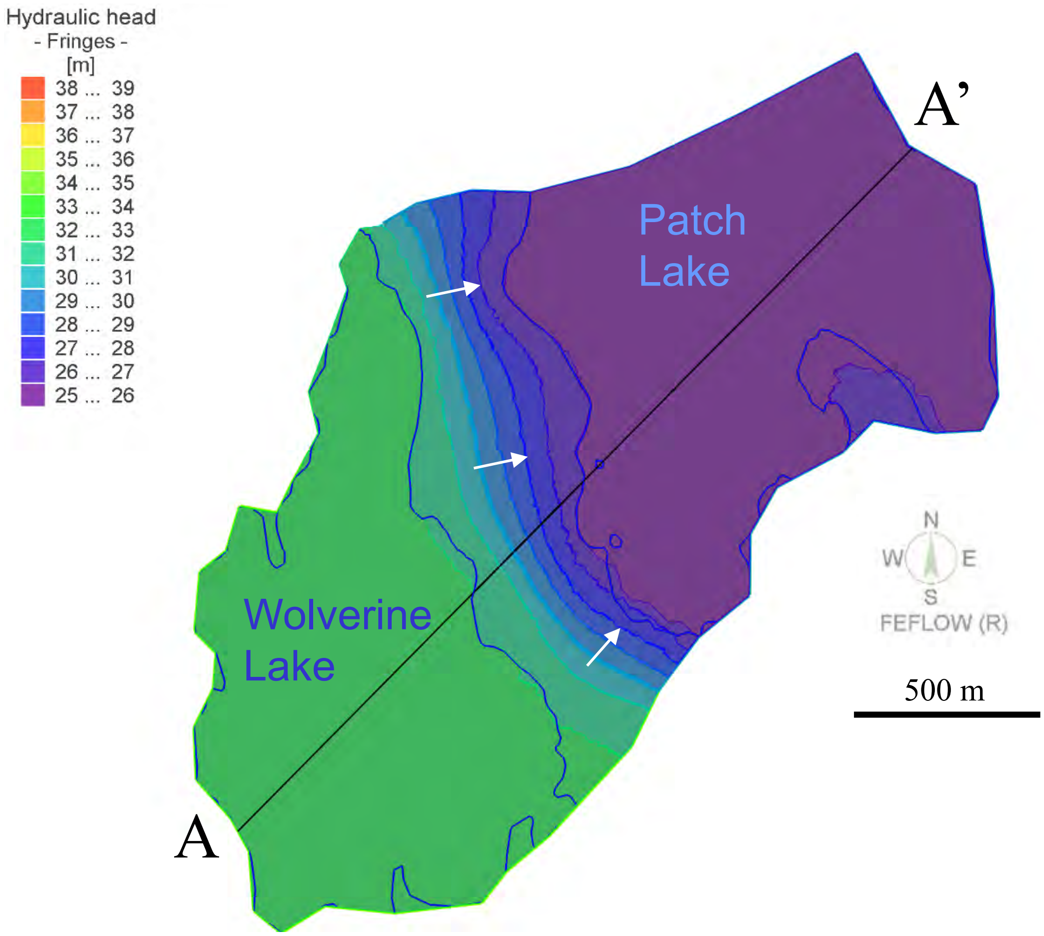
Madrid North Predicted Heads at Current Conditions

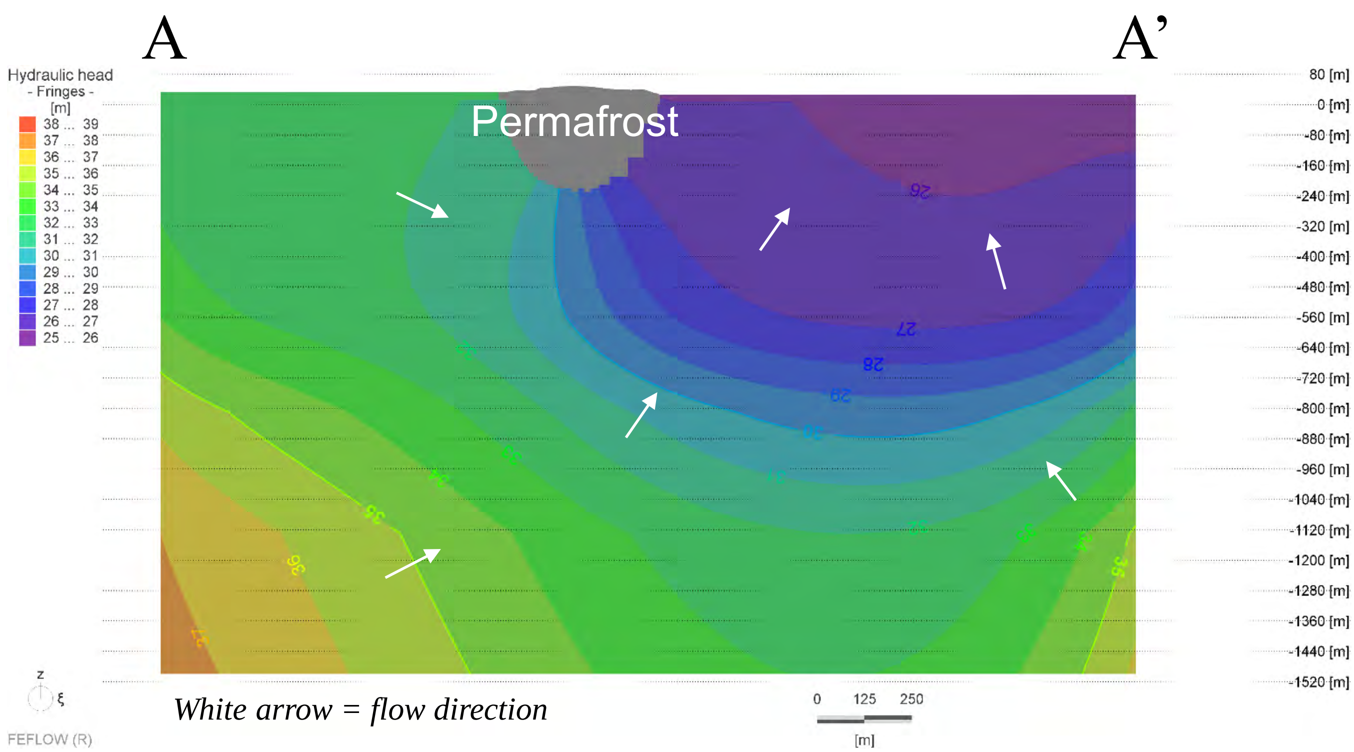
Job No: 1CT022.004

Filename: Figures_8x11_Portrait_r2.pptx

Hope Bay Project

Date:	Approved:	Figure:
Dec 2016	GF	28





White arrow = flow direction

srk consulting	MAC RESOURCES	Hydrogeological Modeling
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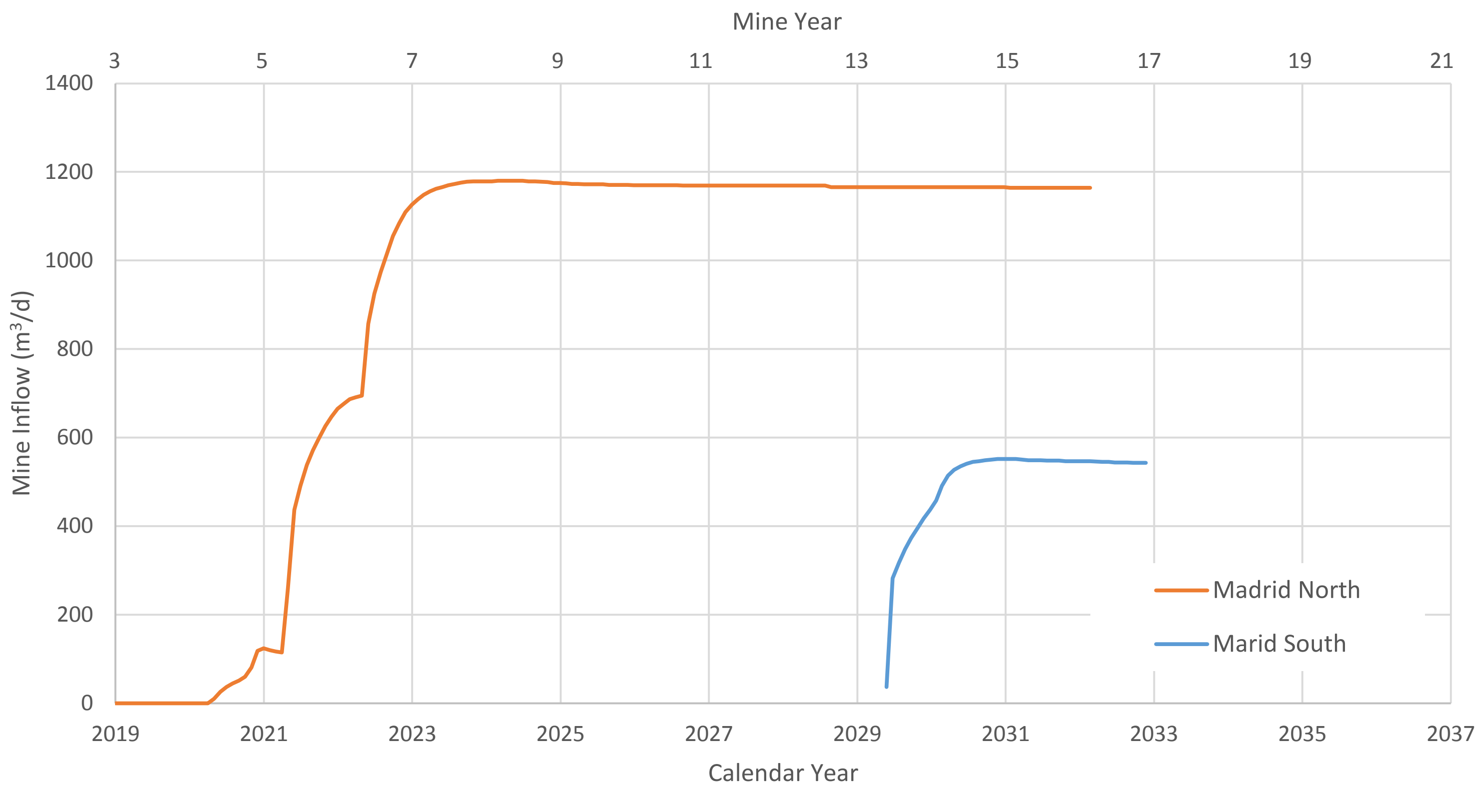
Job No: 1CT022.004 Filename: Figures_8x11_Portrait_r2.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 29



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srk consulting	MAC RESOURCES	Hydrogeological Modeling
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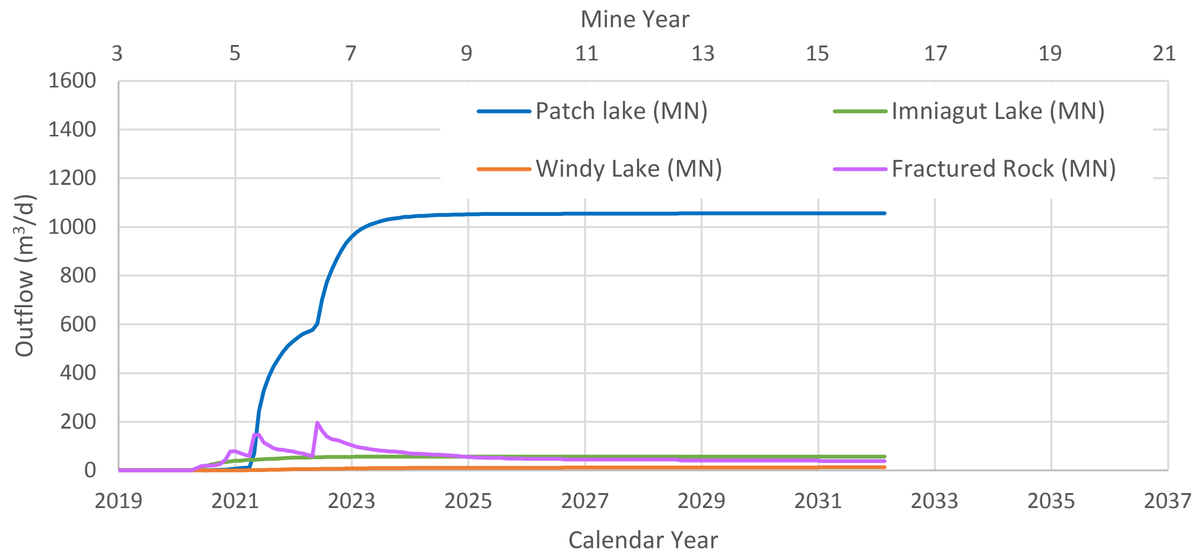

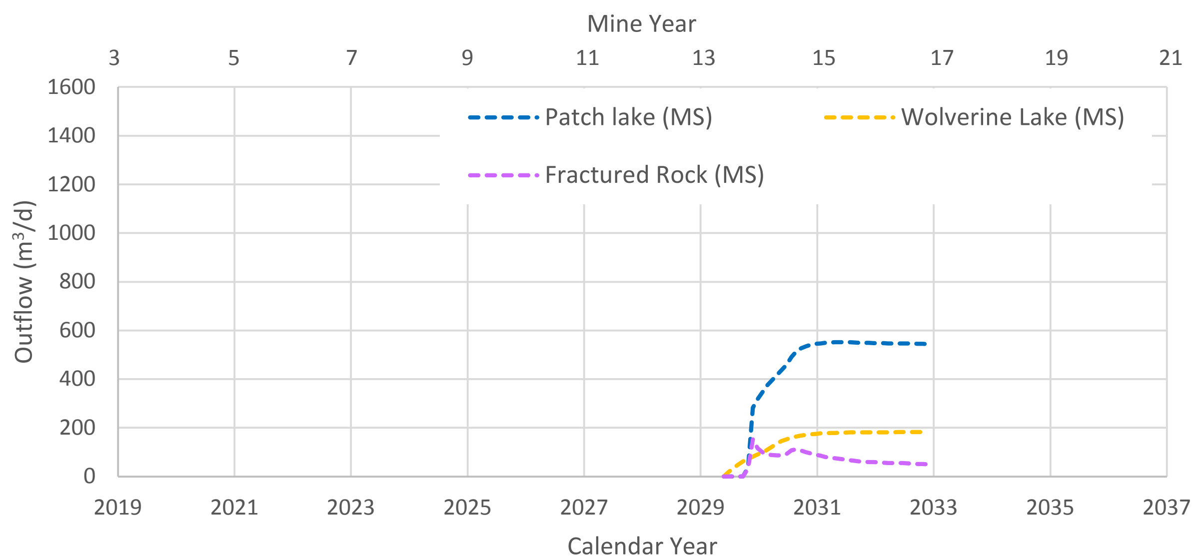

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Note:
MS, Madrid South
MN, Madird North

srk consulting	MAC RESOURCES	Hydrogeological Modeling
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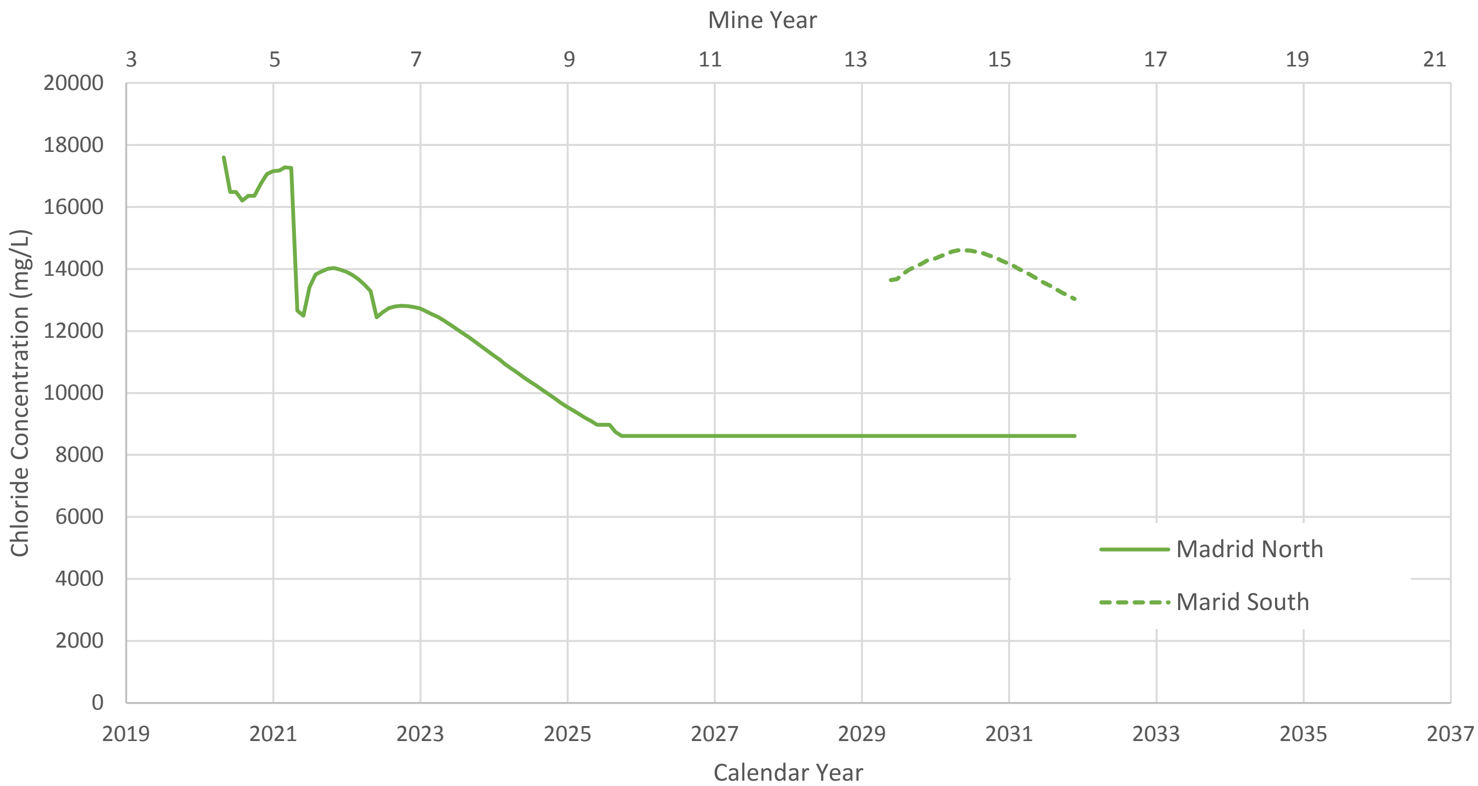
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 / Approved: GF / Figure: 31



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srk consulting	MAC RESOURCES	Hydrogeological Modeling		
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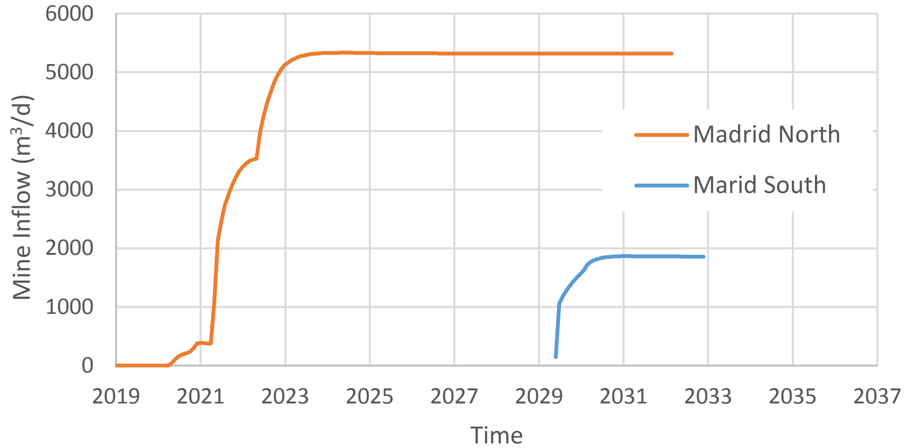
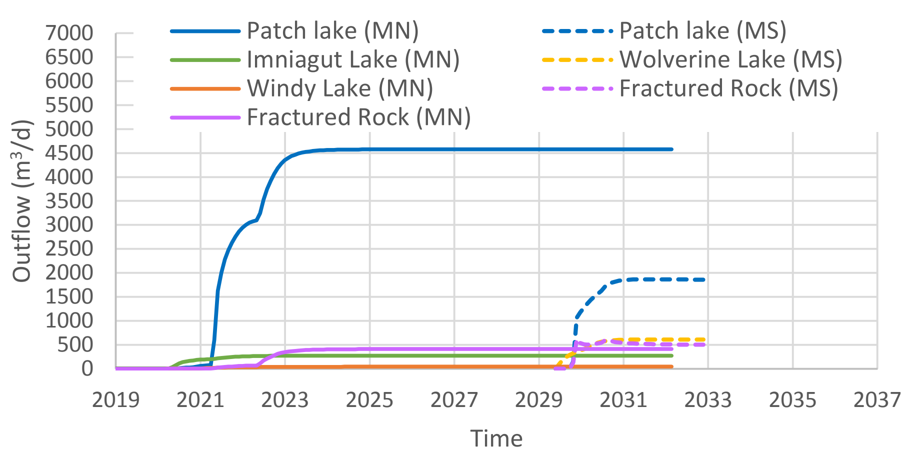
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016	Approved: GF	Figure: 32

Sensitivity: Kxyz based on arithmetic mean

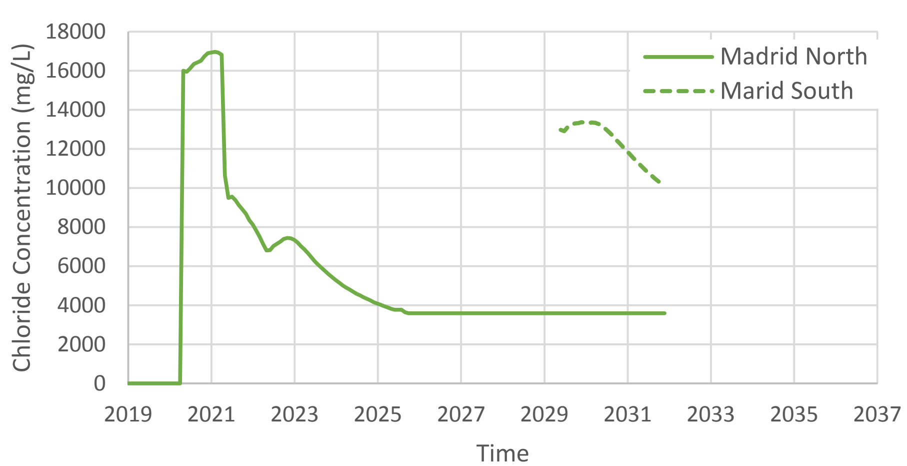
Predicted mine inflows



Predicted infiltrations of water from lakes

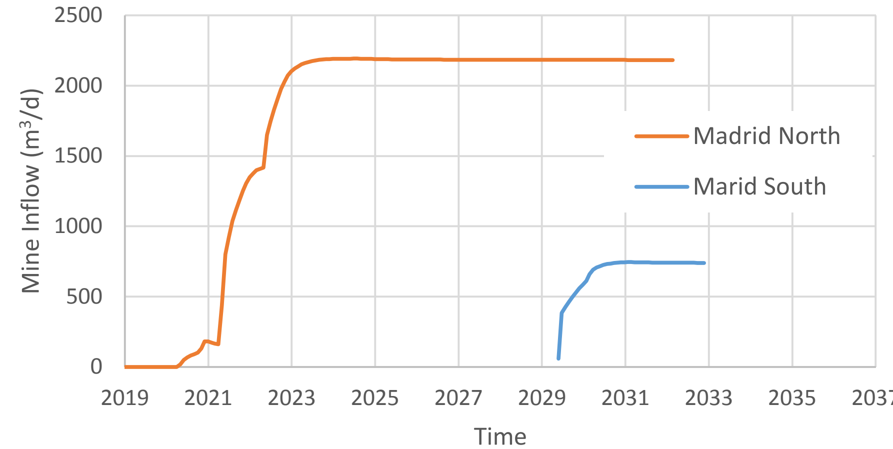


Predicted chloride concentrations of mine inflows

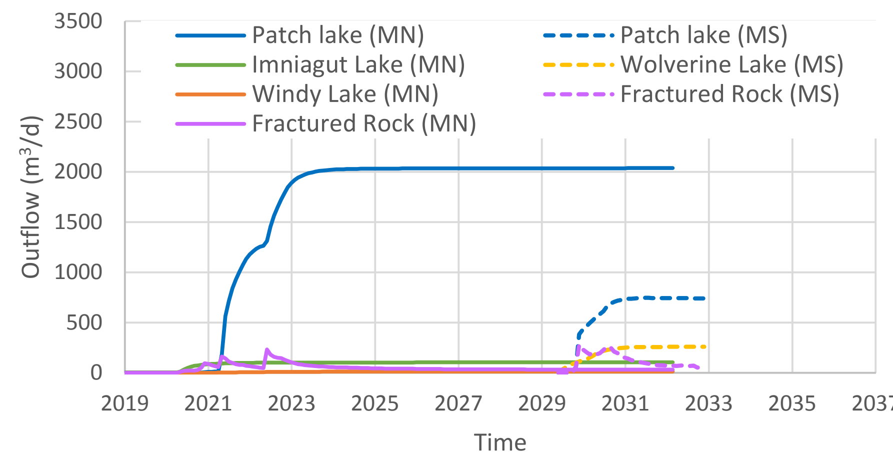


Sensitivity: Kz based on arithmetic mean

Predicted mine inflows



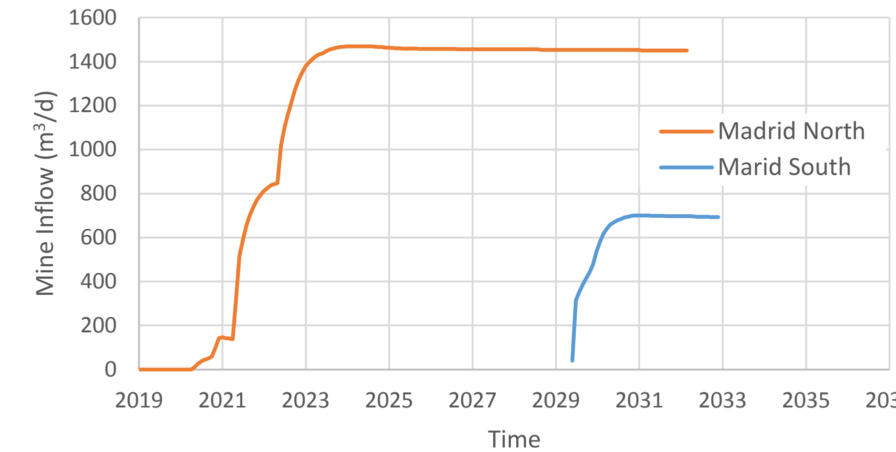
Predicted infiltrations of water from lakes



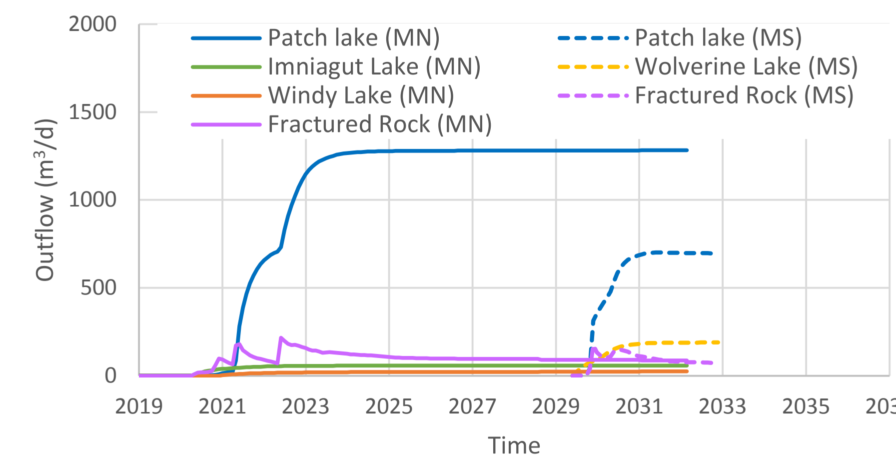
Predicted chloride concentrations of mine inflows

Sensitivity: High K Fault

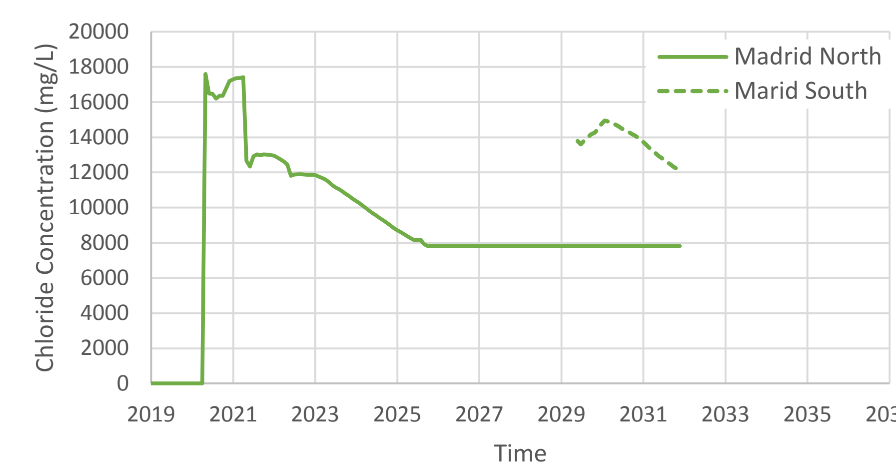
Predicted mine inflows



Predicted infiltrations of water from lakes



Predicted chloride concentrations of mine inflows



Note:
MS, Madrid South
MN, Madird North

Sources:
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Sensitivity Model Results

Job No: 1CT022.004
Filename: App D_FigureD1-D2_Appx_Sensitivity.pptx

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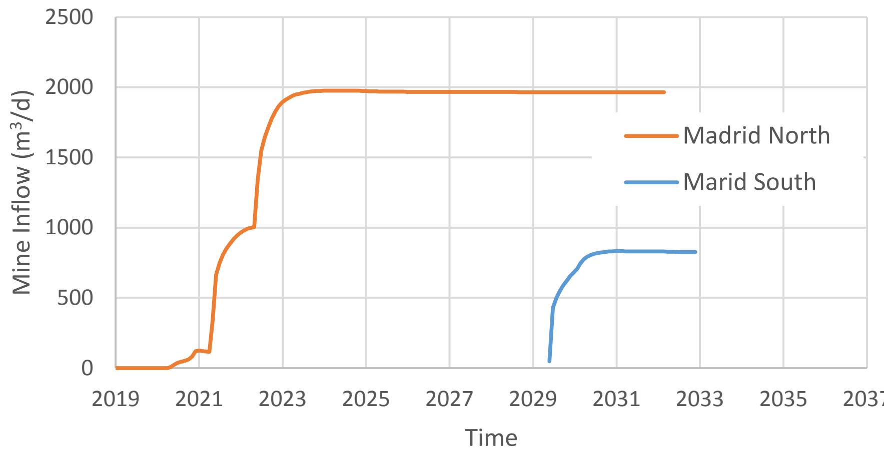
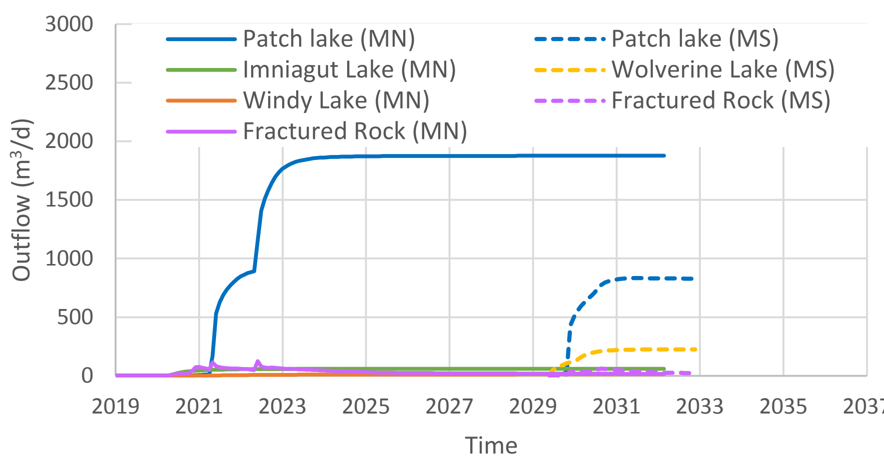
Sensitivity: K Lake Sediments (x10)

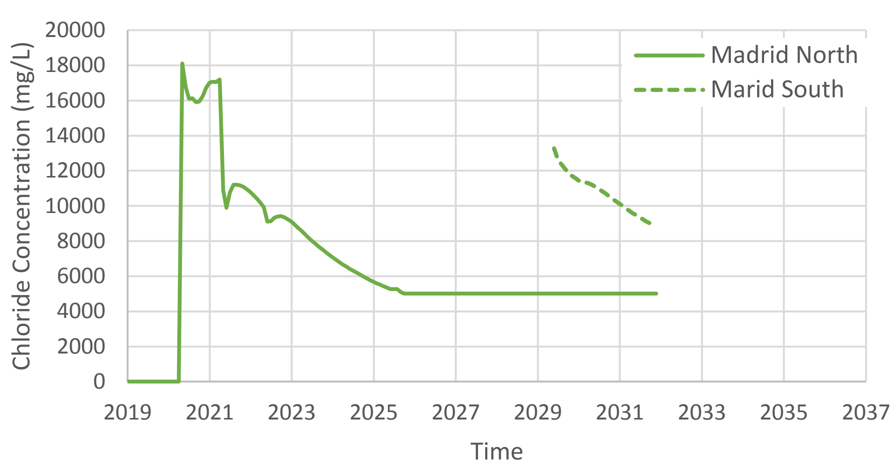
Predicted mine inflows



Predicted infiltrations of water from lakes

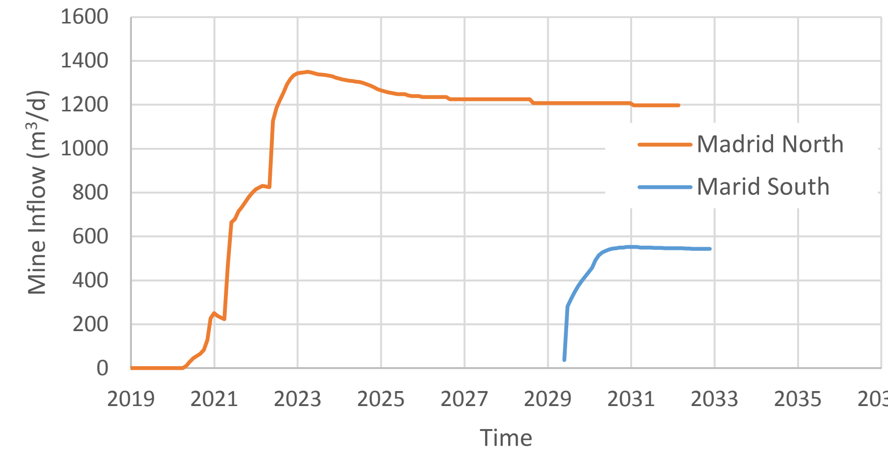


Predicted chloride concentrations of mine inflows

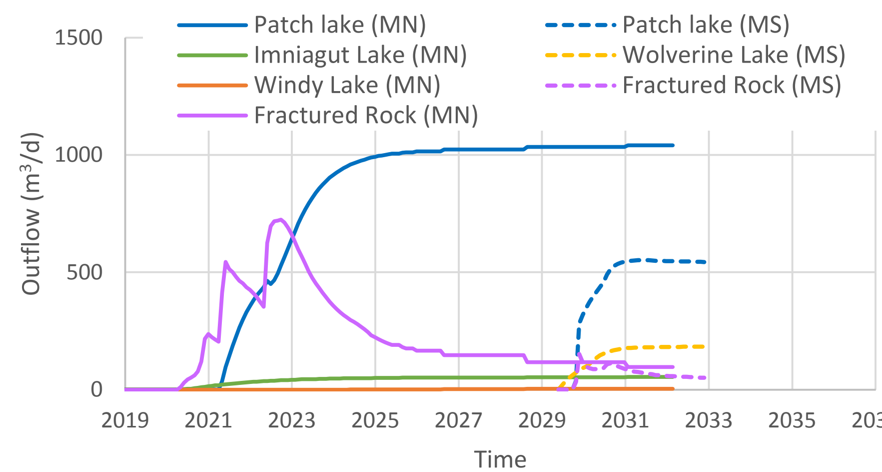


Sensitivity: Storage Coefficients (x10)

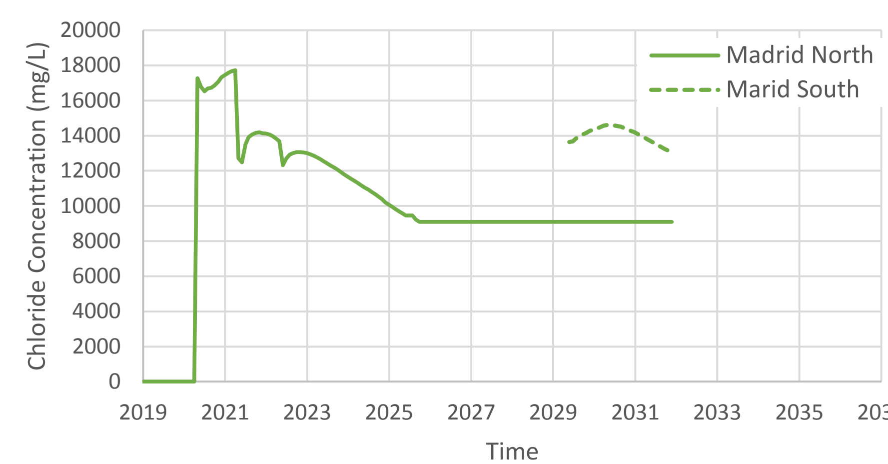
Predicted mine inflows



Predicted infiltrations of water from lakes

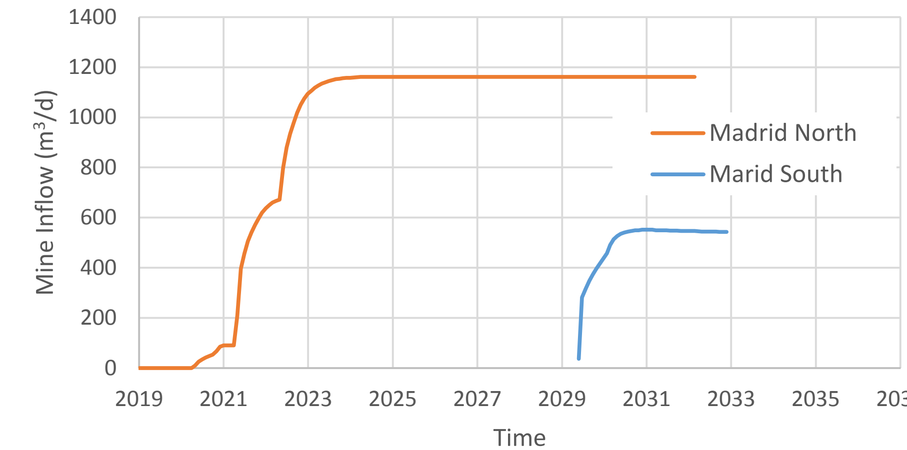


Predicted chloride concentrations of mine inflows

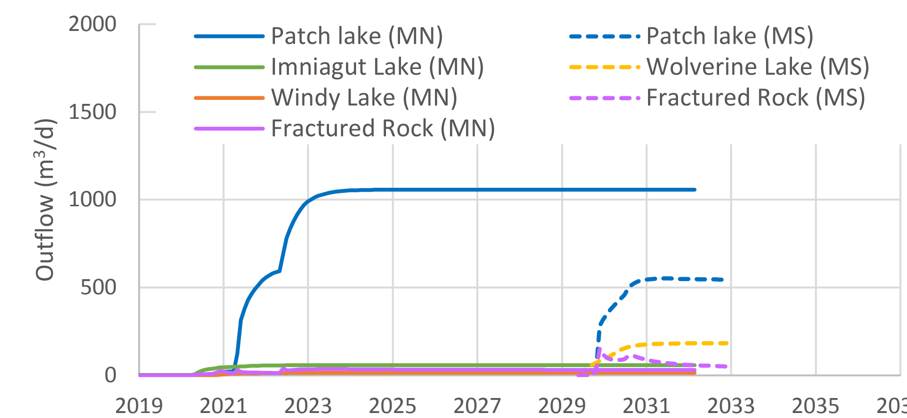


Sensitivity: Storage Coefficients (x0.1)

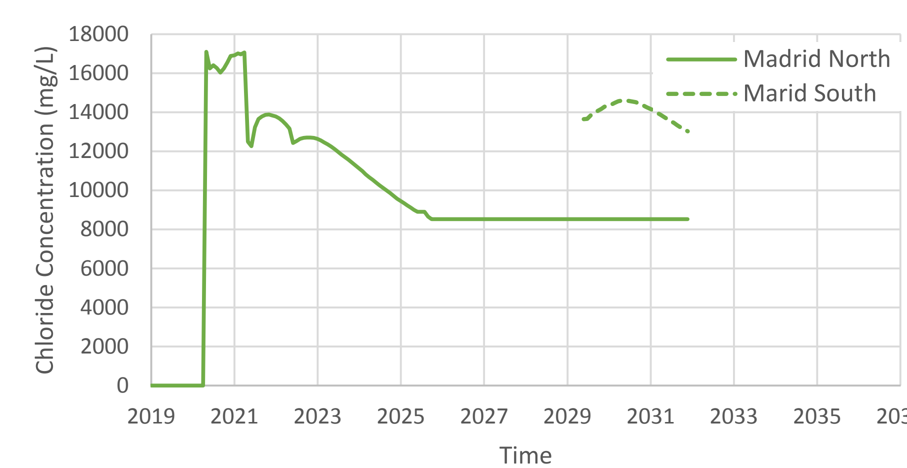
Predicted mine inflows



Predicted infiltrations of water from lakes



Predicted chloride concentrations of mine inflows



Note:
MS, Madrid South
MN, Madird North

Sources:
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Sensitivity Model Results

Job No: 1CT022.004
Filename: App D_FigureD1-D2_Appx_Sensitivity.pptx

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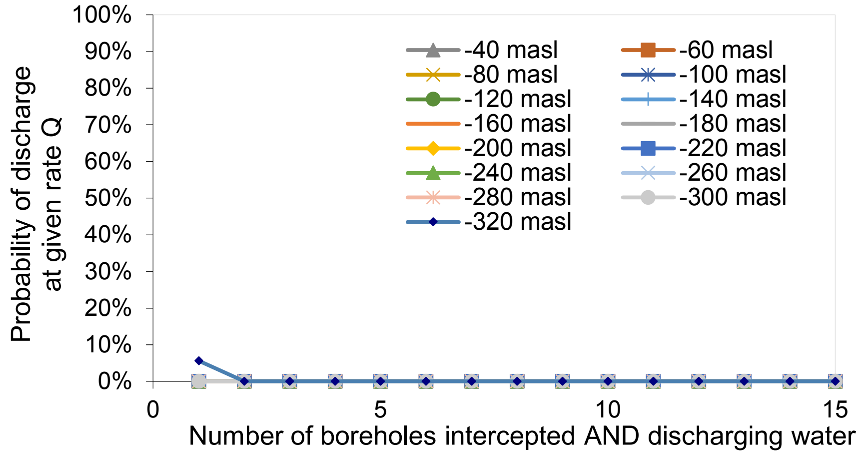
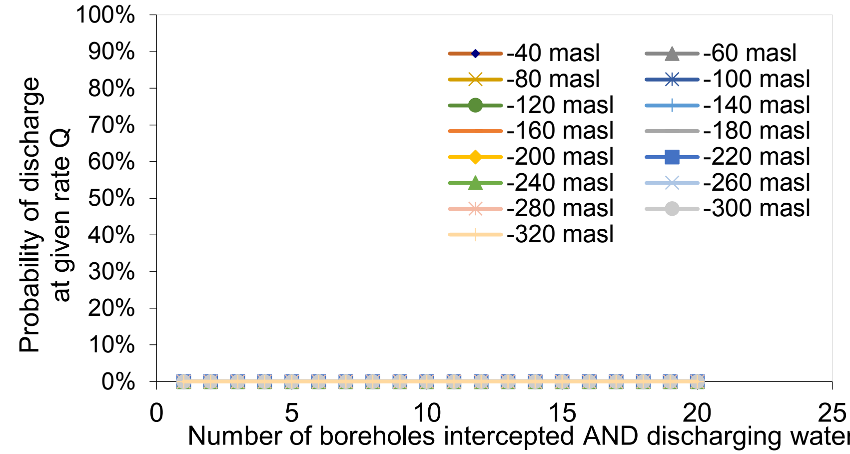
Date: Dec 2016 | Approved: GF | Figure: 34

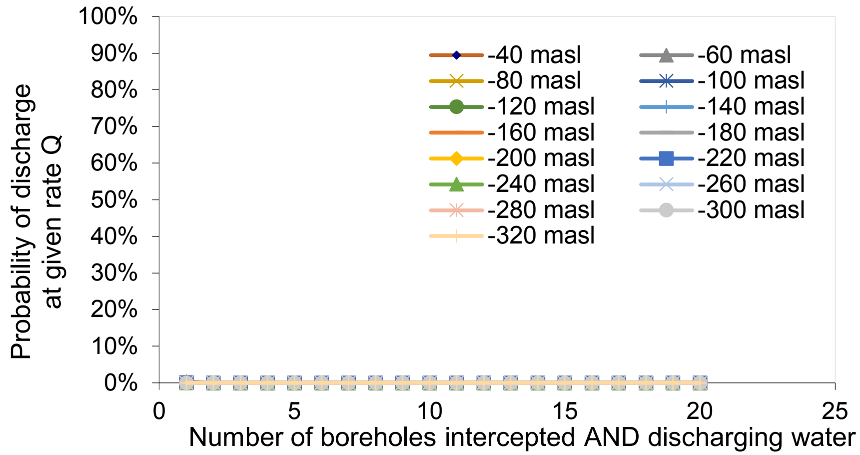
probability of boreholes discharging water, where distance = 0m to mine workings



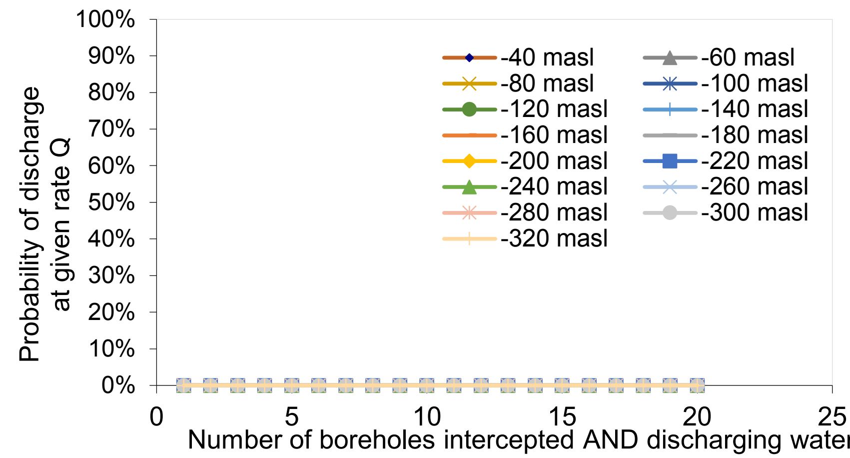
probability of boreholes discharging water, where distance > 0 to 3m to mine workings



probability of boreholes discharging water, where distance > 3 to 10m to mine workings

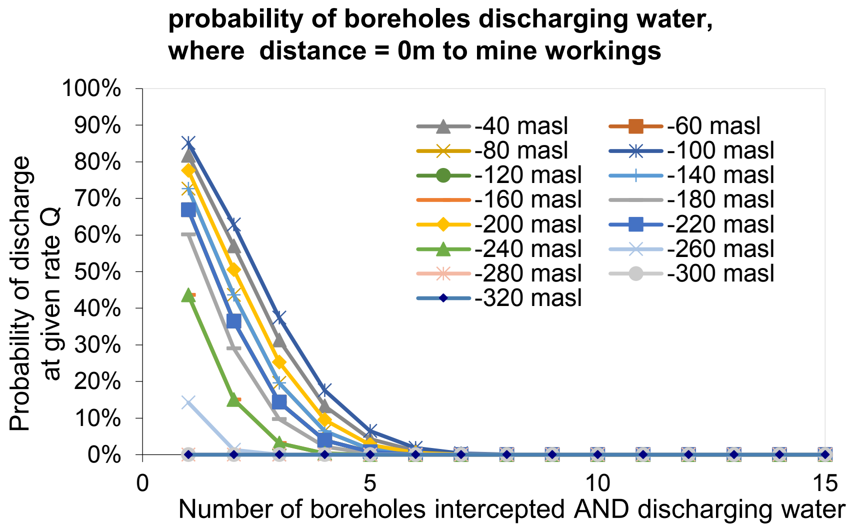


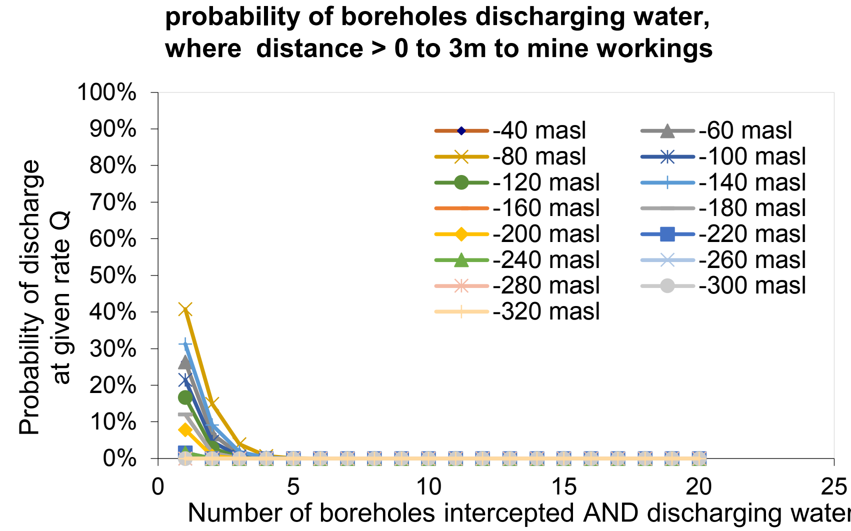
probability of boreholes discharging water, where distance > 10 to 30m to mine workings

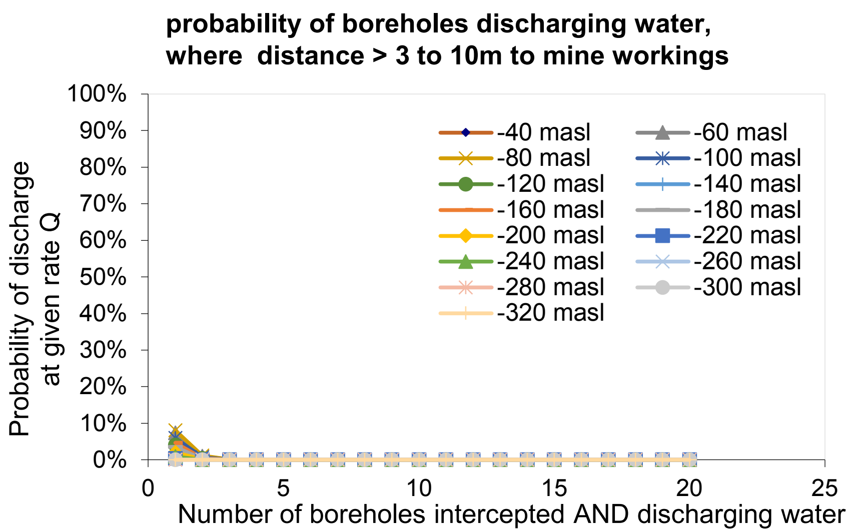


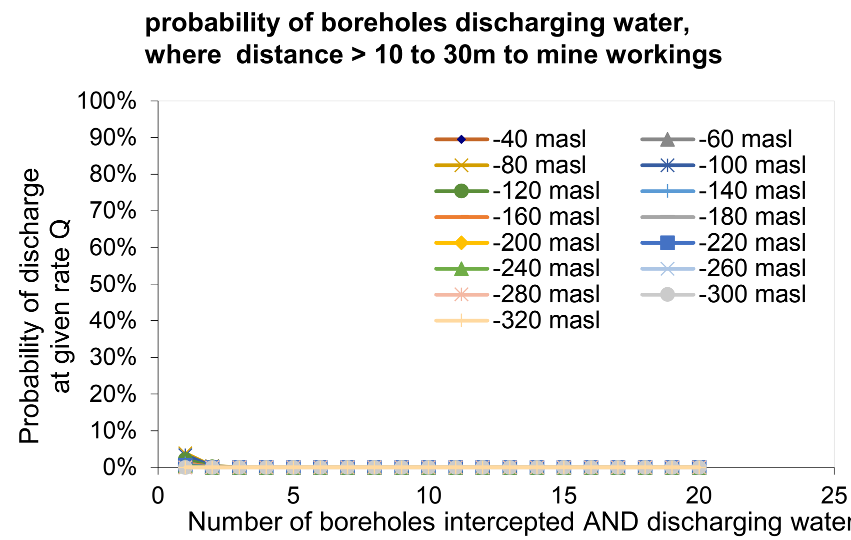
Source: DDH_Intersections_Rev4.xlsx

srk consulting	MAC RESOURCES	Hydrogeological Modeling Probabilities of Intercepting Open Hole Flowing at Maximum Rate at Madrid South
Job No: 1CT022.004 Filename: Figures_8x11_Landscape_r1.pptx	Hope Bay Project	Date: Dec 2016 · Approved: GF · Figure: 35









Source: DDH_Intersections_Rev4.xlsx

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MAC RESOURCES

Hydrogeological Modeling

Probabilities of Intercepting Open Hole Flowing at Maximum Rate at Madrid North

Job No: 1CT022.004

Filename: Figures_8x11_Landscape_r1.pptx

Hope Bay Project

Date: Dec 2016

Approved: GF

Figure: 36

Appendix A: SRK Memo, “Hope Bay Project: Lake Talik Configuration”

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Memo

To:	John Roberts, PEng, Vice President Environment	**Client:**	TMAC Resources Inc.
From:	Christopher W. Stevens, PhD	**Project No:**	1CT022.004
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	December 9, 2016
Subject:	Hope Bay Project, Lake Talik Configuration		

1 Introduction

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Ltd (TMAC). The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project comprises three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris Project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris only, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km due south from Doris respectively.

Although the Project is located in the continuous permafrost region of Canada, an evaluation is necessary to determine if the proposed underground mines will intercept talik zones. Where these talik zones are intercepted by the mine, groundwater inflow may be encountered, requiring appropriate management. Since the extent of these talik zones cannot be completely characterized through field verification, it is best practice to model the talik configuration. This memo provides a description of the modeling and presents the predicted talik configuration for use in subsequent mine inflow modeling.

2 Lake Taliks

2.1 Definition

A talik is defined as "*a layer or body of unfrozen ground occurring in a permafrost area due to local anomalies in thermal, hydrological, hydrogeological or hydrochemical conditions*" (van Everdingen 2005). In most cases, taliks are formed by lakes and other water bodies which cause a local departure in terrestrial ground temperature (Smith and Hwang 1973; Burn 2002).

In this memo, reference is made to both closed and open (or through) taliks. A closed talik is an unfrozen zone beneath a water body that is enclosed at the base and the surrounding sides by permafrost (Figure 1). An open talik is an unfrozen zone beneath a water body that penetrates the permafrost completely and may connect suprapermafrost (i.e. the layer of ground above permafrost) and subpermafrost (i.e. the unfrozen ground below the permafrost) groundwater.

2.2 Talik Configuration

Lake taliks are transient features in permafrost environments. Key factors influencing talik configuration include water bottom temperature, lake size (half width or radius), present and past ground thermal regime, and long-term changes to the landscape. Present-day water bathymetry can also effect talik configuration where shallow water allows for ice to seasonally freeze to the bottom (bottom-fast ice) and conduct heat from the ground (Burn 2002; 2005; Stevens *et al*. 2010a; 2010b).

The long-term thermal and physical evolution of the landscape is a factor in the present-day configuration of taliks that extend hundreds of metres below the surface. Lunardini (1995) showed temperature at depths up to 600 metres below ground surface (mbgs) can be influenced by surface temperatures as far back as 100,000 years.

Kerr (1994a) provides radiocarbon dating and stratigraphic interpretation of glacial and post-glacial deposits from Perry Peninsula and Queen Maud Gulf, and south of the Bathurst Inlet. His work suggests that deglaciation near the Madrid and Boston mining areas was between 9 ka and 8.7 ka (Kerr 1994a). Retreating ice may have been at or near the mining areas at around 9 ka, followed by a period of rapid ice retreat and ice-free conditions by 8.7 ka. Deglaciation was accompanied by synchronous marine incursion of the isostatically depressed terrain. Sea level curves constructed for the southern Bathurst Inlet suggest drainage of the marine water by at least 5 ka years BP (Kerr 1994b).

The sub-aerial exposure of land following drainage of marine water and cold air temperatures would have led to permafrost aggradation. Over time newly formed lakes and changes in water level of existing lakes due to changes in surface hydrology and climate would result in adjustment of lake taliks to a new equilibrium.

Open taliks are expected to be present beneath some lakes at the Property. Open taliks have been inferred from ground temperature measurements collected beneath Doris, Patch, and Aimaokatalok Lakes (SRK 2011a; Appendix A). Previous thermal modeling also supports the inference of open taliks beneath Doris and Tail Lakes, which are elongated lakes with a half-width of about 475 m and 390 m, respectively (SRK 2005a).

3 Ground Conditions

3.1 Permafrost

SRK (2016) provides detailed information on the baseline ground temperature and permafrost characteristics located in the Doris Mine, and the Madrid and Boston mining areas. The average present-day temperature of permafrost is -7.6°C at the Property, with a range from -5.6°C to -9.8°C (SRK 2016). The baseline ground temperature sites do not permit for separate assessment of permafrost temperatures at each of the three mining areas.

The base of permafrost has been estimated from ten sites to be 78 to 570 metres below ground surface(mbgs) based on the 0°C isotherm. Ground temperature sites removed from the thermal effects of nearby lakes indicate the base of permafrost extends to 570 mbgs (Site 08PMD669) at the Madrid mining area and 565 mbgs (Site 08SBD380) at the Boston mining area (Table 1). At Doris, the base of permafrost extent up to 511 mbgs at Site 10WB002. The geothermal gradient calculated from the deeper extent of permafrost averages 0.021°C m^{-1}, with a range of 0.014°C m^{-1} to 0.029°C m^{-1} (Table 1).

Table 1: Summary of Base of Permafrost and Geothermal Gradient

Thermistor Site ID	Northing	Easting	Location	Location Reference	Geothermal Gradient (°C/m)	Base of Permafrost (mbgs)
SRK-50	7,559,177	433,807	Doris Mining Area	Fig. 18	0.019	394
08TDD632	7,559,370	433,915	Doris Mining Area	Fig. 18	0.024	445
10WBW002	7,559,375	433,913	Doris Mining Area	Fig. 18	0.014	511
08PMD669	7,550,955	433,300	Madrid North Mining Area	Fig. 13+16	0.018	570
TM00141	7,546,691	435,141	Madrid South Mining Area	Fig. 13+17	0.023	346
08PSD144	7,548,990	435,178	Patch Lake Island	Fig. 13+15	-	78
08SBD380	7,504,780	441,080	Boston Mining Area	Fig. 5	0.017	565
08SBD381A	7,504,814	441,070	Boston Mining Area	Fig. 5	0.029	281
08SBD382	7,505,141	441,026	Boston Mining Area	Fig. 5	0.027	302
10WBW004	7,505,665	441,018	Boston Mining Area	Fig. 5	0.018	326
97NOD176	7,504,962	441,481	Boston Mining Area	Fig. 5	0.019	556
All Sites				**Average**	**0.021**	**398**
				Minimum	**0.014**	**78**
				Maximum	**0.029**	**570**
				Count	**10**	**11**

Water quality data collected from the Doris Central Westbay well (Site 10WBW001) indicates saline connate groundwater which is comparable to quality measurements observed at the Boston mining area. The lowest freezing point depression calculated from the concentration of dominate components of the groundwater was estimated to be -1.9°C (SRK 2011b). For the purpose of modeling talik extent, ground temperatures warmer than -2°C are expected to be unfrozen.

It should be recognized that the connection between surface water, mined structures, and subpermafrost groundwater is also a function of the hydraulic properties of the bedrock, the geological structures, and the hydraulic gradients that drive water movement; i.e. unfrozen ground does not necessarily constitute significant groundwater movement.

3.2 Lake Bottom Water Temperature

Table 2 shows average lake bottom water temperature (LbT) recorded during the month of April, July, August, and September for five lake locations over the period of 2010-2014 (ERM 2015; ERM 2014; Rescan 2012; Rescan 2011a). The lake bottom water temperatures are based on the deepest measurements collected at each site.

Table 2: Summary of Lake Bottom Water Temperatures

Location	Data Source (See notes)	Temperature (°C)					Ice Thickness (m)
		April	July	August	September	LbT	
Doris Lake North	1,3,4,5,6	1.5	7.8	11.0	6.2	4.7	1.8
Doris Lake South	1,3,4,5,6	1.0	9.0	10.7	5.7	4.2	1.9
Reference Lake A	1	1.6	-	4.3	-	2.5	1.8
Reference Lake B	1,3,4,5,6	2.6	9.1	11.1	3.9	5.5	1.7
Reference Lake C	2	2.0	-	8.3	-	4.1	1.9
Reference Lake D	1,3,4,5,6	0.8	11.4	12.1	2.5	4.6	1.9
Little Roberts Lake	1,3,4,5,6	0.7	10.6	10.9	3.4	4.1	1.9
Wolverine Lake	1	1.4	-	13.2	-	5.3	1.8
Patch Lake North	1	1.2	-	10.8	-	4.4	2.1
Patch Lake South	1	2.1	-	10.3	-	4.8	1.9
P.O. Lake	1	0.2	-	10.0	-	3.5	1.9
Ogama Lake	1	1.8	-	10.0	-	4.5	1.8
Doris Lake North	1	1.1	-	10.0	-	4.1	2.0
Doris Lake South	1	0.9	-	9.7	-	3.8	2.0
Naiqunnguut Lake	1	1.4	-	10.2	-	4.3	1.9
Nkhatok Lake	1	0.4	-	11.7	-	4.2	1.9
Glenn Lake	1	0.5	-	9.9	-	3.6	2.0
Imniagut Lake	1	-	-	12.2	-	-	2.0
Little Roberts Lake	1	1.3	-	10.0	-	4.2	2.1
Stickleback Lake	2	1.1	-	11.2	-	4.5	1.8
Trout Lake	2	0.8	-	12.6	-	4.7	1.8
Windy Lake	1,2	2.0	-	10.1	-	4.7	1.8
Aimaokatalok Lake: Station 2	2	-	-	11.6	-	-	-
Aimaokatalok Lake: Station 5	2	0.0	-	14.8	-	4.9	1.8
Aimaokatalok Lake: Station 6	2	2.3	-	12.1	-	5.6	1.6
Aimaokatalok Lake: Station 11	2	0.1	-	12.1	-	4.1	1.6
Aimaokatalok Lake: Station 13	2	-	-	13.9	-	-	-
All Sites					**Average**	**4.4**	**1.9**
					Minimum	**2.5**	**1.6**
					Maximum	**5.6**	**2.1**
					Count	**24**	**25**

Notes:

1. Average monthly temperature collected over the period of 2009- 2014 (see data source)
2. Annual lake bottom temperature (LbT) calculated using Equation 1
3. Ice thickness measured from ice auger hole drilled in April
4. Data source: 1 – Rescan (2010), 2 – Rescan (2011a), 3 – Rescan (2011b), 4 – Rescan (2012), 5 – ERM Rescan (2014), 6 – ERM (2015)

Mean annual lake bottom water temperature was calculated as a weighted mean of April and August temperatures:

$$LbT = 8LbTApr + 4LbTAug\ /P \qquad \text{Eq. 1}$$

where:

LbT = mean annual lake bottom water temperature (°C)
$LbTApr$ = measured lake bottom water temperature in April (°C)
$LbTAug$ = measured lake bottom water temperature in August (°C)
P = is the period of time

Based on Equation 1, April water temperature is assumed to be representative of the period of ice cover (October to May). August water temperatures represent the warmest measurements and likely over-estimate water temperature throughout the ice-free period. Therefore, a conservative water temperature is computed using this approach, and allowed for in the thermal models.

The annual lake bottom water temperature is calculated to average of +4.4°C, with a range from +2.5°C to +5.6°C (Table 2). A value of +4.4°C is considered to be reasonable for base case conditions.

4 Regional Talik Model

4.1 Analytical Model

The critical lake dimension required for open (through) lake taliks was assessed using a one-dimensional (1D) steady state analytical model for lakes. The regional model was development to provide regional context for taliks in the area. The thermal models used for this assessment are presented by Mackay (1962), Smith (1976), and Burn (2002) for study sites in the Canadian Arctic, and have been used for talik characterization at other proposed mine projects located in the continuous permafrost region of mainland Nunavut, including the Back River Project (SRK 2015), Meliadine (Golder 2013), Kiggavik (Areva Resources Canada 2011), High Lake (Wolfden Resources Inc. 2006), Doris (SRK 2005b), and Meadowbank (Cumberland Resources Ltd. 2005) projects.

The temperature profile beneath the centre of a circular lake without terraces has been modeled by Mackay (1962) as:

$$T_z = T_g + \frac{z}{I} + (LbT - T_g)\left(1 - \frac{z}{\sqrt{z^2+R^2}}\right) \qquad \text{Eq. 2.}$$

Where:
Tz = temperature at depth z (ºC)
LbT = Average annual lake bottom water temperature (°C)
Tg = average annual ground temperature (ºC)
I = inverse of the geothermal gradient (m $ºC^{-1}$)
z = depth below bottom of lake (m)
R = radius of the lake (m)

The temperature profile beneath symmetrical elongated lakes without terraces has been modeled by Smith (1976) as:

$$T_z = T_g + \frac{z}{I} + \frac{LbT - T_g}{\pi}\left(2\tan^{-1}\frac{w}{z}\right) \qquad \text{Eq. 3.}$$

Where:

Tz = Temperature at depth z (ºC)
LbT = Average annual lake bottom water temperature (°C)
Tg = Average annual ground temperature (ºC)
I= inverse of the geothermal gradient (m $ºC^{-1}$)
z = depth below bottom of lake (m)
w = half-width of an elongated lake (m)

For conservatism, shallow-water terraces (lake terraces) which may be thermally influenced by bottom-fast ice were not considered in the analytical model. Table 3 shows the base case and sensitivity values using the in the 1D model. Base case values are representative of average measurements from the mining areas.

Table 3: Thermal Modeling Input Values for Analytical Talik Model

Parameter	Value (Base Case)	Value (Sensitivity Analysis)
Ground temperature (Tg)	-7.6°C	-5°C to -9°C
Mean annual lake-bottom temperature (LbT)	+4.4°C	+3°C to +6°C
Geothermal heat flux (G)	0.021°C m^{-1}	0.014 to 0.029°C m^{-1}

Notes:

1. Measured mean annual permafrost temperature is -7.6°C and mean annual lake bottom temperature is +4.4°C

2. Average geothermal gradient calculated from ground temperature measurements is 0.021°C m^{-1}

4.2 Model Assumptions

The modeling, as presented, is based on the following assumptions:

- Lake geometry is defined in the models as either circular or elongate, and does not account for actual lake geometries which can be quite complex.
- Modeling does not account for the thermal influence of adjacent lakes (lateral heat flow) and spatial variability in ground surface temperature. However, the sensitivity to lake-bottom temperature (LbT) and permafrost temperature are considered (Table 3).
- Water depth is assumed to be greater than the maximum thickness of seasonal ice, and the thermal influence of bottom-fast ice is not considered, making the results more conservative.
- Ground thermal properties and complex mechanisms for heat flow such as convection are not accounted for in the model.

- Geothermal heat flux is based on an average value calculated from ground temperature measurements with sensitivity around the range of values collected at the Property (Table 3).
- Steady-state models are used and therefore the transient effects, such as paleo-climate (i.e. long-term changes in ground surface and water temperature) are not considered.

Talik will naturally adjust to changes in climate and evolution of the landscape. Over the time scale of the Project, the most immediate effects would be an increase in extent of the talik beneath the shoreline, and possible subsidence and erosion of the shoreline at locations with ice-rich permafrost. A reduction in lake ice growth due to climate change would also be expected to widen and deepen existing taliks beneath shallow water bodies which rely on seasonal heat loss though the establishment of bottom-fast ice (Burn 2002; 2005; Stevens *et al*. 2010a; 2010b). The natural development of new ponds at the Property would also result in newly formed closed taliks. On the time scale of hundreds to thousands of years, open taliks may form as permafrost degrades beneath these recently formed water bodies. Natural lowering of lake water level or even complete drainage due to climate change may also result in permafrost aggradation beneath the former lake basin and long-term freezeback of taliks.

4.3 Model Results

The estimated critical dimensions for open (through) taliks beneath lakes at the Property are summarized in Table 4 and Table 5. The findings are based on a groundwater freezing point depression of -2°C and are graphically depicted in Figure 2 and Figure 3.

For the base case scenario, open taliks are estimated to occur beneath circular lakes with a diameter >224 m (i.e. lake radius of >112 m). For elongated lakes, the critical lake width is estimated to be >104 m wide (i.e. lake half-width >52 m).

Sensitivity of the critical lake dimension to change in the geothermal gradient is shown in Figure 4 and Figure 5.

Table 4: Circular Lake Critical Radius for Open (Through) Taliks Based on -2°C Isotherm

Permafrost Temperature	**Annual Lake Bottom Temperature (LbT)**				
	+3.0°C	**+4.0°C**	**+4.4°C**	**+5.0°C**	**+6.0°C**
-9.0°C	169 m	159 m	155 m	151 m	144 m
-8.0°C	138 m	129 m	126 m	122 m	117 m
-7.6°C	123 m	115 m	112 m	109 m	104 m
-7.0°C	108 m	101 m	98 m	95 m	91 m
-6.0°C	80 m	74 m	72 m	70 m	67 m
-5.0°C	54 m	50 m	49 m	47 m	44 m

Table 5: Elongated Lake Critical Half-width for Open (Through) Taliks Based on -2°C Isotherm

Permafrost Temperature	Annual Lake Bottom Temperature (LbT)				
	+3.0°C	+4.0°C	+4.4°C	+5.0°C	+6.0°C
-9.0°C	83 m	76 m	73 m	70 m	65 m
-8.0°C	66 m	60 m	58 m	55m	50 m
-7.6°C	60 m	54 m	52 m	49 m	45 m
-7.0°C	50 m	45 m	43 m	41 m	38 m
-6.0°C	36 m	32 m	30 m	28 m	26 m
-5.0°C	23 m	20 m	19 m	17 m	15 m

5 Site-specific Talik Model

5.1 Approach

Lake talik configuration adjacent to the Boston and Madrid mining areas was estimated using 2D thermal modeling. The model results were fitted to field observations of the -2°C isotherm, and therefore use calculated heat flow as a basis for estimating talik geometry. The modeling was carried out using a finite element code SVHeat developed by SoilVision Systems Ltd. with the FlexPDE solver.

5.1.1 Model Setup and Inputs

A long-term mean annual ground surface temperature was applied to the upper model boundary over areas of land. Long-term ground surface temperature was based on a projection of the thermal gradient from deep ground temperature measurements to the surface. The projected ground surface temperature reflects approximate paleo-surface temperature, which is typically colder than present day permafrost temperature calculated from the baseline ground temperature sites (SRK 2016). At the Madrid and Boston mining areas, the long-term ground surface temperature was estimated to be -9.6°C (Site 08PMD669) and -9.2°C (Site 08SBD380), respectively. A long-term ground surface temperature was used to more closely estimate talik configuration and the base of permafrost which result from paleo conditions. The geothermal gradient applied to the lower boundary of the model was based on Site 08PMD669 for Madrid Mining Area and Site 08SBD380 for the Boston mining area (Table 1).

A mean annual lake bottom water temperature of +4.4°C was applied to the upper boundary for lakes (Table 2). Lake width was based on current extent of water bodies at the underground mining areas. At Aimaokatalok Lake adjacent to the Boston mining area, an annual temperature of -2°C was also applied to lake areas with a water depth less than 1.3 m (i.e. water depth that is two-thirds of the mean annual ice thickness). A value of -2°C was applied to the shallow water lake terrace based on measured temperatures from similar environments (Burn 2002; 2005).The ice across these shallow water lake terraces freezes to the bottom with sufficient heat loss from the lake bottom to sustain permafrost beneath the shallow water terraces of Arctic lakes (Mackay 1992; Burn 2002). The thermal regime of shallow water was not considered at the Madrid underground mining areas due to the relatively rapid increase in water depth from shore.

Model simulations were based on a time step of one year. Table 5 summarises the thermal properties used in the transient lake talik model. The frozen and unfrozen thermal conductivity and heat capacity for bedrock (basalt) was based on previous thermal modeling at Hope Bay (SRK 2005; SRK 2011a).

Table 5: Bedrock Thermal Properties 2D Lake Talik Model

Material	Degree of Saturation (%)	Porosity	Thermal Conductivity (kJ m^{-1} day^{-1} $°C^{-1}$)		Volumetric Heat Capacity (kJ m^{-3} $°C^{-1}$)	
			Unfrozen	Frozen	Unfrozen	Frozen
Basalt Bedrock	100	0.05	260	260	2,380	2,133

5.1.2 Model Assumptions

The 2D thermal modeling, as presented, is based on the following assumptions:

- Lake geometry is defined by current lake extent and does not account for historic lake configuration which can be complex.
- Lake-bottom geometry is not directly considered in the model sections. The relatively shallow lake depths would have limited impact on talik configuration deep below the ground surface.
- Surface topography is not considered in the model sections due to low relatively relief across the Property and its limited influence on talik configuration.
- Long-term paleo ground surface temperatures are based on values projected from deep ground temperature measurements, and do not capture more recent variability in surface temperature.
- Ground thermal properties and complex mechanisms for heat flow such as convection are not accounted for in the model.

5.2 Boston Mine Area

The Boston underground mine will be located on the east side of Aimaokatalok Lake (Figure 6). A total of four sections were used to model the lake talik.

5.2.1 Ground Temperature Measurements

Deep ground temperature measurements have been collected from three deep inclined wells which extend beneath Aimaokatalok Lake; well 08SBD381A, 08SBD382, and 10WBW004 (Figure 7). Well 08SBD380 and 97NOD176 are two additional deep wells that have been drilled inland near the Boston mine workings.

Table 6 summarizes the position of the 0°C and -2°C isotherms for the Boston mining area. At 08SBD380 and 97NOD176, the ground temperature has been measured to a maximum depth of 241 mbgs and 247 mbgs, respectively. The base of permafrost is not directly incepted by these wells and the lowermost thermistors nodes indicate relatively cold permafrost temperatures

(-5.1°C at 08SBD380 and -5.5°C at 97NOD176). The projected base of permafrost based on the 0°C isotherm is 565 mbgs at 08SBD380 and 556 mbgs at 97NOD176 (Table 6). The -2°C isotherm is projected to be 430 mbgs at 08SBD380 and 449 mbgs at 97NOD176.

Ground temperatures measured at three sites beneath Aimaokatalok Lake provide information on the extent of the lake talik adjacent to the shoreline (Figure 6 and Figure 7). Figure 8 shows the depth of the -2°C isotherm and its distance from shore for these sites. The water bathymetry for the three areas with ground temperatures beneath the lake are shown in Figure 9. At site 08SBD382, the -2°C isotherm is up to 115 m from the lake shoreline and located at a depth of 224 mbgs. At site 08SBD381A and 10WBW004, the -2°C isotherm is 17 and 42 metres from shore and located between 202 and 209 mbgs (Table 6).

Table 6: Boston Mining Area Depth of 0°C and -2°C Isotherm from Ground Temperature Data

Site	Location	Maximum Instrumented Depth (mbgs)	-2°C Isotherm (mbgs)	0°C Isotherm (mbgs)
08SBD380	Near Underground Mine	241	430	565
97NOD176	Near Underground Mine	247	449	556
08SBD381A	Extends Beneath Lake	291	202	281
08SBD382	Extends Beneath Lake	313	224	302
10WBW004	Extends Beneath Lake	399	209	326

Notes:

1. Digital data not available for 97NOD176, depth and temperature determined from graphical form of data
2. Thermistor node depth corrected for vertical depth using downhole well survey and surface elevation
3. Depth shown as vertical metres below ground surface (mbgs)

For sites 08SBD381A and 08SBD382, the -2°C is located beneath water depths which are not expected to seasonally freeze to the bottom and therefore do not experience thermal conduction of heat through bottom-fast ice cover. The presence of floating ice at these locations implies that there is no significant means to vertically remove heat gained from the water and the lake bottom. At site 10WBW004, the -2°C isotherm is located beneath water depths that are about two-thirds the maximum ice thickness (i.e. an ice thickness of 1.3 m). It has been suggested that water depth less than two-thirds the maximum later winter ice thickness is required to sustain permafrost beneath shallow water margins of Arctic lakes impacted by bottom-fast ice (Mackay 1992; Burn 2002). This finding was also in agreement with shallow-water permafrost located within the nearshore zone of the Beaufort Sea (Stevens *et al*. 2010b).

Therefore, under present-day lake configuration the offshore position of the -2°C isotherm cannot be explained by heat loss from seasonal bottom-fast ice. Lateral heat flow from the adjacent land also does not explain the current talik extent beneath the lake. Significantly colder ground surface temperatures and lake bottom-temperatures would be required for the talik to extend beneath the Aimaokatalok Lake. Figure 8 shows the expected configuration of the Aimaokatalok Lake talik for steady state compared to the position of the measured position of the -2°C isotherm. For steady state talik configuration to meet the field observations, the mean annual ground surface temperatures would need to be around -20°C.

We postulate that the lateral extent of permafrost beneath Aimaokatalok Lake is a direct physical consequence of the rise in lake level through time. Over time, permafrost formed through terrestrial exposure to cold air temperatures has been submerged with lake expansion. The talik is currently responding to the thermal forcing from the current lake and the talik will adjust to new conditions and evolve with the lake. The talik would be expected to adjust to equilibrium conditions on the time scale of hundreds to thousands of years.

5.2.2 Model Results

The 2D model sections were setup to simulate possible expansion of Aimaokatalok Lake and to allow for talik adjustment to meet ground temperature measured at the site. The model was run for 5,000 years which is estimated to be the approximate duration of time since drainage of the post-glacial marine incursion. The following major periods were included in the thermal model:

- From model year 0 to 4.5 ka, the lake was assumed to occupy a smaller area defined by current water depths greater than 5 m deep. This water depth represents the approximate transition from a relatively shallow to steep gradient in the water depth profile; i.e. the change in water depth verses distance (Figure 9). It was thus assumed that lake expansion would be most rapid across areas with a water depth less than 5 m deep where the gradient is shallow.
- From model year 4.5 to 5.0 ka, the lake was allowed to expand and flood the existing permafrost. This step was included in the model to allow for the interpreted adjustment of the talik over time. The position of the -2°C isotherm modeled was then selected to closely fit to the equivalent isotherm measured at sites 08SBD381A, 08SBD382, and 10WBW004.

Figures 10 to 13 show the model results for the Boston mining area. Table 7 shows a comparison between the model fit and the ground temperatures for the -2°C isotherm which represents the transition from frozen to unfrozen conditions at the three sites. In all cases, the model fit is conservative and underestimates the measured depth of the talik.

Table 7: Measured and Model Fit for Talik Surface

Model Section	Thermistor Site ID	Model (-2°C Isotherm)	Measured (-2°C Isotherm)
T1	10WBW004	192	209
T2	08SBD382	215	224
T3	08SBD381A	196	202

Notes:

1. Model position of the -2C isotherm based on manual fit to field data

5.3 Madrid Mining Area

The Madrid mining area consist of two distinct mines along the west side of Patch Lake. The northern mine (Madrid North) will be located between Windy Lake and Patch Lake, and the southern mine (Madrid South) will be located between Wolverine Lake and Patch Lake.

The 2D models included five sections for Madrid North and four sections for Madrid South (Figure 14). The model sections extend across the underground mining areas with an orientation that is approximately perpendicular to the long axis of the adjacent lakes. The modeled data was fit to the position of the -2°C isotherm measured at Madrid North. At Madrid South, the -2°C isotherm is located beyond the instrumented depth of the ground temperature cable. At this site, the modeled data was fit to the lowermost thermistor sensor (node).

5.3.1 Ground Temperature Measurements

Deep ground temperature measurements have been collected from three inclined wells; 08PMD669, 08PSD144, and TM00141 at the Madrid mining areas (Figure 14 and Figure 15).

Well 08PSD144 is located beneath an island centred within Patch Lake (Figure 16). Ground temperature measurements at the site indicate relatively shallow permafrost beneath the island (base of permafrost 78 mbgs) due to the surrounding heat from the lake.

Well 08PMD669 is located within the area of the Madrid North underground mine workings (Figure 17) and is instrumented to a maximum depth of 474 mbgs. The base of permafrost is 570 mbgs at this location.

Well TM00141 is located within the Madrid South underground mine between Wolverine Lake and Patch Lake (Figure 18). The well extends toward Patch Lake. Ground temperature measured from lowermost thermistors node is -2.6°C at 225 mbgs. The projected base of permafrost is 346 mbgs, intercepting the talik at the edge of the Patch Lake. The range in depth to the base of permafrost at Madrid North and Madrid South is similar to comparable measurements made at the Doris Mining Area (Table 1; Figure 19).

Table 8: Madrid Mining Area Depth of 0°C and -2°C Isotherm from Ground Temperature Data

Site ID	Location	Maximum Instrumented Depth (mbgs)	-2°C Isotherm (mbgs)	0°C Isotherm (mbgs)
08PMD669	Madrid North	474	438	570
08PSD144	Patch Lake Island	275	50	78
TM00141	Madrid South	225	303	346

Notes:

1. Thermistor node depth corrected for vertical depth using downhole well survey and surface elevation
2. Depth shown as vertical metres below ground surface (mbgs)

5.3.2 Model Results

Figures 20 to 24 show the model results for the Madrid North mining area. Lake expansion was not considered in the 2D thermal models since it is not supported by ground temperature data collected at the Madrid mining areas. Table 9 shows a comparison between site ground temperature measurements and the model fit. In all cases, the model fit is conservative and underestimates the depth of the talik

Table 9: Measured and Model Fit for Talik Surface

Model Section	Thermistor Site ID	Model (-2°C Isotherm)	Measured (-2°C Isotherm)
T2 (Madrid North)	08PMD669	412	438
T2* (Madrid South)	TM00141	258	303

Notes:

1. Asterisk indicates model fit with lowermost thermistor sensor.

At Madrid North, the model was fit to the -2°C isotherm at site 08PMD669. At this site, the lowermost sensor (node) measures -1.3°C at 474 mbgs. The equivalent isotherm estimated by the model is located at 453 mbgs or 21 m less than the measured depth.

Figures 25 to 28 show the model result for the Madrid South mining area. At Madrid South, the model was fit to the lowermost thermistor sensor (node) at site TM00141 which measures -2.6°C. The projected depth of the -2°C isotherm is 303 mbgs at the site. The equivalent isotherm estimated by the fitted model is located 258 mbgs. The model underestimates the position of the -2°C by 45 m.

6 References

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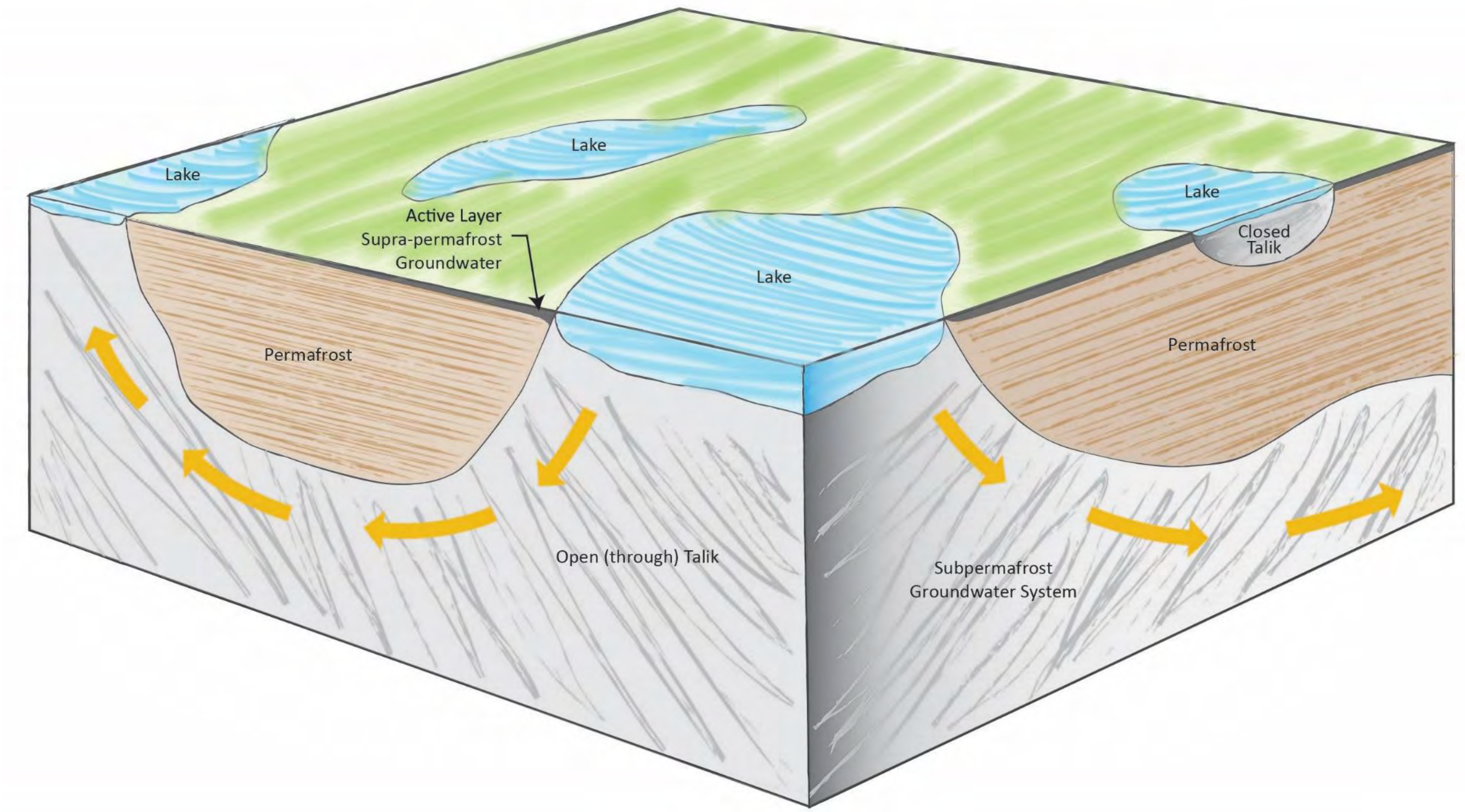
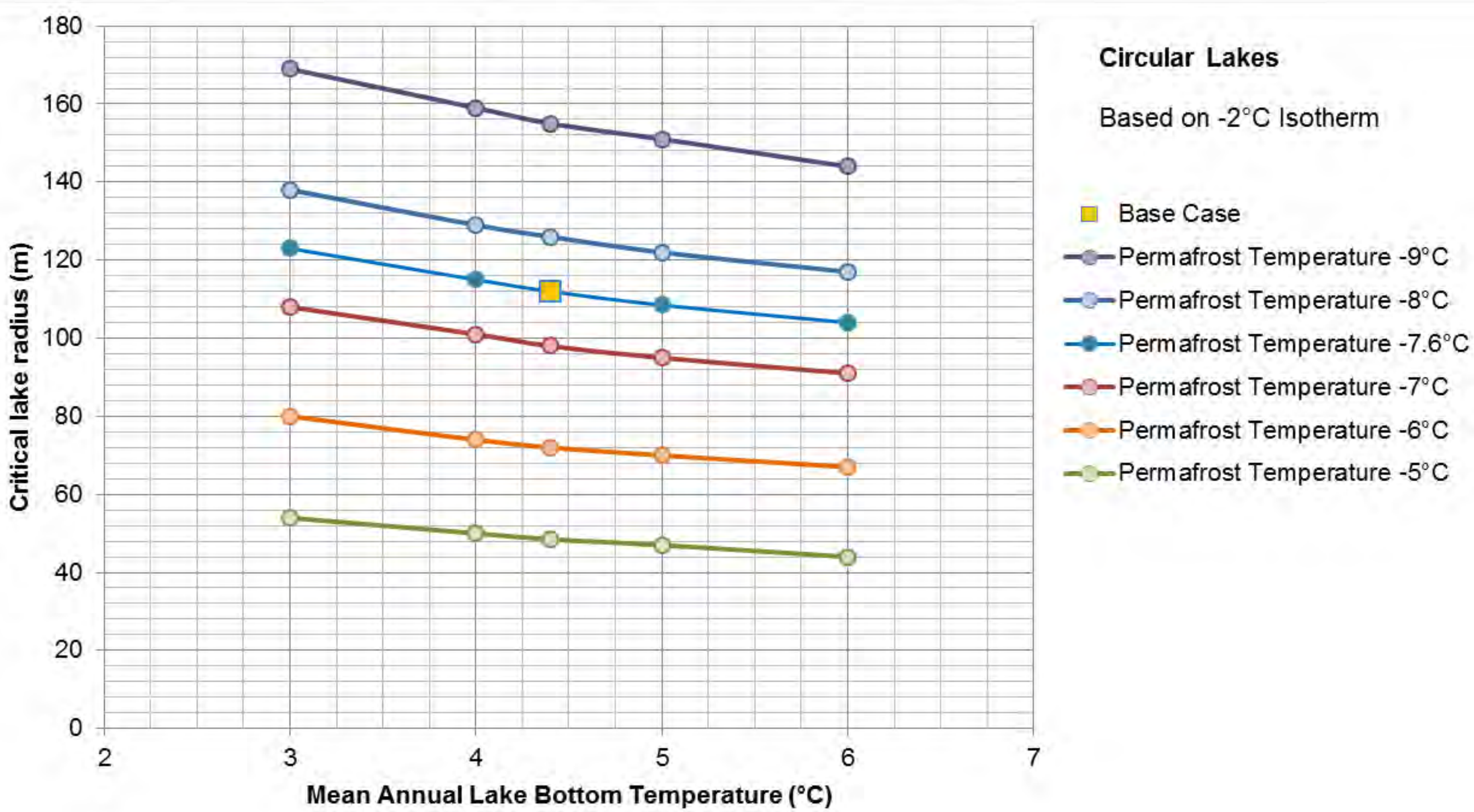
Figures



Notes:

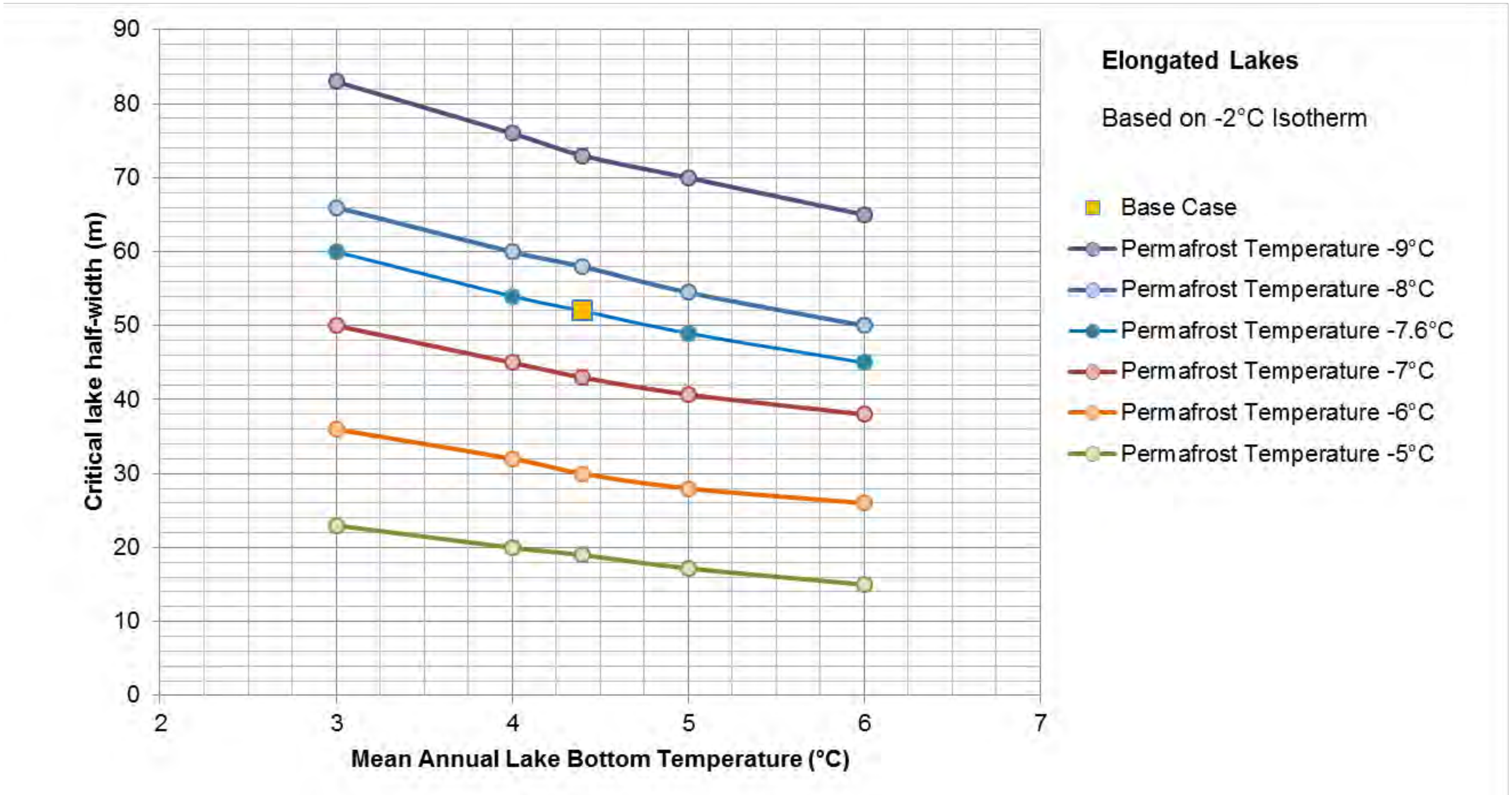
1. Orange arrows show potential direction of groundwater flow for illustrative purposes only

srk consulting	TMAC RESOURCES	Lake Talik Configuration **Conceptual Drawing – Open and Closed Lake Taliks**
Job No: 1CT022.004 Filename: ElongatedLakesCriticalLakeHalf-Width.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: 1



Notes:
1. Open (through) taliks estimated for circular lakes with a dimensions greater than the critical radius
2. Permafrost temperature refers to mean annual ground temperature near the depth of zero annual amplitude
3. Results based on -2°C isotherm

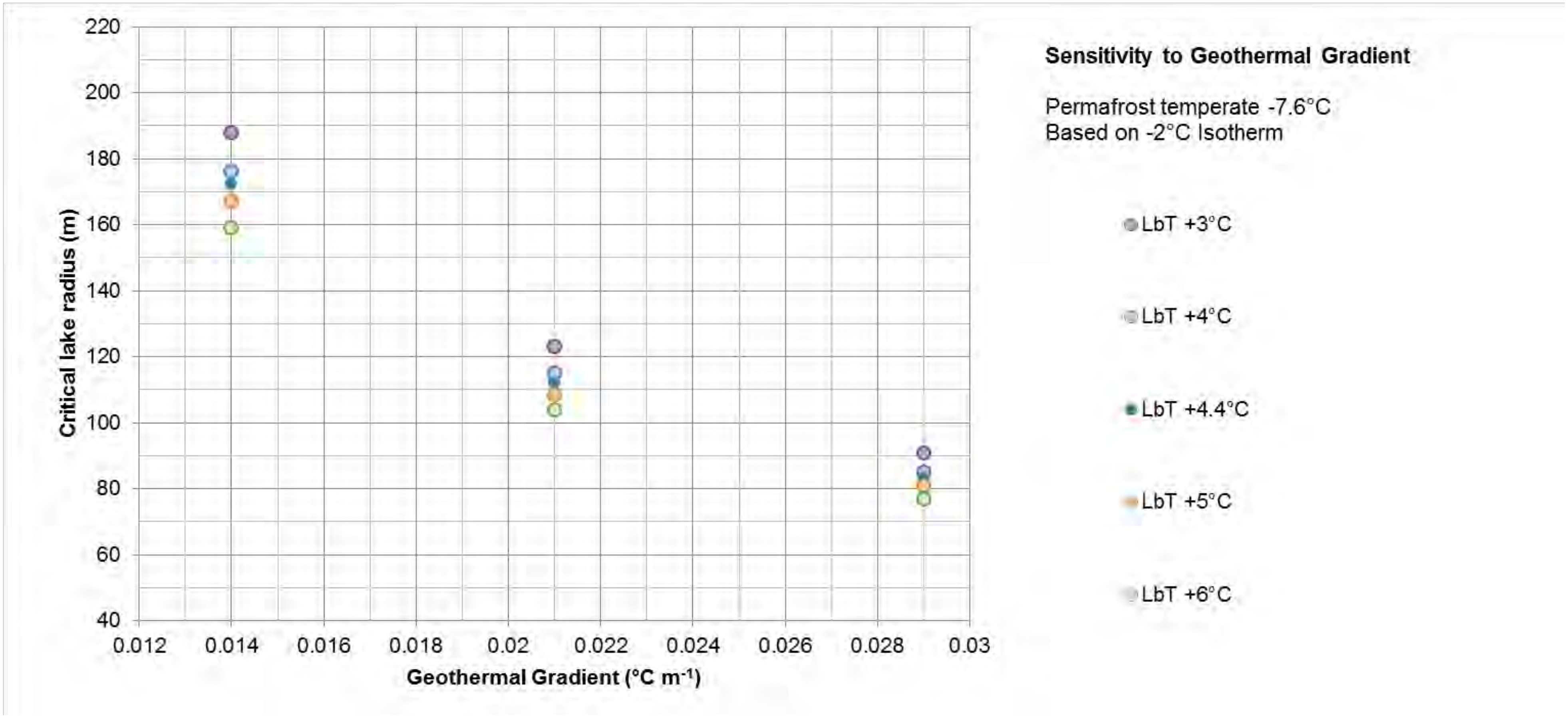
srk consulting	TMAC RESOURCES	Lake Talik Configuration
		Circular Lakes - Critical Half-width for Open Taliks
Job No: 1CT022.004 Filename: ElongatedLakesCriticalLakeHalf-Width.pptx	HOPE BAY PROJECT	Date: 2/12/2016 | Approved: cws | Figure: 2



Notes:

1. Open (through) taliks estimated for circular lakes with a dimensions greater than the critical half-width
2. Permafrost temperature refers to mean annual ground temperature near the depth of zero annual amplitude
3. Results based on -2°C isotherm

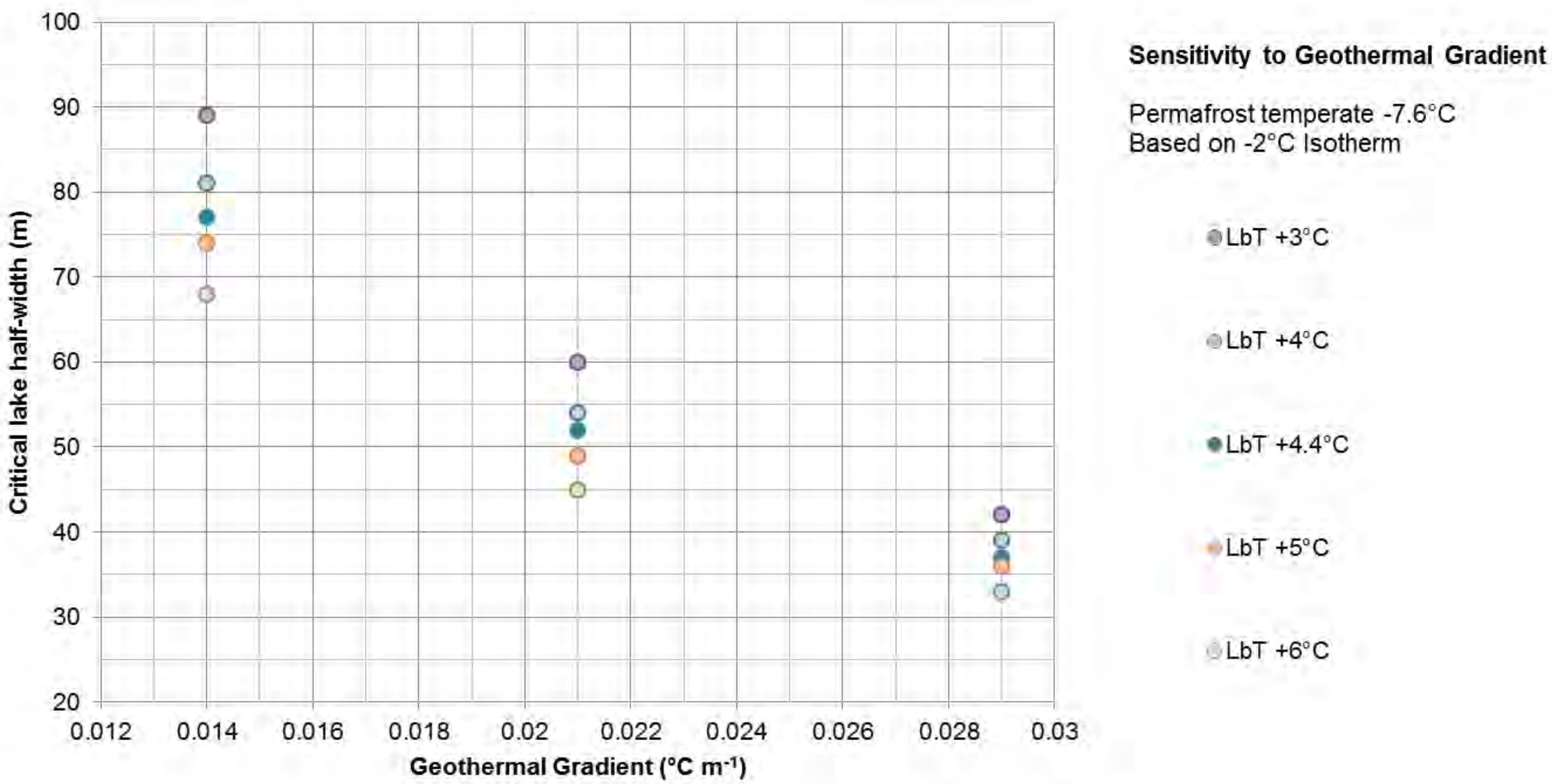
srk consulting	MAC RESOURCES	Lake Talik Configuration
		Elongated Lakes - Critical Half-width for Open Taliks
Job No: 1CT022.004 Filename: ElongatedLakesCriticalLakeHalf-Width.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: 3



Notes:

1. Open (through) taliks estimated for circular lakes with a dimensions greater than the critical radius
2. Sensitivity of critical lake radius based on average geothermal gradient measured at the Doris, Madrid, and Boston mining areas
3. Permafrost temperature based on base case value of -7.6°C
4. LbT – Lake bottom temperature
5. Results based on -2°C isotherm

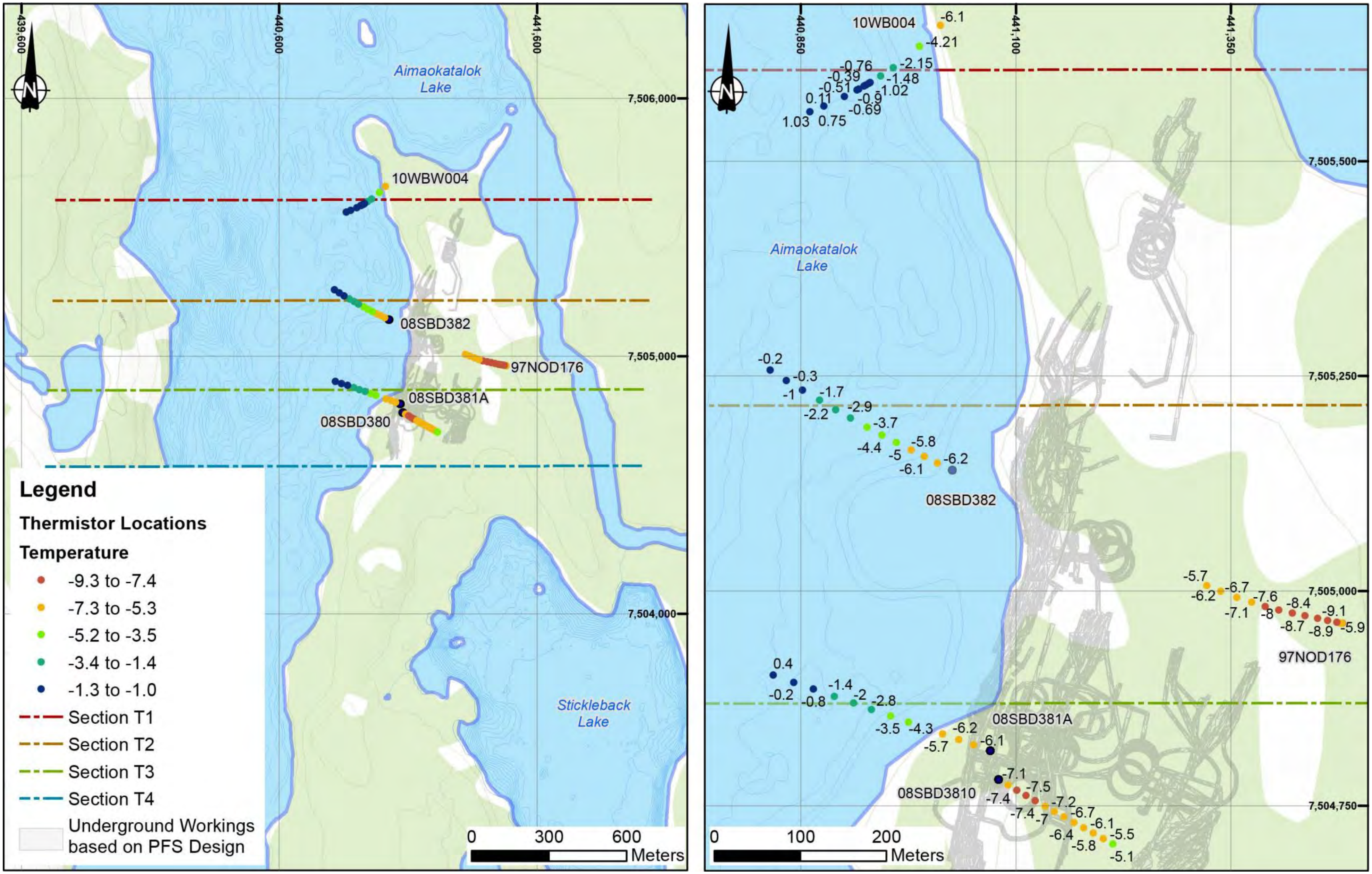
srk consulting	TMAC RESOURCES	Lake Talik Configuration
		Circular Lakes – Sensitivity to Geothermal Gradient
Job No: 1CT022.004 Filename: CircularLakesSensitivitytoGeothermalGradient.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: 4



Notes:

1. Open (through) taliks estimated for circular lakes with a dimensions greater than the critical half-width
2. Sensitivity of critical lake half-width based on average geothermal gradient measured at the Doris, Madrid, and Boston mining areas
3. Permafrost temperature based on base case value of -7.6°C
4. LbT – Lake bottom temperature
5. Results based on -2°C isotherm

srk consulting	TMAC RESOURCES	Lake Talik Configuration
		Elongated Lakes – Sensitivity to Geothermal Gradient
Job No: 1CT022.004 Filename: ElongatedLakesSensitivitytoGeothermalGradient.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: 5



Notes:

1. Coordinate System: UTM NAD 83 Zone13
2. Basemap Credits: ERSI, DeLorme, TomTom, Intermap, NRCAN, GeoBase
3. Underground Workings based on PFS Design

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TMAC RESOURCES

Job No:	1CT022.004
Filename:	BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

Lake Talik Configuration

Boston Mining Area

Date:	Approved:	Figure:
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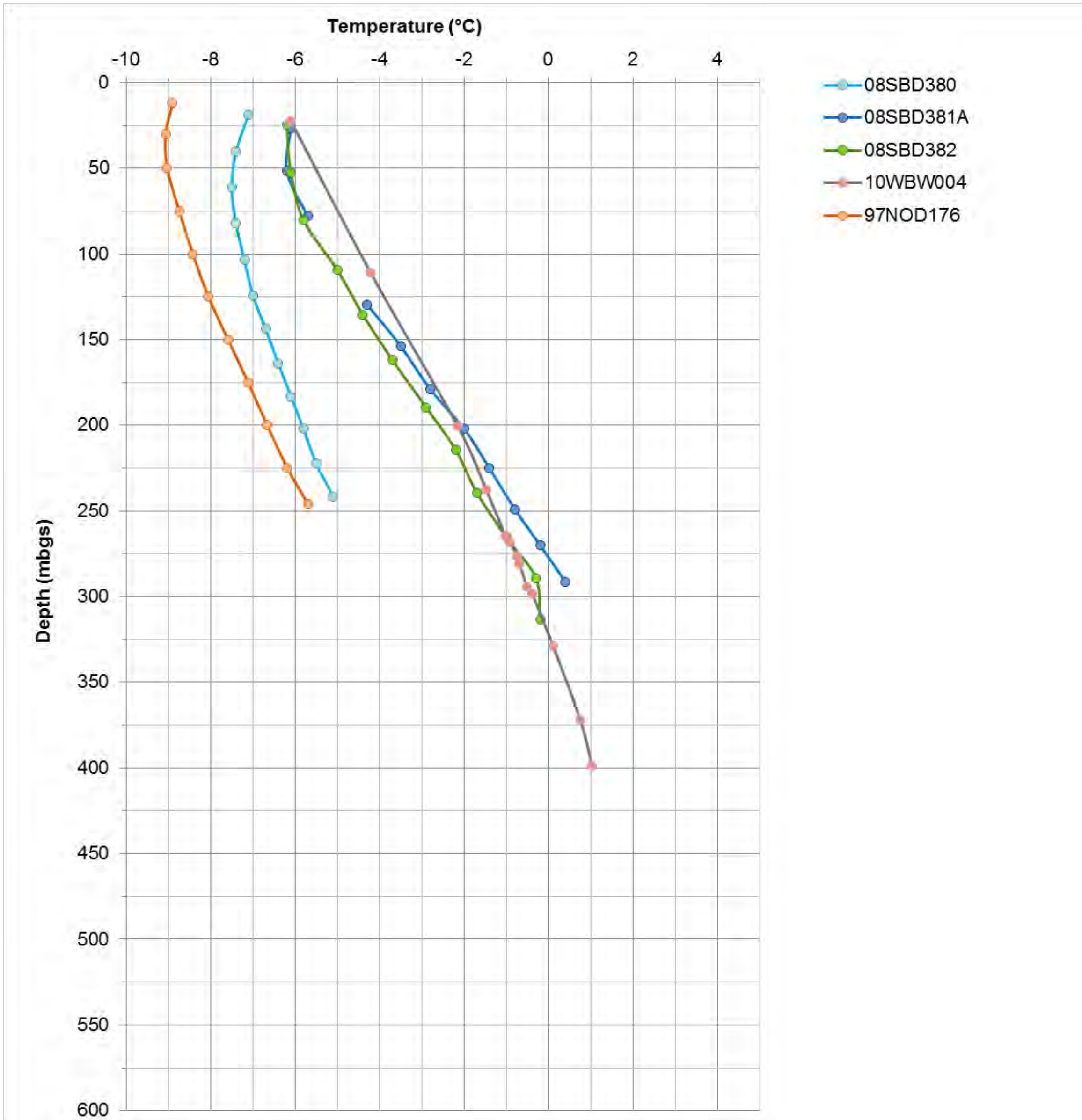
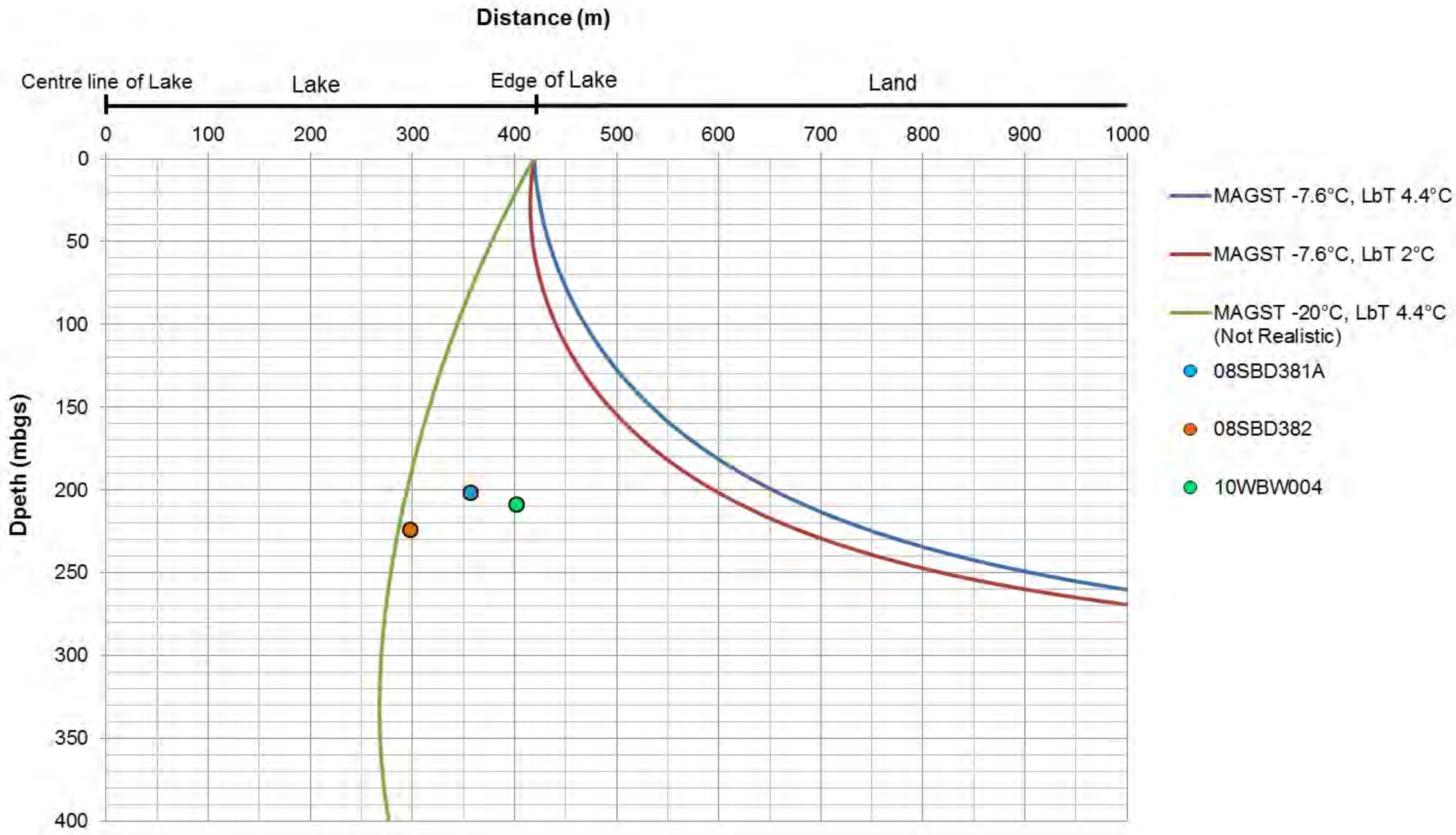


Notes:
1. Depth indicated as vertical metres below ground surface (mbgs)

srk consulting	TMAC RESOURCES	Lake Talik Configuration **Deep Ground Temperatures – Boston Mining Area**
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: 7



Notes:

1. 2D analytical model of steady state talik configuration based on -2°C isotherm (solid lines)
2. Position of -2°C isotherm based on thermistor measurements (solid circles)
3. Depth indicated as vertical metres below ground surface (mbgs)
4. Mean annual ground surface temperature (MAGST)
5. Lake bottom temperature (LbT)

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TMAC RESOURCES

Lake Talik Configuration

Steady State Model – Aimaokatalok Lake Talik

Job No: 1CT022.004

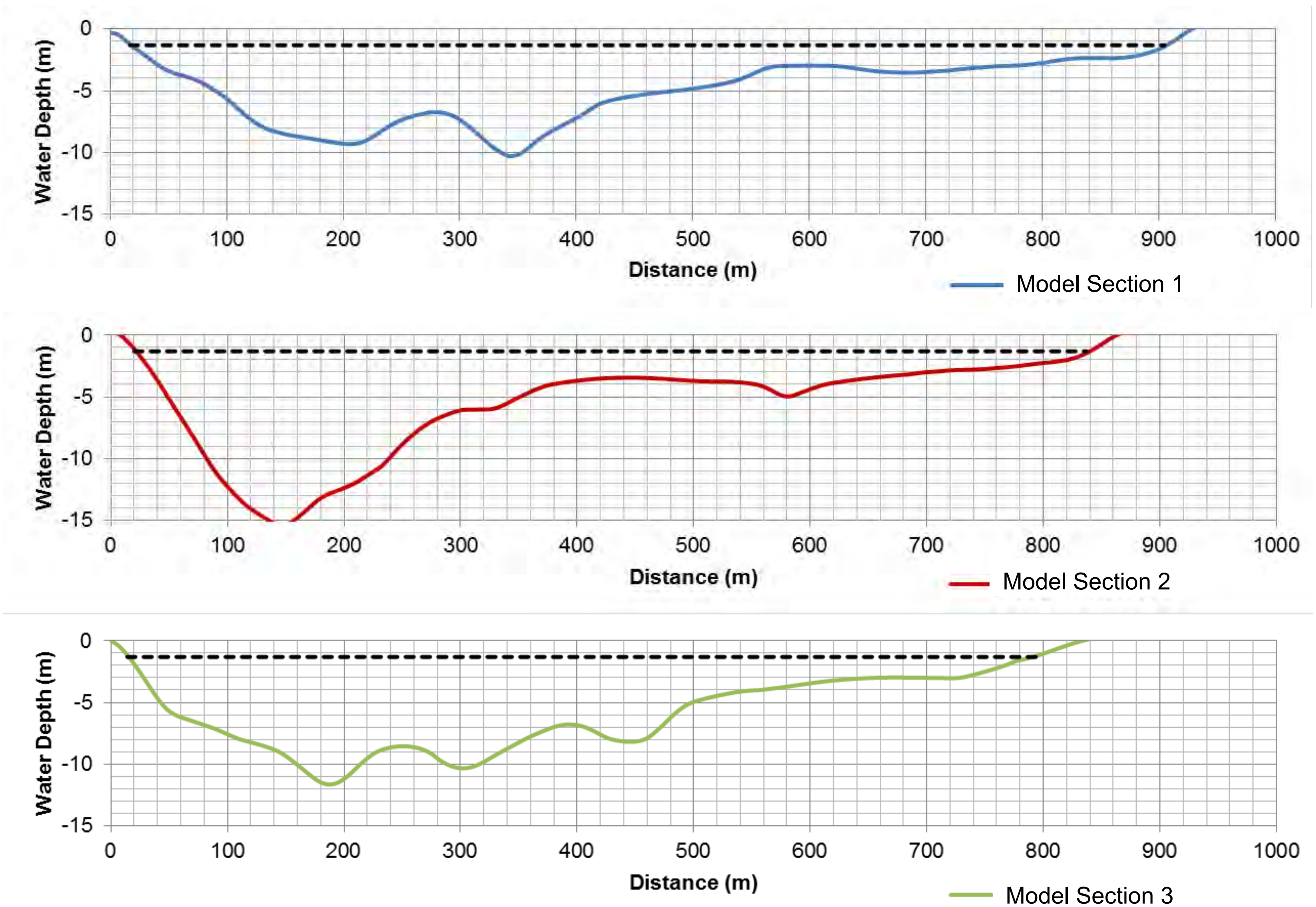
Filename: BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

Date: 2/12/2016

Approved: cws

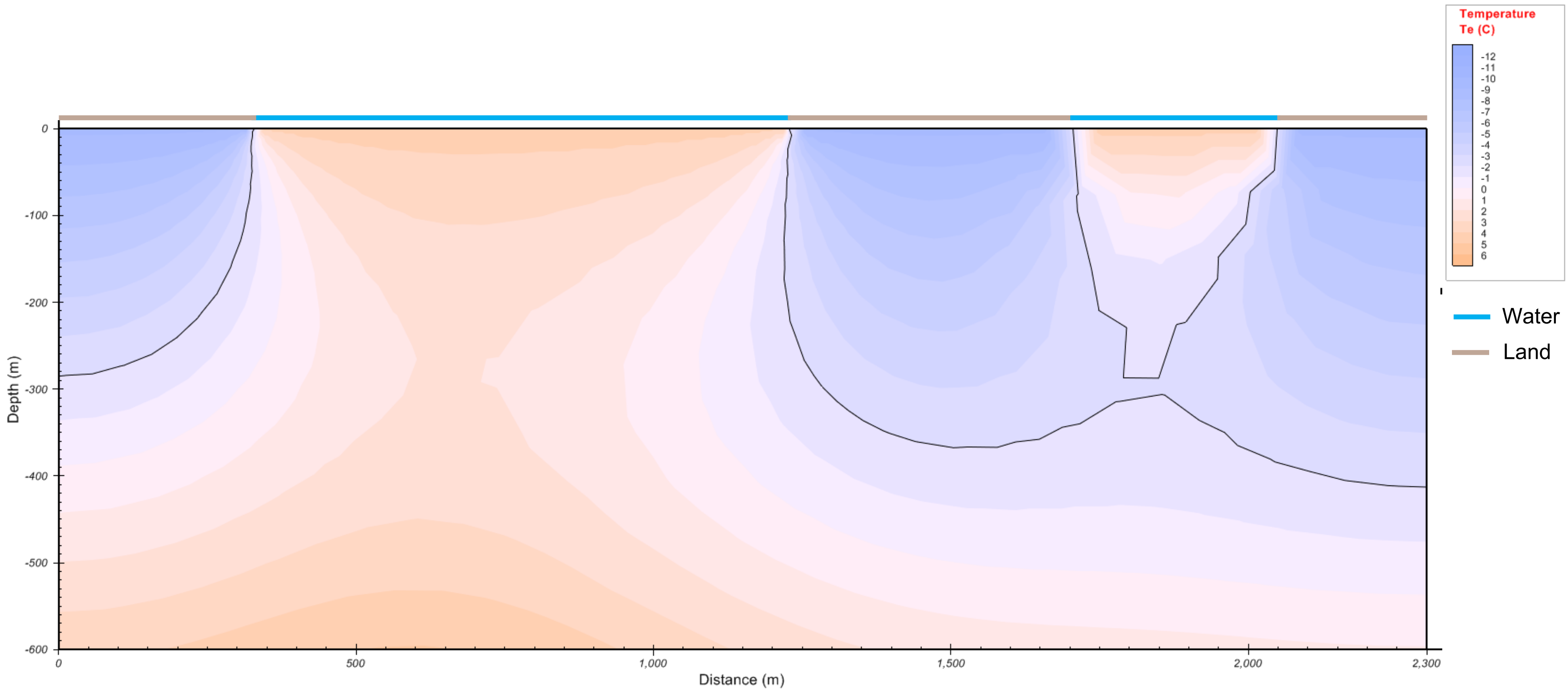
Figure: 8



Notes:

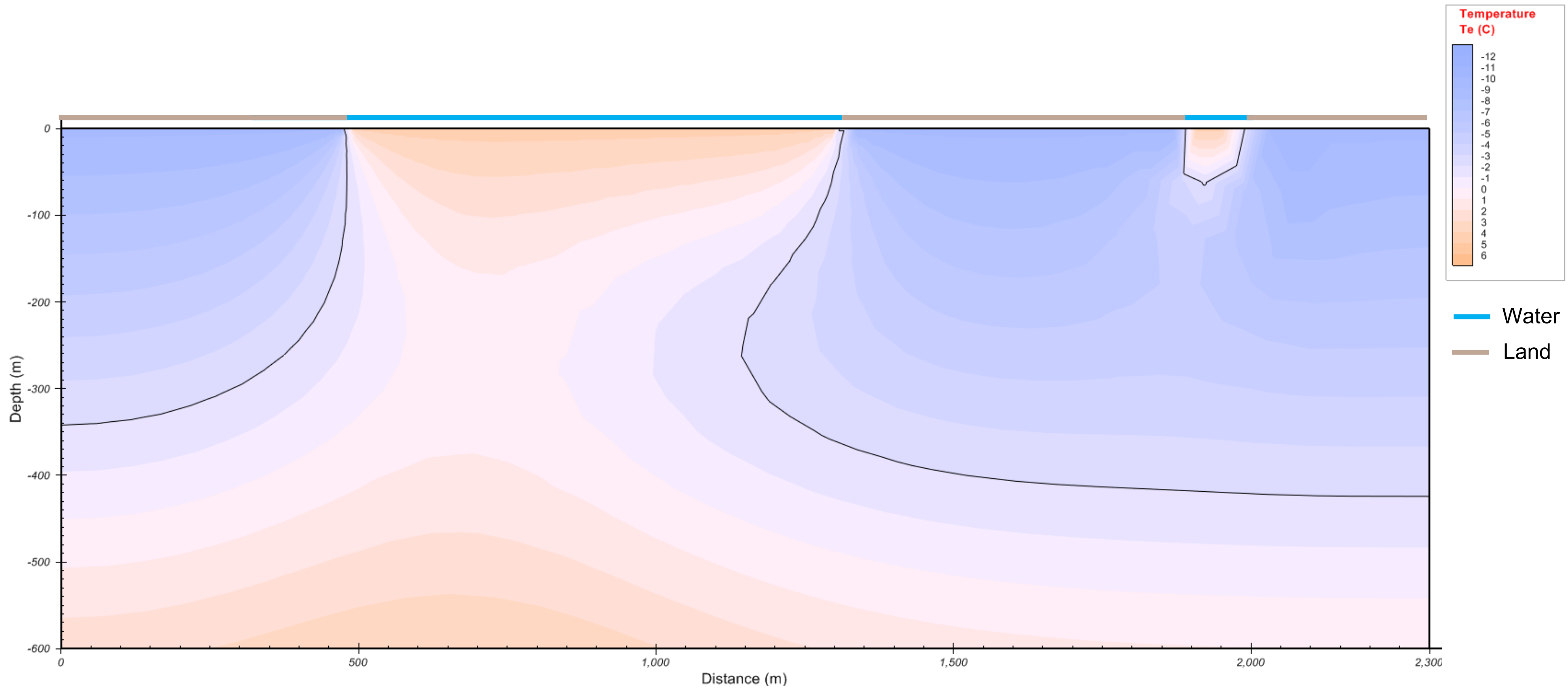
1. Solid line indicates water depth along model section
2. Section only shown for locations where ground temperature measurements extend beneath the lake
3. Dashed black line is two-thirds of the average late-winter ice thickness

srk consulting	MAC RESOURCES	Lake Talik Configuration
		Aimaokatalok Lake Water Bathymetry
Job No: 1CT022.004 Filename: WaterBathymetryModelTransects.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: 9



Notes:
1. -2°C isotherm indicated with solid black line
2. Model section extends from west to east

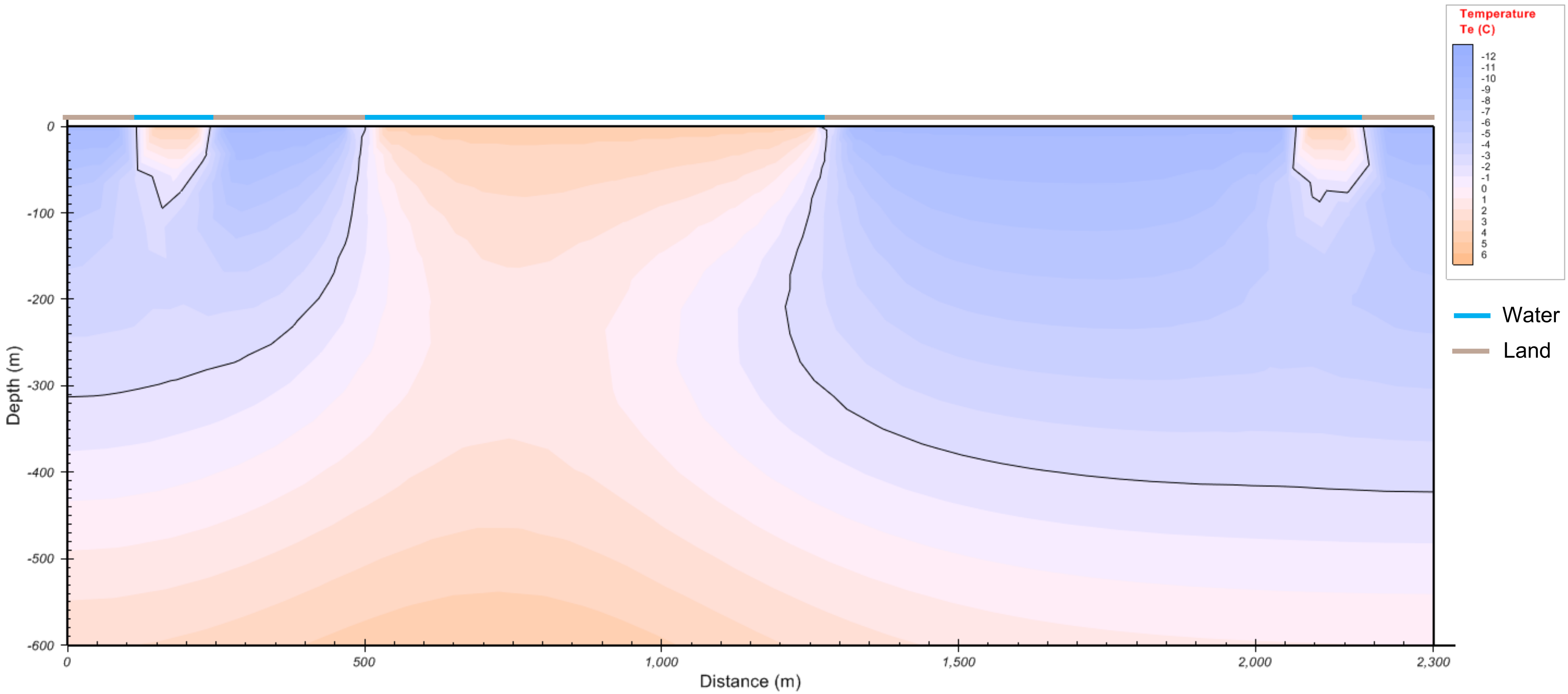
srk consulting	TMAC RESOURCES	Lake Talik Configuration
		Boston Mining Area – 2D Model Section T1
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: **10**



Notes:

1. -2°C isotherm indicated with solid black line
2. Model section extends from west to east

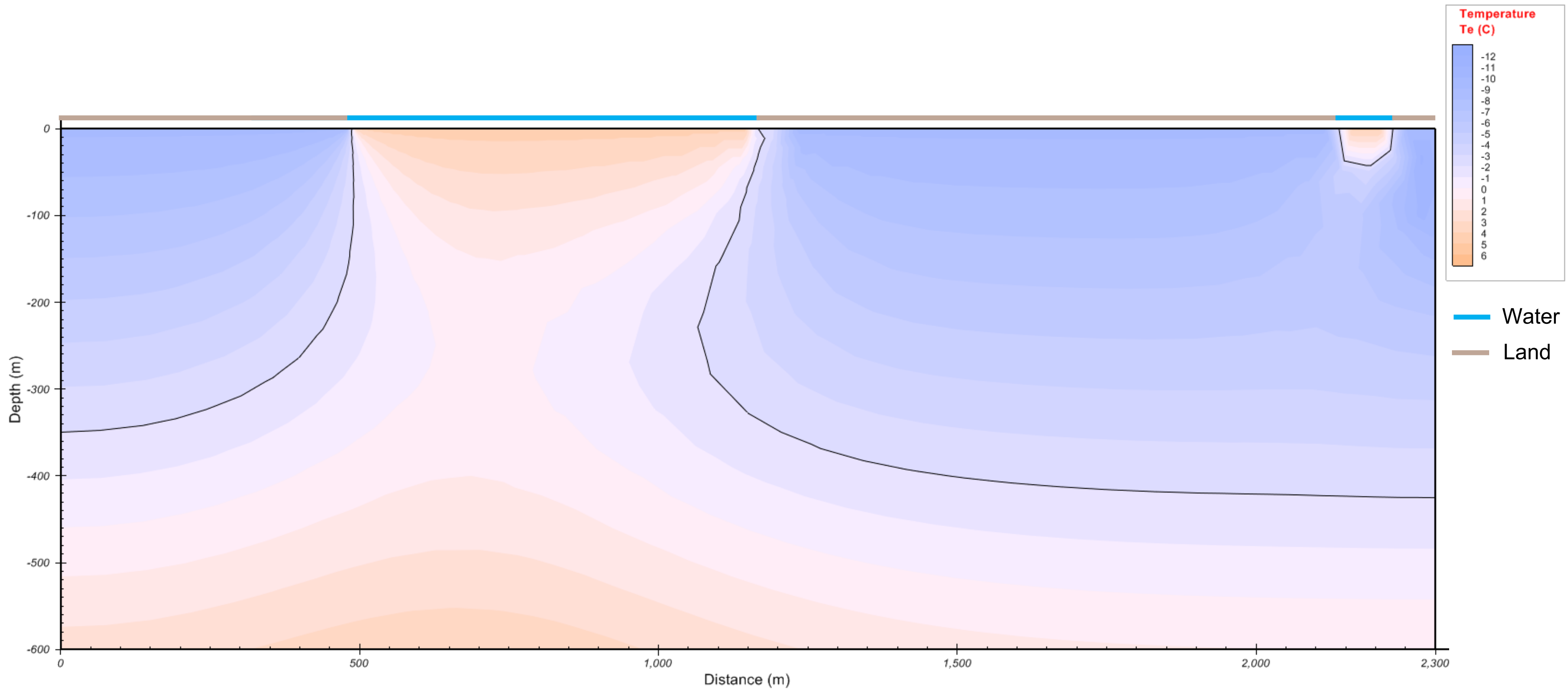
srk consulting	TMAC RESOURCES	Lake Talik Configuration		
		Boston Mining Area – 2D Model Section T2		
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016	Approved: cws	Figure: **11**



Notes:

1. -2°C isotherm indicated with solid black line
2. Model section extends from west to east

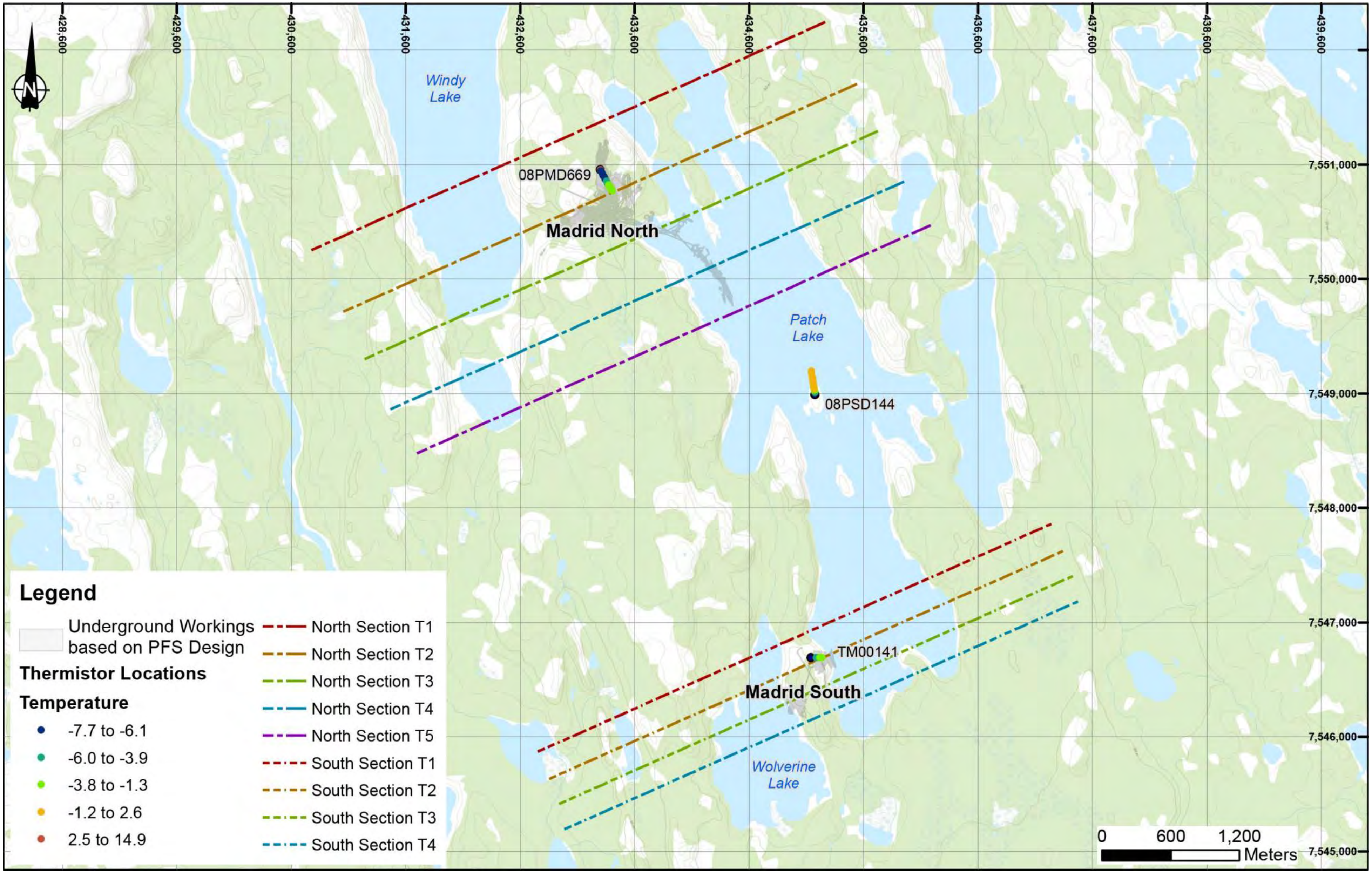
srk consulting	TMAC RESOURCES	Lake Talik Configuration **Boston Mining Area – 2D Model Section T3**
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016 / Approved: cws / Figure: **12**



Notes:

1. -2°C isotherm indicated with solid black line
2. Model section extends from west to east

srk consulting	TMAC RESOURCES	Lake Talik Configuration **Boston Mining Area – 2D Model Section T4**
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016 · Approved: cws · Figure: **13**



Notes:

1. Coordinate System: UTM NAD 83 Zone13
2. Basemap Credits: ERSI, DeLorme, TomTom, Intermap, NRCAN, GeoBase
3. Underground Workings based on PFS Design

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TMAC RESOURCES

Job No: 1CT022.004

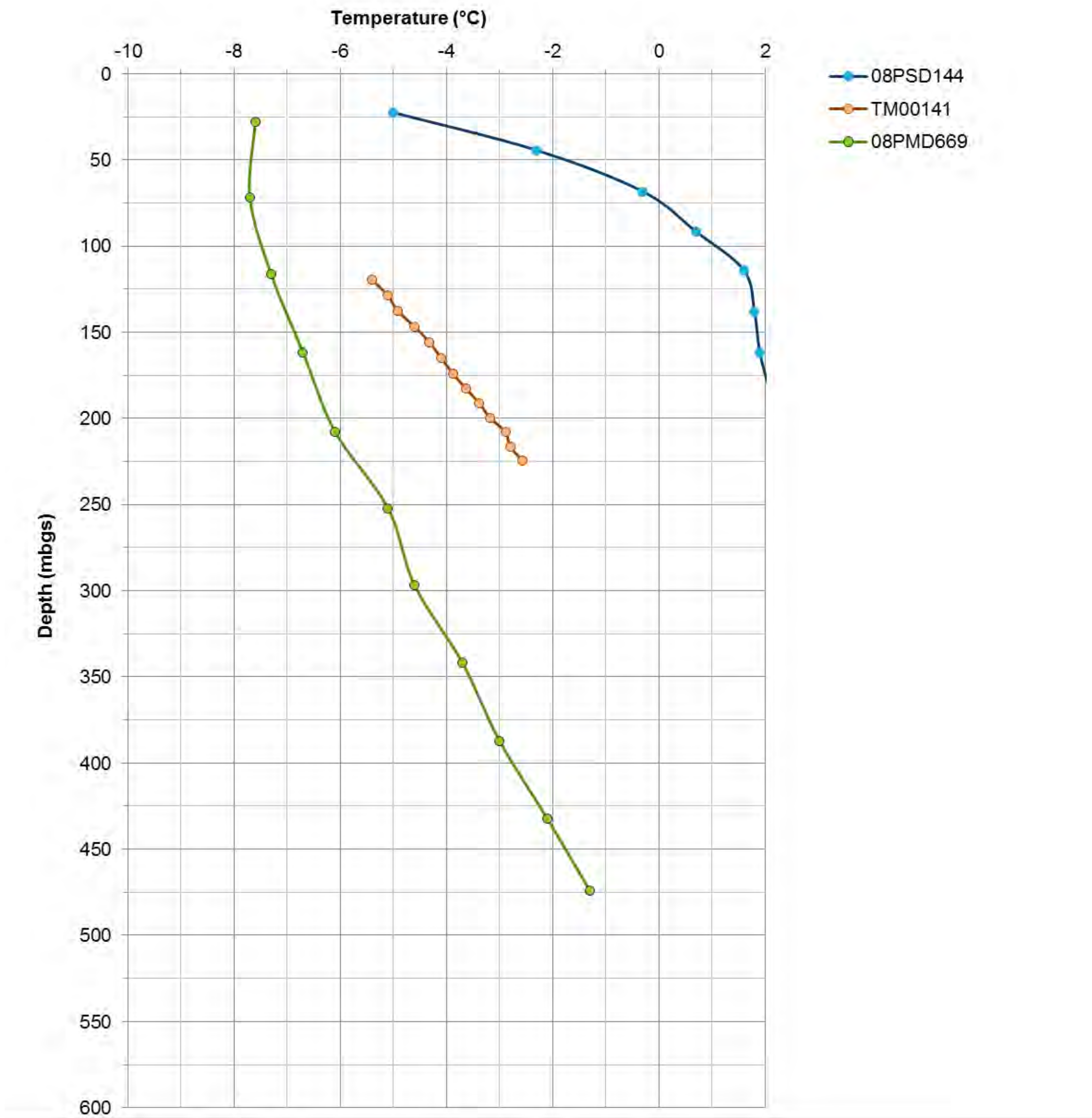
Filename: BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

Lake Talik Configuration

Madrid North and South Mining Areas

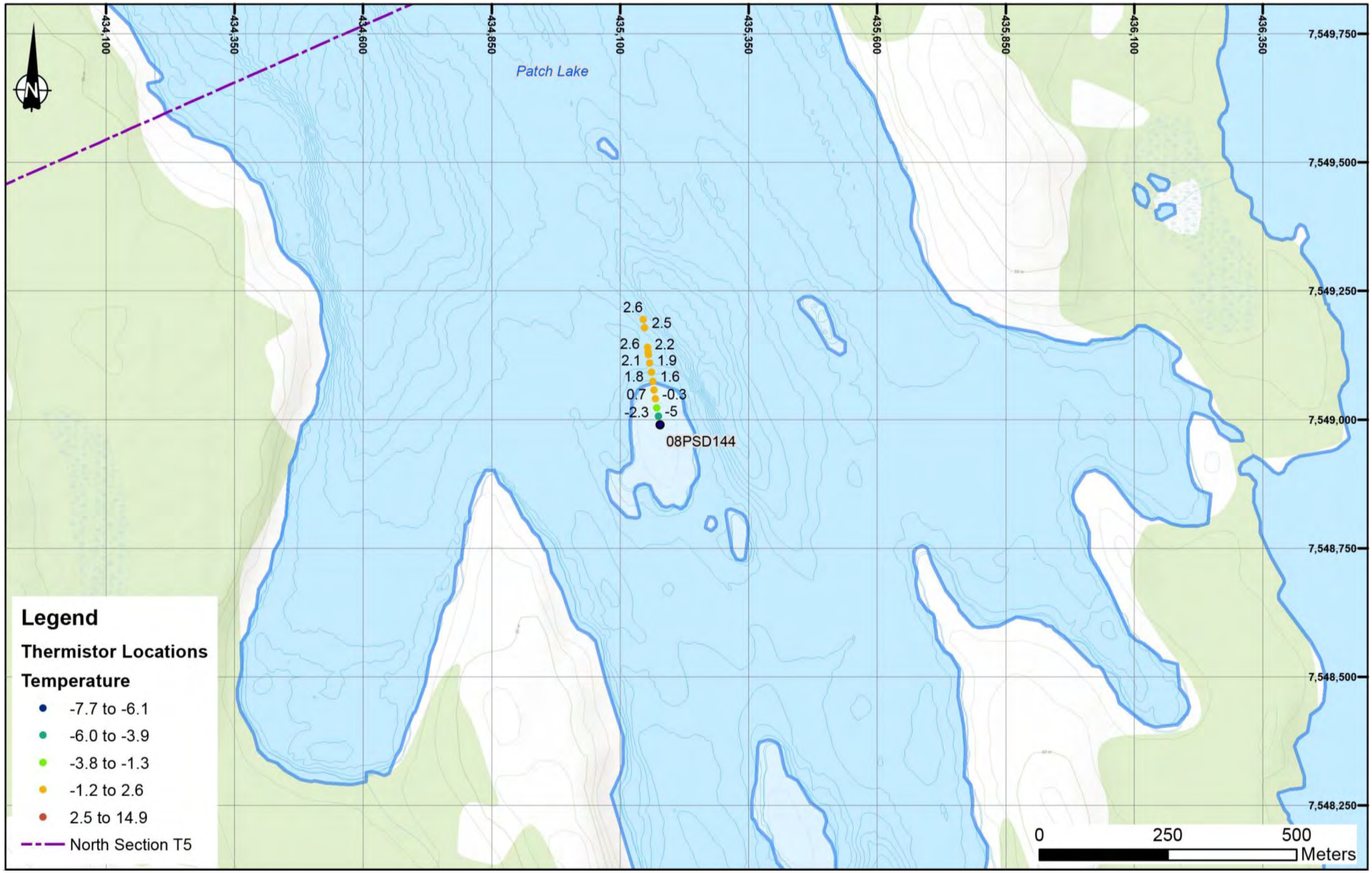
Date:	Approved:	Figure:
2/12/2016	cws	14



Notes:

1. Depth indicated as vertical metres below ground surface (mbgs)

srk consulting	TMAC RESOURCES	Lake Talik Configuration
		Deep Ground Temperatures – Madrid Mining Area
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016 | Approved: cws | Figure: **15**



Notes:

1. Coordinate System: UTM NAD 83 Zone13
2. Basemap Credits: ERSI, DeLorme, TomTom, Intermap, NRCAN, GeoBase
3. Underground Workings based on PFS Design

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TMAC RESOURCES

Job No: 1CT022.004

Filename: BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

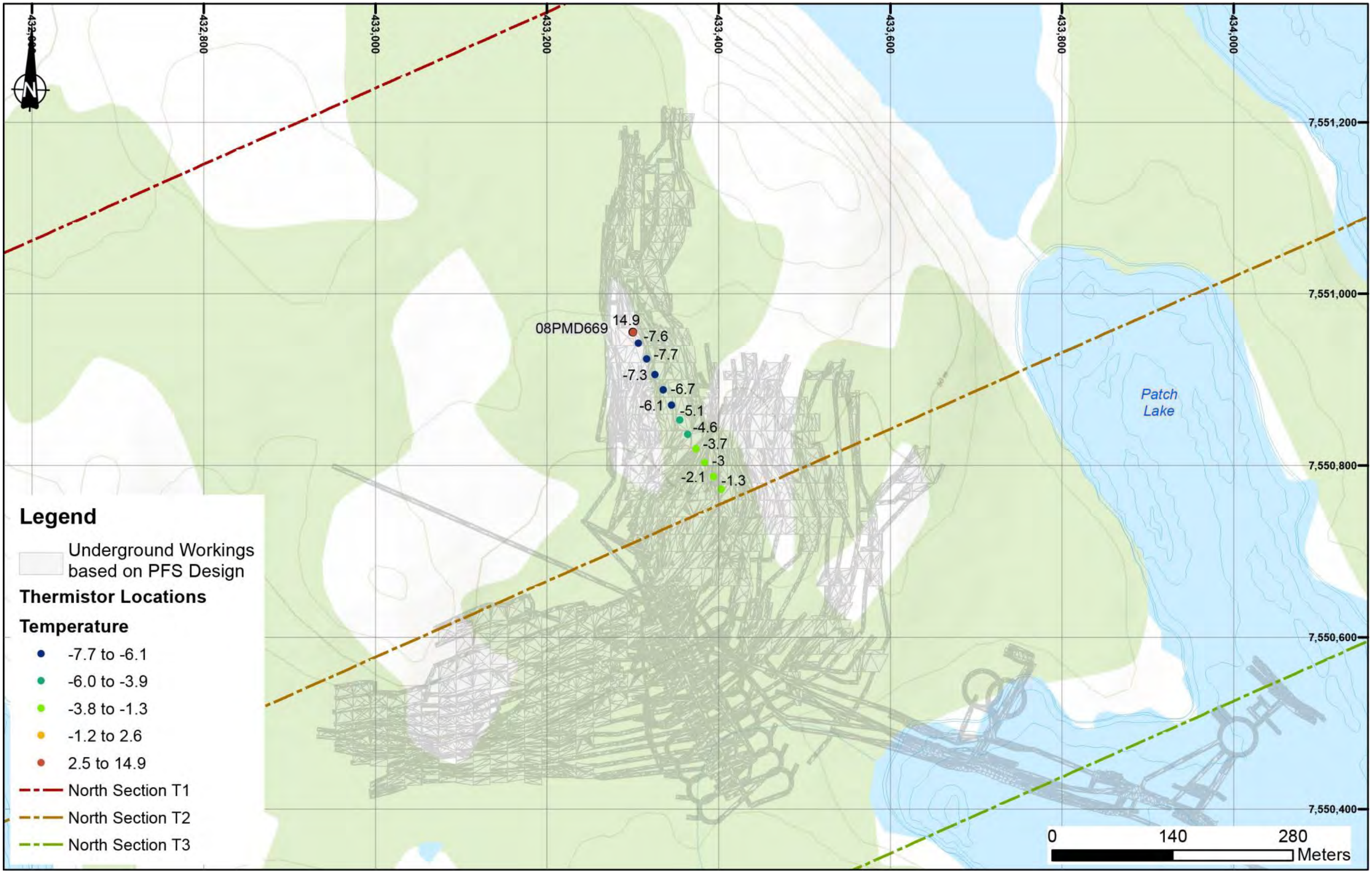
Lake Talik Configuration

Patch Island – Thermistor Site ID 08PSD144

Date: 2/12/2016

Approved: cws

Figure: 16



Notes:

1. Coordinate System: UTM NAD 83 Zone13
2. Basemap Credits: ERSI, DeLorme, TomTom, Intermap, NRCAN, GeoBase
3. Underground Workings based on PFS Design

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TMAC RESOURCES

Job No: 1CT022.004

Filename: BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

Lake Talik Configuration

Madrid North Mining Area – Thermistor Site ID 08PMD669

Date:	Approved:	Figure:
2/12/2016	cws	17

Notes:
1. Coordinate System: UTM NAD 83 Zone13
2. Basemap Credits: ERSI, DeLorme, TomTom, Intermap, NRCAN, GeoBase
3. Underground Workings based on PFS Design

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TMAC RESOURCES

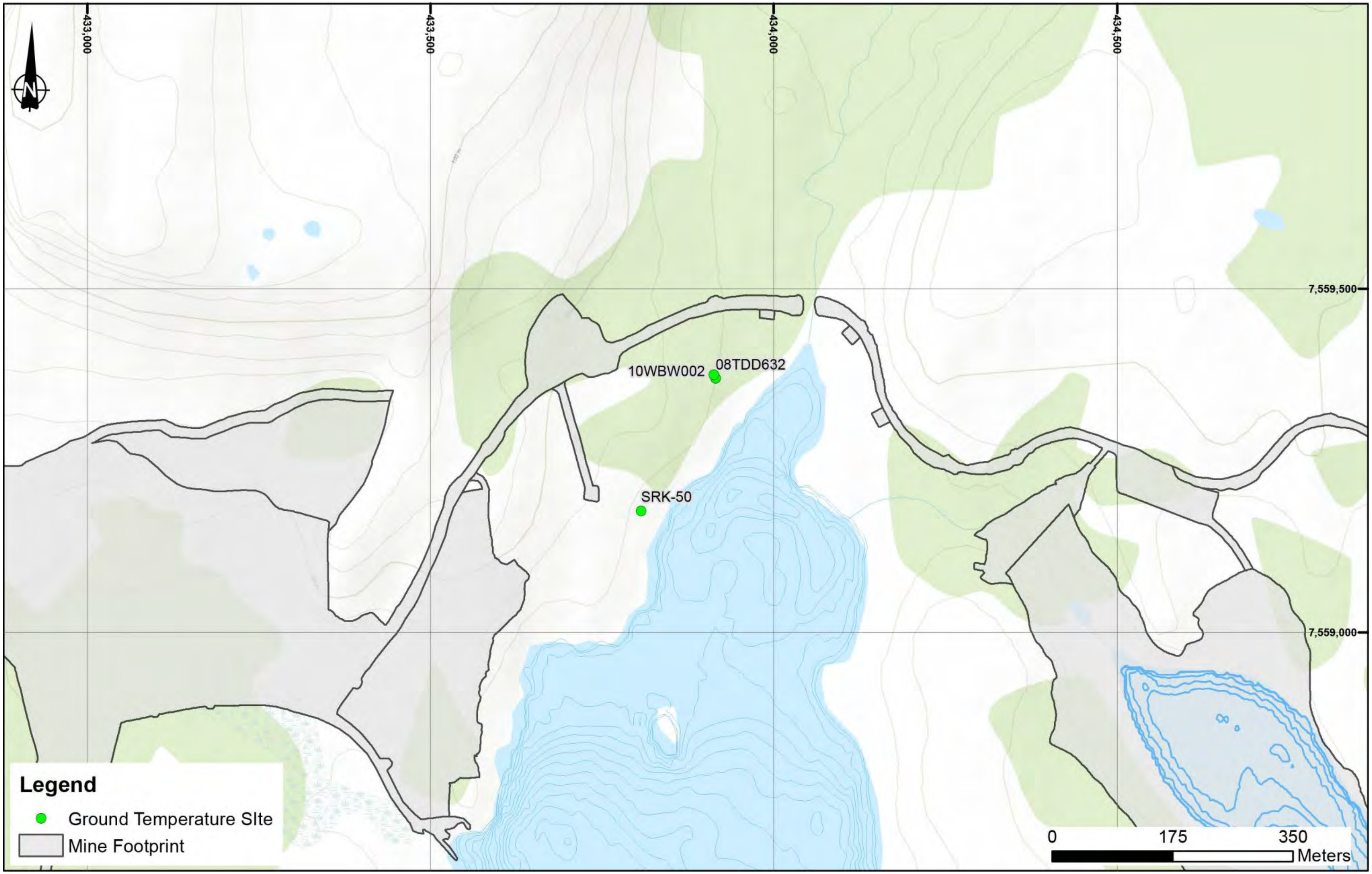
Lake Talik Configuration

Madrid South Mining Area – Thermistor Site ID TM00141

Job No: 1CT022.004
Filename: BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

Date: 2/12/2016
Approved: cws
Figure: 18



Notes:

1. Coordinate System: UTM NAD 83 Zone13
2. Basemap Credits: ERSI, DeLorme, TomTom, Intermap, NRCAN, GeoBase
3. Mine Footprint based on PFS Design

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TMAC RESOURCES

Job No: 1CT022.004

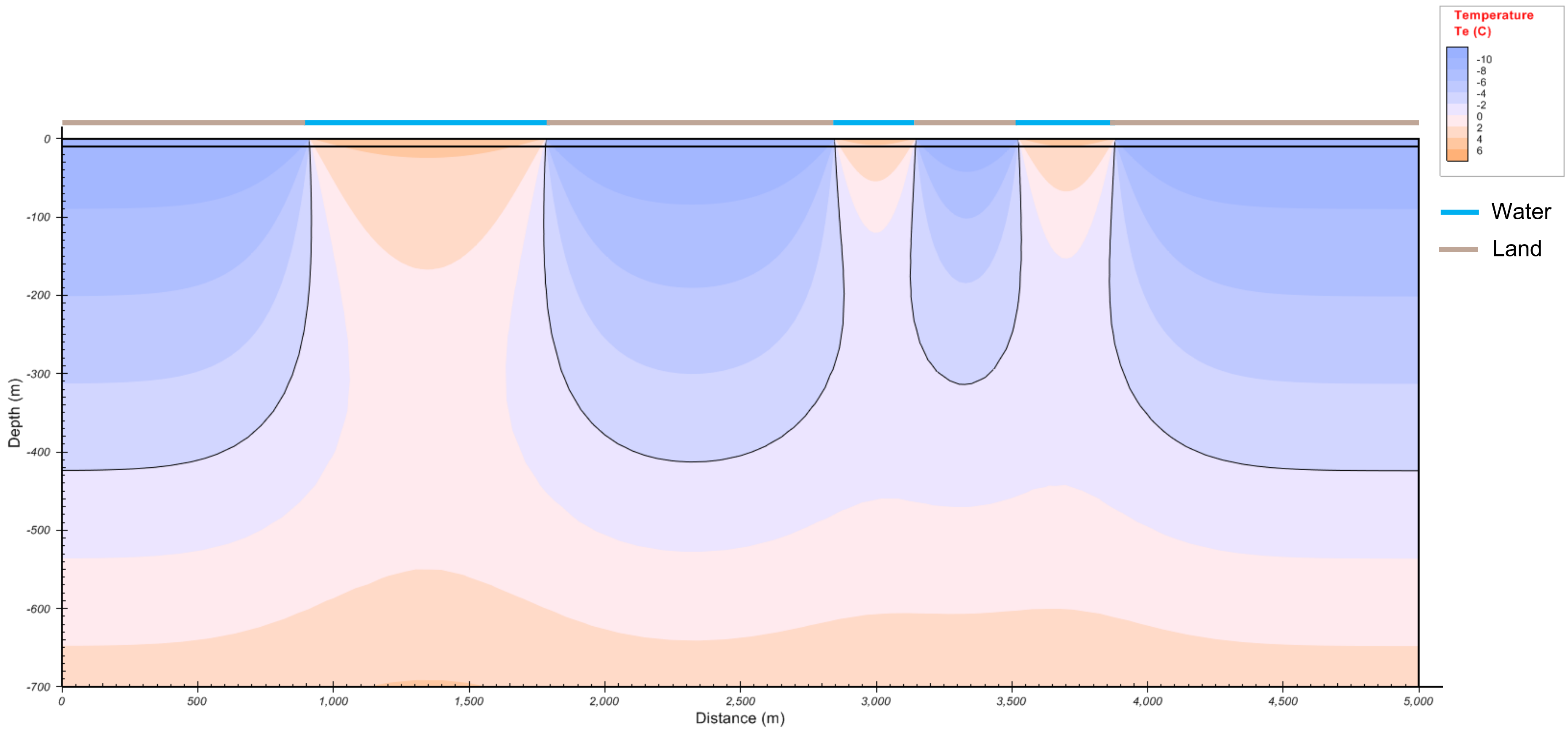
Filename: BostonDeepGroundTemperatures.pptx

HOPE BAY PROJECT

Lake Talik Configuration

Madrid South Mining Area – Thermistor Site ID TM00141

Date:	Approved:	Figure:
2/12/2016	cws	19



Notes:

1. -2°C isotherm indicated with solid black line
2. Model section extends from west to east

srk consulting	TMAC RESOURCES	Lake Talik Configuration
		Madrid North Mining Area – 2D Model Section T1
Job No: 1CT022.004 Filename: BostonDeepGroundTemperatures.pptx	HOPE BAY PROJECT	Date: 2/12/2016 | Approved: cws | Figure: **20**