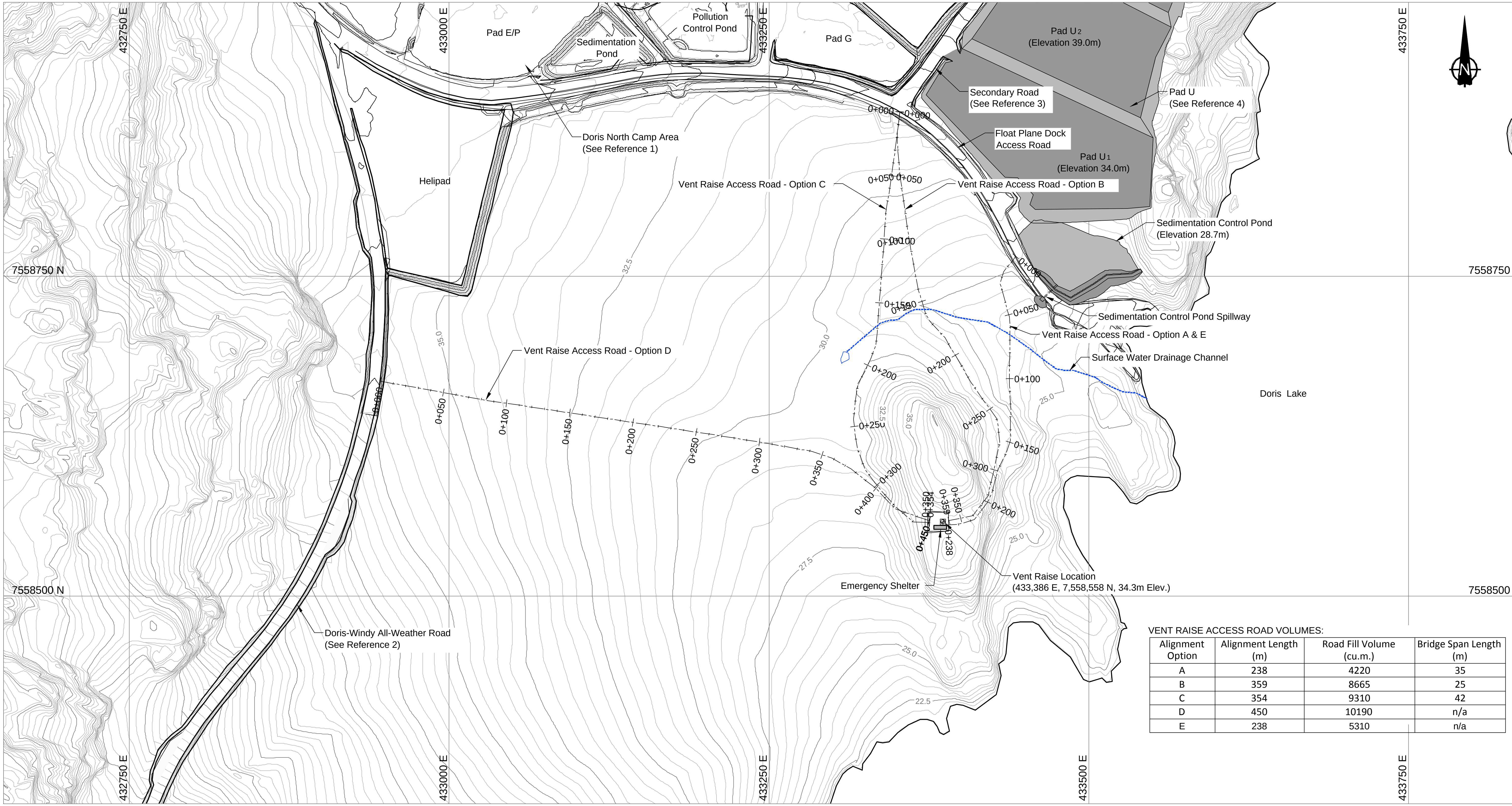


VENT RAISE ACCESS ROAD VOLUMES:

| Alignment Option | Alignment Length (m) | Road Fill Volume (cu.m.) | Bridge Span Length (m) |
|---|---|---|---|
| A | 238 | 4220 | 35 |
| B | 359 | 8665 | 25 |
| C | 354 | 9310 | 42 |
| D | 450 | 10190 | n/a |
| E | 238 | 5310 | n/a |

## REFERENCES


1. SRK Consulting (Canada) Inc., 2012. Engineering Drawings for the Doris North Camp Area, Doris North Project, Nunavut, Canada. Revision AB1. As-Built Drawings Prepared for Hope Bay Mining Limited. Project Number 1CH008.033. May 18, 2012
2. SRK Consulting (Canada) Inc., 2012. Engineering Drawings for the Doris-Windy All-Weather Road, Doris Infrastructure Project, Nunavut, Canada. Revision AB1. As-Built Drawings Prepared for Hope Bay Mining Ltd. Project Number: 1CH008.033/.058. May 11, 2012
3. Engineering Drawings for the Doris North Secondary Road, Doris North Project, Nunavut, Canada. Revision AB. As-Built Drawings prepared for Hope Bay Mining Limited. Project Number 1CH008.033/058. May 14, 2012
4. SRK Consulting (Canada) Inc., 2015. Doris North Expanded Laydown Area (Pad U). Technical Memorandum. Prepared for TMAC Resources Inc.. Project Number: 1CT022.002.200.1400. May 29, 2015.


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TMAC RESOURCES

SRK JOB NO.: 1CT022.002.200.1100

FILE NAME: 1CT022.001_Doris Vent Raise Options ver2.dwg

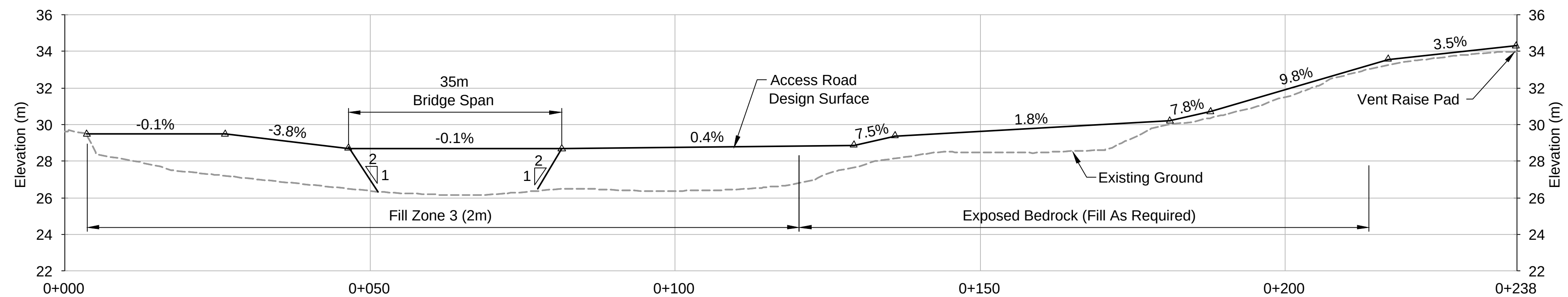
HOPE BAY PROJECT

Doris Connector Vent Raise

Doris Connector Vent Raise Access Road Options

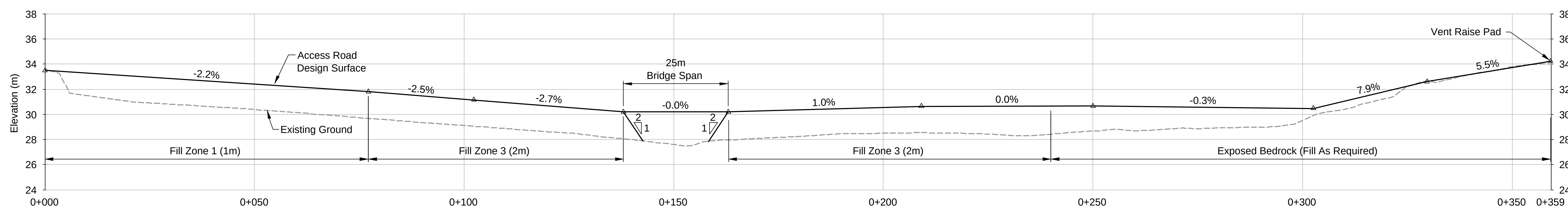
DATE: May 29, 2015 | APPROVED: LW | FIGURE: 1

C:\01_SITES\Hope Bay\Doris Vent Raise\1CT022.001_Doris Vent Raise Options ver2.dwg




**VENT RAISE ACCESS ROAD - OPTION A PROFILE**

0 5 10 15 20 25
Horizontal Scale in Metres
Vertical Exaggeration 3X




**VENT RAISE ACCESS ROAD - OPTION B PROFILE**

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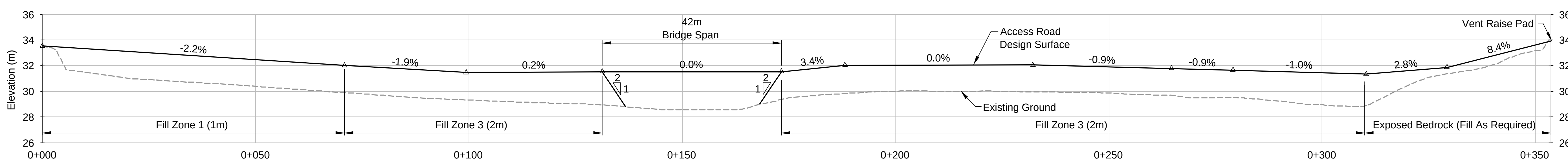
Horizontal Scale in Metres
Vertical Exaggeration 3X

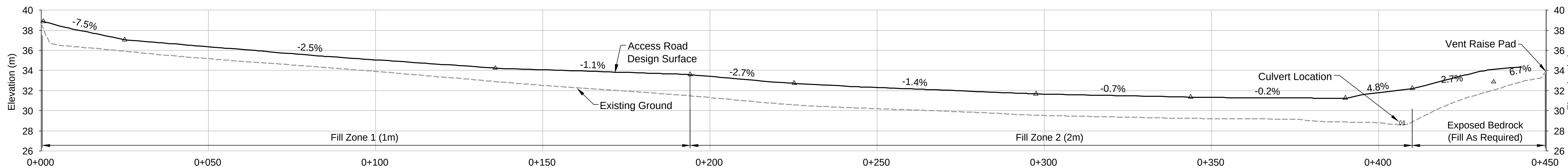



**VENT RAISE ACCESS ROAD - OPTION C PROFILE**

0 5 10 15 20 25
Horizontal Scale in Metres
Vertical Exaggeration 3X

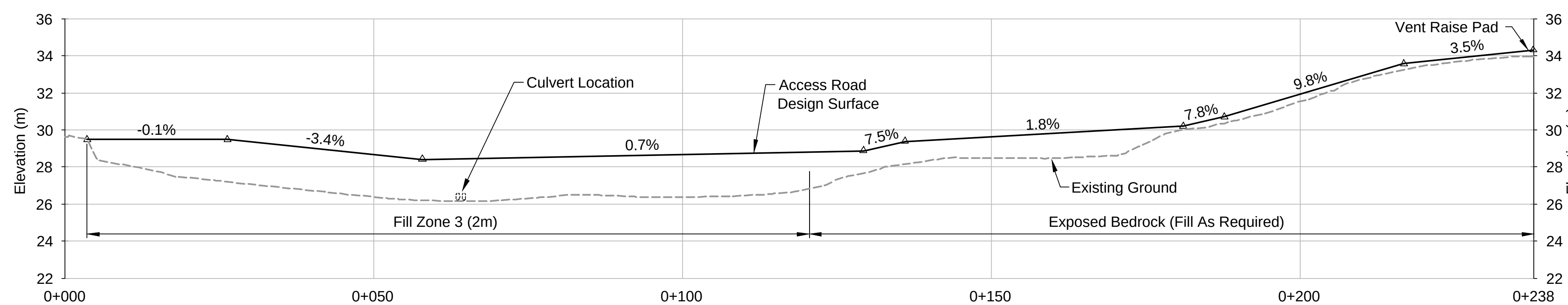
C:\01_SITES\Hope Bay\Doris Vent Raise\1CT022.001_Doris Vent Raise Options ver2.dwg

| srk consulting | TMAC RESOURCES | Doris Connector Vent Raise |
|---|---|---|
| | | Vent Raise Access Road Alignment Options (1 of 2) |
| SRK JOB NO.: 1CT022.002.200.1100 | HOPE BAY PROJECT | DATE: May 29, 2015 |
| FILE NAME: 1CT022.001_Doris Vent Raise Options ver2.dwg | | APPROVED: LW |
| | | FIGURE: 2 |




**VENT RAISE ACCESS ROAD - OPTION D PROFILE**

0 5 10 15 20 25
Horizontal Scale in Metres
Vertical Exaggeration 3X




**VENT RAISE ACCESS ROAD - OPTION E PROFILE**

0 5 10 15 20 25
Horizontal Scale in Metres
Vertical Exaggeration 3X

| srk consulting | TMAC RESOURCES | Doris Connector Vent Raise |
|---|---|---|
| | | Vent Raise Access Road Alignment Options (2 of 2) |
| SRK JOB NO.: 1CT022.002.200.1100 | HOPE BAY PROJECT | DATE: May 29, 2015 |
| FILE NAME: 1CT022.001_Doris Vent Raise Options ver2.dwg | | APPROVED: LW |
| | | FIGURE: 3 |

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# Attachment 1

## Engineering Drawings for the Doris Connector Vent Raise

# Engineering Drawings for the Doris Connector Vent Raise, Doris North Project, Nunavut, Canada

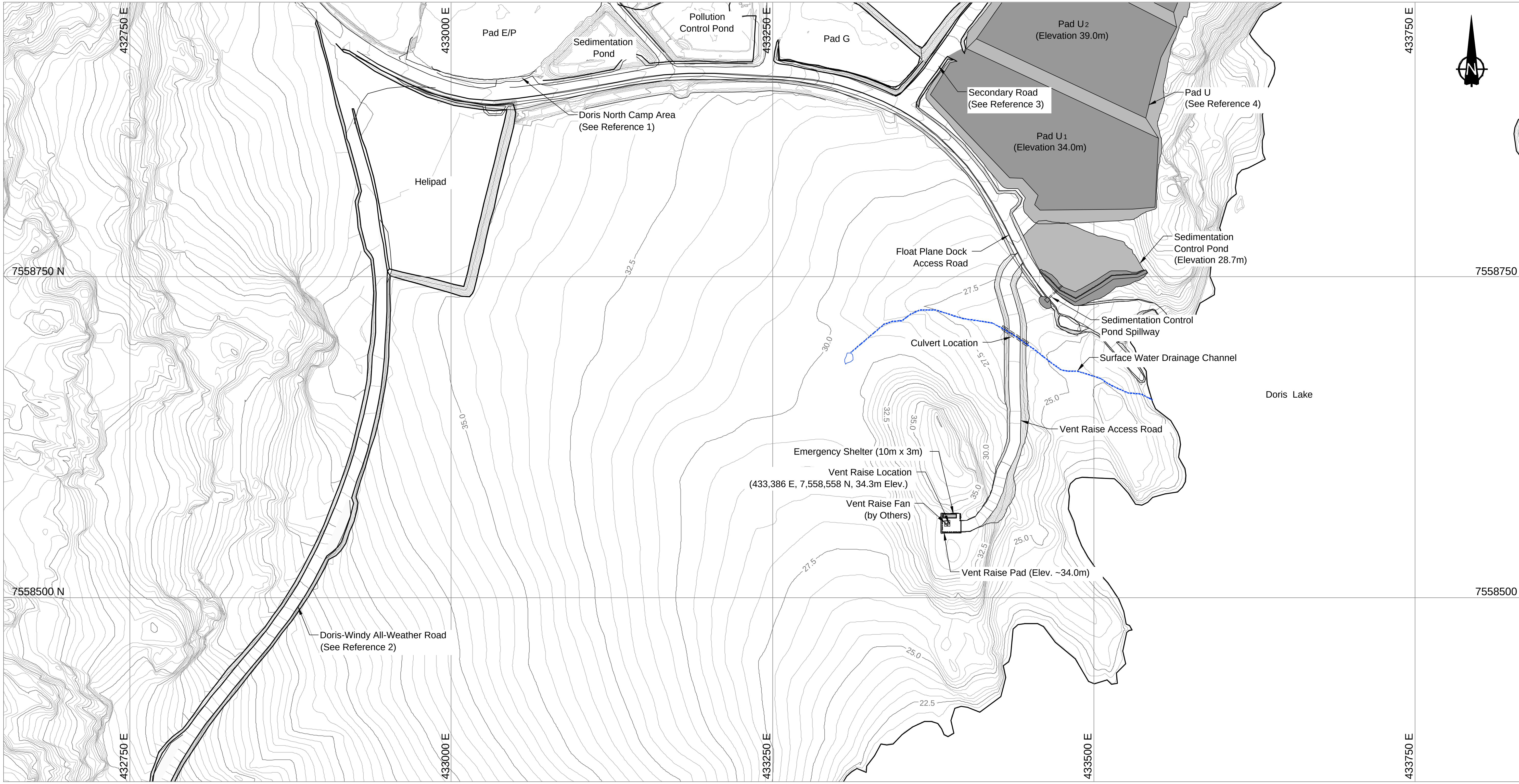
## ACTIVE DRAWING STATUS

| DWG NUMBER | DRAWING TITLE | REVISION | DATE | STATUS |
|---|---|---|---|---|
| DCVR-00 | Engineering Drawings for the Doris Connector Vent Raise, Doris North Project, Nunavut, Canada | B | May 29, 2015 | Issued For Discussion |
| DCVR-01 | General Arrangement | B | May 29, 2015 | Issued For Discussion |
| DCVR-02 | Doris Connector Vent Raise Plan and Profile | B | May 29, 2015 | Issued For Discussion |
| DCVR-03 | Doris Connector Vent Raise Pad Sections | B | May 29, 2015 | Issued For Discussion |
| DCVR-04 | Typical Sections and Details | B | May 29, 2015 | Issued For Discussion |
| DCVR-05 | Material List and Quantity Estimates | B | May 29, 2015 | Issued For Discussion |

TMAC RESOURCES

srk consulting

PROJECT NO: 1CT022.002.200.1100
Revision B
May 29, 2015
Drawing DCVR-00




## NOTES

1. Topographic contour data for the terrain model were provided by Hope Bay Mining, and is based on 2007 Aerial Photography. Contour intervals are 0.5m.
2. The co-ordinate system is UTM NAD 83, Zone 13.
3. All dimensions are in metric units, unless specifically mentioned.
4. Notes in this drawing apply to all other active drawings.

## REFERENCES

1) SRK Consulting (Canada) Inc., 2012. Engineering Drawings for the Doris North Camp Area, Doris North Project, Nunavut, Canada. Revision AB1. As-Built Drawings Prepared for Hope Bay Mining Limited. Project Number 1CH008.033. May 18, 2012

2) SRK Consulting (Canada) Inc., 2012. Engineering Drawings for the Doris-Windy All-Weather Road, Doris Infrastructure Project, Nunavut, Canada. Revision AB1. As-Built Drawings Prepared for Hope Bay Mining Ltd. Project Number: 1CH008.033/.058. May 11, 2012

3) Engineering Drawings for the Doris North Secondary Road, Doris North Project, Nunavut, Canada. Revision AB. As-Built Drawings prepared for Hope Bay Mining Limited. Project Number 1CH008.033/058. May 14, 2012

4. SRK Consulting (Canada) Inc., 2015. Doris North Expanded Laydown Area (Pad U). Technical Memorandum. Prepared for TMAC Resources Inc.. Project Number: 1CT022.002.200.1400. May 29, 2015.

0 10 20 30 40 50
Scale in Metres

| NO. | DESCRIPTION | CHK'D | APP'D | DATE |
|---|---|---|---|---|
| B | Issued for Discussion | LW | EMR | 29May15 |
| A | Issued for Discussion | LW | EMR | 14Mar14 |

REVISIONS

| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE |
|---|---|---|---|

REFERENCE DRAWINGS

PROFESSIONAL ENGINEERS STAMP

srk consulting

DESIGN: LW | DRAWN: NV | REVIEWED: EMR
CHECKED: LW/EMR | APPROVED: EMR | DATE: May 29, 2015
FILE NAME: 1CT022.001_Doris Vent Raise RevB.dwg

TMAC RESOURCES

HOPE BAY PROJECT

SRK JOB NO.: 1CT022.002.200.1100

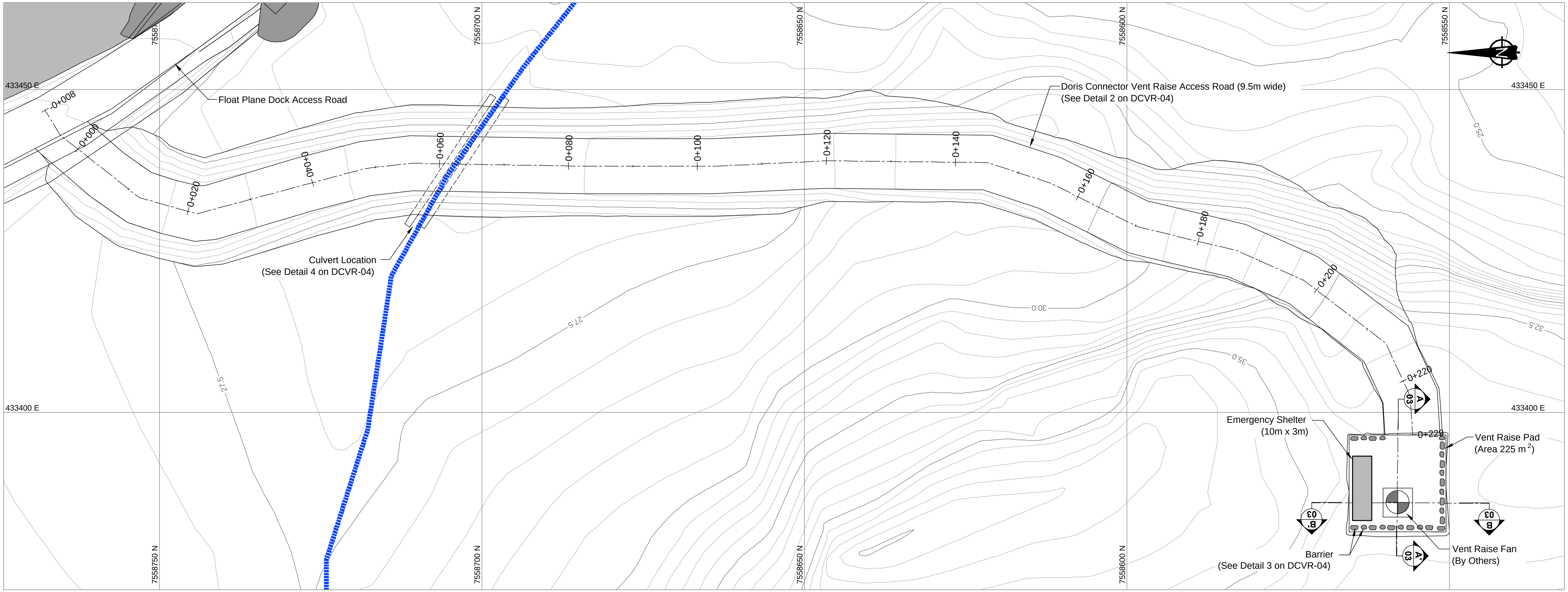
Doris Connector Vent Raise

DRAWING TITLE:

General Arrangement

DRAWING NO.: DCVR-01 | SHEET 2 OF 6 | REVISION NO. B

C:\01_SITES\Hope Bay\Doris Vent Raise\1CT022.001_Doris Vent Raise RevB.dwg




## VENT RAISE ACCESS ROAD AND PAD - PLAN VIEW

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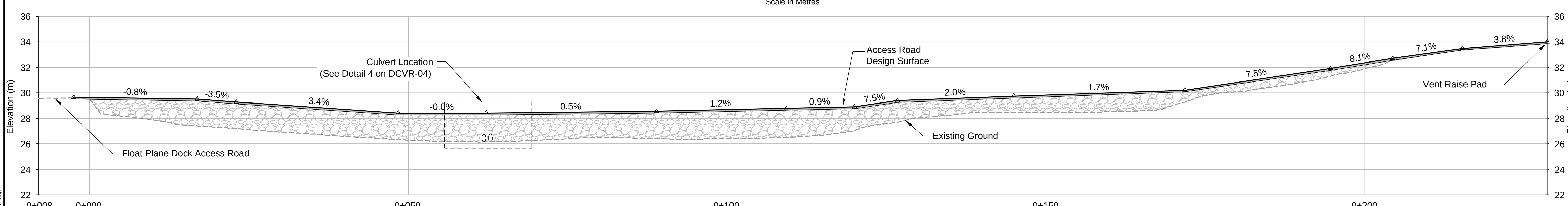
Scale in Metres




## VENT RAISE ACCESS ROAD - PROFILE

0 5 10 15 20 25
Horizontal Scale in Metres
Vertical Exaggeration 3X

## LEGEND

- Surfacing Material
- Run of Quarry Material
- Existing ground surface
- Surface Water Drainage Channel

| NO. | DESCRIPTION | CHK'D | APP'D | DATE |
|---|---|---|---|---|
| B | Issued for Discussion | LW | EMR | 29May15 |
| A | Issued for Discussion | LW | EMR | 14Mar14 |

REFERENCE DRAWINGS: DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE

REVISIONS

PROFESSIONAL ENGINEERS STAMP

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DESIGN: LW | DRAWN: NV | REVIEWED: EMR
CHECKED: LW/EMR | APPROVED: EMR | DATE: May 29, 2015

FILE NAME: 1CT022.001_Doris Vent Raise RevB.dwg

TMAC RESOURCES

HOPE BAY PROJECT

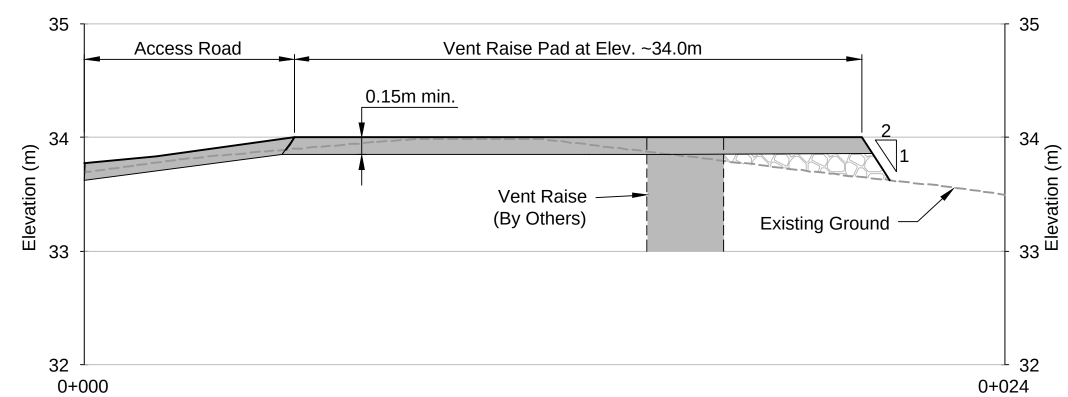
SRK JOB NO.: 1CT022.002.200.1100

Doris Connector Vent Raise

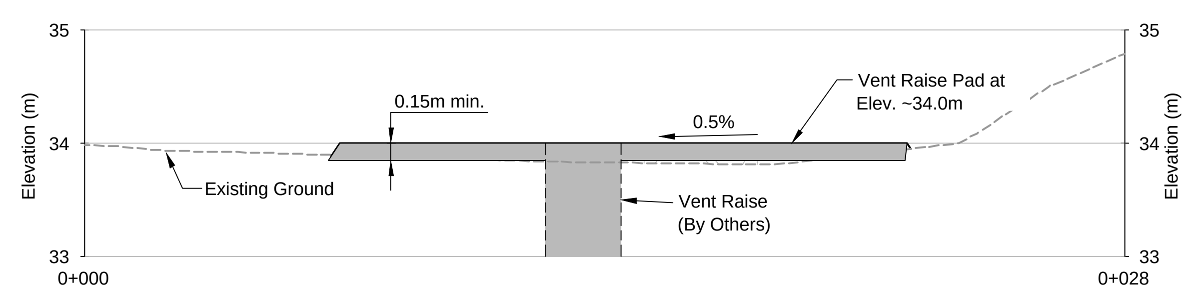
DRAWING TITLE:
Doris Connector Vent Raise
Plan and Profile

DRAWING NO. DCVR-02 | SHEET 3 OF 6 | REVISION NO. B

C:\01_SITES\Hope Bay\Doris Vent Raise\1CT022.001_Doris Vent Raise RevB.dwg




A
02
**SECTION A**
0 1 2 3 4 5
Horizontal Scale in Metres
Vertical Exaggeration X3




B
02
**SECTION B**
0 1 2 3 4 5
Horizontal Scale in Metres
Vertical Exaggeration X3

## LEGEND

- – – – Existing ground surface
- Surfacing Material
- Run of Quarry Material

## NOTES

1. All dimensions in metres unless noted otherwise.
2. Where the thickness of the pads is greater than 3.0m allow for the placement of barriers.
3. The barriers are to consist of boulders larger than 1m in diameter, jersey-barriers (1.82 long X 1.37m high X 0.61m wide) or a rock fill berm 0.5m high. Maximum spacing between barriers is 3.3m.
4. Extents of bedrock outcrop are based on 2007 aerial orthophoto and ground inspection. To ensure layouts match site conditions exact extents of bedrock outcrops are to be surveyed prior to any construction activities.
5. Notes in this drawing apply to all other active drawings.

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| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE | NO. | DESCRIPTION | CHK'D | APP'D | DATE |
|---|---|---|---|---|---|---|---|---|
| | | | | B | Issued for Discussion | LW | EMR | 29May15 |
| | | | | A | Issued for Discussion | LW | EMR | 14Mar14 |

REFERENCE DRAWINGS — REVISIONS

PROFESSIONAL ENGINEERS STAMP

srk consulting

TMAC RESOURCES

| DESIGN: LW | DRAWN: NV | REVIEWED: EMR |
|---|---|---|
| CHECKED: LW/EMR | APPROVED: EMR | DATE: May 29, 2015 |

FILE NAME: 1CT022.001_Doris Vent Raise RevB.dwg

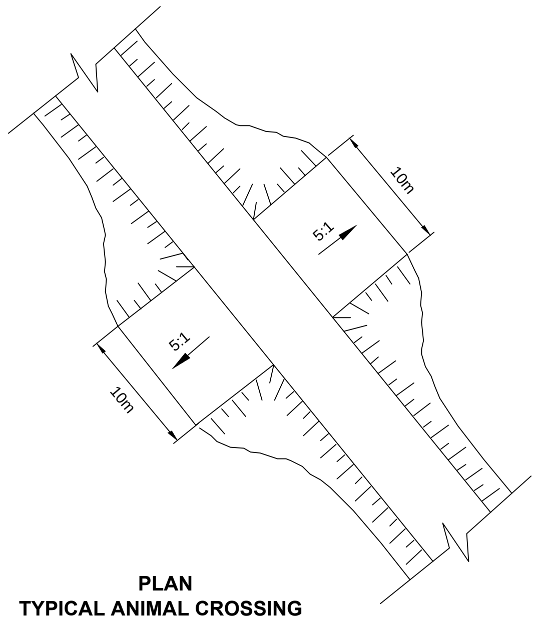
HOPE BAY PROJECT

SRK JOB NO.: 1CT022.002.200.1100

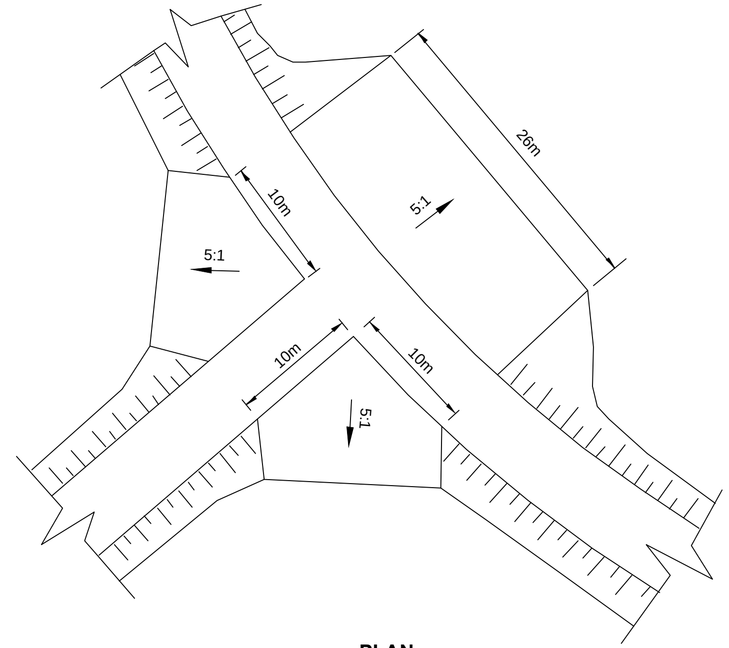
Doris Connector Vent Raise

DRAWING TITLE: Doris Connector Vent Raise Pad Sections

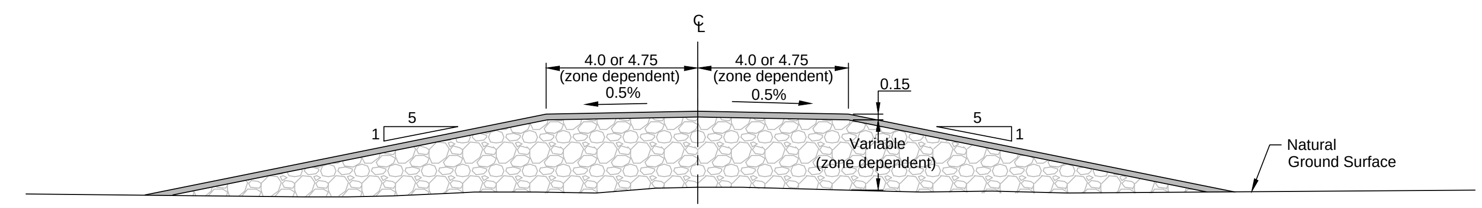
DRAWING NO.: DCVR-03 | SHEET 4 OF 6 | REVISION NO.: B




**PLAN**
**TYPICAL ANIMAL CROSSING**
NTS




**PLAN**
**TYPICAL ANIMAL CROSSING AT ROAD JUNCTION**
NTS



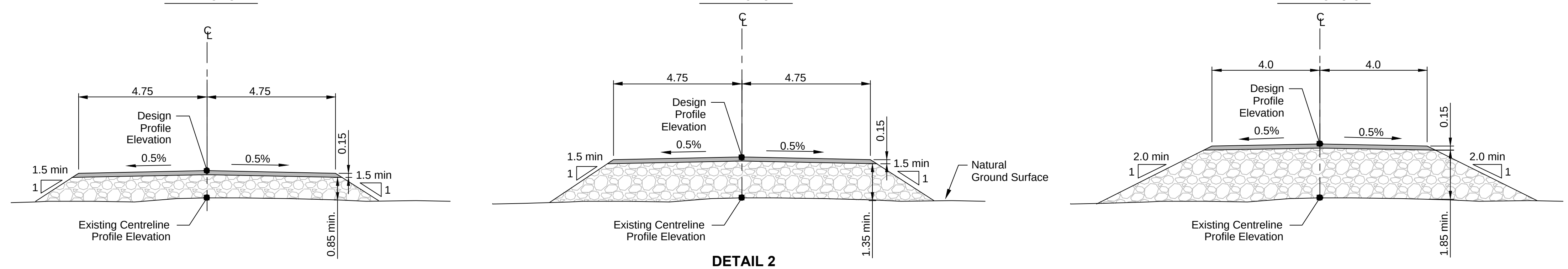

**DETAIL 1**
**1 TYPICAL ANIMAL CROSSING SECTION**

## LEGEND

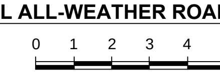
- Surfacing Material
- Run of Quarry Material

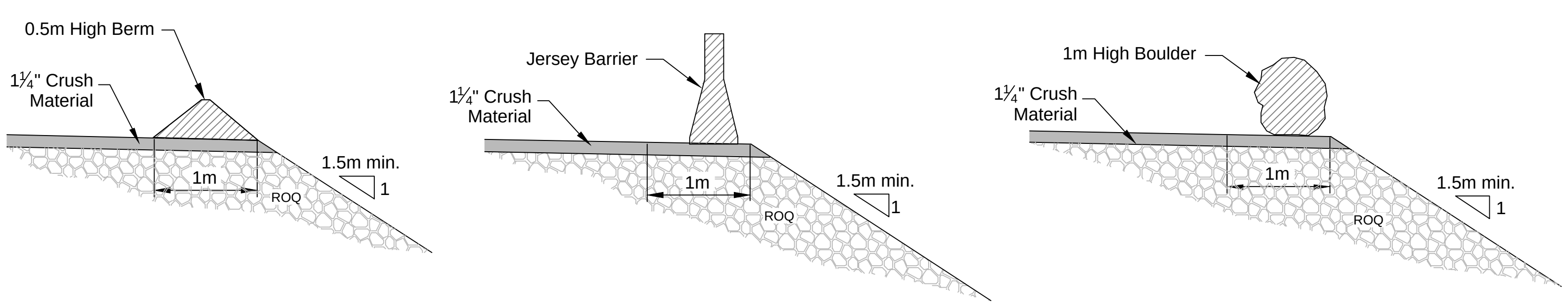
## NOTES

1. All dimensions in metres unless noted otherwise.
2. Minimum design thickness must be maintained for all sections of the all-weather road including turnouts.
3. Locations for animal crossings will be identified by Land Owner and Elders once road construction is completed.
4. Notes in this drawing apply to all other active drawings.

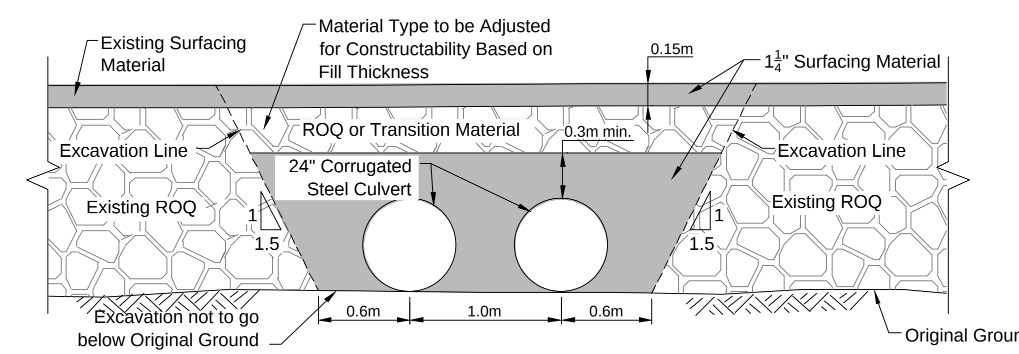



**DETAIL 2**
**2 TYPICAL ALL-WEATHER ROAD SECTION**




**DETAIL 3**
**3 TYPICAL BERM BARRIER OPTIONS**
NTS




**DETAIL 4**
**4 TYPICAL CROSS SECTION OF CULVERT CROSSING**
NOT TO SCALE

| NO. | DESCRIPTION | CHK'D | APP'D | DATE |
|---|---|---|---|---|
| B | Issued for Discussion | LW | EMR | 29May15 |
| A | Issued for Discussion | LW | EMR | 14Mar14 |

REVISIONS

| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE |
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| | | | |

REFERENCE DRAWINGS

PROFESSIONAL ENGINEERS STAMP

srk consulting

| DESIGN: LW | DRAWN: NV | REVIEWED: EMR |
|---|---|---|
| CHECKED: LW/EMR | APPROVED: EMR | DATE: May 29, 2015 |

FILE NAME: 1CT022_001_Doris Vent Raise-Berm3.dwg

TMAC RESOURCES

HOPE BAY PROJECT

SRK JOB NO.: 1CT022.002.200.1100

Doris Connector Vent Raise

DRAWING TITLE: Typical Sections and Details

DRAWING NO. DCVR-04 | SHEET 5 OF 6 | REVISION NO. B

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**Materials List and Quantity Estimates**

| Item | Quantity / Area / Volume | | Description |
|---|---|---|---|
| 1. Run of Quarry Material | | ROQ (cu.m.) | Approximate In-Place Neat-line Volume (3D volume based on Civil 3D surfaces - no allowance has been made for losses and/or tundra embedment) |
| | Float Plane Dock Access Road to Vent Raise Pad | 4,420 | |
| | Vent Raise Pad | 37 | |
| | Total | 4,457 | |
| 2. Surface Grade Material | | Surfacing Material (cu.m.) | Approximate In-Place Neat-line Volume |
| | Float Plane Dock Access Road to Vent Raise Pad | 295 | |
| | Vent Raise Pad | 35 | |
| | Total | 330 | |

**Tolerances on Road Material Placement:**

| Location | Fill (mm) | Excavation (mm) |
|---|---|---|
| Vertical Tolerance on Roads | 0 to +75 | n/a |
| Horizontal Tolerance on Roads | -150 to +150 | |

Note: Grade shall not be uniformly high or low.

| NO. | DESCRIPTION | CHK'D | APP'D | DATE |
|---|---|---|---|---|
| B | Issued for Discussion | LW | EMR | 29May15 |
| A | Issued for Discussion | LW | EMR | 14Mar14 |

REVISIONS

| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE |
|---|---|---|---|

REFERENCE DRAWINGS

PROFESSIONAL ENGINEERS STAMP

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DESIGN: LW | DRAWN: NV | REVIEWED: EMR
CHECKED: LW | APPROVED: EMR | DATE: May 29, 2015

FILE NAME: 1CT022.001_Doris Vent Raise_Material Specs.dwg

TMAC RESOURCES

HOPE BAY PROJECT

SRK JOB NO.: 1CT022.002.200.1100

Doris Connector Vent Raise

DRAWING TITLE: Material List and Quantity Estimates

DRAWING NO.: DCVR-05 | SHEET 6 OF 6 | REVISION NO. B

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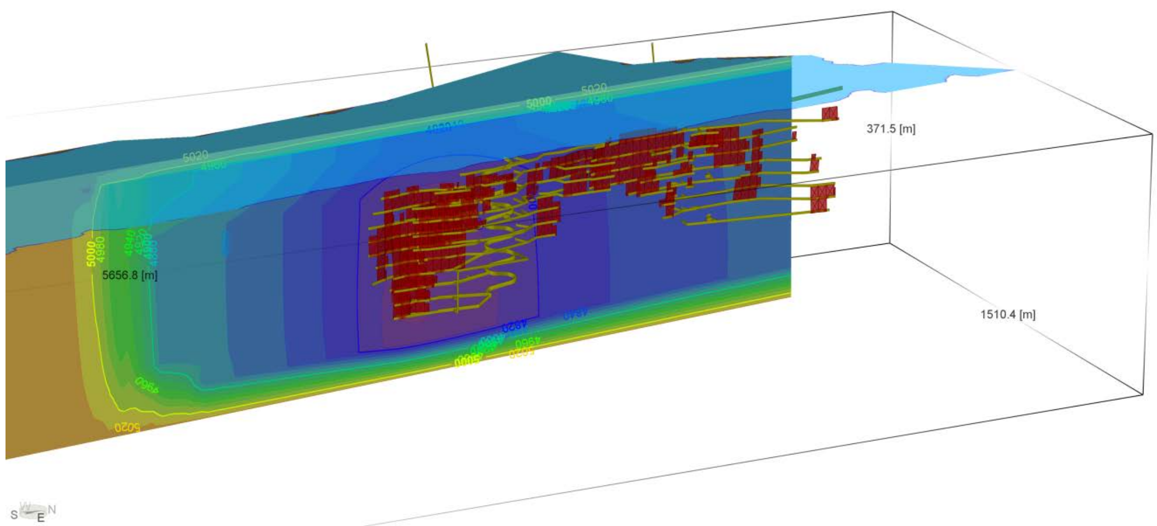
**Package 6**
**Engineering and Design Documents**

# P6-3 Groundwater Inflow and Quality Model

# Hydrogeological Modeling of the Proposed Doris North Project, Hope Bay, Nunavut

**Prepared for**

TMAC Resources Inc.




**Prepared by**

SRK Consulting (Canada) Inc.
1CT022.002.200.1000
June 2015

# Hydrogeological Modeling of the Proposed Doris North Project, Hope Bay, Nunavut

June 2015

| **Prepared for** | **Prepared by** |
|---|---|
| TMAC Resources Inc.<br>PO Box 44<br>Suite 1010 – 95 Wellington Street, West<br>Toronto, ON, M5J 2N7 | SRK Consulting (Canada) Inc.<br>2200–1066 West Hastings Street<br>Vancouver, BC V6E 3X2 |
| Tel: +1 416 628 0216<br>Web: www.tmacresources.com | Tel: +1 604 681 4196<br>Web: www.srk.com |

Project No: 1CT022.002.200.1000

File Name: DorisNorth_GWModel_Report_1CT022-002-200-1000_20150611_FNL



srk consulting 1974 40 2014

# Table of Contents

# List of Figures

# List of Tables



# List of Appendices

# 1 Introduction

## 1.1 Background

TMAC Resources Ltd. (TMAC) plan to increase production from their Doris Mine at their Doris North Project (Project), located in Nunavut, approximately 120 km southwest of Cambridge Bay. The current licensed Project calls for extraction of about 0.4 Mt of ore from the Doris Mine. TMAC has revised their mine plan, increasing the total amount of ore that will be extracted from the mine to about 2.5 Mt.

The Project is located in the continuous permafrost region, in an area where permafrost extends to depths of 400 to 500 metres below ground surface (mbgs), except near large bodies of water where talik zones (i.e. unfrozen ground where groundwater flow can occur) are present. The original mine plan was predominantly within the permafrost; however, the revised mine plan extends into the talik underneath Doris Lake, which has an open talik, meaning the unfrozen ground is connected with the deeper groundwater.

Groundwater inflows to portions of the Doris Mine (Doris Central and Doris Connector zones) are therefore expected. Water quality sampling has confirmed that the groundwater has high salinity and high concentrations of dissolved chloride, ammonia, boron, cadmium, and manganese, and therefore careful management of the groundwater is required.

This document presents results of hydrogeological modeling completed by SRK Consulting (Canada) Inc. to estimate the potential quantity and quality of groundwater flow into the talik zones of the Doris Mine.

## 1.2 Scope of Work

The scope of work covered in this report includes:

- Review and discussion of the baseline hydrogeology characterization data;
- Updating of the conceptual groundwater model for the Doris Mine;
- Developing a numerical model to predict the Doris Mine groundwater inflow rate and quality over the life of the mine; and
- Present the groundwater modeling results in a way that informs engineering of a suitable water management plan, as well as provide input data for inclusion into the site wide water and load balance model (SRK 2015).

## 1.3 Report Layout

Section 2 of this report lists all of the relevant site characterization studies that have been carried out at the Doris site and provides the framework for understanding the proposed mine plan and the current hydrogeological regime. This includes an in-depth evaluation of the available hydrogeological data. Section 3 describes the conceptual groundwater model and details of the numerical model setup. Modeling results are presented in Section 4, and conclusions in Section 5.

# 2 Available Information

## 2.1 Data Sources

The current hydrogeological understanding is based on information from field investigations completed by SRK in 2004, 2008, 2010 and 2011. A summary of the most relevant works is described below; complete reference information is provided in the reference list.

**SRK 2005**: Thermistor data are available from two test holes completed in 2004 near Doris North; one along the southern extent of the Doris North deposit in deep permafrost, the other to the west of the Doris North deposit in shallow permafrost. Data for the two wells have been collected since 2004.

**SRK 2009b:** SRK issued a Stage 2 geotechnical and hydrogeological assessment for the Doris North Open Pit and Doris Central Underground. The assessments were based on field studies completed by SRK in 2008 that included detailed structural review, hydrogeological investigations, and geotechnical assessments (including additional thermistor drill holes). No hydrogeological data were available for the Doris Central area prior to the 2008 program.

**SRK 2011a:** SRK conducted a field program in 2010 involving the installation of several Westbay multi-level monitoring wells for the purpose of characterizing groundwater quality at Doris North, Doris Central, and Boston. Hydraulic tests were also completed during drilling. One of these wells is within the Doris Lake talik; groundwater quality was characterized for each of the sampled zones to a depth of 490 meters below lake elevation.

**SRK 2011b:** SRK provided a memo summarizing results of updated estimates for inflow rates and water quality for Doris Central and Connector, including provision for flow contributions from open exploration drill holes. The updated assessments used data from the 2010 field program (SRK 2011a).

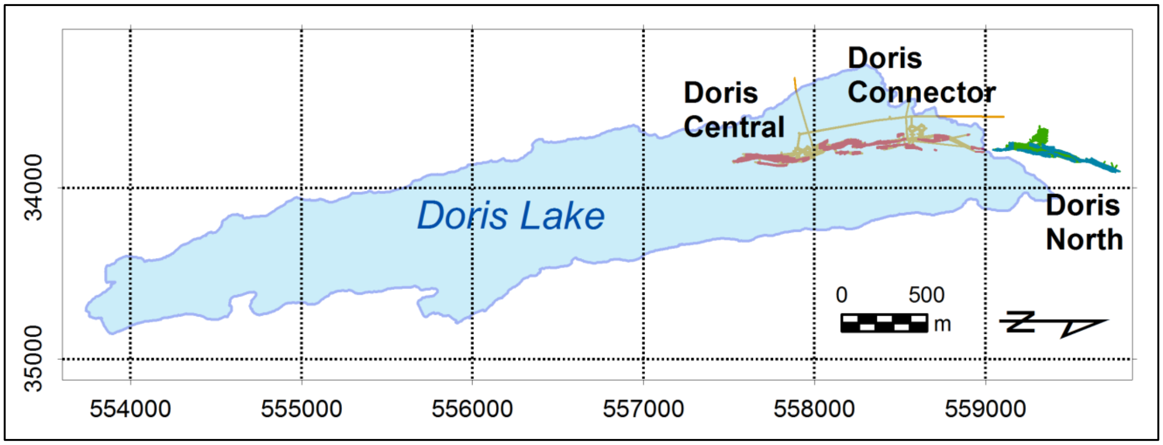
**SRK 2012:** SRK provided a report summarizing results of groundwater quality sampling and analyses from the three existing Westbay wells (Doris North, Doris Central, and Boston).

**SRK 2014:** SRK provided a report that reviewed all the historical data as well as the additional field work conducted in 2011 at the Project, and updated the characterization of the geotechnical and hydrogeological conditions. This document provided information for use in mine and infrastructure design, and to support an internal Stage 2 (pre-feasibility) study.

## 2.2 Mine Plan

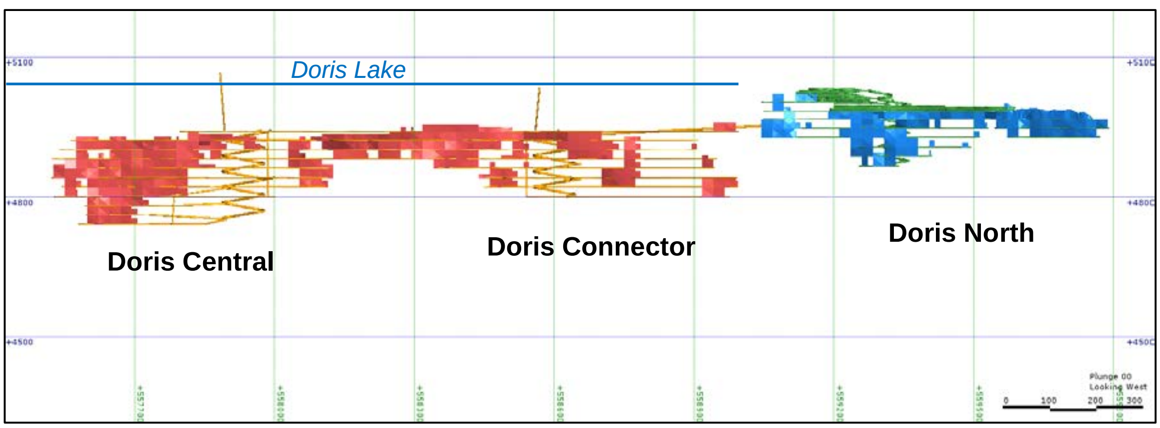
Updated mine plans were provided by TMAC on March 23, 2015. The Doris Mine consists of distinct mining zones, the most relevant to this discussion include: Doris North, which is within permafrost; and, Doris Central and Doris Connector, both of which are under Doris Lake, within an open-talik (see Figure 1 and Figure 2). The Doris Central and Doris Connector zones have potential for groundwater inflow.

The mining method will primarily consist of Longhole Retreat mining with placement of both Unconsolidated Rock Fill (URF) and Cemented Rock Fill (CRF) backfill for support. Drift and Fill mining will be used in zones where the veins are narrower to help control dilution and provide support as mining progresses. The Crown Pillar under Doris Lake is 50 m.




Green and yellow areas are the mine development in permafrost and talik zones respectively. The blue and red areas are the mining stopes in permafrost and talik areas respectively.

**Figure 1: Plan view of the Doris Mine plan layout.**




Green and yellow areas are the mine development in permafrost and talik zones respectively. The blue and red areas are the mining stopes in permafrost and talik areas respectively.

**Figure 2: Cross section of the Doris Mine looking west.**

## 2.3 Hydrogeological Conditions

### 2.3.1 Geology

The overburden soils at the base of Doris Lake are silty clays and clayey silts. There is a layer of limnic sediments ranging between a few centimetres to as much as 2 m thick, under which is a profile that consists of a normally consolidated layer of marine silty clay and clayey silts between 10 and 20 m thick (SRK 2009a).Representative bedrock geology for the Doris deposit is illustrated on the idealized cross-section in Figure 3.

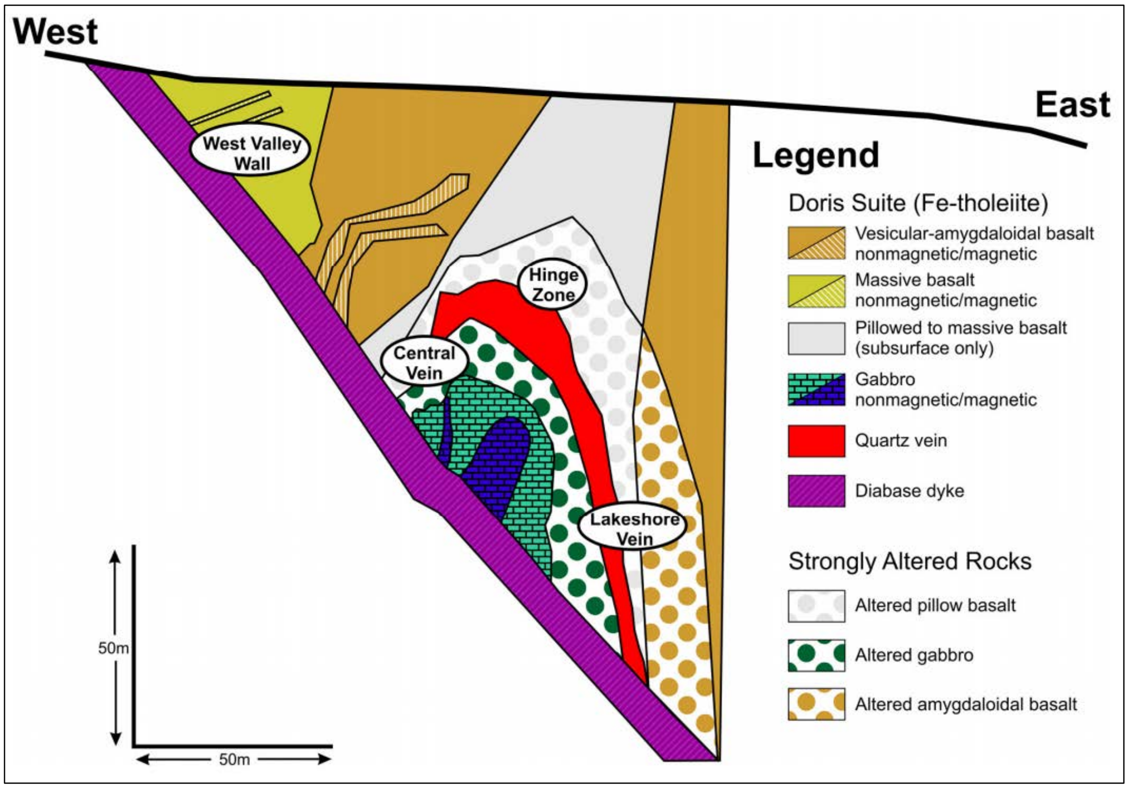



**Figure 3: Idealized Cross-section through Doris North zone at 7559320N (Modified from Carpenter et al 2003).**

Gold mineralization at Doris is principally hosted within quartz veining that has an anti-formal shape, with the Central and Lakeshore veins forming the two fold limbs and the Hinge vein forming the fold closure. Auriferous quartz veins at Doris are hosted by massive and pillowed metabasalt folded around a central coarse gabbroic metavolcanic (SRK 2014).

A series of quartz veins associated with an intense deformation zone (well foliated and altered zone) occurs west of the Doris antiform and form the West Valley veins. These veins and associated deformation zones dip steeply west and strike north-south (SRK 2014).

A large diabase dyke complex crosscuts the gold mineralization. This dyke system strikes north-northeast and can dip both steeply and shallowly to the east. A number of diabase dykes belonging to this system were intersected during drilling. At Doris, the dyke has two distinct geometric features: a vertical dyke and a horizontal dyke. The vertical dyke runs along the west shore of the Doris Lake, from below the lake sediments down to the permafrost base. The horizontal dyke is mapped between a depth of 339 and 488 mbgs (SRK 2014).

### 2.3.2 Structural Geology

All basaltic and gabbroic rocks have been affected by a penetrative north-south striking and steeply west-dipping foliation. The foliation at Doris is characterized by the alignment of chlorite, sericite, quartz, and carbonate minerals. This alignment is present in all lithologies except the diabase dykes. The foliation observed in outcrop has an orientation of 175º to 205º with a vertical to 80º dip to the west (SRK 2014).

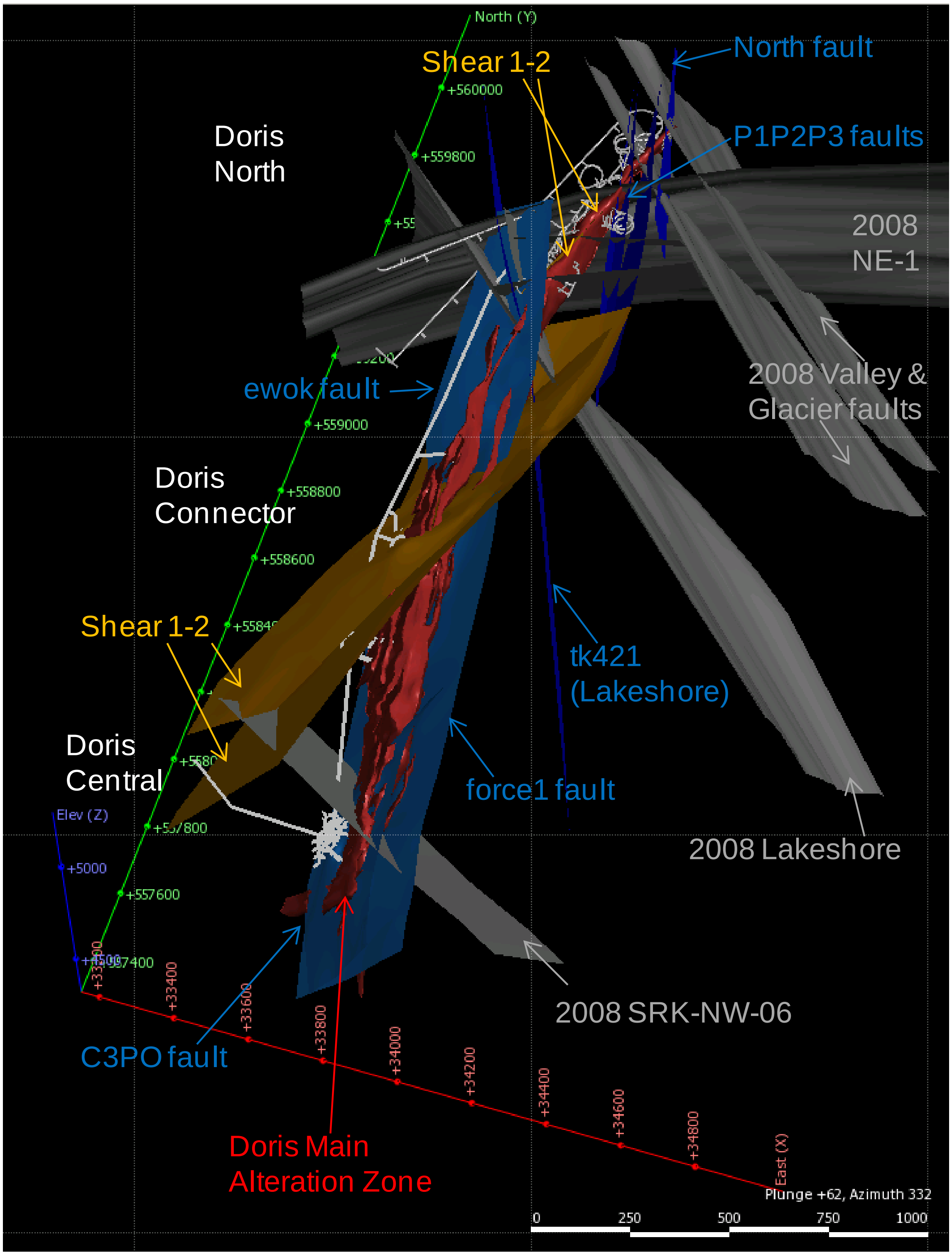
The main quartz vein hinge zone has an anti-formal shape that is doubly plunging: in the Doris North zone it plunges 10° north, whereas in the Doris Central zone it plunges 25° south. Similar to the West Valley Wall, the quartz veining appears to be associated with a zone of high strain a few metres wide (SRK 2014).

Field evidence suggests that two sets of sub-vertical dipping brittle faults transect all rock types other than the diabase at Doris. The general strike of these faults is northwest and northeast, while the dip is generally poorly constrained. Modeled faults are shown in Figure 4. In 2008, three distinct faults were interpreted in the Doris Mine area: the Lakeshore Fault, the Glacier Fault, and the Valley Fault. The Lakeshore Fault is considered the most prominent known fault within the Doris deposit. This fault was observed on surface as approximately one metre wide, striking 130° and dipping steeply, near vertical. Lower confidence faults, representing structures seen in geophysics and drill core, include the northwest-trending Valley, Glacier, and SRK-NW-02 faults, as well as the southwest-trending NE-1, SRK-SW-01, SRK-SW-02, and SRK-NW-06 faults. Five other faults were also identified by the displacement of gold mineralization and drill core fault intervals. These faults include the North Fault, P1P2P3, Ewok, Force1, and C3PO faults. There are also four modeled shear zones, two situated in the Doris North zone and another two in the Doris Connector zone (SRK 2014).

In drill core, all late faults at Doris are typically marked by rubble zones associated with sericitic alteration, slickensides, brecciation, and clay gouge. Most of the drilling at Doris is oriented in an east-west direction at a low angle to the faults, resulting in an unfavourable geometry to penetrate the faults; as such, the orientation and continuity of many of these faults are not well constrained.

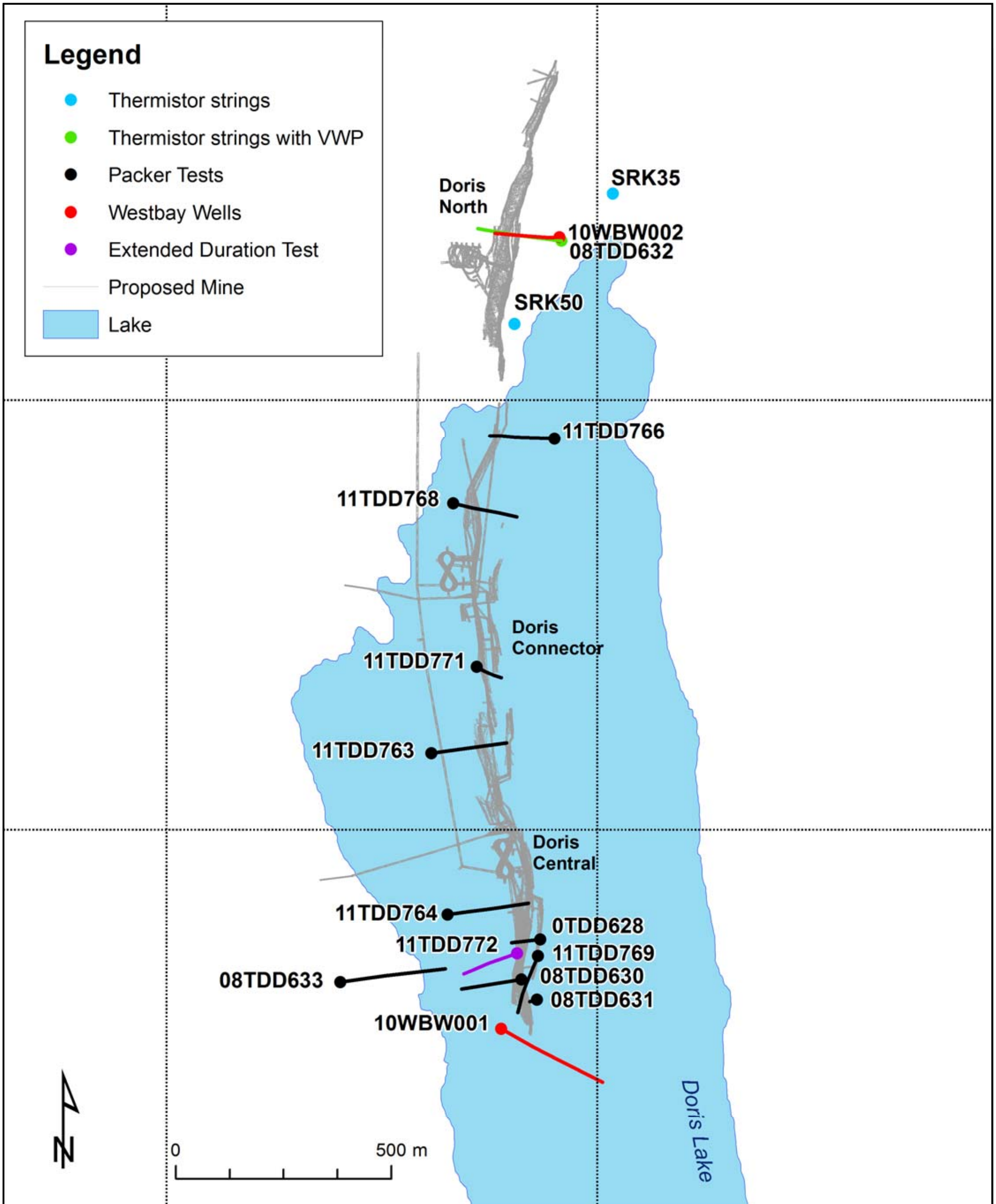
### 2.3.3 Hydraulic Properties

Hydraulic conductivity data are available for the sediments of Doris Lake from 28 in-situ tests and two laboratory tests (SRK 2009a), and for fractured rock from over 50 tests along the length of the Doris Mine. Hydraulic testing in bedrock included short duration packer injection tests (Short Duration Tests) and one long-term (about 12 hours) constant head injection test (Extended Duration Test). A map of the test locations is shown in Figure 5. A table summarizing drillhole details is provided in Appendix A.




Note: Grey: previous faults; Blue: new or modified faults; Orange: new shears; Red: main alteration zone containing Doris veins; White: planned underground developments

**Figure 4: Interpreted faults and shear zones in the Doris Deposit.**




srk consulting

TMAC RESOURCES

Doris Mine Groundwater Model

**Location Map of All the Hydraulic Tests**

| | | | | | |
|---|---|---|---|---|---|
| Job No: | 1CT022.002 | Hope Bay Project | Date: May 2015 | Approved: GF | Figure: 5 |
| Filename: | Figure5_Plan_view_GW_DH_Obs.pptx | | | | |

#### 2.3.3.1 Tests in Lake Sediments

Pressure dissipation tests were conducted in sediments lining the base of Doris Lake, Patch Lake and Spyder Lake, during cone penetration (CPT) drilling (SRK 2009a). Results were interpreted for hydraulic conductivity using the method of Parez and Fauriel (1988). The results for each of the pressure dissipation test are provided in Appendix B. CPT refusal was not associated with bedrock contact, but an indurated layer of lake sediment, estimated to be 3 m thick on average based on the available drillhole information. Two samples of the indurated lake bed sediment (SRK-OB-VS-14-S3 and SRK-OB-VS-31-S2) were sent to a laboratory for consolidation testing. The laboratory measured a hydraulic conductivity of 4.6 x $10^{-10}$ and 3.5 x $10^{-10}$ m/s respectively (SRK 2009a). Table 1 summarizes the estimated properties of the lake bed sediments.

**Table 1: Hydraulic Conductivity of Doris Lake Bed Sediments**

| Type | Number of tests | Average Thickness (m) | Hydraulic Conductivity Geometric Mean (m/s) |
|---|---|---|---|
| Soft lake bed sediments | 28 | 17 | 1 x $10^{-8}$ |
| Indurated lake bed sediments | 2 | 3 | 4 x $10^{-10}$ |

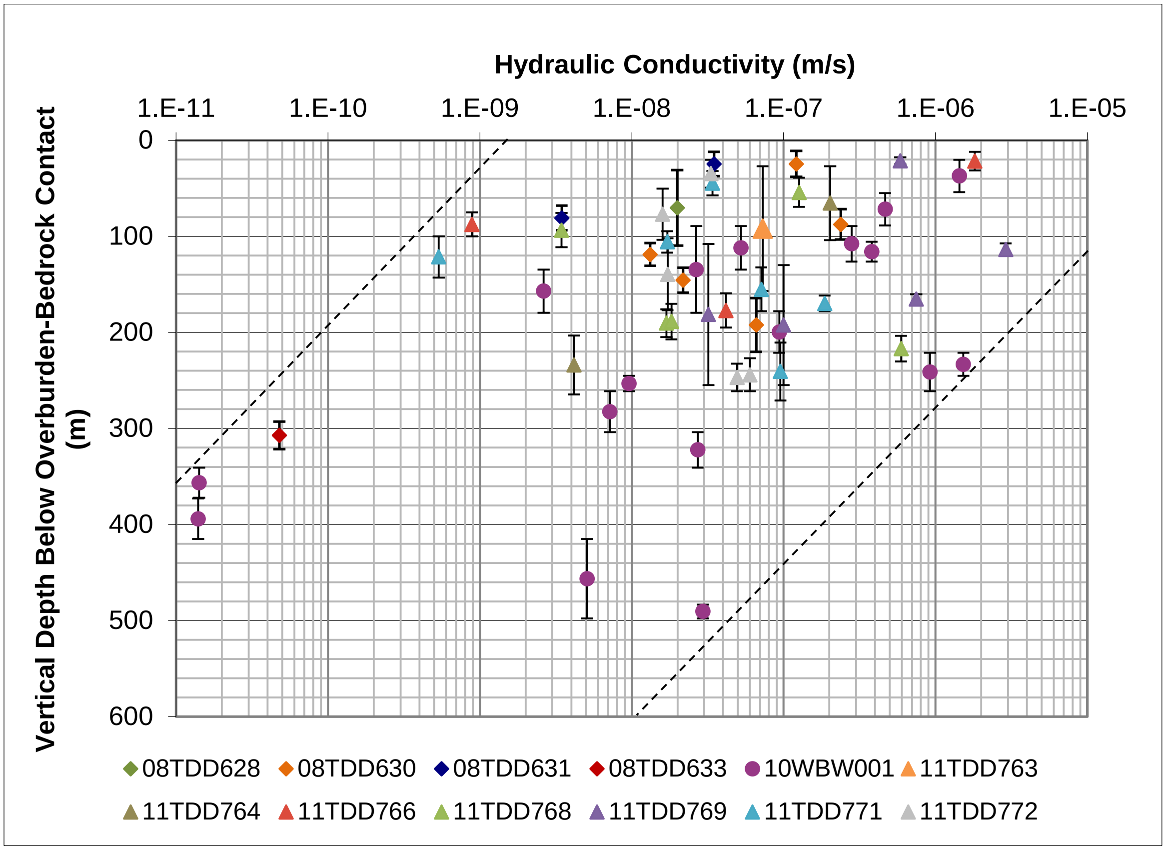
#### 2.3.3.2 Short Duration (Packer) Tests in Fractured Rock

Hydraulic conductivity estimates from short duration tests have a geometric mean of 3 x $10^{-8}$ m/s, with a standard deviation of 5 x $10^{-7}$ m/s. Table 2 shows the geometric mean of the hydraulic conductivity values as a function of depth and lithology. The vertical distribution of hydraulic conductivity is shown in Figure 6.

**Table 2: Hydraulic Conductivity from Short Duration (Packer) Tests in Fractured Rock as a Function of Depth and Lithology**

| Depth (mbgs) | | Hydraulic Conductivity Geometric Mean (m/s) | |
|---|---|---|---|
| | | Volcanic Rock | Diabase |
| 0 | 50 | 7 x $10^{-7}$ | n/a |
| 50 | 100 | 6 x $10^{-8}$ | n/a |
| 100 | 150 | 3 x $10^{-8}$ | n/a |
| 150 | 200 | 4 x $10^{-8}$ | n/a |
| 200 | 250 | 6 x $10^{-8}$ | n/a |
| 250 | 300 | 3 x $10^{-8}$ | n/a |
| 300 | 350 | 3 x $10^{-8}$ | 5 x $10^{-11}$ |
| 350 | 400 | n/a | 2 x 10-$^{11}$ |
| 400 | 450 | n/a | n/a |
| 450 | 500 | 3 x $10^{-8}$ | 5 x $10^{-9}$ |

**Note:** n/a not available

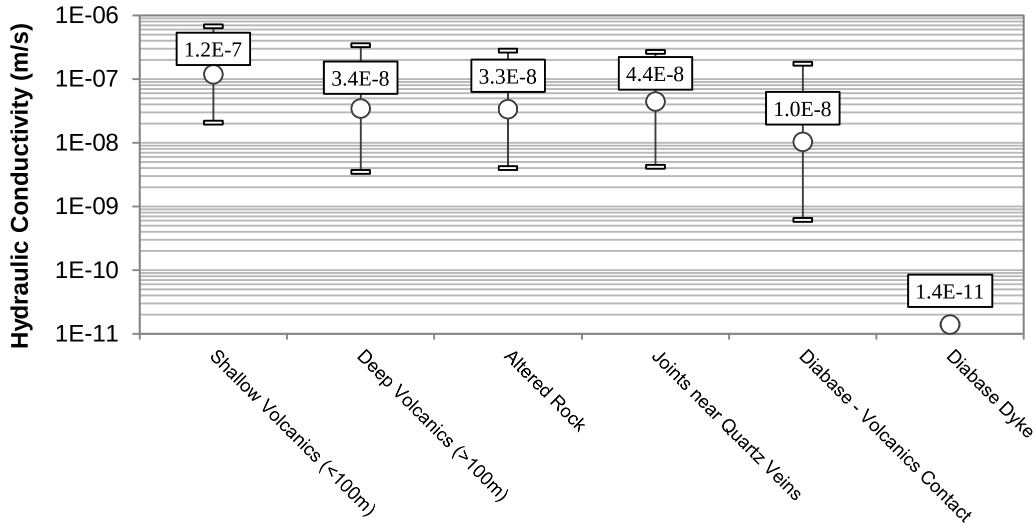



Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CH008.054_2011 Stage 2 Geotech-Hydro\020_Project_Data\SRK\!Hydraulic Conductivity\!REVIEWED\Summary Spreadsheets\Doris_Central_PackerSummary_1CH008.054_101811_jm_rev01.xlsx

**Figure 6: Hydraulic conductivity from short duration (packer) tests in fractured rock as a function of depth.**

A review of the geological, structural, and hydrogeological information was completed together with hydraulic conductivity analysis in an attempt to classify hydrogeological domains within the Doris Central and Connector zones (SRK 2014). The following points summarize the results of the review:

- Most tests included more than one lithological unit (i.e. shallow basalt and alteration near the mineralized zone), resulting in an averaging of any influence of each feature or lithology over the test zone interval. Figure 7 summarizes the geometric mean hydraulic conductivity and standard deviation for different lithological units.
- A slight increase in the geometric mean was observed in shallow bedrock (<100 mbgs), 6 x $10^{-8}$ m/s with a standard deviation of 5 x $10^{-7}$ m/s, suggesting that under non-frozen conditions higher inflow rates are more probable near the top of shallower excavations. A statistically significant, but weak correlation exists between hydraulic conductivity and depth (regression coefficient of -0.42). The decrease in hydraulic conductivity with increasing depth is attributed to increasing confining pressure at depth (Singhal and Gupta 2010).




**NOTE:**

Circles indicate geometric mean with value noted; error bars show one standard deviation.

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CH008.054_2011 Stage 2 Geotech-Hydro\020_Project_Data\SRK\!Hydraulic Conductivity\!REVIEWED\Summary Spreadsheets\HB Doris Central K probability distributions.jm.xlsx

**Figure 7: Summary of hydraulic conductivity by hydrogeological unit.**

- The frequency and orientation of joints will have an effect on hydrogeological conditions. Geotechnical studies identified joint sets in three dominant orientations: Sub-vertical dip, Intermediate dip, and Shallow dip. Sub-vertical dipping features include foliation parallel joints. Intermediate dipping features are considered orthogonal joints. Increased jointing was also observed in the vicinity of structures and shears. If a sufficient number of joints from different joint orientation sets are present, the potential for a higher degree of connectivity exists. A statistically significant, but weak correlation exists between hydraulic conductivity and fracture frequency (regression coefficient = 0.33); higher fracture frequency correlates, albeit not strongly, to higher hydraulic conductivity. These correlations are consistent with observations made in similar fractured rock aquifers, which have observed a weak relationship between the two variables (Singhal and Gupta 2010). Regardless, the weak relationship suggests an increased probability of encountering higher hydraulic conductivities within heavily fractured areas. Ultimately, from the perspective of hydraulics, the potential for a widely connected fracture system cannot be ruled out.

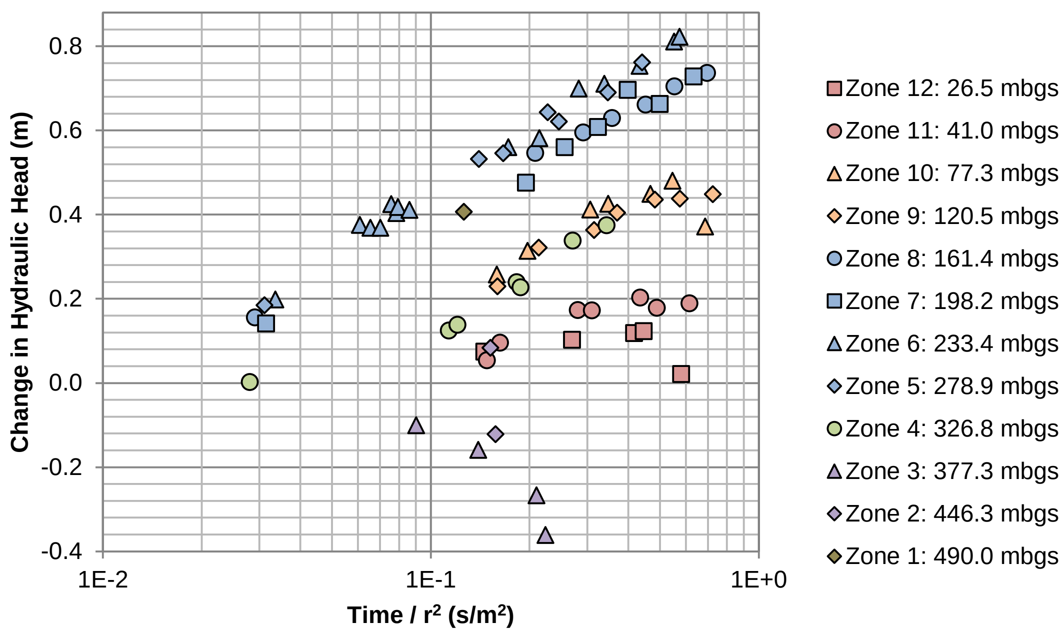
- Many short duration test zones targeted or included a wide range of features, from gouge-filled fractures to rubble zones. Sixteen tests were considered to represent the influence of structural features. Analysis of these tests showed that not all structures necessarily correlate to high hydraulic conductivity, but that it is likely. More than 50% of these test zones had hydraulic conductivity greater than the geometric mean of all data.

- Diabase dykes appear to have a lower bulk rock hydraulic conductivity ($1 \times 10^{-11}$ m/s). However, only two packer tests were conducted exclusively within the diabase dykes so hydrogeological characterization cannot be made with any statistical confidence.

#### 2.3.3.3 Extended Duration (Injection) Test in Fractured Rock

A 14-hour injection test was performed within drillhole 11TDD769 to better assess large-scale hydraulic conductivity, including vertical conductivity, and fracture connectivity. The injection zone (152.0 to 290.2 mbgs) was isolated using a single packer and intersected the western limb of the Doris antiform. Pressure responses were monitored in all 12 zones of the Doris Central Westbay well (10WBW001), which is situated 180 m south of 11TDD769, and dips in the opposite direction (10WBW001 dips 62º towards 118º; 11TD769 dips 65º towards 249º). The Westbay observation zones spanned a depth range of 26 to 490 mbgs.

Pressure responses to the injection test are shown in Figure 8. The signals were analyzed using both analytical and numerical modeling methods. The analytical modeling was performed using the Cooper Jacob Method (Cooper and Jacob 1946). The numerical modeling was completed using the Sandia National Laboratories software nPre version 2.41a (nSites).




**NOTE:** Depths in legend represent the midpoints of the zones.

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CH008.054_2011 Stage 2 Geotech-Hydro\020_Project_Data\SRK\!Hydraulic Conductivity\Long term injection test\Diagnostic_Plots-12hr_Injection_Test-092711-jm-rev01.xlsx

**Figure 8: Cooper Jacob Plot of extended duration (injection) test observations at 10WBW001.**

Interestingly, despite the fact that the Doris groundwater system is fracture-controlled, the hydraulic response tended to show radial or spherical response in a relatively short amount of time. Response data also showed a non-Theis response, which indicates heterogeneity and/or anisotropy within the aquifer (e.g. within a homogenous and isotropic aquifer, the results should plot along the same trend line). A summary of the hydraulic conductivity estimates and the hydrogeological units associated with each zone is presented in Table 3. Hydraulic conductivity estimates based on the nSites solutions vary between 3 x $10^{-6}$ and 8 x $10^{-6}$ m/s. These results are within experimental error of Cooper Jacob estimates (2.6 x $10^{-6}$ m/s to 3.1 x $10^{-6}$ m/s). Results were not calculated for the diabase and lower basalt zones due to an insufficient number of data points.

**Table 3: Hydraulic Conductivity and Specific Storage Estimates for Hydrogeological Units**

| Hydrogeological Unit | Westbay Zone (s) | Hydraulic Conductivity (m/s) | Specific Storage ($m^{-1}$) |
|---|---|---|---|
| Western Limb Zone | 11, 12 | 5.5 x $10^{-6}$ | 1.5 x $10^{-7}$ |
| Hinge Zone | 9, 10 | 7.7 x $10^{-6}$ | 1.3 x $10^{-7}$ |
| Eastern Limb Zone | 5, 6, 7, 8 | 3.6 x $10^{-6}$ | 1.3 x $10^{-7}$ |
| Contact Zone | 4 | 2.7 x $10^{-6}$ | 4.0 x $10^{-7}$ |
| Diabase Zone | 2, 3 | n/a | n/a |
| Lower Basalt Zone | 1 | n/a | n/a |

Note: n/a not available

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CH008.054_2011 Stage 2 Geotech-Hydro\070_Reporting\Stage 2 Doris Geotech Hydro Report\020_Tables\long_term_injection_test_1CH008.054_101811_jm_rev01.xlsx

#### 2.3.3.4 Short versus Extended Duration test Results

When both short and extended duration testing methods are compared, it is noted that the short duration test results may be underestimating the hydraulic conductivity for certain areas or features. This can be explained by the area of influence of the extended duration test, which is larger than that of packer tests, and a higher likelihood of including discrete high-permeability features. Considering this, the results from the extended duration test are used where both short duration and extended duration tests are available. Still, the short duration tests conducted within the Westbay well are consistent with the results of the extended duration test. Both indicated that a high hydraulic conductivity feature(s) exists near Zone 6, about 250 mbgs (short duration test: K = 1.5 x $10^{-6}$ m/s; extended duration: test K = 2.9 x $10^{-6}$ m/s).

Based on the lack of a discernible difference between the hydraulic conductivity of the alteration zone and mafic volcanic rocks, it appears the high permeability feature(s) is/are likely structural in nature. There is however no clear increase in fracture frequency, major lithological change, or obvious structural feature(s) near Zone 6. A large (2.23 m wide) quartz vein was observed in the drill core and was associated with increased alteration and foliation development. Fractures formed along the edges of this vein could be the source of the high hydraulic conductivity, but that cannot be confirmed at this stage. Increased fracturing near the hinge zone of the Doris Antiform and other unidentified features, such as nearby faults (e.g. Force 1 trends through this area) or other fractures, could also be responsible.

Interestingly, during the 2010 geotechnical and hydrogeological drilling programs, many water producing features were encountered below Doris Lake in areas without known or modeled structures. It was noted by onsite geologists that this phenomenon occurred when multiple drills were operating in very close proximity to each other. Nevertheless, this finding indicates that structures are present with high enough permeability to allow for flow to exist. Close examination of the water-producing intersections suggests they are not located along a single feature, but rather associated with more than one structure. In the Doris Central and Connector zones, west of the planned mining, the flow points appear to follow the orientation of either the steeply dipping diabase dykes or potentially a non-modeled north-northwest striking fault sub-parallel to a north-northwest striking diabase dyke that has not been modeled.

During the extended duration test, hydraulic responses were observed across the lower horizontal diabase dyke, suggesting high permeability conduits crosscut the dyke. As a result, dykes may not act as a complete barrier to groundwater flow at the local scale. It can also be noted that increased vug/dissolution cavities were observed within the diabase dyke–mafic volcanic contact zone. This zone, which extends approximately 30 m into the mafic volcanic unit, is likely to have a higher hydraulic conductivity than surrounding rocks and may act as a flow conduit. As of 2011, only one packer test had been conducted within this zone. This test indicated a hydraulic conductivity of 5.1 x $10^{-9}$ m/s, although this value may not be representative of all vuggy areas.

#### 2.3.3.5 Hydraulic Conductivity Domains

Notwithstanding the reality that substantial uncertainty regarding the specific features controlling flow exists, the hydrogeological conditions associated with the Doris Mine is well characterized, and therefore decisions about hydraulic conductivity of geological units can be made with a high degree of confidence. The hydrogeological domains presented in Table 4 summarize the conditions that will be adopted for modeling of the Doris Mine groundwater inflows.

**Table 4: Hydrogeological Domain Hydraulic Conductivity (m/s) for Doris Mine**

<table>
<tr><th rowspan="2">Depth<br>(m)</th><th colspan="4">Hydraulic Conductivity, K<br>(m/s)</th></tr>
<tr><th>Lake Bed Sediments</th><th>Volcanic rock</th><th>Alteration Zone</th><th>Diabase</th></tr>
<tr><td>0 - 17</td><td>1 x $10^{-8}$ (soft)</td><td rowspan="2">n/a</td><td rowspan="4">n/a</td><td rowspan="2">n/a</td></tr>
<tr><td>17 - 20</td><td>4 x $10^{-10}$ (indurated)</td></tr>
<tr><td>20 - 50</td><td rowspan="5">n/a</td><td>7 x $10^{-7}$</td><td rowspan="5">2 x $10^{-11}$</td></tr>
<tr><td>50 - 100</td><td>1 x $10^{-7}$</td></tr>
<tr><td>100 - 250</td><td>6 x $10^{-8}$</td><td rowspan="2">3 x $10^{-6}$</td></tr>
<tr><td>250 - 500</td><td rowspan="2">3 x $10^{-8}$</td></tr>
<tr><td>280 - 500</td><td>n/a</td></tr>
</table>

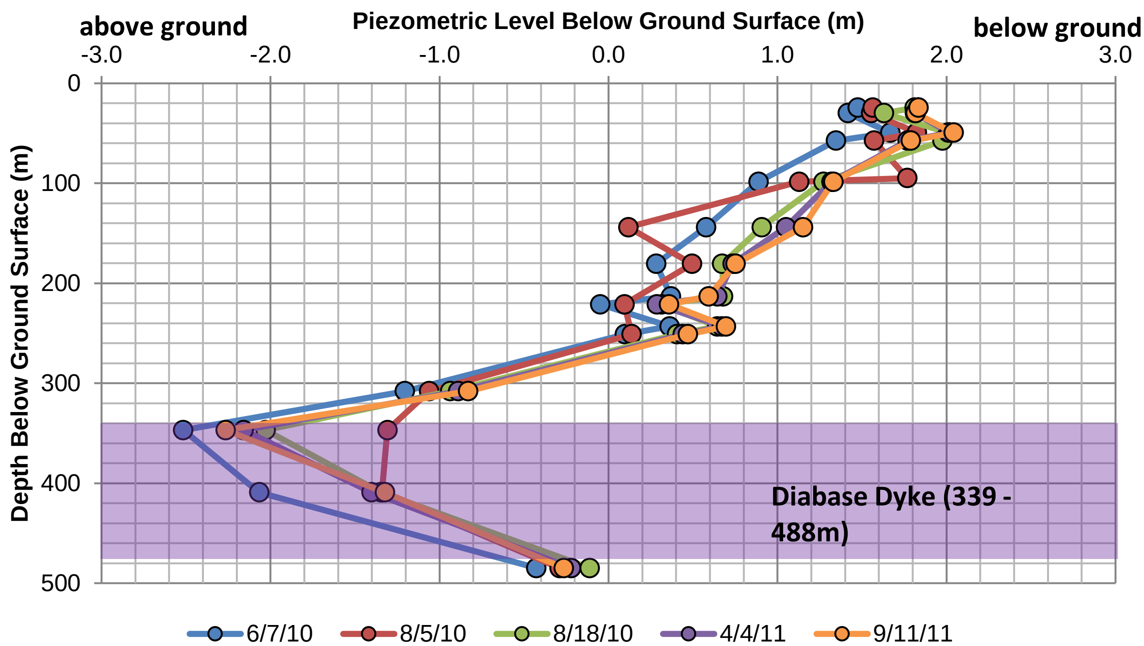
**Note:** n/a. not applicable

### 2.3.4 Water Level

Information on pore pressure is available from the Doris Central Westbay Well (10WBW001), as well as from observations of artesian conditions observed within a number of exploration drill holes. Water density was measured in laboratory for samples from various depths in the Westbay well. Density was reported to be consistent throughout the vertical profile, varying between 1.00 and 1.03 kg/$m^3$, therefore it is assumed the observed pressure gradient is not strongly affected by density changes.

Pore pressure data from 10WBW001indicated that piezometric levels are near the lake surface, with only a slight increase observed near the contact between the diabase dyke and the mafic volcanic rock (Figure 9). Pressures near the contact do not exceed three meters above ground surface, assuming groundwater density is 1.03 kg/m$^3$ (i.e. density value based on average laboratory results from 10WBW001 samples). The difference of head indicates that a positive vertical gradient of 0.0085 exist in the open talik, which suggest that groundwater currently flows from the open talik base upwards to Doris Lake.

The presence of piezometric levels near the lake surface supports the interpretation that the aquifer system beneath Doris Lake and permafrost is controlled by lake levels. As a result, the probability of encountering over-pressurized zones is somewhat greater at depth but overall appears to be generally low above the diabase dyke.




NOTE: Constant density of 1.024 kg/m$^3$ assumed based on average density of samples collected from the Westbay well

\\VAN-SVR0\Projects\01_SITES\Hope.Bay\!Project_Data (Not Job Specific)\03 Westbay Pressure Temp Profiles\10WBW001_All_Pressure_Profiles_20110911.xls

**Figure 9: Pressure profile for Doris Central Westbay Well 10WBW001.**

### 2.3.5 Groundwater Quality

Groundwater samples from the Westbay well were analyzed for standard parameters (conductivity, pH, etc.), cations (chloride, sulphate, etc.), total and dissolved metals. In addition, stable isotopes (O and H) were analyzed to provide improved quality assurance and quality control (QA/QC) on well purging and development, as well as to assess potential variation in water source types.

The 75$^{th}$ percentile concentration from post-purging samples collected in zones 1, 6 and 10 of Westbay Well 10WBW001 are assumed to be representative of the groundwater water quality at the Doris Central and Doris Connector zones (SRK 2012, 2014). These groundwater concentrations are presented in Table 5.

**Table 5: Summary of Groundwater Quality from Samples collected under Doris Mine (75$^{th}$ Percentile)**

| Parameters | | Units | n= 19 to 29 [1] |
|---|---|---|---|
| **Field Parameters** | pH | pH units | 7.73 |
| | Electrical Conductivity (EC) | µS/cm | 52,650 |
| | Dissolved Oxygen (DO) | mg/L | 11.37 |
| | Salinity | % | 31.86 |
| | Oxidation-Reduction Potential (ORP) | mV | 20.5 |
| **Lab Physical Parameters** | EC | µS/cm | 48,500 |
| | Density | kg/m$^3$ | 1.03 |
| | pH | pH units | 7.63 |
| | Total Dissolved Solids (gravimetric) | mg/L | 40,800 |
| **Anions and Nutrients** | Alkalinity, Total (as $CaCO_3$) | mg/L | 93.7 |
| | Ammonia as N | mg/L | 3.5 |
| | Chloride (Cl) | mg/L | 19,000 |
| | Sulfate ($SO_4$) | mg/L | 2,000 |
| **Dissolved Metals** | Aluminum (Al) | mg/L | 0.005 |
| | Arsenic (As) | mg/L | 0.0025 |
| | Boron (B) | mg/L | 3.24 |
| | Cadmium (Cd) | mg/L | 0.00012 |
| | Calcium (Ca) | mg/L | 2050 |
| | Chromium (Cr) | mg/L | 0.0005 |
| | Cobalt (Co) | mg/L | 0.00019 |
| | Copper (Cu) | mg/L | 0.00064 |
| | Iron (Fe) | mg/L | 4.81 |
| | Lead (Pb) | mg/L | 0.0003 |
| | Lithium (Li) | mg/L | 0.35 |
| | Magnesium (Mg) | mg/L | 1,370 |
| | Manganese (Mn) | mg/L | 1.75 |
| | Mercury (Hg) | mg/L | 0.00005 |
| | Molybdenum (Mo) | mg/L | 0.0187 |
| | Nickel (Ni) | mg/L | 0.0014 |
| | Potassium (K) | mg/L | 245 |

| Parameters | | Units | n= 19 to 29 [(1)] |
|---|---|---|---|
| | Selenium (Se) | mg/L | 0.002 |
| | Sodium (Na) | mg/L | 8,980 |
| | Strontium (Sr) | mg/L | 27.6 |
| | Uranium (U) | mg/L | 0.00006 |
| | Zinc (Zn) | mg/L | 0.157 |

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\!Project_Data (Not Job Specific)\04 Groundwater Chemistry\!Master WQ Database\ !MASTER Hope Bay Water Chemistry DB_jm_ja_spb Rev16.xlsx

**Notes:**

[1] n, count of values used to calculate statistics.
Statistics were calculated by assuming that all values below detection limit were at the detection limit. Some samples taken early in the program had high detection limits and were therefore excluded from the statistical summary.

The sample results suggest that the water encountered during mining, at least initially, will be saline, dominated by chloride, and that salinity will likely vary with depth. The groundwater quality results were compared to the following environmental guidelines: Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of marine aquatic life (CCME 2015) and the Metal Mining Effluent Regulations (MMER) limits for deleterious substances (MMER 2015). Based on this comparison, chloride, boron, cadmium, manganese, mercury, cobalt, copper and nickel are considered as the potential constituents of concern because concentrations are above the guideline recommendations. Other observations include:

- Isotope data from Zones 1 and 10 were not similar, suggesting that the water in these zones were from two different sources (SRK 2011a, b). Samples from Zones 6 and 10 were sodium-magnesium-chloride-dominated waters, whereas, samples from Zone 1, which is below the diabase, were calcium-sodium-chloride-dominated waters.
- Water chemistry at the two upper zones (Zones 6 and 10) in the Doris Upper zone was similar, although the isotope data suggest that the water from Zone 10 is different to the waters from Zone 6. Zone 6 waters may be a mixture of water from Zone 10 and from a third source or a different formation, as the isotope signature varied with each sampling round (SRK a, b).
- Samples from Zones 6 and 10 contain somewhat elevated ammonia. Given the age of these waters, this finding is unexpected. However, further laboratory testing has validated that it is likely to be present.
- Samples from Zones 6 and 10 contain elevated concentrations of dissolved iron, manganese, and zinc. As these waters oxidize, the iron and manganese are expected to precipitate as oxyhydroxide minerals and may scavenge other metals from solution. These compounds may contribute to suspended sediments in the groundwater.
- Chloride is the only constituent of concern that shows a correlation with depth. Figure 10 shows the observed and modeled vertical profile for chloride concentration.

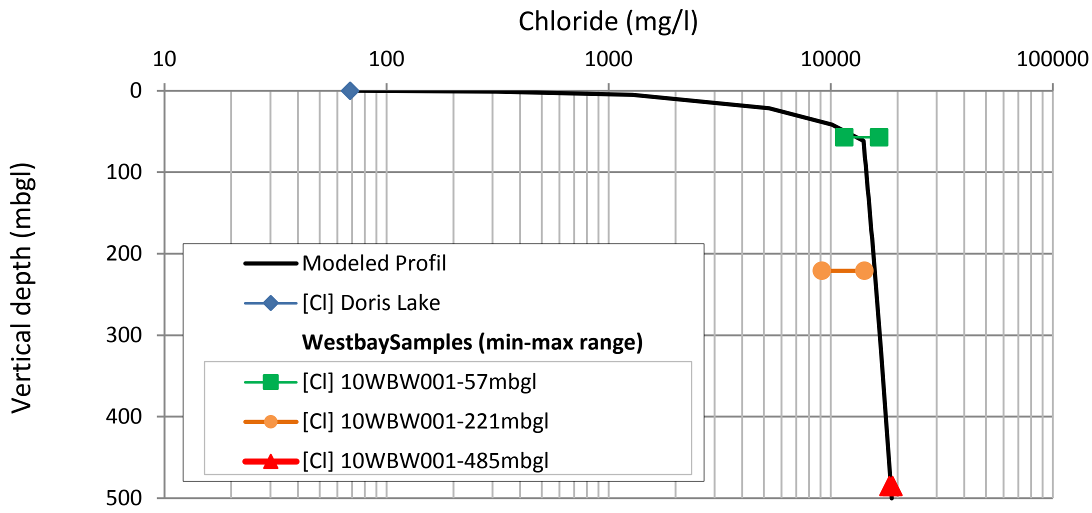



**Figure 10: Observed profile of chloride concentration with depth**

### 2.3.6 Permafrost Extent

The Project is situated within the zone of continuous permafrost, as delineated in a database compiled by the Geological Survey of Canada (NRCan 2002). Although it is generally understood that groundwater flow does not occur in permafrost, it can move in features called talik, where rock is unfrozen. By definition, a talik is "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 1998). Lakes or other waterbodies cause local departure in terrestrial ground temperature as a result of surface climate and microclimatic effects. The mean water bottom temperature, lake half width or radius, and terrestrial ground thermal regime are several variables that influence talik configuration and extent.

Taliks can be expected below lakes with depths greater than two thirds of the maximum thickness of ice forming annually on their surface (Mackay 1992) and with widths up to 150 m when the lake is elongated (Mackay 1962, Smith 1976, and Burn 2002). Doris Lake is a large and relatively deep water body, and has a surface area of (337.8 ha) and a volume of 27,275,094 $m^3$. The maximum length of the lake is 5.6 km, and the maximum width is 0.85 km. The average depth is 8.1 m, and the maximum depth 20.0 m (Rescan 2010a). Therefore it has the capacity to support an open talik a talik that penetrates the permafrost completely and may connect suprapermafrost (the layer of ground above permafrost) and subpermafrost (the non-frozen ground below the permafrost) groundwater. The thermal data collected at the Doris Central Westbay well 10WBW001 indicate that ground temperatures are consistently above 0°C, which supports the interpretation that there is an open talik below Doris Lake.

To estimate where the talik connects with subpermafrost, the quality of the saline connate water observed in 10WBW001 must be considered because salinity induces a freezing point depression and therefore influences the depth of the base of the permafrost. Table 6 summarizes calculated freezing point depression based on Doris Central water quality. These results suggest that water will freeze at a temperature of -2°C, which corresponds to depths of about 400 mbgs.

**Table 6: Isotherm Depression Estimates Based on Water Samples from 10WBW001**

| Sample Name | | 10WBW001 – Zone 1 (548 m) | 10WBW001 – Zone 6 (246 m) | 10WBW001 – Zone 10 (63 m) |
|---|---|---|---|---|
| **Development Stage** | | Zone Volumes Developed = 29.1 | Zone Volumes Developed = 48.3 | Zone Volumes Developed = 11.6 |
| Alkalinity | mg/L | 2 | 44.2 | 49.7 |
| Calcium | mg/L | 4,960 | 749 | 1,010 |
| Magnesium | mg/L | 69.5 | 702 | 849 |
| Potassium | mg/L | 39 | 117 | 160 |
| Sodium | mg/L | 7,290 | 4,130 | 5,400 |
| Chloride | mg/L | 19,000 | 9,130 | 11,500 |
| Sulphate | mg/L | 981 | 940 | 1,160 |
| Calculated Salinity | % | 3.2 | 1.6 | 2.0 |
| **Calculated Theoretical Freezing Point** | **ºC** | **-1.9** | **-0.9** | **-1.2** |

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CH008.054_2011 Stage 2 Geotech-Hydro\070_Reporting\Stage 2 Doris Geotech Hydro Report\020_Tables\freezing_point_depression_1CH008.054_101811_jm_rev01.xlsx

# 3 Hydrogeological Modeling

## 3.1 Conceptual Groundwater Model

### 3.1.1 Flow System

The hydrogeological system for the entire region is considered as a low flux, lake-dominated flow system. Regional flow is primarily controlled by the presence of unfrozen zones in open-talik beneath large lakes. Away from lakes, the permafrost is widespread, deep, and considered to be essentially impermeable.

### 3.1.2 Open Talik Properties

The distribution of hydraulic conductivity in the unfrozen ground is very complex and the specific features that control the flow are not well understood. At the local scale, bedrock hydraulic conductivity is fracture-controlled, comprised of a relatively low bulk hydraulic conductivity background system intersected by distributed, relatively high hydraulic conductivity fractures and geologic structures. At the scale of the open-talik; however, field observations show that a differentiation exists between the lake bed sediments, the diabase, the zone of high conductivity surrounding the Doris deposit, and the volcanic rocks. It is also observed that hydraulic conductivity tends to be relatively higher at shallow depths and to gradually decrease with depth as confining pressure increases.

The zone of high conductivity surrounding the Doris deposit is theorized to represent either a widely connected fracture system near the hinge zone of the Doris Antiform or a permeable and hydraulically well-connected fault.

### 3.1.3 Groundwater Quality

Deep groundwater in the Canadian Shield is often described as connate, meaning old, or emplaced when sediments were originally deposited. This connate water is highly saline and can have elevated concentrations of major ions and metals. The concentrations of calcium, chloride and sodium in connate water are high and show a general trend of increasing concentration with depth (Frape and Fritz 1987, SRK 2012). Other constituents can also have relatively high concentrations in groundwater but do not correlate with depth. This trend has been observed at Diavik (Bieber *et al*. 2006), as well as at many other sites in the Canadian Shield (e.g. Snap Lake, Lupin, Gahcho Kue, Ekati). The quality of groundwater in the Doris Mine is no exception. The samples obtained from the Westbay multi-point monitoring well, through the Doris Central zone, confirmed that groundwater within the talik is highly saline and that salinity increases with depth. When looking at the potential discharge of groundwater to the environment, the constituents of concern are dissolved chloride, ammonia, boron, cadmium, and manganese.

Once mine inflow starts, constituents will come from three sources: Doris Lake, the open talik base and the mined lithology themselves (i.e. groundwater contained within the unfrozen fractured rock). Doris Lake will supply a constant source of fresh water and the open talik base a constant source of saline water. The formation water will also supply saline water; for most constituents the concentrations will be the same as what comes in from the open talik base, but not for chloride as its concentration varies with depth.

### 3.1.4 Mine Interactions with Groundwater

Based on SRK's interpretation of the permafrost distribution, almost all underground development and mining associated with the Doris Central and Connector zones will intersect unfrozen ground associated with the Doris Lake open talik. Exceptions exist for the northern-most portions of the Doris Central and Doris Connector zone declines, where frozen conditions are expected in close proximity to the Doris Lake shoreline.

## 3.2 Base Case Numerical Model

### 3.2.1 Flow System

This groundwater system at the Doris Central and Connector zones can be represented numerically by the volume of the open-talik beneath Doris Lake, with the top surface being the lake and the base corresponding to the permafrost base at 400 mbgs. Within this volume, groundwater flow is driven by the head of Doris Lake and the head measured at the base of the open talik (respectively 21.5 metres above sea level (masl) and 24.5 masl). Along the shoreline of Doris Lake, down to the permafrost base and away from the lake itself, ground is frozen and flow does not occur.

### 3.2.2 Open Talik Properties

The numerical model simplifies the complexity of the local scale geology and structures. It simulates bedrock as an equivalent porous media and assumes that the four hydrogeological domains highlighted by the field testing (see Table 4), as well as the relationship of hydraulic conductivity with depth, are representative of the hydrogeological system. Key points for each unit are discussed below:

- The lake bed sediments form a low hydraulic conductivity layer that covers the entire base of Doris Lake and limits infiltration of lake water. Sediments are divided into two sub-layers, a soft sediment layer and an indurated sediment layer, with average thicknesses of 17 and 3 m, respectively, as observed by field characterization and laboratory testing.
- The diabase consists of a low hydraulic conductivity unit that will act as barrier to groundwater flow. The vertical dyke runs along the west shore of the Doris Lake, from below the lake sediments down to the permafrost base. The horizontal dyke is mapped at about the same depth as the open talik base. It dips gently to the south and only intersects the open talik base in the north, over approximately 40% of the total surface of the open talik base, and beneath the Doris Central and Doris Connector zones. Where the horizontal dyke is absent, the regional deep flow connects freely to the open talik.
- The high conductivity zone identified by the extended duration test is represented as a high hydraulic conductivity zone surrounding the entire Doris Connector and Doris Central zones. This representation is assumed to correspond to a widely connected fracture system, with

increased fracturing near the hinge zone of the Doris Antiform or associated with quartz veins, as discussed in Section 2.3.3.3.

The simulation of a high hydraulic conductivity zone with a single linear structure was purposely not included. It is assumed that during operation, if high inflows are associated to a specific structure, flow will be controlled with techniques such as grouting. The base case scenario assumes instead that the entire mine is enclosed within a high hydraulic conductivity zone, one to two orders of magnitude higher than the surrounding rock units.

- The volcanic rocks correspond to the rock mass that is not part of the three units listed above. They are characterized by the hydraulic conductivity values obtained from the short duration tests, sub-divided by depth range, as indicated in Section 2.3.3.5.

### 3.2.3 Groundwater Quality

Doris Lake is simulated as a constant source of fresh water and the open talik base a constant source of saline water. The formation water is another source of saline water; for most constituents the concentrations will be the same as what comes in from the open talik base, but not for chloride as its concentration varies with depth. For chloride, initial concentration conditions are given by the vertical profile of chloride concentrations inferred from Westbay sampling and shown in Figure 10. For the other constituents, initial concentration conditions are given by the average of 75$^{th}$ percentile concentrations from post-purging samples collected in Zones 1, 6 and 10 of the Doris Central Westbay Well 10WBW001.

### 3.2.4 Mine Interactions with Groundwater

The numerical groundwater model simulate the progressive excavation of the underground mine, represented in three dimensions, according to the planned mining schedule. When in contact with areas of unfrozen pore water, groundwater flow and dissolved constituents report to the mine water management system. The simulation also used the following assumptions to differentiate some of the actual mining practices as it relates to the generalizations of the model:

- Even though the hydrogeological units assume an equivalent homogenous hydraulic conductivity, it is recognized that in all likelihood flow will be dominated by specific fractures or features in the mine. As development and mining advances, these high flow areas will be mitigated through routine practices such as grouting. To account for this reality, the model assumes that all flow in the upper 100 m of the decline would be arrested since this area is the main traffic route for hauling ore from the mine and thus need to be maintained dry. In addition, for all remaining development and mining areas, it is assumes that 75% of all flows can be arrested though routine mining water management practices as described.
- When stopes are mined, they will be backfilled with either URF or CRF. URF will not reduce inflows materially, but CRF will. An additional mitigation measure that could be employed to control groundwater inflow, would be to construct bulkheads to isolate areas that have been mined out. To best simulate inclusion of these mitigation measures in the numerical model, development and mining areas over the life of the mine, which are no longer in use, are assumed to be either backfilled or bulk-headed off and as a result no longer contribute

towards the overall mine inflow. Areas blocked off in this way in the model is assumed to be flooded rapidly such that no further loss of groundwater to the active mine is encountered.

## 3.3 Numerical Model Details

### 3.3.1 Software

Numerical groundwater modeling has been completed using the modeling software FEFLOW v6.2 (P8) (DHI 2015). FEFLOW is a professional software package for modeling fluid flow and transport of dissolved constituents and/or heat transport processes in the subsurface. This program is used extensively for mining groundwater projects around the world.

### 3.3.2 Model Domain

The model domain corresponds to the volume of the open talik beneath Doris Lake. For the purpose of the model the Doris Lake footprint is approximately 5,600 m long and 850 m wide. The top surface of the model is set at the elevation of the lake, 5,021.5 m in mine grid elevation, and the base of the model is at the estimated base of permafrost at 4,650 m in mine grid elevation.

### 3.3.3 Model Assumptions

The model assumptions are:

- Steady state to define current conditions;
- Transient to predict mine inflows;
- 3D saturated media within a confined aquifer;
- Groundwater density does not vary;
- Bedrock is simulated as an equivalent porous media. Use of a fracture network model is not justified for a model of this scale and scope; and
- Homogeneous and anisotropic hydraulic conductivity.

### 3.3.4 Model Limitations

The following limitations/realities should be borne in mind when evaluating the model results:

- The model was constructed to match the available data; however, local variability exists due to local heterogeneities not captured by the model, including variety of structures on different scales, local variations in hydraulic conductivity, water quality or ground temperature (permafrost distribution).
- The analysis does not account for flow that could occur if the mine development intersected flow from open exploration drill holes.

- The analysis does not consider transient thermal conditions that can impact the talik configuration, such as spatial variability in ground surface temperature, or complexities of the lake bathymetry.

### 3.3.5 Model Mesh

The finite element mesh is shown in Figure 11. It has 32,724 elements per layer. The mesh is coarsest in areas outside of the mine footprint (average element dimensions of about 50 x 50 m), and finest close to and at the development and mine openings (average element dimensions of about 5 x 5 m).

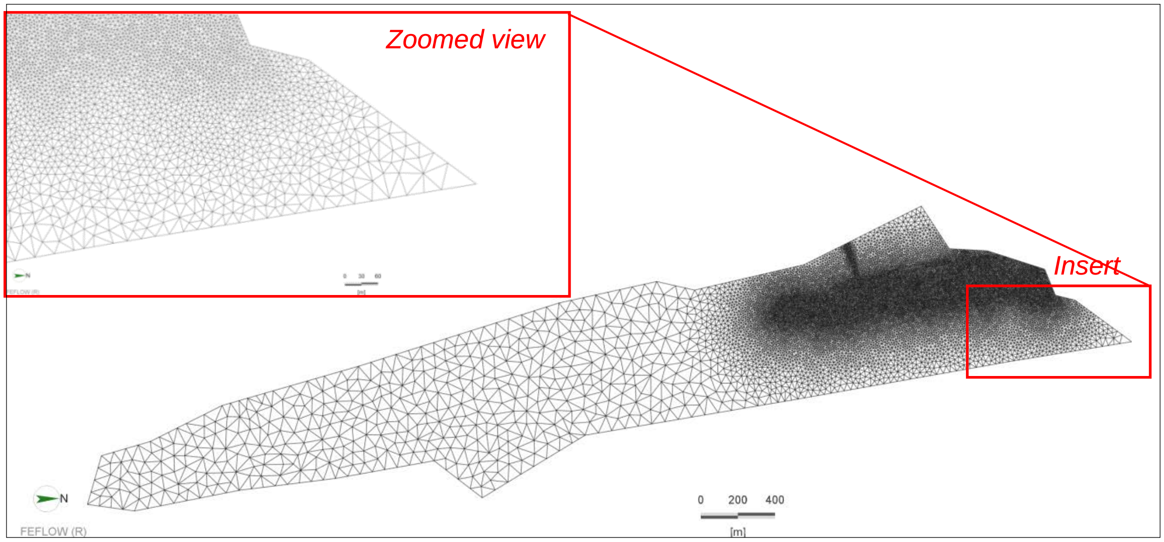



**Figure 11: Model mesh.**

The model is built with 30 horizontal layers, ranging from 5,021.5 m to 4,650 m in mine grid elevation. Layer thicknesses are presented in Table 7.

**Table 7: Numerical Model Layer Thicknesses**

| Layer # | Unit(s) | Top Elevation (m, mine grid) | Base Elevation (m, mine grid) | Layer thickness (m) |
|---|---|---|---|---|
| Layer 1 | Soft lake bed sediment | 5,021.5 | 5,004.5 | 17.0 |
| Layer 2 | Indurated lake bed sediment | 5,004.5 | 5,001.5 | 3.0 |
| Layer 3 | Volcanic rock, diabase | 5,001.5 | 5,000.0 | 1.5 |
| Layer 4 to 5 | Volcanic rock, diabase | 5,000.0 | 4,960.0 | 20.0 |
| Layer 6 to 9 | Volcanic Rock, diabase | 4,960.0 | 4,920.0 | 10.0 |
| Layer 10 to 27 | Volcanic Rock, diabase, alteration zone | 4,920.0 | 4,740.0 | 10.0 |
| Layer 28 | Volcanic Rock, diabase | 4,740.0 | 4,730.0 | 10.0 |
| Layer 29 | Volcanic Rock, diabase | 4,730.0 | 4,700.0 | 30.0 |
| Layer 30 | Volcanic Rock, diabase | 4,700.0 | 4,650.0 | 50.0 |

### 3.3.6 Model Parameters

The material properties are defined as follows:

- The hydraulic conductivities of the lake sediments, diabase, alteration zone and volcanic rocks are assigned as indicated in Table 4. Figure 12 illustrates the hydraulic conductivity distribution in 3D model view and in cross-section. Figure 13 plots the hydraulic conductivity tests against modeled hydraulic conductivities along the vertical depth.
- The specific storage (Ss) is a parameter that describes volume of water released or gained from storage in response to pressure changes under confined conditions. The storage compressibility value for the lake bed sediments is $1 \times 10^{-4}$ $m^{-1}$ and for the rock $3 \times 10^{-7}$ $m^{-1}$. The first value is reasonable for loose sediments. The second value was estimated from the extended duration test.
- The Initial chloride concentrations are assigned through the model domain according to the Cl-depth relationship presented in Figure 10.
- The mass transport model assumes an effective porosity the fractured rock of 0.1%, a longitudinal dispersivity of 30 m and transverse dispersivity of 10 m. These were estimated based on literature values for fractured rock from “Applied Hydrogeology of Fractured Rocks” (Singhal and Gupta 2010).

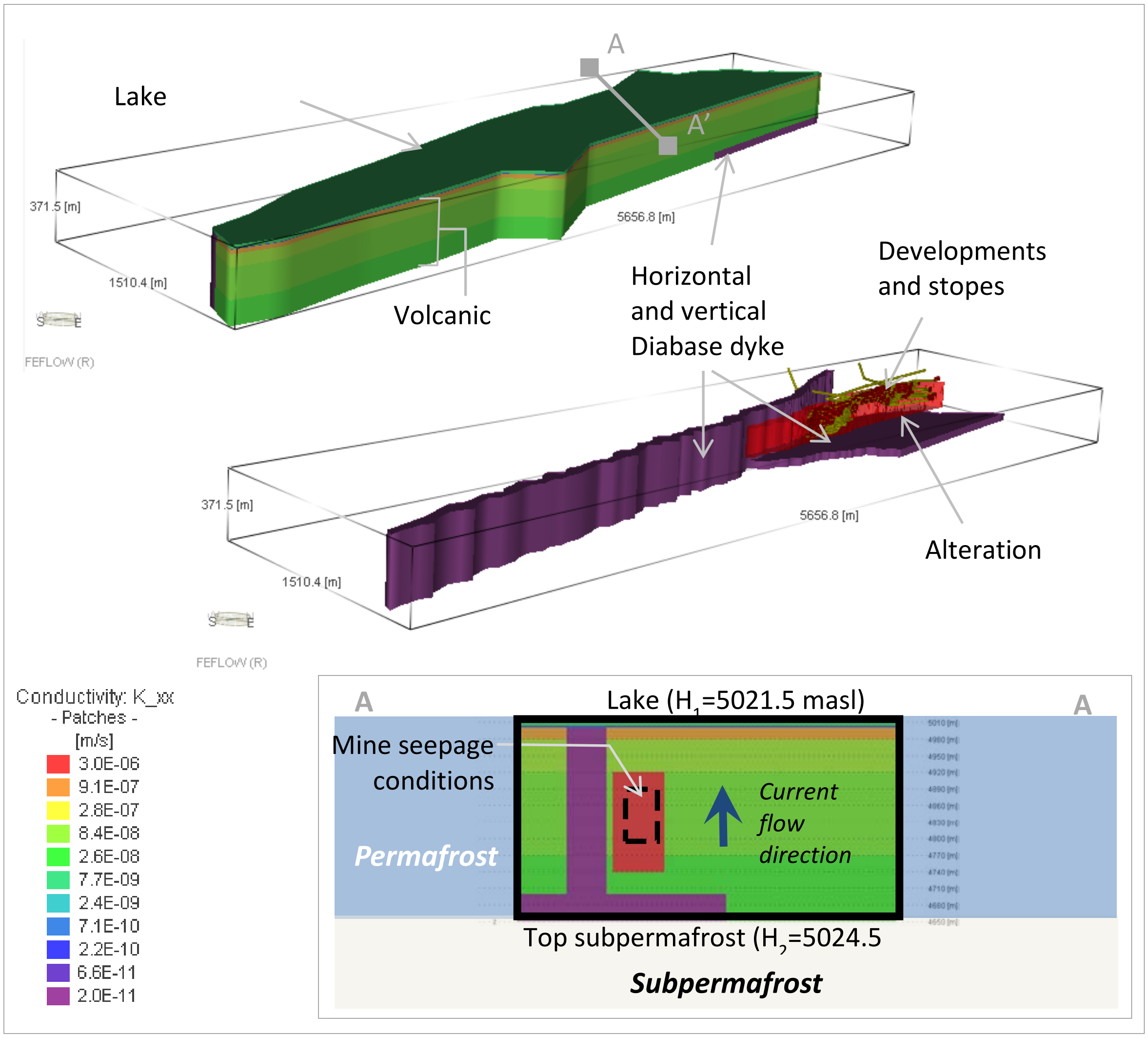



**Figure 12: 3D view and cross-section of the groundwater model.**

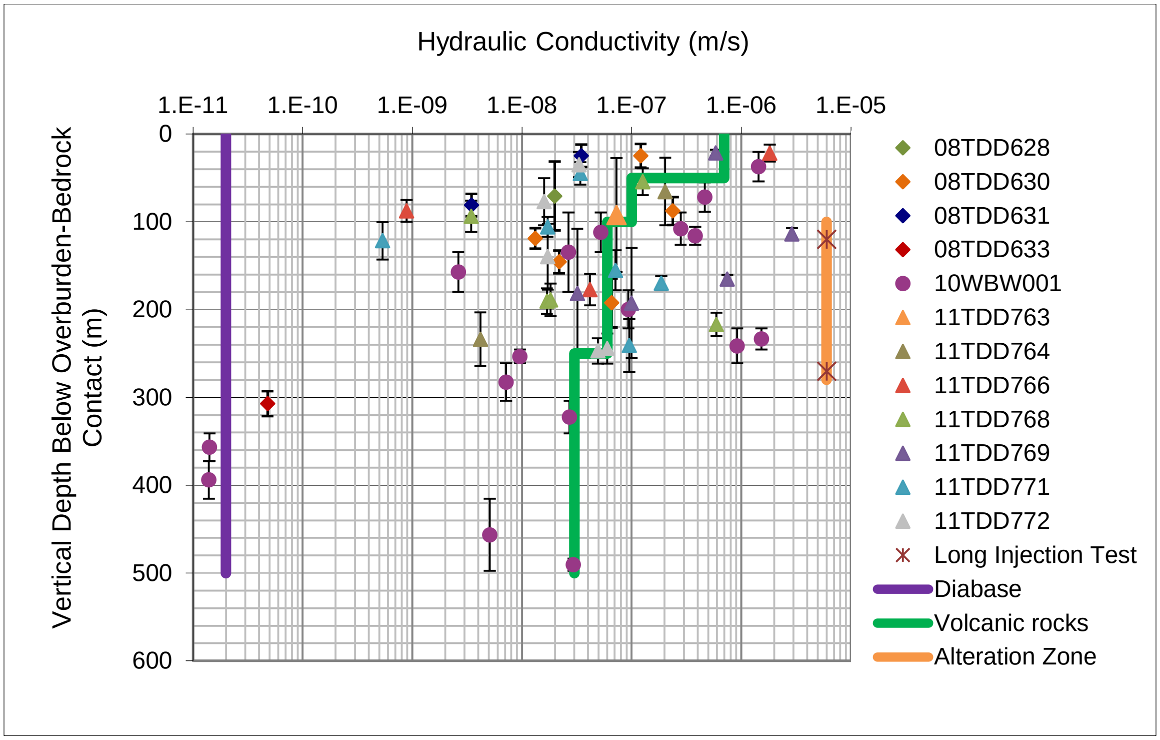



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**Figure 13: Observed and modeled hydraulic conductivity versus depth.**

### 3.3.7 Boundary Conditions

Model boundary conditions are defined as follows:

- Top slice: Doris Lake is represented by a constant head (5,021.5 m, mine datum) and a constant mass conditions (Cl concentration of 68.5 mg/L).
- Internal slices: Underground development and mining stopes are represented as seepage face conditions. Seepage face conditions allow water to exit the model (flow into pits or underground areas) but water cannot enter the groundwater system. These conditions are activated sequentially over time according to the mine production plan (details are presented in the next section).
- Base slice: The open talik base is represented by a constant head (5,024.5 m, mine datum) and constant mass conditions (Cl concentration of 17,454 mg/L).
- External boundary: There is no movement of groundwater (no flow) from the areas outside the contact between the talik and permafrost.

### 3.3.8 Mine Plan and Water Management Assumptions

The numerical simulation starts at Year 2, on 8/20/2018 (time t = 0 days), about one and a half month prior to mining in talik starts in January 2019 (Year 3). Each mine area is activated on a monthly time step according to the mine production plan. Mine areas progressively “turn on” during an active mining period with a progressive increase in depth or development area based on the timeframe of mining.

As mining development progress, it is expected that some areas make water, while some do not. In those areas that do make water, mitigation measures will be implemented to control or limit inflow. For the purpose of modeling, it is assumed that:

- Any flow encountered in the decline within the top 100 m of the workings will be fully controlled and stopped;
- 25% of the mine surface will intersect un-controlled flowing features; these areas are allowed to flow unimpeded for the model time period; and
- As soon as mining is complete in an area, backfill is simulated by assuming those areas are sealed and no longer contribute towards groundwater inflow.

# 4 Modeling Results

## 4.1 Model Time Step and Error

Groundwater inflow and concentrations of key constituents associated with the inflow were calculated using a monthly time step. Model convergence errors was less than 0.1% and the average model flow and mass imbalance error was less than 0.5%.

## 4.2 Mine Inflows

Table 8 and Figure 14 present the combined predicted monthly inflow for the Doris Mine. Mining in talik starts at Year 3, in January 2019. The simulation predicts that mine inflow will increase gradually until June 2020 (Year 4), to a maximum of 2,650 $m^3$/day. Mine inflow will start decreasing after June 2020 when some sections of the mines are completed, and subsequently backfilled and sealed off. By April 2022 (Year 6), after the last stope is mined, the total inflow to the mine is predicted at 1,630 $m^3$/d.

Mine inflows draw from water stored in the rock (storage), from Doris Lake and from the regional flow at the base of the talik. The contributions for each of these sources are predicted to vary over time. At the early stage, inflow is primarily from storage, but is quickly replaced by the inputs from Doris Lake and from the deep regional flow system. The proportions between these two sources are relatively stable once the influence of storage has stabilized, with inflows consisting of about 70% lake water and 30% deep groundwater.

**Table 8: Life of Mine Predicted Mine Inflow**

| Year of Mining | Date | Time | Inflow/Outflow [(1)] Source | | | |
|---|---|---|---|---|---|---|
| | | | Doris Lake | Base Talik | Mine | Storage |
| | | [d] | $m^3$/d | $m^3$/d | $m^3$/d | $m^3$/d |
| Year 2 | 1-Oct-18 | 42 | -15 | 43 | 0 | -28 |
| | 1-Nov-18 | 73 | -28 | 38 | 0 | -10 |
| | 1-Dec-18 | 103 | -33 | 37 | 0 | -5 |
| Year 3 | 1-Jan-19 | 134 | -2 | 67 | -296 | 231 |
| | 1-Feb-19 | 165 | 140 | 154 | -919 | 624 |
| | 1-Mar-19 | 193 | 354 | 229 | -1,118 | 535 |
| | 1-Apr-19 | 224 | 578 | 294 | -1,314 | 453 |
| | 1-May-19 | 254 | 753 | 334 | -1,365 | 287 |
| | 1-Jun-19 | 285 | 876 | 358 | -1,436 | 202 |
| | 1-Jul-19 | 315 | 982 | 400 | -1,690 | 308 |
| | 1-Aug-19 | 346 | 1,094 | 433 | -1,729 | 202 |
| | 1-Sep-19 | 377 | 1,180 | 461 | -1,794 | 153 |
| | 1-Oct-19 | 407 | 1,243 | 487 | -1,845 | 115 |
| | 1-Nov-19 | 438 | 1,298 | 521 | -1,944 | 125 |
| | 1-Dec-19 | 468 | 1,350 | 557 | -2,027 | 121 |

| Year of Mining | Date | Time | Inflow/Outflow (1) Source | | | |
|---|---|---|---|---|---|---|
| | | | Doris Lake | Base Talik | Mine | Storage |
| | | [d] | $m^3/d$ | $m^3/d$ | $m^3/d$ | $m^3/d$ |
| Year 4 | 1-Jan-20 | 499 | 1,397 | 608 | -2,087 | 83 |
| | 1-Feb-20 | 530 | 1,454 | 694 | -2,338 | 203 |
| | 1-Mar-20 | 559 | 1,528 | 753 | -2,442 | 175 |
| | 1-Apr-20 | 590 | 1,593 | 774 | -2,454 | 96 |
| | 1-May-20 | 620 | 1,630 | 806 | -2,473 | 37 |
| | 1-Jun-20 | 651 | 1,665 | 874 | -2,647 | 130 |
| | 1-Jul-20 | 681 | 1,703 | 889 | -2,620 | 47 |
| | 1-Aug-20 | 712 | 1,724 | 892 | -2,577 | 18 |
| | 1-Sep-20 | 743 | 1,732 | 893 | -2,576 | 7 |
| | 1-Oct-20 | 773 | 1,722 | 862 | -2,418 | -99 |
| | 1-Nov-20 | 804 | 1,695 | 855 | -2,450 | -33 |
| | 1-Dec-20 | 834 | 1,680 | 854 | -2,454 | -13 |
| Year 5 | 1-Jan-21 | 865 | 1,674 | 854 | -2,455 | -5 |
| | 1-Feb-21 | 896 | 1,644 | 808 | -2,219 | -191 |
| | 1-Mar-21 | 924 | 1,594 | 798 | -2,281 | -68 |
| | 1-Apr-21 | 955 | 1,561 | 794 | -2,267 | -44 |
| | 1-May-21 | 985 | 1,544 | 793 | -2,275 | -17 |
| | 1-Jun-21 | 1,016 | 1,501 | 712 | -1,953 | -238 |
| | 1-Jul-21 | 1,046 | 1,436 | 696 | -2,033 | -77 |
| | 1-Aug-21 | 1,077 | 1,338 | 592 | -1,449 | -451 |
| | 1-Sep-21 | 1,108 | 1,209 | 570 | -1,601 | -146 |
| | 1-Oct-21 | 1,138 | 1,143 | 567 | -1,621 | -56 |
| | 1-Nov-21 | 1,169 | 1,116 | 565 | -1,628 | -22 |
| | 1-Dec-21 | 1,199 | 1,106 | 565 | -1,630 | -8 |
| Year 6 | 1-Jan-22 | 1,230 | 1,102 | 565 | -1,631 | -3 |
| | 31-Jan-22 | 1,260 | 1,101 | 564 | -1,631 | -1 |
| | 1-Mar-22 | 1,289 | 1,100 | 564 | -1,631 | 0 |
| | 1-Apr-22 | 1,320 | 1,100 | 564 | -1,631 | 0 |

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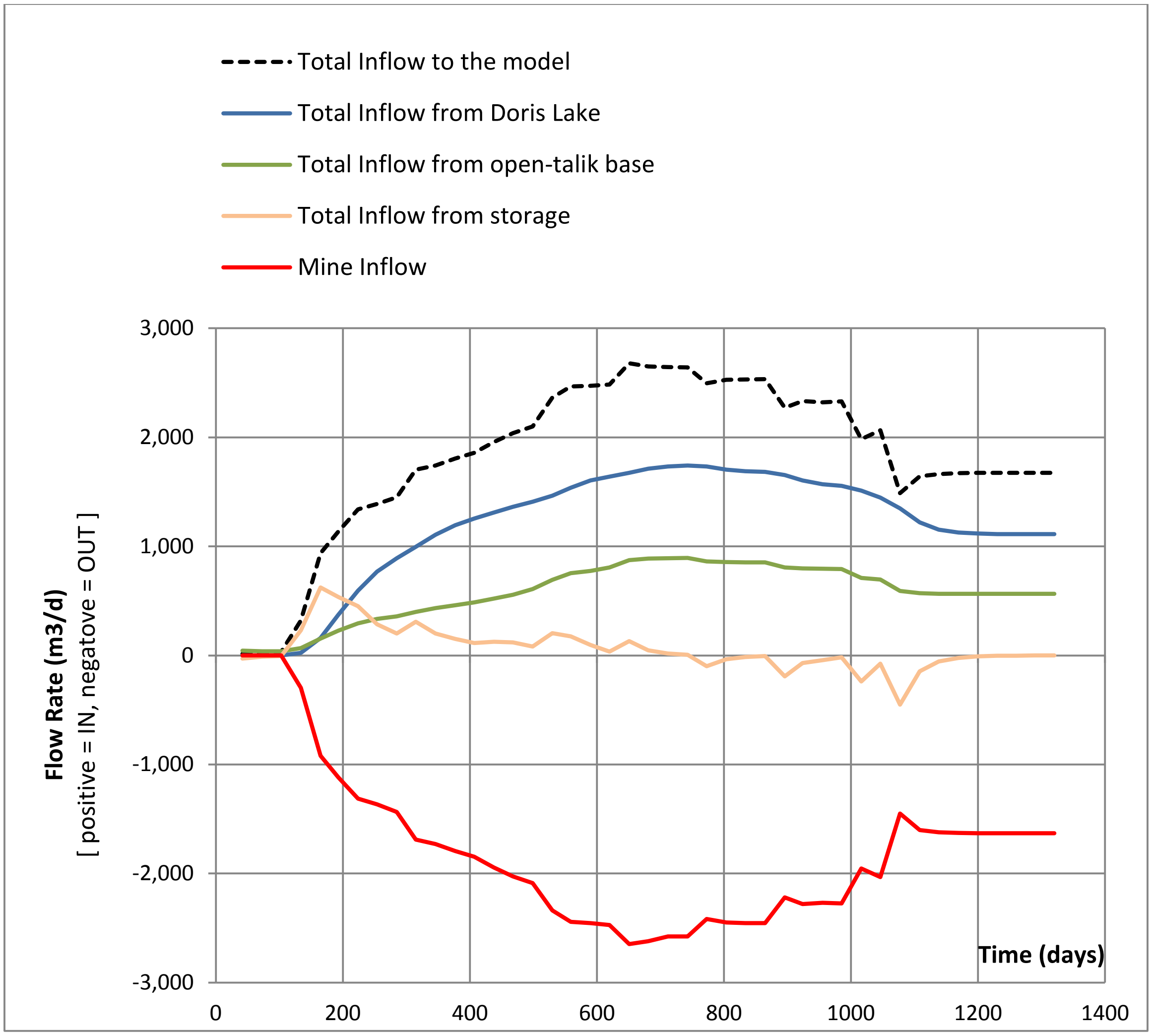
Note: (1) By convention, positive values correspond to flow into the model (inflow) and negative values to flow out of the model (outflow). In the case of storage, positive and negative rates correspond respectively to a capture and a release of storage water.

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Note: By convention, positive values correspond to flow into the model (inflow) and negative values to flow out of the model (outflow). In the case of storage, positive and negative rates correspond respectively to a capture and a release of storage water.

**Figure 14: Graphic Presentation of Overall Mine Inflow over Time**

## 4.3 Groundwater Quality

### 4.3.1 Approach

The results for groundwater quality predictions are subdivided into two subsections: one for chloride and one for the other constituents of concern (N, B, Cd, Mn). The prediction for chloride was calculated directly from the numerical model and accounted for the observed increase of chloride concentration with depth. Since the other constituents do not vary with depth, their concentrations were calculated with a simple mixing model, using the flow predictions, the estimated concentrations in Doris Lake water and groundwater, and assuming conservation of mass.

### 4.3.2 Concentrations of Chloride in Mine Inflow

Table 9 and Figure 15 present the predicted monthly inflow chloride concentration. The simulation predicts that during about the first year of mining, inflows will have a peak chloride concentration of approximately 14,800 mg/L, a value that is representative of the background chloride concentration in rock at the depth where the mine is developed. As the water from storage is progressively replaced by a mix of water from the Doris Lake (70%) and the regional deep groundwater (30%), the concentration of chloride will decrease. Within about two years after mining starts, chloride concentration will stabilize at an average concentration on the order of 5,100 mg/L.

**Table 9: Predicted Concentration of Chloride over Time Associated with Mine Inflow**

| Year of Mining | Date | Time (d) | Chloride Concentration (mg/L) |
|---|---|---|---|
| Year 2 | 1-Oct-18 | 42 | 0 |
| | 1-Nov-18 | 73 | 0 |
| | 1-Dec-18 | 103 | 0 |
| Year 3 | 1-Jan-19 | 134 | 14,750 |
| | 1-Feb-19 | 165 | 13,597 |
| | 1-Mar-19 | 193 | 12,200 |
| | 1-Apr-19 | 224 | 10,551 |
| | 1-May-19 | 254 | 9,161 |
| | 1-Jun-19 | 285 | 8,589 |
| | 1-Jul-19 | 315 | 7,306 |
| | 1-Aug-19 | 346 | 6,415 |
| | 1-Sep-19 | 377 | 5,961 |
| | 1-Oct-19 | 407 | 5,714 |
| | 1-Nov-19 | 438 | 5,743 |
| | 1-Dec-19 | 468 | 5,858 |
| Year 4 | 1-Jan-20 | 499 | 6,034 |
| | 1-Feb-20 | 530 | 6,298 |
| | 1-Mar-20 | 559 | 6,089 |
| | 1-Apr-20 | 590 | 5,887 |
| | 1-May-20 | 620 | 6,217 |
| | 1-Jun-20 | 651 | 6,307 |
| | 1-Jul-20 | 681 | 5,980 |
| | 1-Aug-20 | 712 | 5,828 |
| | 1-Sep-20 | 743 | 5,766 |
| | 1-Oct-20 | 773 | 5,559 |
| | 1-Nov-20 | 804 | 5,576 |
| | 1-Dec-20 | 834 | 5,553 |

| Year of Mining | Date | Time (d) | Chloride Concentration (mg/L) |
|---|---|---|---|
| Year 5 | 1-Jan-21 | 865 | 5,529 |
| | 1-Feb-21 | 896 | 5,653 |
| | 1-Mar-21 | 924 | 5,646 |
| | 1-Apr-21 | 955 | 5,661 |
| | 1-May-21 | 985 | 5,626 |
| | 1-Jun-21 | 1,016 | 5,086 |
| | 1-Jul-21 | 1,046 | 5,375 |
| | 1-Aug-21 | 1,077 | 5,210 |
| | 1-Sep-21 | 1,108 | 5,463 |
| | 1-Oct-21 | 1,138 | 5,513 |
| | 1-Nov-21 | 1,169 | 5,527 |
| | 1-Dec-21 | 1,199 | 5,532 |
| Year 6 | 1-Jan-22 | 1,230 | 5,533 |
| | 31-Jan-22 | 1,260 | 5,533 |
| | 1-Mar-22 | 1,289 | 5,531 |
| | 1-Apr-22 | 1,320 | 5,528 |

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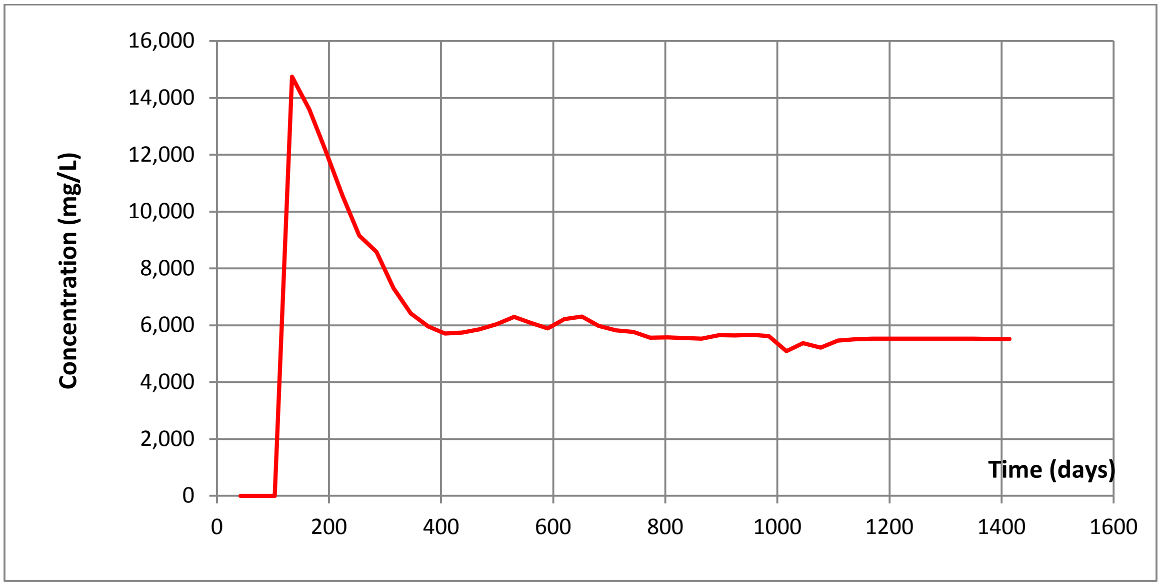


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**Figure 15: Graphic Presentation of Predicted Concentration of Chloride over Time Associated with Mine Inflow**

### 4.3.3 Concentrations of Other Constituents of Concern in Mine Inflows

Table 9 presents the predicted monthly concentrations of ammonia, boron, cadmium and manganese, associated with Doris Mine inflows. Concentrations for these parameters do not change with depth; inflow concentrations are estimated with a simple mixing model based on flow contributions from Doris Lake and deeper water. As for chloride, the simulation predicts that concentrations of these other parameters will peak in the first year of mining, when background water quality from water out of storage dominates. Concentrations decrease until stabilizing after about one year, after which concentrations reflect relatively steady inflows from Doris Lake (70%) and regional deep groundwater (30%).

**Table 10: Predicted Concentration of N, B, Cd, and Mn Over Time in Mine Inflows**

| Year of Mining | Date | Time | Concentration of | | | |
|---|---|---|---|---|---|---|
| | | | Ammonia as N | Boron | Cadmium | Manganese |
| | | [d] | mg/L | mg/L | mg/L | mg/L |
| | | | $[N]_{Lake}$ = 0.005 (1) | $[B]_{Lake}$ = 0.05 (1) | $[Cd]_{Lake}$ = 0.00001 (1) | $[Mn]_{Lake}$ = 0.0188 (1) |
| | | | $[N]_{GW}$ = 3.5 (1) | $[B]_{GW}$ = 3.24 (1) | $[Cd]_{GW}$ = 0.00012 (1) | $[Mn]_{GW}$ = 1.75 (1) |
| Year 2 | 1-Oct-18 | 42 | 0.000 | 0.00 | 0.00000 | 0.0000 |
| | 1-Nov-18 | 73 | 0.000 | 0.00 | 0.00000 | 0.0000 |
| | 1-Dec-18 | 103 | 0.000 | 0.00 | 0.00000 | 0.0000 |
| Year 3 | 1-Jan-19 | 134 | 3.243 | 3.01 | 0.00011 | 1.6227 |
| | 1-Feb-19 | 165 | 2.902 | 2.69 | 0.00010 | 1.4536 |
| | 1-Mar-19 | 193 | 2.355 | 2.20 | 0.00008 | 1.1831 |
| | 1-Apr-19 | 224 | 1.951 | 1.83 | 0.00007 | 0.9828 |
| | 1-May-19 | 254 | 1.567 | 1.48 | 0.00006 | 0.7925 |
| | 1-Jun-19 | 285 | 1.354 | 1.28 | 0.00005 | 0.6872 |
| | 1-Jul-19 | 315 | 1.457 | 1.38 | 0.00006 | 0.7380 |
| | 1-Aug-19 | 346 | 1.278 | 1.21 | 0.00005 | 0.6496 |
| | 1-Sep-19 | 377 | 1.192 | 1.13 | 0.00005 | 0.6066 |
| | 1-Oct-19 | 407 | 1.137 | 1.08 | 0.00005 | 0.5796 |
| | 1-Nov-19 | 438 | 1.159 | 1.10 | 0.00005 | 0.5906 |
| | 1-Dec-19 | 468 | 1.166 | 1.11 | 0.00005 | 0.5940 |
| Year 4 | 1-Jan-20 | 499 | 1.154 | 1.10 | 0.00005 | 0.5879 |
| | 1-Feb-20 | 530 | 1.332 | 1.26 | 0.00005 | 0.6762 |
| | 1-Mar-20 | 559 | 1.320 | 1.25 | 0.00005 | 0.6702 |
| | 1-Apr-20 | 590 | 1.234 | 1.17 | 0.00005 | 0.6276 |
| | 1-May-20 | 620 | 1.190 | 1.13 | 0.00005 | 0.6059 |
| | 1-Jun-20 | 651 | 1.315 | 1.25 | 0.00005 | 0.6675 |
| | 1-Jul-20 | 681 | 1.240 | 1.18 | 0.00005 | 0.6305 |
| | 1-Aug-20 | 712 | 1.208 | 1.15 | 0.00005 | 0.6148 |
| | 1-Sep-20 | 743 | 1.195 | 1.14 | 0.00005 | 0.6084 |

| Year of Mining | Date | Time | Concentration of | | | |
|---|---|---|---|---|---|---|
| | | | Ammonia as N | Boron | Cadmium | Manganese |
| | | [d] | mg/L | mg/L | mg/L | mg/L |
| | | | $[N]_{Lake} = 0.005$ (1) | $[B]_{Lake} = 0.05$ (1) | $[Cd]_{Lake} = 0.00001$ (1) | $[Mn]_{Lake} = 0.0188$ (1) |
| | | | $[N]_{GW} = 3.5$ (1) | $[B]_{GW} = 3.24$ (1) | $[Cd]_{GW} = 0.00012$ (1) | $[Mn]_{GW} = 1.75$ (1) |
| | 1-Oct-20 | 773 | 1.166 | 1.11 | 0.00005 | 0.5941 |
| | 1-Nov-20 | 804 | 1.172 | 1.12 | 0.00005 | 0.5970 |
| | 1-Dec-20 | 834 | 1.178 | 1.12 | 0.00005 | 0.5998 |
| Year 5 | 1-Jan-21 | 865 | 1.181 | 1.12 | 0.00005 | 0.6011 |
| | 1-Feb-21 | 896 | 1.152 | 1.10 | 0.00005 | 0.5868 |
| | 1-Mar-21 | 924 | 1.166 | 1.11 | 0.00005 | 0.5940 |
| | 1-Apr-21 | 955 | 1.179 | 1.12 | 0.00005 | 0.6001 |
| | 1-May-21 | 985 | 1.186 | 1.13 | 0.00005 | 0.6037 |
| | 1-Jun-21 | 1016 | 1.124 | 1.07 | 0.00005 | 0.5731 |
| | 1-Jul-21 | 1046 | 1.140 | 1.09 | 0.00005 | 0.5810 |
| | 1-Aug-21 | 1077 | 1.071 | 1.02 | 0.00004 | 0.5470 |
| | 1-Sep-21 | 1108 | 1.118 | 1.07 | 0.00005 | 0.5704 |
| | 1-Oct-21 | 1138 | 1.156 | 1.10 | 0.00005 | 0.5889 |
| | 1-Nov-21 | 1169 | 1.172 | 1.12 | 0.00005 | 0.5969 |
| | 1-Dec-21 | 1199 | 1.178 | 1.12 | 0.00005 | 0.6000 |
| Year 6 | 1-Jan-22 | 1230 | 1.181 | 1.12 | 0.00005 | 0.6012 |
| | 31-Jan-22 | 1260 | 1.182 | 1.12 | 0.00005 | 0.6016 |
| | 1-Mar-22 | 1289 | 1.182 | 1.12 | 0.00005 | 0.6018 |
| | 1-Apr-22 | 1320 | 1.182 | 1.12 | 0.00005 | 0.6018 |

\\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CT022.002_2015_Hope Bay Ongoing Support\!020_Project_Data\010_SRK\GW Numerical Model\Upd_Dorris\Import+Export\Budget_Output\v8c_Budget.xlsx

Note: (1) Source concentrations in the lake or in groundwater (GW) for N: Ammonia as N, B: Boron, Cd: Cadmium, Mn: Manganese.

## 4.4 Model Sensitivities

Additional models were completed to assess the effects of parameter uncertainties on mine inflow predictions. Emphasis was placed on scenarios that could result in increased inflow to the underground mine compared to the base model. The analysis involved quantification of the effects of four main uncertainties, namely:

- Increased hydraulic gradient caused by higher water elevation in Doris Lake;
- Increased hydraulic conductivity in the lake bed sediments;
- Increased hydraulic conductivity in the volcanic rock; and
- Increased hydraulic conductivity in the diabase.

The results of the sensitivity analyses are summarized in Table 11.

**Table 11: Sensitivity of the Inflow Predictions to Hydraulic Conductivity and Doris Lake Level**

| Parameter | Value Used for Base case | Value Used for Sensitivity | % Relative Change to Lake Inflow | % Relative Change to Mine inflow |
|---|---|---|---|---|
| Head Doris Lake | 5,021.5 m | 5,022.5 m | +1% | +2% |
| K Sediment | Soft sedim. 1 x $10^{-8}$ m/s<br>Ind. sedim. 4 x $10^{-10}$ m/s | K values increased by one order of magnitude | +290% | +160% |
| K Volcanic Rock | 20-50 mbgs: 7 x $10^{-7}$ m/s<br>50-100 mbgs: 1 x $10^{-7}$ m/s<br>100-250 mbgs: 6 x $10^{-8}$ m/s<br>250-500 mbgs: 3 x $10^{-8}$ m/s | | -2% | +183% |
| K Diabase | 2 x $10^{-11}$ m/s | | <1% | <1% |

The analysis shows that predictions of inflows are sensitive to the hydraulic conductivities of volcanic rock and lake sediment, and not sensitive to the surface water elevation in Doris Lake nor to the hydraulic conductivity of the diabase.

# 5 Conclusions and Recommendations

A hydrogeological conceptual model for the Doris Mine was developed based on available data, including an assessment of potential structural controls on groundwater flow. Subsequently a numerical model was developed to simulate the conceptual model.

Results of the Doris Mine groundwater model suggest that mine inflow will increase gradually between January 2019 (Year 3) and June 2020 (Year 4), to a maximum of 2,650 $m^3$/day. Mine inflow will start decreasing after June 2020, when some sections of the mines are completed and sealed off from other areas of active mining. By April 2022 (Year 6), after the last stope is mined, the total inflow to the mine is predicted to be about 1,630 $m^3$/d. About 70% of the mine inflow is associated with water from Doris Lake with the remainder coming from deep regional groundwater.

Results suggest that the water encountered during mining, at least initially, will be saline, and dominated by chloride. Other constituents of concern include ammonia, boron, cadmium, and manganese because concentrations in background groundwater exceed water quality guidelines.

The model predicts that the respective concentrations of each constituent will peak in the early mining stage, when saline connate water is the dominant source of groundwater inflow, and will then progressively decrease as water from storage is progressively replaced by a mix of water from Doris Lake (70%) and regional deep groundwater (30%). Concentrations are predicted to stabilize within about one year after mine inflow starts.

Predicted inflow values represent monthly averages of the mine progression; however, daily inflows are likely to exceed monthly averages, particularly when and where highly conductive structures are intersected. The distribution of hydraulic conductivity in the unfrozen ground is very complex and the specific features that control the flow are not well understood. The base case scenario models the hinge zone of the Doris Antiform as an area with increased fracturing and higher hydraulic conductivity, but other unidentified features, such as nearby faults (Force 1 fault for example) or other fractures, could also be responsible.

Sensitivity analysis suggests that the predictions of inflows are sensitive to the hydraulic conductivities of volcanic rock and lake bed sediment.

The modeling assumes that the groundwater management plan will include active control measures such as advance probe drilling and pre-grouting of highly conductive structures prior to intersection with the mine workings, and additional pumping capacity to handle potentially higher than predicted inflows. This plan may also need to consider ongoing assessment of where and how bulkheads and backfill are used.

This report, **"Hydrogeological Modeling of the Proposed Doris Mine, Hope Bay Project, Nunavut"**, was prepared by



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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

# 6 References

Bieber C., Chorley D., Zawadzki, W, and Reinson J., 2006. Hydrogeologic Data Collection and Development of Conceptual Models to Predict Mine Inflow Quantity and Quality at Diavik Diamond Mine, NWT. 59th Canadian Geotechnical Conference and 7th Joint CGS/IAH-CNC Groundwater Specialty Conference, Vancouver, BC, Canada. M6-B Data Collection II.

Burn, C., 2002. Tundra Lakes and Permafrost, Richards Island, Western Arctic Coast, Canada. Canadian Journal of Earth Sciences, Vol. 39, 1281-1298.

Canadian Council of Ministers of the Environment (CCME), 2015. Canadian Environmental Quality Guidelines Summary Table. http://st-ts.ccme.ca/. Accessed April 2015.

Carpenter, R.L., Sherlock, R.L., Quang, C., Kleespies, P., and McLeod, R., 2003. Geology of the Doris North Gold Deposits, Northern Hope Bay Volcanic Belt, Slave Structural Province, Nunavut. Geological Survey of Canada.

Cooper, H.H. and Jacob, C.E., 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans., vol. 27, pp. 526-534.

DHI, 2015. FEFLOW v6.2 (P8) Advanced Groundwater Modelling. http://www.mikepoweredbydhi.com/products/feflow. March 2015.

Frape, S., & Fritz, P., 1987. Geochemical Trends for Groundwater from the Canadian Shield, in Saline Water and Gases from Crystalline Rocks. Geological Association of Canada Special Paper, Volume 33, 19-38.

Government of Canada, 2002. Natural Resources Canada, Earth Sciences Sector. Canadian Permafrost Thickness.

Mackay, J., 1962. Pingos of the Pleistocene Mackenzie Delta Area. Geographical Bulletin, Volume 18, 21-63.

Mackay, J., 1992. Lake Stability in an Ice-rich Permafrost Environment: Examples from the Western Arctic Coast. Aquatic Ecosystems in Semi-arid Regions: Implications for Resource Management, (Symposium Series 7) (pages 1-26).

Metal Mining Effluent Regulations (MMER), 2015. Authorized Limits of Deleterious Substances - Schedule 4. Last amended February 20, 2015. http://laws-lois.justice.gc.ca/eng/regulations/SOR-2002-222/. Accessed April 2015.

Parez L., and Fauriel R., 1988. Advantages from Piezocone Application to In-situ Tests. Revue Francaise de Geotechnique, Volume 44, 13–27 (in French).

Singhal, B.B.S., and Gupta, R.P., 2010. Applied Hydrogeology of Fractured Rocks. Springer Science + Business Media B.V. 2nd Ed. 2010.

Smith, M., 1976. Permafrost in the Mackenzie Delta, Northwest Territories. Canada Geological Survey Commission. Paper 75-28.

SRK Consulting (Canada) Inc., 2005. Groundwater Assessment, Doris North Project, Hope Bay Nunavut, Canada. Report prepared for Miramar Hope Bay Limited. 1CM014.006. October 2005.

SRK Consulting (Canada) Inc., 2009a. Hope Bay Gold Project: Stage 2 Overburden Characterization Report, Nunavut, Canada. Report prepared for Hope Bay Mining Limited. 1CH008.002. February 2009.

SRK Consulting (Canada) Inc., 2009b. Geotechnical and Hydrogeological Assessment for the Doris North Open Pit and Doris Central Underground. Report prepared for Hope Bay Mining Limited. Project Number: 2CH009.000. June 2009.

SRK Consulting (Canada) Inc., 2011a. Hope Bay 2010 Westbay Program Data Report. Report prepared for Hope Bay Mining Limited. 1CH008.013. February 2011.

SRK Consulting (Canada) Inc., 2011b. Groundwater Inflows and Inflow Water Quality for the Revised Doris North Project Water Licence Amendment Package. 2011.

SRK Consulting (Canada) Inc., 2012. Hope Bay 2011 Groundwater Quality Report. Report prepared for Hope Bay Mining Limited. 1CH008.060. April 2012.

SRK Consulting (Canada) Inc., 2014. 2011 Stage 2 Geotechnical and Hydrogeological Assessment for Doris Central and Connector Underground Mines. Report prepared for TMAC Resources Inc. 1CT022.001. April 2014.

SRK Consulting (Canada) Inc., 2015. Doris North Project, Hope Bay - Water Quality Model Report. Report prepared for TMAC Resources Inc. 1CT022.002. May 2015.

Van Everdingen, 1998 revised May 2005. Multi-language Glossary of Permafrost and Related Ground-ice Terms. Boulder, CO: National Snow and Ice Data Center.

# Appendix A: Summary of the Drillhole Details at Doris

| Area | Drill Hole | Date | Length (m) | Easting UTM | Northing UTM | Elevation UTM | Azimuth | Dip |
|---|---|---|---|---|---|---|---|---|
| *Doris Central* | 08TDD628 | 2008 | 141 | 33868 | 557746 | 5022 | 262.0 | -61.3 |
| | 08TDD630 | 2008 | 317 | 33823 | 557652 | 5022 | 261.3 | -67.0 |
| | 08TDD631 | 2008 | 122 | 33859 | 557605 | 5022 | 260.9 | -81.4 |
| | 08TDD633 | 2008 | 401 | 33402 | 557646 | 5066 | 80.9 | -55.4 |
| | 10WBW001 | 2010 | 564 | 33778 | 557537 | 5026 | 121.6 | -65.2 |
| | 11TDD764 | 2011 | 341 | 33652 | 557804 | 5022 | 82.4 | -56.2 |
| | 11TDD769 | 2011 | 310 | 33812 | 557713 | 5022 | 249.0 | -65.1 |
| | 11TDD772 | 2011 | 330 | 33861 | 557708 | 5023 | 199.7 | -65.1 |
| *Doris Connector* | 11TDD763 | 2011 | 285 | 33615 | 558178 | 5022 | 82.0 | -51.8 |
| | 11TDD766 | 2011 | 297 | 33901 | 558910 | 5022 | 272.1 | -60 |
| | 11TDD768 | 2011 | 299 | 33665 | 558760 | 5022 | 102.0 | -59.8 |
| | 11TDD771 | 2011 | 294 | 33720 | 558380 | 5022 | 115.7 | -78.0 |
| *Doris North (thermal)* | SRK35 | 2004 | 10 | 34037 | 559479 | 5022 | 0 | -90 |
| | SRK50 | 2004 | 200 | 33807 | 559177 | 5038 | 0 | -90 |
| | 08TDD632 | 0208 | 401 | 33915 | 559370 | 5031 | 276.2 | -60.8 |
| | 10WBW002 | 2010 | 601 | 33913 | 559375 | 5030 | 277.6 | -74.4 |

# Appendix B: Pressure Dissipation Tests Details from CPT

**Estimated Hydraulic Conductivity of the Doris Lake Sediment from CPT pressure dissipation tests**

| Area | Drill Hole | Duration (s) | Test Depth (m) | t50 [(1)] (s) | t50 [(2)] comment | K (m/s) | Lithology |
|---|---|---|---|---|---|---|---|
| Doris | SRKCPT08-06 | 2000 | 10.0 | 250 | good | $1x10^{-8}$ | Clayey silt |
| Doris | SRKCPT08-06 | 700 | 11.9 | 50 | max. | $8x10^{-8}$ | Silty sand/sand |
| Doris | SRKCPT08-07 | 2000 | 5.0 | 1200 | min. | $1x10^{-9}$ | Sensitive fines |
| Doris | SRKCPT08-07 | 600 | 7.8 | 100 | good | $3x10^{-8}$ | Silty sand/sand |
| Doris | SRKCPT08-08 | 1600 | 15.0 | 500 | min. | $4x10^{-9}$ | Sensitive fines |
| Doris | SRKCPT08-08 | 3600 | 20.6 | 800 | min. | $2x10^{-9}$ | Silty sand/sand |
| Patch | SRKCPT08-14 | 650 | 10.0 | 100 | max. | $3x10^{-8}$ | Sensitive fines |
| Patch | SRKCPT08-14 | 2200 | 10.5 | 900 | min | $2x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-14 | 2000 | 16.8 | 200 | good | $1x10^{-8}$ | Silty sand/sand |
| Patch | SRKCPT08-15 | 1200 | 10.0 | 600 | min | $3x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-16 | 1800 | 10.0 | 600 | min | $3x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-16 | 200 | 15.8 | 10 | min. | $6x10^{-7}$ | Silty sand/sand |
| Patch | SRKCPT08-17 | 2000 | 8.5 | 450 | min | $5x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-17 | 900 | 25.3 | 200 | min | $1x10^{-8}$ | Sandy silt |
| Patch | SRKCPT08-19 | 2000 | 10.0 | 500 | min | $4x10^{-9}$ | Clayey silt |
| Patch | SRKCPT08-19 | 600 | 14.4 | 30 | good | $1x10^{-7}$ | Sandy silt |
| Patch | SRKCPT08-20 | 6000 | 15.3 | 300 | min. | $8x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-20 | 2905 | 25.1 | 800 | min | $2x10^{-9}$ | Clayey silt |
| Patch | SRKCPT08-21 | 3600 | 10.0 | 130 | min | $2x10^{-8}$ | Sensitive fines |
| Patch | SRKCPT08-21 | 2500 | 20.0 | 800 | min | $2x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-21 | 1200 | 30.0 | 500 | min. | $4x10^{-9}$ | Silt |
| Patch | SRKCPT08-23 | 200 | 3.8 | 10 | good | $6x10^{-7}$ | Sensitive fines |
| Patch | SRKCPT08-23 | 2400 | 10.0 | 400 | min | $6x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-23 | 2700 | 20.0 | 700 | min | $3x10^{-9}$ | Sensitive fines |
| Patch | SRKCPT08-23 | 3000 | 28.5 | 200 | good | $1x10^{-8}$ | Silty sand/sand |
| Spyder | SRKCPT08-29 | 13755 | 5.0 | 200 | min | $1x10^{-8}$ | Sensitive fines |
| Spyder | SRKCPT08-31 | 5000 | 5.0 | 1200 | min. | $1x10^{-9}$ | Sensitive fines |
| Spyder | SRKCPT08-31 | 200 | 9.0 | 10 | min. | $6x10^{-7}$ | Sand |

**Note:**

[1] t50 value represents the time taken to reach 50% pressure recovery between the induced pressure increase and static, or equilibrated, pressure.

[2] "Min." indicates that the equilibrated pressure was often not achieved within the monitored recovery period; therefore t50 value tends to be underestimated and as a consequence the hydraulic conductivity is likely overestimated.

"Good" indicates that the t50 could be clearly estimated from the pressure response.

"Max." indicates that the equilibrated pressure was achieved quickly within the monitored recovery period; therefore t50 value could be overestimated and as a consequence the hydraulic conductivity may be underestimated.

Source: \\VAN-SVR0\Projects\01_SITES\Hope.Bay\1CH008.054_2011 Stage 2 Geotech-Hydro\070_Reporting\Stage 2 Doris Geotech Hydro Report\020_Tables0

**Package 6**
**Engineering and Design Documents**

# P6-4 Landfill

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# Memo

| | | | |
|---|---|---|---|
| **To:** | John Roberts, TMAC | **Client:** | TMAC Resources Ltd. |
| **From:** | Lowell Wade, MSc, PEng<br>Maritz Rykaart, PhD, PEng | **Project No:** | 1CT022.002.200.1500 |
| **Cc:** | | **Date:** | May 29, 2015 |
| **Subject:** | Doris North Project: Quarry #3 Non-Hazardous Waste Landfill Design Brief | | |

# 1 Introduction

TMAC Resources (TMAC) has reviewed the waste management requirements for the Doris North Project (Project) in the Kitikmeot Region of Nunavut, Canada. The non-hazardous waste from the Project's operations and closure will require disposal in a non-hazardous waste landfill. It is proposed to locate the non-hazardous waste landfill in Quarry #3, which will be developed within the Tailings Impoundment Area (TIA) to provide construction materials for the Secondary Road, the Interim Dike, and the South Dam. Once sufficient construction material has been removed, from Quarry #3, the level space created will be used for disposal of non-hazardous waste. The Quarry #3 Non-Hazardous Waste Landfill will have sufficient capacity to receive non-hazardous waste from the now closed Old Windy Camp.

The landfill will be located in the northeast corner of the developed Quarry #3 and will be contained by the bedrock walls of Quarry #3 along the north and east sides and by rock fill berms along the south and west sides. Access into the non-hazardous waste landfill is by a ramp located in the southwest corner. The ultimate capacity of the Quarry #3 non-hazardous waste landfill will be 46,550 $m^3$.

The landfill will contain generally dry, non-leachate generating materials originating from routine mine construction, operations and closure. Accordingly, it is not necessary to completely eliminate moisture migration into and out of the landfill. The landfill is sited on a topographic high within the developed footprint of Quarry #3 so should there be any runoff it will be contained within the TIA. Access to the landfill will be from the Quarry #3 Access Road which connects to the Secondary Road at kilometer 2+345 (SRK 2011a).

The Project, including the proposed Quarry #3 Landfill, is constructed on KIA land and TMAC has secured a Commercial Lease for the property, including the proposed expansion.

This memo provided details of the non-hazardous waste landfill design, and should be read in conjunction with the attached Issued for Discussion (IFD) engineering drawings (Attachment 1).

# 2 Design Concept

The design concept of the Quarry #3 Landfill is based on the Quarry A landfill design by EBA (2010). The landfill will be constructed in the northeast corner of the developed Quarry #3 and will be on competent bedrock within a region of continuous permafrost. The landfill will be hydrogeologically isolated due to the presence of permafrost, and the bedrock is of good quality such that cracks and fractures created by blasting are expected to be surficial and should not propagate any leachate.

The landfill will be contained by two bedrock high walls along the north and east sides and by two 3 m high rock fill berms along the west and south sides. An access ramp will be located in the southeast corner of the landfill next to the bedrock high wall.

# 3 Landfill Concept Alternatives

Three options were considered for the location of the Landfill:

- Quarry #2 Landfill. Miramar (2007) originally proposed the landfill be located in Quarry #2. Quarry #2 is an active quarry used as a source of engineered rock fill for the majority of the surface infrastructure components of the Project. *This option was not selected because of the long term use of this quarry for construction material.*

- Quarry A Landfill. A landfill, in Quarry A, has also been considered (EBA 2010 and Hatch 2011). Quarry A was developed for the construction of the Doris-Windy All-Weather Road (SRK 2012) and is covered under the Hope Bay Regional Exploration Program Water Licence 2BE-HOP1222. Currently, this quarry is being used for the storage of explosives in Type 4 magazines. *This option was not selected because of the long term plan to use this quarry for explosives storage and that it is not covered under the Doris North Project Water Licence 2AM-DOH1323.*

- Quarry #3 Landfill. A landfill, in Quarry #3, is currently being considered. Quarry #3 will be developed for the construction of the Secondary Road as well as all the surface infrastructure components of the Tailings Impoundment Area (i.e. the Secondary Road, the Interim Dike, and the South Dam). Should there be any leachate generated, from the landfill, it will be contained within the Tailings Impoundment Area. *This option was selected as the preferred option since it contains all waste from the Project in one area.*

# 4 System Design

## 4.1 Survey Data

The design of the Quarry #3 Non-Hazardous Waste Landfill and the Quarry #3 Access Road are based on topographic contour maps produced from 2008 aerial photography supplied by Hope Bay Mining Limited (HBML). No detailed ground surveys have been completed.

## 4.2 Foundation Conditions

Comprehensive geotechnical investigations have been carried out at the Hope Bay Site (SRK 2009). This information confirms the Project area lies within the zone of continuous permafrost, with the permafrost being up to 550 m deep. Permafrost temperature at the surface is about -8ºC and the active layer is generally less than 1 m thick. Thermal modelling has determined that a 1 m minimum of rock fill cover would allow permafrost to aggrade into the non-hazardous waste landfill (SRK 2006).

## 4.3 Quarry #3 Non-Hazardous Waste Landfill

### 4.3.1 Design Criteria

The design criteria for the Quarry #3 Non-Hazardous Waste Landfill is based on the Guidelines for the Planning, Design, operations, and Maintenance of Modified Solid Waste Sites in the Northwest Territories (Ferguson et. al. 2003).

The design criteria for the landfill is as follows:

- Relatively level topography.
- Acceptable foundation conditions.
- Low surface run-off through the area.
- A 500 m setback from natural water bodies.
- A relatively close location to the mining activities and camps.
- Ramp grades shall not exceed 5H:1V.
- Ramps shall have a minimum width of 5 m.
- The minimum general drainage gradient shall be 0.5%.

### 4.3.2 Design

The base of Quarry #3 is designed to slope, at 1%, to the west so surface water runoff is directed towards the Tailings Impoundment Area. The non-hazardous waste landfill rock fill berms will be constructed from 6 inch compacted Jaw-Run quarry material and are designed so that any discharge from the non-hazardous waste will be directed to the low point (sump) in the northwest corner of the non-hazardous waste landfill where it will be pumped to the pond within the TIA. The sump will only be required while the non-hazardous waste landfill is in operation. At the end of the end of operations, the sump will be filled with non-hazardous waste and a final cover, as described below.

In accordance with approved waste management practices on site, the non-hazardous waste will be placed in two 0.85 m thick lifts and each lift will be compacted under the weight of heavy equipment. A 0.15 m thick Annual Cover, of 32 mm minus (1 ¼ inch) crushed rock, will be graded over the debris to fill the voids in order to reduce settlement and final cover subsidence. A 0.15 thick Annual Cover will also be placed over the waste during the winter months or extended periods when no landfill activity is anticipated. When non-hazardous waste is being placed within the Quarry #3 Non-Hazardous Waste Landfill, snow and ice will be removed and placed in the pond within the TIA.

At closure, the landfill will be capped with a 1 m thick rock fill cover of Run-of-Quarry (ROQ) material. The final surface of the landfill will be graded similar to the foundation base grade, of 1%, to shed water and minimize infiltration. The capping material will move the active thaw layer away from the stored waste so it is expected that permafrost will partially aggrade into the landfill waste over time.

If additional landfill capacity is required, at some point in the future, additional lifts of non-hazardous waste can be placed along the rock face, on the north and east sides of the landfill. At closure, the cover will then slope from northeast to southwest.

## 4.4 Quarry #3 Access Road

### 4.4.1 Design Criteria

The Quarry #3 Access Road is a 229 m long by 9.5 m wide access road to Quarry #3 which extends from kilometer 2+345 along the Secondary Road east to Quarry #3.

The design criteria for the Quarry #3 Access Road are the same as for the Secondary Road (SRK 2011a). The key design criteria are:

- The maximum allowable grade is 10% (10H:1V); however, wherever possible grades less than 4% will be targeted;
- A minimum thickness of 1 m over tundra must be maintained and 0.3 m over bedrock;
- The roadway will be crowned to promote drainage by means of 0.5% surface grading in both directions from the centreline of the roadway;
- Road shoulders will be graded to 2H:1V in areas where fill thickness is more than 1.5 m otherwise the road shoulders will be graded to 1.5H:1V; and
- No cut is allowed, except in designated rock quarries, and then only to a grade at least 0.5 m above the surrounding tundra elevation.

### 4.4.2 Foundation and Road Fill Materials

The all-weather access road design incorporates ROQ fill material and a layer of surfacing material. On the tundra, fill thicknesses will typically be 1 m minimum. This is based on terrain conditions inferred from the satellite imagery of the area but will be revised based on aerial field reconnaissance as well as on experience gained from surrounding areas. On exposed bedrock, fill thicknesses will be determined by the grade of the alignment.

# 5 Construction Methodology

The Quarry #3 Non-Hazardous Waste Landfill as well as the Quarry #3 Access Road and all surface infrastructure components of the Tailings Impoundment Area will be constructed with engineered fill excavated from the permitted and approved Quarry #3. SRK (2007) discusses the complete details pertaining to geochemical characterization of these rock quarries confirming their suitability for use in construction. The management and monitoring of quarry development for the construction of the infrastructure pads and access roads is discussed in SRK (2014). The geotechnical design parameters for Hope Bay have been summarized in SRK (2011b).

The Quarry #3 Landfill will be constructed in accordance to SRK's Technical Specifications (SRK 2011c).

# 6 References

EBA Engineering Consulting Ltd., 2010. Quarry A Landfill Management Plan, Doris North Property, NU. Report prepared for Hope Bay Mining Ltd., Project Number: E14101082.001. June 2010.

Ferguson, Simek, Clark Engineers & Architects, 2003. Guidelines for the Planning, Design, Operations, and Maintenance of Modified Solid Waste Sites in the Northwest Territories. The Department of Municipal and Community Affairs, Government of Northwest Territories, FSC Project No: 2001-2003, April 21, 2003.

Hatch, 2011. Waste Management and Landfill Facility, General Arrangement. Engineering Drawing prepared for Newmont Mining Corporation. DWG. No. SK0000-10-035-0004. Project Number: 337888. February 2011.

Miramar Hope Bay Ltd., 2007. Revised Water License Application Support Document, Doris North Project, Nunavut, Canada. Report submitted to the Nunavut Water Board. Water License 2AM-DOH0713. April 2007.

SRK Consulting (Canada) Inc., 2006. Doris North Project – Thermal modeling to support design thickness for granular pads. Technical Memorandum, Prepared for Miramar Hope Bay Limited. Project Number 1CM014.008. August 20, 2006.

SRK Consulting (Canada) Inc., 2007. Geochemical Characterization of Quarry Materials, Doris North Project. Hope Bay, Nunavut, Canada (Revised March 2007). Report Prepared for Miramar Hope Bay Limited, Project Number 1CM014.008.241. March 2007.

SRK Consulting (Canada) Inc., 2009. Hope Bay Gold Project: Stage 2 Overburden Characterization Report. Report Prepared for Hope Bay Mining Limited. Project Number 1CH008.002. September 2009.

SRK Consulting (Canada) Inc., 2011a. Engineering Drawings for the Doris North Secondary Road, Doris North Project, Nunavut, Canada. Revision 3. Issued for Construction Drawings Prepared for Hope Bay Mining Limited. Project Number: 1CH008.033. November 2011.

SRK Consulting (Canada) Inc., 2011b. Hope Bay Project – Geotechnical Design Parameters. Revision 0. Report Prepared for Hope Bay Mining Limited. Project Number: 1CH008.033.216. October 2011.

SRK Consulting (Canada) Inc., 2011c. Technical Specifications Earthworks and Geotechnical Engineering. Hope Bay Project, Nunavut, Canada. Revision G – Issued for Construction. Report Prepared for Hope Bay Mining Ltd. Project Number: 1CH008.027. March 2011.

SRK Consulting (Canada) Inc., 2012. Engineering Drawings for the Doris-Windy All-Weather Road, Doris Infrastructure Project, Nunavut, Canada. Revision AB1. As-Built Drawings Prepared for Hope Bay Mining Ltd. Project Number: 1CH008.033/.058. May 11, 2012.

SRK Consulting (Canada) Inc., 2014. Hope Bay Project Quarry Management and Monitoring Plan – Revision 02. Report Prepared for TMAC Resources Inc. Project Number: 1CT022.001. December 2014.

Attachment 1

Engineering Drawings for the Quarry #3 Non-Hazardous Waste Landfill

# Engineering Drawings for the Quarry #3 Non-Hazardous Waste Landfill Doris North Project, Nunavut, Canada

## ACTIVE DRAWING STATUS

| DWG NUMBER | DRAWING TITLE | REVISION | DATE | STATUS |
|---|---|---|---|---|
| TL-LF-00 | Engineering Drawings for<br>the Quarry #3 Non-Hazardous Waste Landfill<br>Doris North Project, Nunavut, Canada | A | May 29, 2015 | Issued for Discussion |
| TL-LF-01 | Quarry #3 Non-Hazardous Waste Landfill Location Map | A | May 29, 2015 | Issued for Discussion |
| TL-LF-02 | Quarry #3 Conceptual Excavation | A | May 29, 2015 | Issued for Discussion |
| TL-LF-03 | Quarry #3 Access Road Design | A | May 29, 2015 | Issued for Discussion |
| TL-LF-04 | Non-Hazardous Waste Landfill Design | A | May 29, 2015 | Issued for Discussion |
| TL-LF-05 | Non-Hazardous Waste Landfill Sections and Details | A | May 29, 2015 | Issued for Discussion |

TMAC RESOURCES

srk consulting

PROJECT NO: 1CT022.002.200.1500
Revision A
May 29, 2015
Drawing TL-LF-00

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