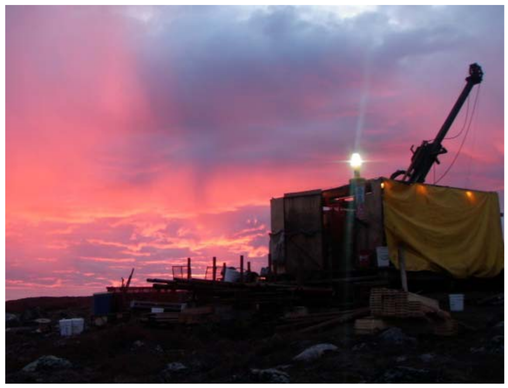
# APPENDIX 1-D

## Scoping Level Open Pit Slope Design

# AGNICO EAGLE MINES LTD. MEADOWBANK DIVISION
# WHALE TAIL PIT



# 6108-MEM-001_R1 UPDATED
# SCOPING LEVEL OPEN PIT SLOPE DESIGN (REVISED)

**PREPARED FOR:**

Agnico Eagle Mines Ltd. Meadowbank Division
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# AGNICO EAGLE MINES LTD. MEADOWBANK DIVISION
# WHALE TAIL PIT

## 6108-MEM-001_R1 UPDATED SCOPING LEVEL OPEN PIT SLOPE DESIGN (REVISED)
## NB101-622/3-3

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# EXECUTIVE SUMMARY

## INTRODUCTION

Agnico Eagle Mines Ltd. Meadowbank Division (AEM) is currently evaluating the potential for mining the satellite Whale Tail deposit using open pit mining methods. The Whale Tail Pit Study Area is located approximately 50 km northwest from AEM's Meadowbank Mine and 160 northwest of Baker Lake in Nunavut, Canada.

In early 2015, Knight Piésold Ltd. (KP) provided conceptual open pit slope recommendations for the Whale Tail Pit. Shortly thereafter, KP was engaged by AEM to complete the geomechanical and hydrogeological work needed to support pre-feasibility level open pit slope design and to provide updated scoping level open pit slope recommendations.

The work completed included:

- A review of all available geological, structural and hydrogeological information
- A geomechanical and hydrogeological site investigation program
- Domain definition and characterization of the rock mass quality and discontinuity orientations in the vicinity of the Whale Tail Pit
- Slope stability analyses
- The development of slope recommendations for the final pit walls

This report summarizes the completed work and presents the updated scoping level final pit slope recommendations for the Whale Tail Pit.

## ROCK MASS CHARACTERIZATION

The data collected from the geomechanical site investigations and laboratory strength testing was used to define geomechanical domains on the basis of both lithology and spatial variation in the discontinuity orientation data. A summary of the rock mass characteristics for each domain is included below:

- **Diorite (I2) -** The Diorite is characterized by an average UCS of 125 MPa. A $m_i$ value of 20 was assigned based on published values (Hoek et. al., 2002). It is classified as GOOD quality rock with a $RMR_{89}$ design value of 70.

- **Greywacke (S3, S6 & V3) -** This domain consists of the greywacke, mafic volcanics, and mudstone lithologies. It is characterized by an average UCS value of 65 MPa and a $m_i$ of 28. It is classified as GOOD quality rock with a $RMR_{89}$ design value of 65.

- **Chert (S10, S10E, S10mSi & S10sSi) -** The Chert domain consists of the chert, graphitic chert, and moderately and significantly silica flooded chert lithologies. It is characterized by an average UCS of 135 MPa. A $m_i$ value of 20 was assigned based on published values (Hoek et. al., 2002). It is classified as GOOD quality rock with a $RMR_{89}$ design value of 65.

- **Altered Ultramafics (V3F & V4Amph) -**The Altered Ultramafics is characterized by an average UCS of 90 MPa and a $m_i$ of 4. It is classified as FAIR to GOOD quality rock with a $RMR_{89}$ design value of 65.

- **Ultramafics-North Limb (V4a) & Ultramafics-South Limb (V3-V4 & V4bio) -** This domain is characterized by variable and locally reduced rock mass quality. It is characterized by an average UCS value of 50 MPa and a $m_i$ of 10. The North Limb is classified as FAIR to GOOD quality rock with a $RMR_{89}$ design value of 55. The South Limb is classified as POOR to GOOD quality rock with a $RMR_{89}$ design value of 50.

**STABILITY ANALYSES AND PIT SLOPE DESIGN**

Based on the location and characteristics of the geomechanical domains, and the open pit design provided by AEM, eight (8) design sectors were identified. Slope stability analyses were undertaken on each sector to evaluate achievable slope configurations. These analyses included Kinematic and Limit-Equilibrium analyses. The results from these analyses provide guidance on achievable bench and inter-ramp geometries.

A slope design summary is included below:

- Design BFA: 65 to 75°
- Design Bench Width: 10 to 14.4 m
- Bench Height: 21 m
- IRA: 41 to 53° (for heights up to 100 m)

The maximum inter-ramp height is set to 100 m, after which a ramp or geotechnical step-out should be included to limit the slope height and provide greater operational flexibility. In general, the potential for planar failures is expected to limit the achievable slope geometry in the East-North, Central-North, West-North and Central-South sectors.

The provided pit slope design recommendations are based upon the geological, structural, geomechanical and hydrogeological data. The completed stability analyses and a review of practices at other operations suggest that the recommended geometries are reasonable and appropriate. To achieve these slope angles, the design assumes that controlled blasting and geotechnical monitoring will be undertaken, along with an on-going commitment to geomechanical data collection and analysis. Maintaining flexibility in the mine plan will be important to accommodate any slope stability issues.

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## APPENDICES

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Appendix A1 UCS and Triaxial Results by Rock Type
Appendix A2 Direct Shear Results by Rock Type
Appendix B RMR Histograms by Rock Type
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Appendix B2 RMR Histograms by Length by Rock Type
Appendix C Introduction to Hoek-Brown Criterion
Appendix D Kinematic Analyses - Results Summary
Appendix E RocPlane Analyses - Results Summary For West-North Sector
Appendix F Limit-Equilibrium Analysis - Results Summary
Appendix F1 Limit-Equilibrium Analyses - Inter-Ramp Slope Results Summary
Appendix F2 Limit-Equilibrium Analyses - Overall Slope Results Summary

# ABBREVIATIONS

AEM ............ Agnico-Eagle Mines Ltd.: Meadowbank Division
AMEC ............ AMEC Foster Wheeler PLC
BFA ............ bench face angle
CFF ............ cumulative frequency of failures
D ............ Disturbance Factor
DS ............ direct shear
FoS ............ Factor of Safety
IRA ............ inter-ramp angle
KP ............ Knight Piésold Ltd.
L-E ............ limit-equilibrium
NGI-Q ............ Norwegian Geological Institute Tunneling Index
OSA ............ overall slope angle
$RMR_{89}$ ............ Rock Mass Rating (1989)
RQD ............ Rock Quality Designation
the Project ............ Whale Tail Pit
UCS ............ uniaxial compressive strength

# 1 – INTRODUCTION

## 1.1 PROJECT DESCRIPTION

Agnico Eagle Mines Ltd. Meadowbank Division (AEM) is developing the Whale Tail Pit (the Project) in Nunavut, Canada. The Project is located 50 km northwest of AEM's Meadowbank Mine and 160 km northwest of Baker Lake. AEM is currently evaluating the potential for mining the satellite Whale Tail deposit using open pit mining methods. Figure 1.1 shows the location of the Project.

## 1.2 SCOPE OF WORK

In early 2015, Knight Piésold Ltd. (KP) provided conceptual open pit slope recommendations for the Whale Tail Pit based on the results of a desktop study. Shortly thereafter, KP was engaged by AEM to complete the geomechanical and hydrogeological work needed to support pre-feasibility level open pit slope design and to provide an updated scoping level open pit slope design.

The work completed included:

- A review of all available geological, structural and hydrogeological information
- A geomechanical and hydrogeological site investigation program
- Domain definition and characterization of the rock mass quality and discontinuity orientations in the vicinity of the Whale Tail Pit
- Slope stability analyses
- The development of slope recommendations for the final pit walls

## 1.3 AVAILABLE INFORMATION

Knight Piésold has completed the following reports and letters relevant to this study:

- Geomechanical and Hydrogeological Site Investigation Summary (KP, 2015a)
- Open Pit Groundwater Inflow Assessment (KP, 2015b)
- Permafrost and Talik Characterization (KP, 2015c)

The information provided by others for this study included:

- 3D lithological model (AEM, February 2015; updated July 2015 and September 2015)
- 3D structural model (AEM, August 2015; updated September 2015)
- Topography and bathymetry of Whale Tail Lake (AEM, February 2015; updated September 2015)
- Exploration drillhole database including Rock Quality Designation (RQD) (AEM, February 2015)
- Open pit mine design (AEM, February 2015; updated March 2015 and September 2015)


**LEGEND:**

- ● COMMUNITY
- ★ MINE SITE LOCATION

**NOTES:**

1. BASE MAP: © ESRI DATA AND MAPS (ONLINE) SERVICE LAYERS (2015). REDLANDS, CA: ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. ALL RIGHTS RESERVED.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 14N.

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AGNICO EAGLE MINES LTD. MEADOWBANK DIVISION

WHALE TAIL PIT

**PROJECT LOCATION MAP**

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**FIGURE 1.1** REV 0

# 2 – BACKGROUND

## 2.1 GENERAL

Background information on the deposit geology and the completed site investigation activities is summarised in this section. The hydrogeology and permafrost conditions were discussed in detail in KP, 2015c.

## 2.2 GEOLOGY

The geological setting of the ore body is important for open pit slope design. Background information on the main lithologies, alteration and large-scale features is provided below. Unless otherwise noted, the information is summarised from data provided by AEM (2015a).

### 2.2.1 Main Lithologies

The main lithologies encountered at the Project are summarized below:

- **Overburden -** The overburden layer in the vicinity of the pit is generally expected to be thin, with observed thicknesses typically less than 10 m.
- **Greywacke (S3) -** The Greywacke is the most common lithology at the Project. This unit hosts the deposit and is also internal to it. The Greywacke is fine to medium grained and can be altered and/or deformed in the vicinity of the mineralized zones.
- **Mafic Volcanics (V3) -** The Mafic Volcanics are present along the southern limit of the deposit and primarily consist of basalt. This package has been heavily folded and is characterized by a schistose or chaotic texture. Biotite and chlorite alteration are common within the Mafic Volcanics. The Mafic Volcanics are a relatively minor unit within the Whale Tail Pit Study Area.
- **Ultramafics (V4A & V3-V4) -** The ultramafic volcanic unit, or Komatiite, comprises a North and a South limb. These limbs bound the northern and southern limits of the deposit. The Ultramafics are commonly altered to a chlorite-talc-carbonate schist (soapstone) with chaotic carbonate veining. The Ultramafics are characterised by variable rock mass quality and can be faulted. The Ultramafics can be locally altered with biotite (V4Bio unit).
- **Altered Ultramafics (V3F & V4Amph) -** The Ultramafics can be locally altered and deformed, notably along the contact with the sedimentary units. The Altered Ultramafics are more competent and have more consistent rock mass quality than the Komatiite. The unit is often mineralized with disseminated sulphides and is one of the primary mineralized zones identified within the deposit.
- **Chert (S10) -** A sedimentary unit consisting of interbedded bands of Chert, sediments and thin beds of iron formation. The Chert is associated with many of the mineralized zones identified within the deposit. The Chert can be flooded with silica (S10mSi and S10sSi units) and has been locally heavily folded.
- **Graphitic Chert (S10E) -** In some areas, the Chert has been interlayered with graphitic mudstone, resulting in a unit known as the Graphitic Chert. The Graphitic Chert has been intensely deformed causing it to appear chaotic and brecciated.

- **Mudstone (S6) -** Well-banded fine grained sedimentary rock. This unit is often transitional with the Chert and Graphitic Chert.

- **Diorite (I2) -** The Diorite is an intrusive unit located to the south of the Whale Tail deposit. The diorite is unmineralized.

A typical cross section of the deposit is shown on Figure 2.1.

### 2.2.2 Alteration

Alteration associated with the hydrothermal fluids is expected to have a significant local impact on the rock mass characteristics and performance. Field observations suggest that the Ultramafics are the most influenced and experience the most variability in rock mass quality as a result of alteration.

The main types of alteration that have been observed at the Project are as follows:

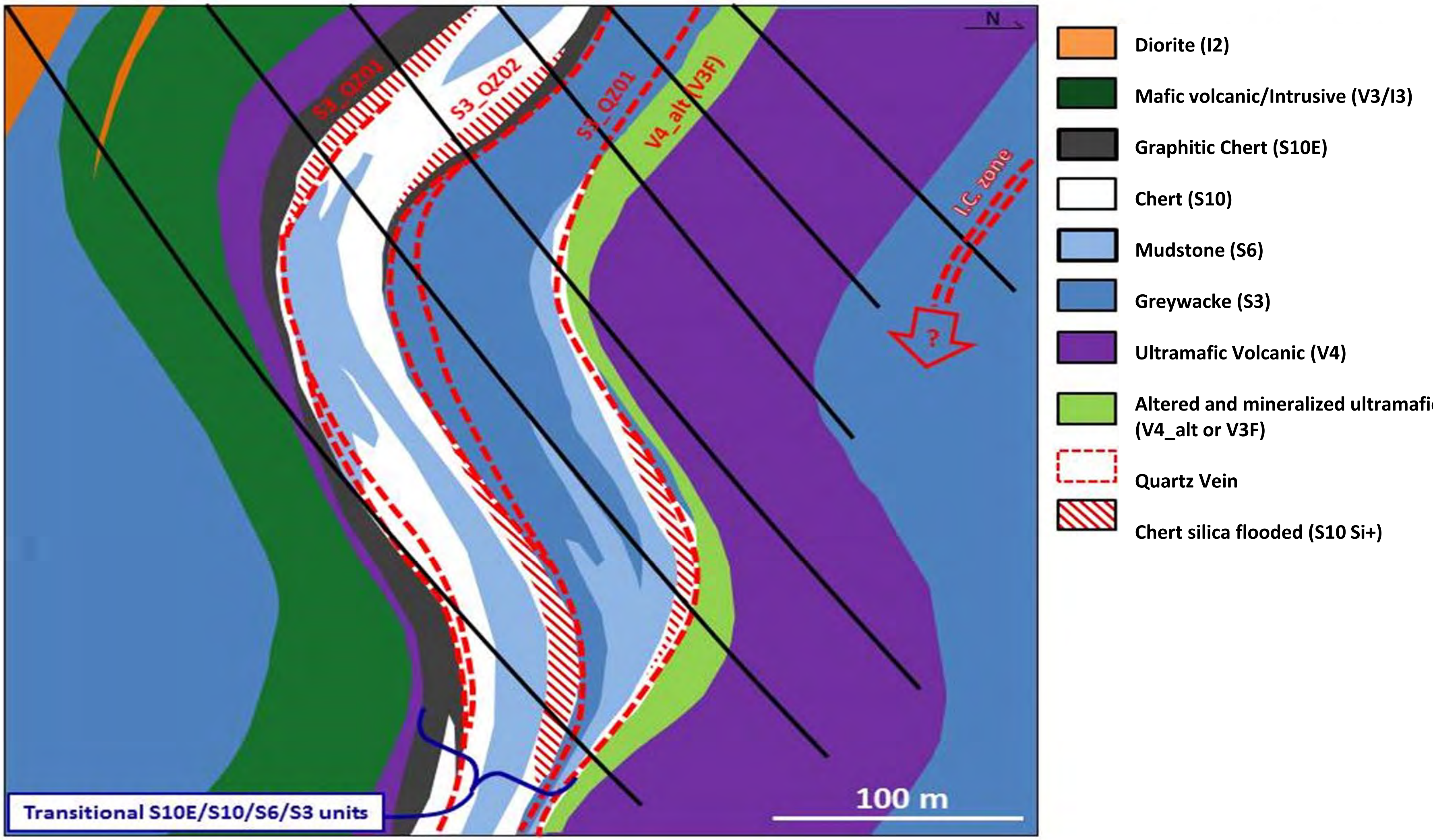
- **Talc -** Characteristic of the Ultramafics. Increasing intensity of the talcose alteration may correspond to a reduction in rock mass quality.
- **Biotite -** This type of alteration occasionally occurs in the Ultramafics, particularly in the southern limb. The biotite alteration generally results in a local improvement in rock mass quality.
- **Amphibolite -** This type of alteration is common in the Altered Ultramafics.
- **Chlorite -** Chloritization is present to a great or lesser extent in most of the lithologies, but is most common in the Greywacke and Ultramafics. Chlorite typically results in a reduction in rock mass quality.
- **Carbonate -** Carbonate veining is common within the deposit rock masses and often occurs as a chaotic stockwork of veinlets.
- **Graphite -** Characteristic of the Graphitic Chert. The graphitic alteration is typically of relatively low intensity and only locally present in fracture planes.
- **Silica -** Silica flooding events have locally improved the rock mass quality of the Chert and Greywacke units. Silification also occurs in the Ultramafics and Altered Utlramafics along the margins of the quartz veins.

### 2.2.3 Mineralization

The gold mineralization at the Project is associated with a system of quartz veins. Four main mineralized zones have been identified and are described below.

- Three of the mineralized zones are associated with quartz veining and silica flooding within the Chert and other sediments internal to the deposit. These zones are identified as S3_QZ01, 02 and 03 and are generally located within the southern half of the proposed pit. The mineralization is characterized by arsenopyrite.

- One of the zones is associated with the Altered Ultramafics along the contact between the Ultramafics and the sediment package internal to the deposit. This zone is generally located within the northern half of the proposed pit and is thought to be associated with a regional structure. Replacement mineralization has occurred within the Altered Ultramafics and is characterized by pyrrhotite.




**NOTES:**
1. CROSS SECTION PROVIDED BY AEM (MARCH 5, 2015).

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WHALE TAIL PIT

**TYPICAL DEPOSIT CROSS SECTION**

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REF. NO. 3

**FIGURE 2.1**

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### 2.2.4 Large-Scale Structures

Evidence of large-scale structures has been observed at the Project (AEM, 2014 and 2015b). The large-scale structures have been identified based on the results of geophysical surveys, exploration drilling, surface mapping and topographic interpretation completed by AEM. The dominant large scale structural orientations identified at the deposit are as follows:

- **ENE-WSW -** The contacts between the lithologies, and the foliation within the lithologies, are generally along this structural orientation. It generally is moderately to steeply dipping to the south-southeast, but rotates to dip to the north-northwest near the base of the proposed pit.
- **NE-SW -** A series of diffuse ductile structures that offset the lithologies and mineralization. The structures are present at a regional scale and are steeply to moderately dipping to the south. The quartz veins are parallel to these structures and likely formed along them. This structural orientation is predominantly within the northeastern portion of the deposit.

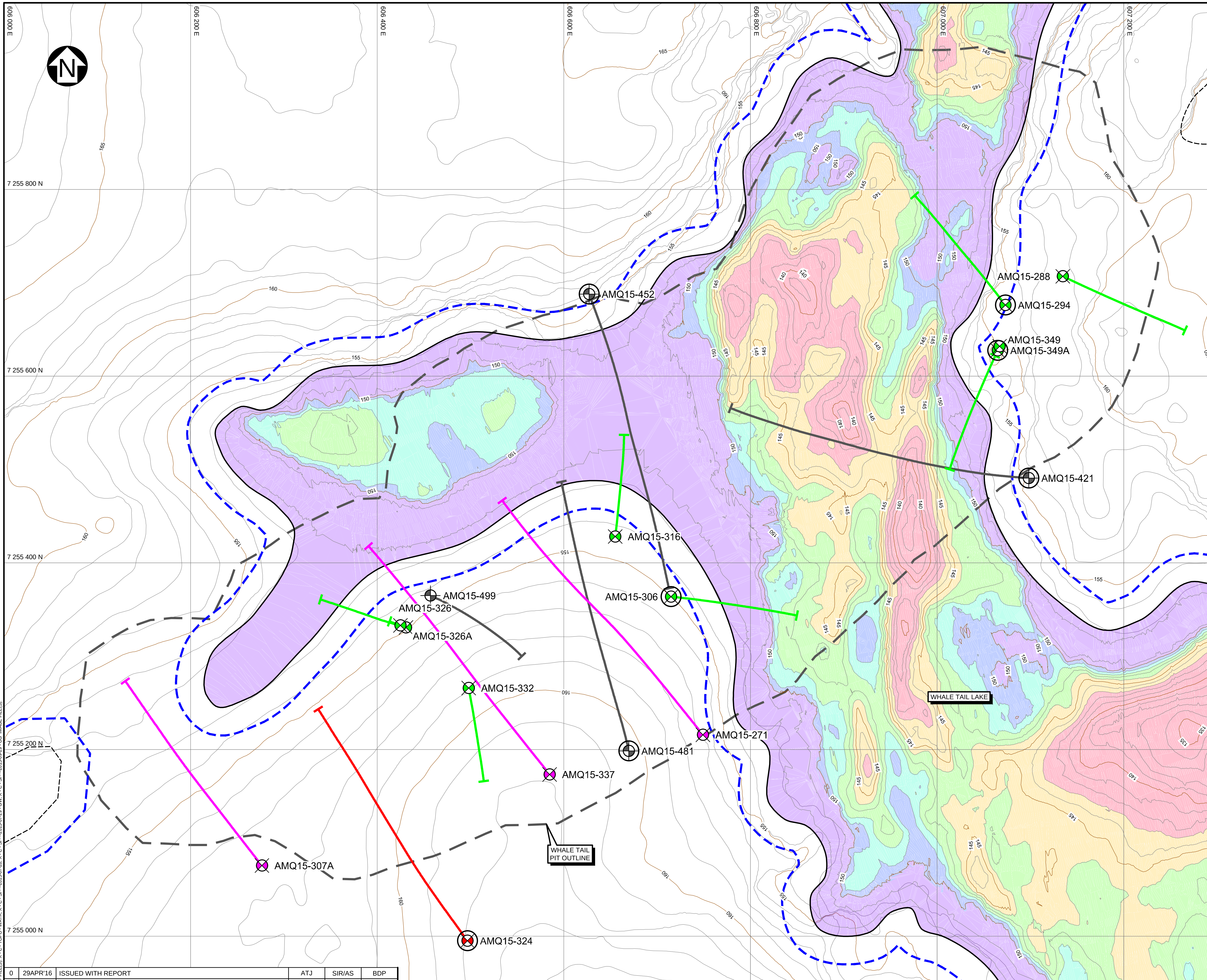
The structural analysis completed to date has focussed on identifying brittle structures rather than more ductile structures. The primary brittle structures identified at the Project to date are as follows:

- **RQD Corridor -** Continuous zones of low RQD have been identified from exploration drilling and are thought to represent a plane of brittle deformation. The faults of the RQD Corridor strike southwest-northeast and dip moderately to the southeast. The quartz veins are parallel to these structures and may have formed along them.
- **Northwest Fault -** A brittle fault that expresses on surface along the eastern edge of Whale Tail Lake. The Northwest fault strikes southeast-northwest and dips shallowly to the northeast.
- **GP Fault -** A brittle fault that intersects the Northwest fault. The GP fault strikes southwest-northeast and dips steeply to the southeast.
- **Flat Faults -** A series of three, flat-lying faults that lie over top one-another. The Flat Faults dip at a shallow angle to the southeast and strike southwest-northeast.

The faults are typically less than 1 m thick (though some may be more than 10 m thick) and consist of zones of broken rock and fault gouge.

## 2.3 SITE INVESTIGATION PROGRAM

A geomechanical and hydrogeological site investigation program was completed between June and September 2015 at the Project in order to support the permitting and mine design process. The program was intended to improve the understanding and characterization of the rock masses at the Project. The site investigations included 11 geomechanical drillholes, 3,240 m of oriented core drilling and 3,440 m of detailed geomechanical logging. Multi-point thermistors, vibrating wire piezometers and an electrical conductivity logger were also installed in select drillholes. Packer hydraulic conductivity testing was completed within areas of potential unfrozen ground. The drillholes associated with the geomechanical and hydrogeological site investigations are shown on Figure 2.2. Additional details on the 2015 site investigations are provided in KP (2015a).




**LEGEND:**

- SHALLOW / DEEP — BATHYMETRY
- GEOMECHANICAL DRILLHOLE FOR OPEN PIT
- GEOMECHANICAL DRILLHOLE FOR UNDERGROUND
- EXPLORATION DRILLHOLE
- EXPLORATION DRILLHOLE WITH GEOMECHANICAL LOGGING
- INSTRUMENTATION INSTALLED IN DRILLHOLE
- 30 m BUFFER FROM WHALE TAIL LAKE
- ULTIMATE PIT BOUNDARY

**NOTES:**

1. COORDINATE GRID IS UTM NAD83 ZONE 14N.
2. PIT DESIGN, TOPOGRAPHY AND BATHYMETRY PROVIDED BY AEM (SEPTEMBER, 2015).
3. CONTOUR INTERVAL IS 1 METRE.
4. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 40 20 0 40 80 120 160 200 m

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WHALE TAIL PIT

**GEOMECHANICAL AND HYDROGEOLOGICAL SITE INVESTIGATION PLAN**

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FIGURE 2.2 — REV 0

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# 3 – ROCK MASS CHARACTERISTICS

## 3.1 GENERAL

Rock mass characteristics are divided between intact material properties and the characteristics of the discontinuities. This section describes the work completed to characterize the geomechanical properties of the domains in the vicinity of the proposed open pit.

## 3.2 INTACT ROCK PROPERTIES

The following intact rock properties have been characterized for each rock type:

- Unconfined Compressive Strength (UCS)
- Triaxial Compressive Strength
- Brazilian Tensile Strength
- Unit weight
- Young's Modulus
- Poisson's Ratio

The intact rock properties were obtained from laboratory strength testing completed during the 2015 site investigation program. The laboratory testing was completed by the Hamilton office of AMEC Foster Wheeler PLC (AMEC) and is discussed in further detail in KP (2015a). The results of the UCS and Triaxial compressive strength testing are summarised by rock type in Appendix A1.

## 3.3 ROCK MASS QUALITY

The rock mass quality of each encountered rock mass has been characterized using the Rock Mass Quality ($RMR_{89}$) (Bieniawski, 1989) and NGI-Q rock mass classification systems. The characterization is based upon the detailed geomechanical logging and field UCS estimates completed during the 2015 site investigation program.

The rock mass quality of the Greywacke, Diorite, Chert and Altered Ultramafics domains are typically of GOOD quality (*i.e.,* $RMR_{89}$ values typically ranging from 60 to 80). While the rock mass quality of the Ultramafics in the north and south limb ranges from FAIR to GOOD (*i.e.,* $RMR_{89}$ values typically ranging from 45 to 75). Discontinuities typically have rough to smooth surfaces spaced 60 to 600 mm apart. Most have no infill or a thin infill (commonly carbonate, chlorite or talc), and show slight to no weathering. Aperture typically ranges from <0.1 mm to 1.0 mm.

## 3.4 DISCONTINUITY ORIENTATIONS

### 3.4.1 Oriented Core Drillholes

Prior to analysis, the drillhole orientation data collected during the site investigation program were corrected for any significant drillhole deviation (>5°) using the results of the gyroscopic surveys completed by AEM at or near the completion of each drillhole. The drillhole orientation data were filtered to exclude discontinuities from runs with run-on-run consistency in the FAIR (20 to 35°) or POOR (>35°) ranges. In addition, all discontinuities logged as a vein or veinlet, or flagged as possible breaks were removed from the data set based on a review of their impact on the results.

### 3.4.2 Dominant Discontinuity Orientations

Four main joint sets and one minor set have been identified in the orientation data from the Project.

- **Joint Set A -** A joint set striking southwest-northeast and moderately dipping to the southeast. This is the dominant structural orientation and corresponds to the foliation. The foliation is generally sub-parallel to the large-scale orientation of the lithologies.
- **Joint Set B (& B') -** A joint set striking northeast-southwest and dipping moderately to steeply to the northwest. This is a secondary, dominant structural orientation, but is only observed in drillhole AMQ15-306 and at the base of drillhole AMQ15-349A. In some instances, the dip of the discontinuities varies through vertical, resulting in pole concentrations on both sides of the stereonet (B and B', respectively).
- **Joint Set C -** A flat-lying joint set.
- **Joint Set D (& D') -** A joint set striking southeast-northwest and steeply-dipping. The dip of the discontinuities often varies through the vertical, resulting in pole concentrations on both sides of the stereonet (D and D', respectively). This joint set corresponds to the orientation of the lamprophyre dykes, but it is not well defined in each drillhole due to directional bias in the drilling.
- **Joint Set E -** A minor joint set striking northeast-southwest and moderately dipping to the northwest. This is essentially a minor version of Joint Set B and was only observed in the western end of the deposit.

A review of the drillhole stereonets suggests that the discontinuity orientations are closely related to the large-scale orientation of the lithologies. The small-scale discontinuity orientations were found to vary along the strike and dip of the ore body. After the evaluation of a number of possible alternatives, it was decided to group the discontinuity orientation data into four structural regions:

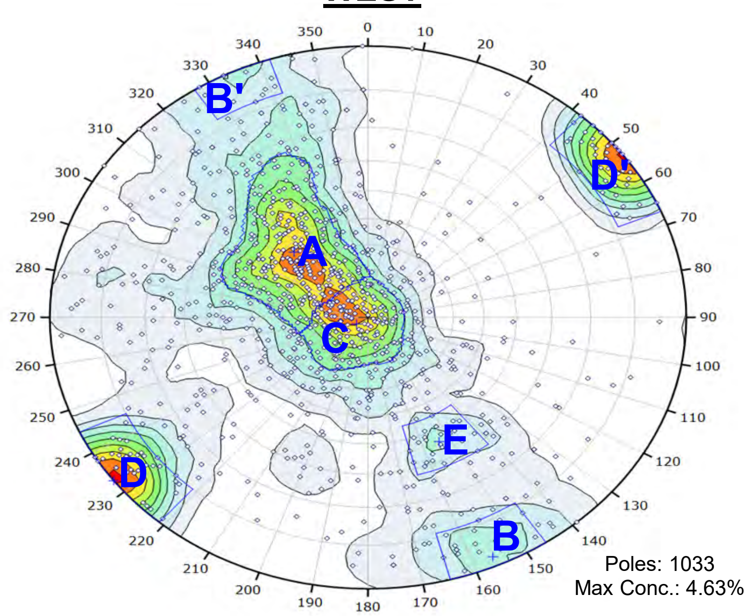
- West Region
- Central-A Region
- Central-B Region
- East Region

The data was grouped by drillhole. The position of each drillhole relative to the current open pit design was also reviewed, and only data from portions of the drillholes in close proximity to the pit and above the base elevation of the pit were included.

Due to observational bias in the orientation data, Joint Set D (& D') was only observed in the Central-A region. However, this joint set is thought to be ubiquitous throughout the deposit and has been added to the stereonets for the other regions. For the East Region, the orientation of Joint Set D was rotated to match the change in the strike of the foliation. Subsequent to the issuing of this report, AEM provided additional data that suggests that the orientation of the lamprophyre dykes to the northeast of the deposit is consist with the orientation of Joint Set D (& D') observed in the Central-A region. As a result, the rotation of Joint Set D for the East Region is no longer considered appropriate. The rotation applied is not expected to meaningfully affect the open pit slope design recommendations and will not be applied to the data in the next level of study. The dominant discontinuity orientations observed within each region are shown on Figure 3.1. All orientation data has been summarized and presented using DIPS (Rocscience Inc., 2012).

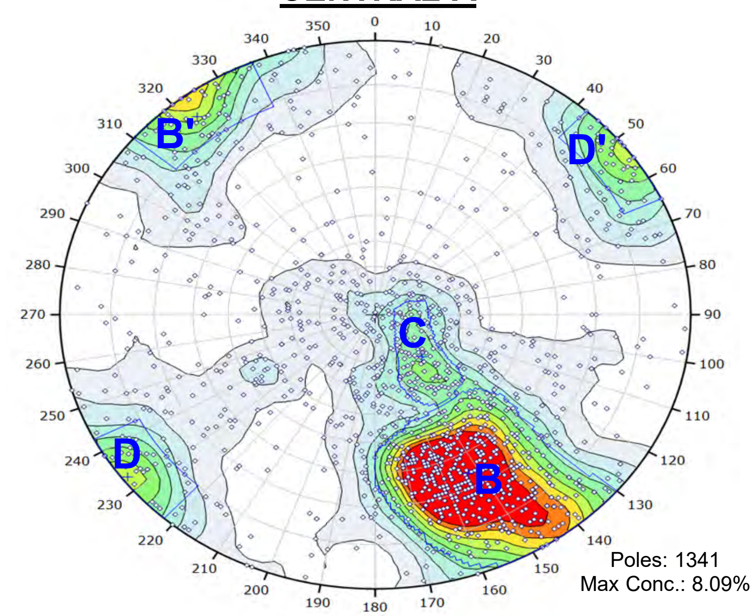
## A) ORIENTATION DATA BY REGION

### WEST



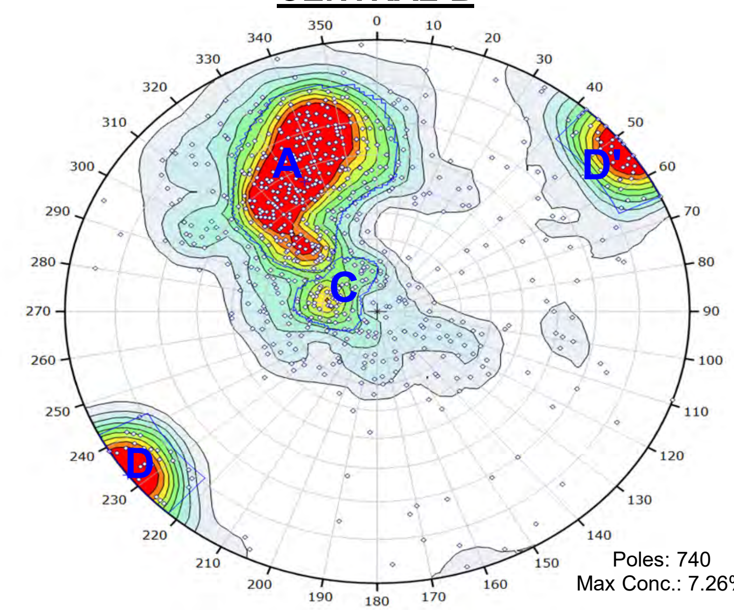

| Joint Set | Dip (°) | Dip Direction (°) |
|---|---|---|
| A | 37 | 136 |
| B/B' | 88 | 336 |
| C | 5 | 65 |
| D/D' | 90 | 53 |
| E | 54 | 334 |

### CENTRAL-A



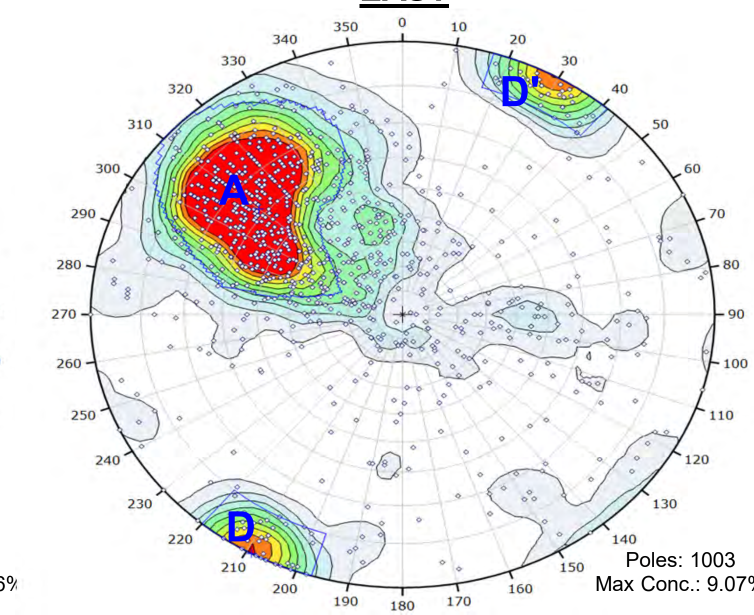

| Joint Set | Dip (°) | Dip Direction (°) |
|---|---|---|
| B | 66 | 333 |
| B' | 85 | 142 |
| C | 24 | 316 |
| D | 89 | 53 |

### CENTRAL-B




| Joint Set | Dip (°) | Dip Direction (°) |
|---|---|---|
| A | 56 | 154 |
| C | 17 | 113 |
| D/D' | 90 | 53 |

### EAST




| Joint Set | Dip (°) | Dip Direction (°) |
|---|---|---|
| A | 62 | 130 |
| D/D' | 90 | 29 |

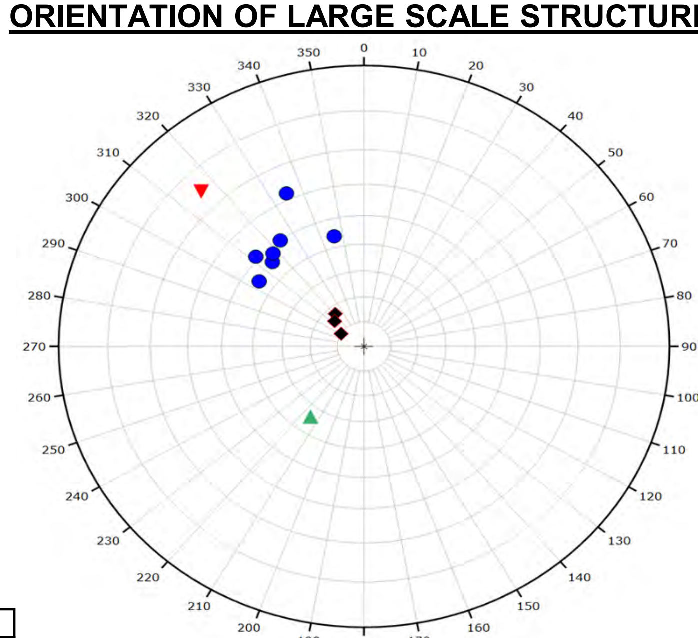
### CONTOUR LEGEND

| Color | Density Concentrations |
|---|---|
| | 0.00 - 0.50 |
| | 0.50 - 1.00 |
| | 1.00 - 1.50 |
| | 1.50 - 2.00 |
| | 2.00 - 2.50 |
| | 2.50 - 3.00 |
| | 3.00 - 3.50 |
| | 3.50 - 4.00 |
| | 4.00 - 4.50 |
| | 4.50 < |

## B) LARGE-SCALE STRUCTURES

| Structure | Dip (°) | Dip Direction (°) |
|---|---|---|
| Flat1 | 17 | 141 |
| Flat2 | 14 | 134 |
| Flat3 | 9 | 121 |
| GP | 74 | 136 |
| NW | 33 | 36 |
| RQD1 | 44 | 167 |
| RQD2 | 45 | 135 |
| RQD3 | 45 | 125 |
| RQD4 | 50 | 145 |
| RQD5 | 47 | 138 |
| RQD6 | 62 | 155 |
| RQD7 | 51 | 132 |

### ORIENTATION OF LARGE SCALE STRUCTURES



### STRUCTURAL LEGEND

| Symbol | FAULT GROUP | Quantity |
|---|---|---|
| ◆ | Flat | 3 |
| ▼ | GP | 1 |
| ▲ | NW | 1 |
| ● | RQD Corridor | 7 |

**NOTES:**
1. STEREONETS ARE EQUAL ANGLE LOWER HEMISPHERE PROJECTIONS.
2. DATA CORRECTED FOR DRILLHOLE DEVIATION.
3. ORIENTATION DATA HAS BEEN FILTERED TO EXCLUDE MECHANICAL BREAKS, VEINS/VEINLETS, AND DATA OF FAIR OR POOR QUALITY.
4. ONLY DATA RELEVANT TO OPEN PIT SHOWN BY EXCLUDING DATA BEYOND A CERTAIN DOWNHOLE DEPTH.
5. LARGE-SCALE STRUCTURE MODEL PROVIDED BY AEM (SEP 29, 2015). INDIVIDUAL PLANE NAMES GIVEN BY KP.

| REV | DATE | DESCRIPTION | PREP'D | RVW'D |
|---|---|---|---|---|
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WHALE TAIL PIT

**ORIENTATION DATA SUMMARY**

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**FIGURE 3.1** | REV 0

## 3.5 STRENGTH OF DISCONTINUITIES

Estimates of the strength of the discontinuities were based on direct shear (DS) laboratory test results for samples from the Greywacke, Chert and Altered Ultramafics lithologies. These rock types were selected as they are expected to form the majority of the open pit slopes. The DS testing was also completed by AMEC and is discussed in detail in KP (2015a). The results of the DS lab testing are summarised by rock type in Appendix A2.

A 30° friction angle was selected as the design discontinuity strength. This value is expected to represent the strength of the discontinuities in the Ultramafics, which is considered to be a limiting case. The discontinuities have been assumed to be cohesionless for the purposes of the completed analyses.

## 3.6 GEOMECHANICAL DOMAIN DEFINITION

### 3.6.1 General

The encountered rock masses are grouped into geomechanical domains in order to simplify the open pit stability analyses. Each domain contains rock masses with similar engineering characteristics and that are expected to perform similarly within the final pit walls.

The overburden in the vicinity of the proposed pit is expected to be relatively shallow (*e.g.,* typically < 10 m). As such, the overburden is expected to form only a minor part of the pit slopes and was not considered in the domain definition process.

### 3.6.2 Domain Definition Process

Various possible domain definitions were considered based on lithology, orientation data and spatial position. Each definition was evaluated based on:

- How well the definition limited the variability within the distribution for each engineering characteristic
- Whether the definition respected the geology and geological history of the deposits
- Whether the definition was relevant to the design of the proposed open pit
- The feasibility of implementing the definition (e.g., a definition based on differences in alteration would be of limited value as a 3D alteration model does not currently exist for the Project)

The domain definition that most effectively met these criteria was considered to be the best of the available alternatives. The domain definitions considered are described below:

- **Lithology -** This approach attempted to classify geomechanical domains based on the current lithology model developed by AEM. Several different combinations of lithologies were also considered.
- **Lithology and Variation in Rock Mass Quality -** The potential for variation in rock mass quality within a given lithology was considered. While some variation was observed, it was not possible to associate the variation with any single factor at this stage in the design process. Possible sources of variation include the influence of large-scale structures and/or alteration.
- **Lithology and Spatial Variation in Orientation Data -** The potential for spatial variation in the orientation data was also considered (as noted in Section 3.4.2).

### 3.6.3 Final Domain Definition

Geomechanical domains were ultimately selected based on the Lithology and Spatial Variation in Orientation definition. The final rock mass domains defined for the Whale Tail Pit include:

- Greywacke (s3) - This also includes the Mafic Volcanics (V3) and mudstone (S6) units
- Chert (s10) - This also includes the graphitic chert (s10e) and silica flooded chert (s10mSi & s10sSi)
- Diorite (I2)
- Altered Ultramafics (V3F, V4bio)
- Ultramafics - North Limb (V4a)
- Ultramafics - South Limb (V3-V4)

The following minor lithological units have been grouped into the above domains due to their limited spatial extents and the limited data available with which to characterize them:

- Lampophyre dykes (I1)
- Quartz vein (Qv)

The final structural domains defined for the Whale Tail Pit include:

- West
- Central-A
- Central-B
- East

Figure 3.2 show the structural domains relative to the proposed Whale Tail Pit.

### 3.6.4 Domain Characterization

The anticipated rock mass quality and strength characteristics of each domain are described below and summarized in Table 3.1. The domains expected to form the ultimate pit walls are shown on Figure 3.3. The design $RMR_{89}$ value for each domain is based on the $30^{th}$ percentile value using a weighted by length approach of the distribution for each domain. Histograms illustrating the distribution of $RMR_{89}$ values for each rock type are included in Appendix B1 and B2.

- **Diorite -** The Diorite is characterized by an average UCS of 125 MPa. A $m_i$ value of 20 was assigned based on published values (Hoek et. al., 2002). It is classified as GOOD quality rock with a $RMR_{89}$ design value of 70.

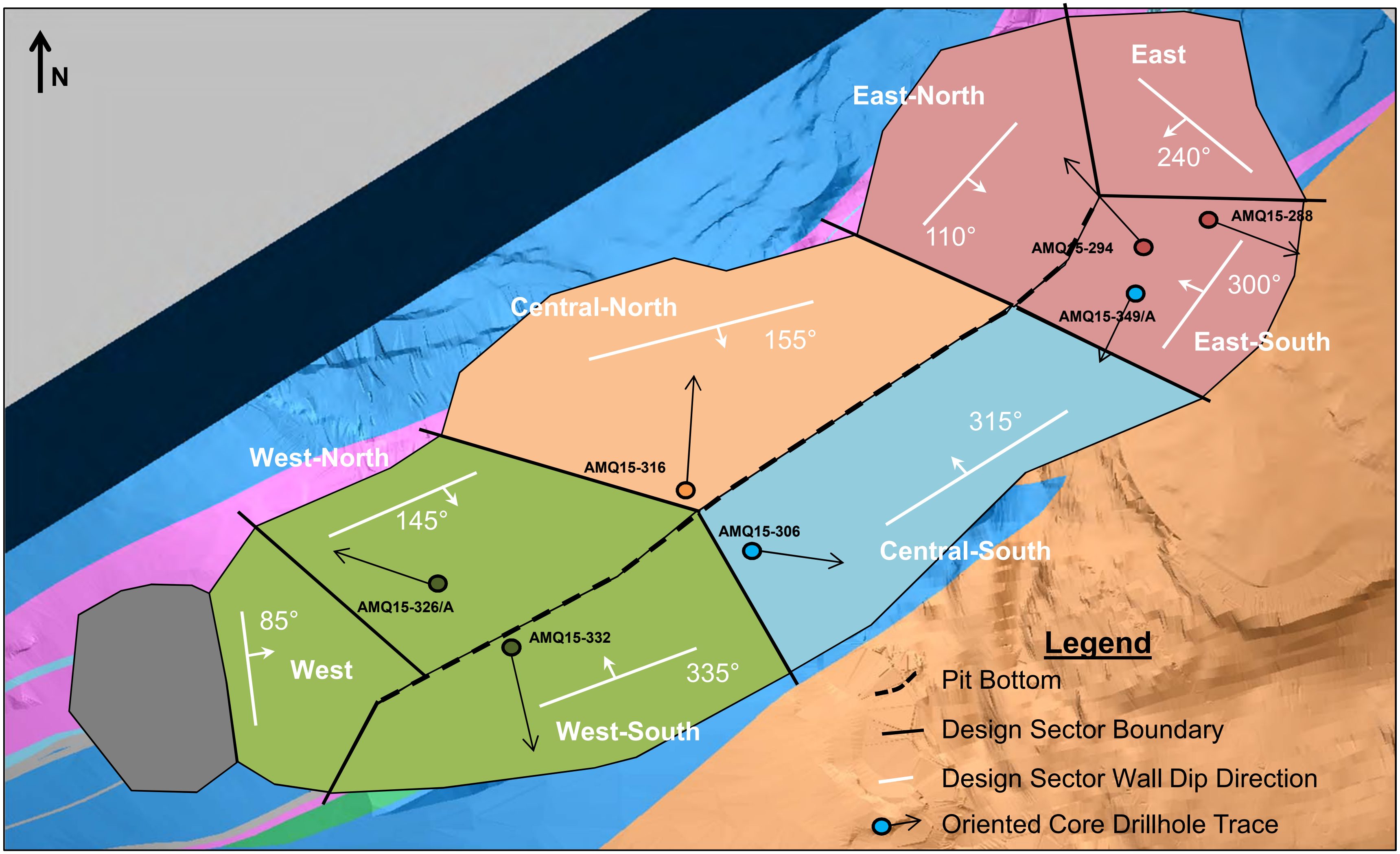
- **Greywacke -** This domain consists of the greywacke, mafic volcanics, and mudstone lithologies. It is characterized by an average UCS value of 65 MPa and a $m_i$ of 28. It is classified as GOOD quality rock with a $RMR_{89}$ design value of 65.

- **Chert -** The Chert domain consists of the chert, graphitic chert, and moderately and significantly silica flooded chert lithologies. It is characterized by an average UCS of 135 MPa. A $m_i$ value of 20 was assigned based on published values (Hoek et. al., 2002). It is classified as GOOD quality rock with a $RMR_{89}$ design value of 65.

- **Altered Ultramafics -**The Altered Ultramafics is characterized by an average UCS of 90 MPa and a $m_i$ of 4. It is classified as FAIR to GOOD quality rock with a $RMR_{89}$ design value of 65.

- **Ultramafics (North and South Limbs) -** This domain is characterized by variable and locally reduced rock mass quality. It is characterized by an average UCS value of 50 MPa and a $m_i$ of 10. The North Limb is classified as FAIR to GOOD quality rock with a $RMR_{89}$ design value of 55. The South Limb is classified as POOR to GOOD quality rock with a RMR89 design value of 50.

The domain definition is based upon the available rock mass data and the current geological understanding of the deposit and should be re-evaluated when more data becomes available.




STRUCTURAL DOMAIN LEGEND

- Not Evaluated
- West Structural Domain
- Central-A Structural Domain
- Central-B Structural Domain
- East Structural Domain

| | | | | |
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WHALE TAIL PIT

**STRUCTURAL DOMAINS**

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| | | |
|---|---|---|
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| FIGURE 3.2 | | REV 0 |

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**TABLE 3.1**

**AGNICO EAGLE MINES LTD. MEADOWBANK DIVISION**
**WHALE TAIL PIT**

**UPDATED SCOPING LEVEL OPEN PIT SLOPE DESIGN (REVISED)**
**TYPICAL $RMR_{89}$ CHARACTERISTICS FOR EACH DOMAIN**

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| Typical $RMR_{89}$ Parameter | DOMAIN | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diorite (I2) | | | Greywacke (S3, S6 & V3) | | | Chert (S10, S10E, S10mSi & S10sSi) | | | Altered Ultramafics (V3F & V4Amph) | | | Ultramafics - North Limb (V4a) | | | Ultramafics - South Limb (V3-V4 & V4Bio) | | |
| **$RMR_{89}$ Classification** | GOOD | | | GOOD | | | GOOD | | | FAIR to GOOD | | | FAIR to GOOD | | | POOR to GOOD | | |
| **$RMR_{89}$ Rating** 10th / 30th / 50th Percentile | 65 | 70 | 71 | 52 | 64 | 67 | 55 | 65 | 67 | 53 | 63 | 67 | 41 | 56 | 61 | 37 | 48 | 59 |
| **Mean UCS (MPa)** (Typical Range) | 125 (100 - 170) | | | 65 (50 - 80) | | | 135 (75 - 160) | | | 90 (60 - 110) | | | 50 (30 - 90) | | | 50 (30 - 90) | | |
| **Mean RQD (%)** (Typical Range) | 96 (95 - 100) | | | 92 (90 - 100) | | | 89 (85 - 100) | | | 93 (90 - 100) | | | 72 (80 - 100) | | | 58 0 - 5; 95 -100 | | |
| **Joint Spacing (mm)** Typical Range (See Note 5) | 200 - 600 | | | 60 - 600 | | | 60 - 600 | | | 60 - 600 | | | 0 - 600 | | | 0 - 600 | | |
| **Aperture (mm)** | 0.1 - 1.0 | | | 0.1 - 1.0 | | | 0.1 - 1.0 | | | 0.1 - 1.0 | | | 0.1 - 1.0 | | | 0.1 - 1.0 | | |
| **Roughness** | Slightly Rough | | | Smooth to Rough | | | Slightly Rough to Rough | | | Slightly Rough to Rough | | | Slightly Rough to Rough | | | Slightly Rough to Rough | | |
| **Infill** | None | | | None | | | None | | | None | | | None | | | None | | |
| **Weathering** | Slightly Weathered to Fresh | | | Fresh | | | Fresh | | | Slightly Weathered to Fresh | | | Slightly Weathered to Fresh | | | Slightly Weathered to Fresh | | |

I:\1\01\00622\03\A\Report\Report 3 Rev 0 Updated Open Pit Scoping Study\Tables\[Table 3.1 - Typical RMR Characteristics for Each Domain.xlsx]Table 3.1

**NOTES:**
1. REPORTED VALUES BASED ON DATA COLLECTED DURING THE 2015 SITE INVESTIGATION PROGRAM.
2. ALL REPORTED VALUES ARE TYPICAL VALUES OR RANGES FOR EACH DOMAIN.
3. RMR89 RATINGS HAVE BEEN WEIGHTED BY LENGTH TO ACCOUNT FOR VARIATIONS IN THE LENGTH OF LOGGING RUNS.
4. MEAN UCS AND TYPICAL RANGE BASED ON LABORATORY TESTING.
5. JOINT SPACING S DOWNHOLE DISTANCE BETWEEN ADJACENT DISCONTINUITIES.

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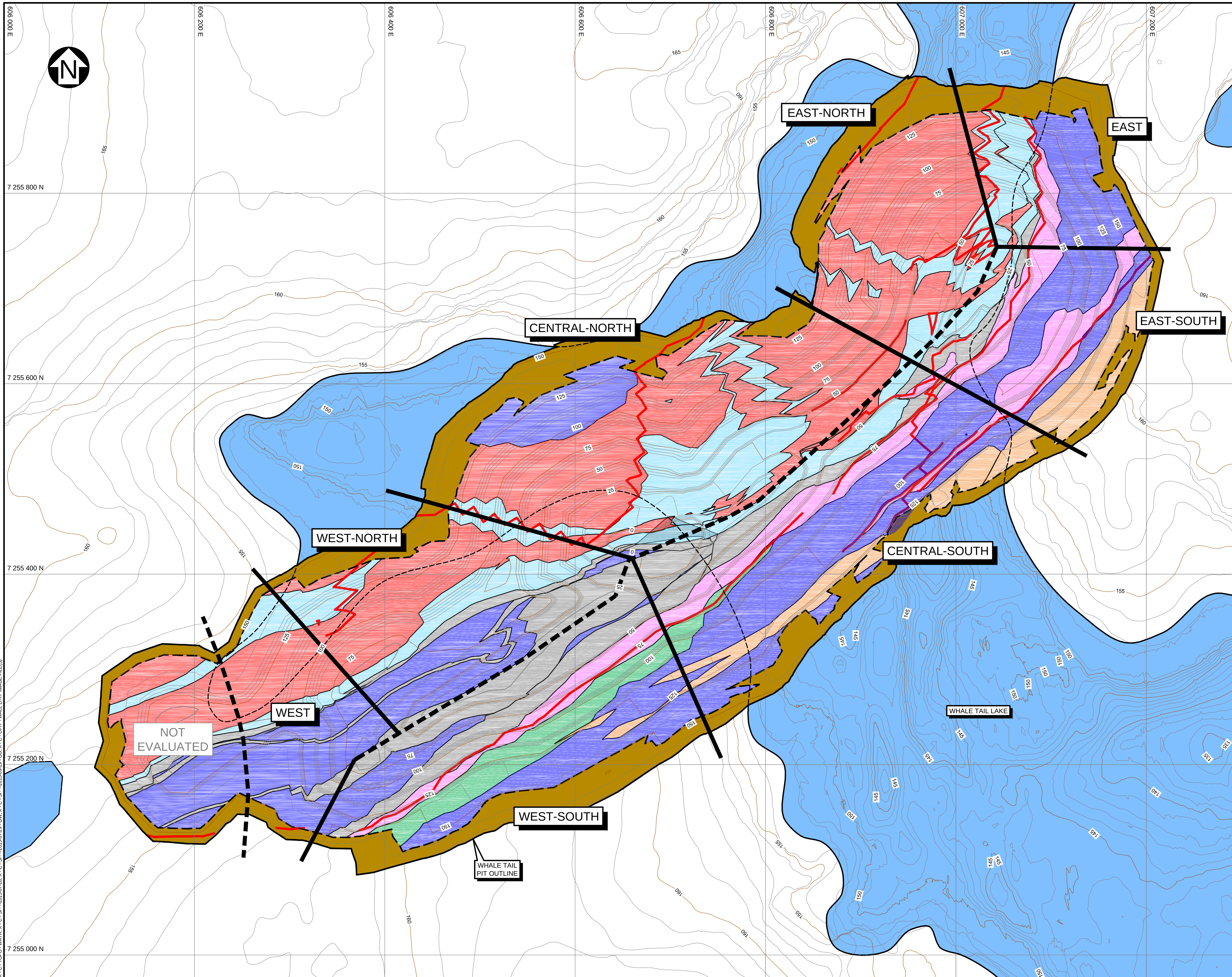


**LEGEND:**

- WATER
- OVERBURDEN
- GREYWACKE
- ULTRAMAFICS (NORTH LIMB)
- ULTRAMAFICS (SOUTH LIMB)
- ALTERED ULTRAMAFICS
- MAFIC VOLCANICS
- CHERT
- DIORITE
- FAULT
- DESIGN SECTOR BOUNDARY
- DESIGN SECTOR BOUNDARY CONTROLLED BY PIT GEOMETRY

**NOTES:**

1. COORDINATE GRID IS UTM NAD83 ZONE 14N.
2. PIT DESIGN, TOPOGRAPHY AND BATHYMETRY PROVIDED BY AEM (SEPTEMBER, 2015).
3. CONTOUR INTERVAL IS 1 METRE.
4. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 40 20 0 40 80 120 160 200 m

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WHALE TAIL PIT

PIT WALL GEOLOGY AND
OPEN PIT DESIGN SECTORS

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FIGURE 3.3 | REV 0

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# 4 – PIT SLOPE DESIGN CONCEPTS

## 4.1 GENERAL

The overall objective of pit slope design is to determine the steepest practical slope angles in order to maximize resource extraction and minimize waste stripping. Balanced against this, is the increased likelihood of slope stability issues associated with steeper slopes that could impact worker safety, mine productivity and profitability. The approach adopted here is to base the pit slope design on achieving an acceptable level of risk. These risk limits are accounted for in the stability analyses by incorporating target Factors of Safety (FoS). Note that pit slopes are generally considered to be overly conservative if no instabilities occur during operation. As such, instabilities should be expected and accommodated during pit development.

The following section briefly introduces pit slope terminology and discusses the slope stability techniques utilized to develop the final slope recommendations.

## 4.2 PIT SLOPE CONFIGURATION

The relationship between bench geometry, inter-ramp slope angle and the overall slope angle is illustrated in Figure 4.1 and described below.

- **Bench Geometry -** The achievable bench geometry was evaluated using Kinematic analyses and the following considerations:
  - The bench height is typically determined by the size of the shovel chosen for the mining operation. AEM has specified a bench height of 7 m in a triple-bench configuration (21 m effective bench height).
  - The bench face angle (BFA) is generally controlled by the structure of the rock mass. The design BFA used in this study were limited to a range of 65° to 75° based on experience and pre-shear blasting practices achievable at the Meadowbank Mine.
  - The bench width considered in this study is based on a combination of local regulations, experience at the Meadowbank Mine and the empirical criterion developed by Ritchie (1963). The Nunavut Mine Health and Safety Regulations specify a minimum final bench width of 8 m (Mine Health and Safety Act, 2011). A minimum bench width of 9.5 m was used for this study. The design bench width was increased to accommodate the expected back-break in cases where the rock mass structure is expected to result in a BFA shallower than the design BFA.

- **Inter-Ramp Slope Geometry -** The achievable inter-ramp slope geometry was evaluated as follows:
  - The maximum inter-ramp angle (IRA) is typically dictated by the bench geometry. The potential for multiple bench-scale instabilities on large-scale structural features (e.g., faults, shears, bedding planes, foliation etc.) is also evaluated, when required. In some cases, these persistent features may control the achievable IRAs and the slope may have to be flattened to account for their presence. In this design, the potential for multi bench instabilities was evaluated using Kinematic and Limit-Equilibrium (L-E) analyses. The IRA was also limited to a maximum of 53° at the request of AEM in order to accommodate some of the uncertainties inherent in scoping level design.

   - o The inter-ramp slope height was limited to 100 m in order to restrict the potential influence of inter-ramp-scale instabilities.
- **Overall Slope Angle -** The overall slope angle (OSA) that is achieved in a pit is typically flatter than the IRA due to the inclusion of haulage ramps, buttresses and/or geotechnical step-outs. In this design, L-E analyses were undertaken to confirm that the OSAs were achievable. The haulage ramps were assumed to have a width of 28 m, based on previous practices at the Meadowbank Mine. The geotechnical step-outs are intended to limit the inter-ramp slope height in sectors without a ramp, and were assumed to have the same width as the ramps.

## 4.3 OPEN PIT DESIGN SECTORS

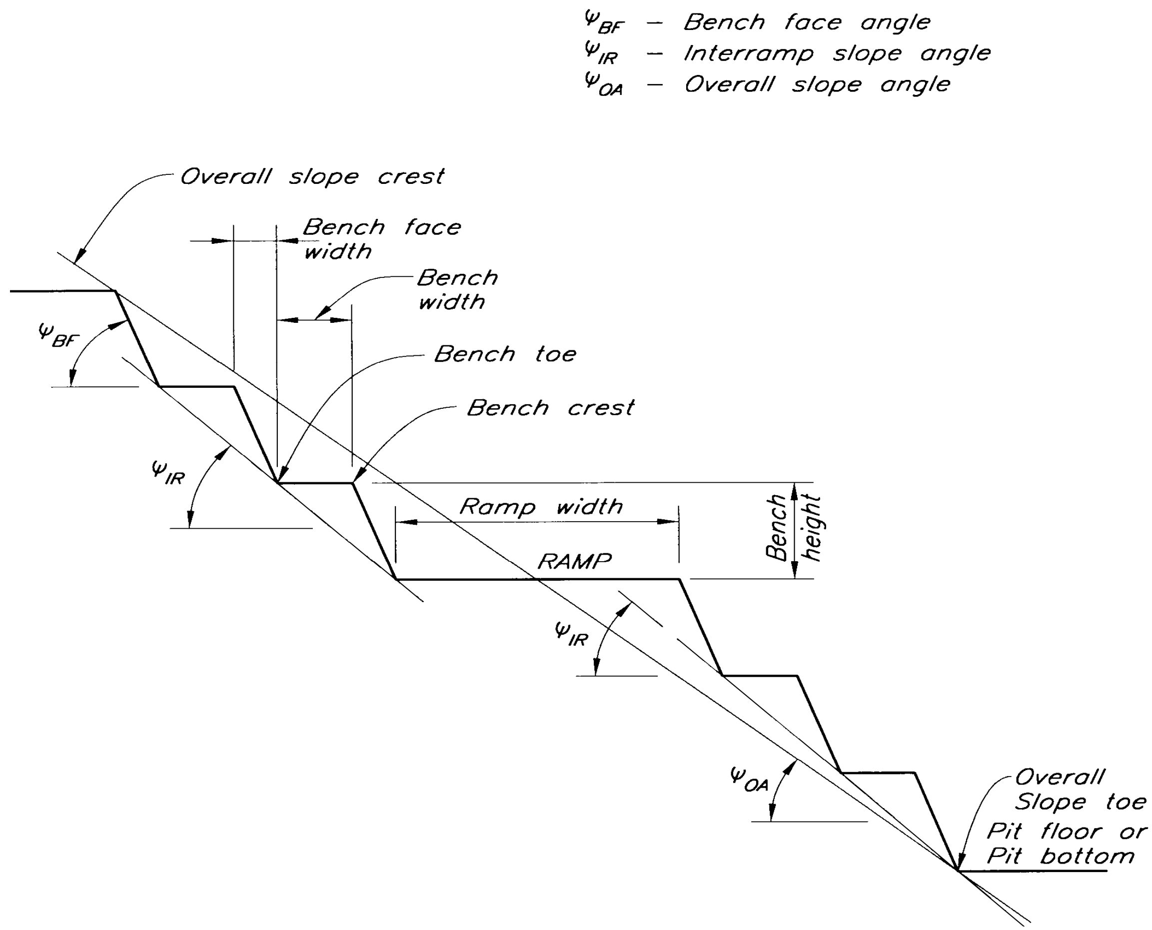
The proposed open pit was divided into eight (8) design sectors to support the stability analyses. The location of each of these sectors can be seen relative to the spatial extents of the domains within the pit wall on Figures 3.2 and 3.3. Sectors are chosen on the basis of consistent slope geometry/orientation, geomechanical domain, structure and expected slope performance. The achievable bench geometry, inter-ramp angles and overall slope angles are evaluated for each sector.

## 4.4 KINEMATIC AND STRUCTURAL ANALYSES

### 4.4.1 General

Kinematic analyses were undertaken to identify kinematically possible rock mass failure modes. These analyses were based upon the dominant small-scale structural trends identified at the Project. Achievable BFAs and IRAs were selected based on the structure of the rock mass. The potential for planar, wedge and toppling failure modes was considered. These failure modes can occur if the discontinuities are persistent (at least at a bench scale), relatively weak and oriented in such a way that they daylight in the pit wall. Kinematic failure modes are summarized on Figure 4.2 and below.

- **Planar Failure -** This failure mode is kinematically possible when a discontinuity plane is inclined less than the slope face (i.e., it daylights) and at an angle steeper than the friction angle.
- **Wedge Failure -** This failure mode is kinematically possible when the plunge of the intersection of two planes (i.e., sliding vector) is inclined less than the slope face (i.e., it daylights) and at an angle greater than the friction angles of the planes forming the wedge.
- **Toppling Failure -** Flexural toppling is kinematically possible when sub-vertical jointing dips into the slope at a steep angle and has a strike close to that of the slope. Flexural toppling most commonly occurs in relatively weak rock masses where the sub-vertical jointing is persistent and tightly spaced.

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WHALE TAIL PIT

**DEFINITIONS OF PIT SLOPE ANGLES**

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REF. NO. 3

**FIGURE 4.1**

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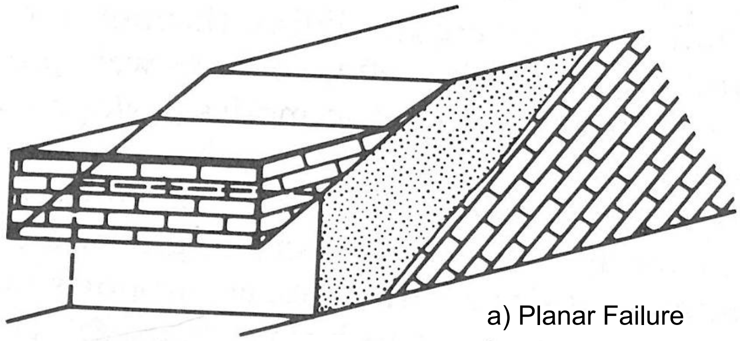
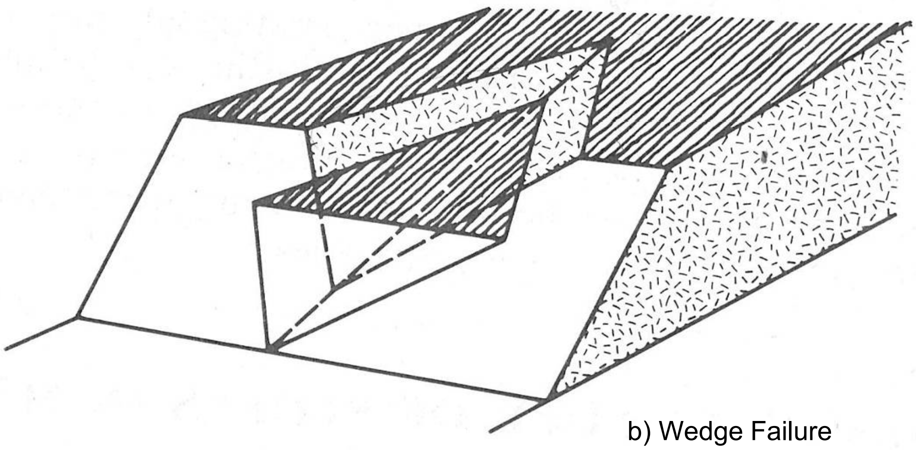
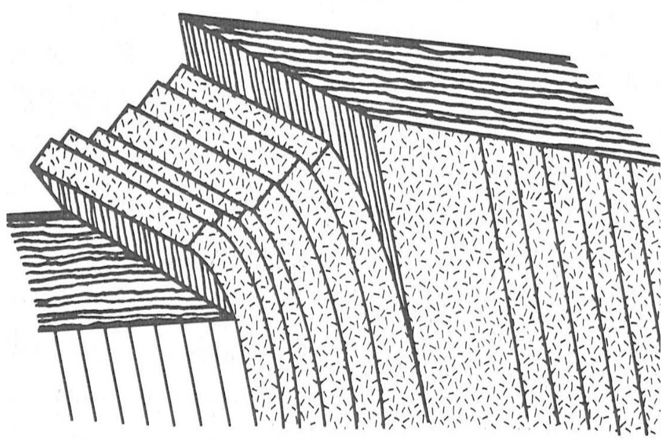


a) Planar Failure



b) Wedge Failure



c) Toppling Failure (Flexural)

**NOTES:**

1. IMAGES FROM GOODMAN (1980).

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WHALE TAIL PIT

**ROCK SLOPE FAILURE MODES**

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**FIGURE 4.2** REV 0

| REV | DATE | DESCRIPTION | PREP'D | RVW'D |
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### 4.4.2 Bench Geometry

Achievable BFAs were predominantly determined through a combination of experience and stereographic analysis using the DIPS software (Rocscience, 2012). The stereographic techniques consider the dominant structural orientations and were used to assess the significance of each potential planar, wedge or toppling failure.

The stereographic analyses focused on the failures that were most likely to impact bench performance. The potential importance of a failure was based on the prominence of the structure (the Set Significance) and the likelihood of the failure occurring (the Effect Significance). The product of these factors was then used to obtain an overall rating, which was converted into the following three descriptive categories: MINOR, MODERATE and MAJOR.

In terms of “Set Significance”, confirmed large-scale structures and major joint sets were rated more highly than less-prominent discontinuities. The “Effect Significance” was based on proximity to the kinematic failure window. A potential failure located in the centre of the kinematic failure window was rated more highly than a potential failure lying on the edge of the window. Only potential failures with MAJOR ratings were considered within the slope design.

Due to the relatively shallow dip of the foliation in the West-North sector, the kinematic analyses for this sector were supplemented with L-E analyses to evaluate the FoS for a sliding block on a single plane. The analyses were carried out using RocPlane (Rocscience, 2014) to determine the FoS against bench-scale planar failure. The analyses were based on the bench geometry, the dip of Joint Set A in the West structural domain, typical discontinuity strengths and assumed the slope was dry.

### 4.4.3 Inter-Ramp Angles

The IRAs were evaluated to consider possible failures resulting from major joint sets and confirmed large-scale structures. These are the features that can be reasonably expected to result in multi-bench instabilities. Potential inter-ramp kinematic failures were evaluated using stereographic methods. The average orientation of the confirmed large-scale structures and major joint sets were compared to the kinematic failure window for each IRA under consideration.

Potential interactions between known large-scale structures and the open pit walls were also evaluated visually using SURPAC™ (Dassault Systèmes, 2015).

## 4.5 LIMIT-EQUILIBRIUM ANALYSES (CIRCULAR ROCK MASS FAILURE)

### 4.5.1 General

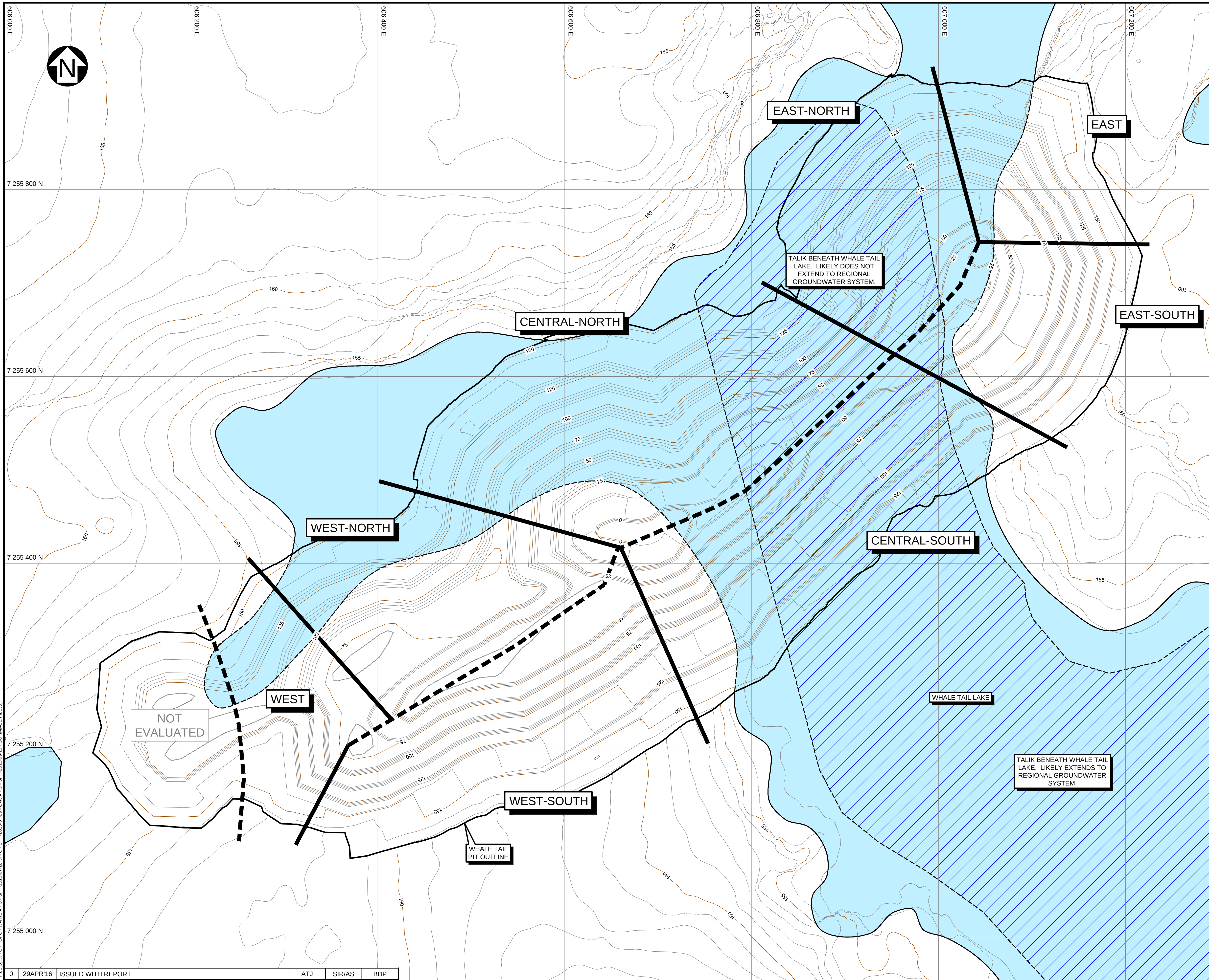
L-E analyses were carried out using SLOPE/W® (Geo-Slope International, 2012) and were used to determine the FoS against circular failure through the rock mass. This type of failure can result in multi-bench (inter-ramp) or overall slope scale instabilities. As such, this technique was utilized to evaluate the suitability of selected IRAs and OSAs.

The conditions typically considered in evaluating circular failure are: slope geometry, rock mass strength and anisotropy, stress conditions, hydrogeological conditions and seismic loading. Each of these conditions is briefly described below:

- **Slope Geometry -** Models were based on the final pit design and were constructed with a simplified geometry (i.e., excluding benches and ramps and removing complex geology). Models were developed for representative and limiting-case design sectors in order to capture any substantial variations in geology, pit wall geometry and slope height. The design sectors used are shown on Figure 3.3.
- **Rock Mass Strength -** Estimates of rock mass strength were obtained using the Hoek-Brown failure criterion (Hoek et. al., 2002). These estimates are based on the intact rock strength (i.e., UCS, mi) and rock mass quality (i.e., RMR). An introduction to this failure criterion is included as Appendix C. The Hoek-Brown design values for each domain are summarized on Table 4.1.

  A Disturbance Factor, (D), is used in the Hoek-Brown criterion to account for rock mass disturbance from blasting and stress change effects. Values of D=0.7, 0.85 and 1.0 have been found from experience to be roughly equivalent to excellent controlled blasting, normal controlled blasting and heavy production blasting, respectively.
- **Stress Conditions -** For deep open pits, stress-induced disturbance is expected to influence rock mass quality and the long-term performance of the slopes. This type of disturbance will occur when the load applied to the pit walls locally exceeds the strength of the rock mass. Disturbance of this type will tend to manifest itself as a reduction in rock mass quality and an increase in deformation. The impact of stress induced disturbance can be estimated and accounted for by adjusting both the depth of the disturbed zone and the level of disturbance. The proposed open pit is relatively shallow and the impact of stress conditions on the slope performance is expected to be minor.
- **Hydrogeological Conditions -** The groundwater conditions incorporated into the L-E analyses were based on the available hydrogeological data and an assessment of the potential for taliks below Whale Lake (KP, 2015c). The groundwater conditions for slopes that could be located within an open talik were modelled using a phreatic surface. The remaining slopes were assumed to be dry due to either the presence of permafrost or the limited groundwater recharge expected within a closed talik. The potential impacts of slope depressurisation on the slopes located within an open talik were also considered. The potential extents of talik relative to the proposed open pit are shown on Figure 4.3.
- **Seismic Loading -** Dynamic loading of the slope during an earthquake would be expected to temporarily influence slope stability. The seismic hazard for the Project is expected to be relatively low based on publicly available hazard maps (Natural Resources Canada, 2010). As a result, the L-E analyses did not consider dynamic loading.

Two general categories of L-E models were developed for each pit: inter-ramp models and overall slope models. The different model configurations are described in the following sections and set out in Table 4.2.




**LEGEND:**

- WATER
- POTENTIAL TALIK
- DESIGN SECTOR BOUNDARY
- DESIGN SECTOR BOUNDARY CONTROLLED BY PIT GEOMETRY

**NOTES:**

1. COORDINATE GRID IS UTM NAD83 ZONE 14N.
2. PIT DESIGN, TOPOGRAPHY AND BATHYMETRY PROVIDED BY AEM (SEPTEMBER, 2015).
3. CONTOUR INTERVAL IS 1 METRE.
4. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 40 20 0 40 80 120 160 200 m

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WHALE TAIL PIT

**WHALE TAIL PIT AND POTENTIAL EXTENTS OF TALIK**

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| P/A NO. | REF NO. |
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**FIGURE 4.3** REV 0

| REV | DATE | DESCRIPTION | DESIGNED | DRAWN | REVIEWED |
|---|---|---|---|---|---|
| 0 | 29APR'16 | ISSUED WITH REPORT | ATJ | SIR/AS | BDP |

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**TABLE 4.1**

**AGNICO EAGLE MINES LTD. MEADOWBANK DIVISION**
**WHALE TAIL PIT**

**UPDATED SCOPING LEVEL OPEN PIT SLOPE DESIGN (REVISED)**
**LIMIT-EQUILIBRIUM PARAMETER SUMMARY**

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| Domain | | Intact Rock Properties | | | Rock Mass Properties | |
|---|---|---|---|---|---|---|
| | | mi | UCS (MPa) | Unit Weight ($kN/m^3$) | $RMR_{89}$ | GSI |
| Diorite | | 20 [3] | 125 | 27.7 | 70 | 65 |
| Greywacke [4] | Greywacke | 28 | 65 | 28.0 | 65 | 60 |
| | Mudstone | | | | | |
| | Mafic Volcanics | | | | | |
| Chert | | 20 [3] | 135 | 28.1 | 65 | 60 |
| Altered Ultramafics | | 4 | 90 | 29.4 | 65 | 60 |
| Ultramafics | North Limb | 10 | 50 | 28.0 | 55 | 50 |
| | South Limb | | | | 50 | 45 |

I:\1\01\00622\03\A\Report\Report 3 Rev 0 Updated Open Pit Scoping Study\Tables\[Table 4.1 - L-E Parameter Summary.xlsx]Table 4.1 - Design Parameters

**NOTES:**
1. $RMR_{89}$ VALUES HAVE BEEN WEIGHTED BY LENGTH TO ACCOUNT FOR THE VARIATION IN THE LENGTH OF LOGGING RUNS. DESIGN VALUES BASED ON 30TH PERCENTILE.
2. UCS, mi AND UNIT WEIGHT BASED ON AVERAGE LABORATORY TESTING RESULTS PROVIDED BY AMEC (SEPT 28, 2015).
3. mi DESIGN VALUE BASED ON HOEK ET AL. (1992) LOWER BOUND VALUES.
4. INTACT PROPERTIES FOR GREYWACKE DOMAIN BASED ON LAB TESTING RESULTS FOR ONLY GREYWACKE SAMPLES (I.E., DO NOT INCLUDE THE TESTING OF THE MAFIC VOLCANICS).

| | | | | |
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| REV | DATE | DESCRIPTION | PREP'D | RVW'D |

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**TABLE 4.2**

**AGNICO EAGLE MINES LTD. MEADOWBANK DIVISION**
**WHALE TAIL PIT**

**UPDATED SCOPING LEVEL OPEN PIT SLOPE DESIGN (REVISED)**
**LIMIT-EQUILIBRIUM MODEL SET-UP PARAMETERS**

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<table>
<tr><th rowspan="2">Parameter</th><th colspan="2">Inter-Ramp Slope Models</th><th colspan="2">Overall Slope Models</th></tr>
<tr><th>Values</th><th>Comments</th><th>Values</th><th>Comments</th></tr>
<tr><td>Geometry and Geology</td><td colspan="2">Based on general slope consisting of a single domain.<br><br>Slope angles varied from 40 to 55° based on recommended bench geometries.<br><br>Slope height varied from 75 to 100 m.</td><td colspan="2">Based on select design sectors to account for sector geology and varying slope heights.<br><br>Models constructed from the Lithology model and Open Pit Design received from AEM on September 29 and 30, 2015, respectively.</td></tr>
<tr><td rowspan="2">Disturbance Factor</td><td rowspan="2">0.7 and 0.85</td><td rowspan="2">Entire slope fully disturbed to reflect production blasting.<br><br>Fully disturbed model considered appropriate as the critical slip surface is expected to lie entirely within the disturbed portion of the pit wall.<br><br>A disturbance factor of 0.85 was used for all domains except the Ultramafics. A disturbance factor of 0.7 was used for the Ultramafics. Due to the lower rock mass quality of this domain, the relative reduction in rock mass quality due to blasting is expected to be less than for the other domains.</td><td>0.7 and 0.85</td><td>Disturbed Zone adjacent to the face of the slope associated with production blasting.<br><br>Zone extends 20 m perpendicular to the pit wall. Damage expected to extend 1 to 1.5 times the bench height in the that wall [1].<br><br>A disturbance factor of 0.85 was used for all domains except the Ultramafics. A disturbance factor of 0.7 was used for the Ultramafics. Due to the lower rock mass quality of this domain, the relative reduction in rock mass quality due to blasting is expected to be less than for the other domains.</td></tr>
<tr><td>0</td><td>Remainder of slope modelled as undisturbed. Limited stress-induced damage expected due to shallow depth of the pits.</td></tr>
<tr><td rowspan="3">Groundwater Conditions</td><td>Fully Saturated</td><td>Slopes within the footprint of Whale Tail Lake may be within an open talik zone. The entire slope was considered fully saturated in these cases.</td><td rowspan="3">Fully Saturated</td><td rowspan="3">The entire slope was considered fully saturated in the overall slope models. A portion of slopes within the footprint of Whale Tail Lake may be within an open talik zone; therefore a fully saturated slope was considered as a worst-case scenario.</td></tr>
<tr><td>10 m Depressurized</td><td>Limited slope depressurization within the potential open talik zone was considered. Depth of depressurization measured perpendicular to the slope.</td></tr>
<tr><td>Dry</td><td>Many pit slopes are expected to be completely within permafrost.</td></tr>
<tr><td>Loading Case</td><td>Static</td><td>Design based on static loading case only.</td><td>Static</td><td>Design based on static loading case only.</td></tr>
<tr><td>Critical Slip-Surface</td><td colspan="2">Must extend over the full height of the inter-ramp slope in order to exclude shallow bench-scale failures.</td><td colspan="2">Must extend over the full height of the slope and into the slope beyond the zone of blast disturbance in order to exclude smaller inter-ramp failures.</td></tr>
<tr><td>Target FoS</td><td>1.2</td><td>Standard design FoS under static loading.</td><td>1.3</td><td>Standard design FoS under static loading.</td></tr>
</table>

I:\1\01\00622\03\A\Report\Report 3 Rev 0 Updated Open Pit Scoping Study\Tables\[Table 4.2 - L-E Model Set-up Parameters.xlsx]Table 4.2

**NOTES:**
1. HOEK, E., 2012. BLAST DAMAGE FACTOR D. TECHNICAL NOTE FOR ROCNEWS WINTER 2012 ISSUE. ROCSCIENCE, TORONTO, ON.

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### 4.5.2 Inter-Ramp Angles

Inter-ramp slope models were developed for each geomechanical domain. The models were independent of any specific pit geometry and were constructed with slope heights between 75 and 100 m. The models were evaluated at varying slope angles until the target FoS was attained.

The rock mass was assumed to be entirely disturbed. The majority of the domains were modelled with a disturbance factor of D=0.85. A reduced disturbance factor of D=0.7 was used for the Ultramafics. Due to the lower rock mass quality of the Ultramafics, the relative reduction in rock mass quality due to blasting is expected to be less than for the other domains.

The models considered several different groundwater scenarios.

- **Dry Slope -** Many of the pit slopes are expected to be entirely within permafrost. As a result, a series of models were run without groundwater.
- **Fully Saturated Slope -** Some of the pit slopes may be partially or entirely within open taliks. As a result, a series of models were run with a fully saturated slope.
- **Partially Saturated Slope -** Partial depressurisation of the slopes within an open talik was also considered. A limited amount of depressurisation can be expected to occur naturally. Dewatering wells or horizontal drains can be used to further depressurise the slope. Depressurisation to a distance of 10 m behind the face of the slope was evaluated.

### 4.5.3 Overall Slope Angles

The purpose of the overall slope models was to confirm that the OSAs resulting from the recommended inter-ramp slope geometry were achievable. These models were based on the open pit geometry provided by AEM (February, 2015). Models were constructed for the deepest design sector in each pit. Additional models where run for areas of special interest *(e.g.*, sectors with significant exposures of the Ultramafics). The models incorporated a 20 m thick disturbed zone (D=0.7 for the Ultramafics, D=0.85 for all other domains) to account for blast-induced disturbance (Hoek, 2012). The remainder of the slope was considered to be undisturbed (D=0). The models were evaluated at the overall slope angles estimated for the relevant sectors based on the bench and inter-ramp scale slope recommendations.

## 4.6 ACCEPTANCE CRITERIA FOR PIT SLOPE DESIGN

### 4.6.1 Factor of Safety

Target Factors of Safety were based on achieving an acceptable level of risk. Target values vary depending on the scale of the slope and the consequences of failure. Experience has shown that designing at a lower FoS will tend to eventually increase deformations within the wall and lead to progressive slope degradation. These degradations increase the exposure of personnel to rock fall or slope stability issues and also increases the likelihood of interruptions to normal mine operations.

The target FoS used in this study were based upon experience and guidelines provided by Read and Stacey (2009) and Wyllie and Mah (2004), among others. The target FoS used as acceptance criteria for the limit-equilibrium stability analyses are described below.

- **FoS 1.3 -** Overall slope analyses under static loading conditions. This value is typically recognized by regulatory agencies for multiple bench stability, providing that a monitoring program has been established.
- **FoS 1.2 -** Inter-ramp scale analyses under static loading conditions. This value is typically recognized by regulatory agencies for multiple bench stability, providing that a monitoring program has been established.
- **FoS 1.1 -** Bench scale analyses under static loading conditions. This target was only used for the bench-scale limit-equilibrium analyses described in Section 4.4.2.

Certain regions of the pit may have a higher FoS than the minimum targets listed above. This is not uncommon in open pit operations, as some changes in slope angle are difficult to accommodate within a practical pit design. Unless otherwise noted, the recommended pit slope angles will meet or exceed the selected minimum stability criteria and are generally specified in a way that a coherent and practical slope configuration can be achieved between adjacent design sectors.

### 4.6.2 Cumulative Frequency of Failure

Cumulative Frequency of Failure (CFF) is a measure used to assess bench performance and bench design. Similar to the target FoS, the target CFF was based on achieving an acceptable level of risk and bench performance. The CFF is the percentage of discontinuities in a given joint set that are expected to result in a kinematic failure.

A target CFF of 30% was used in the bench scale kinematic analyses based upon experience and guidelines provided by Read and Stacey (2009). This target means that 70% of the benches are expected to meet or exceed the recommended geometry.

### 4.6.3 Other

For the inter-ramp scale kinematic analyses, the mean orientations of the confirmed large-scale structures and major joint sets were reviewed to ensure that they were not within the kinematic failure window.

# 5 – PIT SLOPE DESIGN

## 5.1 GENERAL

The stability analyses results and the open pit slope design recommendations are provided in this section. In all cases, the recommendations and results are dependent upon the current understanding of the rock mass and hydrogeological characteristics. Future investigations, analyses and observed slope performance should be used to refine these analyses.

## 5.2 KINEMATIC AND STRUCTURAL ANALYSES

### 5.2.1 General

Kinematic analyses were undertaken on each design sector using the discontinuity orientation and large-scale structural information available for that sector. The discontinuity orientation data was based on the structural domain in which the sector was located.

### 5.2.2 Bench Geometry

Stereographic analyses were used to evaluate the achievable bench geometry for each sector. In the West-North sector, these analyses were supplemented with limit-equilibrium planar analyses.

In the absence of any kinematic controls, a design BFA of 75° was recommended based on experience and AEM's practices at the Meadowbank Mine. In cases where significant kinematic stability issues are expected, the BFA was reduced to limit the amount of back break and/or wider bench widths were recommended to increase rock fall storage capacity. Bench scale kinematic considerations are summarized below. The analyses are summarized in Appendix D.

The potential for kinematic failures is expected to limit the achievable BFA in the following sectors:

- **East-North, Central-North and West-North Sectors -** Planar failures involving the foliation (i.e., Joint Set A) are expected to be the dominant structural control on the achievable slope geometry in these sectors. In particular, planar failures in the West-North and Central-North sectors are expected to limit the achievable BFA to 55°.
- **Central-South Sector -** Planar failures involving a dominant joint set (i.e., Joint Set B) are expected to control the achievable slope geometry in this sector.
- **East-South, Central-South and West-South Sectors -** Toppling failures may occur along the hangingwall of the deposit in these sectors. As other factors strongly influence the potential for toppling failure (e.g., joint spacing and persistence), the bench geometry has not been adjusted to reflect this failure mode.

The analyses also suggest the potential for wedge failure involving Joint Sets A and D in the East-North, Central-North and West-North sectors and involving Joint Sets B and D in the Central-South sector. A review of these potential wedge failures concluded that they were fundamentally a planar failure along the dominant structure (Joint Sets A and B), with steep release planes (Joint Set D). As such, the bench geometry has been based on the results of the planar analyses rather than the wedge analyses for these sectors.

The results of the kinematic analyses for the West-North sector suggest that the achievable BFA will be controlled by planar failure on Joint Set A (foliation). Due to the shallow dip of the foliation in this sector, the kinematic analyses were supplemented by bench scale L-E models that considered the FoS for a block sliding on a single plane. The BFA was varied within reasonable ranges and the dip of the structure was varied within the range of variation seen in the foliation. The results of the analyses are included in Appendix E.

#### 5.2.3 Inter-Ramp Angles

Once an appropriate bench configuration was selected for a design sector, it was used to determine the steepest possible IRA. These IRA values were then used to check for the possibility of multi-bench kinematic failures. The analyses suggest that inter-ramp scale kinematic considerations are not expected to limit the achievable slope geometry. The analyses are summarized in Appendix D.

### 5.3 LIMIT-EQUILIBRIUM ANALYSES (CIRCULAR ROCK MASS FAILURE)

#### 5.3.1 IRA Analyses

In order to evaluate achievable IRAs from a rock mass strength perspective, inter-ramp slope models were developed for each geomechanical domain present within the final pit wall. The height of the slope was varied within reasonable ranges to establish a relationship between achievable angles and slope height. The effects of groundwater depressurisation were also considered within the Ultramafics, when this unit is likely to be within talik.

One result of the analysis strategy employed is that the target FoS can be achieved by different combinations of slope heights and angles. In all cases, the recommended values were thought to be the most appropriate under the circumstances. The results of the analyses are included in Appendix F1.

#### 5.3.2 OSA Analyses

OSA models were constructed for representative design sectors as final checks on the stability of the overall slope. L-E stability analyses were conducted under static conditions only. In all cases, the target FoS was achieved for the OSA models. The results of the analyses are included in Appendix F2.

### 5.4 RECOMMENDED OPEN PIT SLOPE GEOMETRY

The recommended slope configurations and design considerations for each sector of the proposed pit is summarized in Table 5.1. The open pit slope design recommendations are also presented graphically on Figure 5.1. Note that these recommendations are only for slopes excavated in rock.

A summary of the recommendations is provided below:

- Design BFA: 65 to 75°
- Design Bench Width: 10 to 14.4 m
- Bench Height: 21 m
- IRA: 41 to 53°