Minto Mine
QML-0001

Underground Mine Development and Operations Plan Amendment
Copper Keel Zone
February 2020

Prepared by:
Minto Explorations Ltd.

# Table of Contents

# List of Figures

# List of Tables

# 1 Introduction

This document amends the Underground Mine Development and Operations Plan (UMDOP) for the Minto South Underground to include the Copper Keel ore zone.

# 2 Operations Overview

As of January 2020, mining has concluded in the Area 2 zone, and is currently underway in Minto East. Development of the ramp to Copper Keel began in October 2019 and is ongoing.

The Minto East escapeway and ventilation raise are developed and operational. Production is currently underway on the 490 and 505 level of Minto East.

# 3 Deposits and Ore Reserves

The Copper Keel zone located approximately 450m southeast of the Minto East ramp.

Mineral reserves for Copper Keel are provided in the following table.

| | Ore (t) | Cu % | Au g/t | Ag g/t | Cu lbs x $10^6$ |
|---|---|---|---|---|---|
| CK Probable Reserve | 1,616,000 | 1.73 | 0.63 | 6 | 61.6 |
| CK Total Reserve | 1,616,000 | 1.73 | 0.63 | 6 | 61.6 |

.

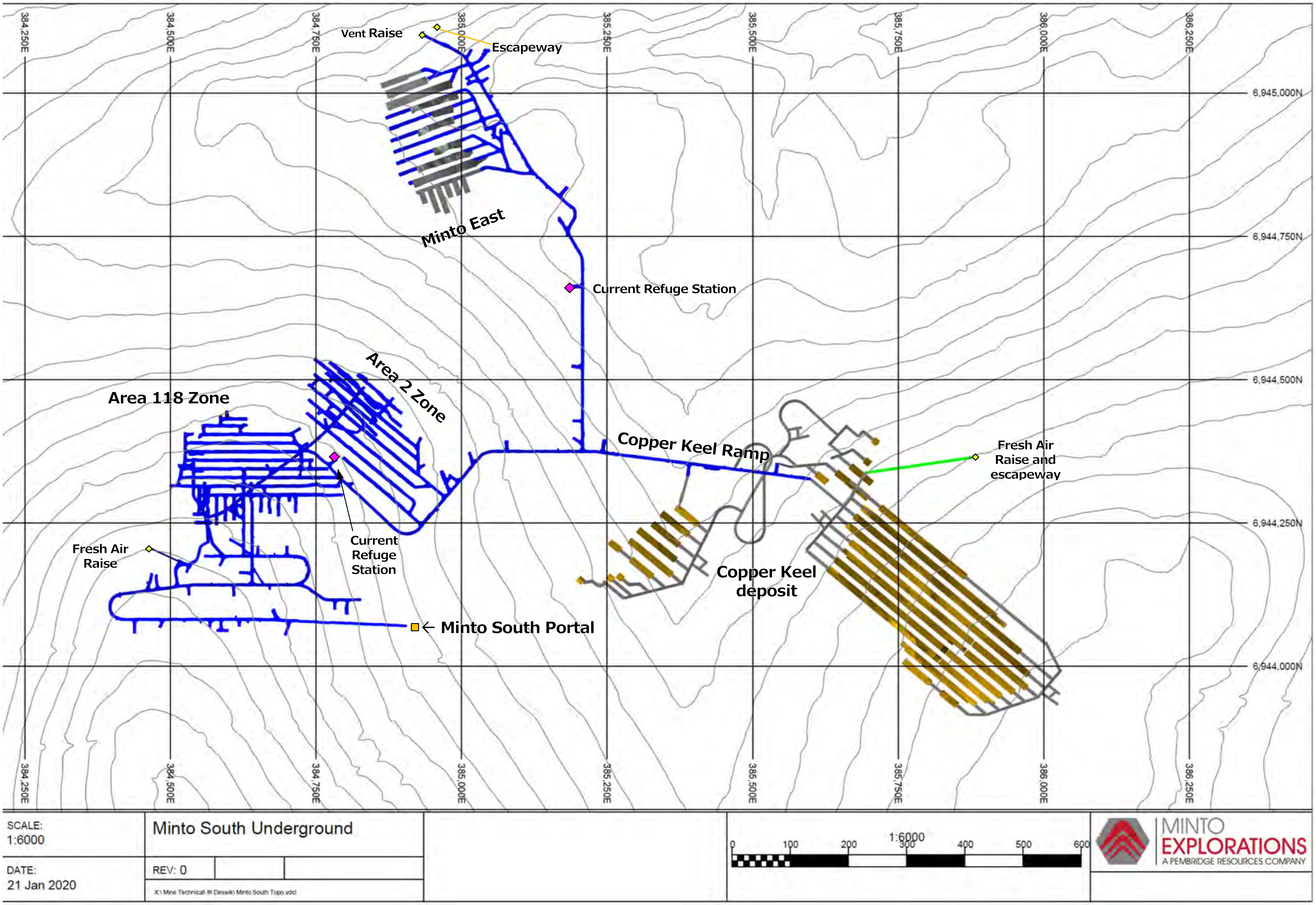


**Figure 3-1: Plan view of underground development and ore zones.**

# 4 Mine Development and Design

## 4.1 Ramp Development

The ramp is 5.0m wide and 5.5m high, consistent with the main ramp to the Area 2 and Minto East zones. It will be used for all ore and waste haulage, personnel/equipment access, and services running to the Copper Keel zone. The back height is increased to 6.5m at remuck intersections to provide the height necessary for the LHD units to load trucks.

Re-muck bays are developed every 150m to improve the efficiency of the development cycle; they are designed to hold two rounds of development muck. The re-muck bays have the same dimensions as the decline and are 20m in length. Additional cut-outs for drill bays, sumps, etc. are developed as required. Safety bays are developed every 30m.

## 4.2 Copper Keel Design

A design for Copper Keel is shown in Figure 3-1. Sill drifts are driven along the footwall contact of the ore zone. Sill drifts are spaced every 20m. The drifts are typically driven at +13% grade. In most of the sill drifts, the footwall contact rises steeper than this; drifts start in ore but end in waste, necessitating that some waste be mined below the footwall contact. For some of the stopes, the ore zone is approached from two sides so that excessive footwall dilution need not be taken.

The constant positive gradient will simplify water management, while the grade has been selected as an acceptable compromise between LHD productivity and dilution.

### 4.2.1 Stope Width and Sill Drift Spacing

The design presented in this document features 20 sill drifts, spaced at 20m intervals.

The design is nominally based on 12m-wide stopes and 8m pillars, but geotechnical analysis indicates that the pillar width must vary as a function of stope height in order to maintain stability and maximize recovery. Pillar thickness is increased where the stope is tall and decreased where the stope is short.

The current design results in an extraction ratio of approxiamtely 60% in Copper Keel deposit. In May 2018, Minto drilled three new geotechnical holes into the Copper Keel Main lens that verified rock quality parameters.

## 4.3 Truck Loadouts

Two truck loadouts are planned for Copper Keel to reduce LHD tram distance. Each consists of a truck bay, a scoop bay / remuck, and a connection between the two. The scoop bay is elevated relative to the truck bay so that the LHD can dump material into the truck box from above.

## 4.4 Water Management

A single sump is planned at the lowest point in the main access. Sumps are typically 15m long and dip at -15%. Water collected in the sump will be pumped to the Minto East pump station, where it is pumped directly to surface through a sub-vertical pipe using multi-stage electric pumps.

## 4.5 Escapeway

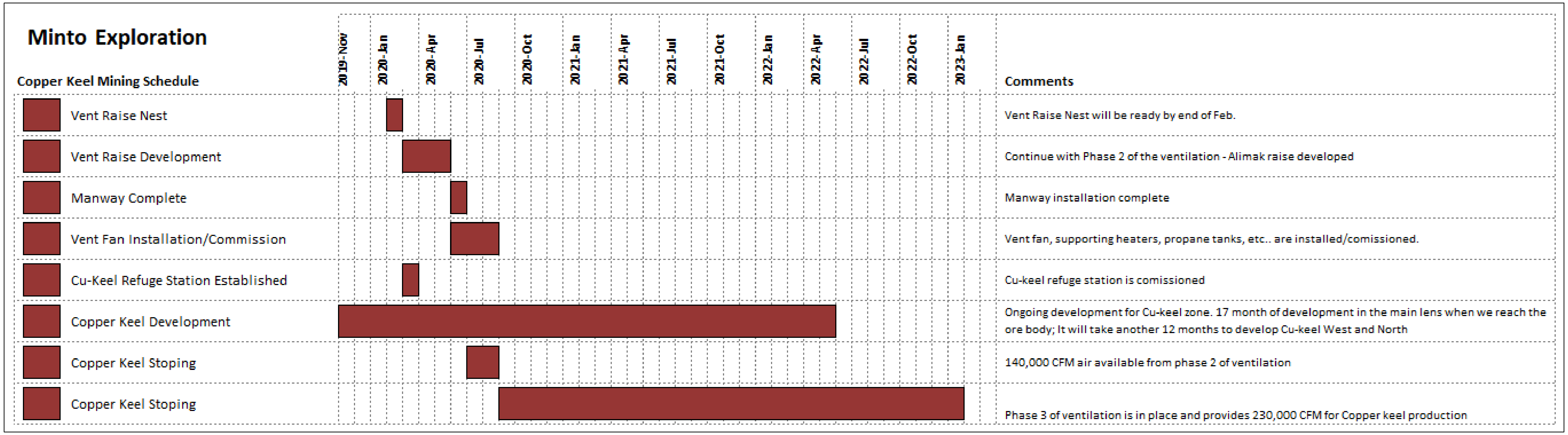
An escapeway from the lowest workings of the mine was completed in the Minto East area in April 2018 and will remain active throughout Copper Keel mining. The Copper Keel fresh air raise is planned to be developed through means of Alimak at a size of 3 x 3 metres and will contain a ladderway as a second means of egress from the Copper Keel mine area.

## 4.6 Vent Raise

A 67 degree Alimak raise, measuring 293m (269m vertical) to surface and 3mX3m, will be developed at Copper Keel. Additional information on future ventilation plans can be found in Section 8.

## 5 Scheduling

The ramp accessing copper keel deposit will be the primary development priority. As development progresses, intersection ground support for sills will be installed, and each will be stubbed in so that services (vent ducting, pipes, electrical cables, etc.) will not be damaged when sill development begins. Concurrently, a second development crew will work on truck loadouts, the electrical bay and sump, and the remaining development before production starts. An access drift will be developed so that the ventilation raise and escapeway breakthrough will be >30m away from the main ramp. The following are major milestones in the schedule for Copper Keel development and production activities (as shown in the gantt chart):



| Copper Keel Mining Schedule | Comments |
|---|---|
| Vent Raise Nest | Vent Raise Nest will be ready by end of Feb. |
| Vent Raise Development | Continue with Phase 2 of the ventilation - Alimak raise developed |
| Manway Complete | Manway installation complete |
| Vent Fan Installation/Commission | Vent fan, supporting heaters, propane tanks, etc.. are installed/comissioned. |
| Cu-Keel Refuge Station Established | Cu-keel refuge station is comissioned |
| Copper Keel Development | Ongoing development for Cu-keel zone. 17 month of development in the main lens when we reach the ore body; It will take another 12 months to develop Cu-keel West and North |
| Copper Keel Stoping | 140,000 CFM air available from phase 2 of ventilation |
| Copper Keel Stoping | Phase 3 of ventilation is in place and provides 230,000 CFM for Copper keel production |

# 6 Mine Operation

## 6.1 Material Handling

Material is mucked from stopes and development headings by a combination of 7- and 8-yard LHD units. Stope mucking operations are carried out via remote control from a stand set up at the open stope brow; the operator is not exposed to the unsupported ground in the open stope.

A fleet of Atlas Copco MT42 and two CAT AD45 haul trucks is currently used for haulage. All haulage is through the Minto South ramp and portal.

Ore from both development and stoping is hauled to a surface stockpile adjacent to the portal, from which it is picked up by a separate fleet of surface haul trucks and loaders and taken to the crushing plant.

Waste rock from development headings is hauled to a surface stockpile adjacent to the portal. Development rounds are assayed and the waste is moved to the appropriate waste dump as outlined in the *Waste Rock and Overburden Management Plan (WROMP)*. The protocols for segregation and placement of waste materials are consistent with the protocols for surface mining.

# 7 Geotechnical

## 7.1 Orebody Geometry

The main lens of the ore body measures approximately 500m in length and is, on average, 190m wide. It strikes at 320 degrees and has an average dip of 13 degrees.

## 7.2 Excavation Dimensions

The following is a summary of the planned excavation and pillar dimensions.

**Table 7-1: Summary of Excavation Dimensions**

| Excavation/Pillar | Copper Keel deposit |
|---|---|
| Development drifts, ramps | 5.0 m (W) x 5.5 m (H) |
| Production drifts | 6.0 m (W) x 4.5 m (H) |
| Longhole stope (non-entry) | 12 m (W) x 9-20 m (H) |
| Longhole pillar | 8 m (W) x 9-20 m (H) |

## 7.3 Rock Mass Characterization

### 7.3.1 Rock Mass Classification

Rock mass characterization is based on core logging and laboratory testing. Summaries of rock mass quality and strength and contained in Table 7-2, and Table 7-3.

**Table 7-2: Summary of RMR values for Copper Keel (results from 2015 and 2018 testing)**

| Simplified Lithology | Total Length Logged (m) | Weighted Average | Rock Mass Quality (avg) |
|---|---|---|---|
| Ore – 2015 | 489.43 | 72 | Good |
| Hangingwall - 2015 | 156.29 | 71 | Good |
| Ore – 2018 | 48.84 | 72 | Good |
| Hangingwall - 2018 | 68.81 | 67 | Good |

**Table 7-3: Summary of Q' values for Copper Keel (results from 2015 and 2018 testing)**

| Simplified Lithology | Total Length Logged (m) | Weighted Average | Rock Mass Quality (avg) |
|---|---|---|---|
| Ore – 2015 | 513.43 | 17.8 | Good |
| Hangingwall - 2015 | 165.29 | 13.9 | Good |
| Ore – 2018 | 48.84 | 29.2 | Good |
| Hangingwall - 2018 | 68.81 | 11.9 | Good |

### 7.3.2 Intact Strength

Laboratory testing of intact rock strength shows the rock in Copper Keel to be strong to very strong.

Further to the existing data, eighteen samples were taken from four diamond drillholes in 2018 for Unconfined Compressive Strength (UCS) testing. Six of the samples were from waste in close proximity to the hangingwall contact, and twelve were ore. Results for waste gave a range of 97 to 146 MPa, with an average of 110 MPa. Results for ore ranged from 81 to 195 MPa, with an average of 124 MPa. These strengths are similar to those in other lenses of the Minto South Underground. Table 7-6 summarizes the UCS test results.

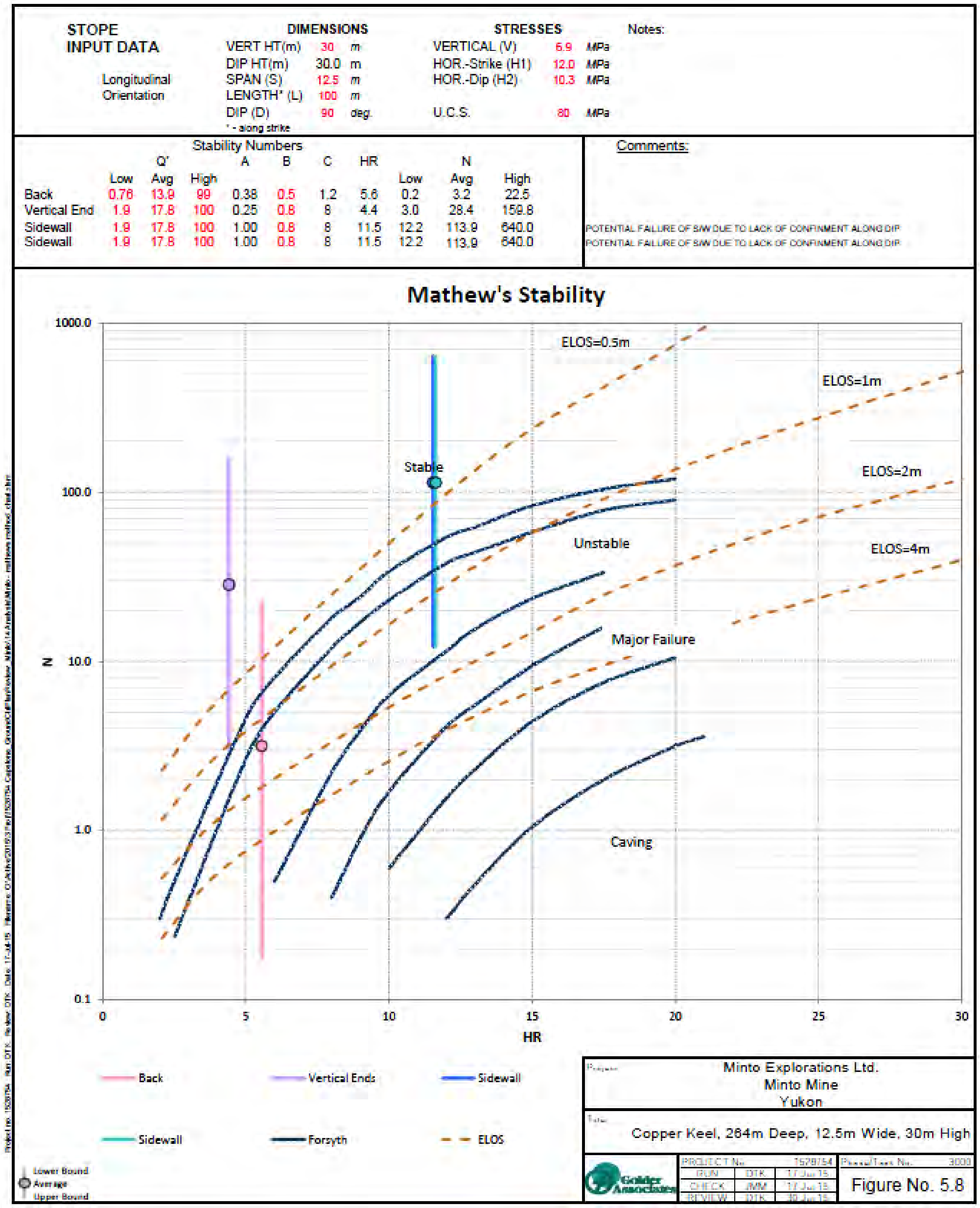
**Table 7-4: Summary of 2015 and 2018 laboratory UCS test results**

| Simplified Lithology | No. of valid Samples | Minimum UCS (MPa) | Maximum UCS (MPa) | Average UCS (MPa) |
|---|---|---|---|---|
| Ore | 7 | 81 | 195 | 124 |
| Hangingwall | 5 | 97 | 146 | 110 |

## 7.4 Stability Analysis

Stope spans for future mining areas were designed using a combination of empirical analysis, numerical modelling, and experience in the Minto underground to date. Figure 7-1 shows the stability graph for 12.5 m wide and 30 m high stopes for Copper Keel as per planned stope and pillar geometry.

**Figure 7-1: Mathew's Method Stability analysis from Golder 2015**



**STOPE INPUT DATA**

Longitudinal Orientation

**DIMENSIONS**

VERT HT(m) 30 m
DIP HT(m) 30.0 m
SPAN (S) 12.5 m
LENGTH* (L) 100 m
DIP (D) 90 deg.
* - along strike

**STRESSES**

VERTICAL (V) 6.9 MPa
HOR.-Strike (H1) 12.0 MPa
HOR.-Dip (H2) 10.3 MPa
U.C.S. 80 MPa

Notes:

Stability Numbers

| | Q' | | | A | B | C | HR | N | | | Comments: |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg | High | | | | | Low | Avg | High | |
| Back | 0.76 | 13.9 | 99 | 0.38 | 0.5 | 1.2 | 5.6 | 0.2 | 3.2 | 22.5 | |
| Vertical End | 1.9 | 17.8 | 100 | 0.25 | 0.8 | 8 | 4.4 | 3.0 | 28.4 | 159.8 | |
| Sidewall | 1.9 | 17.8 | 100 | 1.00 | 0.8 | 8 | 11.5 | 12.2 | 113.9 | 640.0 | POTENTIAL FAILURE OF S/W DUE TO LACK OF CONFINMENT ALONG DIP |
| Sidewall | 1.9 | 17.8 | 100 | 1.00 | 0.8 | 8 | 11.5 | 12.2 | 113.9 | 640.0 | POTENTIAL FAILURE OF S/W DUE TO LACK OF CONFINMENT ALONG DIP |

Project
Minto Explorations Ltd.
Minto Mine
Yukon

Title
Copper Keel, 264m Deep, 12.5m Wide, 30m High

PROJECT No. 1529754
Phase/Task No. 3000
RUN DTK 17 Jul 15
CHECK JMM 17 Jul 15
REVIEW DTK 30 Jul 15
Figure No. 5.8

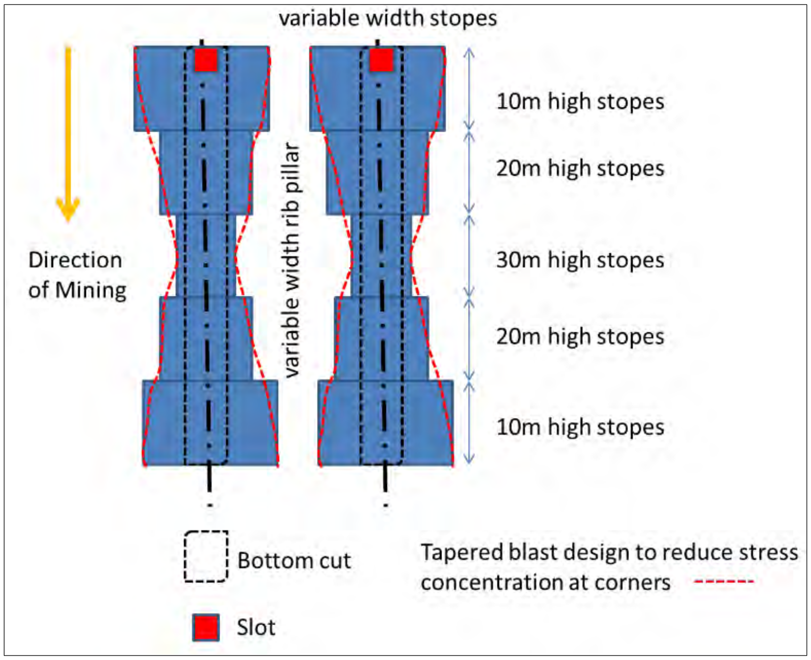
The following is an excerpt from Golder 2015:

*The assessment suggests that 10 m wide stopes in typical ground are stable, but localised areas of poorer quality hanging wall waste could result in challenging back conditions and slough. Increases in stope span beyond 10m will result in increasingly challenging conditions and 15m wide stopes in typical ground would expected to exhibit* *slough that will result in operational challenges. A change in mining approach whereby ground support would be installed in the stope backs would be required to provide confidence in back spans beyond 10 m to 12.5 m.*

The proposed mining method for Copper Keel is consistent with the mining method employed in Minto East and Area 2 UG. The logic behind this mining method is to develop sill drifts that are 20m apart (consistent drill drift centerline). This allows to adjust the pillar size based on the height of stope. The figure below is presented to better explain the mining method.

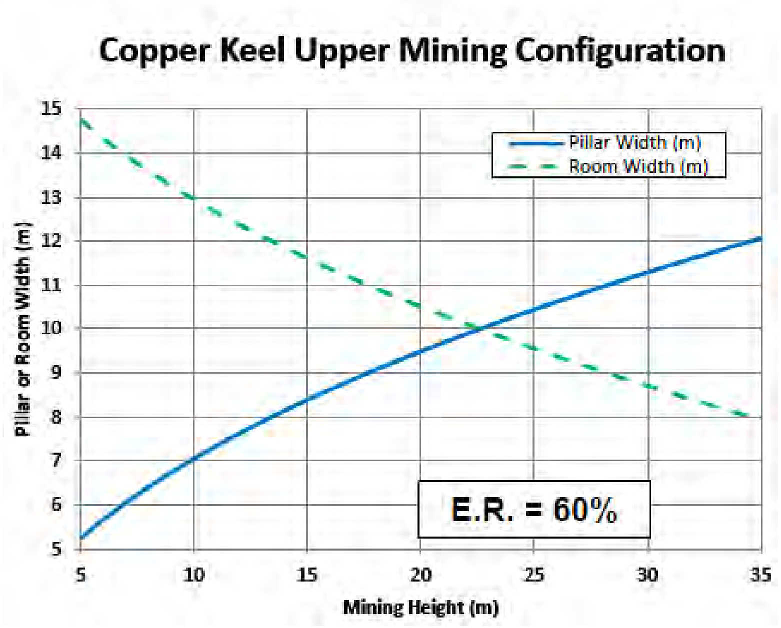
Pillar stability analyses were also carried out by Golder in 2015. Permissible stope and pillar widths were estimated for the range of mining heights in the Copper Keel deposit, shown in Figure 7-3 below. Average extraction ratios shown are based on the distribution of ore thickness. These analyses assumed an intact rock strength for ore of 80 MPa, which recent lab testing indicates is a conservative assumption. Analyses are updated as more information is gained during development of the deposit.

**Figure 7-2: Variable Rib Pillar and Stope Width with Constant Drill Drift Centerline**



It is not feasible to provide a single figure for each stope since the thickness of ore (height of stope) varies in each stope. The figure below shows the required pillar size for different stope heights. As shown in figure 7.2, the pillar width can be 5.3m to 12m; i.e. 14.7m to 8m stope width respectively (resulting in drift centerlines that are 20m apart).

**Figure 7-3: Summary of permissible stope and pillar widths (Golder, 2015)**



## 7.5 Ground Support Requirements

Ground support requirements for underground development are contained in the Minto Underground Ground Control Plan. The following are summaries of ground support elements and requirements for development openings.

**Table 7-5: Ground Support Elements**

| **Support Element** | **Description** | **Minimum Breaking (tensile) Strength** | **Comment** |
|---|---|---|---|
| Bolts | #6 (20mm) (3/4") threaded rebar bolt w/ full column resin | 13 tonnes | - |
| | #6 (20mm) (3/4") forged head rebar bolt w/ full column resin | 18 tonnes | Used for Alimak raise development. |
| | Super Swellex (36 mm) | 24 tonnes | Used for brow support and additional support at junctions or large spans. |
| | Standard Swellex (27 mm) | 12 tonnes | Used for development bolting. |
| | Split-sets (35 mm) | 6 tonnes | Used for face bolting or pinning screen. |
| Plates | Domed - 15 x 15 cm (6" x 6"), 6 mm (1/4") | - | - |

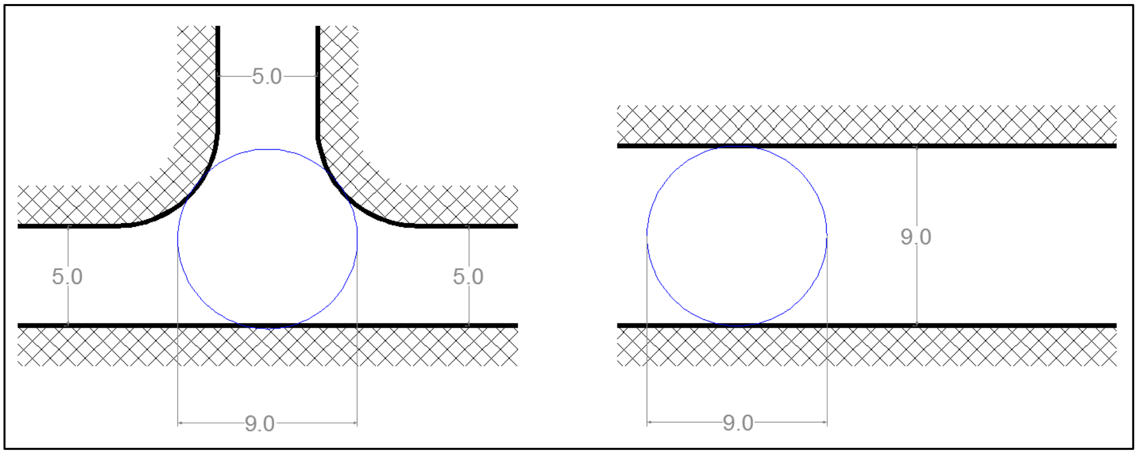
| | | | |
|---|---|---|---|
| Resin | 30mm x 610mm cartridges<br>30 second (fast)<br>180 second (slow) | - | - |
| Mesh | 6 gauge welded wire mesh<br>8 gauge welded wire mesh | ~ 2-3 tonnes bag strength | Galvanized or Bright depending on the use of the excavation. |
| Straps | 0 gauge welded wire mesh straps | - | Used for stope brow support and additional pillar support where required. |

**Table 7-6: Typical Ground Support for Development and Production Openings**

| **Type** | | **Span (m)** | **Primary Support (typical)** | **Comment** |
|---|---|---|---|---|
| **1** | **Development Drifts (typical ground conditions)** | 5.0 | 2.4 m resin rebar in back around perimeter of mesh sheets<br>1.8 m resin rebar in back and walls to pin mesh at center<br>1.8 m resin rebar in walls to 1.5 m above floor<br>1.5 m x 1.5 m bolt spacing in a diamond pattern<br>Welded wire mesh to 1.5 m above floor | Life of mine infrastructure in typical ground conditions.<br>Overlap mesh by three squares. |
| **2** | **Production Drifts (typical ground conditions)** | 6.0 | 2.4 m resin rebar in back around perimeter of mesh sheets<br>1.8 m resin rebar in back and walls to pin mesh at center<br>1.8 m resin rebar in walls to 1.5 m above floor<br>1.5 x 1.5 m bolt spacing in a diamond pattern<br>Welded wire mesh to 1.5 m above floor | Non-permanent development (e.g. stope undercut drifts) in typical ground conditions. Overlap mesh by three squares. |
| **3** | **Poor ground – fault zones** | ≤6.0 | 2.4 m resin rebar in back around perimeter of mesh sheets<br>3.6 m Super Swellex to pin mesh at center<br>1.8 m resin rebar in walls to 1.5 m above floor<br>1.5 x 1.5 m bolt spacing in a diamond pattern<br>Bright/Galvanized welded wire mesh to 1.5 m above floor | Poor ground, typical in fault zones.<br>Overlap mesh by three squares. |
| *Intersection Secondary Support* | | | | |
| **1,2,3** | **Intersections** | ≤9.5* | To be installed in addition to the primary support pattern outlined above:<br>3.6 m Super Swellex in back and shoulders<br>1.8 x 1.8 m bolt spacing - Installed at least one row past the intersection in each direction. | Intersection support to be installed prior to taking wall slash, as per MIN-OP-SWP-005 Underground Intersection Development and Ground Support |

Ground support design of a typical intersections with spans of up to 9.5m can be applied to the support design for a passing lane with a span of up to 9.5m. Span is defined as the diameter of largest circle which can be drawn between pillars and walls (after Pakalnis and Vongpaisal 1993). The centre of the circle represents the point farthest from a wall or pillar carrying load. As seen in the figure below, a circumference is used to identify the maximum effective span of an excavation. In the case of a typical intersection or a passing lane, the span is approximately 9m.

**Figure 7-4 : maximum effective span of an intersection or a passing lane**



## 7.6 Monitoring

Monitoring is described in detail in the Minto Underground Ground Control Plan. The following table summarizes the primary elements of the monitoring programs.

**Table 7-7: Summary of Ground Control Monitoring**

| Element | Description |
|---|---|
| Inspections | • Daily inspections of active production openings by geotechnical engineer, Minto supervision and/or contractor supervision<br>• Monthly inspections of fresh air raise/manway<br>• Quarterly inspections by the geotechnical engineer of all development and production openings<br>• Ground control log book maintained by underground shifters and checked by geotechnical engineer |
| Geotechnical mapping | Rock quality and structure mapping is carried out regularly by geotechnical engineers/geologists to identify major structures and changing conditions for use in geotechnical analysis and mine design. |
| Cavity monitoring surveys (CMS) | Carried out in open stopes, typically after each blast. |

## 7.7 Hydrogeological Assessment

A detailed hydrogeological assessment has not been completed to define the potential inflows in Copper Keel; however, with the development and production completed to date, Minto has extensive experience with the hydrogeological regime and operational requirements at the site. Inflows encountered to date in the Minto South Underground have been associated with discrete water-bearing faults and with un-grouted diamond drillholes. No unmanageable inflows have been intersected and a standard sump and pump dewatering system has been used without any curtain grouting required. The discharge rate from the mine averaged 300 $m^3$/day (55 gpm) in 2017-2018.

# 8 Ventilation

## 8.1 Ducting

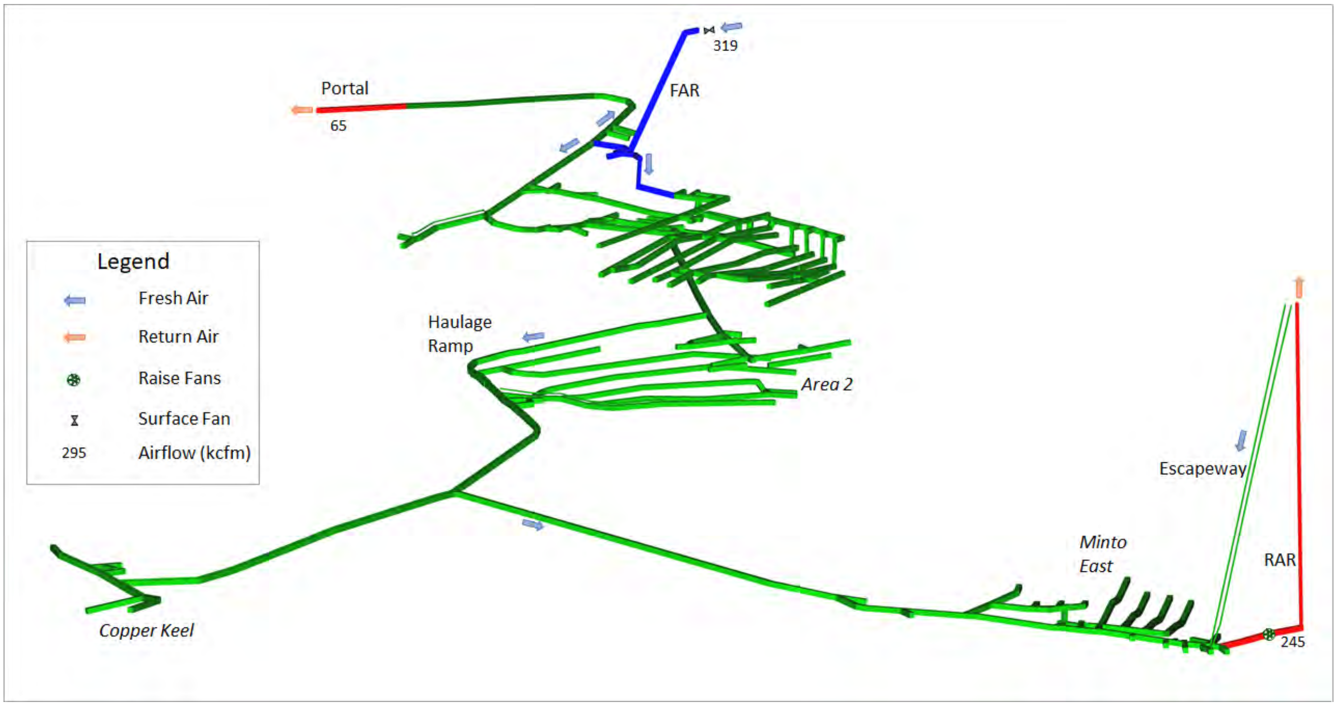
Copper Keel ramp is currently ventilated by two 48” ducts suspended in the ramp. One spiral-welded steel duct segments with in-line 150 hp 48” electric fan. This is hung on the north side of the Copper Keel ramp. The second duct, on the south side of the ramp, is a rigid plastic ducting.

The north duct ventilates the main ramp, remucks, and truck loadouts, while the south duct is put in place to provide air for the remaining development. The two ducts will provide air for development and production until the permanent vent raise is established in Copper Keel.

## 8.2 Vent Configuration, Phase 2 (Minto East vent raise commissioned)

Phase 2 of the ventilation plan commenced with the completion of the Minto East exhaust raise and is shown in Figure 8.1. Fresh air is supplied through 760 fresh air raise from the surface fan and heater assembly. The primary exhaust is now through the Minto East exhaust raise where airflow is managed through the installation of a ventilation wall with exhausting fans at the base of the raise. The overall airflow on the main ramp increased significantly; the primary fresh air fan delivers 319 kcfm. The three exhaust fans at the base of the Minto East ventilation raise will exhaust 245 kcfm with 65 kcfm exiting the portal (providing fresh air throughout the mine). Modeling of this approach has been validated by an external consultant. There is now sufficient airflow to meet the requirements of all equipment operating in both Minto East and Copper Keel. Please see the figure below:

**Figure 8-1: Minto Mine - Phase 2 Ventilation**



Both the north and south ducts ventilating Copper Keel are extended up-ramp. A 150hp fan will be installed on the south duct; as the duct lengthens or airflow requirements increase, a second fan will be added in series. With two fans in series, the plastic duct can deliver 75 kcfm to the end of the Copper Keel main access. The steel duct, can deliver approximately 66 kcfm.

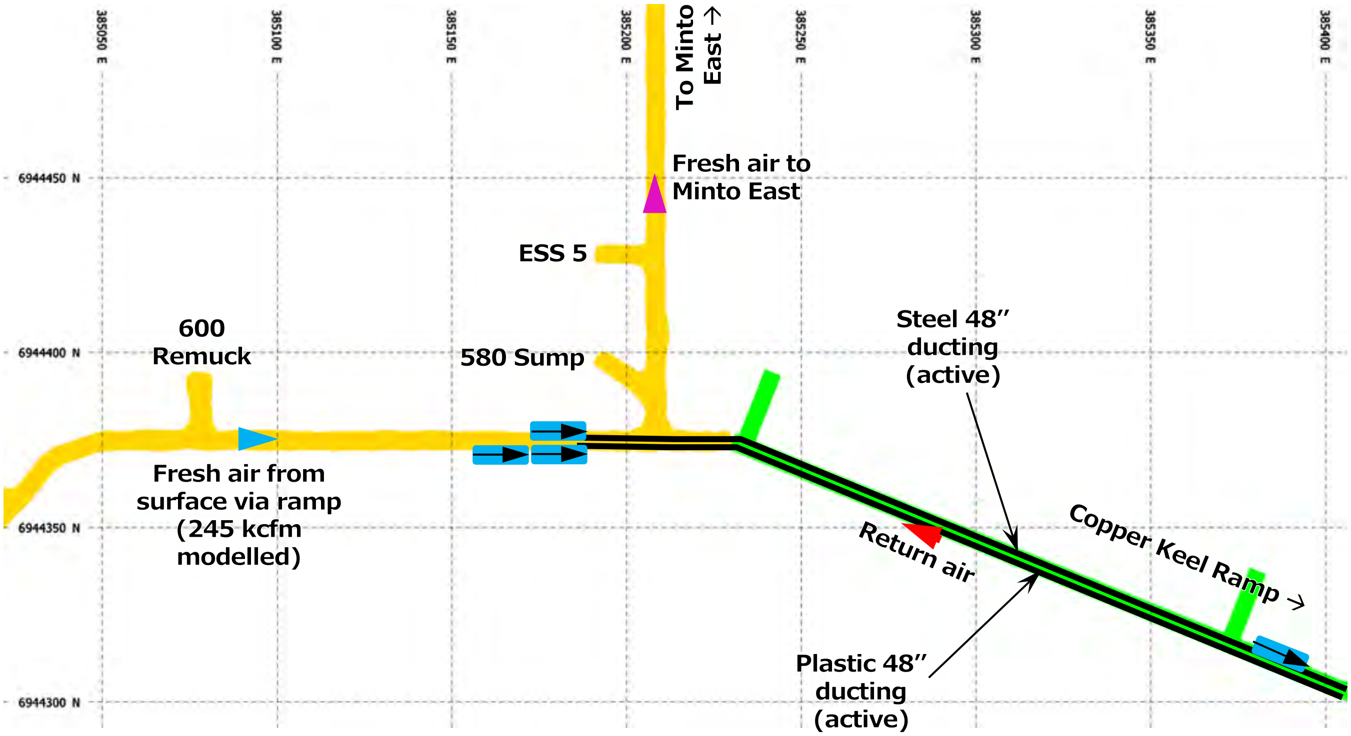


**Figure 8-2: Ventilation configuration for Copper Keel Ramp with Minto East raise commissioned (Phase 2).**

## 8.3 Ventilation Circuit, Phase 3 (after completion of Copper Keel raise)

Once the Copper Keel raise is completed, a new surface fan will be installed, along with air heaters and supporting infrastructure as this is fresh air supply. Minto East return air raise will continue to exhaust the majority of the total mine airflow.

The air volume required for the fleet currently in use is shown in the table below. Air volume requirements are calculated to ensure safe production. The amount of air required is largely determined by the number and size of diesel equipment operating underground. The air volume supplied must be able to dilute and remove dust and noxious gases as well as diesel particulate matter generated by the use of such equipment. The table below shows permitted airflow for each type of equipment underground in cfm.

**Table 8-1: Ventilation requirements for equipment operating in the Minto South Underground**

| Equipment type | Permitted airflow (cfm) |
|---|---|
| Cat 1700G LHD | 21,300 |
| Sandvik LH410 LHD | 17,000 |

| | |
|---|---|
| Cat AD45 Haul Truck | 35,500 |
| Epiroc MT42 Haul Truck | 36,700 |
| Sandvik Jumbo | 9,200 |
| MacLean Bolter | 9,200 |
| MineCat Utility Tractor | 9,900 |
| MineCat Mancarrier | 6,000 |
| Toyota Mancarrier | 7,300 |
| Getman A64 Emulsion Loader | 7,900 |

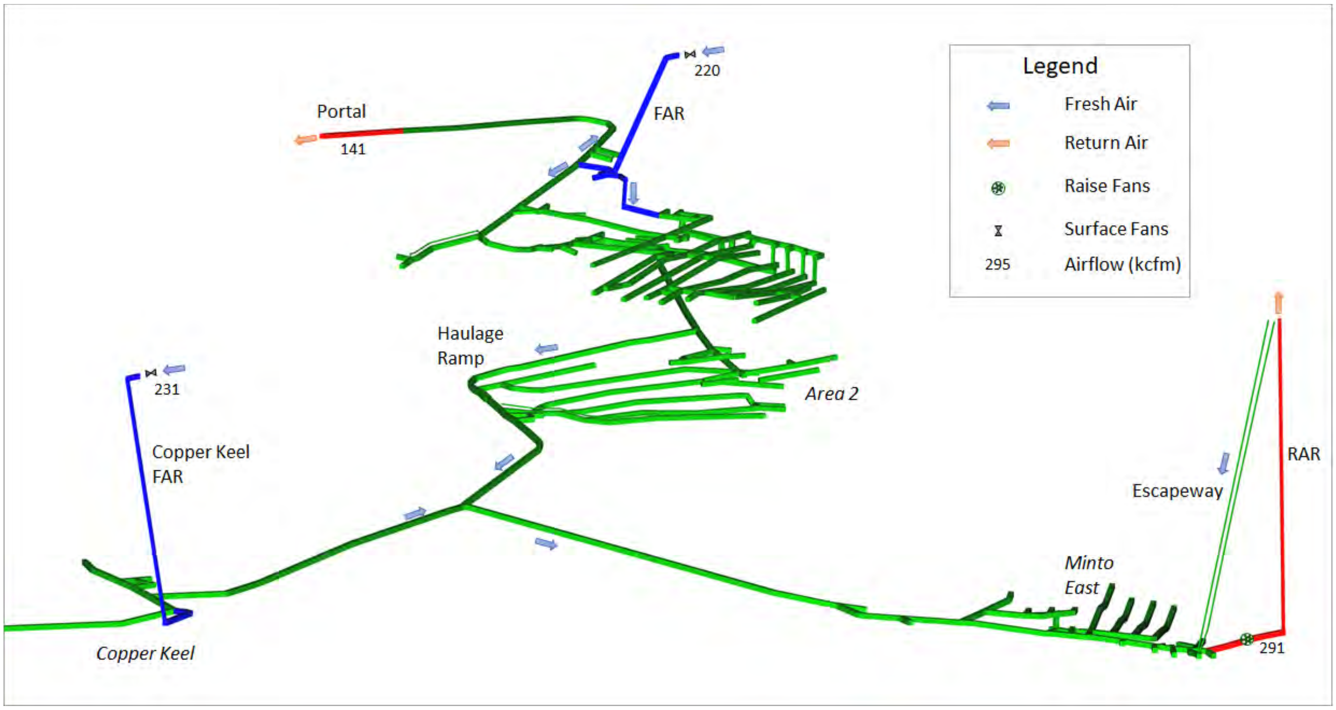
Note Table 8-2 outlines that total equipment available for Minto operations and Copper Keel along with the ventilation allocation requirements in accordance with The Regulations. Understanding that not all equipment operates at the same time, the use ventilation tag boards and continuous vigilance in the management of underground diesel equipment is emphasized.

**Table 8-2: Phase 3 equipment airflow allocation**

| Make / Model | Equip Type | Total Fleet Available for Minto Operation | CFM Required - Each Unit | CFM Required - Total Units | Diesel Units Required for Copper Keel | CFM Required – Copper Keel |
|---|---|---|---|---|---|---|
| Cat 1700G | LHD | 3 | 21,300 | 63,900 | 3 | 63,900 |
| Sadvik LH410 | LHD | 1 | 17,000 | 17,000 | 1 | 17,000 |
| Cat AD45 | Haul Truck | 3 | 35,500 | 106,500 | 2 | 71,000 |
| Epiroc MT42 | Haul Truck | 1 | 36,700 | 36,700 | 0 | 0 |
| Sandvik Jumbo | Jumbo | 2 | 9,200 | 18,400 | 0.25 | 2,300 |
| MacLean Bolter | Bolter | 2 | 9,200 | 18,400 | 0.25 | 2,300 |
| MineCat | Utility Tractor | 1 | 9,900 | 9,900 | 1 | 9,900 |
| MineCat | Mancarrier | 2 | 6,000 | 12,000 | 1 | 6,000 |
| Toyota | Mancarrier | 1 | 7,300 | 7,300 | 0 | 0 |
| Getman A64 | Emulsion Loader | 1 | 7,900 | 7,900 | 1 | 7,900 |
| Marcotte M40 | Transmixer | 1 | 23,800 | 23,800 | 0 | 0 |

A Ventsim ventilation model was developed to ensure these volumetric ventilation requirements were met and to confirm that the overall Minto Mine ventilation strategy was robust and ensured safe working conditions underground. The figure below presents the primary airflows and overall mine ventilation strategy. The Copper Keel fresh air raise is planned to be developed through means of Alimak at a size of 3 x 3 metres and will contain a ladderway as a second means of egress from the Copper Keel mine area. Taking into account the extra resistance incurred due to its dimensions and a ladderway in this raise, the same surface fan/heater arrangement as used at the original fresh air raise will deliver a maximum 231 kcfm. The addition of the Copper Keel fresh air fan arrangement is complementary to the existing fresh air supply. Modelling indicates that the three exhaust fans at the base of the RAR will deliver 291 kcfm to the Minto East exhaust raise with 141 kcfm exiting the portal.

**Figure 8-3: Minto Mine - Phase 3 Ventilation**



It is worth noting that the amount of air available underground dictates what is achievable in terms of development and production (and the utilization of underground equipment). i.e. when each phase of ventilation is complete, then Minto will pursue changes/increase in production. The ventilation phases and plans are developed based on the maximum amount of air required for operating equipment. The equipment will not be utilized UG if there is no adequate air available. This will be confirmed by utilizing a ventilation tag board, weekly ventilation surveys, and regular Work Place Inspections (WPIs) by supervisors and superintendents. We will provide a report from a third party to confirm the ventilation modeling.

# 9 Ancillary Infrastructure

## 9.1 Compressed Air

The Copper Keel Ramp will be supplied with compressed air by extending the existing reticulated 4” air line network.

Minto currently has three Atlas Copco GA-315 (1811 cfm at 125 psi, 350hp) air compressors. One compressor operates steadily, a second automatically supplements the first during periods of high demand, and a third is kept on standby to provide redundancy. These compressors are located in the tailings filtration building adjacent to the mill. Air is piped underground via a borehole from surface to the underground workings in Minto East. An air dryer is installed on surface in the line supplying the underground operation.

Mobile electric equipment such as jumbos and bolters are equipped with their own compressors. The central compressors are needed only for longhole drilling, jackleg / stoper drilling, pneumatic dewatering pumps in development headings, and other minor uses.

## 9.2 Underground Electrical Power

Power enters the Minto South Underground at 4160V via the portal and is distributed with Teck cable, typically 350 MCM three-conductor. It is converted to the 600V working voltage of mobile equipment, pumps, and fans by one of four air-cooled skid-mounted substation units. Minto currently has two 750 kVA units and two 1000 kVA units.

During ramp development, the Copper Keel zone will be supplied with 600V power from an electrical bay located 50m down-ramp of the Minto East / Copper Keel intersection. A 1000 kVA substation is installed at this location, along with starter panels for fans, pumps, and mobile equipment. This infrastructure will be left in place to power fans until the Copper Keel vent raise is established.

## 9.3 Water Supply

The Copper Keel Ramp will be supplied with water for drilling and dust suppression by extending the existing reticulated 4” water line network.

## 9.4 Dewatering

Water will generally drain from each stope sill onto the main access. It will flow along the main access roadway to a sump created at its lowest point, from which it will be piped to the pumping station installed in Minto East.

The pumping station consists of a three-stage settling sump system and redundant high-pressure 125 hp pumps, which transfer water directly to surface via a pipeline installed in a borehole. From the surface breakthrough location, a short section of insulated and heat-traced pipe transfers water to the adjacent Main Pit Tailings Management Facility (MPTMF), which receives the underground water stream.

## 9.5 Communications

The mine-wide VHF leaky feeder radio system will be extended to Copper Keel. This provides three channels: one for ramp traffic, one spare, and one emergency channel. The latter is repeated on surface, providing a unified site-wide emergency channel.

Refuge stations are equipped with radios, telephones connected to the mine’s internal communications network via a fiber optic network, and an analog emergency communication system (Femco phone).

Femco phones are installed inside and outside the refuge stations, the base of the fresh air raise at 760 level, the surface muster station adjacent to the portal, and the underground shop on surface.

## 9.6 Blasting Procedure and Infrastructure

The mine's electric central blasting system will be extended into Copper Keel. This typically fires a single electric blasting cap, which is used to initiate the network of non-electric caps that time and fire each hole in a development blast.

Stope blasts are timed and initiated by electronic detonators; namely, Dyno Nobel Digishot Plus. These are programmed and initiated via the same blast line network.

The mine is completely cleared of personnel for both production and development blasting. Every person entering the mine places a lock on a tag board. The key for the blast box is locked behind the board and can only be accessed when all personnel have removed their locks.

## 9.7 Explosive Storage and Handling

Emulsion is used for both longhole production and development. A bulk emulsion product known as Dyno Titan 7000, formulated for underground use and having high viscosity, is used to load blasts. This product is delivered via one of two dedicated mobile loading units – one for development rounds and a larger unit for longhole stope blasts.

In development, a perimeter blasting product (Dynosplit D) is used where required to reduce overbreak in the back, and Dyno AP (a cartridge emulsion) is used in wet lifter holes.

The following table lists the magazines on site:

**Table 9-1: Explosives magazines**

| License No. | Location | Capacity |
|---|---|---|
| YT-571 | Surface | 40,000 dets |
| YT-572 | Surface | 35,000 kg |
| YT-573 | Surface | 30,000 kg |
| YT-569 | Underground | 4,000 dets |
| YT-569 | Underground | 30,000 kg |

The Minto South Underground has two magazines, one for detonators and one for bulk and packaged explosives. Both are equipped with concrete floors and lockable gates. The powder magazine is large enough to store and handle 1.5 tonne totes of emulsion used by the development loader. The larger longhole loading unit is parked on surface at Dyno Nobel's office / shop / silo complex.

# 10 Mine safety

## 10.1 General Mine Safety

Minto Mine and its contractors emphasize safety in all duties at the mine; this philosophy is shared by senior management and supervisors. Minto's safety program includes the following:

- *Zero Harm Safety System* and associated safety card, used and checked daily by supervisors.
- A central system for tracking incident reports and the corrective actions arising from them.
- Safe work procedures (SWPs) for routine tasks that present a risk of injury.
- Job hazard assessments (JHAs) for non-routine tasks; these are used as the basis for SWPs if a job becomes routine.
- Routine job observations and workplace inspections by supervision and technical personnel.

## 10.2 Emergency Response

Two portable refuge stations are currently maintained in underground workings. They are positioned to provide refuge for the Area 2 and Minto East zones. Once development of the Copper Keel main access is complete, a refuge station will be installed in this area.

Refuge stations are equipped with compressed oxygen cylinders, $CO_2$ scrubbers, potable water, first aid equipment, emergency lighting, emergency food rations, and chemical toilets. With Minto's air compressors moved to surface, they have also been connected to the compressed air system; this provides a second source of breathable air.

Refuge stations are equipped with a digital telephone line, a backup analog telephone (Femco), and mobile radios that can communicate with the mine's leaky feeder system. Each refuge station is equipped to supply oxygen to 16 people for 96 hours, independent of the compressed air now also available.

The mine currently has three escapeways:

1. The fresh air raise from surface to 760 level is equipped with ladders.
2. A sub-level escapeway with ladders connects the Area 2 ramp at the 685m elevation to the 710 level, which receives fresh air directly from surface via open stopes that connect to the 760 level.
3. An escapeway from the lowest point in the mine at Minto East directly to surface 300m above.

All underground personnel are required to carry Ocenco M-20 self-contained self-rescuer (SCSR) devices, which provide oxygen from a compressed gas cylinder for 15 to 20 minutes (up to 32 minutes if the user is resting). In addition to the personal devices, 22 devices with longer performance durations of 60 minutes are available split in two caches located near active mining faces. These caches also contain first aid supplies, an oxygen therapy unit, water, food, flashlights, and blankets.

A mine-wide stench gas warning system is installed at the surface fan to alert underground workers in the event of an emergency. This system can be triggered from the mill control room.

Minto has an emergency response team trained in underground mine rescue techniques. Details are contained in Minto's Emergency Response Plan.

## 10.3 Fire Suppression

Fire extinguishers are provided and maintained in accordance with regulations and best practices at electrical installations, pump stations, wash bays, and refuge stations. Every vehicle carries at least one fire extinguisher of adequate size and proper type. Heavy equipment is equipped with central fire suppression systems.

For the use of the mine's emergency response team, a trailer containing a foam sprayer, hoses, an inflatable bulkhead, and other firefighting supplies is parked near the 760 fresh air raise.

## 10.4 Hours of Work

Minto holds an underground hours-of-work variance issued on April 24, 2018, permitting the following:

- A maximum of 11 hours of work underground for any worker during any 24 hours period if working in enclosed cabs with a HEPA-filtration system.
- A maximum of 10 hours of work underground for all other workers during any 24 hour period.
- A shift schedule of up to 12 hours/day, 7 days/week for up to 4 weeks on and 2 weeks off.

## 10.5 Industrial Hygiene and Fatigue Management Programs

An industrial hygiene (IH) consultant, EHS Partnerships Ltd., was engaged to assist Minto in the development of an underground IH plan and a fatigue risk management programs (acceptable to YWCHSB) for, but not limited to, air quality, noise and fatigue. Regular testing has taken place since underground operations commenced, and results of this program were included in the recent application for an hours of work variance.

## 10.6 First Line Supervisory Training

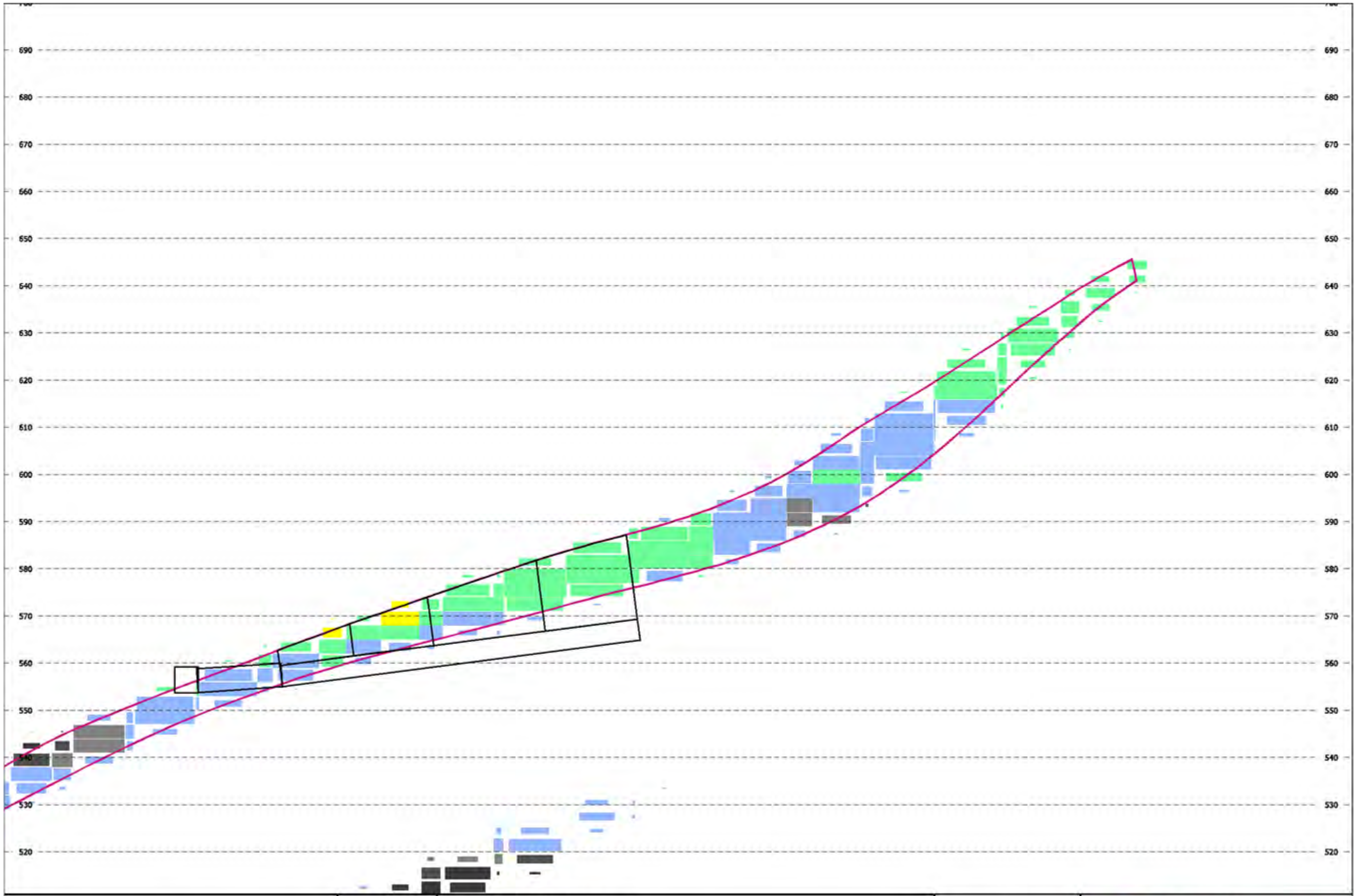
The Contractor will comply with the Yukon Occupational Health and Safety (OH&S) regulation by maintaining First Line Supervisor's Certificates for all supervisors.

## 10.7 Diesel Equipment

All diesel equipment used in the underground operation is permitted and maintained to comply with sections 15.58, 15.59, 15.61 and all related sections of the Yukon Occupational Health and Safety Regulation.

## 10.8 Shotcrete

Shotcrete is not routinely used at Minto; to date, it has seen use as ground support in one section of ramp measuring approximately 10m in length. When required, it is sprayed wet using a unit mounted to a MineCat MC100F utility vehicle. A Marcotte M40 trans-mixer unit is used to mix shotcrete and transport it to the working face.



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

Copper Keel Sections: 01 Stope

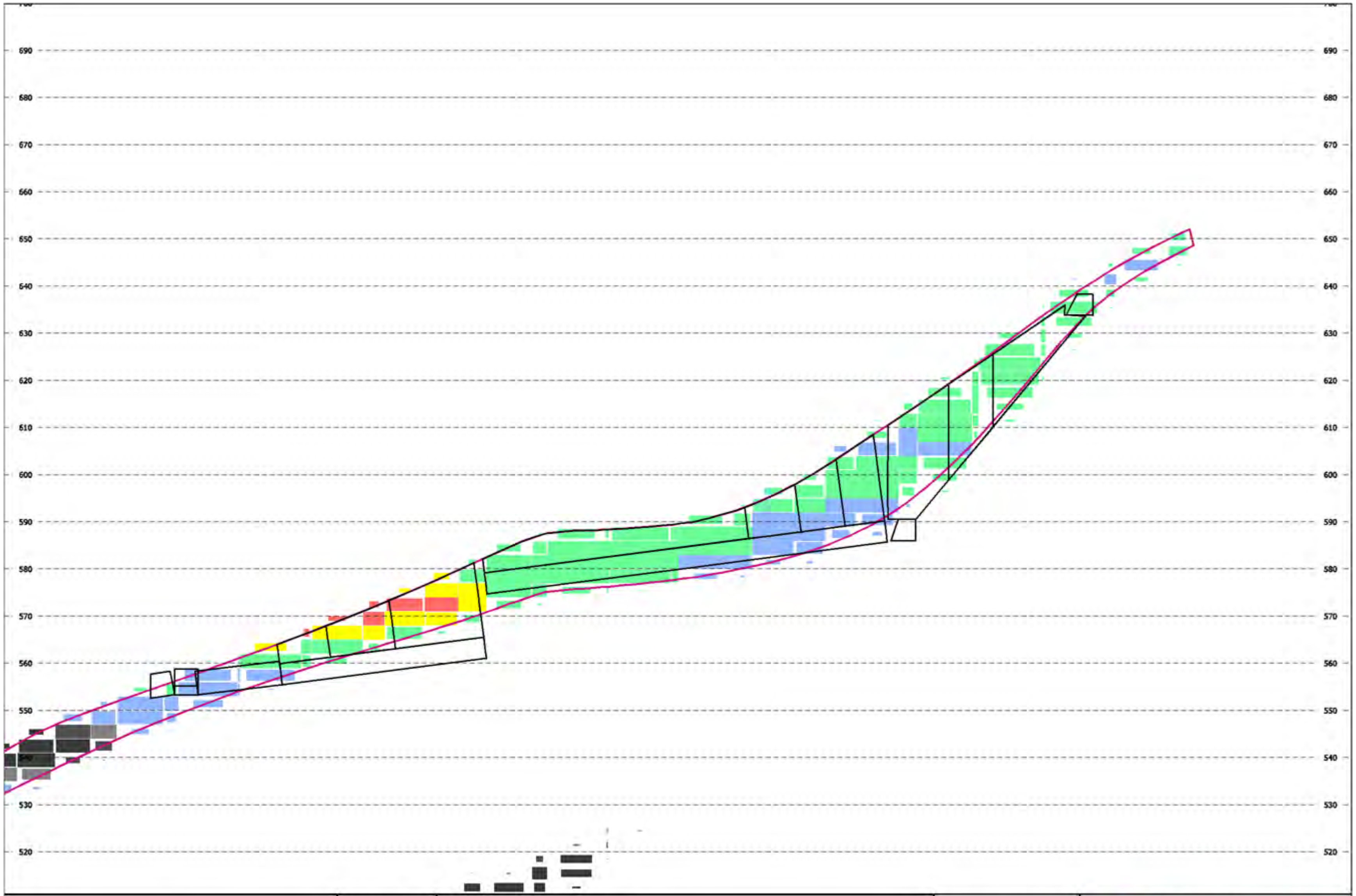
DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION:

Minto South Underground

Copper Keel Sections: 02 Stope

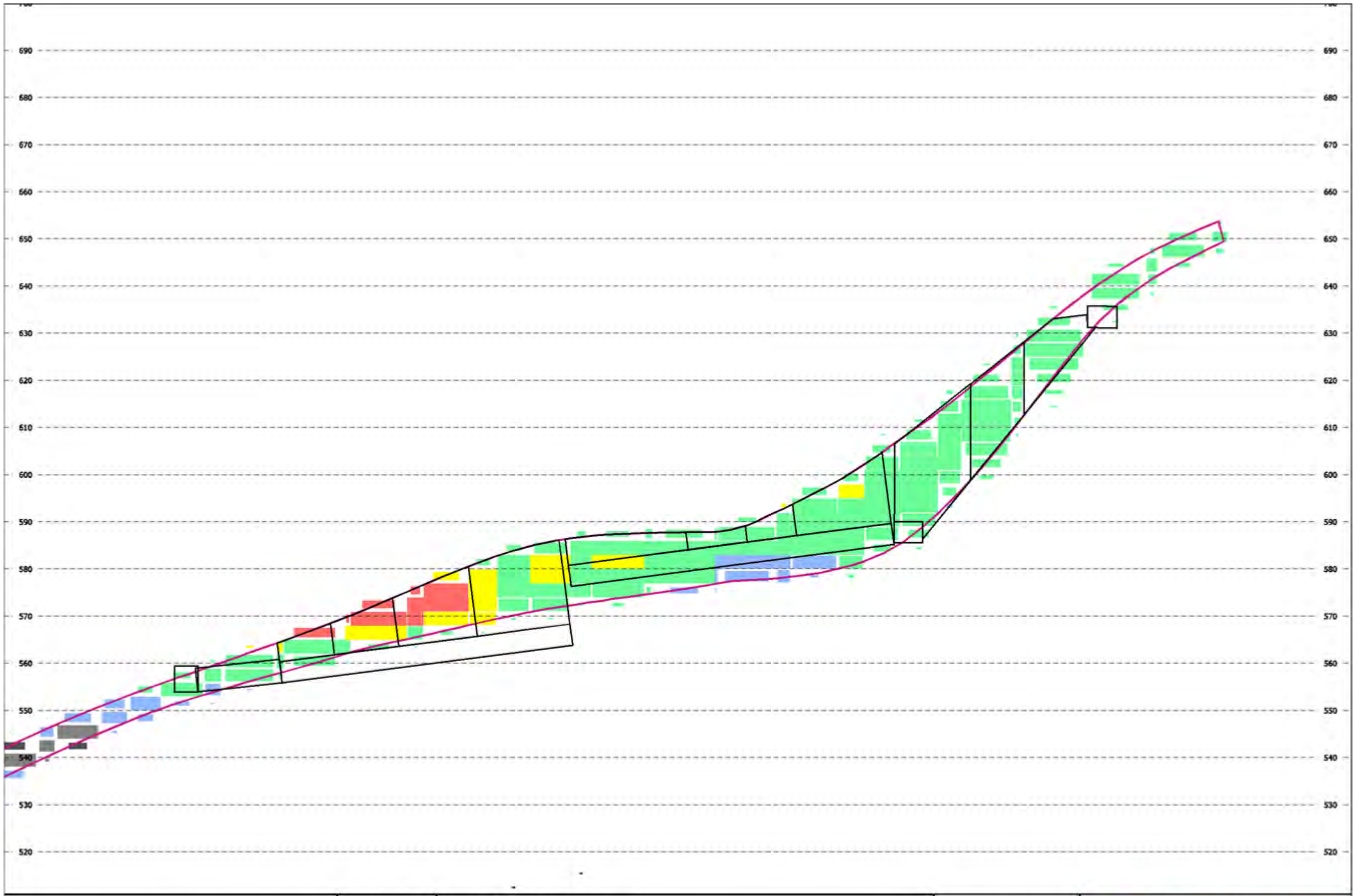
DATE PLOTTED:

2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

DESCRIPTION: Minto South Underground

Copper Keel Sections: 03 Stope

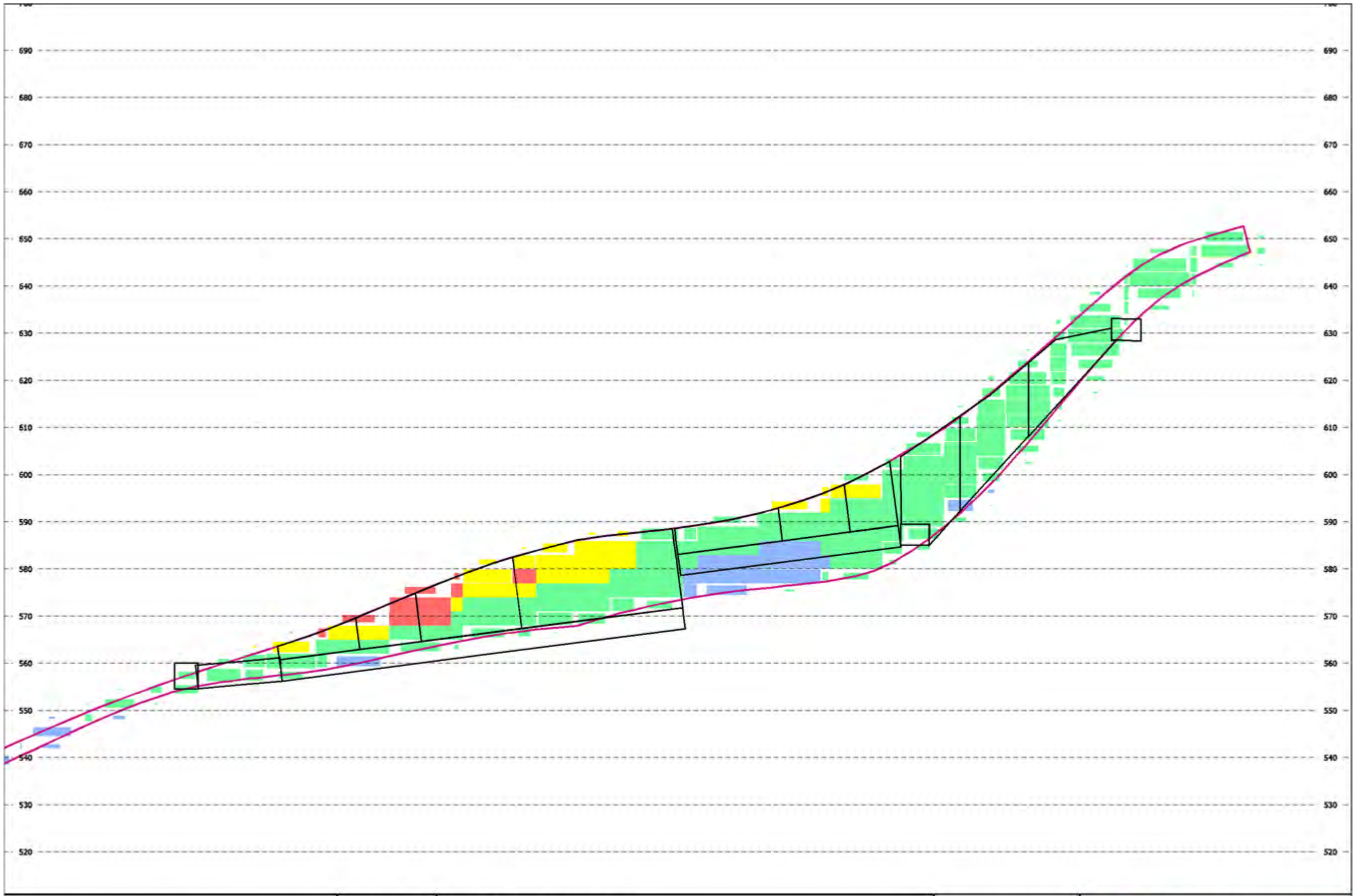
DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

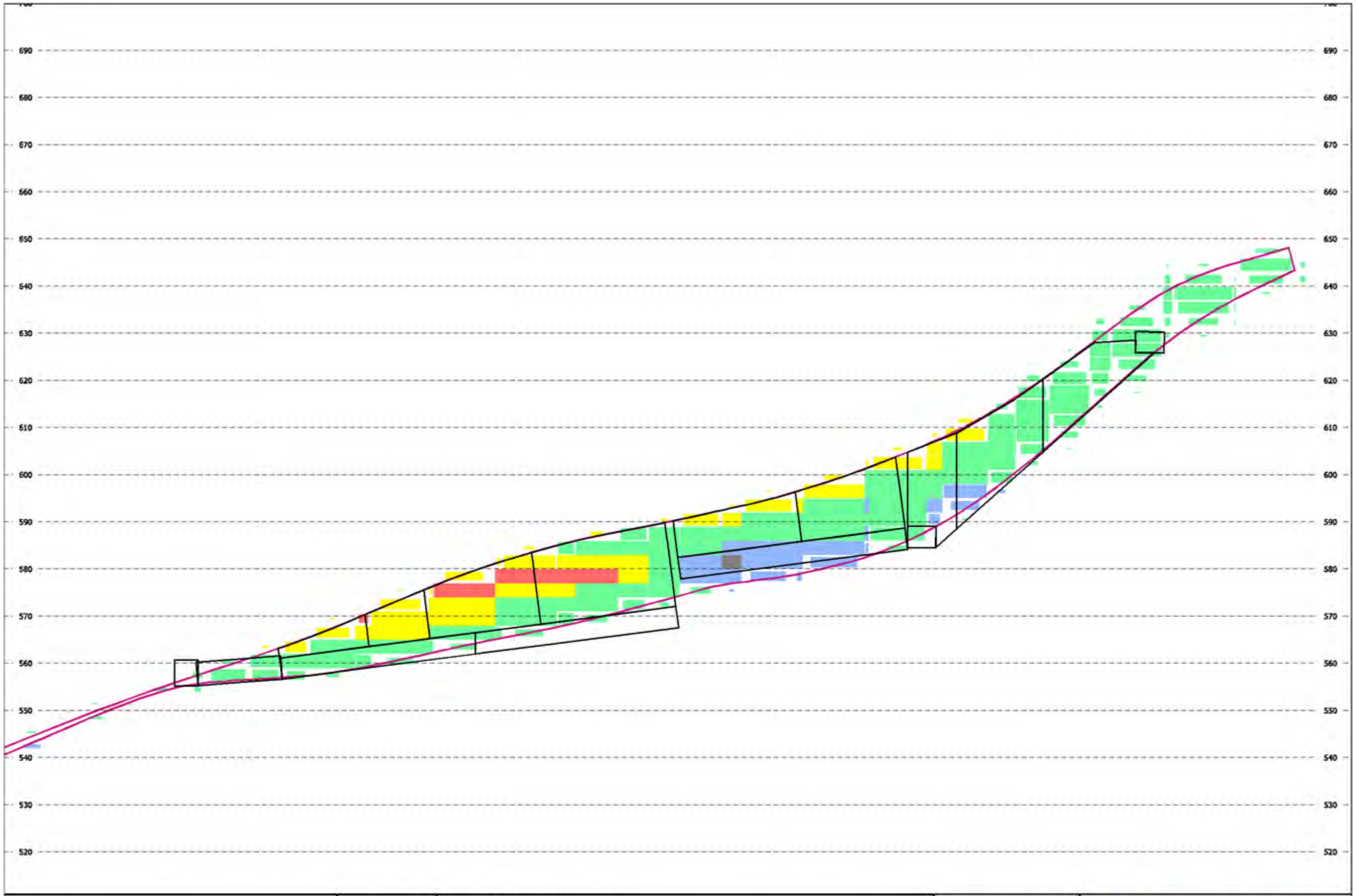
Copper Keel Sections: 04 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

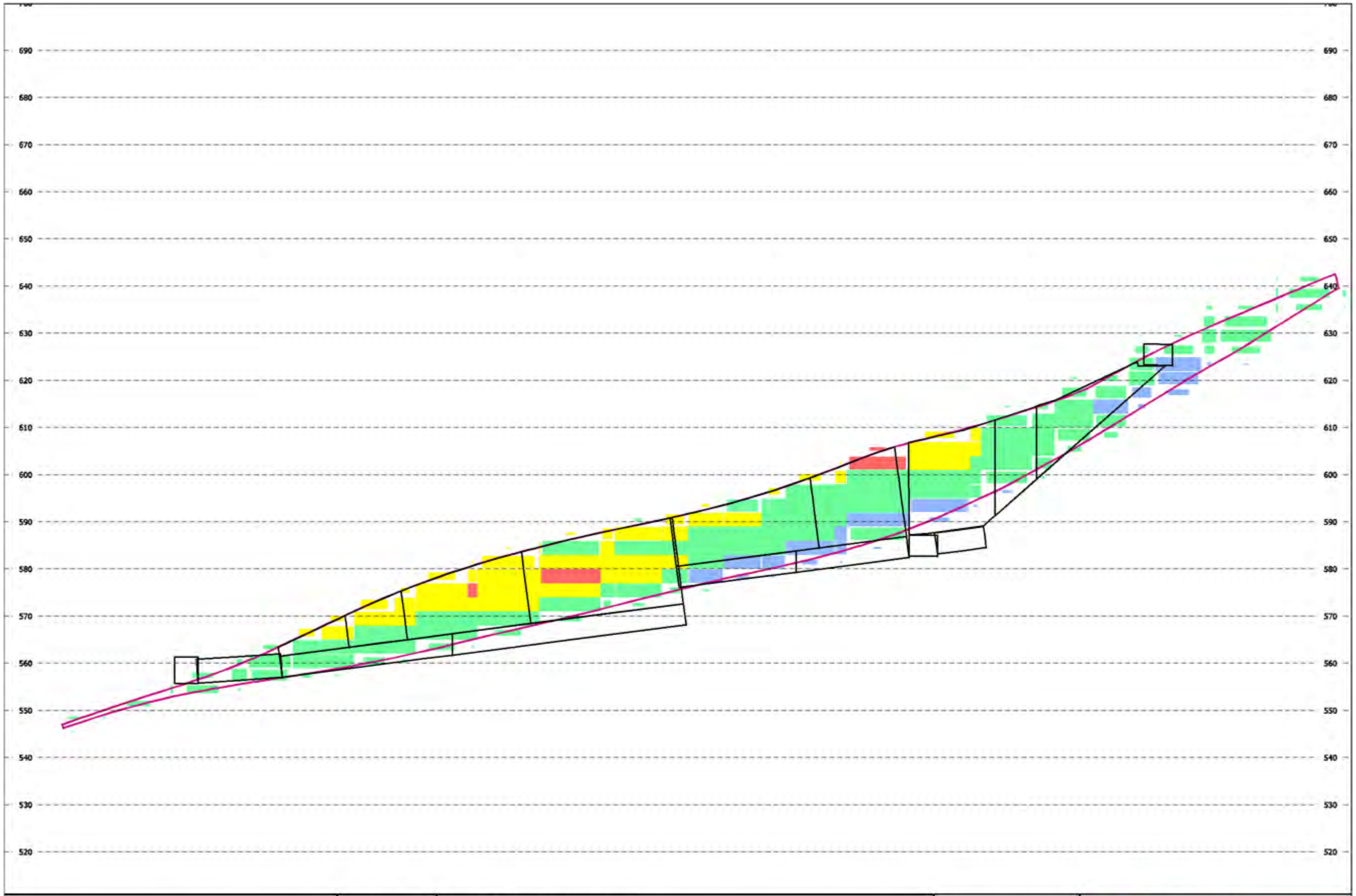
DESCRIPTION: Minto South Underground

Copper Keel Sections: 05 Stope

DATE PLOTTED: 2018/10/08

Z
N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

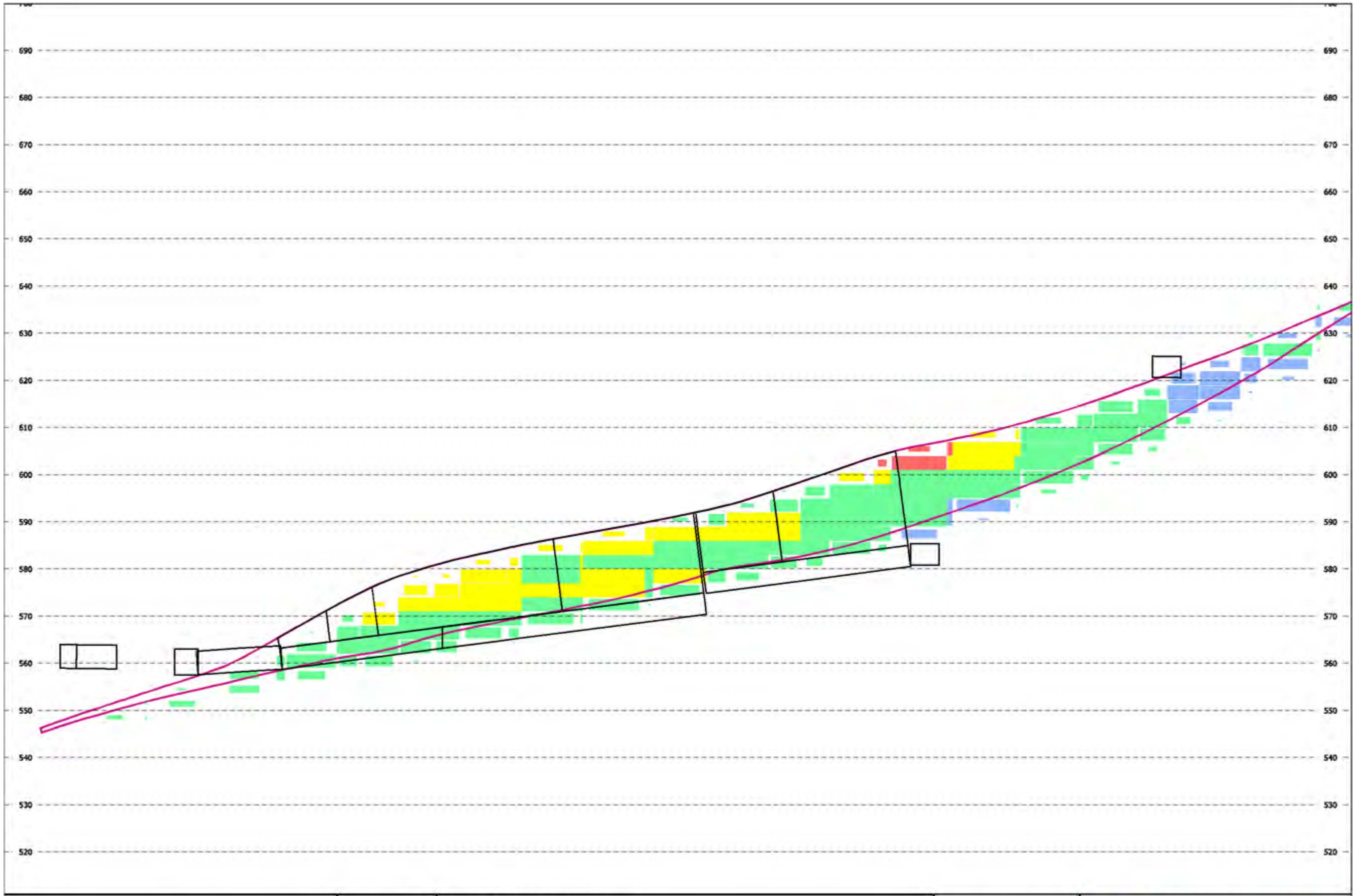
Copper Keel Sections: 06 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

Copper Keel Sections: 07 Stope

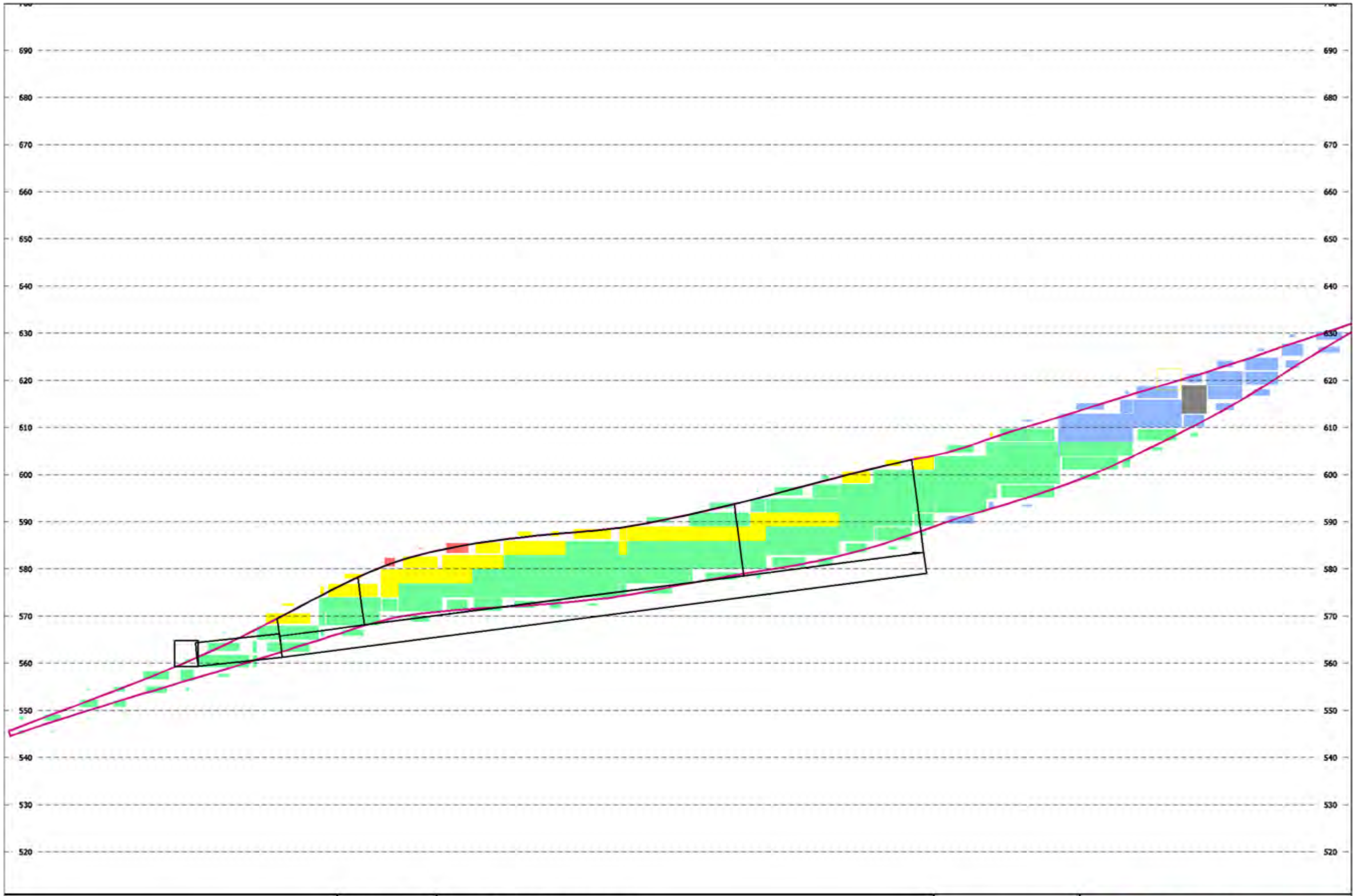
DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

Copper Keel Sections: 08 Stope

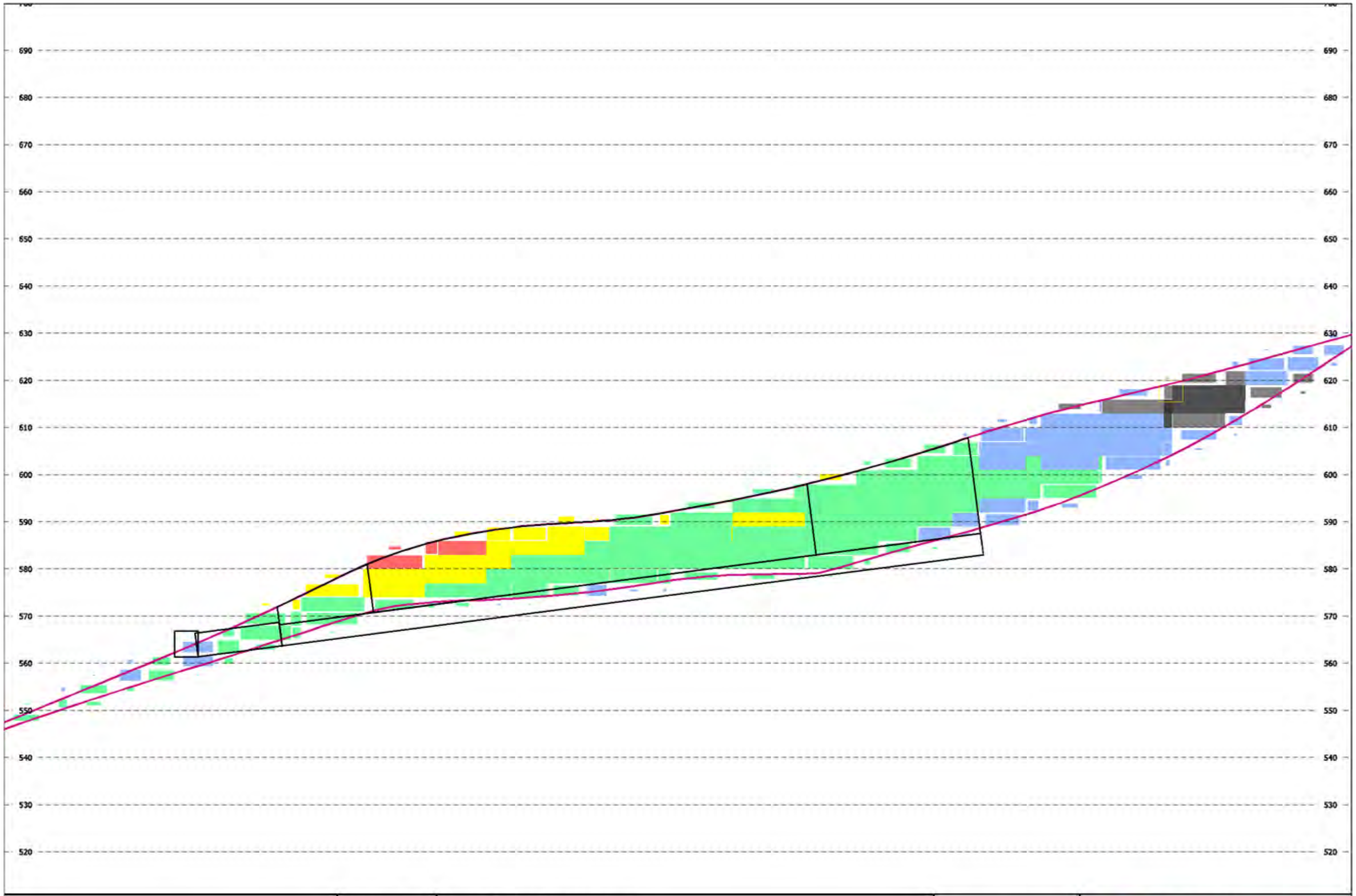
DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

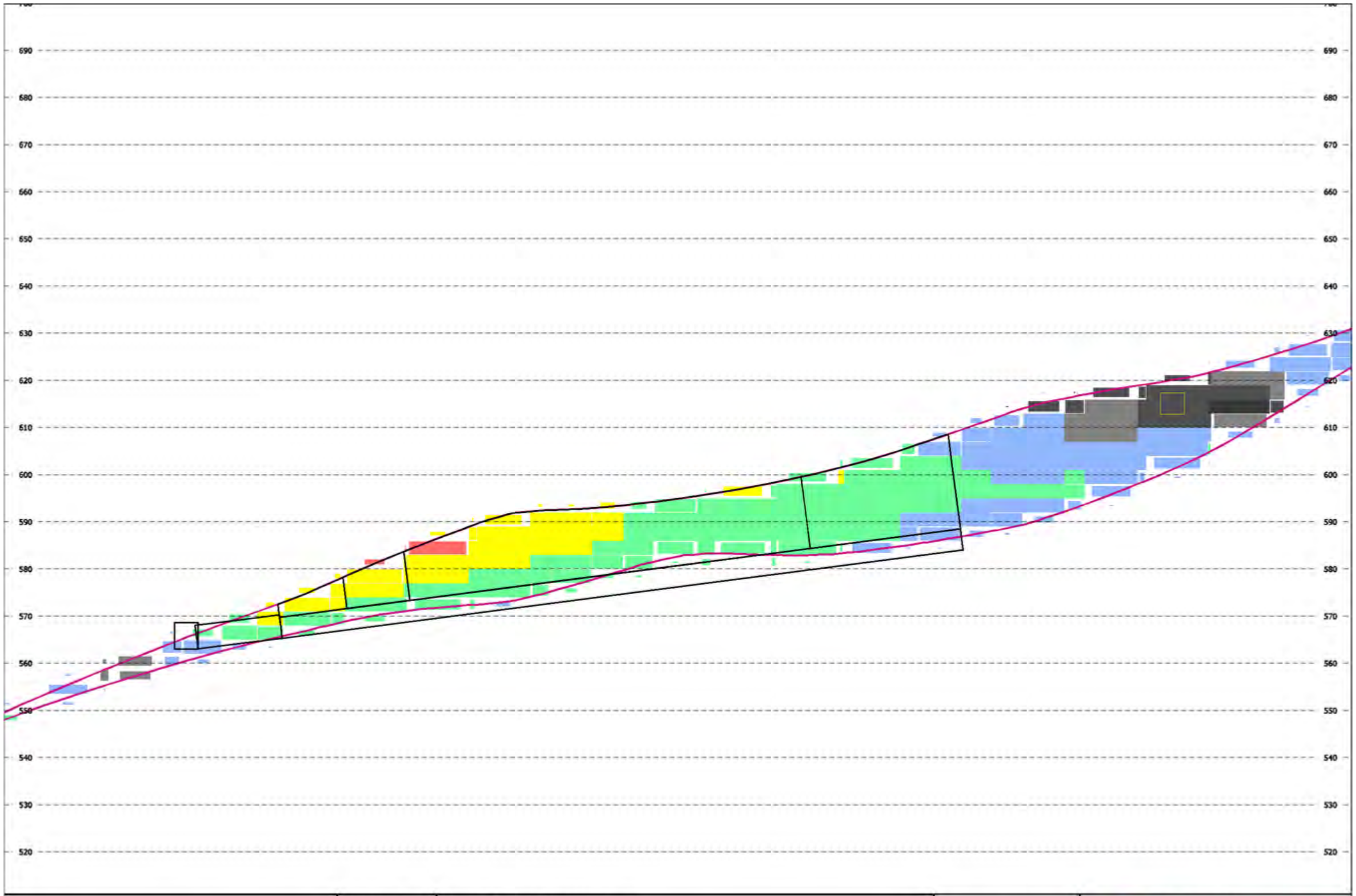
Copper Keel Sections: 09 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

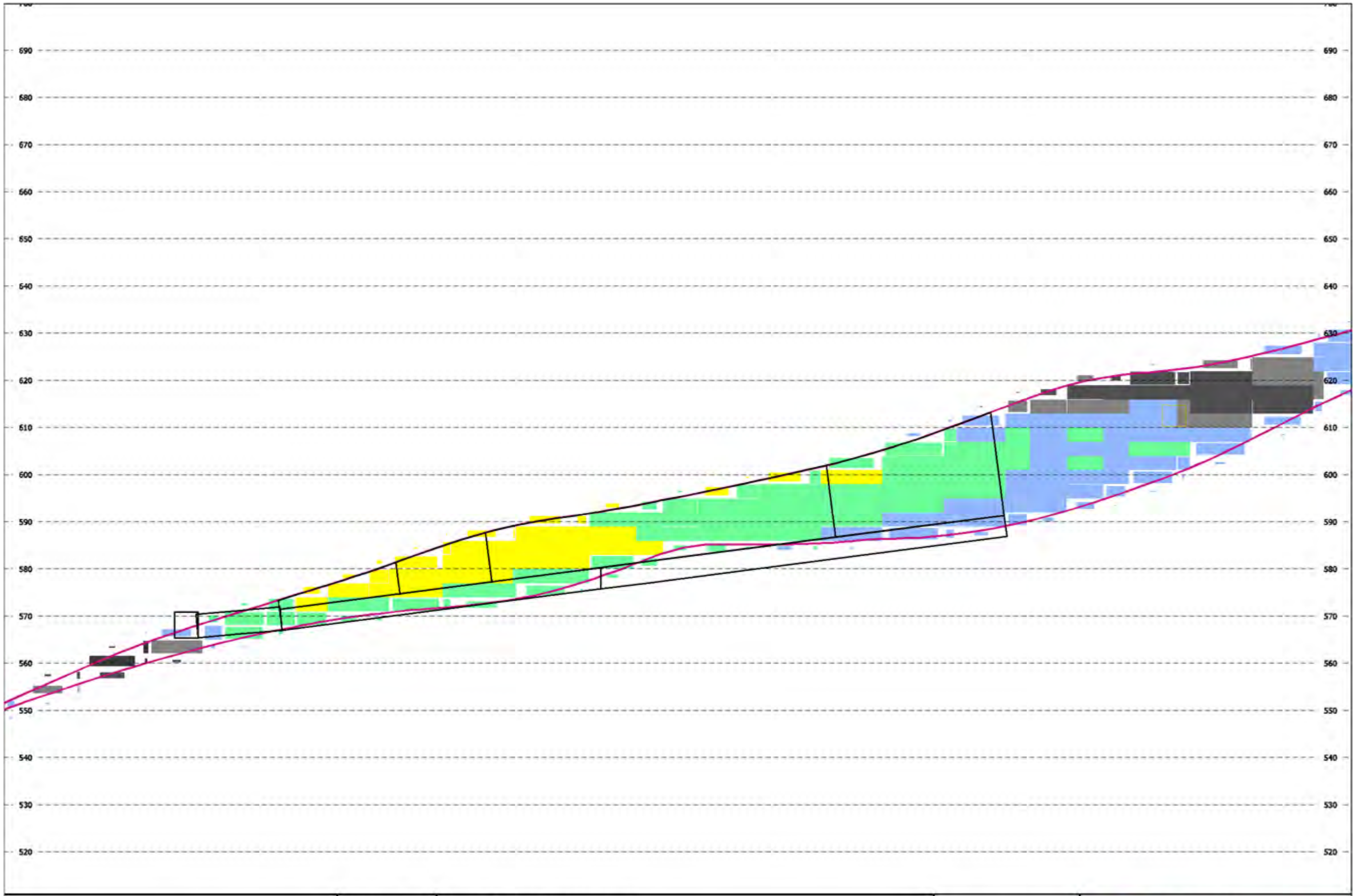
Copper Keel Sections: 10 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

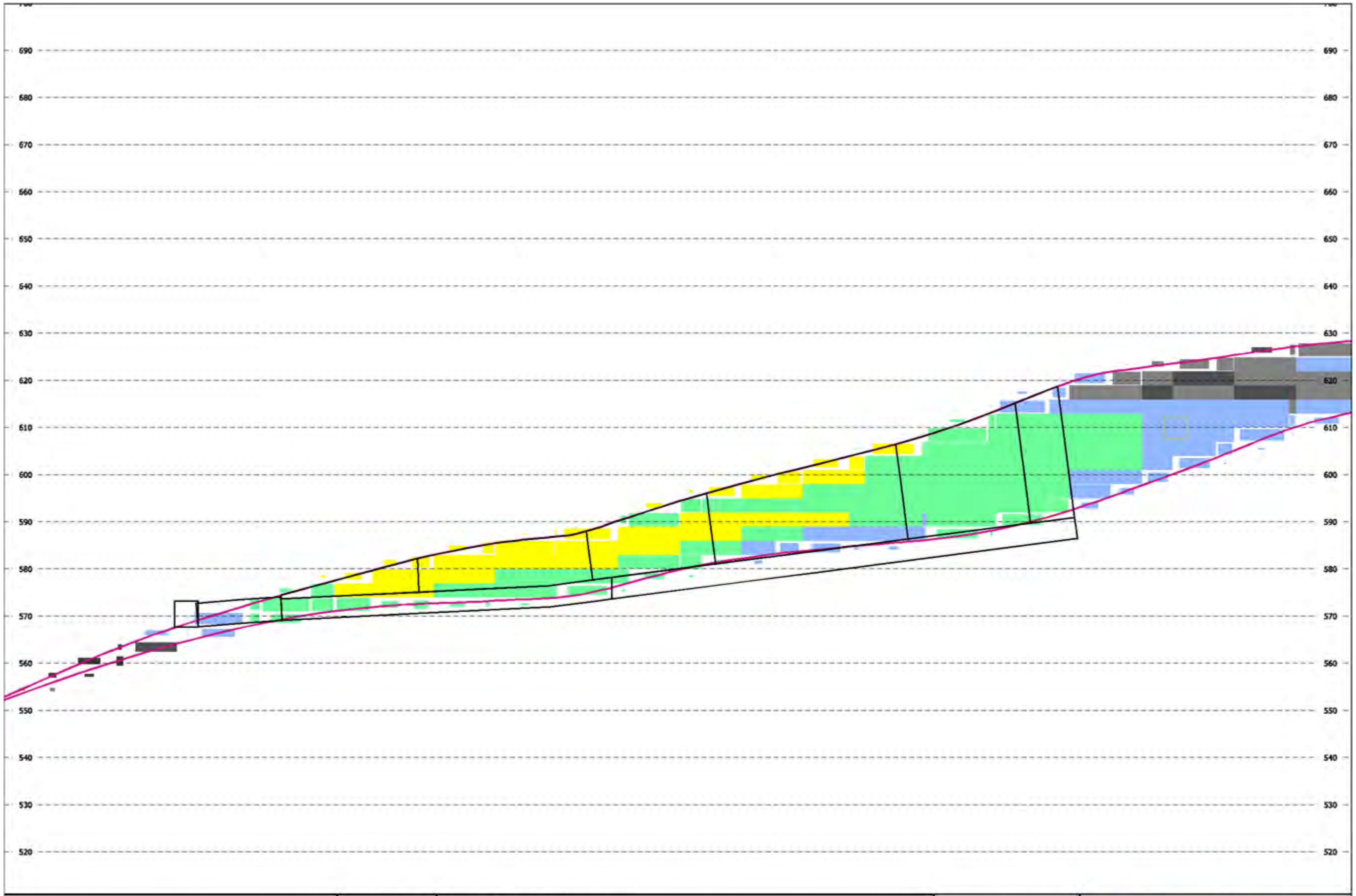
Copper Keel Sections: 11 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

Copper Keel Sections: 12 Stope

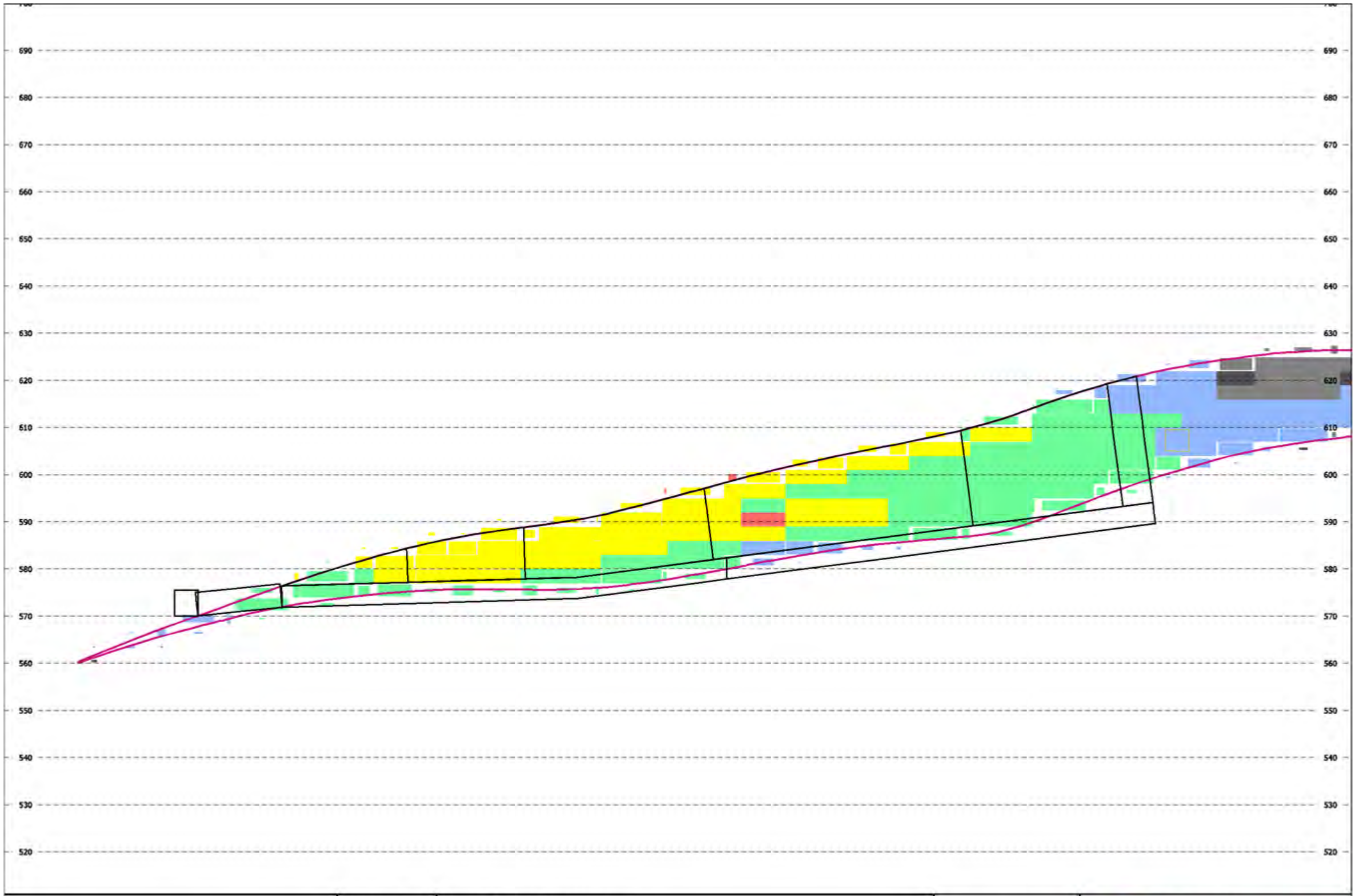
DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



**1 : 1250**

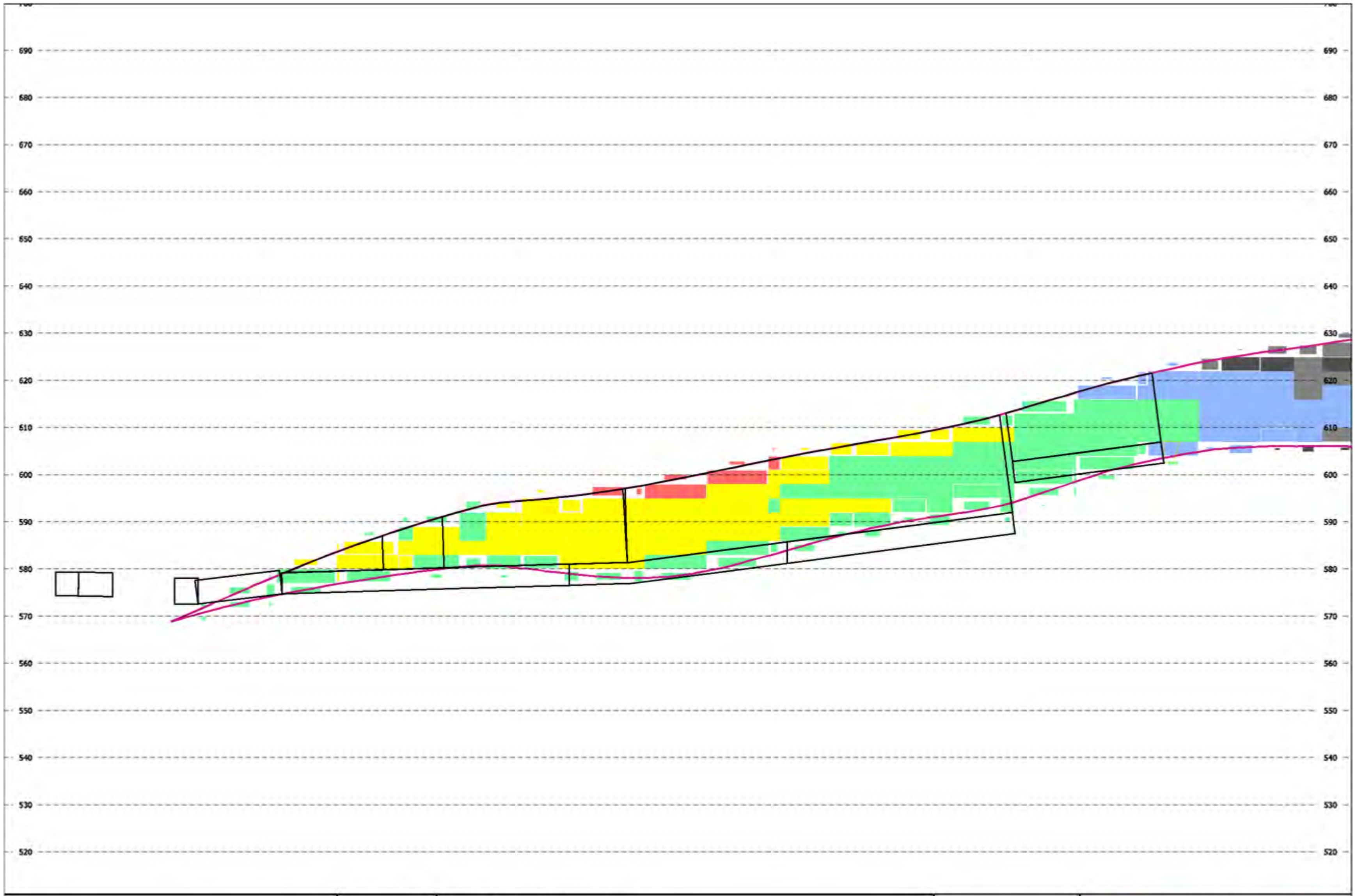
0 20 40 60

| | |
|---|---|
| DESCRIPTION: | Minto South Underground |
| | Copper Keel Sections: 13 Stope |
| DATE PLOTTED: | 2018/10/08 |

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

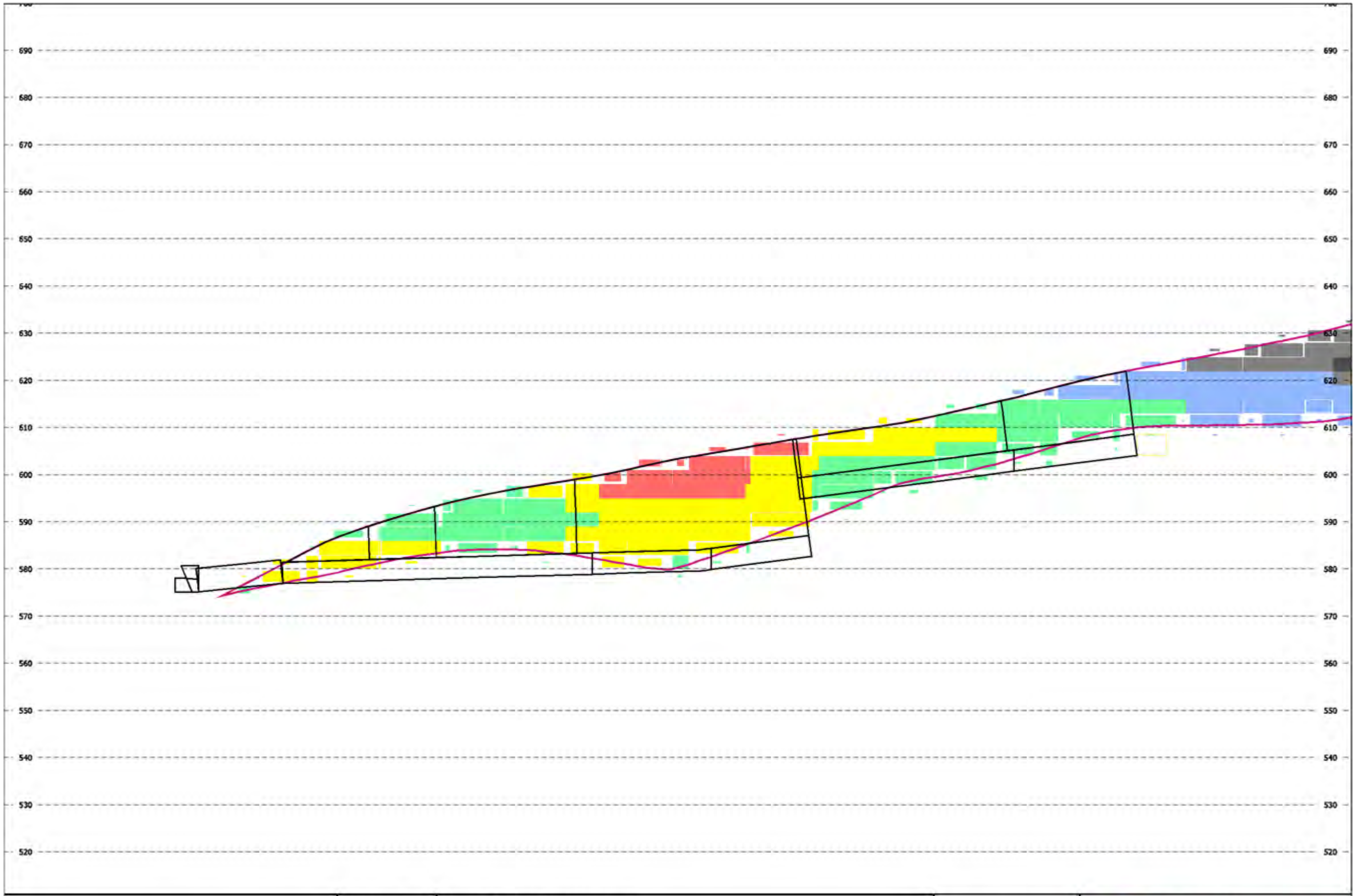
DESCRIPTION: Minto South Underground

Copper Keel Sections: 14 Stope

DATE PLOTTED: 2018/10/08

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

Copper Keel Sections: 15 Stope

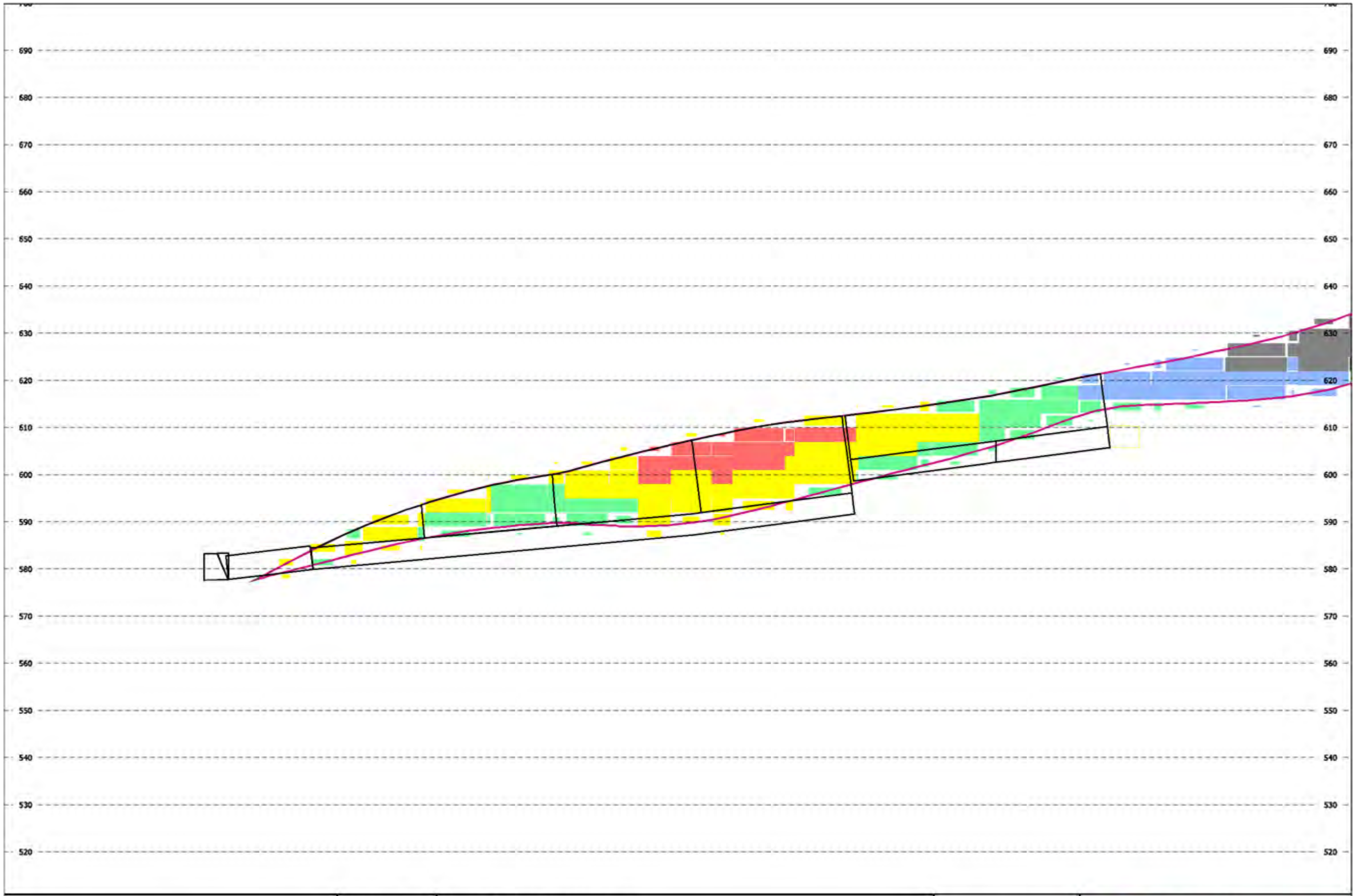
DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS

A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

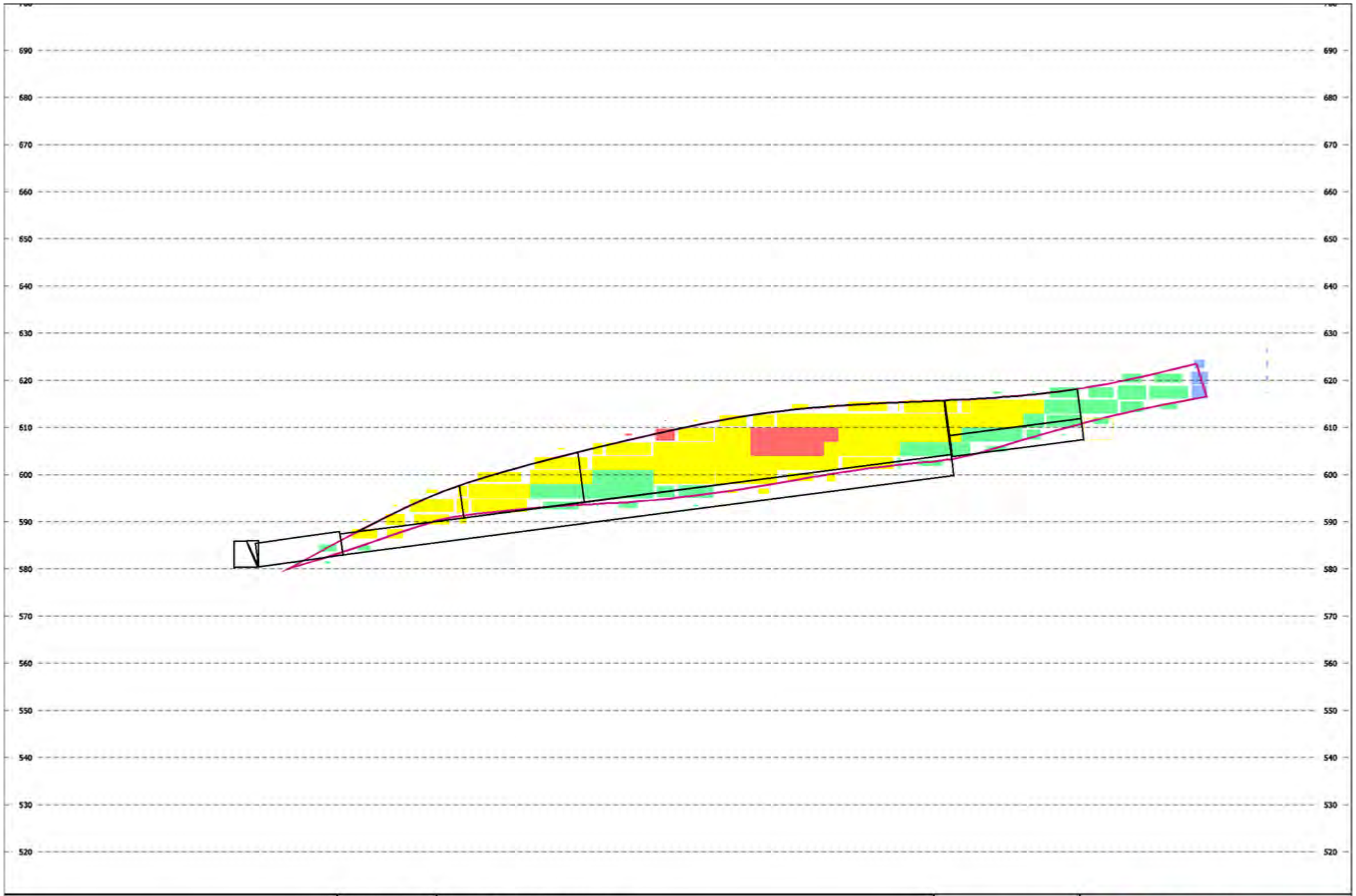
Copper Keel Sections: 16 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

| | |
|---|---|
| DESCRIPTION: | Minto South Underground |
| | Copper Keel Sections: 17 Stope |
| DATE PLOTTED: | 2018/10/08 |

MINTO EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY

1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

Copper Keel Sections: 18 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY

1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

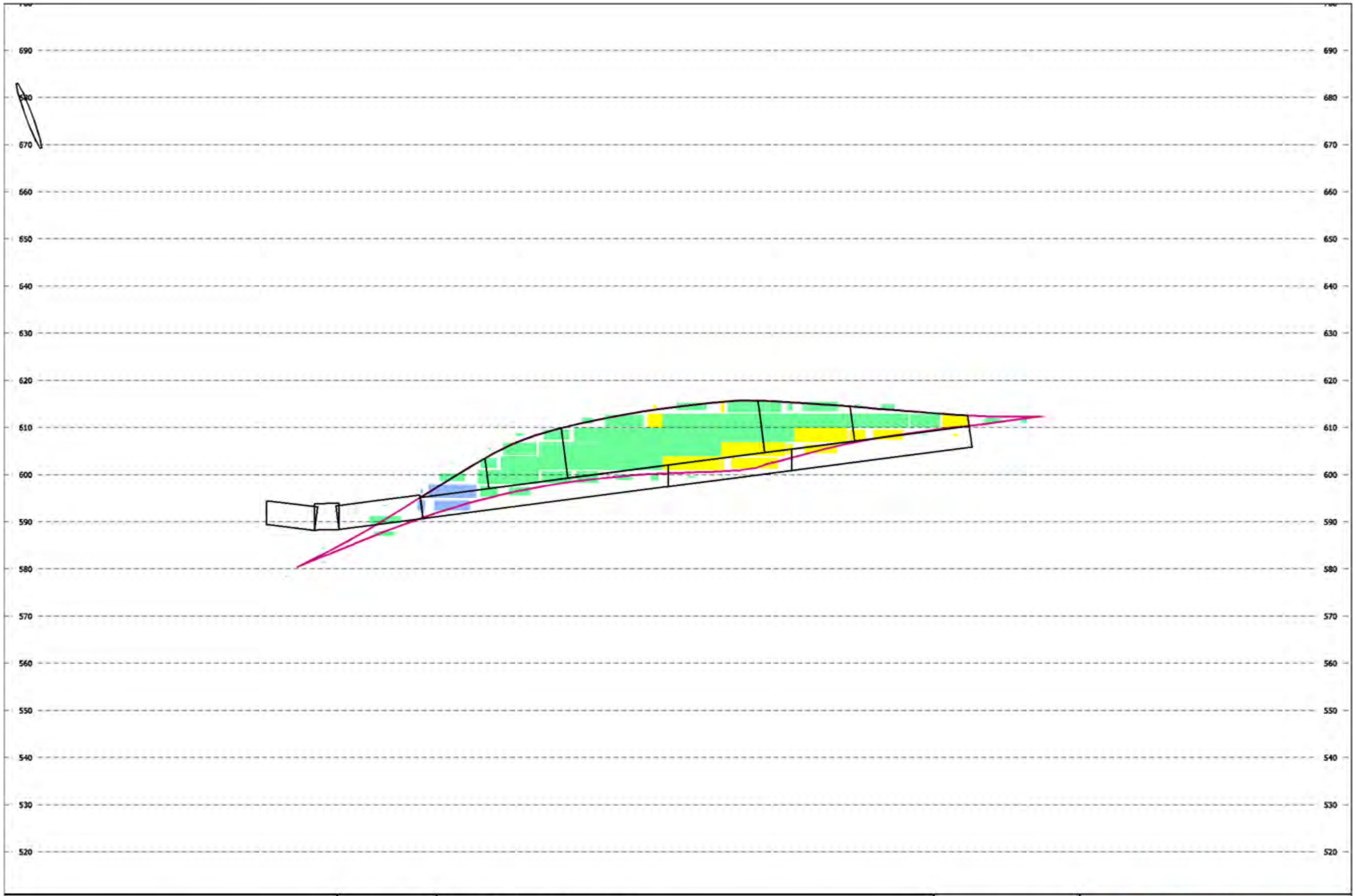
Copper Keel Sections: 19 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



1 : 1250

0 20 40 60

DESCRIPTION: Minto South Underground

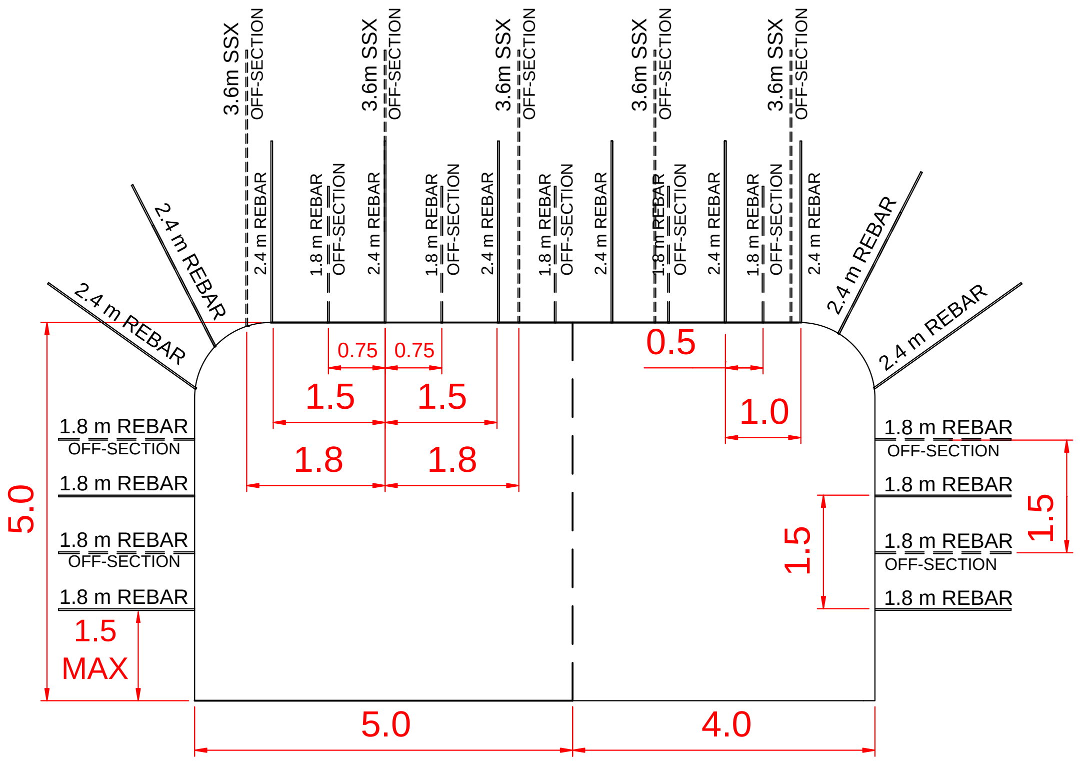
Copper Keel Sections: 20 Stope

DATE PLOTTED: 2018/10/08

Z

N

MINTO
EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY



-SUITABLE FOR EXCAVATIONS REQUIRING TYPE 1 PRIMARY GROUND SUPPORT. TOTAL FINISHED WIDTH NOT TO EXCEED 9.5M

-2.4 m #6 20mm DIAMETER RESIN REBAR IN BACK FOR SCREEN PERIMETER. 1.5 m X 1.5 m SPACING

-1.8 m #6 20mm DIAMETER RESIN REBAR IN BACK FOR SCREEN CENTER BOLT AND SIDE WALL SUPPORT. 1.5 m X 1.5 m SPACING

-3.6 m SUPER SWELLEX (SSX) SPACED 1.8 m X 1.8 m SQUARE PATTERN. MAINTAIN UNTIL TWO ROWS PAST WIDENED SECTION

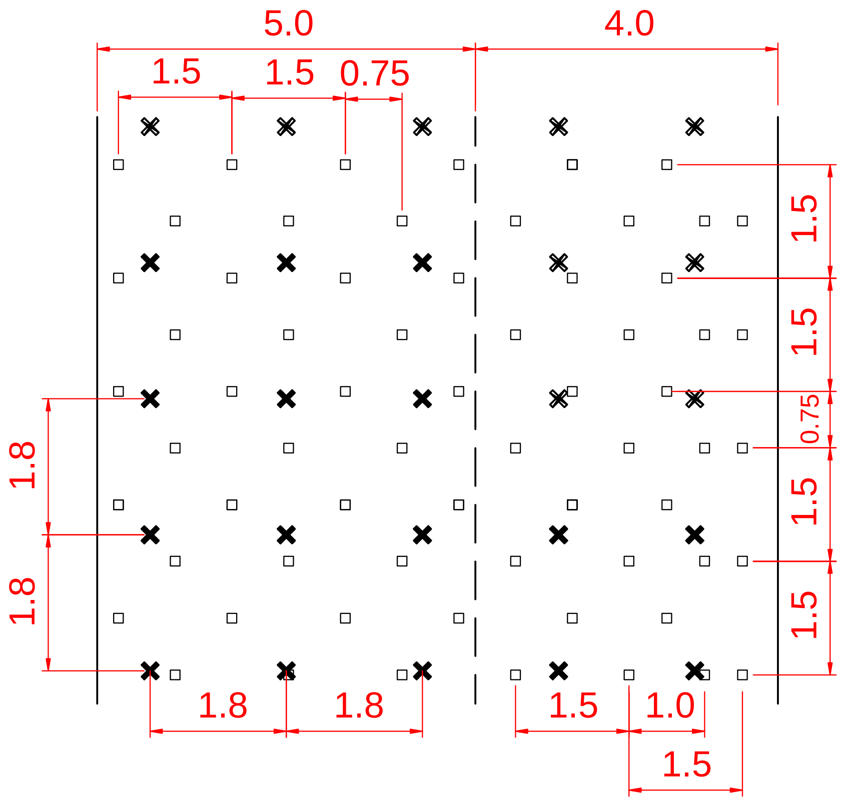
-LAST ROW OF 1.8 m RESIN REBAR AT MAXIMUM OF 1.5 m FROM BASE OF RAIL

-3 SQUARE OVERLAP WHEN INSTALLING SCREEN. INSTALL BOLT IN SECOND SQUARE FROM EDGE

-#6 WELDED WIRE MESH SCREEN BACK AND WALLS

1:100
0 5

TYPICAL DEVELOPMENT SLASH 9.0 mW X 5.0 mH (SECTION)



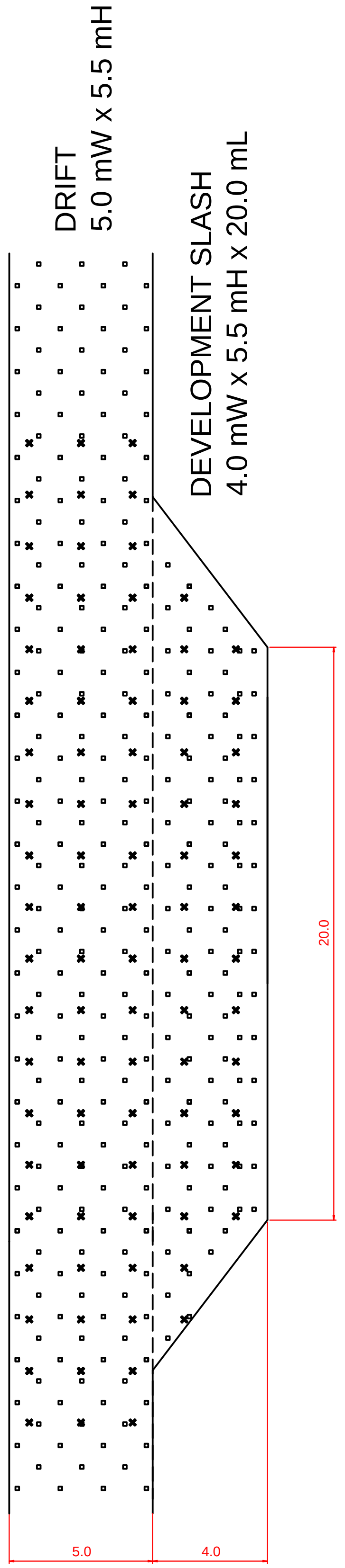
✖ 3.8 m SUPER SWELLEX

□ RESIN REBAR (1.8 m OR 2.4 m)

PERMIT TO PRACTICE
MINTO EXPLORATIONS LTD.
SIGNATURE
Date
PERMIT NUMBER PP343
Association of Professional Engineers of Yukon

1:100
0 5

TYPICAL DEVELOPMENT SLASH 9.0 mW X 5.0 mH (PLAN)



1:250
0 10

TYPICAL PASSING BAY (PLAN)

| | | |
|---|---|---|
| DESIGNED BY:<br>HAYDN DUFFTY | REVIEWED BY:<br>BRENDAN ZUIDEMA | PASSING BAY GROUND SUPPORT DESIGN |
| DRAWN BY:<br>PAUL RICKER | DATE PLOTTED:<br>11 Nov 2019 | |

MINTO EXPLORATIONS
A PEMBRIDGE RESOURCES COMPANY

# Revision 2019-1
# Ground Control Management Plan
# Underground Operations
# Minto Mine, YT

Prepared by:
Minto Explorations Ltd.
Minto Mine
December 2019

# Minto Mine Ground Control Management Plan—Underground Operations

**First Issue: July 2013**

## REVISION INFORMATION

| Rev. Number | Issue Date | Description & Location of Revisions Made |
|---|---|---|
| 0 | July 17, 2013 | First issue |
| 2014-1 | June, 2014 | Update of rock mass characterization. Revisions to ground support standards. |
| 2015-1 | December, 2015 | Update of rock mass characterization with mapping data. Update of mine plan to exclude M-Zone and include the updated Area 118 underground. |
| 2016-1 | December, 2016 | Update of rock mass characterization with mapping and drilling data.<br>Update of mine plan to include the Area 2 underground. |
| 2017-1 | December, 2017 | Update of rock mass characterization with mapping and drilling data.<br>Update of mine plan to include Minto East. |
| 2019-1 | December, 2019 | Update of mining areas.<br>Update to detail of stope design. |

Updated by:

Haydn Duffty, Geotechnical Specialist

Haydn Duffty Date: 03/01/2020

Reviewed by:

Brendan Zuidema, Director Mine Operations

________________________ Date:_______________

Sebastien D Tolgyesi,, P.Eng.,P.Geo. General Manager

S.D. TOLGYESI

________________________ Date___03/01/2020___

PERMIT TO PRACTICE
MINTO EXPLORATIONS LTD.
SIGNATURE
Date
PERMIT NUMBER PP343
Association of Professional
Engineers of Yukon

# Table of Contents

# List of Figures

# List of Tables

# List of Appendices

# General Statement and Corporate Message

Minto Explorations Ltd. Minto Mine maintains the health and safety of the people involved in activities at the mine as the primary value entrenched into everything we do. We strive for “Safe Production” by ensuring people clearly understand that no one is expected to work in substandard conditions, with substandard tools or put them self or others at risk in any way performing their duties at Minto Mine. We maintain a Target: ZERO philosophy that believes all incidents are preventable and that every effort must be made to eliminate significant accidents and reduce minor incidents toward ZERO.

# Introduction

The purpose of this Ground Control Management Plan (GCMP) is to provide a system for the management of ground control at Minto’s underground operations. The Ground Control Management Plan shall:

- outline systems for evaluating, designing, maintaining, and monitoring excavation stability to prevent personal injury, damage to equipment or loss to process;
- present a structure that defines core responsibilities and accountabilities;
- develop and maintain a process for hazard identification and risk management with regard to ground control and geotechnical mine design; and,
- introduce methods to effectively monitor and measure compliance to legislative regulations and corporate policy through audit and review processes.

The intent of the GCMP is therefore to outline the strategies aimed at eliminating or minimising the risk of falls of ground or collapse in the underground operations which may result in fatalities, injuries, equipment damage or loss of production.

The GCMP is a live document that will change continuously with new standards, technology, working procedures and annual reviews, and applies to all personnel at Minto Mine.

## Document Layout

The GCMP has three parts:

### Part One: Design

This section discusses the processes undertaken to determine the excavation design parameters, support requirements, and mining methods applied in the various underground areas. This includes a summary of the site geology, rock mass characterization, minimum ground support standards and practices to manage the predicted ground conditions.

### Part Two: Implementation

This section discusses the procedures and systems for implementing the designed ground control program. This includes Safe Work Practices for ground support installation, a hazard recognition program, ground control communication systems, workforce training and emergency response.

### Part Three: Monitoring and Verification

This section outlines practices and procedures for verifying the ground control design. This includes inspections and data collection, quality assurance/quality control, audits, updates and reviews of the Ground Control Management Plan.

# Accountability and Responsibilities

Responsibilities for personnel involved with the underground operations include the following:

**General Manager**

The General Manager has the overall responsibility for the GCMP. The General Manager shall ensure that:

- suitably trained and qualified persons are formally appointed to the following positions:
    - Mine Manager;
    - Chief Engineer;
    - Safety/Training Coordinator;
    - Geotechnical Engineer.

**Mine Manager**

The Mine Manager shall ensure that:

- the GCMP is implemented and all regulatory requirements are met;
- adequate resources are allocated, and competent technical and operational personnel are appointed.

**Chief Engineer**

The Chief Engineer shall ensure that:

- the GCMP is reviewed/updated at the required frequency;
- adequate training is given to the geotechnical engineer, geologists and mine engineers;
- Safe Work Practices (SWP's) and Safe Job Procedures (SJP's) are developed, reviewed, and modified when needed, in conjunction with the Health and Safety Department.

**Geotechnical Engineer**

The Geotechnical Engineer shall ensure that:

- geotechnical conditions are adequately considered in relation to the mine design and planning;
- monitoring, auditing, and testing systems are developed and maintained;
- on-going mapping, data collection and inspections are carried out to identify variations in ground conditions; and,

- ground control directives are issued for specific conditions/excavations not covered in this document.

**Underground Superintendent and Supervisors**

The Underground Superintendent and Supervisors shall ensure that:

- the work sites and the travel ways are adequately supported through adherence to the ground control requirements set out in the layouts;
- suitable equipment is supplied and maintained to the specifications required for quality ground control;
- Safe Work Practices (SWP's) and Safe Job Procedures (SJP's) are implemented and monitored to ensure compliance;
- any unusual ground conditions are noted and brought to the attention of the engineering group;
- all personnel under their control receive appropriate training;
- the designed support/reinforcement is installed to the specified standards; and,
- reports on ground falls, and variations to ground support standards are addressed and distributed as required. Any anomalies concerning ground control issues are logged in the Ground Control Logbook.

**All Operational Personnel**

All operational personnel shall ensure that:

- no work is undertaken without an approved plan;
- only work in line with current competencies is undertaken;
- Safe Work Practices (SWP's) and Safe Job Procedures (SJP's) are followed;
- ground conditions are inspected in line with workplace inspection standards at every work site;
- ground conditions are monitored during the shift for the presence of loose or unstable ground;
- if any rock noise is heard or the ground being worked appears unsafe, withdraw and barricade the area, then immediately notify the Supervisor; and,
- relevant information in relation to ground conditions/support is reported back to the Supervisor and Geotechnical Engineer.

# Mandatory Requirements

- NO PERSON IS TO ENTER UNSUPPORTED GROUND. Supported (secured) ground is deemed to be ground where a complete ground support system has been applied as per required standards.
- All man-entry excavations must conform to or exceed the minimum ground control standards specified in this document.
- All ground control work must follow established Safe Work Practices (SWP's) and Safe Job Procedures (SJP's).
- All personnel must inspect ground conditions and check the adequacy of ground control when entering an underground heading/access/work area.
- All personnel must immediately report uncontrolled falls of ground and ground control hazards to their supervisor who will be responsible for follow up and documentation.
- All reports of conditions requiring actions outside of standard work will be recorded in the Ground Control Log Book and followed-up with a documented inspection to ensure the efficacy of the remedial action.

# Part One: Design

The mine design is determined by the geological, geotechnical, and hydrogeological data collected to characterize the Minto ore bodies. Data collected for use in mine design and the design processes are detailed in this section.

## 1 Description of the Mine

Minto Mine is situated in the Whitehorse Mining District in the central Yukon Territory. The property is located approximately 240 km northwest of Whitehorse, the Yukon capital. Underground mining is currently taking place in Minto East, The Copper Keel zone is scheduled to be mined between 2019 and 2022. Both areas are accessed by the Minto South portal.

**Figure 1: Plan view of Minto Mine (Aug.2017)**

# 2 Rock Mass Characterization

## 2.1 Geological Overview

Copper sulphide mineralization at Minto is hosted wholly within the Minto pluton, predominantly of granodiorite composition. Hood et al. (2008) distinguish three varieties of the intrusive rocks in the pluton:

- Megacrystic K-feldspar Granodiorite - gradually ranges in mineralogy to quartz diorite and rarely to quartz monzonite or granite, typically maintaining a massive igneous texture. An exception occurs locally where weakly to strongly foliated granodiorite is seen in distinct sub-parallel zones several metres to tens of metres thick.

- Quartzo-feldspathic Gneiss – composed of centimeter-thick compositional layering and folded by centimetre to decimetre-scale disharmonic, gentle to isoclinal folds (Hood et al., 2008).

- Biotite-rich Gneiss.

Minto geologists consider all units to be similar in origin and are variably deformed equivalents of the same intrusion; however, copper sulphide mineralization is found in the rocks that have a structurally imposed fabric, ranging from a weak foliation to strongly developed gneissic banding. For this reason, all logging/mapping separates the foliated to gneissic textured granodiorite as a distinct unit.

Other rock types, albeit volumetrically insignificant, include dykes of simple quartz-feldspar pegmatite, aplite; and an aphanitic textured intermediate composition rock. Bodies of all these units are relatively thin and rarely exceed one metre intersections.

### 2.1.1 Geologic Structure

Both ductile and brittle phases of deformation are found around the Minto deposits. As noted above, copper-sulphide mineralization is strongly associated with foliated granodiorite. This foliation is defined by the alignment of biotite in areas of weak to moderate strain and by the segregation of quartz and feldspar into bands in areas of higher strain, giving the rock a gneissic texture in very strongly deformed areas. The deformation zone forms sub-horizontal horizons within the more massive plutonic rocks of the region that can be traced laterally for more than 1,000 m. The horizons are often stacked in parallel to sub-parallel sequences.

Internally, the foliation exhibits highly variable orientations within individual horizons with the presence of small-scale folds. The foliation is often observed to be at a high angle to contacts with more massive textured rock units.

Late brittle fracturing and faulting is noted throughout the property. The boundary between Area 2 and Area 118 is an intermediate NE dipping fault with significant displacement of mineralization. The easiest zone to identify (based on mineralization and texture) is the “N” zone which has up to

66 m of vertical throw across the boundary fault. Other zones show changes in thickness and orientation, suggesting the presence of pure strain and block rotation.

## 2.2 Geotechnical Model

### 2.2.1 Rock Types

For most of the underground excavations completed at Minto, granodiorite is the major intersected unit. As discussed in Section 2.1, mineralization typically occurs in foliated to gneissic variations of the host granodiorite. Experience to date indicates the waste rock typically has slightly higher intact strength but more continuous fractures than ore, although both are variable and often influenced by fault zones.

### 2.2.2 Discontinuities

Extensive structural mapping has been carried out in Area 118, M-Zone, Area 2 and Minto East as summarized in Table 1.and Table 2.

Structural data collected in the underground workings to date have been combined into ore and waste stereonets, presented in Figures 2 and 3.

In general, the sets result in conditions varying in waste rock from moderately blocky to very blocky and typically wedge-prone. Discontinuities in waste rock are typically very continuous, extending larger than the excavation size. In ore, the sets are less persistent and more widely spaced, resulting in only occasional blocky conditions. Few wedges have been observed in ore exposures to date.

Several faults have been observed in the development at various orientations. Most are relatively discrete structures with limited width and minor alteration of the wall rock; however, several have been intersected in Area 118 and Area 2 that have several meters of weak, altered rock or are water-bearing indicating they are open and continuous. The 320 Fault, which was a major fault seen in the Area 2 pit, and intersected in the A2 ramp, has a more extensive alteration zone up to 25 m, containing altered and filled structures and occasional fault gouge. The 320 Fault is more problematic near surface and did not present major challenges for the underground ramp development. The Minto East Fault has been intersected in the Minto East ramp and is modelled to cross-cut the sill development within the Minto East deposit.

Fault orientations summarized in Table 2, typically align with joint set J8 and follow a regional trend like the Teslin and Tintina Faults.

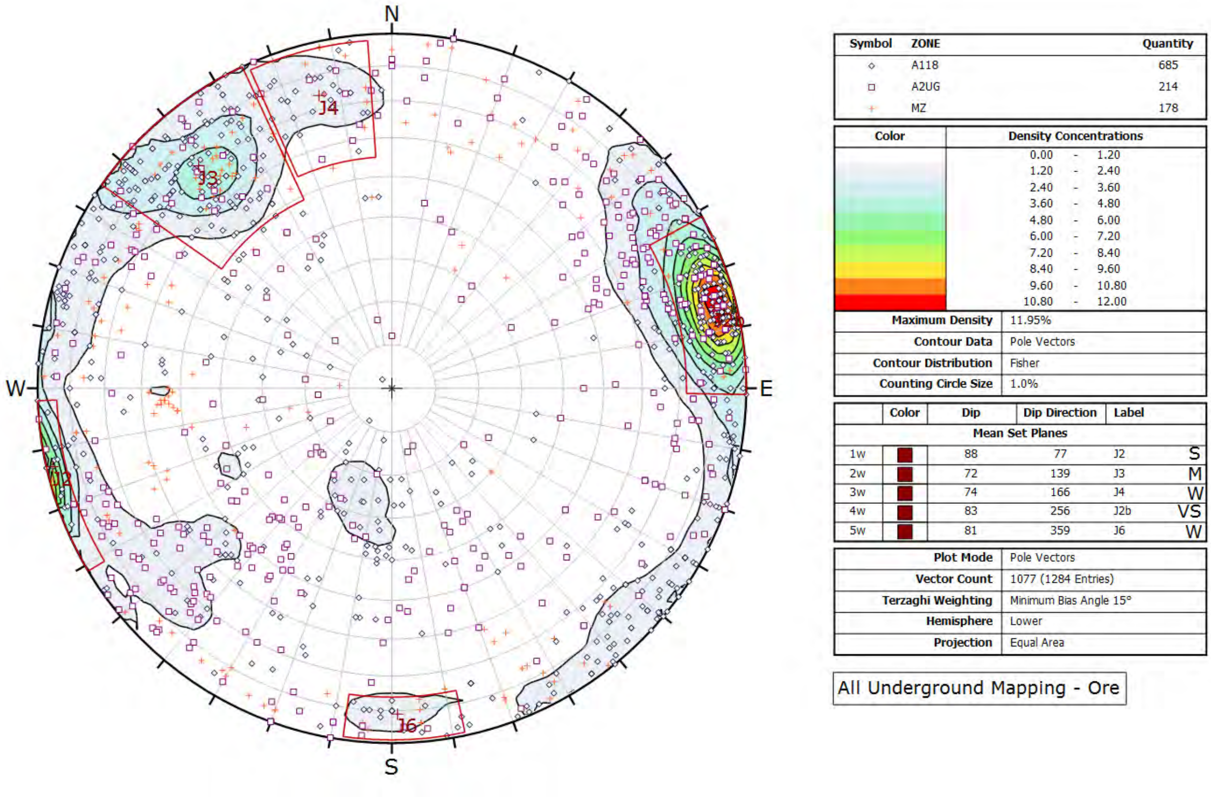
The geotechnical model is updated annually or more frequently as required such as the development of a new area.

**Table 1: Major Joint Sets**

| Major Joint Set | Average Dip | Average Dip Direction | Primary Lithology | Typical Joint Length (m) | Area Observed | Comments |
|---|---|---|---|---|---|---|
| J2 | 88 | 077 | Ore | 2 | • Area 118 | Major set in ore. Not apparent in waste. |
| J2b | 83 | 256 | Ore | 2 | • Area 118<br>• Area 2 | Major set in ore. Not apparent in waste. |
| J3 | 71(waste)<br>72(ore) | 133(waste)<br>139(ore) | Waste | 6(waste)<br>2(ore) | • M-Zone<br>• Area 118<br>• Minto East | Major set in all areas. Not apparent in Area 2. |
| J3b | 39 | 135 | Waste | 6 | • M-Zone<br>• Area 118<br>• Minto East | Major set in all areas. Not apparent in Area 2. |
| J4 | 72(waste)<br>74(ore) | 163(waste)<br>166(ore) | Waste | 6(waste)<br>2(ore) | • M-Zone<br>• Area 118 | Major set in most areas. |
| J6 | 81 | 359 | Ore | 2 | • M-Zone<br>• Area 118 | Minor set in ore. Not apparent in Area 2. |
| J8 | 82 | 043 | Waste | 6 | • Area 118<br>• Area 2<br>• Minto East | Major set in Area 2 Pit. Major set in Area 118 and Minto East. Major set in Area 2 ore – not apparent in Area 2 waste. |
| J8b | 80 | 225 | Waste | 6 | • Area 118<br>• Area 2<br>• Minto East | Major set in Area 2 and Minto East. Minor set in Area 118. |
| J9 | 13 | 103 | Waste | 4 | • Area 118<br>• Area 2 | Minor set in Area 118, Moderate set in Area 2.<br>Not apparent in ore. |
| J11 | 82 | 273 | Waste | 2 | • Area 2 | Moderate set in Area 2 waste. |

**Table 2: Major Structures**

| Structure Description | Average Dip | Average Dip Direction | Comments |
|---|---|---|---|
| Fault | 66 (65-76) | 035 (015-040) | Major fault intersected throughout Area 118 waste and ore development. Zone of up to several meters of altered, weak rock. Often water bearing. Similar structure intersected in the Minto East ramp development. |
| Fault | 64-74 | 040-050 | Major fault zone in Area 2 (“320 Fault”) and regional fault orientation. Up to 5m zone of gouge, altered fractured rock. |
| Fault | 50-55 | 038-036 | Major fault zone in Minto East. Up to 3m zone of gouge, altered fractured rock. Very limited exposure in development to date but modelled to cross all development sills. |
| Fault | 60 | 160 | Gouge filled fault in M-Zone. |
| Fault | 59 | 292 | Minor fault in Area 118 waste rock. |



| Symbol | ZONE | Quantity |
|---|---|---|
| ◇ | A118 | 685 |
| □ | A2UG | 214 |
| + | MZ | 178 |

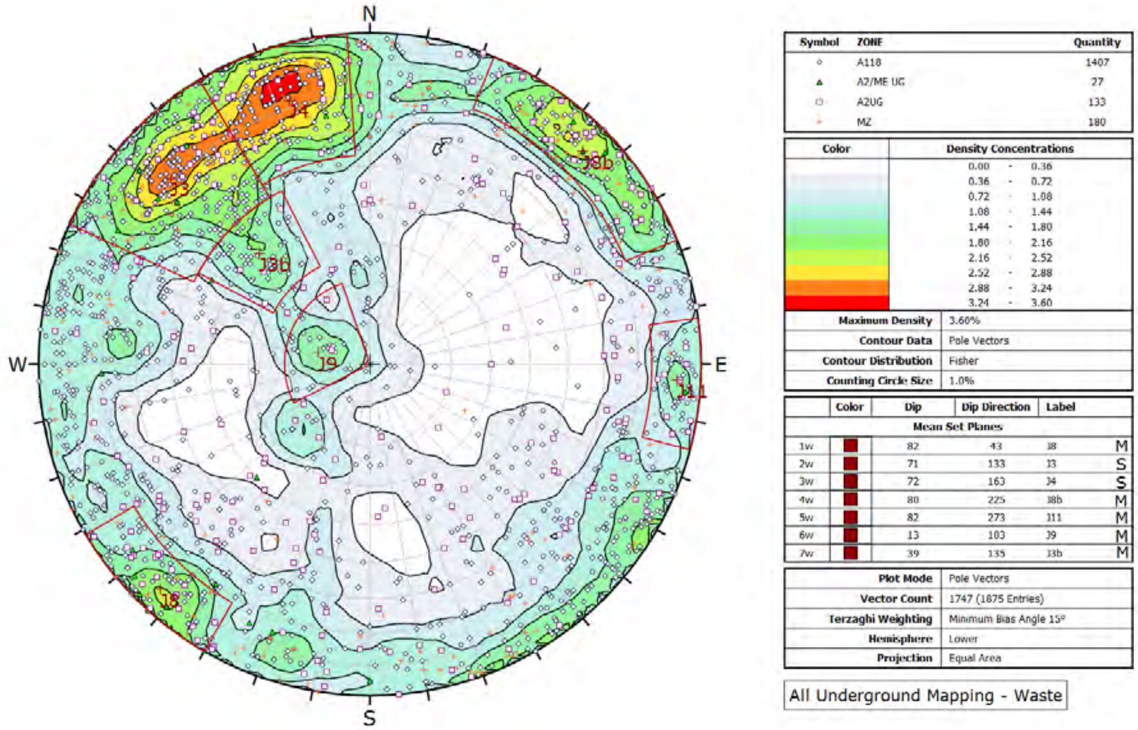
| Color | Density Concentrations |
|---|---|
| | 0.00 - 1.20 |
| | 1.20 - 2.40 |
| | 2.40 - 3.60 |
| | 3.60 - 4.80 |
| | 4.80 - 6.00 |
| | 6.00 - 7.20 |
| | 7.20 - 8.40 |
| | 8.40 - 9.60 |
| | 9.60 - 10.80 |
| | 10.80 - 12.00 |
| Maximum Density | 11.95% |
| Contour Data | Pole Vectors |
| Contour Distribution | Fisher |
| Counting Circle Size | 1.0% |

| | Color | Dip | Dip Direction | Label | |
|---|---|---|---|---|---|
| Mean Set Planes | | | | | |
| 1w | 🟥 | 88 | 77 | J2 | S |
| 2w | 🟥 | 72 | 139 | J3 | M |
| 3w | 🟥 | 74 | 166 | J4 | W |
| 4w | 🟥 | 83 | 256 | J2b | VS |
| 5w | 🟥 | 81 | 359 | J6 | W |

| | |
|---|---|
| Plot Mode | Pole Vectors |
| Vector Count | 1077 (1284 Entries) |
| Terzaghi Weighting | Minimum Bias Angle 15° |
| Hemisphere | Lower |
| Projection | Equal Area |

All Underground Mapping - Ore

**Figure 2: Mapping - Ore**



| Symbol | ZONE | Quantity |
|---|---|---|
| ○ | A118 | 1407 |
| ▲ | A2/ME UG | 27 |
| □ | A2UG | 133 |
| + | MZ | 180 |

| Color | Density Concentrations |
|---|---|
| ⬜ | 0.00 - 0.36 |
| ⬜ | 0.36 - 0.72 |
| 🟦 | 0.72 - 1.08 |
| 🟦 | 1.08 - 1.44 |
| 🟩 | 1.44 - 1.80 |
| 🟩 | 1.80 - 2.16 |
| 🟩 | 2.16 - 2.52 |
| 🟨 | 2.52 - 2.88 |
| 🟧 | 2.88 - 3.24 |
| 🟥 | 3.24 - 3.60 |

|  |  |
|---|---|
| Maximum Density | 3.60% |
| Contour Data | Pole Vectors |
| Contour Distribution | Fisher |
| Counting Circle Size | 1.0% |

|  | Color | Dip | Dip Direction | Label |  |
|---|---|---|---|---|---|
| Mean Set Planes |  |  |  |  |  |
| 1w | 🟥 | 82 | 43 | J8 | M |
| 2w | 🟥 | 71 | 133 | J3 | S |
| 3w | 🟥 | 72 | 163 | J4 | S |
| 4w | 🟥 | 80 | 225 | J8b | M |
| 5w | 🟥 | 82 | 273 | J11 | M |
| 6w | 🟥 | 13 | 103 | J9 | M |
| 7w | 🟥 | 39 | 135 | J3b | M |

|  |  |
|---|---|
| Plot Mode | Pole Vectors |
| Vector Count | 1747 (1875 Entries) |
| Terzaghi Weighting | Minimum Bias Angle 15° |
| Hemisphere | Lower |
| Projection | Equal Area |

All Underground Mapping - Waste

**Figure 3: Mapping - Waste**

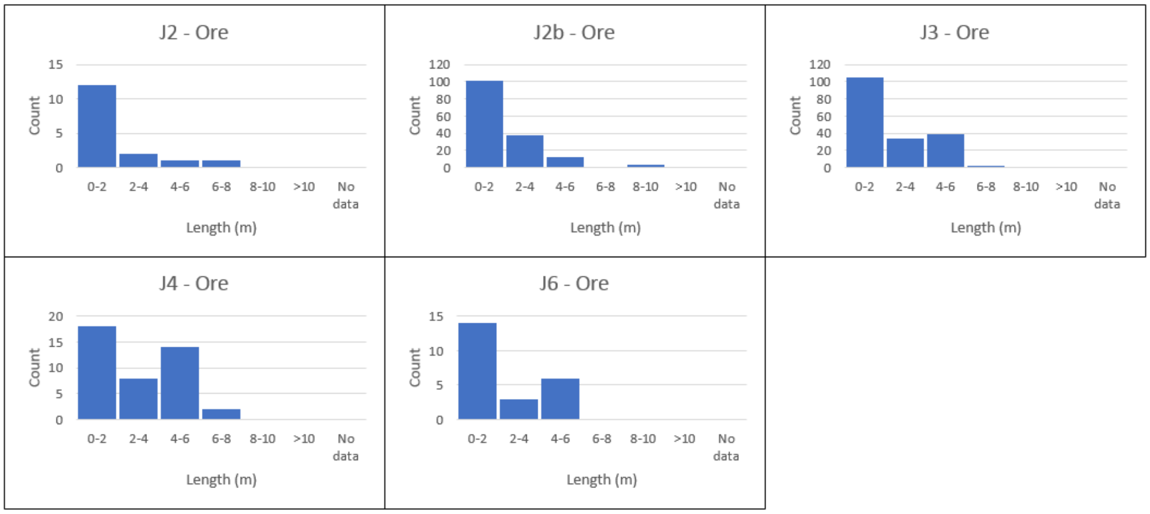


**Figure 4: Mapping – Joint lengths in Ore**

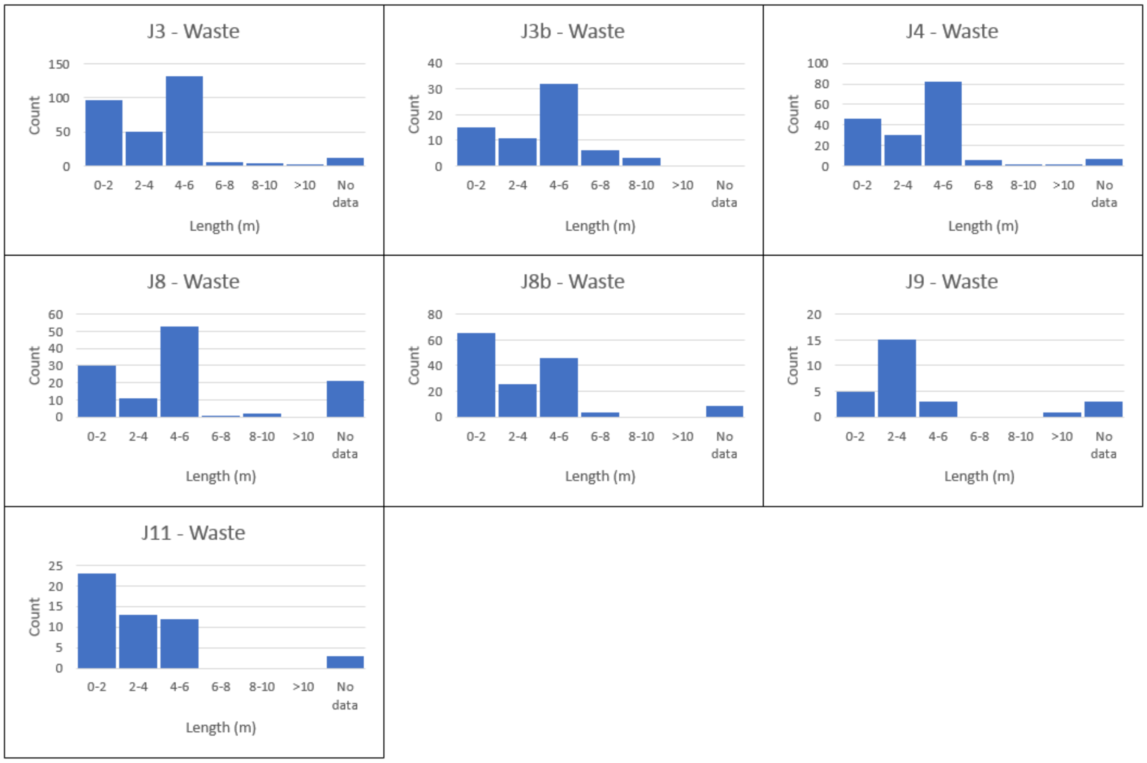


**Figure 5: Mapping – Joint lengths in Waste**

Direct shear testing on discontinuities was carried out in 2009 by SRK at the University of Arizona, summarized in Table 3. Due to the potential for blast damage around underground openings, the following shear strength values are used in kinematic assessments: 35° friction angle and 0 kPa of cohesion.

**Table 3: Direct Shear Strength Testing on Discontinuities**

| Area | Drillhole ID | Depth | Lithology | Friction Angle | Cohesion (kPa) |
|---|---|---|---|---|---|
| Area 2 | C09-03 | 162.55 | Foliated Granodiorite (fG) | 33.7 | 10.0 |
| Area 118 | C09-01 | 49.87 | Porphyroblastic Granodiorite (pG) | 40.7 | 21.6 |
| Area 118 | C09-01 | 103.00 | Porphyroblastic Granodiorite (pG) | 35.0 | 20.5 |
| Area 118 | C09-01 | 212.15 | Porphyroblastic Granodiorite (pG) | 33.4 | 1.3 |
| Area 118 | C09-02 | 211.14 | Porphyroblastic Granodiorite (pG) | 32.9 | 5.7 |
| | | | *Average* | 35.1 | 11.8 |
| | | | *Values used for analysis* | 35 | 0 |

### 2.2.3 Intact Rock Strength

Intact rock strength properties, summarized in Tables 4: and 5: are based on the results on drilling and testing carried out in 2009 (SRK), 2015 (SRK), 2015 (Golder), 2016 (Golder), and Golder (2017).

**Table 4: Summary of Testing for Intact Strength Properties**

| **Area** | **Lithology** | **Condition** | **UCS (MPa) (excluding invalid tests)** | | | | **Young's Modulus (E) (GPa)** | **Poisson's Ration** | **Brazilian Tensile Strength (MPa)** | **Density (kN/m$^3$)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **tests** | **min** | **max** | **mean** | | | | |
| Area 2 Pit | Equigranular Granodiorite (eG) | Fresh | 1 | 103 | 103 | 103 | - | - | - | 26.3 |
| | Foliated Granodiorite (fG) | Fresh | 4 | 94 | 173 | 122 | 47 | 0.23 | 7.6 | 26.4 |
| | Porphyroblastic Granodiorite (pG) | Fresh | 2 | 58 | 150 | 104 | 15 | 0.08 | - | 26.4 |
| | | Weathered | 3 | 21 | 49 | 31 | - | - | - | 25.8 |
| Area 118 | Equigranular Granodiorite (eG) | Fresh | 1 | 150 | 150 | 150 | - | - | - | 26.3 |
| | Foliated Granodiorite (fG) | Fresh | 8 | 86 | 165 | 125 | 67 | 0.30 | - | 26.6 |
| | Porphyroblastic Granodiorite (pG) | Fresh | 6 | 72 | 198 | 141 | 49 | 0.21 | 10.1 | 26.4 |
| | | Weathered | 1 | 88 | 88 | 88 | 51 | 0.22 | - | 26.1 |
| Area 2 UG | Equigranular Granodiorite (eG) | Fresh | 2 | 103 | 111 | 107 | - | - | - | 26.5 |
| | Foliated Granodiorite (fG) | Fresh | 14 | 75 | 138 | 103 | 65 | 0.23 | - | 28.0 |
| | Porphyroblastic Granodiorite (pG) | Fresh | 1 | 88 | 88 | 88 | - | - | - | 26.6 |
| Minto East | Equigranular Granodiorite (eG) | Fresh | 3 | 89 | 132 | 122 | - | - | - | 26.5 |
| | Foliated Granodiorite (fG) | Fresh | 4 | 65 | 142 | 105 | - | - | - | 28.9 |

### 2.2.4 Rock Mass Classification

Rock mass properties, summarized in Table 5, are estimated from diamond drillhole data and geotechnical mapping. Mapping data appears to indicate higher rock quality than logging and is considered more representative of conditions experienced underground to date.

**Table 5: Rock mass parameter summary for underground mining areas**

| Area | Source | Type | Condition | Number of Samples | RMR | | | Q' Range | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | min | max | avg | min | max | avg |
| Area 2 (M-Zone) | Underground mapping | fG | Fresh | 92 m | 55 | 92 | 77 | 0.8 | 50.0 | 9.6 |
| Area 118 | Core Logging (SRK) | eG,pG,fG | Fresh | 334 runs | 22 | 81 | 58 | - | - | - |
| | | | Weathered | 59 runs | 21 | 72 | 51 | - | - | - |
| Area 118 | Underground Mapping | fG | Fresh | 147 m | 59 | 89 | 79 | 1.4 | 150.0 | 17.7 |
| | | eG | Fresh | 204 m | 65 | 92 | 85 | 2.6 | 50.0 | 17.5 |
| Area 2 UG | Core Logging (Minto) | fG | Fresh | 60 runs | 70 | 89 | 72 | 33.8 | 300 | 45.4 |
| | | eG | Fresh | 83 runs | 65 | 94 | 69 | 11.5 | 150 | 23.4 |
| Minto East | Core Logging (Minto) | fG | Fresh | 22 runs | 61 | 89 | 69 | 10.6 | 73.8 | 23.2 |
| Minto East | | eG, Peg, pG | Fresh | 96 runs | 56 | 89 | 64 | 18.2 | 300 | 26.4 |
| Copper Keel | Core Logging / Lab (Golder) | fG | Fresh | 75 runs | 40 | 89 | 71 | 0.2 | 99 | 13.9 |

### 2.2.5 Minto East and Copper Keel geometry/excavation dimensions.

**Table 6: Summary of Minto East geometry**

| Dimension | Minimum | Maximum | Average |
|---|---|---|---|
| Dip (degrees) | 0 | 30 | 15 |
| Elevation (m) | 470 | 505 | - |
| Depth (m) | 278 | 325 | - |
| Length along strike (m) | 100 | 316 | 215 |
| Thickness (m) | 5 | 25 | 10 |

**Table 7: Summary of Minto East excavation dimensions**

| Excavation | Maximum Dimensions | Comment |
|---|---|---|
| Waste development headings | 5.0m W x 5.5m H | Includes ramps, level accesses, remucks |
| Ore development headings | 6.0m W x 4.5m H | - |
| Pillars | Variable | - |
| Stopes | Variable | - |
| Raises | 3 m diameter<br>1.4 m diameter | - |

**Table 8: Summary of Copper Keel geometry**

| Dimension | Minimum | Maximum | Average |
|---|---|---|---|
| Dip (degrees) | 0 | 30 | 15 |
| Elevation (m) | 470 | 505 | - |
| Depth (m) | 278 | 325 | - |
| Length along strike (m) | 100 | 316 | 215 |
| Thickness (m) | 5 | 25 | 10 |

**Table 9: Summary of Copper Keel excavation dimensions**

| Excavation | Maximum Dimensions | Comment |
|---|---|---|
| Waste development headings | 5.0m W x 5.5m H | Includes ramps, level accesses, remucks |
| Ore development headings | 6.0m W x 4.5m H | - |
| Pillars | Variable | - |
| Stopes | Variable | - |
| Raise | 4 m diameter | - |

### 2.2.6 In-Situ Stress

No in-situ stress tests have been carried out on site to date. The magnitude and orientation of the assumed horizontal stresses are based on conditions in western North America with the orientation of the maximum horizontal stress roughly perpendicular to the axis of the trend of the Dawson Range. The following assumptions have been used in geotechnical analyses (Golder, 2015):

- Vertical stress = depth * gravity * rock density (average 2650 kg/m3)
- Maximum horizontal stress = 1.75 * vertical stress, oriented NE/SW
- Minimum horizontal stress = 1.5 * vertical stress, oriented NW/SE

To date, there have been no signs of overstress or stress damage observed at Minto.

## 2.3 Hydrogeology

Based on underground development in Area 118, Area 2 and Minto East to date (down to elevation 470 m), inflows have been manageable without major dewatering infrastructure. Seeps and inflows up to approximately 5 GPM have been encountered in the main ramp, primarily in fault/fractured zones and near the footwall of the orebodies. Un-grouted diamond drill holes have occasionally been encountered which have produced inflows up to approximately 10 GPM.

Table 10: presents the rock mass permeability measurements completed by Golder (1974) and Golder (2017). The 2017 values indicate a higher permeability for both the fault associated zones and the fresh rock and will be used for planning purposes moving forward.

**Table 10: Rock mass permeability values (Hatch, 2006 after Golder, 1974; Golder, 2017)**

| Lithology | Year | Range (cm/sec) | | Design Values (cm/s) |
|---|---|---|---|---|
| | | Lower | Upper | |
| Highly weathered—near surface | 1974 | 9.0x10^-6 | 1.5x10^-4 | 5.0x10^-6 |
| Highly weathered—fault associated | 1974 | 5.3x10^-6 | 7.0x10^-6 | 6.0x10^-6 |
| | 2017 | 2 x 10^-7 | 5 x 10^-5 | 2.5 x 10^-5 |
| Moderately weathered | 1974 | 4.7x10^-6 | 8.4x10^-6 (1) | 6.0x10^-6 |
| | 2017 | - | 5 x 10^-6 | 5 x 10^-6 |
| Fresh rock | 1974 | 1.5x10^-6 | 8.3x10^-6 (1) | 3.5x10^-6 |
| | 2017 | 9 x 10^-6 | 2 x 10^-5 | 1.5 x 10^-5 |

Note 1: Excludes results from shattered zones

# 3 Design Criteria

## 3.1 Design References

Underground design parameters were developed based on analyses and inspections outlined in the following documents, the file location for these documents is shown in Appendix B.

- ME NFold Pillar Stability Assessment (Golder, 2017)
- Underground Mine Development and Operations Plan (Minto, 2017)
- Area 2 Mining Stability Assessment Summary (Golder, 2016)
- Inspection of the Physical Stability of the Minto Mine Underground Ground Support System (Golder, 2016)
- Area 118 Plunge Mining Stability Assessment Summary (Golder, 2015)
- Longhole Open Stope Stability Addendum – Revised Mining Heights (Golder, 2015)
- Ground Control Management Plan Review (Golder, 2015)
- Minto Mine Underground Reserve Update Geotechnical Input (Golder, 2015)
- Geotechnical Characterization of Existing and Proposed Longhole Open Stope Mining Areas (Golder, 2015)
- Minto 118-Zone – 3DEC/DFN Analysis (Itasca, 2014)
- Minto 118-Zone – FLAC3D Analysis of the Longhole Base Case Option (Itasca, 2014)
- Structural Stability Analyses at Minto Mine (Itasca, 2014)
- Itasca Site Visit of April 2014 at Minto Mine (Itasca, 2014)
- Kinematic Analysis-Underground Excavations (Internal, 2014)
- Itasca Site Visit of October 2013 at Minto Mine (Itasca, 2013)
- Itasca June 2013 Site Visit at Minto Mine (Itasca, 2013)
- Report on the Itasca Site Visit of 26-28 February 2013 at Minto Mine (Itasca, 2013)
- Report on the Itasca Site Visit of 16-19 October 2012 at Minto Mine (Itasca, 2012)
- Minto Phase VI Underground Geotech Evaluation –Draft (SRK, 2012)
- Prefeasibility Geotechnical Evaluation, Phase IV (SRK, 2009)

## 3.2 Underground Mine Development and Design

### 3.2.1 Mining Method

The M-zone, Area 118 and Area 2 zones were all mined using a longhole open stoping method; the Minto East zone is being mined in the same manner. All these ore zones can be described as lenses of foliated and variably migmatized metamorphic rocks bounded at their hanging wall and footwall contacts by equigranular, undeformed granodiorite (eG) host rock. The metamorphic zones are typically 5-30m thick and the grade within them varies from 0% to approximately 6% copper. These zones typically dip at 20° to 35°.

The mining method requires a series of parallel sill drifts to be developed along the strike of the deposit following the footwall contact. From these sill drifts, typically 6m wide and 4.5m high, a top-hammer longhole drill rig drills rings of 3” diameter up-holes into the deposit above, stopping at the hanging-wall contact.

To provide adequate void space for blasted muck when starting a new stope, 1.8m x 1.8m inverse raises are drilled. These are composed of six, 6-inch diameter reamed holes, which are left unloaded and surrounded by a pattern of eleven 3½-inch diameter blast holes. Generally, each stope is initiated with one or more rings of blast holes on either side of the inverse raise; subsequent blasts increase the number of rings fired simultaneously to take advantage of the void space in each block.

After drilling is completed, the rings are loaded, blasted, and then mucked out from the sill drift, which serves as a drawpoint. The average blast size is 8000 to 10,000 tonnes. Mucking is via remote-controlled load-haul-dump machines (LHDs); all stopes are non-entry so that no personnel are exposed to the open stope.

Ore is trucked to surface along the main access ramp and out through the Minto South portal.

For the Area 118 zone and M-zone, production drift centerlines were 15m apart; from each 6m-wide sill drift, drill holes fanned out to blast a 10m wide stope. 5m-thick rib pillars separated each stope thus supporting the hanging wall.

For the Area 2 zone and Minto East, production drift centerlines were/are 20m apart. Stope and pillar widths vary based on the ore thickness (stope and pillar height). Typical stope widths were/are 15m and typical pillar widths were/are 5m.

For Copper Keel, The design is nominally based on 12m-wide stopes and 8m pillars, but geotechnical analysis indicates that the pillar width must vary as a function of stope height in order to maintain stability and maximize recovery. Pillar thickness is increased where the stope is tall and decreased where the stope is short

For more details on the stope geometry see Section 3.2.4

Significant variability in copper grade occurs within each ore zone; therefore, core drilling completed as part of earlier exploration is supplemented by infill drilling done from each sill using the production drilling equipment.

In the Area 118 and Area 2 zones additional core drilling was also done from the underground workings.

The mining method does not use backfill; however, small quantities of development waste are sometimes placed in completed stopes to reduce haulage requirements.

### 3.2.2 Mine Access

The main ramp of the Minto South Underground measures 1,677m, extending to Area 2, 630 level. The access to Copper Keel is at 1960m and the designed length of Copper keel ramp is 431m. The first access to the current Minto East zone is 2,440m in length. The upper ramp is 5.0m wide and 5.0m high; the ramp below the 690 level was driven at dimensions of 5.0m wide and 5.5m high to provide additional clearance between vent ducting and haul trucks. This access is used for all ore and waste haulage, personnel/equipment access and services. It is also used as an exhaust airway. Re-muck bays are typically developed every 150 m along the decline to improve the efficiency of the development cycle; they are designed to hold two rounds of development muck. The re-muck bays have the same dimensions as the decline and are generally 15 m in length. Once they are no longer needed for development, they are repurposed as equipment storage, pump stations, drill bays, service bays, etc.

Ground support generally comprises 2.4m-long fully grouted resin rebar bolts on a 1.5m x 1.5m pattern with a 1.8 m bolt in the center for the back and 1.8m bolts for the walls. Welded wire screen is installed to within 1.5 m from the floor. Additional support is installed at all drift intersections.

### 3.2.3 Longhole stoping

Stope spans for mining areas were designed using a combination of empirical analysis, numerical modelling and experience in the Minto underground to date. Examples of stability graphs for the Area 2 and Minto East deposits are shown in Figures 6 and Figure 7 respectively.

Exposures plot in the stable or transition zone with less than 2m of equivalent linear overbreak/slough (ELOS).

To date, no unmanageable instability has been experienced in open stopes. Stope backs have performed well, typically breaking clean to a planar, discrete hanging wall contact. Only one stope in Area 118 experienced overbreak in the back for an approximate 15m length in 710 E2. The overbreak was associated with pervasive structures and broke up to approximately 10m above the planned stope back.

Typical overbreak in stope backs is less than 0.5m and underbreak from the planned back is more common.

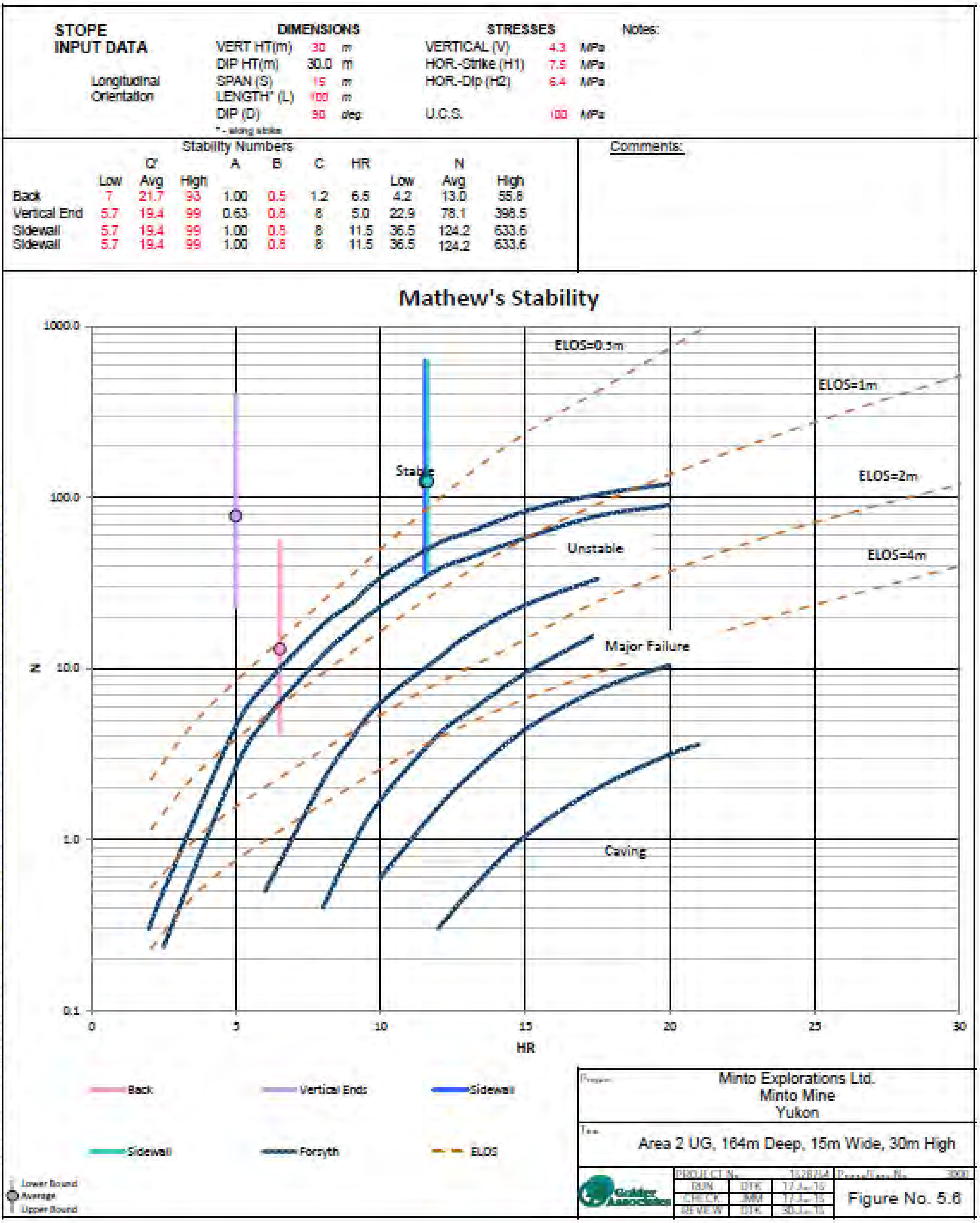
Several trial stopes were mined in Area 118 to investigate the performance of wider spans. These

included four areas in different parts of the deposit successfully mined at widths up to 20m, with little to no overbreak.

Instability in the stope walls has occurred in several places where fault zones result in weak, ravelling type behaviour. Unplanned pillar breakthroughs occurred in two places in Area 118.

In the MZone, two pillars unravelled for approximately 30-40m in length. In all cases, pillars were successfully re-established either by narrowing the subsequent stope blasts or re-slotting to leave a mid-stope pillar.

The mining method allows for flexibility to adapt to changing conditions by leaving wider pillars or mid-stope pillars as conditions dictate.



**STOPE INPUT DATA**

Longitudinal
Orientation

**DIMENSIONS**

| | | |
|---|---|---|
| VERT HT(m) | 30 | m |
| DIP HT(m) | 30.0 | m |
| SPAN (S) | 15 | m |
| LENGTH* (L) | 100 | m |
| DIP (D) | 90 | deg |

* - along strike

**STRESSES**

| | | |
|---|---|---|
| VERTICAL (V) | 4.3 | MPa |
| HOR.-Strike (H1) | 7.5 | MPa |
| HOR.-Dip (H2) | 6.4 | MPa |
| U.C.S. | 100 | MPa |

Notes:

Stability Numbers

| | Q' | | | A | B | C | HR | N | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg | High | | | | | Low | Avg | High |
| Back | 7 | 21.7 | 93 | 1.00 | 0.5 | 1.2 | 6.5 | 4.2 | 13.0 | 55.6 |
| Vertical End | 5.7 | 19.4 | 99 | 0.63 | 0.5 | 8 | 5.0 | 22.9 | 78.1 | 398.5 |
| Sidewall | 5.7 | 19.4 | 99 | 1.00 | 0.5 | 8 | 11.5 | 36.5 | 124.2 | 633.6 |
| Sidewall | 5.7 | 19.4 | 99 | 1.00 | 0.5 | 8 | 11.5 | 36.5 | 124.2 | 633.6 |

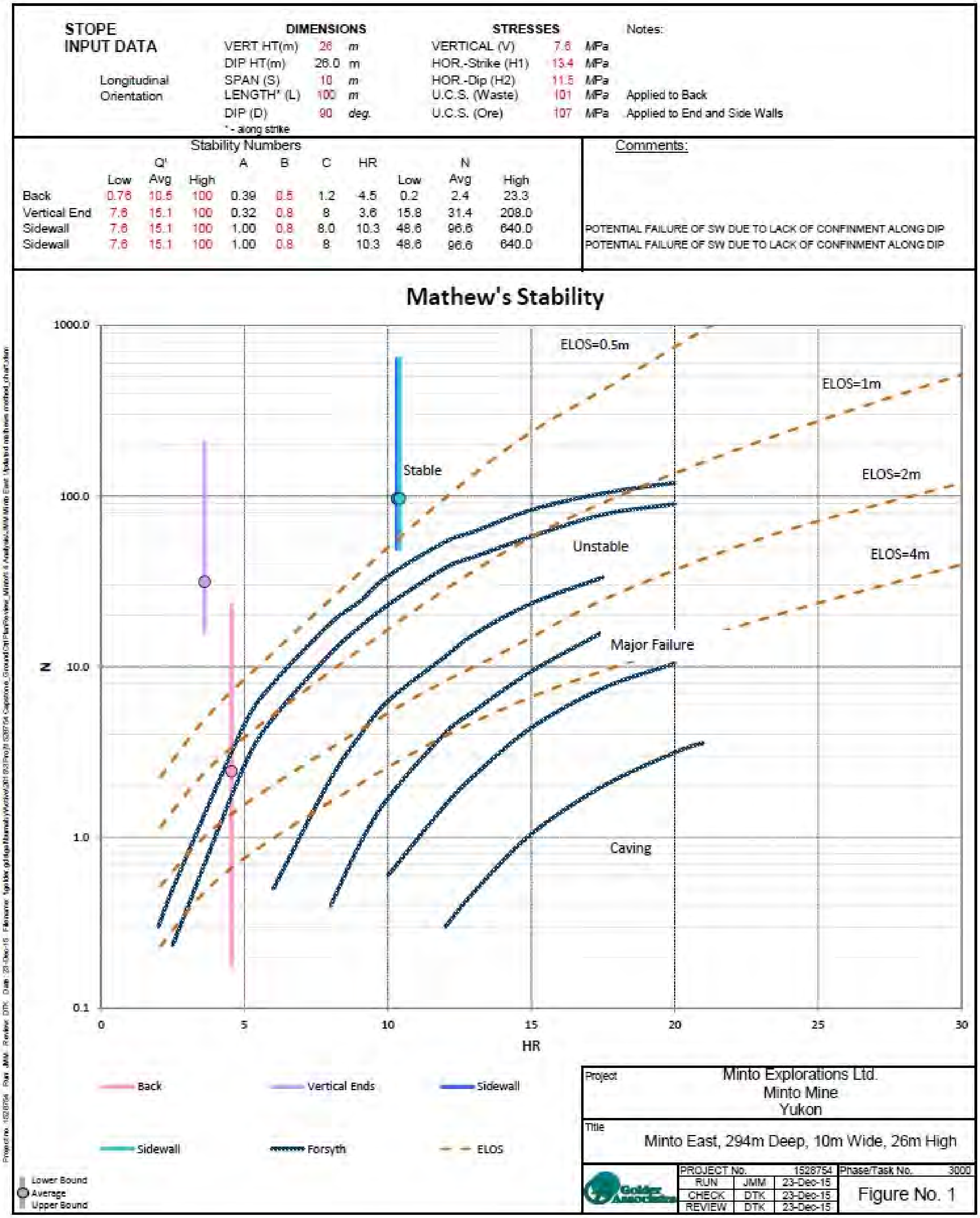
Comments:

Minto Explorations Ltd.
Minto Mine
Yukon

Area 2 UG, 164m Deep, 15m Wide, 30m High

Figure No. 5.6

Figure 6: Area 2 Stability Graph Analysis (Golder, 2015)



**STOPE INPUT DATA**

Longitudinal Orientation

**DIMENSIONS**

| | | |
|---|---|---|
| VERT HT(m) | 26 | m |
| DIP HT(m) | 26.0 | m |
| SPAN (S) | 10 | m |
| LENGTH* (L) | 100 | m |
| DIP (D) | 90 | deg. |

* - along strike

**STRESSES**

| | | | |
|---|---|---|---|
| VERTICAL (V) | 7.6 | MPa | |
| HOR.-Strike (H1) | 13.4 | MPa | |
| HOR.-Dip (H2) | 11.5 | MPa | |
| U.C.S. (Waste) | 101 | MPa | Applied to Back |
| U.C.S. (Ore) | 107 | MPa | Applied to End and Side Walls |

Notes:

Stability Numbers

| | Q' | | | A | B | C | HR | N | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg | High | | | | | Low | Avg | High |
| Back | 0.76 | 10.5 | 100 | 0.39 | 0.5 | 1.2 | 4.5 | 0.2 | 2.4 | 23.3 |
| Vertical End | 7.6 | 15.1 | 100 | 0.32 | 0.8 | 8 | 3.6 | 15.8 | 31.4 | 208.0 |
| Sidewall | 7.6 | 15.1 | 100 | 1.00 | 0.8 | 8.0 | 10.3 | 48.6 | 96.6 | 640.0 |
| Sidewall | 7.6 | 15.1 | 100 | 1.00 | 0.8 | 8 | 10.3 | 48.6 | 96.6 | 640.0 |

Comments:

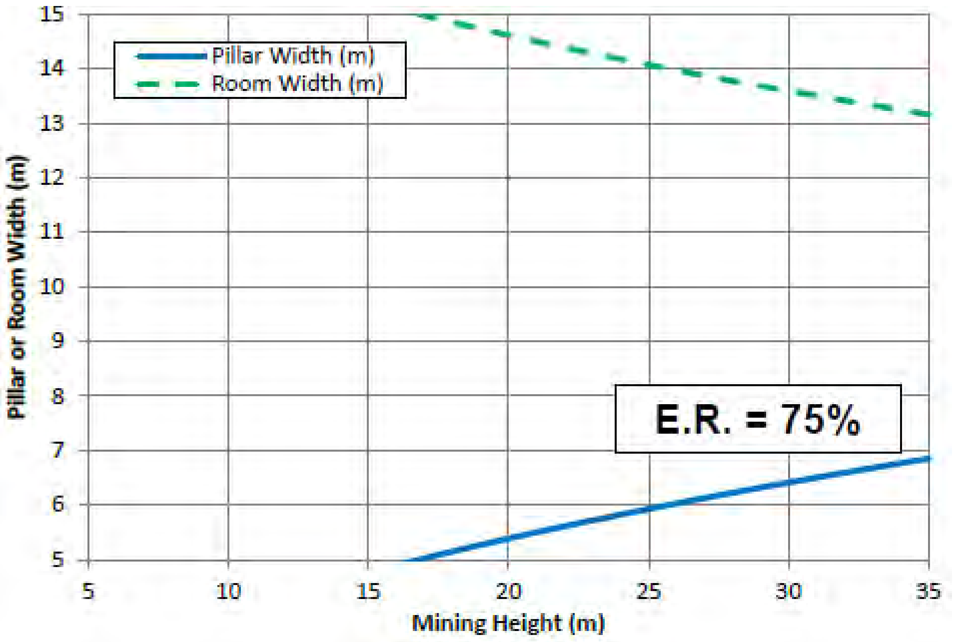
POTENTIAL FAILURE OF SW DUE TO LACK OF CONFINMENT ALONG DIP
POTENTIAL FAILURE OF SW DUE TO LACK OF CONFINMENT ALONG DIP

| | |
|---|---|
| Project | Minto Explorations Ltd.<br>Minto Mine<br>Yukon |
| Title | Minto East, 294m Deep, 10m Wide, 26m High |

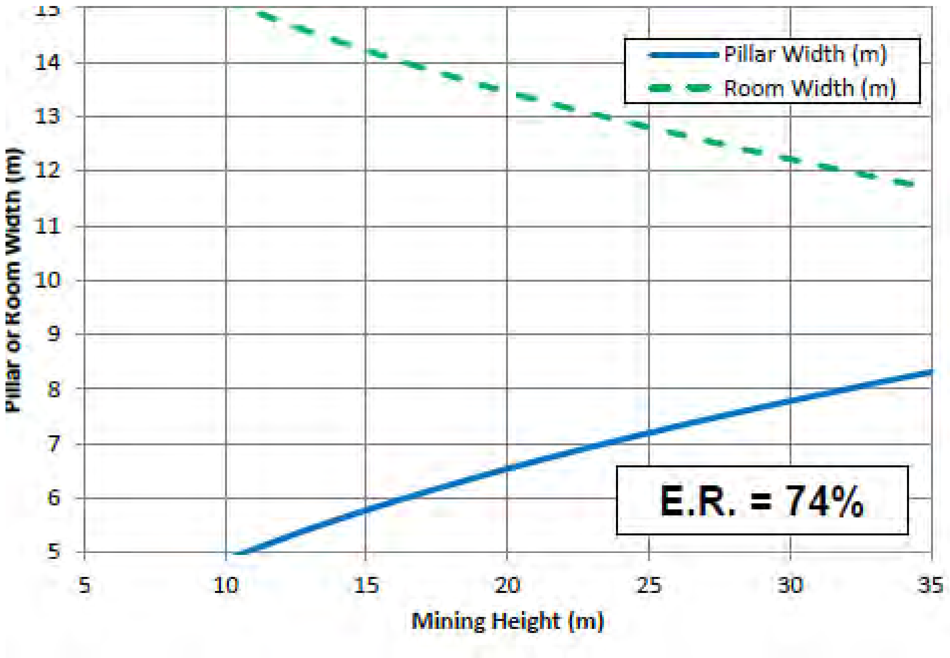
| | | | |
|---|---|---|---|
| PROJECT No. | | 1528754 | Phase/Task No. 3000 |
| RUN | JMM | 23-Dec-15 | Figure No. 1 |
| CHECK | DTK | 23-Dec-15 | |
| REVIEW | DTK | 23-Dec-15 | |

Figure 7: Minto East Stability Graph Analysis (Golder, 2016)

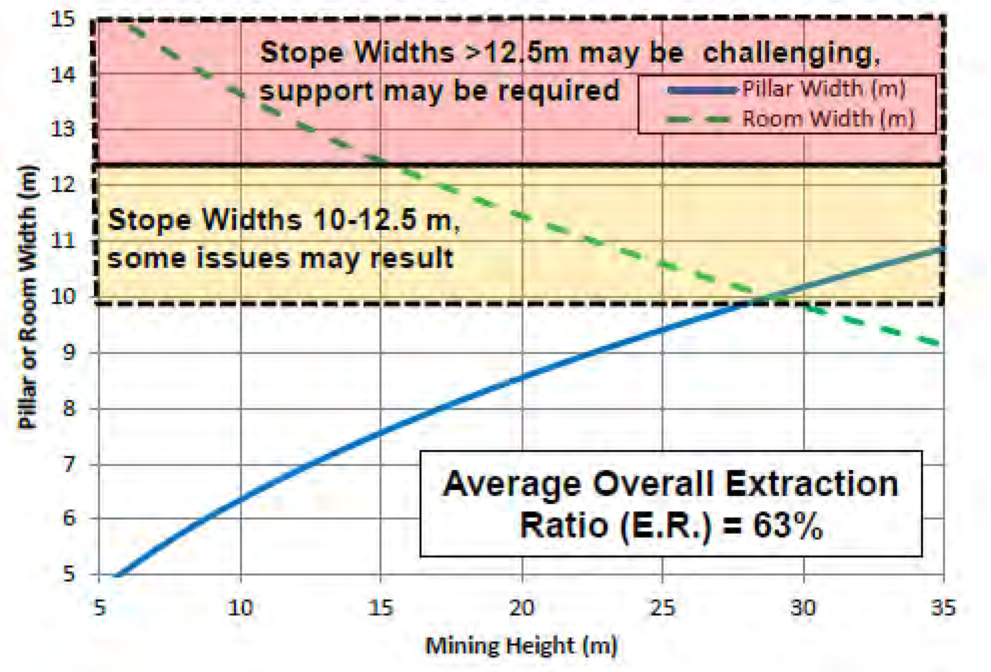
Empirical and numerical analyses were carried out by Golder Associates Ltd (Golder) to assess the Area 118, Area 2 and Minto East zones. Complete results are contained in the report titled: "Minto Mine Underground Reserve Update Geotechnical Input" (Golder, 2015). Permissible stope and pillar widths were estimated for the range of mining heights in each deposit, shown below for Area 2 and Minto East. Copper Keel will be mined within these stope parameters.



Empirical analysis results for Area 2 upper lens (650 level)



Empirical analysis results for Area 2 lower lens (630 level)



Empirical analysis results for Minto East

### 3.2.4 Stope Layout

Fig 8: shows a perspective view of the Minto East stope design looking southwest. The zone is a single lens, and is developed from east to west, then is retreated in the opposite direction.

Fig 9 shows a perspective view of the Copper Keel stope design

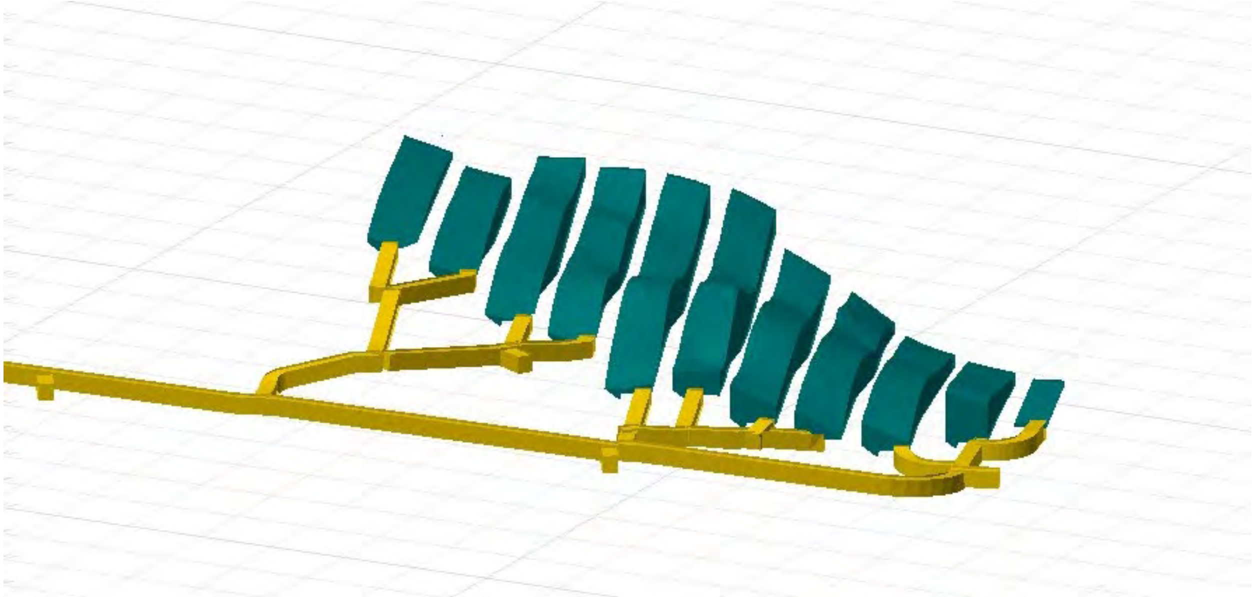


**Figure 8: Perspective view of the Minto East stope design**

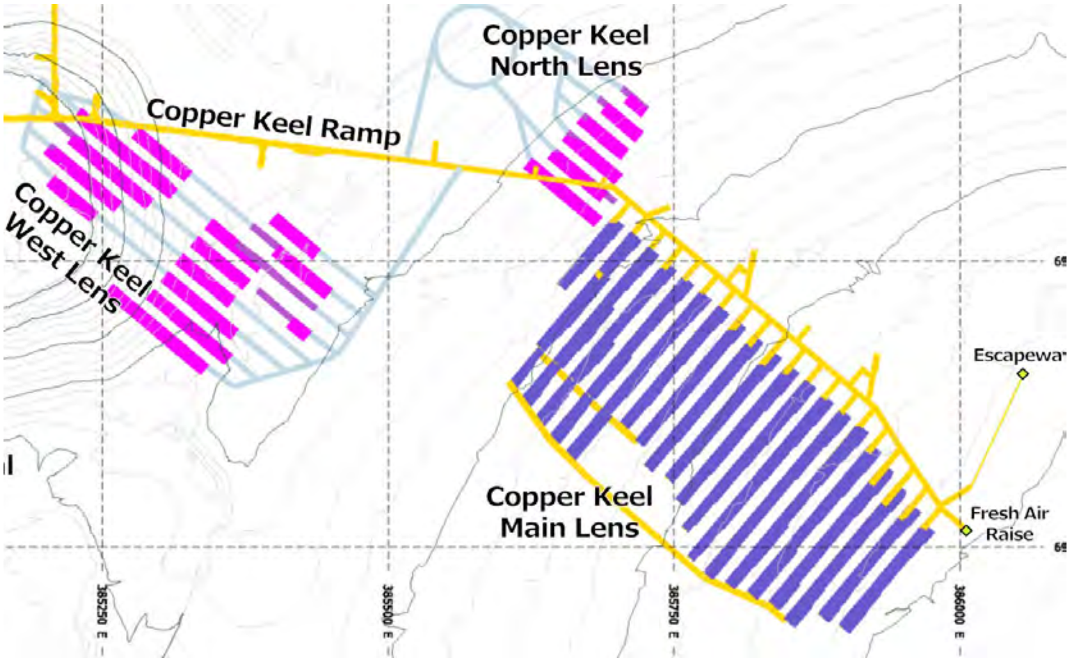


**Figure 9 Plan view of the proposed Copper Keel stope design**

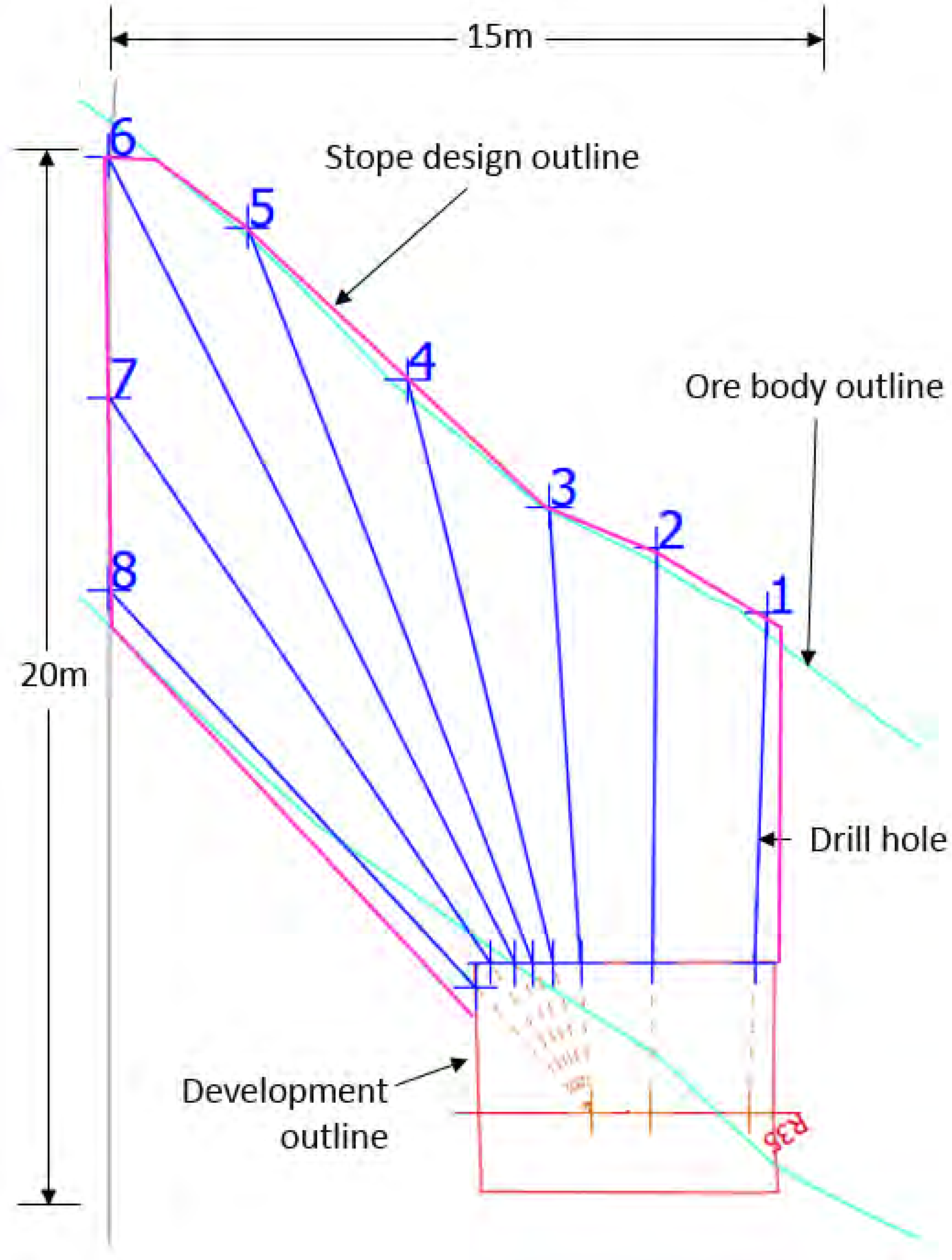


Figure 10: Typical stope layout

### 3.2.5 Material Handling

A combination of 7 and 81/2 -yard LHD units mucking into 42 and 45 tonne trucks are used for ore and waste haulage. The broken ore from the stopes is mucked by LHDs to remuck bays, or loaded directly onto trucks, which carry ore from the mine to a small stockpile adjacent to the portal. The surface mining fleet then takes ore to open pit stockpiles or to the mine crusher daily.

Waste rock from development headings is either hauled to surface in the same manner or trammed to a mined-out stope and dumped there. Development rounds are assayed, and the waste is moved to the appropriate waste dump as outlined in the Waste Rock and Overburden Management Plan (WROMP) (see Appendix B for document location). The protocols for segregation and placement of waste materials are consistent with the protocols for surface mining.

Ground Support Design

Ground support design is carried out using a combination of empirical and kinematic analyses, and experience to date at the Minto site. Assessments of geotechnical characteristics of the underground workings and performance of the ground support system are done during regular inspections and mapping.  Analysis is updated as part of the annual GCMP update and performed throughout the year as required. For kinematic analysis, wedges with an apex height taller than half the span are locked in by clamping stresses. The file location of the kinematic analyses can be found in Appendix B.

### 3.2.6 Ground Support Elements

Details and specifications of ground support elements used in standard support patterns at Minto are listed below in Table 11: Ground Support Elements.

**Table 11: Ground Support Elements**

| Support Element | Description | Minimum Breaking (tensile) Strength | Comment |
|---|---|---|---|
| Bolts | #6 (20mm) (3/4”) threaded rebar bolt w/ full column resin | 13 tonnes | - |
| | #6 (20mm) (3/4”) forged head rebar bolt w/ full column resin | 18 tonnes | Used for Alimak raise development. |
| | Super Swellex (36 mm) | 24 tonnes | Used for brow support and additional support at junctions or large spans. |
| | Standard Swellex (27 mm) | 12 tonnes | Used for development bolting. |
| | Split-sets (35 mm) | 6 tonnes | Used for face bolting or pinning screen. |
| Plates | Domed - 15 x 15 cm (6” x 6”), 6 mm (1/4”) | - | - |
| Resin | 30mm x 610mm cartridges<br>30 second (fast)<br>180 second (slow) | - | - |
| Mesh | 6 gauge welded wire mesh<br>8 gauge welded wire mesh | ~ 2-3 tonnes bag strength | Galvanized or Bright depending on the use of the excavation. |
| Straps | 0 gauge welded wire mesh straps | - | Used for stope brow support and additional pillar support where required. |

### 3.2.7 Ground Support Standards

Support standards for development and production headings have been developed for three types of ground, as summarized in Table 14: below. Detailed ground support drawings are provided in Appendix A. Ground support standards are communicated on design prints. Ground support for excavations not included in the GCMP, including vertical development, is designed on a case by case basis and issued by the Geotechnical Engineer as a Ground Control Directive.

The ground support types outlined below are typical standards - supervisors and workers installing the ground support should assess the conditions and place additional ground support over and above that stated as conditions dictate. A note detailing the reason why the extra support was required, and the type and location of the extra ground support is added to the Ground Control Logbook and communicated to the Geotechnical Engineer during the daily production meetings.

**Table 12: Typical Ground Support for Development and Production Headings**

| **Type** | | **Span (m)** | **Primary Support (typical)** | **Comment** |
|---|---|---|---|---|
| **1** | **Development Drifts (typical ground conditions)** | 5.0 | 2.4 m resin rebar in back around perimeter of mesh sheets<br>1.8 m resin rebar in back and walls to pin mesh at center<br>1.8 m resin rebar in walls to 1.5 m above floor<br>1.5 m x 1.5 m bolt spacing in a diamond pattern<br>Welded wire mesh to 1.5 m above floor | Life of mine infrastructure in typical ground conditions.<br>Overlap mesh by three squares. |
| **2** | **Production Drifts (typical ground conditions)** | 6.0 | 2.4 m resin rebar in back around perimeter of mesh sheets<br>1.8 m resin rebar in back and walls to pin mesh at center<br>1.8 m resin rebar in walls to 1.5 m above floor<br>1.5 x 1.5 m bolt spacing in a diamond pattern<br>Welded wire mesh to 1.5 m above floor | Non-permanent development (e.g. stope undercut drifts) in typical ground conditions.<br>Overlap mesh by three squares. |
| **3** | **Poor ground – fault zones** | ≤6.0 | 2.4 m resin rebar in back around perimeter of mesh sheets<br>3.6 m Super Swellex to pin mesh at center<br>1.8 m resin rebar in walls to 1.5 m above floor<br>1.5 x 1.5 m bolt spacing in a diamond pattern<br>Bright/Galvanized welded wire mesh to 1.5 m above floor | Poor ground, typical in fault zones.<br>Overlap mesh by three squares. |
| *Intersection Secondary Support* | | | | |
| **1,2,3** | **Intersections** | ≤9.5* | To be installed in addition to the primary support pattern outlined above:<br>3.6 m Super Swellex in back and shoulders<br>1.8 x 1.8 m bolt spacing - Installed at least one row past the intersection in each direction. | Intersection support to be installed prior to taking wall slash, as per MIN-OP-SWP-005 Underground Intersection Development and Ground Support |

*Intersection spans are measured using the inscribed circle method.

Intersections are preferentially located in areas of good ground conditions. If an intersection must be developed in an area of poor ground, a specific ground support design will be completed by the Geotechnical Engineer and issued as a Ground Control Directive. Ground Control Directives are filed electronically, file locations can be found in Appendix B. Where as-built surveys indicate an intersection has broken to a span greater than 9.5 m, the Geotechnical Engineer or their designate will conduct an analysis of the intersection to determine whether the standard ground support is adequate. If the findings of the analysis confirm that additional support is required a Ground Control Directive will be issued. These analyses are digitally filed; location listed in Appendix B.

Longhole stopes are pre-supported at the stope brows with secondary support in addition to the standard development support. Four types of brow support are outlined in Table 13: Where jumbo holes are to be loaded, brow support will continue down the wall as outlined in the “Type A Modified” and “Type B Modified” brow plans listed in Table 13. The Geotechnical Engineer will specify which support type to install for each brow and a brow support print will be issued. Supervisors and workers installing the ground support should assess the conditions and may install additional ground support over and above that stated as conditions dictate.

**Table 13: Ground Support Standards for Open Stope Brow Pre-Support**

| **Type** | | **Drift Span (m)** | **Brow Pre-Support** | **Comment** |
|---|---|---|---|---|
| **A** | **Stope Brow in Normal Conditions** | ≤6.0 | 3.6 m (12 ft.) Super Swellex - 1 row at 1.8 m spacing<br>0-gauge welded wire mesh straps | Used in normal ground conditions. |
| **A-Modified** | **Stope Brow in Normal Conditions with jumbo holes** | ≤6.0 | 3.6 m (12 ft.) Super Swellex - 1 row at 1.8 m spacing – row continuing down wall to jumbo holes<br>0-gauge welded wire mesh straps | Comments same as for **Type A**. |
| **B** | **Stope Brow in Fractured/Fault Zone** | ≤6.0 | 3.6 m (12 ft.) Super Swellex - 2 rows at 1.8 m spacing<br>0-gauge welded wire mesh straps on the brow row only | Used where continuous fractures, faults or highly fractured ground is encountered at the planned stope brow. |
| **B-Modified** | **Stope Brow in Fractured/Fault Zone** | ≤6.0 | 3.6 m (12 ft.) Super Swellex - 2 rows at 1.8 m spacing – rows continuing down wall to jumbo holes<br>0-gauge welded wire mesh straps on the brow row only | Comments same as for **Type B** |

# Part Two: Implementation

## 4 Ground Support Installation

All operators must be trained, qualified and authorized to use the ground support installation equipment.

Ground support installation specifications are summarized in Table 14.

**Table 14 Ground Support Installation Specifications**

| Support Element | Hole Diameter | Inflation Pressure | Comment |
|---|---|---|---|
| #6 (20mm) (3/4") threaded rebar | 26 – 33 mm | - | Hole length 10cm (4") shorter than bolt length.<br>Rebar are installed with torque tension (TT) shear pin nut to allow resin mixing and torqueing in the same direction.<br>6 ft. long rebar - 1 fast resin and 2 slow resin.<br>8 ft. long rebar - 1 fast resin and 3 slow resin. |
| Standard Swellex | 32 – 38 mm | 4350 psi (300 bar) | - |
| Super Swellex | 43 – 52 mm | 4350 psi (300 bar) | - |
| Spilt-sets | 35 – 38 mm | - | - |
| Welded wire mesh | - | - | Screen overlapped by 3 squares, with bolt placed in second square from the edge. |

## 5 Scaling

Scaling will only be undertaken by individuals that have undertaken hazard recognition training and who have been trained and certified in scaling procedures.

Appropriate length scaling bars are available on specified machines and located where required.

# 6 Rehabilitation

Areas requiring rehabilitation are identified during regular inspections by the Mine Technical team and by the workforce/supervisors who record the information in the Ground Control Logbook. Rehabilitation prints are generated by the Geotechnical Engineer and are issued to the Shifters and Superintendent. A copy of the prints is kept in the Shifters office.

# 7 Risk Assessment and Management

## 7.1 Hazard Recognition Training Program

Hazard recognition training is to be conducted on an annual basis for every person working underground at Minto. This training is mandatory and applies to new employees as a condition of employment. Specific training modules for scaling and ground support are presented at these sessions.

## 7.2 Hazard Recognition Responsibilities

The following are regulations specific to hazard recognition in the Yukon Occupational Health and Safety Regulations (in effect from May 11, 2006).

Notice of hazards 15.12

> (1) Where there is a non-continuous shift operation at a mine or project, the on-coming shift shall be warned of any abnormal condition affecting the safety of workers.
>
> (2) The warning referenced in subsection (1) shall consist of a written record in a log book under the signature of the person in charge of the off-going shift and be read and countersigned by the person in charge of the on-coming shift before the workers are permitted to assume operations in the area indicated in the record.
>
> (3) The log book referred to in subsection (2) shall be available on request to a joint health and safety committee representative, if any, and to a safety officer.

Underground Support 15.48

> (1) Every adit, tunnel, stope, or other underground opening, where a worker may be exposed to the danger of rock fall or rock burst while working or passing through, shall be supported by wooden or steel support structures, casing, lining, rock-bolts or combination of any of these to make the openings secure and safe.

*Potential rock burst*

> (2) Where ground condition indicates that a rock burst or uncontrolled fall of ground may occur, the condition and the corrective action taken shall be recorded in writing in the daily log book and signed by the shift supervisor.

*Work areas examined*

> (3) A competent person shall examine all working sections of an underground mine or project at least once during each shift.

*Non-work areas examined*

> (4) Non-working sections of an underground mine or project that are not barricaded or to which access is not prevented shall be examined at least once a month.

*Scaling tools*

> (5) An adequate quantity of properly dressed scaling bars, gads, and other equipment necessary for scaling shall be provided in working sections.

## 7.3 Ground Control Communication

Communication of ground control issues and concerns among technical, operational and management staff, and between shifts takes place at several levels and includes:

- Shift boss log book;
- Ground control log book;
- Face to face meeting of the shift supervisors between shifts;
- Verbal communication by the crews at shift change;
- Daily production meetings, and weekly planning meetings, attended by the Underground Superintendent and Minto engineering and management staff;
- Ground control directives issued by the Geotechnical Engineer; and,
- Survey prints showing adverse structure.

### 7.3.1 Review of Design Guidelines

Mine plans are reviewed by the Geotechnical Engineer or designate to assess expected geotechnical conditions and ground control aspects in the planned excavations, considering the geotechnical data and inspections/mapping carried out. Survey prints of planned excavations with prescribed ground support are signed off on by the Geotechnical Engineer or designate prior to mining of the heading. Where significant geotechnical conditions are expected, e.g. fault zones, contacts, water-bearing zones, they are to be shown on the survey prints.

### 7.3.2 Unusual Ground Conditions

The intent of the current Ground Control Standards as outlined in this document are that all expected ground conditions are addressed. In the event conditions beyond those covered in the current version of the Ground Control Standards are encountered by an operator or anyone doing a routine inspection, the area shall be roped off immediately and brought to the attention of the Supervisor. The Supervisor shall notify the Geotechnical Engineer who will inspect the area and develop a path forward. The condition must be documented in the Ground Control Log Book.

## 7.4 Incident Response and Emergency Preparedness

The Minto Mine Emergency Response Plan documents the incident response and emergency preparedness procedure. This plan is updated annually by the Minto Health and Safety Department.

### 7.4.1 Falls of Ground

All rock fall incidents are documented in the Ground Control Log Book. Reportable rock falls are considered unexpected falls greater than 50 tonnes within a man-entry excavation and are fully investigated, reported to Yukon Workers' Compensation Health and Safety Board (YWCHSB) and archived as per Minto incident response procedures.

Details of all reported falls of ground will be recorded electronically in a rock fall database, maintained by the Geotechnical Engineer. The following items are recorded:

- General information: location, date and time, injuries, damage
- Location: depth below surface, excavation type, distance from active face
- Excavation details: age of excavation, dimensions, excavation shape
- Geotechnical conditions: rock quality, structure, water inflows
- Ground support details: implemented support standard, rehabilitation.
- Failure details: dimensions, failure mechanism, types of ground support failure
- Potential contributing factors: ground support, blasting, stress, ground condition, human factor
- Personnel exposure: time of occurrence, activity in area
- Possible preventative actions.

To date, no unexpected falls of ground have occurred in Minto underground development.

# 8 Workforce Training

Underground mining is currently being carried out by a mining contractor. Workforce training consists of Minto safety training, Safe Work Practices (SWP’s), and Safe Job Procedures (SJP’s).

## 8.1 Safe Work Practices (SWP’s) and Safe Job Procedures (SJP’s)

It is a requirement that employees and contractors be trained in the use of relevant Safe Work Practices (SWP’s) and Safe Job Procedures (SJP’s) that apply to their work environment. All SWP’s/SJP’s required for the work are reviewed and signed off by the employees upon induction to the Minto mine site. SWP’s/SJP’s are linked to and used in competency-based training programs. Employees are assessed in the workplace periodically on their understanding and compliance with SWP’s/SJP’s using Planned Job Observations (PJO’s) performed by the supervisor.

## 8.2 Training of Workforce

Training is presented to the general underground workforce by their supervisor at Minto Mine. This training is site specific and includes identification of ground types, structural features such as wedges and blocks, recognition of loose, scaling, minimum support standards and reporting unusual conditions.

## 8.3 Training of Supervision

Training is presented to underground supervisors by the Geotechnical Engineer or designate. This training is site specific and covers all areas pertinent from a supervisory point of view such as: selection of support types, dealing with unusual ground conditions and supervisory reporting requirements in addition to the general training to be provided to the mining workforce.

# Part Three: Monitoring and Verification

# 9 General Practices and Procedures

## 9.1 Ground Inspections

All underground workers will inspect the ground conditions each time the workplace is entered as per the Minto Mine 5 - point safety card system. Unusual conditions such as falls of ground, excessive loose, adverse structures, signs of high stress, or ground support damage must be noted and reported to the supervisor.

Routine ground inspections will be conducted by the Geotechnical Engineer and/or Chief Engineer to assess the stability of mine openings, ground support performance and the quality of ground support installation. A report with the findings from the routine ground support inspections will be prepared by the Geotechnical Engineer and distributed to the Mine Technical Department and contractor supervisors. The file location where these inspection reports are kept can be found in Appendix B.

An annual inspection of ground support conditions shall be conducted by an external consultant. The file location where these inspection reports are kept can be found in Appendix B.

## 9.2 Ground Control Log Book

The Ground Control Log Book is maintained as a live record of ground control related issues such as unusual conditions, falls of ground, incidents or accidents, remedial measures, problems with support consumables etc. This ensures the transfer of information between shifts and Engineering/Technical staff. The Ground Control Log Book is to be updated and signed by both the finishing and oncoming shifter when details of concern are logged. This is then reviewed/signed by the Geotechnical Engineer. The details of concern are investigated by the Geotechnical Engineer and agreed remedial actions entered in the log book.

## 9.3 Geotechnical Mapping

Geotechnical mapping for rock quality and rock structure is carried out to verify rock mass characterization assumptions (summarized in Section 2) used in the geotechnical design. This is performed in the field for development drifts and using digital mapping software for stope mapping. This data is reviewed regularly to identify significant geotechnical features and is summarized and analyzed annually as part of the Ground Control Management Plan update. The file location of where the geotechnical mapping is stored can be found in Appendix B.

## 9.4 Excavation Surveys

Regular surveys of all workings are carried out and transferred to as-built drawings. This provides an estimate of over-break which may indicate poor ground conditions or poor drilling/blasting practices.

Cavity monitor surveys (CMS) are performed on all open stopes. If analysis shows deviation from that planned, subsequent stopes are adjusted to achieve the designed pillar sizes/shape.

## 9.5 Instrumentation

No geotechnical instrumentation is currently installed underground.

# 10 Quality Assurance/Quality Control

## 10.1 Ground Support Testing

Testing of ground support elements is carried out when development is taking place according to Table 15. Only suitably trained personnel who have been trained and signed off on the applicable SWP may carry out ground support testing under the supervision of the Geotechnical Engineer.

**Table 15: Ground Support Testing Frequency and Specifications**

| Element | Ultimate Strength (tonnes) | Yield Strength (tonnes) | Average Bond Strength (based on testing to date) (tonnes/m) | Testing Method | Number of bolts to be tested per month (during development) | Test Load (tonnes) |
|---|---|---|---|---|---|---|
| 20mm threaded rebar w/ resin | 13 | 9 | 40 | Pull test—full column | 3 | 9 |
| | | | | Pull test—short encapsulation | 3 | Until bolt slippage |
| Standard Swellex | 12 | 10 | 12 | Pull test—full inflation | 2 | 8 |
| | | | | Pull test—partial inflation | 2 | Until bolt slippage |
| Super Swellex | 24 | - | 26 | Pull test—full inflation | 2 | 20 |
| | | | | Pull test—partial inflation | 2 | Until bolt slippage |

### 10.1.1 Test Bolt Installation

Bolts for pull-testing are installed by the bolter operator according to the following guidelines:

- Installed and marked specifically for testing purposes and as such are not part of the regular ground support pattern.
- Installed in the lower wall to allow pull testing to be carried out safely from floor level.
- Installation locations are painted by the Geotechnical Engineer and preferentially located in safety bays or cut-outs to allow testing to be carried out safely away from equipment traffic.

- Installed in both ore and waste, and in varying rock type/quality where applicable.
- For bond strength tests (short encapsulation/inflation), the following specifications are used:
    - Rebar – resin encapsulation length less than approximately 30 cm, installed at the toe of the hole. This requires only ½ stick of fast resin to be installed. The remainder of the hole is filled with sticks of inert test resin.
    - Swellex/Super Swellex – inflation length less than approximately 1m, inflated at the toe of the hole. The remaining length at the collar of the hole is sleeved to prevent inflation.

### 10.1.2 **Pull Test Procedure**

Pull tests are conducted according to the SWP ENG-SWP-010 Rock Bolt Pull Testing. If tests fail to meet the set criteria, further tests will be conducted to verify that the problem is not widespread. If the problem is widespread, the area will be shut down and an investigation will be carried out by Minto Mine Technical Services to ascertain the cause of the failures and develop rehabilitation/corrective actions.

### 10.1.3 **Documentation**

Records of all tests are documented in a master Excel spreadsheet; the file location is listed in Appendix B. Information recorded includes bolt type, location, rock type, test result and description. A memorandum is issued monthly communicating test results and pertinent information to Minto Mine Technical and underground operations staff.

## 10.2 Ground Support Quality Assurance / Quality Control

### 10.2.1 Materials Management

Regular checks are required to ensure that all ground support materials are of a suitable standard and quality, fit for intended purpose, and are stored in accordance with manufacturers' recommendations.

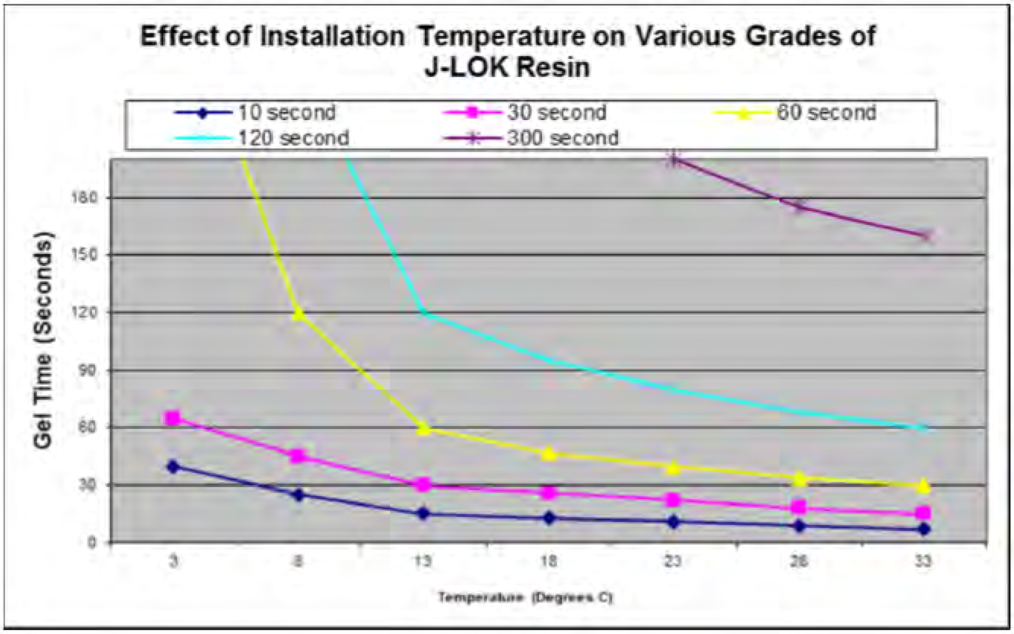
Resin Storage and Handling

The most sensitive ground support element is resin which should be stored and handled with the following guidelines:

- Resin should be stored in a cool and dry location, avoiding direct sunlight and rain. Excessive heat reduces the shelf life of the resin.

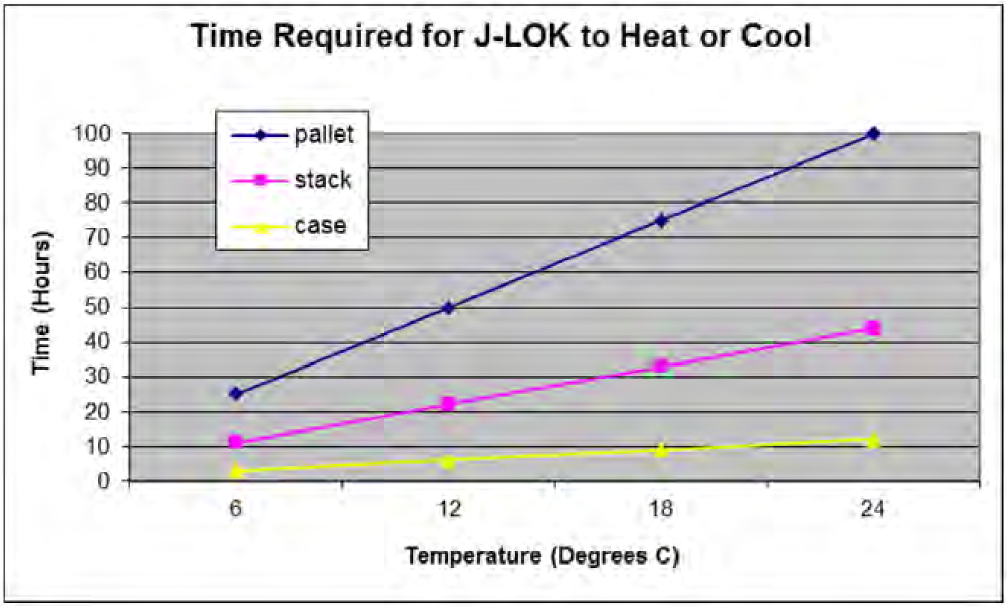
- Stock must be rotated. The resin that is first in should be first out. Out-dated resin should not be used. Resin typically has a one-year shelf life, but 1-2 month inventories are the best way to manage resin.

- Resin performance is highly sensitive to installation temperature.



- Underground, resin boxes should be laid flat, not stood on end. The resin should be moved from storage directly to the machine.

- Frozen cartridges must be thawed before being used. Freezing and thawing does not affect the performance of the resin. Resin boxes should not be left on top of hot locations for extended periods.



- Wear gloves and glasses when working with resin products. Upon contact with skin, wash exposed area immediately. If there is contact with the eyes, flush thoroughly and seek immediate medical counsel and treatment.

### 10.2.2 Task Observation

Task observations are carried out on ground support installation on a regular basis (minimum one per month) by the Ground Control Engineer. The location of where the completed inspection forms are stored is listed in Appendix B. Any findings will be communicated through Ground Control Directives. Typical verification checks include:

- Confirm screen overlap is sufficient.
- Visual check of adherence to bolting pattern as per ground support standard.
- Check that adequate scaling is carried out prior to ground support installation.
- Check that the bit size is within the recommended size range.
- Check of Swellex pump pressures.
- Check that correct resin cartridges are being used (fast vs slow).
- Observe bolt spin time and delay time prior to tensioning.
- Check of rebar tensioning torque.

# 11 Review of the Ground Control Management Plan

## 11.1 Review and Updates

The Mine Manager/Chief Engineer will ensure a review of the Ground Control Management Plan at the following milestones/occurrences:

- Immediately following a ground control related injury to any employee/contractor/visitor;
- Immediately following a ground control related near miss incident;
- As soon as possible following any significant change in mine design, support design/consumables, ground conditions or excavation stability; and,
- Annually.

The Mine Manager/Chief Engineer will ensure that the review/update is carried out by a suitably qualified person.

Following a review of the Ground Control Management Plan, the Mine Manager/Chief Engineer (or designate) will ensure the review outcomes are communicated to the workforce and the Ground Control documentation is updated in a timely manner.

## 11.2 Random Audits

Random audits of ground control are conducted by the Geotechnical Engineer or nominee to monitor compliance with the requirements of the Ground Support Standards and Safe Work Procedures.

## 11.3 External Audits

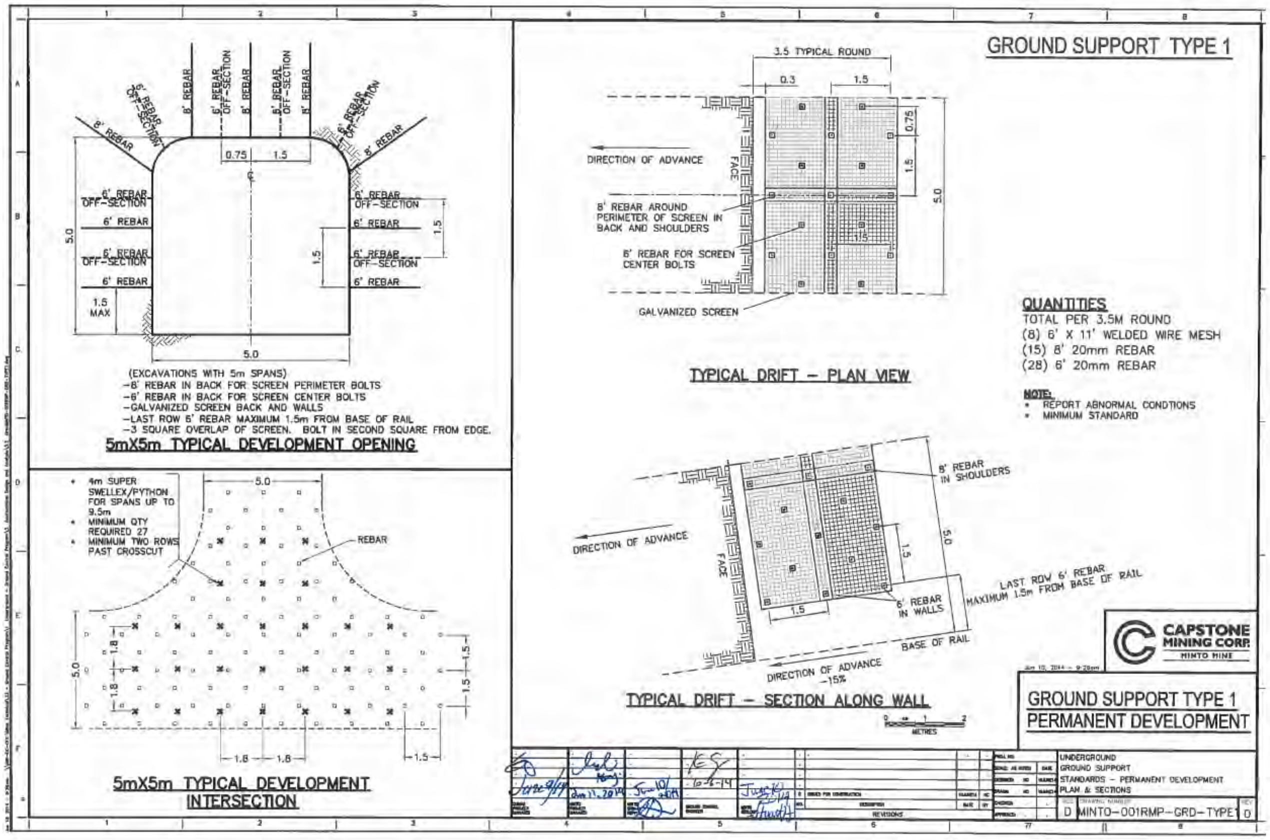
An independent audit of the Ground Control Management Plan is required at least every year.

## 11.4 Conformance to Regulatory Requirements

The Geotechnical Engineer is to ensure that any new legislation or developments that affect best practice in ground control are considered and where relevant incorporated into the revised GCMP. Mining legislation requires keeping track of new developments and design tools. This will involve liaison with both internal and external parties.

# Appendix A

# Ground Support Drawings



(EXCAVATIONS WITH 5m SPANS)
- 8' REBAR IN BACK FOR SCREEN PERIMETER BOLTS
- 6' REBAR IN BACK FOR SCREEN CENTER BOLTS
- GALVANIZED SCREEN BACK AND WALLS
- LAST ROW 6' REBAR MAXIMUM 1.5m FROM BASE OF RAIL
- 3 SQUARE OVERLAP OF SCREEN. BOLT IN SECOND SQUARE FROM EDGE.

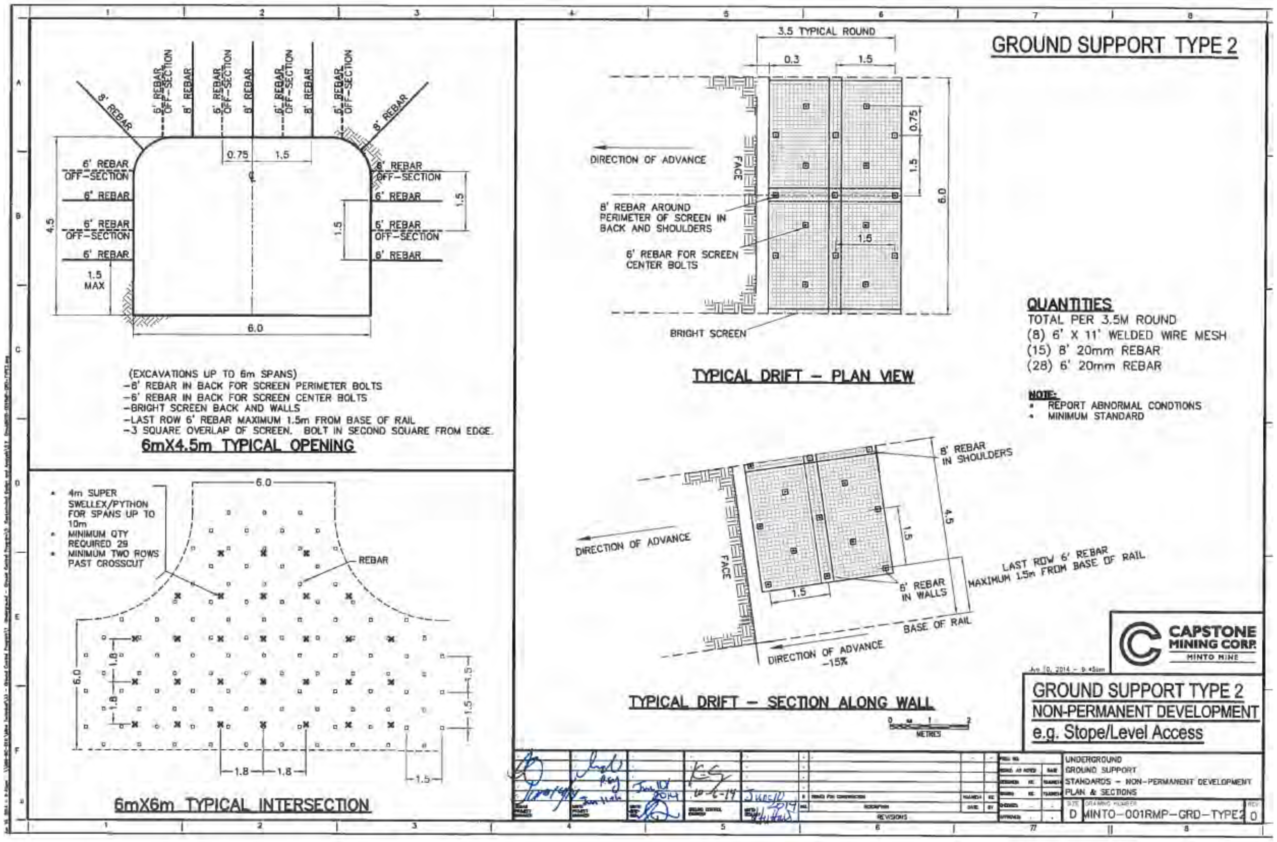
**5mX5m TYPICAL DEVELOPMENT OPENING**

**QUANTITIES**
TOTAL PER 3.5M ROUND
(8) 6' X 11' WELDED WIRE MESH
(15) 8' 20mm REBAR
(28) 6' 20mm REBAR

**NOTE:**
- REPORT ABNORMAL CONDTIONS
- MINIMUM STANDARD

GROUND SUPPORT TYPE 1
PERMANENT DEVELOPMENT

UNDERGROUND
GROUND SUPPORT
STANDARDS – PERMANENT DEVELOPMENT
PLAN & SECTIONS
D MINTO–001RMP–GRD–TYPE1 0



(EXCAVATIONS UP TO 6m SPANS)
- 8' REBAR IN BACK FOR SCREEN PERIMETER BOLTS
- 6' REBAR IN BACK FOR SCREEN CENTER BOLTS
- BRIGHT SCREEN BACK AND WALLS
- LAST ROW 6' REBAR MAXIMUM 1.5m FROM BASE OF RAIL
- 3 SQUARE OVERLAP OF SCREEN. BOLT IN SECOND SQUARE FROM EDGE.

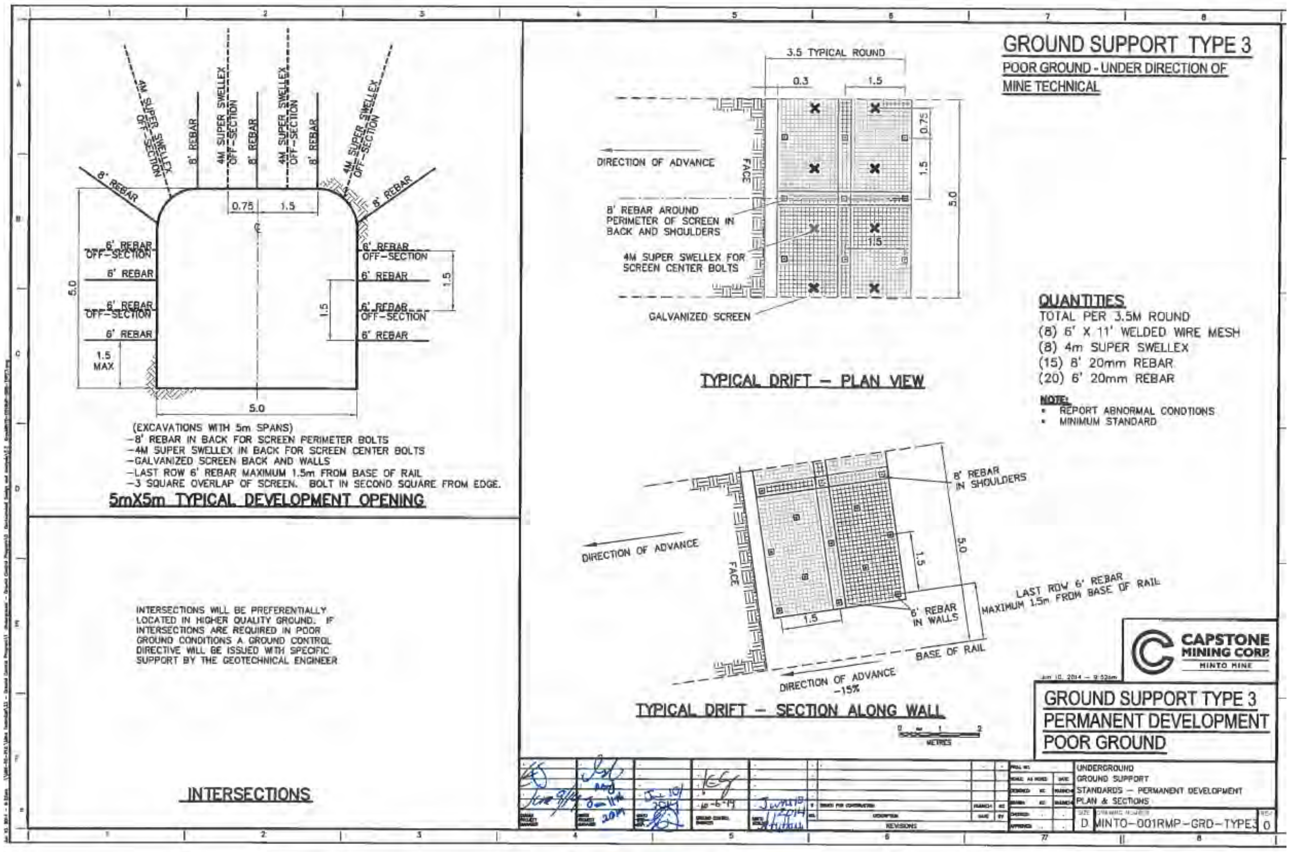
**6mX4.5m TYPICAL OPENING**

**QUANTITIES**
TOTAL PER 3.5M ROUND
(8) 6' X 11' WELDED WIRE MESH
(15) 8' 20mm REBAR
(28) 6' 20mm REBAR

**NOTE:**
- REPORT ABNORMAL CONDTIONS
- MINIMUM STANDARD

GROUND SUPPORT TYPE 2
NON-PERMANENT DEVELOPMENT
e.g. Stope/Level Access

UNDERGROUND
GROUND SUPPORT
STANDARDS – NON-PERMANENT DEVELOPMENT
PLAN & SECTIONS
D MINTO–001RMP–GRD–TYPE2 0



(EXCAVATIONS WITH 5m SPANS)
-8' REBAR IN BACK FOR SCREEN PERIMETER BOLTS
-4M SUPER SWELLEX IN BACK FOR SCREEN CENTER BOLTS
-GALVANIZED SCREEN BACK AND WALLS
-LAST ROW 6' REBAR MAXIMUM 1.5m FROM BASE OF RAIL
-3 SQUARE OVERLAP OF SCREEN. BOLT IN SECOND SQUARE FROM EDGE.

5mX5m TYPICAL DEVELOPMENT OPENING

INTERSECTIONS WILL BE PREFERENTIALLY LOCATED IN HIGHER QUALITY GROUND. IF INTERSECTIONS ARE REQUIRED IN POOR GROUND CONDITIONS A GROUND CONTROL DIRECTIVE WILL BE ISSUED WITH SPECIFIC SUPPORT BY THE GEOTECHNICAL ENGINEER

INTERSECTIONS

GROUND SUPPORT TYPE 3

POOR GROUND - UNDER DIRECTION OF MINE TECHNICAL

TYPICAL DRIFT – PLAN VIEW

**QUANTITIES**
TOTAL PER 3.5M ROUND
(8) 6' X 11' WELDED WIRE MESH
(8) 4m SUPER SWELLEX
(15) 8' 20mm REBAR
(20) 6' 20mm REBAR

**NOTE:**
- REPORT ABNORMAL CONDTIONS
- MINIMUM STANDARD

TYPICAL DRIFT – SECTION ALONG WALL

GROUND SUPPORT TYPE 3
PERMANENT DEVELOPMENT
POOR GROUND

# Appendix B

# File Locations

| Documents | File Locations |
|---|---|
| Reports | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\6 Reports |
| Ground Control Directives | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\2 Design and Analysis\1 Ground Support\Ground Control Directives |
| Ground Falls | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\4 Groundfalls and Rehabilitation\Ground Falls |
| Ground Support Analysis | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\2 Design and Analysis\1 Ground Support\Ground Support Analysis |
| Ground Support Standards | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\2 Design and Analysis\1 Ground Support\Ground Support Standards |
| Inspections | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\3 Monitoring, Inspections and Instrumentation\Inspections |
| Annual Inspections | X:\Mine Technical\23 - Annual Inspection Reports for EMR |
| Mapping and Core Logging | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\1 Mapping and Logging |
| Rehabilitation logbook | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\4 Groundfalls and Rehabilitation\Rehabilitation |
| Pull Testing | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\3 Monitoring, Inspections and Instrumentation\Pull Testing |
| Bolter QA/QC | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\3 Monitoring, Inspections and Instrumentation\Bolter QA-QC |
| Kinematic Analysis | X:\Mine Technical\33 - Ground Control Program\1  Underground - Ground Control Program\2 Design and Analysis\1 Ground Support\Ground Support Analysis\2017 ME |
| WROMP | X:\Mine Technical\17 – Water Management\ 19 - Waste Dumps\8. WROMP |

## SAFE WORK PRACTICE

# MIN-OP-SWP-026_R1 – Underground Stope Blasting Notification for Surface Operations

## 1. PURPOSE

To ensure the safety of surface operations and personnel during stope blasting operations in Copper Keel (Cu-Keel) Underground.

## 2. SCOPE

This safe work practice pertains to all employees and contractors working on surface as well as underground workers involved in blasting operations.

## 3. AFFECTED DEPARTMENTS

- U/G Department
- Technical Service
- Site Services
- IT

## 4. DEFINITIONS

- Underground Stope Blast – Detonation of underground production holes.
- Cu-Keel UG blast zone on surface – The area to the East (right) of Blast Guard (shown within the red box) in Figure 1.

## 5. RESPONSIBILITIES

### Employer Responsibilities

- Ensure workers (including all contractors) have read and understand this Safe Work Practice.

### Safety Department Responsibilities

- Maintain a hard copy and electronic record of this Safe Work Practice for access by site personnel.
- Ensure this Safe Work Practice complies with YWCHSB Act and Regulations.

**Worker Responsibilities**

- Read, understand, and follow this Safe Work Practice.
- Ensure all instructions given by their supervisor are followed and notify their supervisor if any unsafe conditions exist.
- Participate in any required training provided to complete this task.

**Underground Blaster Responsibility**

- Ensure that Surface Operations receives notification of pending Underground Stope Blast.
- Request confirmation that all Surface Operations workers and equipment are clear from the Cu-Keel blast Zone on Surface before initiation of stope blast.

**UG Supervisor Responsibilities**

- Ensure all workers are clear from Cu-Keel UG blast zone on surface prior to Underground Stope Blast.

## 6 SAFE WORK PRACTICE

### 6.1 Underground Stope Blast Notification Email Distribution

The Minto IT department will maintain a blast notification email list. This list will be used to distribute the stope blast notification.

The Minto Underground Mine Engineer/EIT or Technician will send an email to the blast notification email list on the day of the blast, no later than 4 hours prior to the blast time, communicating that there will be an Underground Stope Blast today and the time of the blast.

In the event of a delayed or cancelled blast, the Minto Underground Mine Engineer or Technician will send an email to the blast notification group communicating the change.

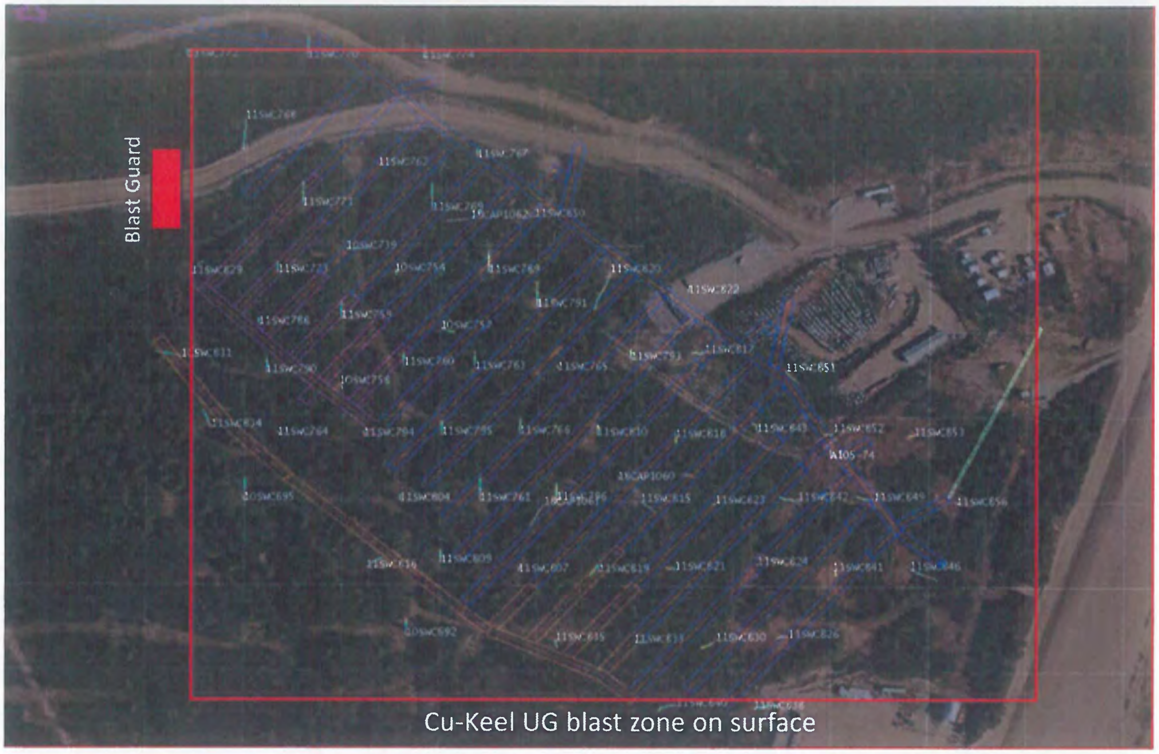


**Figure 1: A map depicting the proximity of the Cu-keel Underground workings to the surface infrastructure.**

### 6.2 Notification of Surface Operations prior to initiation of Underground Stope Blast

The Underground Blaster will call the UG Supervisor on radio channel #13 and give them a 10-minute warning prior to initiating the blast.

The UG Supervisor will direct all workers to clear Cu-Keel UG blast zone on surface and places a blast guard as shown in Figure 1.

Prior to initiation of the blast, the Underground Blaster will radio the UG Supervisor and request confirmation that all personnel are clear from Cu-Keel UG blast zone on surface.

The UG Supervisor will confirm that the personnel are clear.

The Underground Blaster will initiate the Blast.

## SWP Development and Approval

| | **Developed / Revised by:** (Print) | **Date:** |
|---|---|---|
| **Worker:** | Joseph Sen | Jun. 06/20 |
| **Worker:** | | |
| **Supervisor:** | | |
| **Supervisor:** | CORY MACDONALD | JAN. 6. 2020 |
| **JOHSC Representative:** | Kathrine Penney | Jan 6, 2020 |
| **JOHSC Representative:** | | |
| **Departmental Manager:** | | |
| | **Reviewed By:** (Print & Sign) | |
| **Safety Department:** | | |
| **Signature:** | | |
| | **Approved By:** (Print & Sign)<br>Determined by Safety Dept., enter NA if not applicable. | |
| **Departmental Manager:** | Brendan Zuidema | |
| **Signature:** | | |
| **General Manager:** | Sebastien Tolgyesi | 03/01/2020 |
| **Signature:** | | |

**Clarification of this safe work practice can be directed to the Safety Department.**