Minto Mine
QML-0001

Underground Mine Development and Operations Plan
2017-01

Prepared by:
Minto Explorations Ltd.

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1 Introduction

This Underground Mine Development and Operations Plan (UMDOP) has been prepared to satisfy the requirements of Quartz Mining Licence (QML-0001). Previous versions of this plan were created to license the M-zone, Area 118 and Area 2 zones of the Minto South Underground. This revision presents plans for the Minto East zone.

1.1 Background

Minto Mine has been in operation since 2007. Operations consisted solely of open pit mining from 2007 until 2012, at which time development of the Minto South Underground commenced. Development continued through early 2013.

In January 2014, through continued consultation with Yukon Government Department of Energy, Mines and Resources, Minto sought approval for changing the mining sequence such that the “M-zone,” originally the final ore zone to be mined in the Phase IV plan, could be brought ahead in the schedule and accessed from a portal at the bottom of the completed Area 2 Stage 2 pit. Approval to proceed was granted on January 10, 2014.

The M-zone was completed in October 2014, at which time mining commenced in the Area 118 zone. This zone was completed in April 2016 and mining then transitioned to the Area 2 zone. Area 2 is still actively being mined at the time of this document, and is scheduled to be completed in Q3 2016.

This document provides updated plans for the mining of the next zone in the Minto South Underground. This zone, named Minto East, will be mined using the same longhole open stoping method used for all other zones previously and currently being mined at Minto.

This revision to the UMDOP includes information previously submitted and approved, while providing updated as-built drawings, production data, and revised mine designs for the Minto South Underground.

In August 2013, Energy, Mines and Resources published a guidance document for quartz mining projects that details the requirements for a Mine Development and Operations Plan under the QML. Some of those requirements are largely related to the surface mine operations and have been addressed in various other QML-0001 submissions, primarily the "*Mine Development and Operations Plan*.”

2 Operations Overview

Figure 2-1 shows an aerial overview of the mine site as of September 2014, the most recent aerial orthophoto taken. Notable surface changes since then, not shown, include the following:

- Removal of M-zone infrastructure and commencement of tailings deposition to Area 2 pit in April 2015;
- Mining of the Minto North pit from August 2015 to September 2016;
- Dumping of waste rock from Minto North pit to the Main Waste Dump Expansion and Mill Valley Fill Extension Stage 2 in 2015 and 2016;
- Re-sloping of the Southwest Dump, Mill Valley Fill Extension, Dry Stack Tailings Storage Facility, and Main Waste Dump Expansion, as part of progressive reclamation activities in 2017; and,
- Mining of the Area 2 Stage 3 pit, starting in January 2017 and scheduled to be completed in July 2017.

The following sections describe the completed and in progress underground areas. Figures 2-2 to 2-4 show as-built development, Figures 2-5 to 2-6 show as-built stopes.

2.1 M-Zone Underground (completed)

The M-zone underground operation was completed in October 2014. Between January and May 2015, additional surface mining of the Area 2 pit was then undertaken, recovering remnant ore from the pillars between the pit and the adjacent M-zone underground workings. As remnant mining was retreating, backfilling of the Area 2 pit began, burying the portal and the breakthroughs between stopes and surface with tailings.

2.2 Area 118 Underground (completed)

Underground mining in the Area 118 zone was completed in April 2016. Stoping was retreated back to the three accesses at 740, 710 and 690 levels. All are now barricaded and no longer accessible. Water from the zone is pumped from the 690 access to prevent overflow into the Area 2 ramp.

2.3 Area 2 Underground (in progress)

Production in the Area 2 zone commenced in July 2016 and is underway at the time of this report. Sill development is currently in progress on the 620 level; stoping is in progress on the 650 and 630 levels and is expected to be completed in October 2017.

Figure 2-1: Site overview

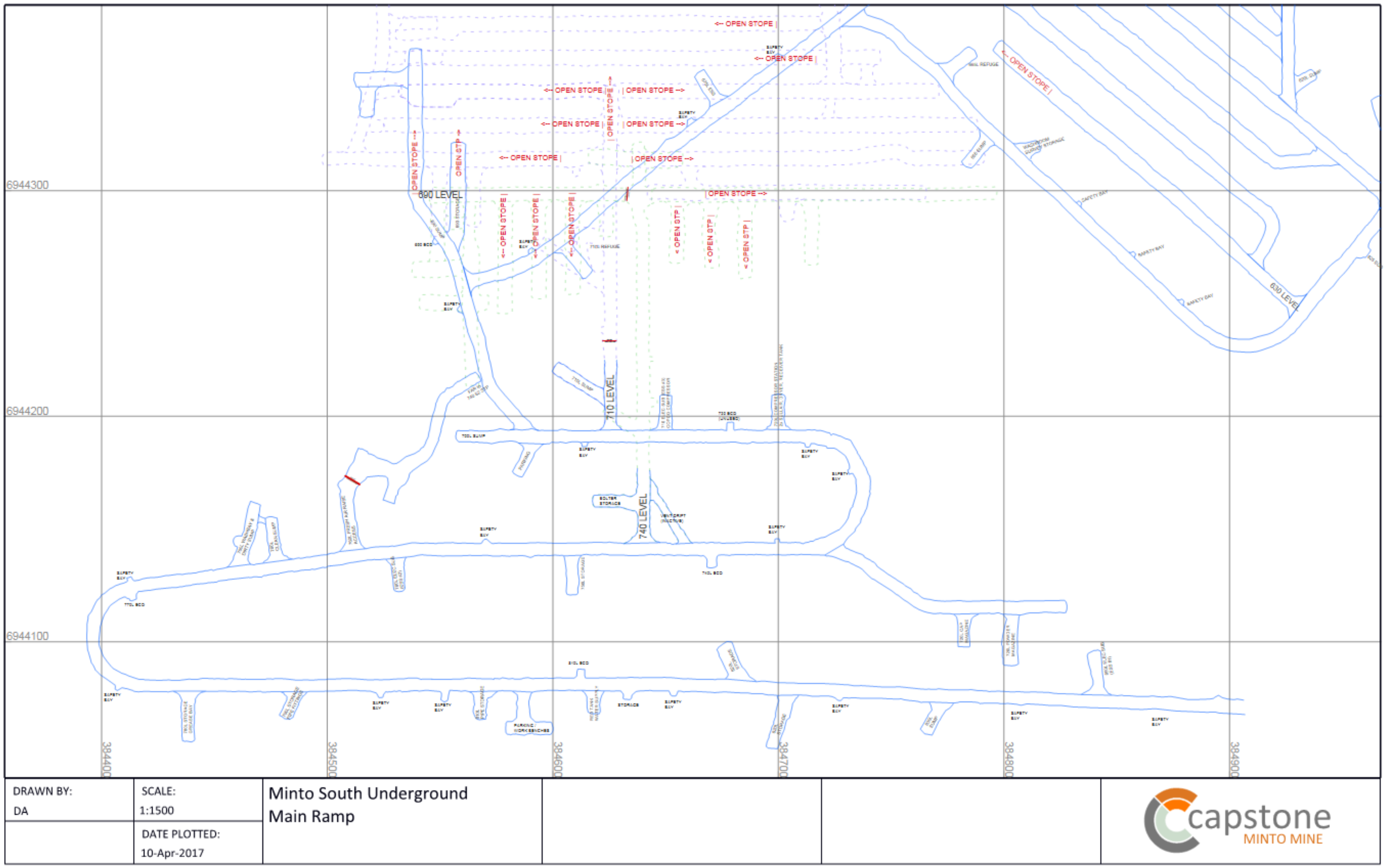


Figure 2-2: As-built main access ramp

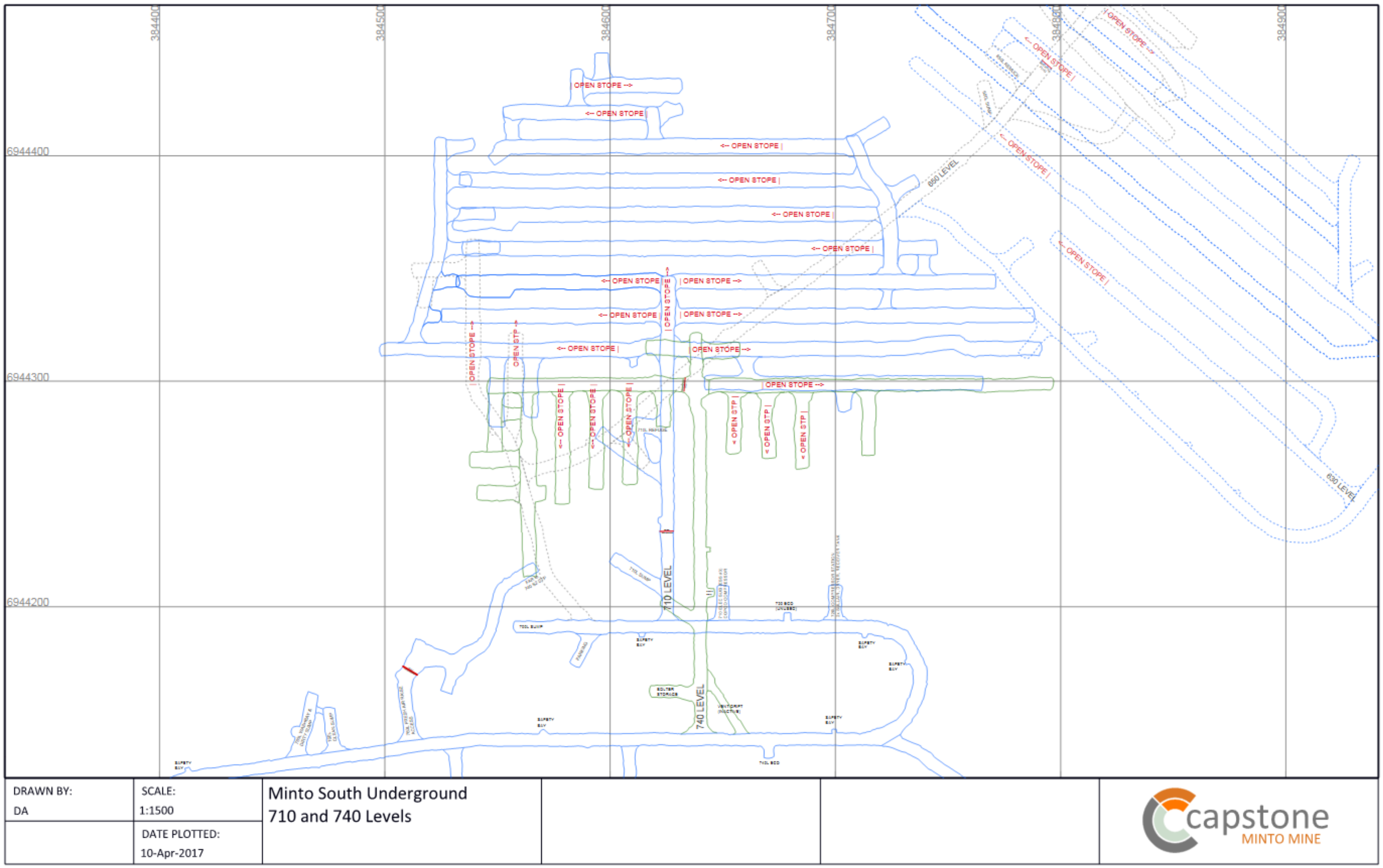


Figure 2-3: As-built Area 118 development

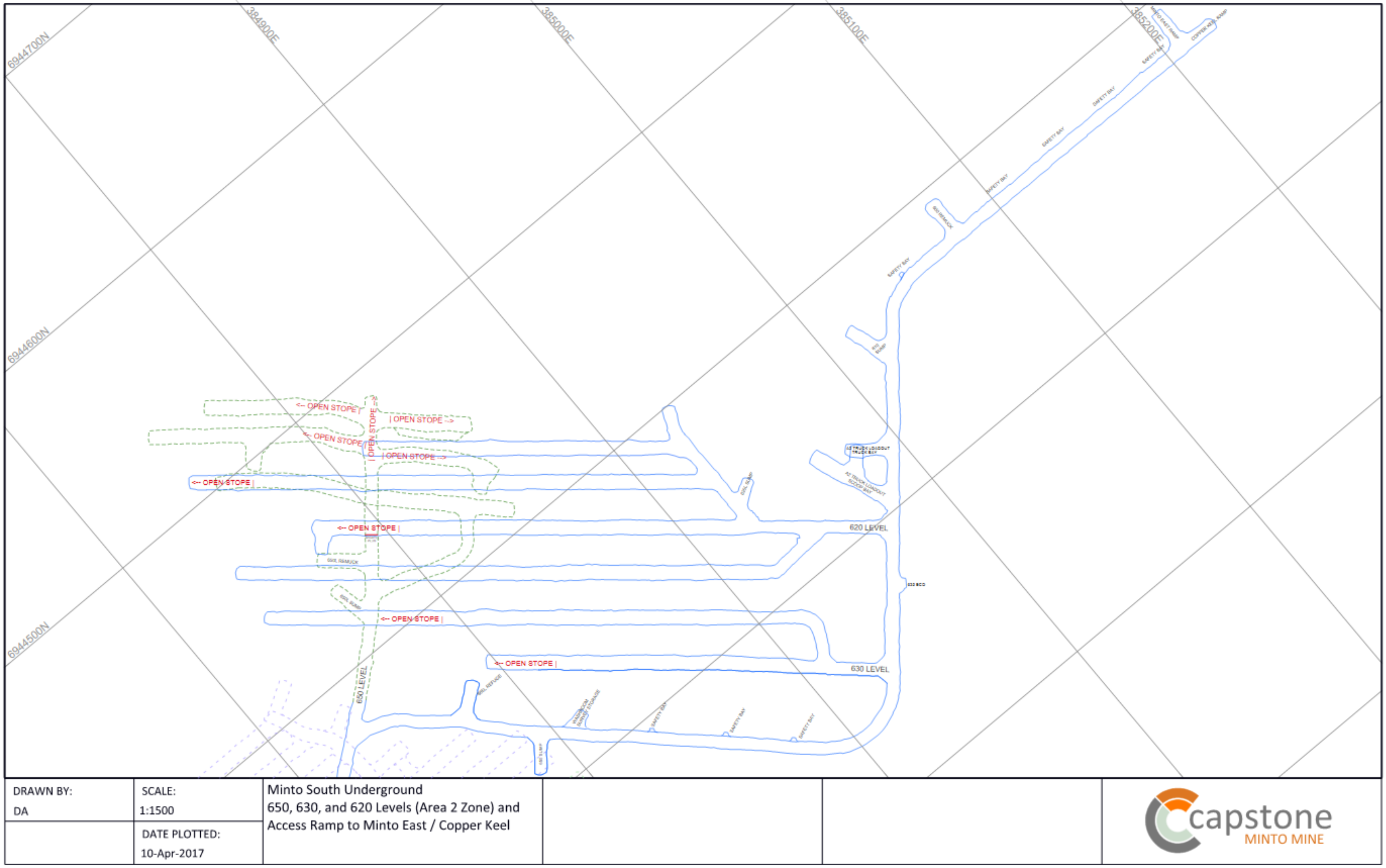


Figure 2-4: As-built Area 2 development

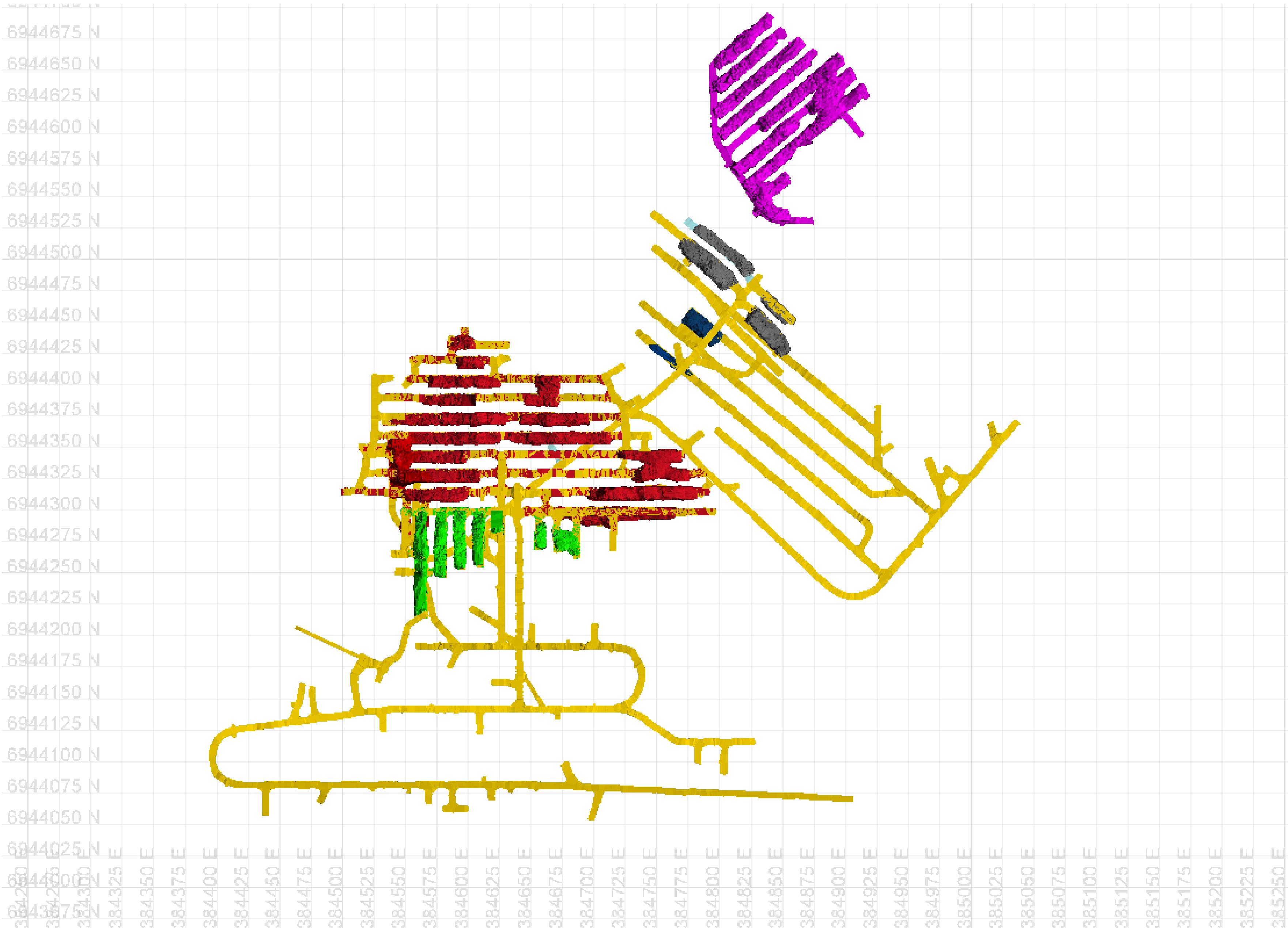


Figure 2-5: Plan view of all existing development and stoping: Area 118 stopes are shown in red and green; Area 2 stopes are shown in grey and blue; and, M-Zone stopes are shown in pink

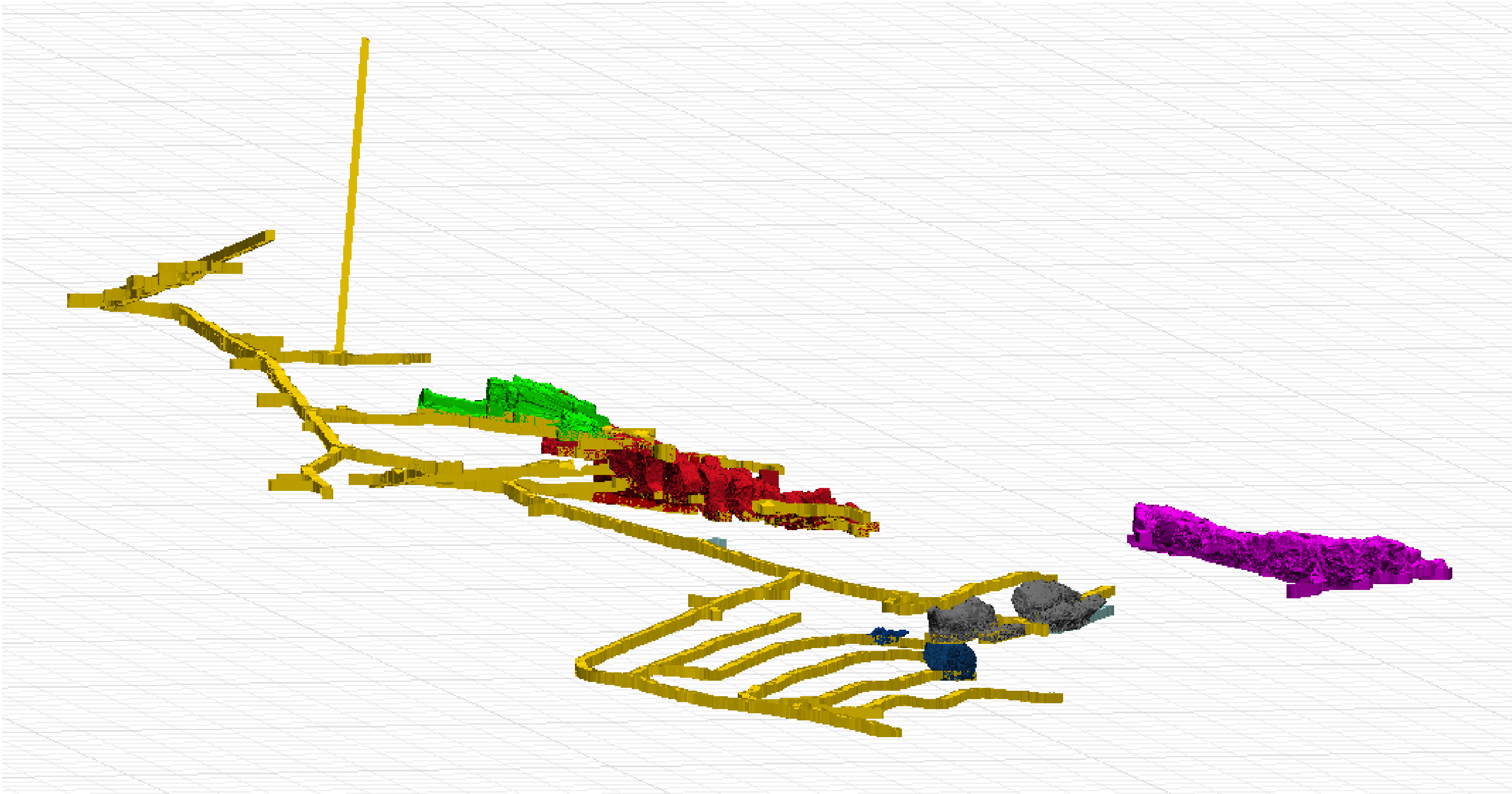


Figure 2-6: Perspective view of all existing development and stoping: Area 118 stopes are shown in red and green; Area 2 stopes are shown in grey and blue; and, M-Zone stopes are shown in pink

3 Deposits and Ore Reserves

The following table summarizes the nomenclature associated with Minto's ore zones and lists the phase of permitting under which each has been assessed.

Underground Complex	Access	Zones	Permitting
Minto South Underground	Minto South Portal	Area 118	Phase IV
		Area 2	Phase IV
		Minto East	Phase V/VI
		Copper Keel	Phase V/VI
	M-zone Portal	M-zone	Phase IV
Wildfire Underground	Wildfire Portal	Wildfire	Phase V/VI

Table 3-1: Nomenclature for underground complexes, portals, and zones at Minto.

A separate underground complex, known as the Wildfire Underground, was presented during the environmental assessment process. This included relatively shallow ore zones from a separate portal with its own dedicated infrastructure. Originally planned to be mined after the completion of the Minto South Underground, it is not currently in the mine plan and is not described in this document.

Figure 3-1 shows preliminary development and stoping designs for the aforementioned ore zones.

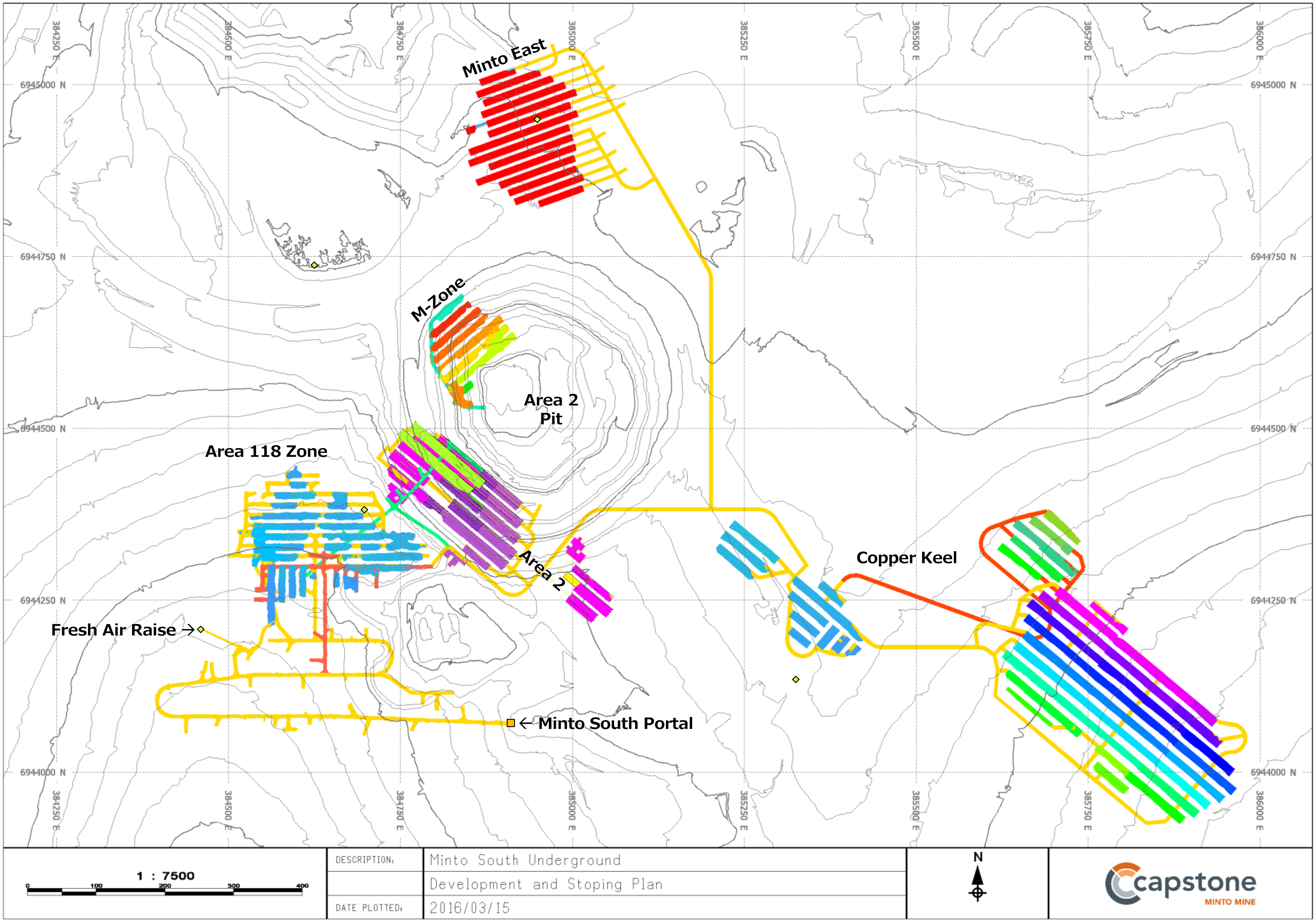


Figure 3-1: Plan view of underground development and ore zones.

3.1 Ore Production and Scheduling

The latest reserve statement included 381 kt of ore at an average grade of 2.06% Cu remaining for Area 2 underground, and 625 kt of ore at an average grade of 2.07% for Minto East underground.

The tonnages produced by the underground mine will change as detailed stope designs are prepared, taking into account the local ground conditions and optimizing the locations of stopes based on in-fill drilling.

The mining rate is currently planned at 1,400 tonnes per day of ore. With continuous mining the Minto East zone would be completed in Q3 2018. The extent of mining and timeframe will be contingent upon market conditions.

4 Mine Development and Design

4.1 Mining Method

The M-zone, Area 118 and Area 2 zones were all mined using a longhole open stoping method, and the Minto East zone will be mined in the same manner. All of these ore zones can be described as lenses of foliated granodiorite (fG), bounded at their hanging wall and footwall contacts by equigranular granodiorite (eG) host rock. The fG zones are typically 5-30m thick, and the grade within them varies from 0% to approximately 6% copper. The fG 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, generally developed 6m wide and 4.5m high, a top-hammer longhole rig drills rings of 3" up-holes into the deposit above, stopping at the hanging-wall contact.

To provide adequate void for blasted muck when starting a new stope, 1.8m x 1.8m inverse raises are drilled. These are composed of six 6" reamed holes, which are left unloaded, surrounded by a pattern of eleven 3" blast holes. Generally, each stope is started 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 complete, the rings are loaded, blasted, and then mucked out from the sill drift, which serves as a drawpoint. The average blast size is 3,000 tonnes. Mucking is via remote-controlled LHD; all stopes are non-entry so no workers are exposed to the open stope. Ore is trucked to surface along the main ramp 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, and 5m thick rib pillars separated each stope, supporting the hanging wall. For the Area 2 zone, production drift centerlines are 20m apart and stope and pillar widths are varied based on the ore thickness (stope and pillar height). Typical stope widths are 15m and pillar widths 5m, for more details on the stope geometry see Section 6.

Significant variability in copper grade is seen within each ore zone; therefore, diamond 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 diamond 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.

4.2 Access

The main ramp of the Minto South Underground measures 1,677m to the currently active Area 2 630 level. The planned first access to the Minto East zone will be at 2,440m. The upper ramp was 5.0m wide and 5.0m high; the ramp below 690 has been driven at 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 in intersections. More detail on ground support is presented in Section 6.

4.3 Stope Layout

Figure 4-1 shows a perspective view of the Minto East stope design. The zone is a single lens, and will developed from the east to the west, then retreated in the opposite direction.

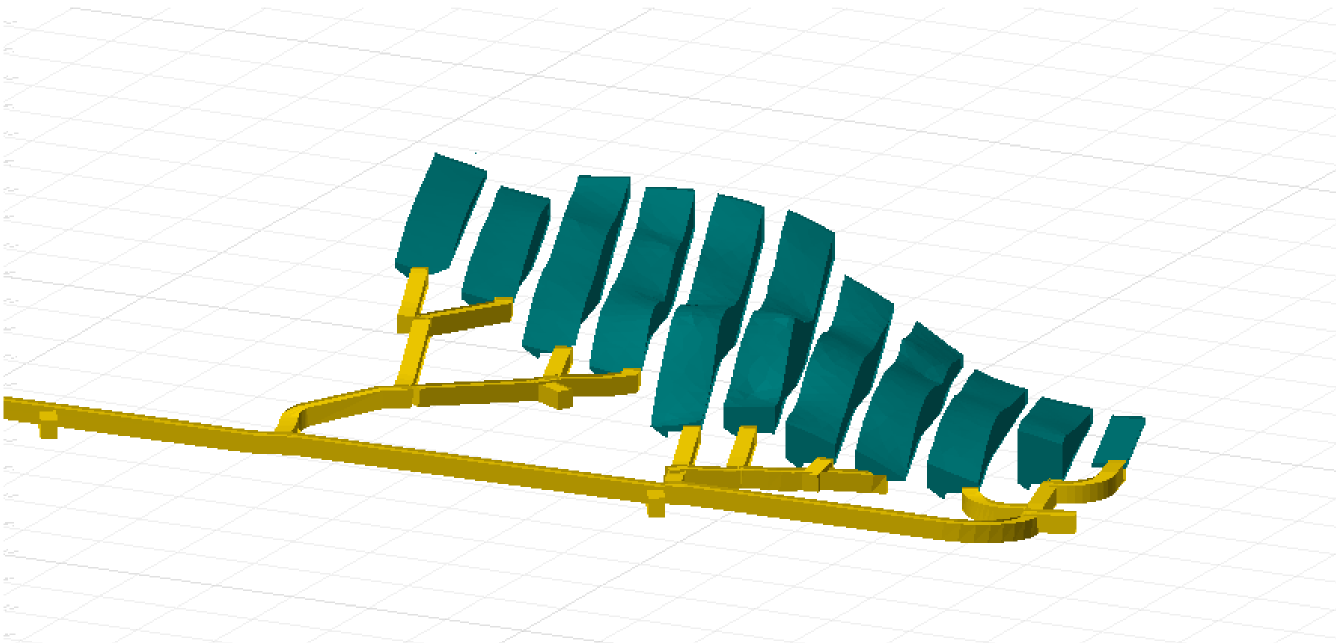


Figure 4-1: Perspective view of the Minto East stope design looking southwest

5 Mine Operation

5.1 Material Handling

A combination of 7, 8 and 10-yard LHD units and 42 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 on a daily basis.

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)*. The protocols for segregation and placement of waste materials are consistent with the protocols for surface mining.

6 Geotechnical Assessment

Geotechnical characterization and design work, summarized in the following sections, were carried out by Golder Associates Ltd. and Minto's Mine Technical Department for the Area 2 and Minto East underground areas. The same methodology was used as for the Area 118 zone. A ground control management plan was developed and implemented in 2013 and has been used for all underground development to date. The plan is updated annually, the most recent update was in December, 2016.

6.1 Orebody Geometry

Table 6-1: Summary of Orebody Geometry

Parameter	M-Zone	Area 118	Area 2 650 Level	Area 2 630 Level	Minto East
Depth (m)	25-110	150-200	110-145	90-225	270-330
Area (m)	120 x 100	235 x 190	135 x 35	220 x 115	220 x 150
Dip (degrees)	10-15	18-45	10-30	10-30	10-30
Vertical Thickness (m)	8-23	5-35	5-21	5-31	5-26

The following points (italicized excerpts from the SRK Phase V Prefeasibility Study) summarize the general ore body conditions:

The (mineralized) zones bifurcate, which means that a mineralized zone can contain a significant amount of waste, or that thinner ore zones can merge with larger zones. A bifurcating geometry complicates geological modelling and may expect to increase internal dilution.

The width and dip of mineralized zones are locally variable. The zones therefore appear to pinch-and-swell. The change in thickness might be as much as an order of magnitude over less than 30 m in horizontal distance.

At least some of the irregularity in the geometry and thickness of the mineralized zones is due to small-scale and large-scale structural displacements. No detailed structural model has been completed for either deposit, but at least two faults appear to be present in Area 2, and three possible faults displace the modelled zones in Area 118. Similar structures may be present throughout the deposit, each with displacements of a few metres or less.

6.2 Hydrogeological Assessment

A detailed hydrogeological assessment has not been completed to define the potential inflows to the underground workings. 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 grouting work required. The average total discharge rate from the mine is currently 35 gpm.

6.3 Excavation Dimensions

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

Table 6-2: Summary of Excavation Dimensions

Excavation/Pillar	Area 118	Area 2	Minto East
Development drifts, ramps	5.0 m (W) x 5.5 m (H)	5.0 m (W) x 5.5 m (H)	5.0 m (W) x 5.5 m (H)
Production drifts	6.0 m (W) x 4.5 m (H)	6.0 m (W) x 4.5 m (H)	6.0 m (W) x 4.5 m (H)
Longhole stope (non-entry)	10 m (W) x 9-25 m (H)	10-15 m (W) x 10-21 m (H)	10-15 m (W) x 10-26 m (H)
Longhole pillar (non-entry)	5 m (W) x 9-25 m (H)	5-10 m (W) x 10-21 m (H)	5-10 m (W) x 10-26 m (H)
Room (entry)	10 m (W) x 5-10 m (H) (5 m lifts with backfill)	10 m (W) x 5-10 m (H) (5 m lifts with backfill)	10 m (W) x 5-10 m (H) (5 m lifts with backfill)
Pillar (entry)	5 m (W) x 5-10 m (H)	5 m (W) x 5-10 m (H)	5 m (W) x 5-10 m (H)

6.4 Rock Mass Characterization

Rock mass characterization is based on core logging and laboratory testing completed by SRK and underground mapping carried out by Minto. Summaries of rock mass quality and strength are contained in Table 6-3 and

Table 6-4.

Table 6-3: Summary of Rock Mass Quality

Area	Source	Rock Type	Total Length Logged (m)	RMR(76)			Q'		
				min	max	avg	min	max	avg
Area 118	Core Logging (SRK)	Ore	1207	31	82	64	0.17	99	21.1
		Waste (HW)	433	31	82	65	0.24	100	21.4
	Underground Mapping (Minto)	Ore	147	59	89	79	1.4	150	17.7
		Waste	204	65	92	85	2.6	50	17.5
Area 2	Core Logging (SRK)	Ore	211	31	82	65	0.05	99	19.4
		Waste (HW)	89	45	79	64	2.07	93	21.7
Minto East	Core Logging (SRK)	Ore	350	24	84	68	0.11	50	15.1
		Waste (HW)	79	40	79	66	0.29	67	10.5

Table 6-4: Summary of Intact Rock Strength

Area	Rock Type	Total Length Logged (m)	Avg. Logged Strength	Total Length Mapped (m)	Avg. Mapped Strength	Number of Point Load Tests	Avg. Point Load Strength (MPa)	Number of UCS Tests	Avg. UCS (MPa)
Area 118	Ore	1443	R4 (50-100 MPa)	126	R5 (100-250 MPa)	3	245	7	125
	Waste (HW)	527	R4 (50-100 MPa)	60	R5 (100-250 MPa)	1	163	8	135

Area 2	Ore	232	R4 (50-100 MPa)	-	-	14	200	1	104
	Waste (HW)	92	R4 (50-100 MPa)	-	-	9	185	2	126
Minto East	Ore	16	R4 (50-100 MPa)	-	-	43	158	10	105
	Waste (HW)	15	R3 (25-50 MPa)	-	-	12	195	3	101

Rock structure has been characterized using mapping in the underground development to date and in the open pits. Rock structure is summarized in Figure 6-1, Figure 6-2 and Figure 6-3, and in Table 6-5 and Table 6-6.

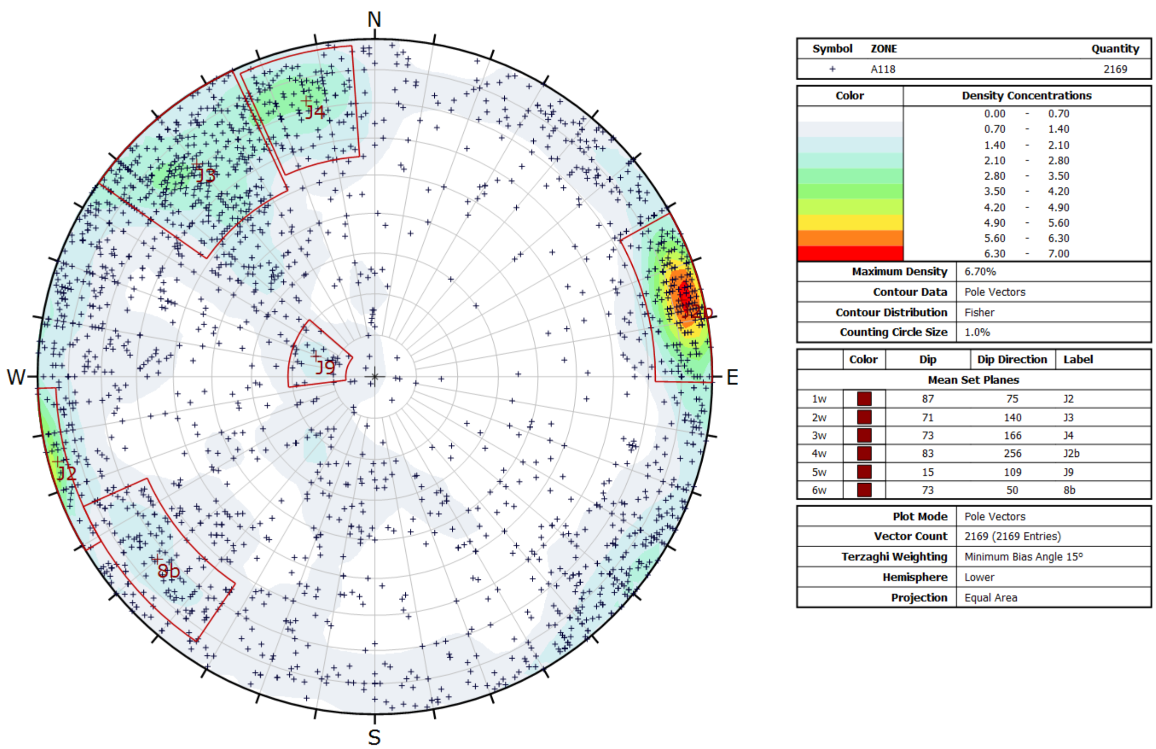
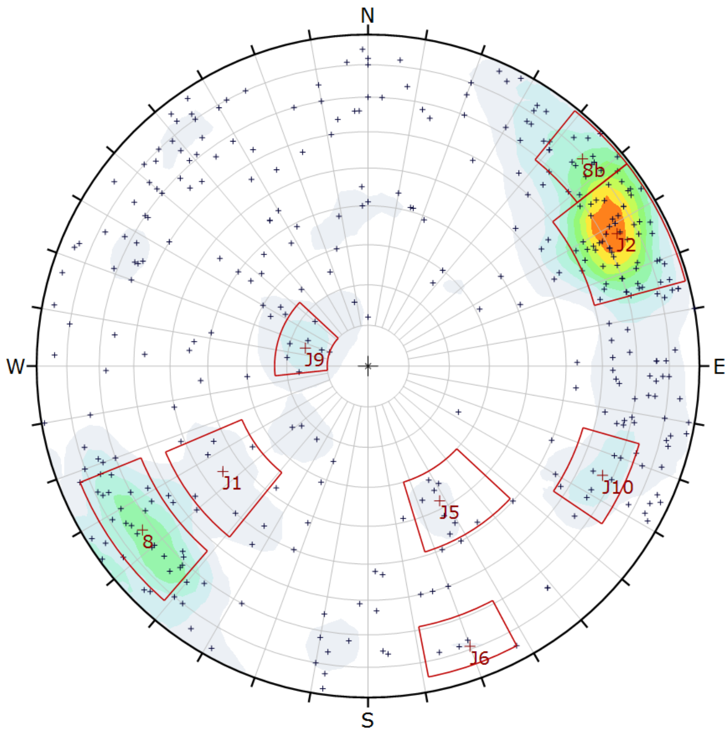


Figure 6-1: Stereonet of Rock Structure in Area 118 Underground



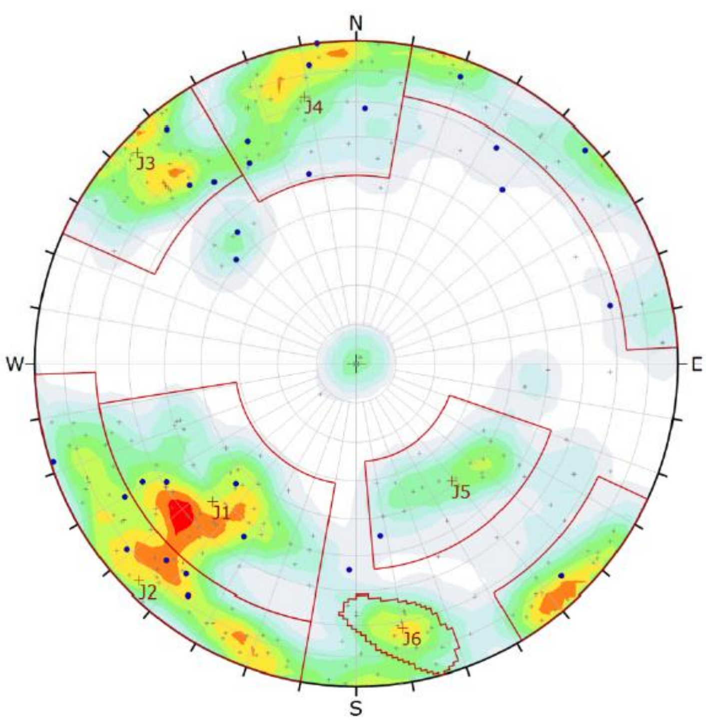
Symbol	ZONE	Quantity
+	A2UG	316

Color	Density Concentrations
	0.00 - 1.00
	1.00 - 2.00
	2.00 - 3.00
	3.00 - 4.00
	4.00 - 5.00
	5.00 - 6.00
	6.00 - 7.00
	7.00 - 8.00
	8.00 - 9.00
	9.00 - 10.00
Maximum Density	9.01%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1w		73	54	8
2w		79	226	8b
3w		67	295	J10
4w		16	106	J9
5w		38	332	J5
7w		45	54	J1
10w		79	340	J6
11w		74	242	J2

Plot Mode	Pole Vectors
Vector Count	316 (370 Entries)
Terzaghi Weighting	Minimum Bias Angle 15°
Hemisphere	Lower
Projection	Equal Area

Figure 6-2: Stereonet of Rock Structure in Area 2 Underground



Symbol	SYMBOL	Quantity
+	Field	20
+	Field-FAI	3
+	Field-FT	4
+	Isite	223
+	Isite-FAI	5
+	Isite-FT	3
•	Isitex	29

Color	Density Concentrations
	0.00 - 0.41
	0.41 - 0.82
	0.82 - 1.23
	1.23 - 1.64
	1.64 - 2.05
	2.05 - 2.46
	2.46 - 2.87
	2.87 - 3.28
	3.28 - 3.69
	3.69 - 4.10
Maximum Density	4.01%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	287 (287 Entries)
Hemisphere	Lower
Projection	Equal Area

02APR2013_Update

Figure 6-3: Stereonet of Rock Structure in Area 2 Open Pit

Table 6-5: Summary of Major Joint Sets

Major Joint Set	Open Pit Mapped Orientation		Underground Mapped Orientation		Area Observed	Comments
	Average Dip	Average Dip Direction	Average Dip	Average Dip Direction		
J1	54	045	-	-	• Area 2 Pit • Area 118 Pit • Minto North Pit • Area 118 UG • Area 2 UG	Major fault orientation in Area 2 Pit and A2 underground (“320 Fault”). Fault orientation in Area 118 underground but not indicated as a major joint set. Minor joint set in Area 2 UG
J2	-	-	84	256	• M-Zone UG • Area 118 UG • Area 2 UG	Slightly steeper set to J8 different orientation. Major ore joint set.
J3	58	137	67	134	• Area 2 Pit • M-Zone UG • Area 118 Pit • Area 118 UG • Minto North Pit	Major set in all areas.
J4	78	163	74	161	• Area 2 Pit • M-Zone UG • Area 118 UG	Major set in most areas. Not apparent in ore.
J5	40	322	-	-	• Area 2 Pit • Area 118 Pit • Minto North Pit • Area 2 UG	Minor set in open pits. Not observed in areas 118 and M-zone underground. Minor set observed in Area 2 UG
J6	73	350	79	340	• Area 2 Pit • M-Zone UG • Area 2 UG	Moderate set in open pits. Minor set in Area 2 UG waste. Not apparent in Area 2 UG ore. Observed as steeper dipping set in M-Zone underground.
J7	-	-	30	014	• M-Zone UG • 118 UG	Major ore joint set.
J8	80	041	80	045	• Area 118 UG • Area 2 Pit • Area 118 Pit • Area 2 UG	Major set in Area 2 Pit. Major set in Area 118 underground. Major set in Area 2 UG ore – not apparent in Area 2 UG waste.
J8b	-	-	82	216	• Area 118UG • Area 2 UG	Major set in Area 2 UG. Minor set in Area 118 UG.
J9	-	-	10	106	• Area 118 UG • Area 2 UG	Minor set in Area 118 underground. Moderate set in Area 2 UG. Not apparent in ore.
J10			67	295	• Area 2 UG	Moderate set in Area 2 UG waste.

Table 6-6: Summary of Major Structures

Structure Description	Average Dip	Average Dip Direction	Comments
Fault	66 (65-76)	35 (15-40)	Major fault intersected throughout Area 118 underground waste and ore development. Zone of up to several meters of altered, weak rock. Often water bearing.
Fault	64-74	40-50	Major fault zone in Area 2 Pit (“320 Fault) and regional fault orientation. Up to 5m zone of gouge, altered fractured rock.
Fault	60	160	Gouge filled fault in M-Zone underground.
Fault	59	292	Minor fault in Area 118 underground waste rock.

6.5 Stability Analyses

6.5.1 Longhole Stoping

Stope spans for future mining areas were designed using a combination of empirical analysis, numerical modelling and experience in the Minto underground to date. Stability graphs for each deposit are shown in Figure 6-4 and Figure 6-5. Exposures plot in the stable or transition zone with less than 2m of ELOS (equivalent linear overbreak/slough).

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 approximately 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 up to 20m wide 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 breakthroughs through pillars occurred in two places in Area 118. In M-Zone, two pillars unravelled for approximately 30-40m 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 where conditions require.

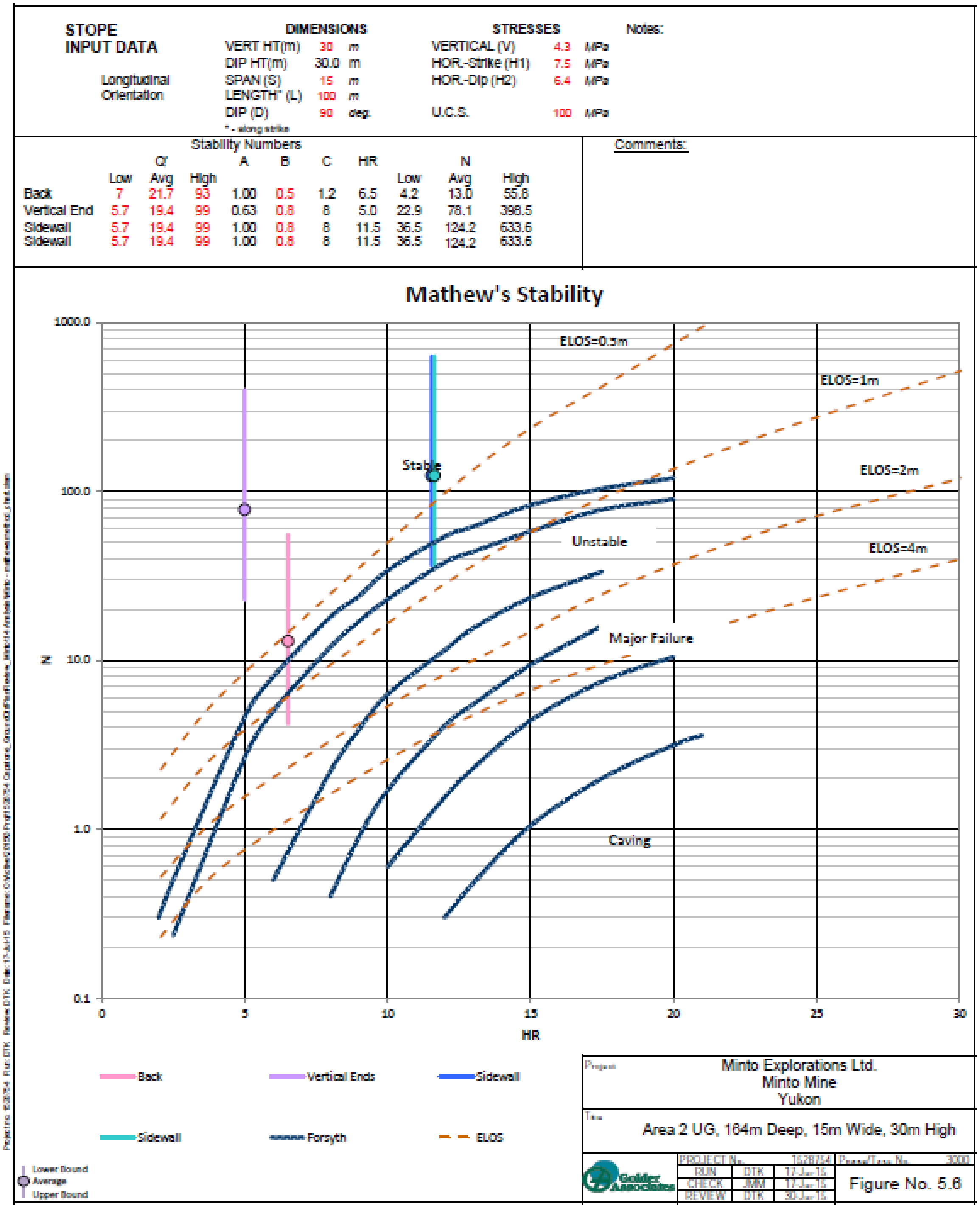


Figure 6-4: Area 2 Stability Graph Analysis (Golder, 2015b)

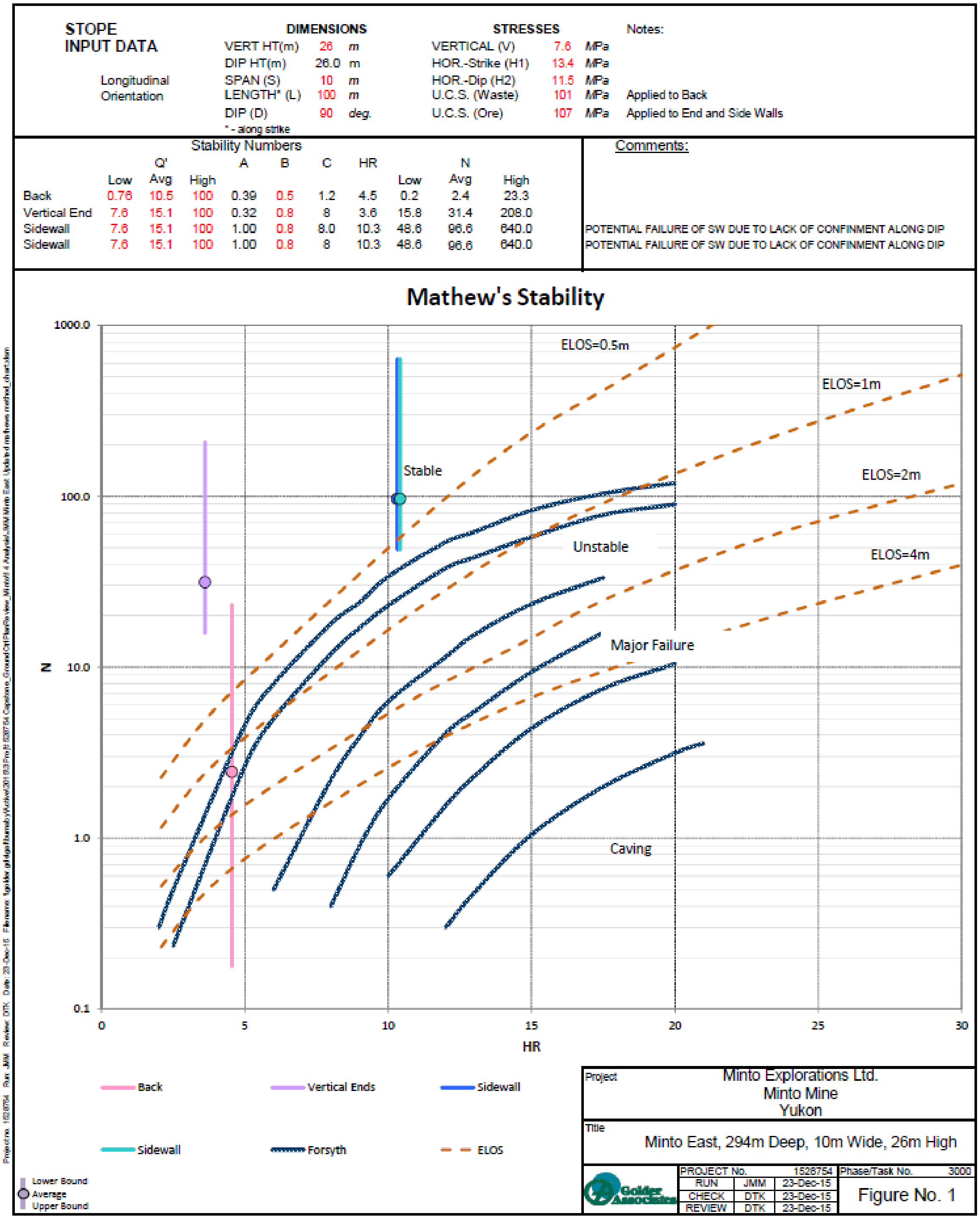


Figure 6-5: Minto East Stability Graph Analysis (Golder, 2016)

Empirical and numerical analyses were carried out by Golder to assess the Area 118, Area 2 and Minto East zones. Complete results are contained in the report "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 for Area 2 and Minto East below.

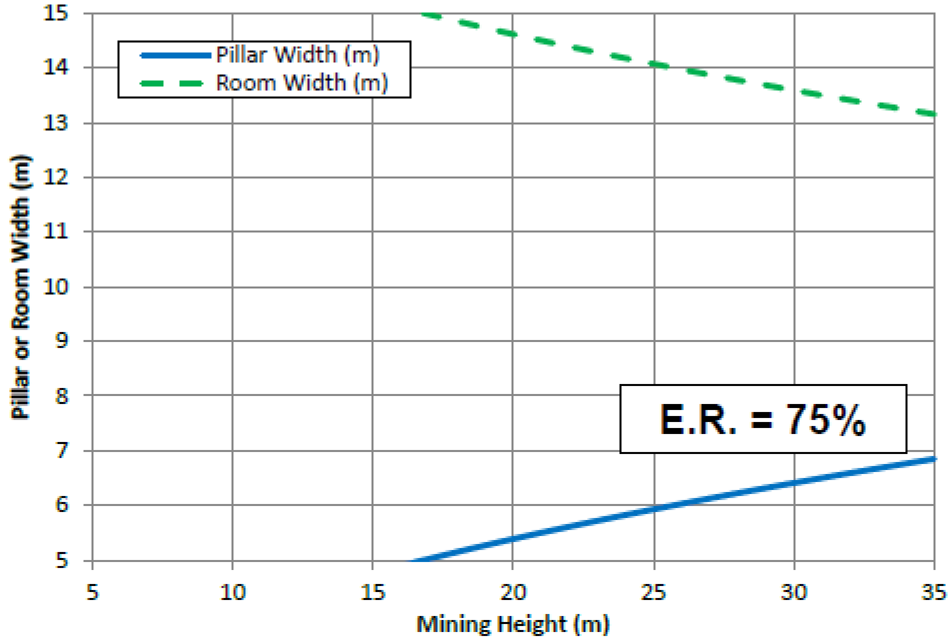


Figure 6-6: Empirical analysis results for Area 2 upper lens (650 level)

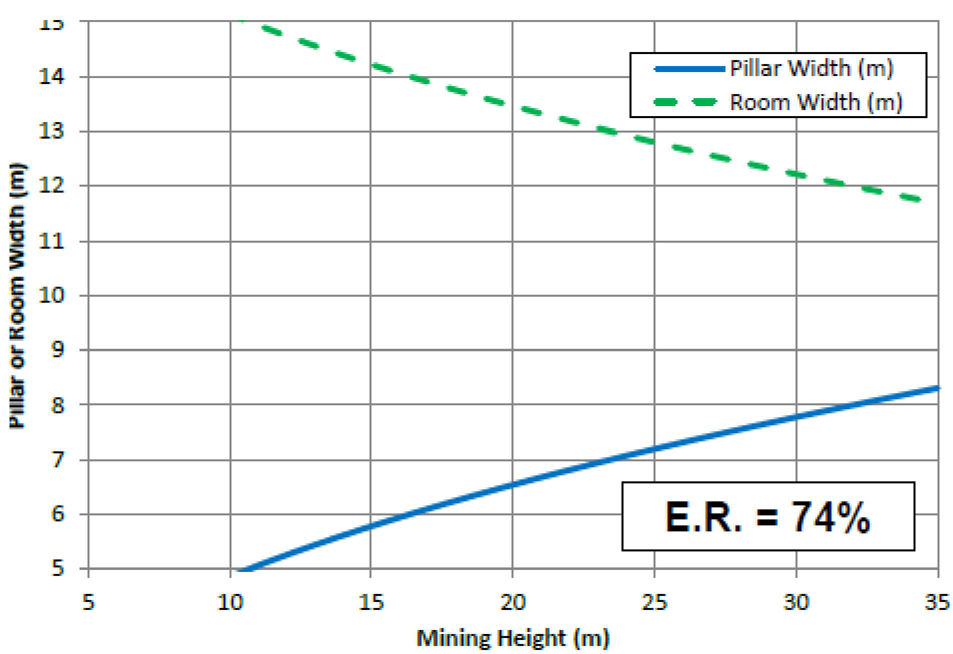


Figure 6-7: Empirical analysis results for Area 2 lower lens (630 level)

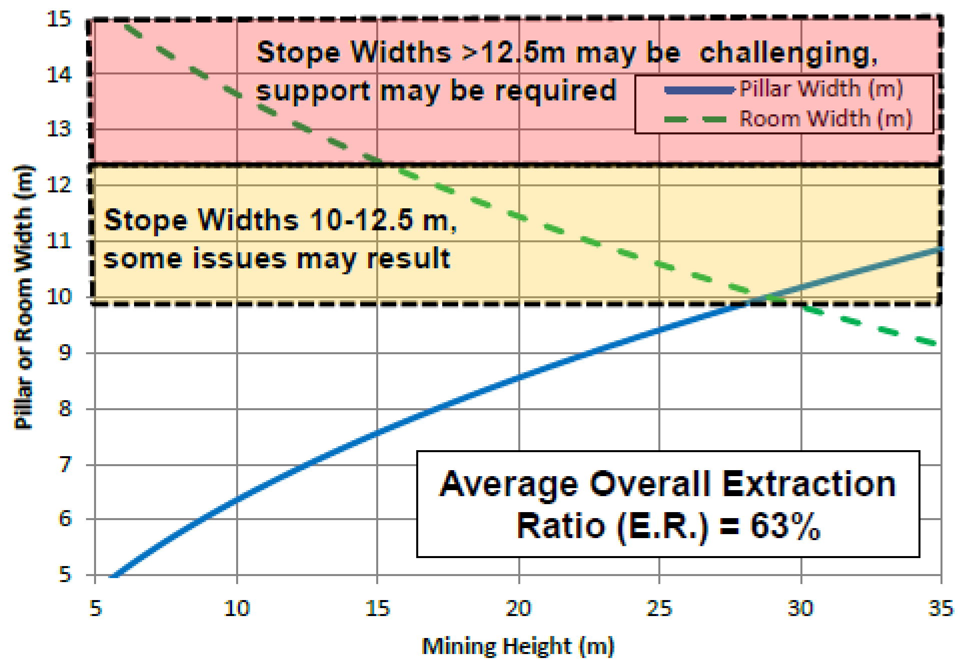


Figure 6-8: Empirical analysis results for Minto East

6.5.2 Room and Pillar

Room and pillar mining is expected to make up a small percentage of the overall mine plan, however it has been assessed to allow flexibility where the geometry of the orebody is not suitable for longhole mining.

Planned mining geometry for room and pillar areas consists of 10m wide by 5m high rooms and crosscuts, and 5m square pillars. In some areas, a second 5m lift may be required in which case the lower lift will be backfilled with uncemented waste rock.

The room size has been assessed using both empirical and numerical methods. The critical span curve for man entry openings (Ouchi et al., 2004) is shown in Figure 6-9. 10m spans are predicted to be stable for both Area 2 and Minto East.

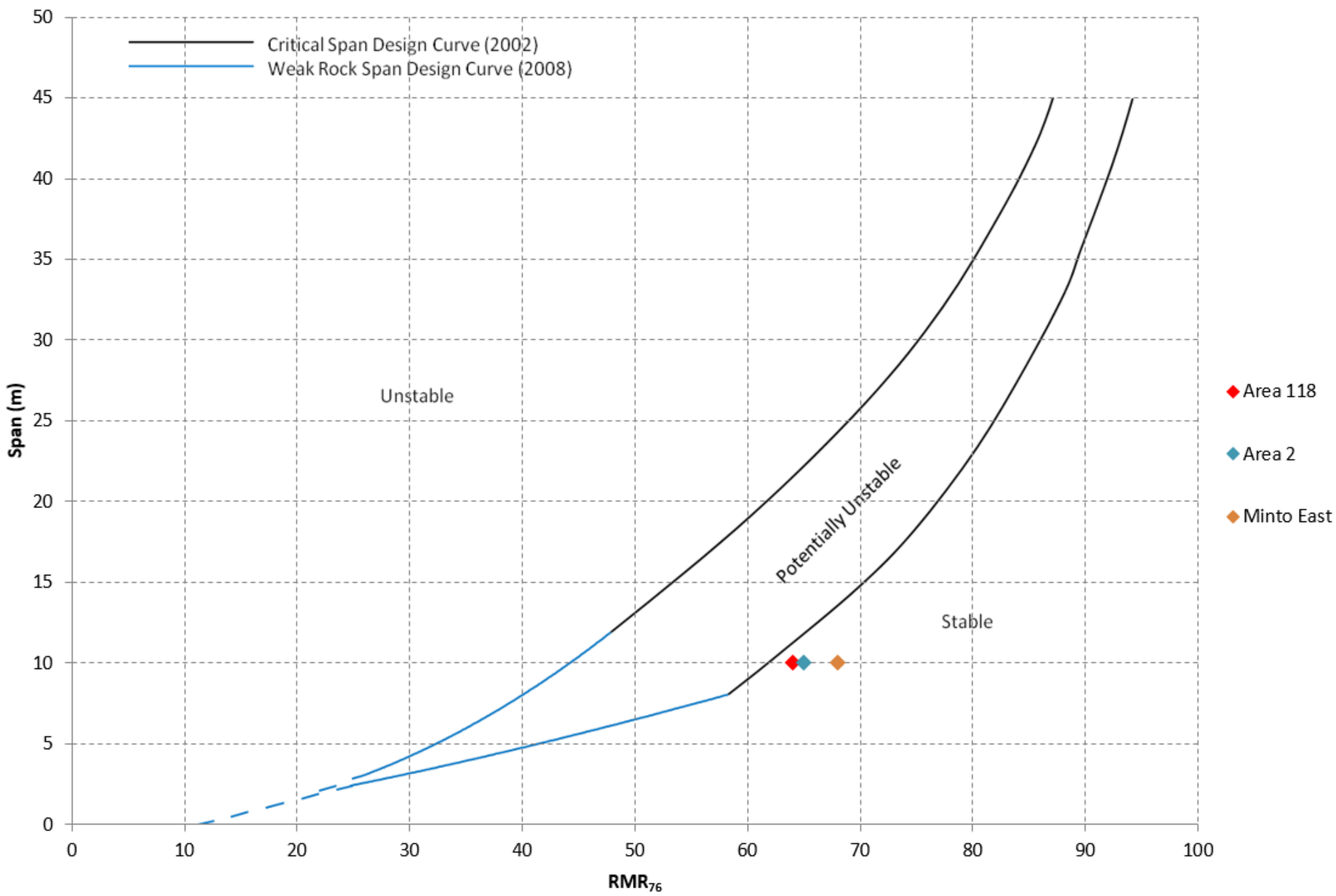


Figure 6-9: Critical Span Design Curve (Ouchi, 2004)

Numerical analyses using a combined discrete fracture network (DFN) and discrete element model were completed by Itasca in 3DEC to further assess room spans, particularly in intersections where greater spans will be required. Complete results are contained in the presentation "Minto 118 Zone – 3DEC/DFN Analyses" (Itasca, 2014). The model used is shown in Figure 6-10.

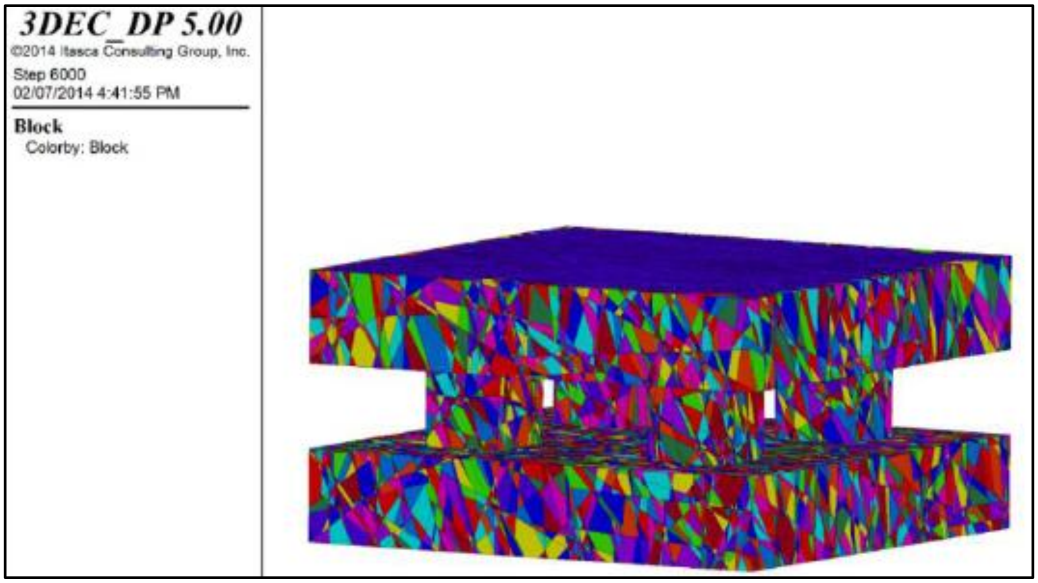


Figure 6-10: 3DEC/DFN Model used for Room Span Analysis (Itasca, 2014)

The analyses were run considering the standard Type 1 ground support, including 2.4m long resin-rebar on 1.5 x 1.5m spacing with a 1.8m center resin-rebar to pin the mesh, as well as secondary intersection support consisting of 5m long Super Swellex on a 1.8m x 1.8m spacing.

The analyses concluded that with no ground support an average of 132 tonnes became unstable in the intersection roof, to a maximum depth of 3.7m into the roof. With ground support installed the roof was predicted to be stable.

Major structures such as faults or highly fractured zones were not considered in the analyses. Where major structures are identified during development mapping, spans will be limited or additional case specific ground support will be designed.

6.6 Ground Support Requirements

Ground support requirements for underground development are contained in the Minto Underground Ground Control Plan, updated in December 2016. The following are summaries of ground support elements and requirements for development openings.

Table 6-7: 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 raise development.
	Super Swellex (36 mm)	24 tonnes	-
	Standard Swellex (27 mm)	12 tonnes	Used for face bolting.
Plates	Domed - 15 x 15 cm (6” x 6”), 6 mm (1/4”)	-	-
Resin	30mm x 610mm cartridge 30 second (fast) 180 second (slow)	-	-
Mesh	6-gauge welded wire mesh	~ 2-3 tonnes bag strength	Galvanized for permanent excavations. Bright for short-term excavations.
Straps	0-gauge welded wire mesh straps	-	Used for stope brow support.

Table 6-8: Minimum Ground Support for Development and Production Openings

Type		Span (m)	Primary Support (minimum)	Comment
1	**Development Drifts (typical ground conditions)**	5.0	2.4 m (8 ft.) rebar in back around perimeter of mesh sheets 1.8 m (6 ft.) rebar in back and walls to pin mesh at center 1.8 m (6 ft.) rebar in walls to 1.5 m above floor 1.5 x 1.5 m bolt spacing diamond pattern Galvanized welded wire mesh to 1.5 m above floor	Life of mine infrastructure in typical ground conditions.
2	**Production Drifts (typical ground conditions)**	6.0	2.4 m (8 ft.) rebar in back around perimeter of mesh sheets 1.8 m (6 ft.) rebar in back and walls to pin mesh at center 1.8 m (6 ft.) rebar in walls to 1.5 m above floor 1.5 x 1.5 m bolt spacing diamond pattern Bright welded wire mesh to 1.5 m above floor	Non-permanent development (e.g. stope/production room crosscuts) in typical ground conditions.
3	**Poor ground – fault zones**	≤6.0	2.4 m (8 ft.) rebar in back around perimeter of mesh sheets 3.6 m (12 ft.) Super Swellex to pin mesh at center 1.8 m (6 ft.) rebar in walls to 1.5 m above floor 1.5 x 1.5 m bolt spacing diamond pattern Bright/Galvanized welded wire mesh to 1.5 m above floor	Poor ground, typical in fault zones.
Intersection Secondary Support				
1,2,3	**Intersections**	≤9.5	To be installed in addition to primary support pattern outlined above: 3.6 m (12 ft.) Super Swellex in back and shoulders 1.8 x 1.8 m bolt spacing - Installed at least two rows past the intersection in each direction.	Intersection support to be installed prior to taking wall slash.

6.7 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 6-9: Summary of Ground Control Monitoring

Element	Description
Inspections	• Daily inspections of active production openings by Geotechnical Engineer/EIT, Minto supervision and/or Dumas supervision • Monthly inspections of fresh air raise/manway • Quarterly inspections by the Geotechnical Engineer of all development and production openings • Ground control log book maintained by underground shifters and checked by Geotechnical Engineer/EIT
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 monitor surveys (CMS)	Carried out in opens stopes after each blast.

7 Ventilation, Ancillary Infrastructure, and Dewatering

This section describes the ventilation configuration for the Minto South Underground.

7.1 Infrastructure

Air is supplied to the mine by a surface installation commissioned in March 2015. The fan specifications are as follows:

Table 7-1: Surface fan specifications

Rated power	344 hp
Motor control	Variable frequency drive
Max rotation speed	880 rpm at 60Hz
Fan specifications	101.5" diameter with adjustable blade pitch
Air heating system	Six propane burners in two modular burner houses
Max air heating capacity	32 million BTU/h

The variable frequency drive on the fan is currently run at 31Hz: with the existing mine layout, this is sufficient to deliver 240,000 cfm. Testing the fan at full speed, airflow was measured at 350,000 cfm.

Air is heated to maintain above-freezing temperatures year-round. The system comprises four burners and their ancillary infrastructure (blower motors, CO and temperature sensors, electronic controls). Six 30,000 gallon propane tanks supply the burner with fuel.

7.2 Ventilation Circuit

The fan is currently installed on top of a 3m x 5m raise running from surface to the 760m elevation. This raise also serves as an emergency escapeway / egress. As part of Minto East mining, two additional raises will be developed, one 3m diameter for ventilation and one 1m diameter for an escapeway. The 344 hp fan and burners will then be moved to the Minto East raise, reversing the circuit so that air will exhaust through the current raise.

Figure 7-1 shows a section through the raise and stopes used to transfer air to the bottom level of the mine. On the 760m level, air flows through a 70m transfer drift, then down a short raise to a stope that is open down to the 710 level. Air then flows through another open stope down to the 690 level. By routing air through open stopes, air resistance is minimized.

The start of the Area 2 decline is a short distance upstream from where the intake air exits the 690 open stope. A bulkhead was constructed on 710 to force all of the airflow down through this path. From there, air is supplied to the Area 2 zone and Minto East ramp via twin 48" steel ducts with in-line 150hp booster fans.

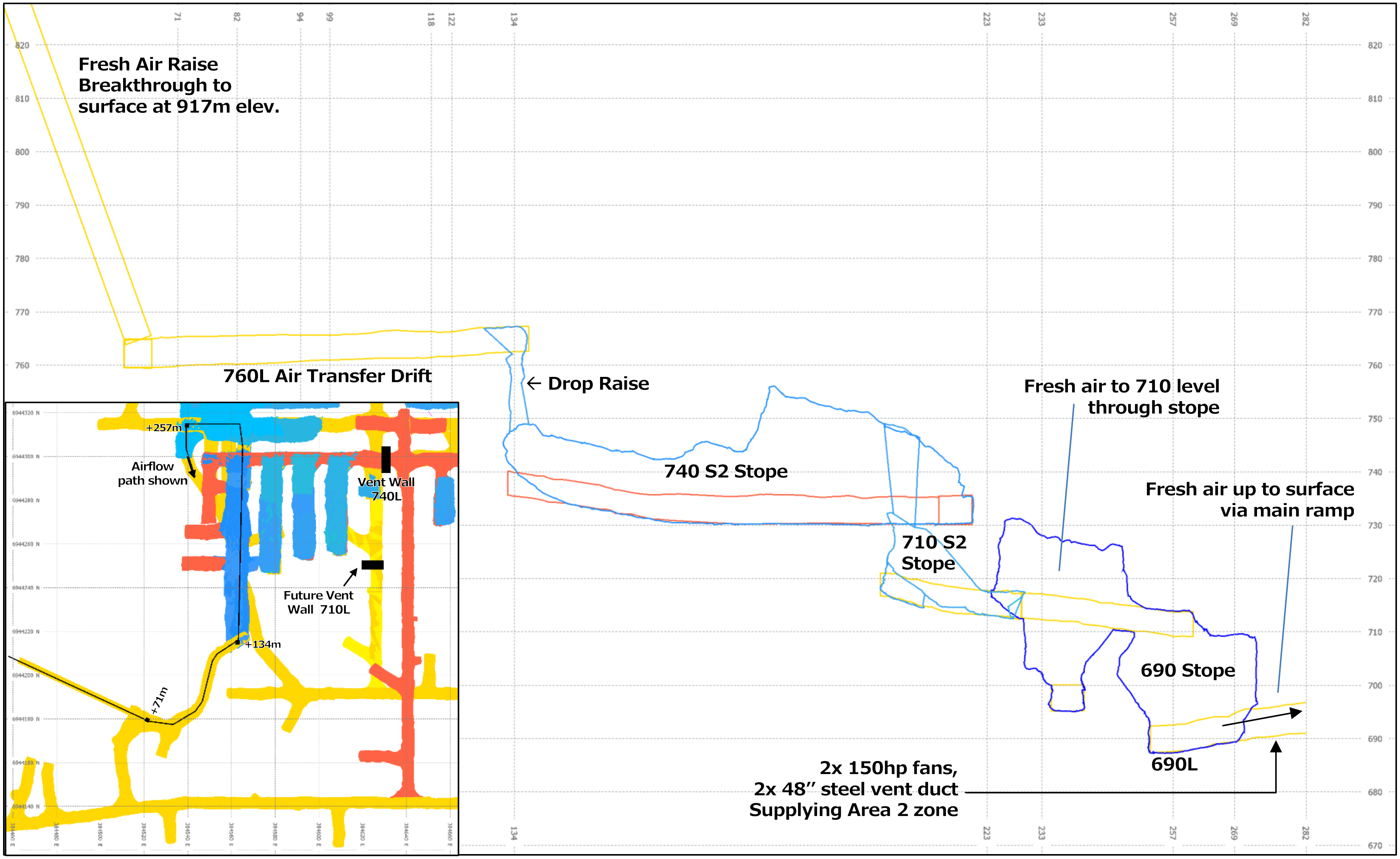


Figure 7-1: Cross-section through fresh air supply path to Minto South Underground.

The air volume required for the fleet currently in use is shown in the table below. The surface fan is controlled by a variable frequency drive, allowing the airflow to be adjusted as requirements change.

Table 7-2: Ventilation requirements for the Minto South Underground

Make / Model	Equipment Type	Fleet	Engine Power (hp)	CFM Required
Atlas Copco ST8B	LHD	3	325	22,000
Atlas Copco ST1520	LHD	2	400	27,200
Sandvik LH410	LHD	2	295	17,000
Atlas Copco MT42	Haul Truck	3	520	36,700
Sandvik Jumbo	Jumbo Drill	1	147	9,200
Atlas Copco M2C Jumbo	Jumbo Drill	1	150	8,100
Maclean MEM-928	Bolter	1	147	9,200
Maclean MEM-946	Bolter	1	150	8,100
Minecat UT100	Tractor w/ forklift, backhoe	2	99	7,000
Walden M-60	Scissor Lift	2	86	7,500
Getman	Emulsion Loader	1	99	7,000
Toyota Land Cruiser	Flatdeck, mancarrier	3	127	7,300

7.3 Compressed Air

Minto currently has three compressors, all of which are installed along the main ramp at approximately 720m elevation:

- 2x Sullair 7509/A (350 cfm at 125 psi, 100hp)
- 1x Atlas Copco GA-315 (1811 cfm at 125 psi, 350hp)

All three compressors are tied into the network of 4” air lines that run throughout the mine. The larger Atlas Copco unit only runs when production drilling is active, as the longhole drills represent a substantial majority of the mine’s compressed air requirement.

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

7.4 Underground Electrical Power

In addition to fixed installations such as fans and compressors, production drilling equipment (jumbos and bolters) run on electric power while stationary.

The mine is supplied with 4160V power via a cable that runs down the decline. This is reduced to 600V, the operating voltage of all mobile equipment, at several substations. The Atlas Copco GA-315 is directly connected to 4160V; all other fixed installations are supplied with 600V three-phase AC. Refuge stations are supplied with single phase 120V power.

7.5 Water

7.5.1 Water Supply

Inflow to the mine through faults and un-grouted diamond drill holes is generally sufficient to supply the mine with water for drilling and dust control. The mine currently recirculates water through a network of sumps.

7.5.2 Dewatering

Water currently collects into three sumps, from which pumps send water to the main dirty water sump at 760L. This is a two-stage clean/dirty sump that removes most suspended solids before water is pumped to a final settling sump near the portal. This portal sump either discharges out to the permanent heat traced line on surface and on to the Area 2 Pit Tailings Management Facility or returns water underground to supply the mine feed storage tank.

7.5.3 Mine Water Quality and Inflow Monitoring

Water Use Licence QZ14-031 – Amendment 1 (WUL) outlines the monitoring and surveillance of the underground at Minto. UG1 and UG4 has been assigned as a station numbers and monitoring frequency as part of the license for the Minto South Portal and the Minto East Deposit. A representative sample of underground inflows is taken regularly. Results of the monitoring work are presented in the monthly WUL reports and summarised in the QML and WUL annual report.

7.6 Communications

Both refuge stations are equipped with telephones connected to the mine's internal communications network; external phone numbers are also reachable. These phones are connected via a fiber optic network that runs throughout the Minto South Underground.

An analog emergency communication system (Femco phone) is also 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, the electrical cut out adjacent to 630 level access, and the Dumas shop on surface.

7.7 Blasting Procedure and Infrastructure

An electric central blasting system runs throughout the Minto South Underground; it is activated from a blasting box located at the portal muster station. 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 blast. The mine is completely cleared of personnel for both production and development blasting.

Prior to blasting, a locked gate is put into place at the portal, preventing entry to the Minto South Underground until the shift supervisor or a designate verifies that concentrations of post-blast gasses have been diluted to safe levels.

7.8 Explosive Storage and Handling

Emulsion is used for both longhole production and development. A bulk emulsion product known as Dyno Titan RU, formulated for underground use and having high viscosity, is used to load most 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.

To provide a backup in the event that the mobile loading unit is out of service, Minto stocks a product known as Dyno SL, which is a cartridge emulsion designed to be manually loaded using a portable pneumatic unit.

In development, a perimeter blasting product (Dynosplit D) is used 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 7-3: Explosives magazines

License No.	Location	Magazine Contents	Capacity
YT-535	Surface	Surface detonators	40,000 dets
YT-533	Surface	Surface explosives	30,000 kg
YT-541	Surface	Underground detonators	75,000 dets
YT-534	Surface	Underground explosives (perimeter control and boosters)	30,000 kg
YT-542	Surface	Surface explosives (pre-shear)	30,000 kg
YT-551	Surface	Underground explosives (packaged emulsion)	35,000 kg
YT-553	Underground	Underground detonators	4,000 dets
YT-550	Underground	Underground explosives	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.

Non-electric caps are used to time and sequence blast holes in both production and development blasts. A single electric cap is used for each blast to tie the first non-electric cap into the mine's electric central blasting system.

7.9 Fuel Storage and Distribution

Haul trucks, LHDs, and service vehicles are fueled at a 50,000 liter EnviroTank fuel station installed on surface. Bolters and jumbo drills are generally fueled by a service vehicle.

All underground personnel are trained in site-wide spill prevention and spill response protocols outlined in Minto Mine's *Spill Contingency Plan* (Minto, 2016a).

8 Mine safety

8.1 General Mine Safety

Minto Mine and the development contractor, Dumas Mining, emphasize safety in all duties at the mine; this philosophy is shared by senior management and supervisors. Minto's safety program includes the following:

- Dumas *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.

8.2 Emergency Response

Two portable refuge stations are maintained in locations shown on Figure 2-2. These are equipped with compressed oxygen cylinders, CO_2 scrubbers, potable water, first aid equipment, emergency lighting, emergency food rations and chemical toilets. They are also equipped with a digital telephone line and a backup analog telephone (Femco). Each refuge station is equipped to supply oxygen to 18 people for 72 hours.

The fresh air raise from surface to 760 level is equipped with ladders and serves as the mine's main escapeway. A sub-level escapeway with ladders connects the Area 2 ramp and the 710 level. Prior to production mining in Minto East, a raise with ladders will be developed as a secondary escapeway from the zone, collared near the mill on surface.

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, six devices with longer performance durations of 60 minutes are available 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.

Minto has an emergency response team trained in underground mine rescue techniques. Details are contained in Minto's *Emergency Response Plan* (Minto, 2016b).

8.3 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 fresh air raise.

8.4 Hours of Work

Minto requested and received an hours of work variance, specific to the first 4,500 meters of ramp development and associated ore removal.

The requested hours of work variance for these 4,500 meters of underground development included:

- 11 hours per shift of underground exposure for workers in enclosed cabs of mobile equipment.
- 10.5 hours per shift of underground exposure for all other employees.
- Shift rotation of 3 weeks on and 3 weeks off for the contractor's staff employees.
- Shift rotation of 4 weeks on and 2 weeks off for the contractor's hourly rated employees.

8.5 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.

Testing has identified some tasks that could result in overexposure to noise and certain airborne contaminants. Testing results are regularly shared with all underground workers. Hearing protection and respirators are available to all underground personnel.

8.6 First Line Supervisory Training

The Contractor will comply with the Yukon Occupational Health and Safety (OH&S) regulation by obtaining First Line Supervisor's Provisional Certificates and working toward full certification during the development.

8.7 Diesel Equipment

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

8.8 Shotcrete

Shotcrete is not routinely used at Minto.

8.9 YWCHSB Reporting

Annual Industrial Hygiene reports will be provided to YWCHSB.

Any variances to defined engineering or administrative controls put in place and defined by the IH program will be reported to YWCHSB as soon as reasonable along with corrective actions that Minto will take toward elimination of further variances.

9 Conclusion

This Underground Mine Development and Operations Plan incorporates the requirements outlined by the Quartz Mining License. Minto recognizes that some changes to the mine plan and methods are likely as operations continue and more is learned about underground activities on site. This plan will be updated as necessary to reflect newly acquired information and knowledge obtained from ongoing operations.

10 References

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