CHAPTER 13
GEOCHEMISTRY AND GEOHAZARDS

BIRD IN HAND GOLD PROJECT
MINING LEASE PROPOSAL

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13 GEOCHEMISTRY AND GEOHAZARDS

This section provides a geochemical and mineralogical assessment of all rock types that are proposed to be disturbed by the Bird in Hand Gold Project ('the Project' or 'BIHGP') based on representative sampling and analyses. Identified and quantified are; sulphide minerals that have the potential to generate acid or mobilise metals into the environment, radioactive minerals and asbestos or minerals that have the potential to produce respirable silica.

Also described in this section is the potential for natural geohazards in the application area. Potential geohazards include major seismic events and structural instability (i.e. slips, faults and karst features).

13.1 APPLICABLE LEGISLATION AND STANDARDS

The primary controlling legislation regarding mining, geochemisty and geohazards (specifically geotechnical stability and subsidence) is the *Mining Act 1971* (SA) (Mining Act). Other applicable legislation regarding geochemisty and geohazards includes:

- *Mines and Works Inspection Act 1920* (SA);
- *Mines and Works Inspection Regulations 2013* (SA);
- *Work Health and Safety Regulations 2012* (SA) – Chapter 10 – outlines requirements for Principal mining hazard management plans;
- Excavation work Code of Practice (SafeWork SA); and
- Managing Risks of Hazardous Chemicals in the Workplace 2012 Model Code of Practice (SafeWork Australia).

Applicable Australian Standards include but are not limited to:

- AS 1726:2017 Geotechnical site investigations;
- AS 4133.0-2005 Methods of testing rocks for engineering purposes - General requirements and list of methods;
- AS 4133.4.2.1-2007 Methods of testing rocks for engineering purposes - Rock strength tests - Determination of uniaxial compressive strength of 50 MPa and greater;
- AS 4133.4.2.2-2013 Methods of testing rocks for engineering purposes - Rock strength tests - Determination of uniaxial compressive strength - Rock strength less than 50 MPa;
- AS 4133.5-2002 (R2013) Methods of testing rocks for engineering purposes - Sampling of rock core;
- AS 1012.16-1996 (R2014) Methods of testing concrete – Determination of creep of concrete cylinders in compression;
- AS 1012.14-1991 Methods of testing concrete – Method for securing and testing cores from hardened concrete for compressive strength;
- AS 1012.3.1:2014 Methods of testing concrete - Determination of properties related to the consistency of concrete - Slump test;
- AS 1012.9:2014 Methods of testing concrete - Compressive strength tests - Concrete, mortar and grout specimens;
- AS 1478.1-2000 Chemical admixtures for concrete, mortar and grout - Admixtures for concrete; and
- AS 1379-2007 Specification and supply of concrete.

13.2 ASSESSMENT METHOD

The information presented in this section is derived from independent consultants, Terramin and public data where available. Baseline characterisation has been established through a number of geochemical, mineralogical and geotechnical investigations across the region, with particular focus on the area of the proposed Mining Lease.

An assessment of the geochemistry, mineralogy and geohazards of the area and the associated risks they pose to public safety, public infrastructure and the environment is presented with areas of risk delineated and receptors are identified.

Terramin considers that the data for the proposed Mining Lease (ML) is representative of the area.

13.3 EXISTING ENVIRONMENT

13.3.1 GEOCHEMICAL ASSESSMENT OF ALL ROCK TYPES THAT ARE PROPOSED TO BE DISTURBED (REPLICATED FROM CHAPTER 7: PUBLIC SAFETY)

There have been multiple phases of geochemical analyses at the Project site starting with the government drilling in the 1930's through to Terramin's drilling in 2016. Over this 80 year period the suites of elements analysed for has increased, initially from gold only being analysed on the 1930's samples to a suite of 48 elements analysed by Terramin for the 2016 infill drilling program.

13.3.1.1 ORE MATERIAL

The results of the geochemical analysis of the ore zone, indicates that lead (Pb) is the only element that occurs at average concentrations above Health based Investigation Levels (HILs) for commercial and industrial sites as described under Schedule B(1) of the National Environmental Protection Council (NEPC) Guideline on Investigation Levels for Soil and Groundwater (Table 13-1). The HIL for lead at commercial or industrial sites is 0.15%; the average concentration of lead of the BIHGP ore is estimated to be 0.27%.

TABLE 13-1 COMMERCIAL/INDUSTRIAL HILS COMPARED TO BIHGP MINERALISATION.

Metal	Commercial/industrial HIL (mg/kg)	Peak individual grade peak (mg/kg)	Average block model (mg/kg)
Arsenic	3,000	869	27
Beryllium	500	9	
Boron	300,000	Below detection	
Cadmium	800	228	
Chromium	3,000	348	
Cobalt	4,000	398	
Copper	250,000	15,900	390
Lead	1,500	478,000	2,700
Manganese	40,000	10,968	
Mercury	200	13	
Nickel	4,000	1,033	
Selenium	10,000	43	

Metal	Commercial/industrial HIL (mg/kg)	Peak individual grade peak (mg/kg)	Average block model (mg/kg)
Zinc	400,000	136,000	3,100

13.3.1.2 MULLOCK (WASTE ROCK)

No elemental concentrations hazardous to human health have been found to occur from geochemical analysis of the mullock to be mined. Trace element concentrations in the host rocks are well below the HILs for commercial and industrial sites, as described under Schedule B(1) of the National Environmental Protection Council (NEPC) Guideline on Investigation Levels for Soil and Groundwater Table 13-2.

TABLE 13-2 | COMMERCIAL/INDUSTRIAL HILS COMPARED TO BIHGP HOST ROCK

Metal	Commercial/industrial HIL (mg/kg)	Tarcowie Siltstone (mg/kg)	Cox Sandstone (mg/kg)	Brighton Limestone (mg/kg)	Tapley Hill Formation (mg/kg)
Arsenic	3,000	ND	ND	5	2
Beryllium	500	2	1	0	2
Boron	300,000				
Cadmium	800	0	0	3	0
Chromium	3,000	29	17	9	23
Cobalt	4,000	17	14	5	11
Copper	250,000	25	30	24	18
Lead	1,500	10	20	170	24
Manganese	40,000	792	113	1,248	551
Mercury	200				
Nickel	4,000	26	32	3	17
Selenium	10,000	Below detection	Below detection	0.3	Below detection
Zinc	400,000	55	8	128	49

13.3.2 MINERALOGICAL ASSESSMENT OF ALL ROCK TYPES

The geology of the BIH deposit is characterised by Proterozoic-aged basement rocks that have undergone extensive alteration. Terramin and its predecessor Maximus have undertaken extensive geological research to understand the various mineral assemblages that exist within the BIH deposit and the paragenetic context of their occurrence.

13.3.2.1 MINERALISATION

In 2016, to assist with the understanding the metallurgical properties of the BIH gold mineralisation Terramin organised petrographic and X-ray Diffraction studies to be undertaken. The petrographic work was undertaken by Gary J McArthur of MODA Mineralogy (McArthur, 2016). From four polished slides the area of each was examined microscopically and all minerals present were identified, Table 13-3.

TABLE 13-3 | RESULTS OF 2016 PETROGRAPHIC STUDY

From sample	Macroscopic Description	Py	Po	As	Ap	Gn	Gn_{ox}	Cp	Bn	Cc	Cv	Au	Go	Qz	Co
BH054 193.3-193.7m	Quartz with goethite	Tr		Tr		Tr		Tr				Tr	25	70	5
BH057 206.1-207.2m	Goethite-pyrite	30						Tr				Tr	55	15	
BH057 210.0-211.1m	Quartz with pyrite veins	10			2	2	1	Tr	Tr	Tr		Tr		75	10
BH057 212.5-213.1m	Massive pyrite-gelena	65	Tr		5	25	Tr	5	Tr		Tr			Tr	Tr

Py=pyrite, Po=pyrrhotite, As=arsenopyrite, Sp=sphalerite, Gn=galena, Gnox=oxidised galena, Cp=chalcopyrite, Bn=bornite, Cc=chalcocite, Cv=covellite, Au=electrum, Go=goethite, Qz=quartz, Co=carbonate. Tr means <0.5vol%.

Following the metallurgical test work McKnight Mineralogy XRD on oxide and sulphide "tails" which were made up of composites from 5 drillholes. The results from the XRD work are presented in Table 13-4 (McKnight, 2017).

TABLE 13-4 | RESULTS OF 2017 XRD STUDY (MCKNIGHT, 2017).

Phase	1019064 T05 Ro Tail	1019085 T08 Ro Tail
Plagioc lase	0.1	0*
Apatite	0.7	1
Calcite	3.4	19
Chlorite	1.6	0
Dolomite	0.9	0*
Galena	0.3	0*
Goethite	2.1	2
Muscovite	5	2
Pyrite	1.2	0*
Pyrrhotite	0	0*
Quartz	84.6	75
Siderite	0*	0*
Sphalerite	0.1*	0*

0* - limit of detection = ~0.2wt.%

13.3.2.2 NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM)

Naturally occurring radioactive material (NORM) is a term describing materials containing radionuclides that exist in the natural environment. Natural radioactivity is common in rocks and soils, in water and oceans.

No significant levels of radioactive material have been discovered at Bird-in-Hand and all measured uranium contents are well below the level of 80 ppm for further investigation. The highest average uranium elemental composition occurs within the ore zone at 4.7ppm and the average concentration in all rock types is below 2.0ppm.

13.3.2.3 ASBESTOS OR MINERALS THAT HAVE THE POTENTIAL TO PRODUCE RESPIRABLE SILICA

"Asbestos" is a commercial term referring to six types of naturally occurring silicate mineral fibres that can be separated into two broad categories – amphibole and serpentine minerals.

There have been 67 petrological descriptions and three XRD scans undertaken on samples collected from the BIHGP area. No chrysotile, anthophyllite, amosite or crocidolite have been identified in these studies. However, tremolite (amphibole) with a fibrous habit was identified in a metasomatised dolerite near the contact between the Brighton Limestone and the Tarcowie Siltstone.

No amphiboles with a fibrous habit have been identified in areas where proposed mining will take place; BIHGP mineralisation, Tapley Hill Formation or in the Brighton Limestone in the footwall or in the immediate hanging wall to the Red Reef.

Samples taken for petrological examination are often biased towards unusual occurrences. Pontifex described fibrous tremolite in PET #Bh5 – BH19 (153.25 – 153.35m), Mineralogical Report No. 8809. Petrological sample Bh#5 was collected to identify the minerals present in an unfamiliar style of veining within a dolerite. The rare type of vein was found to be composed of tourmaline, carbonate and quartz. The identified fibrous tremolite was found in the halo to this vein, Figure 13-1.

FIGURE 13-1 | PETROLOGICAL SAMPLE BH#5, BH019 153.25-153.35M WITH PALE PATCHES OF TREMOLITE, ALBITE SERICITE AND EPIDOTE IDENTIFIED

Dolerites, only make up 3% of all rock types logged at BIHGP and tourmaline veins are recorded to occur in 10% of dolerites. With the average width of the tourmaline veins being around 30mm, tourmaline veins in dolerites are estimated to make up around 0.0055% of the BIHG rock mass. The percentage of fibrous tremolite associated with the tourmaline veins would be substantially smaller again. As tourmaline veins make up roughly 1:20,000 of the rock mass at BIHGP, the alteration halo associated with these veins are not considered a credible source of tremolite fibres.

13.3.3 GEOCHEMICAL HAZARDS

13.3.3.1 ACID AND METALLIFEROUS DRAINAGE

Following the 2016 geotechnical drill program acid and metalliferous drainage (AMD) was identified as a potential risk that needed to be quantified. Terramin engaged Tonkin Consulting Pty Ltd (Tonkin) to undertake an AMD assessment of the BIHGP which involved sampling along potential decline paths and shafts (Appendix M2). A total of 58 primary samples of core were selected for laboratory analysis, with each sample comprising a 2 m section (interval) of the drill core (Table 13-5).

The objective of the sampling program was to obtain representative samples of country rock that; (i) reflect as close as possible the waste rock that would be generated during the mine life by targeting the depth intervals that intersect with the underground mine plan, and (ii) represent zones of potential AMD risk, highlighting areas to avoid or manage during mine planning.

TABLE 13-5 | SUMMARY OF AMD SAMPLING PROGRAM

Boreholes sampled	Geological Formation	Mine Development	No. tested
BH049 and BH052	Tapley Hill	Box cut and initial decline spiral	7
BH047, BH048, BH053	Formation	Primary vent rise	22
BH053, BH055		Decline, lower decline spiral and drives	17
BH057, BH059	Brighton Limestone	Footwall access drives	12
Total			58

The AMD assessment was undertaken using standard, static laboratory testing methods to enable the Acid Base Accounting (ABA) characteristics of samples to assessed and classified as:

- Potential acid forming (PAF)
- Potential acid forming – low capacity (PAF-LC)
- Non-Acid Forming (NAF), and
- Acid consuming material (ACM).

The results of the analyses were modelled in a 3D block model by Terramin and the nature of the material to be mined classified and quantified.

The decline and drives will primarily be within less weathered metasediments of the Tapley Hill Formation to ensure tunnelling occurs within competent rock units. This will ensure that the zone of weathered, low pH rock (Figure 13-2) will largely be avoided during mine development and decrease potential AMD issues.

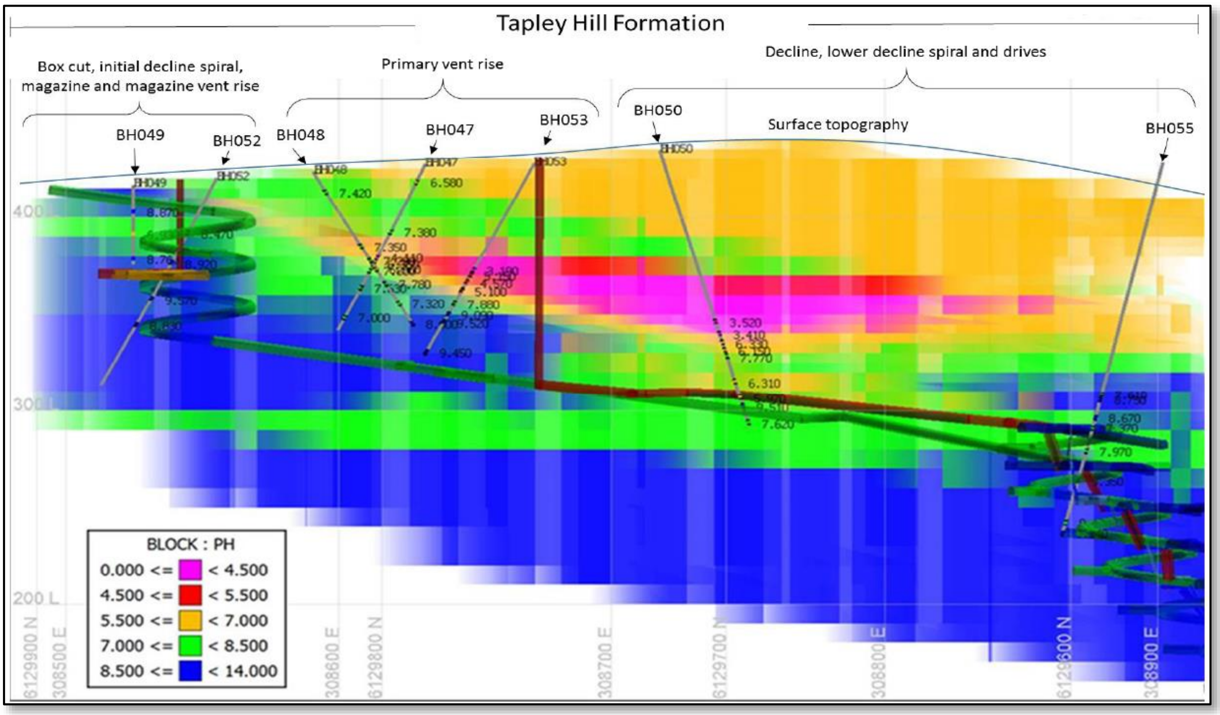


FIGURE 13-2 | LONG SECTION ALONG PROPOSED UNDERGROUND DEVELOPMENT, AMD BLOCK MODEL IS COLOURED BY PH1:2

The spatial distribution of NAGpH and NAPP results for the Tapley Hill Formation is represented by the AMD block model sections in Figure 13-3 and Figure 13-4 respectively, along with the underground development of the current mine plan.

The NAGpH section highlights the supergene sulphide zone that forms a discrete layer above the decline and lower decline spiral. ANC is depleted in the near surface oxidised rock and supergene zones (transition from oxidised to fresh). The NAGpH and NAPP results indicate that, if mined, PAF occurring within the supergene zone has potential to generate acid and remain acidic. In the current mine plan the supergene sulphide zone will be largely avoided, however will be intersected by the primary ventilation rise. Development of the primary vent rise is likely to be limited to a vertical shaft 4 m in radius, which would equate to approximately 100 t of PAF material, which will require management for AMD.

The NAGpH section indicates that PAF also occurs in fresh rock below the decline however the NAPP section indicates that this material is likely to be acid consuming.

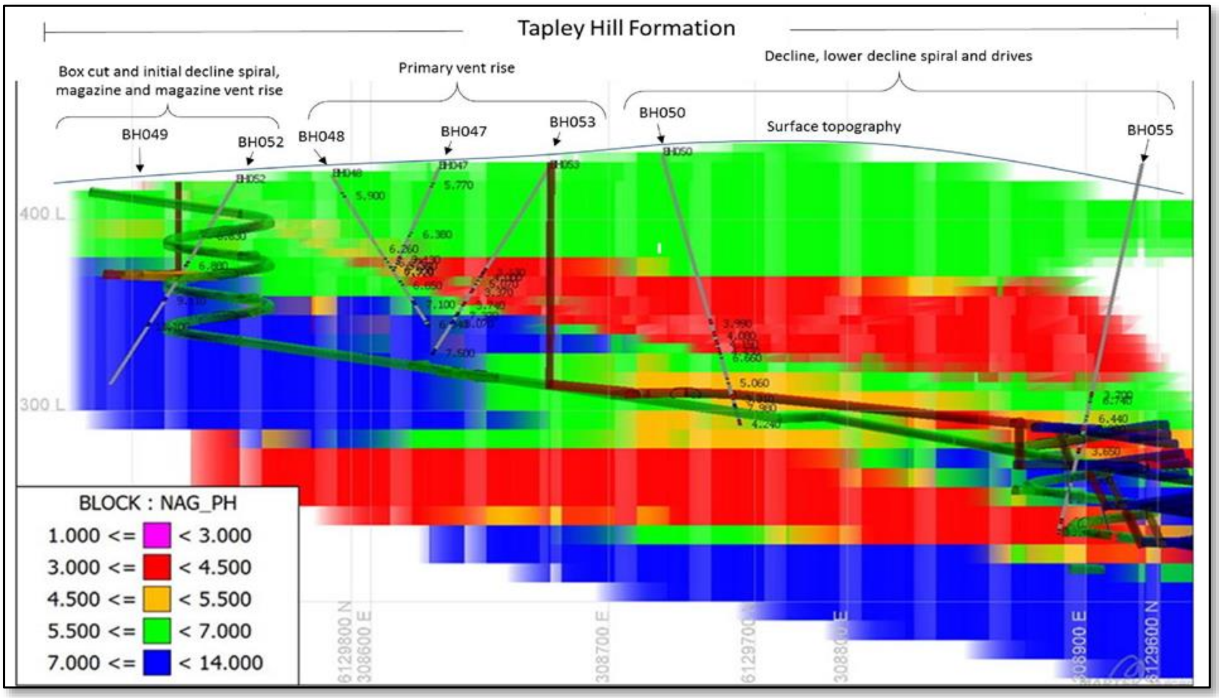


FIGURE 13-3 | AMD BLOCK MODEL SHOWING NAG PH AND PROPOSED UNDERGROUND DEVELOPMENT IN THE TAPLEY HILL FORMATION

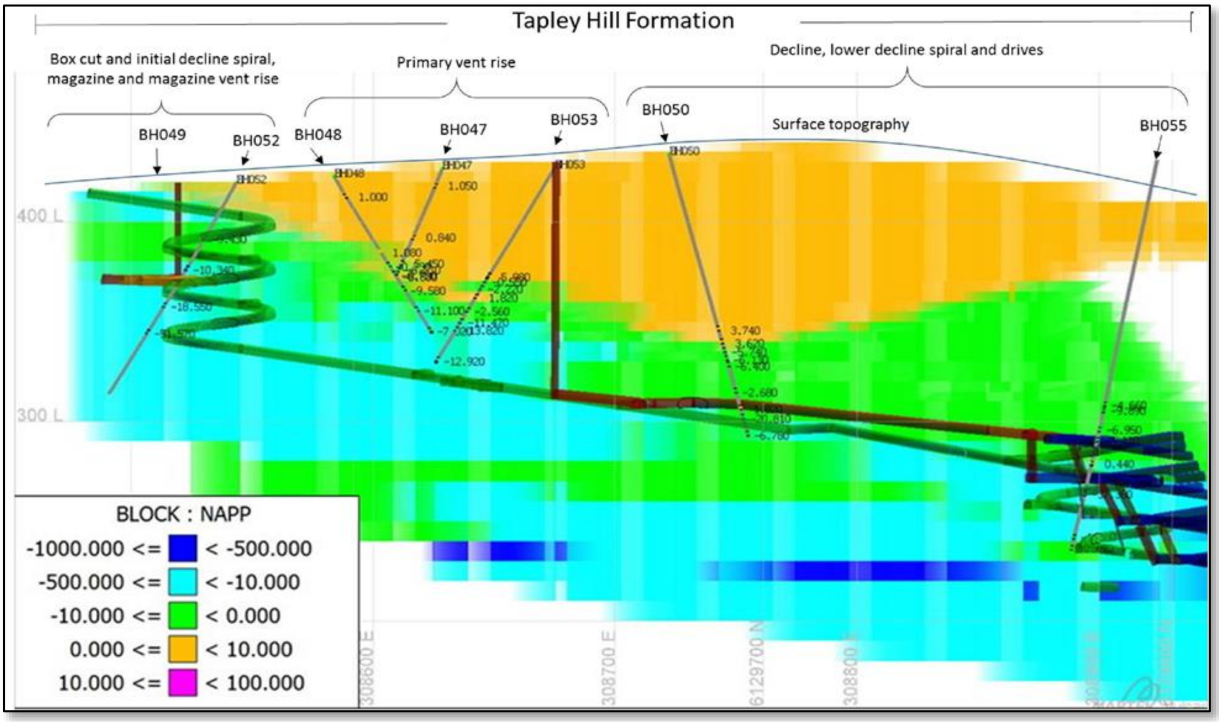


FIGURE 13-4 | AMD BLOCK MODEL SHOWING NAPP AND PROPOSED UNDERGROUND DEVELOPMENT IN THE TAPLEY HILL FORMATION

The Acid and Metalliferous Drainage (AMD) Assessment undertaken by Tonkin Consulting (Appendix M2) (found that pyrite mineralisation within the Tapley Hill Formation at BIHGP is relatively rare, and of the 46 samples tested only five had a Total S% of >0.3%, and only six samples classified as PAF, indicating a low potential for AMD generation.

Brighton Limestone material was classified as NAF with abundant acid neutralising capacity due to the presence of carbonate minerals.

Based on the current AMD block model, the assessment indicates that the PAF material comprises approximately 2% of the waste rock generated. Additionally, the NAF material (98%), incorporating the Brighton Limestone material, has the potential to be used to encapsulate and neutralise any PAF mined.

On the basis of this assessment, and allowing for the appropriate management of PAF material, the risk of significant AMD is considered to be low.

13.3.3.2 SALINE AND NEUTRAL MINE DRAINAGE POTENTIAL

Both the hanging wall (Tapley Hill Formation) and footwall (Brighton Limestone) formations were analysed for the potential for saline and/or neutral mine drainage.

Information supporting this section is located in Appendix M2.

13.3.3.2.1 TAPLEY HILL FORMATION

EC1:2 results of Tapley Hill Formation samples ranged from 0.08 dS/m (non-saline) to 1.49 dS/m (moderately saline) with an average EC1:2 value of 0.56 dS/m (very slightly saline). The variation of EC1:2 extracts was comparable to the salinity of groundwater drawn from the Tapley Hill Formation, which ranges from 0.78-1.56 dS/m (TDS of 500–1000 mg/L) (DWLBC 2002).

Saline samples tended to be from the transitions weathering / supergene zone where samples are sulfidic with low pH1:2 and NAGpH values (Figure 13-5). This relationship is likely due to sulphide oxidation releasing sulphate and acidic conditions intensifying the weathering of salt-bearing minerals, such as scapolites and clays that contain Na, Mg, Ca, Ba, Cl, SO4, SiO4 ions, trace elements and metal ions such as Fe and Al (Fitzpatrick, et al., 2000).

In addition, Neutral Mine Drainage (NMD) (TDS>1000 mg/L) may result due to the inherent buffering capacity (from Ca and Mg carbonates) of Tapley Hill Formation samples.

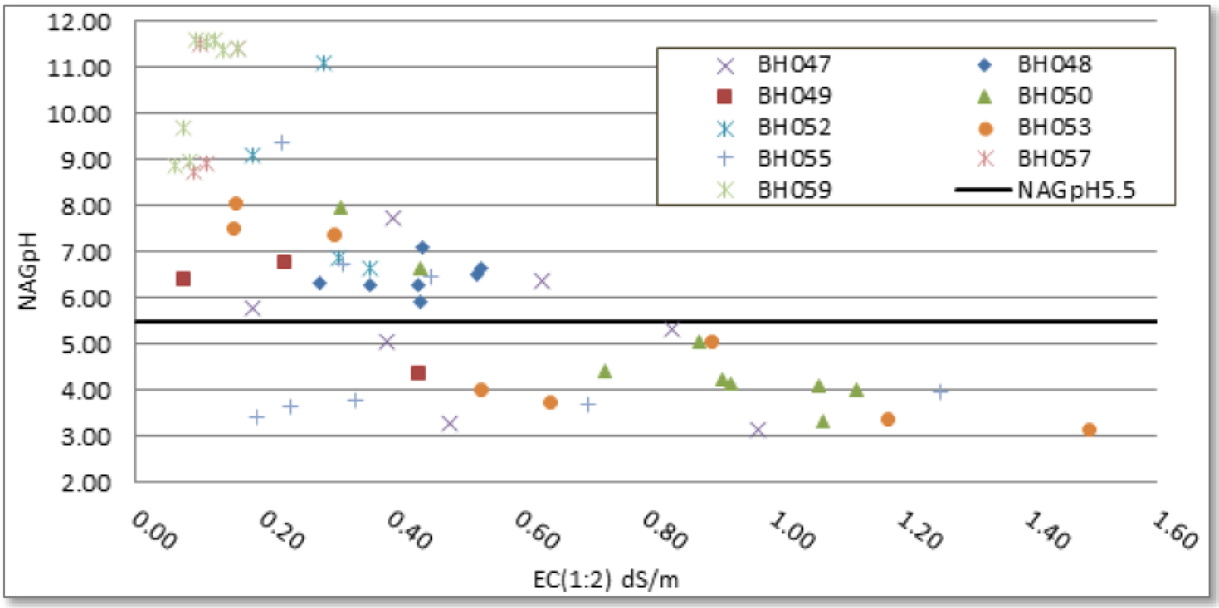


FIGURE 13-5: RELATIONSHIP BETWEEN EC1:2 AND NAGPH FOR ALL SAMPLES

Potential NMD issues to consider during management of Integrated Mullock Landform (IML) may include;

- Co-disposal of PAF with NAF(ACM) or PAF treatment with lime will increase the pH of drainage causing Fe and Al to precipitate. Metals such as Cd, Cr, Cu, Pb and Zn may be adsorbed to ferrihydrite, clays and organic matter, however sulphate and oxides of As, Cr, and Se have potential to be mobilised as pH increases.
- Evapo-concentration can further increase metal and salt concentrations of slightly saline leachate. In AMD and NMD environments there is an increased risk that sodicity may result from runoff or at seepage areas of stockpiles which can cause soils to become clogged with clay and mineral precipitates so that they lose their permeability and vegetative cover.

Salts, metals and metalloids associated with NMD of Tapley Hill Formation waste rock should therefore be included in groundwater and environmental monitoring programs.

13.3.3.2.2 BRIGHTON LIMESTONE – FOOTWALL

Brighton Limestone samples EC1:2 results were non-saline (EC1:2 ranged from 0.06 to 0.16 dS/m), resulting in a very low potential for NMD.

Potential for NMD from temporary ore stockpiles (that may include some material from the footwall access drive) is also considered very low for BIHGP, particularly given ore will be stored in hoppers/bin for the ROM before being transported to Angas Zinc, in conjunction with the low Total S% content of the immediate footwall access samples tested.

XRF analysis undertaken by Terramin indicated that sulfidic features and mineralised zones in BH058 are enriched in metal and metalloids (Al, Fe, S, As, Ag, Co, Cr, Cu, Mn, Pb, S, Ti, W and Zn) with respect to country rock units.

Methods for mitigating the saline and NMD contamination risk potential are included in Chapter 3.

13.3.4 NATURALLY OCCURRING SUBSIDENCE

Fourteen monitoring stations were established around the BIHGP area by VacGroup in August 2016 to monitor the geotechnical stability of the area. Five stations are located along Pfeiffer Rd on the North side of the Terramin Australia property in Woodside. Nine more stations are situated on Bird in Hand Rd to the west of Reefton Rd, spaced approximately 50-70 m apart. Two permanent surveys marks (PSM) are included in the monitoring along Bird In Hand Rd. Locations of all stations can be seen in Figure 13-6.

Over the first year of monitoring, slight variations in levels have been recorded at some of the stations but none of these exceed 10 mm. PSM 1 remains very stable, as do the monitoring stations closest to it (Mon 1 – 5), which all vary less than 5 mm. However over the two plus years of monitoring greater variation can be seen, between 3 and 7mm movements. Monitoring stations 6-9 have shown more variation: up to 24 mm, in line with PSM 2 which has recorded a maximum variation of 12 mm. On Pfeiffer Rd, variations in levels have been minimal with slight increases in stations 11, 13, and 14 (2-9 mm variances), a decrease in monitoring station 10 (17 mm), and steady at monitoring station 12. A table of all subsidence survey data is included in Table 13-6.

The Bird in Hand Mine area has a mix of geology types crossing it. The east side, where the Bird in Hand Rd stations are located, is part of the Inman Hill Formation from the Cambrian system, described as "Grey metamorphosed greywacke, arkose and turbidite, large-scale cross-bedding and slump structures. Unnamed conglomerate members near top, and calc-silicate members near base." This area also has areas of pronounced metamorphism. Moving towards the west, is the Tapley Hill Formation from the Adelaide system which is laminated grey and green siltstone, the Etina Limestone Member: grey gritty algal dolomite and limestone, and Kulpara Limestone: grey, buff-weathering massive dolomite and dolomitic limestone. Cutting across the region south to north is fine grained intermediate dykes of dolerite, microdiorite, and porphyrite.

DEWNR Soil and Land Program describes the soil to the northwest of the Bird in Hand Mine as "Medium thickness red brown loam over a well-structured red clay grading to weathering fine grained basement rock within 100 cm". "Moderately well to well drained. The subsoil clay may perch water for a few days at a time following heavy or prolonged rainfall" (DEWNR Soil and Land Program, 2007, p. CH165).

To the north, by Pfeiffer Rd, the soil is described as "Loamy surface soil overlying a brown, grey and red firm clay subsoil forming in fine grained metamorphic rock". "Moderately well drained. The soil may remain wet for a week or so, due to water lying on top of the clay subsoil" (DEWNR Soil and Land Program, 2007, p. CH043).

To the east, beyond Reefton Rd, the soil is "Thick sandy surface overlying a yellow and grey mottled clay forming in quartzitic rock". Drainage is "Imperfect. The clayey subsoil "perches" water, saturating the bleached layer and the top of the clay for weeks at a time following prolonged rainfall" (DEWNR Soil and Land Program, 2007, p. CH099).

To the west, at the end of Bird In Hand Rd, the soil description is "Loam to clay loam surface overlying red to reddish brown well-structured friable clay subsoil, grading to weathering fine grained metamorphic rock". "Moderately well drained, temporary waterlogging being due to the high clay content, particularly of the subsoil. The soil may remain wet for a week or so" (DEWNR Soil and Land Program, 2007, p. CH041).

Surrounding the Bird in Hand Project area, the stratum contains layers of clayey subsoil, which are likely to be reactive to both seasonal and long term changes in moisture levels. The level of shrink-swell related to these soils is dependent on the plasticity of the clayey subsoil and the amount of other sandy content. The amount of clayey subsoil affected by moisture content changes will also be a variable in the stability of the surface levels.

In summary minor changes in subsidence monitoring of these stations may be attributed to the clayey subsoils upon which the base stations are located shrinking or swelling due to changes in soil moisture levels.

FIGURE 13-6 | LOCATIONS OF MONITORING STATIONS.

TABLE 13-6 | MONITORING RESULTS ROADSIDE SUBSIDENCE MONITORING POINTS 2016 – 2019

Station ID	PSM 1	PSM 2	Mon 01	Mon 02	Mon 03	Mon 04	Mon 05	Mon 06	Mon 07	Mon 08	Mon 09	Mon 10	Mon 11	Mon 12	Mon 13
Easting (MGA94)	308780.82	309117.73	308828.49	308887.18	308923.78	308981.31	309028.64	309074.49	309121.57	309188.09	309252.12	308448.70	308396.60	308346.55	308285.62
Northing (MGA94)	6129629.66	6129765.91	6129610.54	6129611.05	6129614.30	6129630.09	6129667.04	6129717.39	6129761.71	6129775.09	6129794.90	6130358.77	6130310.97	6130264.46	6130225.68
GPS height (m AHD)	446.56	458.58	446.02	446.32	447.77	451.79	455.71	457.36	458.11	455.77	456.22	393.92	392.29	391.79	390.89
26/08/2016	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.37	458.13	455.77	456.22	393.91	392.27	391.81	390.90
27/09/2016	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.37	458.13	455.77	456.22	393.91	392.27	391.81	390.90
27/10/2016	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.37	458.13	455.77	456.22	393.91	392.27	391.81	390.90
27/11/2016	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
22/12/2016	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
3/02/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
25/02/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
28/03/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
27/04/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
30/05/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.28	391.81	390.90
30/06/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.21	393.91	392.28	391.81	390.90
1/08/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
29/08/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.37	458.13	455.77	456.22	393.91	392.27	391.81	390.90
3/10/2017	446.56	458.58	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.76	456.22	393.91	392.27	391.81	390.90

Station ID	PSM 1	PSM 2	Mon 01	Mon 02	Mon 03	Mon 04	Mon 05	Mon 06	Mon 07	Mon 08	Mon 09	Mon 10	Mon 11	Mon 12	Mon 13
31/10/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
26/11/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
24/12/2017	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
1/02/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.90	392.27	391.81	390.90
28/02/2018	446.56	458.58	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.76	456.22	393.90	392.27	391.81	390.90
1/04/2018	446.56	458.58	446.02	446.29	447.80	451.84	455.67	457.35	458.13	455.76	456.21	393.90	392.28	391.81	390.90
2/05/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.76	456.21	393.91	392.28	391.81	390.90
6/06/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.76	456.21	393.91	392.28	391.81	390.90
1/07/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.92	392.28	391.81	390.91
1/08/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.92	392.28	391.81	390.91
2/09/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.91	392.27	391.81	390.90
3/10/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.77	456.22	393.92	392.28	391.81	390.90
29/11/2018	446.56	458.59	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.76	456.21	393.91	392.28	391.81	390.90
5/01/2019	446.56	458.58	446.02	446.29	447.80	451.84	455.67	457.36	458.13	455.76	456.21	393.90	392.28	391.81	390.90

13.3.5 GEOHAZARDS - GEOTECHNICAL

13.3.5.1 HISTORIC SEISMIC ACTIVITY (REPLIACTED FROM CHAPTER 7: PUBLIC SAFETY)

Seismic activity, (earthquakes) are reasonably common in South Australia, with Geoscience Australia recording around 3,922 earthquakes since 1840 to present (2015). Most of these earthquakes have been within the Adelaide Geosyncline, with others spread throughout the state.

The Mount Lofty Ranges, the central part of the Adelaide Geosyncline, are the result of movements along neotectonic structures. The major neotectonic structures in the Woodside region are the Medows and Bremer Faults which are respectively located 4.7 kilometres to the east and 11.0 kilometres to the west of the BIHGP. The second order Nairne Fault is located 2.3 kilometres to the west of the BIHGP, Figure 13-7.

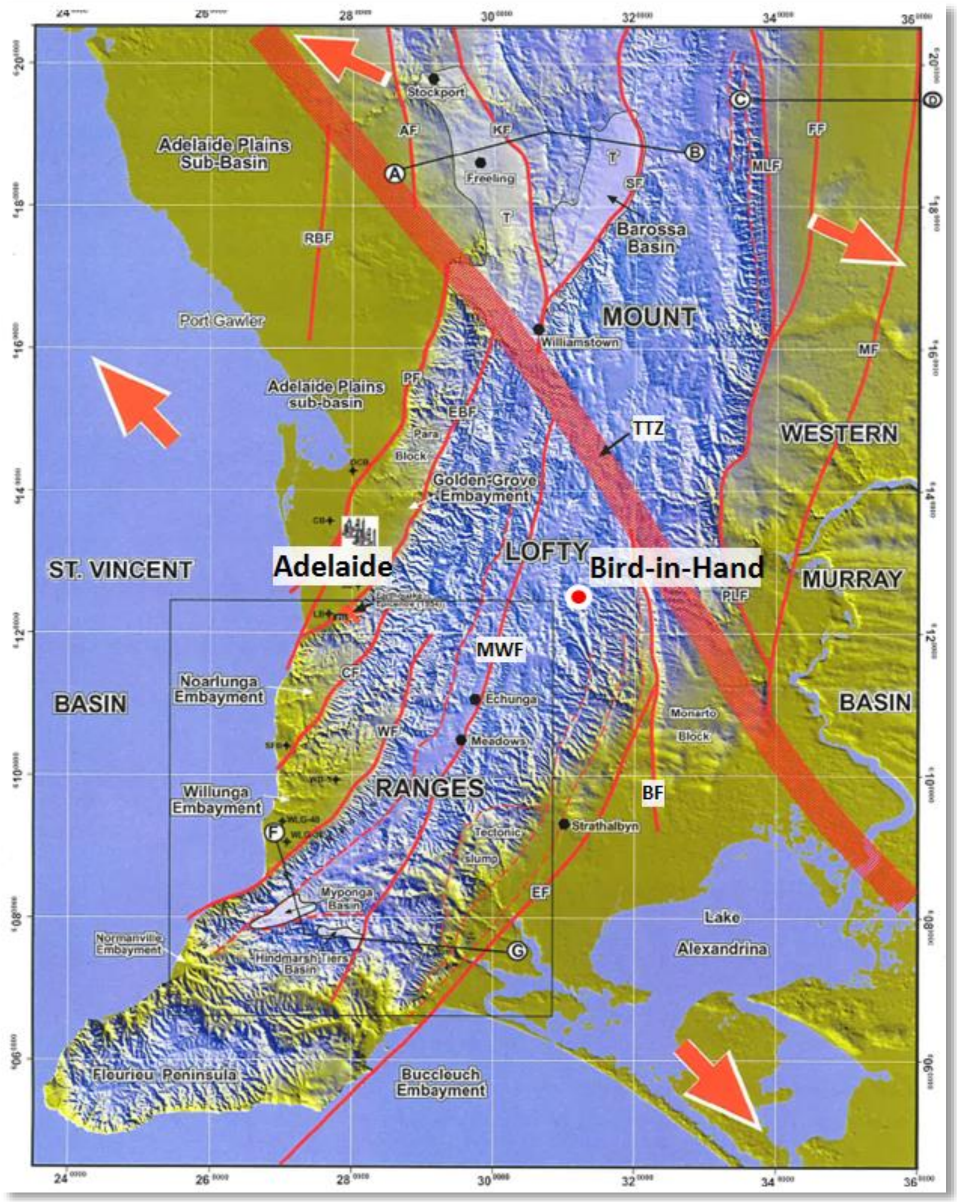


FIGURE 13-7 | NEOTECTONICS OF THE MOUNT LOFTY RANGES-MEADOWS FAULT- MWF, BREMER FAULTS – BF (TOKAREV, 2005)

The Richter scale represents the units used to quantify the magnitude of an earthquake. It compares the maximum heights of seismic waves at a distance of 100km from the epicentre. For every 0.1 increase in Richter scale magnitude, there is a three-fold increase in the energy released by the earthquake.

The magnitude of earthquakes recorded in South Australia range from 0.3 to 6.5 on the Richter scale. With the exception of a 5.6 magnitude earthquake of 1954 that was centred beneath Darlington, south of Adelaide no earthquake greater than magnitude 4.0 has occurred within 50km of BIH since 1866, Figure 13-8.

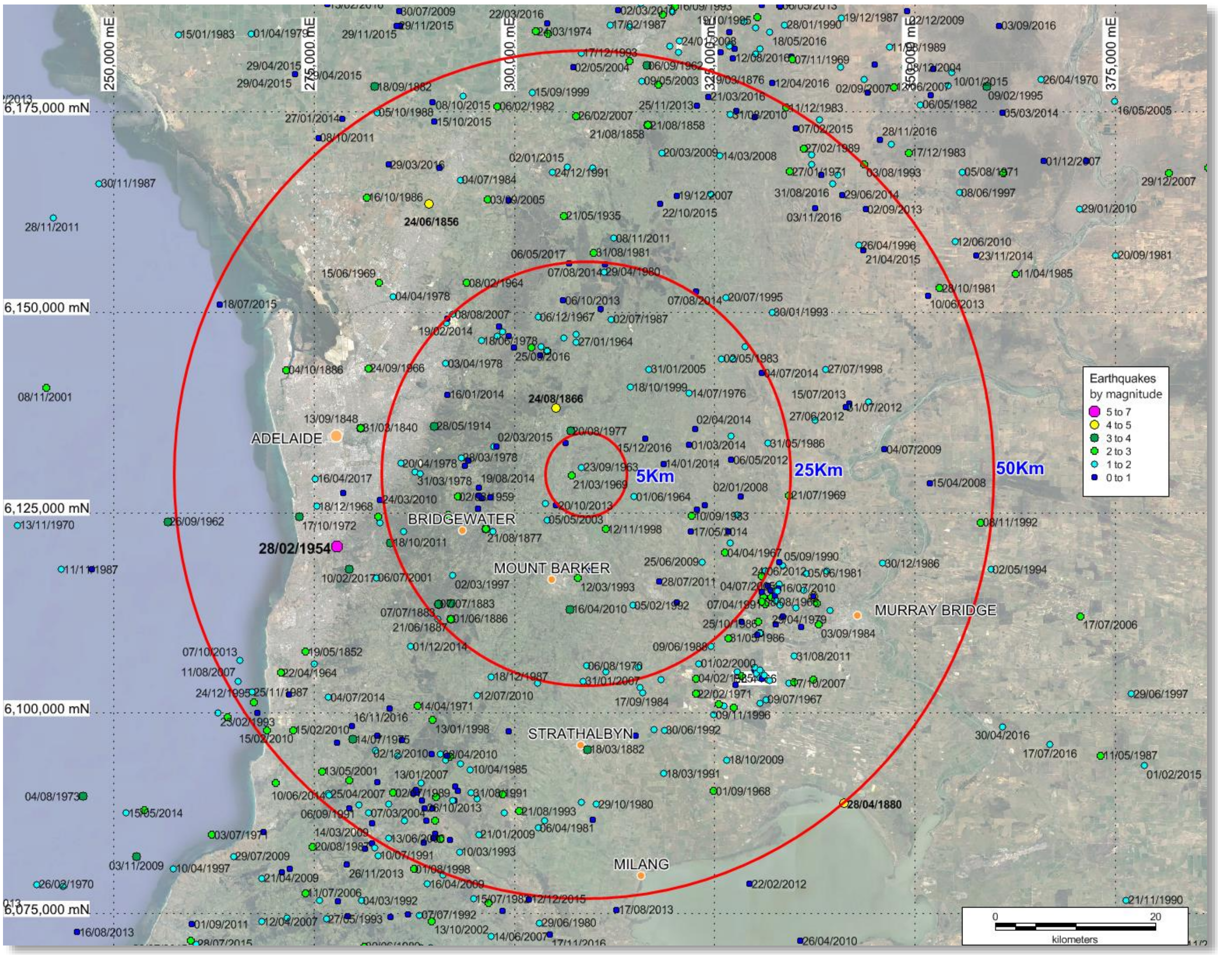


FIGURE 13-8 | LOCATION OF EARTHQUAKE EPICENTRES AND THEIR MAGNITUDE

As of December, 2017, since records began there have been three earthquakes in South Australia which have recorded 6.0 or over on the Richter scale, the most recent of which was in March of 1986. There have been about 10 earthquakes on record for Australia with a magnitude of 6.0 or greater.

Locally, there have been 87 earthquakes within 25km of Woodside between 1848 and 2014. The magnitude of these earthquakes range between 0.3 and 4.2 on the Richter scale.

Historical records from Bird in Hand Gold Mine describe a seismic event in 1897, which "threw the pumps out of line, and allowed the water to submerge the workings". In an abridged prospectus published in the Advertiser in 1934, operations at Bird in Hand reportedly ceased thereafter until the Mines Department began drilling again in the early 1930s.

This earthquake can be attributed to the historic Beachport earthquake of 1897, which registered 6.5 on the Richter scale. It remains the largest earthquake in South Australia on record, with shocks felt as far as Port Augusta and Melbourne. As can be seen in Figure 13-9, the intensity of the earthquake experienced around Woodside is somewhere between four and five on the Modified Mercalli Earthquake Intensity Scale. A rating of four is described as doors, windows, glassware and crockery rattling, standing motorcars may rock and the vibration may be likened to the passing of heavy traffic, where as a rating of five can break glassware and crockery, crack windows, and cause doors and shutters to swing. A Modified Mercalli rating of five is able to stop, start or change the rate of pendulum clocks (Geoscience Australia). (Commonwealth of Australia, 2017)

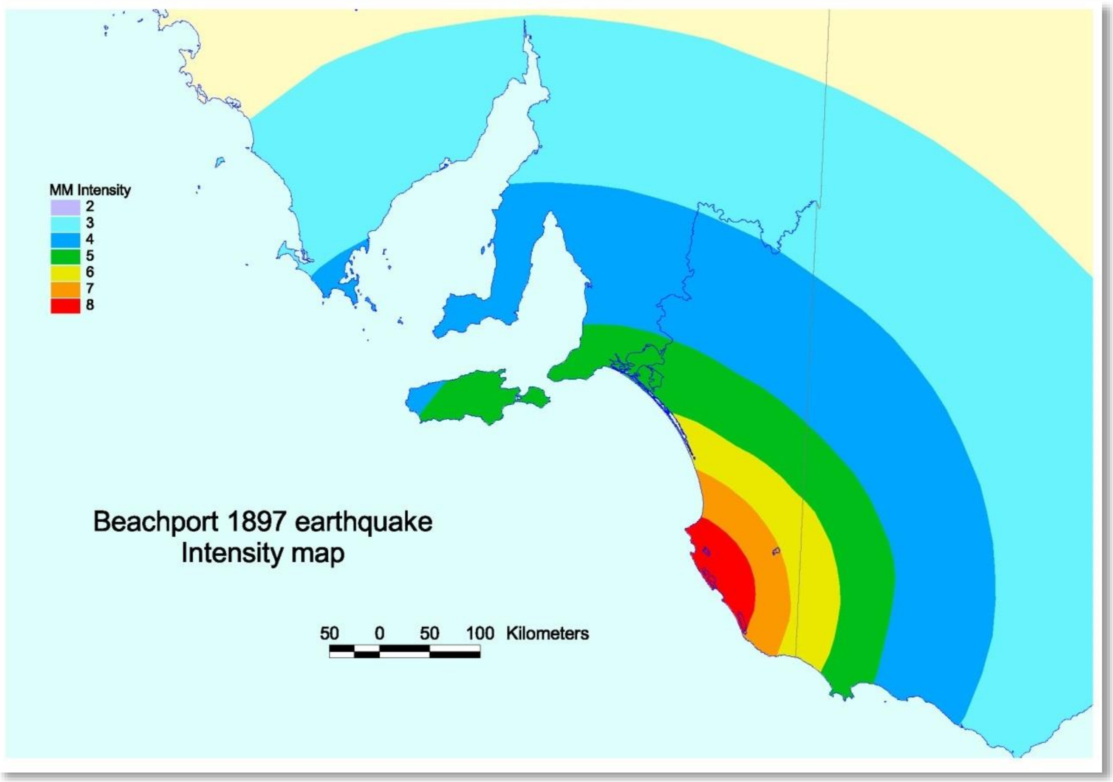
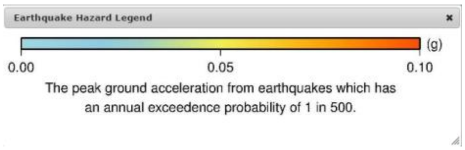


FIGURE 13-9 | PIRSA: MAJOR EARTHQUAKES IN SA: BEACHPORT 1897 INTENSITY MAP (GOVERNMENT OF SOUTH AUSTRALIA)

13.3.5.2 EARTHQUAKE HAZARD RISK

Earthquake Hazard Risks for Australia are based on earthquake measurements taken from the Geoscience Australia Earthquake Database. Earthquake acceleration coefficients are derived for the structural design of buildings and infrastructure and determine the amount of weight that can be applied horizontally during an earthquake. The higher the value of this coefficient, the greater the risk of an earthquake occurring.

The Earthquake Hazard Map of Australia 2012 developed by Geoscience Australia for the most recent AS1170.4 "Structural design actions: Part 4 Earthquake actions in Australia" is shown in (Figure 13-10).



The earthquake hazard map shows the peak acceleration coefficient from earthquakes which have an annual exceedance probability of 1 in 500.

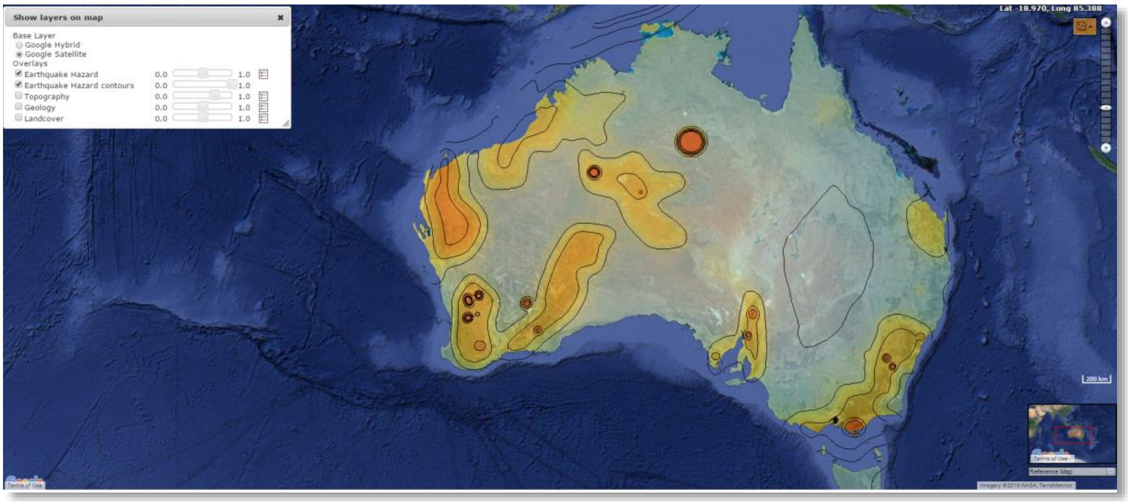


FIGURE 13-10 | EARTHQUAKE HAZARD MAP OF AUSTRALIA 2012, AUSTRALIA VIEW (GEOSCIENCE AUSTRALIA)

BIHGP has a Peak Ground Acceleration of about 0.057*g* (where *g* is the acceleration due to gravity) for a 500 year return period (Geoscience Australia website), Figure 13-11. Therefore there is a 1% chance of 0.057*g* being exceeded in during the Project duration of about 5 years. By Australian standards, this represents a moderate seismic hazard.

For comparison, the highest earthquake hazard zones in Australia have predicted ground accelerations of 0.10*g* to 0.15*g* in southern Gippsland, Victoria, and parts of central Northern Territory and Western Australia. It is common practice to account for earthquake motions in slope designs in areas of high earthquake hazard, and/or for long-term projects where there is more likely to be a significant event during the project period.

Earthquake hazard maps are used for assessment of long-term stability of infrastructure. To ensure the stability of engineered structures Terramin has, and is continuing to address the potential risks associated with both seismic activity and reactive soils. Engineered structures will be developed under stringent modelling assumptions for seismic activity and reactive soils. Earthquake damage to the proposed mine installations would be minimal due to the small scale nature of fixed plant and infrastructure proposed.

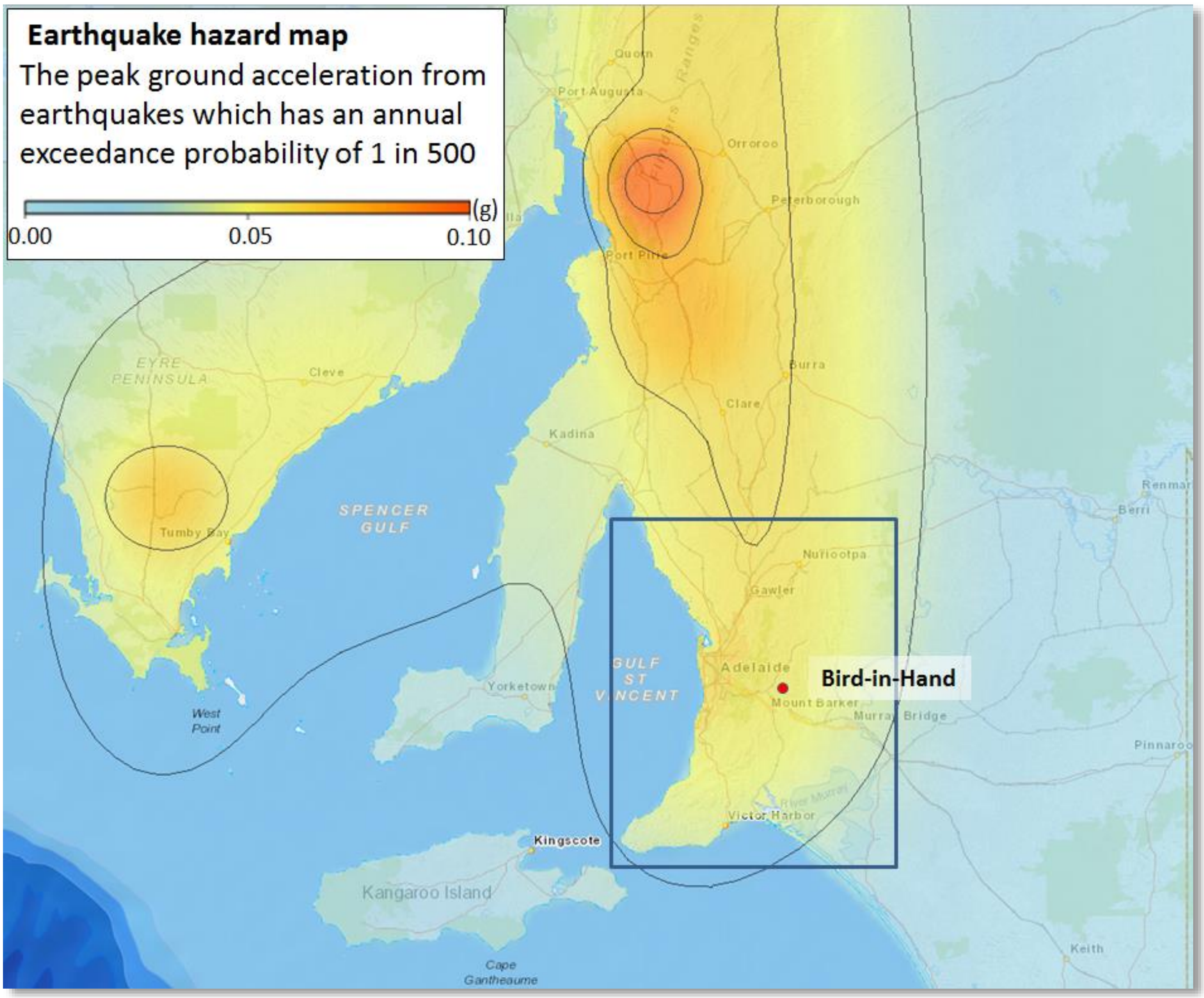


FIGURE 13-11 | SELECTED AREA FROM AUSTRALIAN GOVERNMENT - GEOSCIENCE AUSTRALIA 2012 AUSTRALIAN EARTHQUAKE HAZARD MAP

13.3.5.3 LANDSLIPS

No landslides have been recorded within or immediately adjacent to the proposed ML area (GA 2000a). The area within the proposed ML is characterised by gently undulating topography with low relief and slope gradients. No impacts (direct or indirect) to this environment are anticipated as a result of activities proposed for the Project.

13.3.5.4 CAVES

Caves are known to have developed in the marble of the Brighton Limestone, host rock to the BIHGP gold bearing quartz reefs. Resource drillholes have intersected several small caves (Figure 13-12), the largest possibly up to 3.15m in width intersected in drill hole BH051 but that width may in part be due to core loss. The average width assigned to caves intersected in drilling is 1.25m.

Caves were also recorded on the No. 6 Level of the historic Bird-in-Hand underground workings (DPC plan N0328, 1935). At a depth of 125m beneath surface, 80 meters beneath the groundwater standing water level these are the shallowest caves recorded. Drillholes above this level have not intersected caves.

Caves are not expected to have survived in the near surface environment due to the intense clay alteration. No caves have been located at surface within the Mineral Claim area.

Underground caves, vughs, fractures will be identified and sealed as part of the probe hole and grouting process as described in Chapter 3.

Groundwater sampling has shown that no stygofauna have been found within the mineral claim boundaries and hence will not be present in these caves as described in Chapter 17.

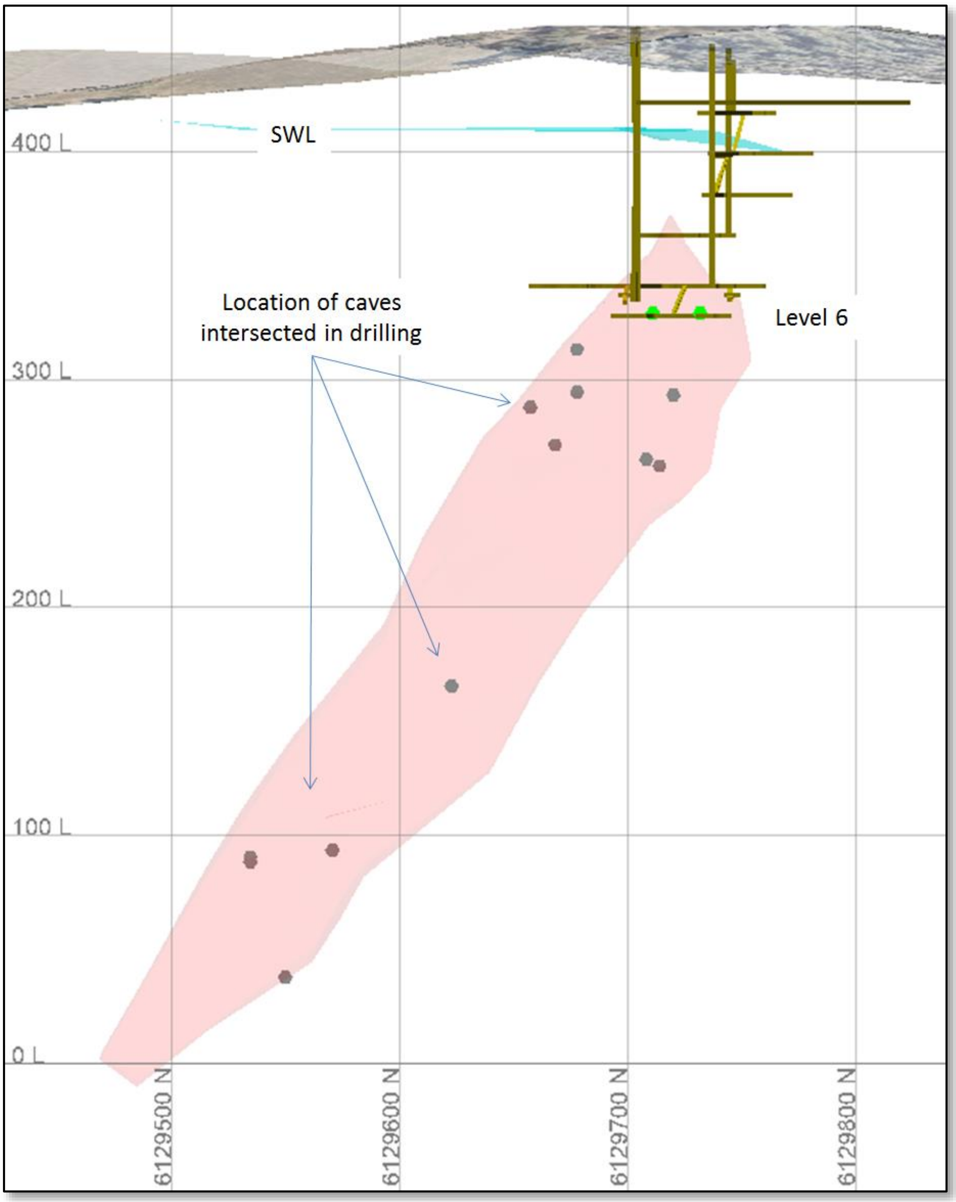


FIGURE 13-12 | LOCATION OF CAVES INTERSECTED IN DRILLING AND AS MAPPED ON PLAN N0328.

13.4 SENSITIVE RECEPTORS

Sensitive receptors to potentially impacting events identified in this chapter include any human or infrastructure located above the underground mine workings, as outlined in Table 13-7 and Figure 13-13.

TABLE 13-7 | IDENTIFIED SENSITIVE RECEPTORS

Sensitive Receptor	Summary	Impact ID
Local community	Defined as the broader region surrounding the Project	PIE_13_06 PIE_13_08
Local community – injury/fatality	Any member of the public accessing land located above the underground workings	PIE_13_01 PIE_13_05
Local community – third party infrastructure including Bird in Hand Road	As identified in map located in Figure 13-13.	PIE_13_02 PIE_13_03 PIE_13_04
Native fauna (both conservation and non-conservation significant)	Includes conservation significant fauna listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) and/or the *National Parks and Wildlife Act 1972* (SA), as identified in Chapter 18. No conservation significant fauna listed in the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) have been identified through field surveys. All other native Australian fauna understood to inhabit the area, as identified in Chapter 18..	PIE_13_07

FIGURE 13-13 | UNDERGROUND WORKINGS

13.5 POTENTIALLY IMPACTING EVENTS

Impact Events regarding Acid and Metalliferous Drainage have been included in Chapter 10: Groundwater, Chapter 11: Surface Water and Chapter 12: Land and Soil Quality.

All potentially impacting events relating to this chapter are detailed in Table 13-8.

TABLE 13-8 | POTENTIALLY IMPACT EVENTS

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	
Surface vibration due to natural earthquake seismicity, which causes mine void failure impacting third party infrastructure/fatality/injury of member of public	Construction, Operation, Closure	Natural Earthquakes	Earthquake causing shaking and instability of surface and underground workings	Local community	Yes	PIE_13_01
Stability of vent shafts effected by ground conditions and water resulting in damage to third party infrastructure	Construction, Operation, Closure	Ground conditions, faults and groundwater	localised lower rockmass strength and higher water pressure	Local community	No	PIE_13_02
Mining subsidence due to BIHGP underground workings using cut and fill method resulting in damage to third party infrastructure	Operation, Closure	Ground conditions, mining method, and underground voids	Loss of stability of ground conditions	Local community	Yes	PIE_13_03
Mining subsidence due to crown pillar failure resulting in damage to third party infrastructure	Operation, Closure	Crown pillar design, ground conditions and mining method	Instability or failure of crown pillar separating old and new workings	Local community	Yes	PIE_13_04
Geotechnical failure of IML structure stability resulting in damage to third party infrastructure/injury/fatality of member of public	Construction, Operation, Closure	Slope stability of infrastructure	Instability of the slopes	Local community	No	PIE_13_05
Sulphide dust explosion impacts air quality and local community	Operation	Sulphide ore	Air – blasting emissions through ventilation system	Local community	No	PIE_13_06
Sulphide dust explosion impacts air quality and native fauna (both conservation and non-conservation significant)	Operation	Sulphide ore	Air – blasting emissions through ventilation system	Native fauna (both conservation and non-conservation significant)	No	PIE_13_07
Ventilation system emits fibrous tremolite impacting local community	Operation	Mining of Fibrous tremolite	Air – blasting emissions through ventilation system	Local community	No	PIE_13_08

13.6 CONTROL MEASURES TO PROTECT ENVIRONMENT

13.6.1 DESIGN MEASURES

Given the information gathered on the existing geotechnical and geochemical environment of the Project, various design measures have be applied to further manage any potential impacts to the local community and members of the public, as well as other identified sensitive receptors.

These design measures include:

- Confirmation on the mining method selected.
- Location and orientation of underground mine excavations, including portal and raises/shafts;
- Size and shape of underground excavation;
- Sequencing of mining to minimise stresses;
- Angles and orientations of surface excavations to maximise stability.
- Additional ground support requirements to increase factors of safety in the design.

13.6.1.1 GEOTECHNICAL AND GEOLOGICAL MODELLING

Details regarding the geotechnical testing and Modelling are described in Appendix M1: Geotechnical Assessment, undertaken by Mining One, and in Chapter 3 discussing the Mining Operations.

Results from exploration activities, including geotechnical and geochemical investigations are logged and entered into a database, as well as samples sent off for various tests to determine further properties for modelling purposes.

- Logging of drill core and test pits;
- Chemical and mineral assays;
- Rock strengths;
- Faults and shear locations, types, orientations;
- Joint spacings and infills;
- Bedding orientations, spacing and fill types

This information (Figure 13-14) is modelling into various 3D models that can be used for design purposes and to predict ground conditions, required ground support, as well as further modelling to run scenarios for stress analysis, hydrogeological modelling etc. It also allows the design to be broken down into different geotechnical or “rock mass domains” (Figure 13-15) to ensure the optimal control measures are applied to different areas, rather than a “blanket” approach.

These models are updated on a regular basis as further information is made available, either through further exploration work, or during mining activities and mapping of rack faces and surfaces as they become available.

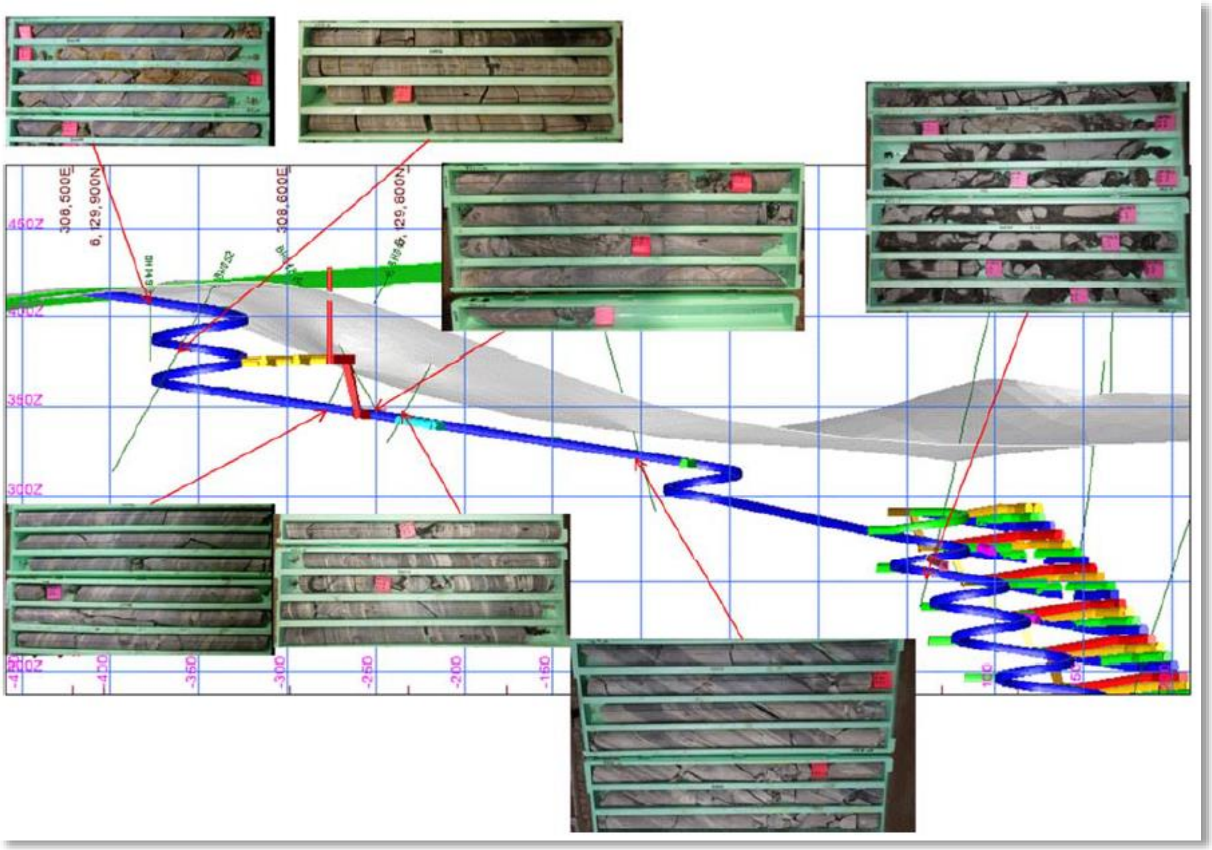


FIGURE 13-14 | TYPICAL GROUND CONDITION CORE PHOTOS OF UPPER DECLINE (APPENDIX M1)

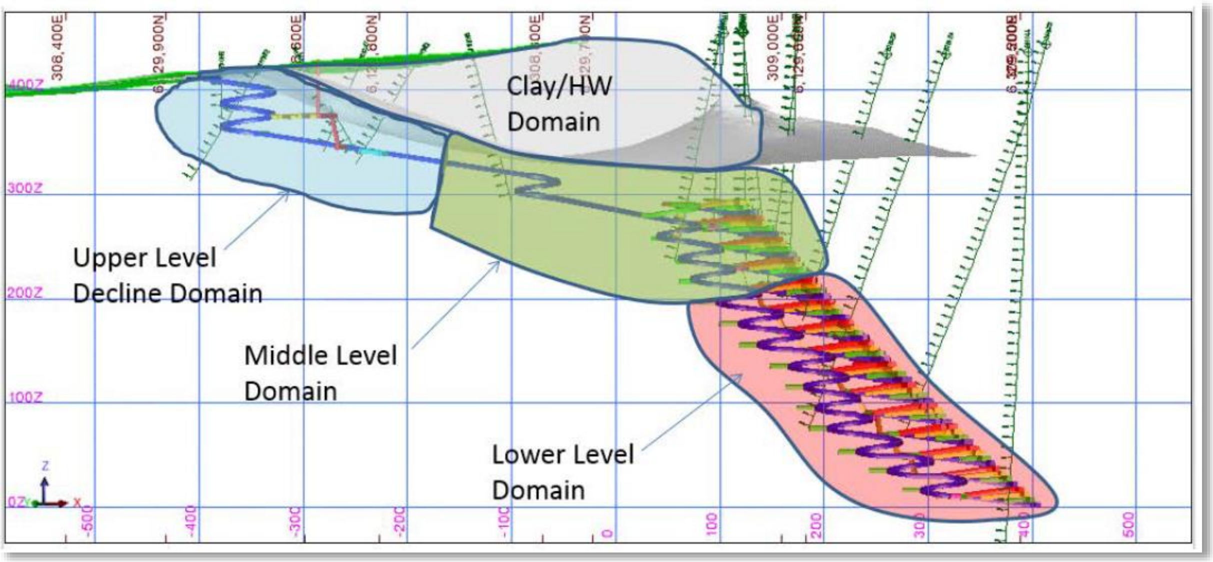


FIGURE 13-15 | ROCK MASS DOMAINS BASED ON GEOTECHNICAL ASSESSMENT OF DATA AVAILABLE

Stress modelling

To assess for the likely mining induced stress conditions based on the mine design, a 3-dimensional stress analysis model was constructed of the BIHGP mine using the software program MAP3D. MAP3D is a Rock Mechanics and Stress Analysis program for the Mining, Civil and Geomechanics Industries.

Map3D is a fully integrated three-dimensional layout (CAD), visualisation (GIS) and stability analysis package using the Boundary Element Method (BEM) of stress analysis. Map3D is suitable for building and modelling rock and soil engineering design problems involving both irregular 3D massive excavations, tunnels and tabular shapes. It can be applied to the analysis of underground layout and mining sequence problems, as well as the assessment of pillar designs, stope span stability and fault stability.

Like most other stress analysis programs, it can be used in two ways:

- Given detailed and accurate input data, to perform precise computations and make firm predictions regarding the response of a system such as an underground mine or mine block; or
- Given qualitative or uncertain data with respect to the rock properties, distributions of different rock units, faults and in situ conditions a comparative study can be completed for various mining methods and sequences to determine the most appropriate for the conditions.

The results of the MAP3D modelling are summarised in Table 5-16. The predicted Sigma 1 stress magnitudes are summarised as follows:

- Low stress magnitudes are predicted in the Upper Level Decline Domain;
- For the Middle Level Domain, the stresses in the backs for the decline and FW infrastructure are in the range of 7 to 15 MPa. This increases for the Lower Level Domain from 14 to 37MPa. Wall stresses are significantly less in magnitude;
- Once the first flatback drive is mined in the Middle Level Domain, typical Sigma 1 stresses in the backs are in the range of 10 to 15 MPa. This increases to 15 to 30 MPa for the Lower Level Domain; and
- The final sill pillar below the CRF has an average Sigma 1 stress magnitude range of 12 to 25 MPa for the Middle Level Domain. This increases to 20 to 46 MPa for the Lower Level Domain.
- Mining One has identified that there is potential for stress driven deterioration of the rockmass around the development openings at the base of the mine. The rockmass response is likely to be progressive, rather than instantaneous. Due to the fast turnover of ore drives, this may not be a significant enough to require rehabilitation prior to excavating the next cut and fill lift.

13.6.1.2 EXCAVATION STABILITIY

The BIHGP boxcut is designed to provide access to the decline and is planned to be backfilled around a self-supporting prefabricated structure. The boxcut will be a temporary excavation, to allow the portal to be positioned within rock material and then permanently backfilled. This will re-establish the natural ground surface level and eliminate the risk of slope instability within the boxcut.

The size and depth of the boxcut design are related to the following:

- The target depth was to achieve 5m of rock material in the crown of the portal face; and
- The boxcut batters were designed to be stable for the duration of excavation and for the installation of the self-supporting structure within the boxcut.

Mining One used the following design methodology for the boxcut design:

- The top of rock surface defined the expected materials within the boxcut. Shallow softer materials are planned to be offset from the boxcut by using a 5m wide berm. Limit equilibrium stability modelling was completed to assess the overall stability of the excavated boxcut (Appendix E of Appendix M1); and
- Structural data collected during the drilling program was used to undertake a kinematic assessment of the boxcut walls (Figure 13-17). During this assessment it was found that bedding will control the stability of the western wall, and this wall was laid back to match the dip of bedding and reduce the likelihood of undercutting it and destabilising the slope.
- Location of portal and boxcut – selection of more competent rock, rather than weathered rock to excavate boxcut and decline.
- Design of suitable batter angles and bench heights based on rock propertied mapped and logged from drill core and geotechnical investigations (test pits).

A number of test pits (Figure 13-16) and a drill hole (BH049) were used to define the ground conditions at the boxcut site.

FIGURE 13-16 | PHOTO OF ONE OF THE GEOTECHNICAL TEST PITS USED BY MINING ONE TO IDENTIFY THE ROCK PROPERTIES USED TO DESIGN THE BOXCUT AND PORTAL LOCATION

The stability analysis used the slope orientations, shown in Figure 13-17 and results in the recommended boxcut dimensions shown in Figure 13-18.

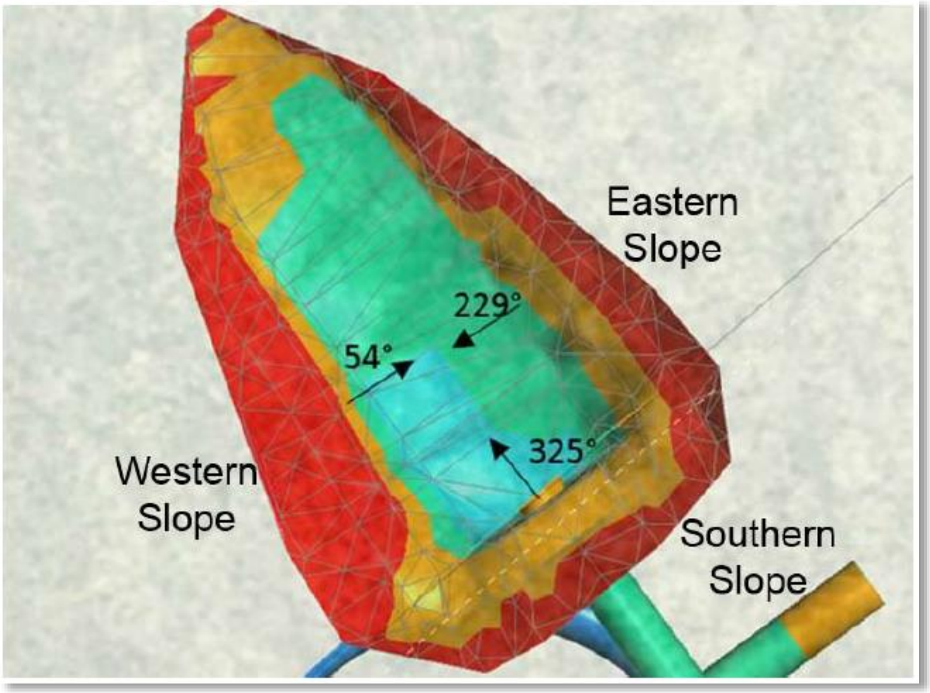


FIGURE 13-17 | SLOP DIRECTION USED IN THE STABILITY ASSESSMENT

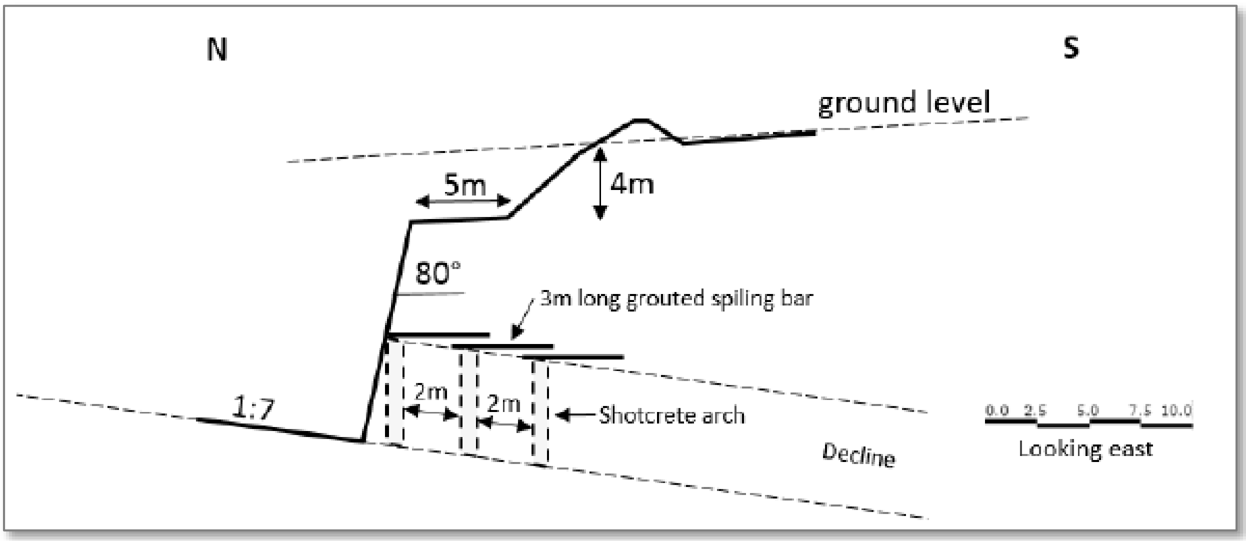


FIGURE 13-18 | LONG SECTION OF PROPOSED BOXCUT SHOWING BENCH ANGLES, AS WELL AS INITIAL PORTAL GROUND SUPPORT RECOMMENDATIONS AS DETERMINED FROM GEOTECHNICAL INVESTIGATIONS (APPENDIX M1)

13.6.1.3 SHAFT LOCATIONS

The 3D geological and geotechnical modelling is used to determine the most suitable location for the ventilation and secondary egress shafts on site. The location of these excavations needs to be optimised based on the cost of the shafts, the method of excavation proposed, the size, shape and angle of the excavation, as well as the ground support required to support.

In the case of the BIHGP mine design, this information was used to select locations where intersections with the fractured rock aquifer were eliminated, rock strength properties were suitable for the required excavation sizes, as well as still be suitable close to the underground excavations to minimise development meters. This is shown by the blue shaft location in Figure 13-19 and outlined in Table 13-9.

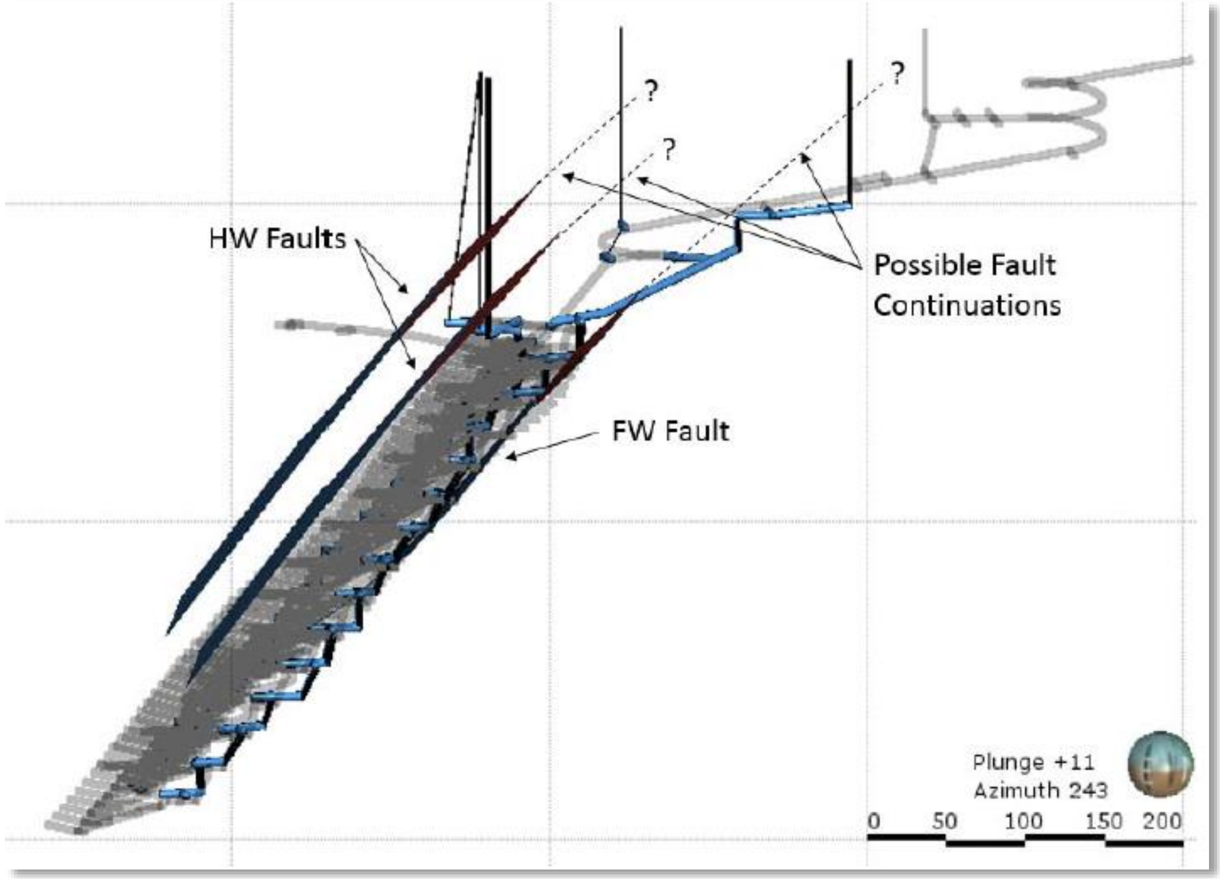


FIGURE 13-19 POSSIBLE FAULTING INFLUENCE ON SHAFT OPTION POSITIONS (APPENDIX M1)

TABLE 13-9 SUMMARY OF SHAFT OPTION ASSESSMENT

Shaft Option	Soft Surficial Materials	Rock Quality	Stress Change (Sig.1 & 3)
Early Decline Return	21m	Extremely Poor to Poor	Insignificant stress change due to mining
Option 1	112m (vent shaft) 127m (egress)	Very Poor, Poor	Insignificant stress change due to mining
Option 2	69m (vent shaft) 113m (egress)	Poor to Good	Insignificant stress change due to mining
Option 3	97m (egress)	Poor to Good	Insignificant stress change due to mining

13.6.1.4 DECLINE DESIGN

The decline is designed to be developed below the extremely weathered, clay/rock surface identified in the geotechnical investigations undertaken by Mining One during 2016-2017(Appendix M1) (Figure

13-20) as well as below the supergene zone indicated as potentially containing potentially acid forming (PAF) material (Figure 13-21).

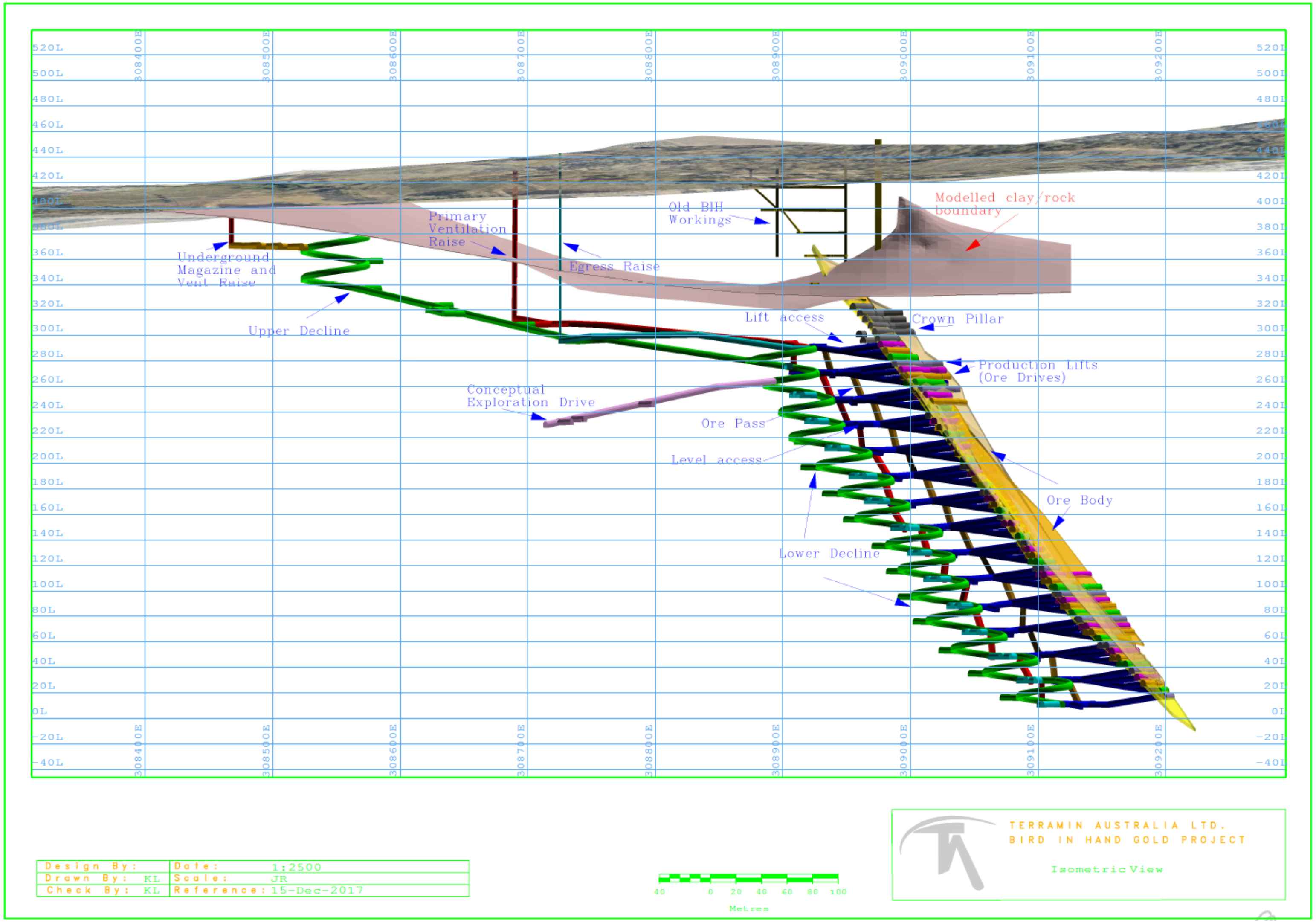


FIGURE 13-20 | ISOMETRIC VIEW OF THE PROPOSED UNDERGROUND BIHGP MINE SHOWING THE MODELLED CLAY/ROCK SURFACE AS MODELLED BY MINING ONE, AS WELL AS THE RELATIVE LOCATION OF THE OLD BIH WORKINGS

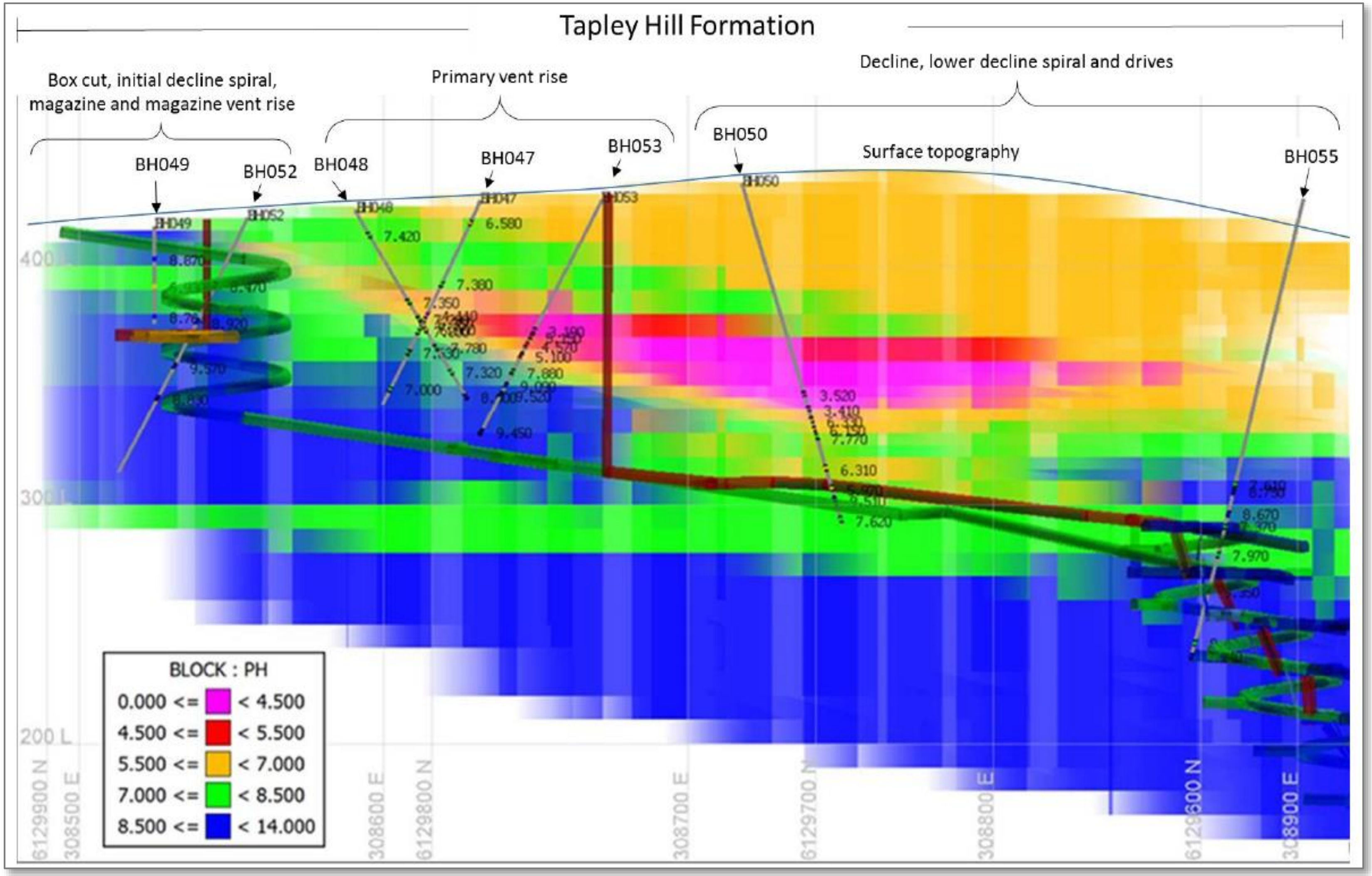


FIGURE 13-21 | ISOMETRIC SECTION VIEW (LOOKING EAST) SHOWING THE MODELLING LOCATION OF THE POTENTIAL AMD ZONE (RED/PINK) AND THE REASON FOR LOCATING THE MINE DECLINE AT A LOWER RL TO AVOID THIS ZONE (APPENDIX M2)

13.6.1.5 DRIVE PROFILES

The decline has been designed using an arched profile to provide sufficient strength to the excavation

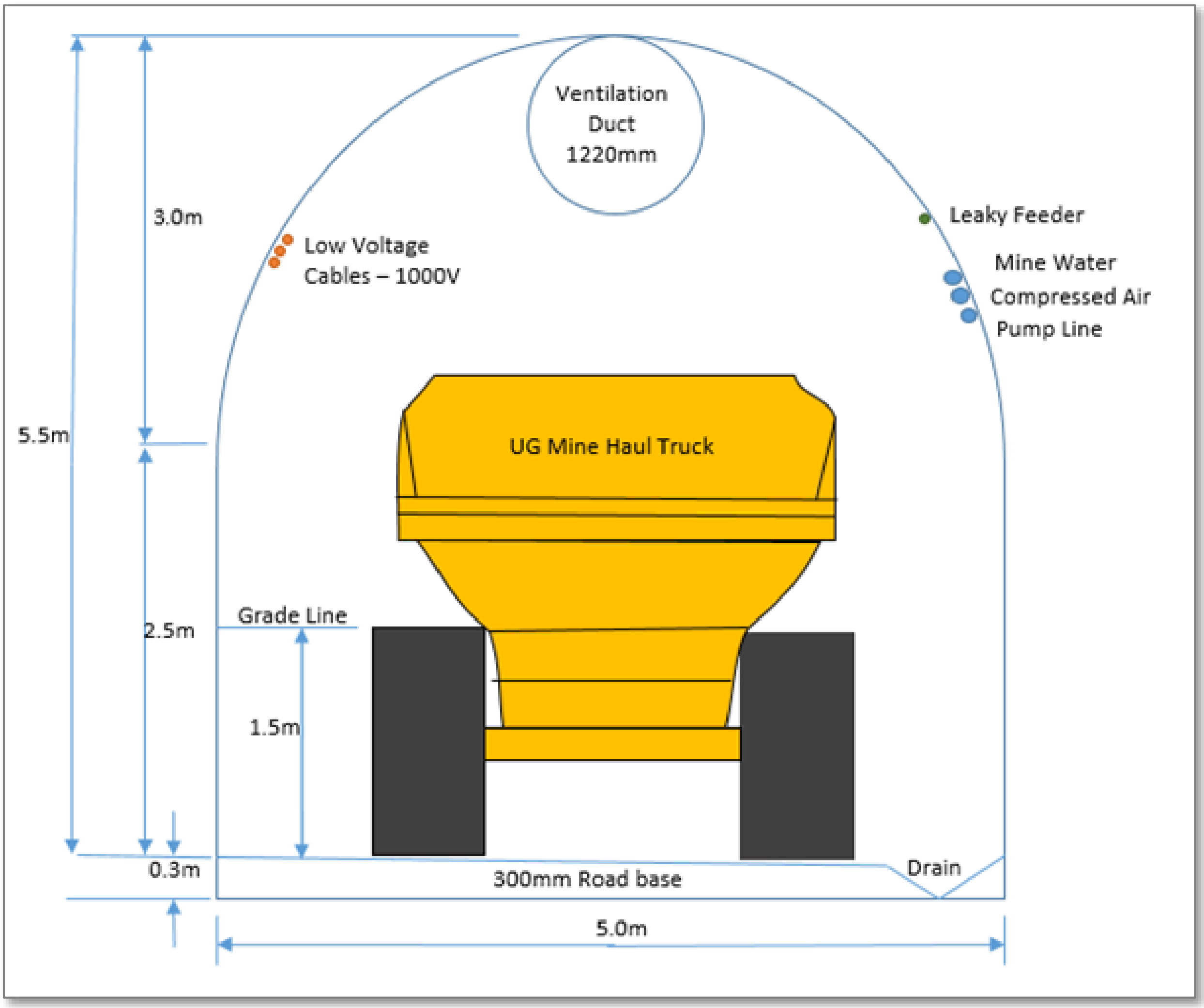


FIGURE 13-22 | TYPICAL CROSS SECTION OF THE 5.5M X 5.0M ARCHED PROFILE DECLINE SHOWING SERVICES AND AN UNDERGROUND HAUL TRUCK

Ore drives will be designed to extract the maximum width of the orebody in a single pass, where ground conditions allow, giving ore drive widths of between 4.5m-6.5m. Drive heights will be typically 5m high resulting in each 20m ore block is mined in four lifts. The ore drives will be excavated with a shanty-back profile, following the geometry of the orebody, to minimise hanging wall dilution and to maximise ore recovery from the footwall. Where the orebody is wider than 7m, twin ore drives have been considered, dependent on ground conditions.

13.6.1.6 PROBE DRILLING

Probe drilling campaigns will be utilised to identify areas where the development will likely intercept groundwater and/or existing voids. Due to the presence of a fractured rock aquifer, determining the location and extent of the fractures along the length of the decline path is beneficial to design with the intent to avoid these areas and plan development schedules. This will allow for preparation of pre-emptive ground support and groundwater management systems.

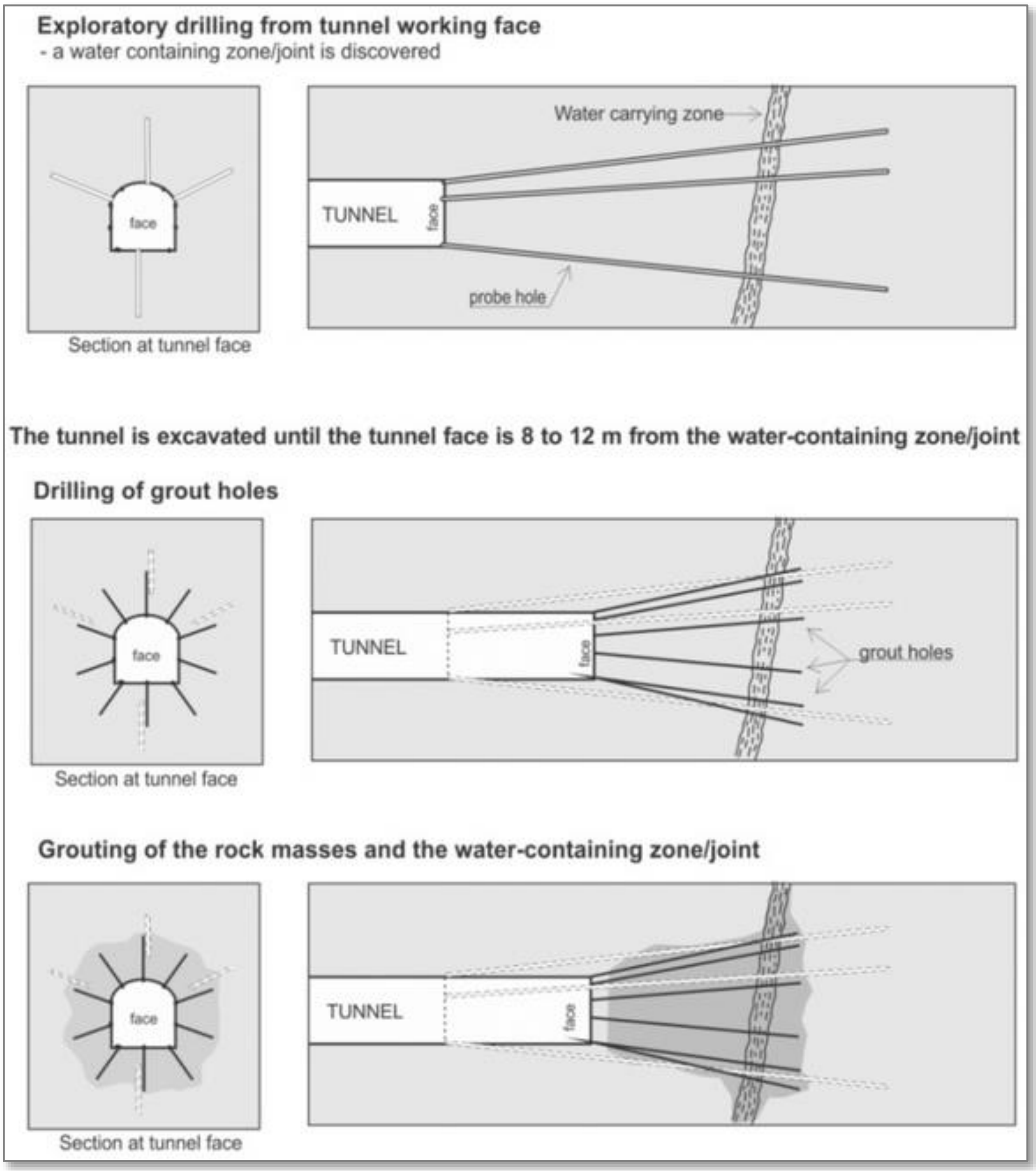


FIGURE 13-23 | LOCATION OF GROUTING MINING ACROSS FRACTURES INVALID SOURCE SPECIFIED.

13.6.1.7 GROUND SUPPORT DESIGN

The types and amount of ground support applied to the different sections of the mine are based on the geotechnical properties of the rock and the size and shape of the excavation.

Ground conditions in the footwall (Tapley Hill Formation) have been classified as “good” using Deere’s classification system Table 13-10), thus all capital infrastructure in the proposed design has been located within this rock type. The decline will be supported appropriately depending on the ground conditions encountered. From current assessments, it is expected that in-cycle mesh and bolts will be used, as well as in cycle shotcreting. (Appendix M1).

TABLE 13-10 | CORRELATION BETWEEN RQD AND ROCK QUALITY (DEERE, 1964)

RQD(%)	Rock Quality
90 to 100	Excellent
75 to 90	Good
50 to 75	Fair
25 to 50	Poor
0 to 25	Very Poor

Conditions in ore drives are expected to be fair and geotechnical recommendations to date (Appendix M1) advise in-cycle shotcreted to a thickness of up to 100mm thick. Friction bolting or resin bolting will be undertaken after shotcreting with an appropriate bolt spacing. Drive intersections are expected to required cables for ground support. It is expected that the majority of the hanging wall will require pre-excavation grouting for groundwater management, again determined by a probing regime used within the development cycle.

13.6.1.8 CROWN PILLAR

The integrity of the crown pillar is of high importance to any underground operation, in particular to avoid the incidence of subsidence on the surface above the mining operation. As historic workings are present a conservative approach has been taken with a standoff of 20m (vertically) allowed for between the lowest known levels of the historic workings, a 1.8m x 1.8m drive, to the highest planned level (accessed from the decline) of the new operation, a 5m x 5m drive. This is conceptually shown in Figure 13-24.

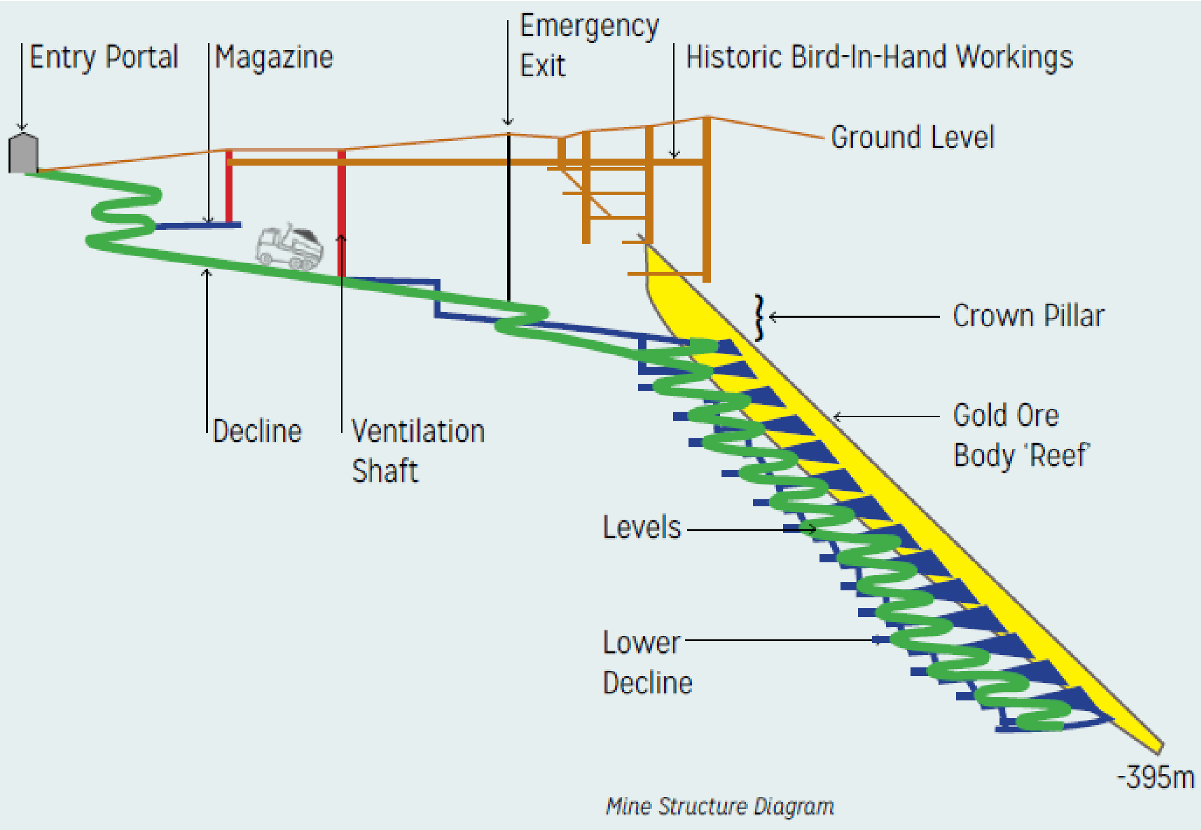


FIGURE 13-24 | CONCEPTUAL DIAGRAM OF THE ~20M CROWN PILLAR AND HISTORICAL WORKINGS

13.6.1.9 DESIGNING FOR SURFACE SUBSIDENCE MANAGEMENT

The current design has ~140m of rock between the mine decline and the nearest residence located directly above and ~170m of rock between where the possible mine exploration decline passes perpendicularly underneath Bird-in-Hand Road, no impact due to subsidence on this road is expected according to the modelling undertaken by Mining One (Appendix M1). In order to measure unlikely surface movement, monitoring prisms have already been installed in the vicinity of the Bird in Hand Road (Figure 13-6), to obtain baseline data, and is planned to continue monitoring throughout the life of the mine.

13.6.1.10 BACKFILL DESIGNS

Fill type selected based on two primary functions: sill pillar stability and wall stability for adjacent drives and surrounding rock (i.e. hanging wall).

Sill pillar stability needs to be assured to allow mining of stopes immediately beneath a filled drive. Sub-level fill also provides an adequate working surface to allow for mining of stope immediately above the filled drive. Backfill serves the secondary purposes of providing hanging wall and regional stability as well as utilising excess development mullock to minimise the surface footprint of the operation. Cemented rock fill (CRF) or cemented aggregate fill (CAF) and unconsolidated Raw Fill (RF) were selected for consideration as suitable backfill methods. Due to offsite processing, no available process tailings were available to consider cemented hydraulic fill or paste fill as viable alternatives.

Sill pillars will require sufficient strength to enable horizontal exposure when mining the crown pillar of each sub-level. Final design and strength requirements will be determined by an external geotechnical/backfill engineering consultant once the actual mullock is available for strength testing. A literature review of other operations indicates that an achievable target strength of 3.5Mpa with 5% cement addition is stable for a 5m thick exposure (Blake, et al., 2005) (Figure 13-25). As part of the site's Backfill Management Plant (BMP) an extensive test program will be undertaken prior to backfilling to optimise the mix design and ensure sufficient CRF strength is achievable. Ongoing QAQC measurements will be continue throughout the usage of the CRF.

Blake, W., MacLaughlin, M., Pakalnis, R., Caceres, C., Clapp, K., Morin, M., . . . Williams, T. (2005). Design Spans - Underhand Cut and Fill Mining. *107th CIM-AGM.* Toronto.

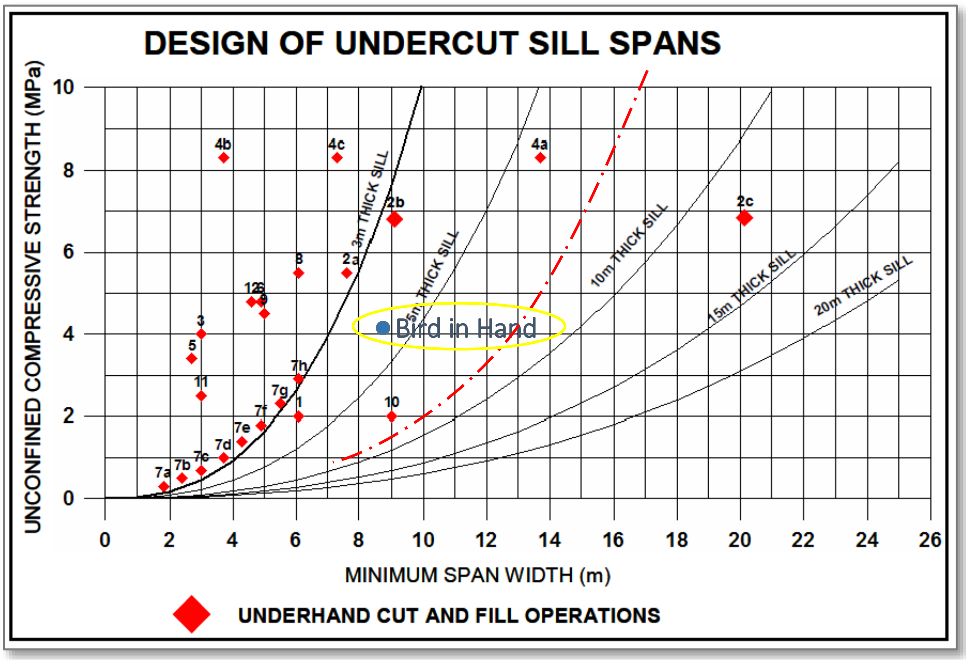


FIGURE 13-25 | STABILITY CHART FOR THE DESIGN OF UNDERHAND SILLS SHOWING THE LOCATION OF THE BIHGP DESIGN (BLAKE, ET AL., 2005)

13.6.1.11 MANAGEMENT OF PAF MATERIAL

Any PAF material identified through the exploration activities and modelled in the 3D geological models, and that cannot be avoided in the excavation, will be prioritised for backfill

Any potentially acid forming material temporarily stockpiled on the IML will be prioritised for CRF applications to minimise the likelihood of oxidation and acid forming potential. Investigations to data (Appendix M2) have indicated that the volume of PAF material is likely to be minimal, and if it does occur, the surrounding host rock that would be brought up as mullock with it would neutralise any PAF effects.

Further test work will need to be undertaken once the actual mullock is available in order to determine the strength and mix ratios required for backfilling the BIHGP drives.

Design measures relevant to this chapter are detailed in Table 13-11.

TABLE 13-11 | DESIGN MEASURES

Design Measures	Impact ID
Probe Drilling Procedure	PIE_13_01 PIE_13_02 PIE_13_03 PIE_13_04 PIE_13_05
Ground Support Management Plan (including site ground support standards; QAQC standards, independent review criteria; excavation standards)	
Groundwater management Plan	
Backfill Management Plan (including site backfill standards – type, placement, curing periods; QAQC standards; independent review criteria)	
Subsidence Management Plan (including monitoring location selection, frequency of surveys, independent review criteria)	
Mine design standards (including proximities/standoffs to geological/geotechnical structures, crown pillar parameters)	
Mining method selection and sequencing (ensures voids are backfilled prior to next lift commencing)	
Geological and geotechnical mapping/logging and sampling programs of faces, drillholes and shafts	
Geological sampling	

13.6.2 MANAGEMENT STRATEGIES

Even though the likelihood of a sulphide dust explosion is unlikely, the identification of sulphur content of the ore to be mine will be included as part of the mining procedure. It is standard practice for mine to have procedures to prevent and to minimise risk including;

- written practices for prevention or confinement of dust explosions;
- training of personnel (including retrain and follow up) in awareness and precautions;
- firing procedures (evacuation of personnel, location of firing boxes etc); and
- records of dust explosions (notification to DEM).

Safety measures include controlling the potential exposure of persons to the effects of the dust explosion aftermath;

- monitoring of SO_2, H_2S etc. if present;
- clearance of the mine or part of the mine before blasting; and
- provision of fresh air bases, respirators or self-contained breathing apparatus.

13.6.2.1 GEOHAZARDS – GEOTECHNICAL

Management strategies for geotechnical stability include:

- Geotechnical logging of drill core taken during exploration;
- Mapping of headings to include geotechnical properties;
- Designing ground support according to ground conditions – limiting wide spans, designing the shape of the drive to be as stable as possible within the limits of the geology (i.e. using shanty back design to avoid over break into hanging wall fractures and potential subsequent over break;
- Mine design matches ore body properties (narrow ore, dipping less than 60 degrees not suited to large scale open underground voids);
- Regular geotechnical inspections and audits (to monitor behaviour of ground as well as checking the installation of support matches plans);

- Underground caves, vughs, fractures will be identified and sealed as part of the probe hole and grouting process as described in Chapter 3.
- QAQC of ground support installations – i.e. regular pull testing of installed ground support (checks that support is selected and installed correctly to give designed strength);
- QAQC of shotcrete applied;
- QAQC of backfill mixes used;
- Using trained, skilled operators for ground support and backfill applications;
- Using reputable suppliers etc. for materials used; and
- Monitoring for subsidence and seismicity.

13.7 IMPACT ASSESSMENT

All impacts regarding Acid and Metalliferous Drainage and Saline and Neutral Mine Drainage have been included in the following chapters:

- Groundwater, Chapter 10
- Surface Water, Chapter 11
- Land and Soil Quality, Chapter 12
- Agricultural Impacts, Chapter 21

13.7.1 SULPHIDE DUST EXPLOSION

Sulphide minerals oxidize rapidly when broken and exposed to air and, in operations where such minerals become dispersed as dusts, sparks or heat flash from blasting can initiate an explosion.

Iron-containing disulphides such as chalcopyrite and pyrite are the most reactive and have the lowest ignition temperatures, shortest thermal exposures for initiation and highest burning intensities. Their dusts are the most susceptible to 'flash' initiation and explosive propagation. In general, all sulphide dusts of fineness below about 50 µm are flammable and can be ignited by thermal energies well below those commonly generated by blasting. Ignition events can thus occur frequently, but will not necessarily be propagated to produce an explosion.

Assessments of the likelihood of explosions can therefore be made on the basis of ore composition and tendency to fragment into the dangerous size range. Monitoring of atmospheric dust content is vital in controlling the hazard. Such monitoring yields not only the dust composition, concentration and size distribution but also points to the occurrence of ignition events which show up through characteristic changes in chemical composition of the dust.

Test work has shown that with faces containing greater than 20% pyritic sulphur, the possibility of a dust explosion exists. The average sulphur content of the BIH deposit or based on the 2016 BIHGP Resource block model is estimated to be 1.8%, reaching a maximum content of 11.5%. Where high levels of sulphur are present, pyrite only makes up a third of the sulphide minerals, with sphalerite and galena making up the majority of sulphides present.

Based on current understanding of the BIH mineralisation the potential of a sulphide dust explosion is considered **unlikely**, and the overall impact of such an event **insignificant** to sensitive receptors.

13.7.2 Geohazards – Geotechnical

Geotechnical risks arise from subsidence, the movement of the ground during and following excavation. Surface subsidence is defined as the downward movement of the natural surface level in response to changes beneath the ground surface. It is normal for the ground surface level to move in response to groundwater level changes over time or following settlement of backfilled materials following excavation without compaction. The surface subsidence assessed by Mining One relates to underground mining and the creation of voids causing the ground surface to subside.

Continuous Trough Subsidence involves a smooth subsidence profile at the ground surface and is usually associated with the mining of thin, flat deposits (like coal) overlain by weak sedimentary rock which needs to fail to fill the mined void. This type of subsidence is not applicable to BIHGP due to the moderate dipping nature of the orebody and the strong strength rock around the orebody. It is normal for the ground level to fluctuate naturally due to the seasonal changes in groundwater storage level.

Discontinuous Subsidence involves large surface displacements over limited surface areas, and may happen suddenly or progressively. Types of discontinuous settlement are shown in the sketches in Figure 13-26 and include:

- Crown holes or Pillar collapse arising from the collapse of the roofs of shallow and open underground workings;
- Chimney failure, piping or funnelling caused by progressive failure of an unsupported open mining cavity through the overlying material to the ground surface. The surface subsidence can be of a similar plan area to the underground void; and
- Plug Failure where a block of material moves downwards into the unfilled open void.

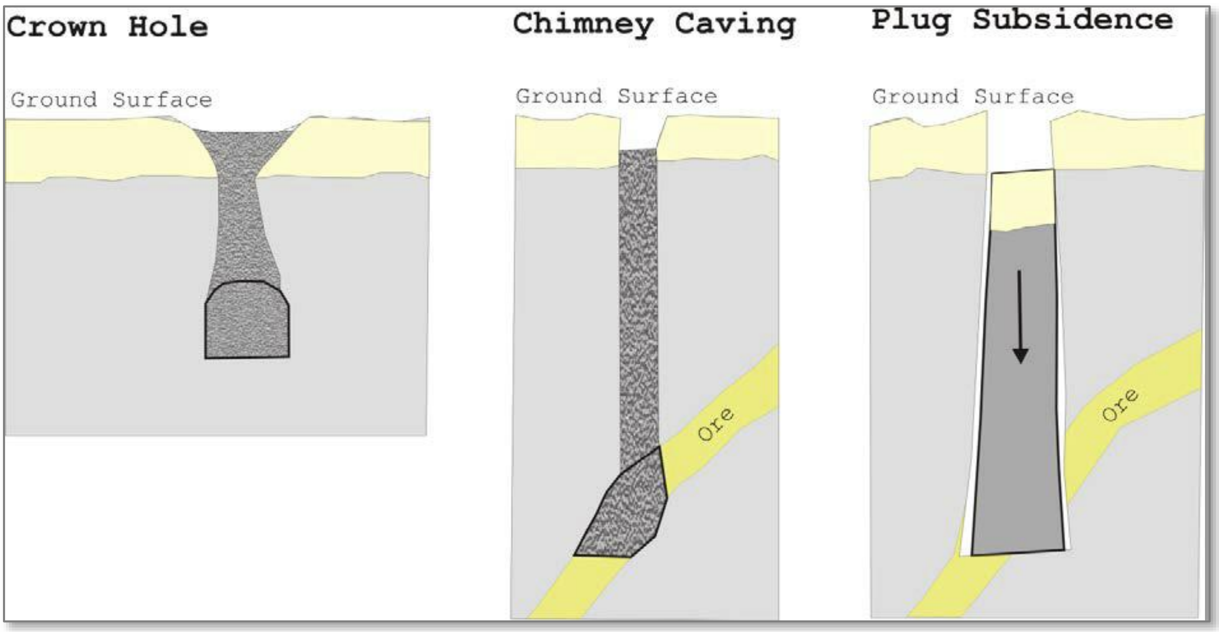


FIGURE 13-26 | DISCONTINUOUS SUBSIDENCE

The cut and fill mining method removes the ore by following an alternating process of mining, and then filling. First a level is mined, and then filled prior to mining the level above, see Figure 13-27. Since it is a requirement to always work on the filled drive, very close to 100% of the ore body is filled during mining. With this method, only small voids are left underground.

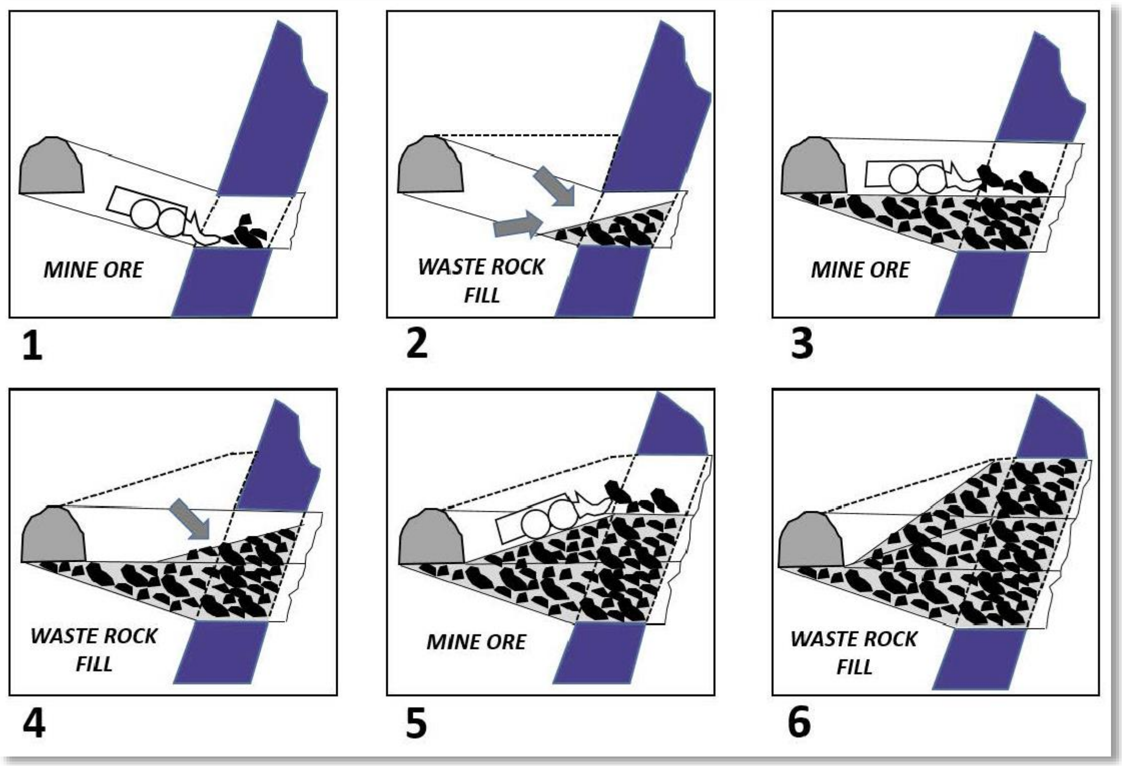


FIGURE 13-27 | GENERALISED SCHEMATIC CROSS SECTION OF OVERHAND CUT AND FILL MINING

The voids formed in the orebody when using this mining method will only be present at the top, or the last level of the mined orebody. Backfilling all the ore drives will mean that a void of about 1m height will be present between the top of the filled drive and the roof.

The ground surface stability and subsidence related to underground mining will be managed by limiting the size of the underground openings and promptly backfilling stopes to ensure there are no long term ground surface stability effects. Due to the small voids created using cut and fill as the mining method, the stability of the Crown Pillar (and resulting surface stability) has been assessed by an empirical method. This method compares the Crown Pillar at BIHGP to case studies of Crown Pillar stability from around the world. The crown pillar requirement for stability is defined as long term, which means a 1000 year design life.

The Scaled Crown Pillar Span method is an empirical method of assessing stability based on a database of over 500 cases from worldwide sources collated by Carter (Ref. 16). In the present case, where mined stopes are almost entirely filled, the Carter method can be used to check whether the Crown Pillar might be subject to failure, however the usual hazards associated with such failure (caving, excessive settlement) cannot occur because cave propagation is restricted by the presence of the fill.

13.7.3 STRUCTURAL INSTABILITY AND VOIDS

13.7.3.1 STRUCTURAL INSTABILITY

Mining One Consultants (Mining One) conducted a geotechnical assessment for the BIH Project during 2016. The Mining One geotechnical assessment report is located in Appendix M1.

The geotechnical assessment was based on drillhole data collected by Terramin in conjunction with Terramin's mining plans. The geotechnical assessment found that the clay material thickness at the surface varies significantly across the site. The rock conditions vary between Poor to Good and bedding/foliation is dominant in a generally blocky rockmass. Major structures are expected to have a very important influence on stability of underground openings. The systematic grouting required to control water inflows will improve the rockmass in terms of rock quality with the grout filling structures and making the rockmass more competent, when compared to the ungrouted state.

The mine was separated into Geotechnical Domains for the geotechnical assessment; the Clay/Highly Weathered, Upper Level Decline, Middle Level and Lower Level Domains, with part of the Middle Level Domain and the Lower Level Domain including the ore body.

Ground support derived for each Domain is dependent on the ground conditions, but fibrecrete and either a resin bar bolt or a grouted splitset are the recommended ground support choices for development and production mine areas. Cablebolts will be required for wide spans in excess of 6m span.

Underground infrastructure is positioned to consider the mining method, induced stress conditions, ground conditions, and proximity to surface infrastructure. Shafts to surface will be influenced by the thickness of the surficial clay materials.

Induced stress conditions are expected to be manageable for the current mining method and depth of mining. Recommended ground support systems utilise methods that are commonly used at many underground mines in Australia and are widely accepted for their success in controlling rock fall risk.

The surface stability of excavations was assessed for two designs provided by Terramin (2016 design and a May 2017 design). All the excavations assessed were found to be stable for the peak production and closure design.

Assessment of surface stability by Mining One is located in Appendix M1.

7.1.1.1 KARST FEATURES

Caves are known to have developed in the marble of the Brighton Limestone, however, the rock type is not karst. Resource drillholes have intersected several small caves, the largest possibly up to 3.15m in width intersected in drillhole BH051 but that width may in part be due to core loss owing to the soft friable nature of decomposed marble. The average width assigned to caves intersected in drilling is 1.25m.

Caves and fractures will be identified as part of the probe hole and grouting process as described in Chapter 3.

7.1.1.2 HISTORIC WORKINGS

Within the proposed ML are several historic underground workings. The largest of these workings are those of the BIH Gold Mine's; other known workings include Blackbird, Brind, Ridge, Bird-Extended and Two-in-the-Bush.

The extent of the BIH Gold Mine's workings were surveyed in the 1930's. Terramin proposes to leave a 20m pillar beneath the historic BIH Gold Mine workings

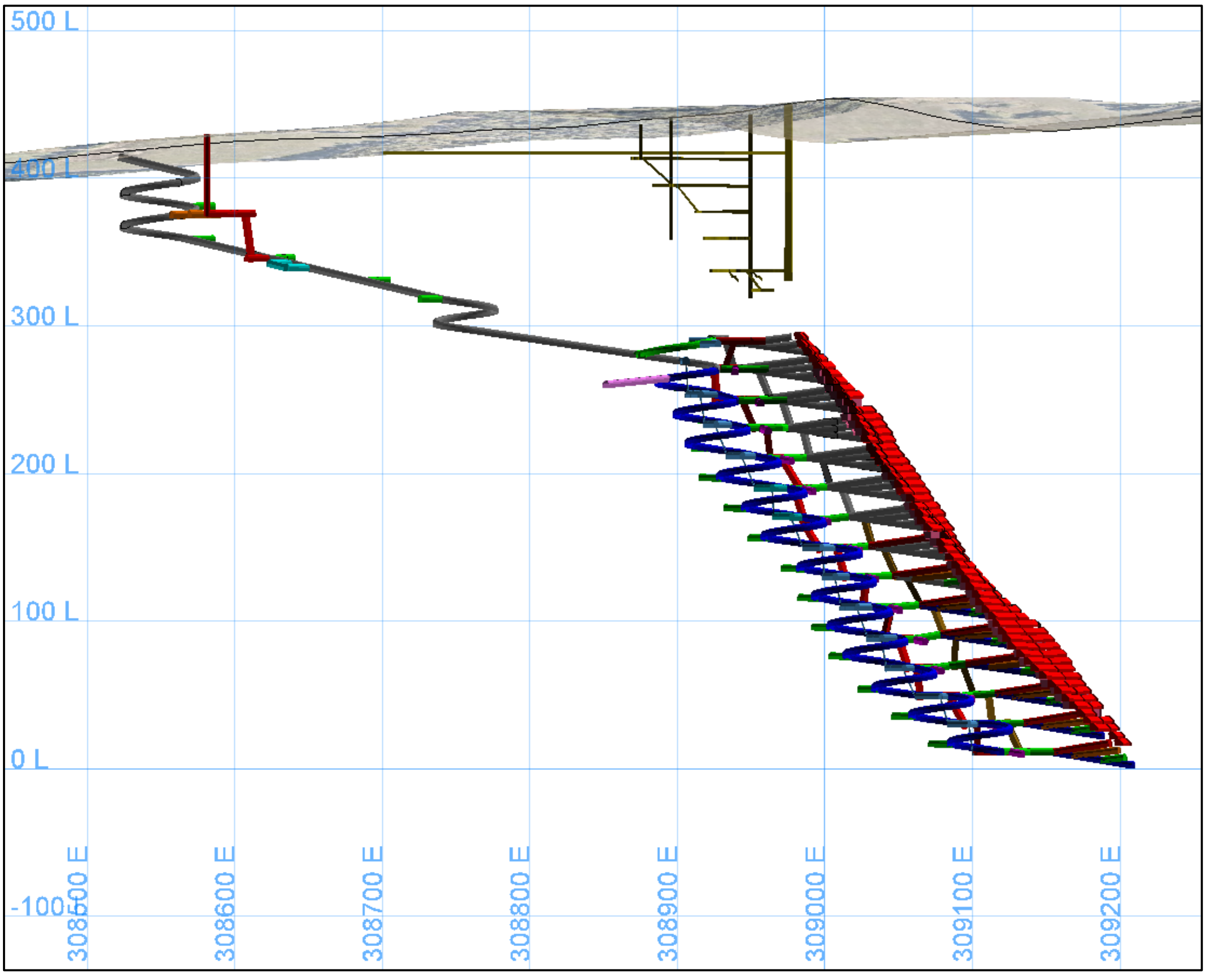


FIGURE 13-28 | CROSS-SECTION OF THE PROPOSED BIH DEVELOPMENT BENEATH THE HISTORIC BIH GOLD MINE WORKINGS (DARK YELLOW), VIEWED LOOKING EAST.

The proposed access road to the BIH site will pass between the Blackbird and Dead Horse workings. The entry point from Pfeifer Road is located on top of a ridge and is therefore regarded the safest location for trucks to pull-out onto the road.

The underground Blackbird workings were surveyed in 1940. The plan of the workings can be spatially located as the survey's origin was the Lone Hand Chimney which is still standing. Further, Capricorn Resources NL surveyed in the shafts in 1997 and several shafts are still identifiable today.

Where the proposed site access road passes between the Blackbird and Dead Horse workings the road coincides with the exiting farm track.

Prior to the construction of the road the area between Blackbird and Dead Horse will be probe drilled to confirm that no voids are present in the area. If voids are identified beneath the proposed access they will be managed to ensure geotechnical stability and prevent any expression of subsidence on the surface.

FIGURE 13-29 | PROPOSED SITE ACCESS IN RELATION TO HISTORIC BLACKBIRD AND DEAD HORSE WORKINGS.

13.7.4 MINING INDUCED SEISMICITY

Mining induced seismicity is usually associated with the ground around the mining voids responding to a redistribution of stress. This type of seismicity is usually caused by rock breaking due to over stressing, known as rock burst or due to the release of energy due to movement on a natural structure (i.e. faults). These events are localised to the underground opening and known as a shakedown event. These types of seismic events are a hazard to underground employees and infrastructure.

Other potential impacts of mine induced seismicity are vibrations that in some cases can be felt on the ground surface. Mines such as Mt Charlotte beneath Kalgoorlie, WA and Stawell Gold Mine, VIC, have surface monitoring and strategic mine plans to help avoid causing mining induced seismic events being felt by members of the public, but are mainly in place to monitor blast vibrations.

In the case of the BIHGP Mine plan, there are a number of items that confirm there is no expectation mine induced seismicity will impact on the underground employees or felt on the surface. These items are:

- The mine is relatively shallow, with the maximum mine depth of 450m. Mine induced seismicity usually requires greater mine depths before becoming noticeable, causing vibration generating events;

- The dimensions of the mine are small, and the underground openings will be filled as we mine. Stress builds up to greater levels when large orebodies are excavated. Also, vibrations can be felt in some cases when unfilled voids collapse, which cannot occur at BIHGP due to the mining method;
- The development and production blast sizes will be small, with only development sized firings. Stress related redistributions at the time of blasting will therefore not be influenced by large stope firings;
- The stress model indicates that there will be stress change following mining, but at levels unlikely to be noticeable during mining. It is thought that the ground control issue facing BIHGP will be low stress, where the ground lacks sufficient clamping and higher capacity rock bolts may be required;
- Mining sill pillars has been checked in the stress model, and due to the relatively shallow mine depth there are levels of stress build up that are not considered likely to cause observable mine induced seismicity; and
- The rockmass itself at BIHGP has been described as Poor to Good, and is relatively broken with RQD's from drill core logging confirming this. Due to the broken nature of the ground, high levels of stress may not be able to be achieved, even if the mine was extended to greater depths.

The well-known cases of mine induced seismicity, such as Beaconsfield and Mt Charlotte examples are mines that extend 1000m below surface level, use larger stoping sizes, and are excavated within ground conditions which are considered strong and competent. The greater mining depth and strong rock mean that higher stresses can develop around the mine openings, in turn causing mine induced seismicity

13.7.5 Ventilation Raises

Two vent shaft position options have been developed by Terramin, and each was assessed by Mining One to determine the most suitable in terms of the expected ground and stress conditions. There are also a number of possible options for escape way rises. Mining One have assessed each option for depth of soft surficial materials (soil like), rock quality and stress. The position of each shaft assessed by Mining One is shown in Figure 13-30. The pictorial results for each shaft option are shown in Appendix G. A summary of each option is presented in Table 13-12.

As a result of the assessment, option 3 was selected, as the rock quality is improved and poses no credible pathway to impacting third party infrastructure and the local community.

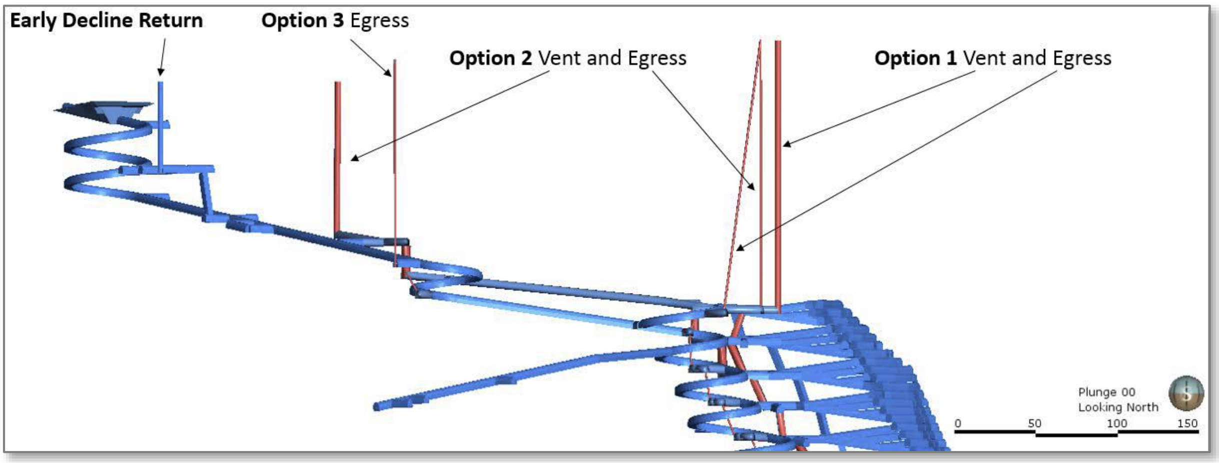


FIGURE 13-30 | SHAFTS ASSESSED BY MINING ONE (LOOKING NORTH)

TABLE 13-12 | SUMMARY OF SHAFT OPTION ASSESSMENT

Shaft Option	Soft Surficial Materials	Rock Quality	Stress Change (Sig.1 & 3)
Early Decline Return	21m	Extremely Poor to Poor	Insignificant stress change due to mining
Option 1	112m (vent shaft) 127m (egress)	Very Poor, Poor	Insignificant stress change due to mining
Option 2	69m (vent shaft) 113m (egress)	Poor to Good	Insignificant stress change due to mining
Option 3	97m (egress)	Poor to Good	Insignificant stress change due to mining

13.7.6 EARTHQUAKE AND MINE FAILURE

As described in existing environment, the Project has a Peak Ground Acceleration of about 0.057*g* for a 500 year return period (Geoscience Australia website).

Mining One considers this to be a negligible acceleration that would not normally be accounted for in stability assessments in an underground mine. The reasons for this are the limited surface exposure and the lack of evidence of underground mines having been damaged by natural earthquakes in the past. There have been a number of studies conducted by others to assess the impact of earthquakes on the stability of underground openings (Refs. 17 to 23). From a review of these references, Mining One has concluded that:

- In a very large magnitude earthquake located in the region, some underground void damage could be expected;
- Generally less damage is seen in deeper voids;
- Voids in soft materials have greater damage due to earthquakes than in rock; and

- There were no reports of catastrophic mine failures as a result of natural earthquakes.

The CRF and rock fill are expected to remain stable and in place following a natural earthquake.

13.7.7 Geotechnical stability of IML

Geotechnical failure of IML structure stability resulting in damage to third party infrastructure/injury/fatality of member of public is removed as a credible pathway, as the IML is located behind two levels of security fencing, preventing unauthorised access and no third party infrastructure is located close enough to the IML.

Further details regarding the construction of the IML can be found in Chapter 3 within Section 3.5.4.3.

13.8 DRAFT OUTCOME(S) AND MEASUREMENT CRITERIA

In accordance with the methodology presented in Chapter 6, an outcome has been developed for geochemistry and geohazard impact events with a confirmed link between a source, pathway and receptor (S-P-R linkage), see Table 13-13.

All outcomes are supported by draft measurement criteria which will be used to assess compliance against the draft outcomes during the relevant phases (construction, operation and closure), and where relevant draft leading indicator criteria. These measurement criteria and leading indicators are indicative only and will be developed further through the PEPR.

All Outcomes for the entire project are presented in Appendix D1.

Draft outcomes and measurable criteria regarding Acid and Metalliferous Drainage have been included in Chapter 10: Groundwater, Chapter 11: Surface Water and Chapter 12: Land and Soil.

Table 13-13 | Draft Outcomes and Measurement Criteria

Draft Outcome	Draft Measurement Criteria	Draft Leading Indicator Criteria
	A letter of compliance summarizing an Independent Geotechnical review (including void assessment) will be submitted annually to demonstrate that less than 15% of underground production levels will remain open at level completion and that the top 100m of the mine contains less than 35% of these voids.	Surveyed plans and representative sections (showing all underground workings, backfill volumes and any completed production level) will be submitted annually to the Chief Inspector of Mines to demonstrate less than 10% of underground production levels will remain open at level completion.
No impact to third party infrastructure caused by mining activities No public injuries or fatalities as a result of mining activities.		Surface survey monitoring will be undertaken every six months at 9 fixed survey stations located along Bird in Hand Road to demonstrate no movement greater than 50 mm from the base coordinates, or as compared to 5 control sites along Pfeiffer Road. Two fixed survey prisms located underground will be monitored quarterly to demonstrate no movement greater than 5 mm from the base coordinates

13.9 FINDINGS AND CONCLUSIONS

All impacts and conclusions regarding Acid and Metalliferous Drainage and Saline and Neutral Mine Drainage have been included in the following chapters:

- Groundwater, Chapter 10
- Surface Water, Chapter 11
- Land and Soil Quality, Chapter 12
- Agricultural Impacts, Chapter 21

In regards to geotechnical hazards, Mining One conducted a geotechnical assessment for the BIHGP during 2016. Underground infrastructure is positioned to consider the mining method, induced stress conditions, ground conditions, and proximity to surface infrastructure and receptors. Surface stability due to underground void collapse and mining induced vibrations were assessed and both found to be unlikely. The mining method and it’s relatively small void openings utilising backfill as mining progresses has a large influence on maintaining surface stability as there are no large underground voids either during or following mining. Due to the small voids created using cut and fill as the mining method, the stability of the Crown Pillar (and resulting surface stability) has been assessed by an empirical method. This method compares the Crown Pillar at BIHGP to case studies of Crown Pillar stability from around the world. The crown pillar requirement for stability is defined as long term, which means a 1000 year design life. The shallow depth of the mine, low induced stress change, small mining area, small blast sizes and blocky rockmass will mean the sudden release of energy due to mining is unlikely and no surface subsidence resulting from mining activities is expected.

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