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SUBJECT: **BLAST VIBRATION ASSESSMENT AT TSF2, FEBRUARY/MARCH 2021**

DATE: 5TH MARCH 2021

BLAST VIBRATION IMPACT ASSESSMENT AT TSF2 EMBANKMENTS FOR THE PROPOSED BOXCUT AND DECLINE AT RASP MINE (MOD6)

INTRODUCTION & SCOPE

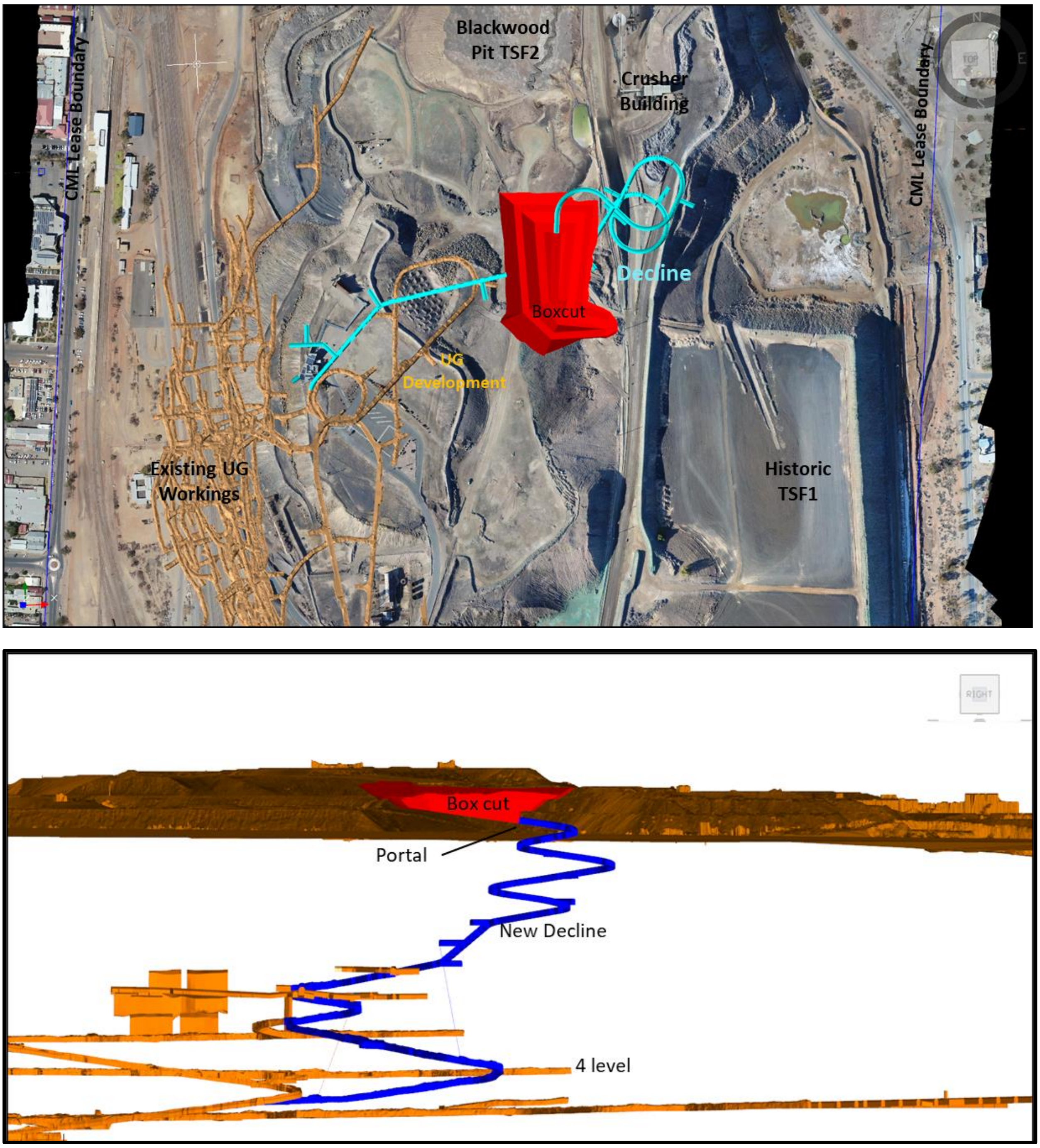
A boxcut, portal and decline, south of TSF2 at the Rasp Mine, are proposed as part of a modification (Mod6) to the project approval (see Figure 1). Much of the boxcut to be excavated is fill material, and will not require blasting. However, the lower sections of the boxcut, the portal entrance, and the decline from the portal will require blasting (see Reference #1, Appendix 3).

This report demonstrates how blasting within the proposed boxcut and decline can be carried out in compliance with ground vibration limits specified by NSW Dams Safety Committee (Reference #2) and recommended by Golder Associates Pty Ltd (Reference #3), for the TSF2 Tailings Facility at Blackwood Pit. These limits should be achievable for both surface boxcut and decline development blasting using conventional methods.

Surface blasting in the boxcut will be carried out using relatively small-scale blast patterns (76mm to 89mm diameter blastholes), on bench heights from less than 8m up to 12m, with maximum charge mass between 35kg/hole and 75kg/hole. Blastholes will be fired sequentially to limit ground vibration impacts at TSF2 and a number of other sensitive receivers surrounding the mine site. Preliminary surface blast parameters used in this assessment are illustrated in Appendix 1, based on methods promoted by Blast Dynamics and Dyno Nobel (Reference #4), and described in more detail in a previous report (Reference #1).

Decline development blasting will be carried out using development blasting methods already in use at Rasp Mine, with 45mm diameter blastholes, a charge mass of 5kg/hole, and maximum instantaneous charge mass (MIC) of up to 60kg, based on up to 12 holes firing simultaneously. The proposed development blast layout is illustrated in Appendix 2.

Figure 1 – Boxcut location with respect to mine infrastructure and surrounds (top) and long-section showing decline to underground workings (bottom).



GROUND VIBRATION ASSESSMENT METHODOLOGY AND TSF2 EMBANKMENT LIMITS

Estimation of mean peak ground vibration, V (peak vector sum in mm/s) at a sensitive receiver, from 'average' free face blasting conditions, is provided in AS2187.2-2006 (Reference #5) as:

$$\mathbf{V=1140 \times [distance/\sqrt{(charge\ mass)}]^{-1.6}}$$

Where distance is from the blast to the monitoring location (metres) and charge mass is the maximum charge per hole (kg) for sequential (hole-by-hole) firing. Site constants of k=1140 and b=-1.6 are suggested in AS2187.2 for 'average' free face blasting conditions. AS2187.2-2006 suggests a range of 0.4 to 4 times the value of V estimated above, but for small scale surface blasts, with blastholes fired sequentially, a range of 0.4 to 2 times the value of V is more realistic as a guide in this case.

Given that surface bench blasting will be confined to a weathered horizon, ground vibration transmission is likely to fall towards the lower end of this range. While decline development blasts will be carried out in harder ground conditions, at a relatively high level of blasting intensity (high powder factor) and with limited relief (confined conditions), such blasting would also be expected to generate relatively low ground vibration impacts at surface as they are of such small size (blasted volume around $150m^3$).

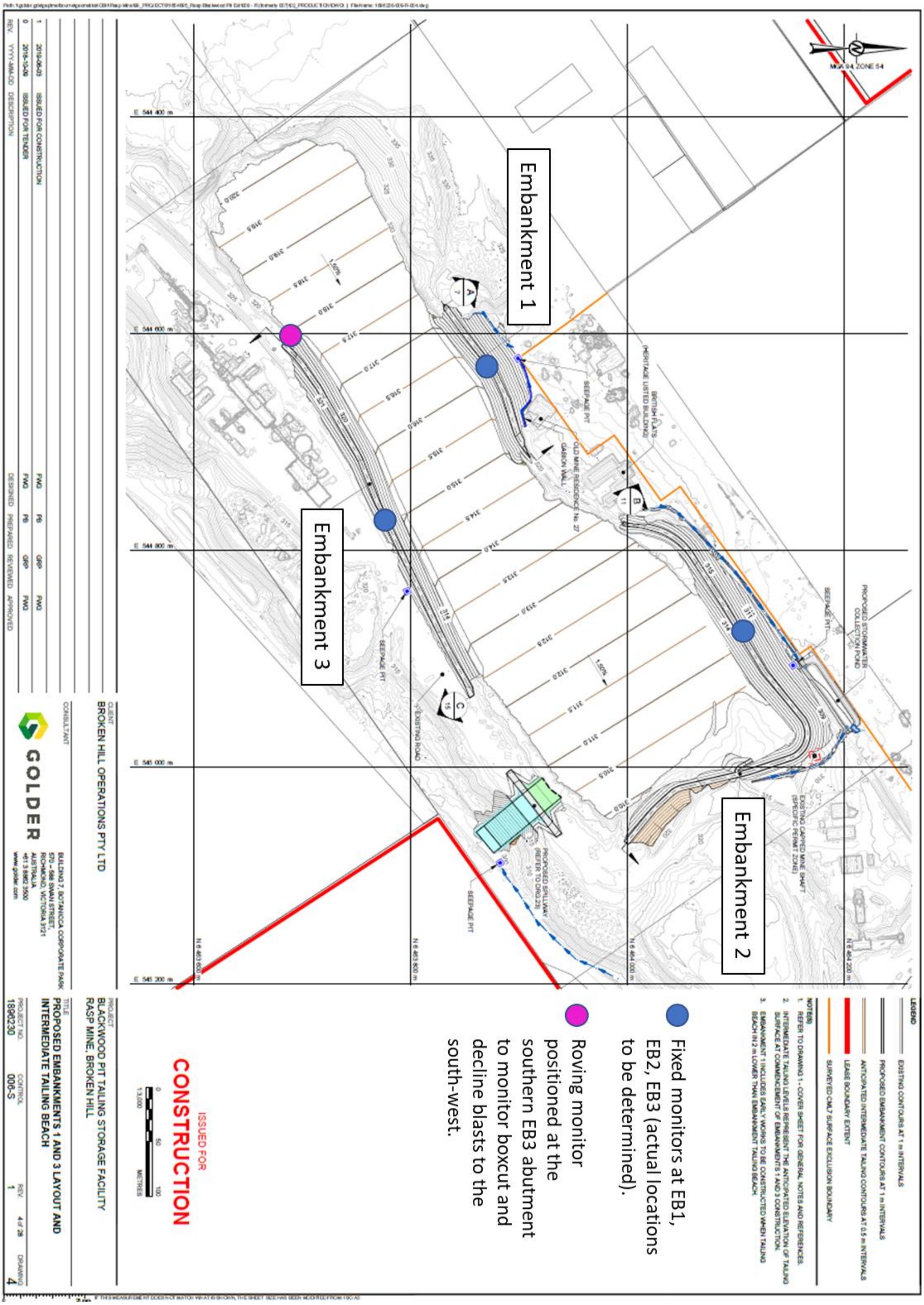
Blast induced ground vibration at Rasp Mine is currently recorded at fixed monitoring locations (V1 to V6), all of which are to the south of the proposed boxcut and not in the vicinity of TSF2. While 'roving' monitors are used at Rasp Mine to measure ground vibration impacts at other sensitive receivers as required, additional fixed monitors are planned for each of the embankments at TSF2 (EB1, EB2, EB3). These are shown in Figure 2, with a 'roving' monitor suggested for the closest part of Embankment 3 to the proposed boxcut and decline (i.e. at the southern abutment).

The NSW Dams Safety Committee (DSC) have imposed a peak particle vibration limit of 30mm/s (assumed to be PVPPV) at the TSF2 embankment structures being constructed (Reference #2). Given the potential for amplification of vibration from the foundations to the top of an embankment, this 30mm/s DSC limit implies ground vibration level limits at the foundations as low as 15mm/s (assuming an amplification factor up to 2). Also, work by Golder Associates (Reference #3) suggests a PPV limit of 15mm/s for embankments with foundations that may be vibration sensitive, and applicable at some of the TSF2 embankments which are partially founded on desiccated tailings.

For surface bench blasts in the boxcut, ground vibration limits have been assessed at the shortest horizontal distance to the closest embankment at TSF2, being approximately 280m to Embankment 3 (EB3). Maximum limits at the closest point on the dam itself (100m north of the boxcut) can therefore be implied as 75mm/s PVPPV in order to meet 15mm/s foundation limits at the more distant embankments (based on likely worst-case trends).

For development blasts in the decline, ground vibration limits have been assessed at the closest distance between the TSF2 embankments and the underlying decline, being 220m.

Figure 2 – Layout of TSF2, showing embankments 1, 2 and 3 (EB1, EB2 and EB3).



ASSESSMENT OF GROUND VIBRATION IMPACTS AT TSF2 EMBANKMENTS

The potential ground vibration impacts at TSF2 embankments have been estimated, using a conservative approach and assuming controlled blast design, implementation and monitoring processes. Adjustments to preliminary blast designs will be made in order to ensure that compliant blasting is maintained, subject to the monitored outcomes from initial blasts.

Based on the methodology and limits previously discussed, peak ground vibration impacts have been estimated based on maximum instantaneous charge mass (MIC), minimum distances, and a conservative k-factor range (see Table 1).

These estimates suggest that peak vector ground vibration levels at the TSF2 embankments, for surface boxcut blasts and decline development blasts, will remain below limits specified by Golder Associates (15mm/s PPV at the embankment foundations) and the NSW Dams Safety Committee (30mm/s PPV on the embankment walls).

Estimates for all embankments are shown in Table 1, while Figure 3 and Figure 4 show the applicable minimum distances for surface boxcut blasts and decline development blasts to the closest embankment (EB3). Peak ground vibration levels at the closest embankment (EB3) have been estimated at up to 10mm/s PVPPV (approximately), based on maximum charge conditions for proposed surface and decline blasting. The estimates provided will need to be validated by monitoring ground vibration levels as blasting takes place, with design modifications made to ensure compliance with limits as required.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made, based on the assessment of available data using generic methods and the assumption of good blasting practice.

Compliant blasting within the proposed boxcut, and associated portal/decline, should be achievable using conventional surface and tunnel development blasting methods, based on the identified distances to the TSF2 embankments and the ground vibration limits quoted.

The development of a blast management plan and operating procedures should be carried out as part of risk assessed process, prior to implementation. Appropriate supervision and management of the drill and blast process should be undertaken, as a controlled exercise.

Blast monitoring should include vibration monitors at the TSF2 embankments, including the closest point on the closest embankment, being the southern abutment of EB3. Monitored data can then be used to validate modelled assumptions and adjust blast design parameters to maintain compliant blasting.

Table 1 – Limiting ground vibration criteria for surface bench blasts and decline development blasts [1, 2, 3]

Location	K factor (average)	K factor (upper)	Exp, b	Min distance (m)	Max charge (kg)	Peak vibration (average) (mm/s)	Peak vibration (upper) (mm/s)	Target / Limit (mm/s)	Achieved (Yes/No)	Comments
Surface boxcut blasts (MIC 75kg)										
TSF2 Embankment 3 (closest point)	1140	2280	-1.6	280	75	4.4	8.8	15 - 30mm/s	Y	15mm/s PVPPV limit at embankment floor (Golder, Reference 3)
TSF2 Embankment 1	1140	2280	-1.6	355	75	3.0	6.0	15 - 30mm/s	Y	
TSF2 Embankment 2	1140	2280	-1.6	615	75	1.2	2.5	15 - 30mm/s	Y	
Decline development blasts (MIC 60kg)										
TSF2 Embankment 3 (closest point)	1140	2280	-1.6	220	60	5.4	10.8	15 - 30mm/s	Y	30mm/s PVPPV limit on embankment wall (NSW DSC, Reference 2).
TSF2 Embankment 1	1140	2280	-1.6	335	60	2.8	5.5	15 - 30mm/s	Y	
TSF2 Embankment 2	1140	2280	-1.6	575	60	1.2	2.3	15 - 30mm/s	Y	

Notes for Table 1

1. Maximum required charge mass of 75kg/hole is based on the ‘worst case’ (i.e. highest impact) blast parameter ranges for surface blasting, presented in Appendix 1. A lower MIC (35kg/blasthole) will be applied on a shallower bench for the first blast.
2. Maximum expected charge mass of 60kg/delay is based on a likely ‘worst case’ scenario (i.e. 12 holes at 5kg/hole) for decline development blasting, presented in Appendix 2. More conservative charge mass can be achieved by reducing the number of blastholes fired simultaneously, particularly through the use of electronic initiation.
3. Site constant ‘k’ and site exponent ‘b’ are used to define the relationship between peak vibration (mm/s) at a distance from the blast (m), with a maximum charge (kg). These parameters should be validated for more accurate vibration estimation once operational blasting begins.

Figure 3 – Surface boxcut blasting to the closest point on EB3. Plan (inset) and long-section (main).

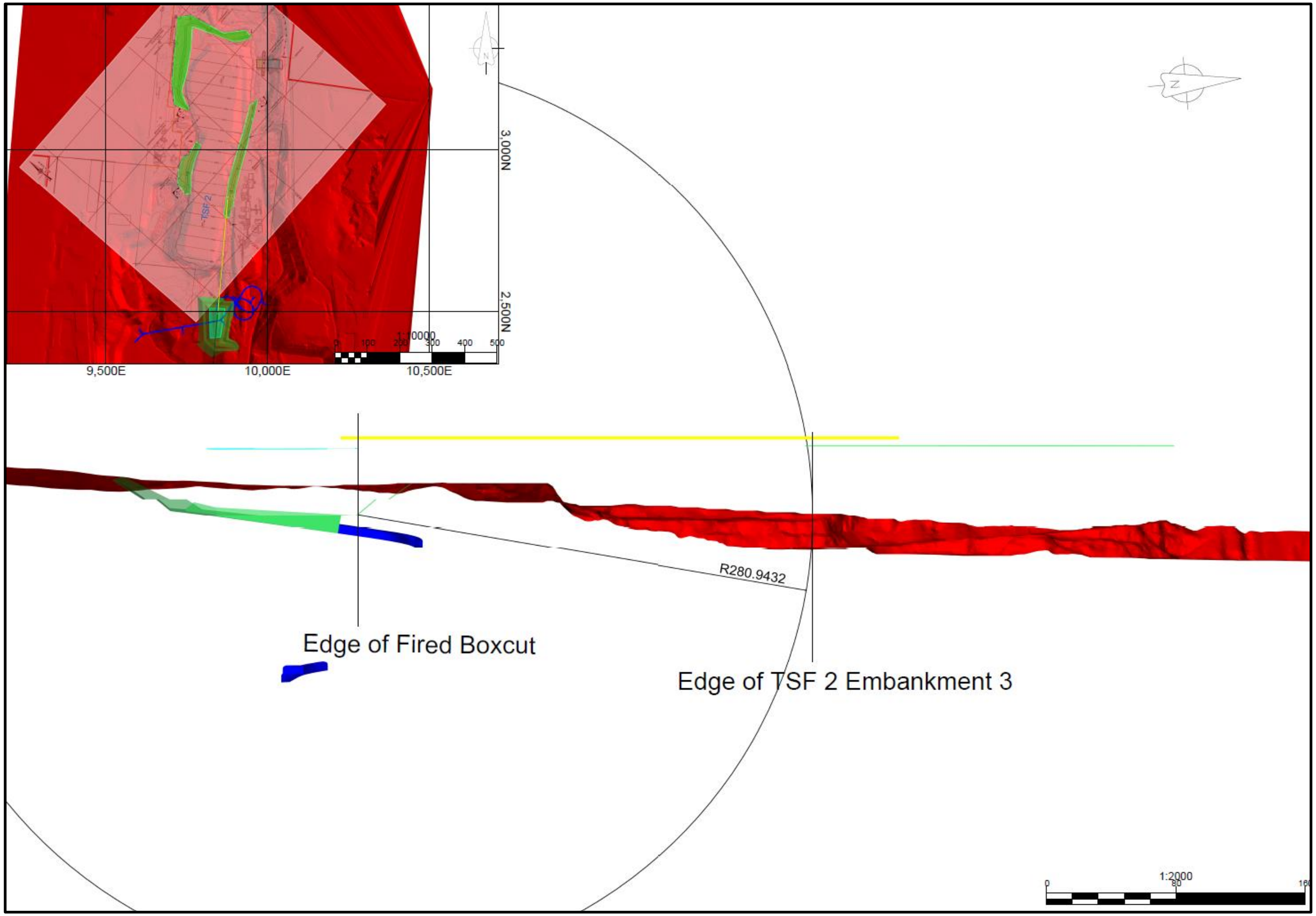
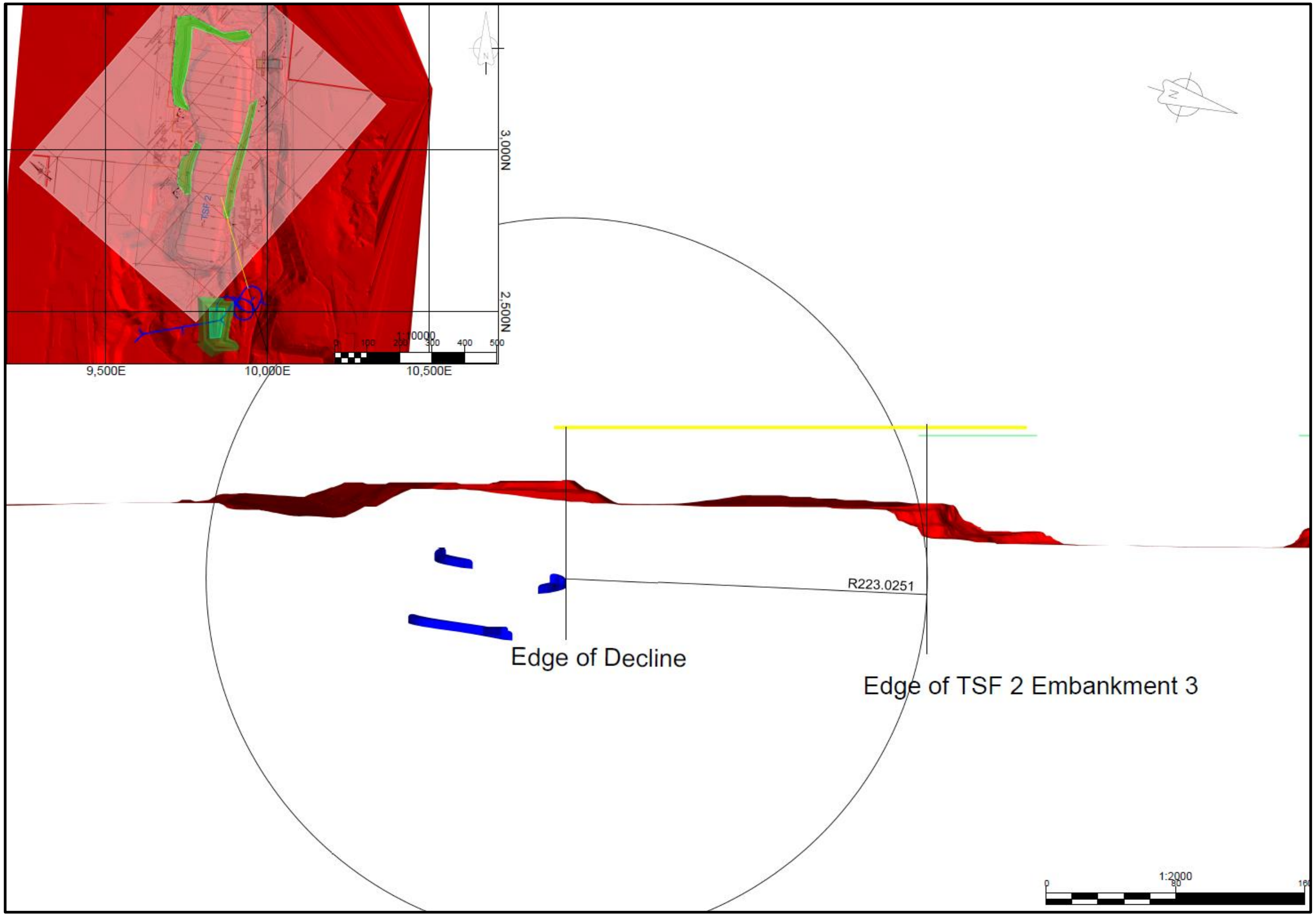


Figure 4 – Decline development blasting to the closest point on EB3. Plan (inset) and long-section (main).



Appendix 1 – Initial blast design parameters for surface boxcut blasts

Figure A1 – Generalised surface bench blasting geometry

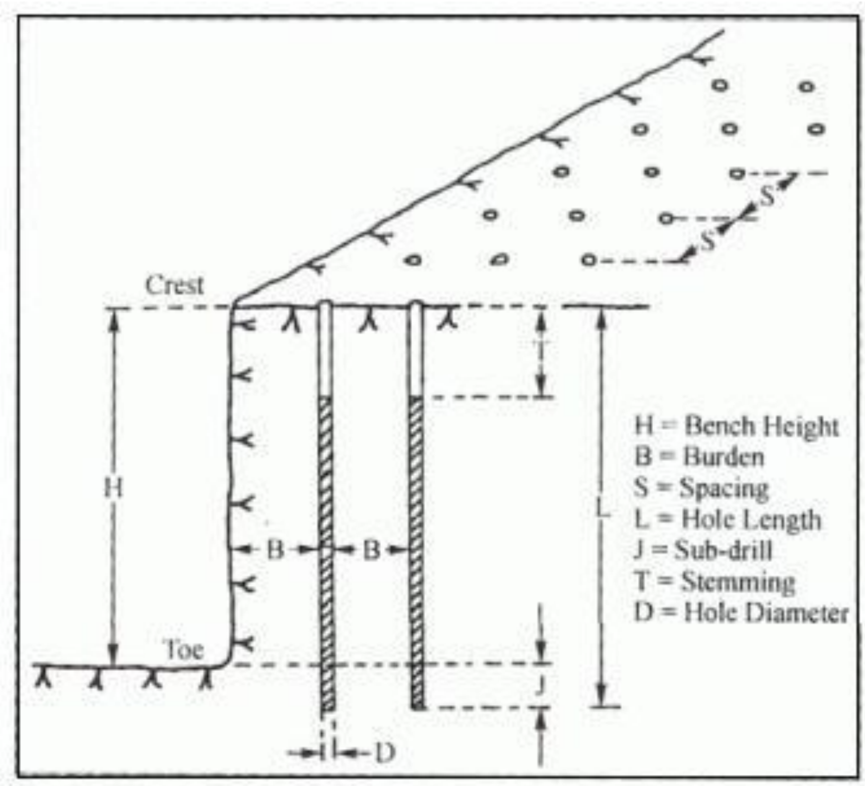
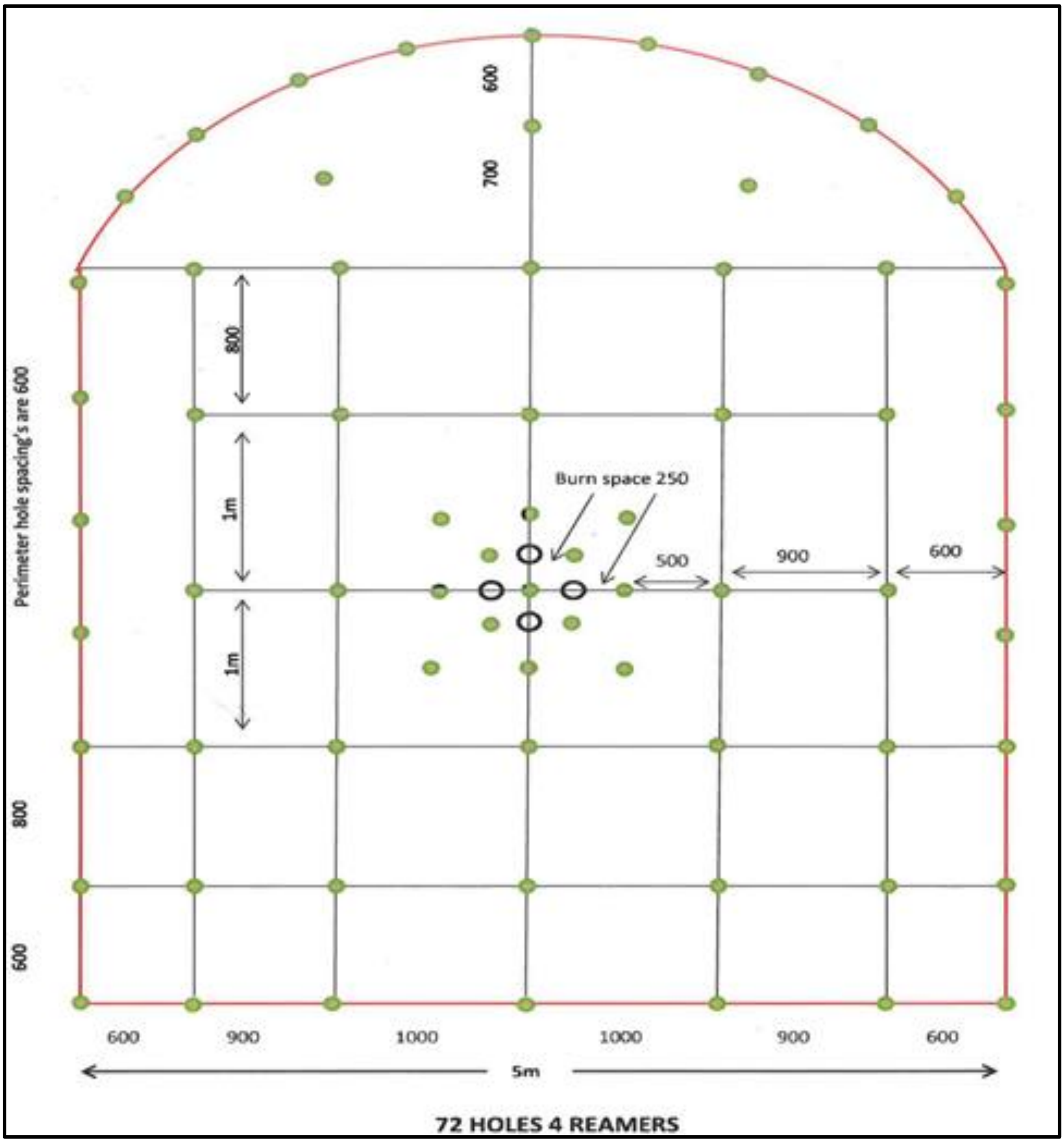


Table A1 – Preliminary surface blast parameters

Parameter	Moderate intensity blasting		Higher intensity blasting	
Blasthole diameter (mm)	76	89	76	89
Bench height (m)	8 to 10	10 to 12	8 to 10	10 to 12
Hole angle (degrees)	90	90	90	90
Rock density (g/cc)	2.2 to 2.6	2.2 to 2.6	2.2 to 2.6	2.2 to 2.6
Ground conditions	Dry / damp / wet	Dry / damp / wet	Dry / damp / wet	Dry / damp / wet
Explosive density (g/cc)	1.1	1.1	1.1	1.1
Charge density (kg/m)	5.0	6.8	5	6.8
Sub-drill (m)	0.7 to 1.2	0.8 to 1.4	0.7 to 1.2	0.8 to 1.4
Burden (m)	2.4	2.8	2.2	2.6
Spacing (m)	2.8	3.2	2.5	3.0
Stem height (m)	2.2	2.5	2.1	2.4
Charge mass per hole (kg)	35 to 45	60 to 75	35 to 45	60 to 75
Powder factor (kg/m^3)	~ 0.65	~ 0.65	~ 0.8	~ 0.8
Energy factor (Kj/tonne)	800 to 900	800 to 900	1000	1000
Timing	17ms to 25ms inter-hole delays and 25 to 42ms or 67ms inter-row delays on a limited number of rows for sequential firing.			

Appendix 2 – Development round proposed for the decline at Rasp Mine

Figure A2 – Proposed decline development pattern



Notes for Figure A2

Overall dimensions – Height 5.8m, Width 5.5m

Blastholes – 45mm diameter, 4.5m length

Charging – 5kg emulsion explosive, primer and detonator (Nonel LP or electronic).

Firing sequence – Up to 12 holes per delay assumed as worst case (60kg), with reduced number of holes fired per delay if required for control of ground vibration at close proximity.

APPENDIX 3 - REFERENCES

The following references have been used in preparing this report.

1. Blasting Impact Assessment for the Proposed Boxcut and Portal/Decline at Rasp Mine (Mod6), Mike Humphreys, Prism Mining Pty Ltd, 25th February 2021
2. Annexure "D" Standard Mining Conditions, NSW Dams Safety Committee, October 2019.
3. Rasp Mine – Potential Impact of Blasting on Tailings Storage Facility, Technical Memorandum, October 2019, Golder Associates Pty Ltd.
4. Efficient Blasting Techniques Course, Blast Dynamics and Dyno Nobel (various dates).
5. Appendix J, Australian Standard for Explosives Storage and Use, AS2187.2-2006.

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