FINAL

BLASTING IMPACT ASSESSMENT FOR THE PROPOSED BOXCUT AND PORTAL/DECLINE AT RASP MINE (MOD6)

BROKEN HILL OPERATIONS PTY LTD

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Prepared for: Broken Hill Operations PTY LTD.

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Disclaimer

This document provides general guidance based on information provided by the client, using generic methodologies for calculating blast parameters and blasting impacts. Site-specific adjustments may be required to achieve desired results and minimise impacts as the project is implemented and additional information collected. For further assistance during implementation contact the author, or other suitable qualified person.

EXECUTIVE SUMMARY

This report demonstrates how blasting within the proposed boxcut and portal/decline at Rasp Mine (Mod6 Proposal), can be carried out in compliance with appropriate standards for ground vibration, overpressure and fly-rock.

ANZEC guidelines for the minimisation of annoyance at sensitive residential locations (Reference #7) can be used to define appropriate ground vibration and overpressure limits at residences surrounding the project, which also correspond with Rasp Mine EPL conditions. Blast parameters have been specifically selected to meet the peak vector (PVPPV) ground vibration limits of less than 5mm/s (95% of blasts) to 10mm/s (100% of blasts), and peak blast overpressure limits of less than 115dBL (95% of blasts) to 120dBL (100% of blasts), at residential locations. The lower levels of 5mm/s PVPPV and 115dBL peak OP have been used for design purposes in this report.

AS2187 guidelines for the avoidance of structural damage at non-residential, commercial and industrial locations (Reference #2) have been used to define appropriate ground vibration and overpressure limits at such locations surrounding the project. Blast parameters selected to meet stringent residential ‘amenity’ limits have been demonstrated to also meet ‘damage’ limits for non-residential, commercial and industrial locations, at closer proximity to the proposed boxcut than the nearest residences.

Guidance regarding appropriate ground vibration limits for the nearest adjacent tailings facilities at TSF1 (historic storage) and TSF2 (Blackwood Pit) has been based on work carried out by Golder Associates Pty Ltd (Reference #9) and mandated requirements by the NSW Dams Safety Committee (Reference #13). These limits should be achievable for surface boxcut and decline development blasting.

Fly-rock risk should be controlled within the mine lease area, using conservative blast parameters. Clearance distances have been based on published industry guidelines (References #4 and #8) and appropriate factors of safety. Minor access restrictions may need to be applied to publicly accessible areas adjacent to the mine lease (Cameron Pipe Band Hall), and within the lease area at the Broken Hill Café and Miner’s Memorial (Café Area), while a limited number of surface boxcut blasts and decline development blasts are fired.

In addition to appropriate blast designs, to suit boxcut geometry and ground conditions, a high level of operational control will also be required for blasting. The adoption of a risk assessed Blast Management Plan and operating procedures is recommended and a number of specific management controls have been identified.

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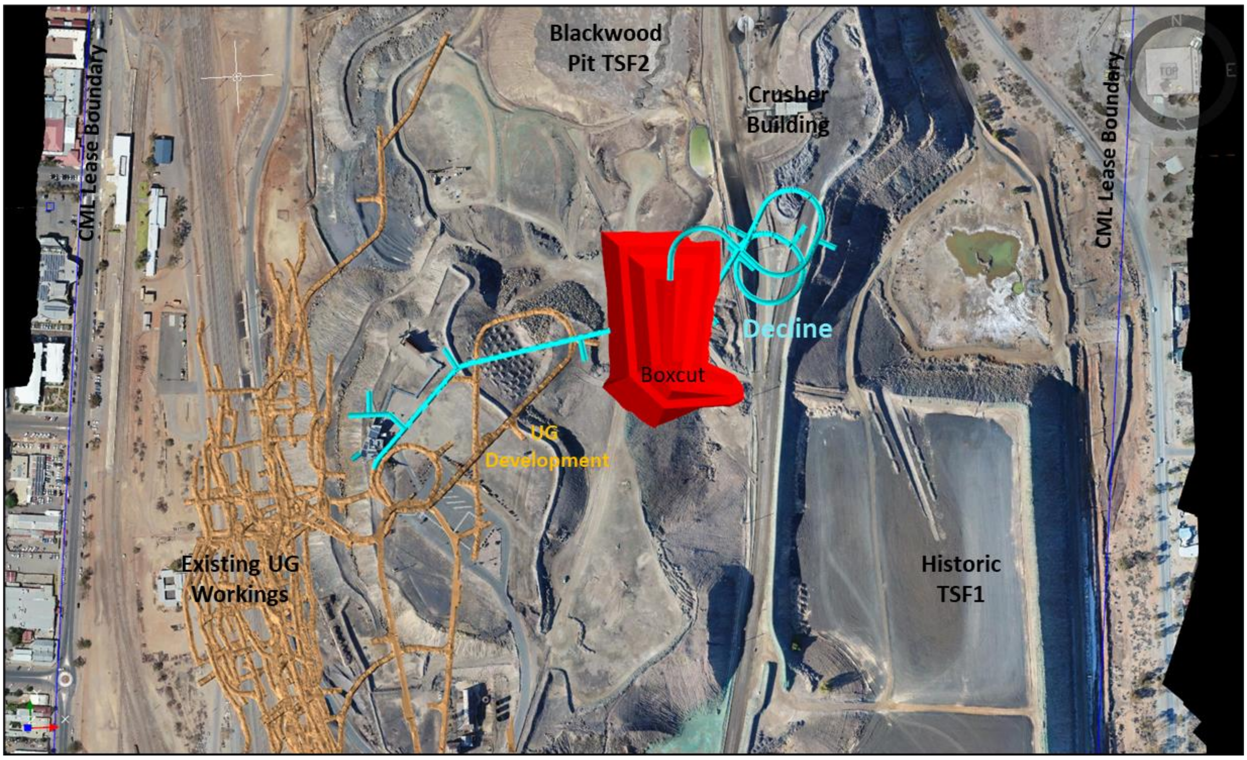
1 LOCATION AND GEOLOGY

The following report is aimed at identifying potential blasting impacts (ground vibration, overpressure and fly-rock), using preliminary blast parameters, for a proposed boxcut and portal/decline, north of TSF1 at the Rasp Mine (operated by Broken Hill Operations Pty Ltd), 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 access slot to the portal, some material above the first catch-bench, the portal entrance and some of the decline from the portal will require blasting from surface (see the plans in Figures 1, 2 and 3 and the cross-section at the start of the portal in Figure 4).

This report demonstrates how blasting can be carried out in compliance with appropriate environmental guidelines for ground vibration and overpressure, including ANZEC guidelines for the minimisation of annoyance at sensitive residential locations (Reference #7), and AS2187 guidelines to avoid damage at non-residential locations (Reference #2). Impacts at tailings facilities TSF1 and TSF2 have been based on work carried out by Golder Associates Pty Lt (Reference #9) and mandated requirements by the NSW Dams Safety Committee (Reference #13). Fly-rock risk should be controlled using appropriate factors of safety, based on maximum expected fly-rock range, to determine an achievable blast clearance area within the mine lease.

Figure 1 – Boxcut location with respect to mine infrastructure and surrounds



The proposed boxcut is approximately 180m in length, 110m wide, and up to 30m deep at the portal end of the excavation. Of the approximate total 180,000m^3 boxcut volume, a blasted volume of approximately 30,000m^3 (81,000 tonnes) has been estimated, subject to the depth to which fill material can be excavated without blasting.

Geotechnical assessment (Reference # 11) suggests that surface bench blasting within the boxcut will be required within 'weathered' material beneath the overlying fill. The decline will then be advanced a relatively short distance (perhaps 20m or less) from the portal entrance into 'transitional' and then 'fresh' rock, with the remaining decline developed from the underground workings.

The weathered material has been described as 'extremely or highly weathered', and 'very low to low strength' with compressive strength of intact material tested in the UCS range of 13.4MPa to 24.3MPa (ie UCS<25MPa) and a density of 2.2 to 2.8g/cc. This suggests that high intensity blasting will not be required, however environmental and fly-rock impacts have been assessed on that more limiting scenario as a 'worst case'.

'Fragmented and highly fractured zones' were intersected during exploration drilling within and around the boxcut area, and characterised by 'sheared, low strength material in various states of weathering'. This may present problems for the drill and blast process, as identified in Section 4.1. While the boxcut is not anticipated to intersect significant underground workings, the long history of mining in the area does require that risks associated with drilling, blasting and mining above voids and adjacent to old shafts need to be considered.

Ground conditions at the portal batter have been described as 'poor to very poor' and blasting in that area will need to be reviewed with respect to slope stability and support requirements, as conditions are encountered. Presplit blasting along the portal batter may or may not be effective, but careful consideration of wall damage from blasts in that area will be necessary, with controlled limits blasting to be assessed once less critical blasting outcomes have been reviewed.

Batter angles have been suggested for permanent slopes in the weathered material to be blasted, from 54 degrees to 70 degrees (at the portal batter), with batter heights up to 11m.

Figure 2 – Approximate area to be blasted within the boxcut, encompassing the access slot to the portal and part of the overlying bench (plan)

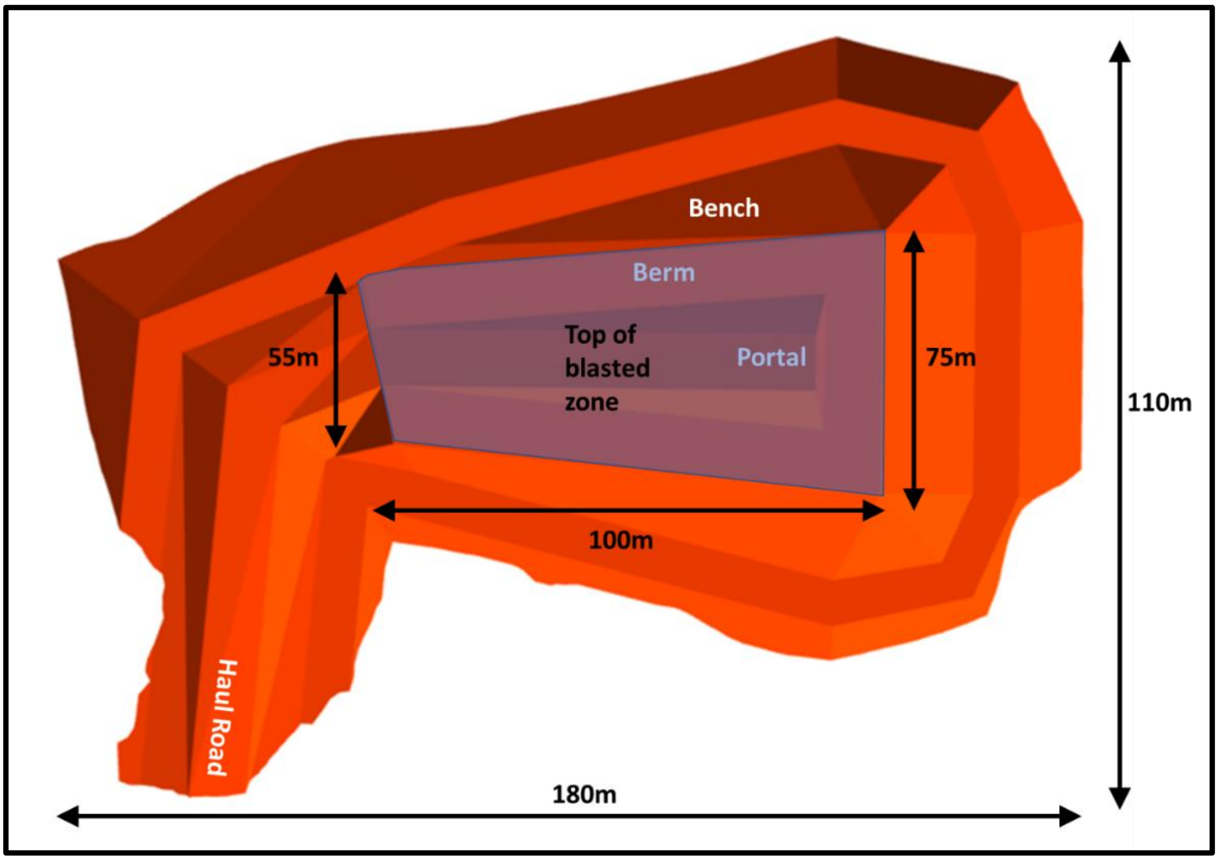


Figure 3 – Area to be blasted within the boxcut. Top pass (stages 1 & 2) followed by access slot to the portal (stage 3). Long section N-S (top), X-section E-W (bottom)

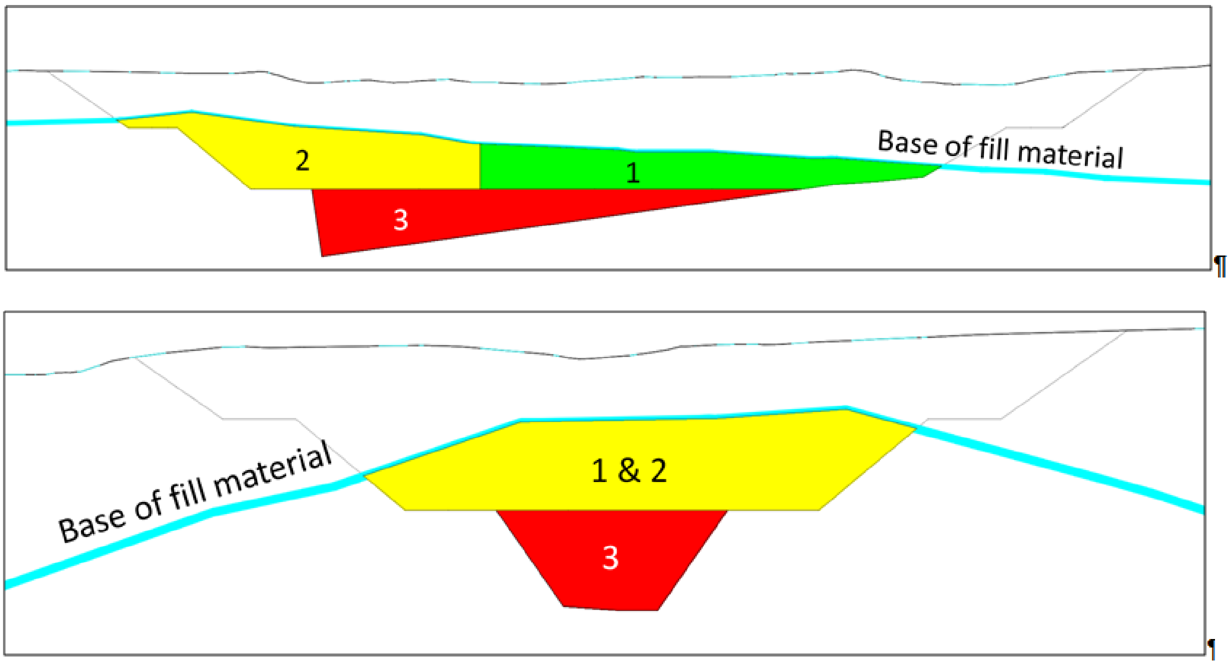
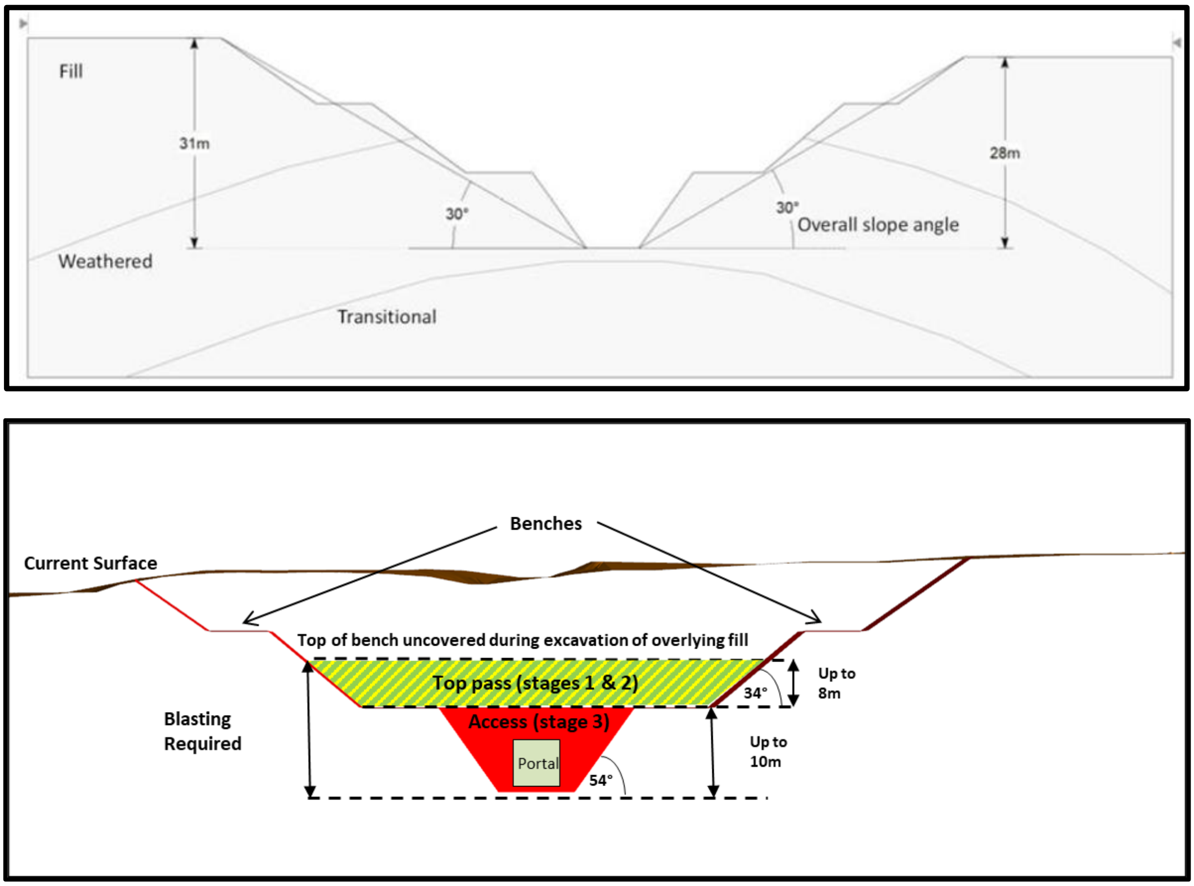


Figure 4 – Cross-section at the portal showing fill, weathered and transitional horizons (top) and expected material to be blasted (bottom)



2 ASSESSMENT METHODOLOGY

2.1 Blast Parameters

The area to be blasted within the proposed boxcut will not be fully defined, until after excavation of the overlying 'fill' material has been completed. This assessment therefore uses generic guidelines to estimate blasting impacts, in order to demonstrate that environmentally compliant and safe blasting can be achieved for a range of likely blast requirements and ground conditions.

At this stage it has been assumed that conventional surface blast designs, yielding powder factors in the range 0.65 to 0.8kg/m^3 will provide adequate fragmentation. Presplit blasting may be appropriate/required at the 70-degree portal batter, or alternative 'smooth wall' and/or 'limits' blasting methods utilised.

A small number of development rounds will also be required to be fired from surface (daytime construction events), in order to establish the portal and the start of approximately 400m of decline. It has been estimated that this may involve as few as 5 or 6 development blasts, fired from the portal entrance and similar to underground development blasts already in use at Rasp Mine.

A general approach has been used to estimate a reasonable range for operational blasting parameters, with assumptions noted. The approach taken in this case is based on that promoted by Blast Dynamics and Dyno Nobel (Reference #1).

2.2 Ground Vibration

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 #2) 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.

Variation of ground vibration generated by blasting also occurs because of changing intervening ground conditions, blast size and orientation, degree of confinement, firing sequence and other factors. 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 at a relatively high level of blasting intensity (powder factor) and with limited relief (confined), such blasting would also be expected to generate relatively low ground vibration impacts at surface as they are of such small size/volume (around 150m^3).

2.3 Overpressure

A method for estimating likely overpressure impacts from surface blasts at sensitive receivers is based on the calculation of distances to the 120dBL contour (D120), in front of the free-face and behind the face (Reference #3) as follows:

D120 = [(Kb x diameter / burden) $^{2.5}$] x [(charge/hole) $^{1/3}$)] in front of a free face

D120 = [(Ks x diameter / stem height) $^{2.5}$] x [(charge/hole) $^{1/3}$)] behind the face

Where the diameter of the blasthole is measured in mm and charge mass is maximum charge per hole (kg) for sequential (hole-by-hole) firing. Calibration factors Kb and Ks can typically vary from Kb=150 to 250 and Ks=80 to 180, for distances to the 120dBL contour, with upper limits being used for this exercise. Similarly, calibration factors Kb and Ks have been estimated for distances to the 115dBL contour, with upper limits being Kb=290 and Ks=220.

Overpressure levels, at distances other than those to the 115dBL and 120dBL contours, can be estimated using an attenuation rate of +/-8.6dBL for every halving/doubling of distance from the calculated reference contour, as illustrated later in Section 5 (Reference #10). These estimates apply prior to any other adjustments that may be appropriate for meteorological conditions, wavefront reinforcement due to firing direction, or the effects of topographic shielding.

For vertical holes at 90 degrees, the D115 and D120 distances 'behind' a buffered blast (i.e. no free face) have been used as the main limiting criteria, as free-face blasting should not be required within the boxcut if properly sequenced.

If free-face blasting is required, such free faces should be orientated towards the mine lease area to the south-west, rather than towards the closest residential locations to the north-west (Crystal Street) or south-east (Eyre Street) in order to mitigate overpressure risks. Such blasts need to be specifically designed following the guidelines in this report, subject to ground conditions and free face burdens, on a blast-by-blast basis.

If presplit blasting is required around the portal (70-degree design batter), conservative levels of confinement using a combination of stemming and conveyor belt matting are recommended to mitigate overpressure levels. This cannot be reliably modelled, but should be achievable at overpressure levels below those generated by larger scale surface bench blasts.

The overpressure impact of unstemmed development rounds fired within the topography of an enclosed boxcut is also difficult to model, but can be mitigated through the use of stemming in some (or all) holes, the installation of a barrier in front of the face, and the shielding effect of the surrounding boxcut topography. Development rounds in the decline, fired from surface, should be treated as 'day-time' events, as required during the construction phase. The surface overpressure impacts from decline development blasts can be minimised by firing most of these (>95%) from underground prior to breaking through at surface.

2.4 Fly-rock

Fly-rock can be generated by different mechanisms (see Figure 5) and maximum fly-rock range can be estimated using a number of published methods. A general 'cratering' model published by McKenzie (Reference #8) uses a scaled depth of burial approach, while empirical models for rifling (stemming ejection) and face burst from a free-face have been published by Moore and Richards (Reference #4).

Cratering model (Reference #8)

$$\textbf{Maximum Range (metres)} = 11 \cdot SDB^{-2.167} \cdot (\Phi/Fs)^{0.667}$$

where SDB = scaled depth of burial (metric) = $(St + 0.0005 \cdot M \cdot \Phi) / (0.00923 \cdot (M \cdot \Phi^3 \cdot d)^{0.333})$

for: Fs (shape factor = 1.1 to 1.3), St = stem height (m), M = charge ratio (M<8 for 89mm holes), Φ = hole diameter (mm), and d = explosive density (g/cc).

Face burst (free face) model (Reference #4)

$$\textbf{Max Range (m)} = (27^2/9.8) \times [(\sqrt{(\text{charge per metre})}/\text{burden}]^{2.6}$$

Rifling (stemming ejection) model (Reference #4)

$$\textbf{Max Range (m)} = (27^2/9.8) \times [(\sqrt{(\text{charge per metre})}/\text{stem height}]^{2.6} \times \text{sine } (2\theta)$$

where θ = hole angle and maximum range takes place 'behind' an angled hole. For vertical holes at 90 degrees, the value of θ is selected as 80 degrees (rather than 90 degrees) to allow for some unfavourable hole deviation (Reference #4).

Given that blasting within the boxcut should be confined (i.e. no free face), fly-rock range is assumed to be stemming controlled as defined by the cratering and rifling models above, rather than burden controlled.

As with overpressure control, if free-face blasting is required, such free faces should be orientated towards the mine lease area to the south-west, in order to mitigate fly-rock risks, and be specifically designed and assessed, subject to ground conditions and free face burdens, on a blast-by-blast basis.

For presplit holes at 70 degrees (if required), conservative levels of confinement using stemming and conveyor belt matting are recommended to mitigate fly-rock risks, in order to contain fly-rock within the box cut. For portal development rounds, blastholes will be oriented close to the horizontal, and confined within the boxcut excavation, with a barrier for overpressure control also facilitating the containment of fly-rock.

Figure 6 illustrates distance contours around the area to be blasted within the boxcut, with respect to the mine lease and surrounding area. This should be used to assess risk when considering access control and fly-rock control when firing, and the selection of an appropriate blast clearance area (see Section 3.3 and Section 5.3).

Figure 5 – Three mechanisms of fly-rock

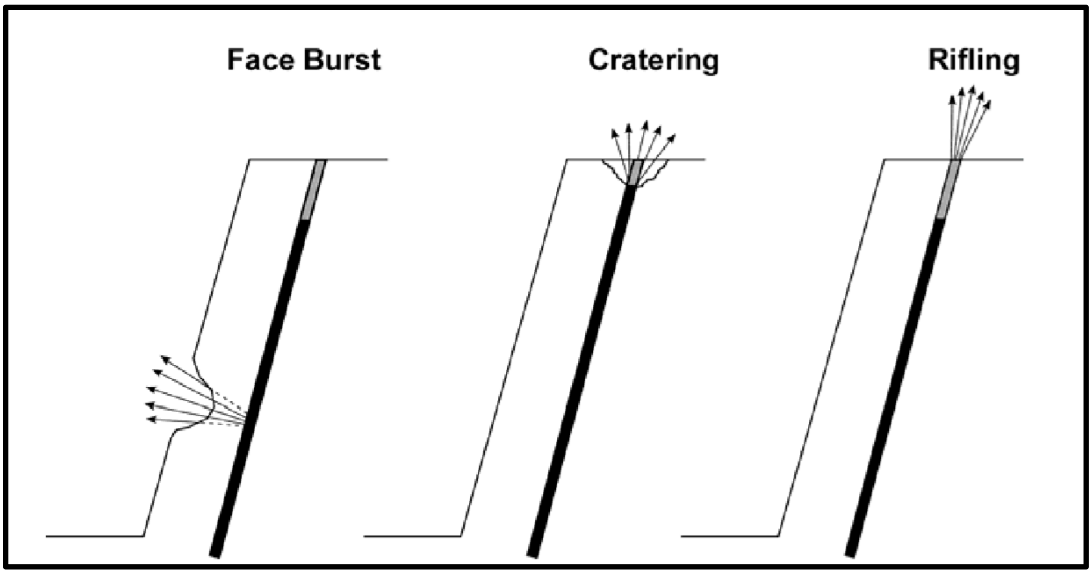
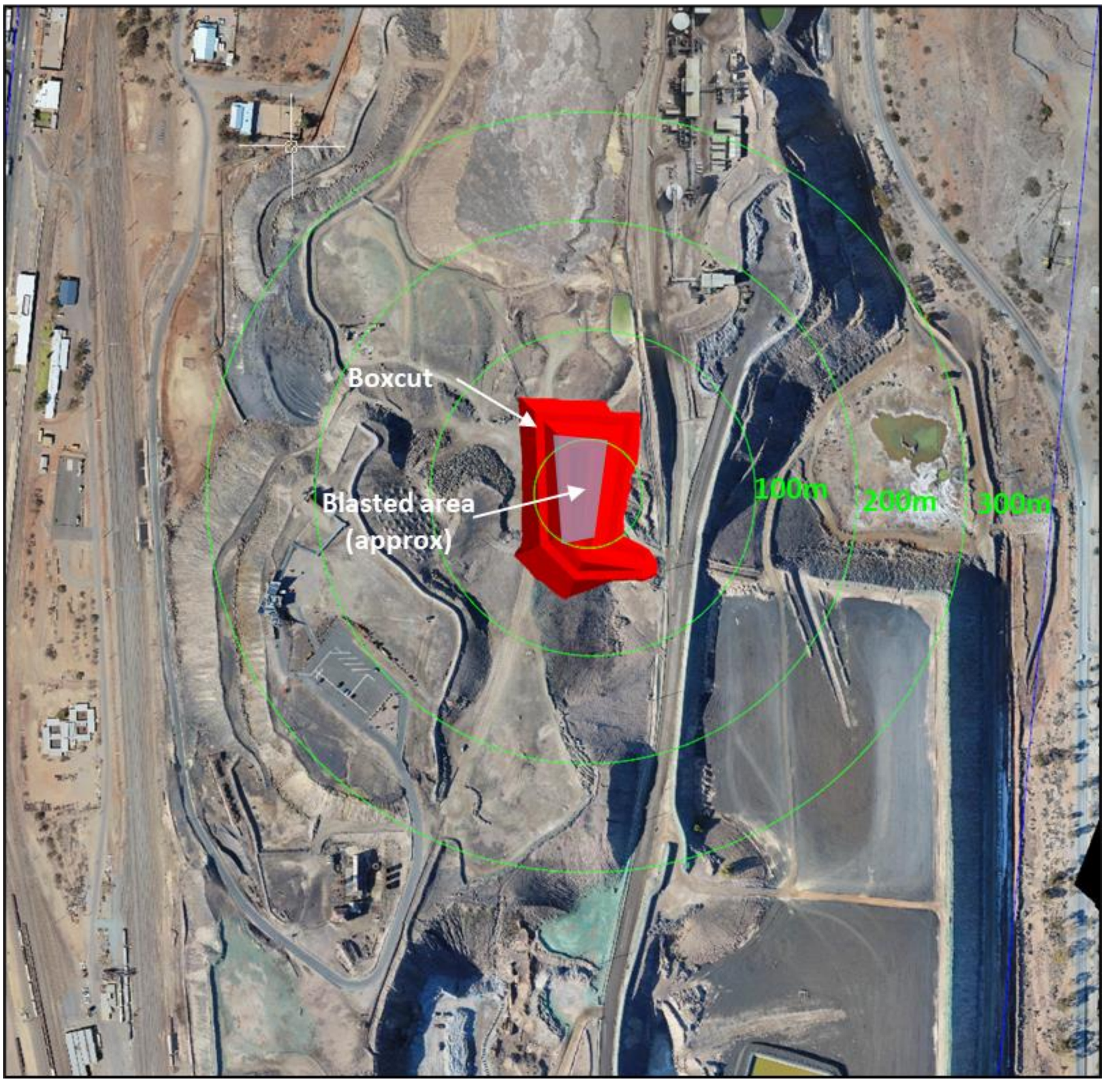


Figure 6 – Distance contours around the area to be blasted within the boxcut

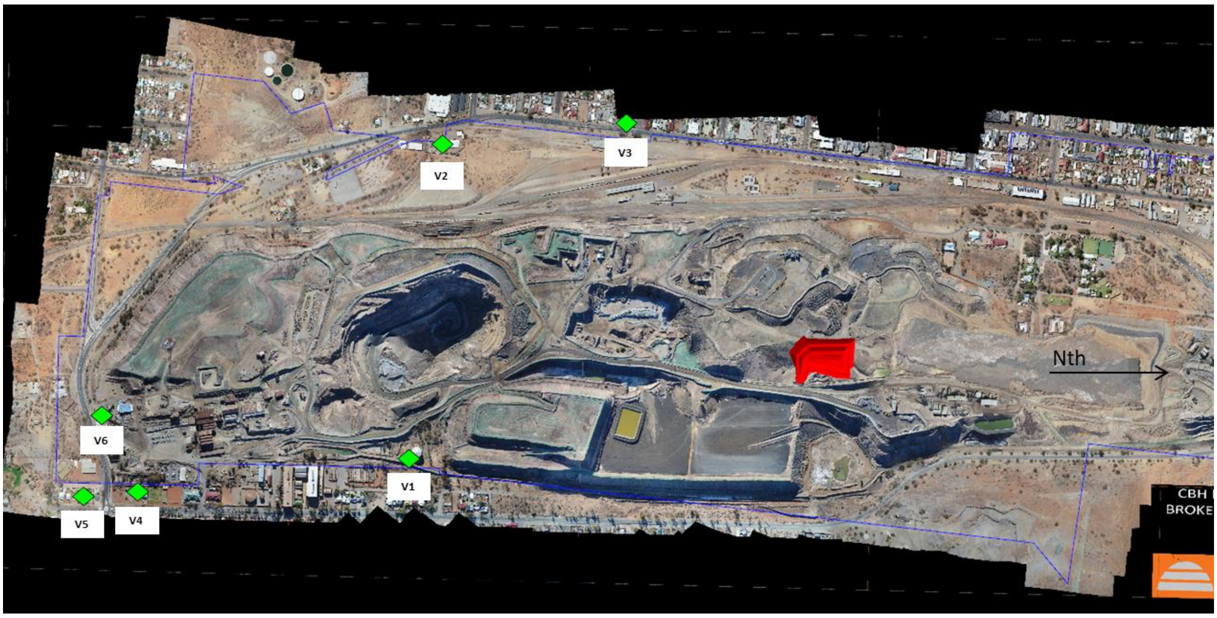


3 ASSESSMENT CRITERIA

Broken Hill Operations’ Rasp Mine currently operates within the consolidated mining lease CML7, under project approval PA07_0018(PA), with the impacts from current underground blasting being limited under the PA and EPL #12559.

Blast induced ground vibration is currently recorded at fixed monitoring locations (V1 to V6), with V1 to V3 being closest to the proposed boxcut (Figure 7), and with ‘roving’ monitors placed at other sensitive receivers as required. While overpressure is also monitored at these monitors, the containment of underground blasting does not generally result in blast induced overpressure at surface receivers. Overpressure will, however, provide a constraint to surface bench blasting within the boxcut itself and portal and decline development rounds that are fired from surface.

Figure 7 – Location of current fixed ground vibration monitoring systems (V1 to V6) relative to the proposed boxcut

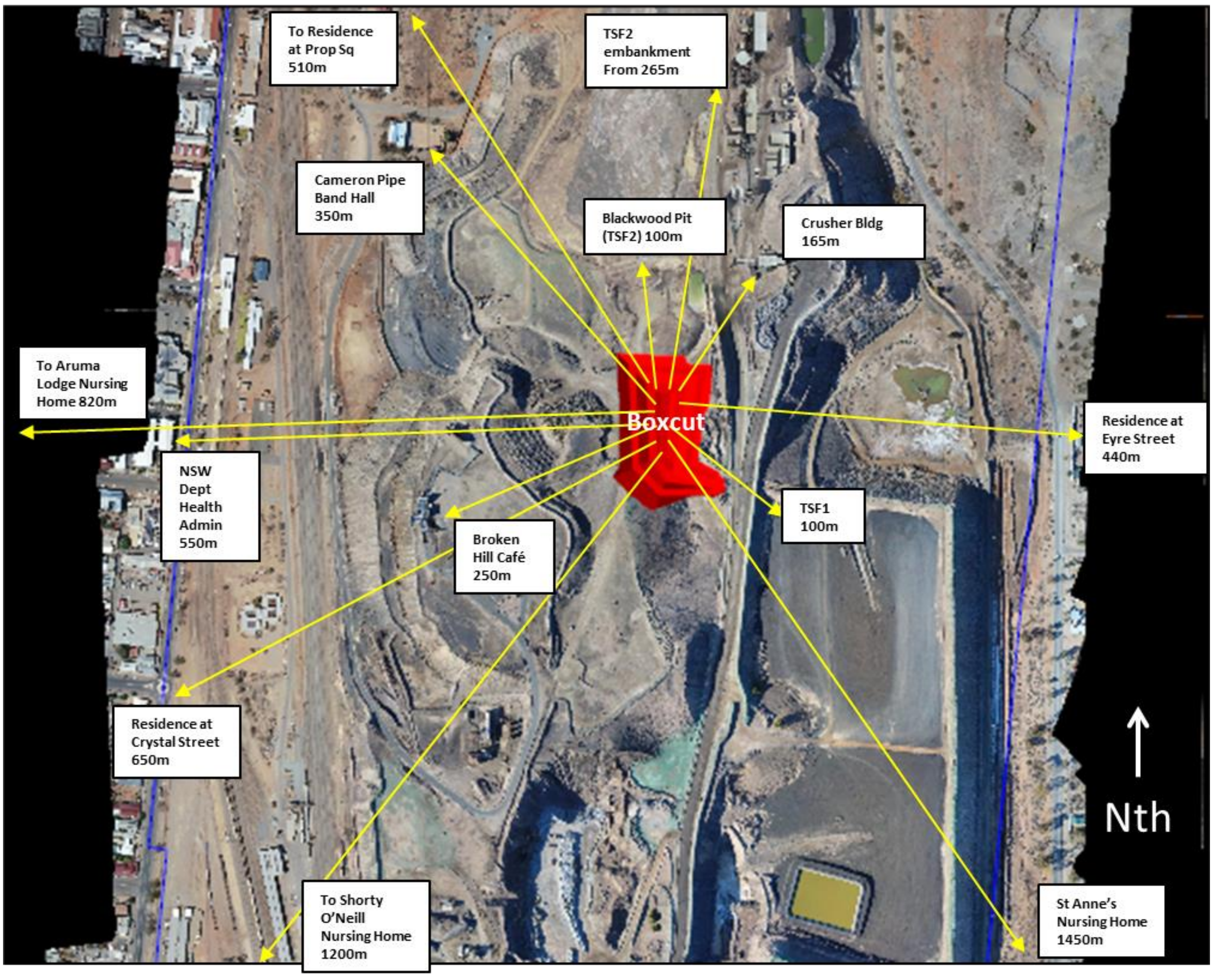


Based on the information provided, there are a number of potentially sensitive locations surrounding proposed boxcut area, where representative impacts have been considered (Figure 8). These include:

- Mine-owned infrastructure from 100m to the north-east and south (TSF2 and TSF1 tailings facilities), from 165m to the north-east (processing plant), and from 280m to the north-east (closest point on the Blackwood Pit TSF2 embankments being constructed).
- Commercial/non-residential premises from 250m and 550m to the north-west (Broken Hill Café Area and NSW Health Admin Building) and 380m to the north (Cameron Pipe Band Hall);

- Closest residential locations from 440m to the south-east (Eyre Street), from 510m to the north (Proprietary Square) and from 650m to the west (Crystal Street).
- Nearby nursing homes were also considered, with Aruma Lodge at 820m, Shorty O'Neills at 1200m, and St Anne's at 1450m from proposed boxcut blasting.
- Ground vibration and overpressure impacts at the closest residential locations are likely to be constraining for surface boxcut blasting, due to a combination of the lowest applicable ground vibration and overpressure limits and their relatively close proximity.
- Conservative ground vibration impacts at TSF1 and TSF2 embankments (foundation limits) may also be constraining for both surface boxcut blasting (TSF1) and some underlying decline development blasts (TSF1 and TSF2) at close proximity from 100m.
- Note that while this report focuses on what are considered 'worst case' locations, for ground vibration, overpressure and fly-rock impacts, the methodologies presented can be followed for other locations if identified later during an operational risk assessment process. It is assumed that controlling blasting impacts at the nearest sensitive locations will generally control impacts at more distant locations.

Figure 8 – Nearest sensitive locations around the proposed boxcut area



3.1 Ground vibration risk

For residential locations, peak vector ground vibration limits less than 5mm/s (95% of blasts) and 10mm/s (100% of blasts) as per ANZECC guidelines, are usually applicable to limit disturbance (Reference #7). This is applicable under current EPL conditions, excluding underground blasting in Block 7, where a more restrictive 3mm/s (95%) limit applies.

- The closest residential location on Eyre Street to the south-east, at a distance of 440m, has been considered as 'worst-case' for assessment purposes.
- Peak ground vibration levels below 5mm/s should be targeted for a small scale, short-term, project of this nature. Note, however, that complaints can arise at levels at (or even below) 2mm/s therefore minimising ground vibration as much as is practical is advised.
- Given that blasting is carried out at the nearby Mawson Quarry, neighbours on Eyre Street are likely to be familiar with ground vibration from surface blasting.

For non-residential locations, a number of criteria are referenced in the applicable Australian Standard (AS2187, Reference #2), as follows:

- Ground vibration limits to avoid cosmetic damage to light commercial buildings are suggested by AS2187 as a peak component particle velocity of 15mm/s at 4Hz to 50mm/s at 40Hz. A peak vector particle velocity of 15mm/s therefore provides a conservative lower threshold, when assessing impacts at non-residential locations.
- A 15mm/s peak vector ground vibration limit is suggested at the Broken Hill Café Area (including the Miner's Memorial), for assessment purposes which will also minimise potential impacts at more distant non-residential commercial locations such as the Cameron Pipe Band Hall and the NSW Health Admin building.
- Ground vibration limits for occupied non-sensitive industrial sites are suggested by AS2187 as a peak component particle velocity below 25mm/s, unless agreement is reached with the owner for higher levels**.** A peak vector particle velocity of 25mm/s therefore provides a conservative lower threshold, when assessing impacts at occupied non-sensitive industrial sites. Note that ground vibration guidelines for cosmetic damage to industrial and heavy commercial structures are suggested by AS2187 as a peak component particle velocity of 50mm/s for frequencies >4Hz. Ground vibration limits for the control of damage to unoccupied concrete and steel structures, are suggested as a peak component particle velocity below 100mm/s unless agreement is reached with the owner for higher levels.
- The most limiting asset of an 'occupied, non-sensitive' nature appears to be the mine-owned crushing and processing plant, at distances from around 165m and greater. A conservative peak vector ground vibration limit of 25mm/s is suggested as a starting point when assessing operational risk, and whether temporary shutdown and/or evacuation is required during blasting.

- In the case of the nearest tailings storage facilities and embankments, TSF1 (historic) and TSF2 (Blackwood Pit), more specific criteria have been suggested by Golder Associates (Reference #9) and the NSW Dams Safety Committee (Reference #13). Ground vibration constraints for the TSF3 facility (Kintore Pit >1000m to the south), are not relevant as boxcut and decline blasting will be completed prior to that facility becoming active.
- The NSW Dams Safety Committee (DSC) have imposed a peak particle vibration limit of 30mm/s (assumed to be PVS) at the TSF2 embankment structures being constructed (Reference #13).
    - 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 #13) suggests a PPV limit of 15mm/s for embankments with foundations that may be vibration sensitive, which is applicable at some of the TSF2 embankments.
    - 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 (100m north of the boxcut) can therefore be implied as 75mm/s PVPPV in order to meet foundation limits at the more distant embankments (based on expected 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.
- Ground vibration limits with regard to TSF1 have been suggested as 25mm/s PVPPV, for both the embankment and saturated tailings (Reference #9). This is identified as a conservative limit and more work may be carried out to validate this.
    - For surface bench blasts in the boxcut, ground vibration limits have been assessed at the shortest horizontal distance to TSF1 as a worst-case, being approximately 100m.
    - For development blasts in the decline, ground vibration limits have been assessed at the closest distance between TSF1 and the underlying decline, being 130m.
- Ground vibration limits for other structures and sensitive equipment are subject to manufacturers recommendations and must be sufficient to avoid adversely affecting equipment operation. Sensitive electrical and computer equipment is typically affected in the vibration range 15mm/s to 50mm/s over the range of dominant frequencies generated by surface blasting but this needs to be assessed on a case-by-case basis (References #5 and #6). The relatively close proximity of residential locations and non-residential/commercial buildings, with associated low ground vibration limits (5mm/s to 15mm/s PVPPV) suggests that sensitive electrical and computer facilities will be limited to those at closer proximity, and owned by the mine (i.e. at the processing plant).

3.2 Overpressure risk

For residential locations, peak overpressure limits less than 115dBL (95% of blasts) and 120dBL (100% of blasts) as per ANZECC guidelines are usually applied to limit disturbance (Reference #7). These limits apply under current EPL conditions, even though underground blasting is unlikely to generate non-compliant overpressure levels on surface in most cases.

- The closest residential locations to the south-east on Eyre Street, from 440m, have been considered for ‘worst-case’ assessment of surface boxcut blasts.
- Peak overpressure levels below 115dBL should be targeted for a small scale, short-term, project of this nature. Note, however, that the potential for overpressure reinforcement from various factors (such as meteorological conditions, stemming ejection, face movement etc) makes it prudent to minimise overpressure impact as much as is practical.
- Given that blasting is carried out at the nearby Mawson Quarry, neighbours are likely to be familiar with overpressure from surface blasting.
- Cosmetic damage to structures from overpressure has not been found at levels below 133dBL (Reference #2).
- If elevated overpressure levels cannot be effectively mitigated for development blasts fired from the surface portal, then additional rounds can be sequenced from the decline developed from underground.

3.3 Fly-rock risk

The nearest occupied and unoccupied locations have been assessed on the basis of fly-rock risk and fly-rock range (see section 2.4 above), when suggesting a blast clearance area. Guidelines for blast clearance from WorkSafe Victoria have also been compared.

- Where sensitive locations are evacuated, it is prudent to consider an initial factor of safety of twice the maximum expected fly-rock range. This suggests, for example, a necessary clearance of at least 150m where fly-rock range up to 75m is expected.
- However, if mine personnel or other persons are present then an initial factor of safety of up to four times the maximum fly-rock range is more prudent unless suitable refuge facilities are available within that distance. This suggests, for example, a necessary clearance of at least 300m where fly-rock range up to 75m is expected.
- In the case of areas accessible to the public then higher factors of safety may be appropriate, subject to consideration under a risk assessment process. The proximity of members of the public, during blast clearance and firing, needs to be controlled and the presence of spectators should be avoided.
- The likely access points to the blast clearance area also need to be risk assessed, in terms of being able to control that area, prior, during and after firing. Proper control of access

to the blast clearance area may justify increasing blast clearance distances further than those specified in order to achieve effective control.

- Calculated clearance distances presented in Section 5.3 can be compared with evacuation distances for general blasting (no free face) published by Worksafe Victoria, shown in Figure 9. Calculated distances are significantly more conservative, but are recommended in this case, given that surface blasting is not normally conducted at this site.

- Distance contours at 100m, 200m, and 300m from the area requiring blasting are shown previously in Figure 6. These contours represent horizontal distances from the blast area and can be used to identify where fly-rock risks may need to be assessed. The depth of blasting within the confines of the boxcut provides an additional level of fly-rock containment.

Figure 9 – Suggested evacuation distances, based on hole diameter, stem height and explosive density for general blasting (WorkSafe Victoria, Reference #12)

Table 1 - Small to intermediate blast hole diameter using ANFO/emulsion blends (1.2g/cc)

Evacuation distance (m)	Minimum stemming length (m)								
	51mm	76mm	89mm	102mm	114mm	127mm	140mm	152mm	165mm
100	1.4	2.3	2.9	3.7	4.3	4.9	5.6	6.3	7.0
150	1.1	1.9	2.3	2.9	3.5	4.0	4.5	5.1	5.7
200	0.9	1.6	2.0	2.5	3.0	3.4	3.9	4.4	4.9
250	0.8	1.4	1.8	2.2	2.6	3.0	3.4	3.9	4.3
300	0.8	1.3	1.6	2.0	2.4	2.7	3.1	3.5	3.9
350	0.7	1.2	1.5	1.6	2.2	2.5	2.8	3.2	3.6
400	0.7	1.1	1.4	1.7	2.0	2.3	2.6	3.0	3.3
450	0.6	1.1	1.3	1.6	1.9	2.2	2.5	2.8	3.1
500	0.6	1.0	1.2	1.5	1.7	2.0	2.3	2.6	2.9
550	0.6	1.0	1.2	1.4	1.7	1.9	2.2	2.5	2.8
600	0.6	0.9	1.1	1.4	1.6	1.8	2.1	2.3	2.6
650	0.5	0.9	1.1	1.3	1.5	1.7	2.0	2.2	2.5
700	0.5	0.8	1.0	1.2	1.4	1.7	1.9	2.1	2.4
750	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.1	2.3
800	0.4	0.7	0.9	1.1	1.3	1.4	1.7	2.0	2.2

Note – shaded areas indicate increase risk of fly rock (stemming lengths less than 25 times the diameter of the hole)

4 MANAGEMENT MEASURES & PRELIMINARY DESIGNS

4.1 Drill & Blast Management

The following measures and controls are suggested to ensure effective operational blasting that complies with applicable environmental consent conditions.

- An appropriately qualified project supervisor should oversee the process of surface blasting with respect to the boxcut and portal/decline development, as a well-controlled 'construction' exercise. This should include participation in all associated processes, including (i) excavation of overlying fill, to ensure appropriate bench preparation for drill & blast; (ii) blast planning and design; (iii) supervision of a tightly controlled blasting process (drilling, charging, stemming, tie-up and firing); and (iv) review of monitored blast outcomes, with adjustment of blast designs and operational processes to ensure safe blasting and environmental compliance.

- Specific controls should be adopted for boxcut and portal/decline blasting, including a blast management plan, operating and monitoring procedures, record keeping systems and risk assessment processes (overall process assessment and pre-blast assessments), with proper consideration for specific risks. The proximity to nearby mine infrastructure and residential/commercial locations warrants tight control and additional monitoring to avoid undesired impacts.

- Exploration drilling has been used prior to the excavation of fill material to identify underlying ground conditions within the boxcut. The location of the fill/weathered horizon should be used to create uniform bench surfaces from which to carry out drilling and blasting, avoiding the creation of 'free face' bench blasts and 'terraced' benches if possible. Exploratory holes drilled within the blast area should be surveyed for location, with measured depths, and preferably backfilled to the top of the blast horizon to reduce overpressure and fly-rock risks from the venting of nearby blastholes.

- While it is not anticipated that the boxcut will intersect voids associated with underground workings, the long history of mining in the area does introduce some uncertainty in this case. Two old shafts (assumed filled) are located within the footprint of the boxcut. The potential for drilling, blasting and mining near/above old workings should be risk assessed.

- The presence of fragmented and fractured zones may present D&B difficulties, including the location and collaring of drill holes, achieving the designed drill depth, and experiencing bulk explosives losses during charging and stemming. Specific controls to manage drilling, charging and stemming should consider these issues.

- Subject to the relative ground conditions at the fill/weathered horizon, blast designs may benefit from a layer of compacted fill to be left in place, as an additional level of cover for fly-rock and overpressure control. Where possible, it is advisable not to maximise the rip and dig process to a 'hard' floor, if this results in shallow blasts, as a proportion of weaker material on surface will allow better bench preparation and allow for more conservative stem heights. This will need to be assessed as conditions are encountered.

- The implementation of single-charge seed waveform blasting could be considered to validate ground vibration estimates prior to bench blasting in the boxcut. This could be implemented with separately fired charges (say 25kg, 50kg, 75kg), monitored at a minimum of three locations (say 100m, 250m, 500m) and would allow the development of more site-specific site constants, prior to the finalisation of boxcut and portal blast designs. Alternatively, the first boxcut blast should be conducted at a conservatively small scale to validate the assumptions used in this report.

- Depending on the extent of overlying fill, blasting will probably be best sequenced as three or four blasts, across two passes (see Figure 3), commencing furthest from the portal entrance. This should allow (i) the completion of each (relatively small) blast on a 'load and shoot' basis over a single day; and (ii) to assess whether blast design and/or environmental adjustments are required before reaching the deepest (most critical) section adjacent to the portal entrance.

- Blasting a first pass to the catch bench above the access slot (depth expected up to 8m), would create a dig horizon level with the lower catch bench (see Figure 3). This will require some level of drilling stand-off from the catch bench to avoid crest damage, and some level of sub-drill into the underlying slot material allowing excavation to the required horizon. Depending on the depth, shorter 'stab' holes may be required to the batter wall, with appropriate stem height to control overpressure and fly-rock.

- A second blasting pass will then be required to the portal access (up to 11m depth at the portal), with presplit/smoothwall blasting at the 70-degree portal batter and short vertical stab holes above the other (flatter) batter walls where necessary.

- Given the narrow (confined) conditions along the floor of the access ramp (10m width), and maximum depth in front of the portal face (around 11m), blasting in that area will need to consider wall stability and more cautious 'limits' blasting will be required. Standoff from the batter crest and face around the boxcut perimeter should be employed to reduce damage to the final catch-bench profile.

- Given the proximity to sensitive locations, any angled presplit blastholes will need to be stemmed and matted with conveyor belting as an added precaution against elevated overpressure and fly-rock.

- Drill patterns below the first blasted pass should be laid out with an off-set from those above, in order to avoid collaring in highly fragmented material around previous toe locations.

- Where very shallow holes create unacceptable overpressure and fly-rock risk, it may be necessary to make use of mechanical rock breaking equipment (which itself has associated short-term noise impacts) rather than blasting. Rather than drilling shallow holes on the second pass (at the start of the access ramp), it would be advisable to consider blasting that material as part of the first pass to allow greater hole depth and stemming.

- Initial portal and decline development rounds may need to be limited in length (minimising the kilograms per hole) to control overpressure impacts from un-stemmed holes. Stemming some (or all) holes could also be considered, using material such as bentonite clay. Some level of barrier/bunding would also be advisable in front of the initial portal to mitigate fly-rock risk and overpressure impact. Consider the use of conveyor belt matting and the use of water spray curtains to assist in noise abatement and dust mitigation once the decline has sufficiently advanced for this to be installed. Alternatively, decline development can be maximised from underground, with no overpressure impact at surface.

- All blasts must be monitored for peak ground vibration and overpressure levels, with monitoring locations at the nearest sensitive receivers on either side of the mine lease area (Eyre Street and Crystal Street). In addition, monitoring (for at least some blasts) will be required to demonstrate compliance with identified limits at the TSF1 and TSF2 facilities, the Broken Hill Café Area and Cameron Pipe Band Hall (non-residential / commercial buildings), and the Rasp Mine processing plant (if deemed sensitive at estimated worst-case ground vibration levels).

- All surface blasts and initial portal/decline blasts must be videoed (for blast behaviour and fly-rock/dust assessment), to ensure that control of the blasting process is maintained.

- Restrictions on firing times are advised, subject to wind speed and the presence of low cloud (potential inversion conditions), to mitigate overpressure impacts. Notification of blast firing times to residential and commercial neighbours will be required.

- Additional constraints may also be applicable to limit the transmission, and off-site impact, of dust generated by blasting, subject to monitored background dust levels and broader dust management processes. Dust associated with excavation, haulage and handling activities is likely to present a greater impact in terms of total dust load, when compared with blasting. Additional dust controls for the drilling and blasting process should include the implementation of dust suppression on drill rigs, and the wetting down of running surfaces and drill cuttings.

- Maintaining good relations with nearby neighbours is important and responding to complaints appropriately is essential to avoid the escalation of minor issues. The visibility of blasting (dust plume or fume cloud) can result in complaints, regardless of whether such plumes leave the project site. Complaint management systems are already in place at Rasp Mine.

- Given that blasting is currently carried out at the adjacent Mawson quarry, neighbours may not be overly concerned with the limited (short-term) blasting proposed for the boxcut and portal, which will be significantly shielded by the topography of the boxcut created prior to the commencement of blasting.

4.2 Preliminary Blast Designs

Surface bench blasting below the floor of excavated fill will be required, from above the lower catch bench to the ramp floor up to the portal entrance (Figures 3 and 4). A generalised surface bench blasting layout, with vertical blastholes, is shown in Figure 10, although in the case of the proposed boxcut, free-face blasting is not recommended, and a more complex blast layout will be required with varying blasthole depth and angled batter walls, as illustrated in Figure 11. The generic blast parameters proposed for surface boxcut blasting (Table 1) are based on a series of guidelines published by Blast Dynamics and Dyno Nobel (Reference #1) for efficient blasting in a range of surface blasting conditions.

Development blasting in the decline, from the portal to underground workings (Figure 12), will be carried out using standard methods in use at Rasp Mine, as summarised in Figure 13.

Figure 10 – Generalised surface bench blasting geometry (Reference #14)

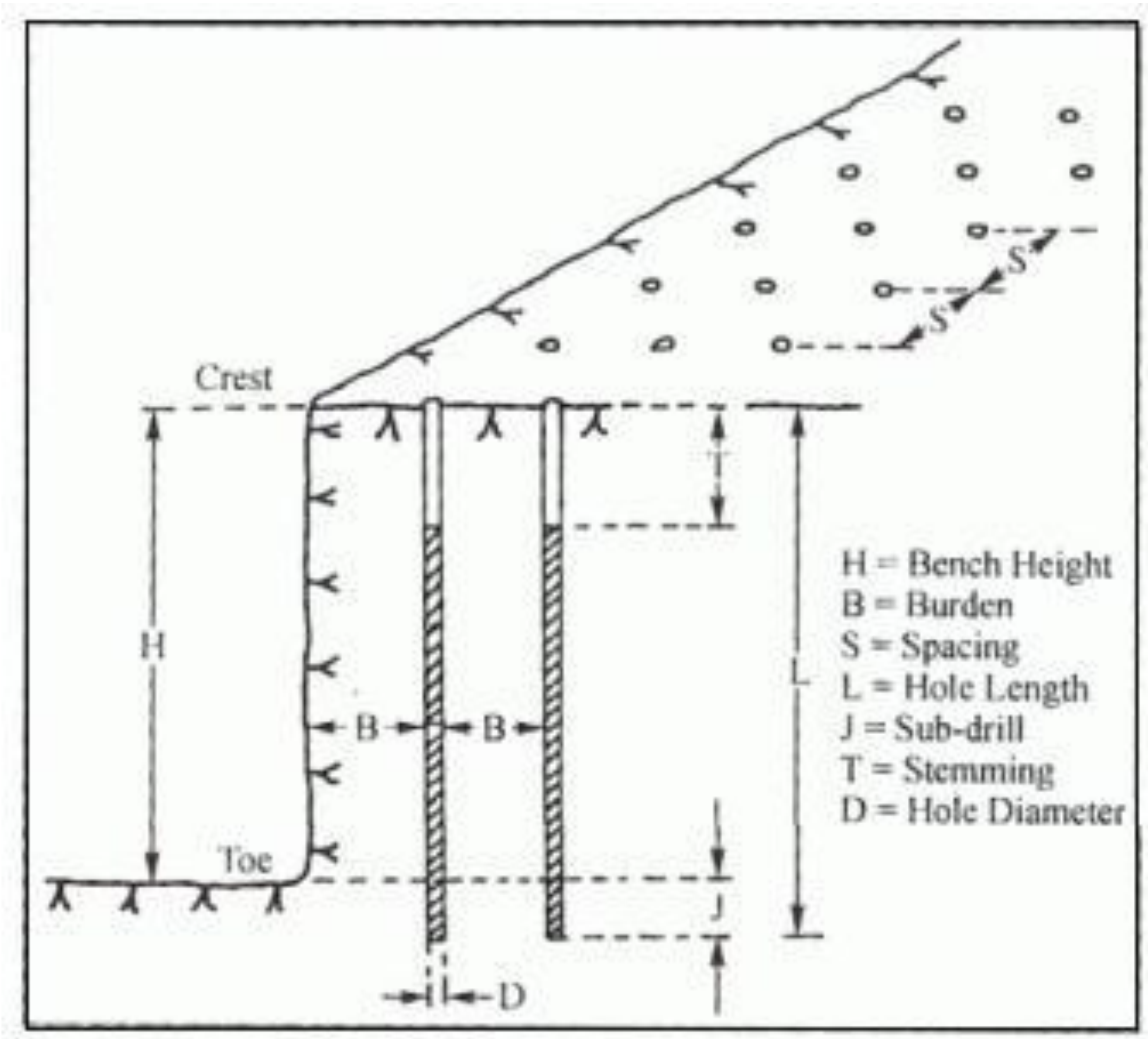


Figure 11 – 3D illustration of a small boxcut blast with varying depth and angled sidewalls (Reference #15). Long-section (top) and cross-section (bottom).

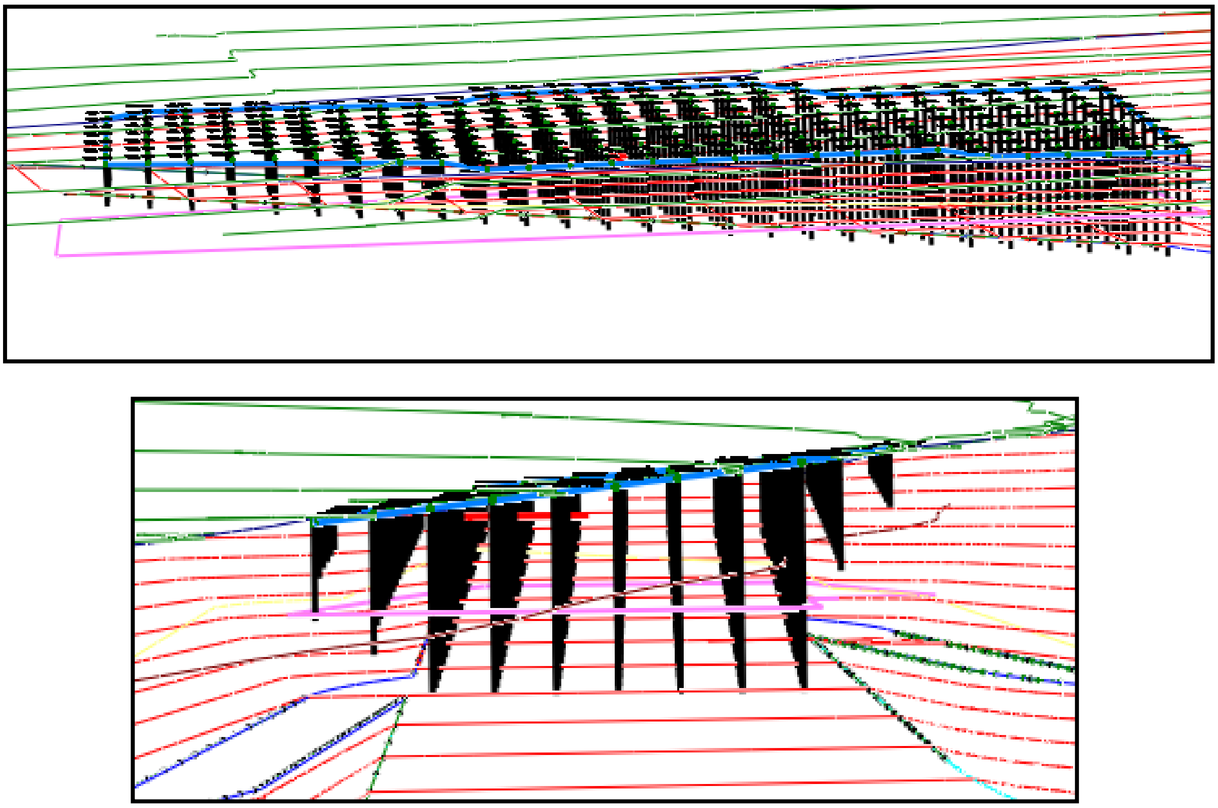


Figure 12 – Long section at Rasp Mine, showing the proposed boxcut and decline

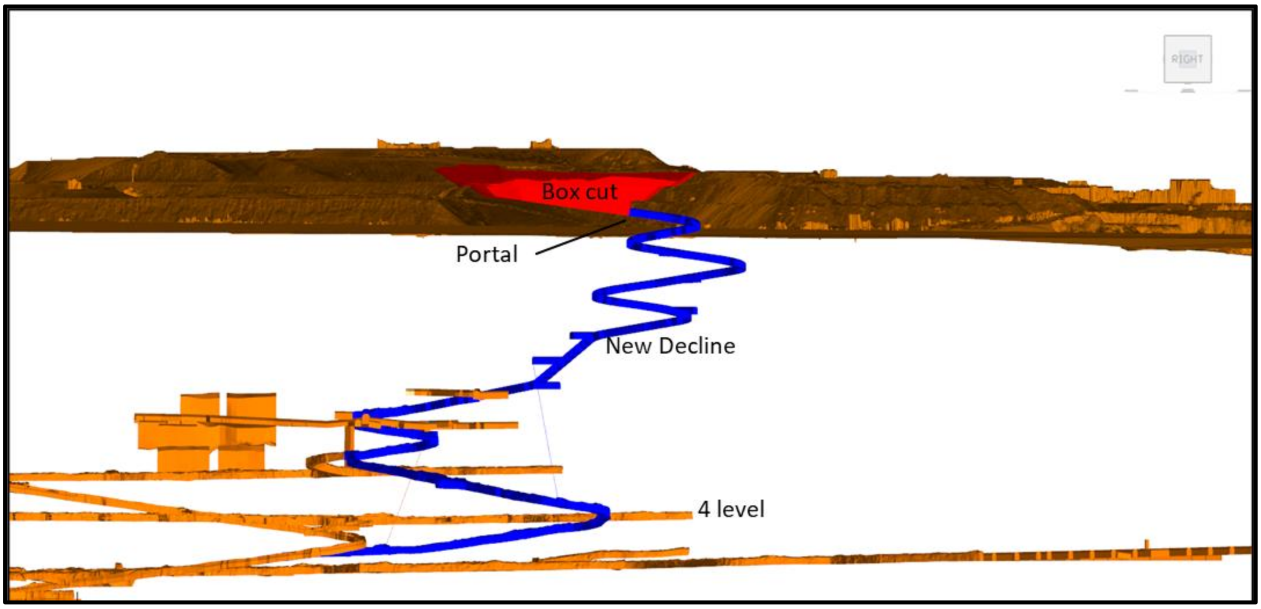
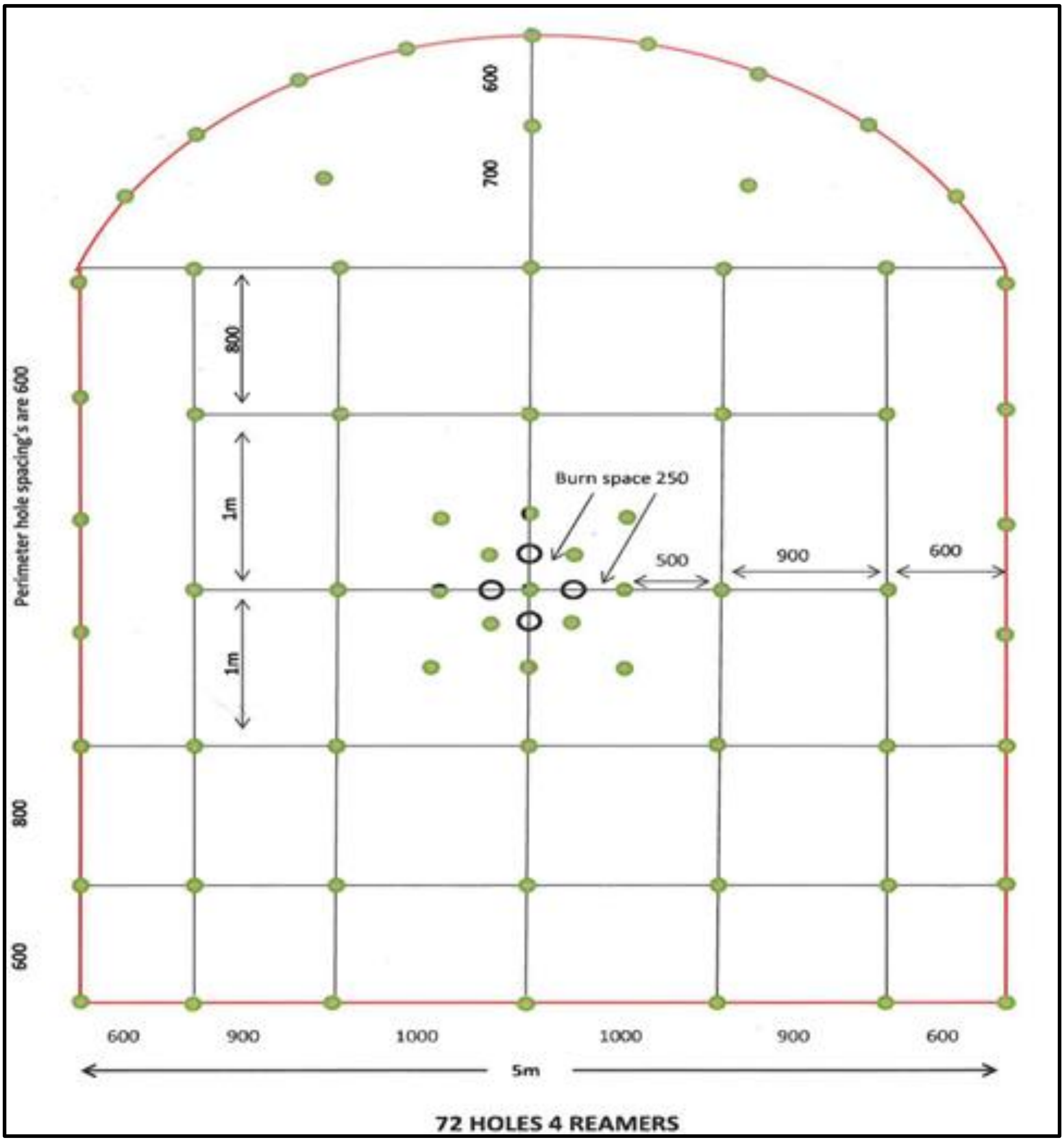


Figure 13 – Development round proposed for the decline at Rasp Mine



Notes for Figure 13

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.

Table 1 – Initial surface blast design parameters for the boxcut

Parameter	Moderate intensity blasting		Higher intensity blasting	
Blasthole diameter (mm)	76	89	76	89
Bench height (m) [1]	8 to 10	10 to 12	8 to 10	10 to 12
Hole angle (degrees) [2]	90	90	90	90
Rock density (g/cc) [3]	2.2 to 2.6	2.2 to 2.6	2.2 to 2.6	2.2 to 2.6
Ground conditions [4]	Dry / damp / wet	Dry / damp / wet	Dry / damp / wet	Dry / damp / wet
Explosive density (g/cc) [4]	1.1	1.1	1.1	1.1
Charge density (kg/m) [5]	5.0	6.8	5	6.8
Sub-drill (m) [6]	0.7 to 1.2	0.8 to 1.4	0.7 to 1.2	0.8 to 1.4
Burden (m) [7]	2.4	2.8	2.2	2.6
Spacing (m) [8]	2.8	3.2	2.5	3.0
Stem height (m) [9]	2.2	2.5	2.1	2.4
Charge mass per hole (kg) [10]	35 to 45	60 to 75	35 to 45	60 to 75
Powder factor (kg/m^3) [11]	~ 0.65	~ 0.65	~ 0.8	~ 0.8
Energy factor (Kj/tonne) [12]	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.			

Notes for Table 1 (based on guidelines published by Blast Dynamics and Dyno Nobel for efficient blasting in a range of blasting conditions, Reference #1)

1. Bench height (m) greater than the hole diameter (mm) divided by 15, and less than 4 times the burden.

2. Nominal vertical drilling assumed, except for presplitting around the 60-degree batter above the portal access road.

3. Rock density nominal at 2.2 to 2.6g/cc until advised.

4. Ground conditions assumed to be damp/wet as this provides a more conservative starting point for vibration/overpressure/fly-rock assessment. Charged with heavy ANFO blend or pumped gassed emulsion to suit ground conditions.

5. Charge mass (kg) per metre length of charged blasthole, based on fully coupled bulk explosives at 1.1g/cc density.

6. Sub-drill 0.3 to 0.5 times the burden (m). Where drilling to a stand-off is required, holes will be shorter, and may need to be drilled on a tightened pattern. The sub-drilled example has been used for assessment purposes as this represents the scenario with highest charge mass for vibration assessment.

7. Burden range of 20 to 35 blasthole diameters, or using Blast Dynamics calculation utilising blasthole diameter, explosive density and rock density for a nominal value.

8. Spacing based on 1.15 times the burden on a staggered pattern for uniform energy distribution (equilateral triangle).

9. Stemming range at 20 to 30 diameters, or 0.5 times the burden plus sub-drill for a nominal value. Crushed aggregate stemming is required for fragmentation, overpressure and fly-rock control, not drill cuttings. Larger

stem heights may be required for overpressure and fly-rock control near sensitive locations (see later comments).

10. Based on an explosive density of 1.1g/cc, hole diameter and charge length excluding stemming.

11. Charge mass (kg) per cubic metre of rock blasted (excluding sub-drill zone). Target powder factor 0.65 to 0.70 kg/m^3 for moderate intensity blasting and around 0.8 kg/m^3 for higher intensity blasting.

12. Energy factor (Kj/tonne) based on an absolute weight strength of 3.3Mj/kg (90% of ANFO) and rock density of 2.2 to 2.4g/cc. Target greater than 800 Kj/tonne as a starting point and greater than 1000 Kj/tonne in harder conditions.

The generalised parameters illustrated for surface bench blasts and decline development rounds are indicative for costing and planning purposes and may need to be adjusted to suit the final blast geometry and to meet environmental constraints (see Section 5).

In the case of surface bench blasts, preliminary blast parameters have been suggested that allow the limitation of instantaneous charge mass, in order to achieve adequate fragmentation, and allow 'worst-case' environmental assessment. This can be done on the basis of maximum charge mass per blasthole, when sequentially firing individual blastholes. More detailed bench blast layout, with charging and timing designs, will be required once excavation of the overlying fill material has established a weathered surface from which to blast. Burden/spacing and charge/stem designs can then be established to suit the varying depths to the boxcut profile once they have been confirmed. These parameters may also need to be modified to suit the nature of ground conditions encountered (rock strength and water level), and the environmental impact from the first blast (overpressure, ground vibration, flyrock).

In the case of decline development blasts, with relatively small charge mass per blasthole (~5kg), it will be the number of blastholes firing together that determine the instantaneous charge mass. While Nonel LP detonators with the same delay have significant scatter, the reliance on that scatter to limit instantaneous charge mass is not particularly reliable. While electronic detonators allow the accurate control of firing times, there are performance benefits in allowing simultaneous or minimal delay firing, particularly at the perimeter. The number of development blastholes fired 'simultaneously' may need to be limited when blasting in close proximity to the TSF1 (130m) and TSF2 (220m) tailings facilities.

5 ASSESSMENT OF IMPACTS

The potential ground vibration, overpressure and fly-rock impacts at nearby identified sensitive locations have been estimated, assuming controlled blast design, implementation and monitoring processes. Adjustments to preliminary blast designs documented in Section 4 are identified for environmental compliance purposes where necessary.

5.1 Ground Vibration

Based on the methodologies discussed in Section 2.2, assessment criteria identified in Section 3.1, and blast parameters proposed in Section 4.2, the following ranges of peak ground vibration impact are estimated based on minimum distances, limiting charge mass quantities[1] and k-factor range[2] (Table 2a). These estimates suggest that:

- The maximum proposed scale of boxcut bench blasting (75kg MIC) should maintain peak vector ground vibration levels between 2mm/s and 4.5mm/s (or less) at the nearest residential locations (all being at distances greater than 440m from a limited number of boxcut blasts). This is below the peak limit of 5mm/s defined by the ANZEC guidelines, to minimise annoyance and discomfort to persons at noise sensitive sites (Reference #7).
- The maximum proposed scale of boxcut blasting should also maintain peak vector ground vibration levels between 5.5mm and 10.5mm/s at the Broken Hill Café Area (located within CML7), with lower levels at more distant non-residential, commercial, and industrial locations. This is below the peak component limit of 15mm/s, to avoid cosmetic damage to light commercial buildings, as quoted in AS 2187.2 (Reference #2).
- Estimated peak vector ground vibration levels, for surface boxcut blasts, at the nearby TSF2 embankments (280m) are 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).
- Estimated peak vector ground vibration levels, for surface boxcut blasts, at the nearest parts of the TSF1 facilities (100m) suggest a <u>potential</u> to exceed the preliminary 25mm/s PPV limits suggested by Golder Associates (Reference #9) and this requires a conservative approach to the first boxcut blast in order to validate the models used in this report. This should be achievable using the 76mm diameter pattern proposed in Table 1, with a maximum bench height of 8m and an MIC of 35kg per sequentially fired blasthole (see assessment in Table 2a).
- The first boxcut bench blast should therefore be charged with no more than 35kg/hole, with holes fired sequentially to avoid reinforcement, in order to satisfy this assessment. It will be likely that subsequent blasting can then be carried out at MIC levels up to 75kg/hole, subject to monitored ground vibration levels.
- Presplit blasts (if required) should be fired with no more than 75kg per delay (or less to remain within maximum charge requirements). For example, this would equate to up to

10 holes per delay, for 11m deep presplit holes with 1m spacing (or less), charged at a powder factor of around 0.6kg/m^2, based on presplit surface area. Fewer blastholes per delay may be prudent for greater overpressure control.

- Portal and decline development blasts are likely to be fired with no more than 60kg per delay (12 holes), or less, to remain within maximum charge guidelines, and are likely to have lesser impact on surface than the boxcut bench blasts.
    - Suggested limits at TSF1 (25mm/s PVPPV) and the TSF2 embankment foundations (15mm/s PVPPV) should remain compliant at the closest applicable distances, based on a 60kg MIC and using the standard vibration models for surface blasting (Table 2b). However, given that these models may not be reliable for small scale (small volume) development blasts, more specific modelling would be helpful.
    - Development blasting at the Rasp Mine has no history of generating unacceptable ground vibration outcomes on surface, and there is currently minimal monitored data available at distances less than 1000m, that can be used to predict peak ground vibration impacts over 1mm/s PVPPV.
    - There is scope to validate surface vibration impacts from development blasts, as the decline is advanced from the underground workings (at greater distance), prior to development from the portal at surface. The following strategy is suggested:
        - Some development blasts between 500m and 300m of surface should be monitored in order to identify peak ground vibration trends.
        - Some development blasts between 500m and 300m of TSF1 and TSF2 facilities should be monitored in order to identify preliminary peak ground vibration impacts at those locations.
        - As development blasting approaches to within 300m of the TSF1 and TSF2 facilities, comparative trials should be carried out while limiting blastholes fired per delay (Nonel LP series) and sequentially fired blastholes (electronic firing).
        - Development blasting should be carried out to suit blast performance requirements, with limitations only applied to firing sequence to meet ground vibration impacts at TSF1 and TSF2 as necessary.
        - Instantaneous charge mass can be reduced as required by reducing the number of simultaneous blastholes firing, but smaller blasthole diameter, reduced round length, and split rounds can also be considered, subject to the monitored results as distance decreases.
- Specific risk assessment of sensitive electronic or electro-mechanical systems at the Rasp Mine processing facilities is recommended.

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

Location	K factor (average)	K factor (upper)	Exponent, b	Minimum distance (m)	Maximum charge (kg)	Peak vibration (average) (mm/s)	Peak vibration (upper) (mm/s)	Target / Limit (mm/s)	Achievable (Yes/No)	Comments
Nearest residential locations										
Nearest residence at Eyre Street	1140	2280	-1.6	440	75	2.1	4.3	<5mm/s	Y	
Nearest residence at Prop Sq	1140	2280	-1.6	510	75	1.7	3.4	<5mm/s	Y	
Nearest residence at Crystal Street	1140	2280	-1.6	650	75	1.1	2.3	<5mm/s	Y	
Nursing home locations										
Aruma Lodge	1140	2280	-1.6	820	75	0.8	1.6	<5mm/s	Y	
Shorty O'Neill's	1140	2280	-1.6	1200	75	0.4	0.9	<5mm/s	Y	
St Anne's	1140	2280	-1.6	1450	75	0.3	0.6	<5mm/s	Y	
Commercial / non-residential locations										
Broken Hill Café	1140	2280	-1.6	250	75	5.3	10.5	<15mm/s	Y	Evacuate for blast
Cameron Hall	1140	2280	-1.6	350	75	3.1	6.1	<15mm/s	Y	May evacuate for blast
NSW Dept Health Admin Building	1140	2280	-1.6	550	75	1.5	3.0	<15mm/s	Y	
Industrial facilities										
Rasp Mine Processing Plant	1140	2280	-1.6	165	75	10.2	20.4	<25mm/s	Y	Subject to CBH risk assessment
TSF2 Blackwood Pit (closest point)	1140	2280	-1.6	100	75	22.7	45.5	<75mm/s	Y	Implied by embankment limits
TSF2 Blackwood Pit (embankment #3)	1140	2280	-1.6	280	75	4.4	8.8	15 - 30mm/s	Y	NSW DSC limit (Ref #13)
TSF1 Historic Pit (closest point)	1140	2280	-1.6	100	75	22.7	45.5	<25mm/s	See note #4	Golders 2019 (Ref #9)
TSF1 Historic Pit (first blast worst case)	1140	2280	-1.6	100	35	12.4	24.7	<25mm/s	Y (note #4)	Initial small scale boxcut blast

Notes for Table 2a

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 Table 1. A conservative MIC of 35kg has been suggested for the first blast in order to assess vibration impact at TSF1 and TSF2.
2. 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.
3. Residential limits defined under ANZEC guidelines (Reference #7). Non-residential limits defined under AS2187 (Reference #2).
4. Blasting proposed with MIC's up to 75kg <u>may</u> present compliance issues for some blasts, with respect to the suggested TSF1 limits of 25mm/s PVPPV. The first boxcut blast has therefore been proposed with an initial MIC of 35kg, in order to validate the ground vibration models used in this report.

Table 2b – Limiting ground vibration criteria for decline development blasts at TSF1 and TSF2 [1, 2, 3]

Location	K factor (average)	K factor (upper)	Exponent, b	Minimum distance (m)	Maximum charge (kg)	Peak vibration (average) (mm/s)	Peak vibration (upper) (mm/s)	Target / Limit (mm/s)	Achievable (Yes/No)	Comments
TSF1 (historic)										
TSF1 shell and/or embankment	1140	2280	-1.6	130	60	12.5	25.0	<25mm/s	Y	12 holes/delay at 5kg/hole
TSF1 shell and/or embankment	1140	2280	-1.6	200	60	6.3	12.6	<25mm/s	Y	12 holes/delay at 5kg/hole
TSF1 shell and/or embankment	1140	2280	-1.6	250	60	4.4	8.8	<25mm/s	Y	12 holes/delay at 5kg/hole
TSF1 shell and/or embankment	1140	2280	-1.6	300	60	3.3	6.6	<25mm/s	Y	12 holes/delay at 5kg/hole
TSF1 shell and/or embankment	1140	2280	-1.6	350	60	2.6	5.1	<25mm/s	Y	12 holes/delay at 5kg/hole
TSF1 shell and/or embankment	1140	2280	-1.6	400	60	2.1	4.1	<25mm/s	Y	12 holes/delay at 5kg/hole
TSF2 (Blackwood Pit)										
TSF2 floor of closest embankment (EB3)	1140	2280	-1.6	220	60	5.4	10.8	<15mm/s	Y	12 holes/delay at 5kg/hole
TSF2 floor of closest embankment (EB3)	1140	2280	-1.6	250	60	4.4	8.8	<15mm/s	Y	12 holes/delay at 5kg/hole
TSF2 floor of closest embankment (EB3)	1140	2280	-1.6	300	60	3.3	6.6	<15mm/s	Y	12 holes/delay at 5kg/hole
TSF2 floor of closest embankment (EB3)	1140	2280	-1.6	350	60	2.6	5.1	<15mm/s	Y	12 holes/delay at 5kg/hole
TSF2 floor of closest embankment (EB3)	1140	2280	-1.6	400	60	2.1	4.1	<15mm/s	Y	12 holes/delay at 5kg/hole

Notes for Table 2b

1. Decline development blasts will generally have lesser impact at surface than boxcut bench blasts due to their much smaller scale. While there is no history of surface impact from underground development blasts at Rasp Mine, there is also only very limited monitored site data. Additional monitoring is therefore recommended as decline development blasting advances closer to surface and closer to the TSF1 and TSF2 facilities.

2. Maximum expected charge mass of 60kg/delay is based on a likely 'worst case' scenario (i.e. 12 holes at 5kg/hole). More conservative charge mass can be achieved by reducing the number of blastholes fired simultaneously, particularly through the use of electronic initiation. This should be validated prior to becoming critical (i.e. at greater distance), to avoid operational delays associated with unexpected ground vibration impacts.

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 as the models used may not reflect site conditions.

5.2 Overpressure

The following overpressure estimates are based on methods discussed in Section 2.3, assessment criteria identified in Section 3.2, and blast parameters proposed in Section 4.2.

Table 3a shows that, from an overpressure point of view, there could be some difficulties with respect to 115dBL and 120dBL compliance at the closest residential locations (from 440m on Eyre Street), when firing buffered blasts with the initial stem heights derived in Table 1 (see Section 4.2).

Table 3b shows that increased stem heights are required, in order to achieve 115dBL overpressure compliance for buffered bench blasts at all residential locations (for distances from 440m), with pattern size adjusted to maintain a target powder factor. Maximum estimated overpressure levels from blasting are shown for all potentially sensitive locations in Table 3c, based on a calculated trend shown in Figure 14.

Note that 115dBL overpressure compliance at residential locations in front of a free-face are only achievable at much larger distances. It is recommended that free-face bench blasting be avoided where possible, but (if required) such free faces should be orientated towards the mine lease area to the south-west (see Figure 15), and assessed for overpressure impact on a case-by-case basis.

Table 3a – Limiting overpressure criteria for preliminary blast parameters (Table 1)

Parameter	Initial parameters for moderate intensity blasting				Initial parameters for higher intensity blasting			
Diameter (mm)	76	76	89	89	76	76	89	89
Bench height (m)	8	10	10	12	8	10	10	12
Burden (m)	2.4	2.4	2.8	2.8	2.2	2.2	2.6	2.6
Spacing (m)	2.8	2.8	3.2	3.2	2.5	2.5	3	3
Charge density (kg/m)	5	5	7	7	5	5	7	7
Charge mass (kg)	34	44	58	72	34	44	59	73
Stem height (m)	2.2	2.2	2.5	2.5	2.1	2.1	2.4	2.4
Stem height (diameters)	29	29	28	28	28	28	27	27
Powder factor (kg/m3)	0.63	0.65	0.65	0.67	0.78	0.81	0.75	0.77
Ka115 Behind	220	220	220	220	220	220	220	220
D115 (m) Behind	515	561	664	713	581	633	738	792
Ka120 Behind	180	180	180	180	180	180	180	180
D120 (m) Behind	312	340	402	432	352	383	447	479
Ka115 In front	290	290	290	290	290	290	290	290
D115 (m) In front	826	901	998	1071	1032	1124	1206	1293
Ka120 In front	250	250	250	250	250	250	250	250
D120 (m) In front	570	621	689	739	712	775	832	892
Overpressure compliance (115 to 120dBL) for buffered blasts at the closest residential locations (from 440m) is not achievable using preliminary design stem heights.								
Overpressure compliance in front of a free face is only achievable when that free face is orientated to the south-west (facing mine lease area).								

Table 3b – Limiting overpressure criteria for modified blast parameters (ie increased stem height)

Parameter	Revised moderate intensity blasting parameters for overpressure control				Revised high intensity blasting parameters for overpressure control			
Diameter (mm)	76	76	89	89	76	76	89	89
Bench height (m)	8	10	10	12	8	10	10	12
Burden (mm)	2.3	2.3	2.7	2.7	2.1	2.1	2.5	2.5
Spacing (m)	2.8	2.8	3.1	3.1	2.5	2.5	2.8	2.8
Charge density (kg/m)	5	5	7	7	5	5	7	7
Charge mass (kg)	33	42	55	68	33	42	55	68
Stem height (m)	2.4	2.5	3	3.1	2.4	2.5	3	3.1
Stem height (diameters)	32	33	34	35	32	33	34	35
Powder factor (kg/m3)	0.64	0.66	0.65	0.67	0.78	0.81	0.78	0.81
Ka115 Behind	220	220	220	220	220	220	220	220
D115 (m) Behind	410	403	413	408	410	403	413	408
Ka120 Behind	180	180	180	180	180	180	180	180
D120 (m) Behind	248	244	250	247	248	244	250	247
Ka115 In front	290	290	290	290	290	290	290	290
D115 (m) In front	910	990	1071	1150	1143	1243	1299	1394
Ka120 In front	250	250	250	250	250	250	250	250
D120 (m) In front	628	683	739	794	788	858	896	962
Overpressure compliance (115 to 120dBL) for buffered blasts at the closest residential locations (from 440m) is achievable using increased stem heights, with pattern size adjusted to achieve powder factor requirements.								
Overpressure compliance in front of a free face is only achievable when that free face is orientated to the south-west (facing mine lease area).								

Table 3c – Maximum overpressure impacts from modified buffer blasting at identified locations

Location	Minimum distance (m)	Estimated peak blasting overpressure (dBL)	Target / Limit (mm/s)	Achievable (Yes/No)	Comments
Nearest residential locations					
Nearest residence at Eyre Street	440	113	<115dBL	Y	Amenity limit
Nearest residence at Prop Sq	510	112	<115dBL	Y	Amenity limit
Nearest residence at Crystal Street	650	109	<115dBL	Y	Amenity limit
Nursing home locations					
Aruma Lodge	820	106	<115dBL	Y	Amenity limit
Shorty O'Neill's	1200	101	<115dBL	Y	Amenity limit
St Anne's	1450	99	<115dBL	Y	Amenity limit
Commercial / non-residential locations					
Broken Hill Café (unoccupied)	250	120	<133dBL	Y	Damage criteria
Cameron Hall (unoccupied)	350	116	<133dBL	Y	Damage criteria
Cameron Hall (occupied)	350	116	<120dBL	Y	Amenity limit (upper limit)
NSW Dept Health Admin Bldg (occupied)	550	111	<120dBL	Y	Amenity limit (upper limit)
Industrial facilities					
Rasp Mine Processing Plant (unoccupied)	165	126	<133dBL	Y	Damage criteria
Rasp Mine Processing Plant (occupied)	300	118	<120dBL	Y	Amenity limit (upper limit) at blast clearance distance

Figure 14 – Overpressure versus distance, based on calculated reference distances to the 115dBL and 120dBL contours from a buffered blast, and an 8.6dBL attenuation for doubling/halving of distance

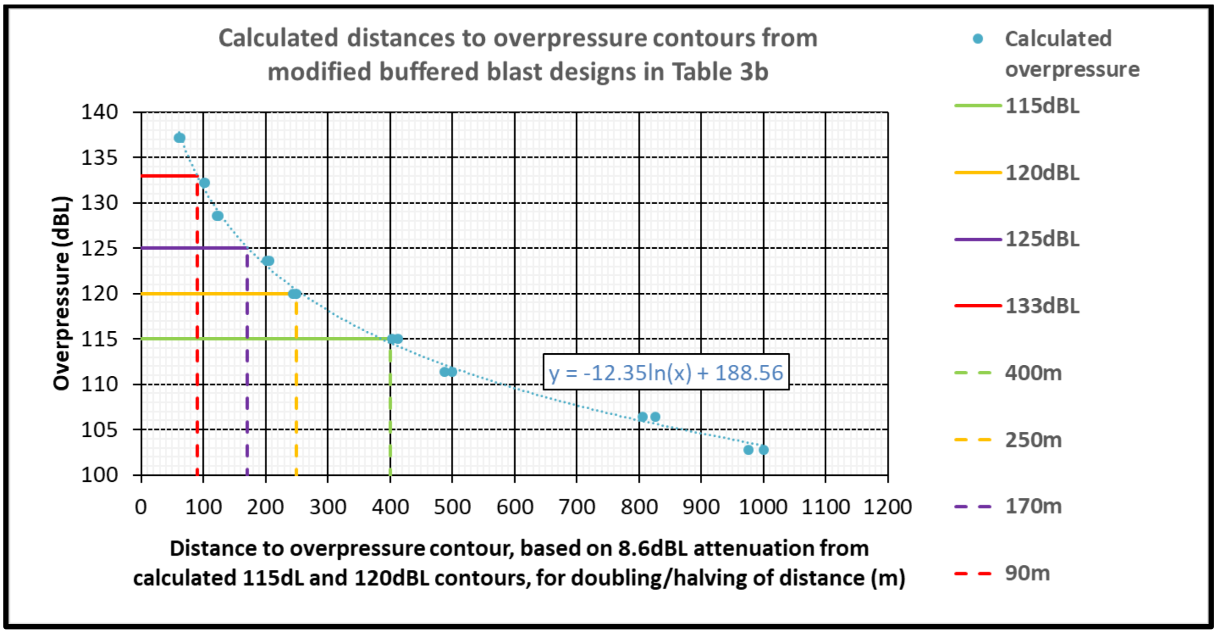
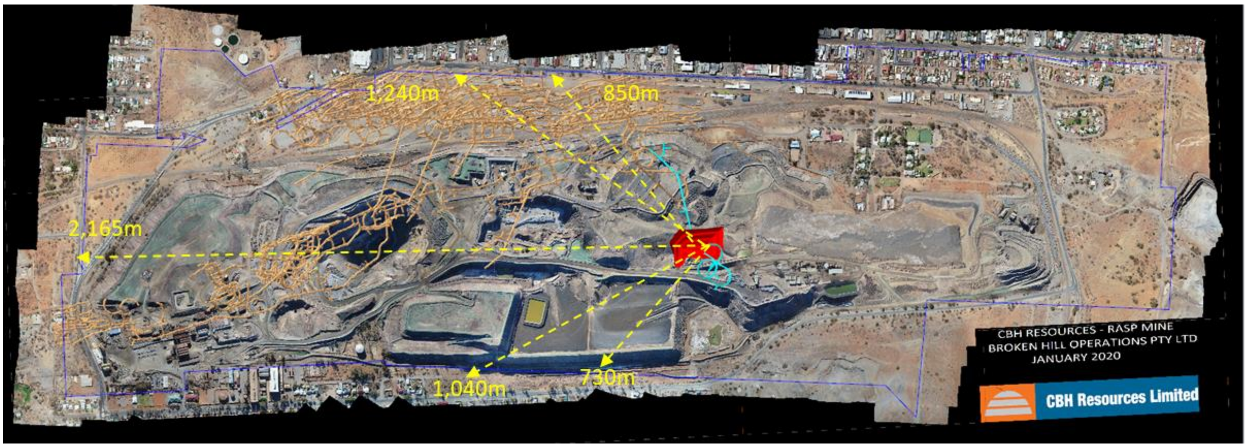


Figure 15 – Increased distances from the proposed boxcut to the mine lease boundary in a south-westerly direction



- Increased stem heights (up to 2.5m for 76mm holes and 3.1m for 89mm holes) are suggested to limit overpressure impacts within ANZEC guidelines. For shallow blasting, these increased stem heights are best achieved in conjunction with leaving some ‘fill’ above the hard floor of any ‘free-dig’ pass, rather than simply increasing stem height within intact material.
- With increased stem heights, a reduced distance of around 400m from a buffered blast to the 115dBL overpressure contour is estimated (Table 3b). Overpressure levels at all residential locations (at 440m and greater) should therefore be expected to remain less

than 115dBL under non-reinforcing meteorological conditions, for appropriately sequenced blastholes (Table 3c).

- With a reduced distance of around 250m from a buffered blast to the 120dBL overpressure contour, overpressure levels greater than 120dBL should only need to be considered at the Rasp Mine processing plant (from 165m) and the Broken Hill Café (from 250m and within CML7). Based on typical attenuation rates, overpressure levels less than 120dBL at the Broken Hill Café Area and less than 126dBL at the processing plant should be achievable.
- Overpressure levels less than 133dBL, representing very conservative limits of damage from overpressure, should be achievable at distances down to approximately 100m.
- Overpressure impact from presplit blasts is difficult to estimate, however limiting the number of holes fired per delay, and the use of stemming and matting, should keep levels at or below those of bench blasts.
- Overpressure from portal and decline development rounds, fired from surface, are also difficult to estimate, however their small size and containment within the boxcut should mitigate impacts due to topographic shielding, and orientation towards the south-west end of the mining lease area. Only a few (5 or 6 rounds) will need to be fired from surface, with the remainder fired from underground and having no overpressure impact on surface.
- Variation of overpressure also occurs because of atmospheric/meteorological conditions, which should be assessed prior to firing (i.e. inversion conditions, low cloud, etc).
- A ‘soft start’ approach utilising a reduced charge in the first two or three blastholes of a surface blast can also further reduce overpressure levels.

5.3 Fly-rock

The following fly-rock range estimates (Table 4) are based on methods shown in Section 2.4, assessment criteria identified in Section 3.3, and modified blast parameters proposed in Section 5.2.

- Maximum fly-rock range for stemming controlled blasts (no free face) is calculated up to 75m for buffered blast designs that had been modified for overpressure control. Based on factors of safety between 2 (infrastructure) and 4 (personnel), this implies blast clearances up to 150m from infrastructure and 300m from personnel. In comparison, WorkSafe Victoria guidelines (Figure 9, Section 3.3, Reference #12) suggest safe clearance distances as low as 100m for general small-scale blasting (no free face), but this is not prudent for a site where surface bench blasting is not currently being undertaken.
- Maximum fly-rock range from angled presplit holes (if required) can be controlled, by making use of decoupled presplit explosive cartridges (with reduced charge density) and appropriate stemming and confinement. Un-stemmed presplit blasting is not considered feasible due to fly-rock risk and likely overpressure outcomes at residential locations.
- Maximum fly-rock range in front of a free face is greater than that from a buffered blast and presents a risk that would need to be appropriately managed on a blast-by-blast basis. While free face bench blasting could be managed with controlled front-row burdens, increased blast clearance distances, and with free faces orientated towards the south-western part of the mine lease, it would be more prudent to avoid free face bench blasting for the boxcut.
- Maximum fly-rock range from development blasts at the portal and in the decline will be limited by the near horizontal orientation of the blastholes within the surrounding topography of the boxcut. Risks associated with fly-rock from development blasts are also mitigated by increased distances to the mine lease boundary in a south-western direction from the portal.
- Based on available clearances around the boxcut, within the mine lease area, a 300m blast clearance is achievable without impacting most public areas and public roads, most adjacent industrial facilities (such as the rail line), and all residential and commercial facilities outside the mine lease area (see Figure 16).
- A 300m blast clearance zone requires evacuation of the Broken Hill Café Area at 250m, with temporary closure of Federation Way and restricted access to the Cameron Pipe Band Hall also recommended to manage public risk.
- Evacuation and operational constraints for the Rasp Mine crushing and processing facilities (from 165m) should be reviewed, subject to the availability of safe refuge facilities when blasting, as part of a specific operational risk assessment.
- Cross-sections and long sections shown in Figures 16a to 16c illustrate the extent to which blasting within the boxcut is shielded by the surrounding topography.

Table 4 – Maximum calculated fly-rock range

Parameter	Revised moderate intensity blasting parameters				Revised high intensity blasting parameters			
Diameter (mm)	76	76	89	89	76	76	89	89
Bench height (m)	8	10	10	12	8	10	10	12
Burden (m)	2.3	2.3	2.7	2.7	2.1	2.1	2.5	2.5
Spacing (m)	2.8	2.8	3.1	3.1	2.5	2.5	2.8	2.8
Charge density at 1.1g/cc (kg/m)	5	5	7	7	5	5	7	7
Charge mass (kg)	33	43	55	68	33	42	55	68
Stem height (m)	2.4	2.5	3	3.1	2.4	2.5	3	3.1
Stem height (diameters)	32	33	34	35	32	33	34	35
Powder factor (kg/m3)	0.64	0.66	0.65	0.67	0.78	0.81	0.78	0.81
Maximum flyrock range (calculated)								
Stemming ejection (vertical holes)	66	63	74	71	66	62	74	71
Stemming ejection (angled presplit holes)	51	48	38	36	51	48	38	36
Cratering (vertical) holes	45	41	44	41	45	41	44	41
Face bursting (if free face required)	204	204	249	249	229	229	275	275
Stem heights modified for overpressure control also mitigate fly-rock risks.								
Blast clearance required at up to 300m to satisfy a factor of safety of up to four times maximum flyrock range.								
Presplit charge density <2kg/m for decoupled cartridge explosives.								
Reasonable blast clearance in front of a free face is only achievable when that free face is orientated to the south-west.								

Figure 16 – Suggested 300m blast clearance around blasts within the boxcut

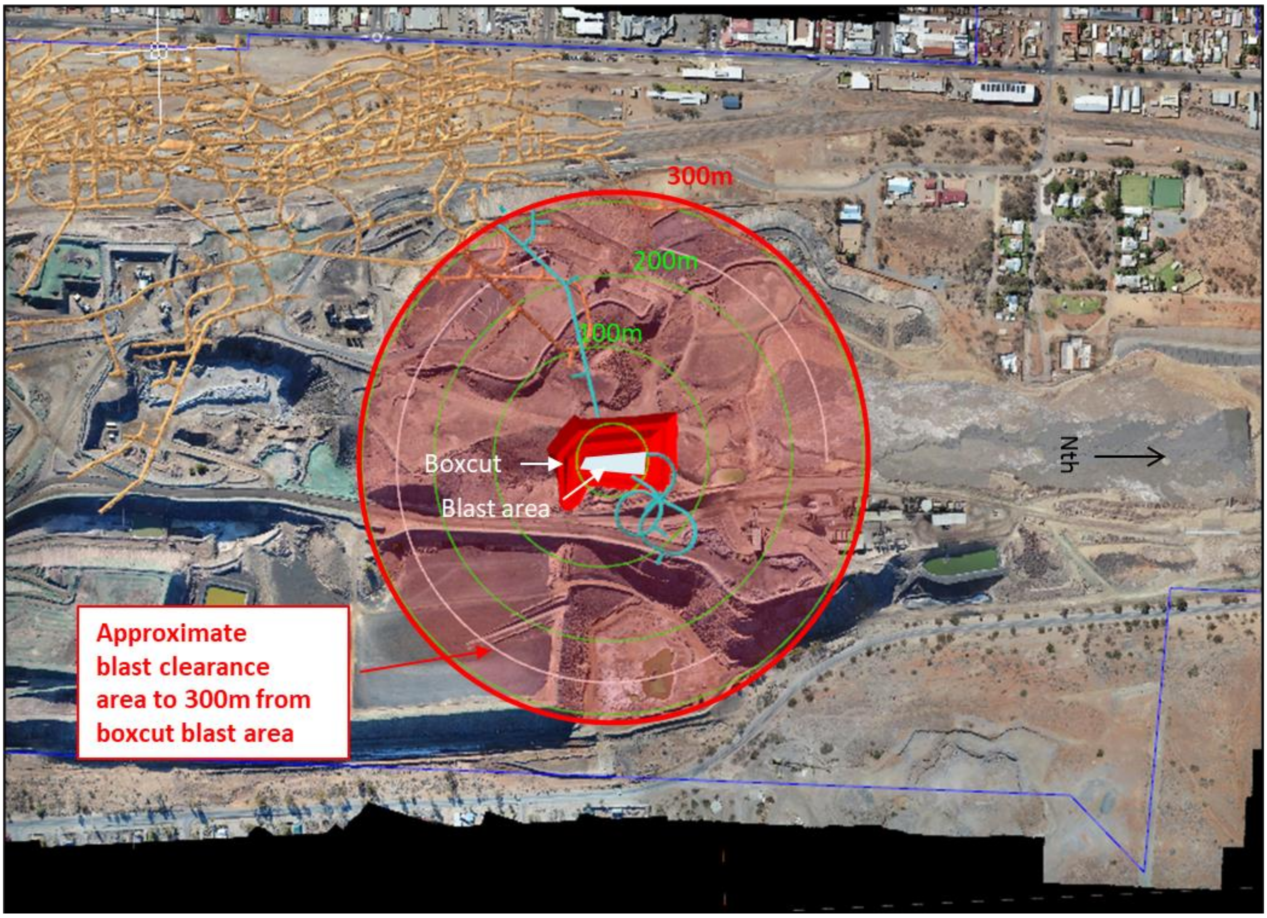


Figure 17a – Orientation of cross sections A-A and B-B, and long section C-C, shown in Figures 17b and 17c

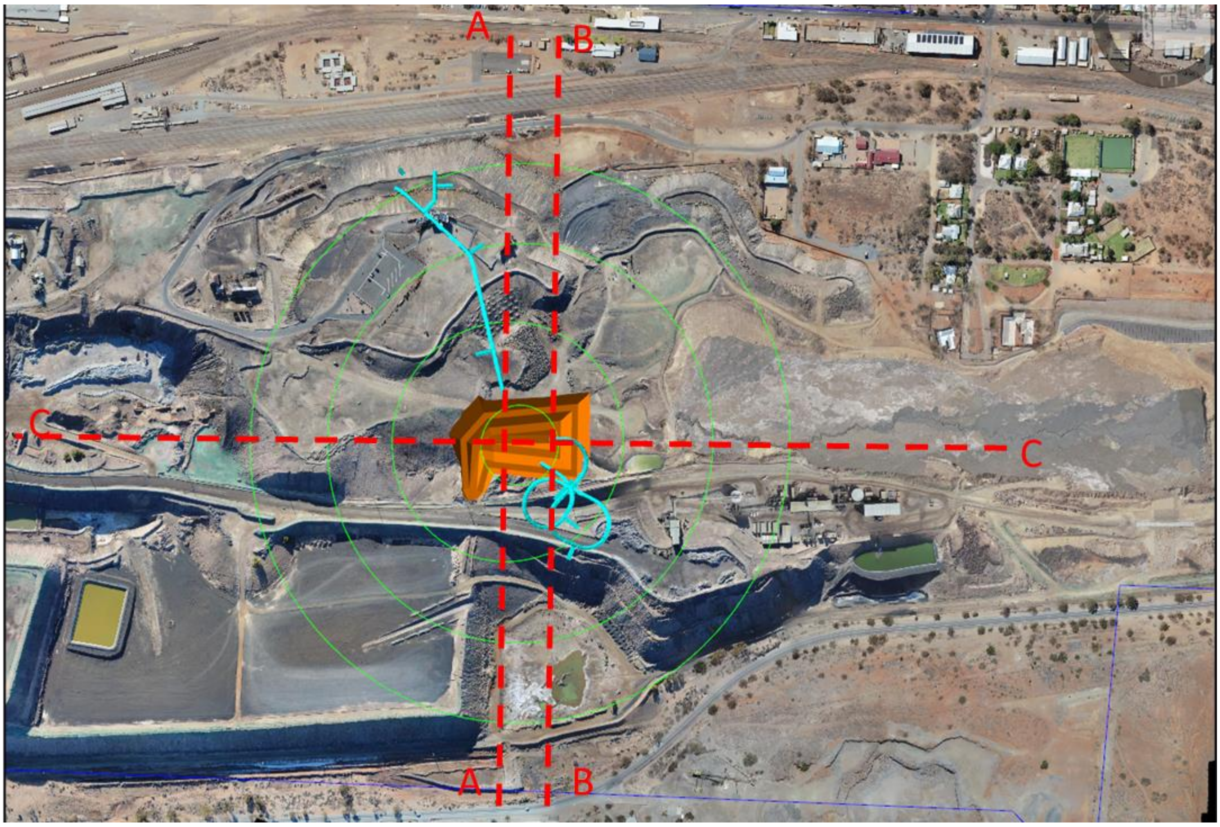


Figure 17b – Cross sections A-A and B-B across the shallowest and deepest sections of the portal access ramp

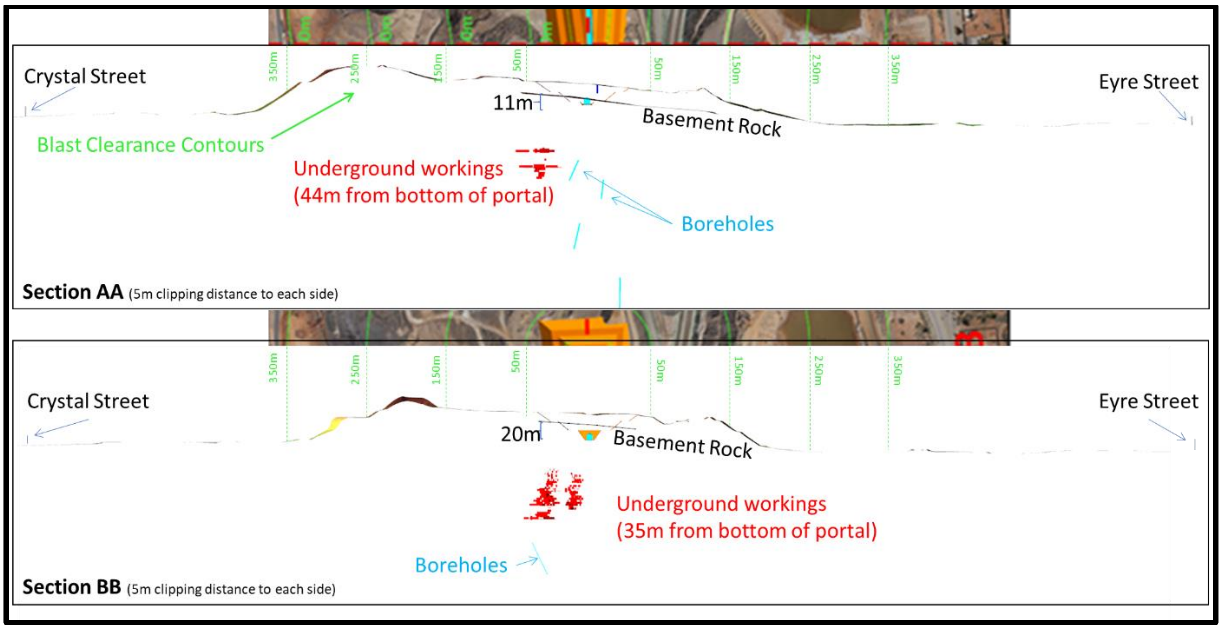
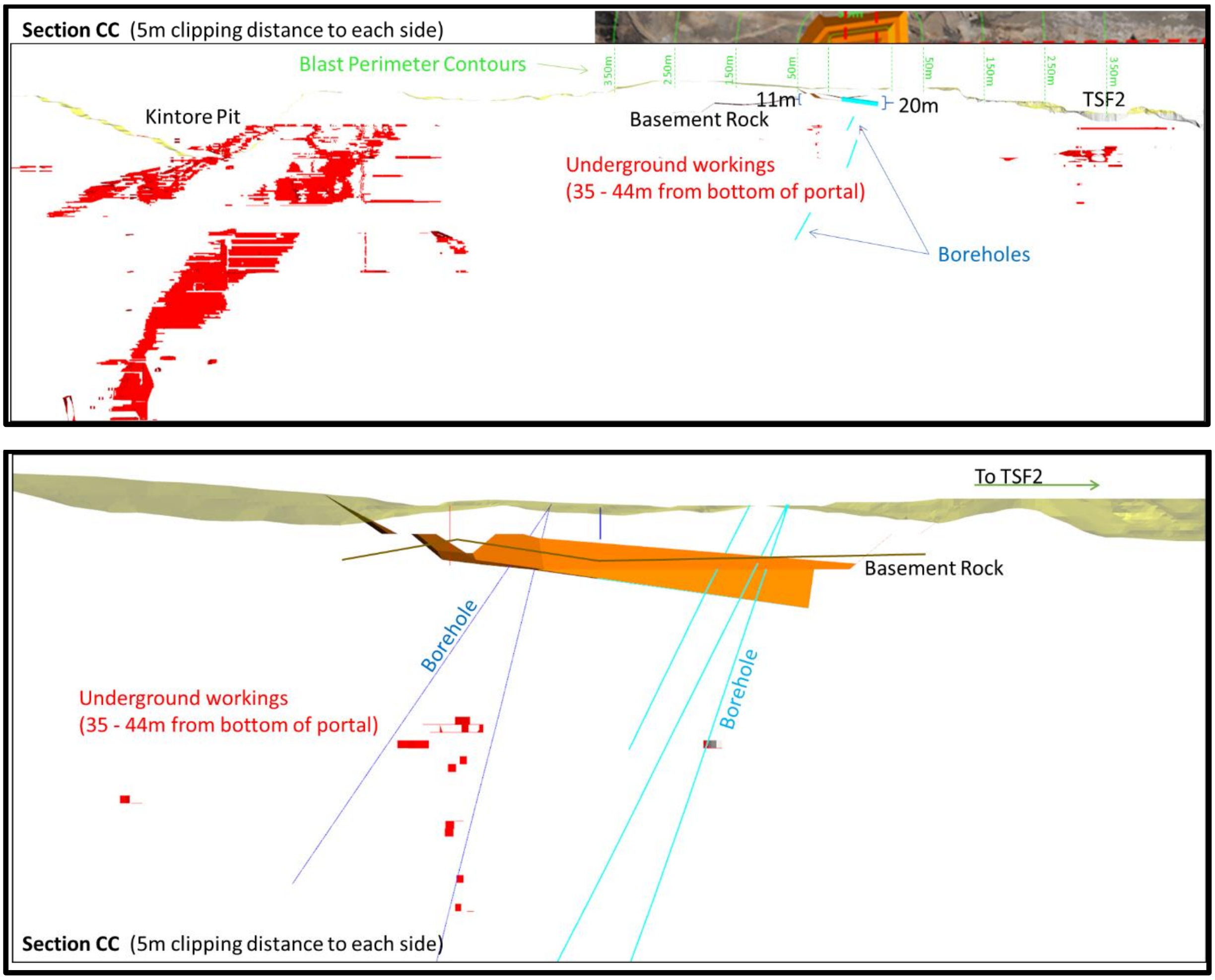


Figure 17c – Long section C-C along the boxcut centre-line, at large scale (top) and closer detail (bottom)



6 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.

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 sensitive receivers, and within ANZEC guidelines to limit disturbance at all nearby residential locations.

Blasting should be achievable while meeting appropriate damage criteria, for non-residential/commercial and industrial buildings and structures, based on AS2187 and other available guidelines), at identified locations.

Estimated peak ground vibration levels and peak overpressure levels, at the Broken Hill Café Area (located within CML7), suggest no significant impact at the more distant rail corridor and associated infrastructure. Blast clearances of 300m from the blast area will not affect the rail corridor for properly controlled blasting, but will require evacuation of the café area.

In order to achieve compliance with all mandated and recommended limitations, the most limiting (estimated) blast parameter constraints are summarised in Table 5 for surface boxcut blasting. Ground vibration constraints for decline development blasting in close proximity to TSF1 and TSF2 were previously illustrated in Table 2b and do not appear to be limiting.

Boxcut blasting should commence using conservative design parameters, particularly charge mass (for vibration control at TSF1) and stem height (for overpressure and fly-rock control), and be modified as blasting progresses subject to blast performance and monitored blast results. The most limiting parameters (overall) are highlighted in Table 5 for the first boxcut blast, in order to target the ground vibration limits currently applied at TSF1.

- Estimated maximum peak ground vibration and overpressure levels from surface boxcut blasting are illustrated in Figure 12 for the locations assessed, based on an MIC of 75kg and specified blasthole diameter, bench height and stem height constraints. The only area of concern for this ‘worst case’ scenario is the potential peak ground vibration level at TSF1, hence a conservative starting point has been suggested.
- Current ground vibration limits of 25mm/s PVPPV at TSF1 may be revised subject to further work (Reference #9). In the meantime, it is recommended that a correspondingly conservative first blast is planned for the boxcut (MIC 35kg/hole), after removal of fill material, and appropriately monitored in order to validate the generic ground vibration models used in this report.
- If current maximum suggested ground vibration limits of 25mm/s PVPPV at TSF1 and 15mm/s PVPPV at TSF2 (foundations) require the limitation of instantaneous charge mass for decline development rounds at closest proximity, this should be achievable (see Table 2b). This should be validated by monitoring more distant development blasts (from at least 300m) as the decline approaches TSF1 and TSF2.

Table 5: Limiting impacts and blast parameters to target acceptable blasting outcomes from surface boxcut blasts. Initial boxcut blast criteria highlighted.

Limiting impact	Limiting value	Parameter	Constraining value
1. Nearest occupied residences: Eyre Street 440m, Prop Square 510m, Crystal Street 650m			
1.1 Ground vibration	5mm/s PVPPV	Max charge mass	75kg/blasthole
1.2 Overpressure	115dBL peak OP	Min stem height	2.4m (76mm diam) 3.0m (89mm diam)
2. Nearest commercial building: Broken Hill Café (unoccupied), 250m			
2.1 Ground vibration	15mm/s PVPPV	Max charge mass	As per 1.1
2.2 Overpressure	133dBL peak OP	Min stem height	As per 1.2
3. Rasp Mine facilities: Mine processing facilities (>165m), TSF1 (>100m), TSF2 (>100m)			
3.1 Unoccupied: Mine processing facilities, >165m			
Ground vibration	25mm/s PVPPV	Max charge mass	As per 1.1
Overpressure	133dBL peak OP	Min stem height	As per 1.2
3.2 Occupied: Mine processing facilities, >300m			
Ground vibration	25mm/s PVPPV	Max charge mass	As per 1.1
Overpressure	120dBL peak OP	Min stem height	As per 1.2
3.3 TSF1 (historic), >100m, **FIRST BOXCUT BLAST** (subsequent blasts subject to monitoring)			
Ground vibration	25mm/s PVPPV	Blasthole diameter Max bench height Max charge mass	76mm 8m 35kg/blasthole
3.3 TSF2 (Blackwood Pit), >100m			
Top of nearest embankment[1]	30mm/s PVPPV at 280m		As per 1.1
Foundation of nearest embankment[2]	15mm/s PVPPV at 280m		As per 1.1
Closest point of TSF2[3]	70mm/s PVPPV at 100m		As per 1.1
4. Blast clearance constraints: Based on a proposed 300m blast clearance zone and FOS[4]			
Occupied facilities	FOS >4	Min stem height	As per 1.2
Unoccupied facilities	FOS >2	Min stem height	As per 1.2

Notes for Table 5

1. Based on a 30mm/s PVPPV limit specified by the NSW Dams Safety Committee (DSC) for any point on the TSF2 embankment walls (Reference #13).

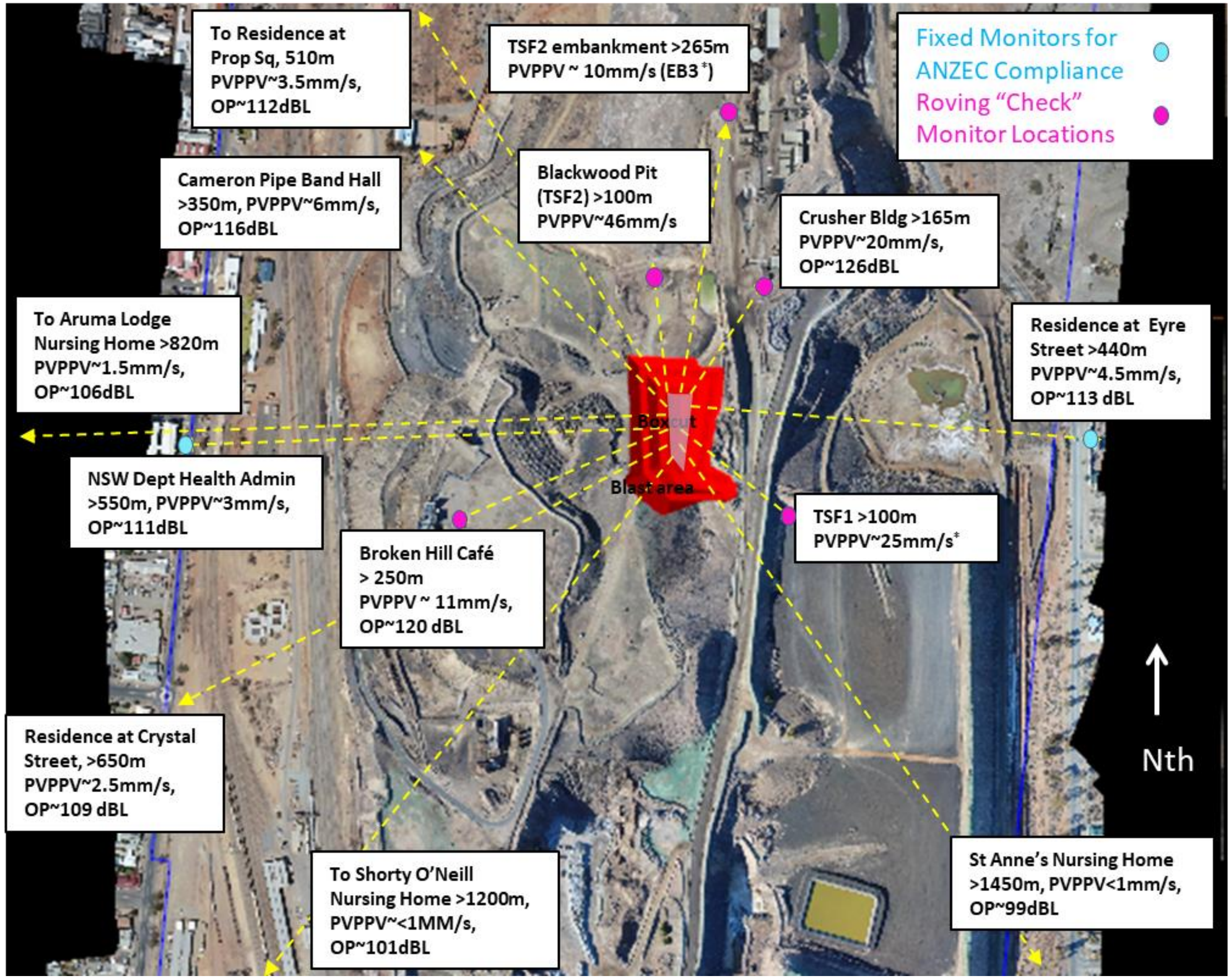
2. Based on a 15mm/s PVPPV limit identified by Golder Associates for embankments with vibration sensitive foundations (Reference #9). This allows for an amplification factor of up to 2 times to meet the 30mm/s NSW DSC limits on the embankment wall.

3. Implied limit at 100m in order to meet the criteria specified in points 1 and 2 above.

4. Blast clearance factor of safety applied to the maximum estimated flyrock range, based on appropriate stemming control.

- Note that the overpressure impacts from initial decline development rounds fired from surface are difficult to estimate and design adjustments may be required, or the decline development extended from underground workings to avoid overpressure impacts altogether.
- 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 construction exercise (see the AEISG Codes of Practice, Reference #16 and Reference #17).
- Free-face and/or terraced bench blasting is not recommended due to increased overpressure and/or fly-rock risk. Presplit and portal blastholes may need to be appropriately stemmed or otherwise buffered, rather than un-stemmed as is the usual practice, for overpressure and fly-rock control.
- Blast monitoring should include vibration/overpressure monitors at representative locations in order to demonstrate environmental (ANZEC) compliance at the nearest residential locations, and structural compliance at the nearest non-residential locations. Suggested locations for 'fixed' monitors and 'roving' monitors are illustrated in Figure 18, with fixed monitors no further than the nearest residence either side of the mine lease. Note that all blasts should be monitored at 'fixed' locations on Eyre Street and Crystal Street, while roving monitors can be placed at any of the suggested locations to validate vibration and overpressure impacts, as required and subject to ongoing monitored results.
- Wind speed and low cloud conditions (potential inversion) may restrict blasting times, in order to avoid reinforcement of blasting overpressure levels. Proposed blasting times and road closures (if required) should be notified in advance to all residential and commercial neighbours.
- Dust/fume constraints may restrict blasting times based on wind speed and direction. Monitored dust levels, and dust management guidelines for excavation, haulage and materials handling, should also be considered when choosing to fire a blast.
- All blasts fired from surface must be videoed as a record of blast behaviour.

Figure 18 – Expected 'worst case' peak ground vibration and blast overpressure levels for surface boxcut blasts (MIC = 75kg), with suggested fixed and roving monitor locations*.



*** Notes: Ground vibration limit of 25mm/s PVPPV at TSF1 requires a lower MIC of 35kg for the first boxcut blast, with subsequent monitored blasts modified (up to an MIC of 75kg) to remain compliant with this limit. Ground vibration impact at TSF2 embankments are based on the distance to the closest point on embankment #3 (EB3).**

7 REFERENCES

The following references have been used in preparing this report.

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END OF DOCUMENT