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HOLCIM (AUSTRALIA) PTY LTD

HOLCIM COLAC QUARRY

BLAST IMPACT ASSESSMENT FOR THE PROPOSED NORTHERN DEVELOPMENT AREA

April 2023

HOLCIM (AUSTRALIA) PTY LTD

HOLCIM COLAC QUARRY - WA158

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BLAST IMPACT ASSESSMENT FOR THE PROPOSED NORTHERN DEVELOPMENT AREA

1 INTRODUCTION

Terrock Consulting Engineers was engaged by Holcim (Australia) Pty. Ltd. to assess the impacts of blasting at the proposed Northern Development Area adjacent to Holcim's Colac Quarry (Work Authority No. 158), Potters Road, Ondit, Victoria. The stone resource underlying the quarry is nearing exhaustion and it is proposed to extend the life of the operation through the development of a Work Plan and an application for a new Work Authority to permit extraction in a recently acquired property immediately north of existing operations.

The purpose of this assessment is to determine the risks and impacts of blasting in the proposed Northern Development Area at nearby infrastructure and sensitive receptors in the surrounding area. The key blasting impacts considered in this report are;

- Ground Vibration levels from blasting
- Airblast Overpressure levels from blasting
- Flyrock risks and controls

Predictive models based on monitoring data from current blasting operations have been developed to determine if compliance with applicable ground vibration and airblast limits can be achieved under the proposal. The risk posed by flyrock (rock fragments thrown from blast sites) and control measures for mitigating flyrock hazards to infrastructure and the Ondit-Warrion Road reserve are also detailed.

2 BACKGROUND

The Holcim Colac Quarry is located at Ondit near the shore of Lake Colac approximately 9km from of the regional city of Colac. The quarry was established by Riordan Quarries Pty Ltd in 1972 and was acquired by CSR Limited (now Holcim [Australia] Pty Ltd) in 1988. Several Work Authority Variations over the proceeding years have permitted extraction in different areas of the quarry. The quarry produces basalt stone aggregate for construction projects in the local and broader region.

The quarry's production rate varies with market demand for aggregate and blast days occur on average every two to three weeks. Two separate blasts are occasionally fired as one with a short millisecond delay between blast sites. The number of individual blasts per year is 25-30. The quarry's average production rates and frequency of blasting are not anticipated to change significantly under the extension proposal.

All things considered, quarry management have maintained good relations with the closest receptors and blast-related concerns have been limited to a few distant residents.

Ground vibration and airblast levels from every blast fired at the quarry since the mid 1990's have been monitored by Terrock Pty. Ltd. A few exceedances of the quarry's regulatory airblast limit have occurred over the years, though these were limited to a few blasts less than 500m from the closest residence to the quarry's Southern Development Area (Primes). This residence is normally unoccupied at blast times and no complaints or concerns have ever been raised by the landowner.

3 EXTENSION PROPOSAL

The proposed extraction area covers approximately 31 Ha of the 40 Ha Northern Development Area. A minimum 20m wide buffer is proposed between the extraction limit and Work Authority boundary to help contain flyrock within the quarry.

Development plans show extraction commencing at the western extraction limit (Stage 1), progressing eastward over a 20-30 year period. The estimated volume of commercial-grade basalt available under the proposal is approximately 6 million tonnes (2.3 million m3). Annual production is estimated to be an average of 300,000 tonnes, a quantity that could be won with approximately 24 standard production blasts per year.

Blasting would largely follow current practice at the existing quarry with medium-scale blasting on a single bench and provision for short-face blasting for quality control and/or to reduce blast impacts.

Terrock is advised the pit floor is to be at depths up to 17.4m below the natural surface. The maximum depth is notably deeper than the pit of adjacent operations and could require additional groundwater management as the area's water table is thought to be 13-15m below the natural surface.

While the final depth of the pit floor will vary throughout the extraction area depending on the depths of basalt flows, the effects of blasting with the maximum potential bench height of 17.4m has been considered in this assessment as such blasts would result in the highest potential ground vibration and airblast levels. Blasts vibration levels from reduced face heights of 14m and 10m have also been assessed.

A site plan showing the existing quarry, proposed extension area, surrounding land areas and sensitive receptors (occupied dwellings) is shown as **Figure 1**.

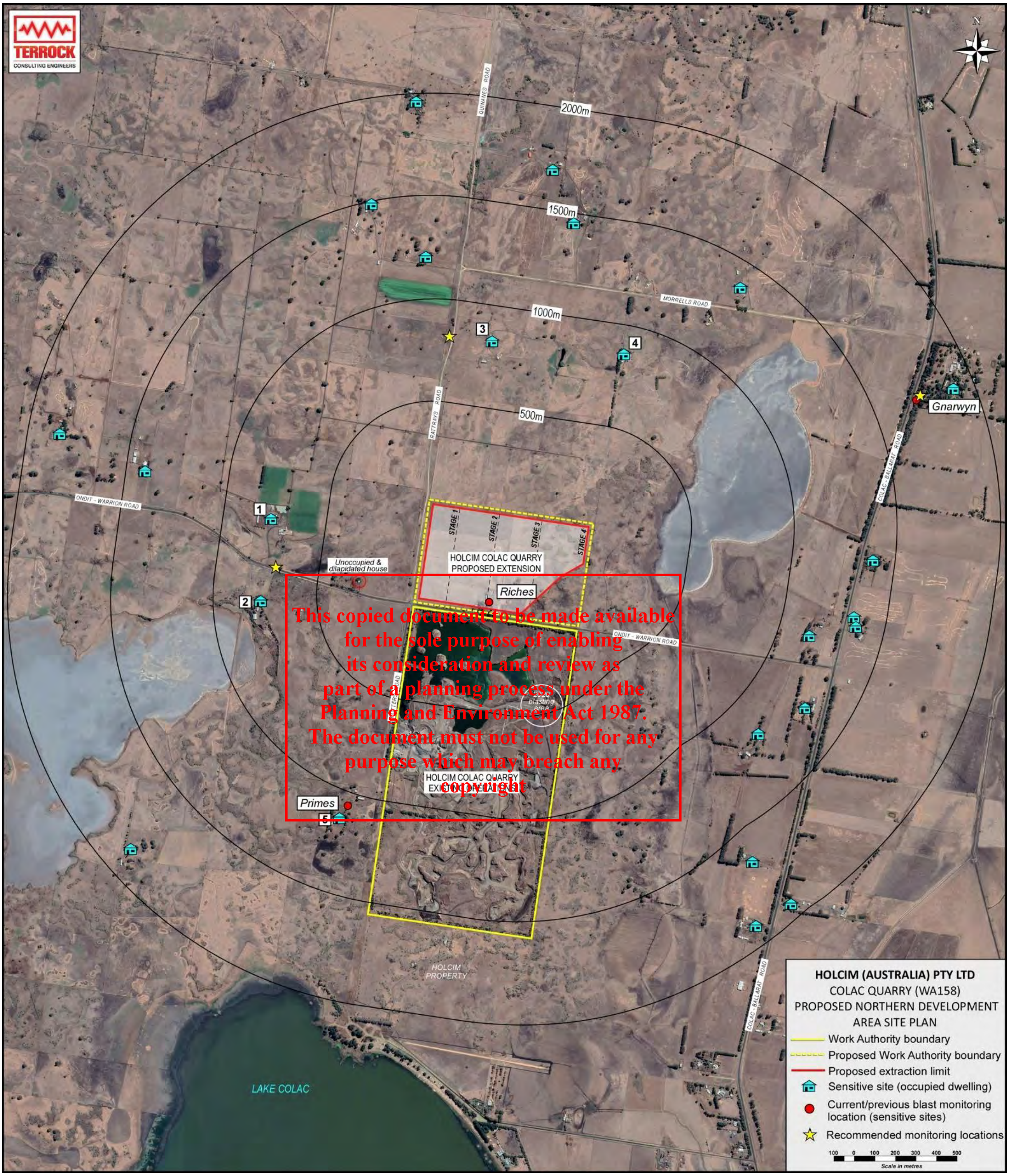

Figure 1 – Site plan showing Holcim Colac Quarry, proposed extension area and sensitive receptors

4 SURROUNDING LAND USE, SENSITIVE RECEPTORS & INFRASTRUCTURE

The land surrounding the existing quarry and proposed Northern Development Area is primarily used for cattle grazing and milk production. The main local thoroughfare of Ondit-Warrion Road traverses the northern boundary of the existing Work Authority and southern boundary of the proposed Northern Development Area. Rattrays Road runs along the western boundary of the proposed extension. The existing quarry entrance is located on Potters Road which runs part way along the western boundary of the existing Work Authority and terminates near the quarry entrance.

Twenty-four (24) residences located within 2km of the Northern Development Area have been identified through aerial imagery. There are;

- No occupied residences within 500m of the proposed extraction area
- Four (4) residences between 500m – 1,000m
- Twelve (12) residences between 1,000m – 1,500m
- Eight (8) residences between 1,500m – 2,000m

The closest building to the Northern Development Area is an unoccupied and dilapidated house located off Ondit-Warrion Road 300m to the west. While the future of this structure is unknown, blasting impacts for both human comfort and damage control are considered in this assessment.

The closest occupied residence is 770m west of the proposed extraction limit, shown as House 1 on the Site Plan **Figure 1**. The four closest houses (Houses 1 – 4) are located between 770m and 850m north and west of the proposed extraction limit.

The effects of blasting on nearby infrastructure must also be considered by shotfirers and quarry operators are liable for any blast-induced damage to assets. Along with the requirement to prevent damage by flyrock, asset owners/managers order ground vibration limits and other conditions to protect infrastructure, and quarry operators may need to provide evidence that compliance is being achieved.

Infrastructure assets near the proposed extension and their respective authorities are identified as;

- Ondit-Warrion Road reserve (Colac Otway Shire)
- Potters Road and Rattrays Road reserves (Colac Otway Shire)
- Low voltage transmission lines and poles along Ondit-Warrion Road (south side) and Rattrays Road east side (Powercor).
- Telecommunication line and poles along Ondit Warrion Road north side (Telstra)
- An asbestos-cement (AC) water supply pipeline buried in an easement south of Ondit-Warrion Road (Barwon Water)

Indicative locations of infrastructure along adjacent roads are shown in **Figures 2a** and **2b**.

Figure 2a – Infrastructure on Ondit-Warrion Road Reserve (camera facing west)

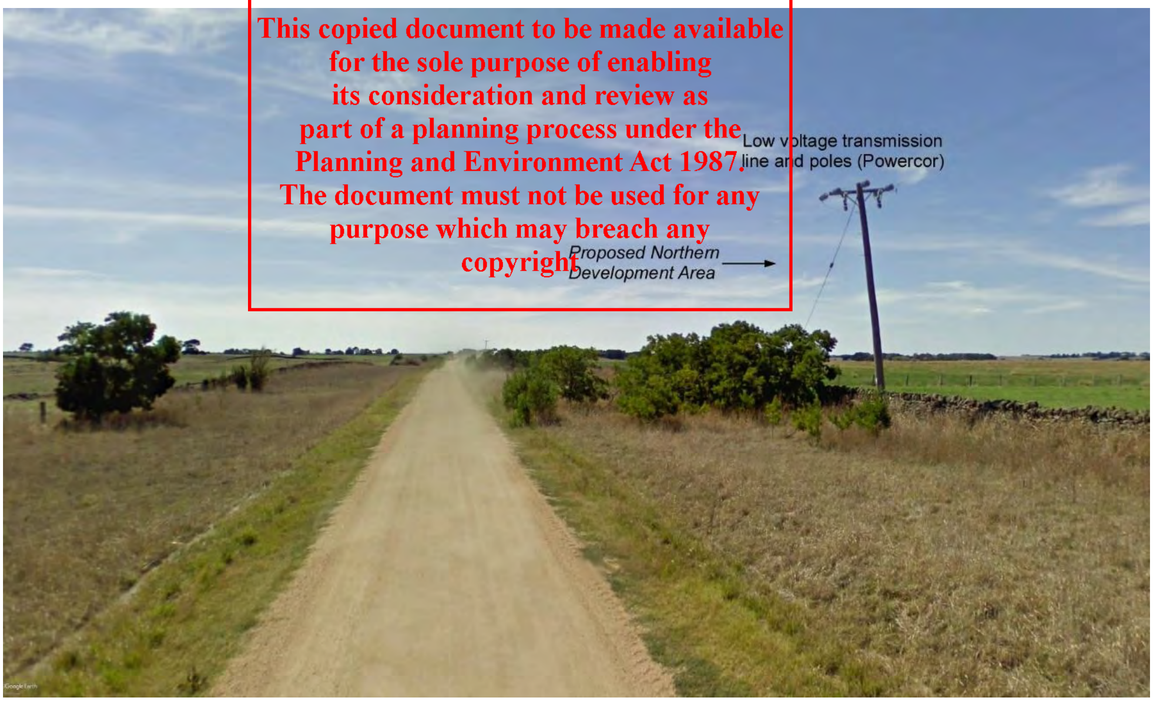

Figure 2b – Infrastructure on Rattrays Road Reserve (camera facing north)

5 SITE GEOMORPHOLOGY AND QUARRY PRACTICE

The geomorphology of the Newer Volcanics basalt underlying Holcim Colac Quarry has a strong influence on the transmission of blast vibration in the surrounding area. The site includes areas of “stony rises” where basalt outcrops in narrow ridges (the rises) have formed in a dendritic pattern by drainage and chemical weathering where the oldest basalt in the shallow valleys between rises has been weathered to clay.

The basalt varies in structure from massive blocks near the surface overlying smaller blocks and naturally fragmented rock within 2-3m of the pit floor. The jointing planes are largely sub-vertical or sub-horizontal which results in faces of irregular, blocky material. In some areas this has presented challenges for blast designers to control both airblast overpressure levels while achieving adequate fragmentation through the upper layer. A more consistent structure is shown in the worked out faces of the northwest corner of the quarry and this more competent rock is thought to extend across most of the proposed Northern Development Area.

The basement at the existing quarry is not exposed though it is known to contain silty clays with ancient lake deposits. This soft material underlying the basalt flows influences the transmission of ground vibration from the quarry, reducing seismic velocities and ground motion frequencies over long distances. The result is that, at locations beyond around 1km from blast sites, ground vibration levels are higher compared to other basalt quarries.

Due to the effects of local geology on ground vibration transmission, and variable rock structure and face heights, the quarry's blast monitoring record shows a wide range of ground vibration and airblast levels between individual blasts.

6 RELEVANT CRITERIA

Quarries with blasting are required to comply with guidelines and regulatory criteria as conditions specified in their approved Work Plan. Blast vibration limits are implemented to help minimise disturbance to neighbouring residents and separate limits may also apply to protect critical infrastructure from potential damage caused by excessive levels of ground vibration. Compliance with blast vibration limits is assessed through blast monitoring, where portable monitors with geophone and microphone attachments are installed at locations of concern. Blast monitoring and reporting requirements, and monitoring locations for quarries may be subject to approval from the extractive industry regulator. Some blast vibration limits and other criteria that would likely become an operating condition for blasting in the proposed Northern Development Area are outlined in the following sections.

6.1 GROUND VIBRATION AND AIRBLAST LIMITS

Ground vibration and overpressure (airblast) levels from quarry blasting are regulated under Victorian State legislation by the Department of Jobs, Precincts and Regions. The department's Earth Resources Regulation (ERR) branch provides guideline limits for ground vibration and airblast overpressure that are found in the ERR Guidelines and Codes of Practice; *Ground Vibration and Airblast Limits for Blasting in Mines and Quarries*, *Section 3.2: New Sites*.

The limits apply at "*sensitive sites*" defined by ERR as *"…any land within 10 metres of a residence, hospital, school, or other premises in which people could reasonably be expected to be free from undue annoyance and nuisance caused by blasting*."

The current ERR Blast Vibration Limits are:

Ground Vibration:	5 mm/s (95% of all blasts within a 12 month period) 10 mm/s for all blasts
Airblast:	115 dBL (95% of all blasts within a 12 month period) 120 dBL for all blasts

The limits above currently apply at the existing Holcim Colac Quarry and would likely remain as a condition for blasting in the Northern Development Area The upper limits (10 mm/s and 120 dBL) are provided as an allowance for the occasional unexpected exceedance of the lower (95%) limits. However, compliance with the lower limits (5mm/s and 115 dBL) is considered by quarry management to be the target for all blasting. It should be noted that the ERR ground vibration and airblast limits are based on human comfort considerations and are below levels at which blast-induced damage to buildings is known to occur.

The ERR ground vibration and airblast limits are the primary environmental control for blasting at quarries and blasts must be designed to achieve compliance at all times. Compliance is assessed through the results of routine blast monitoring at sensitive sites. Exceedances of the limits and other breaches of Work Plan conditions may result in penalties for quarry operators and shotfirers.

6.2 BLAST FIRING TIMES

The quarry is currently restricted to firing blasts during business hours between 11am – 3pm from Monday to Friday and most blasts are fired between 11:00am and 1:00pm. This helps reduce potential impacts to amenity as people are more likely to be outside their homes at blast times. No blasts may be fired on weekends or public holidays. The existing conditions would most likely be maintained for blasting in the Northern Development Area.

6.3 CONTROL OF FLYROCK

It is the responsibility of shotfirers to ensure that rock fragments thrown from blast sites (flyrock) do not present an unacceptable risk to people and property and are fully contained within a quarry's boundary at all times. Flyrock throw is prevented or minimised by industry-standard blasting practice including laser face profiling and blast hole surveying that is undertaken at the Colac quarry as a routine part of the blast design process.

The risk posed by *excessive flyrock* (where rock fragments are thrown well beyond anticipated distances) is substantially mitigated by establishing appropriate clearance zones at blast times. Further details of the risk, nature and causes of flyrock, and approaches for determining appropriate blast clearance distances are contained in **Section 10.2**.

6.4 CONDITIONS FOR INFRASTRUCTURE

Shotfirers must ensure that blasting operations do not damage public or private off-site infrastructure and quarry operators are liable for any damage incurred. Infrastructure asset owners may request evidence that flyrock from routine blasting is contained and that compliance with ground vibration limits and other conditions for infrastructure are maintained.

The ground vibration limit that commonly applies to transmission towers and poles in Victoria and other Australian jurisdictions is 100 mm/s at the footings. This limit is assumed to be applicable to the poles along Ondit-Warrion Road and Rattrays Road reserves though confirmation from the asset owner (Powercor Australia) should be sought. This is a non-damaging limit and research has shown both concrete and timber power poles can tolerate substantially higher PPV levels without adverse effects.

Standard PPV limits for non-critical telecommunications lines and poles are not known to Terrock. Pending confirmation from the asset owner (Telstra), a PPV limit of 200mm/s is considered by the writers to be appropriate.

An asbestos-cement (AC) water pipeline is buried in an easement at the southern side of Ondit-Warrion Road parallel with the existing work authority boundary. The pipeline owner (Barwon Water) has recently advised Holcim that the following conditions apply for future blasting operations in the vicinity of the AC pipeline.

- A maximum ground vibration level of 35 mm/s as measured at the depth of the pipe (approximately ~1.5m from surface level).
- A maximum PPV level of 100 mm/s (measured at the surface) would apply if the nearest section of AC pipe is replaced with more durable material.
- Holcim to pay remedial costs for any blast-induced damage incurred.
- Assessment of pipeline condition to be undertaken after closest blasting (at existing quarry) is completed. Holcim to share cost of pipeline replacement if blasting is deemed to have resulted in deterioration of the pipe condition.

PPV levels recently recorded at the depth of the AC pipe are shown to be on average approximately 50% lower than levels recorded on the surface directly above. This is not unexpected because movement of buried structures is constrained by the mass of the surrounding ground. PPV levels and the blast modifications required for future blasting in the northern area of the existing quarry are subject to ongoing monitoring and assessment. At the time of writing, PPV levels ≤70 mm/s measured at the surface above the pipe are considered to represent compliance with the 35mm/s limit at the depth of the pipe. A surface PPV limit for the AC pipe is yet to be formalised with Barwon Water. A surface limit is desirable due to the impracticality of drilling holes beside the pipeline prior to every blast for monitoring purposes, and also the complication of observing separate PPV models for sub-surface levels.

Information on blasting requirements near infrastructure can be found in **Section 9**.

7 BLAST DESIGN

Blasting practice at the existing quarry would be generally maintained for blasting in the Northern Development Area and the quarry's standard blast design specifications are listed in **Table 1**. The specifications are applied to blasts with face heights of 10m and 14m and the potential maximum height advised to be 17.4m.

Table 1 – Blast Design Specifications for various face heights – Holcim Colac Quarry Northern Extension

Face height	**10m**	**14m**	**17.4m (max.)**
Sub drill (max.)	1.0m	1.0m	1.0m
Hole length	11m	15.0m	18.4m
Hole angle	10°	10°	10°
Hole diameter	89mm	89mm	89mm
Stemming height (min.)	3.0m	3.0m	3.0m
Explosives column length	8.0m	12.0m	15.4m
Burden x Spacing (avg.)	2.7m x 2.7m	2.7m x 2.7m	2.7m x 2.7m
Front row/face burden	3.5 m	3.5 m	3.5 m
Linear charge mass	7.5 kg/m	7.5 kg/m	7.5 kg/m
MIC – Max. Instantaneous Charge/delay	60.0 kg	90.0 kg	115.5 kg
Explosives/density (avg.)	1.2 sg	1.2 sg	1.2 sg
Powder Factor	0.75 kg/m^3	0.82 kg/m^3	0.86 kg/m^3

The extraction of rock at quarries is a dynamic process and design specifications for individual blasts may be modified by shotfirers to improve blast performance, reduce the risk of flyrock or minimise blast vibration levels at sensitive sites. Previous modifications at Colac Quarry include variations of stemming height to reduce the production of oversize rock, short-face blasting at shallow rock depths, and front row burden and stemming height increases to achieve compliance with regulatory airblast limits at sensitive sites.

8 PREDICTIVE ASESSMENT

Levels of ground vibration, airblast overpressure and flyrock throw distance from blasting can be estimated using predictive formulae. The following models have been developed from decades of research and studies of blast vibration and flyrock observations conducted by Terrock and other Australian and overseas researchers. The models have proven reliable and are used to guide numerous mining, quarrying and construction blasting operations across Australia and overseas. This section outlines the formulae used to assess the impacts of blasting in the proposed Northern Development Area.

8.1 GROUND VIBRATION

Ground vibration levels generated by blasting are measured in terms of the ground motion's Peak Particle Velocity (PPV) expressed units of millimetres per seconds (mm/s). PPV levels increase with charge mass and reduce with distance as logarithmic decay. Geological structure and ground conditions between blast sites and receptors also influence PPV levels. A reliable model commonly used to predict ground vibration from blasting is the Scaled Distance Site Law developed by Nicholls et al (1971):

$$PPV = k_v \left(\frac{\sqrt{m}}{D}\right)^e \qquad [1]$$

Where:
- PPV = Peak Particle Velocity (mm/s)
- *m* = Charge mass-MIC (kg/delay)
- *D* = Distance (m)
- k_v = Site constant
- *e* = Site exponent

The model's site constant (k_v) represents the characteristics of the ground that influence the transmission of vibration waves between blast sites and receptors. Factors include localised geology and contact zones, jointing, faults and the depth and nature of surface soils. At Colac, the depth of basalt flows, weathering and basement deposits contribute to the wide range of k_v values shown by blast vibration records.

A summary of the quarry's 2020-21 blast vibration monitoring results is shown as **Table 2.** The three routine monitoring locations used for many years (Primes, Riches, and Gnarwyn) and recent extraction areas are shown on the **Figure 1** site plan. The charge masses (MICs) for blasts in the 2020-21 period ranged from 24 to 72 kg/delay with an average MIC of 46.3kg.

Table 2 – Holcim Colac Quarry ground vibration summary, 2020-21

Monitor	Max. PPV (mm/s)	Avg. PPV (mm/s)	Avg. distance (m)
Riches	2.79	1.56	648
Primes	2.92	1.48	1,070
Gnarwyn	0.92	0.51	2,407

Blasting operations during 2020-21 represent the most northerly blasting in many years and the dataset is therefore relevant for analysis. PPV levels are plotted over their distance from blast sites in the regression analysis **Figure 3**. An unusual feature of the dataset is that PPV levels at around 500m from blast sites are in the same range as PPV levels at around 1,000m.

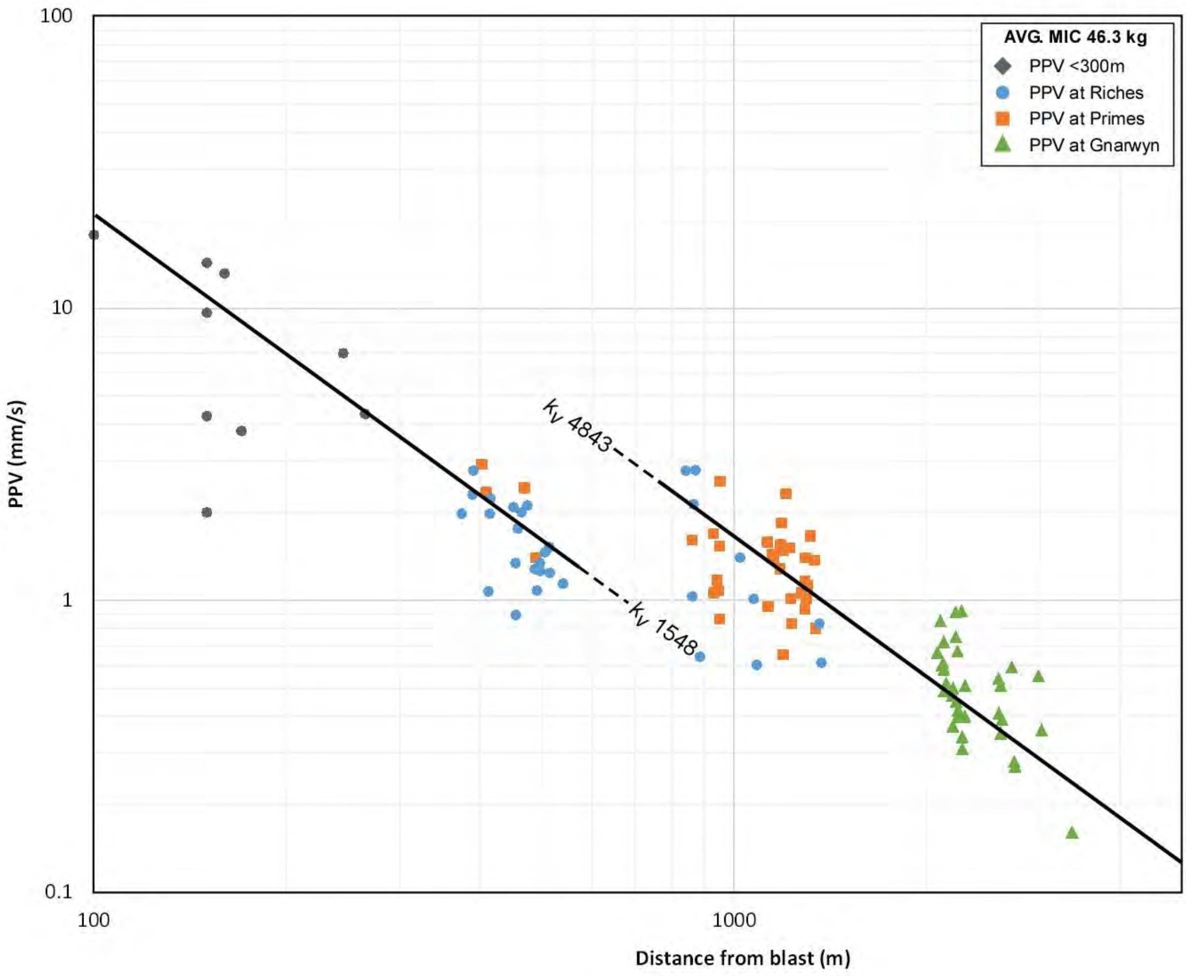

Figure 3 –Holcim Colac Quarry 2020-21 PPV levels and regression lines based on mean kv values

The mean k_v value for measurements taken <600m from blast sites is 1,548.

The mean k_v for measurements taken >800m is 4,843.

The data shows k_v values increase significantly in the area 500-800m from blast sites. The normal reduction of ground vibration over distance does not occur in this area, resulting in higher PPV levels (relative to distance) at locations beyond 800m. This unusual phenomenon can be attributed to local geology though the geotechnical mechanisms are not well understood.

This presents a challenge for predicting PPV levels at sensitive sites within the intermediate zone where the lower k_v value underpredicts levels at locations >500m, and the higher *kv* overpredicts levels at locations <800m. As an interim approach, an average k_v of 3,196 centred the midpoint (650m) has been adopted for the intermediate zone.

A previous assessment of blasting impacts for the existing quarry adopted a more conservative "whole site" value of 4,500. However, this single model provides substantial overestimates of PPV levels at locations <800m from blast sites as confirmed by recent results at Riches and locations <300m from blasts.

The models used in this assessment for predicting PPV levels at sensitive sites are therefore;

$$\text{PPV (<500m from blasting)} = 1{,}548\left(\frac{\sqrt{m}}{D}\right)^{1.6} \qquad [2]$$

$$\text{PPV (500-800m from blasting)} = 3{,}196\left(\frac{\sqrt{m}}{D}\right)^{1.6} \qquad [3]$$

$$\text{PPV (>800m from blasting)} = 4{,}843\left(\frac{\sqrt{m}}{D}\right)^{1.6} \qquad [4]$$

The distances to milestone PPV levels from blasts with a maximum potential charge mass of 115.5 kg are listed in **Table 3**. Because Terrock considers an MIC of 115.5 kg unlikely to be "standard" for many blasts in the extension area, and charge mass reductions are likely to be required in some areas, distances from blasts with reduced face heights of 14m and 10m are also shown.

Table 3 – Distances to milestone PPV levels from standard blast design specifications

	Dist. to PPV 17.4m face, MIC 115.5 kg	**Dist. to PPV 14m face, MIC 90 kg**	**Dist. to PPV 10m face, MIC 60 kg**
10 mm/s	251	222	181
5 mm/s*	**387-609**	**342-538**	**279-439**
2 mm/s	1,401	1,236	1,010
1 mm/s	2,160	1,907	1,557

**ERR Ground Vibration Limit (95% of blasts)*

Predicted PPV levels over distance are also shown in the regression analysis **Figure 4**. The minimum distances from the proposed extraction limit to Houses 1-4 are shown. The minimum distance from blast(s) to regular monitoring locations Primes and Gnarwyn are also shown for reference.

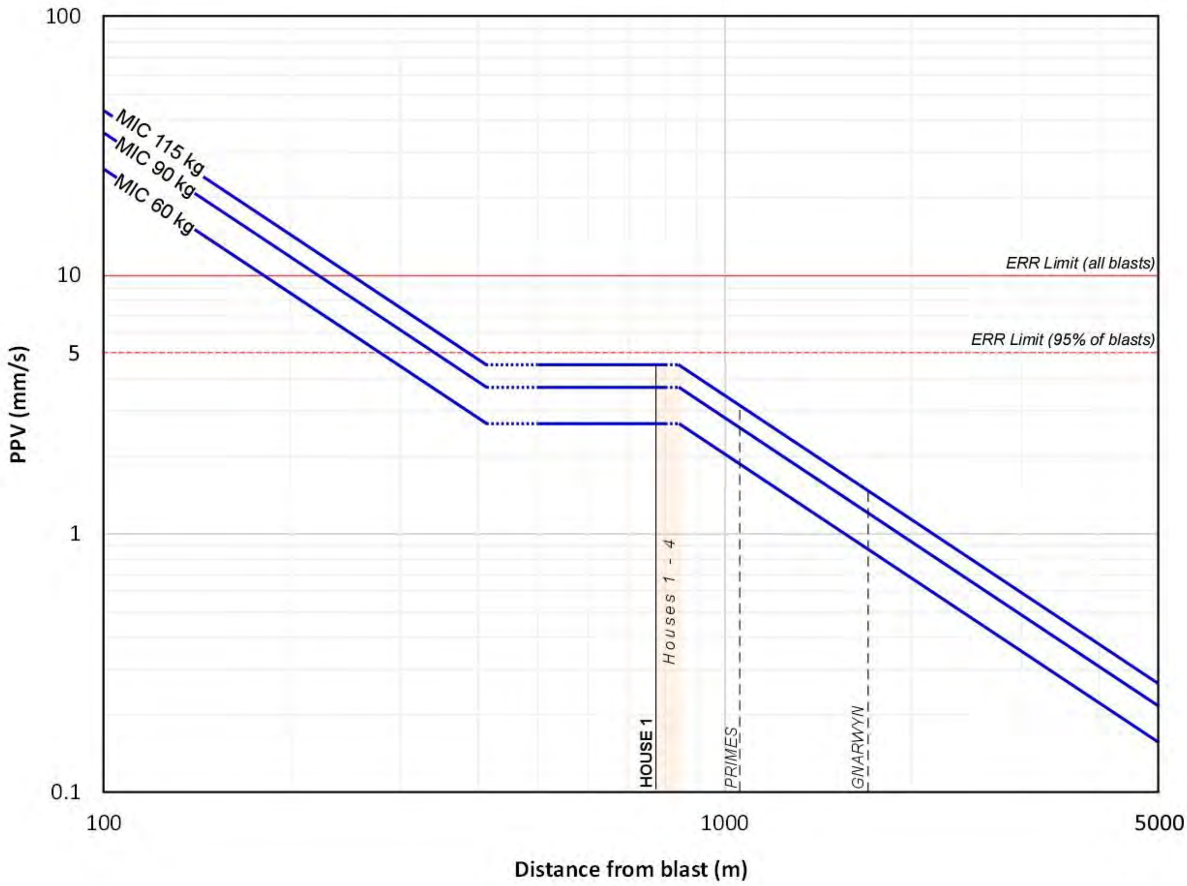

Figure 4 – Regression analysis, predicted PPVs and min. separation distances from closest sensitive sites

Maximum PPV levels at Houses 1-4 are predicted to be 4.5 mm/s (17.4m face), 3.7 mm/s (14m face) and 2.6 mm/s (10m face). It should be noted that such levels could only occur from the closest few blasts at or near the extraction limit and levels from more distant blasts (i.e. the vast majority of blasts) would be reduced.

The maximum (worst-case) PPV levels predicted in the surrounding area from 17.4m face blasts are shown by moving basic ground vibration contours around the proposed extraction limit and observing the positions of the 10, 5, 2, 1 and 0.5 mm/s contours (**Appendix 1**). Note the contours do not represent PPV levels from a single blast but indicate maximum PPV at any location from the closest blast at the extraction limit. The assessment is regarded to be conservative because 17.4m face blasts will not occur across most of the proposed extraction area. Blasts with face heights less than 17.4m would result in lower PPV levels than those shown.

8.2 AIRBLAST (OVERPRESSURE)

Airblast is a sudden, low frequency change of air pressure measured as decibels linear (dBL). The emission is sub-audible (<20 Hz) and is generally perceived by people inside buildings through structural response, e.g. the noise of a window rattling for a few seconds. The effect of airblast on a building can be likened to a sudden wind gust. From experience, the threshold of airblast perception for people inside buildings is around 100-105 dBL though the effect is often indiscernible from the effects of ground vibration that precedes it. There is currently no regulatory requirement for monitoring audible noise emissions (dBA) from blasting.

Airblast levels from free-face blasts at quarries are highest directly in front of the face with lower levels occurring behind and to the sides of a blast, giving airblast contours an ovoid form. Therefore, the orientation of blast faces is an important consideration for minimising airblast levels at sensitive sites.

Airblast levels in front of a blast face are controlled by front row burden provisions. The emission behind and to the sides of a blast is controlled by stemming height.

Airblast levels from individual blasts are also influenced by a range of factors such as small variations in front row burden and stemming height, inconsistent rock structure, and weather conditions at blast time. These are largely accounted for in the standard model with broadly conservative site constants.

Airblast overpressure levels can be predicted using the Terrock Airblast Model (Richards and Moore). This peer-reviewed model observes blast hole confinement provisions to determine the distance to the 115 dBL level (D115). The model is regarded to be conservative and is used to assess airblast levels at numerous mines and quarries around Australia and overseas.

The basic airblast model is:

$$D_{115} = \left(\frac{ka \times d}{B \text{ or } SH}\right)^{2.5} \cdot \sqrt[3]{m} \qquad [3]$$

Where:

D_{115}	=	Distance to 115 dBL level (m)
d	=	Blast Hole Diameter (mm)
m	=	MIC–Max. Instantaneous Charge (kg)
B	=	Front Row Burden (mm)
SH	=	Stemming Height (mm)
Ka	=	A site constant; 290 (front of face) 220 (behind blast)

Airblast is primarily a function of charge mass (MIC), front row burden and stemming height provisions. Using the standard blast design specifications shown in **Table 1**, the airblast models for proposed Northern Development Area are;

Front of Face emission (17.4m face)

$$D_{115} = \left(\frac{290 \times 89}{3,500}\right)^{2.5} \cdot \sqrt[3]{115.5} \qquad [4]$$

Behind blast emission (17.4m face)

$$D_{115} = \left(\frac{220 \times 89}{3,000}\right)^{2.5} \cdot \sqrt[3]{115.5} \qquad [5]$$

Observing the normal attenuation rate of -9 dBL with doubling of distance, the distances to milestone levels airblast from the three nominal face heights are:

Table 4 – Airblast Level Predictions

	17.4m face (115.5 kg)		14m face (90kg)		10m face (60kg)	
Airblast (dBL)	Front of Face (m)	Behind/side (m)	Front of Face (m)	Behind/side (m)	Front of Face (m)	Behind/side (m)
120	496	366	457	337	399	294
115*	**719**	**530**	**662**	**488**	**578**	**426**
110	1,043	768	960	707	838	618
105	1,512	1,114	1,391	1,025	1,215	896
100	2,192	1,616	2,018	1,487	1,762	1,299

**ERR Airblast Limit (95% of blasts)*

Airblast levels at distances up to 3km from the quarry are shown on the airblast regression analysis **Figure 5**. Note the predicted levels are from 17.4m face blasts and are considered "worst-case", with lower levels occurring from blasts with reduced face heights.

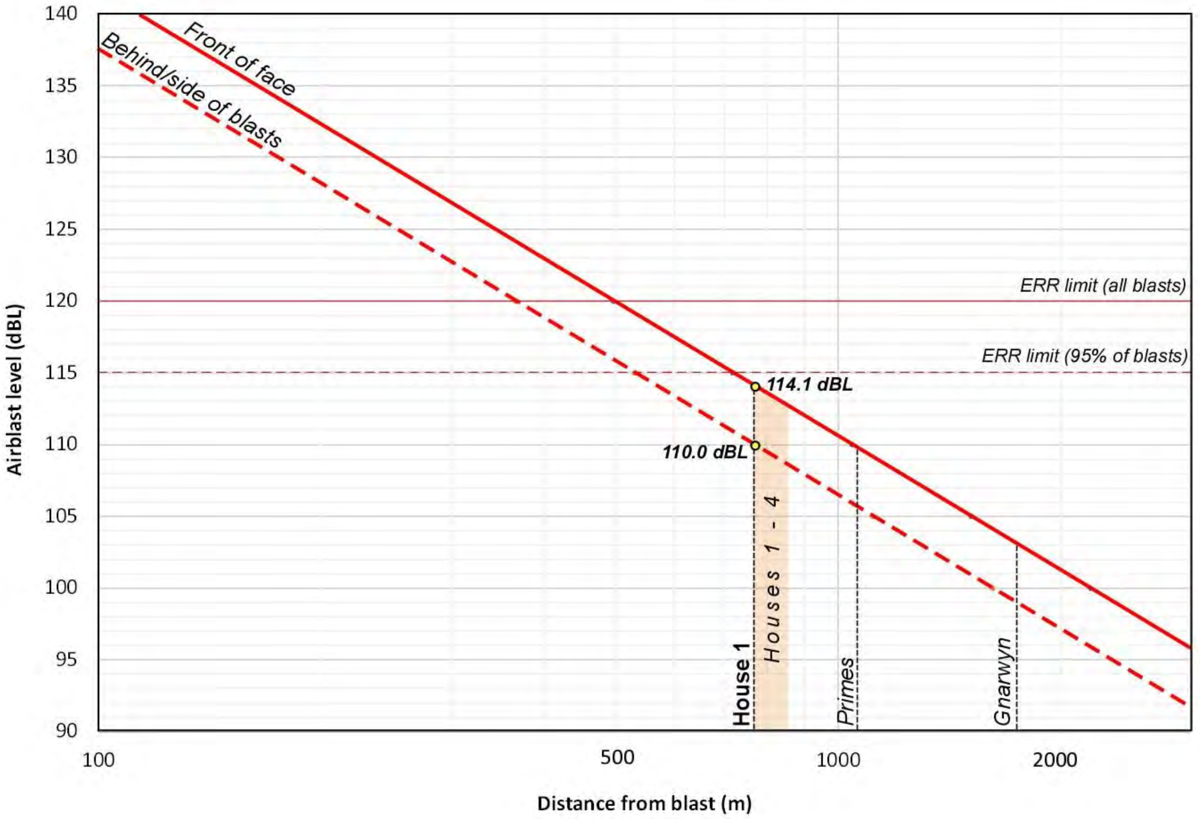

Figure 5 – Airblast regression for 17.4m face blast (maximum)

A set of basic airblast contours (14m face, MIC 90kg) is shown as **Figure 6**. The contours' ovoid form demonstrates the importance of face direction for minimising airblast levels at nearby sensitive sites.

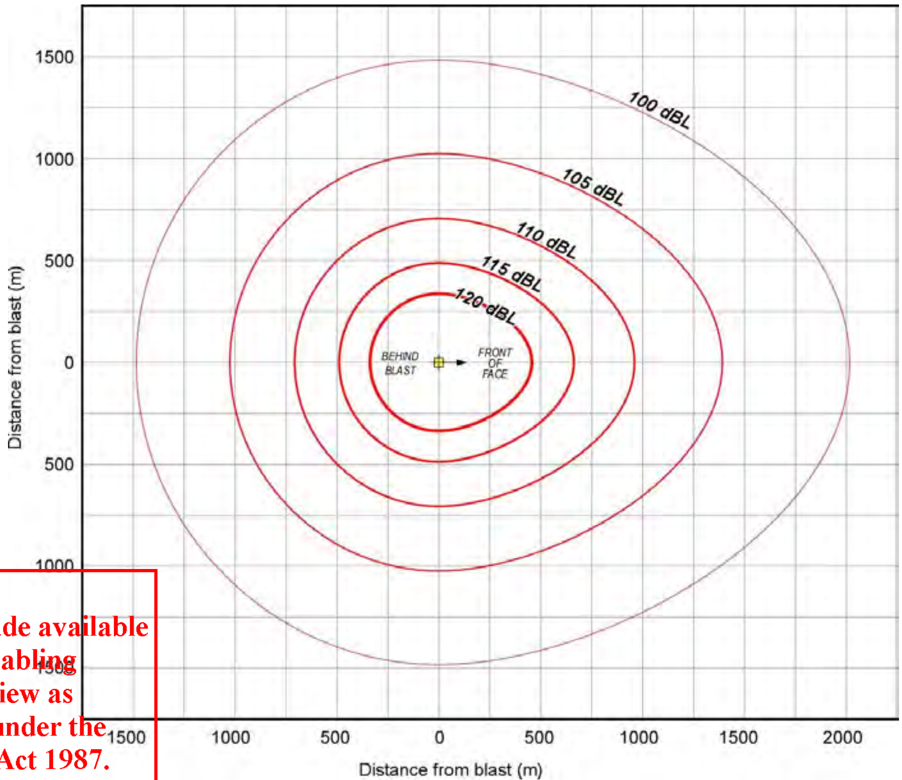

Figure 6 – Basic airblast model contours (14m face blast)

At the minimum separation distance between House 1 and the proposed extraction limit, the front of face airblast level is 114.1 dBL, or around 80% of the ERR 115 dBL limit. However, blasts at the extraction limit cannot face outward and are usually oriented toward the pit. Airblast levels at quarries are minimised by adopting an extraction sequence with blast faces oriented away from the closest sensitive sites and towards remote locations. At the proposed Northern Development Area, a sequence with mostly south-facing blasts would expose the closest houses (to the west and north) to lower, behind/side of blast emissions with a maximum level of 110 dBL at House 1.

If required, airblast levels at quarries can be further reduced by increasing blast hole confinement (see **Section 9.2**). However, the experience at Colac Quarry is that substantial changes result in poor blast performance including unstable muckpiles and the production of massive, oversize blocks that are difficult to move and present a hazard for quarry personnel. Increasing front row burden and stemming height above standard specifications (3.5m and 3.0m respectively) is not recommended for the existing quarry or proposed extension unless strictly necessary.

Peak airblast levels would also be reduced by charge mass reductions needed to comply with PPV limits at nearby infrastructure.

The maximum airblast levels at sensitive sites from 17.4m face blasts are presented by moving the basic model contours (**Figure 5a**) around the extraction limit and observing southerly face directions as shown in **Appendix 2**. The contours do not represent airblast levels from a single blast but indicate the peak dBL level at any location from the closest standard blast at the extraction limit.

8.3 FLYROCK

The maximum distance rock fragments may be thrown under design specifications can be calculated using the Terrock Flyrock Model (Richards and Moore). The model was developed over years of field observations and was reviewed in 2007 by Prof. Peter Lilly (CSIRO Chief Officer of Exploration and Mining) who concluded "*Terrock's flyrock model greatly simplifies what is dynamically a very complex in physics. However, the algorithm is likely yield broadly conservative outcomes and is therefore considered to be appropriate by the writer*."

The maximum throw in front of a blast face ($Lmax_f$) is calculated with the formula:

$$Lmax_f = \frac{{k_f}^2}{g}\left(\frac{\sqrt{m}}{B}\right)^{2.6} \qquad [6]$$

Where:

- m = charge mass, kg/m
- B = front row burden (m)
- $Lmax_f$ = maximum throw in front of face (m)
- g = gravitational constant (9.8)
- k_f = a site constant (27 conservative)

The maximum throw behind a blast site ($Lmax_r$) is calculated by:

$$Lmax_r = \frac{{k_f}^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6} Sin\,2\emptyset \qquad [7]$$

- SH = stemming height (m)
- $Lmax_r$ = maximum throw behind blast (m)
- Ø = launch angle = hole angle from horizontal + dispersal allowance of 10°
  (e.g. Hole angle + dispersal = 70° from horiz.)

The model is conservative and provides an allowance for normal inconsistencies in face rock and minor errors that can occur during hole loading. The distance rock fragments roll after landing is also considered in the model. Studies of flyrock at hard rock quarries shows a site constant (k_f) of 27 to be appropriate, conservative value and the maximum throw distance at most quarries is normally well below calculations.

However, a cautious approach to flyrock and blast clearance is warranted due the serious consequence of flyrock striking a person or property.

Under standard blast design specifications the predicted throw distances are;

$$Lmax_f = \frac{27^2}{9.8}\left(\frac{\sqrt{7.5}}{3.5}\right)^{2.6}$$

Front of face throw = 39.3m (**40m**)

$$Lmax_r = \frac{27^2}{9.8}\left(\frac{\sqrt{7.5}}{3.0}\right)^{2.6} Sin\ 2\ (70°)$$

Behind/side of blast throw = 37.7m (**38m**)

The maximum throw trajectories are shown below in **Figure 7**.

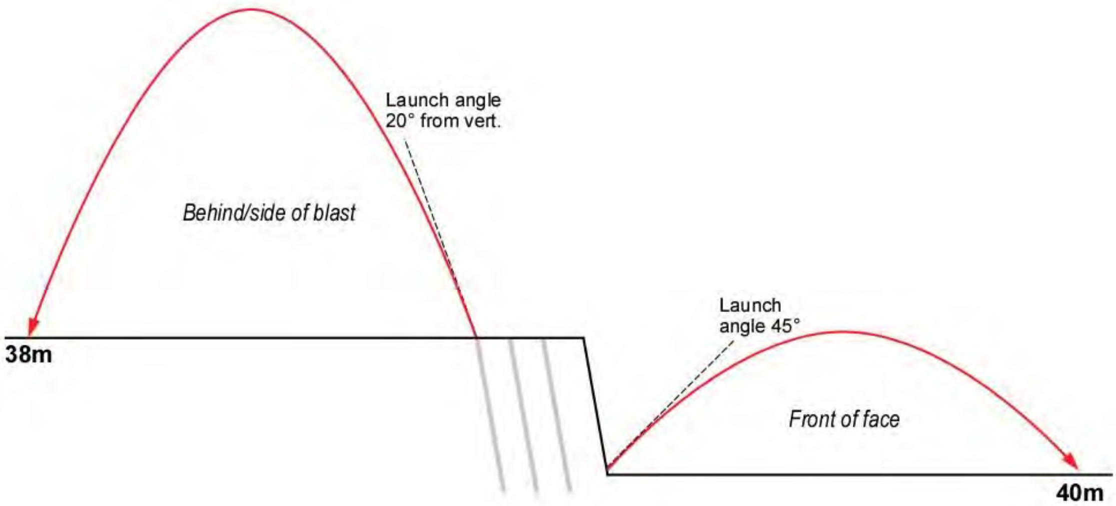

Figure 7 – Flyrock trajectories based on model calculations

Safety factors based on throw calculations can be used to determine appropriate minimum clearance distances for the protection for people and property in the event that rock is thrown beyond anticipated distances. The nature, causes and risk posed by flyrock, and approaches for determining blast clearance zones is discussed in **Section 10.2**.

9 MODIFIED BLASTING

Hard rock blasting generates ground vibration, airblast overpressure and displacement of rock fragments. While these effects cannot be eliminated, ground vibration and airblast levels, and the throw of rock can be reduced through modifications of standard blast designs.

Efficient quarry blasting is achieved within a range of standard blast design specifications. Substantial design changes typically reduce blast efficiency and affect performance, including poor fragmentation and smaller quantities of rock yielded per blast. This can result in other impacts such as the increased requirement for secondary breaking where blocks too large to process need to be broken down by hydraulic rock breakers, generating additional noise. Heavy modifications may also result in a greater number of blasts needed to meet production targets, or blasts with increased numbers of blast holes resulting in longer durations of ground vibration, airblast and noise.

The need for blast design modifications, and the modifications required, should be guided by the results of blast monitoring. For the purpose of this assessment, the blast impact models have been used to identify areas in which design modifications may be needed (shown as "*Modified Blasting Zones*" on site plans), and the degrees of modification potentially required.

9.1 REDUCING PPV LEVELS

The ground vibration Site Law Model shows PPV levels as a function of charge mass, distance and local ground conditions. Therefore, the most practical method for reducing PPV is by reducing MIC (charge mass per delay/hole).

Using the PPV model for sensitive sites located 500-800m from blasts [3], the effect of charge mass reduction on the distance to the 5mm/s ground vibration level ($D5_{mm/s}$) is shown in **Table 5.**

Table 5 – Charge mass (MIC) vs Distance to 5mm/s

MIC (kg)	$D5_{mm/s}$ (m)
120	621
115.5*	609
110	595
100	567
90**	537
80	507
70	474
60#	349
50	401

** MIC - 17.4m face*
*** MIC - 14m face*
 # MIC - 10m face

The most effective methods for reducing charge mass are;

- *Splitting* or reducing the face height, thereby reducing blast hole length and the quantity of explosives in each hole.
- *Deck loading*, a technique where blast holes are loaded with two individual charges separated by a "deck" of inert material (stemming or other device). The two charges are fired separately with delay detonators.

9.1.1 *Split face blasting*

An example of this approach is to split a 17.4m bench into 2 x 8.7m benches, thereby reducing MIC from 115.5kg to 50.3kg as shown in the **Figure 8** below.

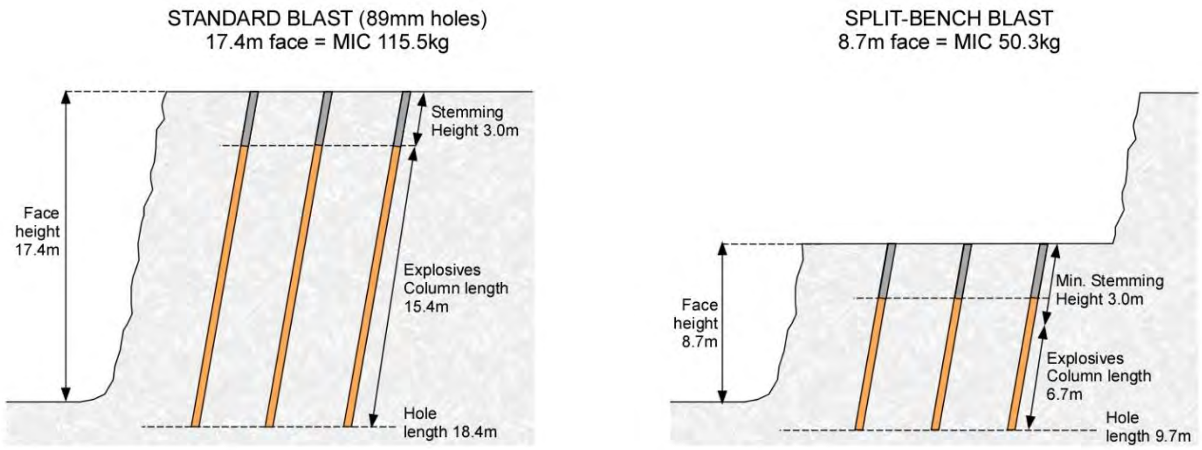

Figure 8 – Charge mass reduction by split face method

For the example above, $D5_{mm/s}$ reduces from 609m to 402m, though blast efficiency is substantially reduced and a greater number of blasts (or greater number of blast holes) would be required to meet production targets. However, this method is effective for reducing PPV and pending the results of blast monitoring, may need to be adopted for the closest blasts to infrastructure to comply with PPV limits.

9.1.2 *Deck loading*

An example of a deck loaded blast with the maximum face height of 17.4m is shown below where two separate explosives columns/charges are loaded in each blast hole, separated by a deck of stemming, and detonate from bottom to top after a short millisecond delay. MIC is reduced from 115.5kg to 54.0 kg.

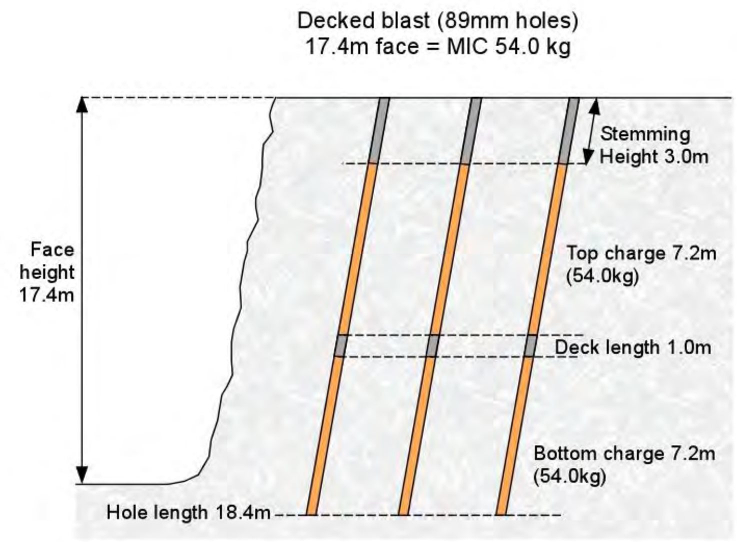

Figure 9 – Charge mass reduction by deck loading method

For this example, $D5_{mm/s}$ reduces from 609m to 417m. The primary benefit of deck loading is that a single bench and standard blasts yields can be maintained. However, blasting costs are substantially increased because a greater number of blasting components are required and more time is needed to load and fire each blast. Additionally, there is increased potential for a decked blast to misfire due to the greater number of initiation components and a more complex initiation sequence. While misfires (where one or more charges fail to initiate) are uncommon, they can present significant hazards to quarry personnel and may be challenging to resolve.

9.1.3 *Requirement for charge mass reductions*

Sensitive sites

PPV predictions indicate compliance with the ERR 5 mm/s ground vibration limit (95% of blasts) would be achieved at all sensitive sites in the surrounding area under standard design specifications. However, due to inherent variables and unknowns, there is potential for 17.4m face blasts near the west and north boundaries of the Northern Development Area to exceed 5 mm/s at the closest houses. Pending the results of blast monitoring, it is recommended that blasts near the north and west boundaries have face heights no greater than 14m (i.e. MIC ≤90kg) that would result in maximum PPV levels ≤3.7 mm/s at House 1.

Infrastructure on Ondit-Warrion Road reserve

PPV limits and conditions that apply to infrastructure in the Ondit-Warrion Road and Rattrays Road reserves are an important consideration for blasting in both the northern area of the existing quarry and the south and west areas of the proposed Northern Development Area. The limits for the AC pipe and poles in adjacent road reserves would require MIC to be reduced for the closest blasts to the assets.

The primary control for blasting near the Ondit-Warrion Road reserve is compliance with the Barwon Water 35mm/s limit at the AC pipeline (70mm/s at the surface). Compliance with this lower limit will help ensure compliance with higher PPV limits that apply at nearby power and telecommunications poles (100mm/s and 200 mm/s respectively).

The PPV model [2] indicates that charge mass reduction would be required for blasts within 74m of the AC pipe (31m from the extraction limit). This can be achieved by progressively reducing face height or by deck loading. A cross section showing distances from the extraction limit wherein charge mass reduction (<115.5kg) is required to meet compliance with a 70 mm/s limit at the surface above the pipe (i.e. 35mm/s at the depth of the pipe) is shown as **Figure 10**.

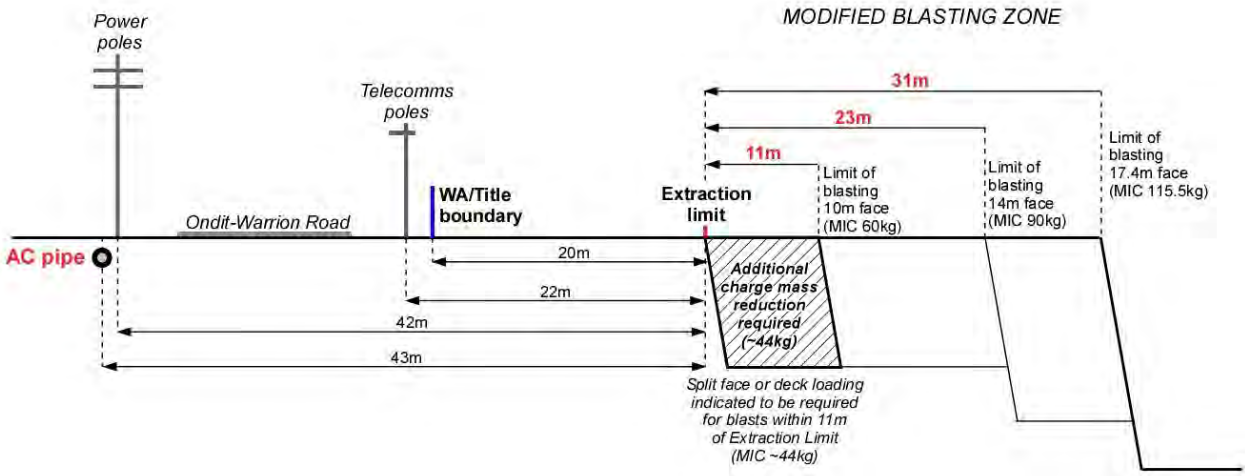

Figure 10 – Indicative charge mass requirements for blasting near southern extraction limit

Maximum PPV levels at infrastructure from the approach shown above are shown in the following table.

Table 7 – PPV levels at infrastructure from modified blasting approach

Dist. from extraction limit (m)	MIC (kg/delay)	PPV at AC pipe- (mm/s at surface) *Limit 70mm/s*	PPV at power poles (mm/s) *Limit 100 mm/s*	PPV at Telecomms poles (mm/s) *Limit 200mm/s*
31	115.5	70	72	120
23	90	69	71	128
11	60	69	71	152
3 (terminal blast)	44	70	72	185

Power poles on Rattrays Road

Pending the results of blast monitoring, to comply with the 100 mm/s limit for power poles, Modified Blasting Zones (i.e. MIC <115.5kg) would be required within 60m of the two pole footings on Rattrays Road reserve. As with infrastructure to the south, compliance can be maintained through progressive charge mass reductions as shown below.

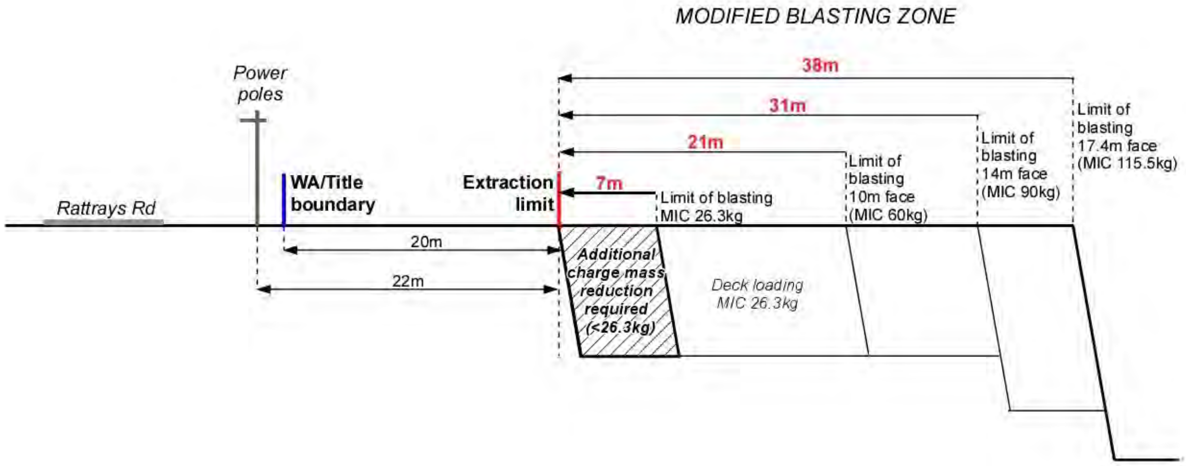

Figure 11 – Indicative charge mass requirements for blasting near western power poles (Rattrays Road)

Reduced face height and/or deck loading approaches would permit blasting as close as 29m from pole footing (7m from the extraction limit). Closer blasting is possible with further charge mass reductions (i.e. <26.3kg), though increased blasting costs and reduced yields may ultimately render blasting commercially unviable within these two small areas.

9.2 REDUCING AIRBLAST LEVELS

Airblast emissions are a function of charge mass, blast hole confinement (front row burden and stemming height) and face direction. If required, airblast levels at sensitive sites can be reduced by;

- Additional confinement by increasing front row burden and stemming height
- Charge mass reduction (see previous section)
- Orienting blasts/benches to face away from sensitive sites

This assessment shows airblast levels would comply with the 115 dBL limit at sensitive sites provided Stage 1 blasts near the west and north boundaries face south (or east) towards more distant receptors. Airblast levels would also be reduced for blasts with shorter face heights (<17.4m) and by charge mass reductions and stemming height increases needed to control PPV levels and flyrock near infrastructure.

The influence of front row burden and stemming height provisions on the distance to the 115 dBL airblast level (MIC 90kg) is shown in **Figure 12**.

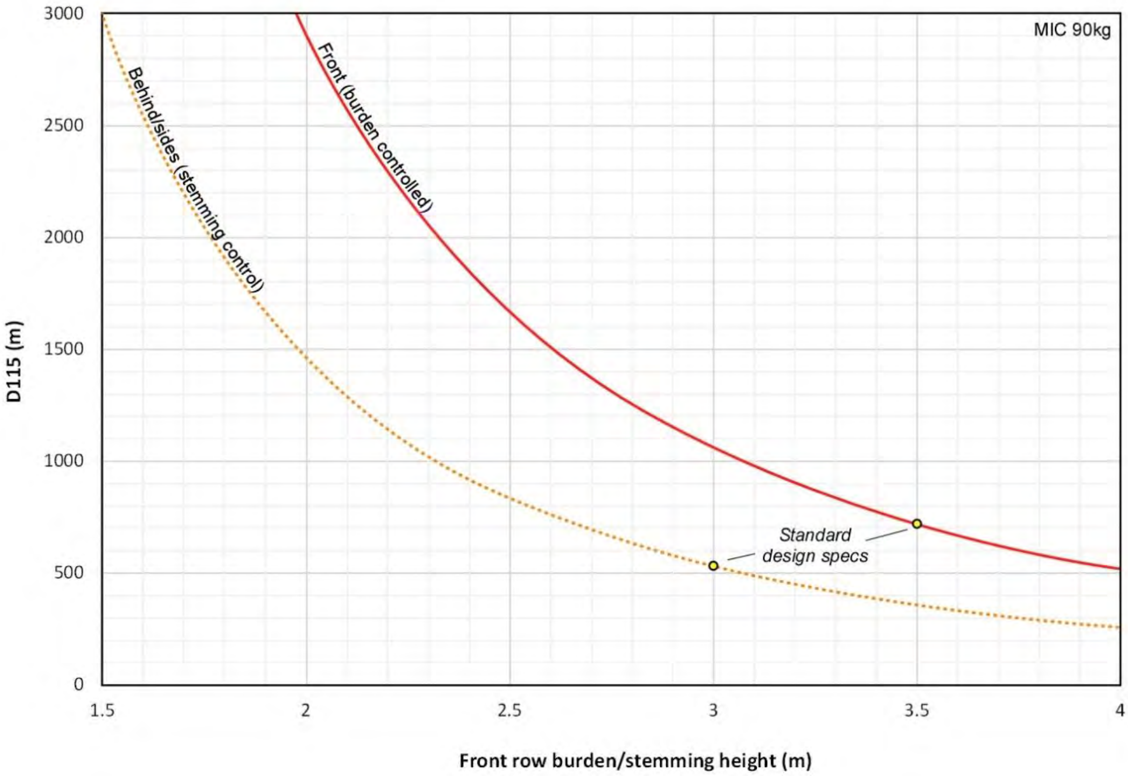

Figure 12 – Relationship between airblast levels and burden and stemming provisions

9.3 REDUCING FLYROCK THROW

The distance rock fragments are thrown from a blast site is a function of charge mass (per linear metre of an explosives column), front row burden (throw distance in front of the face) and stemming height (throw distance behind the blast). As with airblast, increasing blast hole confinement is the most effective method for reducing throw distance. The sensitivity of flyrock throw distance to changes in front row burden and stemming is shown in **Figure 13**.

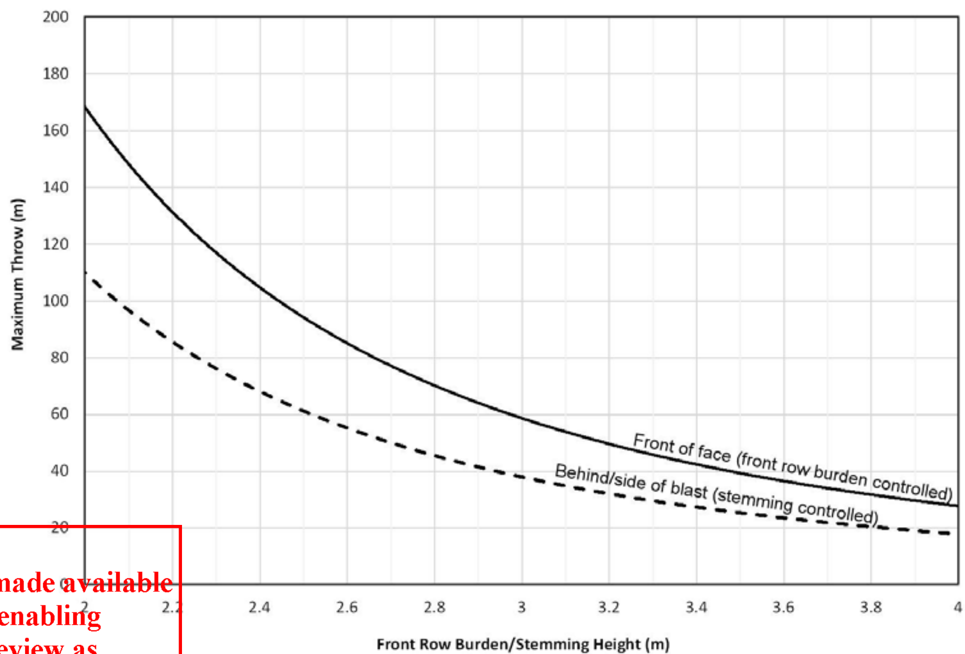

Figure 13 – Relationship of maximum flyrock throw distance to burden and stemming provisions

Because most the extraction limit is shown to be 20m from the proposed Work Authority boundary, stemming height should be increased for blasts within 38m of the boundary to reduce the potential for rock fragments landing in adjacent property. This may only be required for a limited number of blasts at or near the extraction limit where increasing stemming heights from 3.0m to 3.8m would reduce maximum throw from 38m to 20m (**Figure 14**) which is sufficient to contain all rock fragments within the quarry.

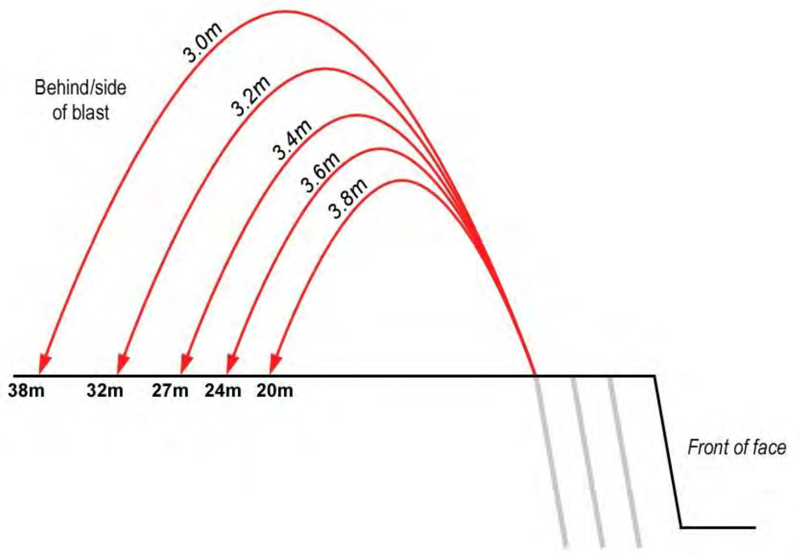

Figure 14 - Reducing maximum throw behind blasts by stemming height increase

The subject of flyrock, its prevention and control, and blast clearance zones are discussed in more detail in **Section 10.2**.

9.4 MODIFIED BLASTING ZONES

Areas of the proposed Northern Development Area in which modified blasting (charge mass reduction and stemming height increase) is indicated to be required are shown in **Figure 15**. Blast areas in which traffic control may be required on adjacent roads under the approach detailed in Section **10.2.4** are also shown.

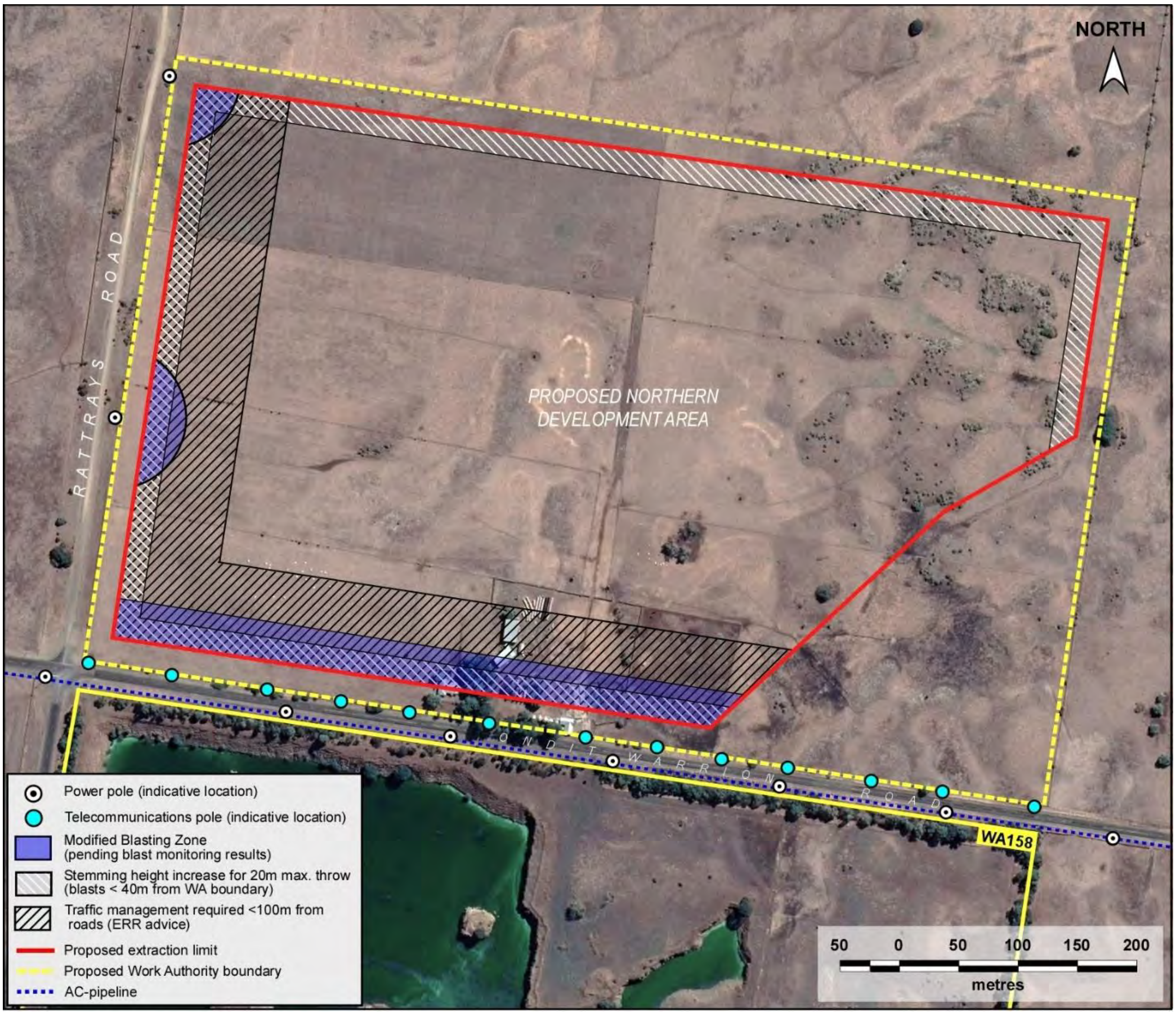

Figure 15 – Infrastructure and indicative modified/restricted blasting areas

10 BLASTING RISKS

Blasting at quarries is a highly regulated operation that is restricted to experienced, licensed shotfirers. Improvements in blast design, surveying techniques, loading procedures, explosives products, and more stringent regulations over recent years have greatly reduced the risks presented by blasting in the past. Some of the remaining blasting risks and their control measures are detailed in the following sections.

10.1 TRANSPORT, HANDLING AND USE OF EXPLOSIVES

Blasting at Victorian quarries is undertaken by shotfirers who are trained and licensed to use blasting explosives in the State of Victoria. Quarry blasting is required to conducted in accordance with National and State regulations and guidelines including;

- *Victorian Dangerous Goods (Explosives) Regulations 2011*
- *Australian Standard AS 2187.2 (2006) Explosives Storage & Use, Part 2: Use of Explosives*
- *Australian Code for the Transport of Explosives by Road and Rail - 3rd Edition*
- *Earth Resources Regulation (ERR) guidelines*
- Other clauses that may be specified by regulators as part a quarry's approved Work Plan.

Blasts at Colac Quarry are typically designed and loaded by a team consisting of a licensed shotfirer, trained quarry personnel and/or technicians from the explosives supply company under contract. Procedures for blast design, site access and security, hole surveying and loading details, and blast clearance and firing that must be followed are detailed in a quarry's Blast Management Plan (BMP) and documentation pertaining to individual blasts. Material Safety Data Sheets and Risk Control documents for explosives products and the handling and transport thereof are available from explosives supply companies.

In line with modern industry practice, no explosives are stored at Holcim Colac Quarry. All explosives products are brought to site by a licenced explosives supplier company on blast days and unused products are returned to the supplier's storage facility after hole loading.

10.2 FLYROCK RISK

The greatest risk to the health and safety of people and property from blasting is *excessive* flyrock throw, where rock fragments from a blast site are projected well beyond normal distances. Excessive flyrock events at quarries have become increasingly uncommon due to improvements in blasting practice. While no injury to a person has been reported from flyrock at a Victorian quarry for several decades, excessive flyrock remains a possibility at all quarries.

Quarry blasting is undertaken to fracture and displace rock for crushing into useable grades of aggregate. Fragments of shattered rock form a "muck pile" in front of the blast site from where it is loaded into haul trucks and transported to a crushing and screening plant for processing. Sometimes rock fragments are thrown beyond the muck pile or behind blast sites and the mechanisms for this are discussed in the following section.

The furthest throw in front of a blast occurs within a 90° arc perpendicular to the face and consists of 100-200mm diameter fragments launched at a 45° angle. Smaller fragments are not thrown as far due to wind resistance and the distance larger fragments may be thrown is limited by their mass.

The furthest throw behind and to the sides of a blast consists of small fragments of ejected stemming material (10-14mm aggregate) or loose rock from around hole collars. These fragments are launched at the blast hole angle (typically 10° from vertical) and may disperse a further ± 10°. Due to the smaller size of fragments, shorter throw distance, steep launch angles and lower velocities on landing, rock fragments thrown behind blast sites generally present a lower risk of serious injury to people than the risk posed by flyrock in front of a blast.

10.2.1 Causes of Flyrock

Excessive flyrock throw is usually the result of human error where insufficient or incompetent face burden (under-burdening) is not identified, or one or more blast holes have been loaded with an inadequate quantity of stemming to contain the explosives energy. Under-burdening is normally identified by laser face profiling and Boretrak surveys and this is undertaken prior to all blasting at Colac Quarry.

Excessive flyrock may also occur from unidentified weaknesses in the rock mass where cavities, clay seams, wide joints or pockets of loose, naturally fragmented rock compromise the confinement of explosives energy. Potentially weak areas of blast faces are identified through thorough visual inspection by shotfirers who are familiar with the characteristics of the rock structure. Driller's logs, where the behaviour of the drill bit is recorded by the rig operator, may also identify cavities, clay seams and areas of weak rock structure. These records are carefully reviewed as part of the blast design process. Where under-confinement is identified or suspected, affected blast holes are loaded with reduced charge mass and in some cases entire blast holes may be left unloaded.

10.2.2 Flyrock from Stemming Ejections

Flyrock thrown behind and to the sides of the face is typically an ejection of stemming material and loose collar rock that is caused by under-stemming or the use of inappropriate stemming material. Appropriate stemming material consists of quality aggregate of a size at least 1/10th the diameter of the blast hole. 10-14mm aggregate is optimal for 89mm blast holes and is used for all blasts at Colac Quarry.

The standard industry practice of reviewing face profiles, driller's logs, visual face inspection and appropriate treatment of under-confined blast holes is effective for preventing excessive flyrock and these procedures are undertaken for all blasting at Holcim Colac Quarry. The remaining risk posed by unexpected, excessive flyrock is mitigated by establishing appropriate clearance zones at blast times.

10.2.3 Blast clearance zones

Terrock recommends minimum blast clearance distances that observe safety factors based on throw calculations. This approach has been adopted at numerous mines and quarries around Australia and overseas and is proven to be effective. The minimum safety factors Terrock recommends for blast clearance at hard rock quarries are;

- Safety Factor 2 – Quarry Plant and Equipment
- Safety Factor 4 – Quarry Personnel and Public areas

Under this approach, the minimum clearance distances for standard specification blasts in the Northern Development Area are:

	Front of Face	*Behind Blast*
Maximum Throw	**40m**	**38m**
S.F. 2 – Plant & Equipment	80m	76m
S.F. 4 – Quarry Personnel & Public	160m	152m

Because both throw distances are similar, a radial clearance zone based on a potential 40m throw in all directions provides a simple approach. The recommended minimum clearance zones are shown in **Figure 16a**.

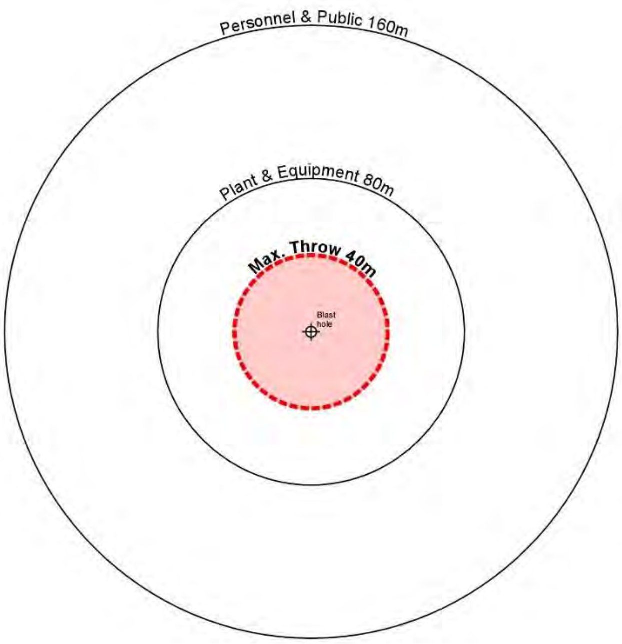

Figure 16a – Recommended minimum clearance zones (standard blasts)

The clearance distances apply from every blast hole and the overall area will be larger and wider than that shown above. For a blast with a surface area of 50 x 20m, the clearance area would take a similar form to that shown in **Figure 16b**.

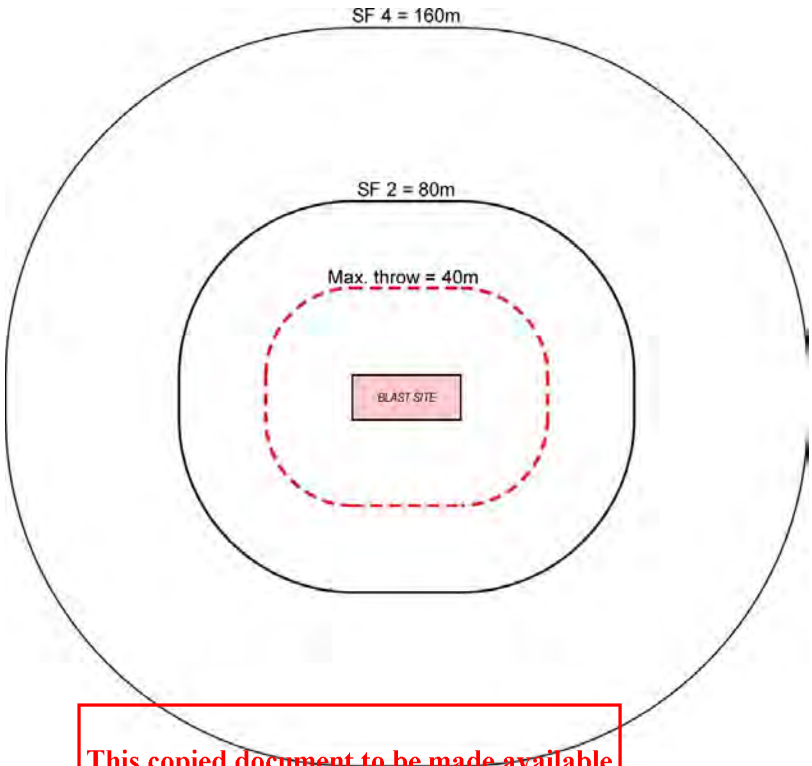

Figure 16b – Extent of clearance zone around a blast site

The clearance zones should be regarded as strictly minimum distances for determining safe locations for blast-related personnel including the shotfirer, blast crew and blast guards. All other quarry personnel and people should be evacuated to more distant locations as far from the blast site as practical.

Establishing blast clearance in the Northern Development Area would be relatively straight forward because workshops, offices, weighbridge and processing plants are not proposed (it is understood that distant infrastructure at the existing quarry would be maintained for future operations).

Providing adequate clearance around blast sites is ultimately the responsibility of shotfirers and standard provisions may require the approval of workplace safety regulators. Shotfirers should aim to provide as much clearance as can be practically achieved without causing unnecessary inconvenience to people in the wider area. Standard clearance may be increased by the shotfirer at any time on consideration of each blast’s design, location, modified hole loadings, the potential for under-confinement and previous flyrock observations. Standard provisions must be reviewed prior to every blast as part of a pre-blast risk assessment and in line with quarry’s Blast Management Plan.

10.2.4 Blast clearance outside the quarry

To provide a minimum flyrock safety factor of 4 in areas outside the quarry, blast sites less than 160m from the Work Authority boundary would require clearance on limited areas of adjacent land. This includes neighbouring areas of adjacent properties to the north, east and west. Blasts notification should be given to affected land holders at least 48 hrs prior to blast time and information on blast clearance and firing procedures should be provided. Clearance zones on neighbouring land can be secured by positioning blast guards at the boundary with a clear view of the surrounding area and a UHF radio for communicating with the shotfirer. In accordance with Dangerous Goods (Explosives) Regulations, no blast may be fired until the shotfirer receives multiple confirmations from all blast guards that the surrounding area is clear and it is safe to fire the blast.

Brief closures of Ondit-Warrion Road and/or Rattrays Road would be required where the road reserves fall within a clearance zone. This includes Rattrays Road for Stage 1 blasts, and Rattrays/Ondit-Warrion Roads for blasts the southern areas of Stages 1-4. There is a low number of vehicle movements on these roads each day and 5 minute road closures would cause minimal inconvenience to road users. ERR have recently advised that, "*blasting is unlikely to be approved within 200m of a freeway or 100m from a public road*". Terrock recommends road closures for all blasts within a minimum 100m of the road reserves though this may need to be increased on consideration of rock structure and flyrock observations. Procedures for road closures would require the approval of regulators including ERR, WorkSafe Victoria, Colac Otway Shire, and conditions should be detailed in the quarry's Blast Management Plan.

10.3 RISK TO INFRASTRUCTURE

From research and experience, the risk to buried pipelines and surface infrastructure from quarry-scale blasting is considered by Terrock and other researchers to be low. Despite increasing caution and concern by asset owners, there are very few instances worldwide in which blasting effects are known to have caused damage to nearby infrastructure.

PPV limits ordered by asset owners are typically conservative and presumably incorporate several factors of safety. They are "safe" (i.e. non-damaging) limits and most infrastructure can tolerate considerably higher levels of blast vibration without damage or adverse effects. The infrastructure near the Colac Quarry services a limited number of local properties and is considered by their respective owners to be non-critical. Early blasting at the existing quarry was conducted as close as 20m from the AC pipeline and power poles without any evidence of damage occurring.

By complying with PPV limits and other conditions ordered by asset owners, the risk to infrastructure from the proposed blasting is regarded to be low. Modified blasting, including progressive charge mass reductions as guided by the results of blast monitoring, will ensure compliance with conservative PPV limits will be achieved (see **Section 9**). In the highly unlikely event that damage to the non-critical infrastructure occurs, Holcim will be liable for remedial works as specified in formal agreements between quarry management and asset owners.

10.4 RISK OF DAMAGE TO BUILDINGS

Blasting is commonly believed to be the cause of cracks and other defects that develop in all buildings over time. While ground vibration and airblast at very high levels can be damaging to buildings, research shows PPV and airblast at regulated levels (i.e. human comfort levels) are non-damaging to light-framed, residential type dwellings. Guidance on PPV and airblast limits used for preventing damage to buildings can be found in criteria in AS2187.2-2006 and overseas standards.

A criterion commonly used to prevent threshold/cosmetic damage is from British Standard BS7385.2-1993 which is reproduced in the Australian Standard. At the dominant ground motion frequencies of >10 Hz that occur from blasts at Colac Quarry, a conservative PPV limit of 18 mm/s is recommended to prevent threshold/cosmetic damage. This damage limit is more than 3 times greater than both the ERR regulatory limit of 5 mm/s and the maximum PPV levels predicted to occur at sensitive sites. British and USBM damage criteria from AS2187.2-2006 are shown in **Appendix 3**.

The most sensitive building element to airblast are glass window panes. A conservative airblast limit from the Australian Standard is 133 dBL though the Standard notes that damage from levels <140 dBL is "*improbable*". For blasts in the Northern Development Area, airblast levels above 140 dBL would only occur within 100m from blast sites and the risk of damage to more distant buildings in the wider area is negligible.

10.5 UNOCCUPIED AND DILAPIDATED HOUSE WEST OF THE QUARRY

A small, unoccupied house (**Figure 17**) is located approximately 298m west of the Northern Development Area extraction limit (as shown in **Figure 1**). The house has not been inspected by Terrock though it is known to be dilapidated and is presumed to be unfit for human habitation.

Figure 17 – Unoccupied and dilapidated house on Ondit-Warrion Road

At the minimum distance of 298m, the maximum PPV levels at the house from the closest blasting are predicted to be 7.6 mm/s (17.4m face) to 4.5 mm/s (10m face). This range of levels is mostly above the ERR human comfort limit of 5 mm/s.

In its current state the house does not meet the ERR definition of a *"sensitive site*" with respect to human comfort. If the house is reoccupied in the near future and designated as a sensitive site by the regulator it would be in Holcim's interests to pursue avenues to remove the building. Otherwise, to maintain compliance with the 5 mm/s limit at the house it would be recommended that Stage 1 blasts have face heights not exceeding 10m (i.e. MIC ≤60kg).

The risk of blast vibration damage to the dilapidated house has not been assessed in detail. While the predicted PPV levels are below levels at which threshold/cosmetic damage is known to occur in competent buildings, structurally unsound buildings in an advanced states of dilapidation can be more sensitive to strong ground motions. If blast "damage" was to occur it would likely be expressed as some growth of existing cracks in plasterboard, sheet-join, cornice and cladding separations. Ground motions from quarry-scale blasting are highly unlikely to cause major-structural damage or the sudden collapse of an old and dilapidated building unless the structure is already in a state of imminent collapse. The reason buildings in poor condition can be more susceptible to blast damage is that they are already structurally compromised and their components are under continuous stress/strain from natural loading to a point of failure.

There is negligible risk of airblast damage to the house where maximum airblast levels behind/side of the closest blasts is 123 dBL (17.4m face) to 120 dBL (10m face).

10.6 RISK TO AMENITY

The question of the impact of blasting on local amenity is highly subjective and people living within a few kilometres of quarries will show a wide range of responses from complete disinterest to high levels of concern. From experience, nearly all quarries receive the occasional blasting complaint and the number of complaints is broadly proportionate to the size of the population in the surrounding area.

While the potential for blast complaints typically increases where PPV levels above 2 mm/s occur, some people show intolerance to any perceptible level of blast vibration. People object to blasting for a variety of reasons, most commonly a belief that blasting causes damage to property. Aside from the occasional complaint, the majority of residents living within a few kilometres of the existing operation appear to be tolerant of blasting.

The impact to amenity from blasting at the proposed Northern Development Area is considered by Terrock to be generally low. Consideration is given to;

- the relatively low number of blast-related complaints Colac Quarry has received during its operation.
- the relatively small number of people living with 1km of the quarry where blast vibration is most perceptible.
- the relative infrequency of blasting with a maximum of 2 to 3 blasts per month.
- ground vibration, airblast and noise effects are limited to around 5-8 seconds per blast.
- blasting effects cause no lasting change to the surrounding environment.

As an extension of the existing quarry operation, the net effects of proposed future blasting are;

- increased PPV and airblast levels to the north, northeast and northwest
- reduced PPV and airblast levels to the south, southeast and southwest
- additional brief road closures on Ondit-Warrion Road at blast times.

Blast vibration from the Northern Development Area would become more perceptible at Houses 1 - 4 and thereby the potential for resident concerns or complaints at these locations is increased. Should the proposal be approved, engaging with these residents and providing details of the proposal, potential blasting effects, progress updates and other information is recommended before blasting commences.

Brief road closures would be required for blasts in the southern and western areas of the extension and this could inconvenience or annoy some local residents. However, Ondit-Warrion Road is not a busy thoroughfare and the number of people affected would be minimal.

While the question of blasting and amenity is subjective, quarry operators can help improve community perceptions of blasting by engaging with residents to listen to concerns and provide information about quarry activities and environmental performance. Blast notifications prior to blast days can also help prevent startling, where people may become annoyed when a blast occurs unexpectedly. Under existing operations, personal blast notifications are provided to subscribing residents and this would be continued into the future.

10.7 RISK TO DOMESTIC AND NATIVE ANIMALS

There is no evidence that quarry blasting alone has adverse effects on the health and wellbeing of nearby animals and Terrock is unaware of any research that suggests otherwise. From many years of observation, dairy cattle located on properties adjacent to the Holcim Colac Quarry (and other mines and quarries) show no notable response to blasting and there are no reports of animal welfare or milk production being affected. As a precaution, any cattle located within a blast clearance zone should be moved to a more distant area during blast times.

Household pets also show little or no interest to ground vibration and airblast at regulated levels. Some dogs bark during blasting though this has shown to be in response to blast warning sirens that are sounded during the blasting procedure.

The effect of blast vibration on native species is also negligible and work authorities with active quarries are inhabited by species found in the wider area. A notable population of water birds can be found on the large pond in the worked out northwest area of the quarry close to active blasting areas. Swallows are common around the quarry and have been observed nesting on terminal faces. The only observed short-term effect is shown by birds located within around 100m from blast sites that normally take flight before returning to the area shortly after when the perceived danger has passed. The response of birds to quarry blasting is the same as that any bird exposed to a sudden, loud, nearby noise though blasting at quarries occurs too infrequently to result in birds permanently leaving an area.

10.8 RISK TO THE STABILITY OF TERMINAL FACES AND BATTER SLOPES

It was requested that the risk of blast vibration to the stability of terminal batters in the existing quarry be considered due to their proximity to the Northern Development Area.

Blasting at Colac Quarry commenced in the northwest corner of the Work Authority in the early 1990s and the existing batter in this area was formed around 30 years ago. Terminal blasts from current operations in the northeast area (Stage 6) will extend the batter to the full length of northern extraction limit over coming years.

There is no evidence that suggests the northern batter is at risk of structural failure due to vibration from blasting. Ground vibration from blasting is not considered a risk to the stability of batters generally because the area of permanent ground deformation is limited to a few metres around each blast hole. Beyond the fracture zone, ground vibration waves are elastic and the ground returns to its original position after the vibration wavefronts have passed.

The closest blasts in the proposed Northern Development Area would be a minimum distance of 60m from the northern batter of the existing quarry. From the PPV model [2], the maximum ground vibration level at this distance is 80.9 mm/s though actual levels may be substantially lower due to the modified blasting zone indicated near the southern extraction limit.

Consideration is also given to the terminal blasts that form the foundations of batter slopes. Terminal faces are exposed to PPVs of several thousand mm/s from the back row holes of terminal blasts without being compromised. At some quarries, localised geology and ground conditions can result in unstable batter sections or faces. However, this is due to the loss of lateral support from the creation of a void, not as a result of ground vibration from blasting.

It is reasonably concluded the risk of blasting in the Northern Development Area to terminal batters in the existing quarry (or elsewhere) is negligible. Existing terminal faces and batters have been exposed to significantly higher PPVs from adjacent and close-proximity blasts without any effect to their structural integrity, and blast vibration is not known to be a cause of batter or slope failure at quarries generally.

11 RISK ASSESSMENT

The blasting risks discussed in the previous section have been rated in accordance with the ERR Risk Matrix (**Figure 18**) as shown in the document *Preparation of Work Plans and Work Plan Variations – Guideline for Extractive Industries* (October 2020). Risks are rated as Low, Medium, High or Very High by consideration of their likelihood and potential consequence.

Likelihood		Insignificant	Minor	Moderate	Major	Critical
	Almost Certain	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	High	High
	Rare	Low	Low	Medium	Medium	High
		Consequence				

Figure 18 – ERR Risk Matrix

The risks pertain to potential hazards to people, property and the environment in areas outside the quarry. The risk posed by flyrock to quarry personnel has also been assessed. The risks and controls associated with transport, storage and handling of explosives should be detailed in a quarry's Blast Management Plan, plans for individual blasts and risk control documents provided by the explosives supplier.

The blasting risks, their likelihood and consequence ratings, based on experience and interpretation of the risk matrix, are summarised below.

The risks from blasting in proposed extension would be mitigated by adopting the control measures outlined in **Table 8**. It should be noted that most of these measures are industry standard controls that are observed Colac Quarry as part of normal blasting practice. Further details of blasting controls and general blasting and clearance procedures should be detailed in a quarry's Blast Management Plan.

Table 8 – Risk rating and control measures for blasting impacts

RISK	INHERENT RISK RATING	RISK CONTROL MEASURES	RESIDUAL RISK RATING
FLYROCK (Risk to Quarry Property and Personnel)	**VERY HIGH** Likelihood **POSSIBLE** Consequence **CRITICAL**	*Implement standard controls including…* - Laser Face Profiling & Boretrak survey. - Visual inspection of blast site and review of drill log/survey results to identify structural weaknesses and guide individual blast hole loading requirements. - Ensure minimum stemming specifications in all blast holes. - Review hole loading records including modifications. - Blasts to be inspected and signed off by authorised person. - Clearance Zones enforced inside quarry and evacuation of site personnel to designated areas (i.e. existing quarry to South). - Flyrock observations noted and video recording of blasts for ongoing performance review.	**HIGH** Likelihood **UNLIKELY** Consequence **CRITICAL**
FLYROCK (Risk to Private Property and Public)	**HIGH** Likelihood **UNLIKELY** Consequence **CRITICAL**	- Adhere to standard flyrock control measures (see above). - Configure extraction for blasts near extraction limit to face away from closest boundary. - Additional stemming (i.e. 3.0m → 3.8m) loaded in blast holes within 40m of WA boundary. - Clearance Zones (i.e. Safety Factor 4) established on adjacent properties. - Traffic control established on Ondit-Warrion Rd (as per Work Plan conditions). - Flyrock observations noted and video recording of blasts for ongoing performance review.	**MEDIUM** Likelihood **RARE** Consequence **MAJOR**
INFRASTRUCTURE	**MEDIUM** Likelihood **UNLIKELY** Consequence **MODERATE**	- Adhere to standard flyrock control measures (see above) - Maintain compliance with asset owner's conditions for blasting - Design blasts with reduce charge mass (MIC) as required to minimise PPV levels at infrastructure.	**LOW** Likelihood **RARE** Consequence **MINOR**
BLAST VIBRATION DAMAGE TO BUILDINGS	**MEDIUM** Likelihood **UNLIKELY** Consequence **MODERATE**	- Maintain Compliance with ERR Ground Vibration & Airblast Limits at sensitive sites; <5 mm/s <115 dBL - Investigate damage claims in a timely manner	**LOW** Likelihood **RARE** Consequence **MINOR**

Table 8 (continued)

RISK	INHERENT RISK RATING	RISK CONTROL MEASURES	RESIDUAL RISK RATING
AMENITY	**HIGH** Likelihood **LIKELY** Consequence **MODERATE**	- Maintain Compliance with ERR Ground Vibration & Airblast Limits at sensitive sites, as confirmed by blast monitoring. - Modify blast designs, if or where needed to reduce PPV and airblast levels at the closest sites as far as practical. - Provide blast notifications to subscribing residents, maintain quarry's Complaints Register and follow up concerns in a timely manner. - Engage community with quarry and blasting information upon request.	**MEDIUM** Likelihood **POSSIBLE** Consequence **MODERATE**
NATIVE AND DOMESTIC SPECIES	**MEDIUM** Likelihood **POSSIBLE** Consequence **MINOR**	- Maintain Compliance with ERR Ground Vibration & Airblast Limits at sensitive sites, as confirmed by blast monitoring. - Implement standard flyrock controls.	**LOW** Likelihood **RARE** Consequence **MINOR**

12 BLAST MONITORING & COMMUNITY ENGAGEMENT

12.1 GROUND VIBRATION AND AIRLBAST MONITORING

Blast monitoring requirements for quarries vary depending on the nature of the operation and community attitudes to blasting. At Holcim Colac Quarry, blast monitoring has been conducted by independent consultants at three routine monitoring locations for every blast fired since the mid-1990s.

It is important to monitor blast vibration at or near the closest sensitive site(s) to assess compliance with ERR guideline limits. If access is not provided by a landowner or resident, data can be obtained on nearby public land in a similar direction and distance from the blast. For blasting in the proposed Northern Development Area, monitoring is recommended at or near the closest sensitive sites to the west (Houses 1 and 2).

Blast monitoring at Gnarwyn should continue in order to maintain the record of blast vibration levels at distances >1.5km. Monitoring at the Primes property is not warranted due to the increased separation distance (>1km) and the cordial relations between Holcim and the property owner. Additional monitors can be installed at other sites on an as-needed basis in response to resident concerns.

It should be noted that routine blast monitoring is undertaken at the AC pipeline for blasts within Stage 6 area of the existing quarry under order of Barwon Water. These measurements can be used to assess compliance with the higher 100 mm/s limit for power poles located in the pipeline easement.

Recommended future blast monitoring locations for the Northern Development Area are shown on **Figure 1**. Blast monitoring and reporting requirements for quarries are subject to approval from the industry regulator and conditions may be specified in approved Work Plans.

12.2 FLYROCK MONITORING

Flyrock is primarily monitored by visual observation and video recording of blasts. If an excessive flyrock event occurs it is important that the maximum throw distance is measured to assist with investigation.

Video recording is a routine part of blast monitoring and can assist with the ongoing assessment of blast performance or investigations into the cause of high airblast emissions and flyrock. Video recording of all blasts is undertaken at Colac Quarry as part of routine blast monitoring procedure and would continue in the Northern Development Area.

12.3 BLAST NOTIFICATIONS

Holcim currently offers personal blast notifications for people living near their quarries to inform residents of blasting dates and firing times and prevent startling. This would be continued for residents near future operations at Colac Quarry.

12.4 MANAGING COMPLAINTS

Maintaining the quarry's register of complaints and community feedback, recording time, date, the name and location of the complainant and nature of the compliant will help inform management of potential issues and resident concerns that should be addressed. While airblast and ground vibration levels from blasting would be non-damaging to buildings, any claims of damage to property that arise should be investigated by quarry management and/or experienced independent consultants in a timely manner.

13 CONCLUDING COMMENTS

The conclusion of this assessment is that blasting in the proposed Northern Development Area can be conducted in accordance with regulatory criteria and the conditions of infrastructure authorities. If PPV levels, airblast levels or flyrock throw exceed the conservative predictions of this assessment at any stage, there are several methods that quarry management can implement to maintain compliance, primarily through charge mass reductions and increased stemming height. Quarry management must ensure that appropriate blast designs are used in extraction areas closest to sensitive sites and infrastructure. The need to modify blast designs would ultimately be guided by the results of routine blast monitoring.

It is important to note that the maximum predicted PPV and airblast levels refer to blasts with a face height of 17.4m and MIC of 115.5kg. The majority of blasts are unlikely to have 17.4m faces, and shorter faces with reduced charge masses would apply across most of the extraction area resulting in lower PPV and airblast levels. Therefore, the maximum levels presented in this assessment are worst-case levels. It should also be noted that peak levels indicated at sensitive sites and infrastructure apply to the closest blasts at the extraction limit with lower levels occurring from more distant blasting.

PPV and airblast levels would increase (from current levels from existing operations) at the closest sensitive sites to the west and north. Blast vibration would become more perceptible at these dwellings and depending on the attitudes of residents there is a potential for blasting concerns or complaints to arise at some time in the future. Quarry management is advised to establish and maintain lines of communication with affected residents, provide information, blast notifications and address concerns in an appropriate, timely manner. This approach can help mitigate perceptions of amenity being adversely affected by blasting. PPV and airblast levels at sensitive sites south of Ondit-Warrion Road would be reduced from current and previous levels from the existing quarry.

Blasting must also comply with conditions ordered by infrastructure authorities as part of agreements made between quarries and asset owners. Holcim have recently made an agreement with Barwon Water in relation to blasting conditions at the AC pipeline easement for blasts occurring within the Stage 6 area of the existing quarry. While quarry blasting near power poles and lines is considered by Terrock to present a low risk of damage, management must also adhere to any conditions imposed by Powercor.

Excessive flyrock is prevented by standard procedures including laser profiling, careful attention to drillers logs and the structure of blast faces. The normal throw distance of rock fragments behind and to the sides of blast sites can be reduced by increasing stemming height as would be required for blasts at/near the extraction limit. The risk posed by excessive flyrock is significantly reduced by establishing appropriate clearance zones at blast times. Blast clearance is wholly the responsibility of both the shotfirer and the quarry manager, and the adequacy of standard provisions must be reviewed by the shotfirer prior to every blast on consideration of blast hole confinement and rock structure.

[redacted]

8 December 2021

14 REFERENCES

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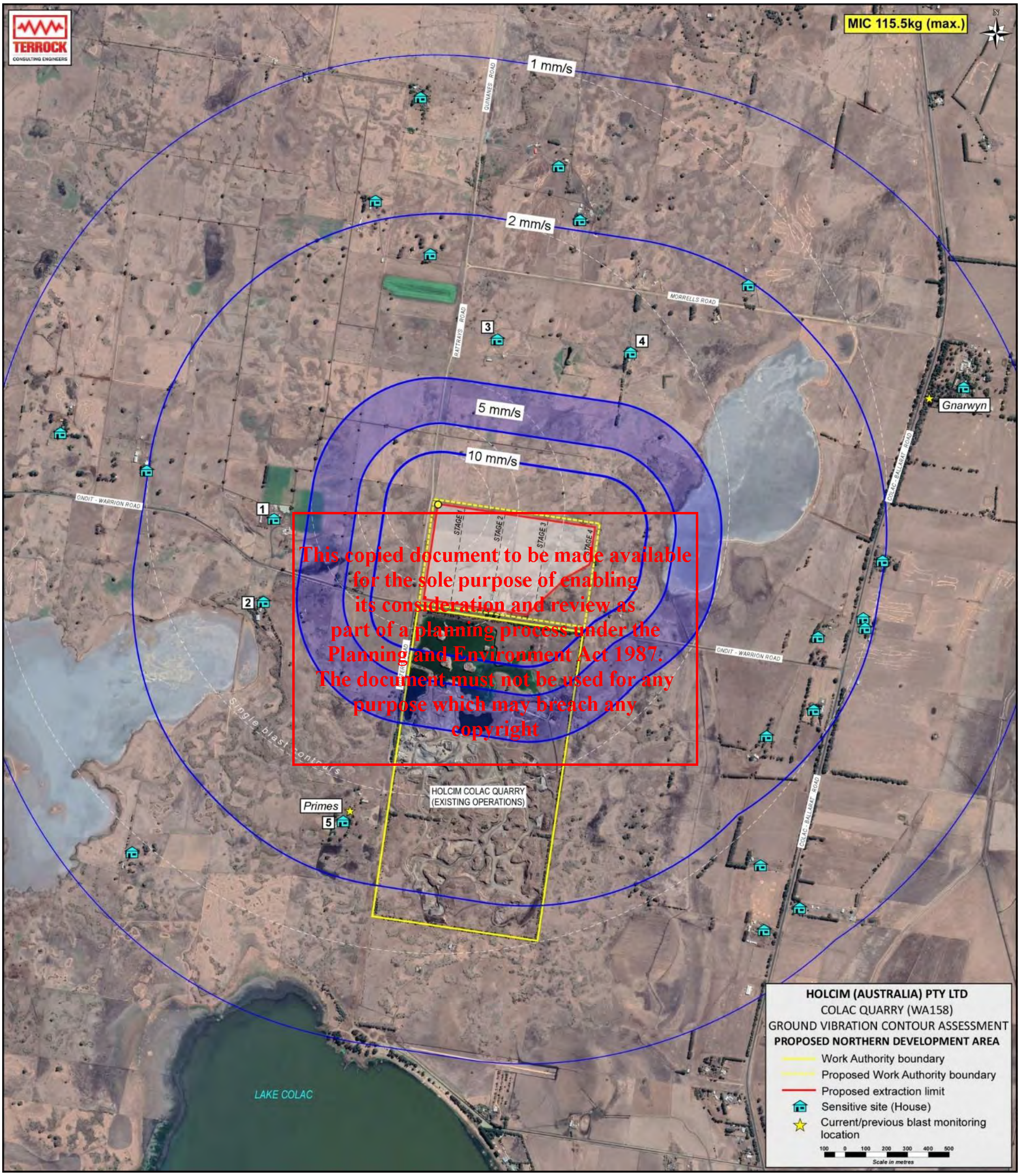
APPENDICES


TERROCK
CONSULTING ENGINEERS
MIC 115.5kg (max.)
1 mm/s
2 mm/s
5 mm/s
10 mm/s
QUINANES ROAD
RATTRAYS ROAD
MORRELLS ROAD
ONDIT - WARRION ROAD
COLAC - BALLARAT ROAD
STAGE 1
STAGE 2
STAGE 3
STAGE 4
1
2
3
4
5
Primes
Gnarwyn
Single blast contours
HOLCIM COLAC QUARRY
(EXISTING OPERATIONS)
LAKE COLAC
HOLCIM (AUSTRALIA) PTY LTD
COLAC QUARRY (WA158)
GROUND VIBRATION CONTOUR ASSESSMENT
PROPOSED NORTHERN DEVELOPMENT AREA
Work Authority boundary
Proposed Work Authority boundary
Proposed extraction limit
Sensitive site (House)
Current/previous blast monitoring location
Scale in metres

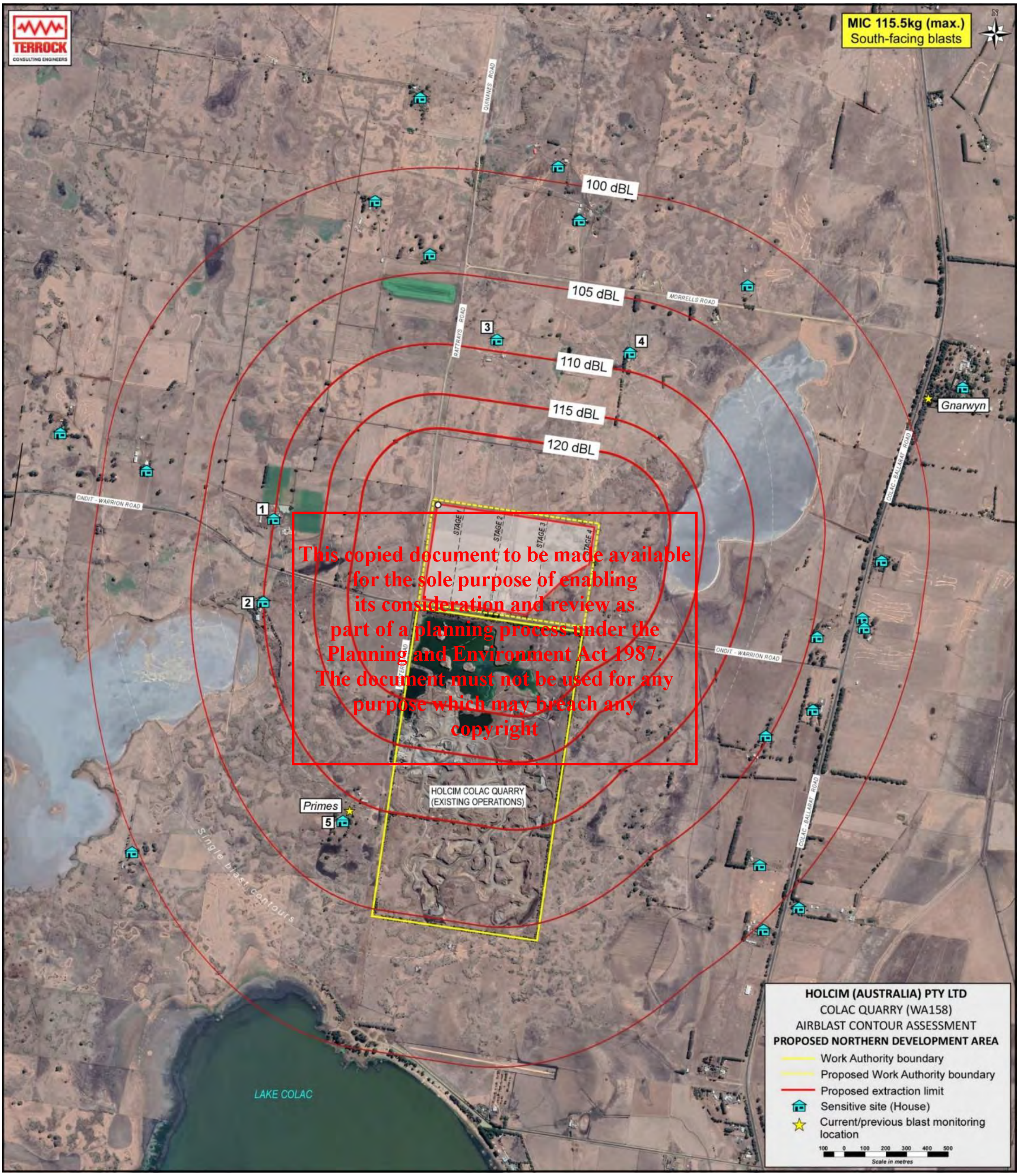

TERROCK
CONSULTING ENGINEERS
MIC 115.5kg (max.)
South-facing blasts
100 dBL
105 dBL
110 dBL
115 dBL
120 dBL
MORRELLS ROAD
RATTRAYS ROAD
ONDIT - WARRION ROAD
COLAC - BALLARAT ROAD
STAGE 1
STAGE 2
STAGE 3
STAGE 4
Gnarwyn
Primes
1
2
3
4
5
HOLCIM COLAC QUARRY
(EXISTING OPERATIONS)
Single blast contours
LAKE COLAC
HOLCIM (AUSTRALIA) PTY LTD
COLAC QUARRY (WA158)
AIRBLAST CONTOUR ASSESSMENT
PROPOSED NORTHERN DEVELOPMENT AREA
Work Authority boundary
Proposed Work Authority boundary
Proposed extraction limit
Sensitive site (House)
Current/previous blast monitoring location
Scale in metres

TABLE J4.5(B)

RECOMMENDED GROUND VIBRATION LIMITS FOR CONTROL OF DAMAGE TO STRUCTURES (see Note)

Category	Type of blasting operations	Peak component particle velocity (mm/s)
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency-dependent damage limit criteria Tables J4.4.2.1 and J4.4.4.1
Unoccupied structures of reinforced concrete or steel construction	All blasting	100 mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables	All blasting	Limit to be determined by structural design methodology

NOTE: Tables J4.5(A) and J4.5(B) do not cover high-rise buildings, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations, which may necessitate taking additional measurements on the structure itself, to detect any magnification of ground vibrations that might occur within the structure. Particular attention should be given to the response of suspended floors.

TABLE J4.4.2.1

TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)

Line	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

NOTES:

1 Values referred to are at the base of the building.

2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

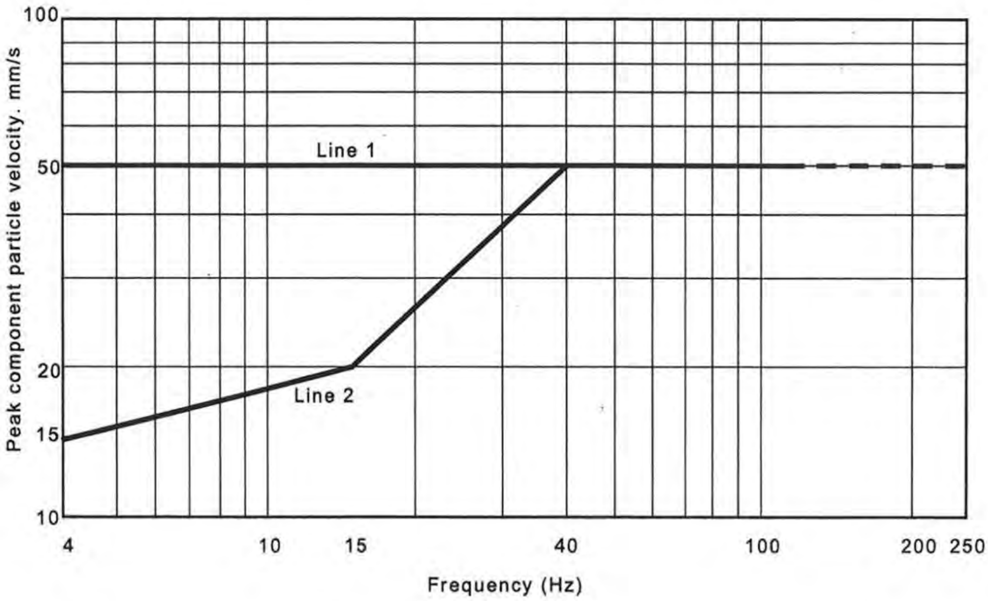


FIGURE J4.4.2.1 TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)

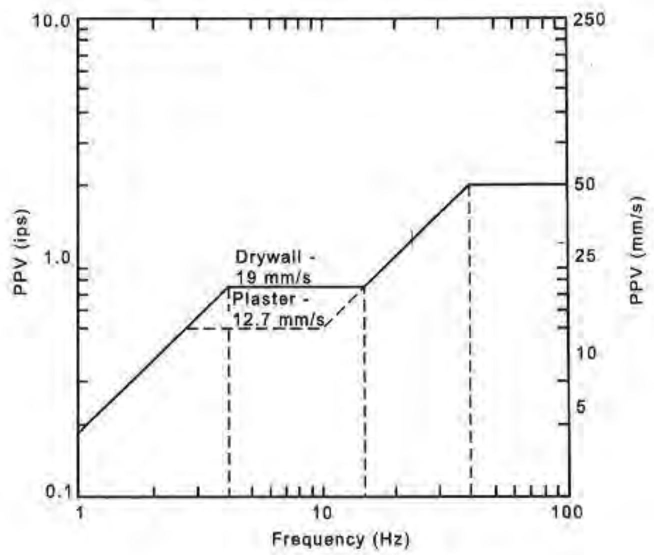


FIGURE J4.4.2.2 USBM 'SAFE' BLASTING VIBRATION LEVEL CRITERIA

USBM damage classifications are shown in Table J4.4.2.3.

TABLE J5.4(B)

RECOMMENDED AIRBLAST LIMITS FOR DAMAGE CONTROL (see Note)

Category	Type of blasting operations	Peak sound pressure level (dBL)
Damage control limits		
Structures that include masonry, plaster and plasterboard in their construction and also unoccupied structures of reinforced concrete or steel construction	All blasting	133 dBL maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables located above the ground	All blasting	Limit to be determined by structural design methodology

NOTE: Tables J5.4(A) and J5.4(B) are intended to be informative and do not override statutory requirements, particularly with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions.