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PLANNING PANELS VICTORIA

AMENDMENT C241 WSEA – CITY OF WHITTLESEA PLANNING SCHEME SHENSTONE PARK PRECINCT STRUCTURE PLAN

EXPERT WITNESS STATEMENT – QUARRY BLASTING (FOR BARRO GROUP PTY LTD)

Adrian J. Moore

ABOUT THE AUTHOR

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Qualifications and experience

Adrian Moore is an engineer with civil and mining qualifications and a background in blasting, blast vibration control, structural response and environmental planning.

After graduating from the Preston Technical College in 1966, he gained surveying, grade control, blasting engineering and supervisory experience at various open cut and underground mines throughout Australia, in addition to municipal engineering experience. In 1983 he completed a Mining Conversion course at Ballarat College of Advanced Education and was awarded a Bachelor of Engineering (Mining).

From 1983 to 1988 he was involved in several mining projects in Central Victoria involving assessment and rehabilitation of old mines, as well as conducting blasting and mining related courses at the Loddon Campaspe College of TAFE and the Bendigo College of Advanced Education.

In 1988 he joined the Terrock Consulting Engineering practice, specialising in blasting, vibration measurement and control, and environmental planning and management. His work has included blast and construction vibration measurement and control, structural damage assessment, environmental planning and the development of expert Blast Vibration Assessment Systems.

In 1992 he was appointed as Technical Director and Principal Engineer of Terrock Consulting Engineers, and in 1997 was awarded a Mining Engineering (Science) Degree from the University of Melbourne after completing a thesis entitled "*Factors Influencing Ground Vibration Caused by Blasting*".

Since then he has a continual involvement in projects throughout Australia and abroad in the preparation of Effects of Blasting reports, solving blast and construction vibration problems, structural damage investigations and has co-written many papers on blasting matters including ground vibration, airblast, flyrock, structural response and damage. Adrian is currently studying for a PhD at the University of Melbourne.

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James Richards has over 20 years experience with Terrock Pty. Ltd. providing blast monitoring and technical services to numerous mine and quarry operators, data processing and analysis, technical and compliance report production, and providing general assistance to Terrock's engineers. James is a licenced shotfirer and holds certificate level qualifications in geospatial information systems, and workplace training and assessment. His contribution to this statement included forwarding relevant documents to the author, word processing and the preparation of diagrams, graphs, site plans and contour assessments to the author's specifications.

Contents

APPENDICES

1 INTRODUCTION

1 The author (Mr. Adrian Moore, Principal Engineer, Terrock Pty. Ltd.) was requested by Leon Ponte (PONTE Business Lawyers for Business) to prepare an expert witness statement to consider, as appropriate;

A. *The appropriateness of the blasting buffers (see Plan 15 – Buffers of the PSP) for the Woody Hill and Phillips Quarries* [including a proposed extension of the Woody Hill Quarry extraction area to the south and an expansion of operations under adjacent Work Authority WA6437].

B. *The appropriateness of the "blast restriction area" to the "proposed water treatment facility" on Plan 15 – Buffers of the PSP and what management strategies and timing arrangements may be able to be put in place to allow both stone extraction and the water treatment facility to occur in proximity to each other.*

2 *Plan 15 – Buffers, Noise Amenity Area and Measurement Length* is shown as Page 51 of the *Shenstone Park Precinct Structure Plan* (September 2019) produced by the Victorian Planning Authority and City of Whittlesea. Plan 15 in the October 2020 version of the *Shenstone Park Precinct Structure Plan* circulated by the Victorian Planning Authority has also been considered. The comments below refer to the September 2019 version, but the effect of the Author's Conclusion in Section 14 below apply to both the September 2019 and October 2020 versions.

3 The issues of audible noise and dust from whole quarry operations (including blasting), and appropriate buffers to minimise impacts on surrounding land uses are outside the author's expertise.

2 EXISTING AND PROPOSED QUARRY OPERATIONS

4 There are three existing or proposed Work Authorities (WAs) within and adjacent to the Shenstone Park Precinct.

- WA492 - Woody Hill Quarry (existing quarry operation plus a proposed extension of the extraction area to the south)
- WA6437 – Woody Hill Quarry (proposed northern operations to adjoin WA492)
- WA6852 – Phillips Quarry (proposed operation adjacent to the southern boundary of the Shenstone Park Precinct)

5 A corridor between WA492 and WA6852 is proposed. Rock extracted at Phillips Quarry would be processed on site then sent to WA492 for stockpiling, onsite use or sale via the existing quarry's Donnybrook Road entrance. No blasting is required within this corridor.

6 All three Work Authorities are under ownership of Barro Group Pty. Ltd. and development of WA6437 and WA6852 as hard rock quarries is currently under application. An expansion of the current approved extraction area under WA492 is also being sought.

7 The current and proposed Work Authority boundaries are not shown on Plan 15 and the quarrying and extraction areas shown in the Precinct Structure Plan (PSP) dated September 2019 do not appear to be accurate. The proposed extraction area under WA6437 is also not shown.

3 QUARRY BUFFERS OF THE PSP

8 Two separate buffers pertaining to blasting impacts are shown for existing and proposed future quarry operations. The buffers are based on the findings of a Quarry Impact Assessment report and addendum produced by GHD for City of Whittlesea. The buffers appear to correspond to quarry extraction/blasting areas rather than the Work Authority boundaries, an approach considered by the author to be appropriate.

9 The buffers and their extents are shown on Plan 15 as;

- Woody Hill blast buffer (200m)
- Woody Hill sensitive use buffer (550m)
- Phillips blast buffer (200m)
- Phillips sensitive use buffer (550m)

10 The purpose of the buffers are interpreted as follows;

- Blast buffer (200m) – No development to occur within 200m of extraction/blasting areas. This buffer is proposed on consideration of the risk of flyrock (i.e. rock fragments thrown from blast sites).

- Sensitive use buffer (550m) – No sensitive land uses (i.e. residences, schools, hospitals, etc.) to be developed with 550m of extraction/blasting areas. This buffer is in consideration of minimising ground vibration levels from blasting at sensitive receptors and is based on blast impact modelling and guideline blast vibration limits shown in the GHD report.

11 The PSP allows for the development of non-sensitive land uses (industrial and commercial activities and premises) in the 350m wide area between blast buffers and sensitive use buffers.

4 BLAST RESTRICTION AREA

12 A water treatment facility is proposed to be developed on adjacent land south and west of the existing Woody Hill Quarry. An area shown near the southeast corner of WA492 is marked on Plan 15 as a "blast restriction area" with reference to PSP Guideline G64 where "*Extractive operations should be managed within the blast restriction area where shown on Plan 15, to reduce the extent of the blasting buffer in the vicinity of the proposed water treatment facility*".

13 In my opinion the two land uses (quarrying and water treatment) are compatible.

14 The blast restriction area shown on Plan 15 is based on the 200m blast buffer recommended by GHD to mitigate the risk of flyrock around quarry boundaries. In my opinion, this approach is excessive. This buffer appears to be an arbitrary decision without technical or regulatory basis, though this distance was apparently suggested to GHD through discussion with Earth Resources Regulation (ERR) personnel.

15 It is current industry practice to establish radial clearance zones around individual blast sites at blast times and no blast may be fired until the shotfirer receives several confirmations that the clearance area is free of people. Clearance zones need only be established for around 30 minutes on blast days and due to the relative infrequency of quarry blasting (once or twice per month at the existing quarry and up to once per week at Phillips Quarry at full production), a permanent flyrock buffer/clearance zone around quarries is not warranted. Therefore, the blast restriction area is not required and the risk of flyrock can be adequately mitigated under standard industry practice and arrangements for the clearance procedures to be observed at blast times.

16 The blast buffer (on which the "blast restriction area" is based) not only applies to the water treatment plant but is shown around all three proposed work authorities/extraction which would prohibit development of any land within 200m, seemingly for the life of the quarries operations. Because potentially high ground vibration and airblast levels from blasts at or near the extraction limits is more of an issue than the risk presented by flyrock, some transition between the quarry and nearby land use is desirable. Rather than tie up possible development within the 200m buffer area for the life of the quarries, a zoning schedule could be implemented that permits compatible land uses with the proviso that areas within blast clearance zones are evacuated at blast times on request of the shotfirer and quarry manager. Compatible land uses without permanent or sensitive structures that can resist high ground vibration and airblast levels without damage include timber yards, landscape suppliers, etc.

17 More information on ground vibration levels, airblast levels, relevant limits, and flyrock considerations and clearance with respect to the water treatment plant is shown in Section 13.

5 RELEVANT CRITERIA

18 Quarries with blasting are required to comply with ground vibration and airblast (overpressure) limits as a condition for approval of Work Plans. These limits are implemented to help minimise disturbance to sensitive receptors, primarily residents in their homes. 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 interest. Blast monitoring, reporting requirements and monitoring locations for quarries may be subject to approval from the industry regulator or may become a work plan condition.

19 The GHD assessment reports (on which the Plan 15 buffers are based) do not refer to the Victorian extractive industry regulator's ground vibration and airblast limits (and other blasting conditions) that currently apply at hard rock quarries in Victoria. Limits and conditions for quarries are issued under Victorian State Legislation by Earth Resources Regulation (ERR), a branch of the Department of Jobs, Precincts and Regions. The current ERR limits and operating conditions for extractive industries override the various standards and guidelines presented in the GHD report.

20 There is no requirement for blast-related buffer zones around quarry boundaries in ERR guidelines. All quarry operators must comply with the regulatory ground vibration and airblast limits regardless of the separation distance between blasting and sensitive receptors.

21 The PPV (i.e. ground vibration) limit of 2 mm/s presented by GHD on which the 550m sensitive use buffer is based is described as "*a long-term regulatory goal*" sourced from a 1990

publication from the Australian and New Zealand Environment and Conservation Council's (ANZECC) *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration*, *September 1990*. However, a PPV level of 2mm/s does not apply as a regulatory limit for quarries in Victoria. The blast vibration limits and other work plan conditions that currently apply at Victorian quarries are outlined in the following sections.

5.1 Ground Vibration and Airblast limits for Sensitive Sites

22 Current ground vibration and airblast limits for sensitive sites are shown in *ERR Guidelines and Codes of Practice; Ground Vibration and Airblast Limits for Blasting in Mines and Quarries*. 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*."

23 The current ERR blast vibration limits for quarries are based on recommended limits for human comfort from ANZECC (1990) criteria and are:

Ground Vibration:	**5 mm/s PPV** (95% of all blasts) **10 mm/s PPV** (all blasting)
Airblast:	**115 dBL** (95% of all blasts) **120 dBL** (all blasting)

24 The upper limits of 10 mm/s and 120 dBL are provided as an allowance for the occasional, unexpected exceedance of the lower (95%) limits. The upper limits are not observed as a performance target by quarry operators and the lower limits are considered to be the control for all blasting. Exceedances of the ERR limits are subject to investigation and failure to meet compliance may result in penalties for quarry operators.

25 The ERR ground vibration and airblast limits for mines and quarries are based on human comfort considerations and are below levels at which cosmetic damage to light-framed, residential type buildings is known to occur. Criteria commonly used to determine ground vibration and airblast limits to prevent damage to buildings are shown in AS2187.2-2006 Appendix J.

26 It should be emphasised that compliance with the ERR limits at sensitive sites does not prevent blast-related complaints. PPV and airblast levels at the guideline limits are perceptible and some people will complain to the quarry operator and/or the regulator if ground vibration and airblast is "felt". Until houses are constructed and occupied within the PSP, the ERR limits will not apply in areas marked for development.

5.2 Blast Firing Times

27 Blasting at quarries is typically restricted to business hours between Monday to Friday and most blasting is conducted between 11am and 2pm. Blasting is not permitted on weekends or public holidays. Blast firing time windows that apply at individual quarries are specified in quarry Work Plans.

5.3 Control of Flyrock

28 Details of flyrock clearance distances and procedures for quarries are not specified in ERR guidelines. The limited advice provided is that "*Operators are required to satisfy the department as to the safety of blasting practices and rigorous control of flyrock is an important consideration*". In practice, it is the responsibility of quarry operators and shotfirers to ensure that rock fragments (flyrock) thrown from blast sites is not excessive, are fully contained within the boundary of a work authority at all times and does not present a risk of injury to quarry personnel, members of the public and private property.

29 An approach adopted by ERR in recent years to assist with the control of flyrock is to require a short buffer (minimum 20m) between the Work Authority boundary and extraction areas as an operating condition. Blasts within 100m or so of a work authority boundary must face away from the boundary so that potential flyrock in front of a face is directed to within the extraction/pit area.

30 The risk posed by *excessive flyrock* (where rock fragments are thrown well beyond anticipated distances) is largely mitigated by establishing appropriate clearance zones at blast times. For blasts near quarry boundaries, clearance zones may extend into neighbouring land areas.

31 A weakness of current regulations is that whereas people beyond work authority boundaries should obey the instructions of a shotfirer at blast times with respect to blast clearance, there is no procedure specified to compel people to move if they refuse. While such cases are uncommon, blasts may be delayed and intervention by authorised officers (WorkSafe or Victoria Police) may be necessary.

5.4 EPA Buffer Zone for Quarries with Blasting

32 EPA Victoria Guideline No. 1518 "*Recommended Separation Distances for Industrial Residual Air Emissions*" recommends a buffer distance from quarries with blasting of 500m. The guideline is in consideration of dust impacts from whole quarry operations. It is not clear whether the EPA 500m buffer applies from the actual extraction limit wherein blasting is conducted, or from a quarry's Work Authority or title property boundary because dust can potentially be generated from activities anywhere within a quarry.

33 While the EPA guideline does not refer specifically to ground vibration and airblast levels from blasting, the 500m buffer distance is considered generally sufficient to maintain compliance with ERR limits. Anecdotally, the EPA buffer is considered by ERR to be an appropriate minimum separation distance between quarry-scale blasting and sensitive sites.

6 BLAST IMPACT MODELLING

34 The appropriateness of buffers for minimising ground vibration and airblast impacts at sensitive sites can be assessed through blast modelling. This was undertaken by GHD, as detailed in their reports, to provide the proposed buffers adopted in the Shenstone Park PSP. The GHD modelling considers a wide range of potential blasting specifications and therefore lacks accuracy that can be formed with site specific knowledge and experience.

35 The GHD assessment refers to airblast (overpressure) as blast "noise" and "sound", those these terms are somewhat misnomers. Regulatory airblast limits (i.e. 115 dBL) apply to the sub-audible (<20 Hz) change of air pressure that occurs from blasting. Overpressure at levels above

100 dBL may cause a brief structural response and the ERR limits are based on consideration of the comfort of people inside a dwelling at blast times. The audible noise component of blasting is not considered under ERR guidelines, is not currently subject to compliance monitoring and no specific guidance for audible blast noise is provided by the EPA Victoria. Previous EPA guidelines suggest audible blast noise was exempt from regulation due to the brief duration of emissions (i.e. noise events lasting less than 1 or 2 seconds).

36 The standard blast design specifications used for this assessment follow current or common quarry practice and are listed in Table 1. Standard specifications used at all quarries may vary between blasts or be modified by shotfirers to comply with environmental and regulatory limits or improve blast performance, if required. The only alteration to the nominated design specifications is that a modest increase of stemming height may be required for a limited number of blasts along the eastern extraction limit of WA492 to maintain airblast levels below the 115 dBL regulatory limit at 500m and reduce the potential for flyrock from these blasts to cross the work authority boundary.

Table 1 – Blast Design Specifications used for modelling blast impacts from Woody Hill (including the southern extension), the proposed expansion under WA6437, and Phillips Quarries

Quarry Site	Woody Hill existing + southern extension (WA492)	Proposed Woody Hill Northern Operations (WA6437)	Proposed Phillips Quarry (WA6852)
Hole diameter (mm)	89	89	89
Hole angle	10°	10°	10°
Face height (m)	15	12	10
Sub-drill (m)	1.0	1.0	1.0
Hole depth (m)	16m	13m	11m
Front row burden (m)	3.0	3.5	3.0
Inter-row burden (m)	3.0	3.0	3.0
Hole spacing (m)	3.0	3.0	3.0
Stemming Height (m)	3.0-3.2*	3.5	3.0
Explosives column (m)	13.0	9.5	8.0
Linear charge mass (kg/m)	7.5	7.5	7.5
Max. Instantaneous Charge (kg)	96.0-97.5	71.25	60.0

**Stemming height increase of 0.2m may be required for a limited number of blasts at eastern extraction limit to maintain airblast level below ERR 115 dBL limit at 500m*

7 GROUND VIBRATION MODELLING

37 Ground vibration from blasting is the result of energy transferred to the ground from the detonation of explosives in blast holes. It is typically measured on the ground surface at or near a point of concern using a properly installed geophone and blast monitor that complies with the requirements of AS2187.2-2006: Appendix J.

38 Ground vibration is usually measured as Peak Particle Velocity (PPV) in units of millimetres per second (mm/s). The common model for analysing and predicting PPV is the square root scaled distance Site Law formula of the form;

$$PPV = k_v \left(\frac{\sqrt{m}}{D}\right)^{1.6}$$

Where: PPV = Peak Particle Velocity (mm/s)
m = Charge mass-MIC (kg/delay)
D = Distance (m)
k_v = A site constant

39 The PPV model is shown in AS2187.2-2006 and was adopted by both GHD and the author for predicting potential ground vibration levels around the existing and proposed quarries. The model's site constant (k_v) recommended in AS2187.2-2006 for *hard rock in average conditions* is 1,140 which was adopted by GHD. The author of this statement has adopted a more conservative value of 1,200 that is based on blast monitoring data obtained near sensitive sites north and west of Woody Hill and data from similar basalt quarries in the Newer Volcanics region.

40 No local data is available for blasting in the proposed Phillips Quarry and Woody Hill (proposed northern expansion) Quarry because operations have not commenced. Therefore, the predictive model contains some uncertainty and may be subject to calibration based on monitoring results from early blasting.

41 The nominated blast design specifications shown in Table 1 have been used as inputs for the Site Law model. The distances from standard blast sites to milestone PPV levels are shown in Table 2. The distances vary because the standard blast design specifications for each operation are different. The attenuation of ground vibration levels over distance is presented graphically on a log-log chart in the regression analysis Figure 1. PPV levels from a single blast (Phillips Quarry example) are also shown as basic circular contours in Figure 2.

Table 2 – PPV level predictions from nominated blasting specifications

PPV level (mm/s)	Dist. to PPV level Woody Hill + southern extension (WA492)	Dist. to PPV level Woody Hill-North (WA6437)	Dist. to PPV level Phillips Quarry (WA6852)
100	47m	40m	37m
50	72m	62m	56m
30	99m	85m	78m
20	128m	109m	100m
10	197m	168m	154m
5*	303m	260m	238m
2	538m	460m	422m
1	830m	709m	651m
0.5	1,278m	1,094m	1,003m

**ERR ground vibration limit (95% of blasts)*

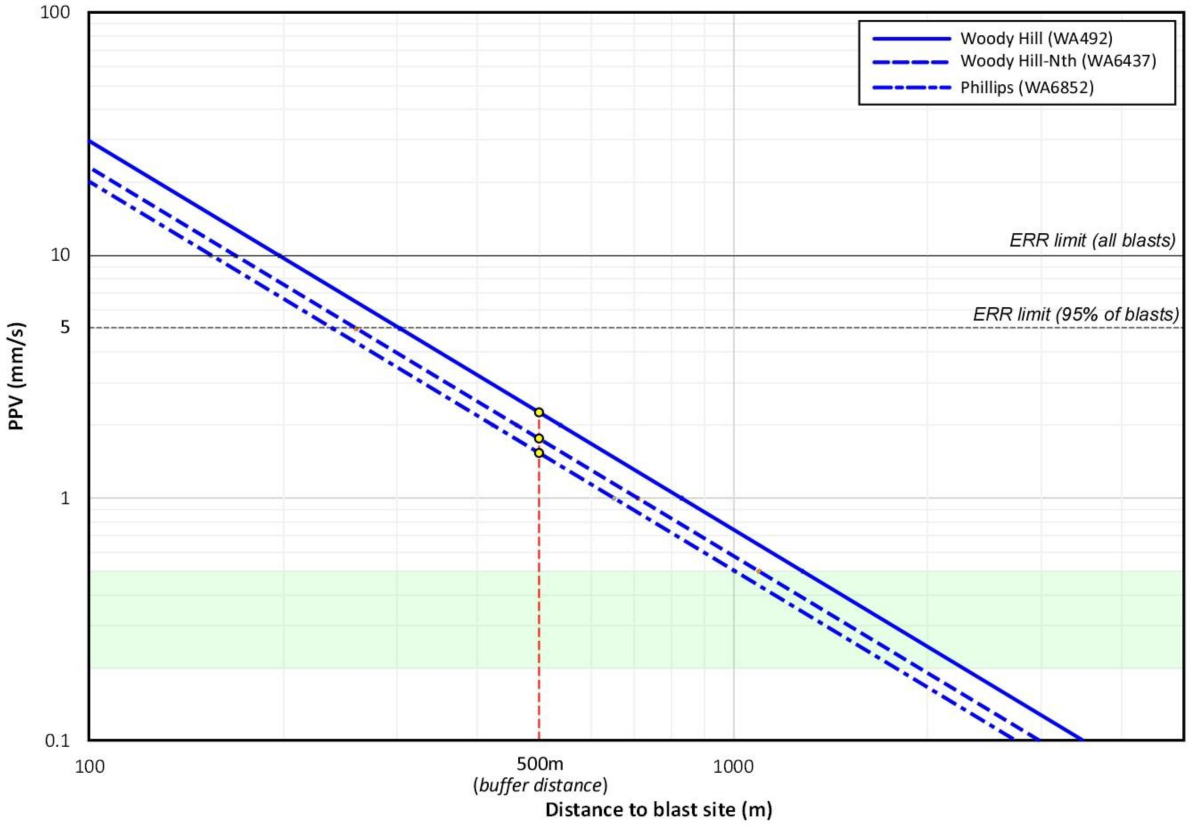


Figure 1 – Ground vibration regression analysis showing PPV levels over distance for the three quarries analysed

Figure 2 – Single blast PPV contours from a standard blast at Phillips Quarry

42 The predicted maximum ground vibration levels in the wider area around the three quarries are shown in the Appendices attached to this statement. It should be noted the contours do not represent PPV levels from a single blast but show the maximum predicted level from the closest blast to any location in the surrounding area. Such levels may only occur from terminal blasts at the extraction limits and reduced levels would result from the majority of blasts that would be fired in more distant/remote areas of the quarries.

8 AIRBLAST MODELLING

43 Airblast (overpressure) is the low frequency energy from a blast that travels through the air as a series of elevated pressure pulses at the speed of sound (approximately 340 m/s). Most of the energy is sub-audible (<20 Hz) and is not perceptible to the human ear. At levels above 100-105 dBL, airblast may induce secondary audible noise by rattling sash windows and sliding doors, etc.

44 Airblast is measured as decibels linear (dBL) as distinct from dBA for audible noise. In decibel equivalents, 115 dBL is approximately 90 dBA. Airblast is only marginally affected by wind itself, however temperature inversion conditions may, when coupled with wind speed and direction changes, cause elevated airblast levels at distances greater than 2km.

45 The airblast model used in the GHD assessment (quoted from AS2187.2-2006) has limited practical application but may be suitable for broad guidance. The main shortcoming is that the model's site constant in practice ranges from 3 for fully confined blasts to over 80 for unconfined blasts. For most quarry blasts the site constant is known to be 10-20. The predicted airblast levels in kilopascals need to be converted to dBL to assess compliance with regulatory limits. The model assumes that air pressure is equal in all directions where for free-face blasting (i.e. quarry production blasts), airblast levels directly in front of the face may be 8-20 dBL higher than levels behind the blast site.

46 Investigations by Terrock over 30 years have shown the contours for airblast levels are elliptical for face blasts and the contributing factors have been recognised, quantified and calibrated for hard rock quarries.

47 The conservative predictive airblast model developed by Terrock for emissions both in front of a blast face and the area behind and to the sides of a blast is;

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

Where:
SH = Stemming height (mm)
B = Front Row Burden (mm)
m = Charge mass-MIC (kg)
D_{115} = Distance to 115 dBL level (m)
d = Blast Hole diameter (mm)
k_a = Site constant
290 front of face (conservative)
220 behind/side of blast (conservative)

48 Using the blast specifications listed in Table 1 as inputs to the airblast model, and distances from blast sites to milestone dBL levels are shown in Table 3.

Table 3 – Airblast level predictions from standard blasting specifications

	Woody Hill existing + southern extension (WA492)		**Woody Hill - Northern Operations (WA6437)**		**Phillips Quarry (WA6852)**	
Airblast level	Front of face (m)	Behind/side of blast (m)	Front of face (m)	Behind/side of blast (m)	Front of face (m)	Behind/side of blast (m)
120 dBL	689	293	422	212	586	294
115 dBL*	999	424	612	307	850	426
110 dBL	1,449	615	888	445	1,232	618
105 dBL	2,101	892	1,287	645	1,787	896
100 dBL	3,046	1,293	1,866	936	2,591	1,299

**ERR airblast limit (95% of blasts)*

49 A set of basic model elliptical airblast contours (Phillips quarry example) are presented as Figure 3 to demonstrate the higher dBL levels that occur on front of blast faces and the importance of face direction to minimise emissions at sensitive receptors The attenuation of dBL levels over distance from each operation (both front and behind blast emissions) is shown in the regression analysis Figure 4.

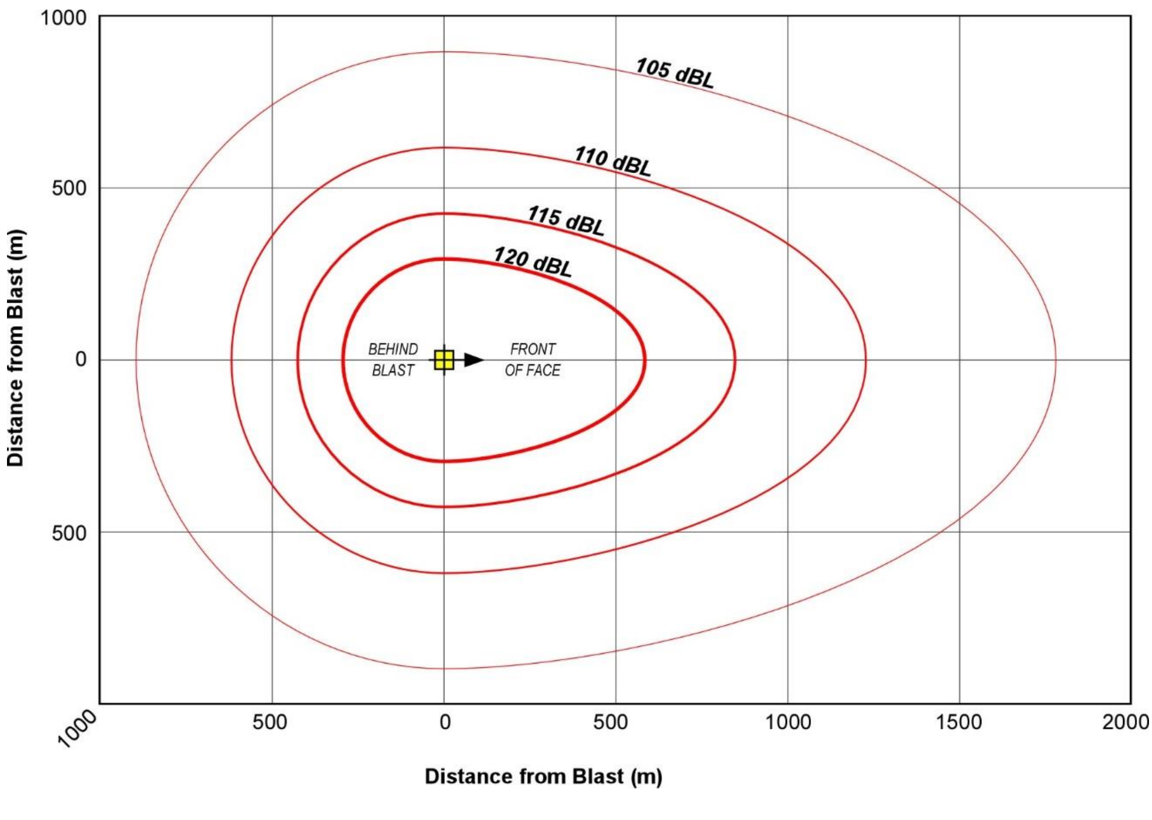


Figure 3 – Single blast elliptical contours showing dBL levels from standard blast at Phillips Quarry

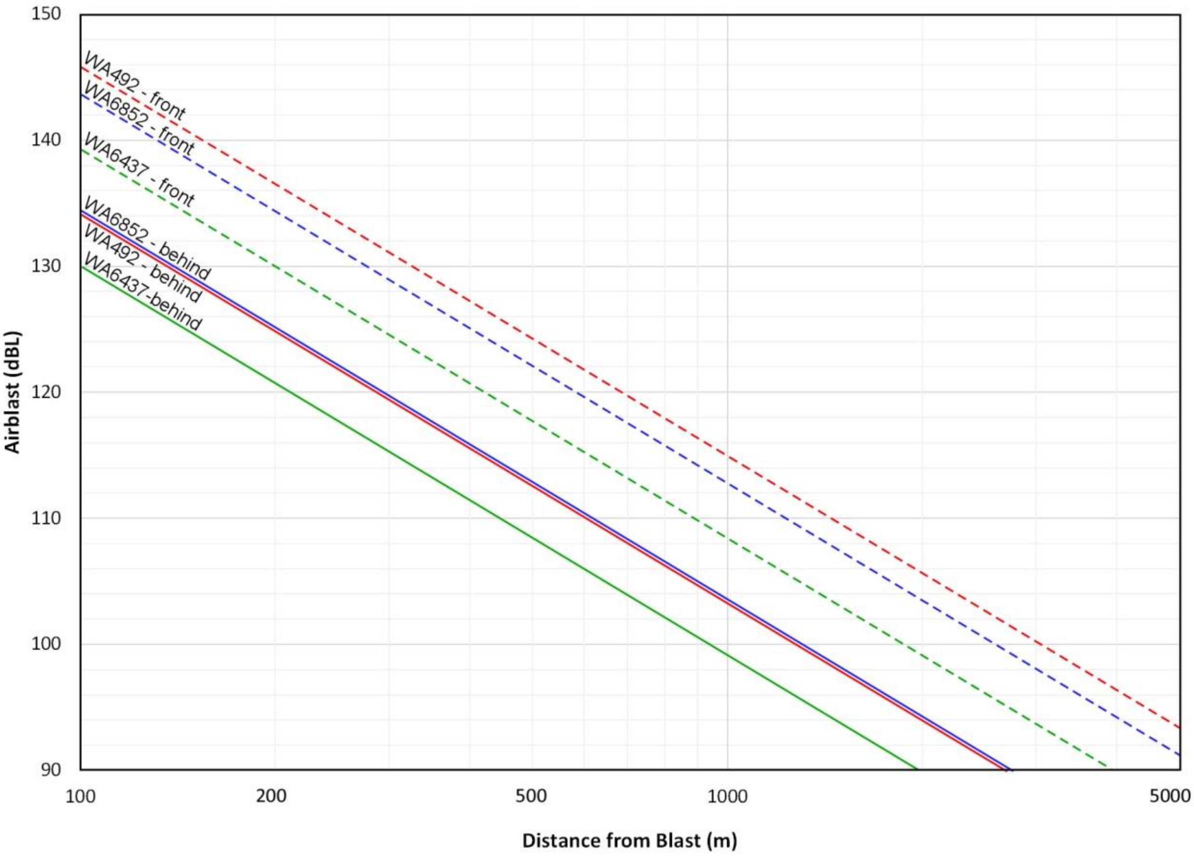


Figure 4 – Regression analysis showing front of face and behind/side of blast airblast levels over distance

50 It is important for the quarries operator to observe the higher front-of-face emissions and adopt an extraction sequence for the closest blasts to face away from the north and east, particularly during blasting in the northern and eastern areas of the quarries. Designing an extraction sequence for production blasts within 1km of sensitive sites to face east or south will be important for maintaining compliance with the ERR 115 dBL airblast limit in the Shenstone Park Precinct. It can be assumed this will occur as required to comply with regulatory conditions for quarry operations. Face direction becomes less important for blasting in more remote areas such as the southern area of Phillips Quarry.

51 Airblast levels in the wider area around the three quarries are shown in the Appendices attached to this statement. It should be noted the levels do represent a single blast and only apply to behind/side of blast emissions at any location from the closest blast (at the extraction limits). Reduced levels would occur from the majority of blasting in more remote areas of the quarries.

9 FLYROCK THROW CALCULATION

52 Investigations over 20 years have enabled the main factors contributing to flyrock to be understood, quantified and included in predictive models. The models combine basic trajectory theory with a scaled depth of burial/confinement of explosives charges. Calibration by investigations at specific sites may further refine the models.

53 The models recognise that flyrock throw in front of a face is usually greater than throw behind a blast site. Provided stemming height is sufficient to prevent cratering (stemming height > 20 blast hole diameters), blast holes may act as a gun barrel where fragments of stemming

material and loose collar rock may be projected at steep launch angles into the air with very little horizontal travel.

54 Terrock Flyrock Models are used at numerous mines and quarries to guide blast planning and minimum blast clearance distances. The models were reviewed by Dr. Peter Lilly (then Chief of the CSIRO Exploration and Mining Division) for another client in 2007 and the following comment was made;

> *"Terrock's flyrock model greatly simplifies what is dynamically a very complex problem in physics. However, the algorithm is likely to yield broadly conservative outcomes and is therefore considered to be appropriate by the writer."*

55 The Terrock Flyrock Models are shown below.

In front of a blast face, the maximum flyrock throw distance can be calculated by the formula;

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

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

56 Behind and to the sides of a blast site, maximum throw can be calculated by;

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

Where:

SH =	stemming height (m)
$Lmax_r$ =	maximum throw behind blast (m)
$\emptyset$ =	launch angle = hole angle from horizontal ± a dispersal allowance of 10° (eg. Hole angle + dispersal = 70° from horiz.)

57 The primary flyrock concern for quarrying in the Shenstone Park PSP area is throw behind a blast site because the closest blasts at or near extraction limits face towards the quarry pit.

58 With a linear charge mass of 7.5 kg/m (for standard 89mm diameter blast holes) and holes drilled at a standard angle of 10° (80° from horizontal), the maximum (worst-case) throw distances are calculated to be;

Table 4 – Flyrock throw distance calculations (conservative) from standard blasting specifications

	Woody Hill existing + southern extension (WA492)		**Woody Hill - Northern Operations (WA6437)**		**Phillips Quarry (WA6852)**	
	Front of face	Behind/side of blast	Front of face	Behind/side of blast	Front of face	Behind/side of blast
Max. Throw	59m	38m	40m	26m	59m	38m

59 The furthest throw distance usually occurs in front of the face from fragments thrown at a launch angle of 45°. Behind and to the sides of a blast, fragments are thrown shorter distances and typically disperse ±10° from the hole angle. Cross-section flyrock trajectories from standard blasting are shown in Figure 5.

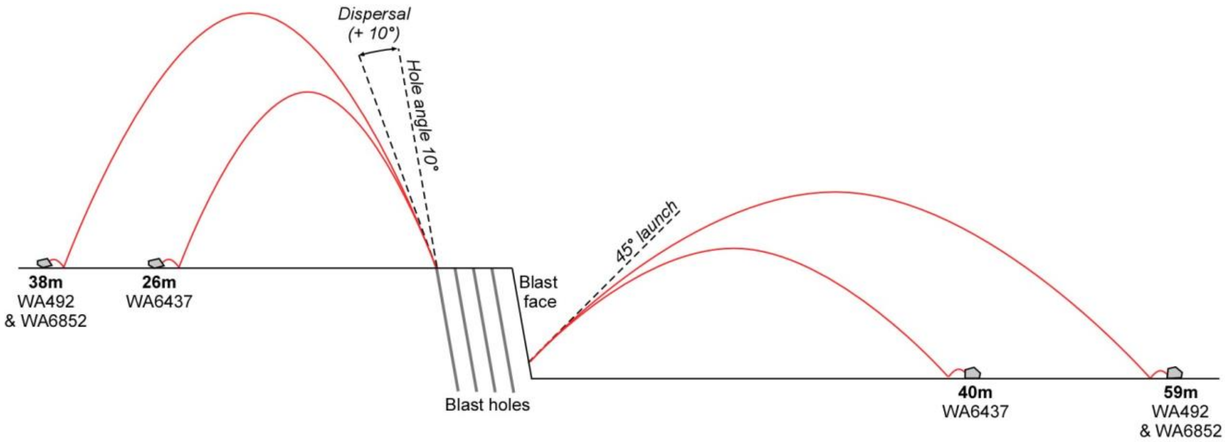


Figure 5 - Flyrock trajectories from standard blasting (conservative)

60 The following Safety Factors are commonly applied to the basic conservative throw calculations to provide the minimum blast clearance distances shown in Table 5;

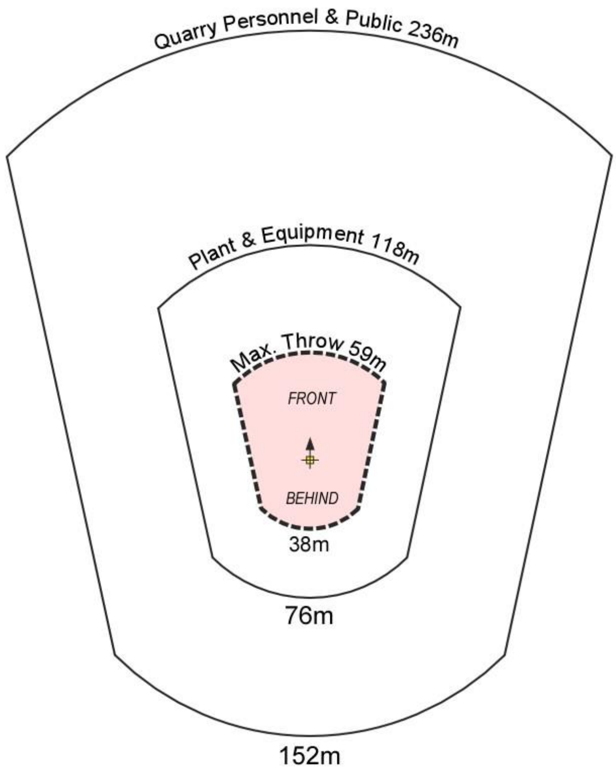
- Safety Factor 2 – Quarry plant, equipment and unoccupied buildings
- Safety Factor 4 – Quarry personnel, members of the public and occupied buildings

Table 5 – Minimum blast clearance distances based on maximum throw calculations

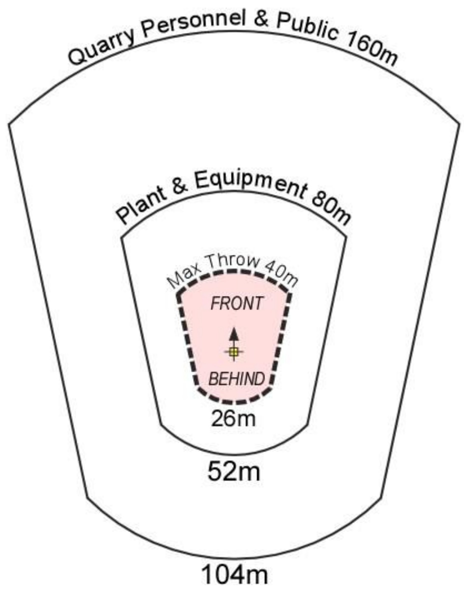
	Woody Hill existing + southern extension (WA492)		**Woody Hill - Northern Operations (WA6437)**		**Phillips Quarry (WA6852)**	
	Front of face (m)	Behind/side of blast (m)	Front of face (m)	Behind/side of blast (m)	Front of face (m)	Behind/side of blast (m)
Max. Throw	**59**	**38**	**40**	**26**	**59**	**38**
Safety Factor 2	118	76	80	52	118	76
Safety Factor 4	236	152	160	104	236	152

61 The safety factors are considered by the author to be appropriate minimum values. For blasts with reduced front-row burden and stemming specifications, clearance distances should be increased accordingly at the shotfirer’s discretion.

62 Combining the front of face and behind blast distances shows the extent of the clearance zones for standard blasting at the three quarries as shown in Figure 6.



Woody Hill (WA492) & Phillips Quarry (WA6852)



Woody Hill-North (WA6437)

Figure 6 - Recommended (minimum clearance zones for standard blasts)

63 If required, throw distance can be reduced through blast design modifications to minimise the potential for rock fragments being thrown across a work authority boundary into adjacent land areas. The relationship between throw distance behind a blast, stemming height provisions and hole angle is shown in Table 6.

Table 6 – Influence of stemming height and hole angle on throw distance behind blasts

	Maximum throw distance behind blast site (m)	
Stemming Height (m)	Hole Angle 10°	Hole Angle 5°
3.0	37.7	29.3
3.5	25.3	19.7
4.0	17.9	13.9
4.5	13.1	10.2

64 The sensitivity of throw distance to changes of front row burden and stemming height is presented graphically in Figure 7.

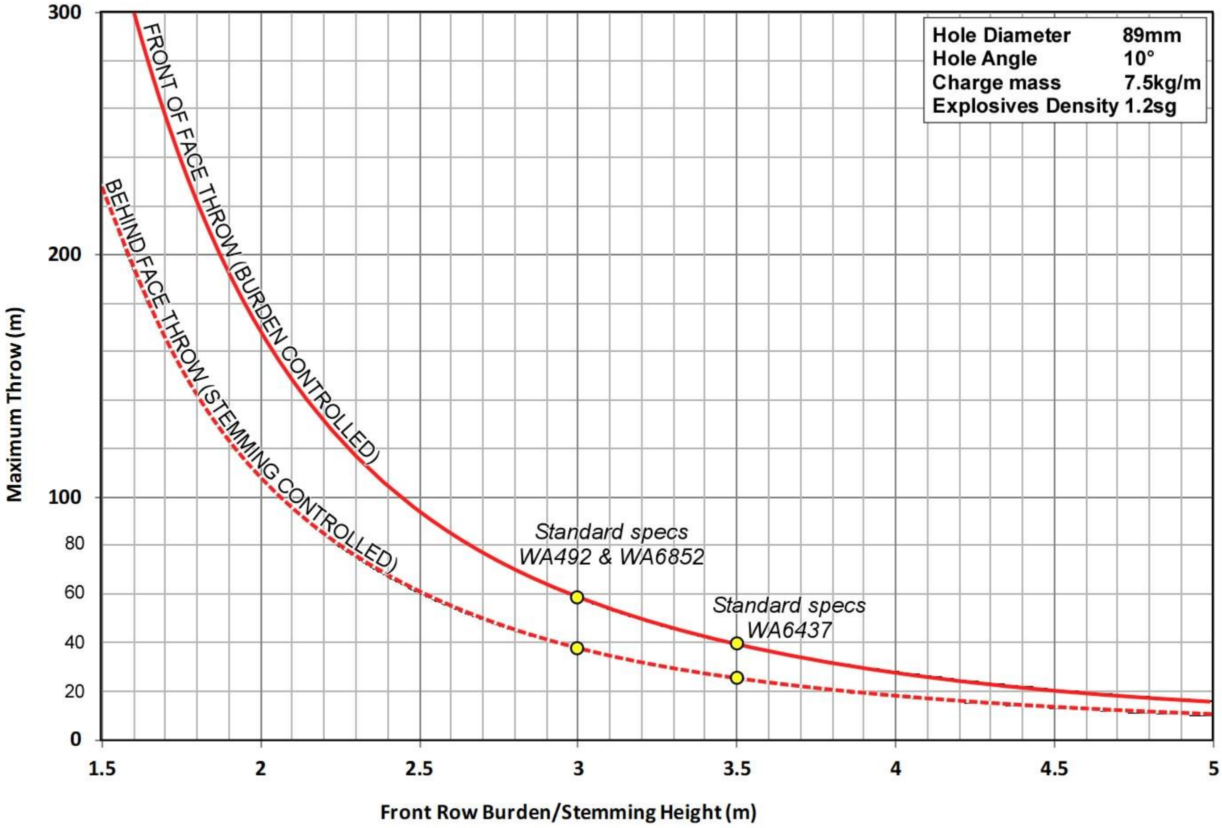


Figure 7 - Recommended (minimum clearance zones for standard blasts)

65 The significance of this is to demonstrate that blasts can be designed to contain all rock throw within a work authority boundary by modifying stemming height and hole angle. The Safety Factor of 2 can also be incorporated into the flyrock distance design. The current and proposed Work Authority extraction limit minimum buffer distance of 20m indicates that such modifications may only be required for a limited number of terminal blasts at the extraction limit.

66 To reduce the predicted throw distances, an approach we have used with other clients is to conduct a campaign of accurate stemming control coupled with flyrock observations from video recordings and throw distance measurements. In these cases, the flyrock model site constant has been reduced to 10-20 (from the conservative 27). The flyrock model and throw calculations are intended as a guide for quarry managers and shotfirers and does not absolve them from their responsibilities as detailed in the *Dangerous Good (Explosives) Regulations* – 2011.

10 DUST FROM BLASTING

67 The effects of airborne dust from whole quarry operations (including blasting) should be discussed in depth by an experienced air quality consultant. Generally, from visual observations at quarries, the time taken for the blasting dust cloud to visually dissipate depends on wind conditions at blast times. On windy days, dust clouds may dissipate in 1-2 minutes. On a still day, dust may linger and settle around the blast/quarry area and usually dissipates to be non-visible at around 3-5 minutes. From advised production schedules, dust from blasting may be generated at each quarry site approximately once or twice per month or weekly at Phillips Quarry at full production. It is generally accepted that the dust from blasting represents a small fraction of the potential dust loads from whole quarry operations and other onsite sources are more significant contributors.

11 APPROPRIATENESS OF PROPOSED BLASTING BUFFER (200m)

68 The instrument for controlling flyrock is standard practice, regulation, work plan conditions and face directions determined by a quarry's adopted extraction sequence. Shotfirers are required to keep all rock fragments from blasting within work authority boundaries and to take all steps necessary to achieve this. If flyrock is thrown beyond a work authority boundary it may result in blasting operations being suspended until it can be demonstrated that further blasting can be safely resumed. Shotfirers should be aware of the high risk flyrock presents and that they may have their blasting credentials suspended or cancelled for unsafe blasting practice, thus depriving him/her of their livelihood.

69 As previously stated, the GHD advice that "*…a 200m radial buffer distance from the boundary of the extraction area is sufficient to mitigate against safety issues from flyrock during blasting*" is purely arbitrary and without technical and scientific basis. An adequate blast clearance area is only required to be established for a limited period on blast days (once or twice per month, or weekly at Phillips Quarry) and should be centred on individual blast sites, not around a quarry's entire extraction limit.

70 All people within a blast's designated clearance area must be evacuated prior to blast times. It is the shotfirer and quarry manager's responsibility to ensure this occurs and no blast may be fired until the shotfirer receives confirmation of this from blast guards positioned on or near neighbouring land with a clear view of the surrounding area. These blast clearance procedures would still be required regardless of any permanent buffer zones that may exist.

71 However, prohibiting development within 200m of a quarry extraction area may be appropriate for other reasons. Blast clearance in areas outside a quarry relies on the cooperation of the occupants of neighbouring properties and this cannot be guaranteed at all times. For example, evacuation of an industrial or commercial premise at blast time may present difficulties for quarry operators if the occupant does not cooperate, regardless of any pre-existing arrangement. Ensuring multiple premises are free of people at blast times would also present a logistical challenge for quarry personnel.

72 A 200m buffer would also help reduce potentially high levels of airblast and ground vibration at non-sensitive sites such as factories or commercial outlets. While PPV and airblast limits for industrial and commercial premises are not currently specified in current ERR guidelines (other than a mention that "*…less stringent standards may be appropriate"),* human comfort limits from previous regulations were 25 mm/s and 120 dBL for all blasting.

73 While the limits to prevent damage to industrial and heavy commercial type buildings are shown as 50 mm/s (from AS2187.2-2006 criteria), some owners and occupants of buildings are likely to raise complaints and damage concerns even where substantially lower levels occur. If the previous human comfort limit of 25mm/s for occupied industrial and heavy commercial premises is considered, the separation distances for such developments from extraction limit blasting is around 100m, as shown in Table 7. A summary of PPV levels at milestone distances including the various buffers are also shown.

Table 7 - PPV levels at milestone and potential buffer distances

	WA492 (Woody Hill + southern extension)	WA6437 (Woody Hill Nth)	WA6852 (Phillips Quarry)
PPV at 50m (mm/s)	88.4	69.8	60.7
PPV at 100m (mm/s)	29.2	23.0	20.0
PPV at 200m - proposed blast buffer (mm/s)	9.5	7.6	6.6
PPV at 300m (mm/s)	5.0	4.0	3.5
PPV at 400m (mm/s)	3.2	2.5	2.2
PPV at 500m -EPA guideline buffer & author's recommendation (mm/s)	2.3	1.8	1.5
PPV at 550m - GHD Sensitive use buffer (mm/s)	1.9	1.5	1.3

74 Consideration could also be given to a progressive sunset clause for blast-related buffer zones when they become no longer relevant because extraction/blasting has moved to more distant areas of the quarries. For example, at Phillips Quarry, if early stage extraction occurs along the northern extraction limit, PPV and airblast levels would gradually reduce to near imperceptible levels as extraction progresses southwards over time. In addition, blast clearance in adjacent land north of the quarry would become unnecessary for blasts located more than 152m from the Work Authority boundary (based on Safety Factor 4 clearance distance for people).

12 APPROPRIATENESS OF PROPOSED SENSITIVE USE BUFFER (550m)

75 The 550m sensitive use buffer shown in the PSP is based on a 2mm/s PPV limit nominated by GHD, though this limit does not apply under existing regulations for Victorian quarries. The proposed buffer distance is considered by the writer to be somewhat excessive and the EPA guideline buffer distance of 500m is deemed more appropriate and would likely satisfy both the EPA and ERR. At 500m, PPV levels from the closest blast(s) are shown to be less than 50% of the ERR 5 mm/s limit. The EPA guideline buffer also provides considerable allowance for uncertainties in the blast modelling should airblast and PPV levels (and site constants) be higher than predicted.

76 It is important to note the PPV and airblast levels shown in Tables 2, 3 and 7 would only occur from a limited number of blasts at or near the extraction limits. The overwhelming majority of blasts in the quarries would occur at more distant locations and therefore result in lower levels at sensitive sites than those shown.

13 CONSIDERATIONS FOR QUARRY BLASTING NEAR THE PROPOSED WATER TREATMENT PLANT

77 The issues for blasting near the proposed water treatment facility are;

- impact damage from flyrock
- establishing adequate clearance zones at blast times
- ground vibration damage to plant concrete and infrastructure
- airblast damage to plant infrastructure

13.1 Impact damage

78 Blasts at or near a quarry's extraction limit face away from the nearest work authority boundary and throw distance behind a blast is relatively simple to control by quality assurance/quality control procedures of stemming practice during blast charging operations.

79 The buffer between the proposed southern extension of the Woody Hill Quarry extraction limit and the WA492 boundary is a minimum of 20m. The maximum (worst-case) throw of 38m can be reduced by stemming height increase and/or adjusting hole angles for a limited number of blasts at the extraction limit. A program of flyrock observation could also be undertaken to calibrate the flyrock model's site constant to reflect local conditions and inform any blast design modifications needed to ensure rock from the closest few blasts are not thrown beyond the Work Authority boundary into the water treatment facility.

80 Generally, rock fragments thrown behind blasts consist of small fragments of stemming material and loose collar rock and represent a lower risk of damage to infrastructure than larger fragments travelling at higher velocities in front of blasts.

13.2 Clearance zones and procedures

81 To provide protection for water treatment plant site personnel at blast times, arrangements must be made between quarry managers and the treatment plant operators to evacuate any nearby personnel to a safe distance during the closest blasts in the event that flyrock is thrown beyond anticipated distances.

13.3 Ground vibration damage

82 There are a number of first principal and observational criteria that provide guidance to the possible effects of ground vibration on water treatment plant infrastructure.

13.3.1 Plane wave strain approach

83 From Plane Wave Strain Theory, the relationship between surface ground strain and PPV can be determined from;

$$Ground\ Strain = \frac{\text{PPV}}{\text{Seismic Velocity}}$$

84 From Terrock experience, seismic velocity can be assumed to be 2,000 m/s for hard rock quarries. The ground strain can be compared to the working strains permitted for concrete in particular and an appropriate PPV level determined.

85 From AS3600-2001 – *Concrete Structures*, the working strains associated with the Ultimate Compressive Strength (UCS) of various strengths of concrete are shown in Table 8.

Table 8 – Concrete strengths (from AS 3600-2001)

Concrete		Flexural Tension		Compression
Ultimate Compression Strength (UCS)	Youngs Modulus E	Tension $0.6\sqrt{f^1c}$	Working Strain	Working Strain με
MPa	MPa	MPa	με	με
20	22,610	2.68	118.5	885
25	25,279	3.0	118.5	989
32	28,599	3.39	118.5	1,119
40	31,975	3.79	118.5	1,250
50	35,749	4.24	118.5	1,398
65	40,760	4.83	118.5	1,472

86 The working strain for flexural tension is shown to be 118.5 με for all concrete. Assuming ground strain plus operating strain is less than flexural tension strain, no damage will occur. Substituting ground strain for working strain gives a working PPV of;

$$118.5 \times 10^{-6} \times 2{,}000\, x\, 10^{3} \quad \therefore \quad PPV = 237\, mm/s$$

87 This may be discounted to allow for operating strain and also for tall structures where an amplification may be expected up the structure. Allowing for an amplification factor of 2 would half the PPV level to 118.5 mm/s, which is similar to the non-damaging determinations from other first principals approaches.

13.3.2 Tennessee Valley Authority (TVA) Criteria

88 For mass concrete, the TVA vibration limit criteria (after Oriard) is listed in Table 9.

Table 9 – TVA mass concrete damage criteria (after Oriard)

Concrete Age from Batching	Allowable PPV (mm/s)	Effective PPV (mm/s)	Distance Factor	
			DF	Distance (m)
0 – 4 hours	100 x DF	100	1.0	0 - 15
4 hours – 1 day	150 x DF	120	0.8	15 – 46
1 – 3 days	225 x DF	156	0.7	46 – 76
3 – 7 days	300 x DF	180	0.6	76+
7 – 10 days	375 x DF	225	-	-
10 or more days	**500 x DF**	**300**	-	-

89 For concrete older than 10 days at distances greater than 76m, the limit derived is 300 m/s. This is similar in magnitude to that derived from Plane Wave Strain Theory.

13.3.3 AS2187.2-2006

90 From the Australian Standard for blasting, the recommended PPV limit for “unoccupied structures of concrete and steel construction” is 100 mm/s (Figure 6). This limit is the most conservative of the limits considered and can be observed under standard blasting.

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.

Figure 6 – Table J5.4(B) from AS2187.2-2006

13.3.4 Earthquake damage observations

91 Further guidance on the effect of ground vibration on treatment plant infrastructure can be guided by the observed effects of earthquakes on similar infrastructure. The earthquake comparison with blasting is valid and highly conservative if the following differences are recognised.

- Earthquakes have low ground motion frequencies (often less than 1 Hz) than vibration from blasting (≥10 Hz)and therefore longer wavelengths.
- Earthquakes have large ground displacements of tens of centimetres or more, compared to millimetre displacements from blasting.
- Earthquakes have longer durations (tens of seconds to minutes) compared to 2-5 second durations from quarry blasting.
- Earthquakes result in many more excitation cycles.

92 The observed effects of earthquakes in New Zealand were recorded by Dowrick (1996) and related to Modified Mercalli and Richter Scale, and their equivalent PPVs, as shown in Table 10.

Table 10 – Earthquake Observations, Dowrick (from Modified Mercalli Intensity Scale)

PPV [mm/s]	MMI	Magnitude [M]	Human response and damage to structures and environment (Dowrick, 1996)
1.5	I	1-2	**People:** Do not feel any Earth movement
3	II	2-3	**People:** A few people might notice some movement if they are on the upper floors of tall buildings
6	III	3-4	**People:** Many people feel movement
11	IV	4	**People:** Most people feel movement **Structures:** Walls and frame of building are heard to creak
22	V	4-5	**People:** Almost everyone feels movement **Structures:** Some windows can crack.
45	VI	5-6	**People:** Everyone feels movement **Structures:** Slight damage to domestic buildings.
90	VII	6	**People:** People have difficulty standing **Structures:** In general damage is slight to moderate and well-built buildings. Damage is considerable in poorly built buildings.
180	VIII	6-7	**Structures:** Domestic buildings heavily damaged, some collapse or with partial collapse. Commercial buildings damaged in some cases. Houses not secured to foundation may move. Tall structures such as towers and chimneys might twist and fall **Environment:** Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations.
360	IX	7	**Structures:** Many residential, moderately constructed buildings destroyed. Residential and commercial buildings well-built heavily damaged, some collapse, some with flexible frames seriously damaged. Houses not secured to foundations shifted off. Some underground pipes are broken **Environment:** Cracking of the ground noticeable. Land sliding general on steep slopes. Liquefaction effects intensified and more widespread.
720	X	7-8	**Structures:** Most buildings are destroyed. Building footings are destroyed. Some bridges are destroyed **Environment:** Dams are seriously damaged. Large landslides occur.

93 The equivalent PPV damage level for the type of concrete structures that may be found in water treatment plants is between 90-180 mm/s. A similar table of damage is produced by Fell et al (2005) reproduced in part as Table 11.

Table 11 – Modified Mercalli Scale, 1956 version (Richter, 1958; Hunt, 1984) after Fell et al (2005)

Intensity	Effects
VII	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII	Steering of motor cars affected. Damage to masonry C, partial collapse. Some damage to masonry B, none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

94 Regarding dams, Fell (2005) states, "V*irtually all well-built dams on a firm foundation can withstand moderate earthquake shaking… with no detrimental effects*" and "*Dams constructed in clay soils on clay or rock foundations have withstood extremely strong shaking from a magnitude 8 earthquakes* [≥180 mm/s] *with no apparent damage.*"

13.3.5 Predicted PPV levels

95 The closest blasting to the water treatment plant footprint area as shown on Plan 15 would occur at the (expanded) extraction limit in the southeast area of the Woody Hill Quarry. For a standard blast at the extraction limit (at a minimum approximate distance of 65m from the treatment plant area), PPV levels are predicted to be 58.9 mm/s, reducing to 20mm/s with doubling of distance (130m).

96 From Phillips Quarry to the east, maximum PPV from the closest blasting is 10 mm/s. PPV levels from all other blasts at both quarries will be less the predicted maximums because they would be more distant from the treatment plant area.

97 The maximum PPV level from the closest blast(s) is predicted to be 59 mm/s and is 59% of the most conservative PPV limit of 100 mm/s provided by the Australian Standard.

98 On consideration of flyrock control requirements for all quarries, PPV levels predicted for the closest standard blasting and the relatively high tolerance of concrete and other infrastructure to ground motions, it is reasonably concluded the "*Blast Restriction Area*" shown in the Shenstone Park PSP Plan 15 has no justification and modified blasting in this area is not required.

13.4 Airblast damage

99 The maximum airblast overpressure levels predicted across the treatment plant footprint area shown on Plan 15 vary from 111-128 dBL for the closest blasting at Phillips Quarry, and 120-140 dBL from the closest blasting at Woody Hill.

100 AS2187.2-2006 lists 133 dBL as a non-damaging airblast limit for structures, though the Standard notes such damage is "…*improbable below 140 dBL*". However, glass window panes are the most airblast sensitive element in buildings and modern windows are designed to withstand wind velocity pressures with an equivalent of at least 150 dBL. In short, airblast is not seen as potentially damaging to treatment plant infrastructure.

13.5 Other Infrastucture

101 While not specified in the expert witness instructions for this statement, other infrastructure assets including a buried high-pressure gas main and high voltage transmission towers are located within easements to the south and east of the proposed Phillips Quarry. The areas of interest are located outside the PSP.

102 The owners of transmission towers in the Hunter Valley (NSW) routinely permit PPV levels up to 100mm/s at similar towers located close to large-scale, open cut mine blasting. This limit also applies at transmission towers and poles near some other Victorian quarries and would likely be adopted for the assets near Phillips Quarry.

103 A suitable PPV limit for the gas main east of Phillips Quarry requires further negotiations with the asset owner. When a limit is determined, a more detailed approach to blasting near the eastern boundary can then follow.

14 AUTHOR'S CONCLUSIONS

A) The appropriateness of the buffer zones (see Plan 15 – Buffers of the PSP)…

104 Rather than separate blasting buffers based on the individual effects and perceived risks of blasting (i.e. ground, vibration, airblast and flyrock), consideration should be given to adopting a single, overarching buffer that is adequate to help maintain PPV and airblast levels at sensitive sites to below the ERR guideline limits for quarries. This can be achieved under standard blast design specifications (and with observance of recommended face directions) for the existing and proposed quarries, and by adopting a buffer distance of 500m for sensitive land uses. This approach would also likely satisfy EPA Victoria with respect to dust impacts from whole quarry operations.

105 The face direction of blasts is important consideration for compliance with airblast limits at sensitive sites and will depend on the extraction sequence proposed for quarry development, the details of which are not known to the author. A 500m buffer is considered appropriate for airblast control provided all production blasts within ~1km of sensitive sites face away from the closest residential areas (i.e. east or south facing blasts).

106 The 200m "Blasting Buffer" shown around all the work authority boundaries does not remove the regulatory requirement for shotfirers to contain all rock fragments thrown from blasting to within quarry boundaries or the requirement to ensure people on neighbouring land areas are evacuated from the vicinity of a blast site prior to firing. Blast clearance zones need only be implemented for a brief period on blast days, most blasting occurs well away from quarry boundaries, and throw distance can be controlled through blast design as needed. Therefore, permanent flyrock exclusion zones (i.e. the 200m "blast buffer") are not required at these (or other) quarries.

107 Rather than exclude any development within 200m of the quarries for the life of the quarry operations, a more sensible solution is to establish a sunset zoning clause which permits compatible land uses with provision for adjacent land areas to be evacuated during the closest blasting. Such non-sensitive land uses include timber yards, nurseries and garden supplies, etc. Further development within 200m could be considered in the future as part of a sunset zoning clause for when the closest resource areas have been exhausted and further blasting occurs at more distant and remote areas of the quarries.

B) The appropriateness of the "Blast Restriction Area" to the proposed "water treatment facility"…

108 The "Blast Restriction Area" within WA492 shown on Plan 15 has no justification in relation to the effects of blasting on the proposed water treatment facility and flyrock risk control around the quarries. Therefore, standard blasting can be conducted up to the proposed extraction limit(s) without adverse effects to water treatment plant infrastructure or presenting an unacceptable risk to plant personnel.

109 Water treatment plants and quarrying are considered to be compatible neighbouring land uses that require some cooperation of management in order to coexist. For example, on the day before a blast the quarry must notify the treatment plant's management that a blast will occur the following day. Further notification of a specific blast time can be confirmed on blast day morning as a part of routine blast clearance procedures. The treatment plant area could include a building (lunch room, etc) located at a sufficient distance from the extraction area for site personnel to withdraw to during blasts located at or near the extraction limit.

Author's Declaration

I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

Adrian J. Moore

27 October 2020

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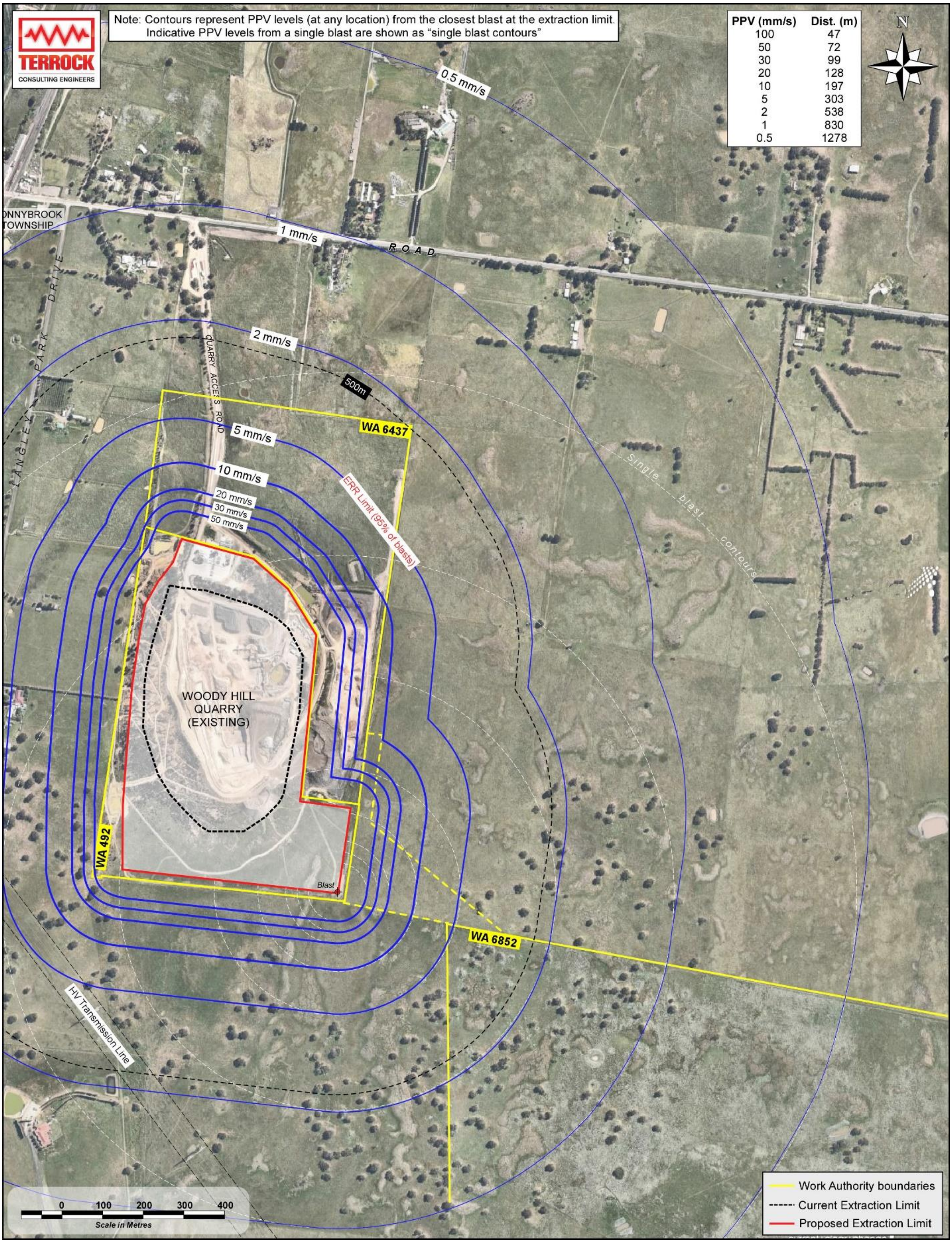
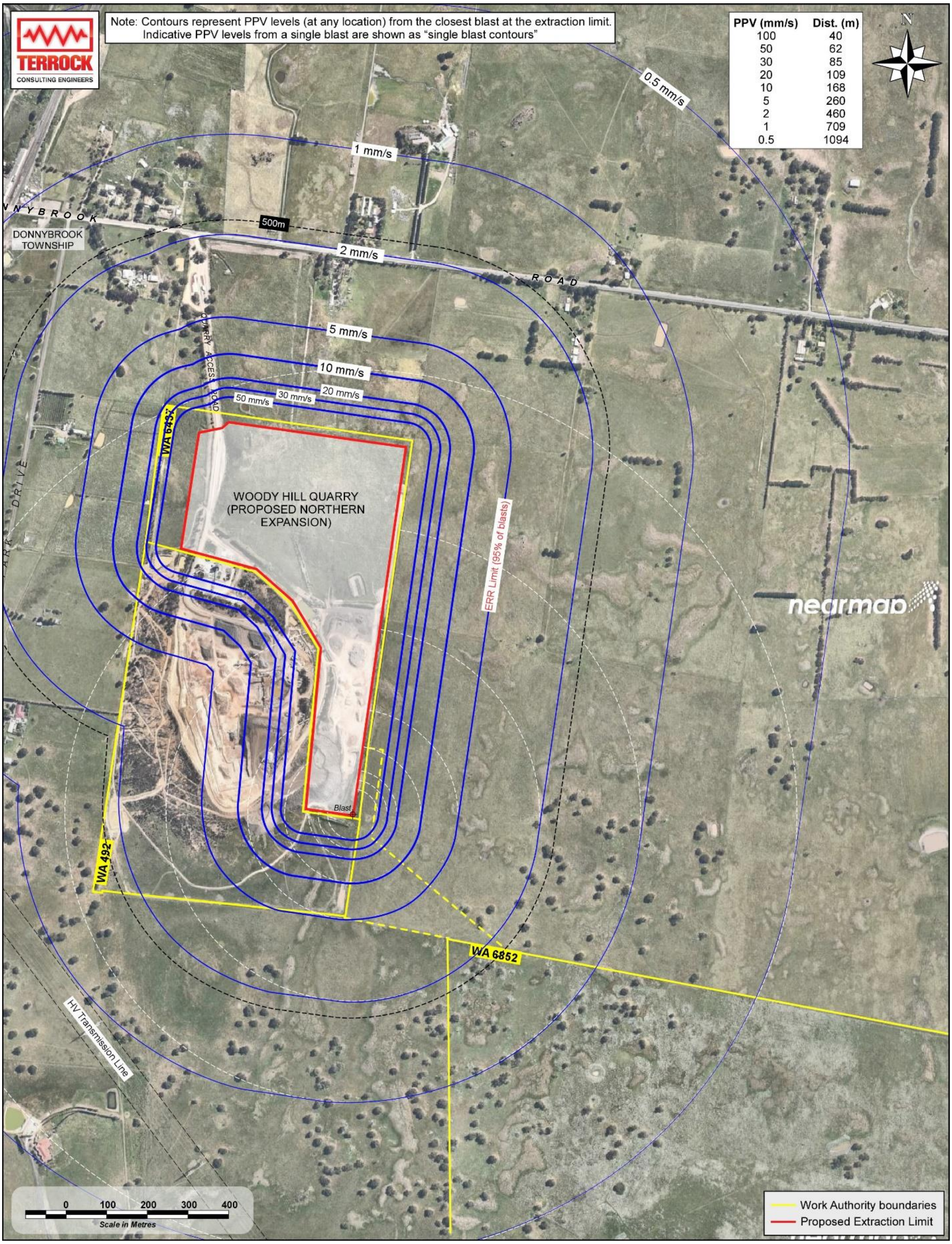
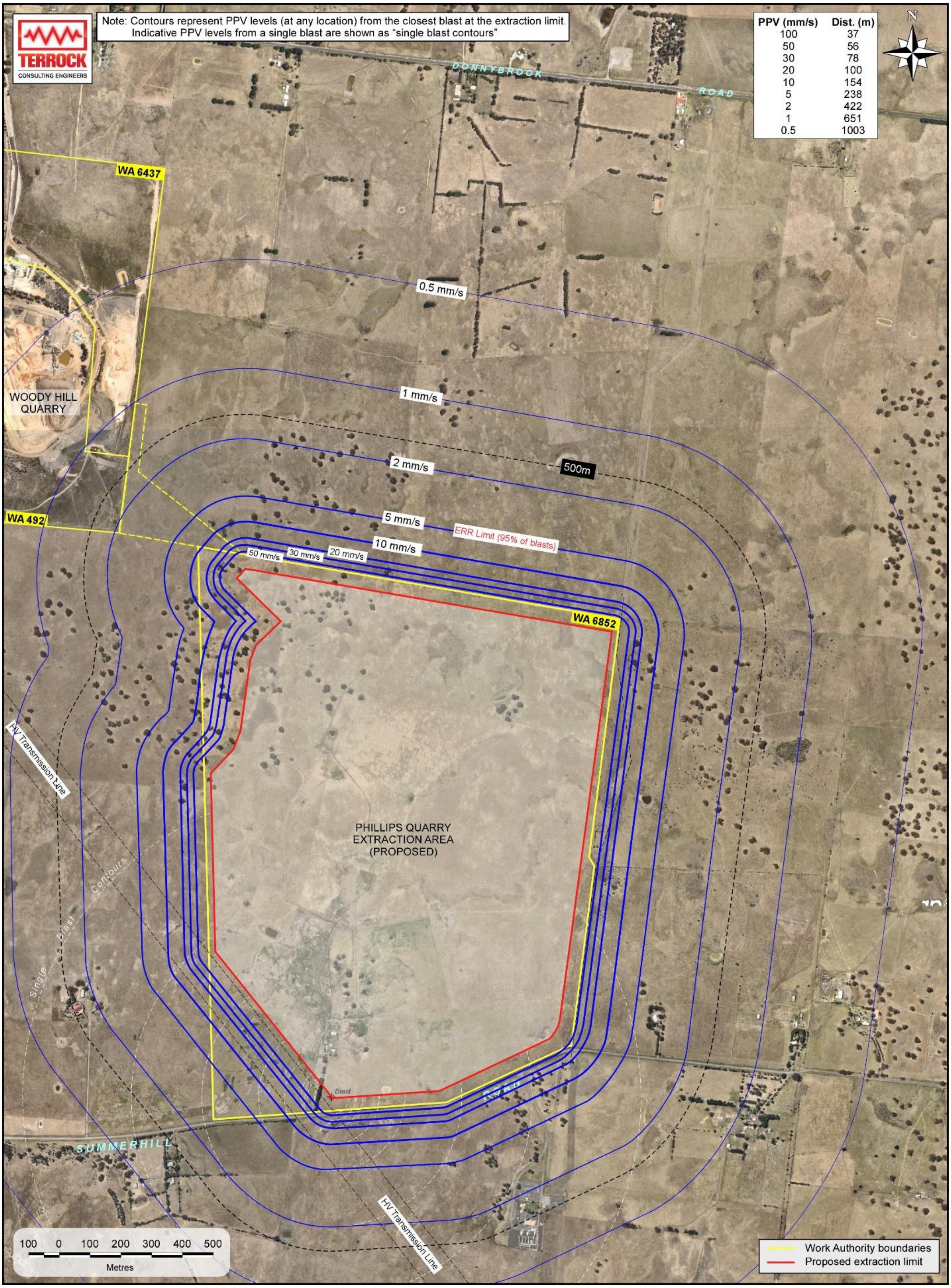
APPENDICES


TERROCK
CONSULTING ENGINEERS
Note: Contours represent PPV levels (at any location) from the closest blast at the extraction limit.
Indicative PPV levels from a single blast are shown as "single blast contours"
PPV (mm/s) Dist. (m)
100 47
50 72
30 99
20 128
10 197
5 303
2 538
1 830
0.5 1278
N
0.5 mm/s
1 mm/s
2 mm/s
500m
5 mm/s
10 mm/s
20 mm/s
30 mm/s
50 mm/s
ERR Limit (95% of blasts)
Single blast contours
ONNYBROOK TOWNSHIP
ROAD
LANGLEY PARK DRIVE
QUARRY ACCESS ROAD
WA 6437
WOODY HILL QUARRY (EXISTING)
WA 492
Blast
WA 6852
HV Transmission Line
0 100 200 300 400
Scale in Metres
Work Authority boundaries
Current Extraction Limit
Proposed Extraction Limit


TERROCK
CONSULTING ENGINEERS
Note: Contours represent airblast levels behind and to the sides of blasts at the extraction limit (from blasts with faces directed west or south.
FRONT OF FACE
Airblast (dBL) Dist. (m)
120 689
115 999
110 1449
105 2101
100 3046
BEHIND/SIDE OF BLAST
Airblast (dBL) Dist. (m)
120 293
115 424
110 615
105 892
100 1293
N
DONNYBROOK TOWNSHIP
DONNYBROOK ROAD
LANGLEY PARK DRIVE
QUARRY ACCESS ROAD
500m
ERR Limit (95% of blasts)
WA 6437
100 dBL
105 dBL
110 dBL
115 dBL
120 dBL
WOODY HILL QUARRY (EXISTING)
WA 492
WA 6852
HV Transmission Line
0 100 200 300 400
Scale in Metres
Work Authority boundaries
Current Extraction Limit
Proposed Extraction Limit


TERROCK
CONSULTING ENGINEERS
Note: Contours represent PPV levels (at any location) from the closest blast at the extraction limit.
Indicative PPV levels from a single blast are shown as "single blast contours"
PPV (mm/s) Dist. (m)
100 40
50 62
30 85
20 109
10 168
5 260
2 460
1 709
0.5 1094
N
0.5 mm/s
1 mm/s
2 mm/s
5 mm/s
10 mm/s
20 mm/s
30 mm/s
50 mm/s
500m
DONNYBROOK TOWNSHIP
DONNYBROOK ROAD
QUARRY ACCESS ROAD
WOODY HILL QUARRY (PROPOSED NORTHERN EXPANSION)
ERR Limit (95% of blasts)
Blast
WA 492
WA 6852
HV Transmission Line
nearmap
0 100 200 300 400
Scale in Metres
Work Authority boundaries
Proposed Extraction Limit


TERROCK
CONSULTING ENGINEERS
Note: Contours represent airblast levels behind and to the sides of blasts at the extraction limit (from blasts with faces directed west or south.
FRONT OF FACE
BEHIND/SIDE OF BLAST
Airblast (dBL) Dist. (m) Airblast (dBL) Dist. (m)
120 422 120 212
115 612 115 307
110 888 110 445
105 1287 105 645
100 1866 100 936
N
100 dBL
105 dBL
110 dBL
115 dBL
120 dBL
500m
DONNYBROOK TOWNSHIP
NYBROOK ROAD
LANGLEY PARK DRIVE
QUARRY ACCESS ROAD
WA 6437
WOODY HILL QUARRY
(PROPOSED NORTHERN EXPANSION)
ERR Limit (95% of blasts)
WA 492
WA 6852
HV Transmission Line
0 100 200 300 400
Scale in Metres
Work Authority boundaries
Proposed Extraction Limit


TERROCK
CONSULTING ENGINEERS
Note: Contours represent PPV levels (at any location) from the closest blast at the extraction limit.
Indicative PPV levels from a single blast are shown as "single blast contours"

PPV (mm/s)	Dist. (m)
100	37
50	56
30	78
20	100
10	154
5	238
2	422
1	651
0.5	1003

N
DONNYBROOK ROAD
WA 6437
WOODY HILL QUARRY
0.5 mm/s
1 mm/s
2 mm/s
500m
5 mm/s
ERR Limit (95% of blasts)
10 mm/s
50 mm/s
30 mm/s
20 mm/s
WA 492
WA 6852
HV Transmission Line
PHILLIPS QUARRY
EXTRACTION AREA
(PROPOSED)
Single Blast Contours
Blast
SUMMERHILL ROAD
100 0 100 200 300 400 500
Metres
Work Authority boundaries
Proposed extraction limit


TERROCK
CONSULTING ENGINEERS
Note: Contours represent airblast levels behind and to the sides of blasts at the extraction limit (from blasts with faces directed west or south.
FRONT OF FACE
Airblast (dBL) Dist. (m)
120 586
115 850
110 1232
105 1787
100 2591
BEHIND/SIDE OF BLAST
Airblast (dBL) Dist. (m)
120 294
115 426
110 618
105 896
100 1299
N
DONNYBROOK ROAD
WA 6437
100 dBL
105 dBL
110 dBL
115 dBL
500m
ERR Limit (95% of blasts)
120 dBL
WA 492
WA 6852
HV Transmission Line
PHILLIPS QUARRY
EXTRACTION AREA
(PROPOSED)
SUMMERHILL ROAD
100 0 100 200 300 400 500
Metres
Work Authority boundaries
Proposed extraction limit