

HEXHAM WIND FARM PTY. LTD.

BLAST IMPACT ASSESSMENT FOR HEXHAM WIND FARM TEMPORARY QUARRY

1 INTRODUCTION

Terrock Consulting Engineers was engaged by Hexham Wind Farm Pty. Ltd. to assess the environmental impacts of blasting at a proposed hard rock quarry at Caramut, Victoria. The quarry would be located on a host property within the proposed Hexham Wind Farm (HWF) and provide an onsite source of aggregate and road base material needed for wind farm construction.

The proposed quarry overlies Newer Volcanics basalt that can be extracted by conventional drill and blast techniques and processed onsite. The proposal is for a temporary operation with an anticipated production phase of 2-3 years. Many wind farms in Australia and overseas have onsite quarries to provide construction and maintenance materials and the land uses are compatible. Regional examples include the Stockyard Hill Wind Farm, Ararat Wind Farm and Golden Plains Wind Farm.

Approval of the quarry is not directly related to Hexham Wind Farm approvals and is undertaken as a standalone process under the *Mineral Resources (Sustainable Development) (Extractive Industries) Regulations 2019* and broader regulatory framework for extractive industries in Victoria. However, the impacts of blasting at the proposed quarry are to be considered as part of the Environmental Effects Statement required for regulatory approval of the wind farm.

The primary blasting risks, effects and impacts assessed in this report are:

- Blast vibration (ground vibration and airblast overpressure)
- The throw of rock fragments from blast sites including the risk of flyrock.
- Effect of blasting on local amenity
- Impact to native fauna and domestic animals
- Risks to wind farm infrastructure.

The topics of geotechnical risk, air quality and audible noise from whole quarry operations (including blasting) are largely outside the writers' experience and may be addressed by qualified consultants in these fields.

2 QUARRY LOCATION AND SURROUNDS

The proposed quarry site is addressed at Barwidgee Road within the Shire of Moyne, approximately 6.5 km south of the township of Caramut and 14 km west of Mortlake. The proposed Work Authority is wholly within privately-owned property on lease to the proponent.

Quarry operations would be undertaken within a 52.3 hectare Work Authority (yet to be designated) including a 21.5 hectare extraction area wherein blasting would occur. Development plans produced by BCA Consulting show a minimum buffer of 20m between the north and south extraction limit and Work Authority boundary, and wider minimum buffers of 75m are shown east and west. The minimum separation between the extraction limit (i.e. the limit of blasting) and closest neighbouring property outside the quarry's title is the Schwartz property located 128m north of the proposed work authority boundary and 350m from the extraction area.

The surrounding area consists of broadacre farmland primarily used for livestock grazing. Access to the quarry is by private roads leading from Keilors Road in the distant south or Four Mile Road from the east, the route to be determined after wind farm EES decision. The closest public road reserve is Saleyards Road located northwest at a minimum distance of 1.7 km. There are no publicly accessible areas in the vicinity of the proposed quarry.

Preliminary project plans show 18 wind turbines would be constructed within a 2 km radius of the extraction (blasting) area, the closest turbine footing being 65m southeast of the extraction limit. Other nearby infrastructure includes overhead power cabling located 160m west of the extraction area, and buried cables located 65m south. Construction activities near the quarry would occur during (or after) the final stages of operations though the precise schedule is not yet known.

A site plan showing the proposed Work Authority, extraction/blasting area, proposed wind farm infrastructure and surrounding land areas is shown as **Appendix 1**. The locations of the closest sensitive sites (occupied residences) are also shown.

3 SITE GEOLOGY AND PROPOSED EXTRACTION METHOD

Exploratory drilling shows Newer Volcanics basalt with highly variable weathering underlies the site. The depths of overburden (near-surface clay soils and highly weathered material) range from 0.5m to floor level, this material being extracted by mechanical methods and stockpiled for site rehabilitation works. Blasting with commercial grade explosives would be required to extract rock with moderate to low weathering that occurs at variable depths across the site.

Design plans show a terminal pit floor depth of 13-14m below existing surface level. In areas with hard rock near the surface, blasting would be conducted on a single bench with a maximum height of 13m. In areas with more variable weathering or greater depths of overburden, the single bench may be split or reduced to 6-7m benches to assist with material quality control. A cross section showing the proposed extraction depth and methods (produced by BCA Consulting) is presented as **Figure 1**.

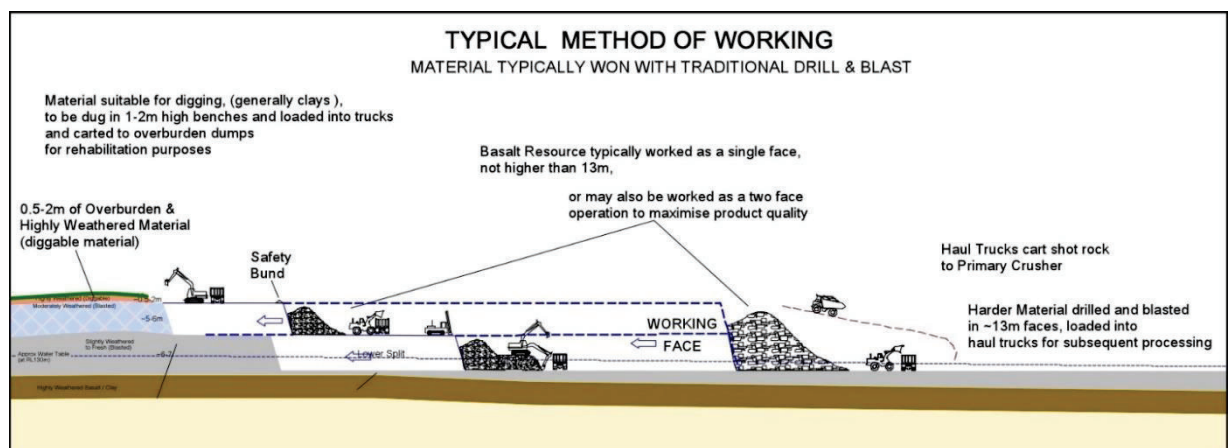


Figure 1 - Cross section of proposed extraction method (courtesy of BCA Consulting)

The total quantity of the resource is estimated at up to 2.1 million tonnes of fresh to moderately weathered rock subject to blasting, and 1.6 million cubic metres of soil and weathered/clayey material for mechanical excavation. Fragmented rock would be processed onsite with mobile crushing and screening plants. Extraction is proposed to occur in six stages progressing from east to west. Highly weathered rock and clay occurs to terminal depth in the central north and northwest corner with limited or no blasting required in these areas.

An average-sized blast with 100 blast holes would yield approximately 20,000-30,000 tonnes of hard rock with around 70-100 blasts indicated for the life of the quarry and an average of 42 blasts per year (i.e. near-weekly blasting). The total number of blasts required would ultimately depend on bench heights, the number of blast holes loaded per blast, the depth and extent of overburden encountered and wind farm construction schedules. Production rates and blast frequency would be highest during the early HWF construction phase (years 1-2).

4 SENSITIVE SITES (RECEPTORS)

The proposed quarry site is remote from “sensitive sites”, defined by the Earth Resources Regulator 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 nearest sensitive site is the residence of the proposed quarry’s title property holder located 2,350m east of the extraction limit. More distant residences are located north, northeast, south and southwest at distances of 2.4 km or greater. The separation between sensitive sites and the proposed quarry is substantial and would result in minor or imperceptible blasting effects at the closest residences.

5 ASSESSMENT CRITERIA

The transport, handling and use of explosives at Victorian quarries are highly regulated activities that must be undertaken in accordance with Australian Standards and State and Federal codes, regulations and guidelines. Site-specific conditions may also apply as detailed in a quarry’s Work Plan, Planning Permit or Work Authority conditions. Blasting regulations and other conditions must be observed to maintain a high level of safety for quarry personnel and the public, minimise blasting impacts, and protect private property and infrastructure from blast-induced damage. Blast vibration limits also apply at dwellings to help minimise disturbance and annoyance to residents from excessive levels of ground vibration and airblast.

Standards, guidelines and regulations that apply to quarry blasting operations in Victoria include;

- *Dangerous Goods (Explosives) Regulations 2011* [State of Victoria]
- Australian Standard AS2187.2-2006: *Explosives – Storage and Use, Part 2: Use of Explosives*
- *Ground Vibration and Airblast Limits for Blasting in Mines and Quarries, Environmental Guidelines* (Earth Resources Regulator, Department of Energy, Environment and Climate Action)
- *Occupational Health and Safety Act 2004* (OHS Act)
- *Environmental Effects Act 1978 (Victoria)*, including the ‘General Environmental Duty’
- *Australian Code for the Transport of Explosives by Road and Rail-3rd Edition (2009)*
- *Mineral Resources (Sustainable Development) (Extractive Industries) Regulations 2019.*

Key criteria that would apply to blasting at the proposed Hexham Wind Farm Quarry are detailed in the following sections.

5.1 Blast vibration limits for sensitive sites

Ground vibration and airblast overpressure from mine and quarry blasting is regulated by the Earth Resources Regulator (ERR), a sub-branch of Resources Victoria within the Department of Energy, Environment and Climate Action (DEECA). Limits for sensitive sites (e.g. occupied residences) are detailed in the *ERR Guidelines and Codes of Practice; Ground Vibration and Airblast Limits for Blasting in Mines and Quarries*, being;

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

The upper limits of 120 dBL and 10 mm/s are provided as an allowance for the occasional, unexpected exceedance of the lower (95%) limits. However, compliance with the lower limits is the performance target for all blasting. Exceedances of the limits are subject to investigation and failure to maintain compliance or improve outcomes may result in penalties for quarry operators.

The ERR limits are based on human comfort considerations and are set well below levels at which damage to light-framed, residential type buildings is known to occur. Further information about the risk of blast-induced damage to residential buildings can be found in **Section 8.5**.

5.2 Blast firing times

Most quarries are restricted to firing blasts on business days (Monday-Friday) between 10am and 4pm to help minimise disturbance at sensitive sites. This standard time window is appropriate for the proposed quarry and would most likely be included in Work Plan conditions. Blasting is prohibited at Victorian quarries on weekends and public holidays.

5.3 Ground vibration limits for infrastructure

Blasting conditions including ground vibration (PPV) limits for infrastructure are at the discretion of asset owners. PPV limits commonly observed for Australian infrastructure are shown in **Table 1**.

Table 1 – PPV limits observed by some infrastructure asset owners

Structure/item	PPV limit
- Cured, reinforced concrete (ref. Tennessee Valley Water Authority)	300-500 mm/s
- Buried comms/fibreoptic and electricity transmission cables (Telstra, Powercor, Ausnet, wind farms operators)	≥ 200 mm/s
- Railway infrastructure – tracks, culverts, bridges and signals (Australian Rail Track Corporation)	100-200 mm/s
- HV transmission (suspension) towers (Transgrid assets, Hunter Valley coal fields)	125 mm/s
- <i>Unoccupied structures of reinforced concrete or steel construction</i> (AS2187.2-2006 Table J4.5B)	100 mm/s
- High Voltage transmission towers (Ausnet & Powercor, Victoria)	
- Wind turbines & meteorology masts (Ararat and Stockyard Hill WF)	
- Concrete and timber communications and electricity service poles (Telstra, Powercor, Ausnet)	
- HV transmission (tension) towers (Transgrid, Hunter Valley coal fields)	60 mm/s
- Concrete drains, culverts, etc. (Melbourne Water, Yarra Valley Water)	50-100 mm/s
- Earthen dam walls and bunds (Melbourne Water, Camberwell coal mine)	50 mm/s
- Timber, concrete and steel transmission poles with transformers (Energy Australia, Powercor)	
- Industrial and heavy commercial-type buildings – cosmetic damage threshold at all frequencies >4 Hz (AS2187.2-2006)	
- Substations, transformers, batteries and computer servers (US MIL-STD-167-1, various Australian sites and owners)	25-50 mm/s

Airblast overpressure from quarry-scale blasting does not present a risk of damage to infrastructure and limits rarely apply. The only exception may be if a facility contains glass window panes that can be sensitive to high overpressure. AS2187.2-2006 suggests a conservative damage limit of 133 dBL while noting that “*window damage at levels below 140 dBL is improbable*”.

5.3.1 Wind turbines and meteorology masts

A PPV limit of 100 mm/s measured at the footings of wind turbines and meteorology masts has been adopted by several Victorian wind farm operators based on manufacturer’s recommendations. While the structural responses of turbines and masts from quarry blasting are not known to have been subject to detailed studies, Terrock considers the 100 mm/s limit to be appropriate and conservative in consideration of the low natural frequencies of tall structures and significant environmental loading turbines and masts are designed to withstand. Numerous wind farms have onsite quarries without reported adverse impacts. A 100 mm/s limit is also recommended in AS2187.2-2006 for “*unoccupied structures of reinforced concrete and steel construction*”.

5.3.2 Overhead power poles and lines

A PPV limit of 100 mm/s also applies to high voltage transmission towers, and electricity and communications poles in Victoria under order of asset owners (Ausnet, Powercor, Telstra, etc.). Studies undertaken for the Australian Coal Association Research Program (ACARP C14057) show poles and towers exhibit relatively minor structural responses and deflections that are a small fraction of the working strains of poles and lines.

5.3.3 Underground cables and conduits

Buried cables and plastic conduits have high flexibility and are effectively impervious to damage from elastic vibration waves. Limits of 200-300 mm/s have previously been observed by Telstra as a precaution for buried fibre-optic cabling.

5.4 Control of Flyrock

It is the responsibility of shotfirers and quarry operators to ensure rock fragments thrown from blast sites are fully contained within the boundaries of a Work Authority or the quarry’s title property at all times. Flyrock is prevented by adherence to regulations, standards and industry-standard procedures including good blast design, laser face profiling, blast hole (Boretrak) surveying, and accurate hole loading practices. The residual risk presented by flyrock (where rock fragments are thrown well beyond anticipated distances) is mitigated by establishing wide clearance zones at blast times. Quarry operators may be required to provide evidence to WorkSafe Victoria and ERR that flyrock is controlled and appropriate risk mitigation practices are in place. Details of the nature and risk of flyrock, and blast clearance requirements are presented in **Section 8.4**.

5.5 Quarry Buffer Zone (EPA)

EPA Victoria recommends a minimum separation (buffer) distance of 500m between quarries and sensitive sites/receptors in accordance with *EPA Guideline 1518: Recommended Separation Distances for Industrial Residual Air Emissions (2013)*. The guideline is in consideration of air quality impacts (e.g. dust and odour) from industrial sites including quarries with blasting. There are no sensitive sites within 500m of the proposed quarry.

6 BLAST DESIGN SPECIFICATIONS

The nominated blast design specifications (**Table 2**) used for this assessment are within the standard range used at numerous single-bench basalt quarries in western Victoria. Two designs are shown in consideration of the maximum potential face height of 13m, and reduced face heights of 7m for areas with deep overburden or quality control purposes.

Table 2 – Standard blast design specifications

	Single bench	Split bench
Face height (max.)	13m	7m
Sub-drill	1.0m	0.5m
Blast hole length (max.)	14.0m	7.5m
Blast hole diameter	89mm	89mm
Blast hole angle	10°	10°
Front row (face) burden	3.0m	3.0m
Inter-row burden	2.7m	2.7m
Spacing	3.0m	3.0m
Stemming height (min.)	3.0m	3.0m
Explosive column length (max.)	11m	4.5m
Linear Charge mass	7.5 kg/m*	7.5 kg/m*
Max. Instantaneous Charge (MIC)	82.5 kg/delay	33.8 kg/delay
Powder Factor (approx.)	0.7-0.8 kg/m ³	0.5-0.6 kg/m ³

*based on bulk explosives density of 1.2 sg

Designs for individual blasts may be modified by shotfirers as needed to maintain compliance with blast vibration limits, minimise blasting impacts, mitigate the risks of flyrock or improve blast performance (fragmentation and heave).

7 BLAST VIBRATION AND FLYROCK ASSESSMENT

The levels of ground vibration and airblast overpressure from blasting can be modelled using predictive formulae and blast design specifications as inputs. The following models have been developed from formal studies, monitoring and observations by Terrock and other researchers over many years. The models have proven reliable and are used to guide numerous mining, quarrying and other blasting operations across Australia and overseas.

7.1 Ground Vibration Levels

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

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

Where: PPV = Peak Particle Velocity (mm/s) [1]
 m = Charge mass-MIC (kg)
 D = Distance (m)
 k_v = A site constant

The model's site constant (k_v) represents local ground conditions that influence the transmission of ground vibration. Australian Standard AS2187.2-2006 Appendix J recommends a site constant of 1,140 for "average field conditions" though this value provides results with a 50% probability of exceeding predicted levels. Because the proposed quarry is a greenfield site, no local blast monitoring data is available for analysis. However, monitoring data and previous assessments from similar operations show that values of 1,500-1,700 provide $\geq 95\%$ confidence for predicting maximum PPVs. A higher value of 1,800 is adopted for this assessment as a more conservative approach to account for variable ground conditions.

The PPV models for standard blasts are;

Single Bench (13m face)

$$PPV = 1,800 \left(\frac{\sqrt{82.5}}{D} \right)^{1.6} \quad [2]$$

Split bench (7m face)

$$PPV = 1,800 \left(\frac{\sqrt{33.8}}{D} \right)^{1.6} \quad [3]$$

If required, blast monitoring data from early operations can be used to validate the model or calibrate the site constant to more accurately reflect local conditions. However, a site constant of 1,800 is sufficient for planning purposes noting that actual PPVs would be somewhat lower than predicted levels.

From the Site Law models [2] and [3], the distance to milestone PPV levels from standard blasts are shown in **Table 3**. The attenuation of PPV levels over distance is also presented graphically in the regression analysis, **Figure 2**.

Table 3 – Distance from blast sites to milestone PPV levels

PPV (mm/s)	Distance from Blast (m)	
	13m face (MIC 82.5 kg)	7m face (MIC 33.8 kg)
100*	55	35
50	85	55
20	151	97
10	233	149
5*	360	230
2	638	408
1	984	630
0.5	1,517	971

**Industry PPV limit for wind turbines, met masts, poles and pylons*

***ERR PPV limit for sensitive site (95% of blasts)*

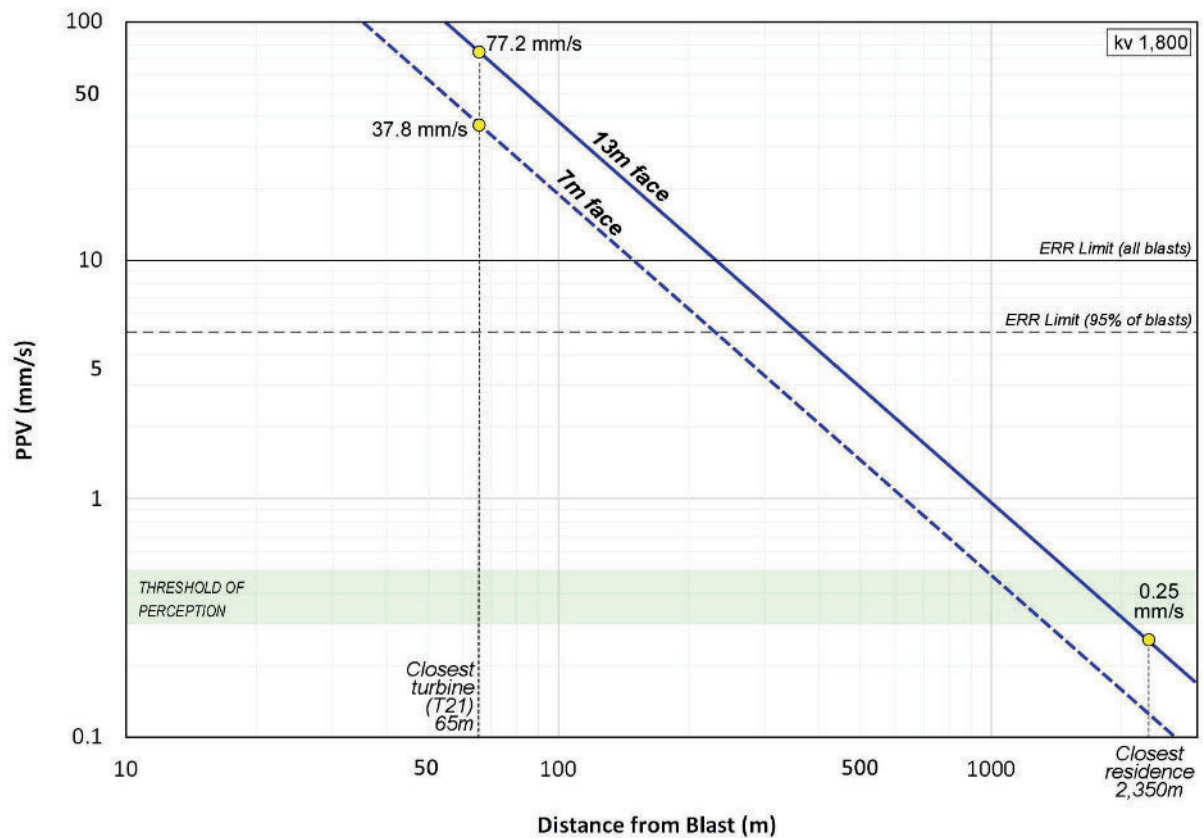


Figure 2 – Regression analysis of maximum PPV levels over distance

Maximum PPV levels at the closest sensitive site are 0.25 mm/s (13m face) and 0.12 mm/s (7m face). The threshold of blast vibration perception for people inside buildings is considered as 0.3-0.5 mm/s and it is most likely that vibration effects will not be felt at sensitive sites from any blast. Compliance with the ERR 5 mm/s limit for human comfort is assured due to the scale of blasting and substantial separation distances between the proposed quarry and sensitive sites.

The closest proposed wind turbine (T21) is located 65m southeast of the extraction limit. Maximum PPV levels at this distance are 77.2 mm/s (13m face) and 37.8 mm/s (7m face). Both levels are below the 100 mm/s limit typically observed for wind turbines, noting that 7m faces would be most likely for terminal blasts at the extraction limit.

The closest overhead transmission lines and poles are near the southwest corner of the proposed Work Authority at an approximate distance of 165m from the extraction limit. The maximum PPVs at this distance are 17.4 mm/s (13m faces) and 8.5 mm/s (7m faces). Both levels are well-below the 100 mm/s limit that typically applies to transmission poles and pylons.

The closest underground cables are approximately 65m from the southeast corner of the proposed extraction limit. Maximum surface PPVs are 77.2 mm/s (13m face) and 37.8 mm/s (7m face). However, PPV levels underground are typically 40-60% lower than surface levels because movement is constrained by the mass of surrounding ground. The maximum (surface) PPVs are below limits of 200-300 mm/s observed for buried cables by other asset owners.

This assessment shows the maximum potential ground vibration levels from the proposed quarry to be below relevant limits for infrastructure, and well below the ERR human comfort limits that apply at sensitive sites.

7.2 Airblast overpressure

Airblast (overpressure) is a low frequency (<20Hz) , sub-audible fluctuation of air pressure that occurs as explosives energy radiates from a blast site through the surrounding atmosphere. Overpressure is measured as decibels Linear (dBL), a separate measure to the audible component of airblast (i.e. blast noise). Overpressure is subject to ERR limits because at high levels can cause structural responses resulting in disturbance to people inside buildings.

The Terrock Airblast Model (Richards & Moore, 1993) has been developed and refined over many years of research and considers the confinement of explosives in blast holes. The peer-reviewed model is broadly conservative and is used to guide blast design requirements at numerous quarry and mining operations around Australia and overseas. The model used in this assessment predicts the distance from a blast site to the 115 dBL level (i.e. the ERR limit for sensitive sites).

$$D_{115} = \left(\frac{k_a \times d}{B \text{ or } SH} \right)^{2.5} \cdot \sqrt[3]{m} \quad \text{Where: } \begin{array}{ll} SH & = \text{Stemming height (mm)} \\ B & = \text{Front Row Burden (mm)} \\ m & = \text{Charge mass-MIC (kg)} \\ D_{115} & = \text{Distance to 115 dBL level (m)} \\ d & = \text{Blast Hole diameter (mm)} \\ k_a & = \text{Site constant(s);} \\ & \quad 250 \text{ (front of face)} \\ & \quad 190 \text{ (behind/side of blast)} \end{array} \quad [4]$$

Airblast attenuates at an approximate rate of 9 dBL with doubling of distance. The highest emissions occur directly in front of free-face blasts because airblast energy is projected horizontally through the face. Behind and to the sides of a blast, emissions are lower because most energy is projected vertically into the atmosphere with lower dBL levels at ground level. Airblast levels in front of blasts is controlled by front row/face burden provisions. Behind and to the sides of a blast, levels are controlled by stemming height specifications.

From standard blast design specifications (Table 2) the airblast models used in this assessment are;

$$\text{Front of Face - Single Bench (13m)} \\ D_{115} = \left(\frac{250 \times 89}{3,000} \right)^{2.5} \cdot \sqrt[3]{82.5} \quad [5]$$

$$\text{Behind/side of Blast - Single Bench (13m)} \\ D_{115} = \left(\frac{190 \times 89}{3,000} \right)^{2.5} \cdot \sqrt[3]{82.5} \quad [6]$$

$$\text{Front of Face - Split Bench (7m)} \\ D_{115} = \left(\frac{250 \times 89}{3,000} \right)^{2.5} \cdot \sqrt[3]{33.8} \quad [7]$$

$$\text{Behind/side of Blast - Split Bench (7m)} \\ D_{115} = \left(\frac{190 \times 89}{3,000} \right)^{2.5} \cdot \sqrt[3]{33.8} \quad [8]$$

The airblast model assumes flat terrain around a blast site without barriers to transmission that may be provided by landforms such as hills and gullies (i.e. topographic shielding). Because the surrounding terrain is flat the effects of topographic shielding would negligible. However, a modest degree of shielding could be provided by overburden stockpiles and bunds around the extraction area.

From the models [5-8], the predicted distances to milestone airblast levels under standard blast design specifications are shown in **Table 4**.

Table 4 – Distances to milestone airblast levels

Airblast (dBL)	13m face (MIC 82.5 kg)		7m face (MIC 33.8 kg)	
	Front of face (m)	Behind/side of blast (m)	Front of face (m)	Behind/side of blast (m)
120	652	328	484	244
115*	946	476	702	354
110	1,371	690	1,018	513
105	1,988	1,001	1,477	744
100	2,881	1,444	2,140	1,073

*ERR Airblast Limit (95% of blasts)

The reduction of airblast levels over distance is shown in the regression analysis **Figure 3**.

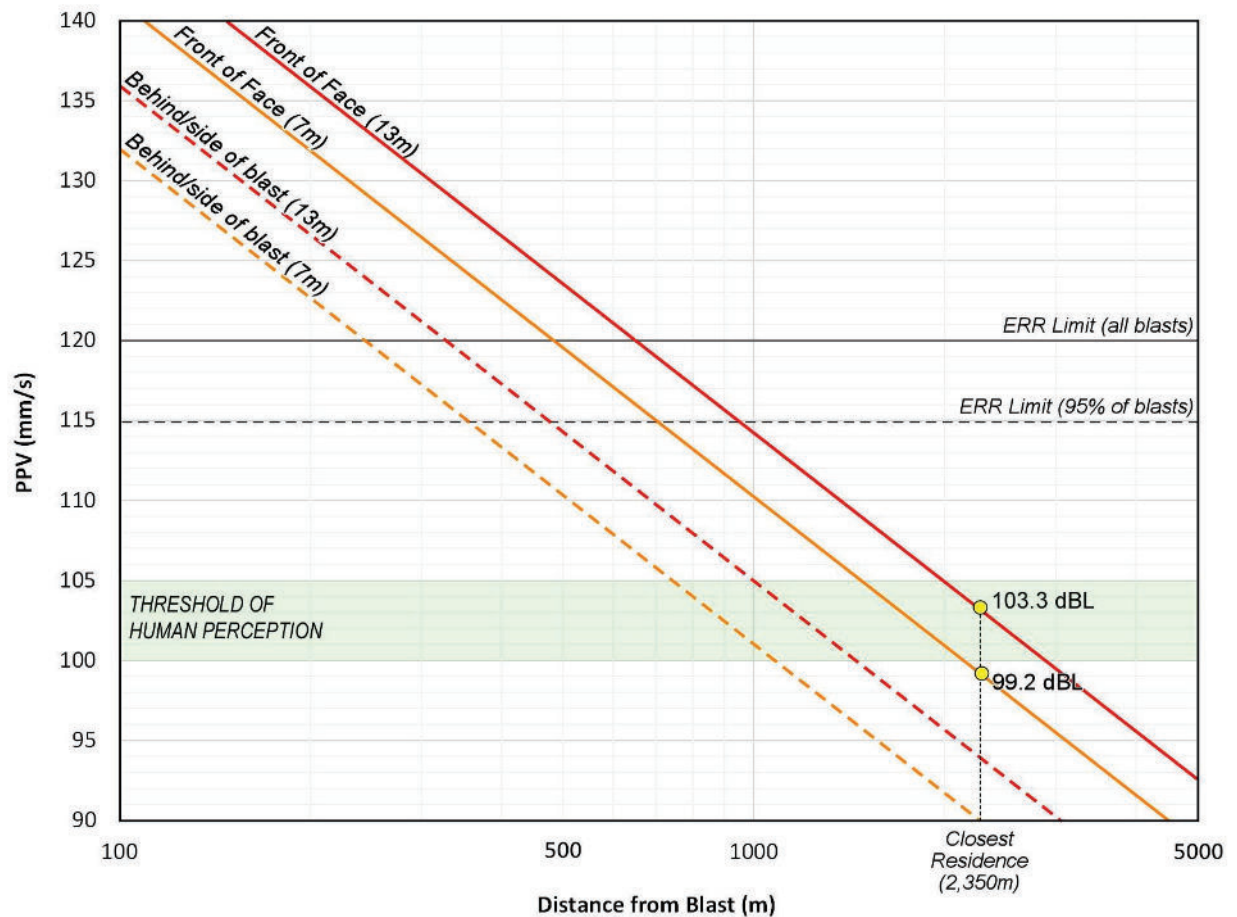


Figure 3 – Airblast Regression Analysis (13m and 7m face)

This assessment shows compliance with the ERR 115 dBL airblast limit for sensitive sites would be met for all standard blasts regardless of face height or direction, with maximum levels of 103.3 dBL to 103.3 dBL at the closest receptor. The threshold of airblast perception is considered 100-105 dBL and the effects would be imperceptible at more distant sensitive sites, though low-level blast noise may be occasional heard at distant locations depending on weather conditions at blast times.

7.3 Flyrock

The maximum throw of rock fragments under a blast's design specifications can be calculated using the Terrock Flyrock Model. The model has proven useful for helping determine minimum clearance distances around blast sites and is used for blast planning at numerous quarries and mines around Australia. The model is conservative by design and provides an allowance for minor inconsistencies in face structure and minor errors that may occur during blast hole loading. The model was reviewed in 2007 by Dr. Peter Lilly (former 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 ($Lmax_f$) can be calculated by:

$$Lmax_f = \frac{k_f^2}{g} \left(\frac{\sqrt{m}}{B} \right)^{2.6} \quad [9] \quad \text{Where:} \quad \begin{array}{l} m = \text{charge mass, kg/m} \\ B = \text{front row burden (m)} \\ Lmax_f = \text{maximum throw in front of face (m)} \\ g = \text{gravitational constant (9.8)} \\ k_f = \text{a site constant (27 conservative)} \end{array}$$

Behind a blast, the maximum throw ($Lmax_r$) is calculated by:

$$Lmax_r = \frac{k_f^2}{g} \left(\frac{\sqrt{m}}{SH} \right)^{2.6} \sin 2\phi \quad [10] \quad \begin{array}{l} SH = \text{stemming height (m)} \\ Lmax_r = \text{maximum throw behind blast (m)} \\ \phi = \text{launch angle = hole angle from horizontal} \\ \quad + \text{a dispersal allowance of } 10^\circ \\ \quad (\text{e.g. Hole angle + dispersal} = 70^\circ \text{ from horiz.}) \end{array}$$

As with airblast, flyrock is largely controlled by face burden and stemming height specifications. Throw measurements from hard rock quarries shows a site constant (k_f) of 27 to be a conservative generic value for the model and actual throws are normally well short of calculated distances. However, a cautious approach to flyrock and blast clearance is warranted due the high consequence of flyrock striking a person or property.

The models used in this assessment are;

Front of face throw

$$Lmax_f = \frac{27^2}{9.8} \left(\frac{\sqrt{7.5}}{3} \right)^{2.6} \quad [11]$$

$$Lmax_f = 59\text{m}$$

Behind/side of blast throw

$$Lmax_r = \frac{27^2}{9.8} \left(\frac{\sqrt{7.5}}{3} \right)^{2.6} \sin 2(70) \quad [12]$$

$$Lmax_r = 38\text{m}$$

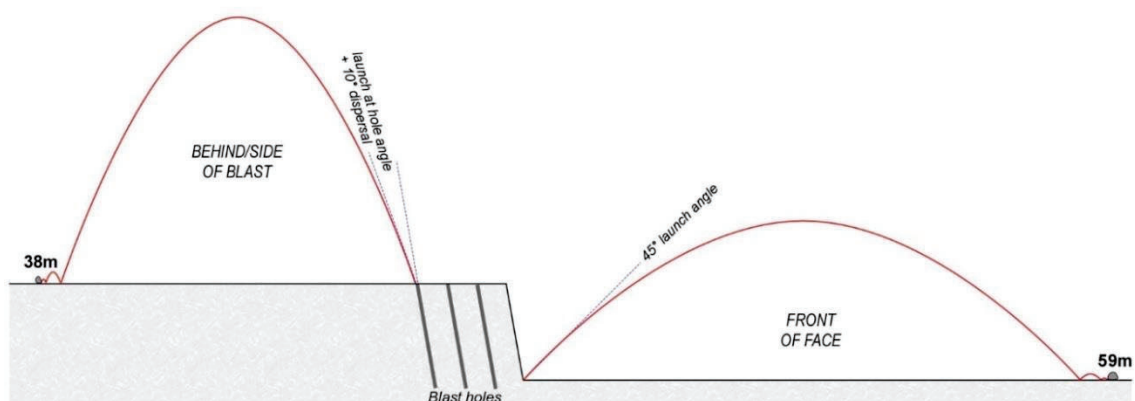


Figure 4 – Flyrock trajectory diagram (Front Row Burden & stemming = 3.0m)

Blasts approaching extraction limits face inwards towards the pit with shorter throws behind blast sites. The maximum throw of 38m exceeds the minimum buffer distance of 20m, though the consequence of a few rock fragments landing a short distance into the surrounding title property (within the blast's clearance zone) is negligible. While the calculations are conservative, stemming height can be increased for terminal blasts to reduce maximum throws if needed. Methods for reducing throw distance are shown in **Section 10.3**. A high level of flyrock safety is provided at the Schwartz property that is located a minimum 350m north of proposed blasting.

8 BLASTING RISKS AND CONTROLS

Well-controlled blasting operations that adhere to existing standards, regulations and best practice present a low risk to people, property and the surrounding environment. The risks to sensitive sites and nearby structures, and the control measures used to mitigate the risks are discussed in the following sections.

8.1 TRANSPORT, HANDLING AND USE OF EXPLOSIVES

Blasting at Victorian quarries is undertaken by qualified personnel who are trained and licensed to use blasting explosives in the State of Victoria. The use of commercial grade explosives must be conducted in accordance with National and State regulations, standards and guidelines including:

- *Victorian Dangerous Goods (Explosives) Regulations 2022*,
- Earth Resources Regulator (ERR) guidelines for quarries
- *Australian Standard AS2187.2-2006*
- *Occupational Health and Safety Act 2004*
- *Australian Explosives Code 3rd Edition*
- Work Authority conditions, as well as any site-specific blasting conditions that may apply as part of a quarry's approved Work Plan.

Blasts at the proposed Hexham Wind Farm Quarry would be designed, loaded and fired by a drill and blast contractor. It is the responsibility of shotfirers and all blast crew personnel to work to Victorian blasting regulations and relevant standards, site rules, and the procedures of an approved Blast Management Plan. It is the responsibility of quarry operators to ensure all blasts are fired in accordance with prescribed regulations, maintain site safety and security, and help coordinate the blast clearance procedure.

Specific risk control measures for explosives transport, onsite handling and security procedures can be found in the quarry's Blast Management Plan, Risk Assessments and Blast Plans for individual blasts, and Material Data Safety Sheets provided by the explosives supplier.

8.2 EXPLOSIVES STORAGE

In line with current industry practice, explosives products would not be stored at the proposed quarry. All explosives and accessories would be brought to site on blast day mornings by a licenced explosives supply company and unused products returned to the supplier's company's facility after each blast is loaded and all items are accounted for.

8.3 RISK TO WIND FARM INFRASTRUCTURE

Wind farm items of immediate interest are:

- Wind turbines within Hexham Wind Farm (during or after construction)
- Overhead transmission cables and poles
- Underground cables

8.3.1 Wind turbines

Wind turbine support towers are reinforced steel structures designed to withstand substantial loading from thermal expansion, strong winds and blade rotation. Tall structures have low natural frequencies (<2hz) that do not align with the higher wave frequencies from nearby blasting and structural responses are minimal. The short durations of quarry blasts are also insufficient to induce and build up strong resonant responses and deflections. While the structural responses of turbines to quarry-scale blasting are not known to have subject to formal studies, maximum PPV amplification factors of ~2 have been recorded on high voltage transmission pylons in the Hunter Valley coalfields and other tall structures, with maximum displacements of 2-3mm at upper sections (ACARP C154057).

Ground vibration waves from blasting are elastic and generate small displacements. Peak Particle Displacement (PPD) can be calculated with the formula;

$$PPD = \frac{PPV}{2 \pi f}$$

For a PPV reading of 100 mm/s with ground motion frequency of 10 Hz, the brief, non-permanent surface displacement is 1.59 mm over a wavelength of 220m, resulting in negligible differential movement of the turbine footings as shown in the schematic diagram **Figure 5**. Actual movement is less than indicated because turbine footings are mostly below surface level where lower PPVs occur. It is reasonably concluded that wind turbines and their components are not sensitive to blast vibration and Terrock is unaware of any instance of blasting operations at a nearby quarry causing adverse effects to turbines or other wind farm infrastructure.

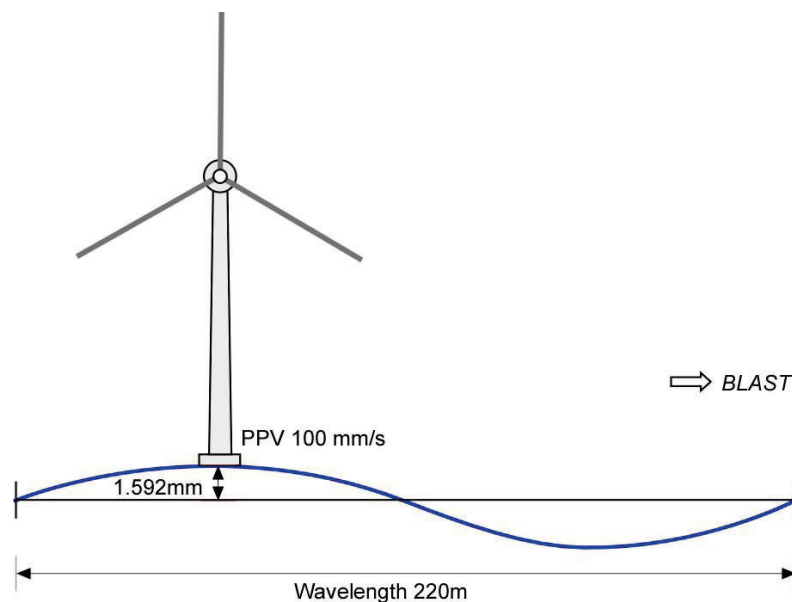


Figure 5 – Ground vibration wavelength and peak displacement at 100 mm/s PPV limit (not to scale)

8.3.2 Concrete footings

Concrete slabs and footings are highly resilient to elastic ground motions. Unlike free-standing structures, embedded concrete exhibits no amplification due to resonance and the only potential for vibration-induced damage is if ground strain from passing waves exceed the working strains of concrete. Experienced researcher Lewis L. Oriard states, “During more than 50 years of observations, the writer has not personally seen a case where a concrete slab was damaged by elastic vibrations from blasting”. This is also the experience of Terrock personnel from monitoring, observing and researching the effects of blasting in Australia for over 40 years.

The working strain of ≥ 20 MPa reinforced concrete is conservatively calculated to be 118.5 microstrain ($\mu\epsilon$) for flexural tension and $\geq 885 \mu\epsilon$ for compression (ref. Australian Standard AS 3600-2018). Using ground strain approximation from plane wave strain theory proposed by Dowding (1986) the limiting PPV level to prevent cracking of reinforced concrete is a conservative 278 mm/s (ACARP C14057).

Evidence that a higher vibration limit may be applied to mass concrete is provided by Oriard (2002) who cites the Tennessee Valley Authority’s application of the following criteria for their projects and assets.

Table 5 – TVA mass concrete damage criteria (after Oriard, 2002)

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	-	-

The limits range from 100 mm/s for freshly poured concrete to 500 mm/s after 10 days of age. The distance-scale reduction recognises that high vibration frequencies occur at closer distances, but the low frequencies at greater distances result in higher strains and displacements with greater damage potential. The maximum PPV at the closest HWF turbine footing (T21) is conservatively predicted to be 77.2 mm/s for a 13m face blast at the extraction limit.

The only plausible mechanism for blast-induced damage to concrete slabs and footings is from ‘block movement’ where the supporting ground structure is directly and permanently displaced by explosive energy. In average ground conditions, block movement is limited to the normal fracture zone within a few metres from back row blast holes. Beyond the fracture zone, residual explosives energy converts to elastic waves that rapidly decay over distance.

8.3.3 Overhead transmission lines, towers and poles

A non-damaging PPV limit of 100mm/s also typically applies for blasting operations near steel transmission towers, and concrete steel and timber poles under the order of asset owners/managers such as AusNet Services, Powercor and Ausgrid. Poles in good condition have sufficient flexibility to accommodate strains from transport, erection, environmental loading, and ground vibration and seismicity. Studies have also shown timber and concrete poles in good condition exhibit no adverse effects from exposure to ground PPV levels as high as 240 mm/s. The closest overhead transmission lines poles are shown to be approximately 160m west of the extraction limit with maximum PPVs of 18 mm/s (13m face) and 9.5 mm/s (7m face).

8.3.4 Underground cables

Buried cables and their PVC conduits are effectively impervious to damage from ground vibration due to their high flexibility PPV levels up to 347 mm/s have been recorded with no adverse effects (ref. ACARP Study 14057). The only possible damage mechanism for buried cables and conduits is by permanent ground deformation, or “block movement”. Such movement can only occur in rocky areas where rock blocks at the trench wall are forced through the bedding material and damage a cable by shearing or compression. However, the zone of permanent ground deformation from quarry-scale blasting is limited to a few metres from blast holes. PPV limits of 200-300 mm/s have been observed by Telstra and other wind farm operators.

The maximum surface PPV at the closest buried cables (65m from the southern extraction limit) is 77.2 mm/s (13m face), though actual levels at the depth of the cable would be somewhat lower.

8.4 FLYROCK RISK

The greatest blasting hazard to the safety of people and property is flyrock, where rock fragments from a blast are thrown well-beyond anticipated distances. Flyrock events at quarries have become uncommon due to improvements of blasting practice and no flyrock injury has been reported at a Victorian quarry for several decades. However, flyrock remains a possibility at all quarries and its prevention and risk mitigation is a critical consideration for shotfirers and quarry managers.

8.4.1 The nature of flyrock

Where blasts are conducted on benches with a free face, fragments of blasted rock heave forward and form a pile in front of the blast site from which they are transported for processing. Sometimes fragments are thrown beyond the pile and land at more distant locations. The furthest potential throws occur within a 90° arc perpendicular to the face and consists of 100-200mm diameter fragments launched at a 45° angle. Smaller fragments have reduced throw due to wind resistance and the throw of larger blocks and boulders is restricted by mass.

The furthest throws behind blast sites typically consist of small fragments of stemming material or loose collar rock that are launched at the blast hole angle and disperse by ~10°. If a blast hole is significantly under-stemmed, collar rock can break out at a 45° angle and be thrown further distances, an occurrence known as “cratering”. Generally, due to the smaller size of fragments, steep launch angles and lower velocities on landing, flyrock behind blast sites presents a lower risk of serious injury than flyrock thrown in front of the face.

8.4.2 Causes and prevention of flyrock

Excessive flyrock throw is the result of human error where insufficient face burden or stemming, overcharged blast holes or structural weaknesses in face rock are not identified prior to firing. The primary mechanisms for flyrock in front of the face are shown in the following cross section diagrams (Figure 6a).

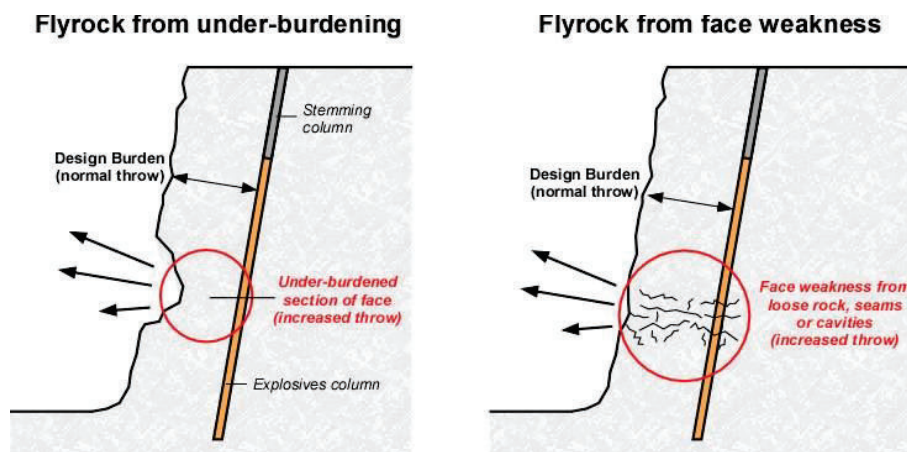


Figure 6a – Mechanisms for flyrock in front of a blast face

Under-burdening is identified by visual inspection, and laser face profiling and Boretrak survey techniques that measure the true burden between the face and front row blast holes, and the depth and deviation of each hole. Structural weakness in blast faces (e.g. wide clay seams and pockets of loose or naturally fragmented rock) are not detected by laser profiling but identified by review of driller’s logs and visual inspection of blast faces. If under-burdening or structural weakness is identified or suspected, affected holes must be loaded in a manner that prevents explosives being placed in under-confined sections.

Flyrock can also be caused when one or more blast holes are overcharged and normal design burden and stemming provisions are insufficient to confine the additional energy. As a rule of thumb, the quantity of explosives loaded into every blast hole should not exceed 10% of the design charge mass. The mechanisms for flyrock behind and to the sides of a blast are shown graphically in **Figure 6b**.

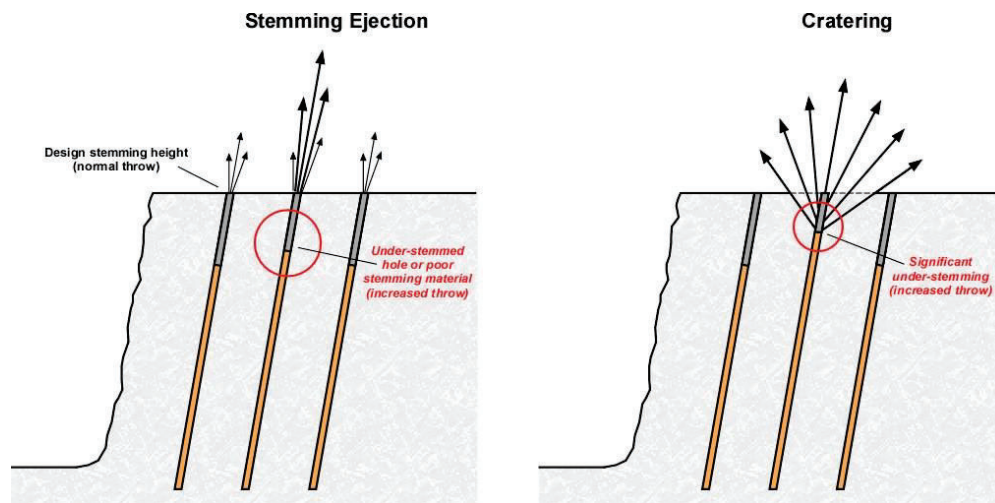


Figure 6b – Mechanisms for flyrock behind and to the sides of a blast

Flyrock behind blast sites is prevented by ensuring an adequate length of stemming is loaded into each hole through careful loading practices and accurate record keeping. The optimum stemming material for 89mm holes is 10-14mm stone aggregate. To prevent cratering, the minimum length of the stemming column should be at least 20 x the blast hole diameter (being 1.8m for 89mm diameter holes). The minimum nominated stemming height of 3.0m is sufficient to prevent cratering.

In summary, flyrock is successfully prevented by review of driller's logs and blast hole survey results, inspection of face structures, careful attention to hole loading practices, and accurate record keeping and review.

8.4.3 Risk of flyrock to infrastructure

If nearby turbines are constructed during the life of the quarry, the risk of rock fragments striking the structures is low. The maximum throw of 38m behind blasts is approximately half the distance to the nearest turbine. A safety factor of 2 (2 x maximum throw) is commonly observed by quarry operators to protect onsite infrastructure from flyrock damage. This safety factor can be increased with additional stemming or front row burden for nearby blasts to reduce maximum throws as guided by observation of the behaviour of rock under blasting.

The only plausible scenario in which rock could strike the closest turbine is if a significant flyrock event such as cratering was to occur due to blast design or loading errors though this is unlikely with industry-standard practices in place. The likelihood of flyrock striking more distant turbines or other wind farm infrastructure is negligible.

8.4.4 Blast Clearance Zone

With standard controls in place, the residual risk presented by flyrock is mitigated by establishing wide clearance zones around blast sites to account for the possibility of increased throw due to human error. Clearance zones are established immediately prior to blast times and are lifted when the shotfirer gives the "all clear" signal after a brief post-blast inspection. The zone is secured by blast guards positioned on access tracks with a clear view of the surrounding area. No blast may be fired until the shotfirer receives confirmation from every guard that the clearance area and pit remains free of people and it is safe to fire the blast.

A recommended approach for determining minimum blast clearance distances is to observe safety factors based on throw calculations. This approach is used at numerous mines and quarries around Australia and has proven effective to protect people and property at blast times. The minimum safety factors Terrock recommends for blast clearance at quarries are;

- Safety Factor 2 – Quarry Plant, Equipment & Wind Farm Infrastructure
- Safety Factor 4 – Quarry Personnel and Public

Under this approach the minimum blast clearance distances for standard blasts at the proposed quarry are:

Table 6 – Minimum blast clearance distances from flyrock model safety factor approach

	Front of Face	Behind Blast
Maximum Throw	(59m) 60m	(38m) 40m
S.F. 2 – Plant & Equipment	120m	80m
S.F. 4 – Quarry Personnel & Public	240m	160m

The footprint of the clearance zone is formed by combining front and behind distances (**Figure 7**). This can be produced as a scaled transparent overlay to be used with site maps during blast planning if required.

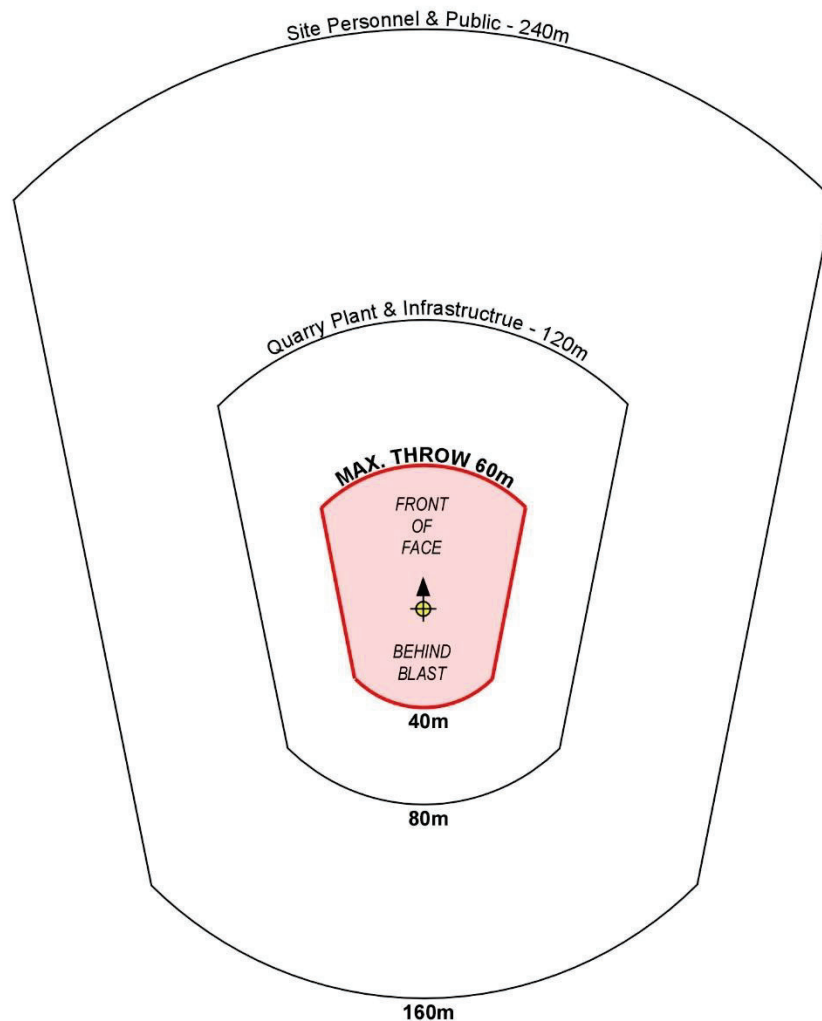


Figure 7 – Recommended Minimum Blast Clearance Distances (Standard Specification Blasts)

The clearance distances above are strictly minimum and can be used to determine safe locations for shotfirers and blast guards. It is recommended that all other quarry and wind farm personnel be evacuated to more distant locations, particularly from areas directly in front of the face. The clearance zone falls entirely within the proposed quarry's title properties and clearance on neighbouring properties (min. 350m) is not warranted. Due to the limited number of people that would be within the quarry or adjacent land areas at blast times, wider clearance areas within the title property would be relatively easy to establish and secure. Effective coordination of activities around the quarry would be relatively straightforward given the working relationships between the title property holder, wind farm management and quarry operator. It is also recommended that any livestock close to blast sites be moved outside the minimum clearance area as a precaution.

Establishing adequate clearance around blast sites is ultimately the responsibility of shotfirers and quarry managers. Clearance distances around individual blasts may be increased by order of the shotfirer at any time on consideration of a blast's design, blast hole survey results, modified hole loadings, localised rock structure and previous throw observations. For example, if true front row burden is shown to be less than the design specification of 3.0m, the minimum clearance in front of the face should be increased accordingly.

Details of blast clearance and firing procedures to be followed (including the quarry's emergency assembly areas and procedures) should be specified in the quarry's Blast Management Plan and relevant information included in documentation pertaining to individual blasts such as Risk Assessments, blast plans, SWMS, etc.

8.5 RISK OF DAMAGE TO BUILDINGS

The risk of blast vibration-induced damage to closest buildings such as residences is negligible due to the remoteness of the quarry and low or imperceptible PPV levels that would occur in distant areas. The risk of damage to buildings can be assessed using criteria from AS2187.2-2006 Appendix J that includes a guide from British Standard BS7385.2-1993 (**Figure 8a**). For light-framed, residential type buildings the minimum threshold of cosmetic damage is 15 mm/s for 4 Hz vibration waves. The maximum PPV of 0.25 mm/s at the nearest house is less than 2% of the cosmetic damage threshold.

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.

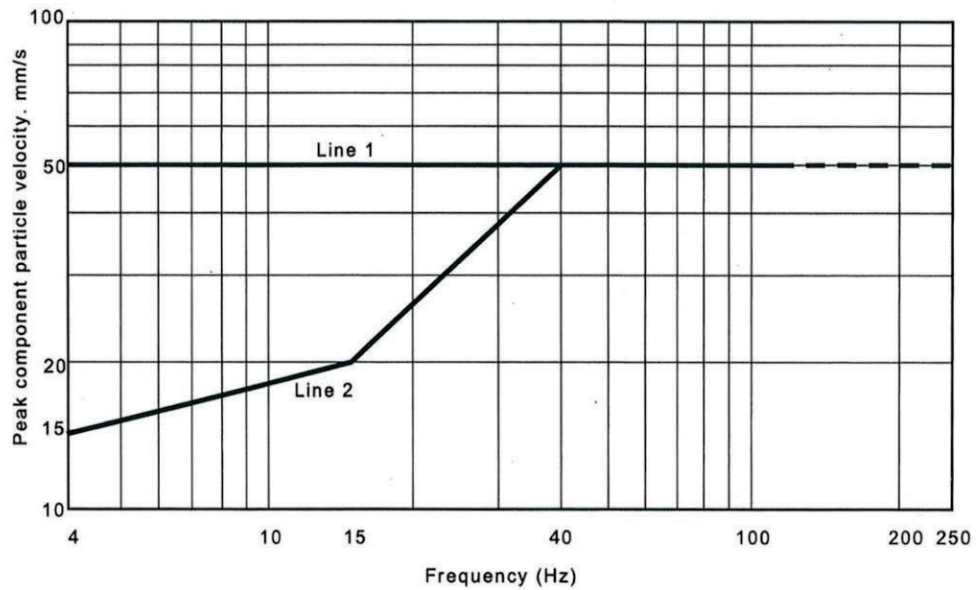


FIGURE J4.4.2.1 TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE
(BS 7385-2)

Figure 8a – Threshold/cosmetic damage criteria from AS2187.2-2006 (source: BS7385.2-1993)

Damage classifications to be used with the guideline are shown as **Figure 8b**. The threshold for minor-type damage is 2 x the cosmetic damage values, and major/structural may occur above 4 x the cosmetic values.

TABLE J4.4.2.2
BS 7385-1:1990—DAMAGE CLASSIFICATION

Damage classification	Description
Cosmetic	The formation of hairline cracks on drywall surfaces or the growth of existing cracks in plaster or drywall surfaces; in addition, the formation of hairline cracks in the mortar joints of brick/concrete block construction
Minor	The formation of cracks or loosening and falling of plaster or drywall surfaces, or cracks through bricks/concrete blocks
Major	Damage to structural elements of the building, cracks in support columns, loosening of joints, splaying of masonry cracks etc.

Figure 8b – Damage classifications from AS2187.2-2006 (source: BS7385.1-1990)

The damage criterion is conservative by design and the values denote PPV levels, “*above which there is an increasing possibility of damage*”. There is consensus among researchers (Oriard, Dowding, etc.) that damage is rare below 50 mm/s and Australian research into the effects of blasting has shown PPV levels below 70 mm/s to be wholly non-damaging to common brick-veneer type houses (ACARP C9040).

8.6 RISK TO LOCAL AMENITY & PUBLIC HEALTH

The impact of blasting on the amenity of the surrounding area would be low because the combined effects of ground vibration and airblast have short durations of around 2-5 seconds per event and PPV and airblast levels at the closest sensitive sites are anticipated to be very low or imperceptible. In addition, blasting would be limited to weekdays during business hours when people are less likely to be inside houses, would occur once or twice per month, and the proposed quarry has a short lifespan.

While unlikely, blast related concerns or complaints raised by residents can be addressed by blast monitoring at sensitive sites and engaging with community members to provide blasting information. Another effective method to alleviate concerns and prevent potential startling is by providing residents with personal notifications of impending blasts. Notifications may be required under Work Plan conditions and can be provided by SMS, email or phone call. A register of complaints must also be maintained by operators.

Blast vibration at regulated levels does not cause physiological harm to humans. While the effect of dust on human health is outside Terrock’s qualifications, dust loads from blasting are short-lived and present a small fraction of potential loads from whole quarry operations and nearby agricultural activities. There is likely to be substantial dissipation of dust loads from blasting over the significant separation distance between the quarry and closest receptors.

Blasting also produces NO_x (nitrogen oxide) fumes that with high concentrations and prolonged exposure can be harmful to human health. NO_x is also produced by common fuel burning processes such as wood fires and combustion engines. High levels of NO_x from blasting are typically produced by a reaction between some explosives products and water in blast holes, or when inadequate mixing of ammonium nitrate and sensitising agents occurs during hole loading from bulk delivery systems. The presence of high NO_x levels from a blast can be identified by the bright yellow-orange fumes produced. High concentrations of NO_x from quarry blasting have become uncommon due to improvements in explosives products and equipment. As a precaution, shotfirers are required to wait a few minutes after blast times to allow NO_x to dissipate before inspecting the blast site.

8.7 EFFECT OF BLASTING ON NATIVE FAUNA AND DOMESTIC ANIMALS

Most quarries are located in rural or semi-rural areas with livestock, pets and native animal habitat on adjacent properties and reserves. To date, Terrock is unaware of any confirmed case of quarry blasting affecting the health or wellbeing of an animal species.

8.7.1 Native Fauna

Many native species reside within active work authorities and adjacent land areas. Wallabies, koalas, wombats and lizards can be found in bushland areas in and close to some Victorian quarries. Eastern grey kangaroos can be found at quarries throughout eastern Australia. Their presence indicates that native animals acclimatise to quarry operations and are not deterred by brief ground vibration and airblast events on blast days.

The behaviour of birds near blast sites has been observed by Terrock over many years. Birds located within a few hundred metres of a blast typically fly away in response before returning to the area after a few minutes when the perceived danger has passed. Many quarries have populations of waterbirds residing in dams and ponds on pit floors. At an active, single-bench, basalt quarry near Colac,

populations of native waterbirds can be found on the quarry’s dams, and swallows are known to nest on terminal faces of worked out areas. Raptors also frequent many quarries, preying on small mammals and other bird species.

While Terrock is unaware of any formal studies of the effect of airblast from quarries on animal physiology and behaviour, comparison can be made with the effects of other noise and overpressure sources. Lightning generates high levels of noise and overpressure that animals have evolved to tolerate, and other common noise sources in rural areas including bird scarers and occasional gunshots are also considered. It can be reasonably concluded that an occasional, brief airblast event has little to no lasting impact to animals in surrounding areas.

8.7.2 Domestic Animals

Regular observations around quarries taken over many years show that quarry blasting presents a negligible risk to the health and wellbeing of domestic animals including livestock. Many Victorian quarries have cattle and horses on neighbouring properties and the typical response of livestock near a blast site is to briefly raise their heads and look around for a few seconds before resuming grazing. Livestock located within 100m of blast sites may walk a short distance away from the source of the disturbance, through spooking or obvious distress has not been observed. As with birds, the impact of airblast to livestock on adjacent land can be likened to the response from a distant thunderclap.

Horse agistment, studs and riding clubs can be found on the properties neighbouring some Victorian quarries with no reported adverse effects from blasting. Cows on dairies neighbouring quarries and mines in Victoria and NSW are routinely exposed to PPV levels up to 10mm/s and airblast levels around 120 dBL with no reported effect on animal wellbeing or milk production.

Some dogs have been observed becoming excitable and bark or howl around blast times, though this is typically in response to a quarry warning siren that is sounded before and after each blast is fired. While individual animals may have particular environmental sensitivities, there is no evidence that blasting causes significant distress to pets and other animals.

9 RISK ASSESSMENT

The primary blasting risks from the previous section are rated in accordance with a Risk Matrix (**Figure 9**) provided by ERR in the document *Preparation of Work Plans and Work Plan Variations – Guideline for Extractive Industries* (December 2020). Risks are rated as Low, Medium, High or Very High in accordance with their likelihood and potential consequences. The risks and controls associated with transport, storage and handling of explosives products are detailed in a quarry’s Blast Management Plan, documentation for individual blasts, and information provided by the explosives supplier.

Likelihood	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
		Insignificant	Minor	Moderate	Major	Critical
		Consequence				

Figure 9 – ERR Risk Matrix

The inherent risks of blasting, control measures to be observed, and residual risks (after controls are in place) are rated in accordance with the matrix in **Table 7**. Most controls are not specific to the proposed quarry and are standard industry practice. Further details of the controls to be observed by the quarry operator can be found in the site's Blast Management Plan.

Important note on flyrock risk

The risk presented by flyrock requires special consideration due to limitations of the ERR matrix definitions. While flyrock events are rare and the probability of a person being struck by a rock fragment is extremely low, the consequence of flyrock strike is critical and therefore the risk is rated high. In reality, the risk posed by flyrock from well-controlled quarry blasting with wide, secure clearance zones in place is low.

Table 7 – Risk ratings and required control measures

RISK	INHERENT RISK RATING	RISK CONTROL MEASURES	RESIDUAL RISK RATING
FLYROCK (AREAS WITHIN THE QUARRY)	VERY HIGH Likelihood POSSIBLE Consequence CRITICAL	<ul style="list-style-type: none"> - Laser Face Profiling & Boretrak survey conducted for all blasts. - Visual inspection of blast site/face and review of drillers log and survey results to identify structural weaknesses and guide individual hole loading requirements. - Ensure minimum stemming heights are loaded into each blast hole. - Review hole loading records including treatment methods used for under-confined blast holes. - Blasts inspected and signed off by authorised persons in accordance with regulations. - Clearance Zone (min. 240m front and 160m behind/side of blasts) established inside quarry and adjacent title property areas. - All site personnel evacuated from pit to more distant locations or assembly area. - Blast guards positioned at access tracks leading to pit and blast site. - All onsite and nearby offsite personnel to be accounted for prior to commencing the firing procedure. - <i>No blast may be fired until the shotfirer receives confirmation from all blast guards that the clearance area is free of people and it is safe to fire the blast.</i> - Flyrock observations and video recording of blasts conducted for performance review and to guide any blast design modifications required for further blasting. 	HIGH Likelihood RARE Consequence CRITICAL
FLYROCK (NEIGHBOURING PROPERTIES AND LAND AREAS)	HIGH Likelihood POSSIBLE Consequence MAJOR	<ul style="list-style-type: none"> - Observe standard flyrock prevention and risk controls (see above). - Prior notification and blast/clearance information provided to wind farm management, contractors and title property owner. 	MEDIUM Likelihood RARE Consequence MAJOR
DAMAGE TO WIND FARM INFRASTRUCTURE AND BUILDINGS	MEDIUM Likelihood POSSIBLE Consequence MODERATE	<ul style="list-style-type: none"> - Maintain appropriate blast design and accurate hole loading practices. - Observe standard flyrock prevention and risk controls (see above). - Record rock throw observations and modify blast designs if or where required. - Undertake blast monitoring at the footings of infrastructure located close to blasts (<100m). - Modify blasts if PPV levels near or exceed limits or maximum predicted levels. 	LOW Likelihood RARE Consequence MINOR

Table 7 (continued)

<p>IMPACT TO LOCAL AMENITY</p>	<p><u>MEDIUM</u></p> <p>Likelihood POSSIBLE</p> <p>Consequence MINOR</p>	<ul style="list-style-type: none"> - Maintain Compliance with ERR Ground Vibration & Airblast Limits at sensitive sites: <ul style="list-style-type: none"> PPV 5 mm/s (95% of blasts) 10 mm/s (all blasts) Airblast 115 dBL (95% of blasts) 120 dBL (all blasts) - Assess compliance with occasional blast monitoring as needed at or or near closest sensitive site(s). - Provide notifications of scheduled blasts to subscribing residents. - Blasts only fired within quarry’s approved firing time window (10am-4pm Monday-Friday only). - Details of all blast-related complaints to be recorded in a Complaints Register. - Individual complaints and concerns to be followed up by quarry management in a timely manner. - Investigate damage claims in a timely manner. - Engage with community to provide general information about quarrying, regulations, and blast performance. 	<p><u>LOW</u></p> <p>Likelihood RARE</p> <p>Consequence MINOR</p>
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10 REDUCING BLAST IMPACTS

Ground vibration levels, airblast levels and flyrock are primarily controlled by blast design specifications. For efficient blasting at quarries, design parameters fall within a standard range of specifications that may be adjusted, where needed, to reduce PPV levels, airblast levels, flyrock, or improve blast performance. Shotfirers must therefore use designs that will achieve efficient blast outcomes while minimising blast impacts and maintaining compliance with regulatory and in-house requirements.

Significant changes to standard blast design specifications may greatly increase production costs from reduced blast efficiency, where blasts result in poor fragmentation, low heave and increased crushing and secondary breaking requirements. Where over-confinement occurs from excessive face burden or stemming, blasting may produce large, oversize blocks cannot be moved without secondary breaking. Oversize rock also presents a significant hazard to quarry personnel, particularly loader operators, as blocks may roll unexpectedly during muck pile digging.

All blast designs used at the proposed quarry must be guided by the following considerations;

- Maintaining compliance with ERR ground vibration and airblast limits at sensitive sites.
- Achieving compliance with PPV limits that apply at nearby infrastructure.
- Preventing flyrock and minimising the normal throw distance of rock fragments.
- Achieving adequate blast performance (good fragmentation and heave, viable drill and blast costs, minimal secondary breaking and overall efficiency).

If ground vibration levels, airblast levels or rock throw distance need to be further reduced at any stage, some of the following measures may be adopted.

10.1 Reducing Ground Vibration Levels

The ground vibration levels from blasting are primarily a function of a blast's MIC, distance from the blast site, and the characteristics of underlying geology. Therefore, PPV levels may only be lowered by reducing a blast's MIC. This can be achieved by;

- Reducing bench height and/or blast hole depths
- Increasing stemming height or reducing sub-drill , thereby reducing the length and mass of the explosives column
- 'Deck loading' of blast holes, where each hole contains two separate charges separated by a column of inert material and fired with a separate delay.
- Reducing blast hole diameter

Note that deck loading and the use of hole diameters < 89mm may result in increased blasting costs and should only be considered where PPV levels could exceed allowable tolerances.

The relationship between MIC and the distance to the 5 mm/s ($D5_{mm/s}$) and 100 mm/s ($D100_{mm/s}$) level (the ERR limit and wind turbine/fresh concrete limit respectively) are shown in **Table 9**. This information may be used as a guide for blast designers if ground vibration levels need to be reduced at sensitive sites or HWF infrastructure at any stage.

Table 8 – Charge mass (MIC) vs Distance to 5mm/s and 100 mm/s levels (k_v 1,800)

Charge Mass/MIC (kg)	$D5_{mm/s}$ (m)	$D100_{mm/s}$ (m)
100	396	61
82.5*	360	55
75.0	343	53
50.0	280	43
33.8 [#]	230	35
25.0	198	30

*Standard MIC for 13m face

[#]Standard MIC for 7m face

10.2 Reducing Airblast Levels

Airblast levels are a function of a blast's MIC and the confinement of explosives energy provided by front row burden and stemming height. If required, airblast levels can be reduced by;

- Additional confinement i.e. increasing standard front row burden and stemming height
- Charge mass reduction (see previous section)
- Configuring blasts/benches to face away from sensitive sites

Airblast levels are most effectively reduced by increasing the front row (face) burden and stemming height. Increasing the length of the stemming column also provides a charge mass reduction that results in a modest decrease of PPV levels.

The sensitivity of airblast levels to changes in burden and stemming is shown in **Figure 10**. It should be noted that front row burden and stemming heights greater than 3.5m typically result in reduced blast performance (i.e. oversize rock and reduced heave) and are not recommended unless needed to meet compliance with regulatory limits.

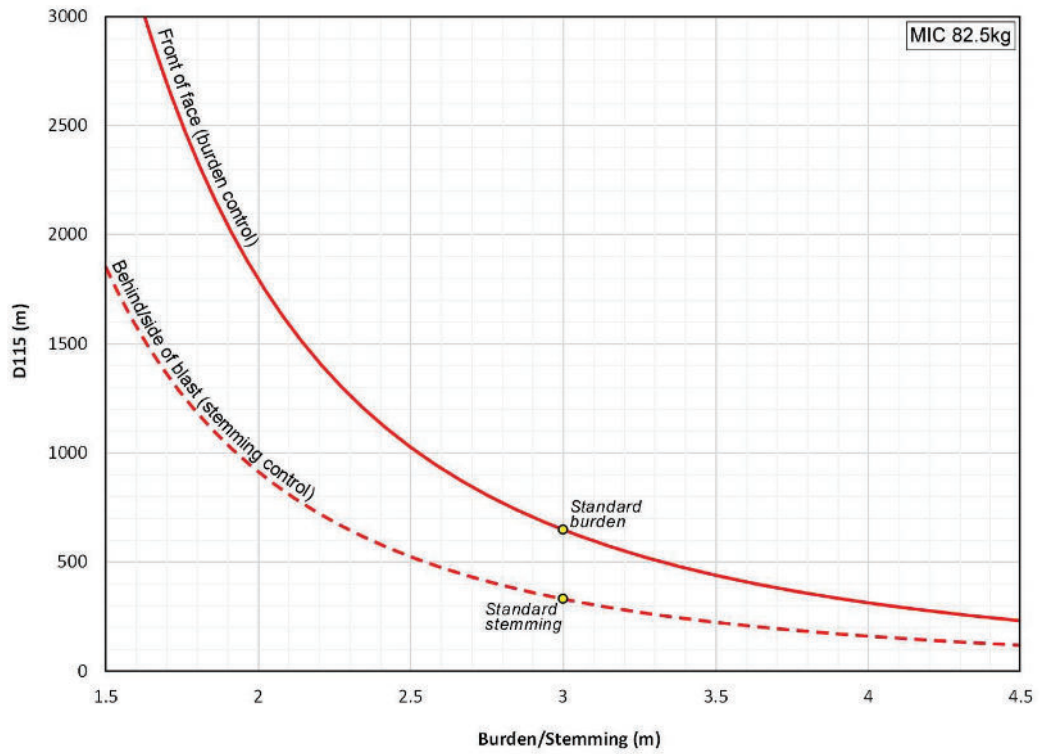


Figure 10 – Relationship of D115 to burden/stemming provisions (13m face only)

10.3 Reducing Throw Distance of Rock Fragments

The throw distance of rock fragments is primarily a function of charge mass (per linear metre of explosives column), front row burden (throw in front of a blast) and stemming height (throw behind and to the sides of a blast). Linear charge mass (kg per metre) is fixed by blast hole diameter and increasing confinement is therefore the primary method to reduce throw distance.

The relationship between maximum throw distance and blast hole confinement (front row burden and stemming) is shown in **Figure 11**.

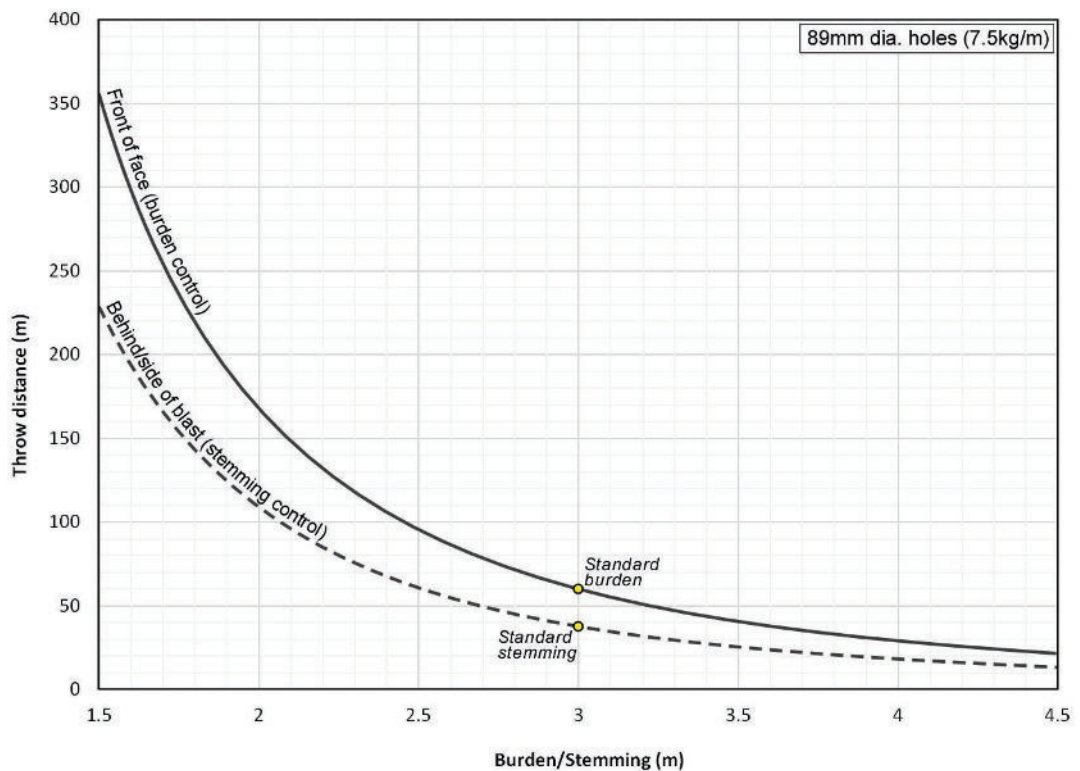


Figure 11 – Relationship of maximum throw distance to hole confinement provisions

While the throw calculations are conservative, stemming height could be increased for blast holes less than 38m from Work Authority boundary to reduce the potential for rocks being thrown onto the adjacent title property. While the minimum flyrock safety factor of 2 at the location of the closest turbine is adequate, the safety factor can be increased by increasing stemming for the closest few blasts. However, the need to reduce the normal throw of fragments should ultimately be guided by ongoing observations of the behaviour of localised rock under blasting.

11 BLAST MANAGEMENT

11.1 Blast Management Plan

Control measures for mitigating the risks and impacts posed by blasting are contained in a Blast Management Plan (BMP) that forms part of a quarry's approved Work Plan. A BMP must detail the procedures and controls required to conduct blasting operations safely and achieve compliance with standards and thresholds set out in regulations, policies and guidelines. Guidance on the requirements of a BMP can be taken from Australian Standard AS 2187.2 (2006) *Appendix A - Blast Management Plan and Records*. A BMP must include (but is not limited to) details of;

- Roles and responsibilities of personnel involved with blasting operations.
- Considerations that inform blast design, including the locations of sensitive sites and structures.
- Details of the Risk Assessments procedure required for every blast.
- Blast site access and security controls.
- PPE requirements and site communications systems.
- Blast hole loading procedures, including treatment methods for under-confined holes and weak rock structure.
- Blast clearance and firing procedures.
- Emergency contacts and emergency assembly areas.
- Misfire procedures.
- Blast monitoring and reporting requirements.
- Blast notifications system and complaints register.
- Record keeping requirements.

11.2 Record Keeping

A detailed record of all blasting operations to be retained by quarry management. This record assists with the planning of future blasts, identifies any design modifications that may be required for further blasting, and provides essential information for investigating exceedances of ERR limits, flyrock events and complaints. Records may include;

- Names, contact details and roles of all blast crew personnel.
- Blast design and drill plans, signed off by shotfirer & blast crew/technician.
- Laser face profile and Boretrak survey reports.
- Driller's logs.
- Risk Assessments for individual blasts.
- Details of modified hole loadings.
- Cart notes showing quantity of explosives used.
- Blast performance observations (e.g. fragmentation, heave, oversize, flyrock).
- Blast video files.
- Blast monitoring reports.

11.3 Blast Monitoring

Routine blast monitoring is usually required at quarries with sensitive sites less than 500m from blasting operations to assess compliance with regulatory blast vibration limits. Due to the remoteness of the proposed quarry, routine blast monitoring is not warranted though some monitoring is recommended should complaints or concerns be raised by a resident. While routine monitoring may not be warranted, ERR may request some monitoring be conducted if complaints are raised with the authority or to validate the findings of this assessment during early operations.

The need for blast monitoring at nearby wind farm infrastructure is at the discretion of the wind farm owner (Hexham Wind Farm Pty Ltd). If infrastructure is installed during the life of the quarry it is recommended that monitoring be undertaken at the footing of the closest item for the initial few blasts or closest future blasts to validate the modelling in this assessment. Monitoring could be undertaken by the drill and blast company or independent contractor with portable installations installed on blast days.

Video recording of blasts should also be taken and retained. Such recordings are essential for investigating high airblast and flyrock events, and can be used to guide modifications of blast designs to improve performance, efficiency and control.

12 CONCLUDING COMMENTS

This assessment demonstrates that blasting operations at the proposed Hexham Wind Farm Temporary Quarry can be undertaken with a high degree of safety, comply with prescribed regulatory criteria for quarry blasting, and with low or minimal impacts to the amenity of surrounding areas and the environment. Ground vibration and airblast overpressure levels would be largely imperceptible at the closest sensitive sites due the remoteness of the quarry, though low-level blast noise may be occasionally heard by residents.

Ground vibration modelling also shows maximum PPV levels at the locations of proposed wind farm infrastructure that are below conservative damage limits typically observed. Blast monitoring is suggested for the initial few blasts (or the closest future blasts to nearby wind farm assets) to help determine the need for an modification of standard blast designs. Monitoring of all blasts may not be necessary if early results show low PPV levels and confirm low-level impacts at the closest sensitive site(s).

Rock fragments can be contained with the proposed Work Authority boundary though a modest stemming height increase may be required for terminal blasts at the southern and northern extraction limit to achieve this. The quarry's title property provides a wide buffer between blasting and the closest neighbouring properties with a minimum flyrock safety factor of 9 (i.e. 9 x maximum throw) for the closest blasts. Blast clearance outside the Work Authority is limited to adjacent areas of the title property and would be relatively easy to establish. Minimum blast clearance distances of 240m (front of face) and 160m (behind and side of blast) are recommended for standard blast design though increased clearance should be provided for non-blast personnel. Clearance procedures including details of communications required between the quarry operator, wind farm management and the title property holder should be specified in the quarry's Blast Management Plan.



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29 September 2025

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APPENDIX 1 – HEXHAM WIND FARM TEMPORARY QUARRY SITE PLAN (BLASTING)

