

---

## HERBERT SMITH FREEHILLS

### AMMENDMENT C162: MT ATKINSON AND TARNEIT PLAINS

### EFFECTS OF BLASTING IN THE BORAL DEER PARK QUARRY (WA 97)

#### 1. INTRODUCTION

Terrock Consulting Engineers were requested by Herbert Smith Freehills to prepare a report that addresses:

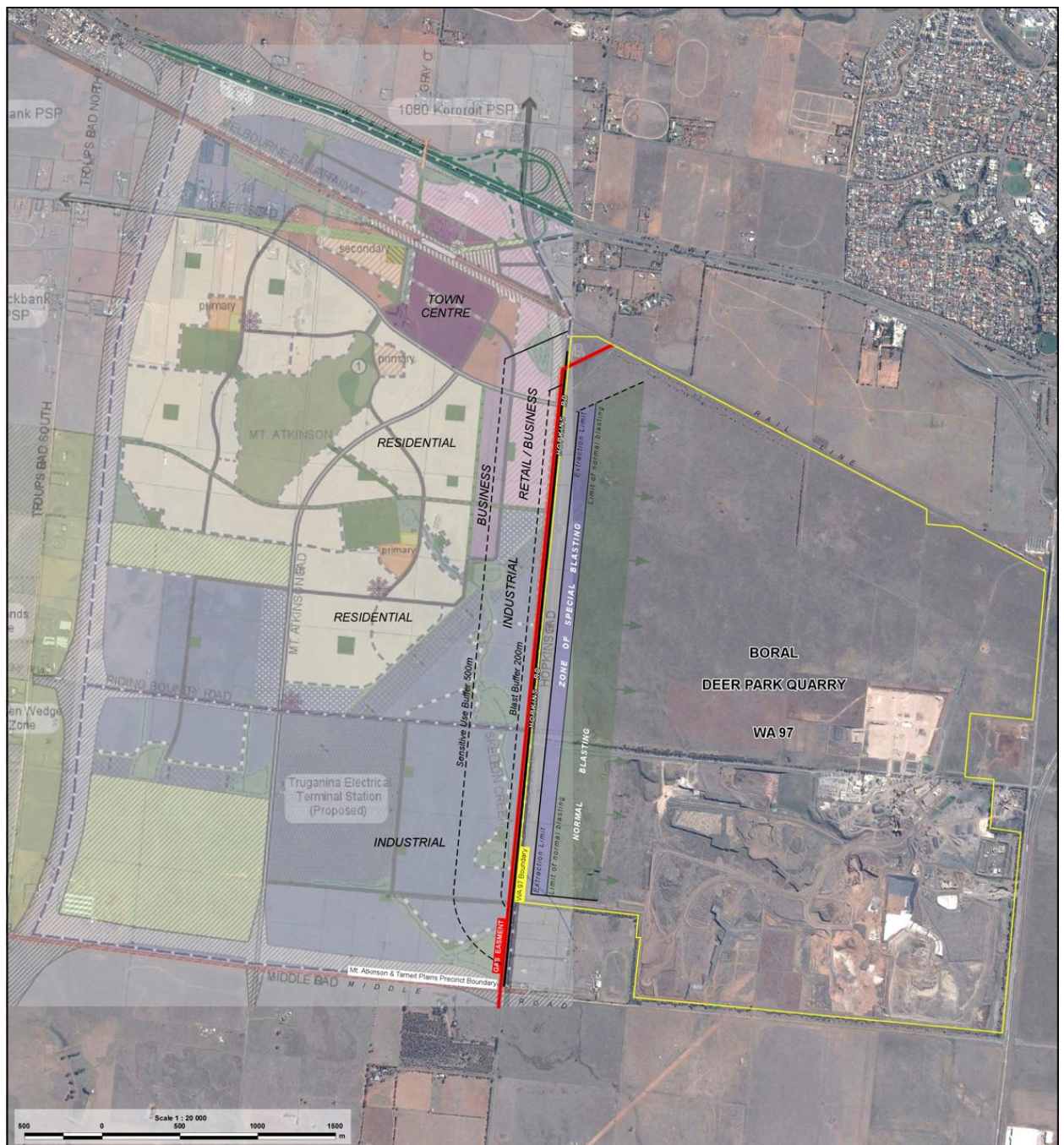
- Consideration of the quarry buffer and sensitive use buffer set out in the PSP and comment on whether the buffers – in particular, the quarry blast buffer – are sufficient in light of expected blasting and vibration impacts arising from quarry operations at the site (assuming standard quarrying industry practice). See in particular, Plan 2 and sections 2.2 and 2.3 (objective O10) of the PSP; and
- Consideration of inter-industry issues and whether there are particular industrial or other non-sensitive uses that would be inappropriate to locate in proximity to the site due to potential blasting and vibration impacts from the quarry operations.

The proposed quarry blast buffers are shown in **Figure 1**. The location plan of the quarry Work Authority in relation to the PSP is also shown in **Figure 1**.

A summary of the important separation distances in the PSP are:

- Quarry limit of extraction at 100 m of the Hopkins Road East Boundary, which is 120 m from the high pressure gas pipeline easement and 128 m from the closest pipeline alignment.
- Quarry Blast Buffer (QBB) at 200 m from quarry extraction limit or 60 m from the gas pipeline easement.
- Quarry Sensitive Use Buffer (QSUB) at 500 m from quarry extraction limit or 360 m from the gas pipeline easement.

Also, the quarry has a zone of special blasting from 200 m to 100 m from the Work Authority Boundary as a licence condition.



**Figure 1 – Plan 3 of the PSP with quarry blast zones and WA Boundary added**

## 2. BLAST VIBRATION LIMITS

Work Authority No. 97 adjacent to the PSP area north of Riding Boundary Road operates under the following conditions that control blast vibration (DEDJTR Guideline Limits):

Ground Vibration

≤ 5 mm/s for 95% blasts in a 12 month period  
≤ 10 mm/s for all blasts

Airblast (Overpressure)

≤ 115 dBL for 95% blasts in a 12 month period  
≤ 120 dBL for all blasts

South of Riding Boundary Road WA97 as an existing site, operates under the following limits for the blast vibration control:

Ground Vibration

≤ 10 mm/s for all blasts

Airblast (Overpressure)

≤ 120 dBL for all blasts

The DEDJTR Guideline Limits have been set to minimise annoyance to people as a result of blasting on mine and quarry sites and are applied at residential premises and other sensitive sites.

In the guidelines, a “sensitive site” is defined as “includes any land within 10 m 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 guideline limits normally apply at ‘sensitive sites’. However, the site specific Work Authority Conditions apply the limits listed above to “the vicinity of **any building** not owned by the Work Authority holder”. If applied, this condition would be a serious impediment to development within the PSP and should be changed by a variation process to only apply at sensitive sites.

The guideline limits do not apply to control of blasting impacts at commercial or industrial premises. However, guidance can be obtained from Australian Standard AS2187.2 – 2006 and British Standard BS6472-2:2008 as to what may be appropriate limits.

Table J4.5 (A) of AS2187.2 – 2006 reproduced as **Table 1** lists 25 mm/s maximum limit for occupied non sensitive sites, such as factories and commercial premises. The exception is for sites containing equipment sensitive to vibration. Table 1 of BS6472-2:2008, reproduced as **Table 2**, lists maximum satisfactory magnitudes of vibration as 14.0 mm/s for offices and workshops.

The Quarry Inspectorate treats each case individually on its merits and has no formal policy as far as I am aware. From our experience, the BS limits of 14.0 mm/s are appropriate for offices and some workshops. A level of 10 mm/s can be alarming in lightweight steel framed factories whereas in concrete tilt slab buildings the response is not as severe.

The policy of consideration of each case on its merits, especially consideration of the construction methods and materials is practical. For example, the AS2187.2 limits of 25 mm/s may cause cosmetic damage to plasterboard cladding in buildings of brick veneer construction as it is above the frequency dependant damage criteria limits for frequencies below 15 hz in **Figures J4.4.2.1** and **J4.4.2.2** of the Standard. The tabular form of J4.4.2 is shown in **Table 4** and the graphical form in **Figure 3**.

**Table 1 – Ground Vibration Limits for Human Comfort chosen by some Regulatory Authorities (see Note to Table J4.5(B))**

Category	Type of blasting operations	Peak component particle velocity (mm/s)
Sensitive site*	Operations lasting longer than 12 months or more than 20 blasts	5 mm/s for 95% blasts per year 10 mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Sensitive site*	Operations lasting less than 12 months or less than 20 blasts	10 mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	25 mm/s maximum unless agreement is reached with the occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely effect the equipment operation
<p>*A sensitive site includes houses and low rise residential buildings, theatres, schools and other similar buildings occupied by people.</p> <p>NOTE: The recommendations in Table J4.5(A) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions.</p>		

**Table 2 – Maximum satisfactory magnitudes of vibration with respect to human response for up to three blast vibration events per day**

Place	Time	Satisfactory magnitude <sup>A)</sup> ppv mm.s <sup>-1</sup>
Residential	Day <sup>D)</sup>	6.0 to 10.0 <sup>C)</sup>
	Night <sup>D)</sup>	2.0
	Other times <sup>D)</sup>	4.5
Offices <sup>B)</sup>	Any time	14.0
Workshops <sup>B)</sup>	Any time	14.0
<p><b>NOTE 1</b> This table recommends magnitudes of vibration below which the probability of adverse comment is low (noise caused by any structural vibration is not considered).</p> <p><b>NOTE 2</b> Doubling the suggested vibration magnitudes could result in adverse comment and this will increase significantly if the magnitudes are quadrupled.</p> <p><b>NOTE 3</b> For more than three occurrences of vibrations per day see the further multiplication factor in <b>5.2</b></p>		
<p><sup>A)</sup> The satisfactory magnitudes are the same for the working day and the rest of the day unless stated otherwise.</p> <p><sup>B)</sup> Critical working areas where delicate tasks impose more stringent criteria than human comfort are outside the scope of this standard.</p> <p><sup>C)</sup> Within residential properties people exhibit a wide variation of tolerance to vibration. Specific values are dependent upon social and cultural factors, psychological attitudes and the expected degree of intrusion. In practice the lower satisfactory magnitude should be used with the higher magnitude being justified on a case-by-case basis.</p> <p><sup>D)</sup> For the purpose of blasting, daytime is considered to be 08h00 to 18h00 Monday to Friday and 08h00 to 13h00 Saturday. Routine blasting would not normally be considered on Sundays or Public Holidays. Other times cover the period outside of the working day but exclude night-time, which is defined as 23h00 to 07h00</p>		

In addition, the Australian Pipeline Authority (APA), the owners/managers of the high pressure gas pipelines enforce a PPV limit of 20 mm/s on any part of the pipeline.

From experience, the PPV levels in a ‘buried pipeline’ are characteristically half that on the surface above. This APA Limit is interpreted to mean that a limit of 40 mm/s measured on the surface above the pipeline alignment at the nearest point to the blast will be the equivalent of 20 mm/s measured on the pipeline. This removes the need to uncover and expose the pipeline to facilitate a measurement with the possibility of damage to the corrosion protection for many blasts at many locations.

Also, flyrock must be contained within the Work Authority boundary and not present a danger to people within the vicinity of the blast.

## 2.1 Human Response to Vibration

In the community there is a wide variation in vibration tolerance. Some people complain about vibration at levels slightly above perception levels, ie. as soon as they feel it. Others become accustomed to and tolerate relatively high levels of vibration, e.g. residents in close proximity to railway lines and freeways. Some of the adverse reactions to vibration include a ‘fright’ factor or being startled by a sudden vibration event.

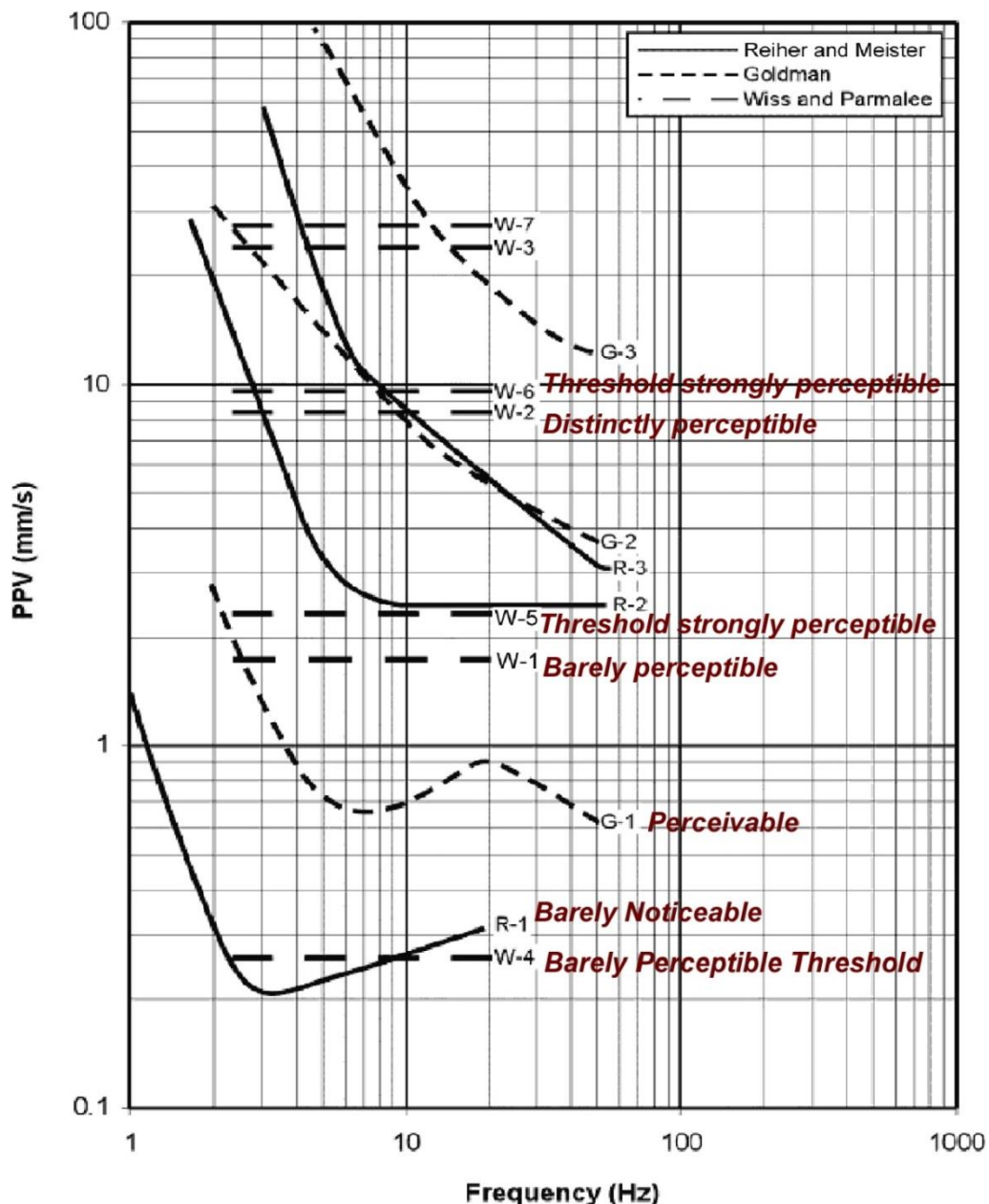
The contributing factors to human perception of vibration are the length of time of the vibration event, the frequency spectrum of the vibration, the number of occurrences per day, the time they occur and the magnitude (displacement, velocity or acceleration) of the vibration. Generally, people are more tolerant of a large blast at longer intervals than many small blasts



occurring more frequently. The perception of blast vibration is further complicated by the presence of both ground vibration and air vibration, which separate with distance because of the different propagation velocities.

Both air and ground vibration are commonly perceived by secondary noise, such as rattling of dishes, windows or sliding doors, and without monitoring it may not be possible to recognise whether air or ground vibration is responsible. Beyond about 500 metres from the blast, air and ground vibration may be felt as two separate events and people will comment that two blasts were fired close together. Ground vibration tends to attenuate quicker than airblast and, at distances greater than one kilometre, often the ground vibration reduces to below perceptible levels and hence airblast is responsible for most complaints.

Attempts have been made to quantify human sensitivity to vibration and a typical human response graph is shown as **Figure 2a**. The graphs are based on the studies listed in **Figure 2b**.



**Figure 2a – Human response to steady-state and transient vibrations**

Authors	Vibration duration, sec	Curve representations, response descriptors, and curve label for data plotted in figure 61
Goldman (18): Various body positions, 5 sources - Do ..... Do .....	5 5 5	Mean values of subject response:  Perceivable (curve G-1). Unpleasant (curve G-2). Intolerable (curve G-3).
Reiher and Meister (40): Standing with vertical vibration ---- Do ..... Do .....	300 300 300	Thresholds:  Barely noticeable (curve R-1). Objectionable (curve R-2). Uncomfortable (curve R-3).
Wiss and Parmalee (58): Standing with vertical vibration ---- Do <sup>1</sup> .....  Do <sup>1</sup> .....  Do <sup>1</sup> ..... Do <sup>2</sup> ..... Do <sup>2</sup> ..... Do <sup>2</sup> ..... Do <sup>2</sup> .....	5 5  5  5 5 5 5	Mean values of subject response:  Barely perceptible (curve W-1). Distinctly perceptible (curve W-2). Strongly perceptible (curve W-3).  Thresholds: Barely perceptible (curve W-4). Distinctly perceptible (curve W-5). Strongly perceptible (curve W-6). Severe (curve W-7).

<sup>1</sup> Transient with 1 pct damping, 5-sec duration is maximum.

<sup>2</sup> Zero damping.

Figure 2b – Studies of human response to vibration

The responses summarised in **Figures 2a and 2b** are consistent with our experience. People begin to feel vibration at 0.2 – 0.5 mm/s. Complaints begin at about 2 mm/s and some people become very upset above 5 mm/s.

## 2.2 Damage Limits Criteria

Table J4.5 (B) from AS2187.2 – 2006 lists recommend ground vibration limits, reproduced as **Table 3**.

Limits for Damage Control refers to the frequency – dependant damage limit tables J4.4.2.1 and J4.4.4.1. The criteria in both tables are similar. The damage criteria from J4.4.4.1. British Standard 7385; Part 2: 1992 *“Guide Values for Transient Vibration Relating to Cosmetic Damage”* are listed in **Table 4** and **Figure 3**. The guide values represent limits for transient vibration above which cosmetic damage could occur.

British Standard 7385; Part 1: 1990 *“Damage Classification”* is listed in **Table 5**. Minor damage is possible at vibration levels which are greater than twice those given in the table, and major damage above four times the guide values given.

The frequency of vibration from blasting is typically 15 – 20 hz, which gives 20 mm/s as a limit to prevent cosmetic damage and 40 mm/s as a limit to prevent minor damage (as described in **Table 5**).

A building specific study may find that individual buildings are not damaged at higher vibration levels. Now buildings should be constructed to resist the loadings from exposure to high vibration levels if they are unavoidable.

On the basalt plains to the west of Melbourne, the surface soils are invariably highly reactive clays with surface movements commonly in excess of 50 mm between winter and summer. Even if the footings of the houses are properly engineered, cracking of new houses is fairly common. People often feel the vibration from quarries, see cracks in their house and automatically blame the quarry. The surface motion due to blast vibration is in the order of microns whereas the surface movement due to foundation soils is in the order of millimetres. New housing developments near existing quarries potentially creates a conflict in the community regarding damage concerns.

Regarding airblast, Table J5.4 (B) from AS2187.2 – 2006 lists 133 dBL as a recommended limit for damage control. Windows are the structural component most sensitive to airblast. Large panes are more susceptible than small panes.

**Table 3 - Australian Standard 2187.2-2006 - Table J4.5(B) – Recommended Ground Vibration Limits for Damage Control (see Note)**

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

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

**Table 4 - Transient vibration guide values for cosmetic damage (British Standard 7385: 1993)**

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.
NOTE 1: Values referred to are at the base of the building.			
NOTE 2: For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.			



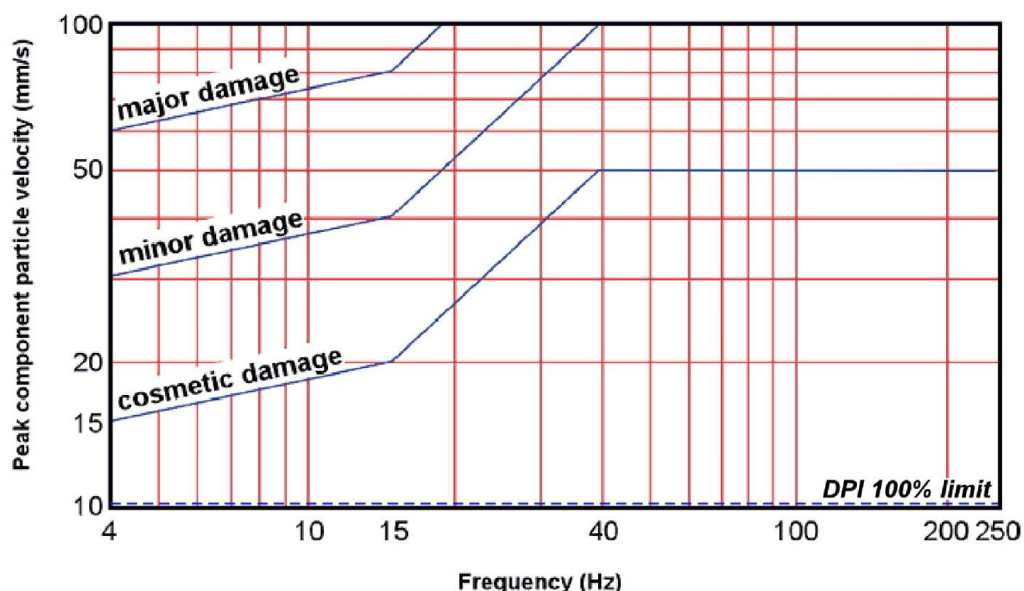


Figure 3 - Transient vibration guide values for cosmetic damage (British Standard 7386: 1993)

Table 5 – British Standard 7385; Part 1: 1990 - Damage Classification

Damage Classification	Description
<b>Cosmetic:</b>	.....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
<b>Minor:</b>	.....the formation of cracks or loosening and falling of plaster or drywall surfaces, or cracks through bricks/concrete blocks
<b>Major:</b>	.....damage to structural elements of the building, cracks in support columns, loosening of joints, splaying of masonry cracks etc.

### 3. PUTTING BLAST VIBRATION INTO PERSPECTIVE

A typical quarry blast likely to be used near Hopkins Road has a duration of about 1 second.

Because of the separation of ground vibration and air blast with distance and because of different propagation velocities, at 1 km, if both air and ground vibrations are 'felt', the total vibration for each blast may be perceived for about 3 – 4 seconds.

In the quarry sensitive use buffer the vibration will be perceptible for about 2 – 2½ seconds.

Blasts in the special blasting zone will occur at about fortnightly intervals, but other blasts may occur elsewhere in the quarry at the same time at more distant locations. On this basis, the vibration from blasting in the special blasting zone will be 'felt' in the quarry sensitive use zone for about 50 – 70 seconds per year.

Sudden exposure to blast vibration may cause a 'startle effect' in many people, regardless of the actual levels.

#### 4. BLASTING SPECIFICATIONS

The following restrictions on blasting near Hopkins Road boundary are conditions specified in Work Authority No 97 documentation:

- normal blasting practice to 200m from Hopkins Road/Work Authority boundary (stemming height 3.0m)
- zone of special blasting from 200m to 100m from Hopkins Road/Work Authority boundary in which:
  - all blasts to face away from Hopkins Road
  - all blasts will have the stemming height increased to 3.5m.

An additional restriction is the 20mm/s limit applied by APA Australia at any point on the gas main pipelines. The pipelines are located in a 20m wide easement located immediately west of the Hopkins Road Reserve. The individual pipeline offsets in the easement are shown to be approximately 8.0 m and 15.0 m west of the Western boundary of the road reserve (PSP Appendix G).

Subsequent exploratory drilling has shown that the basalt depths near the western boundary of the Work Authority vary from 12m to 15m. A maximum hole depth of 15m is assumed in this investigation because the depth zonings have not been delineated.

The blast hole specifications for blasting not restricted by the APA requirement are listed in **Table 6**. Blasting is conducted using either 102 mm diam or 89 mm diameter blastholes. In the zone of special blasting the stemming height is increased to 3.5 m.

**Table 6 –Blasting Specifications and Charge Mass Calculations (unrestricted)**

Basalt Depth	Hole diameter 89mm		Hole diameter 102mm	
	15m		15m	
Sub drill depth m	0	0	0	0
Stem ht. m	3.0	3.5	3.0	3.5
Expl. Column length m	12.0	11.5	12.0	11.5
Charge mass (sg 1.2) kg/m	7.5	7.5	9.8	9.8
Charge Mass/hole (kg)	90*	86	117.6*	112
Burden m	3.0		3.3	
Spacing m	3.5		4.0	
Hole Angle deg	10°		10°	

*\*Max. standard specification charge mass to 200 m from boundary*

As blasting approaches Hopkins Road, the specifications must be varied to comply with ground vibration limits on the high pressure gas transmission pipeline.

The various blasting zones are shown in **Figures 7 and 8**.

## 5. GROUND VIBRATION PREDICTIONS

It is necessary to consider ground vibration resulting from blasting because of the need to comply with the 20mm/s limit placed by the owner/managers (APA) of the high pressure gas mains adjacent to the Hopkins Rd reserve. Previous correspondence with GPU GasNet indicated that this limit will be applied at any point on high pressure gas mains located in the easement west of Hopkins Road. From experience, a limit of 20mm/s at any point on the pipeline equates to 40mm/s on the surface above the pipeline. A 40mm/s limit will be used in this section of the report and applied at the nearest pipeline located 8 m from the eastern boundary of the easement. The separation distances from the blasting zones with the quarry to the nearest pipeline are therefore 128 m and 228 m.

The latest assessment (2000 – 2001) of ground vibration in the Deer Park Quarry produced the following predictive Site Law model.

$$PPV = 9000 \left( \frac{\sqrt{m}}{D} \right)^{1.78} \quad [1]$$

Where:  $PPV$  = Peak Particle Velocity (mm/s)  
 $m$  = Charge mass/hole (kg)  
 $D$  = Distance from the blast (m)

The  $D_{40}$  distance (distance that a PPV of 40mm/s occurs from a blast) for the maximum standard charge mass (117.6kg) is:

$$D_{40} (117.6\text{kg}) = 227\text{m}$$

The maximum standard charge mass listed in **Table 6** can be used for blasting to  $\geq 228\text{m}$  from the gas pipeline which is close enough for the 227 m separation distance from above. Compliance with the 40mm/s limit for blasts closer than 227m requires a reduction in charge mass. This assessment is based solely on ground vibration compliance on gas mains by charge mass limitations. No attempt has been made to consider Powder Factor design or fragmentation implications of the limited charge mass as derived from this approach.

The relationship between  $D_{40}$  and charge mass is shown in **Table 7** to provide guidance as to how the blasting specifications may be altered for the reduced distances to comply with the ground vibration limit at the gas pipeline. At the limit of the Special Blasting Zone (128m from the gas pipeline at the extraction limit), a charge mass limit of 37 kg/delay is predicted to be required to comply with the 40mm/s limit. The required charge mass reduction with reducing distance is shown graphically in **Figure 4**.

Table 7 - D<sub>40</sub> with charge mass variation

Dist to Pipeline D <sub>40</sub> (m)	Dist. from WA boundary (m)	Max. Charge Mass (kg)	Ø 89 (7.5kg/m)	Ø 102 (9.8kg/m)
			Explosives Column Length (m)	Explosives Column Length (m)
228	200	118	*15.7	12
228	200	90	12	
208	180	90	12	
188	160	80	10.7	
168	140	64.2	8.6	
148	120	50	6.7	
128	**100	37.2	5.0	

\*Not applicable due to min. 3.0m stemming height requirement

\*\* Blasting at Extraction limit of Special Blasting Zone (nearest blasting to gas easement)

Compliance with the 40 mm/s limit is dependent on charge mass only. The hole diameter is only important in determining the loading configuration in blastholes where it is necessary to split the charge. In the special blasting zone, 89 mm diameter blastholes will probably be more suitable because the longer explosive column lengths occupy more of the hole length available. 89 mm drain holes will be used exclusively in the Special Blasting Zone. The maximum charge that can be loaded into an 89 mm diam. hole 15 m deep is 90 kg.

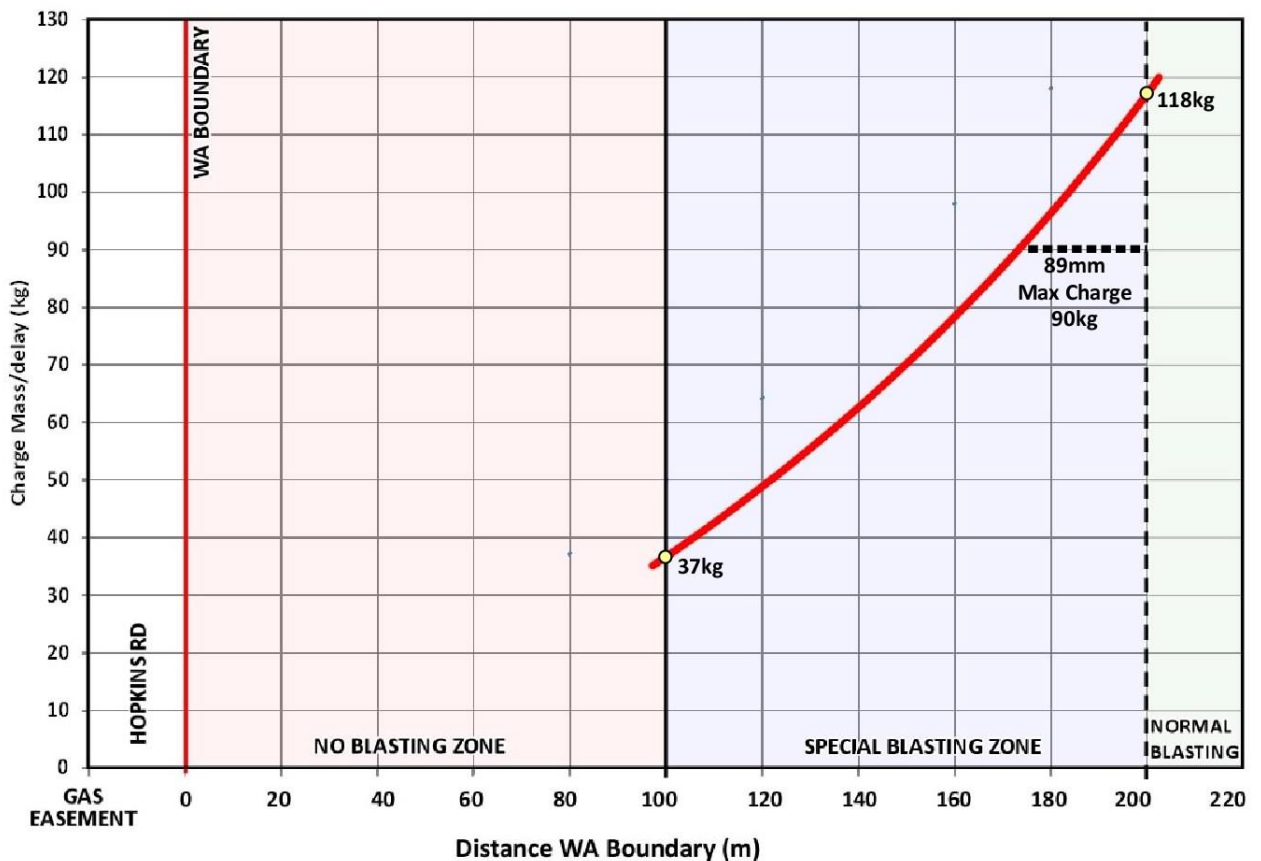


Figure 4 – Charge mass reduction required to comply with 40mm/s limit

The extraction limit proposed in the northwest corner of the quarry has sufficient separation from the pipeline easement that charge mass reduction does not appear necessary in this area to comply with a 20mm/s (40mm/s surface) limit on the pipeline.

In considering ground vibration effects, it is also necessary to comply with the DEDJTR ground vibration limit of 5mm/s at sensitive sites such as houses for 95% of the blasts in a 12 month period. To the west of Hopkins Road, the extent of this limit can be determined by extrapolation from the requirement not to exceed 40mm/s on the ground surface above the pipeline.

A reduction in charge mass to comply with the Pipeline PPV results in a reduced distance to the DEDJTR limit of 5mm/s ( $D_5$ ). The range of  $D_5$  with reduced charge mass into the property to the west of Hopkins Rd is shown in **Table 8**. The exponential relationship between  $D_{40}$  and  $D_5$  is shown graphically in **Figures 5a and 5b**.

The effect of PPV with distance based on 40 mm/s on the surface above the pipeline is shown in **Figures 5a and 5b**. For blasting at 100 m from the WA boundary, the PPV at the QBB (200 m) is 17.9 mm/s and at the QSUB (500 m) is 3.5 mm/s. The effect of attenuation across the various proposed land use zonings is also shown in **Figures 5a and 5b**.

**Table 8 -  $D_{40}$  &  $D_5$  with charge mass reduction**

Charge Mass (kg)	$D_{40}$ (m)	$D_5$ (m)
118	228	732
98	208	667
80	188	603
64	168	540
50	148	476
37	128	411

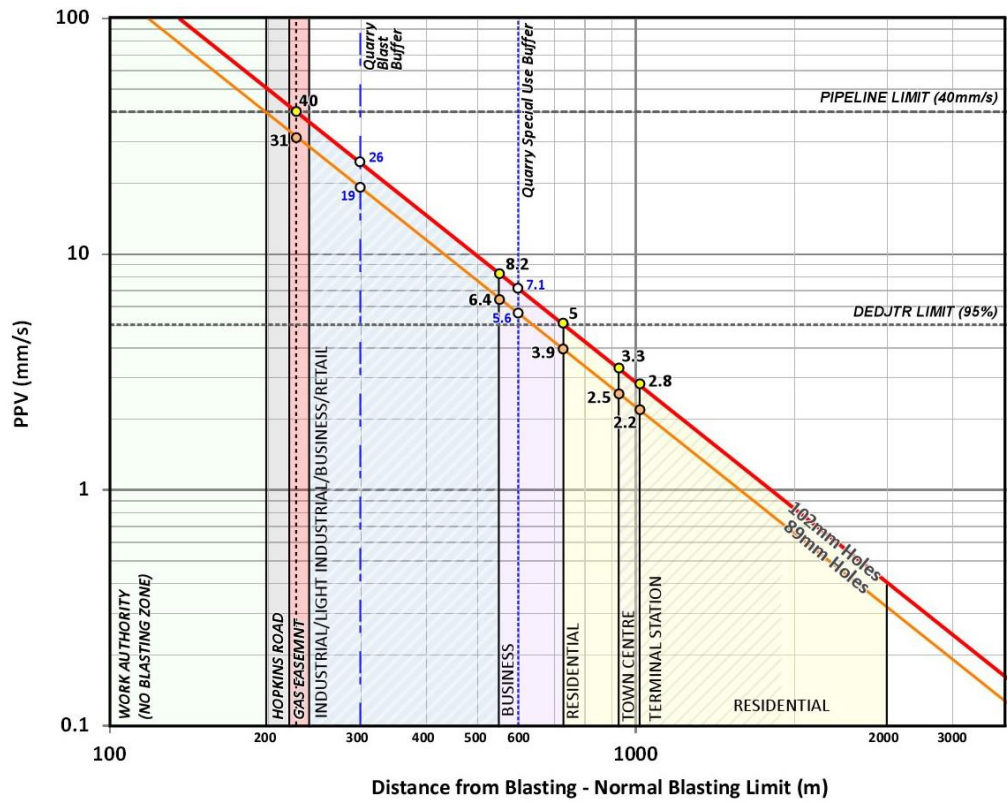


Figure 5a – Predicted Maximum PPV vs Distance from blasts at the Extraction Limit

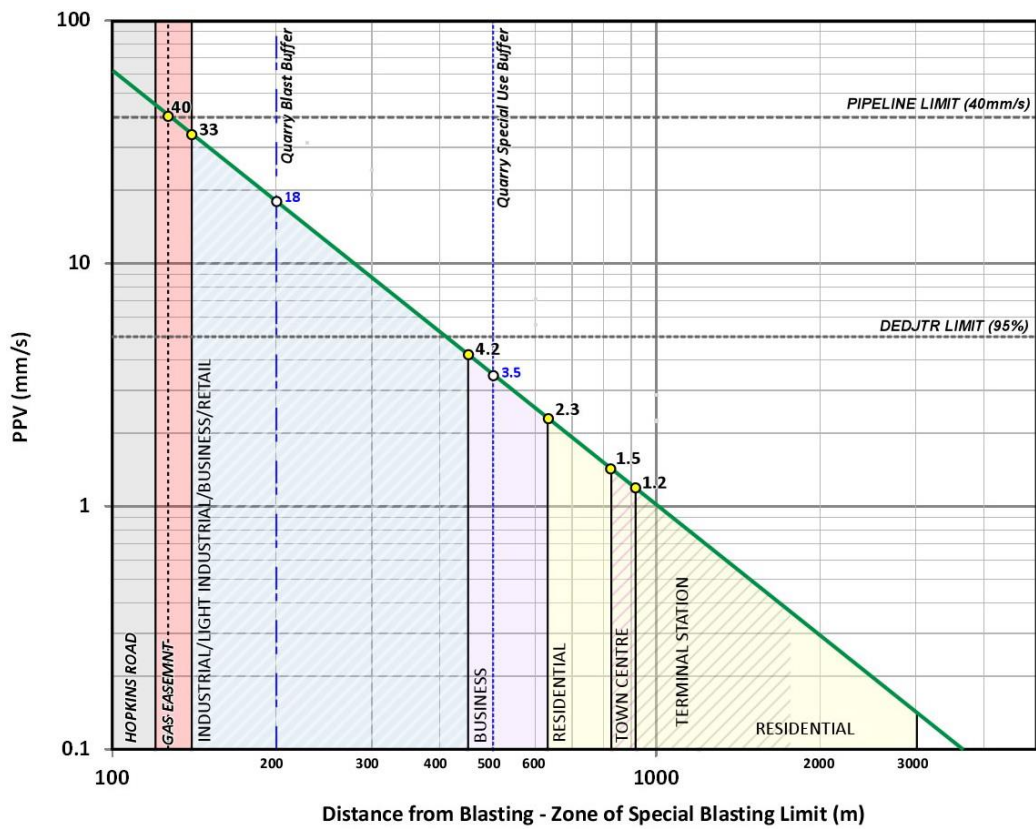


Figure 5b – Distance from Blasting – Zone of Special Blasting Limit (m)



For blasting at the limits for normal blasting 200 m from the WA Boundary, at the QBB the PPV level is 24.4 mm/s for 102 mm diam blast holes and 19.2 mm/s for 89 mm blast holes. At the QSUB the PPV levels are 7.1 mm/s for 102 mm holes and 5.6 mm for 89 mm diam holes.

The extent of the 10, 5, 2 mm/s ground vibration level predictions in relation to blast positions are shown in **Figures 5a** and **5b**. At the QBB, the ground vibration will vary from 18 to 26 mm/s. At the QSUB boundary at 500 m, the ground vibration will vary from 3.5 mm/s to 7.1 mm/s. The 5 mm/s DEDJTR Guideline Limit occurs at 405 m from blasts at the extraction limit and 639 to 732 for blasts at the normal blasting limit.

## 5.1 AIR BLAST CALCULATIONS

The airblast resulting from the blasting specifications for gas main compliance has been calculated using the Terrock air blast predictive model. This model has been used in industry for over 15 years and is based on analysis of hundreds of airblast measurements in mines, quarries and construction sites.

Along with ground vibration, it is also necessary to comply with the DEDJTR airblast overpressure limit of 115dBL at sensitive sites such as houses for 95% of the blasts in a 12 month period. The  $D_{115}$  distances behind a blast face can be predicted using:

$$D_{115} = \left( \frac{220 \times d}{S.H.} \right)^{2.5} \sqrt[3]{m}$$

Where:  $D_{115}$  = distance to the 115 dBL level from the blast (m)

$d$  = hole diameter (mm)

$m$  = charge mass (kg)

$SH$  = stemming height (mm)

The standard blasting minimum stemming height of 3.0m needs to be increased to 3.5m for blasts in the Special Blasting Zone in order to comply with the quarry's Work Authority Conditions for blasts closer than 200 m to the WA boundary. This increased stemming height results in a further reduction in charge mass for blasts in the Special Blasting Zone. The relationships for and standard specification blasts at 200 m from the WA Boundary are shown in **Table 9a**.

**Table 9a – Airblast overpressure summary, 3.0m stemming height @ ≥ 200 m from WA Boundary**

Blasting Mode ≥ 200 m	Basalt Depth (m)	Hole length (m)	Explosives Column Length (m)	Charge Mass/delay (kg)		$D_{115}$ (m)	
				Ø 89	Ø 102	Ø 89	Ø 102
Standard Specs at 200 m	15	15	12	90	117	488 <sup>①</sup>	748 <sup>②</sup>

The airblast predictions for 89 mm holes at 100 m and 200 m from the WA Boundary for 3.5 m stemming heights are shown in **Table 9b**.

**Table 9b – Airblast overpressure summary, 3.5m stemming height (100 – 200 m from WA Boundary)**

				Charge Mass/ delay (kg)	D <sub>115</sub> (m)
Blasting Mode ≥ 200 m	Basalt Depth (m)	Hole length (m)	Explosives Column Length (m)	Ø 89	Ø 89
Standard Specs at 200 m	15	15	11.5	90	331 <sup>③</sup>
Split Charge at 100 m	15	15	4.9	37	246 <sup>④</sup>

The main conclusions from this assessment are:

- In the proposed Industrial and Business/large format retail zoning, the maximum airblast levels will be in excess of the DEDJTR limits, but will not cause damage to windows or other structural elements.
- Similarly in the proposed Business Zone, the maximum airblast levels may be just above the DEDJTR 115 dBL (95%) limit and are reasonable in my opinion.
- In the proposed Residential Zone, the highest airblast levels will comply with the DEDJTR Limits.
- The airblast from some blasts will be perceptible at the proposed town centre.

The relationship between airblast levels (PAV) and distance and the proposed zonings are shown graphically in **Figures 6a** and **6b**.

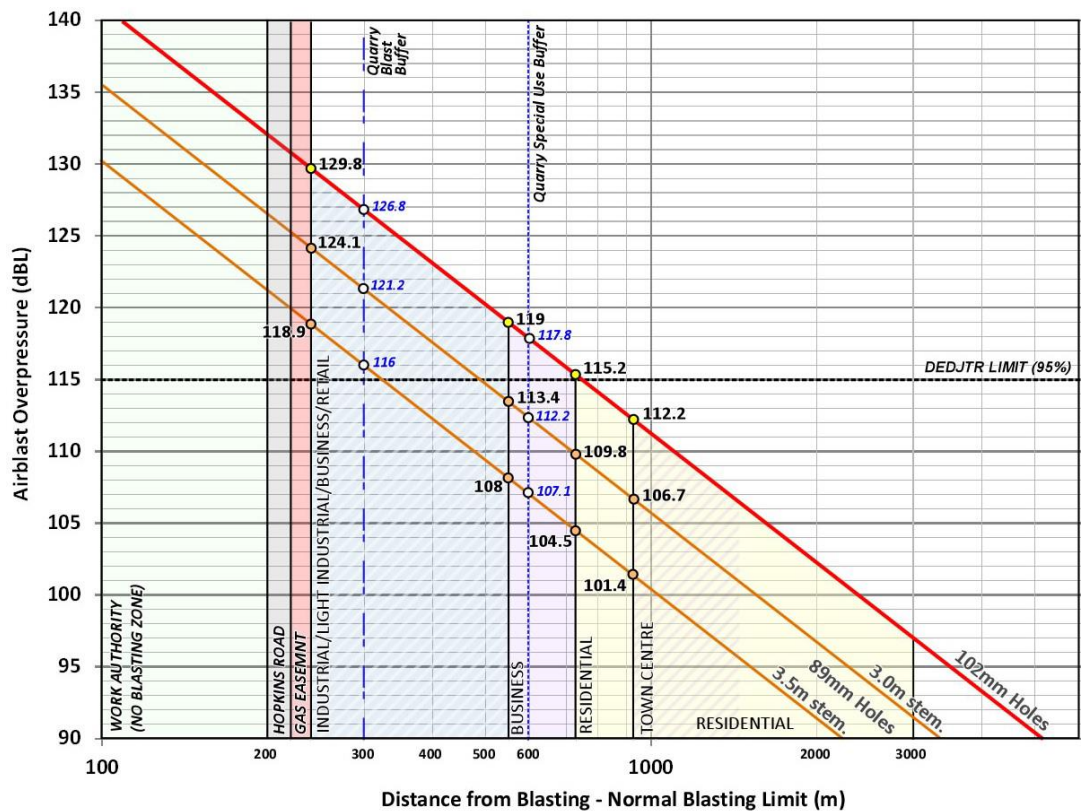


Figure 6a – Airblast Levels (PAV) and Distance Normal Blasting

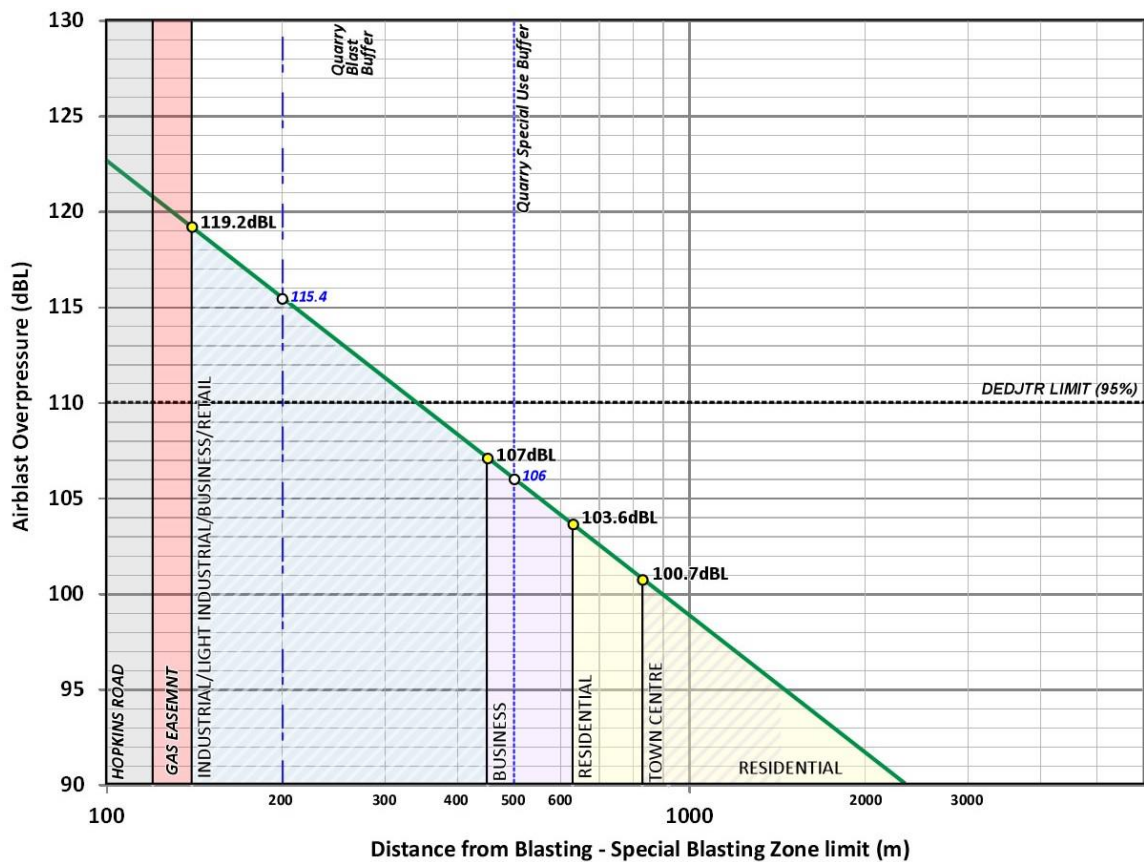


Figure 6b – Airblast Levels (PAV) and Distance Blasts at the Extraction Limit

## 5.2 Charge Mass Reduction in Special Blasting Zone

**Figure 4** shows the charge mass reduction across the Special Blasting Zone to comply with the pipeline limit.

The simplest method of reducing the charge mass is to split the charge with inert stemming between the charge.

The charge mass can be reduced by splitting the explosive column in two by inserting a 1m deck and firing the two charges separately. If we assume a 1m deck, the maximum explosive column is the length to achieve the limiting charge mass for the 40 mm/s limit at the pipeline. The worst case is for 15 m deep blastholes and the maximum charge is 37kg. The explosive charge length for 89 mm diam. Holes is 4.9 m and for 102 mm diam. Holes is 3.8 m. The short column length of 3.8m in 15 m deep holes does not lend itself to two charges with a 3.5 m stemming height ie,  $2 \times 3.8 + 3.5 = 11.1$ , which leaves a 3.9 m gap between the charges. Alternatively, a third smaller explosive charge could be used but it is not considered to be practical. It appears to be more practical for many reasons including safety, flyrock control and blasthole loading that 89 mm diameter holes be used exclusively in the Special Blasting zone from 100 m to 200 m from the Hopkins Road Boundary.

## 6. FLYROCK

Flyrock must be contained within the Work Authority boundary and not present a danger to people in the vicinity of the blast or to property. Stopping traffic at blast time is not an option because of the high volumes of traffic.

Terrock has developed a flyrock model following investigation into flyrock incidents where accurate data, including throw distances face profiles and loading details were available. Blasts approaching Hopkins Road must face towards the east to limit the possibility of flyrock in that direction and to comply with the W.A. Condition.

The flyrock distance behind a face blast can be predicted from:

$$L_{\max} = \frac{Kf^2}{9.8} \left( \frac{\sqrt{m}}{S.H.} \right)^{2.6} \sin 2\phi$$

Where:	$L_{\max}$	Flyrock Throw (m)
	$m$	Maximum Throw (m)
	$S.H.$	Stemming Height (m)
	$Kf$	Flyrock constant
	$\phi$	= 75° (launch angle = hole angle from horizontal with a 5° collar divergence allowance).

**Table 10 – Predicted flyrock throws with Safety Factors**

Stemming Height	m = 7.5 kg/m			m = 9.8 kg/m		
	Lmax m	SF2 m	SF4 m	Lmax m	SF2 m	SF4 m
3.0	29	58	116	42	84	168
3.5	20	40	80	28	56	112
4.0	14	28	56	20	40	80
4.5	10	20	40	14	28	56

The predictions from the model used indicate that 89 mm diameter holes are appropriate with the stemming height increased to 3.5 m to give a Safety Factor of 4 for blasts at 100 m from the WA boundary. The 102 mm diameter holes at 200 m from the WA Boundary have a Safety Factor in excess of 4 (4.8) with a 3.0 m stemming height.

The Terrock model is currently being calibrated for the Deer Park Quarry by quarry personnel using flyrock observation and measurement and recording as part of developing a Flyrock Management Plan to assist in controlling flyrock in the Special Blasting Zone.

## **7. COMMENTS ON SEPARATION DISTANCES AND PLANNED LAND USE ZONINGS**

The relationship between the predicted ground vibration levels, distance and the proposed zonings are shown in **Figures 5a** and **5b**. The relationship between airblast and the zonings are similarly shown in **Figures 6a** and **6b**. The resulting blast vibration levels in relation to the proposed zonings are summarised in **Table 11**.

**Table 11 – Peak blast vibration summary in relation to zonings**

Zoning	Normal Blasting				Special Blasting	
	Ø 102		Ø 89		Ø 89	
	PPV m/s	PAV dBL	PPV m/s	PAV dBL	PPV m/s	PAV dBL
QBB	26	127	20	116-122	18	116
QSUB	7.1	118	5.6	107-112	3.5	106
QBB to gas Easement	26-38	127-130	20-29	122-124	18-33	116-119
Large Format Retail Industrial Light Industrial	8.2-36	119-130	6.4-29	108-124	4.2-33	107-119
Business	5.0-8.2	115-119	3.9-6.4	<90-113	2.3-4.3	104-107
Residential	0.6-5.0	<95-115	0.5-3.9	<90-110	0.2-2.3	<90-104
Town Centre	2.8-3.3	111-112	2.2-2.5	101-107	1.2-1.5	100

In my opinion, the main area of concern is the land between the gas pipeline easement and the QBB. The ground vibration levels from normal blasting are approaching potential minor damage levels in light framed buildings and maybe intolerable to humans. If human annoyance is ignored any buildings proposed for this zone should be reinforced or framed structures industrial and heavy commercial buildings. Therefore, they should be designed to resist the high vibration loadings anticipated. The human annoyance criteria suggests that large format

retail is not appropriate in this zone. Windows should not be broken. Some heavy industry uses with a high level of noise generation may be appropriate.

The next area of concern is the area between the QSUB and the QBB which will be exposed to vibration levels potentially in the range that may result in cosmetic damage to buildings and described as 'strongly perceptible' and 'unpleasant'. Again, the design and construction of any buildings in this zone would have to consider exposure to high levels of ground vibration with possible shielding to ameliorate the airblast levels anticipated.

In the Business zone, the predicted ground vibration and airblast are slightly above the DEDJTR Guideline Limits, but this, in my opinion is appropriate zoning.

The predicted maximum ground vibration and airblast limits in the Residential Zoning comply with the DEDJTR Guideline limits. This is also an appropriate zoning. The blast vibration from some blasts will be perceptible at the Town centre.

## **8. ELECTRICITY TRANSMISSION LINE TOWERS**

Ground vibration limitations may also be necessary at the power line tower in the buffer zone adjacent to Hopkins Road. Negotiation with the asset/managers is necessary, but in the Hunter Valley, the power line owner/managers impose a 100mm/s limit on the towers from coal overburden blasts.

Satisfying the 100mm/s limit may require a minor adjustment to the extraction proposed or changes to the blasting specifications in the vicinity of all towers, but to the group of towers closest to Hopkins Road especially.

The other general requirements electricity towers and poles are:

- There must be access at all times for maintenance vehicles to the towers.
- Blasts must be designed and implemented so as not to damage the towers, insulators and conductors from flyrock.

Ground vibration limitations may also be necessary at the power line tower in the buffer zone adjacent to Hopkins Road. Negotiation with the asset/managers is necessary, but in the Hunter Valley, the power line owner/managers impose a 100mm/s limit on the towers from coal overburden blasts.

Blasting beneath lines required that flyrock must be controlled to prevent damage to conductors, insulators and towers. Blasting is currently being conducted beneath other lines crossing the quarry with the approval of the Asset Managers and without incident.

Blasting in another section of the quarry has recently been conducted beneath conductors with the approval of the owner/managers without incident.

## **9. CONCLUSIONS**

At present, the main limiting issue for blasting in the Deer Park Quarry is compliance with the 20 mm/s limit placed on the high pressure gas pipeline owned/managed by the Australian Pipeline Authority (APA). This has been interpreted to mean 40 mm/s on the surface above the



nearest pipeline in the pipeline easement located 8 m from the eastern boundary of the easement.

The other issue is the Work Authority (WA) condition that requires an increase in stemming height from 3.0 m to 3.5 m in the special blasting zone located between 100 m and 200 m from the WA/Hopkins Road Boundary. This is to minimise the potential for flyrock impacting on traffic in Hopkins Road.

Compliance with the APA limit can be readily achieved by adjusting the charge mass fired per hole or per delay in the special blasting zone as the distance reduces from 200 m to 100 m from the WA boundary.

In the area between the QBB and the gas pipeline easement, the predicted ground vibration levels have two aspects:

- human annoyance
- structural damage.

The ground vibration levels range from 18 to 38 mm/s. In human annoyance terms this level of vibration could be described as 'severe' and 'intolerable' to people.

In structural damage terms, the vibration levels are almost double the guide values to prevent cosmetic damage in 'unreinforced or light framed structure residential or light commercial buildings' (AS2187.2-2006). The vibration levels are approaching the 50 mm/s limit to prevent cosmetic damage in 'Reinforced or framed structures. Industrial and heavy commercial buildings'.

The Airblast levels are predicted to be below potential damage levels.

Buildings within the QBB and pipeline easement would have to be designed to resist vibration damage, but the vibration to people inside the buildings would be intolerable. This, in my opinion, would surely restrict the types of businesses that would be appropriate in this area.

In the area between the QBB and the QSUB, zoned as Industrial and Business/large format retail, the predicted vibration levels can be described as strongly perceptible and 'unpleasant'.

The construction of any buildings in this zone would have to be designed to resist the high levels of vibration expected, and preferably where large numbers of people do not congregate. In my opinion, this would preclude the large scale retail use, before the quarry is worked out.

The airblast and ground vibration levels predicted in the Business zone, while slightly above the DEDJTR Guideline limits, appears to be an appropriate use.

The residential zone outlined has predicted airblast and ground vibration limits that complies with the DEDJTR Guideline Limits. However, with ground vibration perceptible at levels down to 0.2 – 0.5 mm/s, blasts may be 'felt' across the Residential zone.

Perceptible vibration will be felt at the Town Centre from some blasts.

In my opinion, both buffers are required because a cautious approach is necessary to manage blast vibration exposure in the PSP.

Any proposal to limit blasting in the quarry to reduce ground vibration limits to levels more compatible with human annoyance or structure response of buildings would be an unjustified constraint on the operators of the quarry.

A handwritten signature in black ink, reading "Adrian J. Moore." The signature is written in a cursive style with a large, stylized 'A' and 'M'.

**Adrian J. Moore**  
**2<sup>nd</sup> September 2016**