APPENDIX D

BLAST IMPACT
RESPONSE TO PAC REVIEW REPORT

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PAC REVIEW – BLAST MANAGEMENT RESPONSE

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5th March, 2013

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PAC REVIEW – BLAST MANAGEMENT RESPONSE

EXECUTIVE SUMMARY

The NSW Planning Assessment Commission (PAC) in their Review of the Project in December 2012 made "*Recommendation 38: The Commission recommends that there should be no impacts to the pagodas and cliff lines from blasting. The Commission does not accept that a 50m buffer will guarantee this outcome, but is unable to determine a satisfactory buffer distance from the available information. To accommodate this situation the Commission recommends that no blasting occur within 300m of the pagodas or cliff lines without an independent geotechnical surveyor certifying that the blasting proposed will not cause impact to the pagodas or cliff lines. In any event a minimum stand-off distance of 100m must be maintained for blasting from all pagodas, cliffs and other rocky outcrops*".

The incorrect Blast Damage Criteria of 10 mm/s as a Structural Damage Limit and 50 mm/s as a limit for Public Utilities were considered by the PAC when determining the possible effects of blast vibration on the Aboriginal rock shelters, the Cullen Bullen General Cemetery (Cemetery), Significant Pagoda Landforms and Sandstone Outcrops.

A limit of 10 mm/s is not and never has been accepted as a Structural Damage Limit by Australian regulatory authorities.

The recommendation of AS 2187.2 – 2006 is a limit of 100 mm/s PPV for unoccupied structures of reinforced concrete and steel construction. There are many successful examples of blasting in close proximity to structures and infrastructure to support this vibration level. These include Transgrid approving a 100 mm/s PPV limit for transmission towers.

The Cullen Valley Mine conducted controlled blasting as part of open cut mining operations within 32m of the railway line. The maximum vibration (93 mm/s PPV) caused no structural damage to the rail line or cutting walls.

Blasting at the Cullen Valley Mine to within 57m of the Sandstone Outcrop resulted in ground vibrations predicted to be in the range 185 to 213 mm/s without discernible impact.

Blasting at Invincible Colliery to within 205m of the base of the Significant Pagoda Landform (SPL) has resulted in ground vibration predicted to be in the range 16.4 to 24.3 mm/s without discernible impact.

Controlled blasting to within 43m of the Invincible Colliery office resulted in a PPV of 17.7 mm/s using environmental design principles. The highest PPV was 32.3 mm/s recorded at 66m from a blast. There was no discernible impact on the office complex, furniture or electronic equipment as a result of the blasting.

Review of previous blasting close to the rail lines, Sandstone Outcrops, the Invincible Colliery office and Cullen Bullen township has demonstrated:

- Blast vibration can be controlled to a specified limit using accepted blast design principles and implementation of the design;
- Blasting has been conducted to within 32m of the rail lines and 43m from the office complex without causing even threshold damage;
- Blasting has been successfully conducted to within 57m of the Sandstone Outcrops at the Cullen Valley Mine, without applying vibration reduction techniques, and
- The effectiveness of a controlled and closely monitored blasting program close to sensitive receptors at the Cullen Bullen township.

The assessment in this report shows that without any additional control measures, currently approved overpressure limits can be complied with at houses in the Cullen Bullen township.

There are several aspects to representing the ground vibration contour assessment, particularly:

- Limiting ground vibration at houses to 5 mm/s;
- Limiting ground vibration at the SPL and Sandstone Outcrops to 100 mm/s;
- Limiting ground vibration at the Aboriginal Heritage Sites and the Cullen Bullen General Cemetery to 20 mm/s;
- Worst case vibration from blasting is from the thickest interburden 20 – 30m thick between the Moolarben and Irondale coal seams.

The assessment in this report demonstrates that the ANZEC guidelines can be complied with at the houses within the Cullen Bullen township. Blasts at different locations within the planned extraction will result in much lower vibration levels.

The maximum surface movement of grave furniture at the Cullen Bullen General Cemetery is predicted to be about one fifth of the thickness of a human hair, and the possible effect of ground motion is therefore considered to be negligible at the 250 m stand-off distance proposed. The risk to visitors from flyrock is addressed by the Commitment 30 and enforcement of an exclusion zone at time of blasting to ensure that no visitors are present within 500m of a blast. The spatial Factor of Safety for the monuments from flyrock varies from 5 to 12.

Regular condition and vibration compliance monitoring and blast design to achieve the lowest 20 mm/s target PPV limit proposed for the Aboriginal Heritage Sites will ensure that the PAC's Recommendations are achieved. Areas around the rock shelters can be identified where a charge mass reduction may be required to achieve the target PPV limit.

Blast design for ground vibration (PPV) control has been proven to be effective on site and should be part of the Blast Management Plan. It has been shown that blasting closer than 100m to Sandstone Outcrops can occur without detrimental impacts.

It is logical that a PPV limit is a preferred basis for protection of the SPL and Sandstone Outcrops than a stand-off distance, because it is easy to routinely measure and report, and it is also the relevant controlling parameter.

The Proponent has demonstrated that by using environmental blast design techniques, ground vibration can be controlled to a specified target level.
Additional arrays of blast monitors should be located to the east of the proposed southern extension of Invincible Colliery to measure Peak Particle Velocity (PPV) for all blasts, and conduct sufficient strain measurements to confirm the relationship between PPV and strain for blasts on the various horizons as operations progress to the south (Site Factor Kv Exercise). The data would be gathered, collated and analysed to confirm and refine a Scaled Distance Site Law to increase the confidence of initial blast design when moving to the east towards the SPL.

Following a similar program to determine a local Scaled Distance Site Law, the Proponent also proposes to conduct a multi-disciplinary investigation (Non-damaging Limit Exercise) in the northern section of Cullen Valley Mine remote from SPL. This will include analysing the effects of controlled and closely monitored blasts to prove and demonstrate the appropriateness of the 100 mm/s non-damaging limit for SPL and Sandstone Outcrops.

The instrument of control of blast vibration for structures should be a non-damaging limit (i.e. measured as a limit of vibration), rather than an arbitrary distance (i.e. stand-off) limit. The non-damaging limit should be determined by the multi-disciplinary investigation which includes analysing the effects of controlled and closely monitored blasts.

Rather than an arbitrary distance, a more effective control mechanism would be an interim vibration limit at the base of the Sandstone Outcrop of, say 50 mm/s while the Non-damaging Limit Exercise is conducted.

I am informed that the Proponent proposes to undertake these operations to demonstrate and prove the Site Law and Non-damaging ground vibration limit in the first year of operation of the Contracted Project. During this time, other mining faces would be advanced concurrently but would not approach within 200m of the SPL and Sandstone Outcrops before the validation program is completed. The collecting of data and developing of Site Laws at other mining locations is a routine part of a Blast Management Plan.

We are informed that the data gathered in the proposed blasting exercise would be used to introduce a refined blast management program for operations adjacent to SPL and Sandstone Outcrops.

The blast management program should be used as the basis of Blast Management Plan to safely approach to 50m from the SPL and Sandstone Outcrops with confirmation by routine PPV measurements of all blasts coupled with observations of the response of the rock mass.

1. INTRODUCTION

Terrock Consulting Engineers were requested by Mr Dorian Walsh of Hansen Bailey to provide an additional response to address the comments and recommendations of blast impacts made by the NSW Planning Assessment Commission (PAC) in their review of the Project in December, 2012, particularly:

"Recommendation 38: The Commission recommends that there should be no impacts to the pagodas and cliff lines from blasting. The Commission does not accept that a 50m buffer will guarantee this outcome, but is unable to determine a satisfactory buffer distance from the available information. To accommodate this situation the Commission recommends that no blasting occur within 300m of the pagodas or cliff lines without an independent geotechnical surveyor certifying that the blasting proposed will not cause impact to the pagodas or cliff lines. In any event a minimum stand-off distance of 100m must be maintained for blasting from all pagodas, cliffs and other rocky outcrops".

The response is to include:

- Overview of blast damage criteria regarding people, structures and infrastructure;
- Comment on Coalpac's current blasting control practice and experience in managing and minimising vibration and overpressure in the proximity of sensitive receptors;
- A summary of the blast overpressure and vibration impacts predicted for the Project;
- A staged monitoring and management procedure that could be used to allow Project blasting within 100m of pagodas, cliffs and outcrops. This would need to be consistent with existing commitments made in the EA and RTS;
- A justification for this approach;
- A suggested condition that could be inserted in any approval for the project which would give certainty to the community that blasting will not visibly (at least) damage the pagodas, cliffs and escarpments.

Since the EA was submitted to the Department of Planning and Infrastructure and reviewed by the PAC, Coalpac has reviewed the Project and has proposed a number of changes to further reduce noise and other environmental impacts (the Contracted Project). The most significant of the changes proposed for the Contracted Project from a blasting perspective are:

(1) Removal of the Hillcroft Mining Area; and

(2) Reduction in the open cut footprint adjacent to significant pagoda landforms to improve ecological outcomes.

It should be noted that Coalpac, in their Response to the PAC Report, have defined the Narrabeen Group Sandstone Outcrops within the Project Boundary into two geomorphological units that essentially show two different topographic expressions. These are known as Significant Pagoda Landforms (SPL) and Sandstone Outcrops. These are defined elsewhere in Coalpac's Response to the PAC Review Report, however for the purposes of this report the two are treated separately.

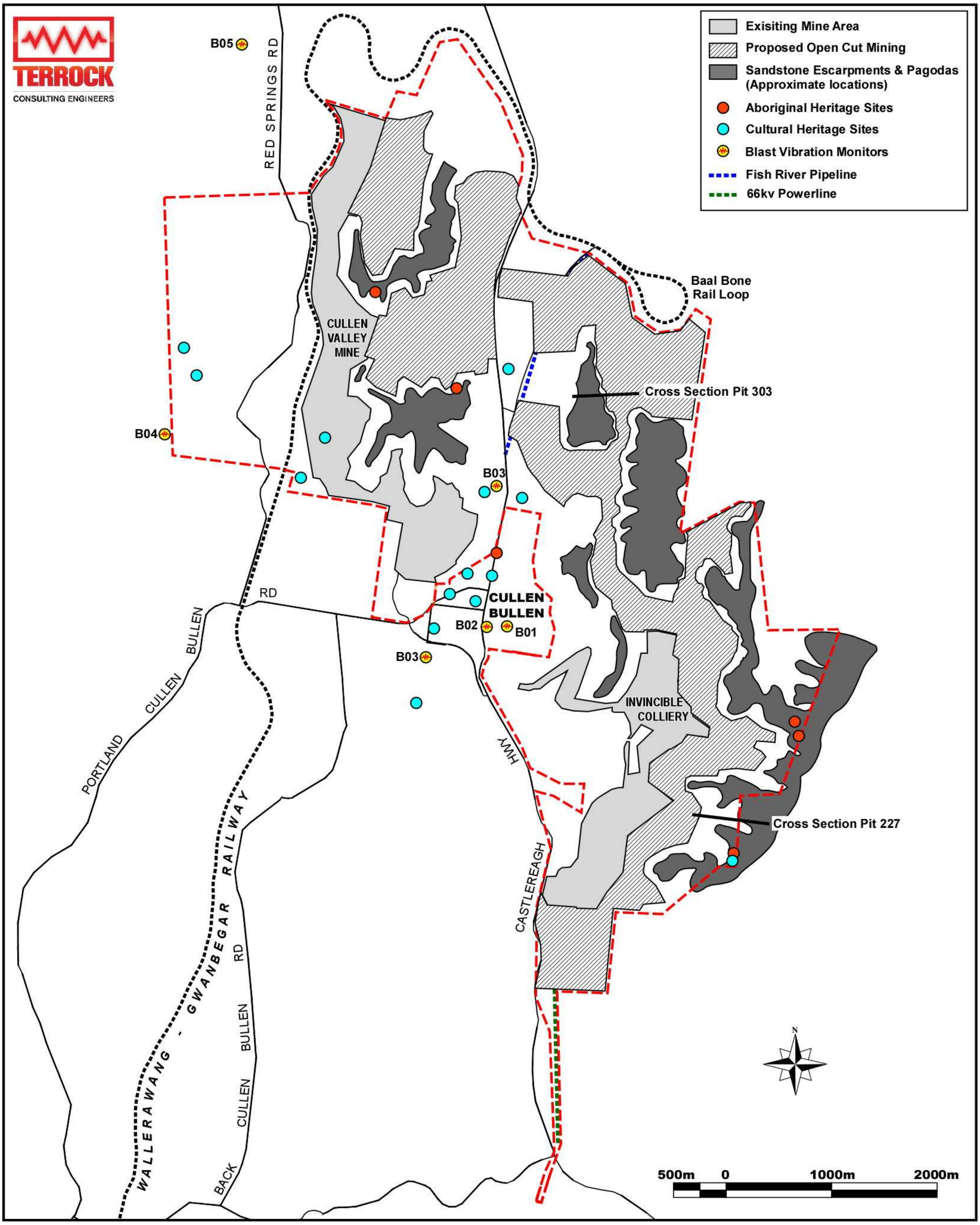

Figure 1 – Location Plan of the Contracted Project

2. BLAST DAMAGE CRITERIA

It was considered necessary to include this section to respond to the inconsistencies in the PAC Review recommendations and conclusions. The incorrect Blast Damage Criteria were considered by the PAC when determining the possible effects of blast vibration on the Cullen Bullen Residences (Residences), Aboriginal Heritage Sites, the Cullen Bullen General Cemetery (Cemetery), SPL and Sandstone Outcrops.

The incorrect Damage Criteria considered by the PAC was 10 mm/s as a Structural Damage Limit and 50 mm/s as a limit for Public Utilities.

2.1 HOUSE AND STRUCTURE DAMAGE CRITERIA

At the outset, an error in Table 5-12: Blast Criteria (reproduced below as **Table 1**) in the PAC Review report of 14th December, 2012 should be corrected as it creates a misapprehension as to what levels of vibration may result in structural damage. It may have led to misunderstandings by the PAC in trying to determine the possible impact of blasting on the Residences, Cemetery, Aboriginal Heritage Sites, SPL and Sandstone Outcrops.

The reference to structures relates to man-made or engineered structures.

Table 1 – "Table 5-12: Blast Criteria" from PAC report 14/12/2012 (Sec. 5.3.1.1, p. 59)

Blast Impact	Amenity Criteria*	Structural Damage Criteria**
Airblast overpressure	115dBL for 95% of blasts in any year	133dBL
Ground Vibration	5mm/sec for 95% of blasts in any year 10mm/sec for 100% of blasts	10mm/sec *Incorrect*

*ANZEC, 1990. Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration (ANZEC, 1990)
**Australian Standard (AS2187.2-2006 Explosives – Storage, Transport and Use (houses and low rise residential buildings)

The 10mm/s ground vibration Structural Damage Criteria referenced as AS 2187.2 – 2006 is incorrect.

A limit of 10 mm/s is not and never has been accepted as a Structural Damage Limit by Australian regulatory authorities.

10mm/s is the upper Human Annoyance or Amenity Criteria from the ANZEC guidelines which is not to be exceeded and applies to 5% of blasts in any year.

AS 2187.2 – 2006 in Table J4.5 (B) lists the following Recommended Ground Vibration Limits for Control of Damage to Structures (included as **Table 2**).

Table 2 – from AS 2187.2 – 2006 – Table J4.5(B) Recommended Ground Vibration Limits for Control of Damage to Structures (see Note)

Category	Type of blasting operations	Peak component particle velocity (mm/s)
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency-dependent damage limit criteria Tables J4.4.2.1 and J4.4.2.2
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 vibration that might occur within the structure. Particular attention should be given to the response of suspended floors.

The frequency–dependant damage limit criteria referred to in **Table 2** (Tables J4.4.2.1 and J4.4.2.2) referred to as the limits for "*Unreinforced or light framed structure. Residential or light commercial type buildings*" (which includes houses etc.) are similar and can be summarised in Table J4.4.2.1 (reproduced as **Table 3** below).

It would appear that the PAC's findings and comments in relation to the potential damage to Residences, Aboriginal Heritage Sites, the Cemetery, SPL and Sandstone Outcrops <u>are influenced by the incorrect information in Table 5-12</u>.

Table 3 – from AS 2187.2 – 2006 – Table J4.4.2.1 Transient Vibration Guide Values for Cosmetic Damage (BS 7385-2) - Frequency Dependant Damage Criteria

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.

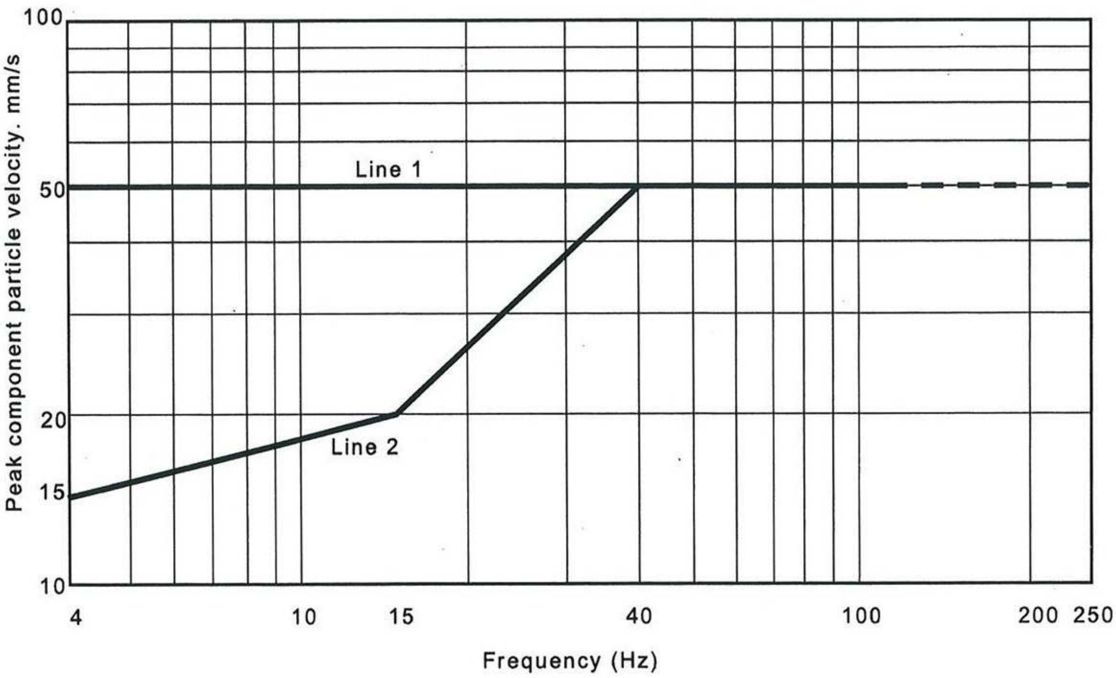

FIGURE J4.4.2.1 TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)

The Damage Classification from BS 7385-2 is reproduced as **Table 4**. BS 7385-2 also states that "*Minor Damage is possible at vibration magnitudes which are greater than twice those given in Table J4.4.2.2 and minor damage to a building structure may occur at values greater than 4 times the tabulated values*".

Table 4 - from AS 2187.2 – 2006 – 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 on 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.

For a typical house the limits for cosmetic damage are 15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz.

The dominant frequency of the ground motion from overpressure is often determined by the slowest delay timings in the initiation sequence, e.g. 100 ms delays produce about 10 Hz frequency, 65 ms delays produce about 15 Hz frequency.

For the usual exposure range of 10 – 15 Hz, which is appropriate for the Contracted Project, the damage control limits for Residences range from 18 mm/s to 20 mm/s. At 18 – 20 mm/s we may expect the start of the formation of hairline cracks and the growth of existing cracks in plasterboard and mortar joints. The listed structural damage limits have proven to be conservative for houses and man-made structures.

It is also to be noted that the limiting values referred to are Peak Component Particle Velocity (PCPV) as distinct from Peak Vector Particle Velocity (PVPV). The PVPV is the vector of the three Component Particle Velocities. The PVPV values are usually at least 20% higher than the PCPV values and may be 70% if all the component values are equal.

> e.g. 18 – 20 mm/s may be 22 – 24 mm/s as PVPV. On this basis, the 100 mm/s Peak Component Particle Velocity Limit for unoccupied structures of reinforced concrete or steel construction is the equivalent of at least 120 mm/s PVPV. The instrument of control in this guide is the Peak Component Particle Velocity, not Peak Vector Particle Velocity.

However, it is common for the PCPV limit to be applied as the PVPV limit and provide a degree of conservatism. The common use of the term PPV or a nominated vibration level implies the Peak Vector vibration.

It must be emphasised that 10 mm/s is not and never has been an accepted damage limit by Australian regulators.

Houses receiving a 10 mm/s are subjected to strains of about 2% - 10% of the failure strains of the common building materials plasterboard and masonry. On the other hand, strains due to 'natural forces' such as foundation movement and thermal expansion of the building components frequently exceed the failure strains and are responsible for many of the cracks and defects observed in houses.

In a Structure Response Investigation (Australian Coal Association Research Program [ACARP] Reference No. C9040) into the effects of blasting on brick veneer houses by Terrock in conjunction with the Universities of Newcastle and Melbourne, it was concluded that *"the stresses, due to blast vibration that are within currently enforced environmental limits, are well below damage levels"* (i.e. 10 mm/s is well below damage levels).

To put structural damage limits into perspective during this project, a 30 year old brick veneer house was subjected to highwall blasting to as close as 50m and exposed to vibration levels up to 220 mm/s. Key observations were:

- At vibration levels from 1.5 mm/s to 20.5 mm/s, no additional damage to the house was recorded;
- At 71.2 mm/s an incorrectly installed section of the plasterboard ceiling sagged and was retrofitted to accepted standards using adhesive; this remained unaffected at 220 mm/s;
- At 222 mm/s the only damage recorded was minor cosmetic damage to plasterboard such as 'popped' nail heads, hairline crack extensions and new hairline cracks at sheet joins;
- Even at 222 mm/s, there was no damage to ceramic wall and floor tiles, concrete floor and paving slabs, concrete water tanks and roof tiles and masonry walls;
- The variation to crack widths and crack lengths showed better correlation with rainfall than vibration levels;
- The floor level of the house moved up to 10mm during the project, and this movement was entirely caused by rainfall.

- The observed damage was classified as 'cosmetic' and could have been repaired simply by an amateur painter with basic plastering skills.

On this basis, the proposed limit on ground vibration of 5 mm/s will provide more than adequate protection for all Residences.

2.2 DAMAGE CRITERIA FOR PUBLIC UTILITIES

The adoption by the NSW Department of Planning and Infrastructure of a blast vibration criterion of 50 mm/s for all public infrastructure and applied by the PAC to similar mining projects is questioned.

The recommendation of AS 2187.2 – 2006 is a limit of 100 mm/s for unoccupied structures of reinforced concrete and steel construction.

The concept of public infrastructure has been somewhat blurred by the corporatisation and privatisation of the public utilities. There are many examples of infrastructure owner/ managers accepting a higher limit than 50 mm/s for their assets, subject to specified conditions. Some examples are included as **Table 5** below:

Table 5 – Examples of Vibration Limits Applied to Public Infrastructure

Australian Rail Track Authority	**PPV**
Railway lines	100 mm/s
Rail Cuttings and embankments	200 mm/s
Culverts	200 mm/s
Fibre Optic Cable & Signalling	100 mm/s
Transgrid	**PPV**
Transmission Towers	100 mm/s
Country Energy	**PPV**
Concrete & Wooden Poles	100 mm/s
Barwon Water (Victoria)	**PPV**
Buried Glass Reinforced Plastic Mains	100 mm/s
Coliban Water (Victoria)	**PPV**
Buried Concrete Lined Steel Mains	100 mm/s
Hunter Water Corporation	**PPV**
Above-ground Concrete Lined Steel Mains	100 mm/s

In the light of the above it is recommended that any Consent Conditions relating to blasting should contain wording such as

> "The vibration limits on externally owned or managed infrastructure should be 50 mm/s without an agreement; with the consent of the owner/manager of the infrastructure a higher PPV limit may apply".

Such wording, or similar, means that the limits between the proponent and the infrastructure owner/manager can be determined by agreement without the need to seek Ministerial Approval for a variation to conditions.

This approach has been adopted by many authorities and asset owners, subject to requiring vibration monitoring and testing. For example, Transgrid has approved of a 100 mm/s limit for transmission towers, subject to Non-Destructive Testing of the footings. At Hunter Valley Operations, steel towers were tested to 220 mm/s without affecting the footings.

3. PREVIOUS BLAST HISTORY ON SITE

3.1 BLASTING NEAR THE ARTC RAIL TRACK

The Cullen Valley Mine conducted open cut mining operations within 32m of the railway line. In order to do this Coalpac had to work closely with rail regulators to manage and minimise blasting impacts upon the rail line, as well as the rock cutting through which is passes. It should be noted that the cutting was in softer Permian strata. The process followed to manage the interaction with the rail line required predictive modelling of blasting coupled with monitoring to validate the predictions.

A photograph of the railway cutting located immediately to the west of the currently Approved mining area at the Cullen Valley Mine is shown in **Figure 2a**. The idealised section through the pit extraction and rail cutting is shown in **Figure 2b**. Blasting was conducted to within 32m of the rail track and using a Kv of 1120 in blast design, combined with a Peak Particle Velocity (PPV) limit of 100 mm/s, the maximum recorded vibration was 93 mm/s.

Figure 2a – Photograph of the railway cutting undamaged by blasting at 30m

The maximum vibration (93 mm/s) caused no structural damage to the rail line or cutting walls.

The only effect was that a small number of loose rocks were displaced and fell to the cutting floor, examples of which can be seen in **Figure 2a** (grey shale lying on rail ballast).

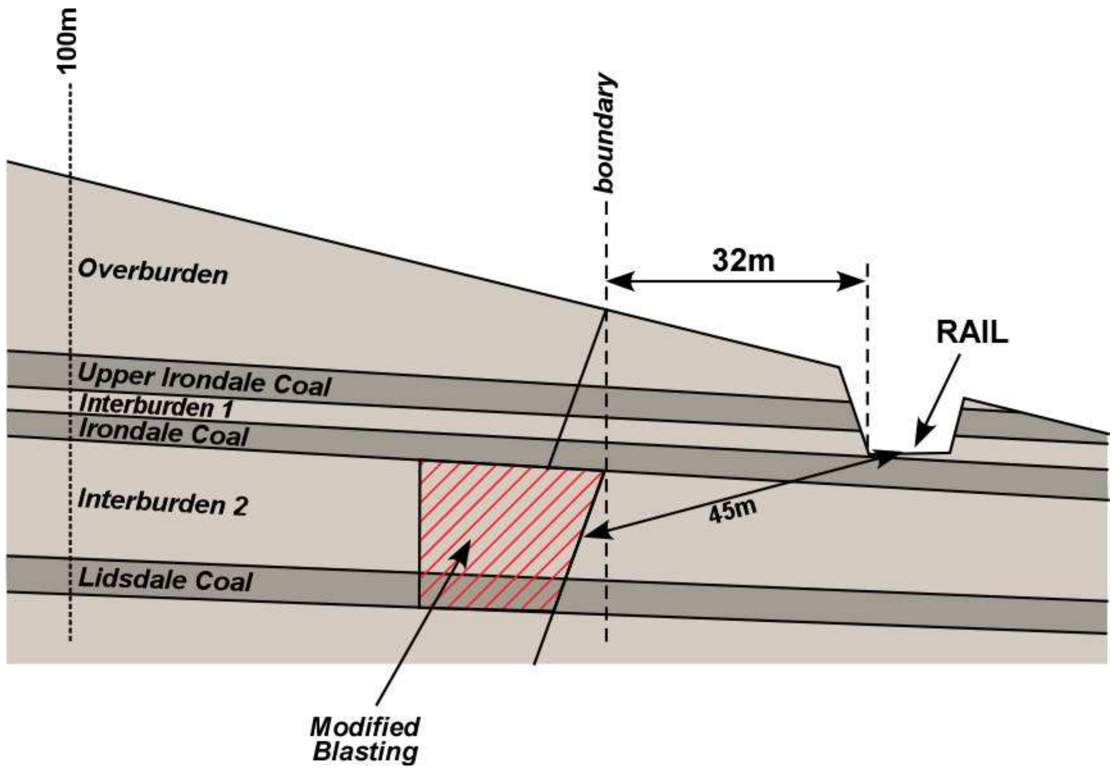

Figure 2b – Idealised cross section through the mine and rail cutting

3.2 PREVIOUS BLASTING NEAR THE SPL AND SANDSTONE OUTCROPS

In **Figure 3a**, locations where previous blasting has been conducted at the Invincible Colliery near SPLs are identified. The locations of examples of blasts near Sandstone Outcrops at the Cullen Valley Mine are shown in **Figure 3b**. The available blasting records were analysed for blasts near the SPL and Sandstone Outcrops. The blasts marked on **Figures 3a** and **3b** are summarised in **Table 6**. The peak vibration levels (PPV) were calculated using assumed Site Constants (Kv) of 1120 which had been proven to be reliable (from the blast management process adjacent to the railway cutting). The predicted range of PPVs is listed in **Table 6.**

Table 6 – Summary of records for blasts close to SPL and Sandstone Outcrops and predicted PPVs at the base of the SPL and Sandstone Outcrops

	Blast ID	Date	Distance to base (m)	Hole Depth (m)	Column Length (m)	Charge Mass (Kg)	Predicted PPV (mm/s) Kv =1120
INVINCIBLE COLLIERY SPLs	4LG42	11.06.10	216	15.1	11.1	377	23.7
	9LG43	17.03.11	205	14.5	10.3	350	24.3
	9LG1710	18.05.12	245	13.2	9.0	306	16.4
CULLEN VALLEY SANDSTONE OUTCROPS	5UI88	26.08.09	57	20.7	15.7	408	213.0
	5IR88	09.10.09	57	3.5	1.0	26	23.5
	5LG88	30.10.09	57	14.1	10.1	343	185.5
	CV2009	2002	94	15.0	10.5	230	60.5

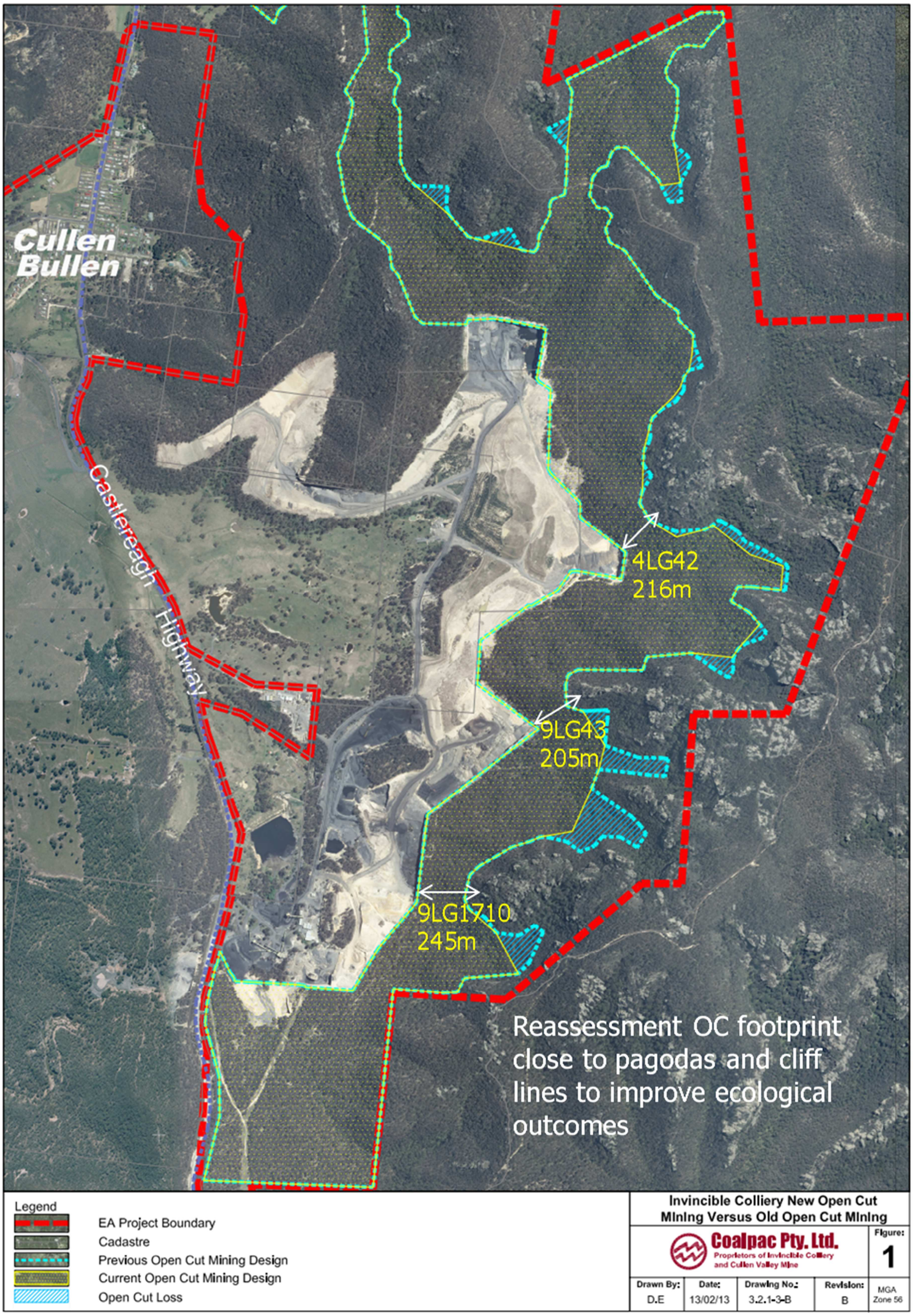

Figure 3a –Blasting locations close to the SPL at the Invincible Colliery

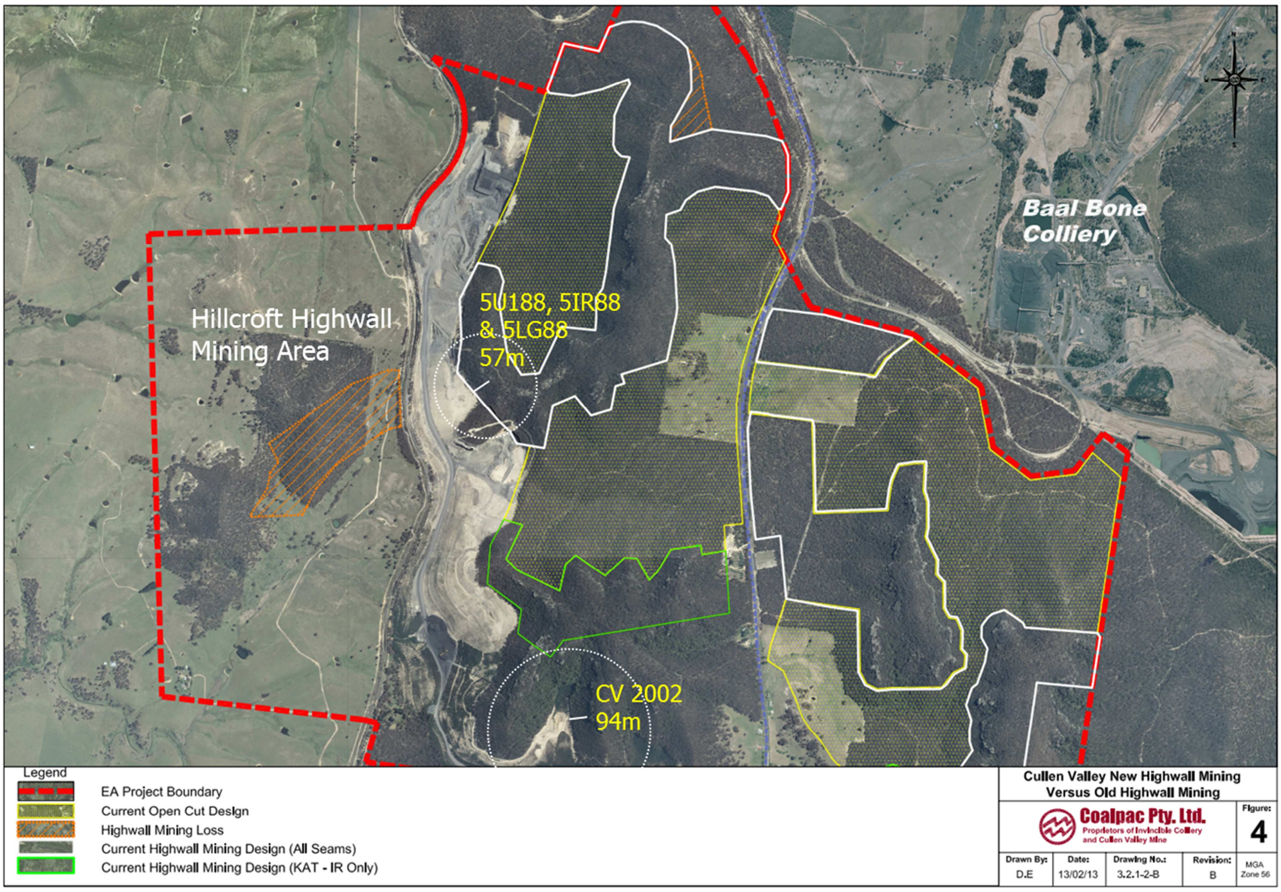

Figure 3b –Location of Cullen Valley Mine blasts near Sandstone Outcrops (57m and 94m)

Blasting at the Cullen Valley Mine to within 57m of the Sandstone Outcrop (5LG88) has resulted in ground vibration predicted to the range 185 to 213 mm/s without discernible impact (see **Figure 4**).

Blasting at Invincible Colliery to within 205m of the base of the SPL has resulted in ground vibration predicted to be in the range 16.4 to 24.3 mm/s without discernible impact (see **Figure 4)**.

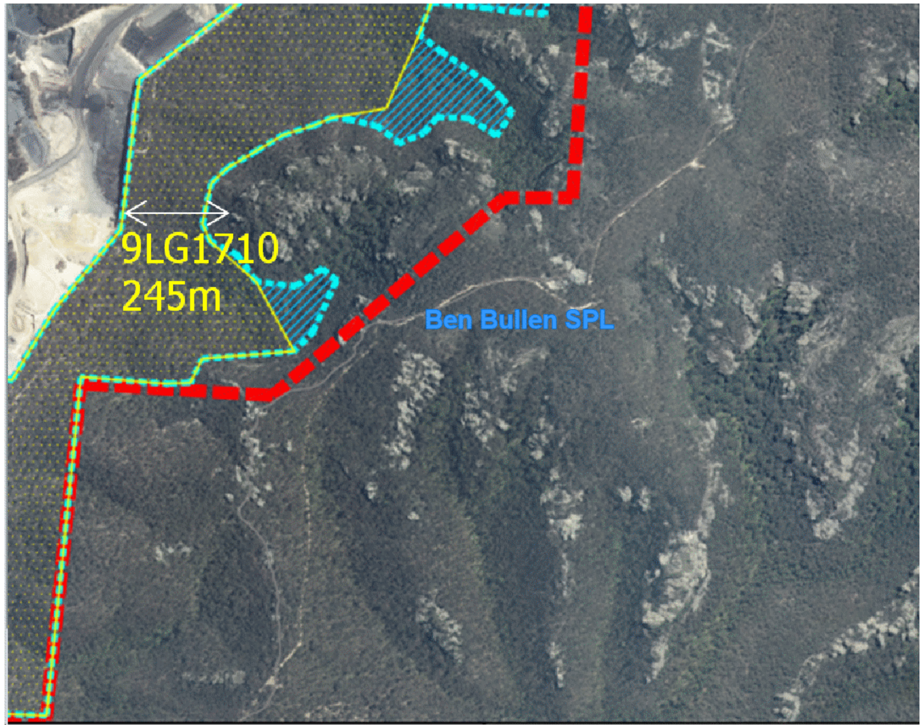

Figure 4 – Cullen Valley Mine (CV 2002) and Invincible Colliery (9LG1710) where blasting has approached SPL and Sandstone Outcrops with no discernible impacts

3.3 BLASTING NEAR THE INVINCIBLE COLLIERY OFFICE

Coalpac has supplied blast data summarised in **Table 7** regarding the blast vibration resulting from close order blasts near the Invincible Colliery administration block (30 year old, brick veneered and glazed structure). The location of the blasts in relation to the mine buildings is shown in **Figure 5a**. A schematic cross section is shown in **Figure 5b**. The distances range from 43m to 102m.

The derived Kv factors ranged from 400 to 900 which are considerably less than the 1120 Kv factor used for blasts near the ARTC rail track. The main reason for the reduction is that the blasts near the office buildings resulted in the vibration travelling through fill material as opposed to travelling along the stratum, as in the case of the rail cutting.

The hypothesis that the Kv factor reduces with distance is demonstrated in the regression analysis shown in **Figure 5c**. The limited data shows a clear reduction of the 1120 Kv factor with distance with the Kv factor applicable to distances from about 118 – 175m.

Table 7 – Vibration Monitoring Results near the Invincible Colliery Office

Shot No.	Location	Date	Distance from Office Monitor (m)	Vibration at Monitor (mm/s)	Overpressure at Monitor (dBL)
INV218	9LG1914	2/11/2012	99	14.0	129.8
INV219	9LG1914B	9/11/2012	102	17.6	121.6
INV220	9LG1916	16/11/2012	66	32.3	128.9
INV221	9LG2014	16/11/2012	85	19.8	128.1
INV222	9LG2016	23/11/2012	52	19.5	135.5
INV223	9LG2114	23/11/2012	88	8.9	125.6
INV224	9LG2116	30/11/2012	43	17.7	129.3

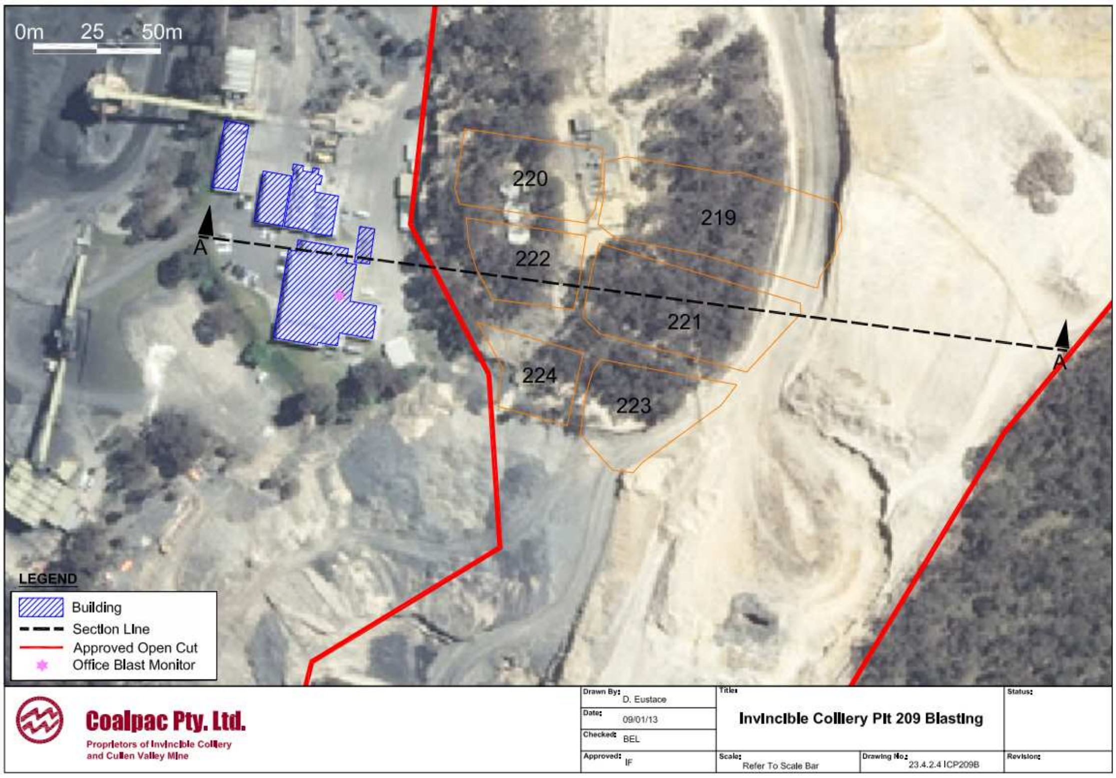

Figure 5a - Extraction limit and blast locations near the Invincible Colliery Offices and other buildings

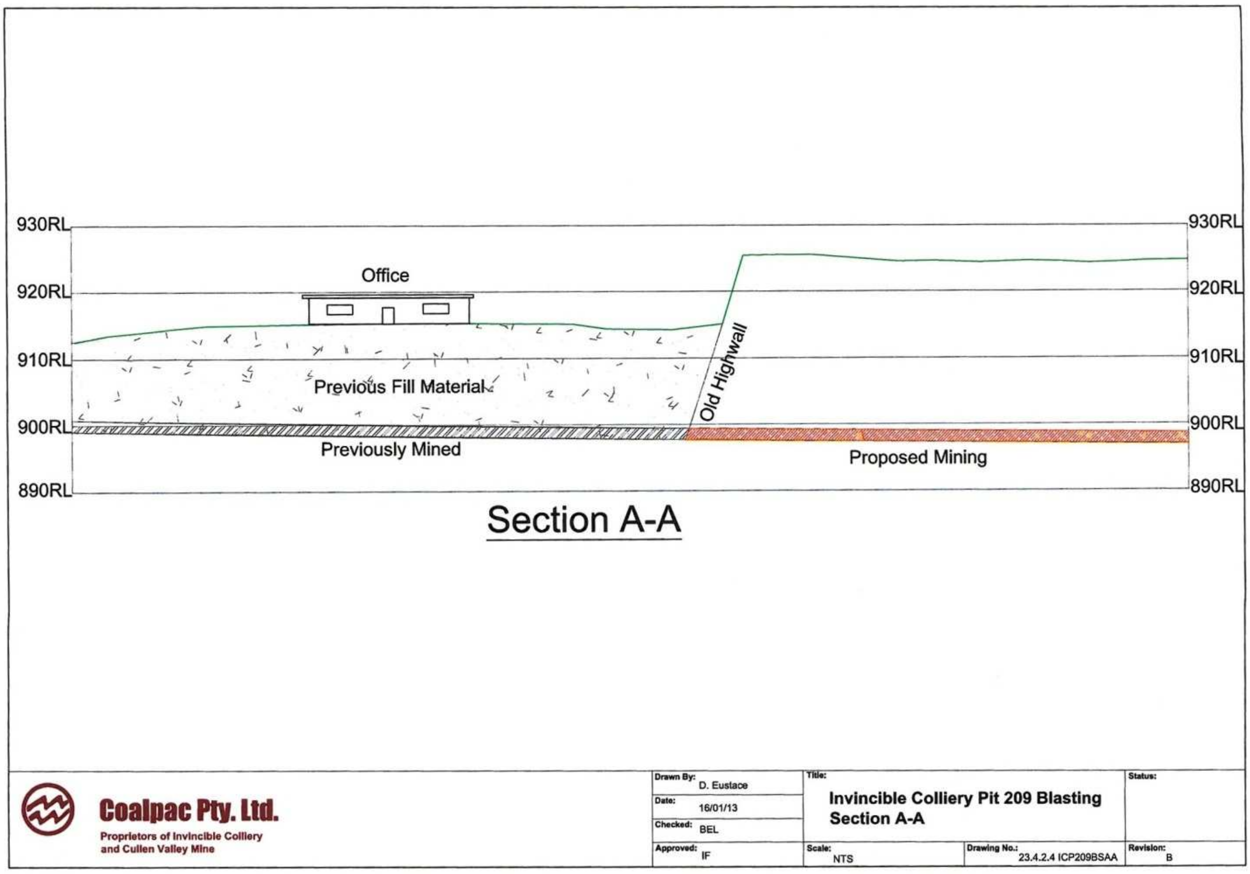

Figure 5b – Schematic cross section

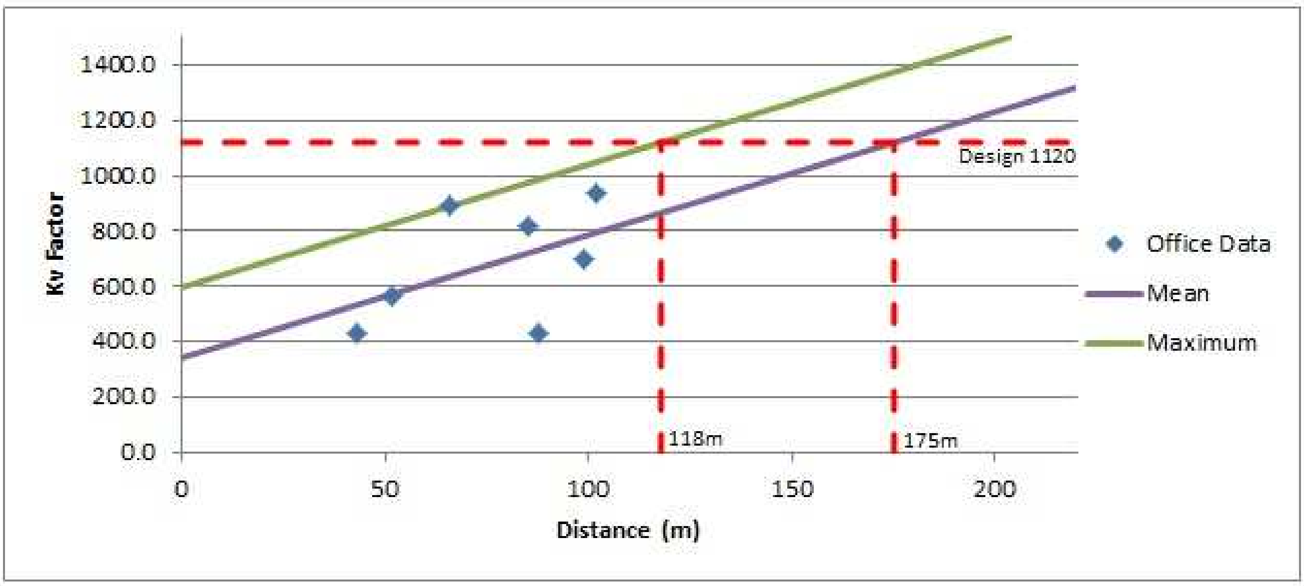

Figure 5c – Regression Analysis (Kv versus distance)

Blasting to within 43m of the Invincible Colliery office resulted in a PPV of 17.7 mm/s using managed design principles. The highest PPV was 32.3 mm/s recorded at 66m from a blast.

<u>The results of the controlled blasting program, utilising electronic detonators and reduced MIC, close to the offices at Invincible Colliery were excellent with no discernible damage occurring to</u>

masonry nor glazing. In fact there was no discernible impact on the office complex, furniture or electronic equipment as a result of the blasting. In addition, no flyrock impacted the building.

3.4 BLAST IMPACTS CONTROL AT CULLEN BULLEN TOWNSHIP

A series of blasts were conducted in Pits 206 and 208 at the Invincible Colliery, the closest recent mining to the Cullen Bullen township. The overpressure and ground vibration from all blasts was measured by instruments BO1 and BO2 located as shown in **Figures 6a** and **6b**.

The highest vibration levels recorded at BO1 and BO2 are shown in **Table 8**. The Site Law Kv factor for the maximum ground vibration from Pit 206 and Pit 208 at the two monitors is also listed in **Table 8**.

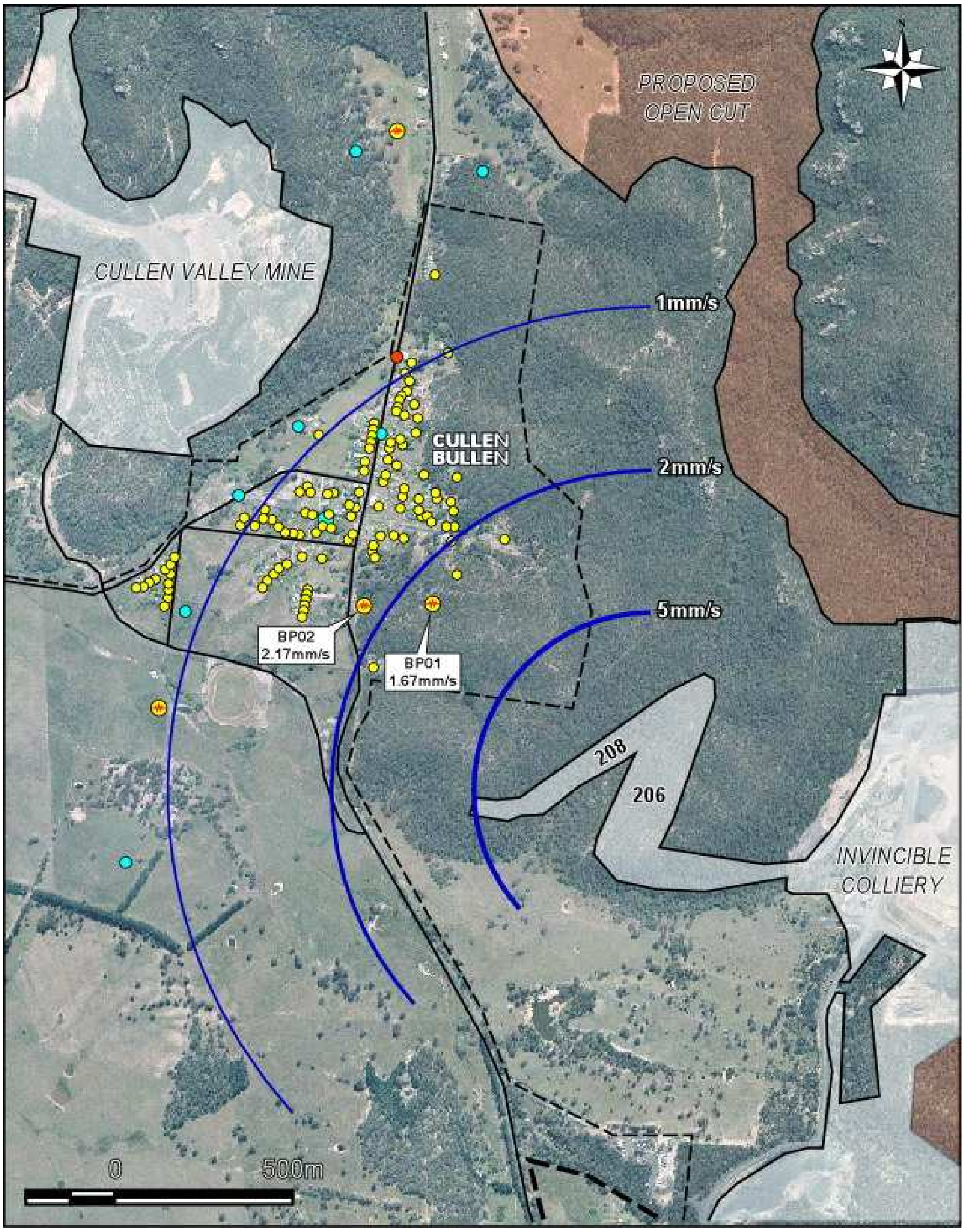

Figure 6a – Contour analysis of ground vibration from Invincible Colliery Pit 206 and 208 Blasts at Cullen Bullen (Blast monitoring locations are BP01 and BP02)

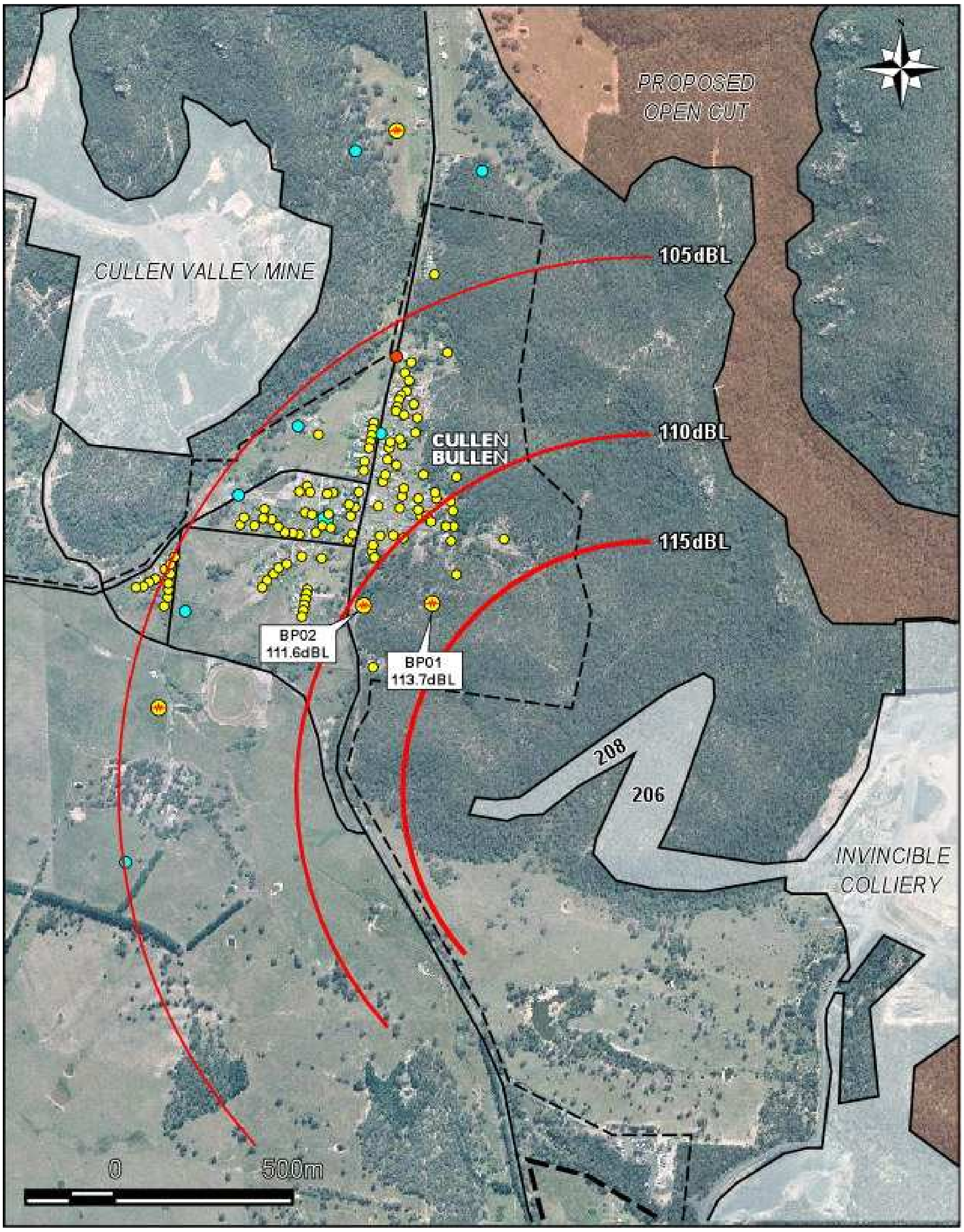

Figure 6b – Contour analysis of overpressure from Invincible Colliery Pit 206 and 208 Blasts at Cullen Bullen (Blast monitoring locations are BP01 and BP02)

Table 8 – Summary of peak ground and overpressure monitoring and analysis – Invincible Colliery Pits 206 and 208

		Monitor BO1	Kv		Monitor BO2	Kv
Pit 206	Peak Overpressure	113.7		**Pit 6**	111.6	
(distance 619 – 880m)	PPV	1.41	1044	*(distance 619 – 880m)*	1.23	1827
Pit 208	Peak Overpressure	107.6		**Pit 8**	107.1	
(distance 615 – 705m)	PPV	1.67	1182	*(distance 615 – 705m)*	2.17	2512

The Kv factors were used in environmental blast design to achieve a target limit of 2.0 mm/s at either monitor in the Cullen Bullen township and was successful, with the peak at BO2 only fractionally exceeding 2.0 mm/s which is only 40% of the currently approved limits.

The peak ground vibration (PPV) was plotted against distance from the blasts. The maximum distances of the 5, 2 and 1 mm/s were determined, and the contours are shown in **Figure 6a**. The contours have a reasonable match to the peak measurements. The maximum extent that the 2 mm/s and 1 mm/s contours extended into the township can be readily seen.

In total, 16 blasts were fired and the vibration levels generally controlled to the target limit of 2.0 mm/s (one measurement at BO2 was 2.17 mm/s, after which further controlled blasting practices were used in this area).

The peak overpressure contours were also plotted against distance and the maximum distances of the 115, 110 and 105 dBL contours determined. The peak readings were represented as the contours shown in **Figure 6b**. The maximum extent of the milestone contour intervals into the Cullen Bullen township can be seen in **Figure 6b**.

The overpressure levels were generally below 111 dBL (one measurement of 113.7 was considered to be an outlier, possibly affected by wind, because it was 7 dBL higher than the corresponding BO2 measurement.

3.5 SUMMARY OF PREVIOUS BLASTING

Review of previous blasting close to the rail lines, SPL, Sandstone Outcrops, the Invincible Colliery administration office and Cullen Bullen township has demonstrated:

- Blast vibration can be controlled to a specified limit using accepted blast design principles and implementation of the design;
- Blasting has been conducted to within 32m of the rail lines and 43m from the office without causing even threshold damage;
- Blasting has been conducted to within 57m of the Sandstone Outcrops at the Cullen Valley Mine, without applying vibration reduction techniques. The peak vibration was predicted to be in the range 185 to 213 mm/s without causing any discernible impacts, and
- The effectiveness of a controlled and closely monitored blasting programme close to sensitive receptors at the Cullen Bullen township.

4. SUMMARY OF BLAST OVERPRESSURE AND VIBRATION IMPACTS FOR THE CONTROLLED PROJECT

The clearest manner in which the overpressure and vibration impacts can be demonstrated is a contour approach representing the predicted worst case contours resulting in the area around the mine from blasting at the extraction limit. This assumes normal production blasting with no special control measures applied.

4.1 BLAST OVERPRESSURE

The blast overpressure has been assessed using the predictive methodology outlined in the Terrock report of 7th August 2012. The highest potential for overpressure comes from blasting the 4.0m parting between the Irondale seams, but this is low down within the sequence where additional topographic shielding would be provided.

The next potential is from blasting the 20 – 30m thick parting between the Moolarben and Irondale coal seams. The contours for a single blast are predicted to be as shown in **Figure 7a**. The maximum extent of the 115, 110 and 105 dBL contours around Cullen Bullen township were determined by moving the single blast contours around the pit outline while observing blast directions, and noting the maximum extent of the contour (see **Figure 7b**).

Additional topographic shielding will be provided by the topographic highs for blasts to the North and North East of the township.

<u>This assessment shows that without any additional control measures, currently approved overpressure limits can be complied with at Residences in the Cullen Bullen township.</u>

There are Residences along the Castlereagh Highway to the North of the town, including the Carleon Coach House where controlled blasting practice may be required in the extraction area to the east of the highway to comply with overpressure limits. Controlled blasting may require additional confinement of the explosives by increasing stemming height or front row burden for blasts in the 20 – 30m thick parting. These measures have been effectively applied to good effect close to the Invincible Colliery administration office as described above.

Limiting overpressure to regulatory limits by the implementation of managed blast design should be part of the Blast Management Plan.

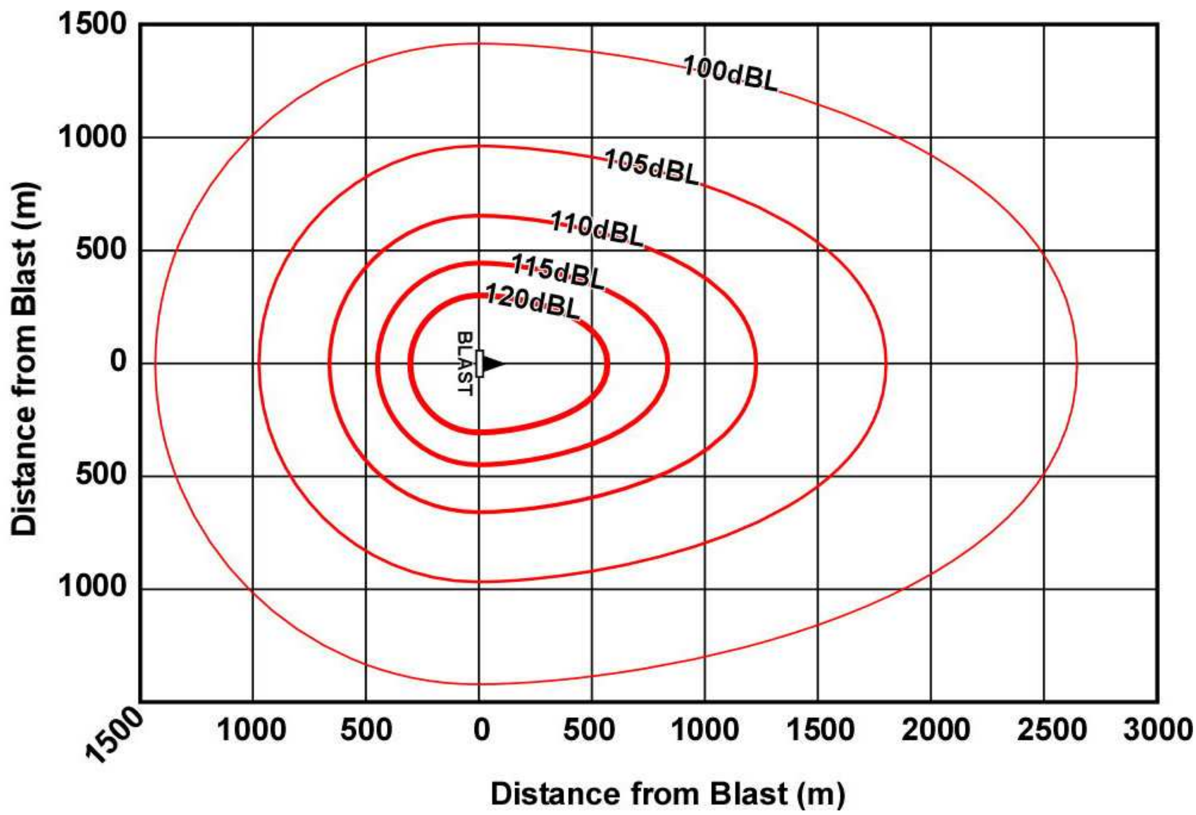

Figure 7a – Modelled Overpressure Contours for a single blast in a 20m high face

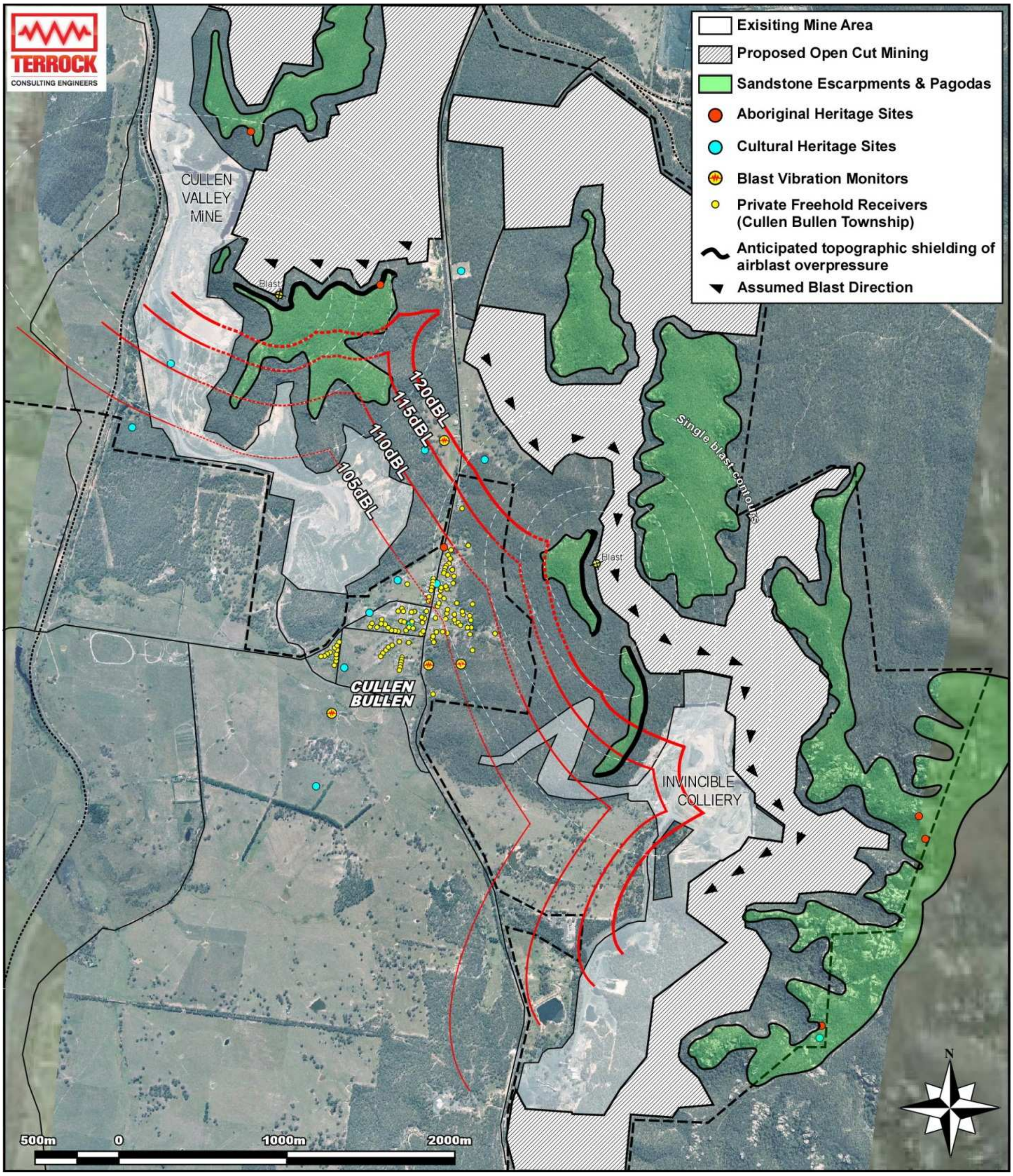

Figure 7b – Modelled Overpressure Assessment, Contracted Project – Cullen Bullen township