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RIX'S CREEK PTY LIMITED

EFFECTS OF BLASTING IN THE RIX'S CREEK CONTINUATION PROJECT AREA

REVISION 2018-3
Effects of Blasting on Historical Coke Ovens

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30th November, 2018

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1 INTRODUCTION

Terrock Consulting Engineers were requested by Rix's Creek Pty Limited (RCPL) to investigate the effects of blasting in the continuation area located in the West Pit (SW of the New England Highway), and in a smaller area in the North Pit (NW of the New England Highway), and this was covered in previous reports prepared by Terrock.

In March 2017, Terrock provided an initial assessment for the continuation project which formed part of the initial revised response to submissions. During the period between receipt of the report and submission of the Revised Response to Submissions, Rix's Creek Mine purchased two of the privately owned receivers where blast monitoring was being undertaken, which had been assessed within the March Report. Subsequently blast monitoring locations were revised following acquisition and in February 2018, Terrock were requested by RCPL to prepare a revised report that provides assessment of the effects of blasting on the revised privately owned receivers.

This revised report provides an update on ground vibration and airblast overpressure levels that will result from the current (February 2018) proposed blasting areas, using the same methodology that was used in previous reports. These changes are included in Sections 7.1 and 7.2 of this updated report, and in the appendices.No change has been made to the sections of the report dealing with all other environmental issues.
The Location Plan in **Figure 1** which shows:

- Current extraction area;
- Both continuation areas;
- Sites sensitive to blast vibration (residential areas);
- Current monitoring locations;
- The New England Highway;
- Historic Coking Oven remains.

Currently the blast vibration is monitored in accordance with current consent conditions at:
- Wright Residence – Maison Dieu Rd
- Mines Rescue – Singleton Heights
- Retreat – Bridgeman Hill
- Watling Residence.

2 ENVIRONMENTAL BLASTING RELATED ISSUES

The related issues for blasting in the continuation areas are:

- Ground vibration control;
- Airblast control;
- Flyrock control;
- Dust and Fume Management;
- Traffic management on New England Highway;
- Stability of the New England Highway;
- Protection of the Historic Coking Oven remains.

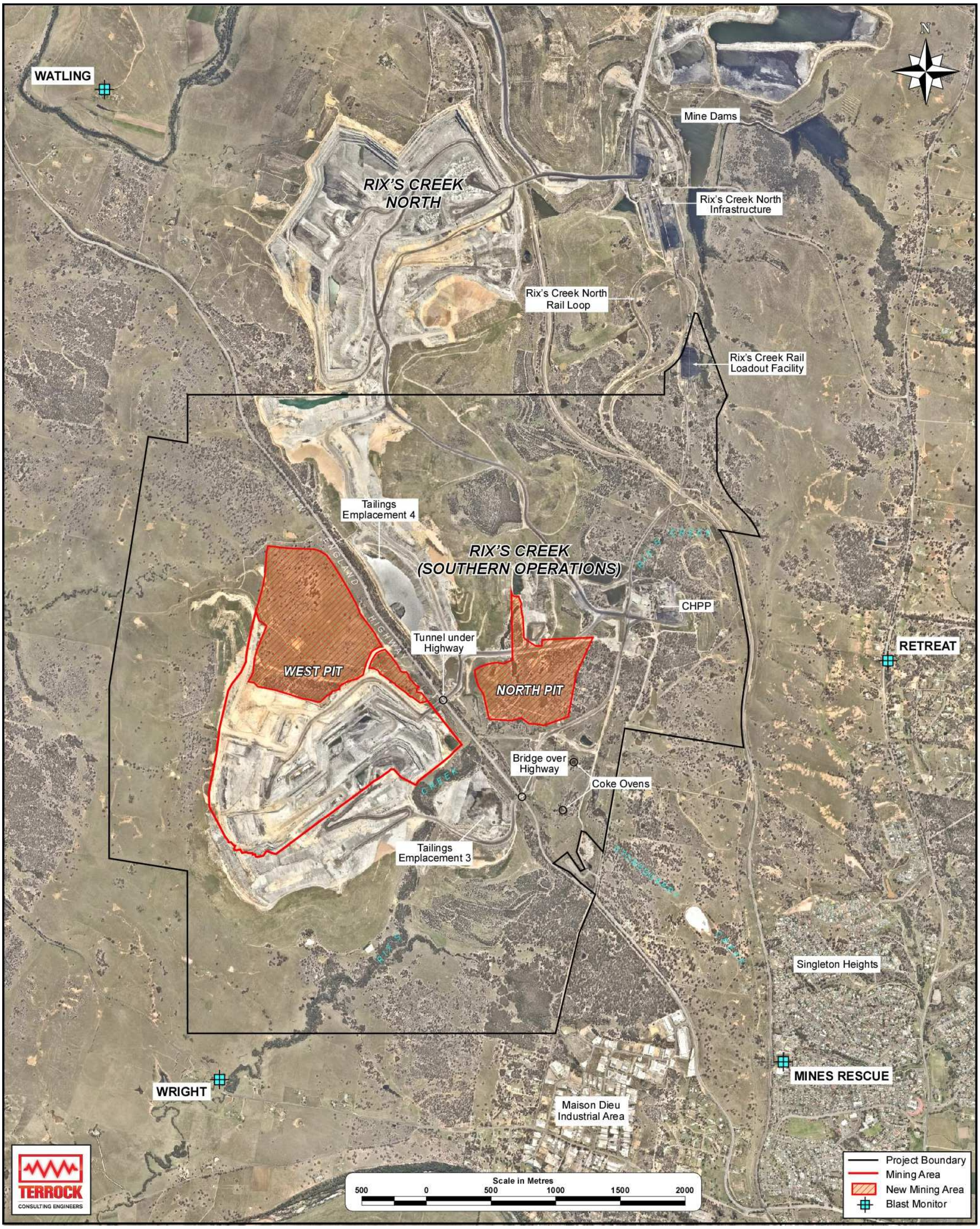


Figure 1 – Location Plan

3 REGULATORY BLAST VIBRATION LIMITS

3.1 The nature and measurement of blast vibration

When an explosive charge is fired, explosive energy produces the following effects:

- Rock shattering and displacement
- Ground transmitted blast vibration - (ground vibration)
- Air transmitted blast vibration - (airblast overpressure)

3.1.1. Ground Vibration

Ground vibration radiates outwards from the blast site and gradually reduces in magnitude, in the same manner as ripples behave when a stone is thrown into a pool of water, schematically shown in **Figure 3.1**. The motion of the wave can be defined by taking measurements of a float on the surface of the water. With suitable instruments we can measure the displacement or amplitude, the velocity, the acceleration of the float and the wave length of the waves.

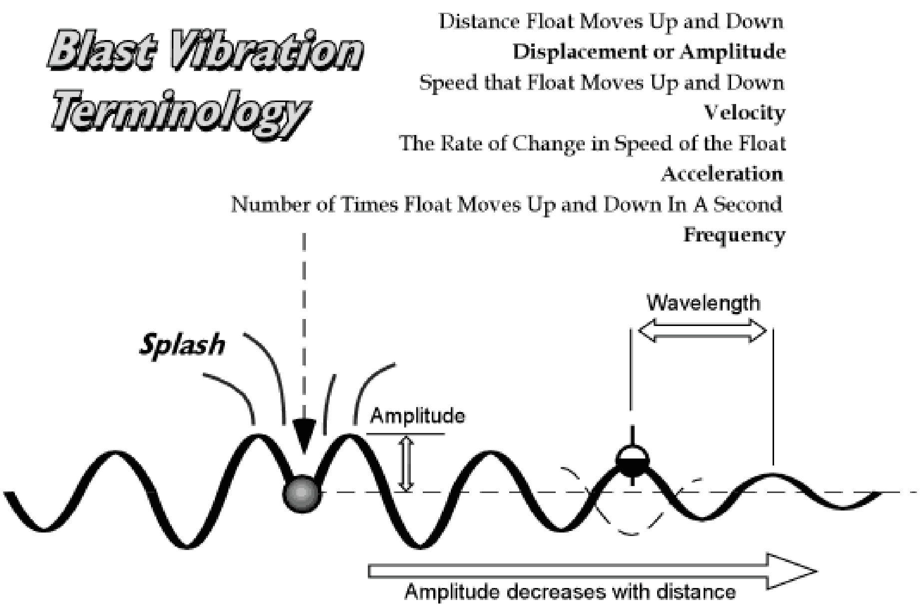


Figure A1.5 - Schematic diagram of vibration terminology

With ground vibration, the motion of the surface of the ground can be measured by coupling a suitable instrument directly to the surface.

For regulatory purposes, it has become common practice to measure ground vibration using a seismograph with a geophone securely attached to the ground.

The geophone measures the velocity that a point (or particle) on the ground moves in three dimensions at the measurement location as the vibration waves pass.

This is called the particle velocity, and the maximum value is called the peak particle velocity (PPV), measured in terms of millimetres per second (mm/s).

To define the motion in three dimensions, it is necessary to use three transducers to measure the vibration in three mutually perpendicular directions and then determine a Peak Particle Velocity or Peak Vector Sum (PVS), which is the instantaneous maximum vector of the three individual measurements:

$$\text{ie. PPV (PVS)} = \sqrt{v_t^{\,2} + v_l^{\,2} + v_v^{\,2}}$$

Ground vibration from blasting must be measured with a blast vibration meter that complies with the requirements of AS2187.2 – 2006.

3.1.2. Airblast Overpressure

When air transmitted vibration is within the range of hearing it is called sound (with frequencies in the range 20 Hz to 200,000 Hz). When its frequencies are below the range of hearing is generally referred to as concussion or airblast.

Noise is generally measured with a sound level meter that simulates the ear by filtering out frequencies below 20 Hz, the results obtained are specified as decibels (A), or dBA.

Airblast overpressure is substantially sub-audible. Although these frequencies are below the range of hearing they affect structures, and the response of the structures can be sensed by people who are inside. This explains why a blast that is barely noticed outside can be noticed by people inside a building.

Airblast overpressure is measured with special sound level meter that does not filter out the low frequencies below 20 Hz that affect structures, and the results obtained are specified as decibel (linear), or dBL.

Airblast overpressure must be measured with a meter that complies with the requirements of AS2187.2-2006.

3.2 Human and Structure Response

3.2.1. Human Response

Humans are more sensitive to blast vibration than structures, and this has resulted in human response limits that are well below levels that will cause damage to structures.

Human response to blast vibration, which is based by the experience of the Terrock personnel over a period of 40 years, is summarised in the table below:

	Ground Vibration	Airblast Overpressure
Threshold of human response	0.1 to 0.5 mm/s	90 to 100 dBL
Levels that acceptable to most people and not result in complaint.	Up to 2 mm/s	Up to 110 dBL
Levels that are likely to cause complaint.	2 to 5 mm/s	110 to 115 dBL
Levels that will result in an increased number of complaints.	5 to 10 mm/s	115 to 120 dBL.
Levels that are generally unacceptable to the Australian community.	Above 10 mm/s	Above 120 dBL.

3.2.2. Structure Response

Structural damage will occur at levels that are well above levels that are considered unacceptable to humans.

Authoritative research (ref ACARP Project C.9040 – Effect of Blasting on Structures) shows that at a ground vibration level of 10 mm/s, the stress induced into a brick veneer house is less than 10% of the strength of the weakest structural element (the interior plasterboard).

AS2187.2-2006 includes recommended ground vibration and airblast overpressure limits for damage control. These structural limits are well above the human response limits specified in environmental licences and development consents.

It should be noted that AS2187.2-2006 does not include a specific limit for historic structures. Appropriate limits for historic structures should be assessed on an individual case basis.

3.3 Development Consent Conditions

The following human ground vibration and airblast limits are specified in the current Development Consent conditions.

Ground Vibration	≤ 5 mm/s for 95% of blasts in a 12 month period ≤ 10 mm/s for all blasts
Airblast	≤ 115 dBL for 95% of blasts in a 12 month period ≤ 120 dBL for all blasts.

These human response limits are based on the Australian & New Zealand Environmental Council (ANZEC) "Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration". This publication specifies the following guideline limits at sensitive sites:

- Ground vibration: 5 mm/s for 95% of blasts within a 12 month period, with exceedance permitted to 10 mm/s for 5% of blasts.
- Airblast overpressure: 115 dBL for 95% of blasts within a 12 month period, with exceedance permitted to 120 dBL for 5% of blasts.

4 DESCRIPTION OF THE BLASTING ENVIRONMENT

Blasting of overburden and interburden is necessary to break the rock to enable it to be removed and the coal seams beneath uncovered. The thickness of the rock layers varies considerably from about 2m to over 30m in the Northern Pit. In the Western Pit the thickest interburden blasting is currently 35m but this may increase to over 40m as the pit advances to the North West.

Geological cross sections through both pits are shown in **Figures 2a & 2b**. Individual blasts are designed and the specifications altered to comply with the regulatory environmental ground vibration and airblast limits at the nearby sensitive sites.

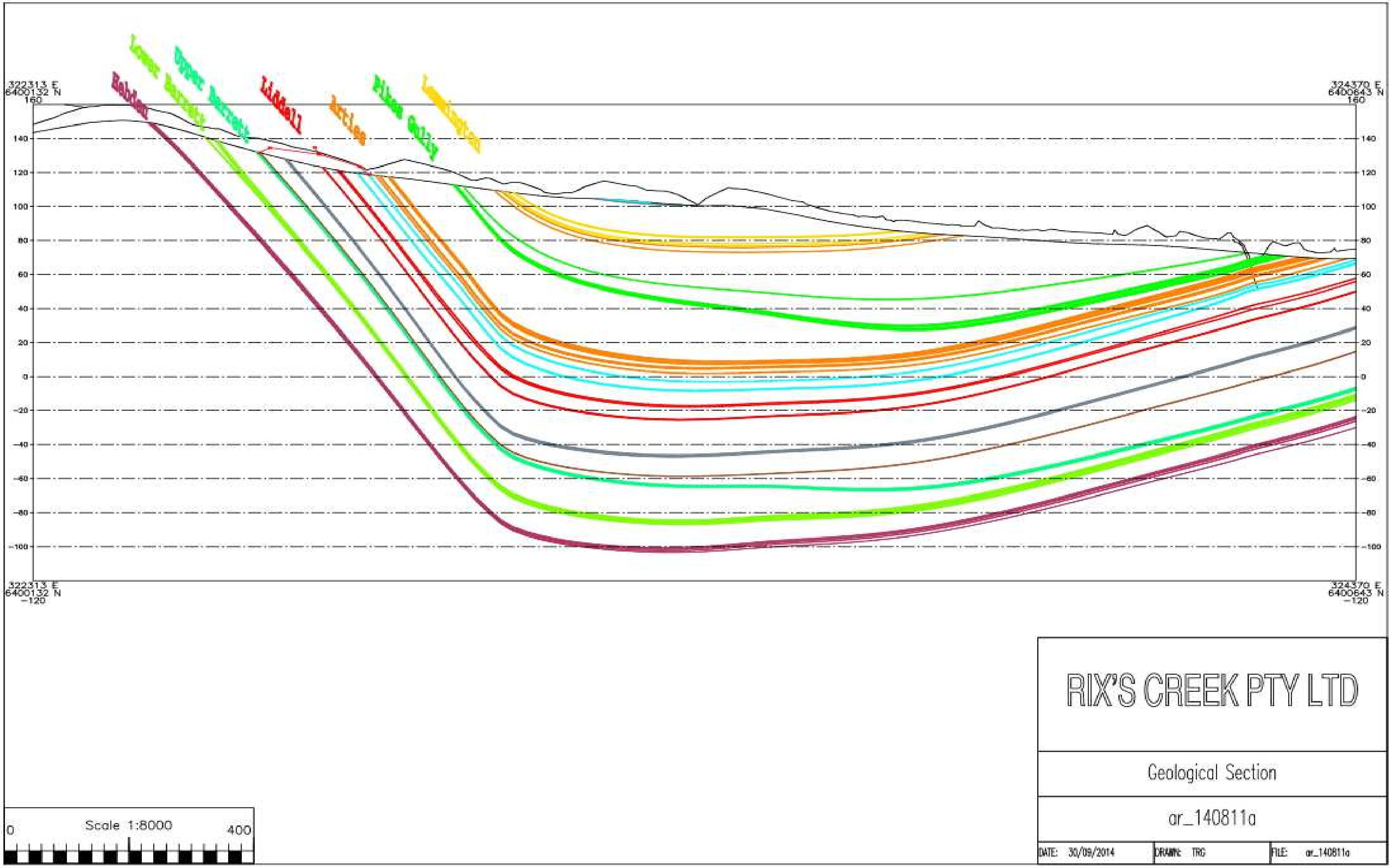


Figure 2a – Geological Cross Section – North Pit

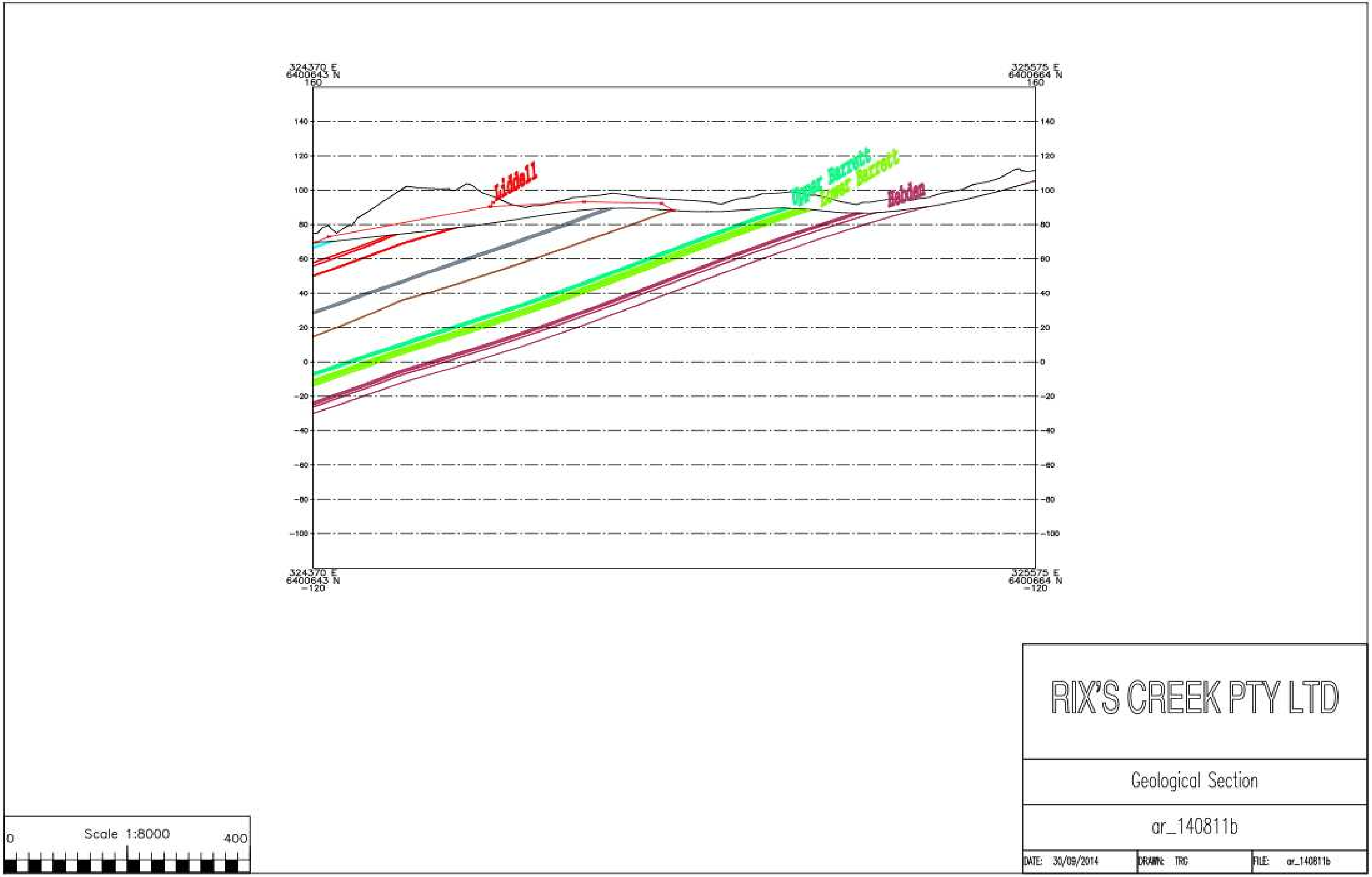


Figure 2b – Geological Cross Section – West Pit

5 DESCRIPTION OF BLASTING PRACTICE

Blasting practice uses environmental blast design principles to adjust the blasting specifications to control airblast and ground vibration to regulatory limits as well as controlling flyrock. To control airblast and flyrock in the shallow partings, the shallowest holes that can be fired are about 2.5m deep and a typical loading would be 0.2 – 0.3m explosives and 2.2 – 2.3m of stemming. In deeper blasts, the burden, spacing and stemming height are varied to achieve the ground vibration and airblast targets.

A range of explosives are also used with densities varying from 0.8 g/cc (ANFO) to 1.1 g/cc (Heavy ANFO 1.1) to 1.3 g/cc (HA 1.3). The explosive is chosen after consideration of the rock blastability and the presence of water in the blast holes.

A typical range of blasting specifications used in the Open Cuts is shown in **Table 1**.

Table 1 – Open Cut nominal blasting specifications

Blast hole diameter:		229mm					
Face Height (hole depth):		2.5 m – 35m					
Stemming height:		2.2 m – 5m					
Explosive column:		0.3 – 30 m					
Explosive	Charge mass/m (kg)	Hole Depth (m)	2.5	10	15	20	35
		Stemming Height (m)	2.2	4.0	4.5	4.5	5.0
ANFO	32.6	Charge Mass (kg)	10	195	342	505	978
HA 1.1	44.0	Charge Mass (kg)	13	264	462	682	1320
HA 1.3	53.0	Charge Mass (kg)	16	318	556	821	1500

The specifications may be varied following environmental blast design to ensure compliance with the regulatory limits.

6 BLAST VIBRATION FROM CURRENT BLASTING OPERATIONS

The range of PPV and Peak Airblast for 2017 at the regulatory monitoring stations is summarised in **Table 2**.

Table 2 – Summary of PPV and Peak Airblast - 2017

		Watling	Retreat	Mines Rescue	Wright
2017					
	PPV (mm/s)	0.01 - 0.83	0.01 - 0.84	0.02 - 1.02	0.08 - 1.92
	AOP (dBL)	85 - 110	83- 115	80 - 110	83 - 110

The ground vibration resulting from all blasts in the investigation period was well below the regulatory limit of 5 mm/s (95%) at all monitoring stations. The airblast overpressure resulting from all blasts did not exceed regulatory limits at all monitoring stations.

7 BLAST ANALYSIS

The blast vibration monitoring results for 2017 have been analysed to determine what is currently being achieved and how this transfers into the continuation area.

7.1 GROUND VIBRATION

There is a considerable variation in the blasting depths (2m to 35m) and the resulting charge mass. The centroidal contour approach was considered to be the best method to demonstrate the worst case ground vibration situation.

7.1.1. Centroidal Contour Approach

This approach is used to demonstrate the worst case ground vibration levels that are being achieved from current blasting operations. The centroid of the blasting operations is identified and radial lines constructed to the monitoring locations. Using a characteristic attenuation rate of 1.6, the milestone intercepts along the radial lines are determined. The 5, 2, 1 and 0.5 mm/s contours are then determined by connecting the intercepts. This worst case contour assessment is shown in **Appendices 1 & 2** - Ground Vibration Contour Assessment.

7.1.2. Predictive Model Approach

The worst case ground vibration can be analysed using the following Site Law model [1] by substituting for the measured values and determining *Kv*.

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

Where:
PPV = Peak Particle Velocity (mm/s)
m = Charge mass per hole or per delay (kg)
D = Distance from blast (m)
k = Site constant
e = The attenuation rate (1.6)

The ground vibration levels recorded during 2017 were used to calibrate the site constants used for predictive modelling, and these are listed in **Table 3**.

Table 3 – Site Constant Determinations

Monitor	Kv
Wright	2420
Watling	2100
Retreat	1850
Mines Rescue	2150

Using the site constants (Kv) listed in Table 3, the distances at which "milestone" PPV levels that will occur in the directions between the North Pit or the West Pit blasting areas, and the Watling, Wright, Retreat, and Mines Rescue Station monitors can be calculated, and these are listed in Table 4.

The most significant "milestone" PPV levels are 5 mm/s and 10 mm/s.

Table 4 – Distances Related to Milestone PPV Levels

	Distance (m)							
	North Pit (charge mass = 500 kg)				West Pit (charge mass = 1500 kg)			
PPV (mm/s)	Wright	Retreat	Watling	Mines Rescue	Wright	Retreat	Watling	Mines Rescue
10	691	584	632	660	1197	1010	1095	1143
5	1065	901	975	1017	1845	1560	1688	1763
2	1889	1597	1728	1805	3272	2770	2994	3126
1	2913	2463	2666	2783	5046	4270	4617	4821
0.5	4493	3799	4112	4293	7782	6580	7122	7435

The minimum distances between the either the North Pit or the West Pit blasting areas, and the Watling, Wright, Retreat, and Mines Rescue Station (M.R.S.) monitors, and the PPV levels that will result at those monitors using the worst case Kv values listed in Tables 5A and 5B:
It may be seen that the PPV levels predicted at any sensitive site will be less than the 5 mms (95%) limit.

Table 5A –Highest PPV Levels that will result at Watling, Wright, Retreat, and M.R.S. Monitors North Pit

Monitor	North Pit (Charge mass = 500 kg)			
	Retreat	M.R.S	Wright	Watling
Minimum Distance (m)	2284	3110	3541	4895
PPV Level at min. distance (mm/s)	1.13	0.84	0.76	0.38

Table 5B – Highest PPV levels that will result at Watling, Wright, Retreat, and M.R.S. Monitors West Pit

Monitor	West Pit (Charge mass = 1500 kg)			
	Retreat	M.R.S	Wright	Watling
Minimum Distance (m)	3577	3883	2089	3662
PPV Level at min. distance (mm/s)	1.33	1.41	4.1	1.45

7.2 AIRBLAST OVERPRESSURE.

The peak airblast overpressure levels recorded during 2017 are listed in **Table 6**.

Table 6 – Peak Recorded Levels 2017

Peak Airblast Level			
Watling	Wright	Mines Rescue	Retreat
110 dBL	110 dBL	110 dBL	115 dBL

The airblast overpressure levels recorded during 2017 were used to calibrate the site constants used for predictive modelling.

7.2.1. Predictive Airblast Model.

Terrock has developed the following predictive airblast models for prediction of airblast for various charge mass, burden, and stemming height specifications.

The airblast due to burden emission can be predicted from:

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

Where: D_{115} = Distance to the 115 dBL contour
d = hole diameter (mm)
m = charge mass/hole (kg)
B = face burden (mm)
ka = a site constant

This model is used in conjunction with a regression line using 9 dBL with doubling of distance as the attenuation rate. The airblast contours resulting from a face blast are elliptical with the airblast directly in front of a blast using 6-10 dBL higher than for the same distance behind or at the side of a blast.

The airblast due to stemming column emission is predicted from:

$$D_{115} = \left(\frac{ka \text{ x } d}{S.H.}\right)^{2.5} \cdot \sqrt[3]{m}$$

Where: *S.H.* = stemming height (m)

The airblast overpressure contours for these blasts are circular (equal emissions) in all directions.

Site calibration using the Rix's Creek data for 2017 gives the following models:

Burden emission model: $D_{115} = \left(\frac{170 \text{ x } d}{B}\right)^{2.5} \cdot \sqrt[3]{m}$

Stemming emission model: $D_{115} = \left(\frac{130 \text{ x } d}{S.H.}\right)^{2.5} \cdot \sqrt[3]{m}$

The stemming emission model predicted the highest levels, and these were used for this current assessment.

A centroidal contour approach was considered to be the most effective to analyse the results of airblast overpressure from current blasting operations.

The contours of the peak airblast are shown in **Appendix 2** – Airblast Contour Assessment.

The milestone airblast levels for the peak airblast (PAV) are listed in **Table 7**

Table 7 – Milestone Airblast Overpressure Distances

PAV (dBL)	Distance (front) (m)	Distance (rear) (m)
115	1950	1250
110	2900	1820
105	4300	2800
100	6200	3900

The maximum airblast overpressure levels that will result at the minimum separation distances are listed in **Table 8.**

Table 8 – Peak Airblast Overpressure Predictions

	Monitor	Minimum Separation Distance (m)	Peak levels predicted at closest dist.(dBL)
West Pit	Wright	2089	112
	Retreat	3577	104
	Mines Rescue	3883	101
	Watling	3662	101
North Pit	Wright	3451	100
	Retreat	2284	97
	Mines Rescue	3110	89
	Watling	4895	99

The airblast overpressure levels predicted at all sensitive sites will be less than the 115 dBL (5%) limit.

7.3 FLYROCK

Flyrock throw and trajectory path can be predicted by the use of the Terrock Flyrock Models:

7.3.1. Burden Control

$$L_{max} = \frac{Kf^2}{g}\left(\frac{\sqrt{M}}{B}\right)^{2.6}$$

Where: [2]

L_{max} = Maximum throw (m)
g = Gravitational constant (g)
M = Charge mass (kg/m)
B = Face burden (mm)
Kf = Flyrock constant
(Interim = 13.5 for coal overburden)

L_{max} occurs when the launch angle is 45°

7.3.3. Stemming Height Control

$$L_{max} = \frac{Kf^2}{g}\left(\frac{\sqrt{M}}{S.H.}\right)^{2.6} \text{Sin } 2\emptyset$$

[3]

$S.H.$ Stemming height (m)
$\emptyset$ = Launch Angle
= hole angle + 10^0 divergence

Kf could be calibrated for the Rix's Creek Site by a program of video review and flyrock throw measurement.

7.3.4. Burden Control Specifications (in front of face)

For Heavy ANFO 1.3g/cc density; M = 53 kg/m *B* = 5m

$$L_{max} = \frac{13.5^2}{9.8}\left(\frac{\sqrt{53}}{5}\right)^{2.6} = 50\text{m}$$

The minimum recommended exclusion zone in front of face becomes:

- Plant and Equipment: Safety Factor **2.0** Minimum Exclusion Zone = 100m
- Personnel, boundaries etc: Safety Factor **4.0** Minimum Exclusion Zone = 200m

7.3.5. Stemming Height Control (at sides and behind blast)

(i) Full Scaled Blasts

For Heavy ANFO 1.3g/cc density; M = 53 kg/m B = 5m S.H. = 5000 10° holes

$$L_{max} = \frac{13.5^2}{9.8}\left(\frac{\sqrt{53}}{5}\right)^{2.6} \text{Sin } 140^{o}$$

= 32.1m (at high trajectory)

Minimum Exclusion: S.F. **2.0** = 65m

S.F. **4.0** = 130m

(ii) Shallow Blasts

For Heavy ANFO 1.3g/cc density; Charge= 0.2m long = .2 x 53 = 10.6 kg S.H. = 2.3m

$$L_{max} = \frac{13.5^2}{9.8}\left(\frac{\sqrt{10.6}}{2.3}\right)^{2.6} \text{Sin } 160^{\circ}$$

= 16m

Minimum Exclusion: S.F. **2.0** = 32m

S.F. **4.0** = 64m

The predicted flyrock trajectory paths are shown in **Figure 3a** and **3b.**

Current operating practice is to stop traffic on the New England Highway when blasting within 500m of the highway. This incorporates a substantial increase in the safety factors applied to the conservative Terrock flyrock model.

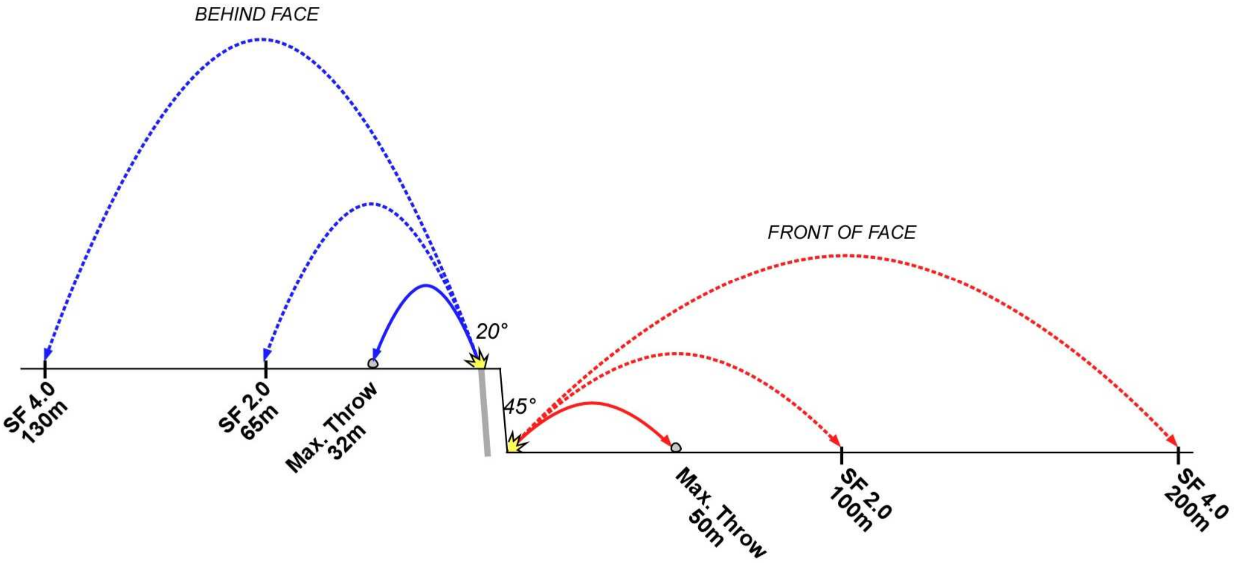


Figure 3a – Flyrock Trajectory Paths, 10° blast holes

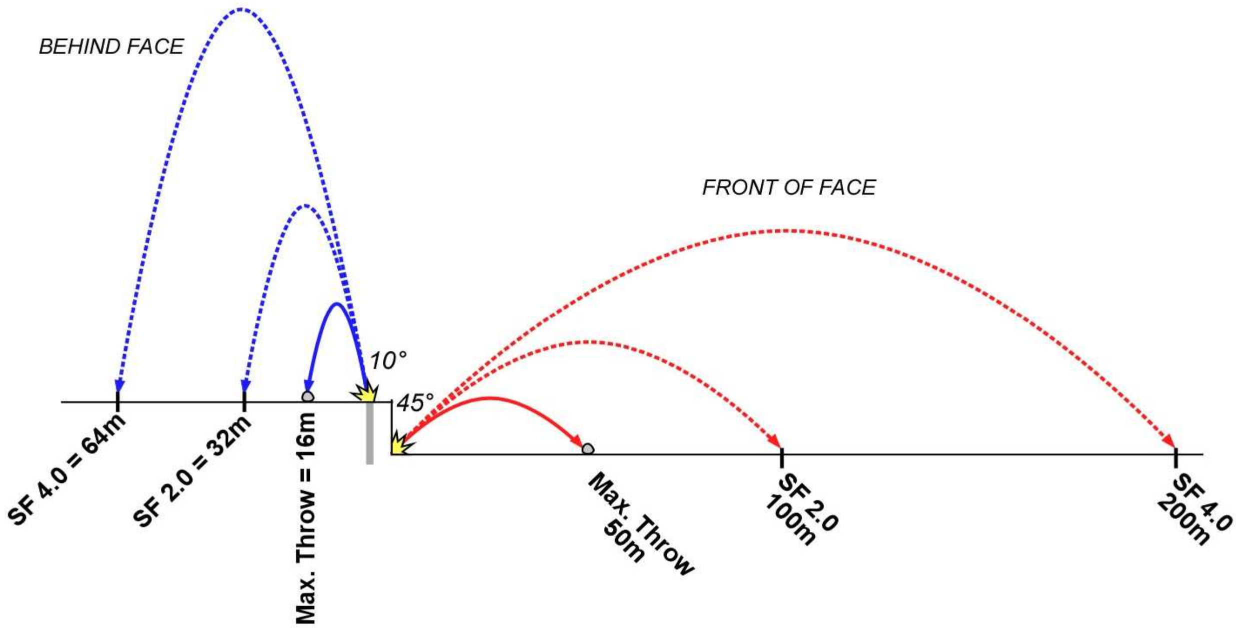


Figure 3b – Flyrock Trajectory Paths, vertical blast holes

8 EFFECT OF METEOROLOGICAL CONDITIONS ON ENVIRONMENTAL BLAST IMPACTS

8.1 METEOROLOGICAL DATA

Meteorological conditions can have a significant effect on airblast overpressure, dust and fume emission.

Control systems that have been developed for use in Hunter Valley open-pit coal mines constitute worlds-best-practice, and Rix's Creek Colliery has strongly supported these developments.

Predictive meteorological data that provides details of temperature and wind velocity at levels of up to 800 metres above the ground is produced by the Hunter Valley Meteorological Sounding Group (HVMSG), a joint venture between Hunter Valley coal mining companies of which Rix's Creek is a founding member. Examples of predictive HVMSG outputs are shown in **Figure 4.**

This meteorological data is used as inputs into models that are used to predict and assess the effect of meteorology on airblast overpressure, dust, and fume emission.

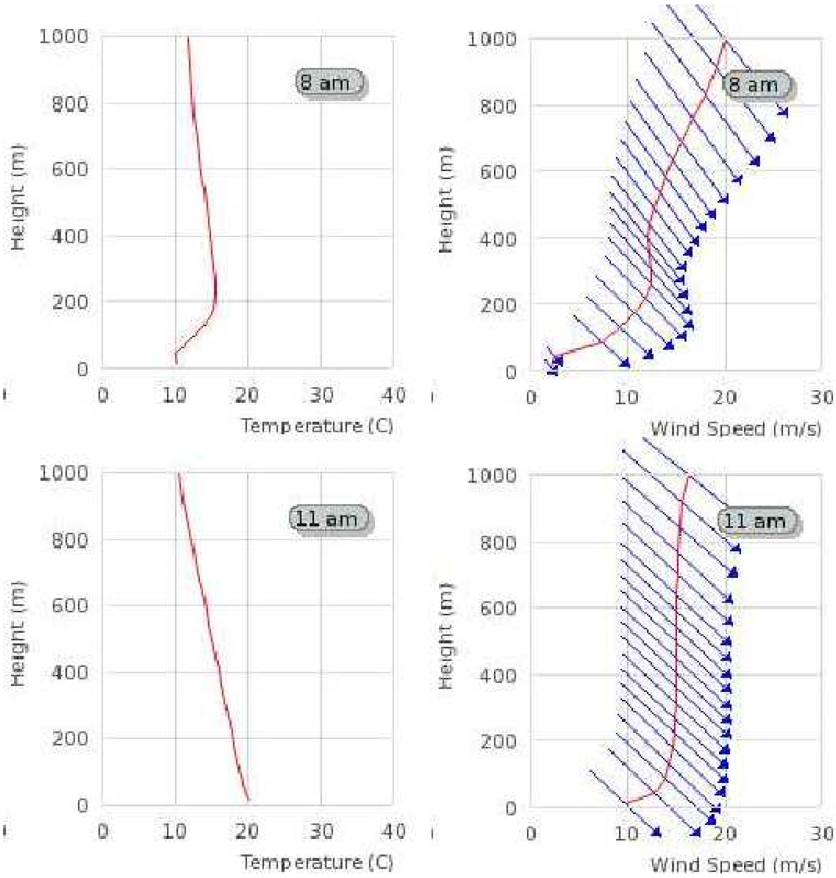


Figure 4 –Predictive HVMSG Data Outputs for 8am and 11am

8.2 AIRBLAST OVERPRESSURE

Rix's Creek (Rix's Creek and Rix's Creek North combined) uses the EnvMet airblast assessment system to predict the effects of meteorology on airblast overpressure. At 7am each morning, predictive outputs are available that give details of any increases in airblast overpressure levels that will result in the area surrounding the mine. An example of these outputs, which are provided at half-hourly intervals, is shown in **Figure 6** below.

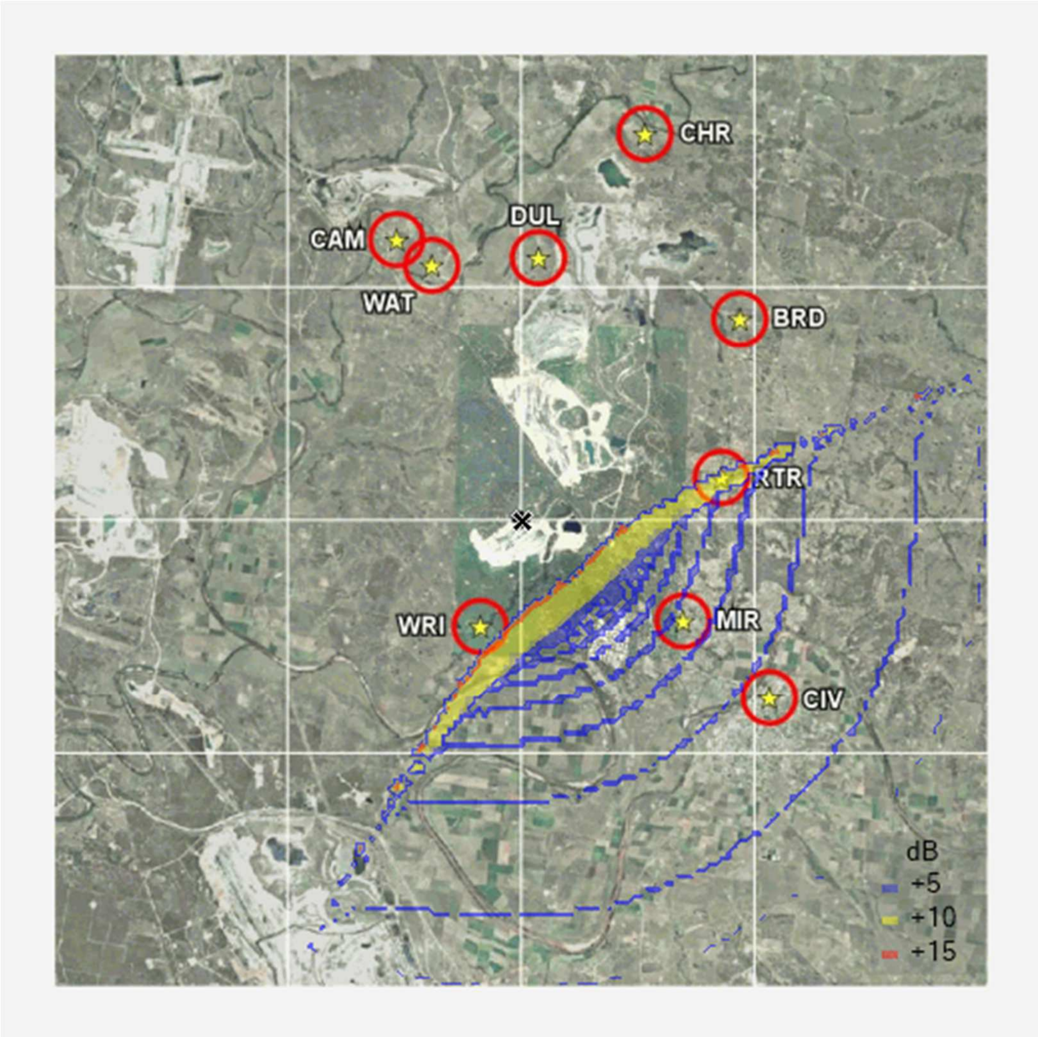


Figure 3 – Increase due to meteorology

The EnvMet system is also used to predict the basic emission levels that will result due to the blast design, as well as providing a prediction of the effect of basic blast emission and meteorological effects. Details of these outputs are shown in **Figures 7 and 8**:

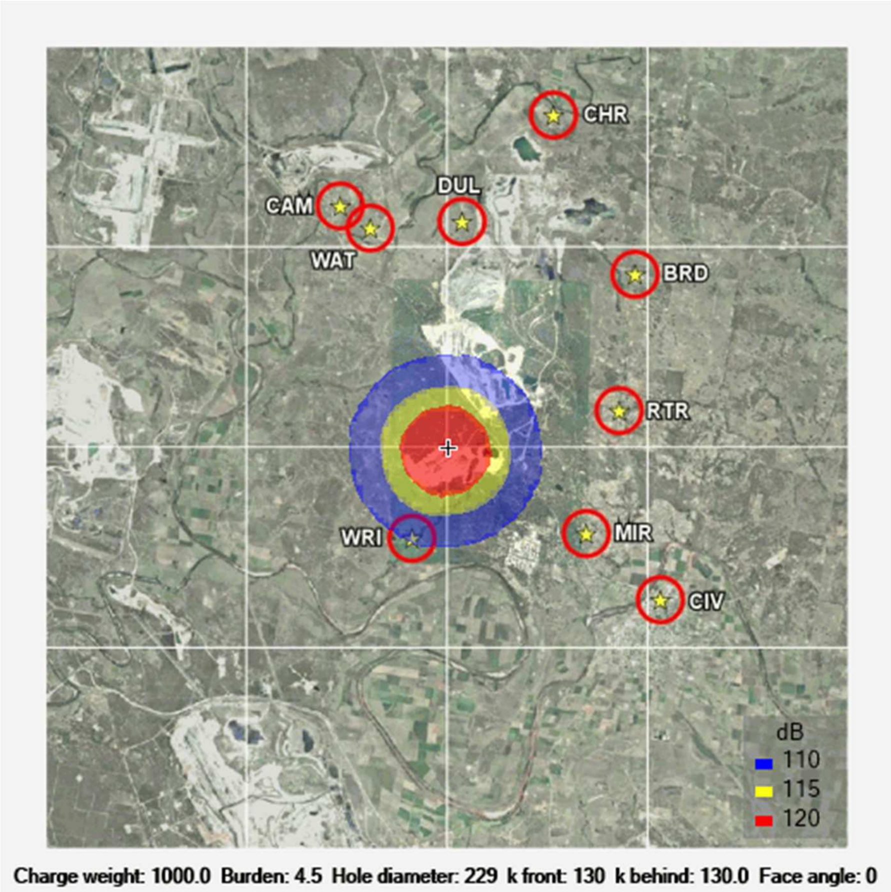


Figure 4 – Basic Emission

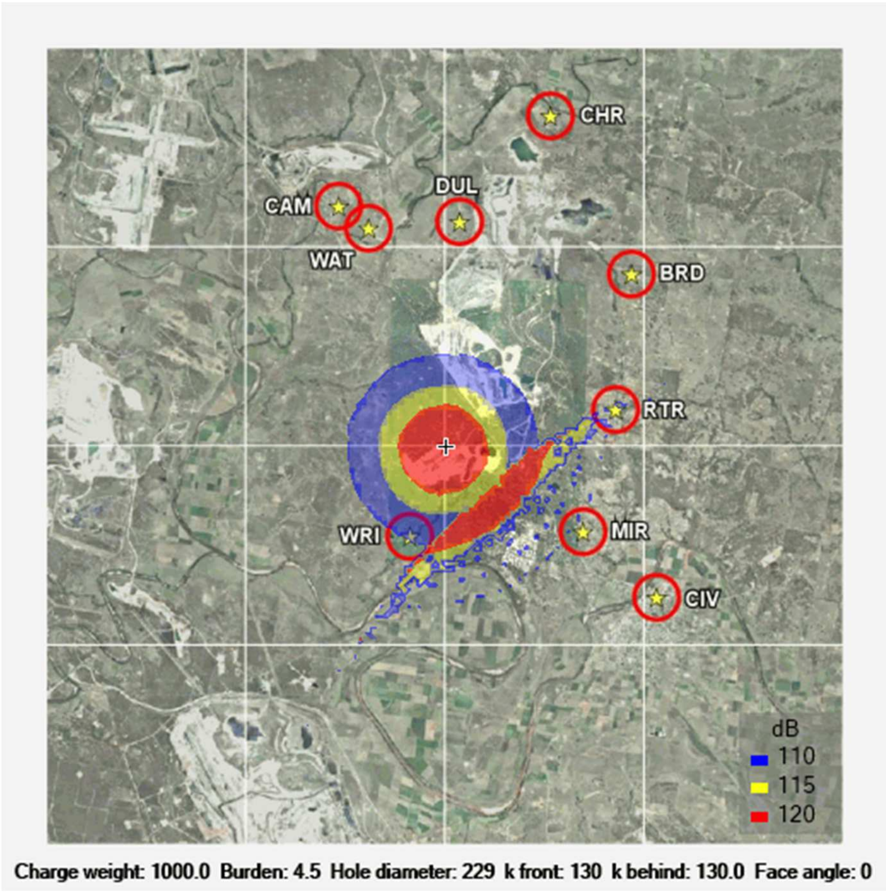


Figure 5 - Combined effect of basic emission and meteorological enhancement

8.3 DUST AND FUME EMISSION

Meteorological conditions strongly influence the control of dust and fume plumes.

Rix's Creek has responded rapidly to the need for an effective plume management system and uses a very effective plume modelling system that was developed by Todoroski Air Sciences. Inputs into the system is information about the size of the plume that is created by the blast, meteorological data provided by the HVMSG which is further refined by the Todoroski system, and detailed topographical information.

8.3.1. Fumes

There are two aspects involved in controlling the effect of fumes resulting from blasting.

These are:

- Limiting the amount of fumes that are emitted from the blast to form a fume plume
- Predicting the movement of the fume plume resulting from a blast, and ensuring that the movement of the plume does not result in fume concentrations that exceed permitted levels at sensitive locations.

8.3.2. Fume Emissions from a Blast

Factors influencing fume emissions resulting from a blast include:

- Explosives specifications
- Confinement
- Ground conditions
- The length of time that the explosives remain in the ground before firing.

It is not possible to control these factors precisely. Even minor variations in the characteristics of the chemicals used to make the explosives may result in an increase in fume emission. The degree of fume emission may also increase as ground conditions, including the type and amount of groundwater, vary.

At Rix's Creek Mine, methods such as minimising the 'sleep' time that explosive charges remain in the ground before firing have been developed.

Although precise prediction is not yet possible, a sufficient degree of correlation between significant factors and the amount of fumes produced has developed at Rix's Creek to permit the possibility of fumes resulting from each blast to be predicted using three categories (low, medium, and high).

8.3.3. Fume Plume Movement

The fume plume management modelling system used at Rix's Creek Mine quantifies the size of the fume plume produced from low/medium/ high emission blasts, and then predicts the movement of the plume.

8.3.4. Blast Dust Control

The system, which is used in conjunction with the fume plume system quantifies the size of the dust plume produced, and then predicts the movement of the plume. Although the amount of dust produced by different blasts will vary, the current system assumes worst case conditions.

8.4 USE OF THE FUME/DUST MODELLING SYSTEM

At 7am each morning predictive outputs are available that give details of the dust and fume plume emissions that will result in the area surrounding the mine. Details of these outputs, which are provided at hourly intervals, are shown in **Figure 9** below.

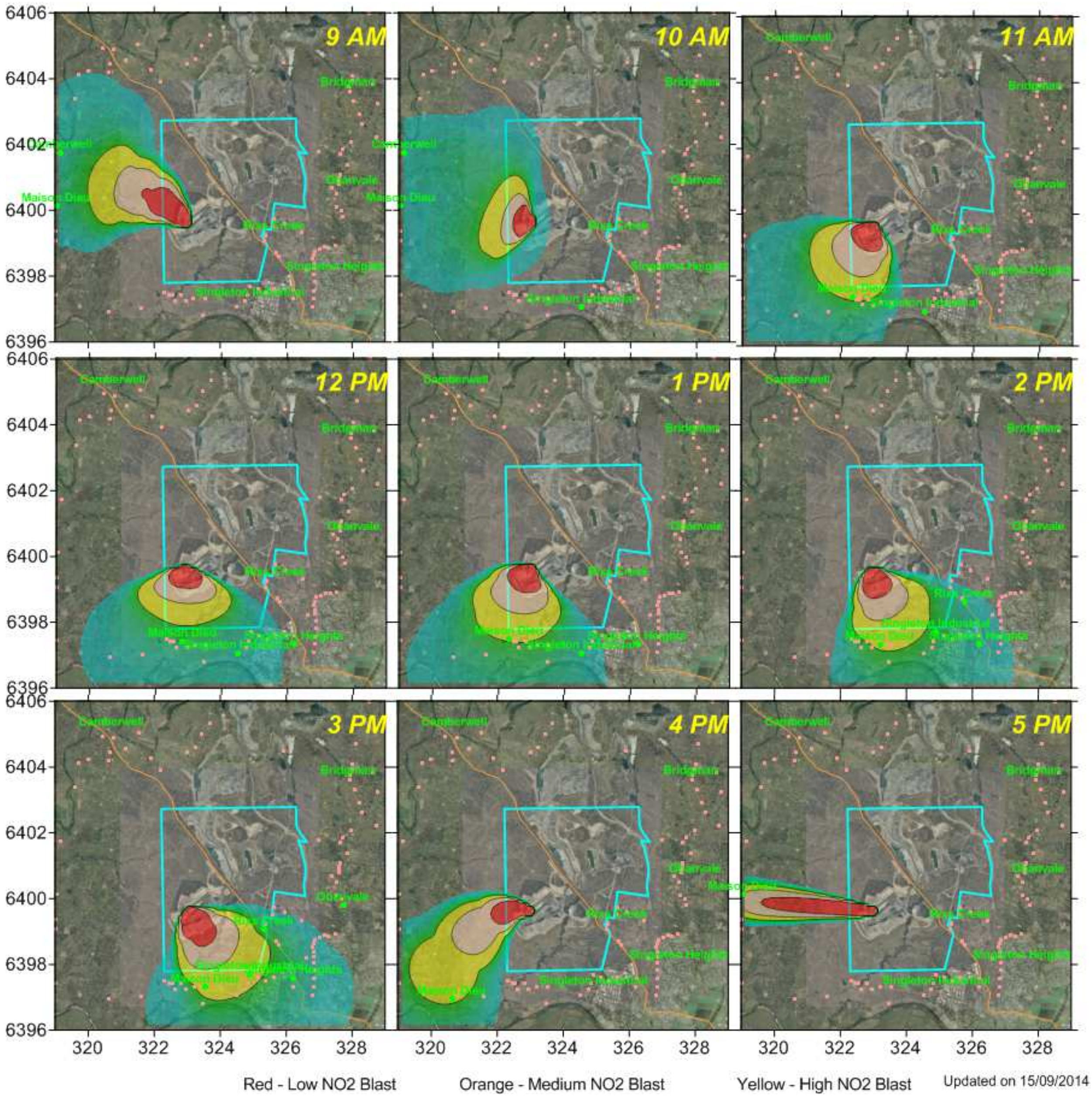


Figure 6 – Fume & Dust Plume Modelling Outputs

Low, medium, and high fume plume emissions are shown in red, pink, and yellow respectively, and a conservative assessment of the maximum dust plume is shown in blue.
Calibration of the dust and fume model was undertaken using App-Tek, model OdaLog Type 7000 gas analysers. Rix's Creek continues to use these gas detectors to monitor for blast gas fumes. This instrumentation allows for continuous refinement of the blasting practices on site.

9 OTHER BLASTING ISSUES

9.1 HIGHWAY STABILITY

The location of the New England Highway in relation to the Continuation Areas is shown in **Figure 11**.

There have been no problems with highway stability in the Singleton area when the underlying rock structure is gently sloping and stable.

Previous mining operations in the Rix's Creek mine north pit area adjacent to the New England Highway from the commencement of mining until 2010 was in stable, gently sloping rock structure. Mining was carried out to within 100 metres of the highway, and the resulting highwall was (and still is) stable.

Most mining in the continuation area adjacent to the New England Highway will be in the same stable rock structure, and there will be no modification to normal blasting practice required to ensure highway stability.

From 2010 – 2014, mining operations in the area adjacent to the New England Highway at the northern end of the north pit were in ground with a steeply sloping rock structure, and modifications to mining practice, including advanced placement of backfill, were required to ensure highway stability.

There is a limited area at the northern end of the western pit in the continuation area where the rock structure will require modifications to mining practice. Further details regarding this are given in the Geotechnical Report.

9.2 HISTORIC COKING OVENS

9.2.1 Review of the Rix's Creek Continuation Project

In 2015, Bloomfield submitted an Environmental Impact Statement (EIS) for the Rix's Creek Continuation of Mining Project (the Project). Terrock Consulting Engineers prepared a blast impact assessment report to accompany the EIS titled "Rix's Creek Pty Ltd. Effects of Blasting in the Continuation Area (Terrock Pty Ltd October 2015). (the EIS blast impact assessment).
In 2018, Bloomfield submitted further information in support of the Revised Response to Submissions which included a review of the EIS blast impact assessment report "Rix's Creek Pty Ltd. Effects of Blasting in the Continuation Area – Revision 2018-2 Effects of Blasting in Current (2018) Proposed Blasting Area). (Terrock Pty Ltd February 2018). (the RRTS revised blast impact assessment).
A recent stage in the approval process for the Project was a review by the Independent Planning Commission of NSW (IPCN). The IPCN review included the following recommendation:

"R7: That the applicant update its Blast Impact Assessment to provide additional monitoring and management measures specifically related to the preservation of the Coke Ovens."

The Revised Blast Impact Assessment report dated February 2018, included a general description of blasting methods which could be used to achieve a ground vibration target and reduce risk of damage to the Coke Ovens. This revised section now provides further specialist assessment and recommendations to eliminate risk of damage, provide additional monitoring and management measures for preservation of the Coke Ovens.

9.2.2 Historical Blasting in Proximity to the Coke Ovens.

Rix's Creek Mine commenced mining operations in 1990. An area immediately adjacent to the coke ovens known as Block 1 and Block 2 was opened in 1991 where blasting was undertaken within 150 metres of the coke ovens from April of that year. (**Figure 10**) Blasting continued until the area was fully mined by September that year. Due to the historical nature and general technology during this time there are no blast records available for the blasting that was conducted during the period.

During the review of potential impacts to the coke ovens, following recommendation by the IPCN, Terrock reviewed an historical report by Australian Blasting Consultants titled "*Rix's Creek Coal Mine Trial Blasting April 1991".* (Trial Report) This report provides early assessment and recommendations of management and measurement strategies for the coke ovens and is included in **Appendix 3.**

A review and update of the previous recommendations within the Australian Blasting Consultants forms the basis of this report and is discussed in Section 9.24 & 9.25

9.2.3 Historical and Recent Condition Assessment Surveys of the Coke Ovens

Throughout the period prior to and post blasting in Blocks 1 and 2, a number of condition assessment surveys have been conducted on the Coke Ovens. A list of the surveys are noted as follows;

- McCarthy.J., Brassil.A., (1992) Assessment of the Heritage Significance of the Rix’s Creek Coke Ovens by the National Trust of Australia. (New South Wales) 1982.
- Lonergan. P., (2007) Rix’s Creek Colliery Coke Ovens Conservation Plan. Cracknell & Lonergan Architects and Heritage Consultants. (Photos take in 1989 and 2006).

The *Rix's Creek Colliery Coke Ovens Conservation Plan* shows photos taken in 1989 prior to open cut mining in the area adjacent to Blocks 1 and 2 which were within 150 metres of the coke ovens. Further photos taken in 2007 show no further deterioration following blasting. Lonergan, 2007, notes in his report that *"the ovens themselves appear to be consistent with the condition report in the McCarthy Study* (1982) and that *"remnant sections of the stone facing... do not appear to be any more deteriorated than is evident in the 1989 photos."* **(Appendix 4)**

From the above reports it is concluded that the blasting undertaken in Blocks 1 and 2 had no detrimental impact on the structure or stability of the coke ovens.

Figure 10 – Location Plan Detailing Location of the Coke Ovens in relation to the Proposed Mining Area.

9.2.4 Blast Vibration Limits

Trial blasting conducted in mining Blocks 1 and 2 in 1991 adopted the blast vibration criteria as set in DA 81/818. (1989 Consent). Vibration limits of 5mm/sec with an allowable exceedance of 5% were conditioned by the State Pollution Control Commission (SPCC) approval as follows;

"Blasting. Condition 15 vii- The Applicant, in respect of the coke ovens structure, shall;

(a) ensure that initial blasting controls are implemented such that a peak particle velocity of 5mm/sec is not received at the coke ovens structure with more than a five (5) percent being exceeded."

The vibration limits as set by the SPCC in 1989 are human response limits for human comfort criteria and are not applicable to structures.

Recent investigations within the Hunter Valley indicate that a higher structure response limit is permissible. Structure response limits take into account the strength of the structure, and conservative civil engineering safety factors. These investigations include Australian Coal Association Research Program (ACARP) Projects specifically related to the assessment of the effects of blasting on structures as follows;

- C9040 – Effect of Blasting on Houses
- C 14057 – Effect of Blasting on Infrastructure.

Assessment of blasting impacts on structures conducted by ACARP, combined with increased site knowledge and blasting technology, has resulted in Terrock proposing an interim PPV limit of 10mm/s on the Coke Ovens. If a higher ground vibration limit is required, further controls such as observation and monitoring of displacement and strain on the nearest ovens will give an indication of whether scientific principles can be used to determine a higher PPV level limit with an appropriate safety factor.

The actual movement of the ground as ground vibration passes can be determined from the wave approximation whereby:

$$Peak\ Displacement = \frac{PPV}{2 \times \pi \times f}$$

The frequency of overburden blasts would be expected in the range of 10-20Hz. The peak surface displacement from a PPV of 10mm/s would in the order of 0.08 – 0.16mm. The whole of the coke oven mound would move as an integral unit with no concentration of strain on any part of the structure.

9.2.5 Blast Vibration Predictions

The general model for the prediction of ground vibration is (Site Law formula);

$$PPV = kv\left(\frac{\sqrt{m}}{D}\right)^{e}$$

Where;
PPV = Peak particle displacement (mm/s)
kv = Site constant
m = Charge mass (kg)
D = Distance (m)
e = Site exponent
A more specific model in common use is;

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

In the 2015 Report '*Effects of Blasting in the Continuation Area*' this model was used with a kv ranging from 254 to 495 for the North Pit blasting. The large range of low values was because of the closest monitoring distance measured were from 2800-3000m. There was no monitoring data available at close distances of 300-600m, which will be necessary to develop a site law to design blasts to the PPV limits proposed.

Blast vibration measurements at the Rix's Creek Open Pit Colliery since 1990 have permitted a range of site constants to be developed for effective blast vibration prediction and control.

The following site specific parameters will be used as blasting operations approach the coke ovens:
Site exponent (b) = -1.6
Site constant (K) = 1500

If we assume a kv of 1500, the charge masses to limit the PPV to 5mm/s and 10mm/s at the coke ovens are;

	Charge Mass (kg)	
Distance (m)	**5mm/s Limit**	**10mm/s Limit**
310	77	184
400	128	305
500	200	476
610	298	709
700	392	935
800	512	1220
1000	800	1905

Historically blasting has been conducted to within 600m of the coke ovens at the Western Pit adjacent to the New England Highway. Typical charge mass used adjacent to the Highway in West Pit was in the order of 600kgs to 800kgs which is theoretically calculated to have subjected the coke oven structures to a level around 10mm/s without causing damage to the ovens.

9.2.6 Measurement and Monitoring Procedures

To measure the impacts associated with blasting in the North Pit on the coke ovens, it is recommended that Rix's Creek Mine will install a series of blast monitors to assess both blast vibrations at ground level and vibration immediately above each group of coke ovens. These series of monitors will assess any potential amplification of the vibration from the ground surface to the top of the coke oven structures which will be used to modify blast design if required.

It is recommended that vibration monitoring of the coke ovens will be combined with post blast visual inspections and annual dilapidation assessments during mining of the North Pit Void. Results of post blast inspections and annual surveys will provide further information and feedback to modify blast designs if required.

The monitors will be installed using the method specified in the Standards Australia Explosive Code AS2187.2-2006, and will have specifications that conform to that code.

9.3 BLASTING IMPACT ON EXTERNALLY OWNED/MANAGED INFRASTRUCTURE

Externally owned/managed infrastructure that could be considered as being possibly impacted by blasting in the continuation area are shown in **Figure 11** and includes:

- New England Highway
  - pavement and culverts
  - bridge over Rix's Creek
  - haul road bridge over the highway
  - cut and cover tunnel under the highway
  - A second proposed cut and cover tunnel
- Buried Fibre Optic Cable beside the highway
- Main Northern Rail Line
- 66Kv Ausgrid power line from Maison Dieu Industrial area traversing Rix's Creek Lane (concrete and timber poles) to the Rix's Creek Mine infrastructure
- A Dam certified by the Dam Safety Committed in the Rix's Creek – Northern Operations mine area.
- Other uncertified dams on the Rix's Creek – Southern Operations and Rix's Creek – Norther Operations mine areas.

The infrastructure associated with the New England Highway has been assessed and approved by RMS as part of the approval process.

The owner/managers of the fibre optic cable are aware of the project having been involved with design and installation of the cut and cover tunnels.

The Main Northern Railway Line is located over 1.3km from the nearest blasting in the North Pit of the Continuation Area. This affords sufficient separation that observance of the appropriate procedures and protocols of the Rail Track Authority for blasting closer than 600m is not necessary.

Ausgrid power lines - Ausgrid routinely applies a limit of 100mm/s on their poles. There is sufficient separation that compliance with their limit can be readily achieved by environmental blast design.

The Certified Possum Skin Dam in the Rix's Creek – Northern Operations property is over 4.0 km from the continuation area blasting so controlling ground vibration to the Dam Safety Committee limit is not an issue.

There are no specified vibration limits on the other dams not under the Dam Safety Committee regulation. The inspection regimes will continue to ascertain any change of condition.

9.4 BLASTING IMPACT ON OTHER MINES

The nearest mine to the continuation area is the Rix's Creek – Northern Operations mine which is owned and operated by Bloomfield.

The main infrastructure of the Rix's Creek – Northern Operations mine is over 3km from the nearest continuation area blasting and the predicted peak ground vibration levels are less than 0.3mm/s, which is at human threshold perception levels with no potential structural issues.

Blasting in the continuation area is a progression of blasting that has been conducted over many years and will impose no additional impacts on the Rix's Creek – Northern Operations mine compared to what has previously happened.

9.5 BLASTING IMPACTS ON LIVESTOCK

Blasting in the continuation areas is not expected to have any impact on live stock because, even in a new mine, the general experience is that domestic animals rapidly become acclimatised to blasting.

At the opening of the Bengalla open-cut coal mine near Muswellbrook, the behaviour of thoroughbred horses to the initial blasts was observed specifically because of concern of the stud owners. The horses were observed to look up momentarily after the blasts and then continued grazing. At the same mine, two commercial dairies (Wantana and Lumeah Dairies) operating on river flats of mine owned land reported that blasting had no adverse impacts on its cows which were exposed to blast vibration levels up to at least 10mm/s without detriment to milk production or animal welfare.

The continuation area is not a new mine and blasting is a progression of blasting that has occurred in the general area from the two adjoining mines over many years. The only possible impact of blasting would be on livestock brought into the area from a non mining area. The experience is that they will rapidly become accustomed once they perceive they are not threatened.

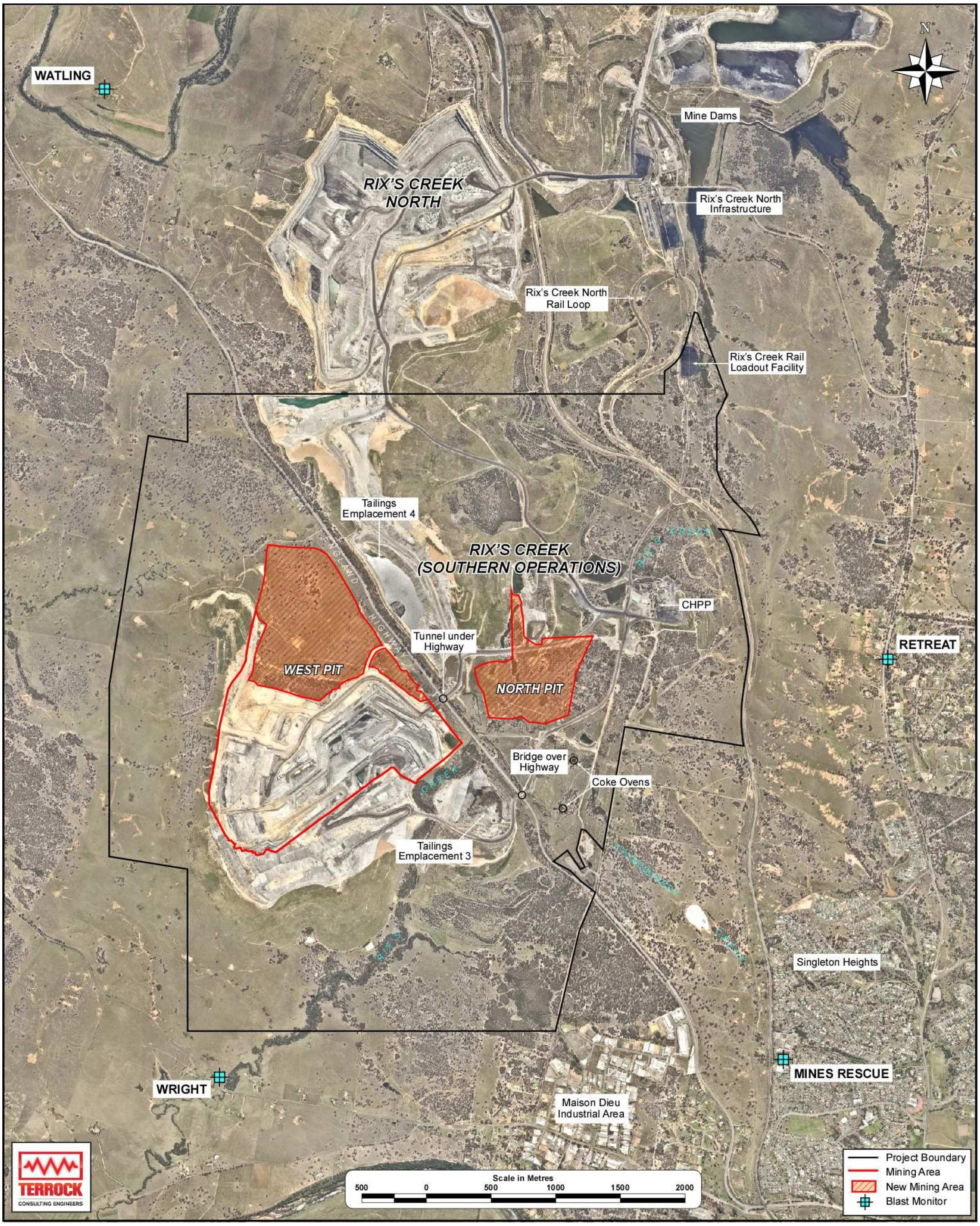


Figure 11 – Location Plan With Nearby Infrastructure

10 CONCLUDING COMMENTS

- The airblast overpressure and ground vibration levels from current blasting operations comply with regulatory limits at all sensitive sites.

- Both ground vibration and airblast overpressure levels from future blasts in the West Pit and North Pit of the continuation area will be below regulatory limits.

- Restrictions to blasting within the North Pit to ensure minimal impact to the coke oven structures may further reduce the scale of blasting operations which will be reflected at Retreat and Mines Rescue by lower ground vibration and airblast overpressure than predicted.

- Dust and fumes are limited by the practices described in this report and further detailed in the Blast Management Plan.

- Mining in the area adjacent to the New England Highway will be predominantly in stable ground. Previous experience when blasting in stable ground in the northern pit has shown that no modification to normal blasting practice to ensure highway stability. There is a limited area at the northern end of the western pit in the continuation area where the rock structure will require modifications to blasting practice, and these will be applied as required.

- Flyrock can be readily controlled by appropriate blast design and loading practice, and if the recommended exclusion zones are observed, will not present a danger to personnel within the mine lease or outside the extraction area.

- Traffic control on the New England Highway will resume when blasting approaches closer than 500m to the Highway.

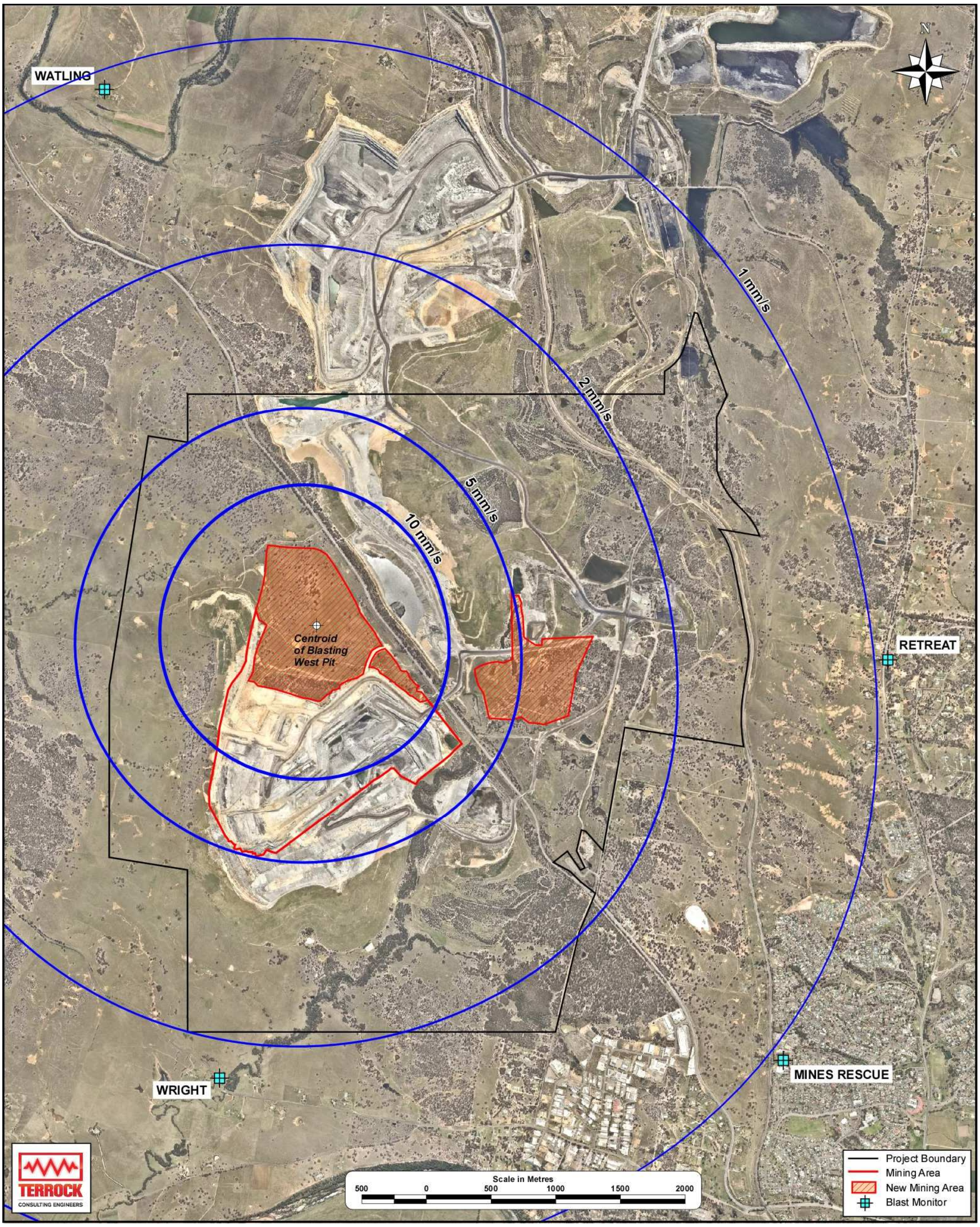
- Blasting in the continuation area will have no significant impact on nearby infrastructure.

- Blasting will continue to have no impact on livestock.

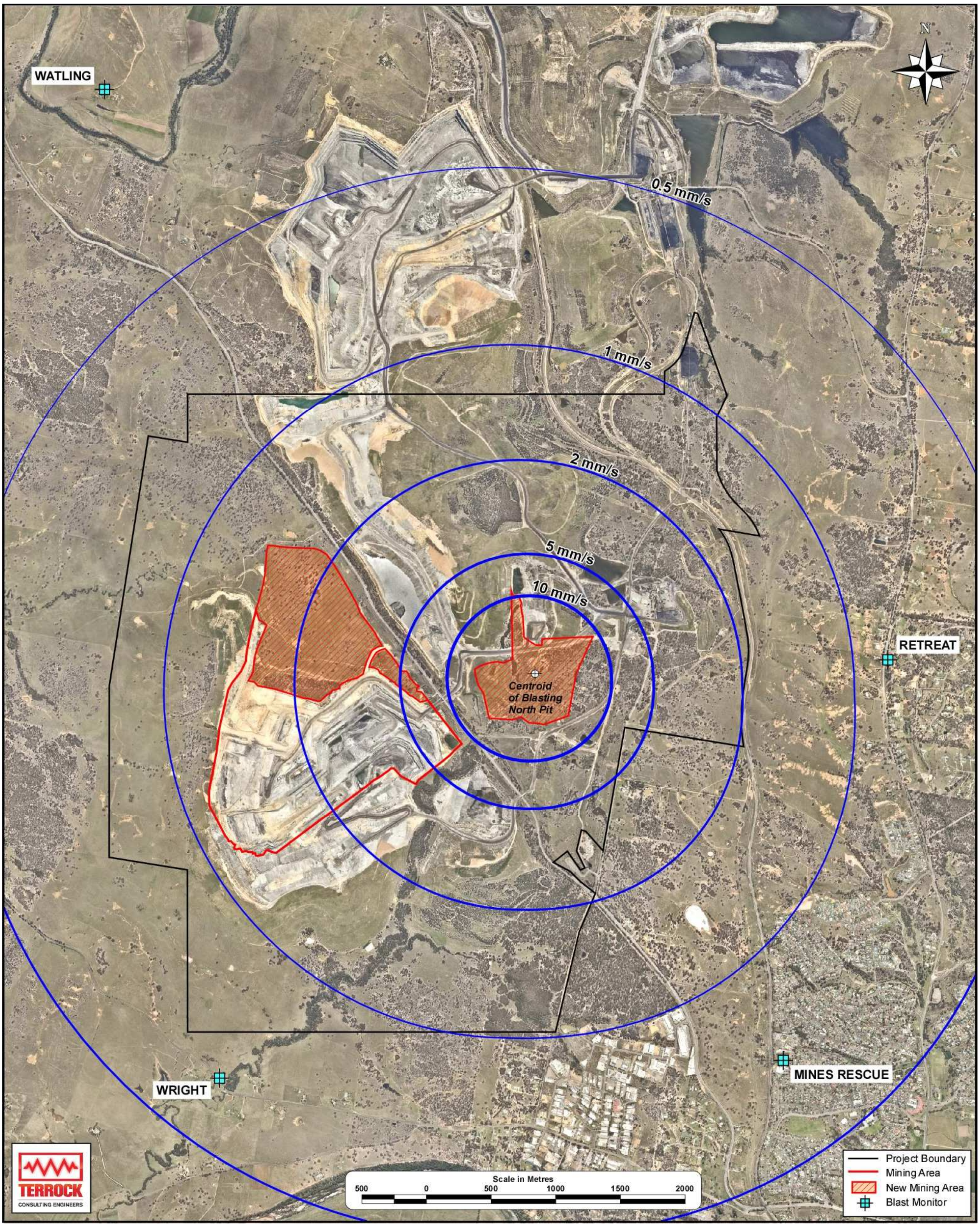
Alan B Richards
28th February 2018.

APPENDICES

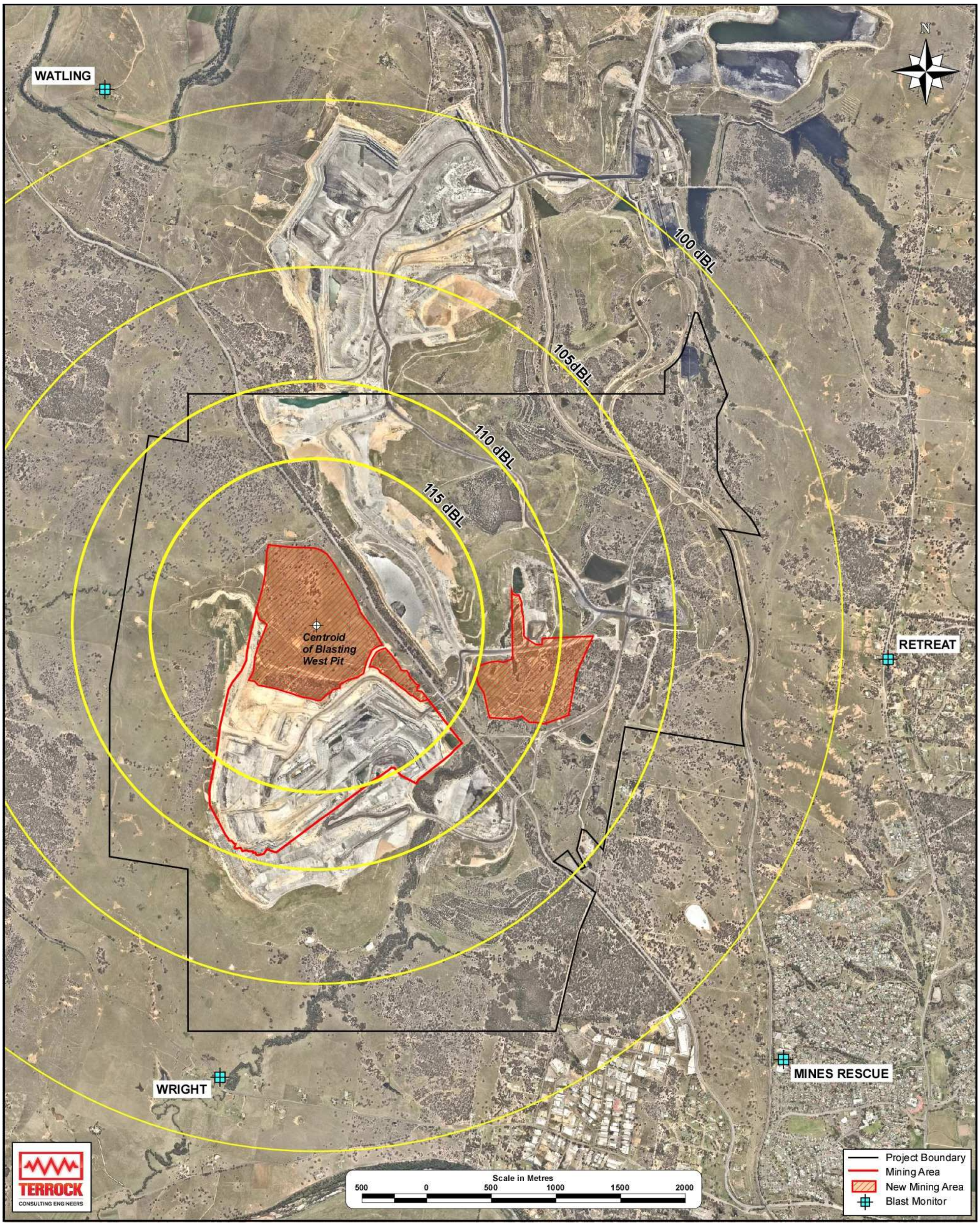
APPENDIX 1A - GROUND VIBRATION CONTOUR ASSESSMENT – WEST PIT



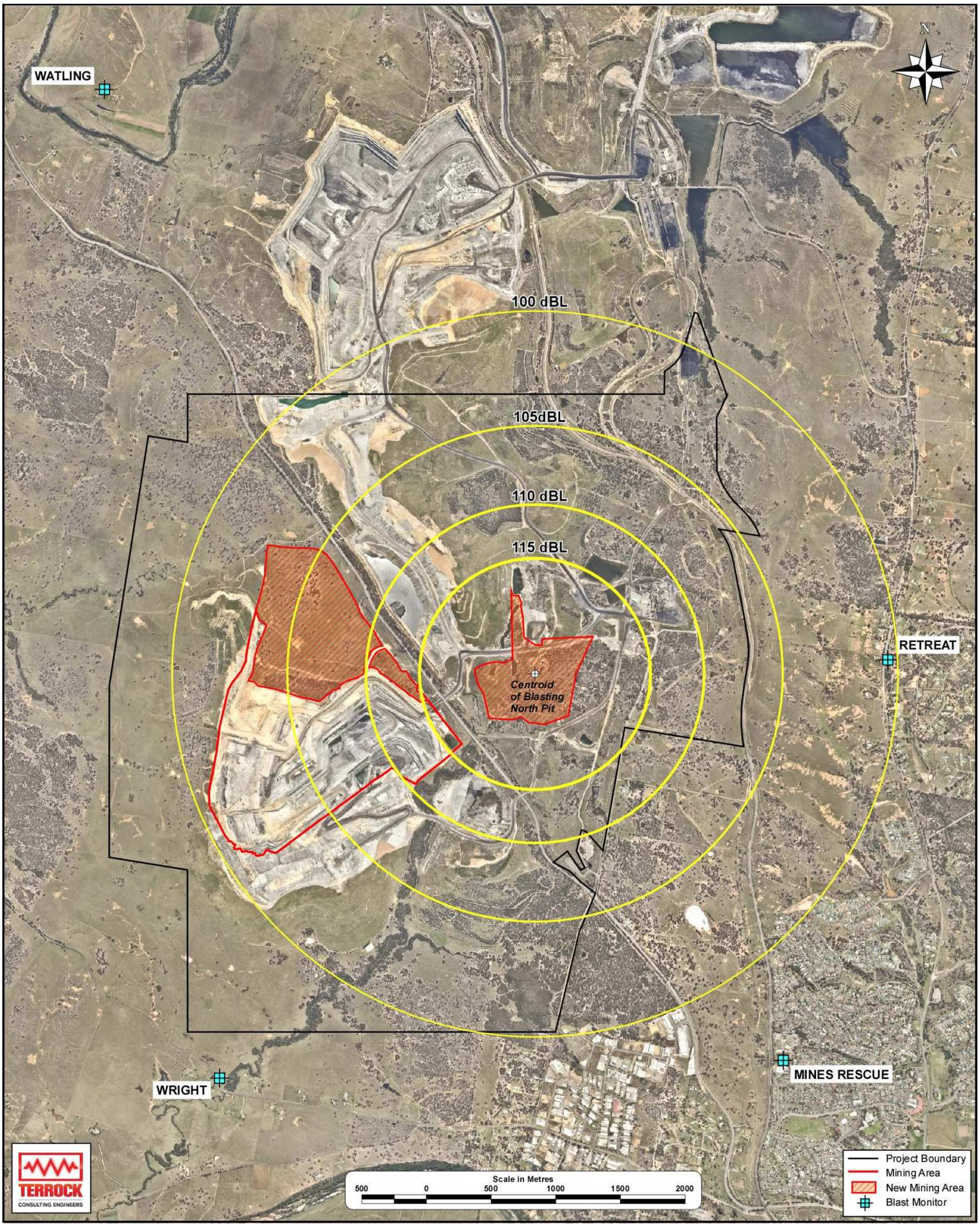
APPENDIX 1B - GROUND VIBRATION CONTOUR ASSESSMENT – NORTH PIT



APPENDIX 2A - AIRBLAST CONTOUR ASSESSMENT – WEST PIT



APPENDIX 2B - AIRBLAST CONTOUR ASSESSMENT – NORTH PIT



APPENDIX 3- RIX'S CREEK COAL MINE, TRIAL BLASTING

Australian Blasting Consultants, (1991) Rix's Creek Coal Mine Trial Blasting, Report Prepared for Bloomfield Collieries Pty Limited. April 1991. Ref 9104 Rix's Creek.

APPENDIX 4- RIX'S CREEK COLLIERY CONSERVATION PLAN

Lonergan. P., (2007) Rix's Creek Colliery Coke Ovens Conservation Plan. Cracknell & Lonergan Architects and Heritage Consultants. (Photos take in 1989 and 2006).

McCarthy.J., Brassil.A., (1992) Assessment of the Heritage Significance of the Rix's Creek Coke Ovens by the National Trust of Australia. (New South Wales) 1982.