Blast Management & Consulting

Report:

Environmental Impact Assessment:
Ground Vibration and Air Blast Study
Butsanani Energy Investment Holdings
Proposed Rietvlei Open Cast Coal Mining Project
Dated 25 April 2014

Ref No: WSP~Rietvlei~EIAReport140425V00.docx

Quality Service on Time

Date: 2014/04/25

Signed:
Name: JD Zeeman

CK 97 31139 / 23
Cell: 082 854 2725
Tel: +27 (0)12 345 1445 Fax: +27 (0)12 345 1443
PO Box 61538 Pierre van Ryneveld Centurion 0045
61 Sovereign Drive Route 21 Corporate Park Irene

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List of Acronyms used in this Report

Air Pressure Pulse	APP
Blasted Tonnage	T
Distance (m)	D
Duration	D
East	E
Explosive Mass (kg)	E
Explosives (Trinitrotoluene)	TNT
Frequency	Freq.
Gas Release Pulse	GRP
Interested and Affected Parties	I&AP
Magnitude/Severity	M/S
North	N
North East	NE
North West	NW
Noxious Fumes	NOx's
Peak Particle Velocity	PPV
Points of Interest	POI
Probability	P
Rock Pressure Pulse	RPP
Scale	S
Site Constant	a and b
South	S
South East	SE
South West	SW
United States Bureau of Mine	USBM
West	W
With Mitigation Measures	WM
Without Mitigation Measures	WOM

List of Units used in this Report

Air Blast	dB
Air Blast Limit	dBL
Ammonium nitrate/fuel oil	ANFO
Blast Management & Consulting	BM&C
Burden (m)	B
Centimetre	cm
Charge Energy	MJ
Charge Height	M
Charge mass / m (kg/m)	Mc

Coordinates (South African)	WGS 84
Cup Density	Gr/cm^3
Drill hole angle	θ
East	E
Energy Factor	MJ/m^3 or MJ/t
Environmental Impact Assessment	EIA
Factor value	k
Frequency	Hz
Gravitational constant	g
Ground Vibration	mm/s
Kilometre	km
kPa	kilopascal
Latitude/Longitude Hours/degrees/minutes/seconds	Lat/Lon hddd°mm'ss.s"
Mass	kg
Maximum Throw (m)	L
Meter	m
Milliseconds	ms
Nitrogen Dioxide	NO_2
Nitrogen Monoxide	NO
Nitrogen Oxide	NOx
Parts per million	ppm
Pascal	Pa
Peak Acceleration	mm/s^2
Peak Displacement	mm
Peak Particle Velocity	mm/s
Percentage	%
Pounds per square inch	psi
Powder Factor	kg/m^3
Powder factor	kg/m^3 or kg/t
Scaled Burden ($m^{3/2}kg^{-1/2}$)	Bs
South	S
Stemming height (m)	SH
Vector Sum Peak Particle Velocity	mm/s
Volume	m^3

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Declaration of independance

JD Zeeman, owner and author of Blast Management & Consulting is an independent blast consultant to the mining and construction blasting industry. All employees' of Blast Management & Consulting works as independent consultants. Blast Management & Consulting CC was registered in July 1997 as an independent blast consulting company. Main areas of service delivery are concentrated on the effect of blasting operations for the mining and construction environment and can be divided into the following, Pre- blast consultation, Insitu monitoring, Post blast monitoring and Specialized projects.

Blast Management & Consulting operates from the following premises:

61 Sovereign Drive
Route 21 Corporate Park
Irene
South Africa

Curriculum Vitae for JD Zeeman:

Jan 1983 - Jan 1990: Joined Permanent Force at the SA Ammunition Core.

Jul 1992 - Des 1995: Worked at AECI Explosives Ltd.

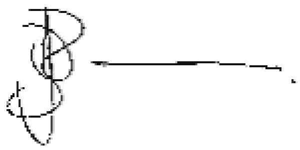
Des 1995 – June 1997: Due to the restructuring of Technical Department I was retrenched but fortunately could take up appointment with AECI Explosives Ltd.'s Pumpable Emulsion explosives group for underground applications. Giving technical support to Underground Bulk Systems Technology business unit and project management on new products.

June 1997 – now Start of company: BLAST MANAGEMENT & CONSULTING

Obtained the following Qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1990 - 1992	BA Degree, University Of Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate: Damelin College
2000	Advanced Certificate in Blasting, Technikon SA

Blast Management & Consulting has been active in the mining industry since 1997 and work has been on various levels for all the major mining companies in South Africa. BM&C is the authorised calibrator for Instantel Inc. seismographs in Sub-Sahara Africa.



Signed: JD Zeeman

Executive Summary

Blast Management & Consulting (BM&C) was contracted as part of Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed new opencast mining operation. Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report concentrates on the ground vibration and air blast intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

Rietvlei Mining Company (Pty) Ltd (RMC) intends establishing and operating an opencast coal mine, referred to as the Rietvlei opencast coal mine (Proposed Project), on the following farm portions:

- Remaining Portion of Rietvlei 397 JS
- Portion 1 of Rietvlei 397 JS

The RMC is a joint venture between Butsanani Energy Investment Holdings (Butsanani) and Emalangeni (Pty) Ltd. Butsanani is in turn a joint venture between Vunani Mining, Anglo American Thermal Coal Division and Anglo Zimele Empowerment Initiative Ltd. The mine will be situated to the south east of the R555 road, and located within the vicinity of Middelburg, within the Steve Tshwete Local municipality. The mine area will extend over 2 225.30ha, with the pit covering approximately 800ha.

The proposed mining area lies within a farming area within the larger Witbank Coalfield and is bordered by private properties on all sides. Opencast operation utilising conventional truck and shovel mining methods is the proposed mining method. Mining will progress from box cuts first to the north and then to the south.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3 500m at least and in some cases further from the mining area considered. The range of structures expected is typical farming community with structures that range from well build to informal building style. The project area consists mainly of one opencast pit area.

The project area has possibility of presence of people and possibly farm animals at close distances to the operations. The location of structures around the pit areas are such that the charge evaluated showed possible influences due to ground vibration, air blast and fly rock.

Ground vibration mitigation will be required for pit area. Four points of interest were identified that could possibly be influenced and require mitigation on drilling and blasting operations. One specific problem identified is the location of the road that is routed directly through the project area. Apart from ground vibration restrictions, the road will require a closure period during blasting times

covering at least 500m from the blast being done. Road closures will require careful planning and the required authorisations. The railway line is also close to the pit on the southern side. Specific care with regards to ground vibration and fly rock will be required.

Air blast levels expected is less of a concern. Air blast levels calculated showed specific damage concerns only at the nearest structures for each pit. Structures within 250m from any of the pit areas boundary showed levels greater than allowed. Up to a distance of at least 1 000m it is expected that levels will be such that complaints may be raised due to airt blast. Mitigation of ground vibration will also contribute to mitigation of air blast. Stemming control will be needed to maintain levels within acceptable norms. Stemming control for air blast will also contribute to control on fly rock. Complaints from air blast are normally based on the actual effects that are experienced due to rattling of roofs, windows, doors etc. These effects could startle people and raise concern of possible damage.

This concludes this investigation for the Rietvlei Open Cast Coal Mining Project. It will be possible to operate this mine in a safe and effective manner provided attention is given to the areas of concern and recommendations as indicated.

1 Introduction

The Proposed Rietvlei Opencast Coal Mine Project is located approximately 50km northeast of the town of Emalahleni and 22km northeast of Middelburg within the Steve Tshwete Local Municipality of the Nkangala District Municipality, in the Mpumalanga Province. It is linked to Middelburg by the R555. The proposed mining area lies within the farm portions: Remaining Portion of Rietvlei 397 JS and Portion 1 of Rietvlei 397 JS and is bordered by private properties on all sides. The Proposed Project is located at geographic coordinates 25°40'22.0"S, 29°38'26.5"E.

The majority of the pre-mining land use is utilized for forestry (Eucalyptus trees) and cultivation (soybeans). Some mining activity is evident along the railway line (to the east of the site), the R555 (to the west and north-east of the site) and the R104 (to the south-west of the site). The Vuna Colliery lies less than 2.5km east of the proposed site. This mining is predominantly opencast coal mining similar to that proposed for the site. Other industrial land uses within the study area include railway lines and power lines.

Blast Management & Consulting (BM&C) was contracted as part of Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed new opencast mining operation. Ground vibration, air blast, fly rock and fumes are some of the aspects that result from blasting operations. This study will review possible influences that blasting may have on the surrounding area in respect of these aspects. The report concentrates on the ground vibration and air blast and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

2 Objectives

The objective of this document is outlining the expected environmental effects that blasting operations could have on the surrounding environment and the proposal of specific mitigation measures that will be required. This study investigates the related influences of expected ground vibration, air blast, fly rock, and noxious fumes. These effects are investigated in relation to the surroundings of the blast site and possible influence on the neighbouring houses and owners or occupants.

The objectives are investigated taking specific protocols into consideration. The protocols applied in this document are based on the author's experience, guidelines from literature research, client requirements and general indicators from the various acts of South Africa. There is no direct reference in the following acts with regards to requirements and limits on the effect of ground vibration and air blast specifically and some of the aspects addressed in this report. The acts consulted are: National Environmental Management Act No. 107 of 1998, Mine Health and Safety Act No. 29 of 1996, Mineral and Petroleum Resources Development Act No. 28 of 2002.

The guidelines and safe blasting criteria are according international accepted standards and specific applied in this document is the United States Bureau of Mines (USBM) criteria for safe blasting for ground vibration and recommendations on air blast. There are no specific South African standard and the USBM is well accepted as standard for South Africa.

However it is sure that the protocols and objectives will fall within the broader spectrum as required by the various acts.

3 Scope of Blast Impact Study

The scope of the study is determined by the terms of reference to achieve the objectives. The terms of reference can be summarized according to the following steps taken as part of the EIA study with regards specifically to ground vibration and air blast due to blasting operations.

- Background information of the proposed site
- Structure Profile
- Mining operations and Blasting Operation Requirements
- Effects of blasting operations:
  - Ground vibration
  - Air blast
  - Fly rock
  - Noxious fumes
- Site specific evaluation blasting effects for each area in relation to the points of interest identified
- Risk Assessment
- Mitigations
- Recommendations
- Conclusion

4 Study Area

The Proposed Rietvlei Opencast Coal Mine Project is located approximately 50km northeast of the town of Emalahleni and 22km northeast of Middelburg within the Steve Tshwete Local Municipality of the Nkangala District Municipality, in the Mpumalanga Province at geographic coordinates 25°40'22.0"S, 29°38'26.5"E. Figure 1 shows a geographical locality plan of the proposed project area. Figure 2 shows view of the proposed mining area.

Figure 1: Locality of the project area

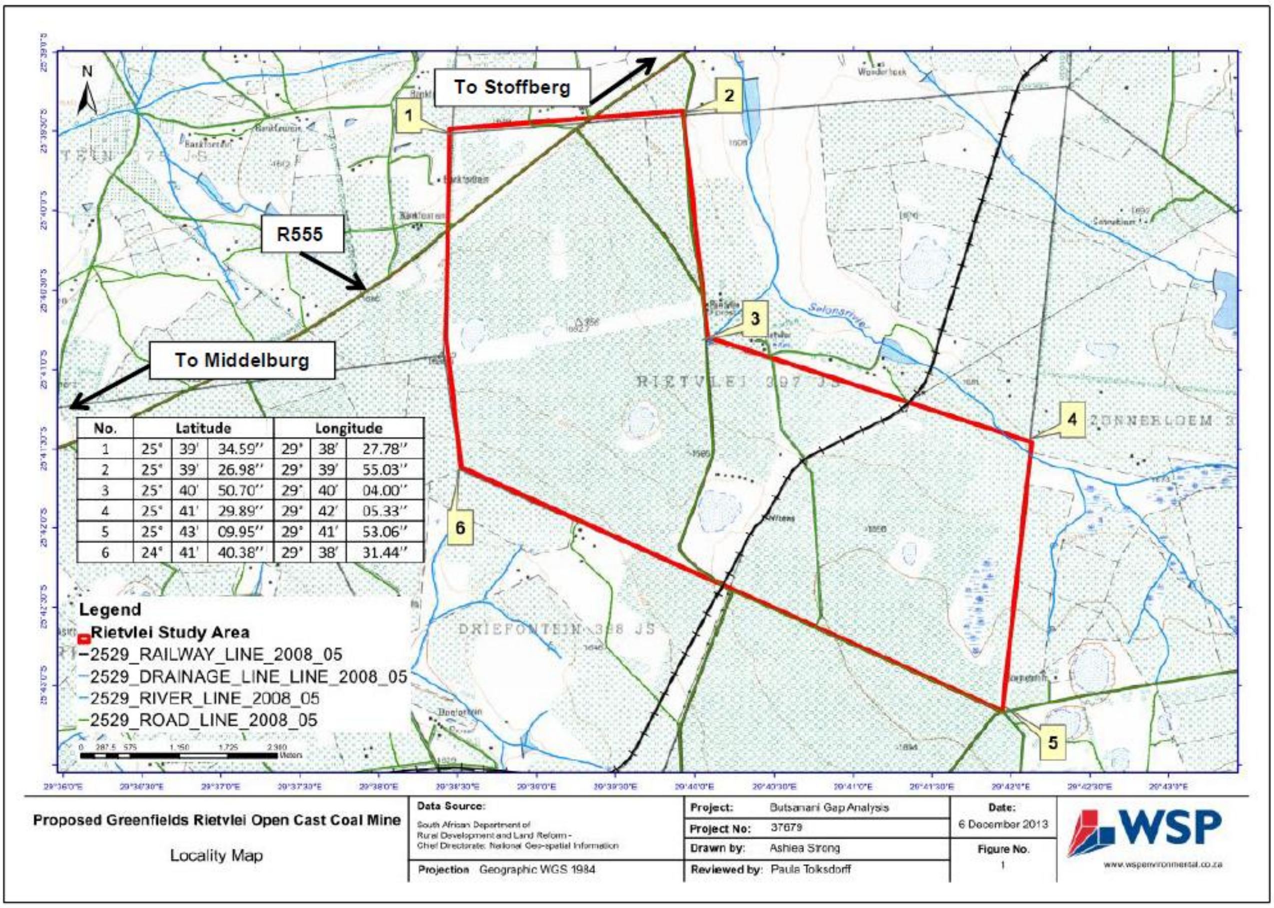


Figure 2: Proposed mining area layout

5 Methodology

The detailed plan of study consists of the following sections.

- Site visit: Intention to understand location of the site and its surroundings,
- Site Structure Profile: Identifying all surface structures / installations that are found with the 3500m possible influence area. A list of POI's are created that will be used for evaluation.
- Site evaluation: This consists of evaluation of the mining operations and the possible influences from blasting operations. The methodology consists of modelling the expected impact based on expected drilling and blasting information for the project. Various accepted mathematical equations are applied to determine the attenuation of ground vibration, air blast and fly rock. These values are then calculated over distance investigated from site and shown as amplitude level contours. Overlay of these contours with the location of the various receptors then give indication of the possible impact and expected result of potential impact. Evaluation of each receptor according to the predicted levels will then give indication of possible mitigation measures to be done or not. The possible environmental or social impacts are then addressed in the detailed EIA phase investigation.
- Reporting: All data is prepared in a single report and provided for review.
- Presentation: Outcome of investigation can then be presented firstly to client and secondly to the public (I&AP) where necessary.

6 Assumptions and Limitations

The project is at a stage where certain assumptions and limitations are applicable. There is at this stage no definite blast design for blasting operations. Blast designs forms the baseline for determining the possible influences from blasting operations. Geological information from the project was used to derive possible drilling and blasting information.
The following drilling and blasting operations was then applied.

6.1 Mining and Blasting Operations

The mining method is expected to be conventional opencast truck and shovel. Limited mining operation detail was defined at time of report and a typical drilling and blasting operation is expected. Typical blast design is required in order to determine expected outcomes from blast operations. The expected outcomes define expected ground vibration, air blast and fly rock influences and levels. The technical information for designs used was prepared from data provided and indicated in Table 1 below.

Table 1: Information on blast designs used

Technical Aspect	Coal	Overburden
B/H Diameter (mm)	115	165
Explosive Density (g/cm^3)	1.15	1.15
Burden (m)	4	5
Spacing (m)	4	5
Bench Height (m)	2.63	15
Min Depth (m)	2.63	15
Average Depth (m)	2.63	15
Linear Charge Mass (kg)	11.94	24.59
P/F Blast hole (kg/m^3)	0.18	0.71
Stemming Length (m)	2.0	4.13
Column Length (incl. Sub drill.) (m)	0.6	10.9
Explosives Per B/H (incl. Sub drill) (kg)	7.5	267
Include Sub Drill (Yes/No)	no	No
Sub-drill (m)	0.00	0.00

6.2 Effects of blasting operations

Blasting operations have effects on their surroundings. These effects can manifest in the form of ground vibration, air blast, fumes, fly rock etc. The application of explosives breaking rock will always have a positive and negative manifestation of different energies. It is the effects that have negative outcome that we concentrate on and that will need to be managed. The following sections address the reason, prediction, modelling and control on aspects like ground vibration, air blast, fly rock and fumes.

6.2.1 Ground vibration

Explosives are used to break rock through the shock waves and gasses yielded from the explosion. Ground vibration is a natural result from blasting activities. The far field vibrations are inevitable, but un-desirable by-products of blasting operations. The shock wave energy that travels beyond the zone of rock breakage is wasted and could cause damage and annoyance. The level or intensity of these far field vibrations is however dependant on various factors. Some of these factors can be controlled to yield desired levels of ground vibration and still produce enough rock breakage energy.

Factors influencing ground vibration are the charge mass per delay, distance from the blast, the delay period and the geometry of the blast. These factors are controlled by planned design and proper blast preparation.

Firstly, the larger the charge mass per delay - not the total mass of the blast - the greater the vibration energy yielded. Blasts are timed to produce effective relief and rock movement for successful breakage of the rock. A certain quantity of holes will detonate within the same time frame or delay and it is the maximum total explosive mass per such delay that will have the greatest influence. All calculations are based on the maximum charge detonating on a specific delay.

Second is the distance between the blast and the point of interest / concern. Ground vibrations attenuate over distance at a rate determined by the mass per delay, timing and geology. Each geological interface a shock wave encounters will reduce the vibration energy due to reflections of the shock wave. Closer to the blast will yield high levels and further from the blast will yield lower levels.

Thirdly the geology of the blast medium and surroundings has influences as well. High density materials have high shock wave transferability where low density materials have low transferability of the shock waves. Solid rock i.e. norite will yield higher levels of ground vibration than sand for the same distance and charge mass. The precise geology in the path of a shock wave cannot be observed easily, but can be tested for if necessary in typical signature trace studies - which are discussed shortly below.

6.2.1.1.1 **Ground Vibration Prediction**

When predicting ground vibration and possible decay, a standard accepted mathematical process of scaled distance is used. The equation applied (Equation 1) uses the charge mass and distance with two site constants. The site constants are specific to a site where blasting is to be done. In new opencast operations a process of testing for the constants is normally done using a signature trace study in order to predict ground vibrations accurately and safely. The utilization of the scaled distance prediction formula is standard practice. The analysis of the data will also give an indication of frequency decay over distance.

Equation 1:

$$PPV = a\left(\frac{D}{\sqrt{E}}\right)^{-b}$$

Where:

PPV = Predicted ground vibration (mm/s)
a = Site constant
b = Site constant
D = Distance (m)
E = Explosive Mass (kg)

Applicable and accepted factors a&b for new operations is as follows:
Factors:

a = 1143
b = -1.65

Utilizing the abovementioned equation and the given factors, allowable levels for specific limits and expected ground vibration levels can then be calculated for various distances.

Review of the type of structures that are found within the possible influence zone of the proposed mining area and the limitations that may be applicable, different limiting levels of ground vibration will be required. This is due to the typical structures observed surrounding the site. Structures types and qualities vary greatly and this calls for limits to be considered as follows: 6mm/s, 12.5mm/s levels and 25mm/s at least.

The blast design for 165mm diameter blast hole indicates that 267kg will be loaded in an overburden blast hole. Considering general timing systems to be used, it is expected that as much as 4 to 6 blast holes could detonate simultaneously. In order to evaluate the possible influence, three charge masses that will span the range of possible charge mass per delay were selected. Therefore a single overburden blast hole drilled 15m deep 165mm in diameter and charged will yield a 267kg charge, 6 coal blast holes detonating simultaneously will yield 45kg and 4 overburden blast holes detonating simultaneously will yield 1069kg. These charge masses were used for modelling aspects in this report. Applying the above charge masses, the following ground vibration calculations were done and considered in this report. Attention is given to levels of 6mm/s, 12.5mm/s and 25mm/s.

Based on the designs presented on expected drilling and charging design, the following Table 2 shows expected ground vibration levels (PPV) for various distances calculated at the three different charge masses. A low charge mass, the expected medium charge mass per delay and a maximum charge mass as worst case scenario. The charge masses are 45kg, 267kg and 1069kg.

Table 2: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 45kg Charge	Expected PPV (mm/s) for 267kg Charge	Expected PPV (mm/s) for 1069kg Charge
1	50.0	41.6	180.6	567.1
2	100.0	21.3	92.5	290.5
3	150.0	6.8	29.5	92.6
4	200.0	4.2	18.3	57.6
5	250.0	2.9	12.7	39.8
6	300.0	2.2	9.4	29.5
7	400.0	1.3	5.8	18.3
8	500.0	0.9	4.0	12.7
9	600.0	0.7	3.0	9.4
10	700.0	0.5	2.3	7.3
11	800.0	0.4	1.9	5.8
12	900.0	0.4	1.5	4.8
13	1000.0	0.3	1.3	4.0
14	1250.0	0.2	0.9	2.8
15	1500.0	0.2	0.7	2.1
16	1750.0	0.1	0.5	1.6
17	2000.0	0.1	0.4	1.3
18	2500.0	0.1	0.3	0.9
19	3000.0	0.0	0.2	0.7
20	3500.0	0.0	0.2	0.5

Figure 3 below shows the relationship of ground vibration over distance for the maximum charge considered as given in Table 2 above. The attenuation of ground vibration over distance is clearly observed. Also indicated on the graph are the limits that should be applicable due to the various structures and types of installations in this area as given above. The graph can be used to scale expected ground vibration at specific distances for the same maximum charges as used in this report.

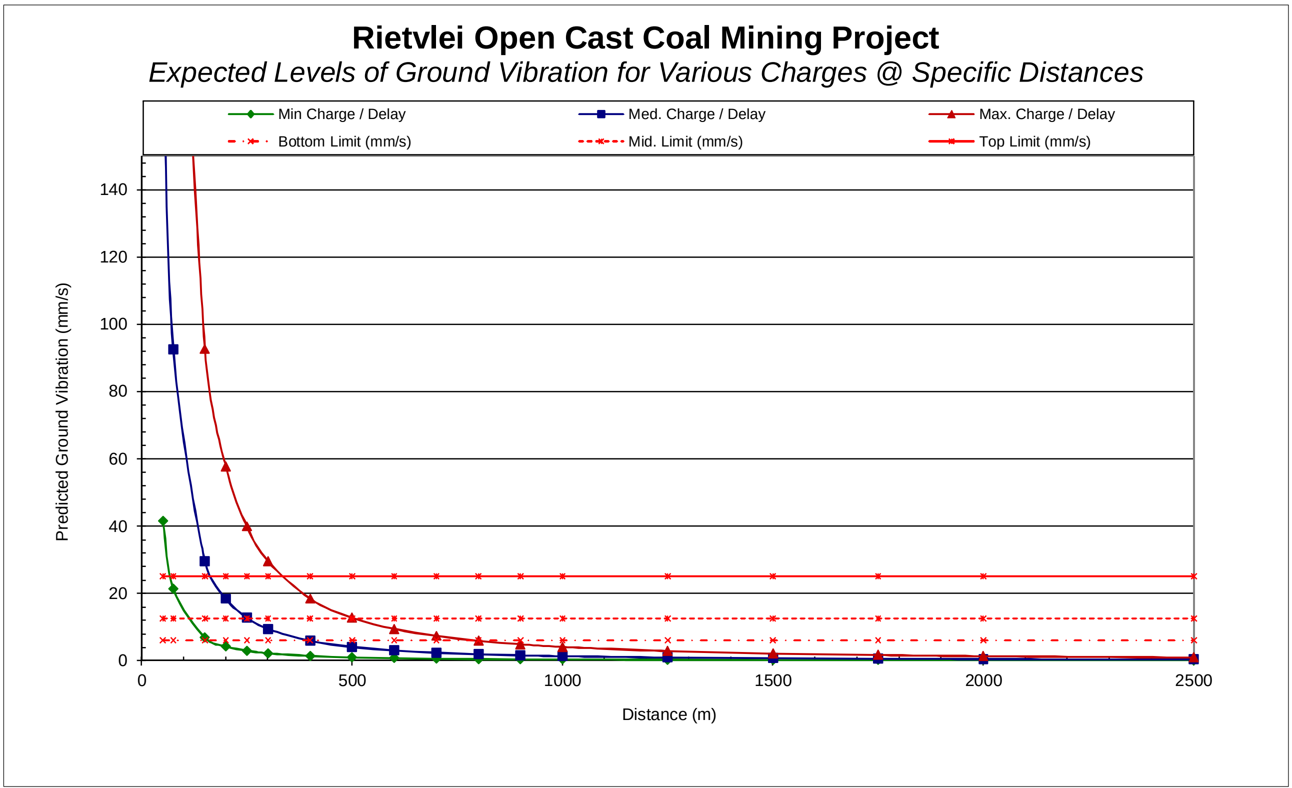


Figure 3: Ground vibration over distance for the three charge masses used in modelling

6.2.1.1.2 **Ground vibration limitations on structures**

Limitations on ground vibration are in the form of maximum allowable levels for different installations and structures. These levels are normally quoted in peak particle velocity or as ground vibration in millimetres per second (mm/s). There are unfortunately no exact South African standard. Thus currently the United States Bureau of Mines (USBM) criterion for safe blasting is applied where private structures are of concern. This is a process of evaluating the vibration amplitudes and frequency of the vibrations according to set rules for preventing damage. The vibration amplitudes and frequency is then plotted on a graph. Figure 4 shows an example of a USBM analysis graph. The graph indicates two main areas:

- The Safe Blasting Criteria Area
- The Unsafe Blasting Criteria Area

When ground vibration is recorded and the amplitude in velocity (mm/s) is analysed for frequency it plots this relationship on the USBM graph. If data falls in the lower part of the graph then the blast was done safely. If the data falls in the upper part of the graph then the probability of inducing damage to mortar and brick structures increases significantly. There is a relationship between amplitude and frequency due to the natural frequencies of structures. This is normally low - below 10 Hz - and thus the lower the frequency, the lower the allowable amplitude. Higher frequencies allows for higher amplitudes. The extra lines on the graph are more detailed for specific type walls and structure configurations. Locally we are only concerned with the lowest line on the USBM graph. Due to possible poor state structures in the area an additional 6mm/s and 12.5mm/s limit lines were added. Figure 4 shows an example of a USBM analysis graph with the 6mm/s and 12.5mm/s guidelines added.

The USBM graph for safe blasting was developed by the United States Bureau of Mines through research and data accumulated from sources other than their own research.

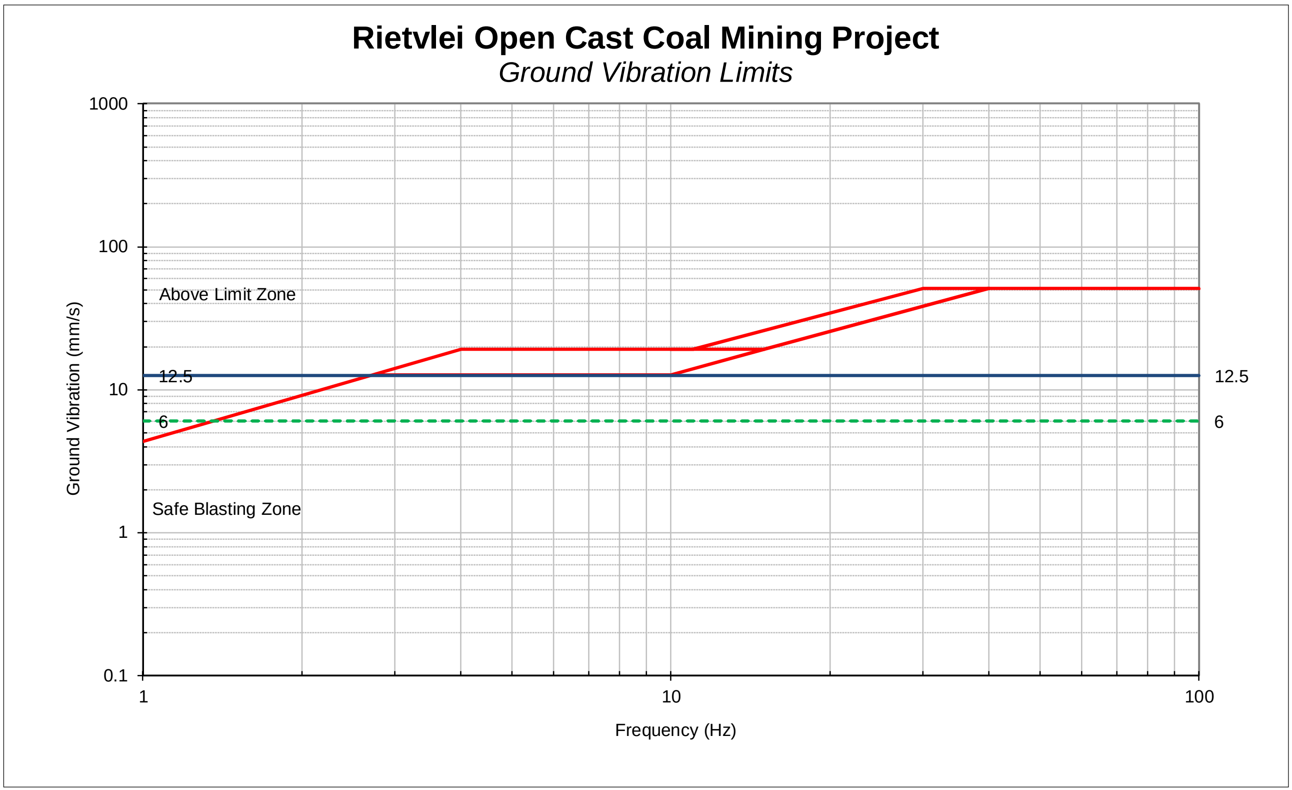


Figure 4: USBM Analysis Graph

Additional limitations that should be considered are as follows, these were determined through research and various institutions:

- National Roads/Tar Roads: 150mm/s
- Steel pipelines: 50mm/s
- Electrical Lines: 75mm/s
- Railway: 150mm/s
- Concrete aged less than 3 days: 5mm/s
- Concrete after 10 days: 200mm/s
- Sensitive Plant equipment: 12mm/s or 25mm/s depending on type – some switches could trip at levels less than 25mm/s.

Considering the above limitations, BM&C work is based on the following:

- USBM criteria for safe blasting
- The additional limitations provided

- Consideration of private structures
- Should these structures be in poor condition is the basic limit of 25mm/s reduced to 12.5mm/s or even when structures are in very poor condition limits will be restricted to 6mm/s
- We also consider the input from other consultants in the field locally and internationally.

6.2.1.1.3 **Ground vibration limitations with regards to human perceptions**

A further aspect of ground vibration and frequency of vibration is the human perception. It should be realized that the legal limit for structures is significantly greater than the comfort zones for people. Humans and animals are sensitive to ground vibration and vibration of the structures. Research has shown that humans will respond to different levels of ground vibration and at different frequencies.

Ground vibration is experienced as “Perceptible”, “Unpleasant” and “Intolerable” (only to name three of the five levels tested) at different vibration levels for different frequencies. This is indicative of the human’s perceptions on ground vibration and clearly indicates that humans are sensitive to ground vibration. This “tool” is only a guideline and helps with managing ground vibration and the respective complaints that people could have due to blast induced ground vibrations. Humans already perceive ground vibration levels of 4.5mm/s as unpleasant. (See Figure 5).
Generally people also assume that any vibrations of the structure - windows or roofs rattling - will cause damage to the structure. Air blast also induces vibration of the structure and is the cause of nine out of ten complaints.

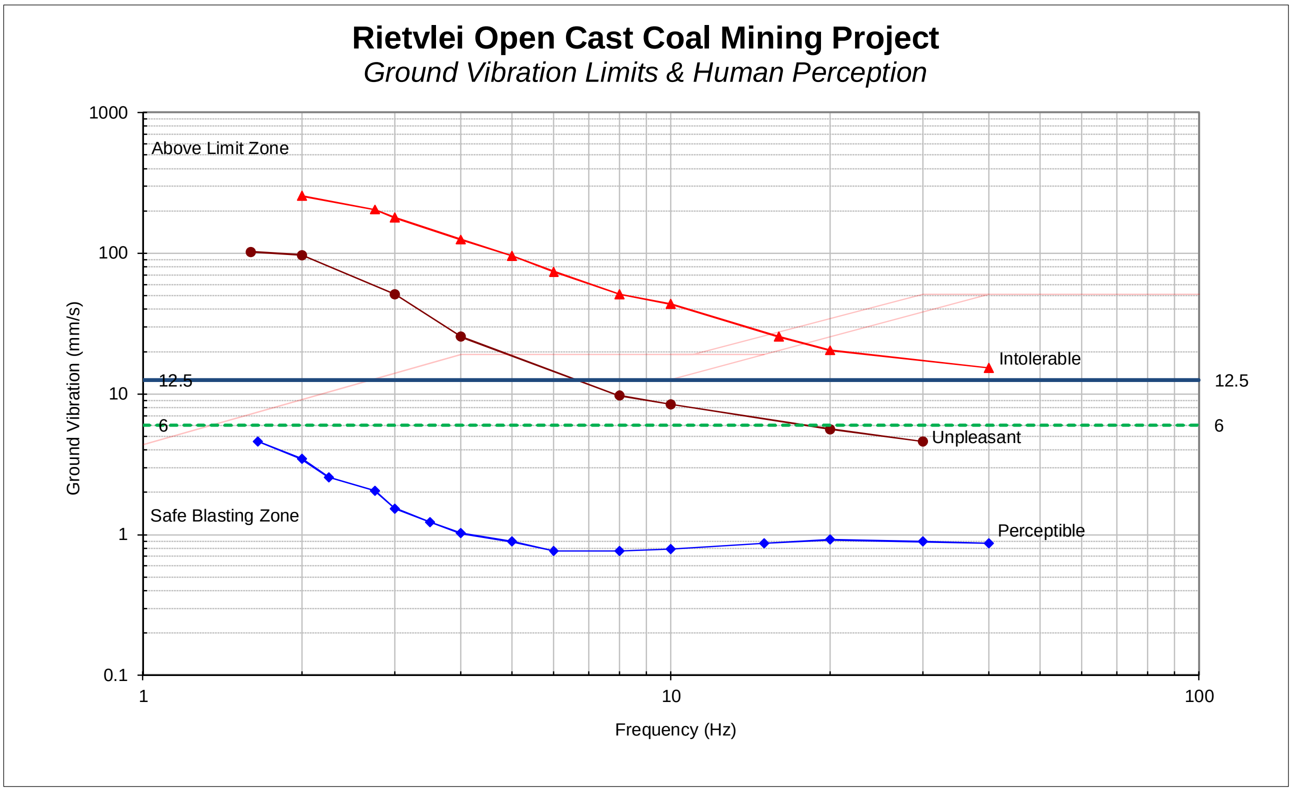


Figure 5: USBM Analysis with Human Perception

6.2.2 Air blast

Air blast or air-overpressure is pressure acting and should not be confused with sound that is within audible range (detected by the human ear). Sound is also a build up from pressure but is at a completely different frequency to air blast. Air blast is normally associated with frequency levels less than 20 Hz, which is the threshold for hearing. Air blast is the direct result from the blast process although influenced by meteorological conditions the final blast layout, timing, stemming, accessories used, covered or not covered etc. all has an influence on the outcome of the result.

The three main causes of air blasts can be observed as:

- Direct rock displacement at the blast; the air pressure pulse (APP)
- Vibrating ground some distance away from the blast; rock pressure pulse (RPP)
- Venting of blast holes or blowouts; the gas release pulse (GRP)

6.2.2.1 Air blast limitations on structures

The recommended limit for air blast currently applied in South Africa is 134dB. This is specifically pertaining to air blast or otherwise known as air-overpressure. This takes into consideration where public is of concern. Air-overpressure is pressure acting and should not be confused with sound that is within audible range (detected by the human ear). However, all attempts should be made to keep air blast levels generated from blasting operations below 120dB or greater magnitude toward critical areas where public is of concern. This will ensure that the minimum amount of disturbance is generated towards the critical areas surrounding the mining area.

Based on work carried out by Siskind *et.al.* (1980), monitored air blast amplitudes up to 135dB are safe for structures, provided the monitoring instrument is sensitive to low frequencies (down to 1Hz). Persson *et.al.* (1994) have published the following estimates of damage thresholds based on empirical data (Table 3). Levels given in Table 3 are at the point of measurement. The weakest point on a structure is the windows and ceilings.

Table 3: Damage Limits for Air Blast

Level	**Description**
>130 dB	Resonant response of large surfaces (roofs, ceilings). Complaints start.
150 dB	Some windows break
170 dB	Most windows break
180 dB	Structural Damage

All attempts should be made to keep air blast levels generated from blasting operations well below 120dB where public is of concern. This will ensure that the minimum amount of disturbance is generated towards the critical areas surrounding the mining area and limit the possibility of complaints due to the secondary effects from air blast.

6.2.2.2 Air blast limitations with regards to human perceptions

Considering the human perception and misunderstanding that could occur between ground vibration and air blast, BM&C generally recommends that blasting be done in such a way that air blast levels are kept below 120dB. In this way it is certain that fewer complaints will be received for blasting operations. The effects on structures that startled people are significantly less – thus no reason for complaining. It is the actual influence on structures like rattling of windows or doors or large roof surface's that startle people. These effects are sometimes misjudged as ground vibration and considered as damaging to the structure.

Initial limits for evaluating conditions have been set at 120dB, 134dB and less than 134dB. USBM limits are 134dB for nuisance, at this level 5% of residents would be expected to complain, because they are startled and frightened; even 120dB could sometimes lead to rattling windows, feelings of annoyance and fright.

6.2.2.3 Air blast prediction

An aspect that is not normally considered as pre-operation definable is the effect of air blast. This is mainly due to the fact that air blast is an aspect that can be controlled to a great degree by applying basic rules. Air blast is the direct result from the blast process, although influenced by meteorological conditions, the final blast layout, timing, stemming, accessories used, covered or not covered etc. all has an influence on the outcome of the result.

Standards do exist and predictions can be made, but it must be taken in to account that predictions of air blast is most effective only when measured and calibrated according to the circumstances where blasting is taking place.

The following equation is associated with predictions of air blast, but is considered by the author as subjective. In this report a standard equation to calculate possible air blast values was used. This equation does not take temperature or any weather conditions into account. Values were calculated using a cube root scaled distance relationship from expected charge masses and distance. Equation 2 is normally used where no actual data exists.

Equation 2:

$$dB = 165 - 24 \log 10 \frac{D}{E^{1/3}}$$

Where:

dB = Air blast level (dB)
D = Distance from source (m)
E = Maximum charge mass per delay (kg)

Although the above equation was applied for prediction of air blast levels, additional measures are also recommended in order to ensure that air blast and associated fly-rock possibilities are minimized as best possible. As discussed earlier the prediction of air blast is very subjective. Following in Table 4 below is a summary of values predicted according to Equation 2. Figure 6 shows the graphical relationship for air blast as set out in Table 4.

Table 4: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 45kg Charge	Air blast (dB) for 267kg Charge	Air blast (dB) for 1069kg Charge
1	50.0	137	144	148
2	100.0	133	139	144
3	150.0	126	132	137
4	200.0	123	129	134
5	250.0	121	127	132
6	300.0	119	125	130
7	400.0	116	122	127
8	500.0	113	120	124
9	600.0	112	118	123
10	700.0	110	116	121
11	800.0	109	115	120
12	900.0	107	114	118
13	1000.0	106	112	117

14	1250.0	104	110	115
15	1500.0	102	108	113
16	1750.0	100	107	111
17	2000.0	99	105	110
18	2500.0	97	103	108
19	3000.0	95	101	106
20	3500.0	93	99	104

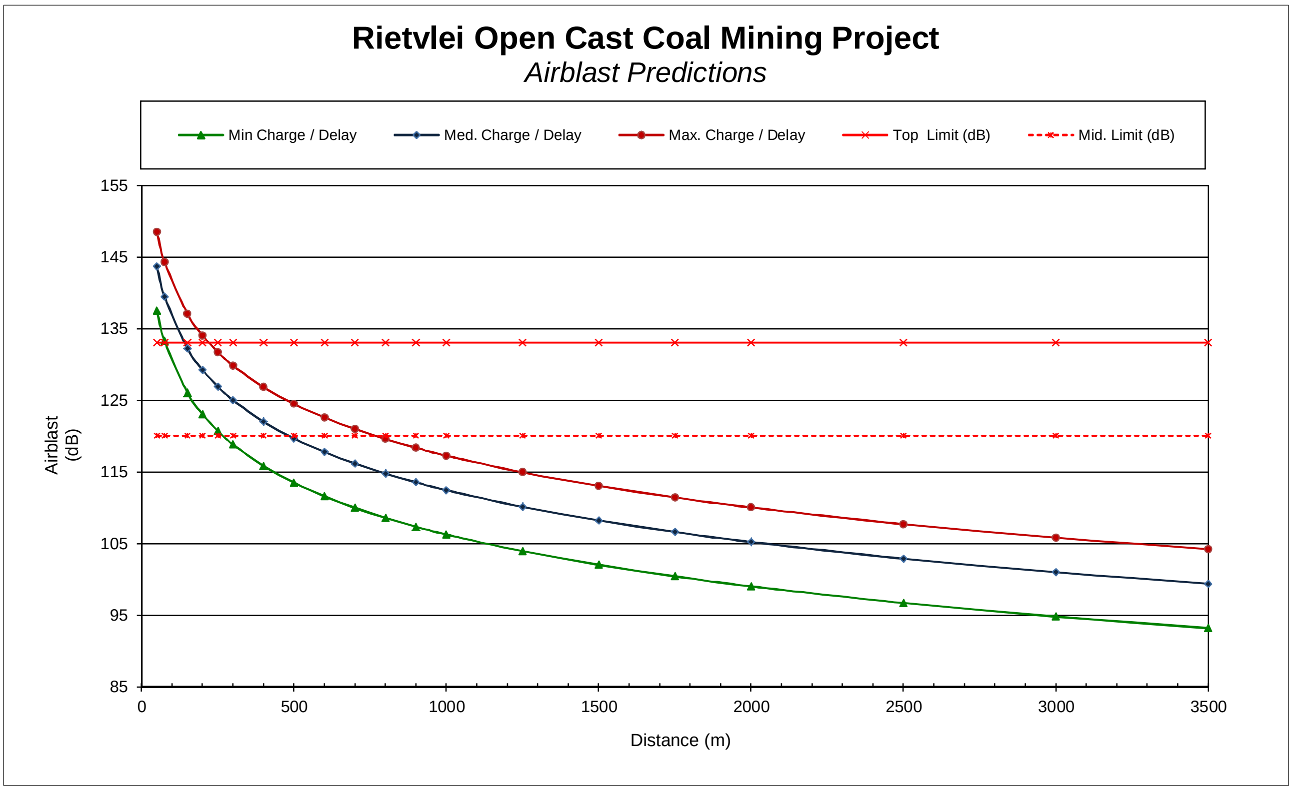


Figure 6: Predicted air blast levels

6.2.3 Fly rock

6.2.3.1 Fly rock causes

Blasting practices require some movement of rock to facilitate the excavation process. The extent of movement is dependent on the scale and type of operation. For example, blasting activities within large coal mines are designed to cast the blasted material much greater distances than practices in a quarrying or hard rock operations. This movement should be in the direction of the free face, and therefore the orientation of the blasting is important. Material or elements travelling outside of this expected range may be considered to be fly rock.

Fly rock from blasting can result from three mechanisms due to the lack of confinement of the energy in the explosive column. The main mechanisms are:

- Face burst - burden conditions usually control fly rock distances in front of the face

- Cratering - If the stemming height to hole diameter ratio is too small or the collar rock is weak
- Rifling - If the stemming material is ejected with insufficient stemming height or inappropriate stemming material is used

In short the following list is typical causes of fly rock:

- Burden to small,
- Burden to large,
- Stemming length to short,
- Out of sequence initiation of blast hole,
- Drilling inaccuracies,
- Incorrect blast hole angles,
- Over charged blast hole.

It is possible to blast without any fly rock with proper confinement of the explosive charges within blast holes using proper stemming procedures and materials. Stemming is further required to ensure that explosive energy is efficiently used to its maximum. Free blasting with no control on stemming cannot be allowed as this will result in poor blast results and possible damage to any nearby structures.

6.2.3.2 Fly rock predictions

The use of prediction calculations for fly rock is in my opinion secondary to the basics of blast preparation. Question is why should there be fly rock? Blasts can be shot without fly rock occurring by using basic guidelines on blast preparation and specifically stemming control. Quality of preparation will certainly have influence on the final blast result. Predictions on the possibility of fly rock are useful for operations that are hampered by the past incidents of fly rock and situations where back tracking needs to be done where fly rock did occur and fault analysis needs to be done. Predictions may also be used to consider what minimum confinement that may be allowed in certain circumstances. Work done in this field did show various considerations of the process of fly rock generation. Considering fly rock predictions will also require that specific “calibration” must be done at the specific site. The blast layout, geology, explosives, stemming material etc. will all play a specific role in the prediction of fly rock and needs to be tested for.

Prediction considered is based on the areas where fly rock may originate from in the blasting process: Face Burst, Cratering and Stemming ejection.

Research as done by Richards, Moore has shown the following equations. The following equations will be applied:

Equation 3: Face Burst

$$L = \frac{k^2}{g} \times \left(\frac{\sqrt{m}}{B}\right)^{2.6}$$

Equation 4: Cratering

$$L = \frac{k^2}{g} \times \left(\frac{\sqrt{m}}{SH}\right)^{2.6}$$

Equation 5: Stemming Ejection

$$L = \frac{k^2}{g} \times \left(\frac{\sqrt{m}}{SH}\right)^{2.6} \times \sin 2\theta$$

Where:

θ	= Drill hole angle
L	= Maximum Throw (m)
m	= Charge mass / m (kg/m)
B	= Burden (m)
SH	= Stemming height (m)
g	= Gravitational constant
k	= Factor value

The Richards & Moore research has shown that a factor applicable for the above equation ranges between 13.5 for a coal environment and 27 for a hard rock environment. Figure 7 below shows the relationship burden or stemming length towards expected throw distance. Throw distance considered here on the same level as the free face. Landing level of elements lower than free face could see longer distances. Optimal throw distance is also observed at 45 degree angles of departure.

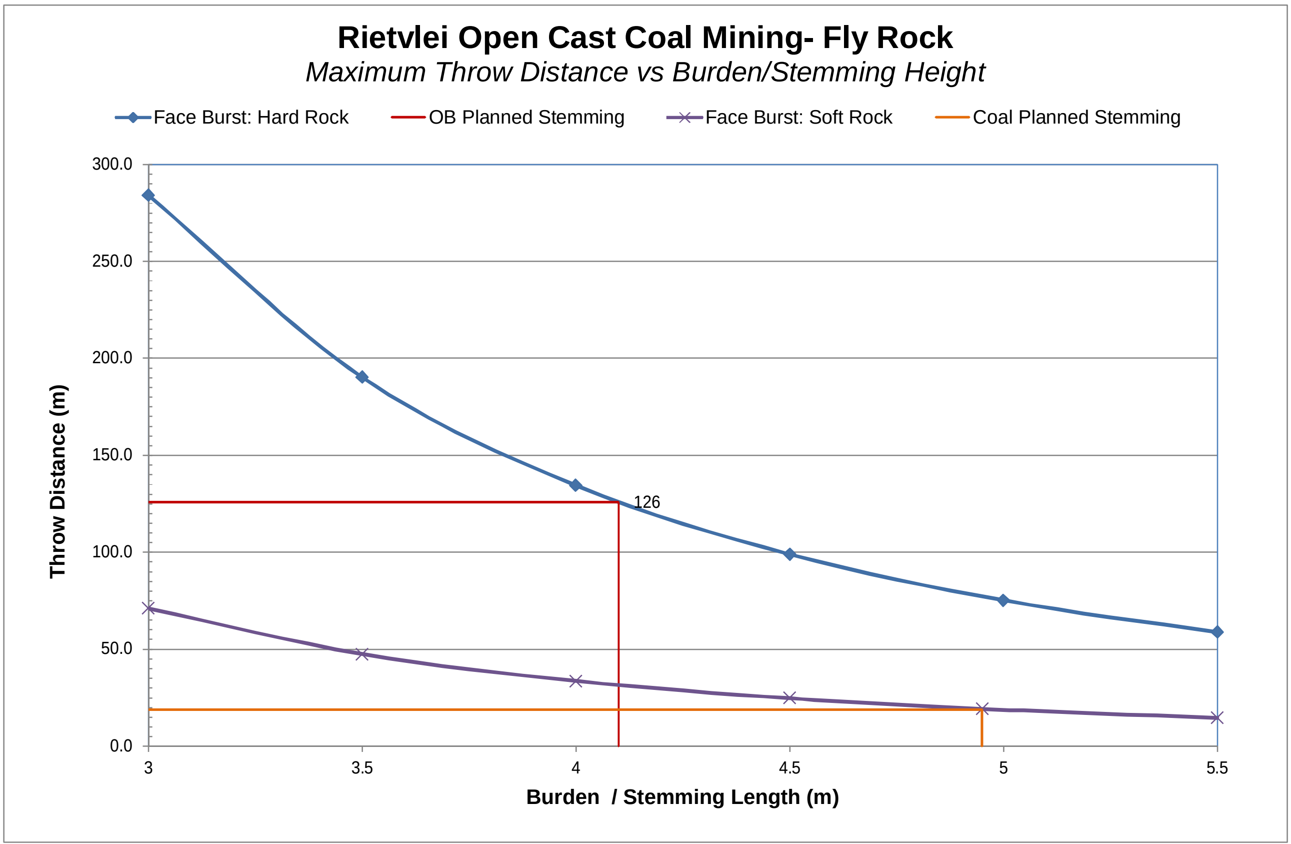


Figure 7: Predicted Fly rock

Face burdens are as important to prevent fly rock as proper stemming controls. There is direct relationship between blast free face burden and probability of fly rock from the face. A further equation can be used for ensuring the face burden is not insufficient. Applying equation 6 and the scaled burden is not less than $0.71 m^{3/2} kg^{-1/2}$ it is not expected to have fly rock from the face.

Equation 6: Scaled burden

$$Bs = \left(\frac{B}{\sqrt{Mc}}\right)$$

Where:

- Bs = Scaled Burden ($m^{3/2} kg^{-1/2}$)
- Mc = Charge mass / m (kg/m)
- B = Burden (m)

Table 5 below shows the relationship of face burdens on the scaled burden and gives indication of which scaled burdens are problematic for the typical designs used in this report.

Table 5: Relationship between face burden and scaled burden for hard rock

Scaled Burden ($m^{3/2} kg^{-1/2}$)	**0.60**	**0.70**	0.80	0.90	1.00	1.09
Min. Face Burden (m)	3	3.5	4	4.5	5	5.5

Red: Problematic areas

6.2.3.3 Impact of fly rock

The occurrence of fly rock in any form will have impact if found to travel outside the safe boundary. This safe boundary may be anything between 10m or 500m. If a road or structure or people or animals are closer than the safe boundary from a blast irrespective of the possibility of fly rock or not precautions should be taken to stop the traffic, remove people or animals for the period of the blast. Fact is fly rock will cause damage to the road, vehicles or even death to people or animals. This safe boundary is determined by the appointed blaster. BM&C normally recommends no shorter distance than 500m.

6.2.4 Noxious Fumes

Explosives currently used are required to be oxygen balanced. Oxygen balance refers to the stoichiometry of the chemical reaction and the nature of gases produced from the detonation of the explosives. The creation of poisonous fumes such as nitrous oxides and carbon monoxide are particular undesirable. These fumes present themselves as red brown cloud after the blast detonated. It has been reported that 10ppm to 20ppm has been mildly irritating. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary edema. It has been predicted that 50% lethality would occur following exposure to 174ppm for 1 hour. Anybody exposed must be taken to hospital for proper treatment.

6.2.4.1 Noxious Fume Causes

Factors contributing to undesirable fumes are typically: poor quality control on explosive manufacture, damage to explosive, lack of confinement, insufficient charge diameter, excessive sleep time, and specific types of ground can also contribute to fumes.

Poor quality control on explosives will yield improper balance of the explosive product. This is typically in the form of too little or too much fuel oil or incorrect quantities of additives to the mixture. Improper quality will cause break down on the explosives product that may result in poor performance. A “burning” may occur that increases the probability of fumes in the form of NO and NO_2.

Damage to explosives occurs when deep blast hole are charged from the top of the hole and literally fall into the hole and get damage at the bottom. The bottom is normally the point of initiation and damaged explosives will not initiate properly. A slow reaction to detonation is forced and again contributes negatively to the explosives performance and fume creating capability.

Studies showed that inadvertent emulsion mixture with drill cuttings can also be a significant contributing factor to NOx production. The NO production from the detonation of emulsion equally mixed (by mass) with drill cuttings increased by a factor of 2.7 over that of emulsion alone. The corresponding NO_2 production increased by factor of 9 while detonation propagated at a steady Velocity of Detonation.

Water also has visible effect on the generation of fumes from emulsion explosives. Tests have shown that the detonation velocity may not be influenced as much but the volumes of fumes generated were significantly higher.

Further is also known that for certain ground types, especially the oxidized type materials could have an advert effect on explosives as well. These ground materials types tends to react with the explosives and causes more than expected fumes.

Drill diameter is also a contributing factor to explosive performance and the subsequent generation of fumes. Explosives are diameter dependant for optimal performance. If the diameter is too small for a specific product improper detonation will occur and may result in a burning of the product rather than detonation. This will have an adverse effect of more fumes created. Each explosive product has a critical diameter. It is the smallest diameter where failure to detonate properly occurs. ANFO blends are normally not good for small diameter blast hole and emulsion explosives can be used in the smaller diameter blast hole.

6.2.4.2 Noxious Fume Control

Control actions on fumes will include the use of the proper quality explosives and proper loading conditions. Quality assurance will need to be achieved from the supplier with quality checks on explosives from time to time. Further action is to prevail from loading blast hole at long periods prior to blasting. Excessive sleeping of charged blast hole will add to fumes generation and should be prevented. Additional measures could include placing stemming plugs at the bottom of the hole and loading emulsion from the bottom up will excluded mixing of drill chippings with the explosives in initiation area. The checking of blast hole for water will ensure that charging crew charges blast hole from the bottom (which should be a standard practise) and displaces the water. This will also ensure proper initiation of the blast hole.

6.2.5 Vibration impact on provincial and national roads

The influence of ground vibration on tarred roads are expected when levels is in the order of 150mm/s and greater. Or when there is actual movement of ground when blasting is done to close to the road or subsidence is caused due to blasting operations. Normally 100 blast hole diameters are a minimum distance between structure and blast hole to prevent any cracks being formed into the surrounds of a blast hole. Crack forming is not restricted to this distance. Improper timing arrangements may also cause excessive back break and cracks further than expected. Fact remain that blasting must be controlled in the vicinity of roads. Air blast does not have influence on air blast by virtue of the type of structure. There is no record of influence on gravel roads due to ground vibration. The only time damage can be induced is when blasting is done next to the road and there is movement of ground. Fly rock will have greater influence on the road as damage from falling debris may impact on the road surface if no control on fly rock is considered.

6.2.6 Vibration will upset adjacent communities

The effects of ground vibration and air blast will have influence on people. These effects tend to create noises on structures in various forms and people react to these occurrences even at low levels. As with human perception given above – people will experience ground vibration at very low levels. These levels are well below damage capability for most structures.
Much work has also been done in the field of public relations in the mining industry. Most probably one aspect that stands out is “Promote good neighbour ship”. This is achieved through communication and more communication with the neighbours. Consider their concerns and address in a proper manner.

The first level of good practice is to avoid unnecessary problems. One problem that can be reduced is the public's reaction to blasting. Concern for a person's home, particularly where they own it, could be reduced by a scheme of precautionary, compensatory and other measures which offer guaranteed remedies without undue argument or excuse.

In general it is also in an operator's financial interests not to blast where there is a viable alternative. Where there is a possibility of avoiding blasting, perhaps through new technology, this should be carefully considered in the light of environmental pressures. Historical precedent may not be a helpful guide to an appropriate decision.

Independent structural surveys are one way of ensuring good neighbour ship. There is a part of inherent difficulty in using surveys as the interpretation of changes in crack patterns that occur may be misunderstood. Cracks open and close with the seasonal changes of temperature, humidity and drainage, and numbers increase as buildings age. Additional actions need to be done in order to supplement the surveys as well.

The means of controlling ground vibration, overpressure and fly rock have many features in common and are used by the better operators. It is said that many of the practices also aid cost-effective production. Together these introduce a tighter regime which should reduce the incidence of fly rock and unusually high levels of ground vibration and overpressure. The measures include the need for the following:

- Correct blast design is essential and should include a survey of the face profile prior to design, ensuring appropriate burden to avoid over-confinement of charges which may increase vibration by a factor of two,

- The setting-out and drilling of blasts should be as accurate as possible and the drilled holes should be surveyed for deviation along their lengths and, if necessary, the blast design adjusted,
- Correct charging is obviously vital, and if free poured bulk explosive is used, its rise during loading should be checked. This is especially important in fragmented ground to avoid accidental overcharging,
- Correct stemming will help control air blast and fly rock and will also aid the control of ground vibration. Controlling the length of the stemming column is important; too short and premature ejection occurs, too long and there can be excessive confinement and poor fragmentation. The length of the stemming column will depend on the diameter of the hole and the type of material being used,
- Monitoring of blasting and re-optimising the blasting design in the light of results, changing conditions and experience should be carried out as standard.

6.2.7 Cracking of houses and consequent devaluation

Houses in general have cracks. It is reported that a house could develop up to 15 cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. are more reason for cracks that have developed. Visual results of actual damage due to blasting operations are limited. There are cases where it did occur and a result is shown in Figure 8 below. A typical X crack formations is observed.

Figure 8: Example of blast induced damage.

Observing cracks of this form on a structure will certainly influence the value as structural damage has occurred. The presence of general vertical cracks or horizontal cracks that are found in all structures does not need to indicate devaluation due to blasting operations but rather devaluation due to construction, building material, age, standards of building applied. Proper building standards are not always applied or else stated was not always applied in the country side when houses were built. Thus damage in the form of cracks will be present. Exact costing of devaluation for normal cracks observed is difficult to estimate. A property valuator will be required for this and I do believe that property value will include the total property and not just the house alone. Mining operations may not have influence to change the status quo of any property.

6.2.8 Vibration impacts on productivity of farm animals (cattle, chickens, pigs, etc.)

Experience in this field is limited. Some work was done but much related to impact from air blast in nuclear blasts or bombs exploding. This was mainly an indication of mid-air detonations occurring and the respective effect. There is not much research done in the field of farm animals in relation to blasting operations specifically with regards to social interaction defects or changes or the influence on wellbeing of animals.

Work was done by Larkin on wildlife and presented here are also some of his conclusions. Personal experience as observed on projects has shown the following on farm animals:
Cattle: Cattle seem to be very accommodating with regards to blasting operations. We have seen that for a first time blast, the blast will upset them. Reaction is shown in taking freight and running a short distance – maybe 10m to 20m – and then carries on grazing. Second blast they will only lift their heads and carry on grazing. Third blast no specific reaction was shown most of the time.

Chickens: Chickens react to sudden noises. Chickens in a broiler will run into opposite corner of the broiler than the noise source and actually trample each other to death. Chickens in a broiler are considered a problem when blasting is done in close proximity without specific mitigation measures.

House animals: Dogs are sensitive to vibration much more than humans and most probably all animals. Significant vibration levels will have them reacting in barking, getting anxious and possibly running away in opposite direction. One can relate to what typically happens when crackers are fired over Christmas and Guy faux days. Loud noises will certainly have an influence.

Noise affects wildlife differently from humans and the effects of noise on wildlife vary from serious to non-existent in different species and situations. Risk of hearing damage in wildlife is probably greater from exposure to nearby blast noise from bombs and large weapons than from long-lasting exposure to continuous noise or from muzzle blast of small arms fire. Direct physiological effects of noise on wildlife, if present, are difficult to measure in the field. Behavioural effects that might decrease chances of surviving and reproducing could include retreat from favourable habitat near noise sources and reduction of time spent feeding with resulting energy depletion. Serious effects such as decreased reproductive success have apparently been documented in some studies. Decreased responsiveness after repeated noises is frequently observed and usually attributed to habituation. Military and civilian blast noise had no unusual effects (beyond other human-generated noise) on wildlife in most studies, although hearing damage was not an issue in the situations studied and animals were often probably habituated to blasts.

The Animal Research centre at Onderstepoort, South Africa was contacted for information as well but to no prevail as studies in this field do not exist at Onderstepoort. There have been claims in the past of farmers claiming that the reproductively of pigs were severely hampered due to mining operations but no scientific evidence was presented for this.

A further question on dairy farms is similar that no scientific evidence exists of deterioration of milk production. However previous projects done by BM&C in the vicinity of dairies, it was considered that it is possible that milk production will be hampered when blasting is done during the milking process. In this instance no blasting was allowed prior to milking time. Thus blasting was only done after the daily milking period. This instance the quarry was approximately 800m away from the blast area.

Work done by Richmond, Damon, Fletcher, Bowen and White considered the effect of air blast on animals from air blast in specific conditions. Animals were tested in shock tubes as well as research from other encompassed into the report. In this research work that was done to define the influence of air blast pressure and the resulting effect on different types and size of animals. Mouse, rabbits, Guinea Pig, hamsters, rat, dog, goat, sheep, cat and cattle were the subjects of this research. The research concentrated on the effect of short duration and long duration pressure pulses, orientation of subject, reflected shock or not and investigated the effect with regards to lethality, lung injury and eardrum rupture. This work was the basis for estimates of pressure and possible influence on humans and the required protection of humans in blast situations. Without going into all the detail of the report the following is a summary of the findings. Long duration and fast rising pressure pulses seem to have most influence on the wellbeing of animals. Long duration pressure pulses are also found in the blasting environment. Long duration pressure pulses are defined as pulses beyond 20msec, and short duration as pulses having duration of less than 5msec. Lungs are considered the critical organs in such a situation. The release of air bubbles from disrupted alveoli of the lungs into the vascular systems accounted for the rapid deaths. The degree of lung haemorrhage was related to the increase in lung weight and blast dosage. Smaller lung sizes were damaged easier. Larger animals showed threshold of petechial haemorrhage was near 10psi to 15psi (68.9476kPa to 103.421kPa) at long durations. Ear damage recorded in sheep showed 38% rupture were recorded at 21.4psi (147.548kPa) for long durations and severity of damage increased with the intensity of the blast. The following figure (Figure 9) shows the mortality curves for the various animals exposed to long duration pressure pulses.

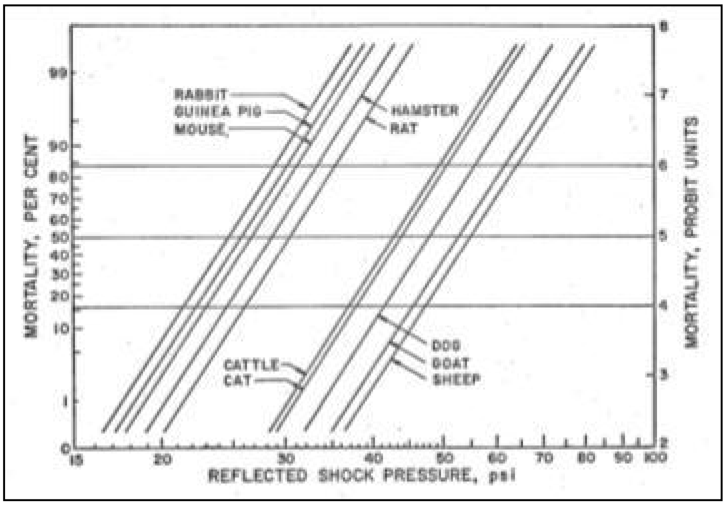


Figure 9: Mortality curve for long duration pressure exposure on animals.

In order to relate to air blast the following table (Table 6) shows the corresponding air blast level in dB and Pascal. Air blast is measured in Pascal (Pa) but converted to the dB scale for ease of use.

Table 6: Corresponding pressure levels to air blast values in the dB scale.

dB	P (Pa)	kPa	PSI
100.0	2.0	0.002	0.000
120.0	20.0	0.020	0.003
140.0	200.0	0.200	0.029
150.0	632.5	0.632	0.092
155.0	1124.7	1.12	0.163
160.0	2000.0	2.00	0.290
165.0	3556.6	3.56	0.516
170.0	6324.6	6.32	0.917
175.0	11246.8	11.25	1.631
180.0	20000.0	20.00	2.901
185.0	35565.6	35.57	5.158
190.0	63245.6	63.25	9.173
195.0	112468.3	112.47	16.312
200.0	200000.0	200.00	29.008
205.0	355655.9	355.66	51.584
210.0	632455.5	632.46	91.730

Distance between source and receptor will certainly be a major consideration. The greater the distance, the lesser will the effect be of noise or air blast.

6.2.9 Water well Influence from Blasting Activities

Water bore holes are present around the proposed site. The author has not had much experience on the effect of blasting on water wells but specific research was done and results from this research work are presented.

Case 1 looked at 36 case histories. Vibration levels up 50mm/s were measured. The well yield and aquifer storage improved as the mining neared the wells, because of the opening of the fractures from loss of lateral confinement, not blasting. This is similar to how stress-relief fractures form. At one site the process was reversed after the mine was backfilled. It was more likely the fractures were recompressed. It was stated that blasting may cause some temporary (transient) turbidity similar to those events that cause turbidity without blasting.

Such as:

1. Natural sloughing off inside of the well bore due to inherent rock instability. This can be accelerated by frequent over pumping. This is common to wells completed through considerable thickness of poorly consolidated and/or highly fractured clay stones and shale's.
2. Significant rainfall events. The apertures of the shallow fractures that are intersected by a domestic well are commonly highly transmissive, thus will transmit substantial amounts of shallow flowing and rapidly recharging water. This water will commonly be turbid and can enter the well in high volumes. The lack of grouting of the near surface casing commonly allows this to happen. Also, if the top of the well is not grouted properly surface water can enter along the side of the casing and flow down the annulus.

The Berger Study observed ground-water impacts from manmade stress-release caused the rock mass removal during mining, but nothing from the blasting. The water quality and water levels were unaffected by the blasting. The "opening up" of the fractures lowered the ground-water levels by increasing the storage or porosity.

A study tested wells 50m from a blast. Wells exhibited no quality or quantity impacts. Blast pressure surges ranged from 3cm to 10cm. Blasting caused no noticeable water table fluctuations and the hydraulic conductivity was unchanged. The pumping of the pit and encroachment of the high wall toward the wells dewatered the water table aquifer.

It may then be concluded from the studies researched as follows: Depending on the well construction, litho logic units encountered, and proximity to the blasting, it is believed that large shots could act as a catalyst for some well sloughing or collapse. However, the well would have to be inherently weak to begin with. The small to moderate shots will not show to impact wells. The minor water fluctuations attributed to blasting may cause a short term turbidity problem, but do not pose any long term problems. This fluctuation would not cause well collapse, as fluctuations from recharge and pumping occurs frequently. Long term changes to the well yield are more likely due to the opening of fractures from loss of lateral confinement. Short term dewatering of wells is caused by the opening of the fractures creating additional storage. A longer term dewatering is caused by encroachment of the high wall and pumping of the pit water. The pit acts like a large pumping well. It is not believed that long term water quality problems will be caused by blasting alone. The possible exception is the introduction of residual nitrates, from the blasting materials, into the ground water system. This is only possible through wells that are hydro logically connected to a blasting site. Most of the long term impacts on water quality are due to the mining (the breakup of the rocks). The influence will also be dependant if wells are beneath the excavation. Stress relief effects occur at shorter distances in this instance.

The results observed and levels recorded during research done showed that levels up to 50mm/s or even higher in certain cases did not have any noticeable effect. It seems that safe conditions will be in the order of the 50mm/s. In addition to this there are certain aspects that will need to be addressed prior to blasting operations.

7 Baseline Results

The base line information for the project is based on zero influence with regards to blast impacts. The project is currently not active with any blasting operations being done. There are other mining in the area but no specific activities in the direct vicinity of the project that could have influence on the baseline.
As part of the baseline all possible structures in a possible influence area are identified.

The site was reviewed and presented hereafter. The site was reviewed / scanned using Google Earth imagery. Information sought from review was typically the kind of surface structures that are present in a 3500m radius from the proposed mine boundary that will require consideration during modelling of blasting operations. This could consists of houses, general structures, power lines, pipe lines, reservoirs, mining activities, roads, shops, schools, gathering places, possible historical sites etc. A list was prepared as best possible for each structure in the vicinity of the pit areas. The list prepared covers structures and points of interest (POI) in the 3500m boundary. A list of structure locations was required for determining the allowable ground vibration limits and air blast limits possible. Figure 10 shows an aerial view of the mining area and surroundings with points of interest. The list compiled is provided in Table 7 below.

Pit Area:

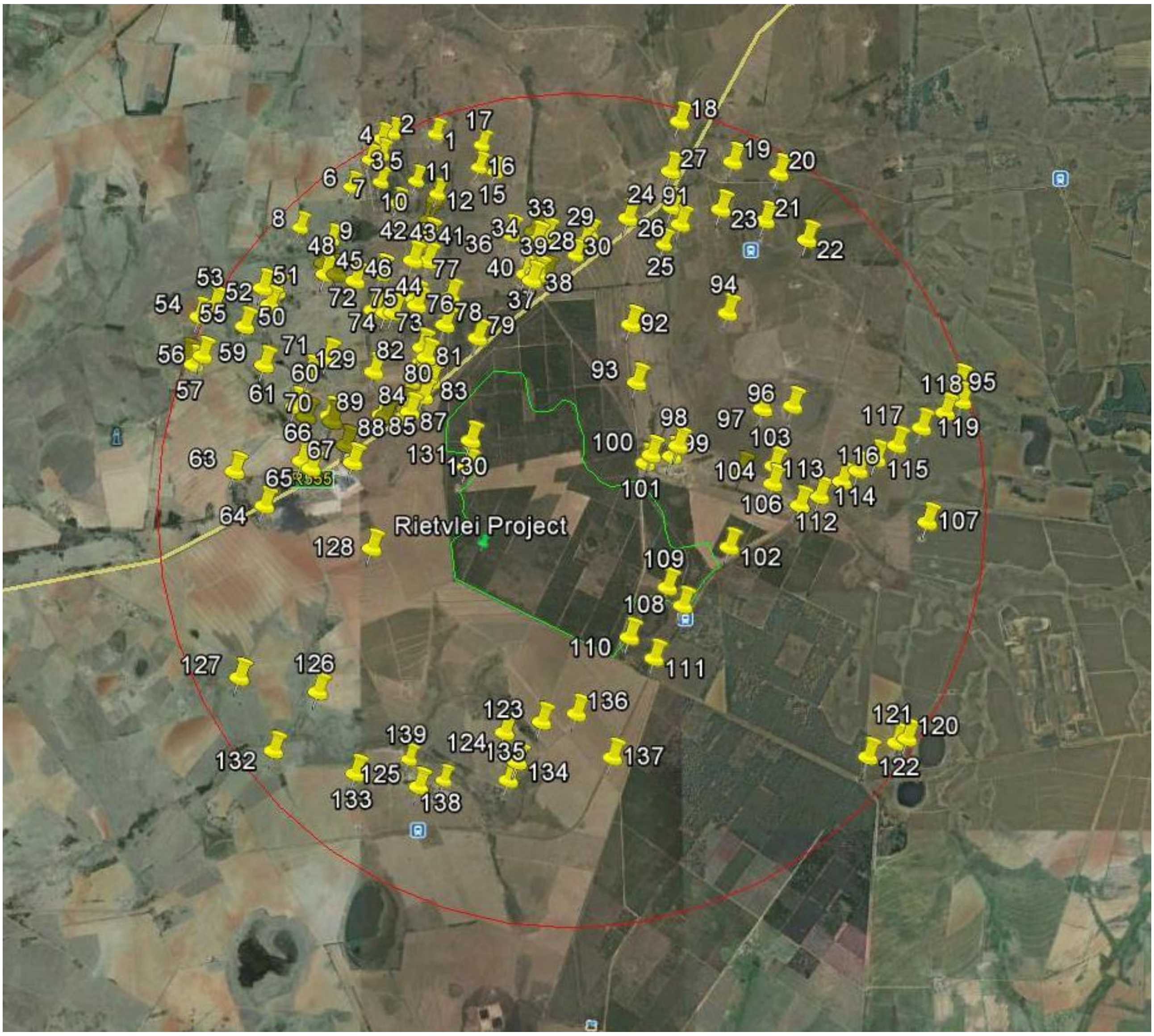


Figure 10: Aerial view and surface plan of the proposed mining area with points of interest identified. Note: Yellow Place marks = POI indicators

Table 7: List of points of interest used (Cape Clarke – LO 29^{o})

Owner	Tag	Description	Classification	Y	X
Private	1	Informal Settlement Houses	2	-64146.68	2836683.55
Private	2	Informal Settlement Houses	2	-63542.13	2836667.69
Private	3	Informal Settlement Houses	2	-63378.03	2836742.60
Private	4	Informal Settlement Houses	2	-63217.51	2837039.12
Private	5	Sports Terrain	5	-63386.20	2836967.37
Private	6	Informal Settlement Houses	2	-62953.01	2837416.63
Private	7	Informal Settlement Houses	2	-63368.33	2837351.13
Private	8	Ruins	2	-62221.35	2837976.61

Owner	Tag	Description	Classification	Y	X
Private	9	Dam	4	-62663.40	2838152.78
Private	10	Farm Buildings/Structures	1	-63600.14	2837647.98
Private	11	Buildings/Structures	1	-63869.38	2837337.90
Private	12	Buildings/Structures	1	-64165.07	2837522.64
Private	13	Buildings/Structures	1	-64124.23	2837605.29
Private	14	Dam	4	-64024.12	2837879.51
Private	15	Buildings/Structures	1	-64984.16	2837220.52
Private	16	Buildings/Structures	1	-64755.42	2837154.99
Private	17	Cement Dams	4	-64796.07	2836840.67
Private	18	Buildings/Structures	1	-67573.62	2836562.53
Private	19	Buildings/Structures	1	-68319.59	2837135.97
Private	20	Dam	4	-68968.38	2837299.77
Private	21	Buildings/Structures	1	-68768.52	2837966.18
Private	22	Dam	4	-69359.56	2838238.60
Private	23	Pivot Irrigation	4	-68149.67	2837800.51
Private	24	Building/Structure	1	-67463.99	2837763.15
Private	25	Dam	4	-67357.57	2838246.14
Private	26	Crossing R555 and Road	5	-66838.31	2837919.94
Private	27	RGW14 (Monitoring Borehole)	5	-67441.44	2837260.04
Private	28	Buildings/Structures	1	-66319.66	2838100.26
Private	29	Buildings/Structures	1	-66231.29	2838202.61
Private	30	Buildings/Structures	1	-66115.33	2838396.31
Private	31	Buildings/Structures	1	-65681.95	2838086.26
Private	32	Farm Buildings/Structures	1	-65723.79	2838627.00
Private	33	Dam	4	-65680.60	2838171.95
Private	34	Cement Dam	4	-65546.66	2838230.53
Private	35	Buildings/Structures	1	-65512.87	2838104.93
Private	36	Ruins	2	-65175.99	2838134.84
Private	37	Farm Buildings/Structures	1	-65400.47	2838701.80
Private	38	RGW20 (Monitoring Borehole)	5	-65531.98	2838681.53
Private	39	RGW16 (Monitoring Borehole)	5	-65568.10	2838709.41
Private	40	RGW17 (Monitoring Borehole)	5	-65484.03	2838789.01
Private	41	Buildings/Structures	1	-64027.14	2838169.26
Private	42	Buildings/Structures	1	-63967.10	2838255.49
Private	43	Buildings/Structures	1	-64010.01	2838509.47
Private	44	Buildings/Structures	1	-63803.28	2838494.78
Private	45	Dam	4	-63353.85	2838673.02
Private	46	Cement Dam	4	-62985.61	2838776.07
Private	47	Farm Buildings/Structures	1	-62724.96	2838680.43
Private	48	Buildings/Structures	1	-62564.52	2838678.62
Private	49	Buildings/Structures	1	-62543.49	2838520.48
Private	50	Buildings/Structures	1	-61861.08	2838913.51
Private	51	RGW29 (Monitoring Borehole)	5	-61673.68	2838866.20
Private	52	Buildings/Structures	1	-61776.18	2839101.72
Private	53	Ruins	2	-60986.52	2839110.75
Private	54	Buildings/Structures	1	-60773.80	2839261.28

Owner	Tag	Description	Classification	Y	X
Private	55	Dam	4	-61414.72	2839400.88
Private	56	Farm Buildings/Structures	1	-60820.42	2839814.47
Private	57	Farm Buildings/Structures	1	-60694.85	2839934.97
Private	58	Farm Buildings/Structures	1	-60586.87	2839840.59
Private	59	Dam	4	-61693.82	2839950.66
Private	60	Buildings/Structures	1	-62337.21	2840087.72
Private	61	Buildings/Structures	1	-62137.83	2840531.08
Private	62	Buildings/Structures	1	-62293.53	2840678.53
Private	63	Dam	4	-61282.43	2841438.52
Private	64	Dam	4	-61705.05	2841922.97
Private	65	Dam	4	-62365.40	2841402.49
Private	66	Dam	4	-62235.18	2841298.60
Private	67	Mine Activity	5	-62953.83	2841324.24
Private	68	Telephone Line	4	-62855.20	2841079.85
Private	69	Buildings/Structures	1	-62663.77	2840746.59
Private	70	Buildings/Structures	1	-62627.22	2840667.36
Private	71	Dam	4	-62598.66	2839852.79
Private	72	Buildings/Structures	1	-63245.37	2839190.24
Private	73	Buildings/Structures	1	-63419.63	2839226.42
Private	74	Buildings/Structures	1	-63528.73	2839226.98
Private	75	Buildings/Structures	1	-63833.23	2839038.50
Private	76	Buildings/Structures	1	-63857.49	2839127.68
Private	77	Buildings/Structures	1	-64334.56	2839022.17
Private	78	Buildings/Structures	1	-64257.05	2839404.78
Private	79	R555 Road	5	-64717.15	2839592.85
Private	80	RGW23 (Monitoring Borehole)	5	-63934.36	2839723.16
Private	81	RGW22 (Monitoring Borehole)	5	-63992.26	2839861.93
Private	82	Buildings/Structures	1	-63926.88	2839933.70
Private	83	R555 Road	5	-64055.38	2840190.96
Private	84	Communication Tower	4	-63952.71	2840407.61
Private	85	Telephone Line	4	-63712.03	2840459.70
Private	86	Weighbridge(Neighbouring Mine)	4	-63711.12	2840576.47
Private	87	Neighbouring Mine Office	4	-63763.43	2840621.01
Private	88	Workshop(Neighbouring Mine)	4	-63664.97	2840702.62
Private	89	Cement Dam	4	-63364.15	2840656.64
Private	90	Telephone Line	4	-63418.95	2840682.01
Private	91	Buildings/Structures	1	-67576.90	2838004.77
Private	92	Road	5	-66875.59	2839412.86
Private	93	Road	5	-66953.10	2840224.32
Private	94	Ruins	2	-68237.61	2839256.74
Private	95	Ruins	2	-71483.17	2840260.46
Private	96	Dam	4	-69145.52	2840563.96
Private	97	Farm Animal Structures	3	-68726.30	2840602.37
Private	98	RGW1 (Monitoring Borehole)	5	-67530.68	2841113.51
Private	99	Buildings/Structures	1	-67442.60	2841256.00
Private	100	RGW2 (Monitoring Borehole)	5	-67156.36	2841237.79

Owner	Tag	Description	Classification	Y	X
Private	101	Road	5	-67068.49	2841349.98
Private	102	Railroad	5	-68245.20	2842532.10
Private	103	Dam	4	-68880.05	2841399.36
Private	104	Informal Settlement Houses	2	-68862.80	2841648.74
Private	105	Buildings/Structures	1	-68419.25	2841476.59
Private	106	Sub Station	4	-69240.75	2841953.30
Private	107	Structure	1	-71031.19	2842197.08
Private	108	Railroad	5	-67587.91	2843347.96
Private	109	Pan	5	-67373.60	2843090.88
Private	110	Road	5	-66835.64	2843785.99
Private	111	Railroad	5	-67180.94	2844082.99
Private	112	Power lines/Pylons	4	-69517.94	2841827.57
Private	113	Power lines/Pylons	4	-69834.68	2841621.81
Private	114	Power lines/Pylons	4	-70064.50	2841471.83
Private	115	Power lines/Pylons	4	-70314.09	2841315.30
Private	116	Power lines/Pylons	4	-70607.94	2841124.07
Private	117	Power lines/Pylons	4	-70956.23	2840878.59
Private	118	Power lines/Pylons	4	-71288.74	2840667.87
Private	119	Power lines/Pylons	4	-71523.70	2840514.13
Private	120	Graveyard (GY01)	1	-70731.54	2845217.09
Private	121	Farm Buildings/Structures	1	-70582.29	2845272.23
Private	122	Buildings/Structures	1	-70179.56	2845469.80
Private	123	RGW6 (Monitoring Borehole)	5	-65590.23	2844966.05
Private	124	RGW5 (Monitoring Borehole)	5	-65065.38	2845114.26
Private	125	RGW9 (Monitoring Borehole)	5	-63849.04	2845868.50
Private	126	Buildings/Structures	1	-62429.03	2844536.03
Private	127	Buildings/Structures	1	-61321.79	2844329.54
Private	128	RGW10 (Monitoring Borehole)	5	-63212.63	2842526.37
Private	129	Buildings/Structures	1	-63251.06	2840057.13
Private	130	Pan	5	-64618.46	2841025.40
Private	131	Pan	5	-64560.28	2841395.18
Private	132	Farm Buildings/Structures	1	-61795.79	2845359.23
Private	133	Buildings/Structures	1	-62955.69	2845682.52
Private	134	Informal Settlement Houses	2	-65240.09	2845527.87
Private	135	Informal Settlement Houses	2	-65117.43	2845780.26
Private	136	Cement Dam	4	-66083.23	2844851.39
Private	137	Cement Dam	4	-66587.08	2845468.10
Private	138	Farm Buildings/Structures	1	-64213.65	2845736.96
Private	139	Farm Buildings/Structures	1	-63728.66	2845439.73

Notes: The type of POI's identified is grouped into different classes. These classes are indicated as "Classification" in table above. Table 8 below shows the descriptions for the classifications used.

Table 8: POI Classification used

Class	Description
1	Private Houses and people sensitive areas
2	Rural Building and structures of poor construction
3	Animal related installations and animal sensitive areas
4	Industrial buildings and installations
5	Earth like structures – no surface structure

Site visit was conducted and structures observed. Structures range from well build structures to informal building styles, industrial structures, dams and pans. There are also various structures in state of dilapidation – basically ruins. Table 9 shows photos of typical structures found in the area.

Table 9: Structure Profile

	Informal Settlement Houses
	Informal Settlement Houses – Brick with corrugated iron

	Railroad
	Power lines/Pylons
	Power lines/Pylons

	Pan
	Ruins
	Farm Buildings/Structures

<table>
<tr><td></td><td>Farm Buildings/Structures</td></tr>
<tr><td></td><td>Farm Buildings/Windmill</td></tr>
<tr><td></td><td>Farmstead</td></tr>
</table>

	Ruins
	Communication Tower

8 Impact Assessment and Mitigation Measures

8.1 Construction Phase

During the construction phase no mining drilling and blasting operations are expected. It is uncertain if any construction blasting will be done. If any blasting will be required for establishment of the plant area it will be reviewed as civil blasting and addressed accordingly.

8.2 Operational Phase

8.2.1 Impact description: Site specific review and modelling of the various aspects from blasting operations

The area surrounding the proposed mining areas was reviewed for structures, traffic, roads, human interface, animals interface etc. Various installations and structures were observed. These are listed in Table 7. This section concentrates on the outcome of modelling the possible effects of ground vibration, air blast and fly rock specifically to these points of interest or possible interfaces. In evaluation the three different charge mass scenarios is considered with regards to ground vibration and air blast. Review of the charge per blast hole and the possible timing of a blast the three different charge mass of 45, 267 and 1069kg were selected to ensure proper source coverage.

Ground vibration and air blast was calculated from the edge of the pit outline and modelled accordingly. Blasting further away from the pit edge will certainly have less influence on the surroundings. A worst case is then applicable with calculation from pit edge. As explained previously reference is only made to some structures and these references covers the extent of all structures surrounding the mine.

The following aspects with comments are addressed for each of the evaluations done:

- Ground Vibration Modelling Results
- Ground Vibration and human perception
- Vibration impact on national and provincial road
- Vibration will upset adjacent communities
- Cracking of houses and consequent devaluation
- Air blast Modelling Results
- Impact of fly rock
- Noxious fumes Influence Results

Please note that this analysis does not take geology, topography or actual final drill and blast pattern into account. The data is based on good practise applied internationally and considered very good estimates based on the information provided and supplied in this document.

8.2.1.1 Review of expected ground vibration

Presented herewith are the expected ground vibration level contours. Discussion of level of ground vibration and relevant influences is also given. Expected ground vibration levels were calculated for each of the structure locations or POI's considered surrounding the mining area. Evaluation is given for each POI with regards to human perception and structure concern. Evaluation is done in form of the criteria what humans experience and where by structures could be damaged. This is according to accepted criteria for prevention of damage to structures and when levels are low enough to have no significant influence. Tables are provided for each of the different charge modelling done with regards to Tag, Description, Specific Limit, Distance (m), Predicted PPV (mm/s), and Possible Concern for Human perception and Structure. The "Tag" No. is number corresponding to the location indicated on POI figures. "Description" indicates the type of the structure. The "Distance" is the distance between the structure and edge of the pit area. The "Specific Limit" is the maximum limit for ground vibration at the specific structure or installation. The "Predicted PPV (mm/s)" is the calculated ground vibration for the structure and the "possible concern" indicates if there is any concern for structure damage or not or human perception. Indicators used are such as “perceptible”, ”unpleasant”, “intolerable” which stems from the humans perception information given and indicators such as “high” or “low” is given whereby there is possibility of damage to a structure or no significant influence is expected and concern is low. Levels below 0.76mm/s could be considered as to be low or negligible possibility of influence.

Ground vibration is calculated and modelled for the pit area at the minimum, medium and maximum charge mass at specific distances from the opencast mining area. The charge masses applied are according to blast designs in section 6. These levels are then plotted and overlaid with current mining plans to observe possible influences at structures identified. Structures or POI’s for consideration are also plotted in this model. Ground vibration predictions were done considering distances ranging from 50m to 3500m around the opencast mining area.

Provided as well with each simulation are indicators of the ground vibration limits used: 6mm/s, 12.5mm/s and 25mm/s. 6mm/s is indicated as a “Solid Blue” line, 12.5mm/s “Intermittent Blue” line and 25mm/s as a “Intermittent Red” line. This enables immediate review of possible concerns that may be applicable to any of the privately owned structures, social gathering areas or installations. Consideration can also then be given to influence on sensitive installations within the mine boundary.

Data is provided as follows: Vibration contours followed by table with predicted ground vibration values and evaluation for each POI. Additional colour codes used in the tables indicates the following:

Vibration levels higher than proposed limit applicable to Structures / Installations are coloured “Mustard”
Vibration levels indicated as Intolerable on human perception scale are coloured “Yellow”

8.2.1.2 Calculated Ground Vibration Levels

Presented are simulations for expected ground vibration levels from three different charge masses.

(Intentionally left open)

- **Minimum Charge per Delay – Pit Area – 45 kg**

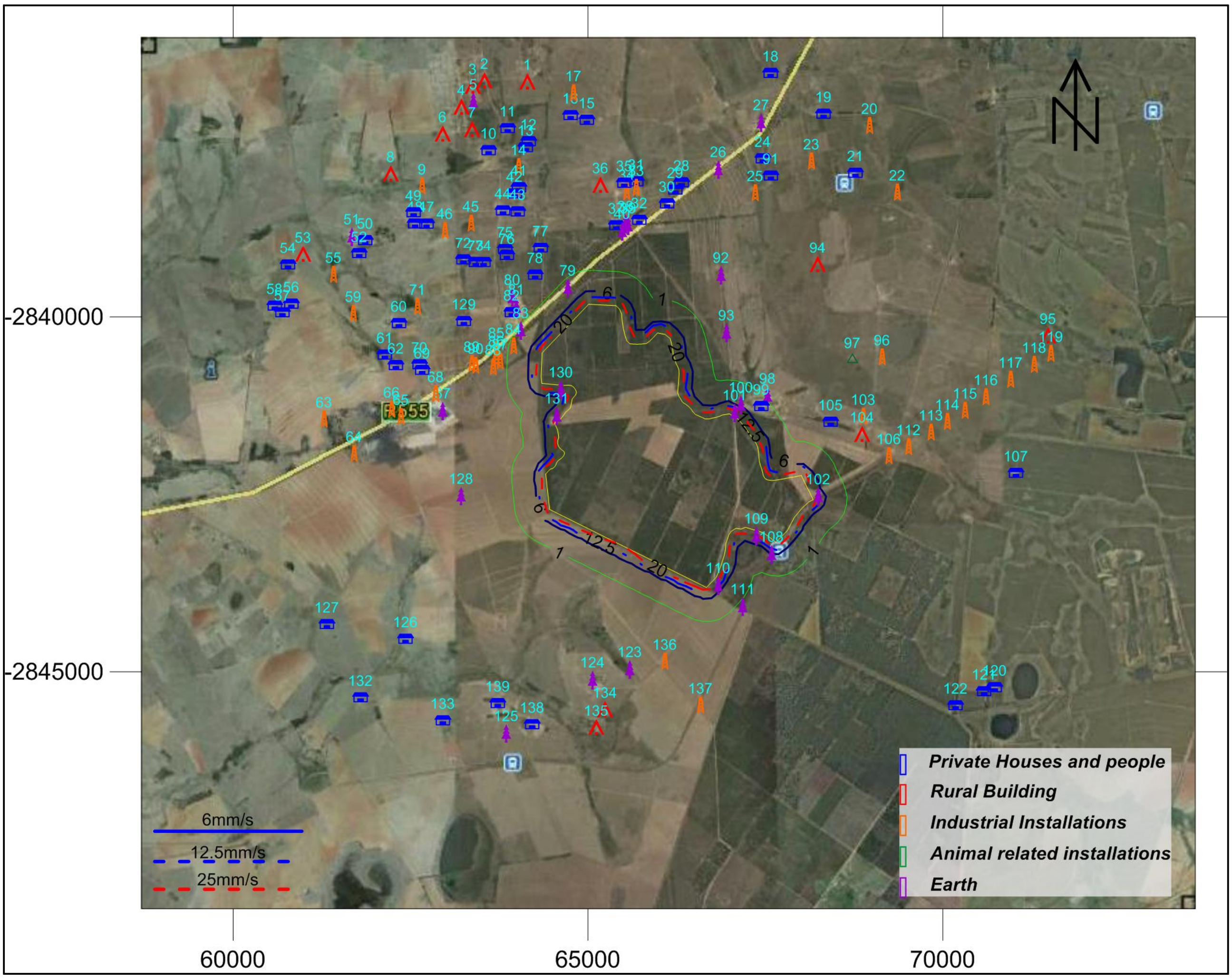


Figure 11: Ground vibration influence from minimum charge

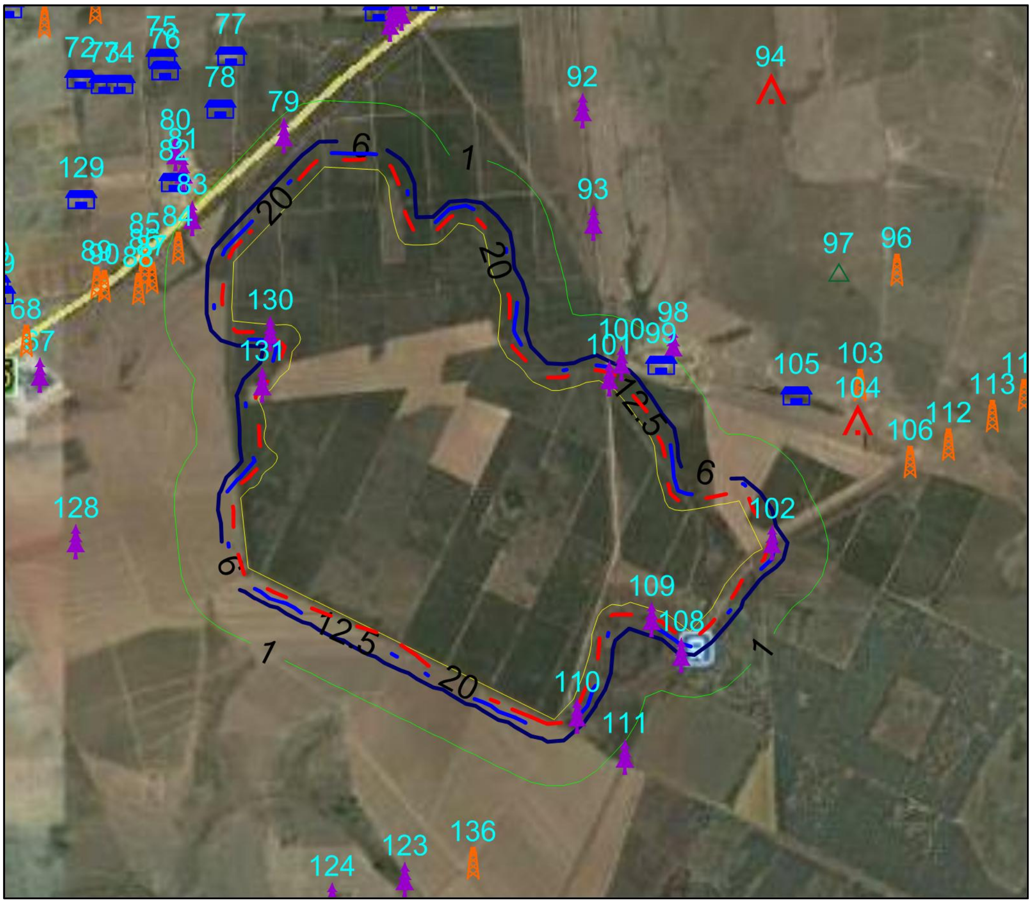


Figure 12: Zoomed area for ground vibration influence from minimum charge

Table 10: Ground vibration evaluation for minimum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
1	Informal Settlement Houses	25	3255	0.0	Too Low	Acceptable
2	Informal Settlement Houses	25	3480	0.0	Too Low	Acceptable
3	Informal Settlement Houses	25	3486	0.0	Too Low	Acceptable
4	Informal Settlement Houses	50	3311	0.0	Too Low	Acceptable
5	Sports Terrain	150	3285	0.0	Too Low	Acceptable
6	Informal Settlement Houses	25	3166	0.0	Too Low	Acceptable
7	Informal Settlement Houses	50	2967	0.0	Too Low	Acceptable
8	Ruins	12.5	3290	0.0	N/A	Acceptable
9	Dam	150	2848	0.1	N/A	Acceptable
10	Farm Buildings/Structures	25	2592	0.1	Too Low	Acceptable
11	Buildings/Structures	25	2734	0.1	Too Low	Acceptable
12	Buildings/Structures	25	2450	0.1	Too Low	Acceptable
13	Buildings/Structures	25	2388	0.1	Too Low	Acceptable
14	Dam	50	2179	0.1	N/A	Acceptable
15	Buildings/Structures	25	2602	0.1	Too Low	Acceptable
16	Buildings/Structures	25	2679	0.1	Too Low	Acceptable
17	Cement Dams	50	2989	0.0	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
18	Buildings/Structures	25	3940	0.0	Too Low	Acceptable
19	Buildings/Structures	25	3831	0.0	Too Low	Acceptable
20	Dam	50	4117	0.0	N/A	Acceptable
21	Buildings/Structures	25	3510	0.0	Too Low	Acceptable
22	Dam	50	3818	0.0	N/A	Acceptable
23	Pivot Irrigation	150	3200	0.0	N/A	Acceptable
24	Building/Structure	25	2844	0.1	Too Low	Acceptable
25	Dam	50	2373	0.1	N/A	Acceptable
26	Crossing R555 and Road	150	2405	0.1	N/A	Acceptable
27	RGW14 (Monitoring Borehole)	50	3285	0.0	N/A	Acceptable
28	Buildings/Structures	25	1976	0.1	Too Low	Acceptable
29	Buildings/Structures	25	1845	0.1	Too Low	Acceptable
30	Buildings/Structures	25	1620	0.1	Too Low	Acceptable
31	Buildings/Structures	25	1784	0.1	Too Low	Acceptable
32	Farm Buildings/Structures	25	1266	0.2	Too Low	Acceptable
33	Dam	50	1699	0.1	N/A	Acceptable
34	Cement Dam	50	1621	0.1	N/A	Acceptable
35	Buildings/Structures	25	1742	0.1	Too Low	Acceptable
36	Ruins	12.5	1694	0.1	N/A	Acceptable
37	Farm Buildings/Structures	25	1140	0.2	Too Low	Acceptable
38	RGW20 (Monitoring Borehole)	50	1172	0.2	N/A	Acceptable
39	RGW16 (Monitoring Borehole)	50	1150	0.2	N/A	Acceptable
40	RGW17 (Monitoring Borehole)	50	1059	0.3	N/A	Acceptable
41	Buildings/Structures	25	1924	0.1	Too Low	Acceptable
42	Buildings/Structures	25	1883	0.1	Too Low	Acceptable
43	Buildings/Structures	25	1651	0.1	Too Low	Acceptable
44	Buildings/Structures	25	1795	0.1	Too Low	Acceptable
45	Dam	50	1990	0.1	N/A	Acceptable
46	Cement Dam	50	2185	0.1	N/A	Acceptable
47	Farm Buildings/Structures	25	2439	0.1	Too Low	Acceptable
48	Buildings/Structures	25	2556	0.1	Too Low	Acceptable
49	Buildings/Structures	25	2681	0.1	Too Low	Acceptable
50	Buildings/Structures	25	2958	0.0	Too Low	Acceptable
51	RGW29 (Monitoring Borehole)	50	3142	0.0	N/A	Acceptable
52	Buildings/Structures	25	2935	0.1	Too Low	Acceptable
53	Ruins	12.5	3645	0.0	N/A	Acceptable
54	Buildings/Structures	25	3790	0.0	Too Low	Acceptable
55	Dam	50	3140	0.0	N/A	Acceptable
56	Farm Buildings/Structures	25	3600	0.0	Too Low	Acceptable
57	Farm Buildings/Structures	25	3703	0.0	Too Low	Acceptable
58	Farm Buildings/Structures	25	3825	0.0	Too Low	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
59	Dam	50	2717	0.1	N/A	Acceptable
60	Buildings/Structures	25	2059	0.1	Too Low	Acceptable
61	Buildings/Structures	25	2213	0.1	Too Low	Acceptable
62	Buildings/Structures	25	2051	0.1	Too Low	Acceptable
63	Dam	50	3107	0.0	N/A	Acceptable
64	Dam	50	2721	0.1	N/A	Acceptable
65	Dam	50	2039	0.1	N/A	Acceptable
66	Dam	50	2145	0.1	N/A	Acceptable
67	Mine Activity	150	1450	0.2	Too Low	Acceptable
68	Telephone Line	75	1499	0.2	N/A	Acceptable
69	Buildings/Structures	25	1678	0.1	Too Low	Acceptable
70	Buildings/Structures	25	1718	0.1	Too Low	Acceptable
71	Dam	50	1873	0.1	N/A	Acceptable
72	Buildings/Structures	25	1711	0.1	Too Low	Acceptable
73	Buildings/Structures	25	1560	0.1	Too Low	Acceptable
74	Buildings/Structures	25	1481	0.2	Too Low	Acceptable
75	Buildings/Structures	25	1391	0.2	Too Low	Acceptable
76	Buildings/Structures	25	1312	0.2	Too Low	Acceptable
77	Buildings/Structures	25	1048	0.3	Too Low	Acceptable
78	Buildings/Structures	25	832	0.4	Too Low	Acceptable
79	R555 Road	150	369	1.5	N/A	Acceptable
80	RGW23 (Monitoring Borehole)	50	845	0.4	N/A	Acceptable
81	RGW22 (Monitoring Borehole)	50	707	0.5	N/A	Acceptable
82	Buildings/Structures	25	705	0.5	Too Low	Acceptable
83	R555 Road	150	434	1.2	N/A	Acceptable
84	Communication Tower	25	413	1.3	N/A	Acceptable
85	Telephone Line	75	643	0.6	N/A	Acceptable
86	Weighbridge(Neighbouring Mine)	50	639	0.6	Too Low	Acceptable
87	Neighbouring Mine Office	25	585	0.7	Too Low	Acceptable
88	Workshop(Neighbouring Mine)	25	680	0.6	Too Low	Acceptable
89	Cement Dam	50	982	0.3	N/A	Acceptable
90	Telephone Line	75	926	0.3	N/A	Acceptable
91	Buildings/Structures	25	2694	0.1	Too Low	Acceptable
92	Road	150	1146	0.2	N/A	Acceptable
93	Road	150	791	0.4	N/A	Acceptable
94	Ruins	12.5	2334	0.1	N/A	Acceptable
95	Ruins	12.5	4000	0.0	N/A	Acceptable
96	Dam	50	2034	0.1	N/A	Acceptable
97	Farm Animal Structures	25	1788	0.1	Too Low	Acceptable
98	RGW1 (Monitoring Borehole)	50	529	0.8	N/A	Acceptable
99	Buildings/Structures	25	369	1.5	Perceptible	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
100	RGW2 (Monitoring Borehole)	50	194	4.4	N/A	Acceptable
101	Road	150	57	33.2	N/A	Acceptable
102	Railroad	150	87	16.8	N/A	Acceptable
103	Dam	50	1216	0.2	N/A	Acceptable
104	Informal Settlement Houses	6	1041	0.3	Too Low	Acceptable
105	Buildings/Structures	25	877	0.4	Too Low	Acceptable
106	Sub Station	12.5	1235	0.2	Too Low	Acceptable
107	Structure	25	2888	0.1	Too Low	Acceptable
108	Railroad	150	192	4.5	N/A	Acceptable
109	Pan	150	74	21.6	N/A	Acceptable
110	Road	150	103	12.7	N/A	Acceptable
111	Railroad	150	555	0.8	N/A	Acceptable
112	Power lines/Pylons	75	1539	0.1	N/A	Acceptable
113	Power lines/Pylons	75	1913	0.1	N/A	Acceptable
114	Power lines/Pylons	75	2186	0.1	N/A	Acceptable
115	Power lines/Pylons	75	2478	0.1	N/A	Acceptable
116	Power lines/Pylons	75	2826	0.1	N/A	Acceptable
117	Power lines/Pylons	75	3246	0.0	N/A	Acceptable
118	Power lines/Pylons	75	3637	0.0	N/A	Acceptable
119	Power lines/Pylons	75	3916	0.0	N/A	Acceptable
120	Graveyard (GY01)	50	3662	0.0	N/A	Acceptable
121	Farm Buildings/Structures	25	3578	0.0	Too Low	Acceptable
122	Buildings/Structures	25	3411	0.0	Too Low	Acceptable
123	RGW6 (Monitoring Borehole)	50	1511	0.2	N/A	Acceptable
124	RGW5 (Monitoring Borehole)	50	1877	0.1	N/A	Acceptable
125	RGW9 (Monitoring Borehole)	50	3093	0.0	N/A	Acceptable
126	Buildings/Structures	25	2734	0.1	Too Low	Acceptable
127	Buildings/Structures	25	3535	0.0	Too Low	Acceptable
128	RGW10 (Monitoring Borehole)	50	1218	0.2	N/A	Acceptable
129	Buildings/Structures	25	1191	0.2	Too Low	Acceptable
130	Pan	150	64	27.7	N/A	Acceptable
131	Pan	150	61	29.7	N/A	Acceptable
132	Farm Buildings/Structures	25	3758	0.0	Too Low	Acceptable
133	Buildings/Structures	25	3324	0.0	Too Low	Acceptable
134	Informal Settlement Houses	6	2170	0.1	Too Low	Acceptable
135	Informal Settlement Houses	6	2450	0.1	Too Low	Acceptable
136	Cement Dam	50	1189	0.2	N/A	Acceptable
137	Cement Dam	50	1660	0.1	N/A	Acceptable
138	Farm Buildings/Structures	25	2813	0.1	Too Low	Acceptable
139	Farm Buildings/Structures	25	2762	0.1	Too Low	Acceptable

- **Medium Charge per Delay – Pit Area – 267 kg**

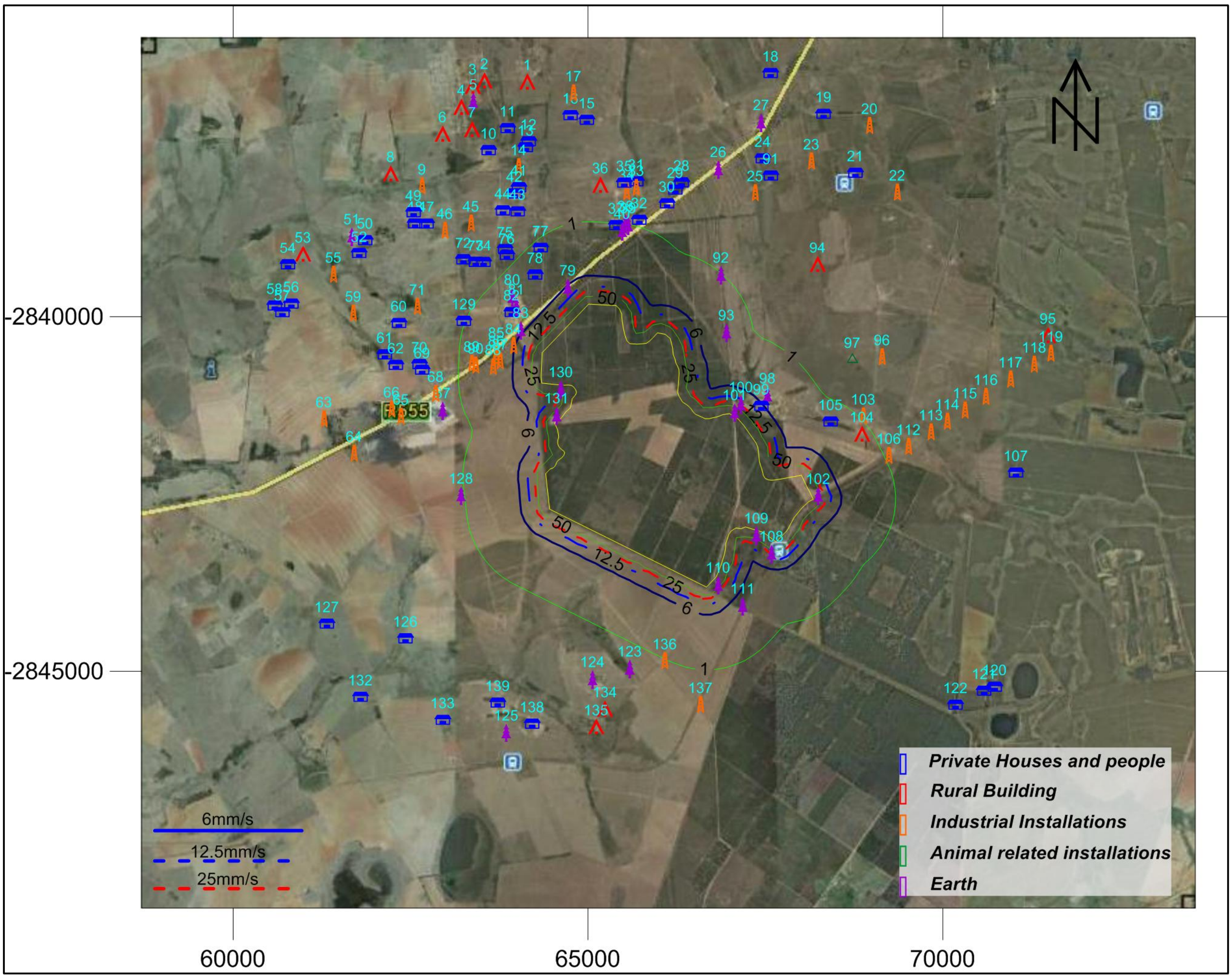


Figure 13: Ground vibration influence from medium charge

Table 11: Ground vibration evaluation for medium charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
1	Informal Settlement Houses	25	3255	0.2	Too Low	Acceptable
2	Informal Settlement Houses	25	3480	0.2	Too Low	Acceptable
3	Informal Settlement Houses	25	3486	0.2	Too Low	Acceptable
4	Informal Settlement Houses	50	3311	0.2	Too Low	Acceptable
5	Sports Terrain	150	3285	0.2	Too Low	Acceptable
6	Informal Settlement Houses	25	3166	0.2	Too Low	Acceptable
7	Informal Settlement Houses	50	2967	0.2	Too Low	Acceptable
8	Ruins	12.5	3290	0.2	N/A	Acceptable
9	Dam	150	2848	0.2	N/A	Acceptable
10	Farm Buildings/Structures	25	2592	0.3	Too Low	Acceptable
11	Buildings/Structures	25	2734	0.2	Too Low	Acceptable
12	Buildings/Structures	25	2450	0.3	Too Low	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
13	Buildings/Structures	25	2388	0.3	Too Low	Acceptable
14	Dam	50	2179	0.4	N/A	Acceptable
15	Buildings/Structures	25	2602	0.3	Too Low	Acceptable
16	Buildings/Structures	25	2679	0.3	Too Low	Acceptable
17	Cement Dams	50	2989	0.2	N/A	Acceptable
18	Buildings/Structures	25	3940	0.1	Too Low	Acceptable
19	Buildings/Structures	25	3831	0.1	Too Low	Acceptable
20	Dam	50	4117	0.1	N/A	Acceptable
21	Buildings/Structures	25	3510	0.2	Too Low	Acceptable
22	Dam	50	3818	0.1	N/A	Acceptable
23	Pivot Irrigation	150	3200	0.2	N/A	Acceptable
24	Building/Structure	25	2844	0.2	Too Low	Acceptable
25	Dam	50	2373	0.3	N/A	Acceptable
26	Crossing R555 and Road	150	2405	0.3	N/A	Acceptable
27	RGW14 (Monitoring Borehole)	50	3285	0.2	N/A	Acceptable
28	Buildings/Structures	25	1976	0.4	Too Low	Acceptable
29	Buildings/Structures	25	1845	0.5	Too Low	Acceptable
30	Buildings/Structures	25	1620	0.6	Too Low	Acceptable
31	Buildings/Structures	25	1784	0.5	Too Low	Acceptable
32	Farm Buildings/Structures	25	1266	0.9	Perceptible	Acceptable
33	Dam	50	1699	0.5	N/A	Acceptable
34	Cement Dam	50	1621	0.6	N/A	Acceptable
35	Buildings/Structures	25	1742	0.5	Too Low	Acceptable
36	Ruins	12.5	1694	0.5	N/A	Acceptable
37	Farm Buildings/Structures	25	1140	1.0	Perceptible	Acceptable
38	RGW20 (Monitoring Borehole)	50	1172	1.0	N/A	Acceptable
39	RGW16 (Monitoring Borehole)	50	1150	1.0	N/A	Acceptable
40	RGW17 (Monitoring Borehole)	50	1059	1.2	N/A	Acceptable
41	Buildings/Structures	25	1924	0.4	Too Low	Acceptable
42	Buildings/Structures	25	1883	0.5	Too Low	Acceptable
43	Buildings/Structures	25	1651	0.6	Too Low	Acceptable
44	Buildings/Structures	25	1795	0.5	Too Low	Acceptable
45	Dam	50	1990	0.4	N/A	Acceptable
46	Cement Dam	50	2185	0.4	N/A	Acceptable
47	Farm Buildings/Structures	25	2439	0.3	Too Low	Acceptable
48	Buildings/Structures	25	2556	0.3	Too Low	Acceptable
49	Buildings/Structures	25	2681	0.3	Too Low	Acceptable
50	Buildings/Structures	25	2958	0.2	Too Low	Acceptable
51	RGW29 (Monitoring Borehole)	50	3142	0.2	N/A	Acceptable
52	Buildings/Structures	25	2935	0.2	Too Low	Acceptable
53	Ruins	12.5	3645	0.2	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
54	Buildings/Structures	25	3790	0.1	Too Low	Acceptable
55	Dam	50	3140	0.2	N/A	Acceptable
56	Farm Buildings/Structures	25	3600	0.2	Too Low	Acceptable
57	Farm Buildings/Structures	25	3703	0.1	Too Low	Acceptable
58	Farm Buildings/Structures	25	3825	0.1	Too Low	Acceptable
59	Dam	50	2717	0.2	N/A	Acceptable
60	Buildings/Structures	25	2059	0.4	Too Low	Acceptable
61	Buildings/Structures	25	2213	0.3	Too Low	Acceptable
62	Buildings/Structures	25	2051	0.4	Too Low	Acceptable
63	Dam	50	3107	0.2	N/A	Acceptable
64	Dam	50	2721	0.2	N/A	Acceptable
65	Dam	50	2039	0.4	N/A	Acceptable
66	Dam	50	2145	0.4	N/A	Acceptable
67	Mine Activity	150	1450	0.7	Too Low	Acceptable
68	Telephone Line	75	1499	0.7	N/A	Acceptable
69	Buildings/Structures	25	1678	0.5	Too Low	Acceptable
70	Buildings/Structures	25	1718	0.5	Too Low	Acceptable
71	Dam	50	1873	0.5	N/A	Acceptable
72	Buildings/Structures	25	1711	0.5	Too Low	Acceptable
73	Buildings/Structures	25	1560	0.6	Too Low	Acceptable
74	Buildings/Structures	25	1481	0.7	Too Low	Acceptable
75	Buildings/Structures	25	1391	0.7	Too Low	Acceptable
76	Buildings/Structures	25	1312	0.8	Perceptible	Acceptable
77	Buildings/Structures	25	1048	1.2	Perceptible	Acceptable
78	Buildings/Structures	25	832	1.7	Perceptible	Acceptable
79	R555 Road	150	369	6.7	N/A	Acceptable
80	RGW23 (Monitoring Borehole)	50	845	1.7	N/A	Acceptable
81	RGW22 (Monitoring Borehole)	50	707	2.3	N/A	Acceptable
82	Buildings/Structures	25	705	2.3	Perceptible	Acceptable
83	R555 Road	150	434	5.1	N/A	Acceptable
84	Communication Tower	25	413	5.5	N/A	Acceptable
85	Telephone Line	75	643	2.7	N/A	Acceptable
86	Weighbridge(Neighbouring Mine)	50	639	2.7	Perceptible	Acceptable
87	Neighbouring Mine Office	25	585	3.1	Perceptible	Acceptable
88	Workshop(Neighbouring Mine)	25	680	2.4	Perceptible	Acceptable
89	Cement Dam	50	982	1.3	N/A	Acceptable
90	Telephone Line	75	926	1.5	N/A	Acceptable
91	Buildings/Structures	25	2694	0.3	Too Low	Acceptable
92	Road	150	1146	1.0	N/A	Acceptable
93	Road	150	791	1.9	N/A	Acceptable
94	Ruins	12.5	2334	0.3	N/A	Acceptable
95	Ruins	12.5	4000	0.1	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
96	Dam	50	2034	0.4	N/A	Acceptable
97	Farm Animal Structures	25	1788	0.5	Too Low	Acceptable
98	RGW1 (Monitoring Borehole)	50	529	3.7	N/A	Acceptable
99	Buildings/Structures	25	369	6.7	Unpleasant	Acceptable
100	RGW2 (Monitoring Borehole)	50	194	19.3	N/A	Acceptable
101	Road	150	57	144.5	N/A	Acceptable
102	Railroad	150	87	73.0	N/A	Acceptable
103	Dam	50	1216	0.9	N/A	Acceptable
104	Informal Settlement Houses	6	1041	1.2	Perceptible	Acceptable
105	Buildings/Structures	25	877	1.6	Perceptible	Acceptable
106	Sub Station	12.5	1235	0.9	Perceptible	Acceptable
107	Structure	25	2888	0.2	Too Low	Acceptable
108	Railroad	150	192	19.6	N/A	Acceptable
109	Pan	150	74	93.8	N/A	Acceptable
110	Road	150	103	55.2	N/A	Acceptable
111	Railroad	150	555	3.4	N/A	Acceptable
112	Power lines/Pylons	75	1539	0.6	N/A	Acceptable
113	Power lines/Pylons	75	1913	0.4	N/A	Acceptable
114	Power lines/Pylons	75	2186	0.4	N/A	Acceptable
115	Power lines/Pylons	75	2478	0.3	N/A	Acceptable
116	Power lines/Pylons	75	2826	0.2	N/A	Acceptable
117	Power lines/Pylons	75	3246	0.2	N/A	Acceptable
118	Power lines/Pylons	75	3637	0.2	N/A	Acceptable
119	Power lines/Pylons	75	3916	0.1	N/A	Acceptable
120	Graveyard (GY01)	50	3662	0.2	N/A	Acceptable
121	Farm Buildings/Structures	25	3578	0.2	Too Low	Acceptable
122	Buildings/Structures	25	3411	0.2	Too Low	Acceptable
123	RGW6 (Monitoring Borehole)	50	1511	0.7	N/A	Acceptable
124	RGW5 (Monitoring Borehole)	50	1877	0.5	N/A	Acceptable
125	RGW9 (Monitoring Borehole)	50	3093	0.2	N/A	Acceptable
126	Buildings/Structures	25	2734	0.2	Too Low	Acceptable
127	Buildings/Structures	25	3535	0.2	Too Low	Acceptable
128	RGW10 (Monitoring Borehole)	50	1218	0.9	N/A	Acceptable
129	Buildings/Structures	25	1191	1.0	Perceptible	Acceptable
130	Pan	150	64	120.5	N/A	Acceptable
131	Pan	150	61	129.2	N/A	Acceptable
132	Farm Buildings/Structures	25	3758	0.1	Too Low	Acceptable
133	Buildings/Structures	25	3324	0.2	Too Low	Acceptable
134	Informal Settlement Houses	6	2170	0.4	Too Low	Acceptable
135	Informal Settlement Houses	6	2450	0.3	Too Low	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
136	Cement Dam	50	1189	1.0	N/A	Acceptable
137	Cement Dam	50	1660	0.6	N/A	Acceptable
138	Farm Buildings/Structures	25	2813	0.2	Too Low	Acceptable
139	Farm Buildings/Structures	25	2762	0.2	Too Low	Acceptable

- **Maximum Charge per Delay – Pit Area – 1069 kg**

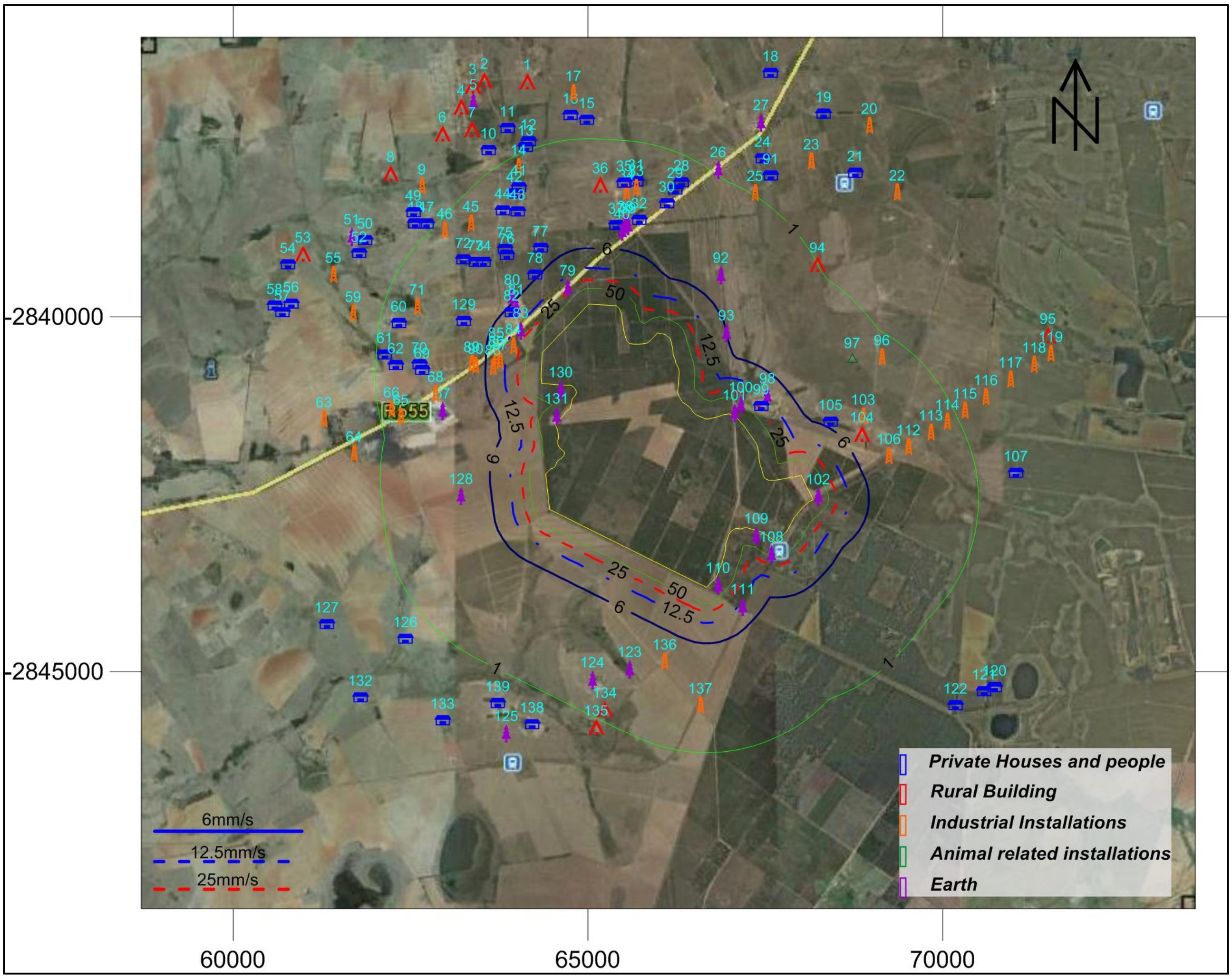


Figure 14: Ground vibration influence from maximum charge

Table 12: Ground vibration evaluation for maximum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
1	Informal Settlement Houses	25	3255	0.6	Too Low	Acceptable
2	Informal Settlement Houses	25	3480	0.5	Too Low	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
3	Informal Settlement Houses	25	3486	0.5	Too Low	Acceptable
4	Informal Settlement Houses	50	3311	0.6	Too Low	Acceptable
5	Sports Terrain	150	3285	0.6	Too Low	Acceptable
6	Informal Settlement Houses	25	3166	0.6	Too Low	Acceptable
7	Informal Settlement Houses	50	2967	0.7	Too Low	Acceptable
8	Ruins	12.5	3290	0.6	N/A	Acceptable
9	Dam	150	2848	0.7	N/A	Acceptable
10	Farm Buildings/Structures	25	2592	0.8	Perceptible	Acceptable
11	Buildings/Structures	25	2734	0.8	Perceptible	Acceptable
12	Buildings/Structures	25	2450	0.9	Perceptible	Acceptable
13	Buildings/Structures	25	2388	1.0	Perceptible	Acceptable
14	Dam	50	2179	1.1	N/A	Acceptable
15	Buildings/Structures	25	2602	0.8	Perceptible	Acceptable
16	Buildings/Structures	25	2679	0.8	Perceptible	Acceptable
17	Cement Dams	50	2989	0.7	N/A	Acceptable
18	Buildings/Structures	25	3940	0.4	Too Low	Acceptable
19	Buildings/Structures	25	3831	0.4	Too Low	Acceptable
20	Dam	50	4117	0.4	N/A	Acceptable
21	Buildings/Structures	25	3510	0.5	Too Low	Acceptable
22	Dam	50	3818	0.4	N/A	Acceptable
23	Pivot Irrigation	150	3200	0.6	N/A	Acceptable
24	Building/Structure	25	2844	0.7	Too Low	Acceptable
25	Dam	50	2373	1.0	N/A	Acceptable
26	Crossing R555 and Road	150	2405	1.0	N/A	Acceptable
27	RGW14 (Monitoring Borehole)	50	3285	0.6	N/A	Acceptable
28	Buildings/Structures	25	1976	1.3	Perceptible	Acceptable
29	Buildings/Structures	25	1845	1.5	Perceptible	Acceptable
30	Buildings/Structures	25	1620	1.8	Perceptible	Acceptable
31	Buildings/Structures	25	1784	1.6	Perceptible	Acceptable
32	Farm Buildings/Structures	25	1266	2.7	Perceptible	Acceptable
33	Dam	50	1699	1.7	N/A	Acceptable
34	Cement Dam	50	1621	1.8	N/A	Acceptable
35	Buildings/Structures	25	1742	1.6	Perceptible	Acceptable
36	Ruins	12.5	1694	1.7	N/A	Acceptable
37	Farm Buildings/Structures	25	1140	3.3	Perceptible	Acceptable
38	RGW20 (Monitoring Borehole)	50	1172	3.1	N/A	Acceptable
39	RGW16 (Monitoring Borehole)	50	1150	3.2	N/A	Acceptable
40	RGW17 (Monitoring Borehole)	50	1059	3.7	N/A	Acceptable
41	Buildings/Structures	25	1924	1.4	Perceptible	Acceptable
42	Buildings/Structures	25	1883	1.4	Perceptible	Acceptable
43	Buildings/Structures	25	1651	1.8	Perceptible	Acceptable
44	Buildings/Structures	25	1795	1.5	Perceptible	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
45	Dam	50	1990	1.3	N/A	Acceptable
46	Cement Dam	50	2185	1.1	N/A	Acceptable
47	Farm Buildings/Structures	25	2439	0.9	Perceptible	Acceptable
48	Buildings/Structures	25	2556	0.9	Perceptible	Acceptable
49	Buildings/Structures	25	2681	0.8	Perceptible	Acceptable
50	Buildings/Structures	25	2958	0.7	Too Low	Acceptable
51	RGW29 (Monitoring Borehole)	50	3142	0.6	N/A	Acceptable
52	Buildings/Structures	25	2935	0.7	Too Low	Acceptable
53	Ruins	12.5	3645	0.5	N/A	Acceptable
54	Buildings/Structures	25	3790	0.4	Too Low	Acceptable
55	Dam	50	3140	0.6	N/A	Acceptable
56	Farm Buildings/Structures	25	3600	0.5	Too Low	Acceptable
57	Farm Buildings/Structures	25	3703	0.5	Too Low	Acceptable
58	Farm Buildings/Structures	25	3825	0.4	Too Low	Acceptable
59	Dam	50	2717	0.8	N/A	Acceptable
60	Buildings/Structures	25	2059	1.2	Perceptible	Acceptable
61	Buildings/Structures	25	2213	1.1	Perceptible	Acceptable
62	Buildings/Structures	25	2051	1.2	Perceptible	Acceptable
63	Dam	50	3107	0.6	N/A	Acceptable
64	Dam	50	2721	0.8	N/A	Acceptable
65	Dam	50	2039	1.2	N/A	Acceptable
66	Dam	50	2145	1.1	N/A	Acceptable
67	Mine Activity	150	1450	2.2	Perceptible	Acceptable
68	Telephone Line	75	1499	2.1	N/A	Acceptable
69	Buildings/Structures	25	1678	1.7	Perceptible	Acceptable
70	Buildings/Structures	25	1718	1.7	Perceptible	Acceptable
71	Dam	50	1873	1.4	N/A	Acceptable
72	Buildings/Structures	25	1711	1.7	Perceptible	Acceptable
73	Buildings/Structures	25	1560	1.9	Perceptible	Acceptable
74	Buildings/Structures	25	1481	2.1	Perceptible	Acceptable
75	Buildings/Structures	25	1391	2.3	Perceptible	Acceptable
76	Buildings/Structures	25	1312	2.6	Perceptible	Acceptable
77	Buildings/Structures	25	1048	3.7	Perceptible	Acceptable
78	Buildings/Structures	25	832	5.5	Perceptible	Acceptable
79	R555 Road	150	369	21.0	N/A	Acceptable
80	RGW23 (Monitoring Borehole)	50	845	5.3	N/A	Acceptable
81	RGW22 (Monitoring Borehole)	50	707	7.2	N/A	Acceptable
82	Buildings/Structures	25	705	7.2	Unpleasant	Acceptable
83	R555 Road	150	434	16.0	N/A	Acceptable
84	Communication Tower	25	413	17.4	N/A	Acceptable
85	Telephone Line	75	643	8.4	N/A	Acceptable
86	Weighbridge(Neighbouring Mine)	50	639	8.5	Unpleasant	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
87	Neighbouring Mine Office	25	585	9.8	Unpleasant	Acceptable
88	Workshop(Neighbouring Mine)	25	680	7.6	Unpleasant	Acceptable
89	Cement Dam	50	982	4.2	N/A	Acceptable
90	Telephone Line	75	926	4.6	N/A	Acceptable
91	Buildings/Structures	25	2694	0.8	Perceptible	Acceptable
92	Road	150	1146	3.2	N/A	Acceptable
93	Road	150	791	6.0	N/A	Acceptable
94	Ruins	12.5	2334	1.0	N/A	Acceptable
95	Ruins	12.5	4000	0.4	N/A	Acceptable
96	Dam	50	2034	1.3	N/A	Acceptable
97	Farm Animal Structures	25	1788	1.6	Perceptible	Acceptable
98	RGW1 (Monitoring Borehole)	50	529	11.6	N/A	Acceptable
99	Buildings/Structures	25	369	21.0	Intolerable	Acceptable
100	RGW2 (Monitoring Borehole)	50	194	60.7	N/A	Problematic
101	Road	150	57	453.7	N/A	Problematic
102	Railroad	150	87	229.3	N/A	Problematic
103	Dam	50	1216	2.9	N/A	Acceptable
104	Informal Settlement Houses	6	1041	3.8	Perceptible	Acceptable
105	Buildings/Structures	25	877	5.0	Perceptible	Acceptable
106	Sub Station	12.5	1235	2.9	Perceptible	Acceptable
107	Structure	25	2888	0.7	Too Low	Acceptable
108	Railroad	150	192	61.6	N/A	Acceptable
109	Pan	150	74	294.5	N/A	N/A
110	Road	150	103	173.4	N/A	Problematic
111	Railroad	150	555	10.7	N/A	Acceptable
112	Power lines/Pylons	75	1539	2.0	N/A	Acceptable
113	Power lines/Pylons	75	1913	1.4	N/A	Acceptable
114	Power lines/Pylons	75	2186	1.1	N/A	Acceptable
115	Power lines/Pylons	75	2478	0.9	N/A	Acceptable
116	Power lines/Pylons	75	2826	0.7	N/A	Acceptable
117	Power lines/Pylons	75	3246	0.6	N/A	Acceptable
118	Power lines/Pylons	75	3637	0.5	N/A	Acceptable
119	Power lines/Pylons	75	3916	0.4	N/A	Acceptable
120	Graveyard (GY01)	50	3662	0.5	N/A	Acceptable
121	Farm Buildings/Structures	25	3578	0.5	Too Low	Acceptable
122	Buildings/Structures	25	3411	0.5	Too Low	Acceptable
123	RGW6 (Monitoring Borehole)	50	1511	2.0	N/A	Acceptable
124	RGW5 (Monitoring Borehole)	50	1877	1.4	N/A	Acceptable
125	RGW9 (Monitoring Borehole)	50	3093	0.6	N/A	Acceptable
126	Buildings/Structures	25	2734	0.8	Perceptible	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
127	Buildings/Structures	25	3535	0.5	Too Low	Acceptable
128	RGW10 (Monitoring Borehole)	50	1218	2.9	N/A	Acceptable
129	Buildings/Structures	25	1191	3.0	Perceptible	Acceptable
130	Pan	150	64	378.4	N/A	N/A
131	Pan	150	61	405.6	N/A	N/A
132	Farm Buildings/Structures	25	3758	0.5	Too Low	Acceptable
133	Buildings/Structures	25	3324	0.6	Too Low	Acceptable
134	Informal Settlement Houses	6	2170	1.1	Perceptible	Acceptable
135	Informal Settlement Houses	6	2450	0.9	Perceptible	Acceptable
136	Cement Dam	50	1189	3.0	N/A	Acceptable
137	Cement Dam	50	1660	1.8	N/A	Acceptable
138	Farm Buildings/Structures	25	2813	0.7	Too Low	Acceptable
139	Farm Buildings/Structures	25	2762	0.8	Too Low	Acceptable

8.2.1.3 Summary of ground vibration levels

The opencast operation was evaluated for expected levels of ground vibration from future blasting operations. Review of the site and the surrounding installations / houses / buildings showed that structures varied in distances from the opencast pit area. The closest structures found are the gravel road, buildings, monitoring boreholes, railroad and pan, ranging from 57m to 369m from the eastern, southern and western boundary of the pit area. The planned minimum and medium charges evaluated showed little influence. Based on the allowed limit of 25mm/s for the buildings (POI 99), the maximum charge shows possible influence. Ground vibration could also be experienced as intolerable on the human perception scale. The Monitoring Borehole (RGW2 – POI 100), located 194m from the pit area, could be problematic. The railroad is identified as a possible concern as well as the Pan's at POI 109, POI 130 and POI 131, located on the southern and western side of the pit area. The road at POI 101 and POI 110 that is routed directly through the project area could be in danger of being damaged if consideration is not given to re-routing.

In some cases structures or installations are directly next to the opencast area. This creates situations where very high ground vibration values are predicted. It must be noted that this is clear indication that care must be taken when blasting is conducted in the areas close to points of interest and proper planning must be done.

There are no other structures identified that are of concern within the evaluated area. Structures are located such that levels of ground vibration are well within the accepted norms and limits.

8.2.1.4 Ground Vibration and human perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (See Figure 15 below). The frequency range selected is the expected average range for frequencies that will be measured for ground vibration.

Review of the maximum charge in relation to human perception it is seen that 2500m from the blast people could possibly experience the ground vibration as *"Perceptible"*. At 900m the expected ground vibration levels are still less than the lower safe blasting limit – less than 6mm/s but will be experienced by people as *"unpleasant"*. At distance of 500m and closer there is strong indication that people will experience the ground vibration as *"Intolerable"*. Distances closer than 800m will exceed the minimum 6mm/s proposed safe limit for poorly constructed structures. Figure 15 below shows this effect of ground vibration with regards to human perception for maximum charge.

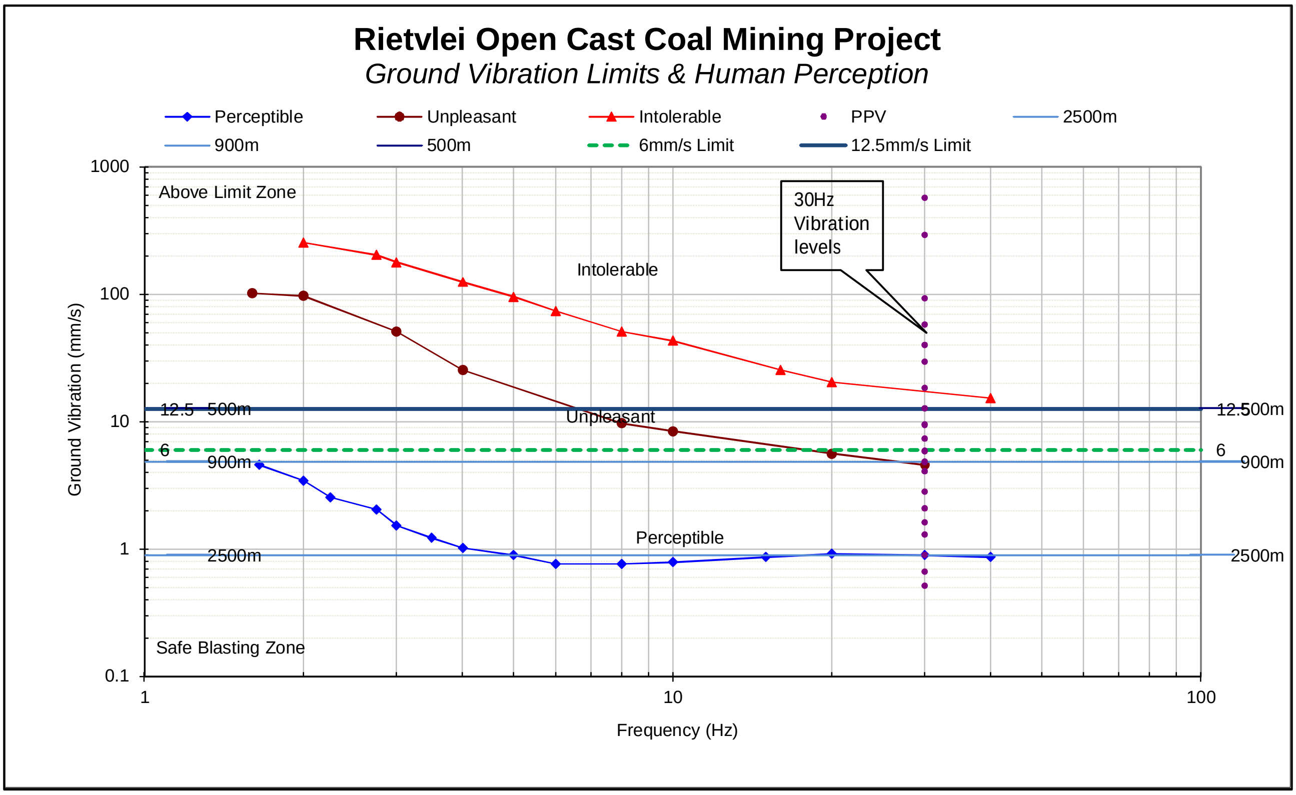


Figure 15: The effect of ground vibration with human perception and vibration limits

8.2.1.5 Vibration impact on roads

The R555 on the north western side of the project area provides access to the project area via Middelburg and is at closest distance 369m from the pit area with no specific concern. The R104 is approximately 7km to the south of the site. The gravel road giving access to the farms and mines is routed directly through the project area and could be in danger of being damaged if consideration is not given to re-routing. The R555 located at 369 m is a concern with regards to safe boundary from blasting. Blasting the northern side of the pit may include the R555 when a 500m safe blasting area is established. The R555 is a very busy road and specific management of blasting operations in the northern side and management of the road during these blasts will have to be considered.

8.2.1.6 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. There are communities, farming areas and roads that are within the evaluated area of influence. There are structures in close proximity of the project area – 369m to 705m on the eastern and north western side of the Pit. Ground vibration levels at POI's 82, 87 and 88 could be regarded as unpleasant and intolerable at POI 99. Levels predicted for the maximum charge are within the limits of 25mm/s. Ground vibration levels at the rest of the structures are less than the limits proposed and will not require mitigation measures.

The importance of good public relations cannot be under stressed. People tend to react negatively on experiencing of effects from blasting such as ground vibration and air blast. Even at low levels when damage to structures is out of the question it may upset people. Proper and appropriate communication with neighbours about blasting, monitoring and actions done for proper control will be required.

8.2.1.7 Cracking of houses and consequent devaluation

The structures found in the areas of concern range from informal building style to brick and mortar structures. There are various farmsteads and farm workers housing found within the 3500m range from the mining area. Building style and materials will certainly contribute to additional cracking apart from influences such as blasting operations.

The presence of general vertical cracks, horizontal and diagonal cracks that are found in all structures does not need to indicate devaluation due to blasting operations but rather devaluation due to construction, building material, age, standards of building applied. Thus damage in the form of cracks will be present. Exact costing of devaluation for normal cracks observed is difficult to estimate. Mining operations may not have influence to change the status quo of any property if correct precautions are considered.

The proposed limits as applied in this document i.e. 6mm/s, 12.5mm/s and 25mm/s is considered sufficient to ensure that additional damage is not introduced to the different categories of structures. It is expected that, should levels of ground vibration be maintained within these limits, the possibility of inducing damage is limited.

8.2.1.8 Air blast

The effect of air blast, if not controlled properly, is in my opinion a factor that could be problematic. Maybe not in the sense of damage being induced but rather having an impact – even at low levels of roofs and windows that could result in complaints from people. In more than one case this effect is misunderstood and people consider this effect as being ground vibration and damaging to their house structures. Section 6 gives detail on the selection of the charge sizes applied.

As with ground vibration, evaluation is given for each structure with regards to the calculated levels of air blast and concerns if applicable. Evaluation is done in form of the criteria what humans experience and where by structures could be damaged. This is according to accepted criteria for prevention of damage to structures and when levels are low enough to have no significant influence. Tables are provided for each of the different charge modelling done with regards to Tag, Description, Specific Limit, Distance (m), Predicted Air blast (dB), and Possible Concern. The "Tag" No. is number corresponding to the location indicated on POI figures. "Description" indicates the type of the structure. The "Distance" is the distance between the structure and edge of the pit area. The "Air Blast (dB)" is the calculated air blast level at the structure and the "possible concern" indicates if there is any concern for structure damage or not or human perception. Indicators used are "Problematic" where there is real concern for possible damage, "Complaint" where people will be complaining due to the experienced effect on structures – not necessarily damaging, "Acceptable" is if levels are less than 120dB and low where there is very limited possibility that the levels will give rise to any influence on people or structures. Levels below 115dB could be considered as to be low or negligible possibility of influence.

Table 13 shows that the applied limits and recommended levels for each of the charges considered. The maximum charge may exceed limits at distances 200m. The recommended limit of 120dB is observed at distance of 800m. The medium charge shows possible exceedance of limit at 150m and recommended limit at 500m. The minimum charge shows exceedance of limit at 100m and recommended limit at 300m. This clearly indicates that with increased charge masses the distances of influence increases. An area of 900m influence would be possible if care is not taken to manage air blast levels.

Table 13: Expected air blast levels

Distance (m)	Air blast (dB) for 45kg Charge	Air blast (dB) for 267kg Charge	Air blast (dB) for 1069kg Charge
50.0	137	144	148
100.0	133	139	144
150.0	126	132	137
200.0	123	129	134
250.0	121	127	132
300.0	119	125	130
400.0	116	122	127
500.0	113	120	124
600.0	112	118	123

700.0	110	116	121
800.0	109	115	120
900.0	107	114	118
1000.0	106	112	117
1250.0	104	110	115
1500.0	102	108	113
1750.0	100	107	111
2000.0	99	105	110
2500.0	97	103	108
3000.0	95	101	106
3500.0	93	99	104

Presented herewith are the expected air blast level contours. Discussion of level of air blast and relevant influences are also given for the pit area. Air blast was calculated and modelled from the boundary for minimum, medium and maximum charge mass at specific distances from each of the pit areas. This means that air blast is taken from the edge – the most outer point of the pit area on plan as if it would be the closest place where drilling and blasting will be done to the area of influence. The calculated levels are then plotted and overlaid with current mining plans to observe possible influences at POI's identified. Air blast predictions were done considering distances ranging from 50 to 3500m around the opencast mining area.

8.2.1.9 Review of expected air blast

Presented are simulations for expected air blast levels from three different charge masses. Minimum, medium and maximum charge evaluations are shown in the figures below and summary table of outcome given after each charge configuration air blast contour.

Colour codes used in tables are as follows:

Air blast levels higher than proposed limit are coloured "Mustard"
Air blast levels indicated as possible Complaint are coloured "Yellow"

- **Minimum Charge per Delay – Pit Area - 45kg**

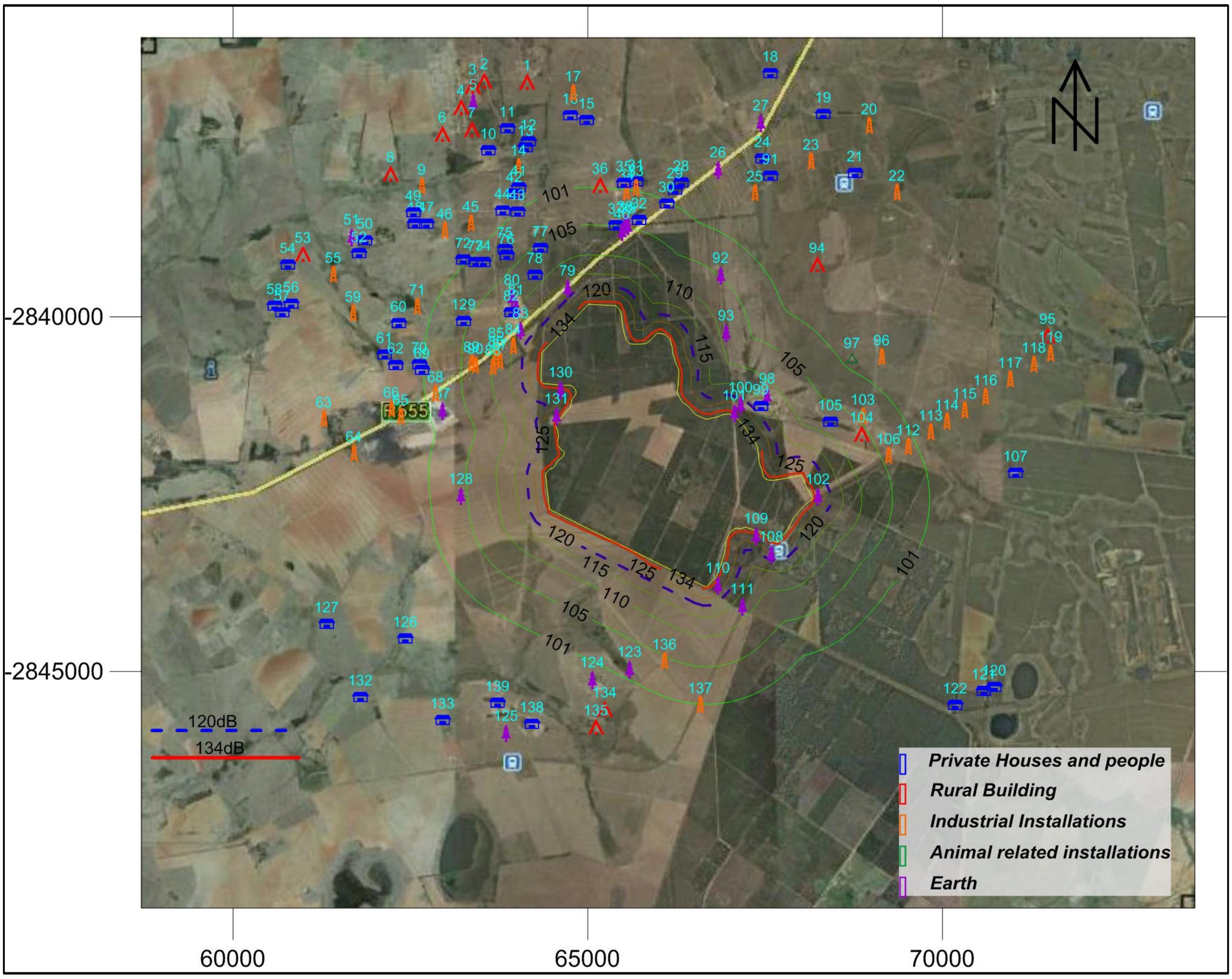


Figure 16: Air blast influence from minimum charge

Table 14: Air blast evaluation for minimum charge

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
1	Informal Settlement Houses	2	3255	93.9	Acceptable
2	Informal Settlement Houses	2	3480	93.2	Acceptable
3	Informal Settlement Houses	2	3486	93.2	Acceptable
4	Informal Settlement Houses	2	3311	93.7	Acceptable
5	Sports Terrain	5	3285	93.8	Acceptable
6	Informal Settlement Houses	2	3166	94.2	Acceptable
7	Informal Settlement Houses	2	2967	94.9	Acceptable
8	Ruins	2	3290	93.8	Acceptable
9	Dam	4	2848	95.3	N/A
10	Farm Buildings/Structures	1	2592	96.3	Acceptable
11	Buildings/Structures	1	2734	95.7	Acceptable
12	Buildings/Structures	1	2450	96.9	Acceptable
13	Buildings/Structures	1	2388	97.2	Acceptable
14	Dam	4	2179	98.1	N/A
15	Buildings/Structures	1	2602	96.3	Acceptable
16	Buildings/Structures	1	2679	96.0	Acceptable

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
17	Cement Dams	4	2989	94.8	N/A
18	Buildings/Structures	1	3940	91.9	Acceptable
19	Buildings/Structures	1	3831	92.2	Acceptable
20	Dam	4	4117	91.5	N/A
21	Buildings/Structures	1	3510	93.1	Acceptable
22	Dam	4	3818	92.3	N/A
23	Pivot Irrigation	4	3200	94.1	N/A
24	Building/Structure	1	2844	95.3	Acceptable
25	Dam	4	2373	97.2	N/A
26	Crossing R555 and Road	5	2405	97.1	N/A
27	RGW14 (Monitoring Borehole)	5	3285	93.8	N/A
28	Buildings/Structures	1	1976	99.1	Acceptable
29	Buildings/Structures	1	1845	99.8	Acceptable
30	Buildings/Structures	1	1620	101.2	Acceptable
31	Buildings/Structures	1	1784	100.2	Acceptable
32	Farm Buildings/Structures	1	1266	103.8	Acceptable
33	Dam	4	1699	100.7	N/A
34	Cement Dam	4	1621	101.2	N/A
35	Buildings/Structures	1	1742	100.4	Acceptable
36	Ruins	2	1694	100.7	Acceptable
37	Farm Buildings/Structures	1	1140	104.9	Acceptable
38	RGW20 (Monitoring Borehole)	5	1172	104.6	N/A
39	RGW16 (Monitoring Borehole)	5	1150	104.8	N/A
40	RGW17 (Monitoring Borehole)	5	1059	105.6	N/A
41	Buildings/Structures	1	1924	99.4	Acceptable
42	Buildings/Structures	1	1883	99.6	Acceptable
43	Buildings/Structures	1	1651	101.0	Acceptable
44	Buildings/Structures	1	1795	100.1	Acceptable
45	Dam	4	1990	99.1	N/A
46	Cement Dam	4	2185	98.1	N/A
47	Farm Buildings/Structures	1	2439	96.9	Acceptable
48	Buildings/Structures	1	2556	96.4	Acceptable
49	Buildings/Structures	1	2681	95.9	Acceptable
50	Buildings/Structures	1	2958	94.9	Acceptable
51	RGW29 (Monitoring Borehole)	5	3142	94.3	N/A
52	Buildings/Structures	1	2935	95.0	Acceptable
53	Ruins	2	3645	92.7	Acceptable
54	Buildings/Structures	1	3790	92.3	Acceptable
55	Dam	4	3140	94.3	N/A
56	Farm Buildings/Structures	1	3600	92.9	Acceptable
57	Farm Buildings/Structures	1	3703	92.6	Acceptable
58	Farm Buildings/Structures	1	3825	92.2	Acceptable
59	Dam	4	2717	95.8	N/A
60	Buildings/Structures	1	2059	98.7	Acceptable
61	Buildings/Structures	1	2213	97.9	Acceptable
62	Buildings/Structures	1	2051	98.7	Acceptable
63	Dam	4	3107	94.4	N/A
64	Dam	4	2721	95.8	N/A
65	Dam	4	2039	98.8	N/A
66	Dam	4	2145	98.3	N/A
67	Mine Activity	5	1450	102.4	Acceptable
68	Telephone Line	4	1499	102.0	N/A
69	Buildings/Structures	1	1678	100.8	Acceptable
70	Buildings/Structures	1	1718	100.6	Acceptable
71	Dam	4	1873	99.7	N/A

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
72	Buildings/Structures	1	1711	100.6	Acceptable
73	Buildings/Structures	1	1560	101.6	Acceptable
74	Buildings/Structures	1	1481	102.1	Acceptable
75	Buildings/Structures	1	1391	102.8	Acceptable
76	Buildings/Structures	1	1312	103.4	Acceptable
77	Buildings/Structures	1	1048	105.7	Acceptable
78	Buildings/Structures	1	832	108.1	Acceptable
79	R555 Road	5	369	116.6	N/A
80	RGW23 (Monitoring Borehole)	5	845	108.0	N/A
81	RGW22 (Monitoring Borehole)	5	707	109.8	N/A
82	Buildings/Structures	1	705	109.9	Acceptable
83	R555 Road	5	434	114.9	N/A
84	Communication Tower	4	413	115.4	N/A
85	Telephone Line	4	643	110.8	N/A
86	Weighbridge(Neighbouring Mine)	4	639	110.9	N/A
87	Neighbouring Mine Office	4	585	111.8	Acceptable
88	Workshop(Neighbouring Mine)	4	680	110.2	Acceptable
89	Cement Dam	4	982	106.4	N/A
90	Telephone Line	4	926	107.0	N/A
91	Buildings/Structures	1	2694	95.9	Acceptable
92	Road	5	1146	104.8	N/A
93	Road	5	791	108.7	N/A
94	Ruins	2	2334	97.4	N/A
95	Ruins	2	4000	91.8	N/A
96	Dam	4	2034	98.8	N/A
97	Farm Animal Structures	3	1788	100.2	Acceptable
98	RGW1 (Monitoring Borehole)	5	529	112.9	N/A
99	Buildings/Structures	1	369	116.6	Acceptable
100	RGW2 (Monitoring Borehole)	5	194	123.3	N/A
101	Road	5	57	136.0	N/A
102	Railroad	5	87	131.7	N/A
103	Dam	4	1216	104.2	N/A
104	Informal Settlement Houses	2	1041	105.8	Acceptable
105	Buildings/Structures	1	877	107.6	Acceptable
106	Sub Station	4	1235	104.0	Acceptable
107	Structure	1	2888	95.2	Acceptable
108	Railroad	5	192	123.4	N/A
109	Pan	5	74	133.3	N/A
110	Road	5	103	130.0	N/A
111	Railroad	5	555	112.4	N/A
112	Power lines/Pylons	4	1539	101.7	N/A
113	Power lines/Pylons	4	1913	99.5	N/A
114	Power lines/Pylons	4	2186	98.1	N/A
115	Power lines/Pylons	4	2478	96.8	N/A
116	Power lines/Pylons	4	2826	95.4	N/A
117	Power lines/Pylons	4	3246	94.0	N/A
118	Power lines/Pylons	4	3637	92.8	N/A
119	Power lines/Pylons	4	3916	92.0	N/A
120	Graveyard (GY01)	1	3662	92.7	N/A
121	Farm Buildings/Structures	1	3578	92.9	Acceptable
122	Buildings/Structures	1	3411	93.4	Acceptable
123	RGW6 (Monitoring Borehole)	5	1511	101.9	N/A
124	RGW5 (Monitoring Borehole)	5	1877	99.7	N/A
125	RGW9 (Monitoring Borehole)	5	3093	94.5	N/A
126	Buildings/Structures	1	2734	95.7	Acceptable

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
127	Buildings/Structures	1	3535	93.1	Acceptable
128	RGW10 (Monitoring Borehole)	5	1218	104.2	N/A
129	Buildings/Structures	1	1191	104.4	Acceptable
130	Pan	5	64	134.9	N/A
131	Pan	5	61	135.3	N/A
132	Farm Buildings/Structures	1	3758	92.4	Acceptable
133	Buildings/Structures	1	3324	93.7	Acceptable
134	Informal Settlement Houses	2	2170	98.2	Acceptable
135	Informal Settlement Houses	2	2450	96.9	Acceptable
136	Cement Dam	4	1189	104.4	N/A
137	Cement Dam	4	1660	100.9	N/A
138	Farm Buildings/Structures	1	2813	95.4	Acceptable
139	Farm Buildings/Structures	1	2762	95.6	Acceptable

- **Medium Charge per Delay – Pit Area - 267kg**

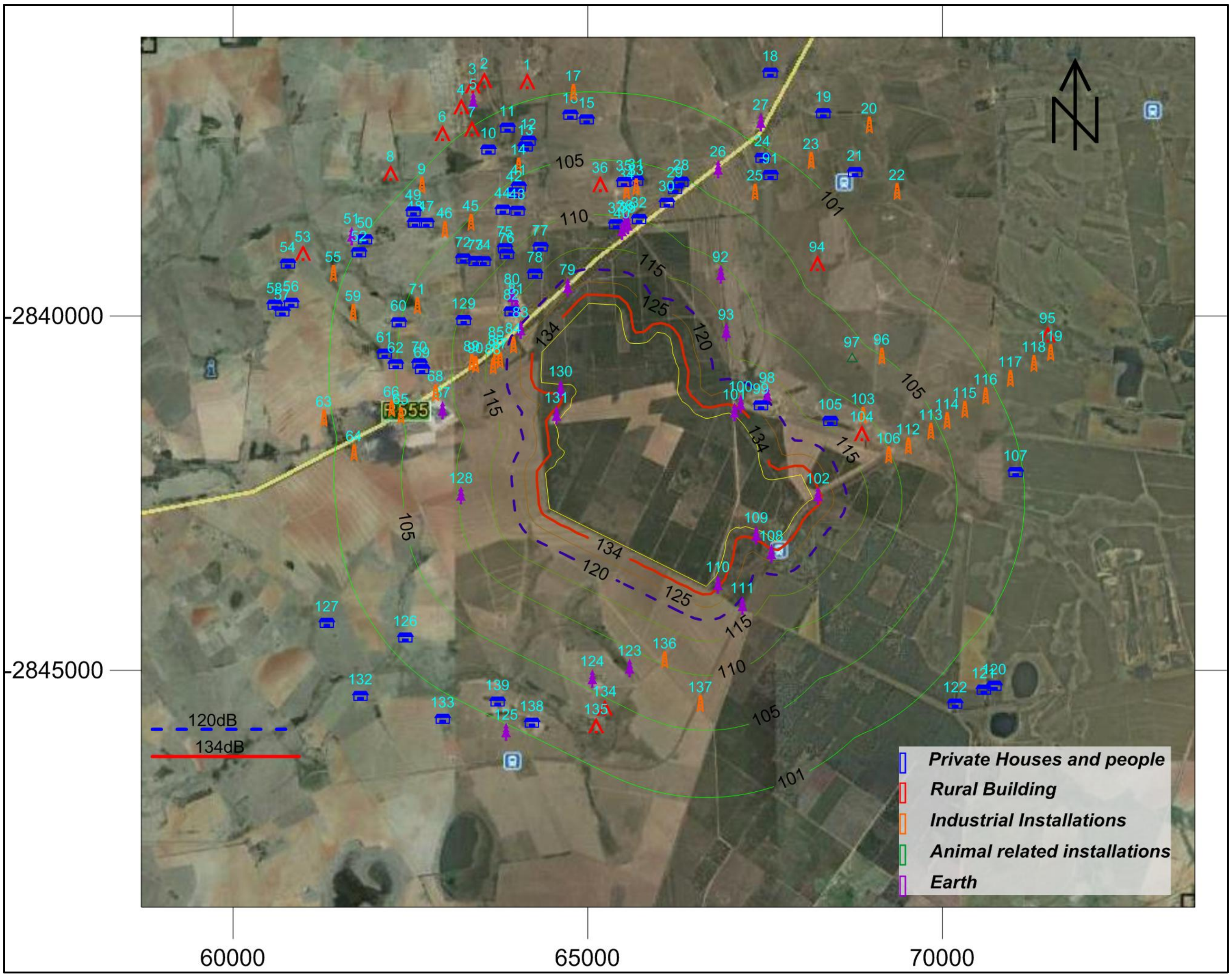


Figure 17: Air blast influence from medium charge

Table 15: Air blast evaluation for medium charge

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
1	Informal Settlement Houses	2	3255	100.1	Acceptable
2	Informal Settlement Houses	2	3480	99.4	Acceptable
3	Informal Settlement Houses	2	3486	99.4	Acceptable
4	Informal Settlement Houses	2	3311	99.9	Acceptable
5	Sports Terrain	5	3285	100.0	Acceptable
6	Informal Settlement Houses	2	3166	100.4	Acceptable
7	Informal Settlement Houses	2	2967	101.1	Acceptable
8	Ruins	2	3290	100.0	Acceptable
9	Dam	4	2848	101.5	N/A
10	Farm Buildings/Structures	1	2592	102.5	Acceptable
11	Buildings/Structures	1	2734	101.9	Acceptable
12	Buildings/Structures	1	2450	103.1	Acceptable
13	Buildings/Structures	1	2388	103.3	Acceptable
14	Dam	4	2179	104.3	N/A
15	Buildings/Structures	1	2602	102.4	Acceptable
16	Buildings/Structures	1	2679	102.1	Acceptable
17	Cement Dams	4	2989	101.0	N/A
18	Buildings/Structures	1	3940	98.1	Acceptable
19	Buildings/Structures	1	3831	98.4	Acceptable
20	Dam	4	4117	97.7	N/A
21	Buildings/Structures	1	3510	99.3	Acceptable
22	Dam	4	3818	98.4	N/A
23	Pivot Irrigation	4	3200	100.3	N/A
24	Building/Structure	1	2844	101.5	Acceptable
25	Dam	4	2373	103.4	N/A
26	Crossing R555 and Road	5	2405	103.3	N/A
27	RGW14 (Monitoring Borehole)	5	3285	100.0	N/A
28	Buildings/Structures	1	1976	105.3	Acceptable
29	Buildings/Structures	1	1845	106.0	Acceptable
30	Buildings/Structures	1	1620	107.4	Acceptable
31	Buildings/Structures	1	1784	106.4	Acceptable
32	Farm Buildings/Structures	1	1266	110.0	Acceptable
33	Dam	4	1699	106.9	N/A
34	Cement Dam	4	1621	107.4	N/A
35	Buildings/Structures	1	1742	106.6	Acceptable
36	Ruins	2	1694	106.9	Acceptable
37	Farm Buildings/Structures	1	1140	111.1	Acceptable
38	RGW20 (Monitoring Borehole)	5	1172	110.8	N/A
39	RGW16 (Monitoring Borehole)	5	1150	111.0	N/A
40	RGW17 (Monitoring Borehole)	5	1059	111.8	N/A
41	Buildings/Structures	1	1924	105.6	Acceptable
42	Buildings/Structures	1	1883	105.8	Acceptable
43	Buildings/Structures	1	1651	107.2	Acceptable
44	Buildings/Structures	1	1795	106.3	Acceptable
45	Dam	4	1990	105.2	N/A
46	Cement Dam	4	2185	104.3	N/A
47	Farm Buildings/Structures	1	2439	103.1	Acceptable
48	Buildings/Structures	1	2556	102.6	Acceptable
49	Buildings/Structures	1	2681	102.1	Acceptable
50	Buildings/Structures	1	2958	101.1	Acceptable
51	RGW29 (Monitoring Borehole)	5	3142	100.5	N/A
52	Buildings/Structures	1	2935	101.2	Acceptable
53	Ruins	2	3645	98.9	Acceptable

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
54	Buildings/Structures	1	3790	98.5	Acceptable
55	Dam	4	3140	100.5	N/A
56	Farm Buildings/Structures	1	3600	99.1	Acceptable
57	Farm Buildings/Structures	1	3703	98.8	Acceptable
58	Farm Buildings/Structures	1	3825	98.4	Acceptable
59	Dam	4	2717	102.0	N/A
60	Buildings/Structures	1	2059	104.9	Acceptable
61	Buildings/Structures	1	2213	104.1	Acceptable
62	Buildings/Structures	1	2051	104.9	Acceptable
63	Dam	4	3107	100.6	N/A
64	Dam	4	2721	102.0	N/A
65	Dam	4	2039	105.0	N/A
66	Dam	4	2145	104.5	N/A
67	Mine Activity	5	1450	108.5	Acceptable
68	Telephone Line	4	1499	108.2	N/A
69	Buildings/Structures	1	1678	107.0	Acceptable
70	Buildings/Structures	1	1718	106.8	Acceptable
71	Dam	4	1873	105.9	N/A
72	Buildings/Structures	1	1711	106.8	Acceptable
73	Buildings/Structures	1	1560	107.8	Acceptable
74	Buildings/Structures	1	1481	108.3	Acceptable
75	Buildings/Structures	1	1391	109.0	Acceptable
76	Buildings/Structures	1	1312	109.6	Acceptable
77	Buildings/Structures	1	1048	111.9	Acceptable
78	Buildings/Structures	1	832	114.3	Acceptable
79	R555 Road	5	369	122.8	N/A
80	RGW23 (Monitoring Borehole)	5	845	114.2	N/A
81	RGW22 (Monitoring Borehole)	5	707	116.0	N/A
82	Buildings/Structures	1	705	116.1	Acceptable
83	R555 Road	5	434	121.1	N/A
84	Communication Tower	4	413	121.6	N/A
85	Telephone Line	4	643	117.0	N/A
86	Weighbridge(Neighbouring Mine)	4	639	117.1	N/A
87	Neighbouring Mine Office	4	585	118.0	Acceptable
88	Workshop(Neighbouring Mine)	4	680	116.4	Acceptable
89	Cement Dam	4	982	112.6	N/A
90	Telephone Line	4	926	113.2	N/A
91	Buildings/Structures	1	2694	102.1	Acceptable
92	Road	5	1146	111.0	N/A
93	Road	5	791	114.9	N/A
94	Ruins	2	2334	103.6	N/A
95	Ruins	2	4000	98.0	N/A
96	Dam	4	2034	105.0	N/A
97	Farm Animal Structures	3	1788	106.4	Acceptable
98	RGW1 (Monitoring Borehole)	5	529	119.1	N/A
99	Buildings/Structures	1	369	122.8	Complaint
100	RGW2 (Monitoring Borehole)	5	194	129.5	N/A
101	Road	5	57	142.2	N/A
102	Railroad	5	87	137.9	N/A
103	Dam	4	1216	110.4	N/A
104	Informal Settlement Houses	2	1041	112.0	Acceptable
105	Buildings/Structures	1	877	113.8	Acceptable
106	Sub Station	4	1235	110.2	Acceptable
107	Structure	1	2888	101.4	Acceptable
108	Railroad	5	192	129.6	N/A

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
109	Pan	5	74	139.5	N/A
110	Road	5	103	136.2	N/A
111	Railroad	5	555	118.5	N/A
112	Power lines/Pylons	4	1539	107.9	N/A
113	Power lines/Pylons	4	1913	105.6	N/A
114	Power lines/Pylons	4	2186	104.3	N/A
115	Power lines/Pylons	4	2478	103.0	N/A
116	Power lines/Pylons	4	2826	101.6	N/A
117	Power lines/Pylons	4	3246	100.1	N/A
118	Power lines/Pylons	4	3637	99.0	N/A
119	Power lines/Pylons	4	3916	98.2	N/A
120	Graveyard (GY01)	1	3662	98.9	N/A
121	Farm Buildings/Structures	1	3578	99.1	Acceptable
122	Buildings/Structures	1	3411	99.6	Acceptable
123	RGW6 (Monitoring Borehole)	5	1511	108.1	N/A
124	RGW5 (Monitoring Borehole)	5	1877	105.9	N/A
125	RGW9 (Monitoring Borehole)	5	3093	100.6	N/A
126	Buildings/Structures	1	2734	101.9	Acceptable
127	Buildings/Structures	1	3535	99.3	Acceptable
128	RGW10 (Monitoring Borehole)	5	1218	110.4	N/A
129	Buildings/Structures	1	1191	110.6	Acceptable
130	Pan	5	64	141.1	N/A
131	Pan	5	61	141.5	N/A
132	Farm Buildings/Structures	1	3758	98.6	Acceptable
133	Buildings/Structures	1	3324	99.9	Acceptable
134	Informal Settlement Houses	2	2170	104.3	Acceptable
135	Informal Settlement Houses	2	2450	103.1	Acceptable
136	Cement Dam	4	1189	110.6	N/A
137	Cement Dam	4	1660	107.1	N/A
138	Farm Buildings/Structures	1	2813	101.6	Acceptable
139	Farm Buildings/Structures	1	2762	101.8	Acceptable

- **Maximum Charge per Delay – Pit Area - 1069kg**

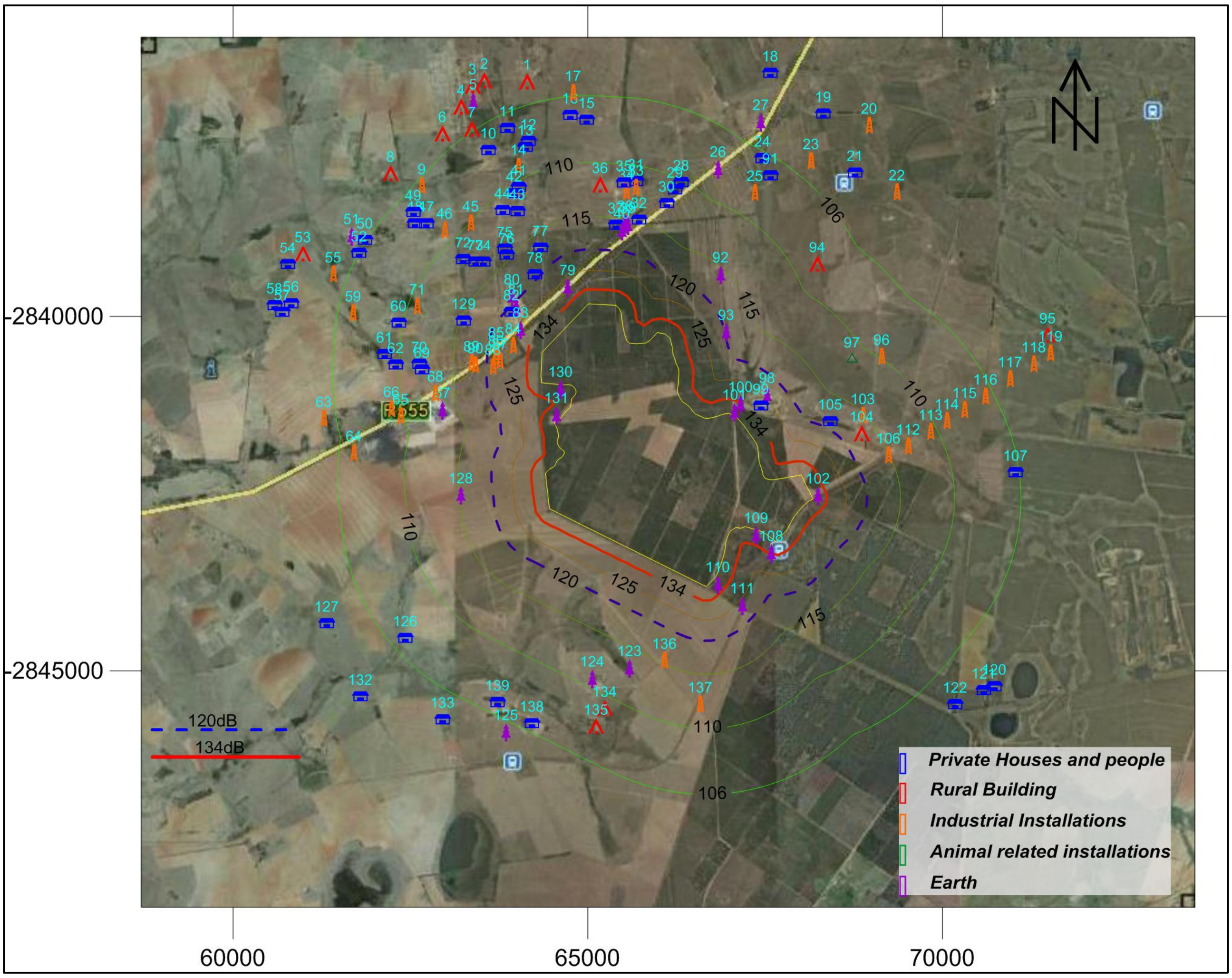


Figure 18: Air blast influence from maximum charge

Table 16: Air blast evaluation for maximum charge

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
1	Informal Settlement Houses	2	3255	104.9	Acceptable
2	Informal Settlement Houses	2	3480	104.2	Acceptable
3	Informal Settlement Houses	2	3486	104.2	Acceptable
4	Informal Settlement Houses	2	3311	104.8	Acceptable
5	Sports Terrain	5	3285	104.8	Acceptable
6	Informal Settlement Houses	2	3166	105.2	Acceptable
7	Informal Settlement Houses	2	2967	105.9	Acceptable
8	Ruins	2	3290	104.8	Acceptable
9	Dam	4	2848	106.3	N/A
10	Farm Buildings/Structures	1	2592	107.3	Acceptable
11	Buildings/Structures	1	2734	106.7	Acceptable
12	Buildings/Structures	1	2450	107.9	Acceptable
13	Buildings/Structures	1	2388	108.2	Acceptable
14	Dam	4	2179	109.1	N/A
15	Buildings/Structures	1	2602	107.3	Acceptable
16	Buildings/Structures	1	2679	107.0	Acceptable
17	Cement Dams	4	2989	105.8	N/A
18	Buildings/Structures	1	3940	102.9	Acceptable

19	Buildings/Structures	1	3831	103.2	Acceptable
20	Dam	4	4117	102.5	N/A
21	Buildings/Structures	1	3510	104.1	Acceptable
22	Dam	4	3818	103.3	N/A
23	Pivot Irrigation	4	3200	105.1	N/A
24	Building/Structure	1	2844	106.3	Acceptable
25	Dam	4	2373	108.2	N/A
26	Crossing R555 and Road	5	2405	108.1	N/A
27	RGW14 (Monitoring Borehole)	5	3285	104.8	N/A
28	Buildings/Structures	1	1976	110.1	Acceptable
29	Buildings/Structures	1	1845	110.8	Acceptable
30	Buildings/Structures	1	1620	112.2	Acceptable
31	Buildings/Structures	1	1784	111.2	Acceptable
32	Farm Buildings/Structures	1	1266	114.8	Acceptable
33	Dam	4	1699	111.7	N/A
34	Cement Dam	4	1621	112.2	N/A
35	Buildings/Structures	1	1742	111.4	Acceptable
36	Ruins	2	1694	111.7	Acceptable
37	Farm Buildings/Structures	1	1140	115.9	Acceptable
38	RGW20 (Monitoring Borehole)	5	1172	115.6	N/A
39	RGW16 (Monitoring Borehole)	5	1150	115.8	N/A
40	RGW17 (Monitoring Borehole)	5	1059	116.6	N/A
41	Buildings/Structures	1	1924	110.4	Acceptable
42	Buildings/Structures	1	1883	110.6	Acceptable
43	Buildings/Structures	1	1651	112.0	Acceptable
44	Buildings/Structures	1	1795	111.1	Acceptable
45	Dam	4	1990	110.1	N/A
46	Cement Dam	4	2185	109.1	N/A
47	Farm Buildings/Structures	1	2439	107.9	Acceptable
48	Buildings/Structures	1	2556	107.4	Acceptable
49	Buildings/Structures	1	2681	107.0	Acceptable
50	Buildings/Structures	1	2958	105.9	Acceptable
51	RGW29 (Monitoring Borehole)	5	3142	105.3	N/A
52	Buildings/Structures	1	2935	106.0	Acceptable
53	Ruins	2	3645	103.8	Acceptable
54	Buildings/Structures	1	3790	103.3	Acceptable
55	Dam	4	3140	105.3	N/A
56	Farm Buildings/Structures	1	3600	103.9	Acceptable
57	Farm Buildings/Structures	1	3703	103.6	Acceptable
58	Farm Buildings/Structures	1	3825	103.2	Acceptable
59	Dam	4	2717	106.8	N/A
60	Buildings/Structures	1	2059	109.7	Acceptable
61	Buildings/Structures	1	2213	109.0	Acceptable
62	Buildings/Structures	1	2051	109.7	Acceptable
63	Dam	4	3107	105.4	N/A
64	Dam	4	2721	106.8	N/A
65	Dam	4	2039	109.8	N/A
66	Dam	4	2145	109.3	N/A
67	Mine Activity	5	1450	113.4	Acceptable
68	Telephone Line	4	1499	113.0	N/A
69	Buildings/Structures	1	1678	111.8	Acceptable
70	Buildings/Structures	1	1718	111.6	Acceptable
71	Dam	4	1873	110.7	N/A
72	Buildings/Structures	1	1711	111.6	Acceptable
73	Buildings/Structures	1	1560	112.6	Acceptable
74	Buildings/Structures	1	1481	113.1	Acceptable
75	Buildings/Structures	1	1391	113.8	Acceptable

76	Buildings/Structures	1	1312	114.4	Acceptable
77	Buildings/Structures	1	1048	116.7	Acceptable
78	Buildings/Structures	1	832	119.2	Acceptable
79	R555 Road	5	369	127.6	N/A
80	RGW23 (Monitoring Borehole)	5	845	119.0	N/A
81	RGW22 (Monitoring Borehole)	5	707	120.8	N/A
82	Buildings/Structures	1	705	120.9	Complaint
83	R555 Road	5	434	125.9	N/A
84	Communication Tower	4	413	126.5	N/A
85	Telephone Line	4	643	121.8	N/A
86	Weighbridge(Neighbouring Mine)	4	639	121.9	N/A
87	Neighbouring Mine Office	4	585	122.8	Complaint
88	Workshop(Neighbouring Mine)	4	680	121.3	Complaint
89	Cement Dam	4	982	117.4	N/A
90	Telephone Line	4	926	118.0	N/A
91	Buildings/Structures	1	2694	106.9	Acceptable
92	Road	5	1146	115.8	N/A
93	Road	5	791	119.7	N/A
94	Ruins	2	2334	108.4	N/A
95	Ruins	2	4000	102.8	N/A
96	Dam	4	2034	109.8	N/A
97	Farm Animal Structures	3	1788	111.2	Acceptable
98	RGW1 (Monitoring Borehole)	5	529	123.9	N/A
99	Buildings/Structures	1	369	127.6	Complaint
100	RGW2 (Monitoring Borehole)	5	194	134.3	N/A
101	Road	5	57	147.0	N/A
102	Railroad	5	87	142.7	N/A
103	Dam	4	1216	115.2	N/A
104	Informal Settlement Houses	2	1041	116.8	Acceptable
105	Buildings/Structures	1	877	118.6	Acceptable
106	Sub Station	4	1235	115.0	Acceptable
107	Structure	1	2888	106.2	Acceptable
108	Railroad	5	192	134.4	N/A
109	Pan	5	74	144.3	N/A
110	Road	5	103	141.0	N/A
111	Railroad	5	555	123.4	N/A
112	Power lines/Pylons	4	1539	112.7	N/A
113	Power lines/Pylons	4	1913	110.5	N/A
114	Power lines/Pylons	4	2186	109.1	N/A
115	Power lines/Pylons	4	2478	107.8	N/A
116	Power lines/Pylons	4	2826	106.4	N/A
117	Power lines/Pylons	4	3246	105.0	N/A
118	Power lines/Pylons	4	3637	103.8	N/A
119	Power lines/Pylons	4	3916	103.0	N/A
120	Graveyard (GY01)	1	3662	103.7	N/A
121	Farm Buildings/Structures	1	3578	103.9	Acceptable
122	Buildings/Structures	1	3411	104.4	Acceptable
123	RGW6 (Monitoring Borehole)	5	1511	112.9	N/A
124	RGW5 (Monitoring Borehole)	5	1877	110.7	N/A
125	RGW9 (Monitoring Borehole)	5	3093	105.5	N/A
126	Buildings/Structures	1	2734	106.8	Acceptable
127	Buildings/Structures	1	3535	104.1	Acceptable
128	RGW10 (Monitoring Borehole)	5	1218	115.2	N/A
129	Buildings/Structures	1	1191	115.4	Acceptable
130	Pan	5	64	145.9	N/A
131	Pan	5	61	146.3	N/A
132	Farm Buildings/Structures	1	3758	103.4	Acceptable

133	Buildings/Structures	1	3324	104.7	Acceptable
134	Informal Settlement Houses	2	2170	109.2	Acceptable
135	Informal Settlement Houses	2	2450	107.9	Acceptable
136	Cement Dam	4	1189	115.4	N/A
137	Cement Dam	4	1660	111.9	N/A
138	Farm Buildings/Structures	1	2813	106.5	Acceptable
139	Farm Buildings/Structures	1	2762	106.6	Acceptable

8.2.1.10 Summary of findings for air blast

Review of the air blast levels indicates fewer concerns than ground vibration. Air blast predicted for the maximum charge ranges between 102.8 and 127.6dB where structures are of concern. The minimum and medium charge showed lower levels. There are four POI's identified where air blast could cause reason for complaints. These structures are located on the eastern and north western side – POI 82 at 705m, POI 87 at 585m, POI 88 at 680m, and POI 99 at 369m.

Structures within 250m from the pit boundaries could possibly experience air blast that is problematic and structures found up to 1000m could experience levels of air blast that could contribute to complaints particularly from maximum charge used. Complaints from air blast are normally based on the actual effects that are experienced due to rattling of roof, windows, doors etc. These effects could startle people and raise concern of possible damage.

The possible negative effects from air blast are expected to be less than that of ground vibration. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. This pit is located such that "free blasting" – meaning no controls on blast preparation – will not be possible.

8.2.1.11 Fly-rock Modelling Results and Impact of fly rock

Review of the factors that contribute to fly rock it is certain that if no stemming control is exerted there will be fly rock. The designed stemming length of 4.2m for blasting will yield possible fly rock up to distances of 126m. Possible reduction of stemming length will see increased fly rock travel distances. This predicted fly rock distance does include identified POI's for pit area. The R555 is worth mentioning although located at 369m and further than 126m. If stemming lengths are not maintained fly rock could be problematic specifically with the traffic on the R555. The railway on the southern side and gravel roads are also of concern. The pit area is close to the railway. Train schedules and management of blasting times with stemming controls will be required. Figure 19 below shows the relationship burden or stemming length towards expected throw distance. Throw distance considered here on the same level as the free face. Landing level of elements lower than free face could see longer distances. Optimal throw distance is also observed at 45 degree angles of departure. Careful attention will need to be given to stemming control to ensure that fly rock minimised as much as possible.

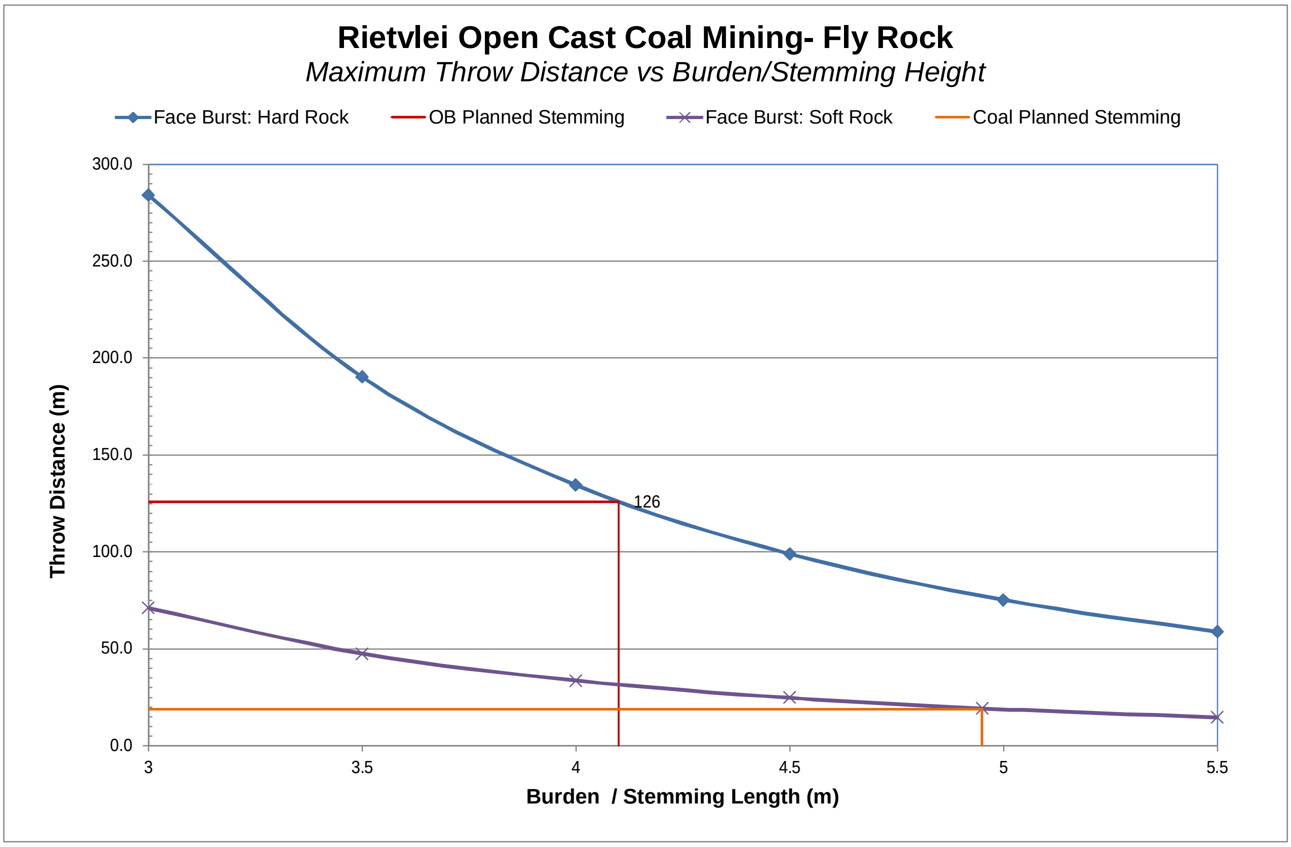


Figure 19: Predicted Fly rock

8.2.1.12 Noxious fumes Influence Results

The occurrence of fumes in the form the NOx gaseous format is not a given and very dependent on various factors. However the occurrences of fumes should be closely monitored. It is not assumed that fumes will travel to any part nearby farm stead but again if anybody is present in the path of cloud travel it could be problematic.

8.2.1.13 Water well influence

13 Monitoring Boreholes are located in the area at distances ranging from 194m to 3285m from the pit area. Ground vibration levels at one of these boreholes (RGW2) are higher than their limit at 60.7mm/s, the rest of the boreholes are within their limits of 50mm/s. It is expected that ground vibration due to blasting operations will have no influence on these boreholes.

8.2.1.14 Vibration impacts on productivity of farm animals (cattle, chickens, pigs, etc.)

The topography is classed as moderately undulating plains and pans and the landscape is characterized by relatively little topographic variation. Land use in the study area is dominated by cultivation and grazing and typical crops under irrigation with a possibility of cattle in the area. There are farm animal structures located east of the pit area at approximately 1788m away. It may be anticipated that cattle could be present at close proximity in the area. It is however considered important that the aspect of influence from blasting is addressed as well.

The influence on productivity of animals over period of time due to blasting operations is not clearly defined and difficult to estimate. Social behaviour and change of social behaviour is unfortunately problematic. It is however the author's opinion that influence will be experienced when animals are located permanently in close proximity of blasting operations. At larger distances, estimated in the region of 500m and greater, cattle or game will get accustomed to the blasting and related noise. This is based on observations made personally when blasting is done and cattle are present.
Review of the charging configurations and air blast levels expected it is clear that in order to induce lung / ear injury or death, animals will have to very close to the blast. This is excluding fright and secondary injury or from flying debris. I do believe that cattle will get used to the blasting operations and fly rock may be the most likely cause of injury or death if not removed to safe distance. As an example review of the pressures required to cause lung damage in larger animals is at 10psi (68.59kPa) to 15psi (103.4kPa). This relates to air blast levels in the order of 190dB (L) and 195dB (L). Table 17 below shows that it will be required that animals be on the blast and again showing that factors apart from air blast would cause death. The following table (Table 17) show air blast levels in dB and kPa at short increment distances from the blast based on the maximum charge used in this report.

Table 17: Expected air blast levels in dB and kilopascal's for short distance increments.

Distance (m)	Air Blast Pressure Levels for Maximum Charge in dB	Air Blast Pressure Levels for Maximum Charge in kPa
5.0	175	10.99
10.0	168	4.79
15.0	163	2.94
20.0	160	2.08
25.0	158	1.59
30.0	156	1.28
35.0	155	1.06
40.0	153	0.91
45.0	152	0.79
50.0	151	0.69

Considering the above information it is certain that injury to animals such as cattle / goats is highly unlikely due to the fact that cattle should never be allowed on top of a blast area. The effect from the blast itself is then more likely to be lethal. It is anticipated that the mining area will be fenced off and animals not be present inside the mining area.

The above excludes the impact on social behaviour in animals. This subject is not yet fully understood in the industry as little research or work has been done on this.

8.2.2 Potential Environmental Impact Assessment: Operational Phase

Assessment Methodology

The following risk assessment model will be used for determination of the *significance* of impacts.

SIGNIFICANCE = (MAGNITUDE + DURATION + SCALE) X PROBABILITY

The maximum potential value for significance of an impact is 100 points. Environmental impacts can therefore be rated as high, medium or low significance on the following basis:

- High environmental significance 60 – 100 points
- Medium environmental significance 30 – 59 points
- Low environmental significance 0 – 29 points

The following table indicates the scale used to determine the overall ranking.

Table 18: Indicates the scale used to determine the overall ranking.

Magnitude (M)	Duration (D)
10 – Very high (or unknown)	5 – Permanent
8 – High	4 – Long-term (ceases at the end of operation)
6 – Moderate	3 – Medium-term (5-15 years)
4 – Low	2 – Short-term (0-5 years)
2 - Minor	1 - Immediate
Scale (S)	**Probability (P)**
5 – International	5 – Definite (or unknown)
4 – National	4 – High probability
3 – Regional	3 – Medium probability
2 – Local	2 – Low probability
1 – Site	1 – Improbable
0 – None	0 – None

The quantification of impacts is calculated for each **Activity** associated with the proposed mining operation for each **phase** of the operation i.e. Construction, Operation, Decommissioning, and Post-closure. The **Activities** related to the operation are:

- **Mining of the opencast pit**
  The removal of vegetation, stripping of topsoil, removal of overburden and mining of chrome (restricted to the opencast pit) and concurrent rehabilitation.
- **Transportation, Materials Handling and Storage**
  Surface infrastructure and services, including the mobile crusher (important – no plant on-site), material stockpiles and the transportation of men and materials.
- **Waste Management**
  Surface infrastructure designed to process and store waste including settling dam, overburden dump, portable sewage facilities.

The significance of each activity was rated without mitigation measures (WOM) and with mitigation (WM) measures for both construction, operational and closure phases of the proposed development. Table 19 below shows outcome of the risk assessment.

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Table 19: Risk Assessment Outcome before mitigation

Nr	Activity	Impact	P		D		S		M/S		Significance Before Mitigation	
			Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude
Pre-Construction and Construction Phase												
1												Negligible
Operational Phase												
1	Blasting	Ground vibration Impact on houses	4	High Probable	3	Medium term	2	Local	4	Low	36	Medium
2	Blasting	Ground vibration Impact on boreholes	4	High Probable	3	Medium term	2	Local	6	Moderate	44	Medium
3	Blasting	Ground vibration Impact on roads	2	Low Probability	3	Medium term	2	Local	6	Moderate	22	Low
4	Blasting	Ground vibration Impact on railway	4	High Probable	3	Medium term	2	Local	6	Moderate	44	Medium
5	Blasting	Air blast Impact on houses	4	High Probable	3	Medium term	2	Local	6	Moderate	44	Medium
6	Blasting	Air blast Impact on boreholes	0	None	3	Medium term	2	Local	2	Minor	0	Low
7	Blasting	Air blast Impact on roads	0	None	3	Medium term	2	Local	2	Minor	0	Low
8	Blasting	Air blast Impact on railway	2	Low Probability	3	Medium term	2	Local	4	Low	18	Low
9	Blasting	Fly Rock Impact on houses	3	Medium probability	3	Medium term	2	Local	4	Low	27	Low
10	Blasting	Fly Rock Impact on boreholes	1	Improbable	3	Medium term	2	Local	2	Minor	7	Low
11	Blasting	Fly Rock Impact on roads	4	High Probable	3	Medium term	2	Local	6	Moderate	44	Medium
12	Blasting	Fly Rock Impact on railway	4	High Probable	3	Medium term	2	Local	6	Moderate	44	Medium
13	Blasting	Impact of Fumes - Houses	0	None	3	Medium term	2	Local	4	Low	0	Low
14	Blasting	Impact of Fumes - Boreholes	0	None	3	Medium term	2	Local	2	Minor	0	Low
15	Blasting	Impact of Fumes - Roads	0	None	3	Medium term	2	Local	2	Minor	0	Low

16	Blasting	Impact of Fumes - Railway	0	None	3	Medium term	2	Local	2	Minor	0	Low
Closure and Post-Closure Phase												
												Negligible

Table 20: Risk Assessment Outcome after mitigation

Nr	Activity	Impact	Mitigation Measures	P	D	S	M / S	Significance After Mitigation	
				Score	**Score**	**Score**	**Score**	**Score**	**Magnitude**
Pre-Construction and Construction Phase									
1									Negligible
Operational Phase									
1	Blasting	Ground vibration Impact on houses	Manage charge mass per delay	2	3	2	4	18	Low
2	Blasting	Ground vibration Impact on boreholes	Manage charge mass per delay	2	3	2	6	22	Low
3	Blasting	Ground vibration Impact on roads		2	3	2	6	22	Low
4	Blasting	Ground vibration Impact on railway	Manage charge mass per delay	2	3	2	6	22	Low
5	Blasting	Air blast Impact on houses	Stemming Control: length and type of material	2	3	2	6	22	Low
6	Blasting	Air blast Impact on boreholes		0	3	2	2	0	Low
7	Blasting	Air blast Impact on roads		0	3	2	2	0	Low
8	Blasting	Air blast Impact on railway		2	3	2	4	18	Low
9	Blasting	Fly Rock Impact on houses		3	3	2	4	27	Low
10	Blasting	Fly Rock Impact on boreholes		1	3	2	2	7	Low
11	Blasting	Fly Rock Impact on roads	Stemming Control: length and type of material	3	3	2	4	27	Low
12	Blasting	Fly Rock Impact on railway	Stemming Control: length and type of material	3	3	2	4	27	Low
13	Blasting	Impact of Fumes - Houses		0	3	2	4	0	Low
14	Blasting	Impact of Fumes - Boreholes		0	3	2	2	0	Low
15	Blasting	Impact of Fumes - Roads		0	3	2	2	0	Low

16	Blasting	Impact of Fumes - Railway		0	3	2	2	0	Low
Closure and Post-Closure Phase									
									Negligible

8.2.2.1 Mitigations

In review of the evaluations made it is certain that specific mitigation will be required with regards to ground vibration, air blast and fly rock. This is specific to the structures at POI 100, 101, 109, 110, 130, and 131 – closest to the pit area. Figure 20 below shows the identified POI's of concern for blasting operations in pit area. Indication is given of structures of concern and structures where ground vibration levels are acceptable.

The greatest concern is ground vibration but the pans at POI 109 and 130 could be contaminated by fly rock and debris. This should be noted as a concern due to the location of the pans.

Ground vibration mitigation can be done in two ways: reduce the charge mass per delay – in other words, plan blasting operations considering different initiation and charging options. Secondly increase distance between the blast and the structure of concern. These are the main factors to be considered for mitigation.

Figure 20: Structures at Pit Area that are identified where mitigation will be required.

Table 21: Structures at Pit Area identified as problematic

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 30Hz
100	RGW2 (Monitoring Borehole)	-67156.36	2841237.79	50	194	1069	60.7	Problematic
101	Road	-67068.49	2841349.98	150	57	1069	453.7	Problematic
102	Railroad	-68245.20	2842532.10	150	87	1069	229.3	Problematic
110	Road	-66835.64	2843785.99	150	103	1069	173.4	Problematic

In order to ensure that levels of ground vibration and that of air blast are within acceptable limits not to induce damage, the following table shows a combination of reduce charge mass per delay and increased distance from the structures of concern. The location of these structures is such that specific design changes are required for the blast operations on the northern side of the pit area. This will be dependent on the actual drill depths, quantity of charge per blasthole and the initiation system used. The recommendations made are based on minimum and maximum charge allowed to facilitate acceptable levels of ground vibration. Charge mass per delay less than that specified will allow for shorter distances. The possible options in order to obtain acceptable ground vibration are more than what is given here but without final blast design and actual position of the specific blast the table below gives the best solution for the moment. Air blast and fly rock can be controlled using proper charging methodology. Blasting operations in any area in the pit further than the distances given below will yield lower levels of ground vibration. It is advisable that a detail plan of action is put in place to manage ground vibrations in the areas of concern. Table 21 shows identified problematic POI's with reduced charge required to facilitate ground vibration levels within limits. Table 22 shows the minimum distance required between blast and POI at the maximum charge used to maintain accepted levels of ground vibration.

Table 22: Mitigation suggested for blasting operations – Reduced charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
101	Road	150	57	275	148.0	Intolerable	Acceptable
102	Railroad	150	87	630	148.2	Intolerable	Acceptable
110	Road	150	103	890	149.0	Intolerable	Acceptable
100	RGW2 (Monitoring Borehole)	50	194	840	49.7	Intolerable	Acceptable

Table 23: Mitigation suggested for blasting operations – Minimum distance required

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
101	Road	150	115	1069	143.5	Intolerable	Acceptable
102	Railroad	150	115	1069	143.5	Intolerable	Acceptable
110	Road	150	115	1069	143.5	Intolerable	Acceptable
100	RGW2 (Monitoring Borehole)	50	220	1069	49.2	Intolerable	Acceptable

8.3 Closure Phase

During the closure phase no mining drilling and blasting operations are expected. It is uncertain if any blasting will be done for demolition. If any demolition blasting will be required of plant it will be reviewed as civil blasting and addressed accordingly.

8.4 Alternatives (Comparison and Recommendation)

No mining alternatives are currently under discussion or considered for drilling and blasting. During the drilling and blasting process one alternative that can be considered is coal blasting. If coal can be mechanically excavated / ripped rather than blasting is an option.

9 Monitoring

It is highly recommended that a blast monitoring program be put in place. This includes monitoring ground vibration and air blast for every blast. Ground vibration and air blast is monitored using a seismograph. Monitoring can be done in permanent stations or on ad hoc basis – per blast basis monitoring. Additionally to this it is recommended that a video of each blast is done as a standard. Monitoring of ground vibration and air blast is done to ensure that the generated levels of ground vibration and air blast comply with recommendations. Proposed positions were also selected to indicate the nearest points of interest at which levels of ground vibration and air blast should be within the accepted norms and standards as proposed in this report. The monitoring of ground vibration will also qualify the expected ground vibration and air blast levels and assist in mitigating these aspects properly. This will also contribute to proper relationships with the neighbours. Currently 10 monitoring positions were identified that will required during the life of mine at least. Not all points may be utilised at once. These points are the most critical. Monitor positions are indicated in Figure 21.

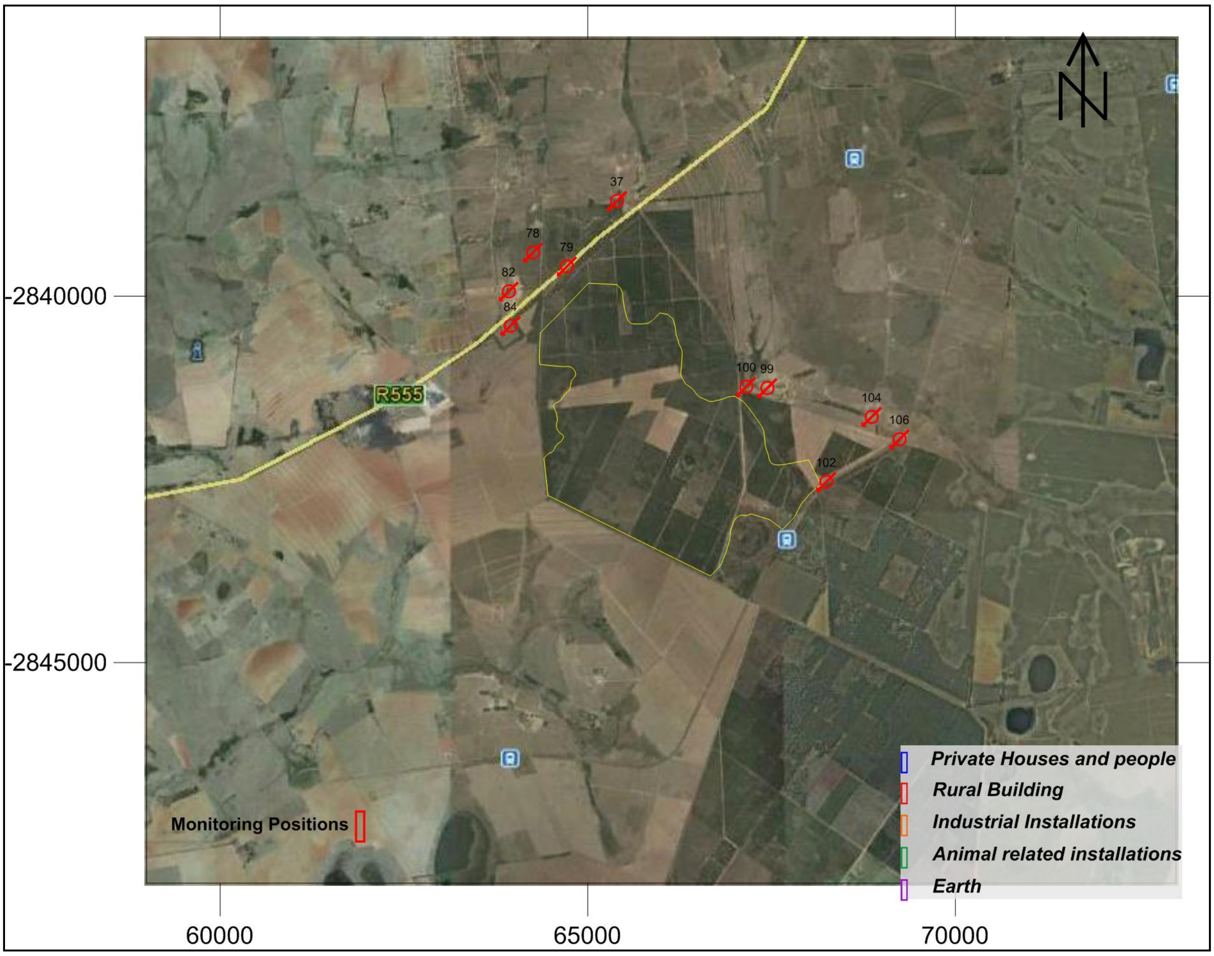

Figure 21: Monitoring Positions suggested.

10 Recommendations

The following recommendations are proposed.

10.1 Safe blasting distance from communities

A minimum safe distance 150m is required but recommended is that a minimum of 500m must be maintained from any blast done. This may be greater but not less. The blaster has a legal obligation concerning the safe distance and he needs to determine this distance.

10.2 Evacuation

All persons and animals within 500m from a blast must be cleared and where necessary evacuation must be conducted with all the required pre-blast negotiations.

10.3 Road Closure

There are public and farm roads closer than 500m to the project area. Proper road closure procedures in conjunction with the necessary authorities will be required. All blasting closer than 500m to roads will require road closure procedures. Farm roads that are used daily may exist and should be considered for closure just when blasting is done in vicinity of these roads.

10.4 Railway

The railway is located close to the pit area on the southern side. The frequency of trains passing through is unknown at this stage. Specific care and attention will have to be given to the following. Blasting should considered train schedules, distance from the railway, contingency plans if fly rock has occurred, fly rock control for railway electrical lines are some of the actions to be considered.

10.5 Photographic Inspections

It will be imperative to conduct a photographic survey (crack survey) of all structures around the pit areas. All structures within 1500m from the pit boundary are to be surveyed prior to any blasting done. A 1500m equates to 2.1mm/s of expected ground vibration for the charge used. This level of ground vibration is already perceptible and people in structures could experience ground vibration negatively. Figure 22 shows the 1500m area.

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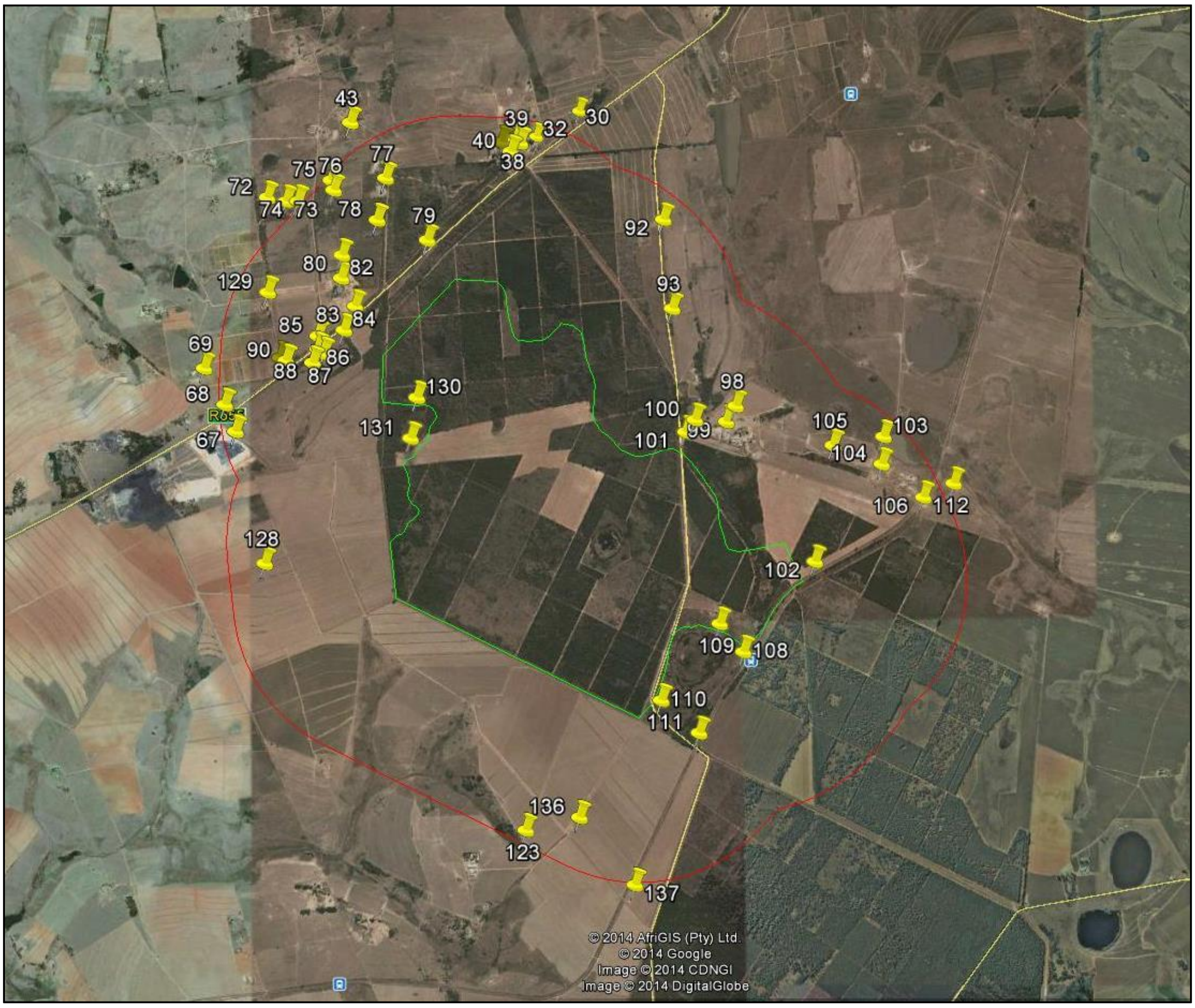

Figure 22: 1500m area around pit identified for structure inspections.

10.6 Recommended ground vibration and air blast levels

The following ground vibration and air blast levels are recommended for blasting operations in this area. Table 23 below gives limits for ground vibration and air blast.

Table 24: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A
Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	Shall not exceed 134dB at point of concern but 120 dB preferred
Houses of lesser proper construction	12.5	
Rural building – Mud houses	6	

10.7 Stemming length

The current proposed stemming lengths at least must be maintained to ensure control on fly rock. Specific designs where distances and blast is known should be considered with this.

10.8 Blasting times

A further consideration of blasting times is when weather conditions could influence the effects yielded by blasting operations. Recommended is not to blast too early in the morning when it is still cool or the possibility of inversion is present or too late in the afternoon in winter as well. Do not blast in fog. Do not blast in the dark. Refrain from blasting when wind is blowing strongly in the direction of an outside receptor. Do not blast with low overcast clouds. These 'do not's stem from the influence that weather has on air blast. The energy of air blast cannot be increased but it is distributed differently to unexpected levels where it was not expected.

It is recommended that a standard blasting time is fixed and blasting notice boards setup at various routes around the project area that will inform the community blasting dates and times.

10.9 Third party monitoring

Third party consultation and monitoring should be considered for all ground vibration and air blast monitoring work. Additionally assistance may be sought when blasting is done close to the highways. This will bring about unbiased evaluation of levels and influence from an independent group. Monitoring could be done using permanent installed stations. Audit functions may also be conducted to assist the mine in maintaining a high level of performance with regards to blast results and the effects related to blasting operations.

11 Knowledge Gaps

Considering the stage of the project, the data observed was sufficient to conduct an initial study. Surface surroundings change continuously and this should be taken into account prior to any final blast design and review of this report. This report is based on data provided and international accepted methods and methodology used for calculations and predictions.

12 Conclusion

Blast Management & Consulting (BM&C) was contracted to perform review of possible impacts with regards to blasting operations in the proposed new opencast mining operation. Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report concentrates on the ground vibration and air blast intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500m at least and in some cases further from the mining area considered. The range of structures expected is typical farming community with structures that range from well build to informal building style. The project area consists mainly of one opencast pit area.

The project area has the possibility of presence of people and possibly farm animals at close distances to the operations. The location of structures around the pit areas are such that the charge evaluated showed possible influences due to ground vibration, air blast and fly rock.

Ground vibration mitigation will be required for pit area. Four points of interest was identified that could possibly be influenced and requires mitigation on drilling and blasting operations. One specific problem identified is the location of the road that is routed directly through the project area. Apart from ground vibration restrictions, the road will require a closure period during blasting times covering at least 500m from the blast being done. Road closures will require careful planning and the required authorisations. The railway line is also close to the pit on the southern side. Specific care with regards to ground vibration and fly rock will be required.

Air blast levels expected is lesser of a concern. Air blast levels calculated showed specific damage concerns only at the nearest structures for each pit. Structures within 250m from any of the pit areas boundary showed levels greater than allowed. Up to a distance of at least 1000m it is expected that levels will be such that complaints may be raised due to airt blast. Mitigation of ground vibration will also contribute to mitigation of air blast. Stemming control will be needed to maintain levels within acceptable norms. Stemming control for air blast will also contribute to control on fly rock. Complaints from air blast are normally based on the actual effects that are experienced due to rattling of roof, windows, doors etc. These effects could startle people and raise concern of possible damage.

This concludes this investigation for the Rietvlei Open Cast Coal Mining Project. It will be possible to operate this mine in a safe and effective manner provided attention is given to the areas of concern and recommendations as indicated.

13 Curriculum Vitae of Author

Author joined Permanent Force at the SA Ammunition Core for period Jan 1983 - Jan 1990. During this period I was involved in testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition. For the period Jul 1992 - Des 1995 Worked at AECI Explosives Ltd. Initially I was involved in testing science on small scale laboratory work and large scale field work. Later on work entailed managing various testing facilities and testing projects. Due to the restructuring of Technical Department I was retrenched but fortunately could take up appointment with AECI Explosives Ltd.'s Pumpable Emulsion explosives group for underground applications. December 1995 to June 1997 I gave technical support to the Underground Bulk Systems Technology business unit and performed project management on new products. I started Blast Management & Consulting in June 1997. Main areas of concern were Pre-blast monitoring, Insitu monitoring, Post blast monitoring and specialized projects.

I have obtained the following Qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1990 - 1992	BA Degree, University Of Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate: Damelin College
2000	Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997 and work has been on various levels for all the major mining companies in South Africa. Some of the projects where BM&C has been involved are:

Iso-Seismic Surveys for Kriel Colliery in conjunction with Bauer & Crosby PTY Ltd, Iso-Seismic surveys for Impala Platinum Limited, Iso-Seismic surveys for Kromdraai Opencast Mine, Photographic Surveys for Kriel Colliery, Photographic Surveys for Goedehoop Colliery, Photographic Surveys for Aquarius Kroondal Platinum – Klipfontein Village, Photographic Surveys for Aquarius – Everest South Project, Photographic Surveys for Kromdraai Opencast Mine, Photographic Inspections for various other companies including Landau Colliery, Platinum Joint Venture – three mini pit areas, Continuous ground vibration and air blast monitoring for various Coal mines, Full auditing and control with consultation on blast preparation, blasting and resultant effects for clients e.g. Anglo Platinum Ltd, Kroondal Platinum Mine, Lonmin Platinum, Blast Monitoring Platinum Joint Venture – New Rustenburg N4 road, Monitoring of ground vibration induced on surface in Underground Mining environment, Monitoring and management of blasting in close relation to water pipelines in opencast mining environment, Specialized testing of explosives characteristics, Supply and service of seismographs and VOD measurement equipment and accessories, Assistance in protection of ancient mining works for Rhino Minerals (PTY) LTD, Planning, design, auditing and monitoring of blasting in new quarry on new road project, Sterkspruit, with Africon, B&E International and Group 5 Roads, Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Pandora Joint Venture 180 houses – whole village, Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Section : 1000 houses / structures.

BM&C have installed a World class calibration facility for seismographs, which is accredited by Instantel, Ontario Canada as an accredited Instantel facility. The projects describe and discussed here are only part of the capability and professional work that is done by BM&C.

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