Blast Management & Consulting

Report: Blast Impact Assessment

Environmental Impact Assessment for a proposed underground and opencast coal mine, Makhado Local Municipal area, Ward 21 in the Vhembe District:
The Duel Coal Project

Prepared for:
Jacana Environmentals cc.

July 2015

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ii. Study Team Qualifications And Background

The study team comprises of JD Zeeman as member of Blast Management & Consulting and Blast Management & Consulting employees. Blast Management & Consulting's main areas of concern are Pre-blast consultation and monitoring, Insitu monitoring, Post blast monitoring and consulting as well as specialised projects. Blast Management & Consulting has been active in the mining industry since 1997 and work has been done on various levels for mining companies in South Africa, Botswana, Namibia, Mozambique, Democratic Republic of Congo, Sierra Leone and Côte d'Ivoire.

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
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2000	Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

iii. Independence Declaration

Blast Management & Consulting is an independent company. The work done for the report was performed in an objective manner and according to national and international standards, even if the results and findings are not favourable to the client. Blast Management & Consulting has the expertise in conducting the specialist report relevant to the study. Blast Management will not engage in any conflicting interests in the undertaking of this study.

Document Control:

Name	Responsibility	Signature	Date
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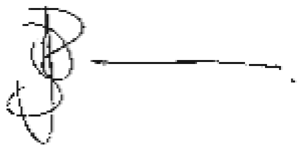
JD Zeeman **Blast Management & Consulting**	**Consultant**		**13/07/2015**

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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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Executive Summary

Blast Management & Consulting (BM&C) was contracted as part of the Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed The Duel Coal Project. Ground vibration, air blast, fly rock and fumes are some of the aspects that result from blasting operations. 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.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500 m and in some cases further from the mining area. The range of structures expected is typical roads (tar and gravel), brick and mortar houses, informal building style, corrugated iron structures, graves and graveyards and water boreholes. The project area consists mainly of one opencast pit area and an underground section. The project is a greenfields project with no existing blasting operations.

The project area has possibility of presence of people and possibly farm / domestic animals at close distances to the operations. The location of structures around the pit areas are such that the charges evaluated showed possible influences due to ground vibration. This is mainly for the rural community houses in Makushu and some boreholes. Ground vibration mitigation will be required for these structures. Ground vibrations predicted ranged between 26.8 mm/s and 5785 mm/s for points of interest identified. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage. There is a possibility that ground vibration may be perceptible at nearest houses. There is also a gravel road that crosses the through the planned pit area that will require specific attention with regards to blasting operations in general.

Air blast levels expected ranged between 120.8 dB and 146.5 dB at the nearest point of interest. Air blast levels predicted showed less concern than ground vibration. Most of the points of concern that are located close to the pit area are the rural community houses in Makushu. Specific structures / houses were identified with concerns that might lead to possible complaints. 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.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 472 m; however, normal practice observed in mines is a 500 m exclusion zone. The use of 500 m exclusion zone is therefore rather recommended.

There are various water boreholes located in close proximity of the pit areas that will need to be considered.. The locations are such that possible permanent damage is highly likely. In the event of damage, new water wells/boreholes will have to be provided.

Recommendations were made that should be considered. Specifically for monitoring of ground vibration and air blast, save blasting zones, structure inspections, safe ground vibration and air blast limits, stemming lengths and blasting times.

This concludes this investigation for The Duel Coal Project. Specific areas of concern were identified and recommendations made that will require attention prior to operation of the mine.

1 Introduction

Subiflex (Pty) Ltd holds a Prospecting Right on the farms Lotsieus 176 MT, Kranspoort 180 MT, Nairobi 181 MT and The Duel 186 MT and is proposing to develop an underground and opencast coal mine on the Remaining Extent of The Duel 186 MT (only). The proposed mine development is located 54 km north of Makhado town (previously Louis Trichardt) in the Makhado Local Municipal area, Ward 21 in the Vhembe District. The planned project is located at coordinates (Lat/Lon WGS84) 22°45'42.22"S 30° 2'26.10"E.

The Duel Coal Project will be a combination of open pit and underground mining and has a potential Life-of-Mine (LOM) of 24 years. The envisaged mining method for the open pit area is a conventional drill and blast operation with truck and shovel, load and haul.

Underground mining operations will commence from year 10 onwards for a period of 5 years. Access will be from selected positions in the open pit and the coal will be mined through the long-wall methodology. After underground activities have been completed, the access to the underground areas will be closed followed by the final rehabilitation of the open pit.

The Duel Coal Project is a new project with no operations currently active. There are currently no drilling and blasting operations conducted that can be used as baseline. The baseline of existing status is considered none influence. No mining activities are being conducted.

Blast Management & Consulting (BM&C) was contracted as part of the 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 to outline the expected environmental effects that blasting operations could have on the surrounding environment and 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 and general indicators from the various act of South Africa to fullfill the mining requirements. 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, as amended.

The guidelines and safe blasting criteria are according international accepted standards and specifically 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.

The protocols and objectives applied are certain to address the requirements from 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 mine development is located 54 km north of Makhado town (previously Louis Trichardt) in the Makhado Local Municipal area, Ward 21 in the Vhembe District. The planned project is located at coordinates (Lat/Lon WGS84) 22°45'42.22"S 30° 2'26.10"E.

Figure 1 shows a geographical locality plan of the proposed project area. Figure 2 shows view of the proposed mining area with layout of expected pit locations.

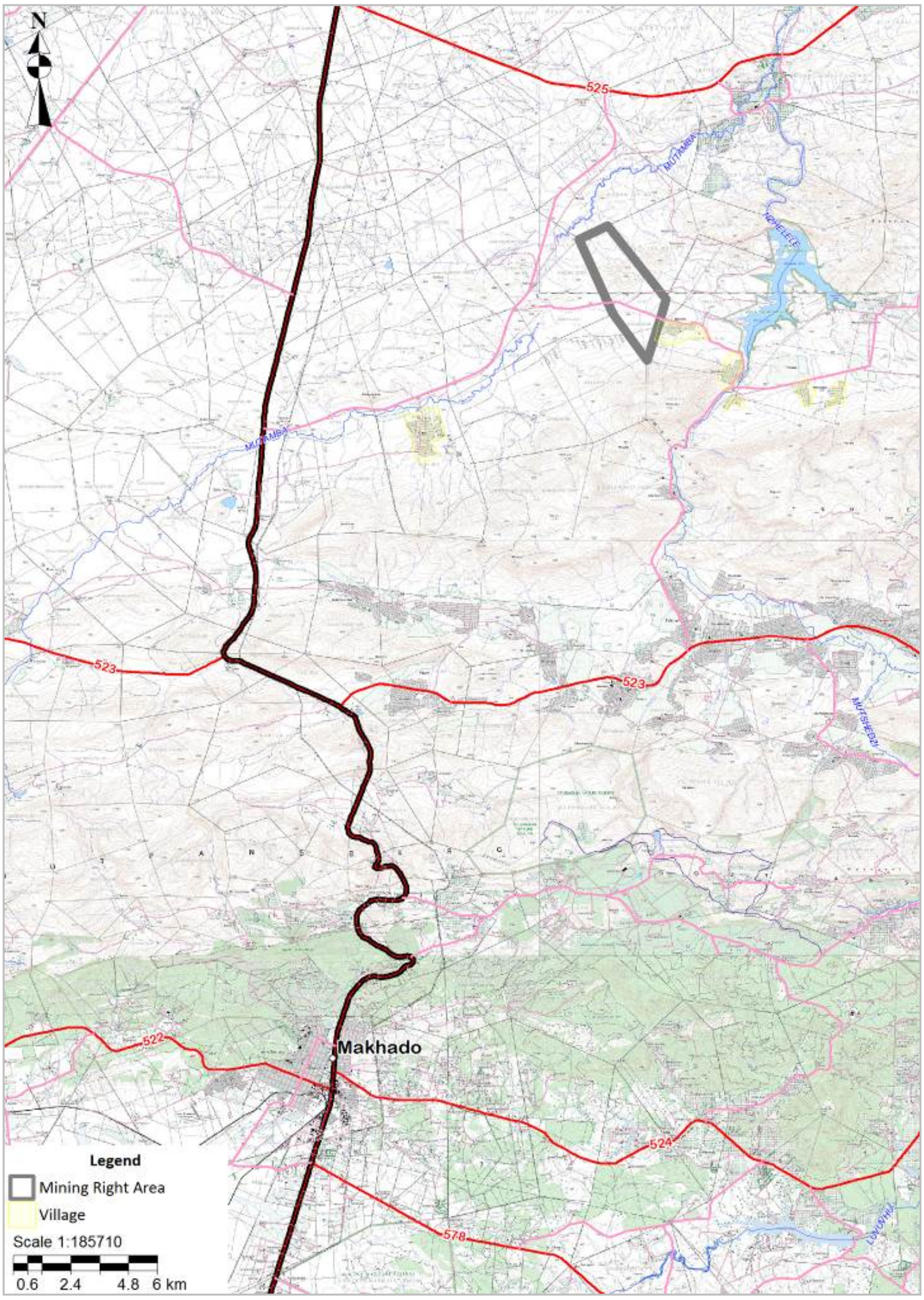

Figure 1: Locality of the project area

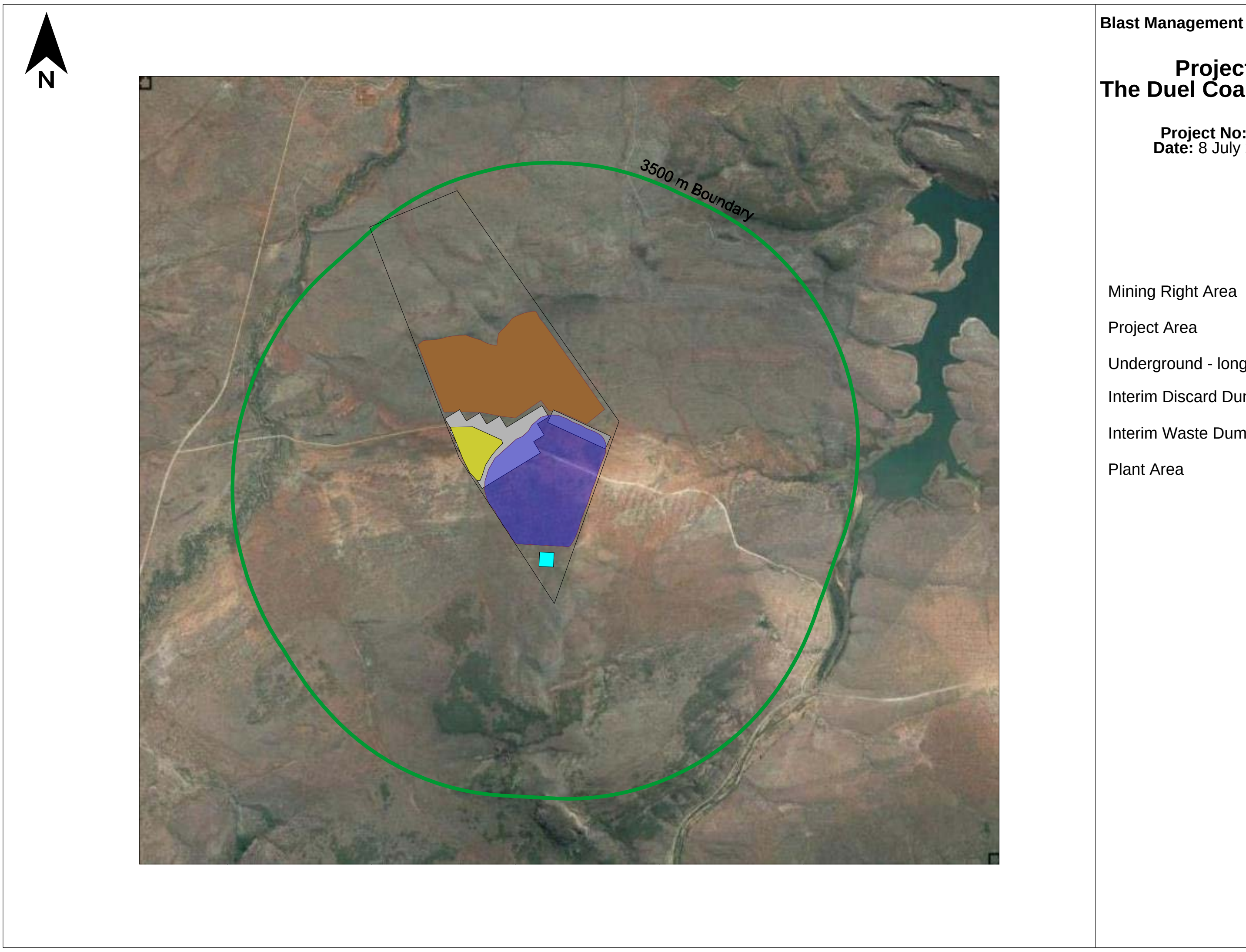

Figure 2: Proposed mining area layout

5 Methodology

The detailed plan of study as presented in the Scoping Report consisted 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.
- Base line influence or Blast Monitoring: The project evaluated is a new operation with no blasting activities currently being done. No monitoring is thus specifically required as baseline is considered zero with no influence.
- 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 specific blast design for blasting operations. Blast design forms the baseline for determining the possible influences from blasting operations. Blast designs applied in this report was provided by the client[1]. Opencast operations have possibility of influence specific in relation to aspects such as ground vibration, air blast and fly rock.

6.1 Mining and Blasting Operations

Conventional drilling, blasting, loading and hauling operations are envisaged. The target coal seams can be accessed from surface after overburden or waste stripping. The proposed bench heights for the project is 10 m with 251 mm diameter blast holes planned for the coal seam and 15 m bench height with 251 mm diameter blast holes for the overburden or waste material. The overburden mining will have greater possibility of influence than mining the coal seam due to higher bench height and thus deeper blast holes. Table 1 below summarises the blast designs provided and the information required for use in this report. Blast design is required in order to determine expected outcomes from blast operations. These designs were then applied to define expected ground vibration, air blast and fly rock influences and levels.

Table 1: Information on blast designs used (See note 1)

Description	Unit	Ore Benches	Waste Benches
Hole diameter	mm	251	251
Bench height	m	10	15
Angle of the hole (90^0 is vertical)	deg.	90	90
Burden	m	7.2	8.6
Spacing	m	8	9.5

[1]VBKom Consulting Engineers (Pty) Ltd, Report: SIGNET COKING COAL (Pty) Ltd - Scoping Study: The Duel Project Dated: March 2015.

Stemming length	m	5.6	5.6
Sub-drill	m	1.8	2.2
Length of hole	m	11.8	17.2
Actual powder factor	**kg/m^3**	0.59	0.55
Mass of explosive per hole	kg	366.36	684.38
Cubic metres blasted per hole	m^3	568.8	1225.5
Explosives	type	Emulsion	Emulsion
Explosive density	t/m^3	1.15	1.15

6.2 The process of a blasting operation

Blasting operations are done to achieve a specific result, breaking rock and moving the material to facilitate effective loading of the broken material. A block identified for blasting is identified and marked. A pattern of blast hole positions are marked and the required depths is drilled. After drilling the blast holes are loaded with an initiation system and explosives. The initiation system will initiate the main explosives column. The explosives energy performs work on the blast hole side wall – cracking the material and eventually moves the material into a desired direction leaving material in one heap. The blast holes are not loaded to the top of the blast hole. Space is left for stemming material that is loaded on top of the explosives to the rim of the blast hole. The stemming material acts to contain the energy of the explosives to ensure the energy is working where it is required – breaking rock. When charging of blast holes is done a surface initiation system is laid out. This surface initiation is designed to ensure initiation of the blast holes in a particular sequence. This sequence provides mechanism for proper fragmentation and movement of the material blasted. Energy of different explosives varies. How the energy work is also dependant on factors such as rock type, burdens, spacing, quantity etc.

Rock is affected by detonating explosives in three principal stages. Firstly crush of blast hole walls. Secondly compressive stress waves in all directions. Thirdly released gas volume is forced into the cracks and the material is moved. In this blast process there are specific effects occurring. Some of the energy not completely used is transmitted outwards from the blast hole, much like a stone thrown in a pool of water and the ripples that moves outwards. This leaves to fact that blast operations do have effects on its immediate surrounding area. These effects manifesting in various forms of which the level or intensity is reason for prediction, evaluation and risk analysis in this report. These effects can manifest in the form of ground vibration and air blast. Additionally to this we need to considered effects such as fumes and fly rock as which are normally specific negative effects that can occur. 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.

7 Legal Requirements

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 and the Explosives Act Explosives Act No. 26 of 1956 and amended No. 15 of 2003.

The guidelines and safe blasting criteria are according to international accepted standards and specifically 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 is no specific South African standard and the USBM is well accepted as a standard for South Africa. Additional criteria as required by various institutions in South Africa i.e. Eskom, Telkom, Transnet, Rand Water Board etc. is also taken into consideration.

8 Sensitivity of Project

The project and surrounding areas were reviewed prior to any specific analysis is done to get an indication of possible sensitive areas. A sensitivity map was done based on typical areas and distances from the proposed mining area. This sensitivity map uses mainly distances normally associated where possible influences may occur or is not expected to occur. Three different areas where identified for this. Firstly a high sensitive area of 500 m area around the mining area is identified. Normally the 500 m is considered an area that should be cleared from all people and animals prior to blasting. Levels of ground vibration and air blast are also expected to be higher closer to the pit area. Secondly an area of 500 m to 1500 m around the pit area that can be considered as medium sensitive is identified. In this area the possibility of influence is still expected but definitely a lower impact. Thirdly an area is identified as least sensitive at distance of 1500 m to 3500 m. The expected level of influence to be low but there may still be reason for concern as levels could be less than to cause structure damage but may still upset people. Figure 3 shows the sensitivity mapping with identified POI's and surrounding areas. The specific influences will be determined through the worked done for this project in this report.

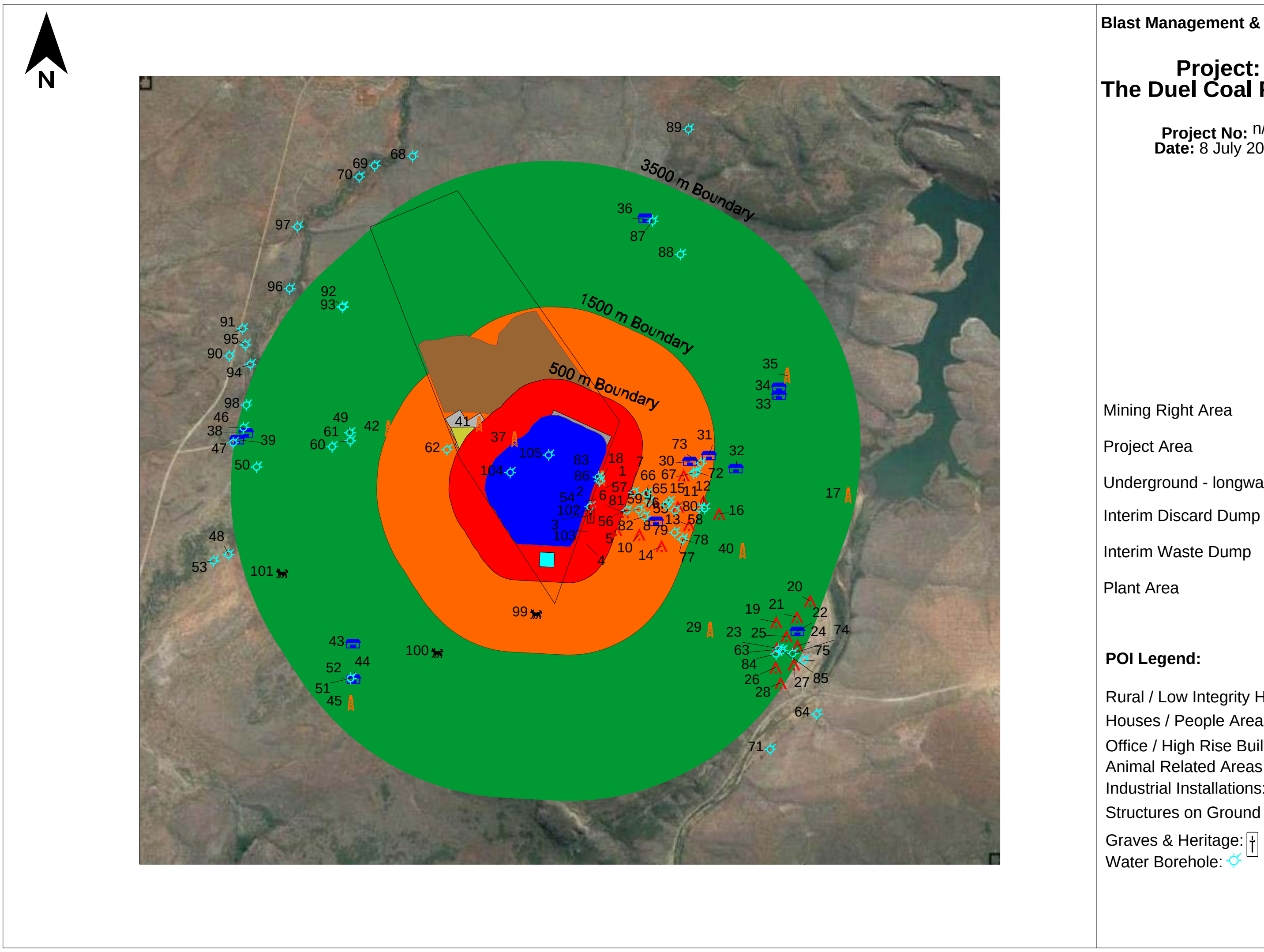

Figure 3: Identified sensitive areas

9 Consultation process

No specific consultation with external parties was utilised. The work done is based on the author's knowledge and information provided by the client[2].

10 The expected effects from blasting operations

Blasting operations have effect to its 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

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[2] VBKom Consulting Engineers (Pty) Ltd, Report: SIGNET COKING COAL (Pty) Ltd - Scoping Study: The Duel Project Dated: March 2015.

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.

10.1 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 vibration 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.

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.

Secondly 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.

10.1.1 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 the absence of actual mining operations being conducted and measurements done from blasting a general set of site constants is used until such time that the site constant can be tested. The specific site constants used are factors that have significant safety factor build in to cater for unknown geology. In new opencast operations a process of testing for the constants can be done using a signature trace study in order to predict ground vibrations more accurately. The analysis of the data in such a study will also give an indication of frequency decay over distance. The utilization of the scaled distance prediction formula is standard practice.

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 and installations observed surrounding the site and location of the project area. Structures types and qualities vary greatly and this calls for limits to be considered as follows: 6 mm/s, 12.5 mm/s levels and 25 mm/s at least.

The blast design indicates 684 kg will be loaded in a 17.2 m 251 mm diameter wasteblast 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, two charge masses that will span the range of possible charge mass per delay were selected. Therefore a single waste blast hole at 684 kg, four times waste blast holes at 2738 kg was selected. This range of charges will span the expected charging to be done in this area. These charge masses were used for modelling aspects in this report. Applying the above charge masses, various ground vibration calculations were done and considered in this report.

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 two different charge masses. A low charge mass and a maximum charge mass as worst case scenario. The charge masses are 684kg and 2738 kg.

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

No.	Distance (m)	Expected PPV (mm/s) for 684kg Charge	Expected PPV (mm/s) for 2738kg Charge
1	50.0	392.3	1232.0
2	100.0	201.0	631.1
3	150.0	64.0	201.1
4	200.0	39.8	125.1
5	250.0	27.6	86.6
6	300.0	20.4	64.1
7	400.0	12.7	39.9
8	500.0	8.8	27.6
9	600.0	6.5	20.4
10	700.0	5.0	15.8
11	800.0	4.0	12.7
12	900.0	3.3	10.5
13	1000.0	2.8	8.8
14	1250.0	1.9	6.1
15	1500.0	1.4	4.5
16	1750.0	1.1	3.5
17	2000.0	0.9	2.8
18	2500.0	0.6	1.9
19	3000.0	0.5	1.4
20	3500.0	0.4	1.1

Figure 4 below shows the relationship of ground vibration over distance for the two charges considered as given in Table 2 above. The attenuation of ground vibration over distance is clearly observed. Ground vibration attenuation follows a logarithmic trend and the graph indicates this trend. Indicated on the graph as well 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. The expected vibration level at specific distance can be read from the graph, provided the same maximum charges are applicable, or by rough estimate if the charge per delay should be between the charge masses applied for this case.

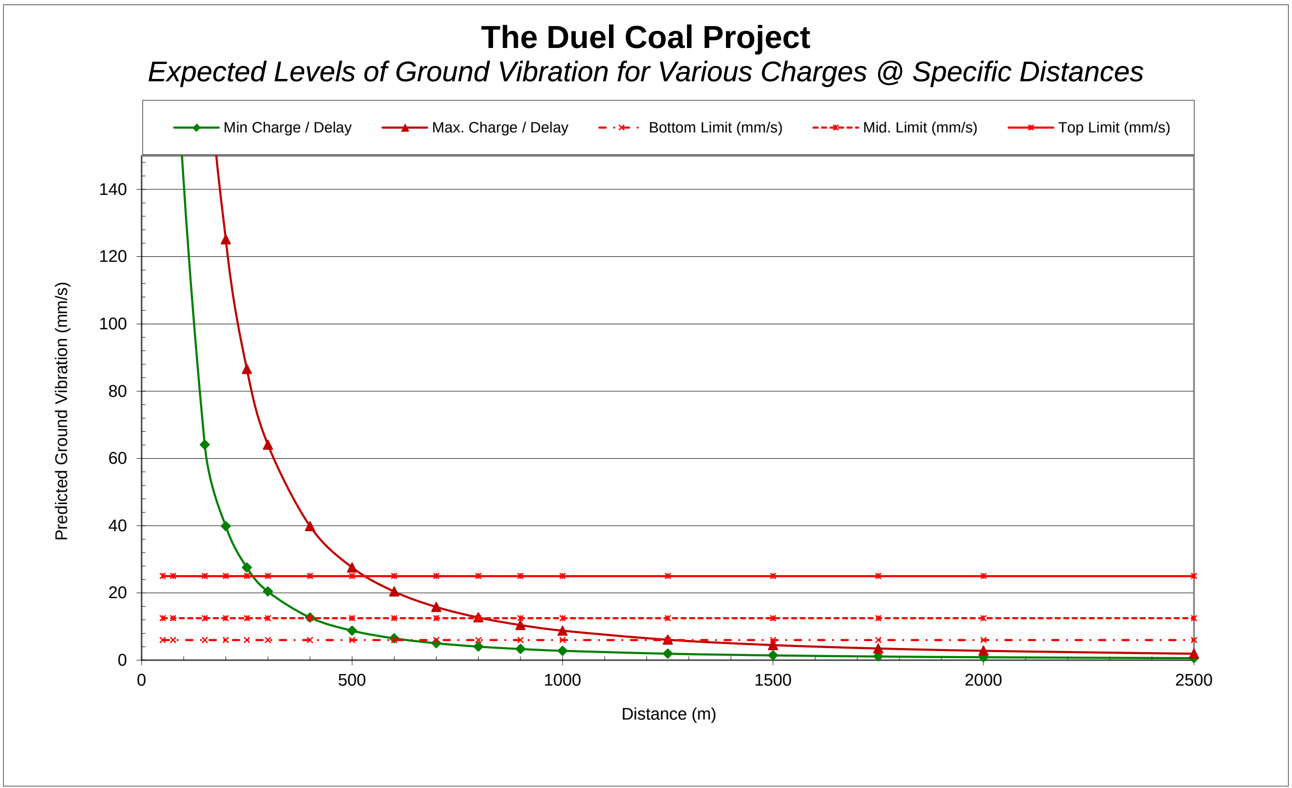

Figure 4: Ground vibration over distance for the two charge masses used in modelling

10.1.2 Ground vibration limitations on structures

Limitations on ground vibration are in the form of maximum allowable levels or intensity for different installations and / or structures. There are no specific South African standards or criteria for safe ground vibration levels. Ground vibration limits are dependent on the intensity and frequency of the ground vibration.

Currently the United States Bureau of Mines (USBM) criterion for safe blasting is applied as an industry standard 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. Low frequency of ground vibration will allow for low levels of ground vibration and high levels of ground vibration will allow for high levels of ground vibration. Figure 5 below shows a graph of the USBM analysis for safe ground vibration levels. Data is inserted to demonstrate typical results. The graph indicates two main areas:

- Safe ground vibration levels: Analysed data is displayed in the bottom half of the graph.
- Unsafe ground vibration levels: Analysed data is displayed in the top half of the graph.

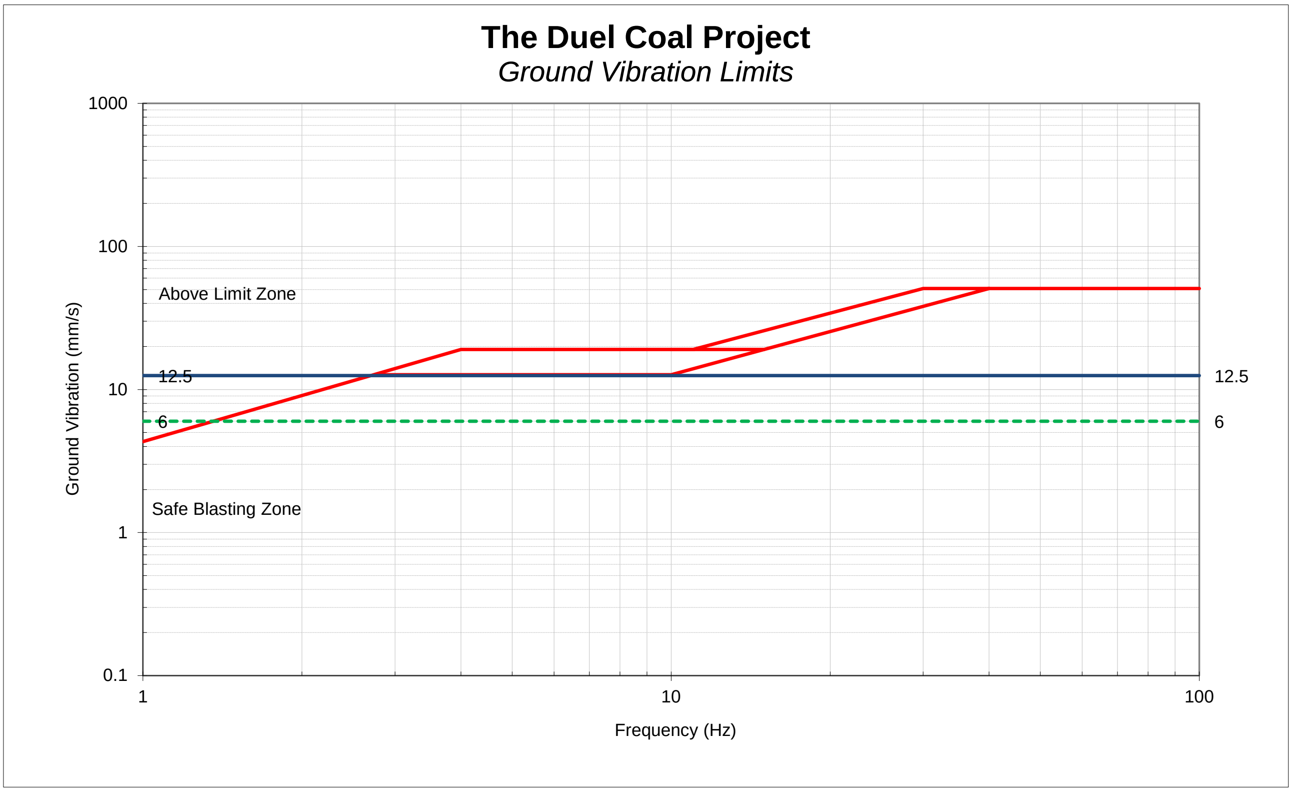

Figure 5: USBM Analysis Graph

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.

10.1.3 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 6).

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.

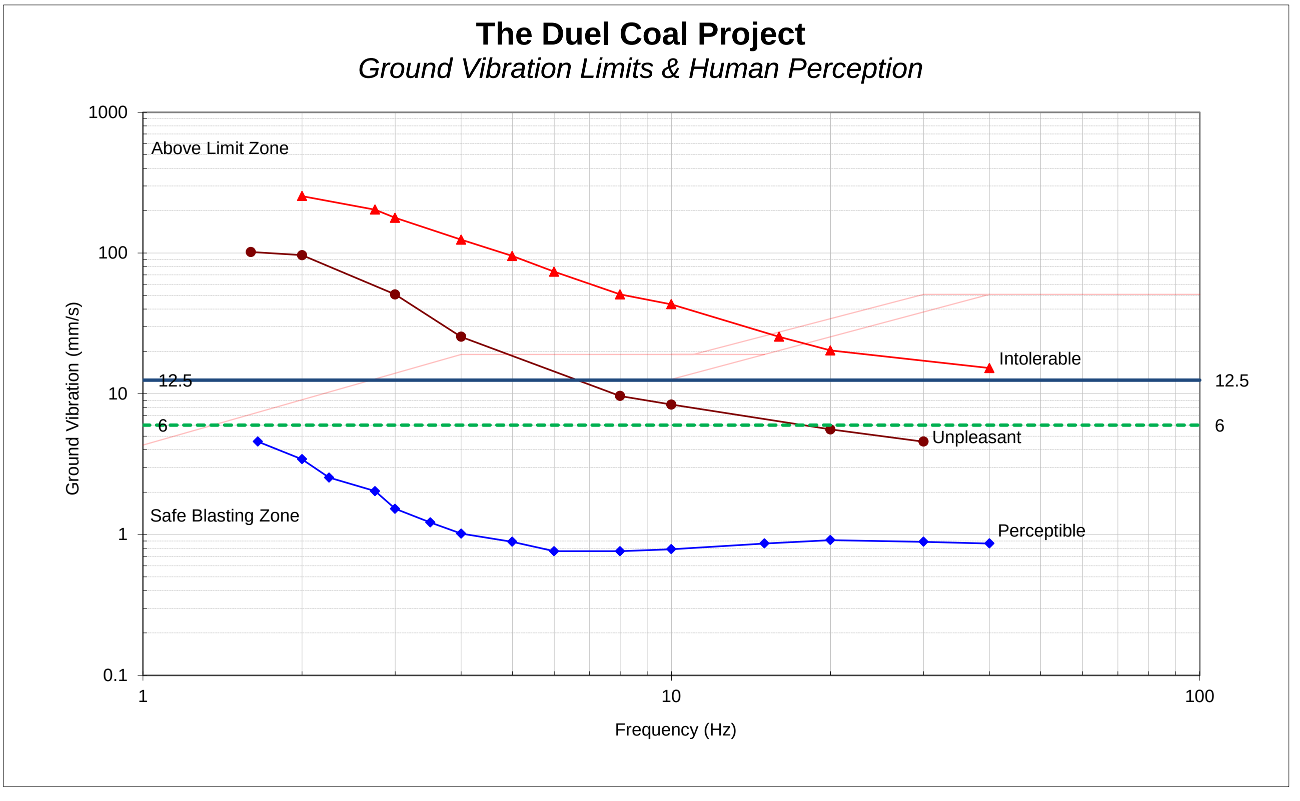

Figure 6: USBM Analysis with Human Perception

10.2 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)

10.2.1 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.

10.2.2 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 is kept below 120dB. In this way it is certain that fewer complaints will be received for blasting operations. The effects on structures that startle 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, 120 dB to 134dB and greater 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.

10.2.3 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. Measured data showed significant variations due to changing meteorological conditions. It was decided to rather apply the basic standard prediction method for air blast prediction and not using the recorded data.

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 7 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 684kg Charge	Air blast (dB) for 2738kg Charge
1	50.0	147	152
2	100.0	142	147
3	150.0	135	140
4	200.0	132	137
5	250.0	130	135
6	300.0	128	133
7	400.0	126	130
8	500.0	124	128
9	600.0	122	126
10	700.0	121	125
11	800.0	119	124
12	900.0	118	123
13	1000.0	117	122
14	1250.0	116	120
15	1500.0	114	118
16	1750.0	113	117
17	2000.0	112	115
18	2500.0	110	114
19	3000.0	108	112
20	3500.0	107	111

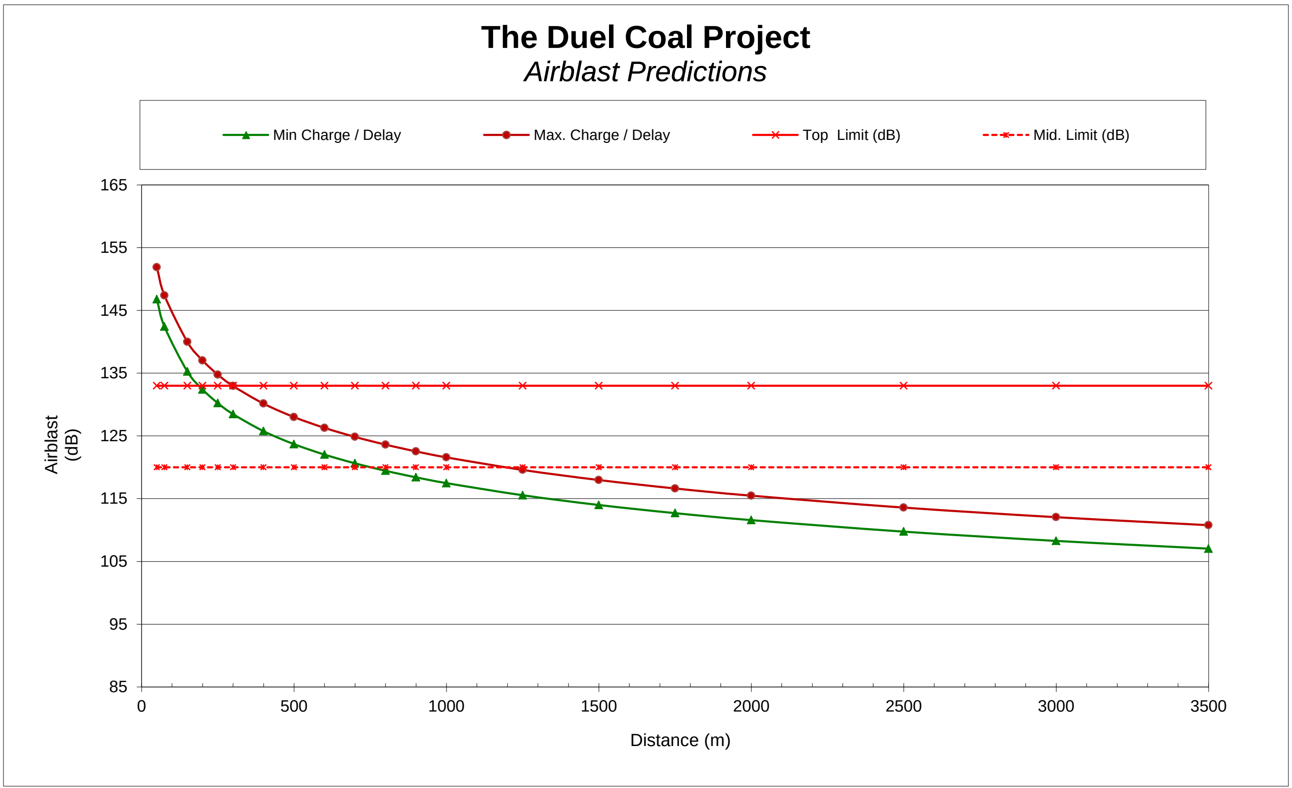

Figure 7: Predicted air blast levels

10.3 Fly rock

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 can be explained and defined in the following three categories:

- Throw - the planned forward movement of rock fragments that form the muck pile within the blast zone.
- Fly rock - the undesired propulsion of rock fragments through the air or along the ground beyond the blast zone by the force of the explosion that is contained within the blast clearance (exclusion) zone. Fly rock using this definition, while undesirable, is only a safety hazard if a breach of the blast clearance (exclusion) zone occurs.
- Wild fly rock - the unexpected propulsion of rock fragments, when there is some abnormality in a blast or a rock mass, which travels beyond the blast clearance (exclusion) zone.

Figure 8below shows the schematic fly rock terminology

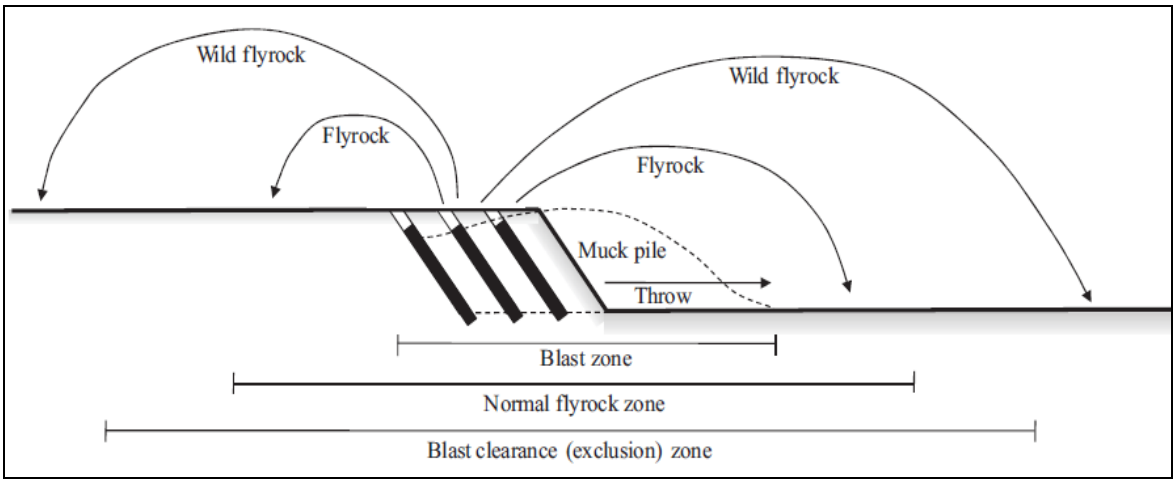

Figure 8: Schematic of fly rock terminology

10.3.1 Fly rock causes

Fly rock from blasting can result from the following conditions:

- When burdens are too small rock elements can be propelled out of the free face area of the blast,
- When burdens are too large and movement of blast material is restricted and stemming length is not correct rock elements can be forced upwards creating a crater forming fly rock from this,
- If the stemming material is of proper quality or too little the stemming is ejected out of the blast hole and fly rock created.

Stemming of correct type and length is required to ensure that explosive energy is efficiently used to its maximum and to control fly rock.

10.3.2 Fly rock predictions

The occurrence of fly rock in any form will have a negative impact if found to travel outside the safe boundary. A general unsafe boundary is normally considered to be within a radius of 500 m. If a road, structure, people or animals are within the 500 m unsafe boundary of the blast, irrespective of the possibility of fly rock or not, precautions must always be taken to stop the traffic, remove people and / or animals for the duration of the blast.

Calculations are also used to help and assist determining safe distances. Method currently applied by BM&C is according to the International Society of Explosives Engineers (ISEE) Blasters Handbook. Using these calculations the minimum safe distances can be determined that should be cleared of people, animals and equipment. Figure 9shows the results from the ISEE calculations for the two types of operations and drill diameter sizes that are applied in the design for this project.

The stemming lengths provided in the designs are based on approximately 22 times the blast hole diameter. The absolute minimum exclusion zone calculated then is 472 m. This calculation is a guideline and any distance cleared should not be less. The occurrence of fly rock can however never be excluded 100%. Best practices can be and are implemented. The occurrence of fly rock can be mitigated but the possibility of the occurrence there off, can never be eliminated.

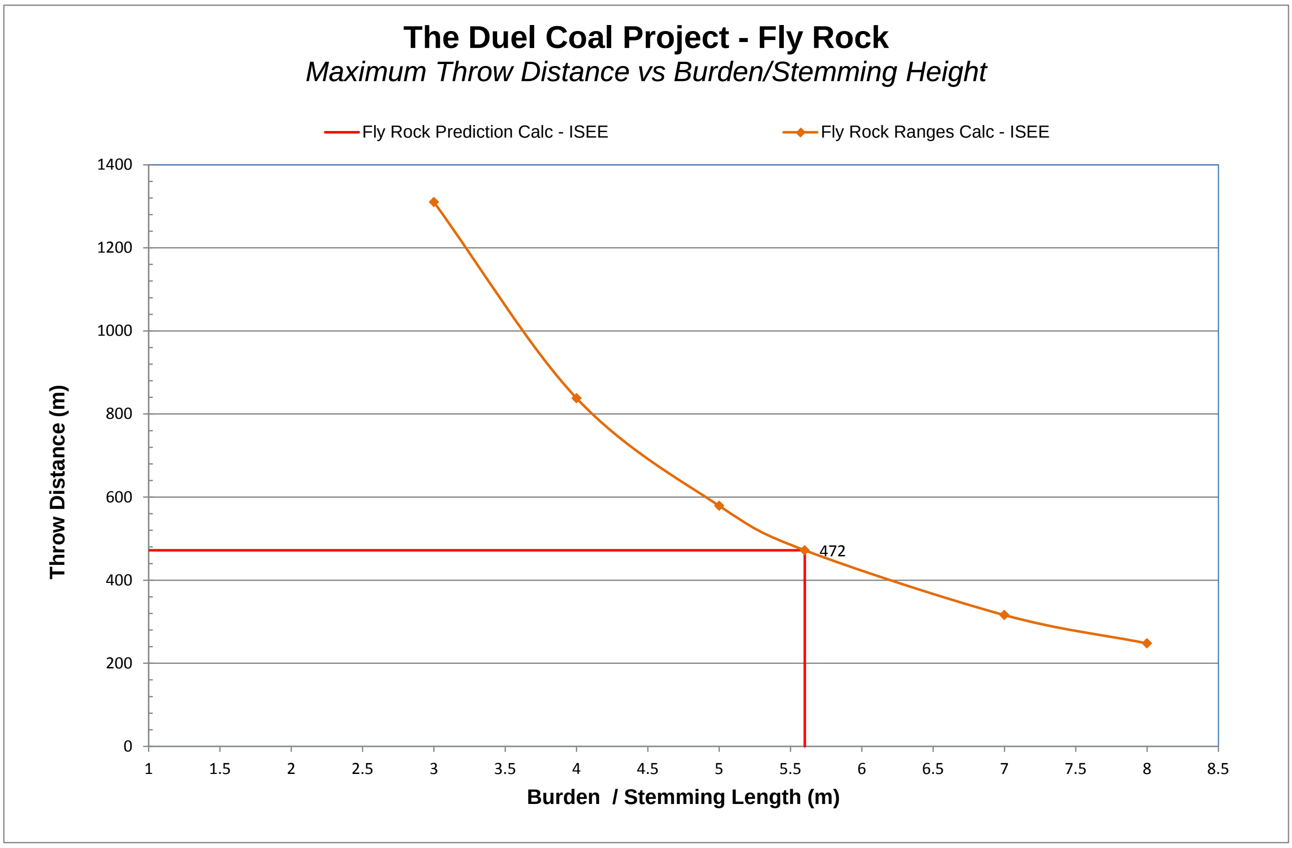

Figure 9: Predicted Fly rock

10.3.3 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.

10.4 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.

10.4.1 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 holes 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 contributing factor to explosive performance and the subsequent generation of fumes. Explosives are diameter dependant for optimal performance. If 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 holes and emulsion explosives can be used in the smaller diameter blast holes.

10.4.2 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 holes at long periods prior to blasting. Excessive sleeping of charged blast holes 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 holes 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.

10.5 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 roads. 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.

10.6 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.

10.7 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 10below. A typical X crack formations is observed.

Figure 10: 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.

10.8 Vibration impacts on productivity of domestic 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 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 some of his conclusions.

Personal experience as observed on projects has shown the following on domestic 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 does not have information on any studies conducted.

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. In 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. Mice, 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 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 11) shows the mortality curves for the various animals exposed to long duration pressure pulses.

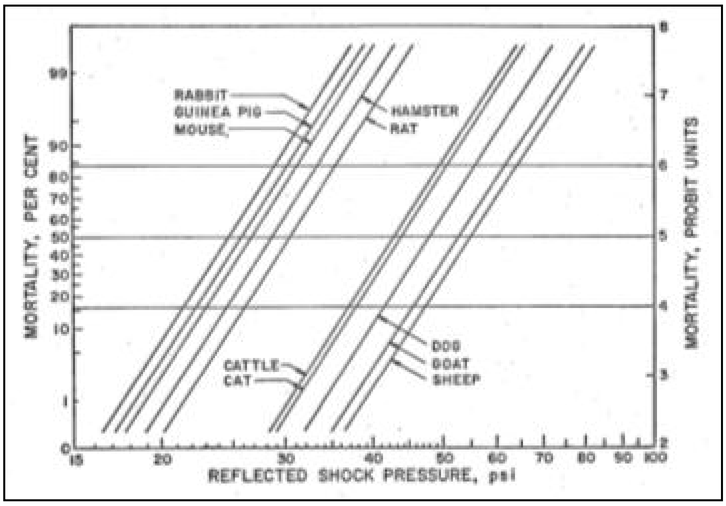

Figure 11: Mortality curve for long duration pressure exposure on animals.

In order to relate to air blast the following table (Table 5) 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 5: 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.

10.9 Water well Influence from Blasting Activities

Domestic, agricultural and monitoring boreholes 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 by Berger et al 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, lithologic 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 hydrologically 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 can therefore be concluded 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.

11 Baseline Results

11.1 General ground vibration and air blast information

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. As part of the baseline all possible structures in a possible influence area is identified.

11.2 Structure Profile

As part of the baseline all possible structures in a possible influence area is 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 is not indicating all the individual structures but in some cases may represent a mulitple of 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 12 shows an aerial view of the mining area and surroundings with points of interest. The list compiled is provided in Table 6 below.

Pit Area:

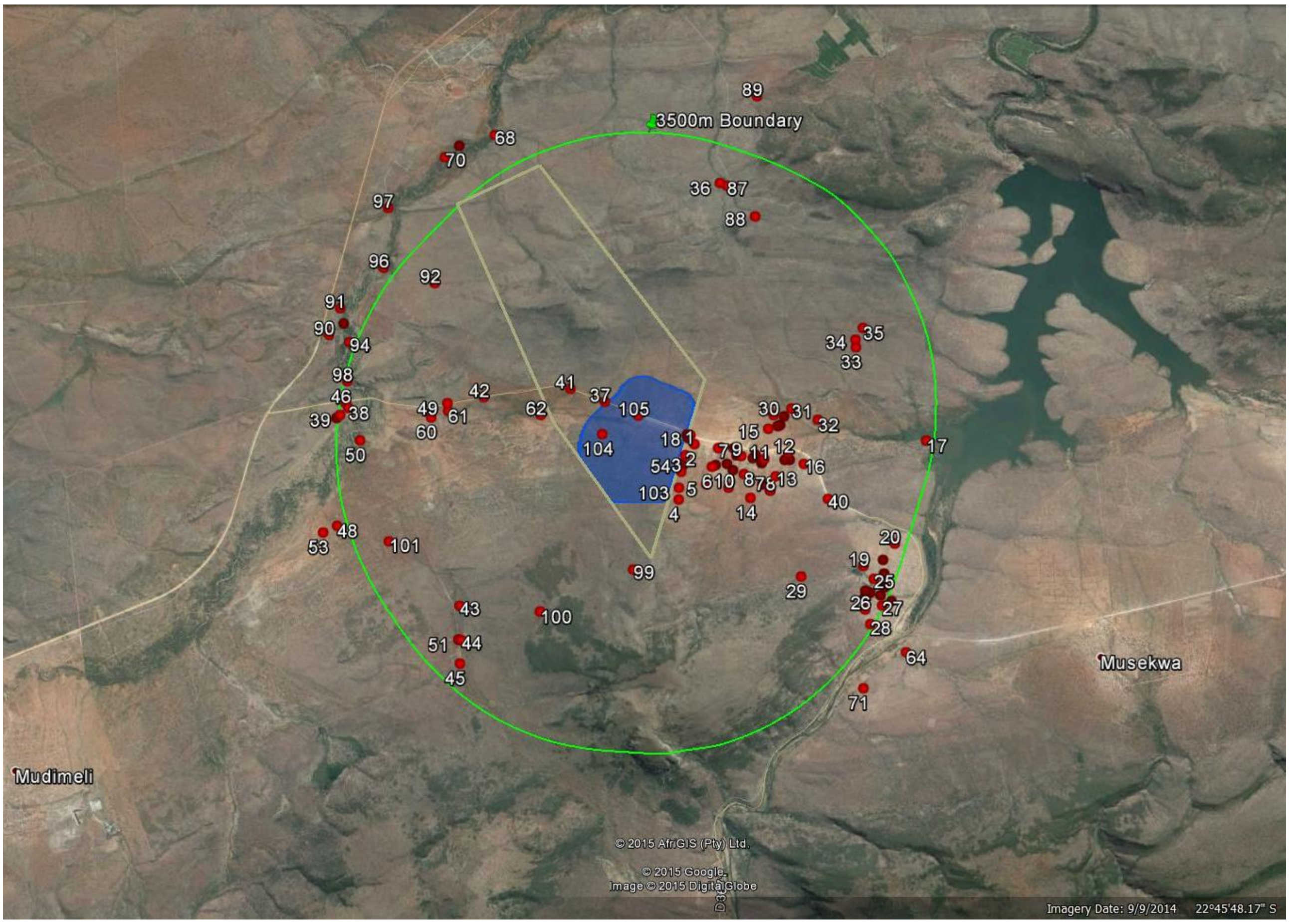

Figure 12: Aerial view and surface plan of the proposed mining area with points of interest identified.

Note: Red Place marks = POI indicators

Table 6: List of points of interest used (WGS – LO 23°)

Tag	Description	Classification	Y	X
1	Rural Community House - Makushu	1	-725244.22	2535397.14
2	Rural Community House - Makushu	1	-725104.99	2535549.45
3	Makushu Graveyard	7	-725033.15	2535783.63
4	Rural Community House - Makushu	1	-724978.26	2536181.28
5	Rural Community House - Makushu	1	-725386.89	2535979.69
6	Rural Community House - Makushu	1	-725481.76	2535734.08
7	Rural Community House - Makushu	1	-725585.36	2535470.08
8	School Structures - Makushu	2	-725940.11	2535860.84
9	Rural Community House - Makushu	1	-725915.88	2535598.95
10	Rural Community House - Makushu	1	-725707.65	2536045.98
11	Rural Community House - Makushu	1	-726243.85	2535658.59
12	Rural Community House - Makushu	1	-726595.89	2535584.18

13	Rural Community House - Makushu	1	-726399.01	2535914.41
14	Rural Community House - Makushu	1	-726017.15	2536207.16
15	Rural Community House - Makushu	1	-726323.08	2535225.62
16	Rural Community House - Makushu	1	-726814.12	2535755.98
17	Nzhelele Dam	5	-728605.32	2535503.35
18	Road	5	-725191.32	2535266.87
19	Rural Community House - Musekwa	1	-727607.42	2537264.53
20	Rural Community House - Musekwa	1	-728078.01	2536965.71
21	Rural Community House - Musekwa	1	-727895.69	2537190.98
22	School Structures - Musekwa	2	-727901.45	2537390.23
23	Rural Community House - Musekwa	1	-727616.30	2537621.63
24	Rural Community House - Musekwa	1	-727901.99	2537587.15
25	Rural Community House - Musekwa	1	-727750.09	2537457.76
26	Rural Community House - Musekwa	1	-727599.36	2537889.76
27	Rural Community House - Musekwa	1	-727852.42	2537847.94
28	Rural Community House - Musekwa	1	-727667.91	2538105.74
29	Cement Dam	5	-726690.17	2537366.46
30	Structure	2	-726410.38	2535032.54
31	Residential Houses	2	-726674.77	2534950.06
32	Buildings/Structures	2	-727047.77	2535129.83
33	Buildings/Structures	2	-727646.81	2534114.58
34	Buildings/Structures	2	-727644.73	2534004.71
35	Cement Dam	5	-727760.54	2533841.42
36	Buildings/Structures	2	-725790.77	2531656.55
37	Road	5	-723976.45	2534725.95
38	Buildings/Structures	2	-720254.67	2534636.41
39	Buildings/Structures (Hunting Camps)	2	-720129.47	2534731.15
40	Road	5	-727139.64	2536275.70
41	Road	5	-723485.87	2534513.40
42	Road	5	-722224.67	2534575.09
43	Buildings/Structures	2	-721737.47	2537560.49
44	Buildings/Structures (Hunting Camps)	2	-721742.25	2538052.73
45	Cement Dam	5	-721705.48	2538386.23
46	Borehole - CAS-1 (BOAS)	8	-720216.23	2534564.77
47	Borehole - CAS-3 (BOAS)	8	-720073.89	2534773.36
48	Borehole - Coalexp (CASTARO)	8	-720009.45	2536325.67
49	Borehole - NHOLE_E (CASTARO)	8	-721691.59	2534636.04
50	Borehole - NHOLE-1 (CASTARO)	8	-720399.34	2535110.16
51	Borehole - LUK-1 (LUKIN)	8	-721702.10	2538043.08
52	Borehole - LUK-5 (LUKIN)	8	-721702.10	2538043.08
53	Borehole - RXXXXX1 (LUKIN)	8	-719801.48	2536412.86
54	Borehole - StandNo210 (MAKUSHU)	8	-725025.47	2535663.24
55	Borehole - StandNoC38 (MAKUSHU)	8	-726203.76	2535715.18
56	Borehole - StandNoE104 (MAKUSHU)	8	-725535.38	2535712.19
57	Borehole - StandNoE83a (MAKUSHU)	8	-725633.18	2535463.56
58	Borehole - StandNoF106 (MAKUSHU)	8	-726539.50	2535684.41
59	Borehole - StandNoG146 (MAKUSHU)	8	-725844.62	2535586.39
60	Borehole - NHOLE-2 (MARTHA)	8	-721446.44	2534829.68
61	Borehole - WCAS-5 (MARTHA)	8	-721697.65	2534747.91
62	Borehole - WMA-1 (MARTHA)	8	-723039.20	2534869.85
63	Borehole - H25-0004 (MSEKWA)	8	-727637.73	2537640.88
64	Borehole - H25-0095 (MSEKWA)	8	-728168.84	2538539.09
65	Borehole - H25-0197 (MUKUSHU)	8	-726121.76	2535590.74
66	Borehole - MUK-1 (MUKUSHU)	8	-725808.22	2535481.99
67	Borehole - MUK-2 (MUKUSHU)	8	-726461.63	2535193.02
68	Borehole - NAK-1 (NAKAP)	8	-722562.44	2530798.94

69	Borehole - NAK-3 (NAKAP)	8	-722037.62	2530930.20
70	Borehole - NAK-4 (NAKAP)	8	-721821.12	2531086.16
71	Borehole - H25-0094 (Njelelepoort)	8	-727524.49	2539028.14
72	Borehole - H25-0002 (TELEMA)	8	-726498.52	2535179.16
73	Borehole - H25-0020 (TELEMA)	8	-726561.23	2535058.30
74	Borehole - H25-0024 (TELEMA)	8	-727833.60	2537699.40
75	Borehole - H25-0025 (TELEMA)	8	-727989.55	2537791.71
76	Borehole - H25-0041 (TELEMA)	8	-726080.12	2535638.96
77	Borehole - H25-0085 (TELEMA)	8	-726309.96	2536111.96
78	Borehole - H25-0086 (TELEMA)	8	-726305.73	2536113.99
79	Borehole - H25-0087 (TELEMA)	8	-726199.47	2536020.74
80	Borehole - H25-0088 (TELEMA)	8	-726612.86	2535686.81
81	Borehole - H25-0089 (TELEMA)	8	-725700.40	2535702.23
82	Borehole - H25-0090 (TELEMA)	8	-725782.76	2535797.68
83	Borehole - H25-0091 (TELEMA)	8	-725142.45	2535251.49
84	Borehole - H25-0104 (TELEMA)	8	-727605.67	2537705.19
85	Borehole - H25-0190 (TELEMA)	8	-727685.67	2537655.46
86	Borehole - NHOLE-10 (TELEMA)	8	-725156.46	2535304.61
87	Borehole - JMAT-1 (THEDUEL)	8	-725890.87	2531699.72
88	Borehole - JMAT-2 (THEDUEL)	8	-726278.65	2532162.39
89	Borehole - JMAT-3 (THEDUEL)	8	-726389.67	2530425.78
90	Borehole - VAND-1 (van Deventer)	8	-720020.29	2533570.25
91	Borehole - WVAND-1 (van Deventer)	8	-720201.71	2533192.81
92	Borehole - WVAND-2 (van Deventer)	8	-721591.25	2532895.09
93	Borehole - WVAND-3 (van Deventer)	8	-721589.60	2532886.08
94	Borehole - WVAND-4 (van Deventer)	8	-720312.72	2533687.90
95	Borehole - WVAND-5 (van Deventer)	8	-720240.81	2533415.59
96	Borehole - WVAND-6 (van Deventer)	8	-720856.23	2532638.12
97	Borehole - WVAND-7 (van Deventer)	8	-720965.31	2531779.69
98	Borehole - WVAND-8 (van Deventer)	8	-720256.95	2534252.06
99	Game Farm Areas	4	-724275.90	2537151.67
100	Game Farm Areas	4	-722904.10	2537688.68
101	Game Farm Areas	4	-720750.69	2536586.30
102	Rural Community House - Makushu	1	-725061.69	2535693.12
103	Rural Community House - Makushu	1	-724989.96	2536012.75
104	Borehole - M-16 (THEDUEL) - Inside Pit Area	8	-723916.04	2535188.42
105	Borehole - NHOLE-3 (THEDUEL) - Inside Pit Area	8	-724450.22	2534946.13

Notes: The type of POI's identified is grouped into different classes. This is a BM&C classification and not related to any standard. It is purely for easy evaluation of type of structures observed. These classes are indicated as "Classification" in table above. Table 7 below shows the descriptions for the classifications used.

Table 7: POI Classification used

Class	**Description**
1	Rural Building and structures of poor construction
2	Private Houses and people sensitive areas
3	Office and High rise buildings
4	Animal related installations and animal sensitive areas

5	Industrial buildings and installations
6	Earth like structures – no surface structure
7	Graves & Heritage
8	Water Borehole

Site visit was conducted and structures observed. Structures range from well-built structures to informal building styles. Table 8 shows photos of structures found in the area.

Table 8: Structure Profile

Structure Photo	**Description**
	Old structure build with mud walls
	Cement brick and mortar structure

	Brick and mortar house being build
	Brick and mortar house and corrugated iron roof

	Corrugated iron structure
	Old structure build with mud walls

	Church building
	Brick and mortar house

	Plastered house with typical damages observed
	Relatively new house

	House and tiled roof
	House being built

	Water Tank
	Relatively new structure

	Cement Dam
	School Building

	House with very prominent vertical crack
	Brick and mortar house

	Rondawel Structure
	Relatively New House

	Cement brick and mortar house
	New House

	Borehole and watertank
	Stone house

	House with very prominent vertical crack
	House with corrugated iron roof

	House
	House

	Old mud house with newer structures
	Grave yard

	Grave yard
	Grave yard

	View on houses in village
	View on houses in village

	Cattle
	Gravel Road

	Pipeline
	Castaro Lodge

12 Construction Phase: Impact Assessment and Mitigation Measures

During the construction no mining drilling and blasting operations is 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.

13 Operational Phase: Impact Assessment and Mitigation Measures

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 6. 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 two different charge mass scenarios is considered with regards to ground vibration and air blast. Review of the charge per blast hole as defined by information provided and the author considered possible timing of a blast, the following two different charge masses of 684 and 2738kg were then selected to ensure proper source coverage.The charge masses selected represents a single blasthole charge detonating and multiple blasthole charges detonating. Normal blast timg systems will yield multiple blast holes detonating simultaneously and a single blasthole detonating is achieved using electronic inititaion systems with blast holes specifically programmed to detonate individually.

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 lesser 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 the possible influence of geology on ground vibration attenuation topography or actual final drill and blast patterns 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.

13.1 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 is coloured "Mustard"
Vibration levels indicated as Intolerable on human perception scale is coloured "Yellow"

13.1.1 Calculated Ground Vibration Levels

Presented are simulations for expected ground vibration levels from minimum and maximum charge masses.

- **Minimum Charge per Delay – Pit Area – 684 kg**

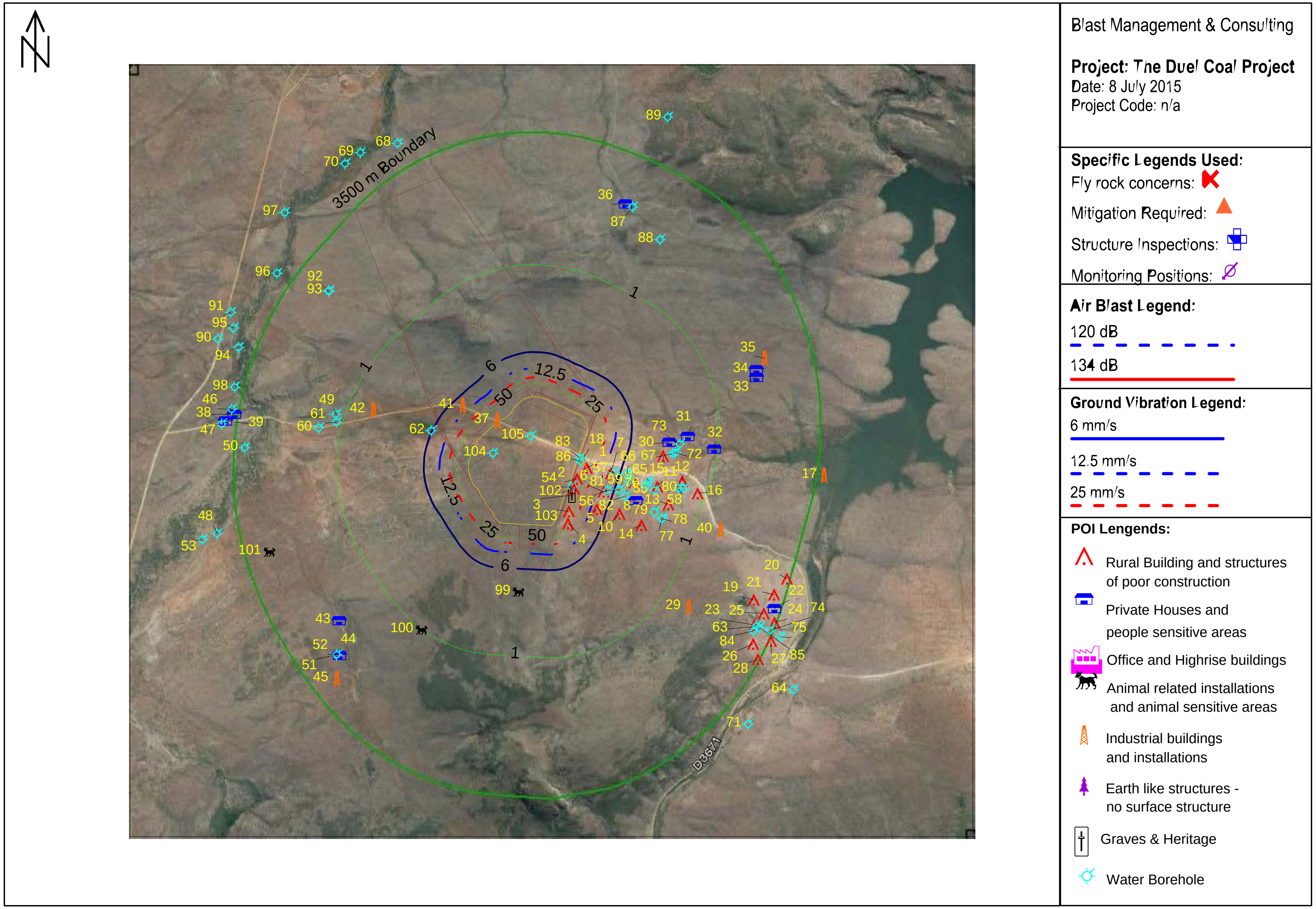

Figure 13: Ground vibration influence from minimum charge

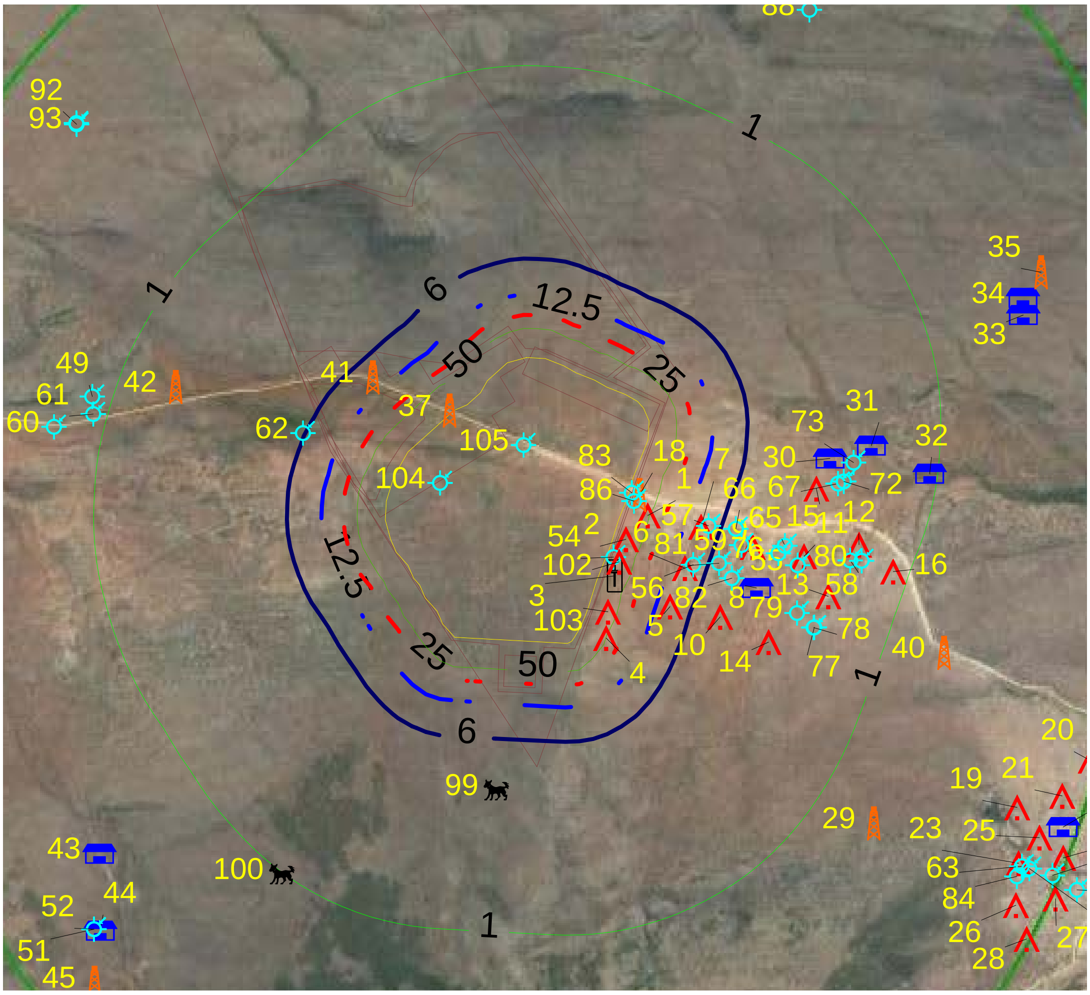

Figure 14: Zoomed area for ground vibration influence from minimum charge

Table 9: Ground vibration evaluation for minimum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Rural Community House - Makushu	12.5	163	55.7	Problematic	Intolerable
2	Rural Community House - Makushu	12.5	82	172.5	Problematic	Intolerable
3	Makushu Graveyard	12.5	96	133.6	Problematic	N/A
4	Rural Community House - Makushu	12.5	179	47.7	Problematic	Intolerable
5	Rural Community House - Makushu	12.5	497	8.9	Acceptable	Unpleasant
6	Rural Community House - Makushu	12.5	496	8.9	Acceptable	Unpleasant
7	Rural Community House - Makushu	12.5	508	8.5	Acceptable	Unpleasant
8	School Structures - Makushu	25	972	2.9	Acceptable	Perceptible
9	Rural Community House - Makushu	12.5	863	3.6	Acceptable	Perceptible
10	Rural Community House -	12.5	820	3.9	Acceptable	Perceptible

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
	Makushu					
11	Rural Community House - Makushu	12.5	1193	2.1	Acceptable	Perceptible
12	Rural Community House - Makushu	12.5	1502	1.4	Acceptable	Perceptible
13	Rural Community House - Makushu	12.5	1426	1.6	Acceptable	Perceptible
14	Rural Community House - Makushu	12.5	1167	2.2	Acceptable	Perceptible
15	Rural Community House - Makushu	12.5	1122	2.3	Acceptable	Perceptible
16	Rural Community House - Makushu	12.5	1766	1.1	Acceptable	Perceptible
17	Nzhelele Dam	50	3412	0.4	Acceptable	N/A
18	Road	150	71	217.9	Problematic	N/A
19	Rural Community House - Musekwa	12.5	3022	0.5	Acceptable	Too Low
20	Rural Community House - Musekwa	12.5	3360	0.4	Acceptable	Too Low
21	Rural Community House - Musekwa	12.5	3262	0.4	Acceptable	Too Low
22	School Structures - Musekwa	25	3342	0.4	Acceptable	Too Low
23	Rural Community House - Musekwa	12.5	3184	0.4	Acceptable	Too Low
24	Rural Community House - Musekwa	12.5	3423	0.4	Acceptable	Too Low
25	Rural Community House - Musekwa	12.5	3231	0.4	Acceptable	Too Low
26	Rural Community House - Musekwa	12.5	3303	0.4	Acceptable	Too Low
27	Rural Community House - Musekwa	12.5	3500	0.4	Acceptable	Too Low
28	Rural Community House - Musekwa	12.5	3477	0.4	Acceptable	Too Low
29	Cement Dam	50	2255	0.7	Acceptable	N/A
30	Structure	25	1171	2.2	Acceptable	Perceptible
31	Residential Houses	25	1428	1.6	Acceptable	Perceptible
32	Buildings/Structures	25	1816	1.0	Acceptable	Perceptible
33	Buildings/Structures	25	2490	0.6	Acceptable	Too Low
34	Buildings/Structures	25	2520	0.6	Acceptable	Too Low
35	Cement Dam	50	2683	0.5	Acceptable	N/A
36	Buildings/Structures	25	2987	0.5	Acceptable	Too Low
37	Road	150	20	1842.2	Problematic	N/A
38	Buildings/Structures	25	3385	0.4	Acceptable	Too Low
39	Buildings/Structures	25	3491	0.4	Acceptable	Too Low

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
	(Hunting Camps)					
40	Road	150	2240	0.7	Acceptable	N/A
41	Road	150	505	8.6	Acceptable	N/A
42	Road	150	1509	1.4	Acceptable	N/A
43	Buildings/Structures	25	2643	0.6	Acceptable	Too Low
44	Buildings/Structures (Hunting Camps)	25	2940	0.5	Acceptable	Too Low
45	Cement Dam	50	3192	0.4	Acceptable	N/A
46	Borehole - CAS-1 (BOAS)	50	3438	0.4	Acceptable	N/A
47	Borehole - CAS-3 (BOAS)	50	3539	0.3	Acceptable	N/A
48	Borehole - Coalexp (CASTARO)	50	3668	0.3	Acceptable	N/A
49	Borehole - NHOLE_E (CASTARO)	50	1994	0.9	Acceptable	N/A
50	Borehole - NHOLE-1 (CASTARO)	50	3179	0.4	Acceptable	N/A
51	Borehole - LUK-1 (LUKIN)	50	2964	0.5	Acceptable	N/A
52	Borehole - LUK-5 (LUKIN)	50	2964	0.5	Acceptable	N/A
53	Borehole - RXXXXX1 (LUKIN)	50	3891	0.3	Acceptable	N/A
54	Borehole - StandNo210 (MAKUSHU)	50	45	469.6	Problematic	N/A
55	Borehole - StandNoC38 (MAKUSHU)	50	1173	2.2	Acceptable	N/A
56	Borehole - StandNoE104 (MAKUSHU)	50	541	7.7	Acceptable	N/A
57	Borehole - StandNoE83a (MAKUSHU)	50	551	7.5	Acceptable	N/A
58	Borehole - StandNoF106 (MAKUSHU)	50	1483	1.5	Acceptable	N/A
59	Borehole - StandNoG146 (MAKUSHU)	50	792	4.1	Acceptable	N/A
60	Borehole - NHOLE-2 (MARTHA)	50	2180	0.8	Acceptable	N/A
61	Borehole - WCAS-5 (MARTHA)	50	1956	0.9	Acceptable	N/A
62	Borehole - WMA-1 (MARTHA)	50	645	5.8	Acceptable	N/A
63	Borehole - H25-0004 (MSEKWA)	50	3212	0.4	Acceptable	N/A
64	Borehole - H25-0095 (MSEKWA)	50	4135	0.3	Acceptable	N/A
65	Borehole - H25-0197 (MUKUSHU)	50	1056	2.6	Acceptable	N/A
66	Borehole - MUK-1 (MUKUSHU)	50	724	4.8	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
67	Borehole - MUK-2 (MUKUSHU)	50	1249	1.9	Acceptable	N/A
68	Borehole - NAK-1 (NAKAP)	50	4039	0.3	Acceptable	N/A
69	Borehole - NAK-3 (NAKAP)	50	4187	0.3	Acceptable	N/A
70	Borehole - NAK-4 (NAKAP)	50	4184	0.3	Acceptable	N/A
71	Borehole - H25-0094 (Njelelepoort)	50	3956	0.3	Acceptable	N/A
72	Borehole - H25-0002 (TELEMA)	50	1282	1.9	Acceptable	N/A
73	Borehole - H25-0020 (TELEMA)	50	1324	1.8	Acceptable	N/A
74	Borehole - H25-0024 (TELEMA)	50	3413	0.4	Acceptable	N/A
75	Borehole - H25-0025 (TELEMA)	50	3594	0.3	Acceptable	N/A
76	Borehole - H25-0041 (TELEMA)	50	1031	2.7	Acceptable	N/A
77	Borehole - H25-0085 (TELEMA)	50	1404	1.6	Acceptable	N/A
78	Borehole - H25-0086 (TELEMA)	50	1401	1.6	Acceptable	N/A
79	Borehole - H25-0087 (TELEMA)	50	1268	1.9	Acceptable	N/A
80	Borehole - H25-0088 (TELEMA)	50	1553	1.4	Acceptable	N/A
81	Borehole - H25-0089 (TELEMA)	50	696	5.1	Acceptable	N/A
82	Borehole - H25-0090 (TELEMA)	50	803	4.0	Acceptable	N/A
83	Borehole - H25-0091 (TELEMA)	50	21	1697.5	Problematic	N/A
84	Borehole - H25-0104 (TELEMA)	50	3215	0.4	Acceptable	N/A
85	Borehole - H25-0190 (TELEMA)	50	3262	0.4	Acceptable	N/A
86	Borehole - NHOLE-10 (TELEMA)	50	50	395.6	Problematic	N/A
87	Borehole - JMAT-1 (THEDUEL)	50	2985	0.5	Acceptable	N/A
88	Borehole - JMAT-2 (THEDUEL)	50	2728	0.5	Acceptable	N/A
89	Borehole - JMAT-3 (THEDUEL)	50	4353	0.2	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
90	Borehole - VAND-1 (van Deventer)	50	3931	0.3	Acceptable	N/A
91	Borehole - WVAND-1 (van Deventer)	50	3938	0.3	Acceptable	N/A
92	Borehole - WVAND-2 (van Deventer)	50	2981	0.5	Acceptable	N/A
93	Borehole - WVAND-3 (van Deventer)	50	2989	0.5	Acceptable	N/A
94	Borehole - WVAND-4 (van Deventer)	50	3616	0.3	Acceptable	N/A
95	Borehole - WVAND-5 (van Deventer)	50	3798	0.3	Acceptable	N/A
96	Borehole - WVAND-6 (van Deventer)	50	3699	0.3	Acceptable	N/A
97	Borehole - WVAND-7 (van Deventer)	50	4223	0.3	Acceptable	N/A
98	Borehole - WVAND-8 (van Deventer)	50	3479	0.4	Acceptable	N/A
99	Game Farm Areas	150	960	3.0	Acceptable	Perceptible
100	Game Farm Areas	150	1873	1.0	Acceptable	Perceptible
101	Game Farm Areas	150	3032	0.4	Acceptable	Too Low
102	Rural Community House - Makushu	12.5	90	149.3	Problematic	Intolerable
103	Rural Community House - Makushu	12.5	128	83.0	Problematic	Intolerable

- **Maximum Charge per Delay – Pit Area – 2738 kg**

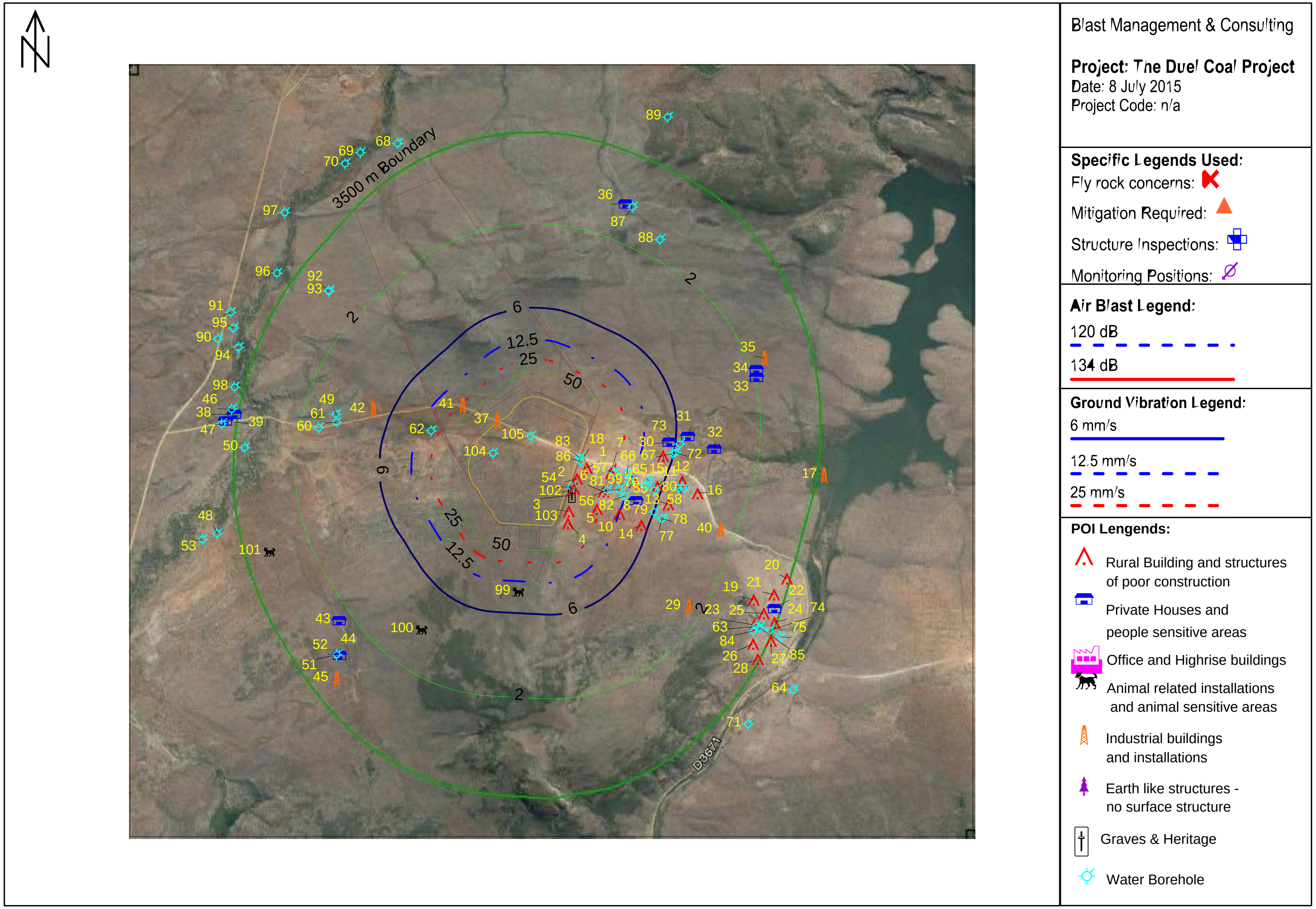

Figure 15: Ground vibration influence from maximum charge

Table 10: Ground vibration evaluation for maximum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Rural Community House - Makushu	12.5	163	174.8	Problematic	Intolerable
2	Rural Community House - Makushu	12.5	82	541.6	Problematic	Intolerable
3	Makushu Graveyard	12.5	96	419.5	Problematic	N/A
4	Rural Community House - Makushu	12.5	179	149.8	Problematic	Intolerable
5	Rural Community House - Makushu	12.5	497	27.9	Problematic	Intolerable
6	Rural Community House - Makushu	12.5	496	27.9	Problematic	Intolerable
7	Rural Community House - Makushu	12.5	508	26.8	Problematic	Intolerable
8	School Structures - Makushu	25	972	9.2	Acceptable	Unpleasant
9	Rural Community House - Makushu	12.5	863	11.2	Acceptable	Unpleasant
10	Rural Community House - Makushu	12.5	820	12.2	Acceptable	Unpleasant
11	Rural Community House - Makushu	12.5	1193	6.6	Acceptable	Unpleasant
12	Rural Community House - Makushu	12.5	1502	4.5	Acceptable	Perceptible
13	Rural Community House - Makushu	12.5	1426	4.9	Acceptable	Perceptible
14	Rural Community House - Makushu	12.5	1167	6.8	Acceptable	Unpleasant
15	Rural Community House - Makushu	12.5	1122	7.3	Acceptable	Unpleasant
16	Rural Community House - Makushu	12.5	1766	3.4	Acceptable	Perceptible
17	Nzhelele Dam	50	3412	1.2	Acceptable	N/A
18	Road	150	71	684.3	Problematic	N/A
19	Rural Community House - Musekwa	12.5	3022	1.4	Acceptable	Perceptible
20	Rural Community House - Musekwa	12.5	3360	1.2	Acceptable	Perceptible
21	Rural Community House - Musekwa	12.5	3262	1.2	Acceptable	Perceptible
22	School Structures - Musekwa	25	3342	1.2	Acceptable	Perceptible
23	Rural Community House - Musekwa	12.5	3184	1.3	Acceptable	Perceptible
24	Rural Community House - Musekwa	12.5	3423	1.2	Acceptable	Perceptible
25	Rural Community House - Musekwa	12.5	3231	1.3	Acceptable	Perceptible

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
26	Rural Community House - Musekwa	12.5	3303	1.2	Acceptable	Perceptible
27	Rural Community House - Musekwa	12.5	3500	1.1	Acceptable	Perceptible
28	Rural Community House - Musekwa	12.5	3477	1.1	Acceptable	Perceptible
29	Cement Dam	50	2255	2.3	Acceptable	N/A
30	Structure	25	1171	6.8	Acceptable	Unpleasant
31	Residential Houses	25	1428	4.9	Acceptable	Perceptible
32	Buildings/Structures	25	1816	3.3	Acceptable	Perceptible
33	Buildings/Structures	25	2490	2.0	Acceptable	Perceptible
34	Buildings/Structures	25	2520	1.9	Acceptable	Perceptible
35	Cement Dam	50	2683	1.7	Acceptable	N/A
36	Buildings/Structures	25	2987	1.4	Acceptable	Perceptible
37	Road	150	20	5785.0	Problematic	N/A
38	Buildings/Structures	25	3385	1.2	Acceptable	Perceptible
39	Buildings/Structures (Hunting Camps)	25	3491	1.1	Acceptable	Perceptible
40	Road	150	2240	2.3	Acceptable	N/A
41	Road	150	505	27.1	Acceptable	N/A
42	Road	150	1509	4.5	Acceptable	N/A
43	Buildings/Structures	25	2643	1.8	Acceptable	Perceptible
44	Buildings/Structures (Hunting Camps)	25	2940	1.5	Acceptable	Perceptible
45	Cement Dam	50	3192	1.3	Acceptable	N/A
46	Borehole - CAS-1 (BOAS)	50	3438	1.1	Acceptable	N/A
47	Borehole - CAS-3 (BOAS)	50	3539	1.1	Acceptable	N/A
48	Borehole - Coalexp (CASTARO)	50	3668	1.0	Acceptable	N/A
49	Borehole - NHOLE_E (CASTARO)	50	1994	2.8	Acceptable	N/A
50	Borehole - NHOLE-1 (CASTARO)	50	3179	1.3	Acceptable	N/A
51	Borehole - LUK-1 (LUKIN)	50	2964	1.5	Acceptable	N/A
52	Borehole - LUK-5 (LUKIN)	50	2964	1.5	Acceptable	N/A
53	Borehole - RXXXXX1 (LUKIN)	50	3891	0.9	Acceptable	N/A
54	Borehole - StandNo210 (MAKUSHU)	50	45	1474.6	Problematic	N/A
55	Borehole - StandNoC38 (MAKUSHU)	50	1173	6.8	Acceptable	N/A
56	Borehole - StandNoE104 (MAKUSHU)	50	541	24.2	Acceptable	N/A
57	Borehole - StandNoE83a (MAKUSHU)	50	551	23.5	Acceptable	N/A
58	Borehole - StandNoF106	50	1483	4.6	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
	(MAKUSHU)					
59	Borehole - StandNoG146 (MAKUSHU)	50	792	12.9	Acceptable	N/A
60	Borehole - NHOLE-2 (MARTHA)	50	2180	2.4	Acceptable	N/A
61	Borehole - WCAS-5 (MARTHA)	50	1956	2.9	Acceptable	N/A
62	Borehole - WMA-1 (MARTHA)	50	645	18.1	Acceptable	N/A
63	Borehole - H25-0004 (MSEKWA)	50	3212	1.3	Acceptable	N/A
64	Borehole - H25-0095 (MSEKWA)	50	4135	0.8	Acceptable	N/A
65	Borehole - H25-0197 (MUKUSHU)	50	1056	8.0	Acceptable	N/A
66	Borehole - MUK-1 (MUKUSHU)	50	724	15.0	Acceptable	N/A
67	Borehole - MUK-2 (MUKUSHU)	50	1249	6.1	Acceptable	N/A
68	Borehole - NAK-1 (NAKAP)	50	4039	0.9	Acceptable	N/A
69	Borehole - NAK-3 (NAKAP)	50	4187	0.8	Acceptable	N/A
70	Borehole - NAK-4 (NAKAP)	50	4184	0.8	Acceptable	N/A
71	Borehole - H25-0094 (Njelelepoort)	50	3956	0.9	Acceptable	N/A
72	Borehole - H25-0002 (TELEMA)	50	1282	5.8	Acceptable	N/A
73	Borehole - H25-0020 (TELEMA)	50	1324	5.5	Acceptable	N/A
74	Borehole - H25-0024 (TELEMA)	50	3413	1.2	Acceptable	N/A
75	Borehole - H25-0025 (TELEMA)	50	3594	1.1	Acceptable	N/A
76	Borehole - H25-0041 (TELEMA)	50	1031	8.4	Acceptable	N/A
77	Borehole - H25-0085 (TELEMA)	50	1404	5.0	Acceptable	N/A
78	Borehole - H25-0086 (TELEMA)	50	1401	5.0	Acceptable	N/A
79	Borehole - H25-0087 (TELEMA)	50	1268	5.9	Acceptable	N/A
80	Borehole - H25-0088 (TELEMA)	50	1553	4.2	Acceptable	N/A
81	Borehole - H25-0089	50	696	16.0	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
	(TELEMA)					
82	Borehole - H25-0090 (TELEMA)	50	803	12.6	Acceptable	N/A
83	Borehole - H25-0091 (TELEMA)	50	21	5330.5	Problematic	N/A
84	Borehole - H25-0104 (TELEMA)	50	3215	1.3	Acceptable	N/A
85	Borehole - H25-0190 (TELEMA)	50	3262	1.2	Acceptable	N/A
86	Borehole - NHOLE-10 (TELEMA)	50	50	1242.4	Problematic	N/A
87	Borehole - JMAT-1 (THEDUEL)	50	2985	1.4	Acceptable	N/A
88	Borehole - JMAT-2 (THEDUEL)	50	2728	1.7	Acceptable	N/A
89	Borehole - JMAT-3 (THEDUEL)	50	4353	0.8	Acceptable	N/A
90	Borehole - VAND-1 (van Deventer)	50	3931	0.9	Acceptable	N/A
91	Borehole - WVAND-1 (van Deventer)	50	3938	0.9	Acceptable	N/A
92	Borehole - WVAND-2 (van Deventer)	50	2981	1.4	Acceptable	N/A
93	Borehole - WVAND-3 (van Deventer)	50	2989	1.4	Acceptable	N/A
94	Borehole - WVAND-4 (van Deventer)	50	3616	1.1	Acceptable	N/A
95	Borehole - WVAND-5 (van Deventer)	50	3798	1.0	Acceptable	N/A
96	Borehole - WVAND-6 (van Deventer)	50	3699	1.0	Acceptable	N/A
97	Borehole - WVAND-7 (van Deventer)	50	4223	0.8	Acceptable	N/A
98	Borehole - WVAND-8 (van Deventer)	50	3479	1.1	Acceptable	N/A
99	Game Farm Areas	150	960	9.4	Acceptable	Unpleasant
100	Game Farm Areas	150	1873	3.1	Acceptable	Perceptible
101	Game Farm Areas	150	3032	1.4	Acceptable	Perceptible
102	Rural Community House - Makushu	12.5	90	468.7	Problematic	Intolerable
103	Rural Community House - Makushu	12.5	128	260.6	Problematic	Intolerable

13.1.2 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 vary in distances from the opencast pit area. Rural Community Houses at Makushu and other structures are relatively well spread on the eastern side of the opencast area. The structures identified range in distance from very close to very far for the pit area and could be problematic. The evaluation took mainly up to 3500 m from the mining areas into consideration. The closest structure found is the road at POI 37 that runs through the pit area. The planned minimum and maximum charge evaluated showed that it could be problematic. The graves and graveyards are very close and could be problematic as well. Water boreholes identified are at close distances of 21m to 50m away from the blasting operations. Problems with regards to ground vibration influence on these boreholes are foreseen.

The distances between the structures and the pit area are the main contributing factor to the levels of ground vibration expected and the subsequent possible influences. It is observed that for the different charge masses evaluated that levels of ground vibration will change as well. In view of the maximum charge specific attention will need to be given to specific areas. Based on a ground vibration limit of 12.5 mm/s for the structures found in the village this limit will be exceeded up to a distance of 800 m from pit boundary. Unfortunately not all houses or structures can be indicated as separate POI's on the plan. The 800 m distance will include a significant number of structures. Figure 16 below shows the 800 m range of possible influence on the western side of the pit.

There are structures that are better built and some that are of lesser quality integrity. Only a detail survey will pin point exactly what type of structure is found where.

In view of the above it is believed that specific mitigations will be required and/or relocation of households. There are areas where blasting will be done that will have influence on structures.

Figure 16: 800 m range influence from maximum charge

13.2 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 17 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 up to 3500 m from the pit area investigated people may experience levels of ground vibration as perceptible. At 1500m 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"*. Distances closer than 700m will exceed the minimum 6mm/s proposed safe limit for poorly constructed structures and general 12.5 mm/s limit. People could also experience ground vibration as intolerable in this range. Figure 17 below shows this effect of ground vibration with regards to human perception for maximum charge.

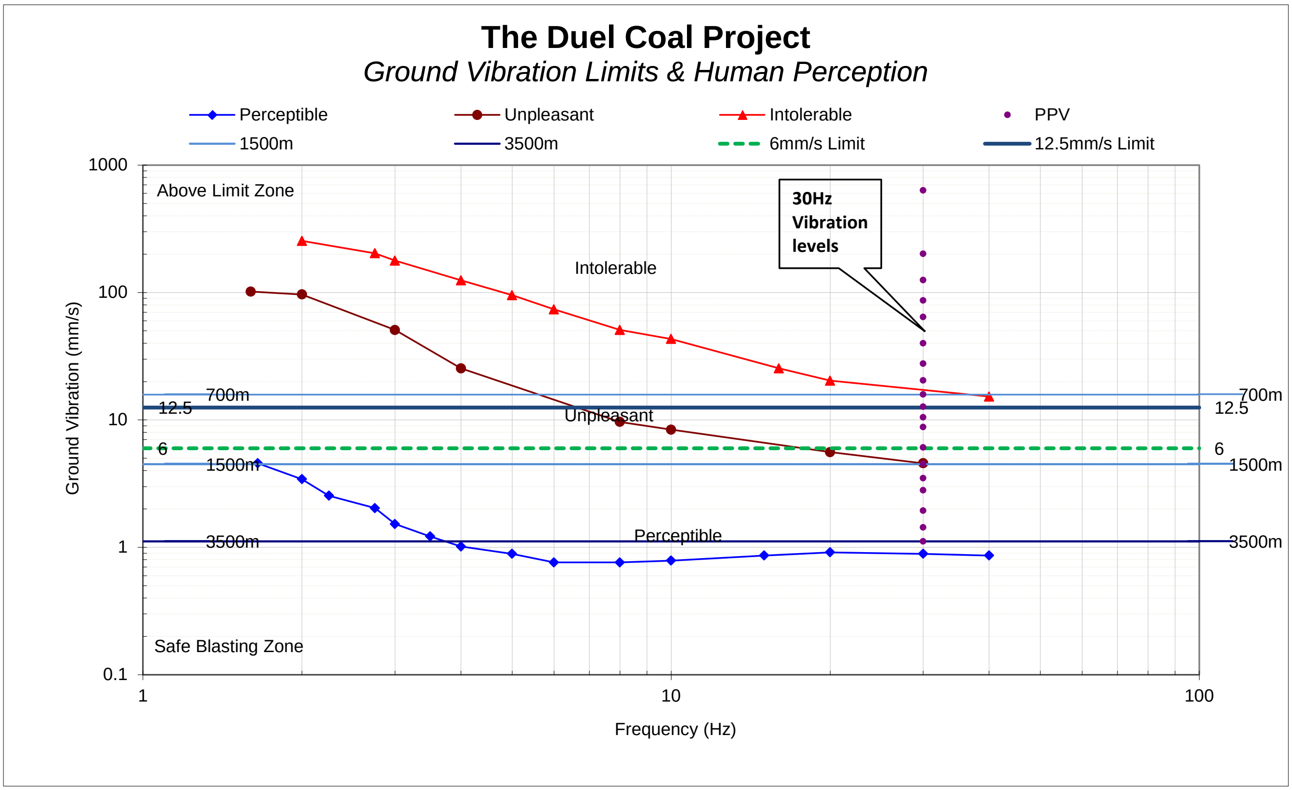

Figure 17: The effect of ground vibration with human perception and vibration limits

13.3 Vibration impact on roads

There are no highways or provincial roads in vicinity of the project area to be considered. There are no tarred roads in the vicinity of the project area. There are gravel roads that link the different villages. There is a gravel road that is running cross the planned opencast area. Expected ground vibration levels at this road are higher than the recommended limits and re-routing or changed blasting parameters will have to be applied to ensure levels are within accepted norms if the road is to remain. There also various smaller paths that are used by people and animals in the areas of the project. These routes are specifically of concern when blasting is done. There may be people and animals on these routes and will require careful planning to main safe blasting radius.

13.4 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, grazing areas and roads that are within the evaluated area of influence. There are structures in close proximity of the pit area. Structures are in some cases right next to the pit area. The houses and village area are located such that levels of ground vibration predicted are higher than allowed limits. Ground vibration levels at other houses may be perceptible and unpleasant but not damaging.

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.

13.5 Cracking of houses and consequent devaluation

The structures found in the areas of concern ranges from informal building style to brick and mortar structures. There are various villages and houses 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.

13.6 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 charges 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 11shows the applied limits and recommended levels for each of the charges considered. The maximum charge may exceed limits at distances up to 300m. The recommended limit of 120dB is observed at distance of 1250m. These distances are reduced to 200m for the minimum charge allowed limit and 800m for recommended limit. This clearly indicates that with increased charge masses the distances of influence increases. An area of 1250m influence would be possible if care is not taken to manage air blast levels.

Table 11: Expected air blast levels

No.	Distance (m)	Air blast (dB) for 684kg Charge	Air blast (dB) for 2738kg Charge
1	50.0	147	152
2	100.0	142	147
3	150.0	135	140
4	200.0	132	137
5	250.0	130	135
6	300.0	128	133
7	400.0	126	130
8	500.0	124	128
9	600.0	122	126
10	700.0	121	125
11	800.0	119	124
12	900.0	118	123
13	1000.0	117	122
14	1250.0	116	120
15	1500.0	114	118
16	1750.0	113	117
17	2000.0	112	115
18	2500.0	110	114
19	3000.0	108	112
20	3500.0	107	111

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.

13.6.1 Review of expected air blast

Presented are simulations for expected air blast levels from two different charge masses. Minimum 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 is coloured "Mustard"
Air blast levels indicated as possible Complaint is coloured "Yellow"

- **Minimum Charge per Delay – Pit Area - 684kg**

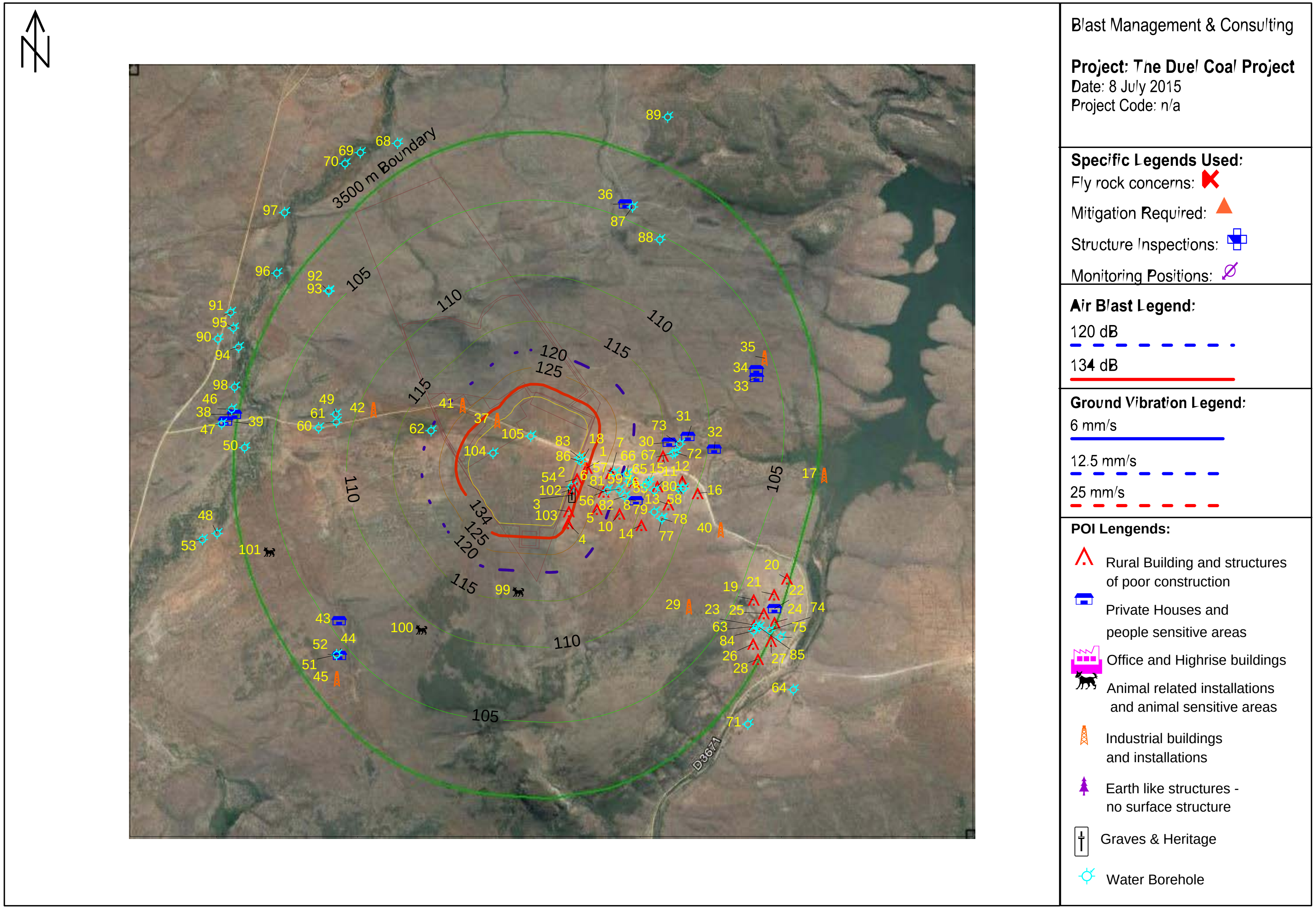

Figure 18: Air blast influence from minimum charge

Table 12: Air blast evaluation for minimum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Rural Community House - Makushu	163	134.6	Problematic
2	Rural Community House - Makushu	82	141.7	Problematic
3	Makushu Graveyard	96	140.1	N/A
4	Rural Community House - Makushu	179	133.6	Problematic
5	Rural Community House - Makushu	497	123.0	Complaint
6	Rural Community House - Makushu	496	123.0	Complaint
7	Rural Community House - Makushu	508	122.7	Complaint
8	School Structures - Makushu	972	116.0	Acceptable
9	Rural Community House - Makushu	863	117.2	Acceptable
10	Rural Community House - Makushu	820	117.8	Acceptable
11	Rural Community House - Makushu	1193	113.8	Acceptable
12	Rural Community House - Makushu	1502	111.4	Acceptable
13	Rural Community House - Makushu	1426	112.0	Acceptable
14	Rural Community House - Makushu	1167	114.1	Acceptable
15	Rural Community House - Makushu	1122	114.5	Acceptable
16	Rural Community House - Makushu	1766	109.8	Acceptable
17	Nzhelele Dam	3412	102.9	N/A
18	Road	71	143.2	N/A
19	Rural Community House - Musekwa	3022	104.2	Acceptable
20	Rural Community House - Musekwa	3360	103.0	Acceptable
21	Rural Community House - Musekwa	3262	103.4	Acceptable
22	School Structures - Musekwa	3342	103.1	Acceptable
23	Rural Community House - Musekwa	3184	103.6	Acceptable
24	Rural Community House - Musekwa	3423	102.9	Acceptable
25	Rural Community House - Musekwa	3231	103.5	Acceptable
26	Rural Community House - Musekwa	3303	103.2	Acceptable
27	Rural Community House - Musekwa	3500	102.6	Acceptable
28	Rural Community House - Musekwa	3477	102.7	Acceptable
29	Cement Dam	2255	107.2	N/A
30	Structure	1171	114.0	Acceptable
31	Residential Houses	1428	112.0	Acceptable
32	Buildings/Structures	1816	109.5	Acceptable
33	Buildings/Structures	2490	106.2	Acceptable
34	Buildings/Structures	2520	106.0	Acceptable
35	Cement Dam	2683	105.4	N/A
36	Buildings/Structures	2987	104.3	Acceptable
37	Road	20	156.7	N/A
38	Buildings/Structures	3385	103.0	Acceptable
39	Buildings/Structures (Hunting Camps)	3491	102.6	Acceptable
40	Road	2240	107.3	N/A
41	Road	505	122.8	N/A
42	Road	1509	111.4	N/A
43	Buildings/Structures	2643	105.5	Acceptable
44	Buildings/Structures (Hunting Camps)	2940	104.4	Acceptable
45	Cement Dam	3192	103.6	N/A
46	Borehole - CAS-1 (BOAS)	3438	102.8	N/A
47	Borehole - CAS-3 (BOAS)	3539	102.5	N/A
48	Borehole - Coalexp (CASTARO)	3668	102.1	N/A
49	Borehole - NHOLE_E (CASTARO)	1994	108.5	N/A
50	Borehole - NHOLE-1 (CASTARO)	3179	103.6	N/A
51	Borehole - LUK-1 (LUKIN)	2964	104.4	N/A
52	Borehole - LUK-5 (LUKIN)	2964	104.4	N/A
53	Borehole - RXXXXX1 (LUKIN)	3891	101.5	N/A
54	Borehole - StandNo210 (MAKUSHU)	45	148.0	N/A

55	Borehole - StandNoC38 (MAKUSHU)	1173	114.0	N/A
56	Borehole - StandNoE104 (MAKUSHU)	541	122.1	N/A
57	Borehole - StandNoE83a (MAKUSHU)	551	121.9	N/A
58	Borehole - StandNoF106 (MAKUSHU)	1483	111.6	N/A
59	Borehole - StandNoG146 (MAKUSHU)	792	118.1	N/A
60	Borehole - NHOLE-2 (MARTHA)	2180	107.6	N/A
61	Borehole - WCAS-5 (MARTHA)	1956	108.7	N/A
62	Borehole - WMA-1 (MARTHA)	645	120.3	N/A
63	Borehole - H25-0004 (MSEKWA)	3212	103.5	N/A
64	Borehole - H25-0095 (MSEKWA)	4135	100.9	N/A
65	Borehole - H25-0197 (MUKUSHU)	1056	115.1	N/A
66	Borehole - MUK-1 (MUKUSHU)	724	119.0	N/A
67	Borehole - MUK-2 (MUKUSHU)	1249	113.4	N/A
68	Borehole - NAK-1 (NAKAP)	4039	101.1	N/A
69	Borehole - NAK-3 (NAKAP)	4187	100.8	N/A
70	Borehole - NAK-4 (NAKAP)	4184	100.8	N/A
71	Borehole - H25-0094 (Njelelepoort)	3956	101.3	N/A
72	Borehole - H25-0002 (TELEMA)	1282	113.1	N/A
73	Borehole - H25-0020 (TELEMA)	1324	112.8	N/A
74	Borehole - H25-0024 (TELEMA)	3413	102.9	N/A
75	Borehole - H25-0025 (TELEMA)	3594	102.3	N/A
76	Borehole - H25-0041 (TELEMA)	1031	115.4	N/A
77	Borehole - H25-0085 (TELEMA)	1404	112.1	N/A
78	Borehole - H25-0086 (TELEMA)	1401	112.2	N/A
79	Borehole - H25-0087 (TELEMA)	1268	113.2	N/A
80	Borehole - H25-0088 (TELEMA)	1553	111.1	N/A
81	Borehole - H25-0089 (TELEMA)	696	119.5	N/A
82	Borehole - H25-0090 (TELEMA)	803	118.0	N/A
83	Borehole - H25-0091 (TELEMA)	21	156.2	N/A
84	Borehole - H25-0104 (TELEMA)	3215	103.5	N/A
85	Borehole - H25-0190 (TELEMA)	3262	103.4	N/A
86	Borehole - NHOLE-10 (TELEMA)	50	147.0	N/A
87	Borehole - JMAT-1 (THEDUEL)	2985	104.3	N/A
88	Borehole - JMAT-2 (THEDUEL)	2728	105.2	N/A
89	Borehole - JMAT-3 (THEDUEL)	4353	100.3	N/A
90	Borehole - VAND-1 (van Deventer)	3931	101.4	N/A
91	Borehole - WVAND-1 (van Deventer)	3938	101.4	N/A
92	Borehole - WVAND-2 (van Deventer)	2981	104.3	N/A
93	Borehole - WVAND-3 (van Deventer)	2989	104.3	N/A
94	Borehole - WVAND-4 (van Deventer)	3616	102.3	N/A
95	Borehole - WVAND-5 (van Deventer)	3798	101.8	N/A
96	Borehole - WVAND-6 (van Deventer)	3699	102.0	N/A
97	Borehole - WVAND-7 (van Deventer)	4223	100.7	N/A
98	Borehole - WVAND-8 (van Deventer)	3479	102.7	N/A
99	Game Farm Areas	960	116.1	Acceptable
100	Game Farm Areas	1873	109.1	Acceptable
101	Game Farm Areas	3032	104.1	Acceptable
102	Rural Community House - Makushu	90	140.8	Problematic
103	Rural Community House - Makushu	128	137.1	Problematic

- **Maximum Charge per Delay – Pit Area - 2738kg**

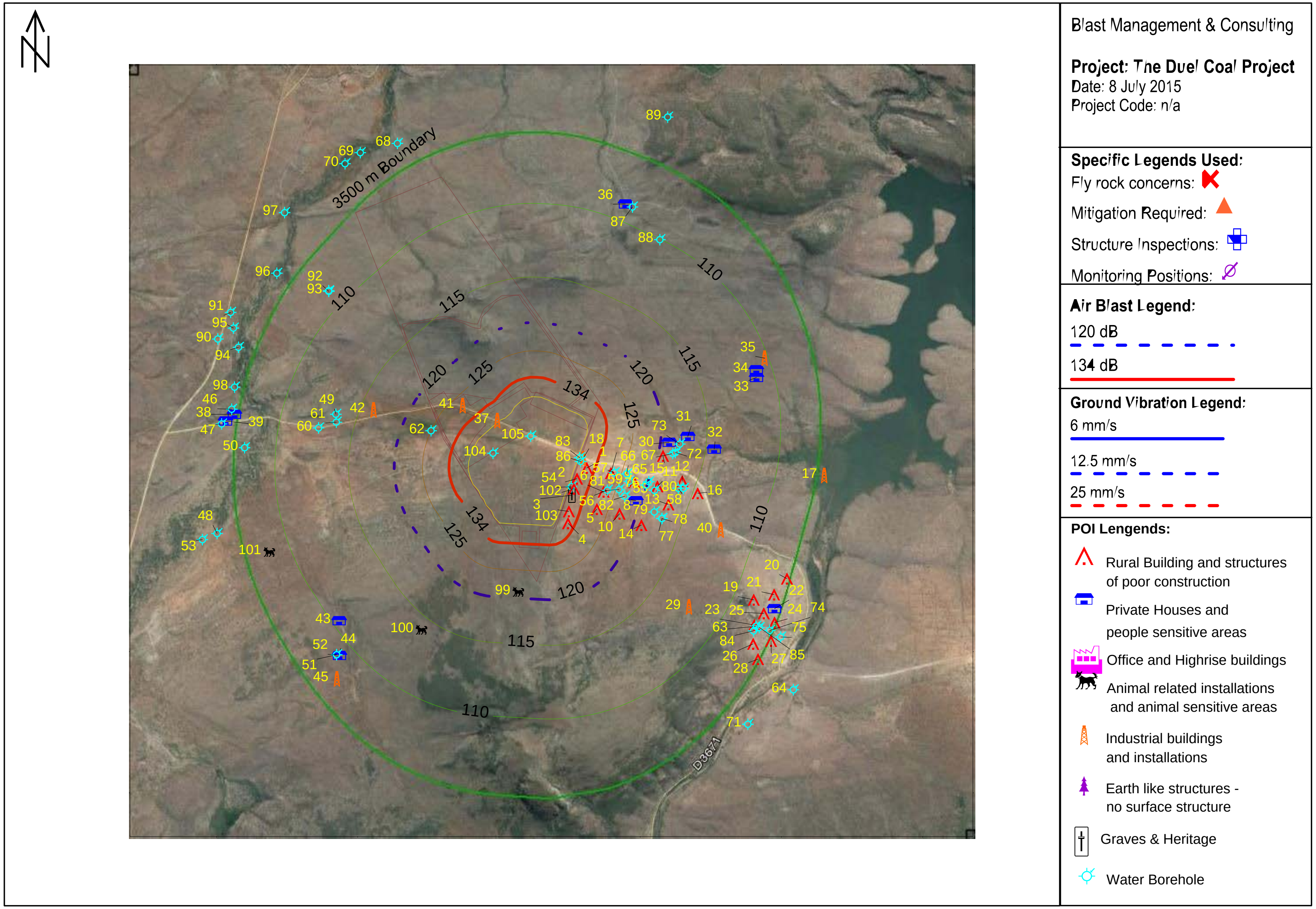

Figure 19: Air blast influence from maximum charge

Table 13: Air blast evaluation for maximum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Rural Community House - Makushu	163	139.4	Problematic
2	Rural Community House - Makushu	82	146.5	Problematic
3	Makushu Graveyard	96	144.9	N/A
4	Rural Community House - Makushu	179	138.4	Problematic
5	Rural Community House - Makushu	497	127.8	Complaint
6	Rural Community House - Makushu	496	127.8	Complaint
7	Rural Community House - Makushu	508	127.6	Complaint
8	School Structures - Makushu	972	120.8	Complaint
9	Rural Community House - Makushu	863	122.0	Complaint
10	Rural Community House - Makushu	820	122.6	Complaint
11	Rural Community House - Makushu	1193	118.7	Acceptable
12	Rural Community House - Makushu	1502	116.3	Acceptable
13	Rural Community House - Makushu	1426	116.8	Acceptable
14	Rural Community House - Makushu	1167	118.9	Acceptable
15	Rural Community House - Makushu	1122	119.3	Acceptable
16	Rural Community House - Makushu	1766	114.6	Acceptable
17	Nzhelele Dam	3412	107.7	N/A
18	Road	71	148.0	N/A
19	Rural Community House - Musekwa	3022	109.0	Acceptable
20	Rural Community House - Musekwa	3360	107.9	Acceptable
21	Rural Community House - Musekwa	3262	108.2	Acceptable
22	School Structures - Musekwa	3342	107.9	Acceptable
23	Rural Community House - Musekwa	3184	108.4	Acceptable
24	Rural Community House - Musekwa	3423	107.7	Acceptable
25	Rural Community House - Musekwa	3231	108.3	Acceptable
26	Rural Community House - Musekwa	3303	108.0	Acceptable
27	Rural Community House - Musekwa	3500	107.4	Acceptable
28	Rural Community House - Musekwa	3477	107.5	Acceptable
29	Cement Dam	2255	112.0	N/A
30	Structure	1171	118.9	Acceptable
31	Residential Houses	1428	116.8	Acceptable
32	Buildings/Structures	1816	114.3	Acceptable
33	Buildings/Structures	2490	111.0	Acceptable
34	Buildings/Structures	2520	110.9	Acceptable
35	Cement Dam	2683	110.2	N/A
36	Buildings/Structures	2987	109.1	Acceptable
37	Road	20	161.5	N/A
38	Buildings/Structures	3385	107.8	Acceptable
39	Buildings/Structures (Hunting Camps)	3491	107.5	Acceptable
40	Road	2240	112.1	N/A
41	Road	505	127.6	N/A
42	Road	1509	116.2	N/A
43	Buildings/Structures	2643	110.4	Acceptable
44	Buildings/Structures (Hunting Camps)	2940	109.3	Acceptable
45	Cement Dam	3192	108.4	N/A
46	Borehole - CAS-1 (BOAS)	3438	107.6	N/A
47	Borehole - CAS-3 (BOAS)	3539	107.3	N/A
48	Borehole - Coalexp (CASTARO)	3668	107.0	N/A
49	Borehole - NHOLE_E (CASTARO)	1994	113.3	N/A
50	Borehole - NHOLE-1 (CASTARO)	3179	108.4	N/A
51	Borehole - LUK-1 (LUKIN)	2964	109.2	N/A
52	Borehole - LUK-5 (LUKIN)	2964	109.2	N/A
53	Borehole - RXXXXX1 (LUKIN)	3891	106.3	N/A
54	Borehole - StandNo210 (MAKUSHU)	45	152.9	N/A

55	Borehole - StandNoC38 (MAKUSHU)	1173	118.8	N/A
56	Borehole - StandNoE104 (MAKUSHU)	541	126.9	N/A
57	Borehole - StandNoE83a (MAKUSHU)	551	126.7	N/A
58	Borehole - StandNoF106 (MAKUSHU)	1483	116.4	N/A
59	Borehole - StandNoG146 (MAKUSHU)	792	122.9	N/A
60	Borehole - NHOLE-2 (MARTHA)	2180	112.4	N/A
61	Borehole - WCAS-5 (MARTHA)	1956	113.5	N/A
62	Borehole - WMA-1 (MARTHA)	645	125.1	N/A
63	Borehole - H25-0004 (MSEKWA)	3212	108.3	N/A
64	Borehole - H25-0095 (MSEKWA)	4135	105.7	N/A
65	Borehole - H25-0197 (MUKUSHU)	1056	119.9	N/A
66	Borehole - MUK-1 (MUKUSHU)	724	123.9	N/A
67	Borehole - MUK-2 (MUKUSHU)	1249	118.2	N/A
68	Borehole - NAK-1 (NAKAP)	4039	105.9	N/A
69	Borehole - NAK-3 (NAKAP)	4187	105.6	N/A
70	Borehole - NAK-4 (NAKAP)	4184	105.6	N/A
71	Borehole - H25-0094 (Njelelepoort)	3956	106.2	N/A
72	Borehole - H25-0002 (TELEMA)	1282	117.9	N/A
73	Borehole - H25-0020 (TELEMA)	1324	117.6	N/A
74	Borehole - H25-0024 (TELEMA)	3413	107.7	N/A
75	Borehole - H25-0025 (TELEMA)	3594	107.2	N/A
76	Borehole - H25-0041 (TELEMA)	1031	120.2	N/A
77	Borehole - H25-0085 (TELEMA)	1404	117.0	N/A
78	Borehole - H25-0086 (TELEMA)	1401	117.0	N/A
79	Borehole - H25-0087 (TELEMA)	1268	118.0	N/A
80	Borehole - H25-0088 (TELEMA)	1553	115.9	N/A
81	Borehole - H25-0089 (TELEMA)	696	124.3	N/A
82	Borehole - H25-0090 (TELEMA)	803	122.8	N/A
83	Borehole - H25-0091 (TELEMA)	21	161.0	N/A
84	Borehole - H25-0104 (TELEMA)	3215	108.3	N/A
85	Borehole - H25-0190 (TELEMA)	3262	108.2	N/A
86	Borehole - NHOLE-10 (TELEMA)	50	151.8	N/A
87	Borehole - JMAT-1 (THEDUEL)	2985	109.1	N/A
88	Borehole - JMAT-2 (THEDUEL)	2728	110.0	N/A
89	Borehole - JMAT-3 (THEDUEL)	4353	105.2	N/A
90	Borehole - VAND-1 (van Deventer)	3931	106.2	N/A
91	Borehole - WVAND-1 (van Deventer)	3938	106.2	N/A
92	Borehole - WVAND-2 (van Deventer)	2981	109.1	N/A
93	Borehole - WVAND-3 (van Deventer)	2989	109.1	N/A
94	Borehole - WVAND-4 (van Deventer)	3616	107.1	N/A
95	Borehole - WVAND-5 (van Deventer)	3798	106.6	N/A
96	Borehole - WVAND-6 (van Deventer)	3699	106.9	N/A
97	Borehole - WVAND-7 (van Deventer)	4223	105.5	N/A
98	Borehole - WVAND-8 (van Deventer)	3479	107.5	N/A
99	Game Farm Areas	960	120.9	Problematic
100	Game Farm Areas	1873	114.0	Acceptable
101	Game Farm Areas	3032	108.9	Acceptable
102	Rural Community House - Makushu	90	145.6	Problematic
103	Rural Community House - Makushu	128	141.9	Problematic

13.6.2 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 107.4 and 146.5dB where structures are of concern.

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.

13.7 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. A stemming length of 5.6 m in the blast is expected to yield fly rock that could travel as far as 472 m. Further reduction of stemming length will certainly see fly rock travelling further. At a distance of 472m as the minimum exclusion zone the following POI's are of concern: 1, 2, 3, 4, 18, 37, 54, 83, 86, 102, 103, 104 and 105. Figure 20 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 and at the elevated levels of blasting care must be taken on fly rock as travel distance may be further than anticipated. Careful attention will need to be given to stemming control to ensure that fly rock minimised as much as possible. Figure 21 shows the area around pit area that incorporates the 472 m exclusion zone.

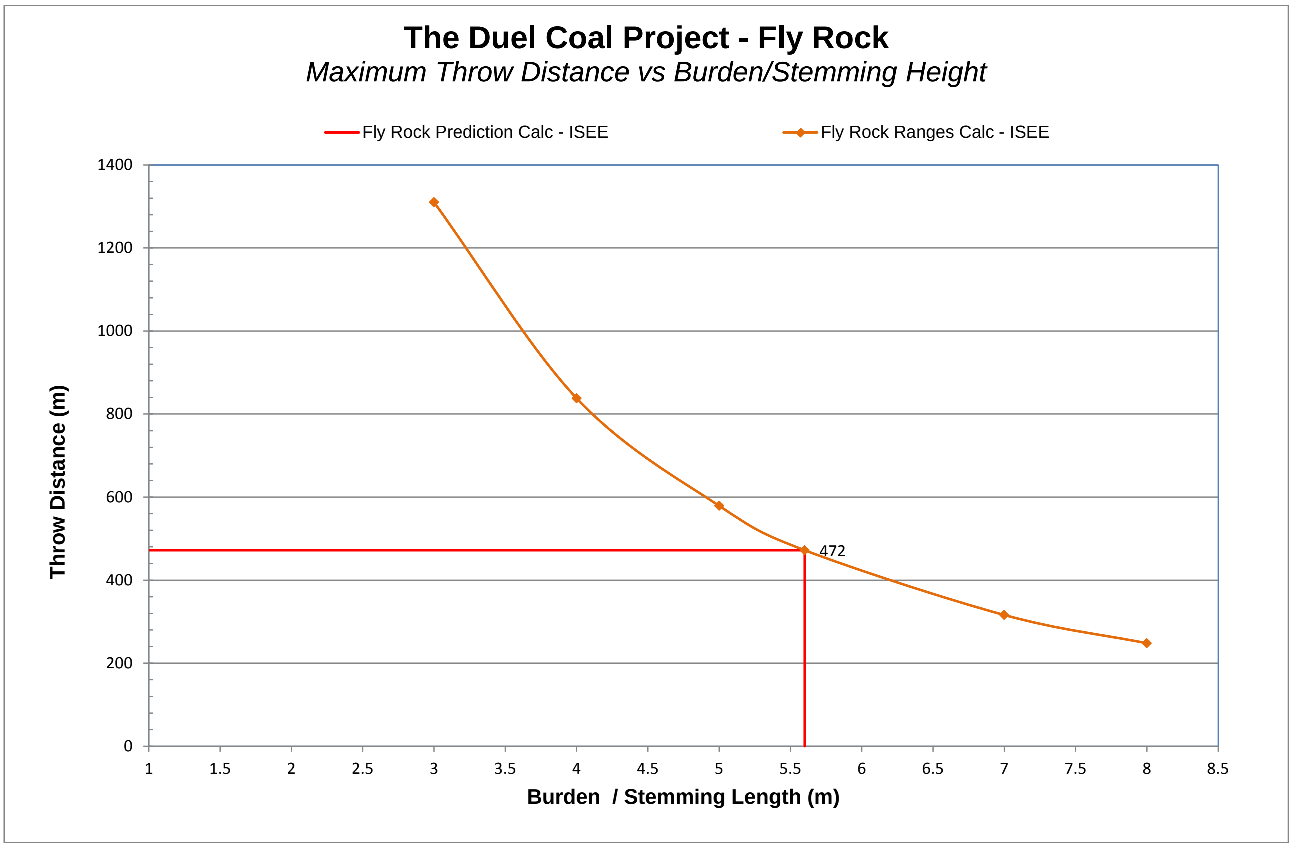

Figure 20: Predicted Fly rock

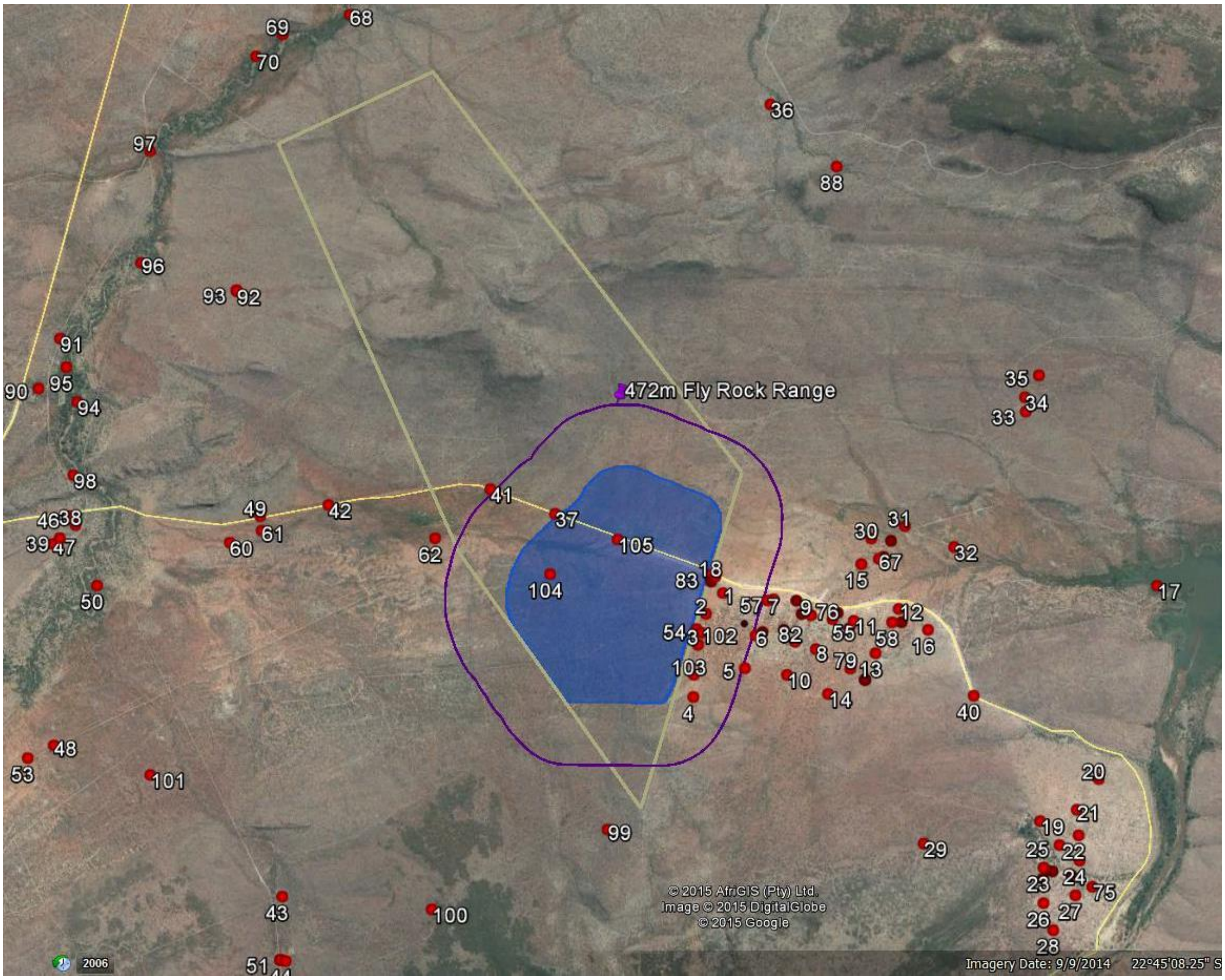

Figure 21: Predicted Fly rock Exclusion Zone

13.8 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 fume will travel to any part nearby farm stead but again if anybody is present in the path of cloud travel it could be problematic.

13.9 Water well influence

Boreholes for water were evaluated for possible influence as well. There are various boreholes in the area. Three boreholes were identified that could possibly be influenced due to excessive ground vibration at minimum and maximum charge. The expected levels of ground vibration are significantly greater than the limit applied for water boreholes. Table 14 shows the boreholes that are of concern and Figure 22 show the location of these water boreholes. These boreholes range from 21 m to 50 m from pit boundary.

Table 14: Problematic water boreholes

Tag	Description	-Y	-X	Specific Limit (mm/s)	Distance (m)
54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.23	50	45
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49	50	21
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61	50	50

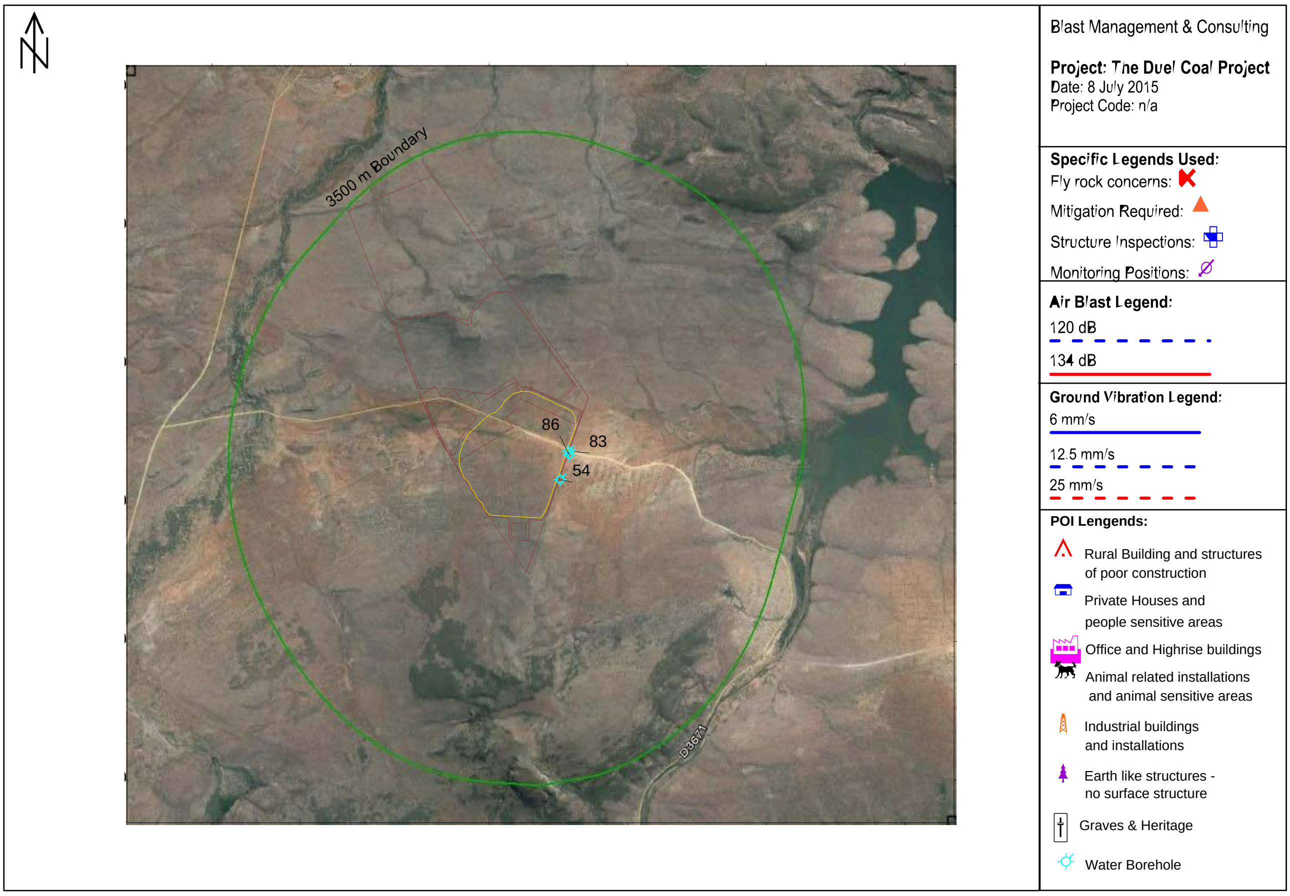

Figure 22: Problematic water boreholes

13.10 Vibration impacts on productivity of domestic animals (cattle, chickens, pigs, etc.)

The area is characterised by mountainous areas and flat areas in between. There are no specific fenced grazing areas. There are also areas fenced off where game farming is found. Cattle and goats can be expected to roam freely throughout the area. It may also be anticipated that cattle could be present from time to time 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 also not well defined in literature. 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 in 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. The typical levels of air blast required to induce physical injuries or death is extremely high and highly unlikely to occur. In order to be prone to such influences animals should almost be on top of the blast area. This however is not likely to occur as a mine must be fenced off and all animals and people removed out of an unsafe zone away from the blast area.

13.11 Potential Environmental Impact Assessment: Operational Phase

The following is the impact assessment of the various concerns covered by this report. The matrix below in Table 15 was used for analysis and evaluation of aspects discussed in this report. The outcome of the analysis is provided in Table 16 before mitigation and Table 17after mitigation. This risk assessment is a one sided analysis and needs to be discussed with role players in order to obtain a proper outcome and mitigation.

13.11.1Assessment Methodology

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human activities related to alternatives under study for meeting a project need.

The significance of the aspects/impacts of the process were rated by using a matrix derived from Plomp (2004) and adapted to some extent to fit this process. These matrixes use the consequence and the likelihood of the different aspects and associated impacts to determine the significance of the impacts.

The significances of the impacts were determined through a synthesis of the criteria below:

Probability. This describes the likelihood of the impact actually occurring.

Improbable:	The possibility of the impact occurring is very low, due to the circumstances, design or experience.
Probable:	There is a probability that the impact will occur to the extent that provision must be made therefore.
Highly Probable:	It is most likely that the impact will occur at some stage of the development.
Definite:	The impact will take place regardless of any prevention plans, and there can only be relied on mitigatory actions or contingency plans to contain the effect.

Duration. The lifetime of the impact

Short term:	The impact will either disappear with mitigation or will be mitigated through natural processes in a time span shorter than any of the phases.
Medium term:	The impact will last up to the end of the phases, where after it will be negated.
Long term:	The impact will last for the entire operational phase of the project but will be mitigated by direct human action or by natural processes thereafter.
Permanent:	Impact that will be non-transitory. Mitigation either by man or natural processes will not occur in such a way or in such a time span that the impact can be considered transient.

Scale. The physical and spatial size of the impact

Local:	The impacted area extends only as far as the activity, e.g. footprint
Site:	The impact could affect the whole, or a measurable portion of the above mentioned properties.
Regional:	The impact could affect the area including the neighbouring residential areas.

Magnitude/ Severity. Does the impact destroy the environment, or alter its function.

Low:	The impact alters the affected environment in such a way that natural processes are not affected.

Medium: The affected environment is altered, but functions and processes continue in a modified way.

High: Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.

Significance. This is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required.

Negligible: The impact is non-existent or unsubstantial and is of no or little importance to any stakeholder and can be ignored.

Low: The impact is limited in extent, has low to medium intensity; whatever its probability of occurrence is, the impact will not have a material effect on the decision and is likely to require management intervention with increased costs.

Moderate: The impact is of importance to one or more stakeholders, and its intensity will be medium or high; therefore, the impact may materially affect the decision, and management intervention will be required.

High: The impact could render development options controversial or the project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor in mitigation.

Table 15: The following weights were assigned to each attribute:

Aspect	Description	Weight
Probability	Improbable	1
	Probable	2
	Highly Probable	4
	Definite	5
Duration	Short term	1
	Medium term	3
	Long term	4
	Permanent	5
Scale	Local	1
	Site	2
	Regional	3
Magnitude/Severity	Low	2
	Medium	6
	High	8
Significance	**Sum (Duration, Scale, Magnitude) x Probability**	
	Negligible	<20
	Low	<40
	Moderate	<60
	High	>60

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. Mitigation measures are discussed in the following section.

13.11.2 Assessment

Table 16: Risk Assessment Outcome before mitigation

No.	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		None									0	Positive
Operational Phase												
1	Blasting	Ground vibration Impact on houses	5	Definite	3	Medium Term	2	Local	8	High	65	Moderate
2	Blasting	Ground vibration Impact on boreholes	5	Definite	3	Medium Term	2	Local	8	High	65	Moderate
3	Blasting	Ground vibration Impact on roads	3	Medium Probability	3	Medium Term	2	Local	8	High	39	Moderate
4	Blasting	Air blast Impact on houses	5	Definite	3	Medium Term	2	Local	8	High	65	Moderate
5	Blasting	Air blast Impact on boreholes	0		3	Medium Term	2	Local	0		0	None
6	Blasting	Air blast Impact on roads	0		3	Medium Term	2	Local	0		0	None
7	Blasting	Fly Rock Impact on houses	5	Definite	3	Medium Term	2	Local	6	Moderate	55	Moderate
8	Blasting	Fly Rock Impact on boreholes	2	Low Probability	3	Medium Term	2	Local	4	Low	18	Low
9	Blasting	Fly Rock Impact on roads	5	Definite	3	Medium Term	2	Local	8	High	65	Moderate
10	Blasting	Impact of Fumes - Houses	3	Medium Probability	3	Medium Term	2	Local	6	Moderate	33	Moderate
11	Blasting	Impact of Fumes - Boreholes	0		3	Medium Term	2	Local	0		0	None
12	Blasting	Impact of Fumes - Roads	0		3	Medium Term	2	Local	0		0	None
Closure and Post-Closure Phase												
1		None									0	Positive

Table 17: Risk Assessment Outcome after mitigation

No.	Activity	Impact	Mitigation Measures	P	D	S	M / S	Significance	
				Score	Score	Score	Score	Score	Magnitude
Pre-Construction and Construction Phase			**Pre-Construction and Construction Phase**						
1		None						0	Positive
Operational Phase			**Operational Phase**						
1	Blasting	Ground vibration Impact on houses	Reduce charge mass per delay, create an increased blast buffer between village and pit, re-design blast.	3	3	2	4	27	Low
2	Blasting	Ground vibration Impact on boreholes	Reduce charge mass per delay, changed or specific blast design, increased buffer between blast and boreholes, drill new boreholes (if affected)	3	3	2	2	21	Low
3	Blasting	Ground vibration Impact on roads	Reduce charge mass per delay, re-route gravel road	3	3	2	2	21	Low
4	Blasting	Air blast Impact on houses	Stemming control and audit, use proper stemming materials, re-design blasts.	3	3	2	4	27	Low
5	Blasting	Air blast Impact on boreholes	None	0	3	2	2	0	Positive
6	Blasting	Air blast Impact on roads	None	0	3	2	2	0	Positive
7	Blasting	Fly Rock Impact on houses	Stemming control and audit, use proper stemming materials, re-design of blasts.	3	3	2	4	27	Low
8	Blasting	Fly Rock Impact on boreholes	Stemming control and audit, use proper stemming materials, re-design of blasts.	2	3	2	2	14	Low
9	Blasting	Fly Rock Impact on roads	Stemming control and audit, use proper stemming materials, re-design of blasts.	2	3	2	4	18	Low
10	Blasting	Impact of Fumes - Houses	Quality explosives use, do not sleep over for periods of time, if water use appropriate explosives, consider wind direction prior to blasting	2	3	2	4	18	Low
11	Blasting	Impact of Fumes - Boreholes	None	0	3	2	2	0	Positive
12	Blasting	Impact of Fumes - Roads	None	0	3	2	2	0	Positive
Closure and Post-Closure Phase			**Closure and Post-Closure Phase**						
1		None						0	Positive

13.11.3 Mitigations

In review of the evaluations made it is certain that specific mitigation will be required with regards to ground vibration. This is specific to the structures at POI 1 – 7, 18, 37, 54, 83, 86, 102 and 103 – closest to the pit area. The POI's listed represents a multiple of POI's and should not be seen as single individual POI's. Figure 23and Table 18 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.

Ground vibration mitigation can be done in various ways but mainly consists of the following 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. In areas where there are people close to opencast operations it is also advisable that proper blasts designs are done and these design with the necessary planning are executed 100%.

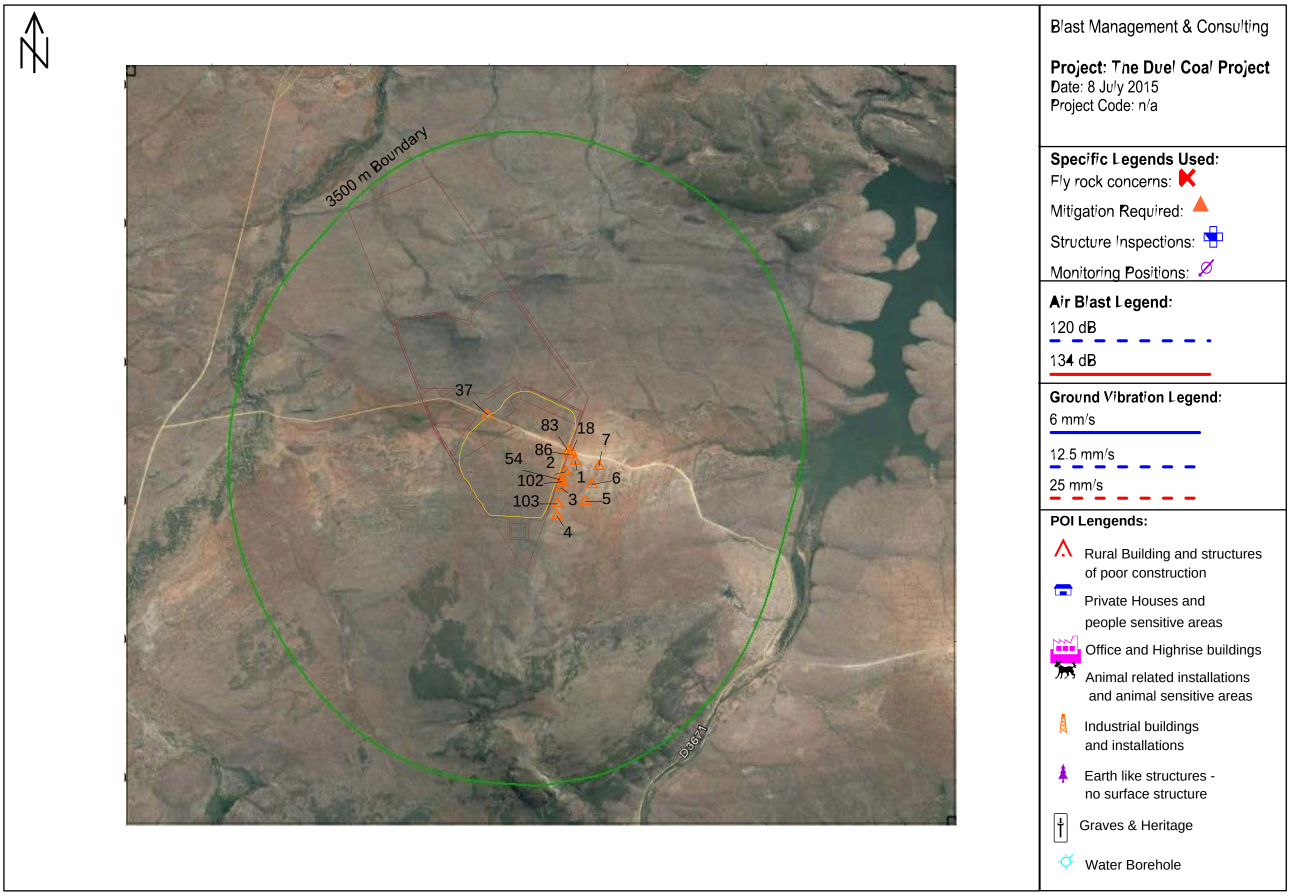

Figure 23: Structures at Pit Area that are identified where mitigation will be required.

Table 18: Structures around pit area identified as problematic from maximum charge

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	Rural Community House - Makushu	-725244.22	2535397.14	12.5	163	2738	174.8	Problematic
2	Rural Community House - Makushu	-725104.99	2535549.45	12.5	82	2738	541.6	Problematic
3	Makushu Graveyard	-725033.15	2535783.63	12.5	96	2738	419.5	Problematic
4	Rural Community House - Makushu	-724978.26	2536181.28	12.5	179	2738	149.8	Problematic
5	Rural Community House - Makushu	-725386.89	2535979.69	12.5	497	2738	27.9	Problematic
6	Rural Community House - Makushu	-725481.76	2535734.08	12.5	496	2738	27.9	Problematic
7	Rural Community House - Makushu	-725585.36	2535470.08	12.5	508	2738	26.8	Problematic
18	Road	-725191.32	2535266.87	150	71	2738	684.3	Problematic
37	Road	-723976.45	2534725.95	150	20	2738	5785.0	Problematic
54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.24	50	45	2738	1474.6	Problematic
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49	50	21	2738	5330.5	Problematic
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61	50	50	2738	1242.4	Problematic
102	Rural Community House - Makushu	-725061.69	2535693.12	12.5	90	2738	468.7	Problematic
103	Rural Community House - Makushu	-724989.96	2536012.75	12.5	128	2738	260.6	Problematic

Table 19: Structures around pit area identified as problematic from minimum charge

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	Rural Community House - Makushu	-725244.22	2535397.14	12.5	163	684	55.7	Problematic
2	Rural Community House - Makushu	-725104.99	2535549.45	12.5	82	684	172.5	Problematic
3	Makushu Graveyard	-725033.15	2535783.63	12.5	96	684	133.6	Problematic
4	Rural Community House - Makushu	-724978.26	2536181.28	12.5	179	684	47.7	Problematic
18	Road	-725191.32	2535266.87	150	71	684	217.9	Problematic
37	Road	-723976.45	2534725.95	150	20	684	1842.2	Problematic
54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.24	50	45	684	469.6	Problematic
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49	50	21	684	1697.5	Problematic
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61	50	50	684	395.6	Problematic
102	Rural Community House - Makushu	-725061.69	2535693.12	12.5	90	684	149.3	Problematic
103	Rural Community House - Makushu	-724989.96	2536012.75	12.5	128	684	83.0	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 tables 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 western side of the opencast pit area. This will be dependent on the actual drill depths, quantity of charge per blast hole 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 the pit area 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 19 shows identified problematic POI's with reduced charge required to facilitate ground vibration levels within limits. Table 20 shows the minimum distance required between blast and POI at the maximum charge used to maintain accepted levels of ground vibration.

Table 20: Mitigation suggested for blasting operations – Reduced charge

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	Rural Community House - Makushu	-725244.2214	2535397.1	12.5	163	112	12.5	Acceptable
2	Rural Community House - Makushu	-725104.99	2535549.45	12.5	82	28	12.5	Acceptable
3	Makushu Graveyard	-725033.15	2535783.63	12.5	96	39	12.5	Acceptable
4	Rural Community House - Makushu	-724978.26	2536181.28	12.5	179	135	12.5	Acceptable
5	Rural Community House - Makushu	-725386.8946	2535979.7	12.5	497	1037	12.5	Acceptable
6	Rural Community House - Makushu	-725481.76	2535734.08	12.5	496	1034	12.5	Acceptable
7	Rural Community House - Makushu	-725585.36	2535470.08	12.5	508	1084	12.5	Acceptable
18	Road	-725191.32	2535266.87	150	71	435	150.0	Acceptable
37	Road	-723976.45	2534725.95	150	20	33	150.0	Acceptable
54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.24	50	45	45	50.0	Acceptable
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49	50	21	10	50.0	Acceptable
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61	50	50	56	50.0	Acceptable
102	Rural Community House - Makushu	-725061.69	2535693.12	12.5	90	34	12.5	Acceptable
103	Rural Community House - Makushu	-724989.96	2536012.75	12.5	128	69	12.5	Acceptable

The information provided in Table 20 indicates that if no changes are made in the location of structures identified around the pit area, the maximum charges allowed maintaining the recommended safe vibration levels are very low at the closest points to these structures. Specific attention to designs and boundaries will be required.

Table 21: Mitigation suggested for blasting operations – minimum distance required for maximum charge

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	Rural Community House - Makushu	-725244.2214	2535397.1	12.5	808	2738	12.5	Acceptable
2	Rural Community House - Makushu	-725104.99	2535549.45	12.5	808	2738	12.5	Acceptable
3	Makushu Graveyard	-725033.15	2535783.63	12.5	808	2738	12.5	Acceptable
4	Rural Community House - Makushu	-724978.26	2536181.28	12.5	808	2738	12.5	Acceptable
5	Rural Community House - Makushu	-725386.8946	2535979.7	12.5	808	2738	12.5	Acceptable
6	Rural Community House - Makushu	-725481.76	2535734.08	12.5	808	2738	12.5	Acceptable
7	Rural Community House - Makushu	-725585.36	2535470.08	12.5	808	2738	12.5	Acceptable
18	Road	-725191.32	2535266.87	150	179	2738	150.0	Acceptable
37	Road	-723976.45	2534725.95	150	179	2738	150.0	Acceptable
54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.24	50	349	2738	50.0	Acceptable
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49	50	349	2738	50.0	Acceptable
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61	50	349	2738	50.0	Acceptable
102	Rural Community House - Makushu	-725061.69	2535693.12	12.5	808	2738	12.5	Acceptable
103	Rural Community House - Makushu	-724989.96	2536012.75	12.5	808	2738	12.5	Acceptable

Reducing the charge mass per delay to the minimum charge the minimum distance required is reduced to 404 m. This is shown in Table 22 below.

Table 22: Mitigation suggested for blasting operations – minimum distance required for minimum charge

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	Rural Community House - Makushu	-725244.2214	2535397.1	12.5	404	684	12.5	Acceptable
2	Rural Community House - Makushu	-725104.99	2535549.45	12.5	404	684	12.5	Acceptable
3	Makushu Graveyard	-725033.15	2535783.63	12.5	404	684	12.5	Acceptable
4	Rural Community House - Makushu	-724978.26	2536181.28	12.5	404	684	12.5	Acceptable
18	Road	-725191.32	2535266.87	150	90	684	150.0	Acceptable
37	Road	-723976.45	2534725.95	150	90	684	150.0	Acceptable
54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.24	50	174	684	50.0	Acceptable
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49	50	174	684	50.0	Acceptable
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61	50	174	684	50.0	Acceptable
102	Rural Community House - Makushu	-725061.69	2535693.12	12.5	404	684	12.5	Acceptable
103	Rural Community House - Makushu	-724989.96	2536012.75	12.5	404	684	12.5	Acceptable

14 Closure Phase

During the closure no mining drilling and blasting operations is 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.

15 Alternatives (Comparison and Recommendation)

No specific alternatives to the opencast mining operations planned are currently under discussion or considered.

16 Monitoring

A ground vibration and air blast monitoring programme will be imperative when mining commences for this project. This will need to include monitoring ground vibration and air blast for every blast. Ground vibration and air blast is monitored using a seismograph. In this case it is recommended that permanent stations are used for monitoring of all blasting done. 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 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 11 monitoring positions were identified around the mining opencast pit area. Monitor positions are indicated in Figure 24 and Table 21 shows the locations with POI number and coordinates. These points will need to be defined finally from testing during first blasts. Only after the first blasts done a final decision should be made with regards to a monitoring programme and this programme shared with all interested and affected parties.

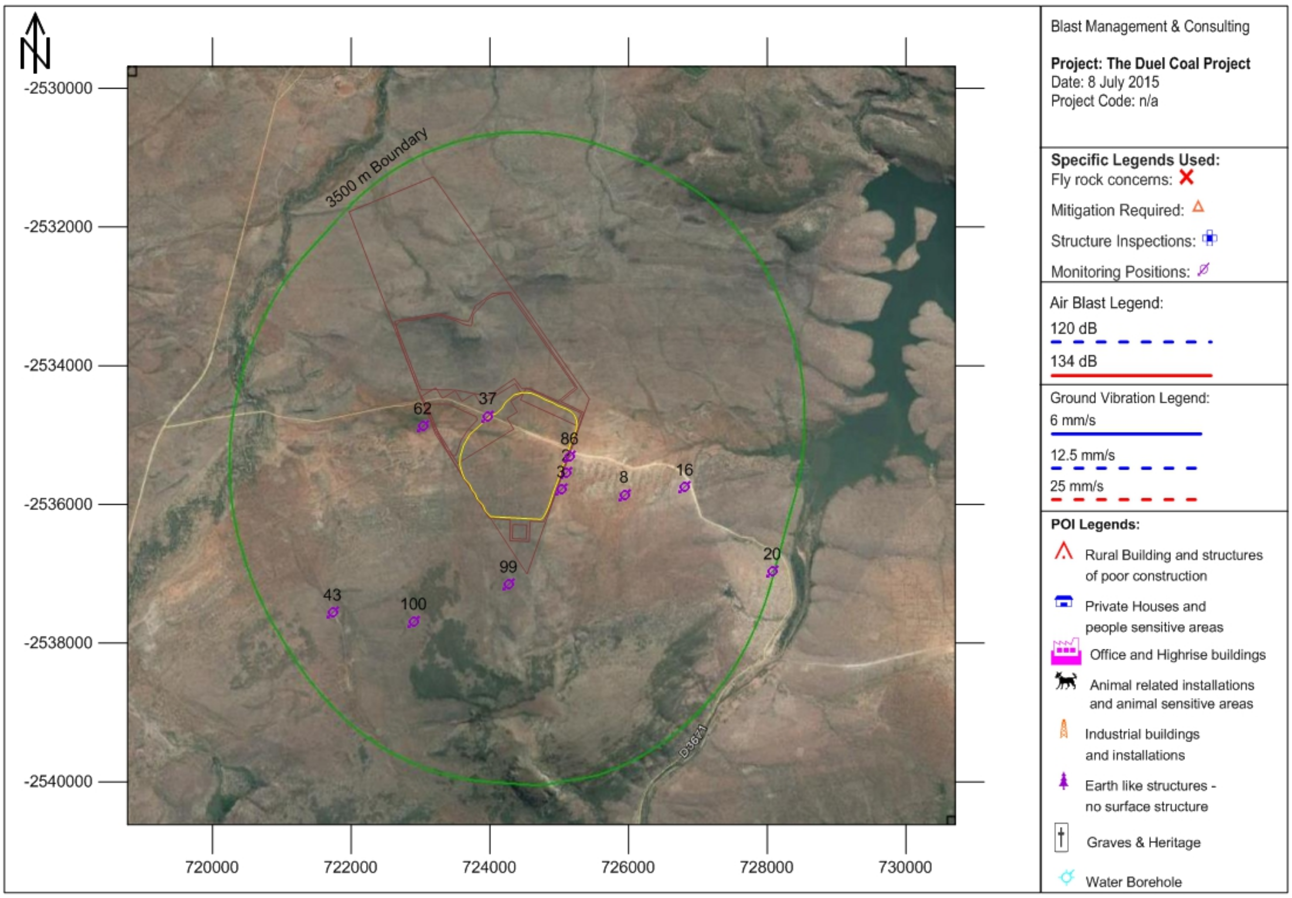

Figure 24: Monitoring Positions suggested.

Table 23: List of possible monitoring positions

Tag	Description	Y	X
2	Rural Community House - Makushu	-725104.985	2535549.452
3	Makushu Graveyard	-725033.154	2535783.631
8	School Structures - Makushu	-725940.109	2535860.844
16	Rural Community House - Makushu	-726814.122	2535755.976
20	Rural Community House - Musekwa	-728078.010	2536965.707
37	Road	-723976.454	2534725.952
43	Buildings/Structures	-721737.467	2537560.489
62	Borehole - WMA-1 (MARTHA)	-723039.202	2534869.845
86	Borehole - NHOLE-10 (TELEMA)	-725156.463	2535304.611
99	Game Farm Areas	-724275.905	2537151.667
100	Game Farm Areas	-722904.095	2537688.683

17 Recommendations

The following recommendations are proposed.

17.1 Safe blasting distance for fly rock

A minimum unsafe zone distance of 472m 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.

17.2 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. Without any re-location it will be required that the mine and the neighbouring Makushu Village must come to some agreement regarding evacuation when blasting is done within at least 500 m from the village.

17.3 Road Closure

There are no highways or provincial roads in vicinity of the project area to be considered. There are no tarred roads in the vicinity of the project area. There are gravel roads that link the different villages. This gravel road also links the Musina and Makhado gravel road on the western side and the D3671 road on the eastern side. This gravel road crosses the planned opencast area. Expected ground vibration levels at this road are calculated to be higher than the recommended limits because of the location. This road and location will need to be considered for re-routing in future or definite changed blasting parameters will have to be applied to ensure levels are within accepted norms. If the road will remain specific management actions will be required for this road with regards to closure at times when blasting is done close to the road. Road closure will be required when blasting is done at distances closer than 500 m to the road. There also various smaller paths that are used by people and animals in the areas of the project. These routes are specifically of concern blasting is done. There may be people and animals on these routes and will require careful planning to main safe blasting radius.

17.4 Photographic Inspections

The option of photographic survey of all structures up to 1500 m from the pit areas is recommended. The mine will be operating for a significant number of years. This will give advantage on any negotiations with regards to complaints from neighbours. This process can however only succeed if done in conjunction with a proper monitoring program. It is expected that ground vibration levels will be significantly less than proposed limits at1500 m but this process will ensure the status of nearest structures to the pit areas. At 1500 m the expected levels is less than the minimum recommended level of 6 mm/s at 4.5 mm/s. Figure 25 shows the structures within the 1500 m area for the pit areas to be considered. Table 22 shows list of structures identified for inspection. The indication of POI’s is only a reference. There are significantly more structures present within the 1500m boundary than the number of POI’s. In the case where boreholes are indicated it is recommended that a full history of the borehole is obtained and proper record is made of the insitu condition.

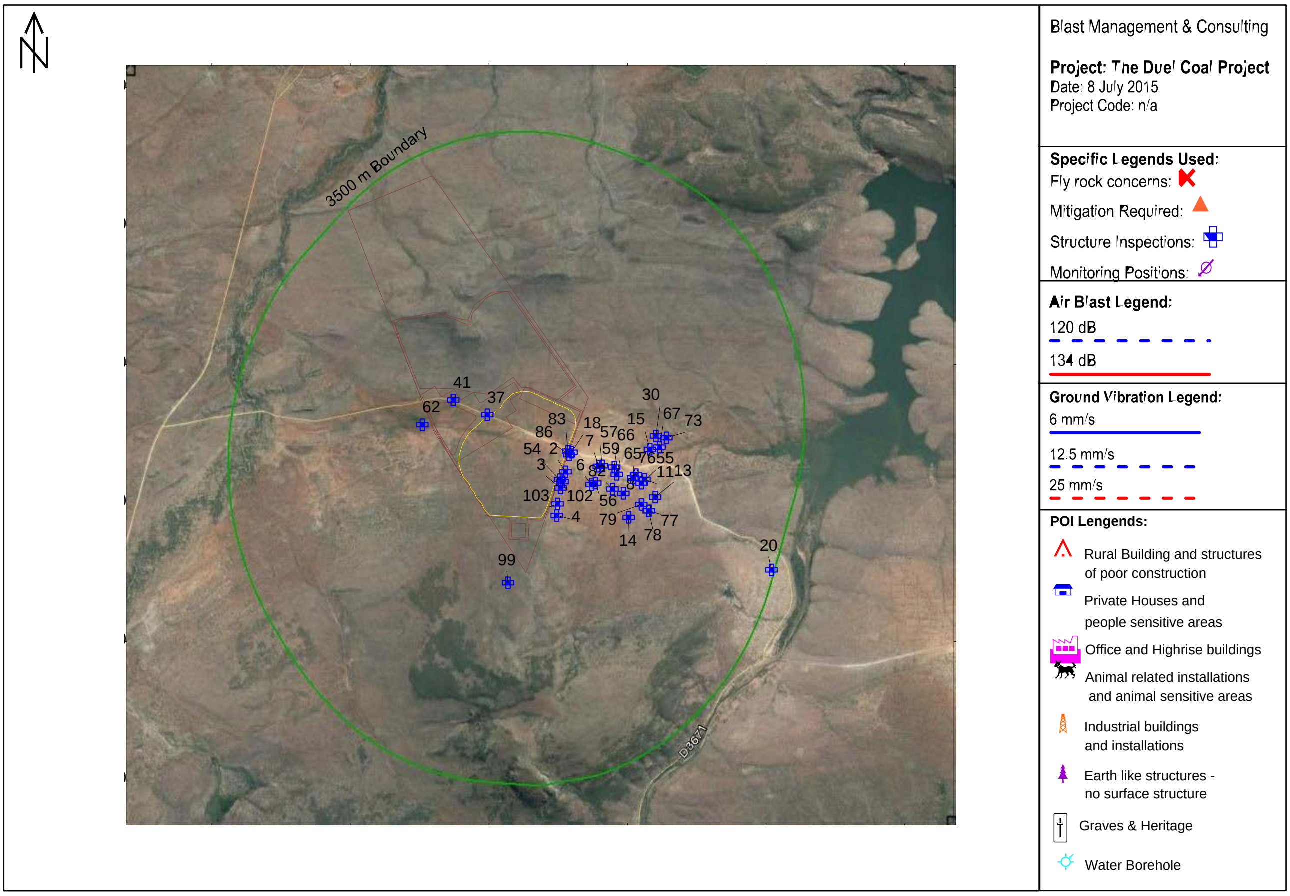

Figure 25: 1500m area around pit identified for structure inspections.

Table 24: Structure Inspection List

Tag	Description	Y	X
2	Rural Community House - Makushu	-725104.99	2535549.45
3	Makushu Graveyard	-725033.15	2535783.63
4	Rural Community House - Makushu	-724978.26	2536181.28
6	Rural Community House - Makushu	-725481.76	2535734.08
7	Rural Community House - Makushu	-725585.36	2535470.08
8	School Structures - Makushu	-725940.11	2535860.84
11	Rural Community House - Makushu	-726243.85	2535658.59
13	Rural Community House - Makushu	-726399.01	2535914.41
14	Rural Community House - Makushu	-726017.15	2536207.16
15	Rural Community House - Makushu	-726323.08	2535225.62
18	Road	-725191.32	2535266.87
20	Rural Community House - Musekwa	-728078.01	2536965.71
30	Structure	-726410.38	2535032.54
37	Road	-723976.45	2534725.95
41	Road	-723485.87	2534513.40

54	Borehole - StandNo210 (MAKUSHU)	-725025.47	2535663.24
55	Borehole - StandNoC38 (MAKUSHU)	-726203.76	2535715.18
56	Borehole - StandNoE104 (MAKUSHU)	-725535.38	2535712.19
57	Borehole - StandNoE83a (MAKUSHU)	-725633.18	2535463.56
59	Borehole - StandNoG146 (MAKUSHU)	-725844.62	2535586.39
62	Borehole - WMA-1 (MARTHA)	-723039.20	2534869.85
65	Borehole - H25-0197 (MUKUSHU)	-726121.76	2535590.74
66	Borehole - MUK-1 (MUKUSHU)	-725808.22	2535481.99
67	Borehole - MUK-2 (MUKUSHU)	-726461.63	2535193.02
73	Borehole - H25-0020 (TELEMA)	-726561.23	2535058.30
76	Borehole - H25-0041 (TELEMA)	-726080.12	2535638.96
77	Borehole - H25-0085 (TELEMA)	-726309.96	2536111.96
78	Borehole - H25-0086 (TELEMA)	-726305.73	2536113.99
79	Borehole - H25-0087 (TELEMA)	-726199.47	2536020.74
82	Borehole - H25-0090 (TELEMA)	-725782.76	2535797.68
83	Borehole - H25-0091 (TELEMA)	-725142.45	2535251.49
86	Borehole - NHOLE-10 (TELEMA)	-725156.46	2535304.61
99	Game Farm Areas	-724275.90	2537151.67
102	Rural Community House - Makushu	-725061.69	2535693.12
103	Rural Community House - Makushu	-724989.96	2536012.75

17.5 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 25: 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	

17.6 Stemming length

The current proposed stemming lengths provided in the blast designs are slightly less than what BM&C will recommend for initial blasting. It is recommended that the stemming lengths should not be less than that specified in the design. Greater will be better for management and control on fly rock. Specific designs where distances between blast and structure of concern is known should always be used when fly rock is of concern, and in this case should be done for all blasts done in the opencast pit area.

17.7 Blasting times

A further consideration of blasting times is when weather conditions could influence the effects yielded by blasting operations. Recommendation 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. The school times should also be considered. Blasting after school could have children in close proximity of the mining area and blasting during school time could have influence on school performance specifically during exam periods. A good idea is to negotiate with the village regarding best time to blast and maintaining the blast time as best as possible. There is always the possibility that blast times will not be met but is such cases there must be a reporting / information system to provide such critical information.

17.8 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.

18 Knowledge Gaps

The data provided from client and information gathered was sufficient to conduct this study. Surface surroundings change continuously and this should be taken into account prior to initial blasting operations considered. This report may need to be reviewed and update if necessary. This report is based on data provided and international accepted methods and methodology used for calculations and predictions.

19 Conclusion

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.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500 m at least and in some cases further from the mining area considered. The range of structures expected is typical roads (tar and gravel), brick and mortar houses, informal building style, corrugated iron structures, graves and graveyards and water boreholes. The project area consists mainly of one opencast pit area and an underground section. The project is a greenfields project with no existing blasting operations.

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 charges evaluated showed possible influences due to ground vibration. This is mainly for the rural community houses in Makushu and some boreholes. Ground vibration mitigation will be required for these structures. Ground vibrations predicted ranged between 26.8 mm/s and 5785 mm/s for points of interest identified. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage. There is a possibility that ground vibration may be perceptible at nearest houses. There is also a gravel road that crosses the through the planned pit area that will require specific attention with regards to blasting operations in general.

Air blast levels expected ranged between 120.8 dB and 146.5 dB at the nearest point of interest. Air blast levels predicted showed less concern than ground vibration. Most of the points of concern that are located close to the pit area are the rural community houses in Makushu. Specific structures / houses were identified with concerns that might lead to possible complaints. 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.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 472 m. Normal practice observed in mines is a 500 m exclusion zone. The use of 500 m exclusion zone is rather recommended.

There various water boreholes that are located in close proximity of the pit areas that will need to be considered. New water wells to be provided for. The locations are such that possible permanent damage is highly likely.

Recommendations were made that should be considered. Specifically for monitoring of ground vibration and air blast, save blasting zones, structure inspections, safe ground vibration and air blast limits, stemming lengths and blasting times.

This concludes this investigation for The Duel Coal Project. Specific areas of concern were identified and recommendations made that will require attention prior to operation of the mine.

20 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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