Blast Management & Consulting

Report: Blast Impact Assessment

Environmental Impact Assessment for a Proposed Open Pit Magnetite Mine and Concentrator Plan, Mokopane, Limpopo Province

Project Number: VMC3049

Prepared for:
Pamish Investments No. 39 (Pty) Ltd

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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 expertise are pre-blast consultation and monitoring, in-situ 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.

JD Zeeman has obtained the following Qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
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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:

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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
Metre	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 an Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed new open pit mining operation for a magnetite mine. 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, 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 at least and in some cases further from the mining area considered. The range of structures expected are typical roads (tar and gravel), brick and mortar houses, informal building style, corrugated iron structures, graves and graveyards and some heritage sites. The project area consists mainly of two open pit areas. 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 charge evaluated showed possible influences due to ground vibration. This is mainly for the D4380 tarred road, between the two pit areas. Ground vibration mitigation will be required for the road. Ground vibrations predicted ranged between 0.4 mm/s and 174.6 mm/s for points of interest identified. Ground vibration at structures and installations other than the road is well below any specific concern for inducing damage. There is slight possibility that ground vibration may be perceptible at the nearest houses.

Air blast levels expected ranged between 103.2 dB and 109.9 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 D4380 road that is not specifically influenced by air blast. No specific structures / houses / farmsteads with concerns other than the possibility of complaints, were identified. 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 311 m. Normal practice observed in mines is a 500 m exclusion zone and this would be recommended for the proposed project.

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

As discussed in this investigation for the Open Pit Magnetite Mine Project, it will be possible to operate this mine in a safe and effective manner provided attention is given to the areas of concern and recommendations as indicated.

1 Introduction

Pamish Investments No. 39 (Pty) Ltd (Pamish) isproposing to develop a new open pit Magnetite mine approximately 45 kilometres (km) northwest of Mokopane town, within Limpopo Province.
The Open Pit Magnetite Mine Project is a greenfields operation and is located on the farms Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions RE/1, RE/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR. The villages of Ditlotswana, Malokong, Mosate and Sepharane fall within the project area. The N11 national route is situated 5 km east and the R518 regional road is situated 2.5 km south of the proposed project area.

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 open pit mining operation. Ground vibration, air blast, fly rock and fumes are some of the aspects that result from blasting operations. This study will review possible influences that blasting may have on the surrounding area in respect of these aspects. The report concentrates on the ground vibration and air blast and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

2 Objectives

The objective of this document is outlining the expected 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, client requirements and general indicators from the various Acts and Regulations 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 and its Regulations and the 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 are no specific South African standard and the USBM is well accepted as standard in South Africa.

However, it is certain that the protocols and objectives will fall within the broader spectrum as required by the various Acts.

3 Scope of Blast Impact Study

The scope of the study is determined by the terms of reference to achieve the objectives. The terms of reference can be summarized according to the following steps taken as part of the EIA study with regard 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 Magnetite Project is situated approximately 45 km north-west of Mokopane and 65 km west of Polokwane and is located on the farms Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR at geographic coordinates 23°52'39.50"S, 28°48'3.48"E.

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

Figure 1: Locality of the project area

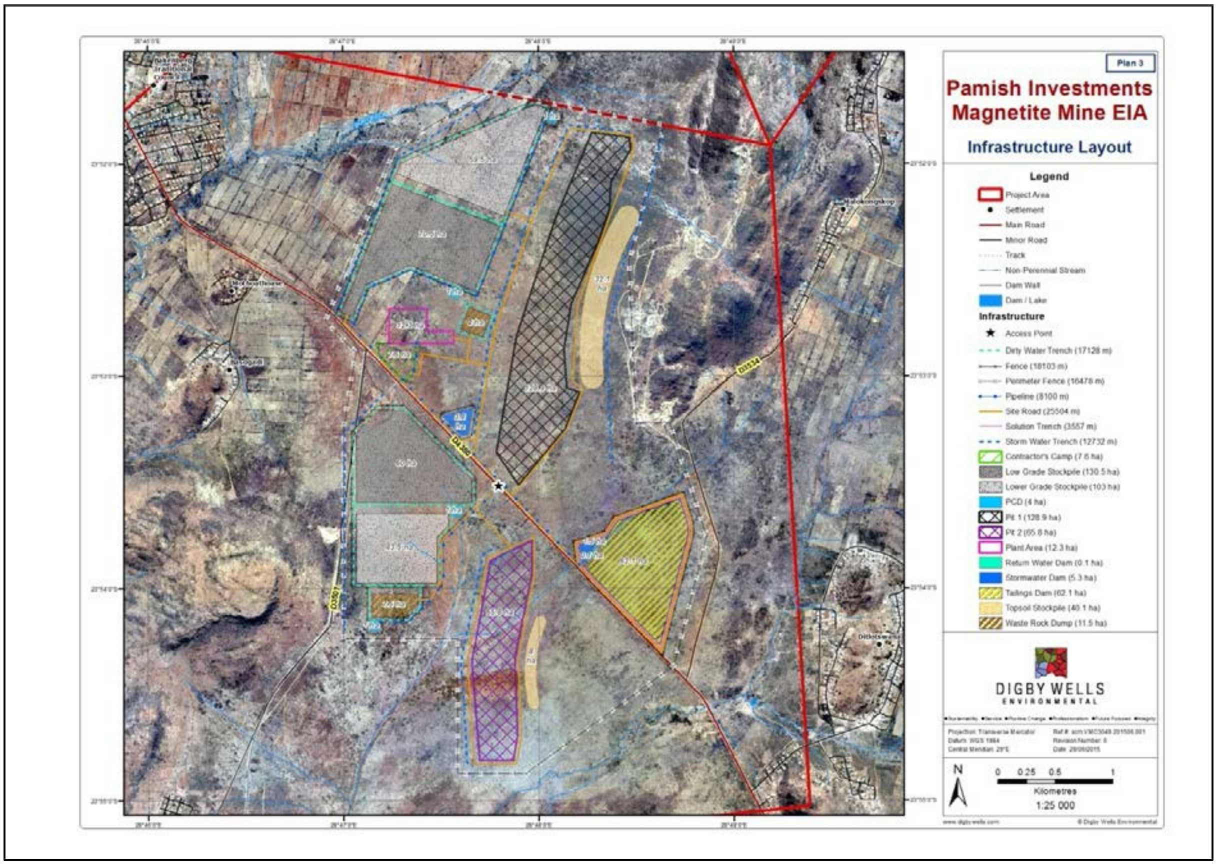

Figure 2: Proposed mining area layout

5 Methodology

The detailed plan of study consists of the following sections.

- Site visit: Intention to understand location of the site and its surroundings,
- Site Structure Profile: Identifying all surface structures / installations that are found with the 3500m possible influence area. A list of POI's are created that will be used for evaluation.
- 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 distances 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 indications 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. Geological information from the project was used to derive possible drilling and blasting information. A significant number of boreholes were drilled to determine the orientation and location of the ore body. Figure 3 shows a basic section view of the orebody. The planned project is an open pit operation with exposure of the orebody from surface. Open pit operations have possibility of influence specific in relation to aspects such as ground vibration, air blast and fly rock.

The geology of the project area is detailed in report "***J3026 Pamish MWP 20150302A***". Without redefining the geology the following figure shows a simplistic view of the formations and specifically the Main Magnetite Layer (MML). Figure 4 shows a schematic view of mining the MML.

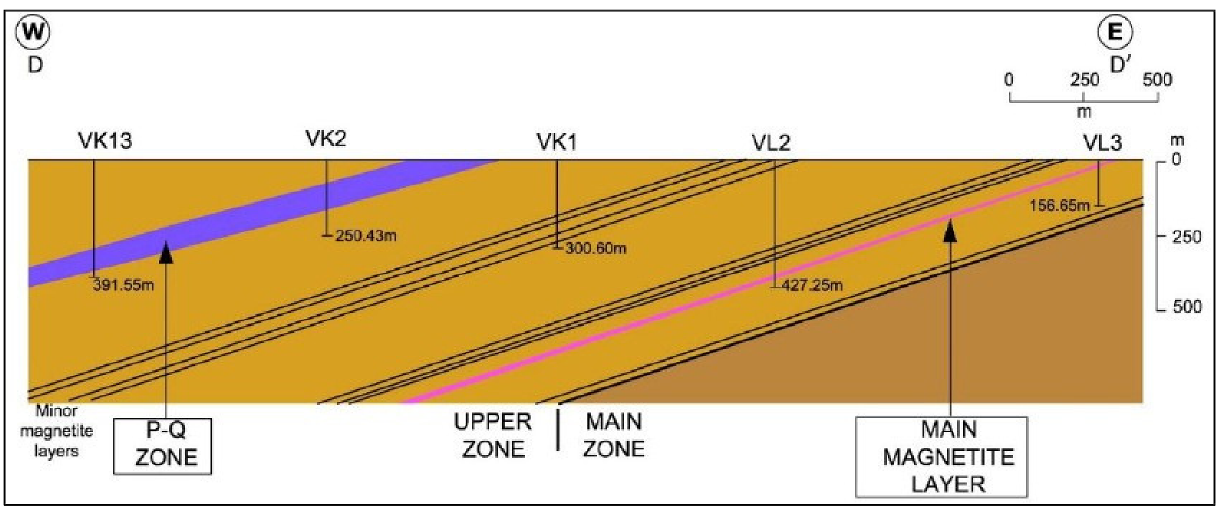

Figure 3: Project geology section view

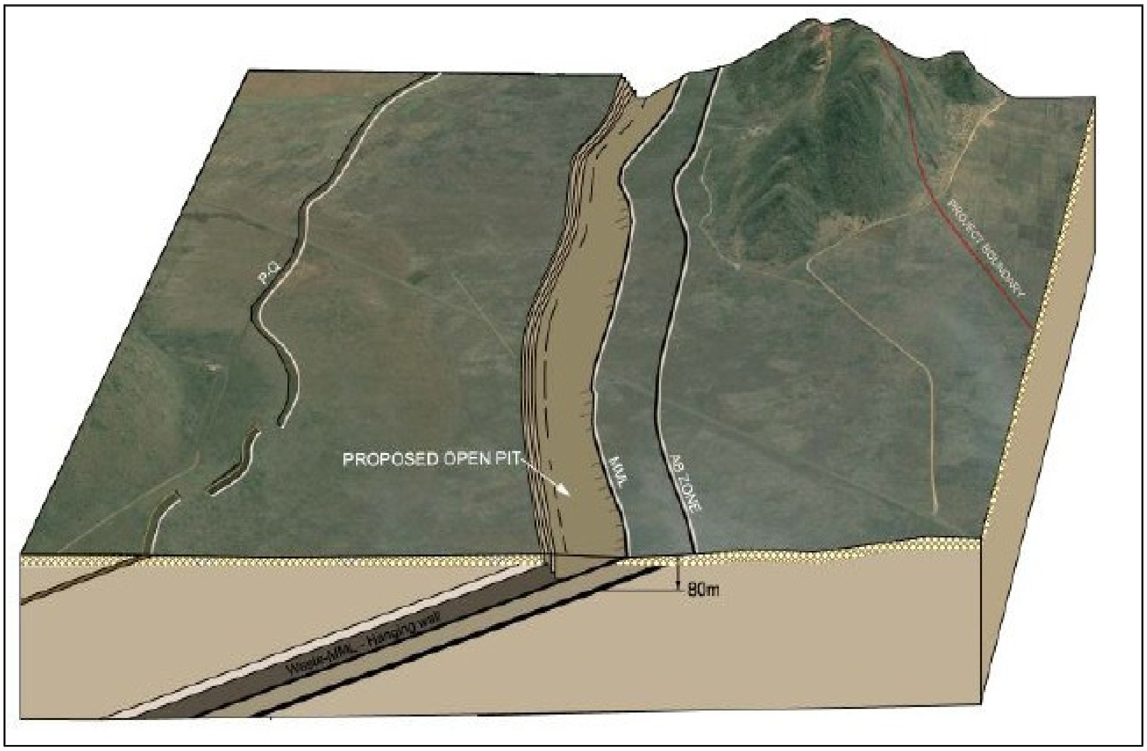

Figure 4: Schematic 3D view of a section of the mine

6.1 Mining and Blasting Operations

Conventional drilling, blasting, loading and hauling operations are envisaged. The ore can be readily accessed from surface after minimal overburden (soil) stripping. It is assumed that mining contractors will be used to undertake mining operations. Stripping ratios increase as depth increases, with a LOM average stripping ratio of 4.39. A significant portion of this strip comprises the MML hanging wall (MML-HW), a mineralised package of up to 60 m thick.

Taking into account planned bench heights of 10 m, an overburden blast design is proposed that should be sufficient for mining of the overburden. The overburden mining will have greater possibility of influence than mining the ore body because larger diameter and deeper blast holes. Table 1 below summarises the blast designs applicable and the information required for use in this report. Blast design is required 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. The blast hole diameter used in the design shown in Table 1 is given as 165 mm. Information provided from client indicated a 160 mm diameter blast hole would be applied. The 160 mm diameter is, however, not a standard size and it is more likely that a 165 mm diameter drill bit will be applied in field and thus the slightly larger diameter blast hole is being used in this evaluation.

Table 1: Information on blast designs used

Technical Aspect	Overburden
B/H Diameter (mm)	165
Explosive Density (g/cm^3)	1.15
Burden (m)	4
Spacing (m)	4
Bench Height (m)	10
Min Depth (m)	10
Average Depth (m)	11.32
Linear Charge Mass (kg)	24.59
P/F Blast hole (kg/m^3)	0.98
Stemming Length (m)	4.13
Column Length (incl. Sub drill.) (m)	7.2
Explosives Per B/H (incl. Sub drill) (kg)	177
Include Sub Drill (Yes/No)	Yes
Sub-drill (m)	1.32

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 is marked and the required depths are drilled. After drilling the blast holes are loaded with an initiation system and explosives. The initiation system will initiated the main explosives column. The explosives energy performs work on the blast hole side wall – cracking the material and eventually moving it 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 complete a surface initiation system is laid out. This surface initiation is designed to ensure initiation of the blast holes in a particular sequence which provides a 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 move outwards. This means that blast operations do have effects on their immediate surrounding area. These effects manifest in various forms and levels of intensity. The prediction, evaluation and risk analysis of these forms and intensity is the purpose of this report. These effects can manifest in the form of ground vibration and air blast. In addition, consideration needs to be given to effects such as fumes and fly rock, 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 should be the focus of attention and that need to be managed. The following sections address the reason, prediction, modelling and control on aspects such as 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 and its Regulations, the Mineral and Petroleum Resources Development Act No. 28 of 2002 and the Explosives Act No 15 of 2003 (which repealed the Explosives Act No. 26 of 1956).

The guidelines and safe blasting criteria are according international accepted standards and specific applied in this document is the United States Bureau of Mines (USBM) criteria for safe blasting for ground vibration and recommendations on air blast. There are no specific South African standard and the USBM is well accepted as standard for South Africa. Additional criteria as required by various institutions in South Africa i.e. Eskom, Telkom, Transnet, Rand Water Board etc. are also taken into consideration.

The protocols and objectives will fall within the broader spectrum as required by the various Acts.

8 Sensitivity of Project

Before any specific analysis is carried out on the project area and surrounding areas, a sensitivity mapping is 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 were identified for this. Firstly, a high sensitivity area of 500 m area around the mining area was 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 sensitivity was identified. In this area the possibility of influence can still be expected but with definite lower impact. Thirdly, an area was identified as least sensitive at a distance of 1500 m to 3500 m. The expected level of influence in this zone is expected to be low but there may still be reason for concern: although levels could be less than to cause structure damage, people may still be affected and alarmed. Figure 5 shows the sensitivity mapping with identified Points of Interest (POI's) and surrounding areas. The specific influences will be determined through the work done for this project in this report.

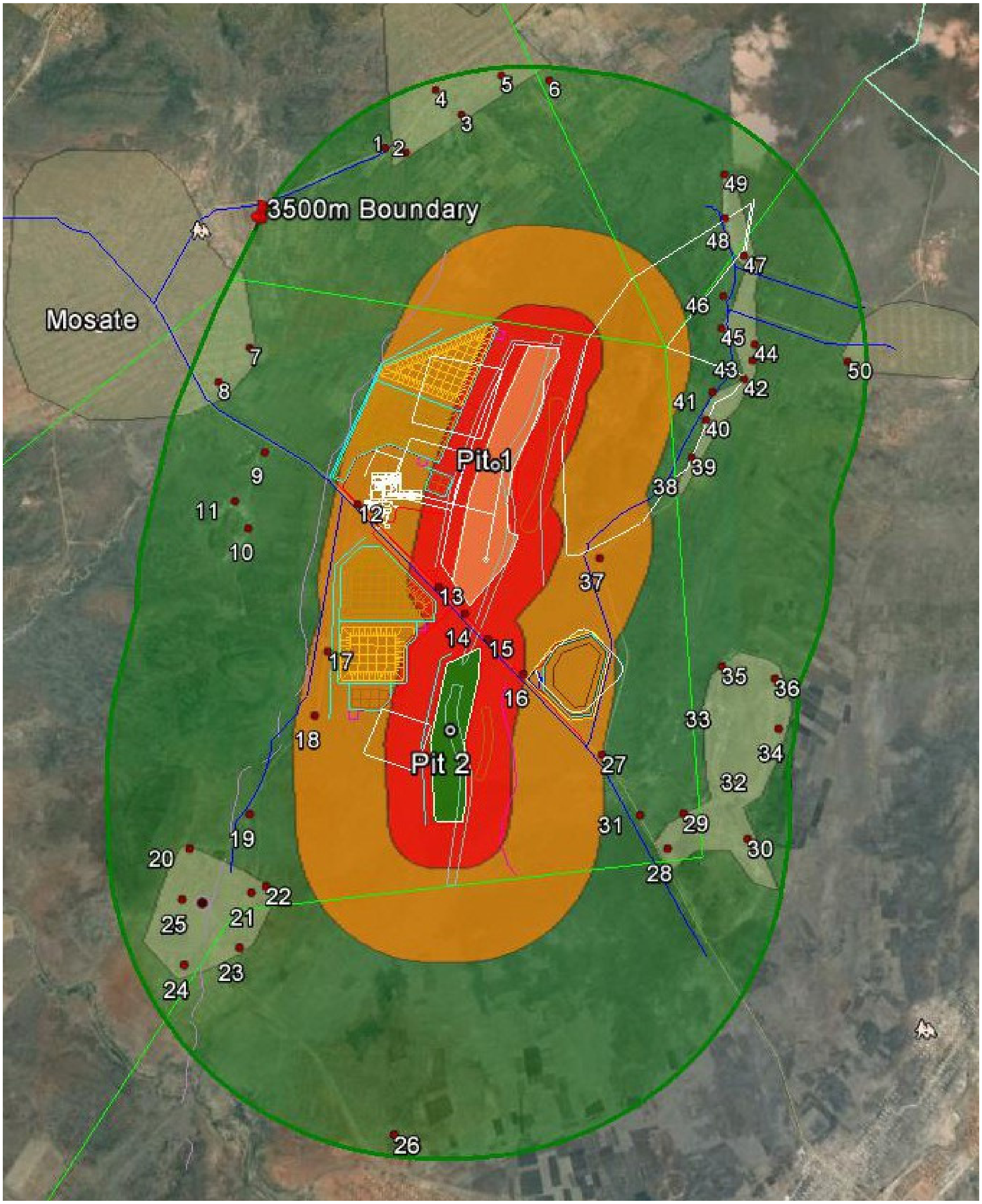

Figure 5: Identified sensitive areas

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.

10 The expected effects from blasting operations

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 undesirable, 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.

A second factor 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 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 open pit operations a process of testing for the constants can be done using a signature trace study 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 are 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.

A 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, may indicate that 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. Structure 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 177 kg will be loaded in a 10 m at 165 mm diameter overburden blast hole. Considering general timing systems to be used, it is expected that as much as 4 to 6 blast holes could detonate simultaneously. To evaluate the possible influence, two charge masses that will span the range of possible charge mass per delay were selected. Therefore a single overburden blast hole at 177 kg, four times overburden blast holes at 707 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 177 kg and 707 kg.

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

No.	Distance (m)	Expected PPV (mm/s) for 177 kg Charge	Expected PPV (mm/s) for 707 kg Charge
1	50.0	128.6	403.2
2	100.0	65.9	206.5
3	150.0	21.0	65.8
4	200.0	13.1	40.9
5	250.0	9.0	28.3
6	300.0	6.7	21.0
7	400.0	4.2	13.0
8	500.0	2.9	9.0
9	600.0	2.1	6.7
10	700.0	1.7	5.2
11	800.0	1.3	4.2
12	900.0	1.1	3.4
13	1000.0	0.9	2.9
14	1250.0	0.6	2.0
15	1500.0	0.5	1.5
16	1750.0	0.4	1.1
17	2000.0	0.3	0.9
18	2500.0	0.2	0.6
19	3000.0	0.1	0.5
20	3500.0	0.1	0.4

Figure 6 below shows the relationship of ground vibration over distance for the three 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.

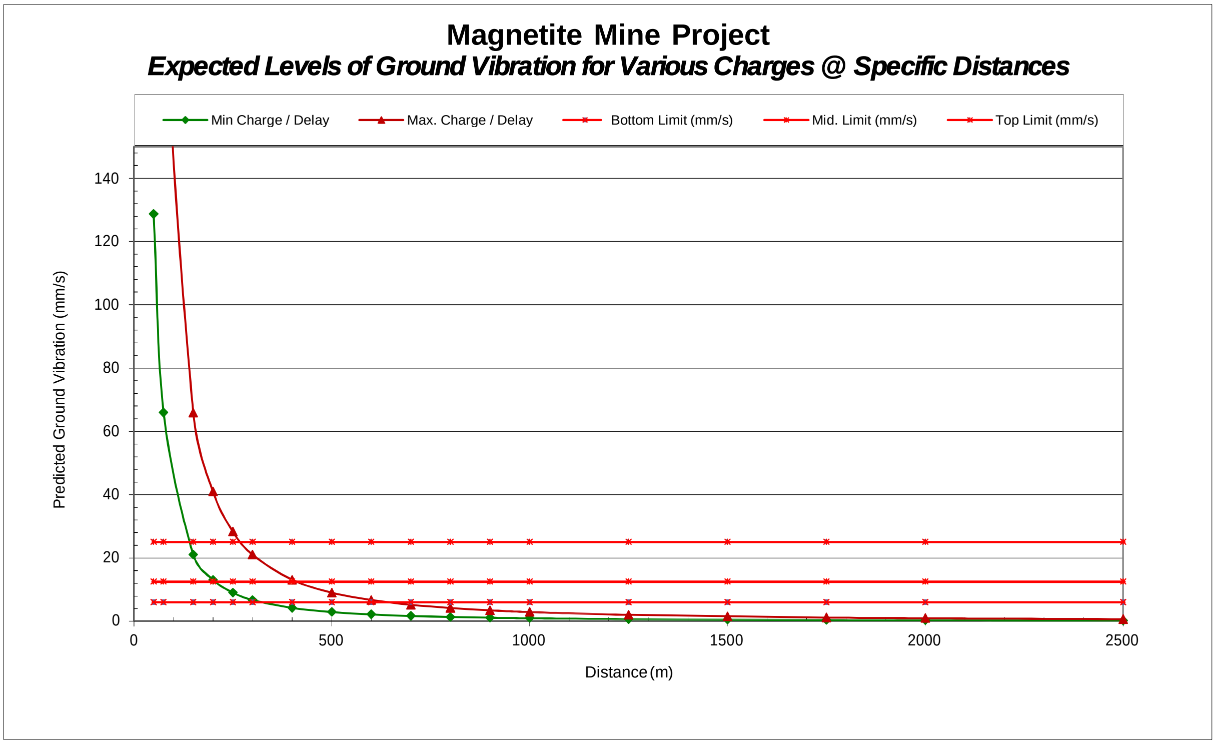

Figure 6: Ground vibration over distance for the two charge masses used in modelling

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 frequency levels of ground vibration will allow for high levels of ground vibration. Figure 7 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.

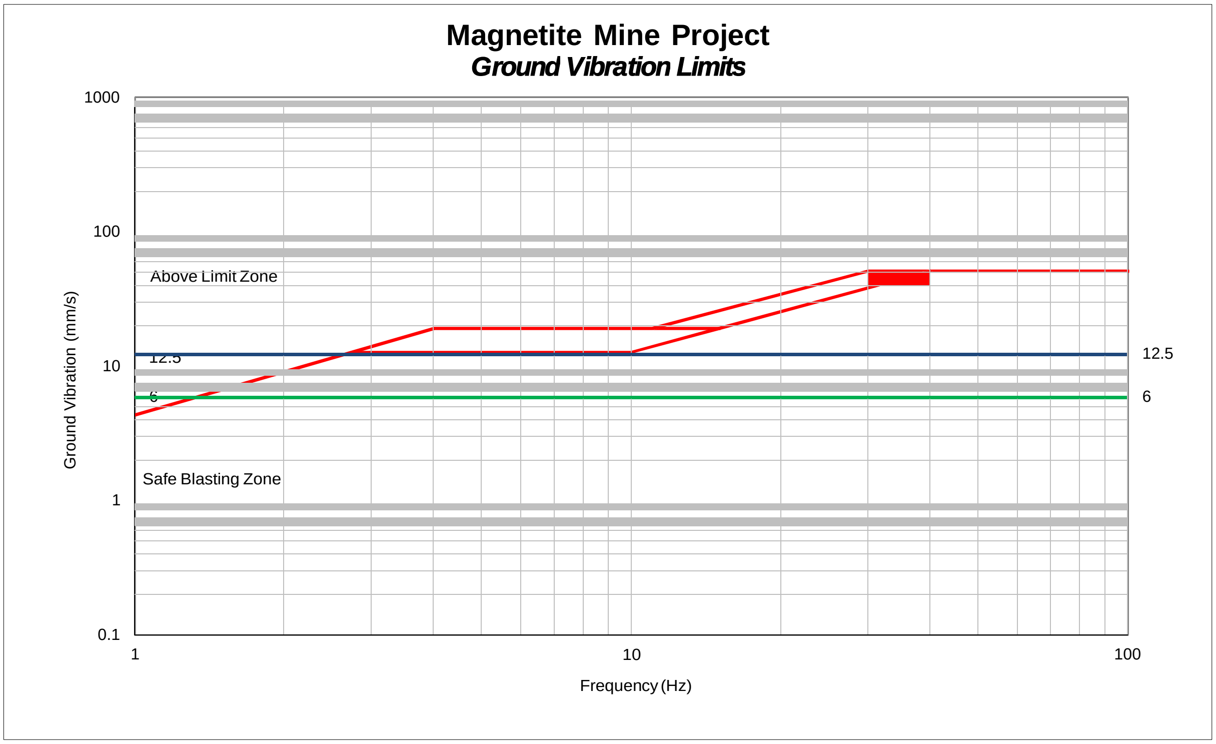

Figure 7: USBM Analysis Graph

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

- National Roads/Tar Roads: 150 mm/s
- Steel pipelines: 50 mm/s
- Electrical Lines: 75 mm/s
- Railway: 150 mm/s
- Concrete aged less than 3 days: 5 mm/s
- Concrete after 10 days: 200 mm/s
- Sensitive Plant equipment: 12 mm/s or 25 mm/s depending on type – some switches could trip at levels less than 25 mm/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 25 mm/s reduced to 12.5 mm/s or even when structures are in very poor condition limits will be restricted to 6 mm/s
- The input from other consultants in the field locally and internationallyis also considered.

10.1.3 Ground vibration limitations with regards to human perceptions

A further aspect of ground vibration and frequency of vibration is 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" (to name only 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 4.5 mm/s as unpleasant. (See Figure 8).

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.

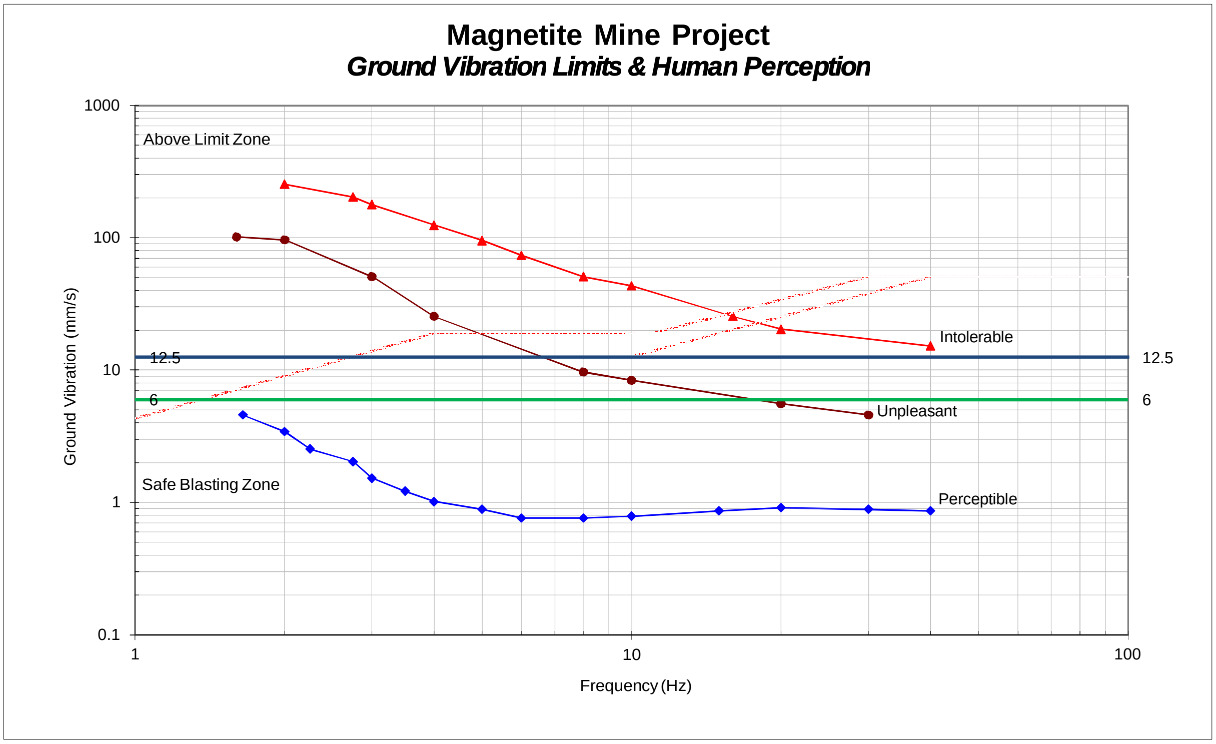

Figure 8: USBM Analysis with Human Perception

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 points on a structure are 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 are kept below 120dB. In this way it is certain that fewer complaints will be received for blasting operations. The effects on structures that startled people are significantly less – thus no reason for complaining. It is the actual influence on structures like rattling of windows or doors or large roof surface's that startle people. These effects are sometimes misjudged as ground vibration and considered as damaging to the structure.

Initial limits for evaluating conditions have been set at 120dB, 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:

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

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 to ensure that air blast and associated fly-rock possibilities are minimized as best as 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 9 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 177 kg Charge	Air blast (dB) for 707 kg Charge
1	50.0	142	147
2	100.0	138	143
3	150.0	131	136
4	200.0	128	133
5	250.0	125	130
6	300.0	124	128
7	400.0	121	125
8	500.0	118	123
9	600.0	116	121
10	700.0	115	120
11	800.0	113	118
12	900.0	112	117
13	1000.0	111	116
14	1250.0	109	113
15	1500.0	107	112
16	1750.0	105	110
17	2000.0	104	109
18	2500.0	101	106
19	3000.0	100	104
20	3500.0	98	103

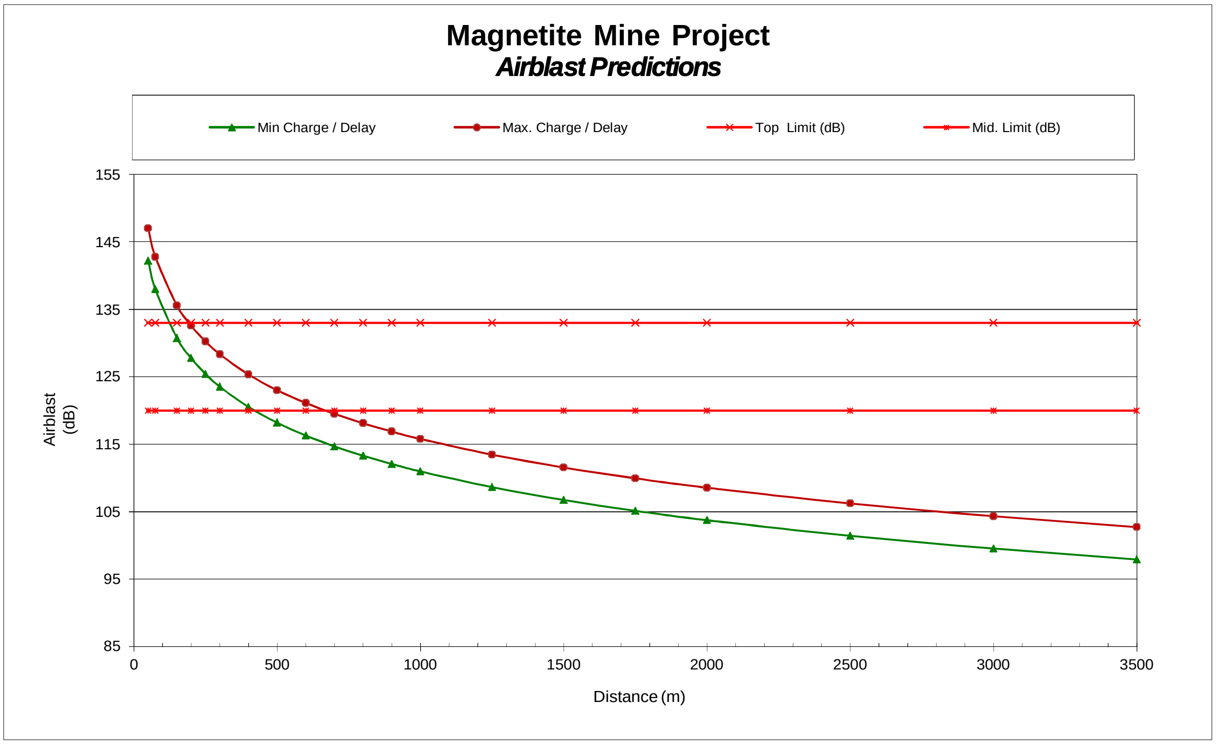

Figure 9: Predicted air blast levels

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 10 below shows the schematic fly rock terminology

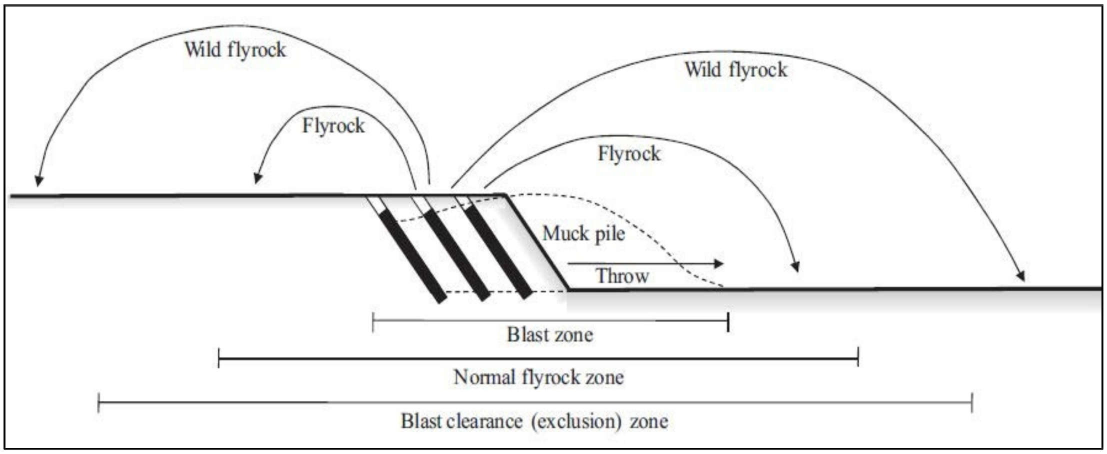

Figure 10: Schematic of fly rock terminology

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 improper quality or is insufficient 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. The 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 11 shows 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 calculations in the designs are based on a midrange 25x blast hole diameter stemming length.

The absolute minimum exclusion zone calculated is 311 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 can never be eliminated.

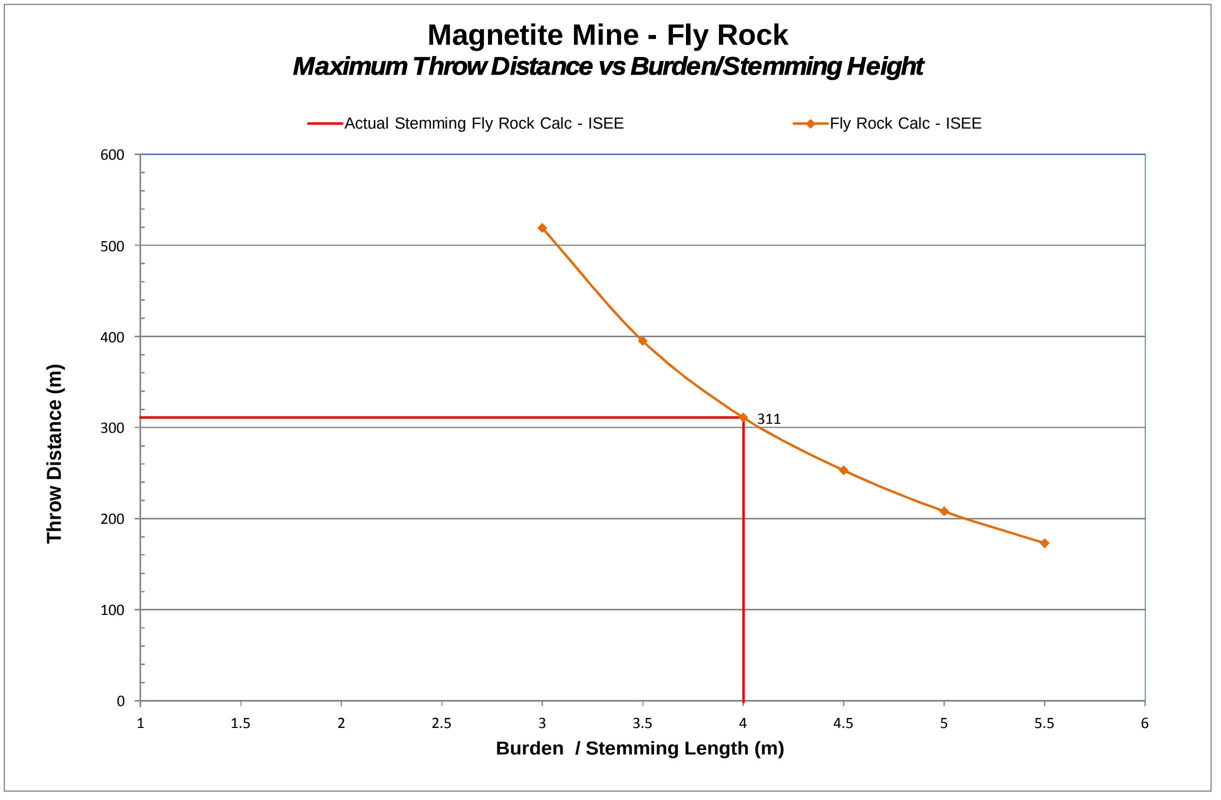

Figure 11: Predicted Fly rock

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. The 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 damaged 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.

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

Drill diameter is also a contributing factor to explosive performance and the subsequent generation of fumes. Explosives are diameter dependant for optimal performance. If 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 should 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. Another preventative action is to refrain 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 which will excluded mixing of drill chippings with the explosives in initiation area. The checking of blast holes for water will ensure that charging crews charge blast holes from the bottom (which should be a standard practice) 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 is expected when levels are of the order of 150mm/s and greater, or when there is actual movement of ground when blasting is done too close to the road or subsidence is caused due to blasting operations. Normally 100 times the blast hole diameter is 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. The fact remains that blasting must be controlled in the vicinity of roads. Air blast does not have influence on roads by virtue of the type of structure. There is no record of influence on gravel roads due to ground vibration. The only time damage can be induced is when blasting is done next to the road and there is movement of ground. Fly rock will have greater influence on the road as damage from falling debris may impact on the road surface if no control on fly rock is considered.

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 neighbourliness”. This is achieved through better communication with the neighbours. Their concerns should be considered and addressed 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 neighbourliness. There is an 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 12 below. A typical X crack formations is observed.


Figure 12: 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, or 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 it must be accepted 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 farm animals (cattle, chickens, pigs, etc.)

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

Work was done by Larkin on wildlife and presented here are also some of his conclusions. Personal experience as observed on projects has shown the following on farm animals:
Cattle: Cattle seem to be very accommodating with regards to blasting operations. It has been seen that for a first time blast, the blast will upset them. Reaction is shown in taking fright and running a short distance – maybe 10m to 20m – and then carrying on grazing. At the second blast they will only lift their heads and carry on grazing. At the 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 Fawkes days. Loud noises will certainly have an influence.

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

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

A further question on dairy farms is similar that no scientific evidence exists of deterioration of milk production. However in 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. Mouse, rabbits, Guinea Pig, hamsters, rat, dog, goat, sheep, cat and cattle were the subjects of this research. The research concentrated on the effect of short duration and long duration pressure pulses, orientation of subject, reflected shock or not and investigated the effect with regards to lethality, lung injury and eardrum rupture. This work was 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 13) shows the mortality curves for the various animals exposed to long duration pressure pulses.

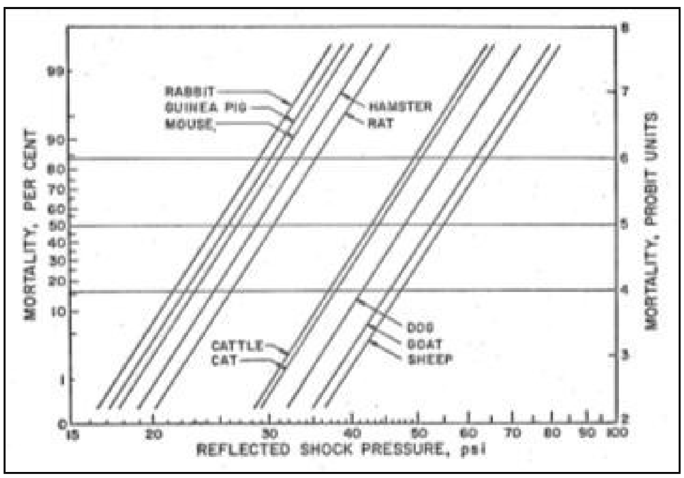

Figure 13: Mortality curve for long duration pressure exposure on animals.

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 and results from this research work are presented.

Case 1 looked at 36 case histories. Vibration levels up 50 mm/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.

as the causes could be:

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

It may then be concluded from the studies researched as follows: Depending on the well construction, litho logic units encountered, and proximity to the blasting, it is believed that large shots could act as a catalyst for some well sloughing or collapse. However, the well would have to be inherently weak to begin with. The small to moderate shots will not show to impact wells. The minor water fluctuations attributed to blasting may cause a short term turbidity problem, but do not pose any long term problems. This fluctuation would not cause well collapse, as fluctuations from recharge and pumping occurs frequently. Long term changes to the well yield are more likely due to the opening of fractures from loss of lateral confinement. Short term dewatering of wells is caused by the opening of the fractures creating additional storage. A longer term dewatering is caused by encroachment of the high wall and pumping of the pit water. The pit acts like a large pumping well. It is not believed that long term water quality problems will be caused by blasting alone. The possible exception is the introduction of residual nitrates, from the blasting materials, into the ground water system. This is only possible through wells that are 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 50 mm/s or even higher in certain cases did not have any noticeable effect. It seems that safe conditions will be in the order of the 50 mm/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 baseline 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 are identified. The site was reviewed and presented hereafter. The site was reviewed / scanned using Google Earth imagery. Information sought from review was typically the kind of surface structures that are present in a 3500 m radius from the proposed mine boundary that will require consideration during modelling of blasting operations. This could consists of houses, general structures, power lines, pipe lines, reservoirs, mining activities, roads, shops, schools, gathering places, possible historical sites etc. A list was prepared as best possible for each structure in the vicinity of the pit areas. The list prepared covers structures and points of interest (POI) in the 3500 m boundary. A list of structure locations was required for determining the allowable ground vibration limits and air blast limits possible. Figure 14 shows an aerial view of the mining area and surroundings with points of interest. The list compiled is provided in Table 6 below.

<u>Pit Area 1 & 2:</u>

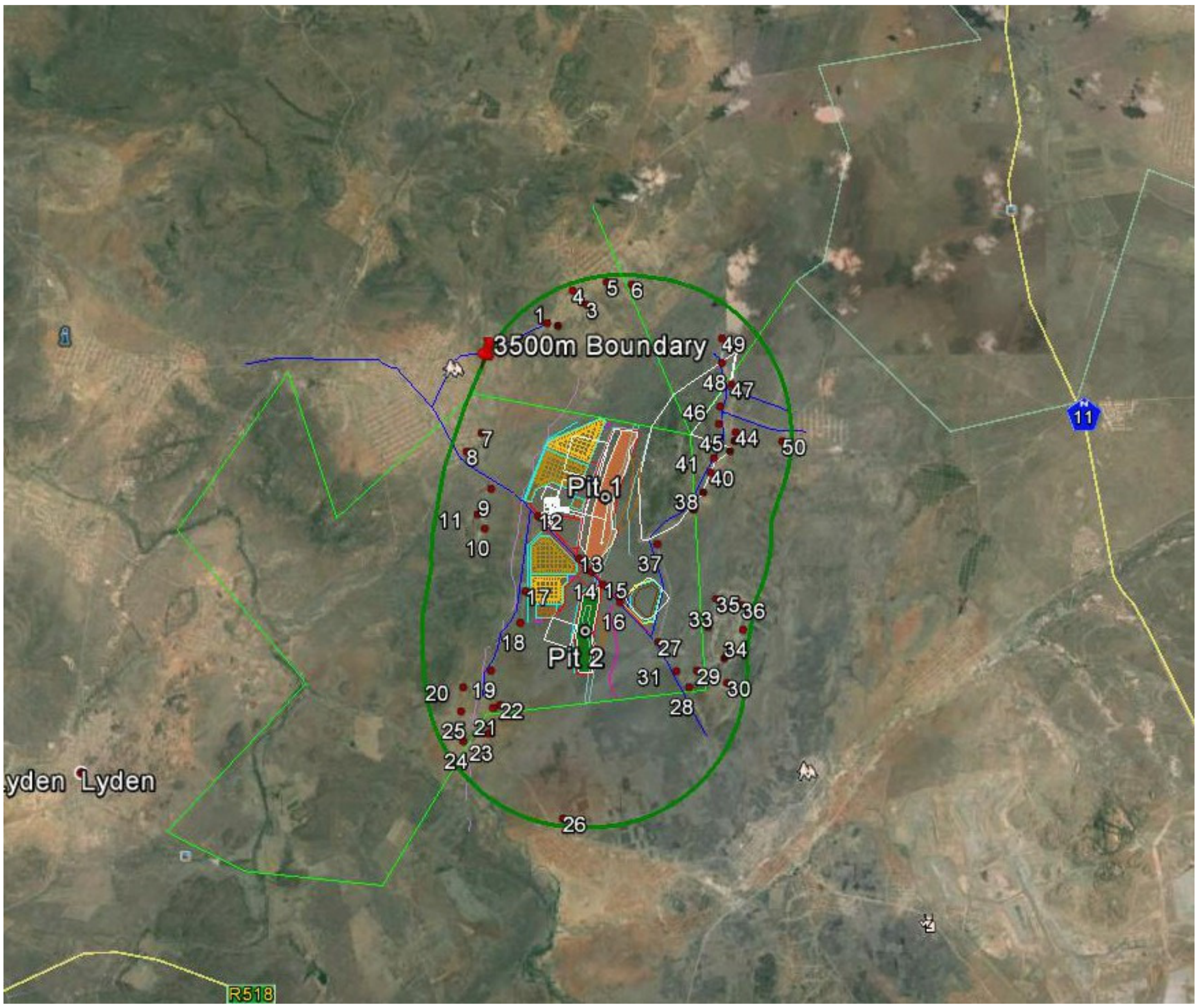

Figure 14: Aerial view and surface plan of the proposed mining area with points of interest identified.

Note: Red Place marks = POI indicators

Table 6: List of points of interest used (WGS – LO 29^{o})

Tag	Description	Classification	Y	X
1	D3537 Road	5	21613.58	2637847.31

2	Pudiyagopa Village Houses	1	21371.76	2637904.45
3	Pudiyagopa Village Buildings/Structures	1	20728.67	2637427.08
4	Pudiyagopa Village Houses	1	21034.96	2637121.10
5	Pudiyagopa Village Houses	1	20266.88	2636924.26
6	Buildings/Structures	2	19698.99	2636975.16
7	Bakenberg Village Houses	1	23103.55	2640321.16
8	Bakenberg Village Houses	1	23440.76	2640739.82
9	Village Houses	1	22882.45	2641578.98
10	Village Houses	1	23023.63	2642480.49
11	Village Houses	1	23189.47	2642159.02
12	D4380 Road	5	21816.09	2642194.00
13	D4380 Road	5	20891.57	2643150.41
14	D4380 Road	5	20596.33	2643456.92
15	D4380 Road	5	20336.66	2643744.09
16	D4380 Road	5	19946.95	2644136.59
17	D3507 Road	5	22092.33	2643890.46
18	D3507 Road	5	22213.04	2644603.51
19	D3507 Road	5	22877.06	2645683.59
20	Sepharane Village Houses	1	23502.53	2646059.54
21	Sepharane Village School	2	22825.52	2646524.28
22	Sepharane Village Buildings/Structures	1	22669.50	2646456.94
23	Sepharane Village Houses	1	22928.75	2647103.52
24	Sepharane Village Houses	1	23504.90	2647285.63
25	Sepharane Village Houses	1	23551.27	2646602.25
26	Building/Structure	2	21239.66	2649021.76
27	D4380 and D3534 Roads	5	19085.17	2645031.87
28	Buildings/Structures	2	18383.29	2646052.51
29	Ditlotswana Village Houses	1	18207.46	2645675.07
30	Ditlotswana Village Houses	1	17525.92	2645949.77
31	D4380 Road	5	18673.11	2645690.52
32	Ditlotswana Village School	2	17581.61	2645388.92
33	Ditlotswana Village Houses	1	17956.52	2644697.09
34	Ditlotswana Village Houses	1	17167.56	2644751.77
35	Ditlotswana Village Houses	1	17771.33	2644057.44
36	Ditlotswana Village Houses	1	17196.61	2644196.10
37	D3534 Road	5	19108.73	2642823.83
38	Malokong Village Houses	1	18287.80	2642054.37
39	Malokong Village Houses	1	18073.43	2641659.48
40	Malokong Village Houses	1	17904.86	2641212.41
41	Malokong Village Houses	1	17830.52	2640885.96
42	Malokong Village Houses	1	17468.06	2640724.57
43	D3534 Road	5	17367.34	2640495.58
44	Malokong Village School	2	17341.19	2640298.51
45	Malokong Village Houses	1	17719.77	2640114.49
46	Malokong Village Houses	1	17690.11	2639721.91
47	Malokong Village Houses	1	17444.77	2639219.03
48	Malokong Village Houses	1	17652.38	2638738.75
49	Malokong Village Houses	1	17649.66	2638185.37
50	Ga-Mabusela Village Houses	1	16284.75	2640502.39
51	Borehole(Vbh31)	8	20994.38	2636948.93
52	Borehole(Vbh29)	8	21057.55	2637178.53
53	Borehole(Vbh30)	8	21033.71	2637143.70
54	Borehole(Vbh36)	8	20878.19	2637151.32
55	Borehole(Vbh37)	8	20146.27	2637853.68
56	Borehole(Vbh38 4052 H03)	8	19840.79	2638041.08
57	Borehole(Vbh39)	8	19755.77	2638107.05
58	Borehole(Vbh50)	8	19588.69	2638151.55

59	Borehole(Vbh76)	8	17413.74	2639166.99
60	Borehole(Vbh72)	8	16762.55	2640072.55
61	Borehole(Vbh73)	8	16393.18	2640242.04
62	Mabusela Grave	7	17926.68	2640569.09
63	Borehole(Vbh2)	8	22310.55	2640027.33
64	Borehole(Vbh1)	8	22726.63	2639949.34
65	Borehole(Vbh5)	8	23203.21	2640016.74
66	Borehole(Vbh3)	8	23264.42	2640026.86
67	Borehole(Vbh4)	8	23234.40	2640077.83
68	Borehole(Vbh23)	8	23564.67	2639968.31
69	Borehole(Vbh24)	8	23555.91	2640065.92
70	Borehole(Vbh26)	8	23769.68	2640629.50
71	Borehole(Vbh27)	8	23654.84	2640866.92
72	Borehole(Vbh28)	8	23638.33	2641063.61
73	Borehole(Vbh57)	8	23187.52	2641061.74
74	Graves 2	7	23036.15	2643415.27
75	Grave	7	18920.21	2642400.92
76	Graves 1	7	18930.79	2645502.28
77	Borehole(Vbh69)	8	18146.32	2644459.65
78	Borehole(Vbh70)	8	18098.59	2644236.93
79	Borehole(Vbh71)	8	17959.57	2644210.21

Notes: The type of POI's identified is grouped into different classes. 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 build structures to informal building styles. Appendix 1 shows photos of structures found in the area.

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 and the possible timing of a blast the two different charge mass of 177 and 707 kg were selected to ensure proper source coverage.

Ground vibration and air blast was calculated from the edge of the pit outline and modelled accordingly. Blasting further away from the pit edge will certainly have 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 geology, topography or actual final drill and blast pattern into account. The data is based on good practise applied internationally and considered very good estimates based on the information provided and supplied in this document.

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 0.76 mm/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 open pit 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 50 m to 3500 m around the open pit mining area.

Provided as well with each simulation are indicators of the ground vibration limits used: 6 mm/s, 12.5 mm/s and 25 mm/s. 6 mm/s is indicated as a “Solid Blue” line, 12.5 mm/s “Intermittent Blue” line and 25 mm/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”

13.2 Calculated Ground Vibration Levels

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

- **Minimum Charge per Delay – Pit Area – 177 kg**

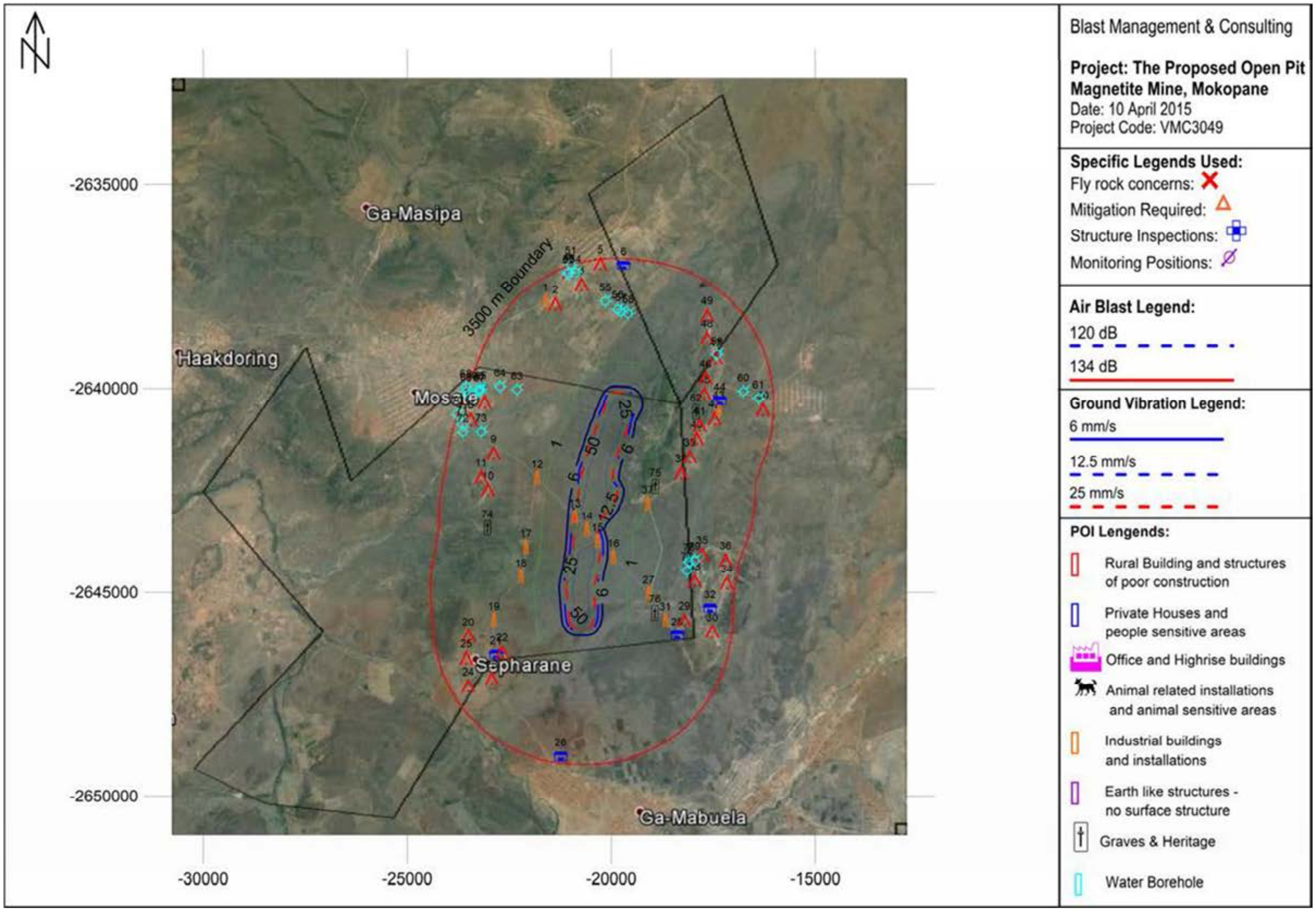

Figure 15: Ground vibration influence from minimum charge

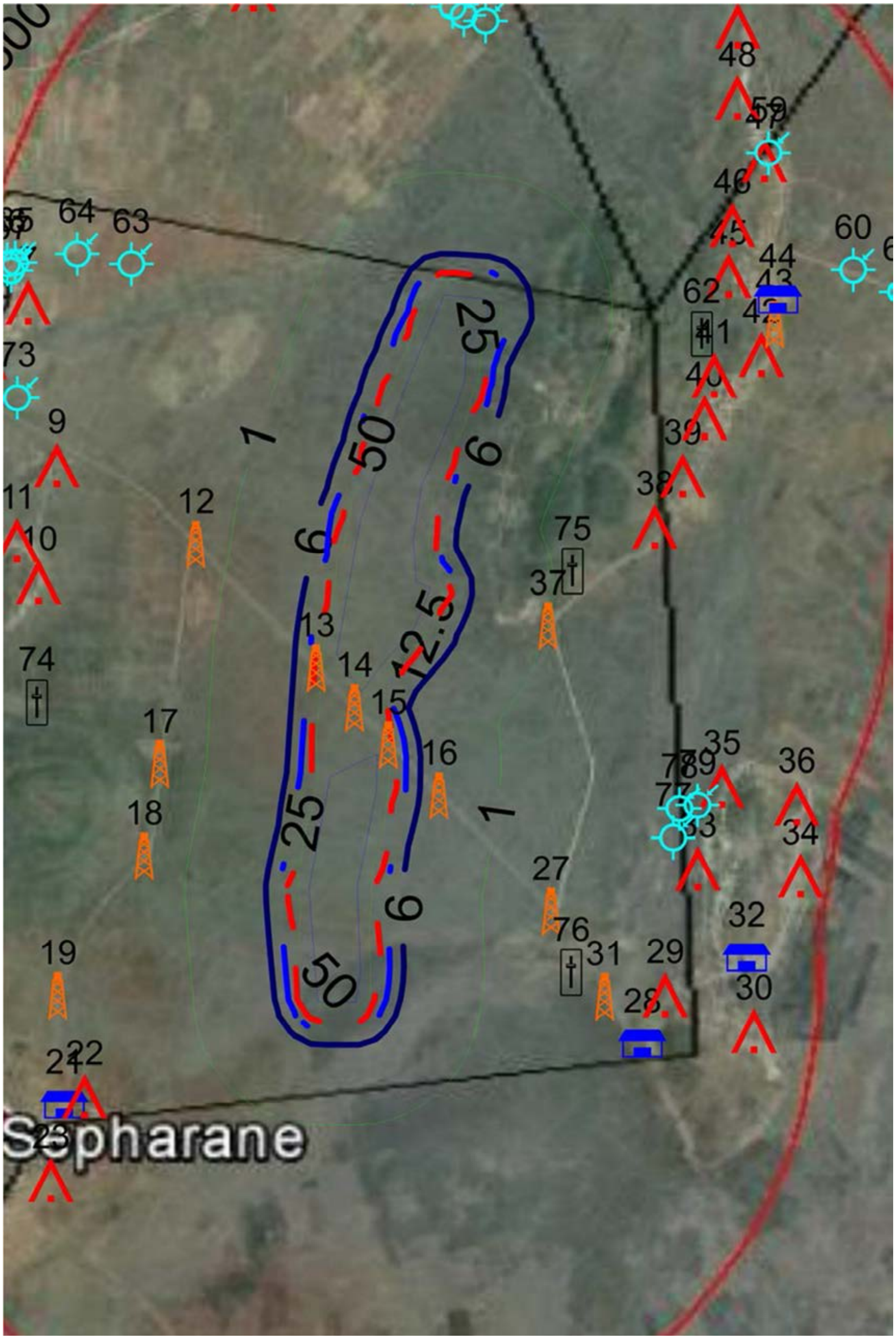

Figure 16: Zoomed area for ground vibration influence from minimum charge

Table 8: 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	D3537 Road	150	2965	0.2	Acceptable	N/A
2	Pudiyagopa Village Houses	12.5	2784	0.2	Acceptable	Too Low
3	Pudiyagopa Village Buildings/Structures	12.5	2959	0.2	Acceptable	Too Low
4	Pudiyagopa Village Houses	12.5	3345	0.1	Acceptable	Too Low
5	Pudiyagopa Village Houses	12.5	3362	0.1	Acceptable	Too Low
6	Buildings/Structures	25	3296	0.1	Acceptable	Too Low
7	Bakenberg Village Houses	12.5	2955	0.2	Acceptable	Too Low
8	Bakenberg Village Houses	12.5	3143	0.1	Acceptable	Too Low
9	Village Houses	12.5	2369	0.2	Acceptable	Too Low
10	Village Houses	12.5	2353	0.2	Acceptable	Too Low
11	Village Houses	12.5	2571	0.2	Acceptable	Too Low
12	D4380 Road	150	1213	0.7	Acceptable	N/A
13	D4380 Road	150	152	20.6	Acceptable	N/A
14	D4380 Road	150	83	55.7	Acceptable	N/A
15	D4380 Road	150	101	40.6	Acceptable	N/A
16	D4380 Road	150	482	3.1	Acceptable	N/A
17	D3507 Road	150	1305	0.6	Acceptable	N/A
18	D3507 Road	150	1292	0.6	Acceptable	N/A
19	D3507 Road	150	1989	0.3	Acceptable	N/A
20	Sepharane Village Houses	12.5	2646	0.2	Acceptable	Too Low
21	Sepharane Village School	25	2108	0.3	Acceptable	Too Low
22	Sepharane Village Buildings/Structures	12.5	1938	0.3	Acceptable	Too Low
23	Sepharane Village Houses	12.5	2476	0.2	Acceptable	Too Low
24	Sepharane Village Houses	12.5	3060	0.1	Acceptable	Too Low
25	Sepharane Village Houses	12.5	2816	0.2	Acceptable	Too Low
26	Building/Structure	25	3317	0.1	Acceptable	Too Low
27	D4380 and D3534 Roads	150	1482	0.5	Acceptable	N/A
28	Buildings/Structures	25	2227	0.2	Acceptable	Too Low
29	Ditlotswana Village Houses	12.5	2349	0.2	Acceptable	Too Low
30	Ditlotswana Village Houses	12.5	3057	0.1	Acceptable	Too Low
31	D4380 Road	150	1887	0.3	Acceptable	N/A
32	Ditlotswana Village School	25	2970	0.2	Acceptable	Too Low
33	Ditlotswana Village Houses	12.5	2539	0.2	Acceptable	Too Low
34	Ditlotswana Village Houses	12.5	3323	0.1	Acceptable	Too Low
35	Ditlotswana Village Houses	12.5	2654	0.2	Acceptable	Too Low
36	Ditlotswana Village Houses	12.5	3232	0.1	Acceptable	Too Low
37	D3534 Road	150	950	1.0	Acceptable	N/A
38	Malokong Village Houses	12.5	1766	0.4	Acceptable	Too Low
39	Malokong Village Houses	12.5	1822	0.3	Acceptable	Too Low
40	Malokong Village Houses	12.5	1846	0.3	Acceptable	Too Low
41	Malokong Village Houses	12.5	1801	0.3	Acceptable	Too Low
42	Malokong Village Houses	12.5	2123	0.3	Acceptable	Too Low
43	D3534 Road	150	2201	0.2	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
44	Malokong Village School	25	2228	0.2	Acceptable	Too Low
45	Malokong Village Houses	12.5	1869	0.3	Acceptable	Too Low
46	Malokong Village Houses	12.5	1978	0.3	Acceptable	Too Low
47	Malokong Village Houses	12.5	2396	0.2	Acceptable	Too Low
48	Malokong Village Houses	12.5	2485	0.2	Acceptable	Too Low
49	Malokong Village Houses	12.5	2869	0.2	Acceptable	Too Low
50	Ga-Mabusela Village Houses	12.5	3284	0.1	Acceptable	Too Low
51	Borehole(Vbh31)	50	3494	0.1	Acceptable	N/A
52	Borehole(Vbh29)	50	3299	0.1	Acceptable	N/A
53	Borehole(Vbh30)	50	3323	0.1	Acceptable	N/A
54	Borehole(Vbh36)	50	3266	0.1	Acceptable	N/A
55	Borehole(Vbh37)	50	2425	0.2	Acceptable	N/A
56	Borehole(Vbh38 4052 H03)	50	2225	0.2	Acceptable	N/A
57	Borehole(Vbh39)	50	2163	0.3	Acceptable	N/A
58	Borehole(Vbh50)	50	2135	0.3	Acceptable	N/A
59	Borehole(Vbh76)	50	2448	0.2	Acceptable	N/A
60	Borehole(Vbh72)	50	2824	0.2	Acceptable	N/A
61	Borehole(Vbh73)	50	3178	0.1	Acceptable	N/A
62	Mabusela Grave	50	1648	0.4	Acceptable	N/A
63	Borehole(Vbh2)	50	2310	0.2	Acceptable	N/A
64	Borehole(Vbh1)	50	2724	0.2	Acceptable	N/A
65	Borehole(Vbh5)	50	3146	0.1	Acceptable	N/A
66	Borehole(Vbh3)	50	3200	0.1	Acceptable	N/A
67	Borehole(Vbh4)	50	3156	0.1	Acceptable	N/A
68	Borehole(Vbh23)	50	3504	0.1	Acceptable	N/A
69	Borehole(Vbh24)	50	3465	0.1	Acceptable	N/A
70	Borehole(Vbh26)	50	3490	0.1	Acceptable	N/A
71	Borehole(Vbh27)	50	3306	0.1	Acceptable	N/A
72	Borehole(Vbh28)	50	3229	0.1	Acceptable	N/A
73	Borehole(Vbh57)	50	2801	0.2	Acceptable	N/A
74	Graves 2	50	2280	0.2	Acceptable	N/A
75	Grave	50	1102	0.8	Acceptable	N/A
76	Graves 1	50	1619	0.4	Acceptable	N/A
77	Borehole(Vbh69)	50	2309	0.2	Acceptable	N/A
78	Borehole(Vbh70)	50	2333	0.2	Acceptable	N/A
79	Borehole(Vbh71)	50	2470	0.2	Acceptable	N/A

- **Maximum Charge per Delay – Pit Area – 707 kg**

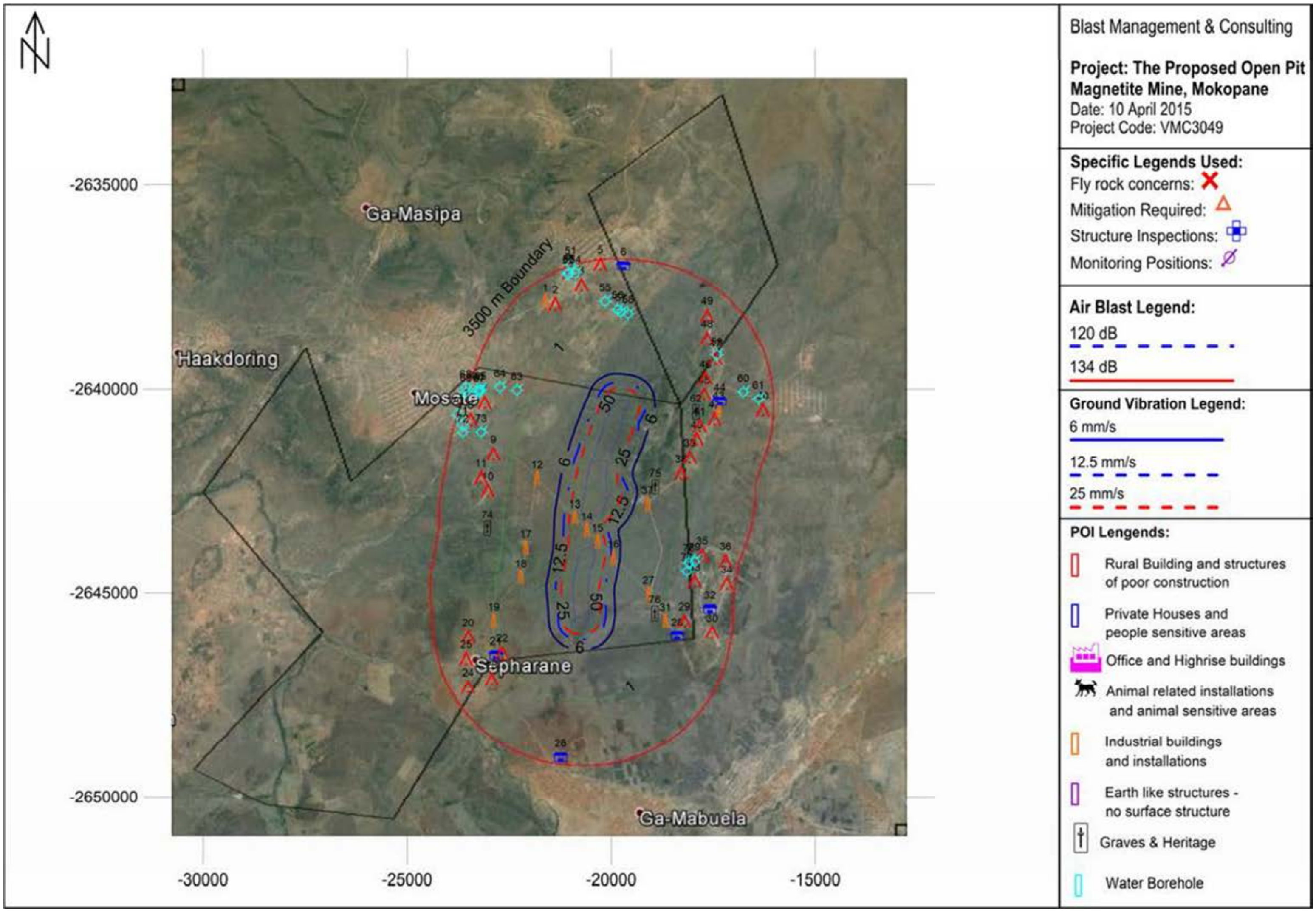

Figure 17: Ground vibration influence from maximum charge

Table 9: 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	D3537 Road	150	2965	0.5	Acceptable	N/A
2	Pudiyagopa Village Houses	12.5	2784	0.5	Acceptable	Too Low
3	Pudiyagopa Village Buildings/Structures	12.5	2959	0.5	Acceptable	Too Low
4	Pudiyagopa Village Houses	12.5	3345	0.4	Acceptable	Too Low
5	Pudiyagopa Village Houses	12.5	3362	0.4	Acceptable	Too Low
6	Buildings/Structures	25	3296	0.4	Acceptable	Too Low
7	Bakenberg Village Houses	12.5	2955	0.5	Acceptable	Too Low
8	Bakenberg Village Houses	12.5	3143	0.4	Acceptable	Too Low
9	Village Houses	12.5	2369	0.7	Acceptable	Too Low
10	Village Houses	12.5	2353	0.7	Acceptable	Too Low
11	Village Houses	12.5	2571	0.6	Acceptable	Too Low
12	D4380 Road	150	1213	2.1	Acceptable	N/A
13	D4380 Road	150	152	64.4	Acceptable	N/A
14	D4380 Road	150	83	174.6	Problematic	N/A
15	D4380 Road	150	101	127.3	Acceptable	N/A
16	D4380 Road	150	482	9.6	Acceptable	N/A
17	D3507 Road	150	1305	1.9	Acceptable	N/A
18	D3507 Road	150	1292	1.9	Acceptable	N/A
19	D3507 Road	150	1989	0.9	Acceptable	N/A
20	Sepharane Village Houses	12.5	2646	0.6	Acceptable	Too Low
21	Sepharane Village School	25	2108	0.8	Acceptable	Perceptible
22	Sepharane Village Buildings/Structures	12.5	1938	1.0	Acceptable	Perceptible
23	Sepharane Village Houses	12.5	2476	0.6	Acceptable	Too Low
24	Sepharane Village Houses	12.5	3060	0.5	Acceptable	Too Low
25	Sepharane Village Houses	12.5	2816	0.5	Acceptable	Too Low
26	Building/Structure	25	3317	0.4	Acceptable	Too Low
27	D4380 and D3534 Roads	150	1482	1.5	Acceptable	N/A
28	Buildings/Structures	25	2227	0.8	Acceptable	Perceptible
29	Ditlotswana Village Houses	12.5	2349	0.7	Acceptable	Too Low
30	Ditlotswana Village Houses	12.5	3057	0.5	Acceptable	Too Low
31	D4380 Road	150	1887	1.0	Acceptable	N/A
32	Ditlotswana Village School	25	2970	0.5	Acceptable	Too Low
33	Ditlotswana Village Houses	12.5	2539	0.6	Acceptable	Too Low
34	Ditlotswana Village Houses	12.5	3323	0.4	Acceptable	Too Low
35	Ditlotswana Village Houses	12.5	2654	0.6	Acceptable	Too Low
36	Ditlotswana Village Houses	12.5	3232	0.4	Acceptable	Too Low
37	D3534 Road	150	950	3.1	Acceptable	N/A
38	Malokong Village Houses	12.5	1766	1.1	Acceptable	Perceptible
39	Malokong Village Houses	12.5	1822	1.1	Acceptable	Perceptible
40	Malokong Village Houses	12.5	1846	1.0	Acceptable	Perceptible
41	Malokong Village Houses	12.5	1801	1.1	Acceptable	Perceptible
42	Malokong Village Houses	12.5	2123	0.8	Acceptable	Perceptible
43	D3534 Road	150	2201	0.8	Acceptable	N/A
44	Malokong Village School	25	2228	0.8	Acceptable	Perceptible

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
45	Malokong Village Houses	12.5	1869	1.0	Acceptable	Perceptible
46	Malokong Village Houses	12.5	1978	0.9	Acceptable	Perceptible
47	Malokong Village Houses	12.5	2396	0.7	Acceptable	Too Low
48	Malokong Village Houses	12.5	2485	0.6	Acceptable	Too Low
49	Malokong Village Houses	12.5	2869	0.5	Acceptable	Too Low
50	Ga-Mabusela Village Houses	12.5	3284	0.4	Acceptable	Too Low
51	Borehole(Vbh31)	50	3494	0.4	Acceptable	N/A
52	Borehole(Vbh29)	50	3299	0.4	Acceptable	N/A
53	Borehole(Vbh30)	50	3323	0.4	Acceptable	N/A
54	Borehole(Vbh36)	50	3266	0.4	Acceptable	N/A
55	Borehole(Vbh37)	50	2425	0.7	Acceptable	N/A
56	Borehole(Vbh38 4052 H03)	50	2225	0.8	Acceptable	N/A
57	Borehole(Vbh39)	50	2163	0.8	Acceptable	N/A
58	Borehole(Vbh50)	50	2135	0.8	Acceptable	N/A
59	Borehole(Vbh76)	50	2448	0.7	Acceptable	N/A
60	Borehole(Vbh72)	50	2824	0.5	Acceptable	N/A
61	Borehole(Vbh73)	50	3178	0.4	Acceptable	N/A
62	Mabusela Grave	50	1648	1.3	Acceptable	N/A
63	Borehole(Vbh2)	50	2310	0.7	Acceptable	N/A
64	Borehole(Vbh1)	50	2724	0.6	Acceptable	N/A
65	Borehole(Vbh5)	50	3146	0.4	Acceptable	N/A
66	Borehole(Vbh3)	50	3200	0.4	Acceptable	N/A
67	Borehole(Vbh4)	50	3156	0.4	Acceptable	N/A
68	Borehole(Vbh23)	50	3504	0.4	Acceptable	N/A
69	Borehole(Vbh24)	50	3465	0.4	Acceptable	N/A
70	Borehole(Vbh26)	50	3490	0.4	Acceptable	N/A
71	Borehole(Vbh27)	50	3306	0.4	Acceptable	N/A
72	Borehole(Vbh28)	50	3229	0.4	Acceptable	N/A
73	Borehole(Vbh57)	50	2801	0.5	Acceptable	N/A
74	Graves 2	50	2280	0.7	Acceptable	N/A
75	Grave	50	1102	2.5	Acceptable	N/A
76	Graves 1	50	1619	1.3	Acceptable	N/A
77	Borehole(Vbh69)	50	2309	0.7	Acceptable	N/A
78	Borehole(Vbh70)	50	2333	0.7	Acceptable	N/A
79	Borehole(Vbh71)	50	2470	0.6	Acceptable	N/A

13.2.1 Summary of ground vibration levels

The open pit 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 open pit pit area. The structures identified range in distance from the pit area between 83 m and 3504 m. The closest structure found is the road at POI 13 at 83 m from the boundary of the pit area. The planned minimum charge evaluated showed little influence but the maximum charge showed greater influence. Ground vibration could also be experienced as unpleasant at the maximum charge on the human perception scale at 11 of these POI's but the rest of houses / structures are relative far away.

Stone walled settlements located on Malokong Hill - sites must be handled according to the correct procedures as define by heritage laws. It is not expected that ground vibration levels will be problematic for these walls. All other heritage installations i.e. graves and graveyards are relatively far away from pit areas and thus not problematic at all.
All water boreholes identified are well away from the blasting operations. No problems with regards to ground vibration influence on these boreholes are foreseen.

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

13.3 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 18 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 within the 3500 m area investigated people may experience levels of ground vibration as perceptible. At 800 m the expected ground vibration levels are still less than the lower safe blasting limit – less than 6 mm/s but will be experienced by people as ***"unpleasant"***. Distances closer than 650 m will exceed the minimum 6 mm/s proposed safe limit for poorly constructed structures. Figure 18 below shows this effect of ground vibration with regards to human perception for maximum charge.

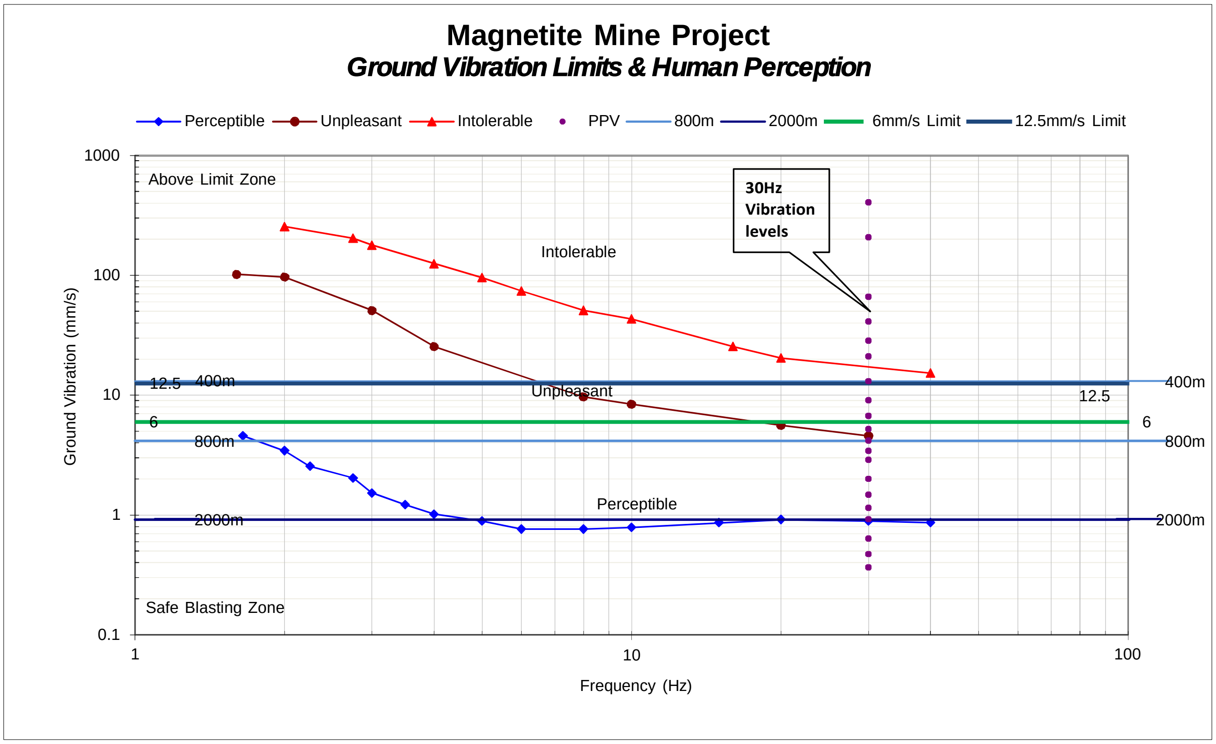

Figure 18: The effect of ground vibration with human perception and vibration limits

13.4 Vibration impact on roads

The D4380 road is located between Pit 1 and Pit 2 of the project area. This road is at closest point 83m from the project area. Expected ground vibration levels at the D4380 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.

13.5 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. There are farming communities, farming areas and roads that are within the evaluated area of influence. There are structures in close proximity of the project area – 83 m to 3362 m. All houses and village area are located such that levels of ground vibration predicted are significantly lower than allow limits. Ground vibration levels may be such at nearest houses that it may be perceptible 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.

13.6 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 3500 m 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. 6 mm/s, 12.5 mm/s and 25 mm/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.

13.7 Air blast

The effect of air blast, if not controlled properly, is considered to be a factor that could be problematic, not necessarily 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 120 dB and low where there is very limited possibility that the levels will give rise to any influence on people or structures. Levels below 115 dB could be considered as to be low or negligible possibility of influence.

Table 11 shows the applied limits and recommended levels for each of the charges considered. The maximum charge may exceed limits at distances up to 200 m. The recommended limit of 120dB is observed at distance of 700 m. These distances are reduced to 150 m for the minimum charge allowed limit and 400 m for recommended limit. This clearly indicates that with increased charge masses the distances of influence increases. An area of 800 m influence would be possible if care is not taken to manage air blast levels.

Table 10: Expected air blast levels

No.	**Distance (m)**	**Air blast (dB) for 177 kg Charge**	**Air blast (dB) for 707 kg Charge**
1	50.0	142	147
2	100.0	138	143
3	150.0	131	136
4	200.0	128	133
5	250.0	125	130
6	300.0	124	128
7	400.0	121	125
8	500.0	118	123
9	600.0	116	121
10	700.0	115	120
11	800.0	113	118
12	900.0	112	117
13	1000.0	111	116
14	1250.0	109	113
15	1500.0	107	112
16	1750.0	105	110
17	2000.0	104	109
18	2500.0	101	106
19	3000.0	100	104
20	3500.0	98	103

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 3500 m around the open pit mining area.

13.7.1 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 - 177kg**

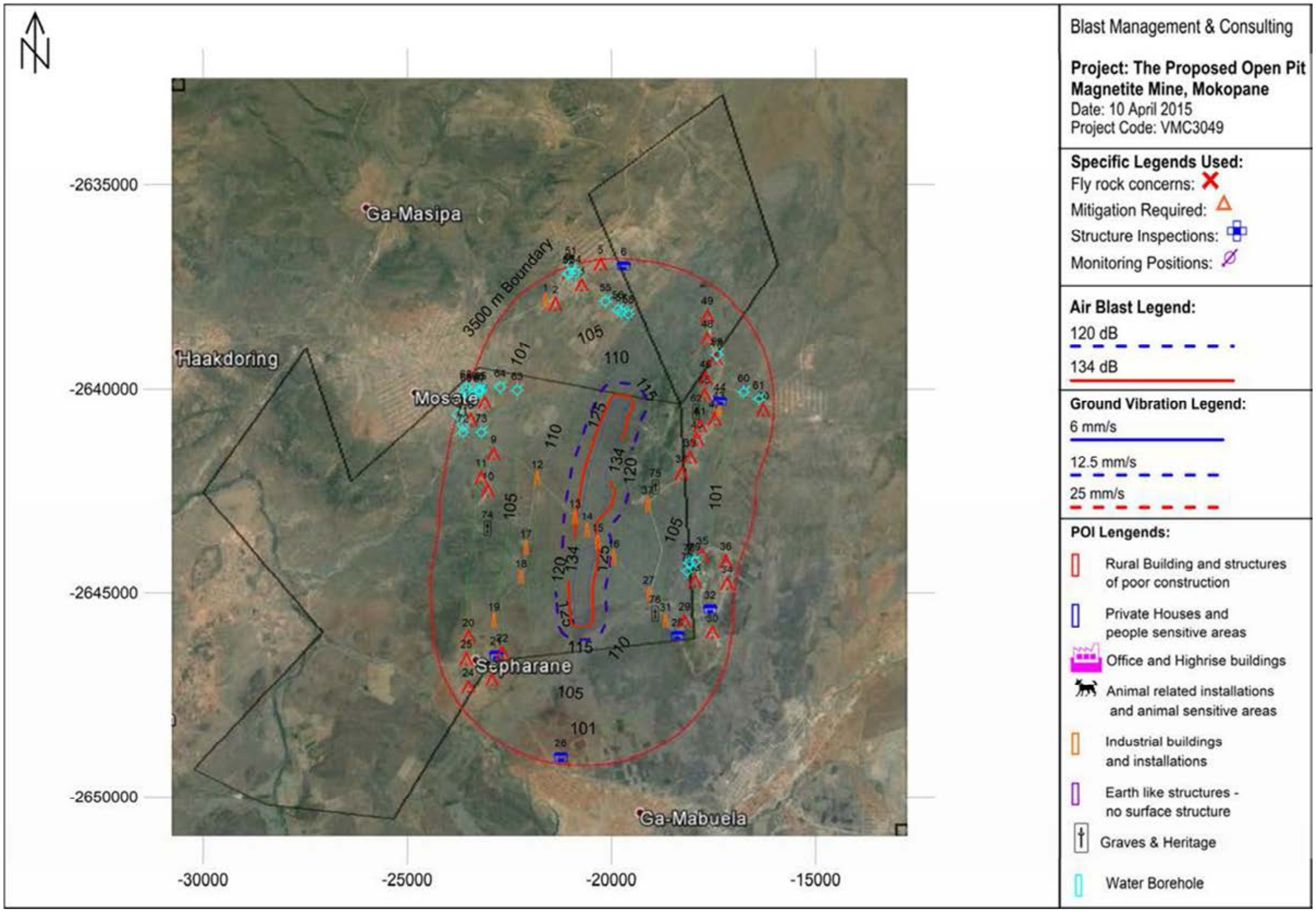

Figure 19: Air blast influence from minimum charge

Table 11: Air blast evaluation for minimum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	D3537 Road	2965	99.7	N/A
2	Pudiyagopa Village Houses	2784	100.3	Acceptable
3	Pudiyagopa Village Buildings/Structures	2959	99.7	Acceptable
4	Pudiyagopa Village Houses	3345	98.4	Acceptable
5	Pudiyagopa Village Houses	3362	98.3	Acceptable
6	Buildings/Structures	3296	98.6	Acceptable
7	Bakenberg Village Houses	2955	99.7	Acceptable
8	Bakenberg Village Houses	3143	99.0	Acceptable
9	Village Houses	2369	102.0	Acceptable
10	Village Houses	2353	102.1	Acceptable
11	Village Houses	2571	101.1	Acceptable
12	D4380 Road	1213	109.0	N/A
13	D4380 Road	152	130.6	N/A
14	D4380 Road	83	136.9	N/A
15	D4380 Road	101	134.9	N/A
16	D4380 Road	482	118.6	N/A
17	D3507 Road	1305	108.2	N/A
18	D3507 Road	1292	108.3	N/A
19	D3507 Road	1989	103.8	N/A
20	Sepharane Village Houses	2646	100.8	Acceptable
21	Sepharane Village School	2108	103.2	Acceptable
22	Sepharane Village Buildings/Structures	1938	104.1	Acceptable
23	Sepharane Village Houses	2476	101.5	Acceptable
24	Sepharane Village Houses	3060	99.3	Acceptable
25	Sepharane Village Houses	2816	100.2	Acceptable
26	Building/Structure	3317	98.5	Acceptable
27	D4380 and D3534 Roads	1482	106.9	N/A
28	Buildings/Structures	2227	102.6	Acceptable
29	Ditlotswana Village Houses	2349	102.1	Acceptable
30	Ditlotswana Village Houses	3057	99.3	Acceptable
31	D4380 Road	1887	104.4	N/A
32	Ditlotswana Village School	2970	99.6	Acceptable
33	Ditlotswana Village Houses	2539	101.3	Acceptable
34	Ditlotswana Village Houses	3323	98.5	Acceptable
35	Ditlotswana Village Houses	2654	100.8	Acceptable
36	Ditlotswana Village Houses	3232	98.8	Acceptable
37	D3534 Road	950	111.5	N/A
38	Malokong Village Houses	1766	105.1	Acceptable
39	Malokong Village Houses	1822	104.7	Acceptable
40	Malokong Village Houses	1846	104.6	Acceptable
41	Malokong Village Houses	1801	104.9	Acceptable
42	Malokong Village Houses	2123	103.1	Acceptable
43	D3534 Road	2201	102.8	N/A
44	Malokong Village School	2228	102.6	Acceptable
45	Malokong Village Houses	1869	104.5	Acceptable
46	Malokong Village Houses	1978	103.9	Acceptable
47	Malokong Village Houses	2396	101.9	Acceptable
48	Malokong Village Houses	2485	101.5	Acceptable
49	Malokong Village Houses	2869	100.0	Acceptable
50	Ga-Mabusela Village Houses	3284	98.6	Acceptable
51	Borehole(Vbh31)	3494	97.9	N/A
52	Borehole(Vbh29)	3299	98.5	N/A
53	Borehole(Vbh30)	3323	98.5	N/A
54	Borehole(Vbh36)	3266	98.6	N/A

55	Borehole(Vbh37)	2425	101.8	N/A
56	Borehole(Vbh38 4052 H03)	2225	102.6	N/A
57	Borehole(Vbh39)	2163	102.9	N/A
58	Borehole(Vbh50)	2135	103.1	N/A
59	Borehole(Vbh76)	2448	101.7	N/A
60	Borehole(Vbh72)	2824	100.2	N/A
61	Borehole(Vbh73)	3178	98.9	N/A
62	Mabusela Grave	1648	105.8	N/A
63	Borehole(Vbh2)	2310	102.3	N/A
64	Borehole(Vbh1)	2724	100.5	N/A
65	Borehole(Vbh5)	3146	99.0	N/A
66	Borehole(Vbh3)	3200	98.9	N/A
67	Borehole(Vbh4)	3156	99.0	N/A
68	Borehole(Vbh23)	3504	97.9	N/A
69	Borehole(Vbh24)	3465	98.0	N/A
70	Borehole(Vbh26)	3490	98.0	N/A
71	Borehole(Vbh27)	3306	98.5	N/A
72	Borehole(Vbh28)	3229	98.8	N/A
73	Borehole(Vbh57)	2801	100.2	N/A
74	Graves 2	2280	102.4	N/A
75	Grave	1102	110.0	N/A
76	Graves 1	1619	106.0	N/A
77	Borehole(Vbh69)	2309	102.3	N/A
78	Borehole(Vbh70)	2333	102.2	N/A
79	Borehole(Vbh71)	2470	101.6	N/A

- **Maximum Charge per Delay – Pit Area - 707kg**

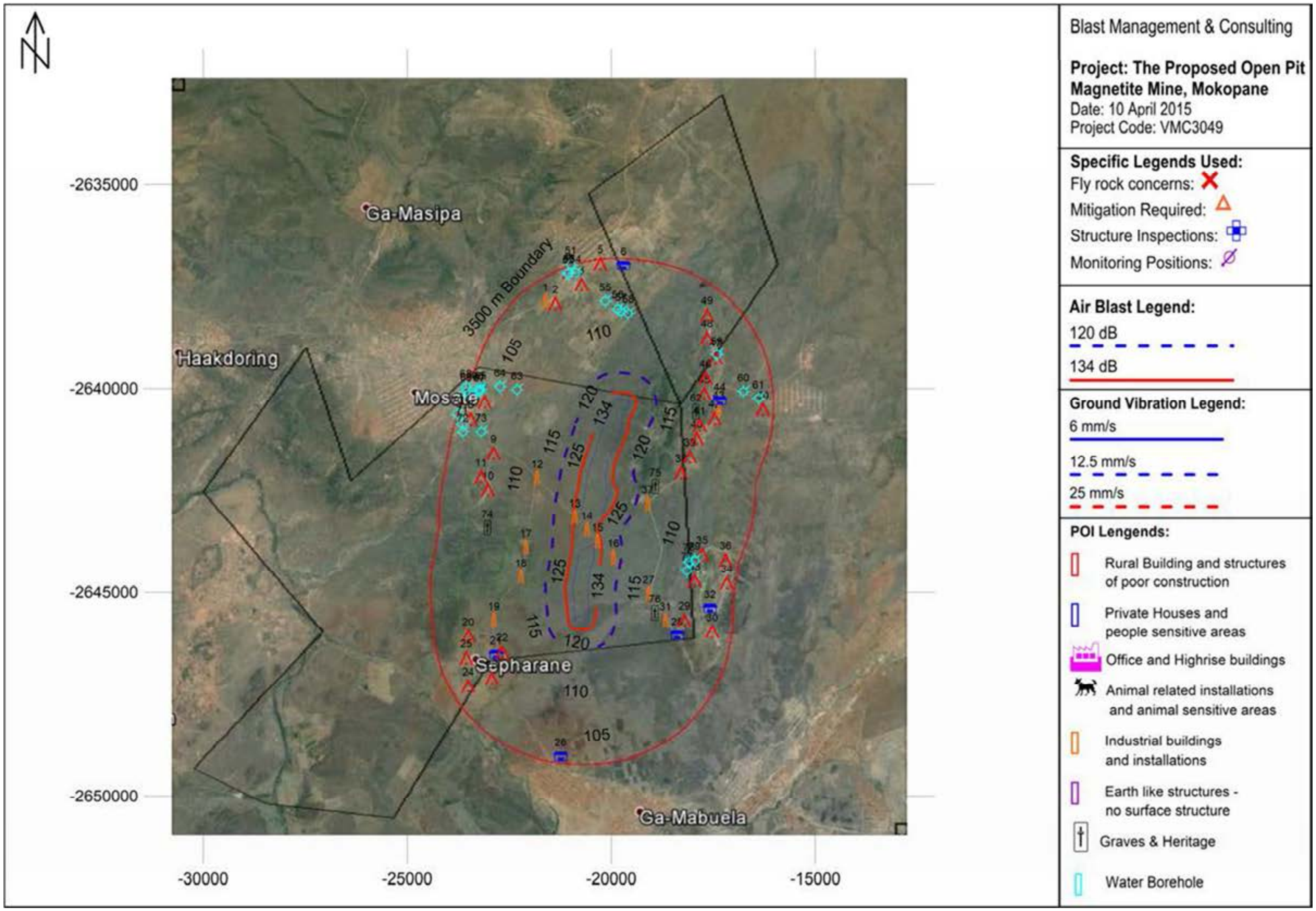

Figure 20: Air blast influence from maximum charge

Table 12: Air blast evaluation for maximum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	D3537 Road	2965	104.5	N/A
2	Pudiyagopa Village Houses	2784	105.1	Acceptable
3	Pudiyagopa Village Buildings/Structures	2959	104.5	Acceptable
4	Pudiyagopa Village Houses	3345	103.2	Acceptable
5	Pudiyagopa Village Houses	3362	103.2	Acceptable
6	Buildings/Structures	3296	103.4	Acceptable
7	Bakenberg Village Houses	2955	104.5	Acceptable
8	Bakenberg Village Houses	3143	103.9	Acceptable
9	Village Houses	2369	106.8	Acceptable
10	Village Houses	2353	106.9	Acceptable
11	Village Houses	2571	106.0	Acceptable
12	D4380 Road	1213	113.8	N/A
13	D4380 Road	152	135.4	N/A
14	D4380 Road	83	141.7	N/A
15	D4380 Road	101	139.7	N/A
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19	D3507 Road	1989	108.6	N/A
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23	Sepharane Village Houses	2476	106.3	Acceptable
24	Sepharane Village Houses	3060	104.1	Acceptable
25	Sepharane Village Houses	2816	105.0	Acceptable
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40	Malokong Village Houses	1846	109.4	Acceptable
41	Malokong Village Houses	1801	109.7	Acceptable
42	Malokong Village Houses	2123	108.0	Acceptable
43	D3534 Road	2201	107.6	N/A
44	Malokong Village School	2228	107.4	Acceptable
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46	Malokong Village Houses	1978	108.7	Acceptable
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49	Malokong Village Houses	2869	104.8	Acceptable
50	Ga-Mabusela Village Houses	3284	103.4	Acceptable
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57	Borehole(Vbh39)	2163	107.8	N/A
58	Borehole(Vbh50)	2135	107.9	N/A
59	Borehole(Vbh76)	2448	106.5	N/A
60	Borehole(Vbh72)	2824	105.0	N/A
61	Borehole(Vbh73)	3178	103.7	N/A
62	Mabusela Grave	1648	110.6	N/A
63	Borehole(Vbh2)	2310	107.1	N/A
64	Borehole(Vbh1)	2724	105.4	N/A
65	Borehole(Vbh5)	3146	103.9	N/A
66	Borehole(Vbh3)	3200	103.7	N/A
67	Borehole(Vbh4)	3156	103.8	N/A
68	Borehole(Vbh23)	3504	102.7	N/A
69	Borehole(Vbh24)	3465	102.8	N/A
70	Borehole(Vbh26)	3490	102.8	N/A
71	Borehole(Vbh27)	3306	103.3	N/A
72	Borehole(Vbh28)	3229	103.6	N/A
73	Borehole(Vbh57)	2801	105.1	N/A
74	Graves 2	2280	107.2	N/A
75	Grave	1102	114.8	N/A
76	Graves 1	1619	110.8	N/A
77	Borehole(Vbh69)	2309	107.1	N/A
78	Borehole(Vbh70)	2333	107.0	N/A
79	Borehole(Vbh71)	2470	106.4	N/A

13.7.2 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 103.2 and 109.9 dB 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.

13.8 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 4.1 m in the blast is expected to yield fly rock that could travel as far as 311 m. Further reduction of stemming length will certainly see fly rock travelling further. At a distance of 311 m as the minimum exclusion zone the following POI’s are of concern: 13, 14 and 15. These POI’s are mainly the D4380 tar road that travels between the two pit areas. Figure 21 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 311 m exclusion zone.

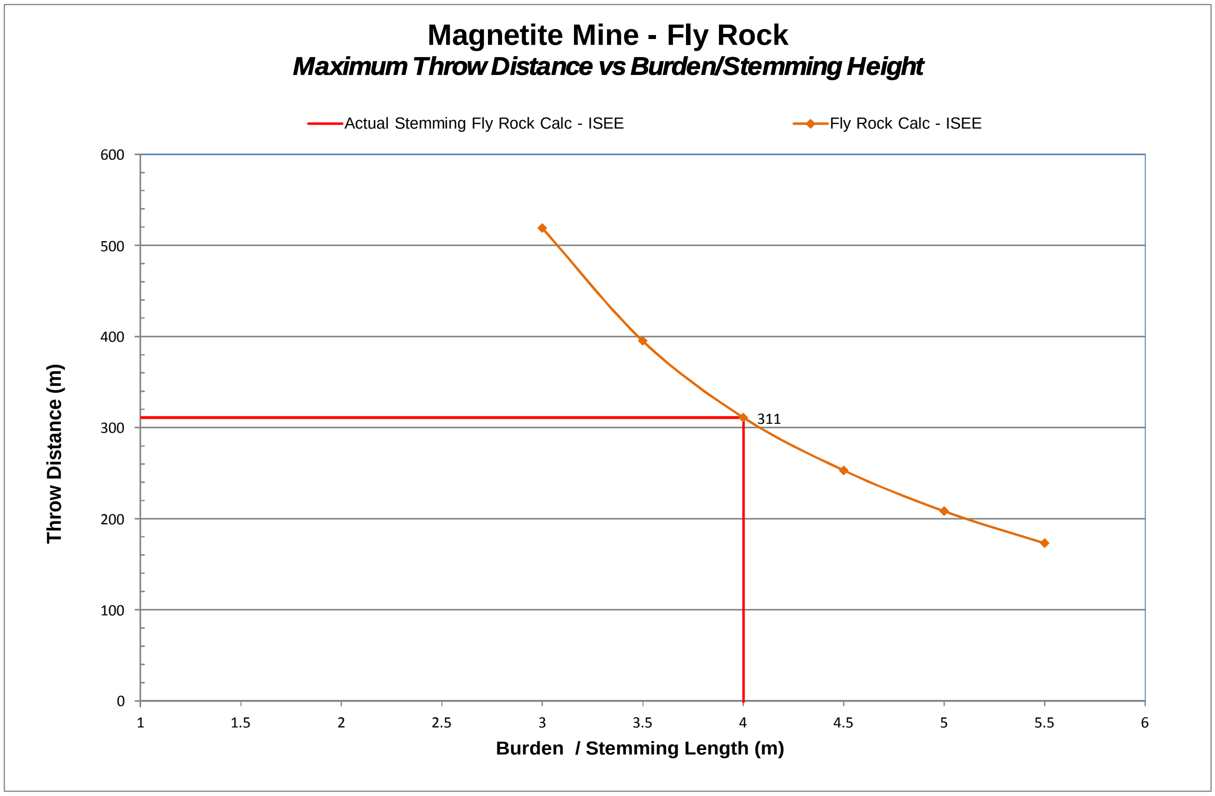

Figure 21: Predicted Fly rock

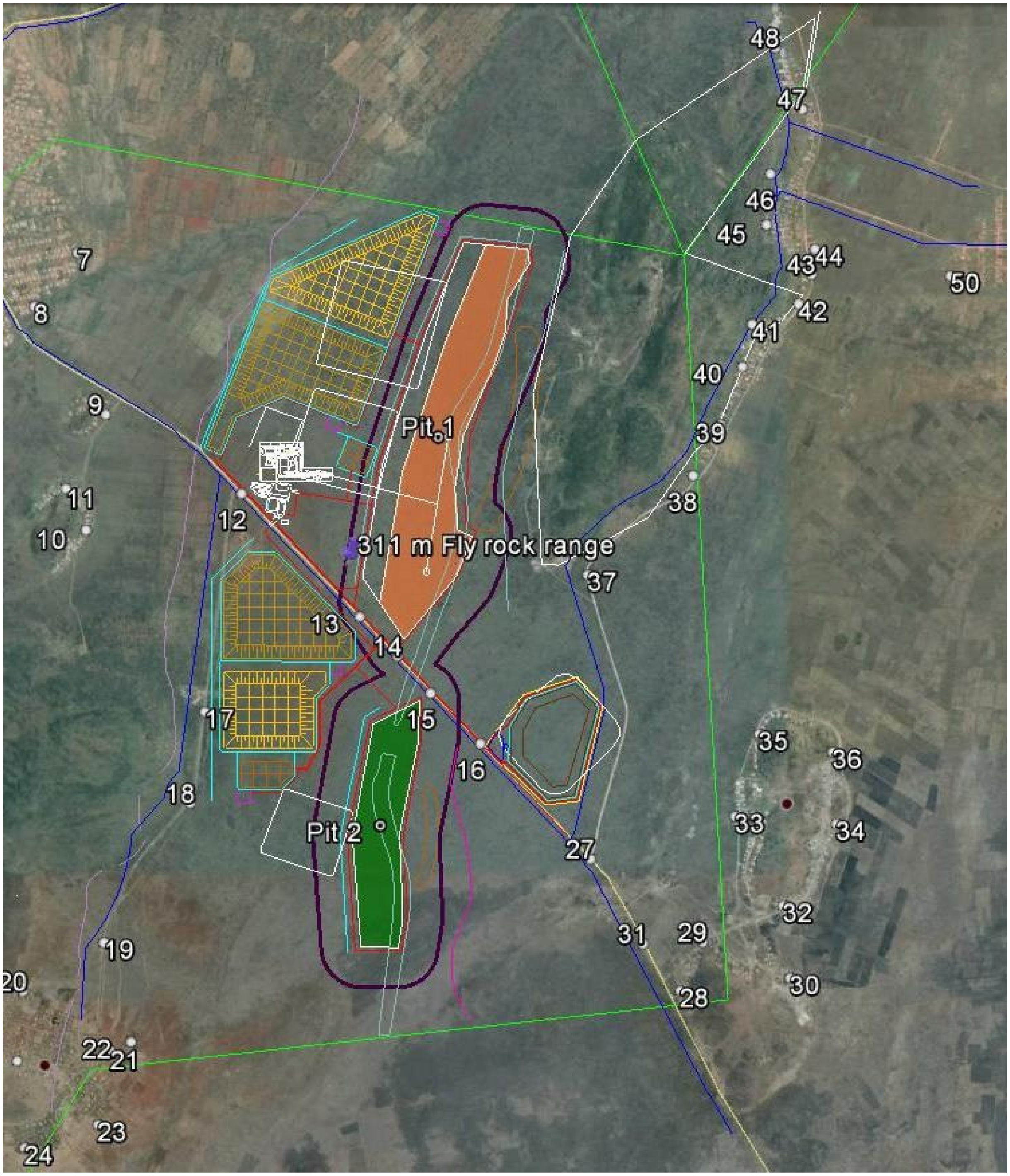

Figure 22: Predicted Fly rock Exclusion Zone

13.9 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.

13.10 Water well influence

25 Domestic and Agricultural Boreholes are located in the area at distances ranging from 1648 m to 3504 m from the pit area. Predicted ground vibration levels at these boreholes are within their limits of 50mm/s. It is expected that ground vibration due to blasting operations will have no influence on these boreholes.

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

The possibility does exist that farm animals such as cattle and donkeys may be found within the 3500 m area from pit areas. No specific formal cattle farming or farming with animals was observed. It is anticipated that the mining area will be fenced and cattle and donkeys kept out of direct influence. However should this not be the case, animals must always be cleared out of the unsafe zone when blasting is done.

The influence on productivity of animals over a period of time due to blasting operations is not clearly defined and difficult to estimate. Social behaviour and change of social behaviour is unfortunately problematic. It is however the author’s opinion that influence will be experienced when animals are located permanently in close proximity of blasting operations. At larger distances, estimated in the region of 500m and greater, cattle or game will get accustomed to the blasting and related noise. This is based 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. It is likely that cattle will get used to the blasting operations and fly rock may be the most likely cause of injury or death if not removed to safe distance. As an example review of the pressures required to cause lung damage in larger animals is at 10psi (68.59 kPa) to 15psi (103.4 kPa). This relates to air blast levels in the order of 190 dB(L) and 195 dB(L). Table 14 below shows that it will be required that animals be on the blast and again showing that factors apart from air blast would cause death. The following table (Table 14) show air blast levels in dB and kPa at short increment distances from the blast based on the maximum charge used in this report.

Table 13: Expected air blast levels in dB and kilopascal’s for short distance increments.

Distance (m)	Air Blast Pressure Levels for Maximum Charge in dB	Air Blast Pressure Levels for Maximum Charge in kPa
5.0	171	7.11
10.0	164	3.10
15.0	160	1.90
20.0	157	1.35
25.0	154	1.03

Distance (m)	Air Blast Pressure Levels for Maximum Charge in dB	Air Blast Pressure Levels for Maximum Charge in kPa
30.0	152	0.83
35.0	151	0.69
40.0	149	0.59
45.0	148	0.51
50.0	147	0.45

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

Direct influence from air blast at the feed lots is not expected. The above excludes the impact on social behaviour in animals. This subject is not yet fully understood in the industry as little research or work has been done on this.

13.12 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 17 before mitigation and after 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.

13.12.1 Impact Identification

Impact identification was performed by use of an Input-Output model which served to guide Digby Wells in assessing all the potential instances of ecological and socio-economic change, pollution and resource consumption that may be associated with the activities required during the construction, operational, closure and post-closure phases of the project.

Outputs may generally be described as any changes to the biophysical and socio-economic environments, both positive and negative in nature, and also included the product and anticipated waste produced by the proposed underground mining activities. Negative impacts could include, dust, noise, vibration, water pollution, safety issues and changes to the bio-physical environment such as destruction of habitats. Positive impacts may include skills transfer or benefits to the socio-economic environment. During the determination of outputs, the effect of outputs on the various components of the environment (e.g. topography and water quality) was considered.

During consultation with stakeholders, perceived impacts were identified. These perceived impacts were included in the impact assessment and significance rating in order to differentiate between probable impacts and perceived impacts.

13.12.2 Impact Rating

The impact rating process is designed to provide a numerical rating of the various environmental impacts identified by use of the Input-Output model. As discussed above, it has to be stressed that the purpose of the ESIA process is not to provide an incontrovertible rating of the significance of various aspects, but rather to provide a structured, traceable and defendable methodology of rating the relative significance of impacts in a specific context. This will give the client a greater understanding of the impacts of his project and the issues which need to be addressed by mitigation. It will also give the regulators information on which to base their decisions.

The equations and calculations were derived using Aucamp (2009). The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability
Where Consequence = Severity + Spatial Scale + Duration
And Probability = Likelihood of an impact occurring

The matrix calculates the rating out of 147, whereby Severity, Spatial Scale, duration and probability is rated out of seven. The weighting is then assigned to the various parameters for positive and negative impacts in the formula.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in the Environmental Management Programme (EMP). The significance of an impact is then determined and categorised into one of four categories, as indicated in Table 15, which is extracted from Table 16.

Table 14: Probability Consequence Matrix

Significance		**Consequence (severity + scale + duration)**								
		1	**3**	**5**	**7**	**9**	**11**	**15**	**18**	**21**
Probability / Likelihood	1	1	3	5	7	9	11	15	18	21
	2	2	6	10	14	18	22	30	36	42
	3	3	9	15	21	27	33	45	54	63
	4	4	12	20	28	36	44	60	72	84
	5	5	15	25	35	45	55	75	90	105
	6	6	18	30	42	54	66	90	108	126
	7	7	21	35	49	63	77	105	126	147

Table 15: Significance threshold limits

Significance		
Major	108- 147	
Moderate	73 - 107	
Minor	36 - 72	
Negligible	0 - 35	

13.12.3 Assessment

Table 16: Risk Assessment Outcome before mitigation and after mitigation

Criteria	Details/ Discussion					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Ground vibration Impact on houses					
Mitigation required	Reduce Charge Mass/Delay over decreasing distance towards POI's of concern, Relocate POI's of concern at least 500m					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	3	4	4	4	44	Minor
Post-Mitigation	3	4	4	4	44	Minor

Criteria	Details/ Discussion					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Ground vibration Impact on boreholes					
Mitigation required	Reduce Charge Mass/Delay over decreasing distance towards POI's of concern, Re-drill boreholes further away					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	1	1	4	1	6	Negligible
Post-Mitigation	1	1	4	1	6	Negligible

Criteria	Details/ Discussion					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Ground vibration Impact on roads					
Mitigation required	Reduce Charge Mass/Delay over decreasing distance towards POI's of concern, Reroute roads					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	5	4	4	6	78	Moderate
Post-Mitigation	3	4	4	4	44	Minor

Criteria	Details/ Discussion					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Air blast Impact on houses					
Mitigation required	Mitigations that can be considered if required: Reduce Charge Mass/Delay over decreasing distance towards POI's of concern.					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	1	2	4	2	14	Negligible
Post-Mitigation	1	2	4	2	14	Negligible

Criteria	Details/ Discussion					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Fly Rock Impact on houses					
Mitigation required	Mitigations that can be considered if required: Increase stemming length, controls put in place for management of stemming lengths					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	1	2	4	1	7	Negligible
Post-Mitigation	1	2	4	1	7	Negligible

Criteria	Details/ Discussion

Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Fly Rock Impact on roads					
Mitigation required	Increase stemming length, controls put in place for management of stemming lengths					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	6	4	4	6	84	Moderate
Post-Mitigation	2	4	4	2	20	Negligible

Criteria	**Details/ Discussion**					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Impact of Fumes - Houses					
Mitigation required	Mitigations that can be considered if required: Use correct product, Control product quality, prevent sleep time for charged blast holes, same day charge and blast (the supplier must produce quality certificates for the product to be used. The correct product will have to be selected as to match the type of blasting to be done. The use of only ANFO and not emulsion because of costs may not be good idea when blast holes are wet or have water. It is preferred that blast holes must be charged and blasted on the same day. Blasts standing over to a next day may be problematic especially when water is present and in oxidised material. This is prone to yield fumes and should be prevented as far as possible.)					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significant rating***	
Pre-Mitigation	3	4	4	3	33	Negligible
Post-Mitigation	3	4	4	3	33	Negligible

13.12.4 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 14 – closest to the pit area. Figure 23 and 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 two ways: reduce the charge mass per delay – in other words, plan blasting operations considering different initiation and charging options. Secondly increase distance between the blast and the structure of concern. These are the main factors to be considered for mitigation.

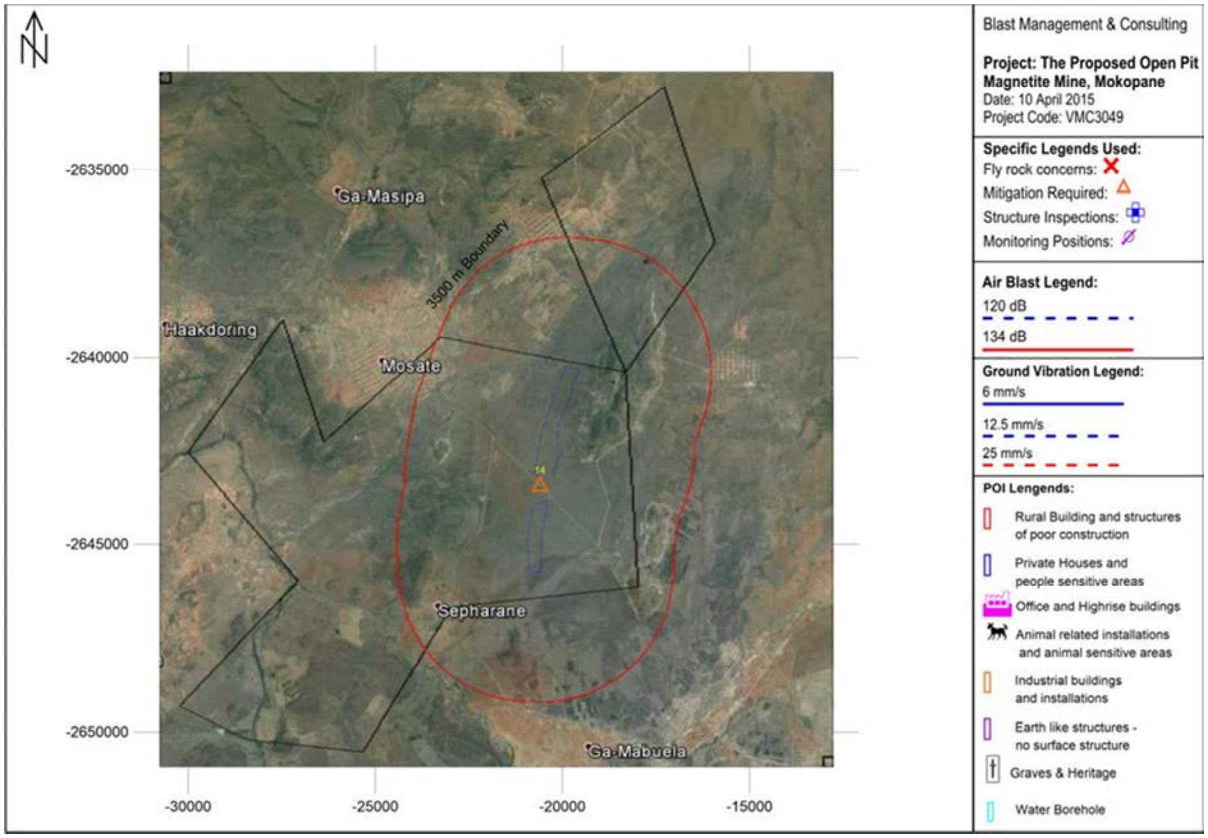

Figure 23: Structures at Pit Area that are identified where mitigation will be required.

Table 17: Structures at Pit Area identified as problematic

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
14	D4380 Road	20596.33	2643456.92	150	83	707	174.6	Problematic

In order to ensure that levels of ground vibration and that of air blast are within acceptable limits not to induce damage, the following table shows a combination of reduce charge mass per delay and increased distance from the structures of concern. The location of these structures is such that specific design changes are required for the blast operations on the southern side of the 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 any area in the pit further than the distances given below will yield lower levels of ground vibration. It is advisable that a detail plan of action is put in place to manage ground vibrations in the areas of concern. Table 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 18: 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
14	D4380 Road	20596.33	2643456.92	150	83	575	147.2	Acceptable

Table 19: Mitigation suggested for blasting operations – Minimum distance required

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
14	D4380 Road	20596.33	2643456.92	150	95	707	139.8	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 the plant, it will be reviewed as civil blasting and addressed accordingly.

15 Alternatives (Comparison and Recommendation)

No specific mining method alternatives are currently under discussion or considered for drilling and blasting.

16 Monitoring

It is highly recommended that a blast monitoring program be put in place. This includes monitoring ground vibration and air blast for every blast. Ground vibration and air blast is monitored using a seismograph. 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 also selected to indicate the nearest points of interest at which levels of ground vibration and air blast should be within the accepted norms and standards as proposed in this report. The monitoring of ground vibration will also qualify the expected ground vibration and air blast levels and assist in mitigating these aspects properly. This will also contribute to proper relationships with the neighbours. Currently 7 monitoring positions were identified around the mining areas. Monitor positions are indicated in Figure 24. These points will need to be defined finally from testing during first blasts.

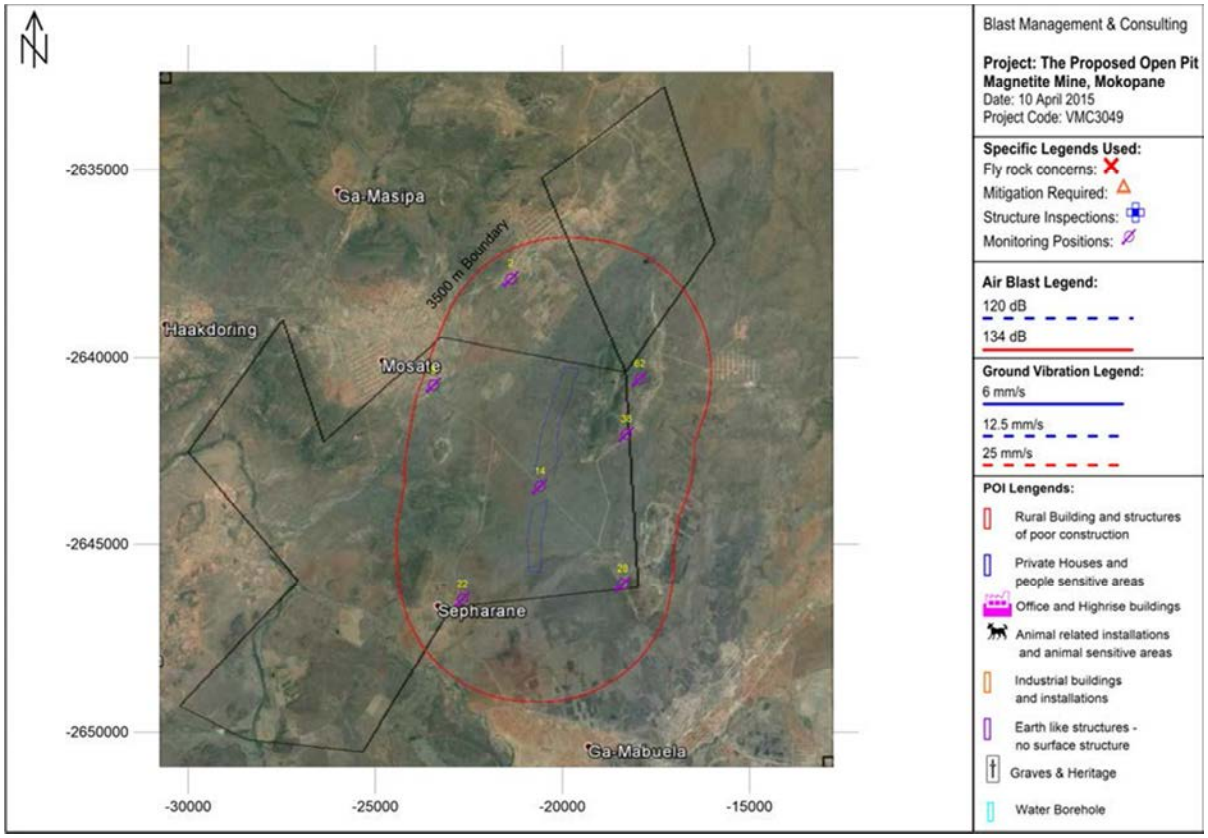

Figure 24: Monitoring Positions suggested.

Table 20: List of possible monitoring positions

Tag	Description	Classification	Y	X
14	D4380 Road	5	20596.33	2643456.92
62	Mabusela Grave	7	17926.68	2640569.09
38	Malokong Village Houses	1	18287.80	2642054.37
22	Sepharane Village Buildings/Structures	1	22669.50	2646456.94
28	Buildings/Structures	2	18383.29	2646052.51
2	Pudiyagopa Village Houses	1	21371.76	2637904.45
8	Bakenberg Village Houses	1	23440.76	2640739.82

17 Recommendations

The following recommendations are proposed.

17.1 Safe blasting distance

A minimum safe distance of 311 m is required but recommended is that a minimum of 500 m 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 500 m from a blast must be cleared and where necessary evacuation must be conducted with all the required pre-blast negotiations.

17.3 Road Closure

The D4380 road is located between Pit 1 and Pit 2 of the project area. This road is at closest point 83m from the project area. Expected ground vibration levels at the D4380 are higher than the recommended limits. Careful consideration should be given to this road. It is a vital link to the villages. Alternatives such as re-routing, stop and go, maintain a safe distance from the road, etc. will have to be included in the final mine works plan.

17.4 Photographic Inspections

The option of photographic survey of all structures up to 2500 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 at 2500 m but this process will ensure the status of nearest structures to the pit areas. At 2500 m the expected levels is just less than the perceptible level. Figure 25 shows the structures within the 2500 m area for the pit areas to be considered. Table 22 shows list of structures identified for inspection.

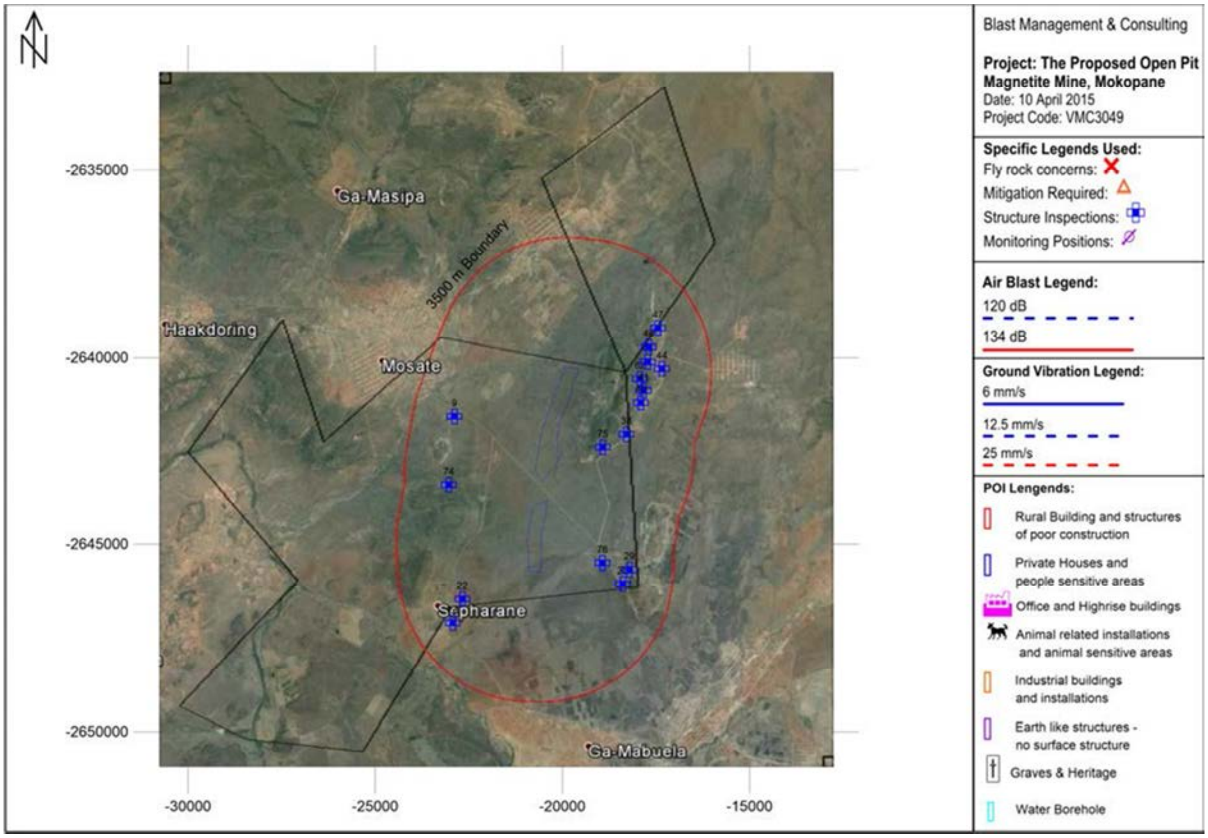

Figure 25: 2500 m area around pit identified for structure inspections.

Table 21: Structure Inspection List

Tag	Description	Y	X
28	Buildings/Structures	18383.29	2646052.51
29	Ditlotswana Village Houses	18207.46	2645675.07
75	Grave	18920.21	2642400.92
76	Graves 1	18930.79	2645502.28
74	Graves 2	23036.15	2643415.27
62	Mabusela Grave	17926.68	2640569.09
41	Malokong Village Houses	17830.52	2640885.96
40	Malokong Village Houses	17904.86	2641212.41
45	Malokong Village Houses	17719.77	2640114.49
46	Malokong Village Houses	17690.11	2639721.91
47	Malokong Village Houses	17444.77	2639219.03
44	Malokong Village School	17341.19	2640298.51
38	Malokong Village Houses	18287.80	2642054.37
22	Sepharane Village Buildings/Structures	22669.50	2646456.94
23	Sepharane Village Houses	22928.75	2647103.52
9	Village Houses	22882.45	2641578.98

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 22: 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 at least must be maintained to ensure control on fly rock. Specific designs where distances and blast is known should be considered with this.

17.7 Blasting times

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

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

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

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

19 Comments and Response

What will happen to houses during blasting?	Sam Kekana	Kwenaite / Moutjane	30 March 2015	Village Meeting	The following village areas were considered in the impact assessment from blasting operations. Bakenberg Village, Ditlotswana Village, Ga-Mabusela, Malokong Village, Pudiyagopa Village and Sepharane Village. The planned drilling and blast design was used to calculate expected ground vibration and air blast levels from blasting. Results from calculation showed low to no vibration influence at these villages. Villages further away have lower probability of influence. Levels of air blast are also expected to be low with a possibility of hearing of blasting. The identified grave sites were also evaluated with no specific concern that the sites with will be disturbed. Ground vibration expected at the nearest house at 1766 m is 1.1 mm/s. This is very low and damage is very highly unlikely. People may feel the vibration. Air blast expected is also low at 110 dBL. This level may be heard but will not cause damage. All other houses are further away and the influences will then be less. A detailed survey of all surrounding properties will be undertaken, prior to the construction phase of this project. This survey will serve as the baseline conditions, prior to mining. Compensation mechanisms for potential damage to properties will be finalised prior to mining.
Will blasting affect our houses?	Johanna Temo	Good Hope	30 March 2015	Village Meeting	The following village areas were considered in the impact assessment from blasting operations. Bakenberg Village, Ditlotswana Village, Ga-Mabusela, Malokong Village, Pudiyagopa Village and Sepharane Village. The planned drilling and blast design was used to calculate expected ground vibration and air blast levels from blasting. Results from calculation showed low to no vibration influence at these villages. Villages further away have lower probability of influence. Levels of air

					blast are also expected to be low with a possibility of hearing of blasting. The identified grave sites were also evaluated with no specific concern that the sites with will be disturbed. Ground vibration expected at the nearest house at 1766 m is 1.1 mm/s. This is very low and damage is very highly unlikely. People may feel the vibration. Air blast expected is also low at 110 dBL. This level may be heard but will not cause damage. All other houses are further away and the influences will then be less. A detailed survey of all surrounding properties will be undertaken, prior to the construction phase of this project. This survey will serve as the baseline conditions, prior to mining. Compensation mechanisms for potential damage to properties will be finalised prior to mining.
Will there be damage to properties?	Mr Sokotla	Good Hope	30 March 2015	Village Meeting	The following village areas were considered in the impact assessment from blasting operations. Bakenberg Village, Ditlotswana Village, Ga-Mabusela, Malokong Village, Pudiyagopa Village and Sepharane Village. The planned drilling and blast design was used to calculate expected ground vibration and air blast levels from blasting. Results from calculation showed low to no vibration influence at these villages. Villages further away have lower probability of influence. Levels of air blast are also expected to be low with a possibility of hearing of blasting. The identified grave sites were also evaluated with no specific concern that the sites with will be disturbed. Ground vibration expected at the nearest house at 1766 m is 1.1 mm/s. This is very low and damage is very highly unlikely. People may feel the vibration. Air blast expected is also low at 110 dBL. This level may be heard but will not cause damage. All other houses are further away and the influences will then be less.

20 Conclusion

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 open pit 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 some heritage sites. The project area consists mainly of two open pit pit areas. The project is a greenfields project with no existing blasting operations.

The project area has a possibility of presence of people and possibly farm animals at close distances to the operations. There are no fences and cattle hereders roaming free with their cattle that could be close to the mining area.The location of structures around the pit areas are such that the charge evaluated showed possible influences due to ground vibration. This is mainly for the D4380 tarred road the travel between the two pit areas. Ground vibration mitigation will be required for the road. Ground vibrations predicted ranged between 0.4 mm/s and 174.6 mm/s for points of interest identified. Ground vibration at structures and installations other than the road is well below any specific concern for inducing damage. There is slight possibility that ground vibration may be perceptible at nearest houses.

Air blast levels expected ranged between 103.2 dB and 109.9 dB at the nearest point of interest. Air blast levels predicted showed less concern than ground vibration. Most of the points of concern that area located close to the pit area are the D4380 road that are not specifically influenced by air blast. No specific structures / houses / farmsteads were identified with concerns greater than possible complaints were identified. 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 311 m. Normal practice observed in mines is a 500 m exclusion zone. The use of 500 m exclusion zone is rather recommended.

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

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

21 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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23 Appendix 01: Structure profile photos

The following photos shows structure types and condition observed during site visit.

Structure Photo	Description
	Old house with specific damages visible
	Group of houses

	Brick and mortar house and corrugated iron roof
	Old structure build with mud walls

	Delapidated house
	Communication tower in village

	House and tiled roof
	House occupied and under construction

	D4380 Road
	Relative new house

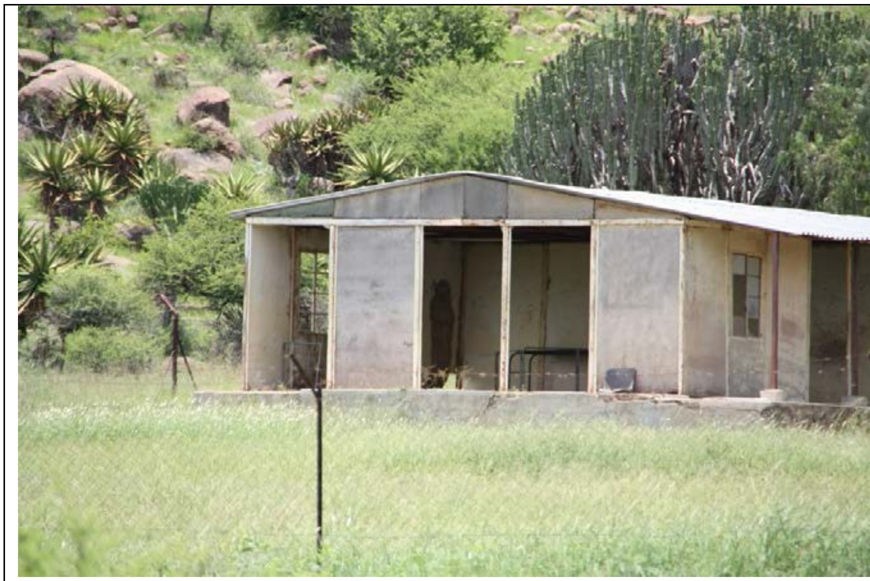
	House
	Corrugated iron house

	House under construction
	Stone building

	Old house
	Donkeys observed

	House
	House

	Mud wall structure
	House with very prominent vertical crack

	Prefab structure
	School buildings

	Brick and mortar house
	Cement dam

	House under construction
	Grave yard

	New buildings being erected
	House with prominent vertical crack

	School buildings
	Grave yard

	Soccer field