Blast Management & Consulting

Report:

Environmental Impact Assessment:
Ground Vibration and Air Blast Study
BHP Billiton Energy Coal South Africa (Pty) Ltd (BECSA)
Klipspruit Extension: Weltevreden Project

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ii. Study Team Qualifications And Background

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

I have obtained the following Qualifications:

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

Member: International Society of Explosives Engineers

iii. Independence Declaration

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

Table of Contents

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
National Home Builders Registration Council	NHBRC
North	N
North East	NE
North West	NW
Noxious Fumes	NOx's
Peak Particle Velocity	PPV
Points of Interest	POI
Probability	P
Rock Pressure Pulse	RPP
Scale	S
Site Constant	a and b
South	S
South East	SE
South West	SW
United States Bureau of Mine	USBM
West	W
With Mitigation Measures	WM
Without Mitigation Measures	WOM

List of Units used in this Report

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

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

List of Figures

List of Tables

Executive Summary

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

The project area consists mainly of two pit areas in the mining rights area. The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500m from the two opencast pit areas. The base areas of the two opencast areas were combined as one for the study. The influences from blasting operations was evaluated for possible influence on surface structures that ranged from well build structures to more informal building style, farming activities, industrial structures such ass power lines, roads and dams.

Ground vibration due to blasting operations was evaluated for identified POI's over the whole area. These POI's ranged in distances between 12 m and 3475 m with resulting ground vibration levels ranging from very high to acceptable levels and as low as 0.9 mm/s. Specific structures and installation were identified where ground vibration levels are expected to be damaging. In these cases mitigation of reduced charging is addressed and recommended. The most concerning is a farm house located on the northern side of the pit area and the N12 highway on the southern side. There are also burial grounds and graveyards that will require specific attention. Structures inside the pit areas will need relocation and negotiations regarding this are recommended.

Air blast levels indicated lesser of concern than ground vibration. Mainly one structure was identified where levels could be problematic. This is based on a stemming length of 25 times the blast hole diameter which is a start level for stemming control. Stemming control will have the greatest influence on air blast control. Air blast levels at the structure of concern are expected to 139.5 dB at 151 m. Levels at closer distances will be higher and further definitely be lower. Mitigations recommended on ground vibration will also contribute to reduction of air blast. However mitigation of air blast is primarily found in proper stemming control measures. 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.

Stemming control for air blast will also contribute to control on fly rock. Predicted fly rock safe exclusion zone is a minimum of 386 m. Various structures and installations are found within this range. Careful planning will be required to manage the effect of fly rock. Safe clearance areas will need to be defined and adhered too at all times.

Various recommendations are submitted that should be considered in the final code of practise for the mine. It is believed that this report will advise and assist in setting up and define a best practise code for operations at the project area.

This concludes this investigation blasting operations impact for the Klipspruit Extension: Weltevreden Project.

1 Introduction

BHP Billiton Energy Coal South Africa (Pty) Limited (BECSA) is the holder of an approved Mining Right (Ref No. MP 30/5/1/2/2/125 MR) and Environmental Management Programme (EMP) for Klipspruit Colliery (KPS), located near Ogies, Mpumalanga Province. The KPS EMP was approved in 2003 in terms of Section 39 of the Minerals Act, 1991 (Act No. 50 of 1991) and in 2009 was subsequently updated to meet the requirements of the Mineral and Petroleum Resources Development Act, 2002 (Act No 28 of 2002) (MPRDA).

BECSA is proposing to extend the Life of Mine (LoM) of its operations by implementing the Klipspruit Extension (KPSX) Project which incorporates Klipspruit South (KPSX: South), as well as BECSA's three neighbouring Prospecting Rights to the north east, collectively referred to as Weltevreden (KPSX: Weltevreden). KPSX: Weltevreden will extend the KPS LoM by at least another twenty (20) years.

The KPSX: Weltevreden Project area is 7 353.9 ha in size and is located to the east and north of the town of Ogies, as well as east of the settlement of Phola. The N12 national road transects the southern third of the Project site. The KPS operations are located towards the southwest of KPSX: Weltevreden, with the northeast of KPS sharing the Project boundary, alongside the N12.

BECSA has applied for an amendment to the Mining Right and the Mining Work Programme for KPS in terms of the provisions of Section 102 of the MPRDA to incorporate the KPSX: Weltevreden resource, which will be mined using opencast strip mining methods. In addition, a Section 102 EIA/EMP Amendment Report will be submitted to the Department of Mineral Resources (DMR). The KPSX: Weltevreden reserve will be mined at a rate of 9 million tonnes per annum for the first 20 years. The saleable production will be circa 7 million tonnes per annum. The increased LoM capacity will enable KPS to maintain its current production profile and thus, also retain the current employment opportunities at the KPS operation. The increased production capacity will have significant contributions to the Gross Domestic Product (GDP) for South Africa due to the generation of export revenues.

The topography of the KPSX: Weltevreden site and its surrounds are undulating with numerous ridges and valleys. The predominant land use on KPSX: Weltevreden is agriculture, with natural areas surrounding the watercourses on site. The immediate surroundings of KPSX: Weltevreden, however, is mining related activities with numerous coal collieries neighbouring the proposed Project.

The proposed KPSX: Weltevreden Project falls in the eMalahleni Local Municipality (ELM) which in turn falls in the Nkangala District Municipality (NDM). The KPSX: Weltevreden Project area is 7 353.9 ha in size and is located to the east and north of the town of Ogies, as well as east of the township of Phola at geographic coordinates 25°58'46.32"S, 29° 4'31.50"E. The N12 national road transects the southern third of the Project site. The KPS operations are located towards the southwest of KPSX: Weltevreden, with the northeast of KPS sharing the Project boundary, alongside the N12.

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

2 Objectives

The objective of this document is outlining the expected environmental effects that blasting operations could have on the surrounding environment and proposal of specific mitigation measures that will be required if possible. 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.

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 summarised according to the following steps taken as part of the EIA study with regards specifically to ground vibration and air blast due to blasting operations.

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

4 Study Area

The study done is not dependent on a specific season. Data calculated is expected to be a worst case scenario that will be applicable to all seasons and blasting operations throughout the year.

The proposed KPSX: Weltevreden Project falls in the eMalahleni Local Municipality (ELM) which in turn falls in the Nkangala District Municipality (NDM). The KPSX: Weltevreden Project area is 7 353.9 ha in size and is located to the east and north of the town of Ogies, as well as east of the township of Phola at geographic coordinates 25°58'46.32"S, 29° 4'31.50"E. The N12 national road transects the southern third of the Project site. The KPS operations are located towards the southwest of KPSX: Weltevreden, with the northeast of KPS sharing the Project boundary, alongside the N12.

Figure 1 shows a geographical locality plan of the proposed project area. Figure 2 shows view of the proposed mining area.

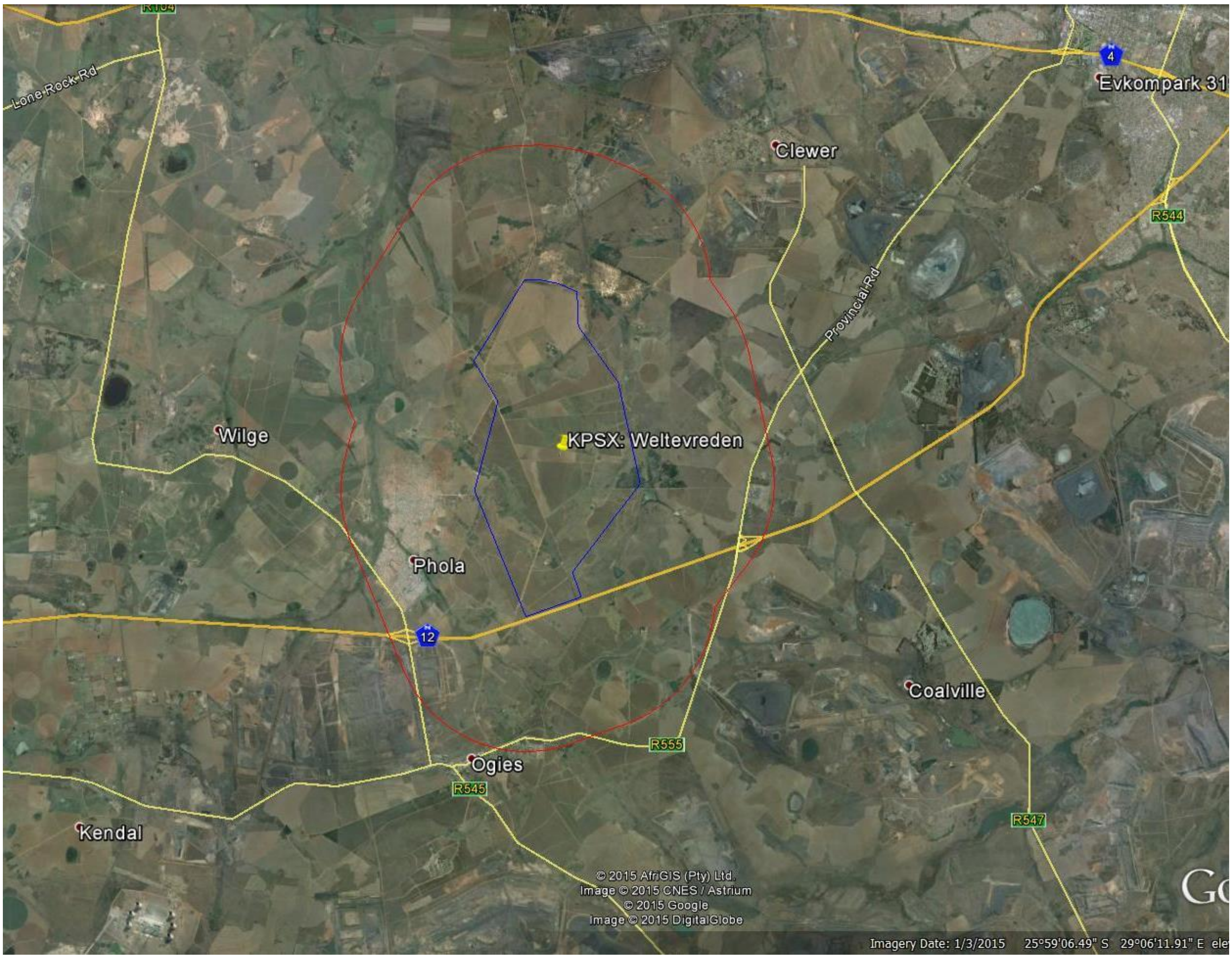

Figure 1: Locality of the project area

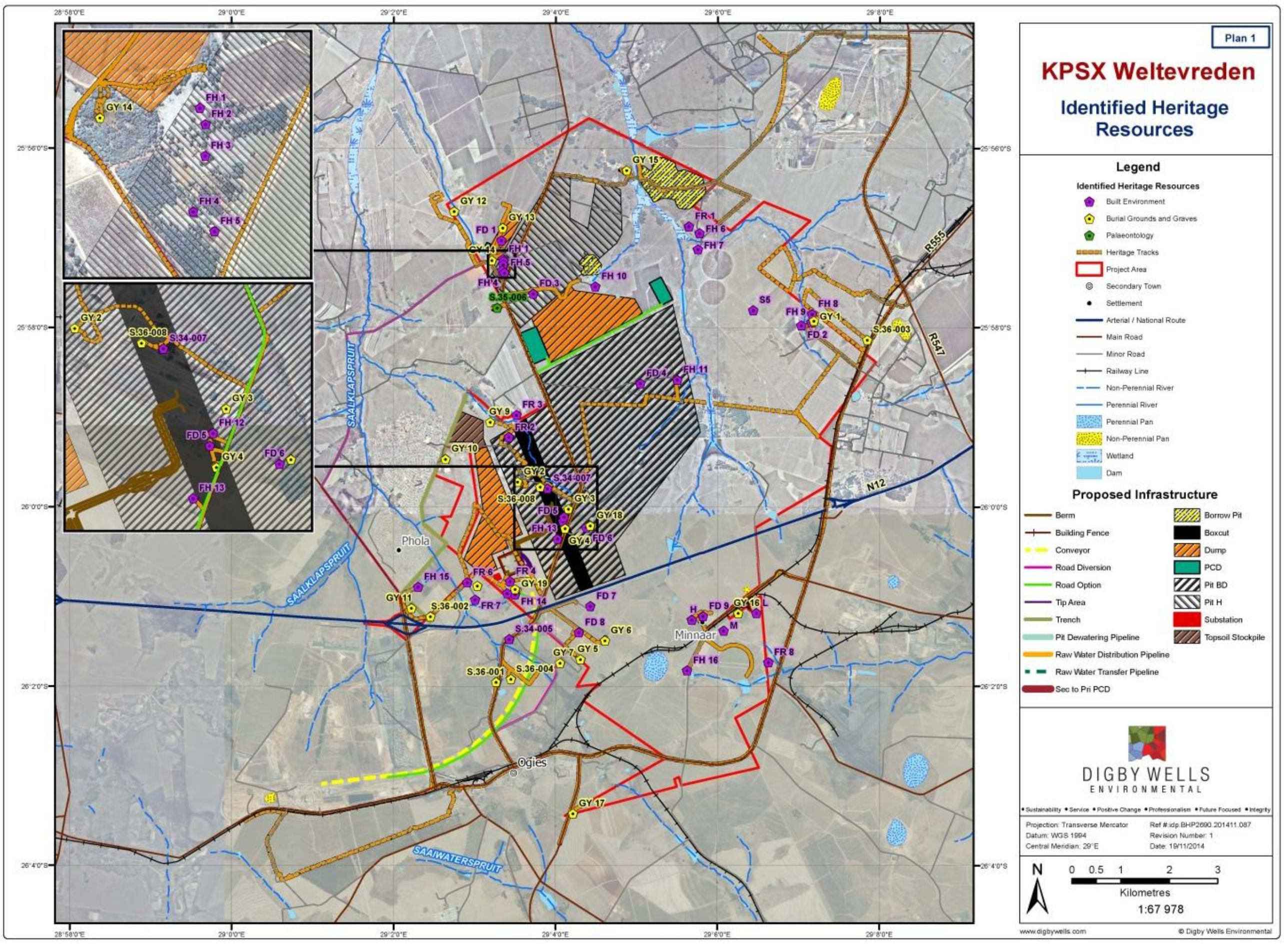

Figure 2: Proposed mining area layout

5 Methodology

The detailed plan of study consists of the following sections.

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

6 Assumptions and Limitations

The Klipspruit Extension: Weltevreden project is an extension of the current operations. Blast design forms the baseline for determining the possible influences from blasting operations. The project is an opencast planned operation. Opencast operations have greatest possibility of influence with specific influence related to aspects such as ground vibration, air blast and fly rock. Geology lithography and information from current operations at Klipspruit mine was used in determining factors required for this study. Figure 3 shows typical geology lithography for the project area.

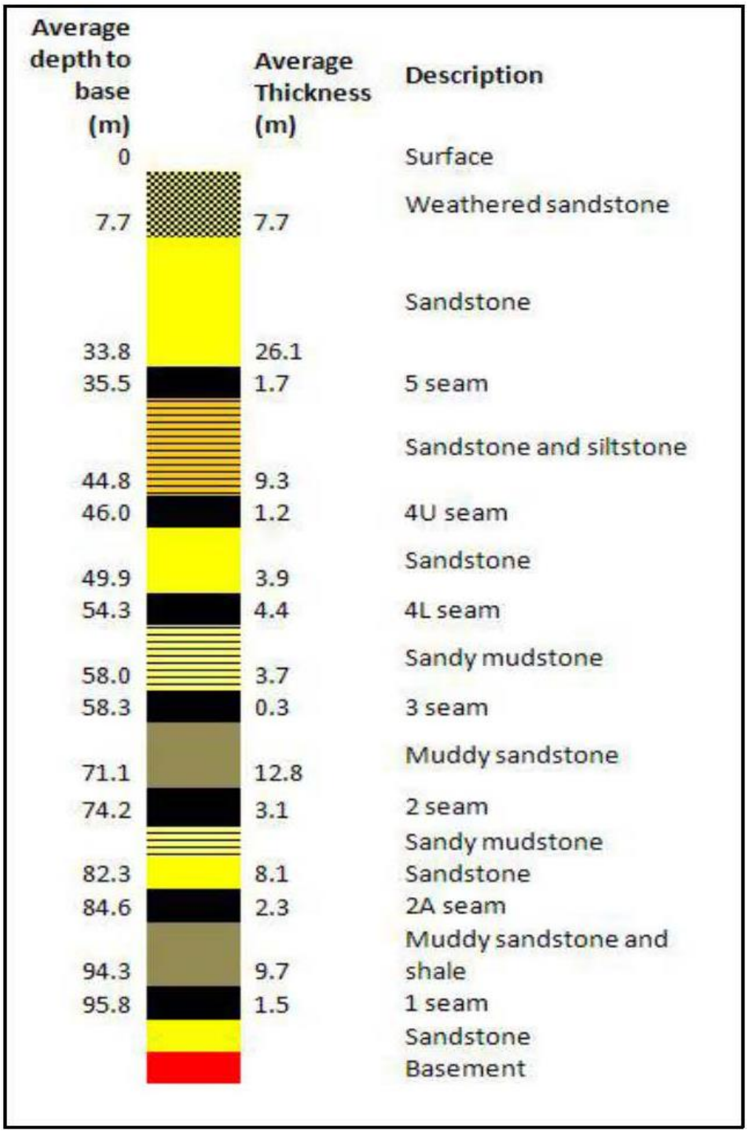

Figure 3: Geology summary information

6.1 Mining and Blasting Operations

The preferred mining method to be utilised on KPSX: Weltevreden will be opencast strip mining, although underground mining is currently also being investigated by BECSA. The strip mining method to be utilised will be investigated by BECSA, with the feasible options comprising of either truck and shovel methods, or the use of a dragline. Box cuts will be created and haul roads will allow the haul trucks to access the mined areas by means of a ramp. Blast designs applied for drilling and blasting is summarised in Table 1.

Table 1: Technical information for blast designs used

Technical Aspect			
Structure of Concern	**Overburden**	**Midburden**	**#5 Seam**
B/H Diameter (mm)	250	140	140
Explosive Density (g/cm^3)	1.15	1.15	1.15
Burden (m)	7	4	4.5
Spacing (m)	8	4	4.5
Bench Height (m)	26	9.3	1.7
Min Depth (m)	26	9.3	1.7
Average Depth (m)	26	9.3	1.7
Linear Charge Mass (kg)	56.45	17.70	17.70
P/F Blast hole (kg/m^3)	0.76	0.69	0.15
Stemming Length (m)	6.30	3.50	1.40
Column Length (incl. Sub drill.) (m)	19.7	5.8	0.3
Explosives Per B/H (incl. Sub drill) (kg)	1112	103	5
Include Sub Drill (Yes/No)	No	No	No
Sub-drill (m)	0	0	0

6.2 The process of a blasting operation

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

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

7 Legal Requirements

The objectives are investigated taking specific protocols into consideration. The protocols applied in this document are based on the author's experience, guidelines from literature research, client requirements and general indicators from the various acts of South Africa. There is no direct reference in the following acts with regards to requirements and limits on the effect of ground vibration and air blast specifically and some of the aspects addressed in this report. The acts consulted are: National Environmental Management Act No. 107 of 1998, Mine Health and Safety Act No. 29 of 1996, Mineral and Petroleum Resources Development Act No. 28 of 2002 and the Explosives Act Explosives Act No. 26 of 1956 and amended No. 15 of 2003.

The guidelines and safe blasting criteria are according 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. is also taken into consideration.
The protocols and objectives will fall within the broader spectrum as required by the various acts.

8 Sensitivity of Project

Review of the project area and areas surrounding before any specific analysis 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 where identified for this. Firstly a high sensitive area of 500 m area around the mining area is identified. Normally the 500 m is considered an area that should be cleared from all people and animals prior to blasting. Levels of ground vibration and air blast are also expected to be higher closer to the pit area. Secondly an area of 500 m to 1500 m around the pit area that can be considered as medium sensitive is identified. In this area the possibility of influence is still expected but definitely lower impact. Thirdly an area is identified as least sensitive at distance of 1500 m to 3500 m. The expected level of influence to be low but there may still be reason for concern as levels could be less than to cause structure damage but may still upset people.

The project area is located north east of Ogies town, east of the Phola village and south west of Clever town area. The N12 highway borders on the south side and various other infrastructure observed around the pit areas. Figure 4 shows the sensitivity mapping with identified POI's and surrounding areas. The specific influences will be determined through the worked done for this project in this report.

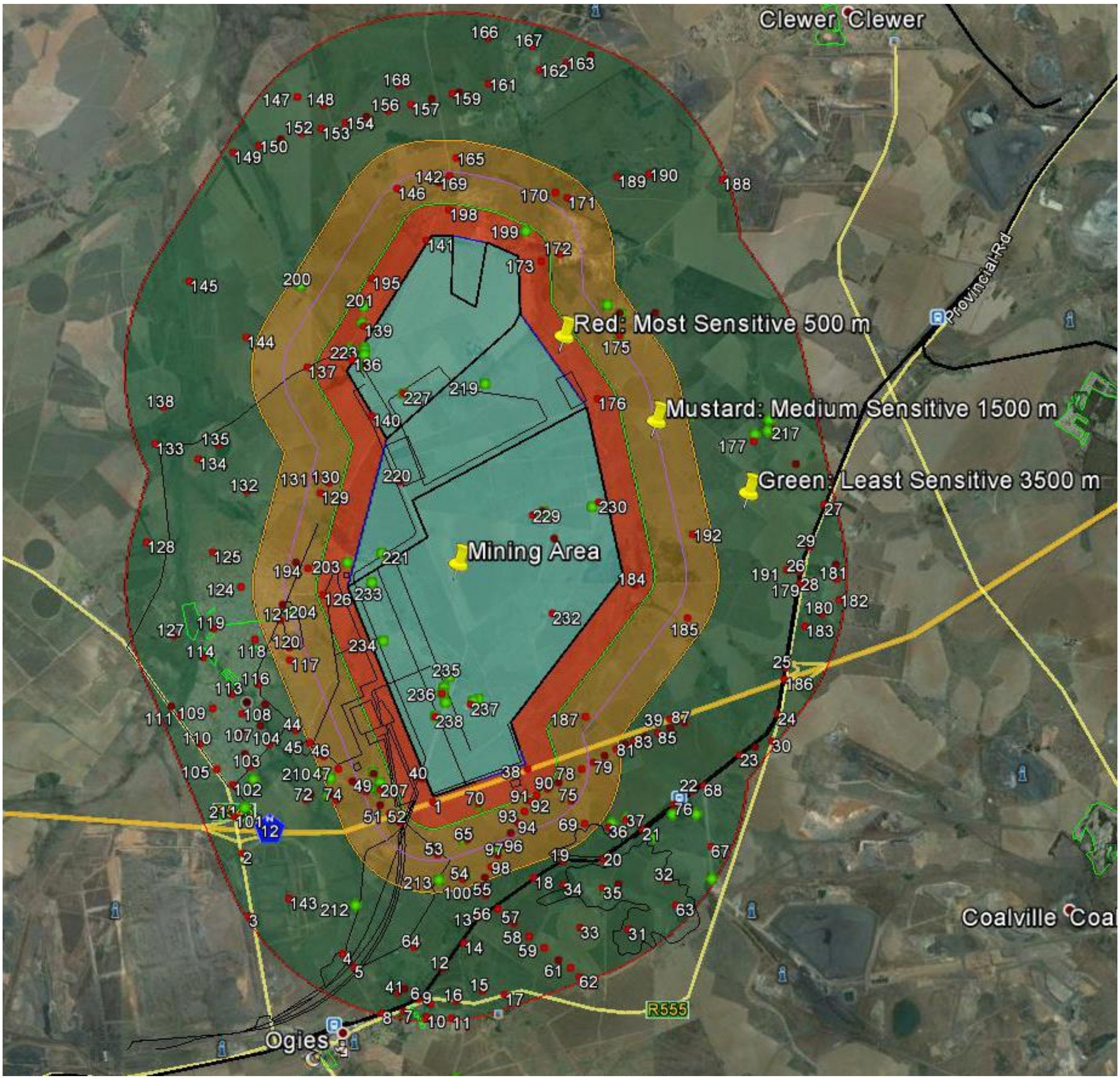

Figure 4: Identified sensitive areas

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

The following section intends to describe the expected effects from blasting operations. These effects are addressed with definitions, predictions, limits, influence and perceptions.

10.1 Ground vibration

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

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 period.

Secondly is the distance between the blast and the point of interest / concern. Ground vibrations attenuate over distance at a rate determined by the mass per delay, timing and geology. Each geological interface a shock wave encounters will reduce the vibration energy due to reflections of the shock wave. Geological interfaces can be changes in topography, different types of material, interfaces with rivers of streams, interfaces with open areas – trenches or previously excavated areas to name a few. Closer to the blast will yield high levels and further from the blast will yield lower levels.

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

10.1.1 Ground Vibration Prediction

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

Equation 1:

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

Where:

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

The constants applied are associated with new operations where there is no specific blast information available. Though this operation could be very similar to the existing Klipspruit mine the area is not adjacent to the existing mine and there is uncertainty if constants applied for Klipspruit mine will be applicable here. There constants used that is applicable and accepted factors for new operations are used and 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.

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

The designs reported in Table 1 are expected to be used in future mining. In order to evaluate the possible influence, two charge masses that will span the range of possible charge mass per delay were selected. Concentration is given to the Overburden and midburden blasts to be done. The planned use of electronic initiation on these blasts is expected to yield two blast holes detonating simultaneously. These two blast holes will contribute to the effects addressed in the report. Firstly two midburden blast holes will yield a charge mass of 205 kg and two overburden blast holes will yield a total charge mass of 2224 kg. This range of minimum and maximum charge will span various alternatives that may be possible including the coal blasts that will be significantly less. These charge masses were used for baseline modelling in this report. Applying the above charge masses, various ground vibration calculations were done and considered in this report. Attention is given to limit levels of 6 mm/s, 12.5 mm/s and 25 mm/s.

Based on the designs presented on expected drilling and charging design, the following Table 2 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. A low charge mass per delay and a maximum charge mass as worst case scenario. The charge masses are 205 kg and 2224 kg.

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

No.	Distance (m)	Expected PPV (mm/s) for 205 kg Charge	Expected PPV (mm/s) for 2224 kg Charge
1	50.0	145.2	1037.8
2	100.0	74.4	531.6
3	150.0	23.7	169.4
4	200.0	14.7	105.4
5	250.0	10.2	86.8
6	300.0	7.6	54.0
7	400.0	4.7	33.6
8	500.0	3.3	23.2
9	600.0	2.4	20.8
10	700.0	1.9	13.3
11	800.0	1.5	10.7
12	900.0	1.2	8.8
13	1000.0	1.0	7.4
14	1250.0	0.7	5.1
15	1500.0	0.5	3.8
16	1750.0	0.4	2.9
17	2000.0	0.3	2.4
18	2500.0	0.2	1.6
19	3000.0	0.2	1.2
20	3500.0	0.1	0.9

Figure 5 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.

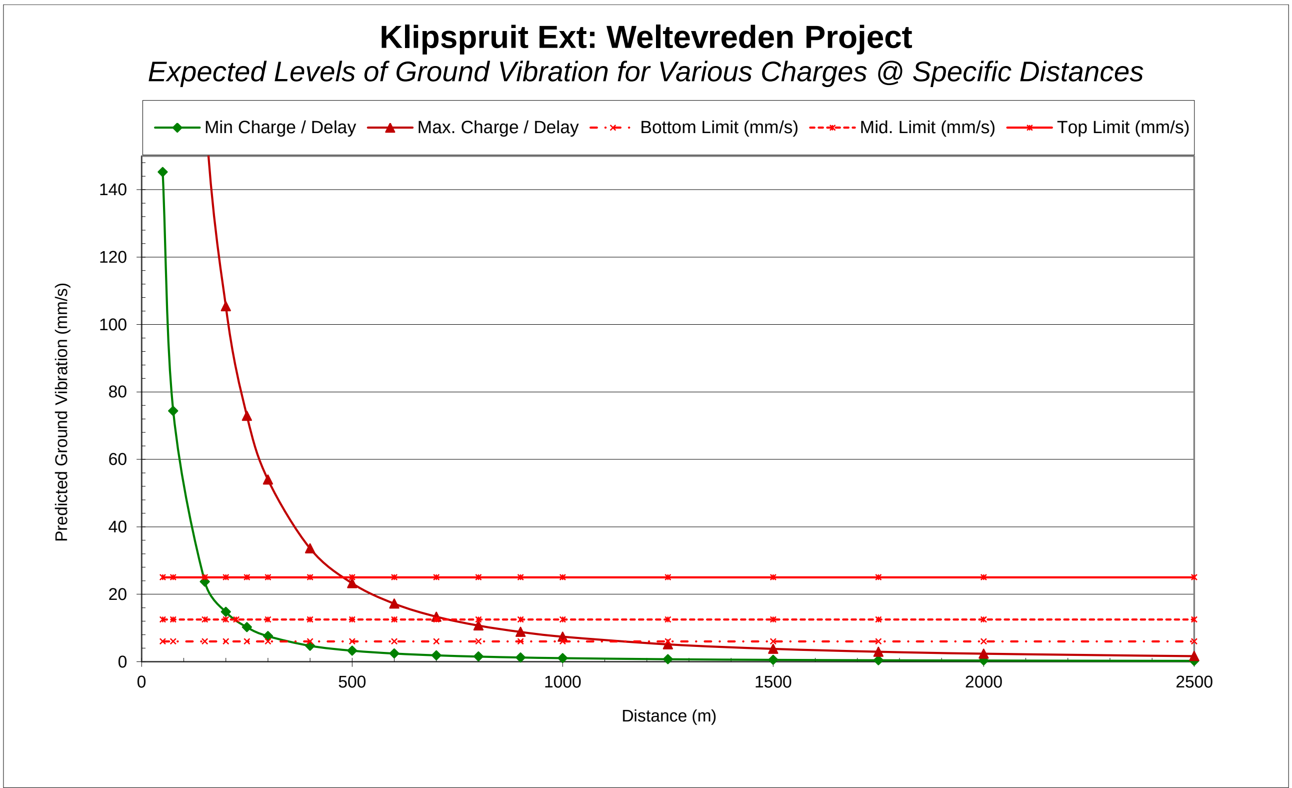

Figure 5: Ground vibration over distance for the two charge masses used in modelling

10.1.2 Ground vibration limitations on structures

Limitations on ground vibration are in the form of maximum allowable levels for different installations and structures. These levels are normally quoted in peak particle velocity or as ground vibration in millimetres per second (mm/s). There are unfortunately no exact South African standard. Thus currently the United States Bureau of Mines (USBM) criterion for safe blasting is applied where private structures are of concern. This is a process of evaluating the vibration amplitudes and frequency of the vibrations according to set rules for preventing damage. The vibration amplitudes and frequency is then plotted on a graph. Figure 6 shows an example of a USBM analysis graph. The graph indicates two main areas:

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

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

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

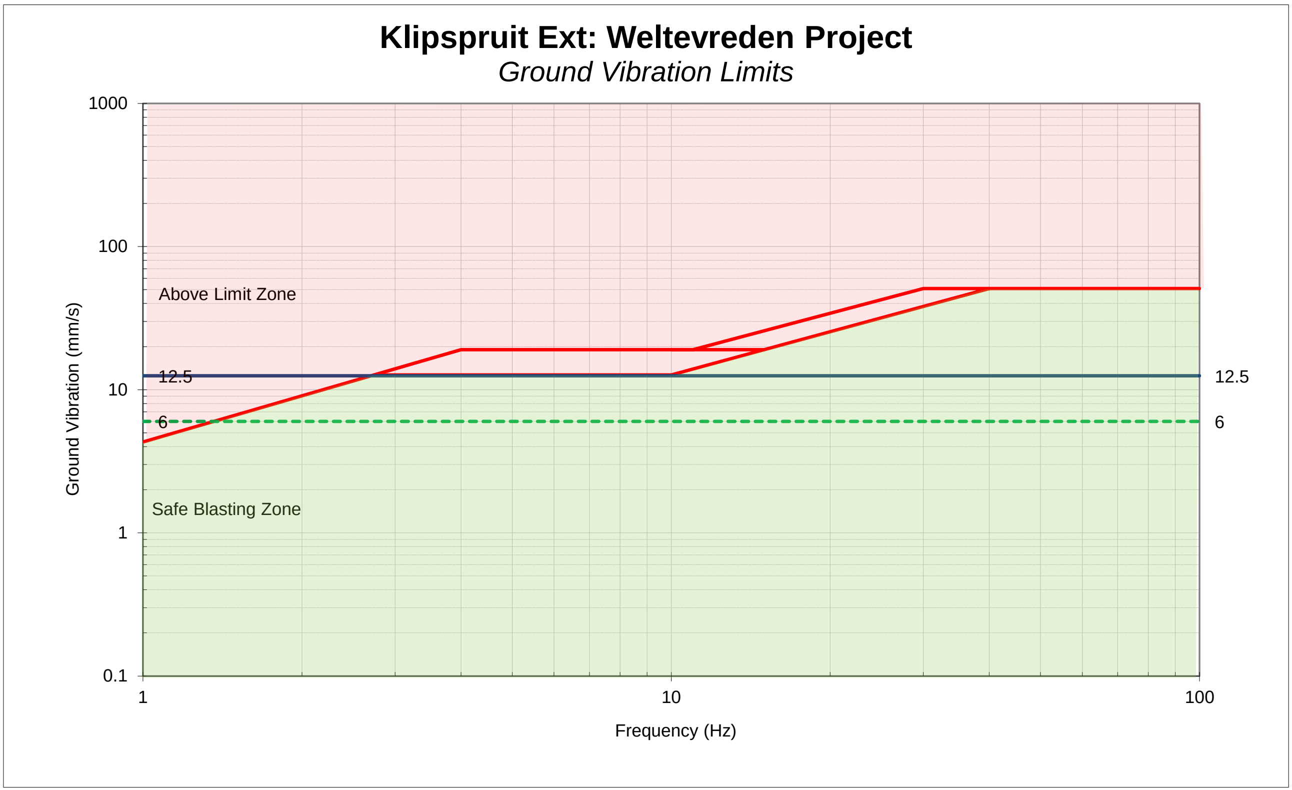

Figure 6: USBM Analysis Graph

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

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

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

- USBM criteria for safe blasting
- The additional limitations provided
- Consideration of private structures
- Should these structures be in lesser structural integrity the basic limit of 25 mm/s reduced to 12.5 mm/s or even when structures indicate less resistance to the effects of ground vibration limits will be restricted to 6 mm/s
- We also consider the input from other consultants in the field locally and internationally.

10.1.3 Ground vibration limitations with regards to human perceptions

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

Ground vibration is experienced as “Perceptible”, “Unpleasant” and “Intolerable” (only to name three of the five levels tested) at different vibration levels for different frequencies. This is indicative of the human’s perceptions on ground vibration and clearly indicates that humans are sensitive to ground vibration. This “tool” is only a guideline and helps with managing ground vibration and the respective complaints that people could have due to blast induced ground vibrations. Humans already perceive ground vibration levels of 4.5 mm/s as unpleasant. (See Figure 7).

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.

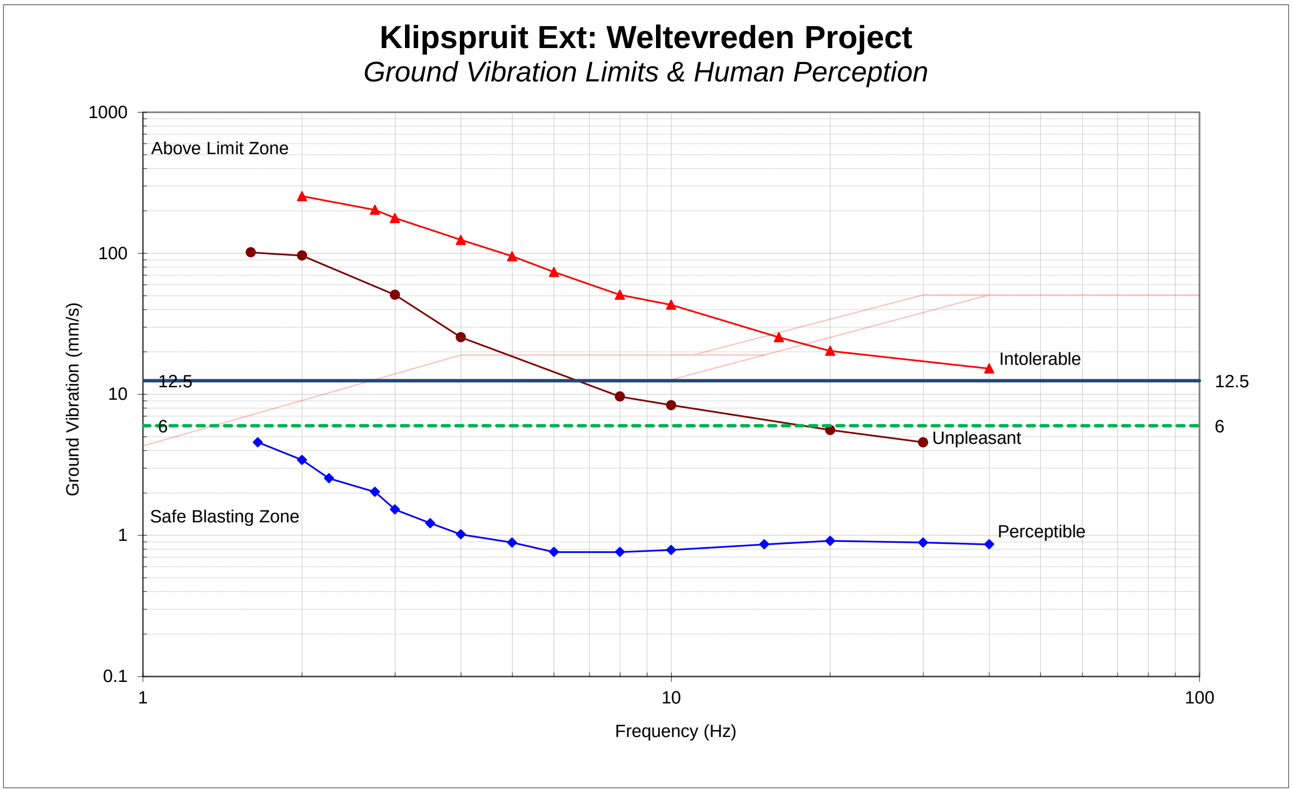

Figure 7: USBM Analysis with Human Perception

10.2 Air blast

Air blast is an inaudible pressure wave. Air blast is the direct result from the blast process. Air blast is normally associated with frequency levels less than 20 Hz, which is the threshold for hearing. The three main causes of air blast can be described as the pressure pulse directly from the rock displacement, ground vibration causing pressure pulses some distance away from the blast and blast holes venting or blowing out during the detonation process. Air blast levels yielded may be influenced by external factors, wind strength, wind direction, meteorological conditions and topography. Air blast is measured in pressure (Pa) but normally converted to a dB scale for ease of interpretation.

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 general public is of concern. In case of schools and hospitals a recommended limit of 128 dB is applicable. 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. Persson *et.al.* (1994) have published the following estimates of damage thresholds based on empirical data (Table 3). Levels given in Table 3 are at the point of measurement. The weakest point on a structure is the windows and ceilings.

Table 3: Damage Limits for Air Blast

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

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

10.2.2 Air blast limitations with regards to human perceptions

Considering the human perception and misunderstanding that could occur between ground vibration and air blast, BM&C generally recommends that blasting be done in such a way that air blast levels is kept below 120dB. In this way it is certain that fewer complaints will be received for blasting operations. The effects on structures that 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 in this project have been set at 120dB, between 120 dB and 134dB and greater than 134dB.

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.

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

Equation 2:

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

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

Although the above equation was applied for prediction of air blast levels, additional measures are also recommended in order to ensure that air blast and associated fly-rock possibilities are minimized as best possible. As discussed earlier the prediction of air blast is very subjective. Following in Table 4 below is a summary of values predicted according to Equation 2. Figure 8 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 205 kg Charge	Air blast (dB) for 2224kg Charge
1	50.0	143	151
2	100.0	138	147
3	150.0	131	140
4	200.0	128	137
5	250.0	126	135
6	300.0	124	132
7	400.0	121	129
8	500.0	119	127
9	600.0	117	126
10	700.0	115	123
11	800.0	114	122
12	900.0	113	121
13	1000.0	111	120
14	1250.0	109	117
15	1500.0	107	116
16	1750.0	106	114
17	2000.0	104	113
18	2500.0	102	110

No.	Distance (m)	Air blast (dB) for 205 kg Charge	Air blast (dB) for 2224kg Charge
19	3000.0	100	108
20	3500.0	98	107

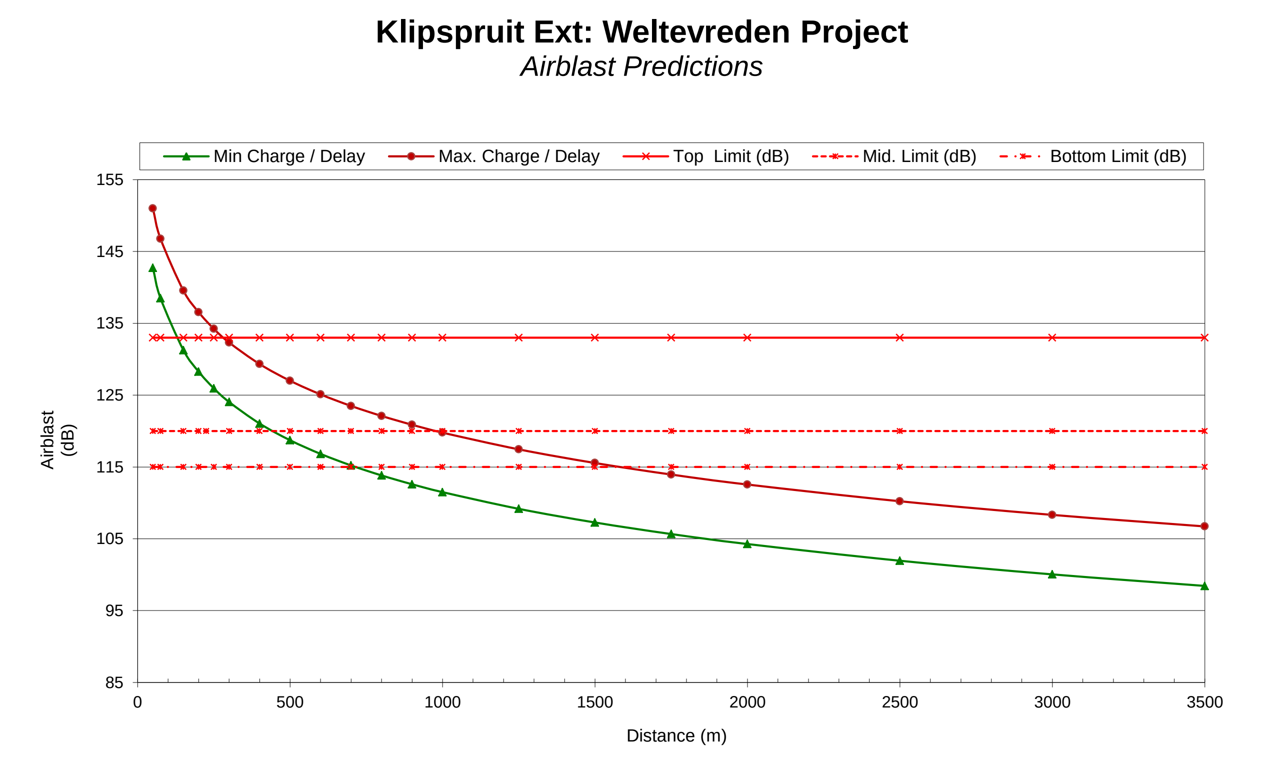

Figure 8: Predicted air blast levels

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 9 below shows the schematic fly rock terminology

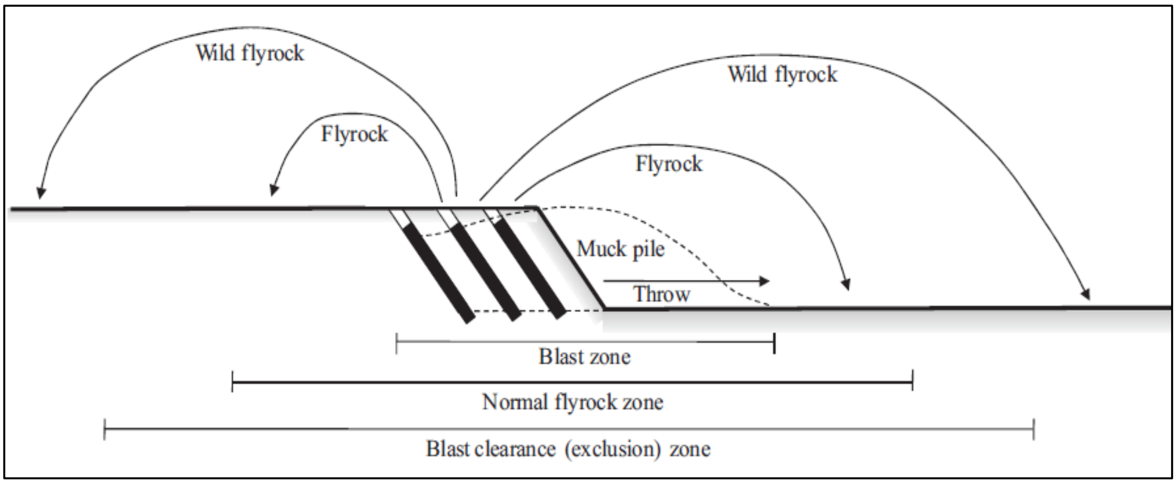

Figure 9: Schematic of fly rock terminology

10.3.1 Fly rock causes

Fly rock from blasting can result from the following conditions:

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

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

10.3.2 Fly rock predictions

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

Calculations are also used to help and assist determining safe distances. Method currently applied by BM&C is according to the International Society of Explosives Engineers (ISEE) Blasters Handbook. Using these calculations the minimum safe distances can be determined that should be cleared of people, animals and equipment. Figure 10 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 for the two scenarios is 249 m and 306 m. These calculations are guidelines and any distance cleared should not be less. The occurrence of fly rock can however never be excluded 100%. Best practices can be and are implemented. The occurrence of fly rock can be mitigated but the possibility of the occurrence there off, can never be eliminated.

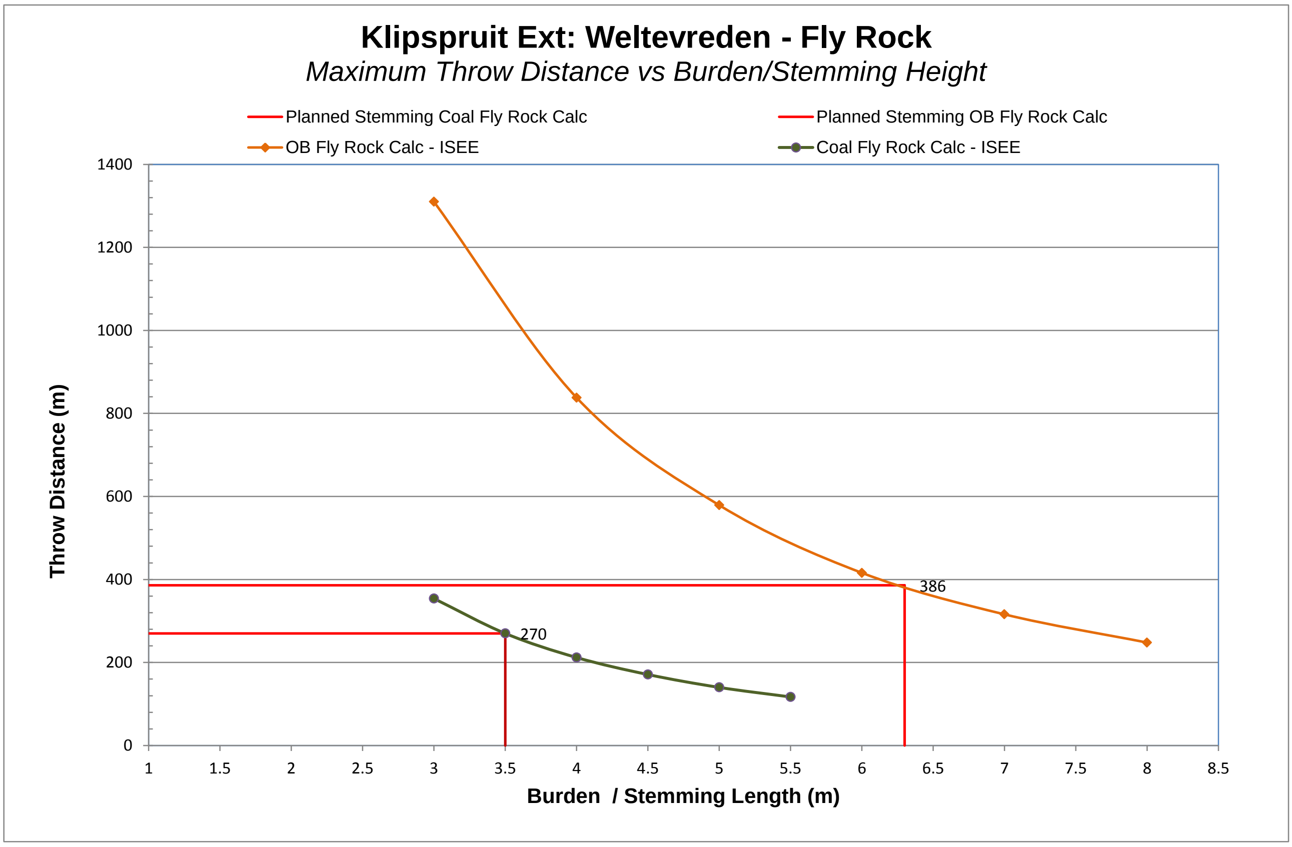

Figure 10: Predicted Fly rock

10.3.3 Impact of fly rock

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

10.4 Noxious Fumes

Explosives are carefully engineered to yield the energy for the purpose it was designed. The chemical composition of commercial explosives currently used is 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 chemical breakdown of the explosives product that may result in poor performance. A “burning” may occur that increases the probability of fumes in the form of NO and NO_2.

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

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

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

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

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

10.4.2 Noxious Fume Control

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

10.5 Vibration impact on provincial and national roads

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

10.6 Vibration will upset adjacent communities

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

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

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

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

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

- Correct blast design is essential and should include a survey of the face profile prior to design, ensuring appropriate burden to avoid over-confinement of charges which may increase vibration by a factor of two,
- The setting-out and drilling of blasts should be as accurate as possible and the drilled holes should be surveyed for deviation along their lengths and, if necessary, the blast design adjusted,
- Correct charging is obviously vital, and if free poured bulk explosive is used, its rise during loading should be checked. This is especially important in fragmented ground to avoid accidental overcharging,

- Correct stemming will help control air blast and fly rock and will also aid the control of ground vibration. Controlling the length of the stemming column is important; too short and premature ejection occurs, too long and there can be excessive confinement and poor fragmentation. The length of the stemming column will depend on the diameter of the hole and the type of material being used,
- Monitoring of blasting and re-optimising the blasting design in the light of results, changing conditions and experience should be carried out as standard.

10.7 Cracking of houses and consequent devaluation

Houses in general have cracks. It is reported that a house could develop up to 15 cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. are more reason for cracks that have developed. Visual results of actual damage due to blasting operations are limited. There are cases where it did occur and a result is shown in Figure 11 below. A typical X crack formations is observed.

Figure 11: Example of blast induced damage.

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

10.8 Water well Influence from Blasting Activities

Domestic and Agricultural boreholes may be present around the proposed site. The author has not had much experience on the effect of blasting on water wells but specific research was done and results from this research work are presented.

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

Such as:

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

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

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

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

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

11 Baseline Results

This is a new mining area with no data that can support any ground vibration and air blast prediction data.

11.1 General ground vibration and air blast information

The base line information for the project is based on zero influence with regards to blast impacts. The project is currently not active with any blasting operations being done. As part of the baseline all possible structures in a possible area of influence are identified.

11.2 Structure Profile

As part of the baseline all possible structures in a possible influence area is identified. The site was reviewed and presented hereafter. The site was reviewed / scanned using Google Earth imagery. Information sought from review was typically the kind of surface structures that are present in a 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 12 shows an aerial view of the mining area and surroundings with points of interest. The list compiled is provided in Table 5 below.

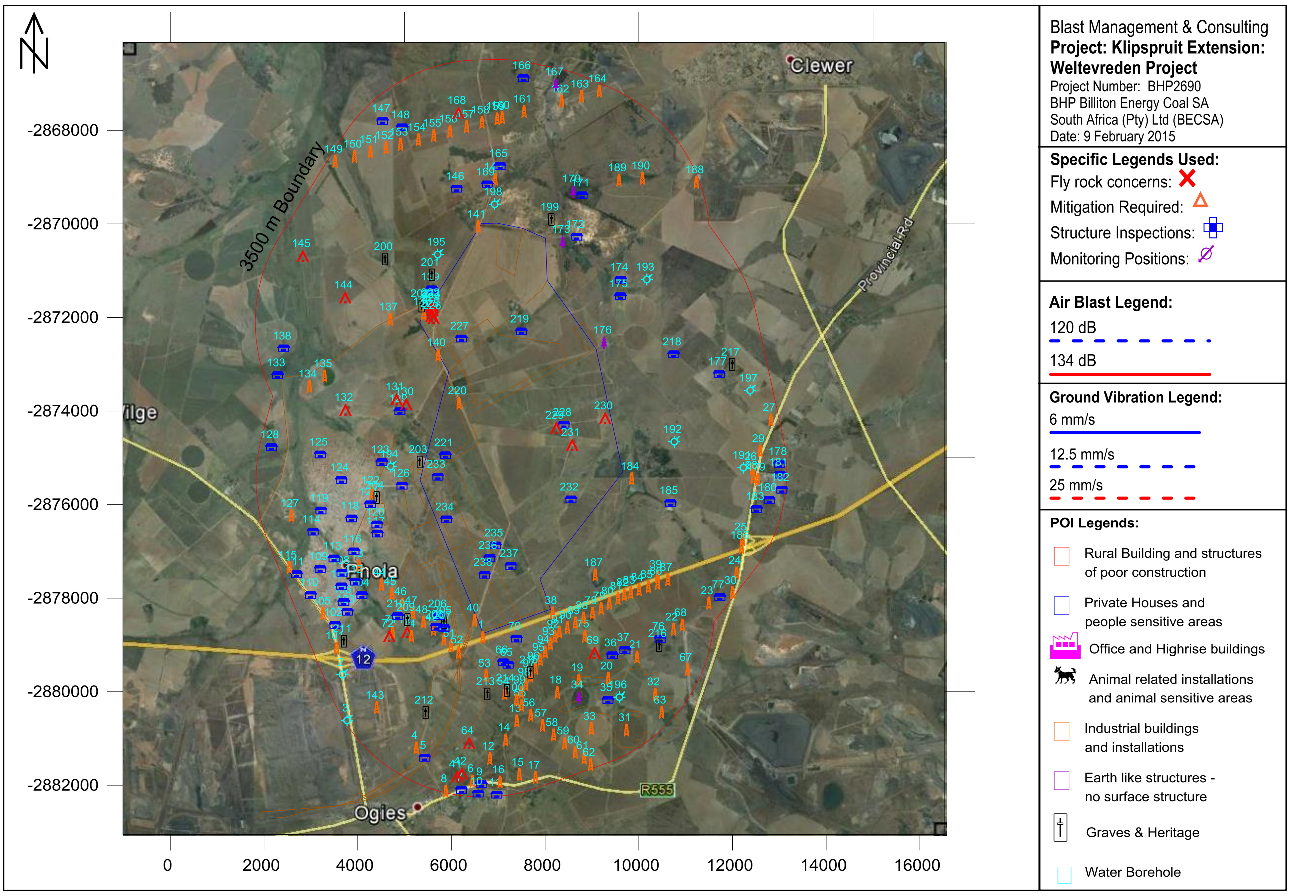

Figure 12: Aerial view and surface plan of the proposed mining area with points of interest identified.

Table 5: List of points of interest used

Tag	Description	Classification	Y	X
1	N12 Road	5	-6671.14	2878834.35
2	Borehole (BSW 3)	8	-3672.98	2879635.57
3	Borehole (KGM B4)	8	-3772.79	2880614.23
4	Substation	5	-5250.75	2881203.64
5	Buildings/Structures	2	-5433.17	2881411.87
6	Railroad	5	-6448.07	2881909.69
7	Houses	2	-6212.37	2882100.11
8	Railroad	5	-5878.85	2882125.63
9	Houses	2	-6635.41	2881977.03
10	Houses	2	-6570.42	2882178.93
11	Sports Terrain	2	-6970.06	2882201.22
12	Railroad	5	-6821.39	2881430.65
13	Railroad	5	-7396.93	2880625.71
14	Railroad	5	-7158.55	2881033.36
15	Railroad	5	-7450.09	2881774.79
16	R555 Road	5	-7038.49	2881930.68
17	R555 Road	5	-7796.20	2881835.80
18	Railroad	5	-8260.06	2880014.86
19	Railroad	5	-8716.41	2879753.73
20	Railroad	5	-9349.07	2879714.89
21	Railroad	5	-9961.67	2879259.90

22	Railroad	5	-10740.77	2878669.13
23	Railroad	5	-11494.82	2878105.69
24	Railroad	5	-12087.94	2877462.55
25	Railroad	5	-12212.33	2876742.93
26	Railroad	5	-12426.47	2875241.52
27	Railroad	5	-12820.50	2874193.49
28	R555 Road	5	-12444.50	2875424.52
29	R555 Road	5	-12589.43	2874855.16
30	R555 Road	5	-11997.26	2877884.84
31	Pivot Irrigation	5	-9737.11	2880820.38
32	Pivot Irrigation	5	-10351.68	2880055.42
33	Pivot Irrigation	5	-8986.70	2880791.39
34	Pan	6	-8722.78	2880118.42
35	Buildings/Structures	2	-9341.97	2880177.27
36	Buildings/Structures(Oakhouse Lodge)	2	-9434.02	2879220.68
37	Buildings/Structures	2	-9703.96	2879107.21
38	N12 Road	5	-8160.59	2878316.95
39	N12 Road	5	-10398.69	2877541.37
40	Road	5	-6496.02	2878474.30
41	Informal Housing	1	-6124.29	2881810.89
42	Informal Housing	1	-6227.38	2881747.92
43	Power Lines/Pylons	5	-4026.14	2877309.75
44	Power Lines/Pylons	5	-4507.46	2877714.50
45	Power Lines/Pylons	5	-4728.68	2877909.90
46	Power Lines/Pylons	5	-4952.24	2878125.76
47	Power Lines/Pylons	5	-5179.57	2878319.95
48	Power Lines/Pylons	5	-5402.94	2878511.80
49	Power Lines/Pylons	5	-5619.43	2878674.36
50	Power Lines/Pylons	5	-5839.63	2878884.89
51	Power Lines/Pylons	5	-5990.93	2879017.62
52	Power Lines/Pylons	5	-6153.21	2879156.70
53	Power Lines/Pylons	5	-6742.13	2879657.18
54	Power Lines/Pylons	5	-7140.66	2880041.29
55	Power Lines/Pylons	5	-7498.93	2880291.07
56	Power Lines/Pylons	5	-7692.67	2880502.58
57	Power Lines/Pylons	5	-7947.46	2880720.98
58	Power Lines/Pylons	5	-8181.38	2880924.46
59	Power Lines/Pylons	5	-8420.01	2881102.46
60	Power Lines/Pylons	5	-8642.62	2881296.43
61	Power Lines/Pylons	5	-8834.07	2881418.58
62	Power Lines/Pylons	5	-8972.54	2881559.93
63	Dam	5	-10489.23	2880443.34
64	Ruins	1	-6379.89	2881098.21
65	Farm Buildings/Structures	2	-7210.78	2879423.37
66	Farm Buildings/Structures	2	-7109.57	2879370.96
67	Dam	5	-11042.16	2879530.79
68	Conveyor	5	-10928.14	2878576.59
69	Informal Housing	1	-9055.45	2879168.13
70	Farm Buildings/Structures	2	-7389.55	2878864.58
71	Dam	5	-4743.45	2878724.49
72	Ruins	1	-4674.73	2878809.31
73	Ruins	1	-5059.54	2878725.19
74	Cement Dams	5	-5146.10	2878812.39
75	Cement Dam	5	-8848.32	2878816.07
76	Building/Structure	2	-10455.22	2878871.91
77	Building/Structure	2	-11731.87	2877977.30
78	Power Lines/Pylons	5	-9010.81	2878320.00

79	Power Lines/Pylons	5	-9195.16	2878216.51
80	Power Lines/Pylons	5	-9369.87	2878112.86
81	Power Lines/Pylons	5	-9555.13	2878008.75
82	Power Lines/Pylons	5	-9691.52	2877932.09
83	Power Lines/Pylons	5	-9829.33	2877882.82
84	Power Lines/Pylons	5	-10005.87	2877820.40
85	Power Lines/Pylons	5	-10204.48	2877759.81
86	Power Lines/Pylons	5	-10403.84	2877687.73
87	Power Lines/Pylons	5	-10620.85	2877607.07
88	Power Lines/Pylons	5	-8821.67	2878424.07
89	Power Lines/Pylons	5	-8647.44	2878530.17
90	Power Lines/Pylons	5	-8475.34	2878629.80
91	Power Lines/Pylons	5	-8304.84	2878724.26
92	Power Lines/Pylons	5	-8207.86	2878819.33
93	Power Lines/Pylons	5	-8110.19	2878977.58
94	Power Lines/Pylons	5	-8002.49	2879151.48
95	Power Lines/Pylons	5	-7895.29	2879315.37
96	Power Lines/Pylons	5	-7791.13	2879501.82
97	Power Lines/Pylons	5	-7692.80	2879667.26
98	Power Lines/Pylons	5	-7587.66	2879846.37
99	Power Lines/Pylons	5	-7488.01	2880012.21
100	Power Lines/Pylons	5	-7388.25	2880178.88
101	R545 Road	5	-3547.10	2879068.54
102	Phola Town Housing Community	2	-3515.04	2878571.20
103	Phola Town Housing Community	2	-3780.52	2878289.97
104	Phola Town Housing Community	2	-4090.58	2877936.29
105	R545 Road	5	-3260.28	2878325.62
106	Phola Town Community Buildings	2	-3704.40	2878084.55
107	Phola Town Community Buildings	2	-3653.95	2877748.52
108	Phola Town Community Buildings	2	-3665.95	2877456.84
109	Phola Town Community Buildings	2	-3198.48	2877375.08
110	Phola Town Housing Community	2	-2997.22	2877931.31
111	Phola Town Housing Community	2	-2692.67	2877488.01
112	Phola Town Housing Community	2	-3949.83	2877646.99
113	Phola Town Housing Community	2	-3495.33	2877152.06
114	Phola Town Housing Community	2	-3048.11	2876577.62
115	R545 Road	5	-2540.26	2877343.04
116	Mandela Village Community Housing	2	-3920.16	2877000.42
117	Mandela Village Community Housing	2	-4421.58	2876618.82
118	Mandela Village Community Buildings	2	-3869.52	2876296.32
119	Mandela Village Community Housing	2	-3215.57	2876127.12
120	Mandela Village Community Building	2	-4411.46	2876425.60
121	Mandela Village Community Housing	2	-4270.93	2875993.78
122	Reservoir	5	-4307.87	2875749.68
123	Mandela Village Community Housing	2	-4516.46	2875092.38
124	Mandela Village Community Housing	2	-3648.50	2875471.99
125	Mandela Village Community Housing	2	-3198.68	2874928.93
126	Buildings/Structures	2	-4946.09	2875595.30
127	Water Treatment Dams	5	-2585.95	2876240.82
128	Farm Buildings/Structures	2	-2157.12	2874772.26
129	Farm Buildings/Structures	2	-4901.12	2874003.96
130	Informal Housing	1	-5035.73	2873850.82
131	Informal Housing	1	-4829.17	2873747.81
132	Informal Housing	1	-3739.42	2873974.83
133	Buildings/Structures	2	-2292.29	2873233.83
134	Pivot Irrigation	5	-2969.44	2873471.33
135	Pivot Irrigation	5	-3292.01	2873251.90

136	Road	5	-5408.85	2871927.66
137	Road	5	-4697.47	2872039.51
138	Farm Buildings/Structures	2	-2421.14	2872660.91
139	Farm Buildings/Structures	2	-5582.09	2871397.78
140	Road	5	-5716.70	2872803.26
141	Road	5	-6571.34	2870057.68
142	Road	5	-6932.99	2869043.76
143	Mine Activity	5	-4404.29	2880343.91
144	Informal Housing	1	-3734.50	2871569.94
145	Informal Housing	1	-2829.07	2870684.28
146	Farm Buildings/Structures	2	-6113.17	2869246.60
147	Farm Buildings/Structures	2	-4532.86	2867798.23
148	Building/Structure	2	-4947.97	2867934.86
149	Power Lines/Pylons	5	-3517.86	2868666.20
150	Power Lines/Pylons	5	-3928.74	2868557.84
151	Power Lines/Pylons	5	-4272.68	2868461.93
152	Power Lines/Pylons	5	-4605.10	2868373.45
153	Power Lines/Pylons	5	-4913.66	2868300.70
154	Power Lines/Pylons	5	-5295.66	2868203.61
155	Power Lines/Pylons	5	-5623.68	2868110.61
156	Power Lines/Pylons	5	-5968.77	2868022.05
157	Power Lines/Pylons	5	-6326.17	2867920.52
158	Power Lines/Pylons	5	-6653.17	2867829.32
159	Power Lines/Pylons	5	-6976.25	2867754.50
160	Power Lines/Pylons	5	-7084.14	2867727.71
161	Power Lines/Pylons	5	-7551.02	2867596.38
162	Power Lines/Pylons	5	-8354.02	2867380.69
163	Power Lines/Pylons	5	-8775.55	2867274.80
164	Power Lines/Pylons	5	-9157.13	2867162.31
165	Farm Buildings/Structures	2	-7038.82	2868761.94
166	Farm Buildings/Structures	2	-7535.03	2866880.93
167	Pan	6	-8232.56	2867014.01
168	Ruins	1	-6150.76	2867624.18
169	Farm Buildings/Structures	2	-6765.44	2869154.33
170	Pan	6	-8600.30	2869302.01
171	Farm Buildings/Structures	2	-8788.78	2869388.17
172	Buildings/Structures	2	-8677.12	2870273.59
173	Pan	6	-8376.19	2870381.20
174	Farm Buildings/Structures	2	-9615.25	2871194.19
175	Farm Buildings/Structures	2	-9606.04	2871544.82
176	Pan	6	-9261.79	2872534.20
177	Farm Buildings/Structures	2	-11715.96	2873207.68
178	Buildings/Structures	2	-13002.21	2875131.78
179	Industrial Area	5	-12543.12	2875463.60
180	Farm Buildings/Structures	2	-12784.07	2875899.44
181	Buildings/Structures	2	-13015.62	2875359.01
182	Buildings/Structures	2	-13054.19	2875682.33
183	Buildings/Structures	2	-12518.00	2876093.54
184	Dam	5	-9848.12	2875449.76
185	Building/Structure	2	-10675.53	2875964.61
186	N12 Road Bridge	5	-12192.90	2876920.60
187	Dam	5	-9070.63	2877506.16
188	Tailings Dam	5	-11228.34	2869108.71
189	Dam	5	-9577.02	2869063.97
190	Dam	5	-10077.81	2869023.02
191	Borehole (BHP_P04)	8	-12232.91	2875211.72
192	Borehole (BHP_P05)	8	-10757.44	2874656.48

193	Borehole (BHP_P06)	8	-10172.34	2871188.36
194	Borehole (BHP_P07)	8	-4706.13	2875184.69
195	Borehole (BHP_P08)	8	-5708.40	2870653.88
196	Borehole (BHP_P10)	8	-9586.87	2880117.42
197	Borehole (BHP_P11)	8	-12377.65	2873561.11
198	Borehole (BHP_P12)	8	-6923.97	2869579.83
199	Burial Grounds and Graves (GY15)	7	-8134.56	2869904.35
200	Burial Grounds and Graves (GY12)	7	-4584.52	2870750.38
201	Burial Grounds and Graves (GY13)	7	-5584.41	2871090.00
202	Burial Grounds and Graves (GY14)	7	-5363.38	2871757.40
203	Burial Grounds and Graves (GY9)	7	-5326.17	2875089.54
204	Burial Grounds and Graves (GY10)	7	-4403.71	2875850.53
205	Burial Grounds and Graves (GY19)	7	-5842.41	2878528.28
206	Built Environment	2	-5739.03	2878389.23
207	Built Environment	2	-5841.14	2878638.81
208	Built Environment	2	-5676.81	2878611.96
209	Burial Grounds and Graves	7	-5061.22	2878459.93
210	Built Environment	2	-4853.53	2878386.40
211	Burial Grounds and Graves (GY 11)	7	-3705.87	2878921.24
212	Burial Grounds and Graves	7	-5450.96	2880445.55
213	Burial Grounds and Graves (GY7)	7	-6766.30	2880049.18
214	Burial Grounds and Graves (GY5)	7	-7188.73	2879971.86
215	Burial Grounds and Graves (GY6)	7	-7687.43	2879585.49
216	Burial Ground and Graves (GY16)	7	-10436.43	2879021.15
217	Burial Grounds and Graves (GY1)	7	-11995.02	2873005.82
218	Built Environment	2	-10746.86	2872786.04
219	Built Environment (No Man's Land)	2	-7493.71	2872297.75
220	Road (No man's land)	5	-6163.98	2873831.79
221	Built Environment (No Man's Land)	2	-5870.45	2874945.42
222	Informal Housing (Inside Pit Area)	1	-5588.64	2871735.22
223	Informal Housing (Inside Pit Area)	1	-5601.45	2871771.79
224	Informal Housing (Inside Pit Area)	1	-5600.32	2871842.80
225	Informal Housing (Inside Pit Area)	1	-5573.42	2871969.09
226	Informal Housing (Inside Pit Area)	1	-5621.58	2872013.31
227	Buildings/Structures (Inside Pit Area)	2	-6212.48	2872449.86
228	Farm Buildings/Structures (Inside Pit Area)	2	-8402.55	2874294.17
229	Informal Housing (Inside Pit Area)	1	-8241.99	2874355.13
230	Informal Housing (Inside Pit Area)	1	-9282.21	2874153.01
231	Informal Housing (Inside Pit Area)	1	-8578.75	2874721.16
232	Farm Buildings/Structures (Inside Pit Area)	2	-8552.56	2875889.64
233	Built Environment (Inside Pit Area)	2	-5711.84	2875403.56
234	Built Environment (Inside Pit Area)	2	-5894.16	2876316.32
235	Built Environment (Inside Pit Area)	2	-6940.34	2876872.53
236	Farm Buildings/Structures (Inside Pit Area)	2	-6816.53	2877139.93
237	Farm Buildings/Structures (Inside Pit Area)	2	-7270.10	2877309.95
238	Farm Buildings (Inside Pit Area)	2	-6710.96	2877499.45

Notes: The type of POI's identified is group into different classes. These classes are indicated as "Classification" in table above. Table 6 below shows the descriptions for the classifications used.

Table 6: 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	Boreholes

Site visit was conducted and structures observed. Structures range from well build structures to informal building styles. Table 7 shows photos of structures found in the area.

Table 7: Structure Profile

	House Structure on northern side
	Rural building style houses

	Farm stead
	Oil storage infrastructure
	Bridge on N12 – east side of project

	Farm stead
	N12 highway
	Houses in Mandela village

	Overview of houses and structures in Mandela Village
	Houses in Phola Village
	Houses in Phola Village

	Old structure
	Houses and schools in Phola Village
	Houses and water tanks in Phola Village

	Powerlines found in 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: Site specific review and modelling of the various aspects from blasting operations

The area surrounding the proposed mining areas was reviewed for structures, traffic, roads, human interface, animals interface etc. Various installations and structures were observed. These are listed in Table 5. 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 masses of 205 kg and 2224 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 roads

- 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. The changes in topography found in the area and river interfaces will have a positive reduction influence on the intensity or level of ground vibration. It can unfortunately not be estimated without specific testing for the specific area.

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 was calculated and modelled for the different pit areas in groups of 2. For each group the minimum, medium and maximum charge mass at specific distances from the opencast mining area was modelled. 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 opencast 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 – 205 kg**

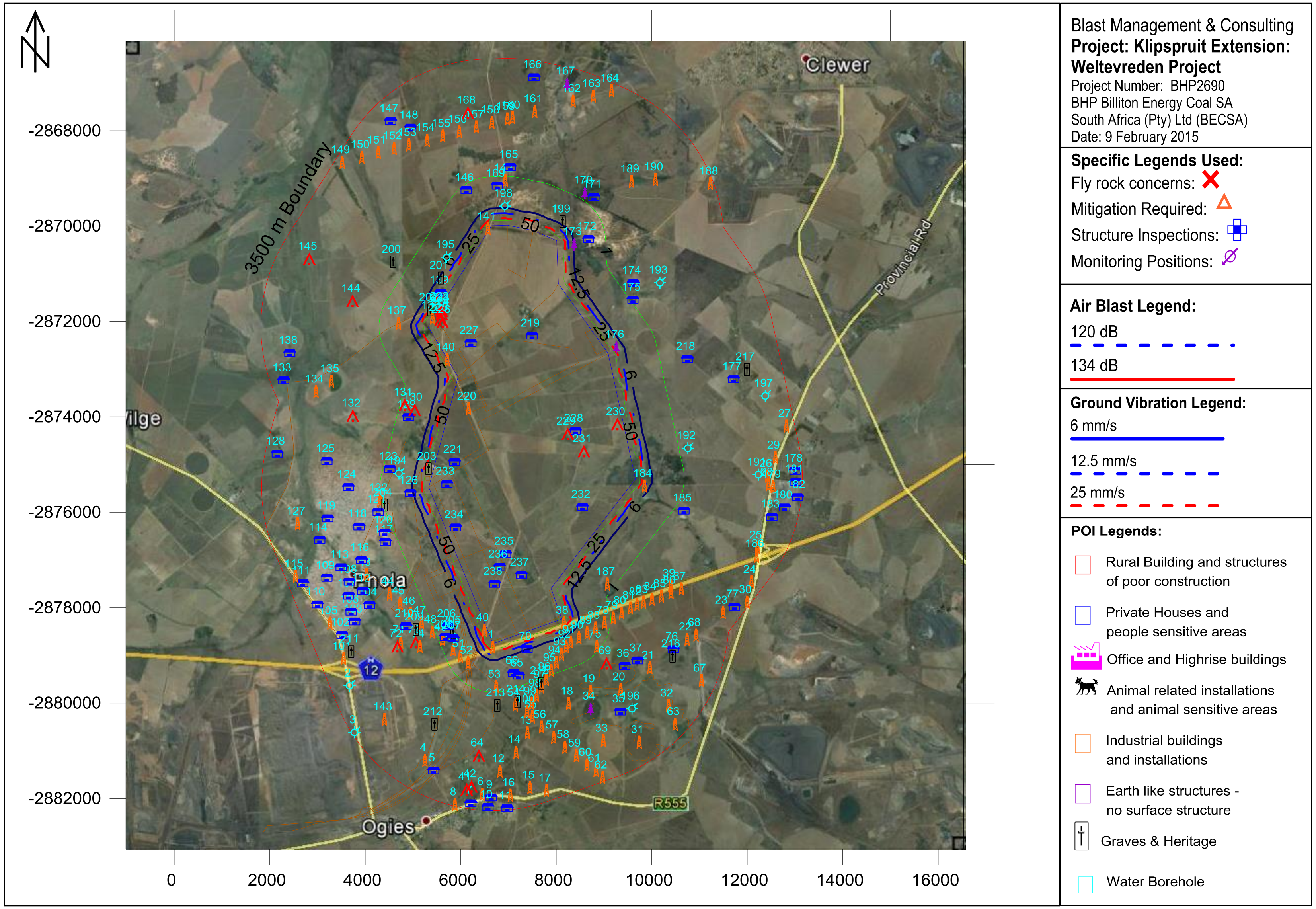

Figure 13: Ground vibration influence from minimum charge for Pit Area

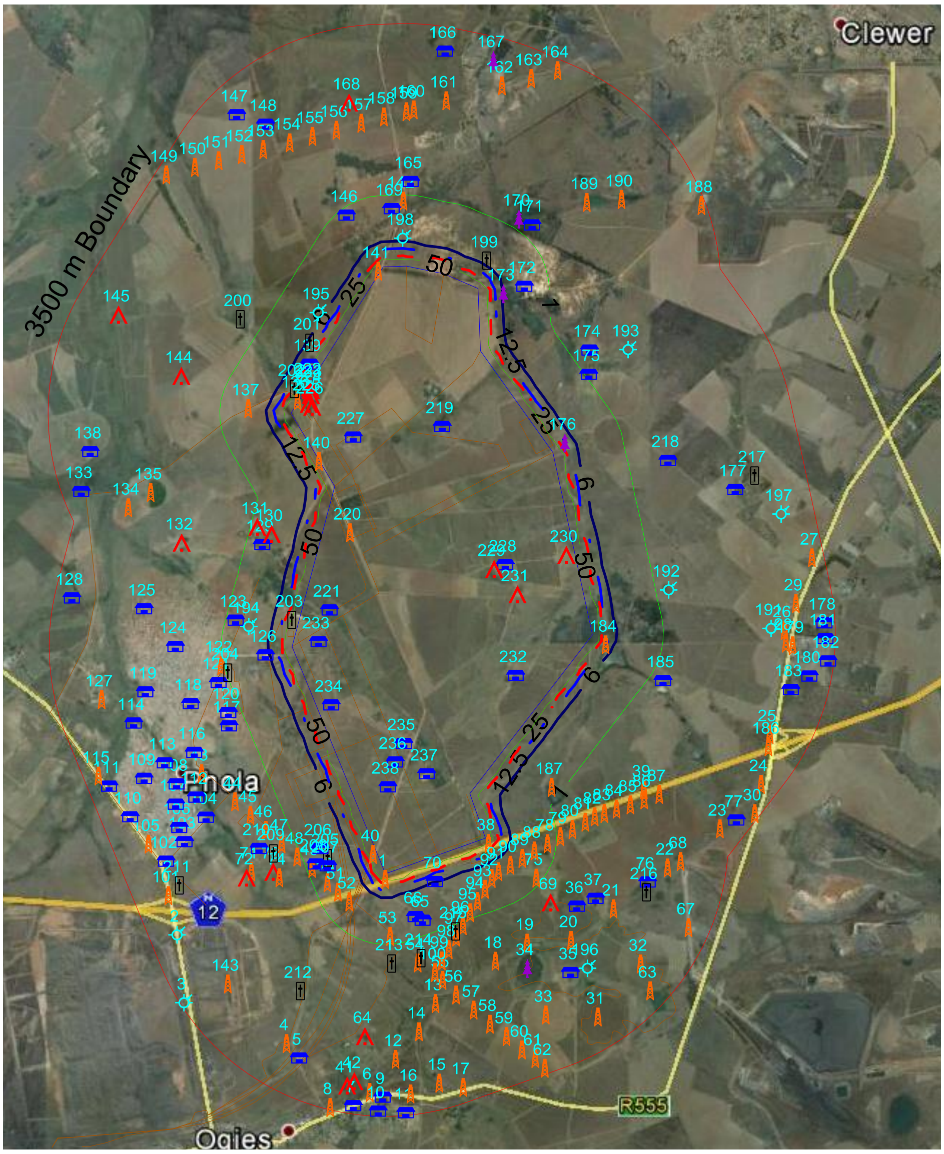

Figure 14: Zoomed area for ground vibration influence from minimum charge for Pit Area

Table 8: Ground vibration evaluation for minimum charge for Pit Area

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
1	N12 Road	150	93	52.5	N/A	Acceptable
2	Borehole (BSW 3)	50	3113	0.2	N/A	Acceptable
3	Borehole (KGM B4)	50	3450	0.1	N/A	Acceptable
4	Substation	25	2842	0.2	N/A	Acceptable
5	Buildings/Structures	25	2943	0.2	Too Low	Acceptable
6	Railroad	150	3176	0.2	N/A	Acceptable
7	Houses	25	3389	0.1	Too Low	Acceptable
8	Railroad	150	3475	0.1	N/A	Acceptable
9	Houses	25	3235	0.1	Too Low	Acceptable
10	Houses	25	3439	0.1	Too Low	Acceptable
11	Sports Terrain	50	3471	0.1	Too Low	Acceptable
12	Railroad	150	2693	0.2	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
13	Railroad	150	2006	0.3	N/A	Acceptable
14	Railroad	150	2336	0.3	N/A	Acceptable
15	Railroad	150	3123	0.2	N/A	Acceptable
16	R555 Road	150	3207	0.2	N/A	Acceptable
17	R555 Road	150	3280	0.1	N/A	Acceptable
18	Railroad	150	1721	0.4	N/A	Acceptable
19	Railroad	150	1631	0.5	N/A	Acceptable
20	Railroad	150	1929	0.4	N/A	Acceptable
21	Railroad	150	2114	0.3	N/A	Acceptable
22	Railroad	150	2663	0.2	N/A	Acceptable
23	Railroad	150	3165	0.2	N/A	Acceptable
24	Railroad	150	3242	0.1	N/A	Acceptable
25	Railroad	150	2934	0.2	N/A	Acceptable
26	Railroad	150	2775	0.2	N/A	Acceptable
27	Railroad	150	3326	0.1	N/A	Acceptable
28	R555 Road	150	2797	0.2	N/A	Acceptable
29	R555 Road	150	2967	0.2	N/A	Acceptable
30	R555 Road	150	3428	0.1	N/A	Acceptable
31	Pivot Irrigation	150	3055	0.2	N/A	Acceptable
32	Pivot Irrigation	150	2886	0.2	N/A	Acceptable
33	Pivot Irrigation	150	2696	0.2	N/A	Acceptable
34	Pan	150	1973	0.3	N/A	Acceptable
35	Buildings/Structures	25	2300	0.3	Too Low	Acceptable
36	Buildings/Structures (Oakhouse Lodge)	25	1649	0.5	Too Low	Acceptable
37	Buildings/Structures	25	1815	0.4	Too Low	Acceptable
38	N12 Road	150	96	49.1	N/A	Acceptable
39	N12 Road	150	1952	0.3	N/A	Acceptable
40	Road	150	62	102.9	N/A	Acceptable
41	Informal Housing	6	3117	0.2	Too Low	Acceptable
42	Informal Housing	6	3039	0.2	Too Low	Acceptable
43	Power Lines/Pylons	75	1903	0.4	N/A	Acceptable
44	Power Lines/Pylons	75	1611	0.5	N/A	Acceptable
45	Power Lines/Pylons	75	1481	0.5	N/A	Acceptable
46	Power Lines/Pylons	75	1356	0.6	N/A	Acceptable
47	Power Lines/Pylons	75	1219	0.7	N/A	Acceptable
48	Power Lines/Pylons	75	1086	0.9	N/A	Acceptable
49	Power Lines/Pylons	75	947	1.1	N/A	Acceptable
50	Power Lines/Pylons	75	823	1.4	N/A	Acceptable
51	Power Lines/Pylons	75	734	1.7	N/A	Acceptable
52	Power Lines/Pylons	75	663	2.0	N/A	Acceptable
53	Power Lines/Pylons	75	917	1.2	N/A	Acceptable
54	Power Lines/Pylons	75	1370	0.6	N/A	Acceptable
55	Power Lines/Pylons	75	1725	0.4	N/A	Acceptable
56	Power Lines/Pylons	75	1990	0.3	N/A	Acceptable
57	Power Lines/Pylons	75	2281	0.3	N/A	Acceptable
58	Power Lines/Pylons	75	2551	0.2	N/A	Acceptable
59	Power Lines/Pylons	75	2799	0.2	N/A	Acceptable
60	Power Lines/Pylons	75	3056	0.2	N/A	Acceptable
61	Power Lines/Pylons	75	3235	0.1	N/A	Acceptable
62	Power Lines/Pylons	75	3415	0.1	N/A	Acceptable
63	Dam	50	3245	0.1	N/A	Acceptable
64	Ruins	6	2374	0.2	Too Low	Acceptable
65	Farm Buildings/Structures	25	811	1.5	Perceptible	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
66	Farm Buildings/Structures	25	728	1.7	Perceptible	Acceptable
67	Dam	50	3203	0.2	N/A	Acceptable
68	Conveyor	150	2835	0.2	N/A	Acceptable
69	Informal Housing	6	1327	0.6	Too Low	Acceptable
70	Farm Buildings/Structures	25	345	6.0	Unpleasant	Acceptable
71	Dam	50	1776	0.4	N/A	Acceptable
72	Ruins	6	1872	0.4	Too Low	Acceptable
73	Ruins	6	1484	0.5	Too Low	Acceptable
74	Cement Dams	50	1437	0.6	N/A	Acceptable
75	Cement Dam	50	938	1.2	N/A	Acceptable
76	Building/Structure	25	2427	0.2	Too Low	Acceptable
77	Building/Structure	25	3274	0.1	Too Low	Acceptable
78	Power Lines/Pylons	75	901	1.2	N/A	Acceptable
79	Power Lines/Pylons	75	1081	0.9	N/A	Acceptable
80	Power Lines/Pylons	75	1261	0.7	N/A	Acceptable
81	Power Lines/Pylons	75	1458	0.6	N/A	Acceptable
82	Power Lines/Pylons	75	1606	0.5	N/A	Acceptable
83	Power Lines/Pylons	75	1710	0.4	N/A	Acceptable
84	Power Lines/Pylons	75	1812	0.4	N/A	Acceptable
85	Power Lines/Pylons	75	1932	0.3	N/A	Acceptable
86	Power Lines/Pylons	75	2046	0.3	N/A	Acceptable
87	Power Lines/Pylons	75	2168	0.3	N/A	Acceptable
88	Power Lines/Pylons	75	733	1.7	N/A	Acceptable
89	Power Lines/Pylons	75	611	2.3	N/A	Acceptable
90	Power Lines/Pylons	75	537	2.9	N/A	Acceptable
91	Power Lines/Pylons	75	523	3.0	N/A	Acceptable
92	Power Lines/Pylons	75	577	2.6	N/A	Acceptable
93	Power Lines/Pylons	75	693	1.9	N/A	Acceptable
94	Power Lines/Pylons	75	821	1.4	N/A	Acceptable
95	Power Lines/Pylons	75	939	1.1	N/A	Acceptable
96	Power Lines/Pylons	75	1080	0.9	N/A	Acceptable
97	Power Lines/Pylons	75	1203	0.8	N/A	Acceptable
98	Power Lines/Pylons	75	1336	0.6	N/A	Acceptable
99	Power Lines/Pylons	75	1459	0.6	N/A	Acceptable
100	Power Lines/Pylons	75	1582	0.5	N/A	Acceptable
101	R545 Road	150	3014	0.2	N/A	Acceptable
102	Phola Town Housing Community	25	2855	0.2	Too Low	Acceptable
103	Phola Town Housing Community	25	2502	0.2	Too Low	Acceptable
104	Phola Town Housing Community	25	2081	0.3	Too Low	Acceptable
105	R545 Road	150	2997	0.2	N/A	Acceptable
106	Phola Town Community Buildings	25	2495	0.2	Too Low	Acceptable
107	Phola Town Community Buildings	25	2414	0.2	Too Low	Acceptable
108	Phola Town Community Buildings	25	2292	0.3	Too Low	Acceptable
109	Phola Town Community Buildings	25	2693	0.2	Too Low	Acceptable
110	Phola Town Housing Community	25	3091	0.2	Too Low	Acceptable
111	Phola Town Housing	25	3204	0.2	Too Low	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
	Community					
112	Phola Town Housing Community	25	2101	0.3	Too Low	Acceptable
113	Phola Town Housing Community	25	2334	0.3	Too Low	Acceptable
114	Phola Town Housing Community	25	2530	0.2	Too Low	Acceptable
115	R545 Road	150	3290	0.1	N/A	Acceptable
116	Mandela Village Community Housing	25	1883	0.4	Too Low	Acceptable
117	Mandela Village Community Housing	25	1275	0.7	Too Low	Acceptable
118	Mandela Village Community Buildings	25	1663	0.4	Too Low	Acceptable
119	Mandela Village Community Housing	25	2216	0.3	Too Low	Acceptable
120	Mandela Village Community Building	25	1211	0.8	Too Low	Acceptable
121	Mandela Village Community Housing	25	1177	0.8	Perceptible	Acceptable
122	Reservoir	50	1063	0.9	N/A	Acceptable
123	Mandela Village Community Housing	25	885	1.3	Perceptible	Acceptable
124	Mandela Village Community Housing	25	1686	0.4	Too Low	Acceptable
125	Mandela Village Community Housing	25	2200	0.3	Too Low	Acceptable
126	Buildings/Structures	25	406	4.6	Perceptible	Acceptable
127	Water Treatment Dams	25	2853	0.2	N/A	Acceptable
128	Farm Buildings/Structures	25	3251	0.1	Too Low	Acceptable
129	Farm Buildings/Structures	25	792	1.5	Perceptible	Acceptable
130	Informal Housing	6	702	1.9	Perceptible	Acceptable
131	Informal Housing	6	928	1.2	Perceptible	Acceptable
132	Informal Housing	6	1923	0.4	Too Low	Acceptable
133	Buildings/Structures	25	3226	0.1	Too Low	Acceptable
134	Pivot Irrigation	150	2713	0.2	N/A	Acceptable
135	Pivot Irrigation	150	2325	0.3	N/A	Acceptable
136	Road	150	16	924.5	N/A	Problematic
137	Road	150	623	2.3	N/A	Acceptable
138	Farm Buildings/Structures	25	2947	0.2	Too Low	Acceptable
139	Farm Buildings/Structures	25	151	23.4	Intolerable	Acceptable
140	Road	150	12	1584.9	N/A	Problematic
141	Road	150	29	364.0	N/A	Problematic
142	Road	150	941	1.1	N/A	Acceptable
143	Mine Activity	200	2776	0.2	N/A	Acceptable
144	Informal Housing	6	1672	0.4	Too Low	Acceptable
145	Informal Housing	6	2866	0.2	Too Low	Acceptable
146	Farm Buildings/Structures	25	917	1.2	Perceptible	Acceptable
147	Farm Buildings/Structures	25	3046	0.2	Too Low	Acceptable
148	Building/Structure	25	2668	0.2	Too Low	Acceptable
149	Power Lines/Pylons	75	3353	0.1	N/A	Acceptable
150	Power Lines/Pylons	75	3063	0.2	N/A	Acceptable
151	Power Lines/Pylons	75	2823	0.2	N/A	Acceptable
152	Power Lines/Pylons	75	2605	0.2	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
153	Power Lines/Pylons	75	2421	0.2	N/A	Acceptable
154	Power Lines/Pylons	75	2241	0.3	N/A	Acceptable
155	Power Lines/Pylons	75	2142	0.3	N/A	Acceptable
156	Power Lines/Pylons	75	2084	0.3	N/A	Acceptable
157	Power Lines/Pylons	75	2098	0.3	N/A	Acceptable
158	Power Lines/Pylons	75	2163	0.3	N/A	Acceptable
159	Power Lines/Pylons	75	2229	0.3	N/A	Acceptable
160	Power Lines/Pylons	75	2258	0.3	N/A	Acceptable
161	Power Lines/Pylons	75	2454	0.2	N/A	Acceptable
162	Power Lines/Pylons	75	2840	0.2	N/A	Acceptable
163	Power Lines/Pylons	75	3087	0.2	N/A	Acceptable
164	Power Lines/Pylons	75	3341	0.1	N/A	Acceptable
165	Farm Buildings/Structures	25	1223	0.7	Too Low	Acceptable
166	Farm Buildings/Structures	25	3153	0.2	Too Low	Acceptable
167	Pan	150	3162	0.2	N/A	Acceptable
168	Ruins	6	2420	0.2	Too Low	Acceptable
169	Farm Buildings/Structures	25	835	1.4	Perceptible	Acceptable
170	Pan	150	1171	0.8	N/A	Acceptable
171	Farm Buildings/Structures	25	1212	0.8	Too Low	Acceptable
172	Buildings/Structures	25	669	2.0	Perceptible	Acceptable
173	Pan	150	364	5.5	N/A	Acceptable
174	Farm Buildings/Structures	25	1286	0.7	Too Low	Acceptable
175	Farm Buildings/Structures	25	1076	0.9	Perceptible	Acceptable
176	Pan	150	223	12.4	N/A	Acceptable
177	Farm Buildings/Structures	25	2455	0.2	Too Low	Acceptable
178	Buildings/Structures	25	3354	0.1	Too Low	Acceptable
179	Industrial Area	50	2898	0.2	N/A	Acceptable
180	Farm Buildings/Structures	25	3190	0.2	Too Low	Acceptable
181	Buildings/Structures	25	3365	0.1	Too Low	Acceptable
182	Buildings/Structures	25	3426	0.1	Too Low	Acceptable
183	Buildings/Structures	25	2973	0.2	Too Low	Acceptable
184	Dam	50	240	10.9	N/A	Acceptable
185	Building/Structure	25	1214	0.8	Too Low	Acceptable
186	N12 Road Bridge	50	3008	0.2	N/A	Acceptable
187	Dam	50	879	1.3	N/A	Acceptable
188	Tailings Dam	25	3438	0.1	N/A	Acceptable
189	Dam	50	2007	0.3	N/A	Acceptable
190	Dam	50	2439	0.2	N/A	Acceptable
191	Borehole (BHP_P04)	50	2582	0.2	N/A	Acceptable
192	Borehole (BHP_P05)	50	1211	0.8	N/A	Acceptable
193	Borehole (BHP_P06)	50	1743	0.4	N/A	Acceptable
194	Borehole (BHP_P07)	50	678	2.0	N/A	Acceptable
195	Borehole (BHP_P08)	50	441	4.0	N/A	Acceptable
196	Borehole (BHP_P10)	50	2392	0.2	N/A	Acceptable
197	Borehole (BHP_P11)	50	3027	0.2	N/A	Acceptable
198	Borehole (BHP_P12)	50	405	4.6	N/A	Acceptable
199	Burial Grounds and Graves (GY15)	50	419	4.4	N/A	Acceptable
200	Burial Grounds and Graves (GY12)	50	1340	0.6	N/A	Acceptable
201	Burial Grounds and Graves (GY13)	50	313	7.0	N/A	Acceptable
202	Burial Grounds and Graves (GY14)	50	147	24.6	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
203	Burial Grounds and Graves (GY9)	50	103	44.2	N/A	Acceptable
204	Burial Grounds and Graves (GY10)	50	1000	1.0	N/A	Acceptable
205	Burial Grounds and Graves (GY19)	50	685	1.9	N/A	Acceptable
206	Built Environment	25	728	1.7	Perceptible	Acceptable
207	Built Environment	25	728	1.7	Perceptible	Acceptable
208	Built Environment	25	870	1.3	Perceptible	Acceptable
209	Burial Grounds and Graves	50	1382	0.6	N/A	Acceptable
210	Built Environment	25	1546	0.5	Too Low	Acceptable
211	Burial Grounds and Graves (GY 11)	50	2811	0.2	N/A	Acceptable
212	Burial Grounds and Graves	50	2095	0.3	N/A	Acceptable
213	Burial Grounds and Graves (GY7)	50	1310	0.7	N/A	Acceptable
214	Burial Grounds and Graves (GY5)	50	1320	0.7	N/A	Acceptable
215	Burial Grounds and Graves (GY6)	50	1124	0.9	N/A	Acceptable
216	Burial Ground and Graves (GY16)	50	2452	0.2	N/A	Acceptable
217	Burial Grounds and Graves (GY1)	50	2770	0.2	N/A	Acceptable
218	Built Environment	25	1597	0.5	Too Low	Acceptable

- **Maximum Charge per Delay – Pit Area – 2224 kg**

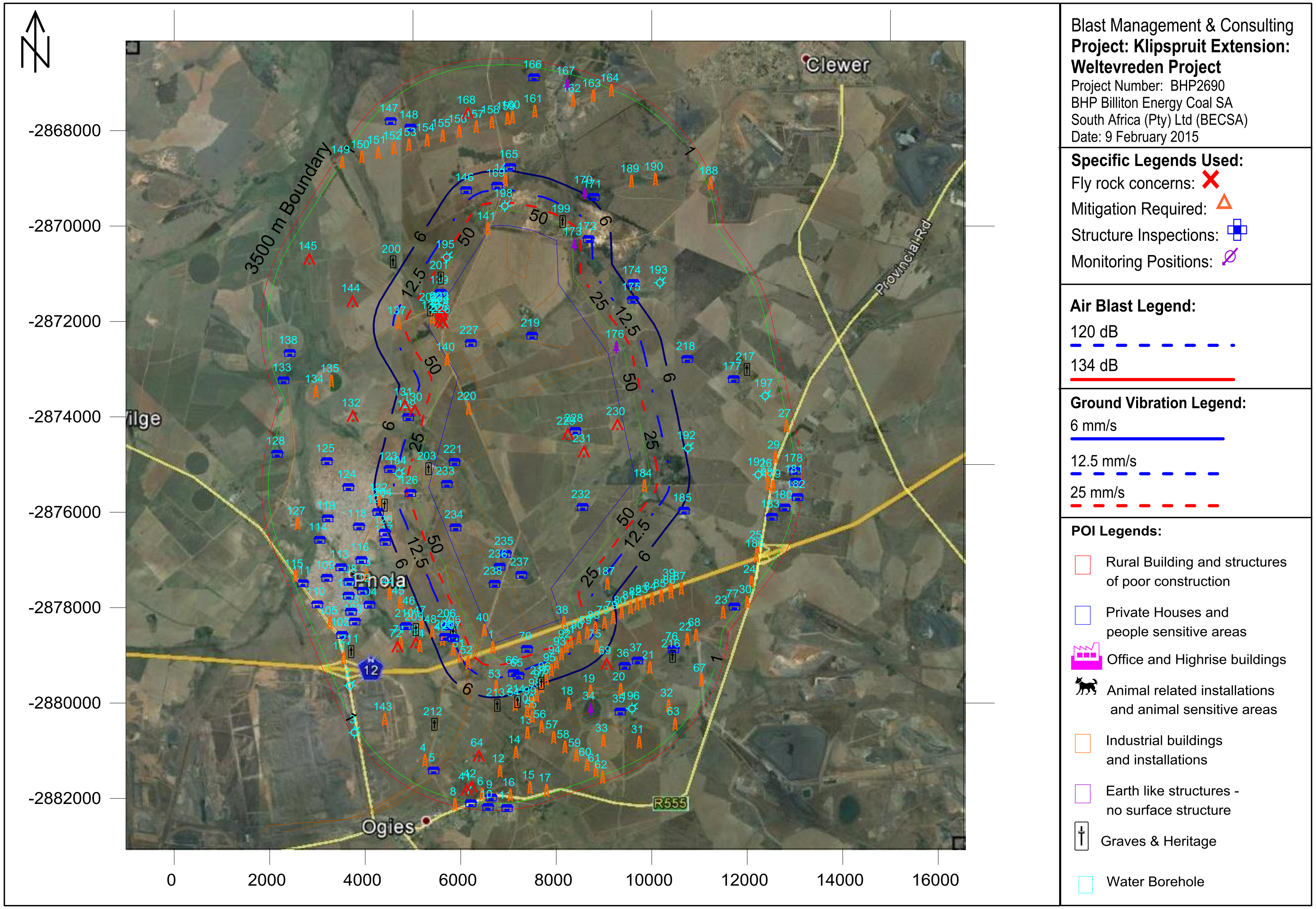

Figure 15: Ground vibration influence from maximum charge for Pit Area

Table 9: Ground vibration evaluation for maximum charge for Pit Area

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
1	N12 Road	150	93	375.6	N/A	Problematic
2	Borehole (BSW 3)	50	3113	1.1	N/A	Acceptable
3	Borehole (KGM B4)	50	3450	1.0	N/A	Acceptable
4	Substation	25	2842	1.3	N/A	Acceptable
5	Buildings/Structures	25	2943	1.2	Perceptible	Acceptable
6	Railroad	150	3176	1.1	N/A	Acceptable
7	Houses	25	3389	1.0	Perceptible	Acceptable
8	Railroad	150	3475	0.9	N/A	Acceptable
9	Houses	25	3235	1.1	Perceptible	Acceptable
10	Houses	25	3439	1.0	Perceptible	Acceptable
11	Sports Terrain	50	3471	1.0	Perceptible	Acceptable
12	Railroad	150	2693	1.4	N/A	Acceptable
13	Railroad	150	2006	2.3	N/A	Acceptable
14	Railroad	150	2336	1.8	N/A	Acceptable
15	Railroad	150	3123	1.1	N/A	Acceptable
16	R555 Road	150	3207	1.1	N/A	Acceptable
17	R555 Road	150	3280	1.0	N/A	Acceptable
18	Railroad	150	1721	3.0	N/A	Acceptable
19	Railroad	150	1631	3.3	N/A	Acceptable
20	Railroad	150	1929	2.5	N/A	Acceptable
21	Railroad	150	2114	2.2	N/A	Acceptable
22	Railroad	150	2663	1.5	N/A	Acceptable
23	Railroad	150	3165	1.1	N/A	Acceptable
24	Railroad	150	3242	1.1	N/A	Acceptable
25	Railroad	150	2934	1.3	N/A	Acceptable
26	Railroad	150	2775	1.4	N/A	Acceptable
27	Railroad	150	3326	1.0	N/A	Acceptable
28	R555 Road	150	2797	1.4	N/A	Acceptable
29	R555 Road	150	2967	1.2	N/A	Acceptable
30	R555 Road	150	3428	1.0	N/A	Acceptable
31	Pivot Irrigation	150	3055	1.2	N/A	Acceptable
32	Pivot Irrigation	150	2886	1.3	N/A	Acceptable
33	Pivot Irrigation	150	2696	1.4	N/A	Acceptable
34	Pan	150	1973	2.4	N/A	Acceptable
35	Buildings/Structures	25	2300	1.9	Perceptible	Acceptable
36	Buildings/Structures (Oakhouse Lodge)	25	1649	3.2	Perceptible	Acceptable
37	Buildings/Structures	25	1815	2.8	Perceptible	Acceptable
38	N12 Road	150	96	350.9	N/A	Problematic
39	N12 Road	150	1952	2.5	N/A	Acceptable
40	Road	150	62	735.8	N/A	Problematic
41	Informal Housing	6	3117	1.1	Perceptible	Acceptable
42	Informal Housing	6	3039	1.2	Perceptible	Acceptable
43	Power Lines/Pylons	75	1903	2.6	N/A	Acceptable
44	Power Lines/Pylons	75	1611	3.4	N/A	Acceptable
45	Power Lines/Pylons	75	1481	3.9	N/A	Acceptable
46	Power Lines/Pylons	75	1356	4.5	N/A	Acceptable
47	Power Lines/Pylons	75	1219	5.3	N/A	Acceptable
48	Power Lines/Pylons	75	1086	6.5	N/A	Acceptable
49	Power Lines/Pylons	75	947	8.1	N/A	Acceptable
50	Power Lines/Pylons	75	823	10.2	N/A	Acceptable
51	Power Lines/Pylons	75	734	12.3	N/A	Acceptable
52	Power Lines/Pylons	75	663	14.6	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
53	Power Lines/Pylons	75	917	8.5	N/A	Acceptable
54	Power Lines/Pylons	75	1370	4.4	N/A	Acceptable
55	Power Lines/Pylons	75	1725	3.0	N/A	Acceptable
56	Power Lines/Pylons	75	1990	2.4	N/A	Acceptable
57	Power Lines/Pylons	75	2281	1.9	N/A	Acceptable
58	Power Lines/Pylons	75	2551	1.6	N/A	Acceptable
59	Power Lines/Pylons	75	2799	1.4	N/A	Acceptable
60	Power Lines/Pylons	75	3056	1.2	N/A	Acceptable
61	Power Lines/Pylons	75	3235	1.1	N/A	Acceptable
62	Power Lines/Pylons	75	3415	1.0	N/A	Acceptable
63	Dam	50	3245	1.1	N/A	Acceptable
64	Ruins	6	2374	1.8	Perceptible	Acceptable
65	Farm Buildings/Structures	25	811	10.5	Unpleasant	Acceptable
66	Farm Buildings/Structures	25	728	12.5	Unpleasant	Acceptable
67	Dam	50	3203	1.1	N/A	Acceptable
68	Conveyor	150	2835	1.3	N/A	Acceptable
69	Informal Housing	6	1327	4.6	Perceptible	Acceptable
70	Farm Buildings/Structures	25	345	42.9	Intolerable	Problematic
71	Dam	50	1776	2.9	N/A	Acceptable
72	Ruins	6	1872	2.6	Perceptible	Acceptable
73	Ruins	6	1484	3.9	Perceptible	Acceptable
74	Cement Dams	50	1437	4.1	N/A	Acceptable
75	Cement Dam	50	938	8.2	N/A	Acceptable
76	Building/Structure	25	2427	1.7	Perceptible	Acceptable
77	Building/Structure	25	3274	1.0	Perceptible	Acceptable
78	Power Lines/Pylons	75	901	8.8	N/A	Acceptable
79	Power Lines/Pylons	75	1081	6.5	N/A	Acceptable
80	Power Lines/Pylons	75	1261	5.0	N/A	Acceptable
81	Power Lines/Pylons	75	1458	4.0	N/A	Acceptable
82	Power Lines/Pylons	75	1606	3.4	N/A	Acceptable
83	Power Lines/Pylons	75	1710	3.1	N/A	Acceptable
84	Power Lines/Pylons	75	1812	2.8	N/A	Acceptable
85	Power Lines/Pylons	75	1932	2.5	N/A	Acceptable
86	Power Lines/Pylons	75	2046	2.3	N/A	Acceptable
87	Power Lines/Pylons	75	2168	2.1	N/A	Acceptable
88	Power Lines/Pylons	75	733	12.4	N/A	Acceptable
89	Power Lines/Pylons	75	611	16.7	N/A	Acceptable
90	Power Lines/Pylons	75	537	20.7	N/A	Acceptable
91	Power Lines/Pylons	75	523	21.6	N/A	Acceptable
92	Power Lines/Pylons	75	577	18.3	N/A	Acceptable
93	Power Lines/Pylons	75	693	13.6	N/A	Acceptable
94	Power Lines/Pylons	75	821	10.2	N/A	Acceptable
95	Power Lines/Pylons	75	939	8.2	N/A	Acceptable
96	Power Lines/Pylons	75	1080	6.5	N/A	Acceptable
97	Power Lines/Pylons	75	1203	5.5	N/A	Acceptable
98	Power Lines/Pylons	75	1336	4.6	N/A	Acceptable
99	Power Lines/Pylons	75	1459	4.0	N/A	Acceptable
100	Power Lines/Pylons	75	1582	3.5	N/A	Acceptable
101	R545 Road	150	3014	1.2	N/A	Acceptable
102	Phola Town Housing Community	25	2855	1.3	Perceptible	Acceptable
103	Phola Town Housing Community	25	2502	1.6	Perceptible	Acceptable
104	Phola Town Housing	25	2081	2.2	Perceptible	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
	Community					
105	R545 Road	150	2997	1.2	N/A	Acceptable
106	Phola Town Community Buildings	25	2495	1.6	Perceptible	Acceptable
107	Phola Town Community Buildings	25	2414	1.7	Perceptible	Acceptable
108	Phola Town Community Buildings	25	2292	1.9	Perceptible	Acceptable
109	Phola Town Community Buildings	25	2693	1.4	Perceptible	Acceptable
110	Phola Town Housing Community	25	3091	1.2	Perceptible	Acceptable
111	Phola Town Housing Community	25	3204	1.1	Perceptible	Acceptable
112	Phola Town Housing Community	25	2101	2.2	Perceptible	Acceptable
113	Phola Town Housing Community	25	2334	1.8	Perceptible	Acceptable
114	Phola Town Housing Community	25	2530	1.6	Perceptible	Acceptable
115	R545 Road	150	3290	1.0	N/A	Acceptable
116	Mandela Village Community Housing	25	1883	2.6	Perceptible	Acceptable
117	Mandela Village Community Housing	25	1275	5.0	Perceptible	Acceptable
118	Mandela Village Community Buildings	25	1663	3.2	Perceptible	Acceptable
119	Mandela Village Community Housing	25	2216	2.0	Perceptible	Acceptable
120	Mandela Village Community Building	25	1211	5.4	Perceptible	Acceptable
121	Mandela Village Community Housing	25	1177	5.7	Unpleasant	Acceptable
122	Reservoir	50	1063	6.7	N/A	Acceptable
123	Mandela Village Community Housing	25	885	9.1	Unpleasant	Acceptable
124	Mandela Village Community Housing	25	1686	3.1	Perceptible	Acceptable
125	Mandela Village Community Housing	25	2200	2.0	Perceptible	Acceptable
126	Buildings/Structures	25	406	32.8	Intolerable	Problematic
127	Water Treatment Dams	25	2853	1.3	N/A	Acceptable
128	Farm Buildings/Structures	25	3251	1.1	Perceptible	Acceptable
129	Farm Buildings/Structures	25	792	10.9	Unpleasant	Acceptable
130	Informal Housing	6	702	13.3	Unpleasant	Problematic
131	Informal Housing	6	928	8.4	Unpleasant	Problematic
132	Informal Housing	6	1923	2.5	Perceptible	Acceptable
133	Buildings/Structures	25	3226	1.1	Perceptible	Acceptable
134	Pivot Irrigation	150	2713	1.4	N/A	Acceptable
135	Pivot Irrigation	150	2325	1.8	N/A	Acceptable
136	Road	150	16	6608.1	N/A	Problematic
137	Road	150	623	16.2	N/A	Acceptable
138	Farm Buildings/Structures	25	2947	1.2	Perceptible	Acceptable
139	Farm Buildings/Structures	25	151	167.3	Intolerable	Problematic

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
140	Road	150	12	11328.8	N/A	Problematic
141	Road	150	29	2602.2	N/A	Problematic
142	Road	150	941	8.2	N/A	Acceptable
143	Mine Activity	200	2776	1.4	N/A	Acceptable
144	Informal Housing	6	1672	3.2	Perceptible	Acceptable
145	Informal Housing	6	2866	1.3	Perceptible	Acceptable
146	Farm Buildings/Structures	25	917	8.5	Unpleasant	Acceptable
147	Farm Buildings/Structures	25	3046	1.2	Perceptible	Acceptable
148	Building/Structure	25	2668	1.5	Perceptible	Acceptable
149	Power Lines/Pylons	75	3353	1.0	N/A	Acceptable
150	Power Lines/Pylons	75	3063	1.2	N/A	Acceptable
151	Power Lines/Pylons	75	2823	1.3	N/A	Acceptable
152	Power Lines/Pylons	75	2605	1.5	N/A	Acceptable
153	Power Lines/Pylons	75	2421	1.7	N/A	Acceptable
154	Power Lines/Pylons	75	2241	2.0	N/A	Acceptable
155	Power Lines/Pylons	75	2142	2.1	N/A	Acceptable
156	Power Lines/Pylons	75	2084	2.2	N/A	Acceptable
157	Power Lines/Pylons	75	2098	2.2	N/A	Acceptable
158	Power Lines/Pylons	75	2163	2.1	N/A	Acceptable
159	Power Lines/Pylons	75	2229	2.0	N/A	Acceptable
160	Power Lines/Pylons	75	2258	1.9	N/A	Acceptable
161	Power Lines/Pylons	75	2454	1.7	N/A	Acceptable
162	Power Lines/Pylons	75	2840	1.3	N/A	Acceptable
163	Power Lines/Pylons	75	3087	1.2	N/A	Acceptable
164	Power Lines/Pylons	75	3341	1.0	N/A	Acceptable
165	Farm Buildings/Structures	25	1223	5.3	Perceptible	Acceptable
166	Farm Buildings/Structures	25	3153	1.1	Perceptible	Acceptable
167	Pan	150	3162	1.1	N/A	Acceptable
168	Ruins	6	2420	1.7	Perceptible	Acceptable
169	Farm Buildings/Structures	25	835	10.0	Unpleasant	Acceptable
170	Pan	150	1171	5.7	N/A	Acceptable
171	Farm Buildings/Structures	25	1212	5.4	Perceptible	Acceptable
172	Buildings/Structures	25	669	14.4	Unpleasant	Acceptable
173	Pan	150	364	39.2	N/A	Acceptable
174	Farm Buildings/Structures	25	1286	4.9	Perceptible	Acceptable
175	Farm Buildings/Structures	25	1076	6.6	Unpleasant	Acceptable
176	Pan	150	223	88.3	N/A	Acceptable
177	Farm Buildings/Structures	25	2455	1.7	Perceptible	Acceptable
178	Buildings/Structures	25	3354	1.0	Perceptible	Acceptable
179	Industrial Area	50	2898	1.3	N/A	Acceptable
180	Farm Buildings/Structures	25	3190	1.1	Perceptible	Acceptable
181	Buildings/Structures	25	3365	1.0	Perceptible	Acceptable
182	Buildings/Structures	25	3426	1.0	Perceptible	Acceptable
183	Buildings/Structures	25	2973	1.2	Perceptible	Acceptable
184	Dam	50	240	78.0	N/A	Problematic
185	Building/Structure	25	1214	5.4	Perceptible	Acceptable
186	N12 Road Bridge	50	3008	1.2	N/A	Acceptable
187	Dam	50	879	9.2	N/A	Acceptable
188	Tailings Dam	25	3438	1.0	N/A	Acceptable
189	Dam	50	2007	2.3	N/A	Acceptable
190	Dam	50	2439	1.7	N/A	Acceptable
191	Borehole (BHP_P04)	50	2582	1.5	N/A	Acceptable
192	Borehole (BHP_P05)	50	1211	5.4	N/A	Acceptable
193	Borehole (BHP_P06)	50	1743	3.0	N/A	Acceptable

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz	Structure Response @ 10Hz
194	Borehole (BHP_P07)	50	678	14.1	N/A	Acceptable
195	Borehole (BHP_P08)	50	441	28.6	N/A	Acceptable
196	Borehole (BHP_P10)	50	2392	1.8	N/A	Acceptable
197	Borehole (BHP_P11)	50	3027	1.2	N/A	Acceptable
198	Borehole (BHP_P12)	50	405	32.9	N/A	Acceptable
199	Burial Grounds and Graves (GY15)	50	419	31.1	N/A	Acceptable
200	Burial Grounds and Graves (GY12)	50	1340	4.6	N/A	Acceptable
201	Burial Grounds and Graves (GY13)	50	313	50.3	N/A	Problematic
202	Burial Grounds and Graves (GY14)	50	147	175.7	N/A	Problematic
203	Burial Grounds and Graves (GY9)	50	103	316.0	N/A	Problematic
204	Burial Grounds and Graves (GY10)	50	1000	7.4	N/A	Acceptable
205	Burial Grounds and Graves (GY19)	50	685	13.8	N/A	Acceptable
206	Built Environment	25	728	12.5	Unpleasant	Acceptable
207	Built Environment	25	728	12.5	Unpleasant	Acceptable
208	Built Environment	25	870	9.3	Unpleasant	Acceptable
209	Burial Grounds and Graves	50	1382	4.3	N/A	Acceptable
210	Built Environment	25	1546	3.6	Perceptible	Acceptable
211	Burial Grounds and Graves (GY 11)	50	2811	1.3	N/A	Acceptable
212	Burial Grounds and Graves	50	2095	2.2	N/A	Acceptable
213	Burial Grounds and Graves (GY7)	50	1310	4.7	N/A	Acceptable
214	Burial Grounds and Graves (GY5)	50	1320	4.7	N/A	Acceptable
215	Burial Grounds and Graves (GY6)	50	1124	6.1	N/A	Acceptable
216	Burial Ground and Graves (GY16)	50	2452	1.7	N/A	Acceptable
217	Burial Grounds and Graves (GY1)	50	2770	1.4	N/A	Acceptable
218	Built Environment	25	1597	3.4	Perceptible	Acceptable

13.3 Summary of ground vibration levels

The opencast operation was evaluated for expected levels of ground vibration from future blasting operations. Review of the site and the surrounding installations / houses / buildings showed that structures varied in distances from the opencast pit area. Houses and other structures are relatively well spread around the opencast area. The structures identified range in distance from very close to very far for the pit areas. The evaluation took mainly up to 3500 m from the mining areas into consideration.

The distances between structures and the pit area is the main contributing factor to the levels of ground vibration expected and the subsequent possible influences. It is observed that for the different charge masses evaluated that levels of ground vibration will change as well. In view of the maximum charge specific attention will need to be given to specific areas. In some cases structures or installations are directly next to the opencast area. This creates situations where very high ground vibration values are predicted. It must be noted that this is clear indication that care must be taken when blasting is conducted in the areas close to points of interest and proper planning must be done.

The minimum charge showed the lowest levels of influence as expected for the pit area. Ground vibration levels calculated for the maximum charge at the pit area shows an increase in levels for surface structures such as the N12 Road at POI 1 and 38, the Gravel Road (Road to Ogies) at POI 40, POI 136, POI 140, POI 141, the Farm Buildings at POI 70, POI 126, POI 139, Informal Housing at POI 130 and POI 131, the Dam at POI 184 and the Burial Grounds and Graves at POI 201, POI 202 and POI 203. It is uncertain at this stage if the Gravel Road will remain and if relocated is not known. Blasting next to the road will require a greater buffer than currently indicated. Ground vibration calculations are high but an aspect probably more problematic is that if blasting to close to the road could lead to damages in the form of ground movement. It is likely that the road could withstand high levels of vibration but if ground movement occurs it will lead to permanent damage. Mitigations will be required in order to ensure that levels of ground vibration are within accepted norms.

Considering the structures further away from the pit area expected ground vibration levels may be within limits but at specific ranges ground vibration may still be perceptible.

13.4 Ground Vibration and human perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (See Figure 16 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 at 3500 m and greater from the blast people could possibly experience the ground vibration as *"Perceptible"*. At 1250 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"*. At distance of 650 m and closer there is strong indication that people will experience the ground vibration as *"Intolerable"*. Distances closer than 1136 m will exceed the minimum 6 mm/s proposed safe limit for structures of lesser integrity. Figure 16 below shows this effect of ground vibration with regards to human perception for maximum charge.

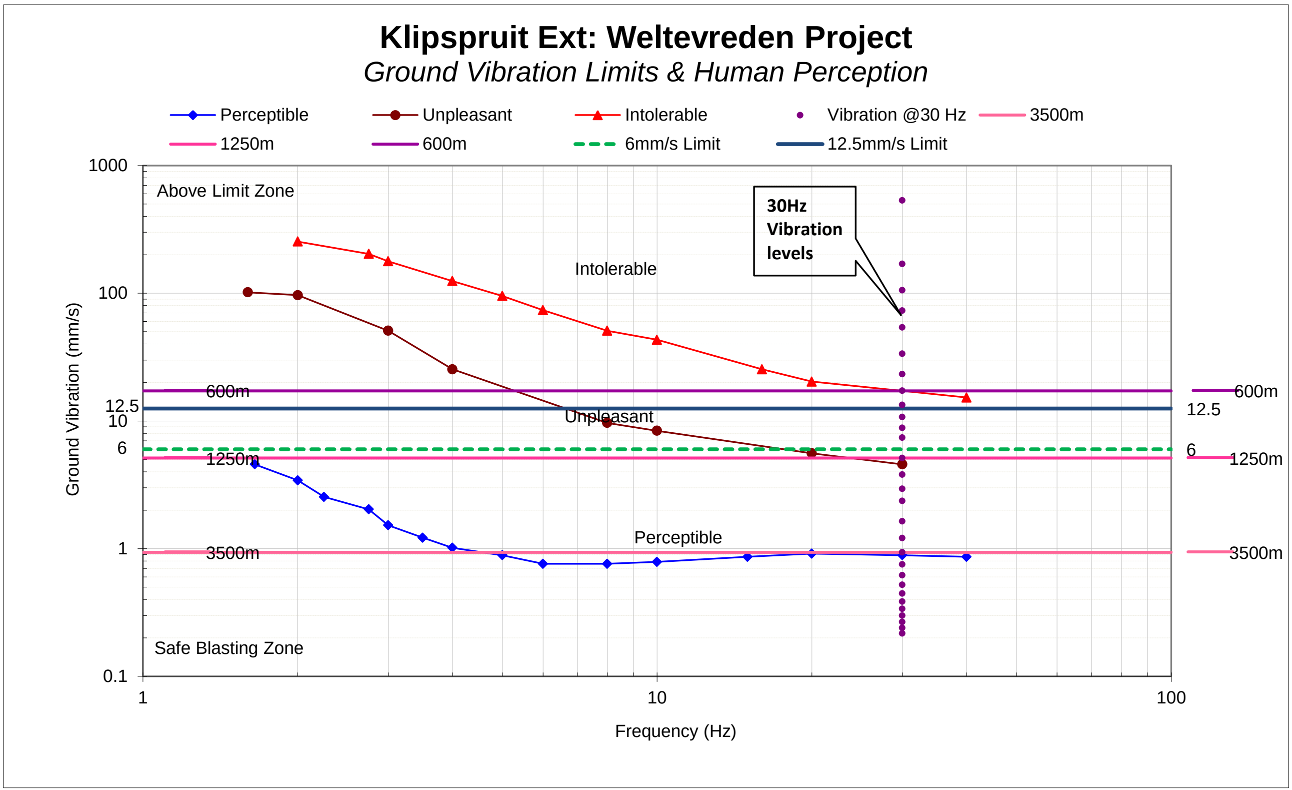

Figure 16: The effect of ground vibration with human perception and vibration limits

13.5 Vibration impact on roads

The R545 and R555 regional roads are in the vicinity of the project area and needs to be considered. These regional roads are at closest points 2997 m and 2797 m for the R545 and R555 respectively from the project area. There is no concern for influence on these two roads.

The N12 National Road is situated approximately 93 m from the project area. There are specific concerns with regards to ground vibration and fly rock at the N12. At closest point ground vibration levels is greater than limit at 375 mm/s. The expected exclusion zone for fly rock is also greater than 93 m. Thus N12 highway will fall within area of fly rock danger. Mitigation will be required with regards to ground vibration and control on fly rock.

There are also various smaller gavel roads/paths that are used by people and animals in the areas of the project. These routes are specifically of concern when blasting is done. There may be people and animals on these routes and will require careful planning to maintain of safe blasting radius. Consideration will need to be given to the gravel road that runs through the project area. Re-routing of this road will need to be considered.

13.6 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. There are communities, grazing areas and roads that are within the evaluated area of influence. The project will be the closest to Mandela Village Community. The Phola Village area is located approximately 2000 m and Ogies town approximately 3389 m from the pit boundary. There is also other smaller structures informal housing in close proximity of the pit area.

Based on the lowest limit applied in this document – 6 mm/s it is expected that this level of ground vibration may be experienced up to 1136 m from the pit area based on the maximum charge. On minimum charge the range is reduced to 345 m. 6 mm/s is considered already “unpleasant” on a human perception scale. It is believed that people in the Mandela Village community, Phola Village and Ogies town are already sensitive concerning the mining operations in the area and it is well expected that people react to significant levels of ground vibration and air blast.

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.

13.7 Cracking of houses and consequent devaluation

There are industrial installations, informal housing, Mandela Village, Phola Village and Ogies town in relative close proximity of the proposed pit area. The structures found in the areas of concern ranges from informal building style, brick and mortar structures and industrial structures. A significant number of structures are found within 3500 m from the pit areas. 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 and specific levels for the different industrial operations are 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.

13.8 Air blast

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

As with ground vibration, evaluation is given for each structure with regards to the calculated levels of air blast and concerns if applicable. Evaluation is done in form of the criteria what humans experience and where by structures could be damaged. This is according to accepted criteria for prevention of damage to structures and when levels are low enough to have no significant influence. Tables are provided for each of the different charge modelling done with regards to Tag, Description, Specific Limit, Distance (m), Predicted Air blast (dB), and Possible Concern. The "Tag" No. is number corresponding to the location indicated on POI figures. "Description" indicates the type of the structure. The "Distance" is the distance between the structure and edge of the pit area. The "Air Blast (dB)" is the calculated air blast level at the structure and the "possible concern" indicates if there is any concern for structure damage or not or human perception. Indicators used are "Problematic" where there is real concern for possible damage, "Complaint" where people will be complaining due to the experienced effect on structures – not necessarily damaging, "Acceptable" is if levels are less than 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 10 shows the applied limits and recommended levels for each of the charges considered. The maximum charge may exceed limits at distances 250 m. The recommended limit of 120 dB is observed at distance of 1000 m. These distances are reduced to just less than 150 m for the minimum charge allowed limit and 500 m for recommended limit. This clearly indicates that with increased charge masses the distances of influence increases. An area of 1250 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 205 kg Charge	Air blast (dB) for 2224 kg Charge
1	50.0	143	151
2	100.0	138	147
3	150.0	131	140
4	200.0	128	137
5	250.0	126	135
6	300.0	124	132
7	400.0	121	129
8	500.0	119	127
9	600.0	117	125
10	700.0	115	123
11	800.0	114	122
12	900.0	113	121
13	1000.0	111	120
14	1250.0	109	117
15	1500.0	107	116

No.	Distance (m)	Air blast (dB) for 205 kg Charge	Air blast (dB) for 2224 kg Charge
16	1750.0	106	114
17	2000.0	104	113
18	2500.0	102	110
19	3000.0	100	108
20	3500.0	98	107

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 opencast mining area.

13.9 Review of expected air blast

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

Colour codes used in tables are as follows:

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

- **Minimum Charge per Delay – Pit Area – 205 kg**

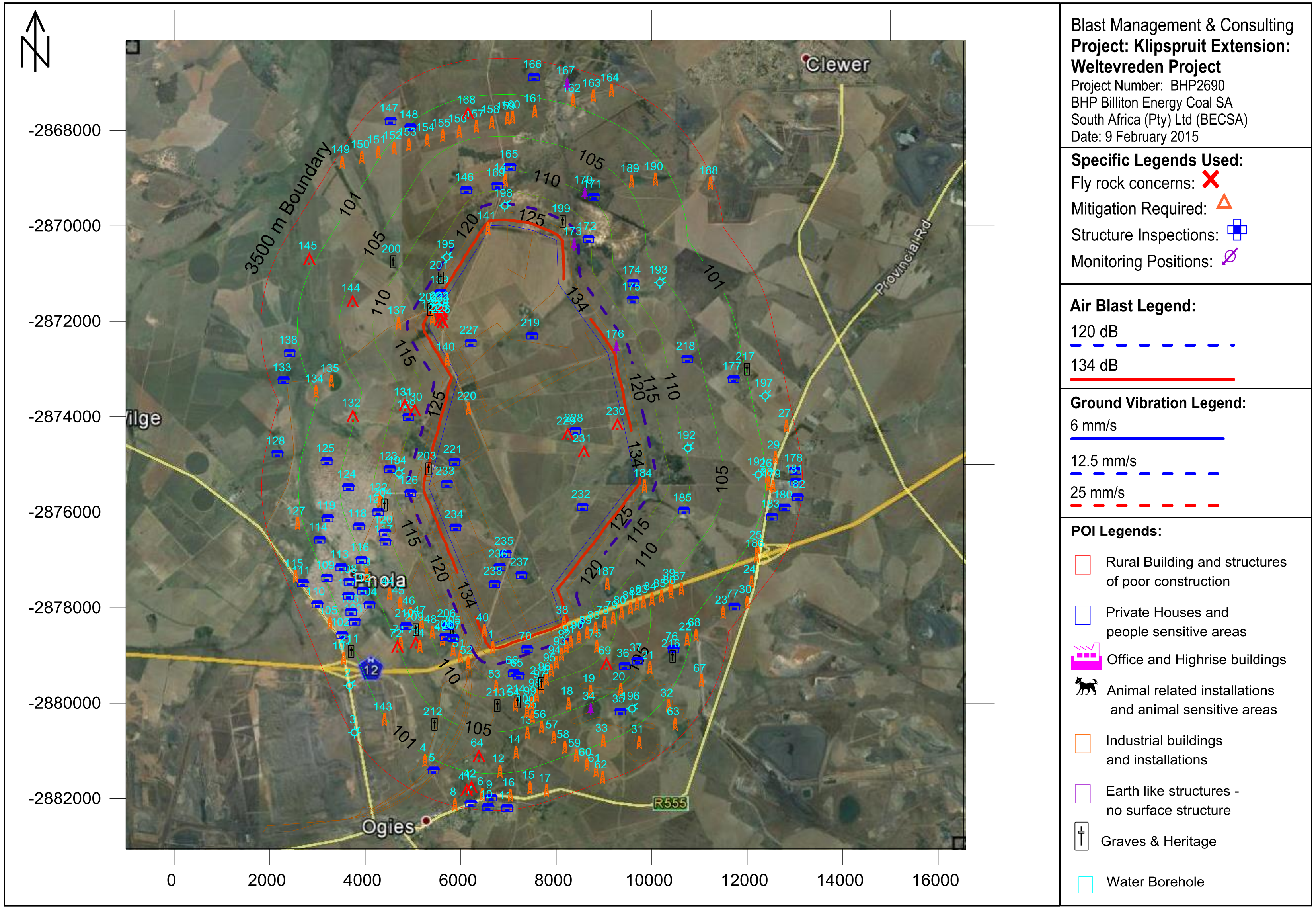

Figure 17: Air blast influence from minimum charge for Pit Area

Table 11: Air blast evaluation for minimum charge for Pit Area

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
1	N12 Road	5	93	136.3	N/A
2	Borehole (BSW 3)	5	3113	99.7	N/A
3	Borehole (KGM B4)	5	3450	98.6	N/A
4	Substation	5	2842	100.6	N/A
5	Buildings/Structures	2	2943	100.2	Acceptable
6	Railroad	5	3176	99.4	N/A
7	Houses	2	3389	98.8	Acceptable
8	Railroad	5	3475	98.5	N/A
9	Houses	2	3235	99.3	Acceptable
10	Houses	2	3439	98.6	Acceptable
11	Sports Terrain	2	3471	98.5	Acceptable
12	Railroad	5	2693	101.2	N/A
13	Railroad	5	2006	104.2	N/A
14	Railroad	5	2336	102.6	N/A
15	Railroad	5	3123	99.6	N/A
16	R555 Road	5	3207	99.3	N/A
17	R555 Road	5	3280	99.1	N/A
18	Railroad	5	1721	105.8	N/A
19	Railroad	5	1631	106.4	N/A
20	Railroad	5	1929	104.6	N/A
21	Railroad	5	2114	103.7	N/A
22	Railroad	5	2663	101.3	N/A
23	Railroad	5	3165	99.5	N/A
24	Railroad	5	3242	99.2	N/A
25	Railroad	5	2934	100.3	N/A
26	Railroad	5	2775	100.9	N/A
27	Railroad	5	3326	99.0	N/A
28	R555 Road	5	2797	100.8	N/A
29	R555 Road	5	2967	100.2	N/A
30	R555 Road	5	3428	98.7	N/A
31	Pivot Irrigation	5	3055	99.9	N/A
32	Pivot Irrigation	5	2886	100.4	N/A
33	Pivot Irrigation	5	2696	101.2	N/A
34	Pan	6	1973	104.4	N/A
35	Buildings/Structures	2	2300	102.8	Acceptable
36	Buildings/Structures(Oakhouse Lodge)	2	1649	106.3	Acceptable
37	Buildings/Structures	2	1815	105.3	Acceptable
38	N12 Road	5	96	135.9	N/A
39	N12 Road	5	1952	104.5	N/A
40	Road	5	62	140.5	N/A
41	Informal Housing	1	3117	99.6	Acceptable
42	Informal Housing	1	3039	99.9	Acceptable
43	Power Lines/Pylons	5	1903	104.8	N/A
44	Power Lines/Pylons	5	1611	106.5	N/A
45	Power Lines/Pylons	5	1481	107.4	N/A
46	Power Lines/Pylons	5	1356	108.3	N/A

47	Power Lines/Pylons	5	1219	109.4	N/A
48	Power Lines/Pylons	5	1086	110.6	N/A
49	Power Lines/Pylons	5	947	112.1	N/A
50	Power Lines/Pylons	5	823	113.5	N/A
51	Power Lines/Pylons	5	734	114.7	N/A
52	Power Lines/Pylons	5	663	115.8	N/A
53	Power Lines/Pylons	5	917	112.4	N/A
54	Power Lines/Pylons	5	1370	108.2	N/A
55	Power Lines/Pylons	5	1725	105.8	N/A
56	Power Lines/Pylons	5	1990	104.3	N/A
57	Power Lines/Pylons	5	2281	102.9	N/A
58	Power Lines/Pylons	5	2551	101.7	N/A
59	Power Lines/Pylons	5	2799	100.8	N/A
60	Power Lines/Pylons	5	3056	99.8	N/A
61	Power Lines/Pylons	5	3235	99.3	N/A
62	Power Lines/Pylons	5	3415	98.7	N/A
63	Dam	5	3245	99.2	N/A
64	Ruins	1	2374	102.5	Acceptable
65	Farm Buildings/Structures	2	811	113.7	Acceptable
66	Farm Buildings/Structures	2	728	114.8	Acceptable
67	Dam	5	3203	99.4	N/A
68	Conveyor	5	2835	100.6	N/A
69	Informal Housing	1	1327	108.5	Acceptable
70	Farm Buildings/Structures	2	345	122.6	Complaint
71	Dam	5	1776	105.5	N/A
72	Ruins	1	1872	105.0	Acceptable
73	Ruins	1	1484	107.4	Acceptable
74	Cement Dams	5	1437	107.7	N/A
75	Cement Dam	5	938	112.2	N/A
76	Building/Structure	2	2427	102.3	Acceptable
77	Building/Structure	2	3274	99.1	Acceptable
78	Power Lines/Pylons	5	901	112.6	N/A
79	Power Lines/Pylons	5	1081	110.7	N/A
80	Power Lines/Pylons	5	1261	109.1	N/A
81	Power Lines/Pylons	5	1458	107.6	N/A
82	Power Lines/Pylons	5	1606	106.6	N/A
83	Power Lines/Pylons	5	1710	105.9	N/A
84	Power Lines/Pylons	5	1812	105.3	N/A
85	Power Lines/Pylons	5	1932	104.6	N/A
86	Power Lines/Pylons	5	2046	104.0	N/A
87	Power Lines/Pylons	5	2168	103.4	N/A
88	Power Lines/Pylons	5	733	114.7	N/A
89	Power Lines/Pylons	5	611	116.6	N/A
90	Power Lines/Pylons	5	537	118.0	N/A
91	Power Lines/Pylons	5	523	118.3	N/A
92	Power Lines/Pylons	5	577	117.2	N/A
93	Power Lines/Pylons	5	693	115.3	N/A
94	Power Lines/Pylons	5	821	113.5	N/A
95	Power Lines/Pylons	5	939	112.1	N/A

96	Power Lines/Pylons	5	1080	110.7	N/A
97	Power Lines/Pylons	5	1203	109.6	N/A
98	Power Lines/Pylons	5	1336	108.5	N/A
99	Power Lines/Pylons	5	1459	107.6	N/A
100	Power Lines/Pylons	5	1582	106.7	N/A
101	R545 Road	5	3014	100.0	N/A
102	Phola Town Housing Community	2	2855	100.6	Acceptable
103	Phola Town Housing Community	2	2502	101.9	Acceptable
104	Phola Town Housing Community	2	2081	103.9	Acceptable
105	R545 Road	5	2997	100.1	N/A
106	Phola Town Community Buildings	2	2495	102.0	Acceptable
107	Phola Town Community Buildings	2	2414	102.3	Acceptable
108	Phola Town Community Buildings	2	2292	102.8	Acceptable
109	Phola Town Community Buildings	2	2693	101.2	Acceptable
110	Phola Town Housing Community	2	3091	99.7	Acceptable
111	Phola Town Housing Community	2	3204	99.4	Acceptable
112	Phola Town Housing Community	2	2101	103.8	Acceptable
113	Phola Town Housing Community	2	2334	102.7	Acceptable
114	Phola Town Housing Community	2	2530	101.8	Acceptable
115	R545 Road	5	3290	99.1	N/A
116	Mandela Village Community Housing	2	1883	104.9	Acceptable
117	Mandela Village Community Housing	2	1275	109.0	Acceptable
118	Mandela Village Community Buildings	2	1663	106.2	Acceptable
119	Mandela Village Community Housing	2	2216	103.2	Acceptable
120	Mandela Village Community Building	2	1211	109.5	Acceptable
121	Mandela Village Community Housing	2	1177	109.8	Acceptable
122	Reservoir	5	1063	110.9	N/A
123	Mandela Village Community Housing	2	885	112.8	Acceptable
124	Mandela Village Community Housing	2	1686	106.0	Acceptable
125	Mandela Village Community Housing	2	2200	103.3	Acceptable
126	Buildings/Structures	2	406	120.9	Complaint
127	Water Treatment Dams	5	2853	100.6	N/A
128	Farm Buildings/Structures	2	3251	99.2	Acceptable
129	Farm Buildings/Structures	2	792	113.9	Acceptable
130	Informal Housing	1	702	115.2	Acceptable
131	Informal Housing	1	928	112.3	Acceptable
132	Informal Housing	1	1923	104.7	Acceptable
133	Buildings/Structures	2	3226	99.3	Acceptable
134	Pivot Irrigation	5	2713	101.1	N/A
135	Pivot Irrigation	5	2325	102.7	N/A
136	Road	5	16	154.4	N/A
137	Road	5	623	116.4	N/A
138	Farm Buildings/Structures	2	2947	100.2	Acceptable
139	Farm Buildings/Structures	2	151	131.2	Complaint
140	Road	5	12	157.8	N/A
141	Road	5	29	148.5	N/A
142	Road	5	941	112.1	N/A
143	Mine Activity	5	2776	100.9	N/A
144	Informal Housing	1	1672	106.1	Acceptable

145	Informal Housing	1	2866	100.5	Acceptable
146	Farm Buildings/Structures	2	917	112.4	Acceptable
147	Farm Buildings/Structures	2	3046	99.9	Acceptable
148	Building/Structure	2	2668	101.3	Acceptable
149	Power Lines/Pylons	5	3353	98.9	N/A
150	Power Lines/Pylons	5	3063	99.8	N/A
151	Power Lines/Pylons	5	2823	100.7	N/A
152	Power Lines/Pylons	5	2605	101.5	N/A
153	Power Lines/Pylons	5	2421	102.3	N/A
154	Power Lines/Pylons	5	2241	103.1	N/A
155	Power Lines/Pylons	5	2142	103.6	N/A
156	Power Lines/Pylons	5	2084	103.8	N/A
157	Power Lines/Pylons	5	2098	103.8	N/A
158	Power Lines/Pylons	5	2163	103.5	N/A
159	Power Lines/Pylons	5	2229	103.1	N/A
160	Power Lines/Pylons	5	2258	103.0	N/A
161	Power Lines/Pylons	5	2454	102.1	N/A
162	Power Lines/Pylons	5	2840	100.6	N/A
163	Power Lines/Pylons	5	3087	99.7	N/A
164	Power Lines/Pylons	5	3341	98.9	N/A
165	Farm Buildings/Structures	2	1223	109.4	Acceptable
166	Farm Buildings/Structures	2	3153	99.5	Acceptable
167	Pan	6	3162	99.5	N/A
168	Ruins	1	2420	102.3	Acceptable
169	Farm Buildings/Structures	2	835	113.4	Acceptable
170	Pan	6	1171	109.9	N/A
171	Farm Buildings/Structures	2	1212	109.5	Acceptable
172	Buildings/Structures	2	669	115.7	Acceptable
173	Pan	6	364	122.0	N/A
174	Farm Buildings/Structures	2	1286	108.9	Acceptable
175	Farm Buildings/Structures	2	1076	110.7	Acceptable
176	Pan	6	223	127.2	N/A
177	Farm Buildings/Structures	2	2455	102.1	Acceptable
178	Buildings/Structures	2	3354	98.9	Acceptable
179	Industrial Area	5	2898	100.4	N/A
180	Farm Buildings/Structures	2	3190	99.4	Acceptable
181	Buildings/Structures	2	3365	98.8	Acceptable
182	Buildings/Structures	2	3426	98.7	Acceptable
183	Buildings/Structures	2	2973	100.1	Acceptable
184	Dam	5	240	126.4	N/A
185	Building/Structure	2	1214	109.5	Acceptable
186	N12 Road Bridge	5	3008	100.0	N/A
187	Dam	5	879	112.8	N/A
188	Tailings Dam	5	3438	98.6	N/A
189	Dam	5	2007	104.2	N/A
190	Dam	5	2439	102.2	N/A
191	Borehole (BHP_P04)	5	2582	101.6	N/A
192	Borehole (BHP_P05)	5	1211	109.5	N/A
193	Borehole (BHP_P06)	5	1743	105.7	N/A

194	Borehole (BHP_P07)	5	678	115.6	N/A
195	Borehole (BHP_P08)	5	441	120.0	N/A
196	Borehole (BHP_P10)	5	2392	102.4	N/A
197	Borehole (BHP_P11)	5	3027	100.0	N/A
198	Borehole (BHP_P12)	5	405	120.9	N/A
199	Burial Grounds and Graves (GY15)	7	419	120.6	N/A
200	Burial Grounds and Graves (GY12)	7	1340	108.4	N/A
201	Burial Grounds and Graves (GY13)	7	313	123.6	N/A
202	Burial Grounds and Graves (GY14)	7	147	131.5	N/A
203	Burial Grounds and Graves (GY9)	7	103	135.2	N/A
204	Burial Grounds and Graves (GY10)	7	1000	111.5	N/A
205	Burial Grounds and Graves (GY19)	7	685	115.4	N/A
206	Built Environment	2	728	114.8	Acceptable
207	Built Environment	2	728	114.8	Acceptable
208	Built Environment	2	870	112.9	Acceptable
209	Burial Grounds and Graves	7	1382	108.1	N/A
210	Built Environment	2	1546	107.0	Acceptable
211	Burial Grounds and Graves (GY 11)	7	2811	100.7	N/A
212	Burial Grounds and Graves	7	2095	103.8	N/A
213	Burial Grounds and Graves (GY7)	7	1310	108.7	N/A
214	Burial Grounds and Graves (GY5)	7	1320	108.6	N/A
215	Burial Grounds and Graves (GY6)	7	1124	110.3	N/A
216	Burial Ground and Graves (GY16)	7	2452	102.1	N/A
217	Burial Grounds and Graves (GY1)	7	2770	100.9	N/A
218	Built Environment	2	1597	106.6	Acceptable

• **Maximum Charge per Delay – Pit Area – 2224 kg**

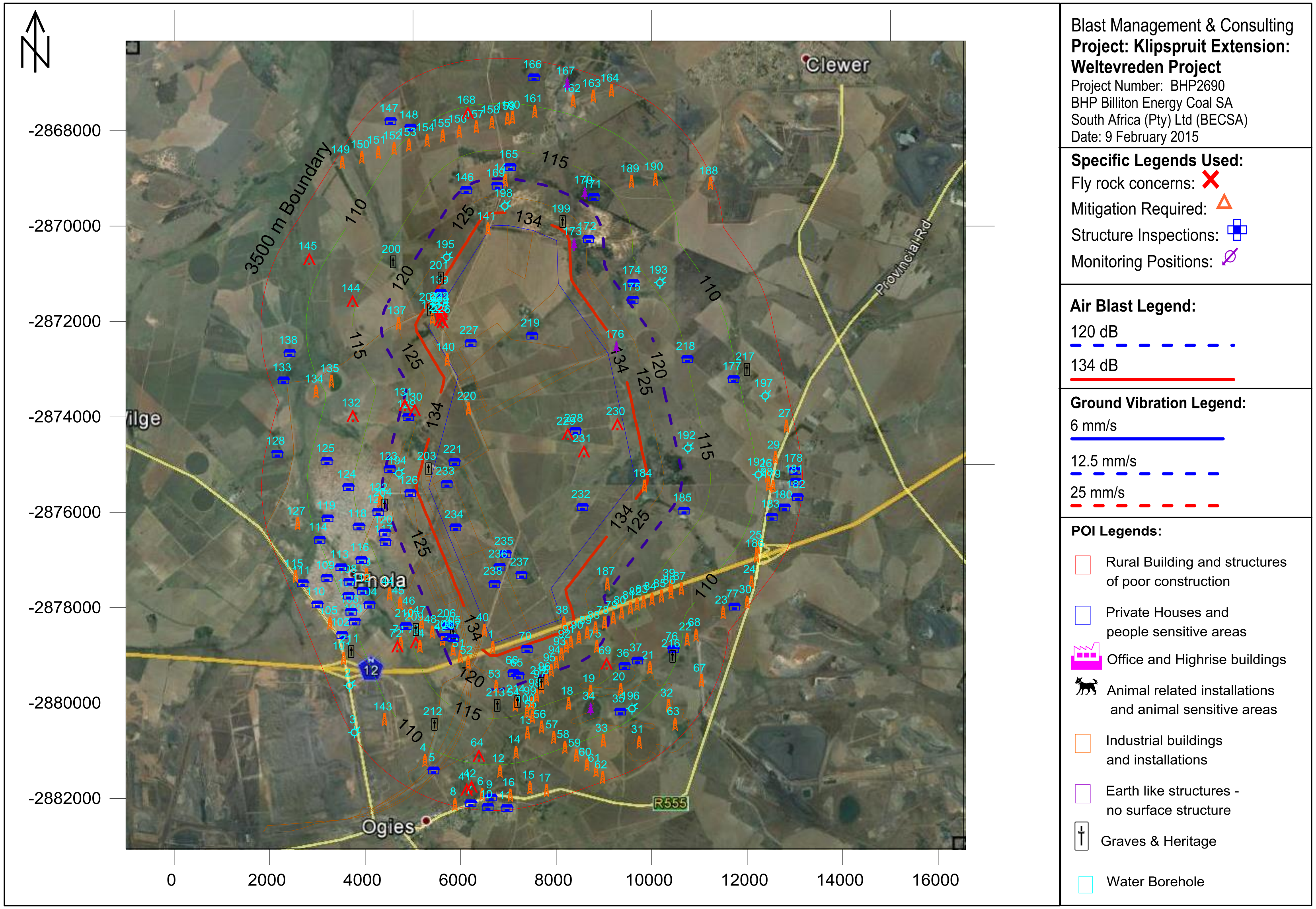

Figure 18: Air blast influence from maximum charge for Pit Area

Table 12: Air blast evaluation for maximum charge for Pit Area

Tag	Description	Classification	Distance (m)	Air blast (dB)	Possible Concern?
1	N12 Road	5	93	144.6	N/A
2	Borehole (BSW 3)	5	3113	107.9	N/A
3	Borehole (KGM B4)	5	3450	106.9	N/A
4	Substation	5	2842	108.9	N/A
5	Buildings/Structures	2	2943	108.5	Acceptable
6	Railroad	5	3176	107.7	N/A
7	Houses	2	3389	107.1	Acceptable
8	Railroad	5	3475	106.8	N/A
9	Houses	2	3235	107.5	Acceptable
10	Houses	2	3439	106.9	Acceptable
11	Sports Terrain	2	3471	106.8	Acceptable
12	Railroad	5	2693	109.5	N/A
13	Railroad	5	2006	112.5	N/A
14	Railroad	5	2336	110.9	N/A
15	Railroad	5	3123	107.9	N/A
16	R555 Road	5	3207	107.6	N/A
17	R555 Road	5	3280	107.4	N/A
18	Railroad	5	1721	114.1	N/A
19	Railroad	5	1631	114.7	N/A
20	Railroad	5	1929	112.9	N/A
21	Railroad	5	2114	112.0	N/A
22	Railroad	5	2663	109.6	N/A
23	Railroad	5	3165	107.8	N/A
24	Railroad	5	3242	107.5	N/A
25	Railroad	5	2934	108.6	N/A
26	Railroad	5	2775	109.1	N/A
27	Railroad	5	3326	107.3	N/A
28	R555 Road	5	2797	109.1	N/A
29	R555 Road	5	2967	108.4	N/A
30	R555 Road	5	3428	106.9	N/A
31	Pivot Irrigation	5	3055	108.1	N/A
32	Pivot Irrigation	5	2886	108.7	N/A
33	Pivot Irrigation	5	2696	109.4	N/A
34	Pan	6	1973	112.7	N/A
35	Buildings/Structures	2	2300	111.1	Acceptable
36	Buildings/Structures (Oakhouse Lodge)	2	1649	114.6	Acceptable
37	Buildings/Structures	2	1815	113.6	Acceptable
38	N12 Road	5	96	144.2	N/A
39	N12 Road	5	1952	112.8	N/A
40	Road	5	62	148.8	N/A
41	Informal Housing	1	3117	107.9	Acceptable
42	Informal Housing	1	3039	108.2	Acceptable
43	Power Lines/Pylons	5	1903	113.1	N/A
44	Power Lines/Pylons	5	1611	114.8	N/A
45	Power Lines/Pylons	5	1481	115.7	N/A
46	Power Lines/Pylons	5	1356	116.6	N/A

47	Power Lines/Pylons	5	1219	117.7	N/A
48	Power Lines/Pylons	5	1086	118.9	N/A
49	Power Lines/Pylons	5	947	120.3	N/A
50	Power Lines/Pylons	5	823	121.8	N/A
51	Power Lines/Pylons	5	734	123.0	N/A
52	Power Lines/Pylons	5	663	124.1	N/A
53	Power Lines/Pylons	5	917	120.7	N/A
54	Power Lines/Pylons	5	1370	116.5	N/A
55	Power Lines/Pylons	5	1725	114.1	N/A
56	Power Lines/Pylons	5	1990	112.6	N/A
57	Power Lines/Pylons	5	2281	111.2	N/A
58	Power Lines/Pylons	5	2551	110.0	N/A
59	Power Lines/Pylons	5	2799	109.0	N/A
60	Power Lines/Pylons	5	3056	108.1	N/A
61	Power Lines/Pylons	5	3235	107.5	N/A
62	Power Lines/Pylons	5	3415	107.0	N/A
63	Dam	5	3245	107.5	N/A
64	Ruins	1	2374	110.8	Acceptable
65	Farm Buildings/Structures	2	811	122.0	Complaint
66	Farm Buildings/Structures	2	728	123.1	Complaint
67	Dam	5	3203	107.6	N/A
68	Conveyor	5	2835	108.9	N/A
69	Informal Housing	1	1327	116.8	Acceptable
70	Farm Buildings/Structures	2	345	130.9	Complaint
71	Dam	5	1776	113.8	N/A
72	Ruins	1	1872	113.2	Acceptable
73	Ruins	1	1484	115.7	Acceptable
74	Cement Dams	5	1437	116.0	N/A
75	Cement Dam	5	938	120.4	N/A
76	Building/Structure	2	2427	110.5	Acceptable
77	Building/Structure	2	3274	107.4	Acceptable
78	Power Lines/Pylons	5	901	120.9	N/A
79	Power Lines/Pylons	5	1081	119.0	N/A
80	Power Lines/Pylons	5	1261	117.4	N/A
81	Power Lines/Pylons	5	1458	115.8	N/A
82	Power Lines/Pylons	5	1606	114.8	N/A
83	Power Lines/Pylons	5	1710	114.2	N/A
84	Power Lines/Pylons	5	1812	113.6	N/A
85	Power Lines/Pylons	5	1932	112.9	N/A
86	Power Lines/Pylons	5	2046	112.3	N/A
87	Power Lines/Pylons	5	2168	111.7	N/A
88	Power Lines/Pylons	5	733	123.0	N/A
89	Power Lines/Pylons	5	611	124.9	N/A
90	Power Lines/Pylons	5	537	126.3	N/A
91	Power Lines/Pylons	5	523	126.5	N/A
92	Power Lines/Pylons	5	577	125.5	N/A
93	Power Lines/Pylons	5	693	123.6	N/A
94	Power Lines/Pylons	5	821	121.8	N/A
95	Power Lines/Pylons	5	939	120.4	N/A

96	Power Lines/Pylons	5	1080	119.0	N/A
97	Power Lines/Pylons	5	1203	117.9	N/A
98	Power Lines/Pylons	5	1336	116.8	N/A
99	Power Lines/Pylons	5	1459	115.8	N/A
100	Power Lines/Pylons	5	1582	115.0	N/A
101	R545 Road	5	3014	108.3	N/A
102	Phola Town Housing Community	2	2855	108.8	Acceptable
103	Phola Town Housing Community	2	2502	110.2	Acceptable
104	Phola Town Housing Community	2	2081	112.1	Acceptable
105	R545 Road	5	2997	108.3	N/A
106	Phola Town Community Buildings	2	2495	110.2	Acceptable
107	Phola Town Community Buildings	2	2414	110.6	Acceptable
108	Phola Town Community Buildings	2	2292	111.1	Acceptable
109	Phola Town Community Buildings	2	2693	109.5	Acceptable
110	Phola Town Housing Community	2	3091	108.0	Acceptable
111	Phola Town Housing Community	2	3204	107.6	Acceptable
112	Phola Town Housing Community	2	2101	112.0	Acceptable
113	Phola Town Housing Community	2	2334	110.9	Acceptable
114	Phola Town Housing Community	2	2530	110.1	Acceptable
115	R545 Road	5	3290	107.4	N/A
116	Mandela Village Community Housing	2	1883	113.2	Acceptable
117	Mandela Village Community Housing	2	1275	117.2	Acceptable
118	Mandela Village Community Buildings	2	1663	114.5	Acceptable
119	Mandela Village Community Housing	2	2216	111.5	Acceptable
120	Mandela Village Community Building	2	1211	117.8	Acceptable
121	Mandela Village Community Housing	2	1177	118.1	Acceptable
122	Reservoir	5	1063	119.1	N/A
123	Mandela Village Community Housing	2	885	121.1	Complaint
124	Mandela Village Community Housing	2	1686	114.3	Acceptable
125	Mandela Village Community Housing	2	2200	111.6	Acceptable
126	Buildings/Structures	2	406	129.2	Complaint
127	Water Treatment Dams	5	2853	108.9	N/A
128	Farm Buildings/Structures	2	3251	107.5	Acceptable
129	Farm Buildings/Structures	2	792	122.2	Complaint
130	Informal Housing	1	702	123.5	Complaint
131	Informal Housing	1	928	120.6	Complaint
132	Informal Housing	1	1923	113.0	Acceptable
133	Buildings/Structures	2	3226	107.6	Acceptable
134	Pivot Irrigation	5	2713	109.4	N/A
135	Pivot Irrigation	5	2325	111.0	N/A
136	Road	5	16	162.7	N/A
137	Road	5	623	124.7	N/A
138	Farm Buildings/Structures	2	2947	108.5	Acceptable
139	Farm Buildings/Structures	2	151	139.5	Problematic
140	Road	5	12	166.1	N/A
141	Road	5	29	156.8	N/A
142	Road	5	941	120.4	N/A
143	Mine Activity	5	2776	109.1	N/A
144	Informal Housing	1	1672	114.4	Acceptable

145	Informal Housing	1	2866	108.8	Acceptable
146	Farm Buildings/Structures	2	917	120.7	Complaint
147	Farm Buildings/Structures	2	3046	108.2	Acceptable
148	Building/Structure	2	2668	109.5	Acceptable
149	Power Lines/Pylons	5	3353	107.2	N/A
150	Power Lines/Pylons	5	3063	108.1	N/A
151	Power Lines/Pylons	5	2823	109.0	N/A
152	Power Lines/Pylons	5	2605	109.8	N/A
153	Power Lines/Pylons	5	2421	110.6	N/A
154	Power Lines/Pylons	5	2241	111.4	N/A
155	Power Lines/Pylons	5	2142	111.8	N/A
156	Power Lines/Pylons	5	2084	112.1	N/A
157	Power Lines/Pylons	5	2098	112.1	N/A
158	Power Lines/Pylons	5	2163	111.7	N/A
159	Power Lines/Pylons	5	2229	111.4	N/A
160	Power Lines/Pylons	5	2258	111.3	N/A
161	Power Lines/Pylons	5	2454	110.4	N/A
162	Power Lines/Pylons	5	2840	108.9	N/A
163	Power Lines/Pylons	5	3087	108.0	N/A
164	Power Lines/Pylons	5	3341	107.2	N/A
165	Farm Buildings/Structures	2	1223	117.7	Acceptable
166	Farm Buildings/Structures	2	3153	107.8	Acceptable
167	Pan	6	3162	107.8	N/A
168	Ruins	1	2420	110.6	Acceptable
169	Farm Buildings/Structures	2	835	121.7	Complaint
170	Pan	6	1171	118.1	N/A
171	Farm Buildings/Structures	2	1212	117.8	Acceptable
172	Buildings/Structures	2	669	124.0	Complaint
173	Pan	6	364	130.3	N/A
174	Farm Buildings/Structures	2	1286	117.2	Acceptable
175	Farm Buildings/Structures	2	1076	119.0	Acceptable
176	Pan	6	223	135.4	N/A
177	Farm Buildings/Structures	2	2455	110.4	Acceptable
178	Buildings/Structures	2	3354	107.2	Acceptable
179	Industrial Area	5	2898	108.7	N/A
180	Farm Buildings/Structures	2	3190	107.7	Acceptable
181	Buildings/Structures	2	3365	107.1	Acceptable
182	Buildings/Structures	2	3426	106.9	Acceptable
183	Buildings/Structures	2	2973	108.4	Acceptable
184	Dam	5	240	134.7	N/A
185	Building/Structure	2	1214	117.8	Acceptable
186	N12 Road Bridge	5	3008	108.3	N/A
187	Dam	5	879	121.1	N/A
188	Tailings Dam	5	3438	106.9	N/A
189	Dam	5	2007	112.5	N/A
190	Dam	5	2439	110.5	N/A
191	Borehole (BHP_P04)	5	2582	109.9	N/A
192	Borehole (BHP_P05)	5	1211	117.8	N/A
193	Borehole (BHP_P06)	5	1743	114.0	N/A

194	Borehole (BHP_P07)	5	678	123.8	N/A
195	Borehole (BHP_P08)	5	441	128.3	N/A
196	Borehole (BHP_P10)	5	2392	110.7	N/A
197	Borehole (BHP_P11)	5	3027	108.2	N/A
198	Borehole (BHP_P12)	5	405	129.2	N/A
199	Burial Grounds and Graves (GY15)	7	419	128.9	N/A
200	Burial Grounds and Graves (GY12)	7	1340	116.7	N/A
201	Burial Grounds and Graves (GY13)	7	313	131.9	N/A
202	Burial Grounds and Graves (GY14)	7	147	139.8	N/A
203	Burial Grounds and Graves (GY9)	7	103	143.5	N/A
204	Burial Grounds and Graves (GY10)	7	1000	119.8	N/A
205	Burial Grounds and Graves (GY19)	7	685	123.7	N/A
206	Built Environment	2	728	123.1	Complaint
207	Built Environment	2	728	123.1	Complaint
208	Built Environment	2	870	121.2	Complaint
209	Burial Grounds and Graves	7	1382	116.4	N/A
210	Built Environment	2	1546	115.2	Acceptable
211	Burial Grounds and Graves (GY 11)	7	2811	109.0	N/A
212	Burial Grounds and Graves	7	2095	112.1	N/A
213	Burial Grounds and Graves (GY7)	7	1310	117.0	N/A
214	Burial Grounds and Graves (GY5)	7	1320	116.9	N/A
215	Burial Grounds and Graves (GY6)	7	1124	118.6	N/A
216	Burial Ground and Graves (GY16)	7	2452	110.4	N/A
217	Burial Grounds and Graves (GY1)	7	2770	109.2	N/A
218	Built Environment	2	1597	114.9	Acceptable

13.10 Summary of findings for air blast

As indicated the prediction of air blast is subjective and is used to help identify critical points as best as possible. Actual blasting operation preparation plays a very significant part in the outcome of air blast levels. It is known that air blast is the aspect that contributes to complaints from neighbours more than ground vibration even at levels not range of causing damage.

Review of the air blast recorded and basis for these calculations do indicate that air blast levels are of lesser concern than ground vibration. Structures within 280 m from the pit boundaries are generally problematic and structures found up to 1000 m could experience levels of air blast that could contribute to complaints. Air blast predicted for the maximum charge ranges between 106.9 and 139.5 dB where structures are of concern. The minimum charge shows significant lower levels.

Concern that complaints may arise from possible secondary influences from levels greater than 120dB reaches the nearest 15 points of interest up to 928m. 1 of these points of interest identified shows levels greater than the limits allowed. This is at POI 139 (Farm Buildings/Structures).

Possible damages to structures are certainly not expected at distances greater than 300 m. Possible influence of rattles and some shaking may be experienced but at levels less than damaging. Rather irritation than damaging.

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. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. This mining area is located such that “free blasting” – meaning no controls on blast preparation – will not be possible.

13.11 Fly-rock Modelling Results and Impact of fly rock

Review of the factors that contribute to fly rock it is certain that if no stemming control is exerted there will be fly rock. Current stemming proposed requires a safe exclusion zone of at least 386 m. Fly could be seen to travel up to this distance. This distance is certain to include various infrastructures located around the pit area. Figure 19 below shows the relationship burden or stemming length towards expected throw distance. Throw distance considered here on the same level as the free face. Landing level of elements lower than free face could see longer distances. Optimal throw distance is also observed at 45 degree angles of departure. The main concern is area on the north western, western and southern side of the pit area. Figure 20 shows POI’s identified where fly rock is of concern and falls within the exclusion zone from the pit boundary.

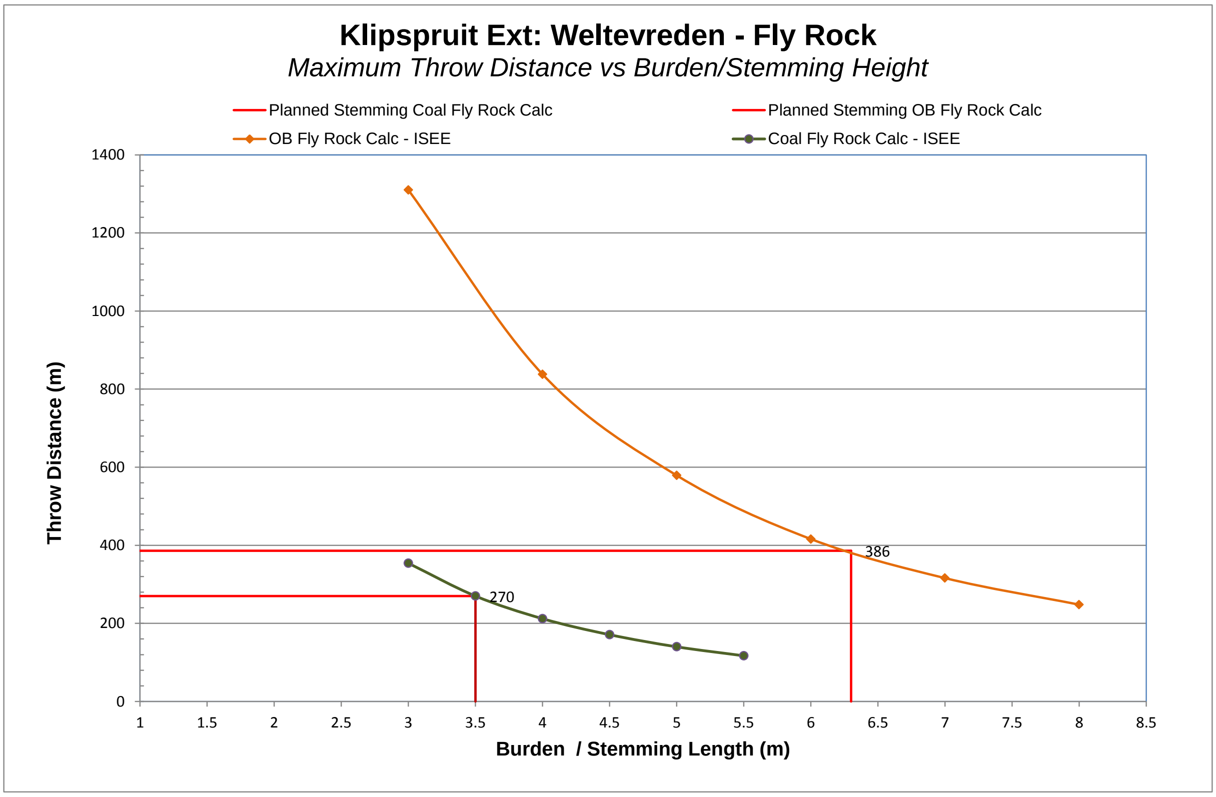

Figure 19: Predicted Fly rock

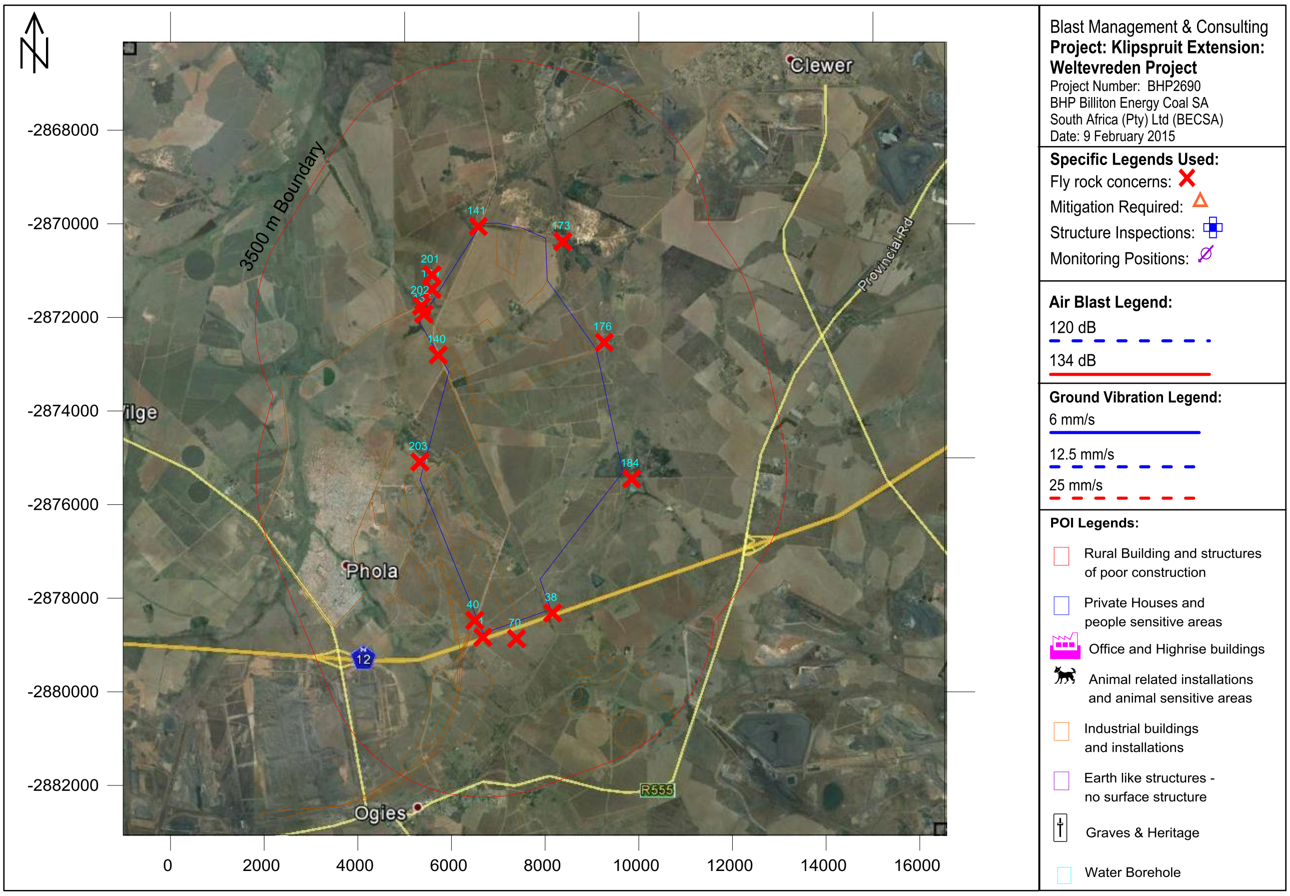

Figure 20: Predicted Fly rock zone areas

13.12 Noxious fumes Influence Results

The occurrence of fumes in the form the NOx gaseous format is not a given and very dependent on various factors. However the occurrences of fumes should be closely monitored. It is not assumed that 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.

13.13 Water well influence

Boreholes for water were evaluated for possible influence as well. There are various boreholes in the area. Ten boreholes were identified. These boreholes range from 405 m to 3450 m from pit boundary. The expected levels of ground vibration are lower than the limit applied for water boreholes.

13.14 Potential Environmental Impact Assessment: Operational Phase

The following is the impact assessment of the various concerns covered by this report. The following section defines methodology applied for assessment. 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.

13.14.1 Assessment Methodology

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.

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 14, which is extracted from Table 13. Table 15 shows the outcomes for the assessment done.

Table 13: 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 14: Significance threshold limits

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

13.14.2 Assessment

Table 15: Risk Assessment Outcome before 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	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	Ground vibration Impact on boreholes					
Mitigation required	Reduce Charge Mass/Delay over decreasing distance towards POI's of concern, Redrill boreholes further away					
Parameters	*Severity*	*Spatial scale*	*Duration*	*Probability*	*Significant rating*	
Pre-Mitigation	6	4	4	6	84	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	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	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	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	Fly Rock Impact on houses					
Mitigation required	Increase stemming length, controls put in place for management of stemming lengths, Relocate POI's of concern at least 500m					
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	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	3	4	4	4	44	Minor

Criteria	**Details/ Discussion**					
Project activity	Activity 1:Blasting operations					
Mining phase/s	Operational Phase					
Description of impact	Impact of Fumes - Houses					
Mitigation required	Use correct product, Control product quality, prevent sleep time for charged blast holes, same day charge and blast					
Parameters	*Severity*	*Spatial scale*	*Duration*	*Probability*	*Significant rating*	
Pre-Mitigation	3	4	4	4	44	Minor
Post-Mitigation	3	4	4	3	33	Negligible

13.14.3 Mitigations

In review of the evaluations made it is certain that specific mitigation will be required with regards to the mining operations with regards to ground vibration, air blast and fly rock. There are specific area that will require changes to drilling and blasting operations to mitigate the effects.

Figure 21 shows identified areas with biggest concerns with regards to ground vibration and air blast. Structures indicated ranges in distances between 12 m and 928 m from the pit area. Considerations of relocation should be given to house structures that are within 500 m area from the pit boundary. These are structures located at POI's listed in Table 16 below.

Table 16: Relocation of structures / houses

Tag	Description	Y	X	Distance (m)
70	Farm Buildings/Structures	-7389.55	2878864.58	345
126	Buildings/Structures	-4946.09261	2875595.3	406
139	Farm Buildings/Structures	-5582.08777	2871397.8	151
140	Road	-5716.69796	2872803.3	12
141	Road	-6571.33799	2870057.7	29
203	Burial Grounds and Graves (GY9)	-5326.17238	2875089.5	103

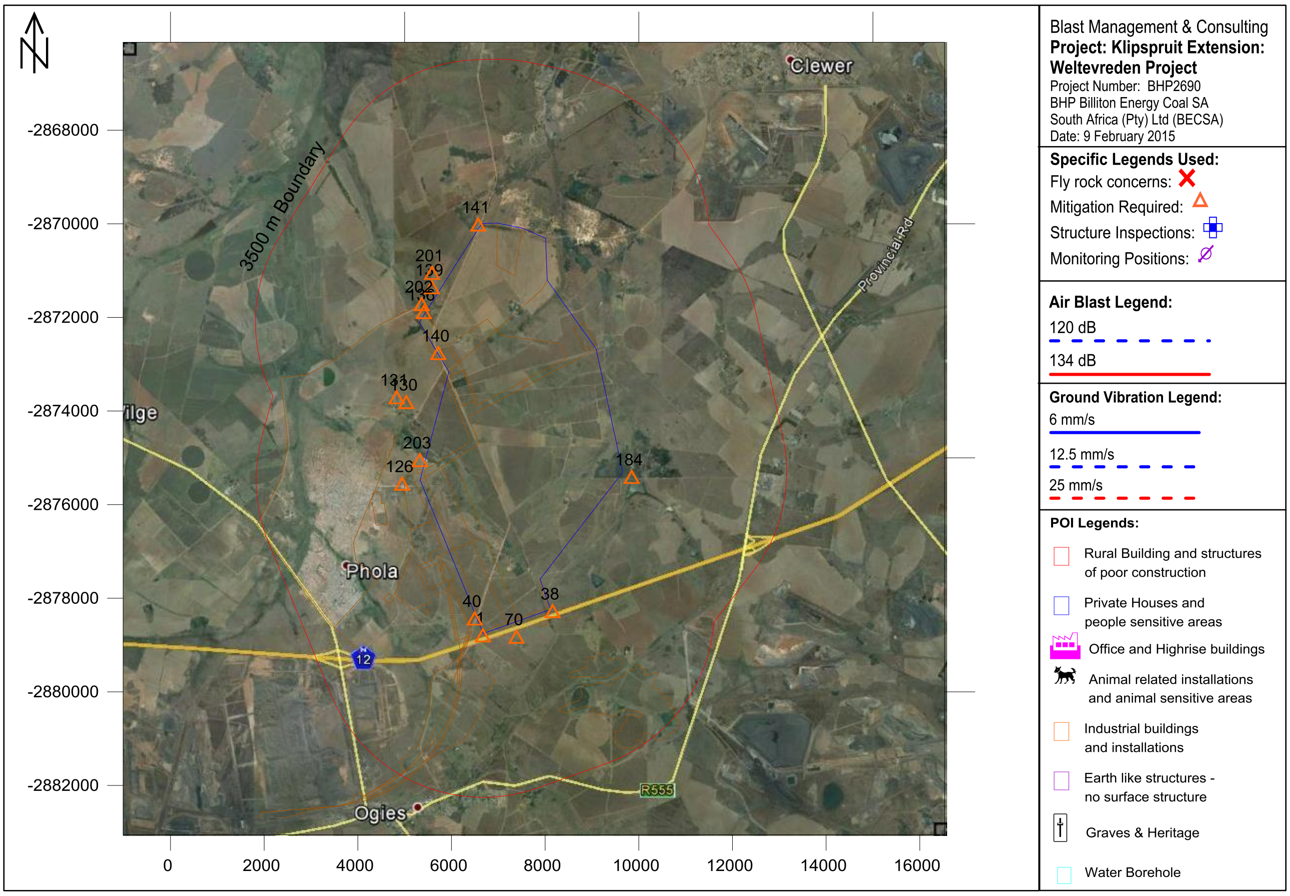

Figure 21: Problematic structures

Mitigation of ground vibration 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.

Reduced charge mass per delay on the current blast design can be done using electronic initiation for the purpose of achieving a single blast hole per delay. This will reduce the effect of vibration significantly. Table 17 below shows POI's that are considered problematic from the maximum charge evaluated. The results from reduced charge mass on POI's currently problematic on maximum charge evaluation are shown in Table 18. Indicated in **red** in Table 18 is POI's that are too close to the respective mining areas that reducing the charge becomes unrealistic and will require relocation or reducing the pit size to increase distance between the structure and the pit.

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 the minimum distance required between blast and POI at the maximum charge used to maintain accepted levels of ground vibration.

Table 17: Structures at North and South Pit Area identified as problematic

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	N12 Road	150	93	2224	375.6	Problematic
38	N12 Road	150	96	2224	350.9	Problematic
40	Road	150	62	2224	735.8	Problematic
70	Farm Buildings/Structures	25	345	2224	42.9	Problematic
126	Buildings/Structures	25	406	2224	32.8	Problematic
130	Informal Housing	6	702	2224	13.3	Problematic
131	Informal Housing	6	928	2224	8.4	Problematic
136	Road	150	16	2224	6608.1	Problematic
139	Farm Buildings/Structures	25	151	2224	167.3	Problematic
140	Road	150	12	2224	11328.8	Problematic
141	Road	150	29	2224	2602.2	Problematic
184	Dam	50	240	2224	78.0	Problematic
201	Burial Grounds and Graves (GY13)	50	313	2224	50.3	Problematic
202	Burial Grounds and Graves (GY14)	50	147	2224	175.7	Problematic
203	Burial Grounds and Graves (GY9)	50	103	2224	316.0	Problematic

Table 18: Mitigation suggested for blasting operations – Reduced charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
1	N12 Road	150	93	731	150.0	Acceptable
38	N12 Road	150	96	794	150.0	Acceptable
40	Road	150	62	324	150.0	Acceptable
70	Farm Buildings/Structures	25	345	1156	25.0	Acceptable

126	Buildings/Structures	25	406	1603	25.0	Acceptable
130	Informal Housing	6	702	850	6.0	Acceptable
131	Informal Housing	6	928	1484	6.0	Acceptable
136	Road	150	16	23	150.0	Acceptable
139	Farm Buildings/Structures	25	151	222	25.0	Acceptable
140	Road	150	12	12	150.0	Acceptable
141	Road	150	29	70	150.0	Acceptable
184	Dam	50	240	1297	50.0	Acceptable
201	Burial Grounds and Graves (GY13)	50	313	2209	50.0	Acceptable
202	Burial Grounds and Graves (GY14)	50	147	485	50.0	Acceptable
203	Burial Grounds and Graves (GY9)	50	103	238	50.0	Acceptable

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

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Human Tolerance @ 30Hz
1	N12 Road	150	166	2338	150.0	Acceptable
38	N12 Road	150	166	2338	150.0	Acceptable
40	Road	150	166	2338	150.0	Acceptable
70	Farm Buildings/Structures	25	490	2338	25.0	Acceptable
126	Buildings/Structures	25	490	2338	25.0	Acceptable
130	Informal Housing	6	1165	2338	6.0	Acceptable
131	Informal Housing	6	1165	2338	6.0	Acceptable
136	Road	150	166	2338	150.0	Acceptable
139	Farm Buildings/Structures	25	490	2338	25.0	Acceptable
140	Road	150	166	2338	150.0	Acceptable
141	Road	150	166	2338	150.0	Acceptable
184	Dam	50	322	2338	50.0	Acceptable
201	Burial Grounds and Graves (GY13)	50	322	2338	50.0	Acceptable
202	Burial Grounds and Graves (GY14)	50	322	2338	50.0	Acceptable
203	Burial Grounds and Graves (GY9)	50	322	2338	50.0	Acceptable

14 Closure Phase

There are no specific indications that drilling and blasting will be required for the closure phase of the project. Thus no specific expected with regards to ground vibration, air blast and fly rock. No specific evaluation done to evaluate any influence from blasting operations.

15 Alternatives

No alternative mining procedure or methodology is currently being investigated as far it is known to the author of this report.

16 Monitoring

This is a new operation with no monitoring program in place yet. It will be highly recommended that a detail monitoring program be put in place. Client need to consider the following suggested monitoring points. These points are not fixed but should be considered in relation to the blast location. Ground vibration and air blast is monitored using a seismograph. Monitoring can be done in permanent stations or on ad hoc basis – per blast basis monitoring. Additionally to this it is recommended that a video of each blast is done as a standard. Monitoring of ground vibration and air blast is done to ensure that the generated levels of ground vibration and air blast comply with recommendations. Proposed positions were also selected to indicate 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. Various monitoring positions were identified should be considered as a minimum. Monitor positions are indicated in Figure 22. Table 20 shows the list of recommended positions.

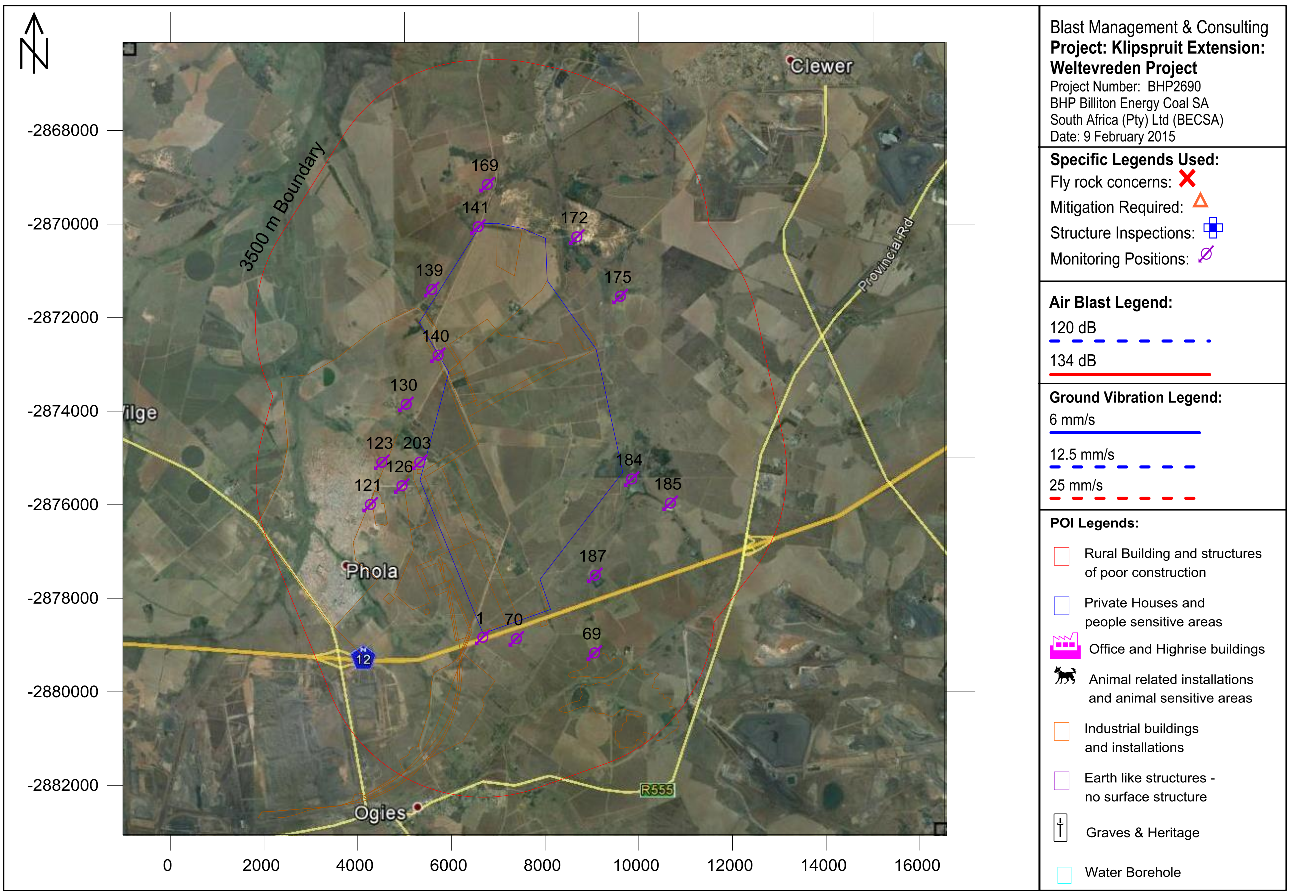

Figure 22: Proposed monitoring points

Table 20: Suggested monitoring positions

Tag	Description	Classification	Y	X
1	N12 Road	5	-6671.14	2878834.35
70	Farm Buildings/Structures	2	-7389.55	2878864.58
126	Buildings/Structures	2	-4946.09261	2875595.3
130	Informal Housing	1	-5035.72773	2873850.8
139	Farm Buildings/Structures	2	-5582.08777	2871397.8
140	Road	5	-5716.69796	2872803.3
141	Road	5	-6571.33799	2870057.7
184	Dam	5	-9848.12253	2875449.8
203	Burial Grounds and Graves (GY9)	7	-5326.17238	2875089.5
69	Informal Housing	1	-9055.45	2879168.13
121	Mandela Village Community Housing	2	-4270.93497	2875993.8
123	Mandela Village Community Housing	2	-4516.46221	2875092.4
169	Farm Buildings/Structures	2	-6765.43879	2869154.3
172	Buildings/Structures	2	-8677.1213	2870273.6
175	Farm Buildings/Structures	2	-9606.04044	2871544.8
185	Building/Structure	2	-10675.52702	2875964.6
187	Dam	5	-9070.62572	2877506.2

17 Recommendations

The location of the site and the current objections will require very detail best blasting practice program. In view of this the following is recommended to be conducted prior and during the operations:

17.1 Best Practice

It is highly recommended that a best practice code of conduct must be written that incorporates all the recommendations below and general blasting practices to ensure safe and efficient operations of the project. Detail of this is not provided here but can be provided if required.

17.2 Relocation

Due to the location of some of the houses in relation to the pit areas relocation should be considered. With regards to influences such as ground vibration and air blast this distance may be closer but no less than 500m. Relocation is a very sensitive process. There are specific specialists in the field that should be engaged to facilitate this process.

17.3 Safe blasting distance from communities

A minimum safe distance 386 m is required but recommended is that a minimum of 500m must be maintained from any blast done. This may be greater but not less. The blaster has a legal obligation concerning the safe distance and he needs to determine this distance.

17.4 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.

17.5 Road Closure

There are various gravel roads and pathways closer than 500m and within the planned pit areas. The gravel road that is routed directly through the pit area should be re-routed around the pit. The N12 is a concern when blasting is done closer than 500 m. The highway will need to be close for the duration of blasting. A temporary road closure procedure must be drawn up with the necessary road agencies and authorities.

17.6 Monitoring

It is highly recommended that a monitoring program be put in place. This 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. Section 16 gives detail of proposed monitoring points for ground vibration and air blast monitoring.

Further to ground vibration and air blast monitoring the following monitoring should be done as well.

17.6.1 Wind and weather station

A weather station will help with wind direction and speed and general weather conditions. This data will help determining if blasting should be postponed if conditions are not perfect.

17.6.2 Video monitoring of each blast

Video of each blast will help to define if fly rock occurred and from where. Immediate mitigation measure can then be applied if necessary. The video will also be a record of blast conditions.

17.6.3 Regular monitoring of water boreholes

Apart from the legal requirement of monitoring water qualities additional monitoring of boreholes close to pit area must be done to review possible damage from blasting.

17.6.4 Structural monitoring

Additional consideration that can be done in order to protect oneself from false claims is that a number of structures are to be identified as a representative sample and these structures are instrumented with crack gauges during the photographic survey and re-inspected on a regular basis. The gauges measures crack changes and tracking of the crack changes can be made on a regular basis. Gauges used for this is the OZA Gauge. The gauge is a mechanical gauge stuck over a crack and the changes of the crack read from a grid. These changes can then be read and plotted.

Figure 23 below shows example of applicable of such gauge and tracking report. Figure 24 shows the resultant movement as recorded from the gauge and Figure 25 shows the displacement as read from the gauge.

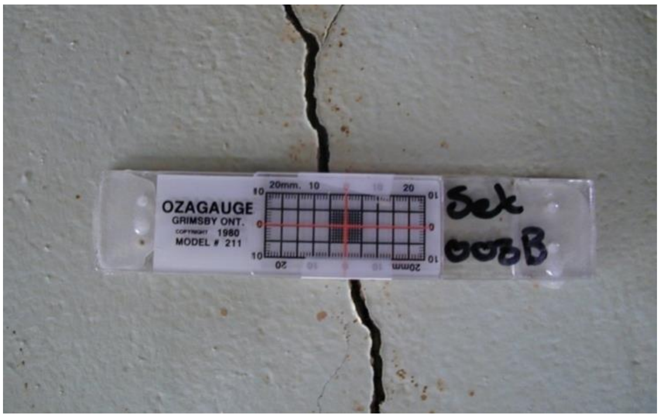

Figure 23: Example of gauge used

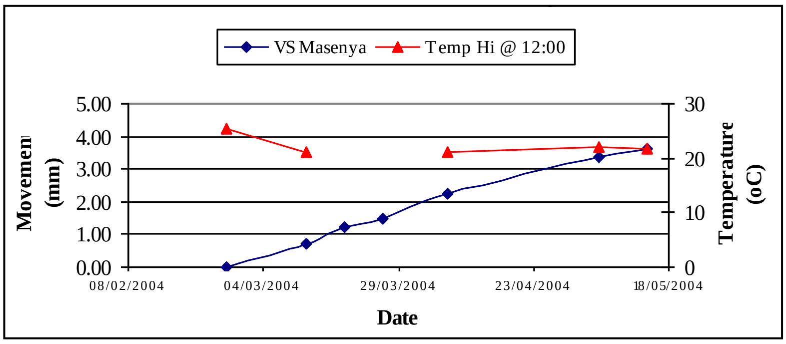

Figure 24: shows movement over period of time as calculated from the gauge readings

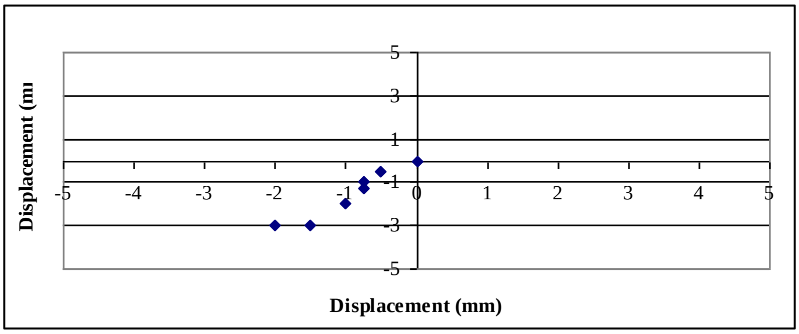

Figure 25: Shows actual displacement as read from the gauge

17.7 Photographic Inspections

The option of photographic survey is recommended in totality as per normal survey. 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. A 1500m equates to 3.8 mm/s of expected ground vibration for the charge used. This level of ground vibration is already perceptible and people in structures could experience ground vibration negatively. Figure 26 shows the 1500m area for the pit areas to be considered. Structures inside the pit are expected to be relocated.

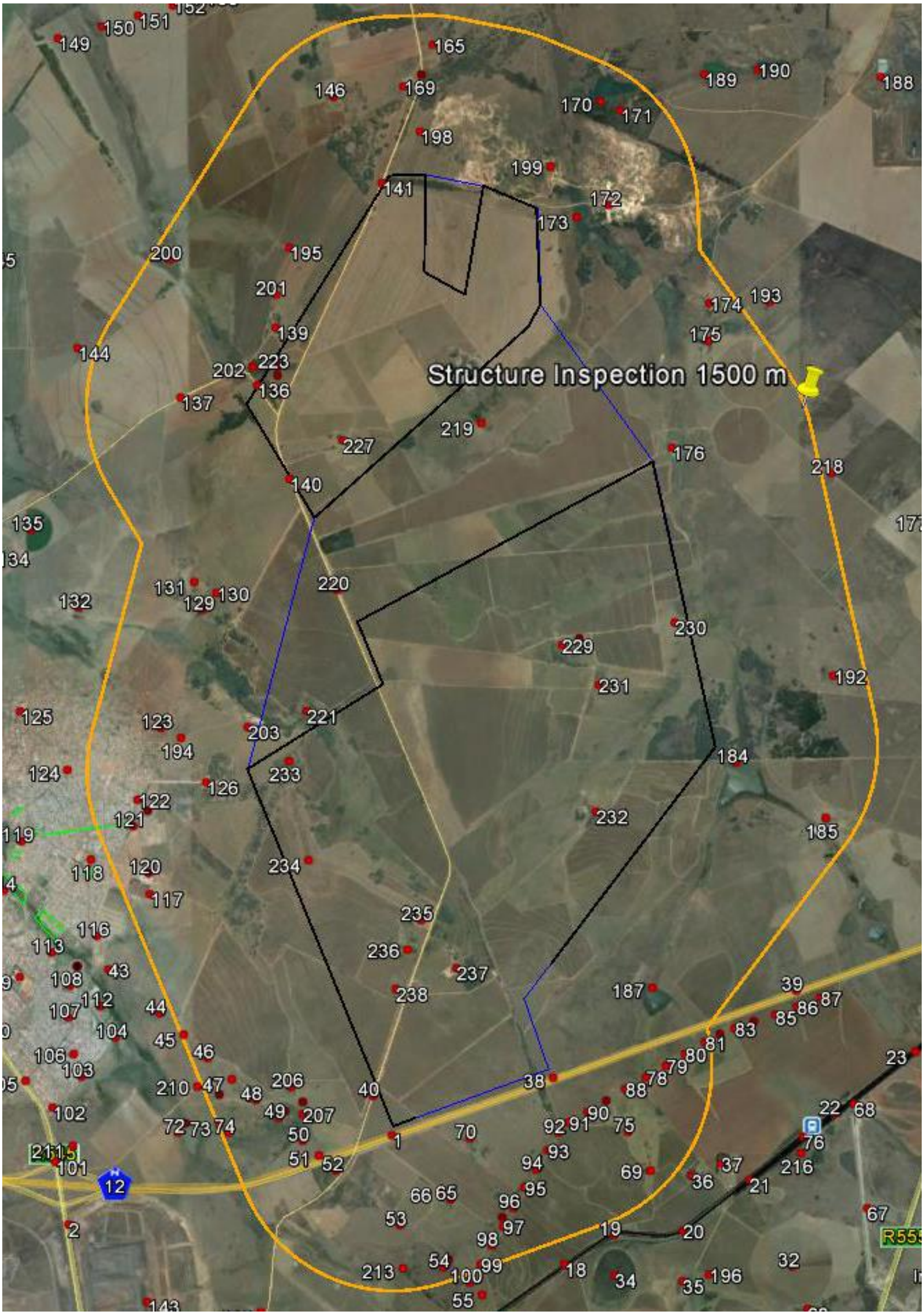

Figure 26: 1500m area around pit area identified for structure inspections.

17.8 Recommended ground vibration and air blast levels

The following ground vibration and air blast levels are recommended for blasting operations in this area. Table 21 below gives limits for ground vibration and air blast.

Table 21: 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 – include structures build according to NHBRC regulations which include schools, government buildings etc.	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 typically found in the project area and traditional mud houses	6	

17.9 Stemming length

The current proposed stemming lengths of 6.3 m for a 250 mm diameter blast hole must be maintained at least to ensure control on fly rock. Specific designs where distances and blast is known should be considered with this. Stemming lengths can be increased but not decreased.

17.10 Blasting times

Blasting times must be selected carefully. There are various schools in the area and should be considered. In most cases it is best to blast just prior to school closing time. Then it is relative certain that school children are in one area gathered.

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. A recommended good blasting time will be between 12:00 and 15:00.

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.

17.11 Ground vibration survey in the form of signature trace

The aim of signature trace study is to quantify the site specific constants. This will aid in predicting ground vibrations caused by the production blasting more accurately. The formula that will be used is the generally accepted scaled distance formula. The utilization of this formula is standard practice. The analysis of the data will also give an indication of frequency decay over distance. The exploration and deployment of the formula is fully explored in sections above. Each blast hole must be charged and then detonated separately. The resulting ground vibration is then measured on multiple seismographs placed at various distances.

The process required for a signature trace study can be described as follows. Test blasts are prepared consisting of three sets or more of three blast holes ranging in depth. A test blast hole is prepared with charge masses close to the expected maximum charge that will be used in this area. Seismographs are placed at varying distances from the test blast hole. The test blast hole is fired and data recorded. The seismographs are kept in the same monitoring position for each of the three trial blasts. The data is then applied in a modelling process that will yield results for prediction of ground vibration in future blasting operations and desired timing between charges detonating without constructive interference. Thus firing times that will help minimize the levels of ground vibration.

17.12 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. The study intends to address as much as possible for the area where the project is located. Assumptions are made based on best practice specifically for ground vibration, air blast and fly rock. These factors can be controlled and is manageable. It must be considered that 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 Conclusion

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

The project area consists mainly of two pit areas in the mining rights area. The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500m from the two opencast pit areas. The base areas of the two opencast areas were combined as one for the study. The influences from blasting operations was evaluated for possible influence on surface structures that ranged from well build structures to more informal building style, farming activities, industrial structures such ass power lines, roads and dams.

Ground vibration due to blasting operations was evaluated for identified POI's over the whole area. These POI's ranged in distances between 12 m and 3475 m with resulting ground vibration levels ranging from very high to acceptable levels and as low as 0.9 mm/s. Specific structures and installation were identified where ground vibration levels are expected to be damaging. In these cases mitigation of reduced charging is addressed and recommended. The most concerning is a farm house located on the northern side of the pit area and the N12 highway on the southern side. There are also burial grounds and graveyards that will require specific attention. Structures inside the pit areas will need relocation and negotiations regarding this are recommended.

Air blast levels indicated lesser of concern than ground vibration. Mainly one structure was identified where levels could be problematic. This is based on a stemming length of 25 times the blast hole diameter which is a start level for stemming control. Stemming control will have the greatest influence on air blast control. Air blast levels at the structure of concern are expected to 139.5 dB at 151 m. Levels at closer distances will be higher and further definitely be lower. Mitigations recommended on ground vibration will also contribute to reduction of air blast. However mitigation of air blast is primarily found in proper stemming control measures. 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.

Stemming control for air blast will also contribute to control on fly rock. Predicted fly rock safe exclusion zone is a minimum of 386 m. Various structures and installations are found within this range. Careful planning will be required to manage the effect of fly rock. Safe clearance areas will need to be defined and adhered too at all times.

Various recommendations are submitted that should be considered in the final code of practise for the mine. It is believed that this report will advise and assist in setting up and define a best practise code for operations at the project area.

This concludes this investigation blasting operations impact for the Klipspruit Extension: Weltevreden Project.

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