APPENDIX E: ADDENDUM TO BLASTING IMPACT ASSESSMENT – UNDERGROUND BLASTING

Blast Management & Consulting

Quality Service on Time

Addendum Report: Underground Blasting Impact Assessment Waterberg JV Resources (Pty) Ltd Proposed Waterberg Project	
Date:	01 November 2019
BM&C Ref No:	Platinum Group Metals_Waterberg Project_EIAReport_190614V00
Clienf Ref No:	n/a
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ii. Study Team Qualifications and Background

The study team comprises J D Zeeman (as the 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 at various levels for mining companies in South Africa, Botswana, Namibia, Mozambique, Democratic Republic of Congo, Sierra Leone and Côte d'Ivoire.

J D Zeeman holds 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 Explosive 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, which means that the results and findings may not all be positive for the client. Blast Management &

Consulting has the required expertise to conduct such an investigation and draft the specialist report relevant to the study. Blast Management & Consulting did not engage in any behaviour that could be result in a conflict of interest in undertaking this study.

iv. Document Control:

Name & Company	Responsibility	Action	Date	Signature
JD Zeeman Blast Management & Consulting	Consultant	Report Finalise	01/11/2019	

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List of Acronyms used in this Report

a and b	Site Constant
B	Burden (m)
BH	Blast Hole
BM&C	Blast Management & Consulting
D	Distance (m)
E	Explosive Mass (kg)
EIA	Environmental Impact Assessment
Freq.	Frequency
k	Factor value
M	Charge Height
m (SH)	Stemming height
M/S	Magnitude/Severity
Mc	Charge mass per metre column
P	Probability
POI	Points of Interest
PPD	Peak particle displacement
PPV	Peak Particle Velocity
PVS	Peak vector sum
SH	Stemming height (m)
T	Blasted Tonnage
USBM	United States Bureau of Mine
WGS 84	Coordinates (South African)
WM	With Mitigation Measures
WOM	Without Mitigation Measures

List of Units used in this Report

%	percentage
cm	centimetre
g/cm^3	gram per cubic centimetre
Hz	frequency
kg	kilogram
kg/m^3	kilogram per cubic metre
kg/t	kilogram per tonne
m	metre
m^2	metre squared
mm/s	millimetres per second

mm/s^2	millimetres per second square
ms	milliseconds

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1 Executive Summary

Blast Management & Consulting (BM&C) was requested to conduct an initial review of possible impacts with regards to underground blasting operations. Ground vibration is the main component as a result from blasting operations. Ground vibration only was considered in this report and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

Planed blasting operations for underground access development and production was considered. The decline access and underground production areas vary in depth from surface over a period. Ground vibration expected was calculated for different depths below surface with consideration of location of the underground workings in relation to surface infrastructure. Levels of ground vibration expected is significant ranging from 3.3 mm/s and 28.9 mm/s for all underground blasting operations. The shaft development has least possible influence as the shafts are far enough away from private infrastructure. The Central Mine underground workings is located away from any village areas. Only the South mine has possible influence as it is located directly under the Keiting Village. Possible influence is limited but will need to be confirmed from actual measurements to be done. Expected levels for the Keiting Village range between 3.3 mm/s and 11.9 mm/s. These levels were calculated as a worst-case scenario. People may experience these levels as unpleasant.

This concludes this investigation for the proposed Waterberg Project underground blasting operations. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

2 Introduction

The Waterberg Project is located approximately 80km northwest of Polokwane and approximately 25km southwest of Bochum in the southern portion of the Blouberg Local Municipality of the Capricorn District Municipality, Limpopo province of the Republic of South Africa at coordinates (Lat/Lon WGS84) 23°22'41.81"S; 28°53'35.62"E and will comprise the following Farms:

- Rosamond 357 LR;
- Millstream 358 LR;
- Disseldorp 369 LR;
- Ketting 368 LR;
- Lomondside 323 LR;
- Early Dawn 361 LR;
- Old Langsine 360 LR;
- Langbryde 324 LR;
- Goedetrouw 366 LR; and
- Portion 1 of Goedetrouw 366 LR
- Portion 1 of Norma 365 LR
- Remaining Extent of Norma 365 LR; and
- Portions 10, 12, 13 and 14 of the Farm Harriet's Wish"

The mineral resources targeted are mineable platinum group metals, mainly palladium. The resources are in a newly discovered part of the Bushveld Complex under cover rocks. Two new layers for platinum group metals were discovered in 2011 and 2012 by the company’s founders. The “T and F reefs” at Waterberg are distinct from the known Merensky, UG-2 and Platreef zones, known previously. The deposit is 3m up to 100m thick and dips at 35-40 degrees. This configuration requires mechanised mining skills and equipment maintenance skills.

This project is a greenfields project with no existing blasting operations.

As part of the Environmental Impact Assessment (EIA), Blast Management & Consulting (BM&C) was contracted to perform a review of possible impacts from blasting operations and specifically for the proposed Waterberg Mine Project. Ground vibration, air blast and fly rock are some of the aspects that result from blasting operations and this study considers the possible influences that blasting may have on the surrounding area in this respect. The report concentrates on ground vibration and air blast and intends to provide information, calculations, predictions, possible influences and mitigating aspects of blasting operations for the project.

3 Objectives

The document is an addendum to original impact assessment report with objective of outlining the expected environmental effects that blasting operations could have from underground blasting operations on the surface areas directly above. This study investigates the related influences mainly of expected ground vibration influence on surface installations, houses and the owners or occupants. Factors such as air blast and fly rock are not effects that will have influence on surface.

The objectives were dealt with whilst taking specific protocols into consideration. The protocols applied in this document are based on the author's experience, guidelines taken from literature research, client requirements and general indicators in the various appropriate pieces of South African legislation. There is no direct reference in the following acts to requirements and limits on the effect of ground vibration and air blast and some of the aspects addressed in this report:

- 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;
- Explosives Act No. 15 of 2003.

The guidelines and safe blasting criteria are based on internationally accepted standards and specifically criteria for safe blasting for ground vibration and recommendations on air blast published by the United States Bureau of Mines (USBM). There are no specific South African standards and the USBM is well accepted as standard for South Africa.

4 Scope of blast impact study

The scope of the addendum study is defined as defining possible impact from underground blasting operations on surface infrastructure. The terms of reference can be summarised according to the following steps with regard to ground vibration only.

- Background information of the proposed site;
- Blasting Operation Requirements;
- Site specific evaluation of blasting operations according to the following:
    - Evaluation of expected ground vibration levels from blasting operations at specific distances and on structures in surrounding areas;
    - Evaluation of expected ground vibration influence on neighbouring communities;
- Impact Assessment;

- Mitigations;
- Recommendations;
- Conclusion.

5 Study area

The Waterberg Project is located approximately 80km northwest of Polokwane and approximately 25km southwest of Bochum in the southern portion of the Blouberg Local Municipality of the Capricorn District Municipality, Limpopo province of the Republic of South Africa at coordinates (Lat/Lon WGS84) 23°22'41.81"S; 28°53'35.62"E.

Figure 1 shows a Locality Map of the proposed Project area. Figure 2 shows the mining area map with infrastructure.

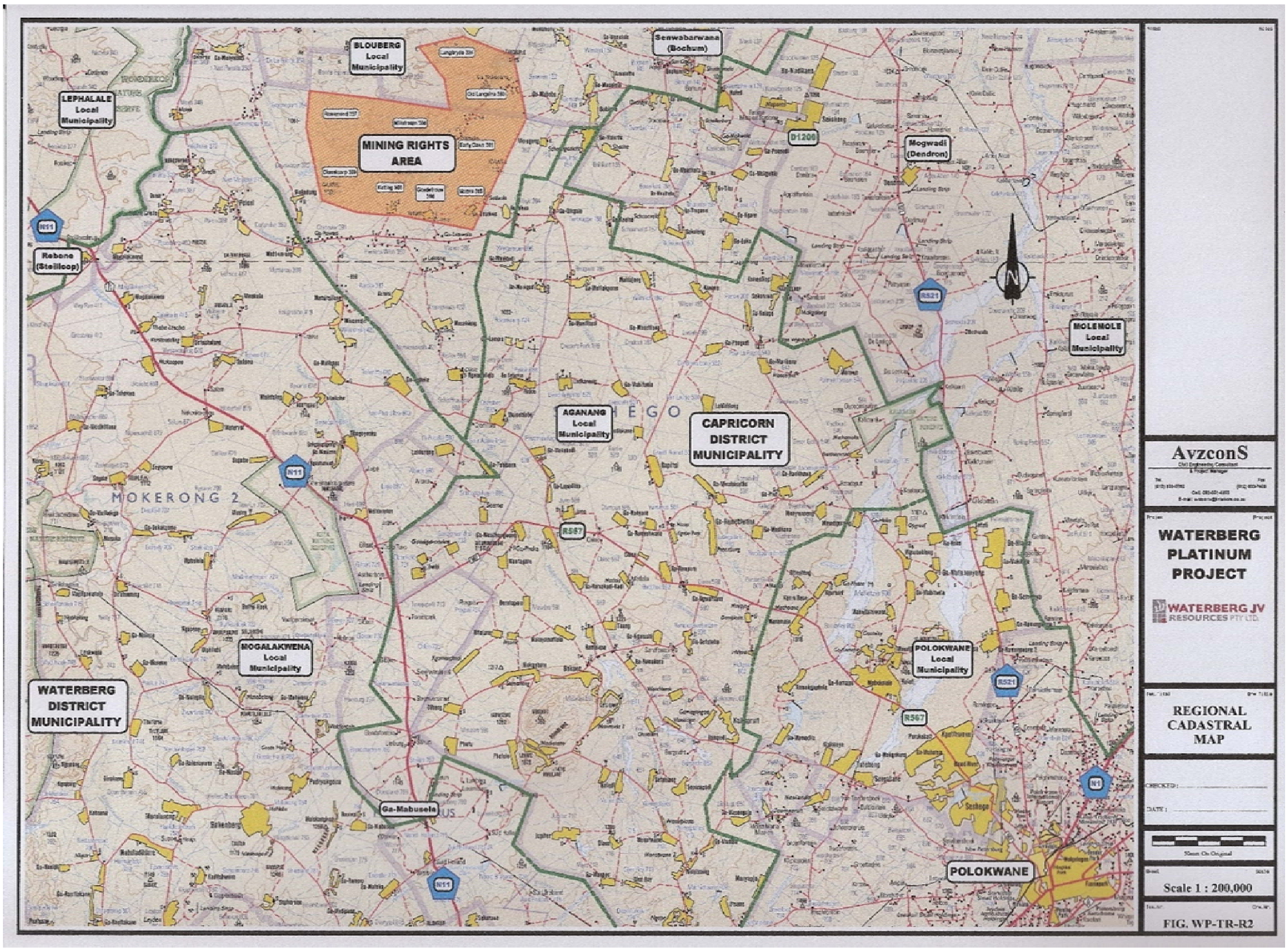

Figure 1: Locality Map of the proposed Project area

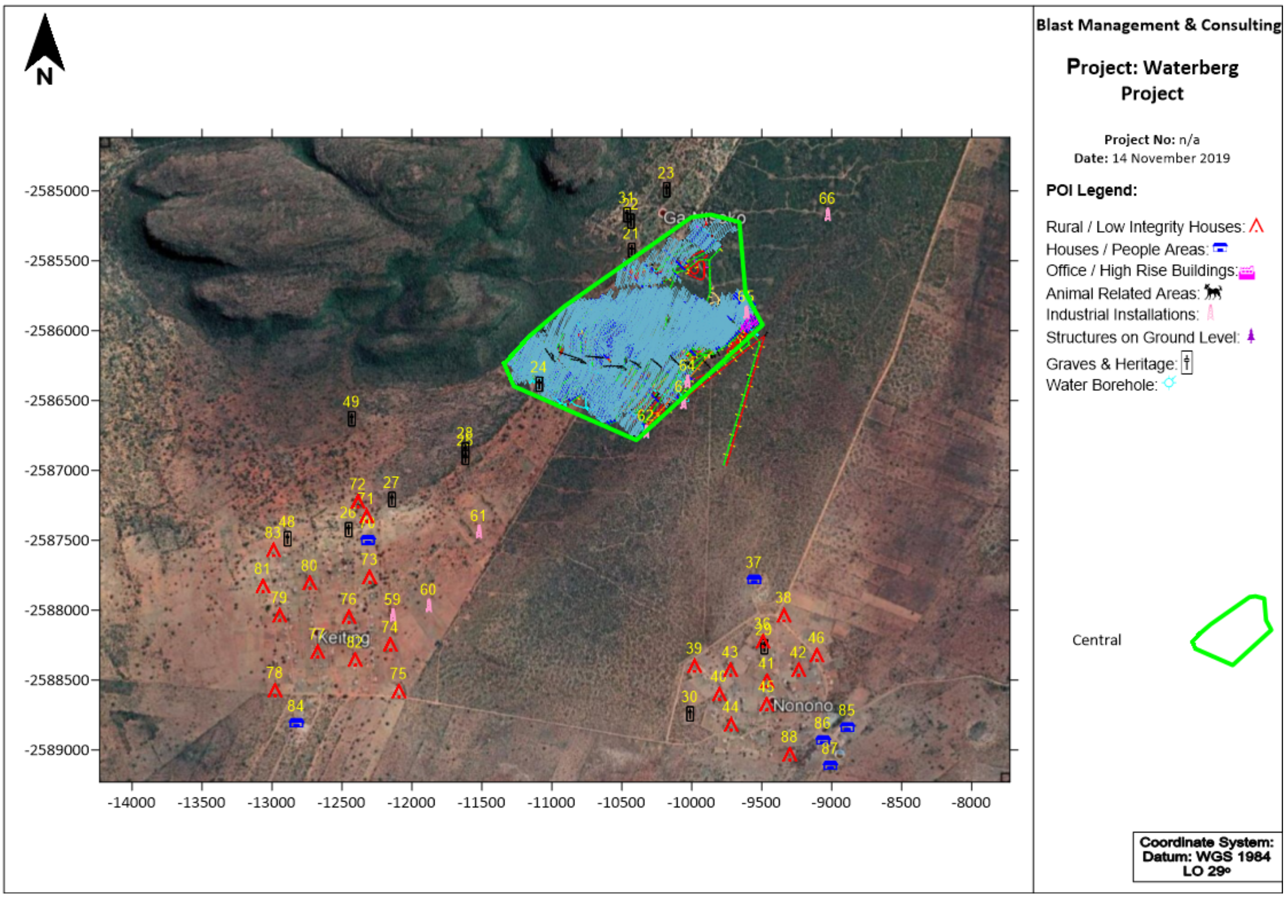

Figure 2: Underground mining area with surface map – Central Shaft and underground area

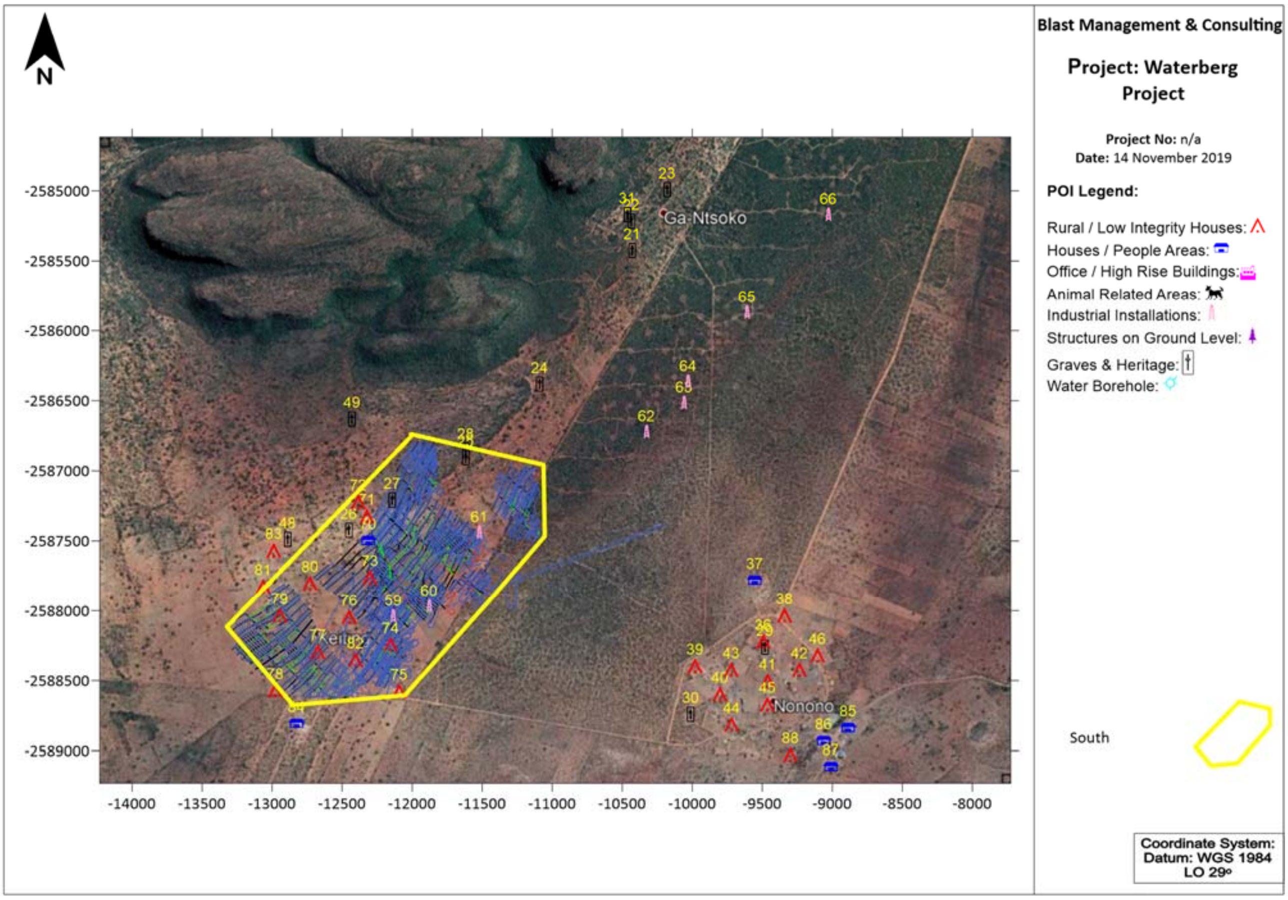

Figure 3: Underground mining area with surface map – South Shaft and underground area

6 Methodology

The detailed plan of study consists of the following sections:

- Identifying surface structures / installations that are found within reason from project site. A list of Point of Interests (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 is calculating the expected impact based on the expected drilling and blasting information provided for the project. Various accepted mathematical equations are applied to determine the attenuation of ground vibration. The expected values are then calculated over the distance (depth of mine) and presented.
- The possible environmental or social impacts are then addressed as part of the detailed EIA phase investigation;
- Reporting: All data is prepared in a single report and provided for review.

7 Assumptions and Limitations

The following assumptions have been made:

- The project is evaluated as a new operation with no blasting activities currently being done.
- The anticipated levels of influence estimated in this report are calculated using standard accepted methodology according to international and local regulations.
- The assumption is made that the predictions are a good estimate with significant safety factors to ensure that expected levels are based on worst case scenarios. These will have to be confirmed with actual measurements once the operation is active.
- Basic design information was supplied to Blast Management & Consulting. Data from the design information was sued for explosive detonation estimates.
- The underground and decline depth information was obtained from the Mine Works Plan and used for calculations.
- It must be noted that the effects such as ground vibration from underground blasting operations on surface is a complex process. Actual measurements are normally best to define specific influences.
- The work done is based on the author's knowledge and information provided by the project applicant.

8 Influence from blasting operations

Blasting operations are required to break rock for excavation to access the targeted ore material. Explosives in blast holes provide the required energy to conduct the work. Ground vibration, air blast and fly rock are result of blasting process. In underground mines air blast and fly rock is restricted to the underground environment and has no influence on surface infrastructure. Based on the regulations of the different acts consulted and international accepted standards these effects are required to be within certain limits. The following sections provide guidelines on these limits. As indicated, there are no specific South African ground vibration and air blast limit standards.

8.1 Ground vibration limitations on structures

Ground vibration is measured in velocity with units of millimetres per second (mm/s). Ground vibration can also be reported in units of acceleration or displacement if required. Different types of structures have different tolerances to ground vibration. A steel structure or a concrete structure will have a higher resistance to vibrations than a well-built brick and mortar house. A brick and mortar house will be more resistant to vibrations than a poorly constructed or a traditionally built mud house. Different limits are then applicable to the different types of structures. Limitations on ground vibration take the form of maximum allowable levels or intensity for different installations or structures. Ground vibration limits are also dependent on the frequency of the ground vibration. Frequency is the rate at which the vibration oscillates. Faster oscillation is synonymous with higher frequency and lower oscillation is synonymous with lower frequency. Lower frequencies are less acceptable than higher frequencies because structures have a low natural frequency. Significant ground vibration at low frequencies could cause increased structure vibrations due to the natural low frequency of the structure and this may lead to crack formation or damages.

Currently, the USBM criteria for safe blasting are applied as the industry standard where private structures are of concern. Ground vibration amplitude and frequency is recorded and analysed. The data is then evaluated accordingly. The USBM graph is used for plotting of data and evaluating the data. Figure 4 below provides a graphic representation of the USBM analysis for safe ground vibration levels. The USBM graph is divided mainly into two parts. The red lines in the figure are the USBM criteria:

- Analysed data displayed in the bottom half of the graph shows safe ground vibration levels,
- Analysed data displayed in the top half of the graph shows potentially unsafe ground vibration levels:

Added to the USBM graph is a blue line and green dotted line that represents 6 mm/s and 12.5 mm/s additional criteria that are used by BM&C.

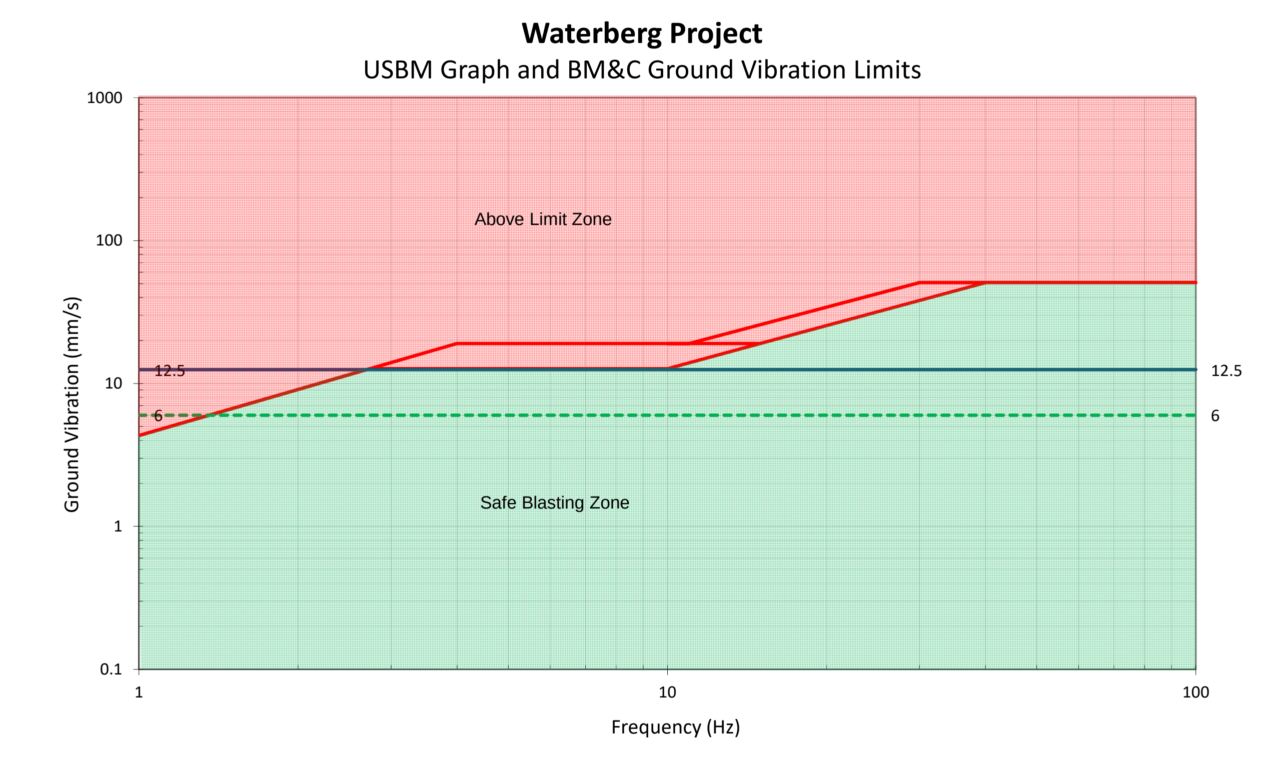

Figure 4: USBM Analysis Graph

Additional limitations that should be considered were determined through research and prescribed by the various institutions; these are as follows:

- National roads/tar roads: 150 mm/s BM&C;
- Steel pipelines: 50 mm/s (Rand Water Board);
- Electrical lines: 75 mm/s (Eskom);
- Sasol Pipelines: 25 mms/s (Sasol);
- Railways: 150 mm/s BM&C;
- Concrete less than 3 days old: 5 mm/s [1];
- Concrete after 10 days: 200 mm/s [2];

[1] Chiapetta F., Van Vreden A., 2000. Vibration/Air blast Controls, Damage Criteria, Record Keeping and Dealing with Complaints. 9th Annual BME Conference on Explosives, Drilling and Blasting Technology, CSIR Conference Centre, Pretoria, 2000.

[2] Chiapetta F., Van Vreden A., 2000. Vibration/Air blast Controls, Damage Criteria, Record Keeping and Dealing with Complaints. 9th Annual BME Conference on Explosives, Drilling and Blasting Technology, CSIR Conference Centre, Pretoria, 2000.

- Sensitive plant equipment: 12 mm/s or 25 mm/s, depending on type. (Some switches could trip at levels of less than 25 mm/s.)[2];
- Waterwells or Boreholes: 50 mm/s [3];

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

- USBM criteria for safe blasting;
- The additional limits provided above;
- Consideration of private structures in the area of influence;
- Should structures be in poor condition, the basic limit of 25 mm/s is halved to 12.5 mm/s or when structures are in very poor condition limits will be restricted to 6 mm/s. It is a standard accepted method to reduce the limit allowed with poorer condition of structures;
- Traditionally built mud houses are limited to 6 mm/s. The 6 mm/s limit is used due to unknowns on how these structures will react to blasting. There is also no specific scientific data available that would indicate otherwise;
- Input from other consultants in the field locally and internationally.

8.2 Ground vibration limitations and human perceptions

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

Ground vibration is experienced at different levels; BM&C considers only the levels that are experienced as “Perceptible”, “Unpleasant” and “Intolerable”. This is indicative of the human being’s perceptions of ground vibration and clearly indicates that humans are sensitive to ground vibration and humans perceive ground vibration levels of 4.5 mm/s as unpleasant (See Figure 5). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.

Indicated on Figure 5 is a blue solid line that indicates a ground vibration level of 12.5 mm/s and a green dotted line that indicates a ground vibration level of 6 mm/s. These are levels that are used in the evaluation.

[3] Berger P. R., & Associates Inc., Bradfordwoods, Pennsylvania, 15015, Nov 1980, Survey of Blasting Effects on Ground Water Supplies in Appalachia., Prepared for United States Department of Interior Bureau of Mines.

Generally, people also assume that any vibration of a structure - windows or roofs rattling - will cause damage to the structure. An air blast is one of the causes of vibration of a structure and is the cause of nine out of ten complaints.

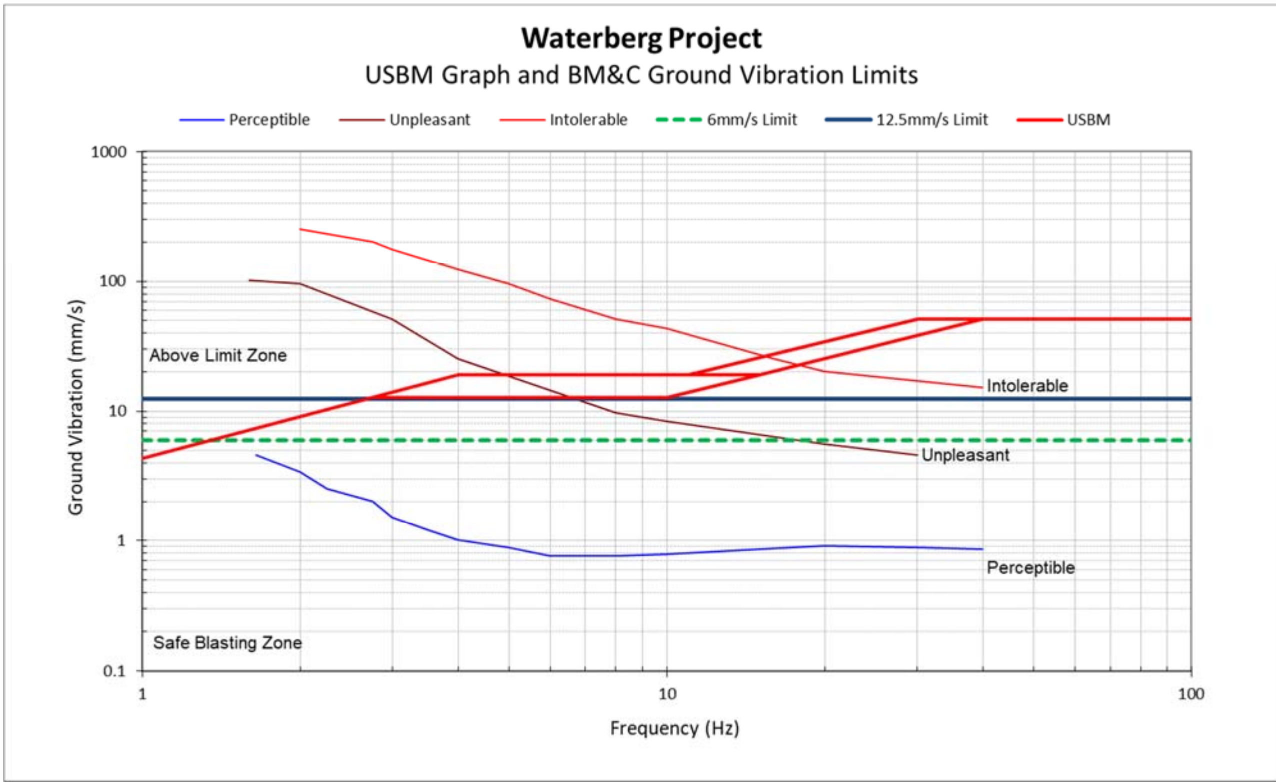

Figure 5: USBM Analysis with Human Perception

9 Baseline Results

The base line information for the project is limited to observation of the surrounding environment only. There is no drilling and blasting activities conducted that could contribute to measurements for a baseline.

9.1 Structure profile

A detail structure profile was presented in the EIA report dated "*Platinum Group Metals Waterberg Project_EIAReport_190614V01".* In this report the POI's are only indicated to identify surface infrastructure directly above underground workings.

Table 2 shows list of POI's representing surface infrastructure. Figure 6 shows an aerial view of the project area and surface POIs. The type of POIs identified is grouped into different classes. These classes are indicated as "Classification" in Table 1. The classification used is a BM&C classification and does not relate to any standard or national or international code or practice. Table 1 shows the descriptions for the classifications used.

Table 1: POI Classification used

Class	Description
1	Rural Building and structures of poor construction
2	Private Houses and people sensitive areas
3	Office and High-rise buildings
4	Animal related installations and animal sensitive areas
5	Industrial buildings and installations
6	Earth like structures – no surface structure
7	Graves & Heritage
8	Water Borehole

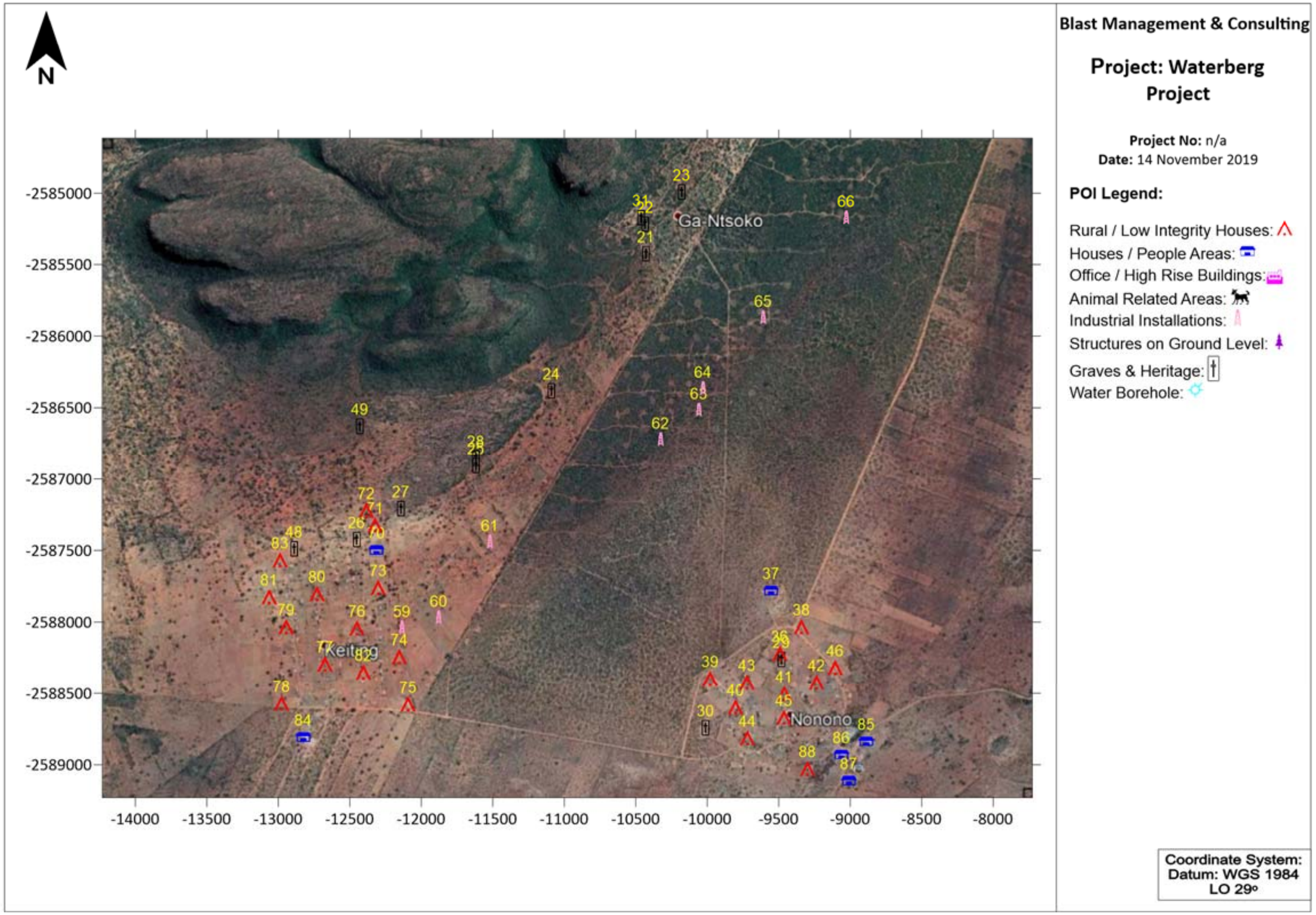

Figure 6: Aerial view of the project area and surface POIs

Table 2: List of points of interest identified (WGS – LO 29º)

Tag	Description	Classification	Y	X
21	Heritage Site (Site 8 - Grave Yard)	7	10428.64	2585425.21
22	Heritage Site (Site 9 - Grave Yard)	7	10434.47	2585216.02
23	Heritage Site (Site 11 - Grave Yard and Historical residential site)	7	10179.01	2584991.27
24	Heritage Site (Site 3 - Iron Age lower grinding stones)	7	11089.65	2586382.45
25	Heritage Site (Site 6 - Grave Yard)	7	11617.45	2586905.84
26	Heritage Site (Site 2 - Grave Yard)	7	12451.91	2587423.35
27	Heritage Site (Site 5 - Historical residential site)	7	12142.56	2587207.75
28	Heritage Site (Site 7 - Circular stone walling)	7	11617.49	2586853.54
29	Heritage Site (Site 25 - Grave Yard)	7	9481.08	2588260.99
30	Heritage Site (Site 26 - Grave Yard)	7	10011.74	2588741.26
31	Heritage Site (Site 1 - Historical residential site)	7	10462.90	2585169.90
32	Heritage Site (Site 16 - Grave Yard)	7	8825.52	2582895.40
33	Heritage Site (Site 17 - Grave Yard)	7	8078.16	2583454.87
34	Heritage Site (Site 12 - Grave Yard)	7	7845.15	2583623.94
35	Heritage Site (Site 13 - Grave Yard)	7	7899.03	2583780.86
36	Community Houses (Nonono)	1	9491.60	2588219.04
37	Buildings/Structures	2	9553.61	2587779.54
38	Community Houses (Nonono)	1	9340.83	2588032.53
39	Community Houses (Nonono)	1	9979.91	2588394.75
40	Community Houses (Nonono)	1	9802.22	2588596.01
41	Community Houses (Nonono)	1	9461.55	2588501.60
42	Community Houses (Nonono)	1	9235.08	2588422.07
43	Community Houses (Nonono)	1	9722.20	2588421.95
44	Community Houses (Nonono)	1	9718.61	2588813.27
45	Community Houses (Nonono)	1	9463.54	2588669.61
46	Community Houses (Nonono)	1	9105.32	2588318.95
47	Heritage Site (Site 24 - Iron Age Pottery)	7	7713.09	2580867.45
48	Heritage Site (Site 1 - Grave Yard)	7	12889.16	2587488.33
49	Heritage Site (Site 4 -Single grave& historical residential site)	7	12429.86	2586629.63
50	Heritage Site (Site 14 - Grave Yard)	7	6340.86	2581020.62
51	Heritage Site (Site 15 - Grave Yard)	7	6551.33	2580470.05
52	Heritage Site (Site 18 - Grave Yard)	7	6445.95	2581063.73
53	Heritage Site (Site 19 - Grave Yard)	7	6338.05	2580956.02
54	Heritage Site (Site 20 - Grave Yard)	7	9788.06	2582179.21
55	Heritage Site (Site 21 - Grave Yard)	7	7883.09	2581719.69
56	Heritage Site (Site 22 - Grave Yard)	7	5139.42	2580269.52
57	Heritage Site (Site 27 - Grave Yard)	7	5900.72	2587643.85
58	Heritage Site (Site 23 - Historical residential site)	7	4917.85	2580171.01
59	Vent Shaft	5	12135.00	2588036.10
60	Vent Shaft	5	11878.00	2587965.40
61	Vent Shaft	5	11519.70	2587437.20
62	Vent Shaft	5	10325.50	2586719.50
63	Vent Shaft	5	10058.00	2586513.00
64	Vent Shaft	5	10029.20	2586362.50
65	Vent Shaft	5	9608.18	2585868.17
66	Vent Shaft	5	9027.27	2585167.12

67	Vent Shaft	5	8649.40	2584176.20
68	Vent Shaft	5	8128.20	2583523.30
69	Vent Shaft	5	7541.20	2582919.70
70	Buildings/Structures (Keiting)	2	12313.63	2587496.56
71	Community Houses (Keiting)	1	12323.03	2587322.16
72	Community Houses (Keiting)	1	12384.30	2587220.39
73	Community Houses (Keiting)	1	12301.47	2587759.35
74	Community Houses (Keiting)	1	12153.09	2588241.96
75	Buildings/Structures (Keiting)	1	12091.98	2588575.35
76	Community Houses (Keiting)	1	12449.66	2588042.47
77	Community Houses (Keiting)	1	12673.62	2588293.12
78	Community Houses (Keiting)	1	12977.40	2588569.19
79	Community Houses (Keiting)	1	12944.94	2588032.19
80	Community Houses (Keiting)	1	12728.82	2587801.25
81	Community Houses (Keiting)	1	13063.83	2587823.93
82	Community Houses (Keiting)	1	12404.57	2588351.07
83	Community Houses (Keiting)	1	12987.90	2587566.74
84	Buildings/Structures	2	12824.81	2588806.30
85	Buildings/Structures	2	8887.22	2588836.32
86	Buildings/Structures	2	9061.52	2588928.91
87	Buildings/Structures	2	9009.33	2589110.75
88	Community Houses (Nonono)	1	9298.60	2589027.25

10 Blasting Operations

The mineral resources targeted are mineable platinum group metals, mainly palladium. The resources are in a newly discovered part of the Bushveld Complex under cover rocks. Two new layers for platinum group metals were discovered in 2011 and 2012 by the company's founders. The "T and F reefs" at Waterberg are distinct from the Merensky, UG-2 and Platreef zones, known previously. The deposit is 3m up to 100m thick and dips at 35-40 degrees. This configuration requires mechanised mining skills and equipment maintenance skills.

The mining method is more fully summarised in the Mining Work Programme ("MWP"), also filed as part of the Mining Right Application. As a result of the orebody thickness, mining is planned to be fully mechanised. During the Pre-feasibility Study ("PFS"), three mining methods were applied, namely; (1) Blind Long Hole Retreat ("BLR"); (2) Longitudinal (Strike) Long Hole Open Stoping ("SLOS"); and (3) Transverse Long Hole Open Stoping ("TLOS").

All three of the above-mentioned methods are being considered as part of the on-going Definitive Feasibility Study ("DFS"). All the methods are fully mechanised and involve large scale underground mining equipment. The mining method has a significant advantage in safety since most of the ore moving work will be done by machine, with employees located inside a cab while operating a mobile piece of equipment. Additionally, the proposed mining methods are advantageous in terms of cost and efficiency.

Planned blast designs were presented and used in this analysis. Table 3 shows technical information of the blast designs.
Blasting operations will also be conducted in two separate stages. Firstly, the shaft development and then underground production blasting. These two types of operations occur at different depths and different type of blasting operations.

Table 3: Blast design technical information for shaft development

Shaft Development			
Waterberg Platinum Project - DFS			
5.5 m x 5 m Development Heading - Design and Quantities			
Drill Depth per Round (m)	4.4		
Break per Round (m)	3.8		
Tonnes Broken (10% Overbreak)	317		
Drilling			
Item	**Value**		
Hole Burden (m)	0.85		
Hole Spacing (m)	0.85		
Perimeter Holes Drilled (back)	7		
Production Holes Drilled (incl. ream)	59		
Total Holes Drilled	66		
Holes Reamed	3		
Lifters	9		
Depth of Drilling (m)	4.4		
Total Drilling/Round including ream(m)	303.6		
Drilled off Area (m²)	27.1		
Specific Gravity	2.8	Area	
Hole Size (mm)	45	0.001590431	m²
Blasting			
Nonels/Hole	1		
Electric Caps/Round	2		
Collar Left - No Powder (m)	0.3		
Primer (m)	0		
Product	**Density (g/cc)**	**kg / metre of blasthole**	
ANFO	1.00	1.59	

Bulk Emulsion	1.15	1.83	
Packaged Emulsion (Primer for lifters)	1.2	1.91	
Perimeter Blasting (Back Holes)	0.95	0.31	

Blast Item	Packaged Emulsion		Perimeter Blasting		Bulk Emulsion		Nonels	Elec. Caps	Bline	Blast Wire	Det Cord
	1 Stick/hole 0.5kg/stick	Total Units (kg)	No. of Units/hole (kg)	Total Units (kg)	No. of Units/hole (kg)	Total Units (kg)	Total Units (ea.)	Total Units (ea.)	Total Units (m)	Total Units (m)	Total Units (m)
Back Holes (perimeter blasting)			1.3	8.9			7				
Production Holes	0.00	0.0			7.5	352	47				
Lifters	0.00	0.0			7.5	67	9				
Blast Hook-Up								2	30	50	
Grand Total		**0**		**9**		**420**	**63**	**2**	**30**	**50**	**0**

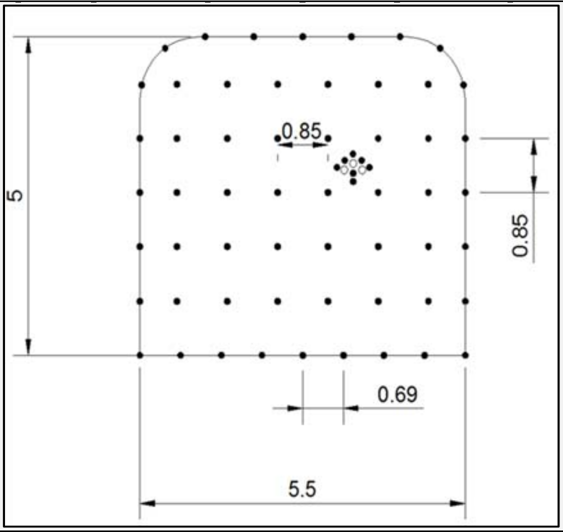

Table 4: Blast design technical information for underground mining

Table 28: Transverse Stope Production Drilling Parameters

Item	Transverse 40 m High 21 m Thick	Transverse 20 m High 21 m Thick	Transverse 40 m High 48 m Thick	Transverse 20 m High 48 m Thick
Hole Diameter	76.0 mm	76.0 mm	76.0 mm	76.0 mm
Ring Spacing	2.2 m	2.2 m	2.2 m	2.2 m
Hole Burden	2.5 m	2.5 m	2.5 m	2.5 m
Total Drilling	8 456.0 m	3 972.0 m	18 156.0 m	8 708.0 m
Stope Tonnes	67 000.0 t	32 200.0 t	149 200.0 t	71 700.0 t
Drill Factor	7.9 tpm	8.1 tpm	8.2 tpm	8.2 tpm
Average Hole Length	17.0 m	14.0 m	17.0 m	14.0 m

Table 29: Longitudinal Stope Production Drilling Parameters

Item	Longitudinal 40 m High 8 m Thick	Longitudinal 20 m High 8 m Thick	Longitudinal 40 m High 3 m Thick	Longitudinal 20 m High 3 m Thick
Hole Diameter	76 mm	76 mm	76 mm	76mm
Ring Spacing	2.2 m	2.2 m	2.2 m	2.2 m
Hole Burden	2.5 m	2.5 m	2.5 m	2.5 m
Total Drilling	2 867 m	1 313 m	1 670 m	725 m
Stope Tonnes	26 600 t	12 400 t	11 400 t	5 100 t
Drill Factor	9.3 tpm	9.4 tpm	6.8 tpm	7.0 tpm
Average Hole Length	17 m	13 m	27 m	23 m

3.8.3 Longhole Blasting

Bulk emulsion will be used for production blasting. A mobile emulsion loading unit will be used to load the holes. The production blasting design basis is summarised in Table 30.

Table 30: Longhole Blasting Parameters

Item	Parameter
Explosives Type	Bulk Emulsion (Density 1 150 kg/m^3)
Detonator	Non-electric Detonator
Initiation	Electric Cap and Detonator Cord Mine wide Central Blast System

The estimated powder factor for each typical stope size is summarised in Table 31 and Table 32.

Table 31: Transverse Longhole Powder Factor

Item	Transverse 40 m High 21 m Thick	Transverse 20 m High 21 m Thick	Transverse 40 m High 48 m Thick	Transverse 20 m High 48 m Thick
Hole Diameter	76 mm	76 mm	76 mm	76 mm
Total Drilling	8 456 m	3 972 m	18 156 m	8 708 m
Loaded Length	5 083 m	2 390 m	10 920 m	5 244 m
Total Emulsion	27 846 kg	13 092 kg	59 816 kg	27 358 kg
Stope Tonnes	67 000 t	32 200 t	149 200 t	71 700 t
Powder Factor	0.42 kg/t	0.41 kg/t	0.40 kg/t	0.38 kg/t

Table 32: Longitudinal Longhole Powder Factor

Item	Longitudinal 40 m High 8 m Thick	Longitudinal 20 m High 8 m Thick	Longitudinal 40 m High 3 m Thick	Longitudinal 20 m High 3 m Thick
Hole Diameter	76 mm	76 mm	76 mm	76 mm
Total Drilling	2 867 m	1 313 m	1 670 m	725 m
Loaded Length	1 724 m	790 m	1 005 m	436 m
Total Emulsion	9 448 kg	4 327 kg	5 504 kg	2 388 kg
Stope Tonnes	26 600 t	12 400 t	11 400 t	5 100 t
Powder Factor	0.36 kg/t	0.35 kg/t	0.48 kg/t	0.46 kg/t

In order to estimate expected ground vibration levels a charge mass per delay is required. The two different types of blasting operations to be done for underground operations will yield different charge mass per delay.

Shaft Development: According to the design the outer production blasthole row contain 18 blastholes. No specific timing was yet provided but based on general timing a maximum of 9 blastholes may detonate on the same time delay. Thus 9 blastholes detonating at the same time.

Underground blasting: in the planned ring blasting a maximum average depth of 27 m is anticipated. Based on this depth and general timing for ring blast it can be expected that two blasthole could detonate simultaneously. Maximum possible charge is defined by these conditions and considered a worst-case scenario.

The following table shows summary data obtained from the information above.

Table 5: Blast design summary for charge mass per delay values

Shaft Development	
Max. No. Holes on sequence	9
Charge mass / Blasthole	7.5
Total Charge per delay (kg)	68
Underground blasting	
Diameter	76
Max. Length (Avg.) (m)	27
Charge per blasthole (kg)	132.9
BH/Delay	2
Total Charge / Delay (kg)	265.8

The maximum charges considered for ground vibration prediction are 68 kg and 265.8 kg. These values were applied in all predictions for ground vibration and air blast.

10.1 Ground Vibration Prediction

When predicting ground vibration and possible decay, a standard accepted mathematical process of scaled distance is used. The equation applied (Equation 1) uses the charge mass and distance with two site constants. The site constants are specific to a site where blasting is to be done. In the absence of measured values an acceptable standard set of constants is applied.

Equation 1:

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

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

Applicable and accepted factors a&b for new operations is as follows:
Factors:
a = 1143
b = -1.65

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

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

Based on the designs presented on expected drilling and charging design, the following Table 6 shows expected ground vibration levels (PPV) for various distances / depths calculated for the two different charge masses. The charge masses are 68 kg and 266 kg for the opencast areas.

Table 6: Expected Ground Vibration at Various Distances Depths from Charges Applied in this Study

No.	Distance (m)	Shaft development Expected PPV (mm/s) for 68 kg Charge	Production Blasting Expected PPV (mm/s) for 266 kg Charge
1	50.0	28.9	
2	75.0	14.8	
3	100.0	9.2	
4	125.0	6.4	
5	150.0	4.7	
6	170.0	3.8	11.9
7	200.0		9.1
8	250.0		6.3
9	300.0		4.7
10	350.0		3.6
11	370.0		3.3

The following figure shows a simplistic cross section view and the impact of ground vibration.

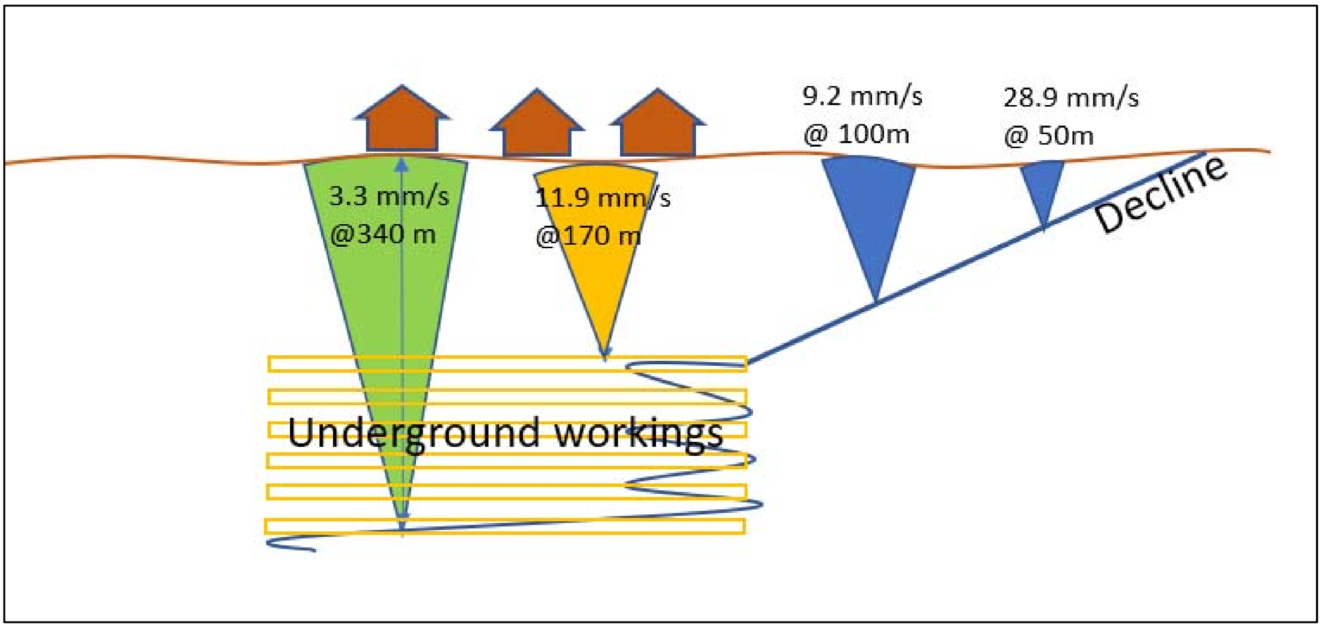

Figure 7: Simplistic cross section view

10.2 Summary of ground vibration levels

Review of ground vibration levels predicted for the different depths it can be observed that the different charges sizes and depths below surface has significant influence on the levels expected. The predictions are based on the worst-case scenarios and is very conservative. During development of the shafts it is expected that for a blast 50 m below surface a maximum of 28.9 mm/s may be expected on surface. At 100 m this level is reduced to 9.2 mm/s. During production blasting the maximum charge length associated with a 27 m long round it is expected that 11.9 mm/s is produced at 170 m. At current deepest level of 340 m, 33 mm/s is expected.
Review of the locations of the Central mine and South mine the Central mine has no specific housing structures above the decline or directly above the underground workings. See Figure 8 below. The South mine decline has no specific house structures above on surface. The underground workings are however located below the Keiting Village area. The mine will progress from the decline into a larger underground operation over time with increased footprint and increased depth underneath the village area. Varying depths and distances will be applicable, and this will lead to varying levels of ground vibration expected.
The underground blasting operations is not expected to have any influence on the Nonono Village area. This village is too far from the underground operations.

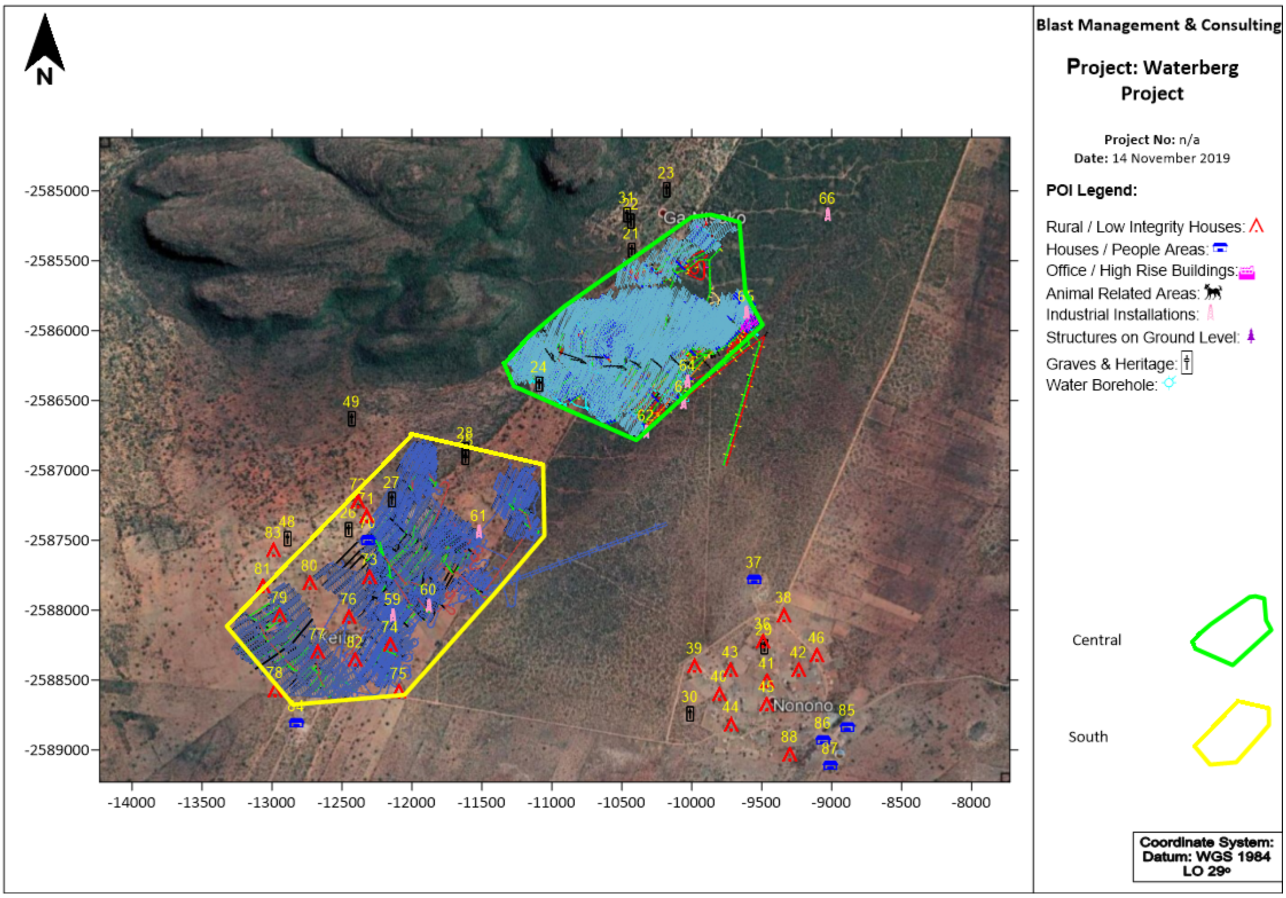

Figure 8: Central and South mine locations with declines

10.3 Ground Vibration and human perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 9 below). The frequency range selected is the expected average range for frequencies that will be measured for ground vibration when blasting is done. Based on the maximum charge and ground vibration predicted over distance it can be seen from Figure 9 that blasting between the 150 m depth and 370 m depths people may experience levels of ground vibration as unpleasant to intolerable. The observations and perceptions may lead to concerns for homeowners and complaints.

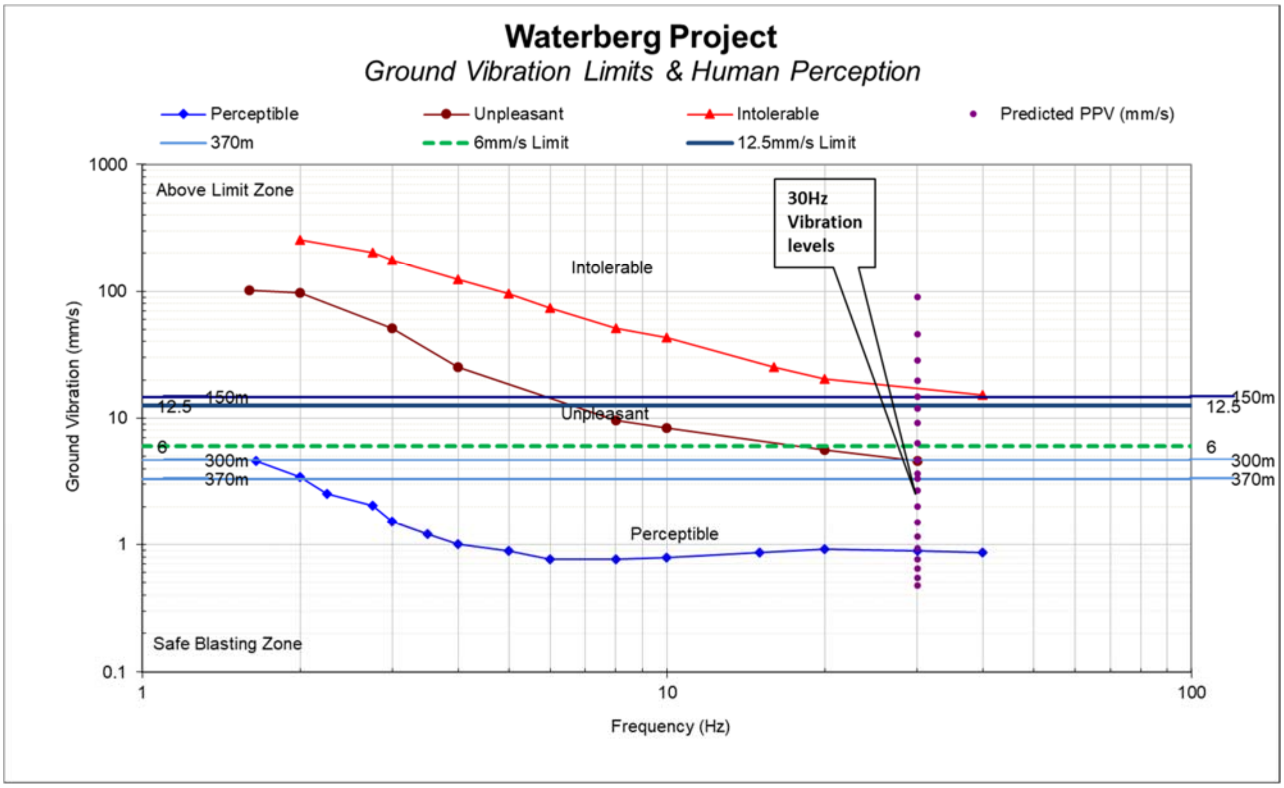

Figure 9: The effect of ground vibration with human perception and vibration limits

10.4 Potential Environmental Impact Assessment

The following is the impact assessment of the various concerns covered by this report. The matrix below in Table 7 was used for analysis and evaluation of aspects discussed in this report. The outcome of the analysis is provided in Table 8 with before mitigation and after mitigation. This risk assessment is a one-sided analysis and needs to be discussed with role players in order to obtain a proper outcome and mitigation.

10.4.1 Assessment Methodology

SIGNIFICANCE = (MAGNITUDE + DURATION + SCALE) X PROBABILITY

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

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

Table 7: Scale used to determine the overall ranking

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

The quantification of impacts is calculated for each **phase** of the operation i.e. Construction, Operation, Decommissioning, Post-closure.

10.4.2 Assessment

Table 8: Risk Assessment Outcome before mitigation

No.	Receptor / Resource	Process/Activity	Environmental Impact	Impact Effect	Magnitude (M)	Duration (D)	Scale (S)	Probability (P)	Significance		Mitigation and Management Measures	Impact Monitoring	
									Rating	Value		Monitoring	Time Frame for Monitoring
1	Community Houses	Blasting	Ground Vibration	Negative	-6	-4	-2	-3	Medium	36	N/A	Yes	Frequent monitoring checks

Table 9: Risk Assessment Outcome after mitigation

No.	Receptor / Resource	Process/Activity	Environmental Impact	Impact Effect	Magnitude (M)	Duration (D)	Scale (S)	Probability (P)	Significance		Mitigation and Management Measures	Impact Monitoring	
									Rating	Value		Monitoring	Time Frame for Monitoring
1	Community Houses	Blasting	Ground Vibration	Negative	-4	-4	-2	-3	Low	30	Specific blast design to be done, shorter blast holes, using electronic initiation instead of shock tube systems to obtain single hole firing.	Yes	Frequent monitoring checks

10.5 Mitigations

Review of the predictions indicate that significant ground vibration may possibly be experienced. The predictions made are currently based on the planned blast designs as presented part of the costing evaluations for the mine. The evaluation done was based on the worst-case scenarios and it is expected that lesser influences may rather be experienced. The author is also of opinion that mitigations can only be presented once actual measurements of surface ground vibration is measured and analysed with knowledge of actual final drilling and blasting plans. Specific mitigations cannot easily be done at this stage. The impacts of changed designs, alternative blasting or any other changed recommendations can only be done with detail consultation with the client. This is unfortunately not a process that is within the scope of this document.

11 Alternatives

No specific alternative mining methods were considered. Drilling and blasting are considered the best method for this process.

12 Monitoring

A ground vibration monitoring programme is recommended. Specifically, to define the influence of underground blasting. Monitoring to be done directly above areas being blasted. Blast location (depth and position) will be crucial to be able to define current and future possible influence.
Monitoring of ground vibration is done to ensure that the generated levels of ground vibration comply with recommendations. Proposed positions will be directly above on surface where blasting will be done. Monitoring will also contribute to proper relationships with the neighbours.

13 Recommendations

The following recommendations are proposed.

13.1 Monitoring and prediction

Added to the monitoring programme discussed above a process of monitoring the shaft development should be done. This process can then be used to evaluate the levels of ground vibration from blasting operations at certain depths to predict expected levels when in full production. This is more specific to the South mine that will be located directly under the Keiting Village.

13.2 Recommended ground vibration levels

The ground vibration and air blast levels limits recommended for blasting operations in this area are provided in Table 10.

Table 10: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)
National Roads/Tar Roads:	150
Electrical Lines:	75
Railway:	150
Transformers	25
Water Wells	50
Telecoms Tower	50
General Houses of proper construction	USBM Criteria or 25 mm/s
Houses of lesser proper construction	12.5
Rural building – Mud houses	6

13.3 Third party monitoring

Third party consultation and monitoring should be considered for all ground vibration and air blast monitoring work. 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.

14 Knowledge Gaps

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

15 Conclusion

Blast Management & Consulting (BM&C) was requested to conduct an initial review of possible impacts with regards to underground blasting operations. Ground vibration is the main component as a result from blasting operations. Ground vibration only was considered in this report and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

Planed blasting operations for underground access development and production was considered. The decline access and underground production areas vary in depth from surface over a period. Ground vibration expected was calculated for different depths below surface with consideration of location of the underground workings in relation to surface infrastructure. Levels of ground vibration expected is significant ranging from 3.3 mm/s and 28.9 mm/s for all underground blasting operations. The shaft development has least possible influence as the shafts are far enough away from private infrastructure. The Central Mine underground workings is located away from any village areas. Only the South mine has possible influence as it is located directly under the Keiting Village. Possible influence is limited but will need to be confirmed from actual measurements to be done. Expected levels for the Keiting Village range between 3.3 mm/s and 11.9 mm/s. These levels were calculated as a worst-case scenario. People may experience these levels as unpleasant.

This concludes this investigation for the proposed Waterberg Project underground blasting operations. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

16 Curriculum Vitae of Author

J D Zeeman was a member of the Permanent Force - SA Ammunition Core for period January 1983 to January 1990. During this period, work involved testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition.

From July 1992 to December 1995, Mr Zeeman worked at AECI Explosives Ltd. Initial work involved testing science on small scale laboratory work and large-scale field work. Later, work entailed managing various testing facilities and testing projects. Due to restructuring of the Technical Department, Mr Zeeman was retrenched but fortunately was able to take up an appointment with AECI Explosives Ltd.'s Pumpable Emulsion Explosives Group for underground applications.

From December 1995 to June 1997 Mr Zeeman provided technical support to the Underground Bulk Systems Technology business unit and performed project management on new products.

Mr Zeeman started Blast Management & Consulting in June 1997. The main areas of focus are Pre-blast monitoring, Insitu monitoring, Post-blast monitoring and specialized projects.

Mr Zeeman holds the following qualifications:

1985 - 1987 Diploma: Explosives Technology, Technikon Pretoria

1990 - 1992 BA Degree, University of Pretoria

1994 National Higher Diploma: Explosives Technology, Technikon Pretoria

1997 Project Management Certificate: Damelin College

2000 Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997, with work being done at various levels for all the major mining companies in South Africa. Some of the projects in which BM&C has been involved include:

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

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

17 References

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