Blast Management & Consulting

Quality Service on Time

Report: Blast Impact Assessment Anglo Operations (Pty)Ltd Dalyshope Coal Mining Project		
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ii. 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.

iii. Legal Requirements

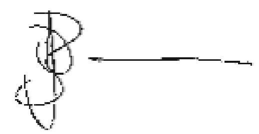
In terms of the NEMA 2014 EIA Regulations contained in GN R982 of 04 December 2014 (as amended by GN R 326 of 07 April 2017) all specialist studies must comply with Appendix 6 of the NEMA EIA Regulations, 2014 (as amended). Table 1 shows the requirements as indicated above.

Table 1: Legal Requirements for All Specialist Studies Conducted

Legal Requirement		Relevant Section in Specialist study
(1)	A specialist report prepared in terms of these Regulations must contain-	
(a)	details of-	
	(i) the specialist who prepared the report; and	i
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Section 25
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section ii

Legal Requirement		Relevant Section in Specialist study
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 4
(d)	the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 8
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process;	Section 6
(f)	the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure;	Section 11
(g)	an identification of any areas to be avoided, including buffers;	Section 11
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 11
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 9
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment;	Section 17
(k)	any mitigation measures for inclusion in the EMPr;	Section 17.13
(l)	any conditions/aspects for inclusion in the environmental authorisation;	Section 21
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 20
(n)	a reasoned opinion (Environmental Impact Statement)-	Section 23
	as to whether the proposed activity or portions thereof should be authorised; and	Section 23
	if the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 23
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 12
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Section 12
(q)	any other information requested by the competent authority.	None

iv. Document Control:

Name & Company	Responsibility	Action	Date	Signature
MJ Louw Blast Management & Consulting	Document Preparation	Report Finalised	15/11/2020	
JD Zeeman Blast Management & Consulting	Consultant	Report Finalise	15/11/2020	

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List of Acronyms used in this Report

a and b	Site Constant
APP	Air Pressure Pulse
B	Burden (m)
BH	Blast Hole
BMC	Blast Management & Consulting
Bs	Scaled Burden ($m^{3/2}kg^{-1/2}$)
D	Distance (m)
E	Explosive Mass (kg)
EIA	Environmental Impact Assessment
Freq.	Frequency
GRP	Gas Release Pulse
I&AP	Interested and Affected Parties
k	Factor value
M	Charge Height
m (SH)	Stemming height
Mc	Charge mass per metre column
N	North
NE	North East
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NOx's	Noxious Fumes
NW	North West
P	Probability
POI	Points of Interest
PPD	Peak particle displacement
PPV	Peak Particle Velocity
PVS	Peak vector sum
RPP	Rock Pressure Pulse
S	South
SE	South East
SH	Stemming height (m)
SW	South West
USBM	United States Bureau of Mine
W	West
WGS 84	Coordinates (South African)
WM	With Mitigation Measures
WOM	Without Mitigation Measures

List of Units used in this Report

%	percentage
cm	centimetre
dB	decibel
dBL	linear decibel
g	acceleration
g/cm^3	gram per cubic centimetre
Hz	frequency
kg	kilogram
kg/m^3	kilogram per cubic metre
kg/t	kilogram per tonne
km	kilometre
kPa	kilopascal
m	metre
m^2	metre squared
MJ	Mega Joules
MJ/m^3	Mega Joules per cubic meter
MJ/t	Mega Joules per tonne
mm/s	millimetres per second
mm/s^2	millimetres per second square
ms	milliseconds
Pa	Pascal
ppm	parts per million
psi	pounds per square inch
θ	theta or angle

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1 Executive Summary

Blast Management & Consulting (BMC) was contracted as part of Environmental Impact Assessment (EIA) to perform a review of possible impacts with regards to blasting operations in the proposed Dalyshope Mining Project opencast 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, air blast and fly rock and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as a 5000 m radius from where blasting will take place. The range of structures observed and considered in this evaluation ranged between, farmsteads, buildings, ruins, graves, cement dams, boreholes and gravel roads.

Various POI's were identified as problematic. Two POI's were found within the boundaries of the opencast pit area. Evaluation of minimum charge showed that ground vibration may be acceptable for three other POI's, but evaluation of maximum charge showed that ground vibration may be problematic in terms of potential structural damage and human perception at the farmstead, and the cement dam at these distances.

Heritage Sites which include graves, ruins were identified by the Heritage Specialist. The ruin was identified as problematic in the study area The Heritage Specialist recommended that certain mitigation measures have to be applied to the historical ruins which will be affected directly or indirectly during the construction and operational phase for the proposed project.

There are two Hydrocencus boreholes identified as problematic at these distances and it is uncertain what the long-term plan will be for these boreholes. Expected levels of ground vibration is greater than proposed limit for these boreholes.

The nearest human settlement the farmstead that will be affected by air blast is located 451 m from the opencast pit area. The predicted air blast for the farmstead is 123 dBL, which could result in complaints from the occupants.

The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL. Prediction shows that air blast will be greater than 134 dB at distance of 75 m and closer to any of the opencast pit boundary

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 213 m. When blasting at the opencast pit area and the gravel road is in the vicinity of the project area, then the gravel road should be closed. Stop and Go will be required when blasting is done within 500 m from these gravel roads. Road closure will be required with inspection for after blast fly rock. There may also be smaller roads that are used by the local communities that may not be clearly indicated on maps and should also be considered for closures when blasting is done. During blasting care must be taken to ensure all people and animals cleared to outside the unsafe area as determined by the blaster.

The option of photographic survey of identified structures up to 2100 m from the opencast pit area is recommended. 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 while the vent shafts are been blasted

The effect of blasting operations on wildlife was investigated and evaluated. It is not expected that blasting in the mine will be causing fatalities. It is however known that initially animals may be frightened but expected to habituate over time.

Recommendations were made and should be considered. specific actions will be required for all pit areas such as Mine Health and Safety Act requirements when blasting is done within 500 m and 100 m from private structures

This concludes this investigation for the proposed Dalyshope Coal Mining Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

2 Introduction

The Project is in the Limpopo Province of South Africa, some 54 km to the west of Lephalale, 39 km northwest of the Matimba and Medupi power stations, close to the Botswana border that is demarcated by the Limpopo River.

The Project is reachable via four routes. The first is via an all-weather gravel road that branches off from the R510 paved provincial road ~ 38 km from Lephalale. The second two routes are all-weather gravel roads that branch off a tar road at the Grootegeluk coal mine, owned and operated by Exxaro Resources. The final route is from the R510 paved provincial road that continues past Lephalale to the Limpopo River and becomes a gravel road that runs up to the Dalyshope Project area. No human settlements are within the planned opencast mining area. The land is currently mainly used for game farming.

As part of Environmental Impact Assessment (EIA), Blast Management & Consulting (BMC) was contracted to perform a review of possible impacts from blasting operations and specifically for the proposed Dalyshope Coal Mining 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 objectives of this document are outlining the expected environmental effects that blasting operations could have on the surrounding environment; proposing the specific mitigation measures that will be required. This study investigates the related influences of expected ground vibration, air blast and fly rock. These effects are investigated in relation to the blast site area and surrounds and the possible influence on nearby private installations, houses and the owners or occupants.

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 (Act No. 107 of 1998) (NEMA
- Mine Health and Safety Act, 1996 (Act No. 29 of 1996)
- Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA)
- Explosives Act, 2003 (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 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 to ground vibration, air blast and fly rock due to blasting operations.

- 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
  - Evaluation of expected blasting influence on national and provincial roads surrounding the blasting operations if present
  - Evaluation of expected ground vibration levels on water boreholes if present within 500 m from blasting operations
  - Evaluation of expected air blast levels at specific distances from the operations and possible influence on structures
  - Evaluation of fly rock unsafe zone
  - Discussion on the occurrence of noxious fumes and dangers of fumes
  - Evaluation of the location of blasting operations in relation to surrounding areas according to the regulations from the applicable Acts
- Undertake an impact assessment and identify suitable mitigation measures

5 Study area

Proposed Dalyshope Coal Mining Project, Situated in the Magisterial District of Lephalale, Limpopo Province, some 54 km to the west of Lephalale, 39 km northwest of the Matimba and Medupi power stations, close to the Botswana border that is demarcated by the Limpopo River. The located is at following coordinates (Lat/Lon WGS84):

- Opencast Pit: -23,569117°S; 27,236330°E

Figure 1 shows a Locality Map of the proposed Project area. Figure 2 shows the for the Dalyshope Coal Mine Project.

Figure 1: Location Map of the proposed Project area

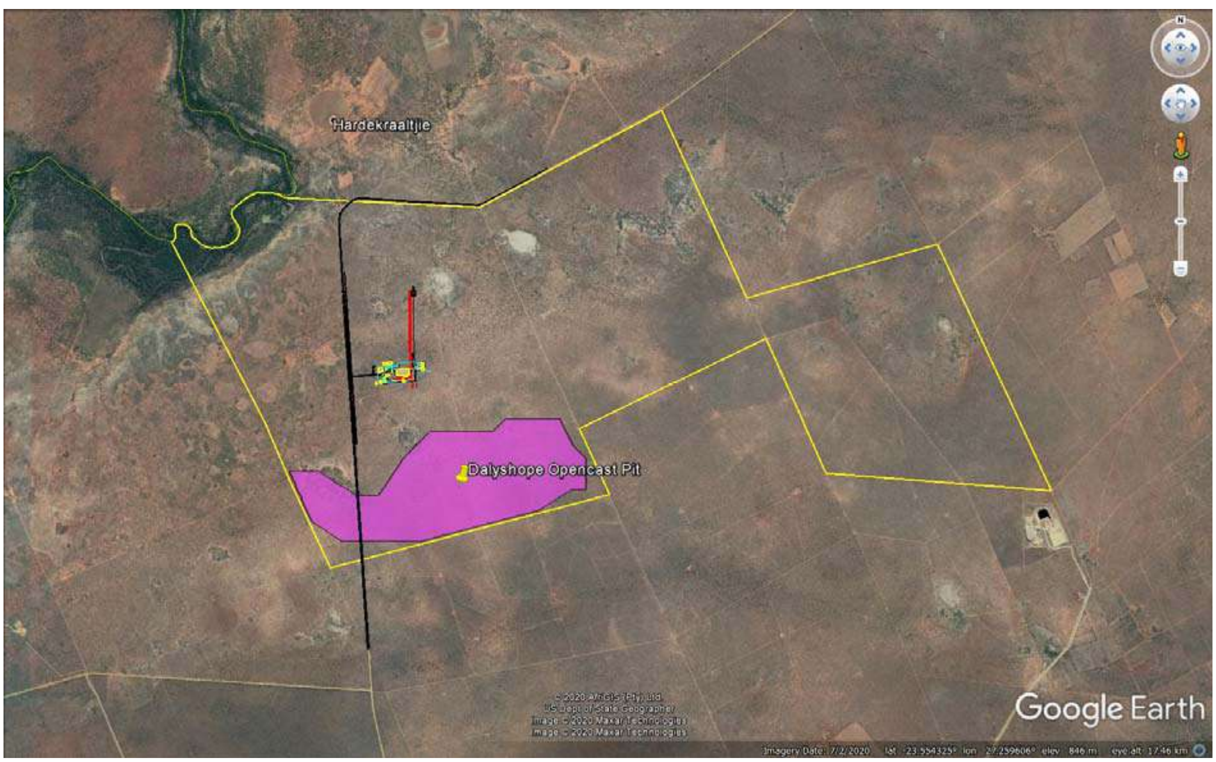


Figure 2: layout of the proposed Opencast Pit and Infrastructure area

6 Methodology

The detailed plan of study consists of the following sections:

- Baseline influence: There are no blasting activities currently being done at the proposed mine areas. The baseline is zero with no specific influence from blasting.
- Identifying surface structures/ installations that are found within reason from the project site. A list of Point of Interests (POI's) was created that will be used for the evaluation.
- Site evaluation: This entails an evaluation of the planned mining, drilling and blasting operations and the possible influences from the blasting operations. The methodology includes the modelling of the expected impacts based on the expected drilling and blasting information provided for the project. Various accepted mathematical equations were applied to determine the attenuation of ground vibration, air blast and fly rock. These values were then calculated over the distance investigated from the site and shown as amplitude level contours. Overlaying these contours on the location of the various receptors gave an indication of the possible impacts and the expected results of potential impacts. Evaluation of each receptor according to the predicted levels further gave an indication of the possible mitigation measures to be applied. The possible environmental or social impacts were addressed in the detailed EIA phase investigation.

7 Site Investigation

The site was visited in August 2020. This site visit was done to get understanding of the location and the structures and installations surrounding the proposed new pit area.

8 Season applicable to the investigation

The drilling and blasting operations are not season dependable. The investigation into the possible effects from blasting operations is not season bounded.

9 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.

- The limitation is that enough data is not available from this operation for a specific confirmation of the predicted values as no blasting activities is currently being done.
- Blast Management & Consulting was not involved in the blast design. The information on blast design applied was provided by the client.
- The work done is based on the author's knowledge and information provided by the project applicant.

10 Legal Requirements

The protocols applied in this document are based on the author's experience, guidelines elicited by the literature research, project applicant requirements and general indicators provided in the various applicable South African Acts. There is no direct reference in the consulted acts specifically regarding limiting levels for ground vibration and air blast. There is however specific requirements and regulations regarding blasting operations and the effect of ground vibration and air blast and some of the aspects addressed in this report. The acts consulted are:

- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA)
- Mine Health and Safety Act, 1996 (Act No. 29 of 1996)
- Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA)
- Explosives Act, 2003 (Act No. 15 of 2003)

There are no specific South African standards providing limiting levels regarding ground vibration and air blast. The guidelines and safe blasting criteria applied in this study are as per internationally accepted standards, and specifically the United States Bureau of Mines (USBM) criteria for safe blasting for ground vibration and the recommendations on air blast. The USBM is well accepted as a standard for South Africa. Additional criteria required by various institutions in South Africa were also taken into consideration, i.e. Eskom, Telkom, Transnet, Rand Water Board, etc. as well as specific limitations regarding traditional built structures where applicable.

In view of the acts consulted the following guidelines and regulations are noted. Only parts of the acts were extracted:

- Mine Health and Safety Act, 1996 (Act No. 29 of 1996)

(Gazette No.17242, Notice No. 967 dated 14 June 1996. Commencement date: 15 January 1997 for all sections with the exception of sections 86(2) and (3), which came into operation on 15 January 1998, [Proc.No.4, Gazette No. 17725])

Mine Health and Safety Regulations

Precautionary measures before initiating explosive charges

4.7 The employer must take reasonable measures to ensure that when blasting takes place, air and ground vibrations, shock waves and fly material are limited to such an extent and at such a distance from any building, public thoroughfare, railway, power line or any place where persons congregate to ensure that there is no significant risk to the health or safety of persons.

General precautions

4.16 The employer must take reasonable measures to ensure that:

4.16(1) in any mine other than a coal mine, no explosive charges are initiated during the shift unless –

(a) such explosive charges are necessary for the purpose of secondary blasting or reinitiating the misfired holes in development faces;

(b) written permission for such initiation has been granted by a person authorised to do so by the employer; and

(c) reasonable precautions have been taken to prevent, as far as possible, any person from being exposed to smoke or fumes from such initiation of explosive charges;

4.16(2) no blasting operations are carried out within a horizontal distance of 500 metres of any public building, public thoroughfare, railway line, power line, any place where people congregate or any other structure, which it may be necessary to protect in order to prevent any significant risk, unless:

(a) a risk assessment has identified a lesser safe distance and any restrictions and conditions to be complied with;

(b) a copy of the risk assessment, restrictions and conditions contemplated, in paragraph (a) have been provided for approval to the Principal Inspector of Mines;

(c) shot holes written permission has been granted by the Principal Inspector of Mines; and

(d) any restrictions and conditions determined by the Principal inspector of Mines are complied with.

- **Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)**

(Gazette No. 23922, Notice No. 1273 dated 10 October 2002. Commencement date: 1 May 2004 [Proc. No. R25, Gazette No. 26264])

Mineral and Petroleum Resources Development Regulations

67. Blasting, vibration and shock management and control

(1) A holder of a right or permit in terms of the Act must comply with the provisions of the Mine Health and Safety Act, 1996, (Act No. 29 of 1996), as well as other applicable law regarding blasting, vibration and shock management and control.

(2) An assessment of impacts relating to blasting, vibration and shock management and control, where applicable, must form part of the environmental impact assessment report and environmental management programme or the environmental management plan, as the case may be.

11 Sensitivity of Project

A review of the project and the surrounding areas is done before any specific analysis is undertaken and sensitivity mapping is done, based on typical areas and distance from the proposed mining area. This sensitivity map uses distances normally associated where possible influences may occur and where influence is expected to be very low or none. Two different areas were identified in this regard:

- A highly sensitive area of 500 m around the mining area. Normally, this 500 m area is considered an area that should be cleared of 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.
- An area 500 m to 1500 m around the pit area can be considered as being a medium sensitive area. In this area, the possibility of impact is still expected, but it is lower. The expected level of influence may be low, but there may still be reason for concern, as levels could be low enough not to cause structural damage but still upset people.
- An area greater than 1500 m is considered low sensitivity area. In this area, it is relatively certain that influences will be low with low possibility of damages and limited possibility to upset people.

Figure 3 shows the sensitivity mapping with the identified points of interest (POI) in the surrounding areas for the proposed Dalyshope Coal Mine Project area. The specific influences will be determined through the work done for this project in this report.

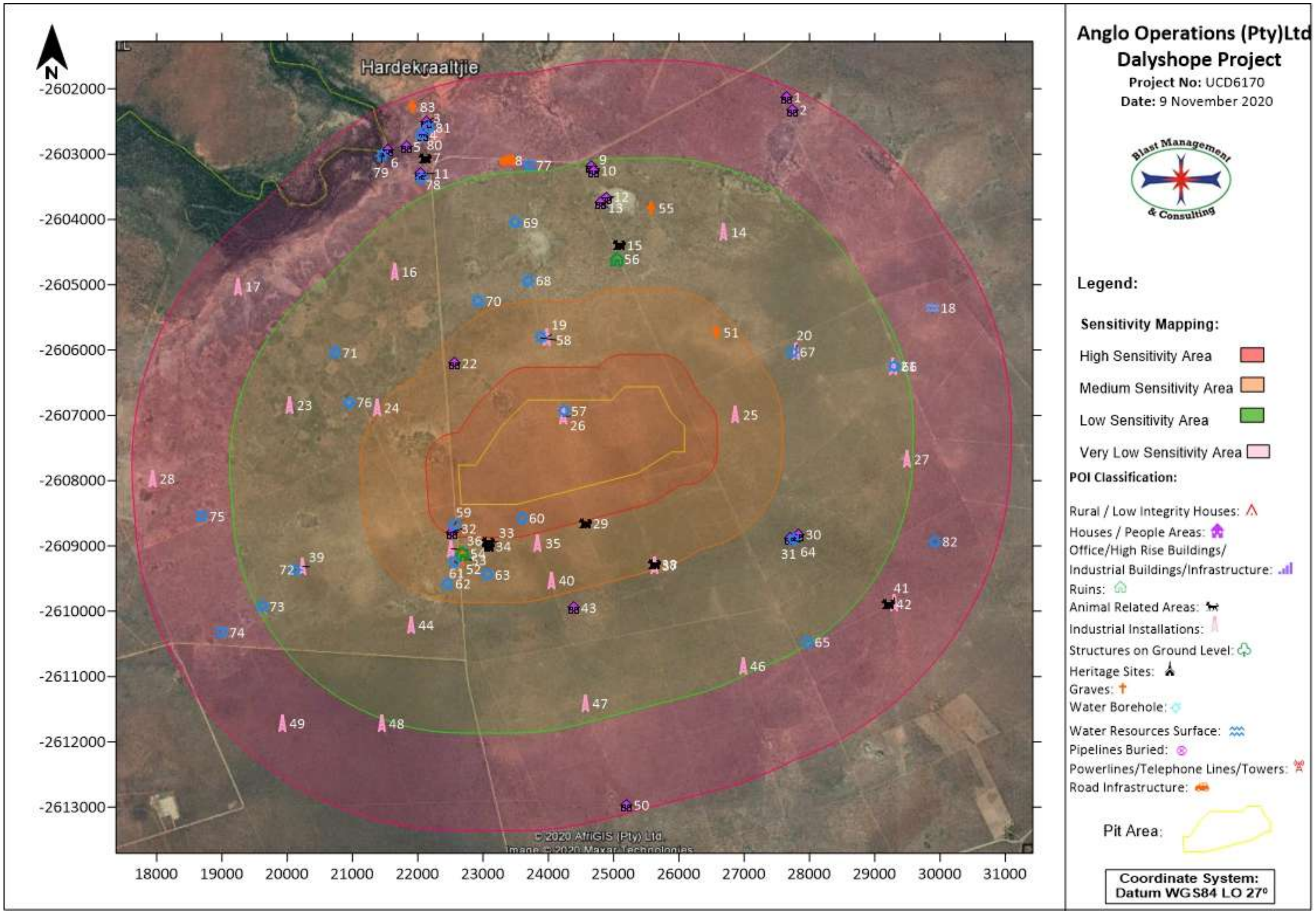


Figure 3: Identified sensitive areas for the proposed Dalyshope Opencast area

12 Consultation process

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

13 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 a result from the blasting process. 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 standard.

13.1 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. Figure 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 BMC.

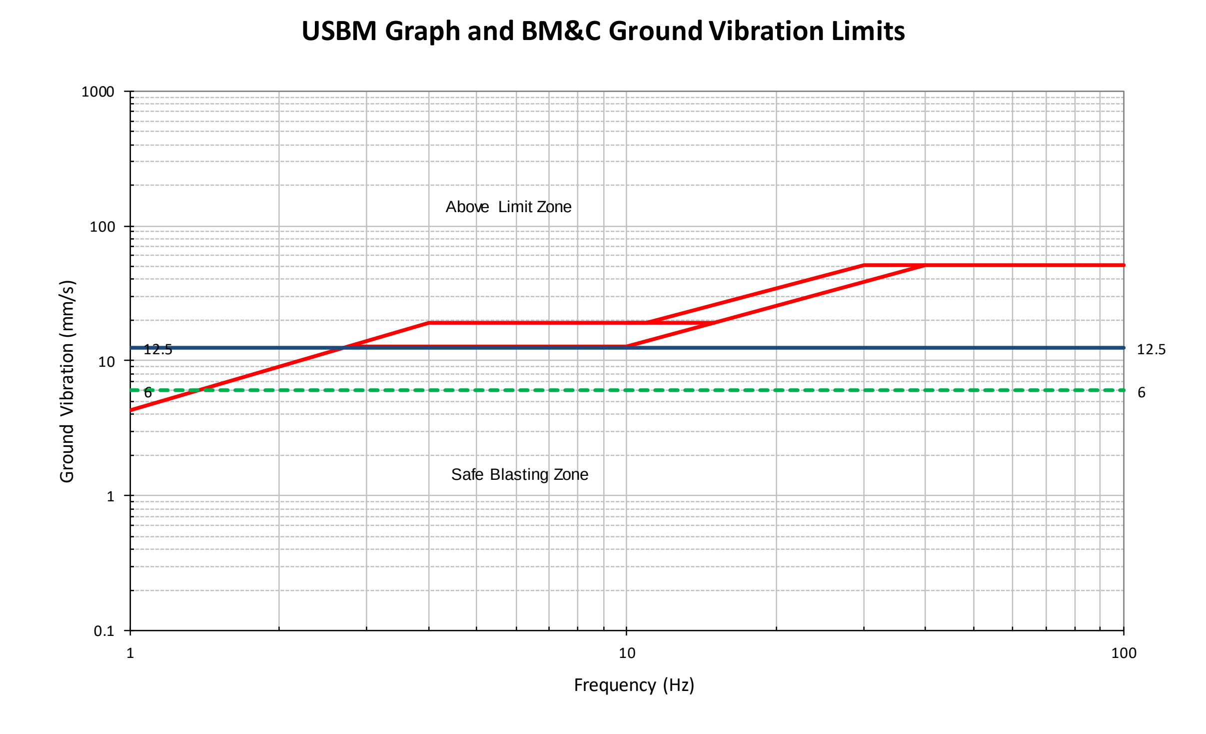


Figure 4: USBM Analysis Graph

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 BMC;
- 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, BMC 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.

13.2 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; BMC 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). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.

Indicated on Figure 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.

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.

[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.

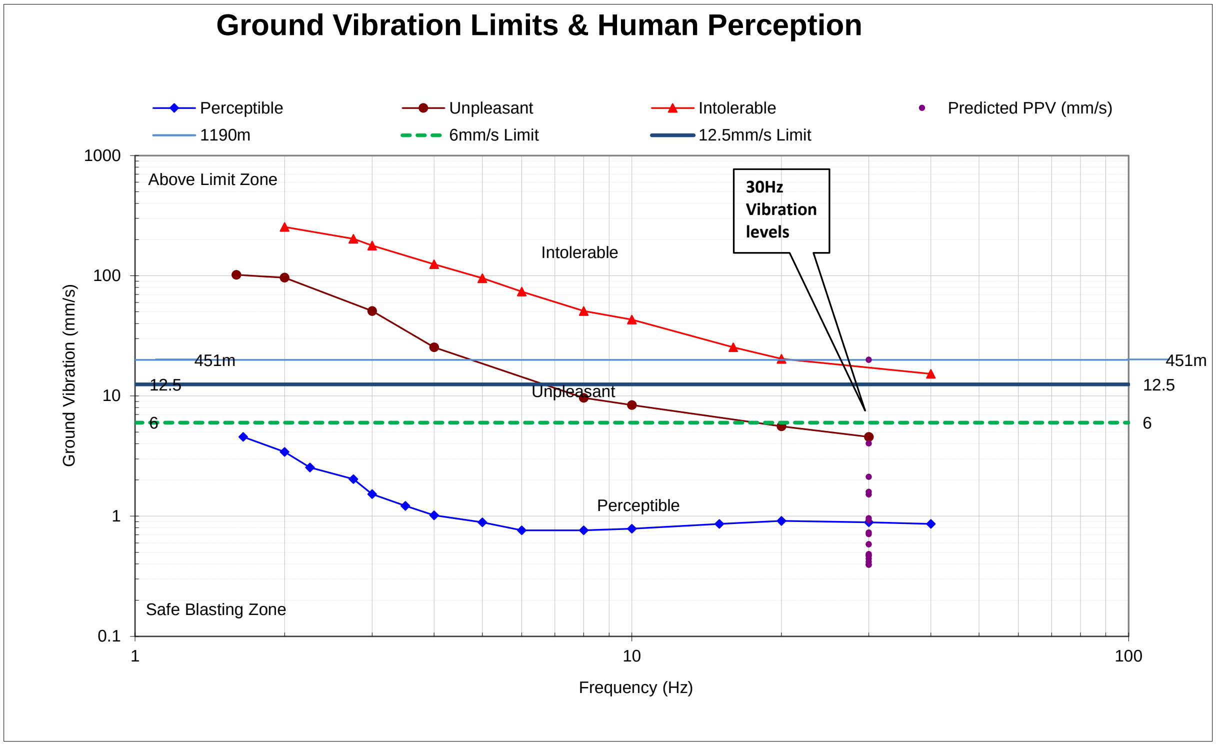


Figure 5: USBM Analysis with Human Perception

13.3 Air blast limitations on structures

Air blast or air-overpressure is a pressure wave generated from the blasting process. Air blast is measured as pressure in pascal (Pa) and reported as a decibel value (dBL). Air blast is normally associated with frequency levels less than 20 Hz, which is at the threshold for hearing. Air blast can be influenced by meteorological conditions such as, the final blast layout, timing, stemming, accessories used, blast covered by a layer of soil or not, etc. Air blast should not be confused with sound that is within the audible range (detected by the human ear). A blast does generate sound as well but for the purpose of possible damage capability we are only concerned with air blast in this report. The three main causes of air blasts can be observed as:

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

The general recommended limit for air blast currently applied in South Africa is 134dB. This is based on work done by the USBM. The USBM also indicates that the level is reduced to 128 dB in proximity of hospitals, schools and sensitive areas where people congregate. Based on work carried out by Siskind *et al.* (1980), monitored air blast amplitudes up to 135dB are safe for structures, provided the monitoring instrument is sensitive to low frequencies. Persson *et al.* (1994) have published estimates of damage thresholds based on empirical data (Table 2). Levels given in Table 2 are at the point of measurement. The weakest points on a structure are the windows and ceilings.

Table 2: 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 from blasting operations well below 120dB where the public is of concern.

13.4 Air blast limitations and human perceptions

Considering human perceptions and the misunderstanding about ground vibration and air blast, BMC generally recommends that blasting be done in such a way that air blast levels are kept below 120dB. This will ensure fewer complaints regarding blasting operations. The effect of air blast on structures that startle people will also be reduced, which in turn reduces the reasons for complaints. It is the effect on structures (like rattling windows, doors or a large roof surface) that startles people. These effects are sometimes erroneously identified as ground vibration and considered to be damaging the structure.

In this report, initial limits for evaluating conditions have been set at 120dBL, 120 dBL to 134dBL and greater than 134dBL. The USBM limits for nuisance are 134dBL.

13.5 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 at large coal mines are designed to cast the blasted material over a greater distance than in quarries or hard rock operations. The movement should be in the direction of the free face, and therefore the orientation of the blast is important. Material or elements travelling outside of this expected range would be considered to be fly rock. Figure 6 shows schematic of fly rock definitions.

Fly rock can be categorised as follows:

- 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. When using this definition, fly rock, 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 that travels beyond the blast clearance (exclusion) zone when there is some abnormality in a blast or a rock mass.

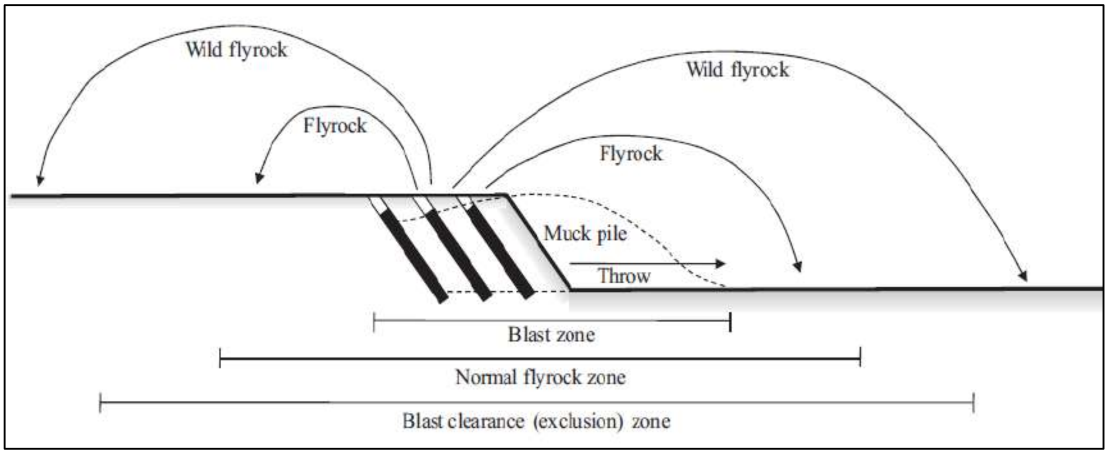


Figure 6: Schematic of fly rock terminology

Fly rock from blasting can result under 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.
- If the stemming material is of poor quality or too little stemming material is applied, the stemming is ejected out of the blast hole, which can result in fly rock.

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

The occurrence of fly rock in any form will have impact if found to travel outside the safe boundary. If a road or structure or people or animals are within the safe boundary of a blast, irrespective of the possibility of fly rock or not, precautions should be taken to stop the traffic, remove people or animals for the period of the blast. The fact is that 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 or as per mine code of practice. BMC uses a prediction calculation defined by the International Society of Explosives Engineers (ISEE) to assist with determining minimum distance.

13.6 Noxious Fumes

Explosives used in the mining environment are required to be oxygen balanced. Oxygen balance refers to the stoichiometry of the chemical reaction and the nature of gases produced from the detonation of the explosives. The creation of poisonous fumes such as nitrous oxides and carbon monoxide are particular undesirable. These fumes present themselves as red brown cloud after the blast has detonated. It has been reported that 10ppm to 20ppm can be mildly irritating. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary oedema. 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.

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, water in blast holes, incorrect product used or product not loaded properly and specific types of rock/geology can also contribute to fumes.

13.7 Vibration impact on provincial and national roads

The influence of ground vibration on tarred roads are expected when levels is in the order of 150 mm/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 from blasting does not have influence on road surfaces. 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.

13.8 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.

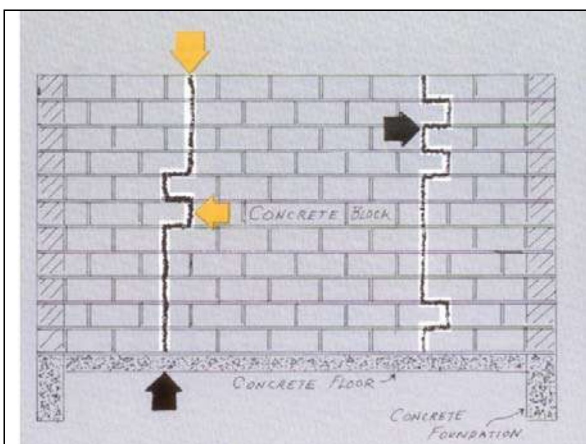
13.9 Cracking of houses and consequent devaluation

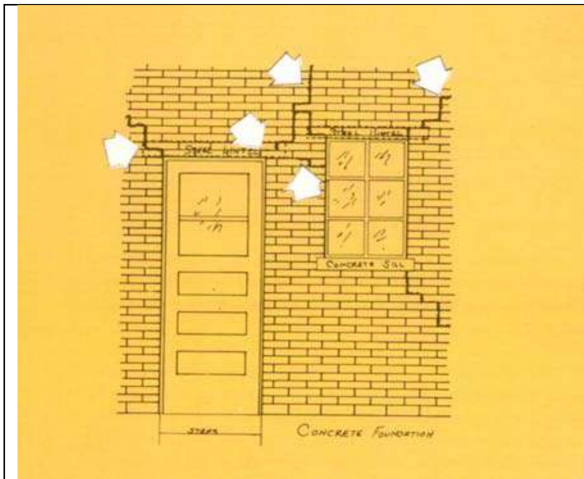
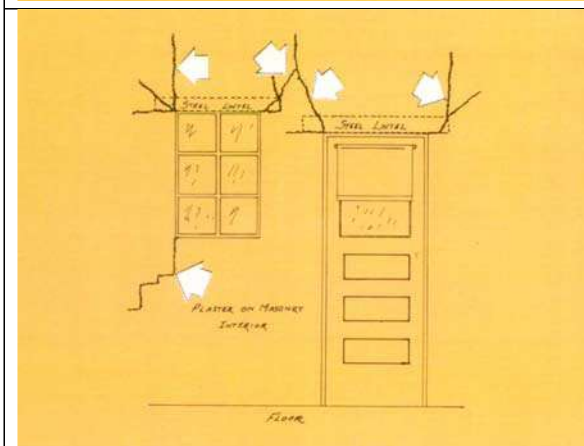
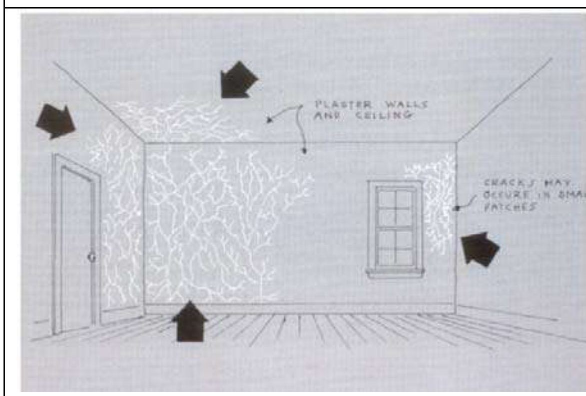
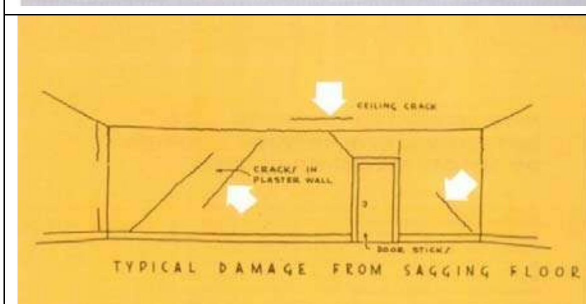
Houses in general have cracks. It is reported that a house could develop up to 15 cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. are more reason 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 7 below. A typical X crack formation is observed.

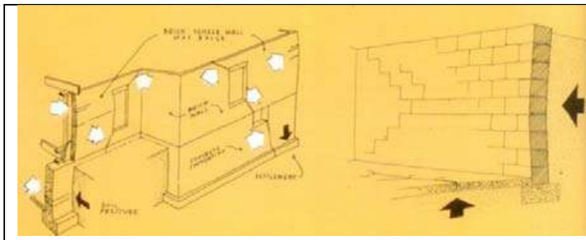
Figure 7: Example of blast induced damage.

The table below with figures show illustrations of non-blasting damage that could be found.

Table 3: Examples of typical non-blasting cracks

	Cracks Resulting from Shrinkage of Concrete Blocks

<table>
<tr><td>
</td><td>Typical Lintel Cracks</td></tr>
<tr><td>
</td><td>Typical Lintel Cracks</td></tr>
<tr><td>
</td><td>“Crazing” Cracks on Plaster</td></tr>
<tr><td>
</td><td>Plaster Cracks Caused by Sagging Floors</td></tr>
</table>

	Cracks Resulting from Foundational Failure

Observing cracks in the form indicated in Figure 7 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, and the general existence of cracks may be due to materials used. 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.

13.10 Vibration impacts on productivity of farm animals and wildlife

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

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

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

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

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

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

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

Work done by Richmond, Damon, Fletcher, Bowen and White considered the effect of air blast on animals from air blast in specific conditions. Animals were tested in shock tubes as well as research from other encompassed into the report. In this research work that was done to define the influence of air blast pressure and the resulting effect on different types and size of animals. Mouse, rabbits, Guinea Pig, hamsters, rat, dog, goat, sheep, cat and cattle were the subjects of this research. The research concentrated on the effect of short duration and long duration pressure pulses, orientation of subject, reflected shock or not and investigated the effect with regards to lethality, lung injury and eardrum rupture. This work was basis for estimates of pressure and possible influence on humans and the required protection of humans in blast situations. Without going into all the detail of the report the following is a summary of the findings. Long duration and fast rising pressure pulses seem to have most influence on the wellbeing of animals. Long duration pressure pulses are also found in the blasting environment. Long duration pressure pulses are defined as pulses beyond 20msec, and short duration as pulses having duration of less than 5msec. Lungs are considered the critical organs in such a situation. The release of air bubbles from disrupted alveoli of the lungs into the vascular systems accounted for the rapid deaths. The degree of lung haemorrhage was related to the increase in lung weight and blast dosage. Smaller lung sizes were damaged easier. Larger animals showed threshold of petechial haemorrhage was near 10 to 15 psi (68.9476 kPa to 103.421 kPa) at long durations. Ear damage recorded in sheep showed 38% rupture were recorded at 21.4 psi (147.548 kPa) for long durations and severity of damage increased with the intensity of the blast. The following figure (Figure 4) shows the mortality curves for the various animals exposed to long duration pressure pulses.

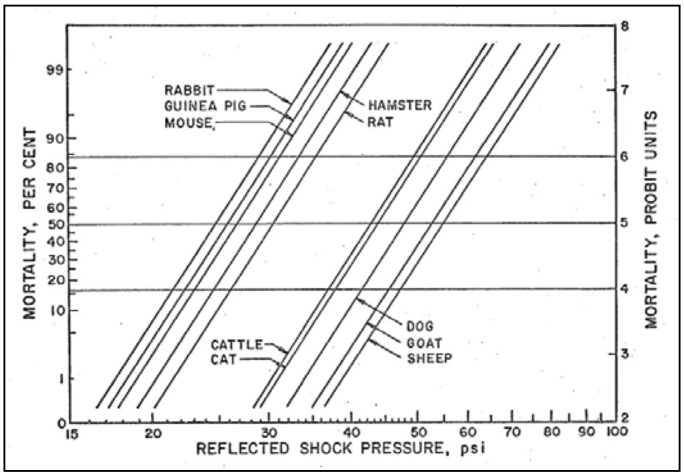


Figure 4: Mortality curve for long duration pressure exposure on animals.

In order to relate to air blast the following table (Table 4) shows the corresponding air blast level in dB and Pascal. Air blast is measured in Pascal (Pa) but converted to the dB scale for ease of use.

Table 4: Corresponding pressure levels to air blast values in the dB scale.

dB	P (Pa)	kPa	PSI	Observation
100.0	2.0	0.002	0.000	Range expected from blasting at Dalyshope at distance range of 50 m to 3500 m
120.0	20.0	0.020	0.003	
140.0	200.0	0.200	0.029	
150.0	632.5	0.632	0.092	No animals will be closer than 50 m to the pit
155.0	1124.7	1.12	0.163	
160.0	2000.0	2.00	0.290	
165.0	3556.6	3.56	0.516	
170.0	6324.6	6.32	0.917	
175.0	11246.8	11.25	1.631	
180.0	20000.0	20.00	2.901	
185.0	35565.6	35.57	5.158	
190.0	63245.6	63.25	9.173	
195.0	112468.3	112.47	16.312	
200.0	200000.0	200.00	29.008	
205.0	355655.9	355.66	51.584	
210.0	632455.5	632.46	91.730	

Distance between source and receptor will certainly be a major consideration. The greater the distance, the lesser will the effect be of noise or air blast. My experienced have not yet been extensively tested at short distances for example less than 100m from a blast.

14 Baseline Results

The baseline information for the project is limited to observation of the current surroundings of the proposed project. There are currently no blasting operations being conducted that can be measured as part of a baseline study. The study area is evaluated as a "green fields" project.

14.1 Structure profile

As part of the baseline, all possible structures in a possible influence area are identified. The site was reviewed and detailed here. The site was reviewed using Google Earth imagery. Information sought during the review was to identify surface structures present within a 3500 m radius from the proposed different opencast boundaries which will require consideration during modelling of blasting operations, e.g. houses, general structures, power lines, pipe lines, reservoirs, mining activity, roads, shops, schools, gathering places, possible historical sites, etc. A list was prepared of all structures in the vicinity of the opencast area. The list includes structures and points of interests (POIs) within the 3500 m boundary – see Table 6 below. A list of structure locations was required in order to determine the allowable ground vibration limits and air blast limits. Figure 8 shows an aerial view of the pit areas and surroundings with POIs. The type of POIs identified is grouped into different classes. These classes are indicated as "Classification" in Table 5. The classification used is a BMC classification and does not relate to any standard or national or international code or practice. Table 5 shows the descriptions for the classifications used.

Table 5: 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	Ruins
5	Animal related installations and animal sensitive areas
6	Industrial buildings and installations
7	Earth like structures – no surface structure
8	Heritage sites (buildings, infrastructure, activity, graves)
9	Graves
10	Water Borehole
11	Water Resources Surface
12	Pipelines Buried
13	Powerlines / Telephone Lines / Towers

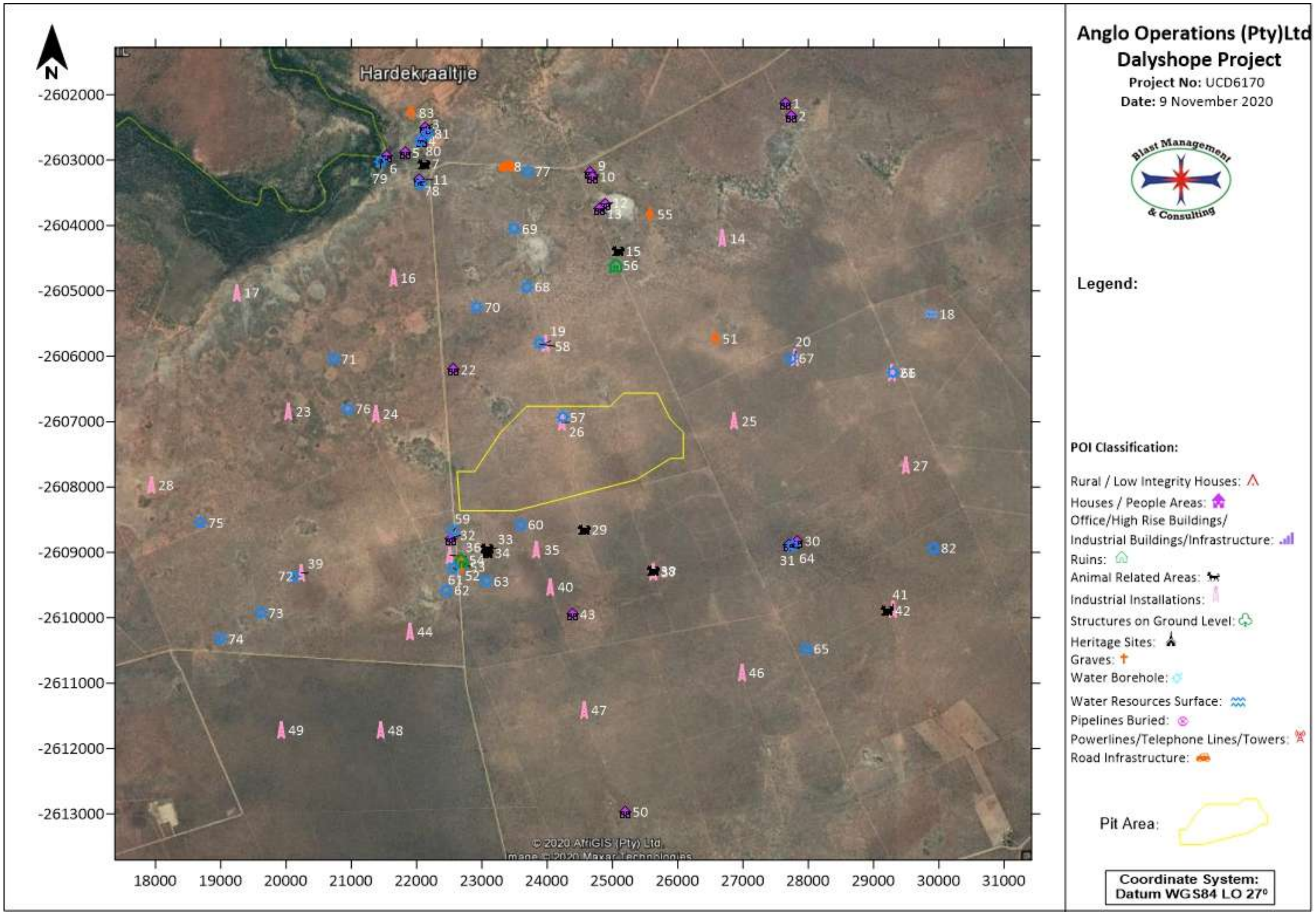


Figure 8: Aerial view and surface plan of the proposed Opencast mining area with points of interest identified

Table 6: List of points of interest identified (WGS – LO 27º)

Tag	Description	Classification	Y	X
1	Farmstead	2	-27644	2602129.58
2	House	2	-27733	2602322.451
3	Farmstead	2	-22123	2602499.892
4	Farmstead	2	-22070	2602705.442
5	House	2	-21820	2602887.82
6	Lodge / Farmstead	2	-21546	2602930.776
7	Farm Structure	5	-22119	2603055.95
8	Gravel Road	14	-23378	2603097.874
9	House	2	-24650	2603189.588
10	House	2	-24691	2603252.53
11	Farmstead	2	-22044	2603299.193
12	Farmstead	2	-24886	2603669.746
13	House	2	-24798	2603750.327
14	Cement Dam	6	-26688	2604196.022
15	Kraal	5	-25089	2604392.947
16	Cement Dam	6	-21640	2604803.506
17	Water trough	6	-19245	2605027.688
18	Pan	11	-29896	2605353.499
19	Cement Dam	6	-23968	2605811.228
20	Cement Dam	6	-27795	2606024.311
21	Cement Dam	6	-29283	2606243.036
22	Structure	2	-22562	2606206.23
23	Cement Dam	6	-20035	2606844.217
24	Cement Dam	6	-21372	2606883.215
25	Cement Dam	6	-26865	2606994.384
26	Cement Dam	6	-24219	2607010.455
27	Cement Dam	6	-29488	2607675.156
28	Cement Dam	6	-17930	2607969.668
29	Kraal	5	-24567	2608652.218
30	Farmstead	2	-27831	2608823.339
31	House	2	-27699	2608886.603
32	Farmstead	2	-22517	2608789.135
33	Kraal	5	-23076	2608939.119
34	Kraal	5	-23083	2609006.946
35	Cement Dam	6	-23842	2608958.704
36	Cement Dam	6	-22515	2609042.487
37	Cement Dam	6	-25631	2609303.745
38	Kraal	5	-25620	2609282.486
39	Cement Dam	6	-20237	2609313.146
40	Cement Dam	6	-24050	2609527.565
41	Cement Dam	6	-29304	2609874.811
42	Kraal	5	-29217	2609892.716
43	Farmstead	2	-24391	2609950.478
44	Cement Dam	6	-21901	2610214.727

Tag	Description	Classification	Y	X
46	Cement Dam	6	-26981	2610838.521
47	Cement Dam	6	-24566	2611411.624
48	Cement Dam	6	-21449	2611724.02
49	Cement Dam	6	-19925	2611719.318
50	Structure	2	-25197	2612966.864
51	Graves (Single Grave)	9	-26571	2605730.518
52	Graves (Single Grave)	9	-22681	2609212.119
53	Graves	9	-22670	2609148.26
54	Ruins	4	-22691	2609114.333
55	Grave	9	-25578	2603825.038
56	Ruins	4	-25048	2604605.671
57	Borehole (DH2)	10	-24239	2606933.895
58	Borehole (KW1)	10	-23879	2605811.842
59	Borehole (GT02)	10	-22562	2608678.722
60	Borehole (LD04)	10	-23594	2608572.914
61	Borehole (LD01)	10	-22563	2609236.042
62	Borehole (GT02)	10	-22463	2609576.599
63	Borehole (LD02)	10	-23070	2609444.446
64	Borehole (GRUIS1)	10	-27767	2608911.162
65	Borehole (DPP6)	10	-27969	2610471.509
66	Borehole (GRUIS4)	10	-29301	2606253.882
67	Borehole (GRUIS3)	10	-27742	2606029.546
68	Borehole (KW4)	10	-23695	2604935.117
69	Borehole (KW3)	10	-23501	2604049.496
70	Borehole (NAZ3)	10	-22928	2605249.107
71	Borehole (W93)	10	-20730	2606044.317
72	Borehole (W26)	10	-20123	2609360.23
73	Borehole (HB1)	10	-19616	2609927.021
74	Borehole (HB2)	10	-19000	2610325.176
75	Borehole (SKP44)	10	-18700	2608547.674
76	Borehole (NZEBH1)	10	-20948	2606801.13
77	Borehole (MBH2)	10	-23701	2603172.616
78	Borehole (NAZ5)	10	-22058	2603362.135
79	Borehole (NAZ2)	10	-21453	2603028.233
80	Borehole (HK1)	10	-22059	2602699.054
81	Borehole (HARMBH1)	10	-22162	2602593.042
82	Borehole (TCD1)	10	-29922	2608931.599
83	Graveyard	9	-21920	2602278.166

During the site visit the structures were observed and the initial POI list ground-truthed and finalised as represented in this section. Structures ranged from well-built structures, mining structures to informal building styles. Table 7 shows photos of structures found in the area.

Table 7: Structure Profile

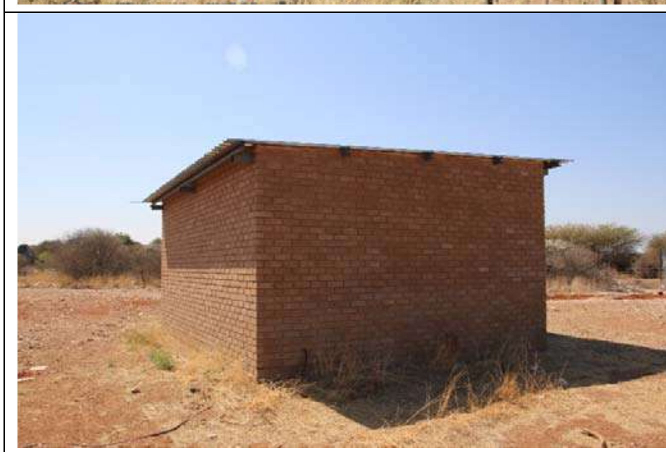
Structure Photo	Description
  	Brick and Mortar Structures

  	Water Reservoir

 	Farmstead
	Kraal

	Kraal
	Kraal
	Farm Structure

	Farm Structure
	Farm Structure
	Cement Dams

 	Boreholes
	Structures

	Structures
	Water Trough
	Game/Livestock

15 Blasting Operations

Blast design forms the basis of all calculations done for impact assessment. The current planned designs as supplied was applied for impact evaluation. Table shows summary technical information of the blast designs provided.

Table 6: Blast design technical information

Blast Geometry	
Type of Rock Blasted:	Shale
Formation of Blast:	Half Chevron
Hole diameter:	171mm
Burden:	5.0m
Spacing:	5.8m
Stemming length:	5.1m
Charge Column length:	14.9m
Hole depth:	20m
Sub-drill:	0m
Block Dimensions:	20m High, 50m Wide, 100-200m in length
Charge mass/delay expected:	17ms spacing delay with a 42ms burden delay
Target Powder Factor:	0.65 kg/m³
Explosive type:	ANFO (Example: Innovex 207)
Charge mass/metre:	25.3 kg/m
Effective charge diameter:	171mm
Average in-hole density:	1.1 g/cm³

The above information is applied for predicting ground vibration and air blast. Evaluation of the blasting operations considered a minimum charge and a maximum charge. The minimum charge was derived from the 171 mm diameter single blast hole and the maximum charge was extracted from the blast simulation in JKSimblast. The maximum charge relates to the total number of blast holes that detonates simultaneously based on a blast layout, initiation and timing of the blast. In this case a shock tube type initiation system is considered and expected to have at least four blastholes detonating simultaneously yielding the maximum mass of explosives detonating at once. The minimum charge relates to 316 kg and the maximum charge relates to 1506 kg. These values were applied in all predictions for ground vibration and air blast.

The following figures shows simulation done using JKSimblast blast design software to obtain maximum charge mass delay. Figure 5 Blast layout with blasthole numbers, depths, and charge. Figure 6 Blast layout with timing. Figure 7 Simulation showing maximum number of blastholes per delay. Figure 8 Simulation showing maximum charge per delay

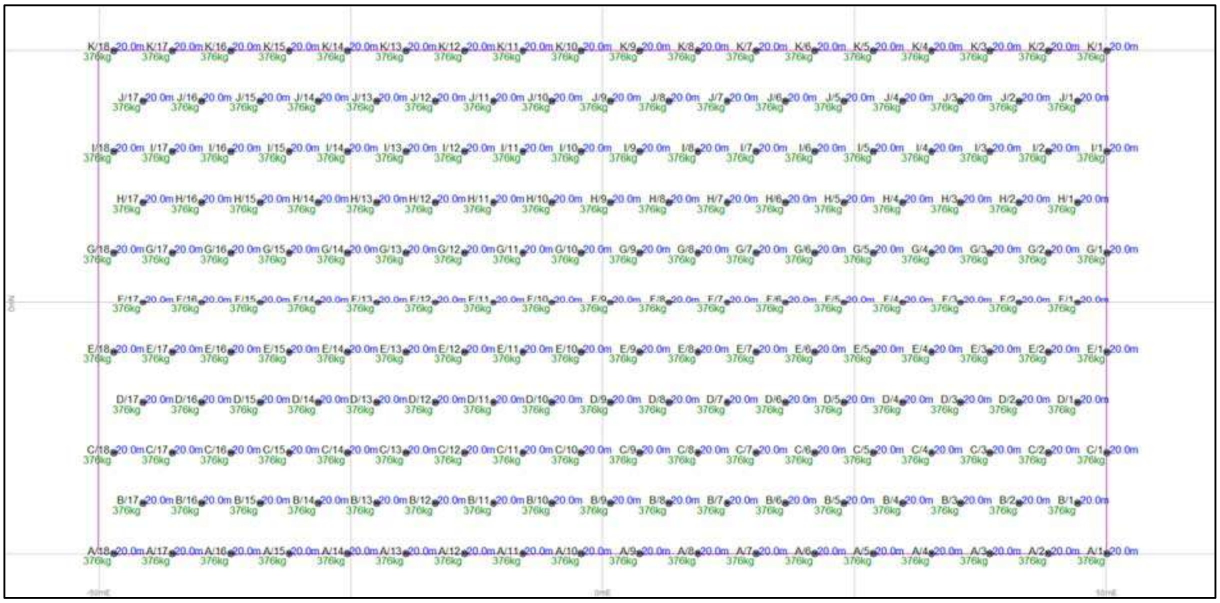


Figure 5: Blast layout with blasthole numbers, depths and charge

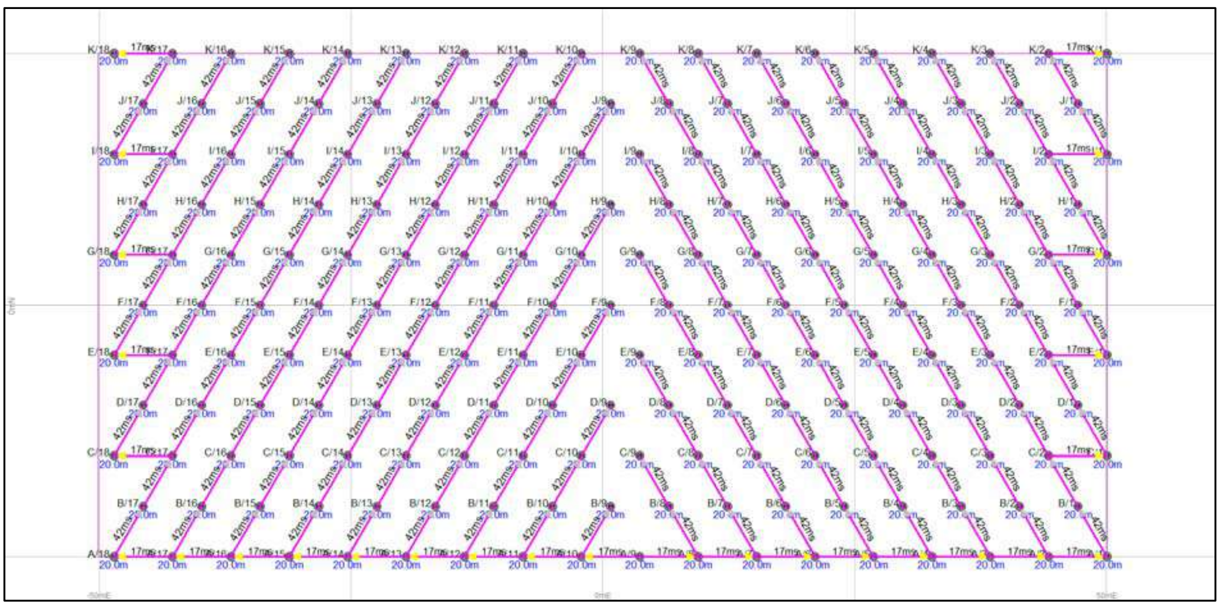


Figure 6: Blast layout with timing

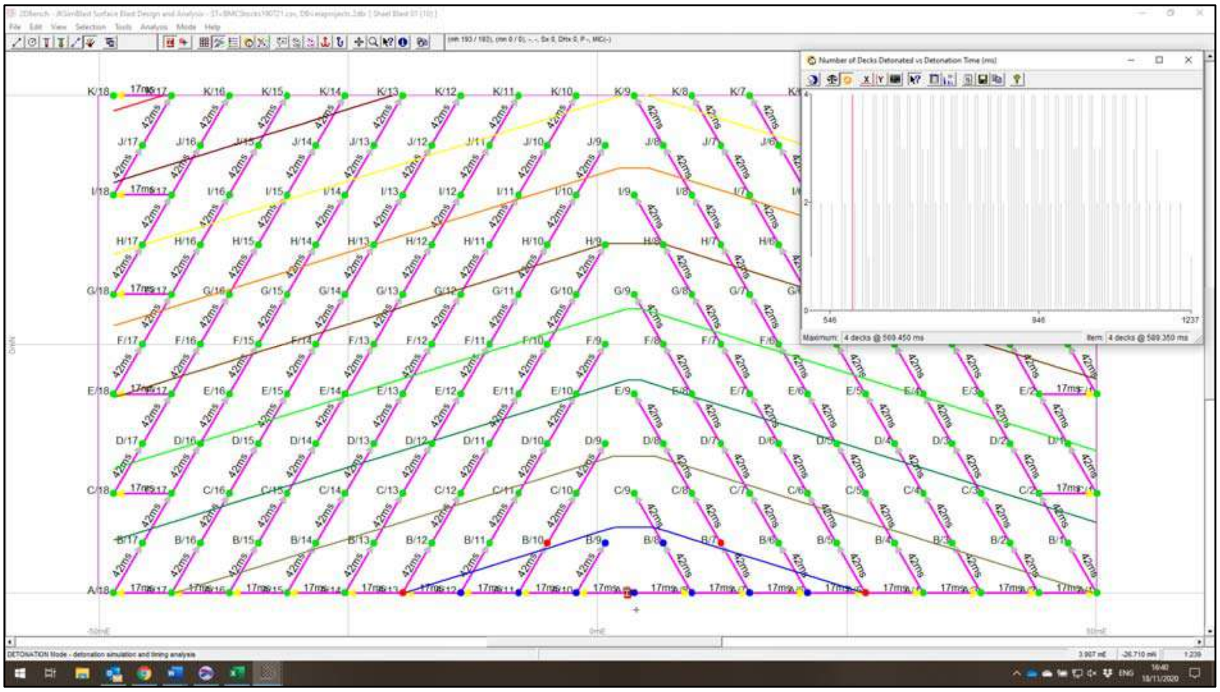


Figure 7: Simulation showing maximum number of blastholes per delay

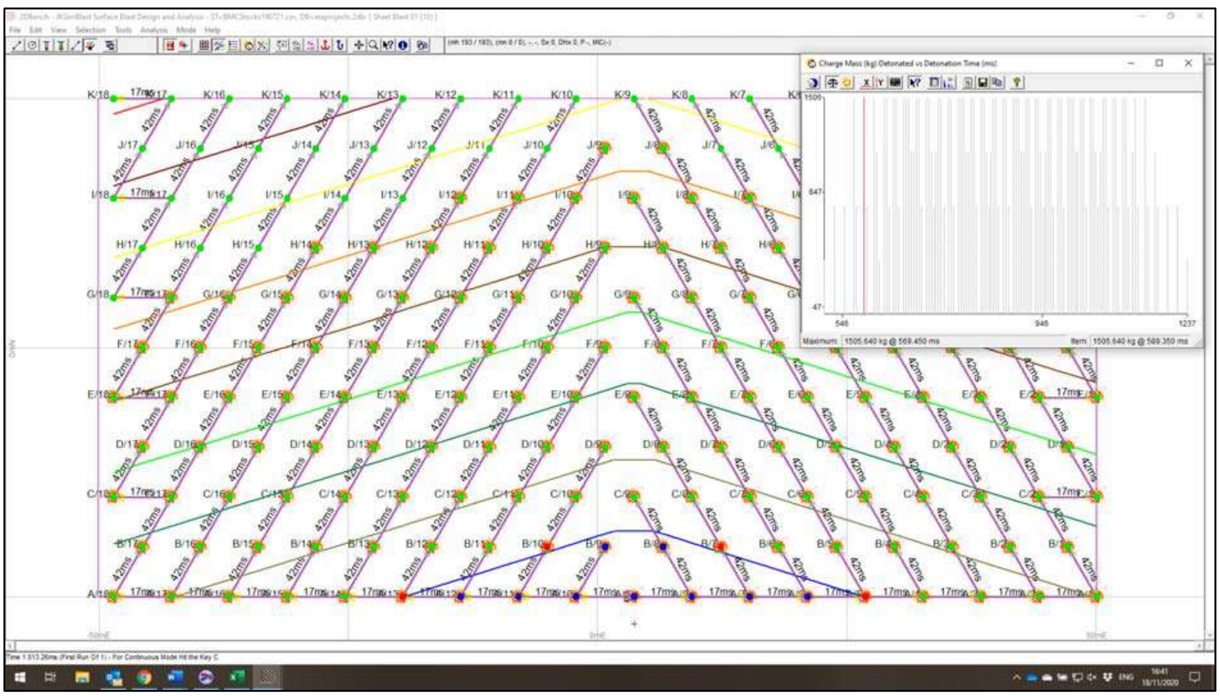


Figure 8: Simulation showing maximum charge per delay

15.1 Ground Vibration

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:

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

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

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

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

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

Based on the designs presented on expected drilling and charging design, the following Table shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. The charge masses are 316 kg and 1506 kg for the opencast area.

Table 7: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 316 kg Charge	Expected PPV (mm/s) for 1506 kg Charge
1	50.0	207.5	752.3
2	100.0	106.3	385.3
3	150.0	33.9	122.8
4	200.0	21.1	76.4
5	250.0	14.6	52.9
6	300.0	10.8	39.1
7	400.0	6.7	24.3
8	500.0	4.6	16.8
9	600.0	3.4	12.5
10	700.0	2.7	9.7

No.	Distance (m)	Expected PPV (mm/s) for 316 kg Charge	Expected PPV (mm/s) for 1506 kg Charge
11	800.0	2.1	7.8
12	900.0	1.8	6.4
13	1000.0	1.5	5.4
14	1250.0	1.0	3.7
15	1500.0	0.8	2.7
16	1750.0	0.6	2.1
17	2000.0	0.5	1.7
18	2500.0	0.3	1.2
19	3000.0	0.2	0.9
20	3500.0	0.2	0.7

15.2 Air blast

The prediction of air blast as a pre-operational effect is difficult to define exactly. There are many variables that have influence on the outcome of air blast. Air blast is the direct result from the blast process, although influenced by meteorological conditions, wind strength and direction, the final blast layout, timing, stemming, accessories used, covered or not covered etc. all has an influence on the outcome of the result. Air blast is also an aspect that can be controlled to a great degree by applying basic rules.
In most cases mainly an indication of typical levels can be obtained. The indication of levels or the prediction of air blast in this report is used to predefine possible indicators of concern.

Standard accepted prediction equations are applied for the prediction of air blast. A standard cube root scaling prediction formula is applied for air blast predictions. The following Equation 2 was used to calculate possible air blast values in millibar. This equation does not take temperature or any weather conditions into account.

Equation 2:

$$P = \mathrm{a} \times \left(\frac{\mathrm{D}}{\mathrm{E}^{\frac{1}{3}}}\right)^{-b}$$

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

a = Constant - (5.37)

b = Constant - (-0.79)

The constants for a and b were then selected according to the information as provided in Figure 9 below. Various types of mining operations are expected to yield different results. The information provided in Figure 9 is based on detailed research that was conducted for each of the different types of mining environments. In this report, the data for "Coal Mines (highwall)" was applied in the prediction or air blast.

Air Overpressure Prediction Equations

Blasting	Metric Equations mb	U.S. Equations psi	Statistical Type	Source
Open air (no confinement)	$P = 3589 \times SD_3^{-1.38}$	$P = 187 \times SD_3^{-1.38}$	Best Fit	Perkins
Coal mines (parting)	$P = 2596 \times SD_3^{-1.62}$	$P = 169 \times SD_3^{-1.62}$	Best Fit	USBM RI 8485
Coal mines (highwall)	$P = 5.37 \times SD_3^{-0.79}$	$P = 0.162 \times SD_3^{-0.79}$	Best Fit	USBM RI 8485
Quarry face	$P = 37.1 \times SD_3^{-0.97}$	$P = 1.32 \times SD_3^{-0.97}$	Best Fit	USBM RI 8485
Metal Mine	$P = 14.3 \times SD_3^{-0.71}$	$P = 0.401 \times SD_3^{-0.71}$	Best Fit	USBM RI 8485
Construction (average)	$P = 24.8 \times SD_3^{-1.1}$	$P = 1 \times SD_3^{-1.1}$	Best Fit	Oriard (2005)
Construction (highly confined)	$P = 2.48 \times SD_3^{-1.1}$	$P = 0.1 \times SD_3^{-1.1}$	Best Fit	Oriard (2005)
Buried (total confinement)	$P = 1.73 \times SD_3^{-0.96}$	$P = 0.061 \times SD_3^{-0.96}$	Best Fit	USBM RI 8485

Table 26.7 - Air overpressure prediction equations.

Figure 9: Proposed prediction equations

The air pressure calculated in Equation 2 is converted to decibels in Equation 3. The reporting of air blast in the decibel scale is more readily accepted in the mining industry.

Equation 3:

$$p_s = 20 \text{ x} \log \frac{P}{P_o}$$

Where:

p_s = Air blast level (dB)

P = Air blast level (Pa (mB x 100))

P_o = Reference Pressure (2 x 10^{-5} Pa)

Although the above equation was applied for prediction of air blast levels, additional measures are also recommended to ensure that air blast and associated fly-rock possibilities are minimized as best possible.

As discussed earlier the prediction of air blast is very subjective. Following in Table below is a summary of values predicted according to Equation 2.

Table 8: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 316 kg Charge	Air blast (dB) for 1506 kg Charge
1	50.0	134.9	138.4
2	100.0	132.1	135.6
3	150.0	127.3	130.9

No.	Distance (m)	Air blast (dB) for 316 kg Charge	Air blast (dB) for 1506 kg Charge
4	200.0	125.3	128.9
5	250.0	123.8	127.4
6	300.0	122.6	126.1
7	400.0	120.6	124.2
8	500.0	119.1	122.7
9	600.0	117.8	121.4
10	700.0	116.8	120.3
11	800.0	115.9	119.4
12	900.0	115.1	118.6
13	1000.0	114.4	117.9
14	1250.0	112.8	116.3
15	1500.0	111.5	115.1
16	1750.0	110.6	114.1
17	2000.0	109.6	113.1
18	2500.0	108.1	111.7
19	3000.0	106.8	110.5
20	3500.0	105.8	109.3

16 Construction Phase: Opencast Impact Assessment and Mitigation Measures

Currently there is no planned drilling and blasting operations for the construction phase. No specific impact is evaluated for the construction phase.

17 Operational Phase: Opencast Impact Assessment and Mitigation Measures

The area surrounding the proposed mining areas was reviewed for structures, traffic, roads, human interface, animal interface etc. Various installations and structures were observed. These are listed in Table 6. This section concentrates on the outcome of modelling the possible effects of ground vibration, air blast and fly rock specifically to these points of interest or possible interfaces. In evaluation, the charge mass scenarios selected as indicated in section 15 is considered with regards to ground vibration and air blast.

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

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

- Ground Vibration Modelling Results
- Ground Vibration and human perception

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

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

17.1 Review of expected ground vibration

Presented herewith are the expected ground vibration level contours and discussion of relevant influences. Expected ground vibration levels were calculated for each POI identified surrounding the mining area and evaluated with regards to possible structural concerns and human perception. Tables are provided for each of the different charge models done with regards to:

- "Tag" No. is the number corresponding to the POI figures.
- "Description" indicates the type of the structure.
- "Distance" is the distance between the structure and edge of the pit area.
- "Specific Limit" is the maximum limit for ground vibration at the specific structure or installation.
- "Predicted PPV (mm/s)" is the calculated ground vibration at the structure.
- The "Structure Response @ 10Hz and Human Tolerance @ 30Hz" indicates the possible concern and if there is any concern for structural damage or potential negative human perception respectively. Indicators used are "perceptible"," unpleasant", "intolerable" which stems from the human perception information given and indicators such as "high" or "low" is given for the possibility of damage to a structure. Levels below 0.76 mm/s could be considered to have negligible possibility of influence.

Ground vibration is calculated and modelled for the pit area at the minimum and maximum charge mass at specific distances from the opencast mining area. The charge masses applied are according to blast designs discussed in Section 15. 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 5000 m around the opencast mining area.

The simulation provided shows ground vibration contours only for a limited number of levels. The levels used are considered the basic limits that will be applicable for the type of structures observed surrounding the pit areas. These levels are: 6 mm/s, 12.5 mm/s, 25 mm/s and 50 mm/s. This enables immediate review of possible concerns that may be applicable to any of the privately-owned structures, social gathering areas or sensitive installations.

Data is provided as follows: Vibration contours; a table with predicted ground vibration values and evaluation for each POI. Additional colour codes used in the tables are as follows:

Structure Evaluations:
Vibration levels higher than proposed limit applicable to Structures / Installations is coloured “Red”
People’s Perception Evaluation:
Vibration levels indicated as Intolerable on human perception scale is coloured “Red”
Vibration levels indicated as Unpleasant on human perception scale is coloured “Mustard”
Vibration levels indicated as Perceptible on human perception scale is coloured “Light Green”
POI’s that are found inside the pit area is coloured “Olive Green”

Simulations for expected ground vibration levels from minimum and maximum charge mass are presented below.

17.1.1 Minimum charge mass per delay – 316 kg –Opencast Pit

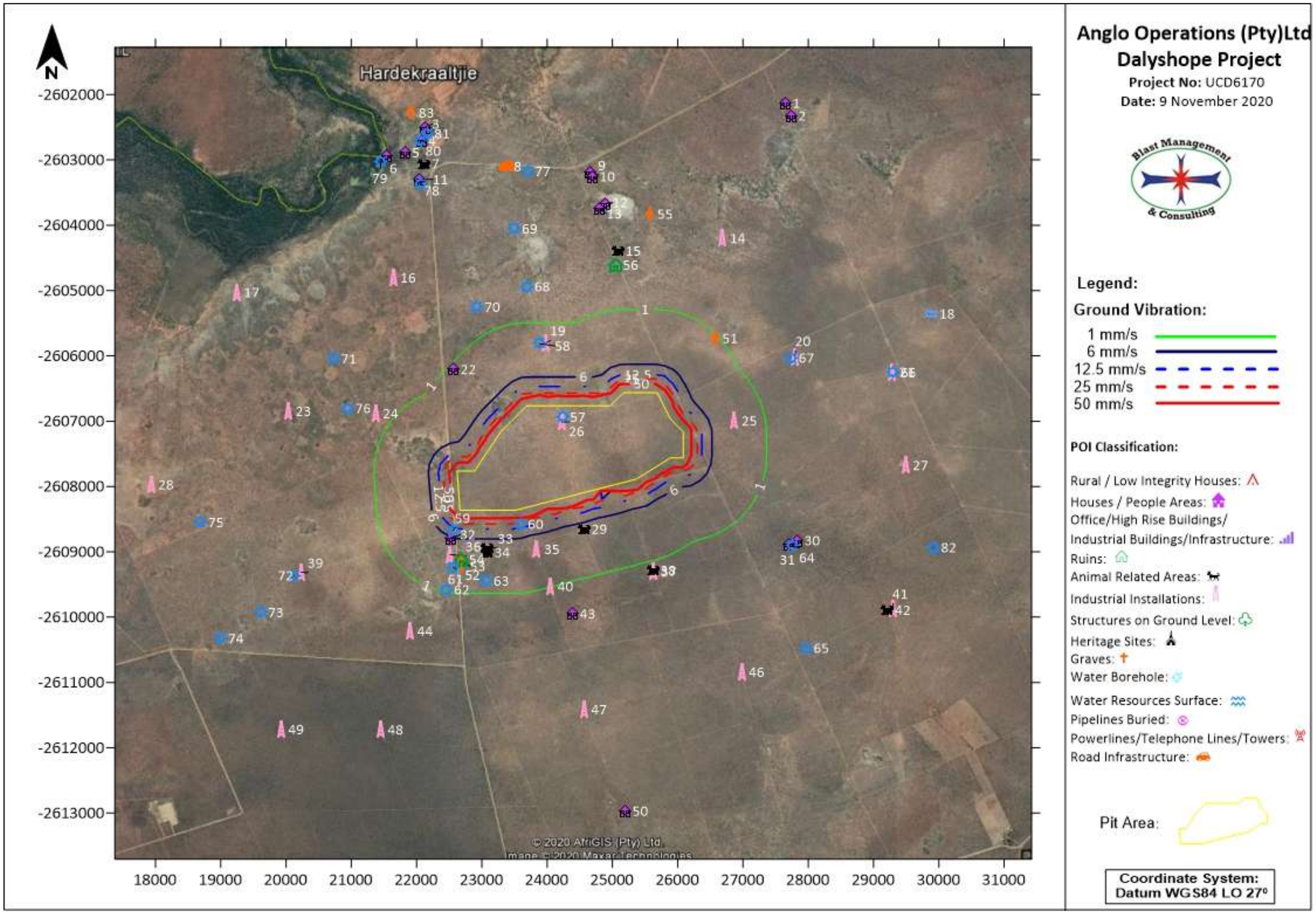


Figure 10: Ground vibration influence from minimum charge for Opencast area

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

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Farmstead	12.5	4849.427	316	0.10937	Acceptable	Too Low
2	House	12.5	4711.833	316	0.11469	Acceptable	Too Low
3	Farmstead	12.5	4543.196	316	0.121798	Acceptable	Too Low
4	Farmstead	12.5	4370.593	316	0.129836	Acceptable	Too Low
5	House	12.5	4304.425	316	0.133146	Acceptable	Too Low
6	Lodge / Farmstead	12.5	4393.116	316	0.12874	Acceptable	Too Low
7	Farm Structure	12.5	4027.812	316	0.148568	Acceptable	N/A
8	Gravel Road	200	3678.959	316	0.172521	Acceptable	Too Low
9	House	12.5	3413.664	316	0.195197	Acceptable	Too Low
10	House	12.5	3345.241	316	0.201829	Acceptable	Too Low
11	Farmstead	12.5	3836.571	316	0.160984	Acceptable	Too Low
12	Farmstead	12.5	2907.548	316	0.254372	Acceptable	Too Low
13	House	12.5	2837.562	316	0.264806	Acceptable	Too Low
14	Cement Dam	50	2572.896	316	0.311237	Acceptable	N/A
15	Kraal	50	2171.919	316	0.41162	Acceptable	N/A
16	Cement Dam	50	2833.099	316	0.265495	Acceptable	N/A
17	Water trough	50	4344.569	316	0.131122	Acceptable	N/A
18	Pan	200	4223.13	316	0.137401	Acceptable	Too Low
19	Cement Dam	50	952.1265	316	1.604877	Acceptable	N/A
20	Cement Dam	50	2056.598	316	0.450393	Acceptable	N/A
21	Cement Dam	50	3329.451	316	0.20341	Acceptable	N/A
22	Structure	12.5	1189.651	316	1.111337	Acceptable	Perceptible
23	Cement Dam	50	2743.784	316	0.279905	Acceptable	N/A
24	Cement Dam	50	1527.375	316	0.735831	Acceptable	N/A
25	Cement Dam	50	799.524	316	2.140997	Acceptable	N/A
26	Cement Dam	50		316			
27	Cement Dam	50	3404.305	316	0.196083	Acceptable	N/A
28	Cement Dam	50	4694.2	316	0.115402	Acceptable	N/A
29	Kraal	50	542.1814	316	4.06396	Acceptable	N/A
30	Farmstead	12.5	2153.845	316	0.417335	Acceptable	Too Low
31	House	12.5	2087.793	316	0.439343	Acceptable	Too Low
32	Farmstead	12.5	451.1109	316	5.504535	Acceptable	Perceptible
33	Kraal	50	575.8713	316	3.679181	Acceptable	N/A
34	Kraal	50	643.612	316	3.062374	Acceptable	N/A
35	Cement Dam	50	657.5108	316	2.956299	Acceptable	N/A
36	Cement Dam	50	696.1836	316	2.690257	Acceptable	N/A
37	Cement Dam	50	1438.977	316	0.811894	Acceptable	N/A
38	Kraal	50	1415.786	316	0.833954	Acceptable	N/A
39	Cement Dam	50	2605.365	316	0.304863	Acceptable	N/A
40	Cement Dam	50	1260.313	316	1.010412	Acceptable	N/A
41	Cement Dam	50	3964.203	316	0.152521	Acceptable	N/A
42	Kraal	50	3904.51	316	0.156388	Acceptable	N/A
43	Farmstead	12.5	1755.062	316	0.585067	Acceptable	Too Low
44	Cement Dam	50	2002.896	316	0.470491	Acceptable	N/A
46	Cement Dam	50	3365.748	316	0.199804	Acceptable	N/A
47	Cement Dam	50	3213.479	316	0.215664	Acceptable	N/A
48	Cement Dam	50	3574.093	316	0.180952	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
49	Cement Dam	50	4331.783	316	0.131761	Acceptable	N/A
50	Structure	12.5	4877.165	316	0.108346	Acceptable	Too Low
51	Graves (Single Grave)	50	1219.268	316	1.067147	Acceptable	N/A
52	Graves (Single Grave)	50	848.8453	316	1.939639	Acceptable	N/A
53	Graves	50	785.2211	316	2.205725	Acceptable	N/A
54	Ruins	6	750.9926	316	2.374046	Acceptable	Perceptible
55	Grave	50	2738.329	316	0.280826	Acceptable	N/A
56	Ruins	6	1961.457	316	0.487004	Acceptable	Too Low
57	Borehole (DH2)	50		315			
58	Borehole (KW1)	50	951.5174	316	1.606573	Acceptable	Perceptible
59	Borehole (GT02)	50	332.1296	316	9.12285	Acceptable	Unpleasant
60	Borehole (LD04)	50	222.0096	316	17.7327	Acceptable	Unpleasant
61	Borehole (LD01)	50	879.5559	316	1.829167	Acceptable	Perceptible
62	Borehole (GT02)	50	1230.802	316	1.050698	Acceptable	Perceptible
63	Borehole (LD02)	50	1081.192	316	1.301212	Acceptable	Perceptible
64	Borehole (GRUIS1)	50	2156.089	316	0.416618	Acceptable	Too Low
65	Borehole (DPP6)	50	3465.617	316	0.190393	Acceptable	Too Low
66	Borehole (GRUIS4)	50	3343.941	316	0.201958	Acceptable	Too Low
67	Borehole (GRUIS3)	50	2009.244	316	0.468041	Acceptable	Too Low
68	Borehole (KW4)	50	1828.224	316	0.54694	Acceptable	Too Low
69	Borehole (KW3)	50	2720.625	316	0.283847	Acceptable	Too Low
70	Borehole (NAZ3)	50	1696.428	316	0.618806	Acceptable	Too Low
71	Borehole (W93)	50	2555.465	316	0.314748	Acceptable	Too Low
72	Borehole (W26)	50	2729.25	316	0.282369	Acceptable	Too Low
73	Borehole (HB1)	50	3425.511	316	0.194085	Acceptable	Too Low
74	Borehole (HB2)	50	4155.441	316	0.141114	Acceptable	Too Low
75	Borehole (SKP44)	50	3966.478	316	0.152377	Acceptable	Too Low
76	Borehole (NZEBH1)	50	1929.261	316	0.500487	Acceptable	Too Low
77	Borehole (MBH2)	50	3590.733	316	0.179571	Acceptable	Too Low
78	Borehole (NAZ5)	50	3773.562	316	0.165443	Acceptable	Too Low
79	Borehole (NAZ2)	50	4355.062	316	0.130601	Acceptable	Too Low
80	Borehole (HK1)	50	4380.405	316	0.129357	Acceptable	Too Low
81	Borehole (HARMBH1)	50	4442.544	316	0.126385	Acceptable	Too Low
82	Borehole (TCD1)	50	4074.557	316	0.145766	Acceptable	Too Low
83	Graveyard	50	4822.838	316	0.110367	Acceptable	N/A

17.1.2 Maximum charge mass per delay – 1506 kg – Opencast Pit

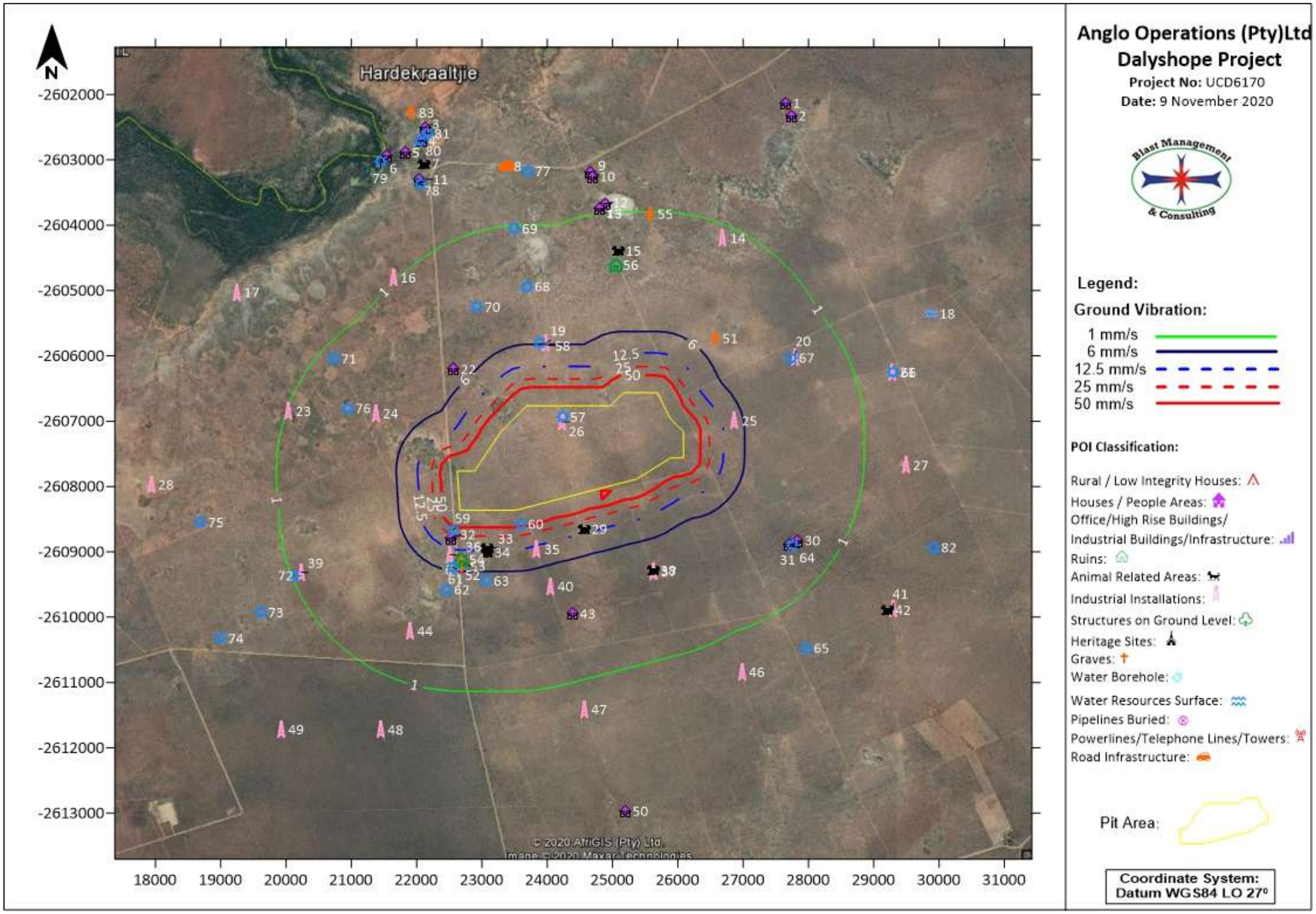


Figure 11: Ground vibration influence from maximum charge for Opencast area

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

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Farmstead	12.5	4849	1506	0.40	Acceptable	Too Low
2	House	12.5	4712	1506	0.42	Acceptable	Too Low
3	Farmstead	12.5	4543	1506	0.44	Acceptable	Too Low
4	Farmstead	12.5	4371	1506	0.47	Acceptable	Too Low
5	House	12.5	4304	1506	0.48	Acceptable	Too Low
6	Lodge / Farmstead	12.5	4393	1506	0.47	Acceptable	Too Low
7	Farm Structure	12.5	4028	1506	0.54	Acceptable	N/A
8	Gravel Road	200	3679	1506	0.63	Acceptable	Too Low
9	House	12.5	3414	1506	0.71	Acceptable	Too Low
10	House	12.5	3345	1506	0.73	Acceptable	Too Low
11	Farmstead	12.5	3837	1506	0.58	Acceptable	Too Low
12	Farmstead	12.5	2908	1506	0.92	Acceptable	Perceptible
13	House	12.5	2838	1506	0.96	Acceptable	Perceptible
14	Cement Dam	50	2573	1506	1.13	Acceptable	N/A
15	Kraal	50	2172	1506	1.49	Acceptable	N/A
16	Cement Dam	50	2833	1506	0.96	Acceptable	N/A
17	Water trough	50	4345	1506	0.48	Acceptable	N/A
18	Pan	200	4223	1506	0.50	Acceptable	Too Low
19	Cement Dam	50	952	1506	5.82	Acceptable	N/A
20	Cement Dam	50	2057	1506	1.63	Acceptable	N/A
21	Cement Dam	50	3329	1506	0.74	Acceptable	N/A
22	Structure	12.5	1190	1506	4.03	Acceptable	Perceptible
23	Cement Dam	50	2744	1506	1.01	Acceptable	N/A
24	Cement Dam	50	1527	1506	2.67	Acceptable	N/A
25	Cement Dam	50	800	1506	7.76	Acceptable	N/A
26	Cement Dam	50		1506			
27	Cement Dam	50	3404	1506	0.71	Acceptable	N/A
28	Cement Dam	50	4694	1506	0.42	Acceptable	N/A
29	Kraal	50	542	1506	14.73	Acceptable	N/A
30	Farmstead	12.5	2154	1506	1.51	Acceptable	Perceptible
31	House	12.5	2088	1506	1.59	Acceptable	Perceptible
32	Farmstead	12.5	451	1506	19.96	Problematic	Unpleasant
33	Kraal	50	576	1506	13.34	Acceptable	N/A
34	Kraal	50	644	1506	11.10	Acceptable	N/A
35	Cement Dam	50	658	1506	10.72	Acceptable	N/A
36	Cement Dam	50	696	1506	9.75	Acceptable	N/A
37	Cement Dam	50	1439	1506	2.94	Acceptable	N/A
38	Kraal	50	1416	1506	3.02	Acceptable	N/A
39	Cement Dam	50	2605	1506	1.11	Acceptable	N/A
40	Cement Dam	50	1260	1506	3.66	Acceptable	N/A
41	Cement Dam	50	3964	1506	0.55	Acceptable	N/A
42	Kraal	50	3905	1506	0.57	Acceptable	N/A
43	Farmstead	12.5	1755	1506	2.12	Acceptable	Perceptible
44	Cement Dam	50	2003	1506	1.71	Acceptable	N/A
46	Cement Dam	50	3366	1506	0.72	Acceptable	N/A
47	Cement Dam	50	3213	1506	0.78	Acceptable	N/A
48	Cement Dam	50	3574	1506	0.66	Acceptable	N/A
49	Cement Dam	50	4332	1506	0.48	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
50	Structure	12.5	4877	1506	0.39	Acceptable	Too Low
51	Graves (Single Grave)	50	1219	1506	3.87	Acceptable	N/A
52	Graves (Single Grave)	50	849	1506	7.03	Acceptable	N/A
53	Graves	50	785	1506	8.00	Acceptable	N/A
54	Ruins	6	751	1506	8.61	Problematic	Unpleasant
55	Grave	50	2738	1506	1.02	Acceptable	N/A
56	Ruins	6	1961	1506	1.77	Acceptable	Perceptible
57	Borehole (DH2)	50		1506			
58	Borehole (KW1)	50	952	1506	5.82	Acceptable	Unpleasant
59	Borehole (GT02)	50	332	1506	33.08	Acceptable	Intolerable
60	Borehole (LD04)	50	222	1506	64.29	Problematic	Intolerable
61	Borehole (LD01)	50	880	1506	6.63	Acceptable	Unpleasant
62	Borehole (GT02)	50	1231	1506	3.81	Acceptable	Perceptible
63	Borehole (LD02)	50	1081	1506	4.72	Acceptable	Perceptible
64	Borehole (GRUIS1)	50	2156	1506	1.51	Acceptable	Perceptible
65	Borehole (DPP6)	50	3466	1506	0.69	Acceptable	Too Low
66	Borehole (GRUIS4)	50	3344	1506	0.73	Acceptable	Too Low
67	Borehole (GRUIS3)	50	2009	1506	1.70	Acceptable	Perceptible
68	Borehole (KW4)	50	1828	1506	1.98	Acceptable	Perceptible
69	Borehole (KW3)	50	2721	1506	1.03	Acceptable	Perceptible
70	Borehole (NAZ3)	50	1696	1506	2.24	Acceptable	Perceptible
71	Borehole (W93)	50	2555	1506	1.14	Acceptable	Perceptible
72	Borehole (W26)	50	2729	1506	1.02	Acceptable	Perceptible
73	Borehole (HB1)	50	3426	1506	0.70	Acceptable	Too Low
74	Borehole (HB2)	50	4155	1506	0.51	Acceptable	Too Low
75	Borehole (SKP44)	50	3966	1506	0.55	Acceptable	Too Low
76	Borehole (NZEBH1)	50	1929	1506	1.81	Acceptable	Perceptible
77	Borehole (MBH2)	50	3591	1506	0.65	Acceptable	Too Low
78	Borehole (NAZ5)	50	3774	1506	0.60	Acceptable	Too Low
79	Borehole (NAZ2)	50	4355	1506	0.47	Acceptable	Too Low
80	Borehole (HK1)	50	4380	1506	0.47	Acceptable	Too Low
81	Borehole (HARMBH1)	50	4443	1506	0.46	Acceptable	Too Low
82	Borehole (TCD1)	50	4075	1506	0.53	Acceptable	Too Low
83	Graveyard	50	4823	1506	0.40	Acceptable	N/A

17.2 Summary of ground vibration levels

The opencast operations were evaluated for expected levels of ground vibration from future blasting operations. Review of the site and the surrounding installations / houses / buildings showed that structures vary in distances from the pit areas. The influences will also vary with distance from the pit areas. The model used for evaluation does indicate low and high levels. It will be imperative to ensure that a monitoring program is done to confirm levels of ground vibration to ensure that ground vibration levels are not exceeded.

The evaluation mainly considered a distance up to 5000 m from the pit areas. Houses and infrastructure found around the opencast area range in distances. Distances ranges from very close to the full extent of the areas considered. The planned maximum charge evaluated showed that for some of these structures and infrastructure ground vibration may be high and could be problematic in terms of potential structural damage and human perception. The ground vibration levels predicted ranged between 0.4 mm/s and very high levels for structures surrounding the pit area. In view of the maximum charge specific attention will need to be given to specific areas.

Various POI's were identified as problematic. Two POI's were found within the boundaries of the opencast pit area. Evaluation of minimum charge showed that ground vibration may be acceptable for three other POI's, but evaluation of maximum charge showed that ground vibration may be problematic in terms of potential structural damage and human perception at the farmstead, and the cement dam at these distances.

Heritage Sites which include graves, ruins were identified by the Heritage Specialist. The ruin was identified as problematic in the study area The Heritage Specialist recommended that certain mitigation measures have to be applied to the historical ruins which will be affected directly or indirectly during the construction and operational phase for the proposed project.

There are two Hydrocencus boreholes identified as problematic at these distances and it is uncertain what the long-term plan will be for these boreholes. Expected levels of ground vibration is greater than proposed limit for these boreholes.

Mitigation of ground vibration was considered and discussed in Section 17.13. A detail inspection of the area and accurate identification of structures will also need to be done to ensure the levels of ground vibration allowable and limit to be applied.

17.3 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 30 Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 11 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 11 that up to a distance of 2907 m people may experience ground vibration as perceptible. Up to 1081 m people may experience ground vibration as unpleasant and up to 451 m as intolerable.

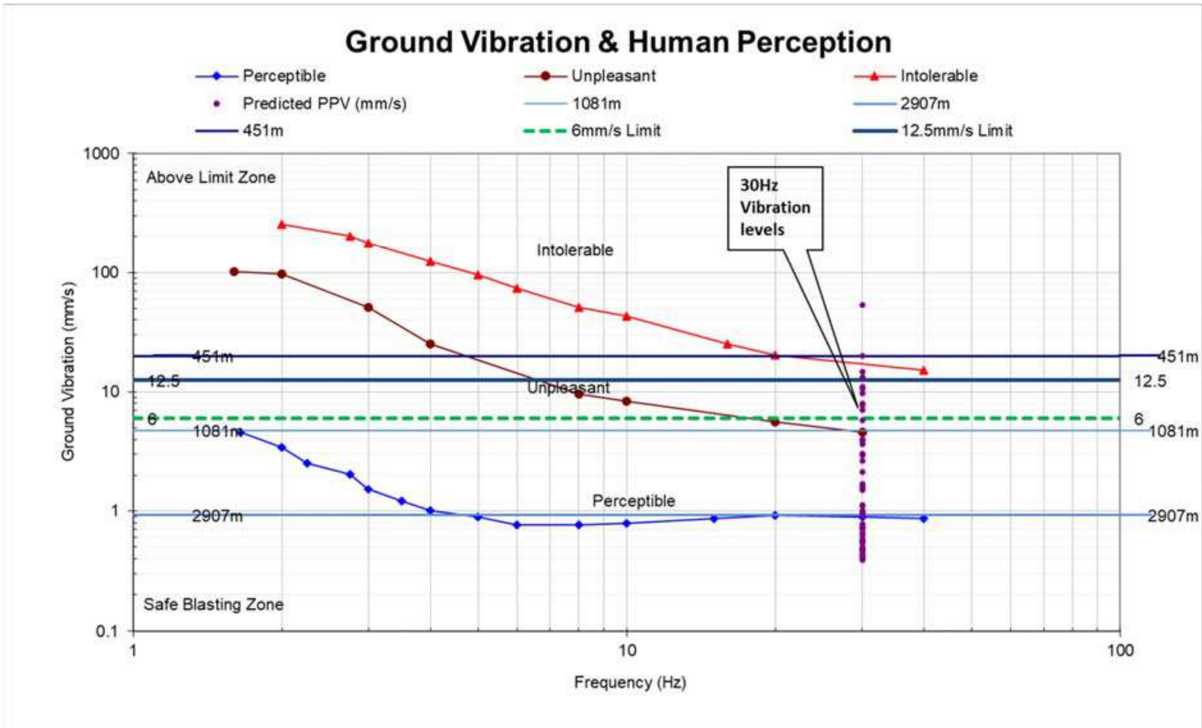


Figure 11: The effect of ground vibration with human perception and vibration limits

17.4 Vibration impact on roads

There are various gravel roads in the vicinity of the project area and needs to be considered. There may be people and animals on these routes and will require careful planning to main safe blasting radius. There is no specific concern regarding the ground vibration impact on the gravel roads. Further it will be required that clearance distances be set, and road travel managed during blasting operations.

17.5 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. There are settlements of people in proximity of planned operations. These buildings/structures are located such that levels of ground vibration predicted may be problematic and damaging.

Ground vibration and air blast generally upset people living in the vicinity of mining operations. The only nearest settlement of people to the opencast area is a farmstead, approximately at 451 m. The Farmstead is located such that levels of ground vibration predicted may be problematic and may cause damage.

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

17.6 Cracking of houses and consequent devaluation

The structures found in the areas of concern ranges from informal building style to brick and mortar structures. There are various buildings found within the 5000 m range from the mining area. Building style and materials will certainly contribute to additional cracking apart from influences such as blasting operations.

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

The proposed limits as applied in this document i.e. 6 mm/s, 12.5 mm/s and 25 mm/s are considered enough 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.

17.7 Review of expected air blast

Presented herewith are the expected air blast level contours and discussion of relevant influences. Expected air blast levels were calculated for each POI identified surrounding the mining areas and evaluated with regards to possible structural concerns. Tables are provided for each of the different charge models done with regards to:

- "Tag" No. is number corresponding to the location indicated on POI figures;
- "Description" indicates the type of the structure;
- "Distance" is the distance between the structure and edge of the pit area;
- "Air Blast (dB)" is the calculated air blast level at the structure;
- "Possible concern" indicates if there is any concern for structural damage or human perception. Indicators used are:
  - o "Problematic" where there is real concern for possible damage – at levels greater than 134 dB;
  - o "Complaint" where people will be complaining due to the experienced effect on structures at levels of 120 dB and higher (not necessarily damaging);
  - o "Acceptable" if levels are less than 120 dB;

- "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 to have low or negligible possibility of influence.

Presented are simulations for expected air blast levels from two different charge masses at each pit area. Colour codes used in tables are as follows:

Air blast levels higher than proposed limit is coloured "Red"
Air blast levels indicated as possible Complaint is coloured "Mustard"
POI's that are found inside the pit area is coloured "Olive Green"

17.7.1 Minimum charge mass per delay – 316 kg – Opencast Pit

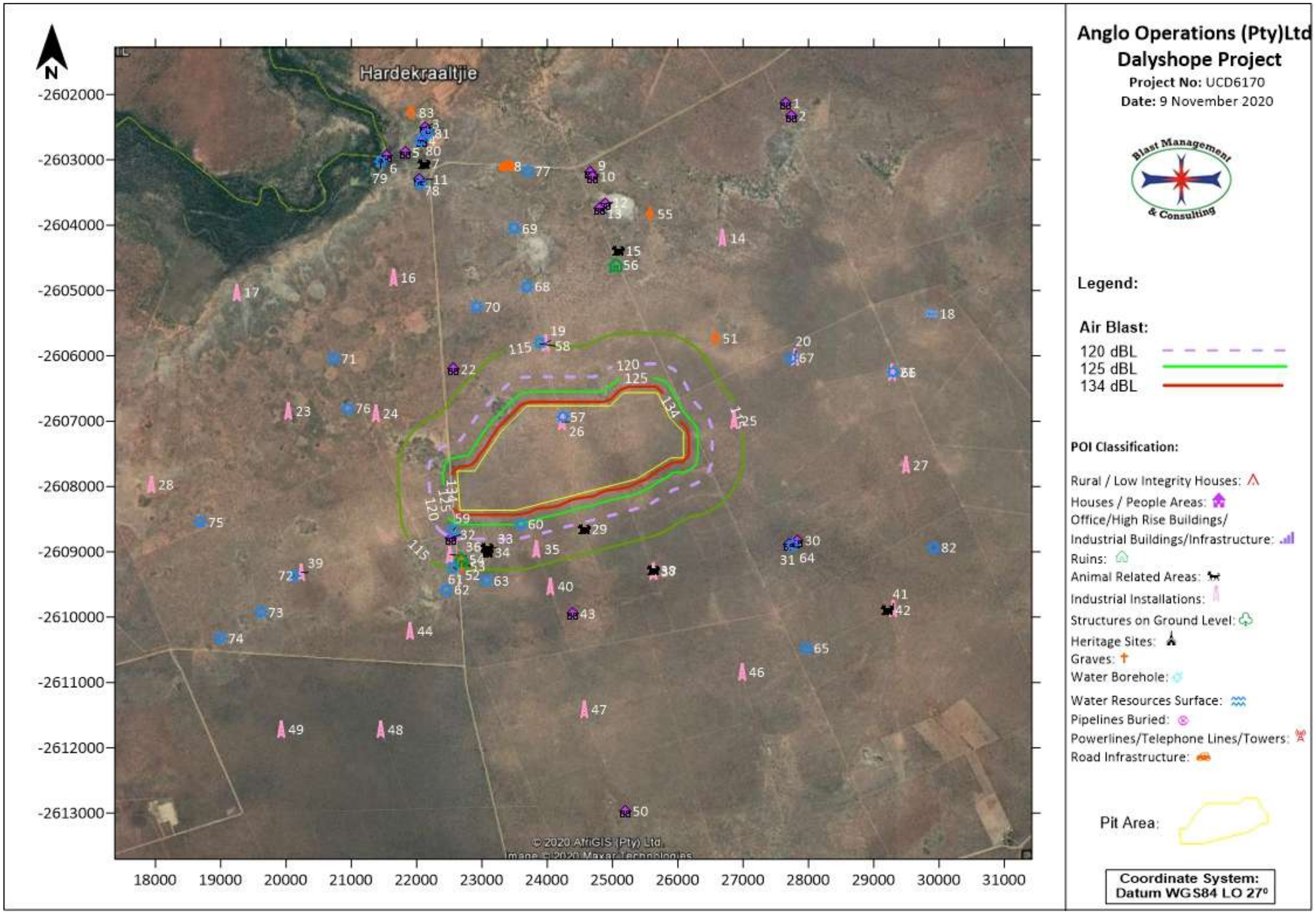


Figure 12: Air blast influence from minimum charge for Opencast area

Table 9: Air blast evaluation for minimum charge for Opencast Area

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Farmstead	4849.427	103.5	Acceptable
2	House	4711.833	103.8	Acceptable
3	Farmstead	4543.196	104	Acceptable
4	Farmstead	4370.593	104.3	Acceptable
5	House	4304.425	104.3	Acceptable
6	Lodge / Farmstead	4393.116	104.3	Acceptable
7	Farm Structure	4027.812	104.8	N/A
8	Gravel Road	3678.959	105.5	Acceptable
9	House	3413.664	106	Acceptable
10	House	3345.241	106.2	Acceptable
11	Farmstead	3836.571	105.3	Acceptable
12	Farmstead	2907.548	107	Acceptable
13	House	2837.562	107.2	Acceptable
14	Cement Dam	2572.896	107.9	N/A
15	Kraal	2171.919	109	N/A
16	Cement Dam	2833.099	107.2	N/A
17	Water trough	4344.569	104.3	N/A
18	Pan	4223.13	104.6	Acceptable
19	Cement Dam	952.1265	114.7	N/A
20	Cement Dam	2056.598	109.3	N/A
21	Cement Dam	3329.451	106.2	N/A
22	Structure	1189.651	113.1	Acceptable
23	Cement Dam	2743.784	107.4	N/A
24	Cement Dam	1527.375	111.4	N/A
25	Cement Dam	799.524	115.9	N/A
26	Cement Dam			
27	Cement Dam	3404.305	106	N/A
28	Cement Dam	4694.2	103.8	N/A
29	Kraal	542.1814	118.5	N/A
30	Farmstead	2153.845	109	Acceptable
31	House	2087.793	109.3	Acceptable
32	Farmstead	451.1109	119.8	Acceptable
33	Kraal	575.8713	118.1	N/A
34	Kraal	643.612	117.3	N/A
35	Cement Dam	657.5108	117.2	N/A
36	Cement Dam	696.1836	116.8	N/A
37	Cement Dam	1438.977	111.9	N/A
38	Kraal	1415.786	112	N/A
39	Cement Dam	2605.365	107.7	N/A
40	Cement Dam	1260.313	112.7	N/A
41	Cement Dam	3964.203	105.1	N/A
42	Kraal	3904.51	105.1	N/A
43	Farmstead	1755.062	110.5	Acceptable
44	Cement Dam	2002.896	109.6	N/A
46	Cement Dam	3365.748	106	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
47	Cement Dam	3213.479	106.4	N/A
48	Cement Dam	3574.093	105.8	N/A
49	Cement Dam	4331.783	104.3	N/A
50	Structure	4877.165	103.5	Acceptable
51	Graves (Single Grave)	1219.268	113	Acceptable
52	Graves (Single Grave)	848.8453	115.4	Acceptable
53	Graves	785.2211	116	Acceptable
54	Ruins	750.9926	116.3	Acceptable
55	Grave	2738.329	107.6	Acceptable
56	Ruins	1961.457	109.8	Acceptable
57	Borehole (DH2)			
58	Borehole (KW1)	951.5174	114.7	Acceptable
59	Borehole (GT02)	332.1296	121.9	N/A
60	Borehole (LD04)	222.0096	124.6	N/A
61	Borehole (LD01)	879.5559	115.2	N/A
62	Borehole (GT02)	1230.802	112.9	N/A
63	Borehole (LD02)	1081.192	113.8	N/A
64	Borehole (GRUIS1)	2156.089	109	N/A
65	Borehole (DPP6)	3465.617	106	N/A
66	Borehole (GRUIS4)	3343.941	106.2	N/A
67	Borehole (GRUIS3)	2009.244	109.6	N/A
68	Borehole (KW4)	1828.224	110.2	N/A
69	Borehole (KW3)	2720.625	107.6	N/A
70	Borehole (NAZ3)	1696.428	110.7	N/A
71	Borehole (W93)	2555.465	107.9	N/A
72	Borehole (W26)	2729.25	107.6	N/A
73	Borehole (HB1)	3425.511	106	N/A
74	Borehole (HB2)	4155.441	104.6	N/A
75	Borehole (SKP44)	3966.478	105.1	N/A
76	Borehole (NZEBH1)	1929.261	109.9	N/A
77	Borehole (MBH2)	3590.733	105.5	N/A
78	Borehole (NAZ5)	3773.562	105.3	N/A
79	Borehole (NAZ2)	4355.062	104.3	N/A
80	Borehole (HK1)	4380.405	104.3	N/A
81	Borehole (HARMBH1)	4442.544	104.3	N/A
82	Borehole (TCD1)	4074.557	104.8	N/A
83	Graveyard	4822.838	103.8	Acceptable

17.7.2 Maximum charge mass per delay – 1506 kg – Opencast Pit

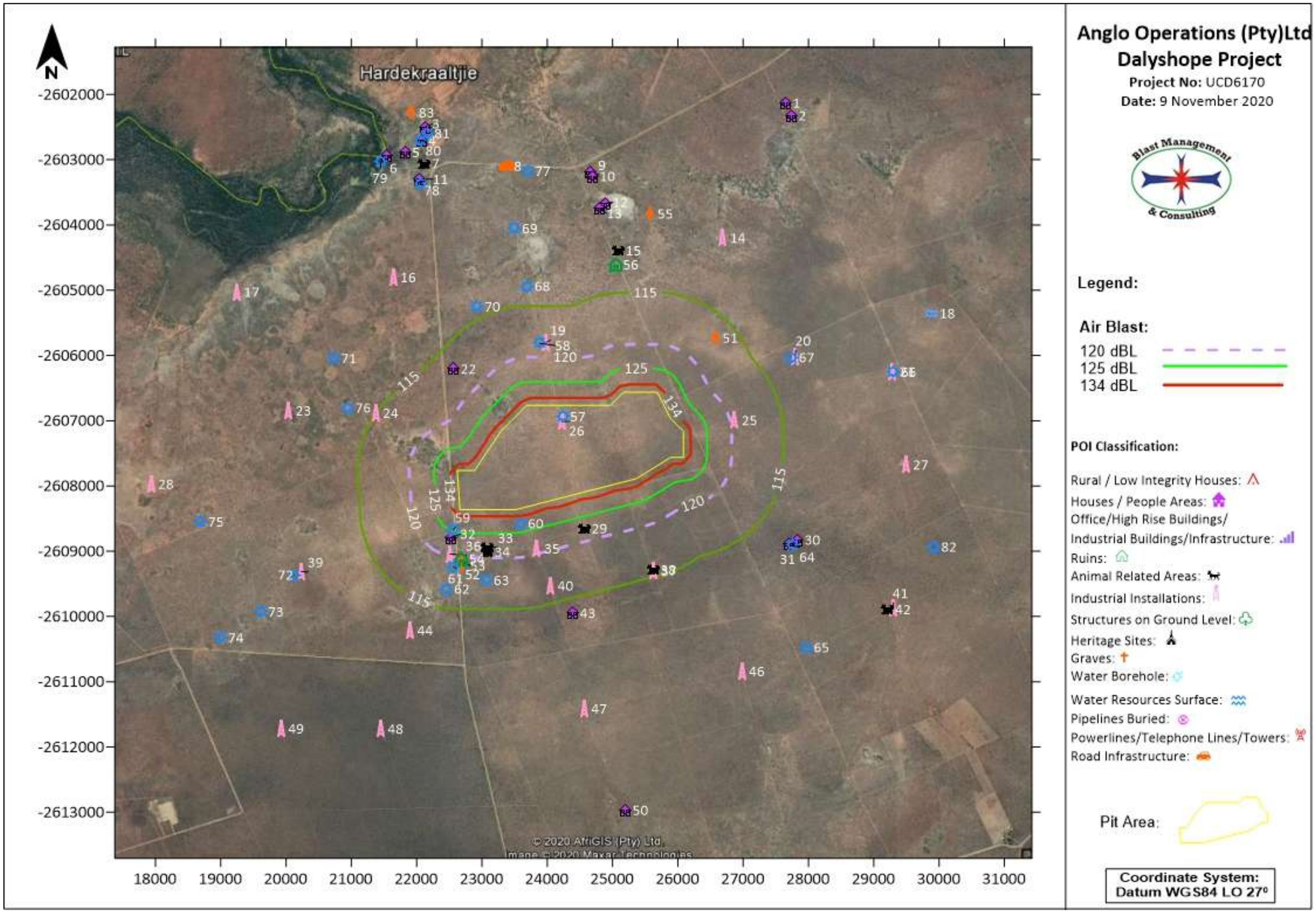


Figure 13: Air blast influence from maximum charge for Opencast area

Table 10: Air blast evaluation for maximum charge for Opencast Area

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Farmstead	4849	107	Acceptable
2	House	4712	107	Acceptable
3	Farmstead	4543	108	Acceptable
4	Farmstead	4371	108	Acceptable
5	House	4304	108	Acceptable
6	Lodge / Farmstead	4393	108	Acceptable
7	Farm Structure	4028	108	N/A
8	Gravel Road	3679	109	Acceptable
9	House	3414	110	Acceptable
10	House	3345	110	Acceptable
11	Farmstead	3837	109	Acceptable
12	Farmstead	2908	111	Acceptable
13	House	2838	111	Acceptable
14	Cement Dam	2573	111	N/A
15	Kraal	2172	113	N/A
16	Cement Dam	2833	111	N/A
17	Water trough	4345	108	N/A
18	Pan	4223	108	Acceptable
19	Cement Dam	952	118	N/A
20	Cement Dam	2057	113	N/A
21	Cement Dam	3329	110	N/A
22	Structure	1190	117	Acceptable
23	Cement Dam	2744	111	N/A
24	Cement Dam	1527	115	N/A
25	Cement Dam	800	119	N/A
26	Cement Dam			
27	Cement Dam	3404	110	N/A
28	Cement Dam	4694	107	N/A
29	Kraal	542	122	N/A
30	Farmstead	2154	113	Acceptable
31	House	2088	113	Acceptable
32	Farmstead	451	123	Complaint
33	Kraal	576	122	N/A
34	Kraal	644	121	N/A
35	Cement Dam	658	121	N/A
36	Cement Dam	696	120	N/A
37	Cement Dam	1439	115	N/A
38	Kraal	1416	116	N/A
39	Cement Dam	2605	111	N/A
40	Cement Dam	1260	116	N/A
41	Cement Dam	3964	108	N/A
42	Kraal	3905	109	N/A
43	Farmstead	1755	114	Acceptable
44	Cement Dam	2003	113	N/A
46	Cement Dam	3366	110	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
47	Cement Dam	3213	110	N/A
48	Cement Dam	3574	109	N/A
49	Cement Dam	4332	108	N/A
50	Structure	4877	107	Acceptable
51	Graves (Single Grave)	1219	117	Acceptable
52	Graves (Single Grave)	849	119	Acceptable
53	Graves	785	120	Acceptable
54	Ruins	751	120	Acceptable
55	Grave	2738	111	Acceptable
56	Ruins	1961	113	Acceptable
57	Borehole (DH2)			
58	Borehole (KW1)	952	118	Acceptable
59	Borehole (GT02)	332	125	N/A
60	Borehole (LD04)	222	128	N/A
61	borehole (LD01)	880	119	N/A
62	Borehole (GT02)	1231	117	N/A
63	Borehole (LD02)	1081	117	N/A
64	Borehole (GRUIS1)	2156	113	N/A
65	Borehole (DPP6)	3466	109	N/A
66	Borehole (GRUIS4)	3344	110	N/A
67	Borehole (GRUIS3)	2009	113	N/A
68	Borehole (KW4)	1828	114	N/A
69	Borehole (KW3)	2721	111	N/A
70	Borehole (NAZ3)	1696	114	N/A
71	Borehole (W93)	2555	111	N/A
72	Borehole (W26)	2729	111	N/A
73	Borehole (HB1)	3426	110	N/A
74	Borehole (HB2)	4155	108	N/A
75	Borehole (SKP44)	3966	108	N/A
76	Borehole (NZEBH1)	1929	113	N/A
77	Borehole (MBH2)	3591	109	N/A
78	Borehole (NAZ5)	3774	109	N/A
79	Borehole (NAZ2)	4355	108	N/A
80	Borehole (HK1)	4380	108	N/A
81	Borehole (HARMBH1)	4443	108	N/A
82	Borehole (TCD1)	4075	108	N/A
83	Graveyard	4823	107	Acceptable

17.8 Summary of findings for air blast

Review of the air blast levels indicates lesser concerns than with ground vibration. Infrastructure such as the ruins, gravel roads, graveyards, cultivated fields, dams and rivers are not specifically influenced by air blast.

The nearest human settlement the farmstead that will be affected by air blast is located 451 m from the opencast pit area. The predicted air blast for the farmstead is 123 dBL, which could result in complaints from the occupants.

The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL. Prediction shows that air blast will be greater than 134 dB at distance of 75 m and closer to any of the opencast pit boundary

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

17.9 Fly-rock unsafe zone

The occurrence of fly rock in any form will have a negative impact if found to travel outside the unsafe zone. This unsafe zone may be anything between 10 m or 1000 m. A general unsafe zone applied by most mines is normally considered to be within a radius of 500 m from the blast; but needs to be qualified and determined as best possible.

Calculations are also used to help and assist determining safe distances. A safe distance from blasting is calculated following rules and guidelines from the International Society of Explosives Engineers (ISEE) Blasters Handbook. Using this calculation, the minimum safe distances can be determined that should be cleared of people, animals and equipment. Figure 14 shows the results from the ISEE calculations for fly rock range based on a 171 mm diameter blast hole and 5.1 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 213 m. The absolute minimum unsafe zone is then the 213 m. This calculation is a guideline and any distance cleared should not be less. The occurrence of fly rock can however never be 100% excluded. Best practices should be implemented at all times. The occurrence of fly rock can be mitigated but the possibility of the occurrence thereof can never be eliminated.

Figure 15 and **Error! Reference source not found.** shows the area around the opencast pits that incorporates the 213 m unsafe zone.

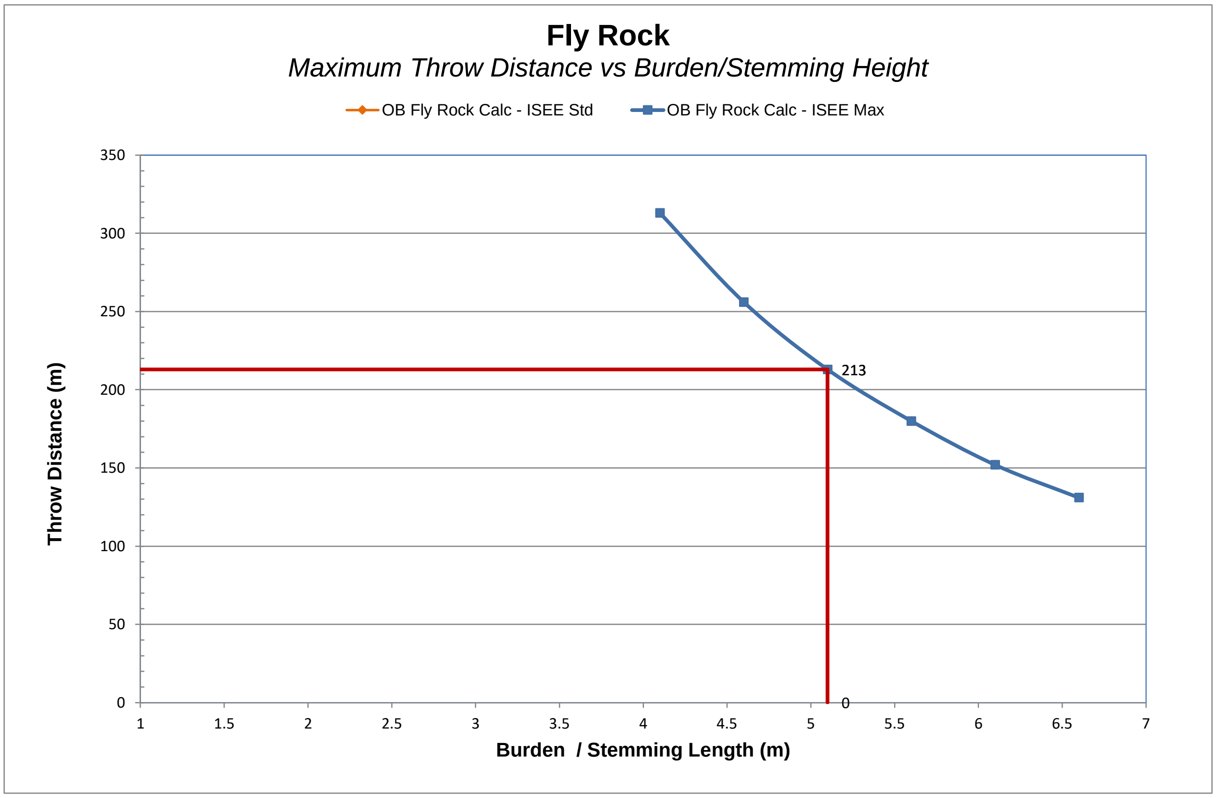


Figure 14: Fly rock prediction calculation

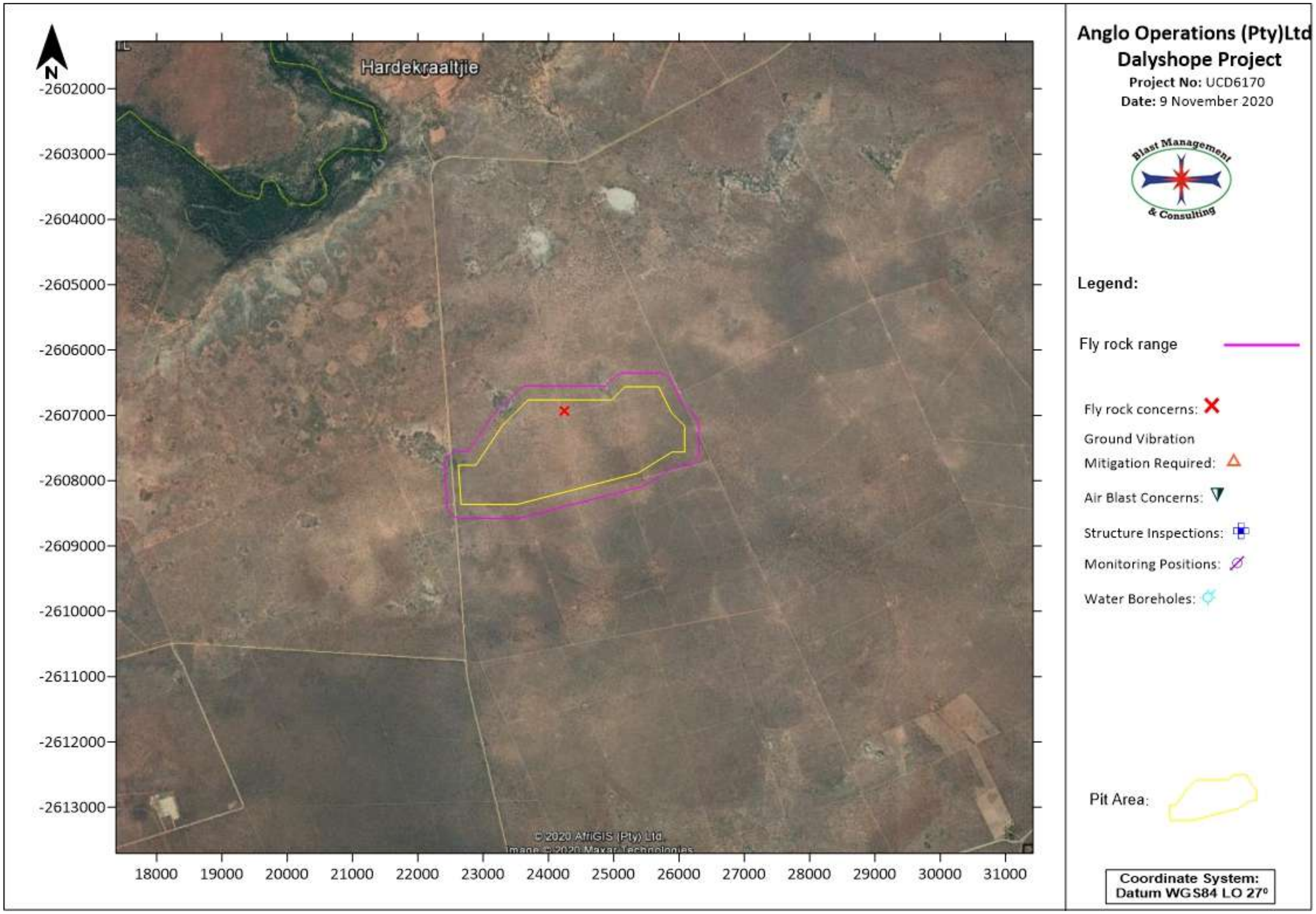


Figure 15: Predicted Fly Rock Exclusion Zone for Opencast area

Review of the calculated unsafe zone showed one POI for Opencast Pit (falls within the Pit area) are within the unsafe zone. Table 11 below shows the POI of concern and coordinates.

Table 11: Fly rock concern POI for Opencast areas

Tag	Description	Y	X
57	Borehole (DH2)	-24238.7	2606934

17.10 Noxious fumes

The occurrence of fumes in the form the NOx gas is not a given and very dependent on various factors as discussed in Section 13.6. However, the occurrence of fumes should be closely monitored. Furthermore, nothing can be stated as to fume dispersal to nearby farmsteads, but if anybody is present in the path of the fume cloud it could be problematic.

17.11 Water borehole influence

Location of boreholes for water was evaluated for possible influence from blasting. Twenty-six Hydrocencus boreholes for opencast area were identified within the influence area for the Dalyshope Coal Mining Project. Only two boreholes in and around the opencast pit area were identified as problematic, with expected levels of ground vibration greater than limits. A mitigation plan will be required to determine if these boreholes will be retained or replaced. Table 12 shows the identified boreholes. Figure 16 shows the location of the identified problematic boreholes in the area.

Table 12: Identified problematic boreholes for the Dalyshope Coal Mining Project

Tag	Description	Y	X
57	Borehole (DH2)	-24238.7	2606934
60	Borehole (LD04)	-23594	2608573

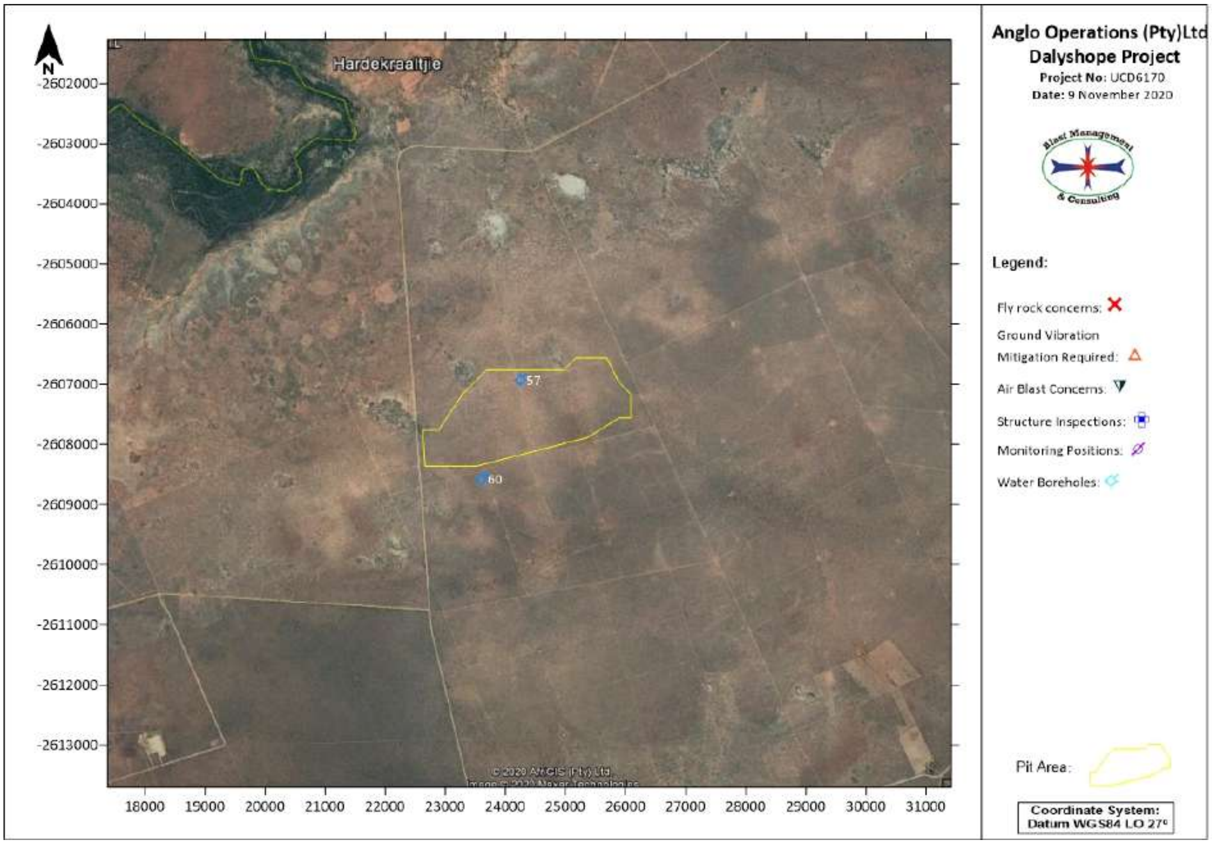


Figure 16: Location of the identified Problematic Boreholes for Opencast Area

17.12 Vibration impacts on productivity of farm animals and wildlife

The area is surrounding the mine is home to various farming activities but probably to a large extent mainly game farming. Game will be found along the edges of the planned mining area. It is also certain that the mining area will be fenced off thus not expecting game within the boundaries of the of the mine.

The influence on productivity of animals over period of time due to blasting operations is not clearly defined and difficult to estimate. Lack of knowledge on social behaviour and change of social behaviour is unfortunately problematic just due to information not being available. It is however the author’s opinion that influence will be experienced when animals are located permanently in close proximity of blasting operations. At larger distances, estimated in the region of 500 m and greater, cattle for instance will get accustomed to the blasting and related noise. This is based in observations made personally when blasting is done, and cattle are present.
Review of the charging configurations and air blast levels expected it is clear that in order to induce lung / ear injury or death, animals will have to very close to the blast. This is excluding fright and secondary injury or from flying debris. I do believe that animals will get used to the blasting operations and fly rock may be the most likely cause of injury or death if not removed to safe distance. Review of the mortality rate for goats (See section 13.10) the air over pressures required

is in the order of 210dB (L). this will require basically animals to be right next to the edge of the blast. The effect from the blast itself is then more likely to be lethal.

Further it is also known fact that many mines have harboured wildlife as part of their operations with success. Mines like Debswana Orapa have game farm directly adjacent to the mine operations where rhinoceros are kept as well. A recent visit to a mine close to Hoedspruit had buffalo roaming the mining area. They were removed from the blast area prior to each blast.
Considering the above information it is certain that injury to animals such as game / cattle / goats is highly unlikely due to the fact that animals should never be allowed on top of a blast area or closer than 500 m from the blast.

Having reviewed the probability of injury or mortality it must be considered that this rural area is a quiet area, and the effects of air blast may be heard further than expected, having damage impact further than expected but sound wise. The farmers adjacent to the mining area must be considered when first blasts are done. Animals in camps adjacent to the mining area should rather be moved to areas further from the blast as possible.

17.13 Potential Environmental Impact Assessment: Operational Phase

Details of the impact assessment methodology used to determine the significance of blasting impacts are provided below.
The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 15: . The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in this report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 14, which is extracted from Table 13. The description of the significance ratings is discussed in Table 15: .

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 13: Impact Assessment Parameter Ratings

Rating	Intensity/Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts **(Nature = -1)**	**Positive Impacts** **(Nature = +1)**			
7	Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.
5	Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.
3	Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.

Rating	Intensity/Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
2	Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	<u>Limited</u> Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.
1	Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	<u>Very limited/Isolated</u> Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 14: Probability/Consequence Matrix

Significance

Probability																																						
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Consequence

Table 15: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

Table 16: Risk Assessment Outcome

Dimension	Rating	Motivation	Significance
Blasting operations in the proposed Dalyshope Coal Mining Project			
Impact Description:			
Ground vibration impact on:			
Farmstead			
Ruins (inside pit)			
Borehole (DH2) (inside pit)			
Cement Dam			
Borehole (LD04)			
Prior to Mitigation/Management			
Duration	4	Ground vibration is expected to be high at nearest infrastructure	Moderate (negative) - 77
Extent	3	Ground vibration may extend nearby settlements	
Intensity	4	Intensity is expected to be greater than permitted levels	
Probability	7	The probability of damage is high due to high levels of ground vibration	
Nature	Negative		
Mitigation/Management Actions			
Specific blast design to be done, shorter blast holes, smaller diameter blast hole, using electronic initiation instead of shock tube systems to obtain single hole firing.			
Monitor ground vibration and air blast from blasting operations			
Purchase of nearest Farmstead			
Protection of sensitive heritage sites with blast design mitigations			
Post-Mitigation			
Duration	4	Duration will depend on area blasted and closest infrastructure	

Extent	3	Management of blasting and possible relocation	Negligible (negative) - 27
Intensity	2	Intensity can be reduced with proper management of blasting operations	
Probability	3	The probability can be reduced.	
Nature	Negative		
Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed Dalyshope Coal Mining Project			
Impact Description:			
Air blast impact on:			
Farmstead			
Borehole (DH2)(inside pit)			
Borehole (GT02)			
Borehole (LD04)			
Prior to Mitigation/Management			
Duration	4	Air blast is expected to be high at nearest infrastructure	Moderate (negative) - 77
Extent	3	Air blast may extend nearby settlements	
Intensity	4	Intensity is expected to be greater than permitted levels	
Probability	7	The probability of damage is high due to high levels of air blast	
Nature	Negative		
Mitigation/Management Actions			
Specific blast design to be done, shorter blast holes, smaller diameter blast hole, use of specific stemming materials to manage air blast, increased stemming lengths to reduce air blast effect. Used of specific stemming to manage fly rock - crushed aggregate of specific size. Re-design with increased stemming lengths.			
Monitor ground vibration and air blast from blasting operations			
Post-Mitigation			
Duration	4	Duration will depend on area blasted and closest infrastructure	Negligible (negative) - 27
Extent	3	Management of blasting and possible relocation	
Intensity	2	Intensity can be reduced with proper management of blasting operations	
Probability	3	The probability can be reduced.	
Nature	Negative		
Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed Dalyshope Coal Mining Project			
Impact Description:			
Fly rock impact on:			
Borehole (DH2) (inside pit)			
Prior to Mitigation/Management			
Duration	4	Fly rock may be experienced during the blasting operations in the pit areas	Moderate (negative) - 77
Extent	3	Infrastructure is present within the unsafe area	
Intensity	4	Damages may occur if fly rock is created	
Probability	7	There is infrastructure in close proximity of the blasting area that could be negatively influenced	
Nature	Negative		
Mitigation/Management Actions			
Specific blast design to be done, shorter blast holes, smaller diameter blast hole, use of specific stemming materials to manage air blast, increased stemming lengths to reduce air blast effect.			
Monitor fly rock situation using video camera			
Protection of sensitive heritage sites with blast design mitigations			
Post-Mitigation			
Duration	4	Duration will depend on area blasted and closest infrastructure	Negligible (negative) - 27
Extent	3	Management of blasting and possible relocation	
Intensity	2	Intensity can be reduced with proper management of blasting operations	

Probability	3	The probability can be reduced.	
Nature	Negative		

17.14 Mitigations

In review of the evaluations made in this report it is certain that specific mitigation will be required with regards to ground vibration. Ground vibration is the primary possible cause of structural damage and requires more detailed planning in preventing damage and maintaining levels within accepted norms. Air blast and fly rock can be controlled using proper charging methodology irrespective of the blasthole diameter and patterns used. Ground vibration requires more detailed planning and forms the focus for mitigation measures.

Specific impacts are expected at the following POI's identified. Table 17 shows list of POI's that will need to be considered. Figure 17 shows the location of these POI's in relation to the pit areas.

Table 17: Structures at Dalyshope Coal Mining Project areas identified as problematic

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz
26	Cement Dam	-24219	2607010.46	50	248	53.73	Problematic
32	Farmstead	-22517	2608789.13	12.5	451	19.96	Problematic
54	Ruins	-22691	2609114.33	6	751	8.61	Problematic
57	Borehole (DH2)	-24239	2606933.90	50	171	99.24	Problematic
60	Borehole (LD04)	-23594	2608572.91	50	222	64.29	Problematic

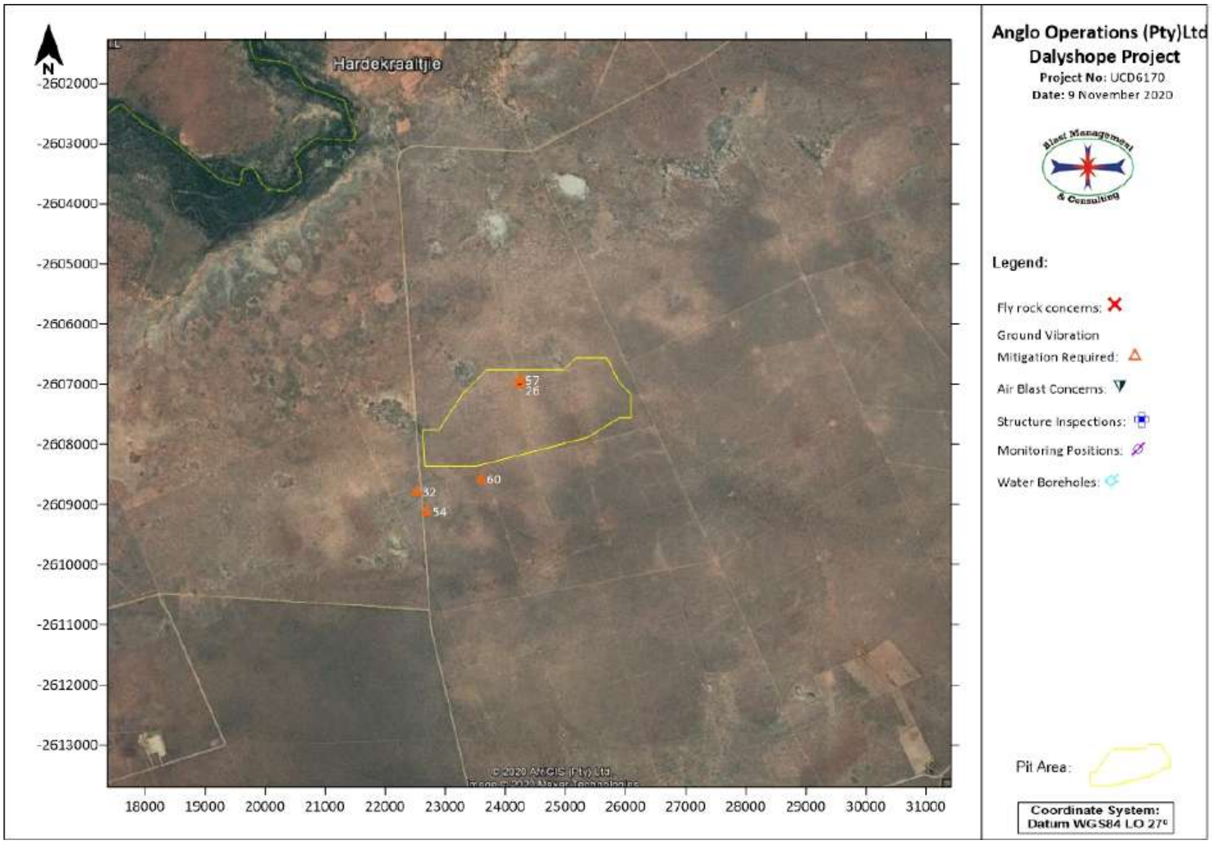


Figure 17: Structures identified at the Opencast Pit area where ground vibration mitigation will be required.

Mitigation of ground vibration for this can be done applying the following methods:

- Do blast design that considers the actual blasting, and the ground vibration levels to be adhered too.
- Only apply electronic initiation systems to facilitate single hole firing.
- Do design for smaller diameter blast holes that will use fewer explosives per blasthole.

The following Table 18 shows mitigation in the form of maximum charge mass that will be allowed to maintain safe levels of ground vibration and minimum distance between blast and POI required for the maximum charge to yield safe levels of ground vibration. Indicated, as well is the minimum distances required to maintain safe ground vibration levels for maximum charge and minimum charge. These factors are highlighted yellow.

Table 18: Mitigation measures for ground vibration

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
Maximum Charge allowed								
26	Cement Dam	-24219	2607010.46	50	248	1379.76	50.00	Acceptable
32	Farmstead	-22517	2608789.13	12.5	451	853.95	12.50	Acceptable

54	Ruins	-22691	2609114.33	6	751	972.21	6.00	Acceptable
57	Borehole (DH2)	-24239	2606933.90	50	171	655.93	50.00	Acceptable
60	Borehole (LD04)	-23594	2608572.91	50	222	1110.14	50.00	Acceptable
Tag	**Description**	**Y**	**X**	**Specific Limit (mm/s)**	**Distance (m)**	**Total Mass/Delay (kg)**	**Predicted PPV (mm/s)**	**Structure Response @ 10Hz**
Minimum Distance Required – Maximum Charge								
26	Cement Dam	-24219	2607010.46	50	259	2506.00	50.00	Acceptable
32	Farmstead	-22517	2608789.13	12.5	599	2506.00	12.50	Acceptable
54	Ruins	-22691	2609114.33	6	935	2506.00	6.00	Acceptable
57	Borehole (DH2)	-24239	2606933.90	50	259	2506.00	50.00	Acceptable
60	Borehole (LD04)	-23594	2608572.91	50	259	2506.00	50.00	Acceptable
Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
Minimum Distance Required – Minimum Charge								
26	Cement Dam	-24219	2607010.46	50	118	316	50.00	Acceptable
32	Farmstead	-22517	2608789.13	12.5	274	316	12.50	Acceptable
54	Ruins	-22691	2609114.33	6	428	316	6.00	Acceptable
57	Borehole (DH2)	-24239	2606933.90	50	118	316	50.00	Acceptable
60	Borehole (LD04)	-23594	2608572.91	50	118	316	50.00	Acceptable

18 Closure Phase: Impact Assessment and Mitigation Measures

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

19 Alternatives (Comparison and Recommendation)

The alternatives to consider will be very dependent on the hardness of the overburden. It is possible that the coal may be soft enough to be mechanically excavated. If hard overburden can be mechanically removed it will reduce risk associated with blasting operations. No specific alternative mining methods are currently under discussion or considered for drilling and blasting.

20 Monitoring

A monitoring programme for recording blasting operations is recommended. The following elements should be part of such a monitoring program:

- Ground vibration and air blast results.
- Blast Information summary.
- Meteorological information at time of the blast.

- Video Recording of the blast.
- Fly rock observations.

Most of the above aspects do not require specific locations of monitoring. Ground vibration and air blast monitoring requires identified locations for monitoring. Monitoring of ground vibration and air blast is done to ensure that the generated levels of ground vibration and air blast comply with recommendations. Proposed positions were selected to indicate the nearest points of interest at which levels of ground vibration and air blast should be within the accepted norms and standards as proposed in this report. The monitoring of ground vibration will also qualify the expected ground vibration and air blast levels and assist in mitigating these aspects properly. This will also contribute to proper relationships with the neighbours.

For monitoring positions were identified as possible locations that will need to be considered. Not all points will be required at once but active monitoring and observation of where blasting is done will dictate the requirements for the area around the pit. Monitoring positions are indicated in Figure 18 and Table 19 lists the positions with coordinates. These points will need to be re-defined after the first blast done and the monitoring programme defined.

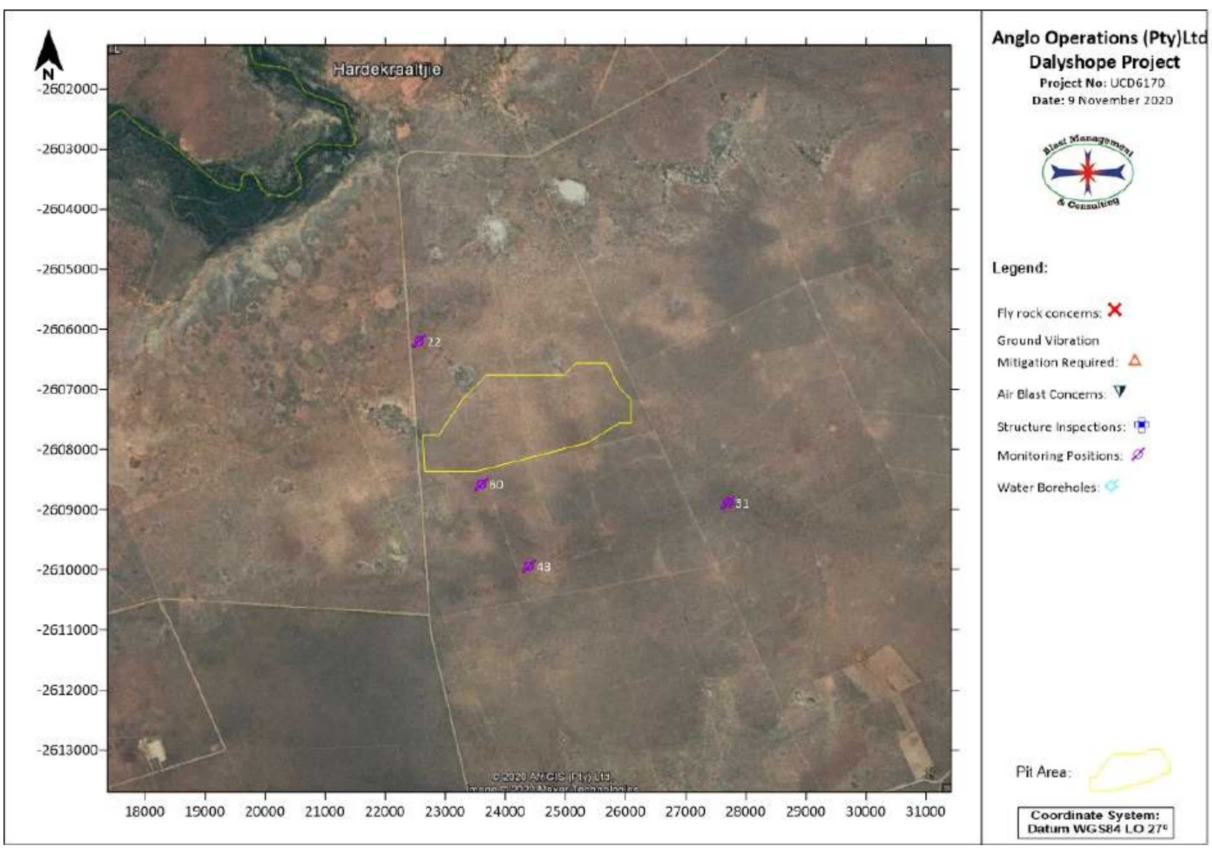


Figure 18: Monitoring Positions suggested for the Opencast area

Table 19: List of possible monitoring positions

Tag	Description	Classification	Y	X
22	Structure	2	-22561.66	2606206.23
31	House	2	-27698.58	2608886.603
43	Farmstead	2	-24390.74	2609950.478
60	Borehole (LD04)	10	-23593.952	2608572.914

21 Recommendations

The following recommendations are proposed.

21.1 Regulatory requirements for Opencast Area – MHSA 500 m

Regulatory requirements indicate specific requirements for all non-mining structures and installations within 500 m from the mining operation. The mine will have to apply for the necessary authorisations as prescribed in the various acts. Table 20 shows list of these installations. Figure 19 below shows the 500 m boundary around the Opencast Pit area.

Table 20: List of possible installations within the regulatory 500 m

Tag	Description	Classification	Y	X
26	Cement Dam (inside pit)	6	-24219.08	2607010.455
32	Farmstead	2	-22517.19	2608789.135
57	Borehole (DH2) (inside pit)	10	-24238.699	2606933.895
59	Borehole (GT02)	10	-22562.27	2608678.722
60	Borehole (LD04)	10	-23593.952	2608572.914

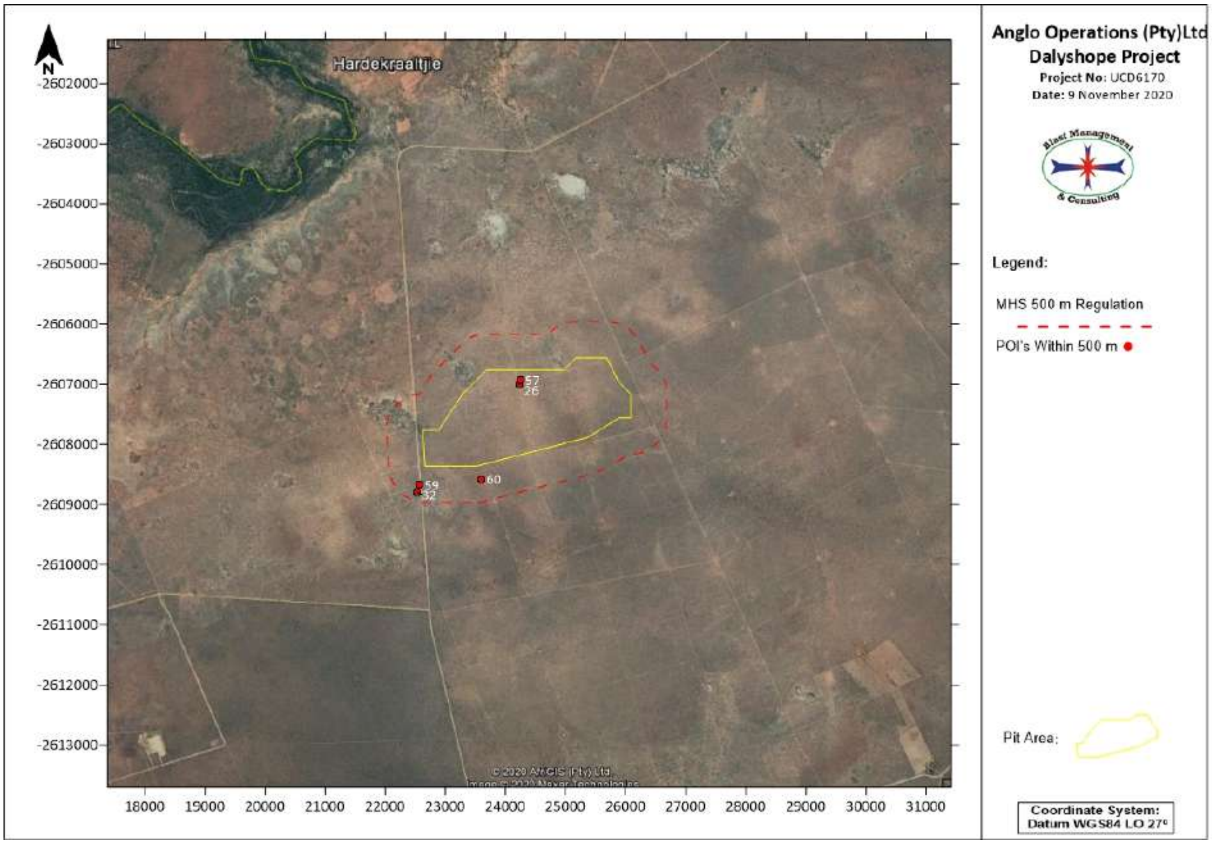


Figure 19: Regulatory 500 m range for the Opencast areas

21.1 Regulatory requirements for Opencast Area – MHSA 100 m

Regulatory requirements indicate specific requirements for all non-mining structures and installations within 100 m from the mining operation. The mine will have to apply for the necessary authorisations as prescribed in the various acts. Table 20 shows list of these installations. Figure 20 below shows the 100 m boundary around the Opencast Pit area.

Table 21: List of possible installations within the regulatory 100 m for Opencast area

Tag	Description	Classification	Y	X
26	Cement Dam (inside pit)	6	-24219.08	2607010.455
57	Borehole (DH2) (inside pit)	10	-24238.699	2606933.895

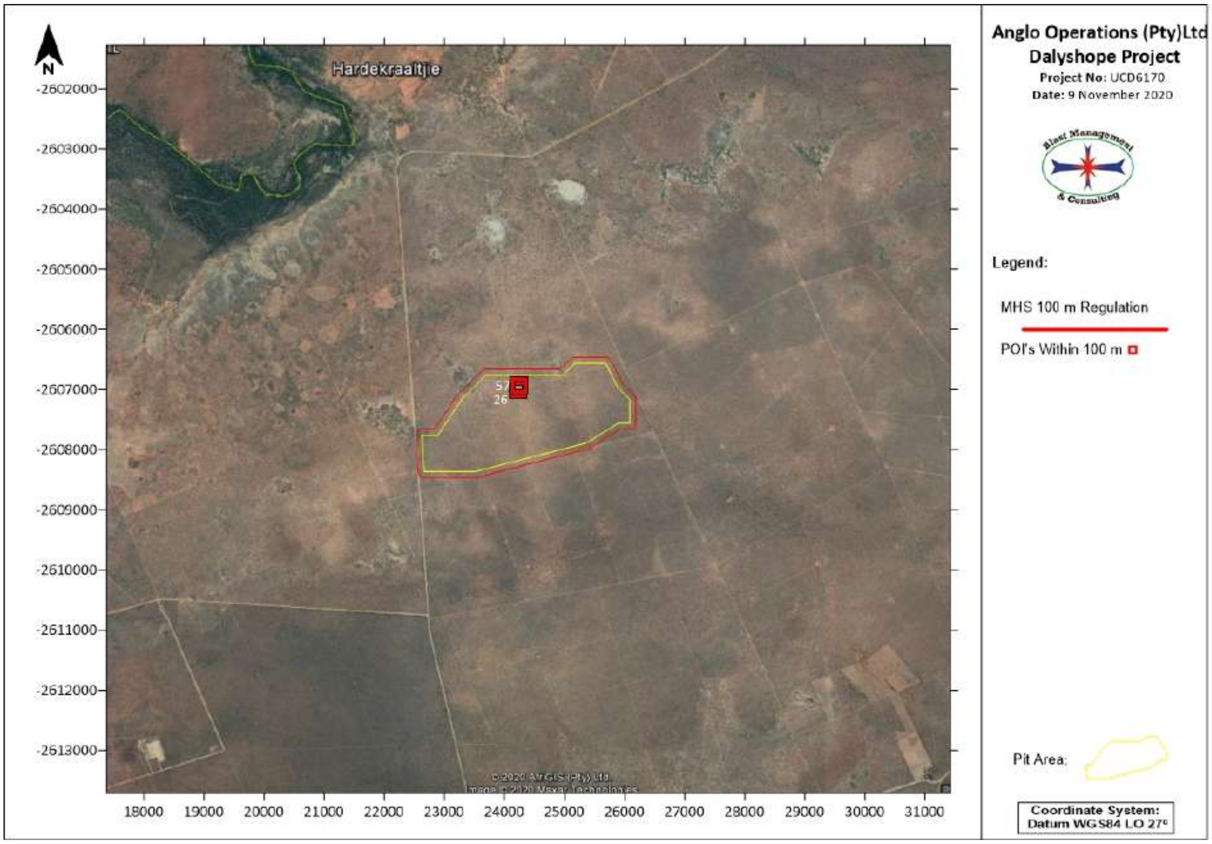


Figure 20: Regulatory 100 m range for the Opencast area

21.2 Possible Relocation/Purchase

There is one Farmstead identified (Tag 32) within 500 m from the Opencast operations. Consideration should be given to relocate/purchase of this farm. Relocation/Purchase will reduce the general impact on the surrounding areas of the opencast pit.

21.3 Blast Designs

Based on the above mitigation requirements it will be necessary to review planned blast design in more detail. A detail design with blast planning will be required for efficient and safe mining of these pits. Blast designs should be reviewed prior to first blast planned and done. The geology for the pit areas and the required drill depths should be confirmed. Due to stripping of topsoil that will take place there may be variances in required final depths and thus design applied to be confirmed.

21.4 Test Blasting

It is always good to conduct a first test blast to confirm levels and ground vibration and air blast. It is recommended that such a blast be done, and detail monitoring done and used to help define blasting operations going forward. This test blast can be based on the existing design and only after this blast it may be necessary to define if changes are required or not.

21.5 Stemming length

The current proposed stemming lengths at least must be maintained to ensure some form of fly rock control. Specific designs where distance between point of concern and blast is known should be considered with this. It may be required to increase stemming lengths for additional control.

21.6 Safe blasting distance and evacuation

Calculated minimum safe distance is 302 m. This is the estimated area that must be cleared at least around a blast before firing. It is recommended that at least 500 m be used as a safe distance from any blast. The final blast designs that may be used will determine the final decision on safe distance to evacuate people and animals. This distance may be greater pending the final code of practice of the mine and responsible blaster's decision on safe distance. The blaster has a legal obligation concerning the safe distance and he needs to determine this distance.

21.7 Road Closure

When blasting at the Opencast pit, the gravel road is in the vicinity of the project area, then it needs to be considered. The gravel road should then be closed. Stop and Go will be required when blasting is done within 500 m from these gravel roads. Road closure will be required with inspection for after blast fly rock. There may also be smaller roads that are used by the local communities that may not be clearly indicated on maps and should also be considered for closures when blasting is done. During blasting care must be taken to ensure all people and animals cleared to outside the unsafe area as determined by the blaster.

21.8 Photographic Inspections

The option of photographic survey of all structures up to 2100 m from the pit area is recommended. The mine will be operating for a significant number of years. This will give advantage on any negotiations with regards to complaints from neighbours on structural issues due to blasting. This process can however only succeed if done in conjunction with a proper monitoring program. It is expected that ground vibration levels will be significantly less than proposed limits at 2100 m, but this process will ensure record of the pre-blasting status of the nearest structures to the pit area. At 2100 m the expected level of ground vibration will be perceptible. Figure 21 shows extent of the range of 2100 m around the Opencast Pit area with POI's identified. It must be noted that a point may represent a group of structures found in the vicinity of the point identified. All structures identified is considered irrespective of possible future re-locations.

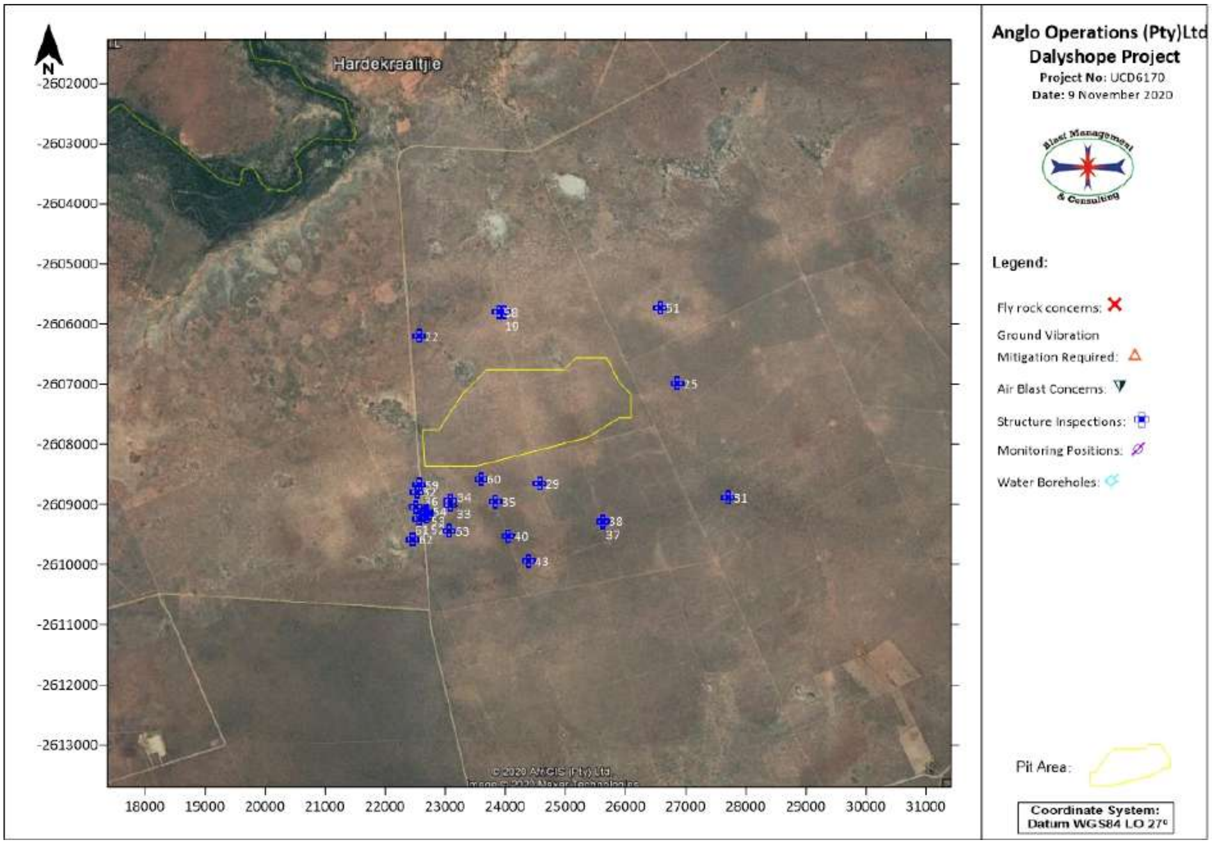


Figure 21: 2100 m area around the Opencast area identified for structure inspections.

Table 22: Combined list of structures identified for inspections

Tag	Description	Y	X
19	Cement Dam	-23968	2605811.23
22	Structure	-22562	2606206.23
25	Cement Dam	-26865	2606994.38
29	Kraal	-24567	2608652.22
31	House	-27699	2608886.60
32	Farmstead	-22517	2608789.13
33	Kraal	-23076	2608939.12
34	Kraal	-23083	2609006.95
35	Cement Dam	-23842	2608958.70
36	Cement Dam	-22515	2609042.49
37	Cement Dam	-25631	2609303.75
38	Kraal	-25620	2609282.49
40	Cement Dam	-24050	2609527.57
43	Farmstead	-24391	2609950.48
51	Graves (Single Grave)	-26571	2605730.52
52	Graves (Single Grave)	-22681	2609212.12
53	Graves	-22670	2609148.26
54	Ruins	-22691	2609114.33

58	Borehole (KW1)	-23879	2605811.84
59	Borehole (GT02)	-22562	2608678.72
60	Borehole (LD04)	-23594	2608572.91
61	Borehole (LD01)	-22563	2609236.04
62	Borehole (GT02)	-22463	2609576.60
63	Borehole (LD02)	-23070	2609444.45

21.9 Heritage Concerns

Heritage Sites which include graves, ruins and historical structures were identified by the Heritage Specialist. The Heritage Specialist recommended that certain mitigation measures must be applied to the historical remains and graveyards and graves which will be affected directly or indirectly during the construction phase for the proposed project. The ruins (Tag 54) will require mitigation measure. (see Table 30 Combined list of structures identified for inspections)

21.10 Wildlife Concerns

Regarding the game farms adjacent to the mining area the following is recommended.
As far as possible game should be moved to area furthest possible away from the first blasts to be done. Recommended that game should not be closer than minimum 500 m from the blast area. Monitoring of the wildlife reaction due to blasting should be done and recorded as well. Communication between farmers and mine will be imperative. Frequent meetings and regular updates on operations must be communicated from both sides.

21.11 Recommended ground vibration and air blast levels

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

Table 23: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A
Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	
Houses of lesser proper construction	12.5	

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
Rural building – Mud houses	6	Shall not exceed 134dB at point of concern but 120 dB preferred

21.12 Blasting times

A further consideration of blasting times is when weather conditions could influence the effects yielded by blasting operations. It is recommended not to blast too early in the morning when it is still cool or when there is a possibility of atmospheric inversion or too late in the afternoon in winter. 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 nots' stem from the influence that weather has on air blast. The energy of air blast cannot be increased but it is distributed differently and therefore is difficult to mitigate.
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 of blasting dates and times.

21.13 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.

21.14 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.

22 Knowledge Gaps

The data provided from client and information gathered was sufficient 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.

23 Project Results

In view of the data evaluated it is the opinion of the author that the project can be executed successfully with proper management and control on the aspects of ground vibration, air blast and fly rock. Recommendations were made on recommended mitigations.

24 Conclusion

Blast Management & Consulting (BMC) was contracted as part of Environmental Impact Assessment (EIA) to perform a review of possible impacts with regards to blasting operations in the proposed Dalyshope Mining Project opencast 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, air blast and fly rock and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as a 5000 m radius from where blasting will take place. The range of structures observed and considered in this evaluation ranged between, farmsteads, buildings, ruins, graves, cement dams, boreholes and gravel roads.

Various POI's were identified as problematic. Two POI's were found within the boundaries of the opencast pit area. Evaluation of minimum charge showed that ground vibration may be acceptable for three other POI's, but evaluation of maximum charge showed that ground vibration may be problematic in terms of potential structural damage and human perception at the farmstead, and the cement dam at these distances.

Heritage Sites which include graves, ruins were identified by the Heritage Specialist. The ruin was identified as problematic in the study area The Heritage Specialist recommended that certain mitigation measures have to be applied to the historical ruins which will be affected directly or indirectly during the construction and operational phase for the proposed project.

There are two Hydrocencus boreholes identified as problematic at these distances and it is uncertain what the long-term plan will be for these boreholes. Expected levels of ground vibration is greater than proposed limit for these boreholes.

The nearest human settlement the farmstead that will be affected by air blast is located 451 m from the opencast pit area. The predicted air blast for the farmstead is 123 dBL, which could result in complaints from the occupants.

The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL. Prediction shows that air blast will be greater than 134 dB at distance of 75 m and closer to any of the opencast pit boundary

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 213 m. When blasting at the opencast pit area and the gravel road is in the vicinity of the project area, then the gravel road should be closed. Stop and Go will be required when blasting is done within 500 m from these gravel roads. Road closure will be required with inspection for after blast fly rock. There may also be smaller roads that are used by the local communities that may not be clearly indicated on maps and should also be considered for closures when blasting is done. During blasting care must be taken to ensure all people and animals cleared to outside the unsafe area as determined by the blaster.

The option of photographic survey of identified structures up to 2100 m from the opencast pit area is recommended. 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 while the vent shafts are been blasted

The effect of blasting operations on wildlife was investigated and evaluated. It is not expected that blasting in the mine will be causing fatalities. It is however known that initially animals may be frightened but expected to habituate over time.

Recommendations were made and should be considered. specific actions will be required for all pit areas such as Mine Health and Safety Act requirements when blasting is done within 500 m and 100 m from private structures

This concludes this investigation for the proposed Dalyshope Coal Mining Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

25 Curriculum Vitae of Author

MJ Louw was a member of the Permanent Force - SA Ammunition Core for period January 1982 to July 1989. During this period, he worked as a Technical Munitions Officer, was responsible for inspection of all military ammunition depots (Army, Air Force, Navy and Special Forces) large and small around SA. Making appointment with very senior officers. Giving verbal and written reports with recommendations addressing problems ….…… etc
From July 1995 to October 1995, MJ Louw worked at AECI Explosives Ltd as Explosive Technology Manger: Testing; Manager the explosive research and testing facilities and had 9 people reporting to me. Service to clients/mines - velocity of detonation & blast timing and detonator timing. Underwater Explosive Testing – Heave and shock energy of different explosive. Gallery _ Test to see

if the explosive formulations passed for underground coal mines. Explosive Testing Range – VOD, gap test, min diameter testing, shockwave test, double pipe test, hotspot pressure test ……. etc
Computer modelling - IDEX (formulation code) see the characteristics (i.e. Vod, Bulk strength, …etc) of the different formulation …. etc
From November 1995 to April 2016 worked at Outbound as own of a print finishing and packaging company. Retired in May 2016.
MJ Louw started working at Blast Management & Consulting in March 2018. The main areas of focus are Pre-blast monitoring, Insitu monitoring, Post-blast monitoring and specialized projects.

Mr Louw holds the following qualifications:

1982 – 1983	National Technical Certificate N5 Vehicle fitter
1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
2020	Advanced Certificate in Blasting, Technikon SA

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.

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