Blast Management & Consulting

Quality Service on Time

Report: Blast Impact Assessment Proposed Arnot South Underground 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 26
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section iii
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 4

Legal Requirement		Relevant Section in Specialist study
(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 16
(k)	any mitigation measures for inclusion in the EMPr;	Section 17.1
(l)	any conditions/aspects for inclusion in the environmental authorisation;	Section 22
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 21
(n)	a reasoned opinion (Environmental Impact Statement)-	Section 24
	as to whether the proposed activity or portions thereof should be authorised; and	Section 24
	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 24
(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
C Zeeman Blast Management & Consulting	Document Preparation	Report Prepared	27/07/2021	
JD Zeeman Blast Management & Consulting	Consultant	Report Finalised	27/07/2021	

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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
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
L	Maximum Throw (m)
Lat/Lon hddd°mm'ss.s"	Latitude/Longitude Hours/degrees/minutes/seconds
M	Charge Height
m (SH)	Stemming height
M/S	Magnitude/Severity
Mc	Charge mass per metre column
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NOx's	Noxious Fumes
P	Probability
POI	Points of Interest
PPV	Peak Particle Velocity
RPP	Rock Pressure Pulse
SH	Stemming height (m)
USBM	United States Bureau of Mine
WGS 84	Coordinates (South African)
WM	With Mitigation Measures
WOM	Without Mitigation Measures

List of Units used in this Report

%	percentage
cm	centimetre
dB	decibel
dBL	linear decibel
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

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1 Executive Summary

Blast Management & Consulting (BMC) was contracted as part of Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed underground mining operation.

Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report evaluates the effects of 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 1500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low cost houses, corrugated iron structures, brick and mortar houses.

The location of structures around the Box cut area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the Farm Buildings/Structures, Gravel Road, Dam and Informal Housing. Ground vibrations predicted for the box cut area ranged between low and very high. The expected levels of ground vibration for some of these structures are high and will require specific mitigations in the way of adjusting charge mass per delay to reduce the levels of ground vibration. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage.

Air blast predicted also showed some concerns for box cut blasting. The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134dB. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The box cut is located such that “free blasting” – meaning no controls on blast preparation – will not be possible.

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 640 m and closer to box cut boundary. Infrastructure at the box cut area such as roads, power line is present, but air blast does not have any influence on these installations.

Fly rock remains a concern for blasting operations. Based on the drilling and blasting parameters values for a possible fly rock range with a safety factor of 2 was calculated to be 266 m. The absolute minimum unsafe zone is then the 266 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.

Specific actions will be required for the box cut area such as Mine Health and Safety Act requirements when blasting is done within 500 m from structures and mining with 100 m for structures. The Gravel Road, Dam, Ruins and Cement Dams falls within the 500 m range from the box cut area.

The box cut area is located such that specific concerns were identified and addressed in the report.

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

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2 Introduction

Exxaro Coal Mpumalanga (Pty) Ltd (hereafter Exxaro or the Applicant) is applying for environmental authorisations required for the proposed Arnot South Underground Coal Mining Project (hereafter Arnot South Project). Exxaro has submitted a Mining Right Application, reference number MP 30/5/1/2/2/1(10292) EM, to mine coal on various farms covering approximately 16,000 hectares (ha) in extent. A box cut is planned to access the underground mining area.

The target area for mining and mining-related infrastructure lies mainly on the farms Weltevreden 174 IS, Mooiplaats 165 IS, Vlakfontein 166 IS, and Schoonoord 164 IS. The farms are located within the jurisdictions of Steve Tshwete Local Municipality (STLM) and Chief Albert Luthuli Local Municipality (CALLM), situated in the Nkangala District Municipality (NDM) and Gert Sibanda District Municipality (GSDM), respectively, in the Mpumalanga Province.

The proposed Arnot South Project is located within the Witbank Coalfield of Mpumalanga Province. The Project area lies on the eastern margin of the Witbank Coalfield and comprises sediments of the coal-bearing Ecca Group of the Karoo Basin. The Witbank Coalfield falls within the Vryheid Formation of the Ecca Group. Exxaro proposes to extract coal through underground mining methods with a confirmed Life of Mine (LoM) of 17 years. The mineral reserve consists of one economically mineable underground block (No. 2 coal seam), producing approximately 2.4 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal for approximately 17 years. Further drilling will be required to confirm a resource to the south of the Mining Right area. The potential future resource of the remaining ROM coal is approximately 32,912,300 tonnes, allowing an additional mining period of approximately 13 years. Mechanical mining using continuous miners is planned for the underground extraction of the resource.

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 Arnot South 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; and 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;
- Mine Health and Safety Act No. 29 of 1996;
- Mineral and Petroleum Resources Development Act No. 28 of 2002;
- Explosives Act No. 15 of 2003.

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

4 Scope of blast impact study

The scope of the 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.

- Background information of the proposed site, defining the study area.
- Blasting Operation Requirements.
- Site specific evaluation of blasting operations according to the following:
  - Evaluation of expected ground vibration levels from blasting operations at specific distances and on structures in surrounding areas;
  - Evaluation of expected ground vibration influence on neighbouring communities;
  - 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 1500 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 the location of blasting operations in relation to surrounding areas according to the regulations from the applicable Acts.
- Impact Assessment.
- Mitigations.
- Recommendations.
- Conclusion.

5 Study area

The Arnot South Project is situated approximately 10 km east of the town of Hendrina, 25 km west of Carolina, and 50 km southeast of Middelburg in the Mpumalanga Province of South Africa. The centre point of the site is 26°2'11.19"S and 29°50'43.96"E. Figure 1 shows the layout map of the proposed Box Cut and underground mining areas.

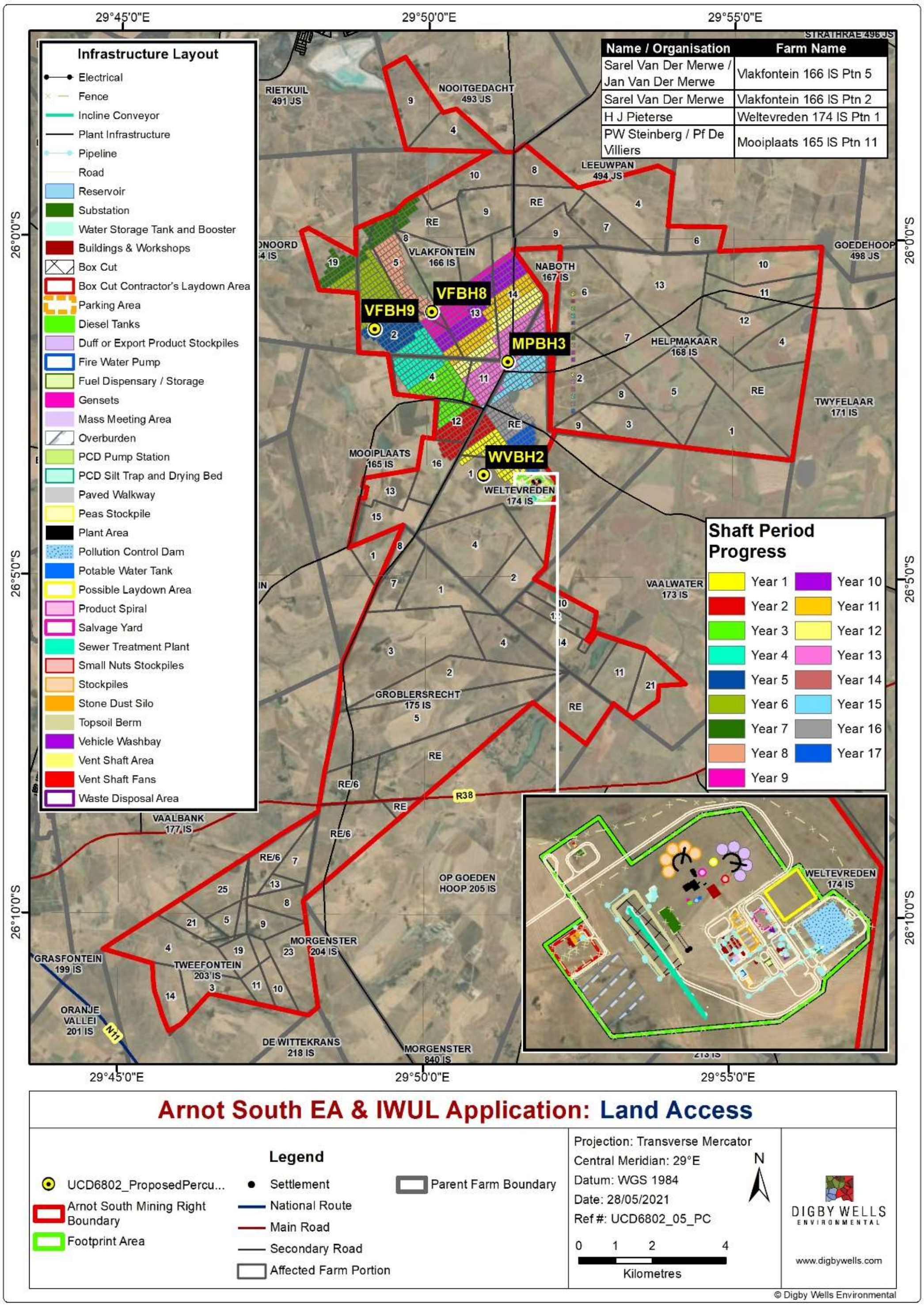

Figure 1: Layout of the proposed box cut and underground mining areas

6 Methodology

The detailed plan of study consists of the following sections:

- Site visit: Intention to understand location of the site and its surroundings.
- Identifying surface structures / installations that are found within reason from project site. A list of Point of Interests (POI's) is created that will be used for evaluation.

- Base line influence or Blast Monitoring: The project is evaluated as a new operation with no blasting activities currently being done in the project area specific. Information from similar type operations were considered.
- Site evaluation: This consists of evaluation of the mining operations and the possible influences from blasting operations. The methodology is modelling the expected impact based on the expected drilling and blasting information provided for the project. Various accepted mathematical equations are applied to determine the attenuation of ground vibration, air blast and fly rock. These values are then calculated over the distance investigated from site and shown as amplitude level contours. Overlaying these contours on the location of the various receptors then gives an indication of the possible impacts and the expected results of potential impacts. Evaluation of each receptor according to the predicted levels then gives an indication of the possible mitigation measures to be applied. The possible environmental or social impacts are then addressed in the detailed EIA phase investigation.
- Reporting: All data is prepared in a single report and provided for review.

7 Site Investigation

The site was visited on 05 August 2021. This site visit was done to get understanding of the location and the structures and installations surrounding the proposed new box cut 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 area is not currently an active full-scale mining operation.
- 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.
- No baseline data exist for this project as the mine is not operational.
- Blasting operations will be mainly concentrated in establishing the box cut for access to the underground workings. A blast design is required for determining the extend of influences to be evaluated. In the process of the project no specific blast design is available for the box cut blasts. A blast design was done by BMC based on what could typically be use for similar operations. This design is not the final blast design for the box cut.

- The mine is an underground operation. Continuous miners will be used for extraction of coal. No specific ground vibration influences are anticipated.
- 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, client requirements and general indicators provided in the various applicable South African acts. There is no direct reference in the consulted acts specifically with regard to limiting levels for ground vibration and air blast. There is however specific requirements and regulations with regards to 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 No. 107 of 1998; Mine Health and Safety Act No. 29 of 1996; Mineral and Petroleum Resources Development Act No. 28 of 2002; and the Explosives Act No. 15 of 2003.

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. There are no specific South African standards and the USBM is well accepted as standard for South Africa. Additional criteria required by various institutions in South Africa was also taken into consideration, i.e. Eskom, Telkom, Transnet, Rand Water Board, etc.

In view of the acts consulted, the following guidelines and regulations are noted: (where possible detail was omitted and only some of the information indicated)

- **MINE HEALTH AND SAFETY ACT 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 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.

The current box cut layout indicates that the planned box cut area may be close to private installations. The Mine Health and Safety Act has specific requirements regarding blasting within 500 m from private installations. This condition will be addressed in the recommendations.

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. Three different areas were identified in this regard:

- A highly sensitive area of 500 m around the box-cut 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 box cut area.
- An area 500 m to 1000 m around the box cut 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 1000 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 2 and Figure 3 shows the sensitivity mapping with the identified points of interest (POI) in the surrounding areas for the proposed Project area. The specific influences will be determined through the work done for this project in this report.

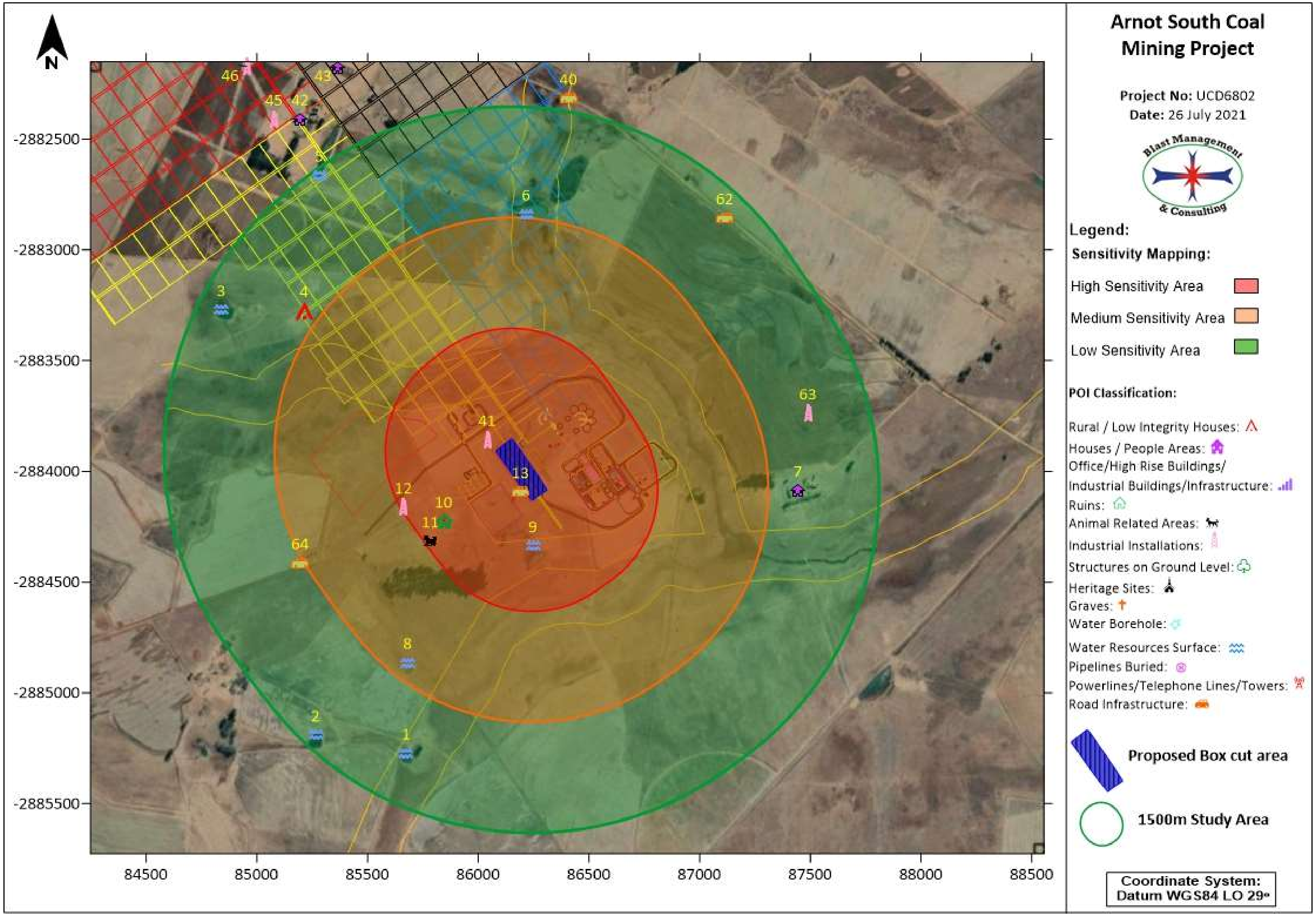

Figure 2: Identified sensitive areas for Box Cut

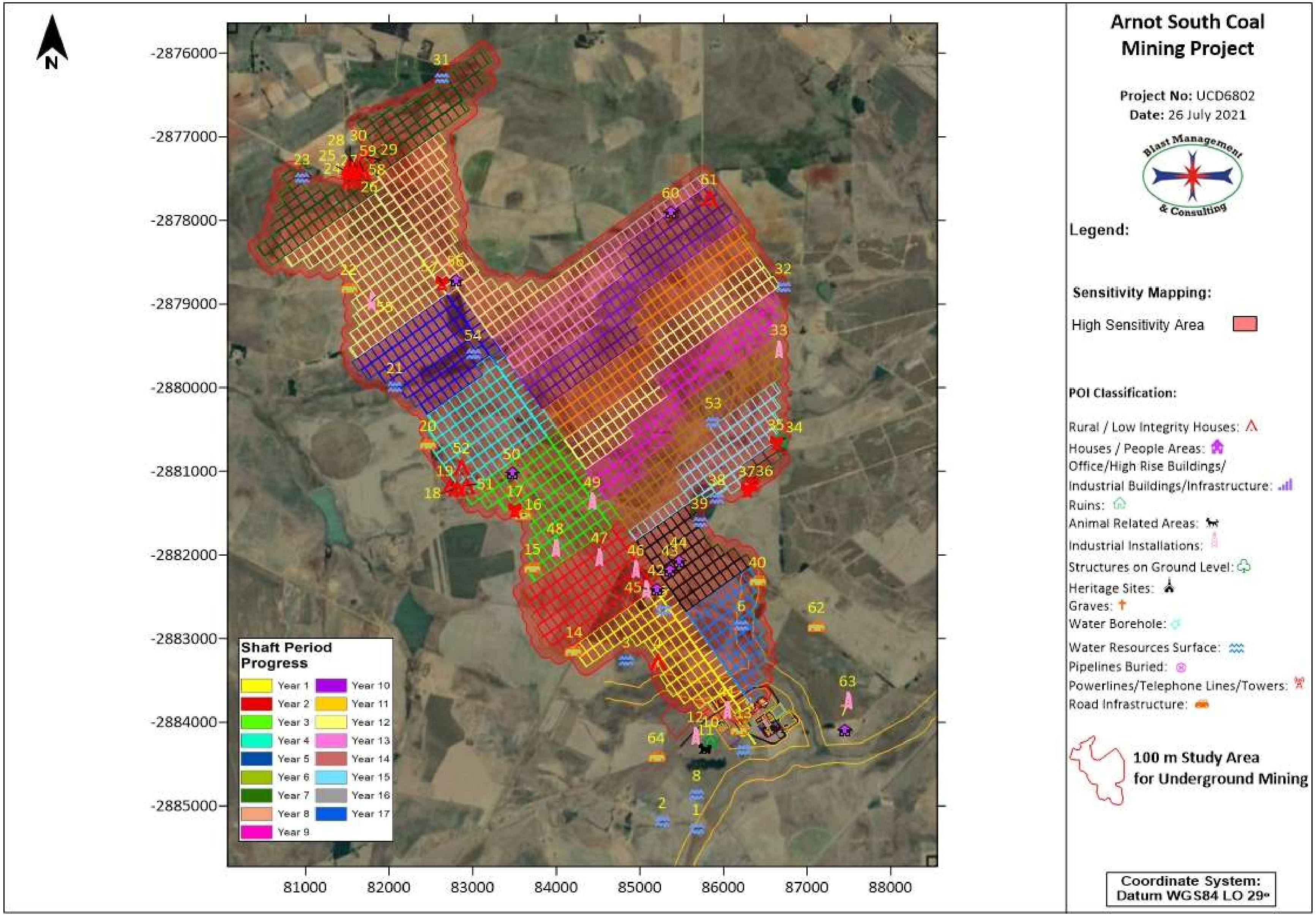

Figure 3: Identified sensitive areas for Underground Mining

12 Consultation process

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

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 of 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. The USBM graph is used for plotting of data and evaluating the data. Figure 4 below provides a graphic representation of the USBM analysis for safe ground vibration levels. The USBM graph is divided mainly into two parts. The red lines in the figure are the USBM criteria:

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

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

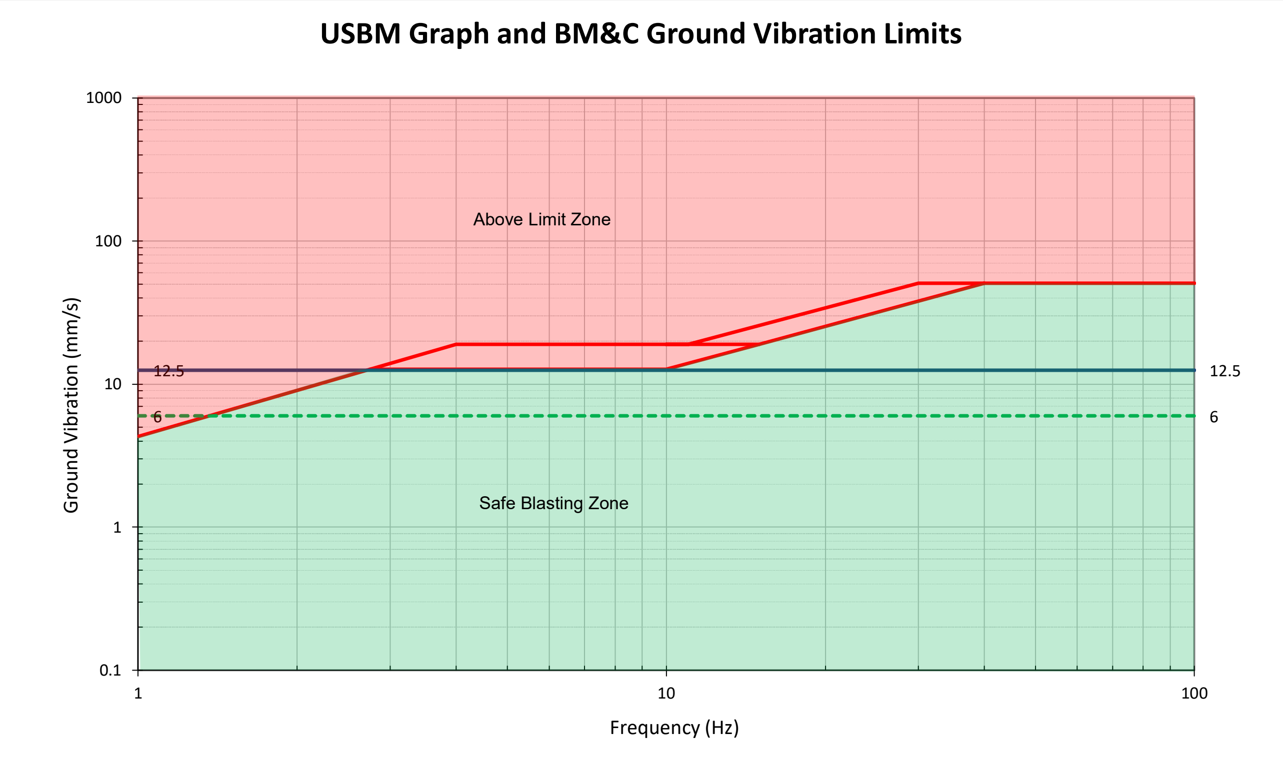

Figure 4: USBM Analysis Graph

The following additional limitations used by BMC in general and that should be considered were determined through research and prescribed by the various institutions; these are as follows:

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

[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.

- Concrete after 10 days: 200 mm/s [2].
- 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 0.8 mm/s as perceptible (See Figure 5). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.

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[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.

[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.

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

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

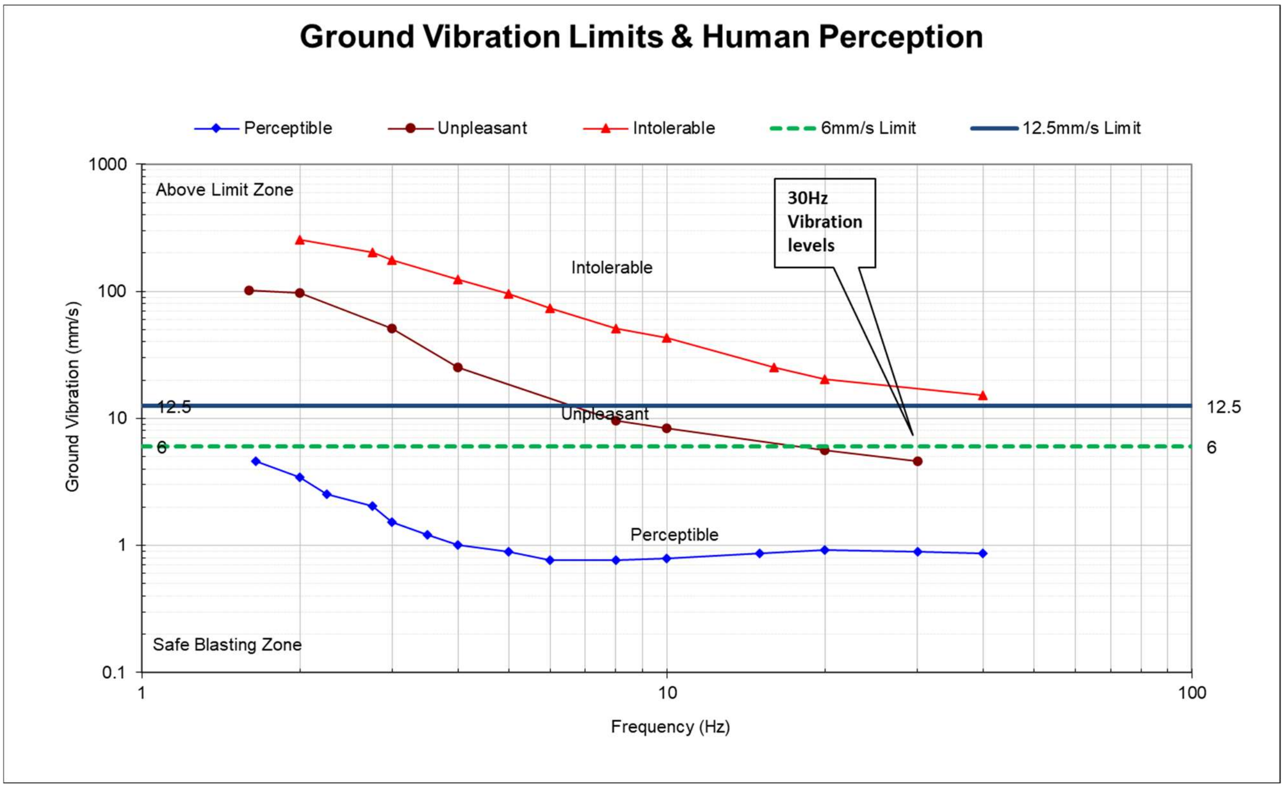


Figure 5: Human Perception of ground vibration

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 Causing Levels 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

The following table showing summary of air blast limits applied in this report applicable:

Table 3: Air Blast Limits

Level	Description
<120 dB	Preferred levels to avoid complaints
120 dB	Bottom limit applied for start of complains
128 dB	USBM Proposed Limit for Schools and Hospitals
134 dB	USBM Proposed Limit and accepted current RSA Limit

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 120dB, 120 dB to 134dB and greater than 134dB. The USBM limits for nuisance are 134dB.

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.

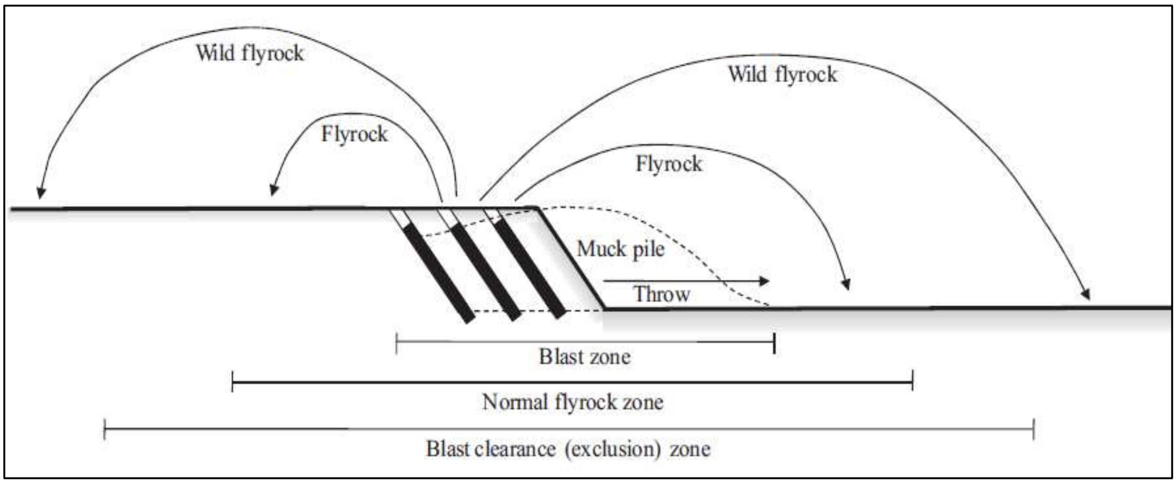


Figure 6: Schematic of fly rock terminology

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. BM&C 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 too 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.

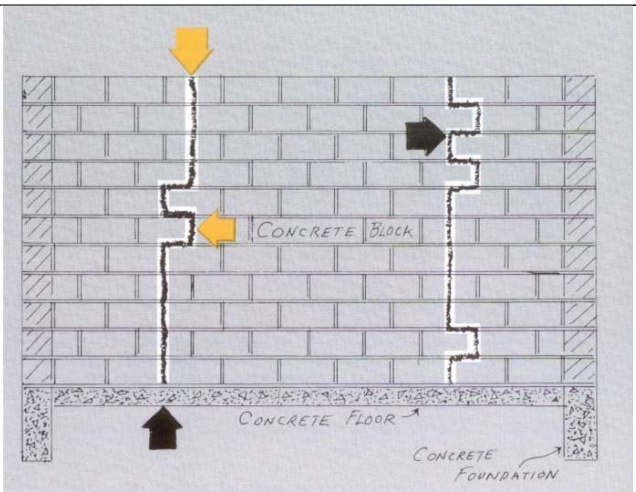
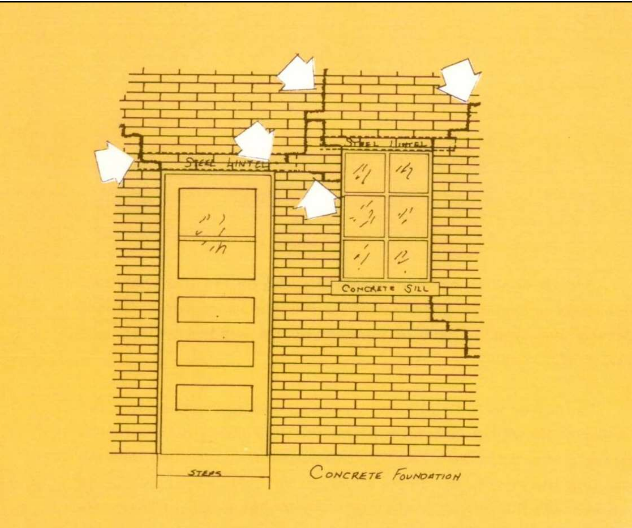
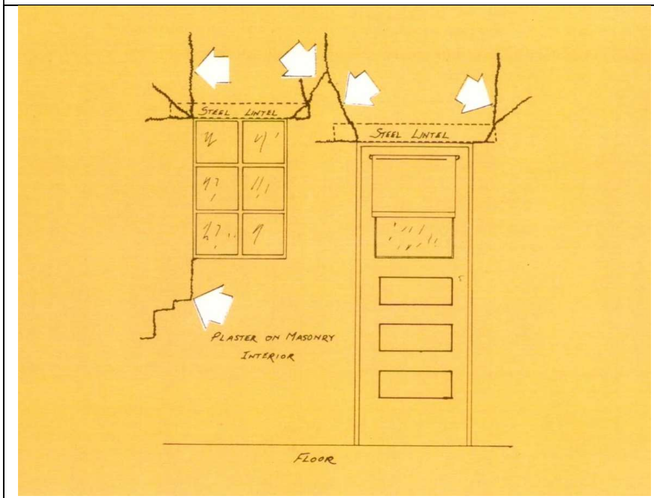
13.9 Cracking of houses and consequent devaluation

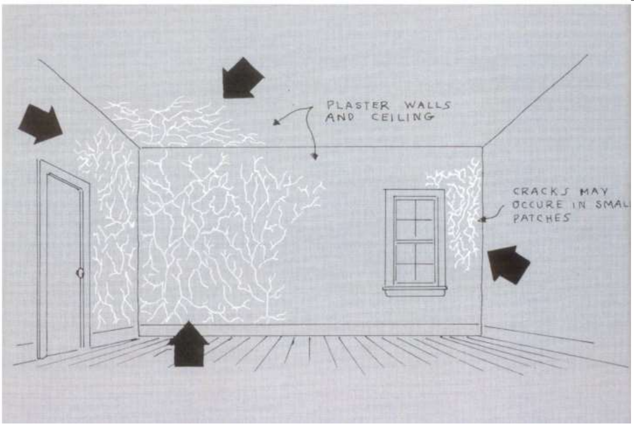
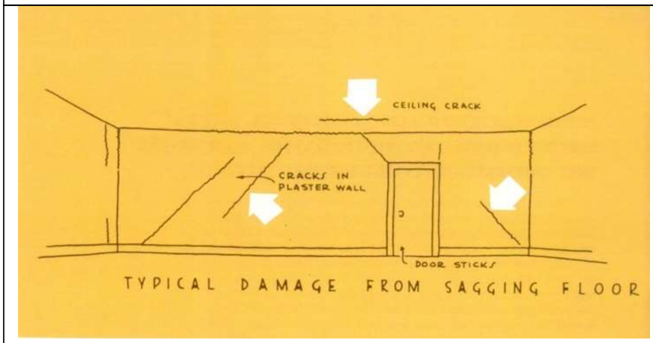
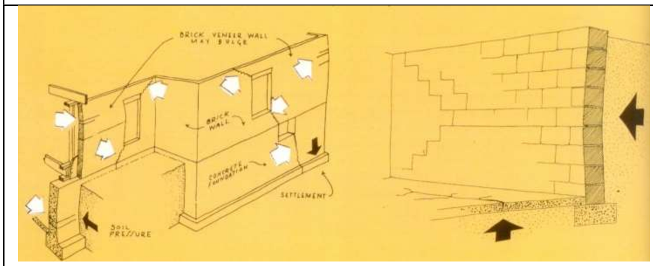
Houses in general have cracks. It is reported that a house could develop up to 15 non-blasting cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. 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 4: Examples of typical non-blasting cracks

	Cracks Resulting from Shrinkage of Concrete Blocks
	Typical Lintel Cracks
	Typical Lintel Cracks

	“Crazing” Cracks on Plaster
	Plaster Cracks Caused by Sagging Floors
	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.

14 Baseline Results

Baseline work for this report normally consists of two parts. The first part is monitoring of blasting operations if the mine is operational. The second part of baseline work done is familiarising oneself with the surroundings and the typical structures that are found in the area of the project. The information for this is presented below.

14.1 Baseline influence

The project is currently not an operational mine. Baseline data is assumed to be zero.

14.2 Structure profile

As part of the baseline, all possible structures in a possible influence area are identified. The site was reviewed using Google Earth imagery. Information sought during the review was to identify surface structures present in a 1500 m radius from the proposed box cut area, which will require consideration during modelling of blasting operations, e.g. houses, general structures, power lines, pipelines, reservoirs, mining activity, roads, shops, schools, gathering places, possible historical sites, etc. A list was prepared of all structures in the vicinity of the box cut area. The list includes structures and POI within the 3500 m boundary – see Table 6 below. A list of structure locations was required to determine the allowable ground vibration limits and air blast limits. Figure 2 shows an aerial view of the planned box cut area 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 BM&C 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, High-rise buildings and Industrial buildings / Infrastructure
4	Ruins
5	Animal related installations and animal sensitive areas
6	Industrial Installations
7	Earth like structures – no surface structure
8	Heritage sites (buildings, infrastructure, activity)
9	Graves
10	Water Borehole
11	Water Resources Surface
12	Pipelines Buried
13	Powerlines / Telephone Lines / Towers
14	Road Infrastructure

Table 6: List of points of interest identified (WGS – LO 29°)

Tag	Description	Classification	Y	X
1	Dam	11	-85674.32	2885273.3
2	Dam	11	-85266.76	2885191.2
3	Dam	11	-84841.57	2883271.9
4	Informal Housing	1	-85213.19	2883275.8
5	Dam	11	-85281.95	2882663.6
6	Dam	11	-86216.73	2882839.2

Tag	Description	Classification	Y	X
7	Farm Buildings/Structures	2	-87444.24	2884087
8	Dam	11	-85681.05	2884863.3
9	Dam	11	-86247.3	2884337.7
10	Ruins	4	-85844.16	2884226.2
11	Kraal	5	-85784.71	2884315.7
12	Cement Dam	6	-85662.65	2884162.4
13	Gravel Road	14	-86191.87	2884093
14	Gravel Road	14	-84211.97	2883150.3
15	Gravel Road	14	-83715.88	2882156
16	Gravel Road	14	-83598.24	2881524.9
17	Grain Storage	13	-83503.16	2881464.7
18	Informal Housing	1	-82816.61	2881200.2
19	Informal Housing	1	-82732.68	2881173.7
20	Gravel Road	14	-82465.69	2880681
21	Dam	11	-82070.16	2879993.8
22	Gravel Road	14	-81517.64	2878816
23	Dam	11	-80960.95	2877498.9
24	Informal Housing	1	-81519.42	2877526.6
25	Informal Housing	1	-81551.46	2877464.3
26	Informal Housing	1	-81630.93	2877439
27	Informal Housing	1	-81540.59	2877411.7
28	Informal Housing	1	-81613.22	2877372.6
29	Informal Housing	1	-81720.41	2877240.2
30	Informal Housing	1	-81528.82	2877358.2
31	Dam	11	-82628.37	2876303.5
32	Dam	11	-86717.64	2878804.2
33	Cement Dam	6	-86665.61	2879537.2
34	Ruins	4	-86671.79	2880630.8
35	Power Line/Pylon	13	-86629.47	2880672.6
36	Power Line/Pylon	13	-86351.57	2881152.5
37	Power Line/Pylon	13	-86282.39	2881230.7
38	Dam	11	-85921.56	2881332.4
39	Dam	11	-85716.41	2881611.6
40	Gravel Road	14	-86407.53	2882316.3
41	Cement Dam	6	-86040.94	2883856.8
42	Buildings/Structures	2	-85196.65	2882409.3
43	Structures	2	-85362.14	2882177.6
44	Structures	2	-85463.22	2882074.7
45	Cement Dam	6	-85077.9	2882411.4
46	Cement Dam	6	-84953.35	2882171
47	Cement Dam	6	-84520.09	2882022.6
48	Cement Dam	6	-83989.98	2881910.5
49	Cement Dam	6	-84430.41	2881360
50	Farm Buildings/Structures	2	-83469.02	2881023.1
51	Informal Housing	1	-82922.48	2881168.5
52	Informal Housing	1	-82868.83	2880948.6

Tag	Description	Classification	Y	X
53	Dam	11	-85881.79	2880413
54	Dam	11	-83006.38	2879599.7
55	Cement Dam	6	-81790.03	2878961.4
56	Farm Buildings/Structures	2	-82796.28	2878712.3
57	Silo's	13	-82633.99	2878764.2
58	Informal Housing	1	-81591.66	2877520.4
59	Informal Housing	1	-81693.79	2877419
60	Farm Buildings/Structures	2	-85368.77	2877898
61	Informal Housing	1	-85829.65	2877736.5
62	Gravel Road	14	-87114.83	2882856.6
63	Cement Dam	6	-87489.5	2883738
64	Gravel Road	14	-85196.44	2884414.7

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 to informal building styles. Table 7 shows photos of structures found in the area.

Table 7: Structure Profile

Structure Photo	Description
	Farmstructures
	Farmhouse

	Informal Housing
	Grain storage sleeves
	Cement Dam
	Cement dame and windmill

	Ploughed mealie fields
	Gravel road and Powerline
	Gravel Road
	Windmill

	Powerline
	Informal Houses
	Ruins
	Small Dam

15 Blasting Operations

The following mining process is envisaged. Development of a box-cut to provide access to the underground coal resource. The underground operations will be mined mechanically using continuous miners. The box-cut will be established using conventional drilling and blasting operations.

The drill and blasting operations in the box-cut will be evaluated for the possible influence with regards to ground vibration, air blast and fly rock according to the blast design applied. Using the data supplied JKSimblast blast design software was used to design and simulate the blast. This designed blast was applied for the evaluation of the box-cut done in this report. The simulation of the blast provided the best prediction possible. Table 8 shows summary technical information of the blast designed. Outcome of the design on JKSimblast is summarised in Table 9. Figure 8 below shows the blast layout with blast holes, simulation and maximum charge mass per delay. Figure 10 shows simulation with maximum charge per delay from the typical timing applied. Figure 11 shows simulation with number of blast holes per delay from the typical timing applied.

Table 8: Blast design technical information

Blast Type	Box Cut
Design	Design 01
Bench Height (m)	20.0
Blast Depth Min. (m)	5.0
Blast Depth Max. (m)	20.0
Include Sub Drill (Yes/No)	No
Sub-drill (m)	0.00
Explosive Type	Emulsion
Explo. Density (gr/cm3)	1.15
Diameter (mm)	140
Burden (m):	4.00
Spacing (m):	4.00
Pattern	Staggered1
Average Depth (m)	12.5
Explosives Per B/H (incl. Sub drill) (kg)	159.3
Average Column Length (incl. Sub drill.)	9.0
Linear Charge (kg/m)	17.70
Stemming Length (m):	3.5
Stemming Ratio	25.0
Powder Factor (kg/m3)	0.80

Table 9: Blast design information from simulation

DESIGN FACTORS FOR:		
Blast Name:	Arnot South Boxcut	
Scenario:	10	Scenario 10
Area Option:	Arnot South Boxcut	130
Hole Option:	Arnot South Boxcut	131
Deck Option:	Arnot South Boxcut	132
Downhole Delay Option:	Arnot South Boxcut	133

Surface Delay Option:	Arnot South Boxcut	134
Using Marked Holes and Nearest Polygon:		
Polygon Number	1	
Polygon Label	BOXCUT	
Polygon Area	25 908.389	m^2
Bench Height	20	m
Volume	518 167.787	m^3
Rock SG	2.65	
Tonnage	1 373 144.634	tonnes
Marked Holes	1576	
Charge Mass	380 220.500	kg
Charge Energy	946 749.044	MJ
POWDER FACTOR	0.734	kg/m^3
POWDER FACTOR	0.277	kg/t
ENERGY FACTOR	1.827	MJ/m^3
ENERGY FACTOR	0.689	MJ/t
Using Marked Holes and blast Parameters:		
Av. Burden	4	m
Av. Spacing	4	m
All Hole Lengths	26 993.896	m
Volume	431 902.336	m^3
Rock SG	2.65	
Tonnage	1 144 541.190	tonnes
Marked Holes	1576	
Charge Mass	380 220.500	kg
Charge Energy	946 749.044	MJ
POWDER FACTOR	0.88	kg/m^3
POWDER FACTOR	0.332	kg/t
ENERGY FACTOR	2.192	MJ/m^3
ENERGY FACTOR	0.827	MJ/t

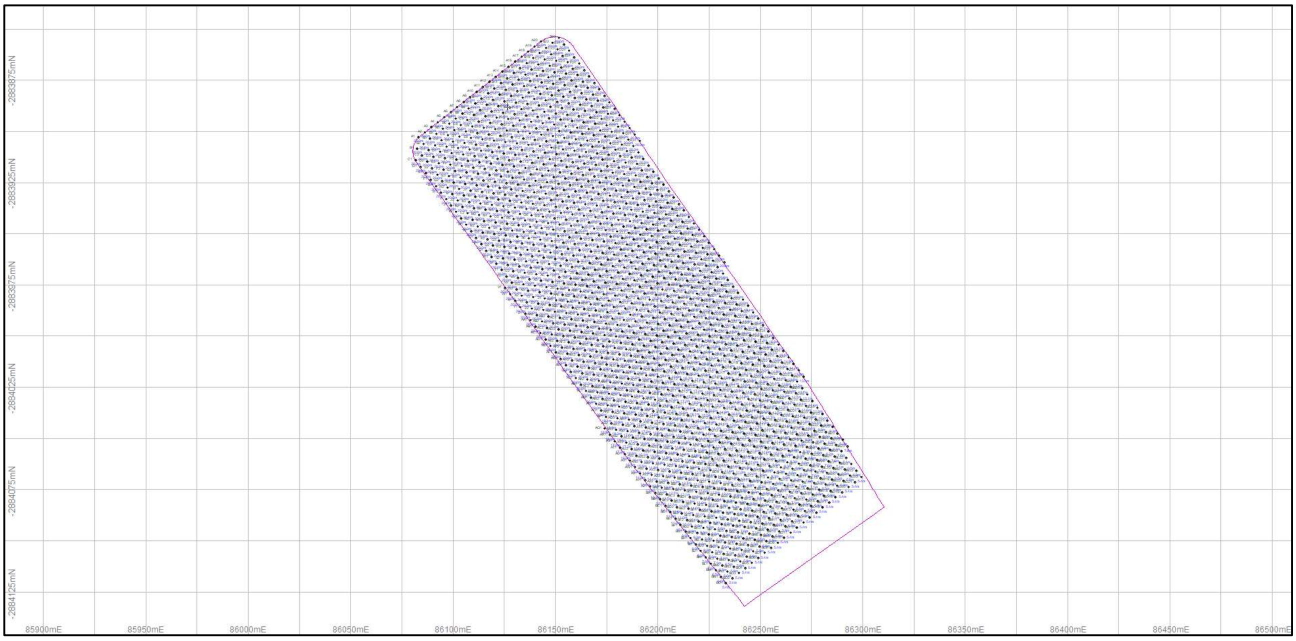


Figure 8: Blast holes layout with charge mass per blasthole

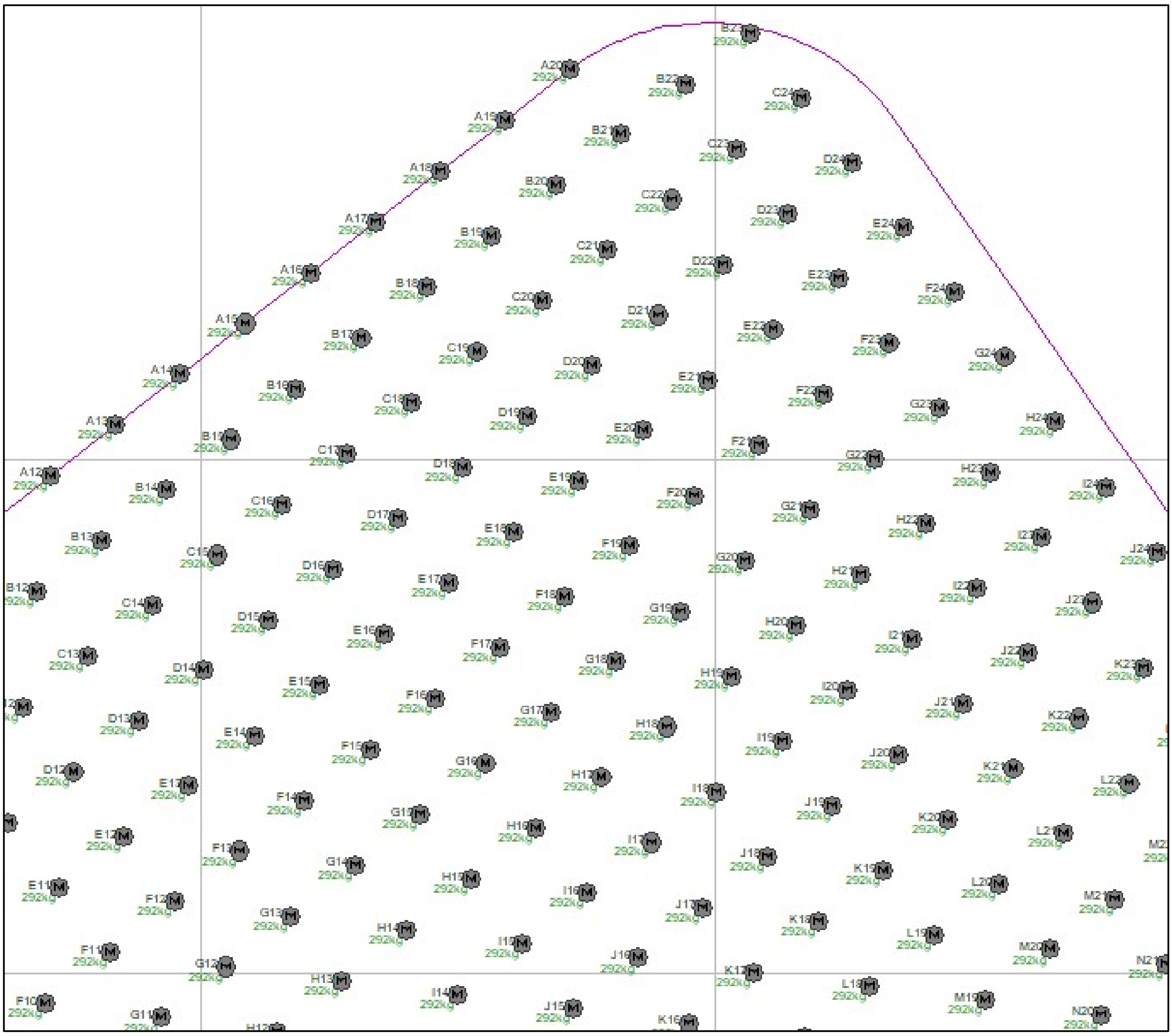


Figure 9: Blast holes layout with charge mass per blasthole - Zoomed

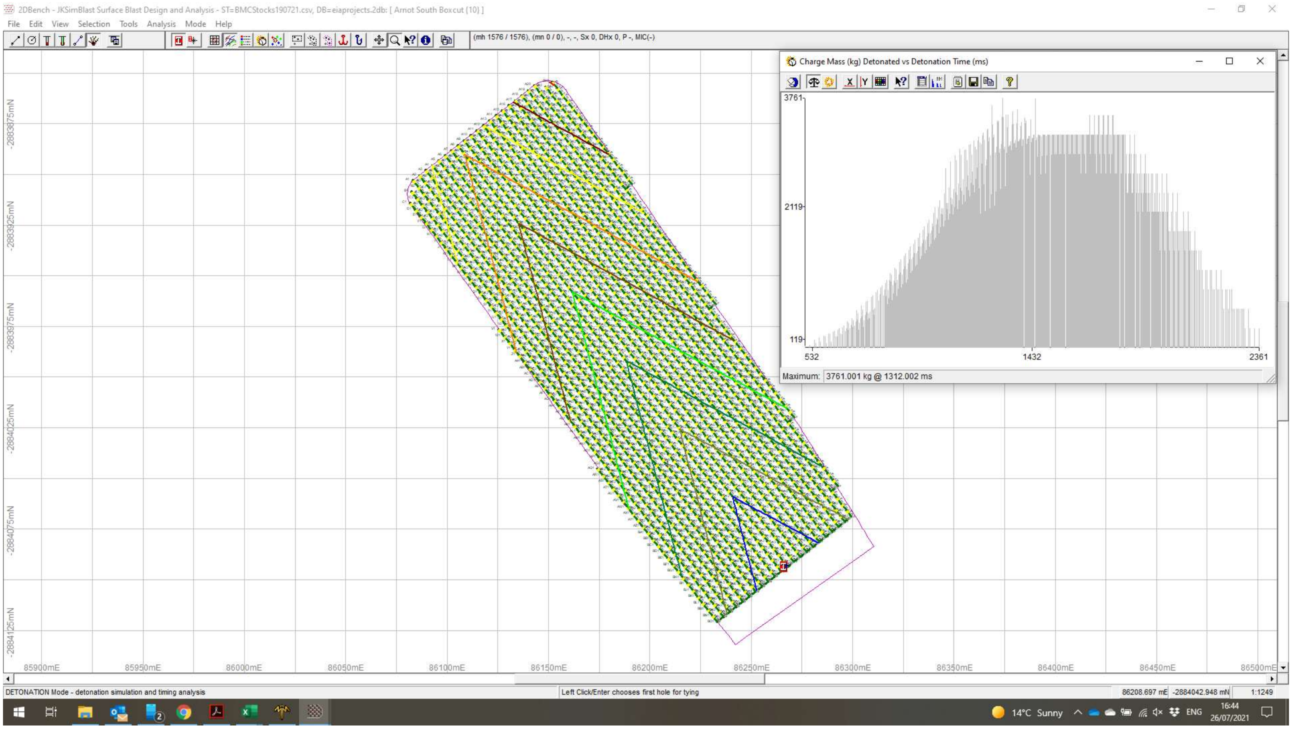


Figure 10: Simulation and charge mass per delay graph

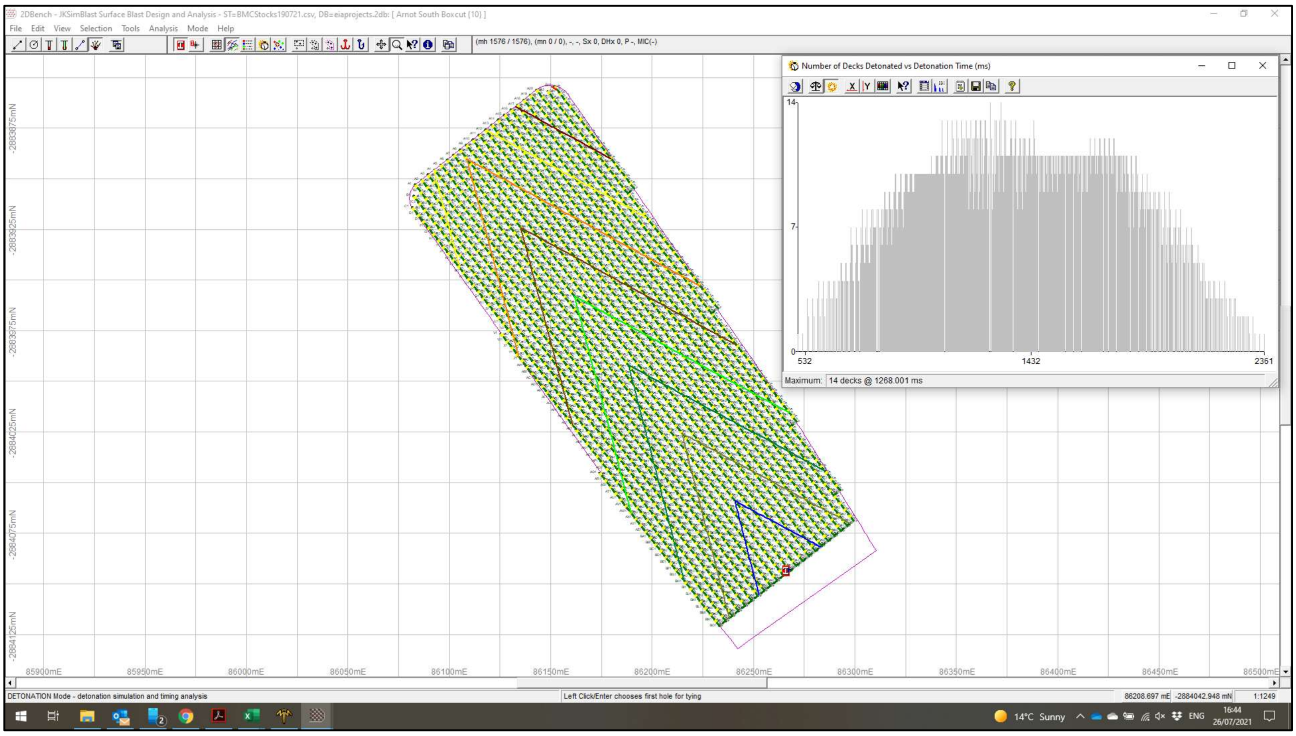


Figure 11: Simulation and number of decks per delay graph

The simulation work done provided information that 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 140 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 the blast layout and initiation timing of the blast. Thus, the maximum mass of explosives detonating at once. The minimum charge relates to 292 kg and the maximum charge relates to 3761 kg. These values were applied in all predictions for ground vibration and air blast.

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 (m)
E = Explosive Mass (kg)

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

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

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

Based on the designs presented on expected drilling and charging design, the following Table 10 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. The charge masses are 292 kg and 3761 kg for the box cut area.

Table 10: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 292 kg Charge	Expected PPV (mm/s) for 3761 kg Charge
1	50.0	194.4	1600.9
2	100.0	99.6	820.0
3	150.0	31.7	261.3
4	200.0	19.7	162.5
5	250.0	13.7	112.5
6	300.0	10.1	83.3
7	400.0	6.3	51.8
8	500.0	4.4	35.8
9	600.0	3.2	26.5
10	700.0	2.5	20.6
11	800.0	2.0	16.5
12	900.0	1.7	13.6
13	1000.0	1.4	11.4
14	1250.0	1.0	7.9
15	1500.0	0.7	5.8
16	1750.0	0.6	4.5
17	2000.0	0.4	3.6
18	2500.0	0.3	2.5
19	3000.0	0.2	1.9
20	3500.0	0.2	1.4

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:

$$P = \mathrm{A\ x\ }\left(\frac{\mathrm{D}}{\mathrm{E}^{\frac{1}{3}}}\right)^{-B}$$

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

A = Constant - (37.1)

B = Constant – (-0.97)

The constants for A and B were then selected according to the information as provided in Figure 12 below. Various types of mining operations are expected to yield different results. The information provided in Figure 12 is based on detailed research that was conducted for each of the different types of mining environments. In this report, the data for "Quarry face" 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 12: 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 11 below is a summary of values predicted according to Equation 2.

Table 11: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 292 kg Charge	Air blast (dB) for 3761 kg Charge
1	50.0	148.3	155.5
2	100.0	144.9	152.1
3	150.0	139.0	146.2
4	200.0	136.6	143.8
5	250.0	134.7	141.9
6	300.0	133.2	140.4
7	400.0	130.8	138.0
8	500.0	128.9	136.1
9	600.0	127.4	134.5
10	700.0	126.1	133.2
11	800.0	125.0	132.1
12	900.0	124.0	131.1
13	1000.0	123.1	130.2
14	1250.0	121.2	128.4
15	1500.0	119.7	126.8
16	1750.0	118.4	125.5
17	2000.0	117.3	124.4
18	2500.0	115.4	122.5
19	3000.0	113.8	121.0
20	3500.0	112.5	119.7

16 Construction Phase: Impact Assessment and Mitigation Measures

The development of the box-cut is considered part of the construction phase of the project and will be evaluated accordingly.
The area surrounding the proposed box-cut area was reviewed for structures, traffic, roads, human interface, animals' interface etc. Various installations and structures were observed. These are listed in Table 6. This section concentrates on the outcome of modelling the possible effects of ground vibration, air blast and fly rock specifically to these points of interest or possible interfaces. In evaluation, the charge mass scenarios selected as indicated in section 14.2 is considered with regards to ground vibration and air blast.

Ground vibration and air blast was calculated from the edge of the box cut outline and modelled accordingly. Blasting further away from the box cut edge will certainly have lesser influence on the surroundings. A worst case is then applicable with calculation from box-cut 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.

16.1 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 box cut 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 box cut area at the minimum and maximum charge mass at specific distances from the box cut 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 1500 m around the box cut 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 box cut area. 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 box cut area is coloured "Olive Green"

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

16.1.1 Ground vibration minimum charge mass per delay – 292 kg

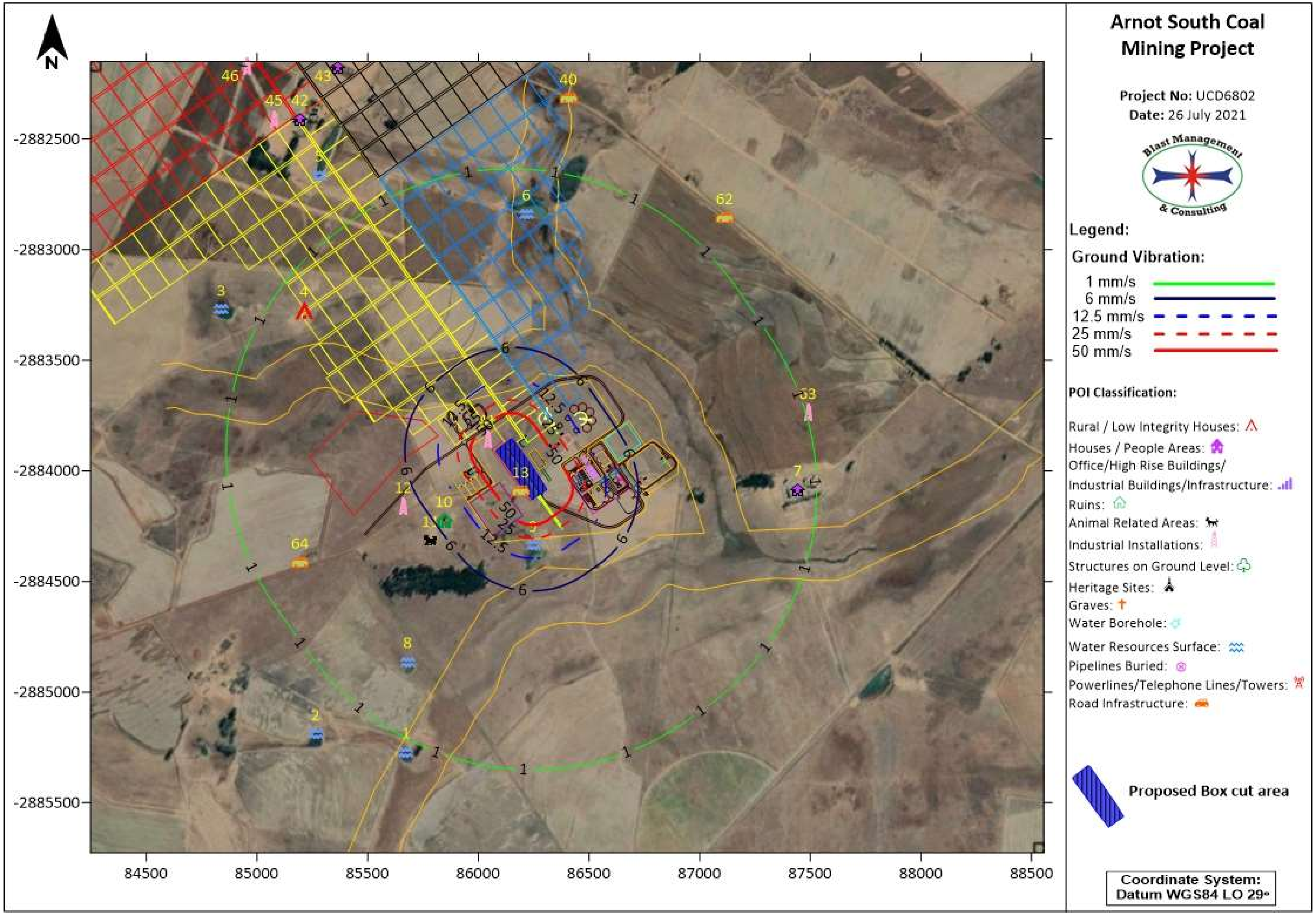


Figure 13: Ground vibration influence from minimum charge per delay

Table 12: Ground vibration evaluation for minimum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Dam	50	1276	292	0.9	Acceptable	N/A
2	Dam	50	1441	292	0.8	Acceptable	N/A
3	Dam	50	1392	292	0.8	Acceptable	N/A
4	Informal Housing	6	1073	292	1.2	Acceptable	Perceptible
5	Dam	50	1471	292	0.7	Acceptable	N/A
6	Dam	50	1017	292	1.3	Acceptable	N/A
7	Farm Buildings/Structures	12.5	1134	292	1.1	Acceptable	Perceptible
8	Dam	50	923	292	1.6	Acceptable	N/A
9	Dam	50	207	292	18.7	Acceptable	N/A
10	Ruins	6	374	292	7.0	Problematic	N/A
11	Kraal	50	475	292	4.7	Acceptable	Perceptible
12	Cement Dam	50	487	292	4.5	Acceptable	Perceptible
13	Gravel Road	200	15	292	1370.6	Problematic	N/A
14	Gravel Road	200	2016	292	0.4	Acceptable	N/A
15	Gravel Road	200	2942	292	0.2	Acceptable	N/A
16	Gravel Road	200	3439	292	0.2	Acceptable	N/A
17	Grain Storage	50	3550	292	0.2	Acceptable	N/A
18	Informal Housing	6	4240	292	0.1	Acceptable	Too Low
19	Informal Housing	6	4321	292	0.1	Acceptable	Too Low
20	Gravel Road	200	4844	292	0.1	Acceptable	N/A
21	Dam	50	5602	292	0.1	Acceptable	N/A
22	Gravel Road	200	6835	292	0.1	Acceptable	N/A
23	Dam	50	8201	292	0.0	Acceptable	N/A
24	Informal Housing	6	7838	292	0.0	Acceptable	Too Low
25	Informal Housing	6	7870	292	0.0	Acceptable	Too Low
26	Informal Housing	6	7845	292	0.0	Acceptable	Too Low
27	Informal Housing	6	7919	292	0.0	Acceptable	Too Low
28	Informal Housing	6	7909	292	0.0	Acceptable	Too Low
29	Informal Housing	6	7958	292	0.0	Acceptable	Too Low
30	Informal Housing	6	7969	292	0.0	Acceptable	Too Low
31	Dam	50	8330	292	0.0	Acceptable	N/A
32	Dam	50	5081	292	0.1	Acceptable	N/A
33	Cement Dam	50	4347	292	0.1	Acceptable	Too Low
34	Ruins	6	3265	292	0.2	Acceptable	N/A
35	Power Line/Pylon	75	3217	292	0.2	Acceptable	N/A
36	Power Line/Pylon	75	2709	292	0.3	Acceptable	N/A
37	Power Line/Pylon	75	2627	292	0.3	Acceptable	N/A
38	Dam	50	2532	292	0.3	Acceptable	N/A
39	Dam	50	2283	292	0.4	Acceptable	N/A
40	Gravel Road	200	1559	292	0.7	Acceptable	N/A
41	Cement Dam	50	63	292	134.3	Problematic	Intolerable
42	Buildings/Structures	12.5	1729	292	0.6	Acceptable	Too Low
43	Structures	12.5	1851	292	0.5	Acceptable	Too Low
44	Structures	12.5	1906	292	0.5	Acceptable	Too Low
45	Cement Dam	50	1795	292	0.5	Acceptable	Too Low
46	Cement Dam	50	2063	292	0.4	Acceptable	Too Low
47	Cement Dam	50	2445	292	0.3	Acceptable	Too Low
48	Cement Dam	50	2890	292	0.2	Acceptable	Too Low

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	3027	292	0.2	Acceptable	Too Low
50	Farm Buildings/Structures	12.5	3889	292	0.1	Acceptable	Too Low
51	Informal Housing	6	4179	292	0.1	Acceptable	Too Low
52	Informal Housing	6	4366	292	0.1	Acceptable	Too Low
53	Dam	50	3451	292	0.2	Acceptable	N/A
54	Dam	50	5287	292	0.1	Acceptable	N/A
55	Cement Dam	50	6546	292	0.1	Acceptable	Too Low
56	Farm Buildings/Structures	12.5	6137	292	0.1	Acceptable	Too Low
57	Silo's	50	6184	292	0.1	Acceptable	N/A
58	Informal Housing	6	7801	292	0.0	Acceptable	Too Low
59	Informal Housing	6	7825	292	0.0	Acceptable	Too Low
60	Farm Buildings/Structures	12.5	6007	292	0.1	Acceptable	Too Low
61	Informal Housing	6	6126	292	0.1	Acceptable	Too Low
62	Gravel Road	200	1385	292	0.8	Acceptable	N/A
63	Cement Dam	50	1229	292	1.0	Acceptable	Perceptible
64	Gravel Road	200	1017	292	1.3	Acceptable	N/A

16.1.2 Ground vibration maximum charge mass per delay - 3761 kg

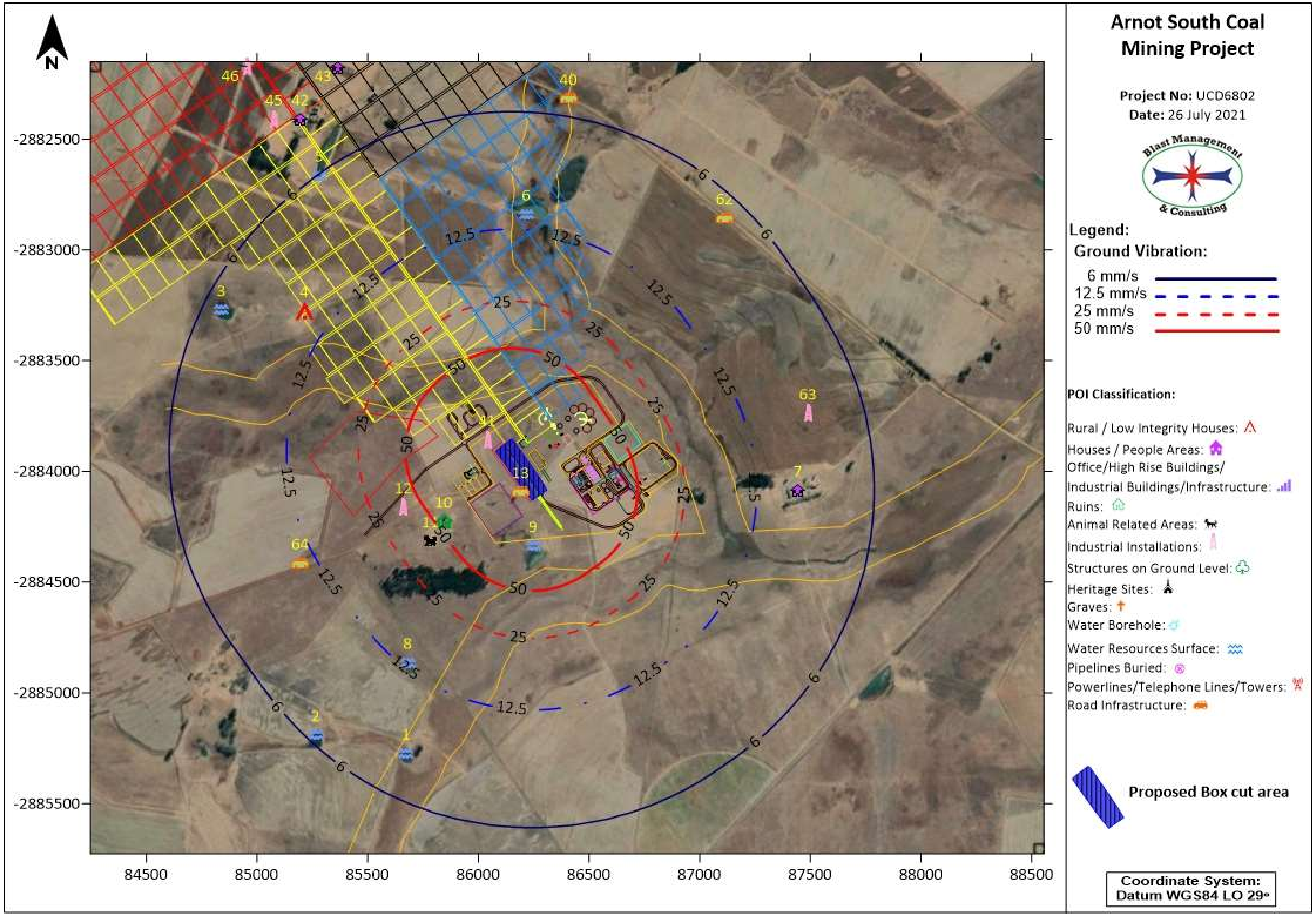


Figure 14: Ground vibration influence from maximum charge per delay

Table 13: Ground vibration evaluation for maximum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Dam	50	1276	3761	7.6	Acceptable	N/A
2	Dam	50	1441	3761	6.3	Acceptable	N/A
3	Dam	50	1392	3761	6.6	Acceptable	N/A
4	Informal Housing	6	1073	3761	10.2	Problematic	Unpleasant
5	Dam	50	1471	3761	6.0	Acceptable	N/A
6	Dam	50	1017	3761	11.1	Acceptable	N/A
7	Farm Buildings/Structures	12.5	1134	3761	9.3	Acceptable	Unpleasant
8	Dam	50	923	3761	13.0	Acceptable	N/A
9	Dam	50	207	3761	153.8	Problematic	N/A
10	Ruins	6	374	3761	57.8	Problematic	N/A
11	Kraal	50	475	3761	39.1	Acceptable	Intolerable
12	Cement Dam	50	487	3761	37.4	Acceptable	Intolerable
13	Gravel Road	200	15	3761	11287.1	Problematic	N/A
14	Gravel Road	200	2016	3761	3.6	Acceptable	N/A
15	Gravel Road	200	2942	3761	1.9	Acceptable	N/A
16	Gravel Road	200	3439	3761	1.5	Acceptable	N/A
17	Grain Storage	50	3550	3761	1.4	Acceptable	N/A
18	Informal Housing	6	4240	3761	1.1	Acceptable	Perceptible
19	Informal Housing	6	4321	3761	1.0	Acceptable	Perceptible
20	Gravel Road	200	4844	3761	0.8	Acceptable	N/A
21	Dam	50	5602	3761	0.7	Acceptable	N/A
22	Gravel Road	200	6835	3761	0.5	Acceptable	N/A
23	Dam	50	8201	3761	0.4	Acceptable	N/A
24	Informal Housing	6	7838	3761	0.4	Acceptable	Too Low
25	Informal Housing	6	7870	3761	0.4	Acceptable	Too Low
26	Informal Housing	6	7845	3761	0.4	Acceptable	Too Low
27	Informal Housing	6	7919	3761	0.4	Acceptable	Too Low
28	Informal Housing	6	7909	3761	0.4	Acceptable	Too Low
29	Informal Housing	6	7958	3761	0.4	Acceptable	Too Low
30	Informal Housing	6	7969	3761	0.4	Acceptable	Too Low
31	Dam	50	8330	3761	0.3	Acceptable	N/A
32	Dam	50	5081	3761	0.8	Acceptable	N/A
33	Cement Dam	50	4347	3761	1.0	Acceptable	Perceptible
34	Ruins	6	3265	3761	1.6	Acceptable	N/A
35	Power Line/Pylon	75	3217	3761	1.7	Acceptable	N/A
36	Power Line/Pylon	75	2709	3761	2.2	Acceptable	N/A
37	Power Line/Pylon	75	2627	3761	2.3	Acceptable	N/A
38	Dam	50	2532	3761	2.5	Acceptable	N/A
39	Dam	50	2283	3761	2.9	Acceptable	N/A
40	Gravel Road	200	1559	3761	5.5	Acceptable	N/A
41	Cement Dam	50	63	3761	1105.8	Problematic	Intolerable
42	Buildings/Structures	12.5	1729	3761	4.6	Acceptable	Perceptible
43	Structures	12.5	1851	3761	4.1	Acceptable	Perceptible
44	Structures	12.5	1906	3761	3.9	Acceptable	Perceptible
45	Cement Dam	50	1795	3761	4.4	Acceptable	Perceptible
46	Cement Dam	50	2063	3761	3.5	Acceptable	Perceptible
47	Cement Dam	50	2445	3761	2.6	Acceptable	Perceptible
48	Cement Dam	50	2890	3761	2.0	Acceptable	Perceptible

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	3027	3761	1.8	Acceptable	Perceptible
50	Farm Buildings/Structures	12.5	3889	3761	1.2	Acceptable	Perceptible
51	Informal Housing	6	4179	3761	1.1	Acceptable	Perceptible
52	Informal Housing	6	4366	3761	1.0	Acceptable	Perceptible
53	Dam	50	3451	3761	1.5	Acceptable	N/A
54	Dam	50	5287	3761	0.7	Acceptable	N/A
55	Cement Dam	50	6546	3761	0.5	Acceptable	Too Low
56	Farm Buildings/Structures	12.5	6137	3761	0.6	Acceptable	Too Low
57	Silo's	50	6184	3761	0.6	Acceptable	N/A
58	Informal Housing	6	7801	3761	0.4	Acceptable	Too Low
59	Informal Housing	6	7825	3761	0.4	Acceptable	Too Low
60	Farm Buildings/Structures	12.5	6007	3761	0.6	Acceptable	Too Low
61	Informal Housing	6	6126	3761	0.6	Acceptable	Too Low
62	Gravel Road	200	1385	3761	6.7	Acceptable	N/A
63	Cement Dam	50	1229	3761	8.1	Acceptable	Unpleasant
64	Gravel Road	200	1017	3761	11.1	Acceptable	N/A

16.2 Summary of ground vibration levels

The box cut 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 box cut area. The influences will also vary with distance from the box cut area. The model used for evaluation does indicate significant 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 distances between structures and the box cut area are a contributing factor to the levels of ground vibration expected and the subsequent possible influences. It is observed that for the different charge masses evaluated those levels of ground vibration will change as well. In view of the minimum and maximum charge specific attention will need to be given to specific areas. The minimum charge used indicated three POI's of concern and the maximum charge indicated five POI's of concern in relation to possible structural damage.

On a human perception scale five POI's were identified where vibration levels may be perceptible and lower for the minimum charge and fourteen POI's for the maximum charge. Three POI's were identified where vibration levels may be unpleasant for the maximum charge. Based on the maximum charge perceptible levels of vibration may be experienced up to 4365 m and unpleasant up to 1728 m. Problematic levels of ground vibration – levels greater than the proposed limit – are expected up to 1073 m from the box cut edge for the maximum charge. Any blast operations further away from the boundary will have lesser influence on these points.

The evaluation mainly considered a distance up to 1500 m from the box cut area. The closest structures observed are the Farm Buildings/Structures, Gravel Road, Dam and Informal Housing. The planned maximum charge evaluated showed that it could be problematic in terms of potential structural damage. The ground vibration levels predicted for these POI's ranged between 0.3 mm/s and 11287.1 mm/s for structures surrounding the box cut area.

The nearest public houses are located 1073 m from the box cut boundary. Ground vibration level predicted at this structure where people may be present is 10.2 mm/s for the maximum charge. In view of this specific mitigations will be required.

Structure conditions ranged from industrial construction to poor condition structures.

Mitigation of ground vibration was considered and discussed in Section 17.1. 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.

16.3 Ground Vibration and human perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 15 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 15 that up to a distance of 4365 m people may experience levels of ground vibration as perceptible. At 1728 m and closer the perception of ground vibration could be unpleasant for structures in the areas.

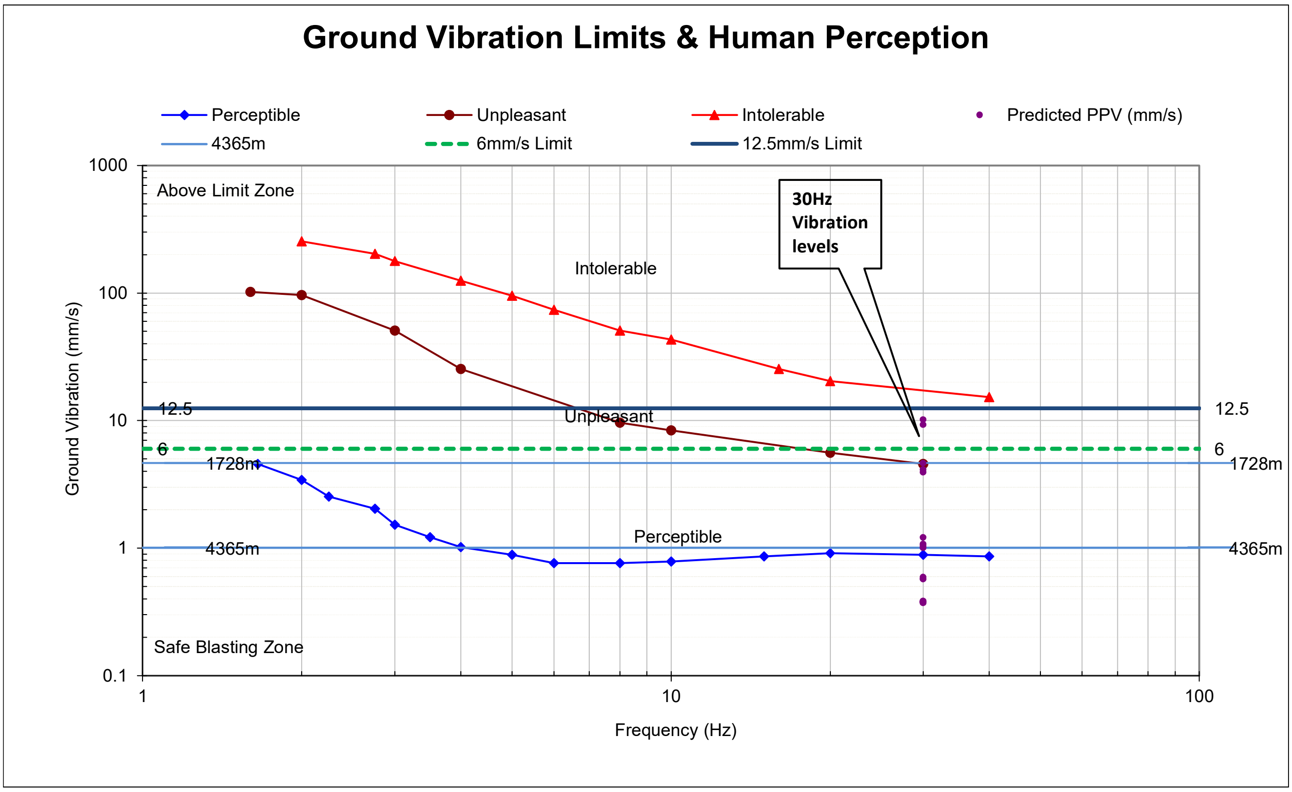


Figure 15: The effect of ground vibration with human perception and vibration limits

16.4 Vibration impact on roads

There are now national or provincial roads in close proximity to the project area. There are various gravel roads surrounding the box cut area and needs to be considered during construction of the box cut. There are farm roads the cut through the box-cut area. It is anticipated that these roads will be rerouted to avoid the laydown area of the mine. There are no specific ground vibration concerns to be noted.

16.5 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. The nearest houses (POI 4) are approximately 1073 m from the planned operation. These buildings are located such that levels of ground vibration predicted may be problematic and damaging based on the maximum charge evaluated.

Ground vibration levels expected from maximum charge has possibility to be perceptible up to 4365 m. It is certain that lesser charges will reduce this distance for instance at minimum charge this distance is expected to be 1229 m. Within these distance ranges there are only a limited number of houses. The anticipated ground vibration levels are certain to have possibility of upsetting the house holds within these ranges.

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

16.6 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 1500 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 sufficient to ensure that additional damage is not introduced to the different categories of structures. It is expected that, should levels of ground vibration be maintained within these limits, the possibility of inducing damage is limited.

16.7 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 area 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 box cut 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:
  - "Problematic" where there is real concern for possible damage – at levels greater than 134 dB;
  - "Complaint" where people will be complaining due to the experienced effect on structures at levels of 120 dB and higher (not necessarily damaging);

- "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 box cut 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 box cut area is coloured "Olive Green"

16.7.1 Air blast minimum charge mass per delay – 292 kg

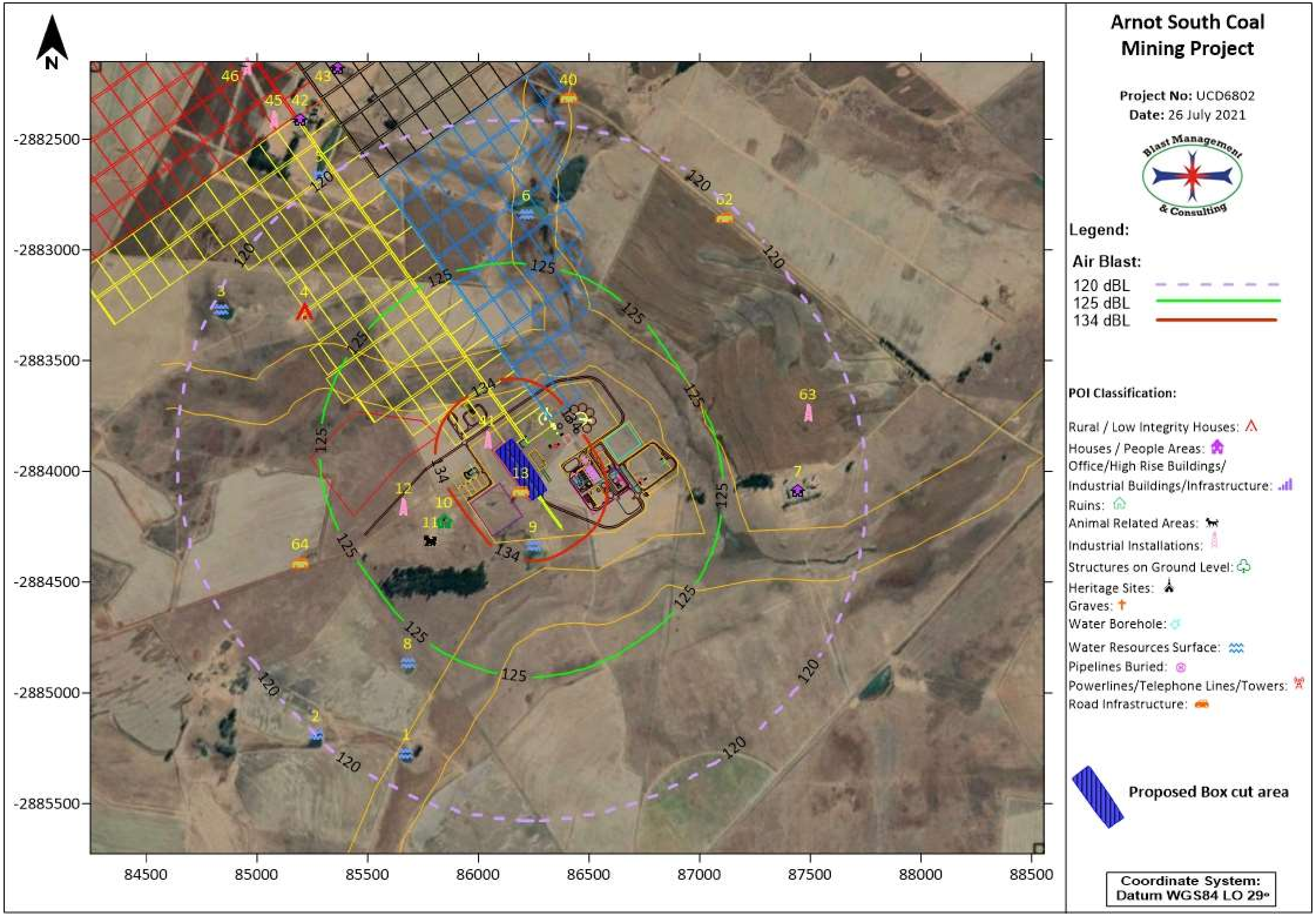


Figure 16: Air blast influence from minimum charge

Table 14: Air blast evaluation for minimum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Dam	1276	121.0	N/A
2	Dam	1441	120.0	N/A
3	Dam	1392	120.3	N/A
4	Informal Housing	1073	122.5	Complaint
5	Dam	1471	119.8	N/A
6	Dam	1017	122.9	N/A
7	Farm Buildings/Structures	1134	122.0	Complaint
8	Dam	923	123.8	N/A
9	Dam	207	136.3	N/A
10	Ruins	374	131.3	Complaint
11	Kraal	475	129.3	N/A
12	Cement Dam	487	129.1	N/A
13	Gravel Road	15	158.3	N/A
14	Gravel Road	2016	117.2	N/A
15	Gravel Road	2942	114.0	N/A
16	Gravel Road	3439	112.7	N/A
17	Grain Storage	3550	112.4	Acceptable
18	Informal Housing	4240	111.0	Acceptable
19	Informal Housing	4321	110.8	Acceptable
20	Gravel Road	4844	109.8	N/A
21	Dam	5602	108.6	N/A
22	Gravel Road	6835	107.0	N/A
23	Dam	8201	105.5	N/A
24	Informal Housing	7838	105.8	Acceptable
25	Informal Housing	7870	105.8	Acceptable
26	Informal Housing	7845	105.8	Acceptable
27	Informal Housing	7919	105.8	Acceptable
28	Informal Housing	7909	105.8	Acceptable
29	Informal Housing	7958	105.8	Acceptable
30	Informal Housing	7969	105.8	Acceptable
31	Dam	8330	105.3	N/A
32	Dam	5081	109.5	N/A
33	Cement Dam	4347	110.7	N/A
34	Ruins	3265	113.1	Acceptable
35	Power Line/Pylon	3217	113.3	N/A
36	Power Line/Pylon	2709	114.7	N/A
37	Power Line/Pylon	2627	115.0	N/A
38	Dam	2532	115.3	N/A
39	Dam	2283	116.1	N/A
40	Gravel Road	1559	119.3	N/A
41	Cement Dam	63	146.4	N/A
42	Buildings/Structures	1729	118.5	Acceptable
43	Structures	1851	117.9	Acceptable

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
44	Structures	1906	117.7	Acceptable
45	Cement Dam	1795	118.2	N/A
46	Cement Dam	2063	117.0	N/A
47	Cement Dam	2445	115.6	N/A
48	Cement Dam	2890	114.2	N/A
49	Cement Dam	3027	113.8	N/A
50	Farm Buildings/Structures	3889	111.7	Acceptable
51	Informal Housing	4179	111.1	Acceptable
52	Informal Housing	4366	110.7	Acceptable
53	Dam	3451	112.7	N/A
54	Dam	5287	109.0	N/A
55	Cement Dam	6546	107.4	N/A
56	Farm Buildings/Structures	6137	107.9	Acceptable
57	Silo's	6184	107.7	Acceptable
58	Informal Housing	7801	106.0	Acceptable
59	Informal Housing	7825	105.8	Acceptable
60	Farm Buildings/Structures	6007	108.1	Acceptable
61	Informal Housing	6126	107.9	Acceptable
62	Gravel Road	1385	120.3	N/A
63	Cement Dam	1229	121.4	N/A
64	Gravel Road	1017	122.9	N/A

16.7.2 Air blast maximum charge mass per delay - 3761 kg

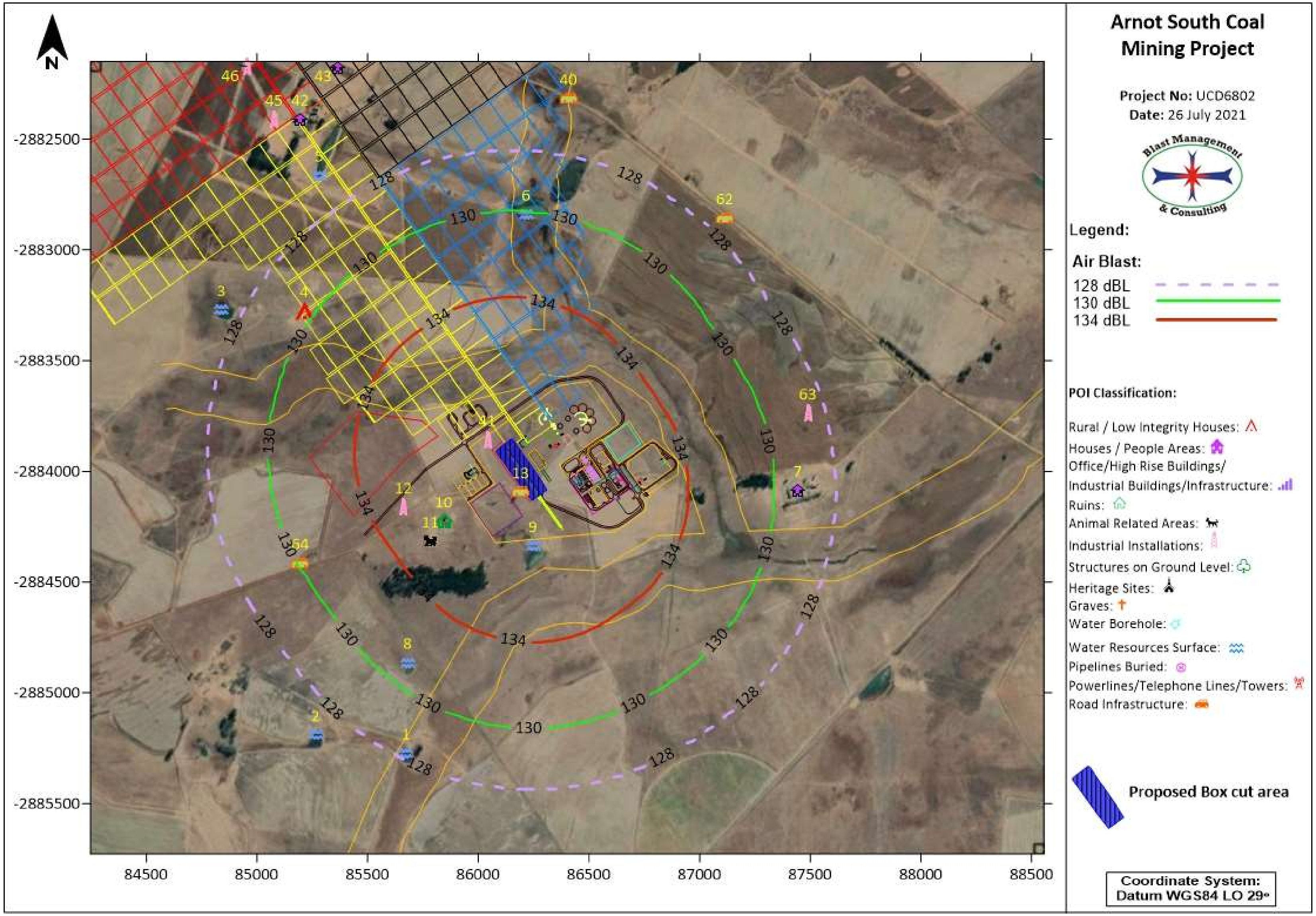


Figure 17: Air blast influence from maximum charge

Table 15: Air blast influence from maximum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Dam	1276	128.2	N/A
2	Dam	1441	127.2	N/A
3	Dam	1392	127.5	N/A
4	Informal Housing	1073	129.7	Complaint
5	Dam	1471	127.0	N/A
6	Dam	1017	130.1	N/A
7	Farm Buildings/Structures	1134	129.2	Complaint
8	Dam	923	130.9	N/A
9	Dam	207	143.5	N/A
10	Ruins	374	138.5	N/A
11	Kraal	475	136.5	N/A
12	Cement Dam	487	136.3	N/A
13	Gravel Road	15	165.5	N/A
14	Gravel Road	2016	124.4	N/A
15	Gravel Road	2942	121.2	N/A
16	Gravel Road	3439	119.9	N/A
17	Grain Storage	3550	119.6	Acceptable
18	Informal Housing	4240	118.1	Acceptable
19	Informal Housing	4321	118.0	Acceptable
20	Gravel Road	4844	117.0	N/A
21	Dam	5602	115.7	N/A
22	Gravel Road	6835	114.1	N/A
23	Dam	8201	112.5	N/A
24	Informal Housing	7838	112.9	Acceptable
25	Informal Housing	7870	112.9	Acceptable
26	Informal Housing	7845	112.9	Acceptable
27	Informal Housing	7919	112.8	Acceptable
28	Informal Housing	7909	112.8	Acceptable
29	Informal Housing	7958	112.8	Acceptable
30	Informal Housing	7969	112.8	Acceptable
31	Dam	8330	112.4	N/A
32	Dam	5081	116.6	N/A
33	Cement Dam	4347	117.9	N/A
34	Ruins	3265	120.3	N/A
35	Power Line/Pylon	3217	120.4	N/A
36	Power Line/Pylon	2709	121.9	N/A
37	Power Line/Pylon	2627	122.1	N/A
38	Dam	2532	122.4	N/A
39	Dam	2283	123.3	N/A
40	Gravel Road	1559	126.5	N/A
41	Cement Dam	63	153.6	N/A
42	Buildings/Structures	1729	125.6	Complaint
43	Structures	1851	125.1	Complaint

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
44	Structures	1906	124.8	Complaint
45	Cement Dam	1795	125.3	N/A
46	Cement Dam	2063	124.1	N/A
47	Cement Dam	2445	122.7	N/A
48	Cement Dam	2890	121.3	N/A
49	Cement Dam	3027	120.9	N/A
50	Farm Buildings/Structures	3889	118.8	Acceptable
51	Informal Housing	4179	118.2	Acceptable
52	Informal Housing	4366	117.8	Acceptable
53	Dam	3451	119.8	N/A
54	Dam	5287	116.2	N/A
55	Cement Dam	6546	114.4	N/A
56	Farm Buildings/Structures	6137	115.0	Acceptable
57	Silo's	6184	114.9	Acceptable
58	Informal Housing	7801	113.0	Acceptable
59	Informal Housing	7825	112.9	Acceptable
60	Farm Buildings/Structures	6007	115.1	Acceptable
61	Informal Housing	6126	115.0	Acceptable
62	Gravel Road	1385	127.5	N/A
63	Cement Dam	1229	128.5	N/A
64	Gravel Road	1017	130.1	N/A

16.8 Summary of findings for air blast

Review of the air blast levels indicate some concerns. Air blast predicted for the maximum charge ranges between 112.8 and 138.5 dB for all the POI's considered. This includes the nearest points such as the Informal Housing and Farm Buildings/Structures.

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 640 m and closer to box cut boundary. Infrastructure at the box cut area such as roads, power lines/pylons are present, but air blast does not have any influence on these installations.

The possible negative effects from air blast are expected to be the same 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 box cut is located such that "free blasting" – meaning no controls on blast preparation – will not be possible. The effect of stemming control will need to be considered. In many cases the lack of proper control on stemming material and length contributes mostly to complaints from neighbours.

16.9 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 18 shows the results from the ISEE calculations for fly rock range based on a 140 mm diameter blast hole and 3.5 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 266 m. The absolute minimum unsafe zone is then the 266 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 19 shows the area around the box cut area that incorporates the 266 m unsafe zone.

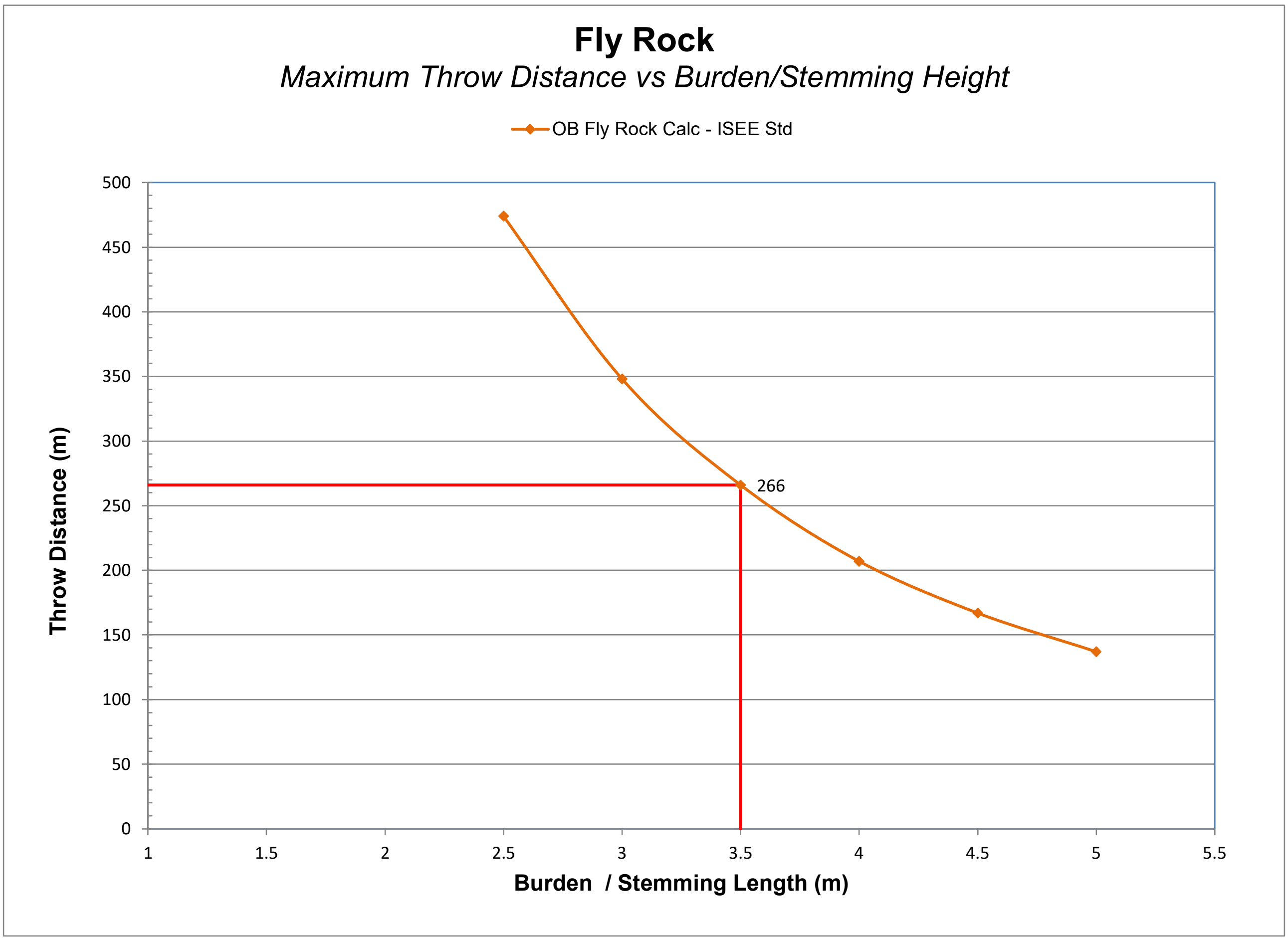


Figure 18: Fly rock prediction calculation

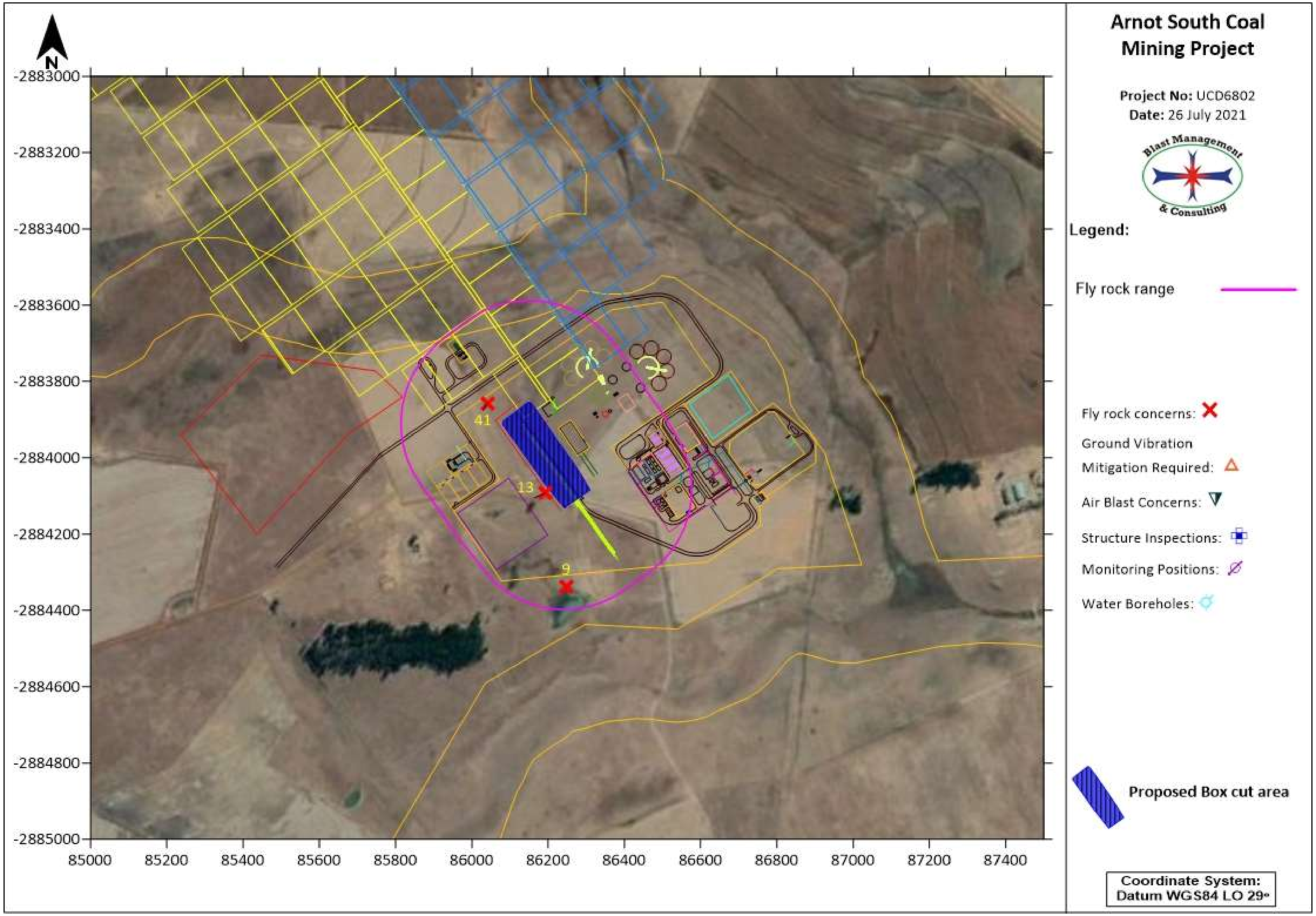


Figure 19: Predicted Fly Rock Exclusion Zone for the Box cut area

Review of the calculated unsafe zone showed three POI's for the box cut area are within the unsafe zone. Table 16 below shows the POI's of concern and coordinates.

Table 16: Fly rock concern POI's

Tag	Description	Y	X
9	Dam	-86247.3	2884337.7
13	Gravel Road	-86191.87	2884093
41	Cement Dam	-86040.94	2883856.8

16.10 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 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 19: . 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 18, which is extracted from Table 17. The description of the significance ratings is discussed in Table 19: .

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 17: 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.	Limited 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.	Very limited/Isolated 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 18: 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 19: 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 20: Risk Assessment Outcome

Dimension	Rating	Motivation	Significance
Blasting operations in the proposed box-cut for Arnot South Underground Coal Mining Project			
Impact Description: Ground Vibration			
Informal Housing			
Dam			
Ruins			
Cement Dam			
Prior to Mitigation/Management			
Duration	2	Ground vibration may be perceptible during the blasting operations in the box-cut.	Minor (negative) -40
Extent	3	Ground vibration may extend at low levels even to nearby settlements	
Intensity	4	Intensity is expected to be less than damaging but may be perceptible	
Probability	5	The probability of damage is low but could be experienced as highly perceptible.	
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			
Post-Mitigation			
Duration	2		Negligible (negative) -16
Extent	3		
Intensity	2	Specific blast designs to consider the closest infrastructure for anticipated levels of ground vibration	
Probability	3		
Nature	Negative		
Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed box-cut for Arnot South Underground Coal Mining Project			
Impact Description: Air blast			
Informal Housing			
Prior to Mitigation/Management			
Duration	2	Air blast may be perceptible during the blasting operations in the box-cut.	Negligible (negative) -16
Extent	3	Air blast may extend to nearby settlements and be perceived as a nuisance and lead to complaints	
Intensity	2	Intensity is expected to be less than damaging but will be perceptible	
Probability	3	The probability of damage is low due to low levels expected	
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	2		Negligible (negative) -16
Extent	3		
Intensity	2	Specific blast design with increased stemming length will assist in reducing effects.	
Probability	3		
Nature	Negative		
Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed box-cut for Arnot South Underground Coal Mining Project			
Impact Description: Fly rock			
Informal Housing			
Dam			
Ruins			
Cement Dam			
Prior to Mitigation/Management			

Duration	2	Fly rock may be experienced during the blasting operations in the box-cut.	Negligible (negative) -10
Extent	2	Fly rock is expected to be limited to the immediate area around the box-cut.	
Intensity	2	No damaging effects expected at nearby settlements or houses.	
Probability	1	No houses are 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			
Post-Mitigation			
Duration	2	No specific mitigation required	Negligible (negative) -10
Extent	2		
Intensity	2		
Probability	1		
Nature	Negative		

17.1 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 blast hole 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 21 shows list of POI's that will need to be considered. Figure 20 shows the location of these POI's in relation to the box cut area.

Table 21: Structures identified as problematic in and around the project area

Tag	Description	Classification	Y	X
4	Informal Housing	1	-85213.19	2883275.8
9	Dam	11	-86247.3	2884337.7
10	Ruins	4	-85844.16	2884226.2
13	Gravel Road	14	-86191.87	2884093
41	Cement Dam	6	-86040.94	2883856.8

Table above shows various points of concern that needs to be considered. The following is applicable to the points identified:

1. The ruins (POI 10) identified must be evaluated if of value to protect or not. If not required to be protected then no mitigation will be required.
2. The gravel road (POI 13) crosses the layout area for the box-cut. Road to be re-routed and if closed off it should be closed off at least minimum fly rock travel distance from the box-cut – 266 m. this may be greater but no less.
3. Consideration must be given to the cement dam (POI41) if in use or not. If no more in use no mitigation will be required.
4. The Informal settlement (POI4) and dam (POI9) will need to be considered with regards to ground vibration, air blast and fly rock.

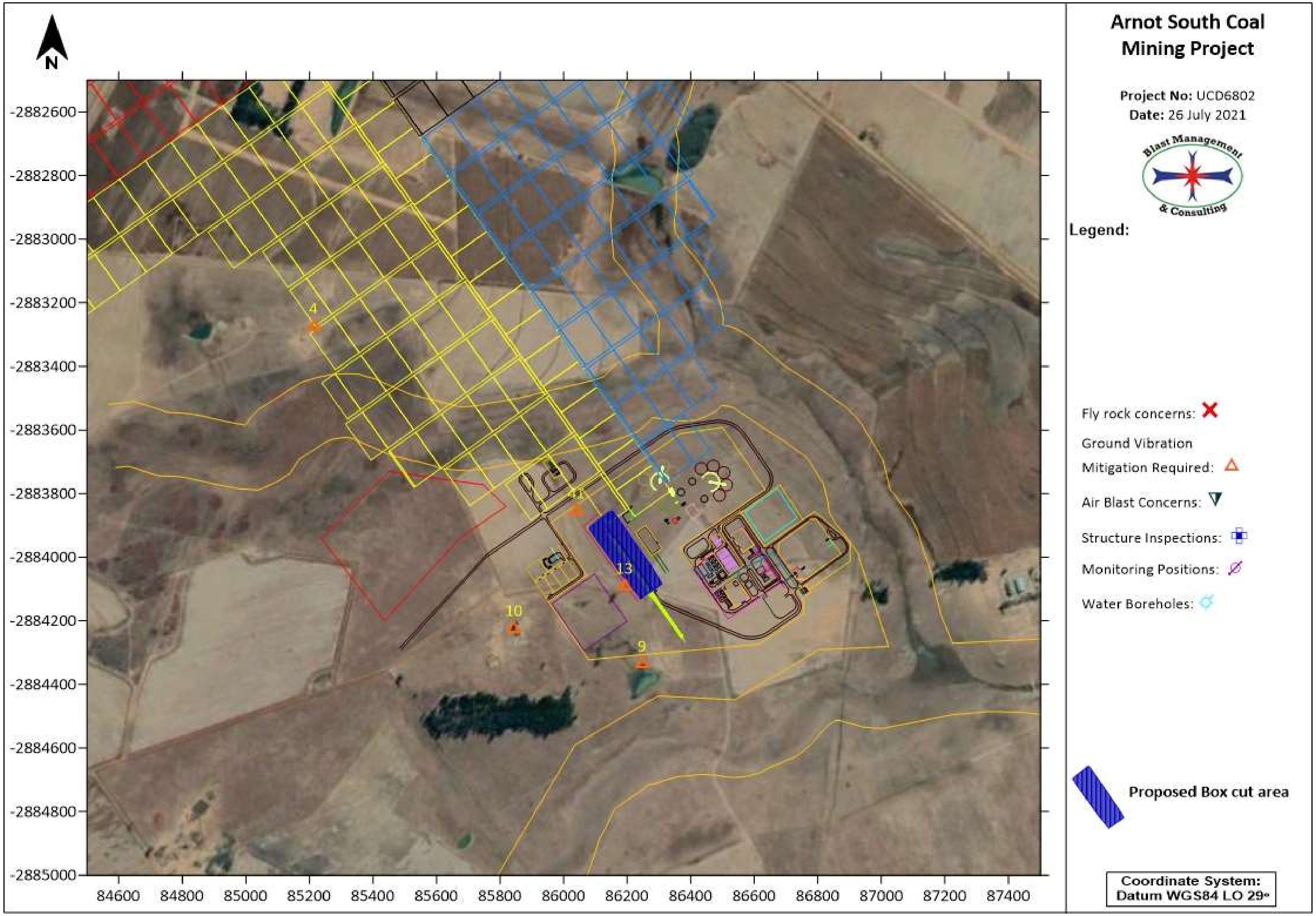


Figure 20: Structures identified where ground vibration mitigation will be required.

Mitigation of ground vibration for the identified POI's of concern can be done applying the following methods:

- Do blast design that considers the actual blasting, distance to the POI's and the ground vibration levels to be adhered too for these POI's.
- Only apply electronic initiation systems to facilitate lesser charge mass per delay or if required single hole firing.
- Do design for smaller diameter blast holes that will use fewer explosives per blast hole.

The identified POI's of concern is found in close proximity of the actual operations. In order to give indication of the possible of mitigation to consider the maximum charge per delay that can be allowed for the shortest distance between blast and POI is presented. This gives indication of possible charge that can be considered when finalizing blast design for the box-cut area.

Table 22 do show mitigation in the form of maximum charge mass that will be allowed to maintain safe levels of ground vibration at the identified POI's. This must be considered with the notes provided with Table 21.

Table 22: Mitigation measures: Maximum charge per delay for distance to POI

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
4	Informal Housing	-85213.19	2883275.8	6	1073	1983	6	Acceptable
9	Dam	-86247.3	2884337.7	50	207	964	50	Acceptable
10	Ruins	-85844.16	2884226.2	6	374	241	6	Acceptable
13	Gravel Road	-86191.87	2884093	200	15	28	200	Acceptable
41	Cement Dam	-86040.94	2883856.8	50	63	88	50	Acceptable

These POI's vary in distance and it will be required that each be evaluated in relation to a blast to be done. The distance should be checked, the charge mass allowed be calculated and then a design of charging or timing applied to ensure that the limits are not exceed. In most cases basic planned design does not need to change but timing can be adjusted or electronic timing can used to reduce the charge mass per delay. This must be confirmed with monitoring of ground vibration at the POI.

18 Operational Phase: Impact Assessment and Mitigation Measures

The underground mining operations will be conducted with continuous miners – mechanical mining. Due to the type of mining there will be no air blast and fly rock. Ground vibration will only be limited to the immediate area of the continuous miners. Thus there will be no impact on surface from this type of operation. No further evaluation is then required.

19 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.

20 Alternatives (Comparison and Recommendation)

No specific alternative mining methods are currently under discussion or considered for drilling and blasting.

21 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.

Four monitoring points 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 areas around the box cut Monitoring positions are indicated in Figure 21 and Table 23 lists the positions with coordinates. These points will need to be re-defined after the first blasts done and the monitoring programme defined.

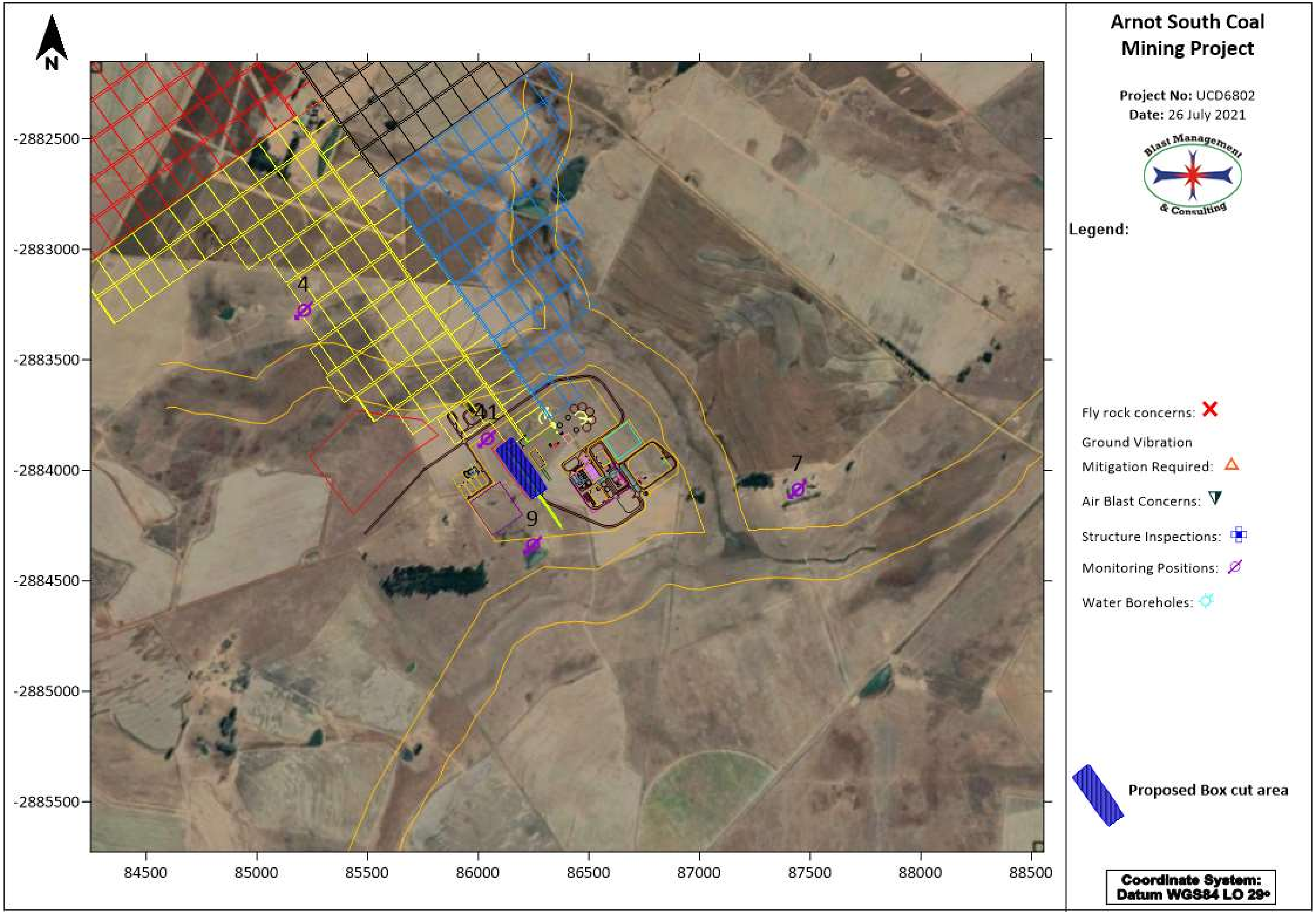


Figure 21: Suggested monitoring positions

Table 23: List of possible monitoring positions

Tag	Description	Y	X
4	Informal Housing	-85213.19	2883275.8
7	Farm Buildings/Structures	-87444.24	2884087
9	Dam	-86247.3	2884337.7
41	Cement Dam	-86040.94	2883856.8

22 Recommendations

The following recommendations are proposed.

22.1 Regulatory requirements – MHSA Reg. 4.16(2)

Regulatory requirements indicate specific requirements for all non-mining structures and installations within 500 m from the mining operation. Various POI's are observed that needs consideration within 500 m from the mining area. The mine will have to apply for the necessary authorisations as prescribed in the various acts, and specifically Mine Health and Safety Act Reg 4.16. Table 24 shows list of these installations. Figure 22 below shows the 500 m boundary around the box cut area. The location of non-mining installations is clearly observed.

Table 24: List of possible installations within the regulatory 500 m

Tag	Description	Y	X
9	Dam	-86247.3	2884337.7
10	Ruins	-85844.16	2884226.2
11	Kraal	-85784.71	2884315.7
12	Cement Dam	-85662.65	2884162.4
13	Gravel Road	-86191.87	2884093
41	Cement Dam	-86040.94	2883856.8

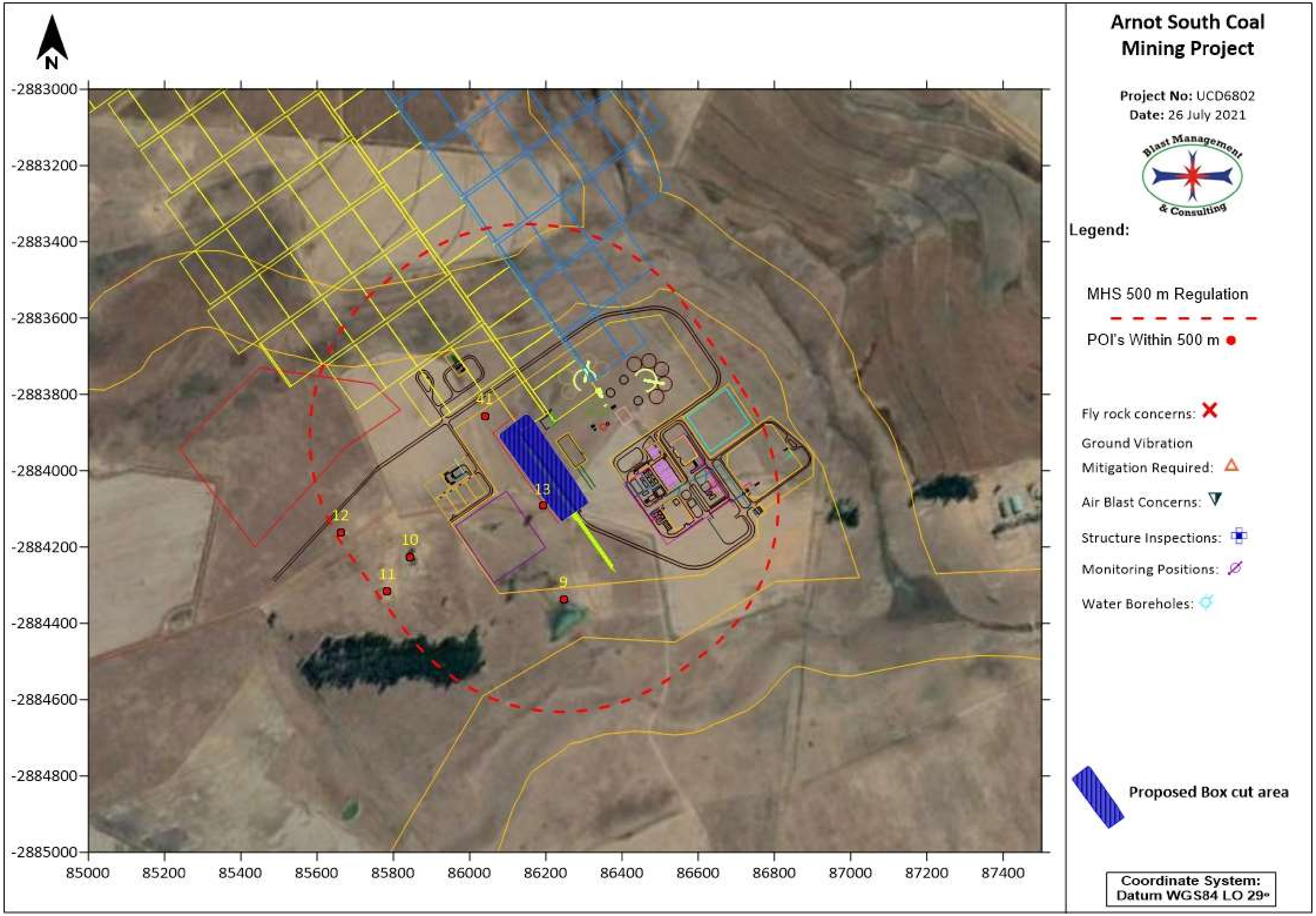


Figure 22: Regulatory 500 m range for the box cut area

22.1 Regulatory requirements – MHSA Reg. 17.6(a)

On review of the box cut area location, it is such that Mine Health and Safety act regulation 17.6(a) will be applicable and will need to be considered. The location of the box cut boundary is closer than 100 m from private installations and the necessary legal requirements will need to be addressed. Figure 23 shows the box cut with 100 m boundary that will need to be considered with indication of infrastructure within the 100 m. Please note that an icon may represent more than one structure / installation. Table 25 shows list of POI's identified.

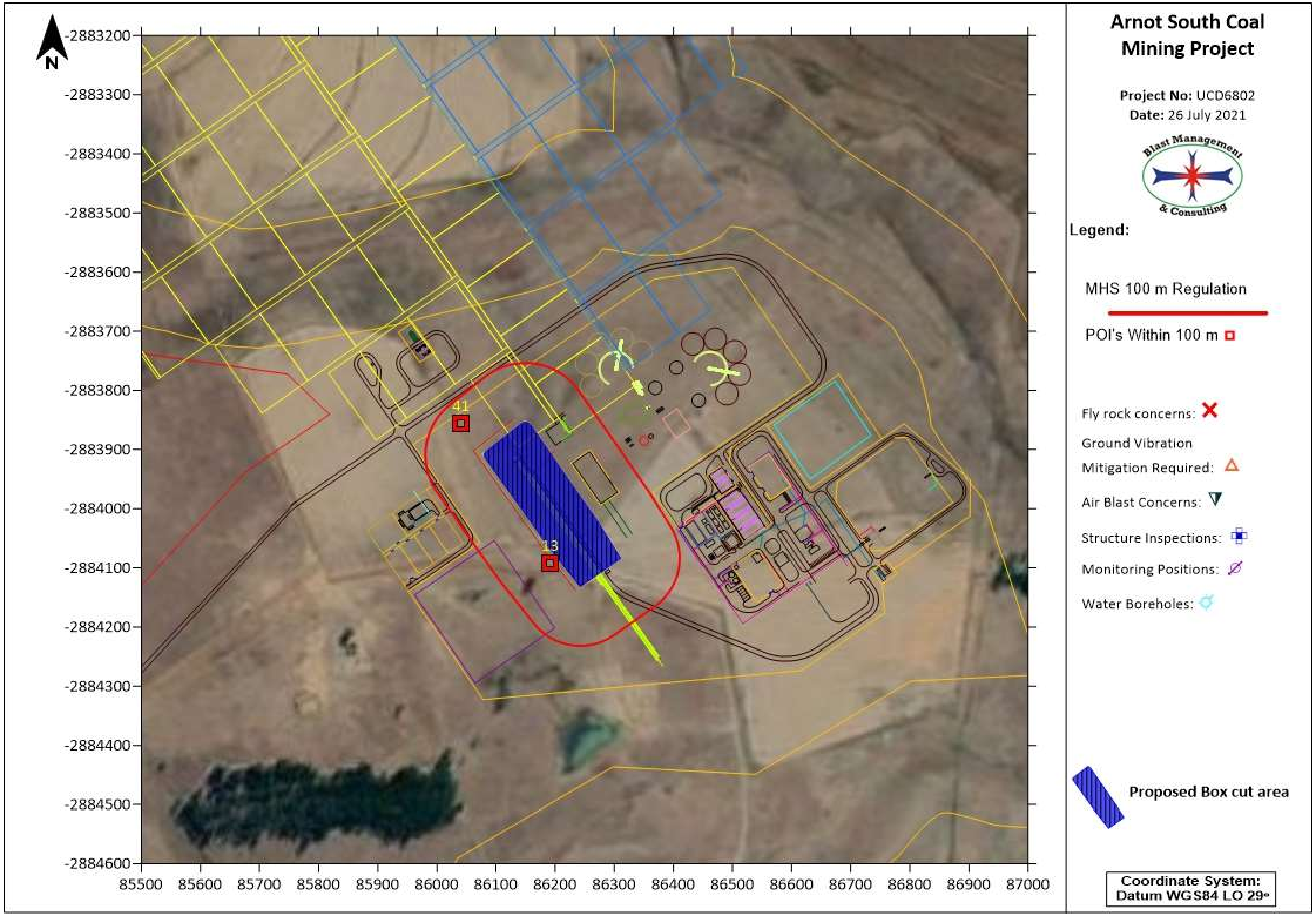


Figure 23: Regulatory 100 m range for box cut area

Table 25: List of possible installations within the regulatory 100 m

Tag	Description	Y	X
13	Gravel Road	-86191.87	2884093
41	Cement Dam	-86040.94	2883856.8

22.2 Blast Designs

Blast designs must be done considering the requirements for box-cut and maintaining low impact on identified POI's of concern. Specific attention can be given to the possible use of electronic initiation rather than conventional timing systems. This will allow for single blast hole firing instead of multiple blast holes. Single blast hole firing will provide single hole firing – thus less charge mass per delay and less influence.

22.3 Stemming length

The current proposed stemming lengths used provides for some control on fly rock. Consideration can be given to increase this length for better control. Specific designs where distances between blast and point of concern are known should be considered. Recommended stemming length should range between 20 and 30 times the blast hole diameter. In cases for better fly control this should range between 30 and 34 times the blast holes diameter. Increased stemming lengths will also contribute to more acceptable air blast levels.

22.4 Safe blasting distance and evacuation

Calculated minimum safe distance is 266 m. 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.

Further it must be confirmed with the respective authorities for the road and the powerlines what the minimum distance between box cut and these infrastructure must be. The current distances are very small, and it is certain that the minimum requirements from the authorities will indicate distances further than current.

22.5 Road management

There are now national or provincial roads close to the project area that will require specific management. There are various farm roads and gravel roads in the vicinity that must be considered when blasting is done. During periods of blasting travelling on these routes must be controlled.

22.6 Photographic Inspections

The option of photographic survey of all structures up to 1000 m from the box cut area is recommended. Though the box-cut is a short term operation it will provide information on condition of structures and proper records of structures. 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 1000 m, but this process will ensure record of the pre-blasting status of the nearest structures to the box cut area. At 1000 m the expected level of ground vibration will be perceptible. Figure 24 shows extent of the range of 1000 m around the box cut 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. Only the ruins at POI 10 was identified as potential infrastructure to be surveyed. It will be required to confirm if these structures need to be protected or not. If not then structure inspections may not be required.

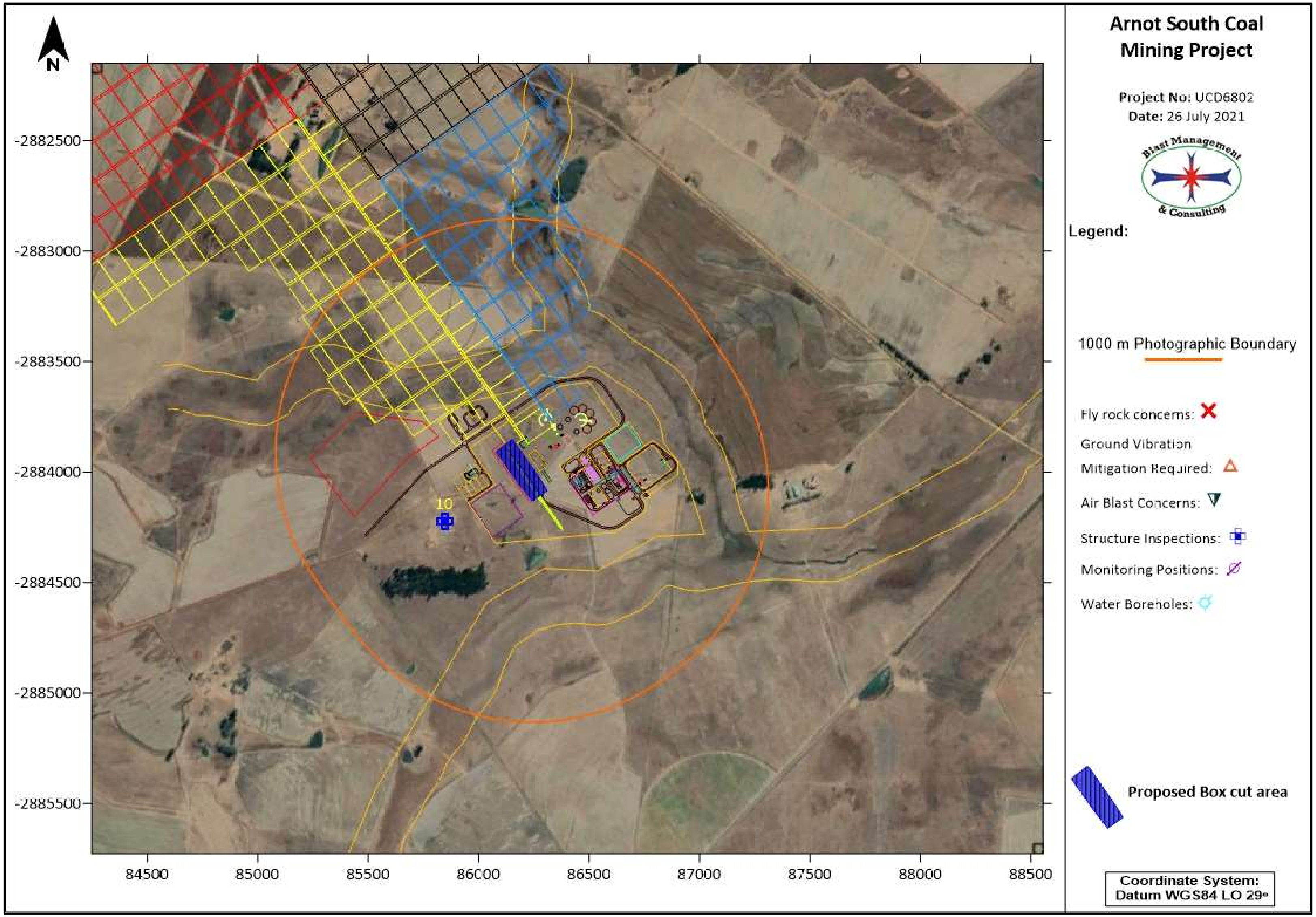


Figure 24: 1000 m area around box cut identified for structure inspections.

Table 26: Combined list of structures identified for inspections

Tag	Description	Y	X
10	Ruins	-85844.16	2884226.2

22.7 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 27.

Table 27: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A
Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	Shall not exceed 134dB at point of concern but 120 dB preferred
Houses of lesser proper construction (preferred)	12.5	
Rural building – Mud houses	6	

22.8 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.

22.9 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.

22.10 Video monitoring of each blast

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

23 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.

24 Project Result

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. Specific problems were identified, and recommendations made.

25 Conclusion

Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report evaluates the effects of 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 1500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low cost houses, corrugated iron structures, brick and mortar houses.

The location of structures around the Box cut area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the Farm Buildings/Structures, Gravel Road, Dam and Informal Housing. Ground vibrations predicted for the box cut area ranged between low and very high. The expected levels of ground vibration for some of these structures are high and will require specific mitigations in the way of adjusting charge mass per delay to reduce the levels of ground vibration. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage.

Air blast predicted also showed some concerns for box cut blasting. The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134dB. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The box cut is located such that “free blasting” – meaning no controls on blast preparation – will not be possible.

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 640 m and closer to box cut boundary. Infrastructure at the box cut area such as roads, power line is present, but air blast does not have any influence on these installations.

Fly rock remains a concern for blasting operations. Based on the drilling and blasting parameters values for a possible fly rock range with a safety factor of 2 was calculated to be 266 m. The absolute minimum unsafe zone is then the 266 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.

Specific actions will be required for the box cut area such as Mine Health and Safety Act requirements when blasting is done within 500 m from structures and mining with 100 m for structures. The Gravel Road, Dam, Ruins and Cement Dams falls within the 500 m range from the box cut area.

The box cut area is located such that specific concerns were identified and addressed in the report.

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

26 Curriculum Vitae of Author

J D Zeeman was a member of the Permanent Force - SA Ammunition Core for period January 1983 to January 1990. During this period, work involved testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition.
From July 1992 to December 1995, Mr Zeeman worked at AECI Explosives Ltd. Initial work involved testing science on small scale laboratory work and large-scale field work. Later, work entailed managing various testing facilities and testing projects. Due to restructuring of the Technical Department, Mr Zeeman was retrenched but fortunately was able to take up an appointment with AECI Explosives Ltd.’s Pumpable Emulsion Explosives Group for underground applications.

From December 1995 to June 1997 Mr Zeeman provided technical support to the Underground Bulk Systems Technology business unit and performed project management on new products.
Mr Zeeman started Blast Management & Consulting in June 1997. The main areas of focus are Pre-blast monitoring, Insitu monitoring, Post-blast monitoring and specialized projects.

Mr Zeeman holds the following qualifications:

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

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997, with work being done at various levels for all the major mining companies in South Africa. Some of the projects in which BM&C has been involved include:
Iso-Seismic Surveys for Kriel Colliery in conjunction with Bauer & Crosby Pty Ltd.; Iso-Seismic surveys for Impala Platinum Limited; Iso-Seismic surveys for Kromdraai Opencast Mine; Photographic Surveys for Kriel Colliery; Photographic Surveys for Goedehoop Colliery; Photographic Surveys for Aquarius Kroondal Platinum – Klipfontein Village; Photographic Surveys for Aquarius – Everest South Project; Photographic Surveys for Kromdraai Opencast Mine; Photographic inspections for various other companies, including Landau Colliery, Platinum Joint Venture – three mini-pit areas; Continuous ground vibration and air blast monitoring for various coal mines; Full auditing and control with consultation on blast preparation, blasting and resultant effects for clients, e.g. Anglo Platinum Ltd, Kroondal Platinum Mine, Lonmin Platinum, Blast Monitoring Platinum Joint Venture – New Rustenburg N4 road; Monitoring of ground vibration induced on surface in underground mining environment; Monitoring and management of blasting in close relation to water pipelines in opencast mining environment; Specialized testing of explosives characteristics; Supply and service of seismographs and VOD measurement equipment and accessories; Assistance in protection of ancient mining works for Rhino Minerals (Pty) Ltd.; Planning, design, auditing and monitoring of blasting in new quarry on new road project, Sterkspruit, with Africon, B&E International and Group 5 Roads; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Pandora Joint Venture 180 houses – whole village; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Section - 1000 houses / structures.

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

27 References

1. BME Training Module – Vibration, air blast and fly rock, Module V, Dated 5 August 2001.
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.
3. Dowding C.H., Construction Vibrations, 1996, Prentice Hall, Upper Saddle River, NJ 07458.
4. ISEE The Blasters' Handbook, 18th Edition, Cleveland, Ohio: International Society of Explosives Engineers; 2011.
5. Mechanical vibration and shock – Vibration of buildings – Guidelines for the measurement and evaluation of their effects on buildings, SABS ISO 4886:1990.
6. Oriard, L.L., 1999, The Effects of Vibration and Environmental Forces: A guide for Investigation of Structures, International Society of Explosives Engineers, Cleveland, Ohio, USA.
7. Persson P.A., Holmberg R. and Lee J., 1994, Rock Blasting and Explosives Engineering, Boca Raton, Florida: CRC Press.
8. Richards A. B., Moore A.J., Terrock Consulting Engineers Pty Ltd., 2002, Fly rock Control – By Chance or Design, Paper Presented at ISEE Conference – New Orleans.
9. Rowland, J.H.(III), Mainiero R., and Hurd D.A.(Jr.), Factors Affecting Fumes Production of an Emulsion and Anfo/Emulsion Blends.
10. Sapko M., Rowland J., Mainiero R., Zlochower I., Chemical and Physical Factors that Influence no Production during Blasting – Exploratory Study.
11. Scott A., Open Pit Blast Design, 1996, Julius Kruttschnitt Mineral Research Centre, The University of Queensland.
12. Siskind D.E., Stachura V.J., Stagg M.S. and Kopp J.W., 1980. Structure Response and Damage Produced by Air Blast from Surface Mining. US Bureau of Mines RI 8485.