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Report: Blast Impact Assessment The proposed Omitiomire Copper Mine on ML 197 Project Khomas Region - Namibia		
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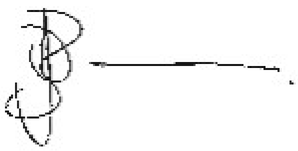
ii. Independence Declaration

A declaration that the specialist is independent in a form as may be specified by the competent authority.

I, JD Zeeman, declare that -

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the relevant legislation and any guidelines that have relevance to the proposed activity;
- I will comply with the applicable legislation;
- I have not, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct.



Signature of the Specialist

iii. Document Control:

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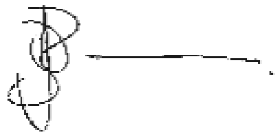
JD Zeeman Blast Management & Consulting	Consultant	Report Finalised	6/12/2023	
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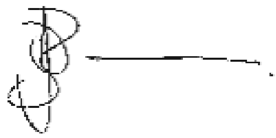
JD Zeeman Blast Management & Consulting	Consultant	Report Finalised	12/02/2024	

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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)
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
POI	Points of Interest
PPV	Peak Particle Velocity
RPP	Rock Pressure Pulse
USBM	United States Bureau of Mine
WGS 84	Coordinates (South African)

List of Units used in this Report

%	percentage
cm	centimetre
dBL	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
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 opencast 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 3500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low-cost houses, corrugated iron structures, industrial buildings, brick and mortar houses, power lines/pylons.

The location of structures around the Pit area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the M53 Road, Black Nossob River, Cement Dam, Hydrocensus Borehole and Power Lines. The ground vibration levels predicted for these POI's ranged between 0.6 mm/s and 4083 mm/s for Points of Interest (POI's) surrounding the open pit area. The Black Nossob River and the M53 district road is currently located close to the pit but client is planning to divert the Black Nossob River and the M53 district road away from the mine infrastructure and the open pit area. This reduces possible impact from ground vibration significantly.

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

Expected levels of air blast ranges between 118 dBL and 151 dBL for the minimum charge evaluated and between 121 dBL and 154 dBL for the maximum charge. Nearest structure to the pit area is POI 23, 24 and 25. Expected levels of air blast is greater than the limit applied at these POI's. 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 dBL at distance of 490 m and closer to pit boundary. Infrastructure at the pit areas such as roads and power lines/pylons, are 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 472 m. The absolute minimum unsafe zone is then the 472 m. This calculation is a guideline and any distance cleared should not be less. Eleven POI's are found within this range. These POI's consist of buildings, powerline, pan, dam and boreholes. 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.

Generally 500 m are applied for a safe blasting / clearance distance. Specific actions will be required when blasting is done within 500 m from structures. The Cement Dam, Buildings/Structures, Pan, Power Lines and Hydrocensus Borehole falls within the 500 m range from the pit area.

The pit area is located such that specific concerns were identified and addressed in the report. There are public structures located very close to the pit boundary. Specific mitigation will be required for these concerns. Recommendation have been made regarding these.

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

2 Introduction

Omitiomire is situated in central Namibia, within a semi-arid savannah-type grazing area, approximately 140 km northeast of Windhoek, in the Magisterial District of the Khomas Region. The project is under the management of Craton Mining and Exploration (Pty) Ltd (Craton), a Namibian registered subsidiary of Omico Copper Limited. Omico Copper Limited is partially owned by the Australian-based International Base Metals Limited.

Craton holds both Mining Licence ML197 and Exclusive Prospecting Licence EPL8550, encompassing a vast 30,000-hectare area known as the Omitiomire Copper Project. The current mining licence is valid until March 2036. The primary development plan involves the production of 30,000 tonnes per annum of LME Grade A copper cathode for a minimum of 10 years, focusing exclusively on open-pit mineralization.

The mine and related infrastructure will comprise the following:

- Workshops;
- Open-pit mining;
- Heap leach pads;
- Waste rock dumps (WRD),
- Leached ore deposition facility (ripios);
- Process plant including Solvent extraction and Electrowinning (SXEW) facility producing pure copper cathode;
- Water management infrastructure;
- Support services and facilities (offices, communications structures, etc.);
- Accommodation, with a canteen and recreation facilities; and
- Fencing around the entire site, with security fencing around the mine and accommodation facilities.

Rock fragmentation will be undertaken by drill and blast. The weathered zones require blasting with lower powder factors as the Omitiomire weathering profile is irregular and varies according to fracture intensity and rock type. Weathering has resulted in clay minerals, mainly from the breakdown of feldspars, biotite, and amphibole. Blasting can substantially modify and control material flow within the mining operation, including the feed size to the primary crusher. Blast performance must be assessed in terms of the following outcomes:

- Fragmentation, relating to the feed size supplied to the primary crusher, as well as oversize material and the requirement for rehandling of material, and secondary breakage,
- Shovel productivity, including wear and maintenance costs,
- Use of track dozers to condition the bench floor and rip high bottoms,
- Grade control,
- Primary crusher power consumption, throughput, maintenance costs, and

- Disruption to material flow during digging and crushing that affects truck efficiency.

Effective blasting is an important factor influencing a mine's production costs. Related to this is the overall pushback design of the open pit to access the ore body.

Figure 1 indicates the location of the proposed open pit.

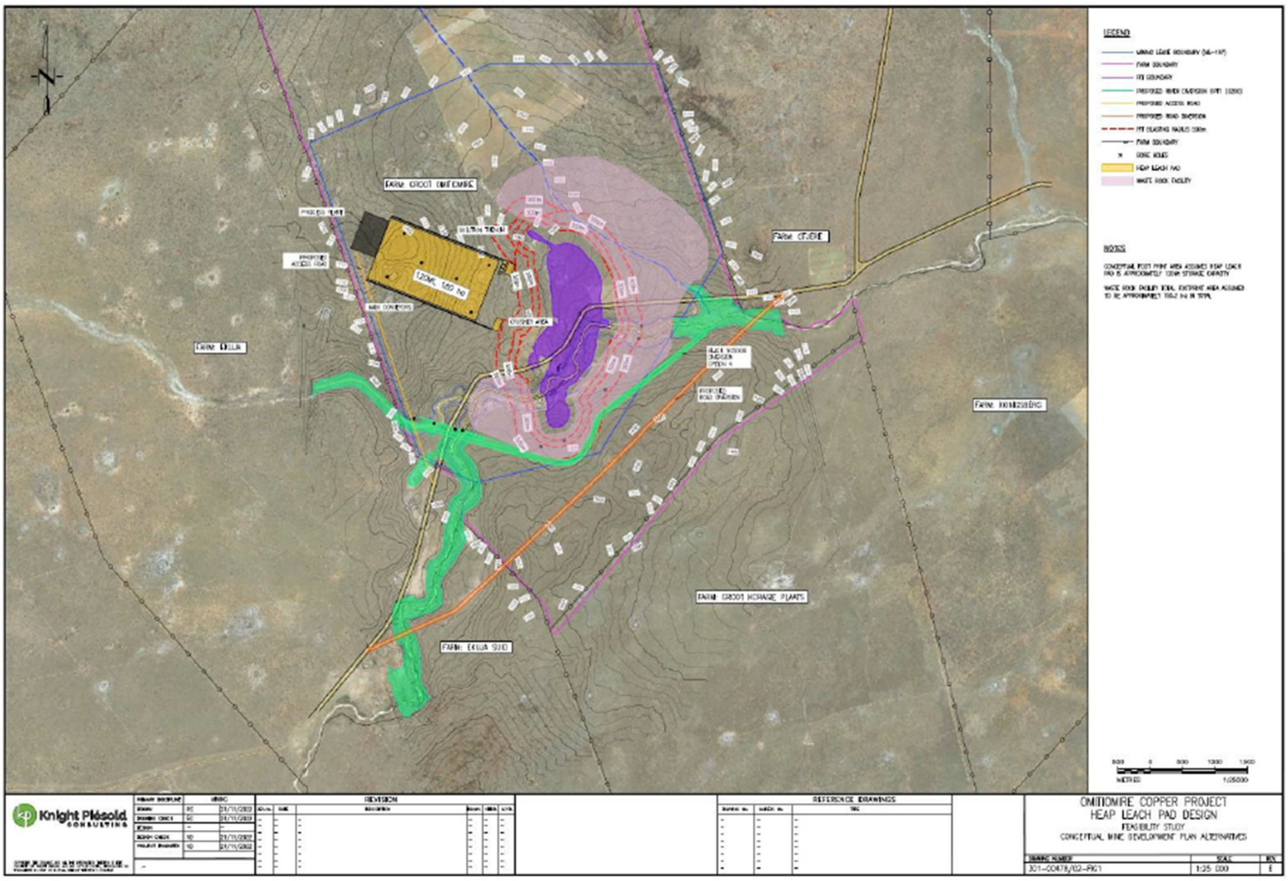

Figure 1: The location of the proposed open pit

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.
- 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

Craton Mining and Exploration (Pty) Ltd holds the mining licence 197 (ML 197) over farm Omitiomire, located 140 km northeast of Windhoek (by road) and approximately 39 km south of

Hochfeld, in the Khomas Region of Namibia. The centre point of the site is 21°49'39.97"S and 17°56'4.84"E.

Figure 2 shows the Locality map of the proposed opencast mining area.

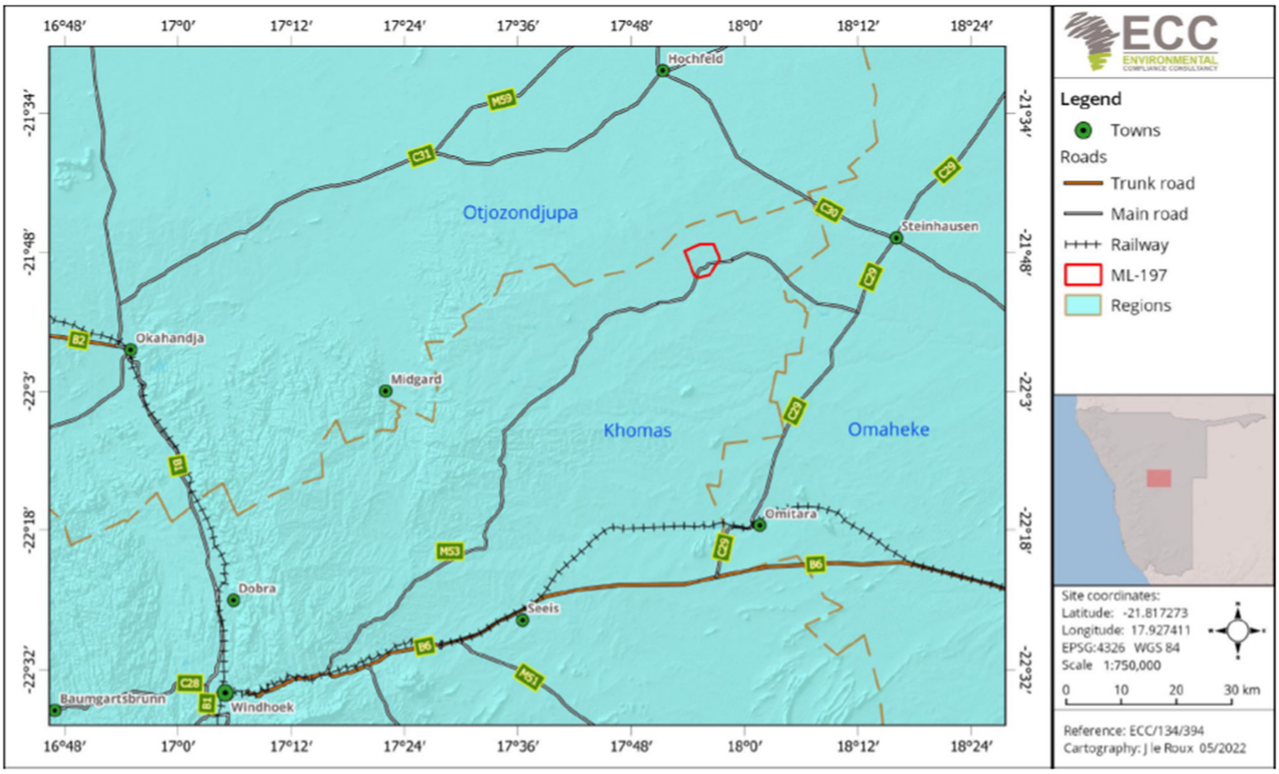

Figure 2: Locality map of the proposed mine on ML 197, Khomas Region, Namibia

6 Methodology

The detailed plan of study consists of the following sections:

- A desktop impact assessment study was done.
- 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 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.

8 Assumptions and Limitations

The following assumptions have been made:

- The anticipated levels of influence estimated in this report are calculated using standard accepted methodology according to international and local regulations.
- The assumption is made that the predictions are a good estimate with significant safety factors to ensure that expected levels are based on worst case scenarios. These will have to be confirmed with actual measurements once the operation is active.
- The site is evaluated as a new operation with no drilling and blasting being done. No confirmation of the predicted values could be made.
- Basic blast design parameters were provided. BMC used the parameters and did typical timing of the blast.
- The work done is based on the author's knowledge and information provided by the project applicant.

9 Legal Requirements

The following acts and guidelines contain references that will be applicable to the study. There is currently uncertainty on the specific Namibian law requirements for blasting operations in relation to limits for ground vibration and air blast. The shortfall in direct legislation is supported by international standards and other guidelines as well as relevant project experience of the consultants.

The following acts and supporting detail are considered:

- Mine Health and Safety Act of Namibia – to be considered,
- Ground vibration and air blast is also evaluated according to the USBM (United States Bureau of Mines) guidelines for safe blasting,
- Ground vibration and air blast is also evaluated according to guidelines as used by Blast Management & Consulting based on experience and knowledge.

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

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

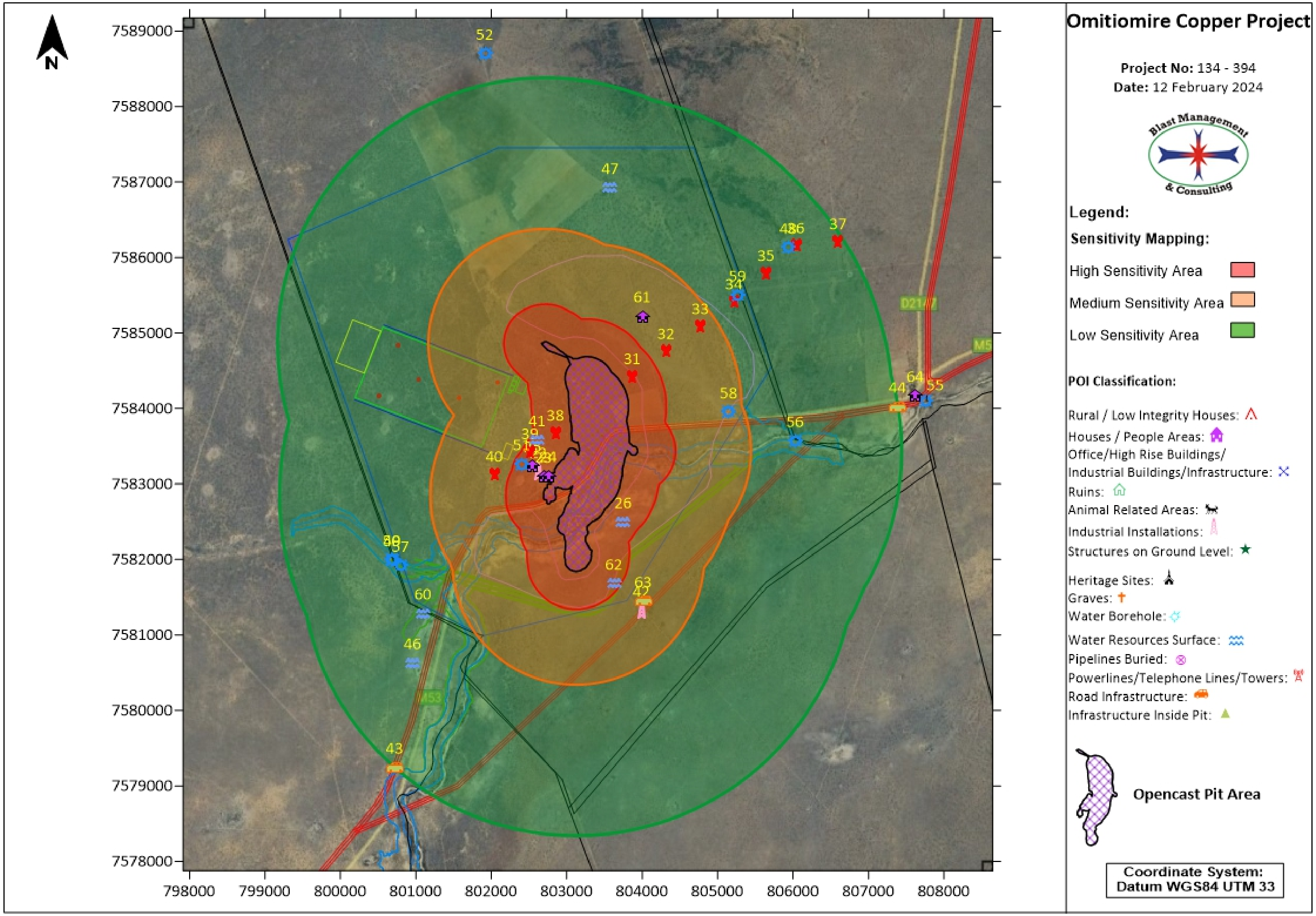

Figure 3: Identified sensitive areas

11 Consultation process

Consultation was only done with the client via the Environmental Practitioner. No other consultation with external parties was utilised. The work done is based on the author's knowledge, information provided by the client and information captured during site visit.

12 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.

12.1 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.

Guidelines applied in this document consists of the United States Bureau of Mines (USBM) according to report RI8507[1] and levels recommended by BMC as safe for the structures observed.

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1. Siskind, D. E., Stagg, M.S., Kopp, J. W. and Dowding, C. H. (1980). Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting. Report of Investigations 8507. US Bureau of Mines.

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 BMC.

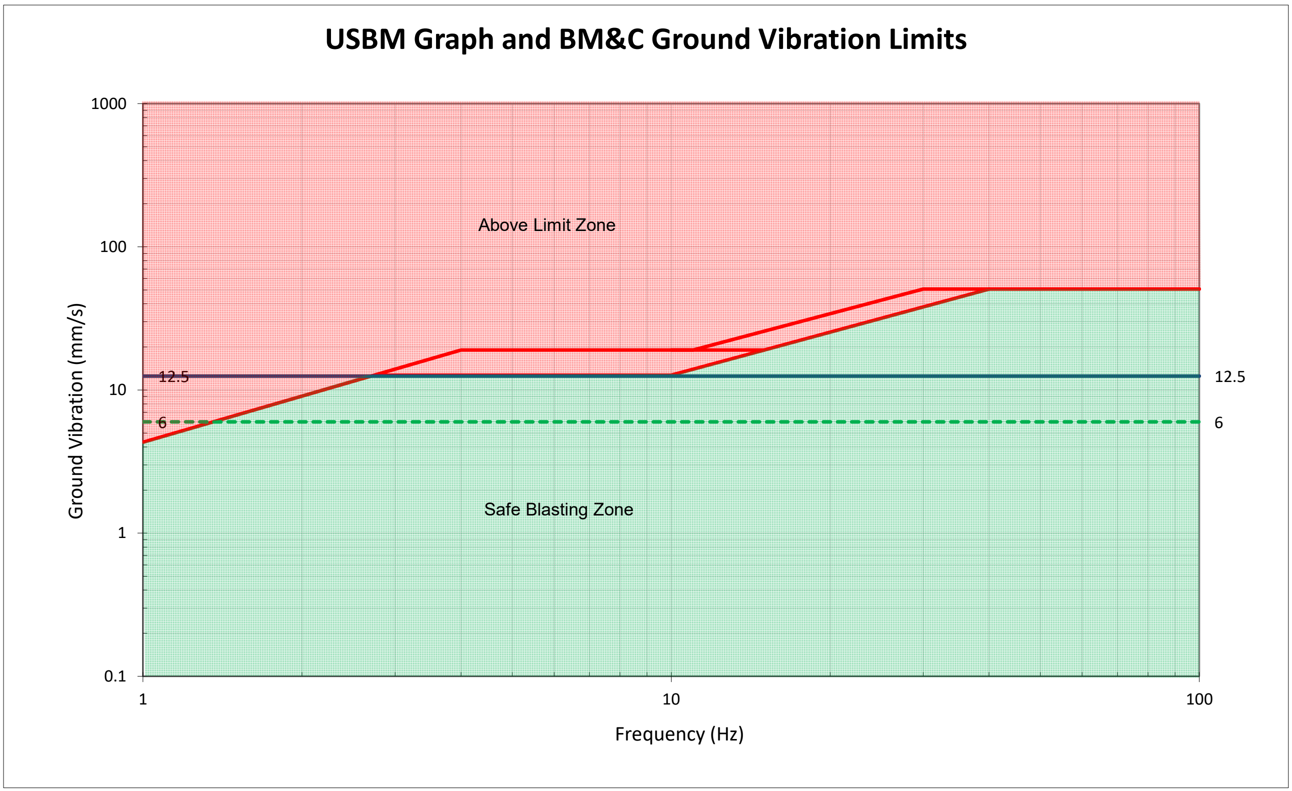

Figure 4: USBM Analysis Graph

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 (BMC).
- Steel pipelines: 50 mm/s.
- Electrical lines: 75 mm/s.
- Fuel Pipelines: 25 mms/s.
- Railways: 150 mm/s (BMC).

- Concrete less than 3 days old: 5 mm/s [2].
- Concrete after 10 days: 200 mm/s [3].
- 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 [4].

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.

12.2 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).

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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] 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.

[4] 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.

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

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

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.

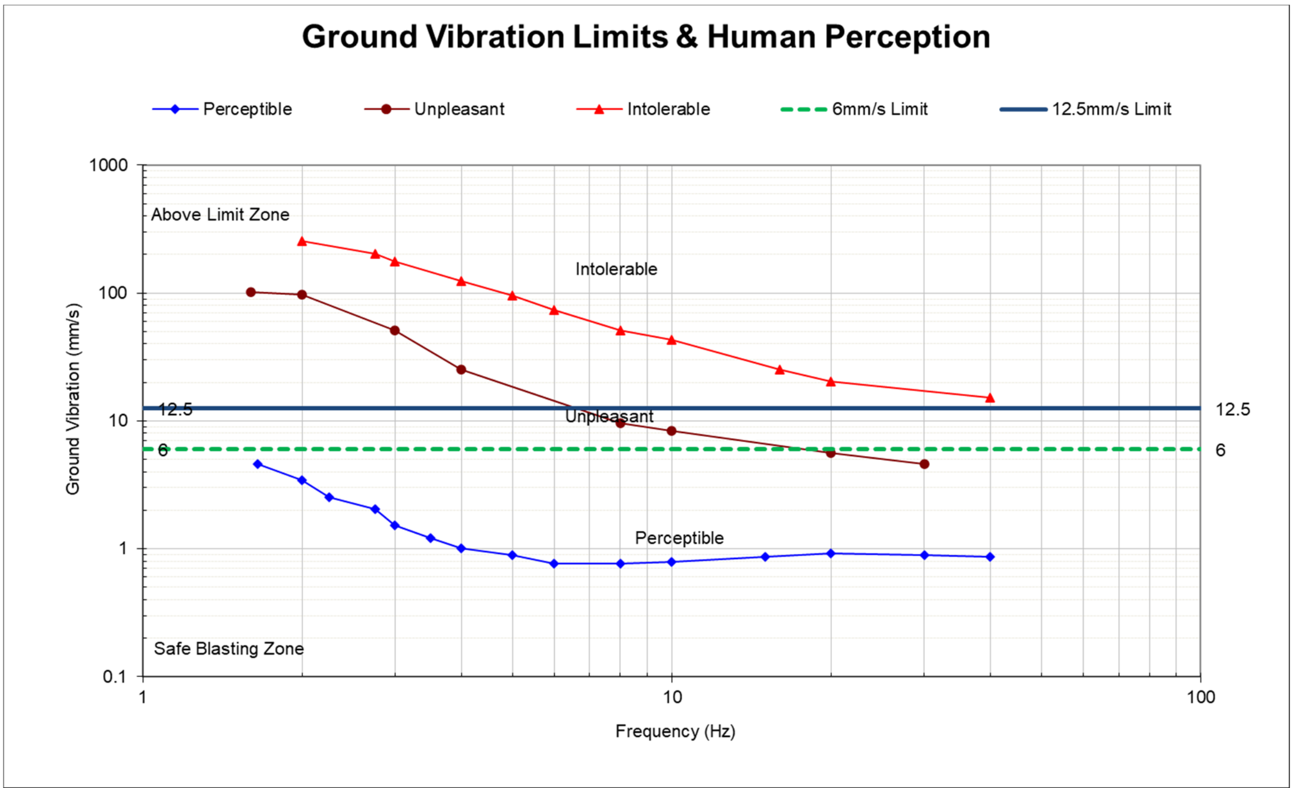


Figure 5: Ground Vibration and Human Perception

12.3 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 USBM general recommended limit for air blast is 134dBL. The USBM also indicates that the level is reduced to 128 dBL 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 135dBL 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 1). Levels given in Table 1 are at the point of measurement. The weakest points on a structure are the windows and ceilings. Table 2 provides air blast limits applied.

Table 1: Damage Causing Levels for Air Blast

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

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

Table 2: Air Blast Limits

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

All attempts should be made to keep air blast levels from blasting operations well below 120dBL where the public is of concern.

12.4 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 120dBL. This will ensure fewer complaints regarding blasting operations. The effect of air blast on structures that startle people will also be reduced, which in turn reduces the reasons for complaints. It is the effect on structures (like rattling windows, doors or a large roof surface) that startles people. These effects are sometimes erroneously identified as ground vibration and considered to be damaging the structure.

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

12.5 Fly rock

Blasting practices require some movement of rock to facilitate the excavation process. The extent of movement is dependent on the scale and type of operation. For example, blasting activities at large coal mines are designed to cast the blasted material over a greater distance than in quarries or hard rock operations. The movement should be in the direction of the free face, and therefore the orientation of the blast is important. Material or elements travelling outside of this expected range would be considered to be fly rock. Figure 6 shows schematic of fly rock definitions.

Fly rock can be categorised as follows:

- Throw - the planned forward movement of rock fragments that form the muck pile within the blast zone.
- Fly rock - the undesired propulsion of rock fragments through the air or along the ground beyond the blast zone by the force of the explosion that is contained within the blast clearance (exclusion) zone. When using this definition, fly rock, while undesirable, is only a safety hazard if a breach of the blast clearance (exclusion) zone occurs.
- Wild fly rock - the unexpected propulsion of rock fragments that travels beyond the blast clearance (exclusion) zone when there is some abnormality in a blast or a rock mass.

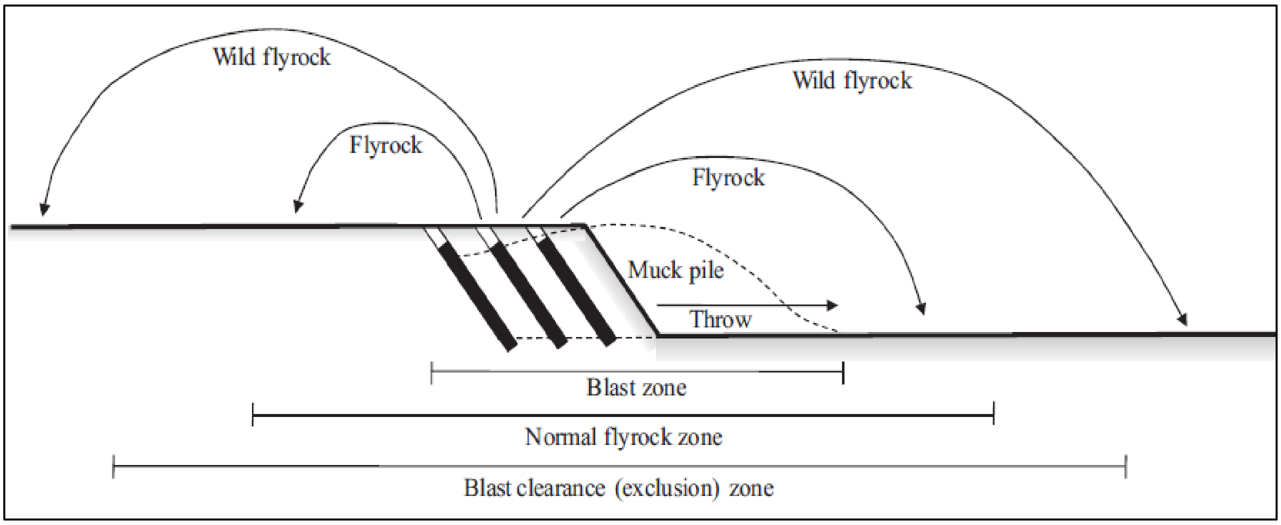


Figure 6: Schematic of fly rock terminology

Fly rock from blasting can result under the following conditions:
When burdens are too small, rock elements can be propelled out of the free face area of the blast.
When burdens are too large and movement of blast material is restricted and stemming length is not correct, rock elements can be forced upwards creating a crater forming fly rock.
If the stemming material is of poor quality or too little stemming material is applied, the stemming is ejected out of the blast hole, which can result in fly rock.
Stemming of correct type and length is required to ensure that explosive energy is efficiently used to its maximum and to control fly rock.

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

12.6 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.

12.7 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.

12.8 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.

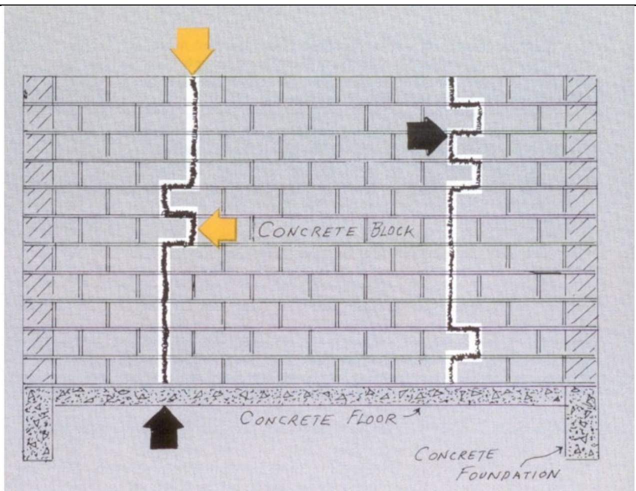
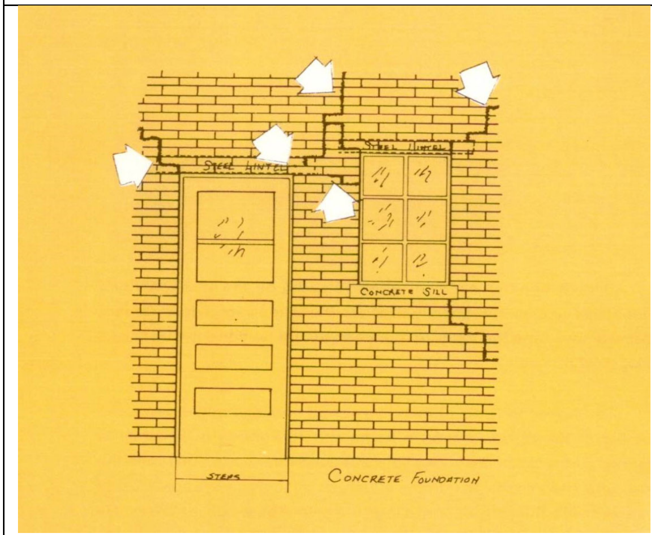
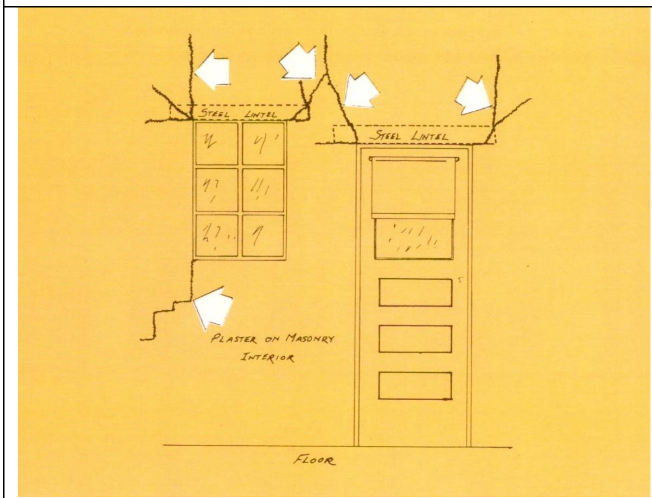
12.9 Cracking of houses and consequent devaluation

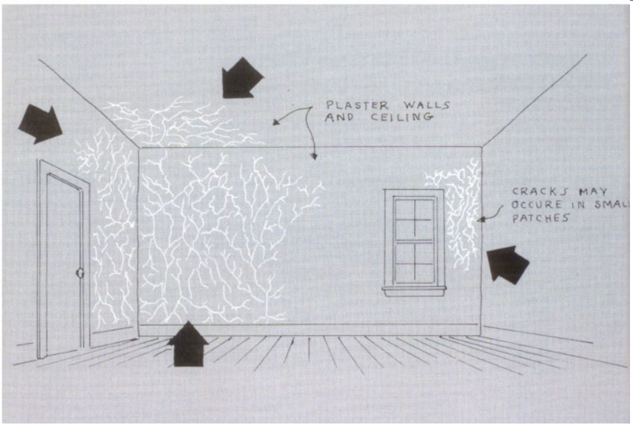
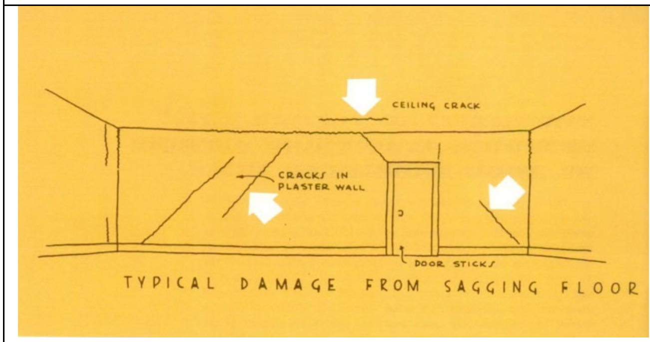
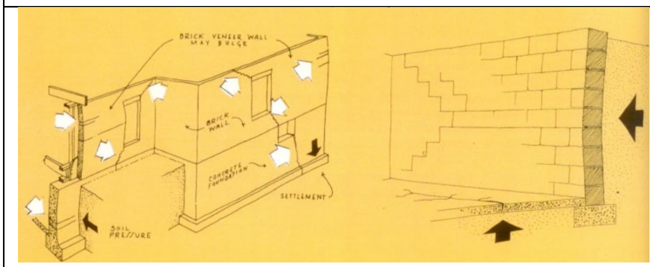
Houses in general have cracks. It is reported that a house could develop up to 15 non-blasting cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. 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 3: 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.

13 Baseline Structure Profile

Work was done familiarising oneself with the surroundings. The site was reviewed using Google Earth imagery. All possible structures in a possible influence area are identified. Information sought during the review was to identify surface structures present in a 3500 m radius from the proposed open pit 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 open pit area. The list includes structures and POI within the 3500 m boundary – see Table 5 below. A list of structure locations was required to determine the allowable ground vibration limits and air blast limits. Figure 3 shows an aerial view of the planned open pit area and surroundings with POIs. The type of POIs identified is grouped into different classes. These classes are indicated as "Classification" in Table 4. The classification used is a BMC classification and does not relate to any standard or national or international code or practice. Table 4 shows the descriptions for the classifications used.

Table 4: 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
15	Infrastructure Inside Pit

Table 5: List of points of interest identified (WGS84 – UTM 33)

Tag	Description	Classification	Y	X
1	M53 Road (Inside Pit Area) (To be Relocated)	14	7583247.19	803343.67
2	M53 Road (To be Relocated)	14	7583720.07	803824.78
3	M53 Road (To be Relocated)	14	7582915.65	803052.58
4	M53 Road (To be Relocated)	14	7583753.40	804368.41
5	M53 Road (To be Relocated)	14	7582682.47	802204.45
6	M53 Road (To be Relocated)	14	7583818.28	805403.76
7	M53 Road (To be Relocated)	14	7581841.97	801476.07
8	Pan (Inside Pit Area)	11	7583180.53	803149.30
9	Black Nossob River (Inside Pit Area) (To be Diverted)	11	7583083.84	803472.72
10	Black Nossob River (To be Diverted)	11	7582347.07	802913.58
11	Black Nossob River (To be Diverted)	11	7583401.92	803936.12
12	Black Nossob River (To be Diverted)	11	7583296.21	804433.75
13	Black Nossob River (To be Diverted)	11	7583393.80	805445.01
14	Black Nossob River (To be Diverted)	11	7582349.61	802377.54
15	Black Nossob River (To be Diverted)	11	7581570.34	801522.14
16	Black Nossob River (To be Diverted)	11	7579024.83	801005.46
17	Black Nossob River (To be Diverted)	11	7583429.14	807394.06
18	M35 Road (Inside Pit Area) (To be Relocated)	14	7582803.80	802792.14

Tag	Description	Classification	Y	X
19	Cement Dam (Inside Pit Area)	6	7582705.93	802989.98
20	Dam/Dam Wall (Inside Pit Area)	11	7582386.18	803016.50
21	Pan (Inside Pit Area)	11	7584366.94	803110.02
22	Cement Dam	6	7583159.37	802630.92
23	Buildings/Structures	2	7583097.15	802694.04
24	Buildings/Structures	2	7583106.91	802758.08
25	Buildings/Structures	2	7583237.47	802549.81
26	Pan	11	7582498.26	803750.72
27	Gravel Road (Inside Pit Area)	14	7582260.36	803127.26
28	Power Lines (Inside Pit Area)	13	7583848.21	803078.39
29	Power Lines (Inside Pit Area)	13	7584096.84	803418.48
30	Power Lines (Inside Pit Area)	13	7584264.18	803644.02
31	Power Lines	13	7584429.15	803870.83
32	Power Lines	13	7584761.66	804320.12
33	Power Lines	13	7585091.08	804775.32
34	Power Lines	13	7585417.77	805219.30
35	Power Lines	13	7585795.20	805644.82
36	Power Lines	13	7586161.19	806040.64
37	Power Lines	13	7586214.33	806599.83
38	Power Lines	13	7583680.07	802854.72
39	Power Lines	13	7583433.43	802516.62
40	Power Lines	13	7583134.03	802043.64
41	Pan	11	7583580.44	802610.85
42	Cement Dam	6	7581320.01	803991.59
43	M53 Road (To be Relocated)	14	7579245.99	800723.80
44	M53 Road (To be Relocated)	14	7584026.30	807386.48
45	Gravel Road (Inside Pit Area)	14	7583618.04	803384.04
46	Dam/Dam Wall	11	7580630.76	800959.39
47	Reservoir	11	7586923.67	803579.21
48	Hydrocensus Borehole (OT-2)	10	7586130.99	805939.01
49	Hydrocensus Borehole (EN-3)	10	7581990.99	800687.01
50	Hydrocensus Borehole (EN-4)	10	7581993.99	800685.01
51	Hydrocensus Borehole (GO-2)	10	7583262.99	802406.01
52	Hydrocensus Borehole (GO-4)	10	7588700.99	801917.01
53	Hydrocensus Borehole (ORC-153) - Inside Pit Area	10	7582669.99	803301.01
54	Hydrocensus Borehole (ORC-515) - Inside Pit Area	10	7582622.99	803151.01
55	Hydrocensus Borehole (OT-1)	10	7584099.99	807767.01
56	Hydrocensus Borehole (WW202120)	10	7583570.99	806030.01
57	Hydrocensus Borehole (WW202121)	10	7581916.99	800800.01
58	Hydrocensus Borehole (WW202122)	10	7583949.99	805150.01
59	Hydrocensus Borehole (WW202123)	10	7585499.99	805265.01
60	Pan	11	7581288.03	801098.15
61	Buildings/Structures	2	7585221.45	804003.22
62	Black Nossob River Diverted	11	7581679.64	803628.00
63	M53 Diverted	14	7581446.62	804016.98
64	Farm House (Otjere)	2	7584167.51	807620.90

14 Blasting Operations

In order to evaluate the possible influence from blasting operations with regards to ground vibration, air blast and fly rock a planned blast design is required to determine possible influences. In the mining process blasting will definitely be required for the overburden material.

This report concentrates on the drilling and blasting of the overburden. Ore blasts requires less explosives per unit than the overburden. The overburden blasts are then considered as a worst-case scenario and is used as indicator of possible influence.

Planned blast design technical information was provided and used for defining expected outcomes. Using this data provided JKSimblast blast design software was used to simulate the blast with typical timing done by BMC. This designed blast was applied for the evaluation done in this report. The simulation of the blast provided the best prediction possible.

Table 6 shows summary technical information of the blast provided.

Table 6: Blast design technical information

	Blast Design 1	Blast Design 2	Blast Design 3	Blast Design 4	Blast Design 5	Blast Design 6	Blast Design 7
Blast Type	**Ore - Fresh**	**Ore - Oxide**	**Ore - Oxide**	**Waste - Fresh**	**Waste - Oxide**	**Waste - Oxide**	Pre-split
Bench Height	15	15	10	15	15	10	15
Hole Diameter	115	115	115	165	165	165	115
Burden	3.30	4.00	3.80	4.60	5.30	4.60	2.30
Burden Height Factor	4.55	3.75	2.63	3.26	2.83	2.17	
Burden Hole Factor	28.70	34.78	33.04	27.88	32.12	27.88	
Spacing	3.80	4.80	4.40	5.30	6.00	5.40	1.44
Spacing-Burden Ratio	1.15	1.20	1.16	1.15	1.13	1.17	
Sub-drill factor	0.21	0.18	0.11	0.15	0.13	0.04	
Sub-drill	0.7	0.7	0.4	0.7	0.7	0.2	
Stemming Factor	20	20	20	19	19	19	
Stemming	2.3	2.3	2.3	3.2	3.2	3.2	
Charge Length	13.4	13.4	8.1	12.5	12.5	7	

Charge Length (Above Grade)	12.7	12.7	7.7	11.8	11.8	6.8	
		0	0	0	0	0	
Powder Factor (Technical)	**0.84**	**0.55**	**0.57**	**0.83**	**0.63**	**0.70**	
Powder Factor (Actual)	**0.89**	**0.58**	**0.60**	**0.88**	**0.67**	**0.72**	
Explosive Density	1.2	1.2	1.2	1.2	1.2	1.2	
Linear Charge Density (kg/m)	12.46	12.46	12.46	25.66	25.66	25.66	
Linear Charge Density (Check)	12.47	12.47	12.47	25.66	25.66	25.66	
Charged Weight Per hole	167.02	167.02	100.96	320.74	320.74	179.61	
Stiffness Ratio	4.55	3.75	2.63	3.26	2.83	2.17	

Note: Orange highlighted data was used in design.

Outcome of the design on JKSimblast is summarised in Table 7. Figure 8 below shows the blast layout with blast holes, simulation and maximum charge mass per delay. Figure 9 shows simulation with maximum charge per delay from the typical timing applied. Figure 10 shows simulation with number of blast holes per delay from the typical timing applied.

Table 7: Blast design information from simulation

DESIGN FACTORS FOR:		
Blast Name:	Blast Design 4 Waste - Fresh	
Av. Burden	4.6	m
Av. Spacing	5.3	m
All Hole Lengths	3 600.000	m
Volume	87 768.001	m^3
Rock SG	2.65	
Tonnage	232 585.204	tonnes
Marked Holes	240	
Charge Mass	76 976.874	kg
Charge Energy	257 102.759	MJ
POWDER FACTOR	0.877	kg/m^3
POWDER FACTOR	0.331	kg/t
ENERGY FACTOR	2.929	MJ/m^3
ENERGY FACTOR	1.105	MJ/t

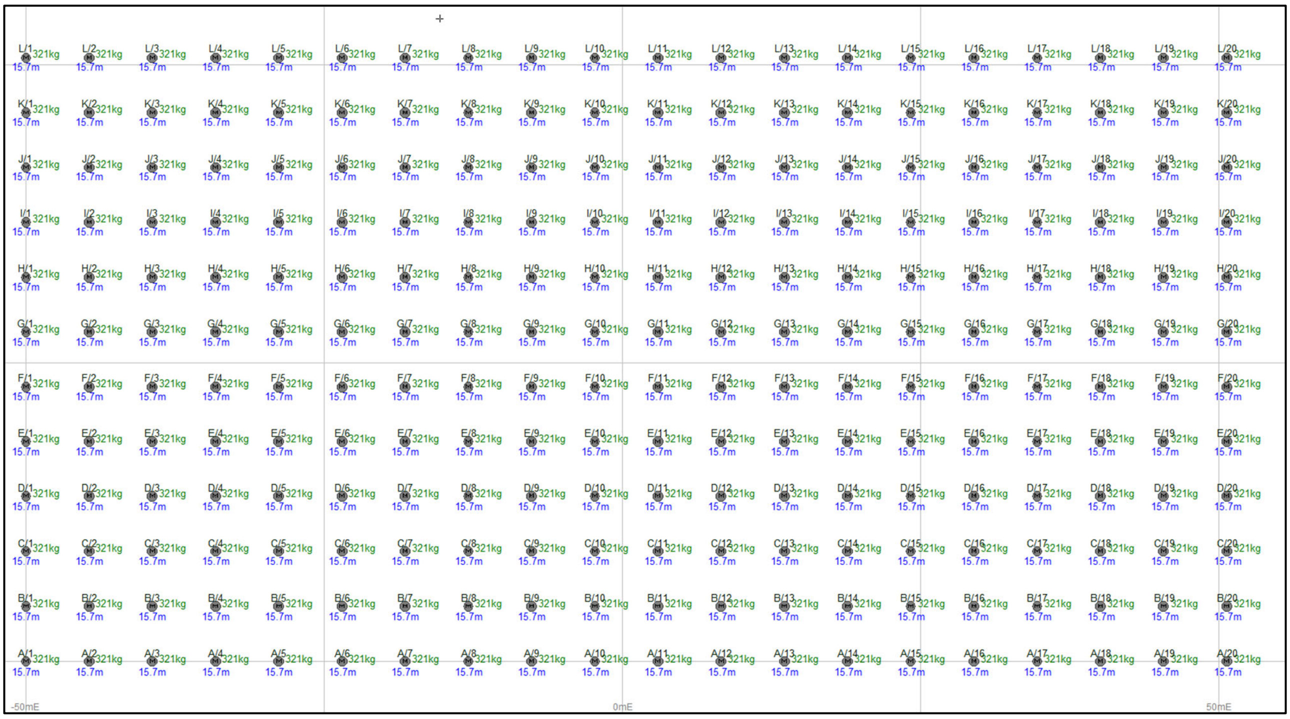


Figure 8: Blast holes layout with charge mass per blasthole

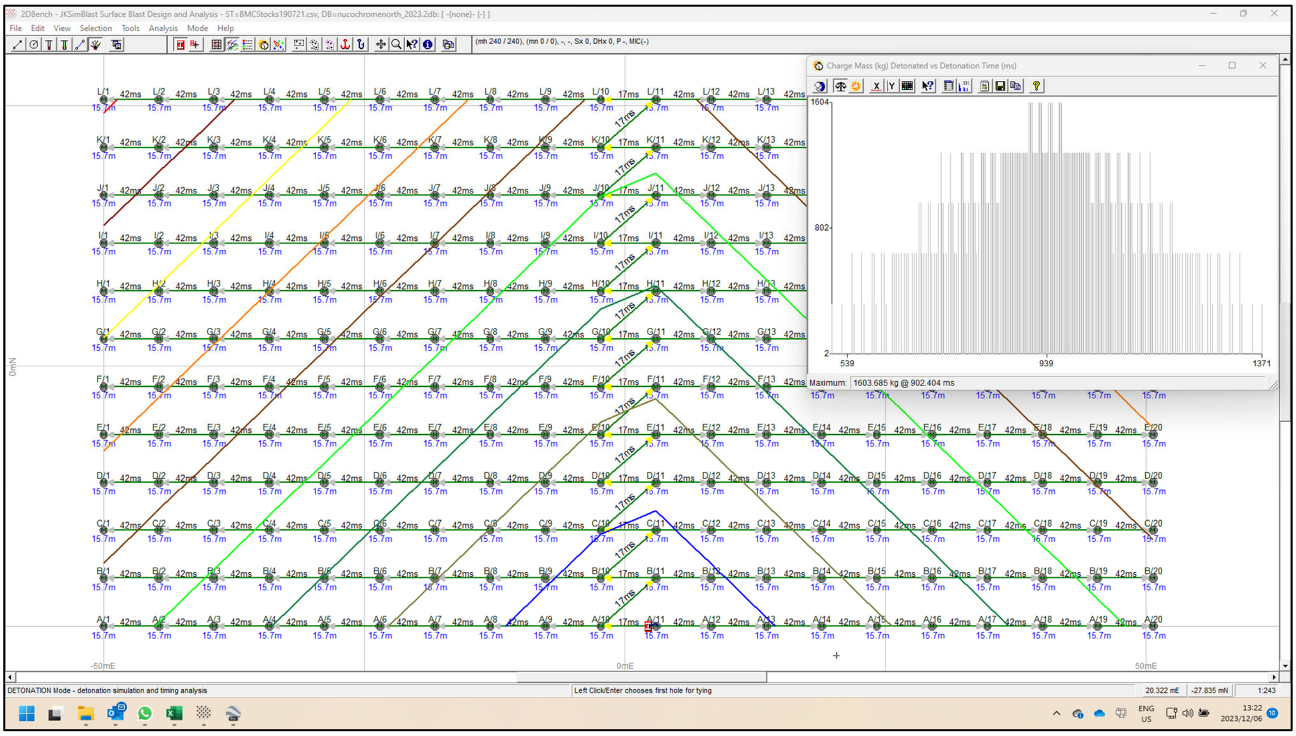


Figure 9: Simulation and charge mass per delay graph

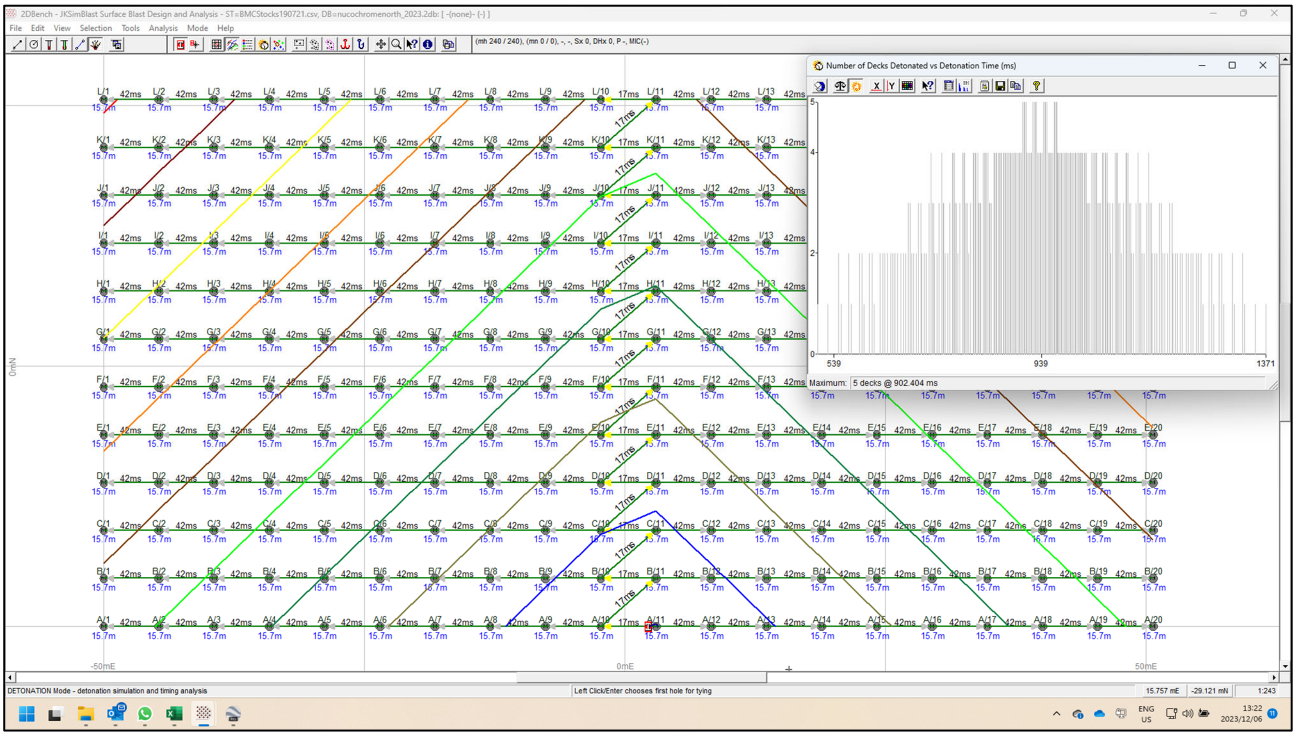


Figure 10: Simulation and number of decks per delay graph

Evaluation of the blasting operations considered a minimum charge and a maximum charge. The minimum charge was derived from the 165 mm diameter single blast hole and the maximum charge was based on typical 5 blastholes detonating using shock tube initiation. The minimum charge relates to 321 kg and the maximum charge relates to 1604 kg. These values were applied in all predictions for ground vibration and air blast.

14.1 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:

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

Where:

PPV = Predicted ground vibration (mm/s)

a = Site constant

b = Site constant

D = Distance (m)

E = Explosive Mass (kg)

Applicable and accepted factors a 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 8 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. The charge masses are 321 kg and 1604 kg for the Pit area.

Table 8: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 321 kg Charge	Expected PPV (mm/s) for 1604 kg Charge
1	50.0	210.2	792.6
2	100.0	107.7	406.0
3	150.0	34.3	129.4
4	200.0	21.3	80.5
5	250.0	14.8	55.7
6	300.0	10.9	41.2
7	400.0	6.8	25.6
8	500.0	4.7	17.7
9	600.0	3.5	13.1
10	700.0	2.7	10.2
11	800.0	2.2	8.2
12	900.0	1.9	6.7
13	1000.0	1.5	5.7
14	1250.0	1.0	3.9
15	1500.0	0.8	2.9
16	1750.0	0.6	2.2
17	2000.0	0.5	1.8
18	2500.0	0.3	1.2
19	3000.0	0.2	0.9
20	3500.0	0.2	0.7

14.2 Air blast

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

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

Equation 2:

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

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

A = Constant - (14.3)

B = Constant – (-0.71)

The constants for A and B were then selected according to the information as provided in Figure 11 below. Various types of mining operations are expected to yield different results. The information provided in Figure 11 is based on detailed research that was conducted for each of the different types of mining environments. In this report, the data for “Metal Mine” 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 11: 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 (dBL)

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 9 below is a summary of values predicted according to Equation 2.

Table 9: Air Blast Predicted Values

No.	Distance (m)	Air blast (dBL) for 321 kg Charge	Air blast (dBL) for 1604 kg Charge
1	50.0	144.8	148.1
2	100.0	142.3	145.6
3	150.0	138.0	141.3
4	200.0	136.2	139.5
5	250.0	134.9	138.2
6	300.0	133.7	137.0
7	400.0	132.0	135.3
8	500.0	130.6	133.9
9	600.0	129.5	132.8
10	700.0	128.5	131.8

No.	Distance (m)	Air blast (dBL) for 321 kg Charge	Air blast (dBL) for 1604 kg Charge
11	800.0	127.7	131.0
12	900.0	127.2	130.3
13	1000.0	126.3	129.6
14	1250.0	124.9	128.2
15	1500.0	123.8	127.1
16	1750.0	122.9	126.2
17	2000.0	122.0	125.3
18	2500.0	120.7	124.0
19	3000.0	119.6	122.8
20	3500.0	118.6	121.9

15 Construction Phase: Impact Assessment and Mitigation Measures

During the construction phase no mining drilling and blasting operations is expected. No detail impact evaluation was done during the construction phase.

16 Operational Phase: Impact Assessment and Mitigation Measures

The area surrounding the proposed mining area was reviewed for structures, traffic, roads, human interface, animals' interface etc. Various installations and structures were observed. These are listed in Table 5. This section concentrates on the outcome of modelling the possible effects of ground vibration, air blast and fly rock specifically to these points of interest or possible interfaces. In evaluation, the charge mass scenarios selected as indicated in section 14 is considered with regards to ground vibration and air blast.

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

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

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

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

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 pit area.
- "Specific Limit" is the maximum limit for ground vibration at the specific structure or installation.
- "Predicted PPV (mm/s)" is the calculated ground vibration at the structure.
- The "Structure Response @ 10Hz and Human Tolerance @ 30Hz" indicates the possible concern and if there is any concern for structural damage or potential negative human perception, respectively. Indicators used are "perceptible"," unpleasant", "intolerable" which stems from the human perception information given and indicators such as "high" or "low" is given for the possibility of damage to a structure. Levels below 0.76 mm/s could be considered to have negligible possibility of influence.

Ground vibration is calculated and modelled for the pit area at the minimum and maximum charge mass at specific distances from the opencast mining area. The charge masses applied are according to blast designs discussed in Section 15. These levels are then plotted and overlaid with current mining plans to observe possible influences at structures identified. Structures or POI's for consideration are also plotted in this model. Ground vibration predictions were done considering distances ranging from 50 m to 3500 m around the opencast mining area.

The simulation provided shows ground vibration contours only for a limited number of levels. The levels used are considered the basic limits that will be applicable for the type of structures observed surrounding the pit 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 pit 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 – 321 kg

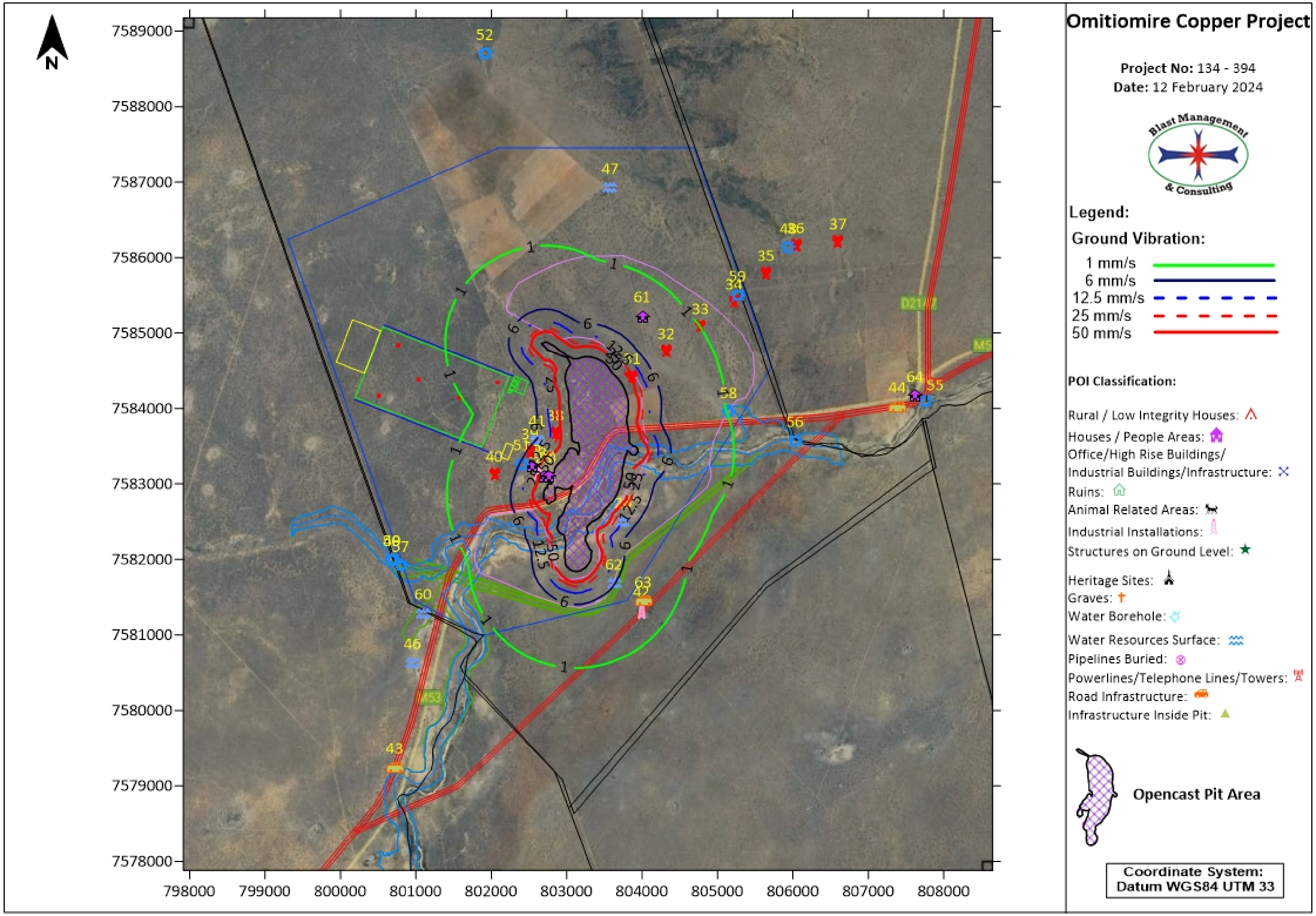


Figure 12: Ground vibration influence from minimum charge per delay

Table 10: 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	M53 Road (Inside Pit Area)	150	To Be Diverted				
8	Pan (Inside Pit Area)	200	-	321	-	-	-
9	Black Nossob River (Inside Pit Area)	200	To Be Diverted				
19	Cement Dam (Inside Pit Area)	50	-	321	-	-	-
20	Dam/Dam Wall (Inside Pit Area)	50	-	321	-	-	-
21	Pan (Inside Pit Area)	200	-	321	-	-	-
22	Cement Dam	50	152	321	33.4	Acceptable	N/A
23	Buildings/Structures	12.5	71	321	116.7	Problematic	Intolerable
24	Buildings/Structures	12.5	19	321	1082.8	Problematic	Intolerable
25	Buildings/Structures	12.5	263	321	13.6	Problematic	Unpleasant
26	Pan	200	291	321	11.5	Acceptable	N/A
27	Gravel Road (Inside Pit Area)	200	-	321	-	-	-
28	Power Lines (Inside Pit Area)	75	-	321	-	-	-
29	Power Lines (Inside Pit Area)	75	-	321	-	-	-
30	Power Lines (Inside Pit Area)	75	-	321	-	-	-
31	Power Lines	75	172	321	27.5	Acceptable	N/A
32	Power Lines	75	730	321	2.5	Acceptable	N/A
33	Power Lines	75	1292	321	1.0	Acceptable	N/A
34	Power Lines	75	1843	321	0.5	Acceptable	N/A
35	Power Lines	75	2408	321	0.4	Acceptable	N/A
36	Power Lines	75	2944	321	0.3	Acceptable	N/A
37	Power Lines	75	3433	321	0.2	Acceptable	N/A
38	Power Lines	75	206	321	20.3	Acceptable	N/A
39	Power Lines	75	399	321	6.8	Acceptable	N/A
40	Power Lines	75	693	321	2.7	Acceptable	N/A
41	Pan	200	417	321	6.4	Acceptable	N/A
42	Cement Dam	50	932	321	1.7	Acceptable	N/A
45	Gravel Road (Inside Pit Area)	200	-	321	-	-	-
46	Dam/Dam Wall	50	2408	321	0.4	Acceptable	N/A
47	Reservoir	50	2212	321	0.4	Acceptable	N/A
48	Hydrocensus Borehole (OT-2)	50	2845	321	0.3	Acceptable	N/A
49	Hydrocensus Borehole (EN-3)	50	2167	321	0.4	Acceptable	N/A
50	Hydrocensus Borehole (EN-4)	50	2168	321	0.4	Acceptable	N/A
51	Hydrocensus Borehole (GO-2)	50	400	321	6.8	Acceptable	N/A
52	Hydrocensus Borehole (GO-4)	50	3902	321	0.2	Acceptable	N/A
53	Hydrocensus Borehole (ORC-153) - Inside Pit Area	50	-	321	-	-	-
54	Hydrocensus Borehole (ORC-515) - Inside Pit Area	50	-	321	-	-	-
55	Hydrocensus Borehole (OT-1)	50	3882	321	0.2	Acceptable	N/A
56	Hydrocensus Borehole (WW202120)	50	2093	321	0.4	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
57	Hydrocensus Borehole (WW202121)	50	2093	321	0.4	Acceptable	N/A
58	Hydrocensus Borehole (WW202122)	50	1308	321	1.0	Acceptable	N/A
59	Hydrocensus Borehole (WW202123)	50	1928	321	0.5	Acceptable	N/A
60	Pan	200	1995	321	0.5	Acceptable	N/A
61	Buildings/Structures	12.5	797	321	2.2	Acceptable	Perceptible
62	River Diverted	200	425	321	6.1	Acceptable	N/A
63	M53 Diverted	150	878	321	1.9	Acceptable	N/A
64	Farm House (Otjere)	12.5	3750	321	0.2	Acceptable	Too Low

16.1.2 Ground vibration maximum charge mass per delay - 1604 kg

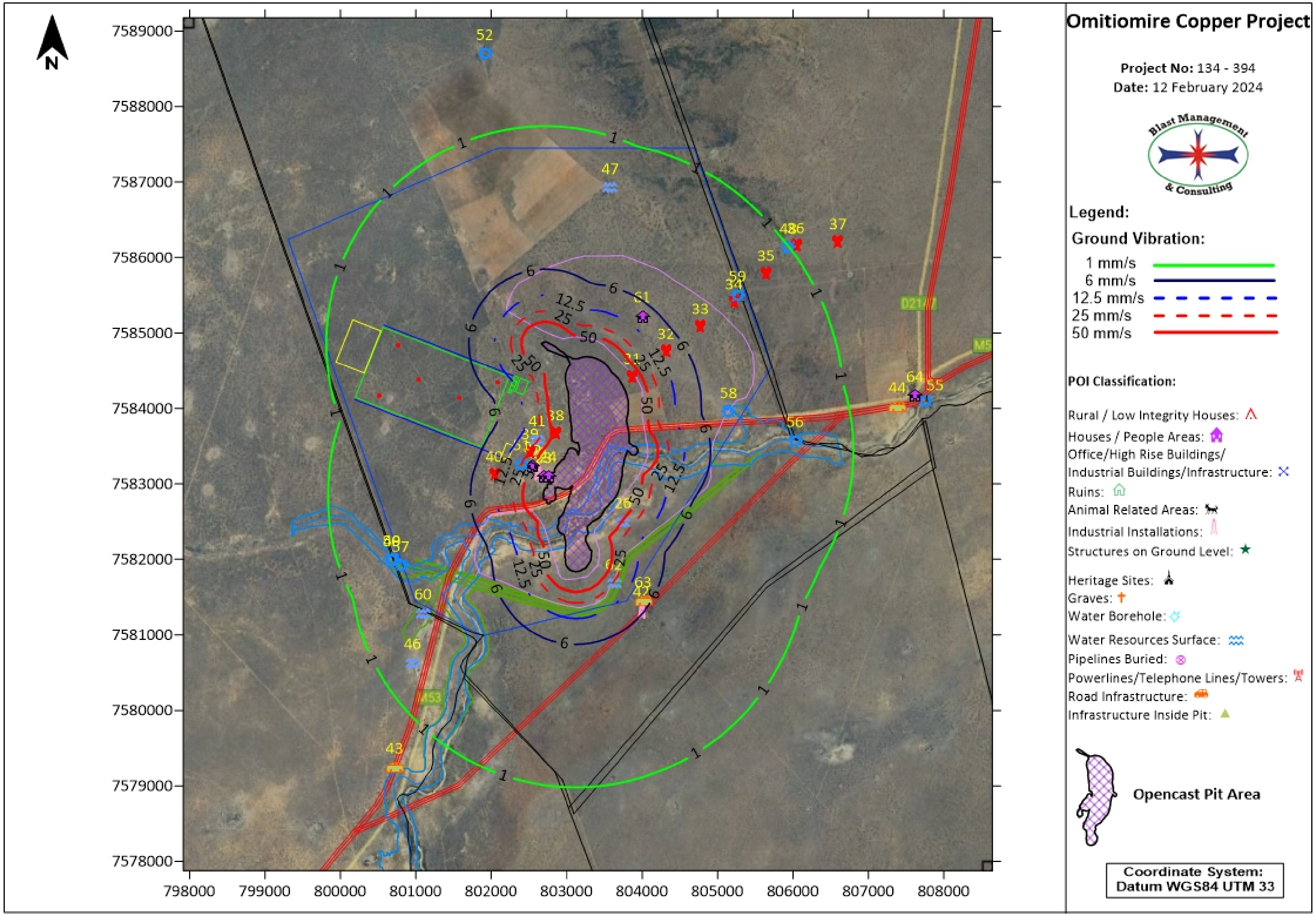


Figure 13: Ground vibration influence from maximum charge per delay

Table 11: 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	M53 Road (Inside Pit Area)	150	To be diverted				
8	Pan (Inside Pit Area)	200	-	1604	-	-	-
9	Black Nossob River (Inside Pit Area)	200	To be diverted				
19	Cement Dam (Inside Pit Area)	50	-	1604	-	-	-
20	Dam/Dam Wall (Inside Pit Area)	50	-	1604	-	-	-
21	Pan (Inside Pit Area)	200	-	1604	-	-	-
22	Cement Dam	50	152	1604	126.1	Problematic	N/A
23	Buildings/Structures	12.5	71	1604	440.2	Problematic	Intolerable
24	Buildings/Structures	12.5	19	1604	4083.0	Problematic	Intolerable
25	Buildings/Structures	12.5	263	1604	51.3	Problematic	Intolerable
26	Pan	200	291	1604	43.3	Acceptable	N/A
27	Gravel Road (Inside Pit Area)	200	-	1604	-	-	-
28	Power Lines (Inside Pit Area)	75	-	1604	-	-	-
29	Power Lines (Inside Pit Area)	75	-	1604	-	-	-
30	Power Lines (Inside Pit Area)	75	-	1604	-	-	-
31	Power Lines	75	172	1604	103.5	Problematic	N/A
32	Power Lines	75	730	1604	9.5	Acceptable	N/A
33	Power Lines	75	1292	1604	3.7	Acceptable	N/A
34	Power Lines	75	1843	1604	2.1	Acceptable	N/A
35	Power Lines	75	2408	1604	1.3	Acceptable	N/A
36	Power Lines	75	2944	1604	1.0	Acceptable	N/A
37	Power Lines	75	3433	1604	0.7	Acceptable	N/A
38	Power Lines	75	206	1604	76.4	Problematic	N/A
39	Power Lines	75	399	1604	25.8	Acceptable	N/A
40	Power Lines	75	693	1604	10.4	Acceptable	N/A
41	Pan	200	417	1604	24.0	Acceptable	N/A
42	Cement Dam	50	932	1604	6.3	Acceptable	N/A
45	Gravel Road (Inside Pit Area)	200	-	1604	-	-	-
46	Dam/Dam Wall	50	2408	1604	1.3	Acceptable	N/A
47	Reservoir	50	2212	1604	1.5	Acceptable	N/A
48	Hydrocensus Borehole (OT-2)	50	2845	1604	1.0	Acceptable	N/A
49	Hydrocensus Borehole (EN-3)	50	2167	1604	1.6	Acceptable	N/A
50	Hydrocensus Borehole (EN-4)	50	2168	1604	1.6	Acceptable	N/A
51	Hydrocensus Borehole (GO-2)	50	400	1604	25.7	Acceptable	N/A
52	Hydrocensus Borehole (GO-4)	50	3902	1604	0.6	Acceptable	N/A
53	Hydrocensus Borehole (ORC-153) - Inside Pit Area	50	-	1604	-	-	-
54	Hydrocensus Borehole (ORC-515) - Inside Pit Area	50	-	1604	-	-	-
55	Hydrocensus Borehole (OT-1)	50	3882	1604	0.6	Acceptable	N/A
56	Hydrocensus Borehole (WW202120)	50	2093	1604	1.7	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
57	Hydrocensus Borehole (WW202121)	50	2093	1604	1.7	Acceptable	N/A
58	Hydrocensus Borehole (WW202122)	50	1308	1604	3.6	Acceptable	N/A
59	Hydrocensus Borehole (WW202123)	50	1928	1604	1.9	Acceptable	N/A
60	Pan	200	1995	1604	1.8	Acceptable	N/A
61	Buildings/Structures	12.5	797	1604	8.2	Acceptable	Unpleasant
62	River Diverted	200	425	1604	23.2	Acceptable	N/A
63	M53 Diverted	150	878	1604	7.0	Acceptable	N/A
64	Farm House (Otjere)	12.5	3750	1604	0.6	Acceptable	Too Low

16.2 Summary of ground vibration levels

The opencast operation was evaluated for expected levels of ground vibration from future blasting operations. Review of the site and the surrounding installations / houses / buildings showed that structures vary in distances from the pit area. The influences will also vary with distance from the pit 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 restriction on ground vibration levels is not exceeded.

The evaluation considered a distance up to 3500 m from the pit area. The location of structures around the Pit area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the M53 Road, Black Nossob River, Cement Dam, Hydrocensus Borehole and Power Lines. The ground vibration levels predicted for these POI's ranged between 0.6 mm/s and 4083 mm/s for POI's surrounding the open pit area. The Black Nossob River and the M53 district road is currently located close to the pit but client is planning to divert the Black Nossob River and the M53 district road away from the mine infrastructure and the open pit area. This reduces possible impact from ground vibration significantly.

The distances between structures and the pit 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 seven POI's of concern and the maximum charge indicated twelve POI's of concern in relation to possible structural damage.

Minimum charge on a human perception scale indicated one POI where vibration levels may be perceptible, one POI that may be unpleasant and two POI's where vibration levels may be intolerable. Maximum charge on a human perception scale indicated one POI that may be unpleasant and three POI's where vibration levels may be intolerable.

Perceptible levels of vibration may be experienced up to 3374 m and unpleasant up to 1005 m and intolerable up to 460 m. Problematic levels of ground vibration – levels greater than the proposed limit – are expected up to 263 m from the pit edge for the maximum charge. Any blast operations further away from the boundary will have lesser influence on these points.

The nearest public structures are located 19 m from the pit boundary. Ground vibration level predicted at this building where people may be present is very high for the maximum charge. In view of this specific mitigations will be required.

Structure conditions ranged from industrial construction to poor condition structures.

There are twelve water boreholes identified within the mining rights area and it is uncertain what the long-term plan will be for these boreholes. A mitigation plan will be required to determine if these boreholes will be retained or replaced.

Mitigation of ground vibration was considered and discussed in Section 18.3. 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 14 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 14 that up to a distance of 3374 m people may experience levels of ground vibration as perceptible. At 1005 m and closer the perception of ground vibration could be unpleasant. Closer than 460 m the levels will be intolerable and generally greater than limits applied for structures in the areas.

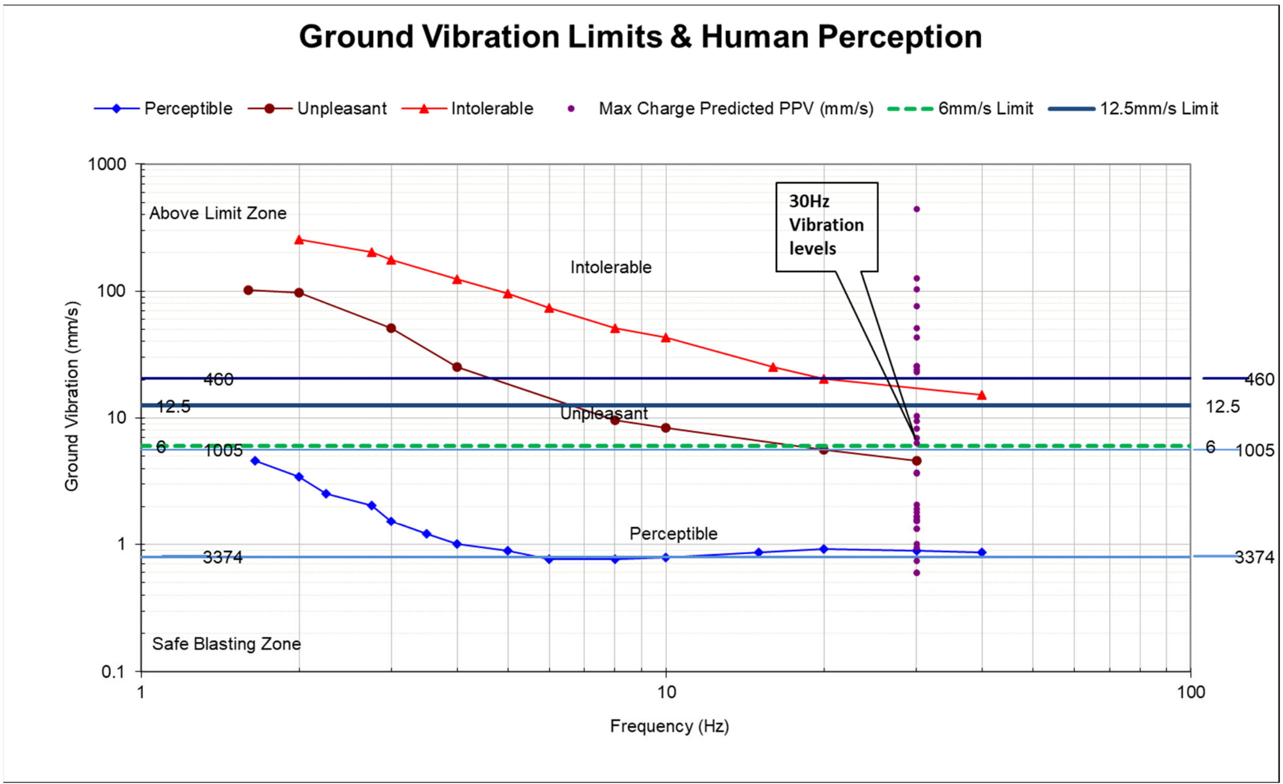


Figure 14: The effect of ground vibration with human perception and vibration limits

16.4 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. The nearest building/structure is at POI 24 and are approximately 19 m from the planned operation. These buildings are located such that levels of ground vibration predicted from minimum charge may be intolerable and could lead to structural damage. Charge mass per delay greater than minimum charge will show increased levels of ground vibration and higher probability of damage.

Ground vibration levels expected from maximum charge has possibility to be perceptible up to 3374 m. It is certain that lesser charges will reduce this distance for instance at minimum charge this distance is expected to be 1509 m. Within these distance ranges there are only houses / structures located indicated at POI's 23, 24 and 25. The anticipated ground vibration levels are certain to have possibility of upsetting the house holds within these ranges. Currently it is uncertain what the future actions are for these houses. There are no other houses in the vicinity of the pit or within 3500 m from the pit area.

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.

16.5 Cracking of houses and consequent devaluation

The structures found in the areas of concern ranges from informal building style to brick, mortar structures and steel structures. There are various buildings found within the 3500 m range from the mining area. Building style and materials will certainly contribute to additional cracking apart from influences such as blasting operations.

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

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

16.6 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 pit area;
- "Air Blast (dBL)" 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 dBL;
    - "Complaint" where people will be complaining due to the experienced effect on structures at levels of 120 dBL and higher (not necessarily damaging);
    - "Acceptable" if levels are less than 120 dBL;
    - "Low" where there is very limited possibility that the levels will give rise to any influence on people or structures. Levels below 115 dBL could be considered to have low or negligible possibility of influence.

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

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

16.6.1 Air blast minimum charge mass per delay – 321 kg

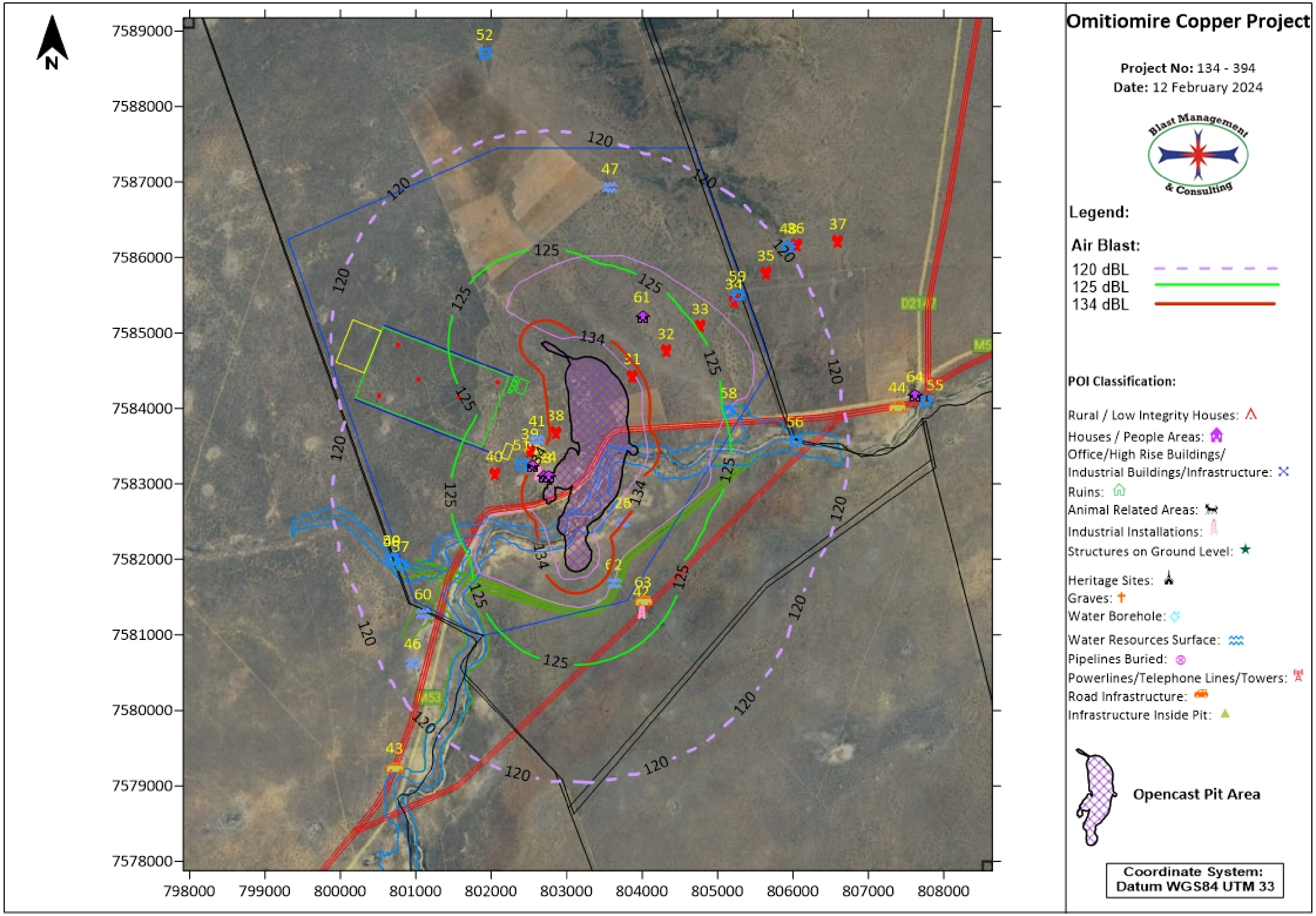


Figure 15: Air blast influence from minimum charge

Table 12: Air blast evaluation for minimum charge

Tag	Description	Distance (m)	Air blast (dBL)	Possible Concern?
1	M53 Road (Inside Pit Area)	To be diverted		
8	Pan (Inside Pit Area)	-	-	-
9	Black Nossob River (Inside Pit Area)	To be diverted		
19	Cement Dam (Inside Pit Area)	-	-	-
20	Dam/Dam Wall (Inside Pit Area)	-	-	-
21	Pan (Inside Pit Area)	-	-	-
22	Cement Dam	152	137.9	N/A
23	Buildings/Structures	71	142.6	Problematic
24	Buildings/Structures	19	150.9	Problematic
25	Buildings/Structures	263	134.5	Problematic
26	Pan	291	133.9	N/A
27	Gravel Road (Inside Pit Area)	-	-	-
28	Power Lines (Inside Pit Area)	-	-	-
29	Power Lines (Inside Pit Area)	-	-	-
30	Power Lines (Inside Pit Area)	-	-	-
31	Power Lines	172	137.2	N/A
32	Power Lines	730	128.2	N/A
33	Power Lines	1292	124.7	N/A
34	Power Lines	1843	122.6	N/A
35	Power Lines	2408	120.9	N/A
36	Power Lines	2944	119.7	N/A
37	Power Lines	3433	118.7	N/A
38	Power Lines	206	136.0	N/A
39	Power Lines	399	132.0	N/A
40	Power Lines	693	128.6	N/A
41	Pan	417	131.7	N/A
42	Cement Dam	932	126.7	N/A
45	Gravel Road (Inside Pit Area)	-	-	-
46	Dam/Dam Wall	2408	120.9	N/A
47	Reservoir	2212	121.4	N/A
48	Hydrocensus Borehole (OT-2)	2845	119.9	N/A
49	Hydrocensus Borehole (EN-3)	2167	121.5	N/A
50	Hydrocensus Borehole (EN-4)	2168	121.5	N/A
51	Hydrocensus Borehole (GO-2)	400	132.0	N/A
52	Hydrocensus Borehole (GO-4)	3902	118.0	N/A
53	Hydrocensus Borehole (ORC-153) - Inside Pit Area	-	-	-
54	Hydrocensus Borehole (ORC-515) - Inside Pit Area	-	-	-
55	Hydrocensus Borehole (OT-1)	3882	118.0	N/A
56	Hydrocensus Borehole (WW202120)	2093	121.7	N/A
57	Hydrocensus Borehole (WW202121)	2093	121.7	N/A
58	Hydrocensus Borehole (WW202122)	1308	124.7	N/A
59	Hydrocensus Borehole (WW202123)	1928	122.3	N/A
60	Pan	1995	122.1	N/A

Tag	Description	Distance (m)	Air blast (dBL)	Possible Concern?
61	Buildings/Structures	797	127.7	Complaint
62	River Diverted	425	131.6	N/A
63	M53 Diverted	878	127.1	N/A
64	Farm House (Otjere)	3750	118.2	Acceptable

16.6.2 Air blast maximum charge mass per delay – 1604 kg

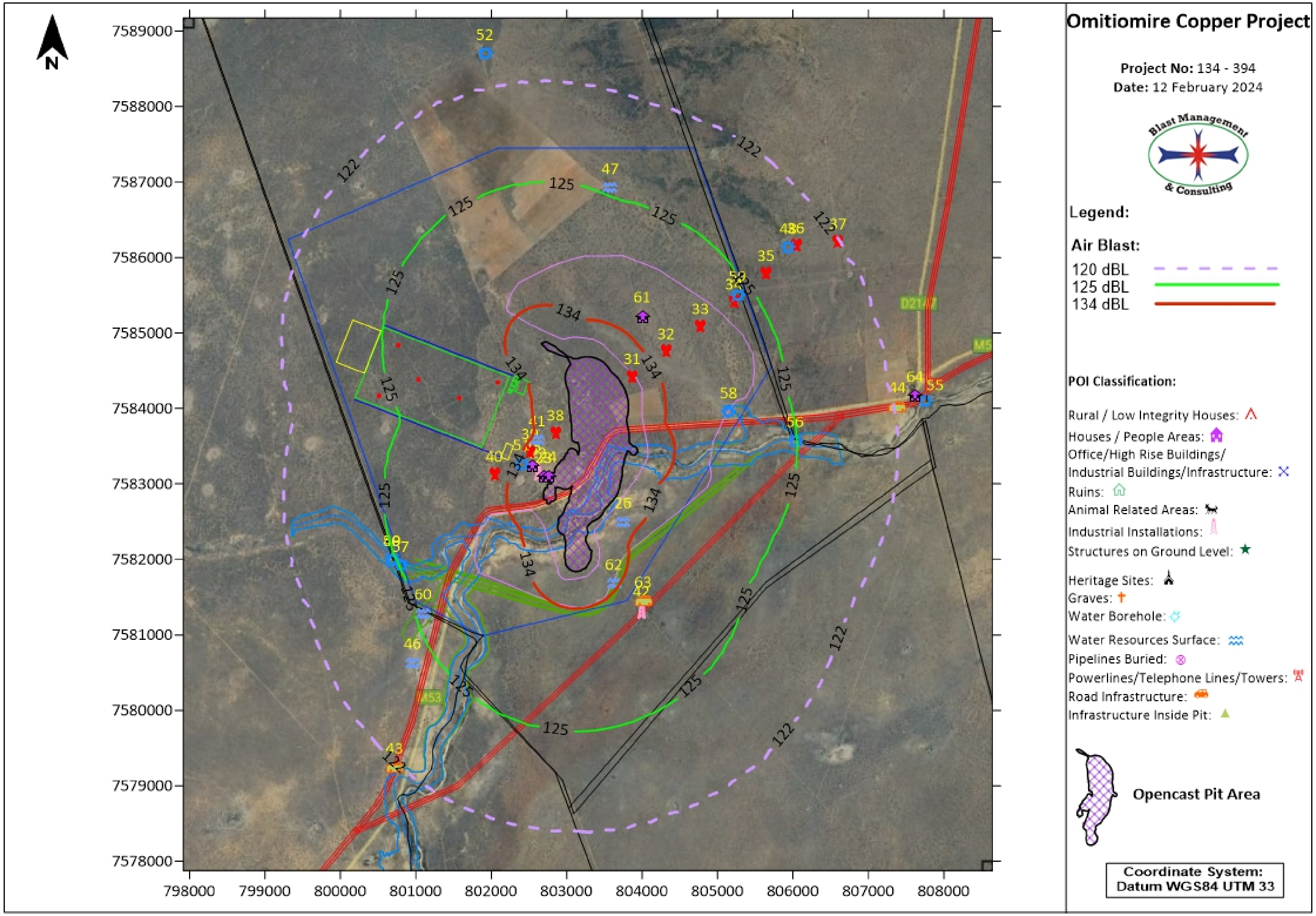


Figure 16: Air blast influence from maximum charge

Table 13: Air blast influence from maximum charge – Opencast 1

Tag	Description	Distance (m)	Air blast (dBL)	Possible Concern?
1	M53 Road (Inside Pit Area)	To be diverted		
8	Pan (Inside Pit Area)	-	-	-
9	Black Nossob River (Inside Pit Area)	To be diverted		
19	Cement Dam (Inside Pit Area)	-	-	-
20	Dam/Dam Wall (Inside Pit Area)	-	-	-
21	Pan (Inside Pit Area)	-	-	-
22	Cement Dam	152	141.2	N/A
23	Buildings/Structures	71	145.9	Problematic
24	Buildings/Structures	19	154.2	Problematic
25	Buildings/Structures	263	137.9	Problematic
26	Pan	291	137.2	N/A
27	Gravel Road (Inside Pit Area)	-	-	-
28	Power Lines (Inside Pit Area)	-	-	-
29	Power Lines (Inside Pit Area)	-	-	-
30	Power Lines (Inside Pit Area)	-	-	-
31	Power Lines	172	140.5	N/A
32	Power Lines	730	131.6	N/A
33	Power Lines	1292	128.0	N/A
34	Power Lines	1843	125.8	N/A
35	Power Lines	2408	124.2	N/A
36	Power Lines	2944	123.0	N/A
37	Power Lines	3433	122.0	N/A
38	Power Lines	206	139.3	N/A
39	Power Lines	399	135.3	N/A
40	Power Lines	693	131.9	N/A
41	Pan	417	135.0	N/A
42	Cement Dam	932	130.0	N/A
45	Gravel Road (Inside Pit Area)	-	-	-
46	Dam/Dam Wall	2408	124.2	N/A
47	Reservoir	2212	124.7	N/A
48	Hydrocensus Borehole (OT-2)	2845	123.2	N/A
49	Hydrocensus Borehole (EN-3)	2167	124.9	N/A
50	Hydrocensus Borehole (EN-4)	2168	124.9	N/A
51	Hydrocensus Borehole (GO-2)	400	135.3	N/A
52	Hydrocensus Borehole (GO-4)	3902	121.2	N/A
53	Hydrocensus Borehole (ORC-153) - Inside Pit Area	-	-	-
54	Hydrocensus Borehole (ORC-515) - Inside Pit Area	-	-	-
55	Hydrocensus Borehole (OT-1)	3882	121.3	N/A
56	Hydrocensus Borehole (WW202120)	2093	125.1	N/A
57	Hydrocensus Borehole (WW202121)	2093	125.1	N/A
58	Hydrocensus Borehole (WW202122)	1308	128.0	N/A
59	Hydrocensus Borehole (WW202123)	1928	125.6	N/A
60	Pan	1995	125.4	N/A

Tag	Description	Distance (m)	Air blast (dBL)	Possible Concern?
61	Buildings/Structures	797	131.0	Complaint
62	River Diverted	425	134.9	N/A
63	M53 Diverted	878	130.4	N/A
64	Farm House (Otjere)	3750	121.5	Complaint

16.7 Summary of findings for air blast

Review of the air blast levels predicted for the maximum charge ranges between 121.2 and 154.2 dBL for all the POI's considered. This includes the nearest points such as the Buildings/Structures. These levels may contribute to effects such as rattling of roofs or door or windows with several points that are expected to be damaging and that could lead to complaints.

Minimum and Maximum charge predictions identified that two POI's could experience levels of air blast that could lead to complaints – POI's 61 and 64. Three POI's were identified where damage may be induced – POI 23, 24 and 25.

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 dBL at distance of 490 m and closer to pit boundary. Infrastructure at the pit areas such as roads and 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 pit 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.

16.8 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 17 shows the results from the ISEE calculations for fly rock range based on a 165 mm diameter blast hole and 3.2 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 472 m. The absolute minimum unsafe zone is then the 472 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 18 shows the area around the Pit area that incorporates the 472 m unsafe zone.

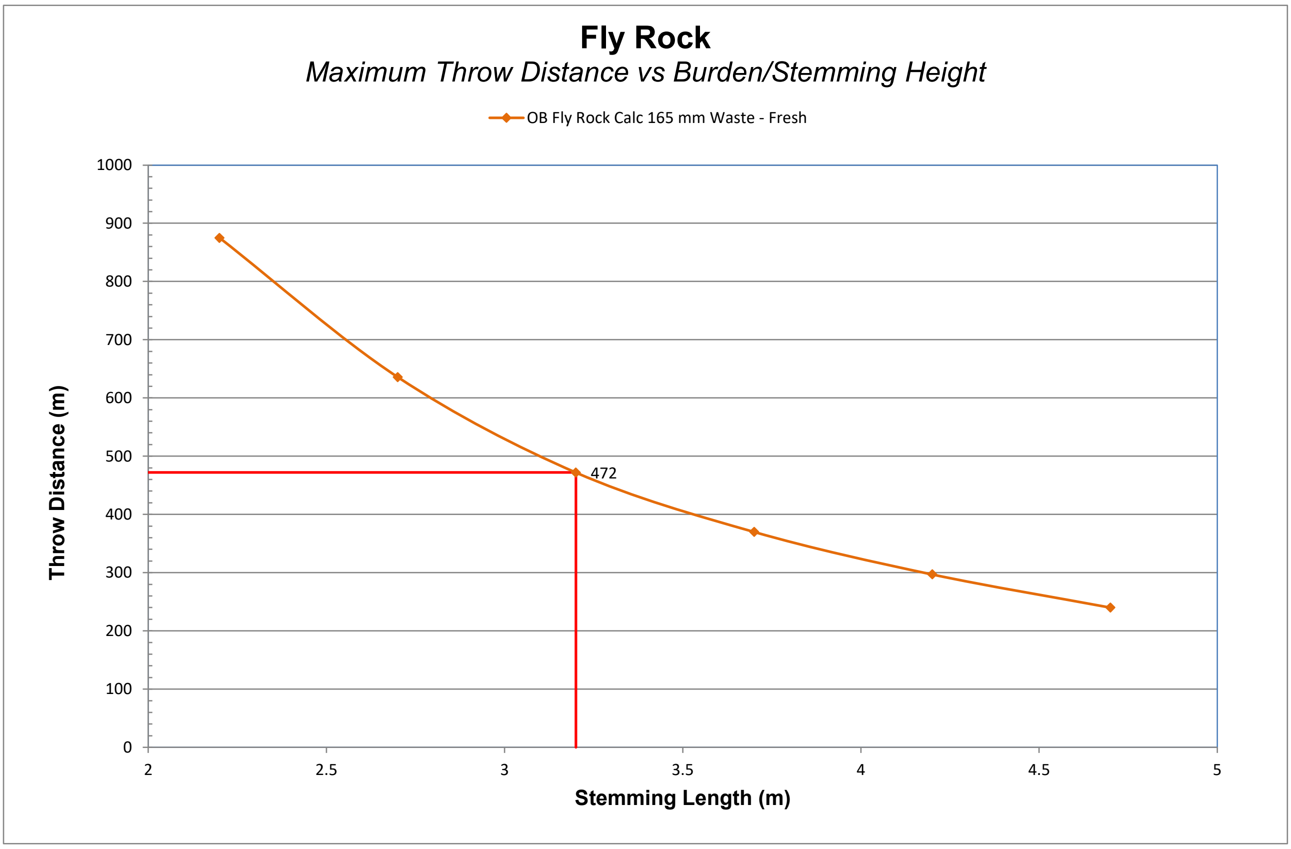


Figure 17: Fly rock prediction calculation

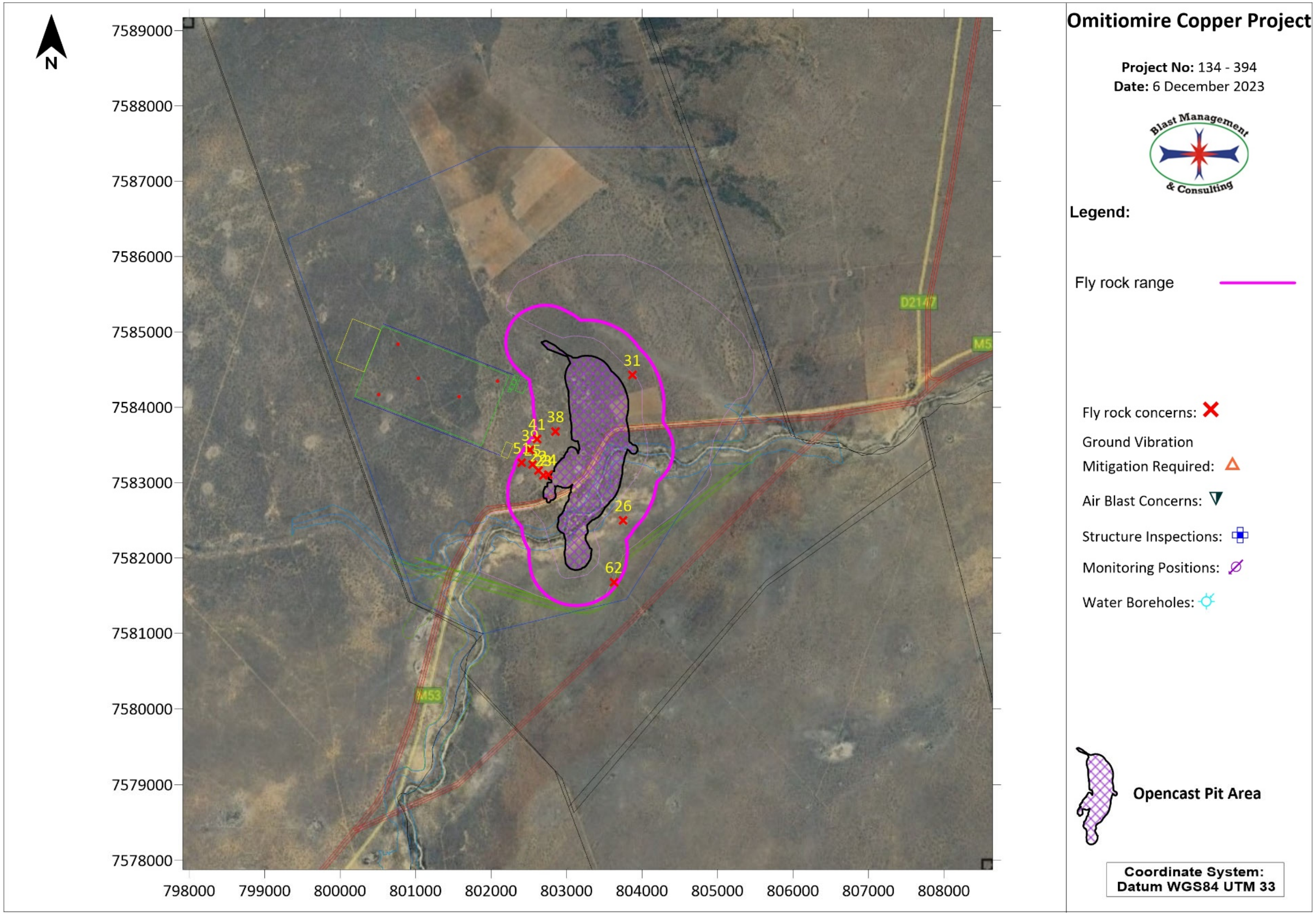


Figure 18: Predicted Fly Rock Exclusion Zone for the Opencast Pit area

Review of the calculated unsafe zone showed fourteen POI's for the Pit area are within the unsafe zone. Table 14 below shows the POI's of concern and coordinates.

Table 14: Fly rock concern POI's

Tag	Description	Y	X
22	Cement Dam	7583159.37	802630.92
23	Buildings/Structures	7583097.15	802694.04
24	Buildings/Structures	7583106.91	802758.08
25	Buildings/Structures	7583237.47	802549.81
26	Pan	7582498.26	803750.72
31	Power Lines	7584429.15	803870.83
38	Power Lines	7583680.07	802854.72
39	Power Lines	7583433.43	802516.62
41	Pan	7583580.44	802610.85
51	Hydrocensus Borehole (GO-2)	7583262.99	802406.01

16.9 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.

16.10 Water Borehole Influence

Location of boreholes for water was evaluated for possible influence from blasting. Hydrocensus boreholes were identified within the influence area of the Pit. There are two boreholes that falls inside the pit area. Table 15 shows all the identified boreholes and Table 16 shows the possible problematic borehole. Figure 19 shows the location of the boreholes in relation to the pit areas.

Table 15: Identified Water Boreholes

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to Pit	Predicted PPV (mm/s)
48	Hydrocensus Borehole (OT-2)	7586130.99	805939.01	50	2845	1.0
49	Hydrocensus Borehole (EN-3)	7581990.99	800687.01	50	2167	1.6
50	Hydrocensus Borehole (EN-4)	7581993.99	800685.01	50	2168	1.6
51	Hydrocensus Borehole (GO-2)	7583262.99	802406.01	50	400	25.7
52	Hydrocensus Borehole (GO-4)	7588700.99	801917.01	50	3902	0.6
55	Hydrocensus Borehole (OT-1)	7584099.99	807767.01	50	3882	0.6
56	Hydrocensus Borehole (WW202120)	7583570.99	806030.01	50	2093	1.7
57	Hydrocensus Borehole (WW202121)	7581916.99	800800.01	50	2093	1.7
58	Hydrocensus Borehole (WW202122)	7583949.99	805150.01	50	1308	3.6

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to Pit	Predicted PPV (mm/s)
59	Hydrocensus Borehole (WW202123)	7585499.99	805265.01	50	1928	1.9

Table 16: Problematic Water Borehole

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to Pit	Predicted PPV (mm/s)
53	Hydrocensus Borehole (ORC-153) - Inside Pit Area	7582669.99	803301.01	50	-	-
54	Hydrocensus Borehole (ORC-515) - Inside Pit Area	7582622.99	803151.01	50	-	-

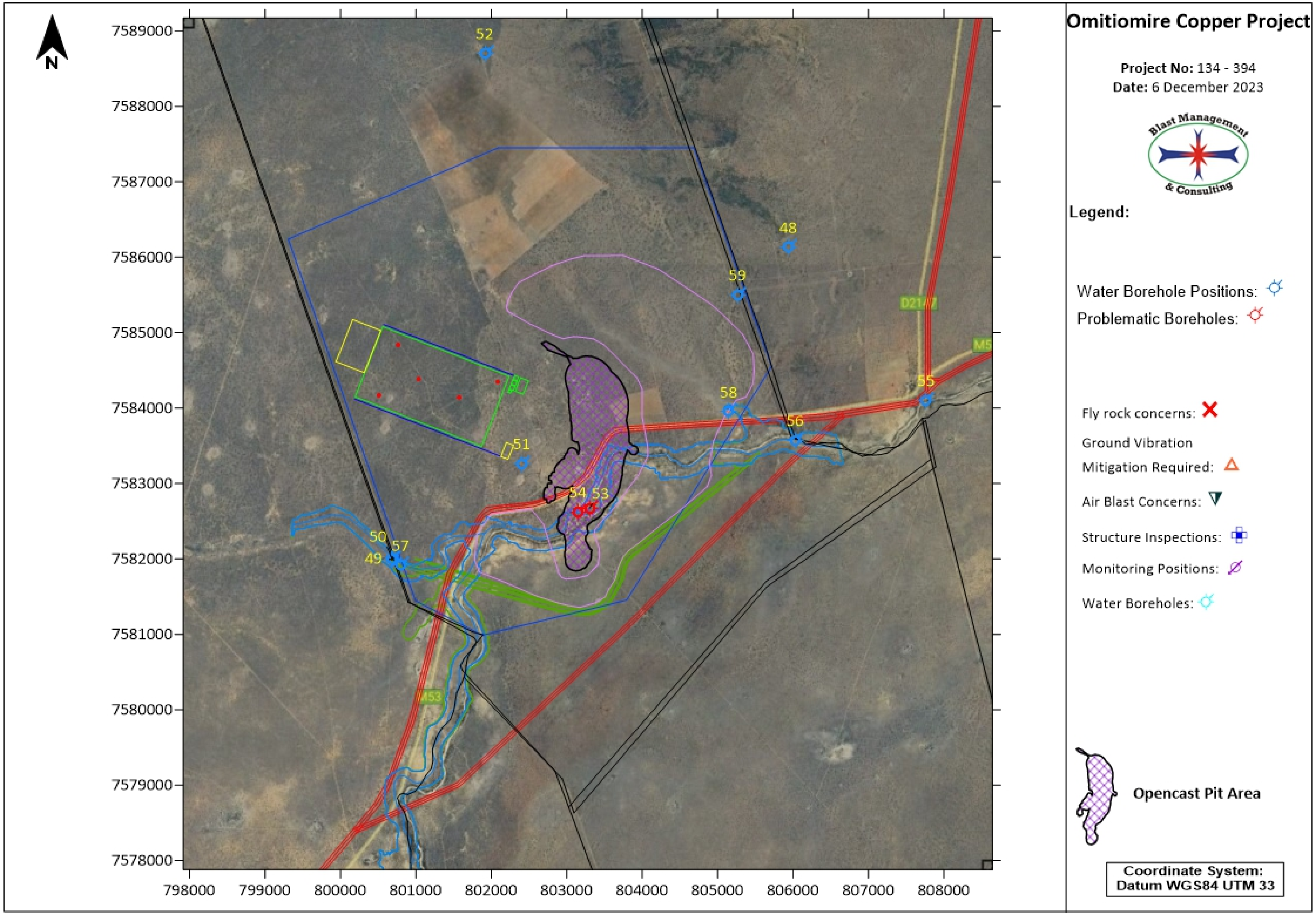


Figure 19: Location of the Boreholes

17 Potential Environmental Impact Assessment: Operational Phase

The following is the impact assessment of the various concerns covered by this report. The impact assessment and evaluation below were used for analysis and evaluation of aspects discussed in this report. The outcome of the analysis is provided in Table 17 with before mitigation and after mitigation. This risk assessment is a one-sided analysis and needs to be discussed with role players in order to obtain a proper outcome and mitigation.

Chapter 2 provides an overview of the approach used in this ESIA process, and details each of the steps undertaken to date. Predication and evaluation of impacts is a key step in the ESIA process. This chapter outlines the methods followed, to identify and evaluate the impacts arising from the proposed Project. The findings of the assessment are presented in chapter 7.

This chapter provides comprehensive details of the following:

- The assessment guidance used to assess impacts;
- The limitations, uncertainties, and assumptions with regards to the assessment methodology;
- How impacts are identified and evaluated, and how the level of significance derived;
- How mitigation is applied in the assessment, and how additional mitigation will be identified; and
- The cumulative impact assessment (CIA) method used.

The aims of this assessment are to determine which impacts are likely to be significant; to scope the available data and identify any gaps that need to be filled; to determine the spatial and temporal scope; and to identify the assessment methodology.

The scope of the assessment was determined through undertaking a preliminary assessment of the proposed Project against the receiving environment, and was obtained through a desktop review, available site-specific literature, monitoring data, and site reports, as set out in the existing 2021 scoping report and 2022 ESIA report.

17.1 Assessment Criteria

The following principal documents were used to inform the assessment method:

- International Finance Corporation standards and models, in particular performance standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2012 and 2017);
- International Finance Corporation Cumulative Impact Assessment (CIA) and Management Good Practice Handbook (International Finance Corporation, 2013);
- Namibian Draft Procedures and Guidance for EIA and EMP (Republic of Namibia, 2008); and

- Requirements encapsulated in IFC Performance Standard 3 (PS 3)
- Equator Principles 4 (ep 4) - Guidance on environmental and social impact assessment

17.2 Limitations, Uncertainties and Assumptions

The following limitations and uncertainties associated with the assessment methodology were considered in the assessment phase:

- Topic specific assessment guidance has not been developed in Namibia. A generic assessment methodology will be applied to all topics using IFC guidance and professional judgement;
- Guidance for CIA has not been developed in Namibia, but a single accepted state of global practice has been established. The IFC's guidance document (International Finance Corporation, 2013) will be used for the CIA; and
- The climate change methodology was determined by an external specialist in this field in order to comply with international, national and lender reporting requirements.

17.3 Assessment Methodology

The ESIA methodology applied to this assessment has been developed by ECC using the International Finance Corporation (IFC) standards and models, in particular performance standard 1: 'Assessment and management of environmental and social risks and impacts' (International Finance Corporation, 2017); Namibian Draft Procedures and Guidance for EIA and EMP (Republic of Namibia, 2008); international and national best practice; and over 25 years of combined ESIA experience. The methodology is set out in Figure 20 and Figure 21.

The methodology utilised for the climate change assessment was developed by the specialist conducting this assessment to adhere to the requirements of IFC Performance Standard 3 (PS 3) and Equator Principles 4 (ep 4). ECC will not amend this methodology used, however impact significance will be scored.

The evaluation and identification of the environmental and social impacts require the assessment of the Project characteristics against the baseline characteristics, ensuring that all potentially significant impacts are identified and assessed. The significance of an impact is determined by taking into consideration the combination of the sensitivity and importance/value of environmental and social receptors that may be affected by the proposed Project, the nature and characteristics of the impact, and the magnitude of any potential change. The magnitude of change (the impact) is the identifiable changes to the existing environment that may be negligible, low, minor, moderate, high, or very high; temporary/short-term, long-term or permanent; and either beneficial or adverse.

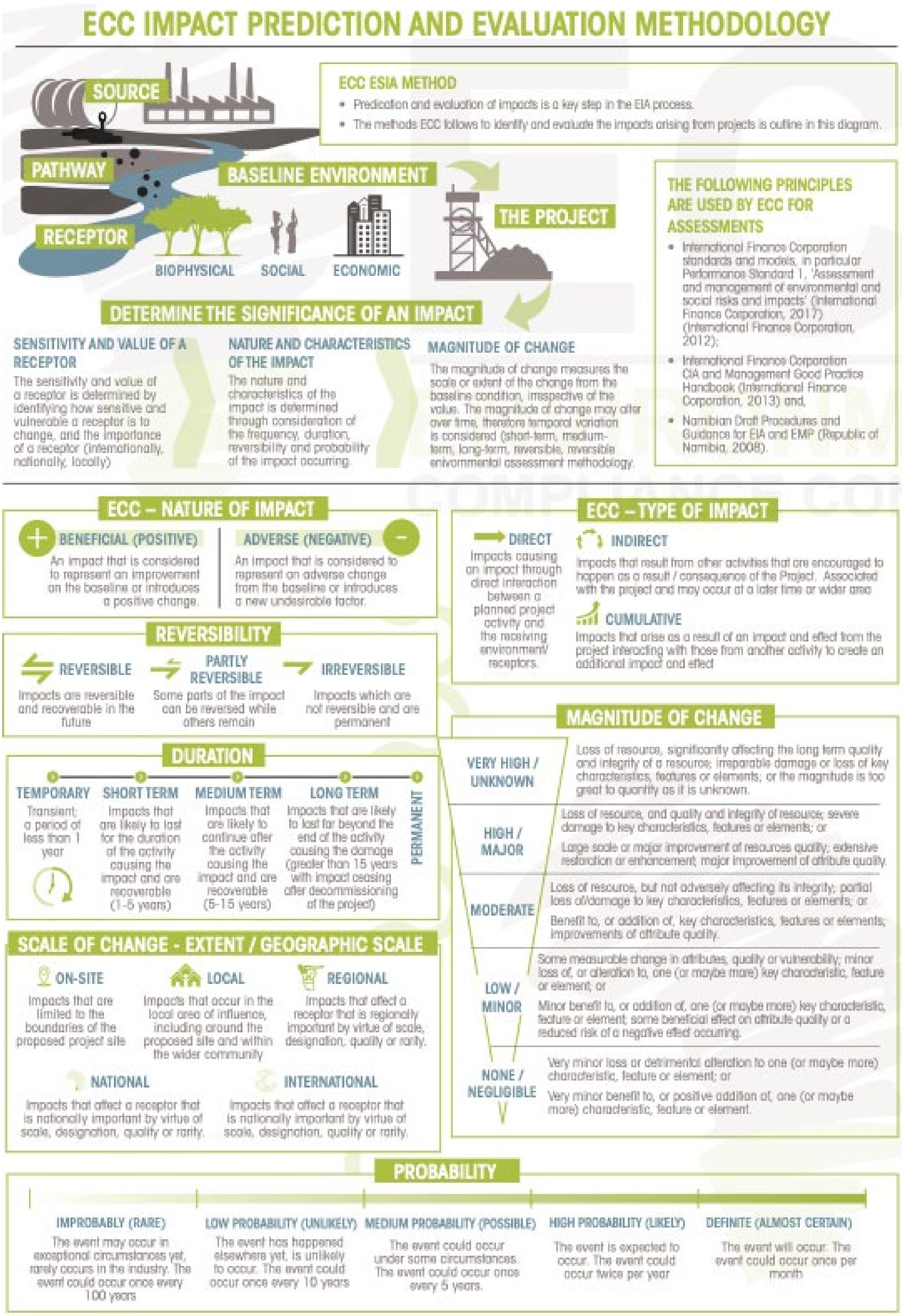


Figure 20: ECC ESIA methodology based on IFC standards

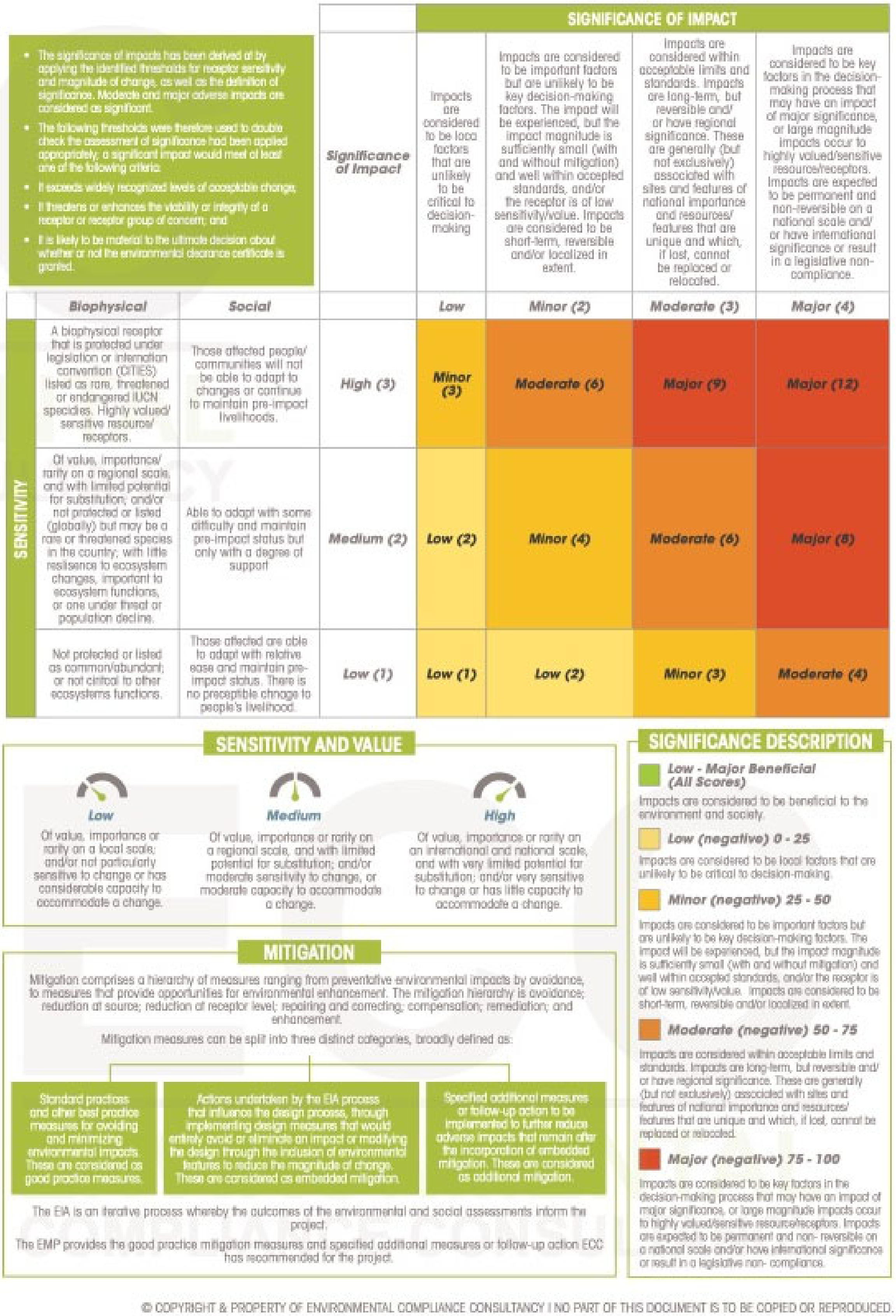


Figure 21: ECC ESIA methodology based on IFC standards

17.4 Assessment

The assessment done was based on evaluating the points of interested that showed expected levels greater than limits. This is however based on the worst-case scenario where blasting is done at the shortest distance from pit area to the point of interest. In after mitigation consideration was given to the fact that blasting will not be constantly at the short distance and the period of time that the influence may be present is significantly reduced due to that only areas or blocks will be blasted at a time.

Table 17: Potential Impacts Without Mitigation Measures Mitigation

No.	Activity	Tag	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
1	Blasting	22	Cement Dam	Ground Vibration	Regional, Life of Mine	High	High	Major
2	Blasting	23	Buildings/Structures	Ground Vibration	Regional, Life of Mine	High	High	Major
3	Blasting	24	Buildings/Structures	Ground Vibration	Regional, Life of Mine	High	High	Major
4	Blasting	25	Buildings/Structures	Ground Vibration	Regional, Life of Mine	High	High	Major
5	Blasting	26	Pan	Ground Vibration	Regional, Life of Mine	High	High	Major
6	Blasting	31	Power Lines	Ground Vibration	Regional, Life of Mine	High	High	Major
7	Blasting	32	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
8	Blasting	33	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
9	Blasting	34	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
10	Blasting	35	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
11	Blasting	36	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
12	Blasting	37	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
13	Blasting	38	Power Lines	Ground Vibration	Regional, Life of Mine	High	Medium	Moderate
14	Blasting	39	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
15	Blasting	40	Power Lines	Ground Vibration	Regional, Life of Mine	Low	Low	Low
16	Blasting	41	Pan	Ground Vibration	Regional, Life of Mine	Low	Low	Low
17	Blasting	42	Cement Dam	Ground Vibration	Regional, Life of Mine	Low	Low	Low
18	Blasting	46	Dam/Dam Wall	Ground Vibration	Regional, Life of Mine	Low	Low	Low
19	Blasting	47	Reservoir	Ground Vibration	Regional, Life of Mine	Low	Low	Low
20	Blasting	48	Hydrocensus Borehole (OT-2)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
21	Blasting	49	Hydrocensus Borehole (EN-3)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
22	Blasting	50	Hydrocensus Borehole (EN-4)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
23	Blasting	51	Hydrocensus Borehole (GO-2)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
24	Blasting	52	Hydrocensus Borehole (GO-4)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
25	Blasting	55	Hydrocensus Borehole (OT-1)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
26	Blasting	56	Hydrocensus Borehole (WW202120)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
27	Blasting	57	Hydrocensus Borehole (WW202121)	Ground Vibration	Regional, Life of Mine	Low	Low	Low

No.	Activity	Tag	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
28	Blasting	58	Hydrocensus Borehole (WW202122)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
29	Blasting	59	Hydrocensus Borehole (WW202123)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
30	Blasting	60	Pan	Ground Vibration	Regional, Life of Mine	Low	Low	Low
31	Blasting	61	Buildings/Structures	Ground Vibration	Regional, Life of Mine	Low	Low	Low
32	Blasting	62	River Diverted	Ground Vibration	Regional, Life of Mine	Low	Low	Low
33	Blasting	63	M53 Diverted	Ground Vibration	Regional, Life of Mine	Low	Low	Low
34	Blasting	64	Farm House (Otjere)	Ground Vibration	Regional, Life of Mine	Low	Low	Low
1	Blasting	22	Cement Dam	Air Blast	Regional, Life of Mine	Low	Low	Low
2	Blasting	23	Buildings/Structures	Air Blast	Regional, Life of Mine	High	High	Major
3	Blasting	24	Buildings/Structures	Air Blast	Regional, Life of Mine	High	High	Major
4	Blasting	25	Buildings/Structures	Air Blast	Regional, Life of Mine	High	High	Major
5	Blasting	26	Pan	Air Blast	Regional, Life of Mine	Low	Low	Low
6	Blasting	31	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
7	Blasting	32	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
8	Blasting	33	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
9	Blasting	34	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
10	Blasting	35	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
11	Blasting	36	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
12	Blasting	37	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
13	Blasting	38	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
14	Blasting	39	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
15	Blasting	40	Power Lines	Air Blast	Regional, Life of Mine	Low	Low	Low
16	Blasting	41	Pan	Air Blast	Regional, Life of Mine	Low	Low	Low
17	Blasting	42	Cement Dam	Air Blast	Regional, Life of Mine	Low	Low	Low
18	Blasting	46	Dam/Dam Wall	Air Blast	Regional, Life of Mine	Low	Low	Low
19	Blasting	47	Reservoir	Air Blast	Regional, Life of Mine	Low	Low	Low
20	Blasting	48	Hydrocensus Borehole (OT-2)	Air Blast	Regional, Life of Mine	Low	Low	Low
21	Blasting	49	Hydrocensus Borehole (EN-3)	Air Blast	Regional, Life of Mine	Low	Low	Low

No.	Activity	Tag	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
22	Blasting	50	Hydrocensus Borehole (EN-4)	Air Blast	Regional, Life of Mine	Low	Low	Low
23	Blasting	51	Hydrocensus Borehole (GO-2)	Air Blast	Regional, Life of Mine	Low	Low	Low
24	Blasting	52	Hydrocensus Borehole (GO-4)	Air Blast	Regional, Life of Mine	Low	Low	Low
25	Blasting	55	Hydrocensus Borehole (OT-1)	Air Blast	Regional, Life of Mine	Low	Low	Low
26	Blasting	56	Hydrocensus Borehole (WW202120)	Air Blast	Regional, Life of Mine	Low	Low	Low
27	Blasting	57	Hydrocensus Borehole (WW202121)	Air Blast	Regional, Life of Mine	Low	Low	Low
28	Blasting	58	Hydrocensus Borehole (WW202122)	Air Blast	Regional, Life of Mine	Low	Low	Low
29	Blasting	59	Hydrocensus Borehole (WW202123)	Air Blast	Regional, Life of Mine	Low	Low	Low
30	Blasting	60	Pan	Air Blast	Regional, Life of Mine	Low	Low	Low
31	Blasting	61	Buildings/Structures	Air Blast	Regional, Life of Mine	Low	Low	Low
32	Blasting	62	River Diverted	Air Blast	Regional, Life of Mine	Low	Low	Low
33	Blasting	63	M53 Diverted	Air Blast	Regional, Life of Mine	Low	Low	Low
34	Blasting	64	Farm House (Otjere)	Air Blast	Regional, Life of Mine	Low	Low	Minor
1	Blasting	22	Cement Dam	Fly Rock	Regional, Life of Mine	High	Medium	Moderate
2	Blasting	23	Buildings/Structures	Fly Rock	Regional, Life of Mine	High	High	Major
3	Blasting	24	Buildings/Structures	Fly Rock	Regional, Life of Mine	High	High	Major
4	Blasting	25	Buildings/Structures	Fly Rock	Regional, Life of Mine	High	High	Major
5	Blasting	26	Pan	Fly Rock	Regional, Life of Mine	Medium	Medium	Moderate
6	Blasting	31	Power Lines	Fly Rock	Regional, Life of Mine	High	High	Major
7	Blasting	32	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low
8	Blasting	33	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low
9	Blasting	34	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low
10	Blasting	35	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low
11	Blasting	36	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low
12	Blasting	37	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low
13	Blasting	38	Power Lines	Fly Rock	Regional, Life of Mine	High	Medium	Moderate
14	Blasting	39	Power Lines	Fly Rock	Regional, Life of Mine	High	Medium	Moderate
15	Blasting	40	Power Lines	Fly Rock	Regional, Life of Mine	Low	Low	Low

No.	Activity	Tag	Receptor	Impact	Nature of impact	Value & Sensitivity	Magnitude of change	Significance of impact
16	Blasting	41	Pan	Fly Rock	Regional, Life of Mine	Medium	Medium	Moderate
17	Blasting	42	Cement Dam	Fly Rock	Regional, Life of Mine	Low	Low	Low
18	Blasting	46	Dam/Dam Wall	Fly Rock	Regional, Life of Mine	Low	Low	Low
19	Blasting	47	Reservoir	Fly Rock	Regional, Life of Mine	Low	Low	Low
20	Blasting	48	Hydrocensus Borehole (OT-2)	Fly Rock	Regional, Life of Mine	Low	Low	Low
21	Blasting	49	Hydrocensus Borehole (EN-3)	Fly Rock	Regional, Life of Mine	Low	Low	Low
22	Blasting	50	Hydrocensus Borehole (EN-4)	Fly Rock	Regional, Life of Mine	Low	Low	Low
23	Blasting	51	Hydrocensus Borehole (GO-2)	Fly Rock	Regional, Life of Mine	Medium	Medium	Moderate
24	Blasting	52	Hydrocensus Borehole (GO-4)	Fly Rock	Regional, Life of Mine	Low	Low	Low
25	Blasting	55	Hydrocensus Borehole (OT-1)	Fly Rock	Regional, Life of Mine	Low	Low	Low
26	Blasting	56	Hydrocensus Borehole (WW202120)	Fly Rock	Regional, Life of Mine	Low	Low	Low
27	Blasting	57	Hydrocensus Borehole (WW202121)	Fly Rock	Regional, Life of Mine	Low	Low	Low
28	Blasting	58	Hydrocensus Borehole (WW202122)	Fly Rock	Regional, Life of Mine	Low	Low	Low
29	Blasting	59	Hydrocensus Borehole (WW202123)	Fly Rock	Regional, Life of Mine	Low	Low	Low
30	Blasting	60	Pan	Fly Rock	Regional, Life of Mine	Low	Low	Low
31	Blasting	61	Buildings/Structures	Fly Rock	Regional, Life of Mine	Low	Low	Low
32	Blasting	62	River Diverted	Fly Rock	Regional, Life of Mine	High	Medium	Moderate
33	Blasting	63	M53 Diverted	Fly Rock	Regional, Life of Mine	Low	Low	Low
34	Blasting	64	Farm House (Otjere)	Fly Rock	Regional, Life of Mine	Low	Low	Low

17.5 Mitigations

In review of the evaluations made in this report it is certain that specific mitigation will be required with regards to ground vibration, air blast and fly rock. 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 18 shows list of POI's that will need to be considered. Figure 22 shows the location of these POI's in relation to the pit areas.

Table 18: Structures identified as problematic in and around the project area

Tag	Description	Classification	Y	X
22	Cement Dam	6	7583159.37	802630.92
23	Buildings/Structures	2	7583097.15	802694.04
24	Buildings/Structures	2	7583106.91	802758.08
25	Buildings/Structures	2	7583237.47	802549.81
31	Power Lines	13	7584429.15	803870.83
38	Power Lines	13	7583680.07	802854.72

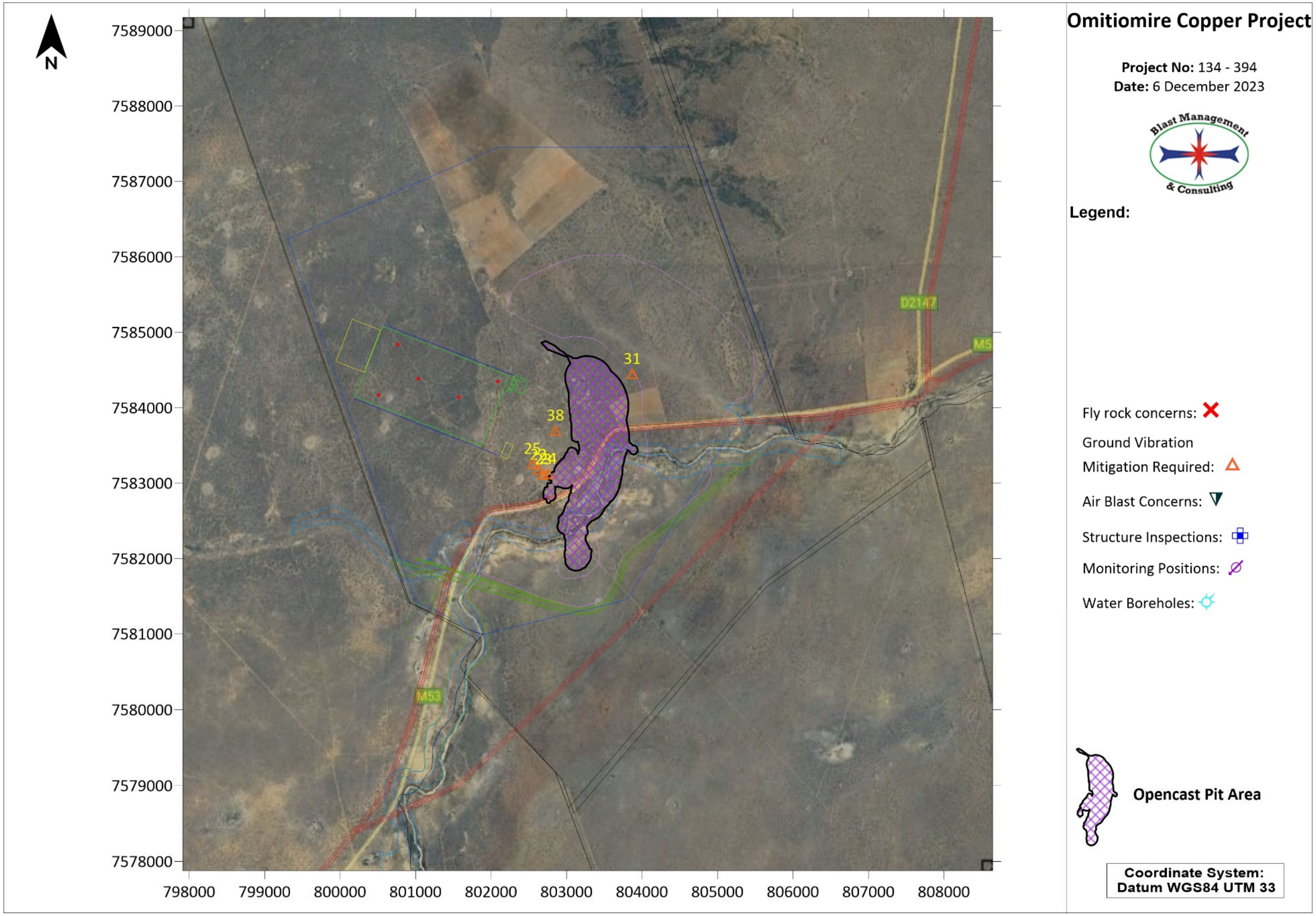


Figure 22: Mitigation POI's

Based on the modelling done, high levels of influence are specifically observed up to 263 m from the pit boundary. There are influences further but to lesser extent. The following specific mitigations may be considered.:

1. Relocation of households within the 263 m boundary from the mine.
2. Changes to drill and blast design to mitigate ground vibration.
3. Changes to charging designs to mitigate air blast and fly rock.

Relocation:

Relocation of households closer than 263 m from the pit boundary is recommended as an option as part of the mitigation of ground vibration, air blast and fly rock.

Air blast and Fly rock:

Air blast and fly rock is mitigated by the following means:

1. Increasing the stemming length ratio to blasthole diameter – either changing to a smaller diameter blasthole or increasing the actual stemming length.
2. The use of aggregate stemming material of correct size ratio – 10 % of the blasthole diameter.

Ground Vibration:

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

- Do blast design that considers the actual blasting, and the ground vibration levels to be adhered too.
- Change to bench heights with smaller diameter blastholes can be considered.
- Multiple charge decks in a blastholes initiated separately to reduce the charge mass per delay can be considered.
- Only apply electronic initiation systems to facilitate 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 possibilities of mitigation to consider two basic indicators are presented. Firstly, the maximum charge per delay that can be allowed for the shortest distance between blast and POI. Secondly the minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay. These table gives indication for planning of blasts when blasts at shortest distance to the POI's.

Table 19 do show mitigation in the form of maximum charge mass that will be allowed to maintain safe levels of ground vibration. Table 20 shows minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay.

Table 19: 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
24	Buildings/Structures	7583106.91	802758.08	12.5	19	1	12.5	Acceptable
23	Buildings/Structures	7583097.15	802694.04	12.5	71	21	12.5	Acceptable
22	Cement Dam	7583159.37	802630.92	50	152	523	50	Acceptable
31	Power Lines	7584429.15	803870.83	75	172	1085	75	Acceptable
38	Power Lines	7583680.07	802854.72	75	206	1568	75	Acceptable
25	Buildings/Structures	7583237.47	802549.81	12.5	263	289	12.5	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 as well electronic timing can used to reduce the charge mass per delay. This must be confirmed with monitoring of ground vibration at the POI.

The following Table 20 shows the minimum distance required between blast and POI for the minimum and maximum charge per delay to maintain the ground vibration limits applied.

Table 20: Mitigation measures: Minimum distances required

Tag	Example POI	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)
Minimum charge per delay				
	Buildings/Structures	12.5	277	321
	Cement Dam	50	119	321
	Power Lines	75	93	321
Maximum charge per delay				
	Buildings/Structures	12.5	618	1604
	Cement Dam	50	267	1604
	Power Lines	75	209	1604

Data provided in tables above clearly indicate that distance between blast and POI will have influence on the allowed charge mass per delay with regards to the different ground vibration limits.

18 Closure Phase: Impact Assessment and Mitigation Measures

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

19 Alternatives (Comparison and Recommendation)

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

20 Monitoring

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

- Ground vibration and air blast results;
- Blast Information summary;
- Meteorological information at time of the blast;
- Video Recording of the blast;
- Fly rock observations.

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

Three monitoring points were identified as possible locations that will need to be considered for the pit area. Not all the identified points will be required simultaneously. The identified points are guidelines to consider for the pit area. Monitoring positions are indicated in Figure 23 and Table 21 lists the positions with coordinates. These points will need to be re-defined after the first blasts done and the monitoring programme defined.

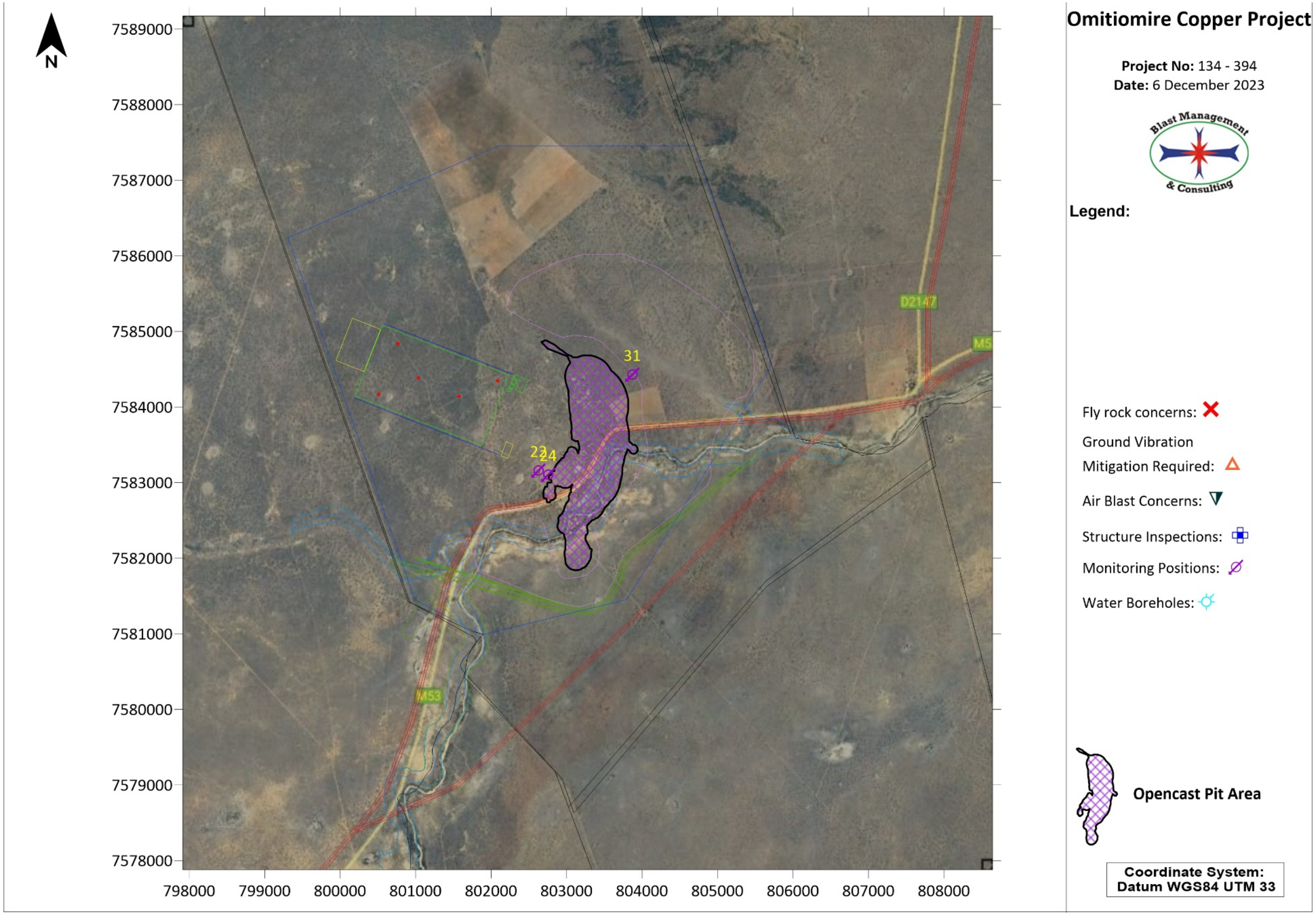


Figure 23: Suggested monitoring positions

Table 21: List of possible monitoring positions

Tag	Description	Y	X
22	Cement Dam	7583159.37	802630.92
24	Buildings/Structures	7583106.91	802758.08
31	Power Lines	7584429.15	803870.83

21 Recommendations

The following recommendations are proposed.

21.1 Regulatory requirements

Various non-mining related POI's are observed within 500 m from the pit that needs consideration. Table 22 shows list of these installations. Figure 24 below shows the 500 m boundary around the opencast pit area. The location of non-mining installations is clearly observed.

Table 22: List of possible installations within the regulatory 500 m

Tag	Description	Y	X
22	Cement Dam	7583159.37	802630.92
23	Buildings/Structures	7583097.15	802694.04
24	Buildings/Structures	7583106.91	802758.08
25	Buildings/Structures	7583237.47	802549.81
26	Pan	7582498.26	803750.72
31	Power Lines	7584429.15	803870.83
38	Power Lines	7583680.07	802854.72
39	Power Lines	7583433.43	802516.62
41	Pan	7583580.44	802610.85
51	Hydrocensus Borehole (GO-2)	7583262.99	802406.01

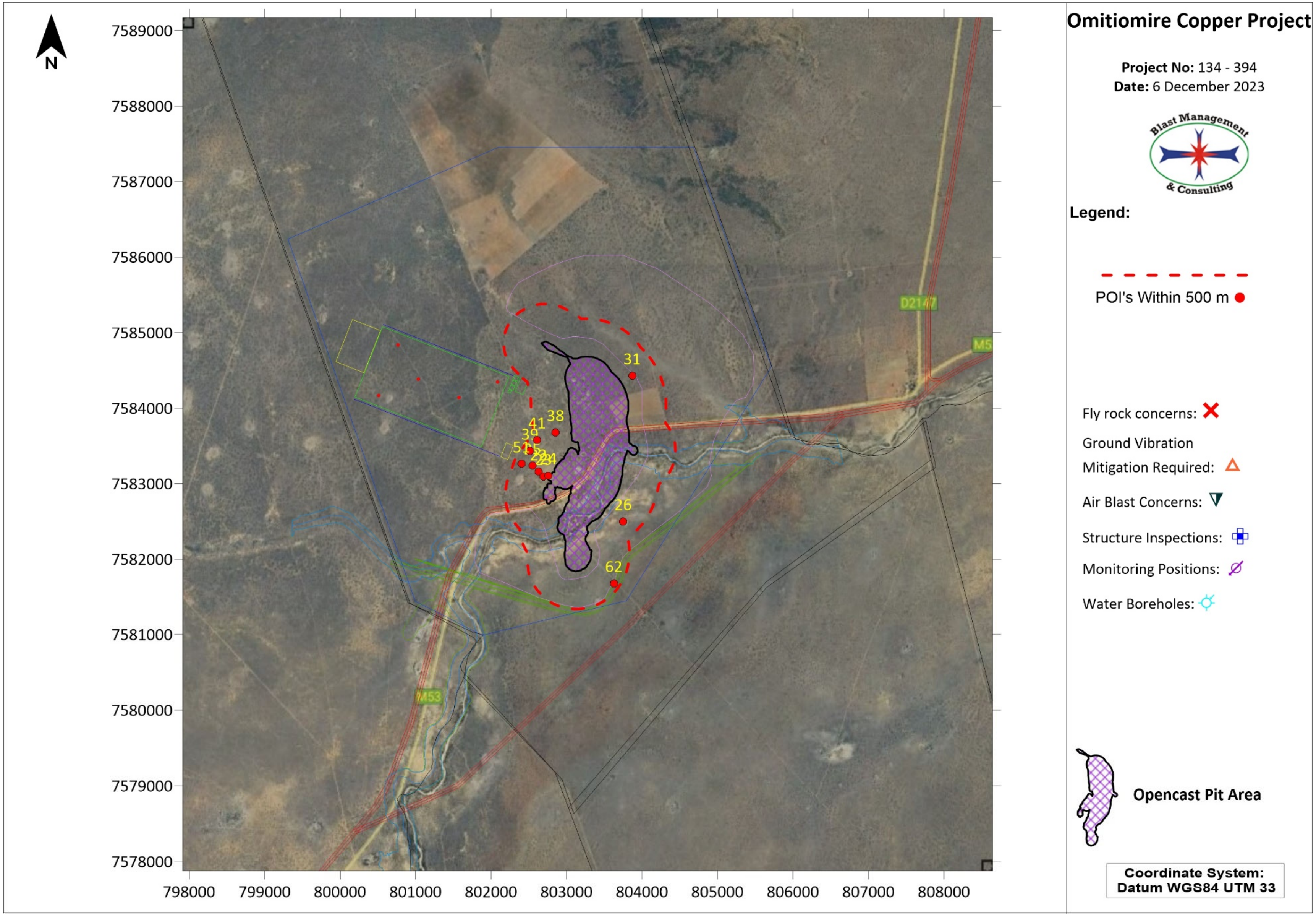


Figure 24: Regulatory 500 m range for the opencast area

21.2 Relocation

Review of possible impacts it is recommended that households within 263 m at least should be relocated. Expected levels of ground vibration and air blast is greatest up to 263 m.

21.3 Blast Designs

Blast designs can be reviewed prior to first blast planned and done. 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. Please refer to section 17.5 for detail regarding mitigations required.

21.4 Test Blasting

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

21.5 Stemming length

The current proposed stemming lengths 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.

21.6 Safe blasting distance and evacuation

Calculated minimum safe distance is 472 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.

21.7 Road management

The M53 road currently passes through the mining licence area and across the future mine pit area. This same road continues and branches into another district road, the D2102 east of ML 197. The alternative that is proposed is the construction of a new section of the M53 around the southern boundary of the mine pit area that will re-join the exiting M53 route east of the mining licence area, thereby allowing a throughfare for district road users. The M53 road is located such that when blasting is done within 500 m from this road travel management will be required. Stop and Go procedures during blasting will be required.

There are gravel roads that traverse through the existing approved mining area. There is no specific ground vibration concern for these roads. There are also other smaller gravel roads in the area. These roads are specifically of concern when blasting is done in regards with fly rock concerns more than ground vibration. No specific consideration regarding effects from blasting operations will be required for these roads. There may however be people and animals on these routes and will require careful planning to maintain safe blasting radius. It will be required that clearance distances be set, and road travel managed during blasting operations.

21.8 Photographic Inspections

The option of photographic survey of all structures up to 1500 m from the pit area is recommended. The mine will be operating for a significant number of years. This will give advantage on any negotiations with regards to complaints from neighbours on structural issues due to blasting. This process can however only succeed if done in conjunction with a proper monitoring program. It is expected that ground vibration levels will be significantly less than proposed limits at 1500 m, but this process will ensure record of the pre-blasting status of the nearest structures to the pit area. At 1500 m the expected level of ground vibration will be perceptible. Figure 25 shows extent of the range of 1500 m around the pit areas 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.

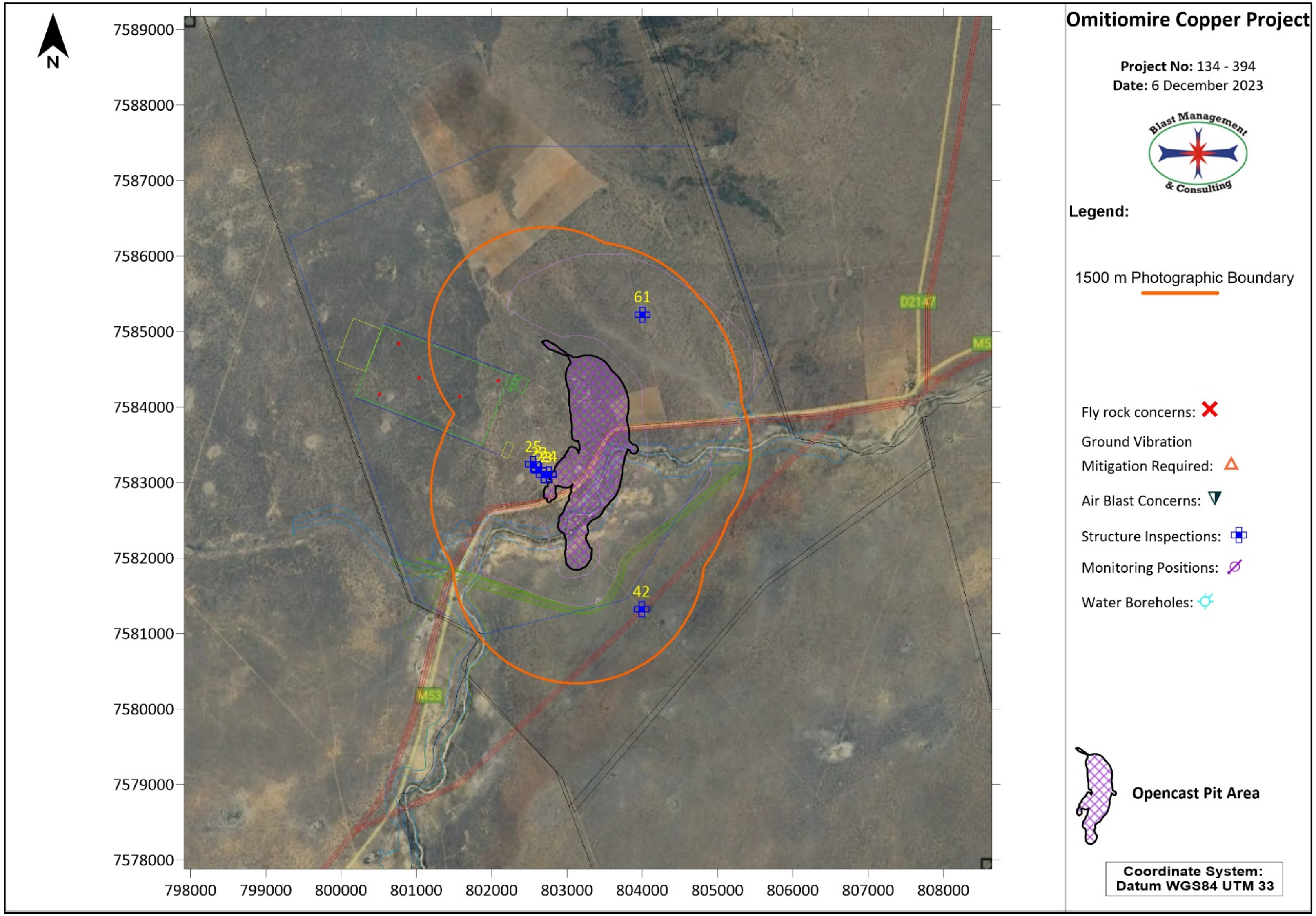


Figure 25: 1500 m area around Opencast pit identified for structure inspections.

Table 23: Combined list of structures identified for inspections

Tag	Description	Y	X
22	Cement Dam	7583159.37	802630.92
23	Buildings/Structures	7583097.15	802694.04
24	Buildings/Structures	7583106.91	802758.08
25	Buildings/Structures	7583237.47	802549.81
42	Cement Dam	7581320.01	803991.59
61	Buildings/Structures	7585221.45	804003.22

21.9 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 24.

Table 24: 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 134dBL at point of concern but 120 dBL preferred
Houses of lesser proper construction (preferred)	12.5	
Rural building – Mud houses	6	

21.10 Blasting times

A further consideration of blasting times is when weather conditions could influence the effects yielded by blasting operations. It is recommended not to blast too early in the morning when it is still cool or when there is a possibility of atmospheric inversion or too late in the afternoon in winter. Do not blast in fog. Do not blast in the dark. Refrain from blasting when wind is blowing strongly in the direction of an outside receptor. Do not blast with low overcast clouds. These 'do nots' stem from the influence that weather has on air blast. The energy of air blast cannot be increased but it is distributed differently and therefore is difficult to mitigate.

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

21.11 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. Please refer to section 20 regarding proposed monitoring positions.

21.12 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.

22 Knowledge Gaps

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

23 Project Result

Specific problems were identified, and recommendations made. The successful resolving of these concerns will allow that the project can be executed successfully with proper management and control on the aspects of ground vibration, air blast and fly rock.

24 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 3500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low-cost houses, corrugated iron structures, industrial buildings, brick and mortar houses, power lines/pylons.

The location of structures around the Pit area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the M53 Road, Black Nossob River, Cement Dam, Hydrocensus Borehole and Power Lines. The ground vibration levels predicted for these POI's ranged between 0.6 mm/s and 4083 mm/s for POI's surrounding the open pit area. The Black Nossob River and the M53 district road is currently located close to the pit but client is planning to divert the Black Nossob River and the M53 district road away from the mine infrastructure and the open pit area. This reduces possible impact from ground vibration significantly.

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

Expected levels of air blast ranges between 118 dBL and 151 dBL for the minimum charge evaluated and between 121 dBL and 154 dBL for the maximum charge. Nearest structure to the pit area is POI 23, 24 and 25. Expected levels of air blast is greater than the limit applied at these POI's. 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 dBL at distance of 490 m and closer to pit boundary. Infrastructure at the pit areas such as roads and power lines/pylons, are 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 472 m. The absolute minimum unsafe zone is then the 472 m. This calculation is a guideline and any distance cleared should not be less. Eleven POI's are found within this range. These POI's consist of buildings, powerline, pan, dam and boreholes. 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.

Generally 500 m are applied for a safe blasting / clearance distance. Specific actions will be required when blasting is done within 500 m from structures. The Cement Dam, Buildings/Structures, Pan, Power Lines and Hydrocensus Borehole falls within the 500 m range from the pit area.

The pit area is located such that specific concerns were identified and addressed in the report. There are public structures located very close to the pit boundary. Specific mitigation will be required for these concerns. Recommendation have been made regarding these.

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

25 Curriculum Vitae of Author

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.

26 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. 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.
6. Persson P.A., Holmberg R. and Lee J., 1994, Rock Blasting and Explosives Engineering, Boca Raton, Florida: CRC Press.

7. 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.
8. Rowland, J.H.(III), Mainiero R., and Hurd D.A.(Jr.), Factors Affecting Fumes Production of an Emulsion and Anfo/Emulsion Blends.
9. Sapko M., Rowland J., Mainiero R., Zlochower I., Chemical and Physical Factors that Influence no Production during Blasting – Exploratory Study.
10. 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.
11. Siskind, D. E., Stagg, M.S., Kopp, J. W. and Dowding, C. H. (1980). Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting. Report of Investigations 8507. US Bureau of Mines.