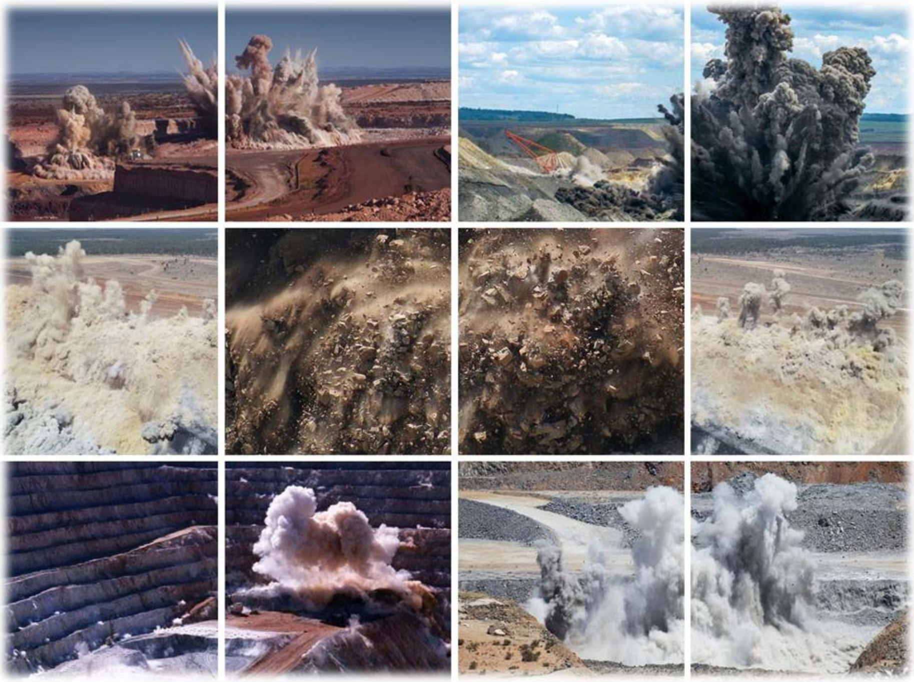
Seriti Power (Pty) Ltd

BLASTING IMPACT ASSESSMENT

for the

Proposed Naudesbank Coal Project west of Carolina,

Mpumalanga Province



Study done for:

ZYNTHA CONSULTING

Prepared by:

EARES Enviro Acoustic Research

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EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Zyntha Consulting (Pty) Ltd to determine the potential impact from blasting activities on the surrounding environment due to the proposed development of the Naudesbank Coal project. This project is proposed west of the town of Carolina in the Mpumalanga Province.

This report describes the potential blasting impacts that the operation may have on the surrounding built environment, highlighting the methods used, potential issues identified, findings and recommendations. This study considered local regulations and international guidelines.

PROJECT DESCRIPTION

Seriti Power (Pty) Ltd (the applicant) is proposing a mining operation, referred to as the Naudesbank Coal Project. This will be an opencast as well as underground mining operation.

Opencast mining will be an advancing open pit mining method, using trucks and shovels to mine the coal resource. Typical activities associated with opencast mining will include:

- The removal of vegetation, followed with the stripping of the available topsoil up to a predefined depth;
- The removal of subsoils and soft overburden till hard material is reached;
- The drilling of boreholes (blastholes) using a designed pattern and the charging of the blastholes with explosives (both overburden and coal resource);
- The loading and hauling of the material (both overburden and coal resource) to the mining residue deposit(s) or the run of mine ("RoM") stockpile area;
- Crushing and screening of the RoM, stockpiling and material handling (loading of road trucks);
- Traffic moving around onsite (including road trucks hauling coal product to the market);
- Rehabilitation activities; and
- Various ancillary activities to support the mining process.

To allow the mining of the underground coal resource, the mine would develop:

- An adit to allow the hauling of coal resource from the underground workings; and
- A vertical shaft to provide access to the underground working, as well as ensure adequate ventilation to the underground workings.

This assessment specifically focuses on the potential impact of vibration, airblast levels and the risk of flyrock associated with the blasting activities within the opencast pits. The blasting assessment only consider potential impacts associated with overburden blasting, as this is the major blasting activity associated with most opencast projects. Coal blasting in general is significantly smaller, with the coal resource much softer than the overburden geology resulting in significantly lower blasting related impacts.

This assessment in addition does not consider blasting from the development of the adit nor underground blasting activities. This is because blasting impacts associated with the development of underground infrastructure and underground mining is insignificant when compared with blasting impacts associated with opencast mining.

BLASTING PARAMETERS

A blast design was not available and this assessment used a conceptual design, considering a potential 10m bench height and optimal borehole diameter (considering the Dyno (2017) "*Rule of Thumb*" recommendations) considering the geology and resource depth. And it is recommended that the mine review, or redo the Blasting Vibration Assessment once the blast design is finalized for the Naudesbank project.

Blasting vibration and air blast levels as well as the potential zone of impact for fly rock was calculated considering the potential blasting impact from a single blast per charge (potential best scenario) as well as a potential worst-case where up to ten (10) blastholes are detonated simultaneously.

It should be noted that the number of blastholes that may be detonated simultaneously could vary from blast to blast. Similarly, the depth of the blastholes is similarly not constant, but may vary on a day-to-day basis, depending on the mine planning (such as the planned final void profile) or geology. This assessment also considered a number of alternative blast parameters as presented in the table below.

Design parameter	150 mm drill diameter
Average depth of borehole (m)	10.0
Bench height (m)	10.0
Subdrill (m)	0.0
Borehole diameter (mm)	150.0
Burden (m)	4.5
Spacing (m)	5.2
Burden stiffness ratio	2.2
Stemming Length (m)	2.2
Column length (m)	7.8
Explosive density (g/cm^3)	1.15
Explosives per borehole (kg)	158.5
Charge mass per meter (kg/m)	20.3
Maximum number of blast holes per delay	10
Maximum explosives per delay (kg)	1 585
Powder Factor (kg/m^3)	0.68
Vibration at 500 m, one borehole per blast delay (mm/s)	4.4
Airblast level at 500 m, one borehole per blast delay (dBA)	117.8
Potential maximum flyrock distance (m)	479.9
Vibration at 500 m, maximum number of blastholes per delay (mm/s)	25.2
Airblast level at 500 m, maximum number of blastholes per delay (dBA)	125.8

BLASTING IMPACT FINDINGS

The potential impacts of ground vibration, air blast levels and fly rock risks were determined using methods provided by the USBM. A potential blast design was estimated considering the potential bench height (when considering the depth to the coal resource), with this assessment indicating:

- That ground vibration levels may be unpleasant to Blast Sensitive Receptors ("BSR") when blasting take place within approximately 2,200 m from structures used for residential or business activities (precautious evaluation using a worst-case scenario). The impact is of a potential **High** significance and mitigation is required and proposed that could reduce the significance of potential impact of vibration levels on BSR to **Low**. However, due to the sensitivity to blast effects, it is possible that people may still complain about the perceived blast effects even after the implementation of mitigation measures;
- That ground vibration levels could be of **High** significance to any brick buildings located within 500 m from the proposed opencast pits. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on such buildings to **Low**;
- That ground vibration levels could be of **High** significance once blasting activities take place closer than 200 m from any cement dams. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on the dams to **Low**;
- That ground vibration levels could be of **Medium** significance once blasting activities take place closer than 160 m from the tar road and railway line. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on these structures to **Low**;
- Air blast levels will be clearly audible to all surrounding receptors and the significance will be **High** for the closest BSRs. Additional mitigation is recommended and included to reduce potential complaints and annoyance with the project. Due to the sensitivity of people to the significant loud noise as well as secondary vibration of large surfaces (due to the change in air pressure) associated with a blasting event, BSRs must be informed about the potential impacts. It is possible that people may still complain about the perceived blast effects even after the implementation of mitigation measures;
- There may be a risk of **High** significance of fly rock to BSRs or BSSs, and blasting close to the mine equipment and infrastructure may result in fly rock damage. Management measures are available to ensure that risks are minimised.

Blasting will take place closer than 500 m from any roads and the mine must note that GNR.584 of 2015 does limit blasting within 500 m from certain structures (such as roads, railway lines or overhead power lines) unless certain conditions are met. The mine will have to discuss the project with the relevant provincial authorities to authorize the temporary closure of the roads and implement the agreed upon mitigation measures. The mine must obtain the schedule of rail traffic and plan blasting times accordingly. Warning signs should be erected within 1,000 m during blasting events along the roads and railway line.

PROPOSED MITIGATION

Blasting must be carefully planned and executed to ensure that people, livestock, structures and equipment are protected. The following should be noted and considered by the mine:

- BSR staying closer than 500 m from opencast area (where blasting may take place in future) to be relocated;
- The potential vibration levels should be discussed with the surrounding BSRs during the EIA process. They should be notified that the vibration levels were calculated but some people may find the vibration levels unpleasant. BSRs should be notified that, while they can feel the vibration level, their houses and other structures are in no danger (very low risk of potential damage);
- Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive. Feedback regarding vibration monitoring should be provided at these forums;
- The mine must conduct a photographic (crack) survey at all buildings and structures, as well as define the status of water boreholes, located within 2,000 m from areas where future blasting is to take place. Cracks will develop with time, which may be due to construction of the structures, standards of building, the age of the structure, the underlying geology and soils, maintenance etc., and not necessarily due to blasting;
- The mine should undertake a survey of all buildings and structures (during the recommended photo survey) located within 2,000 m from the proposed mining opencast pits to determine the building material and potential sensitivities of the structures. If any potential sensitive structures are identified, blasting closer than 1,200 m from these structures should be designed to consider the 6 mm/s vibration limit;
- The mine should measure blasting vibration levels during blasts to define onsite constants when mining the west pit. These constants can be used to update the blasting report and potential blasting impacts before mining start at the east pit;
- The developer should erect clear signs indicating blast dates and times on all roads within 1,000 m from the blasting areas. A blast schedule should be provided to the BSRs staying in the area;
- The R38 tar road as well as a number of unpaved district roads (D983 and D1252) is located within 500 m from locations where blasting may occur in the future. The mine must take notice of GNR.584 of 2015, that does limit blasting within 500 m from certain structures unless certain conditions are met. It will be necessary to close this road during blasting closer than 500 m, though the mine must implement measures to warn road users that blasting is taking place (to prevent road users being startled increasing risks of road accidents) when blasting takes place closer than 1,000 m. Road closure will require permission from the Provincial Authorities;
- Cement dams located within 200 m should be decommissioned, livestock using these dams should be relocated and alternative sources of water should be supplied to users of these dams (if relevant);
- Any evidence of fly rock must be noted and the blast be analysed for possible improvements;

- That the mine considers the findings and recommendations of the Heritage Specialist/Adviser for this project;
- That the mine considers the findings and recommendations of the Wetland and Surface Water Specialist/Adviser for this project;
- That the mine considers the findings and recommendations of the Fauna and Flora Specialists/Advisors for this project;
- All people working within 500 m from a potential blast must be evacuated before the detonation of the blast;
- All livestock within 500 m from a blast should be moved before a blast;
- The mine should erect clear warning signs indicating blast times along all tar roads located within 1,000 m from potential blasting areas. Road users should be warned when blasting events are taking place within 1,000 m;
- The mine should schedule blasting at the same time in the early afternoons, to minimise airblast levels. No blasting should take place early in the mornings, late in the afternoons, during overcast conditions or in foggy conditions;
- Potential airblast levels to be calculated for each blast to take place within 1, 000 m from any BSR; and,
- The use of detonating cord should be minimised to control airblast levels. When used within 1,000 m from identified BSRs, the cord should be covered with cuttings or aggregate to minimise airblast levels from this source.

RECOMMENDATIONS AND CONCLUSIONS

The project is proposed in an area with a number of BSRs and BSSs such as residential houses, cement dams, sheds and informal houses (constructed of wood and corrugated iron) and the R38 tar road. While the risks from blasting impacts are manageable, people are always concerned about the potential effects and dangers of blasting and measures are recommended for the mine to consider and implement. This assessment also assumes that receptors (BSR 1 and 2) located directly on the areas to be developed (plant area and opencast areas) will be relocated before mining activities are closer than 500 m. Similarly, all structures associated with these BSR will no longer be used.

Community involvement throughout the project is of utmost importance. This is especially true for any mining projects where blasting may take place, irrespective of the temporary nature of blasting. Blasting related impacts may potentially upset the surrounding community and complaints could be one of the tools that the community may use to express their annoyance with the project, rather than a rational reaction to the vibration or air blast levels itself.

At all stages surrounding receptors should be informed about the project, providing them with factual information without setting unrealistic expectations. Even with the best measures, blasting related impacts will be perceived negatively and the community members may complain. It is therefore in the best interest of the mine to continually monitor and manage the blast in an effort to improve and minimise potential blasting effects.

It is highly recommended that the mine conduct a detailed photographic survey at structures (that does not belong to the mine) located within 2,000 m from the mine (from locations where blasting may take place) before any mining activities start (before the construction phase start where blasting is to take place). This should include a survey (condition assessment with photographic records) of residential structures (within 2,000 m from opencast pits), heritage structures (of high cultural or archaeological value – if relevant), water boreholes (within 2,000 m from opencast pits) and cement dams (within 500 m from opencast pits) to determine the status of these structures.

It is concluded that, if the mine considers the recommendations in this report (incorporated in the Environmental Management Plan), that blasting risks do not constitute a fatal flaw. It is, therefore, the recommendation that the blasting activities associated with the Naudesbank Coal project be authorized subject to compliance with the conditions of the EMP, on condition that:

- That this report be updated once the actual blast design at the mine is finalized;
- This report be updated if the blast design is changed where more than 1,585 kg explosives are detonated per delay;
- This report be updated if the location of the opencast pit is moved with more than 100 m; and,
- This report be updated if the blast parameters changed with the mine making use of borehole with a larger diameter than considered in this report (150 mm) or the burden and spacing distances are increased.

Morné de Jager
Enviro-Acoustic Research cc
2023 – 06 – 02

CONTENTS OF THE SPECIALIST REPORT – CHECKLIST

Contents of this report in terms of Regulation GNR 982 of 2014, Appendix 6 (as amended 2017)		Relevant Section of Specialist study
(1)	A specialist report prepared in terms of these Regulations must contain-	
(a)	details of-	
	(i) the specialist who prepared the report; and	Section 1
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Section 1
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section 2
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 3.1
(cA)	an indication of the quality and age of base data used for the specialist report;	Not relevant for blasting vibration assessment
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Not relevant for blasting vibration assessment
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Not relevant for blasting vibration assessment
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 3.4
(f)	details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Sections 3.2.3
(g)	an identification of any areas to be avoided, including buffers;	Sections 3.2.3 and 8
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Sections 3.2.3 and 8
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 0
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Sections 8 and 9
(k)	any mitigation measures for inclusion in the EMPr;	Section 10.3
(l)	any conditions for inclusion in the environmental authorisation;	Section 10.3
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 10.3
(n)	a reasoned opinion -	Section 0
	whether the proposed activity, activities or portions thereof should be authorised;	Section 0
	regarding the acceptability of the proposed activity or activities; and	Section 0

Contents of this report in terms of Regulation GNR 982 of 2014, Appendix 6 (as amended 2017)		**Relevant Section of Specialist study**
	if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 0
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	No comments received
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	No comments received
(q)	any other information requested by the competent authority.	No comments received

This report should be cited as:

De Jager, M. (2023): "*Blasting Impact Assessment for the Proposed Naudesbank Coal Project west of Carolina, Mpumalanga Province*". Enviro-Acoustic Research CC, Pretoria

Client:

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ZC-SPNCP/BIA/202306-Rev 0

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Date:

June 2023

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APPENDICES

GLOSSARY OF ABBREVIATIONS

BSS	Blast Sensitive Structure
BSR	Blast Sensitive Receptors
DMRE	Department of Mineral Resources and Energy
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme report
EHS	Environmental, Health, and Safety
IAP	Interested and Affected Party
LOM	Life of Mine
mbs	Meter below surface
MWP	Mine Works Program
PSS	Potential Sensitive Structure
PPV	Peak particle velocity
USBM	United States Bureau of Mines

GLOSSARY OF UNITS

dB	Decibel (expression of the relative loudness of the un-weighted sound level in air)
dBA	Decibel (expression of the relative loudness of the A-weighted sound level in air)
Bcm	Bank cubic meters (of in-situ rock)
Hz	Hertz (measurement of frequency)
kg/m^2	Surface density (measurement of surface density)
km	kilometre (measurement of distance)
m	Meter (measurement of distance)
m^2	Square meter (measurement of area)
m^3	Cubic meter (measurement of volume)
mamsl	Meters above mean sea level
m/s	Meter per second (measurement for velocity)
Mtpa	Million tons per annum
mm/s	Millimetres per second (representing PPV)
µPa	Micro pascal (measurement of pressure – in air in this document)

1 THE AUTHOR

The Author started his career in the mining industry as a bursar Learner Official (JCI, Randfontein), working in the mining industry, doing various mining-related courses (Mining [stoping and development], Rock Mechanics, Surveying, Sampling, Safety and Health [Ventilation, noise, illumination etc.] and Metallurgy. He did work in both underground (Coal, Gold and Platinum) as well as opencast (Coal) for 4 years, the last two during which he studied Mining Engineering. He used to be a holder of a temporary blasting certificate during the period he mined at JCI: Cook 2 shaft. He changed course from Mining Engineering to Chemical Engineering after the second year of his studies at the University of Pretoria.

After graduation he worked as a Water Pollution Control Officer at the Department of Water Affairs and Forestry for two years (first year seconded from Wates, Meiring and Barnard), where duties included the perusal (evaluation, commenting and recommendation) of various regulatory required documents (such as EMPR's, Water Licence Applications and EIA's), auditing of licence conditions as well as the compilation of Technical Documents.

Since leaving the Department of Water Affairs, Morné has been in private consulting for the last 20 years, managing various projects for the mining and industrial sector, private developers, business, other environmental consulting firms as well as the Department of Water Affairs. During that period, he has been involved in various projects, either as specialist, consultant, trainer or project manager, successfully completing these projects within budget and timeframe. During that period, he gradually moved towards environmental acoustics and vibration, focusing on this field exclusively since 2007.

He has been interested in acoustics as from school days, doing projects mainly related to loudspeaker design. Interest in the matter brought him into the field of Environmental Noise Measurement, Prediction and Control that ultimately resulted in the addition of blasting impact assessments to services supplied. Blasting vibration was investigated for the following projects in the past two years:

- Vlakfontein Colliery – BCR Coal (Pty) Ltd
- Tumela Mine - Bierspruit Opencast - Anglo American Platinum Limited
- Vygenhoek Platinum Project - Nomamix (Pty) Ltd
- Gruisfontein Colliery - Nozala Coal (Pty) Ltd
- Bloemendal Coal Project – INSA Coal Holdings
- Dunbar Coal Project – INSA Coal Holdings
- Salene Manganese Project – Thari Resources (Pty) Ltd
- Ericure Coal Project – Ericure (Pty) Ltd
- VTM Mining Project – Ikwezi Vanadium (Pty) Ltd
- Goedgevonden Complex - Glencore Coal Operations South Africa (Pty) Ltd
- Arengo Iron Project - Arengo 297 (Pty) Ltd

2 DECLARATION OF INDEPENDENCE

I, Morné de Jager declare that:

- I act as the independent specialist on this project;
- I will perform the work relating to this specialist study 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 environmental impact assessments, including knowledge of the National Environmental Management Act (107 of 1998), the Environmental Impact Assessment Regulations of 2014, and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, 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 this project;
- all the particulars furnished by me in this form are true and correct;
- will perform all other obligations as expected from an environmental assessment practitioner in terms of the Regulations; and
- I realise that a false declaration is an offence in terms of regulation 71 and is punishable in terms of section 24F of the Act.

Disclosure of Vested Interest

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014.

____

Signature of the Specialist:

Name of company:

Enviro-Acoustic Research cc

Date:

2023 – 06 – 02

3 INTRODUCTION

3.1 INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Zyntha Consulting (Pty) Ltd to determine the potential impact from blasting activities on the surrounding environment due to the proposed development of the Naudesbank Coal project. This project is proposed west of the town of Carolina in the Mpumalanga Province.

This desktop report describes the potential blasting impacts that the operation may have on the surrounding built environment, highlighting the methods used, potential issues identified, findings and recommendations. This study considered local regulations and international guidelines.

3.2 BRIEF PROJECT DESCRIPTION

3.2.1 Overview of the Project

Seriti Power (Pty) Ltd (the mine) is proposing a mining operation, referred to as the Naudesbank Coal Project, with the regional location highlighted in **Figure 3-1**. This will be an opencast as well as underground mining operation.

Opencast mining will be an advancing open pit mining method, using trucks and shovels to mine the coal resource. Typical activities associated with opencast mining will include:

- The removal of vegetation, followed with the stripping of the available topsoil up to a predefined depth;
- The removal of subsoils and soft overburden till hard material is reached;
- The drilling of boreholes (blastholes) using a designed pattern and the charging of the blastholes with explosives (both overburden and coal resource);
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- Crushing and screening of the RoM, stockpiling and material handling (loading of road trucks);
- Traffic moving around onsite (including road trucks hauling coal product to the market);
- Rehabilitation activities; and
- Various ancillary activities to support the mining process.

To allow the mining of the underground coal resource, the mine would develop:

- An adit to allow the hauling of coal resource from the underground workings; and
- A vertical shaft to provide access to the underground working, as well as ensure adequate ventilation to the underground workings.

This assessment specifically focuses on the potential impact of vibration, airblast levels and the risk of flyrock associated with the blasting activities within the opencast pits. The blasting assessment only consider potential impacts associated with overburden blasting, as this is the major blasting activity associated with most opencast projects. Coal blasting in general is significantly smaller, with the coal resource much softer than the overburden geology resulting in significantly lower blasting related impacts.

This assessment in addition does not consider blasting from the development of the adit nor underground blasting activities. This is because blasting impacts associated with the development of underground infrastructure and underground mining is insignificant when compared with blasting impacts associated with opencast mining.

3.2.2 Project Alternatives

The mine proposes the mining of the coal resource as illustrated in **Figure 3-2**. This alternative is the result of a number of mining iterations to allow the optimal extraction of the coal resource with the minimum environmental impact. There are no location alternatives for the coal mining project, as the location is determined by the underlying geology and the location of the coal mineral resource.

3.2.3 Study area and Potential Sensitive Structures

The project focus area ("PFA") is an area selected to enclose, up to 2,000 m, from all potential locations where blasting may take place. **Figure 3-3** also illustrates the representative potential Blast Sensitive Receptors ("BSR"), with potential Blast Sensitive Structures ("BSS") located within 2,000 m of the proposed mining areas (that may be affected by blasting activities) illustrated in **Figure 3-4**. It is critical to note that each icon may represent a number of different receptors and/or structures. The following should be noted:

- Area within the 500 m buffer from areas where blasting may take place: Area around the future mining opencast area (where blasting may take place) where people and animals must be moved prior to blasting taking place. Ground vibration and air blast levels likely to be significant, with a high risk of fly-rock closer to the blast area. There are risks that structures within this area may be damaged or destroyed (when blasting taking place within 500 m).
- Area 500 to 2,000 m from areas where blasting may take place: Area outside the zone where fly rock may be a concern, but:
  - noise from the airblast could be very high;
  - in the unmanaged situation, ground vibration and air blast levels could be of a significant concern.
  - in a managed situation ground vibration and air blast levels may be insufficient to result in structural damage to most structures, but vibration and air blast levels will be sufficiently high to create annoyance with the blasting and project.
- Area further than 2000 m from locations where blasting may take place:
  - Noise from the airblast could be high and will be clearly audible;
  - In the unmanaged situation ground vibration and air blast levels could result in concerns and potential complaints;
  - In a managed situation ground vibration and air blast levels will be low and unlikely to result in reasonable concerns and complaints at distances further than 2,000 m. People however may still be apprehensive about potential blasting issues.

People however may still be concerned about blasting due to the secondary effects of blasting (such as the resonance from flat surfaces potentially perceived as vibration) as well as the perceived risks and dangers at significant distances from a blasting activity. It should be noted that there is no agreed distance where people may not experience annoyance with blasting activities, whether audible (due to airblast noises) or detectable (due to a ground vibration).

3.2.3.1 Sensitive Buildings (such as houses constructed using mud or adobe bricks)

The site was visited in September 2022, and no sensitive structures (typically adobe or buildings constructed from mud) were identified.

3.2.3.2 Sites of Archaeological, Cultural and Heritage importance

This assessment does acknowledge that a number of structures of potential cultural or archaeological significance may be located within, or close to the proposed mining opencast. Blasting activities may destroy the sites located directly within the mining opencast areas, though this should be investigated by the archaeology specialists.

3.2.3.3 Brick buildings and potential boreholes

There are a number of brick buildings (and other structures - indicated at markers 1 and 2) located within the areas where the plant or opencast mining activities may take place. All such buildings and structures will be destroyed (see also **Figure 3-3** and **Figure 3-4**). It is assumed that the receptors and livestock in this area will be relocated. A number of other structures are located within 500 m (markers 6, 7, 8, 9 and 10) as well as various other buildings and structures within 2,000 m. It is assumed that there will be a number of boreholes and small reservoirs associated with residential buildings.

3.2.3.4 Pipelines and Water Reservoirs (cement dams)

There are a number of cement dams within 2,000 m from the proposed opencast pits (where blasting may take place). It is assumed that there will be a number of small reservoirs associated with residential buildings (also see **Figure 3-4**).

3.2.3.5 Power Pylons and lines

No major power lines were identified within the PFA.

3.2.3.6 Steel Structures

Structures located at markers 1 and 2 are mainly constructed from wood and corrugated iron, but these structures are located within areas where mining infrastructure will be developed. There are a number of other steel structures used for residential purposes, as well as sheds (used as animal shelters, the storage of farming material and equipment).

3.2.3.7 Roads and Railway Lines

The R38 tar road pass south of Naudesbank pits 1 and 3, with the D1252 road passing very close to Naudesbank pit 4 (as per the MP-RAMS website[1]) (see **Figure 3-2**, **Figure 3-3** and **Figure 3-4**).

3.2.3.8 Water Resources, Wetlands and Natural Features

There are a number of water resources within the area that would be disturbed and destroyed by blasting activities. Opencast mining invariable destroy natural resources due to the nature of the activity, though this study will not provide an opinion on the magnitude of blasting impacts on such areas. This is a function of the aquatic specialist, that should:

- Identify and delineate the water resources, wetlands and similar natural features;
- Classify the importance of the water resources, wetlands and similar natural features; and
- Recommend measures to protect (which may include the use of appropriate buffer areas), or the implementation of offset strategies.

3.2.3.9 Animals and associated habitat

There are farming activities in the area, including animal husbandry (domestic animals). There will also be a number of different animal species within, and close to the proposed mining areas. Blasting activities will both destroy the available habitat and disturb the animals in the area. Wild animals however will naturally move away from the active mining area due to increased vehicular movement and mining activities, though blasting noises and vibration may affect domesticated animals during blasting events as discussed in **section 6.1**. This study however will not provide an opinion on the impact on animals, as this should be the function of a faunal specialist that should:

- Identify the various species located in the area;
- Define the sensitivities of the various species, recommending potential measures to manage the impact of blasting activities on these species. This may include the implementation of buffer areas or development of offset areas.

3.2.3.10 Vegetation and plant resources

Blasting activities will completely destroy vegetation located within the areas to be mined. This study however will not provide an opinion on the impact on flora, as this should be the function of a flora specialist that should:

- Identify the various species located in the area;
- Define the sensitivities of the various species, recommending potential measures to manage the impact of blasting activities on these species. This may include the relocation of certain plants, the implementation of buffer areas or development of offset areas.

[1] Mpumalanga Provincial Road Asset Management System (RAMS) (mp-rams.co.za)

3.2.3.11 Existing Mining Infrastructure

There is an existing mine located just east of the Vaalbank section of the Naudesbank Coal project. This assessment does not consider the potential impact of blasting activities on the equipment and infrastructure of this mine, though the recommendations contained in this report will be valid for the equipment and infrastructure of this mine.

3.3 SITE SENSITIVITY IN TERMS OF REGULATION 320 OF 2020

The online screening tool does not cover blasting vibration as a potential environmental theme that needs further investigation.

3.4 TERMS OF REFERENCE

Unfortunately, there are no guidelines, standards or legislation in South Africa that specifically covers vibration from blasting activities, air blast levels and fly rock control. Therefore, this report is based on available literature used in other countries, specifically the standards and guidelines developed by the United States Bureau of Mines (USBM).

Ground vibration is associated with various different activities, including amongst others from heavy equipment operating, traffic movement, tunnelling, underground blasting etc[2]. These vibrations however are minor when compared to blasting associated with the development of boxcuts, adits as well as opencast mining activities.

This study specifically would assess the potential blasting impacts from the development of the boxcut as well as the mining (blasting) associated with the Opencast Pit.

A blasting impact assessment is done to estimate the potential risk that blasting activities may pose to receptors staying in the vicinity of the operation as well as any infrastructure located within the potential zone of impact. This assessment investigates the potential magnitude of ground vibration, air blast sound pressure levels as well as the potential zone of influence from fly rock due to blasting activities. The potential magnitude of blasting related impacts (ground vibration, air overpressure and fly rock dangers) is calculated in a scientific manner, using that information to rate the potential significance of these dangers and provide mitigation and management measures if a potential medium or high significance risk is identified. The mitigation measures should be sufficient to reduce the potential risk to a low significance.

[2] The upper range of vibration levels from pile driving activities are ± 3 mm/s at 40 m, although typical levels are far less. Vibration levels from a large bulldozer or a loaded truck working or operating at 10 m from a location are around ±1.5 mm/s.

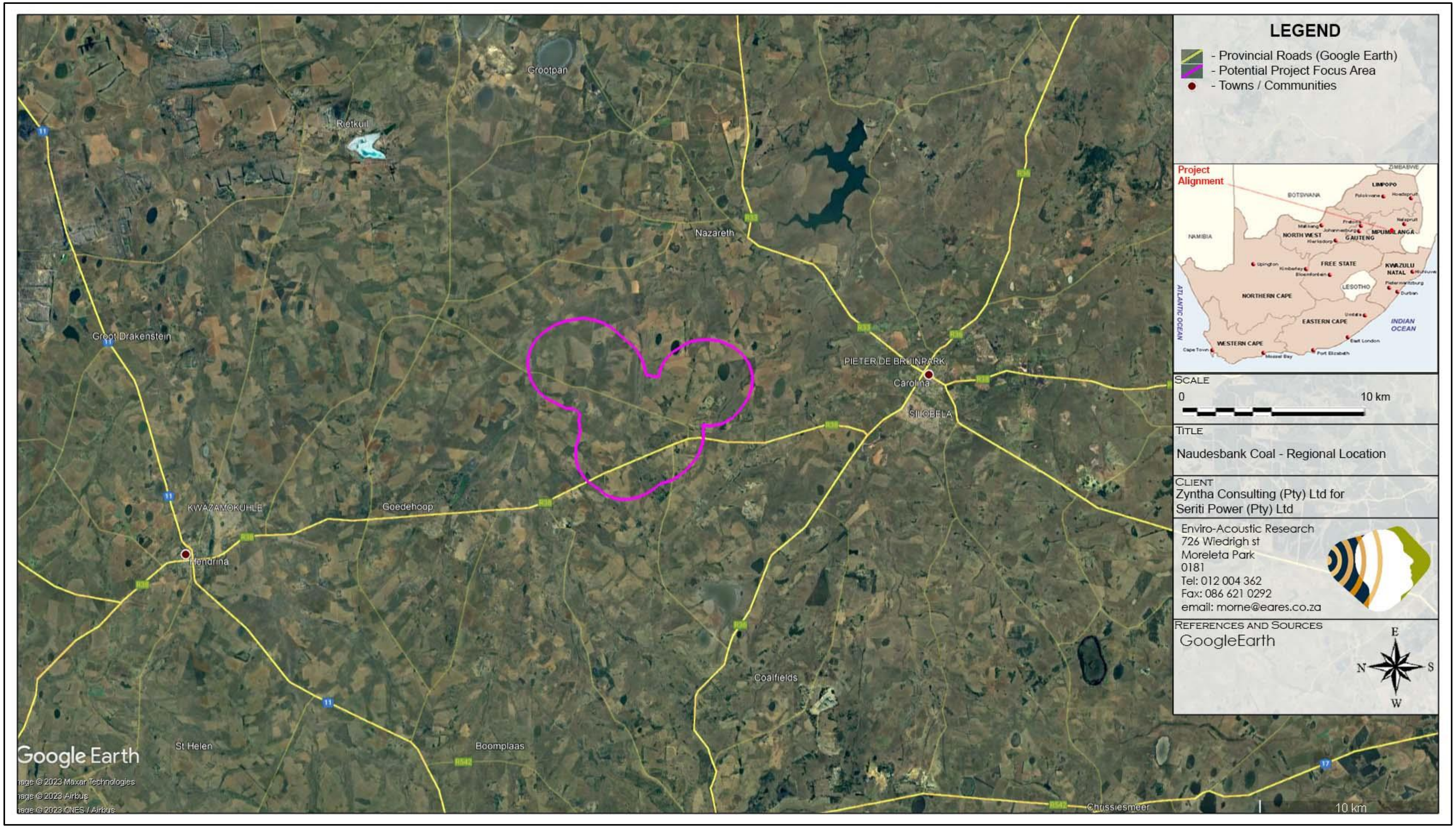

Figure 3-1: Regional location of the proposed Naudesbank Coal project

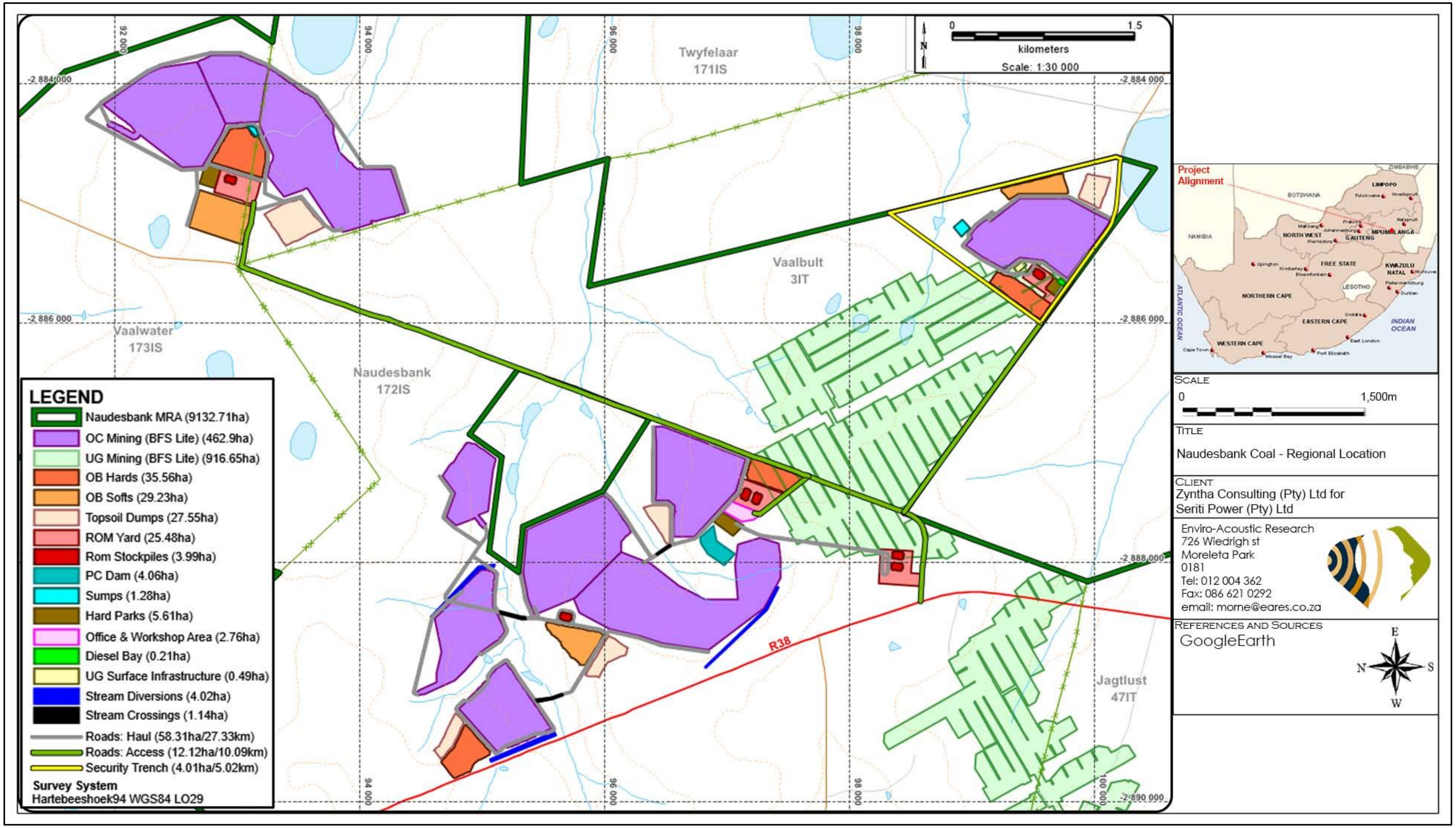

Figure 3-2: Project layout and potential layout alternatives

Figure 3-3: Aerial image indicating potential BSR within 2,000 m of potential blasting areas (opencast areas)

Figure 3-4: Aerial image indicating potential BSS and Infrastructure within 2,000 m of potential blasting areas (opencast areas)

4 LEGAL CONTEXT, POLICIES AND GUIDELINES

4.1 MINERAL AND PETROLEUM RESOURCES DEVELOPMENT ACT, 2002 (ACT 28 OF 2002)

The Mineral and Petroleum Resources Development Act (MPRDA) governs the acquisition, use and disposal of mineral rights. It however does refer the management and control of blasting, vibration and shock to the Mine Health and Safety Act (Act 29 of 1996), as well as other applicable law in section 67. It stipulates that impacts relating to blasting, vibration and shocks be assessed and form part of the environmental management and authorization reports.

4.2 MINE HEALTH AND SAFETY ACT NO. 29 OF 1996 (AS AMENDED, ACT 74 OF 2008)

The Mine Health and Safety Act was established to assist the Department of Mineral Resources to safeguard the health and safety of mine employees and communities affected by mining operations.

Regulations (Government Notice R.584 of 2015) were made in terms of Section 98 of this Act (Act 29 of 1998) covering the safe use of Explosives on a mine.

This Act and associated regulations do not stipulate limits for ground vibration and air blast levels, nor limit the distances that fly rock travel. GNR.584 of 2015 does limit blasting within 500 m from certain structures unless various conditions are met.

It does state:

Precautionary measures before initiating explosive charges

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

General precautions

Clause 4.16. The employer must take reasonable measures to ensure that:

(1) in any mine other than a coal mine, no explosive charges are initiated during the shift unless –
  (a) such explosive charges are necessary for the purpose of secondary blasting or reinitiating the misfired holes in development faces;
  (b) written permission for such initiation has been granted by a person authorised to do so by the employer; and
  (c) reasonable precautions have been taken to prevent, as far as possible, any person from being exposed to smoke or fumes from such initiation of explosive charges;

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

  (a) a risk assessment has identified a lesser safe distance and any restrictions and conditions to be complied with;
  (b) a copy of the risk assessment, restrictions and conditions contemplated, in paragraph (a) have been provided for approval to the Principal Inspector of Mines;
  (c) shot holes written permission has been granted by the Principal Inspector of Mines; and
  (d) any restrictions and conditions determined by the Principal inspector of Mines are complied with.

4.3 EXPLOSIVES ACT (AS AMENDED, NO. 15 OF 2003)

The Explosive Act manage the manufacture, importation, exportation, transportation, distribution, destruction, storage and any other use of explosives. The regulations define the requirements for the person that manages blasting activities, including the safe use of explosives. This Act and associated regulations do not stipulate limits for ground vibration and air blast levels, nor for limiting the distances that fly rock travel.

4.4 OCCUPATIONAL HEALTH AND SAFETY ACT (ACT 85 OF 1993)

The Occupational Health and Safety Act aims to provide for the health and safety of persons at work and for the health and safety of persons in connection with the activities of persons at work and to establish an advisory council for occupational health and safety.

The Occupational Health and Safety Act are supported by subordinate legislation, Regulations and Codes of Practice, which give practical guidelines on how to manage health and safety issues. The health and safety standards for employers and users of explosives at the workplace are covered in the Explosives Regulation promulgated under this Act. This Act and associated regulations do not stipulate limits for ground vibration and air blast levels, nor can limiting the distances that fly rock travel.

4.5 INTERNATIONAL FINANCE CORPORATION GUIDELINES

4.5.1 IFC: Environmental, Health and Safety Guidelines - Mining

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry specific examples of Good International Industry Practice (GIIP). When one or more members of the World Bank Group are involved in a project, the EHS Guidelines are applied as required by their respective policies and standards.

The guideline provides a summary of EHS issues associated with mining activities (and including ore processing facilities) which may occur during the exploration, development and construction, operation, closure and decommissioning, and post-closure phases, along with recommendations for their management.

It identifies potential environmental issues associated with mining activities, including noise and vibrations that may require management.

4.5.2 IFC: Environmental, Health and Safety Guidelines – General EHS Guidelines: Occupational Health and Safety

The guideline obliges Employers and supervisors to implement all reasonable precautions to protect the health and safety of workers. It provides guidance and examples of reasonable precautions to implement in managing principal risks to occupational health and safety.

5 BLASTING RELATED IMPACTS – THEORY AND CALCULATION

5.1 CRITICAL BLAST DESIGN TERMINOLOGY

The following terms are highlighted as illustrated in **Figure 5-1** as it is referred in this report, with additional terms defined in Appendix A (Glossary of Terms).

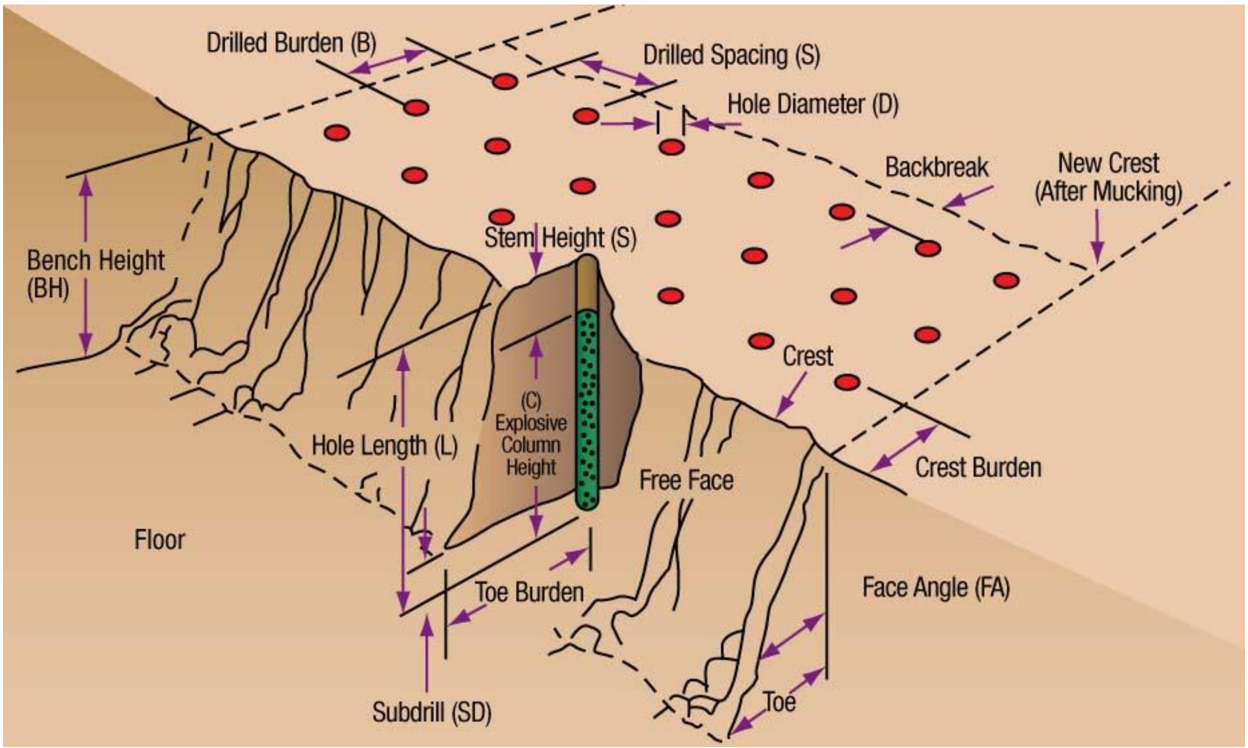

Figure 5-1: Blast Design Terms (from Explosives Engineers' Guide)

5.2 FACTORS THAT INFLUENCE BLASTING DESIGN AND BLAST IMPACTS

Before a blast is designed, the blaster will consider factors such as:

- Desired fragmentation – Material digging/handling/crushing equipment available, any sizing requirements of the blasted rock;
- Rock quality and character – Type of rock (hard, porous, soft), presence of joints, faults, dykes, other intrusions, voids or incomplete zones, presence of water in boreholes;
- Site and safety limitations – Location of structures or property to be protected, distance to utilities or infrastructure, vibration and airblast considerations, traffic control requirements, sensitivity of blast sensitive receptors; and
- Equipment and material limitations – Type and sizes of available drilling equipment, type of explosives available.

For a new project, when little information is available, the following principles are considered:

- The blast is more efficient when one or more free face is available (the rock being blasted can break into a certain direction). This is generally possible during typical opencast mine blasting[3];
- For boxcut or developmental blasting (blasting in a confined environment) an open void or space must be available into which the blasted rock can move/expand. In such instances sufficient timing delays should be implemented to ensure that fractured rock from the initial blastholes is expelled to allow room for following blastholes to expand;
- The better the explosives are confined in the borehole (charging process, or the use of an explosive such as an emulsion) the more efficiently the energy is converted to breaking the rock;
- Local geology (strength and character of the rock) and the amount of energy available (from explosion) will determine the burden spacing that can be successfully blasted;
- The optimal borehole diameter should consider fragmentation required, bench height (or the depth of the development/shaft/boxcut), the local geology though the availability of certain drilling equipment may at times be a determining factor;
- Smaller borehole diameters (with smaller burden and spacings) will allow better fragmentation with lower blasting vibration impacts. Smaller borehole diameters unfortunately increase borehole drilling and blasthole loading costs;
- Larger borehole diameters will allow taller bench heights, with larger burden and spacing distances. Drilling and explosive loading costs are less, though blasting vibration impacts could increase.

VARIABLES THAT CANNOT BE CONTROLLED	
Geology	Rock mass characteristics
Faults, fractures, joints, dykes, intrusions, voids	Presence of water

VARIABLES THAT CAN BE CONTROLLED		
DRILLING	CHARGING / LOADING	FIRING / DETONATION
Borehole diameter and depth	Type of explosives	Detonator system
Burden and spacing	Charge method and design	Timing delays
Sub drilling and bench height	Charge/column length	No. of free faces
Inclination and deviation	Delay pattern	Water ingress / presence of water

BLAST RESULTS
Fragmentation achieved
Post blast rock pile profile and throw
Presence of fly-rock
Magnitude of blast vibration
Under and over-breaking
Misfires

EVALUATION OF BLAST RESULTS

Figure 5-2: Flow diagram illustrating continious optimization of blasting parameters

[3] A presplit blast is done during the initial development of the boxcut to provide a partial open face.

Once a borehole diameter is selected, an initial blast design could be created using available guidelines and reference manuals. The performance of the blast must continuously be monitored to ensure that the blast is optimized as illustrated in the flow diagram illustrated in **Figure 5-2** on the previous page.

5.3 GROUND VIBRATION: THEORY AND CALCULATION

When an explosive charge is detonated in rock, the charge is converted into hot gases that generate intense pressure over a very short time period. This pressure will melt and crush the rock directly around the blast hole to a certain point. Radial cracks will develop until the rock loses its inelastic properties. The lengths of these cracks are usually determined by the rock properties, explosive properties and the blast design. Broken rock will move upwards and outwards with the level of movement depending on the type and quantity of explosive as well as blast design. The initial shock front causes waves similar to sound waves on the surface and within the body of the earth. Body waves may be reflected or refracted to the surface to become surface waves. These different waves can be further classified but this is beyond the purpose of this assessment.

Compressional and shear body waves propagate spherically from the blast and can be described in three dimensions, namely up-down ("vertical"), back-forth ("longitudinal") and side-to-side ("transverse"). These differences are also important from the damage standpoint; vibrations in the transverse and longitudinal (sometimes referred as "radial") directions cause potentially damaging "shear" (differing directions or speeds of movement) within structures. Vertical movement is usually less damaging, though not entirely without consequence, because structures are built to withstand vertical forces.

The vibrational waves can be measured using a seismograph and described in terms of displacement, velocity, acceleration as well as the frequency components of these complex waves.

It is also possible to estimate, with a level of confidence, the peak amplitude level of the ground vibration wave. There is an inverse square relationship from the blast as the vibrational energy spread in a spherical manner from the source. While there are a number of empirical formula (Kumar, 2016) that can be used to calculate the magnitude of the vibration, this report uses the square root scaled distance method as developed by the United States Bureau of Mines (Rosenthal, 1987; RI 8507). This formula considers the three most important factors in the magnitude of vibration, namely:

- the distance from the blast – this is the most significant factor to determine the magnitude of the vibration level;
- the magnitude of the blast, defined by the instantaneous explosive mass (also referred as charge per delay) as the source of vibration energy;
- the geology of the site. This is represented by constants that can be experimentally determined for a specific site with vibration measurements.

$$\boldsymbol{v = k\left(\frac{D}{\sqrt{Q}}\right)^{e}}$$ **Equation 1**

Where:

v = peak vibration (PPV) (mm/s)

D = distance from blast (m)

Q = instantaneous charge mass (kg)

k = site constant (initially assumed and can be experimentally determined)

e = site constant (initially assumed and can be experimentally determined)

The site constant 'k' has been determined for different locations and are available in literature, although onsite measurements will allow the more accurate determination of this constant. Firing to a free face, in hard or highly structured rock this constant could be:

- Coal mining or quarries: k = 500 (or less),
- **For a free face in average conditions: k = 1149 (which this assessment will use),**
- For heavily confined blasting, near field: k = 5000.

Typical values of constant 'e' for different rock types are:

- Rhyodacite/Rhyolite: e = 2.2 – 2.5,
- Granite: e = 2.1 – 2.4,
- Limestone: e = 2.1,
- Ordovican sediments: e = 2.8,
- **Hard mine overburden: e = 1.5 – 1.8 (this assessment will use 1.51)**,
- Coal and Basalt (clay floor): e = 1.4 – 1.6,
- Basalt (massive): e = 1.9 – 3.0.

5.4 AIR BLAST: THEORY AND CALCULATION

The term air blast (also known as air overpressure) is used to describe air vibrations generated by blasting activities. Although not quite impossible, it is quite unusual for blasting activities to create air waves that will reach potential damaging level to buildings. If this occurs the evidence is present and clearly identifiable in the form of shattered or broken windows.

Although this phenomenon might be rare, much interest is attracted to air waves when they generate sound. The sound is what normally causes an alarm to receptors especially if they are unaware of such activities. The air wave carries acoustic energy from less than 1 Hz to the ultrasound range, although most of this energy is concentrated in the lower frequency range. Acoustic energy below 20Hz is referred to as air blast and above 20Hz (the audible range) as noise. When in the audible range it can be extremely annoying to receptors.

As with ground vibration calculations, the calculation of air blast levels is based on empirical formulas, also developed by the USBM.

$$\boldsymbol{L_{USBM} = 165 - 24.\log\left(\frac{D}{\sqrt[3]{Q}}\right)}$$ **Equation 2**

Where:

L_{USBM} = Noise levels due to air blast (dB) as per the USBM method

D = distance from blast (m)

Q = instantaneous charge mass (kg)

An alternative method is employed by the Australian Department of Mines (and Petroleum), defined in Australian Standard AS 2187.2 presented in in **Equation 3** below:

$$\boldsymbol{P = K\left(\frac{D}{\sqrt[3]{Q}}\right)^{a}}$$ **Equation 3**

and

$$\boldsymbol{L_{AS} = 10\log\left(\frac{P}{P_0}\right)}$$ **Equation 4**

Where:

L_{AB} = Noise levels due to air blast (dB) as per the Australian Department of Mines method

D = distance from blast (m)

Q = instantaneous charge mass (kg)

K = a site constant in the region of 1 – 10,000 (using 5,000 initially)

a = a site constant in the region of -1 to -2 (using -1.45 initially)

The Australian Department of Mines method can be employed when data (noise levels) from a number of blasts are available and the site-specific constants can be calculated. This assessment will consider both the USBM and AS 2187.2 methods, reporting on the highest airblast levels.

5.5 FLY ROCK: THEORY AND CALCULATION

The main purpose of blasting is the adequate fragmentation of the rock mass, with secondary purpose (at times) of moving as much as possible of the rock mass to minimise additional ground movement using trucks, draglines or other heavy equipment from the blast area. Unfortunately, a portion of the explosive energy is lost due to the generation of blast rock that may result in face bursting, cratering and rifling. This is depicted in **Figure 5-3**.

Fly rock is generally perceived as the rock propelled beyond the blast area. IME (1997) has defined fly rock as the rock(s) propelled from the blast area by the force of an explosion. Generally, fly rock is caused by a mismatch of the explosive energy with the geo-mechanical strength of the rock mass surrounding the explosive charge. Factors responsible for this mismatch include:

- Abrupt decrease in rock resistance due to joint systems, bedding layers, fracture planes, geological faults, mud seams, voids, localized weakness of rock mass, etc.
- High explosive concentration leading to localized high energy density,
- Inadequate delay between the holes in the same row or between the rows,
- Inappropriate blast design,
- Deviation of blast holes from its intended directions,
- Improper loading and firing practice, including secondary blasting of boulders and toe holes.

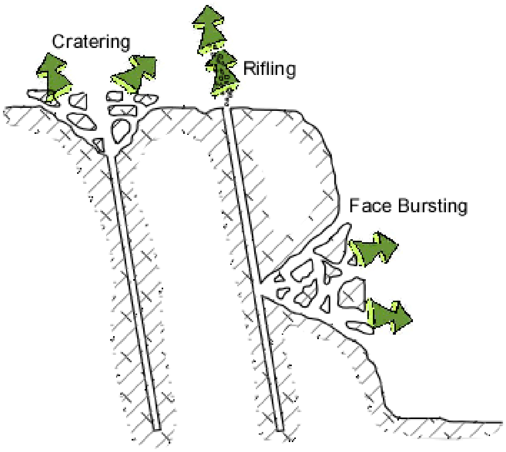

Figure 5-3: Illustration of sources of fly rock

The potential throw distances of fly rock can be estimated using tables or empirical formulas highlighted below:

$$\textit{Face bursting} \quad D_{FB} = \frac{k^2}{g}\left(\frac{\sqrt{m}}{B}\right)^{2.6}$$ **Equation 5**

$$\textit{Cratering} \quad D_C = \frac{k^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6}$$ **Equation 6**

$$\textit{Rifling} \quad D_R = \frac{k^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6} \sin\theta$$ **Equation 7**

Where:

Θ = drill hole angle (worse case 80°)

D_{FB}, D_C, D_R = maximum throw (m)

m = charge weight/m (kg/m)

B = burden (m)

SH = stemming height (m)

g = gravitational constant (9.81 m/s^2)

k = a constant (can be refined with measurements)

Ghasemi *et al* (2012) also developed an empirical formula, based on the analysed data from various blasts, with this formula considering various input parameters (see **equation 8** below).

$$\boldsymbol{Flyrock\ D_{FR} = 6946.547\left[B^{-0.796}S^{0.783}SH^{1.994}H^{1.649}D^{1.766}\left(\frac{PF}{Q}\right)^{1.465}\right]}$$ **Equation 8**

Where (if not defined above):

S = Spacing (m)

H = Depth of borehole (m)

d = Borehole diameter (m)

PF = Powder Factor (kg/m^3)

Q = mean charge per blast-hole (m)

This assessment will consider the various equations and report the potential worst-case fly rock throw distances.

As this study use general constants, it may be required that the mine measure the ground vibration as mining continue. This data can then be analysed to derive site-specific constants that must be used to review and update this blasting impact assessment in the future.

6 IMPACT ASSESSMENT AND SIGNIFICANCE

6.1 BLASTING IMPACTS ON ANIMALS

Currently there are no government policies or accepted guidelines with regard to noise (or vibration) criteria for animals (Blickley et al., 2010). The effect of noise on wildlife can be similar to the effects observed in humans. Noise can adversely affect wildlife by interfering with communication, masking the sounds of predators and prey, cause "stress" or avoidance reactions and (in the extreme) result in temporary or permanent hearing damage.

A significant amount of research was undertaken during the 1960's and 70's on the effects of aircraft noise on animals (Autumn, 2007; Noise quest, 2010). While aircraft noise has a specific characteristic that might not be comparable with industrial or mining noises, the findings should be relevant to most noise sources. A general animal behavioural reaction to aircraft noise is the startle response with the strength and length of the startle response to be dependent on the following:

- which species is exposed;
- whether there is one animal or a group of animals, and
- whether there have been some previous exposures.

Overall, the research suggests that species differ in their response to noise depending on the duration, magnitude, characteristic and source of the noise, as well as how accustomed the animals are to the noise (previous exposure). It is likely that animal responses depend on the intensity of the perceived threat rather than the intensity of noise (Barber et al., 2011), with Bejder et al. (2009) classifying the behavioural responses into three categories as follows:

- Habituation to the noise as animals learn that there are neither adverse nor beneficial consequences associated with the noise – an ongoing behavioural process;
- Sensitisation to the noise as animals learn that repeated or ongoing noises has consequences for the animal – an ongoing behavioural process; and
- Tolerance is the intensity of a disturbance (or stimulus) that an animal may tolerate without responding in a defined way – Tolerance in a behavioural state.

While guidelines levels are not available, an internet search highlighted a study where the response of zoo animals were observed and recorded (Fraser et al., 2000) during blasting activities as close as 100 m from various zoo animals. The project recorded noise and vibration levels, measuring cortisol levels in faeces and urine of three animal species as well as documented the responses of a number of species[4] during eight blast events.

The author(s) (Fraser *et al.*, 2000) stated the following: "*it is clear that many animals perceived the noise of the first few blasts and reacted to the noise in ways that suggest mild alarm It also would appear that animals are*

[4] Fruit bats, elephant, Francois Tree Monkey, Impala, Mangabey Money, Mole Rat, Mole Snake, Monitor, Rough Skinned Newt, River Otter, Penguin, Rhino, Snow leopard, Spotter owl and trout.

habituating to the noise by the eights blast. It is noteworthy that the elephants were amongst the most reactive although their exhibit is furthest away from the blast zone. It is tempting to speculate that this may be due to increased sensitivity to low frequency sound in these animals."

Due to a lack of any guidelines or standards, it is difficult to assess the potential significant of noise or vibration effects on animals.

6.2 BLASTING IMPACTS AND HUMAN PERCEPTIONS

Beginning in the 1930s, research was conducted with volunteers to determine sensitivities to vibrations (Griffin, 1996). Although people are sensitive to sounds and vibrations, it is difficult to quantify perceptions. Inside a structure, people will feel the building shake and hear the objects around them rattle such as windows and knick-knacks on walls. When an event is perceived, some people will say that they felt very strong vibrations, even if the vibration was too low to be felt outside. The reactions of people are best understood when observed in their own homes during times of real-life events. These reactions may not be the same as those of volunteers under controlled conditions.

Human response to blasting is subjective, as two people will react differently to the same vibration event depending on where they are in a structure, their frame of mind and their personality. Unfavourable reactions to vibrations may often result in complaints. When residents feel a blast, they may become concerned about damage to their home.

The threshold peak particle velocity of ground vibration perception is about 0.51 mm/s for most people. This is 1/100 of the limit of 50 mm/s commonly used for construction blasting.

People in different living environments normally perceive blasting as negative. If a project is not perceived as beneficial to a community, blasting on the project may be unwelcome.

In addition, during a blast event, people inside a building tend to perceive\experience\feel the vibrations differently than people outside a building. People inside a structure are immersed in the vibration event and often cannot tell the source of the vibration. The windows may rattle and there may be other structure responses that enhance their perception of the event. They can also perceive structure vibrations that are well below levels that could possibly cause threshold damage, yet, due to the fear of potential damage, this perception could be result in an increased response (stress, complaints, etc.). On the other hand, a person outside a structure will not notice any of the structure responses. Therefore, their perception of the event will generally be much less, mainly relating to the audible noise or the pressure changes relating to the air blast.

6.3 WHY BLASTING CONCERNS COMMUNITIES

For hard rock mining, blasting is considered as the most efficient and economical method used for fragmenting rocks masses. Nonetheless, in reality only 20-30% of the available energy is used for rocks fragmentation and displacement, while the rest is wasted in the form of ground vibration, air blast, noise and fly-rocks.

Ground vibration and air blast are a matter of great concern as they could result in damage to existing surface structures and generate nuisances to the receptors in the vicinity of mines.

Currently there are no specific legislation pertaining to blasting vibration levels, air blast levels and fly rock control in South Africa. However, most developed countries have ground vibration standards, although most of these standards are based on the following three standards/guidelines, namely:

- Vibration criteria as published by the US Bureau of Mines (USMB) and the US Office of Surface Mining (OSM) – USBM RI 8507 only focus on potential blasting impacts.
- The Swiss standards (SN 640 312a) that are effectively three different standards; one used for blasting, one for pile driving and one used for machines and traffic.
- Vibration limits as developed by the Federal Transit Administration (FTA Noise and Vibration Manual) – used for road construction and traffic.

This report will use the vibration criteria as published by the US Bureau of Mines (USMB) to define the potential impact of blasting vibration on the surrounding environment.

6.3.1 Ground Vibration

Humans begin to perceive ground vibration at around 0.12 mm/s PPV, a level significantly lower than the vibration level where damage may start to occur. The longer a vibration of a given peak velocity lasts; the more disturbing people will find it. In addition, the longer a vibration lasts, the greater the probability of it causing damage, all other things being equal. It should be noted that there is no correlation between vibration complaints and the ground vibration level, as people may start to complain about vibration even at very low levels.

Chiappetta (2000) and Griffin (1996) defined ground vibration levels for different frequencies as defined in **Table 6-1** and illustrated in **Figure 6-1**.

Table 6-1: Human response to ground vibration

Effects on Humans	Ground vibration Level (mm/s)	Comment (FRA, 2012)
Imperceptible	0.025 – 0.076	The vibration level ± 270 - 130 m from a vibratory roller
Barely perceptible	0.076 – 0.254	The vibration level ± 130 - 58 m from a vibratory roller
Distinctly perceptible	0.254 – 0.762	The vibration level ± 58 - 28 m from a vibratory roller
Strongly perceptible	0.762 – 2.540	The vibration level ± 28 - 13 m from a vibratory roller
Disturbing	2.540 – 7.620	The vibration level closer than 13 m from a vibratory roller
Very disturbing	7.620 – 25.400	The vibration level right next to a vibratory roller

Vibration damage probability, as with many other quantities in science, roughly follows an S-shaped "sigmoid curve", as a function of vibration intensity. Over a range of low vibration intensities, no houses are damaged. At these low intensities, people may be able to feel the vibration, even though no visible damage is done. At the highest vibration velocities (intensities), virtually all structures experiencing the vibration can visibly be damaged. Essentially all the people feeling such a high intensity vibration will be made distinctly uncomfortable by it. This report uses a limit of 2.54 mm/s as a potentially disturbing and 7.6 mm/s very disturbing.

The USBM RI 8507 standard is generally accepted in South Africa. This standard was developed through research and available data over a number of years and focus on the protection of structures from potential damage. It uses an analysis graph that considers vibration amplitudes and frequency to define the risk of potential structural damage due to ground vibration (See also **Figure 6-1**). To minimise complaints from receptors, vibration levels should ideally be kept beneath the "unpleasant" curve (this is measured from actual blasts).

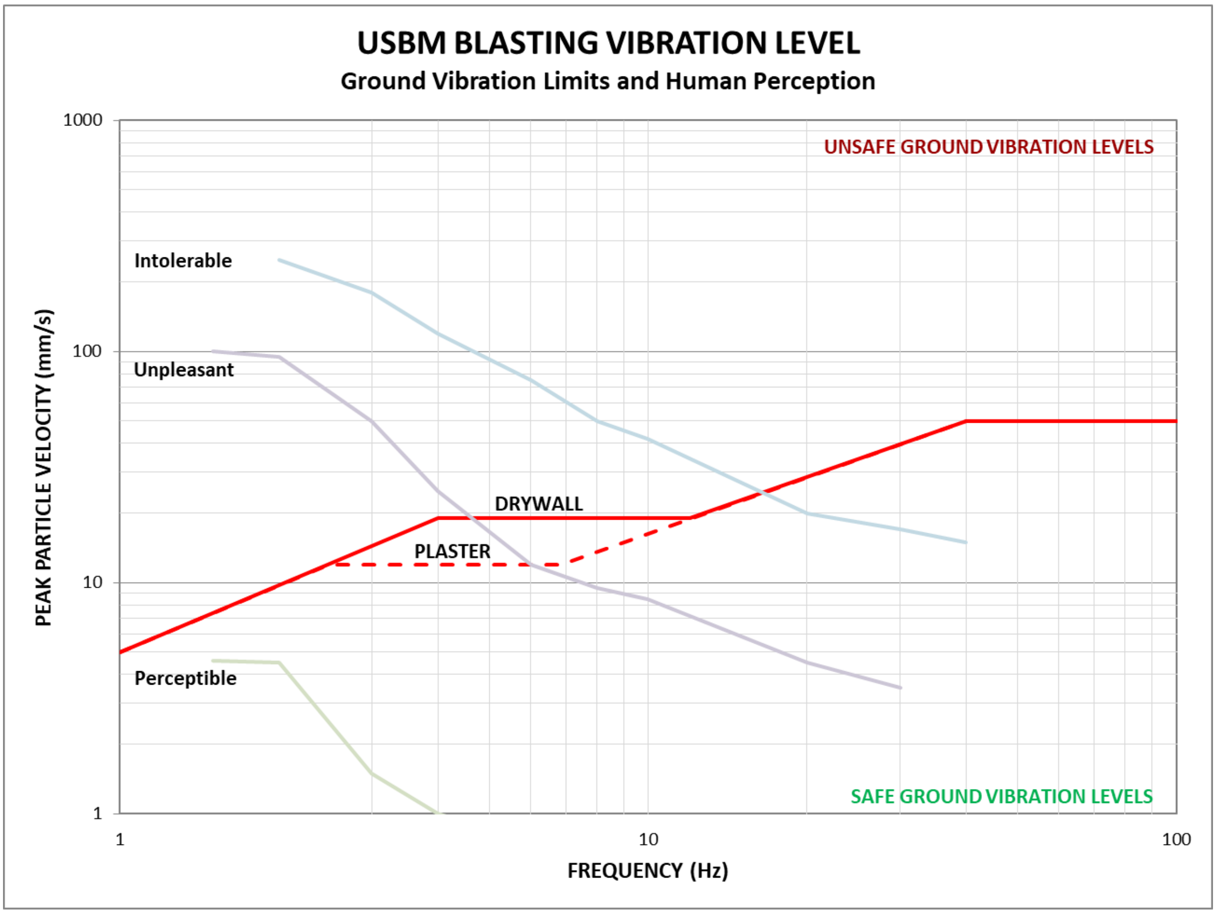

Figure 6-1: Human vibration sensitivities and potential structural damage compared to the RI 8507 limits

To avoid damage to buildings, ground vibration levels should be within the "safe" area as highlighted in **Figure 6-1**. Information from USBM RI 8507 indicates that 50% of homes will experience "threshold damage" at a velocity of about 51 mm/s. For "minor" damage, that 50% point is at about 76 mm/s, while for "major" damage, it is at about 100 mm/s. At the 5% probability level, the PPV for threshold damage from blasting vibrations is about 18 mm/s, based on the same data (drywall construction). The OSM and RI 8507 19 mm/s mid-frequency limits are, thus, set at a level which has approximately a 5% probability of causing damage to a drywall from direct ground vibration.

These limits are developed for different types of structures and materials and highlighted in **Table 6-2** (also refer to **Appendix B** for a more complete list and the sources). This report will use the vibration limits as defined below, including a 6 mm/s limit for potential sensitive structures (though none were identified for this project). This assessment will also use a limit of 50 mm/s for potential cement dams, even though Bauer (1977) reports cracking of concrete blocks at a PPV of 203 mm/s. This may be a very precautious approach, as the cement structures may be reinforced concrete (which would be more resilient to vibration impacts). There are no guidelines for graves and sites of cultural importance, with this report considering a limit of 150 mm/s for graves and sites of cultural significance.

Table 6-2: Ground vibration limits for various structures

Material / Structure	Ground vibration limit (mm/s)
National Roads / Tar Roads / Railways	150
Electrical Lines (steel pylons) and steel structures	75
Steel pipelines, cement dams	50
Sensitive Plant equipment, mortar and brick houses, boreholes[5]	25
Sensitive structures, adobe and informal houses	6
Buildings extremely susceptible to vibration damage	3

6.3.2 Air blast concerns

Air blasts can cause discomfort to persons and, at high levels, damage to structures. At very high levels, it may even cause injury to people. Air blasts could also interact with structures and create secondary noises which people detect, raising their concern about the blasting activity. While rare, window breakage may be the result of an air blast. Air blast levels that may result in damage were estimated by Persson (1994) and Oriard (2002) and is defined in **Table 6-3**.

Table 6-3: Air blast levels that may result in damage or complaints

Descriptor	Acoustic Level (dB)
Air pressure from an 11 m/s wind gust.	110
Annoyance threshold in Australia. Mildly unpleasant.	115
Recommended limit in Australia for sensitive sites.	**120**
Resonant response of large surfaces (roofs, ceilings). Complaints start.	130
Limit for human irritability. USBM and OSMRE limit.	**134**
Some windows break.	150
Most windows break.	170
Structural Damage.	180

[5] Boreholes may be associated with the cement dams, water reservoirs and BSR

6.3.3 Fly-rock concerns

Fly rock is a significant danger to people, equipment and structures with damage due to this being undeniable. Mines therefore go through significant effort to ensure that the risks from fly rock are absolutely minimized due to the potential penalties to the mine if fly-rock complaints are registered. These penalties may be institutional consequences (regulatory directives, fines, legal action) and monetary compensation. As such there should be no risk of fly rock at structures or where people or animals may congregate. This is the main reason for the 500 m exclusion zone around blasting activities.

6.4 DETERMINING THE SIGNIFICANCE OF THE BLASTING IMPACTS

Regulation 50(c), of the MPRDR (2004) under the MPRDA (2002) requires an assessment of nature (status), extent, duration, probability and significance of the identified potential environmental impacts of the proposed mining operation.

Once a potential impact has been determined it is necessary to identify which project activity will cause the impact, the probability of occurrence of the impact, and its magnitude and extent (spatial and temporal). This information is important for evaluating the significance of the impact, and for defining mitigation and monitoring strategies. Direct and indirect impacts of the impacts identified during the specialist investigations were assessed in terms of five standard rating scales to determine their significance.

The rating system used for assessing impacts (or when specific impacts cannot be identified, the broader term issue should apply) is based on five criteria, namely:

- **Spatial extent** of impacts (**Table 6-4**) – determines the spatial scale of the impact on a scale of localised to global effect. While ground vibration and air blast effects can be perceived over distances as far as 10 km, potential damages relating to ground vibration and air blast are normally limited to a zone within 2,000 m from the blast and the effect of blasting will be limited to Local/Regional (medium – rating level of 3);
- **Duration** of impacts (**Table 6-5**) – refers to the length of time that the aspect may cause a change either positively or negatively on the environment. Potential impact is expressed numerically on a scale of 1 (project duration) to 5 (permanent), with blasting activities for this project associated with the construction period (temporary to short term, with this assessment using short-term [rating level of 2]);
- **Severity** of impacts (**Table 6-6**) – quantifies the impact in terms of the magnitude of the effect on the baseline environment, and includes consideration of the following factors:
    - The reversibility of the impact;
    - The sensitivity of the receptor to the stressor;
    - The impact duration, its permanency and whether it increases or decreases with time;
    - Whether the aspect is controversial or would set a precedent;
    - The threat to environmental and health standards and objectives;
- **Probability** of impacts (**Table 6-7**) – quantifies the impact in terms of the likelihood of the impact occurring on a percentage scale of <5% (improbable) to >95% (definite).

The Consequence Rating is calculated by summing Spatial Scale (Extent), Duration and Severity, with the Likelihood (of the impact) Rating calculated by summing Frequency and Probability. The significance is estimated by multiplying the Consequence with Likelihood ratings as defined in the following equation.

$$\boldsymbol{Significance} = (\boldsymbol{Extent} + \boldsymbol{Duration} + \boldsymbol{Magnitude})\ \boldsymbol{x}\ \boldsymbol{Probability} \qquad \textbf{Equation 9}$$

Table 6-4: Impact Assessment Criteria – Extent of Impacts

Rating	Description	Quantitative Rating
Footprint	Impacts confined within the project boundary, mainly the footprint of the mining pits.	**1**
Site	The impact could affect the whole, or a significant portion of the site.	**2**
Local/ Regional	The impact could affect the area including the neighbouring farms, the transport routes and the adjoining towns.	**3**
National	The impact could have an effect that expands throughout the country (South Africa).	**4**
International	Where the impact has international ramifications that extend beyond the boundaries of South Africa.	**5**

Table 6-5: Impact Assessment Criteria – Duration

Rating	Description	Quantitative Rating
Short term	The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than that of the construction phase.	**1**
Short to Medium term	The impact will be relevant through to the end of a construction phase (1.5 years).	**2**
Medium term	The impact will last up to the end of the development phases, where after it will be entirely negated.	**3**
Long term	The impact will continue or last for the entire operational lifetime i.e. exceed 30 years of the development, but will be mitigated by direct human action or by natural processes thereafter.	**4**
Permanent	This is the only class of impact, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient.	**5**

Table 6-6: Impact Assessment Criteria – Severity of Impact (Magnitude / Intensity)

Rating	Description	Quantitative Rating
Very Low	Ground vibration levels less than 0.254 mm/s (see **Table 6-1**). The projected vibration level is less than 5% of the appropriate limit for a specific structure as identified in **Table 6-2**. Air blast levels less than 115 dB	**2**
Low	Ground vibration levels more than 0.254 but less than 0.762 mm/s (see **Table 6-1**). The projected vibration level is more than 5%, but still less than 10% of the appropriate limit for a specific structure as identified in **Table 6-2**. Air blast levels more than 115 but less than 120 dB	**4**
Medium	Ground vibration levels more than 0.762 but less than 2.54 mm/s (see **Table 6-1**). The projected vibration level is more than 10%, but still less than 25% of the appropriate limit for a specific structure as identified in **Table 6-2**. Air blast levels more than 120 but less than 130 dB	**6**
High	Ground vibration levels more than 2.54 but less than 7.62 mm/s (see **Table 6-1**). The projected vibration level is more than 25%, but still less than 100% of the appropriate limit for a specific structure as identified in in **Table 6-2**.	**8**

	Air blast levels more than 120 but less than 134 dB	
Very High	Ground vibration levels more than 7.62 mm/s (see **Table 6-1**). The projected vibration level is higher than the appropriate limit for a specific structure as identified in **Table 6-2**. Air blast levels exceeding 134 dB	**10**

Table 6-7: Impact Assessment Criteria – Probability of Impact Occuring

Rating	Description	Quantitative Rating
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience. The chance of this impact occurring is zero (0 %).	1
Possible	The possibility of the impact occurring is very low, due either to the circumstances, design or experience. The chances of this impact occurring is defined as 25 %.	2
Likely	There is a possibility that the impact will occur to the extent that provisions must therefore be made. The chances of this impact occurring is defined as 50 %.	3
Highly Likely	It is most likely that the impacts will occur at some stage of the development. Plans must be drawn up before carrying out the activity. The chances of this impact occurring is defined as 75 %.	4
Definite	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of this impact occurring is defined as 100 %.	5

Determination of Impact Significance

Significance is determined through a synthesis of impact characteristics as described in the above paragraphs. It provides an indication of the importance of the impact in terms of both tangible and intangible characteristics. The significance of the impact "without mitigation" is the prime determinant of the nature and degree of mitigation required. Where the impact is positive, significance is noted as "positive". The significance before the implementation of mitigation is rated as highlighted in **Table 6-8**, with the significance after the implementation of the mitigation measures defined in **Table 6-9**.

Table 6-8: Significance - Without Mitigation

Rating	Description	Rating Level
LOW	The impact from blasting is of little importance.	**< 30**
MEDIUM	The impact is of importance and is therefore considered to have a negative impact. Mitigation is recommended to reduce the negative impacts to **Low**, especially in areas that are very sensitive to blasting impacts.	**31 - 60**
HIGH	The impact is of major importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.	**> 61**

Table 6-9: Significance - With Mitigation

Rating	Description	Rating Level
LOW	The impact was mitigated to the point where it is of limited importance.	**< 30**
MEDIUM	Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.	**30 - 60**
HIGH	The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable.	**> 61**

7 ASSUMPTIONS AND LIMITATIONS

It is not the purpose of this assessment to calculate exact vibration levels, or the precise level of the air overpressure, but to use various tools to identify potential issues of concern. Due to unknowns this assessment leans towards a precautious approach, rather over-estimate the distance that fly-rock may travel, the ground vibration or the air blast levels. However, the following assumptions and limitations must be noted:

- A blast design was not available, and this assessment used a conceptual design, considering a potential 10m bench height and optimal borehole diameter (considering the Dyno (2017) "*Rule of Thumb*" recommendations) considering the geology and resource depth;
- Optimal burden and spacing information were calculated using the Dyno (2017) "*Rule of Thumb*" calculations when considering the assumed bench height and borehole diameter. Stemming length is based on the maximum length possible to allow a powder factor of approximately 0.7 kg/m^3 (typical powder factor for hard rock);
- This impact assessment does not make a statement on the acceptability of the blast design as evaluated (viable bench height, fracturing, throw, powder factors, drilling cost, blasting cost, etc.) and only assesses the potential impacts considering the available information;
- The report is based on a desktop assessment, considering feedback from the project EAP. The status of structures and the associated uses were not assessed. It is required that the mine completes a survey of all structures and boreholes (location, depth, yield, static water level, ground water quality, usage, etc.) located within 2,000 m from the proposed opencast pits. The mine must determine the status and state of the structures (before first blasting taking place);
- Boreholes was not identified and verified, and it was assumed that boreholes may be located close to residential structures and water dams/reservoirs;
- Attenuation rates for ground vibration levels, air blast levels and fly rock distances are site-specific. Empirical formula has been developed by a number of researchers, yet all these equations use constants that should be developed considering site specifics (geology, rock characteristics, etc). These site constants can initially be assumed but should be refined considering the results of blasting vibration and air pressure measurements. Vibration levels should be measured, with the data analysed to calculate site-specific onsite constants. The initial constants for ground vibration (**section 5.3**) are based on typical constants for coal mining projects in the area, using 1149 and 1.51;
- Calculations are based on an ideal situation, with the bedrock having constant characteristics, whereas in practice the geology is complex with faults, dykes, folds, stratigrapical layers etc. This means that each blast may be different;
- This report assumed that blasting will take place during the afternoon when atmospheric conditions are the most unstable with no inversion layer, or a potential inversion layer that is high with no overcast conditions; and
- There are a residential house and a number of cement dams within the area earmarked for opencast mining. It is assumed that the people and livestock located in this area will be relocated and that any cement dams and water reservoirs will be destroyed (have no further use).

8 PROJECTED MAGNITUDE OF BLASTING IMPACTS

When a blast is detonated, a great deal of energy is liberated, although only 20 – 30% of the energy used for rock fragmentation and displacing (Aloui, 2016). The rest of the explosive energy is wasted in the form of ground vibration, air overpressure (or airblast), noise as well as fly rocks (all undesired from a blasting perspective as energy is lost).

Blasting vibration and air blast levels as well as the potential zone of impact for fly rock was calculated using the selected blast design parameters defined in **Table 8-1** (though alternative blasting parameters were considered). It should be noted that the number of blastholes that may be detonated simultaneously may vary from blast to blast. The depth of the blastholes is similarly not constant, but may vary on a day-to-day basis, depending on the mine planning (such as the planned bench height) or geology.

Table 8-1: Blast design – various preliminary parameters (as reported by mine representative)

Design parameter	150 mm drill diameter
Average depth of borehole (m)	10.0
Bench height (m)	10.0
Subdrill (m)	0.0
Borehole diameter (mm)	150.0
Burden (m)	4.5
Spacing (m)	5.2
Burden stiffness ratio	2.2
Stemming Length (m)	2.2
Column length (m)	7.8
Explosive density (g/cm^3)	1.15
Explosives per borehole (kg)	158.5
Charge mass per meter (kg/m)	20.3
Maximum number of blast holes per delay	10
Maximum explosives per delay (kg)	1 585
Powder Factor (kg/m^3)	0.68
Vibration at 500 m, one borehole per blast delay (mm/s)	4.4
Airblast level at 500 m, one borehole per blast delay (dBA)	117.8
Potential maximum flyrock distance (m)	479.9
Vibration at 500 m, maximum number of blastholes per delay (mm/s)	25.2
Airblast level at 500 m, maximum number of blastholes per delay (dBA)	125.8

8.1 PROJECTED MAGNITUDE OF GROUND VIBRATION

As discussed in **section 5.1**, the accepted method of a scaled distance is used. This equation mainly uses two constants (initially assumed until it can be calculated using data from blasts), the quantity of explosives used (in kg) and the distance from the blast in meters. For any specific blast, distance to the closest BSR and/or PSS is fixed and cannot be changed with the only parameter that can be changed being the mass of explosives detonated per instance (per charge).

The larger the explosive mass (per delay), the higher the amplitude of the ground vibration. As such the amplitude of the ground vibration can be reduced by reducing the mass of the explosives fired at the same time, or with the appropriate use of delays (using timed blasts) to reduce the mass of explosives detonated per instance. This is referred to as the "charge per delay mass". Therefore, using **Equation 1** (**section 5.3**), the potential ground vibration can be calculated for the estimated blast parameters (see **Figure 8-1**). **Figure 8-2** illustrates the distance from a potential blast (mass per charge) for various vibration limits.

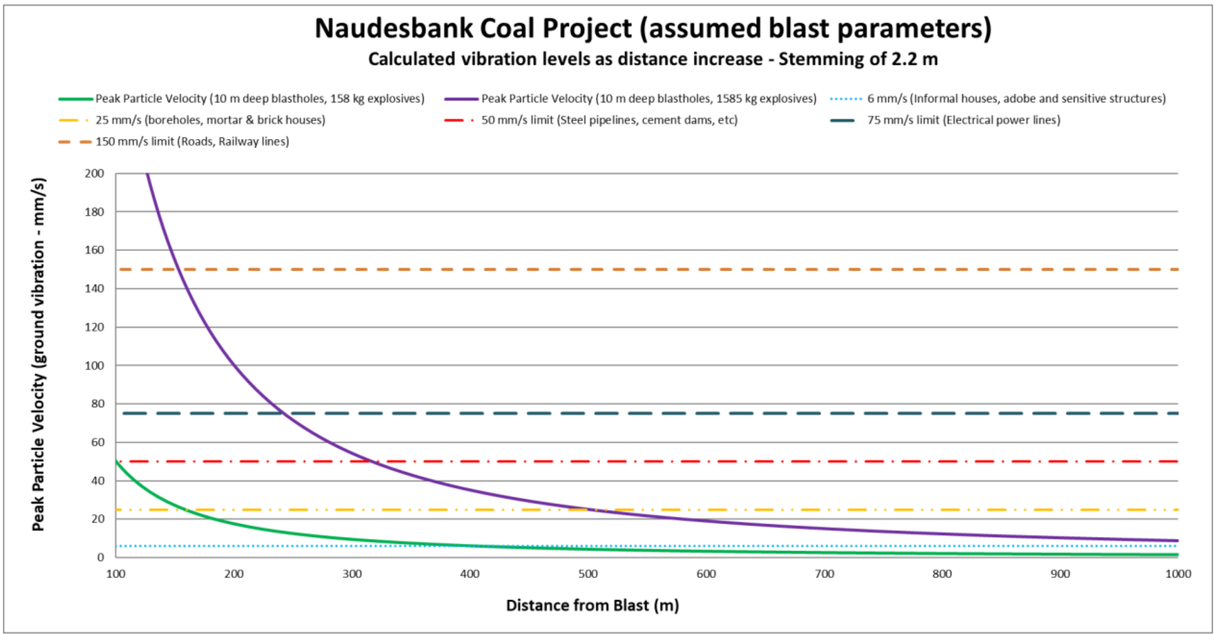

Figure 8-1: Ground vibration levels as the distance increase for assumed blast parameters

For the assumed blast parameters potential buffers are illustrated in:

- **Figure 8-5**, the buffer area where vibration levels of 2.54 mm/s may result in a response from human receptors;
- **Figure 8-6**, the buffer area where vibration levels of 6.0 mm/s may result in potential damage to sensitive structures (buildings such as informal, mud or adobe houses –not identified onsite but included);
- **Figure 8-7**, the buffer area where vibration levels of 25.0 mm/s may result in potential damage to sensitive plant equipment, boreholes or brick houses;
- **Figure 8-8**, the buffer area where vibration levels of 50.0 mm/s may result in potential damage to cement dams or large steel pipelines; and
- **Figure 8-9**, the buffer area where vibration levels of 150.0 mm/s may result in potential damage to tar roads or railway lines (no railway lines identified onsite).

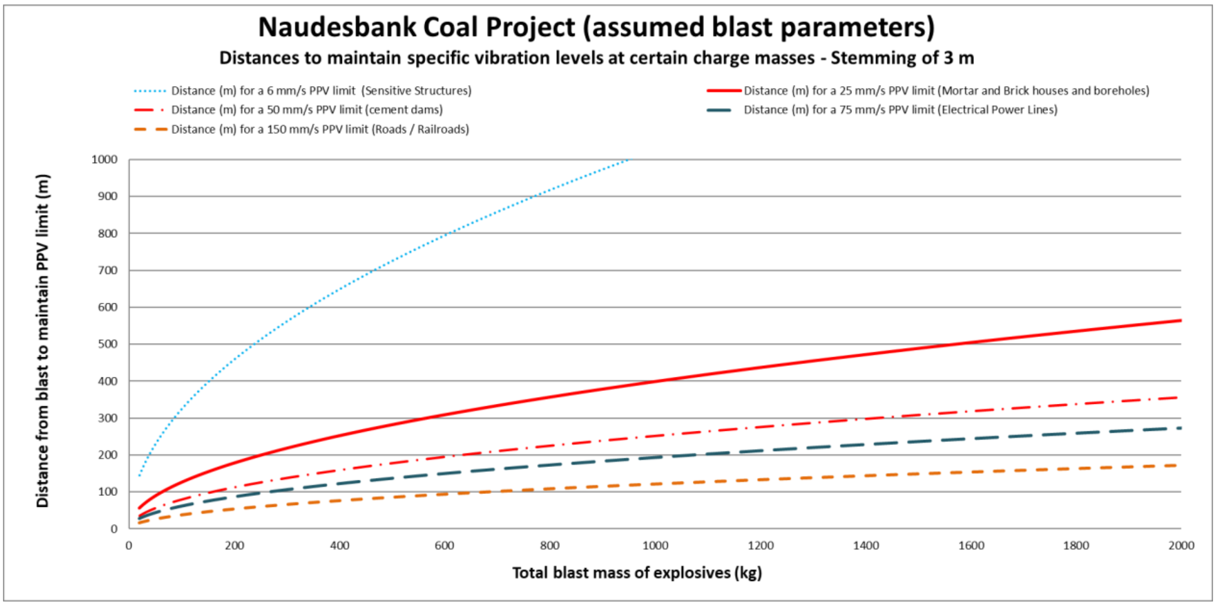

Figure 8-2: Required distances to maintain specific vibration levels at certain charge masses

8.2 PROJECTED MAGNITUDE OF AIR BLAST LEVEL

As discussed in **section 5.4**, as with ground vibration, the method used to calculate the air blast level is also based on a scaled distance formula. The USBM formula only consider the mass of explosives used (in kg) and the distance from the blast in meters where the AS2187.2 method in addition also use two constants that allow the refinement for site specific conditions. Both the methods were considered with the USBM being the more pre-cautious method (higher air pressure level at the same distance than the Australian method).

As can be seen from equation 2, the air blast level can be reduced by reducing the mass of the explosives fired at the same instance (controlled or timed blasting). Using Equation 2, the potential air blast level can be calculated for the options as indicated in:

- **Figure 8-3** for the assumed blast parameters using the USBM method; and
- **Figure 8-4** for the assumed blast parameters using the AS 2187.2 method.

Using the more precautious USBM method, the potential extent of the impact (120 dBA noise limit) is illustrated on an aerial image in **Figure 8-10**.

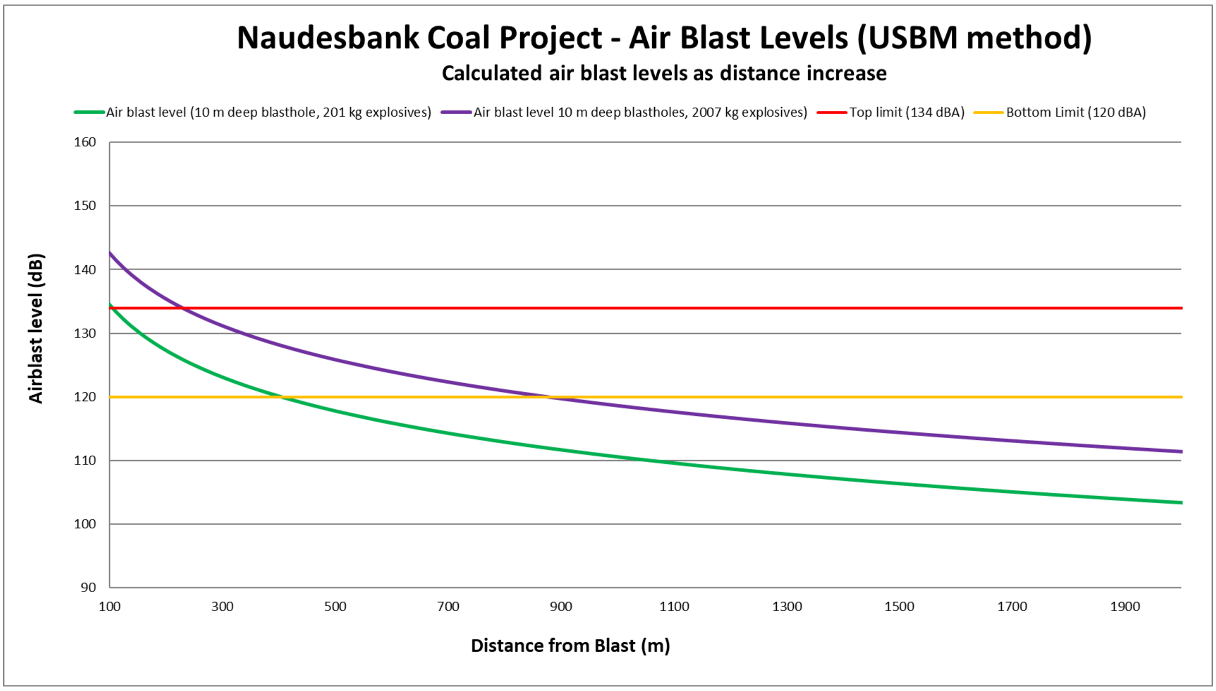

Figure 8-3: Air blast levels as the distance increase for assumed blast parameters using the USBM method

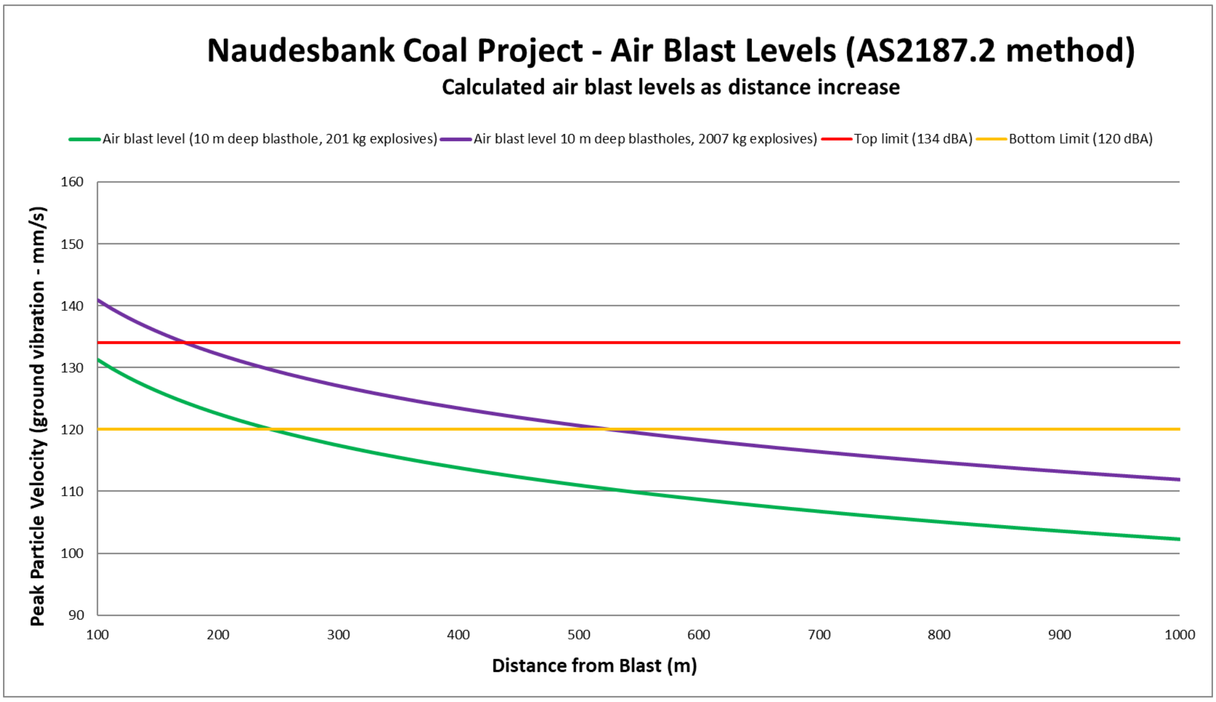

Figure 8-4: Air blast levels as the distance increase for assumed blast parameters using the AS2187.2 method

8.3 PROJECTED MAGNITUDE OF FLY ROCK RISKS

Section 5.5 discusses the different ways that fly rock may be created as well as the methods how it can be calculated. The explosive mass (per meter) is used for all three methods (Face bursting, Cratering, Rifling), with blast design (the burden and stemming length) playing a very important role. Using these equations, the potential extent of fly rock was calculated and defined in **Table 8-2** with the potential extent of the risk illustrated on an aerial image on **Figure 8-11**.

It should be noted, that, even with the best precautions, fly rock will occur and could travel further than the distances indicated in this report. As such a safety factor is recommended, which in some cases could be as high as 4 times the maximum throw distance. Using a minimum safety factor of 2 would set a minimum unsafe zone of 960 m from the active blasting area, although it is critical to note that the occurrence of fly rock can never be excluded. It is recommended that the mine at all times use a minimum exclusion zone of 500 m (equipment, people and livestock).

It must be highlighted that if blastholes are shallow (due to profile requirements), requiring a lower stemming height (boreholes less than 4 m), the potential dangers of fly rock increases, due to inadequately confined explosives increasing dangers due to cratering. When shallow boreholes must be drilled and blasted, it is recommended that the borehole diameter, burden and spacing be reduced accordingly.

Table 8-2: Type of Fly rock and potential area of risk

Fly rock type	Blast Parameters considering 8.5 m bench height, 127 mm borehole diameter
Face bursting - IME (1997)	75 m (for a 4.5 m burden)
Cratering - IME (1997)	480 m (for a 2.2 m stemming depth)
Rifling - IME (1997)	164 m (for a 2.2 m stemming depth and a maximum inclination of 80°)
Method as per Ghasemi *et al* (2012)	20 m (for 4.5 m burden, 5.2 m spacing, 2.2 m stemming length, a powder factor of 0.69 kg/m^3 and mean charge per blasthole of 158 kg)

8.4 POTENTIAL DECOMMISSIONING, CLOSURE AND POST-CLOSURE BLASTING IMPACTS

There is no, or a small blasting impact risk once the construction and operational phases are completed. At worst, a small blast may be required to ensure that the profile of the final pit isn't too steep and dangerous, but the impact will be less than the blasting evaluated for the mining activity. This risk is significantly lower than construction or operational blasting and this will not be investigated further.

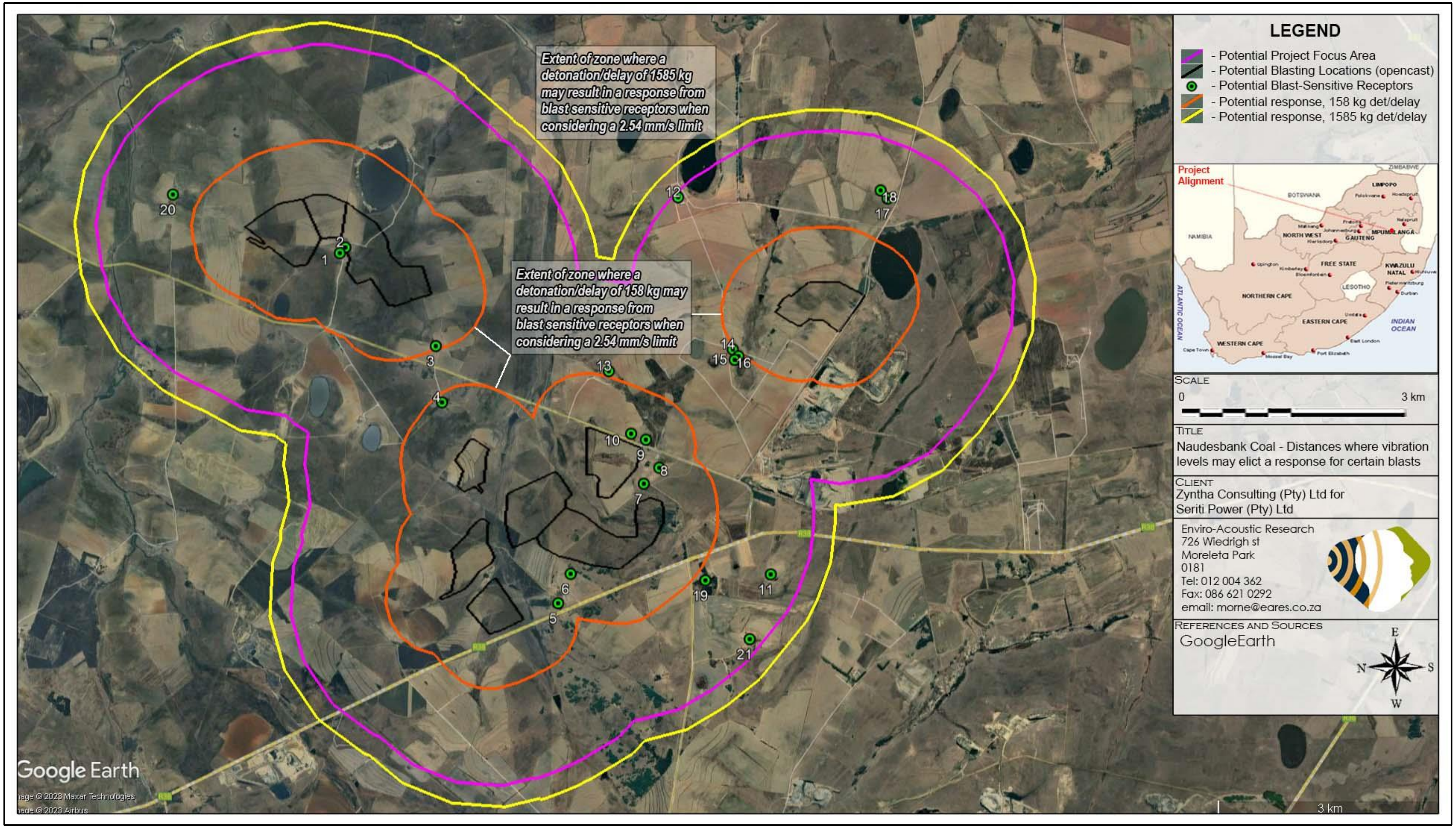

Figure 8-5: Projected Extent of Blasting Vibration Impacts – Potential area where people may respond to blasting vibration for the assessed blast parameters

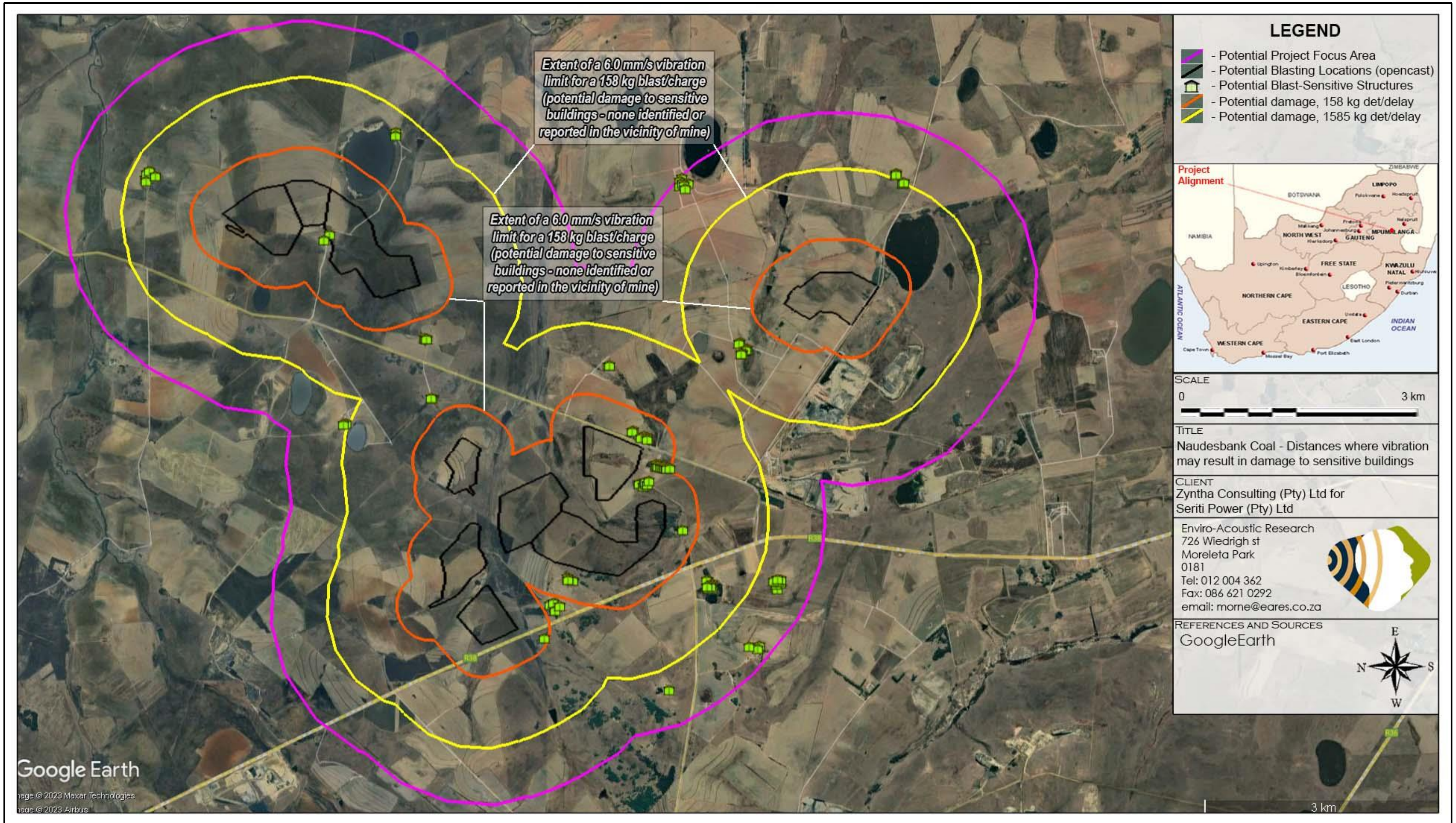

Figure 8-6: Projected Extent of Blasting Vibration Impacts – Potential area where sensitive structures (such as mud or adobe) may be damaged [none reported onsite]

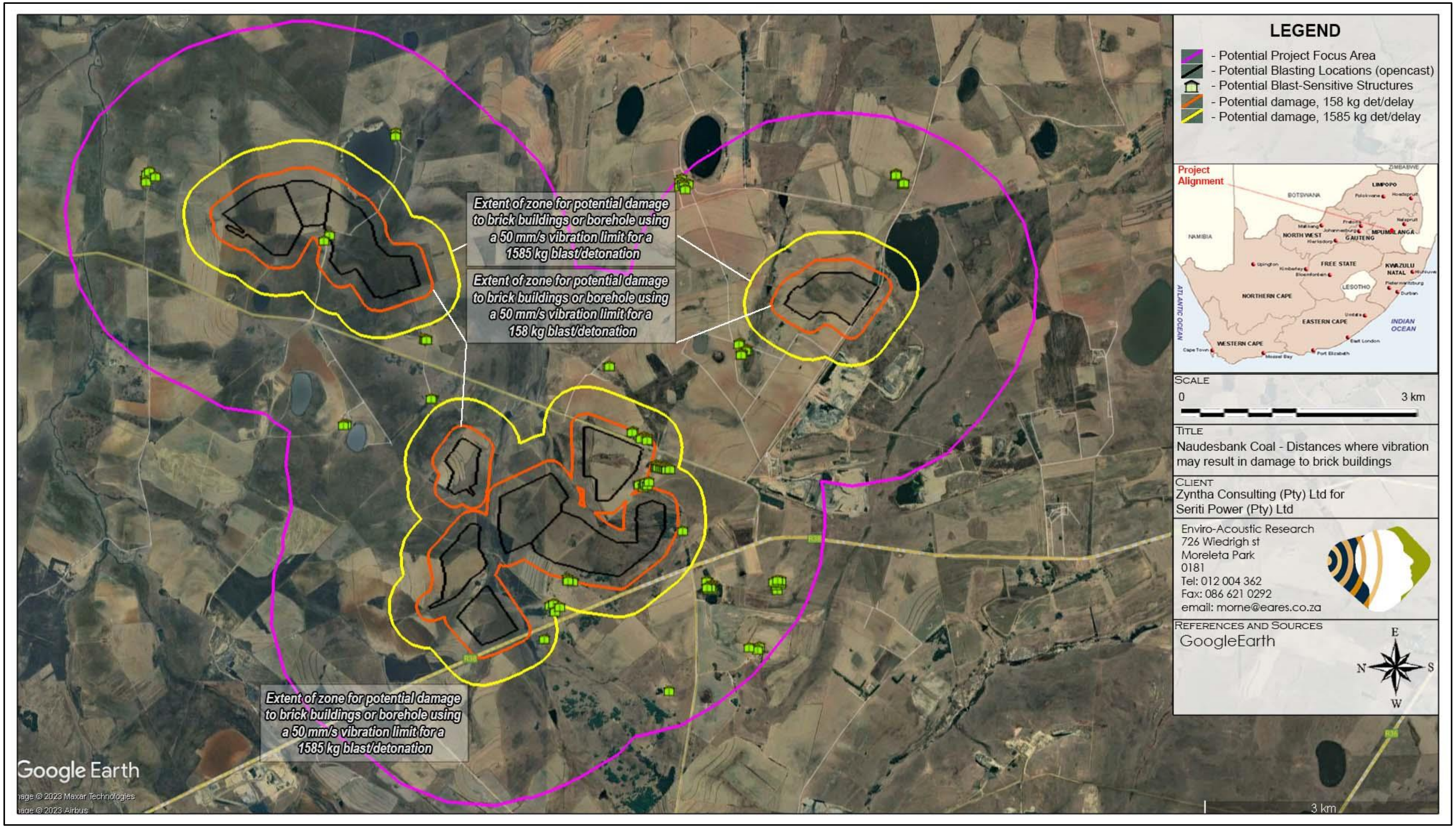

Figure 8-7: Projected Extent of Blasting Vibration Impacts – Potential area where brick houses (or boreholes) may be damaged

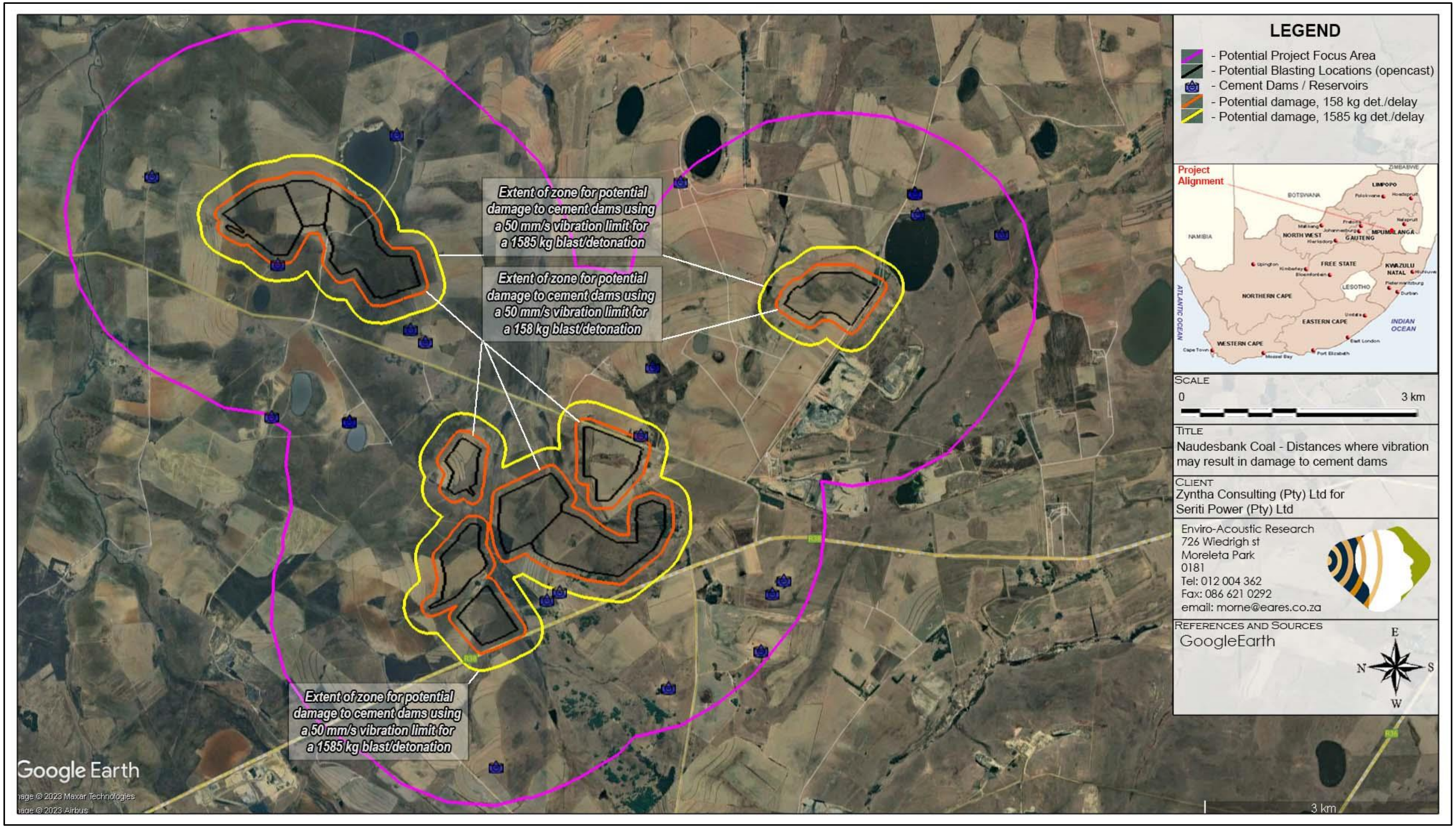

Figure 8-8: Projected Extent of Blasting Vibration Impacts – Potential area where cement dams may be damaged

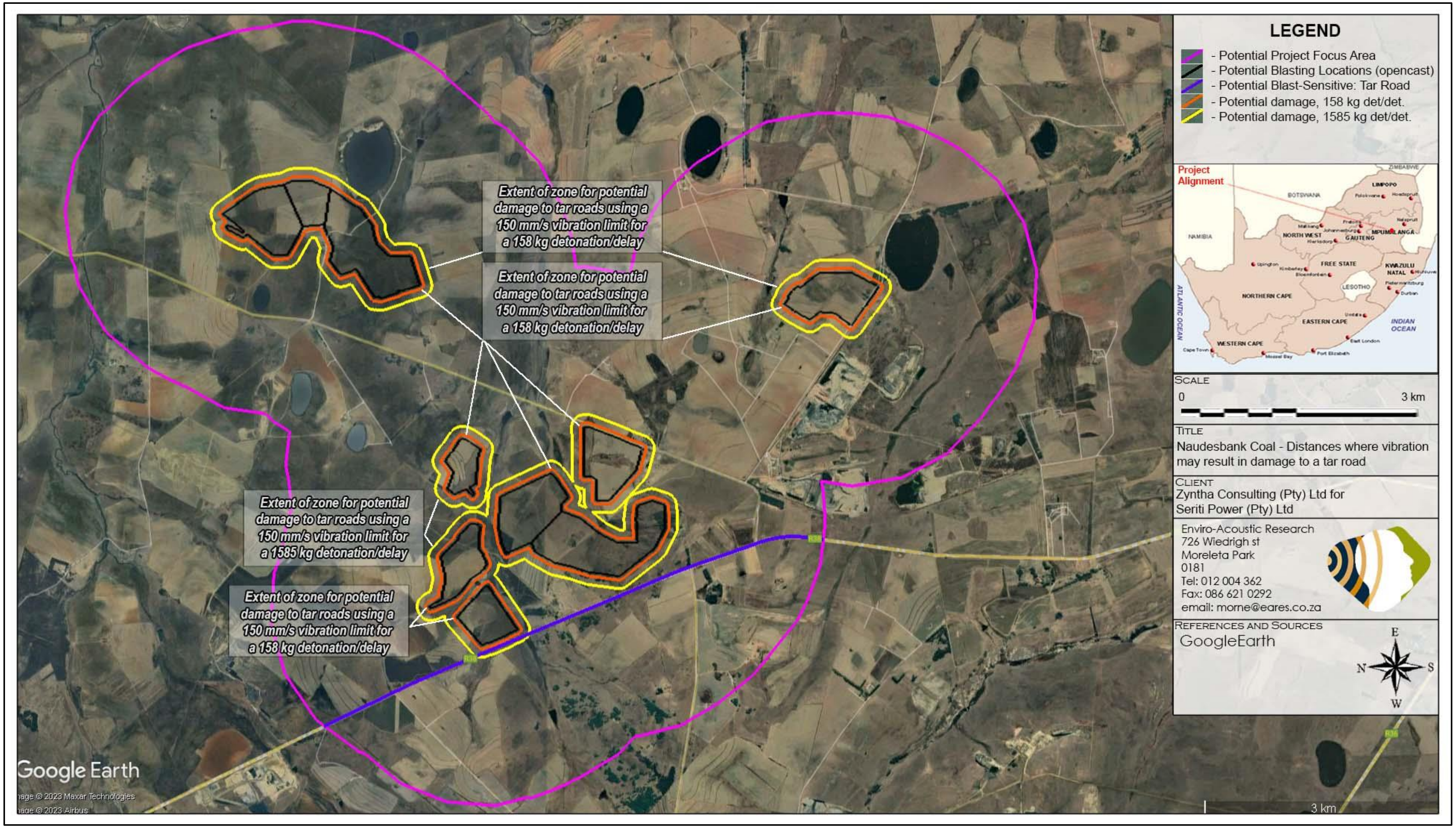

Figure 8-9: Projected Extent of Blasting Vibration Impacts – Potential area where tar roads may be damaged

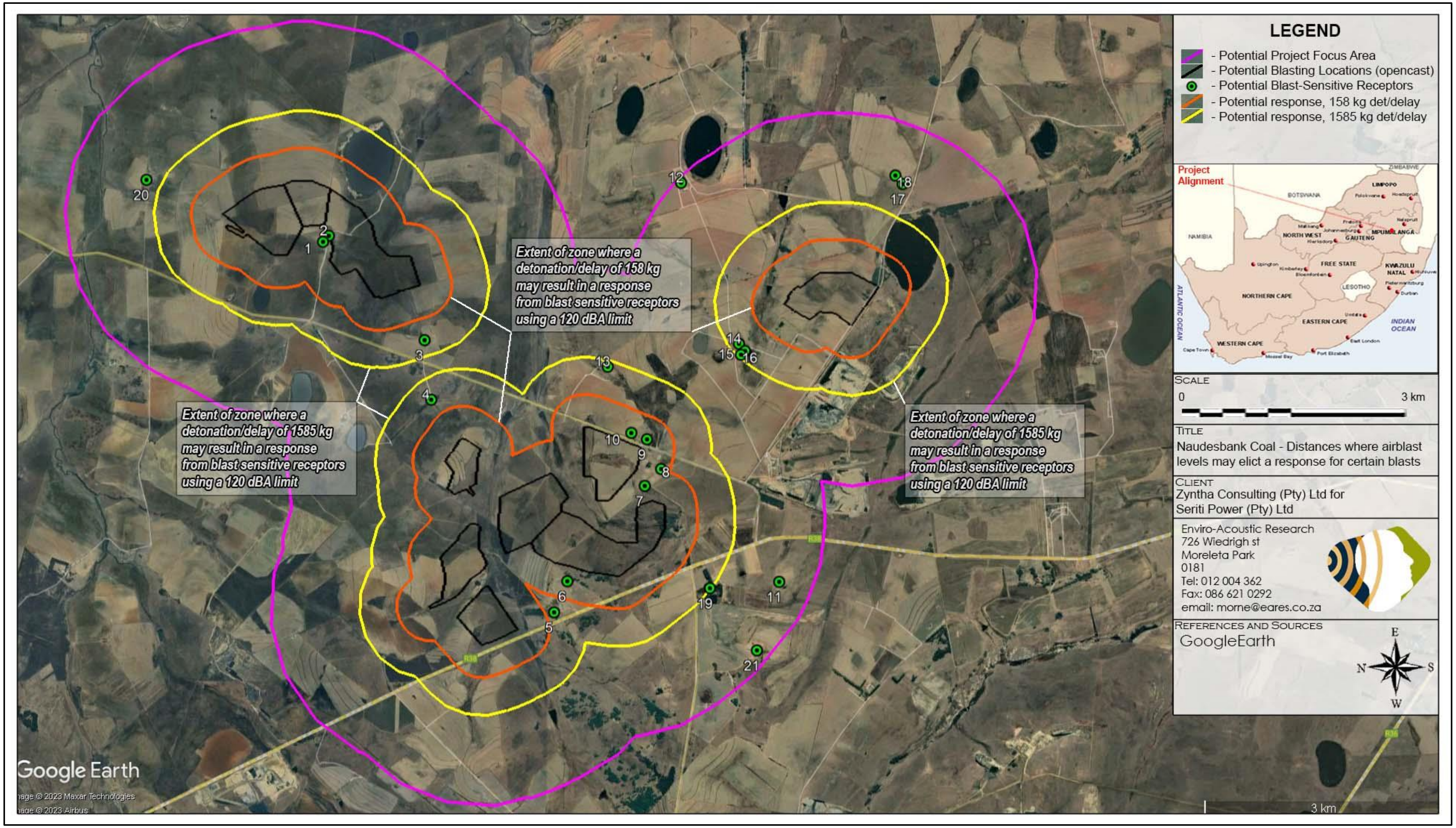

Figure 8-10: Projected Extent of Blasting Impacts – Air blast level for the selected blast parameters

Figure 8-11: Projected Extent of Blasting Impacts – Fly rock risks on surrounding Blast Sensitive Structures

9 SIGNIFICANCE OF THE BLASTING IMPACTS

The impact assessment tables are based on the levels and potential response as defined in **section 6**.

9.1 SIGNIFICANCE OF GROUND VIBRATION IMPACTS

9.1.1 Significance of vibration levels on Human Receptors

The magnitude of the ground vibration levels was calculated in section **8.1**, with the potential vibration levels as well as the significance defined per BSR in **Appendix C, Table 1**, with the potential impact summarized in **Table 9-1**.

Table 9-1: Impact Assessment: Ground vibration impacts (Human Responses)

Acceptable Level (Table 6-1)	Use the level of 2.54 mm/s as the limit where people may start to find the vibration level to be unpleasant (see **Figure 6-1**, **Table 6-1**, **Figure 8-5** and **Appendix C, Table 1**)	
	Without Mitigation (conceptually considering the detonation of 10 blastholes simultaneously for a 1585kg detonation/delay)	***With Mitigation (detonating only 1 blasthole at a time for a 158 kg detonation/delay)***
Extent (Table 6-4)	Regional (3)	Site (2)
Duration (Table 6-5)	Long term (4)	Long term (4)
Severity (Table 6-6)	Very High (10) – all BSR within 1,060m	Medium (6)
Probability (Table 6-7)	Definite (5 – BSR within ±275m)	Improbable (1)
Significance of Impact (Table 6-8 & Table 6-9)	**High (85)**	**Low (12)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Significance is **High** and mitigation is required and recommended for the conceptual scenario evaluated. The developer must consider the following measures to reduce the vibration level that receptors may perceive as unpleasant: ▪ BSR staying closer than 500 m from opencast area (where blasting may take place in future) to be relocated; ▪ The potential vibration levels should be discussed with the surrounding BSRs during the EIA process. They should be notified that the vibration levels were calculated but some people may find the vibration levels unpleasant (especially during a large blasts). BSRs should be notified that, while they can feel the vibration level, their houses and other structures are in no danger (very low risk of potential damage); ▪ Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive. ▪ When blasting closer than 2,200 m from any BSR, the blast can be controlled (reducing the detonation/charge per delay - with a delay of at least 8 ms between consecutive detonations) for a vibration level less than 2.54 mm/s at the identified BSR;	

	▪ The mine can use a smaller borehole diameter (and a tighter associated drilling pattern) that would reduce the quantity of explosive detonated per delay; ▪ The mine should measure blasting vibration levels during blasts to define onsite constants. These constants can be used to update the blasting report within a year after mining started; ▪ The developer should erect clear signs indicating blast dates and times on all roads within 1,000 m from the blasting areas. A blast schedule should be provided to the BSRs staying in the area.

9.1.2 Significance of vibration levels on Structures

The magnitude of the ground vibration levels was calculated in section **8.1**, with the potential vibration levels as well as the significance defined for various types of structures in:

- **Appendix C, Table 2** for potential damage to brick buildings, with the potential impact summarized in **Table 9-2**;
- **Appendix C, Table 3** for potential damage to cement structures, cement dams or pipelines, with the potential impact summarized in **Table 9-3**; and
- **Appendix C, Table 4** for potential damage to surfaced roads and railway lines, with the potential impact summarized in **Table 9-4**.

Table 9-2: Impact Assessment: Ground vibration impacts (Damage to residential structures in area)

Acceptable Level (Table 6-2)	Use the level of 25 mm/s as the limit for brick houses in the area (see **Figure 6-1**, **Table 6-2**, and **Figure 8-7**).	
	Without Mitigation (conceptually considering the detonation of 10 blastholes simultaneously for a 1585 kg detonation/delay)	***With Mitigation (detonating only 1 blasthole at a time for a 158 kg detonation/delay)***
Extent (Table 6-4)	Site (2)	Site (2)
Duration (Table 6-5)	Long term (4)	Long term (4)
Severity (Table 6-6)	Very High (10 – BSS located within 500 m from blast)	Medium (6)
Probability (Table 6-7)	Definite (5 – BSS located within 175m from blast)	Improbable (1)
Significance of Impact (Table 6-8 & Table 6-9)	**High (80)**	**Low (12)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Significance is **High** and additional mitigation is recommended, though mainly for brick buildings located within 500 m from potential blasting areas. Potential measures that would minimize the potential impact include: ▪ BSR staying closer than 500 m from opencast area (where blasting may take place in future) to be relocated; and ▪ The mine should undertake a survey of all buildings and structures (during the recommended photo survey) located within 2,000 m from the proposed mining opencast pits to determine the building material and potential sensitivities of the structures; and ▪ If brick buildings (located within 500 m) are to be used for residential purposes during the mining period, blasts closer than 500 m from brick buildings should be controlled (detonation	

	per delay - with a delay of at least 8 ms between consecutive detonations) for a vibration level less than 25.0 mm/s at the identified BSS; and/or ▪ If brick buildings (located within 500 m) are to be used for residential purposes during the mining period, the mine can use a smaller borehole diameter (and a tighter associated drilling pattern) that would reduce the quantity of explosive detonated per delay.

Table 9-3: Impact Assessment: Ground vibration impacts (Damage to cement dams, bridges and pipelines)

Acceptable Level (Table 6-2)	Use the level of 50 mm/s as the limit for cement dams in the area (see **Figure 6-1**, **Table 6-2** & **Figure 8-8**).	
	Without Mitigation (conceptually considering the detonation of 10 blastholes simultaneously for a 1585kg detonation/delay)	***With Mitigation (detonating only 1 blasthole at a time for a 158 kg detonation/delay)***
Extent (Table 6-4)	Site (2)	Site (2)
Duration (Table 6-5)	Long term (4)	Long term (4)
Severity (Table 6-6)	Very High (10)	High (8)
Probability (Table 6-7)	Highly Likely (4 – Cement Dams D4 & D12)	Improbable (1)
Significance of Impact (Table 6-8 & Table 6-9)	**High (64)**	**Low (14)**
Reversibility	High	High
Degree of Confidence	**High**	
Mitigation:	Significance is **high** for cement dams located within 200 m from potential blasting locations (dams D4 & D12). It is recommended that the mine undertake a photo survey at all cement dams located within 500 m from the proposed opencast pits. The mine must also undertake and determine the status and use of all water boreholes located within 2000 m from the future blasting locations (before blasting activities start). Any dams located within 200 m should be decommissioned and livestock using these dams should be relocated and alternative sources of water should be supplied to users of these dams (if relevant).	

Table 9-4: Impact Assessment: Ground vibration impacts (Damage to the R38 tar roads)

Acceptable Level (Table 6-2)	Use the level of 150 mm/s as the limit for tar roads, considering a potential blast (based on a 1585 kg charge mass per delay) (see **Figure 6-1**, **Table 6-2** & **Figure 8-9**).	
	Without Mitigation (conceptually considering the detonation of 10 blastholes simultaneously for a 1585 kg detonation/delay)	***With Mitigation (detonating only 1 blasthole at a time for a 158 kg detonation/delay)***
Extent (Table 6-4)	Site (2)	Site (2)
Duration (Table 6-5)	Long term (4)	Long term (4)
Severity (Table 6-6)	Very High (10)	High (8)
Probability (Table 6-7)	Likely (3)	Improbable (1)
Significance of Impact	**Medium (48)**	**Low (14)**

(Table 6-8 & Table 6-9)		
Reversibility	High	High
Degree of Confidence	**High**	
Mitigation:	Significance is **medium** and mitigation is required to protect the R38 road. Mitigation would be: ▪ For the blast design assessed, the mine must reduce the charge per detonation (detonation per delay) when blasting is to take place close than 160 m from the R38; ▪ The mine should calculate potential vibration levels at the tar roads and railway line for each blast (considering the actual blasting parameters) once blasting is closer than 500 m from the roads/se structures. The mine should reduce the charge mass per detonation to ensure that vibration levels are less than 150 mm/s when blasting closer than 500 m from the R38 road; and ▪ The mine must implement a blast monitoring programme. This data is to be processed to calculate the site-specific constants to allow more accurate calculation of the potential blast impacts. In addition, the mine must take notice of GNR.584 of 2015, that does limit blasting within 500 m from certain structures unless certain conditions are met (also see **section 4.2**). The mine will have to discuss the project with the relevant authorities to authorize the closure and implement the agreed upon mitigation measures once mining (with blasting) take place closer than 500 m from the tar road.	

9.2 SIGNIFICANCE OF AIR BLAST IMPACTS

The magnitude of the air blast levels was calculated in **section 8.2**, defined in **Appendix C, Table 5** with the significance summarised in **Table 9-5**.

Table 9-5: Impact Assessment: Air blast Impacts (worst-case)

Acceptable Level (Table 6-3)	Use the level of 120 dB as the limit for people staying in the area (see **Table 6-3** and **Appendix C, Table 5**).	
	Without Mitigation (conceptually considering the detonation of 10 blastholes simultaneously for a 1585 kg detonation/delay)	***With Mitigation (detonating only 1 blasthole at a time for a 158 kg detonation/delay)***
Extent (Table 6-4)	Regional (3)	Site (2)
Duration (Table 6-5)	Long term (4)	Long term (4)
Severity (Table 6-6)	Very High (10 – any blast closer than 225 m from BSR)	Very Low (2)
Probability (Table 6-7)	Definite (5 – any blast closer than 225 m from BSR)	Possible (2)
Significance of Impact (Table 6-8 & Table 6-9)	**High (85)**	**Low (18)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Significance is **high** and additional mitigation is required and recommended. Blasting activities generate significant air overpressure that could result in large flat surfaces vibrating, frequently perceived negatively by surrounding BSR (at times living further than the area identified to be negatively affected).	

	As such the following measures are recommended to ensure that air blast levels are minimized: ▪ Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive. ▪ Mine to erect blasting notice boards and clear warnings in the area (along the tar roads located within 500 m from future blasting activities) with blasting dates and times highlighted. ▪ Mine to prevent blasting in adverse meteorological conditions where possible (overcast conditions, strong wind blowing in direction of local community, early in the mornings or late in the afternoon). ▪ Potential airblast levels to be calculated for each blast to take place within 1, 000 m from any BSR and the mine can reduce the number of holes detonated per delay when mining closer than 1,000 from BSR (to ensure airblast levels less than 120 dBA at BSR). ▪ The use of detonating cord should be minimised to control airblast levels. When used within 1,000 m from identified BSRs, the cord should be covered with cuttings or aggregate to minimise airblast levels from this source; ▪ The mine must implement a blast monitoring programme when blasting is to take place closer than 1, 000 m from verified BSR.

9.3 SIGNIFICANCE OF FLY ROCK IMPACTS

The magnitude of potential fly rock risk levels was calculated in section **8.3** and the significance is summarised in **Table 9-6**.

Table 9-6: Impact Assessment: Flyrock Risks

Acceptable Level	There should be no risk of fly rock that can pose a risk to people, structures or equipment.	
	Without Mitigation (stemming from 2.2 m associated with the assumed blast parameters)	***With Mitigation***
Extent (Table 6-4)	Site (2)	Site (2)
Duration (Table 6-5)	Long term (4)	Long term (4)
Severity (Table 6-6)	Very High (10)	Very Low (2)
Probability (Table 6-7)	Definite (5)	Improbable (1)
Significance of Impact (Table 6-8 & Table 6-9)	**High (80)**	**Low (6)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Mitigation is required and the mine should: ▪ Recommend that equipment, buildings and structures closer than 500 m from potential blasting sites be moved, relocated or protected; ▪ People and livestock to be moved further than 500 m from active blast before a blast is detonated; ▪ Any evidence of fly rock is noted and the blast be analysed for possible improvements; ▪ Consider the blast design to increase the stemming length, or reducing the charge weight per linear meter (e.g., smaller blast hole diameter or different type of explosive) if fly rock problems are encountered;	

	▪ Blaster to keep full records of blast (blast design, timing, explosive mass per blast hole, stemming, subdrill, spacing, burden, etc.).

9.4 CLOSURE AND DECOMMISSIONING PHASE IMPACTS

No drilling and blasting are expected during the closure and decommissioning phase, excluding minimal blasting to ensure that the profile of the final opencast void is acceptable for final land use. These blasts will be much smaller than the blasts evaluated, and, the risks from such blasts are very low.

10 MITIGATION OPTIONS

While the risks from blasting impacts are manageable, people are always concerned about the potential effects and dangers of blasting and measures are recommended for the mine to consider and implement. This assessment also assumes that receptors (BSR 1 and 2) located directly on the areas to be developed (plant and opencast mine) will be relocated before mining activities are closer than 500 m. Similarly, it is assumed that all structures associated with these BSR will no longer be used.

10.1 GENERAL MANAGEMENT AND MEASURES TO MANAGE BLASTING IMPACTS

The project is proposed in an area with a number of BSRs and BSSs such as residential houses, cement dams, sheds and informal houses (constructed of wood and corrugated iron), the tar roads and railway line. As such blasting must be carefully planned and executed to ensure that people, livestock, structures and equipment are protected. The following should be noted and considered by the mine:

- BSR staying closer than 500 m from opencast area (where blasting may take place in future) to be relocated;
- The potential vibration levels should be discussed with the surrounding BSRs during the EIA process. They should be notified that the vibration levels were calculated but some people may find the vibration levels unpleasant. BSRs should be notified that, while they can feel the vibration level, their houses and other structures are in no danger (very low risk of potential damage);
- Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive. Feedback regarding vibration monitoring should be provided at these forums;
- The mine must conduct a photographic (crack) survey at all buildings and structures, as well as define the status of water boreholes, located within 2,000 m from areas where future blasting is to take place. Cracks will develop with time, which may be due to construction of the structures, standards of building, the age of the structure, the underlying geology and soils, maintenance etc., and not necessarily due to blasting;
- The mine should undertake a survey of all buildings and structures (during the recommended photo survey) located within 2,000 m from the proposed mining opencast pits to determine the building material and potential sensitivities of the structures. If any potential sensitive structures are identified, blasting closer than 1,200 m from these structures should be designed to consider the 6 mm/s vibration limit;
- If complaints are registered from BSR staying closer than 2,000 m from a location where blasting is taking place, the mine can:

- Calculate the potential vibration levels at BSR, designing and controlling the blast (charge detonated per delay - with a delay of at least 8 ms between consecutive blasts) to reduce the vibration levels at the identified BSR; and
- The mine can use a smaller borehole diameter (and a tighter associated drilling pattern) to reduce the quantity of explosive detonated per delay;

- The mine should measure blasting vibration levels during blasts to define onsite constants. These constants can be used to update the blasting report and potential blasting impacts within a year after mining started;
- The developer should erect clear signs indicating blast dates and times on all roads within 1,000 m from the blasting areas. A blast schedule should be provided to the BSRs staying in the area;
- The R38 tar road as well as a number of unpaved district roads (D983 and D1252) is located within 500 m from locations where blasting may occur in the future. The mine must take notice of GNR.584 of 2015, that does limit blasting within 500 m from certain structures unless certain conditions are met (also see **section 4.2**). It will be necessary to close this road during blasting closer than 500 m, though the mine must implement measures to warn road users that blasting is taking place (to prevent road users being startled increasing risks of road accidents) when blasting takes place closer than 1,000 m. Road closure will require permission from the Provincial Authorities;
- Cement dams located within 200 m should be decommissioned, livestock using these dams should be relocated and alternative sources of water should be supplied to users of these dams (if relevant);
- Any evidence of fly rock must be noted and the blast be analysed for possible improvements;
- That the mine considers the findings and recommendations of the Heritage Specialist/Adviser for this project;
- That the mine considers the findings and recommendations of the Wetland and Surface Water Specialist/Adviser for this project; and
- That the mine considers the findings and recommendations of the Fauna and Flora Specialists/Advisors for this project.

10.2 SPECIFIC MITIGATION OPTIONS TO PROTECT BSRS AND BSSS

It is recommended that:

- BSR staying closer than 500 m from opencast area (where blasting may take place in future) to be relocated; and
- All people working within 500 m from a potential blast must be evacuated before the detonation of the blast;
- All livestock within 500 m from a blast should be moved before, and during a blast;
- All roads must be closed when blasting is to take place within 500 m from the roads;
- The mine should erect clear warning signs indicating blast times along all tar roads located within 1,000 m from potential blasting areas. Road users should be warned when blasting events are taking place within 1,000 m;

- The mine should schedule blasting at the same time in the early afternoons, to minimise airblast levels. No blasting should take place early in the mornings, late in the afternoons, during overcast conditions or in foggy conditions;
- Potential airblast levels to be calculated for each blast to take place within 1, 000 m from any BSR and the mine can reduce the number of holes detonated per delay when mining closer than 1,000 from BSR (to ensure airblast levels less than 120 dBA at BSR); and
- The use of detonating cord should be minimised to control airblast levels. When used within 1,000 m from identified BSRs, the cord should be covered with cuttings or aggregate to minimise airblast levels from this source.

10.3 MITIGATION OPTIONS THAT SHOULD BE INCLUDED IN THE EMPR AND ENVIRONMENTAL AUTHORIZATION

Measures to be included in the EMPr and Environmental Authorization include:

- This report must be updated if the blast design is changed where more than 1585 kg explosives are detonated per delay;
- This report must be updated if the location of the proposed opencast pits is moved with more than 100 m;
- This report must be updated if the blast parameters changed with the mine making use of borehole with a larger diameter than considered in this report (150 mm);
- All people or livestock within 500 m from a blast should be moved before and during a blast;
- Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive. The local community members must be notified of times when blasts will be undertaken and the community must know that the potential impact of vibration was assessed.
- The mine should warn road users on the tar road transecting the mining area before and during blasting events (such as a red light flashing with clear signs that blasting is taking place);
- Mine to prevent blasting in adverse meteorological conditions (overcast conditions, strong wind blowing in direction of local community, early in the mornings or late in the afternoon);
- The mine must keep full records of each blast (blast design, timing, explosive mass per blast hole, stemming, subdrill, spacing, burden, meteorological conditions during the blast, etc.); and
- Any evidence of fly rock is noted and the blast be analysed for possible improvements.

11 CONCLUSIONS AND RECOMMENDATIONS

This blasting impact assessment covers the proposed development of the proposed Naudesbank Coal project west of Carolina in the Mpumalanga Province, evaluating the potential impact due to blasting activities at the mine.

The potential impacts of ground vibration, air blast levels and fly rock risks were determined using methods provided by the USBM. A potential blast design was estimated considering the potential bench height (when considering the depth to the coal resource), with this assessment indicating that:

- That ground vibration levels may be unpleasant to BSRs when blasting take place within approximately 2,200 m from structures used for residential or business activities (precautious evaluation using a worst-case scenario). The impact is of a potential **High** significance and mitigation is required and proposed that could reduce the significance of potential impact of vibration levels on BSR to **Low**. However, due to the sensitivity to blast effects, it is possible that people may still complain about the perceived blast effects even after the implementation of mitigation measures;
- That ground vibration levels could be of **High** significance to any brick buildings located within 500 m from the proposed opencast pits. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on such buildings to **Low**;
- That ground vibration levels could be of **High** significance once blasting activities take place closer than 200 m from any cement dams. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on the dams to **Low**;
- That ground vibration levels could be of **Medium** significance once blasting activities take place closer than 160 m from the tar road and railway line. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on these structures to **Low**;
- Air blast levels will be clearly audible to all surrounding receptors and the significance will be **High** for the closest BSRs. Additional mitigation is recommended and included to reduce potential complaints and annoyance with the project. Due to the sensitivity of people to the significant loud noise as well as secondary vibration of large surfaces (due to the change in air pressure) associated with a blasting event, BSRs must be informed about the potential impacts. It is possible that people may still complain about the perceived blast effects even after the implementation of mitigation measures;
- There may be a risk of **High** significance of fly rock to BSRs or BSSs, and blasting close to the mine equipment and infrastructure may result in fly rock damage. Management measures are available to ensure that risks are minimised.

In addition, community involvement throughout the project is of utmost importance. This is especially true for any mining projects where blasting may take place, irrespective of the temporary nature of blasting. Blasting related impacts may potentially upset the surrounding community and complaints could be one of the tools that the community may use to express their annoyance with the project, rather than a rational reaction to the vibration or air blast levels itself.

At all stages surrounding receptors should be informed about the project, providing them with factual information without setting unrealistic expectations. Even with the best measures, blasting related impacts will be perceived negatively and the community members may complain. It is therefore in the best interest of the mine to continually monitor and manage the blast in an effort to improve and minimise potential blasting effects. It is highly recommended that the mine conducts a detailed photographic survey at selected structures (that does not belong to the mine) located within 2,000 m from the mine (from locations where blasting may take place) before any mining activities start (before the construction phase start where blasting is to take place). This should include a survey (condition assessment with photographic records) of residential structures (within 2,000 m from opencast pits), heritage structures (of high cultural or archaeological value – if relevant), water boreholes (within 2,000 m from opencast pits) and cement dams (within 500 m from opencast pits) to determine the status of these structures.

Blasting will take place closer than 500 m from any roads and the mine must note that GNR.584 of 2015 does limit blasting within 500 m from certain structures (such as roads, railway lines or overhead power lines) unless certain conditions are met. The mine will have to discuss the project with the relevant provincial authorities to authorize the temporary closure of the roads and implement the agreed upon mitigation measures. The mine must obtain the schedule of rail traffic and plan blasting times accordingly. Warning signs should be erected within 1,000 m during blasting events along the roads and railway line.

It is concluded that, if the mine considers the recommendations in this report (incorporated in the Environmental Management Plan), that blasting risks do not constitute a fatal flaw. It is, therefore, the recommendation that the blasting activities associated with the Naudesbank Coal project be authorized subject to compliance with the conditions of the EMP, on condition that:

- That this report be updated once the actual blast design at the mine is finalized;
- This report be updated if the blast design is changed where more than 1,585 kg explosives are detonated per delay;
- This report be updated if the location of the opencast pit is moved with more than 100 m; and,
- This report be updated if the blast parameters changed with the mine making use of borehole with a larger diameter than considered in this report (150 mm) or the burden and spacing distances are increased.

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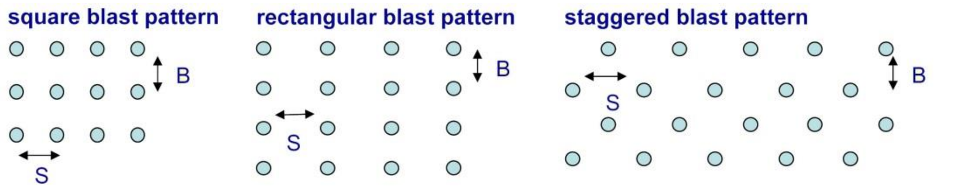
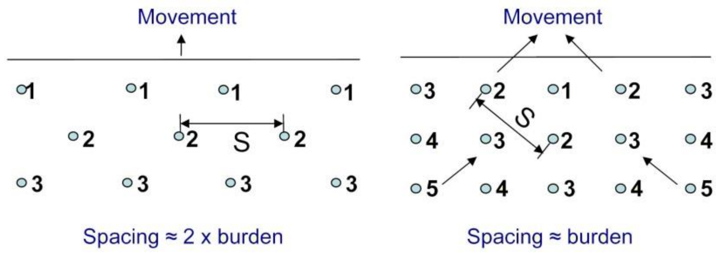
APPENDIX A

Glossary of Blasting Terms, Definitions and General Information

Air blast	Any blast delivers a shock wave through the air that begins with the actual explosion.
Ammonium Nitrate	NH_4NO_3, which is the ammonium salt of nitric acid.
ANFO	An amalgamation of ammonium nitrate and fuel oil that is highly explosive.
Blast Area	The full area that can experience any flying rock, debris or gas during and after a blast.
Blast Pattern	The array of locations for blast holes and/or the relationship between burden (B) and spacing (S) distance. 
Blasting Vibrations	The post-blast energy that travels through the earth away from the blast area.
Burden	The amount of rock broken and displaced by a blast as measured by the distance between the closest free face and the actual blasting hole.
Charge per Delay	The total charge mass firing during any given span of 8 milliseconds, also known as blast hole(s) per delay
Decibel	A unit typically used to measure the air overpressure of an air blast.
Decking	The use of hole plugs or inert material to create a section without explosives in a blast hole, dividing the charge hole into a “top” and “bottom” deck. It is used to reduce either the charge load per hole, the amount of explosives detonated per delay, to keep explosives out of weak zones or a combination of these.
Delay	A pre-planned and distinct pause between detonations or initiations to allow for explosive to fire separately.
Detonation	The explosive reaction that moves through explosive materials at a speed greater than the speed of sound.
Fly rock	The rocks propelled by an explosion’s force in the blast area.
Free Face	Rock surfaces adjacent to water or air that allow for expansion at the time of fragmentation.
Ground Vibration	The shaking of the ground as caused by the shock waves emanating from a blast.
Interested and Affected Party	These are individuals or groups concerned with or affected by the environmental impacts and performance of a project. Interested groups include those exercising statutory environmental control over the project, local residents/communities (people living and/or working close to the project), the project’s employees, customers, consumers, investors and insurers, environmental interest groups, the general public, etc. It covers: • Host Communities • Landowners (Traditional and Title Deed owners) • Traditional Authority • Land Claimants • Lawful land occupier • Any other person (including on adjacent and non-adjacent properties) whose socio-economic conditions may be directly affected by the proposed prospecting or mining operation • The Local Municipality • The relevant Government Departments, agencies and institutions responsible for the various aspects of the environment and for infrastructure which may be affected by the proposed project.
Particle Velocity	The rate at which vibrations travel through the ground as measured by the time rate of change of the ground vibration’s amplitude.

Peak Particle Velocity	The maximum intensity of ground vibration during a blast.
Pre-blast Condition Survey	The area within 200 meter of the blasting site is commonly surveyed within a month of the blasting, including utilities, buildings, improvements and more.
Presplitting	A technique for controlled blasting that creates a continuous or semi-continuous fracture in the space between blast holes.
Propagation	When explosive charges detonate due to an impulse from another nearby or adjacent detonation of explosives.
Receptor	Target or object on which the impact, stressor or hazard is expected to have an effect.
Scaled Distance	The relative vibration energy as measured by the distance between a charge per delay and a structure.
Seismograph	An instrument used to record ground vibrations.
Shock Wave	The transient pressure pulse that moves at a supersonic velocity.
Spacing	The distance spanning blast holes lined up in a row, measured perpendicular to the burden. 
Specific Gravity	A ratio that expresses the weight of pure water to the weight of an equal volume of another substance.
Stemming	A technique used for limited air-overpressure and rock movement that involves drilling a blast hole beyond or below the desired excavation limit or depth. Stemming contains explosive energy within a blast hole, so that it will break and move the rock without generating flyrock. Sized crushed stone or drill cuttings should be used as stemming.
Sub drilling	The drilling of a blast hole or a portion of a blast hole below or beyond the planned excavation depth or limit. The subdrill portion of a borehole is generally backfilled with drill cuttings or other stemming material and does not contain explosives.
Under-burdened	A hole drilled too close to the face of the blast with not enough rock to effectively contain the explosion and expanding gasses resulting in dangerous fly rock and excessive air blast.
Vibration Limits	Blasting causes vibration in surrounding structures, and this vibration is limited (in inches per second) depending on the types of buildings in the immediate vicinity (residential, commercial, public, historic, etc.)
Warning Signal	Any signal given visually or audibly that warns personnel and bystanders in a blast area's vicinity of the impending explosion.

APPENDIX B

Effect of Blast Vibration on Materials and Structures

PPV (Inch/s)	PPV (mm/s)	Application	Effect	Source
600	15240	Explosive inside concrete	Explosive inside concrete Mass blowout of concrete	Tart, 1980
375	9525	Explosive inside concrete	Explosive inside concrete Radial cracks develop in concrete	Tart, 1980
200	5080	Explosive inside concrete	Explosive inside concrete Spalling of loose/weathered concrete skin	Tart, 1980
> 100	>2540	Rock	Complete breakup of rock masses	Bauer, 1978
100	2540	Explosive inside concrete	Spalling of fresh grout	Tart, 1980
100	2540	Explosive near concrete	No damage	Oriard, 1980
50 - 150	1270 - 3810	Explosive near buried pipe	No damage	Oriard, 1994
25 - 100	635 - 2540	Rock	Tensile and some radial cracking	Bauer, 1978
40	1016	Mechanical equipment	Shafts misaligned	Bauer, 1977
25	635	Explosive near buried pipe	No damage	Siskind, 1993
25	635	Rock	Damage can occur in rock masses	Oriard, 1970
25	635	Rock	Minor tensile slabbing	Bauer, 1978
24	610	Rock	Rock fracturing	Langefors, 1948
15	381	Cased drill holes	Horizontal offset	Bauer, 1977
> 12	>305	Rock	Rockfalls in underground tunnels	Langefors, 1948
12	305	Rock	Rockfalls in unlined tunnels	Blasters' Handbook, 1977
< 10	<254	Rock	No fracturing of intact rock	Bauer, 1978
9.1	231	Residential structures	Serious cracking	Langefors, 1948
8	203	Concrete blocks	Cracking in blocks	Bauer, 1977
8	203	Plaster	Major cracking	Northwood, 1963
7.6	193	Plaster	50% probability of major damage	Blasters' Handbook, 1977
7.0 - 8.0	178 - 203	Cased water wells	No adverse effect on well	Rose, 1991
> 7.0	> 178	Residential structure	Major damage possible	Nicholls, 1971
4.0 - 7.0	101 - 178	Residential structure	Minor damage possible e	Nicholls, 1971
6.3	160	Residential structure	Plaster and masonry walls crack	Langefors, 1948
5.44	138	Water wells	No change in well performance	Robertson, 1980
5.4	137	Plaster	50% probability of minor damage	Blasters' Handbook, 1977
4.5	114	Plaster	Minor cracking	Northwood, 1963
4.3	109	Residential structure	Fine cracks in plaster	Langefors, 1948
> 4.0	> 102	Residential structure	Probable damage	Edwards, 1960
2.0 - 4.0	50 - 100	Residential structure	Residential structure Plaster cracking (cosmetic)	Nicholls, 1971
2.8 - 3.3	71 - 83.8	Plaster	Threshold of damage (from close-in blasts)	Blasters' Handbook, 1977
3	76.2	Plaster	Threshold of cosmetic cracking	Northwood, 1963
1.2 - 3.0	31 - 76	Residential structure	Equals stress from daily environmental changes	Stagg, 1980
2.8	71	Residential structure	No damage	Langefors, 1948
2	50	Residential structure	Plaster can start to crack	Bauer, 1977
2	50	Plaster	Safe level of vibration	Blasters' Handbook, 1977
< 2.0	< 50	Residential structure	No damage	Nicholls, 1971
< 2.0	< 50	Residential structure	No damage	Edwards, 1960
0.9	23	Residential structure	Equivalent to nail driving	Stagg, 1980
0.5	13	Mercury switch	Trip switch	Bauer, 1977
0.5	13	Residential structure	Equivalent to door slam	Stagg, 1980
0.1 - 0.5	2.54 - 12	Residential structure	Equates to normal daily family activity	Stagg, 1980
0.3	7.62	Residential structure	Equivalent to jumping on the floor	Stagg, 1980
0.03	0.762	Residential structure	Equivalent to walking on the floor	Stagg, 1980

APPENDIX C

Effect of Blasting Impacts on Receptors and Structures –

Development of Opencast Pit

Appendix C, Table 1: Potential human response and significance of impact due to blasting vibration impacts

Human response - Vibration								
Use	X (UTM, S 35)	Y (UTM, S 35)	Ref.	Closest distance from potential blast site	PPV, 158 kg Blast/delay (Small blast)	PPV, 1585 kg Blast/delay (Large blast)	Potential response, 158 kg blast/delay (Small blast)	Potential response, 1585 kg blast/delay (Large blast)
BSR	793251	7113668	1	77	**74.6**	**424.4**	Intolerable.	Intolerable.
BSR	793325	7113742	2	2	**18484.8**	**105151.1**	Intolerable.	Intolerable.
BSR	794503	7112410	3	671	**2.8**	**16.1**	Unpleasant	Unpleasant
BSR	794569	7111665	4	615	**3.2**	**18.4**	Unpleasant	Intolerable.
BSR	796051	7108979	5	525	**4.1**	**23.4**	Unpleasant	Intolerable.
BSR	796226	7109364	6	182	**20.4**	**115.8**	Intolerable.	Intolerable.
BSR	797226	7110530	7	210	**16.4**	**93.3**	Unpleasant	Intolerable.
BSR	797436	7110736	8	304	**9.4**	**53.4**	Unpleasant	Intolerable.
BSR	797266	7111110	9	137	**31.3**	**177.8**	Intolerable.	Intolerable.
BSR	797071	7111194	10	140	**30.2**	**172.1**	Intolerable.	Intolerable.
BSR	798883	7109298	11	1584	**0.8**	**4.4**	Detectable	Unpleasant
BSR	797766	7114302	12	1941	**0.6**	**3.2**	Detectable	Unpleasant
BSR	796791	7112027	13	801	**2.2**	**12.4**	Detectable	Unpleasant
BSR	798447	7112274	14	741	**2.4**	**13.9**	Detectable	Unpleasant
BSR	798521	7112183	15	752	**2.4**	**13.6**	Detectable	Unpleasant
BSR	798469	7112137	16	821	**2.1**	**11.9**	Detectable	Unpleasant
BSR	800549.9	7114221	17	1292	**1.1**	**6.0**	Detectable	Unpleasant
BSR	800460.8	7114331	18	1345	**1.0**	**5.6**	Detectable	Unpleasant
BSR	798014	7109241	19	851	**2.0**	**11.3**	Detectable	Unpleasant
BSR	791036	7114498	20	1056	**1.4**	**8.1**	Detectable	Unpleasant
BSR	798584	7108452	21	1803	**0.6**	**3.6**	Detectable	Unpleasant

Significance of impact (human response due to vibration)									
Ref.	Vibration Limit (mm/s)	Extent	Duration	Severity (unmitigated, large blast)	Probability (unmitigated, large blast)	Significance (unmitigated, large blast)	Severity (Mitigated, small blast)	Probability (Mitigated, small blast)	Significance (Mitigated, small blast)
1	2.54	3	4	10	5	**85**	10	5	**85**
2	2.54	3	4	10	5	**85**	10	5	**85**
3	2.54	3	4	10	5	**85**	8	2	**30**
4	2.54	3	4	10	5	**85**	8	2	**30**
5	2.54	3	4	10	5	**85**	8	2	**30**
6	2.54	3	4	10	5	**85**	10	5	**85**
7	2.54	3	4	10	5	**85**	10	5	**85**
8	2.54	3	4	10	5	**85**	10	4	**68**
9	2.54	3	4	10	5	**85**	10	5	**85**
10	2.54	3	4	10	5	**85**	10	5	**85**
11	2.54	3	4	8	2	**30**	6	1	**13**
12	2.54	3	4	8	2	**30**	4	1	**11**
13	2.54	3	4	10	5	**85**	6	1	**13**
14	2.54	3	4	10	5	**85**	6	1	**13**
15	2.54	3	4	10	5	**85**	6	1	**13**
16	2.54	3	4	10	5	**85**	6	1	**13**
17	2.54	3	4	8	3	**45**	6	1	**13**
18	2.54	3	4	8	3	**45**	6	1	**13**
19	2.54	3	4	10	5	**85**	6	1	**13**
20	2.54	3	4	10	4	**68**	6	1	**13**
21	2.54	3	4	8	2	**30**	4	1	**11**

Appendix C, Table 2: Potential response and significance of impact from blasting vibrations on structures

Vibration Damage - Brick houses (25 mm/s) and/or steel structures (75 mm/s)								
Use	X (UTM, S 35)	Y (UTM, S 35)	Ref.	Closest distance from potential blast site	PPV, 158 kg Blast/delay (Small blast)	PPV, 1585 kg Blast/delay (Large blast)	Potential structural damage for a 158 kg blast/charge	Potential structural damage for a 1585 kg blast/charge
House/Shed	793252	7113674	1	74	**79.2**	**450.6**	Risks	Risks
House/Shed	793324	7113743	2	2	**18484.8**	**105151.1**	Risks	Risks
House/Shed	794503	7112413	3A	668	**2.9**	**16.3**	Very Low Risk	Very Low Risk
House/Shed	794518	7112408	3B	677	**2.8**	**15.9**	Very Low Risk	Very Low Risk
House/Shed	794491	7112421	3C	657	**2.9**	**16.7**	Very Low Risk	Very Low Risk
House/Shed	794521	7112411	3D	675	**2.8**	**16.0**	Very Low Risk	Very Low Risk
House/Shed	794572	7111661	4A	610	**3.3**	**18.6**	Very Low Risk	Very Low Risk
House/Shed	794559	7111672	4B	627	**3.1**	**17.9**	Very Low Risk	Very Low Risk
House/Shed	796053	7108981	5A	528	**4.1**	**23.2**	Very Low Risk	Very Low Risk
House/Shed	795990	7109057	5B	510	**4.3**	**24.4**	Very Low Risk	Very Low Risk
House/Shed	796036	7109080	5C	506	**4.3**	**24.7**	Very Low Risk	Very Low Risk
House/Shed	796114	7109038	5D	523	**4.1**	**23.5**	Very Low Risk	Very Low Risk
House/Shed	796226	7109364	6A	182	**20.4**	**115.8**	Very Low Risk	Risks
House/Shed	796218	7109390	6B	159	**25.0**	**142.0**	Very Low Risk	Risks
House/Shed	796286	7109352	6C	173	**22.0**	**125.0**	Very Low Risk	Risks
House/Shed	797226	7110535	7A	209	**16.5**	**94.0**	Very Low Risk	Risks
House/Shed	797197	7110510	7B	199	**17.8**	**101.2**	Very Low Risk	Risks
House/Shed	797145	7110543	7C	146	**28.4**	**161.5**	Risks	Risks
House/Shed	797269	7110573	7D	218	**15.5**	**88.2**	Very Low Risk	Risks
House/Shed	797224	7110564	7E	189	**19.2**	**109.4**	Very Low Risk	Risks
House/Shed	797211	7110552	7F	187	**19.5**	**111.1**	Very Low Risk	Risks
House/Shed	797249	7110531	7G	204	**17.1**	**97.5**	Very Low Risk	Risks
House/Shed	797436	7110741	8A	303	**9.4**	**53.6**	Very Low Risk	Risks
House/Shed	797455	7110733	8B	323	**8.6**	**48.7**	Very Low Risk	Risks
House/Shed	797471	7110728	8C	340	**7.9**	**45.1**	Very Low Risk	Risks
House/Shed	797487	7110725	8D	356	**7.4**	**42.0**	Very Low Risk	Risks
House/Shed	797496	7110723	8E	365	**7.1**	**40.5**	Very Low Risk	Risks
House/Shed	797506	7110741	8F	370	**7.0**	**39.7**	Very Low Risk	Risks
House/Shed	797536	7110724	8G	403	**6.1**	**34.9**	Very Low Risk	Risks
House/Shed	797415	7110741	8I	283	**10.5**	**59.5**	Very Low Risk	Risks
House/Shed	797385	7110753	8J	251	**12.5**	**71.3**	Very Low Risk	Risks
House/Shed	797372	7110751	8K	239	**13.5**	**76.7**	Very Low Risk	Risks
House/Shed	797363	7110757	8L	229	**14.4**	**81.8**	Very Low Risk	Risks
House/Shed	797360	7110777	8M	219	**15.4**	**87.6**	Very Low Risk	Risks
House/Shed	797371	7110782	8N	228	**14.5**	**82.4**	Very Low Risk	Risks
House/Shed	797266	7111112	9A	139	**30.6**	**173.9**	Risks	Risks
House/Shed	797217	7111136	9B	141	**29.9**	**170.2**	Risks	Risks
House/Shed	797259	7111091	9C	118	**39.2**	**222.8**	Risks	Risks
House/Shed	797182	7111114	9D	108	**44.8**	**254.6**	Risks	Risks
House/Shed	797072	7111195	10A	141	**29.9**	**170.2**	Risks	Risks
House/Shed	797084	7111206	10B	157	**25.4**	**144.7**	Risks	Risks
House/Shed	798896	7109306	11A	1592	**0.8**	**4.4**	Very Low Risk	Very Low Risk
House/Shed	798865	7109280	11B	1576	**0.8**	**4.4**	Very Low Risk	Very Low Risk
House/Shed	798836	7109277	11C	1551	**0.8**	**4.6**	Very Low Risk	Very Low Risk
House/Shed	798836	7109247	11D	1565	**0.8**	**4.5**	Very Low Risk	Very Low Risk
House/Shed	798888	7109256	11E	1607	**0.8**	**4.3**	Very Low Risk	Very Low Risk
House/Shed	798847	7109188	11F	1604	**0.8**	**4.3**	Very Low Risk	Very Low Risk
House/Shed	798854	7109313	11G	1551	**0.8**	**4.6**	Very Low Risk	Very Low Risk
House/Shed	798805	7109293	11H	1516	**0.8**	**4.7**	Very Low Risk	Very Low Risk
House/Shed	797766	7114347	12A	1974	**0.6**	**3.2**	Very Low Risk	Very Low Risk
House/Shed	797741	7114309	12B	1964	**0.6**	**3.2**	Very Low Risk	Very Low Risk
House/Shed	797773	7114282	12C	1922	**0.6**	**3.3**	Very Low Risk	Very Low Risk
House/Shed	797738	7114250	12D	1924	**0.6**	**3.3**	Very Low Risk	Very Low Risk
House/Shed	797807	7114212	12E	1848	**0.6**	**3.5**	Very Low Risk	Very Low Risk

House/Shed	797792	7114258	12F	1892	**0.6**	**3.4**	Very Low Risk	Very Low Risk
House/Shed	797846	7114280	12G	1870	**0.6**	**3.4**	Very Low Risk	Very Low Risk
House/Shed	796788	7112025	13A	798	**2.2**	**12.4**	Very Low Risk	Very Low Risk
House/Shed	796804	7112026	13B	805	**2.2**	**12.3**	Very Low Risk	Very Low Risk
House/Shed	798449	7112275	14A	739	**2.5**	**14.0**	Very Low Risk	Very Low Risk
House/Shed	798437	7112262	14B	757	**2.4**	**13.5**	Very Low Risk	Very Low Risk
House/Shed	798520	7112180	15A	755	**2.4**	**13.5**	Very Low Risk	Very Low Risk
House/Shed	798535	7112184	15B	742	**2.4**	**13.9**	Very Low Risk	Very Low Risk
House/Shed	798535	7112194	15C	734	**2.5**	**14.1**	Very Low Risk	Very Low Risk
House/Shed	798462	7112131	16A	830	**2.1**	**11.7**	Very Low Risk	Very Low Risk
House/Shed	798472	7112144	16B	814	**2.1**	**12.1**	Very Low Risk	Very Low Risk
House/Shed	798474	7112128	16C	824	**2.1**	**11.8**	Very Low Risk	Very Low Risk
House/Shed	798473	7112136	16D	819	**2.1**	**11.9**	Very Low Risk	Very Low Risk
House/Shed	800555.2	7114228	17A	1300	**1.0**	**5.9**	Very Low Risk	Very Low Risk
House/Shed	800540	7114224	17B	1288	**1.1**	**6.0**	Very Low Risk	Very Low Risk
House/Shed	800541.4	7114213	17C	1280	**1.1**	**6.1**	Very Low Risk	Very Low Risk
House/Shed	800462.5	7114345	18A	1358	**1.0**	**5.6**	Very Low Risk	Very Low Risk
House/Shed	800460.8	7114332	18B	1345	**1.0**	**5.6**	Very Low Risk	Very Low Risk
House/Shed	800452.3	7114320	18C	1331	**1.0**	**5.7**	Very Low Risk	Very Low Risk
House/Shed	798013	7109243	19A	849	**2.0**	**11.3**	Very Low Risk	Very Low Risk
House/Shed	798035	7109276	19B	849	**2.0**	**11.3**	Very Low Risk	Very Low Risk
House/Shed	797979	7109321	19C	777	**2.3**	**12.9**	Very Low Risk	Very Low Risk
House/Shed	797969	7109244	19D	814	**2.1**	**12.1**	Very Low Risk	Very Low Risk
House/Shed	797984	7109221	19E	840	**2.0**	**11.5**	Very Low Risk	Very Low Risk
House/Shed	798032	7109224	19F	876	**1.9**	**10.8**	Very Low Risk	Very Low Risk
House/Shed	798020	7109258	19G	846	**2.0**	**11.4**	Very Low Risk	Very Low Risk
House/Shed	797966	7109322	19H	766	**2.3**	**13.2**	Very Low Risk	Very Low Risk
House/Shed	791014	7114497	20A	1075	**1.4**	**7.9**	Very Low Risk	Very Low Risk
House/Shed	791023	7114468	20B	1055	**1.4**	**8.2**	Very Low Risk	Very Low Risk
House/Shed	791066	7114595	20C	1076	**1.4**	**7.9**	Very Low Risk	Very Low Risk
House/Shed	791030	7114562	20D	1091	**1.4**	**7.7**	Very Low Risk	Very Low Risk
House/Shed	791141	7114529	20E	978	**1.6**	**9.1**	Very Low Risk	Very Low Risk
House/Shed	798584	7108452	21A	1803	**0.6**	**3.6**	Very Low Risk	Very Low Risk
House/Shed	798607	7108490	21B	1792	**0.6**	**3.7**	Very Low Risk	Very Low Risk
House/Shed	798477	7108482	21C	1707	**0.7**	**3.9**	Very Low Risk	Very Low Risk
Use not defined	794176	7114966	22A	1012	**1.5**	**8.7**	Very Low Risk	Very Low Risk
Use not defined	794181	7115008	22B	1052	**1.4**	**8.2**	Very Low Risk	Very Low Risk
Use not defined	797678	7109953	23A	220	**15.3**	**87.0**	Very Low Risk	Risks
Use not defined	795908	7108637	24A	359	**7.3**	**41.5**	Very Low Risk	Risks
Use not defined	793489	7111376	25A	1319	**1.0**	**5.8**	Very Low Risk	Very Low Risk
Use not defined	793455	7111366	25B	1347	**1.0**	**5.6**	Very Low Risk	Very Low Risk
Use not defined	797463	7107965	26A	1741	**0.7**	**3.8**	Very Low Risk	Very Low Risk

Significance of impact (Vibration damage on brick house)									
Ref.	Vibration Limit (mm/s)	Extent	Duration	Severity (unmitigated, large blast)	Probability (unmitigated, large blast)	Significance (unmitigated, large blast)	Severity (Mitigated, small blast)	Probability (Mitigated, small blast)	Significance (Mitigated, small blast)
1	25	2	4	10	5	**80**	10	4	**64**
2	25	2	4	10	5	**80**	10	5	**80**
3A	25	2	4	8	1	**14**	6	1	**12**
3B	25	2	4	8	1	**14**	6	1	**12**
3C	75	2	4	6	1	**12**	2	1	**8**
3D	25	2	4	8	1	**14**	6	1	**12**
4A	25	2	4	8	1	**14**	6	1	**12**
4B	75	2	4	6	1	**12**	2	1	**8**
5A	75	2	4	8	1	**14**	4	1	**10**
5B	25	2	4	8	1	**14**	6	1	**12**
5C	25	2	4	8	1	**14**	6	1	**12**
5D	25	2	4	8	1	**14**	6	1	**12**
6A	25	2	4	10	4	**64**	8	1	**14**
6B	25	2	4	10	5	**80**	8	1	**14**
6C	25	2	4	10	5	**80**	8	1	**14**

7A	25	2	4	10	4	64	8	1	14
7B	25	2	4	10	4	64	8	1	14
7C	25	2	4	10	5	80	10	2	32
7D	25	2	4	10	4	64	8	1	14
7E	25	2	4	10	4	64	8	1	14
7F	25	2	4	10	4	64	8	1	14
7G	25	2	4	10	4	64	8	1	14
8A	25	2	4	10	3	48	8	1	14
8B	25	2	4	10	2	32	8	1	14
8C	25	2	4	10	2	32	8	1	14
8D	25	2	4	10	2	32	8	1	14
8E	75	2	4	8	1	14	4	1	10
8F	75	2	4	8	1	14	4	1	10
8G	75	2	4	8	1	14	4	1	10
8I	25	2	4	10	3	48	8	1	14
8J	75	2	4	8	1	14	6	1	12
8K	75	2	4	10	2	32	6	1	12
8L	75	2	4	10	2	32	6	1	12
8M	75	2	4	10	2	32	6	1	12
8N	75	2	4	10	2	32	6	1	12
9A	75	2	4	10	3	48	8	1	14
9B	25	2	4	10	5	80	10	2	32
9C	25	2	4	10	5	80	10	2	32
9D	25	2	4	10	5	80	10	2	32
10A	25	2	4	10	5	80	10	2	32
10B	25	2	4	10	5	80	10	2	32
11A	75	2	4	4	1	10	2	1	8
11B	75	2	4	4	1	10	2	1	8
11C	25	2	4	6	1	12	2	1	8
11D	25	2	4	6	1	12	2	1	8
11E	25	2	4	6	1	12	2	1	8
11F	75	2	4	4	1	10	2	1	8
11G	25	2	4	6	1	12	2	1	8
11H	25	2	4	6	1	12	2	1	8
12A	25	2	4	6	1	12	2	1	8
12B	25	2	4	6	1	12	2	1	8
12C	25	2	4	6	1	12	2	1	8
12D	25	2	4	6	1	12	2	1	8
12E	25	2	4	6	1	12	2	1	8
12F	25	2	4	6	1	12	2	1	8
12G	25	2	4	6	1	12	2	1	8
13A	25	2	4	8	1	14	4	1	10
13B	25	2	4	8	1	14	4	1	10
14A	25	2	4	8	1	14	4	1	10
14B	25	2	4	8	1	14	4	1	10
15A	25	2	4	8	1	14	4	1	10
15B	25	2	4	8	1	14	4	1	10
15C	25	2	4	8	1	14	4	1	10
16A	25	2	4	8	1	14	4	1	10
16B	25	2	4	8	1	14	4	1	10
16C	25	2	4	8	1	14	4	1	10
16D	25	2	4	8	1	14	4	1	10
17A	25	2	4	6	1	12	2	1	8
17B	25	2	4	6	1	12	2	1	8
17C	25	2	4	6	1	12	2	1	8
18A	25	2	4	6	1	12	2	1	8
18B	25	2	4	6	1	12	2	1	8
18C	25	2	4	6	1	12	2	1	8
19A	25	2	4	8	1	14	4	1	10
19B	25	2	4	8	1	14	4	1	10
19C	25	2	4	8	1	14	4	1	10
19D	25	2	4	8	1	14	4	1	10
19E	25	2	4	8	1	14	4	1	10
19F	25	2	4	8	1	14	4	1	10

19G	25	2	4	8	1	**14**	4	1	**10**
19H	25	2	4	8	1	**14**	4	1	**10**
20A	25	2	4	8	1	**14**	4	1	**10**
20B	25	2	4	8	1	**14**	4	1	**10**
20C	25	2	4	8	1	**14**	4	1	**10**
20D	25	2	4	8	1	**14**	4	1	**10**
20E	25	2	4	8	1	**14**	4	1	**10**
21A	25	2	4	6	1	**12**	2	1	**8**
21B	25	2	4	6	1	**12**	2	1	**8**
21C	25	2	4	6	1	**12**	2	1	**8**
22A	25	2	4	8	1	**14**	4	1	**10**
22B	25	2	4	8	1	**14**	4	1	**10**
23A	25	2	4	10	4	**64**	8	1	**14**
24A	25	2	4	10	2	**32**	8	1	**14**
25A	25	2	4	6	1	**12**	2	1	**8**
25B	25	2	4	6	1	**12**	2	1	**8**
26A	25	2	4	6	1	**12**	2	1	**8**

Appendix C, Table 3: Potential response and significance of impact from blasting vibrations on cement structures

Vibration Damage - Steel pipelines, Cement Dams and cement bridge (50 mm/s)								
Description	X (UTM, S 35)	Y (UTM, S 35)	Ref.	Distance from potential blast site	PPV, 158 kg Blast/delay (Small blast)	PPV, 1585 kg Blast/delay (Large blast)	Potential structural damage for a 158 kg blast/charge	Potential structural damage for a 1585 kg blast/charge
Cement dams	794503	7112382	D1	698	**2.7**	**15.2**	Very Low Risk	Very Low Risk
Cement dams	795954	7109127	D2	503	**4.4**	**24.9**	Very Low Risk	Very Low Risk
Cement dams	796118	7109228	D3	339	**8.0**	**45.3**	Very Low Risk	Very Low Risk
Cement dams	797181	7111157	D4	147	**28.1**	**159.9**	Very Low Risk	Risks
Cement dams	798932	7109308	D5	1623	**0.7**	**4.3**	Very Low Risk	Very Low Risk
Cement dams	798784	7109146	D6	1570	**0.8**	**4.5**	Very Low Risk	Very Low Risk
Cement dams	800697.2	7114094	D7	1249	**1.1**	**6.3**	Very Low Risk	Very Low Risk
Cement dams	800685.4	7114100	D8	1248	**1.1**	**6.3**	Very Low Risk	Very Low Risk
Cement dams	797751	7114307	D9	1955	**0.6**	**3.2**	Very Low Risk	Very Low Risk
Cement dams	798626	7108440	D10	1841	**0.6**	**3.5**	Very Low Risk	Very Low Risk
Cement dams	791098	7114536	D11	1018	**1.5**	**8.6**	Very Low Risk	Very Low Risk
Cement dams	792671	7113391	D12	110	**43.5**	**247.7**	Risks	Risks
Cement dams	794318	7112543	D13	485	**4.6**	**26.4**	Very Low Risk	Risks
Cement dams	794190	7114985	D14	1035	**1.5**	**8.4**	Very Low Risk	Very Low Risk
Cement dams	797346	7112003	D15	991	**1.6**	**9.0**	Very Low Risk	Very Low Risk
Cement dams	800721.4	7113838	D16	1035	**1.5**	**8.4**	Very Low Risk	Very Low Risk
Cement dams	801770.9	7113563	D17	1686	**0.7**	**4.0**	Very Low Risk	Very Low Risk
Cement dams	793534	7111416	D18	1293	**1.1**	**6.0**	Very Low Risk	Very Low Risk
Cement dams	793530	7111408	D19	1293	**1.1**	**6.0**	Very Low Risk	Very Low Risk
Cement dams	792555	7111494	D20	2217	**0.5**	**2.7**	Very Low Risk	Very Low Risk
Cement dams	795273	7107069	D21	1721	**0.7**	**3.9**	Very Low Risk	Very Low Risk
Cement dams	797457	7108003	D22	1702	**0.7**	**4.0**	Very Low Risk	Very Low Risk

Significance of impact (Vibration damage on Steel pipelines, Cement Dams and cement bridge)									
Ref.	Vibration Limit (mm/s)	Extent	Duration	Severity (unmitigated, large blast)	Probability (unmitigated, large blast)	Significance (unmitigated, large blast)	Severity (Mitigated, small blast)	Probability (Mitigated, small blast)	Significance (Mitigated, small blast)
D1	50	2	4	8	1	**14**	4	1	**10**
D2	50	2	4	8	1	**14**	4	1	**10**
D3	50	2	4	8	1	**14**	6	1	**12**
D4	50	2	4	10	4	**64**	8	1	**14**
D5	50	2	4	4	1	**10**	2	1	**8**
D6	50	2	4	4	1	**10**	2	1	**8**
D7	50	2	4	6	1	**12**	2	1	**8**

D8	50	2	4	6	1	**12**	2	1	**8**
D9	50	2	4	4	1	**10**	2	1	**8**
D10	50	2	4	4	1	**10**	2	1	**8**
D11	50	2	4	6	1	**12**	2	1	**8**
D12	50	2	4	10	4	**64**	8	1	**14**
D13	50	2	4	8	1	**14**	4	1	**10**
D14	50	2	4	6	1	**12**	2	1	**8**
D15	50	2	4	6	1	**12**	2	1	**8**
D16	50	2	4	6	1	**12**	2	1	**8**
D17	50	2	4	4	1	**10**	2	1	**8**
D18	50	2	4	6	1	**12**	2	1	**8**
D19	50	2	4	6	1	**12**	2	1	**8**
D20	50	2	4	4	1	**10**	2	1	**8**
D21	50	2	4	4	1	**10**	2	1	**8**
D22	50	2	4	4	1	**10**	2	1	**8**

Appendix C, Table 4: Potential response and significance of impact from blasting vibrations on roads and railway line

Vibration Damage - Roads and Railway Lines (150 mm/s)								
Description	X (UTM, S 35)	Y (UTM, S 35)	Ref.	Distance from potential blast site	PPV, 158 kg Blast/delay (Small blast)	PPV, 1585 kg Blast/delay (Large blast)	Potential structural damage for a 158 kg blast/charge	Potential structural damage for a 1585 kg blast/charge
R38 road	795295	7108541	R38	80	**70.4**	**400.6**	Very Low Risk	Risks

Significance of impact (Vibration damage on roads and railway lines)									
Use	Vibration Limit (mm/s)	Extent	Duration	Severity (unmitigated, large blast)	Probability (unmitigated, large blast)	Significance (unmitigated, large blast)	Severity (Mitigated, small blast)	Probability (Mitigated, small blast)	Significance (Mitigated, small blast)
R38 road	150	2	4	10	3	**48**	8	1	**14**

Appendix C, Table 5: Potential human response and significance of impact due to airblast level

Human response - Airblast								
	X (UTM, S 35)	Y (UTM, S 35)	Ref.	Distance from potential blast site	Air Blast Level, 158 kg Blast/delay (dB)	Air Blast Level, 1585 kg Blast/delay (dB)	Potential response, 158 kg blast/delay (Small blast)	Potential response, 1585 kg blast/delay (Large blast)
BSR	793251	7113668	1	77	**137.3**	**145.3**	Complains.	Complains.
BSR	793325	7113742	2	2	**175.4**	**183.4**	Complains.	Complains.
BSR	794503	7112410	3	671	**114.8**	**122.8**	No Response	Complains.
BSR	794569	7111665	4	615	**115.7**	**123.7**	No Response	Complains.
BSR	796051	7108979	5	525	**117.3**	**125.3**	No Response	Complains.
BSR	796226	7109364	6	182	**128.4**	**136.4**	Complains.	Complains.
BSR	797226	7110530	7	210	**126.9**	**134.9**	Complains.	Complains.
BSR	797436	7110736	8	304	**123.0**	**131.0**	Complains.	Complains.
BSR	797266	7111110	9	137	**131.3**	**139.3**	Complains.	Complains.
BSR	797071	7111194	10	140	**131.1**	**139.1**	Complains.	Complains.
BSR	798883	7109298	11	1584	**105.8**	**113.8**	No Response	No Response
BSR	797766	7114302	12	1941	**103.7**	**111.7**	No Response	No Response
BSR	796791	7112027	13	801	**112.9**	**120.9**	No Response	Complains.
BSR	798447	7112274	14	741	**113.7**	**121.7**	No Response	Complains.
BSR	798521	7112183	15	752	**113.6**	**121.6**	No Response	Complains.
BSR	798469	7112137	16	821	**112.7**	**120.7**	No Response	Complains.
BSR	800549.9	7114221	17	1292	**107.9**	**115.9**	No Response	No Response
BSR	800460.8	7114331	18	1345	**107.5**	**115.5**	No Response	No Response
BSR	798014	7109241	19	851	**112.3**	**120.3**	No Response	Complains.
BSR	791036	7114498	20	1056	**110.0**	**118.0**	No Response	No Response

BSR	798584	7108452	21	1803	**104.5**	**112.5**	No Response	No Response

Significance of impact (human response due to airblast levels)									
Ref.	Airblast Limit (dBA)	Extent	Duration	Severity (unmitigated, large blast)	Probability (unmitigated, large blast)	Significance (unmitigated, large blast)	Severity (Mitigated, small blast)	Probability (Mitigated, small blast)	Significance (Mitigated, small blast)
1	120	3	4	10	5	**85**	10	5	**85**
2	120	3	4	10	5	**85**	10	5	**85**
3	120	3	4	6	4	**52**	2	2	**18**
4	120	3	4	6	4	**52**	4	3	**33**
5	120	3	4	6	4	**52**	4	3	**33**
6	120	3	4	10	5	**85**	6	4	**52**
7	120	3	4	10	5	**85**	6	4	**52**
8	120	3	4	8	4	**60**	6	4	**52**
9	120	3	4	10	5	**85**	8	4	**60**
10	120	3	4	10	5	**85**	8	4	**60**
11	120	3	4	2	2	**18**	2	1	**9**
12	120	3	4	2	2	**18**	2	1	**9**
13	120	3	4	6	4	**52**	2	2	**18**
14	120	3	4	6	4	**52**	2	2	**18**
15	120	3	4	6	4	**52**	2	2	**18**
16	120	3	4	6	4	**52**	2	2	**18**
17	120	3	4	4	3	**33**	2	1	**9**
18	120	3	4	4	3	**33**	2	1	**9**
19	120	3	4	6	4	**52**	2	2	**18**
20	120	3	4	4	3	**33**	2	2	**18**
21	120	3	4	2	2	**18**	2	1	**9**

End of Report

EARES
Enviro Acoustic Research

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Date: 11 August 2023
Ref: Naudesbank Blasting

Zyntha Consulting (Pty) Ltd
Midlands Office Park
Block A, Unit 3, 2
Walter Sisulu Street
Middelburg

Attention: Mr. Jaco Kleynhans

Dear Sir

SPECIALIST OPINION: CHANGES IN THE NAUDESBANK PROJECT OPENCAST PITS AND INFLUENCE ON THE FINDINGS OF THE BLASTING IMPACT ASSESSMENT

The above-mentioned issue as well as the report titled: "De Jager, M. (2023): "*Blasting Impact Assessment for the Proposed Naudesbank Coal Project west of Carolina, Mpumalanga Province*". Enviro-Acoustic Research CC, Pretoria", Report no: ZC-SPNCP/BIA/202305-Rev 0 (dated June 2023) is of reference.

The June 2023 report covered the potential blasting impact associated opencast blasting activities associated with the Naudesbank project, considering the infrastructure locations as presented in **Figure 1**. The potential impacts of ground vibration, air blast levels and fly rock risks were determined using methods provided by the USBM. A potential blast design was estimated considering the potential bench height (when considering the depth to the coal resource), with this assessment indicating:

- That ground vibration levels may be unpleasant to Blast Sensitive Receptors ("BSR") when blasting take place within approximately 2,200 m from structures used for residential or business activities (precautious evaluation using a worst-case scenario). The impact is of a potential **High** significance and mitigation is required and proposed that could reduce the significance of potential impact of vibration levels on BSR to **Low**. However, due to the sensitivity to blast effects, it is possible that people may still complain about the perceived blast effects even after the implementation of mitigation measures;
- That ground vibration levels could be of **High** significance to any brick buildings located within 500 m from the proposed opencast pits. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on such buildings to **Low**;
- That ground vibration levels could be of **High** significance once blasting activities take place closer than 200 m from any cement dams. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on the dams to **Low**;
- That ground vibration levels could be of **Medium** significance once blasting activities take place closer than 160 m from the tar road and railway line. Mitigation is required and included that could reduce the significance of potential impact of vibration levels on these structures to **Low**;
- Air blast levels will be clearly audible to all surrounding receptors and the significance will be **High** for the closest BSRs. Additional mitigation is recommended and included to reduce

potential complaints and annoyance with the project. Due to the sensitivity of people to the significant loud noise as well as secondary vibration of large surfaces (due to the change in air pressure) associated with a blasting event, BSRs must be informed about the potential impacts. It is possible that people may still complain about the perceived blast effects even after the implementation of mitigation measures;

- There may be a risk of **High** significance of fly rock to BSRs or BSSs, and blasting close to the mine equipment and infrastructure may result in fly rock damage. Management measures are available to ensure that risks are minimised.

Since the blasting impact assessment was completed in June 2023, Seriti Power (Pty) Ltd (the Applicant) has updated the mining layout to optimize the extraction of the coal resource. The expansion resulted in changes to the opencast pit locations (see **Figure 2**). Of these changes, the expansion of the opencast mining pits of the Vaalwater and Twyfelaar section to the south is the most significant, with the expansion introducing potential locations where blasting may take place closer to BSR01 and BSR17 (with these BSR not being part of the May 2023 report), as well as structures associated with these receptors (see also **Figure 3**).

The project expansion however will not result in the changes in the findings of the blasting impact assessment, nor the proposed mitigation measures. The expansion of the Naudesbank project will result in potential blasting related impacts (vibration, noises, air-overpressure and flyrock) at BSR22 and BSR23 (and the structures associated with the receivers). However, BSR22 and BSR23 and the structures associated with them are located further than 1,000 m from locations where blasting may take place and the potential impact from blasting related impact is expected to be low at these receptors.

It is therefore not required that the blasting impact assessment be reviewed or updated, as the existing findings and recommendations included in report ZC-SPNCP/BIA/202305-Rev 0 (dated June 2023) will be adequate for the proposed changes to the project infrastructure layout.

Should you require any further details, or have any additional questions, please do not hesitate to call me on the above numbers.

Yours Faithfully,

Morné de Jager
Enviro-Acoustic Research cc

Figure 1: Original layout and potential blast-sensitive receptors as evaluated

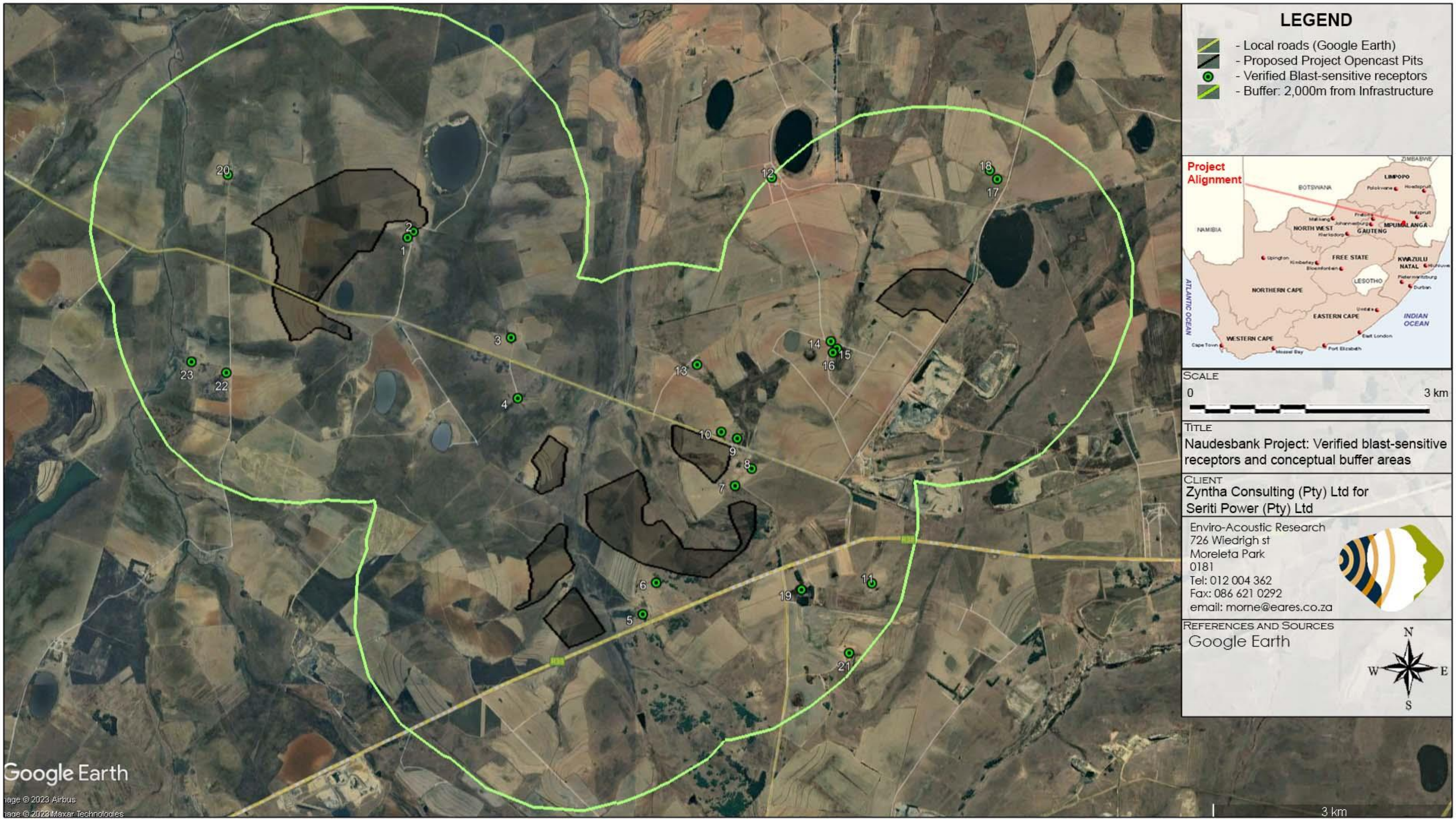

Figure 2: Proposed changes in layout and potential blast-sensitive receptors (as verified)

Figure 3: Proposed changes in layout and potential blast-sensitive structures