ENVIRONMENTAL & ENGINEERING

REPORT

IPP EQUIPMENT (PTY) LTD NNDANGANENI COLLIERY S102

AIR QUALITY IMPACT ASSESSMENT (AQIA)

REPORT REF: 22-1732

PORTION 15 OF THE FARM HARTOGS HOF 413 JS - MPUMALANGA PROVINCE.)

2022-11-08

VERSION BB

Document and Quality Control:

Document No:	22-1732 (Nndanganeni - AQIA)			
AA – draft	2022-11-08	Neel Breitenbach	[signature]	First draft for review / comments
BB – draft	2022-11-10	Lian Roos	[signature]	Quality Review (1)
CC– draft				Technical review
DD– draft				Client review
EE - draft				Final Review
Approved for Distribution:				
0.0				Final report

Quality Control BY:

Nature of Signoff	Responsible Person	Role / Responsibility	Qualification
Author	Neel Breitenbach	Visual Impact and Air Quality specialist	Senior Environmental Consultant B.Sc. Geography
Quality Reviewer	Lian Roos	Environmental Consultant	B.Sc. Environmental Science
Technical Reviewer	Henno Engelbrecht	Senior Environmental Consultant	BSc Honns Env Mgmt & Analysis MSc Project Mgmt
Client			

DISCLAIMER:

EXPERTISE OF THE REVIEWER

Name	Henno
Surname	Engelbrecht
Company	Eco Elementum (Pty) Ltd
Position	Director – Senior Environmental Scientist
Location	The Willows Office Park, Die Wilgers, Pretoria
Email	henno@ecoe.co.za
Telephone Number	082 690 9105 / 012 348 5214
Education	- Senior Certificate Matric (Cum Laude). - B.Sc. Geography (Cum Laude) (University of Pretoria). - BSc Honours Environmental Management and Analysis (Cum Laude) (University of Pretoria). - MSc Project Management (Thesis Cum Laude) (University of Pretoria).
Professional skills	Mr. Henno Engelbrecht has 10 years working experience as an Environmental Consultant and specialized in Environmental Management and Analysis. Henno worked for Environmental Assurance Pty (Ltd) as an environmental consultant since completing his studies until mid-2013 and served an array of clients in various fields of environmental practice. He has vast environmental monitoring & measurement, environmental authorisations, mine closure, and environmental impact assessment experience and worked within various project teams, up to the level of Programme Manager being responsible for all projects which fell within the Environmental Assurance (Pty) Ltd programme. His expertise led to his specialist inputs and studies to be used in several Environmental Impact Assessments, Water Use License Applications, Waste License Applications, Air Emission License Applications and Mine Closure/Rehabilitation Planning Activities. Henno holds the MSc Project Management degree at the Engineering Faculty with the University of Pretoria. He worked in mining, industrial, natural and construction environments but his expertise lies mainly within the mining sector and currently holds the position of Director at Eco Elementum (Pty) Ltd.
Skills	- Mine Closure financial quantum determination, mine closure planning and reporting. - Rehabilitation planning, reporting, management and coordination of opencast and underground mining. - Ambient air quality monitoring, measurement and implementation (passive and active) in accordance to the National Environmental Management: Air Quality Act 39 of 2004, Government Notice 248 NEM: AQA (39/2004) which contains the Listed Activities, and the National Ambient Air Quality Standards (SANS 1929: 2005). - Noise monitoring and measurement according to SANS 10103:2008, the measurement and rating of environmental noise with respect to annoyance and to speech communication & SANS 10328:2008, Methods for environmental noise impact assessment. - Water quality monitoring, measurement, reporting and data analyses including surface water, ground water, process water, sewage water and biological indicators. - Groundwater hydrocensus studies – borehole surface water depth monitoring, measurement, transections and analysis. - ISO 14001 Environmental Management Systems auditing, system implementation, training and environmental analysis (creation of aspect/impact registers, contractor training, general environmental awareness training, legal compliance audits, GAP analysis, documentation reviews, roles and authority allocations etc.) - Legal compliance auditing and reporting in accordance with the National Environmental Management Acts and other associated environmental related (NEMA listed activities, Air Quality Act listed activities, Water Use Licensing, Waste Licensing, Air Emissions Licensing etc.) - Environmental training (contractor training, monitoring and measurement training, awareness training). - Environmental impact assessments and Integrated Water Use License Applications. - Environmental Management Plan development, monitoring, compliance auditing etc. - Environmental Control Officer Site inspections- non-conformance reporting (NCR), corrective action request (CAR) and preventative action request (PAR).

EXECUTIVE SUMMARY

IPP Equipment (Pty) Ltd (hereafter IPP) appointed Eco Elementum (Pty) Ltd to undertake environmental authorisations associated with the proposed Nndanganeni project. The applicant wants to conduct opencast rollover mining on an area of 60 ha comprising of portion 15 the farm Hartogs Hof 413 JS in the Mpumalanga Province of South Africa.

Eco Elementum (Pty) Ltd is to undertake the Air Quality Impact Assessment for the Nndanganeni project.

IPP wants to expand the existing Nndanganeni opencast rollover mining operations.

The coal will be processed on-site then transported by road to the clients.

The purpose of this study is to:

1. Study the available information relevant to the pre and post-development ambient air quality pollution concentrations in the environment;
2. Identify the major existing air emission sources in the environment;
3. Identify the existing sensitive air pollution areas in the environment;
4. Estimate by means of measurements and integration of the results with those of any relevant existing information the present ambient air quality climate;
5. Identify the mining related processes and equipment that will cause the major contribution to the future air quality impact;
6. Consider, evaluate and rate the potential air quality impacts; and
7. Propose relevant management and mitigation measures to lessen the anticipated impacts.

SUMMARY OF FINDINGS

The air quality impact assessment undertaken for the project includes a meteorological overview of the area. An emissions inventory was undertaken with the aim of quantifying emissions associated with the activities involved in the mining of coal. The emissions for specific activities such as tipping, wind erosion and material handling activities were calculated and the cumulative impacts were compared to the relevant ambient air quality standards to determine legal compliance.

The findings reported here is therefore a combination of historical, observed and previously modelled data and provided the background and predicted scenario of various pollutants in the proposed project mining area. The construction and operational phases were assessed. Based on the dispersion modelling simulations, the following conclusions can be summarised as follows:

PM10

For the unmitigated Daily PM10 concentrations it was predicted to be higher than the 75 µg/m³ limit for 3 of the sensitive receptors as can be seen in Table 19.

When comparing the Daily Mitigated PM10 modelled concentrations, the sensitive receptors exceeding the 75 µg/m³ limit dropped to 0 of the identified sensitive receptors. This as well, is the highest levels predicted for a 24 hour period, within the period. Due to site specific atmospheric conditions these exceedances may still occur within the limit of 4 per year.

The annual average PM10 limit of 40 µg/m³ are predicted not to exceed at any of the identified sensitive receptors for the unmitigated or mitigated scenarios.

TSP

In the unmitigated and mitigated scenarios, no sensitive receptors are predicted to exceed the monthly dust fallout for the highest month residential limit of 600 mg/m²/day.

The predicted annual dust fall out for the unmitigated and mitigated scenarios are not predicted to exceed the annual limit of 300 mg/m²/day at any of the sensitive receptors.

MITIGATION MEASURES

The mitigation measures as seen in Table 22 are recommended at the various sources:

Table 1: Mitigation Method Summary

Operation	Reduction	Method
Material Handling	50%	Water Sprays
Loading Stockpile	50%	Water Sprays
Loading Trucks	50%	Water Sprays
Wind Erosion	50%	Water Sprays
	90%	Revegetation on OB and Topsoil
Haul Road	90%	Sealed or Salt-Encrusted roads
Access Road	90%	Sealed or Salt-Encrusted roads
Primary Crushing	50%	Water Sprays
Secondary Crushing	50%	Water Sprays

Based on the results presented the following further recommendations are outlined:

- It is recommended that ambient air quality monitoring be established to get a baseline condition prior to the onset of the operations and in order to establish the level at which the proposed operations are noted to impact on the ambient air quality.
- Fallout monitoring should be continued for the life of mine to better assess the level of nuisance dust associated with both mining and process related operations. Sampling of fallout should be undertaken within the neighbouring areas as well as on-site. Dust fallout monitoring is recommended locations to be determined.
- If it is found that dust levels are measured to be exceeding limits, it is highly recommended to establish a Real-Time indicative monitoring network to quantitatively help identify the sources and to assist in the management of the mitigation of these sources.

The impacts from dust fallout and Particulate matter can be reduced by implementing dust control measures. The highest intensity of the construction work should be carried out during the summer months and not over the harsh winter months as can result in increased dispersion of fugitive dust. The mine should ensure that unpaved roads are continuously watered and treated with dust binding additive products to reduce the volume of fugitive dust emitted from unpaved roads.

Mitigation and management measures for mining operation as discussed in this report should be sufficient to ensure the mining operation can be conducted with minimal impact on the receiving environment and therefore not have a detrimental effect and can go ahead.

CONTENTS

List of Figures

List of Tables

Glossary

Assessment	A systematic, independent and documented review of operations and practises to ensure that relevant requirements are met. Qualified professionals with relevant auditing experience should conduct audits and, where possible, independent external auditors should also be used.
Construction	The time period that corresponds to any event, process, or activity that occurs during the Construction phase (e.g., building of site, buildings, and processing units) of the proposed project. This phase terminates when the project goes into full operation or use.
Director-General	means the Director-General of the Department;
Environmental Component	An attribute or constituent of the environment (i.e., air quality; marine water; waste management; geology, seismicity, soil, and groundwater; marine ecology; terrestrial ecology, noise, traffic, socio-economic) that may be impacted by the proposed project.
Environmental Impact	A positive or negative condition that occurs to an environmental component as a result of the activity of a project or facility. This impact can be directly or indirectly caused by the project's different phases (i.e., Construction, Operation, and Decommissioning).
Record of Decision	Is an environmental authorisation issued by a state department.
Responsible authority	in relation to a specific power or duty in respect of water uses, means - (a) if that power or duty has been assigned by the Minister to a catchment management agency, that catchment management agency; or (b) if that power or duty has not been so assigned, the Minister;
Air quality	A measure of exposure to air which is not harmful to your health. Air quality is measured against health risk thresholds (levels) which are designed to protect ambient air quality. Various countries including South Africa have Air Quality Standards (legally binding health risk thresholds) which aim to protect human health due to exposure to pollutants within the living space.
Ambient air	The air of the surrounding environment.
Baseline	The current and existing condition before any development or action.
Boundary layer	Within the earth's atmosphere, the boundary layer is defined as the planets boundary layer which is the air layer near the ground affected by diurnal heat, moisture or momentum transfer to or from the surface.
Climatology	The study of the long term effect of weather over a certain area during a certain period.
Concentration	When a pollutant is measured in ambient air it is referred to as the concentration of that pollutant in air. Pollutant concentrations are measured in ambient air for various reasons, i.e. to determine whether concentrations are exceeding available health risk thresholds (air quality standards); to determine how different sources of pollution contribute to ambient air concentrations in an area; to validate dispersion modelling conducted for an area; to determine how pollutant concentrations fluctuate over time in an area; and to determine the areas with the highest pollution concentrations.
Condensation	The change of physical state of matter from a gaseous phase into a liquid phase.
Dispersion model	A mathematical model which can be used to assess pollutant concentrations and deposition rates from a wide variety of sources. Various dispersion modelling computer programs have been developed.
Dispersion potential	The potential a pollutant has of being transported from the source of emission by wind or upward diffusion. Dispersion potential is determined by wind velocity, wind direction, height of the mixing layer, atmospheric stability, presence of inversion layers and various other meteorological conditions.
Emission	The rate at which a pollutant is emitted from a source of pollution.
Emission factor	A representative value, relating the quantity of a pollutant to a specific activity resulting in the release of the pollutant to atmosphere.
Evaporation	The opposite of condensation.
Front	A synoptic-scale swath of cloud and precipitation associated with a significant horizontal zonal temperature gradient. A front is warm when warm air replaces cold on the passage of the front; with a cold front cold air replaces warm air.
Fugitive dust	Dust generated from an open source and is not discharged to the atmosphere in a confined flow stream.
Inversion	An increase of atmospheric temperature with an increase in height.
Mixing layer	The layer of air within which pollutants are mixed by turbulence. Mixing depth is the height of this layer from the earth's surface
Particulate matter (PM)	The collective name for fine solid or liquid particles added to the atmosphere by processes at the earth's surface and includes dust, smoke, soot, pollen and soil particles. Particulate matter is classified as a criteria pollutant, thus national air quality standards have been developed in order to protect the public from exposure to the inhalable fractions. PM can be principally characterised as discrete particles spanning several orders of magnitude in size, with inhalable particles falling into the following general size fractions: * PM10 (generally defined as all particles equal to and less than 10 microns in aerodynamic diameter; particles larger than this are not generally deposited in the lung); * PM2.5, also known as fine fraction particles (generally defined as those particles with an aerodynamic diameter of 2.5 microns or less); * PM10-2.5, also known as coarse fraction particles (generally defined as those particles with an aerodynamic diameter greater than 2.5 microns, but equal to or less than a nominal 10 microns); and * Ultra fine particles generally defined as those less than 0.1 microns.
Precipitation	Ice particles or water droplets large enough to fall at least 100 m below the cloud base before evaporating.
Relative Humidity	The vapour content of the air as a percentage of the vapour content needed to saturate air at the same temperature.

PROJECT INFORMATION

Table 2: Applicant Details

Name of Applicant:	IPP Equipment (Pty) Ltd
Contact Person:	Steven MacDougal
Contact Number:	013 656 0191
Email:	steven@ippmining.co.za
Postal Address:	PO Box 8283, Die Heuwel, Witbank
Physical Address:	Plot 54 Prinsberg Road, Seekoeiwater AH, Emalahleni 1035
File Reference Number DMR:	MP-00167-MR/102

Table 3: EAP Details

EAP Company:	Eco Elementum (Pty) Ltd
Company Reg. No.:	2012/021578/07
Physical Address:	361 Oberon Ave, Glenfield Office Park, Faeire Glen, Pretoria, 0040
Postal Address:	Postnet Suite #252, Private Bag X025. Lynnwood Ridge, Pretoria, 0040
Contact Person:	Neel Breitenbach
Contact Number:	012 807 0383
Email:	info@ecoe.co.za
Website:	

Table 4: Specialist Details

Specialist Company:	Eco Elementum (Pty) Ltd
Company Reg. No.:	2012/021578/07
Physical Address:	442 Rodericks Road, Lynwood, Pretoria, 0081
Postal Address:	Postnet Suite #252, Private Bag X025. Lynnwood Ridge, Pretoria, 0040
Contact Person:	Neel Breitenbach
Contact Number:	012 807 0383
Email:	info@ecoe.co.za
Website:	

SPECIALIST DECLARATION OF INDEPENDENCE

In support of an application in terms of the National Environmental Management Act 107 of 1998 (GNR983, GNR984 and GNR985, GG38282 of 4 December 2014 ("Listed Activities") that will require an environmental authorisation if triggered. As amended by GNR 327, GNR 325 and GNR 324.

I, **Neel Breitenbach** as specialist, has been appointed in terms of regulation 12(1) or 12(2), and can confirm that I shall —

a. Be independent;
b. have expertise in undertaking specialist work as required, including knowledge of the Act, these Regulations and any guidelines that have relevance to the proposed activity;
c. ensure compliance with these Regulations;
d. perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the application;
e. take into account, to the extent possible, the matters referred to in regulation 18 when preparing the application and any report, plan or document relating to the application; and
f. disclose to the proponent or applicant, registered interested and affected parties to the proponent or applicant, registered interested and affected parties and the competent authority all material information in the possession of the EAP and, where applicable, the specialist, that reasonably has or may have the potential of influencing –
g. any decision to be taken with respect to the application by the competent authority in terms of these Regulations; or
h. the objectivity of any report, plan or document to be prepared by the EAP or specialist, in terms of these Regulations for submission to the competent authority;
i. Unless access to that information is protected by law, in which case it must be indicated that such protected information exists and is only provided to the competent authority.

Neel Breitenbach	[signature]
Name and Surname	**Signature**
2022-11-08	George
Date	**Signed at**

1. INTRODUCTION

IPP Equipment (Pty) Ltd (hereafter IPP) appointed Eco Elementum (Pty) Ltd to undertake environmental authorisations associated with the proposed Nndanganeni project. The applicant wants to conduct opencast rollover mining on an area of 60 ha comprising of portion 15 the farm Hartogs Hof 413 JS in the Mpumalanga Province of South Africa. Eco Elementum (Pty) Ltd is to undertake the Air Quality Impact Assessment for the Nndanganeni project. IPP wants to expand the existing Nndanganeni opencast rollover mining operations.

The coal will be processed on-site then transported by road to the clients.

1.1 Mining Techniques

1.1.1 Description of Mining Method

Opencast rollover mining are planned. The box cut will be established during the construction phase. Topsoil and overburden from the box cut will be stockpiled separately at the extremities of the pit for final rehabilitation.

Once the box cut has been established the normal strip mining roll-over methodology will be applied to the mining operation whereby topsoil is stripped two strips in advance of the current working strip and is either stockpiled or placed directly on the rehabilitated area behind the advancing strip, thereafter subsoil is removed.

The soft overburden will be removed by mechanical methods. The hard overburden will be drilled and blasted and then removed by mechanical methods. The coal will be drilled and blasted prior to removal.

Replacement of overburden materials into the mining pit will be according to the following sequence:

- Placement of hard overburden at base of pit;
- Placement of soft overburden; and
- Final cover of topsoil.

Table 5: Project Locality

Farm Name:	Portion 15 of the farm Hartogs Hof 413 JS – Mpumalanga Province - South Africa
Application Area:	80 ha
Magisterial District:	Nkangala District Municipality, Mpumalanga Province South Africa
Distance and direction from nearest town:	The Project Area is ~ 19km west of . See Figure 1

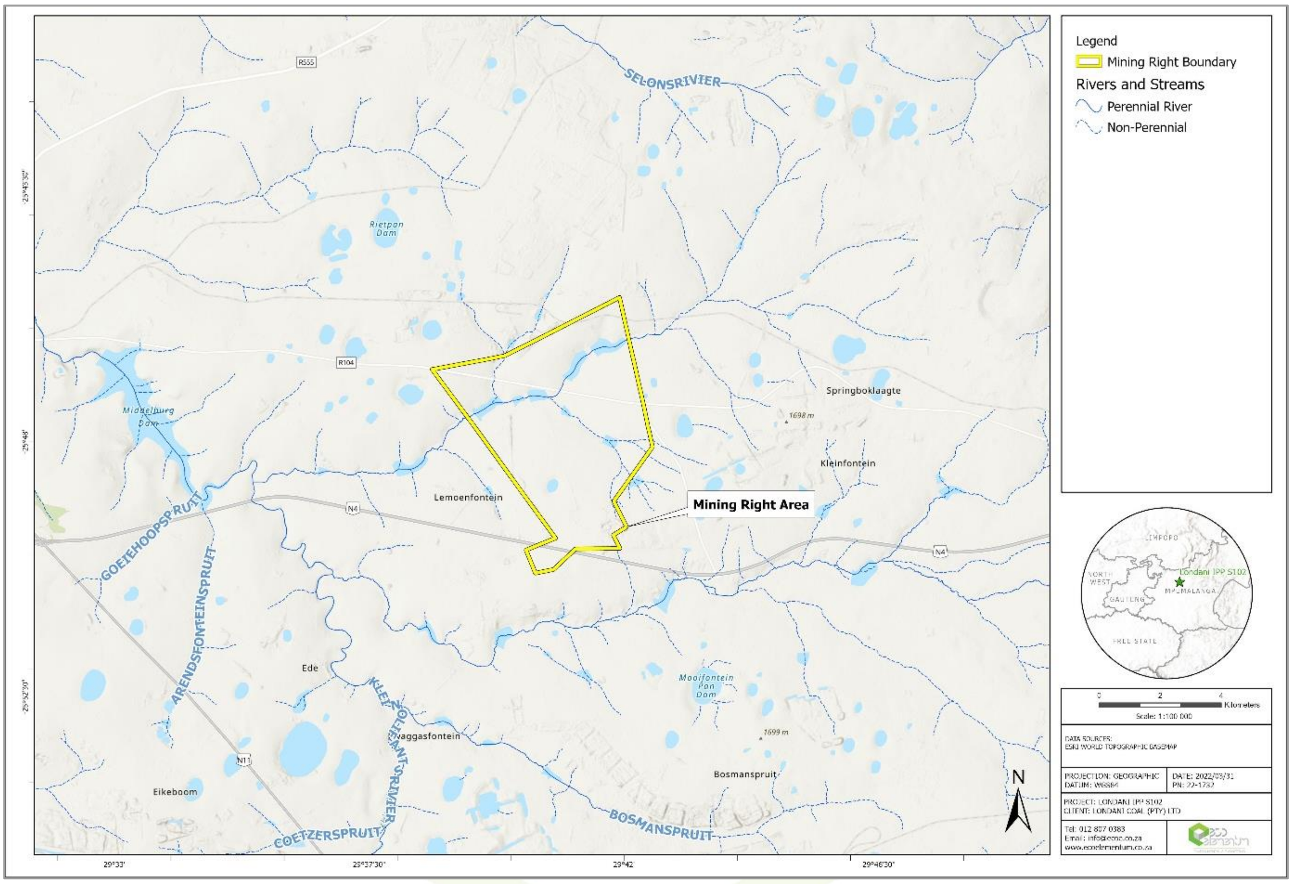

Figure 1: Locality map of the proposed Nndanganeni project.

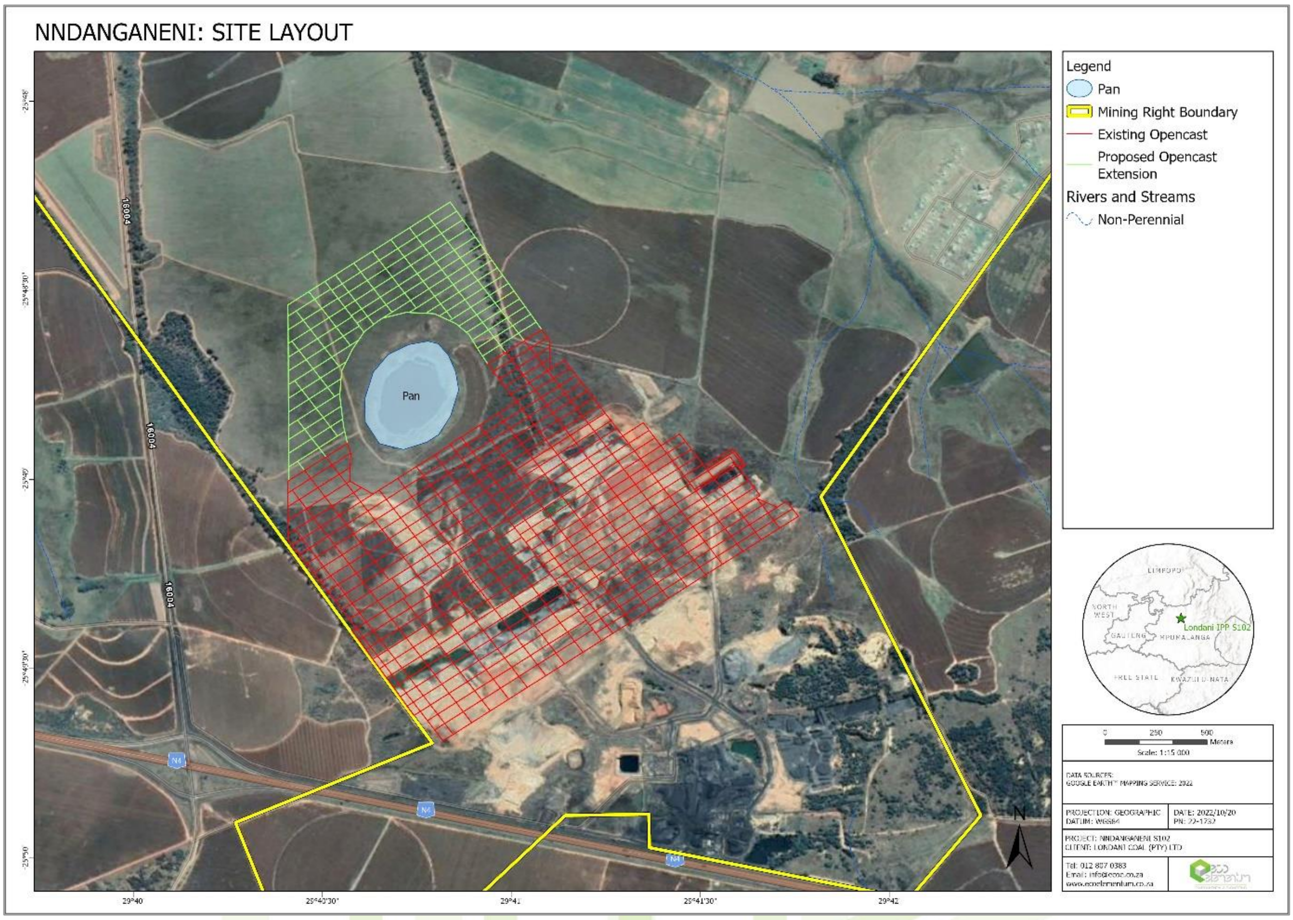

Figure 2: Proposed Site Layout for the proposed Nndanganeni project.

2. SCOPE OF WORK

The purpose of this study is to:

1. Study the available information relevant to the pre and post-development ambient air quality pollution concentrations in the environment;
2. Identify the major existing air emission sources in the environment;
3. Identify the existing sensitive air pollution areas in the environment;
4. Estimate by means of measurements and integration of the results with those of any relevant existing information the present ambient air quality climate;
5. Identify the mining related processes and equipment that will cause the major contribution to the future air quality impact;
6. Consider, evaluate and rate the potential air quality impacts; and
7. Propose relevant management and mitigation measures to lessen the anticipated impacts.

3. STUDY AREA

3.1 Location

3.1.1 Industries

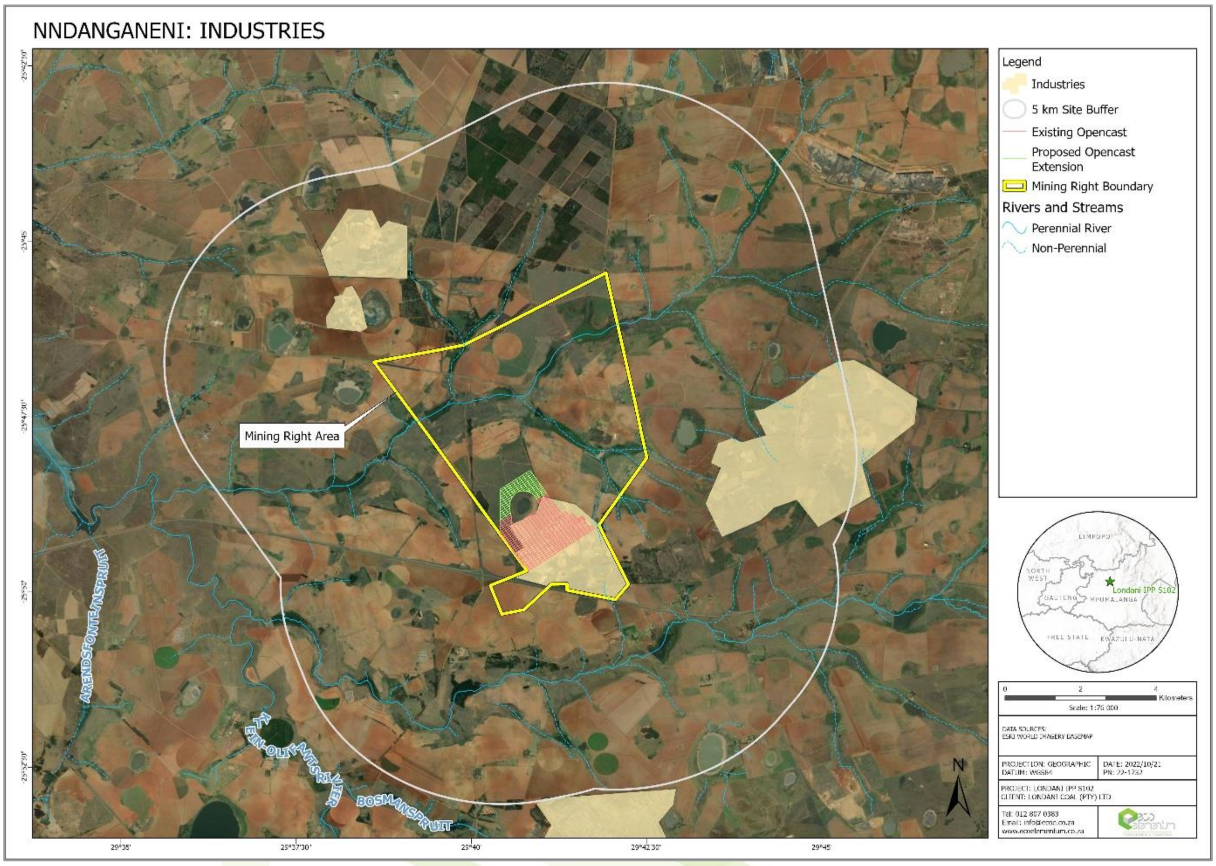

Figure 3: Other industries in the immediate vicinity of the proposed Nndanganeni project.

From a desktop study of satellite imagery, other mining operations were identified to the north and east of the proposed Nndanganeni project as can be seen in Figure 3.

3.1.2 Population

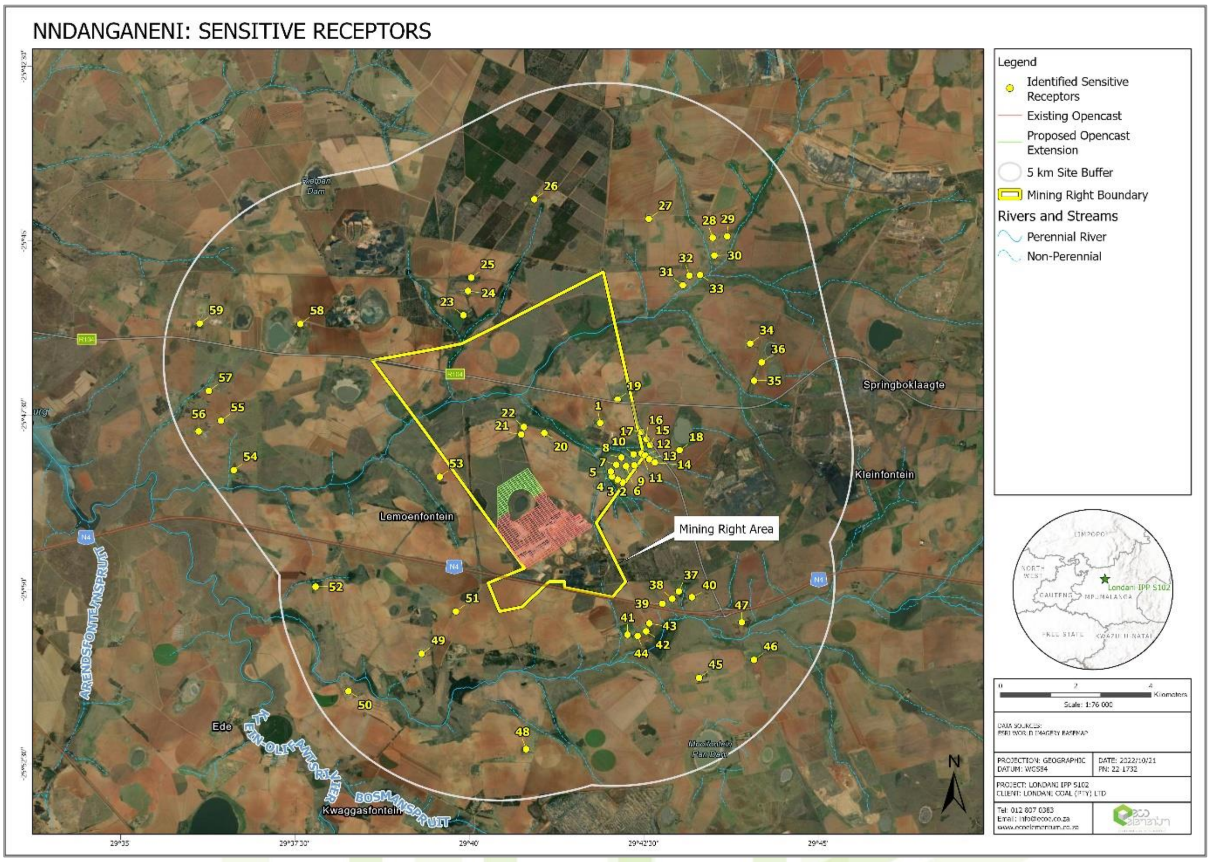

Figure 4: Population areas within the immediate vicinity of the proposed Nndanganeni project.

From a desktop study of satellite imagery various sensitive receptors in the form of human habitation areas, consisting of dispersed homesteads were identified in proximity to the proposed Nndanganeni project area as can be seen in Figure 4. It should be noted that the sensitive receptors in the area may differ from those identified as not all areas may have been identified from the imagery successfully.

3.1.3 Topography

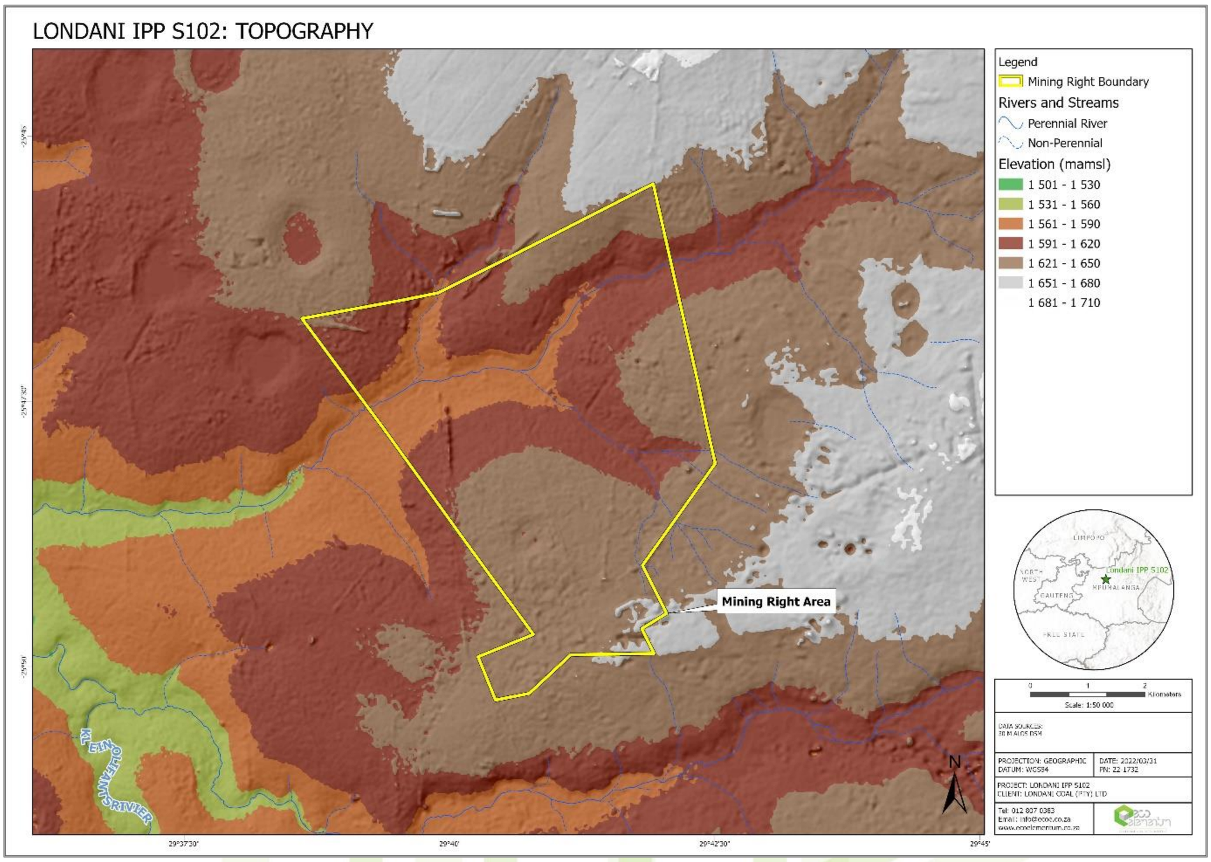

Figure 5: 3D map showing the terrain relief of the area around the proposed Nndanganeni project.

The proposed mining operation area is situated in undulated terrain with no major topographical features found in the immediate vicinity as can be seen in Figure 5 above.

3.2 Meteorological Data

3.2.1 Regional Air Quality

South Africa is located in the sub-tropics where high pressures and subsidence dominate. However, the southern part of the continent can serve as a source of hot air that intrudes sub-tropics, and that sometimes lead to convective movement of air masses. On average, a low pressure will develop over the southern part of the continent, while the normal high pressures will remain over the surrounding oceans. These high pressures are known as Indian High Pressure Cells and Atlantic High pressure Cells. The intrusion of continents will allow for the development of circulation patterns that draw moisture (rain) from either tropics (hot air masses over equator) or from the mid-latitude and temperate latitudes.

Southern Africa is influenced by two major high pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperate latitudes. The mean circulation of the atmosphere over Southern Africa is anticyclonic throughout the year (except near the surface) due to the dominance of the three high pressure cells, namely South Atlantic High Pressure, off the west coast, the South Indian High Pressure off the east coast and the Continental High Pressure over the interior.

It is these climatic conditions and circulation movements that are responsible for the distribution and dispersion of air pollutants within the proposed Nndanganeni Project area and between neighbouring provinces and countries bordering South Africa.

3.2.2 Meso-Scale Meteorology

The nature of the local climate will determine what will happen to the pollution when it is released into the atmosphere (Tyson and Preston-Whyte, 2000). Pollution levels fluctuate daily and hourly, in response to changes in atmospheric stability and variations in mixing depth. Similarly, atmospheric circulation patterns will have an effect on the rate of transport and dispersion of pollution.

The release of atmospheric pollutants into a large volume of air results in the dilution of those pollutants. This is best achieved during conditions of free convection and when the mixing layer is deep (unstable atmospheric conditions). These conditions occur most frequently in summer during the daytime. This dilution effect can however be inhibited under stable atmospheric conditions in the boundary layer (shallow mixing layer). Most surface pollution is thus trapped under a surface inversion (Tyson and Preston-Whyte, 2000).

Inversion occurs under conditions of stability when a layer of warm air is situated directly above a layer of cool air. This layer prevents a pollutant from diffusing freely upward, resulting in an increased pollutant concentration at or close to the earth's surface. Surface inversions develop under conditions of clear, calm and dry conditions and often occur at night and during winter (Tyson and Preston-Whyte, 2000). Radiative loss during the night results in the development of a cold layer of air close to the earth's surface. These surface inversions are however, usually destroyed as soon as the sun rises and warm the earth's surface. With the absence of surface inversions, the pollutants are able to diffuse freely upward; this upward motion may however be prevented by the presence of an elevated inversion (Tyson and Preston-Whyte, 2000).

Elevated inversions occur commonly in high pressure areas. Sinking air warms adiabatically to temperatures in excess of those in the mixed boundary layer. The interface between the upper, gently subsiding air is marked by an absolutely stable layer or an elevated subsidence inversion. This type of elevated inversions is most common over Southern Africa (Tyson and Preston-Whyte, 2000).

The climate and atmospheric dispersion potential of the interior of South Africa is determined by atmospheric conditions associated with the continental high pressure cell located over the interior. The continental high pressure present over the region in the winter months results in fine conditions with little rainfall and light winds with a northerly flow. Elevated inversions are common in such high pressure areas due to the subsidence of air. This reduces the mixing depth and suppresses the vertical dispersion of pollutants, causing increased pollutant concentrations (Tyson and Preston- Whyte, 2000).

Seasonal variations in the positions of the high pressure cells have an effect on atmospheric conditions over the region. For most of the year the tropical easterlies cause an air flow with a north-easterly to north-westerly component. In the winter months the high pressure cells move northward, displacing the tropical easterlies northward resulting in disruptions to the westerly circulation. The disruptions result in a succession of cold fronts over the area in winter with pronounced variations in wind direction, wind speeds, temperature, humidity, and surface pressure.

Airflow ahead of a cold front passing over the area has a strong north-north-westerly to north-easterly component, with stable and generally cloud-free conditions. Once the front has passed, the airflow is reflected as having a dominant southerly component (Tyson and Preston-Whyte, 2000).

Easterly and westerly wave disturbances cause a southerly wind flow and tend to hinder the persistence of inversions by destroying them or increasing their altitude, thereby facilitating the dilution and dispersion of pollutants. Pre-frontal conditions tend to reduce the mixing depth. The potential for the accumulation of pollutants during pre-frontal conditions is therefore enhanced over the plateau (Tyson and Preston-Whyte, 2000).

3.2.3 Site-Specific Dispersion Potential

A period wind rose for the site is presented in Figure 7 below. Wind roses comprise of 16 spokes which represents the direction from which winds blew during the period. The colours reflect the different categories of wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories.

Based on an evaluation of the meteorological data simulations run from a global WRF weather model at ~10 km resolution from 2019 to 2021 of the project area. The following deductions regarding the prevailing wind direction and wind frequency can be assessed. Looking at Figure 7 below, the predominant wind direction is predicted to occur mainly from the E 1348 hours per year respectively. A secondary direction is predicted from ESE 931 hours per year, respectively, with wind speeds higher than 5 km/h.

From Figure 6, at the site, calm conditions with wind speeds of 12 km/h or less, are predicted 20 days per month throughout the year. 12-19 km/h winds are predicted 6 days per month through the year. Wind speeds of more than 19 km/h are predicted to occur 4 days per year on average.

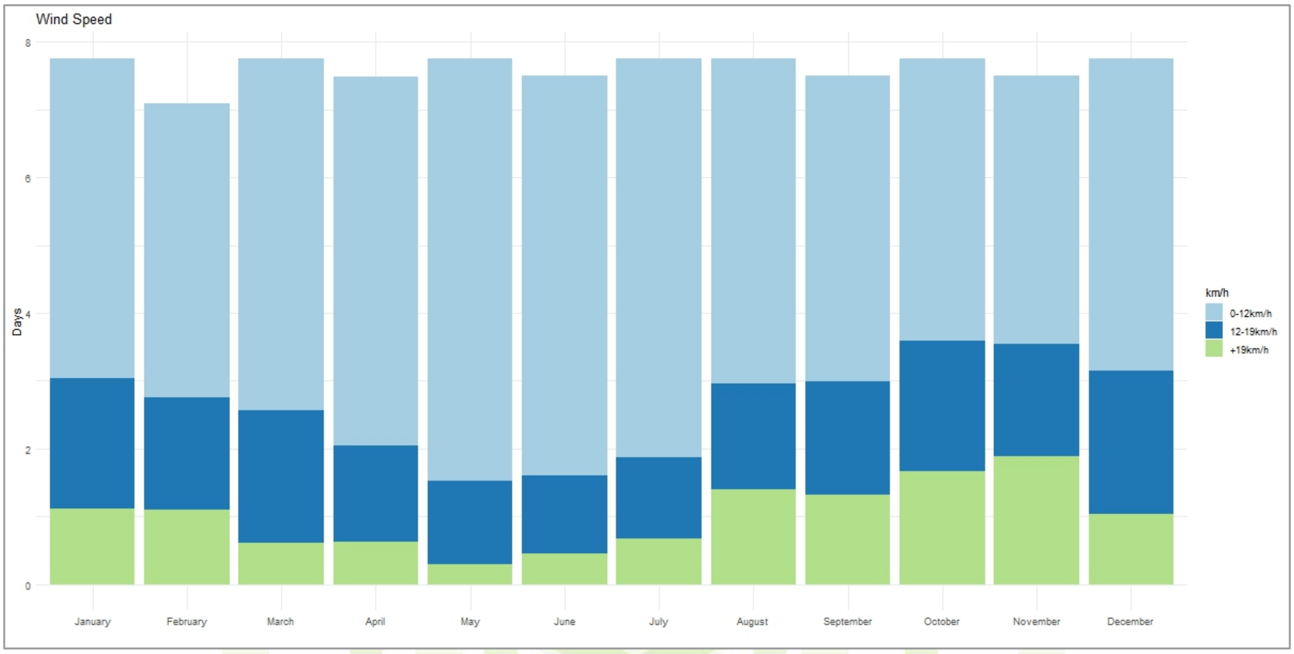

Figure 6: Wind Class Frequency Distribution per month.

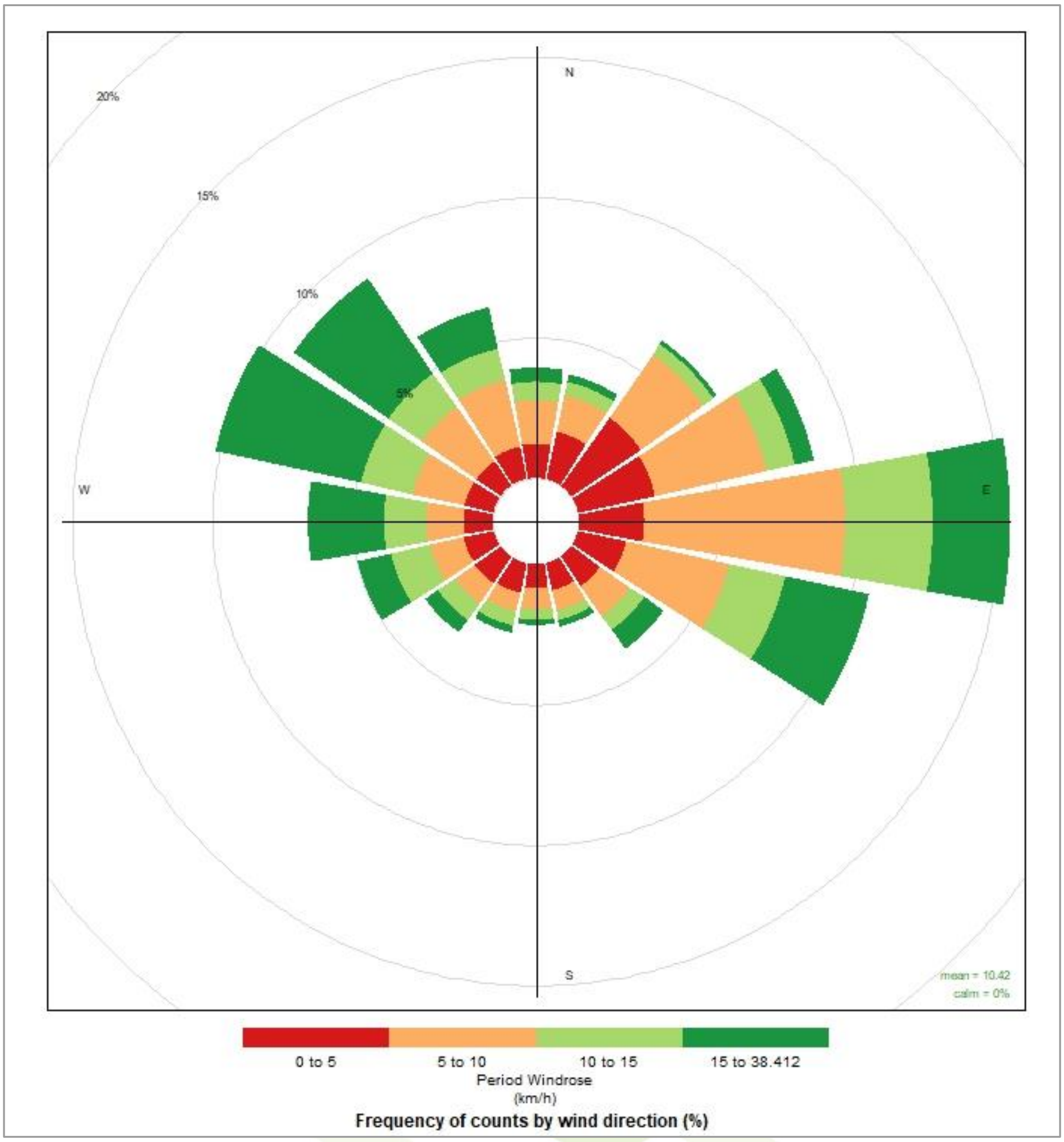

Figure 7: WRF 10 km simulation model wind rose for the proposed Nndanganeni project area for the period 2019 to 2021.

3.2.4 Atmospheric Stability

The tendency of the atmosphere to resist or enhance vertical motion and thus turbulence is termed atmospheric stability. Stability is related to both the change of temperature with height and wind speed. A neutral atmosphere neither enhances nor inhibits mechanical turbulence. An unstable atmosphere enhances turbulence, whereas a stable atmosphere inhibits mechanical turbulence. The turbulence of the atmosphere is the most important parameter affecting dilution of air pollution as the more unstable the atmosphere, the greater the dilution of air pollution.

Atmospheric stability is commonly categorised into six stability classes as per Table 6 below. The atmospheric boundary layer is usually unstable during the day due to turbulence caused by the sun's heating effect on the earth's surface. The depth of this mixing layer depends mainly on the amount of solar radiation, increasing in size gradually from sunrise to reach a maximum at about 5 - 6 hours after sunrise. The degree of thermal turbulence is increased on clear warm days with light winds. During the night-time a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

Table 6: Atmospheric Stability Classes

A	Very unstable	calm wind, clear skies, hot daytime conditions
B	Moderately unstable	clear skies, daytime conditions
C	Unstable	moderate wind, slightly overcast daytime conditions
D	Neutral	high winds or cloudy days and nights
E	Stable	moderate wind, slightly overcast night-time conditions
F	Very stable	low winds, clear skies, cold night-time conditions

A neutral atmospheric potential neither enhances nor inhibits mechanical turbulences. Unstable atmospheric condition enhances turbulence, whereas stable conditions inhibit mechanical turbulence as seen in Table 6.

3.2.5 Temperature

Temperature affects the formation, action, and interactions of pollutants in various ways (Kupchella and Hyland, 1993). Chemical reaction rates tend to increase with temperature and the warmer the air, the more water it can hold and hence the higher the humidity. When relative humidity exceeds 70%, light scattering by suspended particles begins to increase, as a function of increased water uptake by the particles (CEPA / FPAC Working Group, 1999). This results in decreased visibility due to the resultant haze. Many pollutants may dissolve in water to form acids. Temperature also provides an indication of the rate of development and dissipation of the mixing layer.

Based on an evaluation of the meteorological data simulations run from the global WRF weather model at ~10 km resolution from 2019 to 2021 of the project area. The following deductions can be made from Figure 8; in the summer months' maximum average daily temperatures are predicted to be 24°C - 25°C on average with a maximum of 32°C possible during hot days, dropping to a predicted 17°C on average at night and 8°C minimum on cold nights. During winter months the average day time temperature are predicted in the 12°C - 15°C range while cold winter night time temperatures predicted to drop to -3°C.

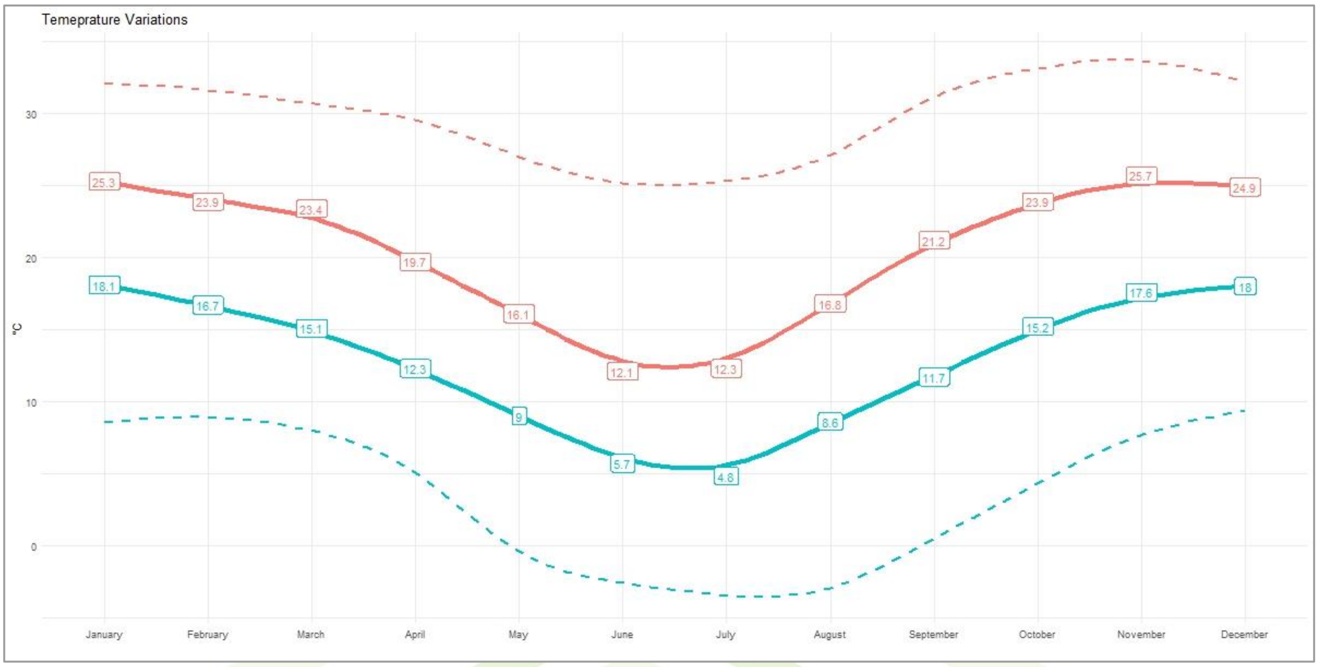

Figure 8: Temp and precipitation simulation results from the WRF model for the Nndanganeni project area (2019 - 2021).

3.2.6 Precipitation

Precipitation cleanses the air by washing out particles suspended in the atmosphere (Kupchella & Hyland, 1993). It is calculated that precipitation accounts for about 80-90% of the mass of particles removed from the atmosphere (CEPA/FPAC Working Group, 1999).

Falling in a summer rainfall area, the location is predicted to receive the most precipitation in the summer months of October - March overall as can be seen in Figure 8. December - February are predicted the highest rainfall months with between 31-43mm predicted per month during these months. March, November and October is predicted to receive 3-11mm precipitation. All other months are predicted to receive less than < 3mm precipitation on average during the month.

The total precipitation days predicted at the Nndanganeni project area is shown in Figure 9 below.

The highest precipitation days are predicted during the months of October - March. During these months' precipitation is predicted to only occur 4-11 days on average. The rest of the year precipitation is predicted to occur less than 3 days per month.

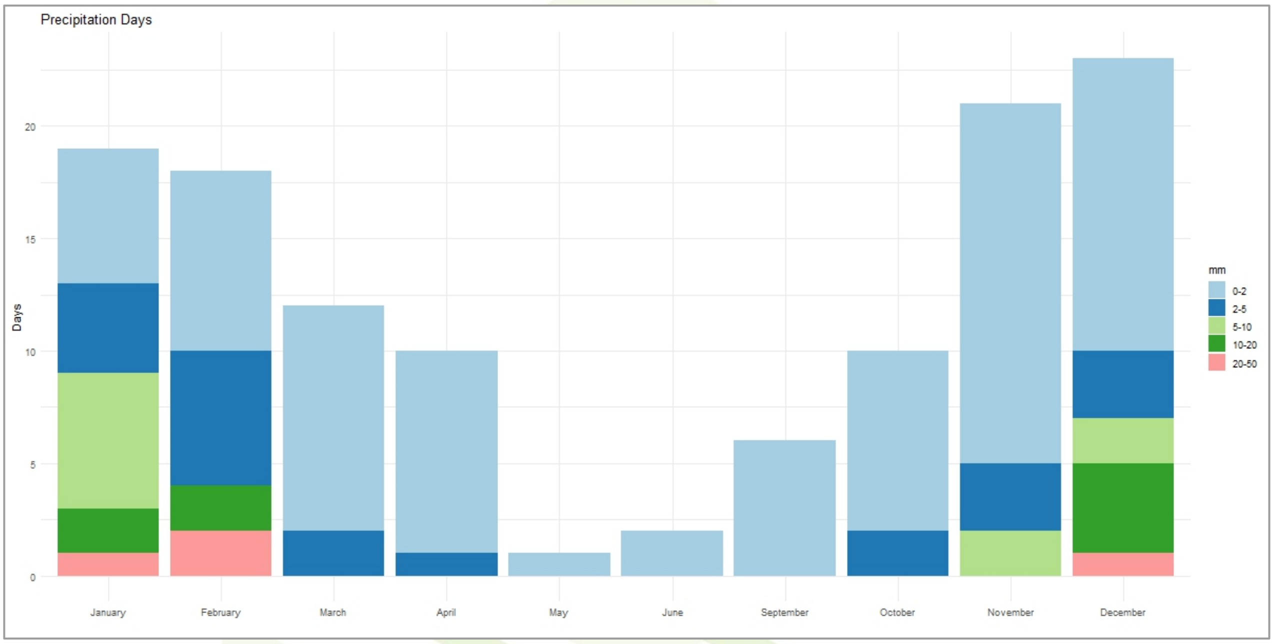

Figure 9: Day count of total daily precipitation per month for the proposed Nndanganeni project area for the period 2019 – 2021.

3.3 Description Of The activities To Be Undertaken

3.3.1 Description of Mining Method

The box cut will be established during the construction phase. Topsoil and overburden from the box cut will be stockpiled separately at the extremities of the pit for final rehabilitation.

Once the box cut has been established the normal strip mining roll-over methodology will be applied to the mining operation whereby topsoil is stripped two strips in advance of the current working strip and is either stockpiled or placed directly on the rehabilitated area behind the advancing strip, thereafter subsoil is removed as can be seen in Figure 10.

The soft overburden will be removed by mechanical methods. The hard overburden will be drilled and blasted and then removed by mechanical methods. The coal will be drilled and blasted prior to removal.

Replacement of overburden materials into the mining pit will be according to the following sequence:

- Placement of hard overburden at base of pit;
- Placement of soft overburden;
- Final cover of topsoil.

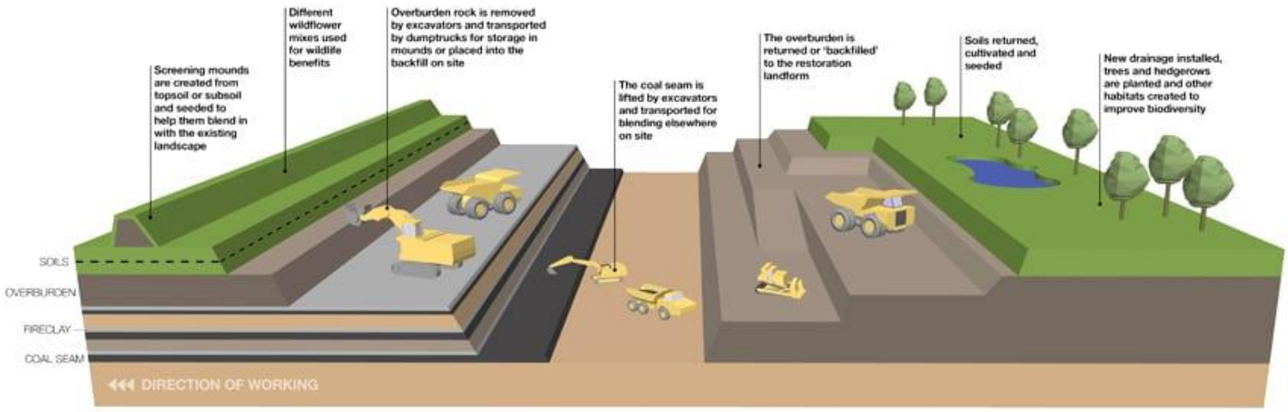

Figure 10: Illustration of a typical opencast rollover mining operation

4. OVERVIEW

The National Environmental Management: Air Quality Act, Act No. 39 of 2004 is in the process of replacing, and has to a large extent already replaced, the Atmospheric Pollution Prevention Act (APPA), Act 45 of 1965. The Air Quality Act requires a shift from source-based air pollution control to a receiving environment, air quality management approach. Key features of the new approach to air quality governance include:

1. Decentralisation of air quality management responsibilities.
2. A requirement that all significant sources be identified, quantified and addressed.
3. Setting of ambient air quality targets as goals to achieve emission reductions.
4. Recognition of source-based, command-and-control measures (i.e. authorities set source requirements and emission limits requiring adherence by responsible parties), in addition to alternative measures, including market incentives and disincentives, voluntary programmes, and education and awareness.
5. Promotion of cost-optimised mitigation and management measures.
6. Required air quality management planning by authorities and emission reduction and management planning by sources.
7. Access to information and public consultation.
8. The new approach has significant implications for government, business and civil society.

This report and investigation aims to identify potential air quality impacts as a result of the proposed operations and therefore propose management and mitigation measures to mitigate the impact. This assessment forms part of the environmental impact assessment phase of this investigation and will focus on the impacts from the proposed mine in order to provide a better understanding of the magnitude of these impacts.

As a summary the following proposed activities related to air emissions will be established and executed and are associated with the Nndanganeni project:

1. Site preparation;
2. Opencast mining;
3. Wind-blown emissions;
4. Materials handling;
5. Mine closure and rehabilitation.

4.1 Particulate Matter

Particulate matter (PM) is the collective name for fine solid or liquid particles added to the atmosphere by processes at the earth's surface. PM includes dust, smoke, pollen and soil particles (Kemp, 1998). PM has been linked to a range of serious respiratory and cardiovascular health problems. The key effects associated with exposure to ambient particulate matter include: premature mortality, aggravation of respiratory and cardiovascular disease, aggravated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function, and an increased risk of myocardial infarction (USEPA, 1996).

PM can principally be characterised as discrete particles spanning several orders of magnitude in size, with inhalable particles falling into the following general size fractions (USEPA, 1996):

1. PM10 (generally defined as all particles equal to and less than 10 microns in aerodynamic diameter; particles larger than this are generally not deposited in the lung);
2. PM2.5, also known as fine fraction particles (generally defined as those particles with an aerodynamic diameter of 2.5 microns or less);
3. PM10-2.5, also known as coarse fraction particles (generally defined as those particles with an aerodynamic diameter greater than 2.5 microns, but equal to or less than a nominal 10 microns); and

4. Ultra-fine particles generally defined as those less than 0.1 microns.

Particles can be classified by their aerodynamic properties into coarse particles, PM10 (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, PM2.5 (particulate matter with an aerodynamic diameter of less than 2.5 µm) (Harrison and van Grieken, 1998). The fine particles contain the secondarily formed aerosols such as sulphates and nitrates, combustion particles and re-condensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dust from roads and industries (Fenger, 2002).

Fine and coarse particles are distinct in terms of the emission sources, formation processes, chemical composition, atmospheric residence times, transport distances and other parameters. Fine particles are directly emitted from combustion sources and are also formed secondarily from gaseous precursors such as sulphur dioxide, nitrogen oxides, or organic compounds. Fine particles are generally composed of sulphate, nitrate, chloride and ammonium compounds, organic and elemental carbon, and metals. Combustion of coal, oil, diesel, gasoline, and wood, as well as high temperature process sources such as smelters and steel mills, produce emissions that contribute to fine particle formation. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometres, while coarsest particles typically deposit to the earth within minutes to hours and within tens of kilometres from the emission source.

Some scientists have postulated that ultra-fine particles, by virtue of their small size and large surface area to mass ratio may be especially toxic. There are studies that suggest these particles may leave the lung and travel through the blood to other organs, including the heart. Coarse particles are typically mechanically generated by crushing or grinding and are often dominated by resuspended dusts and crustal material from paved or unpaved roads or from construction, farming, and mining activities (USEPA, 1996).

In terms of health impacts, particulate air pollution effects are broad, but are predominately associated with effects of the respiratory and cardiovascular systems (WHO, 2005). Particle size is important for health because it controls where in the respiratory system a given particle deposits. Fine particles have been found to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extra thoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

A study by Pope and Burnett (2002) indicated that PM2.5 leads to high plaque deposits in arteries, causing vascular inflammation and atherosclerosis (Kaonga and Kgabi, 2009). No evidence of a threshold in the relationship between particulate concentrations and adverse human health effects has been determined (Burger and Scorgie, 2000a; Burger and Scorgie 2000b; WHO 2005).

4.1.1 Short-Term Exposure

Recent studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 µg/m³). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function.

4.1.2 Long-Term Exposure

Long-term exposure to low concentrations (~10 µg/m³) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000). Those most at risk include the elderly, individuals with pre-existing heart or lung disease, asthmatics and children; with an increased risk associated with an increase in exposure (WHO 2005).

4.1.3 Nuisance Dust

Nuisance dust may be defined as coarse fraction of airborne particulates. Nuisance dust is known to result in the soiling of materials and has the potential to reduce visibility. Nuisance dust has a long history of having little adverse effect on the lungs. Any reaction that may occur from nuisance dust is potentially reversible. However, excessive concentrations of nuisance dust in the workplace may reduce visibility, may cause unpleasant deposits in eyes, nasal passages and may cause injury to the skin or mucous membranes by the chemical or mechanical action. The light is scattered and visibility is diminished by the atmospheric particulate.

Various costs are associated with the loss of visibility, including: the need for artificial illumination and heating; delays, disruption and accidents involving traffic; vegetation growth reduction associated with reduced photosynthesis; and commercial losses associated with aesthetics. The soiling of building and materials due to dust frequently gives rise to damages and costs related to the increased need for washing, cleaning and repainting. Dustfall may also impact negatively on sensitive industries, e.g. bakeries or textile industries. Certain elements in dust may damage materials. For instance, it was found that sulphur and chlorine if present in dust may cause damage to copper (Maeda et al., 2001).

Nuisance dust can also cause serious aesthetic deterioration in the surrounding environment and communities. Fortunately, due to relatively large particulate matter sizes associated with the mining emissions and the relatively short release height of the pollutants, such negative impacts are usually confined in relatively small areas. Within these areas of impact, fugitive dust may result in damage to the vegetation and agriculture. The deposited particulate matter may block the plant leaf stomata hence inhibit gas exchange, or smother the plant leaf surfaces reducing photosynthesis levels. Besides the impacts on vegetation, health effects of particulates on mine personnel and public may also be significant.

Air pollution is a recognized health hazard for man and domestic animals (Newman et al., 1979). Air pollutants have had a worldwide effect on both wild birds and wild mammals, often causing decreases in local animal populations (Newman et al., 1979). The major effects of industrial air pollution on wildlife include direct mortality, debilitating industrial-related injury and disease, physiological stress, anaemia, and bioaccumulation. Some air pollutants have caused a change in the distribution of certain wildlife species.

4.2 The Importance of Managing Dust

Managing dust from mines is important as it can impact local and regional air quality, adversely affect local amenity and pose a risk to public health.

4.3 Protecting Local And Regional Air Quality

An important aspect of the protection of air quality from mining operations is to minimise dust generated from sources such as wind erosion, crushing & screening, vehicles using unsealed roads and blasting. Mines are required by the National Environmental Management Air Quality Act to meet certain criteria for ambient air quality. In order to meet these criteria, mines must manage the emissions of dust from their activities in a competent manner.

4.3.1 Community Health

Health impacts of mine dust vary depending on the nature of the particles, their origin and their size, which is measured as particulate matter (PM). Exposure to fine particles can have potential health impacts on the respiratory system. Infants and children, elderly people, people with existing respiratory conditions, heart disease or diabetes may be more susceptible to the health effects from fine and coarse particles. Mines must be operated with proper dust controls to ensure that people are not affected by the dust generated.

4.3.2 Community Amenity

If not properly managed, dust from mines can be a nuisance to local communities. Nuisance dust usually has a particle size larger than 10 microns (gravimetric dust fallout). High levels of nuisance dust may reduce visibility and amenity. The presence of nuisance dust can also cause a perceived increase in health risk. The impact of dust from mines on local amenity depends on the distance from the mine site and climatic conditions including wind speed and direction. Concerns about amenity from mine site dust often relate to the ‘visibility’ of dust plumes and dust sources. Visible dust is usually due to short-term episodes of high emissions, such as blasting. Other amenity impacts include dust depositing on fabrics (such as washing) or on house roofs, and dust transported from roofs to water tanks during rain.

5. RELEVANT LEGISLATION, GUIDELINES AND STANDARDS

5.1 National Environmental Management: Air Quality, 2004 (Act 39 Of 2004)

The National Environmental Management: Air Quality Act 39 of 2004 shifted the approach of air quality management from source-based control to receptor-based control. The Act made provision for National ambient air quality standards, however it is generally accepted that more stringent standards can be established at the Provincial and Local levels. Emissions are controlled through the listing of activities that are sources of emission and the issuing of emission licences for these listed activities. Atmospheric emission standards have been established for each of these activities and an atmospheric licence is now required to operate.

The issuing of emission licences for Listed Activities will be the responsibility of the Metropolitan and District Municipalities. Municipalities are required to 'designate an Air Quality Officer to be responsible for co-ordinating matters pertaining to air quality management in the Municipality'. The appointed Air Quality Officer will be responsible for the issuing of atmospheric emission licences or the Air Quality Officer could delegate the responsibility to the Director of Community Environmental Services.

According to the Act, the Department of Environmental Affairs) (DEA), the provincial environmental departments and local authorities (district and local municipalities) are separately and jointly responsible for the implementation and enforcement of various aspects of NEM: AQA. Each of these spheres of government is obliged to appoint an Air Quality Officer and to co-operate with each other and co-ordinate their activities through mechanisms provided for in the National Environment Management Act, 1998 (Act 107 of 1998) (NEMA).

The purpose of NEM: AQA is to set norms and standards that relate to:

- Institutional frameworks, roles and responsibilities;
- Air quality management planning;
- Air quality monitoring and information management;
- Air quality management measures; and
- General compliance and enforcement.

5.1.1 National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) - National Dust Control Regulations (Government Gazette No. 36794 - No. R 827)

The National Dust Control Regulations were published on 1 November 2013, in terms of the National Environmental Management Air Quality Act, which prescribes general measures for the control of dust.

Table 7: Dust Fallout permitted rates

Restriction Areas	Dust Fall Rate (mg/m³/day - 30 day average)	Permitted Frequency of exceeding dust fall rate
Residential Areas	D < 600	2 within a year, not sequential months.
Non-Residential Area	600 < D < 1200	2 within a year, not sequential months.

According to regulations, any person conducting any activity in such a way that would give rise to dust in quantities and concentrations that exceeded the dustfall standard set out in the regulation was impelled to, upon receipt of a notice from an air quality officer, implement a dustfall monitoring programme.

The method to be used for measuring the dustfall rate and the guideline for locating sampling points would be the American Standards for Testing and Materials method, or an equivalent method approved by any internally recognised body.

The regulation further stated that an Air Quality Officer could require any person, through a written notice, to undertake a dustfall monitoring programme if the officer reasonably suspected that the person was contravening the regulations or that the activity being conducted required a fugitive dust emission management plan. A person required to implement the programme must then, within a specified period, submit a dustfall monitoring report to the air quality officer. A dustfall monitoring report must provide information on the location of sampling sites, classification of the area where samplers were located, as well as reference to the standard methods used for site selection, sampling and analysis.

The report would also be required to provide meteorological data for the sampling area, the dustfall monitoring results, including a comparison of current year and historical results for each site, as well as a tabular summary of compliance with the dustfall standard. Any person that had exceeded the dustfall standard must, within three months after submission of the dustfall monitoring report, develop and submit a dustfall management plan to the Air Quality Officer for approval. This management plan must identify all possible sources of dust within the affected site, detail the best practicable measures to be undertaken to mitigate dust emissions, identify the line management responsible for implementation and incorporate the dust fallout monitoring plan. Such a plan would need to be implemented within a month of the date of approval and an implementation progress report must be submitted to the Air Quality Officer at agreed time intervals.

5.1.2 Legislation for Local Government

The Local Government: Municipal Systems Act 32 of 2000, together with the Municipal Structures Act 117 of 1998, establishes local government as an autonomous sphere of government with specific powers and functions as defined by the Constitution. Section 155 of the Constitution provides for the establishment of Category A, B and C municipalities each having different levels of municipal executive and legislative authorities. According to Section 156(1) of the Constitution, a municipality has the executive authority in respect of, and has the right to, administer the local government matters (listed in Part B of Schedule 4 and Part B of Schedule 5) that deal with air pollution.

5.1.3 Ambient Air Quality Guidelines and Standards

Guidelines provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants of air that are known or likely to be hazardous to human health and well-being (WHO, 2000). Once the guidelines are adopted as standards, they become legally enforceable. The South African Bureau of Standards (SABS), in collaboration with DEA, established ambient air quality standards for gravimetric dust fallout and is listed in the Table 8 below.

5.2 South African National Standard – SANS 1929:2011

5.2.1 Ambient Air Quality – Limits for Common Pollutants

Table 8: Limits for PM10 in ug/m³

Average period	Concentration (µg/m³)	Frequency of exceedances
Target		
24 h	75	4
1 year	40	0

Table 9: Four-band scale evaluation criteria for dust deposition in mg/m²/day

Band Number	Band Description Label	Dust Fall Rate (mg/m²/day - 30 day average)	Comment
1	Residential	D < 600	Permissible for residential and light commercial.
2	Industrial	D < 1200	Permissible for heavy commercial and industrial.
3	Action	1200 < D < 2400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	Alert	D > 2400	Immediate action and remediation required following the first incidence of the dustfall rate being exceeded. Incident report to be submitted to the relevant authority.

Table 10: Target, action and alert thresholds for dust deposition in mg/m²/day

Level	Dust Fall Rate (mg/m²/day - 30 day average)	Average Period	Permitted frequency of exceeding dustfall rate
Target	300	Annual	
Action Residential	600	30 days	2 within any year, no 2 sequential months.
Action Industrial	1 200	30 days	2 within any year, not sequential months.
Alert Threshold	2 400	30 days	None. First incidence of dustfall rate being exceeded requires remediation and compulsory report to the relevant authorities.

6. METHODOLOGY

6.1 Dispersion Model

Emission factors are quantified using the Australian National Pollutant Inventory (NPI) which is an improvement on the US Environmental Protection Agency (US.EPA) AP-42 document of Air Pollution Emission Factors for Australian conditions, for fugitive dust deriving from material handling, on-site roads, milling and crushing operations, drilling and blasting, and wind erosion from exposed surfaces. Various mitigation measures were incorporated into the project design as discussed in the emission factor section.

Dispersion models represents the most likely outcome of experimental results; it does not contain all the features of a real world system but contain the feature of interest for management of an issue. Gaussian plume models have an uncertainty range of between -50% to 200%.

There will always be some error in any geophysical model, the total uncertainty can be described as the sum of three components:

- Uncertainty due to errors in the model physics;
- Uncertainty due to data errors; and
- Uncertainty due to the atmospheric conditions.

6.1.1 Model Selection

Increasing reliance has been placed on estimates from models as the primary basis for environmental and health impact assessments. It is therefore important to carefully select a dispersion model for the purpose. Dispersion models compute ambient concentrations as a function of source configurations, and meteorological characteristics, providing a tool to calculate the spatial and temporal patterns in the ground level concentrations arising from the emissions of emissions sources.

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The most widely used Gaussian plume model is the US.EPA AERMOD model.

The regulatory model of the US.EPA, AERMET/AERMOD dispersion model suite, was chosen for the study. AERMET uses both surface and upper air data. The model also has a terrain pre-processor (AERMAP) for including a large topography into the model. The AERMET / AERMOD suite was developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective was to include state-of the-art science in regulatory models.

1. AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources.
2. AERMET is a meteorological pre-processor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters.
3. AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for AERMOD. Input data includes receptor terrain elevation data which are used for the computation of air flow around hills.

A disadvantage of the model is the range of uncertainty of the model predictions could to be -50% to 200% and spatial varying wind fields, due to topography or other factors cannot be included. The accuracy of the model improves with fairly strong wind speeds and during neutral atmospheric conditions.

The stochastic uncertainty includes all errors or uncertainties in data such as source variability, observed concentrations, and meteorological data. Model evaluation studies suggest that the data input error term is often a major contributor to total uncertainty. Even in the best tracer studies, the source emissions are known only with an accuracy of ±5%, which translates directly into a minimum error of that magnitude in the model predictions. It is also well known that wind direction errors are the major cause of poor agreement, especially for relatively short-term predictions (minutes to hourly) and long downwind distances. All of the above factors contribute to the inaccuracies not associated with the mathematical models themselves.

Input data required for the AERMOD model include:

- Source emissions and type data;
- Meteorological data (pre-processed by the AERMET model);
- Terrain data; and
- The receptor grid.

6.1.2 Meteorological Data

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database).

Use was made of the MM5 AERMET ready weather data as provided by Lakes Environmental for the period 1 January 2019 to 31 December 2021.

6.1.3 Source Data

AERMOD is able to model point, area, volume, pit and line sources. Wind erosion sources such as stockpiles and unpaved roads modelled as area sources. Material transfer points and crushing and screening were modelled as volume sources. With the input sources using factors applied to the emission as described in the Australian NPI.

6.1.4 Sensitive Receptor Grid

The pollutant dispersion is setup for a modelled domain of 10 km (north-south) by 10 km (east-west) with the centre of the proposed project area in the centre of the modelling domain. The area was divided into a variable grid with the following resolutions:

- 1 km from Centre:
  - 50 m (north-south) by 50 m (east-west).
- 2.5 km from boundary of first grid box:
  - 100 m (north-south) by 100 m (east-west).
- 4 km from the boundary of the second grid box:
  - 200 m (north-south) by 200 m (east-west).

6.1.5 Modelling Runs

Modelling was undertaken for two proposed operational phase scenarios.

1. Unmitigated – Material handled dry.
2. Mitigated – Mitigation measures applied as per Table 14.

The construction and decommissioning phases were qualitatively assessed.

6.1.6 Model Results

Dispersion modelling was undertaken to determine 2nd highest daily and annual average ground level concentrations (GLCs) for PM10 Total daily dust fallout rates were also simulated. These averaging periods are selected to draw comparisons between PM10 predicted concentrations / deposition with relevant air quality guidelines and dust fallout limits, respectively.

Isopleths plots are also generated, to visually display the interpolated values from the concentrations predicted by the model for each of the receptor grid points. Plots reflecting daily averaging periods contain only the 2nd highest predicted ground level concentrations for the daily concentration, over the entire period for which simulations were undertaken. It is therefore possible that even though a high hourly or daily average concentration is predicted at certain locations, this may only be true for one day during the modelling period.

7. BASELINE AIR QUALITY MEASUREMENT RESULTS

7.1 Discussion Of The Baseline Air Quality

7.1.1 Sensitive Receptors

Sensitive receptors identified in the immediate vicinity (Figure 11) of the study area and proposed project area have been listed below:

- Various dispersed homesteads.

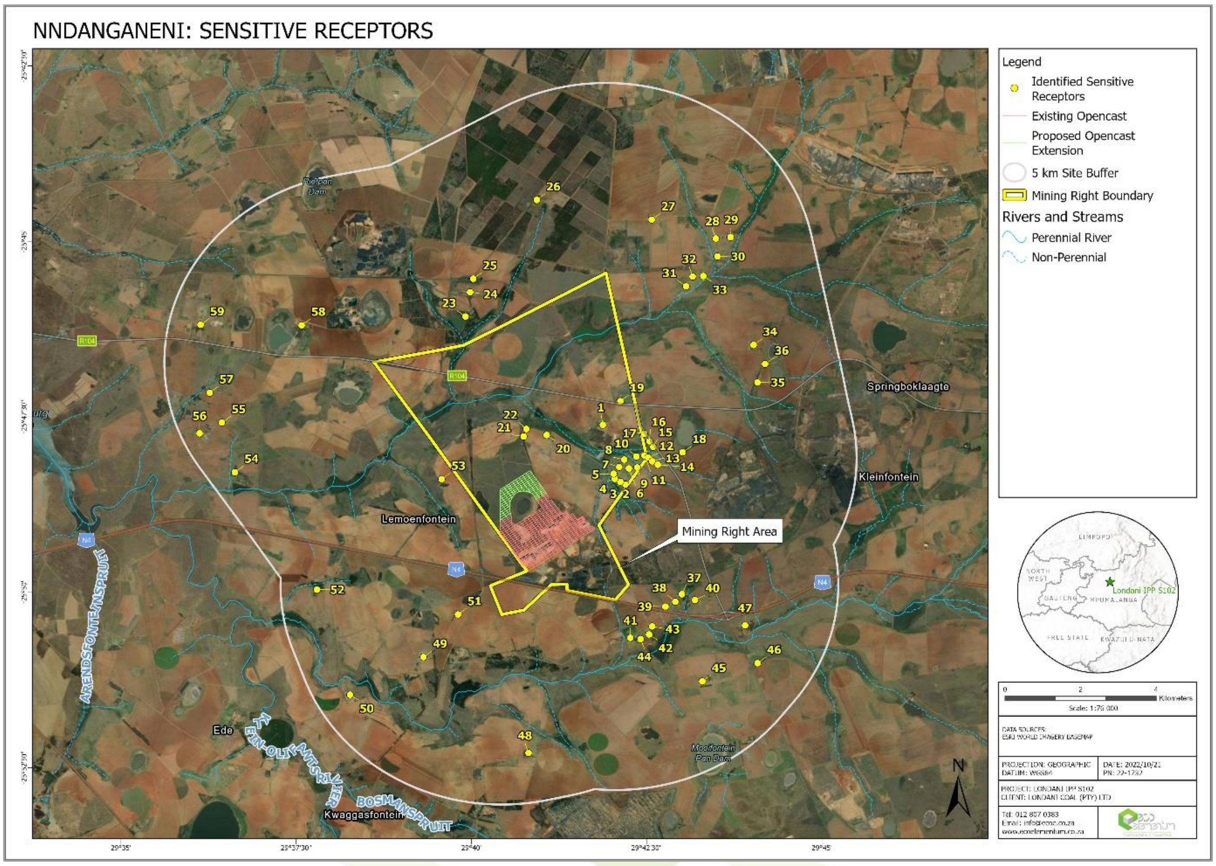

Figure 11: Sensitive receptors in the immediate area of the mining boundary.

7.1.2 Sources of Emissions

7.1.2.1 Vehicle Exhaust Gases

Vehicle exhausts contain a number of pollutants including carbon dioxide (CO^2), carbon monoxide (CO), hydrocarbons, oxides of nitrogen (NOx), sulphur and PM10. Tiny amounts of poisonous trace elements such as lead, cadmium and nickel are also present. The quantity of each pollutant emitted depends upon the type and quantity of fuel used, engine size, speed of the vehicle and abatement equipment fitted. Once emitted, the pollutants are diluted and dispersed in the ambient air. Pollutant concentrations in the air can be measured or modelled and then compared with ambient air quality criteria.

7.1.2.2 Veld Fires

Veld fires are widespread across the world, occurring in autumn, winter and early spring. In addition to controlled burning for fire-breaks and veld management, many fires are set deliberately for mischievous reasons. Some are accidental, notably those started by motorists throwing cigarettes out of car windows. Emissions from veld fires are similar to those generated by coal and wood combustion. Whilst veld fire smoke primarily impacts visibility and landscape aesthetic quality, it also contributes to the degradation of regional scale air quality. Dry combustible material is consumed first when a fire starts. Surrounding live, green material is dried by the large amount of heat that is released when there are veld fires, sometimes this material also burn. The major pollutants from veld burning are particulate matter, carbon monoxide, and volatile organics. Nitrogen oxides are emitted at rates from 1 to 4 g/kg burned, depending on combustion temperatures. Emissions of sulphur oxides are negligible (USEPA, 1996).

7.1.2.3 Trucks Passing on the Roads, Loading and Offloading Raw Materials

Dust emissions occur when soil is crushed by a vehicle, as a result of the soil moisture level being low. Vehicles used on the roads will generate PM-10 emissions throughout the area and they carry soils onto the paved roads which would increase entrainment PM-10 emissions. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

7.1.2.4 Wind Erosion as a Result Of ROM Material and Topsoil Stockpiles

The topsoil and waste rock stockpiles generated during the construction phase will be minimal and probably used for construction purposes on site (berm and foundations for buildings), reason being that this will be limited to the mining areas – since the project is mainly an opencast operation. At the ROM stockpile, there will be constant transfer of ore from the opencast to the stockpile.

7.1.2.5 Material Handling (Loading, Hauling and Tipping)

Material handling during loading, hauling and tipping as mining processes has been known to have influence on dust generation in terms of increasing the fugitive dust emissions being generated. With the different kind of materials – topsoil, soft, and hard, tipping will be negligible. The tipping is mostly associated with the ROM at the processing plant vicinity. During these activities factors such as the surrounding wind regime, the material tipping rate, and the moisture content of the material all have an influence on the dust generation at the tipping transfer points.

7.1.2.6 Other Mining Activities

Other mining operations in the area contribute to emissions in the project area, the following an be likely sources:

- Particulate emissions generated due to wind erosion from exposed areas;
- Material handling; and
- Vehicle entrained dust on paved and unpaved road surfaces.

8. DISPERSION MODEL

8.1 Emissions Inventory

Table 11 below describes the through put rates on which the calculations were based. In the quantification of the emissions the emission factor equations published by the US.EPA as well as the NPI compiled by the Australian Government were used. See Table 12. Table 14 shows the summarised Emissions Inventory.

Table 11: Modelling Parameter Summary

Project Specific Information			
Type	**Spec**	**Quantity**	**Unit**
Material	ROM	50 000	tpm
Material Bulk Density	ROM*	1.4	g/cm^3
	OVB*	2.65	g/cm^3
Operations	Hours	24	
	Days	30	
Stockpile	Height*	10	m
Access Road	Width*	10	m
	Length*	2	km
Haul Road	Width*	10	m
	Length*	3	km
Commercial Trucks	Type	Side Tipper Interlink	
	Height	3.1	m
	Width	2.6	m
	Payload	38	t
	Trips	3.54	per h
	VKT	10.26	per h
Haul Trucks	Type	Bell B40D	
	Height	4.2	m
	Width	3.8	m

Project Specific Information			
Type	**Spec**	**Quantity**	**Unit**
	Payload	37	t
	Trips	3.63	per h
	VKT	10.90	per h
Note:	* Assumed		

Table 12: NPI Emission Factors

NPI Emission Factors				
Operation	**TSP**	**PM10**	**Units**	**Rating**
Material Handling	0.06	0.03	kg/t	C
Wind Erosion	0.4	0.2	kg/ha/h	U
Haul Road	4.23	1.25	kg/VKT	B
Truck Dumping (ROM)	0.01	0.0042	kg/t	U
Unloading Stockpiles	0.004	0.0017	kg/t	U
Primary Crushing	0.03	0.013	kg/t	U
Secondary Crushing	0.01	0.004	kg/t	

Many published emission factors have and associated emission factor rating (EFR) code. These EFR codes are based on rating systems developed by the USEPA and by the European Environmental Agency. See Table 13 below.

Table 13: Emission Factor Ratings

Factor Ratings	
A	Excellent
B	Above Average
C	Average
D	Below Average
E	Poor
U	Unrated

8.1.1 Mitigation Measures

8.1.1.1 Material Handling

According to the Australian NPI, dust generation from material transfer points can be reduced by 50% where water sprays are applied. Adding wind break can reduce the dust emissions with 30%. Enclosing the operations, the emissions will become insignificant.

8.1.1.2 Opencast Pit

50% mitigation on the various operations can be achieved using water sprays according to the Australian NPI.

8.1.1.3 Stockpile

Wind erosion from stockpiles can be mitigated by 50% using water sprays according to the Australian NPI. Revegetation of stockpiles can bring 90% mitigation.

Total enclosure of the stockpiles can mitigate erosion by 99%. (Also from the Australian NPI.)

Vegetal cover retards erosion by binding the residue with a root network, by sheltering the residue surface and by trapping material already eroded. Vegetation is considered the most effective control measure in terms of its ability to control water erosion. In investigating the feasibility of vegetation types the following properties are normally taken into account: indigenous plants; ability to establish and regenerate quickly; proven effective for reclamation elsewhere; tolerant to the climatic conditions of the area; high rate of root production; easily propagated by seed or cuttings; and nitrogen-fixing ability.

The long-term effectiveness of suitable vegetation selected for the site will be dependent on (a) the nature of the cover, and (b) the availability of aftercare. The Department of Minerals and Energy in Western Australia in its Guidelines on the Safe Design and Operating Standards for Tailings Storages (1996), for example, stipulates a covering of a minimum of 500 mm of suitable waste rock, followed by a layer of topsoil (or growth medium) and subsequent seeding. According to these guidelines all external surfaces should have a self-generating cover compatible with the surrounding environment

8.1.1.4 Haul Road

For haul roads the Australian NPI indicate that dust emissions can be mitigated by 50% for level 1 watering (2 litres/m²/h) or 75% for level 2 watering (>2 litres/m²/h).

Sealing the road or salt-encrusted roads can mitigate 100% according to the Australian NPI.

The roads on-site were identified as the most significant source of dust emissions. Three types of measures may be taken to reduce emissions from unpaved roads:

- measures aimed at reducing the extent of unpaved roads, e.g. paving,
- traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and
- measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (EPA, 1987; Cowherd *et al.*, 1988; APCD, 1995).

Given the indication that unsurfaced roads would be watered, control efficiencies which may be achieved through wet suppression were investigated. In addition, the reduction in vehicle entrainment due to reduced vehicle kilometres travelled are also included.

Permanent improvements in travel surfaces, such as the paving of a road, results in continuous control efficiencies. The control efficiencies obtained by wet suppression and the use of chemical stabilizers are, however, cyclic rather than continuous by nature as indicated previously. The efficiency afforded by the application of water or chemicals decay over time, requiring periodic reapplication to maintain the desired average efficiency (Cowherd et al., 1988). The following empirical model for the estimation of the average control efficiency of watering, developed by the US-EPA (EPA, 1996), can be applied in the estimation of control efficiencies achievable by unpaved road watering programmes:

$$C = 100 - \left(\frac{0.8pdt}{i}\right)$$

Where,

c = average control efficiency (%)

d = average hourly daytime traffic rate (hr-1)

i = application intensity (litres per m2)

t = time between applications (hr)

p = potential average hourly daytime evaporation rate (mm/hr)

Table 14: Calculated Source Emission Rates Summary

Emissions Released								
	Unmitigated			Mitigated				
Operation	TSP	PM10	Unit	TSP	PM10	Unit	Reduction	Method
Material Handling	1.120	0.560	g/s	0.560	0.280	g/s	50%	Water Sprays
Loading Stockpile	0.187	0.078	g/s	0.093	0.039	g/s	50%	Water Sprays
Loading Trucks	0.560	0.243	g/s	0.280	0.121	g/s	50%	Water Sprays
Wind Erosion	1.11E-05	5.56E-06	g/s/m²	5.56E-06	2.78E-06	g/s/m²	50%	Water Sprays
				1.11E-06	5.56E-07	g/s/m²	90%	Revegetation on OB and Topsoil
Haul Road	1.28E-03	3.78E-04	g/s/m²	1.28E-04	3.78E-05	g/s/m²	90%	Sealed or Salt-Encrusted roads
Access Road	1.21E-03	3.56E-04	g/s/m²	1.21E-04	3.56E-05	g/s/m²	90%	Sealed or Salt-Encrusted roads
Primary Crushing	0.187	0.075	g/s	0.093	0.037	g/s	50%	Water Sprays
Secondary Crushing	0.560	0.224	g/s	0.280	0.112	g/s	50%	Water Sprays

8.2 Modelling Results

Due to time constraints at the time of this report, full modelling could not be done at this time.

Modelling were done with only the sensitive receptors as receptors to speed up the process.

Isopleth plots showing the predicted ground level concentrations of PM10 and dust fallout levels to be completed.

9. IMPACT ASSESSMENT

9.1 Impact Assessment Methodology

The level of detail as depicted in the EIA regulations were fine-tuned by assigning specific values to each impact. In order to establish a coherent framework within which all impacts could be objectively assessed, it was necessary to establish a rating system, which was applied consistently to all the criteria. For such purposes each aspect was assigned a value, ranging from one (1) to five (5), depending on its definition. This assessment is a relative evaluation within the context of all the activities and the other impacts within the framework of the project.

The impact assessment criteria used to determine the impact of the proposed development are as follows:

1. ***Severity*** of the impact;
2. **Spatial Scale** - The physical and spatial scale of the impact;
3. ***Duration*** - The lifetime of the impact, measured in relation to the lifetime of the proposed development;
4. ***Frequency of the Activity*** – How often do the activity take place;
5. ***Frequency of the incident/impact*** – How often does the activity impact on the environment;
6. ***Legal Issues*** – How is the activity governed by legislation; and
7. ***Detection*** – How quickly/easily the impacts/risks of the activity be detected on the environment, people and property.

To ensure uniformity, the assessment of potential impacts will be addressed in a standard manner so that a wide range of impacts is comparable. For this reason a clearly defined rating scale will be provided to the specialist to assess the impacts associated with their investigation. See Table 15

Table 15: Assessment criteria

SEVERITY	
Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful / within a regulated sensitive area	5
SPATIAL SCALE	
Area specific (at impact site)	1
Whole site (entire surface right)	2
Local (within 5 km)	3
Regional / Neighbouring areas (5 km to 50 km)	4
National	5
DURATION	
One day to one month (immediate)	1
One month to one year (Short term)	2
One year to 10 years (medium term)	3
Life of the activity (long term)	4
Beyond life of the activity (permanent)	5
FREQUENCY OF THE ACTIVITY	

Annually or less	1
6 monthly	2
Monthly	3
Weekly	4
Daily	5
FREQUENCY OF THE INCIDENT/IMPACT	
Almost never / almost impossible / >20%	1
Very seldom / highly unlikely / >40%	2
Infrequent / unlikely / seldom / >60%	3
Often / regularly / likely / possible / >80%	4
Daily / highly likely / definitely / >100%	5
LEGAL ISSUES	
No legislation	1
Fully covered by legislation	5
DETECTION	
Immediately	1
Without much effort	2
Need some effort	3
Remote and difficult to observe	4
Covered	5
Immediately	1

The impacts that are generated by the development can be minimised if measures are implemented in order to reduce the impacts. The mitigation measures ensure that the development considers the environment and the predicted impacts in order to minimise impacts and achieve sustainable development.

9.1.1 Consequence

Consequence is determined by the following equation after the assessment of each impact.

Consequence = Severity + Spatial Scale + Duration

9.1.2 Likelihood

The Likelihood of the activity is then calculated based on frequency of the activity and impact, how easily it can be detected and whether the activity is governed by legislation. Thus:

Likelihood = Frequency of activity + frequency of impact + legal issues + detection

9.1.3 Risk

The risk is then based on the consequence and likelihood.

Risk = Consequence x likelihood

9.1.4 Impact Ratings

The impact is then rated according to Table 16:

Table 16: Impact Rating Table

Rating	Class
1-55	(L) Low Risk
56-169	(M) Moderate Risk
170-600	(H) High Risk

9.2 Predicted Impacts

9.2.1 Summarised Impacts According To Development Phases

Table 17 Summarises the activities from each phase of the project.

Table 17: Impacts according to Development Phases

PHASE	ACTIVITIES
Construction Phase	**Typical Activities** - Site clearing, removal of topsoil and vegetation, Construction of Infrastructure, General Transportation and hauling of material.
Operational Phase	**Typical Activities** – Mining Operations such as Drilling and blasting, Hauling of ROM, Crushing and Screening etc.
Closure and Decommissioning	**Typical Activities** - Demolition & Removal of all infrastructure (incl. transportation off site) and Rehabilitation (Spreading of soil, revegetation, profiling / contouring)

9.2.2 Construction Phase

- **Typical Activities** - Site clearing, removal of topsoil and vegetation, construction of Infrastructure, general transportation and hauling of material. (Table 18)

Table 18: Summarizing the significance of the impacts on the sensitive receptors for the Construction phase.

	Construction Phase		
		Unmitigated	**Mitigated**
Assessment Criteria	**Severity** [Insignificant / non-harmful (1); Small / potentially harmful (2); Significant / slightly harmful (3); Great / harmful (4); Disastrous / extremely harmful / within a regulated sensitive area (5)]	**2**	**2**
	Spatial Scale [Area specific (at impact site) (1); Whole site (entire surface right) (2); Local (within 5 km) (3); Regional / neighbouring areas (5 km to 50 km) (4); National (5)]	**1**	**1**
	Duration [One day to one month (immediate) (1); One month to one year (Short term) (2); One year to 10 years (medium term) (3); Life of the activity (long term) (4); Beyond life of the activity (permanent) (5)]	**2**	**2**
	Frequency of Activity [Annually or less (1); 6 monthly (2); Monthly (3); Weekly (4); Daily (5)]	**4**	**4**

	Construction Phase		
	Frequency of Incident/Impact [Almost never / almost impossible / >20% (1); Very seldom / highly unlikely / >40% (2); Infrequent / unlikely / seldom / >60% (3); Often / regularly / likely / possible / >80% (4); Daily / highly likely / definitely / >100% (5)	**4**	**3**
	Legal Issues [No legislation(1); Fully covered by legislation (5)]	**5**	**5**
	Detection [Immediately(1); Without much effort (2); Need some effort (3); Remote and difficult to observe (4); Covered (5)]	**2**	**2**
Consequence	Severity + Spatial Scale + Duration	**5**	**5**
Likelihood	Frequency of Activity + Frequency of impact + Legal issues + Detection	**15**	**14**
Risk	Consequence * Likelihood	**MODERATE (75)**	**MODERATE (70)**

9.2.3 Operational Phases

The following activities during the Operational Phases are identified as possible fugitive emission sources and may impact on the ambient air quality at the relevant environmental sensitive receivers:

1. Use and maintenance of access road.
2. Dust from material handling.
   - Inside and outside the pit area.
3. Haul roads; for transporting the ROM.
4. Wind erosion from stockpiles.

These sources were uses as inputs in the AERMOD model as unmitigated and mitigated, as discussed earlier.

9.2.3.1 PM10

For the unmitigated Daily PM10 concentrations it was predicted to be higher than the 75 µg/m³ limit for 3 of the sensitive receptors as can be seen in Table 19.

When comparing the Daily Mitigated PM10 modelled concentrations, the sensitive receptors exceeding the 75 µg/m³ limit dropped to 0 of the identified sensitive receptors. This as well is the highest levels predicted for a 24 hour period within the period. Due to site specific atmospheric conditions these exceedances may still occur within the limit of 4 per year.

The annual average PM10 limit of 40 µg/m³ are predicted not to exceed at any of the identified sensitive receptors for the unmitigated or mitigated scenarios.

Table 19: PM Concentrations at sensitive receptors

Receptor	PM10 2nd Highest Daily (µg/m³)		PM10 Annual Average (µg/m³)	
	Unmitigated	Mitigated	Unmitigated	Mitigated
1	24.0	3.3	1.3	0.2
2	44.3	4.9	2.6	0.4
3	45.8	5.0	2.6	0.4
4	47.7	5.2	2.6	0.3
5	46.8	4.8	2.5	0.3
6	40.6	4.4	2.1	0.3
7	41.0	4.3	2.2	0.3
8	35.4	4.0	1.9	0.3
9	38.2	4.2	1.9	0.3
10	36.3	3.9	1.7	0.2
11	35.3	3.8	1.6	0.2
12	34.9	3.8	1.6	0.2
13	35.7	4.0	1.6	0.2
14	37.2	4.4	1.6	0.2
15	32.7	3.5	1.4	0.2
16	27.1	3.4	1.4	0.2
17	20.8	3.5	1.3	0.2
18	32.0	4.2	1.3	0.2
19	19.6	2.6	1.0	0.1
20	29.9	4.4	1.5	0.2
21	36.4	5.1	1.6	0.2
22	27.3	3.5	1.4	0.2
23	13.1	1.6	0.5	0.1
24	12.1	1.5	0.4	0.1
25	9.1	1.3	0.4	0.1
26	6.1	0.8	0.2	0.0
27	5.8	0.8	0.3	0.0

Receptor	PM10 2nd Highest Daily ($\mu g/m^3$)		PM10 Annual Average ($\mu g/m^3$)	
	Unmitigated	Mitigated	Unmitigated	Mitigated
28	5.9	0.8	0.3	0.0
29	6.2	0.8	0.3	0.0
30	6.8	0.8	0.3	0.0
31	7.8	1.0	0.4	0.1
32	7.4	0.9	0.4	0.1
33	7.6	0.9	0.4	0.0
34	8.2	1.3	0.5	0.1
35	18.7	2.5	0.6	0.1
36	15.0	2.4	0.5	0.1
37	64.8	7.9	3.1	0.4
38	67.8	8.6	3.4	0.5
39	67.3	8.2	4.0	0.6
40	61.3	7.4	2.6	0.4
41	68.7	9.8	6.5	0.9
42	59.0	7.7	4.9	0.7
43	85.9	9.1	4.9	0.7
44	59.4	8.5	5.4	0.8
45	35.5	5.0	2.3	0.3
46	41.0	4.8	1.5	0.2
47	38.9	4.6	1.6	0.2
48	29.1	3.6	2.0	0.3
49	75.2	8.3	9.1	1.1
50	41.0	5.0	4.4	0.5
51	115.1	13.4	22.3	2.6
52	60.2	6.8	6.5	0.8
53	35.8	5.6	4.0	0.6
54	22.9	2.7	2.1	0.3
55	19.9	2.3	1.3	0.2
56	18.1	2.1	1.4	0.2
57	17.9	2.2	1.0	0.1
58	13.7	1.8	0.7	0.1
59	15.6	2.0	0.7	0.1

9.2.3.2 Total Dust Fallout

In the unmitigated and mitigated scenarios, no sensitive receptors are predicted to exceed the monthly dust fallout for the highest month residential limit of 600 mg/m²/day.

The predicted annual dust fall out for the unmitigated and mitigated scenarios are not predicted to exceed the annual limit of 300 mg/m²/day at any of the sensitive receptors.

Table 20: TSP Deposition rates at the sensitive receptors

Receptor	TSP Highest Monthly (mg/m²/day)		TSP Annual Average (mg/m²/day)	
	Unmitigated	Mitigated	Unmitigated	Mitigated
1	7.1	0.8	2.7	0.3
2	24.8	2.8	10.7	1.2
3	24.1	2.7	10.6	1.2
4	23.3	2.6	10.3	1.2
5	20.9	2.3	9.2	1.0
6	16.5	1.8	6.9	0.8
7	16.4	1.8	7.2	0.8
8	13.1	1.5	5.7	0.7
9	14.4	1.6	6.3	0.7
10	10.8	1.3	4.8	0.6
11	10.0	1.2	4.4	0.5
12	9.9	1.2	4.5	0.5
13	10.1	1.3	4.7	0.6
14	10.1	1.2	4.8	0.6
15	7.8	1.0	3.6	0.4
16	7.6	0.9	3.3	0.4
17	7.3	0.9	2.9	0.3
18	7.1	0.8	3.2	0.4
19	5.3	0.6	1.6	0.2
20	14.3	1.6	3.6	0.4
21	13.4	1.4	3.6	0.4
22	10.6	1.2	2.9	0.3
23	1.0	0.1	0.3	0.0
24	1.0	0.1	0.3	0.0
25	0.9	0.1	0.2	0.0
26	0.4	0.0	0.1	0.0
27	0.4	0.0	0.1	0.0
28	0.6	0.1	0.2	0.0
29	0.6	0.1	0.2	0.0
30	0.7	0.1	0.2	0.0
31	1.1	0.1	0.2	0.0
32	1.0	0.1	0.2	0.0
33	1.0	0.1	0.2	0.0

Receptor	TSP Highest Monthly (mg/m²/day)		TSP Annual Average (mg/m²/day)	
	Unmitigated	Mitigated	Unmitigated	Mitigated
34	1.5	0.2	0.4	0.1
35	1.7	0.2	0.6	0.1
36	1.4	0.2	0.5	0.1
37	45.5	6.4	24.0	3.5
38	54.5	7.3	26.8	4.0
39	65.5	9.3	30.8	4.6
40	38.6	5.2	19.2	2.8
41	71.0	9.7	24.2	3.6
42	72.4	10.0	25.5	3.9
43	76.7	10.6	29.2	4.5
44	69.8	9.7	23.7	3.6
45	24.6	3.4	7.8	1.1
46	20.3	2.7	6.1	0.9
47	20.8	2.9	8.6	1.2
48	3.5	0.4	0.7	0.1
49	10.4	1.1	1.8	0.2
50	2.6	0.3	0.6	0.1
51	64.7	6.6	9.0	1.1
52	6.6	0.8	2.0	0.2
53	22.9	2.7	6.2	0.7
54	3.4	0.4	0.9	0.1
55	2.0	0.3	0.5	0.1
56	1.9	0.2	0.5	0.1
57	1.5	0.2	0.4	0.0
58	1.3	0.2	0.3	0.0
59	1.2	0.2	0.2	0.0

9.2.4 Decommissioning and Closure Phase

- **Typical Activities** - Demolition & Removal of all infrastructure (incl. transportation off site) and Rehabilitation (Spreading of soil, revegetation, profiling / contouring). (Table 21)

Table 21: Summarizing the significance of the impacts on the sensitive receptors for the Closure and Decommissioning phase.

	Closure and Decommissioning Phase		
		Unmitigated	**Mitigated**
Assessment Criteria	**Severity** [Insignificant / non-harmful (1); Small / potentially harmful (2); Significant / slightly harmful (3); Great / harmful (4); Disastrous / extremely harmful / within a regulated sensitive area (5)]	**3**	**3**
	Spatial Scale [Area specific (at impact site) (1); Whole site (entire surface right) (2); Local (within 5 km) (3); Regional / neighbouring areas (5 km to 50 km) (4); National (5)]	**2**	**2**
	Duration [One day to one month (immediate) (1); One month to one year (Short term) (2); One year to 10 years (medium term) (3); Life of the activity (long term) (4); Beyond life of the activity (permanent) (5)]	**2**	**2**
	Frequency of Activity [Annually or less (1); 6 monthly (2); Monthly (3); Weekly (4); Daily (5)]	**4**	**4**
	Frequency of Incident/Impact [Almost never / almost impossible / >20% (1); Very seldom / highly unlikely / >40% (2); Infrequent / unlikely / seldom / >60% (3); Often / regularly / likely / possible / >80% (4); Daily / highly likely / definitely / >100% (5)	**4**	**3**
	Legal Issues [No legislation(1); Fully covered by legislation (5)]	**5**	**5**
	Detection [Immediately(1); Without much effort (2); Need some effort (3); Remote and difficult to observe (4); Covered (5)]	**2**	**2**
Consequence	Severity + Spatial Scale + Duration	**7**	**7**
Likelihood	Frequency of Activity + Frequency of impact + Legal issues + Detection	**15**	**14**
Risk	Consequence * Likelihood	**MODERATE (105)**	**MODERATE (98)**
Mitigation Measures	- Demolition should not be performed during windy periods (August, September and October), as dust levels and the area affected by dust fallout will increase. - The area of disturbance must be kept to a minimum, as demolition should be done judiciously avoid the exposure of larger areas to wind erosion. - Cabs of machines should be swept or vacuumed regularly to remove accumulated dust. - Exhaust pipes of vehicles should be directed so that they do not raise dust. - Engine cooling fans of vehicles should be shrouded so that they do not raise dust. - Hard surfaced haul roads or standing areas should be washed down and swept to remove accumulated dust. - Dust suppression of roads being used during rehabilitation should be enforced. - Revegetation of exposed areas for long-term dust and water erosion control is commonly used and is the most cost-effective option. - Plants with roots that bind the soil, and vegetation cover should be used that breaks the impact of falling raindrops, thus preventing wind and water erosion. - Plants used for revegetation should be indigenous to the area, hardy, fast-growing, nitrogen-fixing, provide high plant cover, be adapted to growing on exposed and disturbed soil (pioneer plants) and should easily be propagated by seed or cuttings.		

	Closure and Decommissioning Phase
	- The area of disturbance must be kept to a minimum, as demolition should be done judiciously avoid the exposure of larger areas to wind erosion. - Spreading of soil must be performed on less windy days. - The bare soil will be prone to erosion and therefore there is need to reduce the velocity near the surface of the soil by re-vegetation. - Leaving the surface of soil in a coarse condition reduces wind erosion and ultimately reduces dust levels. - Additional mitigation measures include keeping soil moist using sprays or water tanks, using wind breaks. - The best time to re-vegetate the area must be linked to the distribution and reliability of rainfall. - Cabs of machines should be swept or vacuumed regularly to remove accumulated dust. - Exhaust pipes of vehicles should be directed so that they do not raise dust. - Engine cooling fans of vehicles should be shrouded so that they do not raise dust. - Hard surfaced haul roads or standing areas to be washed down and swept to remove accumulated dust. - Dust suppression of roads being used during rehabilitation should be enforced. - It is recommended that the rehabilitation by vegetating should begin during the operational phase already as the objective is to minimise the erosion. - These measures should be aimed to reduce the potential for fugitive dust generation and render the impacts on ambient air quality negligible.

9.3 Cumulative Impacts

The proposed Nndanganeni project area surrounded by other mining areas. These mining operations will also generate fugitive dust and particulate matter emissions. The Nndanganeni project will contribute to the cumulative air quality impacts of the region.

The impacts of projects are often assessed by comparing the post-project situation to a pre-existing baseline. Where projects can be considered in isolation this provides a good method of assessing a project's impact. However, in areas where baselines have already been affected, or where future development will continue to add to the impacts in an area or region, it is appropriate to consider the cumulative effects of development. This is similar to the concept of shifting baselines, which describes how the environmental baseline at a point in time may represent a significant change from the original state of the system. Cumulative impacts refer to the incremental effect of several projects that may have an individually minor, but collectively significant, impact on air quality.

Cumulative impact can be defined as:

- Two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts, and
- The change in the environment which results from the incremental impact of the project when added to other closely related past, present, or reasonably foreseeable future projects, and can result from individually minor, but collectively significant, projects taking place over a period of time.

This section describes the potential impacts of the project that are cumulative. There are three separate levels of cumulative impacts considered: project site localised cumulative impacts; regional cumulative impacts; and global cumulative impacts.

- **Project site localised cumulative impacts**

These are the cumulative impacts that result from mining operations in the immediate vicinity of the project site. Project site localised cumulative impacts include the cumulative effects from operations that are close enough to potentially cause additive effects on the environment or sensitive receivers. These include mainly dust deposition. From this air impact assessment conducted for the proposed project the modelling indicates the cumulative pollution plume emanating from this site as a combination of activities and shows that the impacts will be mainly localised around and in the vicinity of the operations.

- **Regional cumulative impacts**

Regional cumulative impacts include the project's contribution to impacts that are caused by mining operations throughout the region. Each mining operation in itself may not represent a substantial impact, however the cumulative effect on air quality in the region may warrant consideration. The coal mining sector in South Africa is growing steadily as the requirement for electricity also grows and therefore this project will also contribute to the larger regional impact that will be experienced.

- **Global cumulative impacts**

The only impact from the project that is potentially global is the generation of potential greenhouse gas emissions. However, the level of emissions from the project represents a very minor and insignificant contribution at this scale.

Recommendations to limit cumulative impacts:

Adoption of a combination of engineering controls, dust suppression measures, rehabilitation of exposed surfaces, operational procedures, and measurement of ambient air quality is expected to result in adequate management of dust emissions from the project, and the cumulative impacts from these emissions. An ambient air monitoring program has been developed to monitor the impact of dust-generating emission sources at sensitive receptor locations around the project site. The information obtained from the monitoring program will feed into the operational management of site-based dust emission sources.

Therefore, the overall impact on the air quality as a result of the project would not be cumulatively considerable, and would be less than significant if the sound implementation of mitigation measures identified reducing emissions are implemented. If emissions are kept below the relevant threshold levels by ensuring the management and mitigation measures prescribed are adhered to there is no significant cumulative impacts expected as the air quality impacts would be limited to the site level.

9.4 CLIMATE CHANGE

During an assessment in 2016 of South Africa's coal mining sectors' response to climate change adaption demands undertaken by B. Chavalala from UNISA, Climate change adaptation has received limited attention compared to mitigation across all spatial levels. This is besides the documented adverse impacts of climate change in different sectors of societies including mining in general and coal mining specifically.

Against this background, the study set three objectives:

- **The first objective** was to identify current and possible future climate change impacts that may affect selected coal mines in South Africa.
- **The second objective** was to establish the nature and extent to which these mines were ready to address and implement adaptation measures.
- **The last objective** was to determine and document existing climate change adaptation practices in selected mines.

Employing the mixed methods approach, the research engaged five coal mines located in Mpumalanga, Free State and Kwa Zulu-Natal, gathering both the qualitative and quantitative data. This data was analysed thematically.

The research made three major findings:

- The first finding was that the climatic conditions in the research areas have been changing over the observed period. In general, rainfall has been declining and temperatures have been increasing, leading to increased cases of extreme fog, mist and heatwaves.
- The second finding was that there has been an increase in frequency and intensity of extreme weather events, most notably, floods and droughts. These changes in the climate and associated weather events have frequently affected mine operations particularly at the production sub-chain of the coal mining value chain.
- The third major finding was that despite this evidence of adverse impact of climate change on the production sub-chain of the South African coal mining value chain, adaption responses in all the studied mines showed reactive adaptation to extreme events instead of proactive adaptation planning and implementation.

South Africa depends on coal-derived energy, electricity in particular and the coal mines are implicitly exposed and vulnerable to the adverse impacts of climate change. Reducing this exposure and vulnerability dictates the urgent need to implement anticipatory adaptation measures in all the sub-chains of the coal mining value chain.

Coal is the world's most abundant and widely distributed fossil fuel source, and will remain so well into the future. At present approximately 23% of primary global energy needs are met by coal and 40% of electricity is generated from coal. About 70% of world steel production depends on coal feedstock.

The combustion of coal is the largest contributor to the human-made increase of CO_2 in the atmosphere. Electric generation using coal burning produces approximately twice the greenhouse gasses per kilowatt compared to generation using natural gas.

Coal mining releases methane, a potent greenhouse gas. Methane is the naturally occurring product of the decay of organic matter as coal deposits are formed with increasing depths of burial, rising temperatures, and rising pressure over geological time. A portion of the methane produced is absorbed by the coal and later released from the coal seam (and surrounding disturbed strata) during the mining process. Methane accounts for 10.55% of greenhouse-gas emissions created through human activity. According to the Intergovernmental Panel on Climate Change, methane has a global warming potential 21 times greater than that of carbon dioxide over a 100-year timeline. The process of mining can release pockets of methane, and these gases may pose a threat to coal miners, as well as being a source of air pollution. This is due to the relaxation of pressure and fracturing of the strata during mining activity, which gives rise to safety concerns for the coal miners if not managed properly. The build-up of pressure in the strata can lead to explosions during (or after) the mining process if prevention methods, such as "methane draining", are not taken.

In 2008 James E. Hansen and Pushker Kharecha published a peer-reviewed scientific study analysing the effect of a coal phase-out on atmospheric CO_2 levels. Their baseline mitigation scenario was a phase-out of global coal emissions by 2050. Under the *Business as Usual* scenario, atmospheric CO_2 peaks at 563 parts per million (ppm) in the year 2100. Under the four coal phase-out scenarios, atmospheric CO_2 peaks at 422–446 ppm between 2045 and 2060 and declines thereafter.

Climate change is unlikely to have a major direct impact on the mining industry, for which regulations and management strategies are already in place to manage factors such as water usage, water conservation and demand strategies and environmental issues relating to rehabilitation and the provision of rehabilitation guarantees. While a lack of access to water may affect some mining projects, most mining processes do not generally require potable water. Where high-quality water is required, some mines are already installing water treatment units.

Changes in the frequency and intensity of storm events have the potential to impact on mining operations (e.g. tailing dams, sediment and erosion control); however, these impacts can normally be addressed as part of the mine's storm water management plan.

The highest risk to the mining industry from climate change is most likely to come from meeting growing community concerns over environmental issues. This is likely to increase the difficulty in obtaining approvals for mining projects (particularly for coal). Additional constraints on mining may also affect the economic viability of individual mines, leading to flow-on effects to communities, through job losses and a decline in regional revenue. Work to develop clean coal technologies may ameliorate this risk to some extent; however, the actual process of mining is likely to face increasing community pressure.

Clean Coal technologies not only limited to the mining operations but also the end users of the coal will be a key factor in adapting to climate change and a carbon constrained future. Such technologies include:

- Pre and post carbon capture and storage technologies.
- New pollution control devices - like advanced scrubbers - that clean pollutants from flue gases before they exit a plant's smokestack.
- Chemical looping combustion technology to concentrate CO_2 levels in exhaust.
- Production of ultra clean coal which reduces ash from the coal allowing it to be directly fired in gas turbines at higher efficiency and lower greenhouse gas emissions.
- Efficiency upgrades and co-firing with less greenhouse intensive fuels in coal fired power stations.
- Low – NOx burners which allow coal-fired plants to reduce nitrogen oxide emissions.
- High temperature solar thermal applications integrated into coal fired power generation.
- Stack Gas Treatment - applied to gaseous emissions from Pulverised Fuel (PF) Combustion.
- Advanced Pulverised Fuel Combustion (PF).
- Fluidised Bed Combustion (FBC).
- Gasification and Integrated Coal Gasification Combined Cycle Systems.
- Hybrid and advanced systems.
- Fuel cell technologies utilising gas from coal.
- Oxy-firing technology to raise the concentration of CO_2 in flue gases to better enable its capture.
- Coal Gasification including underground gasification in situ.
- Capture and utilisation of fugitive emissions from coal mines.

10. MONITORING PROGRAMME

No information on the current monitoring campaign were available at the time of this report. It is highly recommended that a dust monitoring campaign be conducted prior to the proposed mining operations commence and then continue for the life of mine in order to establish historical repository of data needed to fully understand/address fugitive and airborne dust emissions from the construction, operation and closure activities. Managing dust fallout effectively will result in the reduction of respiratory diseases that are as a result of air pollution, reduced risk of damage to property, improved visibility, and fewer disturbances to existing flora and fauna habitats.

Monitoring locations to be determined.

10.1.1 Proposed Monitor Locations

To be determined

10.2 Gravimetrical Dust Fallout – (Milligram/Square Meter/Day) or (mg/m²/day) (Monthly 8 Samples)

Site layout for sampling points must be carried out according to the eight main compass directions; the site layout and equipment placement must be done in accordance with the ASTM standard, D 1739 – 2010, thereafter relevant sampling reference numbers will be allocated to the receptors accordingly. At each gravimetric dust fallout gauge/receptor point there is a stand built according to specification containing the dust sample collection bucket. Samples will be collected after a 1 month running period (+-30 day's exposure). After sample collection, the samples are taken to a SANAS accredited laboratory as required. A visual site investigation is done where after correlations are drawn and findings are identified and reported on.

Dust buckets of a standard size and shape are prepared and set up at locations related to the eight main compass points on the borders of the property so that dust can settle in them for periods of 30+/-2 days. The dust buckets are then sealed and replaced with new empty ones and send away to the SANAS accredited laboratory for analysis. The masses of the water-soluble and –insoluble components of the material collected are then determined and results are reported as mg/m²/day. This methodology is described according to South African National Standards 1929:2004 and the American Society for Testing and Materials (ASTM) Designation: D 1739-98 (2010). The results for this method of testing are obtained by gravimetrical weighing. The apparatus required include open top buckets/containers not less than 150 mm in diameter with a height not less than twice its diameter. The buckets must be placed on a stand at a height of 2 +/-0.2 m above the ground.

10.3 Indicative Sampling

New technology to perform cost effective real-time dust and particulate matter is currently becoming a cost-effective option. This type of technology can record real-time wind speed and direction together with particulate concentrations. It can thus be used more effectively for management purposes. Actionable intelligence is generated on dust and particulate matter emissions, which in turn can then be used to determine the origin of the particulate emissions. In a scenario where operations are situated in close proximity to each other and residential areas, this type of technology can become instrumental in decision making on the management of dust for a mining operation

EcoE developed a cost effective, MCERTS certified, Remote Active Indicative Real-Time Particulate Matter Dust Monitoring solution;

- This particular service offering is backed up and supported by a team of experienced Environmental Scientists, Electronic and Information Technology Engineers.
- Our dust monitoring stations are proudly manufactured in-house in South Africa.
- The design allows to have full remote telemetry with real-time live feed alerts for corrective actions.
- Stations incorporate sensors for single or simultaneously Particulate Matter fraction measurements ranging from Pm_1 to Pm_{10}
- In addition to this the stations also include weather sensors to ensure ease of integrated data interpretation, analysis and future predictive modelling.

- Units are wireless, mobile and solar powered with built in battery banks, to allow the stations to run for up to 10 days during inclement weather.
- Data is pushed via FTP to our secure cloud-based server, or can be viewed/accessed via any web-enabled device on our remote monitoring data portal.
- A network of nodes can be utilized to better understand the specific operation emissions and assist in managing the emissions.

Further analysis of the data include, but not limited to:

- Trend Analysis to determine trends in the particulate emissions and assist in when extra mitigation measures and specific operations should occur to limit dust emission.
- Polar plots to determine at what wind direction and speed higher emissions occur to help determine if exceedances recorded by compliance instruments are from neighbouring sites or the project site.
- Site specific weather data to help in management decision making on mitigation measure increases during certain hours of the day or night.

Figure 12: Typical Real-Time Ambient Particulate Matter monitoring dashboard communication interface

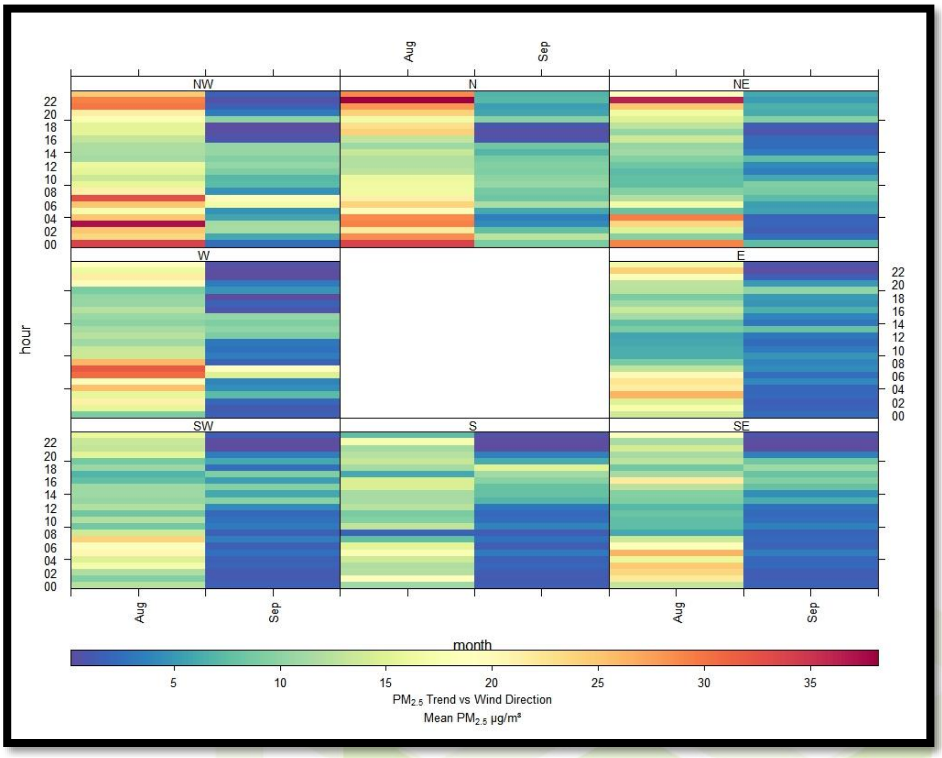

Figure 13: Trend Analysis showing trends in higher emissions at specific hours and wind direction.

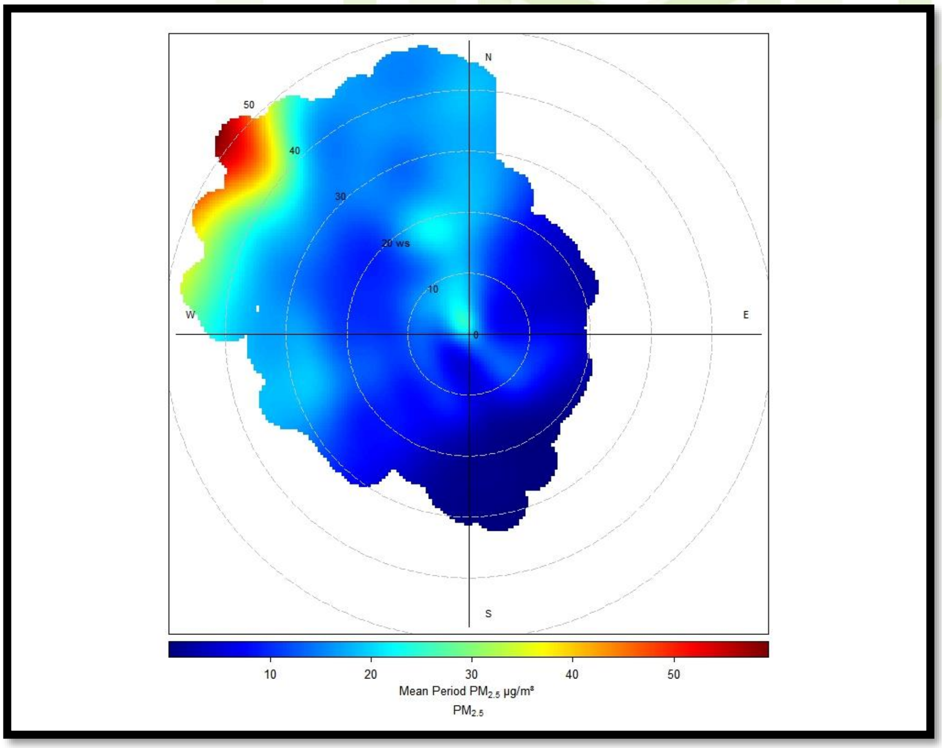

Figure 14: Polar Plot indicating higher emissions at higher windspeeds from the north-west.

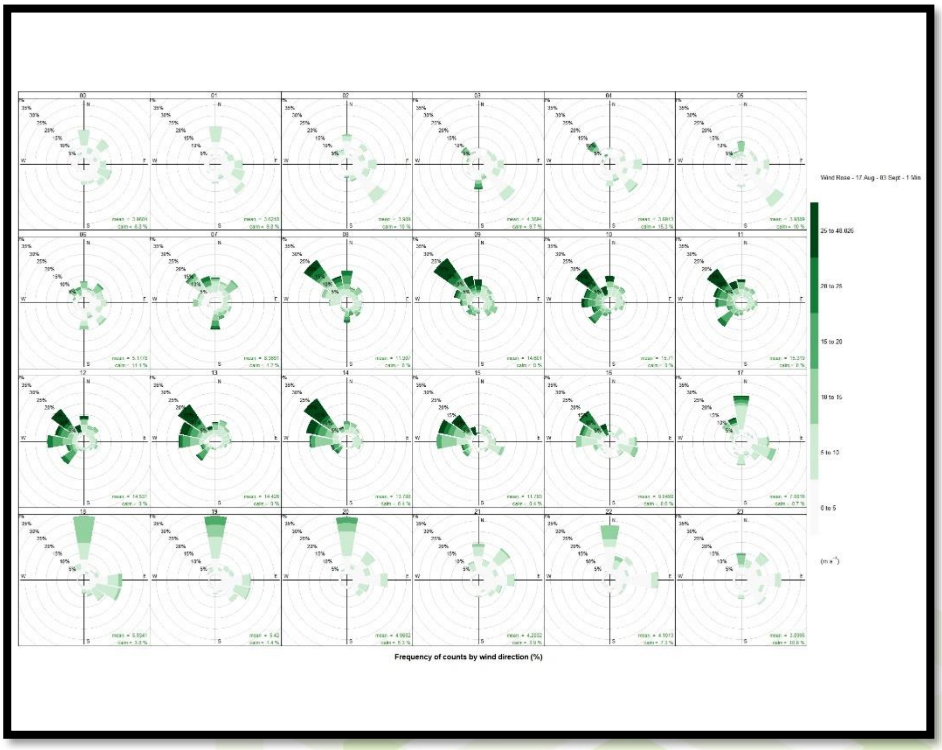

Figure 15: Hourly average wind roses to assist in decision making.

CSA GROUP™ MCERTS Environment Agency

PRODUCT CONFORMITY CERTIFICATE

This is to certify that the

SPS30 Particulate Matter Sensor

Manufactured by:

SENSIRION AG
4F, Building 2, No. 800
Jiuxin Highway
Jiuting Town
Songjiang District
SHANGHAI 201615
China

has been assessed by Sira Certification Service
and for the conditions stated on this certificate complies with:

MCERTS Performance Standards for Indicative Ambient Particulate Monitors, Version 4 dated August 2017

Certification Range :

$PM_{2.5}$ 0 - 75µg/m³

Project No.: 80010867
Certificate No: Sira MC200350/00
Initial Certification: 08 January 2020
This Certificate issued: 08 January 2020
Renewal Date: 07 January 2025

Holly Blincow
Environmental Project Engineer

MCERTS is operated on behalf of the Environment Agency by
Sira Certification Service
Unit 6, Hawarden Industrial Park
Hawarden, Deeside, CH5 3US
Tel: +44 (0)1244 670 900

The MCERTS certificate consists of this document in its entirety.
For conditions of use, please consider all the information within.
This certificate may only be reproduced in its entirety and without change
To authenticate the validity of this certificate please visit www.csagroupuk.org/mcerts

Page 1 of 4

Form 1335
Issue 8

CSA GROUP™ MCERTS Environment Agency

Certificate Contents

Approved Site Application

Any potential user should ensure, in consultation with the manufacturer, that the monitoring system is suitable for the intended application. For general guidance on monitoring techniques refer to the Environment Agency Monitoring Technical Guidance Notes available at www.mcerts.net

The indicative dust monitoring analyser(s) can be operated in one of two ways:

For qualitative measurements: Providing qualitative measurement data for the analysis of particulate pollution trends, and source identification studies based for example on pollution roses etc. Such application can rely on instrument factory calibration only.

For quantitative measurements: Providing measurement data with the uncertainty defined for indicative instruments (±50%), as specified by the Air Quality Directive (2008). This can be achieved on condition that each instrument used for measurement has been calibrated on the specific site where monitoring is taking place against a standard reference method for a period of two weeks and the resulting slope and intercept have been used for instrument calibration. Using non-standard filters and procedures for this purpose is not acceptable. To maintain the validity of data this calibration has to be repeated at least every twelve months or when the instrument is moved to a different site. Consistent results of the calibration may lead to less frequent repetition of the calibration process, in agreement with a competent authority, such as the Environment Agency or other Environmental regulator.

They cannot be used as a substitute for continuous ambient air quality monitoring systems (CAMs) employed in national air quality monitoring networks for the EU Air Quality Directive

Basis of Certification

This certification is based on the following Test Report(s) and on Sira's assessment and ongoing surveillance of the product and the manufacturing process:

MCERTS Report 80010867 dated 25/11/2019

Product Certified

The measuring system consists of the following parts:

- SPS30 Particulate Matter Sensor

This certificate applies to all instruments fitted with firmware version 1.0 and manufactured date 28/11/2019 onwards.

Certificate No : Sira MC200350/00
This Certificate issued : 08 January 2020

This certificate may only be reproduced in its entirety and without change
To authenticate the validity of this certificate please visit www.csagroupuk.org/mcerts

Page 2 of 4

Figure 16: MCERTS Performance Standards for Indicative Ambient Particulate Monitors Certificate

11. CONCLUSION

The draft air quality impact assessment undertaken for the project includes a meteorological overview of the area. An emissions inventory was undertaken with the aim of quantifying emissions associated with the activities involved in the mining of coal. The emissions for specific activities such as tipping, wind erosion and materials handling activities were calculated for the sensitive recptors only and the cumulative impacts were compared to the relevant ambient air quality standards to determine legal compliance.

The findings reported here is therefore a combination of historical, observed and previously modelled data and provided the background and predicted scenario of various pollutants in the proposed Nndanganeni project mining area. The construction and operational phases were assessed. Based on the dispersion modelling simulations, the following conclusions can be summarised as follows:

11.1 PM10

For the unmitigated Daily PM10 concentrations it was predicted to be higher than the 75 µg/m³ limit for 3 of the sensitive receptors as can be seen in Table 19.

When comparing the Daily Mitigated PM10 modelled concentrations, the sensitive receptors exceeding the 75 µg/m³ limit dropped to 0 of the identified sensitive receptors. This as well is the highest levels predicted for a 24 hour period within the period. Due to site specific atmospheric conditions these exceedances may still occur within the limit of 4 per year.

The annual average PM10 limit of 40 µg/m³ are predicted not to exceed at any of the identified sensitive receptors for the unmitigated or mitigated scenarios.

11.2 TSP

In the unmitigated and mitigated scenarios, no sensitive receptors are predicted to exceed the monthly dust fallout for the highest month residential limit of 600 mg/m²/day.

The predicted annual dust fall out for the unmitigated and mitigated scenarios are not predicted to exceed the annual limit of 300 mg/m²/day at any of the sensitive receptors.

11.3 Mitigation Measures

The mitigation measures as seen in Table 22 are recommended at the various sources:

Table 22: Mitigation Method Summary

Operation	Reduction	Method
Material Handling	50%	Water Sprays
Loading Stockpile	50%	Water Sprays
Loading Trucks	50%	Water Sprays
Wind Erosion	50%	Water Sprays
	90%	Revegetation on OB and Topsoil
Haul Road	90%	Sealed or Salt-Encrusted roads
Access Road	90%	Sealed or Salt-Encrusted roads
Primary Crushing	50%	Water Sprays
Secondary Crushing	50%	Water Sprays

Based on the results presented the following further recommendations are outlined:

- It is recommended that ambient air quality monitoring be established to get a baseline condition prior to the onset of the operations and in order to establish the level at which the proposed operations are noted to impact on the ambient air quality.
- Fallout monitoring should be continued for the life of mine to better assess the level of nuisance dust associated with both mining and process related operations. Sampling of fallout should be undertaken within the neighbouring areas as well as on-site. Dust fallout monitoring is recommended locations to be determined.
- If it is found that dust levels are measured to be exceeding limits, it is highly recommended to establish a Real-Time indicative monitoring network to quantitatively help identify the sources and to assist in the management of the mitigation of these sources.

The impacts from dust fallout and Particulate matter can be reduced by implementing dust control measures. The highest intensity of the construction work should be carried out during the summer months and not over the harsh winter months as can result in increased dispersion of fugitive dust. The mine should ensure that unpaved roads are continuously watered and treated with dust binding additive products to reduce the volume of fugitive dust emitted from unpaved roads.

Mitigation and management measures for mining operation as discussed in this report should be sufficient to ensure the mining operation can be conducted with minimal impact on the receiving environment and therefore not have a detrimental effect and can go ahead.

12. REFERENCES

- *BROOKS, K., SVANAS, N., and GLASSER, D. 1988.* ***Evaluating the risk of spontaneous combustion in coal stockpiles. Fuel,*** *Vol. 67, no. 5.*

- *Chavalala, B. (2016),* ***An assessment of South Africa's coal mining sector response to climate change adaptation demands****, http://uir.unisa.ac.za/handle/10500/22834.*

- *Cowherd C., Muleski G.E. and Kinsey J.S. (1988).* ***Control of Open Fugitive Dust Sources****, EPA-450/3-88-008, US Environmental Protection Agency, Research Triangle Park, North Carolina.*

- *DME Western Australia (1999).* ***Guidelines on the Safe Design and Operating Standards for Tailings Storage****, Department of Minerals and Energy of Western Australia, May 1999.*

- *DME Western Australia (1998).* ***Guidelines on the Development of an Operating Manual for Tailings Storage****, Department of Minerals and Energy of Western Australia, October 1998.*

- *Dominici, F., Peng, R.D., Bell, M.L., Pham, L., McDermott, A., Zeger, S.L. and Samet, J.M. (2006).* ***Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases****. Journal of the American Medical Association, 295(10):1127–1134. [Online] Available at: http:/ / 0- jama.ama assn.org.innopac.up.ac.za/content/ 295/ 10/ 1127.full.pdf+html (accessed on 24 August 2011).*

- *EPA (1987).* ***PM10 SIP Development Guideline****, EPA-450/2-86-001, US Environmental Protection Agency, Research Triangle Park, North Carolina.*

- *Epstein, P.R., Buonocore, J.J., Eckerle, K., Hendryx, M., Stout III, B.M., Heinberg, R., Clapp, R.W., May, B., Reinhart, N.L., Ahern, M.M., Doshi, S.K. and Glustrom, L. (2011).* ***Full cost accounting for the life cycle of coal****. Annals of the New York Academy of Sciences, 1219(February):73–98. [Online] Available at: http:/ / 0- onlinelibrary.wiley.com.innopac.up.ac.za/doi/ 10.1111/ j.1749-6632.2010.05890.x/pdf (accessed on12 July 2011).*

- *Fenger, J., 2002: Urban air quality, In J. Austin, P. Brimblecombe and W. Sturges (eds),* ***Air pollution science for the 21st century****, Elsevier, Oxford.*

- *Harrison, R.M. and R.E. van Grieken, 1998:* ***Atmospheric Aerosols****. John Wiley: Great Britain.*

- *Jewell R J and Newson T A (1997).* ***Decommissioning of Gold Tailings Storage Facilities in Western Australia****, in Bouazza A, Kodikara J and Parker R (Eds), Balkema,* ***Environmental Geotechnics****, Rotterdam.*

- *Kaonga, B. And Kgabi, Nnensi. 2009:* ***Atmospheric Particulate Matter in the Marikana Mining Area of Rustenburg****, South Africa, European Journal of Scientific Research, 34, 271-279.*

- *Kemp, David D. 1998.* ***The environment dictionary****. Routledge. London.*

- *Kharecha P.A.; Hansen J.E. (2008).* ***"Implications of "peak oil" for atmospheric CO2 and climate"****. Global Biogeochem. Cycles.*

- *Manahan, S.E., 1991:* ***Environmental Chemistry****, Lewis Publishers Inc., United States of America.*

- *Maeda, Y., Morioka, J., Tsujino, Y., Satoh, Y., Zhang, X., Mizoguchi, T. and Hatakeyama, S. 2001.* ***Material Damage Caused by Acidic Air Pollution in East Asia****. Water, Air & Soil Poll. 130(1-4), 141-150.*

- *Newman, J.R. 1979.* ***Effects of industrial air pollution on wildlife****. Biol. Conserv., 15(3), 181-190.*

- *Pope III, C.A., Ezzati, M. and Dockery, D.W. (2009).* ***Fine-particulate air pollution and life expectancy in the United States****. The New England Journal of Medicine, 360:376–86. [Online] Available at: http:/ / 0-www.nejm.org.innopac.up.ac.za/doi/pdf/ 10.1056/*

- *Ritcey G M (1989).* ***Tailings Management. Problems and Solutions in the Mining Industry****, Eslevier, Amsterdam.*

- *South African National Standards (SANS), 2011.* ***South African National Standard, Ambient Air Quality – Limits for Common Pollutants****. SANS 1929:2011. Standards South Africa, Pretoria.*

- *Tyson, P.D. and R.A. Preston-Whyte, 2000.* ***The Weather and Climate of Southern Africa****. Oxford University Press, Cape Town.*

- *Foster, Vivien, Bedrosyan, Daron, World Bank, 2014.* ***Understanding CO2 emissions from the global energy sector****.*
- ***Unearthing the Carbon Footprint, Australian Mining****, March 2009.*
- *U.S Environmental Protection Agency, (1996).* ***Compilation of Air Pollution Emission Factors (AP-42)****, 6th Edition, Volume 1, as contained in the Air CHIEF (AIR Clearinghouse for Inventories and Emission Factors) CD-ROM (compact disk read only memory), US Environmental Protection Agency, Research Triangle Park, North Carolina. Also available at URL: http://www.epa.gov/ttn/chief/ap42/.*
- *Van Horen, C. (1996).* ***Counting the social costs: Electricity and externalities in South Africa****. Cape Town: University of Cape Town Press and Elan Press.*
- *World Health Organization.* ***2000, WHO Air Quality Guidelines for Europe****, 2nd edition, WHO Regional Office for Europe, Copenhagen, Denmark (WHO Regional Publications, European Series, No 91).*
- *World Health Organization (WHO), 2002,* ***The World Health Report, Annex Table 9, 2002****, http://www.who.int/whr/2002/en/whr2002_annex9_10.pdf.*
- *Zunckel, M, Naicker, Y., Raghunandan, A., Fischer, T., Crouse, H., Ebrahim, A and Carter, W., 2011.* ***The Highveld Priority Area Air Quality Management Plan****, Department of Environmental Affairs, Pretoria.*