Air Quality Baseline Assessment - Pure Source Mine Project in the Free State

Project done for **Shango Solutions**

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Report Details

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Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
AMS	American Meteorological Society
ASTM	American Society for Testing and Materials
DEA	Department of Environmental Affairs
EPA	Environmental Protection Agency
mamsl	Meters above mean sea level
MM5	Fifth-Generation NCAR / Penn State Mesoscale Model
NAAQS	National Ambient Air Quality Standard(s)
NAEIS	National Atmospheric Emissions Inventory System
NDCR(s)	National Dust Control Regulation(s)
SA	South African
SAAQIS	South African Air Quality Information System
TSP	Total Suspended Particulates
US EPA	United States Environmental Protection Agency

Glossary

Air pollution[a]	The presence of substances in the atmosphere, particularly those that do not occur naturally
Dispersion[a]	The spreading of atmospheric constituents, such as air pollutants
Dust[a]	Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size
Instability[a]	A property of the steady state of a system such that certain disturbances or perturbations introduced into the steady state will increase in magnitude, the maximum perturbation amplitude always remaining larger than the initial amplitude
Mechanical mixing[a]	Any mixing process that utilizes the kinetic energy of relative fluid motion
Oxides of nitrogen (NO_x)	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide (NO_2)
Particulate matter (PM)	Total particulate matter, that is solid matter contained in the gas stream in the solid state as well as insoluble and soluble solid matter contained in entrained droplets in the gas stream
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5 µm
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10 µm
Stability[a]	The characteristic of a system if sufficiently small disturbances have only small effects, either decreasing in amplitude or oscillating periodically; it is asymptotically stable if the effect of small disturbances vanishes for long time periods

Notes:

(a) Definition from American Meteorological Society's glossary of meteorology (AMS, 2014)

Symbols and Units

°C	Degree Celsius
C	Carbon
CH_4	Methane
C_6H_6	Benzene
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_{2eq}	Carbon dioxide equivalent
g	Gram(s)
H_2O	Water vapour
HFC(s)	Hydrofluorocarbon(s)
kg	Kilogram(s)
Kilogram	1 000 grams
km	Kilometre(s)
Kilometre	1 000 meters
kWh	Kilowatt Hour
L_{Mo}	Monin-Obukhov length
m/s	Meters per second
µg	Microgram(s)
µg/m³	Micrograms per square meter
mg	Milligram(s)
mg/m²/day	Milligrams per square meter per day
m²	Square meter
mm	Millimetres
MWh	Megawatt hour
N_2	Nitrogen
N_2O	Nitrous oxide
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
PAH(s)	Polycyclic aromatic hydrocarbon(s)
PFC(s)	Perfluorocarbon(s)
Pb	Lead
$PM_{2.5}$	Inhalable particulate matter
PM_{10}	Thoracic particulate matter
SF6	sulphur hexafluoride
SO_2	Sulfur dioxide
1 tonne	1 000 000 grams
TJ	terajoule
1 terajoule	$1x10^{12}$ joules

Executive Summary

The proposed Pure Source Mine Project, located approximately 20 km north-east of Parys in the Free State Province along a stretch of the Vaal river, will involve the development of an open pit sand and gravel mine, topsoil stockpiles, run-of-mine stockpiles, conveyors, mobile crushers, mobile screening plants and product stockpiles. Mined material will be processed in a processing plant comprising a sand washing plant, a sand drying plant, a diamond sorting plant and product stockpiles. Additional associated infrastructure includes change houses, offices, workshops, stores and clean and dirty water management infrastructure.

The proposed open pit surface mining and processing activities will result in air quality impacts in the study area. Particulates represent the main pollutant of concern in the assessment of activities from the proposed operations. Other pollutants include combustion products due to vehicle tailpipe emissions and dryer stack (s). Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Shango Solutions to undertake an environmental air quality specialist study for the project as part of the Environmental Impact Report (EIR) process.

The air quality investigation comprises both a baseline study and an impact assessment. This report outlines the findings of the **baseline** component of the air quality specialist study for inclusion in the environmental impact scoping report.

Baseline characterisation

The baseline study included a summary of the legal requirements pertaining to air quality, analysis of meteorological data, identification of air quality sensitive receptors, and an analysis of current ambient air quality in the region. Reference was made to modelled hourly sequential MM5 meteorological data for the period January 2015 to December 2017; receptors were identified from satellite imagery and maps provided by the client; and data on existing air quality within the area was obtained from a site visit conducted over a 22-hour period.

The following was found with regards to the receiving environment:

- The wind field is dominated by winds from the northern sector during the entire period, day- and night, with very little wind from the south and an average wind speed of 3.22 m/s. Calm conditions occurred 12.9% of the time.

- The current usage of land surrounding the proposed mine includes mining, residential and agriculture. Mining operations within the study area almost exclusively include mineral sand mining activities. Direct surrounding large communities include Vaal Oewer and Lindequesdrift. An analysis of topographical data indicates slopes of more than 1:10 to the northwest and south of the project area. Agricultural activities include sheep farming and intensive crop farming.

- Based on the nature of the project and expected air quality impacts, a study area of 8 km east-west by 6 km north-south, with the project site located centrally, was selected. All residences in the vicinity of the proposed site that fall within the modelling domain were included as individual receptors for off-site air quality assessment.

- Measured air quality concentrations at a sensitive receptor located at the eastern border of the mining rights area showed high variability throughout the 22-hour sampling period.

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1 INTRODUCTION

1.1 Background

The proposed Pure Source Mine Project is located on portion 3 of the farm Woodlands 407, the remaining extent of portion 1 of the farm Woodlands 407 and the remaining extent of the farm Woodlands 407, located approximately 20 km north-east of Parys in the Free State Province (Figure 1). The properties are located along a stretch of the Vaal river and covers an area of approximately 875 hectares.

The proposed Pure Source Mine Project will involve opencast mining with trucks and shovels, of sand, gravel and possibly diamonds (based on potential established via exploration). Reject material will be backfilled into mined voids and topsoil stockpiles established for rehabilitation. Mined sand will either be screened in the pit or transported by truck to the washing plant. Once the sand is removed the underlying gravel will be exposed and test pits established to ascertain gravel quality and diamond potential. Where appropriate the gravel will be excavated and crushed in the pit by a mobile crusher and then either loaded onto customer's trucks or transported to the plant to extract diamonds. In the areas where there is no silica sand the topsoil will be stripped and stockpiled to expose the underlying aggregate. Where the presence of high yield diamondiferous gravel is anticipated the silica sand will be stockpiled. The sand from the northern pit is expected to be screened and loaded at the location and will be sold as unprocessed sand directly. The sand from the main and east pit is exclusively identified to be beneficiated and sold as specialised sand.

The proposed open pit surface mining and processing activities will result in air quality impacts in the study area. Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Shango Solutions to undertake an environmental air quality specialist study for the project as part of the Environmental Impact Report (EIR) process. The air quality investigation comprises both a baseline study and an impact assessment. This report outlines the findings of the **baseline** component of the air quality specialist study for inclusion in the environmental impact scoping report.

The main objective of the air quality specialist study will be to determine the significance of impacts on the surrounding environment and human health at selected air quality sensitive receptors (AQSRs) given air emissions generated by activities proposed as part of the project. The objective of the baseline component of the study is to identify AQSRs in the study area, assess the local dispersion potential of the study area and to survey and study existing ambient air quality in the study area. During the impact assessment phase of the specialist study, all sources of particulate, silica and exhaust gas emissions associated with the Pure Source Mine will be quantified and dispersion modelling simulations undertaken using the US EPA AERMOD dispersion model. Three scenarios have been identified to assess the worst case air quality impacts when the mining operations are closest to sensitive receptor locations. These three scenarios will be for mining operations during years 12, 18 and 29. Isopleth plots will be generated for the three scenarios and simulated concentrations compared to standards and guidelines as described in Section 2. Based on the impact assessment management and mitigation measures will be recommended and suitable monitoring locations identified and recommended.

1.2 Study Scope

To meet the objective of the baseline assessment, the following tasks were included in the Scope of Work (SoW):

1. A review of available technical project information.
2. A review of the legal requirements and applicable environmental air quality guidelines.
3. A study of the receiving (baseline) environment, including:

a. The identification of AQSRs from available maps, field observations and information supplied by the client;
b. A study of local dispersion potential by referring to available weather records, land use, and topography; and
c. Determining baseline ambient air quality through the analysis of ambient air concentrations measured during a short 22-hour sampling period.

4. The preparation of a comprehensive specialist air quality baseline assessment report.

1.3 Description of Project Activities from an Air Quality Perspective

1.3.1 Construction Phase

Construction phase activities will include bulk earthworks (for the establishment of the open pit, stockpiles, conveyors, access routes, water management infrastructure, the processing plant and infrastructure such as offices, change houses and workshops), as well as metal and concrete works for the erection of the processing plant and other infrastructure. The construction phase is expected to take approximately 6 months to complete.

Access to site will be via the Vaal Eden Road (S171) located south of the project area. An access road to the mine will be established at the start of construction and will be utilised throughout the life of the project. Existing dirt roads traverse the property; these may be used in addition to the main access road during the construction phase.

Gaseous and particulate emissions are expected to arise from construction activities. Typical sources of the fugitive emissions likely to occur during the construction phase are shown in Table 1.

Table 1: Typical sources of fugitive emissions associated with construction

Impact	Source	Activity
Gases	Vehicle tailpipe	Transport and general construction activities
Dustfall, PM_{10} and $PM_{2.5}$	Plant infrastructure	Clearing of groundcover
		Levelling of area
		Wind erosion from open areas
		Materials handling
	Transport infrastructure	Clearing of vegetation and topsoil
		Levelling of proposed transportation route areas

Each of the operations in Table 1 has their own duration and potential for dust generation. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Emissions will be calculated for general infrastructure construction activities (requiring clearing of ~13.5 ha of land).

1.3.2 Operational Phase

Mining will comprise the mining of sand, gravel and diamondiferous gravel to recover diamonds. The estimated locations of sand deposits and gravel aggregates are shown in Figure 1. The proposed mining method will be a dry mining process, using excavators and front-end loaders. Mobile screening plants and mobile crushers will be utilised in the open pit.

Gravel and sand not directly trucked to market will be hauled to a processing plant comprising a sand washing plant, a sand drying plant, a diamond sorting plant and product stockpiles. The anticipated mining rates and processing rates are as follows: 810 000 m^3 sand per year (from year 3 to year 11) and 740 000 m^3 sand per year (from year 12 onwards), 130 000 m^3 gravel per year (from year 2 to year 10) and 416 502 m^3 gravel per year (from year 11 onwards). Because of the nature of the sand and gravel mine, no drilling or blasting will be conducted. The anticipated life of mine is 30 years.

The potential air emissions that may result from the operations are dependent on the nature of the source material itself (Table 2). Particulate matter, SO_2 and NO_2 are classified as criteria pollutants, with South African Ambient Air Quality standards established to regulate ambient concentrations of these pollutants.

Table 2: Typical sources of emissions associated with the operational phase

Impact	Source	Activity
Combustion products including NO_x (oxides of nitrogen), CO_2 (carbon dioxide), CO (carbon monoxide), SO_2 (sulfur dioxide); particulate matter	Vehicle exhaust	Tailpipe emissions from vehicles utilised during the operational phase
	Dryer stack	Drying of sand that has been washed
Dustfall, PM_{10} and $PM_{2.5}$	Materials handling	Loading, offloading, conveyer transfer, backfilling and other tipping operations
	Crushing	Primary crushing using a mobile crusher inside the pit
	Vehicle entrainment	Transport of sand, gravel, diamond gravel, discard and product
	Windblown dust	Wind erosion from open areas

1.3.3 Decommissioning Phase

During decommissioning, bulk earthworks and demolishing activities are expected (Table 3). Very little information regarding specific activities during the decommissioning phase was available for consideration. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during closure. Simulations of the decommissioning phase will not be included in the current study due to its temporary impacting nature.

Table 3: Activities and aspects identified for the decommissioning phase

Impact	Source	Activity
Dustfall, PM_{10} and $PM_{2.5}$	Stockpiles and mine pit	Dust generated during rehabilitation activities
	Plant and infrastructure	Demolition of the process plant and infrastructure
Gases	Vehicles	Tailpipe emissions from vehicles utilised during the closure phase

1.4 Assumptions, Exclusions and Limitations

The most important limitations of the baseline assessment are summarised as follows:

- There is no on-site meteorological station. Modelled MM5 data was obtained for the period January 2015 to December 2017 to describe atmospheric dispersion potential and for future use in the dispersion model.
- Ambient air quality monitoring was conducted over a 22-hour period (concurrent with a noise baseline survey) to

provide a general impression of background $PM_{2.5}$ and PM_{10} concentrations. It is important to note that this was not a formal ambient monitoring campaign, and that results may not be truly representative of long term baseline air quality in the study area.

1.5 Report Structure

This report is structured as follows:

Section 1	An introduction to the study including a description of the project and the scope of work, exclusions and limitations.
Section 2	A summary of applicable environmental air quality guidelines is presented.
Section 3	A description of the receiving environment is given. It addresses AQSRs, dispersion potential as well as baseline air quality.
Section 4	References

2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

2.1 Listed Activities and Emissions Standards

The National Environmental Management: Air Quality Act (NEM:AQA) makes provision for the setting of ambient air quality standards and emission limits at National level, which provides the objective for air quality management. More stringent ambient standards may be implemented by provincial and metropolitan authorities. Listed activities will be identified by the Minister and will include all activities regarded to have a significant detrimental effect on the environment, including health. In addition, the Minister may declare priority pollutants for which an industry emitting this substance will be required to implement air pollution prevention plans.

The NEM:AQA was developed to reform and update air quality legislation in South Africa with the intention to reflect the overarching principles within the National Environmental Management Act. It also aims to comply with general environmental policies and to bring legislation in line with local and international good air quality management practices. Given the specific requirements of the NEM:AQA, various projects had to be initiated to ensure these requirements are met. One of these included the development of the Listed Activities and Minimum National Emission Standards. These standards were first published on 31 March 2010 (Government Gazette No. 33064) and later the revised regulation was published in Government Notice No. 893, Gazette No. 37054 on 22 November 2013.

According to the process description, the Listed Activities, and applicable Minimum Emissions Standards (MES), that apply to the Pure Source Mine Project include Category 5.2 (see Table 4).

Table 4: Listed Activities Subcategory 5.2 - Drying

Description	**The drying of mineral solids including ore, using dedicated combustion installations**		
Application	Facilities with a capacity of more than 100 tons/month product		
Substance or mixture of substances		Plant status	Mg/Nm³ under normal conditions of 273 Kelvin and 101.3 kPa
Common name	Chemical Symbol		
Particulate Matter	N/A	New	50
Sulphur dioxide	SO_2	New	1000
Oxides of nitrogen	NOx expressed as NO_2	New	5000

2.2 National Ambient Air Quality Standards

The South African Bureau of Standards (SABS) assisted the Department of Environmental Affairs (DEA) in the development of ambient air quality standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), $PM_{2.5}$, PM_{10}, ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene (Table 5).

Table 5: National Ambient Air Quality Standards (Government Gazette 32816, 2009)

Substance	Molecular Formula / Notation	Averaging Period	Concentration (µg/m³)	Permitted Frequency of Exceedance	Compliance Date
Sulfur Dioxide	SO_2	10 minutes	500	526	**Immediate**
		1 hour	350	88	**Immediate**
		24 hours	125	4	**Immediate**
		1 year	50	0	**Immediate**
Nitrogen Dioxide	NO_2	1 hour	200	88	**Immediate**
		1 year	40	0	**Immediate**
Particulate Matter	$PM_{2.5}$	24 hour	40	4	**1 Jan 2016 – 31 Dec 2029**
			25	4	**1 Jan 2030**
		1 year	20	0	**1 Jan 2016 – 31 Dec 2029**
			15	0	**1 Jan 2030**
	PM_{10}	24 hour	120	4	**Immediate – 31 Dec 2014**
			75	4	**1 Jan 2015**
		1 year	50	0	**Immediate – 31 Dec 2014**
			40	**0**	**1 Jan 2015**

2.3 National Dust Control Regulations

The National Dust Control Regulations were gazetted on 1 November 2013 (No. 36974). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. The standard for acceptable dustfall rate is set out in Table 6.

The method to be used for measuring dustfall rate and the guideline for locating sampling points shall be ASTM D1739: 1970, or equivalent method approved by any internationally recognized body.

Table 6: Acceptable dustfall rates

Restriction Area	Dustfall Rate (D) (mg/m²/day, 30 days average)	Permitted Frequency of Exceeding Dustfall Rate
Residential area	D<600	Two on a year, not sequential months
Non-residential area	600<D<1200	Two on a year, not sequential months

2.4 Silica

Several polymorphs exist for crystaline silica, of which alpha-quartz is the most abundant, constituting 12% of the earth's crust (Elzea, 1997). Inhalation of crystalline silica initially causes respiratory irritation and an inflammatory reaction in the lungs (e.g., Vallyathan *et al.*, 1995). Acute exposures to high concentrations cause cough, shortness of breath, and pulmonary alveolar lipoproteinosis (acute silicosis). After chronic but lower workplace exposures to silica for six to sixteen years, the small airways become obstructed as measured by pulmonary function tests (Chia *et al.*, 1992).

The Californian Office of Environmental Health Hazard Assessment provides a chronic inhalation reference expose level of 3 µg/m³ for respirable crystaline silica.

2.5 Reporting of Atmospheric Emissions

The National Atmospheric Emission Reporting Regulations (Government Gazette No. R283) came into effect on 2 April 2015. The purpose of the regulations is to regulate the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories. The NAEIS is a component of the South African Air Quality Information System (SAAQIS); its objective is to provide all stakeholders with relevant, up to date and accurate information on South Africa's emissions profile for informed decision making.

2.5.1 Classification of Emission Sources and Data Providers

Emission sources and data providers are classified according to groups A to D (listed in Table 7). According to Table 7 the Pure Source Mine Project would be classified under Group C ("Mines").

Table 7: Emission source groups, associated data providers, emission reporting requirements and relevant authorities

Group	Emission Source	Data Provider	NAEIS Reporting Requirements	Relevant Authority
A	Listed activity published in terms of section 21(1) of the Act.	Any person that undertakes a listed activity in terms of section 21(1) of the Act.	Emission reports must be made in the format required for NAEIS and should be in accordance with the atmospheric emission license or provisional atmospheric emission license.	Licensing authority.
B	Controlled emitter declared in terms of section 23(1) of the Act.	Any person that undertakes a listed activity in terms of section 21(1) of the Act and uses an appliance or conducts an activity which has been declared a controlled emitter in terms of section 23(1) of the Act. Any relevant air quality officer receiving emission reports as contemplated	Any information that is required to be reported in terms of the notice published in the Gazette in term of section 23 of the Act.	The relevant air quality officer as contemplated under the notice made in terms of section 23 of the Act.

		under notice made in terms of section 23 of the Act.		
C	Mines.	Any person, that holds a mining right or permit in term of the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002).	Emission reports must be made in the format required for NAEIS.	Relevant air quality officer.
D	Facilities identified in accordance with the applicable municipal by-law.	Any person that operates facilities which generate criteria pollutants and has been identified in accordance with the applicable municipal By-law.	Emission reports must be made in the format required for NAEIS.	Relevant air quality officer.

2.5.2 Registration as Data Provider

The regulations specify that emission sources and data providers as classified in Table 7 must register on the NAEIS within 30 days from the date upon which these activities or activity commence.

Data providers must inform the relevant authority of changes if there are any:

- Change in registration details;
- Transfer of ownership; or
- Activities being discontinued.

2.5.3 Reporting or Submission of Information

A data provider must submit the required information for the **preceding calendar year** to the NAEIS **by 31 March** of each year. Records of data submitted must be kept for a period of 5 years and must be made available for inspection by the relevant authority.

2.5.4 Verification of Information

The relevant authority must request, in writing, a data provider to verify the information submitted if the information is incomplete or incorrect. The data provider then has 60 days to verify the information. If the verified information is incorrect or incomplete the relevant authority must instruct a data provider, in writing, to submit supporting documentation prepared by an independent person. The relevant authority cannot be held liable for cost of the verification of data.

2.5.5 Penalties

A person guilty of an offence in term of regulation 13 of these Regulations is liable in the case of a first conviction to a fine not exceeding R5 million or to imprisonment of a period not exceeding five years, and in the case of a second or subsequent conviction to a fine not exceeding R10 million or imprisonment for a period not exceeding 10 years and in respect of both instances to both such imprisonment.

3 DESCRIPTION OF THE RECEIVING/BASELINE ENVIRONMENT

The proposed Pure Source Mine Project is located on portion 3 of the farm Woodlands 407, the remaining extent of portion 1 of the farm Woodlands 407 and the remaining extent of the farm Woodlands 407, located approximately 20 km north-east of Parys in the Free State Province (Figure 1). The properties are located along a stretch of the Vaal river and covers an area of approximately 875 hectares.

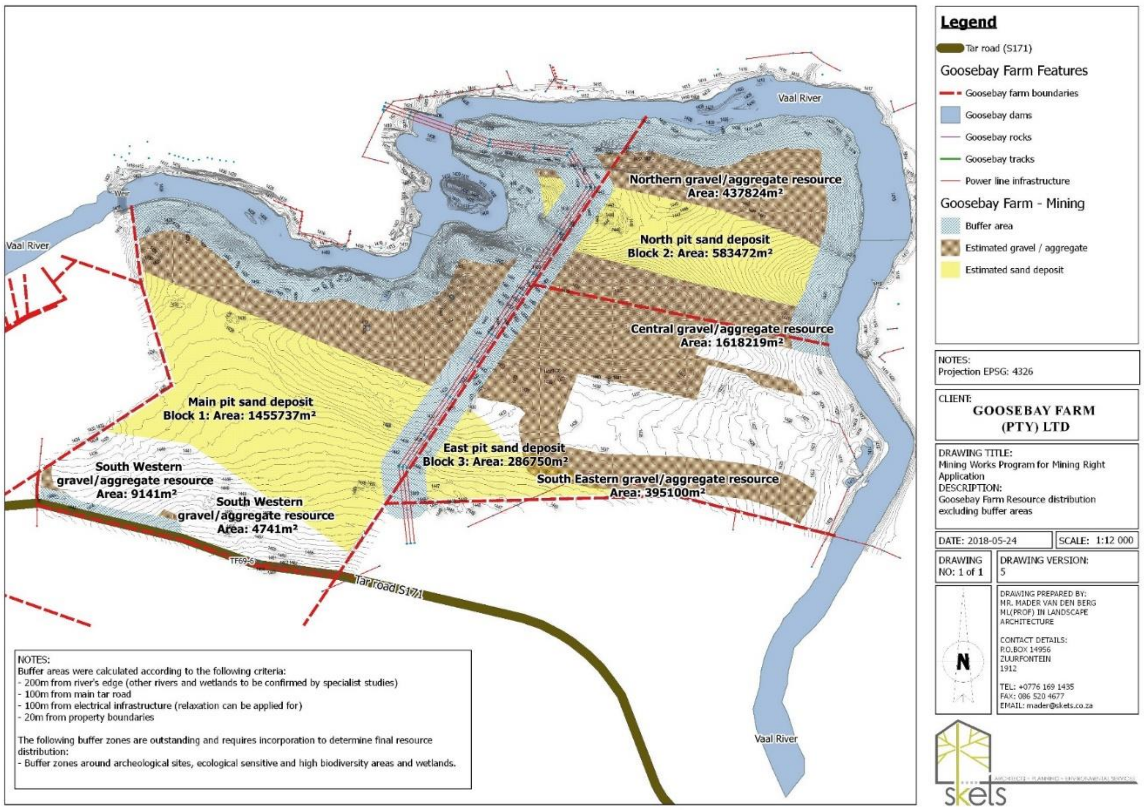

Figure 1: Local setting and mine layout

3.1 Air Quality Sensitive Receptors

The current usage of land surrounding the proposed mine includes mining, residential and agriculture. Direct surrounding large communities include Vaal Oewer and Lindequesdrift. Residences in the vicinity of the proposed site that fall within the modelling domain were included as individual receptors for the purpose of off-site air quality assessment (Figure 2).

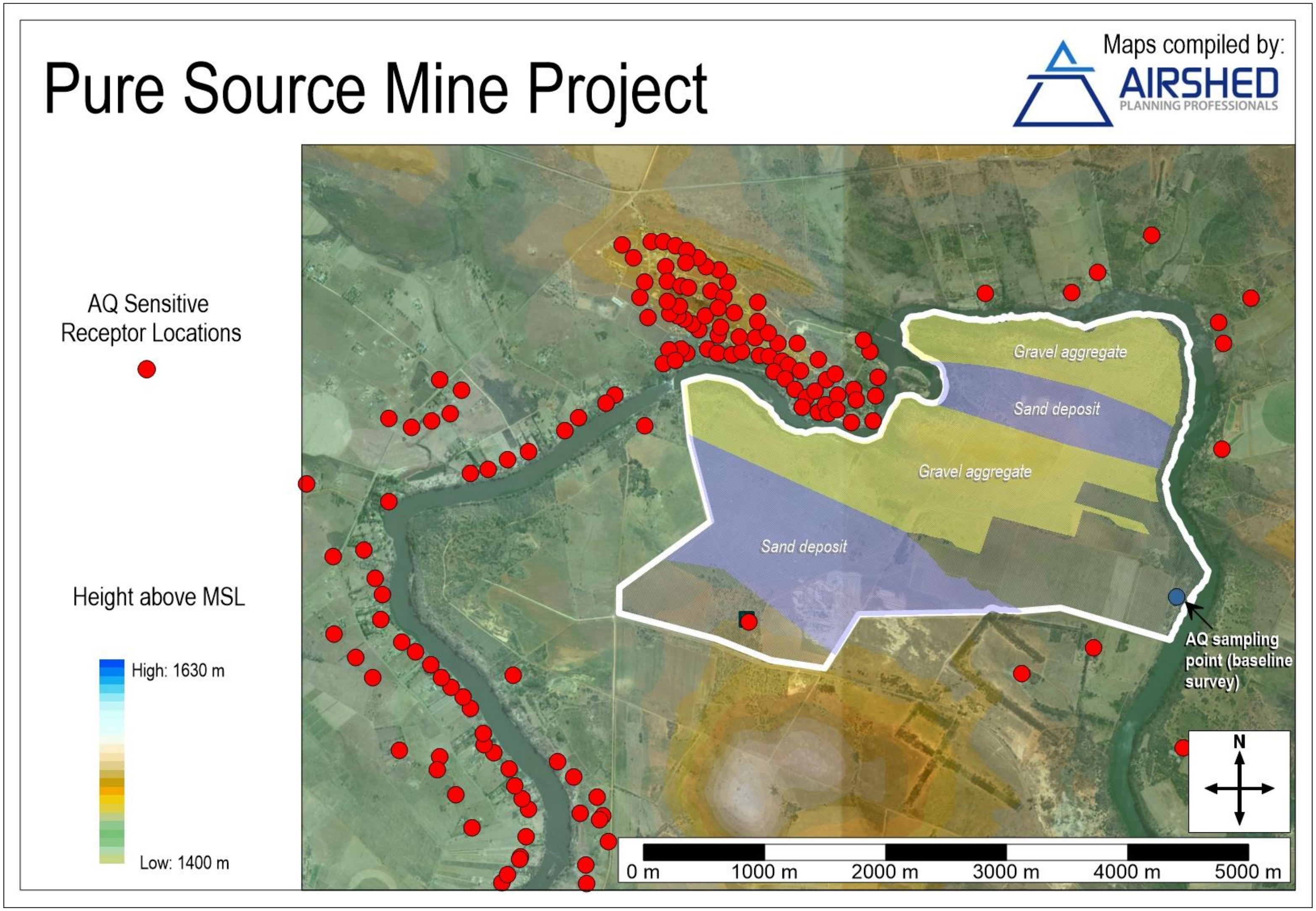

Figure 2: Layout with sensitive receptors included in modelling

3.2 Potential Area of Impact[1]

The impact (in terms of air quality) from mines is usually up to a distance of 5 km from the emitting source. However, without substantial control measures being implemented the impact from mines can reach further depending on the terrain, wind speeds and properties of the material mined. The impact area also depends largely on what sources of emissions are present at the mine site and the throughput of material. For example, if material is transported via haul roads there will be greater emissions than if it were conveyed.

3.3 Topography

An analysis of topographical data indicates slopes of more than 1:10 to the northwest and south of the project area (Figure 2). Dispersion modelling guidance recommends the inclusion of topographical data in dispersion simulations in areas where the slope exceeds 1:10 (US EPA, 2004).

3.4 Atmospheric Dispersion Potential

The analysis of meteorological data for the study area provides the basis for the parameterisation of the mesoscale ventilation potential of the site, and to provide the input requirements for the dispersion simulations. Parameters that need to be taken into account in the characterisation of mesoscale ventilation potential include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. A comprehensive data set for at least one year of site specific hourly average wind speed, wind direction and temperature data are needed for the dispersion simulations.

There is no meteorological station operational at the proposed site. Hourly sequential MM5 modelled data for the study site for the period January 2015 to December 2017 was obtained. The meteorological dataset has sufficient data availability for modelling thus this dataset will be used for modelling purposes. The dataset is discussed in this section.

3.4.1 Surface Wind Field

The dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The topography of an area normally has an effect on the localised wind flow.

The results of the wind field modelling are given in the form of wind roses. Wind roses comprise 16 spokes which represent the directions *from* which winds blew during the period. The colours of the spokes reflect the different categories of wind speeds, the yellow area in Figure 3 for example representing winds of 4 m/s to 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. For Figure 3 each dotted circle represents a 3% frequency of occurrence. The number given as a percentage next to calms below the legend describes the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

Figure 3 depicts the period, day-time and night-time wind roses based on the MM5 modelled data for the study site. The figure indicates a wind field dominated by winds from the northern sector during the entire period, day- and night, with very little wind from the south. Day- and night-time average wind speeds are 3.2 m/s and 3.3 m/s respectively. Calm conditions occur 15.7% of time during the day 10.0% during the night. On average, air quality impacts are expected to be slightly more notable to the south of the project activities.

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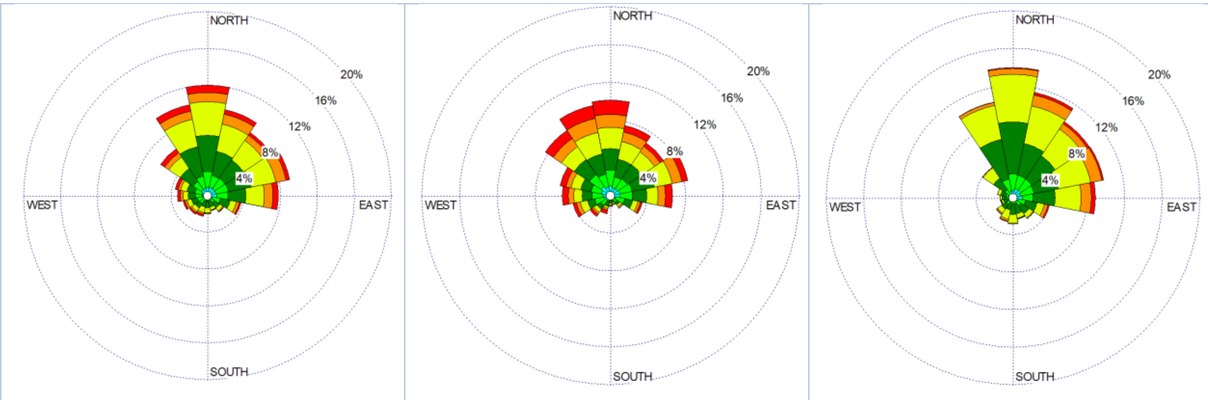
[1] The area of impact or impact area is the area in which exceedances of the air quality standards may occur. The mine will probably affect a large area but air quality standards are likely to be exceeded only in and around the mine property.

The significance in the diurnal shifts in the wind field will become clear when investigating the predicted ground level concentrations. Night-time conditions are normally associated with stable atmospheres, whereas daytime conditions are more unstable. Limited vertical dispersion occurs under stable conditions, and hence near ground level releases can result in relatively high concentrations during the night. Elevated releases will travel relatively far downwind before this "stable" plume reaches ground level and may therefore be sufficiently diluted not to cause high ground level concentrations. This may not be the case for low-level releases. Unstable conditions, particularly convective conditions normally occur during low wind speeds and can result in high ground level concentrations from elevated releases.

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required initiating particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface.

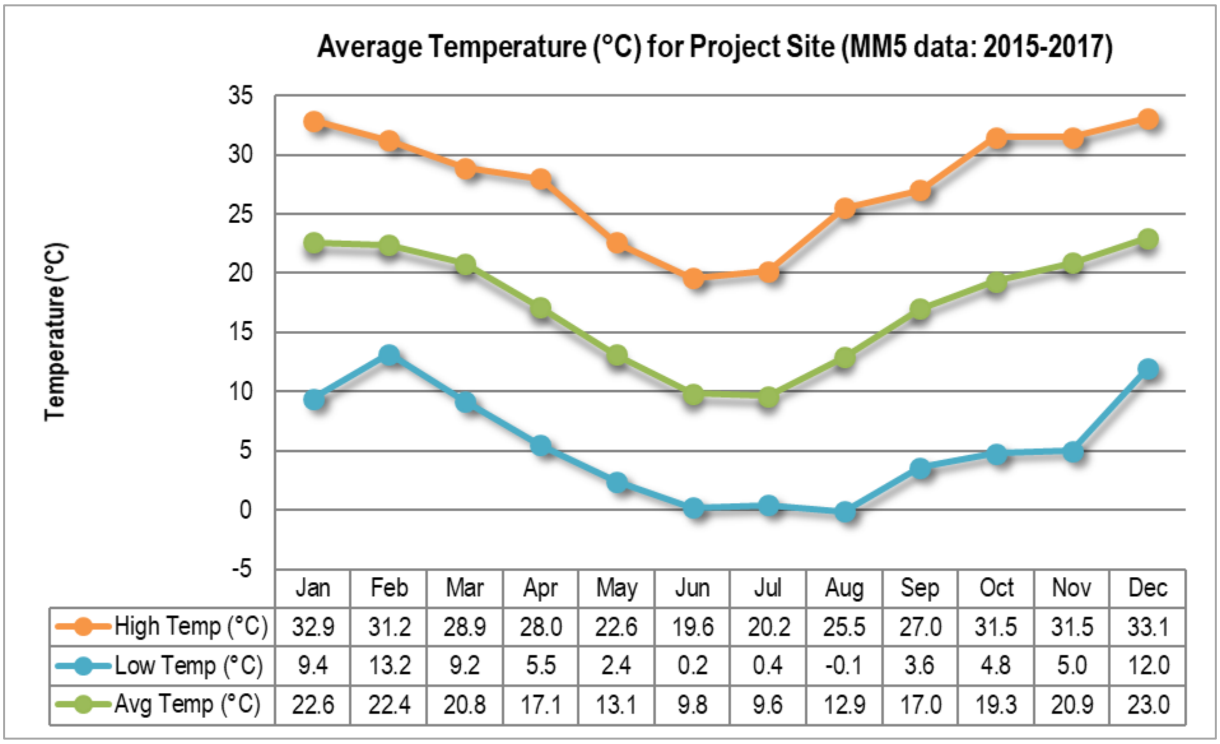


Period	Day-time	Night-time
Calms: 12.87%	Calms: 15.69%	Calms: 10.06%

Figure 3: Period, day-time and night-time wind roses based on modelled MM5 data for the study site (January 2015 to December 2017)

3.4.2 Temperature

The air temperature is important for determining the development of the mixing and inversion layers and for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise). The period mean, maximum and minimum temperatures for the study site was 17°C, 33°C and 0°C respectively for the period January 2015 to December 2017 (Figure 4). The months with the highest average temperatures are November, December, January and February. The months with the lowest average temperatures are June and August. The maximum temperatures were reached between 10H00 and 14H00, while the coldest temperatures were experienced between 04H00 and 07H00, just before sunrise (Figure 5).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High Temp (°C)	32.9	31.2	28.9	28.0	22.6	19.6	20.2	25.5	27.0	31.5	31.5	33.1
Low Temp (°C)	9.4	13.2	9.2	5.5	2.4	0.2	0.4	-0.1	3.6	4.8	5.0	12.0
Avg Temp (°C)	22.6	22.4	20.8	17.1	13.1	9.8	9.6	12.9	17.0	19.3	20.9	23.0

Figure 4: Monthly temperature profile based on modelled MM5 data for the study site (January 2015 to December 2017)

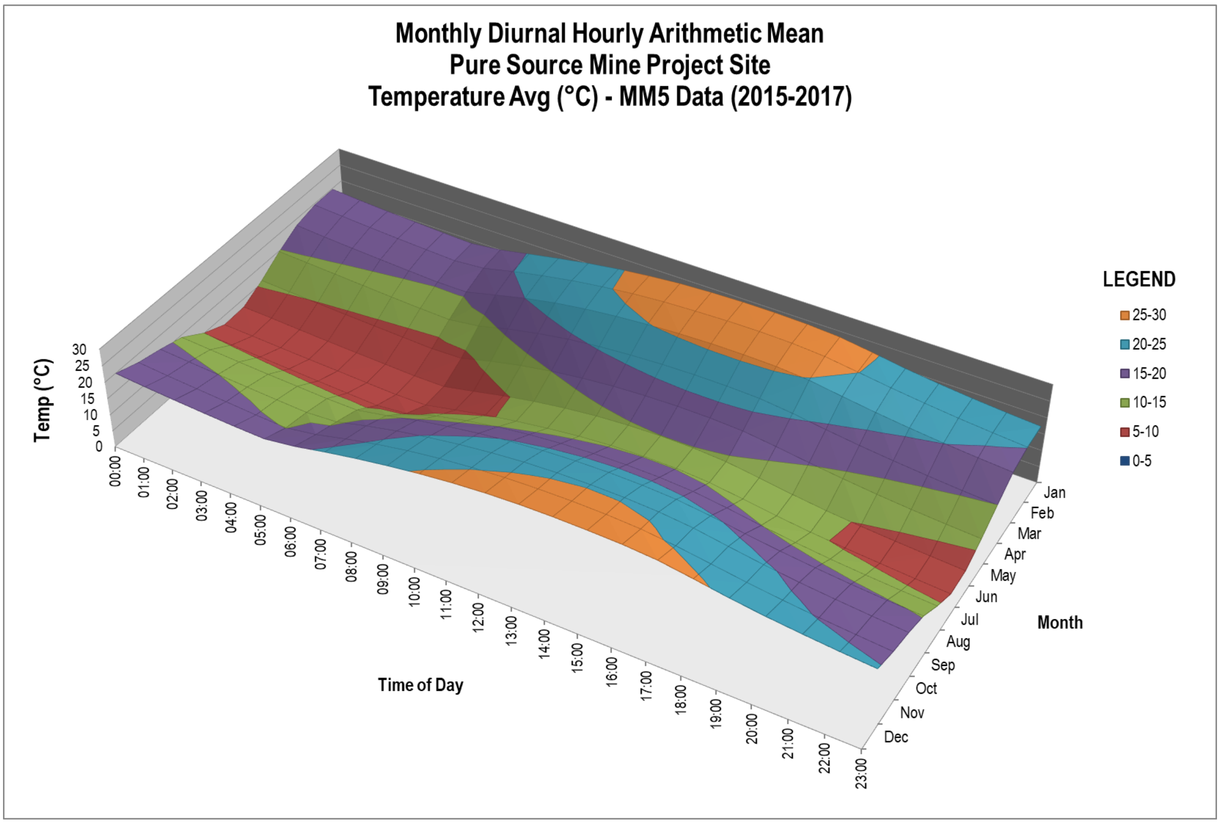
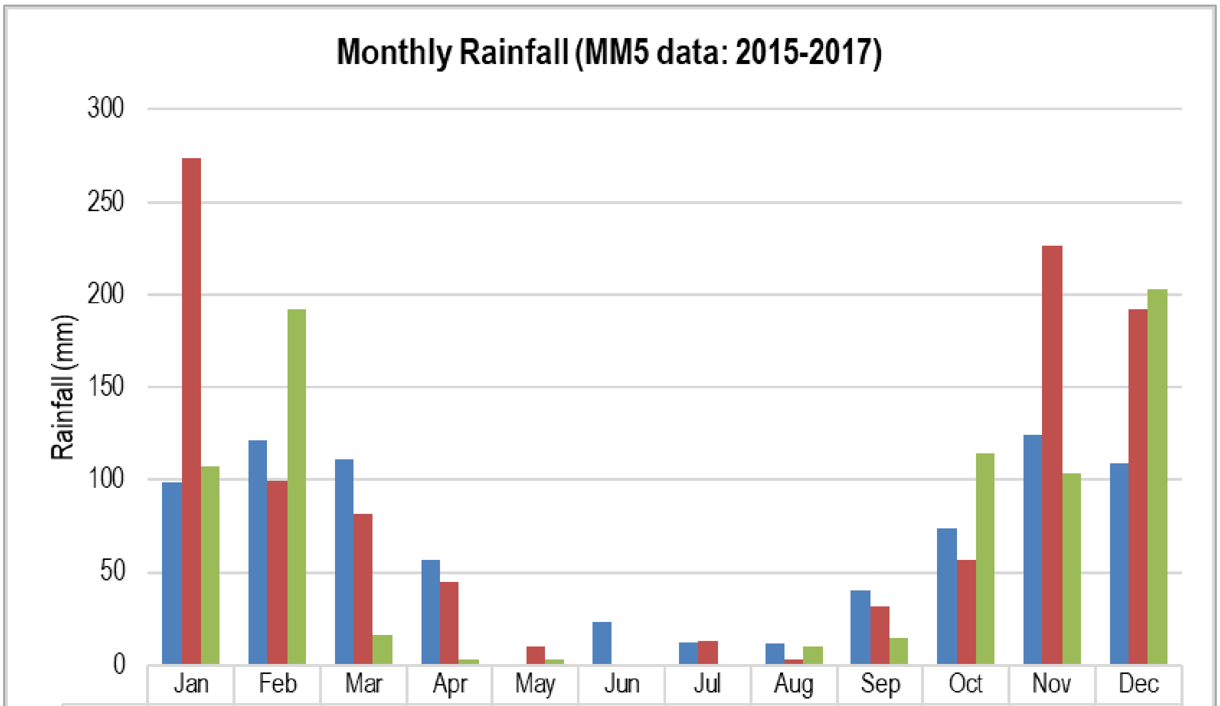


Figure 5: Diurnal temperature trends based on modelled MM5 data for the study site (January 2015 to December 2017)

3.4.3 Precipitation

Rainfall represents an effective removal mechanism of atmospheric pollutants and is therefore frequently considered during air pollution studies. Rain typically occurs primarily as storms. This creates an uneven rainfall distribution over the wet season (November to March). Dust is generated by strong winds that sometimes accompany storms. This dust generally occurs in areas with dry soils and sparse vegetation. The total monthly rainfall for each year is shown in Figure 6. The average annual rainfall for the study area is 862 mm, based on MM5 data for the period 2015-2017.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	99	121	111	56	1	23	13	11	40	74	125	109
2016	274	99	82	45	10	1	13	3	31	57	226	192
2017	107	192	16	3	3	0	0	10	15	114	104	203

Figure 6: Total monthly rainfall based on modelled MM5 data for the study site (January 2015 to December 2017)

3.4.4 Atmospheric Stability and Mixing Depth

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class.

The Monin-Obukhov length (L_{Mo}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

Diurnal variation in atmospheric stability, as calculated from on-site data, and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 7. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning*. Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Tiwary and Colls, 2010). For ground level releases the highest ground level concentrations occur during stable night-time conditions.

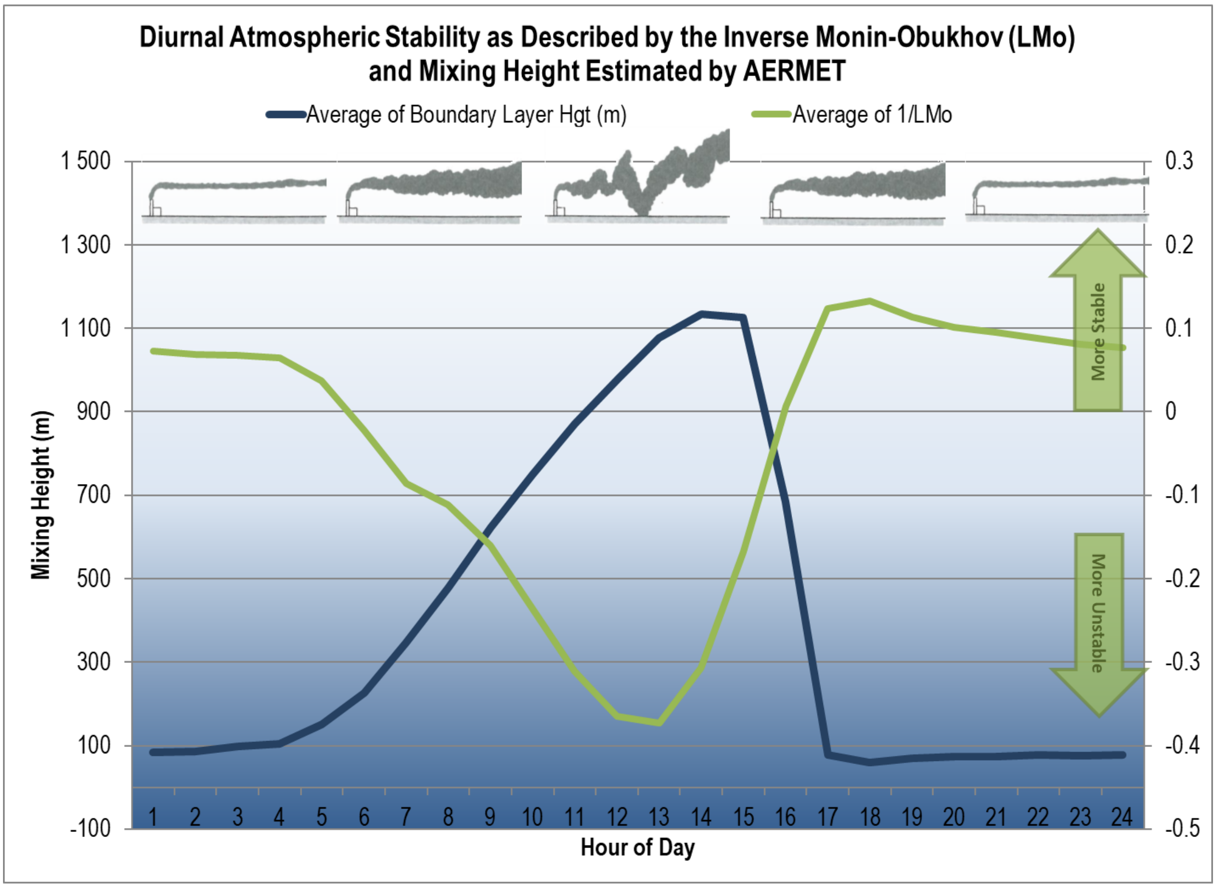


Figure 7: Diurnal atmospheric stability based on modelled MM5 data for the study site (January 2015 to December 2017)

3.5 Existing sources of Air Pollution in the Area

This section includes only the general pollutants of the region. The identification of existing sources of emission in the region and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the proposed operation and its associated emissions. Source types present in the area and the pollutants associated with such source types are noted with the aim of identifying pollutants, which may be of importance in terms of cumulative impact potentials.

- Mining activities;
- Vehicle tailpipe emissions;
- Domestic fuel combustion;
- Biomass burning (veld fires);

- Various miscellaneous fugitive dust sources (agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads).

3.5.1 Mining operations

Mining operations within the study area almost exclusively include mineral sand mining activities. Fugitive emissions sources from mining operations mainly comprise of land clearing operations (i.e. scraping, dozing and excavating), materials handling operations (i.e. tipping, off-loading and loading, conveyor transfer points), vehicle entrainment from haul roads and wind erosion from open areas. These activities mainly result in fugitive dust releases with small amounts of NO_x, CO, SO_2, CH_4, CO_2 and N_2O being released from vehicle exhaust.

3.5.2 Transport operations

Vehicles are included in this category. The main source of concern in the area is vehicle tailpipe emissions. The main national roads include the N1 from Johannesburg in the north to Kroonstad in the south. Various main and secondary roads link the rural and urban areas within the municipality. The study site is located about 4 km from the N1 at its nearest side.

3.5.2.1 Unpaved and paved roads

Emissions from unpaved roads constitute a major source of emissions to the atmosphere in the South African context. When a vehicle travels on an unpaved road the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads vary in relation to the vehicle traffic and the silt content on the roads. Emission from paved roads are significantly less than those originating from unpaved roads, however they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface.

3.5.2.2 Vehicle tailpipe emissions

Emissions resulting from motor vehicles can be grouped into primary and secondary pollutants. While primary pollutants are emitted directly into the atmosphere, secondary pollutants form in the atmosphere as a result of chemical reactions. Significant primary pollutants emitted by internal combustion engines include CO_2, CO, carbon (C), SO_2, oxides of nitrogen (mainly NO), particulates and Pb. Secondary pollutants include NO_2, photochemical oxidants such as ozone, sulphur acid, sulphates, nitric acid, and nitrate aerosols (particulate matter). Vehicle (i.e. model-year, fuel delivery system), fuel (i.e. type, oxygen content), operating (i.e. vehicle speed, load), and environmental parameters (i.e. altitude, humidity) influence vehicle emission rates (Onursal, 1997).

3.5.3 Domestic fuel combustion

Domestic households are known to have the potential to be one the most important sources contributing to poor air quality within residential areas. Individual households are low volume emitters, but their cumulative impact is significant. It is likely that some households within the local communities/settlements utilise coal, paraffin and /or wood for cooking and/or space heating (mainly during winter) purposes. Pollutants arising from the combustion of wood include respirable particulates, CO and SO_2 with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

Coal is relatively inexpensive. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, total and respirable particulates including heavy metals and inorganic ash, CO, PAHs such as benzo(a)pyrene, NO_2 and various toxins. Polyaromatic hydrocarbons are recognised as carcinogens. The main pollutants emitted from the combustion of paraffin are NO_2, particulates carbon monoxide and polycyclic aromatic hydrocarbons.

3.5.4 Biomass burning

Biomass burning includes the burning of grasslands and agricultural lands. Within the project vicinity, crop-residue burning and wild fires (locally known as veld fires) may represent significant sources of combustion-related emissions.

Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held *et al*, 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the proposed mining activity, long-range transported emissions from this source can be expected to impact on the air quality between the months August to October. It is impossible to control this source of atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

3.5.5 Agricultural operations

Agriculture is a land-use within the area surrounding the site. Particulate matter is the main pollutant of concern from agricultural activities as particulate emissions are deriving from windblown dust, burning crop residue, and dust entrainment as a result of vehicles travelling along dirt roads. In addition, pollen grains, mould spores and plant and insect parts from agricultural activities all contribute to the particulate load. Should chemicals be used for crop spraying, they would typically result in odiferous emissions. Crop residue burning is an additional source of particulate emissions and other toxins.

3.5.6 Wind erosion of open areas

Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface. Every time that a surface is disturbed, its erosion potential is restored (US EPA, 2006). Further erodible surfaces may occur as a result of agriculture and/or grazing activities.

3.6 Status Quo Ambient Air Quality

3.6.1 WHO International Indicators (World Bank Database)

3.6.1.1 Carbon Dioxide (CO_2) Emissions

The Carbon Dioxide Information Analysis Center at the Oak Ridge National Laboratory in Tennessee, United States has calculated estimated emissions per country for CO_2. CO_2 emissions are those resulting from the burning of fossil fuels and the manufacture of cement. CO_2 produced during consumption of solid, liquid, and gas fuels and gas flaring are the sources included. South Africa's estimated CO_{2eq} emissions for 2009 is 503 941 kiloton (Kt) and for 2010 460 124 Kt.

3.6.2 Department of Environmental Affairs (DEA)

The proposed mine falls just outside of the Vaal Triangle Airshed Priority Area (VTAPA). The closest air quality monitoring stations to the study site are Zamdela (located 24 km to the southeast) and Sharpeville (located 24.5 km to the northeast), both of which fall within the VTAPA and are operated by the DEA. The ambient data collected for these stations are likely not representative of the ambient air quality at the study site, due to the far proximity of the monitoring stations and different type of emission sources that affect the air quality in the VTAPA.

3.6.3 Site Measurements

PM_{10} and $PM_{2.5}$ concentrations were sampled over a 22-hour period at the sampling point indicated in Figure 2 (27.632888°E, 26.754727°S) to provide a general idea of existing ambient air quality in the study area. Concentrations were sampled using a DustTrakTM DRX Handheld Aerosol Monitor, Model 8534, which can concurrently measure mass and size fraction (TSI, 2016). A summary of the sampled particulate concentrations is provided in Table 8 and illustrated in Figure 8.

Table 8: Summary of particulate concentrations measured at sampling point within the mining rights area

	Concentration (µg/m³)	
	$PM_{2.5}$	PM_{10}
Average Concentration	71.8	74.6
Median Concentration	41	42
Minimum Concentration	12	14

The large difference between the minimum and maximum concentrations (as well as between average and median concentrations) in Table 8 shows that concentrations are highly variable in the study area and are likely mostly influenced by localised sources.

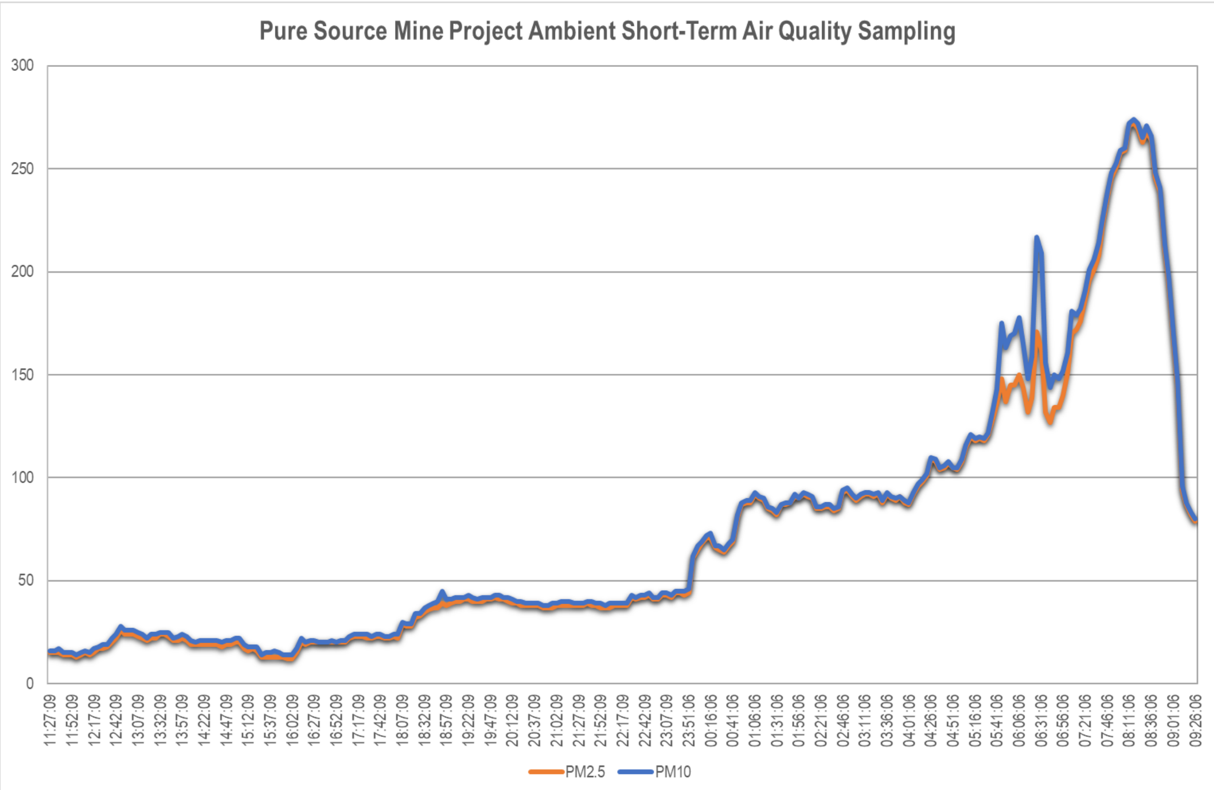


Figure 8: PM_{10} and $PM_{2.5}$ concentrations sampled at 5-minute intervals during a site visit

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