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

Project done for **Shango Solutions**

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Revision Record

Version	Date	Comments
Draft	March 2019	For Client Review
Version 1	March 2019	Added Impact Significance Ratings
Version 2	March 2019	Addressed client comments
Version 3	March 2019	Addressed client comments
Version 4	April 2019	Removed filled contours from isopleth plots
Version 5	April 2019	Description of cumulative impacts in Section 6
Version 6	July 2019	Additional conclusions and recommendations added in Section 7.

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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
DPM	Diesel Particulate Matter
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)
$µg/m^3$	Micrograms per square meter
mg	Milligram(s)
$mg/m^2/day$	Milligrams per square meter per day
m^2	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
SiO_2	Alpha quartz
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 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), as well as alpha quartz (silica) emissions from the material handling and crushing operations. 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 both component of the air quality specialist study for inclusion in the environmental impact assessment report.

The main findings from the baseline assessment are as follows:

The wind field in the study is dominated by winds from the northern sector during the 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 and 10.0% at night.

Existing sources of emissions in the study area include other sand mining operations, vehicle exhaust and entrainment on paved and unpaved roads, household fuel burning, biomass burning (veld fires), wind erosion from open areas and agricultural activities.

Sensitive receptors in the study area include the residential areas of Vaal Oewer and Lindiquesdrift as well as various other residences and small holdings on both sides of the Vaal river. There are very few sensitive receptor locations directly to the south of the proposed mining operations.

The main findings from the impact assessment are as follows:

Emission sources from the proposed Pure Source Mine Project operations include fugitive dust emissions from material handling, crushing and screening, vehicle entrainment and wind erosion from stockpiles and exposed areas, as well as gaseous emission from vehicle exhausts and the dryer. Pollutants of concern expected to be emitted by the Pure Source Mining Project operations include particulates with aerodynamic diameters less than 10µm and 2.5µm (PM_{10} and $PM_{2.5}$ respectively), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), crystalline silica (SiO_2) and diesel particulate matter (DPM)

To assess worst case air quality impacts, three scenarios were included in the dispersion modelling. These three scenarios represent the identified operating years that would likely result in the highest air quality impacts at sensitive receptor locations. The three scenarios are representative of operational years 12, 18 and 29.

Even with best practice mitigation measures applied to dust generating sources, simulated 99th percentile daily PM_{10} concentrations due to the Pure Source Mine Project sources exceed the South African National Ambient Air Quality Standard (SA NAAQS) (more than 4 days exceeding 75 µg/m³ per year) at a variety of sensitive receptor locations, including at the residential area of Vaal Oewer, for all three scenarios. Based on the large impact area, it can be reasonably predicted that these exceedances would also be experienced during other years of the mining operations. Depending on the active area being mined at the time, additional exceedances could occur at other sensitive receptor locations to the north, east and west of the Vaal river.

Simulated annual average PM_{10} and $PM_{2.5}$ concentrations, as well as simulated NO_2 and SO_2 concentrations for all averaging periods, are in compliance with the SA NAAQS at all sensitive receptor locations.

Simulated annual average SiO_2 concentrations could exceed the California Office of Environmental Health Hazard Assessment (OEHHA) Reference Exposure Level (REL) in the immediate vicinity of the mining operations but are well below the REL at all sensitive receptor locations.

Worst-case diesel particulate concentrations (if all vehicles are operational simultaneously), could exceed the United States Environmental Protection Agency Integrated Risk Information System (US EPA IRIS) guideline value of 5 µg/m³ up to 400 m from the mining operations, including at some sensitive receptor locations when mining operations are closest to these locations. It is however highly unlikely that all vehicles will be simultaneously operational for 12 hours per day, and this simulated impact is highly conservative.

Simulated highest monthly dust fallout rates exceed the SA National Dust Control Regulations (NDCR) non-residential limit up to 300m from of the mining operations and haul roads and the residential limit up to 600 m from the mining operations and haul road. This means that when mining operations are active at the northern and south western aggregate resources respectively, the NDCR is likely to be exceeded at Vaal Oewer and other sensitive receptors to the north of the Vaal river.

Based on the findings above the following recommendations are made if mining operations proceed:

Emission rates from the dryer stack must comply with the Subcategory 5.2 (Drying) "New Plant" Minimum Emission Standards. The plant must be designed, or additional abatement equipment implemented to make sure emission from the dryer stack are in compliance with these standards.

Based on the dispersion modelling results, it is highly unlikely that 99th percentile daily PM_{10} concentrations and highest monthly dust fallout rates would be in compliance with the SA NAAQS at Vaal Oewer and other sensitive receptor locations to the north of Vaal river, due to the relatively small distance between these receptors and the northern and south western aggregate resources. Based on simulated dust fallout rates, it is recommended that no mining activities, including crushing and screening, be undertaken within 400 m to the south, east and west of any sensitive receptor location and within 800m to the north of any sensitive receptor locations.

It is recommended that aggregate crushing not be conducted in the gravel pits but rather located closer to the plant and further from any sensitive receptor locations.

It is recommended that any disturbed areas be immediately rehabilitated to avoid wind erosion emission during periods of high wind speeds.

Best practice mitigation measures (wind breaks, wet suppression etc.) must be implemented. Air quality impacts at nearby sensitive receptor locations would be very high if mining operations proceed without adequate mitigation measures in place.

A complaints register should be kept on-site as well as at secure locations in Vaal Oewer and Lindiquesdrift once operations commence. Staff and the neighbouring communities should be encouraged to report all air quality related problems. Frequent community liaison meetings should be held with the neighbouring communities to address air quality related concerns;

Wet suppression techniques must be used to control dust emissions, especially in areas where dry material is handled or stockpiled.

Exposed soils and other erodible materials should be re-vegetated or covered immediately;

New areas should be cleared and opened-up only when absolutely necessary;

Surfaces should be re-vegetated or otherwise rendered non-dust forming when inactive;

Storage for dusty materials should be enclosed or operated with efficient dust suppressing measures;

Loading, transfer, and discharge of materials should take place with a minimum height of fall, and be shielded against the wind, and the use of dust suppression spray systems should be considered;

Vehicles should be fitted with catalytic converters and low sulfur fuel should be used to minimise NO_2 and SO_2 impacts.

Vehicle idle times should be kept to a minimum to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.

Strict speed limits should be imposed to reduce entrained emissions and fuel consumption rates.

The vehicle fleet should be regularly serviced and maintained to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.

Older vehicles in the fleet should be replaced with newer, more fuel-efficient alternatives where feasible.

PM_{10} and dust fallout monitoring is recommended for the duration of the mining and rehabilitation phases. Dust fallout monitoring should be conducted at all recommended locations while PM_{10} monitoring can be moved to sample concentrations at the closest sensitive receptor locations. Monitoring of both dust fallout rates and PM_{10} concentrations should be started before the mining activities commence in order to establish baseline levels.

If PM_{10} concentrations are found to be in exceedance of the NAAQS or dust fallout rates found to be in exceedance of the NDCR residential limit at the closest sensitive receptor locations additional dust suppression measures must be investigated and implemented timeously until recorded concentration and dust fallout rates are in compliance with the NAAQS and NDCR respectively. If the mitigation measures employed are considered best practise, additional offset measures should be considered. Such offset measures include upgrading of public road surfaces, electrification of houses for cooking and heating or supply of cleaner burning fuel for cooking and heating purposes. Offsets should be in line with the Air Quality Offsets Guidelines.

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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. 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 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.

The main objective of the air quality specialist study was 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 were quantified and dispersion modelling simulations undertaken using the US EPA AERMOD dispersion model. Three scenarios were identified to assess the worst-case air quality impacts when the mining operations are closest to sensitive receptor locations. These three scenarios were for mining operations during years 12, 18 and 29. Isopleth plots were generated for the three scenarios and simulated concentrations compared to standards and guidelines as described in Section 2. Based on the findings of the impact assessment management and mitigation measures are recommended, and suitable monitoring locations identified and recommended.

1.2 Study Scope

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

1. A **review** of available detailed project information.
2. Desktop study of the **receiving (baseline) air quality environment**, incl.:
    a) The identification of air quality sensitive receptors from available maps.
    b) A study of atmospheric dispersion potential by referring to available weather records or simulated hourly sequential meteorological data for a period of at least 3 years (required for dispersion modelling), land use and topography data.

   c) A review of emission limits, ambient air quality criteria, inhalation reference concentrations, cancer risk factors and dust control regulations.
   d) Available ambient air quality data.
3. The **quantification and assessment of air quality impacts**, including:
   a) The establishment of an **atmospheric emissions inventory** for proposed operations. Pollutants quantified will include particulate matter (TSP, PM_{10} and $PM_{2.5}$), gaseous pollutants i.e. carbon monoxide (CO), oxides of nitrogen (NO_x) and sulfur dioxide (SO_2) as well as selected metals. Use will be made of design emission standards, emissions factors published by the United States Environmental Protection Agency (US EPA) and Australian National Pollutant Inventory (NPI).
   b) **Atmospheric dispersion modelling** to determine ambient air pollutant concentrations. The US EPA AERMOD model will be used.
   c) The **screening** of simulated ambient pollutant concentrations against National Ambient Air Quality Standards (NAAQSs), National Dust Control Regulations (NDCRs) and other applicable air quality criteria.
4. The compilation of a comprehensive **Air Quality Impact 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. Section 3 includes more detail on the location of sand and gravel deposits. 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 trucked directly 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 m³ sand per year (from year 3 to year 11) and 740 000 m³ sand per year (from year 12 onwards), 130 000 m³ gravel per year (from year 2 to year 10) and 416 502 m³ 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 dispersion modelling.
- 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.
- Information required to calculate emissions from fugitive dust sources for mining operations (throughputs, operating hours, equipment type) was provided by the client. It was assumed that this information was correct.
- Due to the absence of locally-generated emission factors, use was made of the comprehensive set of emission factors published by the US Environmental Protection Agency (US-EPA) in its AP-42 document Compilation of Air Pollution Emission Factors, as well as the Australian National Pollutant Inventory (NPI) emission estimation documents. These emission factors are based on US and Australian conditions and, due to non-availability of emission factors based on South African conditions, these are regarded to be the best estimates.
- No site-specific data was available for unpaved roads and the silt content was assumed to be 4.8%, the average for sand and gravel processing as published by the United States Environmental Protection Agency (US EPA).
- The mitigated scenario assumed 50% control efficiency on material handling operations and the crusher, achievable by reducing drop height, use of wind breaks and keeping material being handled moist.
- The mitigated scenario assumed 70% control efficiency of vehicle entrainment emissions from haul roads, achievable with chemical dust suppressants and regular water sprays.
- Dust fallout sampling as reported in Section 3.5.3 was not conducted by Airshed. It was assumed that the correct sampling and laboratory procedures was followed.
- There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

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
Sulfur dioxide	SO_2	New	1000
Oxides of nitrogen	NO_x 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. A draft amendment to the NDCR was gazetted on 25 May 2018 (No. 41650). Changes to the NDCR in the draft amendment include that the test method and guideline for locating the sampling points shall be ASTM D1739, the latest version (rather than the 1970 version). The amendment also makes provision for exemption of exceedances occurring as a result of natural, non-anthropogenic sources, extreme weather events or geological event.

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 Inhalation Health Criteria and Unit Risk Factors for Non-criteria Pollutants

The potential for health impacts associated with non-criteria pollutants emitted from mobile and stationary diesel combustion sources and sources generating crystalline silica are assessed according to guidelines published by the following institutions:

1. Inhalation reference concentrations (RfCs) and cancer URFs published by the US EPA IRIS.
2. Reference Exposure Levels (RELs) and Cancer Potency Values (CPV) published by the California Environmental Protection Agency (CAL EPA)
3. The RfC's by the Texas Commission on Environmental Quality (TCEQ)
4. Reference exposure levels (RELs) published by the California Office of Environmental Health Hazard Assessment (OEHHA).

Chronic inhalation criteria and URFs/CPVs for pollutants considered in the study are summarised in Table 7. Increased lifetime cancer risk is conservatively calculated by applying the unit risk factors to predicted long term (annual average) pollutant concentrations.

Several polymorphs exist for crystalline 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).

Table 7: Chronic and acute inhalation screening criteria and cancer URFs for pollutants relevant to the Project

Pollutant	Chronic Screening Criteria ($\mu g/m^3$)	Inhalation URF ($(\mu g/m^3)^{-1}$)
Diesel Exhaust as DPM	5 (US EPA IRIS)	0.0003 (CAL EPA)
Respirable crystalline silica	3 CAL OEHHA	-

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 8). According to Table 8 the Pure Source Mine Project would be classified under Group C ("Mines").

Table 8: 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 under notice made in terms of section 23 of the Act.	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.
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 8 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.

2.6 Regulations Regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Regulations regarding Air Dispersion Modelling were promulgated in Government Gazette No. 37804 vol. 589; 11 July 2014, (DEA, 2014) and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

(a) in the development of an air quality management plan, as contemplated in Chapter 3 of the Air Quality Act (AQA);
(b) in the development of a priority area air quality management plan, as contemplated in section 19 of the AQA;
(c) in the development of an atmospheric impact report, as contemplated in section 30 of the AQA; and,
(d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the AQA.

The Regulations have been applied to the development of this report. The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives direction to the choice of the dispersion model most suited for the purpose. Chapter 2 of the Regulations present the typical levels of assessments, technical summaries of the prescribed models (SCREEN3, AERSCREEN, AERMOD, SCIPUFF, and

CALPUFF) and good practice steps to be taken for modelling applications. The proposed operation falls under a Level 2 assessment – described as follows;

- The distribution of pollutants concentrations and depositions are required in time and space.
- Pollutant dispersion can be reasonably treated by a straight-line, steady-state, Gaussian plume model with first order chemical transformation. The model specifically to be used in the air quality impact assessment of the proposed operation is AERMOD.
- Emissions are from sources where the greatest impacts are in the order of a few kilometres (less than 50 km) downwind.

Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Chapter 3 of the Regulations prescribe the source data input to be used in the models. Dispersion modelling can typically be used in the:

- Apportionment of individual sources for installations with multiple sources. In this way, the individual contribution of each source to the maximum ambient predicted concentration can be determined. This may be extended to the study of cumulative impact assessments where modelling can be used to model numerous installations and to investigate the impact of individual installations and sources on the maximum ambient pollutant concentrations.
- Analysis of ground level concentration changes as a result of different release conditions (e.g. by changing stack heights, diameters and operating conditions such as exit gas velocity and temperatures).
- Assessment of variable emissions as a result of process variations, start-up, shut-down or abnormal operations.
- Specification and planning of ambient air monitoring programs which, in addition to the location of sensitive receptors, are often based on the prediction of air quality hotspots.

The above options can be used to determine the most cost-effective strategy for compliance with the NAAQS. Dispersion models are particularly useful under circumstances where the maximum ambient concentration approaches the ambient air quality limit value and provide a means for establishing the preferred combination of mitigation measures that may be required including:

- Stack height increases;
- Reduction in pollutant emissions through the use of air pollution control systems (APCS) or process variations;
- Switching from continuous to non-continuous process operations or from full to partial load.

Chapter 4 of the Regulations prescribe meteorological data input from onsite observations to simulated meteorological data. The chapter also gives information on how missing data and calm conditions are to be treated in modelling applications. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the diluting effect of the atmosphere. Therefore, it is important that meteorology is carefully considered when modelling.

Topography is also an important geophysical parameter. The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result. Thus, the accurate determination of terrain elevations in air dispersion models is very important.

The modelling domain would normally be decided on the expected zone of influence; the latter extent being defined by the predicted ground level concentrations from initial model runs. The modelling domain must include all areas where the ground level concentration is significant when compared to the air quality limit value (or other guideline).

Air dispersion models require a receptor grid at which ground-level concentrations can be calculated. The receptor grid size should include the entire modelling domain to ensure that the maximum ground-level concentration is captured and the grid resolution (distance between grid points) sufficiently small to ensure that areas of maximum impact adequately covered. No receptors however should be located within the property line as health and safety legislation (rather than ambient air quality standards) is applicable within the site.

Chapter 5 provides general guidance on geophysical data, model domain and coordinates system required in dispersion modelling, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air concentration data. The chapter also provides guidance on the treatment of NO_2 formation from NO_x emissions, chemical transformation of sulfur dioxide into sulfates and deposition processes.

Chapter 7 of the Regulations outline how the plan of study and modelling assessment reports are to be presented to authorities.

2.7 Vaal Triangle Priority Area

The Pure Source Mining project falls just outside the western boundary of the Vaal Triangle Airshed Priority Area (VTAPA) (Figure 1) with the Vaal river to the north and east of the Pure Source Mining operations forming the boundary of the VTAPA. The identified sensitive receptors, including the town of Vaal Oewer however fall within the VTAPA. The Vaal Triangle Airshed was declared the first priority area by the minister on 21 April 2006 (Figure 2-1). New developments in the VTAPA which are associated with atmospheric emissions and hence the potential for contributing to air pollutant concentrations are being subject to intense scrutiny by national air pollution control officers. Emphasis is being placed on ensuring that best practice control measures are being proposed for implementation and that the development will not substantially add to the existing air pollution burden in the region. Objectives to minimise both gaseous and particulate emissions from mining activities in the VTAPA, as stated in the VTAPA Air Quality Management Plan (Government Gazette No 32263 Published on 28 May 2009) include:

- Good materials handling practices,
- Controlled crushing and screening, and
- Best practice techniques to minimise emissions from waste dumps, stockpiles and dust entrainment along haul roads.

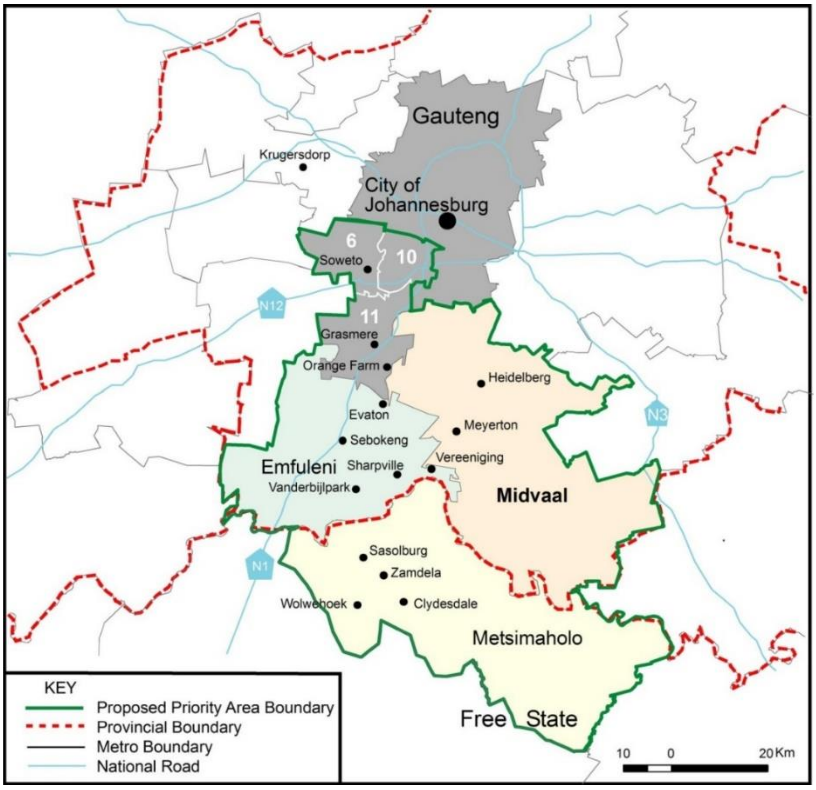


Figure 1: Boundaries of the Vaal Triangle Airshed Priority Area, as declared on 21 April 2006

2.8 Air Quality Offset Guidelines

The Department of Environmental Affairs published the Air Quality Offsets Guidelines on 16 March 2016 (Government Gazette No 39833). Offsets provide one of the measures to counterbalance the negative environmental impacts that are unavoidable within reasonable boundaries. Offsets provide the opportunity to remedy the impacts of pollutions where it cannot be completely avoided or minimised further. Offsets focus primarily on air pollutants whose ambient air quality standards are being exceeded or likely to be exceeded in a region. Air quality offsets are recommended in the following circumstances:

- During an application for postponement of compliance timeframes,
- During an application for the variation of a licence, and
- During an application of an atmospheric emissions licence in areas where the NAAQS are being or likely to be exceeded.

Affected communities need to be consulted in relation to proposed offsets prior to it being adopted.

2.9 Greenhouse Gas Emissions

The Department of Environmental Affairs has published the Declaration of Greenhouse Gases as Priority Air Pollutants and the National Pollution Prevention Plans Regulations on 21 July 2017 (Government Gazette No 40996), as well as the National Greenhouse Gas Emission Reporting Regulations on 3 April 2017 (Government Gazette No 40762).

As part of these regulations, certain industries are required to submit Pollution Prevention Plans to the Minister, but gold mining is not included in the list of industries.

Furthermore, as part of the National Greenhouse Gas Emission Reporting Regulations, any person in control on conducting an activity with a capacity equal or above the threshold indicated as per Annexure 1 of these Regulations needs to submit a Greenhouse Gas Emissions Inventory to the competent authority annually.

Although Mining and Quarrying is listed in Annexure A under category 1A2i, a threshold of 10MW(th) is applicable to this category. Based on the total fuel consumption of all stationary and mobile equipment at the Pure Source Mining operations, the combined thermal power of all equipment (mobile and stationary) at the Pure Source Mining operations will fall below the 10MW threshold. Therefore, Pure Source Mining need not report on greenhouse gas emissions as stipulated in the National Greenhouse Gas Emission Reporting Regulations.

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 2). The properties are located along a stretch of the Vaal river and covers an area of approximately 875 hectares.

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 5).

3.2 Topography

An analysis of topographical data indicates slopes of more than 1:10 to the northwest and south of the project area (Figure 5). Dispersion modelling guidance recommends the inclusion of topographical data in dispersion simulations in areas where the slope exceeds 1:10 (US EPA, 2004).

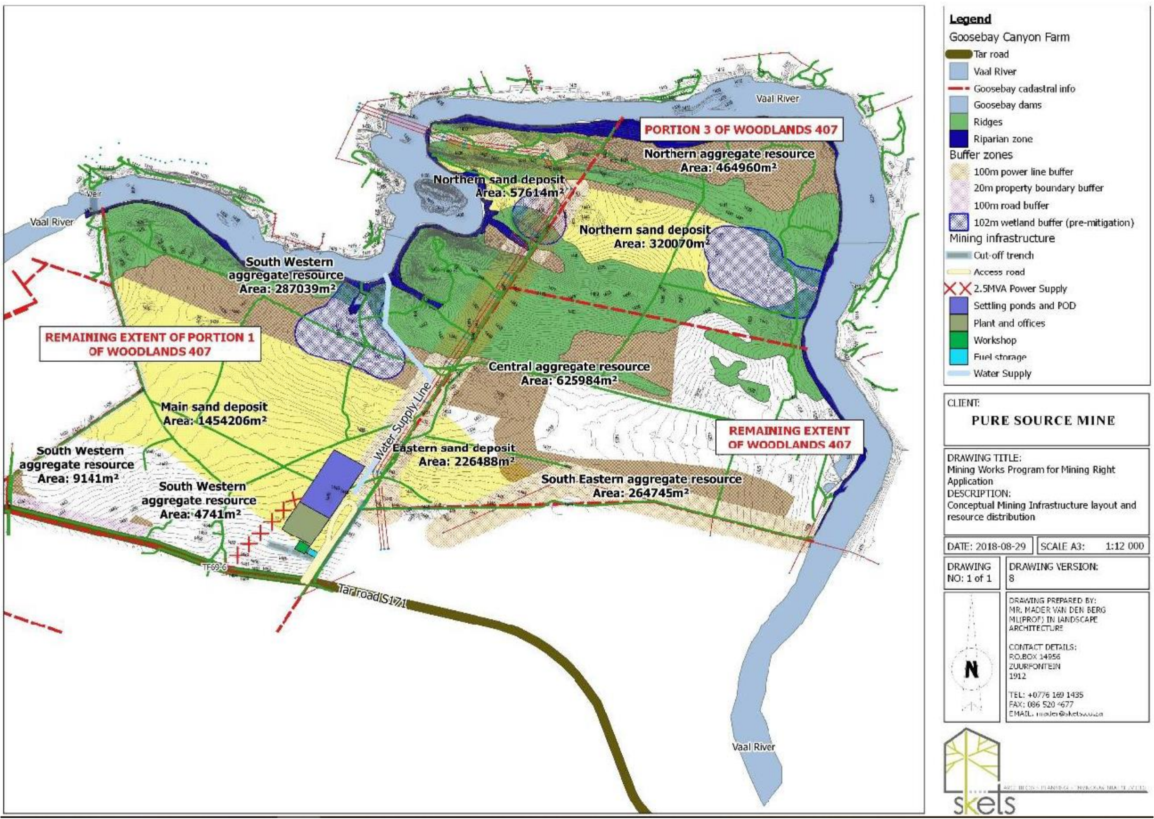


Figure 2: Local setting and mine layout

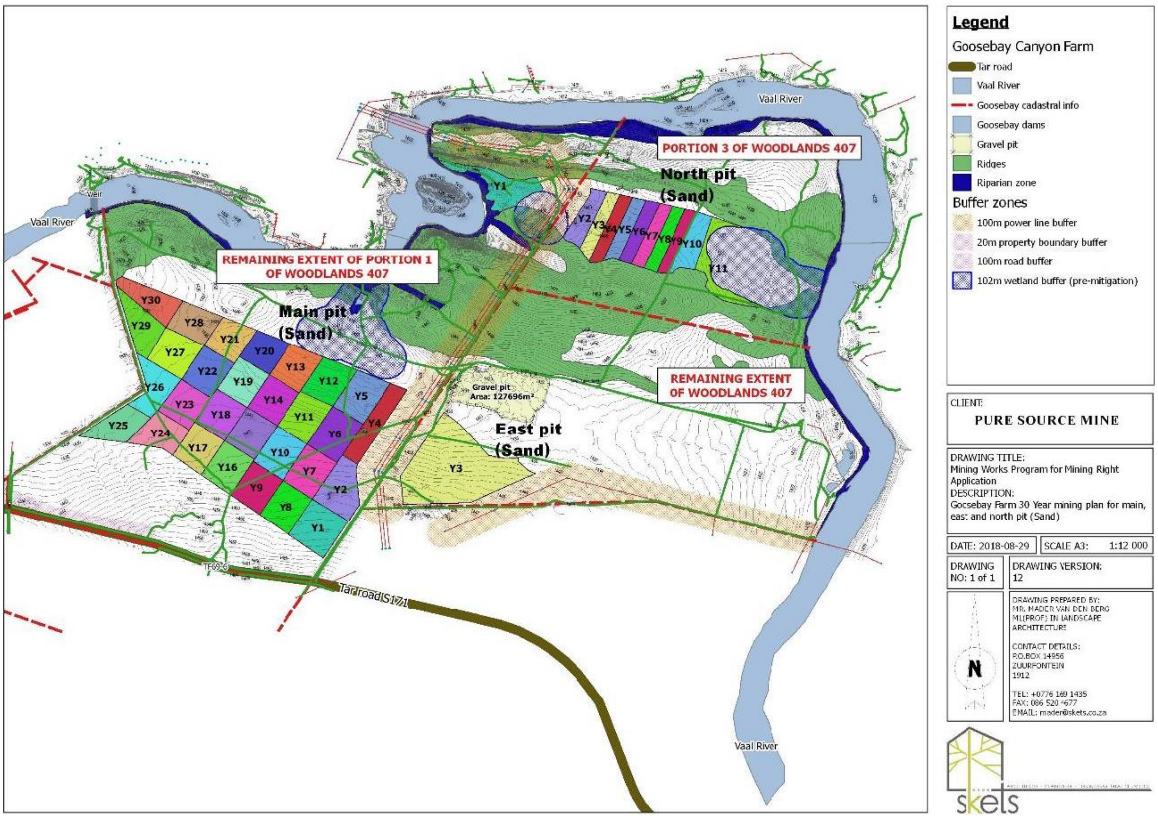


Figure 3: Sand mining schedule

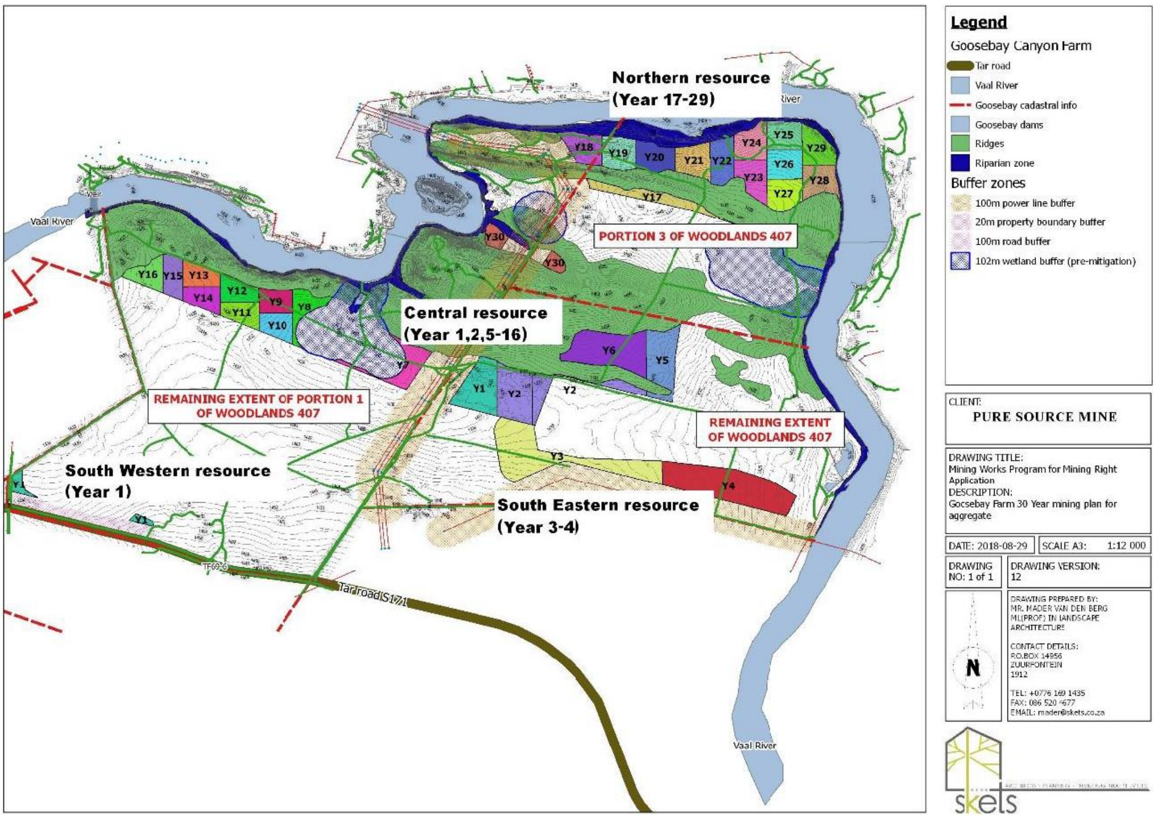


Figure 4: Gravel mining schedule

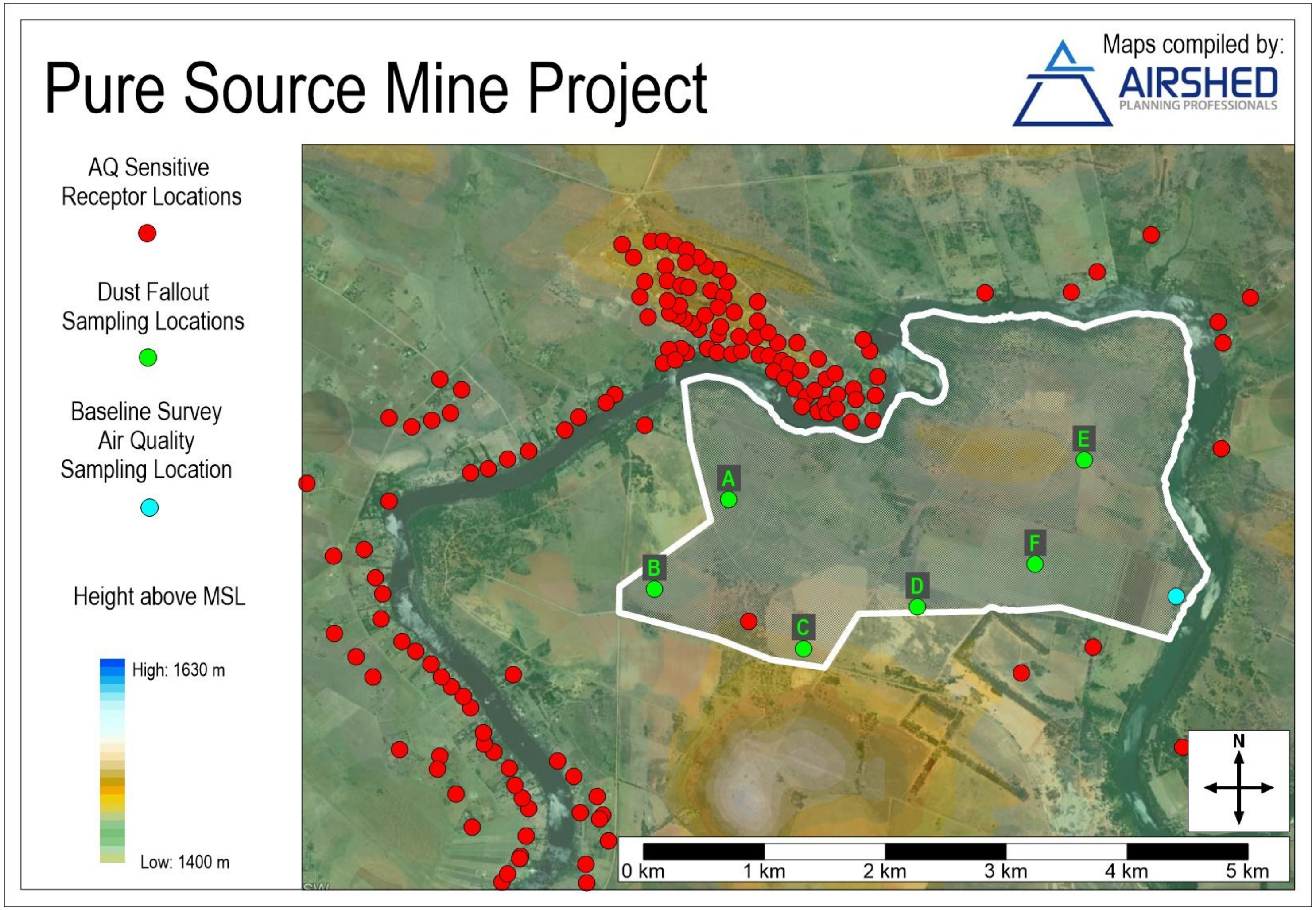


Figure 5: Layout with sensitive receptors and dust fallout sampling locations

3.3 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.

3.3.1 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 6 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 6 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 6 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.

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.

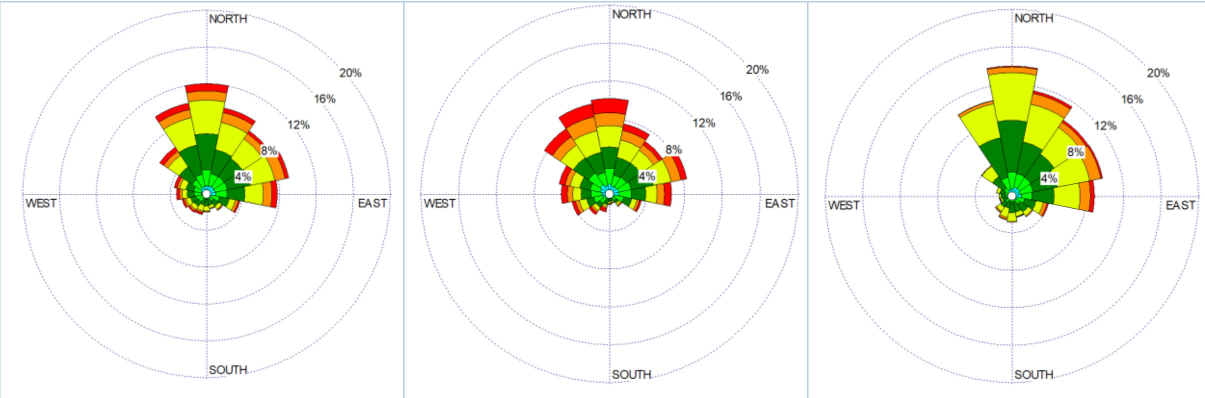
		
Period	**Day-time**	**Night-time**
Calms: 12.87%	Calms: 15.69%	Calms: 10.06%

Figure 6: Period, day-time and night-time wind roses based on modelled MM5 data for the study site (January 2015 to December 2017)

A comparison to historic wind fields recorded (Figure 7 - from www.windfinder.com, accessed on 14 March 2019) at Vereeniging (35km East), Potchefstroom (50km West), Klerksdorp (100km WSW) and Kroonstad (100km SSW) is made to the MM5 data set. In general, the wind field from the MM5 data compares well with historic monitored data with the main wind direction from the north, north-western and north-eastern sectors. Historic monitoring data shows a higher contribution from the south west than is seen in the MM5 data set. It is possible that simulated impacts (as shown in Section 5.2) could be underestimated to the north of the operations.

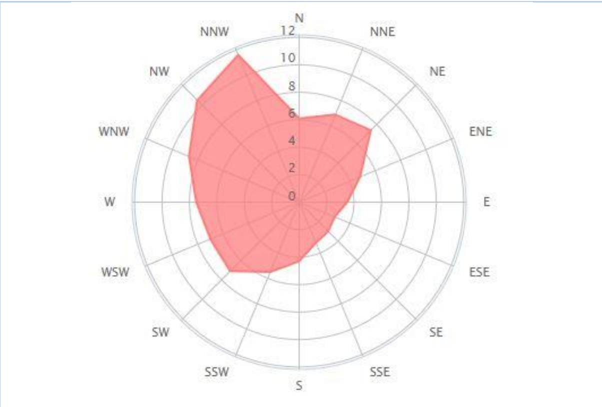
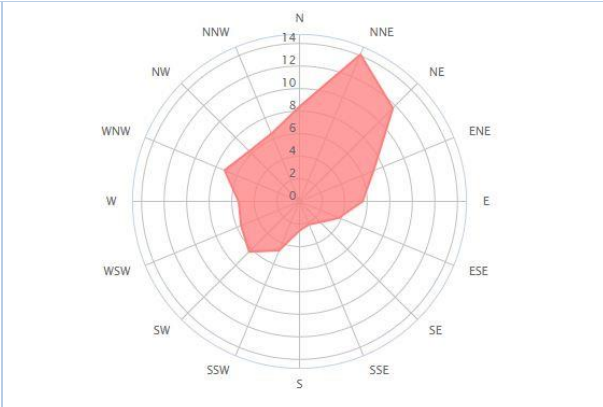
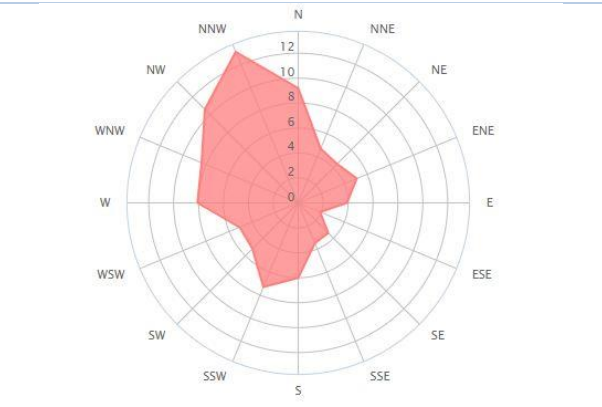
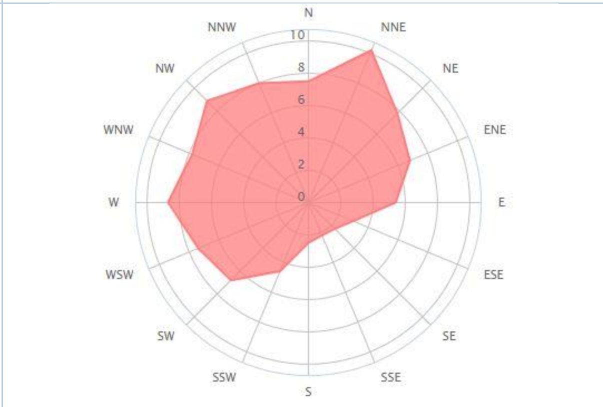
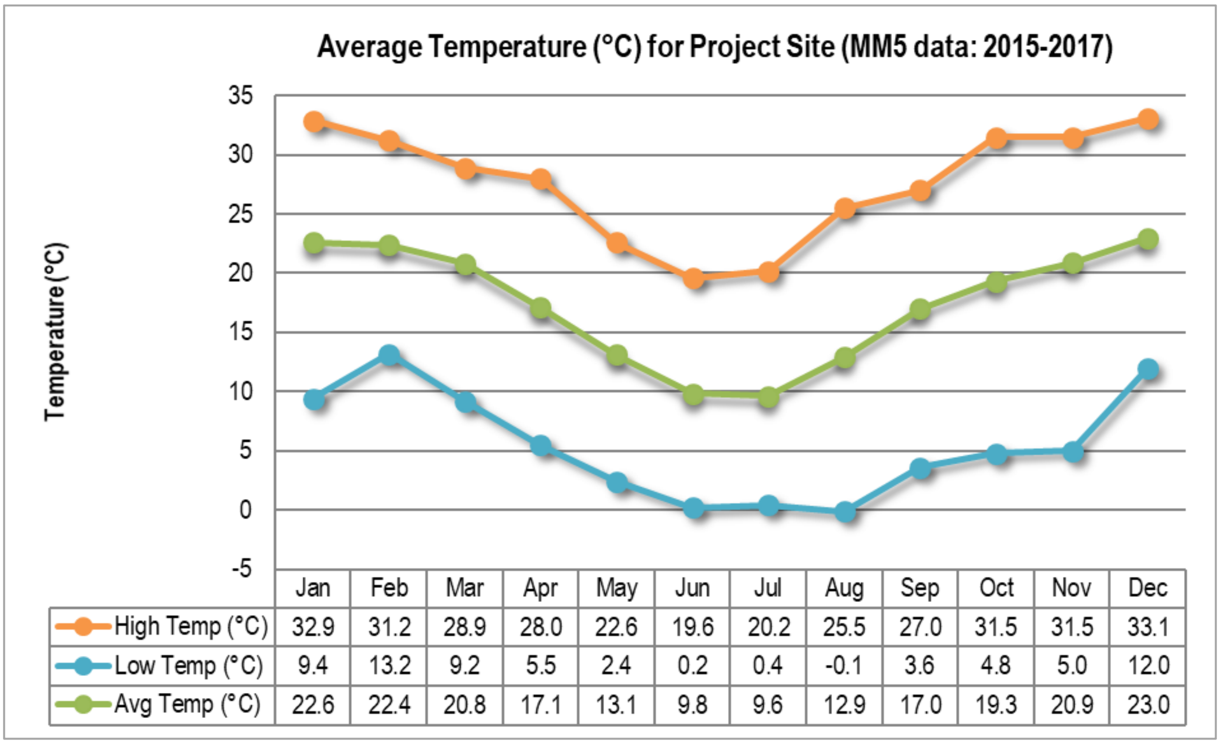
	
Vereeninging	**Potchefstroom**
	
Klerksdorp	**Kroonstad**

Figure 7: Long term historic wind-roses at the nearest monitoring locations.

3.3.2 *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 8). 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 9).



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

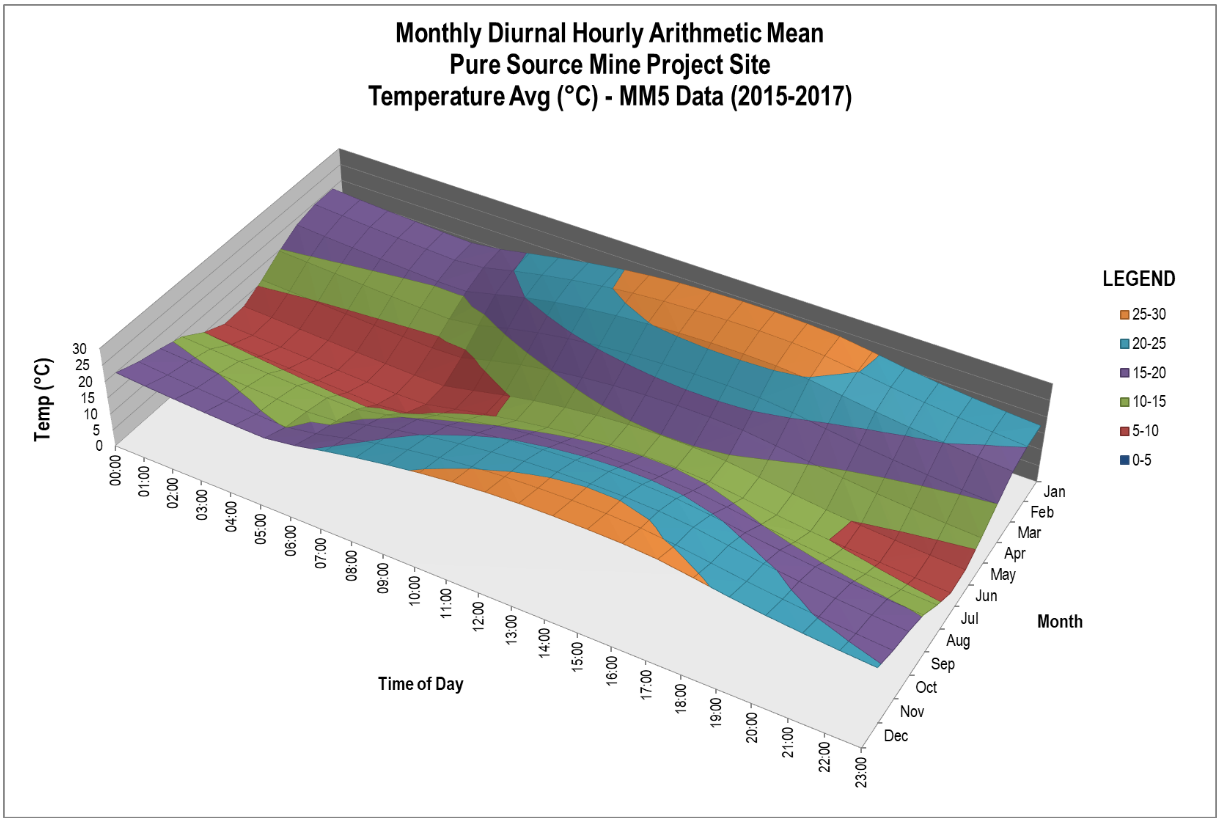


Figure 9: Diurnal temperature trends based on modelled MM5 data for the study site (January 2015 to December 2017)

3.3.3 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 10. The average annual rainfall for the study area is 862 mm, based on MM5 data for the period 2015-2017.

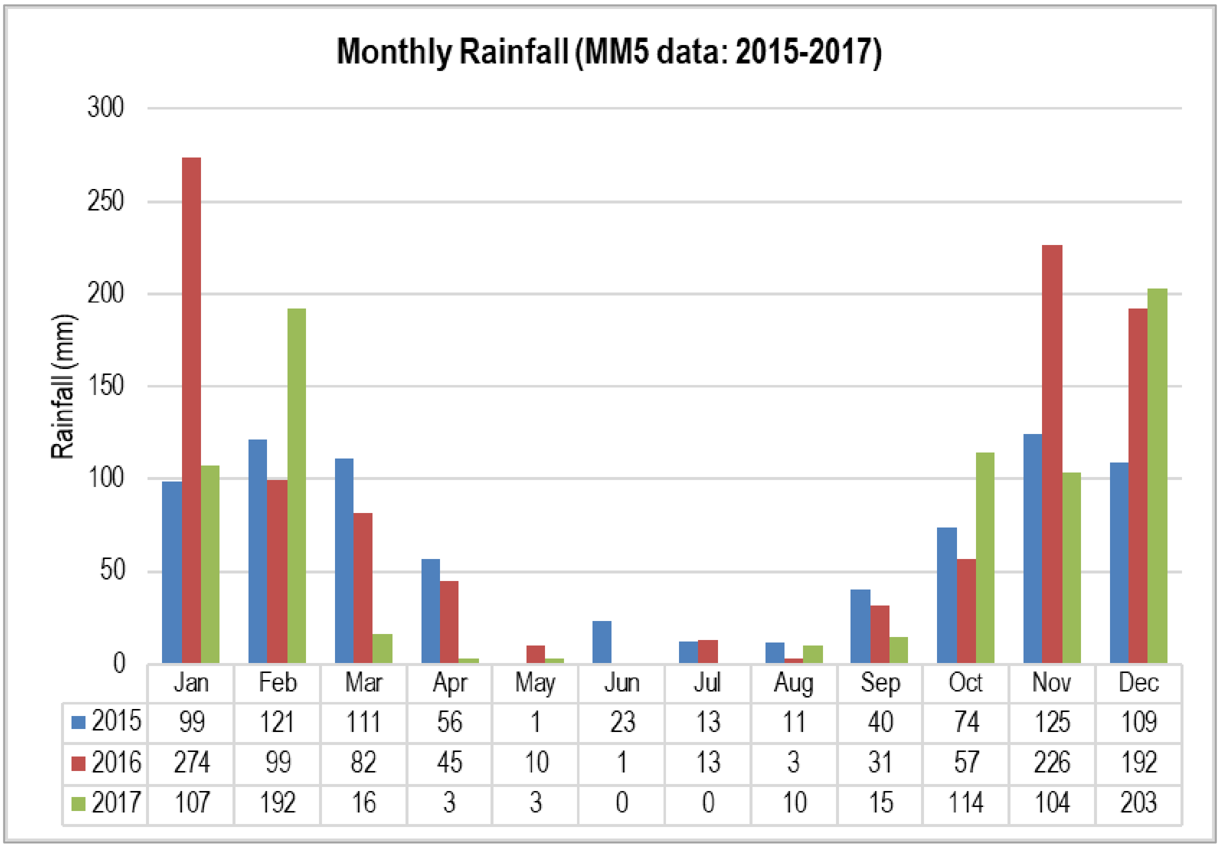


Figure 10: Total monthly rainfall based on modelled MM5 data for the study site (January 2015 to December 2017)

3.3.4 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 11. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources (such as haul roads) 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 such as mining operations the highest ground level concentrations occur during stable night-time conditions, while unstable daytime atmospheric conditions result in better dispersion of ground level emissions and consequently lower ground level concentrations compared to night time conditions.

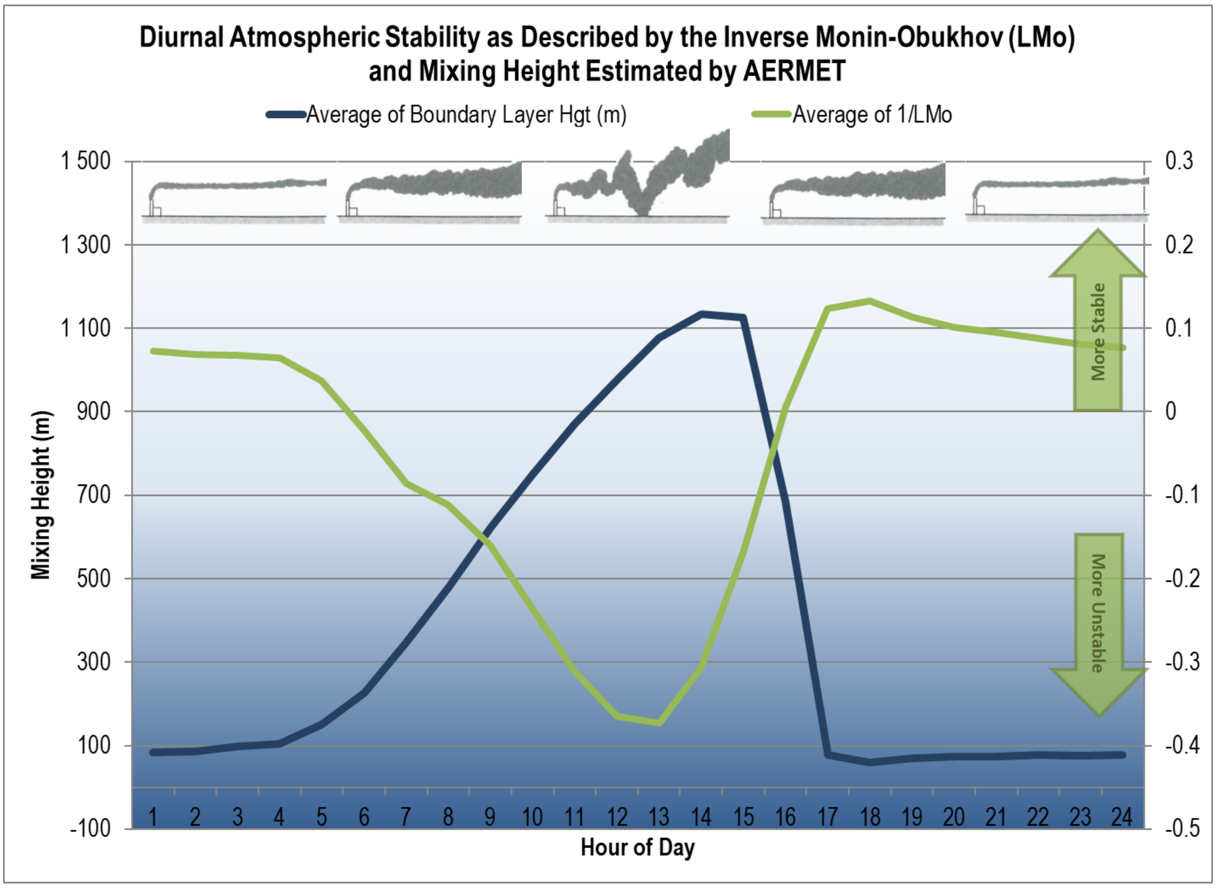


Figure 11: Diurnal atmospheric stability based on modelled MM5 data for the study site (January 2015 to December 2017)

3.4 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).

3.4.1 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.

3.4.2 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.

3.4.2.1 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.

3.4.2.2 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, sulfuric 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).

3.4.3 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.

3.4.4 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.

3.4.5 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.

3.4.6 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.

3.5 Status Quo Ambient Air Quality

3.5.1 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.

3.5.2 Short term PM_{10} and $PM_{2.5}$ monitoring

PM_{10} and $PM_{2.5}$ concentrations were sampled over a 22-hour period on 28 February and 1 March 2018 at the sampling point indicated in Figure 5 (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 9 and illustrated in Figure 12. The large difference between the minimum and maximum concentrations (as well as between average and median concentrations) (Table 9) shows that concentrations are highly variable in the study area and are likely mostly influenced by localised sources. Wind speed and direction samples taken during the sampling period indicate that the wind speed during the sampling period was very low (<1 m/s) with the wind generally coming from the east. The peak in particulate concentrations on the morning of 1 March 2018 were likely due to a localised source, such as wind erosion from an open area or vehicle entrainment on a nearby unpaved road.

Table 9: Summary of one day 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

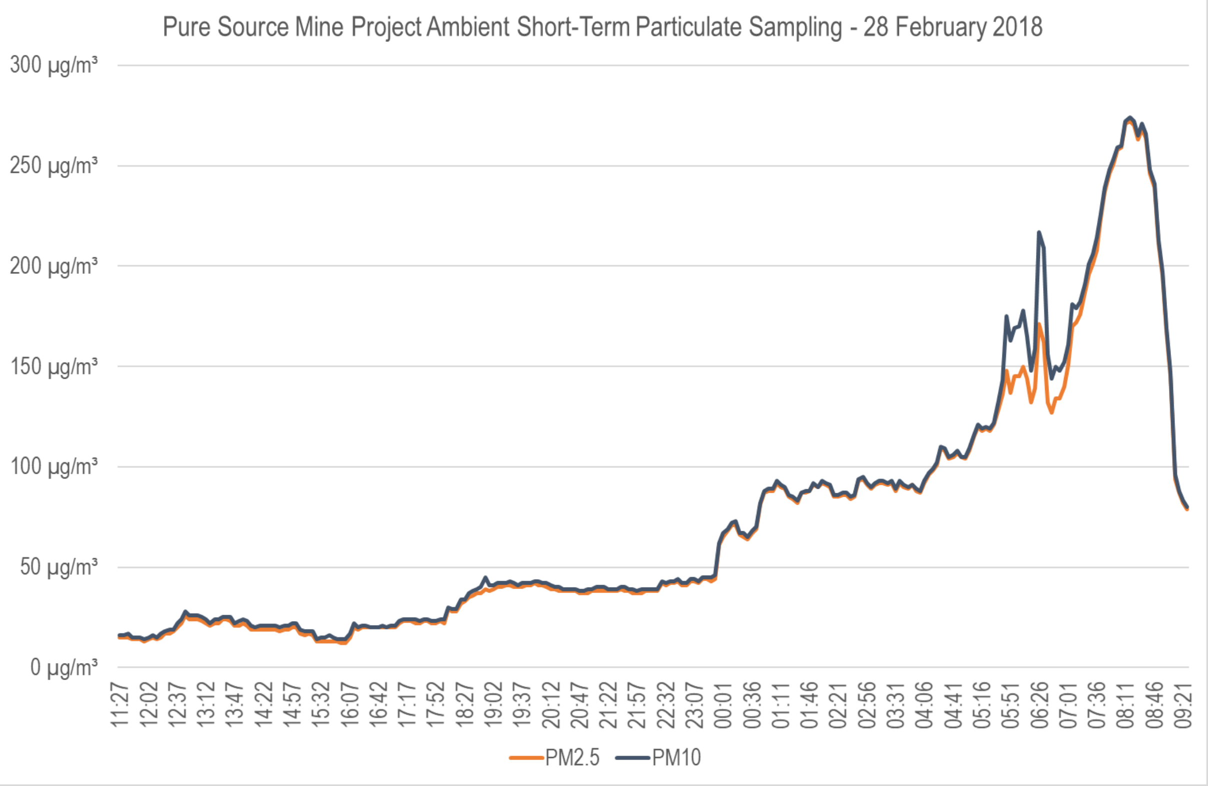


Figure 12: PM_{10} and $PM_{2.5}$ concentrations sampled at 5-minute intervals during a site visit on 28 February 2018.

3.5.3 Sampled Dust Fallout

A dust fallout sampling network is in operation in the study area, with sampling points as shown in Figure 5. Dust fallout was sampled at four locations surrounding the historic sand mining area (named A to D in anticlockwise order from sampling location to the north of the operations). In September 2017 the dust fallout sampling network was expanded to include two additional background sampling locations (E & F) to the east of the historic sand mining operations.

Dust fallout sampling results recorded during 2017 when mining operations were active in the study area are shown in Figure 13. Sampled dust fallout rates were below the SA NDCR non-residential limit at all locations during all months. During the dry and windy spring months from August to October, a total of five exceedances of the NDCR residential limit of 600 mg/m²/day were recorded at three of the locations surrounding the mining operations, with two consecutive monthly exceedances recorded at the A and D sampling locations.

While dust fallout rates recorded at the four locations surrounding the mining operations were in compliance with the NDCR non-residential limit, it is clear that dust fallout rates at these four locations are significantly higher than those recorded at the two "background" sampling locations (PA2 and PA3).

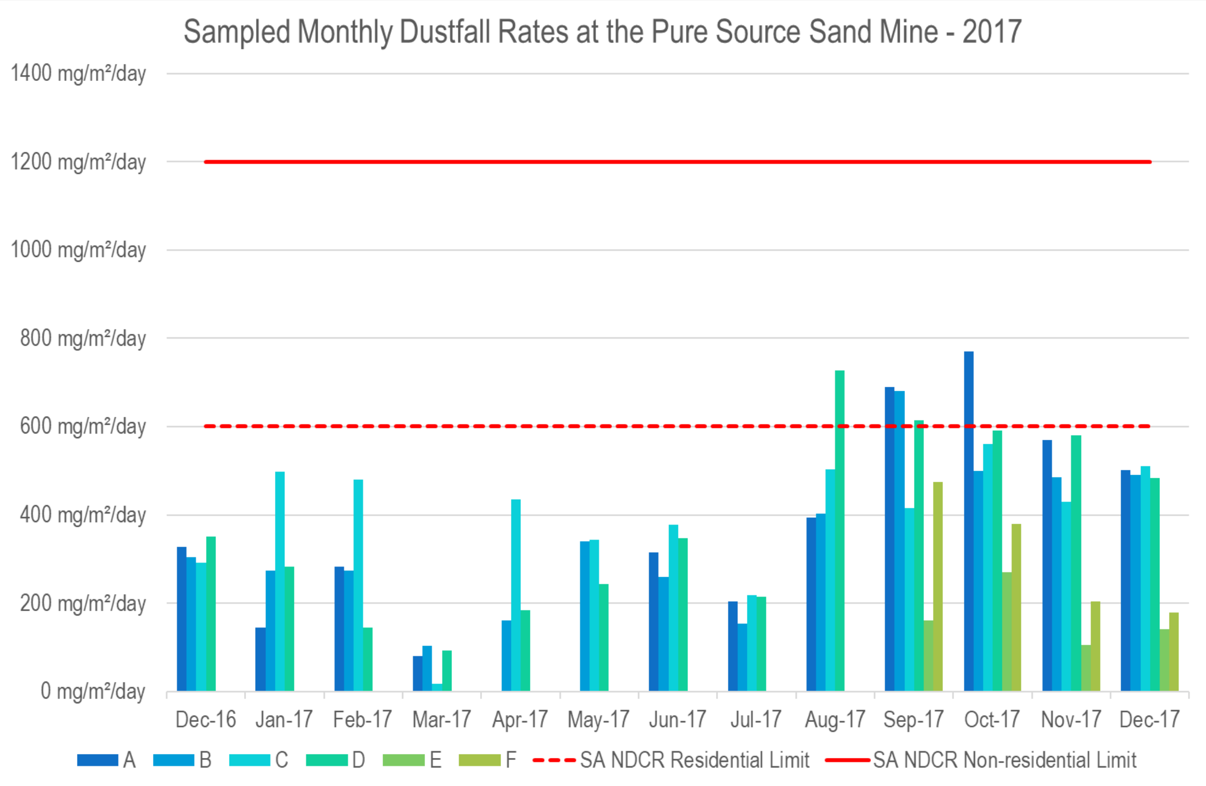


Figure 13: Dust fallout sampling results – 2017.

4 EMISSIONS INVENTORY

Emission sources due to the Pure Source Mine Project operations include:

- Fugitive dust emissions from loading and unloading of sand and gravel in the open pits.
- Fugitive dust emissions from crushing of gravel in the gravel pits.
- Fugitive dust emissions from dozers and graders.
- Fugitive dust emissions from unloading of sand at the processing plant.
- Wind erosion emissions from raw material, product and topsoil stockpiles, exposed areas and unrehabilitated areas.
- Material handling emissions from loading and offloading of material at the plant.
- Screening of material in the pits or at the plant.
- Point source emissions from the dryer.
- Vehicle entrained emissions from the haul roads used to transport sand and gravel to the plant and off-site.
- Vehicle exhaust emissions from the on-site vehicle fleet.

Emissions from the Pure Source Mine Project were calculated using emissions factors published by the US EPA AP42 Section 13.2.4 (Aggregate Handling and Storage Piles) and Section 13.2.2 (Unpaved Roads), and the Australian NPi Emission Estimation Technique Manuals for Combustion Engines (Version 3.0) and Mining (Version 3.1). Mining at the Pure Source Mine Project will take place from 6:00 to 18:00 with a 5.5 day work week. Diamond sorting alone is expected to be 24 hours for a 6-day week. Based on results of previous occupational health sampling conducted in 2017 the SiO_2 content of dust emissions was assumed to be 2.36%. A summary of the emission estimation techniques used is given in Table 12.

Because of the mining schedule, emissions are expected to be variable from year to year, depending on the area being mined and the mining rate at the time. Based on the mining rates as well as the mining areas, three years were chosen from the 30-year schedule for emission estimation and impact quantification. These three years are expected to represent the years when impacts are likely to be at a maximum at the different sensitive receptors based on the locations of the pits and the mining rates during these years.

The three years with the expected maximum impacts at sensitive receptor locations are years 12, 18 and 29. The location of the sand and gravel pits during these years are shown in Figure 14. Mining rates, topsoil removal rates and estimated number of haul trips required during each of these years are given in Table 10.

Table 10: Mining Rates for the three Dispersion Modelling Scenario years

	Units	Year 12	Year 18	Year 29
Sand ROM moved	m³	740 000	740 000	630 073
Topsoil moved – Sand Pit	m³	26 912	25 218	26 033
Gravel ROM moved	m³	416 502	416 502	416 502
Topsoil moved – Gravel Pit	m³	9 224	11 714	11 714
Sand haul distance	km	~1.5	~2.1	~3.1
Gravel haul distance	km	~2.4	~2.7	4.0
Sand haul trips	trips/day	~103	~103	~88
Gravel haul trips	trips/day	~57	~57	~57

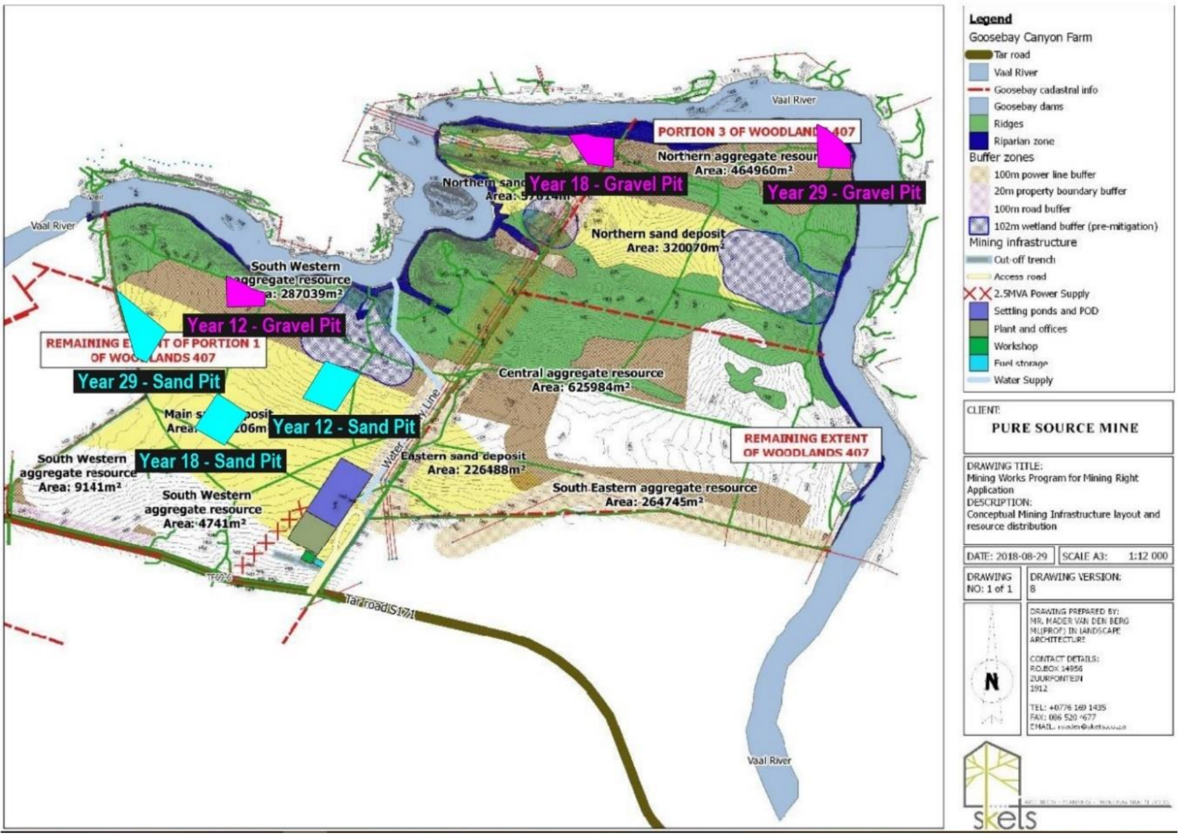


Figure 14: Location of pits during the three years chosen for emission estimation and impact quantification.

Estimated fugitive dust and vehicle exhaust emissions from the Pure Source Mine Project operations is shown in Table 11. A breakdown of source contributions to particulate emission during Year 29 is shown in Figure 15. Total particulate emissions during Years 12 & 18 will be slightly lower – 9.3 g/s & 10.1 g/s – compared to Year 29 – 11.2 g/s – due to the longer haul distance during Year 29.

As with any construction activities, construction of the plant is expected to result in dust fallout in the immediate vicinity of the plant area. Dust emissions during the construction phase is expected to vary substantially from day to day depending on the activities. Dust fallout impacts during the construction phase are expected to be short term and restricted to the immediate vicinity of the construction activities.

Table 11: Estimated emissions from the Pure Source Mining Project during Years 12, 18 & 29

Source	Emission Rate – grams per second				
	TSP	PM_{10}	$PM_{2.5}$	NO_2	SO_2
In pit material handling - Sand pit	1.8	0.8	0.1		
In pit vehicle entrainment - Sand pit	0.4	0.1	0.0		
Vehicle entrainment - Haul from sand pit to plant	3.3	1.0	0.1		
Material handling at the plant	1.0	0.5	0.1		
Dryer stack emissions	0.5	0.5	0.5	5.0	10.0
In pit material handling - Gravel pit	1.2	0.6	0.1		
In pit vehicle entrainment - Gravel pit	0.2	0.0	0.0		
Vehicle entrainment - Haul from gravel pit	2.8	0.9	0.1		
Vehicle exhaust emissions		0.8		10.7	0.4

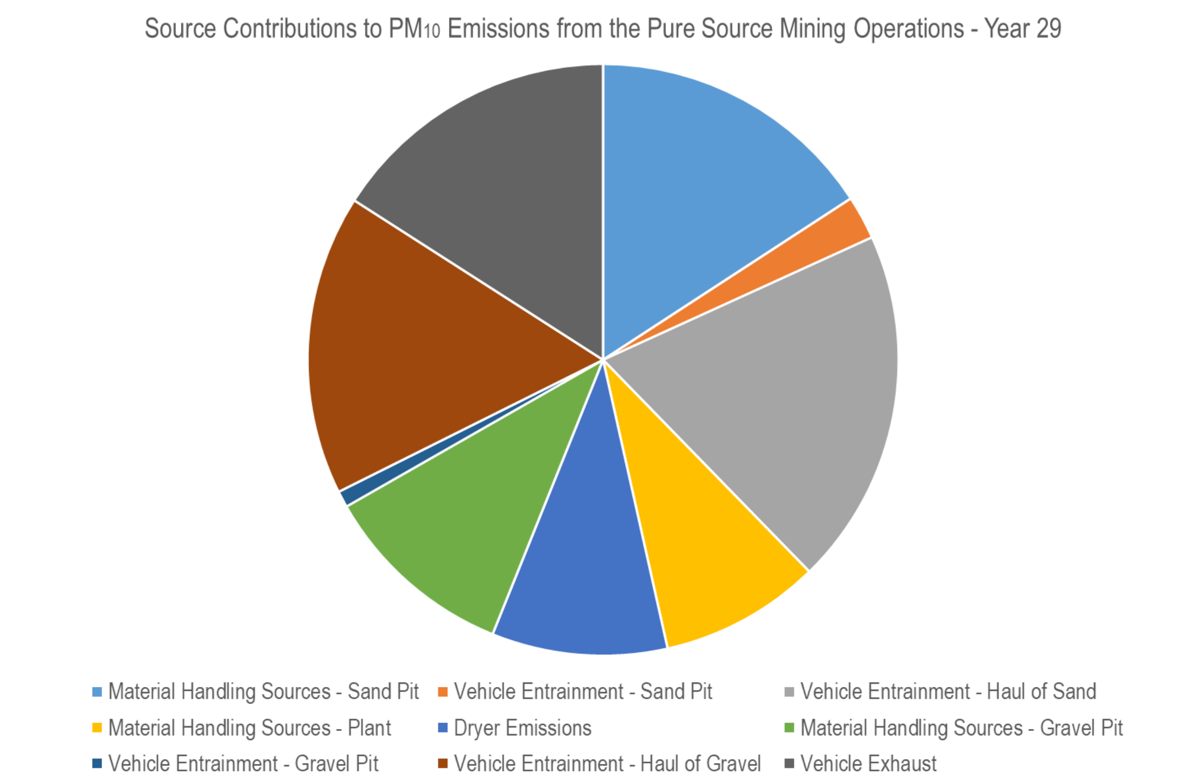


Figure 15: Source contributions to particulate emissions (Year 29)

Table 12: Emission estimation techniques and activity data

Source Group	Emission Estimation Technique	Input Parameters/Notes
Materials Handling	US EPA emission factor equation (US EPA, 2006a) $$EF = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$$ Where EF is the emission factor in kg/tonne material handled k is the particle size multiplier (k_{TSP} – 0.74, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.053) U is the average wind speed in m/s M is the material moisture content in %	• Handling rates as per Table 10. • An average **wind speed of 3.22 m/s** was determined from the MM5 data set • **Hours of operation:** 66 hours per week. • **Mitigation:** 50% mitigation, achievable by keeping material being handled moist, reducing drop heights and use of wind enclosures where possible.
Crushing and Screening	US EPA emission factor equation USA EPA AP42 (2004) for primary crushing and screening • Crushing TSP – 0.0027 kg/tonne PM_{10} – 0.0012 kg/tonne PM2.5 – 0.00012 kg/tonne • Screening TSP – 0.0125 kg/tonne PM_{10} – 0.0043 kg/tonne $PM_{2.5}$ – 0.00043 kg/tonne	Crushing rate same as mining rate as per Table 10. Only gravel crushed. Gravel crushed and screened in-pit. Sand screened in pit and at plant. **Hours of operation:** 66 hours per week. **Mitigation:** 50% achievable with wet suppression
Vehicle Entrained Dust from Unpaved Roads	US EPA emission factor equation (US EPA, 2006b) $$EF = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot e$$ Where EF is the emission factor in g/vehicle kilometre travelled (VKT)	Transport activities include the transport of sand from the sand pit to the plant and from the gravel pit off-site. Road lengths and number of trips as per Table 10. **Haul roads** truck capacity 30 tonnes assumed for all roads

	k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) s is the road surface material silt content in % W is the average weight vehicles in tonnes a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) b is an empirical constant (b_{TSP} – 0.45, b_{PM10} – 0.45, $b_{PM2.5}$ – 0.45) e is the metric converter of 281.9 (1 lb/VMT = 281.9 g/VKT)	**Surface silt content of 4.8 %** (US EPA, 2006b) was applied in calculations for all unpaved roads **Hours of operation:** 66 hours per week. **Mitigation:** Water Sprays, chemical dust suppressants to achieve **70%** mitigation
Vehicle Exhaust Emissions	NPI Combustion Engines V3 (ADE, 2008) **SO_2 emissions were based on a diesel sulfur content of 500ppm. If 50ppm diesel is used, impacts will be approximately 10 times lower.**	As per vehicle fleet and fuel use specifications provided. **Hours of operation:** 66 hours per week. **Mitigation:** None
Wind Erosion	Australian NPI Emission Factor for Mining. Wind erosion from active stockpiles = 0.04 kg/ha/h for TSP and 0.02 kg/ha/hr for PM_{10}	

5 DISPERSION MODELLING SELECTION AND RESULTS

5.1 Study Methodology

The study methodology may be divided into a “preparatory phase” and an “execution phase”.

The preparatory phase included the flowing basic steps prior to performing the actual dispersion modelling and analyses:

1. Understand Scope of Work
2. Assign Appropriate Specialists (See Annexure B)
3. Review of legal requirements (see Section 5.1.2)
4. Decide on Dispersion Model (see Section 5.1.1)

The Regulations Regarding Air Dispersion Modelling (Gazette No 37804 published 11 July 2014) (DEA, 2014) was referenced for the dispersion model selection.

Three levels of assessment are defined in the Regulations regarding Air Dispersion Modelling:

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50 km)
- Level 3: requires more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situations:
  - where a detailed understanding of air quality impacts, in time and space, is required;
  - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types, and chemical transformations;
  - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
  - when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an airshed; or,
  - when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level ozone (O_3), particulate formation, visibility).

This study was considered to meet the requirements of a Level 2 assessment, and AERMOD was selected on the basis that this Gaussian plume model is well suited to simulate dispersion where transport distances are likely to be less than 50 km.

The execution phase (i.e. dispersion modelling and analyses) firstly involves gathering specific information in relation to the emission source(s) and site(s) to be assessed. This includes:

- Source information: Emission rate, exit temperature, volume flow, exit velocity, etc.;
- Site information: Site building layout, terrain information, land use data;
- Meteorological data: Wind speed, wind direction, temperature, cloud cover, mixing height;
- Receptor information: Locations using discrete receptors and/or gridded receptors.

The model uses this specific input data to run various algorithms to estimate the dispersion of pollutants between the source and receptor. The model output is in the form of a predicted time-averaged concentration at the receptor. These predicted concentrations are added to suitable background concentrations and compared with the relevant ambient air quality standard or guideline. In some cases, post-processing can be carried out to produce percentile concentrations or contour plots that can be prepared for reporting purposes. AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources. AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature however retains the single straight-line trajectory limitation. 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. 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. The terrain data may be in the form of digital terrain data. The output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model include: source data, meteorological data (pre-processed by the AERMET model), terrain data and information on the nature of the receptor grid. Model details and domain parameters are summarised in Table 13 and Table 14 below.

Table 13: Model details

Pollutants	Model Version	Executable
All pollutants	AERMOD 7.2.5	EPA 09292

Table 14: Simulation domain

Simulation domain	Details
South-western corner of simulation domain	557 075 m; 7 039 581m
Domain size	7.5 x 4.0 km
Projection	Grid: UTM Zone 35J, Datum: WGS 84
Resolution	50 m

5.2 Dispersion Modelling Results

Dispersion modelling simulations were undertaken to determine highest hourly, highest daily and annual average ground level concentrations for each of the pollutants considered for the operational phase. Averaging periods were selected to facilitate the comparison of simulated pollutant concentrations to the SA NAAQS and international guidelines as described in Section 2.

Ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, which are generally outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access. For this assessment the ambient criteria were assumed to be applicable for all areas outside the area actively being mined at any given time.

A summary of the isopleth plots and averaging periods considered for each pollutant is given in Table 15. The assessment criteria (the relevant standard or guideline) is indicated as a black line on each isopleth plot (two lines are shown on the dust fallout isopleth plot to indicate the residential and non-residential limits).

Table 15: Dispersion modelling results – isopleth plots

Pollutant Symbol	Pollutant Name	Averaging Period	Assessment Criteria	Allowed Frequency of Exceedance	Assessment Criteria Source	Isopleth Plot
PM_{10}	Inhalable Particulates	Daily	75 µg/m³	4	SA NAAQS	Figure 16
		Annual	40 µg/m³	None	SA NAAQS	Figure 17
$PM_{2.5}$	Respirable Particulates	Daily	40 µg/m³	4	SA NAAQS	Figure 18
		Annual	20 µg/m³	None	SA NAAQS	Figure 19
Dust Fallout	Dust fallout	Monthly	600 mg/m²/day	1	SA NDCR	Figure 20
NO_2	Nitrogen Dioxide	Hourly	200 µg/m³	88	SA NAAQS	Figure 21
		Annual	40 µg/m³	None	SA NAAQS	Figure 22
SO_2	Sulfur Dioxide	Hourly	350 µg/m³	88	SA NAAQS	Figure 23
		Annual	125 µg/m³	4	SA NAAQS	Figure 24
		Daily	50 µg/m³	None	SA NAAQS	Figure 25
SiO_2	Crystalline Silica	Annual	3 µg/m³	None	Cal OEHHA	Figure 26
DPM	Diesel Particulate Matter	Annual	5 µg/m³	None	US EPA IRIS	Figure 27

Even with best practice mitigation measures applied to dust generating sources, simulated 99^{th} percentile daily PM_{10} concentrations due to the Pure Source Mine Project sources exceed the SA NAAQS (more than 4 days exceeding 75 µg/m³) at a variety of sensitive receptor locations, including at the residential area of Vaal Oewer for all three scenarios. Based on the large impact area, it can be reasonably assumed that these exceedances would also be experienced during other years of the mining operations, not only those for which dispersion modelling simulations were run. Depending on the active area being mined at the time, additional exceedances could occur at other sensitive receptor locations to the north, east and west of the Vaal river.

Simulated 99^{th} percentile daily $PM_{2.5}$ concentrations could exceed the SA NAAQS at the closest sensitive receptors to the mining operations. The impact area where highest daily $PM_{2.5}$ concentrations exceed the SA NAAQS is estimated at approximately 300 m from the sand and gravel mining operations.

Simulated annual average PM_{10} and $PM_{2.5}$ concentrations, as well as simulated NO_2 and SO_2 concentrations for all averaging periods, are in compliance with the SA NAAQS at all sensitive receptor locations. Simulated annual average SiO_2 concentrations could exceed the California OEHHA REL in the immediate vicinity of the mining operations but are well below the REL at all sensitive receptor locations. Worst-case diesel particulate concentrations (if all vehicles are operational simultaneously) could exceed the US EPA IRIS guideline value of 5 µg/m³ up to 400 m from the mining operations, including at some sensitive receptor locations when mining operations are closest to these locations. It is, however, highly unlikely that all vehicles will be operational for 12 hours per day, and this simulated impact is highly conservative.

Simulated highest monthly dust fallout rates exceed the SA NDCR non-residential limit up to 300 m to the north of the mining operations and haul roads, and the residential limit up to 00 m to the north of the mining operations and haul road. This means that when mining operations are active at the northern and south western aggregate resources respectively, the NDCR is likely to be exceeded at Vaal Oewer and other sensitive receptors to the north of the Vaal river. Due to the prevailing wind direction in the study area, dust fallout impacts are expected to be higher to the south of the operations.

Based on simulated dust fallout rates, it is recommended that no mining activities, including crushing and screening, be undertaken within 400 m to the south, east and west of any sensitive receptor location and within 800m to the north of any sensitive receptor locations.

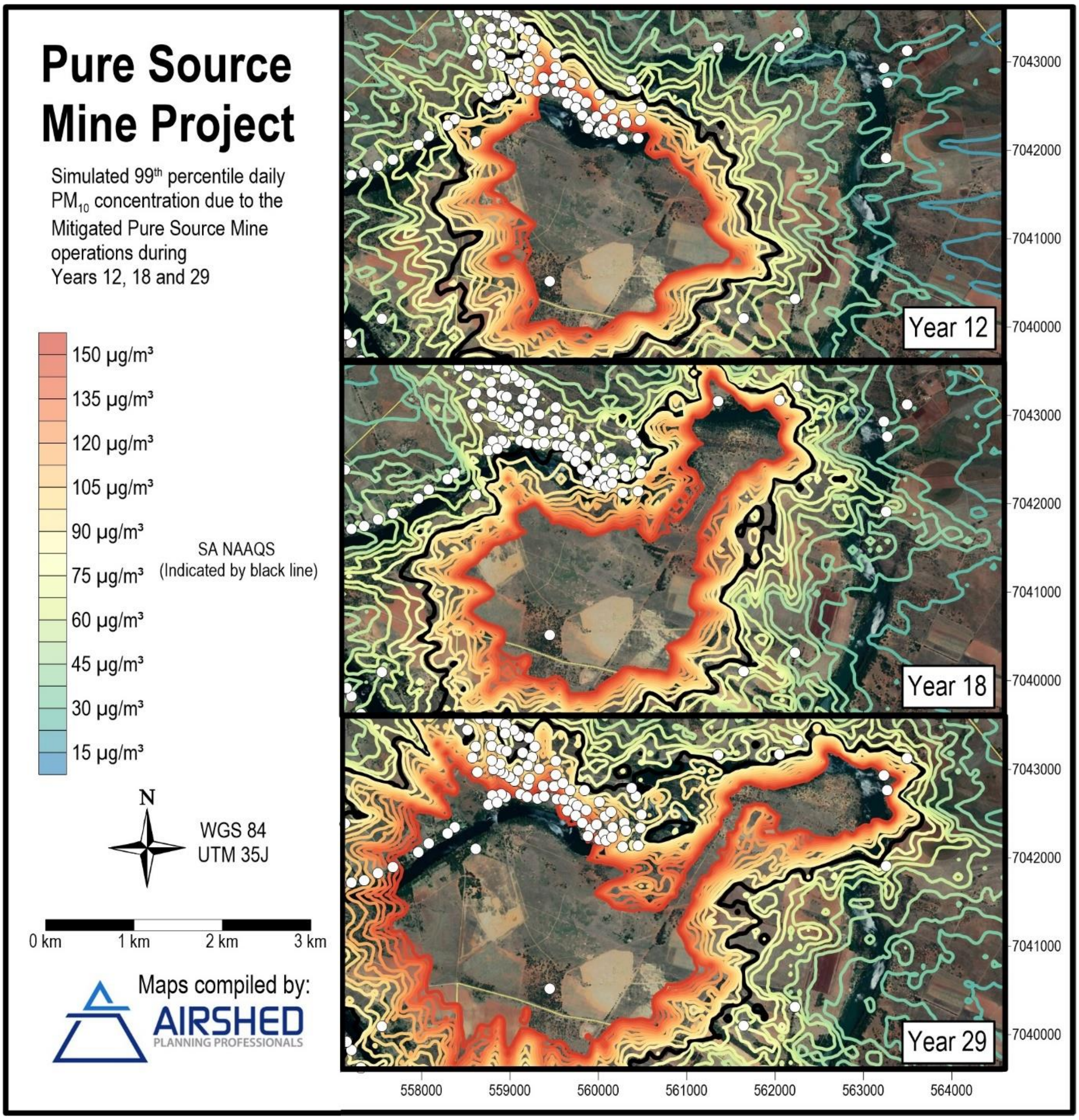


Figure 16: Simulated 99th percentile (5th highest) daily PM_{10} concentrations

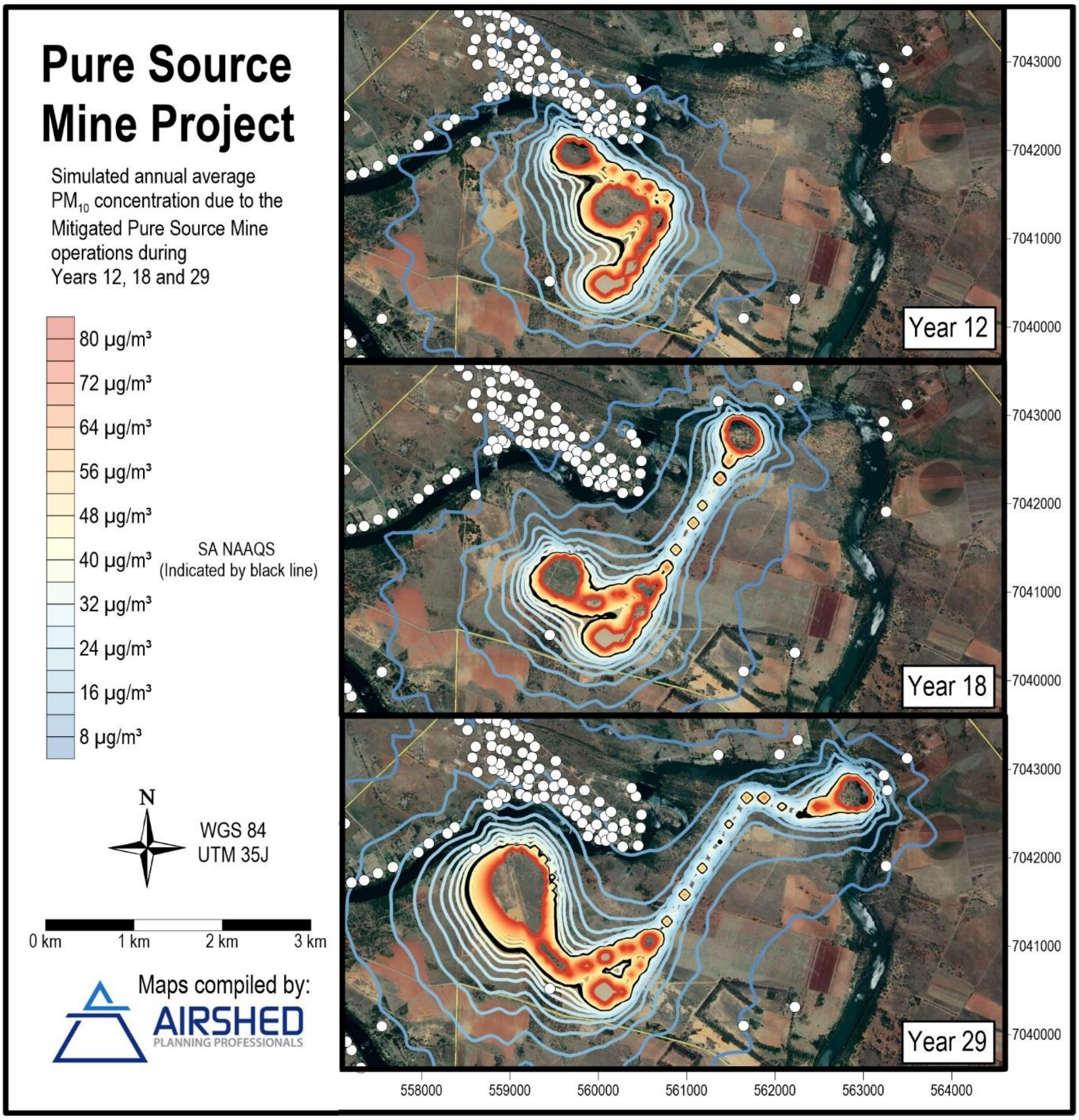


Figure 17: Simulated annual average PM_{10} concentrations

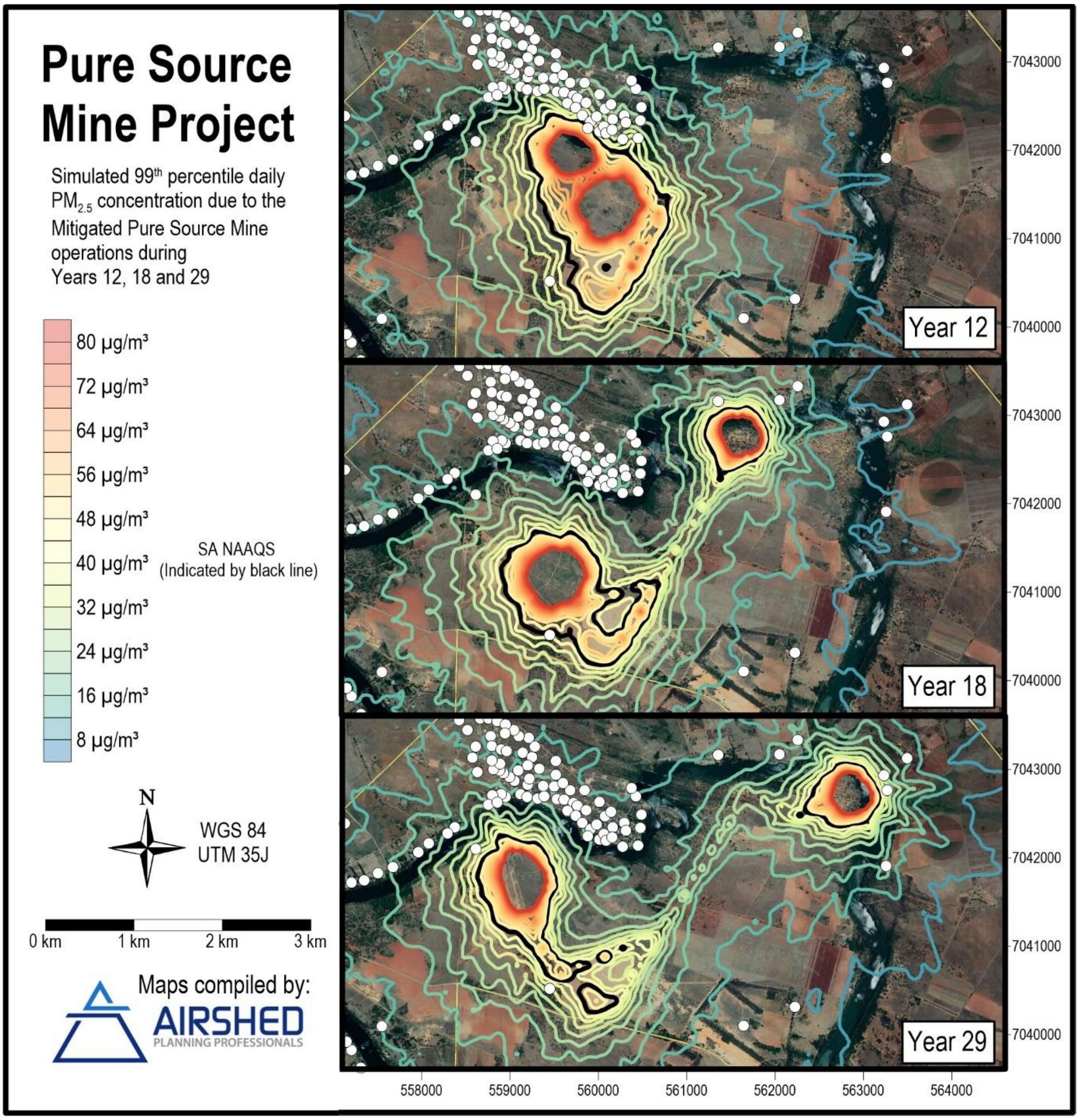


Figure 18: Simulated 99th percentile (5th highest) daily $PM_{2.5}$ concentrations

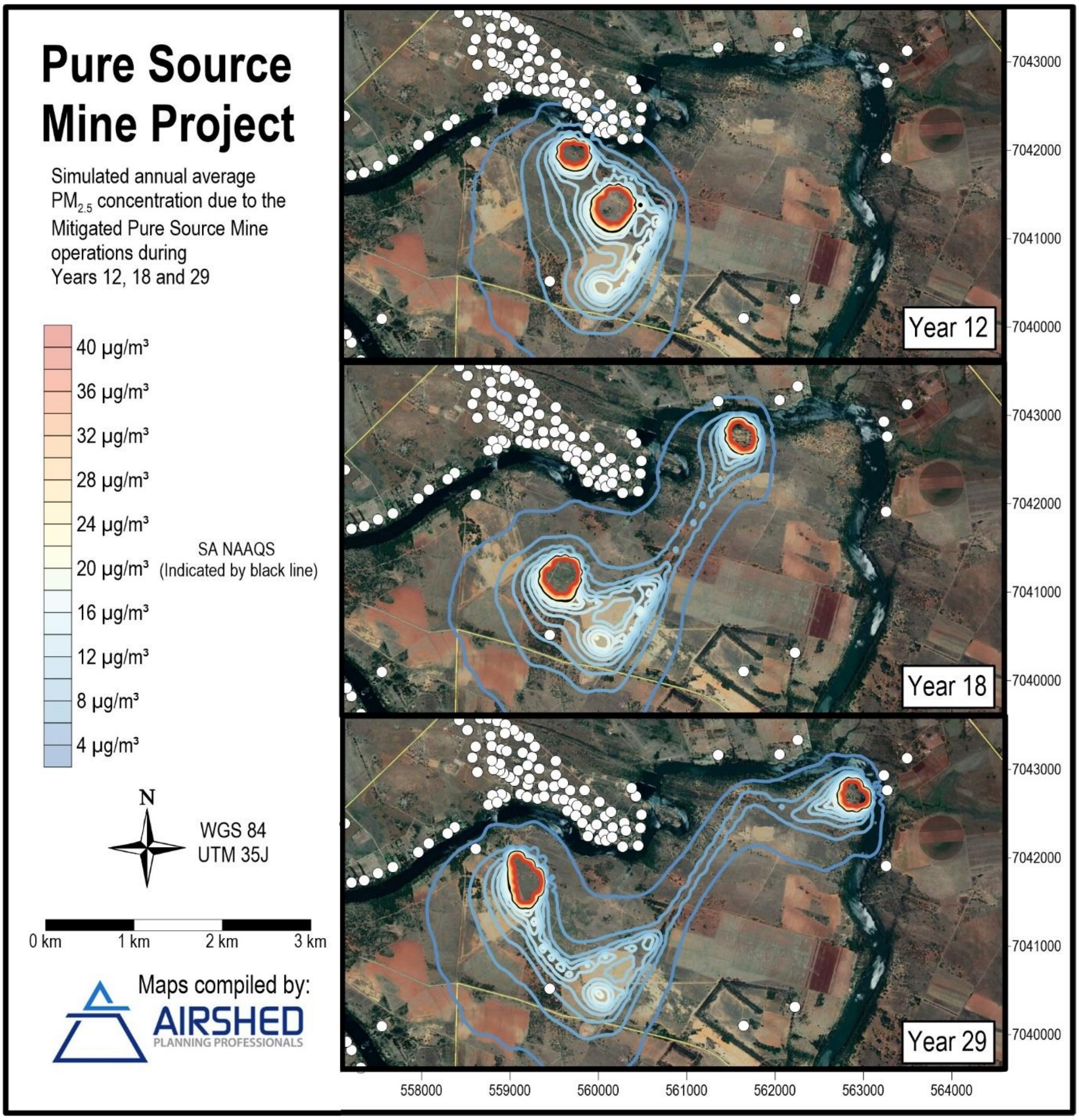


Figure 19: Simulated annual average $PM_{2.5}$ concentrations

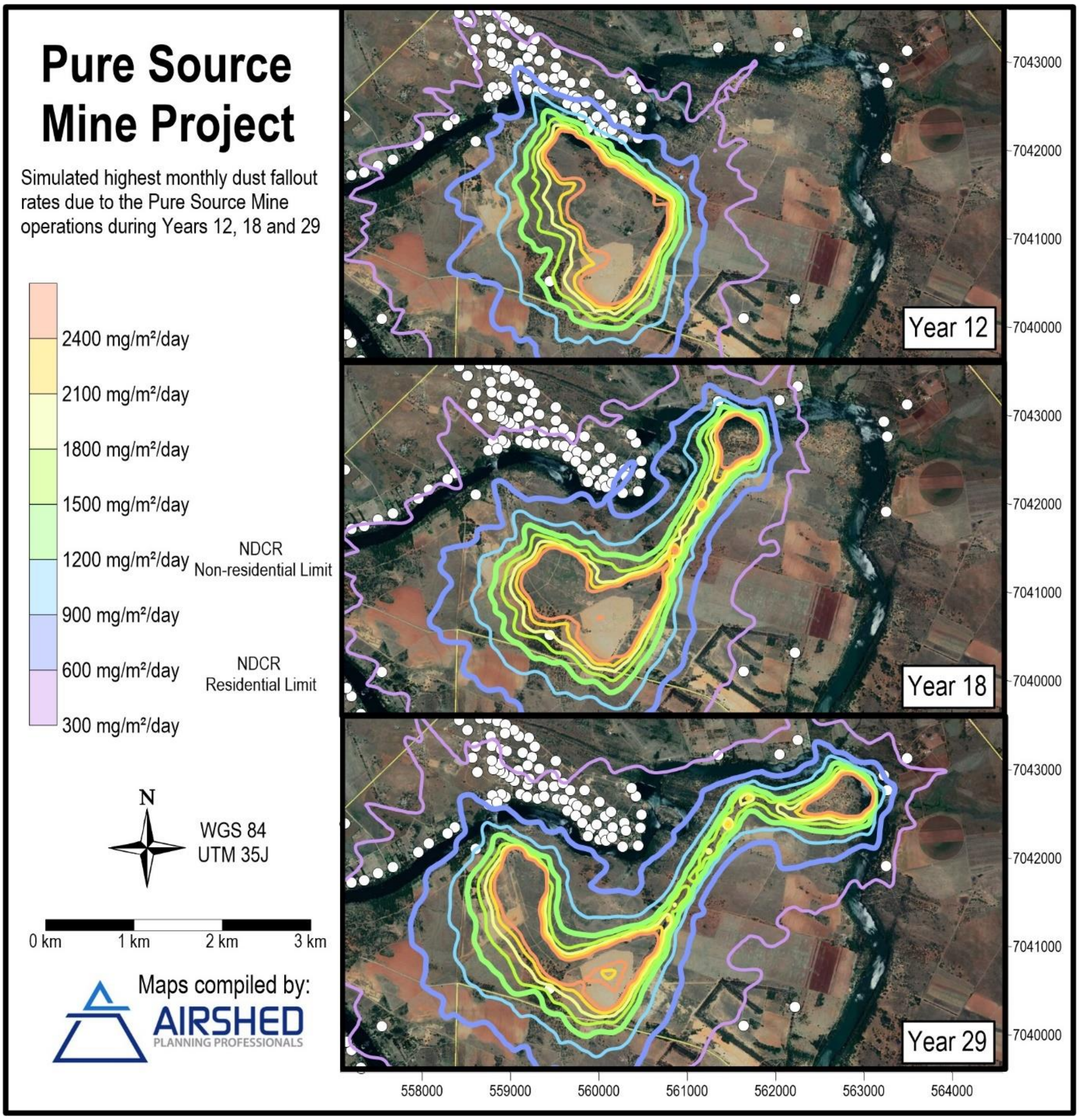


Figure 20: Simulated highest monthly dust fallout rates

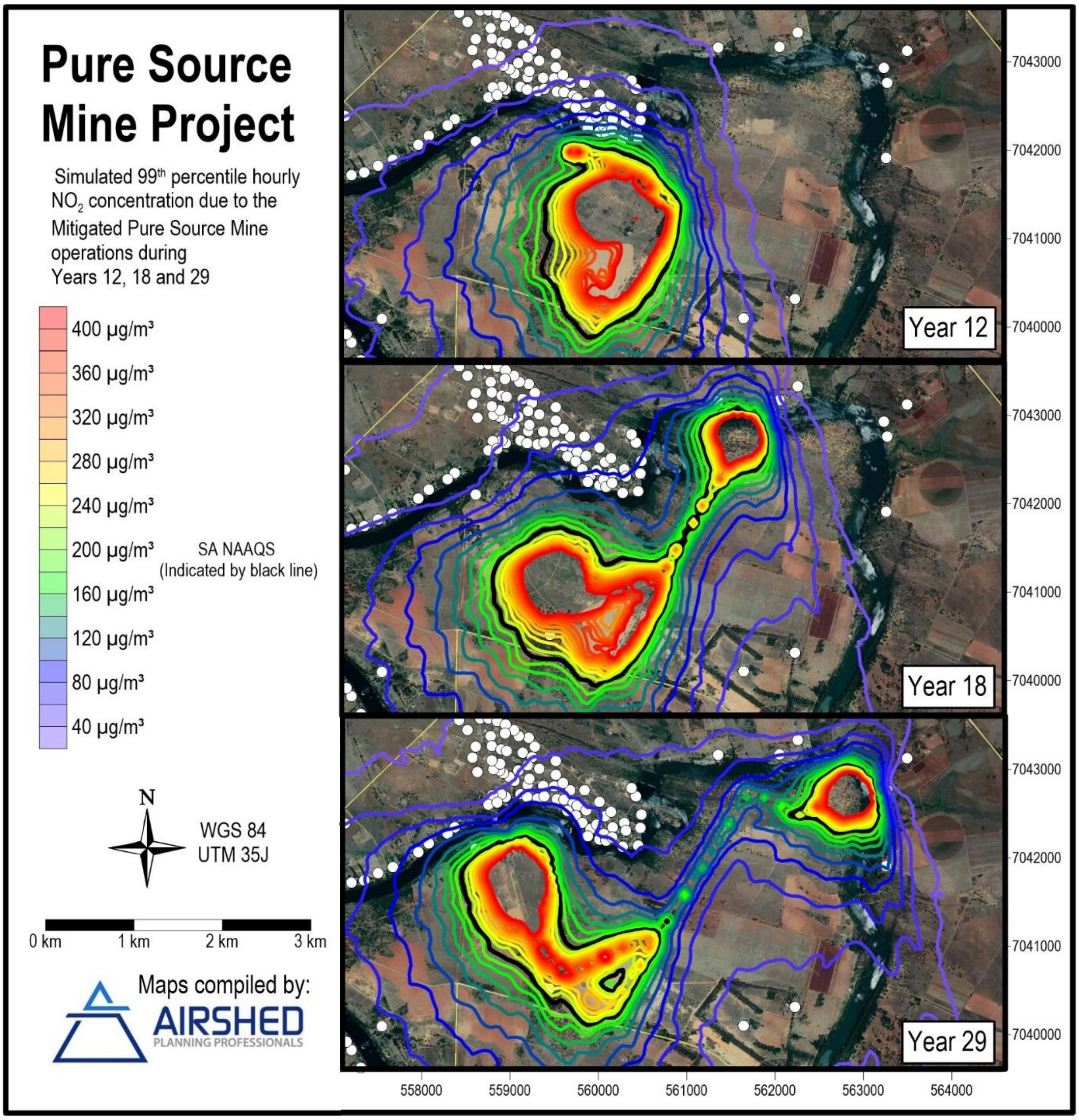


Figure 21: Simulated 99th percentile (89th highest) hourly NO_2 concentrations

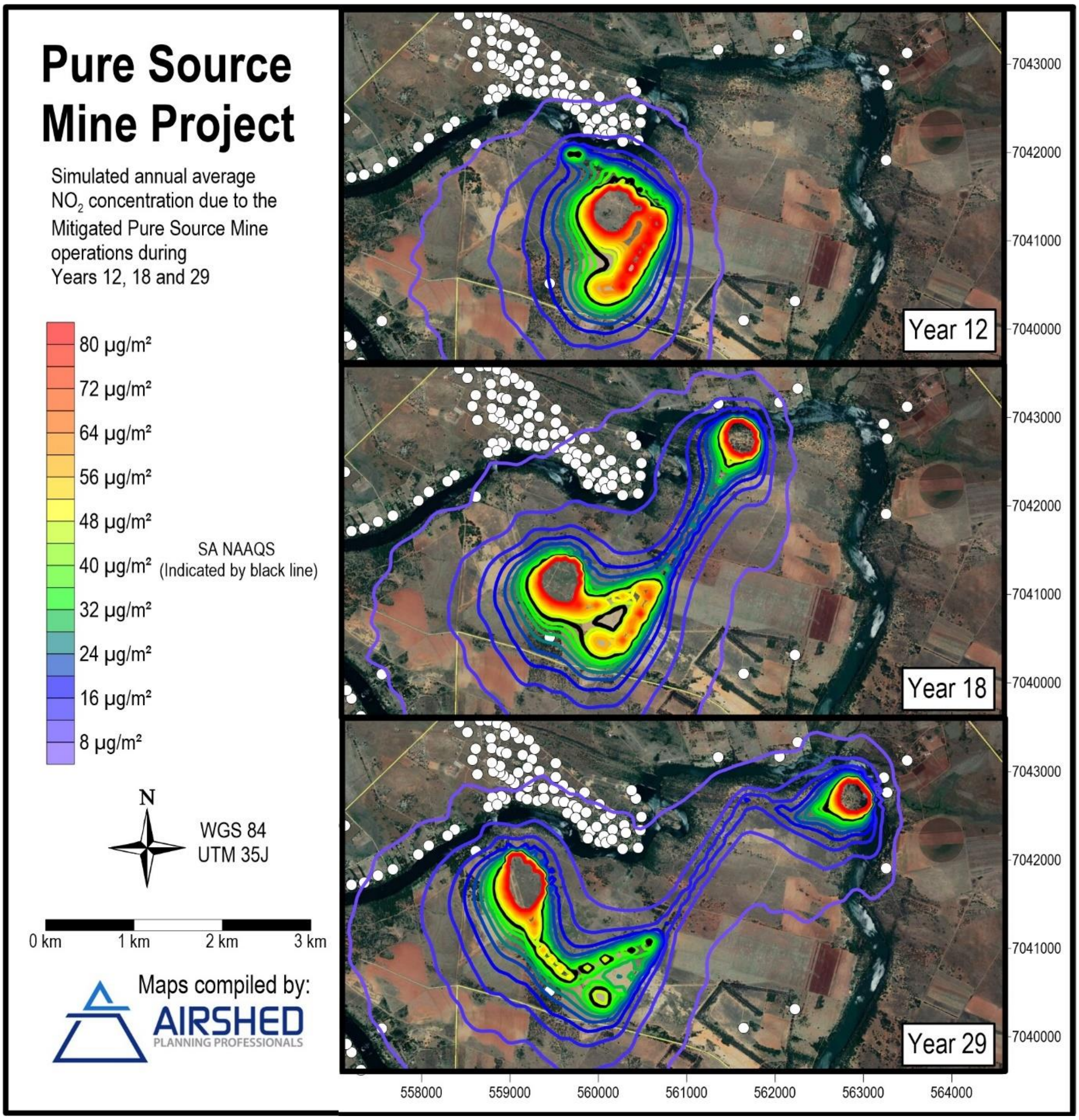


Figure 22: Simulated annual average NO_2 concentrations

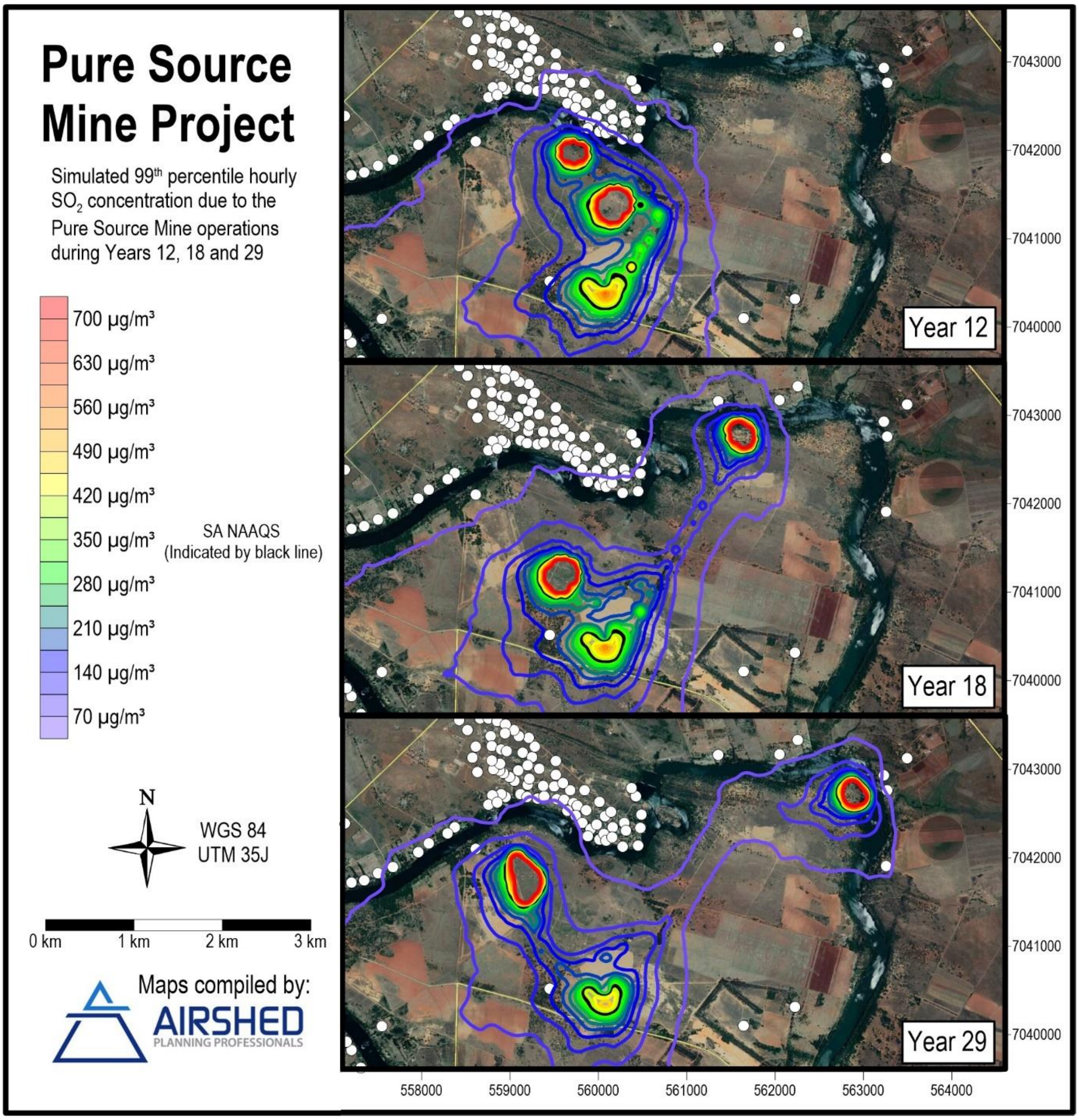


Figure 23: Simulated 99th percentile (89th highest) hourly SO_2 concentrations

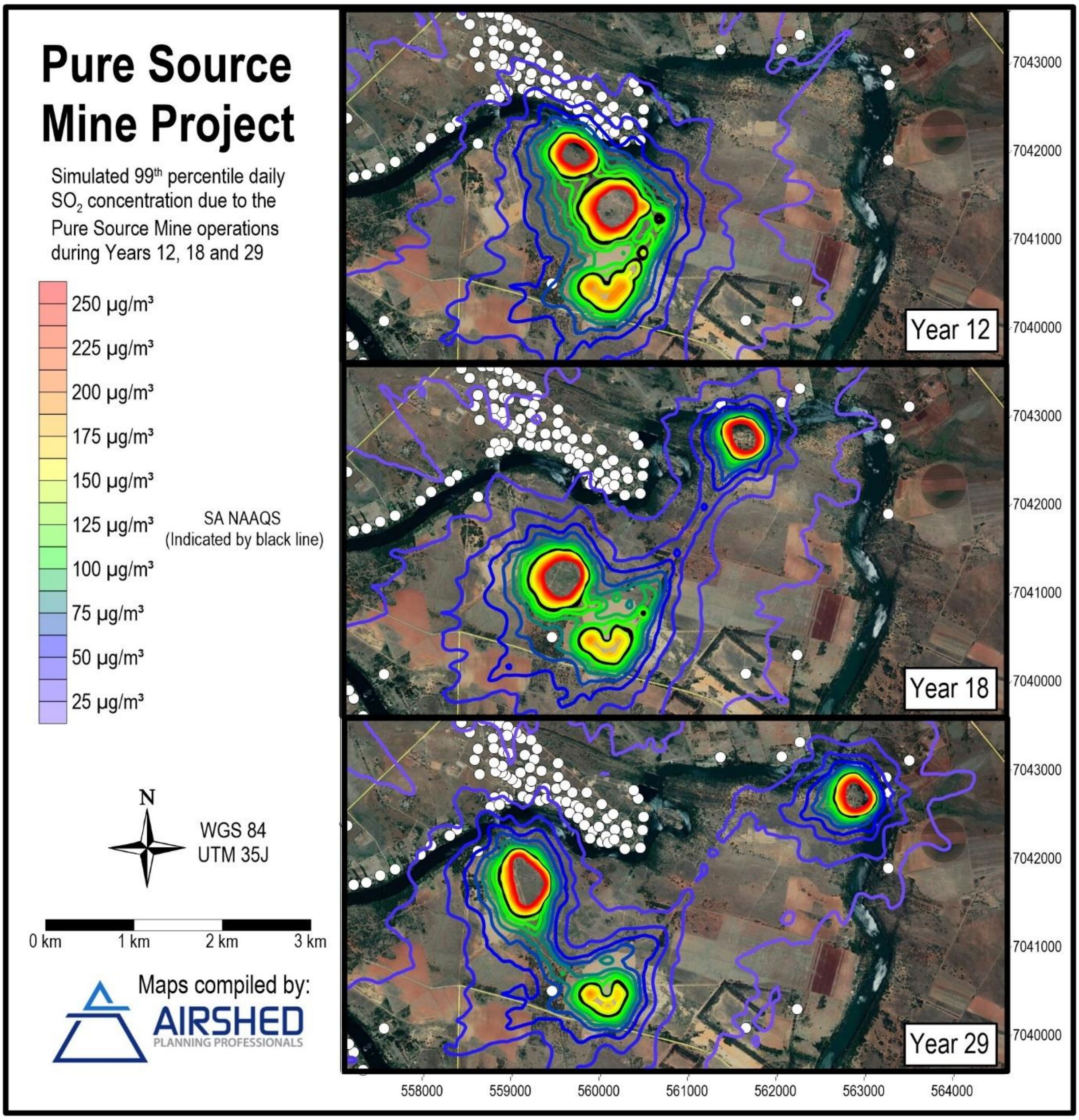


Figure 24: Simulated 99th percentile (5th highest) daily SO_2 concentrations

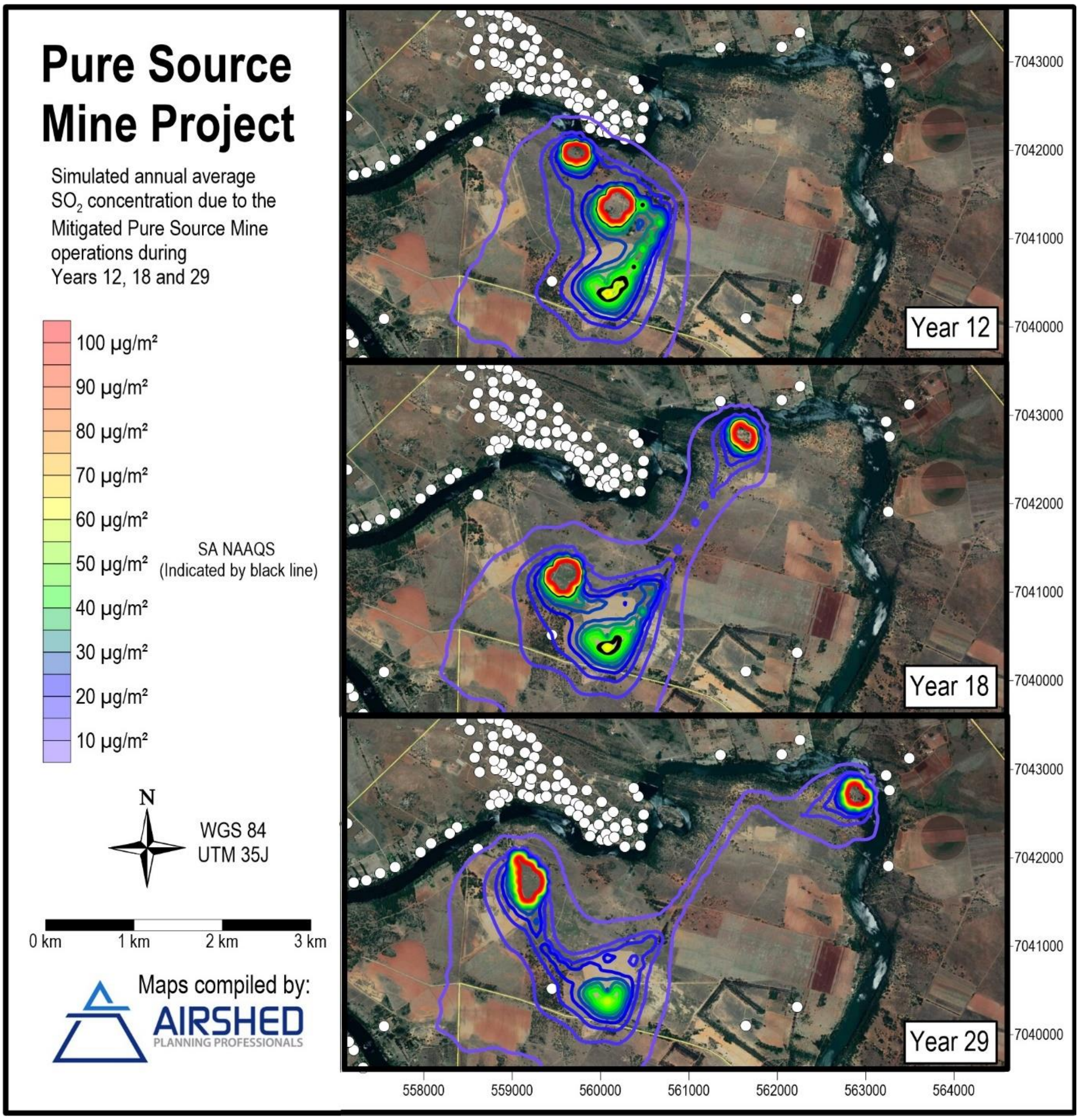


Figure 25: Simulated annual average SO_2 concentrations

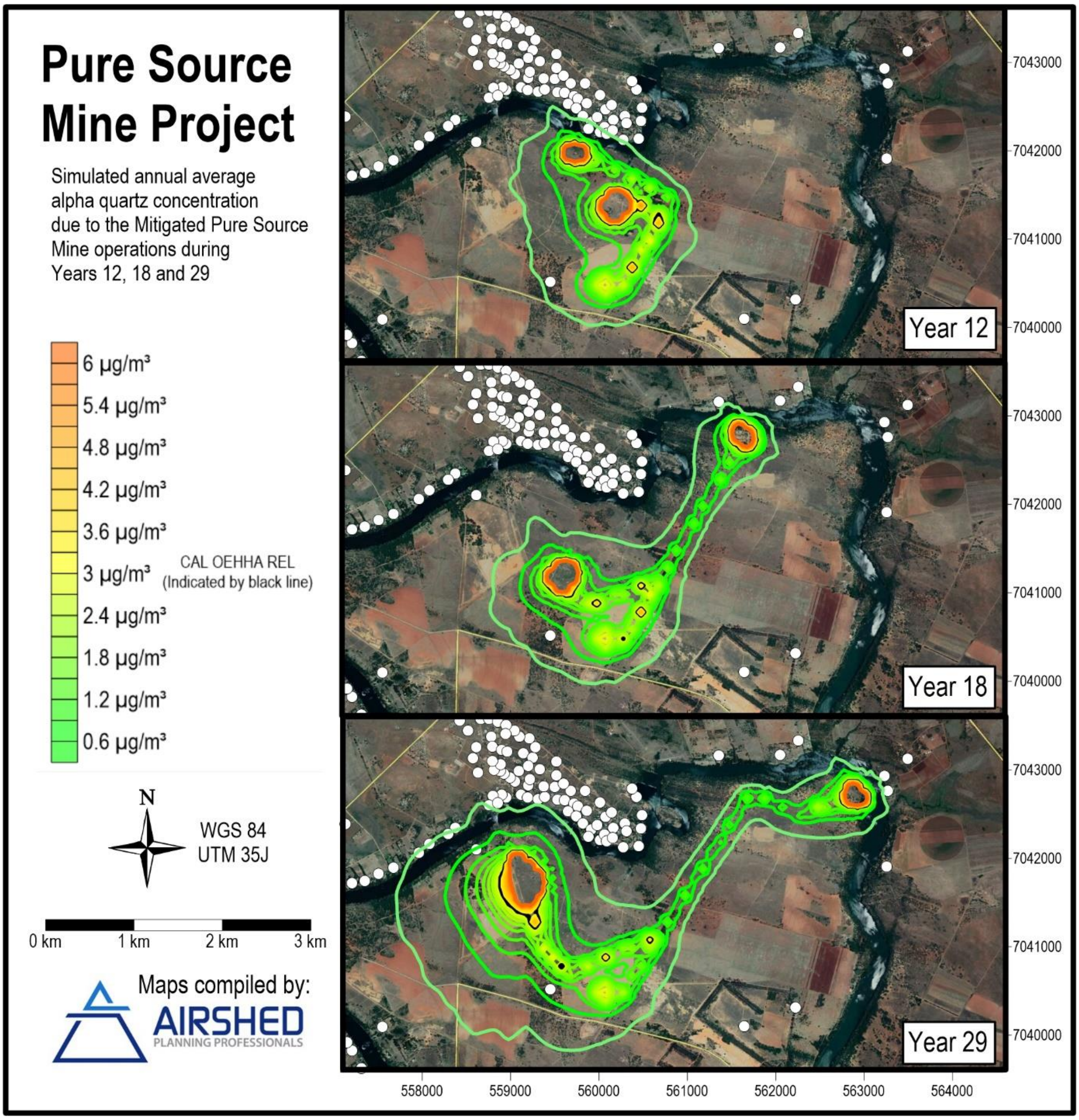


Figure 26: Simulated annual average SiO_2 concentrations

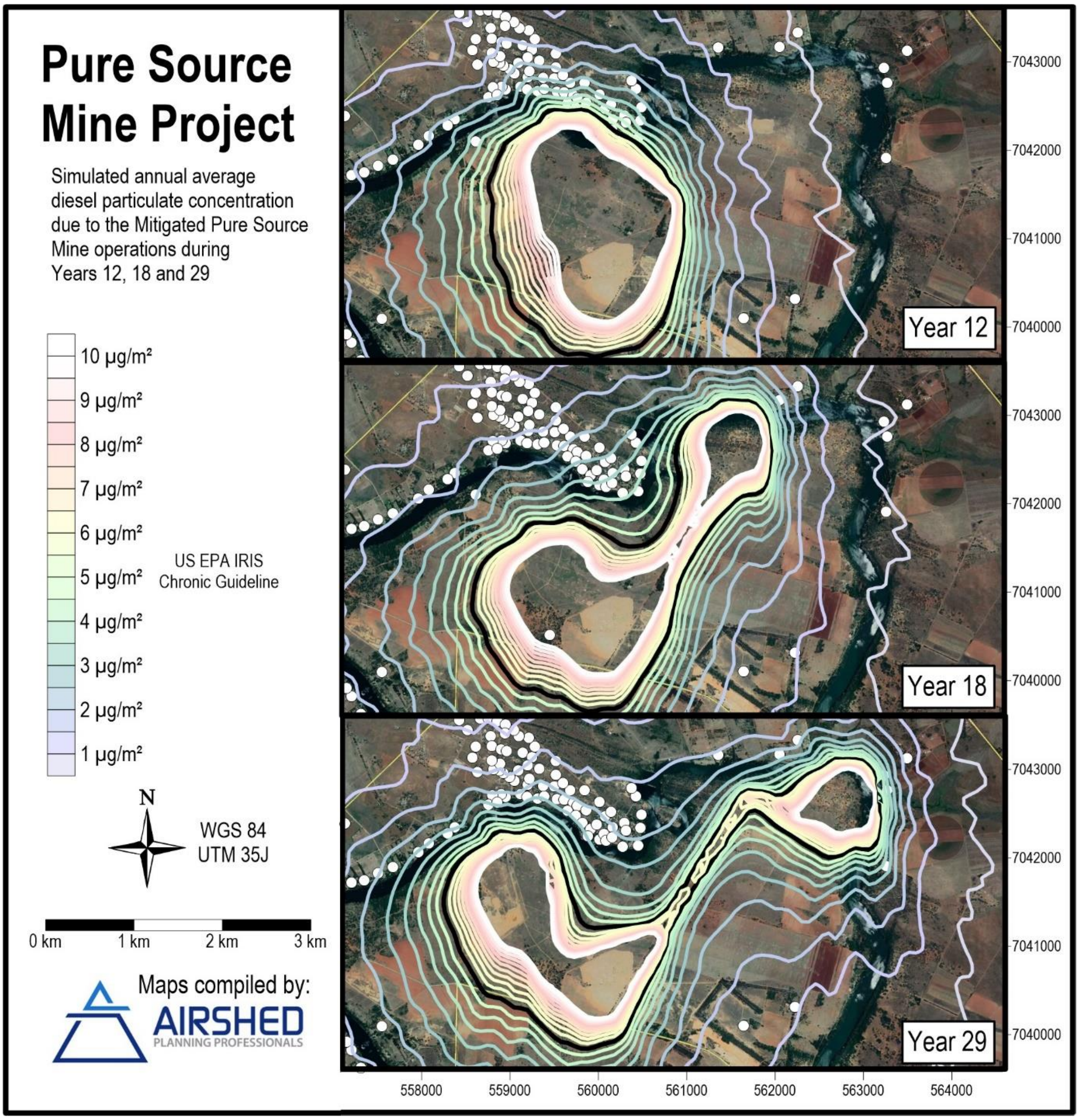


Figure 27: Simulated annual average DPM concentrations

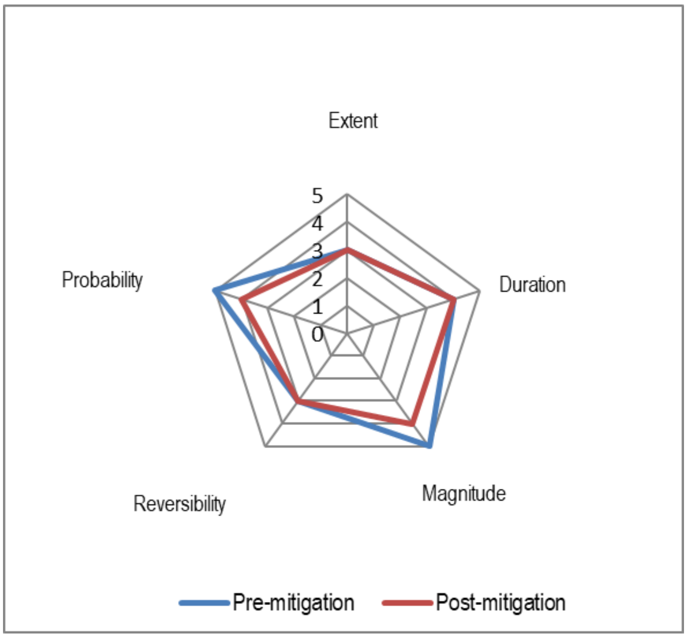
6 IMPACT SIGNIFICANCE RATING

The significance of the impact of the Pure Source Mine Project on ambient air quality, as described in the previous sections, is given a rating in this section according to the methodology provided by Shango Solutions (given in Appendix B).

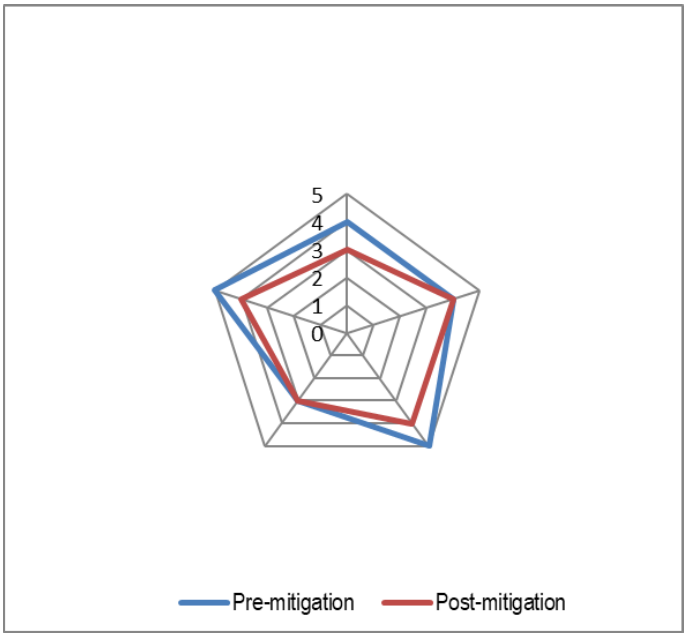
The cumulative impact of the Pure Source Sand Mine together with the Tja Naledi and Sweet Sensations operations was not accessed, as no information was available for the other two mining operations. Based on the historic dustfall results described in Section 3.5.3 as well as the dispersion modelling results presented in Section 5.2, it is estimated that the cumulative impact of dust fallout and annual average particulate concentrations from the three mines will be similar to the incremental impact of each operation, as both dispersion modelling and historic sampling show that the impact of these pollutants over these sampling periods are localised to the immediate vicinity of the operations. Cumulative highest daily particulate concentrations from the three operations could however be significant, especially at the sensitive receptors that are located close to the boundaries of two of the operations (such as Vaal Eden to the north west of the Pure Source Sand Mine and Goosebay Canyon to the south east of the Pure Source Sand Mine).

A Community Health Risk Assessment undertaken by Infotox (van Niekerk & Fourie, 2019) concluded that the increased risk for cardiovascular and respiratory hospital admissions due to $PM_{2.5}$ emissions from the Pure Source Sand Mining Operations is low. The assessment also concluded that rock crushing activities at the Pure Source Sand Mine will not lead to a risk of silicosis in the communities. Both of the above conclusions were based on mitigated conditions, with mitigation measures as described in Section 4.

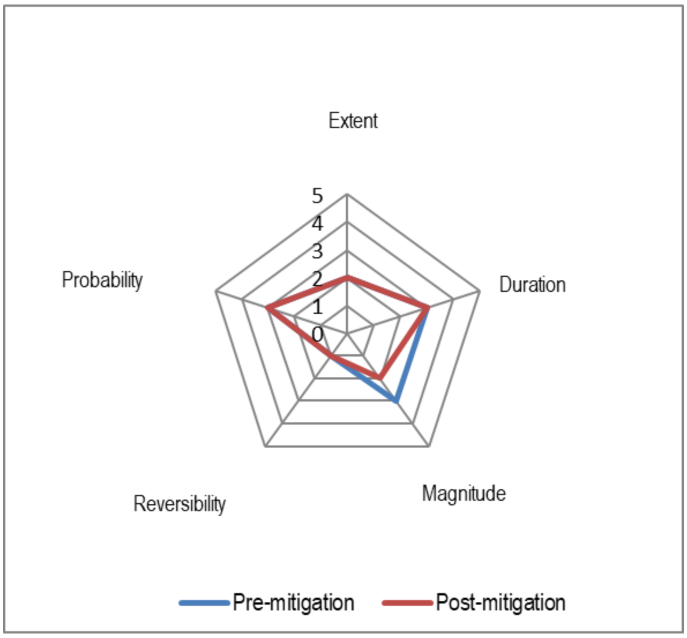
Dust fallout					
Impact Name	**Dust fallout**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	4
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	5	4
Environmental Risk (Pre-mitigation)					-18.75
Mitigation Measures					
Environmental Risk (Post-mitigation)					-14.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.33
Final Significance					-18.67



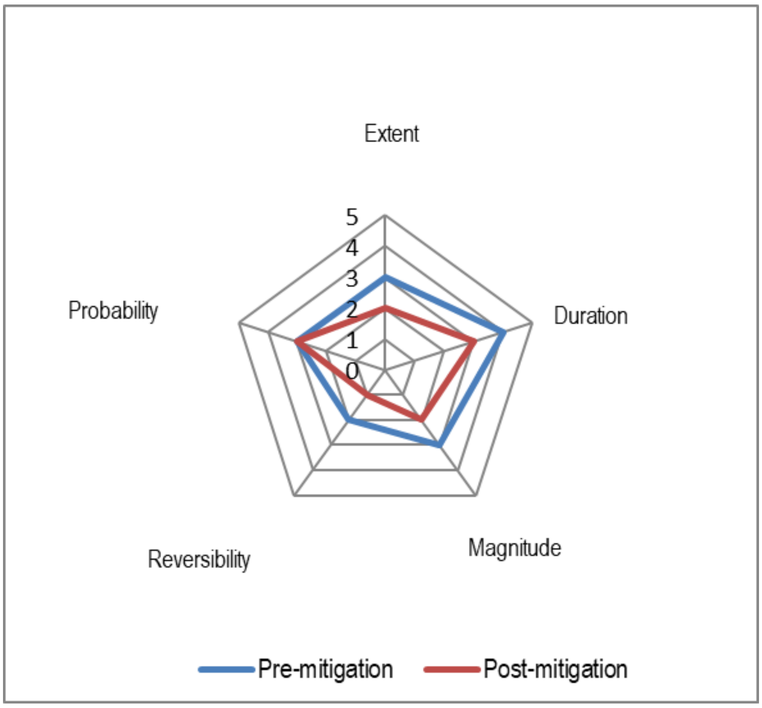
Particulate Concentrations -					
Impact Name	**Particulate Concentrations**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	4
Extent of Impact	4	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	5	4
Environmental Risk (Pre-mitigation)					-20.00
Mitigation Measures					
Environmental Risk (Post-mitigation)					-14.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-16.33



Gaseous Pollutant Concentrations (NO_2, SO_2, DPM) -					
Impact Name	**Gaseous Pollutant Concentrations (NO_2, SO_2, DPM)**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	2	2	Reversibility of Impact	1	1
Duration of Impact	3	3	Probability	3	3
Environmental Risk (Pre-mitigation)					-6.75
Mitigation Measures					
-					
Environmental Risk (Post-mitigation)					-6.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-6.00



Crystalline Silica Concentrations -					
Impact Name	**Crystalline Silica Concentrations**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	2	1
Duration of Impact	4	3	Probability	3	3
Environmental Risk (Pre-mitigation)					-9.00
Mitigation Measures					
-					
Environmental Risk (Post-mitigation)					-6.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-7.00



7 Conclusions

The main findings from the baseline assessment are as follows:

- The wind field in the study is dominated by winds from the northern sector during the 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% at night.
- Existing sources of emissions in the study area include other sand mining operations, vehicle exhaust and entrainment on paved and unpaved roads, household fuel burning, biomass burning (veld fires), wind erosion from open areas and agricultural activities.
- Sensitive receptors in the study area include the residential areas of Vaal Oewer and Lindiquesdrift as well as various other residences and small holdings on both sides of the Vaal river. There are very few sensitive receptor locations directly to the south of the proposed mining operations.

The main findings from the impact assessment are as follows:

- Emission sources from the proposed Pure Source Mine Project operations include fugitive dust emissions from material handling, crushing and screening, vehicle entrainment and wind erosion from stockpiles and exposed areas, as well as gaseous emission from vehicle exhausts and the dryer. Pollutants of concern expected to be emitted by the Pure Source Mining Project operations include particulates (PM_{10} and $PM_{2.5}$), NO_2, SO_2, crystalline silica and diesel particulate matter.
- To assess worst case air quality impacts, three scenarios were included in the dispersion modelling. These three scenarios represent the identified operating years that would likely result in the highest air quality impacts at sensitive receptor locations. The three scenarios are representative of operational years 12, 18 and 29.
- Even with best practice mitigation measures applied to dust generating sources, simulated highest daily PM_{10} concentrations due to the Pure Source Mine Project sources exceed the SA NAAQS (more than 4 days exceeding 75 µg/m³ per year) at a variety of sensitive receptor locations, including at the residential area of Vaal Oewer, for all three scenarios. Based on the large impact area, it can be reasonably predicted that these exceedances would also be experienced during other years of the mining operations. Depending on the active area being mined at the time, additional exceedances could occur at other sensitive receptor locations to the north, east and west of the Vaal river.
- Simulated annual average PM_{10} and $PM_{2.5}$ concentrations, as well as simulated NO_2 and SO_2 concentrations for all averaging periods, are in compliance with the SA NAAQS at all sensitive receptor locations.
- Simulated annual average SiO_2 concentrations could exceed the California OEHHA REL in the immediate vicinity of the mining operations but are well below the REL at all sensitive receptor locations.
- Worst-case diesel particulate concentrations (if all vehicles are operational simultaneously), could exceed the US EPA IRIS guideline value of 5 µg/m³ up to 400 m from the mining operations, including at some sensitive receptor locations when mining operations are closest to these locations. It is however highly unlikely that all vehicles will be simultaneously operational for 12 hours per day, and this simulated impact is highly conservative.
- Simulated highest monthly dust fallout rates exceed the SA National Dust Control Regulations (NDCR) non-residential limit up to 300m from of the mining operations and haul roads and the residential limit up to 600 m from the mining operations and haul road. This means that when mining operations are active at the northern and south western aggregate resources respectively, the NDCR is likely to be exceeded at Vaal Oewer and other sensitive receptors to the north of the Vaal river.
- A Community Health Risk Assessment undertaken by Infotox (van Niekerk & Fourie, 2019) concluded that the increased risk for cardiovascular and respiratory hospital admissions due to $PM_{2.5}$ emissions from the Pure Source Sand Mining Operations is low. The assessment also concluded that rock crushing activities at the Pure Source Sand Mine will not lead to a risk of silicosis in the communities. Both of the above conclusions were based on mitigated conditions, with mitigation measures as described in Section 4.

Based on the findings above the following recommendations are made if mining operations proceed:

- Emission rates from the dryer stack must comply with the Subcategory 5.2 (Drying) "New Plant" Minimum Emission Standards. The plant must be designed, or additional abatement equipment implemented, to make sure emission from the dryer stack are in compliance with these standards.
- Based on the dispersion modelling results, it is highly unlikely that daily average PM_{10} concentrations would be in compliance with the SA NAAQS at Vaal Oewer and other sensitive receptor locations to the north of Vaal river, especially during hot, dry and windy conditions, regardless of the mitigation measures employed, due to the relatively small distance between these receptors and the northern and south western aggregate resources.
- Based on simulated dust fallout rates, it is recommended that no mining activities, including crushing and screening, be undertaken within 400 m to the south, east and west of any sensitive receptor location and within 800m to the north of any sensitive receptor locations.
- It is recommended that, if possible, aggregate crushing not be conducted in the gravel pits but rather located closer to the plant and further from any sensitive receptor locations. If crushing is conducted at a fixed site rather than with a mobile crusher, better and more effective mitigation could be implemented on crushing and screening activities.
- It is recommended that any disturbed areas be immediately rehabilitated to avoid wind erosion emission during periods of high wind speeds.
- Best practice mitigation measures such as wind breaks and wet suppression must be implemented around in-pit material handling, crushing and screening activities. Air quality impacts at nearby sensitive receptor locations could be very high if mining operations proceed without adequate mitigation measures in place.
- A complaints register should be kept on-site as well as at secure locations in Vaal Oewer and Lindiquesdrift once operations commence. An example complaints register is shown in Table 16. Staff and the neighbouring communities should be encouraged to report all air quality related problems. Frequent community liaison meetings should be held with the neighbouring communities to address air quality related concerns. Complainants should be encouraged to note down as much details as possible regarding incidents, including the nature of incident, the approximate area where the incident occurs, the time of the incident and the perceived meteorological conditions during the incident.
- It is recommended that an on-site meteorological station be installed. The station could be used to pre-emptively apply additional mitigation measures during adverse meteorological conditions (such as periods with high winds). Additionally, recorded meteorological data can be used, together with monitoring data and the complaints register, to identify problem areas where additional mitigation might be required.
- Wet suppression techniques must be used to control dust emissions, especially in areas where dry material is handled or stockpiled. A Generac Dust Fighter has been proposed by the client for in-pit mitigation of dust emissions in both the sand and gravel pits.
- Exposed soils and other erodible materials should be re-vegetated, covered or otherwise rendered non-dust forming immediately;
- New areas should be cleared and opened-up only when absolutely necessary;
- Storage for dusty materials should be enclosed on at least three sides, or operated with efficient dust suppressing measures;
- Loading, transfer, and discharge of materials should take place with a minimum height of fall, and be shielded against the wind, and the use of dust suppression spray systems should be considered;

- Vehicles should be fitted with catalytic converters and low sulfur fuel should be used to minimise NO_2 and SO_2 impacts.
- Vehicle idle times should be kept to a minimum to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.
- Strict speed limits should be imposed to reduce entrained emissions and fuel consumption rates.
- The vehicle fleet should be regularly serviced and maintained to minimise CO, NO_2, SO_2, diesel particulate and greenhouse gas emissions.
- Older vehicles in the fleet should be regularly replaced with newer, more fuel-efficient alternatives where feasible.
- Based on the evaporation rate in the study area, the optimum watering rate on all unpaved roads is 20 litres per square meter of road per day to minimise dust emissions. It is recommended that a water bowser be employed with a watering rate of at least 650 litres per minute to ensure adequate mitigation of entrained dust from unpaved roads. It is furthermore recommended that chemical dust suppressants be applied to all roads at least once per month, but preferably every two weeks.
- Allowance should be made for the use of 1150 litres per minute (or 300 000 m² per annum) of water for dust suppression. This would be sufficient for a net watering rate of 10 mm/day on 48000 m² of roads (650 litres per minute) as well as the operation of two Generac Dust Fighters, each consuming 180 litres per minute of water. A further 150 litres per minute of water is allowed for mitigation on crushers, screens and conveyor transfer points.
- PM_{10} and dust fallout monitoring is recommended for the duration of the mining and rehabilitation phases. Dust fallout monitoring should be conducted at all recommended locations while PM_{10} monitoring can be moved to sample concentrations at the closest sensitive receptor locations. Monitoring of both dust fallout rates and PM_{10} concentrations should be started before the mining activities commence in order to establish baseline levels.
- If PM_{10} concentrations are found to be in exceedance of the NAAQS or dust fallout rates found to be in exceedance of the NDCR residential limit at the closest sensitive receptor locations additional dust suppression measures must be investigated and implemented timeously until recorded concentration and dust fallout rates are in compliance with the NAAQS and NDCR respectively. If the mitigation measures employed are considered best practise, additional offset measures should be considered. Such offset measures include upgrading of public road surfaces, electrification of houses for cooking and heating or supply of cleaner burning fuel for cooking and heating purposes. Offsets should be in line with the Air Quality Offsets Guidelines.

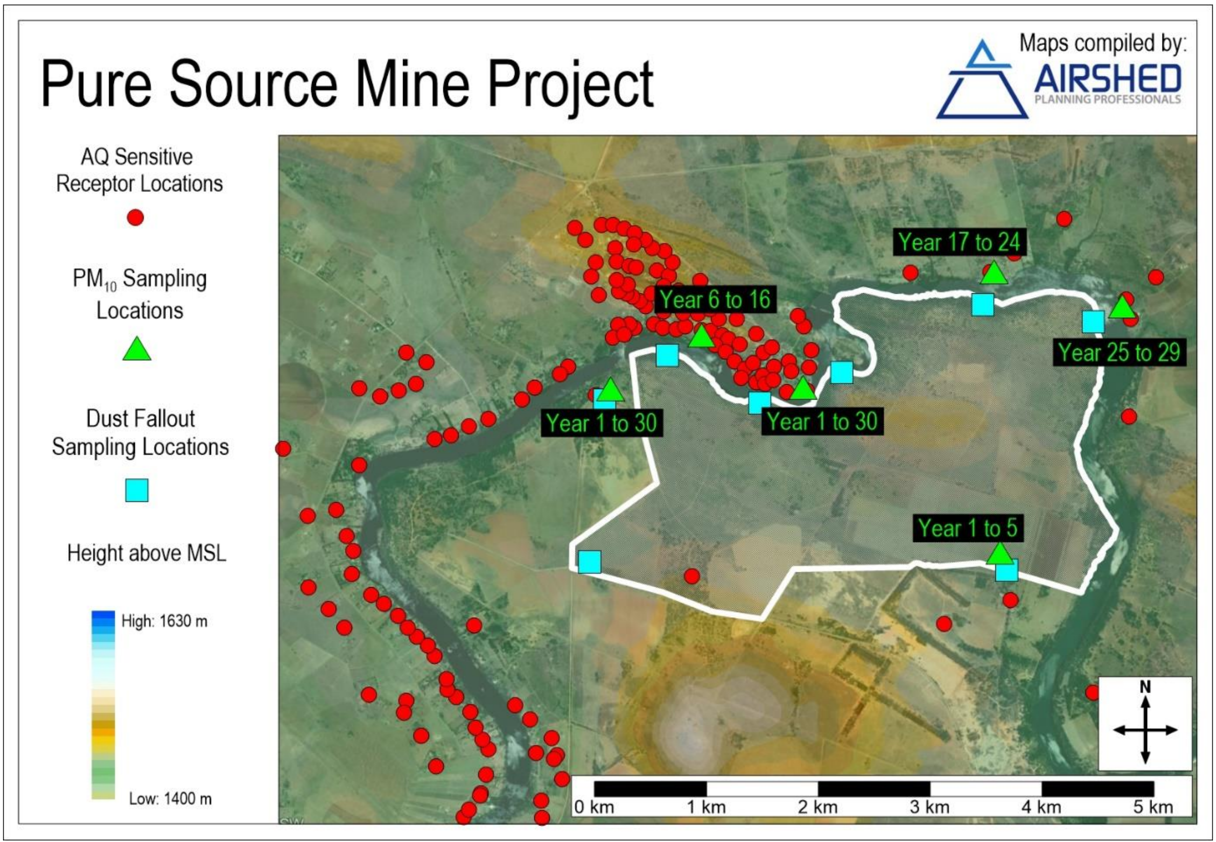


Figure 28: Recommended Dust Fallout and PM_{10} Monitoring Locations

- Diligent record should be kept of all mitigation measures implemented. This includes a water spray log book (Table 17) on unpaved haul roads and a cleaning logbook for paved areas or spillages where re-entrainment of dust might occur.
- A dust inspection logbook (an example is given in Table 18) should be established, with a dedicated officer conducting dust inspections during every shift.

Based on the findings and provided that all of the above recommendations, buffer zones, mitigation measures and monitoring measures are implemented, it is the specialist opinion that the project can be authorised.

A summary of mitigation, management and monitoring measures discussed above are given in the format requested by Shango Solutions in Table 19.

Table 16: Complaints Register Example

Complaint Number	Complainant	Contact Details	Date and Time	Description (as detailed as possible)	Results	Resolution
0	*Someone Example*	*082 111 1111 (someone@example.co.za)*	*20/12/2012 15:06*	*High fugitive dust levels were observed from the Aggregate Pit to the south west of Vaal Oewer. The wind was moderate and from the south at the time.*	*Exceptionally high wind speeds resulted in dust emissions from the material handling operations, this is a rare occurrence*	*Resolved*

Table 17: Water spray or cleaning logbook

Date			
Operator's name:			
Location	Water spray applied/Area cleaned		
	Frequency of watering	Frequency of cleaning	Problems
Access Road			
Road to sand pit			
Road to gravel pit			
Sand stockpiles			

Table 18: Dust inspection logbook

Date						
Inspector's name:						
Location	Surface dust assessment			Visible Dust Plume Assessment		
	Very little	Thin coating	Thick coating	No Visible Plume	Slightly Visible Plume	Clearly Visible Plume
Access Road						
Road to sand pit						
Road to gravel pit						
Stockpiles						
Washing and drying plant						

Table 19. Mitigation and Management measures including timeframes, roles and responsibilities

No.	Mitigation Measures	Phase	Timeframe	Responsible Party for Implementation	Monitoring Party (Frequency)	Target	Performance Indicators (Monitoring Tool)
Mitigation Measures							
A	Design of the drying plant (and possible corresponding abatement equipment) to ensure compliance with the Subcategory 5.1 New Plant Minimum Emission Standards	Planning and design. Construction	Prior to construction of the drying plant	Plant designers.	External – Annual monitoring or as per AEL issued by the licencing authority.	Compliance with the relevant MES	Compliance with the Subcategory 5.1 New Plant MES for particulate matter, SO_2 and NO_x
B	Best practise mitigation measures (as per recommendation in the section above) applied to mining, haul and material handling	Operation	Throughout lifespan of mine	Applicant Mining contractor	**As per monitoring recommendations below**		
C	Management and mitigation measures of vehicle fleet emissions as per section above	Construction Operation	During construction and throughout lifespan of mine	Applicant Mining contractor	**As per monitoring recommendations below**		
D	Covering and rehabilitation of any exposed areas to minimise wind erosion emissions.	Construction Operation Decommissioning Post closure	During and post mining operations	Applicant	**As per monitoring recommendations below**		
Monitoring Measures							

E	Monitoring of ambient PM_{10} concentrations at sensitive receptor locations	Pre-construction Construction Operation Decommissioning Post closure	Sampling to be conducted prior to construction to determine baseline levels. Sampling to be continued throughout the life of mine at the closest sensitive receptor locations	Applicant	External – Daily Sampling	Compliance with the SA NAAQS	Daily and annual PM_{10} concentrations should be in compliance with the SA NAAQS at all sensitive receptor locations, including at those closest to the mining operations. If PM10 concentrations exceed the SA NAAQS at the closest sensitive receptor locations additional mitigation measures should immediately be investigated and implemented
F	**Monitoring of dust fallout rates at the property boundary.**	**Pre-construction** **Construction** **Operation** **Decommissioning** **Post closure**		**Applicant**	**External – Monthly Sampling**	**Compliance with the SA NDCR**	Monthly dust fallout rates should be below the SA NDCR non-residential limit at the property boundary and below the SA NDCR residential limit at all sensitive receptor locations.
G	Frequent dust inspections, diligent record keeping of mitigation measures, detailed complaints register, meteorological monitoring	**Operation**	**Throughout lifespan of mine**	Applicant	Mine Manager – per Shift	Compliance with the SA NAAQS and NDCR limits.	Limited complaints from surrounding communities.

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9 APPENDIX A - EFFECT OF DUST ON VEGETATION, ANIMALS AND SUSCEPTIBLE HUMAN RECEPTORS

9.1 Effects of Particular Matter on Vegetation

Since plants are constantly exposed to air, they are the primary receptors for both gaseous and particulate pollutants of the atmosphere. In terrestrial plant species, the enormous foliar surface area acts as a natural sink for pollutants especially the particulate ones. Vegetation is an effective indicator of the overall impact of air pollution particularly in context of Particulate matter (PM) (Rai, 2016).

There are two main types of direct injury that PM pollution can cause on plants: acute and chronic injury. Acute injury results from exposure to a high concentration of gas for a relatively short period and is manifested by clear visible symptoms on the foliage, often in the form of necrotic lesions. While this type of injury is very easy to detect (although not necessarily to diagnose), chronic injury is subtler: it results from prolonged exposure to lower gas concentrations and takes the form of growth and/or yield reductions, often with no clear visible symptoms. Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. It reported that depending on their sensitivity level, plants show visible changes which would include alteration in the biochemical processes or accumulation of certain metabolites (Rai, 2016). Pollutants can cause leaf injury, stomatal damage (Ricks and Williams, 1974, Hirano et al., 1995; Naidoo and Chirkoot; 2004; Harmens et al., 2005), premature senescence, decrease photosynthetic activity, disturb membrane permeability (Ernst, 1981; Naidoo and Chirkoot, 2004; Harmens et al., 2005) and reduce growth and yield in sensitive plant species. The long term, low-concentration exposures of air pollution produces harmful impacts on plant leaves without visible injury. Several studies have been conducted to assess the effects of pollution on different aspects of plant life such as overall growth and development, foliar morphology, anatomy, and bio chemical changes (Rai, 2016).

Plant leaves are the primary receptors for both gaseous and PM pollutants of the atmosphere. Before these pollutants enter the leaf tissue, they interact with foliar surface and modify its configuration. Dust deposition on leaf surface, consisting of ultra-fine and coarse particles, showed reduction in plant growth through its effect on leaf gas exchange, flowering and reproduction of plants, number of leaves and leaf area, one of the most common driving variables in growth analyses. Reduction in leaf area and leaf number may be due to decreased leaf production rate and enhanced senescence (Rai, 2016).

The chemical composition of the dust particles can also affect exposed plant tissue and have indirect effects on the soil pH (Spencer, 2001).

To determine the impact of dust deposition on vegetation, two factors are of importance: (i) Does dust accumulate on vegetation surfaces and if it does, what are the factors influencing the rate of deposition (ii) Once the dust has been deposited, what is the impact of the dust on the vegetation? Regarding the first question, there is adequate evidence that dust does accumulate on all types of vegetation. Any type of vegetation causes a change in the local wind fields, increasing turbulence and enhancing the collection efficiency. Vegetation structure alters the rate of dust deposition such that the larger the "collecting elements" (branches and leaves), the lower the impaction efficiency per element. Therefore, for the same volume of tree/shrub canopy, finer leaves will have better collection efficiencies. However, the roughness of the leaves themselves, in particularly the presence of hairs on the leaves and stems, plays a significant role, with venous surfaces increasing deposition of 1-5 µm particles by up to seven-times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size for moderate wind speeds (Tiwary and Colls, 2010). Wind tunnel studies also show that windbreaks or "shelter belts" of three rows of trees have a decrease of between 35 and 56% of the downwind mass transport of inorganic particles.

After deposition onto vegetation, the effect of particulate matter depends on the composition of the dust. South African ambient standards are set in terms of $PM_{2.5}$ and PM_{10} (particulate matter smaller than 2.5 µm and 10 µm aerodynamic diameter) but internationally it is recognised that there are major differences in the chemical composition of the fine PM (the fraction between 0 and 2.5 µm in aerodynamic diameter) and coarse PM (the fraction between 2.5 µm and 10 µm in aerodynamic diameter). The former is often the result of chemical reactions in the atmosphere and may have a high proportion of black carbon, sulfate and nitrate; whereas the latter often consists of primary particles as a result of abrasion, crushing, soil disturbances and wind erosion (Grantz et al., 2003). Sulfate is however often hygroscopic and may exist in significant fractions in coarse PM. This has been shown at the Elandsfontein Eskom air quality monitoring station where the PM_{10} has been shown to vary between

15% (winter) and 49% (spring) sulfate (Alade, 2010). Grantz et al. (op. cit.) however indicate that sulfate is much less phototoxic than gaseous sulfur dioxide and that "it is unusual for injurious levels of particular sulfate to be deposited upon vegetation".

According to the Canadian Environmental Protection Agency (CEPA), generally air pollution adversely affects plants in one of two ways. Either the quantity of output or yield is reduced, or the quality of the product is lowered. The former (invisible) injury results from pollutant impacts on plant physiological or biochemical processes and can lead to significant loss of growth or yield in nutritional quality (e.g. protein content). The latter (visible) may take the form of discolouration of the leaf surface caused by internal cellular damage. Such injury can reduce the market value of agricultural crops for which visual appearance is important (e.g. lettuce and spinach). Visible injury tends to be associated with acute exposures at high pollutant concentrations whilst invisible injury is generally a consequence of chronic exposures to moderately elevated pollutant concentrations. However, given the limited information available, specifically the lack of quantitative dose-effect information, it is not possible to define a reference level for vegetation and particulate matter (CEPA, 1998).

Exposure to a given concentration of airborne PM may therefore lead to widely differing phytotoxic responses, depending on the mix of the deposited particles. The majority of documented toxic effects indicate responses to the chemical composition of the particles. Direct effects have most often been observed around heavily industrialised point sources, but even there, effects are often associated with the chemistry of the particulate rather than with the mass of particulate. A review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dust fall rates greater than 400 mg/m²/day. Little direct evidence of the effects of dust-fall on South African vegetation, including crops, exists.

9.2 Effects of Particulate Matter on Animals

As presented by the Canadian Environmental Protection Agency (CEPA, 1998) studies using experimental animals have not provided convincing evidence of particle toxicity at ambient levels. Acute exposures (4-6 hour single exposures) of laboratory animals to a variety of types of particles, almost always at concentrations well above those occurring in the environment have been shown to cause:

- decreases in ventilatory lung function;
- changes in mucociliary clearance of particles from the lower respiratory tract (front line of defence in the conducting airways);
- increased number of alveolar macrophages and polymorphonuclear leukocytes in the alveoli (primary line of defence of the alveolar region against inhaled particles);
- alterations in immunologic responses (particle composition a factor, since particles with known cytotoxic properties, such as metals, affect the immune system to a significantly greater degree);
- changes in airway defence mechanisms against microbial infections (appears to be related to particle composition and not strictly a particle effect);
- increase or decrease in the ability of macrophages to phagocytize particles (also related to particle composition);
- a range of histologic, cellular and biochemical disturbances, including the production of proinflammatory cytokines and other mediators by the lung's alveolar macrophages (may be related to particle size, with greater effects occurring with ultrafine particles);
- increased electrocardiographic abnormalities (an indication of cardiovascular disturbance); and
- increased mortality.

Bronchial hypersensitivity to non-specific stimuli, and increased morbidity and mortality from cardio-respiratory symptoms, are most likely to occur in animals with pre-existing cardio-respiratory diseases. Sub-chronic and chronic exposure tests involved repeated exposures for at least half the lifetime of the test species. Particle mass concentrations to which test animals were exposed were very high (> 1 mg m-³), greatly exceeding levels reported in the ambient environment. Exposure resulted in significant compromises in various lung functions similar to those seen in the acute studies, but including also:

- reductions in lung clearance;

- induction of histopathologic and cytologic changes (regardless of particle types, mass, concentration, duration of exposure or species examined);
- development of chronic alveolitis and fibrosis; and
- development of lung cancer (a particle and/or chemical effect).

The epidemiological finding of an association between 24-hour ambient particle levels below 100 µg/m³ and mortality has not been substantiated by animal studies as far as PM_{10} and $PM_{2.5}$ are concerned. At ambient concentrations, none of the other particle types and sizes used in animal inhalation studies result in acute effects, including high mortality, with exception of ultrafine particles (0.1 µm). The lowest concentration of $PM_{2.5}$ reported that caused acute death in rats with acute pulmonary inflammation or chronic bronchitis was 250 g/m³ (3 days, 6 hour day-1), using continuous exposure to concentrated ambient particles.

Most of the literature regarding air quality impacts on cattle refers to the impacts from feedlots on the surrounding environment, hence where the feedlot is seen as the source of pollution. This mainly pertains to odours and dust generation. The US-EPA recently focussed on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter. However, the link between particulates and public health is considered to be understudied (Sneeringer, 2009).

A study was conducted by the State University of Iowa on the effects of air contaminants and emissions on animal health in swine facilities. Air pollutants included gases, particulates, bioaerosols, and toxic microbial by-products. The main findings were that ammonia is associated with lowered average number of pigs weaned, arthritis, porcine stress syndrome, muscle lesions, abscesses, and liver ascarid scars. Particulates are associated with the reduction in growth and turbine pathology, and bioaerosols could lower feed efficiency, decrease growth, and increase morbidity and mortality. The authors highlighted the general lack of information on the health effects and productivity-problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulfide are regarded the two most important inorganic gases affecting the respiratory system of cattle raised in confinement facilities, affecting the mucociliary transport and alveolar macrophage functions. Holland et al., (2002) found that the fine inhalable particulate fraction is mainly derived from dried faecal dust.

Inhalation of confinement-house dust and gases produces a complex set of respiratory responses. An individual's response depends on characteristics of the inhaled components (such as composition, particle size and antigenicity) and of the individual's susceptibility, which is tempered by extant respiratory conditions (Davidson et al., 2005). Most studies concurred that the main implication of dusty environments is the stress caused to animals which is detrimental to their general health. However, no threshold levels exist to indicate at what levels these are having a negative effect. In this light it was decided to use the same screening criteria applied to human health, i.e. the South African Standards and SANS limit values.

9.3 Effect of Particulate Matter on Susceptible Human Receptors

The impact of particles on human health is largely depended on particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. These larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. The smaller particles (PM_{10}) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Then particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA, 1998; Dockery and Pope, 1994).

The air quality guidelines for particulates are given for various particle size fractions, including TSP, thoracic particulates or PM_{10}, and respirable particulates or $PM_{2.5}$. Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. The PM_{10} and $PM_{2.5}$ are of concern due to their health impact potentials. As indicated previously, such fine particles are deposited in, and damage the lower airways and gas-exchanging portions of the lung.

The World Health Organization states that the evidence on airborne particulates and public health consistently shows adverse health effects at exposures experienced by urban populations throughout the world. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending from children to adults including large susceptible groups within the general population. Long-term exposure to particulate matter has been found to have adverse effects on human respiratory health (Abbey et al., 1995). Respiratory symptoms in children resident in an industrialised city were initially found not to be associated with long-term exposure to particulate matter; however non-asthmatic symptoms and hospitalizations did increase with increased total suspended particulate concentrations (Hruba et al., 2001). Subsequently, epidemiological evidence shows adverse effects of particles after both short-term and long-term exposures. Current scientific evidence indicates that guidelines cannot be proposed that will lead to complete protection against adverse health effects as thresholds (or no adverse effect levels (NOAEL) have not been identified.

Many scientific studies have linked inhaled particulate matter to a series of significant health problems, including:

- Aggravated asthma and associated hospitalisation or emergence department admission, even for coarse particulate ($PM_{2.5}$ to PM_{10}) (Keet et al 2017);
- Hospital admissions for respiratory and cardiovascular diseases associated with fine particulate ($PM_{2.5}$) exposure, even at levels consistently below limit values (Makar et al 2017)
- Kidney, bladder and colorectal cancer (Turner et al 2017)
- Ischaemic heart disease (Lim et al 2015)
- Increases in respiratory symptoms like coughing and difficult or painful breathing;
- Chronic bronchitis;
- Decreased lung function; and,
- Premature death.

PM_{10} is the standard measure of particulate air pollution used worldwide and studies suggest that asthma symptoms can be worsened by increases in the levels of PM_{10}, which is a complex mixture of particle types. PM_{10} has many components and there is no general agreement regarding which component(s) could exacerbate asthma. However, pro-inflammatory effects of transition metals, hydrocarbons, ultrafine particles (due to combustion processes) and endotoxins - all present to varying degrees in PM_{10} - could be important.

Exposure to motor traffic emissions can have a significant effect on respiratory function in children and adults. Studies show that children living near heavily travelled roadways have significantly higher rates of wheezing and diagnosed asthma.

APPENDIX B – SIGNIFICANCE RATING METHODOLOGY

Method of Assessing Impacts

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2014). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Determination of Environmental Risk

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER).

The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the nature (N), extent (E), duration (D), magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E+D+M+R)}{4} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 1.

Table 1: Criteria for determining impact consequence.

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary)
	3	Local (i.e. the area within 5 km of the site)
	4	Regional (i.e. extends between 5 and 50 km from the site)

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Aspect	Score	Definition
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years)
	3	Medium term (6-15 years)
	4	Long term (the impact will cease after the operational life span of the project)
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction)
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected)
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way)
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease)
	5	Very high/don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease)
Reversibility	1	Impact is reversible without any time and cost
	2	Impact is reversible without incurring significant time and cost
	3	Impact is reversible only by incurring significant time and cost
	4	Impact is reversible only by incurring prohibitively high time and cost
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table 2.

Table 2: Probability scoring.

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%)
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%)
	3	Medium probability (the impact may occur; >50% and <75%)
	4	High probability (it is most likely that the impact will occur- > 75% probability)
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact (Table 3). ER is therefore calculated as follows:

ER= C x P

Table 3: Determination of environmental risk.

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 4.

Table 4: Significance classes.

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk)

≥9 and <17	Medium (i.e. where the impact could have a significant environmental risk)
≥ 17	High (i.e. where the impact will have a significant environmental risk)

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation

In accordance with Appendix 1 of the NEMA 2014 EIA Regulations (GN R.982, as amended), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts
- The degree to which the impact may cause irreplaceable loss of resources

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented (Table 5).

Table 5: Criteria for determining prioritisation.

Public response (PR)	Low (1)	Issue not raised in public response
	Medium (2)	Issue has received a meaningful and justifiable public response
	High (3)	Issue has received an intense meaningful and justifiable public response
Cumulative impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change
	High (3)	Considering the potential incremental, interactive, sequential,

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		and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions)

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 5.

The impact priority is therefore determined as follows:

Priority = PR + CI + LR

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Table 6).

Table 6: Determination of prioritisation factor.

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance (Table 7).

Table 7: Final environmental significance rating.

Environmental Significance Rating	
Value	Description
< -10	Low Negative (i.e. where this impact would not have a direct influence on the decision to develop in the area)
≥ -10 and < -20	Medium Negative (i.e. where the impact could influence the decision to develop in the area)
≥ -20	High Negative (i.e. where the impact must have an influence on the decision process to develop in the area)
< 10	Low Positive (i.e. where this impact would not have a direct influence on the decision to develop in the area)
≥ 10 and < 20	Medium Positive (i.e. where the impact could influence the decision to develop in the area)
≥ 20	High Positive (i.e. where the impact must have an influence on the decision process to develop in the area)

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.