Air Quality Impact Assessment for Activities at the Sasol Sigma Mooikraal 3 Shaft Complex

Project done for **Digby Wells & Associates (Pty) Ltd**

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Rochelle Bornman started her professional career in Air Quality in 2008 when she joined Airshed Planning Professionals (Pty) Ltd after having worked in malaria research at the Medical Research Council in Durban. Rochelle has worked on several air quality specialist studies between 2008 and 2018. She has experience on the various components including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality. Whilst most of his working experience has been in South Africa, a number of investigations were made in countries elsewhere, including Mozambique, Namibia, Saudi Arabia and Mali.

NEMA Regulation (2014), Appendix 6

NEMA Regulations (2014) - Appendix 6	**Relevant section in report**
Details of the specialist who prepared the report.	Report details (page ii)
The expertise of that person to compile a specialist report including curriculum vitae.	Report details (page ii) Appendix A
A declaration that the person is independent in a form as may be specified by the competent authority.	Report details (page i)
An indication of the scope of, and the purpose for which, the report was prepared.	Introduction and background (Executive Summary) Section 1.2: Scope of Work Section 1.4: Project Approach and Methodology
The date and season of the site investigation and the relevance of the season to the outcome of the assessment.	Section 3.2: Atmospheric Dispersion Potential Section 3.4: Measured ambient concentrations and dustfall levels
A description of the methodology adopted in preparing the report or carrying out the specialised process.	Introduction and background (Executive Summary) Section 1.4: Project Approach and Methodology Section 4.2: Atmospheric Dispersion Modelling
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure.	Section 3.1: Receiving Environment
An identification of any areas to be avoided, including buffers.	Not applicable
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers.	Section 3.1: Receiving Environment
A description of any assumptions made and any uncertainties or gaps in knowledge.	Section 1.5: Assumptions and Limitations
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment.	Section 4: Impact Assessment This assessment investigates the impacts of the Operational Phase (baseline scenario) and Operational Phase (project scenario)
Any mitigation measures for inclusion in the environmental management programme report	Section 6: Air Quality Management Measures
Any conditions for inclusion in the environmental authorisation	Section 6: Air Quality Management Measures
Any monitoring requirements for inclusion in the environmental management programme report or environmental authorisation.	Section 6: Air Quality Management Measures
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised.	Section 7.2: Conclusion
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the environmental management programme report, and where applicable, the closure plan.	Section 6: Air Quality Management Measures Section 7.3: Recommendations
A description of any consultation process that was undertaken during the course of carrying out the study.	Not applicable
A summary and copies if any comments that were received during any consultation process.	Not applicable.
Any other information requested by the competent authority.	Not applicable.

Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
APPA	Air Pollution Prevention Act
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
AQSR	Air Quality Sensitive Receptors
ASTM	American Standard Testing Method
DEA	Department of Environmental Affairs
EHS	Environmental, Health, and Safety (IFC)
EIA	Environmental Impact Assessment
ERP	Environmental Regulatory Process
GLC	Ground Level Concentration
I&APs	Interested and Affected Parties
IFC	International Finance Corporation
Ltd	Limited
NAAQS	National Ambient Air Quality Standard
NDCR	National Dust Control Regulations
NEMAQA	National Environment Management Air Quality Act
NPI	National Pollutant Inventory (Australia)
Pty	Proprietary
ROM	Run-of-mine
SABS	South African Bureau of Standards
SANS	South African National Standards
SA NAAQS	South African National Ambient Air Quality Standards
SA NDCR	South African National Dust Control Regulations
SoW	Scope of Work
SSO	Sasol Sasolburg Operations
US EPA	United States Environmental Protection Agency
VTAPA	Vaal Triangle Air-shed Priority Area
WBG	World Bank Group
WHO	World Health Organisation

Symbols and Units

°C	Degrees Celsius
µg	Microgram(s)
µg/m³	Micrograms per cubic meter
km	kilometres
L_{MO}	Monin-Obukhov Length
m	metres
m/s	Meters per second
m²	Metres squared
masl	Meters above sea level
mg	Milligram(s)
mg/m²/day	Milligram per metre squared per day
mm	Millimetres
Mtpa	million tons per annum
PM	Particulate Matter
PM_{10}	Thoracic particulate matter
$PM_{2.5}$	Respirable particulate matter
tpa	Tonnes per annum
tpd	Tonnes per day
tpm	Tonnes per month
TSP	Total Suspended Particulate
%	Percentage

Glossary

Air pollution	This means any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances
Ambient air	This is defined as any area not regulated by Occupational Health and Safety regulations
Atmospheric emission or emission	Any emission or entrainment process emanating from a point, non-point or mobile source that results in air pollution
Averaging period	This implies a period of time over which an average value is determined
Dispersion	The spreading of atmospheric constituents, such as air pollutants
Dust	Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size
Frequency of exceedance	A frequency (number/time) related to a limit value representing the tolerated exceedance of that limit value, i.e. if exceedances of limit value are within the tolerances, then there is still compliance with the standard
Mechanical mixing	Any mixing process that utilizes the kinetic energy of relative fluid motion
Particulate Matter (PM)	These comprise a mixture of organic and inorganic substances, ranging in size and shape. These can be divided into coarse and fine particulate matter. The former is called Total Suspended Particulates (TSP), whilst PM_{10} and $PM_{2.5}$ fall in the finer fraction.
PM_{10}	Particulate Matter with an aerodynamic diameter less than or equal to 10 µm. it is also referred to as thoracic particulates and is associated with health impacts due to its tendency to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than or equal to 2.5 µm. it is also referred to as respirable particulates. It is associated with health impacts due to its high tendency to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung
Vehicle entrainment	This is the lifting and dropping of particles by the rolling wheels leaving the road surface exposed to strong air current in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed

Executive Summary

Sigma Colliery Mooikraal (Mooikraal) is a subsidiary of Sasol Mining (Pty) Ltd and situated in the Sasolburg area. Mooikraal is currently an operational underground coal mine which produces approximately 1.5 million tonnes of coal per annum.

The run of mine (ROM) coal is transported from Mooikraal via an overland conveyor system, within an existing Sasol Mining servitude, to the coal handling facility/plant at the Sigma Colliery 3 Shaft complex. ROM coal is crushed and screened at 3 Shaft prior to being transported to Sasol`s Sasolburg Operations at a rate of 8,000 tonnes per day (tpd) for further industrial use.

Mooikraal is proposing to:

- Demolish the existing conveyor belts, crushing facility and coal bunker situated in the delineated wetland area and establish a new crushing facility with the latest technology south of the existing stockpile area well outside the wetland area in order to implement best practice water and dust management principles;
- Reconfigure the conveying arrangement at 3 Shaft;
- Clean-up and rehabilitate the already disturbed wetland area once the new infrastructure has been established; and
- Improve the coal blending on the current stockpile area.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Digby Wells & Associates to conduct an air quality impact assessment study as part of the Environmental Regulatory Process (ERP).

The main objective of the investigation is to quantify the potential impacts resulting from the proposed activities on the surrounding environment and human health. A specific concern is windblown dust from the coal stockpile resulting in dust deposition and potential health impacts in the nearby residential area of Zamdela. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the current and potential future air quality.

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

- A desktop air quality impact study, including:
  - A review and identification of legal requirements pertaining to air quality;
  - A desktop study of the receiving atmospheric environment (baseline) incl.:
    - the identification of air quality sensitive receptors;
    - an analysis of regional climate and site-specific atmospheric dispersion taking into account local meteorology, land-use and topography; and
    - and analysis and assessment of existing (baseline) ambient air quality data (if available).

- The establishment of the Sasol Sigma Mooikraal 3 Shaft Complex operations' emissions inventory (current and future);
- Atmospheric dispersion simulations for the Sasol Sigma Mooikraal 3 Shaft Complex operations (pre- and post-mitigation);
- A human health risk and nuisance impact screening assessment based on dispersion simulation results;
- An Air Quality Impact Assessment (AQIA) Report as part of the Environmental Regulatory Process in the prescribed specialist report format.

Air quality impacts are associated with four distinct phases namely: the construction phase, the operational phase (current), the operational phase (future) and the closure and post-closure phase.

Construction phase activities include bulk earthworks (for the establishment of topsoil stockpiles, conveyor belt, haul routes and rehabilitation of wetland), as well as metal and concrete works for the crusher facility including stormwater management.

Operational phase (current): Crushing and screening at the current location of primary plant, of 1.5 million tonnes per annum (Mtpa) coal from Mooikraal Colliery and 200 000 tonnes per annum (tpa) imported coal.

Operational phase (future): Crushing and screening at the future location of primary plant, of 1.5 Mtpa coal from Mooikraal Colliery and 200 000 tpa imported coal.

During ***closure***, bulk earthworks and demolishing activities are expected. Very little information regarding the decommissioning phase was available for consideration, from an air quality perspective it is however likely to be similar in character and impact to the construction phase.

Due to the lack of detailed information and the relatively short duration of most of the activities associated with the construction, closure and post-closure phases, the assessment of impacts for these phases was done qualitatively.

A quantitative assessment was done for the operational phase. Emissions were quantified for current activities at the 3 Shaft Complex (where design mitigation is already applied). For the future scenario, emissions due to design mitigated activities at the new plant were quantified, and two options for additional mitigation were explored, viz. the use of (i) windbreaks, and (ii) fog cannons at the easternmost fence perimeter to mitigate windblown dust from the project site.

The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels and determination of the significance of impacts.

Main Findings

The findings from the baseline assessment can be summarised as follows:

- The prevailing wind field in the area consists of easterly and westerly winds, with infrequent winds from the south and south-east. During the day the winds were predominantly from the northwest to southwest, with the strongest winds from the northwest. The wind conditions shifted during the night-time with strong winds predominantly from the east-northeast and easterly directions. Day-time calms occurred for 11.77% of the time, with night-time calms for 11.34% of the time.
- The area experiences hot summers and cold winters with an average annual rainfall of 550 mm.
- Ambient air pollutant levels in the project area are currently affected by the following sources of emission: petrochemical processes (Sasol and Natref); domestic fuel burning, windblown dust emissions from ash dumps, vehicle tailpipe emissions and agriculture.
- Air quality sensitive receptors (AQSRs) around the project site include schools, hospitals and clinics, as well as the residential areas of Zamdela to the southeast, and Sasolburg to the north.
- Monitoring data from the Department of Environmental Affairs (DEA) Zamdela site (approximately 1.75 km from the project site) for the period January 2015 to December 2017 was analysed. The daily 99th percentiles for PM_{10} exceed the limit value (75 µg/m³) at Zamdela station for all three years, where non-compliance varied between 15% and 30% of the three years assessed.
- Time variation plots (mean with 95% confidence interval) of ambient particulate matter (PM_{10} and $PM_{2.5}$) concentrations measured at Zamdela station were created to show the variation of these pollutants over a daily, weekly and annual cycle. Monthly variation of particulate matter shows elevated concentrations during winter months due to the larger contribution from domestic fuel burning, dust from uncovered soil and the lack of the settling influence of rainfall.

The impact of the proposed Project can be summarized as follows:

<u>Construction phase:</u>

- Likely activities to result in dust impacts during construction are: Infrastructure removal/demolition of existing primary plant infrastructure; topsoil recovered from stockpiles for rehabilitation and re-vegetation of the old primary plant surroundings; construction of new plant infrastructure and buildings; construction of the conveyor belt within 3 shaft, scraping of topsoil and clearing of land to build the new primary plant; and vehicle entrainment on unpaved roads during construction.
- Construction: the impacts are expected to be **Low**.

<u>Operational phase (Scenario 1):</u>

- The main source of design mitigated emissions for $PM_{2.5}$ is crushing (63.8%); windblown dust from the coal stockpile for PM_{10} (45.3%) and unpaved roads for TSP (44.4%). The second most significant source is unpaved roads for $PM_{2.5}$ and PM_{10} (23.1% and 29.0% respectively), and windblown dust from the coal stockpile for TSP (28.3%).

- The main source of impact during the baseline is roads (for PM_{10}) and crushing (for $PM_{2.5}$). For daily dustfall rates the main source of impact is windblown dust from the coal stockpile at 9 receptors within 1.8 km of the Project boundary (viz. SR9-SR11, SR13, SR16-SR17, SR20, and SR22-SR23) and 2 receptors further afield (SR25-SR26); at the other 15 receptors (5 receptors to the east and all 10 receptors to the north of the Project boundary) the main source of impact is unpaved roads. Values simulated at sensitive receptors were within compliance for all pollutants.
- Mitigation measures assumed during Scenario 1 are: water sprays on haul roads and materials transfer points; covering of conveyor transfer points and enclosure of secondary crushing and screening.
- Scenario 1 (baseline) operations resulted in ***Low*** impact significance for design mitigated activities. This applies to $PM_{2.5}$ and PM_{10} concentrations, as well as dustfall rates.
- Background concentrations – contribution from sources other than the current activities at 3 Shaft – were estimated by comparing modelled hourly concentrations against measured hourly concentrations at the ranked position. It was found that the activities at 3 Shaft are not likely to contribute to ambient PM_{10} concentrations measured at the DEA Zamdela monitoring station (located 1.7 km to the southeast of the Project site) and that background air quality at Zamdela are likely from other sources in the area.

Operational phase (Scenario 2):

- Similar as for Scenario 1, the main source of design mitigated emissions for $PM_{2.5}$ is crushing (68.7%); windblown dust from the coal stockpile for PM_{10} (49.8%) and unpaved roads for TSP (36.0%). The second most significant source is unpaved roads for $PM_{2.5}$ and PM_{10} (17.4% and 22.3% respectively), and windblown dust from the coal stockpile for TSP (32.8%).
- The source contributions for $PM_{2.5}$ and PM_{10} impacts are the same as those discussed for Scenario 1. For daily dustfall rates, the source contributions for Scenarios 2a and 2b remain the same as for the baseline scenario, but for Scenario 2c the main source contributor is unpaved roads at 25 of the 26 AQSRs, with windblown dust the main source of impact only at SR17. Values simulated at sensitive receptors were within compliance for all pollutants and for all three sub-scenarios.
- Mitigation measures assumed during Scenario 2 are: Design mitigation (water sprays on haul roads and materials transfer points; covering of conveyor transfer points and enclosure of secondary crushing and screening) for Scenario 2a; design mitigation and windbreaks for Scenario 2b; and design mitigation and fog cannons for Scenario 2c.
- Scenario 2 operations resulted in ***Low*** impact significance for Scenario 2a, Scenario 2b and Scenario 2c. This applies to $PM_{2.5}$ and PM_{10} concentrations, as well as dustfall rates.

Closure and post-closure phases:

- Likely activities to result in dust impacts during closure are: Infrastructure removal/demolition; topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings; and vehicle entrainment on unpaved road surfaces during rehabilitation – once that is done, vehicle activity associated with the operations should cease.

- Closure and Post-closure: the impacts are expected to be **Low**.

Conclusion

The proposed Sasol Mooikraal Shaft 3 Complex operations are likely to result in ground level PM_{10} concentrations and dustfall levels which are within the daily SA NAAQS and NDCR for residential areas with design mitigation measures in place. With additional mitigation measures in place (the application of wind breaks and/or the installation of fog cannons on the fence perimeter), the $PM_{2.5}$, PM_{10} and dustfall impacts reduce only slightly. From an air quality perspective, the proposed project can be authorised permitted the recommended mitigation measures are applied.

Recommendations

A summary of the recommendations and management measures is given below:

- The implementation of emission controls for the management of emission sources, such as the onsite coal stockpile, as well as the crusher and unpaved haul roads. These include:
  - Limiting the speed of haul trucks; limiting unnecessary travelling of vehicles on untreated roads; and application of water sprays on unpaved road sections, as well as materials handling and exposed areas to wind erosion during construction and closure phase;
  - Water sprays, or other dust control measures, at all material transfer points that would result in at least 50% control efficiency.
  - Side and top cover at the conveyor system and controlling dust from secondary crushing and screening operations through enclosure.
- Undertaking a 3-month PM_{10} and $PM_{2.5}$ sampling campaign at the Zamdela residential AQSR (SR20) to measure the immediate air quality impacts occurring as a result of 3 Shaft activities. An E-Sampler should be used to obtain hourly concentrations coupled with an anemometer to record wind speed and wind direction. Creating a polar plot from the results will provide a clear indication on the actual contribution from the 3 Shaft project on the closest receptors. This will inform decision making on whether to apply additional control measures to reduce windblown dust from the coal stockpile.
- Continuous monitoring of dustfall must be conducted as part of the Project's air quality management plan.

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1 Introduction

Sigma Colliery Mooikraal (Mooikraal) is a subsidiary of Sasol Mining (Pty) Ltd and situated in the Sasolburg area within the Fezile Dabi District Municipality in the Free State Province. Mooikraal is currently an operational underground coal mine which produces approximately 1.5 million tonnes of coal per annum.

The run of mine (ROM) coal is transported from Mooikraal via an overland conveyor system, within an existing Sasol Mining servitude, to the coal handling facility/plant at the Sigma Colliery: 3 Shaft ("3 Shaft") complex. The extent of this conveyor is approximately 18 km. ROM coal is crushed and screened prior to being stockpiled at 3 Shaft. The coal is transported to Sasol`s Sasolburg Operations (SSO) at a rate of 8,000 tonnes per day (tpd) for further industrial use.

Mooikraal is proposing to:

- Demolish the existing conveyor belts, crushing facility and coal bunker situated in the delineated wetland area and establish a new crushing facility with the latest technology south of the existing stockpile area well outside the wetland area in order to implement best practice water and dust management principles;
- Reconfigure the conveying arrangement at 3 Shaft;
- Clean-up and rehabilitate the already disturbed wetland area once the new infrastructure has been established; and
- Improve the coal blending on the current stockpile area.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Digby Wells & Associates to conduct an air quality impact assessment study as part of the Environmental Regulatory Process (ERP).

1.1 Study Objective

The main objective of the investigation is to quantify the potential impacts resulting from the proposed activities on the surrounding environment and human health. A specific concern is windblown dust from the coal stockpile resulting in dust deposition and potential health impacts in the nearby residential area of Zamdela. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the current and potential future air quality. The layout of the current and future project site (once the new crushing facility and conveyor infrastructure have been established) is provided in Figure 1.

1.2 Scope of Work

Based on the required scope, the following tasks have been identified:

- A desktop air quality impact study, including:
    - A review and identification of legal requirements pertaining to air quality;
    - A desktop study of the receiving atmospheric environment (baseline) incl.:

        - the identification of air quality sensitive receptors;
        - an analysis of regional climate and site-specific atmospheric dispersion taking into account local meteorology, land-use and topography; and
        - analysis and assessment of existing (baseline) ambient air quality data (if available).
    - The establishment of the Sasol Sigma Mooikraal Colliery (3 Shaft Complex) operations' emissions inventory (current and future);
    - Atmospheric dispersion simulations for the Sasol Sigma Mooikraal Colliery (3 Shaft Complex) operations (pre- and post-mitigation);
    - A human health risk and nuisance impact screening assessment based on dispersion simulation results;
    - An Air Quality Impact Assessment (AQIA) Report as part of the Environmental Regulatory Process (ERP) process in the prescribed specialist report format.

1.3 Description of Plant Activities from an Air Quality Perspective

Primary processing of coal

Run of mine coal from Mooikraal is transported by overland conveyor to 3 Shaft, the coal enters 3 Shaft via MK8 belt, the MK 8 belt splits to either MK9 or MK 10, the latter is a belt which feeds the 4 Shaft bunker. Ultimately coal enters the crusher via CP4 belt. The crusher crushes and sizes the coal prior to stockpiling the coal on the stockpile area.

Stockpiling of coal

The crushed coal leaves the crusher and passes through a sieve/ screen and a magnet. The coal enters the stockpile via CO2 belt and ultimately is stacked on the stockpile via a stacker/ reclaimer on the CO3 belt. The ROM coal is handled and blended on the stockpile manually with front end loaders, the ROM coal is blended with import coal with a lower ash content, in order to meet contractual requirements.

Imported coal arrives at 3 Shaft via 30 ton haul trucks which passes over a weighbridge, and travels along the unpaved haul road, which runs parallel with the perimeter fence, the trucks offload the import coal on the stockpile area. Various mobile crushers are present on the stockpile area to crush and size the blended coal. The blended coal (coal at the correct ash percentage) is manually loaded into chutes and bins onto the CS1, CS2 and CO1a and b belts.

Transport of coal to Sasolburg Operations

The blended coal is transported to Sasolburg Operations via CO4 belt at a rate of approximately 7000 tons/day.

The throughput of ROM coal and imported coal was given as 1.5 million tpa and 200 000 tpa respectively. Only secondary crushing takes place at the plant facility. The throughput of material being crushed was given as 200 000 tonnes per month.

Air quality impacts will be associated with four distinct phases namely: the construction phase, the operational phase (current), the operational phase (future) and the closure and post-closure phase.

Construction phase activities will include bulk earthworks (for the establishment of topsoil stockpiles, conveyors and haul routes), as well as metal and concrete works for the relocation of the primary plant and other infrastructure.

Operational phase (current): Coal handling/processing at the current location of primary plant, of 1.5 Mtpa coal from Mooikraal Colliery and 200 000 tpa imported coal.

Operational phase (future): Coal handling/processing at the future location of primary plant, of 1.5 Mtpa coal from Mooikraal Colliery and 200 000 tpa imported coal.

During ***closure***, bulk earthworks and demolishing activities are expected. Very little information regarding the decommissioning phase was available for consideration, from an air quality perspective it is however likely to be similar in character and impact to the construction phase.

Due to the lack of detailed information and the relatively short duration of most of the activities associated with the construction, closure and post-closure phases, the assessment of impacts for these phases will be done qualitatively.

A quantitative assessment has been done for the operational phase. Emissions were quantified for current activities at the 3 Shaft Complex (where design mitigation is already applied). For the future scenario, emissions due to design mitigated activities at the new plant were quantified, and two options for additional mitigation were explored, viz. the use of (i) windbreaks, and (ii) fog cannons at the easternmost fence perimeter to mitigate windblown dust from the project site.

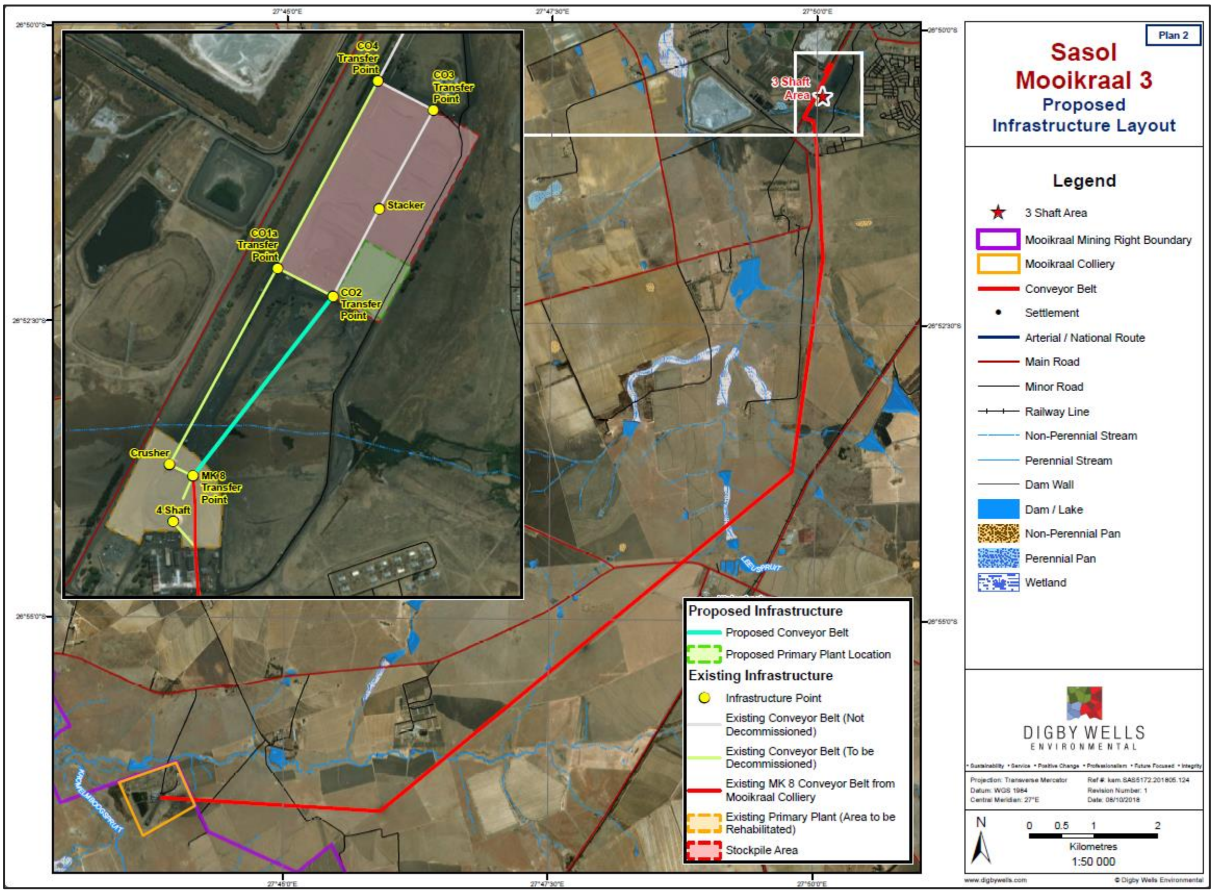


Figure 1: Current layout at 3 shaft complex (layout provided by DWA)

1.4 Project Approach and Methodology

The project methodology followed in the completion of tasks as part of the SoW is provided in Table 1.

Table 1: Project Approach and Methodology

Task	Activity	Description	Section of Report
Legal Review	A study of legal requirements pertaining to air quality – National Ambient Air Quality Standards; National Dust Control Regulations and applicable international legal guidelines and limits, including: Legislation pertaining to air quality impact assessments, such as Regulations on Dispersion Modelling, is also discussed.	International air quality criteria referenced, include: • World Health Organisation (WHO); • World Bank Group (WBG); • International Finance Corporation (IFC); and • US Environmental Protection Agency (EPA) Limited information is available on the impact of dust on vegetation and grazing quality	Section 1
Baseline Assessment	Desktop review of all available project and associated data, including meteorological data, previous air quality assessments, EIAs and technical air quality data and models.		Section 3
	Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include: • terrain, • land cover, and • meteorology.	Meteorological data from the nearby DEA Zamdela ambient monitoring station was obtained for the period 1 January 2014 to 31 December 2016 for dispersion modelling purposes and to describe the local dispersion potential.	Section 3.2
	Identification of existing air pollution sources (other mines; power stations; industries; etc.).	The Vaal Triangle Airshed Priority Area (VTAPA) baseline assessment was used to identify existing air pollution sources.	Section 3.3
	Identification of air quality-sensitive receptors, including any nearby residential dwellings and proposed receptors (temporary or permanent workers accommodation site(s)) near the facility.	The locations of schools, hospitals and clinics near the plant facility that were identified in SSO atmospheric impact report (February 2017) were used for the current study. The residential areas of Zamdela and Sasolburg closest to the project site were identified and included as sensitive receptors.	Section 3.1
	Analysis of available ambient air quality data for the area. PM data from the nearby DEA Zamdela monitoring station is provided. Dustfall rates from the Sasol Sigma Colliery dustfall monitoring network are assessed.	The analyses of ambient air quality data at the nearby DEA Zamdela monitoring station were sourced from SSO atmospheric impact report. A dustfall monitoring network of 3 single dustfall units was established at Sigma Colliery in August 2012, and the most recent data reported (1 January 2017 to 1 June 2018). Dust fallout is reported monthly.	Section 3.4.1 Section 0

Task	Activity	Description	Section of Report
Impact Assessment	The compilation of an emissions inventory incl. the identification and quantification of all emissions associated with the existing and proposed operations.	Air quality impacts will be associated with four distinct phases namely: the construction phase, the operational phase (current), the operational phase (future) and the closure and post-closure phase. Pollutants quantified include particulate matter (TSP, PM_{10} and $PM_{2.5}$). Use was made of process description, throughput rates and infrastructure maps to quantify activity emissions through the application of emissions factors and emission equations as published by the United States Environmental Protection Agency (US EPA) and Australian National Pollutant Inventory (NPI).	Section 4.1
	Atmospheric dispersion simulations of all pollutants (PM_{10}, $PM_{2.5}$ and dust fallout) for the operations reflecting highest daily and annual average concentrations due to routine emissions from the mining operations were done using the US EPA approved AERMOD model.	As per the National Code of Practice for Air Dispersion Modelling use is made of the US EPA approved AERMOD atmospheric dispersion modelling suite for the simulation of ambient air pollutant concentrations and dustfall rates. AERMOD is a Gaussian plume model, which is best used for near-field applications where the steady-state meteorology assumption is most likely to apply.	Section 4.2
	Dispersion modelling results and compliance evaluation for Current and Future Operational phases, with three sub-scenarios for the future scenario. Closure and Decommissioning phases are assessed qualitatively.	Compliance is assessed by comparing modelled ambient PM ($PM_{2.5}$ and PM_{10}) concentrations and dustfall rates to the relevant National Ambient Air Quality Standards (NAAQSs) and National Dustfall Regulations (NDR).	Section 4.3
	Dispersion model validation	The portion of air quality due to air emission sources that could not be included in the model's inventory (i.e. the background concentration) was determined by using a certain percentile of modelled and observed concentrations for comparison.	Section 4.4
	AQIA	The impact significance is based on a generic impact significance rating methodology.	Section 5
	The identification of air quality management and mitigation measures based on the findings of the compliance and impact assessment.	Practical mitigation and optimisation measures that can be implemented effectively to reduce or enhance the significance of impacts were identified.	Section 6

1.5 Limitations and Assumptions

The main assumptions, exclusions and limitations are summarized below:

- Meteorological data: No onsite meteorological data was available. Data from the DEA Zamdela ambient monitoring station (~1.75 km away) over the period January 2014 – December 2016 was used.
- Operational hours for all activities were provided as 24 hours per day, 7 days a week. It was assumed that this information is correct.
- Emissions:
    - The quantification of sources of emission was for Sasol Mooikraal 3 Shaft activities. Background sources, in the form of three Sasol ash disposal facilities to the west of the project site were also included, but not modelled since there are other background sources which could not be quantified.
    - Information required for the calculation of emissions from fugitive dust sources for the facility's operations were provided. The assumption was made that this information is accurate.
    - Crushing emissions were calculated for the design capacity of the crusher, viz. 200 000 tonnes per month (tpm) (from information provided).
    - The current crusher is housed in a "crusher house" – it was assumed that the future crusher will also be enclosed.
    - Only routine emissions were estimated and modelled. This was done for the provided operational hours.
    - It was assumed that the MK8 conveyor belt is covered (personal communication, L. Grobler, 7 August 2018).
    - Gaseous emissions from vehicle exhaust and other auxiliary equipment were not quantified as the impacts from these sources are usually localized and unlikely to exceed health screening limits outside the project area. The main pollutant of concern from the operations at Sasol Mooikraal is particulate matter and hence formed the focus of the study.
    - Particle size distribution for ash material was based on information from similar mining processes, whereas the particle size distribution for coal materials was based on site-specific reports.
    - To calculate emissions due to windblown dust with mitigation measures in the form of windbreaks or fog cannons in place, it was assumed that the 30% reduction in emissions (for windbreaks) and 90% reduction in emissions (for fog cannons) apply to hours when the wind originated from the west-northwest and northwest (i.e. the wind direction which would result in impacts in Zamdela residential area).

- Impact assessment:
    - Impacts due to the current and future operational phases were assessed quantitatively, whilst the construction, closure and decommissioning phases were assessed qualitatively due to the limited information available.
    - The impact assessment was limited to airborne particulate (including TSP, PM_{10} and $PM_{2.5}$).

- Since it is a difficult task to calculate real-life variations in impacts due to the variability of the operation, design maximum processing rates were utilized in the simulations. Though the nature of the mining operations will change over the life of the facility, the proposed sources were modelled to reflect the worst-case conditions (i.e. resulting in the highest impacts and/or closest to AQSRs). For this reason, the operational phase scenario was modelled assuming the maximum crushing throughput (i.e. 200 000 tpm).
- Only incremental impacts (due to the Project only, excluding surrounding ash disposal facilities) were modelled.
- Instead of assessing the cumulative impacts, the modelled results were added to the measured results at Zamdela, to determine the significance of the contribution from the proposed project.
- There will always be some degree of uncertainty in any geophysical model, but it is desirable to structure the model in such a way to minimize 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. Nevertheless, dispersion modelling is generally accepted as a necessary and valuable tool in air quality management.

2 Regulatory Requirements and Impact Assessment Criteria

Prior to assessing the impact of proposed activities on human health and the environment, reference needs to be made to the environmental regulations governing the impact of such operations i.e. air emission standards, ambient air quality standards and dust control regulations.

Air emission standards are generally provided for point sources and specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging or exposure periods.

This section summarises legislation for particulate matter (PM) concentrations and dustfall. Discussions on regulations regarding dispersion modelling and emissions reporting are also provided.

2.1 Emission Standards

The NEMAQA (Act No. 39 of 2004 as amended) (DEA, 2005) mandates the Minister of Environment to publish a list of activities which result in atmospheric emissions and consequently cause significant detrimental effects on the environment, human health and social welfare. All scheduled processes as previously stipulated under the Air Pollution Prevention Act (APPA) (Dept of Labour, 1993) are included as listed activities with additional activities added to the list. The updated Listed Activities and Minimum National Emission Standards (MES) were published on the 22nd November 2013 (Government Gazette No. 37054). An amendment to this Act was published in June 2015.

According to the Project description, none of the Project activities trigger the MES's nor the need for an AEL application.

2.1.1 Ambient Air Quality Standards for Criteria Pollutants

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. These include carbon monoxide (CO), nitrogen dioxide (NO_2,), sulfur dioxide (SO_2), $PM_{2.5}$ and PM_{10}. The main pollutant of concern in this study is particulate matter.

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 PM_{10}, $PM_{2.5}$, dustfall, SO_2, NO_2, O_3, CO, lead and benzene.

The final revised SA NAAQSs were published in the Government Gazette on 24 of December 2009 (DEA, 2009) and in some instances included a margin of tolerance and linked implementation timelines. SA NAAQSs for $PM_{2.5}$ were published on 29 June 2012 (DEA, 2012). SA NAAQSs for the criteria pollutants assessed in this study are listed in Table 2. Currently, only $PM_{2.5}$ has a margin of tolerance, which is applicable until 31 December 2029. Short-term standards (daily) are represented by a limit value based on the 99th percentile of the observation (or simulated concentration) for that averaging period.

Table 2: Air quality standards for specific criteria pollutants (SA NAAQS)

Pollutant	Averaging Period	Limit Value (µg/m³)	Frequency of Exceedance	Compliance Date
PM_{10}	24-hour	75	4	1 Jan 2015
	1 year	40	0	1 Jan 2015
$PM_{2.5}$	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

2.1.2 National Dust Control Regulations

The National Dust Control Regulations (NDCR) were published on the 1st of November 2013 (DEA, 2013). The purpose of the regulations is to prescribe general measures for the control of dust from areas operations identified by a local Air Quality Officer as potentially causing a nuisance. Acceptable dustfall rates for residential and non-residential areas according to the regulation is summarised in Table 3.

Table 3: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m²-day over a 30 day average	Permitted frequency of exceedance
Residential areas	D < 600	Two within a year, not sequential months.
Non-residential areas	600 < D < 1 200	Two within a year, not sequential months.

The regulation also specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be American Standard Testing Method (ASTM, 1970)[1], or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

[1] ASTM 1739:70 is a previous version of ASTM 1739 which did not prescribe a wind shield around the opening of the bucket; the addition of a wind shield is intended to deflect wind away from the lip of the container, allowing for a more laminar flow across the top of the collecting container (Kornelius *et al*., 2015). SANS 1929-2004 does however refer to ASTM 1739-98 (ASTM, 1998), which has a wind shield.

2.2 International Conventions

International guidelines are referenced as part of this project to comply with the requirements of the International Finance Corporation (IFC) in cases where no national legislated standards exist (IFC, 2007). In South Africa, national air quality standards have been established which are in line with international criteria (Section 2.1).

The IFC Environmental Health and Safety (EHS) Guidelines provide a general approach to air quality management for a facility, including the following:

- Identifying possible risks and hazards associated with the project as early on as possible and understanding the magnitude of the risks, based on:
    - the nature of the project activities; and,
    - the potential consequences to workers, communities, or the environment if these hazards are not adequately managed or controlled.
- Preparing project- or activity-specific plans and procedures incorporating technical recommendations relevant to the project or facility;
- Prioritising the risk management strategies with the objective of achieving an overall reduction of risk to human health and the environment, focusing on the prevention of irreversible and / or significant impacts;
- When impact avoidance is not feasible, implementing engineering and management controls to reduce or minimise the possibility and magnitude of undesired consequence; and,
- Continuously improving performance through a combination of ongoing monitoring of facility performance and effective accountability.

Significant impacts to air quality should be prevented or minimised by ensuring that:

- Emissions to air do not result in pollutant concentrations exceeding the relevant ambient air quality standards. These standards can be national guidelines or standards (or in their absence WHO AQGs or any other international recognised sources).
- Emissions do not contribute significantly to the relevant ambient air quality standards. It is recommended that 25% of the applicable air quality standards are allowed to enable future development in a given airshed.
- The EHS recognises the use of dispersion models to assess potential ground level concentrations. The models used should be internationally recognised or comparable.

2.3 Screening criteria for animals and vegetation

Limited information is available on the impact of dust on vegetation and grazing quality. While there is little direct evidence of the impact of dustfall on vegetation in the South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dustfall rates greater than 400 mg/m²/day (Farmer, 1993). In addition, there is anecdotal evidence to indicate that over extended periods, high dustfall levels in grazing lands can soil vegetation and this can impact the teeth of livestock (Farmer, 1993).

2.4 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 assess 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 NEMAQA;
b) in the development of a priority area air quality management plan, as contemplated in section 19 of the NEMAQA;
c) in the development of an atmospheric impact report, as contemplated in section 30 of the NEMAQA; and,
d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the NEMAQA.

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 clear 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 project falls under a Level 2 assessment – which is described as follows:

- The distribution of pollutant concentrations and deposition 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 kilometers (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 Regulation prescribe the source data input to be used in the model. 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.

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.

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.

The modelling domain would normally be decided on the expected zone of influence; the extent being defined by simulated 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 should however 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 requirements, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air pollutant concentration data. Chapter 6 also provides guidance on the treatment of NO_2 formation from NOx emissions, chemical transformation of SO_2 into sulphates and deposition processes.

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

2.5 Vaal Triangle Priority Area

Sasol Sigma Mooikraal falls within the Vaal Triangle Air-shed Priority Area (VTAPA). The Vaal Triangle Air-shed was declared a priority area in April 2006 by the Minister of Environmental Affairs and Tourism (for the boundaries of the proclaimed area, see Figure 2). The VTAPA is the first priority area in South Africa declared under the National Environmental management – Air Quality Act (Act 39/2004) and was declared such due to the concern of elevated pollutant concentrations within the area, specifically particulate matter.

The Vaal Triangle is a highly industrialised area housing numerous industries, a coal fired power station, and various smaller industrial and commercial activities in addition to a few collieries and quarries giving rise to noxious and offensive gasses. The Vaal Triangle is also home to a number of large informal settlements mainly using coal and wood as fuel source. This in return impacts directly on the health and well-being of the people residing there. Other sources of concern contributing to the pollution mixture within the area include vehicle tailpipe emissions, biomass burning, water treatment works and landfill areas, agricultural activities and various other fugitive sources.

An Air Quality Management Plan (AQMP), providing detailed intervention strategies, was developed for the Vaal Triangle Priority area between 2007 and 2009, with the final plan published 29 May 2009 (Government Gazette No. 32254). It should be noted that the development of this plan preceded the publication of National Ambient Air Quality Standards (Government Gazette No. 32816, 24 December 2009) and Minimum Emission Standards (Government Gazette No. 33064, 31 March 2010 and revised on 23 November 2013, Government Gazette No. 37054).

The 2009 Vaal Triangle Priority Area AQMP is currently under revision to determine the improvement, if any that resulted from the implementation of the 2009 AQMP and to provide new/ additional reductions strategies.

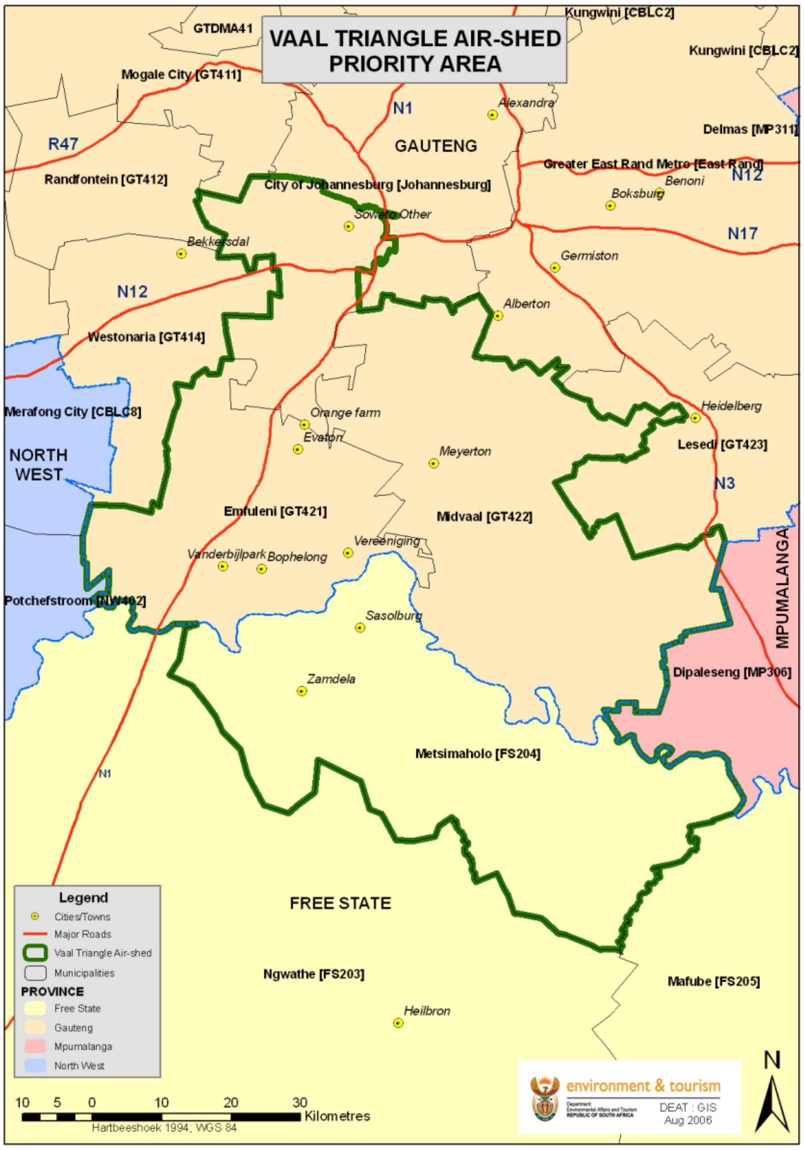


Figure 2: Demarcation of the Vaal Triangle Air-shed Priority Area.

3 Description of the Receiving Environment

This chapter provides details of the receiving environment which is described in terms of:

- The identification of AQSRs from available maps;
- A study of the atmospheric dispersion potential of the area taking into consideration local meteorology, land-use and topography;
- The identification of existing sources of emissions in the study area; and
- The analysis of all available ambient air quality information/data to determine pre-development ambient pollutant levels and dustfall rates.

3.1 Receiving Environment

Air Quality Sensitive Receptors (AQSRs) primarily refer to places where people reside; however, it may also refer to other sensitive environments that may adversely be affected by air pollutants. Ambient air quality guidelines and standards, as discussed under Section 2.1, have been developed to protect human health. Ambient air quality, in contrast to occupation exposure, pertains to areas outside of an industrial site/mine boundary where the public has access to and according to the NEMAQA, excludes areas regulated under the Occupational Health and Safety Act (Act No 85 of 1993) (Dept of Labour, 1993).

Prior to dispersion modelling, 33 receptors were identified in the vicinity of the Project (within the 10-by-10 km modelling domain)[2]. Sensitive receptors included schools, hospitals and clinics; other receptors included ambient monitoring stations and dustfall sampling points, as well as the residential areas of Zamdela and Sasolburg closest to the project site (Figure 3 and Table 4). Sensitive receptors were included in the dispersion model and are presented in the isopleth plots. The residential areas of Zamdela to the southeast, and Sasolburg to the north were included in the discussion and interpretation of isopleth plots.

[2] The schools, hospitals and clinics, and ambient monitoring stations are a subset of receptors identified as part of SSO atmospheric impact report (February 2017).

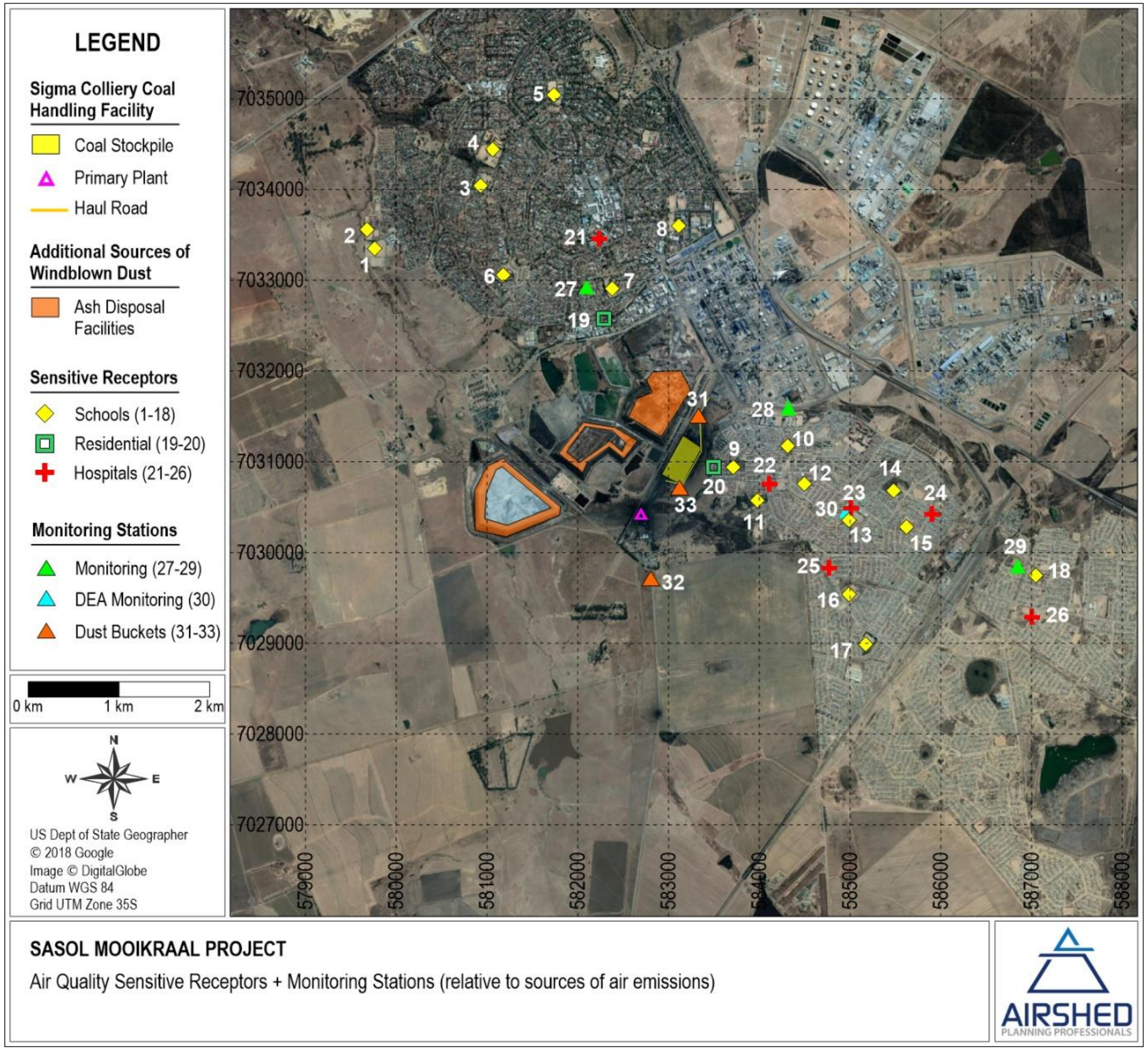


Figure 3: Location of potential air quality sensitive receptors and monitoring stations

Table 4: Receptors identified for assessment of impact as a result of Sasol Sigma Mooikraal emissions as well as surrounding monitoring stations

Receptor code	Receptor details	Receptor type	Distance from centre of operations (km)
1	Afrikaans H/S Secondary	School	4.1
2	Leeuwspruit Primary	School	4.3
3	Fakkel Secondary	School	3.7
4	Sasolburg high school Secondary	School	4.0
5	Fonteine Primary	School	4.3
6	Kahobotjha-sakubusha Secondary	School	2.9
7	AJ Jacobs Primary	School	2.1
8	HTS Secondary	School	2.6
9	Tsatsi Primary	School	0.5
10	Malakabeng Primary	School	1.2
11	Nkopoleng Secondary	School	0.9
12	Bofula- Tshepe Primary	School	1.4
13	Iketsetseng Secondary	School	2.0
14	Cedar Secondary	School	2.3
15	Isaac Mhlambi Primary	School	2.6
16	Theha Setjhaba Primary	School	2.4
17	Lehutso Primary	School	2.8
18	Credo Primary	School	4.1
19	Sasolburg Residential	Residential	1.6
20	Zamdela Residential	Residential	0.2
21	Sasolburg Clinic	Hospital	2.6
22	Zamdela Hospital Zumayear	Hospital	0.9
23	Clinic A Zamdela	Hospital	1.9
24	Clinic B Zamdela	Hospital	2.8
25	Szamdela community clinic	Hospital	2.0
26	Harry Gwala Clinic | Creche	Hospital	4.2
27	Sasol AJ Jacobs monitoring station	Ambient Monitoring	2.2
28	Sasol1 (Fence) monitoring station	Ambient Monitoring	1.3
29	Sasol Leitrim monitoring station	Ambient Monitoring	3.8
30	VTAPA Zamdela monitoring station	Ambient Monitoring	1.8
31	Sasol Mooikraal dust monitoring station SOS 01	Dust Monitoring	0.3
32	Sasol Mooikraal dust monitoring station SOS 02	Dust Monitoring	0.1
33	Sasol Mooikraal dust monitoring station SOS 03	Dust Monitoring	1.1

3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. Parameters useful in describing the dispersion and dilution potential of the site i.e. wind speed, wind direction, temperature and atmospheric stability, are subsequently discussed.

The DEA Zamdela weather station, located approximately 1.8 km east-southeast of the Project, is regarded representative of the local meteorology. Data from this station was available for 3 years as required by the regulations on Air Dispersion Modelling (DEA, 2014) (Section 2.4), and use was made of this data to quantify the atmospheric dispersion potential of the area.

3.2.1 Surface Wind Field

The wind field determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is a function of the wind speed, in combination with the surface roughness. The wind field for the study area is described with the use of wind roses. Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 4 and 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. Calm conditions are periods when the wind speed was below 1 m/s. These low values can be due to “meteorological” calm conditions when there is no air movement; or, when there may be wind, but it is below the anemometer starting threshold.

The period wind field and diurnal variability in the wind field are shown in Figure 4. The predominant wind field for the 2014-2016 period was from the east-northeast and east, with an equally strong component from the northwest through southwestern sector. Wind speeds above 6 m/s occurred from most directions except from the south and south-east. Calm conditions occurred 11.56% of the time. During the day the winds were predominantly from the northwest to southwest, with the strongest winds from the northwest. The wind conditions shifted during the night-time with strong winds predominantly from the east-northeast and easterly directions. Day-time calms occurred for 11.77% of the time, with night-time calms for 11.34% of the time.

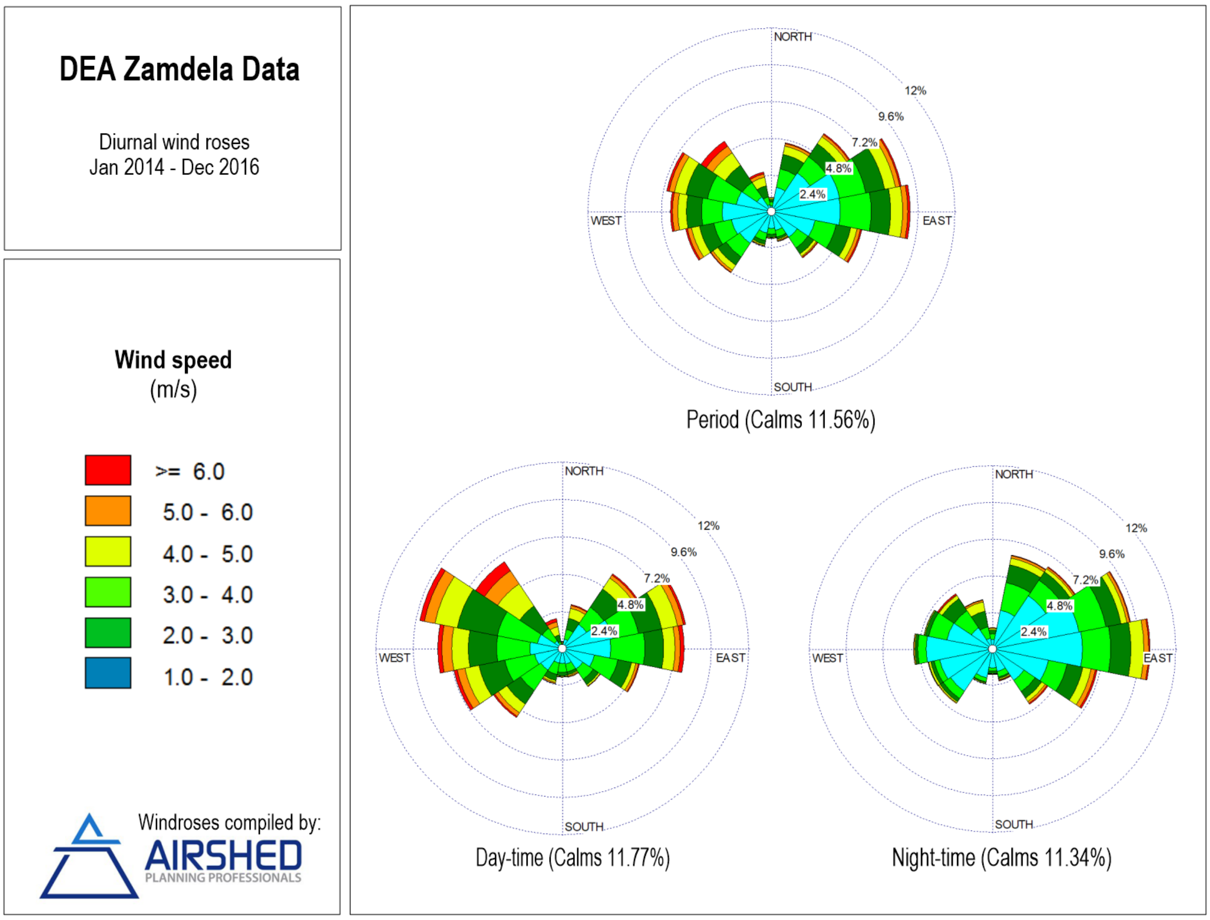


Figure 4: Period, day- and night-time wind roses (DEA data; 2014 to 2016)

According to the Beaufort wind force scale (https://www.metoffice.gov.uk/guide/weather/marine/beaufort-scale), wind speeds between 6-8 m/s equates to a moderate breeze, with wind speeds between 9-11 m/s referred to as a fresh breeze. Wind speeds between 11-14 m/s are described as a strong breeze with winds between 14-17 m/s near gale force winds and 17 - 21 m/s as gale force winds. Based on the three years of DEA data, wind speeds exceeding 6 m/s occurred for 1.5% of the time. No exceedances of the thresholds 9-11 m/s, or 14-17 m/s were recorded.

3.2.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher a pollution plume is able to rise) and determining the development of the mixing and inversion layers. The monthly temperature pattern is shown in Figure 5. The annual maximum, minimum and mean temperatures for Zamdela are given as 33°C, -7°C and 14°C respectively. Average maximum temperatures ranged from 33°C in January to 20°C in July, with minima between -7°C in June and 11°C in January. The diurnal temperature profile for the site is given in Figure 6. During the day, temperatures increase to reach maximum at around 12:00 in the afternoon. Ambient air temperature decreases to reach a minimum at around 07:00 i.e. just before sunrise.

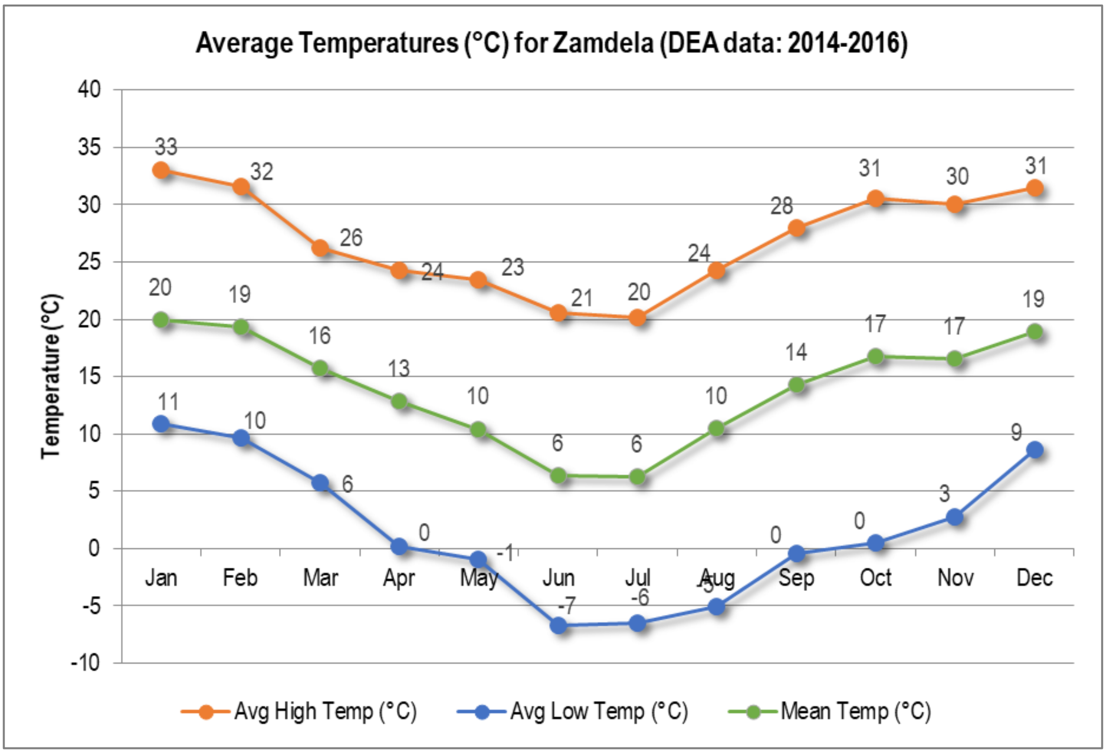


Figure 5: Monthly temperature profile (DEA data; 2014 to 2016)

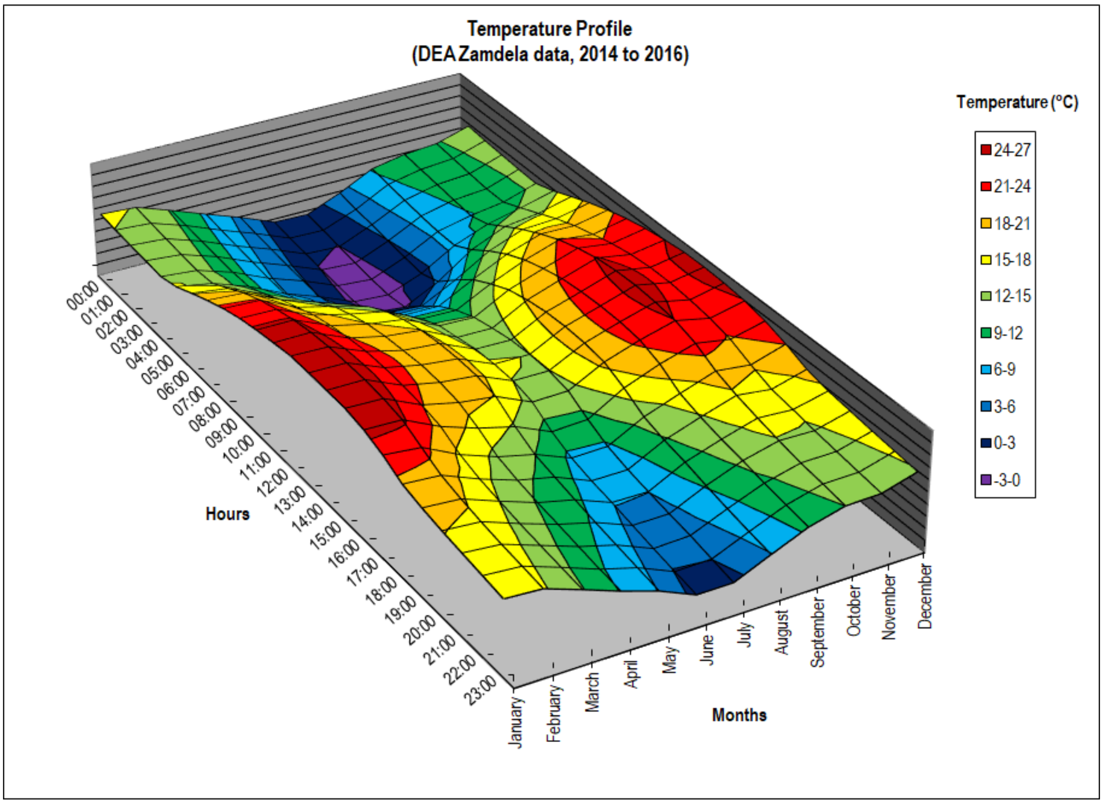


Figure 6: Diurnal temperature profile (DEA data; 2014 to 2016)

3.2.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Monthly rainfall for the Sasolburg region (based on 30-year historical data from Meteoblue[3]) is given in Figure 7. Monthly rainfall for the site (based on data from January 2017 to June 2018) is given in Figure 8. Months wherein the most rain occurred ranged between October and April. The most rain was received during the month of December (for both datasets) and the least rain during the months from June to August.

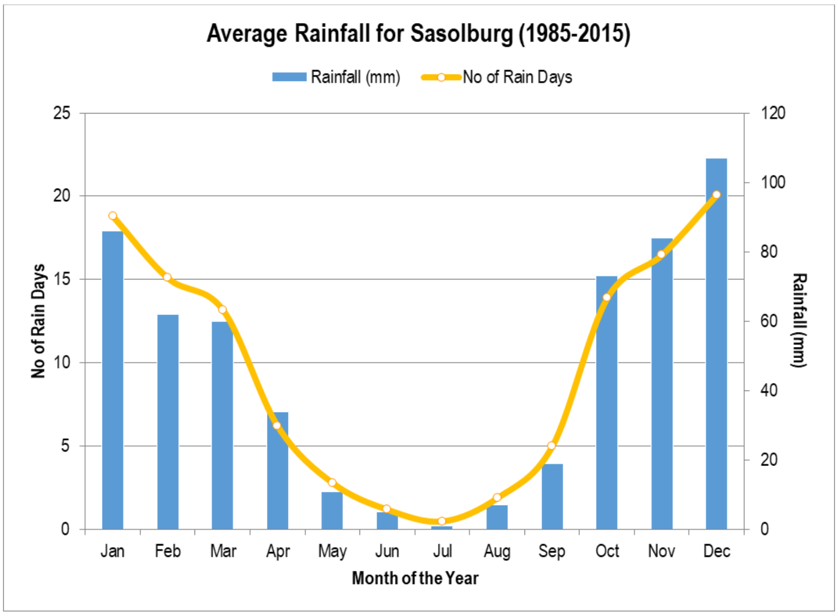


Figure 7: Monthly precipitation (Meteoblue data for Sasolburg: 1985-2015)

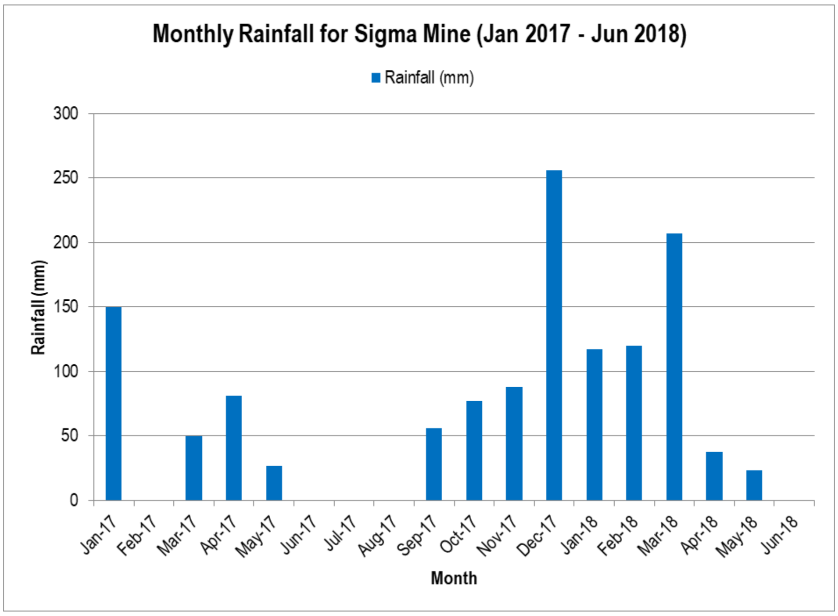


Figure 8: Monthly precipitation (Onsite data from Sigma Colliery: Jan-2017 to Jun-2018)

[3] https://www.meteoblue.com/en/weather/forecast/modelclimate/sasolburg_south-africa_957487

3.2.4 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in several 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 the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the predominance of an unstable layer. In unstable conditions, ground level pollution is readily dispersed thereby reducing ground level concentrations (Figure 9). 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 less dilution potential (Figure 9). During windy and/or cloudy conditions, the atmosphere is normally neutral (which causes sound scattering in the presence of mechanical turbulence).

Atmospheric stability is frequently categorised into one of six stability classes – these are briefly described in Table 5 with the percentage time each class occurred at the study site. Diurnal variation in atmospheric stability described by the inverse Monin-Obukhov length and the mixing height is provided in Figure 10. For low level releases, such as activities associated with mining operations, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions, which relates to 7% of the time at the study site. However, windblown dust is likely to occur under high winds (neutral conditions) which is for 4% of the time.

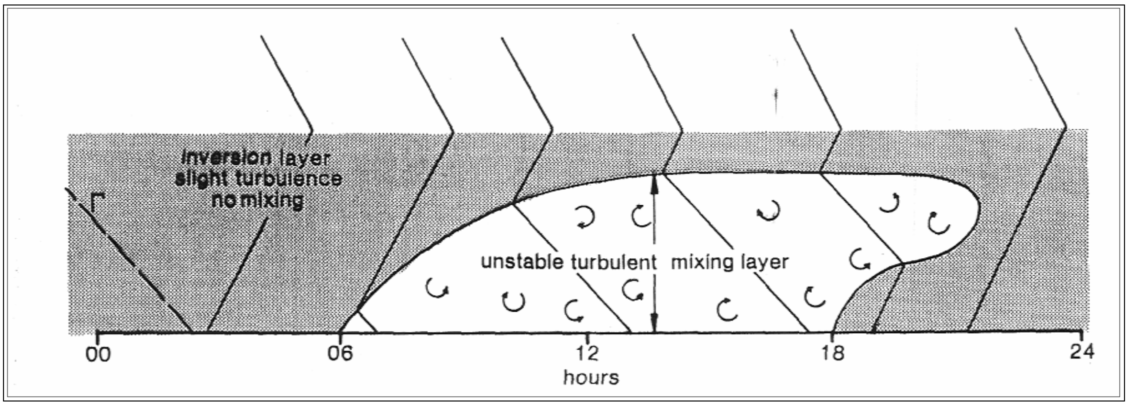


Figure 9: Daytime development of a turbulent mixing layer (Preston-Whyte & Tyson, 1988)

Table 5: Atmospheric stability classes

Designation	Stability Class	Atmospheric Condition	Frequency of occurrence
A	Very unstable	calm wind, clear skies, hot daytime conditions	11%
B	Moderately unstable	clear skies, daytime conditions	16%
C	Unstable	moderate wind, slightly overcast daytime conditions	20%
D	Neutral	high winds or cloudy days and nights	4%
E	Stable	moderate wind, slightly overcast night-time conditions	7%
F	Very stable	low winds, clear skies, cold night-time conditions	41%

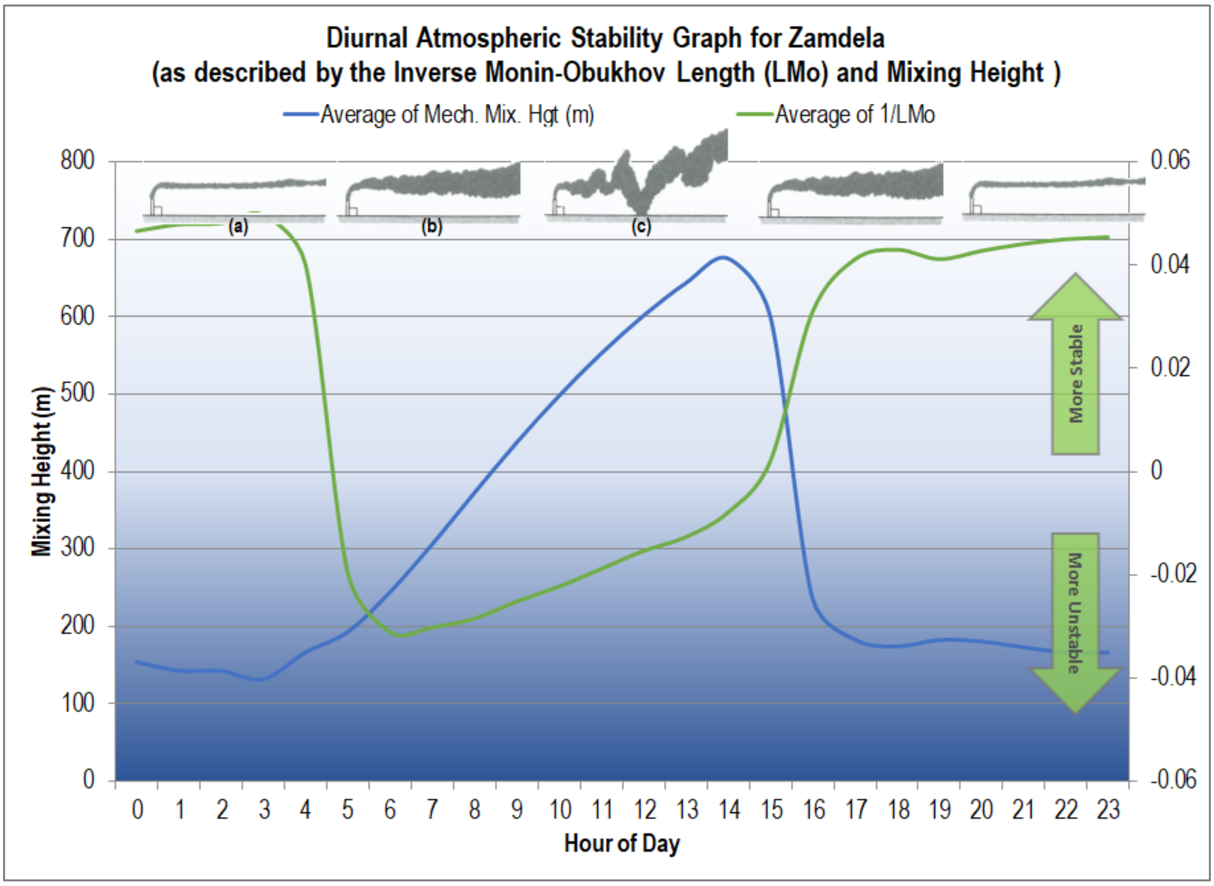


Figure 10: Diurnal atmospheric stability graph for Zamdela

3.3 Existing Sources of Emissions near the Project Site

The main sources of emissions in the study region are petrochemical processes. According to the Vaal Triangle Priority Area baseline study (Liebenberg-Enslin *et al.*, 2007) more than 90% of the SO_2, NO and NO_2 emissions in the study area are due to petrochemical processes (Sasol and Natref). For PM_{10} emissions within the area, petrochemical processes contribute 70% and mining activities 18%. Secondary sources are domestic fuel burning, fugitive emissions from opencast coal mining operations, windblown dust emissions from ash dumps, and vehicle tailpipe emissions.

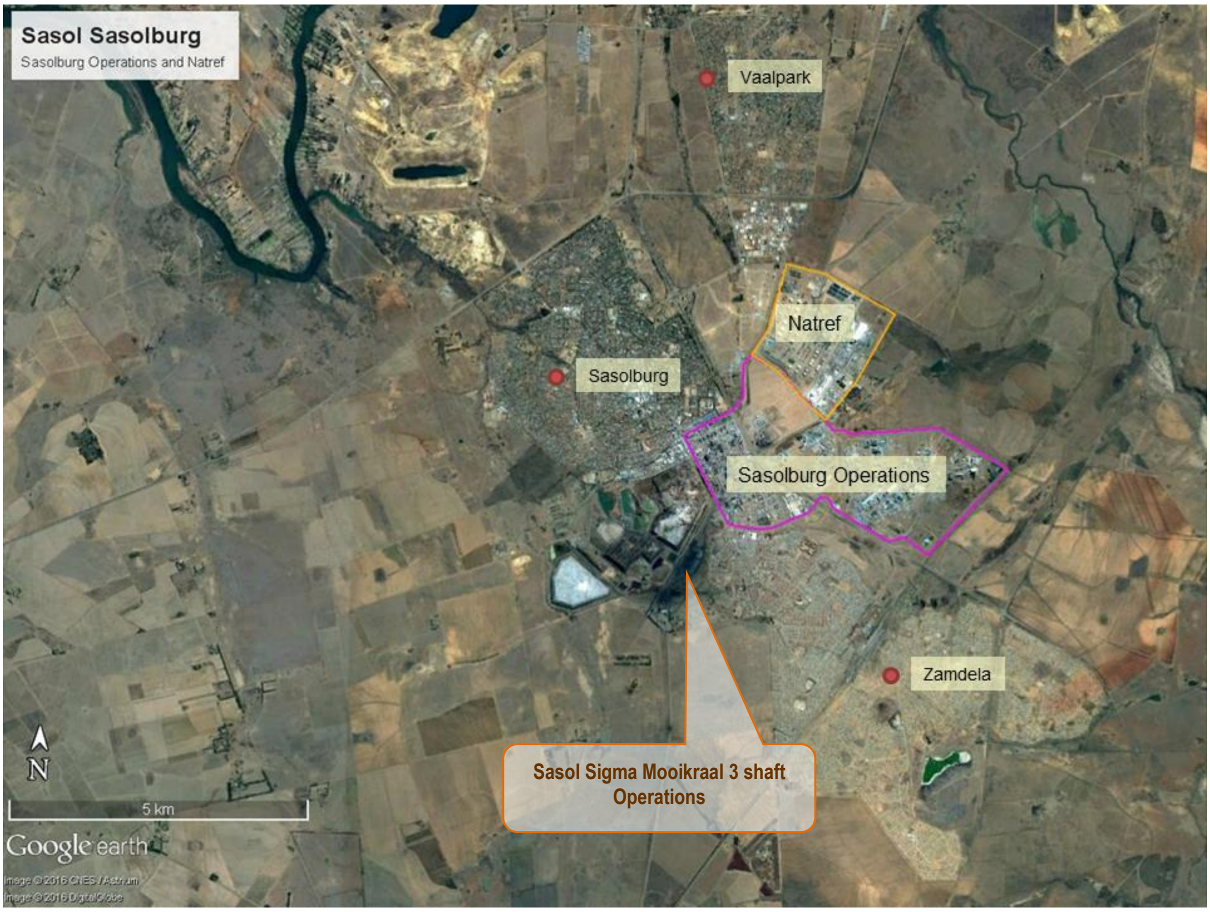


Figure 11: Locality map of the Project in relation to surrounding residential and industrial areas

3.3.1 Petrochemical Operations

Emissions due to petrochemical operations arise from production processes, combustion, fugitives and storage and handling emissions. These activities result in PM, NO_x, SO_2, VOC, greenhouse gases and contribute to ozone formation.

3.3.2 Mining Operations

The closest mine is Sigma Colliery, at present an underground coal mining operation 15 km to the southwest of the Project. Fugitive emissions sources from mining operations mainly comprise of materials handling operations (i.e. tipping, off-loading and loading, conveyor transfer points), vehicle entrainment from haul roads, wind erosion from open areas and primary crushing operations. These activities mainly result in fugitive PM releases.

3.3.3 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 derive 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. Chemicals used for crop spraying would typically result in odiferous emissions. Crop residue burning is an additional source of particulate emissions and other toxins.

3.3.4 Miscellaneous Fugitive Dust Sources

Fugitive PM emissions are generated through entrainment from local paved and unpaved roads, and erosion of open or sparsely vegetated areas. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and the silt loading on the roadways. The extent, nature and duration of road-use activity and the moisture and silt content of soils are required to be known in order to quantify fugitive emissions from this source. The quantity of windblown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

3.3.5 Vehicle Tailpipe Emissions

The R59 to the north of the site, and the R57 to the east are busy national roads. Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. Notable primary pollutants emitted by vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, DPM and Pb. Secondary pollutants include: NO_2, photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses. Vehicle tailpipe emissions are localised sources and unlikely to impact far-afield.

3.3.6 Household Fuel Burning

Energy use within the residential sector is given as falling within three main categories, viz.: (i) traditional - consisting of wood, dung and bagasse, (ii) transitional - consisting of coal, paraffin and liquefied petroleum gas (LPG), and (iii) modern - consisting of electricity (increasingly this includes the use of renewable energy). The typical universal trend is given as being from (i) through (ii) to (iii). Pollutants include products of combustion (CO, NO_x, SO_2 and VOC), unburned HC and PM.

3.4 Monitored Ambient Concentrations and Dustfall Levels

3.4.1 Ambient Monitoring[4]

The graphs in this section summarise the observed concentrations of PM_{10} at the DEA monitoring site for Zamdela for the years 2015, 2016 and 2017.

The NAAQS have been included for PM_{10} daily average (4 daily exceedances of 75 µg/m³).

The daily 99th percentiles for PM_{10} exceed the limit value (75 µg/m³) at Zamdela station for all three years (Figure 12) where non-compliance varied between 15% and 30% of the three years assessed.

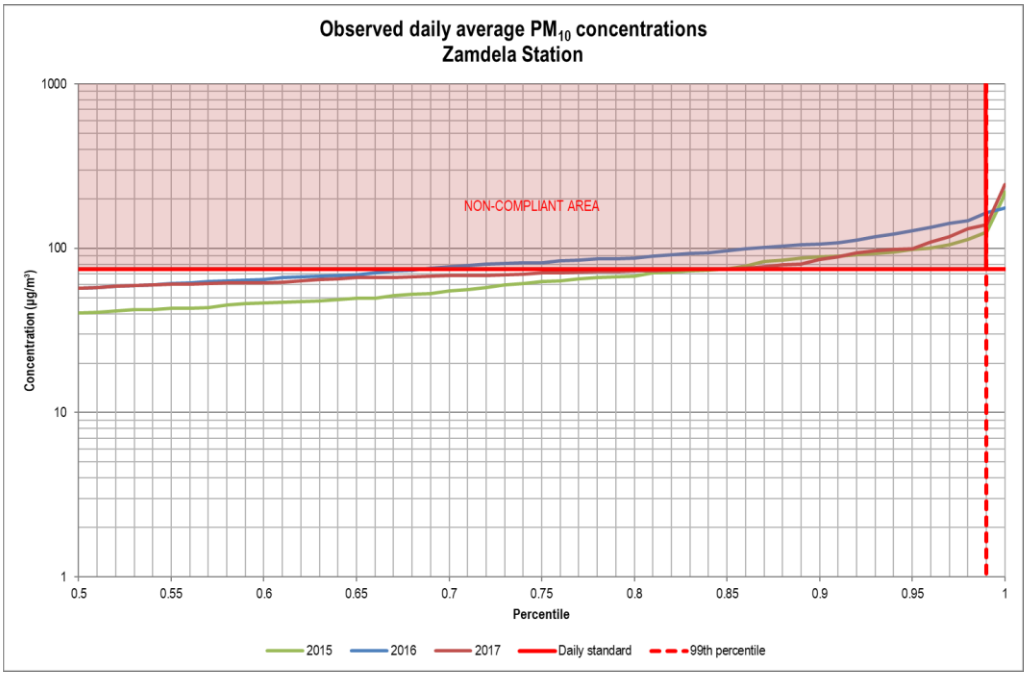


Figure 12: Observed daily average PM_{10} concentrations at Zamdela

Time variation plots (mean with 95% confidence interval) of ambient particulate matter (PM_{10} and $PM_{2.5}$) concentrations measured at Zamdela station show the variation of these pollutants over daily, weekly and annual cycles (Figure 13).

Monthly variation of particulate matter shows elevated concentrations during winter months due to the larger contribution from domestic fuel burning, dust from uncovered soil and the lack of the settling influence of rainfall (Figure 13).

[4] This section draws largely from the analysis presented in Sasol's Sasolburg Operations (SO) atmospheric impact report (Bird *et al*, 2017).

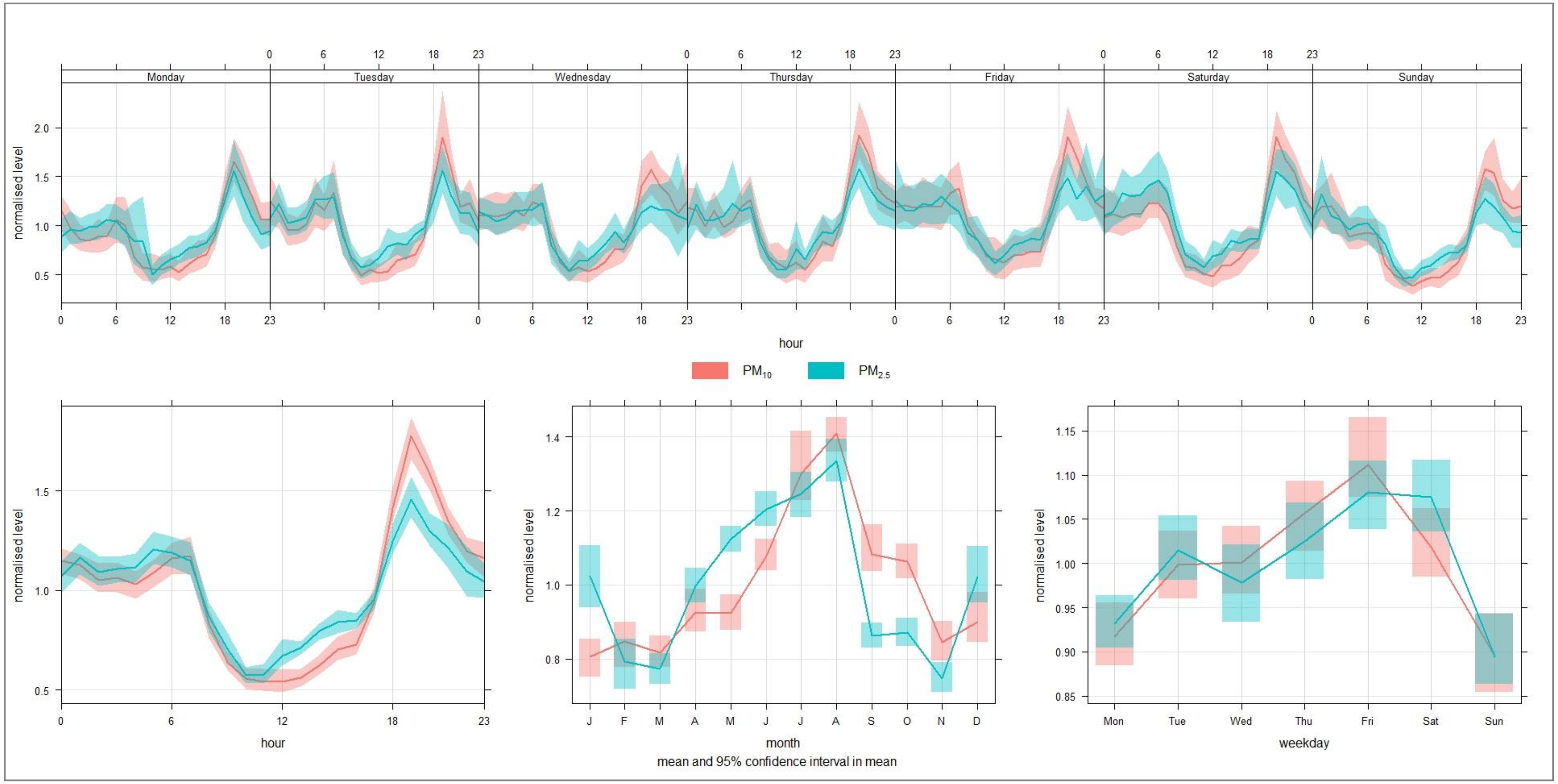


Figure 13: Time variation plot of normalised observed PM_{10} and $PM_{2.5}$ concentrations at Zamdela

An analysis of the observed PM_{10} concentrations at Zamdela was completed, in which the concentration values were categorised into wind speed and direction bins for different concentrations, and visualised in the form of polar plots, where the centre of the polar plot refers to the location of the monitoring station. These polar plots (Carslaw and Ropkins, 2012; Carslaw, 2013) provide an indication of the directional contribution as well as the dependence of concentrations on wind speed. Whereas the directional display is fairly obvious, i.e. when higher concentrations are shown to occur in a certain sector, it is understood that most of the high concentrations occur when winds blow from that sector (i.e. east or south). When the high concentration pattern is more symmetrical around the centre of the plot, it is an indication that the contributions are near-equally distributed.

Particulate concentrations recorded at the Zamdela show high concentrations from the north-west and north-east, at high wind speeds (above 4 m/s), and a local source at low wind speeds (Figure 14). Sources in the south-westerly sector contribute the lowest concentrations, especially at higher wind speeds.

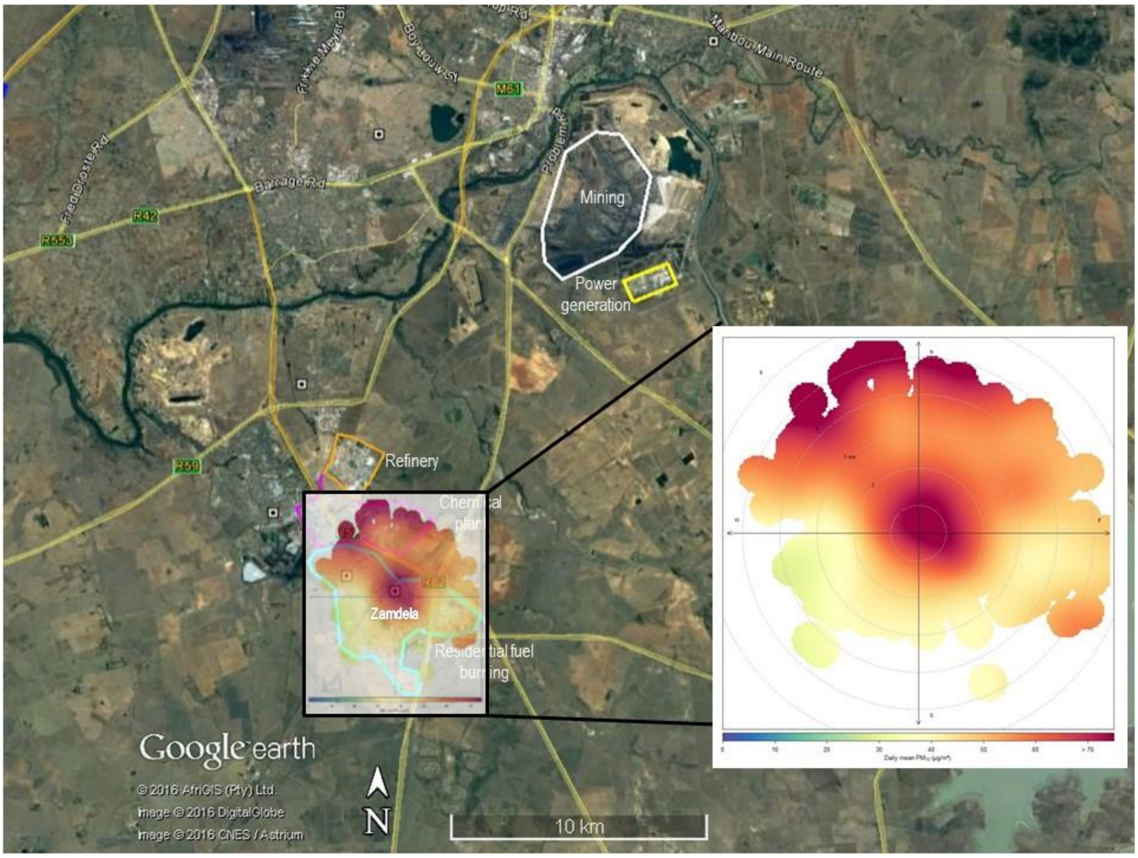


Figure 14: Polar plot of hourly median PM_{10} concentration observations at Zamdela for 2015 to 2017

3.4.2 Dustfall Monitoring

3.4.2.1 Dustfall sampling sites

Dustfall sampling has been conducted around the 3 Shaft Complex at three sites since August 2012. The coordinates of the sampling sites are listed in Table 6. A map of the dustfall sampling network is included in Figure 15.

Figure 15: Dustfall sampling sites

As shown in Figure 15, the dustfall sampling sites are located in close proximity to the 3 Shaft Complex, with SOS-01 located next to the haul road to the north of the coal stockpile, SOS-02 located 600m southeast from the primary plant, and SOS-03 located directly south of the coal stockpile. According to the NDCRs, only buckets classified as “residential” and “non-residential” need to comply with the dustfall limits. However, for the purpose of baseline monitoring, all buckets were evaluated against the dustfall limit values for non-residential areas (Table 6).

The closest residential area is the town of Zamdela, located 200m to the east of the Project site.

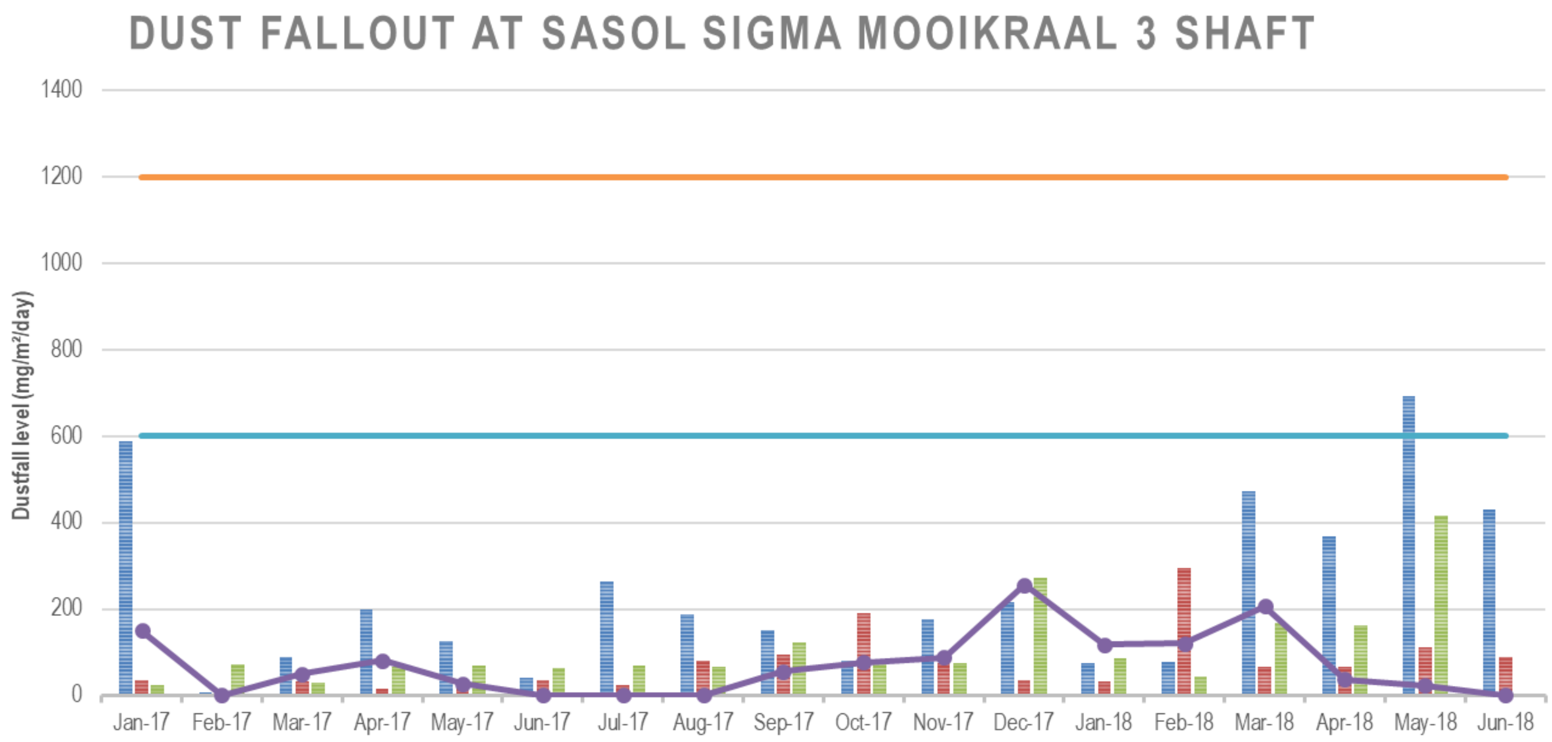
Table 6: Sampling site coordinates

Site	Longitude	Latitude	Elevation (m)	NDCR Classification	Applicable Limit
SOS 01	27.83868	-26.8355	1486	Non-Residential	1 200 mg/m²-day
SOS 02	27.83351	-26.8518	1478	Non-Residential	1 200 mg/m²-day
SOS 03	27.83663	-26.8427	1476	Non-Residential	1 200 mg/m²-day

3.4.2.2 Dustfall Rates

During 1 January 2017 to 30 June 2018 (period of eighteen months), dustfall rates never exceeded the 1 200 mg/m²/day limit for non-residential areas at any of the sites, nor the residential limit of 600 mg/m²/day except during the May 2018 sampling period at SOS-01 (Figure 16). Dustfall rates were low overall, with the highest dustfall rates measured during the May 2018 sampling period when dustfall rates were noticeably higher than the other months (as shown in the box-and-whisker plot of on-site dustfall rates) (Figure 17) – the reason for this is not clear. The highest dustfall rate over the eighteen months is 693 mg/m²/day collected at SOS-01 during the May 2018 sampling period (the only time it exceeded the residential limit) with the lowest of 6 mg/m²/day (at SOS-01 and SOS-02) in February 2017. The average dustfall rate over the eighteen months is 140 mg/m²/day.

To assess or identify trends in dustfall rates, a box-and-whisker plot is included in Figure 17. A box-and-whisker plot shows the median, the upper quartile (25% of data greater than the median), lower quartile (25% of data less than the median), and the minimum and maximum values. From Figure 17 it is apparent that there is an upward trend in the data, and that dustfall at SOS-01 is consistently higher than the other two sampling sites.



	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
SOS 01	587	6	88	198	126	42	265	187	151	81	175	216	76	77	473	369	693	431
SOS 02	34	6	31	16	35	35	25	80	94	189	74	35	33	294	66	67	110	90
SOS 03	24	72	29	67	70	64	70	67	122	82	75	271	85	43	169	163	415	
Rainfall	150	0	49.5	81	27	0	0	0	56	77	88	256	117	120	207	37.5	23	0
Residential limit	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Industrial limit	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200

Figure 16: Sampled dustfall rates for the period January 2017 to June 2018 (eighteen months)

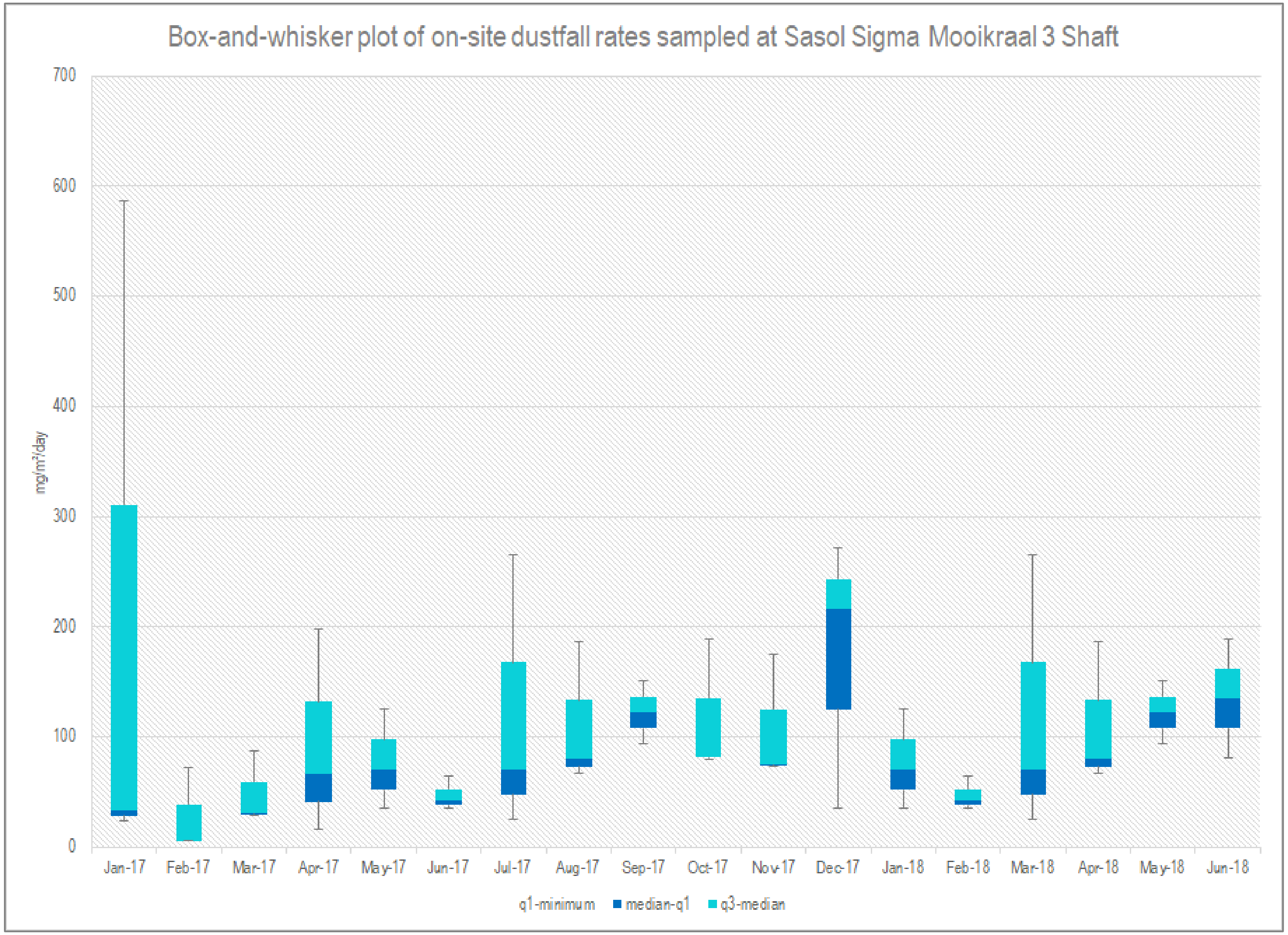


Figure 17: Box-and-whisker plot of on-site dustfall for the period January 2017 to June 2018 (eighteen months)

4 Impact Assessment

The emissions inventory, dispersion modelling and results are discussed in Section 4.1 and Section 4.2 respectively.

4.1 Atmospheric Emissions

4.1.1 Construction Phase

The area directly to the east of the new proposed conveyor (refer to Figure 1) is proposed for the construction laydown area. The area will extend over an area of 10 800 m^2. The establishment of the construction camp area will include but will not be limited to:

- Site offices;
- Dedicated eating areas;
- Storage of construction and other materials;
- Including hazardous substance storage;
- General and hazardous waste disposal and collection area; and
- Dedicated equipment and vehicle maintenance and storage area.

A detailed construction plan for the new crusher plant is required to quantitatively assess the impacts from this phase. Due to the lack of detailed information and the relatively short duration of most of the activities associated with the construction phase, no dispersion simulations were undertaken, and a qualitative assessment was done.

The main pollutant of concern from construction operations is particulate matter, including PM_{10}, $PM_{2.5}$ and TSP. PM_{10} and $PM_{2.5}$ concentrations are associated with potential health impacts due to the size of the particulates being small enough to be inhaled. Nuisance effects are caused by the TSP fraction (20 µm to 75 µm in diameter) resulting in soiling of materials and visibility reductions. This could in effect also have financial implications due to the requirement for more cleaning materials.

From the proposed operations, the main construction activities likely to result in noticeable impacts of PM_{10}, $PM_{2.5}$ and TSP, include construction of the new camp area and the demolition of the current processing plant buildings and infrastructure. The impacts due to construction activities are likely to be localised and will depend on the dispersion potential of the site.

4.1.2 Operational Phase

To determine the significance of air pollution impacts from the proposed Project, the following two scenarios were assessed:

- **Scenario 1** (Baseline) – representative of coal handling/processing at the current location of primary plant, of 1.5 Mtpa coal from Mooikraal Colliery (transported on-site via MK8 conveyor belt) and 200 000 tpa imported coal (transported on-site via haul trucks); and
- **Scenario 2** (Project) – representative of coal handling/processing at the new location of primary plant, of 1.5 Mtpa coal from Mooikraal Colliery (transported on-site via new conveyor belt) and 200 000 tpa imported coal (transported on-site via haul trucks).

The large active ash disposal facility to the west-southwest of the Project area and two inactive ash disposal facilities to the west and northwest respectively was included in the emissions quantification, but not the dispersion modelling.

For **Scenario 1**, current mitigated activities were assessed, with the following control efficiencies applied: 75% CE on unpaved haul roads (water sprays), 90% on secondary crushing (enclosed), 50% CE on materials handling (water sprays) and 70% CE on conveyor transfer (enclosed). No mitigation was applied on windblown dust from the coal stockpile and nearby ash disposal facilities.

For **Scenario 2**, three sub-scenarios were assessed:

- **Scenario 2a**: Design mitigated activities, no mitigation of windblown dust from the coal stockpile;
- **Scenario 2b**: Design mitigated activities, wind breaks to control windblown dust from the coal stockpile (30% control efficiency on windblown dust from the northwest); and
- **Scenario 2c**: Design mitigated activities, fog cannons to control windblown dust from the coal stockpile (90% control efficiency on windblown dust from the northwest).

Aspects associated with the operational phase in terms of air quality are outlined in Table 7. These aspects are explained further in Sections 4.1.2.2 to 4.1.2.5.

Table 7: Environmental impacts and associated activities during the operational phase

Impact	Source	Activity
Particulates	Conveyor	Windblown dust from conveyor
	Various points at the coal handling/ processing facility	Materials handling of coal at the 3 Shaft area, crushing facility and coal stockpile area.
	Crusher house	Secondary crushing
	Unpaved roads	Vehicle entrainment on unpaved road surfaces
	Wind erosion	Windblown dust from coal stockpile and ash disposal facilities

4.1.2.1 Windblown Dust from Conveyor

The dust emissions from conventional conveyors are wind speed dependent with stronger wind speeds causing dust particles to be entrained by the wind. The degree of entrained dust also depends on the level of enclosure, i.e. roof cover and/or sides. The wind speed dependence has been based on the recommendations of Parrett

(1992) where the dust emission rate (as grams per metre of conveyor) is equivalent to a constant multiplied by the difference between the friction velocity (u^*) and the threshold friction velocity of the coal (u^*_t):

$$E = c(u^* - u_t^*)$$

An estimate for the constant (c) has been made on data reported by GHD/Oceanics (1975) for measured conveyor emissions at a wind speed of 10 m/s. The PM_{10} fraction has been estimated as 45% of the TSP. The approach outlined is conservative since it assumes emissions from a conventional conveyor and based on emission factors provided for coal dust.

As the Sasol Mooikraal conveyor is covered[5], it is not expected that dust would be generated from the conveying process.

4.1.2.2 Materials Handling

The materials handling points are shown in Figure 1. Materials handling of ROM coal from Mooikraal takes place at the MK8 transfer point, from where it is transferred to the crusher house for processing. Imported coal is unloaded at the primary plant stockpile. From the primary plant the coal gets transferred via the MK9 conveyor belt to the coal stockpile via the C01a, C02 and C03 conveyor belts and transfer points. The coal stacker is used to load coal stockpiles on the Coal Stockpile Area, which is concrete-lined. Coal is manually reclaimed with front-end loaders from the stockpiles and processed. Processing is required for the correct coal quality in terms of ash percentage, prior to being loaded into a series of chutes and bins along the conveyor CS1. This provides Sasolburg Operations (SO) with coal at volumes of approximately 8 000 tpd, via CO4 conveyor and transfer points. The emission equations for materials handling are provided in Table 8. The total emissions due to materials handling are shown in Table 11 (for baseline operations) and Table 12 (for Project operations).

4.1.2.3 Crushing

Primary and secondary crushing operations represent significant dust-generating sources if uncontrolled. Dust fallout in the vicinity of crushers also gives rise to the potential for the re-entrainment of emitted dust by vehicles or by the wind at a later date. The large percentage of fines in this dustfall material enhances the potential for it to become airborne.

Crushing emissions were calculated for secondary crushing operations only, since primary crushing is done at the Mooikraal Colliery itself and secondary crushing at the plant facility. The throughput of material being crushed was given as 200 000 tpm. From Figure 1 it is apparent that the crusher is enclosed (baseline scenario). It was assumed that the crusher at the new location will also be enclosed (for the Project scenario). The default emission factors used for the calculation of emissions for crushing and screening activities are given in Table 8. Emissions were calculated under the assumption of 90% mitigation on crushers (through enclosure). The calculated emissions for $PM_{2.5}$, PM_{10} and TSP at the crusher plant are summarized in Table 11 (for baseline operations) and Table 12 (for Project operations).

[5] Per personal communication – L. Grobler, 7 August 2018.

4.1.2.4 Unpaved Roads

Imported coal is currently being hauled to the primary plant area via a stretch of unpaved road (shown in Figure 3) (Scenario 1). Once the new crusher has been built the haul road will be shorter, with lower emissions as a result (Scenario 2). The emission equations for vehicle entrainment of dust are provided in Table 8. The total emissions due to vehicle entrainment during construction are shown in Table 11 (for baseline operations) and Table 12 (for Project operations).

4.1.2.5 Wind Erosion

Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the friction velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them. The velocity at which this occurs is called the threshold friction velocity (Shao, 2008). Thus, the likelihood exists for wind erosion to occur from open and exposed surfaces, with loose fine material, when the wind speed exceeds at least the friction velocity.

The storage piles that will be subject to wind erosion during the construction phase are the coal stockpile and three ash disposal facilities located to the west of the Project area (Figure 1). Figure 1 shows the areas that were taken into account when calculating emissions due to wind erosion, and for dispersion modelling. It was assumed that only the outer rims of the two active Sasol ash disposal facilities would be available for wind erosion. An area representative of the sum total of erodible areas at the old Sasol ash dump (Figure 1) was also included.

Unmitigated emissions due to windblown dust from the three ash disposal facilities and coal stockpile were included in Scenario 1 and Scenario 2a. For Scenario 2b, mitigation in the form of windbreaks was assumed (30% control efficiency) and for Scenario 2c, mitigation in the form of fog cannons was assumed (90% control efficiency). The hourly emission file calculated for Scenario 1 and 2a was adjusted for Scenario 2b and 2c with the respective control efficiency factors for hours when the wind came from the west-northwest and northwest (i.e. the wind direction which would result in impacts in Zamdela residential area). The hourly emission files exclude the ash disposal facilities.

The equations used in the calculation of wind erosion are given in Table 8. The particle size distributions for the respective materials are given in Table 9. The total emissions due to wind erosion during construction are shown in Table 11 (for baseline operations) and Table 12 (for Project operations).

Table 8: Emission equations used to quantify fugitive dust emissions from the proposed Project

Activity	Emission Equation	Source	Information assumed/provided
Materials handling (including conveying)	$$E = 0.0016 \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$ Where, E = Emission factor (kg dust / t transferred) U = Mean wind speed (m/s) M = Material moisture content (%) The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively. An average wind speed of 2.05 m/s was used based on the DEA data for the period 2014 – 2016.	US-EPA AP42 Section 13.2.4	The moisture contents of materials are as follows: Coal: 8% (provided) The respective throughput of materials during the operational phase was calculated as 171 tph (ROM coal from Mooikraal), and 23 tph (imported coal).
Materials handling (loading stockpiles)	Secondary: $$E_{TSP} = 0.004\ kg/t\ material\ processed$$ $$E_{PM10} = 0.0017\ kg/t\ material\ processed$$ $$E_{PM2.5} = 0.006\ kg/t\ material\ processed$$ Where, E = Default emission factor Fraction of $PM_{2.5}$ taken from US-EPA emission factor ratio for materials handling	NPI Section: Mining	The throughput of material from the crusher was provided as 1 700 000 tpa coal to be stockpiled via coal stacker on the concrete-lined coal stockpile area. Hours of operation were given as 24 hrs per day, 7 days per week.
Vehicle entrainment on unpaved surfaces	$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} \cdot 281.9$$ Where, E = particulate emission factor in grams per vehicle km travelled (g/VKT) k = basic emission factor for particle size range and units of interest s = road surface silt content (%) W = average weight (tonnes) of the vehicles travelling the road = 50 t	US-EPA AP42 Section 13.2.2	In the absence of site-specific silt data, use was made of the US EPA default mean silt content for mine roads of 8.4%. Operational transport activities onsite include the transport of imported coal to the plant. Hours of operation were assumed as 24 hrs per day, 7 days per week.

Activity	Emission Equation	Source	Information assumed/provided
	The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$ and 1.5 for PM_{10}, and as 4.9 for TSP The empirical constant (a) is given as 0.9 for $PM_{2.5}$ and PM_{10}, and 4.9 for TSP The empirical constant (b) is given as 0.45 for $PM_{2.5}$, PM_{10} and TSP		The capacity of the haul trucks to be used was given as 30 t. The layout of the roads was provided. The throughput of material was provided as 200 000 tpa.
Crushing and screening	Secondary: $E_{TSP} = 0.03\ kg/t\ material\ processed$ $E_{PM10} = \ 0.012\ kg/t\ material\ processed$ $E_{PM2.5} = 0.006\ kg/t\ material\ processed$ Where, E = Default emission factor for <u>high moisture</u> content ore Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing	NPI Section: Mining	The throughput of material was provided as 1 500 000 tpa coal (from Sigma Colliery) and 200 000 tpa coal (imported). Hours of operation were given as 24 hrs per day, 7 days per week. Primary crushing done at Sigma Colliery. Secondary crushing occurring at the plant.
Wind Erosion	$E(i) = G(i)10^{(0.134(\%clay)-6)}$ For $G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$ And $R = \frac{u_*^{\ t}}{u^*}$ where, $E_{(i)}$ = emission rate (g/m²/s) for particle size class i P_a = air density (g/cm³) G = gravitational acceleration (cm/s³) u_*^t = threshold friction velocity (m/s) for particle size i u^* = friction velocity (m/s)	Marticorena & Bergametti, 1995	Coal particle size distributions were obtained from the mine (see Table 9). Ash particle distribution was obtained from similar processes. The moisture content and particle density of stockpile coal were assumed as 1% and 1.4 t/m³ respectively. The moisture content of ash was assumed to be 0.1%. The particle density was assumed as 0.95 t/m³ (from similar processes). Layout of coal stockpile was provided. Layout of ash disposal facilities was obtained from Google Earth satellite imagery. Hourly emission rate file was calculated and simulated for the coal stockpile.

Table 9: Particle size distributions of ash dump and coal materials (given as a fraction)

Ash		Coal	
Size µm	Mass Fraction	Size µm	Mass Fraction
478	0.0018	1019.52	0.00
259	0.0539	890.12	0.00
103	0.1982	394.24	0.05
76	0.0910	229.08	0.20
30	0.2829	101.46	0.14
23	0.0773	67.52	0.30
10	0.1411	22.8	0.23
6	0.0720	10.10	0.07
2	0.0519	5.12	0.01
1	0.0300	2.27	0.00

Table 10: Estimated control factors for various mining operations

Operation/Activity	Control method and emission reduction
Windblown dust from ash dumps & coal stockpile	No control
Haul roads	75% CE for water sprays
Materials handling (loading and unloading)	50% CE for water sprays
Materials handling (covered conveyor tipping points)	70% CE for enclosure
Crushing and Screening of coal material	90% CE for crusher enclosure
Windblown dust from conveyors	100% CE for enclosure

Note: CE is Control Efficiency

Table 11: Calculated emission rates in tonnes per annum due to baseline operations (Scenario 1)

Description	Emissions (tpa)		
	Scenario 1		
	$PM_{2.5}$	PM_{10}	TSP
Materials Handling	0.26	1.74	4.02
Crushing	1.44	2.88	7.20
Vehicle entrainment	0.52	5.22	18.31
Wind Erosion – coal stockpile	0.03	8.16	11.67
Wind Erosion – ash dump 1	51.19	177.66	449.48
Wind Erosion – ash dump 2	22.71	78.82	199.41
Wind Erosion – ash dump 3	56.97	197.75	500.30
Total (Project + ash dumps)	**133**	**472**	**1 190**
Total (Project only)	**2**	**18**	**41**

Table 12: Calculated emission rates in tonnes per annum due to Project operations (Scenario 2a, 2b and 2c)

Description	Emissions (tpa)								
	Scenario 2a			Scenario 2b			Scenario 2c		
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Materials Handling	0.26	1.70	3.93	0.26	1.70	3.93	0.26	1.70	3.93
Crushing	1.44	2.88	7.20	1.44	2.88	7.20	1.44	2.88	7.20
Vehicle entrainment	0.36	3.65	12.80	0.36	3.65	12.80	0.36	3.65	12.80
Wind Erosion – coal stockpile	0.03	8.16	11.67	0.03	7.29	10.42	0.02	5.54	7.93
Wind Erosion – ash dump 1	51.19	177.66	449.48	46.91	162.82	411.94	38.36	133.14	336.85
Wind Erosion – ash dump 2	22.71	78.82	199.41	20.81	72.24	182.76	17.02	59.07	149.44
Wind Erosion – ash dump 3	56.97	197.75	500.30	52.21	181.23	458.51	42.70	148.19	374.94
Total (Project + ash dumps)	**133**	**471**	**1 185**	**122**	**432**	**1 088**	**100**	**354**	**893**
Total (Project only)	**2**	**16**	**36**	**2**	**16**	**34**	**2**	**14**	**32**

4.2 Atmospheric Dispersion Modelling

The impact assessment of the project's operations on the environment is discussed in this section. To assess impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 1);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2);
- The AQSRs in the vicinity of the proposed mine (Section 3.1); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 1.4).

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. Dispersion models simulate ambient pollutant concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

4.2.1 Dispersion Model Selection

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. One of the most widely used Gaussian plume model is the US EPA AERMOD model that was used in this study. AERMOD is a model developed with the support of AERMIC, whose objective has been to include state-of-the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

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, information on the nature of the receptor grid and pre-development or background pollutant concentrations or dustfall rates. Version 7.9 of AERMOD and its pre-processors were used in the study.

4.2.2 Meteorological Requirements

For the current study, use was made of measured DEA data for Zamdela for the period 2014-2016 (Section 3.2).

4.2.3 Source Data Requirements

The AERMOD model can model point, jet, area, line and volume sources. Sources were modelled as follows:

- Materials handling – modelled as volume sources;
- Crushing and Screening – modelled as volume sources;
- Unpaved roads windblown dust – modelled as area sources; and
- Windblown dust from coal stockpiles – modelled as area sources[6].

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 10 km (east-west) by 10 km (north-south). The area was divided into a grid matrix with a resolution of 100 m by 100m, with the project located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor points (AQSRs).

[6] Although windblown dust from nearby ash dumps were quantified, they were not included in the model as they are not the only background sources in the vicinity of the Project area, and it was not feasible to quantify other sources to realistically model cumulative concentrations.

4.3 Dispersion Modelling Results

Dispersion modelling was undertaken to determine highest daily and annual average ground level concentrations. Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations.

Pollutants with the potential to result in human health impacts which are assessed in this study include $PM_{2.5}$ and PM_{10}. Dustfall is assessed for its nuisance potential. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified.

Isopleth plots reflect the incremental ground level concentrations (GLCs) for $PM_{2.5}$ and PM_{10} where exceedances of the relevant NAAQSs were simulated.

It should also be noted that ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus 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 i.e. off-site.

4.3.1 $PM_{2.5}$

The simulated highest daily $PM_{2.5}$ concentrations for Scenario 1 and Scenario 2a are provided in Figure 18 to Figure 19 respectively, with the GLCs at each of the AQSRs provided in Table 13. *Scenarios 2b and 2c were not modelled for $PM_{2.5}$, since the hourly emission rates due to windblown dust from the coal stockpile were negligibly low (see Table 12).*

The main findings are:

- **Scenario 1:** ***$PM_{2.5}$*** daily GLCs, with design mitigation in place, are likely to be in non-compliance with the current and 2030 NAAQSs for an area extending over the crusher area (Figure 18). From Table 13 no exceedances are expected at any of the AQSRs. Over an annual average the GLCs are low and well within the standard.
- **Scenario 2a:** ***$PM_{2.5}$*** daily GLCs show similar impacting areas as with Scenario 1, but with exceedances over the crusher area now closer to Zamdela residential area (Figure 19). Compliance with the NAAQS for both daily and annual averages are shown at all the AQSRs (Table 13).

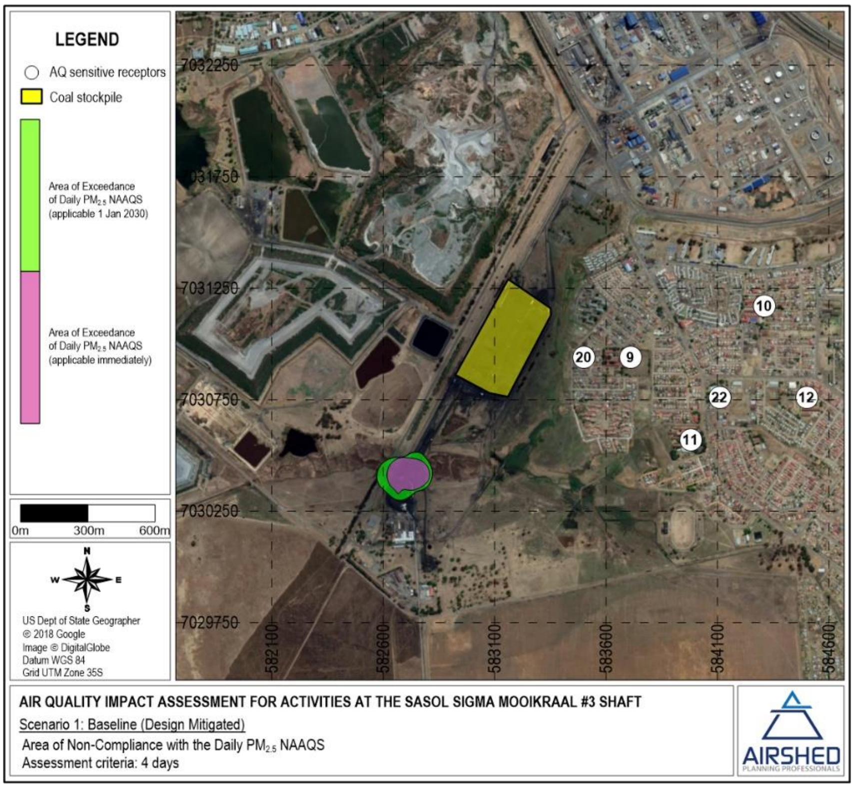


Figure 18: Scenario 1 – Area of non-compliance of daily $PM_{2.5}$ NAAQS due to design mitigated emissions[7]

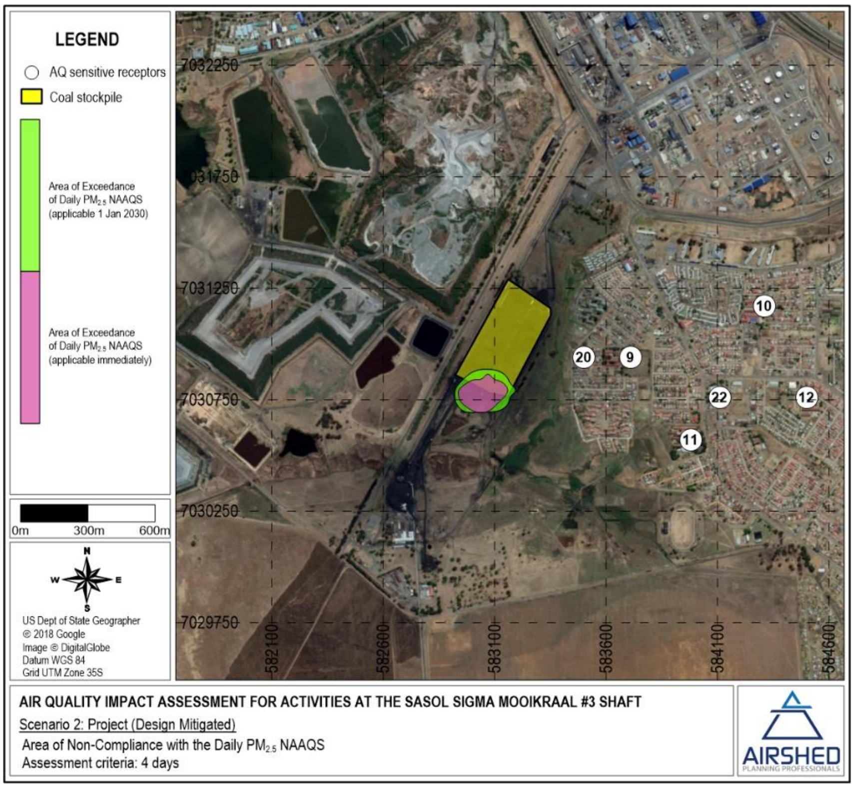


Figure 19: Scenario 2 – Area of non-compliance of daily $PM_{2.5}$ NAAQS due to design mitigated emissions[7]

[7] Design mitigation: Haul roads with 75% CE; materials handling with 50% CE on loading and unloading; 70% CE on covered conveyor tipping points; and 90% CE on enclosed crushing and screening.

Table 13: Simulated AQSR $PM_{2.5}$ concentrations (in µg/m³) for Scenario 1 and Scenario 2a (compliance evaluation 1 Jan 2030 NAAQSs)

AQ SR	Scenario 1				Scenario 2a			
	Highest Daily	Annual	No of Exceedances	Within Compliance (Yes/No)	Highest Daily	Annual	No of Exceedances	Within Compliance (Yes/No)
1	0.1	0.0	0	Yes	0.2	0.0	0	Yes
2	0.1	0.0	0	Yes	0.2	0.0	0	Yes
3	0.1	0.0	0	Yes	0.1	0.0	0	Yes
4	0.1	0.0	0	Yes	0.1	0.0	0	Yes
5	0.1	0.0	0	Yes	0.1	0.0	0	Yes
6	0.2	0.0	0	Yes	0.2	0.0	0	Yes
7	0.2	0.0	0	Yes	0.2	0.0	0	Yes
8	0.1	0.0	0	Yes	0.2	0.0	0	Yes
9	1.6	0.3	0	Yes	2.8	0.5	0	Yes
10	0.8	0.1	0	Yes	1.1	0.2	0	Yes
11	0.9	0.2	0	Yes	1.5	0.2	0	Yes
12	0.6	0.1	0	Yes	0.9	0.1	0	Yes
13	0.4	0.1	0	Yes	0.5	0.1	0	Yes
14	0.3	0.0	0	Yes	0.4	0.1	0	Yes
15	0.3	0.0	0	Yes	0.4	0.0	0	Yes
16	0.4	0.0	0	Yes	0.4	0.0	0	Yes
17	0.3	0.0	0	Yes	0.2	0.0	0	Yes
18	0.2	0.0	0	Yes	0.2	0.0	0	Yes
19	0.2	0.0	0	Yes	0.3	0.0	0	Yes
20	2.3	0.4	0	Yes	4.7	0.8	0	Yes
21	0.1	0.0	0	Yes	0.2	0.0	0	Yes
22	0.9	0.2	0	Yes	1.4	0.2	0	Yes
23	0.4	0.1	0	Yes	0.5	0.1	0	Yes
24	0.3	0.0	0	Yes	0.3	0.0	0	Yes
25	0.4	0.1	0	Yes	0.5	0.0	0	Yes
26	0.2	0.0	0	Yes	0.2	0.0	0	Yes

4.3.2 PM_{10}

The simulated highest daily PM_{10} concentrations for Scenario 1 and Scenarios 2a, 2b and 2c are provided in Figure 20 and Figure 21 respectively, with the GLCs at each of the AQSRs provided in Table 14.

The main findings are:

- **Scenario 1:** ***PM_{10}*** daily GLCs, with design mitigation in place, are likely to be in non-compliance with the NAAQS for an area extending over the coal stockpile and crusher area (Figure 20). From Table 14 no exceedances are expected at any of the AQSRs (Table 4). Over an annual average the GLCs are low and well within the standard.
- **Scenario 2a, b and c:** ***PM_{10}*** daily GLCs show similar impacting areas as with Scenario 1, but with exceedances over the crusher area now closer to Zamdela residential area (Figure 21). A comparison between the impact areas for Scenarios 2a, 2b and 2c reveals only a slight reduction in impacts when additional mitigation in the form of wind breaks and fog cannons are applied. Compliance with the NAAQS for both daily and annual averages are shown at all the AQSRs (Table 14).

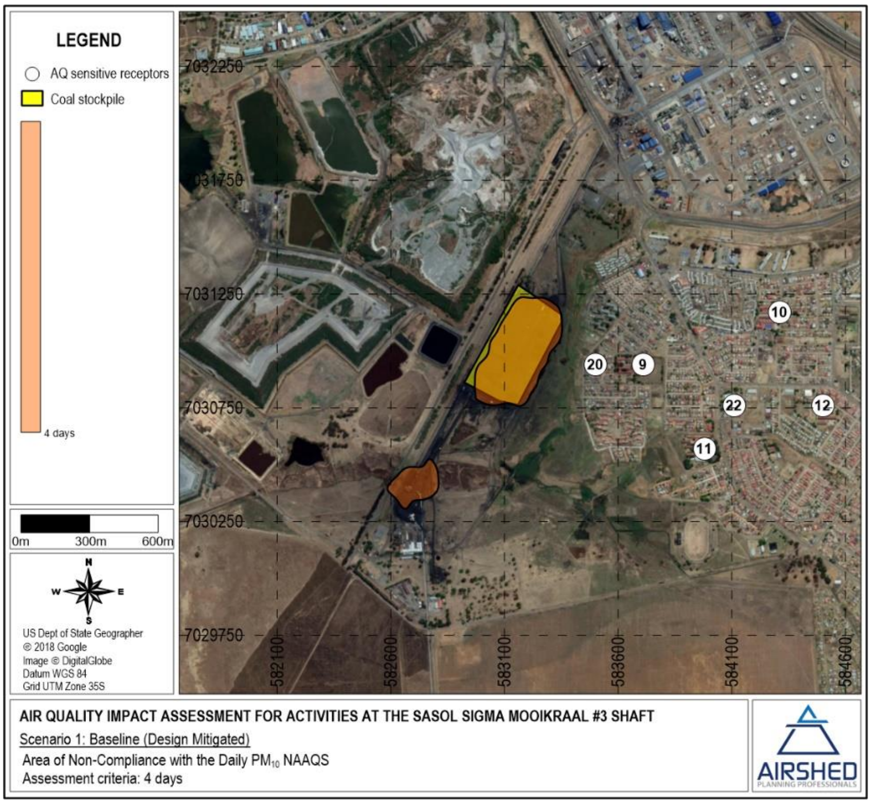


Figure 20: Scenario 1 – Area of non-compliance of daily PM_{10} NAAQS due to design mitigated emissions[8]

[8] Design mitigation: Haul roads with 75% CE; materials handling with 50% CE on loading and unloading; 70% CE on covered conveyor tipping points; and 90% CE on enclosed crushing and screening

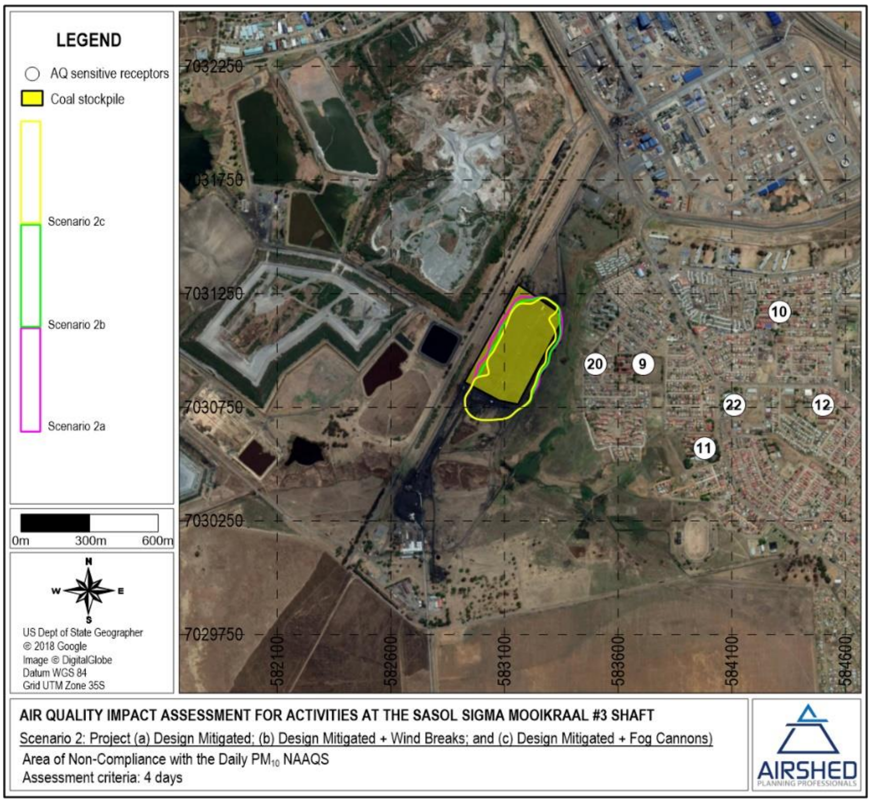


Figure 21: Scenario 2 – Area of non-compliance of daily PM_{10} NAAQS due to (a) design mitigated emissions[8], (b) design mitigated + wind breaks, and (c) design mitigated +fog cannons

Table 14: Simulated AQSR PM_{10} concentrations (in µg/m³) for Scenario 1, Scenario 2a, Scenario 2b and Scenario 2c

AQ SR	Scenario 1				Scenario 2a				Scenario 2b				Scenario 2c			
	Highest Daily	Annual	No of Excee-dances	Within Compliance (Yes/No)	Highest Daily	Annual	No of Exceedances	Within Compliance (Yes/No)	Highest Daily	Annual	No of Excee-dances	Within Compliance (Yes/No)	Highest Daily	Annual	No of Excee-dances	Within Compliance (Yes/No)
1	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes
2	0.7	0.1	0	Yes	0.7	0.1	0	Yes	0.7	0.1	0	Yes	0.7	0.1	0	Yes
3	0.5	0.1	0	Yes	0.5	0.0	0	Yes	0.5	0.0	0	Yes	0.5	0.0	0	Yes
4	0.4	0.0	0	Yes	0.4	0.0	0	Yes	0.4	0.0	0	Yes	0.4	0.0	0	Yes
5	0.4	0.0	0	Yes	0.4	0.0	0	Yes	0.4	0.0	0	Yes	0.4	0.0	0	Yes
6	0.8	0.1	0	Yes	0.7	0.1	0	Yes	0.7	0.1	0	Yes	0.7	0.1	0	Yes
7	1.1	0.1	0	Yes	1.0	0.1	0	Yes	1.0	0.1	0	Yes	1.0	0.1	0	Yes
8	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes
9	24.3	1.8	0	Yes	25.0	1.9	0	Yes	18.6	1.9	0	Yes	9.5	1.8	0	Yes
10	10.3	0.7	0	Yes	10.2	0.7	0	Yes	8.8	0.7	0	Yes	4.3	0.7	0	Yes
11	16.0	0.8	0	Yes	16.0	0.8	0	Yes	11.3	0.8	0	Yes	5.2	0.7	0	Yes
12	4.6	0.5	0	Yes	4.8	0.5	0	Yes	4.1	0.5	0	Yes	3.3	0.5	0	Yes
13	3.1	0.3	0	Yes	3.1	0.3	0	Yes	2.2	0.2	0	Yes	2.1	0.2	0	Yes
14	1.8	0.2	0	Yes	1.7	0.2	0	Yes	1.6	0.2	0	Yes	1.5	0.2	0	Yes
15	1.7	0.2	0	Yes	1.6	0.2	0	Yes	1.5	0.2	0	Yes	1.4	0.2	0	Yes
16	2.1	0.2	0	Yes	2.2	0.1	0	Yes	2.2	0.1	0	Yes	1.0	0.1	0	Yes
17	1.7	0.1	0	Yes	1.4	0.1	0	Yes	1.4	0.1	0	Yes	0.8	0.1	0	Yes
18	0.9	0.1	0	Yes	0.8	0.1	0	Yes	0.7	0.1	0	Yes	0.7	0.1	0	Yes
19	1.2	0.2	0	Yes	1.2	0.1	0	Yes	1.2	0.1	0	Yes	1.2	0.1	0	Yes
20	87.8	3.3	1	Yes	87.7	3.7	1	Yes	67.3	3.6	0	Yes	26.4	3.4	0	Yes
21	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes
22	9.1	0.8	0	Yes	9.5	0.8	0	Yes	6.9	0.8	0	Yes	4.8	0.8	0	Yes
23	2.7	0.3	0	Yes	2.6	0.3	0	Yes	2.3	0.3	0	Yes	2.1	0.3	0	Yes
24	1.5	0.2	0	Yes	1.4	0.1	0	Yes	1.3	0.1	0	Yes	1.3	0.1	0	Yes
25	3.5	0.2	0	Yes	3.5	0.2	0	Yes	2.7	0.2	0	Yes	1.6	0.2	0	Yes
26	0.9	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes	0.8	0.1	0	Yes

4.3.3 Dust Fallout

The simulated maximum daily ***dustfall rates*** for Scenario 1 and Scenarios 2a, 2b and 2c are provided in Figure 22 and Figure 23 respectively, with the values at each of the AQSRs provided in Table 15.

The main findings are:

- **Scenario 1:** Maximum daily ***dustfall rates***, with design mitigation in place, are likely to be in non-compliance with the NDCR residential limit (600 mg/m²/day) for the area extending over the coal stockpile and crusher area (Figure 22 and Table 15). From Table 15 no exceedances are expected at any of the AQSRs.
- **Scenario 2a, b and c:** Maximum daily ***dustfall rates***, with the new crusher and conveyor system in place, show similar impacting areas as for Scenario 1 (Figure 23). Figure 23 shows very little reduction in the areas of non-compliance between design mitigated activities (Scenario 2a) and Scenarios 2b and c (with additional mitigation in the form of wind breaks and fog cannons respectively). Compliance with the NDCR residential limit (600 mg/m²/day) are shown at all the AQSRs for all three of the sub-scenarios (Table 15).

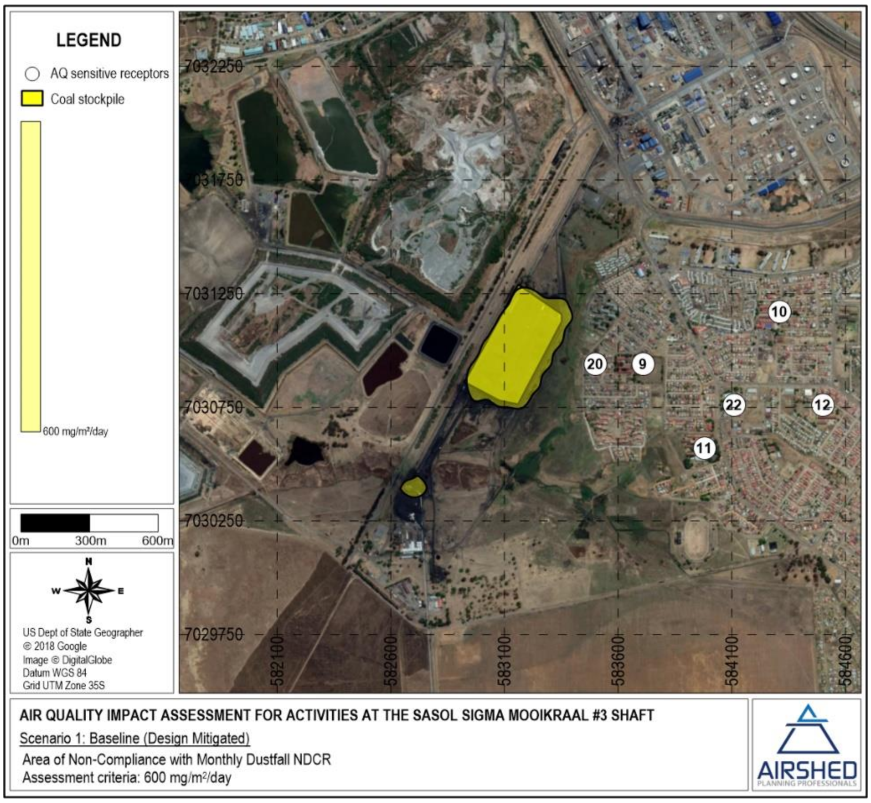


Figure 22: Scenario 1 – Simulated dustfall deposition rates due to due to design mitigated emissions[9]

[9] Design mitigation: Haul roads with 75% CE; materials handling with 50% CE on loading and unloading; 70% CE on covered conveyor tipping points; and 90% CE on enclosed crushing and screening

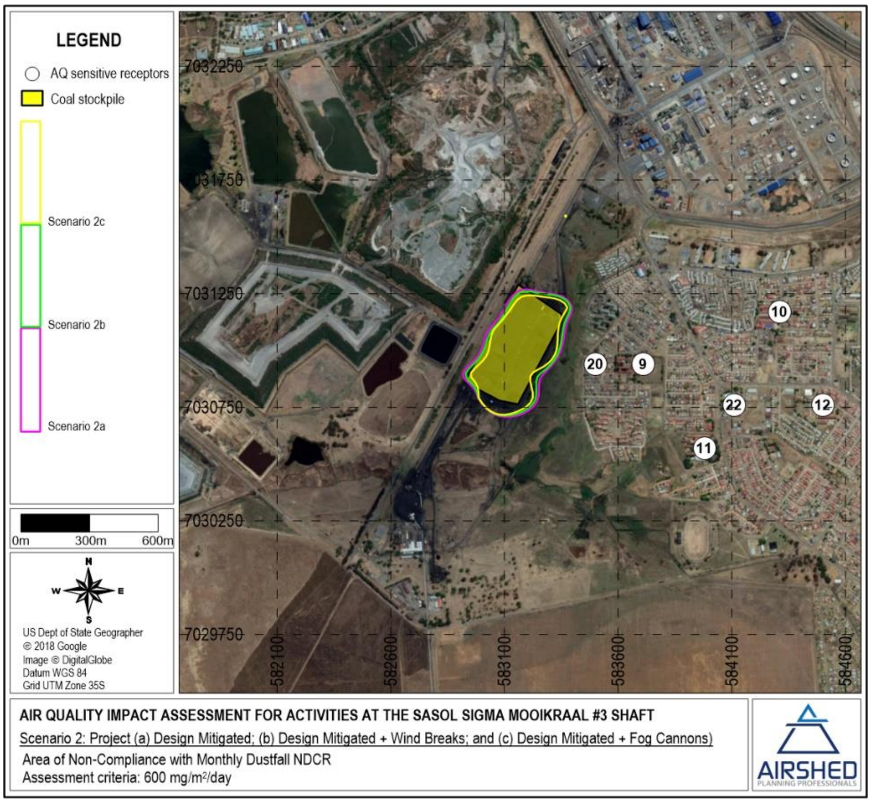


Figure 23: Scenario 2 – Simulated dustfall deposition rates due to due to design mitigated emissions[9], (b) design mitigated + wind breaks, and (c) design mitigated +fog cannons

Table 15: Simulated AQSR total dustfall rates (in mg/m²/day) for Scenario 1, Scenario 2a, Scenario 2b and Scenario 2c

AQSR	Scenario 1	Scenario 2a	Scenario 2b	Scenario 2c
	Highest 30-day avg	Highest 30-day avg	Highest 30-day avg	Highest 30-day avg
1	0.4	0.4	0.4	0.4
2	0.4	0.4	0.3	0.4
3	0.1	0.1	0.1	0.1
4	0.1	0.1	0.1	0.1
5	0.1	0.1	0.1	0.1
6	0.3	0.3	0.2	0.3
7	0.5	0.5	0.4	0.5
8	0.1	0.1	0.0	0.1
9	32.8	32.9	22.9	11.1
10	13.4	13.4	9.6	4.9
11	23.2	23.3	15.5	5.4
12	4.0	3.9	2.4	2.2
13	3.0	3.0	2.0	1.1
14	1.5	1.4	0.9	0.8
15	1.2	1.2	0.7	0.6
16	6.8	6.8	4.7	1.4
17	5.0	5.0	3.6	1.4
18	0.5	0.5	0.3	0.2

AQSR	Scenario 1	Scenario 2a	Scenario 2b	Scenario 2c
	Highest 30-day avg	Highest 30-day avg	Highest 30-day avg	Highest 30-day avg
19	0.7	0.6	0.5	0.6
20	104.7	105.2	70.6	35.8
21	0.3	0.3	0.2	0.3
22	9.0	8.9	5.8	4.0
23	2.1	2.1	1.2	1.1
24	1.1	1.1	0.7	0.5
25	8.5	8.4	5.8	1.7
26	1.1	1.1	0.8	0.2

Note: Screened against the residential dustfall limit of 600 mg/m²/day

4.4 Model Validation

Measured concentrations of PM_{10} at the DEA Zamdela monitoring station help provide an understanding of existing ambient air concentrations, as well as a means of verifying the dispersion model results. In terms of the current investigation, the portion of air quality due to air emission sources that could not be included in the model's emissions inventory, constitutes the background concentration.

In order to establish model performance under average emission conditions, it is not uncommon to use a certain percentile of modelled and observed concentrations for comparison. Although these may range from a 90^{th} to 99.9^{th} percentile, it was decided to use the DEA NAAQS for guidance. For criteria pollutants, including $PM_{2.5}$ and PM_{10}, the NAAQS requires compliance with the 99^{th} percentile. As daily averages, this allows exceedances of the limit value of four (4) days per year.

Estimates of background concentrations were obtained from the measured values at the ranked position where no contributions from the simulated sources were predicted. This was done by comparing the modelled hourly concentrations against the measured hourly concentrations at the ranked position. Measured concentrations include the "background" sources unaccounted for in the modelling results, thus percentiles from each dataset (modelled and measured) were compared against each other to determine the fraction unaccounted for.

Summarized in Table 16 are the comparisons between simulated (Scenario 1) and measured PM_{10} concentrations at the DEA Zamdela monitoring station in the study area (see Figure 3), for each year of the meteorological dataset used as input in the AERMOD model as well as for the entire 2014-2016 period. Eighty percent (80%) of the measured peak concentrations could not be accounted for the years 2014, 2016 and over the 2014-2016 period, whereas ninety percent (90%) of the measured peak concentrations could not be accounted for the year 2015 (see Table 16). The difference between simulated and measured increases significantly when considering long-term comparisons (i.e. 50^{th} percentile and annual average) at these stations. The contribution of emission sources not included in the dispersion model's emissions inventory were taken where the modelled concentration is close to 0 µg/m³ – a threshold modelled concentration of 0.1 µg/m³ was used.

Table 16: Comparison of simulated and observed PM_{10} concentrations at the DEA Zamdela monitoring station

	PM_{10} concentration (µg/m³)			Unaccounted Fraction*
	Simulated	Measured	Unaccounted	
2014				
Peak	54	950	896	0.94
99th Percentile	7	284	277	0.98
90thPercentile	0	114	114	1.00
50th Percentile	0	32	32	1.00
Annual Average	0	49	49	0.98
Background (80th percentile)	<0.1	78	78	1.00
2015				
Peak	25	863	838	0.97
99th Percentile	6	186	180	0.97
90thPercentile	0	77	77	1.00
50th Percentile	0	7	7	1.00
Annual Average	0	27	27	0.98
Background (90th percentile)	<0.1	77	77	1.00
2016				
Peak	11	863	852	0.99
99th Percentile	6	289	283	0.98
90thPercentile	0	133	133	1.00
50th Percentile	0	40	40	1.00
Annual Average	0	57	57	0.98
Background (80th percentile)	<0.1	92	92	1.00
Period (2014-2016)				
Peak	54	950	896	0.94
99th Percentile	6	265	258	0.98
90thPercentile	0	110	110	1.00
50th Percentile	0	27	27	1.00
Annual Average	7	44	44	0.98
Background (80th percentile)	<0.1	74	74	1.00

Notes: [a] unaccounted fraction as a percentage of observed concentration

[b] observed value when simulation indicated little contribution (0.1 µg/m³)

From the above it may be concluded that the air quality impacts due to the current and proposed activities at 3 Shaft are not likely to contribute to ambient PM_{10} concentrations measured at the DEA Zamdela monitoring station (located 1.7 km to the southeast of the Project site – see Figure 3). The polar plot in Figure 14 for particulates measured at Zamdela station indicates high concentrations from the north-west and north-east at high wind speeds (above 4 m/s), and a local source at low wind speeds. The contributing sources to the background air quality at Zamdela are likely to include windblown dust from far-afield stockpiles to the northwest and agricultural activities to the northeast, and local sources such as vehicle entrained dust from unpaved roads and industrial sources to the north of the station.

5 Impact Significance Rating

The significance of air quality impacts was assessed according to a generic impact significance rating methodology. Refer to Appendix B of this report for the methodology.

The significance of the air quality impacts due to project activities were found to be:

- **Scenario 1 (Baseline)** operations ***Low*** (Table 17) for design mitigated activities. This applies to $PM_{2.5}$ and PM_{10} concentrations, as well as dustfall rates.
- **Scenario 2 (Project)** operations ***Low*** (Table 18) for Scenario 2a (design-mitigated activities), Scenario 2b (design mitigated activities + windbreaks) and Scenario 2c (design mitigated activities + fog cannons). This applies to $PM_{2.5}$ and PM_{10} concentrations, as well as dustfall rates.

Table 17: Significance rating for air quality impacts due to current activities (Scenario 1)

Project Activity	Air Quality		Consequence				Probability	
Scenario 1								
Elevated PM_{10} and $PM_{2.5}$ concentrations as a result of design-mitigated activities	Phase of Project	Operational Phase	Duration of Activity	Severity	Spatial Scope	Reversibility	Probability of Impact	Significance Rating
	Impact Classification	Direct Impact	Significance (Design Mitigation)					
	Resulting Impact from Activity	Elevated PM_{10} and $PM_{2.5}$ Concentrations	4	2	2	2	3	**30**
Dustfall due to design-mitigated activities	Impact Classification	Direct Impact	Significance (Design Mitigation)					
	Resulting Impact from Activity	Elevated Dust Fall Levels	4	2	2	2	3	**30**

Table 18: Significance rating for air quality impacts due to proposed project activities (Scenario 2)

Project Activity	Air Quality		Consequence				Probability	
Scenario 2a								
Elevated PM_{10} and $PM_{2.5}$ concentrations as a result of design-mitigated activities	Phase of Project	Operational Phase	Duration of Activity	Severity	Spatial Scope	Reversibility	Probability of Impact	Significance Rating
	Impact Classification	Direct Impact	Significance (Design Mitigation)					
	Resulting Impact from Activity	Elevated PM_{10} and $PM_{2.5}$ Concentrations	4	2	1	2	3	**27**
Dustfall due to design-mitigated activities	Impact Classification	Direct Impact	Significance (Design Mitigation)					
	Resulting Impact from Activity	Elevated Dust Fall Levels	4	2	2	2	3	**30**
Scenario 2b								

Project Activity	Air Quality		Consequence				Probability	
Elevated PM_{10} concentrations as a result of design-mitigated activities + wind breaks	Phase of Project	Operational Phase	Duration of Activity	Severity	Spatial Scope	Reversibility	Probability of Impact	Significance Rating
	Impact Classification	Direct Impact	Significance (Design Mitigation + Windbreaks)					
	Resulting Impact from Activity	Elevated PM_{10} and $PM_{2.5}$ Concentrations	4	2	1	2	3	**27**
Dustfall due to design-mitigated activities + wind breaks	Impact Classification	Direct Impact	Significance (Design Mitigation + Windbreaks)					
	Resulting Impact from Activity	Elevated Dust Fall Levels	4	2	2	2	3	**30**
Scenario 2c								
Elevated PM_{10} concentrations as a result of design-mitigated activities + fog cannons	Phase of Project	Operational Phase	Duration of Activity	Severity	Spatial Scope	Reversibility	Probability of Impact	Significance Rating
	Impact Classification	Direct Impact	Significance (Design Mitigation + Fog Cannons)					
	Resulting Impact from Activity	Elevated PM_{10} and $PM_{2.5}$ Concentrations	4	2	1	2	3	**27**
Dustfall due to design-mitigated activities + fog cannons	Impact Classification	Direct Impact	Significance (Design Mitigation + Fog Cannons)					
	Resulting Impact from Activity	Elevated Dust Fall Levels	4	2	1	2	3	**27**

6 Air Quality Management Measures

In the light of the elevated air quality around the Sigma Colliery 3 Shaft complex, even though the contribution from 3 Shaft to the ambient air quality is regarded to be low, it is recommended that the project proponent commit to adequate air quality management planning throughout the life of the proposed project. The air quality management plan provides options on the control of dust particles at the main sources, while the monitoring network is designed to track the effectiveness of the mitigation measures.

Based on the findings of the impact assessment, the following mitigation, management and monitoring recommendations are proposed.

6.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the project is to ensure that operations result in ambient air concentrations (specifically $PM_{2.5}$ and PM_{10}) and dustfall rates that are within the relevant ambient air quality standards and regulations outside the mining area and at the relevant AQSRs. In order to define site specific management objectives, the main sources of pollution need to be identified. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

6.1.1 Ranking of Sources

The ranking of sources serves to confirm the current understanding of the significance of specific sources, and to evaluate the emission reduction potentials required for each. Sources ranking can be established on:

- Emissions ranking; based on the comprehensive emissions inventory established for the Project operations (Section 4.1); and
- Impacts ranking; based on the simulated pollutant GLCs.

Ranking of sources based on Project emissions (excluding the contribution from nearby ash dumps), are as follows:

- **Scenario 1 (Baseline)**: The main source of design mitigated emissions for $PM_{2.5}$ is crushing (63.8%); windblown dust from the coal stockpile for PM_{10} (45.3%) and unpaved roads for TSP (44.4%). The second most significant source is unpaved roads for $PM_{2.5}$ and PM_{10} (23.1% and 29.0% respectively), and windblown dust from the coal stockpile for TSP (28.3%).
- **Scenario 2 (Project)**: Similar as for Scenario 1, the main source of design mitigated emissions for $PM_{2.5}$ is crushing (68.7%); windblown dust from the coal stockpile for PM_{10} (49.8%) and unpaved roads for TSP (36.0%). The second most significant source is unpaved roads for $PM_{2.5}$ and PM_{10} (17.4% and 22.3% respectively), and windblown dust from the coal stockpile for TSP (32.8%).

Ranking of sources based on impacts, are as follows:

- **Construction**: Likely activities to result in dust impacts during construction are:
  - existing primary plant infrastructure removal/demolition;
  - topsoil recovered from stockpiles for rehabilitation of the area surrounding the old primary plant;
  - construction of new plant infrastructure and buildings;
  - scraping of topsoil and land clearing to build the new primary plant;
  - vehicle entrainment on unpaved road surfaces during construction.
- **Scenario 1 (Baseline)**: the main source of impact during the baseline is roads (for PM_{10}) and crushing (for $PM_{2.5}$). For daily dustfall rates the main source of impact is windblown dust from the coal stockpile at 9 receptors within 1.8 km of the Project boundary (viz. SR9-SR11, SR13, SR16-SR17, SR20, and SR22-SR23) and 2 receptors further afield (SR25-SR26); at the other 15 receptors (viz. 5 receptors to the east and all 10 receptors to the north of the Project boundary) the main source of impact is unpaved roads.. Incremental values simulated at sensitive receptors were low and within compliance for all pollutants.
- **Scenario 2 (Project)**: the source contributions for $PM_{2.5}$ and PM_{10} are the same as those discussed for Scenario 1. For daily dustfall rates, the source contributions for Scenarios 2a and 2b remain the same as for the baseline scenario, but for Scenario 2c the main source contributor is unpaved roads at 25 of the 26 receptors, with windblown dust the main source of impact only at SR17.
- **Closure and Post-closure**: Likely activities to result in dust impacts during closure are:
  - infrastructure removal/demolition;
  - topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings; and
  - vehicle entrainment on unpaved road surfaces during rehabilitation – once that is done, vehicle activity associated with the operations should cease.

6.2 Proposed Mitigation and Management Measures

6.2.1 Proposed Mitigation Measures and/or Target Control Efficiencies

From the above discussion it is recommended that the project include the following measures:

- Construction and closure phase:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on untreated roads; and to apply water sprays on regularly travelled, unpaved sections.
  - When haul trucks need to use public roads, the vehicles need to be cleaned of all mud and the material transported must be covered to minimise windblown dust.
  - The access road to the Project also needs to be kept clean to minimise carry-through of mud on to public roads.

- Operational phases (the control efficiencies are from (NPI, 2012)):
    - For the control of vehicle entrained dust it is recommended that water (at an application rate >2 litre/m²/hour), be applied. Literature reports an emissions reduction efficiency of 50%. Applying chemical suppressants on the unpaved haul roads a control efficiency of more than 90% is possible.
    - In controlling dust from crushing and screening operations, it is recommended that the crusher be enclosed, to achieve a control efficiency of up to 90% (as is currently being done).
    - In mitigating air quality impacts due to conveyors, it is recommended that the conveyor be fitted with a roof and covering on one of its sides (as is currently being done). A mitigation efficiency of 70% is anticipated. (NPI, 2012).
    - Mitigation of materials transfer points should be done using water sprays at the tip points (and when forming stockpiles using the coal stacker). This should result in a 50% CE.
    - In minimizing windblown dust from stockpile areas, it is recommended that fog cannons be used to mitigate windblown dust by 90%.

6.3 Performance Indicators

Key performance indicators against which progress of implemented mitigation and management measures may be assessed, form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly (source monitoring) and the impact on the receiving environment (ambient air quality monitoring). Ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels, at the identified AQSRs, to below 600 mg/m²-day represents an impact- or receptor-based performance indicator.

Except for vehicle/equipment emission testing, source monitoring at operational activities can be challenging due to the fugitive and wind-dependent nature of particulate emissions. The focus is therefore rather on receptor-based performance indicators i.e. compliance with ambient air quality standards and dustfall regulations.

6.3.1 Ambient Air Quality Monitoring

Ambient air quality monitoring can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal and spatial trend analysis;
- Source quantification; and,

- Tracking progress made by control measures.

It is recommended that the existing dustfall monitoring network as discussed in Section 0 remain in place with monthly dustfall collection be conducted throughout the life of mine. This will not only provide air quality trends, but also provide an indication of dustfall increases, if any, due to the mining activities.

Monthly dustfall reporting should continue, providing information on:

- monthly dustfall rates compared to the applicable dustfall limits (as listed in Table 6),
- temporal and spatial dustfall trends to indicate potential source contributions.

6.4 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly), with annual environmental audits being conducted. Annual environmental audits should be continued at least until closure. Results from site inspections and monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

The criteria to be taken into account in the inspections and audits must be made transparent by way of minimum requirement checklists included in the management plan. Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

6.5 Liaison Strategy for Communication with Interested and Affected Parties (I&APs)

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans should stipulate specific intervals at which forums will be held and provide information on how people will be notified of such meetings. Given the close proximity of the study site to the town of Zamdela, it is recommended that such meetings be scheduled and held at least on a bi-annual basis. A complaints register must be kept at all times.

6.6 Financial Provision

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and I&APs liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures. The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

7 Conclusions and Recommendations

7.1 Main Findings

A quantitative air quality impact assessment was conducted for the current and proposed operational phase activities for the Sasol Mooikraal Sigma 3 Shaft project. Closure and post-closure activities were assessed qualitatively. The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels, the validation of the dispersion model and determination of the significance of impacts.

7.1.1 Baseline Assessment

The findings from the baseline assessment can be summarised as follows:

- The prevailing wind field in the area consists of easterly and westerly winds, with infrequent winds from the south and south-east. During the day the winds were predominantly from the northwest to southwest, with the strongest winds from the northwest. The wind conditions shifted during the night-time with strong winds predominantly from the east-northeast and easterly directions. Day-time calms occurred for 11.77% of the time, with night-time calms for 11.34% of the time.
- The area experiences hot summers and cold winters with an average annual rainfall of 550 mm.
- Ambient air pollutant levels in the project area are currently affected by the following sources of emission: petrochemical processes (Sasol and Natref); domestic fuel burning, windblown dust emissions from ash dumps, vehicle tailpipe emissions and agriculture.
- AQSRs around the project site include schools, hospitals and clinics, as well as the residential areas of Zamdela to the southeast, and Sasolburg to the north.
- Monitoring data from the DEA Zamdela site (approximately 1.75 km from the project site) for the period January 2015 to December 2017 was analysed. The daily 99th percentiles for PM_{10} exceeded the limit value (75 µg/m^3) at Zamdela station for all three years, where non-compliance varied between 15% and 30% of the three years assessed.
- Time variation plots (mean with 95% confidence interval) of ambient particulate matter (PM_{10} and $PM_{2.5}$) concentrations measured at Zamdela station were created to show the variation of these pollutants over a daily, weekly and annual cycle. Monthly variation of particulate matter shows elevated concentrations during winter months due to the larger contribution from domestic fuel burning, dust from uncovered soil and the lack of the settling influence of rainfall.

7.1.2 Impact Assessment

The impact of the proposed Project can be summarized as follows:

Construction phase:

- Likely activities to result in dust impacts during construction are: Infrastructure removal/demolition of existing primary plant infrastructure; topsoil recovered from stockpiles for rehabilitation and re-vegetation of the old primary plant surroundings; construction of new plant infrastructure and buildings; scraping of topsoil and clearing of land to build the new primary plant; and vehicle entrainment on unpaved roads during construction.
- Construction: the impacts are expected to be **Low**.

Operational phase (Scenario 1):

- The main source of design mitigated emissions for $PM_{2.5}$ is crushing (63.8%); windblown dust from the coal stockpile for PM_{10} (45.3%) and unpaved roads for TSP (44.4%). The second most significant source is unpaved roads for $PM_{2.5}$ and PM_{10} (23.1% and 29.0% respectively), and windblown dust from the coal stockpile for TSP (28.3%).
- The main source of impact during the baseline is roads (for PM_{10}) and crushing (for $PM_{2.5}$). For daily dustfall rates the main source of impact is windblown dust from the coal stockpile at 9 receptors within 1.8 km of the Project boundary (viz. SR9-SR11, SR13, SR16-SR17, SR20, and SR22-SR23) and 2 receptors further afield (SR25-SR26); at the other 15 receptors (5 receptors to the east and all 10 receptors to the north of the Project boundary) the main source of impact is unpaved roads. Values simulated at sensitive receptors were within compliance for all pollutants.
- Mitigation measures assumed during Scenario 1 are: water sprays on haul roads and materials transfer points; covering of conveyor transfer points and enclosure of secondary crushing and screening.
- Scenario 1 (baseline) operations resulted in ***Low*** impact significance for design mitigated activities. This applies to $PM_{2.5}$ and PM_{10} concentrations, as well as dustfall rates.
- Background concentrations – contribution from sources other than the current activities at 3 Shaft – were estimated by comparing modelled hourly concentrations against measured hourly concentrations at the ranked position. It was found that the activities at 3 Shaft are not likely to contribute to ambient PM_{10} concentrations measured at the DEA Zamdela monitoring station (located 1.7 km to the southeast of the Project site) and that background air quality at Zamdela are likely from other sources in the area.

Operational phase (Scenario 2):

- Similar as for Scenario 1, the main source of design mitigated emissions for $PM_{2.5}$ is crushing (68.7%); windblown dust from the coal stockpile for PM_{10} (49.8%) and unpaved roads for TSP (36.0%). The second most significant source is unpaved roads for $PM_{2.5}$ and PM_{10} (17.4% and 22.3% respectively), and windblown dust from the coal stockpile for TSP (32.8%).
- The source contributions for $PM_{2.5}$ and PM_{10} impacts are the same as those discussed for Scenario 1. For daily dustfall rates, the source contributions for Scenarios 2a and 2b remain the same as for the baseline scenario, but for Scenario 2c the main source contributor is unpaved roads at 25 of the 26

receptors, with windblown dust the main source of impact only at SR17. Values simulated at sensitive receptors were within compliance for all pollutants and for all three sub-scenarios.

- Mitigation measures assumed during Scenario 2 are: Design mitigation (water sprays on haul roads and materials transfer points; covering of conveyor transfer points and enclosure of secondary crushing and screening) for Scenario 2a; design mitigation and windbreaks for Scenario 2b; and design mitigation and fog cannons for Scenario 2c.
- Scenario 2 operations resulted in ***Low*** impact significance for Scenario 2a, Scenario 2b and Scenario 2c. This applies to $PM_{2.5}$ and PM_{10} concentrations, as well as dustfall rates.

<u>Closure and post-closure phases:</u>

- Likely activities to result in dust impacts during closure are: Infrastructure removal/demolition; topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings; and vehicle entrainment on unpaved road surfaces during rehabilitation – once that is done, vehicle activity associated with the operations should cease.
- Closure and Post-closure: the impacts are expected to be **Low**.

7.2 Conclusions

The proposed Sasol Mooikraal Shaft 3 Complex operations are likely to result in ground level PM_{10} concentrations and dustfall levels which are within the daily SA NAAQS and NDCR for residential areas with design mitigation measures in place. With additional mitigation measures in place (the application of wind breaks and/or the installation of fog cannons on the fence perimeter), the $PM_{2.5}$, PM_{10} and dustfall impacts reduce only slightly. From an air quality perspective, the proposed project can be authorised permitted the recommended mitigation measures are applied.

7.3 Recommendations

A summary of the recommendations and management measures is given below:

- The implementation of emission controls for the management of emission sources, such as the onsite coal stockpile, as well as the crusher and unpaved haul roads. These include:
  - Limiting the speed of haul trucks; limiting unnecessary travelling of vehicles on untreated roads; and application of water sprays on unpaved road sections, as well as materials handling and exposed areas to wind erosion during construction and closure phase;
  - Water sprays, or other dust control measures, at all material transfer points that would result in at least 50% control efficiency.
  - Side and top cover at the conveyor system and controlling dust from secondary crushing and screening operations through enclosure.
- Undertaking a 3-month PM_{10} and $PM_{2.5}$ sampling campaign at the Zamdela residential receptor (SR20) to measure the immediate air quality impacts occurring as a result of 3 Shaft activities. An E-Sampler

should be used to obtain hourly concentrations coupled with an anemometer to record wind speed and wind direction. Creating a polar plot from the results will provide a clear indication on the actual contribution from the 3 Shaft project on the closest receptors. This will inform decision making on whether to apply additional control measures to reduce windblown dust from the coal stockpile.

- Continuous monitoring of dustfall must be conducted as part of the Project's air quality management plan.

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Appendix A – Specialist Curriculum Vitae

CURRICULUM VITAE

Name	Rochelle Bornman
Date of Birth	24 August 1974
Nationality	South African
Employer	Airshed Planning Professionals (Pty) Ltd
Position	Air Quality Specialist
Profession	Scientist
Years with Firm	10

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Member of National Association for Clean Air (NACA)

EXPERIENCE

- Atmospheric Dispersion Models: AERMOD, ISC, CALPUFF, ADMS (United Kingdom), TANKS
- Other: Golden Software Surfer, Lakes Environmental WRPlot, MS Word, MS Excel, MS PowerPoint, ArcMap, ArcView

EDUCATION

- B. Land Surveying: 1997, *University of Pretoria*
- MPhil: (Geographical Information Systems and Remote Sensing) 1998, *University of Cambridge*

COURSES COMPLETED AND CONFERENCES ATTENDED

- NACA Conference 2010, 2011
- Laboratory Systems Course (ISO 17025: 2017) March 2018

COURSES PRESENTED

- Geodesy and Land Surveying at the University of Pretoria (1999)

COUNTRIES OF WORK EXPERIENCE

- South Africa, Namibia, Mozambique, Saudi Arabia, Mali

LANGUAGES

Language	Proficiency
English	Full professional proficiency
Afrikaans	Full professional proficiency

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CERTIFICATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications and my experience.

18 March 2019

Appendix B – Significance Rating Methodology

A generic methodology was used for assessing the significance of the impact.

Impact Significance Rating Methodology

Aspects which must be taken into consideration to determine the significance of an environmental impact are the *consequence* of an environmental impact and the *probability* of it occurring (Table B1).

Table B1: Aspects in the assessment of impact significance

PROBABILITY	CONSEQUENCE			
Probability of occurrence	Magnitude of impact	Extent of Impact	Reversibility of impact	Duration of impact

The ranking scales used to assess the *consequence* of the impact (the sum of magnitude, extent, reversibility and duration) are described in Table B2.

Table B2: Ranking scales used in the assessment of impact consequence

Criterion	Description	Possible Results		
		Term	Description	Ranking
Magnitude	The degree of alteration of the affected environmental receptor: typically very low; low; medium; high or very high.	Low	The impact has no effect on natural, cultural and social functions and processes beyond that of nuisance value.	1
		Low-moderate	Natural processes and cultural and social functions continue, but in a slightly modified way.	2
		Moderate	Natural processes and cultural and social functions continue, but in a modified way.	3
		High	Natural processes or cultural or social functions are altered to the extent that they temporarily or permanently cease, resulting in severe deterioration of the impacted environment.	4
		Very High	Environmental processes cease completely or societies are completely disrupted.	5
Extent	The geographical extent of the impact on a given environmental receptor: typically site (only); local (within specific activity area); regional (outside activity area but localised); national (within national scope) or international (across international boundaries/borders).	Site only	The impact is limited to the tenement/mine site	1
		Local	The impact will extend beyond the immediate boundaries of the mining tenement, affecting the environment/one or more of the communities in surrounding areas.	2
		Regional	The impact will affect the Mpumalanga Region.	3
		National	The impact will affect South Africa	4
		International	The impact will have an international affect, i.e. trans-boundary.	5

Criterion	Description	Possible Results		
		Term	Description	Ranking
Reversibility	The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change: typically, reversible (recovery without the application of rehabilitation means); recoverable (recovery resulting from specific mitigation or action); and irreversible (recovery is not possible, despite action).	Very high	Intensity of the impact is low and the receiving environment has the capacity, resources and mechanisms to mitigate or optimize the impact.	1
		High	Intensity of the impact is low to moderate and the receiving environment has the capacity, resources and mechanisms to mitigate or optimize the impact.	2
		Moderate	Impact is moderate, and the receiving environment has some mechanisms to mitigate or optimize the impact, as well as resources that can be called upon.	3
		Moderate – low	Potential for mitigation/optimisation is limited because of the severity of the impact and a lack of capacity/resources and coping mechanisms in the receiving environment.	4
		Low	Potential for mitigation/optimisation is highly / severely limited because of the severity of the impact and a lack of capacity/resources and coping mechanisms in the receiving environment.	5
Duration	The length of permanence of the impact on the environmental receptor: typically, short-term (0-5 yrs.); medium-term (5-15 yrs.); long-term (ceases after operational life) and permanent.	Temporary	During construction only (can have temporary effects during operation as well).	1
		Short term	0-5 years, the effects can be reversed in a short time	2
		Medium term	5-15 years, the effects could be reversed over a medium time period, possibly coinciding with the life of mine.	3
		Long term	The impact will only cease after the operational life of the project.	4
		Permanent	The impact on the receiving environment will effectively be irreversible.	5

The following ranking scale was used to assess the *probability* of the impact:

Table B3: Ranking scale used in the assessment of impact probability of occurrence

Criterion	Description	Possible Results		
		Term	Description	Ranking
Probability of occurrence	The likelihood of an impact occurring.	Uncertain	Where insufficient information is available to determine probability.	1
		Low	Where the possibility of the impact materialising is low to unlikely.	2
		Probable	Where there is a distinct possibility that the impact will occur.	3
		Highly probable	Where it is most likely that the impact will occur.	4
		Definite	Where the impact will occur regardless of any preventative measures.	5

The significance is determined by combining the criteria in the following formula:

$$S = (E + D + M + R) \cdot P$$

Where;

S is the significance weighting

E is the extent

D is the duration

M is the magnitude

R is the reversibility

P is the probability

The significance of the two aspects (probability and consequence) was then assessed by using the following formula:

SP (significance points) = consequence × probability

Table B4: Rating of impact significance according to its probability and consequence

Significance Points	Significance Rating	Description
-	Positive	The impact is expected to have a positive impact, but measures may be implemented to enhance any positive outcomes.
$\geq 4 < 20$	Very low	The impact will not affect the decision to proceed with the project and will not need to be considered in the project design.
$\geq 20 < 40$	Low	This impact will be avoided with general mitigation measures
$\geq 40 < 60$	Moderate	This impact will not be avoided unless mitigation measures are put in place and could require modification of the project design.
$\geq 60 < 80$	High	For negative impacts, should the decision be to proceed with the project, stringent mitigation measures must be applied.
≥ 80	Very high	For negative impacts, the decision should be not to proceed with the project.