Air Quality Specialist Report for the Proposed Alexander Project in Mpumalanga

Project done on behalf of **Synergistics Environmental Services, an SLR Group Company**

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Report Title	Air Quality Specialist Report for the Proposed Alexander Project in Mpumalanga
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Declaration	I, Oladapo Akinshipe, as authorised representative of Airshed Planning Professionals (Pty) Ltd hereby confirm my independence as a specialist and declare that neither I nor Airshed Planning Professionals (Pty) Ltd have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Airshed Planning Professionals (Pty) Ltd was appointed as air quality specialists in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for worked performed, specifically in connection with the assessment summarised in this report. I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in this report.
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Acknowledgements	The authors would like to thank Eskom for providing the meteorological and ambient monitoring data from its monitoring station at Kriel Village and Elandsfontein.

Revision Record

Revision Number	Date	Reason for Revision
0	15th June 2016	Draft for client review
0.1	28th July 2016	Incorporation of client review

Specialist Report Requirements

	A specialist report prepared in terms of the Environmental Impact Regulations of 2014 must contain:	**Relevant section in report**
a	details of- (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Report details (page i) Section 11 (Appendix C)
b	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Report details (page i)
c	an indication of the scope of, and the purpose for which, the report was prepared;	Section 1.1
d	the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 3.4.2
e	a description of the methodology adopted in preparing the report or carrying out the specialised process;	Sections 1.3, 4.1 and 4.2
f	the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure;	Section 3.1
g	an identification of any areas to be avoided, including buffers;	Sections 4.3, 6.5
h	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 1.2, Figure 1 and Section 4.3
i	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 1.4 – Assumptions, exclusions and limitations
j	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, Section 5 and Section 7 – Conclusions and recommendations
k	any mitigation measures for inclusion in the EMPr;	Section 6
l	any conditions for inclusion in the environmental authorisation;	Section 6
m	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 6.3.1
n	a reasoned opinion- (I) as to whether the proposed activity or portions thereof should be authorised; and (ii) 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 EMPr, and where applicable, the closure plan;	Section 7 – Conclusions and recommendations
o	a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 6.4
p	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Not applicable
q	any other information requested by the competent authority.	Not applicable

Abbreviations

AAIC	Anglo American Inyosi Coal (Pty) Ltd
AERMIC	AMS/EPA Regulatory Model Improvement Committee
Airshed	Airshed Planning Professionals (Pty) Ltd
APPA	Air Pollution and Prevention Act
AQG	Air Quality Guideline (World Health Organisation)
AQSR	Air Quality Sensitive Receptor
ASG	Atmospheric Studies Group
ASTM	American Society for Testing and Materials
DEA	Department of Environmental Affairs (South Africa)
EETM	Emissions Estimation Technique Manual
ESL	Effects Screening Levels
FEL(s)	Front-end loaders
GLC(s)	Ground Level concentration(s)
GLCC	Global Land Cover Characterisation
IFC	International Finance Corporation
MES	Minimum Emission Standards
NAAQS	National Ambient Air Quality Standards (South Africa)
NDCR	National Dust Control Regulations
NEMAQA	National Environmental Management Air Quality Act (South Africa)
NPI	National Pollutant Inventory (Australia)
RoM	Run-of-Mine
SA	South Africa(n)
SABS	South African Bureau of Standards
Synergistics	Synergistics Environmental Services, an SLR Group Company
TCEQ	Texas Commission for Environmental Quality
TSP	Total Suspended Particulates
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VKT	Vehicle kilometres travelled
WHO	World Health Organization

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
Oxides of nitrogen (NO_x)	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide (NO_2)
Particulate Matter (PM)	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 of up 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 of up 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

Symbols and Units

°C	Degree Celsius
µg	Microgram(s)
$\mu g/m^3$	Micrograms per cubic meter
CO	Carbon monoxide
CO_2	Carbon dioxide
L_{MO}	Monin-Obukhov Length
m/s	Meters per second
m^2	Metres squared
mg	Milligram(s)
mg/m^3	Milligrams per cubic meter
mm	Millimeters
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
Pb	Lead
PM	Particulate Matter
PM_{10}	Thoracic particulate matter
$PM_{2.5}$	Respirable particulate matter
SO_2	Sulphur dioxide
VOC(s)	Volatile organic compound(s)

Executive Summary

Introduction

Anglo American Inyosi Coal (Pty) Ltd (AAIC) is proposing to establish a new underground coal mine in Mpumalanga through the Alexander Project ('the Project'). The Alexander coal resource lies within the current AAIC Kriel East and Elders Underground Extension prospecting right areas (proposed Alexander mining right area) and covers an area of approximately ~ 7,300ha. The Project will involve the development of surface and underground facilities. In broad terms the proposed Alexander Project will comprise an underground mine, a waste rock dump, topsoil stockpiles, mine related facilities such as workshops, stores and various support infrastructure and services. Further to this, the Project will require construction of an overland conveyor to transport run-of-mine coal from the proposed Alexander incline shaft to the stockpile area at the Elders Colliery from where it will be transported via the Elders overland conveyor to Goedehoop Colliery for beneficiation purposes. The coal resources from the Project, which will produce 6 million tonnes per annum at maximum operating capacity, will be a replacement for the depleting coal resources at Elders Colliery.

The Project is located approximately 12 km northwest of Bethal and directly to the south and south-east of Kriel, in the Gert Sibande District Municipality (DM) and Nkangala DM of the Mpumalanga Province. The Alexander resource lies between the R547 provincial road to the west and the R35 provincial road to the east, with the R545 provincial road bisecting the resource in a north-west to south-east direction.

The construction, operation and decommissioning phases of the project may impact ambient air quality in the vicinity of the project. Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Synergistics Environmental Services (Synergistics), an SLR Group Company, to undertake the air quality impact assessment for the Project. The study is conducted as part of the Environmental Impact Assessment (EIA) process.

Scope and Approach

The aim of this investigation was to determine baseline air quality conditions, delineate sensitive receptors and identify potential impacts to air quality that may arise from the project. This formed the basis for the air quality impact assessment conducted for the proposed project.

The following tasks, typical of an air quality impact assessment, were included in the scope of work:

- A review of proposed project activities in order to identify sources of emission and associated pollutants.
- A study of regulatory requirements and health thresholds for identified key pollutants against which compliance was assessed and health risks screened.
- A study of the receiving environment in the vicinity of the project; including:
    - The identification of potential air quality sensitive receptors (AQSRs);
    - A study of the atmospheric dispersion potential of the area taking into consideration local meteorology, land-use and topography; and
    - The analysis of available ambient air quality information/data to determine pre-development ambient pollutant levels and dustfall rates.
- The compilation of a comprehensive emissions inventory which included both process and fugitive emissions.
- Atmospheric dispersion modelling to simulate ambient air pollutant concentrations as a result of the project.
- A screening assessment to determine:
    - Compliance of criteria pollutants with National Ambient Air Quality Standards (NAAQSs);

    - Potential health risks as a result of exposure to non-criteria pollutants; and
    - Nuisance dustfall gauged against the National Dust Control Regulations (NDCR).
  - The compilation of a comprehensive air quality specialist report detailing the study approach, limitations, assumption, results and recommendations of mitigation and management of air quality impacts.

The air quality impact assessment included a study of the receiving environment and the quantification and assessment of the impact of the proposed project on human health and the environment. The receiving environment was described in terms of local atmospheric dispersion potential, the location of AQSRs in relation to proposed activities as well as ambient pollutant levels and dustfall rates.

A comprehensive atmospheric emissions inventory was compiled for the operational phase of the project. Pollutants quantified included those most commonly associated with underground mining i.e. particulate matter (PM) (TSP, PM_{10}, and $PM_{2.5}$[1]), carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO_2) and volatile organic compounds (VOCs). In the quantification of operational phase impacts, the mine design mitigation as provided by Synergistics was utilized.

Main Findings

This section summarises the main findings of the assessment.

- The receiving environment:
  - The area is dominated by winds from the north westerly, north easterly and south westerly sectors. Long-term air quality impacts are therefore expected to be the more prevalent to the southwest, southeast and northeast of the project area.
  - Ambient air pollutant levels in the project area are currently affected by the following sources of emission: mining, power generation, vehicle tailpipe emissions, household fuel combustion, biomass burning/forest fires and open areas exposed to the wind.
  - AQSRs around the project site include towns and villages such as Kriel, Bethal, Evander, Secunda, Kinross and Thubelihle. The closest AQSRs include residences farm houses, private holdings or informal settlements.
  - Measured PM_{10} concentrations were obtained from the Alexander Monitoring campaign. An annual average concentration of 26.2 $\mu g/m^3$ was utilized as baseline concentration for the Project site. This was used in the assessment of cumulative impacts for PM_{10}.

- Impact of the proposed Project:

  - Construction and closure phases:
    - Construction phase PM emissions ($PM_{2.5}$, PM_{10} and TSP) were quantified for the Alexander Project albeit at a screening level since the required detail and schedules to complete a more comprehensive analysis were not available at the time of finalising the assessment. Furthermore, since the construction emissions were lower than the operational phase emissions, due to their temporary nature and the likelihood that these activities will not occur concurrently at all portions of the site, dispersion simulations were not undertaken for construction emissions.
    - Closure phase impacts were not quantified or simulated, since closure schedule was not available; and the release of emission are intermittent in nature and generally less than construction emissions. These

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[1] See Glossary for definitions

    impacts will depend on the extent of rehabilitation efforts to be undertaken at the shaft, infrastructure area and conveyor route.
  - A significance rating of ‘low’ was assigned to potential inhalation health impacts associated with all PM and gaseous pollutants during the construction and closure phases.

- Operational phase:
  - Sources of emission quantified material handling, vehicles travelling on unpaved roads, windblown dust from the stockpiles, vehicle exhaust (diesel engines), conveyor and underground ventilation.
  - Operational phase PM emissions (PM$_{2.5}$, PM$_{10}$ and TSP), and gaseous emissions (CO, NO$_x$, SO$_2$ and VOC) were quantified and utilized in the dispersion simulations.
  - The direct greenhouse gas (GHG) emissions calculated for the Project (assuming the tier 1 and 2 approach) is **111 118** tCO$_2$eq; indicating that the Alexander Project will require the submission of a pollution prevention plan as stipulated by the Department of Environmental Affairs (DEA).
  - Simulated PM$_{10}$ impacts during the operational phase exceed both long-term (annual) and short-term (24-hour) ambient air quality standards only at R29, and not at any other AQSRs. A significance weighting of *‘**medium**’* was assigned to potential inhalation health impacts associated with PM$_{10}$.

    Simulated PM$_{10}$ impacts due to conveyor emissions exceeded only the short-term (24-hour) ambient air quality standards up to 180 m (for unmitigated scenario); and up to 160 m (for mitigated scenario) away from the conveyor edge (in both directions), but not at any other AQSRs.

    PM$_{10}$ impacts reduced when mitigation was applied. However, exceedances of both long-term (annual) and short-term (24-hour) ambient air quality standards at R29 remained. The assigned significance weighting of ***‘medium’*** was sustained.

    Cumulative annual PM$_{10}$ GLCs for unmitigated and mitigated scenarios respectively. Simulations indicate that exceedances of the annual SA NAAQS for PM$_{10}$ (40 µg/m^3) occur only at R29, and not at any other AQSRs.
  - Simulated PM$_{2.5}$ impacts during the operational phase exceed both long-term (annual) and short-term (24-hour) ambient air quality standards only at R29, but not at any other AQSRs. A significance weighting of *‘**medium**’* was assigned to potential inhalation health impacts associated with PM$_{2.5}$.

    Simulated PM$_{2.5}$ impacts due to conveyor emissions exceeded only the short-term (24-hour) ambient air quality standards up to 180 m (for unmitigated scenario); and 120 m (for mitigated scenario) away from the conveyor edge (in both directions), but not at any other AQSRs.

    PM$_{2.5}$ impacts reduced when mitigation was applied. However, exceedances of both long-term (annual) and short-term (24-hour) ambient air quality standards at R29 remained. The assigned significance weighting of ***‘medium’*** was sustained.
  - Simulated maximum daily dustfall rates are in exceedance of the NDCR for residential areas (600 mg/m^2-day) only at AQSR R29 (mitigated and unmitigated scenarios). A significance weighting of ***‘low’*** was assigned to potential impacts associated with dustfall. Also, simulated dustfall deposition rates due to conveyor emission exceed the NDCR residential area limit (600 mg/m^2-day) up to 160 m (for unmitigated scenario); and up to 80 m (for mitigated scenario) away from the conveyor edge (in both directions).
  - Simulated CO, NO$_2$, SO$_2$ and VOC concentrations were low and did not result in exceedances at AQSRs. A significance weighting of ***‘low’*** was assigned to potential inhalation health impacts associated with these pollutants.

- Alternative location of the mine shaft, associated infrastructure and conveyor route:
    - An alternative location for the mine shaft, associated infrastructure and conveyor route for the Project was also proposed. This involves shifting the location of the proposed mine shaft and infrastructure by approximately 300 m to the northeast. From an air quality point of view, impacts due to alternative location of the mine shaft and associated infrastructure will have the same magnitude and extent, as simulated for the original layout. Exceedances of the NAAQS standards are expected to occur at AQSRs to the north and east of the mine shaft including R29.
    - Impacts due to alternative siting of the conveyor are anticipated to exhibit similar trends, as simulated for the original layout, with exceedance occurring at 150 m to 200 m perpendicular to the conveyor. Exceedances of the NAAQS standards are expected at R28.
    - With the proposed mitigation measures in place, impacts due to alternative mine shaft location and siting of the conveyor are expected to reduce. However, exceedances of the NAAQS standards are still anticipated at R29 (due to mine shaft emissions) and R28 (due to conveyor emissions).

Recommendations

To ensure the lowest possible impact on AQSRs and the environment, it is recommended that the air quality management plan as set out in this report be adopted. From an air quality point of view, specialist opinion for authorization of the application for the Project is premised on the implementation of mitigation recommended in this report. Based on the findings in this report and provided the recommended mitigation measures are in place, it is the specialist opinion that the project may be authorised.

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

- The implementation of emission controls for the management of significant emission sources at Alexander Project is recommended. 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;
    - Roofing and covering of conveyor side; application of water sprays on unpaved road sections, as well as materials handling and exposed areas to wind erosion during the operational phase.
- The continuous monitoring of dustfall and PM_{10}/$PM_{2.5}$ be conducted as part of the Project's air quality management plan;
- The Alexander Project falls within the Highveld Priority Area (HPA) footprint and it will contribute to the pollution within the Highveld airshed. It is recommended that the management plan for the HPA as published by the Department of Environmental Affairs (DEA) be included in all management plans employed for the project.
- Furthermore, it is recommended that the project comply with the provisions of the National Atmospheric Emission Reporting Regulations (NAERR) 2015 as summarized in this report. The NAERR aims to standardize the reporting of data and information from an identified data provider to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories.

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Air Quality Specialist Report for the Proposed Alexander Project in Mpumalanga

1 INTRODUCTION

Anglo American Inyosi Coal (Pty) Ltd (AAIC) is proposing to establish a new underground coal mine through the Alexander Project ('the Project'). The Alexander coal resource lies within the current AAIC Kriel East and Elders Underground Extension prospecting right areas (proposed Alexander mining right area) and covers an area of approximately ~ 7,300ha. The Project will involve the development of surface and underground facilities. In broad terms the proposed Alexander Project will comprise an underground mine, a waste rock dump, topsoil stockpiles, mine related facilities such as workshops, stores and various support infrastructure and services. Further to this, the Project will require construction of an overland conveyor to transport run-of mine coal from the proposed Alexander incline shaft to the stockpile area at the Elders Colliery from where it will be transported via the Elders overland conveyor to Goedehoop Colliery for beneficiation purposes.

The Project is located approximately 12 km northwest of Bethal and directly to the south and south-east of Kriel, in the Gert Sibande District Municipality (DM) and Nkangala DM of the Mpumalanga Province. The Alexander resource lies between the R547 provincial road to the west and the R35 provincial road to the east, with the R545 provincial road bisecting the resource in a north-west to south-east direction. The Project site boundary is located on the following farm portions as depicted in Figure 1:

- Portions 3, 4, 6, 7, 8, 16, 17, 19, 31 34, 36, 37 and 18 of the farm Aangewys 81 IS;
- Portions 1, 3, 10, 12, 13, 14, 4, 9 and 2 of the farm Alexander 102 IS;
- Remaining extent of the farm Caley 77 IS;
- RE and portion 6 of the farm Dorstfontein 71 IS;
- Portions 4, 5, 6, 7, 8, 18, 25 and 22 of the farm Witrand 103 IS;
- Portions 1, 3, 4, 6, 7, 10, 11, 12, 14, 15, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 37, 32, 8, 17 and 13 of the farm Witbank 80 IS;
- RE of the farm Witbank 576 IS;
- Portions 2, 6, 7, 8, 9, 10, 11, 14, 17 and 19 of the farm Kafferstad 79 IS;
- Portions 2, 5 and 7 of the farm Rensburgshoop 74 IS;
- Portions 3 and 4 of the farm Onverwacht 70 IS; and
- Portion 2 of the farm Elandsfontein 75 IS.

The coal resources from the Project, which will produce 6 million tonnes per annum at maximum operating capacity, is a replacement for the depleting coal resources at the existing Kriel Colliery. Construction is estimated to elapse over 36 months before commissioning of the Project. The expected life of the mine is between 30 and 35 years.

The construction, operation and decommissioning phases of the project may impact ambient air quality in the vicinity of the project. Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Synergistics Environmental Services (Synergistics), an SLR Group Company, to undertake the air quality impact assessment for the Project. The study is conducted as part of the Environmental Impact Assessment (EIA) process.

1.1 Scope of Work

The following tasks were included in the scope of work:

- A review of proposed project activities in order to identify sources of emission and associated pollutants.
- A study of regulatory requirements and health thresholds for identified key pollutants against which compliance is to be assessed and health risks screened.
- A study of the receiving environment in the vicinity of the project; including:
    - The identification of potential air quality sensitive receptors (AQSRs);
    - A study of the atmospheric dispersion potential of the area taking into consideration local meteorology, land-use and topography; and
    - The analysis of all available ambient air quality information/data to determine pre-development ambient pollutant levels and dustfall rates.
- The compilation of a comprehensive emissions inventory;
- Atmospheric dispersion modelling to simulate ambient air pollutant concentrations and dustfall rates as a result of the project.
- A screening assessment to determine:
    - Compliance of criteria pollutants with National Ambient Air Quality Standards (NAAQSs);
    - Potential health risks as a result of exposure to non-criteria pollutants; and
    - Nuisance dustfall gauged against the National Dust Control Regulations (NDCR).
- The ranking of impact significance based on the methodology adopted by Synergistics.
- The compilation of a comprehensive air quality specialist report detailing the study approach, limitations, assumption, results and recommendations of mitigation and management of air quality impacts.

1.2 Description of Project Activities from an Air Quality Perspective

Air quality impacts will be associated with four distinct phases namely: the construction phase, the operational phase, the decommissioning phase and the post-closure phase. A description of each of these phases, from an air quality impact perspective is summarised below.

Construction will typically include land clearing of the construction footprint, general construction activities (i.e. bulk earthworks and infrastructure development for the plant, buildings, dams, onsite roads etc.), bulldozing, loading and grading activities. These operations will likely result in fugitive[2] PM emissions as well as particulate and gaseous vehicle exhaust emissions. Gaseous emissions, associated with the combustion of diesel, mainly include carbon monoxide (CO), oxides of nitrogen (NO_x), sulphur dioxide (SO_2) and volatile organic compounds (VOC). VOCs are also released from diesel storage tanks.

It is important to note that, in the discussion, regulation and estimation of PM emissions and impacts, a distinction is made between different particle size fractions, *viz*. TSP, PM_{10} and $PM_{2.5}$. PM_{10} is defined as particulate matter with an aerodynamic diameter of less than 10 µm and is also referred to as thoracic particulates. Respirable particulate matter, $PM_{2.5}$, is defined as particulate matter with an aerodynamic diameter of less than 2.5 µm. Whereas PM_{10} and $PM_{2.5}$ fractions are taken into account to determine the potential for human health risks, total suspended particulate matter (TSP) is included to assess nuisance effects.

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[2] Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007).

During the **operational phase** fugitive $PM_{2.5}$, PM_{10} and TSP emissions will result mainly as a result of the following; drilling, blasting, ore and waste handling, truck traffic on unpaved haul routes and open dusty areas exposed to the wind. Diesel generators and exhaust from diesel mobile equipment will result in additional $PM_{2.5}$, PM_{10} and TSP as well as CO, NO_x, SO_2 and VOC emissions. As with construction, the storage of diesel to be used during the operational phase may also result in VOC emission in the form of working and standing losses.

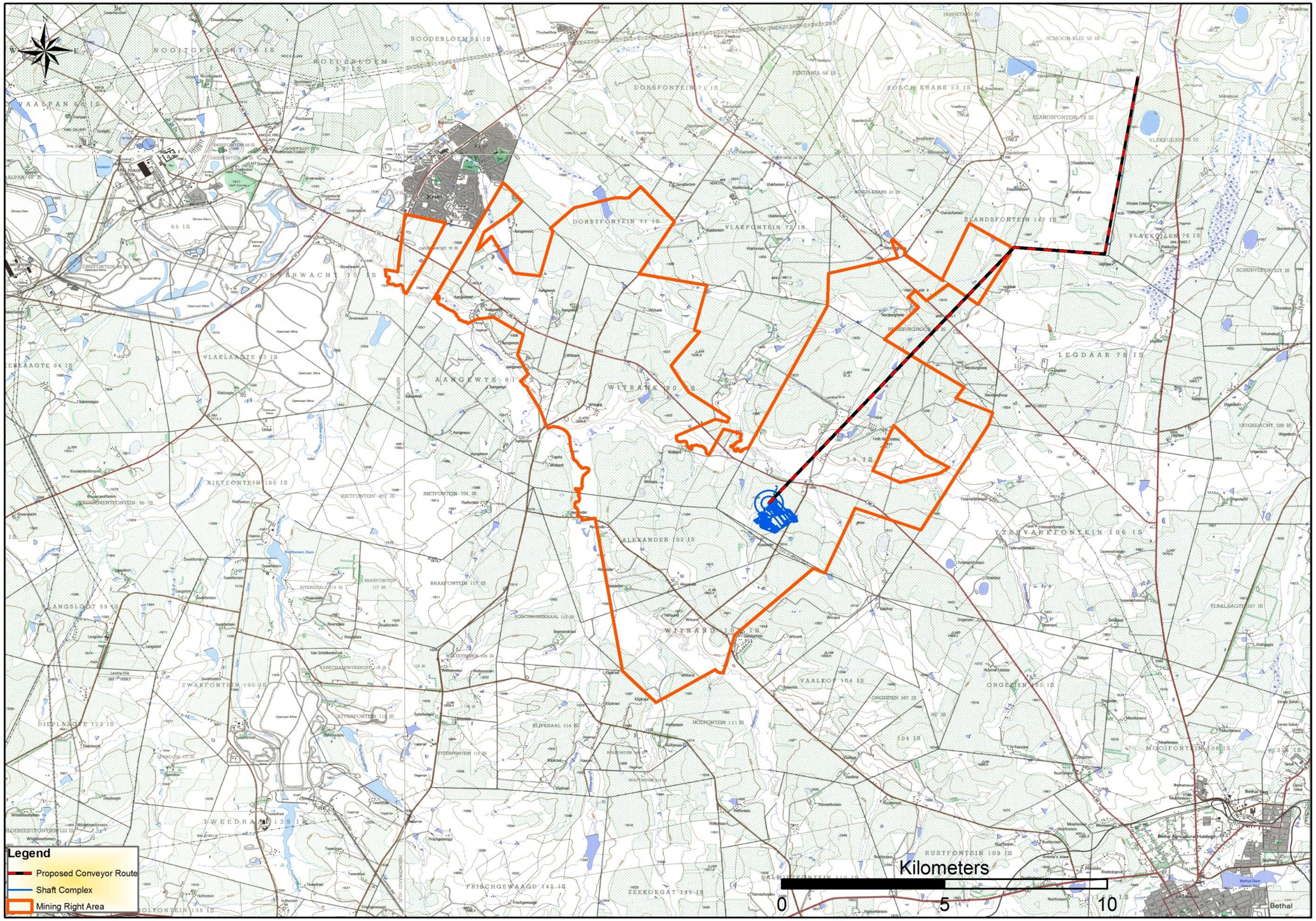

Figure 1: Site layout showing Alexander Project boundary

The **decommissioning** (**closure) and post closure phase** will include fugitive PM generating activities such as bulk earthworks, demolition and re-vegetation, as well as gaseous emissions from the use of diesel storage and combustion sources. With the successful implementation of a closure and rehabilitation plan, no atmospheric emissions will be expected during the **post-closure phase**.

1.3 Approach and Methodology

The approach to, and methodology followed in the completion of tasks completed as part of the scope of work are discussed.

1.3.1 Project Information and Activity Review

All project/process related information referred to in this study was provided by Synergistics.

1.3.2 The Identification of Regulatory Requirements and Health Thresholds

In the evaluation of ambient air quality impacts and dustfall rates reference was made to:

- South African National Ambient Air Quality Standards (SA NAAQS) and National Dust Control Regulations (SA NDCR) as set out in the National Environmental Management Air Quality Act (Act No. 39 of 2004) (NEMAQA); and
- Screening levels for non-criteria pollutants published by various international institutions.

1.3.3 Study of the Receiving Environment

Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology. Existing pre-development ambient air quality in the study area is also considered. Readily available terrain and land cover data was obtained from the Atmospheric Studies Group (ASG) via the United States Geological Survey (USGS) web site at (ASG, 2011). Use was made of Shuttle Radar Topography Mission (SRTM) (90 m, 3 arc-sec) data and Global Land Cover Characterisation (GLCC) data for Africa.

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. Three years (2013 to 2015) of meteorological data (from Eskom's Kriel Village ambient air quality monitoring station) was used in the atmospheric dispersion modelling.

1.3.4 Determining the Impact of the Project on the Receiving Environment

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's emissions on the receiving environment. In the quantification of emissions, use was made of emission factors which associate the quantity of release of a pollutant to the activity. Emissions were calculated using emission factors and equations published by the United States Environmental Protection Agency (US EPA) and Environment Australia (EA) in their National Pollutant Inventory (NPI) Emission Estimation Technique Manuals (EETMs).

1.3.5 Compliance Assessment and Health Risk Screening

Compliance was assessed by comparing simulated ambient criteria pollutant concentrations (CO, NO_2, $PM_{2.5}$, PM_{10} and SO_2) and dustfall rates to selected ambient air quality and dustfall criteria. Health risk screening was done through the comparison of simulated non-criteria pollutant concentrations (VOCs) to selected inhalation screening levels.

1.3.6 Impact Significance

The significance of impacts was determined in accordance with the procedure adopted and prescribed by Synergistics.

1.3.7 The Development of an Air Quality Management Plan

The findings of the above components informed recommendations of air quality management measures, including mitigation and monitoring.

1.4 Assumptions, Exclusions and Limitations

- Project information required to calculate emissions for proposed operations were provided by Synergistics. Where necessary, assumptions were made based on company and specialist's experience.
- Emission factors were used to estimate all fugitive and processing emissions resulting from mining activities and transport. These emission factors generally assume average operating conditions.
- The exact locations of some sources (such as waste dumps and vehicle exhaust emissions) were not known and these are bound to change throughout the mine lifetime. Allocation of the unknown sources into a representative volume or area source was done during the study.
- The impact assessment was limited to airborne particulates (including TSP, PM_{10} and $PM_{2.5}$) and gaseous pollutants from diesel engines, including CO, NOx, VOCs and SO_2.
- Nitrogen monoxide (NO) emissions are rapidly converted in the atmosphere into the much more poisonous nitrogen dioxide (NO_2). NO_2 impacts where calculated by AERMOD using the ozone limiting method assuming constant monthly average background ozone concentrations of 30 ppb (Zunckel, et al., 2004) and a short-term NO_2/NOx emission ratio of 0.2 (Howard, 1988).
- Since it is a difficult task to calculate real-life variations in impacts due to the variability of the operation, design maximum mining rates were utilized in the simulations. Though the nature of the mining operations (active mining area and roads) will change over the life of mine, the proposed sources were modelled to reflect the worst case condition (i.e. resulting in the highest impacts and/or closest to AQSRs).
- 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 criteria pollutants and dustfall, as well as inhalation health risk for VOCs. Discussions on regulations regarding dispersion modelling and emissions reporting, as well as screening criteria for animals and vegetation, are also provided.

2.1 Emission Standards

The NEMAQA (Act No. 39 of 2004 as amended) 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) are included as listed activities with additional activities being 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.

Only the on-site storage of diesel, proposed as part of the Project, is considered a listed activity. Subcategory 2.4, *'the storage and handling of petroleum products'*, are however only applicable to permanent immobile liquid storage facilities at a single site with a combined storage capacity of more than 1 000 m^3. According to the Project description the total installed storage capacity will be such that it does therefore not trigger Subcategory 2.4 MES's or the need for an AEL application.

2.2 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. In the context of this project, these include CO, NO_2, $PM_{2.5}$, PM_{10} and SO_2 (Table 1).

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 and in some instances included a margin of tolerance and implementation timelines linked to it. SA NAAQSs for $PM_{2.5}$ were published on 29 July 2012. SA NAAQSs referred to in this study are listed in Table 1. Currently, only $PM_{2.5}$ has a margin of tolerance, which is applicable until 31 December 2029. Short-term standards (hourly and daily) are represented by a limit value based on the 99th percentile of the observation (or simulated concentration) for that averaging period.

Table 1: Air quality standards for specific criteria pollutants (SA NAAQS)

Pollutant	Averaging Period	Limit Value (µg/m³)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
CO	1 hour	30 000	26 000	88	Immediate
	8 hour	10 000	8 700	11	Immediate
NO_2	1 hour	200	106	88	Immediate
	1 year	40	21	0	Immediate
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 230
	1 year	20	-	0	1 Jan 2016 – 31 Dec 2029
		15		0	1 Jan 230
SO_2	10 minutes	500	191	526	Immediate
	1 hour	350	134	88	Immediate
	24 hour	125	48	4	Immediate
	1 year	50	19	0	Immediate
Pb	1 year	0.5	-	0	Immediate
O_3	8 hour	120	61	11	Immediate
C_6H_6	1 year	5	-	0	1 Jan 2015

2.3 Inhalation Health Criteria for Non-criteria Pollutants

The potential for health impacts associated with non-criteria pollutants (VOCs) emitted from mobile stationery sources are assessed according to guidelines published by the Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs)

Acute and chronic inhalation criteria for non-criteria pollutants considered in the study are summarised in Table 2 (TCEQ (2013).

Table 2: Acute and Chronic inhalation screening criteria for non-criteria pollutants

Pollutant	Acute/Short term Screening Criteria (µg/m³)	Chronic/Long term Screening Criteria (µg/m³)	Source
VOC (*Diesel fuel* used as indicator)	1000	100	TCEQ

2.4 National Dust Control Regulations

The National Dust Control Regulations (NDCR) was published on the 1st of November 2013. The purpose of the regulation is to prescribe general measures for the control of dust in all areas including residential and non-residential areas. Acceptable dustfall rates according to the regulation are summarised in Table 3.

Table 3: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m^2-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 ASTM D1739 (1970), 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.

2.5 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 dust fall 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).

2.6 Regulations regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to 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 proposed operation 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.

2.7 Regulations Regarding Reporting of Atmospheric Emissions

The National Atmospheric Emission Reporting Regulations (NAERR) was published on the 2nd of April 2015 by the Minister of Environmental Affairs. The Regulation aims to standardize the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories (DEA , 2015).

Annexure 1 of the NAERR classify **mines** (holders of a mining right or permit in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) as a data provider under **Group C**. Sections of the regulation that applies to data providers are summarized below.

With regards to registration, the regulation stipulates that:

(a) A person classified as a data provider must register on the NAEIS within 30 days from the date upon which these Regulation came into effect;

(b) A person classified as a data provider and who commences with an activity or activities classified as emission source in terms of the regulation 4(1) after the commencement of the Regulation, must register on the NAEIS within 30 days after commencing with such an activity or activities.

With regards to reporting and record keeping, the regulation stipulates that:

(a) A data provider must submit the required information for the preceding calendar year, as specified in Annexure 1 to these Regulations, to the NAEIS by **31 March of each calendar year.**

(b) A data provider must keep a record of the information submitted to the NAEIS for five years and such record must, on request, be made available for inspection by the relevant authority.

With regards to verification of information, the Regulation requires data providers to verify requested information within 60 days after receiving the written request from the relevant authority.

2.8 Greenhouse Gas Emissions

Draft regulations pertaining to Greenhouse Gas (GHG) reporting using the NAEIS was published in May 2015 (Government Gazette 38779, Notice 411 of 11 May 2015).

The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

The NAEIS web-based monitoring and reporting system will also be used to collect GHG information in a standard format for comparison and analyses. The system forms part of the National Atmospheric Emission Inventory component of SAAQIS.

The DEA is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the Intergovernmental Panel on Climate Change's (IPCC) default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors.

Also, a draft carbon tax bill will be introduced later this year for a further round of public consultation. The Carbon Tax Policy Paper (CTPP) (Department of National Treasury, 2013) stated consideration will be given to sectors where the potential for emissions reduction is limited. Also in draft is that GHG in excess of 0.1 Mt, measured as $CO_{2\text{-eq}}$, is required to submit a pollution prevention plan to the Minister for approval (DEA, 2014).

3 DESCRIPTION OF THE RECEIVING ENVIRONMENT

3.1 Air Quality Sensitive Receptors

AQSRs primarily refer to places where humans 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, 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 Air Quality Act, excludes areas regulated under the Occupational Health and Safety Act (Act No 85 of 1993).

Sensitive receptors are located within and around the boundary of the proposed Alexander Project. Towns and major settlement within the locality include:

- Kriel – A town that bounds the Project boundary to the northwest;
- Bethal – A town located about 13 km southeast of the Project boundary;
- Evander and Kinross – Both towns are located about 20 km southwest of the Project boundary;
- Secunda – An industrial area located about 15 km southwest of the Project boundary and;
- Thubelihle - A residential area located about 5 km north of the Project boundary.

Farm houses and other settlement in close proximity of the Project are illustrated in Figure 2.

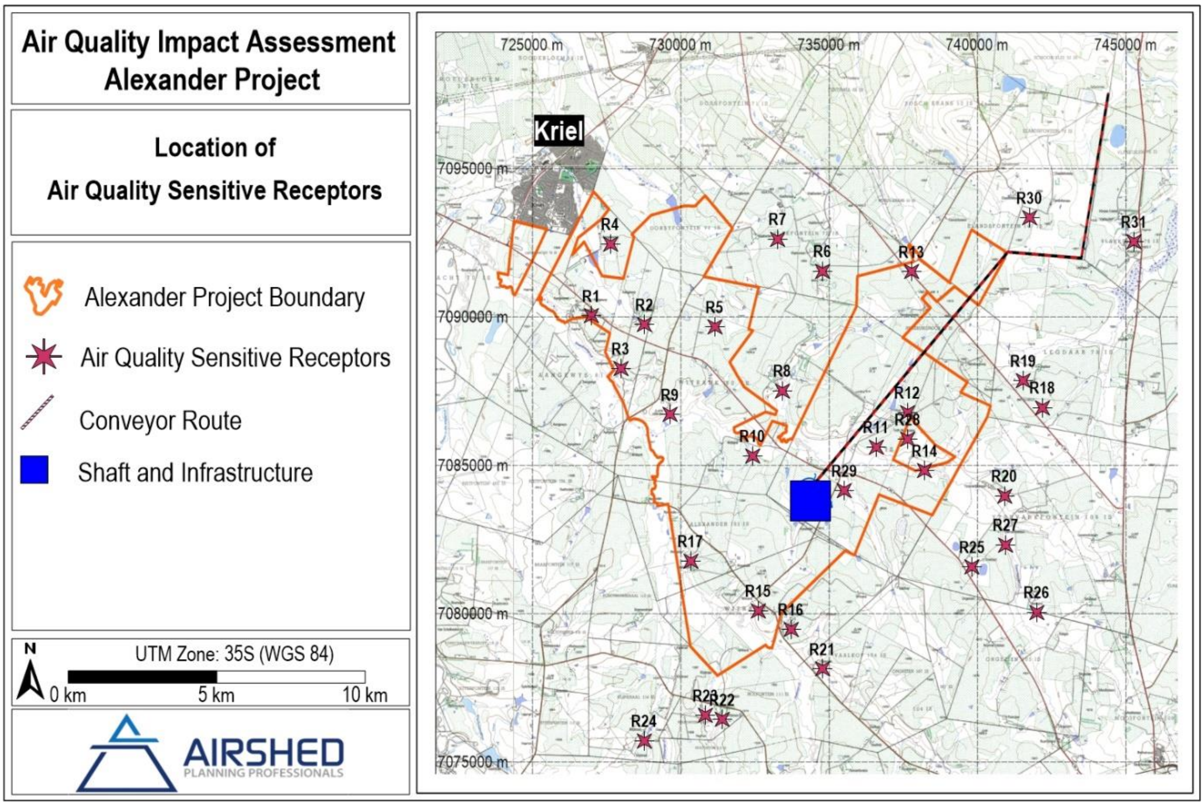

Figure 2: AQSRs (R1 – R31) in close proximity to the Project

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 nearest meteorological station to the Project is Eskom's Kriel Village meteorological station, which is located about 13 km to the northwest of the proposed underground mine shaft. Data for the period January 2013 to December 2015 (3 years) were obtained and is regarded representative of the weather conditions at the project site. Data availability for the period is shown in Table 4.

Table 4: Availability of meteorological data from Eskom's Kriel Village air quality monitoring station

Year	Wind speed	Wind direction	Temperature	Relative humidity	Pressure	Solar radiation	Rainfall
2013	87%	87%	87%	87%	87%	87%	87%
2014	87%	87%	87%	87%	87%	69%	87%
2015	86%	86%	86%	86%	90%	78%	90%
Total	**87%**	**87%**	**87%**	**87%**	**88%**	**78%**	**88%**

3.2.1 Topography

Changes in terrain around an air pollution source can significantly influence the way the plume is dispersed. Hills or rough terrain influence the wind speed, wind direction and turbulence characteristics. Significant valleys can cause persistent drainage flows and restrict horizontal movement whereas sloping terrain may help provide katabatic or anabatic flows.
The topography of the area surrounding the Project site is depicted in Figure 3. The topography of the study area is fairly flat, comprising of undulating terrain slightly increasing in height above mean sea level to the northeast of the area.

An analysis of topographical data indicated a slope of less than 1:10 from over most of the project area. Dispersion modelling guidance recommends the inclusion of topographical data in dispersion simulations only in areas where the slope exceeds 1:10 (US EPA, 2004).

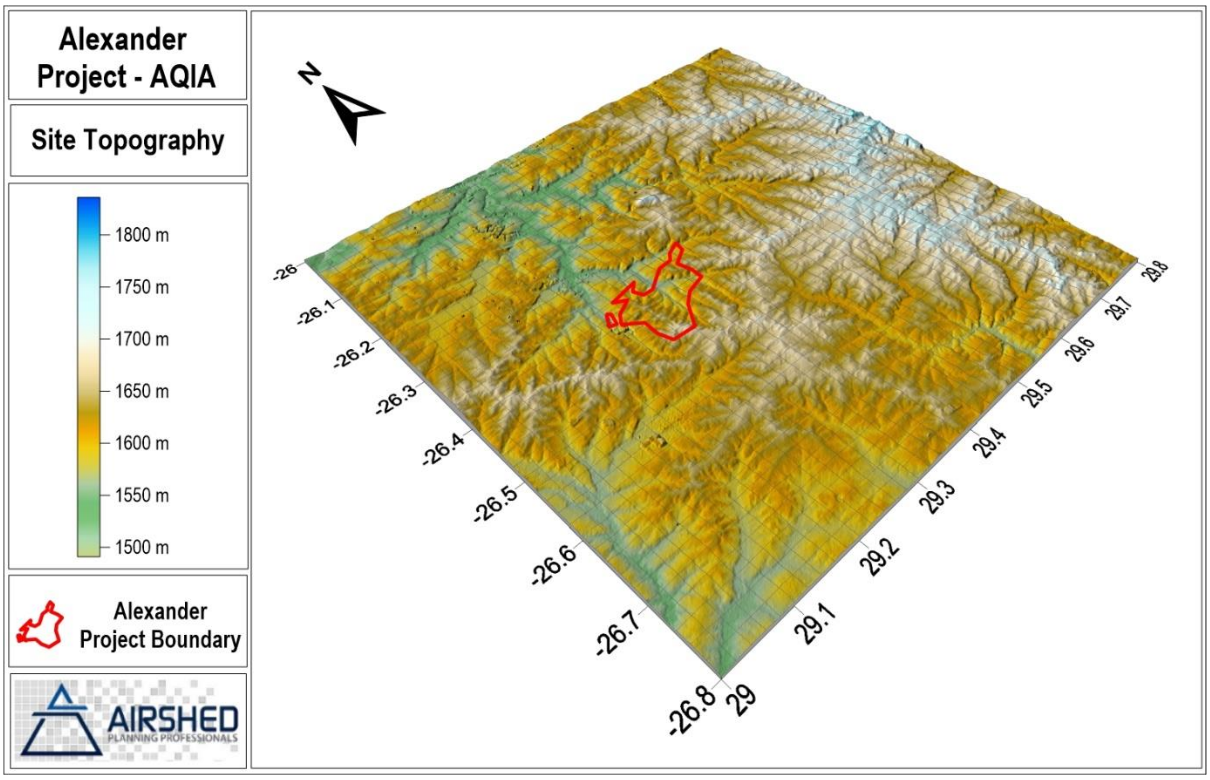

Figure 3: Topography of the study area

3.2.2 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. AERMET, the meteorological pre-processor to AERMOD, treats calm conditions (wind speeds <1 m/s) as missing data, which can result in overly conservative concentration estimates simulated in AERMOD. The Regulations regarding Air Dispersion Modelling (DEA, 2014) suggest that all wind speeds greater than or equal to the anemometer starting threshold and less than 1 m/s be replaced with the value of 1 m/s. This approach was used with the Kriel Village data and 7 535 hours of the data set were corrected with of 1 m/s.

The period wind field and diurnal variability in the wind field are shown in Figure 4. Seasonal variations in the wind field are provided in Figure 5. The wind field was dominated by winds from the north-west; north-east; and, less frequently the south-west. Calm conditions, after correction, occurred less than 1% of the time. During the day, winds at higher wind speeds occurred more frequently from the north westerly sector, with 0.2% calm conditions. Night-time airflow had winds also most frequently from the easterly sector but at lower wind speeds. The frequency of night-time calm conditions increased to 0.9%, relative to day-time. Summer and spring show similar wind direction profiles to the period average, while autumn and winter show the more frequent winds from the south-west. There is an increased frequency of wind speeds of 3 m/s or more in spring.

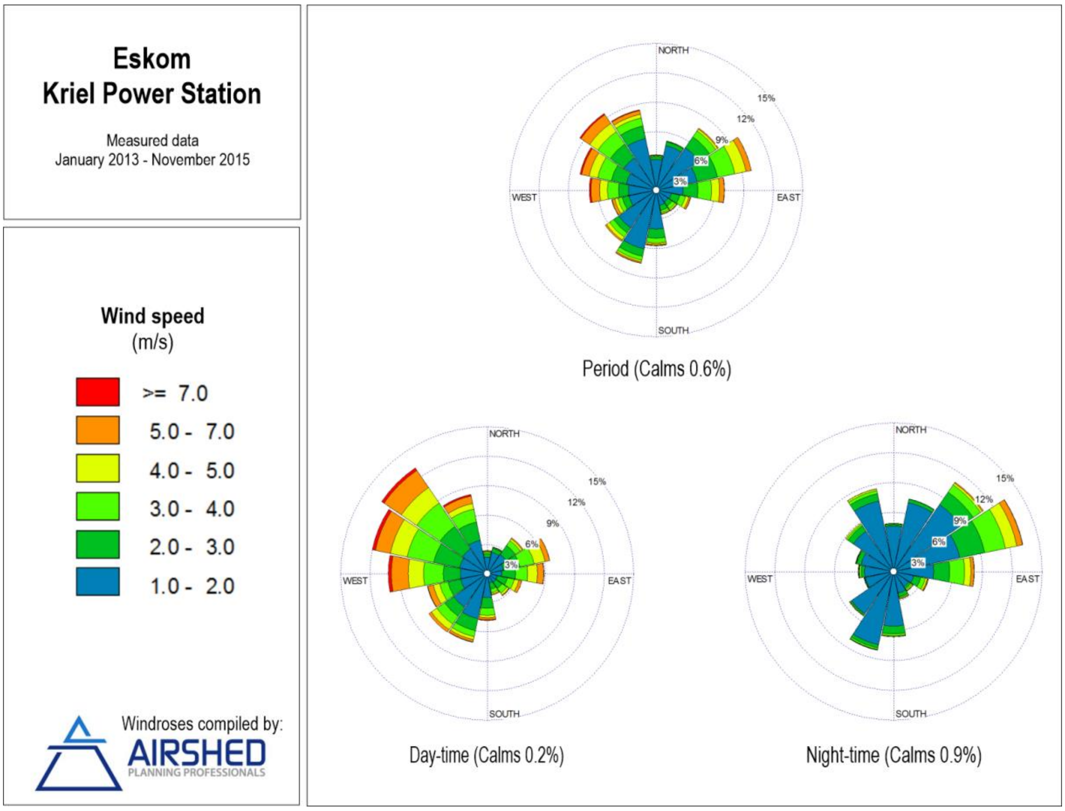

Figure 4: Period, day- and night-time wind roses (measured data; 2013 to 2015)

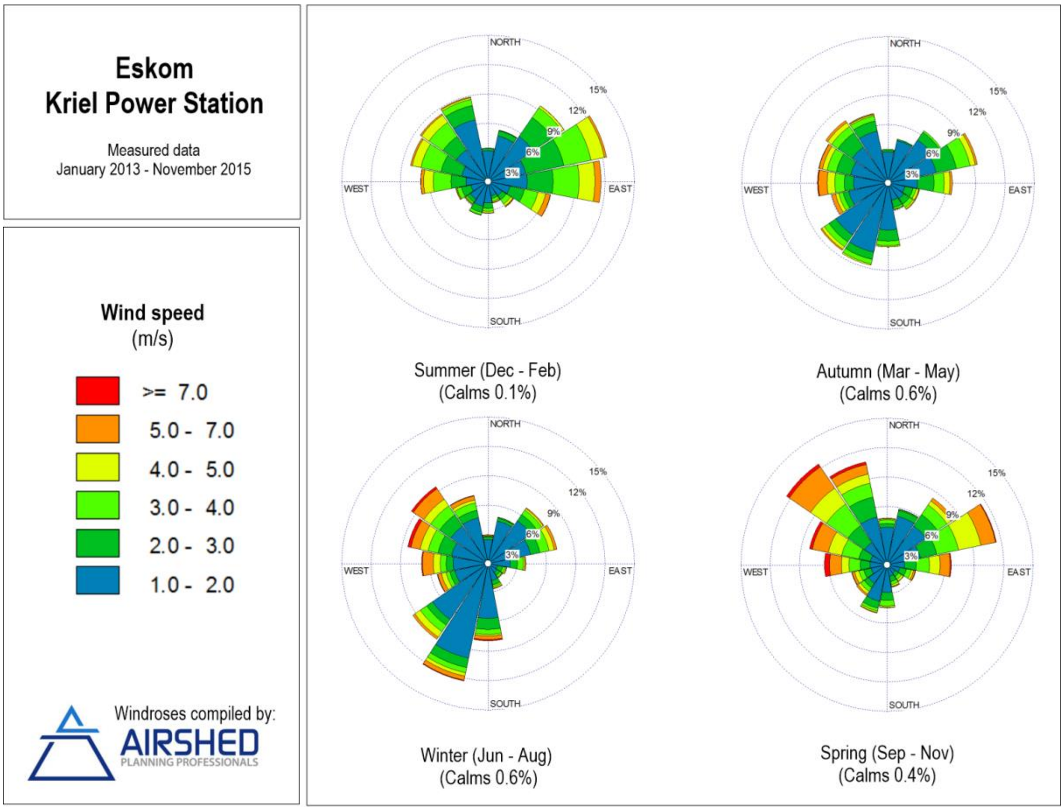

Figure 5: Seasonal wind roses (measured data; 2013 to 2015)

3.2.3 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 6. The area experienced warm temperatures above 24°C during summer. Winter temperatures were relatively low especially in the months of June and July. Average daily maximum temperatures range from 27.9°C in February to 18.9°C in July, with daily minima is between -1.0°C in July and 11.0°C in October.

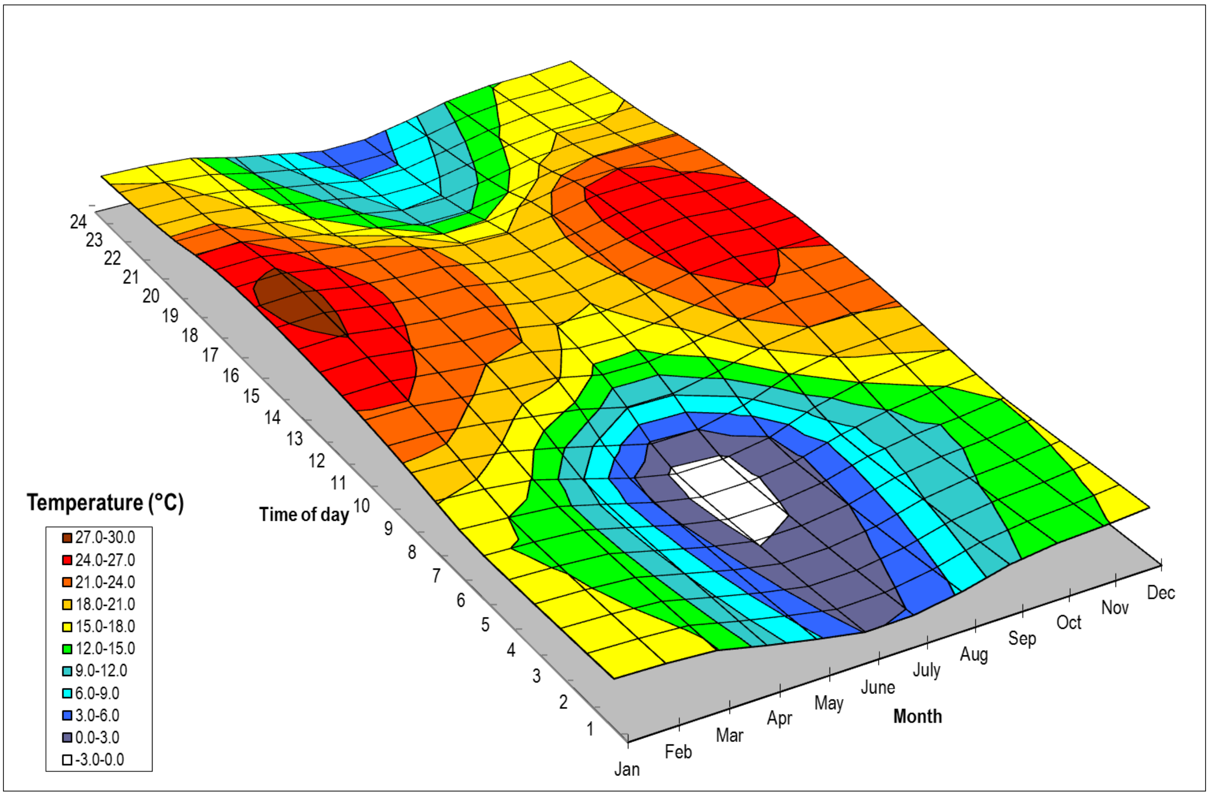

Figure 6: Diurnal temperature profile (measured data; 2013 to 2015)

3.3 Sources of Air Pollution in the Region

Power generation, mining activities, farming and residential land-uses occur in the vicinity of the proposed Alexander Project. These land-uses contribute to baseline pollutant concentrations via vehicle tailpipe emissions, household fuel combustion, biomass burning and various fugitive dust sources. Long-range transport of particulates, emitted from remote tall stacks and from large-scale biomass burning in countries to the north of South Africa, has been found to contribute significantly to background fine particulate concentrations within the South African boundary (Andreae, et al., 1996; Garstang, Tyson, Swap, & Edwards, 1996; Piketh, Annegarn, & Kneen, 1996).

3.3.1 Power Generation

Operational power stations are in close proximity of the proposed Alexander coal. The main emissions from such electricity generation operations are carbon dioxide (CO_2), SO_2, NOx and ash (PM). Fly-ash particles emitted comprise various trace elements such as arsenic, chromium, cadmium, lead, manganese, nickel, vanadium and zinc. Small quantities of volatile organic compounds are also released from such operations.

The power stations are large sources of SO_2, which oxidizes in the atmosphere to particulate sulfate at a rate of between 1 and 4% per hour. Fine particulate sulfate has been used to trace the transportation of power station plumes across the southern African sub-continent. The location of power stations in close proximity of the Project is illustrated in Figure 7.

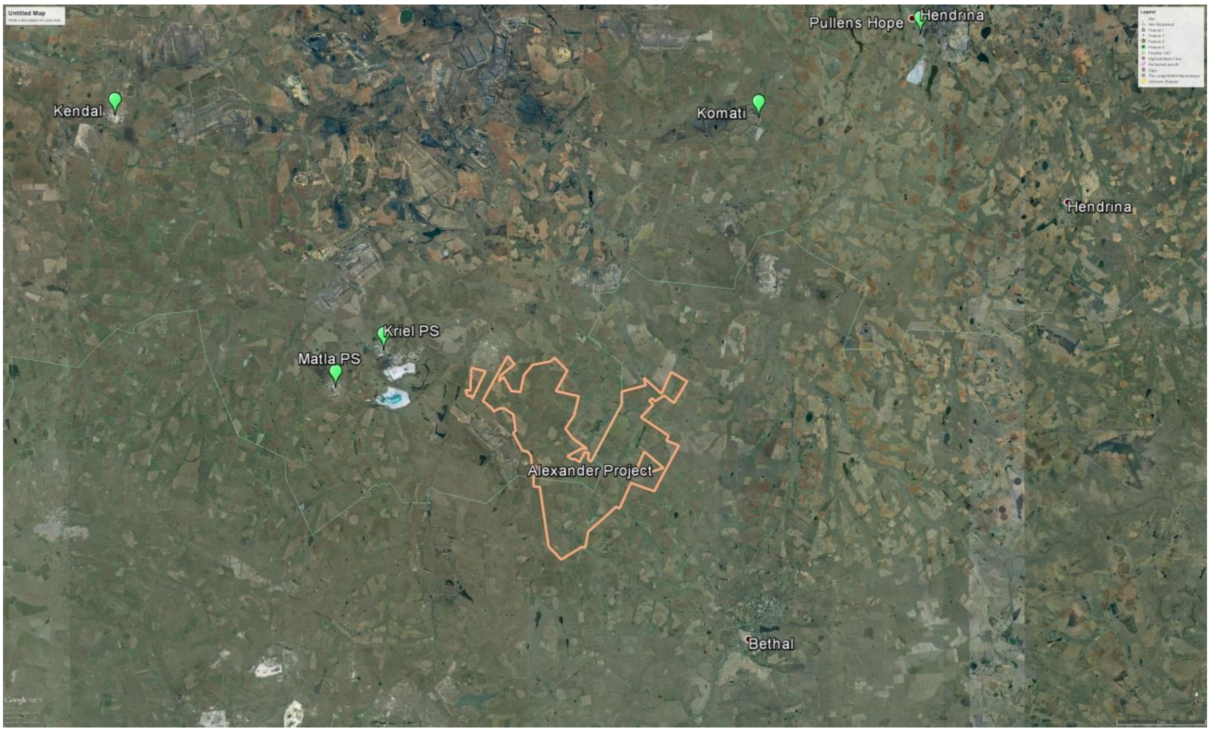

Figure 7: Location of power stations in close proximity of the proposed Alexander Project site

3.3.2 *Mining Operations*

Fugitive emissions from open cast and underground mining operations mainly comprise of land clearing operations (i.e. scraping, dozing and excavating), materials handling operations (i.e. tipping, off-loading and loading, conveyor transfer points), vehicle entrainment from haul roads, wind erosion from open areas, drilling and blasting. These activities mainly result in particulates and dust emissions, with small amounts of oxides of nitrogen (NO_x), carbon monoxide (CO), SO_2, methane and CO_2 being released during blasting operations. Open cast and underground coal mines in this region include the Kriel, Elders, Impunzi Division, New Clydesdale, Isibonelo, Goedhoop, Zibulo and Tweefontein Collieries.

3.3.3 *Fugitive Dust Sources*

These sources are termed fugitive because they are not discharged to the atmosphere in a confined flow stream. Sources of fugitive dust identified to potentially occur in the study area include paved and unpaved roads; agricultural tilling operations; and wind erosion of sparsely vegetated surfaces.

3.3.4 *Unpaved and paved roads*

Emissions from unpaved roads constitute a major source of emissions to the atmosphere in the South African context. The force of the wheels of a vehicle traveling on an unpaved road results in the pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface.

The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads vary in relation to the vehicle traffic (including average vehicle speed, mean vehicle weight, average number of wheels per vehicle) and the silt loading on the roads.

Emissions from paved roads are significantly less than those originating from unpaved roads; however, they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface. Major paved roads in the area include the R544, R545, R35 and R547.

3.3.5 Wind erosion of open areas

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold 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, its erosion potential has to be restored; that is, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity. Erodible surfaces may occur as a result of agriculture and/or grazing activities.

3.3.6 Domestic Fuel Combustion

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

Coal is relatively inexpensive in the Mpumalanga region and is easily accessible due to the proximity of the region to coal mines and the well-developed coal merchant industry. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, PM including heavy metals and inorganic ash, CO, PAHs (recognized carcinogens), NO_2 and various toxins. The main pollutants emitted from the combustion of paraffin are NO_2, particulates, CO and PAHs.

3.3.7 Biomass Burning

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, crop-residue burning and wild fires (locally known as veld fires) may represent significant sources of combustion-related emissions. The frequency of wildfires in the Highveld grasslands varies between annual and triennial.
Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held, et al., 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the proposed mining activity, long-range transported emissions from this source can be expected to impact on the air quality between the months of August to October. It is impossible to control this source of

atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

3.3.8 Vehicle Tailpipe Emissions

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

Both small and heavy private and industrial vehicles travelling along the R544, R545, R35 and R547 (public) roads as well as unpaved public and private roads, are notable sources of vehicle tailpipe emissions.

3.4 Measured Ambient Air Quality within the Region

The identification of existing sources of emission and the characterisation of ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts in the region. Ambient monitoring locations in the surroundings of the proposed Alexander project are illustrated in Figure 8. Ambient monitoring data was obtained from Eskom's Elandsfontein and Kriel Village monitoring stations, AAIC's Isibonelo dustfall sampling network and Alexander monitoring campaign.

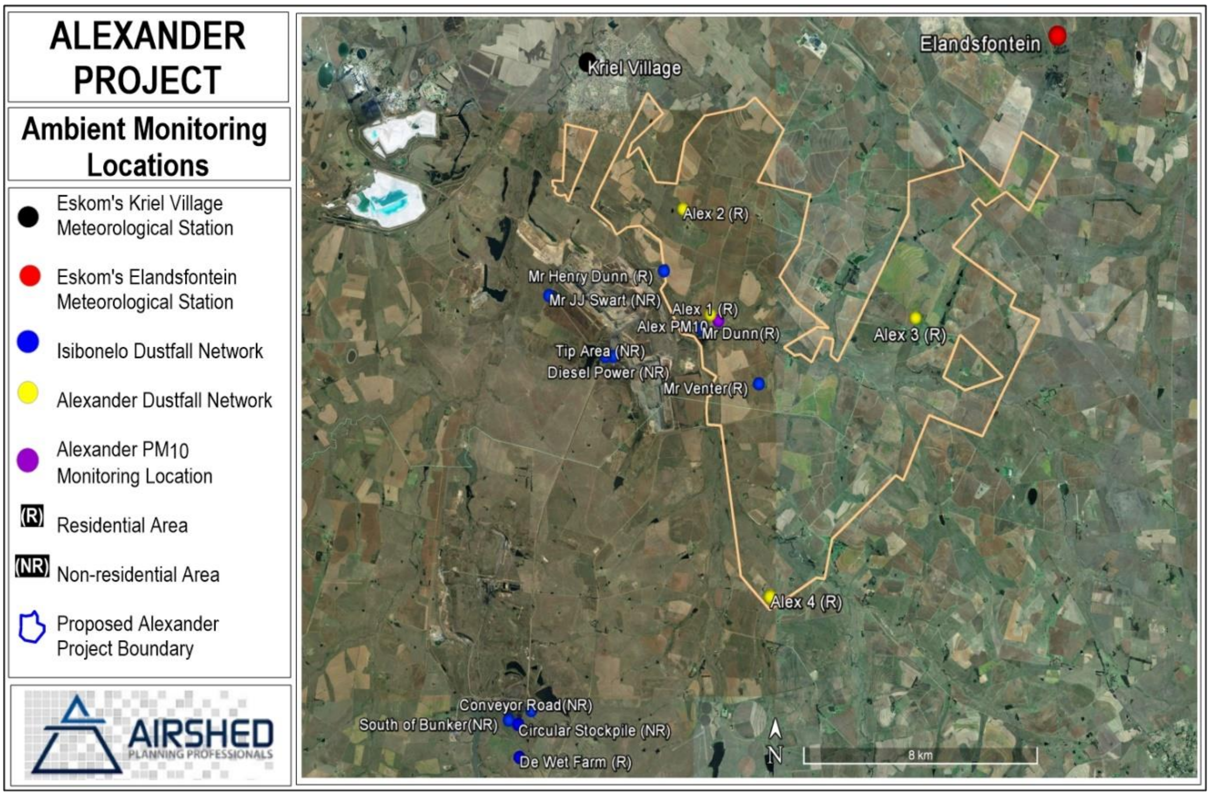

Figure 8: Ambient monitoring locations in the Project region

3.4.1 *Eskom's Kriel Village Ambient Monitoring Station*

Together with the meteorological data made available by Eskom for this assessment, PM_{10} concentrations measured at the Kriel Village ambient monitoring station were also provided for analysis. The period assessed was (as for the meteorological data) from the 8th January 2013 to 30 November 2015. During this period, the ambient PM_{10} concentrations recorded at the Kriel Village station exceeded the NAAQS (maximum allowable number of days exceeding the limit concentration – 75 µg/m³ is 4 days per year) (Table 5; and Figure 9). Annual average concentrations also exceeded the NAAQS.

Table 5: Summary of PM_{10} concentrations measured at the Kriel Village station (2013 to 2015)

Year	Number of days in dataset	Days exceeding NAAQ limit concentration	Annual average concentration (µg/m³)
2013	358	**96**	**60.4**
2014	365	**71**	**60.9**
2015	334	**37**	**42.9**

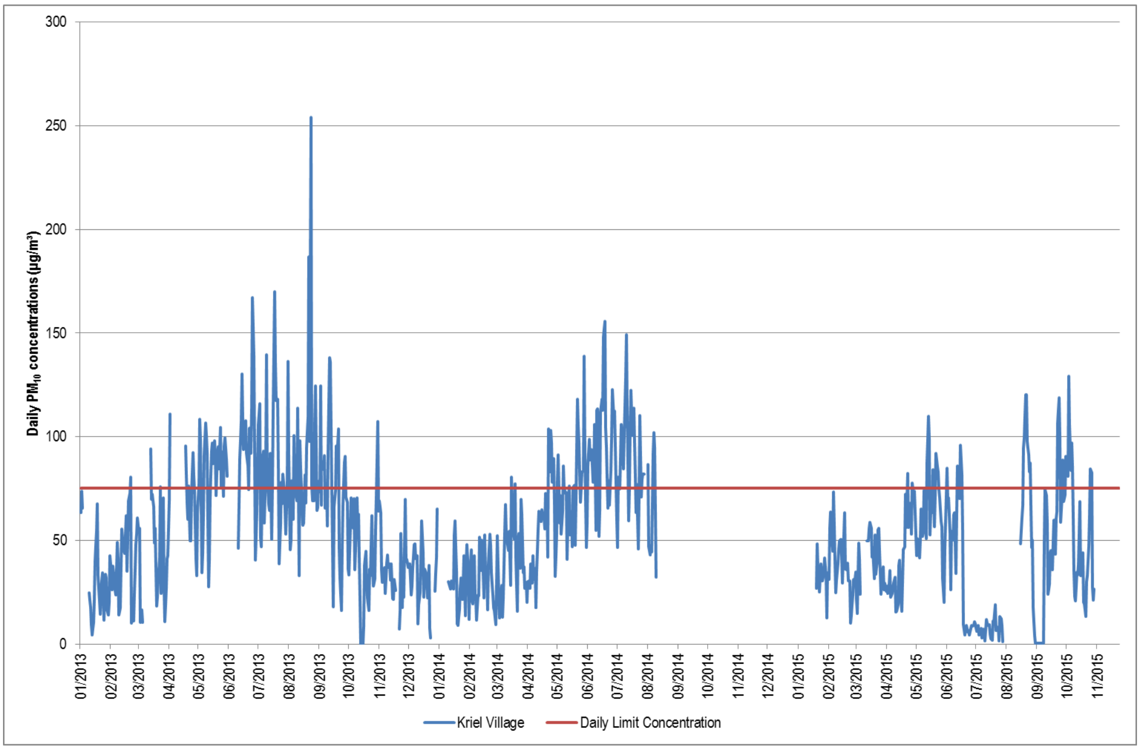

Figure 9: Daily average PM_{10} concentrations measured at Kriel Village (2013 to 2015)

The 'openair' statistical package (Carslaw & Ropkins, 2012; Carslaw, 2014) was used to plot the ambient pollutant concentrations measured at the Kriel Village monitoring station. An analysis of the observed PM_{10} concentrations at the Kriel Village monitoring station involved categorising the concentration values into wind speed and direction bins for different concentrations (Figure 10). Polar plots can provide an indication of the directional contribution as well as the dependence of concentrations on wind speed, by providing a graphical impression of the potential sources of a pollutant at a specific location. The directional display is fairly obvious, i.e. when higher concentrations are shown to occur in a certain sector, e.g. westerly for PM_{10} at Kriel Village, it is understood that most of the high concentrations occur when winds blow from that sector. The dotted circular lines indicate the wind-speed with which the concentrations are associated. Therefore, high concentrations (80 µg/m³ or above) originate to the north-westerly sector at wind speeds greater than 4 m/s. Similarly, low wind speeds (<1 m/s) result in an almost equal contribution to PM_{10} concentrations from all wind sectors, with daily average concentrations of approximately 60 µg/m³.

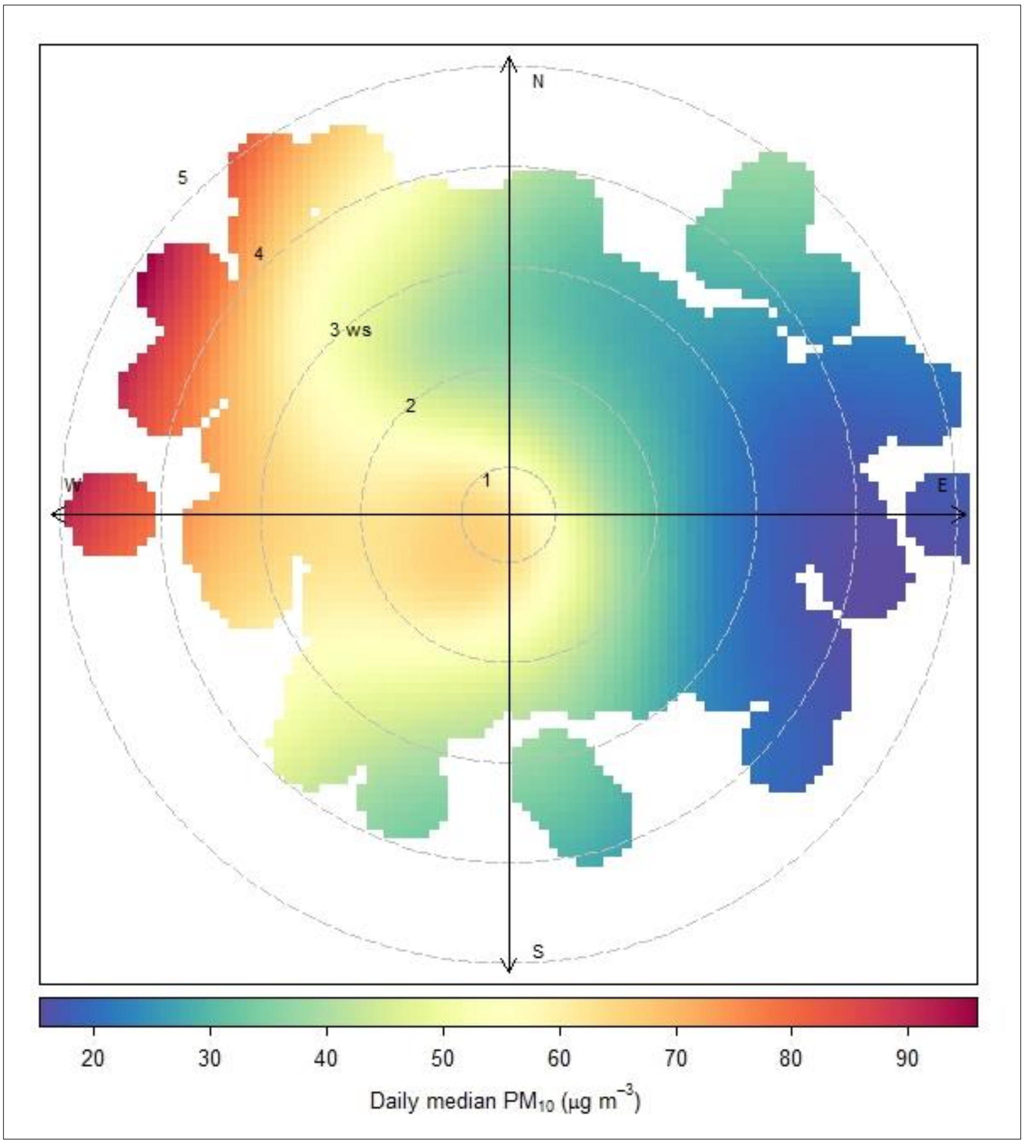

Figure 10: Daily median PM_{10} polar plot

A time variation plot (Figure 11) provides information regarding any time-based variations in pollutant concentrations. The figures indicate the mean ± the 95% confidence interval. PM_{10} concentrations show a diurnal fluctuation with peaks in the evening, probably associated with domestic fuel combustion for cooking requirements. The increase in PM_{10} concentrations during winter (May to August) is likely to be associated with the use of coal, wood and gas for heating requirements, especially in informal settlements or areas where electrification is less common.

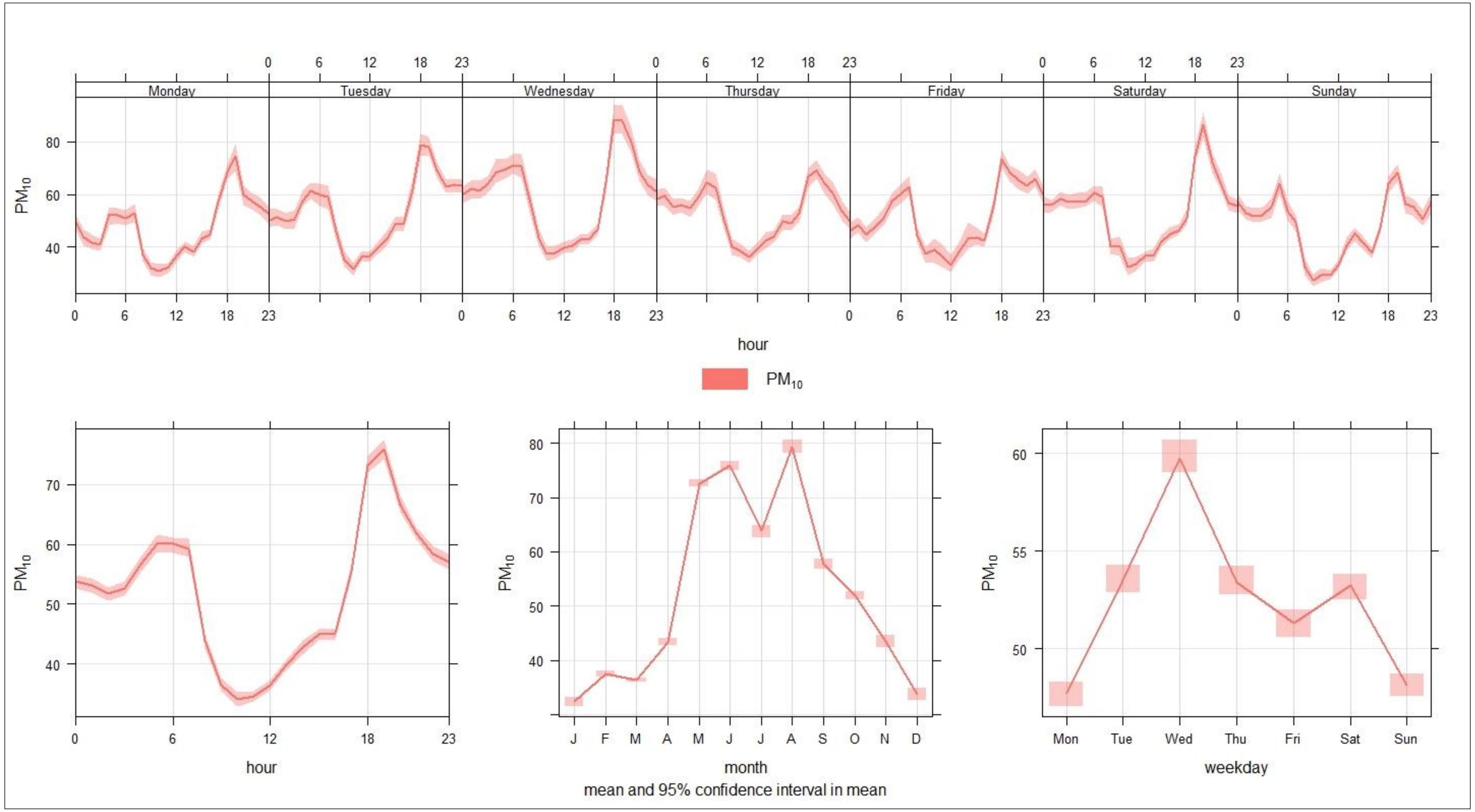

Figure 11: Time variation of PM_{10} concentrations at the Kriel Village monitoring station

3.4.2 Alexander Monitoring Campaign

A 3-month PM_{10} monitoring and dustfall sampling campaign was undertaken between January and April 2014 at the project site, as illustrated in Figure 8.

Ambient PM_{10} concentrations are shown in Figure 12 while dustfall rates are depicted in Figure 13. The NAAQS daily limit of 75 µg/m³ for PM_{10} was marginally exceeded for 1 day over the sampling period, equating to 3.33 % exceedance. A period average of 26.2 µg/m³ was recorded. This average value was utilized as baseline for the proposed project area in assessing cumulative impacts. This average concentration was measured over the summer and autumn months; when ambient concentrations of pollutants are generally lower than for the rest of the year. As such, annual average concentration over the entire year may exceed this estimate.

Also, deposition rates for the period are within the NDCR limit of 600 mg/m²-day for residential areas. Unavailability of on-site meteorological data makes it difficult to assess the effect of wind conditions on the PM_{10} measurement results.

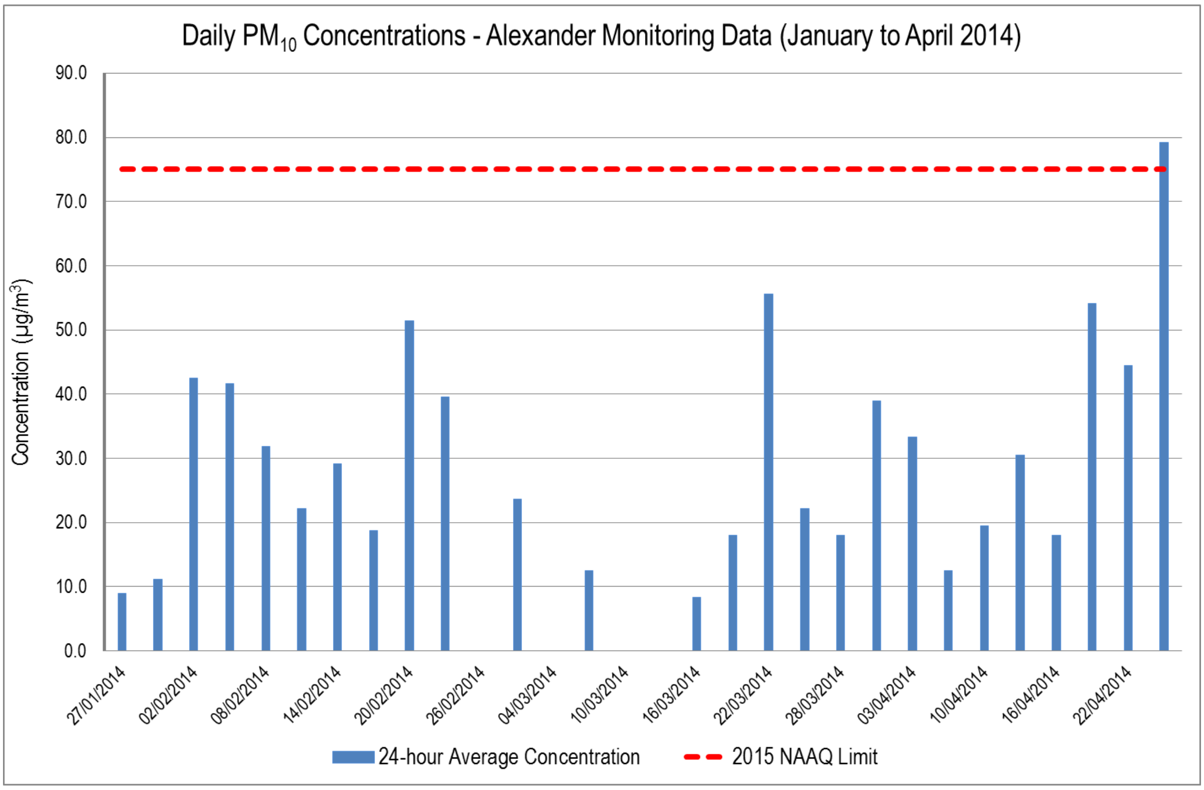

Figure 12: Daily PM_{10} concentrations recorded at Alexander (January to April 2014)

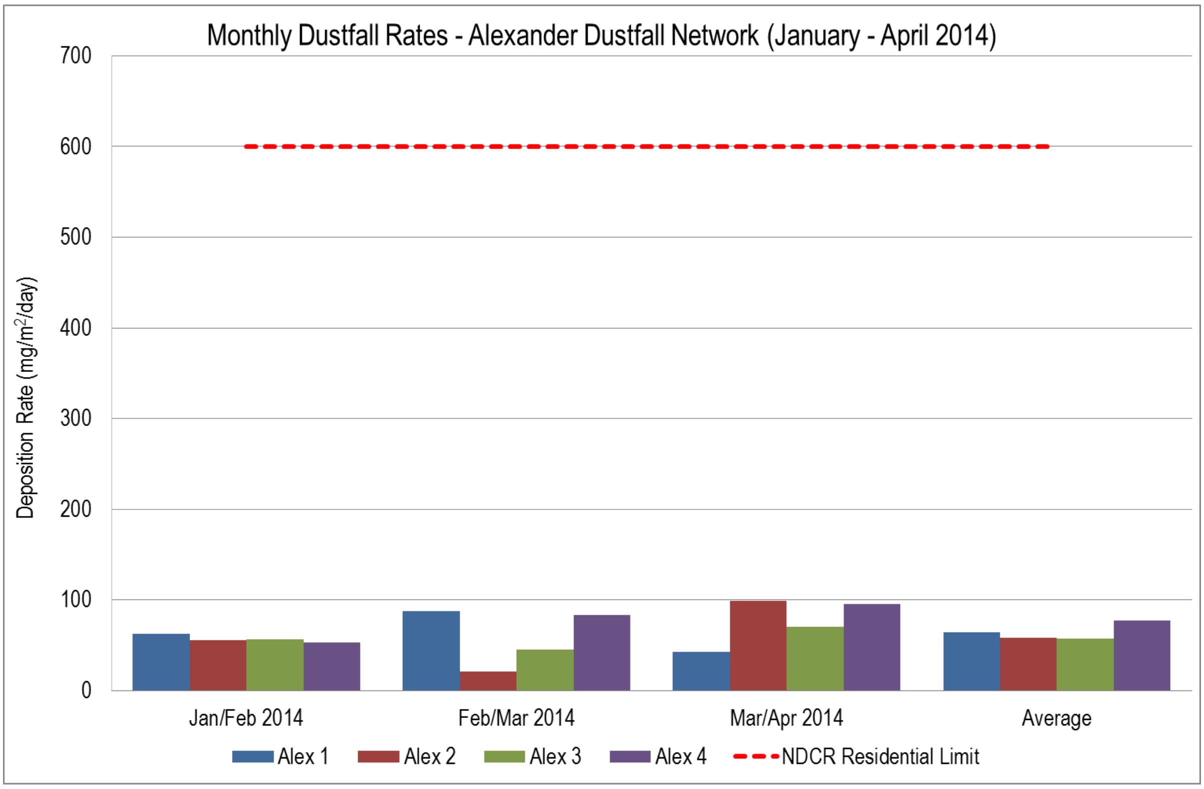

Figure 13: Measured dustfall rates from Alexander sampling network (January to April 2014)

3.4.3 Eskom's Elandsfontein Monitoring Station

Background data were obtained from the Eskom Elandsfontein monitoring station for the period January 2011 to December 2013. Data availability was recorded as 25.1 % for PM_{10}, 63.2 % for NO_2 and 80.8 % for SO_2. The relatively low data availability for some of these pollutants should be taken into account when interpreting the data.

3.4.3.1 Sulphur dioxide (SO_2)

The recorded hourly SO_2 concentrations are presented in Figure 14. The NAAQS hourly limit for SO_2 (134 ppb) is exceeded on 41 occasions over the entire 3-year period, which is within the allowable 88 exceedances per year. Annual concentrations ranged from 13.0 µg/m³ in 2012 to 41.9 µg/m³ in 2013.

The mean hourly SO_2 concentrations show a diurnal pattern (Figure 15), with higher mean SO_2 concentrations during the day. This may be due to primary SO_2 emissions from the surrounding coal fired power stations at an elevated source, which daytime convective conditions mix down to the surface, resulting in elevated SO_2 concentrations in the region.

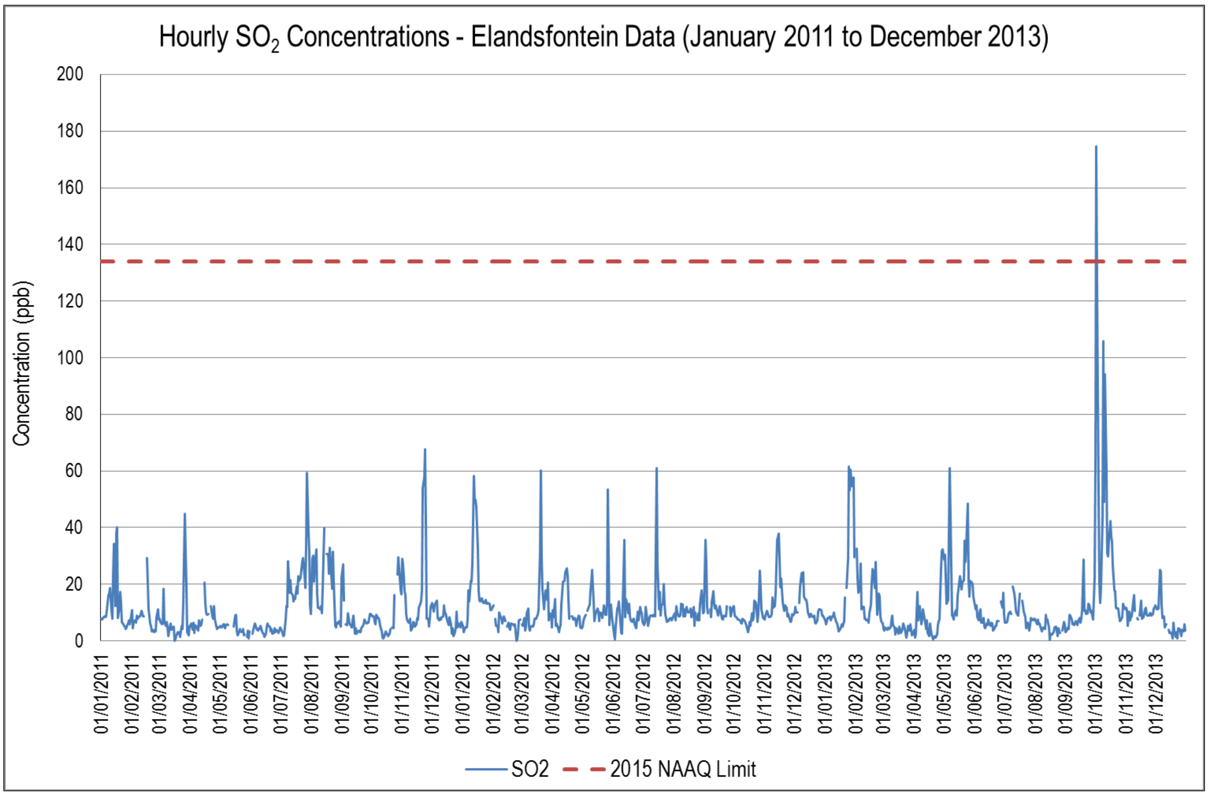

Figure 14: Hourly SO₂ concentrations recorded at Elandsfontein (January 2011 to December 2013)

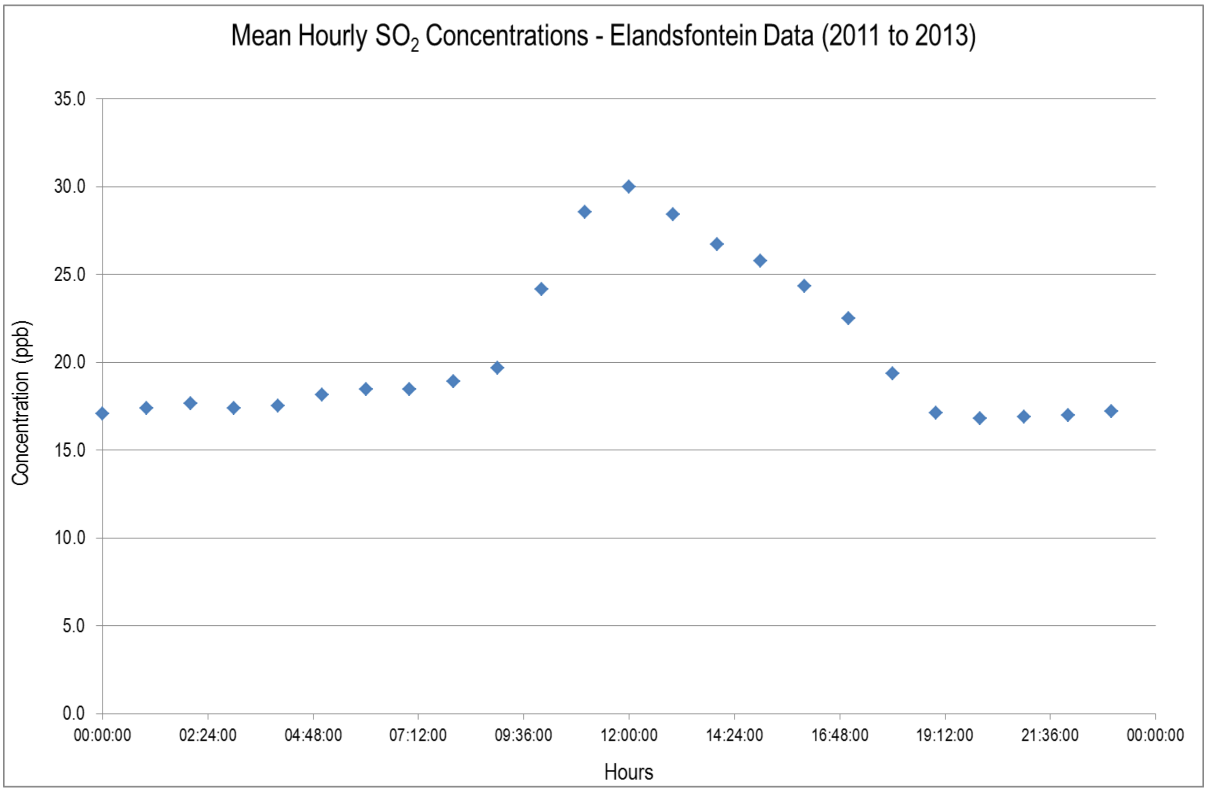

Figure 15: Mean hourly SO₂ concentrations recorded at Elandsfontein (January 2011 to December 2013)

3.4.3.2 Nitrogen Dioxide (NO_2)

The mean hourly concentrations of NO_2 are presented in Figure 16. The NAAQS has an hourly limit of 106 ppb for NO_2 with 88 allowed exceedances of this limit annually. Over the period 2011 to 2013, the hourly NO_2 concentration exceeded the 106 ppb limit on 6 occasions, considerably less than the allowed 88 hours per year. Annual concentrations ranged from 7.8 µg/m³ in 2012 to 12.6 µg/m³ in 2013.

The mean hourly NO_2 concentrations also show a diurnal pattern (Figure 17), with higher mean NO_2 concentrations during the day which can also be attributed to daytime convective mixing of NO_2 from industrial and vehicular sources within the region.

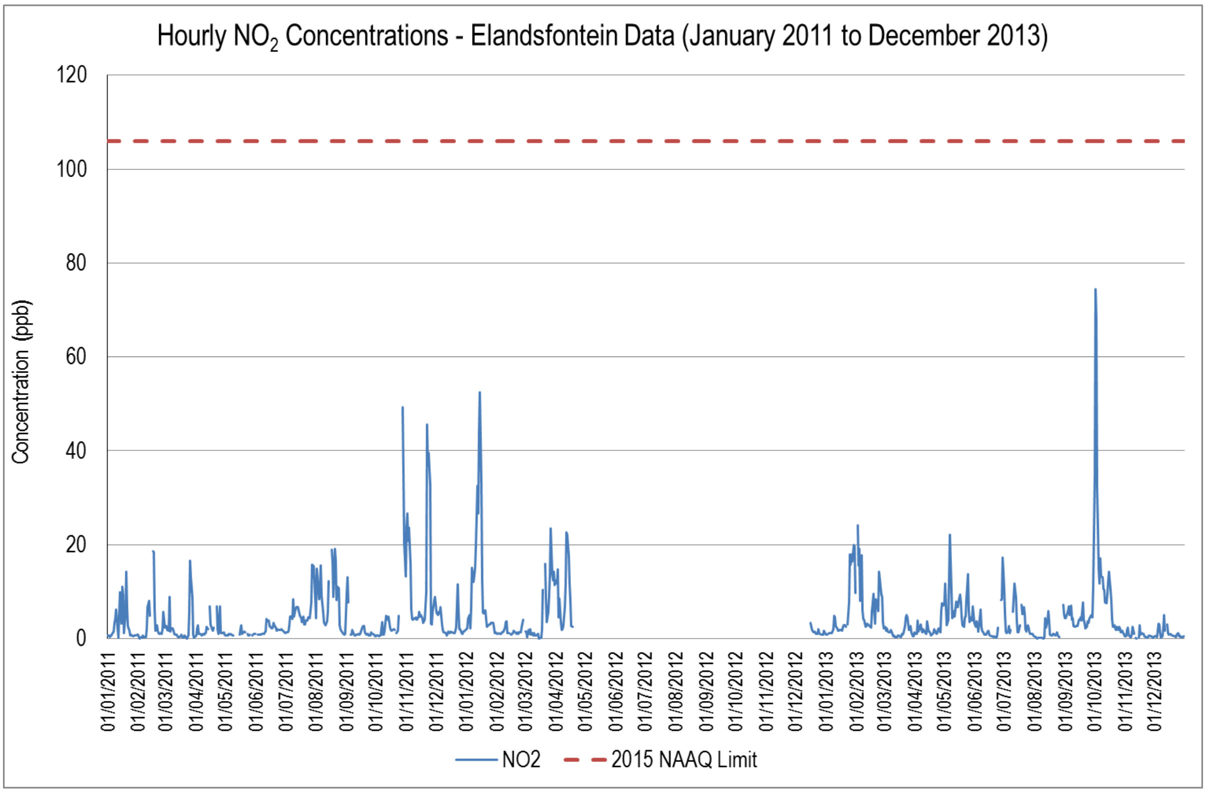

Figure 16: Hourly NO_2 concentrations recorded at Elandsfontein (January 2011 to December 2013)

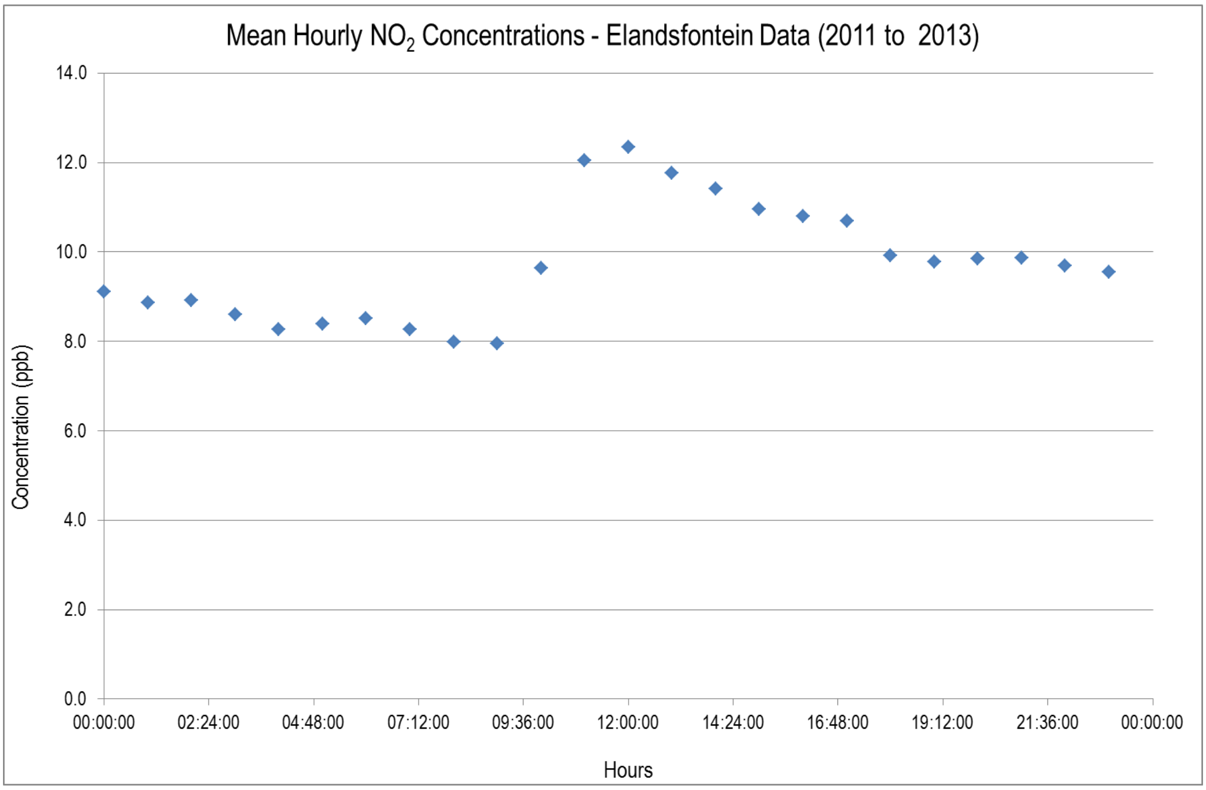

Figure 17: Mean hourly NO_2 concentrations recorded at Elandsfontein (January 2011 to December 2013)

3.4.3.3 Thoracic particulate matter (PM_{10})

Measured daily PM_{10} concentrations, with data availability below 50%, are presented in Figure 18. Exceedances of the NAAQS daily limit of 75 µg/m³ occurred 18 times in 2011, none in 2012 and once in 2013. The yearly frequency of exceedance and annual average is provided in Table 6. Annual concentrations ranged from 14.8 µg/m³ in 2011 to 26.9 µg/m³ in 2013.

A diurnal PM_{10} concentration profile is provided in Figure 19, showing peak PM_{10} concentrations in the afternoon and evening. This may be related to anthropogenic activities such as vehicular transport or industrial activities in the region.

Table 6: Measured exceedances of the daily NAAQ Limits and annual average concentrations

Year	Daily FOE of the NAAQS Limit of 75 µg/m³)	Annual average concentration (µg/m³)
2011	**18** [1]	25.2
2012	0	14.8
2013	1	26.9
Average	-	22.3

NOTE: [1] values in bold indicate non-compliance with the NAAQS limit

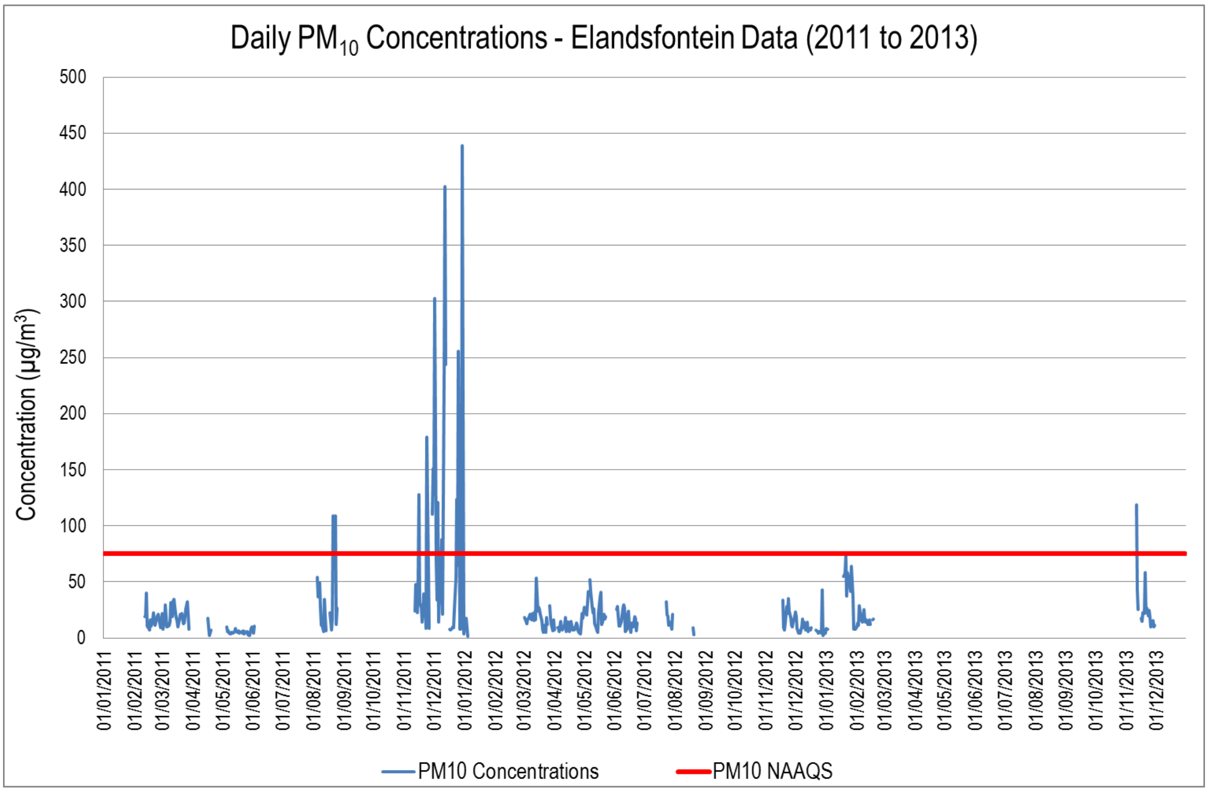

Figure 18: Daily PM_{10} concentrations recorded at Elandsfontein (January 2011 to December 2013)

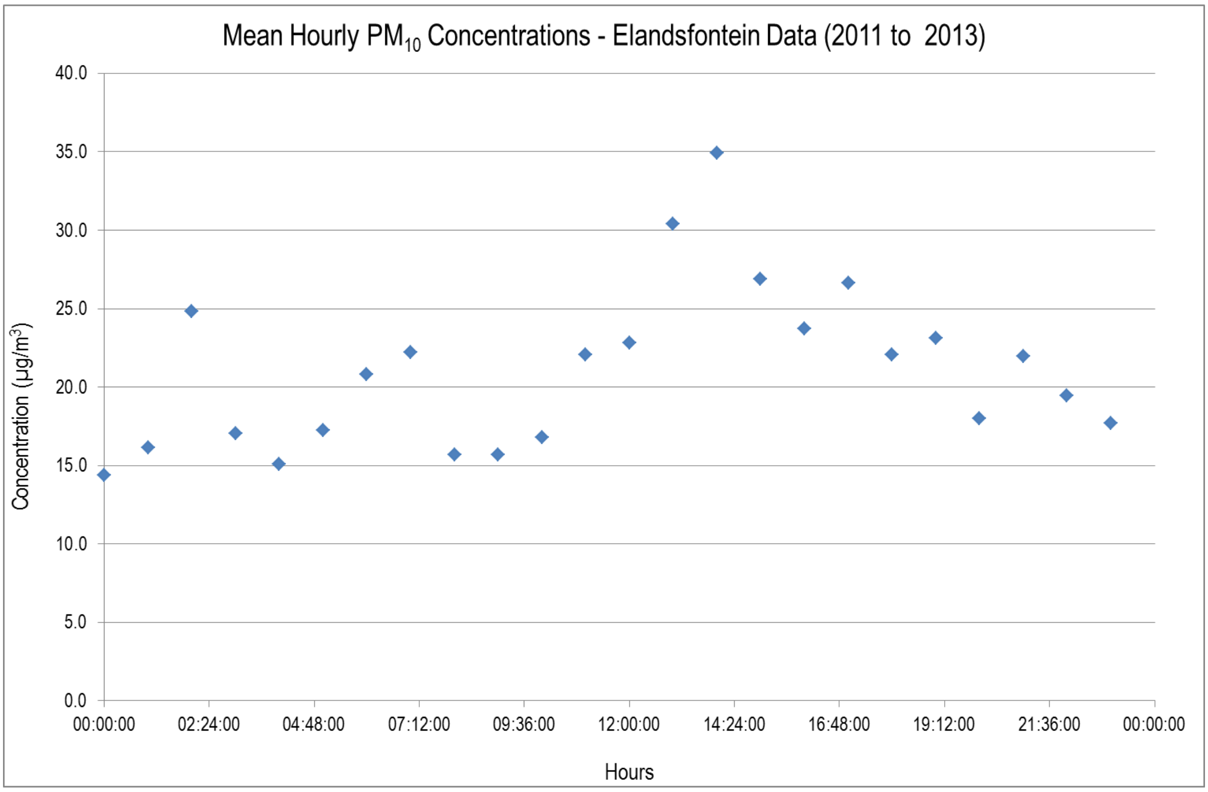

Figure 19: Mean hourly PM_{10} concentrations recorded at Elandsfontein (January 2011 to December 2013)

3.4.4 Isibonelo Dustfall Sampling Network

A network of ten single dustfall units following the American Society for Testing and Materials (ASTM) Standard Method of testing for collection and analysis of dustfall (ASTM D1739-98), implemented at Isibonelo Colliery, provides additional ambient dustfall data for the project. The ASTM method employs a simple device consisting of a cylindrical container (not less than 150 mm in diameter) exposed for one calendar month (30 ± 2 days). Even though the method provides for a dry bucket, de-ionised water can be added to ensure the dust remains trapped in the bucket.

The bucket stand comprises a wind shield at the level of the rim of the bucket to provide an aerodynamic shield. The bucket holder is connected to a 2 m galvanized steel pole, which is attached to a galvanized steel base plate. This allows for a variety of placement options for the fallout samplers. Exposed buckets, when returned to the laboratories, are rinsed with deionised water to remove residue from the sides of the bucket, and the bucket contents filtered through a coarse (>1 mm) filter to remove insects and other course organic detritus. The sample is then filtered through a pre-weighed paper filter to remove the insoluble fraction, or dustfall. This residue and filter are dried, and gravimetrically analysed to determine the insoluble fraction (dustfall).

Measured dustfall rates for 2011, 2012 and 2013 are presented in Figure 20, Figure 21 and Figure 22 respectively. The reader is referred to Figure 8 for the location of the Isibonelo dustfall sampling network. Deposition results are generally below the residential limit (600 mg/m^2-day) for the 2011 to 2013 period except in non-residential locations such as “Diesel power” which recorded 5 months of exceedance of both the residential (600 mg/m^2-day) and non-residential limit (1200 mg/m^2-day) in 2011; 2 months in 2012 and none in 2013. The “Tip Area” also exceeded the non-residential limit (1200 mg/m^2-day) 3 times in 2012.
Annual trends indicate a decrease in average deposition rates from 2011 to 2013 at nearly all locations except “Tip area”, “conveyor belt” and “Mr JJ Swart”.

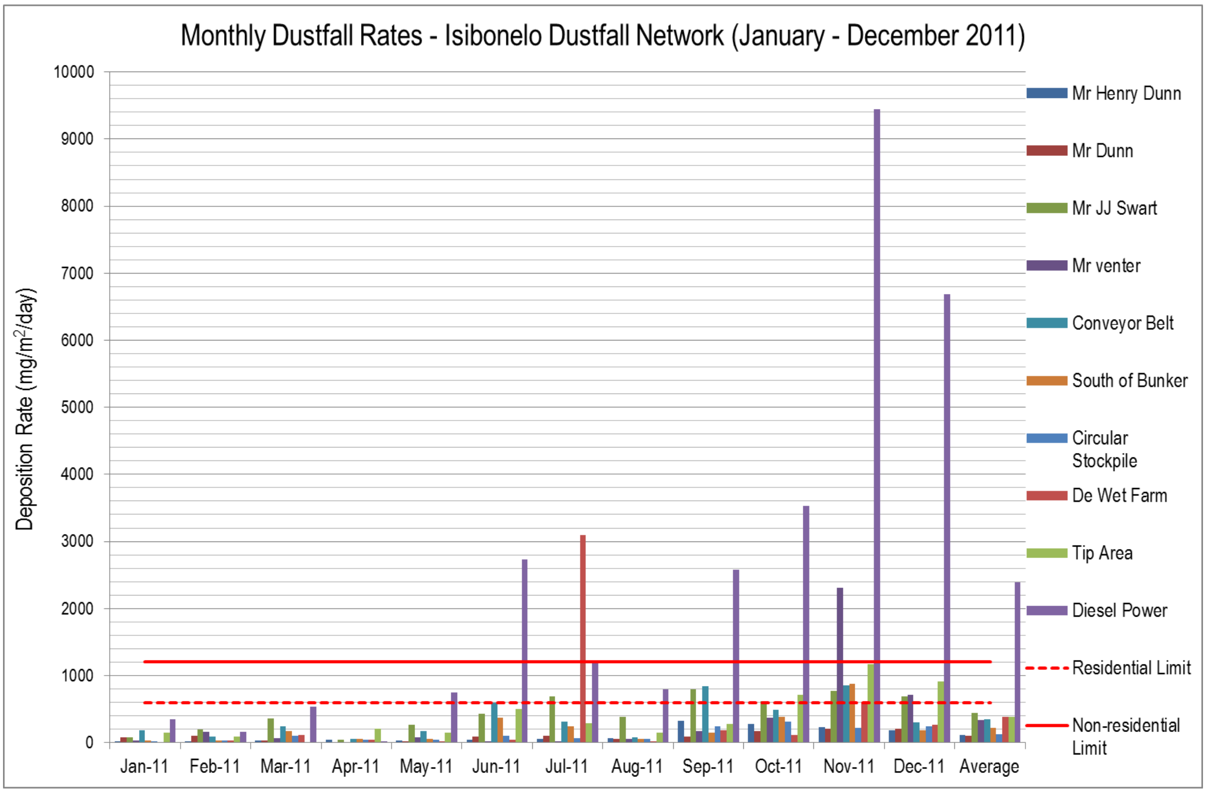

Figure 20: Sampled dustfall rates from the Isibonelo dustfall sampling network (2011)

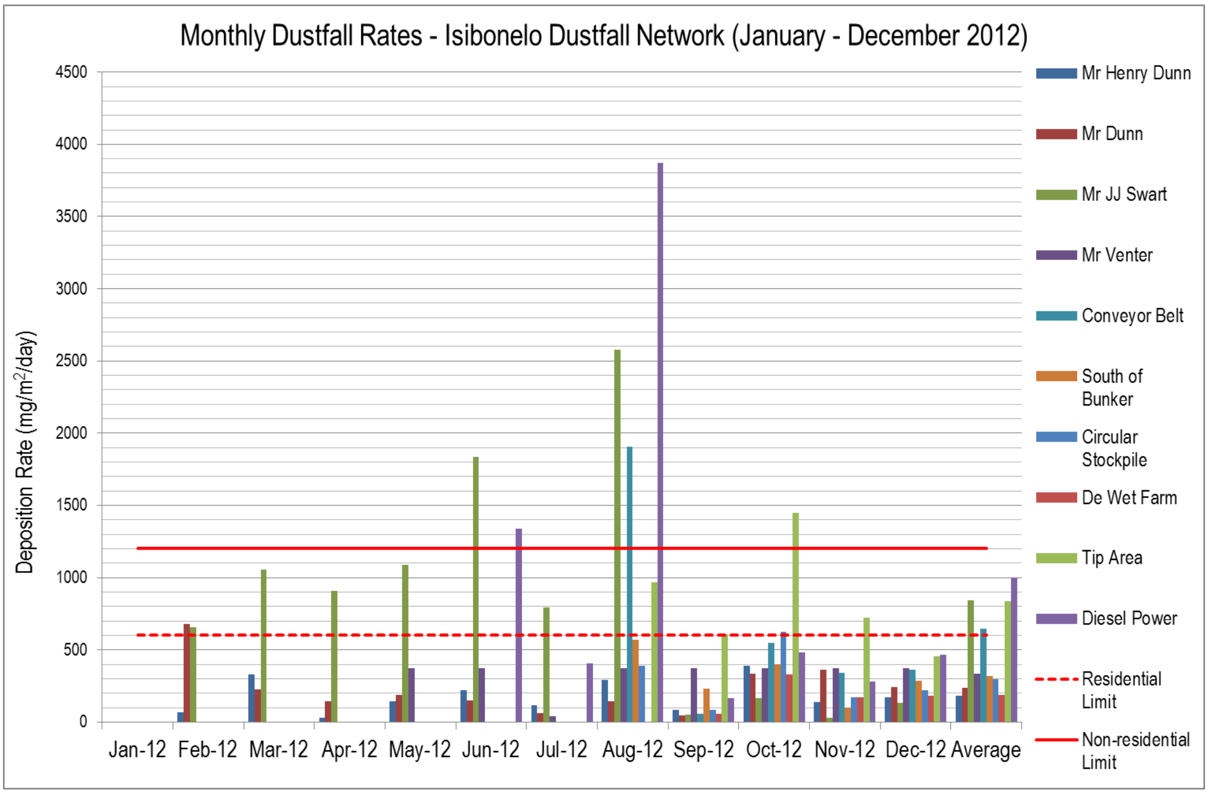

Figure 21: Sampled dustfall rates from the Isibonelo dustfall sampling network (2012)

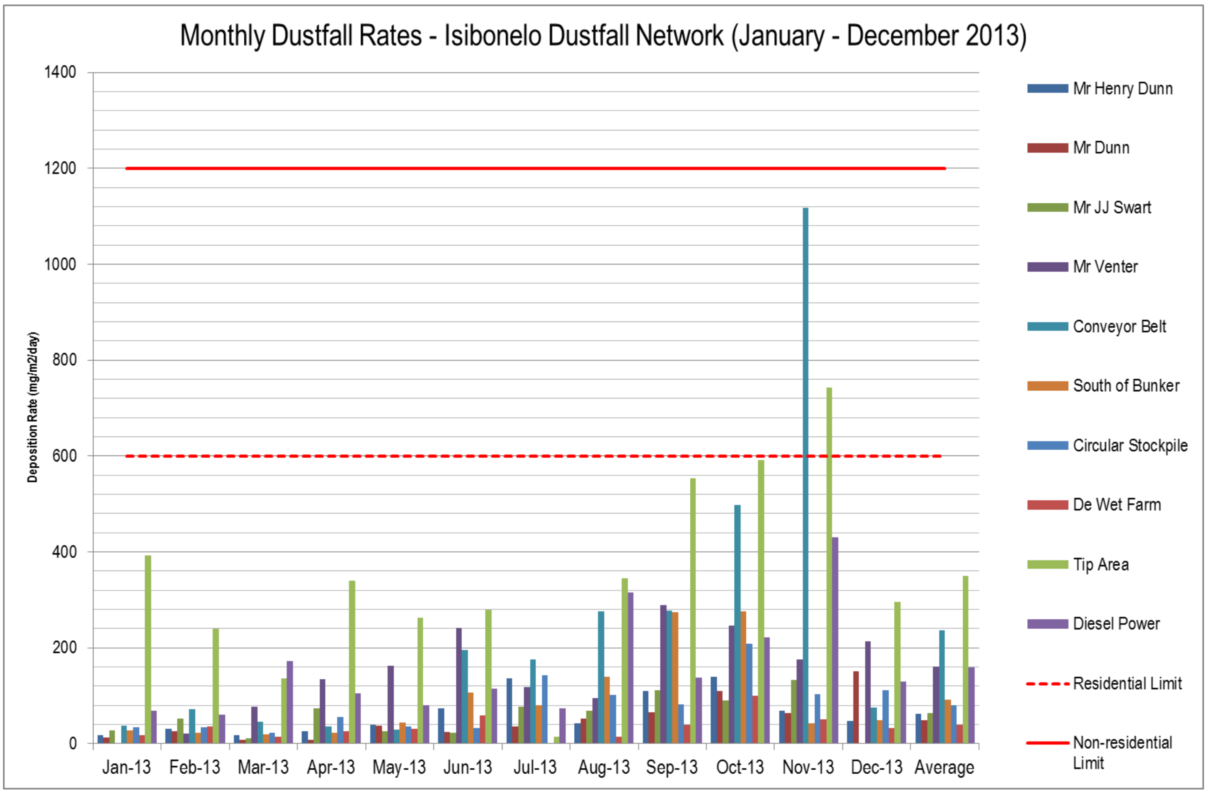

Figure 22: Sampled dustfall rates from the Isibonelo dustfall sampling network (2013)

3.5 Modelled Ambient Air Quality – Mpumalanga Highveld Priority Area

The Project is located in the Mpumalanga Highveld and is therefore situated within the boundaries of the HPA, which is an area that has been identified as characterized with poor air quality. As a result of the concerns over the poor ambient air quality over the Highveld area, the Minister of Environmental Affairs declared a portion of Mpumalanga and Gauteng provinces an air quality priority area in November 2007.

A comprehensive emissions inventory was completed for the region as part of the HPA baseline study. The results of the inventory were used to carry out a comprehensive dispersion modelling study over the area using the CALPUFF model (DEA, 2011b). Results of this dispersion study are illustrated in Figure 23 and Figure 24 for SO_2 and PM_{10} respectively. These figures show areas over which NAAQS are exceeded, as determined through simulation. The eMalahleni area already experiences elevated PM_{10} and SO_2 concentrations. Based on these dispersion modelling results, the Air Quality Management Plan (AQMP) identified Baseline Hotspots for SO_2 and for PM_{10}. The project design should therefore also ensure minimal contribution to ambient SO_2 and PM_{10} concentrations.

Ambient CO concentrations were not included in the HPA ambient monitoring or simulation but in residential areas of high wood and coal combustion there is high potential for increased CO concentrations.

Power generation in the HPA is the major source of SO_2 (82%) and NOx emissions (73%) while it is only responsible for a relatively small contribution to the total PM_{10} (12%) (DEA, 2011b). Simulated source contributions to NOx, SO_2 and PM_{10} are shown in Figure 25. The largest contributors to all three pollutants are power generation, residential fuel burning and motor vehicles. The lowest contributors to NOx, SO_2 and PM_{10}, according to DEA (2011b), are coal mines and motor vehicles.

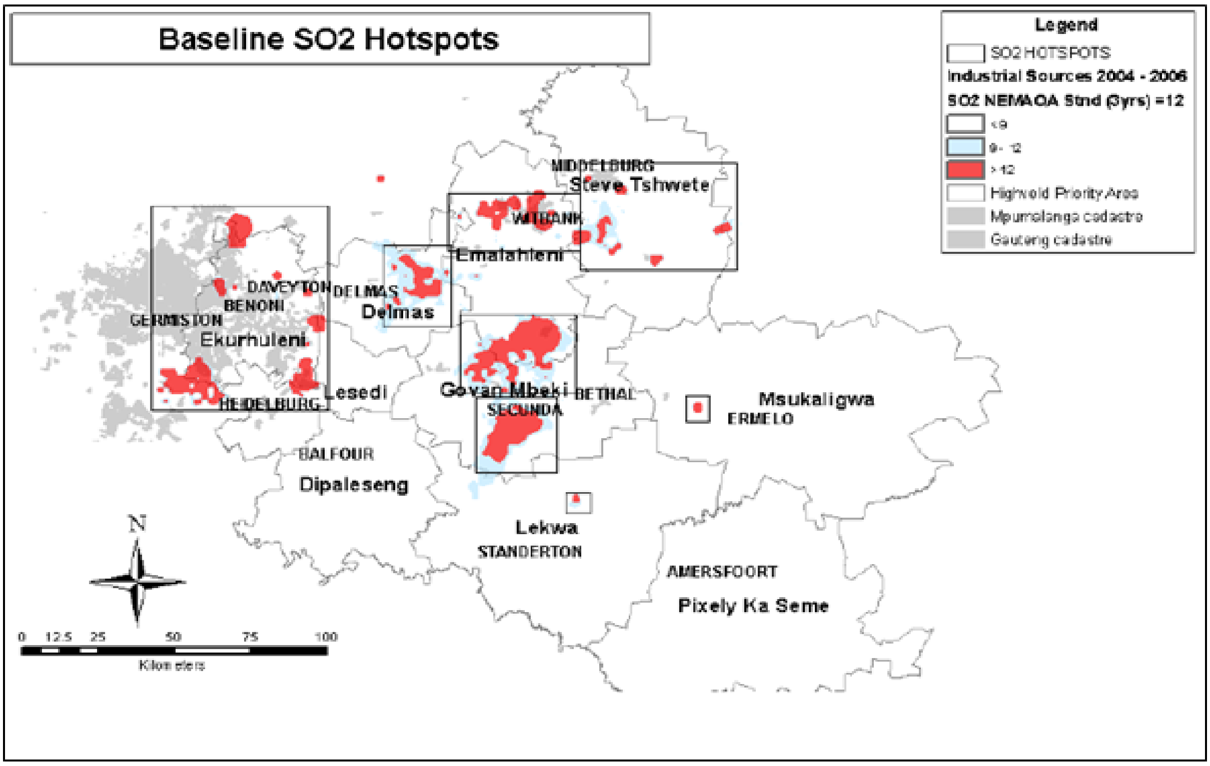

Figure 23: Simulated frequencies of exceedence of SA ambient SO2 standards (DEA, 2010)

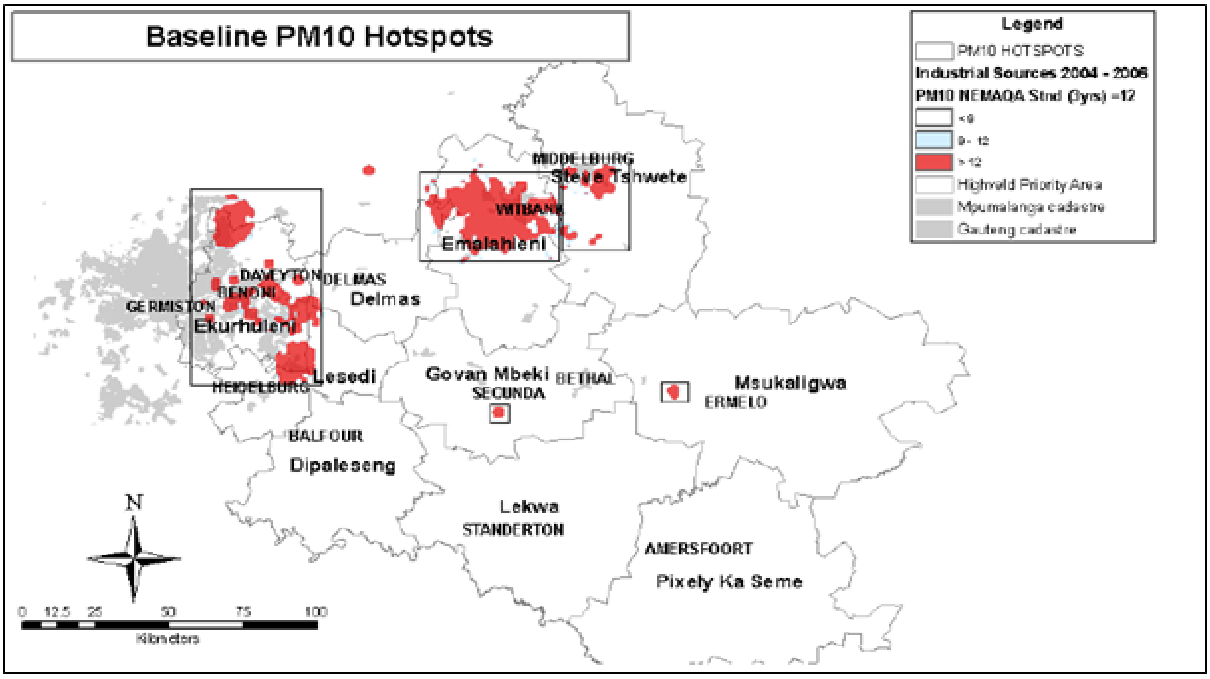

Figure 24: Simulated frequencies of exceedence of SA ambient PM_{10} standards (DEA, 2010)

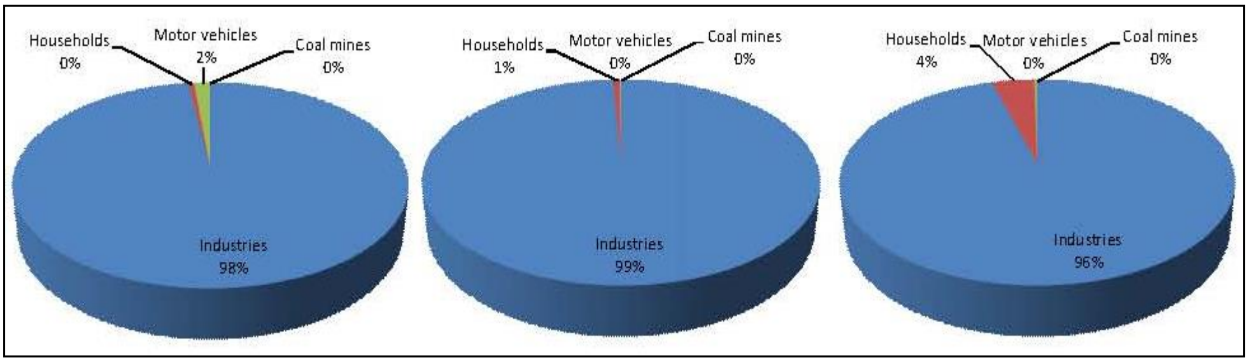

Figure 25: Contribution of different sources to ambient concentrations of NOx (left), SO_2 (middle) and PM_{10} (right) in the Kriel Hot Spot (DEA, 2011)

4 IMPACT ON THE RECEIVING ENVIRONMENT

4.1 Atmospheric Emissions

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's operations on the receiving environment. The proposed project operations will consist of a construction phase, an operational phase and a closure (decommissioning and post-closure) phase. Emissions are quantified for criteria pollutants associated with underground mines (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and VOCs such as benzene) and can be divided into two categories, namely; fugitive emissions and process emissions. Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007).

A short discussion on the expected activities, typical of an underground coal mine is provided in the sections below with a summary on the typical sources and associated activities for construction, operational and closure phase of the project.

4.1.1 Construction Phase

Pollutants associated with the construction phase are typically $PM_{2.5}$, PM_{10} and TSP (dustfall). The activities associated with the release of these pollutants during the construction of the underground shaft, associated infrastructure and overland conveyor include land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc. Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process.

Annual construction emissions for the Alexander Project were quantified as indicated in Table 7 and Table 8. Quantified construction emissions were lower than operational phase emissions and since construction schedule was not available (and due to their temporary nature); and the likelihood that these activities will not occur concurrently at all portions of the site; dispersion simulation was not undertaken for construction emissions.

4.1.2 Operational Phase

Sources of emission and associated pollutants considered in the emissions inventory for the operational phase include[3]:

- Conveyor emissions – $PM_{2.5}$, PM_{10} and TSP
- Underground ventilation emissions – $PM_{2.5}$, PM_{10} and TSP
- Materials handling emissions – $PM_{2.5}$, PM_{10} and TSP
- Diesel engines emissions – CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2 and VOC
- Windblown PM from material stockpile – $PM_{2.5}$, PM_{10} and TSP
- Entrained PM from unpaved roads – $PM_{2.5}$, PM_{10}, and TSP

All emissions were determined through the application of emission factors published by the US EPA and the Australian NPI. As part of the management of PM emissions, the efficiencies of some basic mitigation measures were also quantified. A

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[3] Refer to Section 1.4, *'Assumptions, Exclusions and Limitations'*, for more details about sources of emission not included in the assessment.

summary of emission sources quantified, estimation techniques applied, and source input parameters are included in Table 7. As part of the management of dust emissions, the efficiencies of some basic mitigation measures were also quantified (mitigated scenario). Estimated annual average emissions, per source group, are presented in Table 8. The contributions of each source group's emissions to the total are graphically presented in Figure 27.

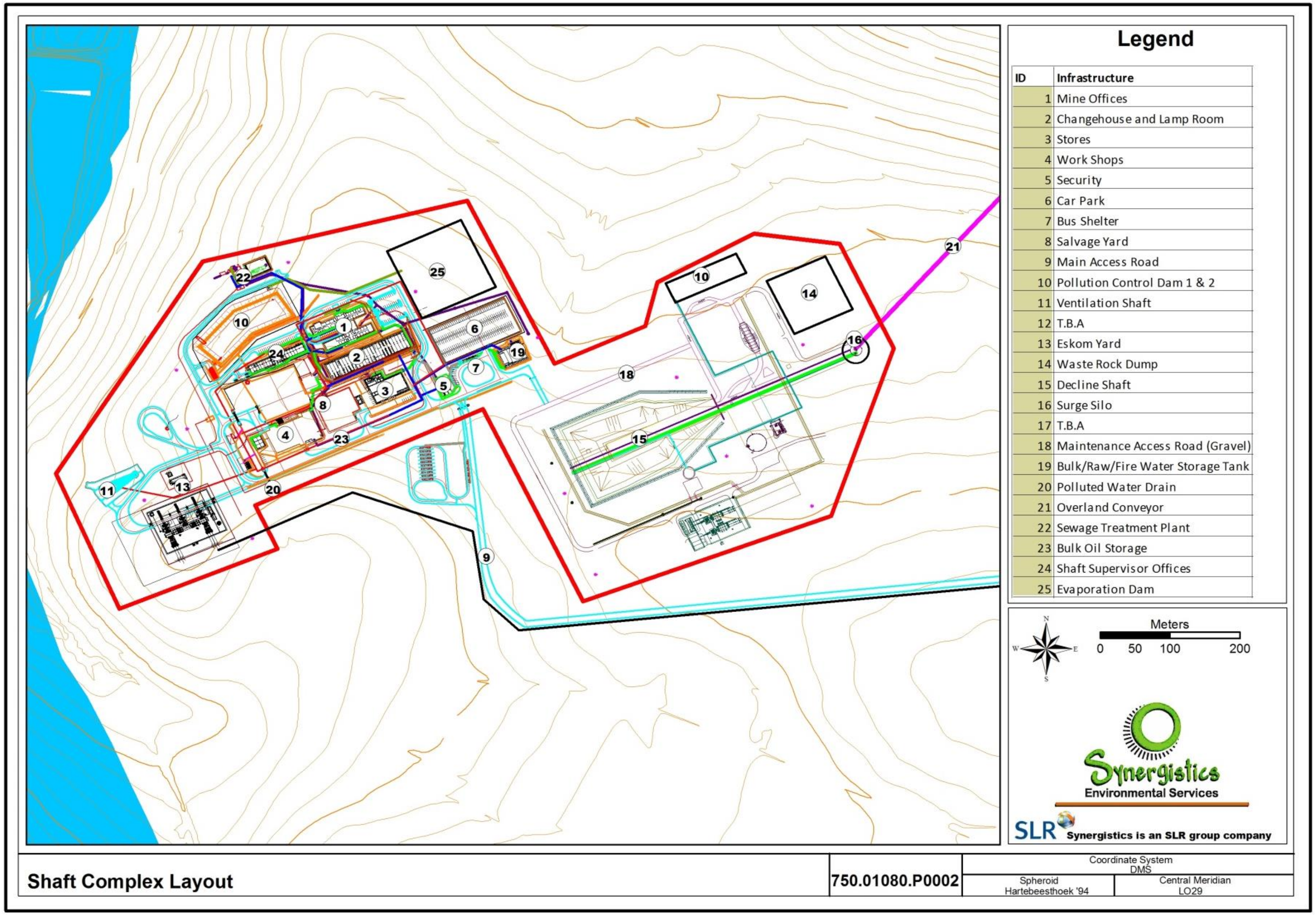

Figure 26: Proposed mine shaft and associated infrastructure

Table 7: Emission estimation techniques and parameters

Source Group	Emission Estimation Technique	Input Parameters and Activities
Construction	US EPA Single valued emission factor**Invalid source specified.** TSP – 2.69 Mg/ha/month PM_{10} – 2.02 Mg/ha/month $PM_{2.5}$ – 0.28 Mg/ha/month (PM_{10} and $PM_{2.5}$ calculated from PM ratio in Table 11.9-2 of US EPA **Invalid source specified.**).	Construction area was estimated to include underground shaft, conveyor route, waste rock dump, topsoil stockpiles, mine related facilities such as workshops, stores and various support infrastructure and services: • Estimated rate = 68 hectares/year **Mitigation:** 50 % control efficiency achieved through water sprays (NPI, 2011).
Materials Handling	US EPA emission factor equation (US EPA, 2006) $EF = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$ Where EF is the emission factor in kg/tonne material handled k is the particle size multiplier (k_{TSP} – 0.74, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.053) U is the average wind speed in m/s M is the material moisture content in %	All ore and waste handling steps (excavation, truck loading, truck off-loading, and conveyor transfer) were included. An average **wind speed of 3.4 m/s** was determined from the weather data set. A **moisture content** of **3 %** was utilized. **Hours of operation:** 24 hrs per day, 5.5 days per week. **Activities:** The number of transfer points used in the estimation of emissions are: Conveyor transfer points Silo Coal dumping at elders **Mitigation**: 50% control efficiency achieved through effective water sprays (NPI, 2011).
Vehicle Entrained PM from Unpaved Roads	US EPA emission factor equation (US EPA, 2006) $E = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{0.45} \cdot 281.9$ Where EF is the emission factor in g/vehicle kilometre travelled (VKT) k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) s is the road surface material silt content in % W is the average weight vehicles in tonnes	Vehicular activities include the transportation on the main access and maintenance road. A default road **surface silt content of 8.4%** (US EPA, 2006) was applied in calculations **Hours of operation:** 24 hrs per day, 5.5 days per week **Mitigation**: 50 % control efficiency utilized through effective water sprays (NPI, 2011).

Source Group	Emission Estimation Technique	Input Parameters and Activities
Windblown Dust	NPI single valued emission factors (NPI, 2011) TSP – 0.4 kg-ha-h PM_{10} – 0.2 kg-ha-h $PM_{2.5}$ – 0.1 kg/tonne (*Assumed* $PM_{2.5}$ fraction)	Exposed dry areas of stockpiles were included in emission estimations. - Estimated surface waste stockpile area = 65 900 m² 25 % of area assumed to be exposed / erodible per time. **Hours of operation:** Continuous **Mitigation**: 50 % control efficiency achieved through effective water sprays (NPI, 2011).
Vehicle/Exhaust Emissions **(Diesel Engines)**	NPI single valued emission factors for miscellaneous industrial combustion engine (NPI, 2008) CO – 6.16E-03 kg/kWh $PM_{2.5}$ – 1.11E-03 kg/kWh PM_{10} – 1.21E-03 kg/kWh SO_2 – 8.00E-6 kg/kWh (estimated based on 50 ppm sulphur) VOC – 1.35E-03 kg/kWh NOx – 1.5E-02 kg/kWh	Annual diesel fuel consumption was estimated for each significant portion of the site and utilized in calculation of emissions: - Surface and shaft area fuel consumption = 56 000 litres/year Since no distinction was made between equipment quantities for different years of operation, emissions were distributed over entire applicable area. A load factor of 0.5 (NPI, 2008) was applied to account for variation in engine load i.e. full load and idling. **Hours of operation:** 24 hrs per day, 5.5 days per week **Mitigation:** None
Conveyor **Emissions**	PM emissions from conveyor were estimated from wind speed dependent equation recommended by (Parret, 1992) $E = c(u^* - u_t^*)$ Where E = Emission factor in g/m of conveyor c = constant u^* = friction velocity u_t^* = threshold friction velocity of the coal	**Length of Conveyor =** 18 km **Width of conveyor** = 1.5 m **Hours of operation:** 24 hrs per day, 6 days per week others) Particle density of coal was assumed to be 1.6 g/cm^3 **Mitigation:** 65% control efficiency – based on roofing and one side coverage of the conveyor, (NPI, 2011).
Underground Ventilation Emissions	Emissions released from the ventilation shafts of the underground mine based on occupational health emission limit (10 mg/Nm^3). PM_{10} emissions estimated as 30 % of TSP $PM_{2.5}$ emissions estimated as 15 % of TSP	**Ventilation Shaft Parameters (given)** **Vent diameter** = 6m; **Flow rate** = 400 m^3/s; **Temperature** = 25°C; **Assumed height** = 3 m **Mitigation:** None **Hours of operation:** 24 hrs per day, 5.5 days per week

Table 8: Estimated annual average emission rates per source group

Annual Emissions (without mitigation)							
Sources	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**NOx**	**VOC**	**SO2**	**CO**
Materials Handling	2.5	16.6	35.0				
Roads	1.7	16.7	58.7				
Conveyor	40.2	80.5	178.8				
Vehicle Exhaust	0.2	0.2	0.2	2.5	0.2	0.0	1.0
Wind Erosion	1.4	2.9	5.8				
Ventilation shaft	14.3	28.5	95.0				
Materials Handling	2.5	16.6	35.0				
Total	**60.3**	**145.4**	**373.5**	**2.5**	**0.2**	**0.0**	**1.0**
Construction	11.67	83.39	111.18				

Annual Emissions (with mitigation)							
Sources	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**NOx**	**VOC**	**SO2**	**CO**
Materials Handling	1.3	8.3	17.5				
Roads	0.8	8.4	29.3				
Conveyor	14.1	28.2	62.6				
Vehicle Exhaust	0.2	0.2	0.2	2.5	0.2	0.0	1.0
Wind Erosion	0.7	1.4	2.9				
Ventilation shaft	14.3	28.5	95.0				
Materials Handling	1.3	8.3	17.5				
Total	**31.3**	**75.0**	**207.6**	**2.5**	**0.2**	**0.0**	**1.0**
Construction	5.84	41.69	55.59				

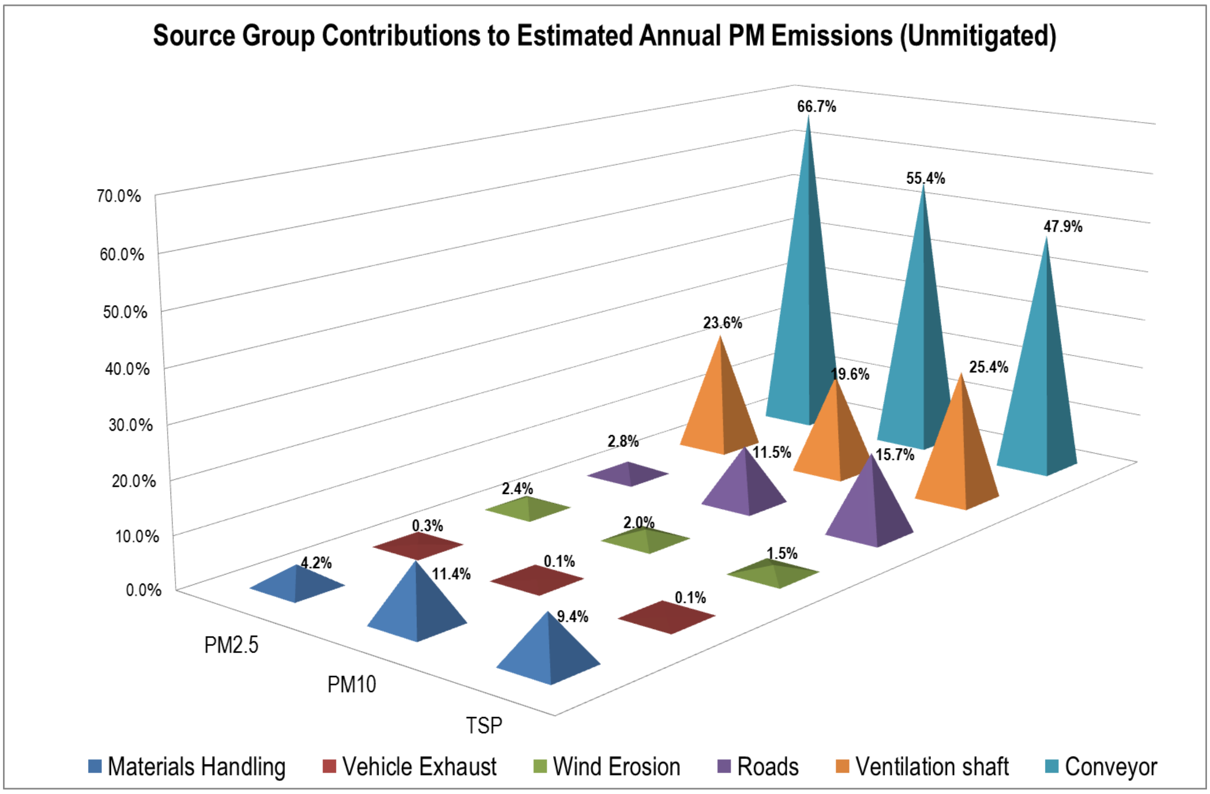

Figure 27: Source group contributions to estimated annual emissions (unmitigated)

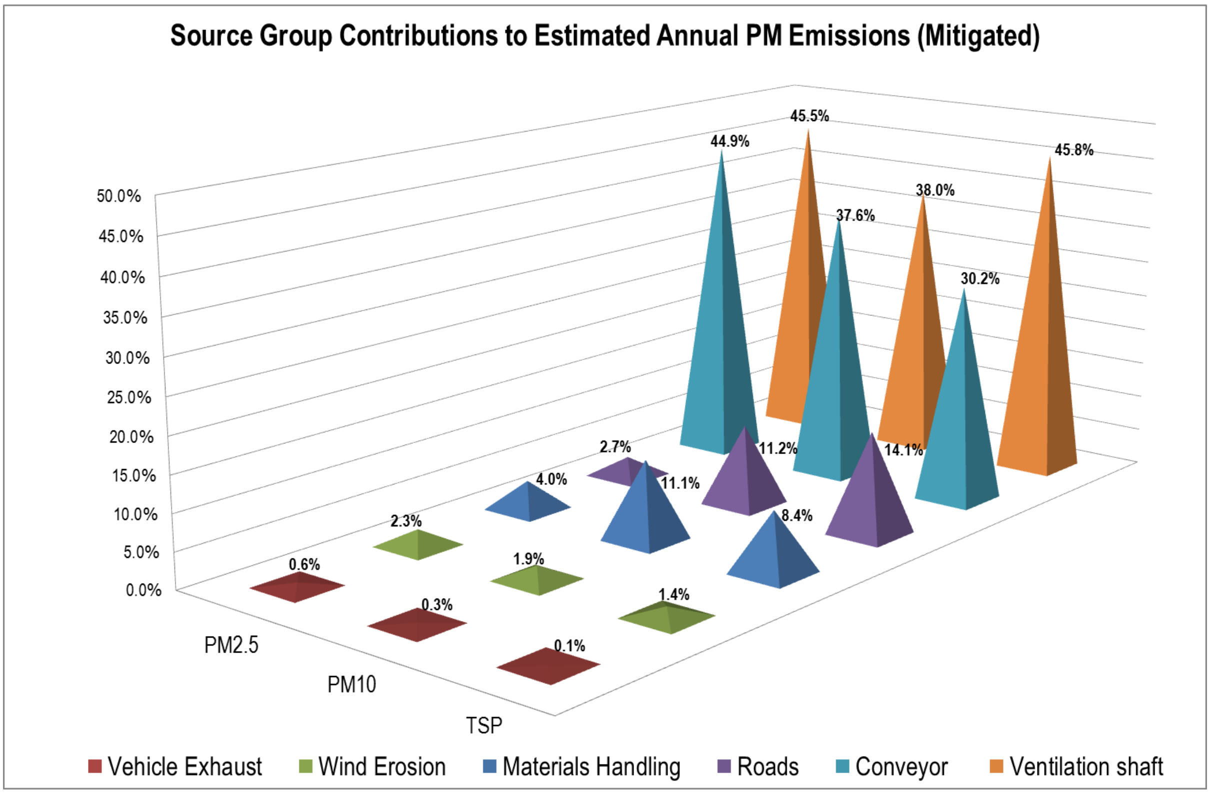

Figure 28: Source group contributions to estimated annual emissions (mitigated)

The following should be noted with regards to the emissions inventory:

- Conveyor emission contributes most notably to estimated PM emissions during the project's operational phase. About 48 % to 67 % of emissions are expected to be from conveyors when no mitigation is applied. Its contribution decreases to between 38 % and 46% with mitigation measures in place. Ventilation shaft emissions are the second highest emission source.
- CO, VOCs, NO_x and SO_2 emissions are only emitted by diesel engines.

4.1.2.1 Methane Emissions (GHG Emissions Inventory)

The geological processes of coal formation produce CH_4 and CO_2. CH_4 is the major GHG emitted from coal mining and handling (Department of Environmental Affairs, 2013). In underground mines, ventilation of the mines causes significant amounts of CH_4 to be pumped into the atmosphere. Such ventilation is the main source of CH_4 emissions in hard coal mining activities. CH_4 releases from surface coal mining operation are low. In addition CH_4 can continue to be emitted from abandoned coal mines after mining has ceased.

The newly published "Draft National Greenhouse Gas Emission Reporting Regulations" (Department of Environmental Affairs, 2015) state methods for determining greenhouse gas emissions as required by the IPCC. The following methods are given:

- Tier 1 method: Default IPCC emission factors available in the 2006 IPCC Guidelines are used to calculate emissions from activity data;
- Tier 2 method: Country specific emission factors published in the Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by industry are used to calculate emissions from activity data;
- Tier 3 method: Emission models, material carbon balances and continuous emission measurements in the Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry available on the DEA website (www.environment.gov.za) are used.

A summary of all direct GHG emissions from the Alexander Project (assuming the tier 1 and 2 approach) is given in Table 9 (CH_4, expressed as tonne CO_2 equivalent or tCO_2eq). CO_2eq is a term for describing different GHG in a common unit. For any quantity and type of GHG, CO_2eq signifies the amount of CO_2 which would have the equivalent global warming impact. A quantity of GHG can be expressed as CO_2eq by multiplying the amount of the GHG by its global warming potential (GWP). E.g. if 1kg of CH_4 is emitted, this can be expressed as 23kg of CO_2eq (1kg CH_4 * 23 = 23kg CO_2eq).

The basis for the calculation of these emission rates are given in Table 10.

Table 9: Greenhouse Gas Emissions Inventory for the Alexander Project

Emission Source	Description	Quantity	Units	Emission Factor	Emission Rate (tCH_4)	Emission Rate (tCO_2eq)
Coal mining	CH_4 liberated from the underground mining of coal (determined per ton coal mined)	6 000 000	tonne/a	1.2 m³ CH_4/tonne coal mined (804 g CH_4/tonne coal mined)	**4824 tpa CH_4** *Calculation:* Given: 6 000 000 coal mined per annum (tpa) Total CH_4 Emissions = 1.2 m³ CH_4/tonne coal mined x 6 000 000 coal mined per annum x 670 g/m³ / 1 000 000 g per tonne = 4824	110 952
	Use of explosives to mine the coal (based on stonework development of 10-15 faces per day x 30 holes per face (using 200-300g explosives per hole)	40.5	tonne/a	0.17 tonne CO_2eq/tonne	-	6.90
Fuel Use	Diesel fuel use	56 000 (2134)	l/a (GJ/a)	0.0741 tonne CO_2eq/GJ fuel	-	158.13
Total						**111 118**

Table 10: Basis for Emission Rates

Emission Source	Description	Basis for Emissions Rate
Coal mining	CH_4 liberated from the underground mining of coal (determined per ton coal mined)	IPCC approved factor for SA – average tier 2 value (Department of Environmental Affairs, 2013)
	Use of explosives to mine the coal	National Greenhouse Accounts (NGA) Factors (Australian Government, 2008)
Fuel Use	Diesel fuel use	(IPCC, 2006)

Underground coal mining is listed as one of the greenhouse gas emitters in which emission of GHG in excess of 0.1 Megatonnes (i.e. 100 000 tonnes CO_2eq) or more annually will require the submission of a pollution prevention plan (DEA, 2014).

The Alexander Project will therefore require the submission of a pollution prevention plan as it may emit more than 100 000 tCO_2eq (**111 118** tCO_2eq).

4.1.3 Closure Phase

All operational activities will have ceased by the closure (decommissioning and post-closure) phase of the project. This will obviously result in a positive impact on the surrounding environment and human health. The potential for impacts during the closure phase will therefore depend on the extent of rehabilitation efforts to be undertaken at the shaft, infrastructure area and conveyor route. Aspects and activities associated with the closure phase of the proposed project are listed in Table 11.

Table 11: Activities and aspects identified for the closure phase

Aspects	Activities
Fugitive dust	Demolition and stripping away of buildings and facilities
Fugitive dust	Wind-blown dust from stockpile and exposed areas
Fugitive dust	Degradation of roads resulting in exposed areas surfaces

4.2 Atmospheric Dispersion Modelling

The assessment of the impact 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 2);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 1.3.4)

The impact of operations on the atmospheric environment was determined through the simulation of dustfall rates and ambient pollutant concentrations. Dispersion models simulate ambient pollutant concentrations and dustfall rates 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 purpose of the current study use was made of hourly MM5 surface and profile data for the period 2011 to 2013 (Section 3.2).

4.2.3 Source and Emission Data Requirements

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

- Materials handling – modelled as volume sources;
- Ventilation shaft – modelled as point sources; and
- Unpaved roads, conveyors, vehicle exhaust, and windblown dust – modelled as area sources.

4.2.4 Simulation of NO/NO_2 Transformation

Nitrogen monoxide (NO) emissions are rapidly converted in the atmosphere into the much more poisonous nitrogen dioxide (NO_2) which is regulated by SA NAAQS. NO_2 concentrations were calculated by AERMOD using the ozone limiting method and applying an annual average background O_3 concentration of 30 ppb (Zunckel, et al., 2004). A diesel exhaust NO_2/NO_x emission ratio of 0.2 (Howard, 1988) was used.

4.2.5 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 25 km (east-west) by 25 km (north-south). The area was divided into a grid matrix with a resolution of 200 m, 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 point.

4.2.6 Presentation of Results

Dispersion modelling was undertaken to determine highest hourly, highest daily and annual average ground level concentrations as well as dustfall rates for each of the pollutants considered in the study. 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.

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. The reader should take note that isopleths showing 1-hour or 24-hour concentrations reflect the 2nd highest 1-hour or 24-hour concentration simulated at grid receptor locations and not the frequency at which the specific concentration occurred over the simulation period. Separate isopleth plots are given to indicate the frequencies of exceedance.

Isopleth plots reflect the incremental ground level concentrations (GLCs) for $PM_{2.5}$, PM_{10}, NO_2 and SO_2. Due to the unavailability of ambient baseline concentrations, the total cumulative pollutant concentrations could not be quantitatively determined but qualitative commentary is provided in the discussion of impact significance in section 5.

It should also be noted that ambient air quality criteria applies 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 Dispersion Simulation Results, Health Risk and Nuisance Screening

Pollutants with the potential to result in human health impacts which are assessed in this study include CO, NO_2, $PM_{2.5}$, PM_{10}, SO_2 and VOC. Dustfall is assessed for its nuisance potential.

The impact assessment methodology as discussed under section 4.2 was followed. Isopleth plots are provided for all pollutants where exceedances of the relevant NAAQSs were simulated. Isopleth plots reflect the incremental GLCs for $PM_{2.5}$, PM_{10} and TSP; as well as cumulative GLCs for PM_{10}.

While there is a case for assessing the impacts of the proposed project individually, i.e. the incremental effect, potentially affected receptors are more interested in the overall end result, i.e. the cumulative effect. The National Environmental Management Act (NEMA), 107 of 1998 Act 1991 also requires this. This means that modelling results must be added to current background air pollution discharged by other sources. In order to estimate the current ambient PM_{10} concentrations at and near the site, use was made of available monitoring data from the Alexander monitoring campaign (Section 3.4.2).

Unless hour-by-hour data are available, cumulative impacts can at best only be approximated. Simply adding short-term concentrations together (i.e. background and incremental) to provide an estimate of the cumulative impact may lead to an over-estimate. This is partly because it is difficult to know whether the background data are representative of the point at which the modelled peak occurs. In general they will not be, leading to an overestimate of the cumulative effect. Furthermore, both the modelled and the background concentrations vary with time of day, and may in most cases, not coincide in time. Hence, only annual cumulative PM_{10} impacts were assessed, utilizing an annual average concentration of 26.2 $\mu g/m^3$.

4.3.1 $PM_{2.5}$ Impact

The areas over which the 24-hour NAAQS are exceeded are shown in Figure 29 and Figure 30 for unmitigated and mitigated scenarios respectively. Simulated $PM_{2.5}$ concentrations exceed the 24 hour SA NAAQS (4 days of exceedance of 40 $\mu g/m^3$ permitted per year) only at R29, and not at any other AQSRs. Simulations also indicate that exceedances of the annual SA NAAQS for $PM_{2.5}$ (20 $\mu g/m^3$) occur only at R29, and not at any other AQSRs (Figure 31 and Figure 32).

Simulated $PM_{2.5}$ GLCs (Figure 33) due to conveyor emissions exceed the 24 hour SA NAAQS (4 days of exceedance of 40 $\mu g/m^3$ permitted per year) up to 180 m (for unmitigated scenario); and 120 m (for mitigated scenario) away from the conveyor edge (in both directions). However, simulated annual $PM_{2.5}$ GLCs (Figure 34) due to conveyor emissions (mitigated and unmitigated scenarios) did not exceed the NAAQS limit (20 $\mu g/m^3$) at the conveyor (in both directions).

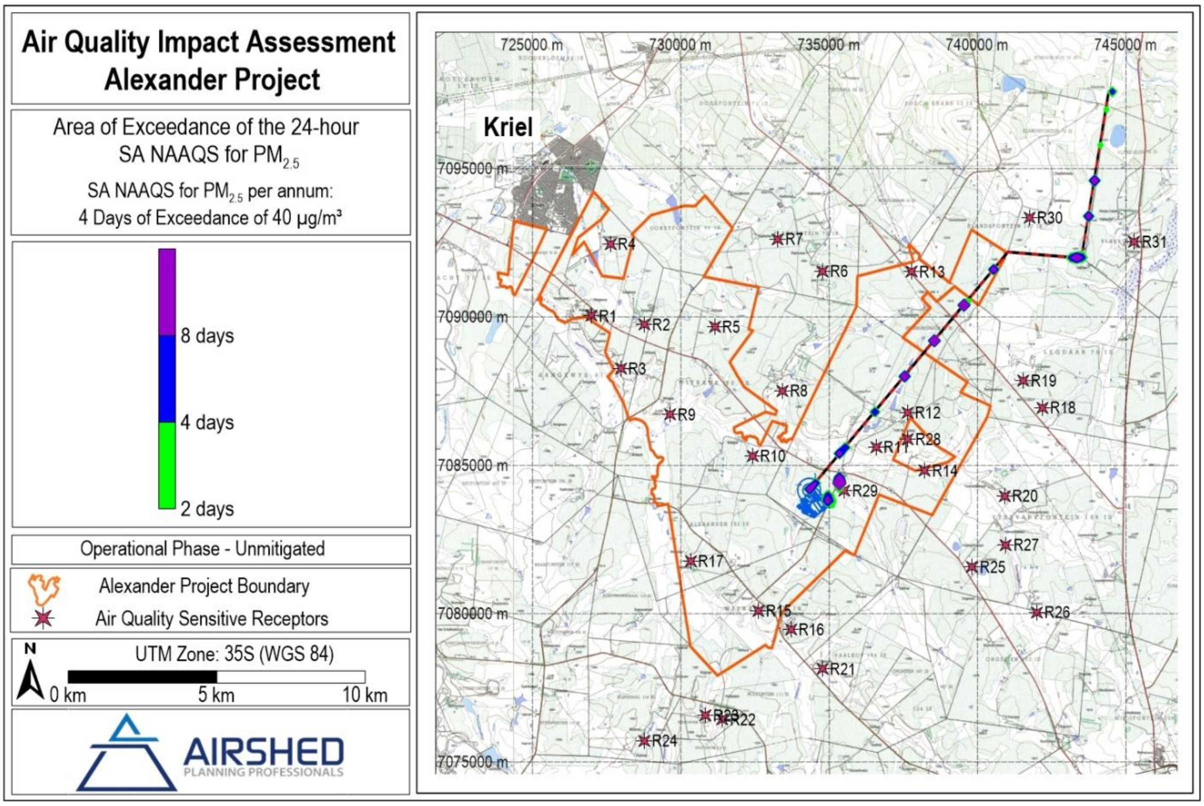

Figure 29: Area of exceedance of the 24-Hour SA NAAQS for $PM_{2.5}$ due to unmitigated emissions (incremental)

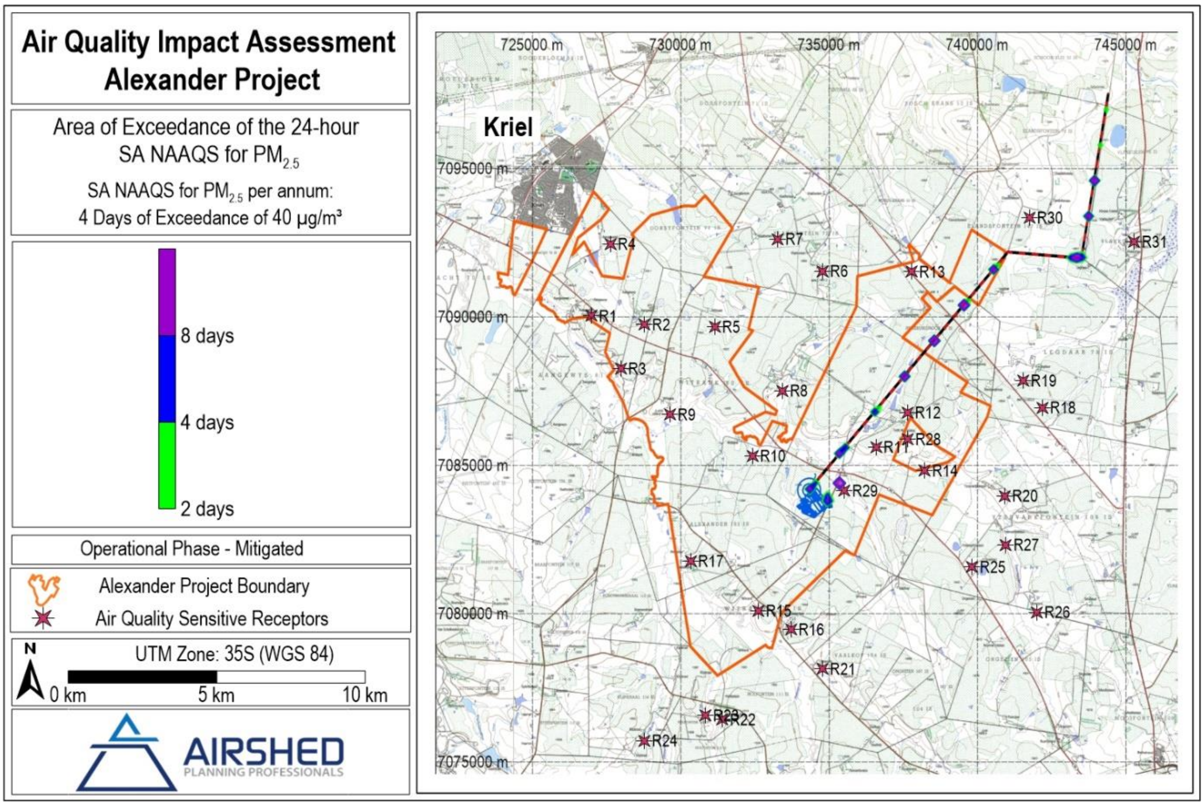

Figure 30: Area of exceedance of the 24-Hour SA NAAQS for $PM_{2.5}$ due to mitigated emissions (incremental)

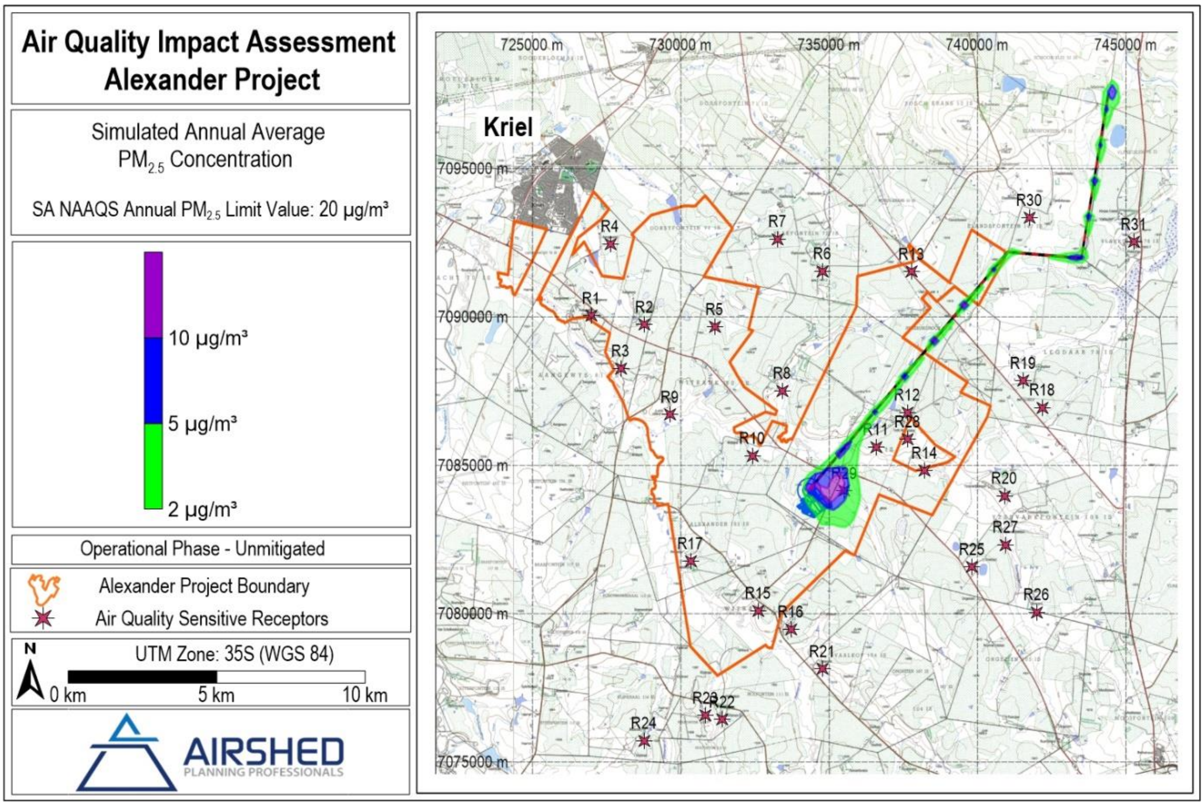

Figure 31: Simulated annual average PM2.5 GLCs due to unmitigated operational phase emissions (incremental)

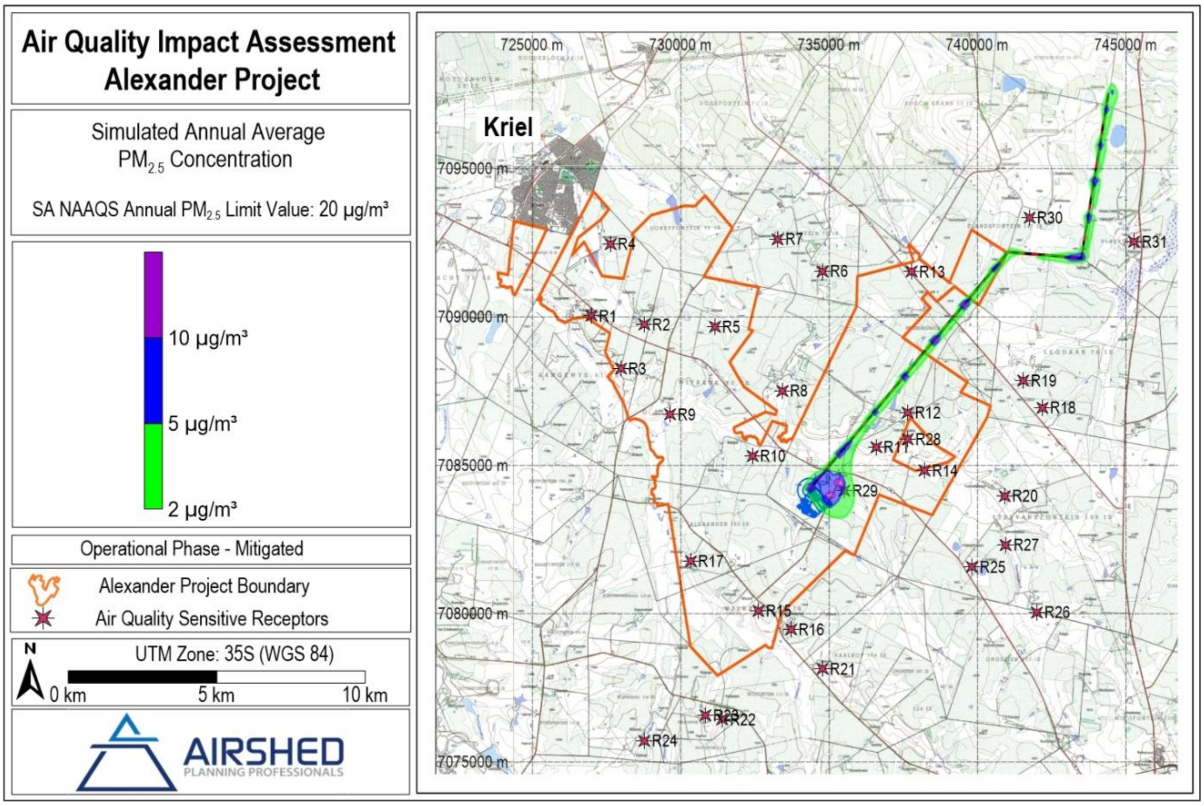

Figure 32: Simulated annual average PM2.5 GLCs due to mitigated operational phase emissions (incremental)

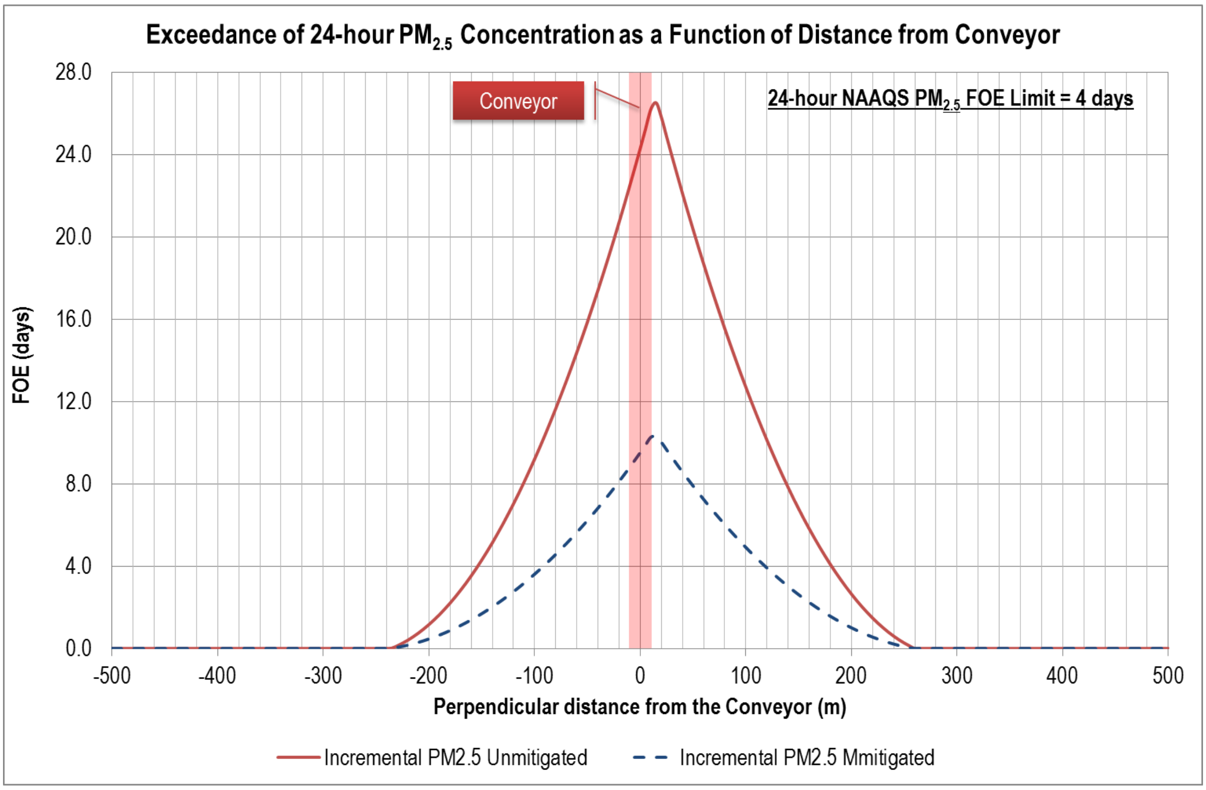

Figure 33: Simulated exceedances of the 24-hour $PM_{2.5}$ SA NAAQS limit (40 µg/m³) due to conveyor emissions

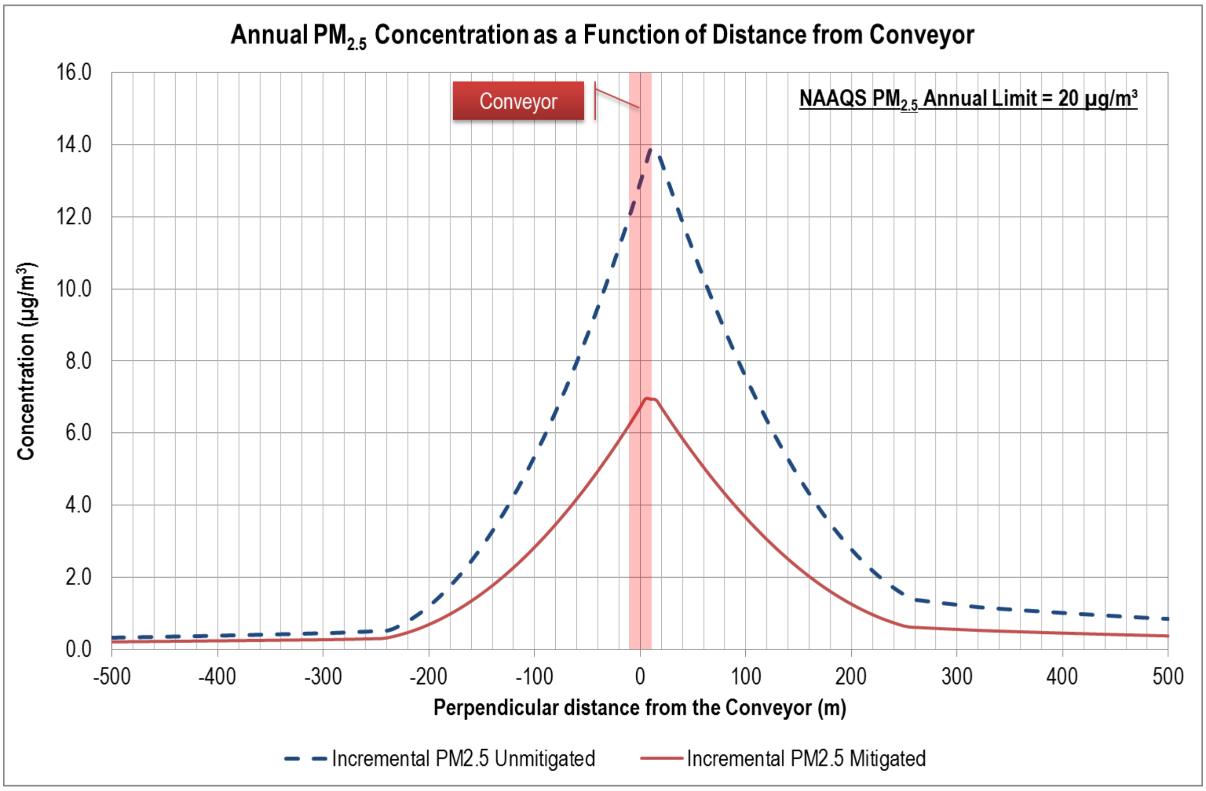

Figure 34: Simulated annual average $PM_{2.5}$ GLCs due to conveyor emissions

4.3.2 PM_{10} Impact

The areas over which the 24-hour NAAQS are exceeded are shown in Figure 35 and Figure 36 for unmitigated and mitigated scenarios respectively. Simulated PM_{10} concentrations exceed the 24 hour SA NAAQS (4 days of exceedance of 75 µg/m^3 permitted per year) only at R29, and not at any other AQSRs. Simulations also indicate that exceedances of the annual SA NAAQS for PM_{10} (40 µg/m^3) occur only at R29, and not at any other AQSRs (Figure 37 and Figure 38).

Simulated PM_{10} GLCs (Figure 41) due to conveyor emissions exceed the 24 hour SA NAAQS (4 days of exceedance of 75 µg/m^3 permitted per year) up to 180 m (for unmitigated scenario); and up to 160 m (for mitigated scenario) away from the conveyor edge (in both directions). However, simulated annual PM_{10} GLCs (Figure 42) due to conveyor emissions (mitigated and unmitigated scenarios) did not exceed the NAAQS limit (40 µg/m^3) at the conveyor (in both directions).

Cumulative annual PM_{10} GLCs are shown in Figure 39 and Figure 40 for unmitigated and mitigated scenarios respectively. Simulations indicate that exceedances of the annual SA NAAQS for $PM_{2.5}$ (40 µg/m^3) occur only at R29, and not at any other AQSRs.

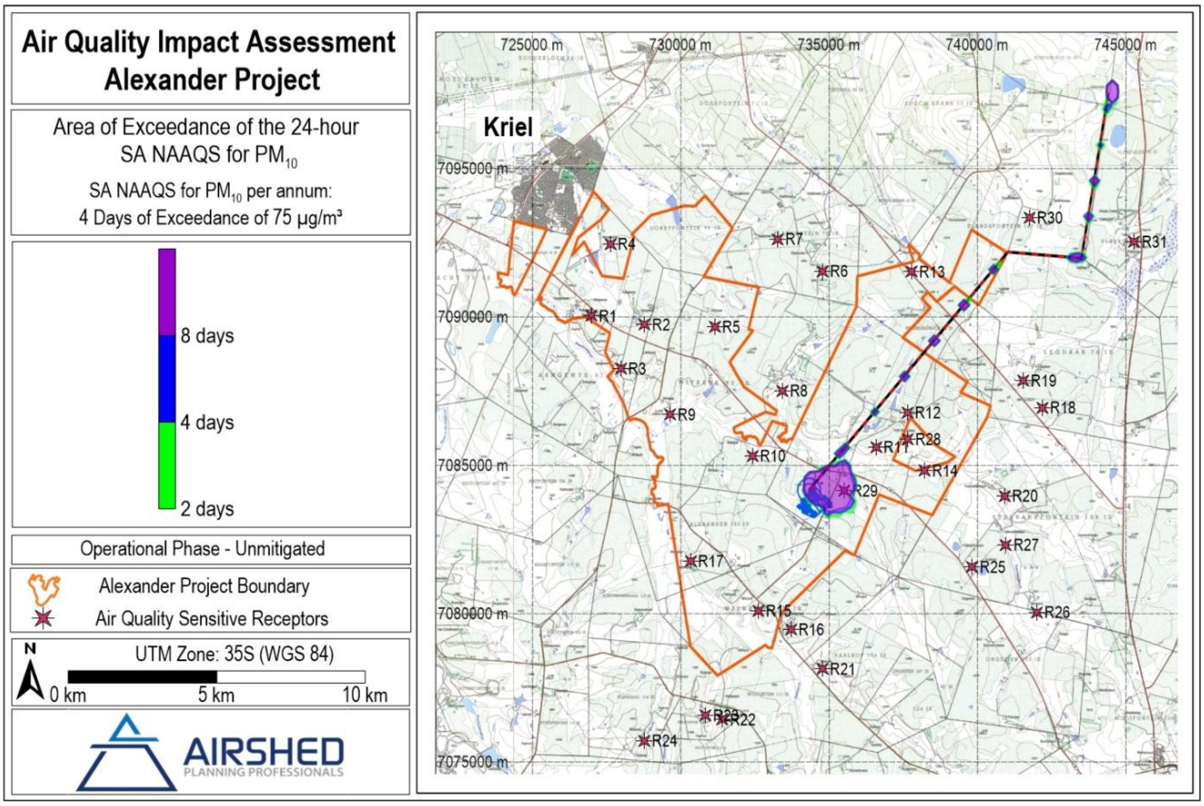

Figure 35: Area of exceedance of the 24-Hour SA NAAQS for PM_{10} due to unmitigated emissions (incremental)

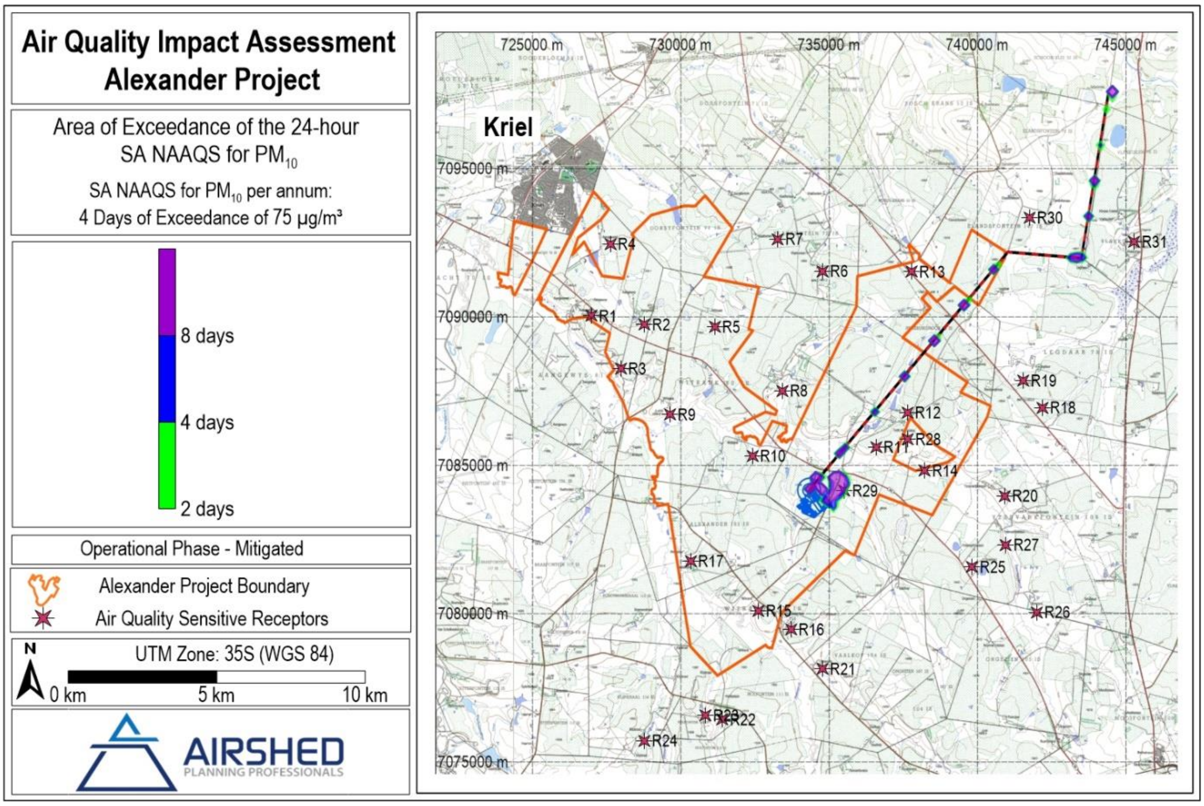

Figure 36: Area of exceedance of the 24-Hour SA NAAQS for PM_{10} due to mitigated emissions (incremental)

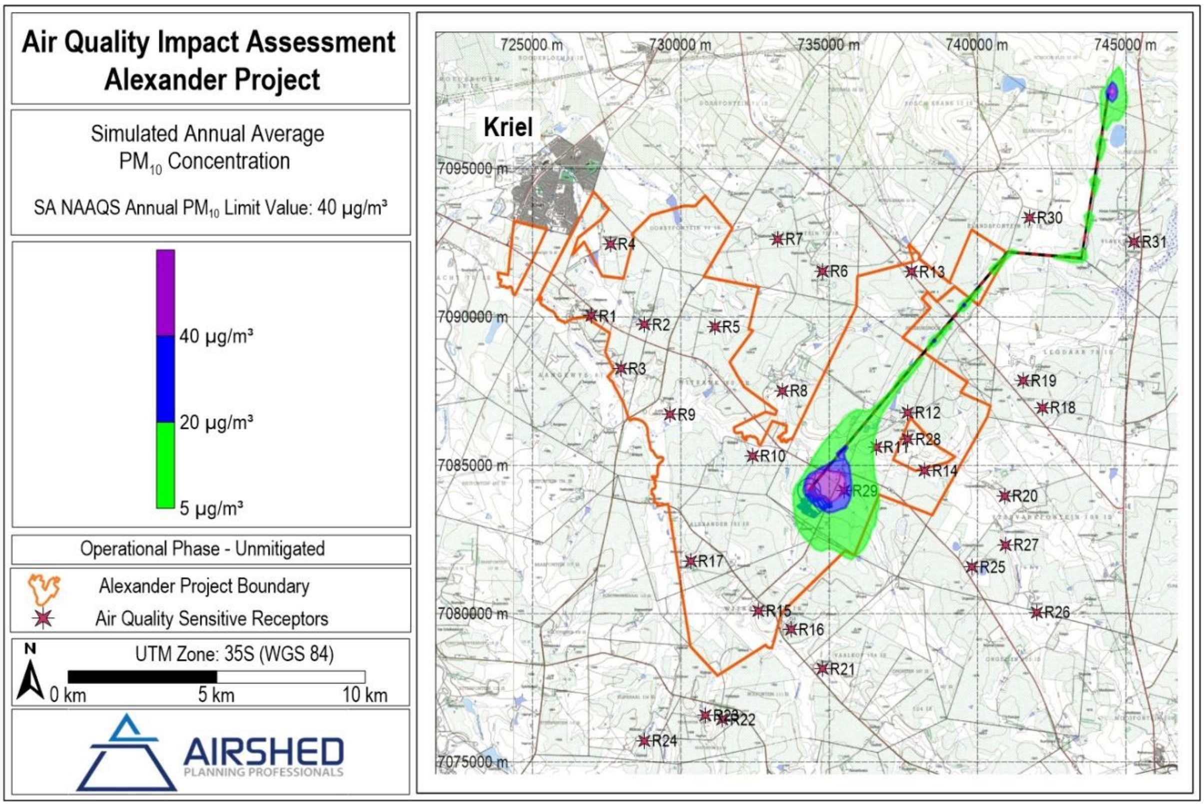

Figure 37: Simulated annual average PM_{10} GLCs due to unmitigated emissions (incremental)

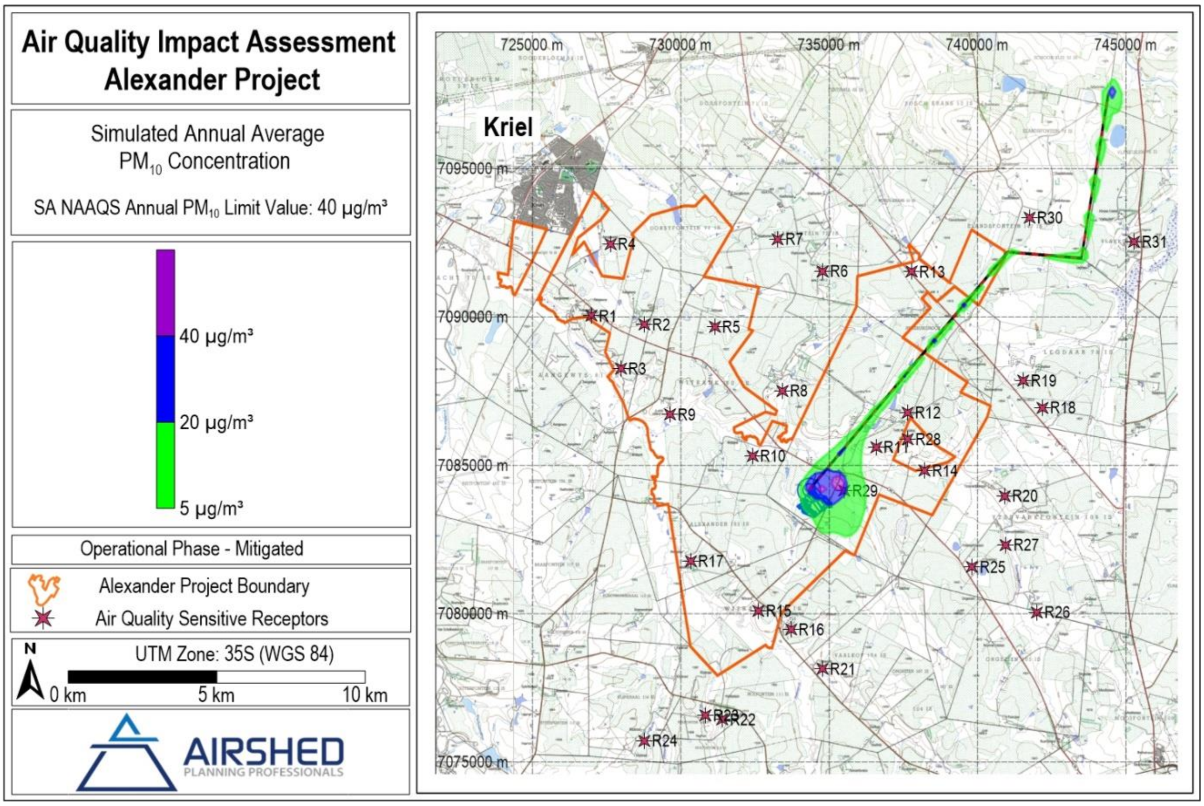

Figure 38: Simulated annual average PM_{10} GLCs due to mitigated operational phase emissions (incremental)

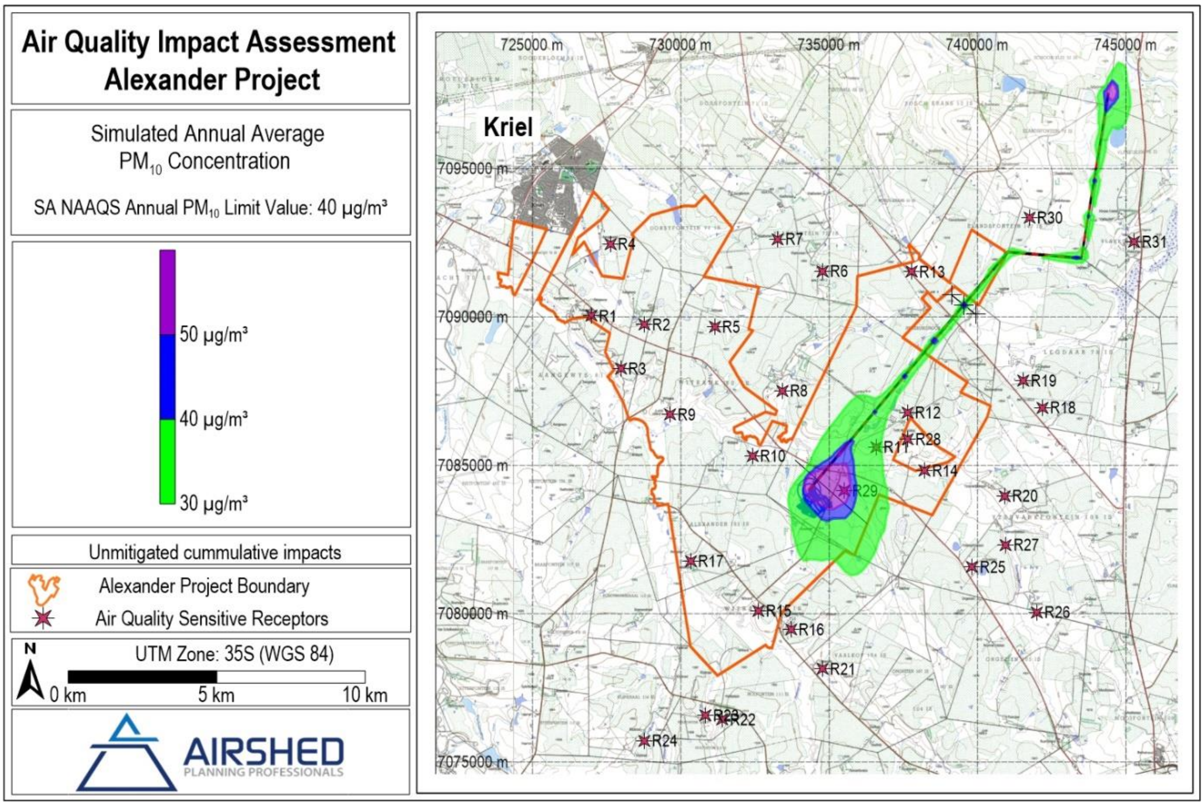

Figure 39: Simulated annual average PM_{10} GLCs due to unmitigated operational phase emissions (cumulative)

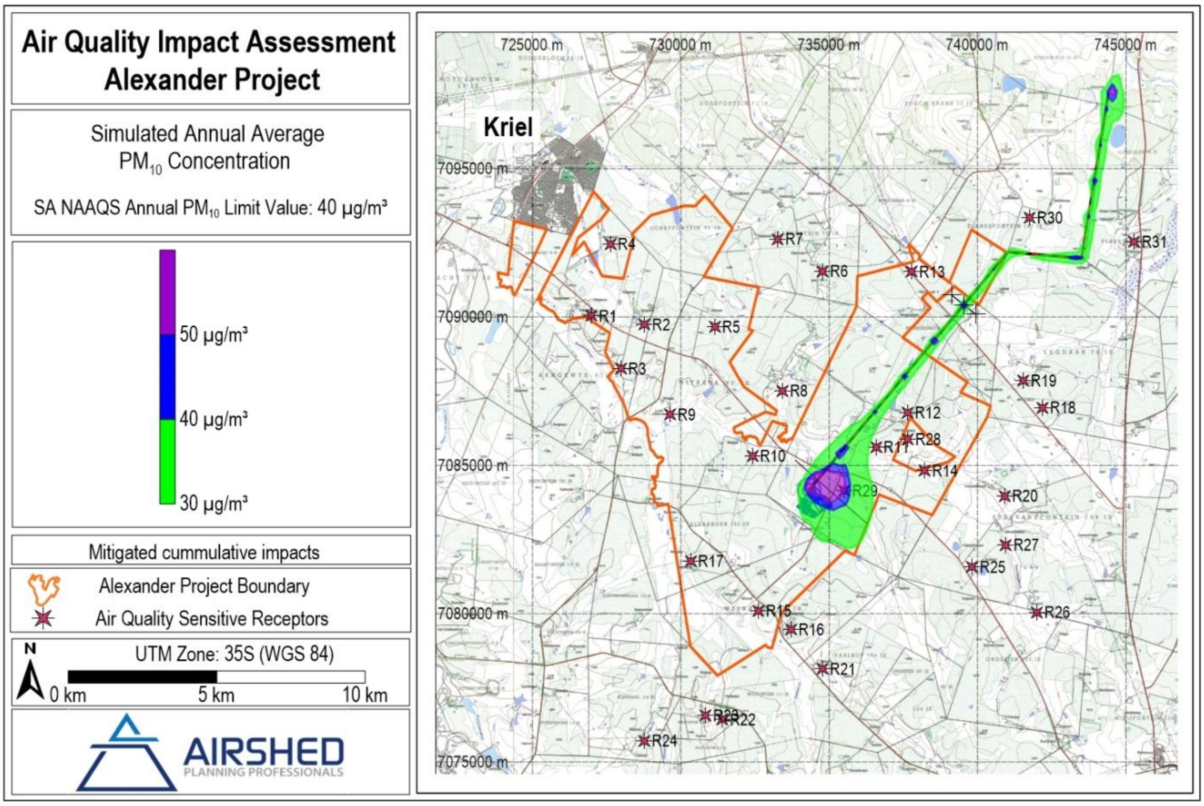

Figure 40: Simulated annual average PM$_{10}$ GLCs due to mitigated operational phase emissions (cumulative)

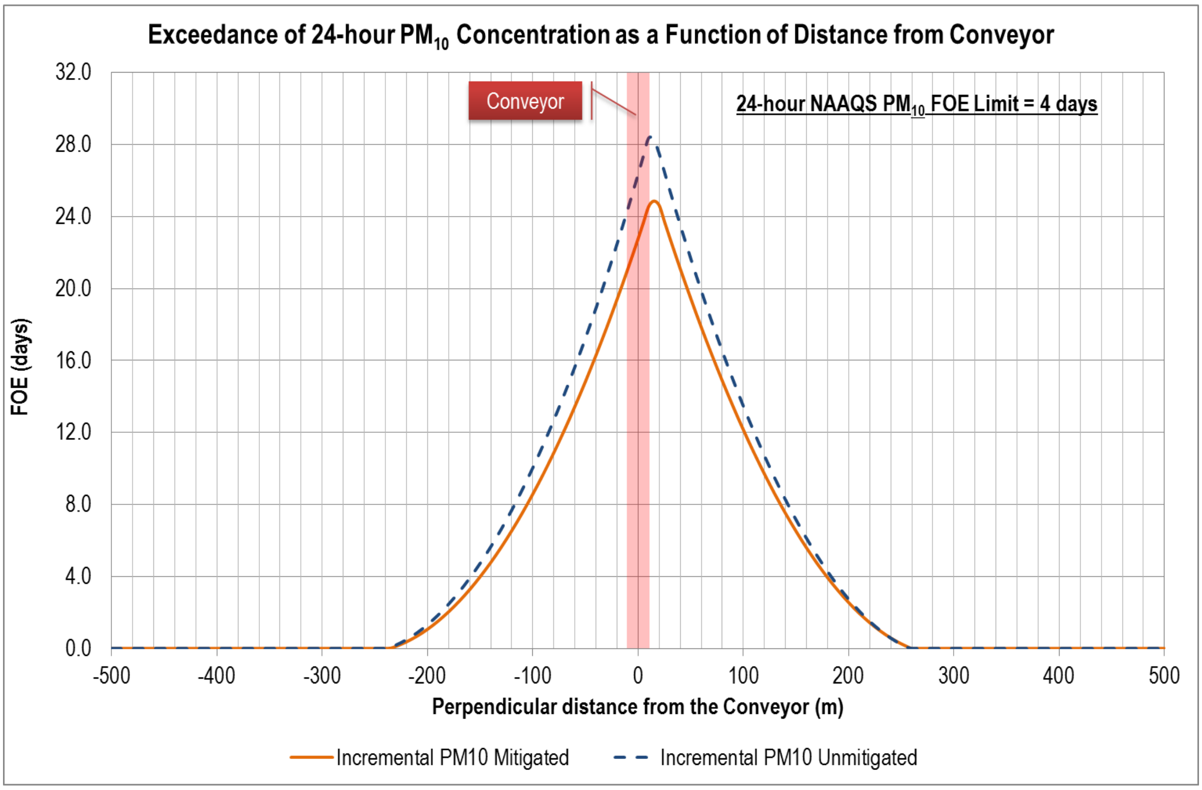

Figure 41: Simulated exceedances of the 24-hour PM$_{10}$ SA NAAQS limit (40 µg/m³) due to simulated conveyor emissions with the addition of estimated baseline concentrations, i.e. cumulative impact.

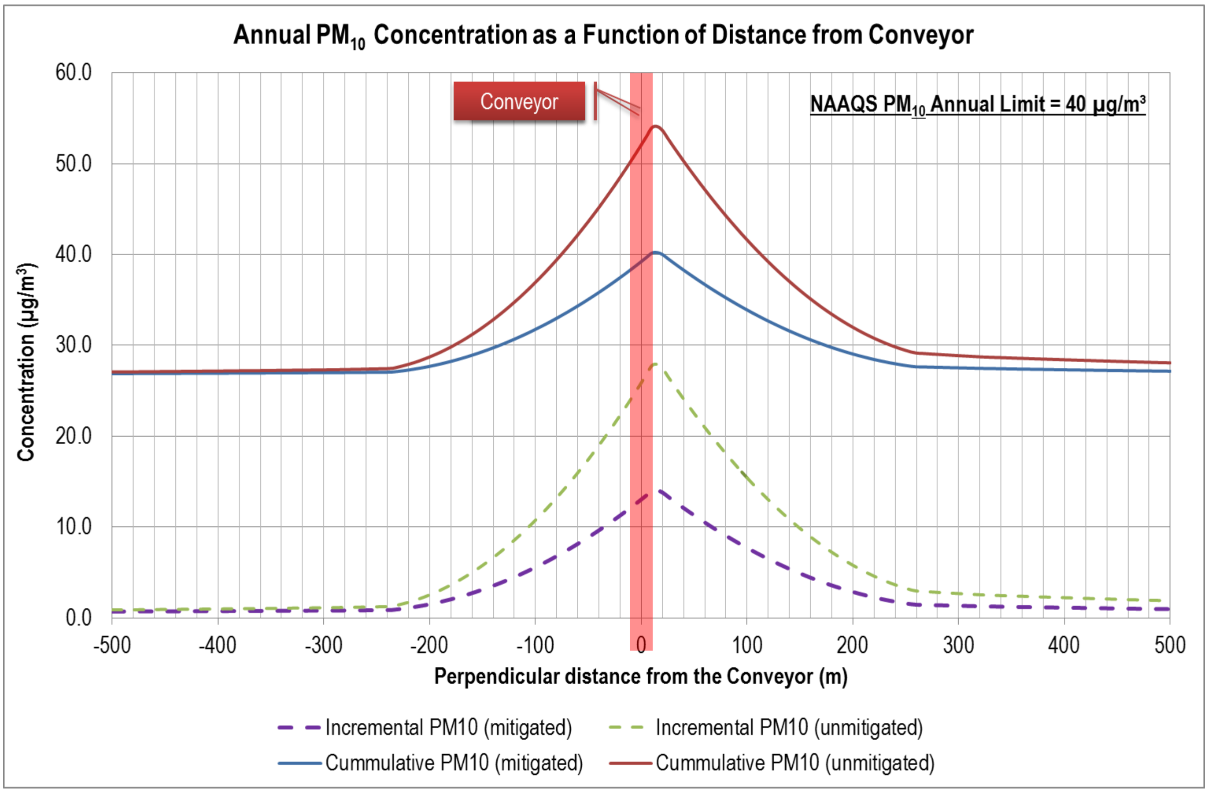

Figure 42: Simulated annual average PM_{10} GLCs due to conveyor emissions (cumulative impact)

4.3.3 Dustfall Impact

Isopleth plots showing the area of exceedance of the residential and non-residential limits due to dustfall are provided in Figure 43 and Figure 44 respectively. The simulated maximum daily dustfall rates due to unmitigated and mitigated scenarios are in exceedance of the NDCR for residential areas (600 mg/m^2-day) only at AQSR 29 but not at any other AQSRs.

Simulated dustfall deposition rates (Figure 45) due to conveyor emission exceed the NDCR residential area limit (600 mg/m^2-day) up to 160 m (for unmitigated scenario); and up to 80 m (for mitigated scenario) away from the conveyor edge (in both directions).

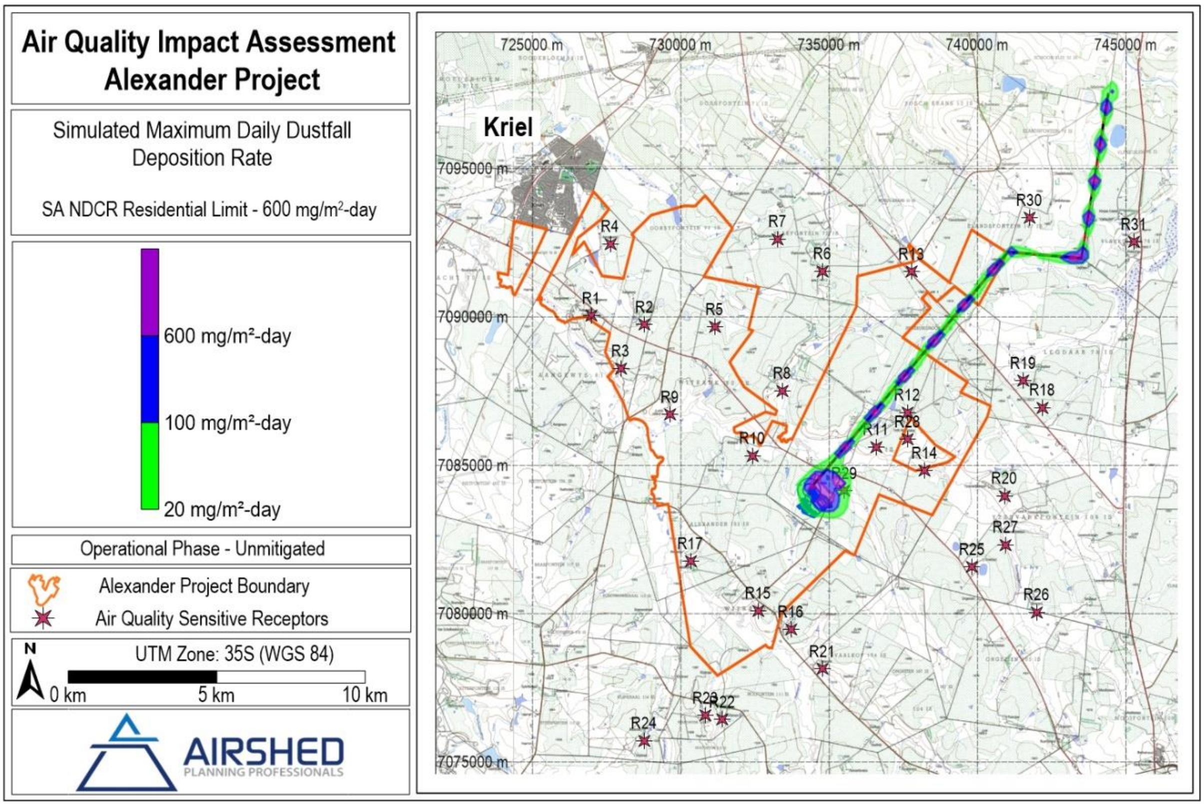

Figure 43: Simulated dustfall deposition rates due to unmitigated operational phase emissions (incremental)

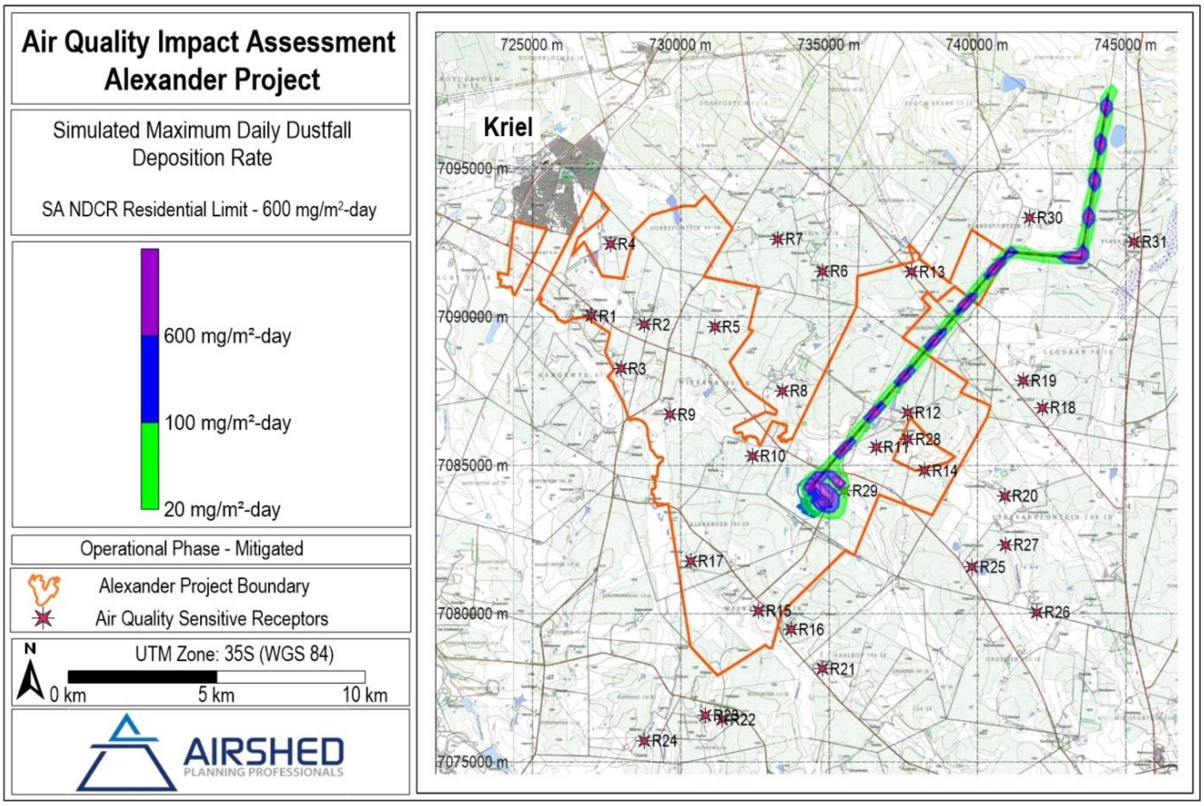

Figure 44: Simulated dustfall deposition rates due to mitigated operational phase emissions (incremental)

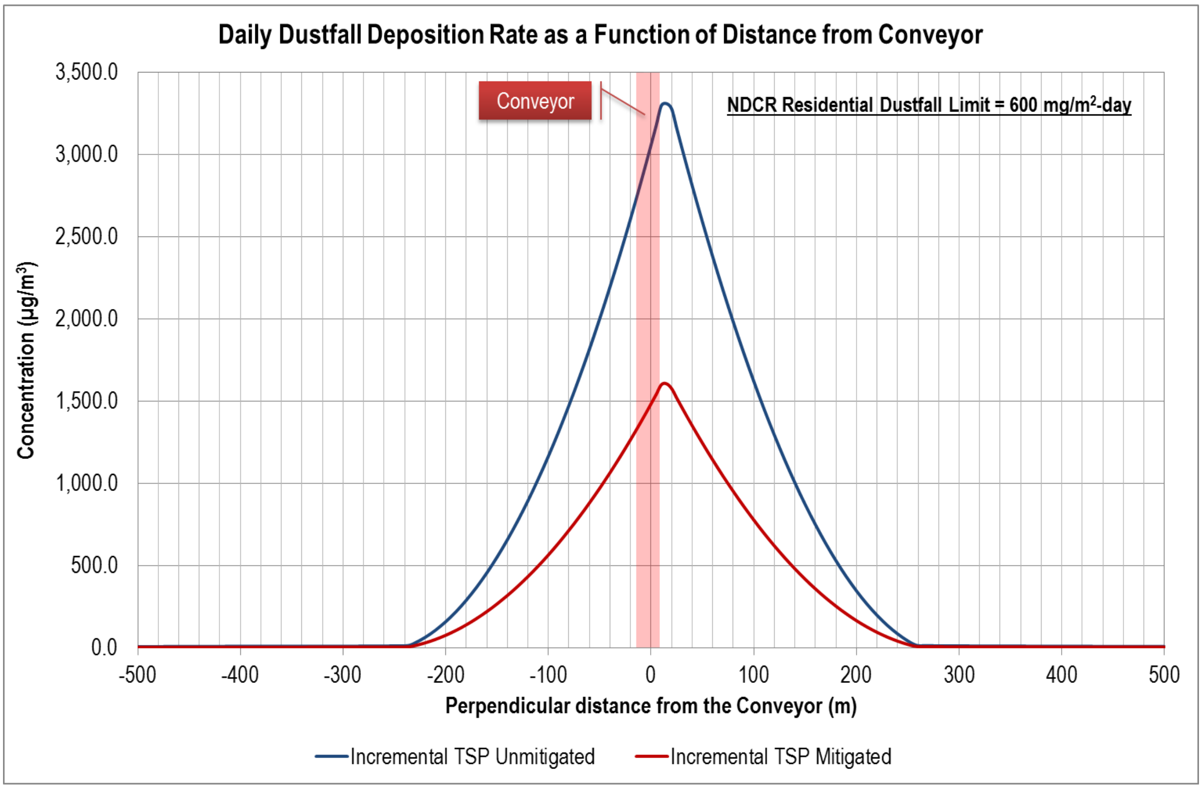

Figure 45: Simulated maximum daily dustfall deposition rate due to conveyor emissions

4.3.4 VOCs, NO_2, CO and SO_2 Impact

SO_2, CO, VOC and NO_2 impacts were simulated for the operational phase of the Project. Simulated SO_2, CO, VOC and NO_2 concentrations were low and did not result in any off-site exceedances of assessment criteria. This is typical of mining processes. Simulated maximum SO_2, CO, VOC and NO_2 GLCs at AQSRs are presented in Table 12, alongside PM emissions.

4.4 Impacts Due to Alternative Siting of the Mine shaft and Infrastructure

An alternative location for the mine shaft, associated infrastructure and conveyor route for the Project was also proposed. This involves shifting the proposed mine shaft and infrastructure by approximately 300 m to the northeast (Figure 46).

From an air quality point of view, impacts due to alternative location of the mine shaft and associated infrastructure will have the same magnitude and extent, as simulated for the original layout. Exceedances of the NAAQS standards are expected to occur at AQSRs to the north and east of the mine shaft including R29 (refer to Figure 29, Figure 31, Figure 35, Figure 37, Figure 39 and Figure 40).

Impacts due to alternative siting of the conveyor are anticipated to exhibit similar trends, as simulated for the original layout, with exceedance occurring at 150 m to 200 m perpendicular to the conveyor. Exceedances of the NAAQS standards are expected at R28 (refer to Figure 33, Figure 41, Figure 42 and Figure 45).

With the proposed mitigation measures in place, the impacts at the alternative mine shaft location and alternative siting of the conveyor are expected to reduce. However, exceedances of the NAAQS standards are still anticipated at R29 (due to mine shaft emissions) and R28 (due to conveyor emissions).

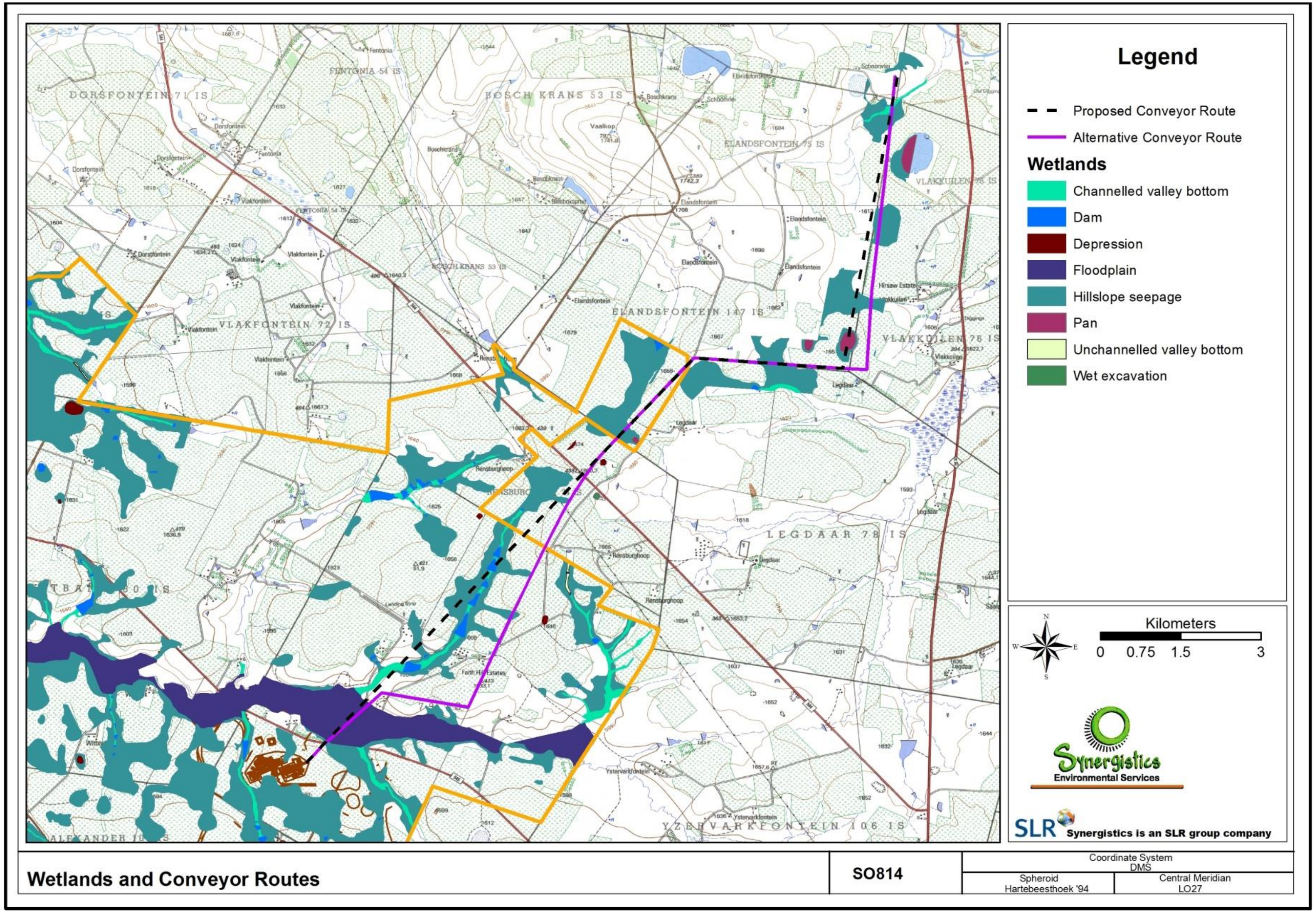

Figure 46: Proposed alternative to mine shaft and associated infrastructure

Table 12: Simulated annual incremental GLCs and deposition rates at AQSRs

AQSRs	Annual $PM_{2.5}$ ($\mu g/m^3$)		Annual PM_{10} ($\mu g/m^3$)		Daily TSP (mg/m^2-day)		Annual NO_2 ($\mu g/m^3$)	Annual SO_2 ($\mu g/m^3$)	Annual VOCs ($\mu g/m^3$)	Hourly CO ($\mu g/m^3$)
	Unmitigated	Mitigated	Unmitigated	Mitigated	Unmitigated	Mitigated	Unmitigated	Unmitigated	Unmitigated	Unmitigated
R1	0.07	0.05	0.03	0.03	0.16	0.08	0.00	0.00	0.00	0.16
R2	0.09	0.06	0.05	0.04	0.20	0.10	0.00	0.00	0.00	0.26
R3	0.10	0.07	0.05	0.04	0.22	0.11	0.00	0.00	0.00	0.26
R4	0.07	0.04	0.03	0.03	0.12	0.06	0.00	0.00	0.00	0.19
R5	0.14	0.09	0.07	0.05	0.28	0.14	0.01	0.00	0.00	0.43
R6	0.27	0.18	0.13	0.10	0.39	0.20	0.02	0.00	0.00	0.97
R7	0.15	0.10	0.07	0.06	0.24	0.12	0.01	0.00	0.00	0.49
R8	0.38	0.25	0.20	0.15	0.67	0.34	0.02	0.00	0.00	1.26
R9	0.17	0.11	0.08	0.06	0.37	0.19	0.01	0.00	0.00	0.50
R10	0.55	0.37	0.26	0.20	1.01	0.51	0.03	0.00	0.00	1.78
R11	6.31	4.23	3.29	2.48	3.02	1.53	0.42	0.00	0.04	24.07
R12	2.99	2.00	1.82	1.38	2.49	1.27	0.18	0.00	0.02	10.21
R13	1.31	0.88	0.65	0.49	0.60	0.30	0.09	0.00	0.01	5.38
R14	2.40	1.60	1.26	0.95	1.33	0.68	0.16	0.00	0.02	8.96
R15	0.89	0.60	0.39	0.30	0.31	0.15	0.05	0.00	0.00	2.81
R16	2.51	1.68	1.14	0.86	0.21	0.11	0.20	0.00	0.02	11.50
R17	0.57	0.38	0.26	0.19	0.62	0.31	0.04	0.00	0.00	2.38
R18	0.77	0.51	0.47	0.36	0.49	0.25	0.04	0.00	0.00	2.22
R19	0.83	0.56	0.52	0.39	0.60	0.30	0.04	0.00	0.00	2.21
R20	1.06	0.71	0.57	0.43	0.70	0.36	0.06	0.00	0.01	3.57
R21	0.76	0.51	0.36	0.27	0.10	0.05	0.04	0.00	0.00	2.30
R22	0.58	0.39	0.25	0.19	0.10	0.05	0.04	0.00	0.00	2.16
R23	0.33	0.22	0.14	0.11	0.11	0.05	0.02	0.00	0.00	1.05
R24	0.20	0.13	0.09	0.07	0.09	0.05	0.01	0.00	0.00	0.78
R25	1.41	0.94	0.66	0.50	0.79	0.40	0.10	0.00	0.01	5.56
R26	0.78	0.52	0.37	0.28	0.42	0.21	0.05	0.00	0.01	2.89
R27	1.06	0.71	0.54	0.41	0.66	0.34	0.07	0.00	0.01	3.88
R28	2.77	1.86	1.45	1.09	1.71	0.87	0.17	0.00	0.02	9.95
R29	7.42	4.97	33.39	25.21	50.51	25.66	5.46	0.00	0.55	310.88
R30	0.28	0.19	0.16	0.12	0.10	0.05	0.02	0.00	0.00	1.05
R31	0.37	0.25	0.22	0.17	0.14	0.07	0.02	0.00	0.00	1.13
Criteria	**20**		**40**		**600**		**40**	**50**	**100**	**30000**

5 IMPACT SIGNIFICANCE

The significance of air quality related impacts were assessed in accordance with the procedure set out by Synergistics. The proposed method for the assessment of environmental issues is presented in Table 13.

This assessment methodology enables the assessment of environmental issues including: cumulative impacts, the severity of impacts (including the nature of impacts and the degree to which impacts may cause irreplaceable loss of resources), the extent of the impacts, the duration and reversibility of impacts, the probability of the impact occurring, and the degree to which the impacts can be mitigated.

The significance rankings of the various impacts assessed in the study are presented in Table 14, Table 15, Table 16 and Table 17 respectively.

Table 13: Criteria for assessing impacts as provided by Synergistics

PART A: DEFINITION AND CRITERIA		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY/NATURE of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. Irreplaceable loss of resources.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. Noticeable loss of resources.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. Limited loss of resources.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE

SEVERITY = L

DURATION	Long term	**H**	Medium	Medium	Medium
	Medium term	**M**	Low	Low	Medium
	Short term	**L**	Low	Low	Medium

SEVERITY = M

DURATION	Long term	**H**	Medium	High	High
	Medium term	**M**	Medium	Medium	High
	Short term	**L**	Low	Medium	Medium

SEVERITY = H

DURATION	Long term	**H**	High	High	High
	Medium term	**M**	Medium	Medium	High
	Short term	**L**	Medium	Medium	High
			L	**M**	**H**
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
			SPATIAL SCALE		

PART C: DETERMINING SIGNIFICANCE

PROBABILITY **(of exposure to impacts)**	Definite/ Continuous	**H**	Medium	Medium	High
	Possible/ frequent	**M**	Medium	Medium	High
	Unlikely/ seldom	**L**	Low	Low	Medium
			L	**M**	**H**
			CONSEQUENCE		

PART D: INTERPRETATION OF SIGNIFICANCE

Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

Table 14: Assessment of the significance of operational phase air quality impacts associated with PM emissions (no mitigation)

Activity	Impact	Severity of Impact	Spatial Scale of Impacts	Duration of Impact	Consequence of Impact	Probability of Impact	Significance
							No Mitigation
Operational phase	$PM_{2.5}$	Medium	Low	Medium	Low	Medium	Medium
	PM_{10}	Medium	Low	Medium	Medium	Medium	Medium
	Dustfall (nuisance PM)	Low	Low	Medium	Low	Low	Low

Table 15: Assessment of the significance of operational phase air quality impacts associated with NO_2, CO, SO_2 and VOC emissions (no mitigation)

Activity	Impact	Severity of Impact	Spatial Scale of Impacts	Duration of Impact	Consequence of Impact	Probability of Impact	Significance
							No Mitigation
Operational phase	NO_2	Low	Low	Medium	Low	Low	Low
	CO	Low	Low	Medium	Low	Low	Low
	SO_2	Low	Low	Medium	Low	Low	Low
	VOC	Low	Low	Medium	Low	Low	Low

Table 16: Assessment of the significance of construction and closure phase air quality impacts associated with PM emissions (mitigated)

Activity	Impact	Severity of Impact	Spatial Scale of Impacts	Duration of Impact	Consequence of Impact	Probability of Impact	Significance
							Mitigated
Construction phase	$PM_{2.5}$	Low	Low	Low	Low	Low	Low
	PM_{10}	Low	Low	Low	Low	Low	Low
	Dustfall (nuisance PM)	Low	Low	Low	Low	Low	Low
Closure phase	All PM emissions	Low	Low	Low	Low	Low	Low

Table 17: Assessment of the significance of operational phase air quality impacts associated with PM emissions (mitigated)

Activity	Impact	Severity of Impact	Spatial Scale of Impacts	Duration of Impact	Consequence of Impact	Probability of Impact	Significance
							Mitigated
Operational phase	$PM_{2.5}$	Low	Low	Medium	Low	Medium	Medium
	PM_{10}	Low	Low	Medium	Low	Medium	Medium
	Dustfall (nuisance PM)	Low	Low	Medium	Low	Low	Low

6 RECOMMENDED AIR QUALITY MANAGEMENT MEASURES

In the light of the potential exceedances of the air quality limits, it is recommended that the project proponent commit itself 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 and gases 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 $PM_{2.5}$, PM_{10} and NO_2) and dustfall rates that are within the relevant ambient air quality standards at the relevant off site receptors. 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 operations, as published in Figure 27; and
- Impacts ranking; based on the simulated pollutant GLCs.

The source impact ranking with respect to entire study area and AQSRs are presented in Figure 47 for PM. The major source contributors to GLCs are conveyors. Source impact ranking is not reflected for pollutant gases due to the low simulated GLCs.

It is evident from Figure 47 that, in order to most effectively reduce impacts on the receiving environment, efforts should be directed at reducing emissions from conveyors, and from unpaved roads and materials handling.

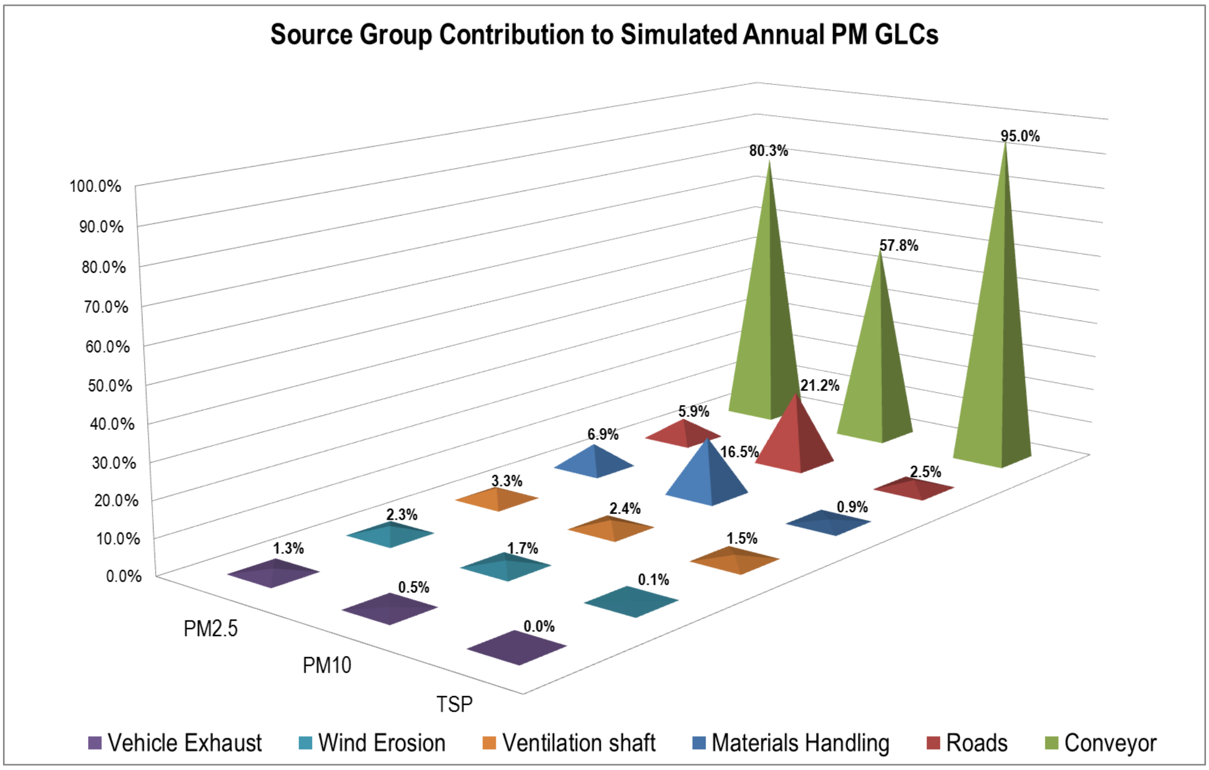

Figure 47: Source group contribution to simulated annual average ground level PM concentrations

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 measure:

- 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 haul material covered to minimise any fly-off dust.
  - The access road to the Project also needs to be kept clean to minimise carry-through of mud on to public roads.

- Operational phase:
  - For the control of vehicle entrained dust it is recommended that water (at an application rate >2 litre/m^2-hour), be applied. Literature reports an emissions reduction efficiency of 50 %.
  - 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. A mitigation efficiency of 65 % is anticipated. (NPI, 2011).
  - In minimizing windblown dust from stockpile areas, water sprays should be used to keep surface material moist and wind breaks installed to reduce wind speeds over the area. A mitigation efficiency of 50 % is anticipated. (NPI, 2011).
  - To ensure lower diesel exhaust emissions, equipment suppliers or contractors should be required to ensure compliance with appropriate emission standards for mining fleets.

Further literature on source specific mitigation measures is provided in Appendix A.

6.2.2 Air Quality Management within the Highveld Priority Area

The DEA published the management plan for the HPA in September 2011. Included in this management plan are 7 goals, each of which has a further list of objectives that has to be met. The 7 goals for the HPA are as follows:

- **Goal 1:** By 2015, organisational capacity in government is optimised to efficiently and effectively maintain, monitor and enforce compliance with ambient air quality standards.
- **Goal 2:** By 2020, industrial emissions are equitably reduced to achieve compliance with ambient air quality standards and dustfall limit values.
- **Goal 3:** By 2020, air quality in all low-income settlements is in full compliance with ambient air quality standards.
- **Goal 4:** By 2020, all vehicles comply with the requirements of the National Vehicle Emission Strategy.
- **Goal 5:** By 2020, a measurable increase in awareness and knowledge of air quality exists.
- **Goal 6:** By 2020, biomass burning and agricultural emissions will be 30% less than current.
- **Goal 7:** By 2020, emissions from waste management are 40% less than current.

The Alexander Project falls within the HPA footprint and it will contribute to the pollution within the Highveld airshed. It is recommended that the management plan for the HPA as published by the DEA be included in all management plans employed for the Project.

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 to below 600 mg/m²-day represents an impact- or receptor-based performance indicator.

Except for vehicle/equipment emission testing, source monitoring at mining activities can be challenging due to the fugitive and wind-dependant 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 continuous dustfall and $PM_{10}/PM_{2.5}$ monitoring be conducted as part of the project's air quality management plan. This should be undertaken throughout the life of mine to provide air quality trends. Recommended dustfall and $PM_{10}/PM_{2.5}$ monitoring locations are presented in Figure 48. The description of these locations is given in Table 18.

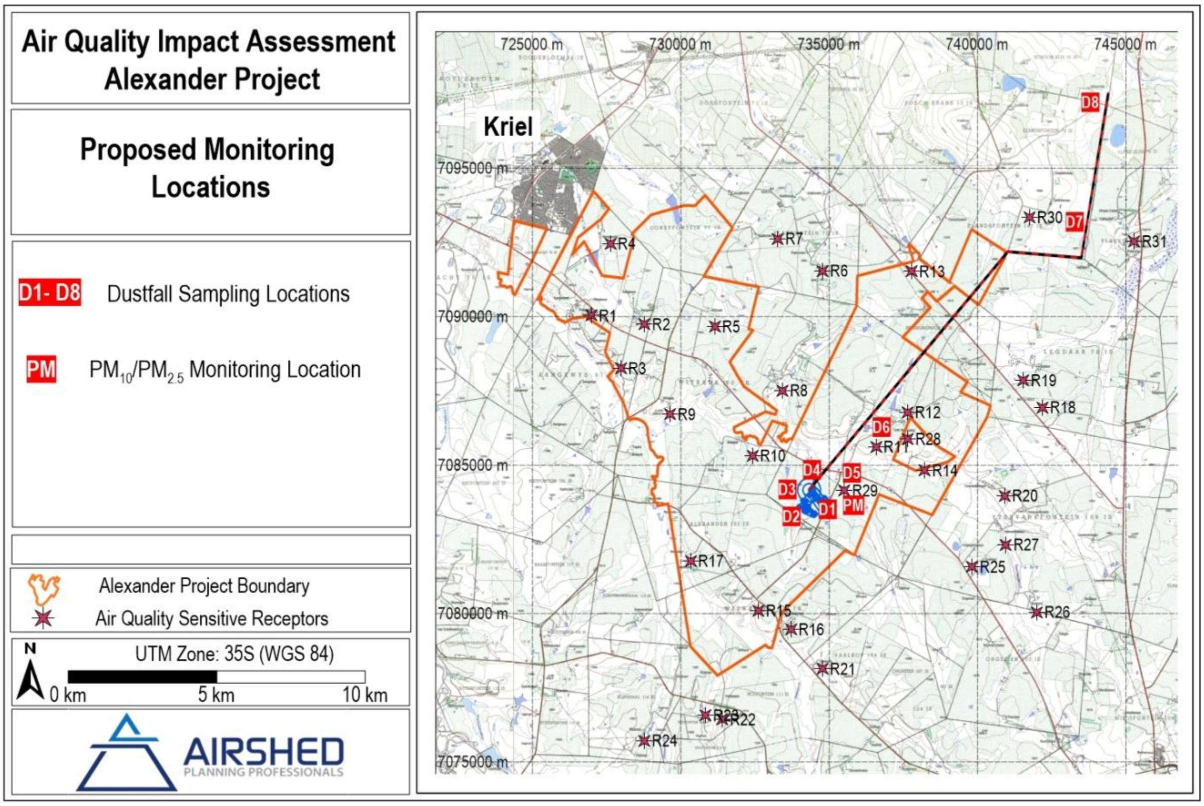

Figure 48: Dustfall and PM monitoring locations at the Project area

Table 18: Dustfall and PM monitoring locations and description

ID No.	Longitude	Latitude	Description	Pollutant(s) to be Sampled
D1	29.3539729	-26.3489853	East of mine shaft and stockpile area	Dustfall
D2	29.3439893	-26.3499684	South of mine shaft	Dustfall
D3	29.3420556	-26.3442648	West of mine shaft and close to R10 (AQSR)	Dustfall
D4	29.3496834	-26.3392238	North of mine shaft and conveyor	Dustfall
D5/PM	29.3605500	-26.3369968	At R29 (AQSR)	Dustfall/$PM_{10}/PM_{2.5}$
D6	29.3716452	-26.3237044	Conveyor and close to R11 (AQSR)	Dustfall
D7	29.4371526	-26.2607480	Conveyor and close to R30 (AQSR)	Dustfall
D8	29.4409239	-26.2238153	Conveyor	Dustfall

NOTE: The coordinates merely serve to provide an indication of the recommended location, and should not be seen as an exact point.

6.4 Periodic Inspections, Audits and Community Liaison

6.4.1 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.

6.4.2 Consultation with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. The consultation process should be undertaken as part of the EIA and EMP process for the Project.

6.5 Buffer Zone

The delineation of an air quality buffer zone is not deemed necessary, considering the “low” to “medium” significance rating assigned to pollutants impacts.

7 CONCLUSIONS AND RECOMMENDATION

7.1 Main Findings

A quantitative air quality impact assessment was conducted for construction and operational phase activities for the Alexander Project. Construction and closure activities were assessed qualitatively. The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels and determination of the significance of impacts.

This section summarises the main findings of the assessment.

- The receiving environment:
  - The area is dominated by winds from the north westerly, north easterly and south westerly sectors. Long-term air quality impacts are therefore expected to be the more prevalent to the southwest, southeast and northeast of the project area.
  - Ambient air pollutant levels in the project area are currently affected by the following sources of emission: mining, power generation, vehicle tailpipe emissions, household fuel combustion, biomass burning/forest fires and open areas exposed to the wind.
  - AQSRs around the project site include towns and villages such as Kriel, Bethal, Evander, Secunda, Kinross and Thubelihle. The closest AQSRs include residences farm houses, private holdings or informal settlements.
  - Measured PM_{10} concentrations obtained from the Alexander Monitoring campaign. An annual average concentration of 26.2 µg/m³ was utilized as baseline concentration for the Project site. This was used in the assessment of cumulative impacts for PM_{10}.

- Impact of the proposed Project:

  - Construction and closure phases:
    - Construction phase PM emissions ($PM_{2.5}$, PM_{10} and TSP) were quantified for the Alexander Project albeit at a screening level since the required detail and schedules to complete a more comprehensive analysis were not available at the time of finalising the assessment. Furthermore, since the construction emissions were lower than the operational phase emissions, due to their temporary nature and the likelihood that these activities will not occur concurrently at all portions of the site, dispersion simulations were not undertaken for construction emissions.
    - Closure phase impacts were not quantified or simulated, since closure schedule was not available; and the release of emission are intermittent in nature and generally less than construction emissions. These impacts will depend on the extent of rehabilitation efforts to be undertaken at the shaft, infrastructure area and conveyor route.
    - A significance rating of 'low' was assigned to potential inhalation health impacts associated with all PM and gaseous pollutants during the construction and closure phases.

  - Operational phase:
    - Sources of emission quantified material handling, vehicles travelling on unpaved roads, windblown dust from the stockpiles, vehicle exhaust (diesel engines), conveyor and underground ventilation.
    - Operational phase PM emissions ($PM_{2.5}$, PM_{10} and TSP), and gaseous emissions (CO, NO_x, SO_2 and VOC) were quantified and utilized in the dispersion simulations.

- The direct greenhouse gas (GHG) emissions calculated for the Project (assuming the tier 1 and 2 approach) is **111 118** tCO_2eq; indicating that the Alexander Project will require the submission of a pollution prevention plan as stipulated by the Department of Environmental Affairs (DEA).
- Simulated PM_{10} impacts during the operational phase exceed both long-term (annual) and short-term (24-hour) ambient air quality standards only at R29, and not at any other AQSRs. A significance weighting of '***medium***' was assigned to potential inhalation health impacts associated with PM_{10}.

  Simulated PM_{10} impacts due to conveyor emissions exceeded only the short-term (24-hour) ambient air quality standards up to 180 m (for unmitigated scenario); and up to 160 m (for mitigated scenario) away from the conveyor edge (in both directions), but not at any other AQSRs.

  PM_{10} impacts reduced when mitigation was applied. However, exceedances of both long-term (annual) and short-term (24-hour) ambient air quality standards at R29 remained. The assigned significance weighting of ***'medium'*** was sustained.

  Cumulative annual PM_{10} GLCs for unmitigated and mitigated scenarios respectively. Simulations indicate that exceedances of the annual SA NAAQS for PM_{10} (40 µg/m³) occur only at R29, and not at any other AQSRs.
- Simulated $PM_{2.5}$ impacts during the operational phase exceed both long-term (annual) and short-term (24-hour) ambient air quality standards only at R29, but not at any other AQSRs. A significance weighting of '***medium***' was assigned to potential inhalation health impacts associated with $PM_{2.5}$.

  Simulated $PM_{2.5}$ impacts due to conveyor emissions exceeded only the short-term (24-hour) ambient air quality standards up to 180 m (for unmitigated scenario); and 120 m (for mitigated scenario) away from the conveyor edge (in both directions), but not at any other AQSRs.

  $PM_{2.5}$ impacts reduced when mitigation was applied. However, exceedances of both long-term (annual) and short-term (24-hour) ambient air quality standards at R29 remained. The assigned significance weighting of ***'medium'*** was sustained.
- Simulated maximum daily dustfall rates are in exceedance of the NDCR for residential areas (600 mg/m^2-day) only at AQSR R29 (mitigated and unmitigated scenarios). A significance weighting of ***'low'*** was assigned to potential impacts associated with dustfall. Also, simulated dustfall deposition rates due to conveyor emission exceed the NDCR residential area limit (600 mg/m^2-day) up to 160 m (for unmitigated scenario); and up to 80 m (for mitigated scenario) away from the conveyor edge (in both directions).
- Simulated CO, NO_2, SO_2 and VOC concentrations were low and did not result in exceedances at AQSRs. A significance weighting of ***'low'*** was assigned to potential inhalation health impacts associated with these pollutants.

- Alternative location of the mine shaft, associated infrastructure and conveyor route:
  - An alternative location for the mine shaft, associated infrastructure and conveyor route for the Project was also proposed. This involves shifting the location of the proposed mine shaft and infrastructure by approximately 300 m to the northeast. From an air quality point of view, impacts due to alternative location of the mine shaft and associated infrastructure will have the same magnitude and extent, as simulated for the original layout. Exceedances of the NAAQS standards are expected to occur at AQSRs to the north and east of the mine shaft including R29.

- Impacts due to alternative siting of the conveyor are anticipated to exhibit similar trends, as simulated for the original layout, with exceedance occurring at 150 m to 200 m perpendicular to the conveyor. Exceedances of the NAAQS standards are expected at R28.
- With the proposed mitigation measures in place, impacts due to alternative mine shaft location and siting of the conveyor are expected to reduce. However, exceedances of the NAAQS standards are still anticipated at R29 (due to mine shaft emissions) and R28 (due to conveyor emissions).

7.2 Recommendations

To ensure the lowest possible impact on AQSRs and the environment, it is recommended that the air quality management plan as set out in this report be adopted. From an air quality point of view, specialist opinion for authorization of the application for the Project is premised on the implementation of mitigation recommended in this report. Based on the findings in this report and provided the recommended mitigation measures are in place, it is the specialist opinion that the project may be authorised.

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

- The implementation of emission controls for the management of significant emission sources at Alexander Project is recommended. 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;
    - Roofing and covering of conveyor side; application of water sprays on unpaved road sections, as well as materials handling and exposed areas to wind erosion during the operational phase.
- The continuous monitoring of dustfall and $PM_{10}/PM_{2.5}$ be conducted as part of the Project's air quality management plan;
- The Alexander Project falls within the Highveld Priority Area (HPA) footprint and it will contribute to the pollution within the Highveld airshed. It is recommended that the management plan for the HPA as published by the Department of Environmental Affairs (DEA) be included in all management plans employed for the project.
- Furthermore, it is recommended that the project comply with the provisions of the National Atmospheric Emission Reporting Regulations (NAERR) 2015 as summarized in this report. The NAERR aims to standardize the reporting of data and information from an identified data provider to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories.

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9 APPENDIX A – SOURCE SPECIFIC MANAGEMENT AND MITIGATION MEASURES

9.1 Dust Control Options for Unpaved Roads

Three types of measures may be taken to reduce emissions from unpaved roads:

- Measures aimed at reducing the extent of unpaved roads, e.g. paving;
- Traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds; and
- Measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (Cowherd, Muleski, & Kinsey, 1988).

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds;
- Number of wheels per vehicle;
- Traffic volumes;
- Particle size distribution of the aggregate;
- Compaction of the surface material ;
- Surface moisture; and
- Climate

According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 16 km per hour resulted in an increase in PM_{10} emissions of between 1.5 and 3 times. A similar study conducted by Flocchini (Flocchini, Cahill, Matsumura, Carvacho, & Lu, 1994) found a decrease in PM_{10} emissions of 42±35% with a speed reduction from 40 km/hr to 24 km/hr (Stevenson, 2004). An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads.

Water sprays on unpaved roads is the most common means of suppressing fugitive dust due to vehicle entrainment at mines, but it is not necessarily the most efficient means (Thompson & Visser, 2000). Thompson and Visser (2000) developed a model to determine the cost and management implications of dust suppression on mine haul roads using water or other chemical palliatives. The study was undertaken at 10 mine sites in Southern Africa. The model was first developed looking at the re-application frequency of water required for maintaining a specific degree of dust palliation. From this the cost effectiveness of water spray suppression could be determined and compared to other strategies. Factors accounted for in the model included climate, traffic, vehicle speed and the road aggregate material. A number of chemical palliative products, including hygroscopic salts, lignosulponates, petroleum resins, polymer emulsions and tar and bitumen products were assessed to benchmark their performance and identify appropriate management strategies. Cost elements taken into consideration included amongst others capital equipment, operation and maintenance costs, material costs and activity related costs. The main findings were that water-based spraying is the cheapest dust suppression option over the short term. Over the longer term however, the polymer-emulsion option is marginally cheaper with added benefits such as improved road surfaces during wet weather, reduced erosion and dry skid resistance (Thompson & Visser, 2000). The empirical model, developed by the US EPA (US EPA, 1996), can also be used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account rainfall, evaporation rates and traffic.

Chemical suppressant has been proven to be effective due to the binding of fine particulates in the road surface, hence increasing the density of the surface material. In addition, dust control additives are beneficial in the fact that it also improves the compaction and stability of the road. The effectiveness of a dust palliative include numerous factors such as the application rate, method of application, moisture content of the surface material during application, palliative concentrations, mineralogy of aggregate and environmental conditions. Thus, for different climates and conditions you need different chemicals, one chemical might not be as effective as another under the same conditions and each product comes with various advantages and limitations of its own. In general, chemical suppressants are given to achieve a PM_{10} control efficiency of 80% when applied regularly on the road surfaces (Stevenson, 2004).

Spillage and track-on from the surrounding unpaved areas may result in the deposition of materials onto the chemically treated or watered road resulting in the need for periodic “housekeeping” activities (Cowherd, Muleski, & Kinsey, 1988). In addition, the gradual abrasion of the chemically treated surface by traffic will result in loose material on the surface which would have to be controlled. The minimum frequency for the reapplication of watering or chemical stabilizers thus depends not only on the control efficiency of the suppressant but also on the degree of spillage and track-on from adjacent areas, and the rate at which the treated surface is abraded.

The best way to avoid dust generating problems from unpaved roads is to properly maintain the surface by grading and shaping to prevent dust generation caused by excessive road surface wear (Stevenson, 2004).

9.2 Options for Reducing Windblown Dust Emissions

The main techniques adopted to reduce windblown dust potential include source extent reduction and source improvement and surface treatment methods:

- Source extent reduction:
    - Disturbed area reduction.
    - Disturbance frequency reduction.
    - Dust spillage prevention and/or removal.
- Source Improvement:
    - Disturbed area wind exposure reduction, e.g. wind fences and enclosure of source areas.

10 APPENDIX B – AMBIENT AIR QUALITY MONITORING METHODOLOGY

10.1 Dustfall Sampling

The ASTM method covers the procedure of collection of dustfall and its measurement and employs a simple device consisting of a cylindrical container (not less than 150 mm in diameter) exposed for one calendar month (30 ±2 days). Even though the method provides for a dry bucket, de-ionised (distilled) water can be added to ensure the dust remains trapped in the bucket.

The bucket stand includes a wind shield at the level of the rim of the bucket to provide an aerodynamic shield. The bucket holder is connected to a 2 m galvanized steel pole, which is either planted and cemented or directly attached to a fence post (Figure 49). This allows for a variety of placement options for the fallout samplers. Two buckets are usually provided for each dust bucket stand. Thus, after the first month, the buckets get exchanged with the second set.

Collected sampled are sent to an accredited laboratory for gravimetric analysis. At the laboratory, each sample is rinsed with clean water to remove residue from the sides, and the contents filtered through a coarse (>1 mm) filter to remove insects and other course organic detritus. The sample is then filtered through a pre-weighed paper filter to remove the insoluble fraction. This residue and filter are dried, and gravimetrically analysed to determine total dustfall.

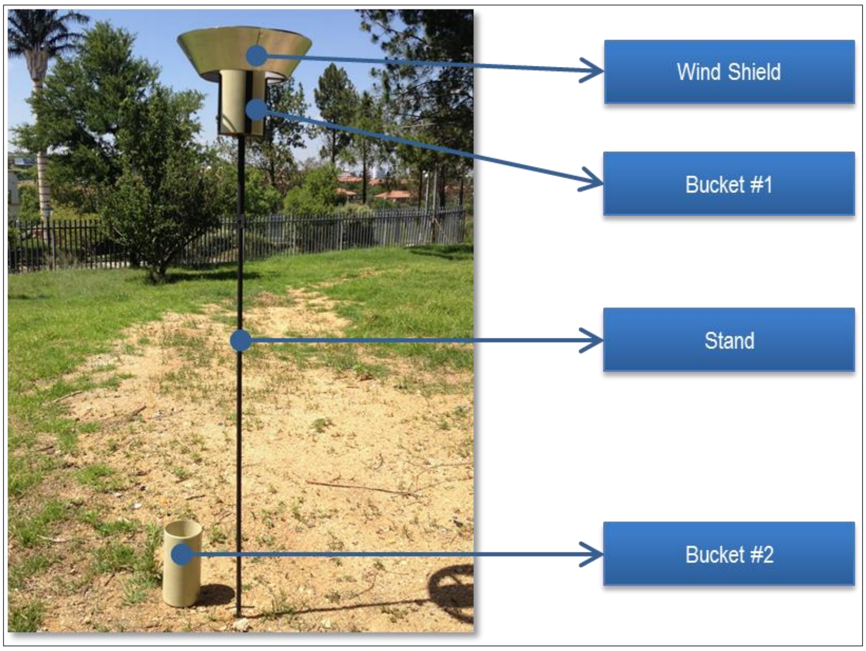

Figure 49: Example of a dustfall collection unit setup

10.2 $PM_{10}/PM_{2.5}$ Sampling

Ambient $PM_{10}/PM_{2.5}$ concentrations can be determined through the use a MiniVol sampler (Figure 50). In summary, the monitoring methodology is as follows:

- The MiniVol sampler is programmed to draw air over a pre-weighed filter at a constant rate over a 24-hour period.
- At a specific interval (for instance, 1 in 3 days or 1 in 6 days), the used filter is removed, a new filter put in place, the battery exchanged (each MiniVol is equipped with two batteries) and the MinVol re-programmed.
- The used filter is removed from the filter holder assembly in a clean environment and sealed in its dish.

- At each exchange, the date, location, filter number, pump run time etc. need to be noted in the data sheet that will be sent to an accredited laboratory with the sealed samples for gravimetric analysis.

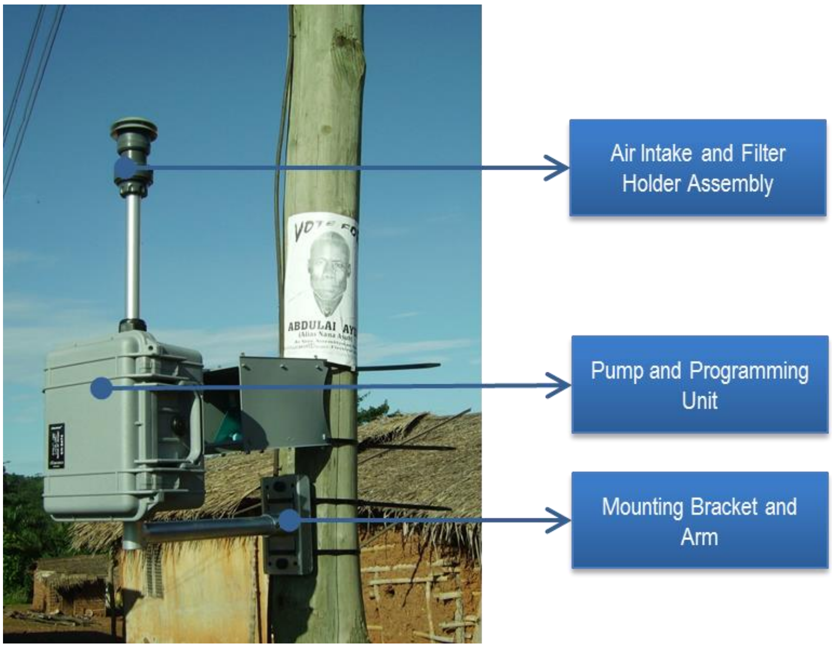

Figure 50: Example of a typical PM_{10}/$PM_{2.5}$ MiniVol setup

11 APPENDIX C – CURRICULUM VITAE OF AUTHOR

CURRICULUM VITAE	OLADAPO B. AKINSHIPE

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Oladapo Akinshipe
Profession	Senior Air Quality Specialist
Years with Firm/ entity	4 years
Nationalities	Nigerian

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Member of the National Association for Clean Air (NACA)

KEY QUALIFICATIONS

Oladapo has developed professional and technical experience in the following areas:

- Air Quality Impact Assessment,
- AEL and AIR Applications
- Noise monitoring and impact assessment
- Air Quality Monitoring
- Environmental research and Reporting
- Emission Quantification and Inventories (Mining and Ore Handling, Metal Recovery, Petrochemical Industry, Power Generation, Waste Disposal and Recycling etc.)

Oladapo has developed technical and specialist skills in various dispersion modelling packages including the industrial source complex models (SCREEN3), EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS).

He has also developed specialist skills in the following packages for simulation of noise propagation: SANS 10357:2004 and SANS 10103:2008 (South African National Standards).

RELEVANT EXPERIENCE

Mining and Ore Handling

Oladapo has undertaken numerous air quality impact assessments and management plans for coal, manganese, uranium, copper, cobalt and andalusite mines. These include air quality impact assessments for Alexander Coal Mine (Mpumalanga), Delmas coal mine (Delmas), Pumpi copper and cobalt mine (Congo DR), Vlakfontein coal mine (Mpumalanga). Ongoing projects include Mokala manganese project, Panda Hill Niobium project, Rhino Andalusite project, Hattinspruit siding project.

Metal Recovery

Air quality impact assessment has been carried out for the Transalloys ferromanganese furnace (eMalahleni).

Chemical Industry

Air quality impact assessment and Atmospheric impact report has been completed for the Flexilube refinery plant (Meyerton).

Petrochemical Industry

Air quality impact assessments have been completed for Sasol's Petroleum Sharing Agreement Development Project and Liquefied Petroleum Gas in Mozambique – Inhassoro Early Oil Project (Mozambique).

Noise Impact Assessment

Noise impact assessments have been completed for Pumpi copper and cobalt mine (Congo DR), Mokala manganese Project (Hotazel), Panda Hill Niobium Project (Tanzania).

Power Generation

Air quality impact assessment has been completed for the Transalloys coal fired power station (eMalahleni).

Clay brick Industry

Research project and studies conducted in the clay brick industry include: The Development of an 'emission inventory tool' for Brickmaking Clamp Kilns; application of Atmospheric Emission Licences (AEL) for over 20 clay brick factories in South Africa.

Monitoring Projects

Various ambient and stack monitoring projects have been undertaken in the following industries: clay brick, mining (coal, copper and cobalt, uranium etc.)

EDUCATION

PhD Environmental Technology	University of Pretoria, Pretoria, South Africa (Ongoing) Title: *Atmospheric emissions from clamp kilns in the South African clay brick industry*
M.Sc. Environmental Technology	University of Pretoria, Pretoria, South Africa (2013) Title: *The Development of an 'emission inventory tool' for Brickmaking Clamp Kilns*
B.Sc. Honours	University of Pretoria, Pretoria South Africa (2011) Environmental Technology
B.Sc.(Hons)	Olabisi Onabanjo University, Nigeria (2008) Microbiology

COUNTRIES OF WORK EXPERIENCE

Countries of work experience include South Africa, Nigeria, Mozambique, Democratic Republic of Congo, Tanzania and Namibia.

EMPLOYMENT RECORD

July 2013 - Present

Airshed Planning Professionals (Pty) Ltd, Air Quality Specialist, Midrand, South Africa.

February 2011 – June 2013

University of Pretoria, Research Associate and Teaching Assistant, Pretoria, South Africa.

LANGUAGES

	Speak	**Read**	**Write**
English	Excellent	Excellent	Excellent

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- The Development of an ‘emission inventory tool’ for Brickmaking Clamp Kilns. Akinshipe O., Kornelius G. International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) World Clean Air conference, Cape Town South Africa (2013). Peer reviewed.
- Atmospheric emissions from Clamp Kilns in the South African Clay Brick Industry. Akinshipe O., Kornelius G. National Association for Clean Air (NACA) Annual Conference, Bloemfontein, South Africa (2015). Peer reviewed.