Project done on behalf of

Lidwala Consulting Engineers (Pty) Ltd

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED GROOTVLEI POWER STATION FFP RETROFIT AT UNITS 2, 3 & 4

Report No.: APP/12/LCE-01 Rev 0.2

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REPORT DETAILS

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EXECUTIVE SUMMARY

Grootvlei Power Station is a 1200 MW installed capacity base load coal fired power station, consisting of 6x200MW units. Eskom commenced construction of Grootvlei in the late 1960's and the station was mothballed in the early 1990's. In 1995, the decision was taken to return the station to service (RTS) due to the increase in electricity demand.

The National Environmental Management Air Quality Act (Act no 39 of 2004), Minimum Emission Standards Notice 248 (31 March 2010) requires that all existing power stations conform to the standard of 100 mg/Nm^3 for particulate emissions. All six units where originally commissioned with Electrostatic Precipitator (ESP) technology for particulate abatement. During the RTS project in 2005, units 1, 5 and 6 where retrofitted to Fabric Filter Plants (FFPs) while units 2, 3 and 4 ESP units were refurbished to fully operational conditions. The functioning of the ESPs does not allow the station to meet the new emission standards promulgated by the Department of Environmental Affairs (DEA), and as such it is proposed that the remaining three ESPs be retrofitted to FFPs.

Airshed Planning Professionals (Pty) Limited was appointed by Lidwala Consulting Engineers (Pty) Ltd (hereafter referred to as Lidwala) to undertake an air quality impact assessment for the proposed Grootvlei Power Station Units 2, 3 and 4 Fabric Filter Plant (FFP) Retrofit.

The aim of the investigation was to quantify the possible particulate impacts (before and after the proposed FFP Retrofit) on the surrounding environment and human health. To achieve this, a good understanding of the local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

The investigation followed the methodology required for a specialist report, comprising the baseline characterisation and the impact assessment study.

Baseline Assessment

The baseline study encompassed the analysis of meteorological data and impact assessment of Grootvlei Power Station operations.

Impact Assessment Criteria

The predicted impacts assessed in the study were compared to National Ambient Air Quality Standard (NAAQS).

Emissions Inventory

Emissions inventories provide the source input required for the simulation of ambient air concentrations. Emissions for the stacks were provided by Eskom for the current assessment. For fugitive sources (i.e. windblown dust from the ash dam and coal stockpile) were calculated for every hour.

Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important *limitations* of the air quality impact assessment are summarised as follows:

- The quantification of sources of emission was restricted to the Grootvlei Power Station and emissions after the fabric filter plants at units 2, 3 and 4 retrofit only. The windblown dust from the coal stockpile and ash dam located within the plant boundary was also quantified as part of the assessment. Although other background sources were identified, such sources were not quantified.
- Routine emissions from the power plant were provided and modelled. Atmospheric releases occurring as a result of accidents, maintenance or start-up conditions were not accounted for.
- A minimum of 1 year, and typically 3 to 5 years of meteorological data are generally recommended for use in atmospheric dispersion modelling for air quality impact assessment purposes. Three years of meteorological data were used in the atmospheric dispersion modelling with a data availability of over 95%.
- The impact assessment was limited to airborne particulates that are less than 10 µm in diameter (PM_{10}). Although ash dams also contain trace elements (i.e. arsenic, barium, mercury, etc.), the quantities of these elements were not available for the current assessment. The trace elements from these sources, however, are expected to be low.

- The construction was assessed qualitatively due to the temporary nature of these operations.
- Proposed operations were assumed to be twenty-four hours over a 365 day year as a conservative approach.

Impact Prediction Study

Particulate concentrations and dust deposition rates due to the current power station operations and after the FFP retrofit at units 2, 3 and 4 was simulated using the AERMOD dispersion model. Ambient concentrations were simulated to ascertain highest daily and annual averaging levels occurring as a result of the current power station operations and after the FFP retrofit at units 2, 3 and 4.

Conclusions

The main findings from the baseline assessment were as follows:

- The main sources likely to contribute to cumulative PM_{10} impact in the vicinity of Grootvlei Power Station are surrounding agricultural activities, biomass burning, domestic fuel burning as well as vehicle entrainment on unpaved road surfaces.

- The nearest sensitive receptors to the Grootvlei Power Station are the town of Grootvlei and the surrounding settlements (including farm houses), some of which are located ~1 km from the Grootvlei Power Station.

- Eskom operates an ambient monitoring station at the Grootvlei town just west of the Grootvlei monitoring station. The annual average PM_{10} ground level concentrations for the period January 2009 to December 2010 was 16.3 µg/m³.

The main findings from the impact assessment due to current operations proposed FFP retrofit at units 2, 3 and 4 were as follows:

- The predicted PM_{10} impacts at the closest sensitive receptors (due to current and future power station stack releases, existing ash dam operations and coal stockpile operations only) were within the NAAQS.

- The fabric filter plant retrofit at units 2, 3 and 4 will result in the predicted annual ground level concentration (GLC) of particulate matter from Grootvlei's stacks alone being reduced by 73%. Before and after the retrofit the annual ground level concentrations (GLC) (due to stack emissions only) was predicted to be a maximum of 4 µg/m³ and 1.08 µg/m³ respectively.

- The predicted annual PM_{10} ground level concentrations at the closest sensitive receptor (due to all power station sources) are 9% and 5% of the annual PM10 National Ambient Air Quality Standards (applicable in 2015) before and after the retrofit respectively. The predicted annual PM_{10} ground level concentrations at the closest sensitive receptor (due to all power station sources) are 7% and 4% of the annual PM_{10} National Ambient Air Quality Standards (applicable immediately till 31 December 2014) before and after the retrofit respectively.

Recommendations

In light of the findings it was recommended that air quality management measures (as stipulated in Section 5) for the FFP retrofit at units 2, 3 and 4 be implemented to ensure the lowest possible impacts on the surrounding environment from the proposed FFP retrofit and that the FFP retrofit be conducted, given the positive impact on ambient air quality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED GROOTVLEI POWER STATION FFP RETROFIT AT UNIT 2, 3 AND 4

1 INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Lidwala Consulting Engineers (Pty) Ltd (hereafter referred to as Lidwala) to undertake an air quality impact assessment for the proposed Grootvlei Power Station FFP retrofitting procedure at Unit 2, 3 and 4.

The aim of the investigation is to quantify the possible impacts resulting from the proposed activities on the surrounding environment and human health. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

Typical of specialist investigations conducted, the air quality investigation comprises both a baseline study and an impact assessment. The baseline study includes the review of site-specific atmospheric dispersion potentials, and existing ambient air quality in the region, in addition to the identification of potentially sensitive receptors.

Particulates represent the pollutant of interest in the assessment of operations from the proposed operations. Particulate matter is classified as a criteria pollutant, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of this pollutant. Particulates in the atmosphere may contribute to visibility reduction, pose a threat to human health, or simply be a nuisance due to their soiling potential.

1.1 Terms of Reference

The proposed terms of reference for the *baseline air quality characterisation* component of the assessment are as follows:

- The site-specific atmospheric dispersion potential;
- Identification of the potential sensitive receptors within the vicinity of the proposed site;
- Preparation of hourly average meteorological data for the model input;
- Identification of existing sources of emissions in the area;
- Characterisation of ambient air quality in the region based on observational data recorded to date (if available);
- The legislative and regulatory context.

The proposed terms of reference for *assessing the air quality impacts* associated with the proposed activities:

- Compilation of an emissions inventory, comprising the identification and quantification of all potential *routine* sources of emission from the proposed operations;
- Dispersion simulations of PM_{10} ambient concentrations from the proposed activities;
- Analysis of dispersion modelling results from the proposed operations;
- Evaluation of potential for human health and environmental impacts;
- Develop an air quality management plan.

1.2 Methodological Approach

1.2.1 Atmospheric Dispersion Model Selection

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

It was decided to employ the most recently US Environmental Protection Agency's (US EPA) approved regulatory model. The most widely used US EPA model has been the Industrial Source Complex Short Term model (ISCST3). This model is based on a Gaussian plume model. However this model has been replaced by the new generation AERMET/AERMOD suite of models. AERMOD is a dispersion model, which was developed under the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). The 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 (Trinity Consultants, 2004). 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 of ISCST3 (Hanna, Egan, Purdum, & Wagler, 1999).

- AERMET is a meteorological pre-processor for the AERMOD model. 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 standardize the input of terrain data for the AERMOD model. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. Output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

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

Similar to the ISC model, a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Although the model has been shown to be an improvement on the ISC model, especially short-term predictions, the range of uncertainty of the model predictions is -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

Input data types required for the AERMOD model include: meteorological data, source data, and information on the nature of the receptor grid. Each of these data types will be described below.

1.2.2 Meteorological Data Requirements

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database). As no on-site meteorological data was available for the assessment, use was made of calculated MM5 meteorological data for the period 2009 to 2011.

1.2.3 Source Data Requirements

The AERMOD model is able to model point, area, volume and line sources. The stacks emissions due to the Grootvlei Power Station operations were modelled as point sources, both before and after the proposed FFP retrofitting process at units 2, 3 and 4. The ash dam and coal stockpile were modelled as area sources.

1.2.4 Modelling Domain

The dispersion of pollutants was modelled for an area covering ~10 km (east-west) by ~10 km (north-south). This area was divided into a grid with a resolution of ~200 m (east-west) by ~200 m (north-south). AERMOD simulates ground-level concentrations (GLC's) for each of the receptor grid points.

1.3 Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important *limitations* of the air quality impact assessment are summarised as follows:

- The quantification of sources of emission was restricted to the Grootvlei Power Station and emissions after the fabric filter plants at units 2, 3 and 4 retrofit only. The windblown dust from the coal stockpile and ash dam located within the plant boundary was also quantified as part of the assessment. Although other background sources were identified, such sources were not quantified.
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- The construction was assessed qualitatively due to the temporary nature of these operations.

- Proposed operations were assumed to be twenty-four hours over a 365 day year as a conservative approach.

1.4 Outline of report

The ambient air quality evaluation criteria are described in Section 2. The baseline characterisation comprising of atmospheric dispersion potential and existing sources of air pollution are discussed in the subsequent section (Section 3), as well as the predicted PM_{10} impacts due to current operations. The impact assessment for the proposed FFP retrofit is provided in Section 4. Section 5 outlines the recommended air quality management plan with Section 6 providing the conclusions and recommendations.

2 LEGAL REQUIREMENTS AND HUMAN HEALTH CRITERIA

Prior to assessing the impacts from the Grootvlei Power Station FFP retrofit at units 2, 3 and 4, reference needs to be made to the environmental regulations and guidelines governing the emissions and impact of such operations.

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 limits are intended to 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 periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average. The application of these standards varies, with some countries allowing a certain number of exceedances of each of the standards per year.

2.1 Ambient Air Quality Criteria

2.1.1 National Ambient Air Quality Standards

The South African Bureau of Standards (SABS) was engaged to assist Department of Environmental Affairs (DEA) in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for PM_{10}, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene. The NAAQS were published in the Government Gazette (no. 32816) on 24 December 2009 (Table 2-1).

Draft $PM_{2.5}$ national ambient air quality standards were gazetted for comment on the 5 August 2010 (Table 2-2).

Table 2-1: National ambient air quality standards

Substance	Molecular Formula / Notation	Averaging Period	Concentration (µg/m³)	Frequency of Exceedance	Compliance Date
Sulphur Dioxide	SO_2	10 minutes	500	526	Immediate
		1 hour	350	88	Immediate
		24 hours	125	4	Immediate
		1 year	50	0	Immediate
Nitrogen Dioxide	NO_2	1 hour	200	88	Immediate
		1 year	40	0	Immediate
Particulate Matter	PM_{10}	24 hour	120	4	Immediate – 31 Dec 2014
			75	4	1 Jan 2015
		1 year	50	0	Immediate – 31 Dec 2014
			40	0	1 Jan 2015
Ozone	O_3	8 hours (running)	120	11	Immediate
Benzene	C_6H_6	1 year	10	0	Immediate – 31 December 2014
			5	0	1 January 2015
Lead	Pb	1 year	0.5	0	Immediate
Carbon Monoxide	CO	1 hour	30 000	88	Immediate
		8 hour (calculated on 1 hour averages)	10 000	11	Immediate

Table 2-2: Draft national ambient air quality standards for $PM_{2.5}$

Substance	Molecular Formula / Notation	Averaging Period	Concentration ($\mu g/m^3$)	Frequency of Exceedance	Compliance Date
Particulate Matter	$PM_{2.5}$	24 hour	65	0	Immediate – 31 Dec 2015
			40	0	1 Jan 2016 – 31 Dec 2029
			25	0	1 Jan 2030
		1 year	25	0	Immediate – 31 Dec 2015
			20	0	1 Jan 2016 – 31 Dec 2029
			15	0	1 Jan 2030

2.1.2 Listed Activities and Minimum Emissions Standards

Power Generation was a Scheduled Process under the Atmospheric Pollution Prevention Act of 1965 (Process 29) and a Listed Activity under the NEM Air Quality Act of 2004 (AQA). Thus minimum national emission limits have been developed for Combustion Installations with a design capacity of more than or equal to 50 MW heat input. All existing and new applications are subject to a new Atmospheric Emissions License (AEL). This license requires provision of all sources of pollution from a Listed Activity facility, including point and non-point emissions. The Listed Activities and Associated Minimum Emission Standards were published in terms of Section 21 of the NEM Air Quality Act on the 31st of March 2010 (Government Gazette No. 33064).

The National Environmental Management: Air Quality Act (Act no.39 of 2004) commenced with on the 11th of September 2005 as published in the Government Gazette on the 9th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61.

Table 2-3 provides the requirements as set out in the published Listed Activities and Associated Minimum Emission Standards for Combustion Installations (31 March 2010). Note that "New plant" relates per definition to all installations applying for authorisation after the final publication of these regulations. "Existing plant" include operations legally authorised to commence before the publication of the Listed Activities and Associated Minimum Emission Standards. "New Plants" must comply with the minimum emissions standards on the date of publication of the Listed Activities and Minimum Emission Standards. "Existing plants" are granted five years to comply with the existing plant standards and another five to comply with "new plant" standards.

The minimum emission standards apply to normal operating conditions. Should normal start-up, maintenance, upset and shut-down conditions exceed a period of 48 hours, Section 30 of NEMA (as amended) shall apply unless otherwise stipulated by the Licensing Authority.

Additional requirements, as set out in the published Section 21 include specific requirements for continuous monitoring, include:

- The averaging period for the purposes of compliance monitoring is one calendar month.
- The emissions monitoring system must be maintained to yield a minimum of 80% valid hourly average values during the reporting period.
- No more than five half-hourly average values in any day, and ten daily average values per year, may be disregarded due to malfunction or maintenance.
- Continuous monitoring systems must be audited by a SANAS accredited laboratory at least once every two years.

Table 2-3: Section 1 on Combustion Installations, Subcategory 1.1. Solid Fuel Combustion Installations

Description:	Solid fuels (excluding biomass) combustion installations used primarily for steam raising or electricity generation		
Application:	All installations with design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used		
Substance or mixture of substances		**Plant status**	**mg/Nm³ under normal condition of 10% O3, 273 K and 101.3 kPa**
Common name	**Chemical symbol**		
Particulate matter	N/A	New	50
		Existing	100
Sulphur dioxide	SO_2	New	500
		Existing	3500
Oxides of nitrogen	NO_x expressed as NO_2	New	750
		Existing	1100

a) The following special agreement shall apply:

   a. Continuous monitoring of PM, SO_2 and NO_x is required

2.2 Highveld Priority Area

Highveld Airshed Priority Area Air Quality Management Plan – the Highveld Airshed was declared the second priority area by the minister at the end of 2007. This requires that an Air Quality Management Plan for the area be developed. The plan includes the establishment of an emissions reduction strategies and intervention programmes based on the findings of a baseline characterisation of the area. The implication of this is that all contributing sources in the area will be assessed to determine the emission reduction targets to be achieved over the following few years.

The Grootvlei Power Station is within the footprint demarcated as the Highveld Priority Area. Emission reduction strategies will be included for the numerous operations in the area with specific targets associated with it. The DEA has in September 2011 published the management plan for the Highveld Priority Area. 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 Highveld Priority area 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 dust fallout 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

Goal 2 applies directly to the Grootvlei Power Station, the objectives associated with this goal include:

- Emissions are quantified from all sources.
- Gaseous and particulate emissions are reduced.
- Fugitive emissions are minimised.
- Emissions from dust generating activities are reduced.
- Incidences of spontaneous combustion are reduced.
- Abatement technology is appropriate and operational.
- Industrial Air Quality Management (AQM) decision making is robust and well-informed, with necessary information available.
- Clean technologies and processes are implemented.
- Adequate resources are available for AQM in industry.

- Ambient air quality standard and dust fallout limit value exceedances as a result of industrial emissions are assessed.
- A line of communication exists between industry and communities.

Each of these objectives is further divided into activities, each of which has a timeframe, responsibility and indicator. Refer to the DEA (2011) Highveld Priority Management Plan for further details.

2.3 Effect of Particulate Matter on Susceptible Human Receptors

The World Health Organization states that the evidence on airborne particulates and public health is consistent in showing adverse health effects at exposures experienced by urban populations throughout the world. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending to children and adults and to a number of large, susceptible groups within a general population. The epidemiological evidence shows adverse effects of particles after both short-term and long-term exposures. However, current scientific evidence indicates that guidelines cannot be proposed that will lead to complete protection against adverse health effects as thresholds have not been identified.

The Agency for Toxic Substances and Disease Registry (ATSDR, 2007) states that particulate matter causes a wide variety of health and environmental impacts. Many scientific studies have linked breathing particulate matter to a series of significant health problems, including:

- aggravated asthma
- increases in respiratory symptoms like coughing and difficult or painful breathing
- chronic bronchitis
- decreased lung function
- premature death

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

Exposure to motor traffic emissions can have a significant effect on respiratory function in children and adults. Studies show that children living near heavily travelled roadways have significantly higher rates of wheezing and diagnosed asthma. Epidemiologic studies suggest that diesel exhaust may be particularly aggravating to children.

A summary of adverse health effects from particulate matter exposure and susceptible populations is given in Table 2-4.

Table 2-4: Summary of adverse health effects from particulate matter exposure and susceptible populations

Health Effects	Susceptible Groups	Notes
Acute (short-term) exposure		
Mortality	Elderly, infants, persons with chronic cardiopulmonary disease, influenze or asthma	How much lie shortening is involved and how much is due to short-term mortality displacement is uncertain.
Hospitalisation / other health care visits	Elderly, infants, persons with chronic cardiopulmonary disease, pneumonia, influenza or asthma	Reflects substantive health impacts in terms of illness, discomfort, treatment costs, work or school time lost, etc.
Increased respiratory symptoms	Most consistently observed in people with astma, and children	Mostly transient with minimal overall health consequences, although for a few there may be short-term absence from work or school due to illness.
Decreased lung function	Observed in both children and adults	For most, effects seem to be small and transient. For a few, lung function losses may be clinically relevant.
Chronic (long-term) exposure		
Increased mortality rates, reduced survival times, chronic cardiopulmonary disease, reduced lung function, lung cancer	Observed in broad-based cohorts or samples of adults and children (including infants). All chronically exposed are potentially affected.	Long-term repeated exposure appears to increase the risk of cardiopulmonary disease and mortality. May result in lower lung function. Average loss of life expectancy is highly polluted cities may be as much as a few years.

Source: Adopted from Pope (2000) and Pope et al (2002)

3 BASELINE CHARACTERISATION

3.1 Site Description

The current land uses in the region include farming, power generation facilities and small residential communities. The general topography is characterised by gently rolling terrain with no steep inclines (Figure 3-2).

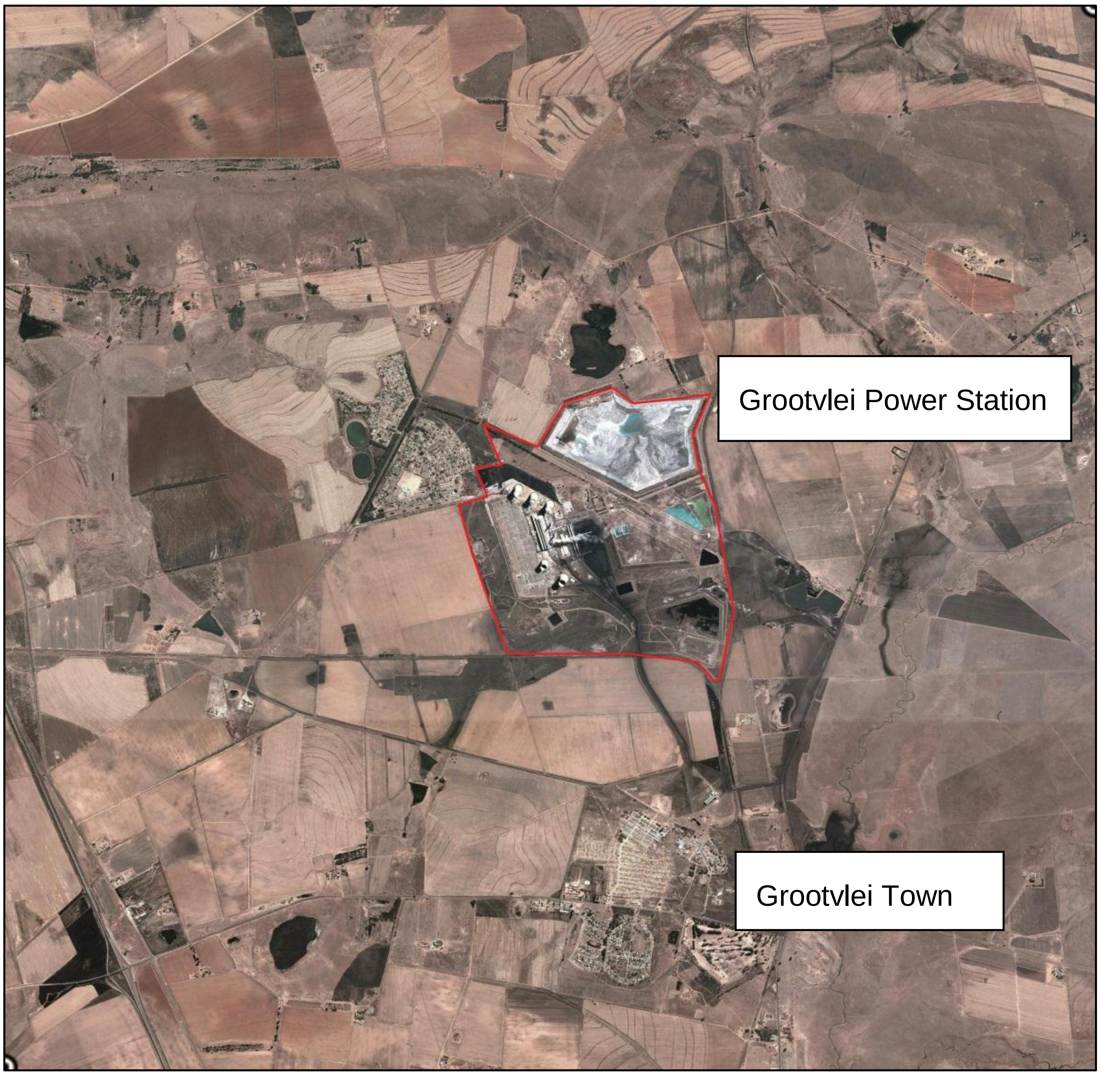

Figure 3-1: Location of the Grootvlei Power Station

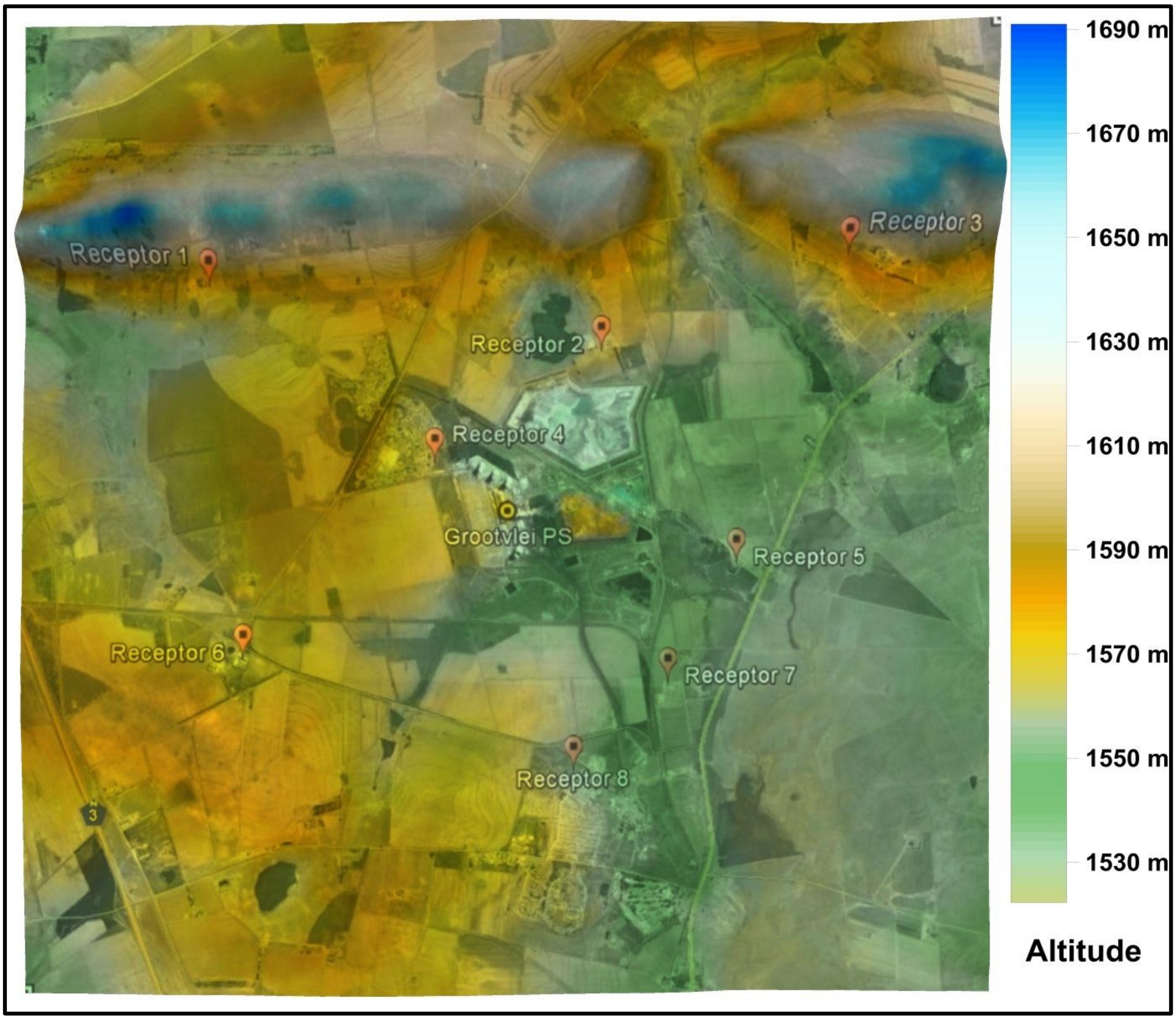

Figure 3-2: Topographical map of the area surrounding the Grootvlei Power Station

3.2 Sensitive Receptors

In the area surrounding the Grootvlei Power Station, the nearest town is Grootvlei (~3km south-southeast of the Power Station), represented by Receptor 8 in Figure 3-3 below. Receptors 1 to 3 and 5 to 7 were identified as farm houses, while Receptor 4 was identified as a residential area serving the Power Station and its employees.

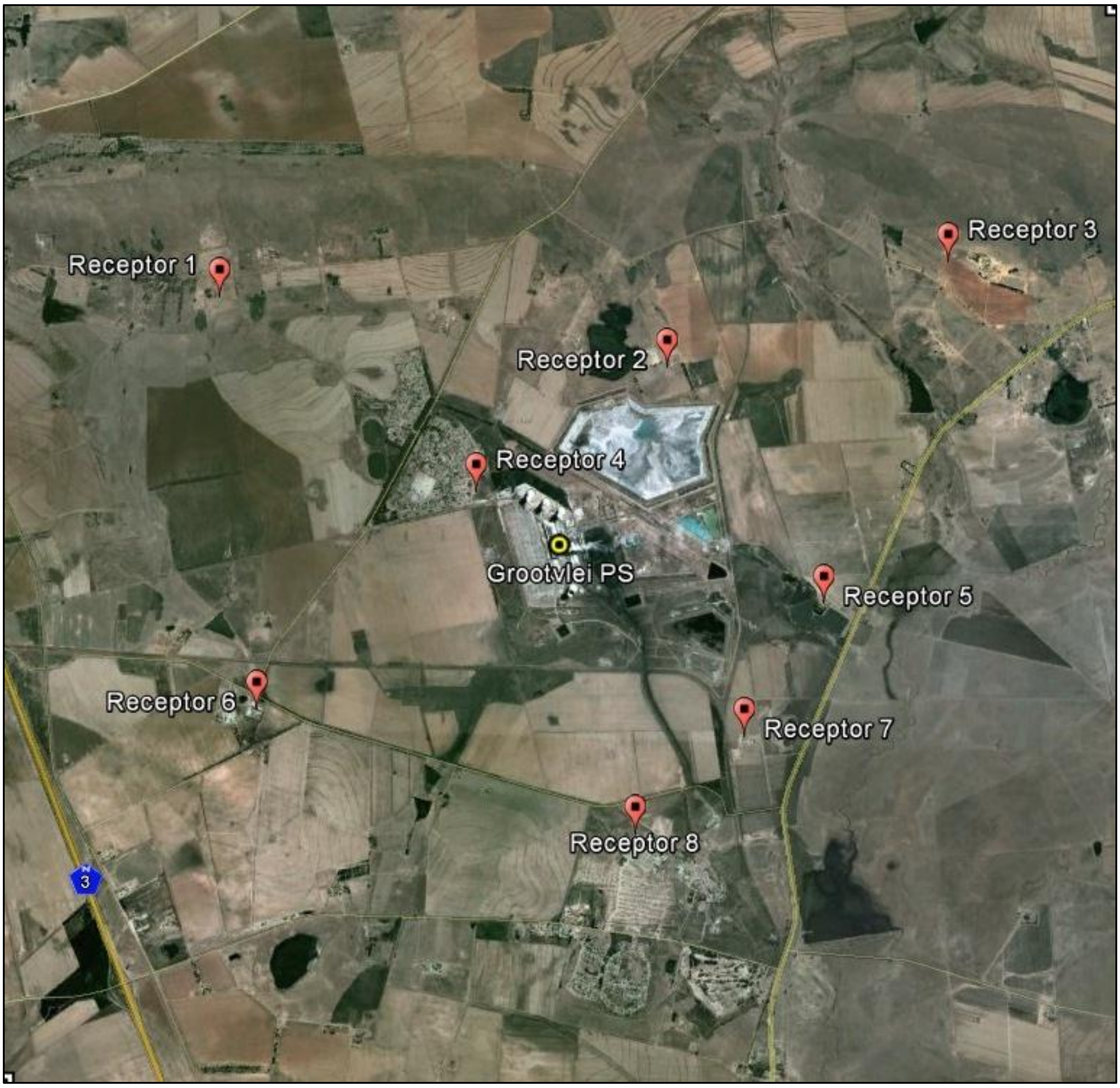

Figure 3-3: Location of the sensitive receptors to the Grootvlei Power Station

3.3 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume ‘stretching’. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field.

Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic systems determining the macro-ventilation potential of the region may be provided based on the review of pertinent literature. Meso-scale systems may be investigated through the analysis of meteorological data observed for the region.

3.3.1 Synoptic-Scale Circulations and Regional Atmospheric Dispersion Potential

Situated in the subtropical high-pressure belt, southern Africa is influenced by several high-pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperate latitudes. The mean circulation of the atmosphere over the subcontinent is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic High Pressure (HP), the South Indian HP off the east coast, and the continental HP over the interior.

Seasonal variations in the positioning and intensity of the HP cells determine the extent to which the circumpolar westerlies impact on the atmosphere over the region. In winter, the high-pressure belt intensifies and moves northward and the upper level circumpolar westerlies are able to impact significantly on the region. The winter weather of the region is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or ridging anticyclones moving eastwards around the South African coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards and the influence of the circumpolar westerlies diminishes. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic wintertime circulation (Preston-Whyte and Tyson, 1988; Schulze, 1980).

The general circulation of the atmosphere over southern Africa as a whole is anticyclonic throughout the year above the 700 hPa level (i.e. altitude of ~3 000m). Anticyclones are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions and little to no rainfall occur as a result of such airflow. The climatology of the highveld region has been studied extensively in the past, where the frequency of anticyclonic conditions reaches a maximum in winter. The dominant effect of the winter subsidence is that, averaged over the year, the mean vertical motion is downward. The clear, dry air and light winds, often associated with anticyclonic circulation are ideal for surface radiation inversions of temperature, responsible for limited dispersion of especially low level pollution emissions (e.g. domestic coal fires). Surface inversions increase in frequency during night-time and vary in depth between ~300 m to more than 500 m. The mean inversion strength during the winter is about 5°C – 6°C, whereas, in summer the strength is less than 2°C.

Circumpolar westerly waves are characterised by concomitant surface convergence and upper-level divergence that produce sustained uplift, cloud and the potential for precipitation. Cold fronts, which are associated with westerly waves, occur predominantly during winter when the amplitude of such disturbances is greatest. The passage of a cold front is characterised by distinctive cloud bands and pronounced variations in wind direction, wind speed, temperature, humidity, and surface pressure. Airflow ahead of a front passing over has a distinct north-northeasterly component and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. Following the passage of the cold front the north-easterly wind is replaced by winds with a distinct southerly component. The low-level convergence in the south-westerly airflow to the rear of the front produces favourable conditions for convection. Temperature decreases immediately after the passage of the front, with minimum temperatures being experienced on the first morning after the cloud associated with the front clears. Strong radiation cooling due to the absence of cloud cover, and the advection of cold southerly air combining to produce the lowest temperatures

The tropical easterlies, and the occurrence of easterly waves and lows affect most of southern Africa throughout the year, but occur almost exclusively during summer months. The easterly waves and lows are largely responsible for the summer rainfall pattern and the northeasterly wind component that occurs over the region (Weather Services, 1986; Preston-Whyte and Tyson, 1988).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the persistence of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, destroy, weaken, or increase the altitude of elevated inversions. Easterly and westerly wave disturbances therefore facilitate the dispersion and dilution of accumulated atmospheric pollution.

3.3.2 Meso-scale ventilation and site-specific dispersion potential

3.3.2.1 Local wind field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

Wind roses for Grootvlei are given in Figure 3-4 and Figure 3-5 for the period January 2009 to December 2011. These wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours reflected the different categories of wind speeds with the dotted circles indicating the frequency of occurrence.

The period wind field at Grootvlei (Figure 3-4) is bimodal with the dominant wind direction being from the north and the easterly sectors. The wind speed is generally low, with an average value of 3.23 m/s. There is a large frequency of calm conditions recorded at the Grootvlei site. Differences in the day time and night time wind fields occur. During the day (06:00 to 17:00) the dominant winds are from the north, east and south-westerly sectors, pointing toward varying wind directions/shifts within the day. During night time conditions (18:00 to 05:00) the dominant winds come from the north and easterly sectors, while the contribution from the southwest is reduced (Figure 3-4). The measured wind flow at the Grootvlei monitoring station (Figure 3-5) is similar with predominant northerly, westerly and easterly flow fields.

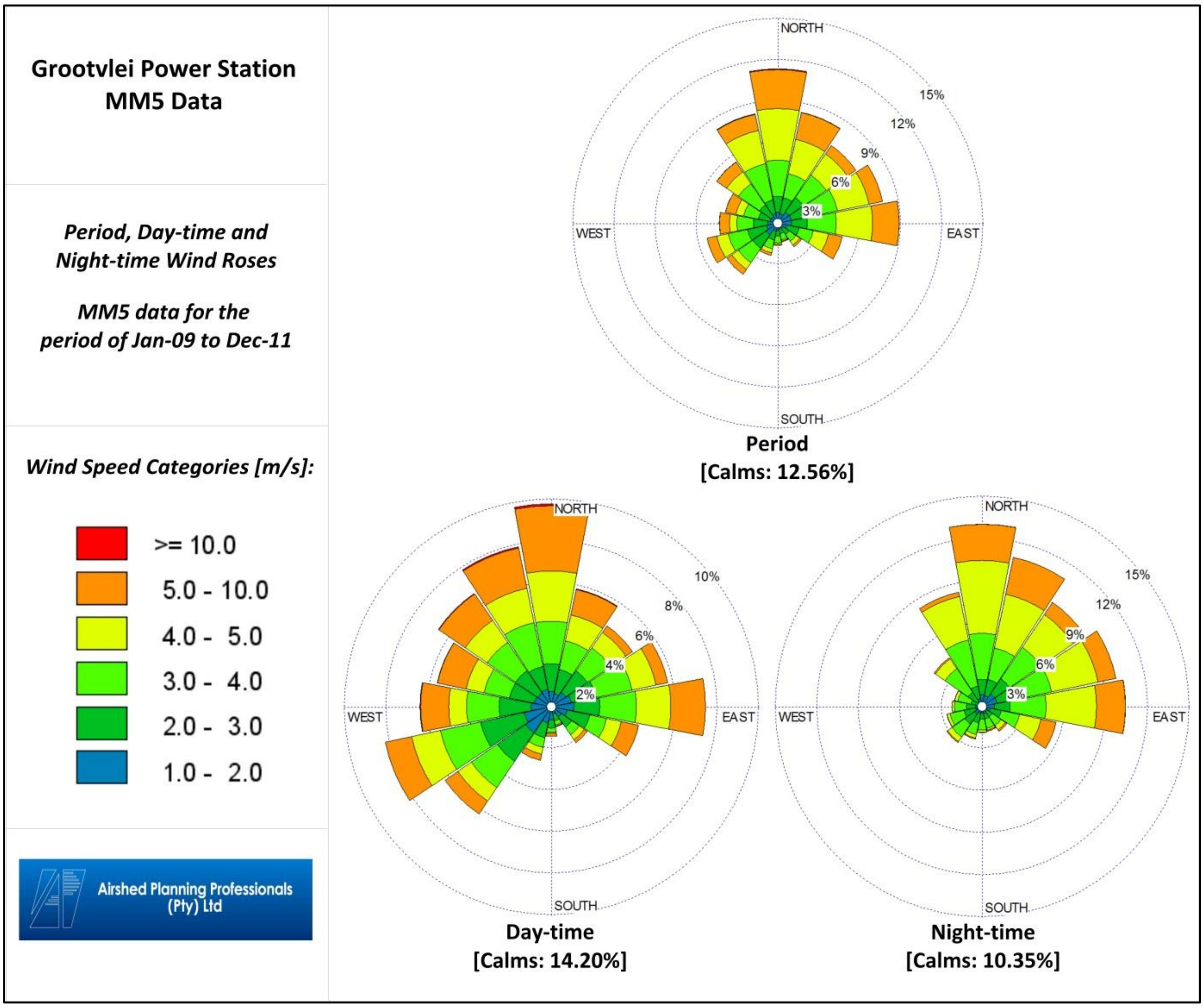

Figure 3-4: Period, daytime and night-time wind roses for Grootvlei (MM5) (January 2009 – Dec 2011)

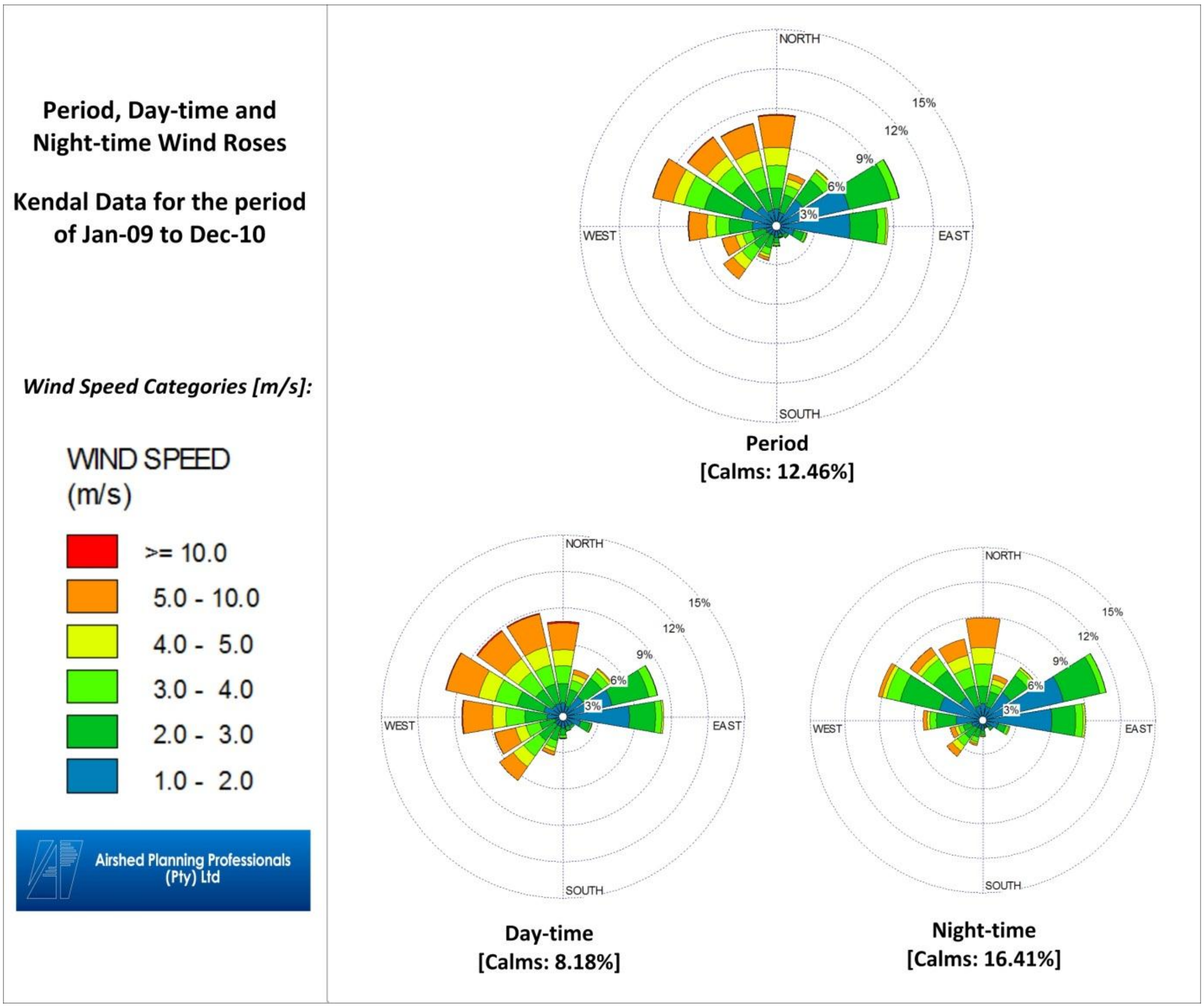

Figure 3-5: Period, daytime and night-time wind roses for Grootvlei (Eskom monitoring site) (January 2009 – Dec 2010)

3.3.2.2 Ambient Temperature

The air temperature is important, for determining the development of the mixing and inversion layers. The diurnal temperature profile for Grootvlei (2009-2011) is given in Figure 3-6. The period mean, maximum and minimum temperatures for Grootvlei are 15°C, 30.4°C and -3.9°C respectively for the period January 2009 to December 2011. The month with the highest mean temperature is January (21.1°C) while the coldest month is July (6.8°C).

The diurnal temperature profile for Grootvlei (2009-2010) as obtained from the Eskom monitoring statopn is given in Figure 3-7. The period mean, maximum and minimum temperatures for Grootvlei are 16°C, 33°C and -7°C respectively for the period January 2009 to December 2010. The month with the highest mean temperature is January (21.2°C) while the coldest month is July (7.9°C).

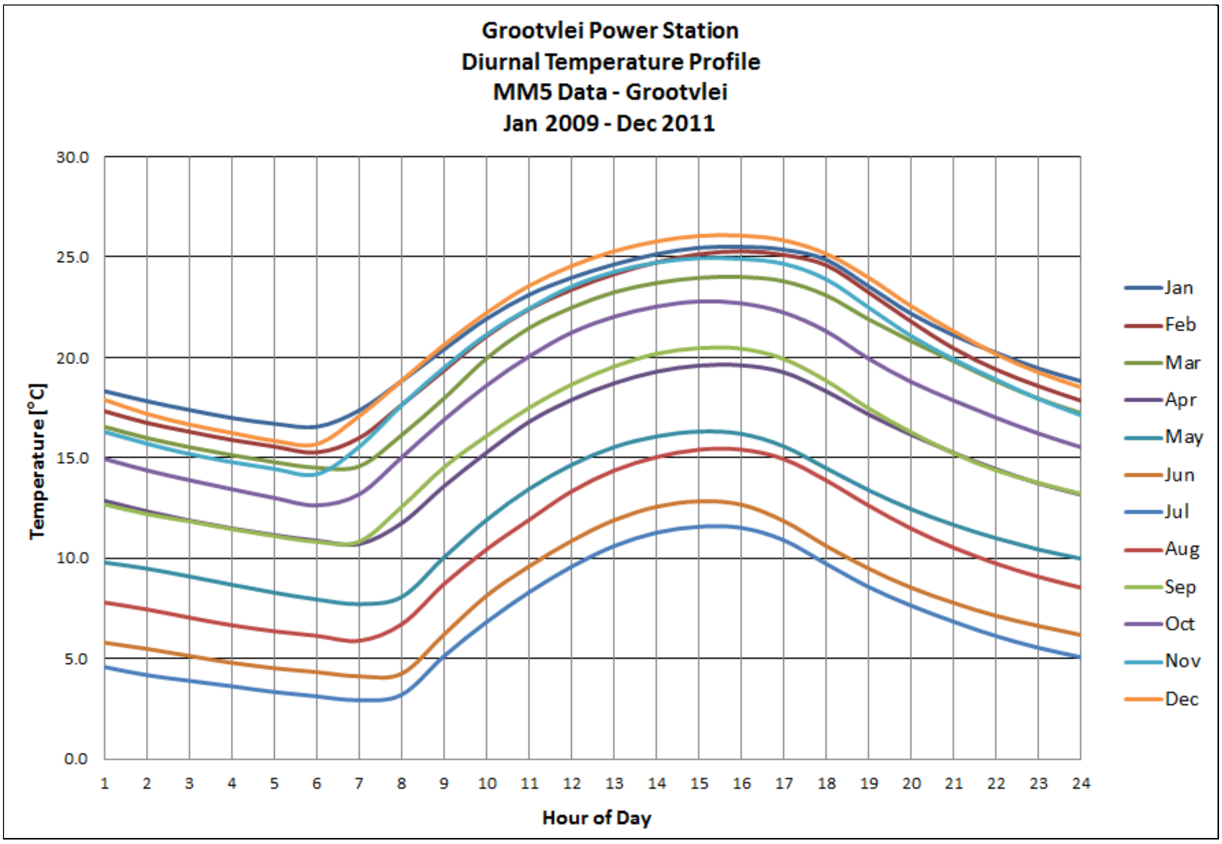

Figure 3-6: Diurnal temperature profile for Grootvlei (MM5 data) for the period January 2009 – December 2011

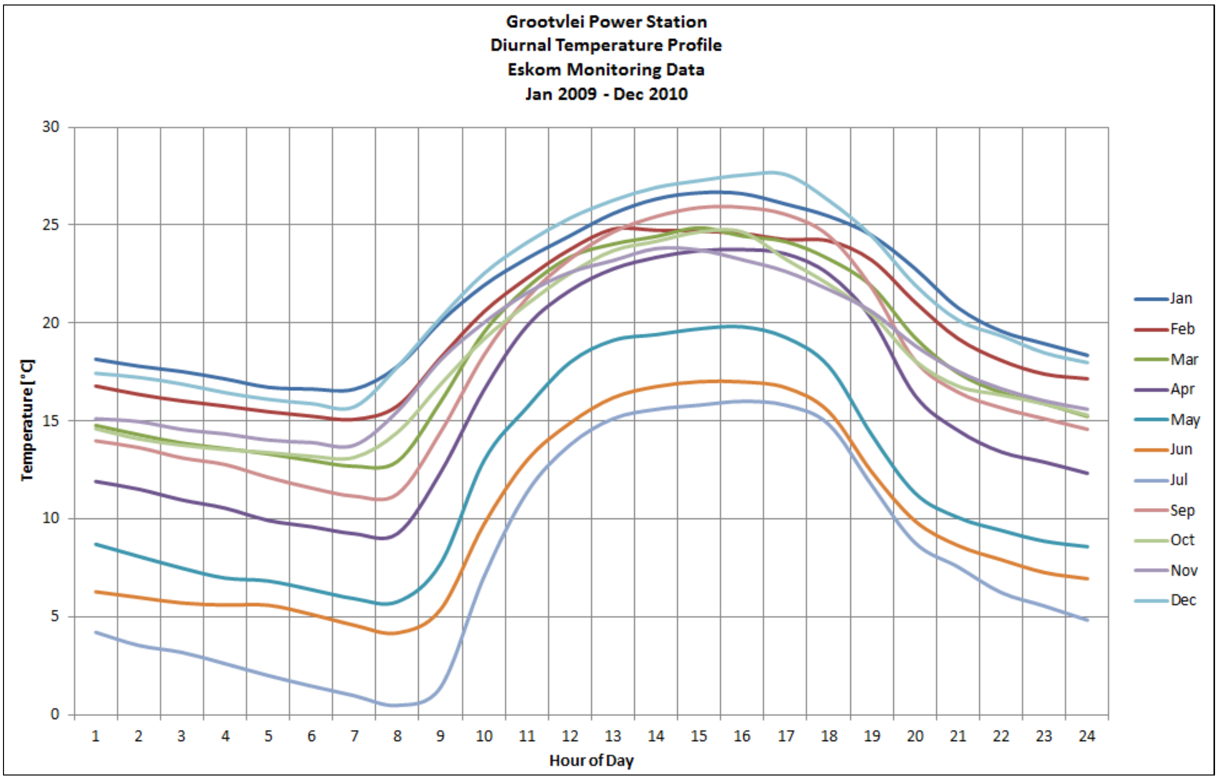

Figure 3-7: Diurnal temperature profile for Grootvlei (Eskom monitoring site) for the period January 2009 – December 2010

3.3.2.3 Atmospheric Stability and Mixing Depth

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. The radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. The night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer ranges in depth from a few metres (i.e. stable or neutral layers) during night times to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons and on some occasions as many as five may occur in the first 1000 m above the surface. The lowest-level elevated inversion is located at a mean height above ground of 1 550 m during winter months with a 78% frequency of occurrence. By contrast, the mean summer subsidence inversion occurs at 2600 m with a 40% frequency.

The atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3-1.

Table 3-1: Atmospheric stability classes

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

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and a slower developing mixing layer. Then during the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. In contrast, the highest concentrations for ground level non-wind dependent releases would occur during weak wind speeds and stable (night time) atmospheric conditions.

The frequency of occurrence of the various stability classes is presented in Figure 3-8, the most commonly occurring stability class calculated at Grootvlei is Class E representing stable conditions, the occurrence of stable conditions occurs for approximately 30% of the time while neutral and unstable conditions are at 16% and 24% occurrence respectively.

The association between wind direction and stability class is presented in Figure 3-9, generally the wind direction has little impact on the occurrence of the stability classes, although there is a slight increase in the occurrence of stable and very stable conditions with winds from the north easterly sectors while the occurrence of unstable to very unstable conditions is greater with winds from the south easterly to north westerly sectors.

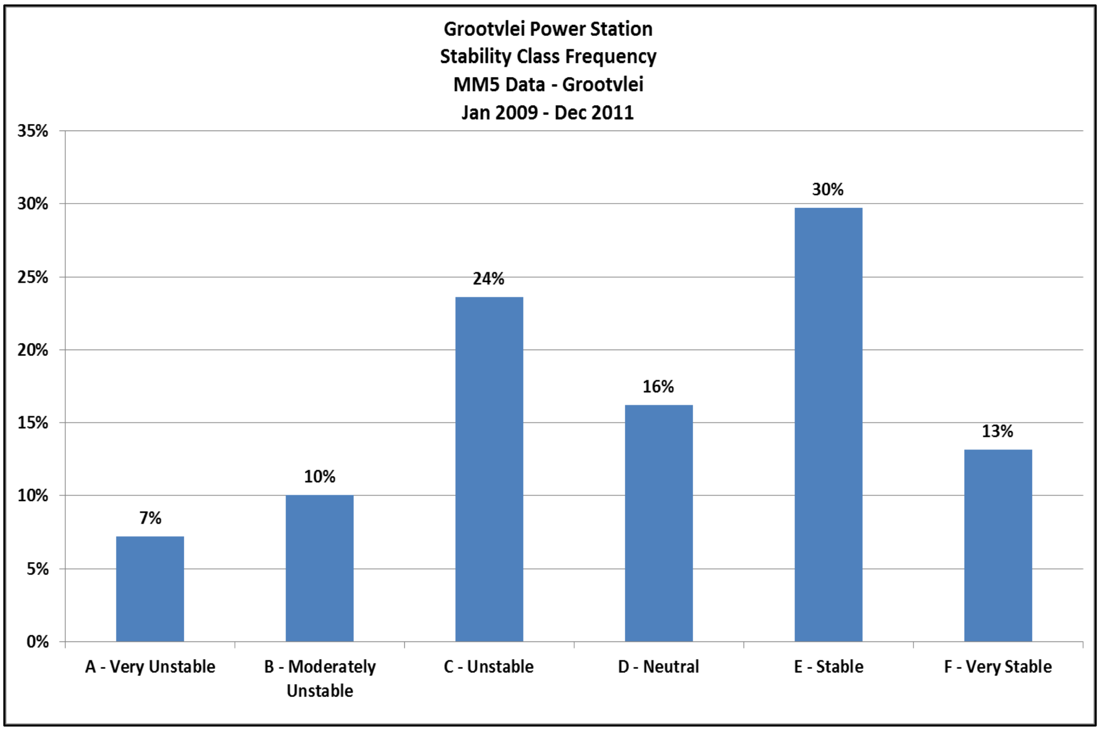

Figure 3-8: Stability Class frequency for Grootvlei (January 2009 – December 2011)

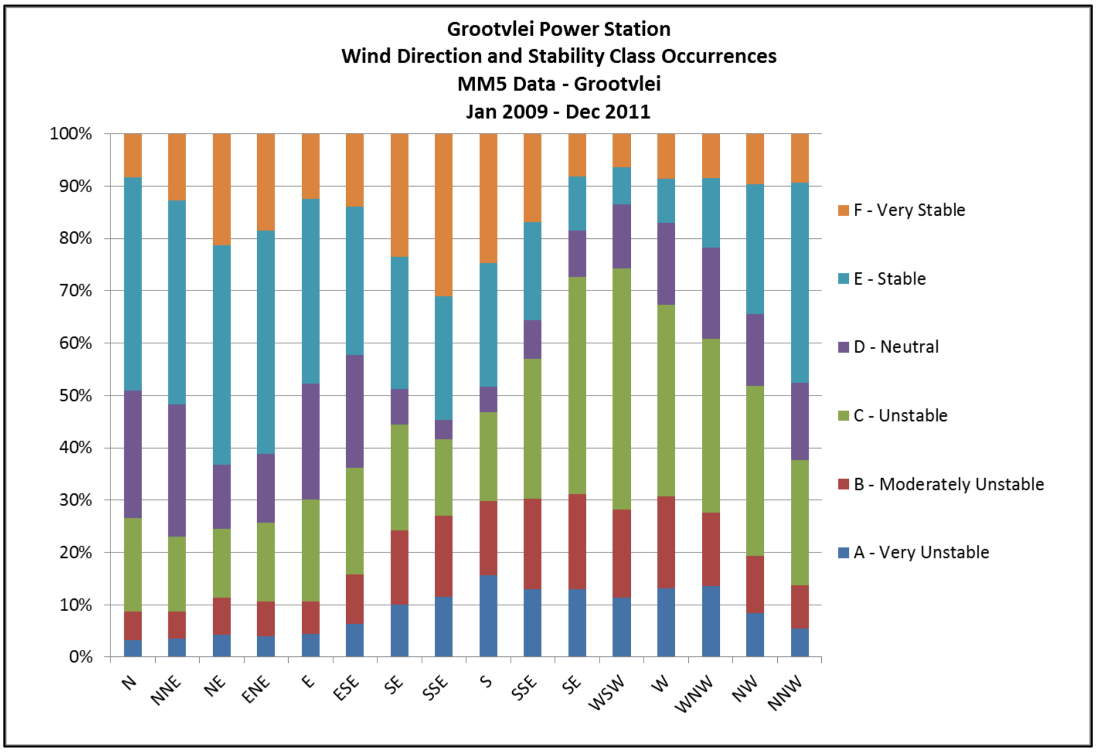

Figure 3-9: Stability Class and wind direction

3.4 Existing Sources of Emissions near the Grootvlei Power Station

A comprehensive emissions inventory for the study area was not available for the current assessment and the establishment of such an inventory was not within the scope of the current study. Instead source types present in the area and the pollutants associated with such source types are noted with the aim of identifying pollutants which may be of importance in terms of cumulative impact potentials. The main types of sources include:

- Vehicle tailpipe emissions (from the N3 and R51),
- Household fuel combustion (particularly coal and wood used by lower income communities)
- Biomass burning (veld fires in agricultural areas within the region), and
- Various miscellaneous fugitive dust sources (i.e. agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads, etc.).

3.4.1 Vehicle tailpipe emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, particulates and lead. Secondary pollutants resulting from vehicular emissions include: NO_2, photochemical oxidants (e.g. ozone), HCs, sulphuric acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses.

3.4.2 Household fuel combustion

It is likely that certain households within local communities are using coal or wood for space heating and/or cooking purposes. Pollutants arising due to the combustion of wood include respirable particulates, carbon monoxide and sulphur dioxide with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Coal burning emits a large amount of gaseous and particulate pollutants including SO2, heavy metals, total and respirable particulates including heavy metals and inorganic ash, CO, polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene, NO_2 and various toxins. Pollutants from wood burning include respirable particulates, NO_2, CO, PAHs (benzo(a)pyrene and formaldehyde). Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

3.4.3 Biomass burning

Crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. The quantity of dry, combustible matter per unit area is on approximately 6 tons per hectare for African Grasslands receiving 750 mm precipitation/ year; grass biomass is largely controlled by the precipitation. Biomass burning is an incomplete combustion process with carbon monoxide, methane and nitrogen dioxide being emitted during the process. About 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. The visibility of smoke plumes from vegetation fires is due to their aerosol content.

3.4.4 Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g. tilling) and mining. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways. The extent, nature and duration of agricultural activities and the moisture and silt content of soils is required to be known in order to quantify fugitive emissions from this source. The quantity of windblown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

The pollutants listed above are released directly by sources and are therefore termed 'primary pollutants'. 'Secondary pollutants' which form in the atmosphere as a result of chemical transformations and reactions between various compounds include: NO_2, various photochemical oxidants (e.g. ozone), hydrocarbon compounds, sulphuric acid, sulphates, nitric acid and nitrate aerosols.

The sources of SO_2 and NO_x that occur in the region include veld burning, vehicle exhaust emissions and household fuel burning.

Various local and remote sources are expected to contribute to the suspended fine particulate concentrations in the region. Local sources include wind erosion from exposed areas, fugitive dust from agricultural and mining operations, vehicle entrainment from roadways and veld burning. 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 over the interior (Andrea et al., 1996; Garstang et al., 1996; Piketh, 1996).

3.5 Measured Baseline Ambient Air Quality

The pollutant of interest for the FFP retrofit at units 2, 3 and 4 is particulate matter. Eskom operate an ambient monitoring station at the residential area just west of the Grootvlei Power Station. The annual average PM_{10} ground level concentrations for the period January 2009 to December 2010 was 16.3 µg/m³. The daily PM_{10} NAAQ limit (applicable till 31 December 2014) was exceeded once for the period 2009 and twice for the period 2010. The daily PM_{10} NAAQ limit (applicable from 1 January 2015) was exceeded 9 times for the period 2009 and 8 times for the period 2010. It should be noted that the daily NAAQS for PM_{10} allows for 4 exceedances in 1 calendar year.

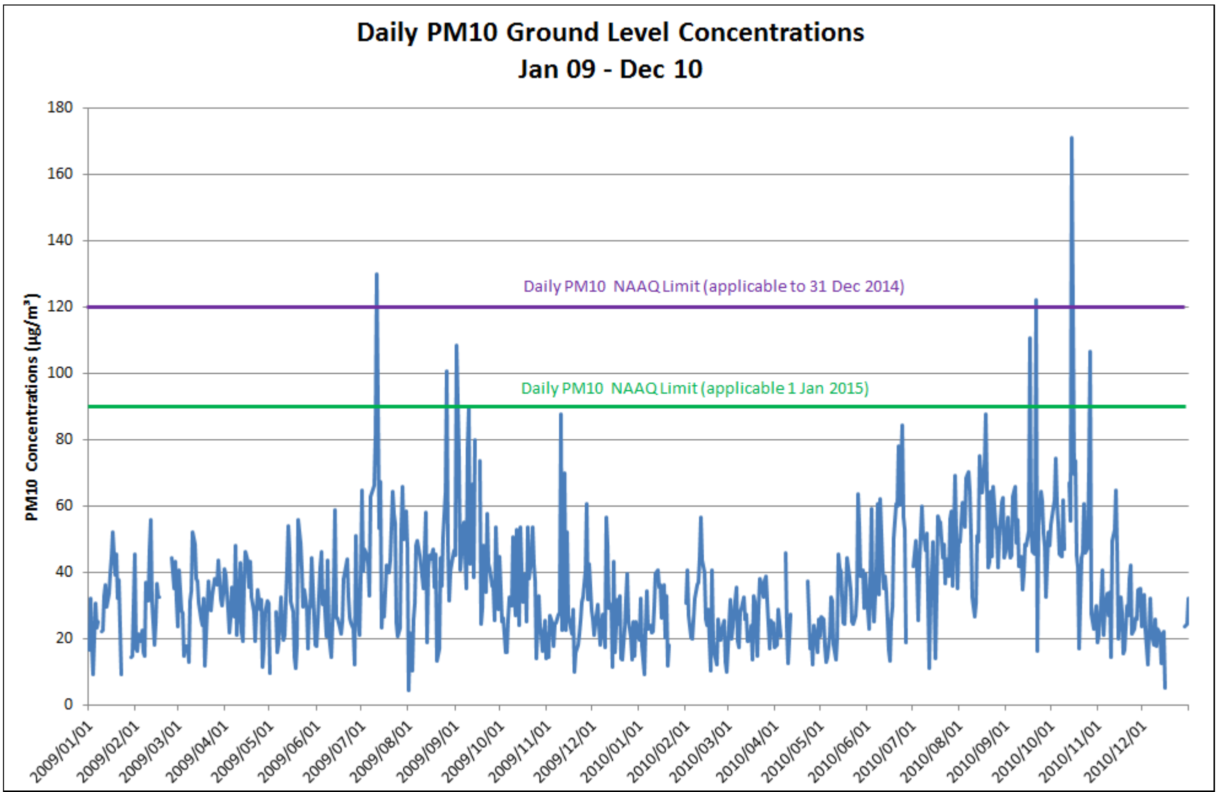

Figure 3-10: Daily measured PM_{10} ground level concentrations at Grootvlei for the period January 2009 to December 2010

3.6 Modelled Baseline Ambient Air Quality

As part of the current assessment the existing ash dam and coal stockpile for the Grootvlei Power Station as well as the Grootvlei power generation stack releases were modelled (for current operations). The emissions inventory for these current sources as well as the modelled impacts is provided in the following section. It should be noted that agricultural activities and domestic fire burning in the study area will also contribute to the overall cumulative particulate concentrations. These sources, however, were not modelled.

3.6.1 Emissions Inventory

A detailed description of the emission factors used in the calculation of the wind erosion on the ash dam and coal stockpile is provided in Appendix A.

3.6.1.1 Wind Erosion

Emissions may arise due to the mechanical disturbance of granular material from open stockpiles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the moisture content of the material transported, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. The particle size distribution of the material is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

The potential emission due to windblown dust from the existing Grootvlei ash dam and coal stockpile were assessed (Figure 3-11). The properties of the ash dam and coal stockpile material and particle size distribution (as obtained from similar processes) is given in Table 3-2 and Table 3-3 respectively. It should be noted that consideration of grassed sidewalls on the ash dam and wet ashing operations were taken into consideration for dispersion modelling purposes. The compaction of the coal stockpile was also taken into consideration for the quantification of windblown dust from this source.

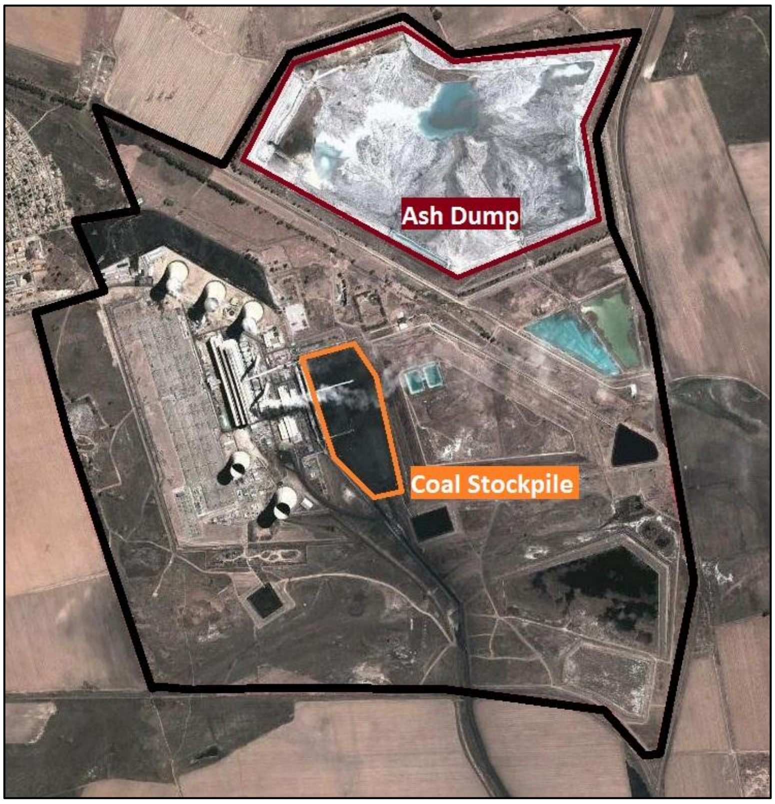

Figure 3-11: Existing Grootvlei ash dam and coal stockpile

Table 3-2: Ash dam and coal stockpile properties

Sample ID	Bulk Density (t/m³)	Component >2mm (%)	Component <2mm >1mm (%)	Component <1mm (%)
Ash Dam	2.28	43	5	52
Coal Stockpile	1.65	22	38	39

Table 3-3: Particle size distribution (given as a percentage) of the ash dam and the coal stockpile

Ash Dam		Coal Stockpile	
Size (µm)	Percentage (%)	Size (µm)	Percentage (%)
1000	43	355	22
190.8	1	212	11
103.58	3	125	27
76.32	4	75	11
48.27	9	45	7

Ash Dam		Coal Stockpile	
Size (µm)	Percentage (%)	Size (µm)	Percentage (%)
30.53	3	30	7
19.31	15	15	3
14.22	5	10	4
10.45	4	5	2
4.88	7	3	3
3.09	2	1	3
1.95	1		
1.06	2		

3.6.1.2 Stack Emissions

Source parameters for the Grootvlei Power Station stacks required for the dispersion modelling study, as provided by the client, are summarised in Table 3-4. With PM_{10} being the main pollutant of concern for the Grootvlei Power Station retrofit, this pollutant was modelled for the stacks.

Table 3-4: Stack parameters and particulate emissions from the Grootvlei Power Station

Parameter	North Stack	South Stack	Units
Height	152.4	152.4	m
Diameter	11.58	11.58	m
Exit velocity for current operations	5.26	5.51	m/s
PM_{10} emissions for current operations	252.62	126.48	g/s
PM_{10} concentration for current operations	228	109	mg/Nm^3

3.6.2 Dispersion Simulation Results for Current Operating Conditions

The plots provided for the relevant pollutants of concern are given in Table 3-5. Plots where exceedances of the National Ambient Air Quality Standards (NAAQS), were included for all sources. The predicted ground level concentrations (GLC) are shown due to current operations at the Grootvlei Power Station, i.e. before the FFP retrofit at unit 2, 3 and 4.

Table 3-5: Isopleths plots presented in the current section

Pollutant	Averaging Period	Figure
PM_{10}	Frequency of exceedance of daily NAAQS (all sources [a])	Figure 3-12
	Predicted annual concentrations (all power station sources [a])	Figure 3-13
	Predicted daily concentrations (stacks only)	Figure 3-14
	Predicted annual concentrations (stacks only)	Figure 3-15

a) Windblown dust from the coal stockpile and ash dam as well as the Grootvlei Power Station stacks

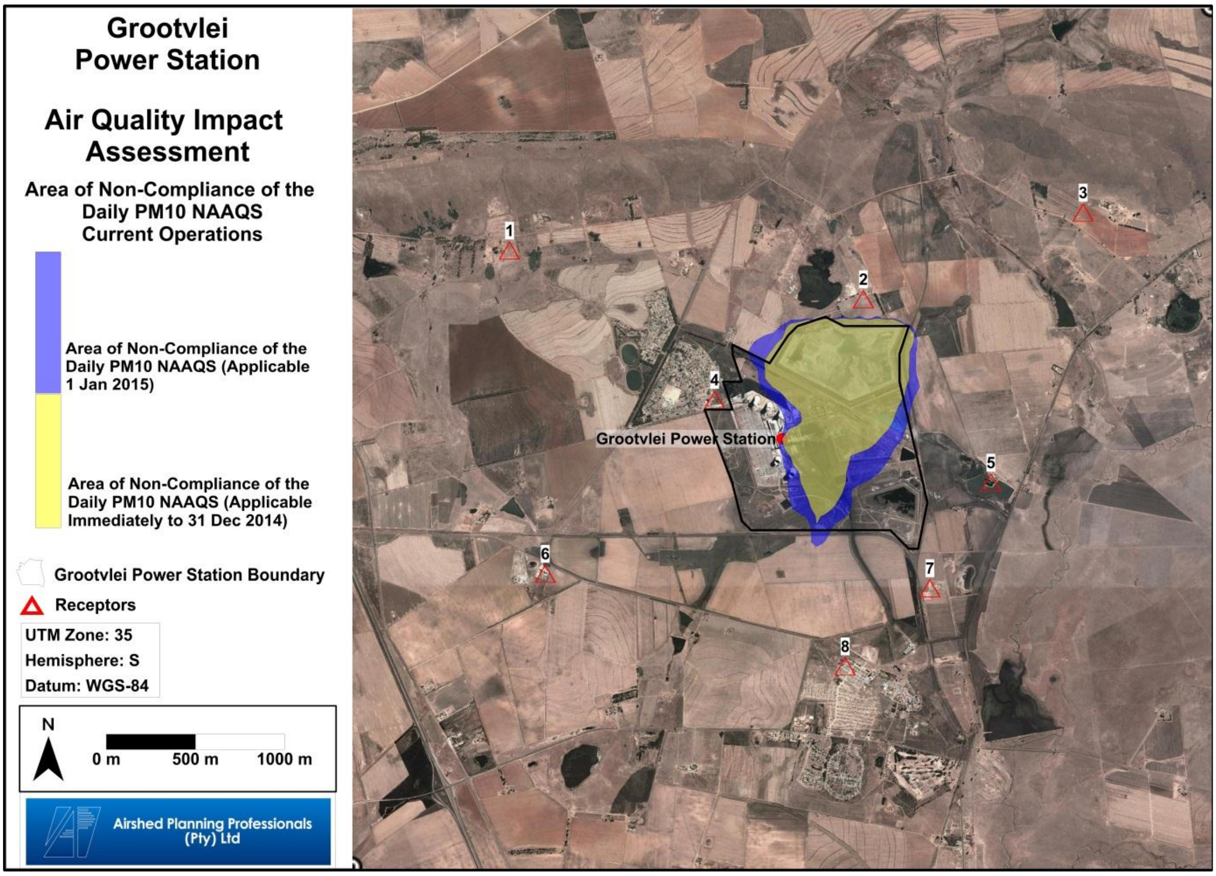

Figure 3-12: Area of exceedance of daily PM_{10} NAAQS due to current Grootvlei Power Station operations. Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

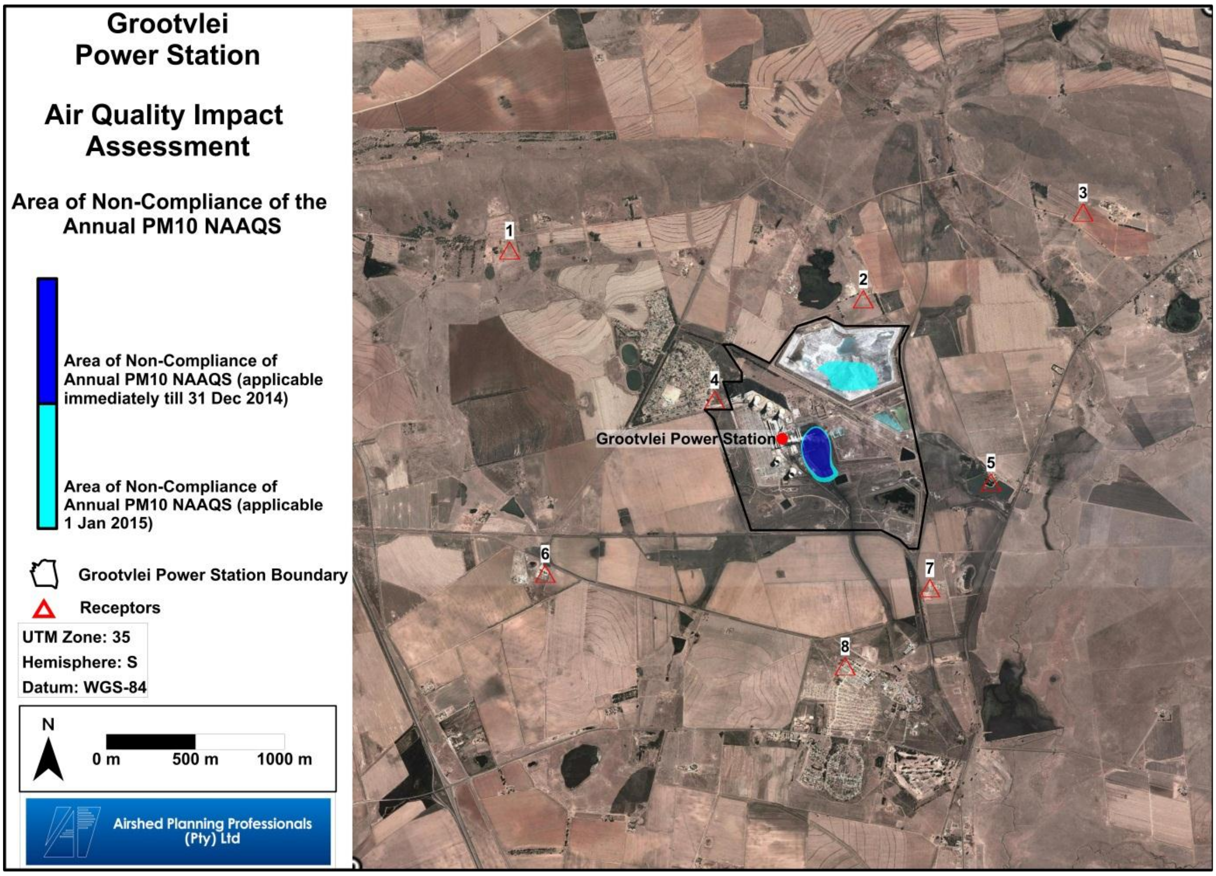

Figure 3-13: Annual predicted GLC for PM_{10} due to current Grootvlei Power Station operations. Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

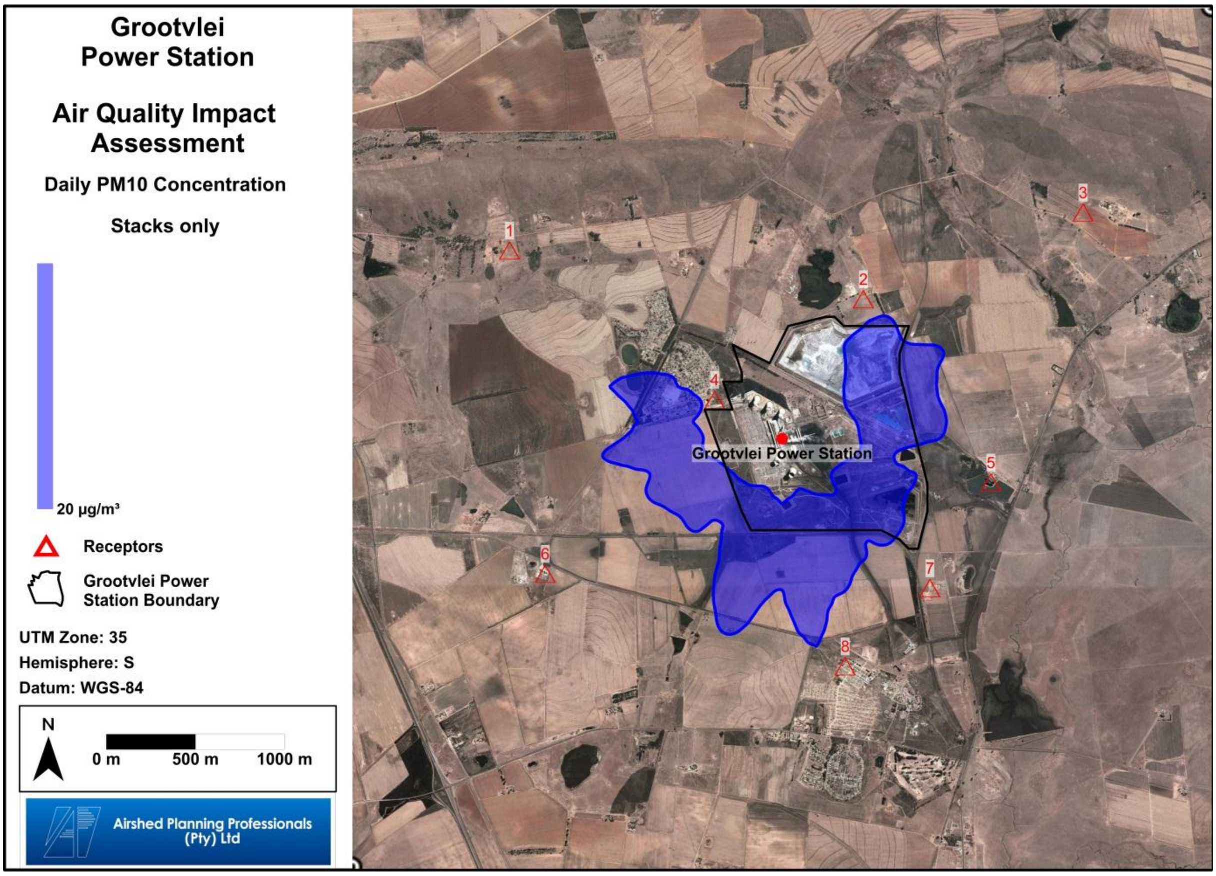

Figure 3-14: Highest predicted daily GLC for PM_{10} (stacks only). Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

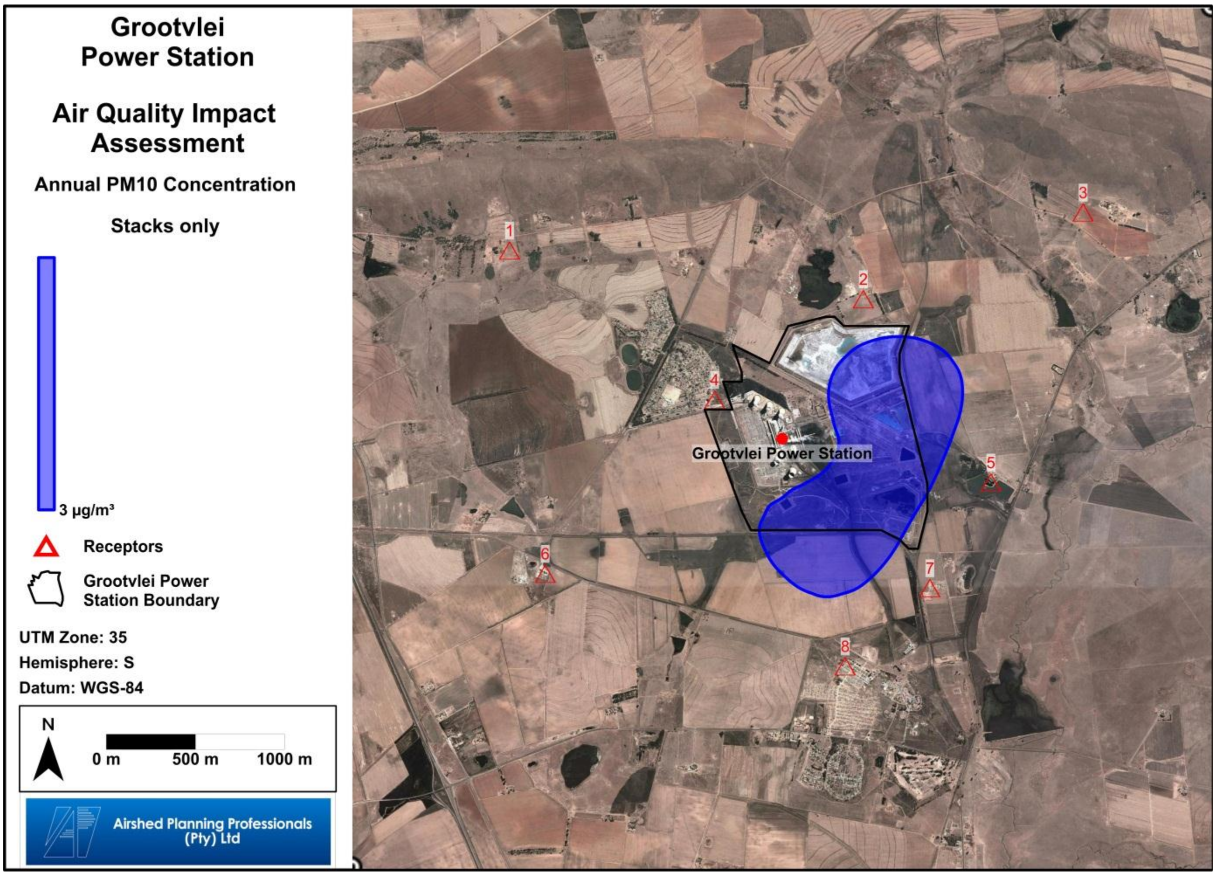

Figure 3-15: Annual predicted GLC for PM_{10} (stacks only). Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

3.6.3 Compliance Assessment of Predicted Impacts

3.6.3.1 Inhalable Particulate Matter of less than 10 µm (PM_{10})

Predicted PM_{10} ground level concentrations at sensitive receptors included in the study area are presented in Table 3-6 and illustrated in Figure 3-12 to Figure 3-14. The predicted PM_{10} impacts at the nearest sensitive receptors (due to current power station operations including stack releases, coal stockpile and ash dam operations only) are within the NAAQS.

Table 3-6: Predicted annual PM_{10} ground level concentrations at the nearest sensitive receptors due to the current operations at Grootvlei Power Station

Location	Current Operations (Annual PM_{10} Concentration - µg/m³)	
	All Sources [(b)]	Stacks only
Study Area Median [(a)]	1.18	1.03
Receptor 1 - farm house	0.92	0.77
Receptor 2 - farm house	2.34	1.9
Receptor 3 - farm house	1.25	1.16
Receptor 4 - GVPS residential	3.01	2.24
Receptor 5 - farm house	2.6	2.26
Receptor 6 - farm house	1.21	1.18
Receptor 7 - farm house	2.89	2.29
Receptor 8 - Grootvlei	2.86	2.21

a) The median value and not average as distribution of concentration values was not a normal but a skewed distribution.

b) Windblown dust from the coal stockpile and ash dam as well as the Grootvlei Power Station stacks

4 IMPACTS DUE TO PROPOSED GROOTVLEI FFP RETROFIT AT UNITS 2, 3 AND 4

4.1 Construction Activities

4.1.1 Identification of Environmental Aspects and Impact Classification

Construction normally comprises a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has their own duration and potential for dust generation. It is anticipated 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.

A list of all the potential dust generation activities expected during the construction phase is provided in Table 4-1. Unmitigated construction activities provide the potential for impacts on local communities, primarily due to nuisance and aesthetic impacts associated with fugitive dust emissions. On-site dustfall may also represent a nuisance to employees.

Table 4-1: Typical sources of fugitive particulate emission associated with construction

Pollutant(s)	Aspect	Activity
Particulates	Construction of Fabric Filter Plants for unit 2,3 & 4	Modification to existing units
		Wind erosion from building material storage piles
		Tipping of excess/old cement to storage pile
	Vehicle activity on-site	Vehicle and construction equipment activity during construction operations
Gases and particles	Vehicle and construction equipment activity	Tailpipe emissions from vehicles

4.1.2 Mitigation Measures Recommended

Incremental PM_{10} concentrations due to the Construction Phase will be of relatively short-term and of localised impact. The implementation of effective controls, however, during this phase would also serve to set the president for mitigation during the operational phase.

Dust control measures (dust which will contain PM_{10}) which may be implemented during the construction phase are outlined in Table 4-2. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed though the use of windbreaks and source enclosures.

Table 4-2: Dust (containing PM_{10}) control measures that may be implemented during construction activities

Construction Activity	Recommended Control Measure(s)
Debris handling	Wind speed reduction through sheltering
	Wet suppression
Truck transport and road dust entrainment	Wet suppression or chemical stabilization of unpaved roads Haul trucks to be restricted to specified haul roads
	Reduction of unnecessary traffic
	Require haul trucks to be covered
	Strict speed control
Materials storage, handling and transfer operations	Wet suppression where feasible
Open areas (windblown emissions)	Reduction of extent of open areas
	Reduction of frequency of disturbance

4.2 Operational Phase

4.2.1 Emissions Inventory

A detailed description of the emission factors used in the calculation of the wind erosion on the ash dam and coal stockpile is provided in Appendix A.

4.2.1.1 Wind Erosion

Emissions may arise due to the mechanical disturbance of granular material from open stockpiles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the moisture content of the material transported, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. The particle size distribution of the material is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

The potential emission due to windblown dust from the existing Grootvlei ash dam and coal stockpile were assessed. The properties of the ash dam and coal stockpile material and particle size distribution is given in Section 3.6.1.

4.2.1.2 Stack Emissions

Source parameters for the Grootvlei Power Station required for input to the dispersion modelling study, as provided by the client is summarised in Table 4-3 below. With PM_{10} being the pollutant of concern for the Grootvlei Power Station retrofit, this pollutant was thus modelled from the power station stacks.

Table 4-3: Stack parameters and particulate emissions from the Grootvlei Power Station

Parameter	North Stack	South Stack	Units
Height	152.4	152.4	m
Diameter	11.58	11.58	m
Exit velocity Before FFP	5.26	5.51	m/s
Exit velocity After FFP	7.1	6.43	m/s
PM_{10} emissions before FFP	252.62	126.48	g/s
PM_{10} emissions after FFP	59.86	54.9	g/s
PM_{10} concentration Before FFP	228	109	mg/Nm^3
PM_{10} concentration after FFP	40	40	mg/Nm^3

4.2.2 Dispersion Simulation Results

Simulations were undertaken to determine the particulate matter concentrations from operations due to the Grootvlei Power Station FFP retrofit at units 2, 3 and 4. The proposed impacts were assessed with the current operations of the Grootvlei Power Station stacks as well as the existing ash dam and coal stockpile activities.

Plots where exceedances of the National Ambient Air Quality Standards (NAAQS) (as applicable on 1 January 2015), were included for all sources. The predicted ground level concentrations (GLC) are shown due to future operations at the Grootvlei Power Station, i.e. after the retrofitting procedure is finalised for unit 2, 3 and 4.

Due to the uncertainty in moisture content of the coal stockpile, two scenarios were modelled (i.e. at 1% moisture content (i.e. likely "worst case" scenario) and 3% moisture content (i.e. likely "average" scenario)).

Table 4-4: Isopleths plots presented in the current section

Pollutant	Averaging Period	Figure
PM_{10}	Frequency of exceedance of daily NAAQS (all sources [a])	Figure 4-1
	Predicted annual concentrations (all power station sources [a])	Figure 4-2
	Predicted daily concentrations (stacks only)	Figure 4-3
	Predicted annual concentrations (stacks only)	Figure 4-4

a) Windblown dust from the coal stockpile and ash dam as well as the Grootvlei Power Station stacks

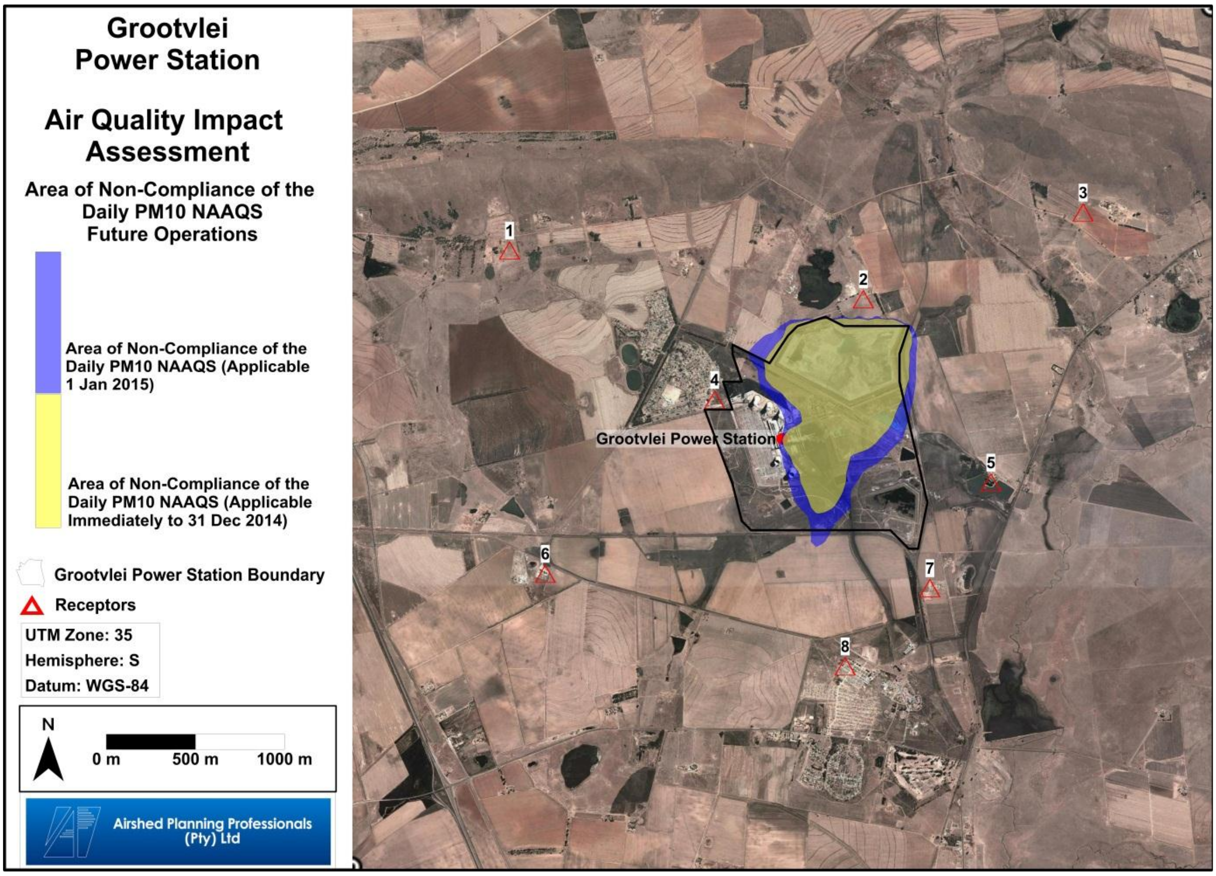

Figure 4-1: Area of exceedance of daily PM_{10} NAAQS due to Grootvlei Power Station operations (after FFP retrofit at units 2, 3 and 4). Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

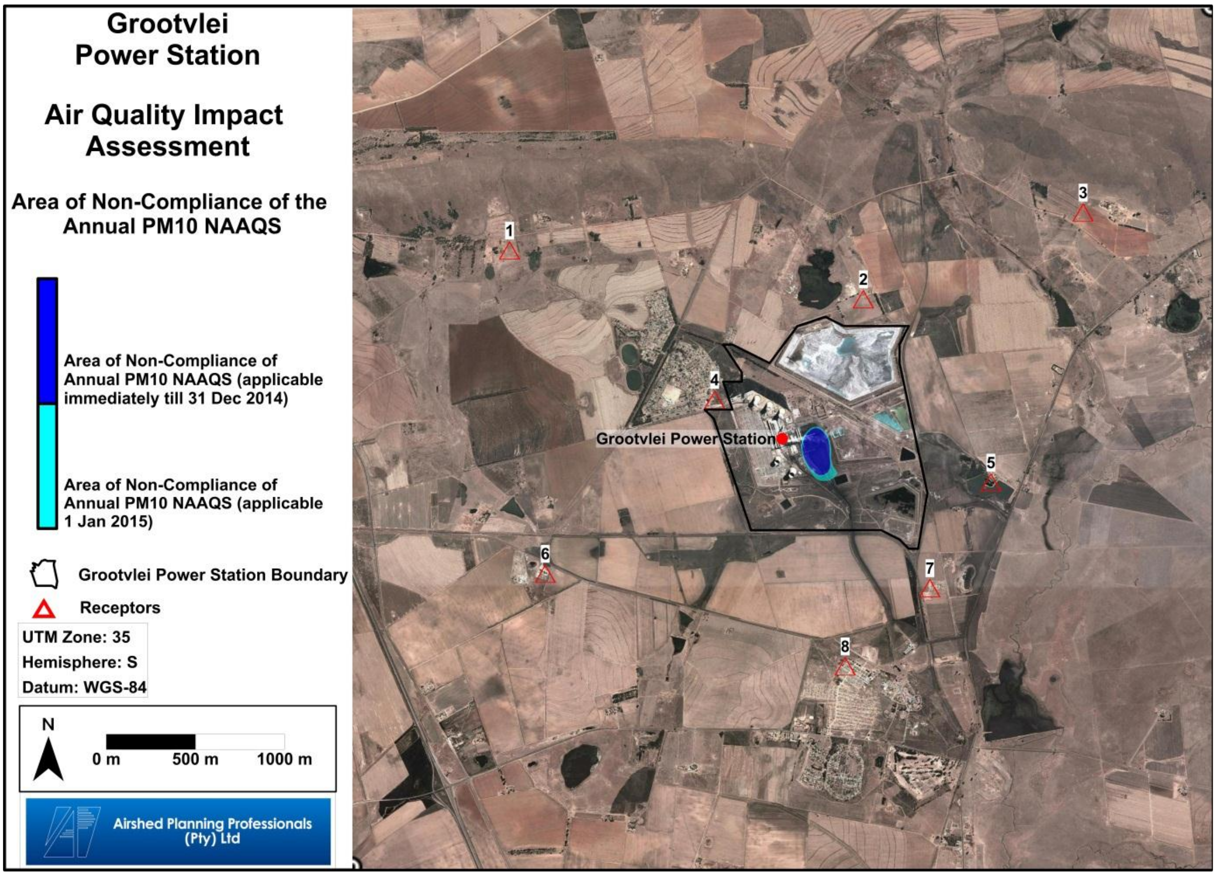

Figure 4-2: Annual predicted GLC for PM_{10} due to Grootvlei Power Station operations (after FFP retrofit at units 2, 3 and 4). Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

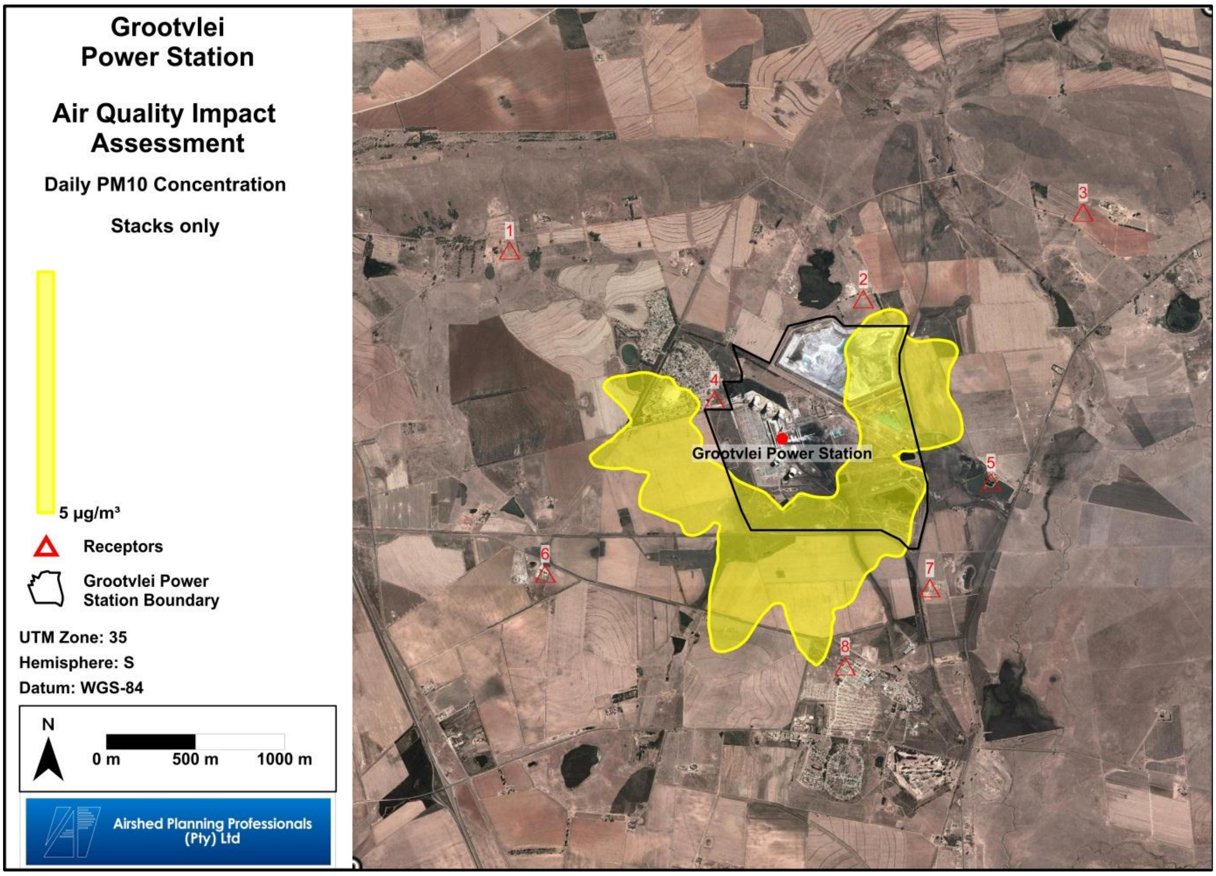

Figure 4-3: Highest predicted daily GLC for PM_{10} (stacks only after FFP retrofit at units 2, 3 and 4). Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

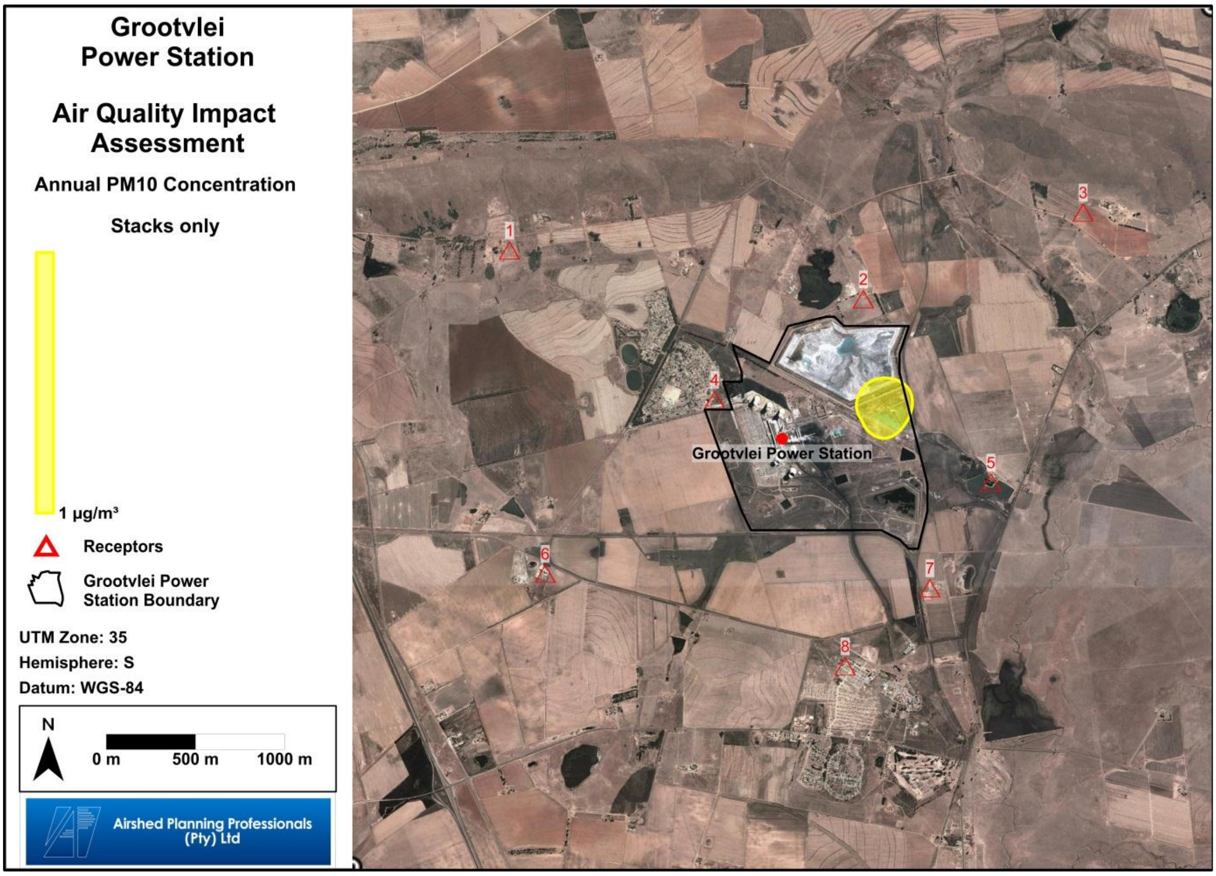

Figure 4-4: Annual predicted GLC for PM_{10} (stacks only after FFP retrofit at units 2, 3 and 4). Sensitive receptors shown on the plot are as follows: 1 – farm house; 2 – farm house; 3 – farm house; 4 - GVPS residential; 5 – farm house; 6 – farm house; 7 – farm house; 8 – Grootvlei.

4.2.3 Compliance Assessment of Predicted Impacts

4.2.3.1 Inhalable Particulate Matter of less than 10 µm (PM_{10})

Predicted PM_{10} ground level concentrations at sensitive receptors included in the study area are presented in Table 4-5 and illustrated in Figure 4-1 to Figure 4-4. The predicted PM_{10} impacts at the sensitive receptors (due to current power station stack releases, existing ash dam operations and proposed ash dam operations only) are within the NAAQS. The percent decrease in PM_{10} GLC's originating from the stacks is shown in Table 4-6. It should be noted that the frequency of exceedance of the daily NAAQS due to all sources (i.e. to power station stack releases, existing ash dam and coal stockpile operations only) does not vary significantly in spatial distribution from current to proposed operations due to the decrease (through retrofit procedure) of the stack particulate releases.

Table 4-5: Predicted PM_{10} GLC's and Frequencies of exceedance at sensitive receptors after retrofitting procedure (all sources [(a)])

Scenario	Sensitive Receptor	Frequency of Exceedance of daily PM_{10} NAAQ limit applicable immediately till 31 December 2014	Frequency of Exceedance of daily PM_{10} NAAQ limit applicable 1 January 2015	Annual Average Concentration ($\mu g/m^3$)[(a)]	Within PM_{10} NAAQS applicable immediately till 31 December 2014	Within PM_{10} NAAQS applicable from 1 January 2015
Unit 2, 3 & 4 Retrofitted	1 – Farm house	0	0	0.58	Y	Y
	2 – Farm house	0	1	1.27	Y	Y
	3 - Farm house	0	0	0.62	Y	Y
	4 - GVPS residential	1	2	5.24	Y	Y
	5 – Farm house	0	0	2.12	Y	Y
	6 – Farm house	0	0	0.96	Y	Y
	7 – Farm house	0	0	3.05	Y	Y
	8 - Grootvlei	1	1	3.47	Y	Y

a) Windblown dust from the coal stockpile and ash dam as well as the Grootvlei Power Station stacks

Table 4-6: Percent decrease in annual PM_{10} GLC's after the retrofit procedure

Location	After FFP Retrofit at Units 2, 3 and 4 (Reduction Percentage in annual PM_{10} GLC's)	
	All Sources [(b)]	Stacks
Study Area Median[(a)]	**65%**	**72%**
1 – Farm house	61%	72%
2 – Farm house	60%	74%
3 - Farm house	67%	72%
4 - GVPS residential	56%	75%
5 – Farm house	63%	73%
6 – Farm house	70%	73%
7 – Farm house	58%	73%
8 - Grootvlei	56%	73%

a) Median value was used as distribution of predicted concentrations over 3 years is not a normal distribution; therefore using the average is not an accurate representation.

b) Windblown dust from the coal stockpile and ash dam as well as the Grootvlei Power Station stacks

4.2.3.2 Cumulative Impacts for Inhalable Particulate Matter of less than 10 µm (PM_{10})

The Grootvlei Power Station falls within the Highveld Priority Area. The management plan objectives for this priority area are to consider the reduction of baseline concentrations in order to make room for new development.

In assessing the cumulative PM_{10} impacts, reference is made to the data provided from the Grootvlei monitoring station for the period 2009 to 2010. The modelled PM_{10} predictions (which excluded the mining operations and domestic fuel burning operations) as provided in the Highveld Priority Area Management Plan consistently under-predicted measured PM_{10} concentrations (DEA, 2011) and were thus not used for the estimation of cumulative PM_{10} impacts.

Based on measured daily PM_{10} concentrations at Grootvlei monitoring station, it is likely that PM_{10} concentrations will be in non-compliance with daily PM_{10} NAAQS (applicable 1 January 2015) at this sensitive receptor (located to the west of the Grootvlei Power Station) due to elevated background PM_{10} levels (even though PM_{10} emissions due to the FFP retrofit at units 2, 3 and 4 decreases from the current Grootvlei Power Station operations).

It is recommended that monitored PM_{10} concentrations at Grootvlei be continued to understand Grootvlei Power Station contributions to PM_{10} impacts after the FFP retrofit at units 2, 3 and 4.

5 AIR QUALITY MANAGEMENT PLAN

An air quality impact assessment was conducted for the proposed Grootvlei Power Station FFP retrofit at units 2, 3 and 4. The main objective of this study was to determine the significance of the predicted impacts from the proposed FFP retrofit on the surrounding environment and on human health.

5.1 Site Specific Management Objectives

The main objective of air quality management measures is to ensure that the FFP retrofit at units 2, 3 and 4 will be within National Ambient Air Quality Standards and the Minimum Emission Standards. From the assessment PM_{10} emissions after FFP retrofit at units 2, 3 and 4 is within the Minimum Emission Standards, with predicted ground level concentrations from the boilers being below NAAQS.

5.2 Project-specific Management Measures

5.2.1 Mitigation Measures

5.2.1.1 Proposed FFP Technology

Primary kinds of particulate control used for coal combustion, according to the Air Pollution Engineering Manual (AWMA, 2000), include multiple cyclones, ESPs, fabric filters and venture scrubbers. The type of technology is guided by the type of furnace, coal properties and operating conditions. In the USA, ESPs were the preferred technology for emissions control in the 1970's. Due to significant progress in the recent years in the design and operation of fabric filter collectors, specifically for the collection of coal fly ash, these have become more popular for use in coal-fired power stations (AWMA, 2000).

Whereas ESPs remove particles from the gas stream through electrical forces, fabric filters remove dust by passing the gas stream through porous fabric. The affectivity of dust removal by bag filters is dependent on the design parameters. Bag filter designs are usually either reverse-air or pulse-jet types. The latter, as the option considered by the Grootvlei Power Station, removes the particles by sending a pulsed jet of compressed air into the bag, resulting in an effective way of cleaning (AWMA, 2000).

Bag filters in general, have a higher removal efficiency for fine, submicrometer particles than ESPs (AWMA, 2000).

According to the information provided by Eskom, the FFP is given to limit particulate emissions to 40 mg/Nm³.

5.2.1.2 Relation of FFP to World-Wide Best Practice

Best Available Techniques (BAT) according to the Integrated Pollution Prevention and Control (IPPC, 2004) on Large Combustion Plants includes either ESPs of FFPs. It states that particulate emission control of less than 20 mg/Nm³ can be achieved for coal and lignite plants of more than 300 MWth through ESPs and/ or FFPs.

The IPPC confirms that FFPs achieve higher control efficiencies on the removal of small particles (i.e. 99.6% on particles <1 μm) than ESPs (i.e. 96.5% on particles <1 μm). Both technology options can achieve 99.95% removal of particles larger than 10 μm (IPPC, 2004).

The World Bank emission limits for Boilers (Solid Fuels Plant >/=600 MWth) in degraded areas is 30 mg/Nm³ (IFC, 2008). The South African Minimum Emission Limits are however based on international best practice and applied. The FFP should therefore achieve as a minimum, 50 mg/Nm³.

5.2.2 Monitoring

The Minimum Emission Standards require continuous stack emissions for Combustion Installations with design capacity of equal to or greater than 50 MW heat input per unit.

Table 5-1: Recommended source based performance indicators

Source	Emission Monitoring	Quality Assurance
Boilers	*Continuously* monitor PM_{10}, SO_2 and NO_x emissions by means of online stack monitoring. These continuous measurements will provide a solid foundation for minimum emission standards compliance assessment. A contractor can be used for this purpose.	The emissions monitoring system must be maintained to yield a minimum of 80% valid hourly average values during the reporting period. No more than five half-hourly average values in any day, and ten daily average values per year, may be disregarded due to malfunction or maintenance. Continuous monitoring systems must be audited by a SANAS accredited laboratory at least once every two years.

5.2.2.1 Receptor based Performance Indicators

Monitoring Network

A ambient monitoring network provides management with an indication of what the increase (or decrease) in GLC's and dust-fall out is. In addition, a monitoring network 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 trend analysis;
- Spatial trend analysis;
- Source quantification; and
- Tracking progress made by control measures.

PM_{10} ambient monitoring is currently undertaken at the residential area just west of the Grootvlei Power Station. The measured PM_{10} data from this monitoring site will provide a good understanding of baseline PM_{10} ground level concentrations before FFP retrofit at units

2, 3 and 4 and changes to PM_{10} ambient levels after FFP retrofit at units 2, 3 and 4. It is therefore recommended that the operation of this monitoring station be continued.

6 CONCLUSIONS AND RECOMMENDATIONS

The main findings from the baseline assessment were as follows:

- The main sources likely to contribute to cumulative PM_{10} impact in the vicinity of Grootvlei Power Station are surrounding agricultural activities, biomass burning, domestic fuel burning as well as vehicle entrainment on unpaved road surfaces.

- The nearest sensitive receptors to the Grootvlei Power Station are the town of Grootvlei and the surrounding settlements (including farm houses), some of which are located ~1 km from the Grootvlei Power Station.

- Eskom operates an ambient monitoring station at the Grootvlei town just west of the Grootvlei monitoring station. The annual average PM_{10} ground level concentrations for the period January 2009 to December 2010 was 16.3 µg/m³.

The main findings from the impact assessment due to current operations proposed FFP retrofit at units 2, 3 and 4 were as follows:

- The predicted PM_{10} impacts at the closest sensitive receptors (due to current and future power station stack releases, existing ash dam operations and coal stockpile operations only) were within the NAAQS.

- The fabric filter plant retrofit at units 2, 3 and 4 will result in the predicted annual ground level concentration (GLC) of particulate matter from Grootvlei's stacks alone being reduced by 73%. Before and after the retrofit the annual ground level concentrations (GLC) (due to stack emissions only) was predicted to be a maximum of 4 µg/m³ and 1.08 µg/m³ respectively.

- The predicted annual PM_{10} ground level concentrations at the closest sensitive receptor (due to all power station sources) are 9% and 5% of the annual PM10 National Ambient Air Quality Standards (applicable in 2015) before and after the retrofit respectively. The predicted annual PM_{10} ground level concentrations at the closest sensitive receptor (due to all power station sources) are 7% and 4% of the annual PM_{10} National Ambient Air Quality Standards (applicable immediately till 31 December 2014) before and after the retrofit respectively.

6.1 Recommendations

In light of the findings it was recommended that air quality management measures (as stipulated in Section 5) for the FFP retrofit at units 2, 3 and 4 be implemented to ensure the lowest possible impacts on the surrounding environment from the proposed FFP retrofit and that the FFP retrofit be conducted, given the positive impact on ambient air quality.

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APPENDIX A: EMISSION FACTORS AND EQUATIONS

Wind Erosion

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

An hourly emissions file was created for the ash dam as well as the coal stockpile. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface.

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are as follows:

$$E(i) = G(i)10^{(0.134(\%clay)-6)}$$

for

$$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$

and $$R = \frac{u_*^{\ t}}{u^*}$$

where,

$E_{(i)}$	=	emission rate (g/m²/s) for particle size class i
P_a	=	air density (g/cm³)
g	=	gravitational acceleration (cm/s³)
$u_*^{\ t}$	=	threshold friction velocity (m/s) for particle size i
u^*	=	friction velocity (m/s)

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure A-1.

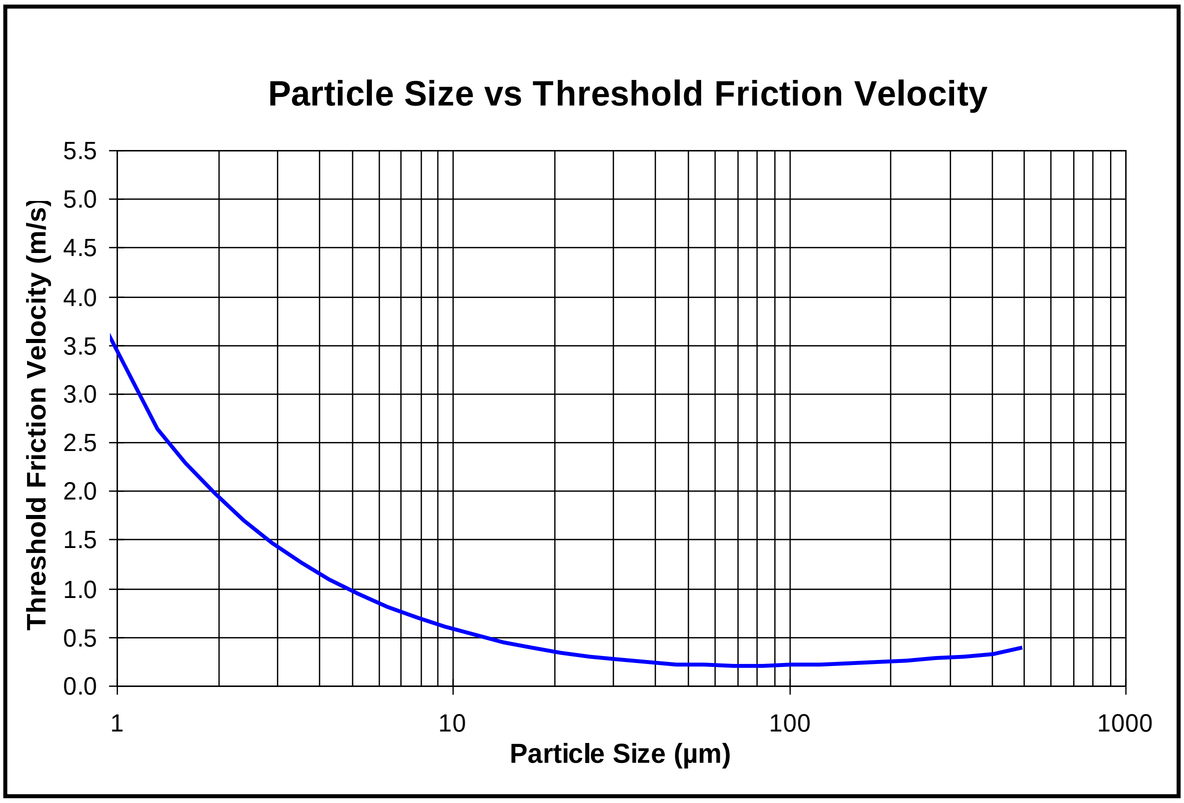

Figure A-1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995)