ANNEXURE C

ATMOSPHERIC IMPACT REPORT
In support of

Eskom's application for postponement of the Minimum Emission Standards compliance timeframes for the Grootvlei Power Station

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EXECUTIVE SUMMARY

Eskom's coal-fired Grootvlei Power Station in Mpumalanga Province has a total installed capacity of 1 150 MW. Grootvlei. Power generation is a Listed Activity in terms of Section 21 of the NEMAQA and Grootvlei should comply with the prescribed Minimum Emission Standards (MES) for existing plants by 2015 and for new plants by 2020. Grootvlei currently does not comply with any of the 'existing plant' or 'new plant' MES limits. Due to water resource, financial and electricity supply capacity constraints (presented in more detail in this document and supporting Annexures), Eskom's Grootvlei Power Station will not be able to comply with either the 'new plant' or continuously with the 'existing plant' MES for Sulphur dioxide (SO_2) nor for Nitrogen oxides (NO_x). Grootvlei Power Station will also not be able to comply with the 'new plant' MES for Particulate Matter (PM), however it will be able to comply with the 'existing plant' limit once the Fabric Filter Plant (FFP) retrofit is complete. This will not be completed by the April 2015 timeframe stipulated in the MES, however. The inability to comply with the MES exists despite the transitional provisions contained in GNR 893 and is unlikely to change in the foreseeable future. As such, Eskom with this Application is applying for postponement of MES limits for NO_x, SO_2, and PM, and proposed alternative emissions limits that are achievable but less stringent than the 'new plant' standards. The purpose of this AIR has been to assess the likely implications of the postponement and the requested alternative emissions limits for human health and the environment.

An assessment of monitored ambient air quality data at the Grootvlei monitoring station reveals that although SO_2 loading is elevated, there is compliance with the National Ambient Air Quality Standards (NAAQS). Although there are exceedances of the hourly ambient limit value for SO_2, there is still compliance with the SO_2 NAAQS. Exceedances of the ten-minute limit values may have occurred, but 10-minute data is not logged. Ambient daily PM_{10} concentrations indicate sustained high loading and exceedance of the daily average NAAQS. Analysis of diurnal data shows that the Grootvlei Power Station does not contribute significantly to ambient PM_{10} and that the exceedances derive from ground level emissions such as domestic fuel use. Maximum hourly ambient NO_2 averages are seen to be well below the hourly limit and the annual averages are also seen to be well below the NAAQS.

Dispersion modelling indicates that Eskom's requested emission limits for NO_X for Grootvlei Power Station pose no risk of exceedance of the NAAQS. There is also predicted to be no risk of non-compliance as a result of Eskom's requested emission limits for SO_2 over most of the domain, although predicted marginal non-compliance with the daily SO_2 NAAQS is predicted in the immediate vicinity of Grootvlei Power Station, if Grootvlei emits continuously at the requested emission limit. In all probability this will not occur, however, as actual SO_2 emissions in future will be similar to current emission levels, an average 30-40% below the requested emission limit. It is thus likely that there will still be compliance with the SO_2 NAAQS if Grootvlei operates according to the requested SO_2 emission limit. Current and future Particulate emissions from the power station contribute only marginally to the measured ambient concentrations.

The implication is that areas of full compliance with the SO_2, NO_x and PM_{10} NAAQS are deemed not to be free of health risks necessarily but the health risks are considered to be permissible.

LIST OF ACRONYMS

µm	1 µm = 10^{-6} m
AEL	Atmospheric Emission License
AIR	Atmospheric Impact Report
APPA	Atmospheric Pollution Prevention Act, 1965 (Act No. 45 of 1965)
AQMP	Air Quality Management Plan
BID	Background Information Document
DEA	Department of Environmental Affairs
DoE	Department of Energy
ESP	Electrostatic precipitator
FFP	Fabric Filter Plant
FGD	Flue gas desulphurisation
IRP	Integrated Resource Plan
LNB	Low NO_x Burner
LPG	Liquid Petroleum Gas
NAAQS	National Ambient Air Quality Standards
NEMAQA	National Environment Management: Air Quality Act, 2004 (Act No. 39 of 2004)
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen (NO_X = NO + NO_2)
OFA	Overfire Air
PM	Particulate Matter
PM_{10}	Particulate Matter with a diameter of less than 10 µm
$PM_{2.5}$	Particulate Matter with a diameter of less than 2.5 µm
SO_2	Sulphur Dioxide
TSP	Total Suspended Particulates
WHO	World Health Organisation

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1. Enterprise Details

1.1 Enterprise Details

Entity details for Eskom's Grootvlei Power Station are listed in Table 1.

Table 1: Enterprise details

Entity Name:	Eskom Holdings SOC Limited
Trading as:	Grootvlei Power Station
Type of Enterprise, e.g. Company/Close Corporation/Trust, etc.:	State owned company
Company/Close Corporation/Trust Registration Number (Registration Numbers if Joint Venture):	2002/015527/06
Registered Address:	Megawatt Park, Maxwell Drive, Sunninghill, Sandton
Postal Address:	Private Bag X2016, Standerton, 2430
Telephone Number (General):	(017) 749 9111
Fax Number (General):	(017) 749 5736
Company Website:	www.eskom.co.za
Industry Type/Nature of Trade:	Coal-fired power stations that generate electricity. Listed activity (Sub-category 1.1) in terms of the NEMAQA (Section 21), i.e. combustion installations using solid fuels (excluding biomass) primarily for steam raising or electricity generation (DEA, 2013).
Land Use Zoning as per Town Planning Scheme:	Agricultural/Heavy industry
Land Use Rights if outside Town Planning Scheme:	-
Responsible Person:	Gersh Bonga
Emissions Control Officer:	Gersh Bonga
Telephone Number:	017 779 8641
Cell Phone Number:	082 965 8177
Fax Number:	017 779 0021
Email Address:	BongaMG@eskom.co.za
After Hours Contact Details:	082 965 8177

1.2 Location and extent of the Plant

Grootvlei Power Station is located 15 km southwest of Balfour in the Mpumalanga Province (Figure 1). Site information is provided in Table 2 and the relative location to key landmarks is shown in Figure 2.

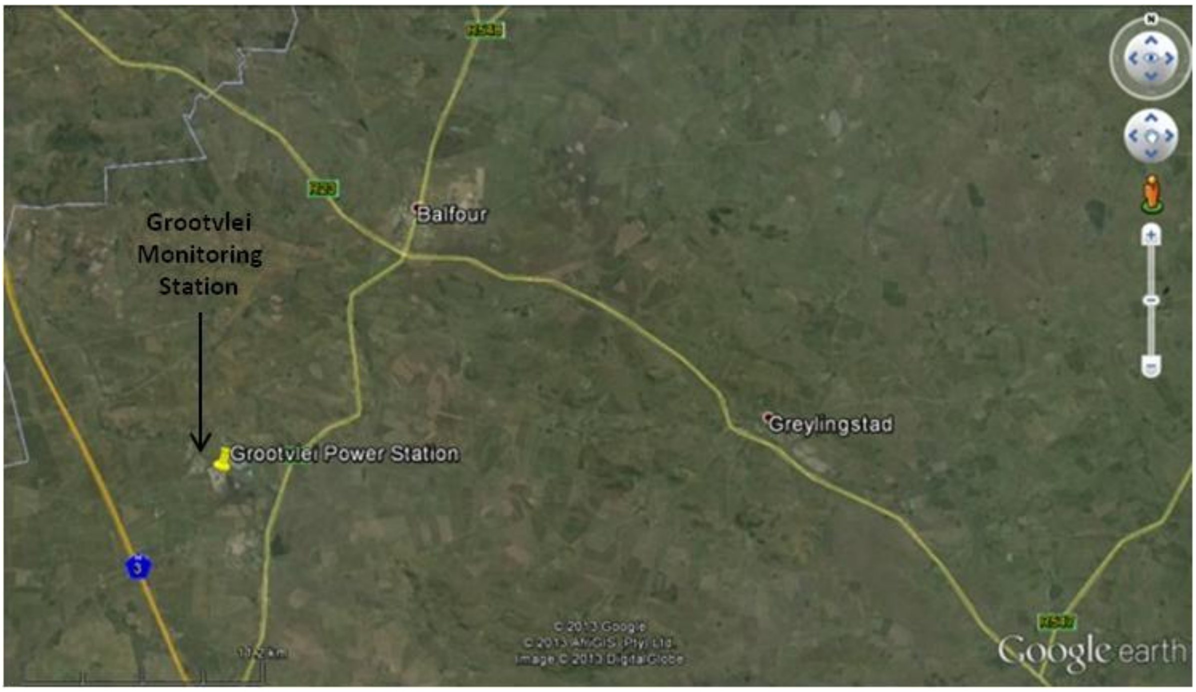
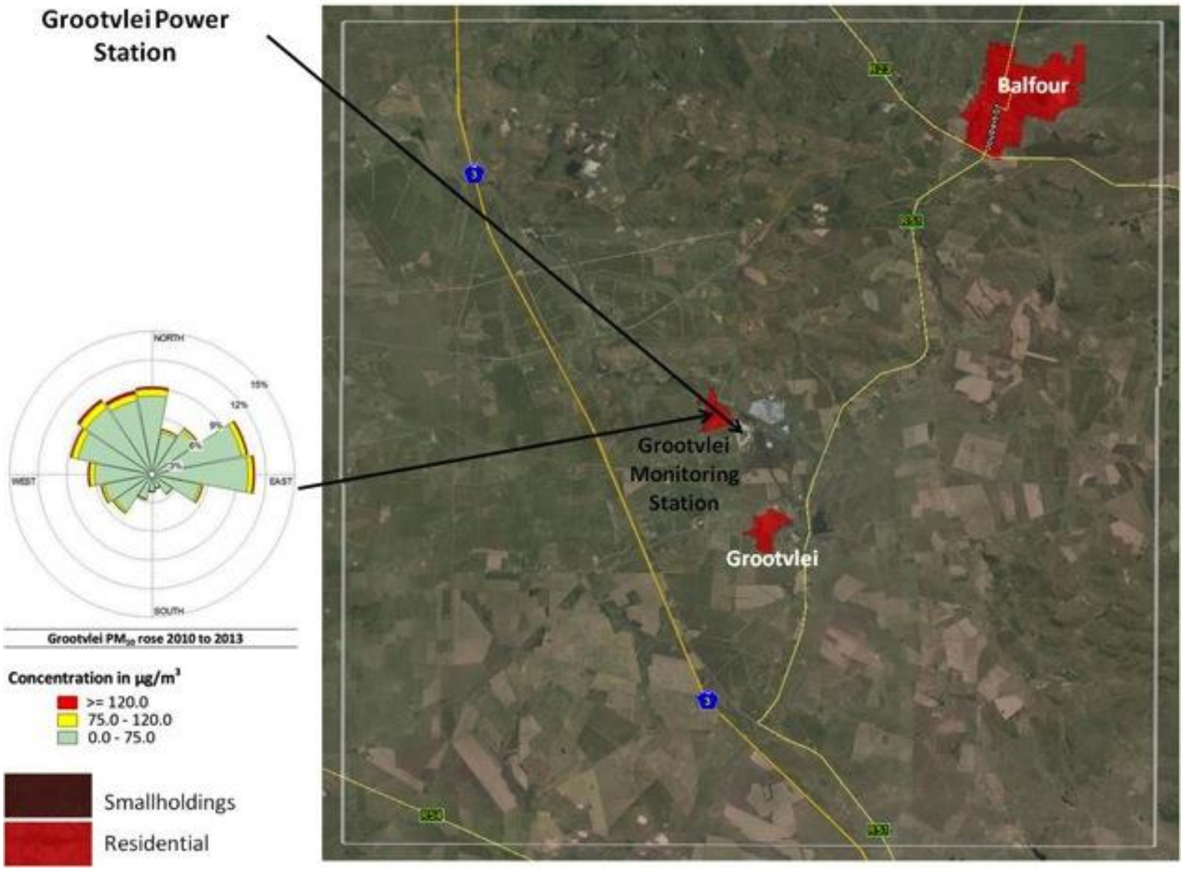


Figure 1: Relative location of the Grootvlei Power Station (Google Earth, 2013)

Table 2: Site information

Physical Address of the Plant (Licenced Premises):	Grootvlei Power Station, Farm Panfontein 452IR)
Description of Site (Where No Street Address):	Grootvlei Power Station, Farm Panfontein 452IR)
Coordinates (latitude, longitude) of Approximate Centre of Operations (Decimal Degrees):	26º46'13, 87'"" S 28º29'43, 95" E
Coordinates (UTM) of Approximate Centre of Operations:	648734 E 7 038 298 S
Extent (km²):	5.28
Elevation Above Mean Sea Level (m)	1 571
Province:	Mpumalanga
District/Metropolitan Municipality:	Gert Sibande District Municipality
Local Municipality:	Dipaleseng Local Municipality
Designated Priority Area (if applicable):	Highveld Priority Area



Receptor	Distance (km)	Direction
Grootvlei	3	S
Balfour	13	NE
Residential area	0.5	NW
Agricultural land	Immediate	Surrounding

Figure 2: Land-use and sensitive receptors within a 30x30 km block of the Grootvlei Power Station (shown by the white square)

1.3 Atmospheric Emission License and Other Authorisations

An APPA Registration Certificate (No. 242/2) was issued to Grootvlei Power Station by the Chief Air Pollution Control Officer (CAPCO) on 6 November 2009, in terms of Section 10 of the Atmospheric Pollution Prevention Act, 1965 (Act No. 45 of 1965) (APPA) for electricity production and bulk storage of coal. This certificate is valid until 1 April 2014 in terms of the transitional arrangements in the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) (NEMAQA). An application for an Atmospheric Emission Licence (AEL) was submitted, but an AEL has not yet been issued by the authorities.

The Registration Certificate specifies permissible stack emission concentrations for Particulate Matter, Sulphur dioxide (SO_2) and oxides of Nitrogen (NO_X). The Registration Certificate specifies a number of compliance conditions as well as conditions for emission monitoring, management of abnormal releases and management of fugitive dust resulting from coal handling and storage.

The current governmental authorisations, permits and licenses related to air quality management is provided in Table 3.

Table 3: Current government authorisations related to air quality

APPA Registration Certificate Number:	Date of Registration Certificate:	Scheduled Process Number:	Scheduled Process Description:
242/2	06/11/2009	No. 29	Power generation processes
		No. 59	Bulk storage and handling of ore or coal

1.3.1 Minimum Emission Standards

In terms of NEMAQA, all of Eskom's coal- and liquid fuel-fired power stations are required to meet the Minimum Emission Standards (MES) contained in GNR 893 on 22 November 2013 ("GNR 893") promulgated in terms of Section 21 of the NEMAQA. GNR 893 does provide for transitional arrangements in respect of the requirement for existing plants to meet the MES and provides that less stringent limits must be achieved by existing plants by 1 April 2015, and the more stringent ‘new plant’ limits must be achieved by existing plants by 1 April 2020. The MES are listed in Table 4.

Table 4: Minimum Emission Standards for combustion installations (Category 1) using solid fuel for electricity generation (Sub-category 1.1) with a design capacity equal or greater to 50 MW heat input per unit

Substance	Plant status	MES mg/Nm^3 under normal conditions of 10% O_2, 273 K and 101.3 kPa
Particulate Matter	New	50
	Existing	100
Sulphur dioxide	New	500
	Existing	3 500
Oxides of nitrogen	New	750
	Existing	1 100

1.3.2 National Ambient Air Quality Standards (NAAQS)

The effects of air pollutants on human health occur in a number of ways with short-term, or acute effects, and chronic, or long-term, effects. Different groups of people are affected differently, depending on their level of sensitivity, with the elderly and young children being more susceptible. Factors that link the concentration of an air pollutant to an observed health effect are the concentration and the duration of the exposure to that particular air pollutant.

Criteria pollutants occur ubiquitously in urban and industrial environments. Their effects on human health and the environment are well documented (e.g. WHO, 1999; 2003; 2005). South Africa has accordingly established National Ambient Air Quality Standards (NAAQS) for the criteria pollutants, i.e. sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), respirable particulate matter (PM_{10}), ozone (O_3), lead (Pb) and benzene (C_6H_6) (DEA, 2009) and $PM_{2.5}$ (DEA, 2012a). The NAAQS for SO_2, NO_2, PM_{10} and $PM_{2.5}$ are listed in Table 5.

The NAAQS consists of a ‘limit’ value and a permitted frequency of exceedance. The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant. The permitted frequency of exceedance represents the acceptable number of exceedances of the limit value expressed as the 99th percentile. Compliance with the ambient standard implies that the frequency of exceedance of the limit value does not exceed the permitted tolerance. Being a health-based standard, ambient concentrations below the standard imply that air quality poses an acceptable risk to human health, while exposure to ambient concentrations above the standard implies that there is an unacceptable risk to human health.

Table 5: National Ambient Air Quality Standards for SO_2, NO_2 and PM_{10} (DEA, 2009) and $PM_{2.5}$ (DEA, 2012a). Because the applications apply to regulations that commence in 2015, the 2015 and 2016 standards are deemed to apply.

Pollutants	Averaging period	Limit value (µg/m^3)	Number of permissible exceedances per annum
SO_2	1 hour	350	88
	24 hour	125	4
	1 year	50	0
NO_2	1 hour	200	88
	1 year	40	0
PM_{10}	24-hour	120 (75[1])	4
	Calendar year	50 (40[1])	0
$PM_{2.5}$	24-hour	65 (40[2]) (25[3])	4
	Calendar year	25 (20[2]) (15[3])	0

1: Implementation date 1 January 2015
2: Implementation date 1 January 2016
3: Implementation date 1 January 2030

2. Nature of the Process

2.1 Listed Activity or Activities

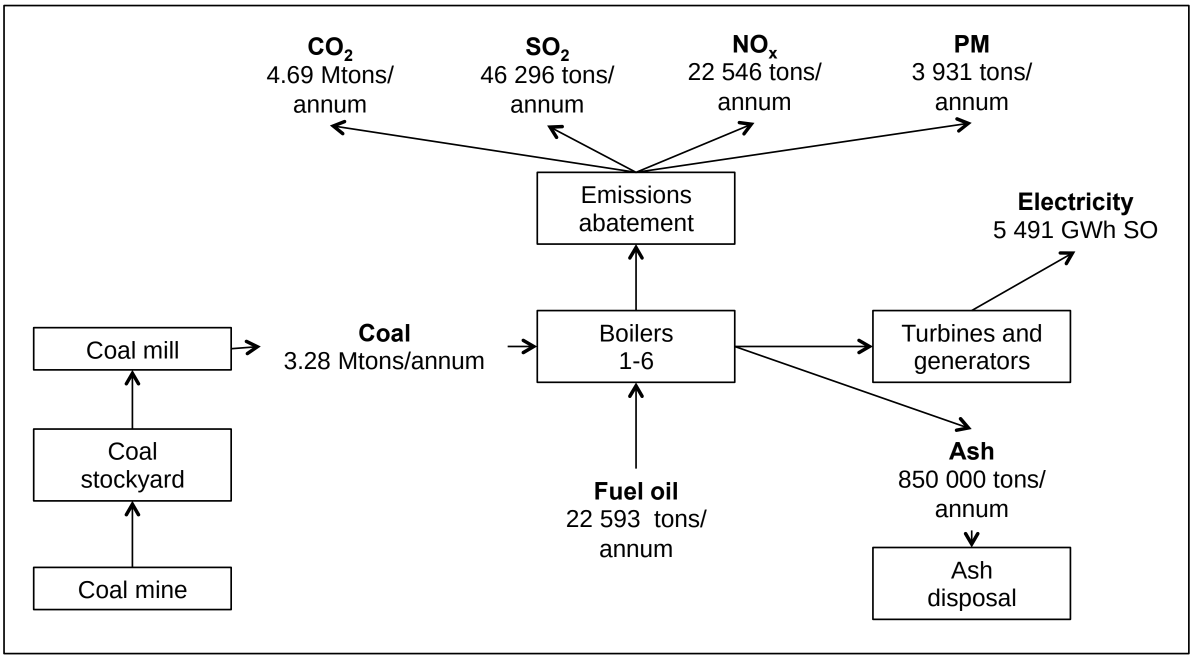
Table 6: Activities listed in GN 893 which are 'triggered' by the Grootvlei Power Station.

Category of Listed Activities	Sub-category of the Listed Activity	Description and Application of the Listed Activity
1: Combustion Installations	1.1: Solid Fuel Combustion Installations	Solid fuels combustion installations used primarily for steam raising or electricity generation. 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.
2: Petroleum Industry, the production of gaseous and liquid fuels as well as petrochemicals from crude oil, coal, gas or biomass	2.4: Storage and Handling of Petroleum Products	All permanent immobile liquid storage facilities at a single site with a combined storage capacity of greater than 1000 cubic metres.
5: Mineral Processing, Storage and Handling	5.1 Storage and Handling of Ore and Coal	Storage and handling of ore and coal not situated on the premises of a mine or works as defined in the Mines Health and Safety Act 29/1996.

2.2 Process Description

Eskom Holdings SOC Limited is a South African utility that generates, transmits and distributes electricity. The bulk of that electricity is generated by large coal-fired power stations that are situated close to the sources of coal, with most of the stations occurring on the Mpumalanga Highveld. The Grootvlei coal-fired Power Station is located in the Mpumalanga Province (Figure 1). It has a total installed capacity of 1150 MW, generated in 6 units.

At Grootvlei, and indeed all the coal-fired power stations, pulverised coal is combusted in order to heat water in boilers to generate steam at high temperatures (between 500°C and 535°C) and pressures. The steam, in turn, is used to drive the turbines, which are connected, to rotating magnets and electricity is generated. The energy in the fuel (coal) is thus converted to electricity (Figure 3).



Figures based on 2012/2013 financial year
Coal figures include mill discards, and are based on coal that is moved from the stockyard to the mill

Figure 3: A basic atmospheric emissions mass balance for Grootvlei Power Station showing the key inputs and outputs. Note that all quantities are expressed in tonnes per annum unless otherwise stated.

Grootvlei Power Station receives coal from the mine. The coal is conveyed from the mine to the coal stockyard on site where it is milled to pulverised fuel and fed to the nine boilers. Combustion of the coal in the boilers heats water to superheated steam, which drives the turbines. In turn, the turbines drive the generators which generate electricity. By-products from coal combustion include SO_2, NO_X and Particulate Matter. A detailed description of the process is contained in the assessment of technology options for Eskom's coal fired power stations (Appendix B).

2.2.1 Atmospheric emissions resulting from power generation

Atmospheric emissions depend on the fuel composition and rate of consumption, boiler design and operation, and the efficacy of pollution control devices. Emissions from Grootvlei include Sulphur dioxide (SO_2), oxides of Nitrogen ($NO + NO_2 = NO_X$) and Particulate Matter (PM).

SO_2 is produced from the combustion of sulphur bound in coal. The stoichiometric ratio of SO_2 to sulphur dictates that 2 kg of SO_2 are produced from every kilogram of sulphur combusted. The coal used by the Grootvlei has a sulphur content (wt %) of less than 1.2 %. NO_X is produced from thermal fixation of atmospheric nitrogen in the combustion flame and from oxidation of nitrogen bound in the coal. The quantity of NO_X produced is directly proportional to the temperature of the flame.

The non-combustible portion of the fuel remains as solid waste. The coarser, heavier waste is called 'bottom ash' and is extracted from the boiler, and the lighter, finer portion is 'fly ash' and is usually suspended in the flue gas, and in the absence of any emission control would be emitted as PM through the stack. The coal used at Grootvlei has an ash content of less than 33%.

2.3 Unit Processes

A summary of the different unit process is provided in Table 7. The relative location of these is shown in Figure 4.

Table 7: Unit processes at Grootvlei Power Station

Unit Process	Function of Unit Process	Batch or Continuous Process
Boiler Unit 1	Power generation process	Continuous
Boiler Unit 2	Power generation process	Continuous
Boiler Unit 3	Power generation process	Continuous
Boiler Unit 4	Power generation process	Continuous
Boiler Unit 5	Power generation process	Continuous
Boiler Unit 6	Power generation process	Continuous
Coal stockpile	Storage of coal	Continuous
Fuel oil storage tanks	Storage of fuel oil	Continuous

Figure 4: Relative location of the different process units at Grootvlei Power Station

3. Technical Information

3.1 Raw Materials Used

The permitted raw materials consumption rate, the permitted production rates and the energy sources at Grootvlei Power Station are listed in Tables 8 to 10 according to the Registration Certificate.

Table 8: Raw material used at Grootvlei Power Station

Raw material	Maximum permitted consumption rate (Volume)	Units (quantity / period)
Coal	500 000	tons/month
Fuel oil	6 000	tons/month

Table 9: Production rates at Grootvlei Power Station

Product/by-product	Maximum Production capacity permitted (Volume)	Units (quantity / period)
Electricity	1 200	MW
Ash	175 000	tons/month

Table 10: Energy sources used at Grootvlei Power Station

Energy source	Sulphur content of fuel (%)	Ash content of fuel (%)	Maximum permitted consumption rate (Volume)	Units (quantity / period)
Coal	1.49	30-35	500 000	tons/month
Fuel oil	NA	NA	6 000	tons/month

3.2 Appliances and Abatement Equipment Control Technology

Abatement equipment control technology at Grootvlei is presented in Table 11. It should be noted that the abatement equipment is only for the control of PM emissions. Neither NO_x nor SO_2 emissions are controlled directly at the power station.

Table 11: Appliance and abatement equipment control technology currently used at Grootvlei Power Station.

Appliance Name	Appliance Type/ Description	Appliance Function / Purpose
Units 1, 5, 6: Pulse Jet Fabric Filter Plant	Pulse Jet Fabric Filter Plant	Removes fly ash from the gas stream (i.e. reduces PM load)
Units 2, 3, 4: Electrostatic Precipitators (ESPs)	Electrostatic Precipitator (ESPs)	An ESP removes particles from the flue stream using the force of an induced electrostatic charge on the ash particle that is then attracted to and held on a plate. The efficiency of ESPs is dependent on the electrical resistivity of the ash particles (and the particle size). SO_3 injection decreases the resistivity of the particles, and significantly improves the performance of the ESP.
Units 2, 3, 4: SO_3 plant (i.e. Flue Gas Conditioning Plant)	SO_3 Injection	

4. Atmospheric emissions

4.1 Point source parameters

The physical data for the stacks at Grootvlei Power Station are listed in Table 12. Emission concentrations and emission rates for current production and proposed operational levels are shown in Table 13. The boiler units operate continuously, i.e. 24 hours a day.

Table 12: Point sources at Grootvlei Power Station

Point Source Code	Source name	Latitude (UTM) (m)	Longitude (UTM) (m)	Height of Release Above Ground (m)	Height above nearby building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temp (^0C)	Actual stack gas volumetric flow (m^3/s)	Actual Gas Exit Velocity (m/s)	Type of emission (continuous/ batch)
Stack 1	Boiler unit 1 Boiler unit 2 Boiler unit 3	648888.00 E	7038364.00 S	152	85.5	8.99*	140	1243	19.57	Continuous
Stack 2	Boiler unit 4 Boiler unit 5 Boiler unit 6	648924.00 E	7038251.00 S	152	85.5	8.99*	140	1243	19.57	Continuous

* Diameter of combined stack.

4.2 Point source maximum emission rates (normal operating conditions)

Table 13: Current emission limits under normal operating conditions at Grootvlei Power Station

Point source number	Point source name (as in paragraph 4.1. above)	Pollutant name	Maximum emission rate		Duration of emissions
			(mg/Nm^3)	Averaging period	
Stack 1	Boiler units 1-3	SO_2	4 000	Monthly	Continuous
		NO_x	1 700	Monthly	Continuous
		PM	100*/200**	Monthly	Continuous
Stack 2	Boiler units 4-6	SO_2	4000	Monthly	Continuous
		NO_x	1700	Monthly	Continuous
		PM	100*/200**	Monthly	Continuous

** May be exceeded for 90 hours/stack/month*

*** Cap limit: Station should take a load loss or shut down to avoid exceeding the cap limit*

4.3 Point source maximum emission rates (start-up, shut-down, upset and maintenance conditions)

Grootvlei Power Station maintains a record of all start-ups that occur, as well as the type of start-up. Full details of these for the years 2010 – 2013 are provided in Table 14.

Table 14: Start-ups at Grootvlei Power Station for the period 2010 to 2013.

Month	Number of Start-ups	Type of Start-up	Month	Number of Start-ups	Type of Start-up	Month	Number of Start-ups	Type of Start-up	Month	Number of Start-ups	Type of Start-up
2010			2011			2012			2013		
April	8	Hot	January	4	Hot	January	2	Cold	January	2	Warm
April	1	Cold	January	2	Cold	January	6	Hot	January	2	Cold
April	3	Warm	February	1	Cold	February	3	Hot	January	1	Hot
May	5	Cold	February	1	Warm	February	2	Cold	February	1	Hot
May	4	Warm	February	1	Hot	February	3	Warm	February	1	Warm
May	1	Hot	March	3	Hot	March	3	Hot	February	1	Cold
June	2	Cold	March	3	Cold	March	3	Cold	March	3	Warm
June	3	Hot	March	2	Warm	March	1	Warm	March	5	Hot
July	3	Cold	April	3	Hot	April	3	Warm	March	2	Cold
August	1	Cold	April	4	Warm	April	5	Hot	April	4	Hot
August	5	Hot	April	1	Cold	April	4	Cold	April	4	Cold
August	1	Warm	May	3	Warm	May	5	Cold	May	2	Hot
September	2	Warm	May	1	Hot	May	3	Hot	May	2	Cold
September	4	Hot	June	5	Hot	June	1	Cold	June	5	Hot
September	3	Cold	June	2	Warm	June	2	Hot	June	1	Warm
October	3	Cold	July	2	Warm	July	3	Cold	June	2	Cold
October	1	Warm	July	3	Hot	July	2	Warm	July	3	Cold
October	3	Hot	July	2	Cold	July	3	Hot	July	1	Warm
November	3	Hot	August	1	Warm	August	1	Cold	July	2	Hot
November	2	Cold	August	2	Cold	August	1	Warm	August	5	Hot
November	2	Warm	August	6	Hot	September	2	Warm	August	3	Warm
December	6	Hot	September	4	Cold	September	4	Hot	August	1	Cold
			September	2	Warm	September	4	Cold	September	1	Cold
			September	6	Hot	October	3	Hot	September	2	Warm
			October	3	Hot	October	2	Cold	September	5	Hot
			October	2	Cold	October	2	Warm			
			October	3	Warm	November	2	Hot			
			November	1	Warm	November	1	Warm			
			November	4	Hot	November	2	Cold			
			November	1	Cold	December	1	Cold			
			December	4	Cold	December	3	Hot			
			December	5	Hot						

A hot start follows an off-load period of less than 8 hours.
A warm start follows an off-load period of between 8 and 30 hours.
A cold start follows an off-load period of more than 30 hours.

At times, power stations can experience upset conditions, or conditions which differ to normal operations. A record is kept of all upset conditions which the power station experiences. Details of these are provided in Table 15.

Table 15: Upset Conditions experienced at Grootvlei Power Station

Station	Date of event	Description
Grootvlei North and South stacks	July 1 2012 – FFP retrofit	Grootvlei is unable to comply with the particulate emission limits because the coal is much worse that the station is designed to burn.
Grootvlei North Stack	March 25 2013	Precip problems on unit 2 and SO_3 plant problems on Unit 3.
Grootvlei	May 01 – 31 2013	Units running on full load due to system demand.
Grootvlei	October 1 - 30 2013	System and plant related challenges

4.4 Fugitive emissions

Fugitive emissions at Grootvlei Power Station result from coal storage and handling, and ashing activities The APPA Registration Certificate requires a fugitive dust management plan, but emission limits do not apply. Fugitive emissions are not assessed in this AIR.

See the power station's fugitive emission management plan included as Annexure G for a description of fugitive emission sources and measures that have been put in place to manage them. Fugitive emissions are extremely difficult to quantify, as they are highly variable in time and space. Fugitive emissions from the ashing facility are highest on the active face (especially in the case of dry ashing) and when wind speeds are high. Fugitive emissions also depend on measures that have been put in place to suppress dust generation, for example vegetation of the ashing facility and sprinklers to suppress dust. The dust fall-out resulting from the fugitive emissions will be monitored with dust buckets.

4.5 Emergency Incidents

A record is maintained of all emergency incidents occurring at Eskom Power Stations. Only one emergency incident has occurred at Grootvlei Power Station, details of which are provided below (Table 16).

Table 16: Record of emergency incidents which have occurred at Grootvlei Power Station during the period 2010 – 2013.

Date of Incident	Emergency Incident	Nature and Cause of the Incident	Actions taken immediately	Actions taken subsequently
06-Sep-11	Unit 3 Generator Transformer Failure	On Tuesday 6 September 2011 at 18:10 an oil spill occurred at Grootvlei's Generator Transformer 3. This incident was declared a level 1 major incident. 55 000 litres of transformer oil spilled into the bund area connected to the station's cemented closed loop drainage system en route to the pollution and oil skimmer.	The oil was completely contained at the pollution plant and was prevented from entering in to the East Terrace Dam. Fire protection system activated automatically. Plant immediately isolated from all sources of supply. Drizit Environmental (Pty) Ltd immediately called to assist with the scooping of the 55 000l of spilled transformer oil. Rapid Spill Response assisted with the cleaning of the wall next to the transformer as well as the cemented surrounding and bund area. DWA and DEA were notified telephonically.	A safe disposal certificate was issued after the disposal of the waste at Holfontein.

5. Impact of Enterprise on the Receiving Environment

5.1 Analysis of emissions

5.1.1 Overview

The application for postponement means that Grootvlei's emissions will remain unchanged from what they are currently. In addition the requested interim emissions have been expressed as a ceiling limit to ensure that Eskom can comply with the same under all normal operating circumstances given the variability of emissions from day to day. As such, assessing the impact of Grootvlei on the receiving environment requires that:

- The existing state of the environment must be assessed in terms of prevailing climate and air quality, including those areas where there are no direct measurements of air quality;
- The air quality that could prevail if the ceiling limits are approved must also be assessed; and,
- The air quality state must then be assessed in terms of the risks to human health and the environment.

This assessment is then based on a detailed analysis of the prevailing climate together with an analysis of air quality monitoring data. Thereafter dispersion modelling is used to predict ambient air pollution concentrations in the areas where there are no physical measurements for worst case scenario under the requested PM, NO_x and SO_2 emissions limits. This analysis is presented in the following section.

5.1.2 Prevailing climatic conditions

Temperature and rainfall

The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation. The climate classification scheme originally developed by Wladimir Köppen is commonly used.

The Grootvlei Power Station is located at 23°40′ S and 27°′37' E, and approximately 880 m above sea level. It experiences a northern steppe climate according to the Köppen Climate Classification system (SAWB, 1965). Winters are mild with average maximum temperatures dropping between 26 °C and 24 ºC between May and August, but are relatively cold at night. Summers are hot and maximums may exceed 30 °C.

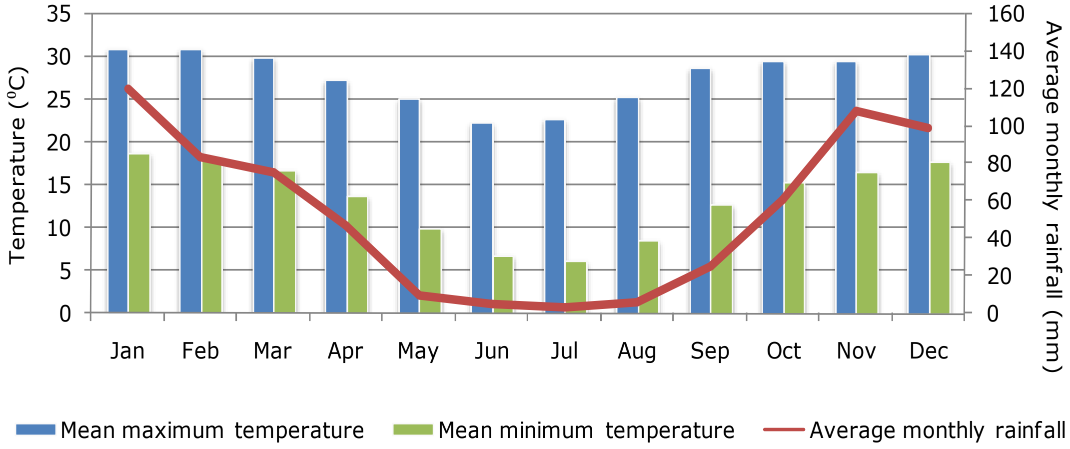


Figure 5: Average monthly maximum and minimum temperature, and average monthly rainfall at *Loskop Dam from 1961 to 1990*

Wind

The mean synoptic-scale circulation over the area is mostly anti-cyclonic throughout the year as a result of the semi-permanent high pressure system over South Africa. The winds are generally light and variable with a northerly component as a result of the anticyclone subsidence. Seasonal variations in the position and intensity of the high pressure system cells determine the extent to which tropical easterly and mid-latitude westerly circulation is able to impact on the over the region. The tropical easterlies affect the region throughout the year resulting in a north-easterly to north-westerly wind flow. In the winter the dominant high pressure system is occasionally disturbed by the passage cold frontal systems moving across the country (Preston-Whyte and Tyson, 1988; Schulze, 1980). Airflow ahead of a passing front is north-north-westerly to north-easterly which is replaced by southerly winds behind the front. Surface wind is also influenced by topography and the physical nature of the surface of the earth which alter the general synoptic winds and induces so-called mesoscale wind flows.

The Grootvlei area is relatively flat with little influence by topography on the wind flow. The prevailing north-easterly to easterly winds are illustrated by the annual windrose in Figure 6. The windrose illustrates the frequency of hourly wind from the 16 cardinal wind directions, with wind indicated from the direction it blows, i.e. easterly winds blow from the east. It also illustrates the frequency of average hourly wind speed in six wind speed classes.

Winds are predominantly from the west to northwest, and the east to east-northeast. The winds are generally light with 63% of all winds less than 3 m/s and 87% of all winds less than 6 m/s (Figure 6).

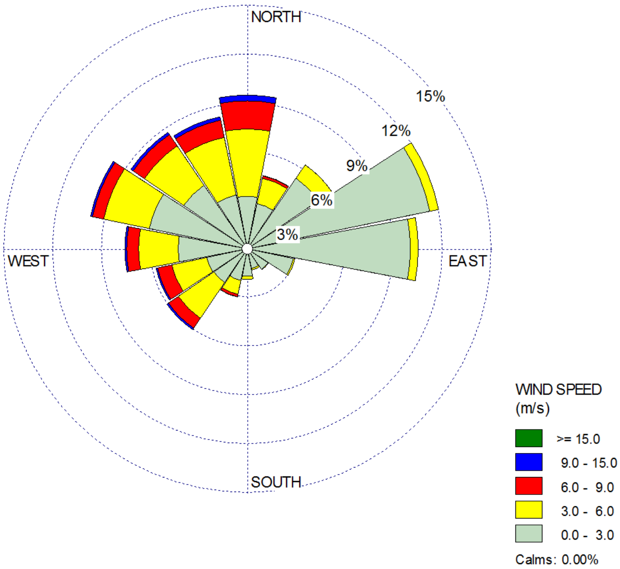


Figure 6: Annual windrose for Grootvlei

5.2 Current status of ambient air quality

The rich coal and mineral reserves in the Mpumalanga Highveld area have led to the establishment of the power generation hub including, amongst others, the Kendal, Matla, Kriel, Hendrina and Grootvlei Power Stations and the construction of the Kusile Power Station. It also houses considerable coal mining activities, ferrometal processing plants, and other major industry. Other sources of air pollution in the Mpumalanga area include the domestic burning of coal. A comprehensive description of sources of air pollution on the Highveld is continued in the Air Quality Management Plan for the Highveld priority Area (DEA, 2012a). This section provides a summary of air quality pertinent to the Grootvlei Power Station.

5.2.1 Ambient air quality monitoring

Eskom established an ambient air quality monitoring station at Grootvlei in 2007, measuring, amongst others, ambient SO_2, NO_2 and PM_{10} concentrations and meteorological parameters. Ambient data for the three year period 2010, 2011 and 2012 at the Grootvlei monitoring station provide some indication of ambient air quality in the area and of the sources that influence air quality at the site. The data are presented in frequency distributions that serve to indicate the frequency of different concentrations measured.

Sulphur dioxide (SO_2)

Frequency distributions of hourly average SO_2 concentrations at Grootvlei are shown in Figure 6. It can be seen from the frequency distribution that relatively low concentrations are maintained for most of the year with far fewer occurrences of higher concentrations. For more than 95% of the time hourly average SO_2 concentrations of less than 100 μg/m^3 prevail. Hourly average concentrations in excess of the limit value are seen in the data record, but these occur for far less than 1% indicating compliance with the NAAQS. The values of the 99th percentile and the percentile at which the limit value is reached are shown in Table 17. The table shows that the limit value is exceeded for 0,1, 0,2 and 0,3% of the time for 2010, 2011 and 2012.

Table 17: Ambient hourly average concentrations of SO_2 for the 99th percentile (in μg/m³), together with the percentile at which the limit value was reached for the three monitoring years, at Grootvlei.

Parameter	2010	2011	2012	NAAQS limit value
Value of 99th percentile	156 μg/m³	183 μg/m³	211 μg/m³	350
Limit value reached at percentile	99,9%	99,8%	99,7%	

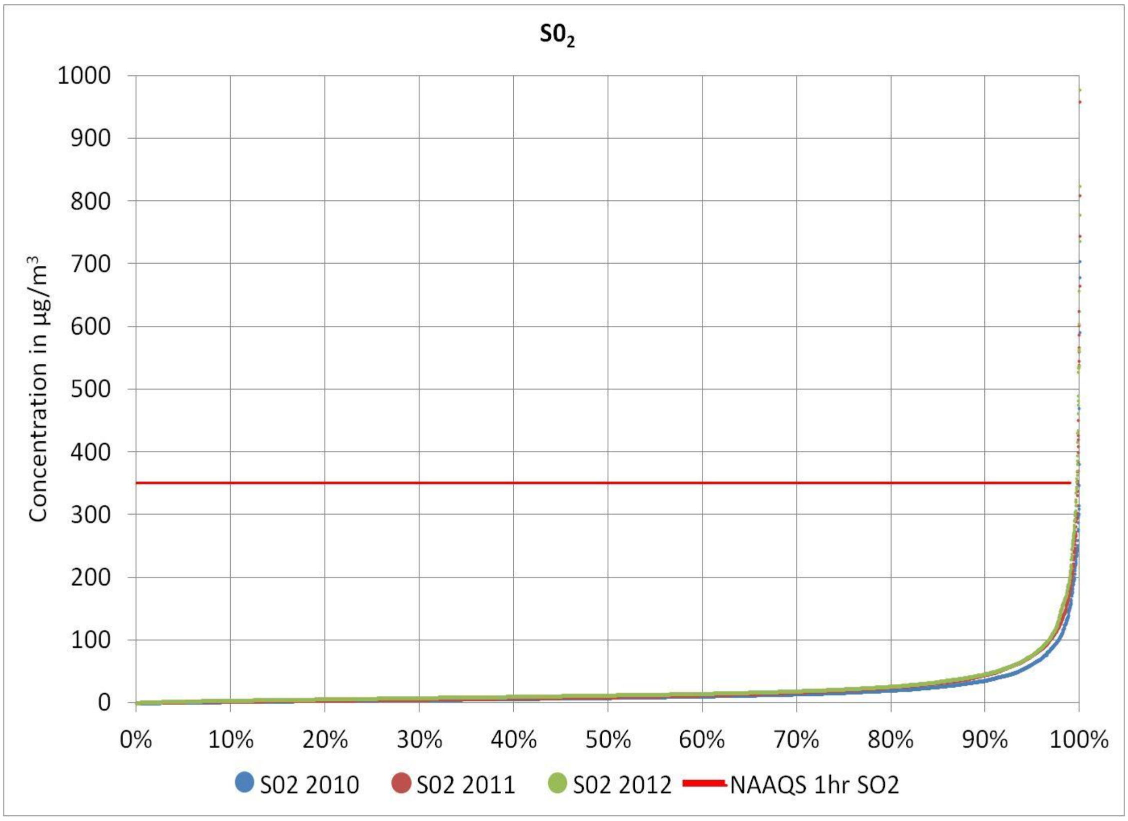


Figure 7: Frequency distribution of hourly average ambient SO_2 concentrations measured at the Grootvlei monitoring station from 2010 to 2012. The NAAQS limit value of 350 μg/m³ is shown by the red horizontal line.

The daily (24-hour) average concentrations are shown in Figure 8. Here a similar pattern is evident as with the hourly concentrations, with average concentrations for the bulk of the monitoring period being seen to be relatively low. A maximum daily average value of 115 μg/m³ was recorded in 2010 with 99th percentile values of 59, 67 and 78 μg/m³ for 2010, 2011 and 2012, respectively (the limit value in the NAAQS is 125 μg/m³).

Finally, but importantly, the annual averages for the 3 years of monitoring are 17, 21 and 24 μg/m³ for 2010, 2011 and 2012, respectively against an annual limit of 50 μg/m³. Unfortunately, ten minute averaging data is not available for Grootvlei.

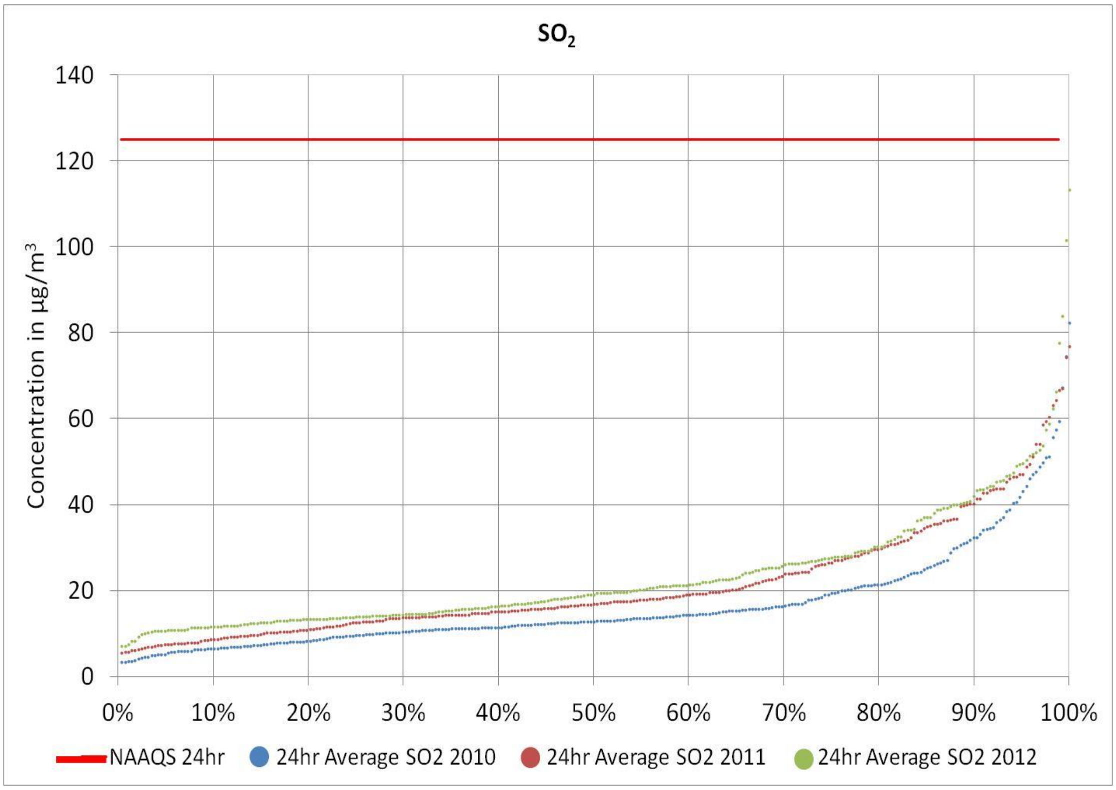


Figure 8: Frequency distribution of daily (24-hour) average ambient SO_2 concentrations measured at the Grootvlei monitoring station from 2010 to 2012. The NAAQS limit value of 125 µg/m^3 is shown by the red horizontal line.

In summary ambient SO_2 loading at Grootvlei is seen to follow a pattern of frequent low concentrations and infrequent higher concentrations. No exceedances of the 1-hour, 24 hour or annual average NAAQS for SO_2 are evident in the monitoring record. SO_2 concentrations are seen to increased as Grootvlei Power Station was commissioned.

Particulate Matter

Frequency distributions of measured ambient 24-hour PM_{10} concentrations are shown in Figure 9. The daily NAAQS for PM_{10} is not complied with in 2010 and 2012 with the limit value being exceeded for more than 5% of the time in 2012. There is compliance with the NAAQS in 2011. In addition the annual average concentrations of 38, 34 and 34 µg/m^3 in 2010, 2011 and 2012 are seen to comply with the annual average limit of 40 µg/m^3 (albeit just in the case of 2010) and thereby the NAAQS. PM_{10} loading is generally lower at Grootvlei than the other monitoring stations.

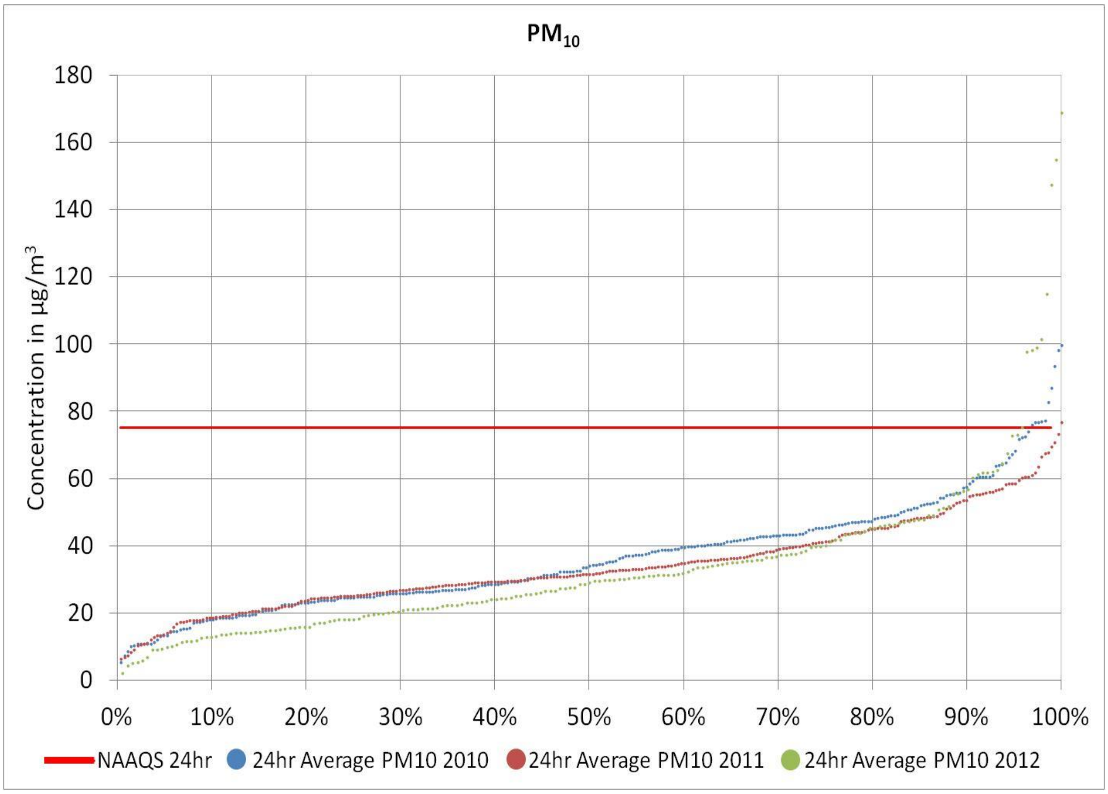


Figure 9: Frequency distribution of daily average ambient PM_{10} concentrations measured at the Grootvlei monitoring station from 2010 to 2012. The 2015 NAAQS limit value of 75 µg/m^3 is shown by the red horizontal line.

Nitrogen oxides

Frequency distributions of ambient hourly average concentrations of NO_2 are shown in Figure 10. It can be seen from the graph that the limit value is not exceeded during the three monitoring years indicating compliance with the hourly average NO_2 NAAQS. Annual average NO_2 concentrations of 13, 13 and 15 µg/m^3 are evident for 2010, 2011 and 2012, which complies with the NAAQS of 40 µg/m^3.

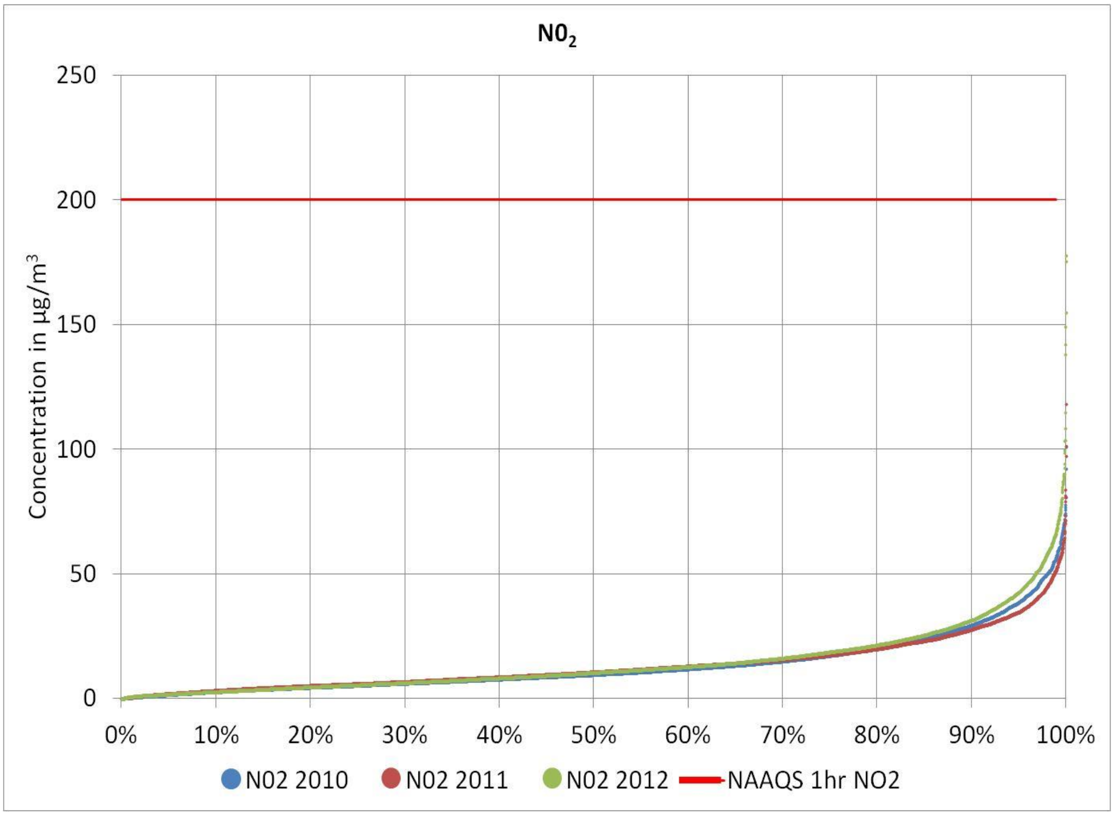


Figure 10: Frequency distribution of hourly average ambient NO_2 concentrations measured at the Grootvlei monitoring station from 2010 to 2012. The NAAQS limit value of 200 µg/m^3 is shown by the red horizontal line.

5.2.2 Source apportionment

The question that then arises is the extent to which Eskom contributes to the measured ambient PM_{10} concentrations. Apportioning the sources of measured ambient concentrations is not a straightforward exercise and as such is presented qualitatively rather than quantitatively in the section that follows. Reference is made to Figure 11 in which average hourly concentrations are shown, to present the diurnal cycle typically experienced in terms of concentrations of SO_2, NO_2 and PM_{10}. The use of domestic fuels for cooking and space heating is a well-known phenomenon in South Africa. These various activities result in emissions of SO_2, NO_2 and PM_{10} at ground level. In Figure 11 a clear diurnal pattern is evident which is considerably more pronounced in winter, but also evident in the summer months.

The pattern is one where ambient concentrations of PM_{10} and NO_2 are seen to be generally higher at night than during the day with a morning peak at about 7:00 am and an evening peak at about 18:00 for PM_{10} and about 21:00 for NO_2. Concentrations of SO_2 on the other hand are seen to be higher during the day than at night, peaking just before midday (Figure 11) and then gradually decreasing as the day wears on.

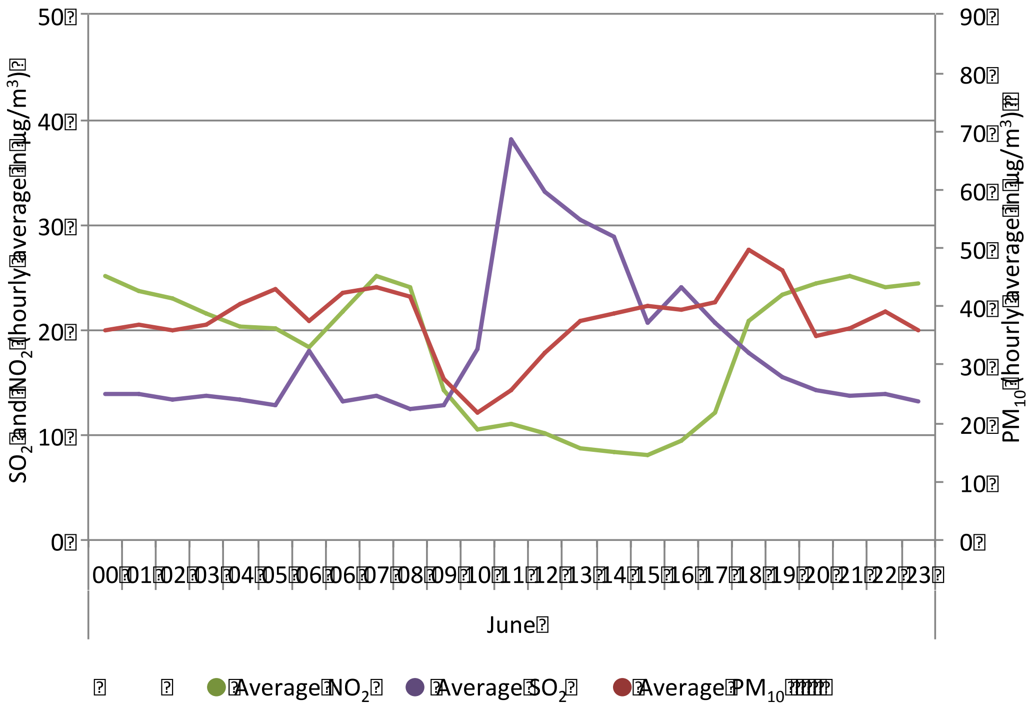


Figure 11: Average hourly SO_2, NO_2 and PM_{10} concentrations for January at Grootvlei calculated over the period 2010 to 2012

The diurnal patterns described above can be explained as follows. During the night the atmosphere becomes stable with inversions often occurring. When the atmosphere is stable, emissions from power station stacks do not come to ground-level as they are released above, and simply cannot penetrate, the stable layer of the atmosphere. In the early hours of the morning when the atmosphere is at its most stable, low-level emissions such as domestic fuel burning and traffic emissions are trapped at ground level and cannot disperse, resulting in an increase in the ambient concentrations.

When the sun rises the heating of the earth's surface sees the break-up of the surface inversion and the start of turbulence and mixing in the atmosphere. That mixing sees a reduction in ground level concentrations of PM_{10}. The mixing gets deeper and deeper as the day progresses until at some point in the day the power station plume is brought to ground-level. As the power station plume comes to ground, there is a significant increase in the SO_2 concentration.

As the afternoon wears on the earth's surface cools and the atmosphere becomes more stable with reduced atmospheric mixing. The stable atmosphere results in the SO_2 concentration reducing significantly as once again the power station plume is prevented from reaching the ground. At about the same time the PM_{10} and NO_2 concentrations are seen to increase as the ground level emissions are again trapped by the progressive reduction in mixing and concentrated at ground level. In these terms it can be argued that almost all measured ambient SO_2 derives from the power station whereas most measured PM_{10} derives from other sources especially domestic fuel burning and vehicles. Secondary aerosol formation does not appear to contribute significantly to episodes of high PM concentrations, given the strong association between high PM levels and the increase in the intensity of emissions from surface sources. Measured ambient NO_2 concentration sources appear to be a function of vehicle emissions especially given the proximity of the N3 highway to Grootvlei.

5.3 Dispersion modelling

The approach to the dispersion modelling in this assessment is based on the requirements of the DEA guideline for dispersion modelling (DEA, 2012c) and is described in detail in the Plan of Study report (uMoya-NILU, 2013), made available during the public consultation process. An overview of the dispersion modelling approach for Grootvlei Power Station is provided here.

5.3.1 Models used

A number of models with different features are available for air dispersion studies. The selection of the most appropriate model for an air quality assessment needs to consider the complexity of the problem and factors such as the nature of the development and its sources, the physical and chemical characteristics of the emitted pollutants and the location of the sources. This assessment is considered a level 2 assessment, according to the definition on the dispersion modelling guideline (DEA, 2012c). The CALPUFF suite of models (http://www.src.com/calpuff/calpuff1.htm) was therefore used. The U.S. EPA Guideline of Air Quality Models also provides for the use of CALPUFF on a case-by-case basis for air quality estimates involving complex meteorological flow conditions, where steady-state straight-line transport assumptions are inappropriate.

CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that simulates the effects of time- and space-varying meteorological conditions on pollution transport, transformation and removal. CALPUFF can be applied on scales of tens to hundreds of kilometres. It includes algorithms for sub-grid scale effects (such as terrain impingement), as well as, longer-range effects (such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, and visibility effects of particulate matter concentrations).

The Air Pollution Model (TAPM) (Hurley, 2000; Hurley et al., 2001; Hurley et al., 2002) is used to model surface and upper air meteorological data for the study domain. TAPM uses global gridded synoptic-scale meteorological data with observed surface data to simulate surface and upper air meteorology at given locations in the domain, taking the underlying topography and land cover into account. The global gridded data sets that are used are developed from surface and upper air data that are submitted routinely by all meteorological observing stations to the Global Telecommunication System of the World Meteorological Organisation. TAPM has been used successfully in Australia where it was developed (Hurley, 2000; Hurley et al., 2001; Hurley et al., 2002), and in South Africa (Raghunandan et al., 2007). It is considered to be an ideal tool for modelling applications where meteorological data does not adequately meet requirements for dispersion modelling. TAPM modelled output data is therefore used to augment the site-specific surface meteorological data for upper air data for input to CALPUFF.

5.3.2 Model parameterisation

TAPM

In the southern Mpumalanga Highveld TAPM is set-up in a nested configuration of two domains. The outer domain is 540 km by 456 km with a 12 km grid resolution and the inner domain is 135 km by 114 km with a 3 km grid resolution (Figure 12). Three years (2010-2012) of hourly observed meteorological data from Eskom's stations at Camden and Majuba are input to TAPM to 'nudge' the modelled meteorology towards the observations. The nesting configuration ensures that topographical effects on meteorology are captured and that meteorology is well resolved and characterised across the boundaries of the inner domain.

Twenty-seven vertical levels are modelled in each nest from 10 m to 5 000 m, with a finer resolution in the lowest 1 000 m. The vertical levels are 10, 25, 50, 75, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 3000, 3500, 4000, 4500 and 5000 m.

The 3-dimensional TAPM meteorological output on the inner grid hourly wind speed and direction, temperature, relative humidity, total solar radiation, net radiation, sensible heat flux, evaporative heat flux, convective velocity scale, precipitation, mixing height, friction velocity and Obukhov length. The spatially and temporally resolved TAPM surface and upper air meteorological data is used as input to CALPUFF's meteorological pre-processor, CALMET.

CALPUFF

The CALMET grid (light blue square in Figure 12), which is 3 600 km^2 is 60 km (west-east) by 60 km (north-south). It is a subdomain of the TAPM inner grid and is centred on Grootvlei Power Station (Figure 12). It consists of a uniformly spaced receptor grid with 500 m spacing, giving 14 400 grid cells (120 X 120 grid cells). The CALPUFF modelling domain is the same as the CALMET modelling domain.

The topographical and land use for the respective modelling domains is obtained from the dataset accompanying the CSIRO's The Air Pollution Model (TAPM) modelling package. This dataset includes global terrain elevation and land use classification data on a longitude/latitude grid at 30-second grid spacing from the US Geological Survey, Earth Resources Observation Systems (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC).

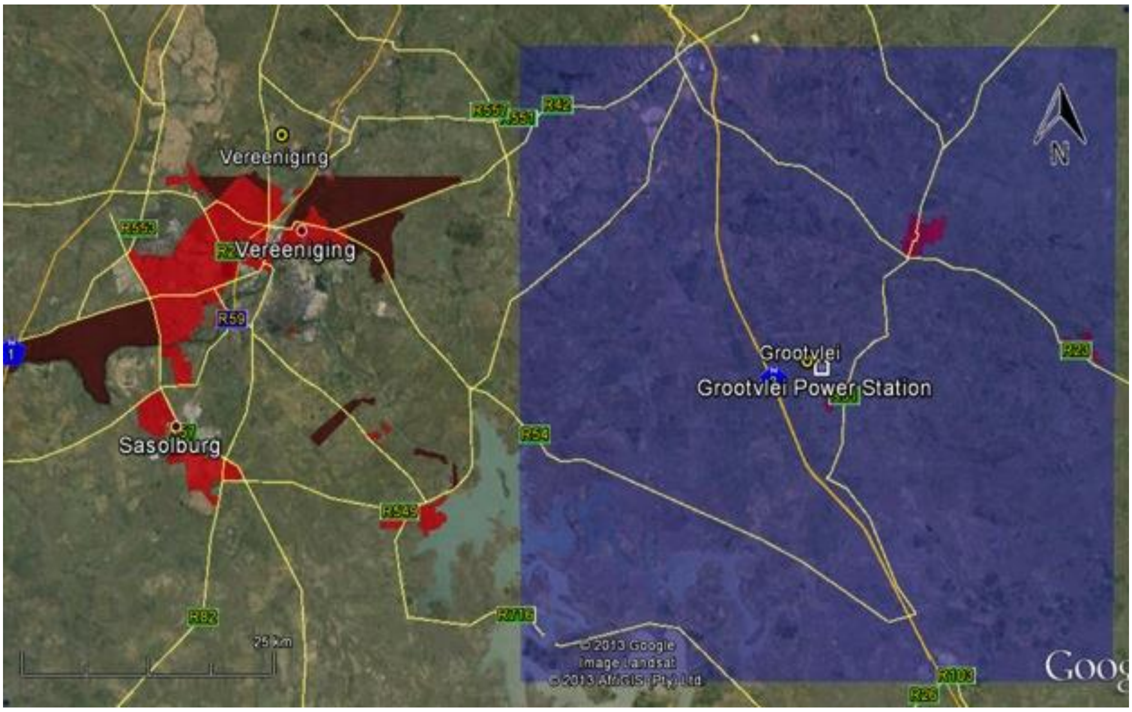


Figure 12: TAPM and CALPUFF modelling domains for Grootvlei, showing the relative locations of the meteorological stations

The parameterisation of key variables that are applied in CALMET and CALPUFF are indicated in Table 18 and Table 19.

Table 18: Parameterisation of key variables for CALMET

Parameter	Model value
12 vertical cell face heights (m)	0, 20, 40, 80, 160, 320, 640, 1000, 1500, 2000, 2500, 3000, 4000
Coriolis parameter (per second)	0.0001
Empirical constants for mixing height equation	Neutral, mechanical: 1.41 Convective: 0.15 Stable: 2400 Overwater, mechanical: 0.12
Minimum potential temperature lapse rate (K/m)	0.001
Depth of layer above convective mixing height through which lapse rate is computed (m)	200
Wind field model	Diagnostic wind module
Surface wind extrapolation	Similarity theory
Restrictions on extrapolation of surface data	No extrapolation as modelled upper air data field is applied
Radius of influence of terrain features (km)	5
Radius of influence of surface stations (km)	Not used as continuous surface data field is applied
Conversion of NO_x to NO_2	75%

Table 19: Parameterisation of key variables for CALPUFF

Parameter	Model value
Chemical transformation	Default NO_2 conversion factor of 0.75 is applied (DEA, 2012c).
Wind speed profile	Rural
Calm conditions	Wind speed < 0.5 m/s
Plume rise	Transitional plume rise, stack tip downwash, and partial plume penetration is modelled
Dispersion	CALPUFF used in PUFF mode
Dispersion option	Dispersion coefficients use turbulence computed from micrometeorology
Terrain adjustment method	Partial plume path adjustment

5.3.3 Model accuracy

Air quality models attempt to predict ambient concentrations based on "known" or measured parameters, such as wind speed, temperature profiles, solar radiation and emissions. There are however, variations in the parameters that are not measured, the so-called "unknown" parameters as well as unresolved details of atmospheric turbulent flow. Variations in these "unknown" parameters can result in deviations of the predicted concentrations of the same event, even though the "known" parameters are fixed.

There are also "reducible" uncertainties that result from inaccuracies in the model, errors in input values and errors in the measured concentrations. These might include poor quality or unrepresentative meteorological, geophysical and source emission data, errors in the measured concentrations that are used to compare with model predictions and inadequate model physics and formulation used to predict the concentrations. "Reducible" uncertainties can be controlled or minimised. This is achieved by making use of the most appropriate input data, preparing the input files correctly, checking and re-checking for errors, correcting for odd model behaviour, ensuring that the errors in the measured data are minimised and applying appropriate model physics.

Models recommended in the DEA dispersion modelling guideline (DEA, 2012b) have been evaluated using a range of modelling test kits (http://www.epa.gov./scram001). It is therefore not mandatory to perform any modelling evaluations. Rather the accuracy of the modelling in this assessment is enhanced by every effort to minimise the "reducible" uncertainties in input data and model parameterisation.

For Grootvlei Power Station the reducible uncertainty in CALMET and CALPUFF is minimised by:

- Using representative quality controlled observed hourly meteorological data to nudge the meteorological processor to the actual values;
- Using 3-years of spatially and temporally continuous surface and upper air meteorological data field for the modelling domain;
- Appropriate parameterisation of both models (Tables 18 and 19);
- Using representative emission data;
- Applying representative background concentrations to include the contribution of other sources;
- Using a competent modelling team with considerable experience using CALPUFF; and,
- For the most part NO_2 concentrations were over predicted by the model (in some cases the predictions were considerable higher than the measured values) which

seems attributable to the rate assumed for the modelling at which NO_x would be converted to NO_2.

Earlier in this report mention was made of model accuracy and reducible error. That does not change the fact that there remains an obvious question as to how well the model predicts the concentrations that are measured at the various monitoring stations. A comparison between the measured and modelled concentrations is not straight forward because the measured concentrations reflect all sources of pollution whereas the model can obviously only predict the ambient concentrations that occur as a function of the emissions included in the model. Past experience (especially in modelling air quality on the Highveld) has shown that is well-nigh impossible to account from all the emissions that may manifest as ambient air quality concentrations.

For this reason only emissions from the power station have been modelled. Despite the complexity of the sources there are three specific power stations where modelled (predicted) concentrations can be expected to be reasonably well correlated with ambient measurements. These are Matimba Power Station and the monitoring station at Marapong 2 km north-east of the power station (SO_2); Camden Power Station and the Camden monitoring station 2 km east of the power station (SO_2 and NO_2) and Majuba Power Station and the Majuba monitoring station 3 km east-south-east of the power station (SO_2 and NO_2). A comparison of the measured and modelled concentrations on the basis of 99th percentile comparisons is summarised below.

The short-term (hourly and daily) 99th percentile values are generally predicted to within a factor of 2, which is considered to be an acceptable level of accuracy for a dispersion model. In most cases, the model has under-predicted the measured concentrations, which is to be expected since the model only considers emissions from the power station, while in reality many sources contribute to ambient levels. The model under-predicts annual average concentrations, which again is to be expected as background levels are more significant for annual average concentrations than for the shorter averaging periods. The model does not predict the high frequency of low concentrations that are evident in the monitoring record, which has the effect of reducing the accuracy of the predicted annual average concentrations.

Table 20: Comparison between measured and modelled concentrations for those power stations where a reasonable correlation between eth two can be expected. The range derives from the three-year monitoring period where the best and worst correlation of the three years is presented.

Station	Pollutant and averaging time		Ratio of modelled to measured concentrations, expressed as a %	
			Best*	Worst*
Matimba - Marapong	SO_2	1 hr	91%	54%
		Daily	93%	340%
		Annual	40%	20%
Camden and Camden	SO_2	1 hr	76%	60%
		Daily	95%	80%
		Annual	41%	29%
	NO_2	1 hr	104%	83%
		Annual	27%	25%
Majuba and Majuba	SO_2	1 hr	59%	30%
		Daily	104%	77%
		Annual	29%	23%
	NO_2	1 hr	99%	43%
		Annual	25%	12%

** Numbers less than 100% indicate an under-prediction, with numbers greater than 100% indicating an over-prediction.*

5.4 Modelled ambient concentrations

Two scenarios are assessed for Grootvlei Power Station:

Scenario 1: Current actual emissions to assess the relative contribution to ambient concentrations near the Grootvlei Power Station.

Scenario 2a: Eskom's requested emission limits. Emission limits that Eskom believes are achievable at Grootvlei Power Station at the moment, to assess the likely ambient concentrations of NO_2, SO_2 and PM_{10} near the Grootvlei Power Station.

Scenario 2b: Eskom's requested emission limits. PM_{10} emission limits that Eskom believe are achievable at Grootvlei Power Station after the FFP retrofit, from 1 April 2018 to 1 April 2020.

Scenario 2c: Eskom's requested emission limits. PM_{10} emission limits that Eskom believe are achievable at Grootvlei Power Station after the optimisation of the FFP, from 1 April 2020 onwards.

Table 21: Current emission rates (tons/annum) and Eskom requested emission limits (mg/Nm³) for Grootvlei Power Station

Pollutant	Source	Scenario 1: Current Actual Emissions	Scenario 2a: Requested Emissions Limits from now	Scenario 2b: Requested Emissions Limits: After FFP retrofit	Scenario 2c: Requested Emissions Limits: April 2020
			Now to 1 April 2018	1 April 2018-1 April 2020	1 April 2020 onwards
		Emission rates (tons/annum)	Emission concentrations (mg/Nm³)		
NO_X	Stack 1	12,376	1,200		
	Stack 2	12,376	1,200		
SO_2	Stack 1	23,929	3,800		
	Stack 2	23,929	3,800		
PM_{10}	Stack 1	4,084	350*	100	75
	Stack 2	4,084	300**	100	75

* for 25 days/month with 1000 mg/Nm³ for 6 days/month
** for 25 days/month with 700 mg/Nm³ for 6 days/month

Note that the current actual emission rates (tons/annum) have been calculated from a station-specific emission factor for NO_x, and from mass balance based on the sulphur content in the coal for SO_2. PM emissions are continually measured using continuous emission (opacity) monitors. The concentration for actual emissions has then been derived from the emission rates, and so it is an average concentration.

The proposed emission limits are the upper limit of expected emissions. Actual average emissions need to be 30-40% lower than the emission limit to ensure that the emission limit is consistently achieved.

5.4.1 Modelled operational scenarios

The 99th percentile predicted ambient SO_2, NO_2 and PM_{10} concentrations from the dispersion modelling for Grootvlei Power Station for emission Scenarios 1 and 2a to 2c are presented as isopleth maps over the modelling domain. The DEA (2012c) recommend the 99th percentile concentrations for short-term assessment with the National Ambient Air Quality Standards since the highest predicted ground-level concentrations can be considered outliers due to complex variability of meteorological processes. This might cause exceptionally high concentrations that the facility may never actually exceed in its lifetime.

The impact assessment therefore compares the predicted 99th percentile concentrations with the respective ambient air quality standards (limit values and the permitted frequency of exceedance) for Scenarios 1 and 2a to 2c, with consideration of populated areas in the modelling domain.

The predicted annual average concentration and the 99th percentile concentration at the points of maximum ground-level impact for Current Actual Emissions and Requested Emission Limits Scenarios are presented in Table 22.

Table 22: Predicted annual average concentration and the 99th percentile concentration at the points of maximum ground-level impact for the Actual Emissions and Requested Limits for Grootvlei Power Station

	Scenario 1: Current Actual Emissions	Scenario 2a: Requested Emission Limits from now	Scenario 2b: Requested Emission Limits: 1 April 2018 to 1 April 2020	Scenario 2c: Requested Emission Limits: 1 April 2020 onwards	NAAQS Limit Value ($\mu g/m^3$)
SO_2 ($\mu g/m^3$)					
1-hour	87	343			350
24-hour	35	137			125
Annual	4.3	16.7			50
NO_2 ($\mu g/m^3$)					
1-hour	34	81			200
Annual	1.7	4			40
PM_{10} ($\mu g/m^3$)					
24-hour	6	24	5	4	75
Annual	0.7	3.2	0.6	0.5	40

5.4.2 Scenario 1: Current actual emissions

Sulphur dioxide

For current emissions at Grootvlei Power Station the predicted annual average SO_2 concentration (which is 4.3 $\mu g/m^3$ at the point of highest impact in the domain) is significantly less than the SO_2 NAAQS of 50 $\mu g/m^3$ (Figure 13 and Table 22). Similarly the 99th percentile of the predicted 24-hour SO_2 concentrations does not exceed the NAAQS limit value of 125 $\mu g/m^3$ (Figure 14 and Table 22). At the point of maximum ground-level impact, the 99th percentile 1-hour SO_2 concentration is 87 $\mu g/m^3$, which is well below the limit value of 350 $\mu g/m^3$ (Figure 15 and Table 22).

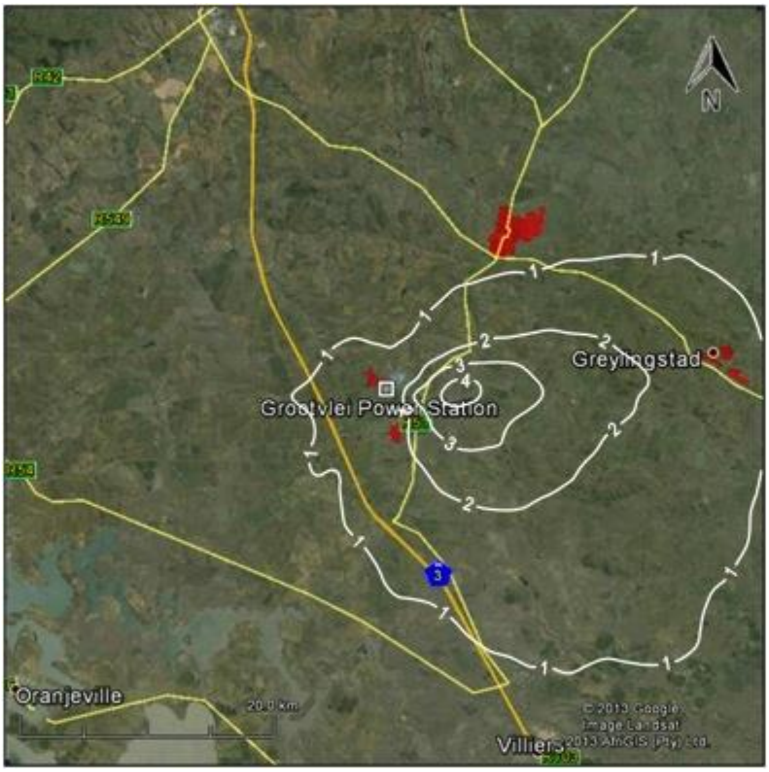


Figure 13: Annual average SO_2 concentrations (µg/m^3) resulting from actual emissions from Grootvlei Power Station emissions (Scenario 1)

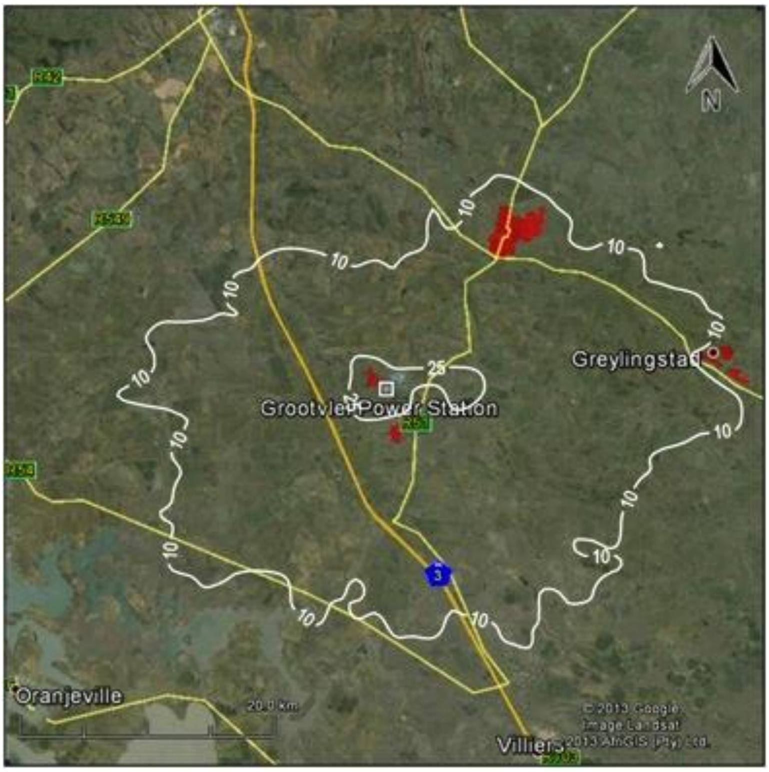


Figure 14: Predicted 99th percentile 24-hour average SO_2 concentrations (µg/m^3) resulting from actual emissions from Grootvlei Power Station (Scenario 1)

Figure 15: Predicted 99th percentile hourly SO_2 concentrations (µg/m^3) resulting from actual emissions from Grootvlei Power Station emissions (Scenario 1)

Nitrogen dioxide

For current emissions at Grootvlei Power Station the predicted annual average NO_2 concentration (which is 1.7 µg/m^3 at the point of highest impact in the domain) is significantly less than the NO_2 NAAQS of 40 µg/m^3 (Figure 16 and Table 22). At the point of maximum ground-level impact, the predicted 99th percentile of the 1-hour NO_2 concentration is 34 µg/m^3, which is well below the NAAQS of 200 µg/m^3 (Figure 17 and Table 22).

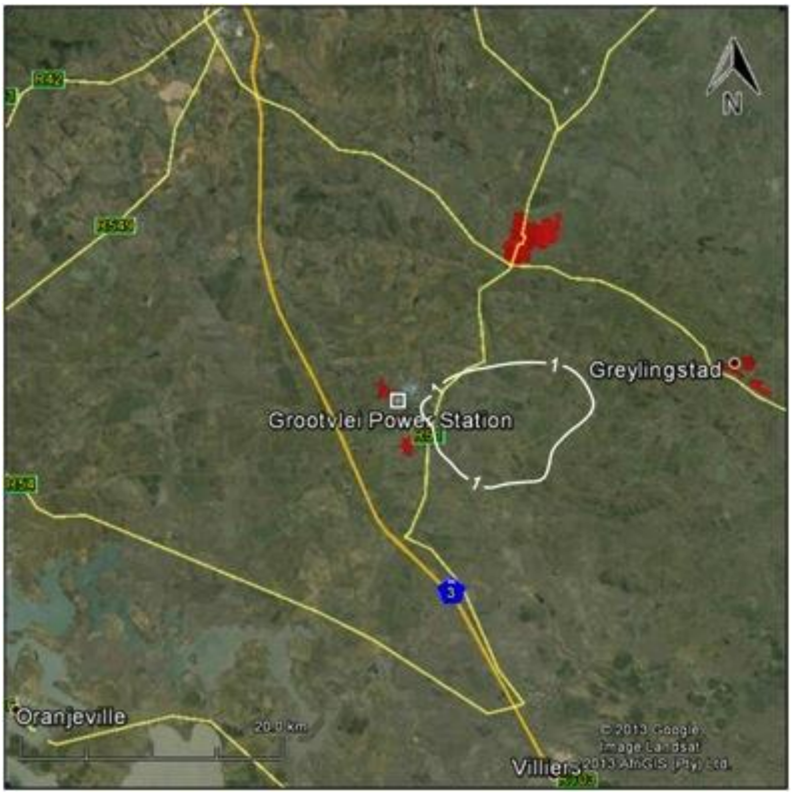


Figure 16: Annual average NO_2 concentrations (µg/m^3) resulting from actual emissions from Grootvlei Power Station emissions (Scenario 1)

Figure 17: Predicted 99th percentile 24-hour NO_2 concentrations (µg/m^3) resulting from actual emissions from Grootvlei Power Station emissions (Scenario 1)

PM₁₀

For current emissions at Grootvlei Power Station the predicted annual average PM_{10} concentration (which is 0.7 µg/m^3 at the point of highest impact in the domain) is significantly less than the PM_{10} NAAQS of 40 µg/m^3 (Figure 18 and Table 22). At the point of maximum ground-level impact, the predicted 99th percentile of the 1-hour NO_2 concentration is 6 µg/m^3, which is well below the NAAQS of 75 µg/m^3 (Figure 19 and Table 22).

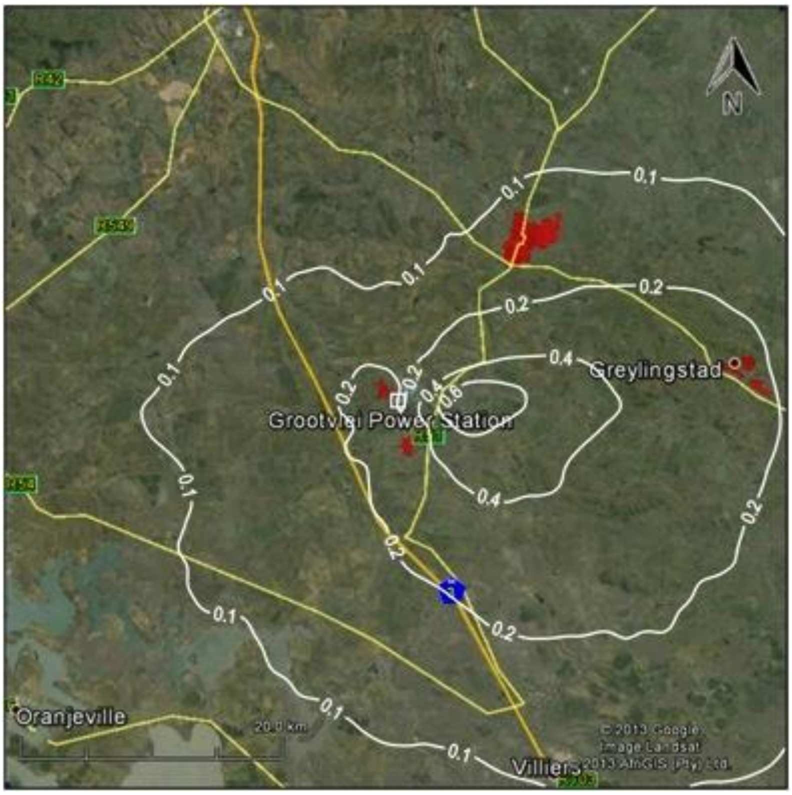


Figure 18: Predicted annual average PM_{10} concentrations (µg/m^3) resulting from current actual emissions from Grootvlei Power Station (Scenario 1)

Figure 19: 99th percentile of the predicted 1-hour PM_{10} concentrations (µg/m³) resulting from current actual emissions from Grootvlei Power Station (Scenario 1)

5.4.3 Scenario 2a: Requested emission limits from now

Sulphur dioxide

For requested emission limits at Grootvlei Power Station the predicted annual average SO_2 concentration (which is 16.7 µg/m³ at the point of highest impact in the domain) is somewhat higher than for current actual emissions and significantly less than the SO_2 NAAQS of 50 µg/m³ (Figure 20 and Table 22). For the 99th percentile of the predicted 24-hour SO_2 concentrations, the NAAQS limit value of 125 µg/m³ is exceeded immediately at the Grootvlei Power Station (there are 4.7 exceedances on average per annum; the allowed frequency of exceedance in terms of the NAAQS is 4 exceedances per annum) (Figure 21 and Table 22). No non-compliance is predicted in any of the identified inhabited areas in Figure 2. At the point of maximum ground-level impact, the 99th percentile 1-hour SO_2 concentration is 343 µg/m³, which is just below the limit value of 350 µg/m³ (Figure 22 and Table 22).

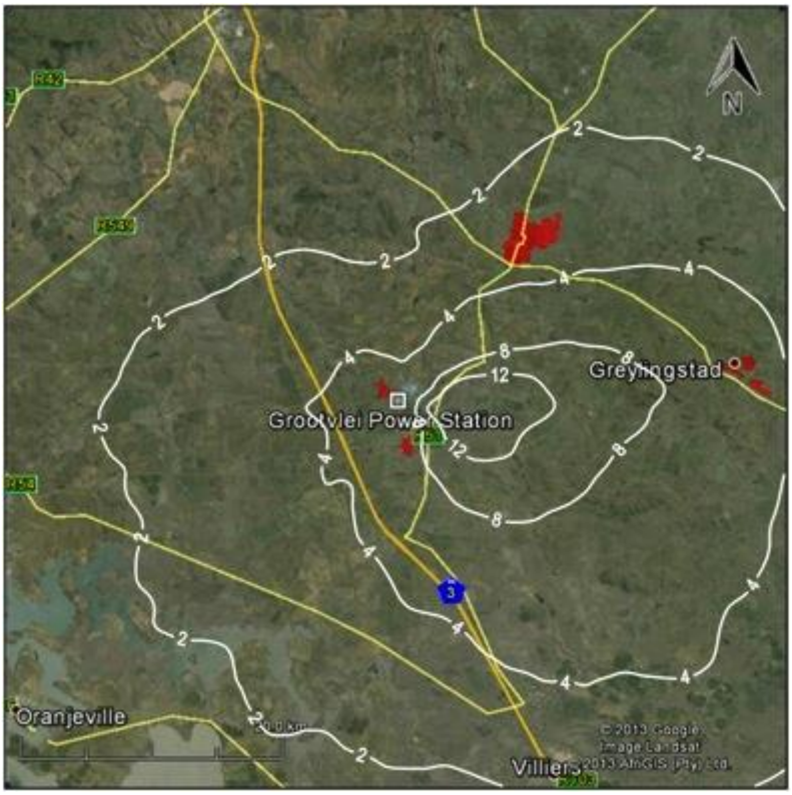


Figure 20: Annual average SO_2 concentrations (µg/m^3) resulting from Eskom's requested emission limit for Grootvlei Power Station (Scenario 2a)

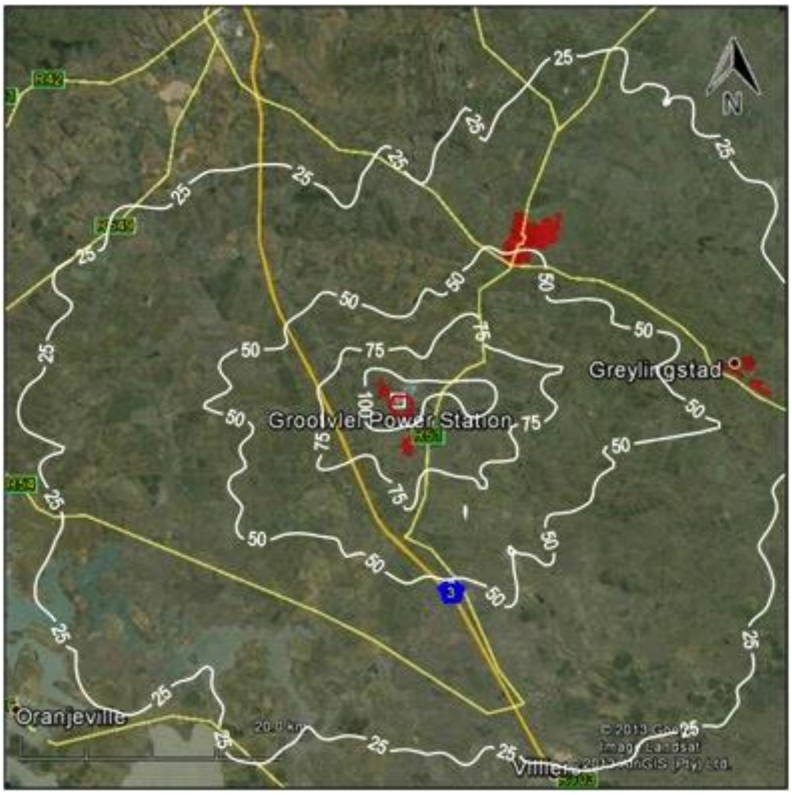


Figure 21: Predicted 99th percentile 24-hour SO_2 concentrations (µg/m^3) resulting from Eskom's requested emission limit for Grootvlei Power Station (Scenario 2a)

Figure 22: Predicted 99th percentile of the predicted 1-hour SO_2 concentrations (µg/m³) for requested emissions from Grootvlei Power Station (Scenario 2a)

Nitrogen dioxide

For requested emission limits at Grootvlei Power Station the predicted annual average NO_2 concentration (which is 4 µg/m³ at the point of highest impact in the domain) is somewhat higher than for current actual emissions and significantly less than the NO_2 NAAQS of 40 µg/m³ (Figure 23 and Table 22). At the point of maximum ground-level impact, the predicted 99th percentile 1-hour concentration for NO_2 is 81 µg/m³, which is well below the NAAQS of 200 µg/m³ (Figure 24 and Table 22).

Figure 23: Annual average NO_2 concentrations (µg/m^3) resulting from Eskom's requested emission limits for Grootvlei Power Station (Scenario 2a)

Figure 24: Predicted 99th percentile 1-hour NO_2 concentrations (µg/m^3) resulting from Eskom's requested emission limits for Grootvlei Power Station (Scenario 2a)

PM10

For requested emission limits at Grootvlei Power Station the predicted annual average PM_{10} concentration (which is 3.2 µg/m^3 at the point of highest impact in the domain) is somewhat higher than for current actual emissions and significantly less than the 2015 PM_{10} NAAQS of 40 µg/m^3 (Figure 25 and Table 22). At the point of maximum ground-level impact, the predicted 99th percentile 24-hour concentration for PM_{10} is 24 µg/m^3, which is below the 2015 NAAQS of 75 µg/m^3 (Figure 26 and Table 22).

Figure 25: Predicted annual average PM_{10} concentrations (µg/m^3) resulting from requested emission limits from Grootvlei Power Station (Scenario 2a)

Figure 26: 99th percentile of the predicted 24-hour PM_{10} concentrations (µg/m^3) resulting from requested emission limits from Grootvlei Power Station (Scenario 2a)

5.4.4 Scenario 2b: Requested emission limits: PM_{10}: After FFP retrofit 1 April 2018 to 1 April 2020

For requested emission limits after the FFP retrofit at Grootvlei Power Station the predicted annual average PM_{10} concentration (which is 0.6 µg/m^3 at the point of highest impact in the domain) is again lower than before the FFP retrofit and significantly less than the 2015 PM_{10} NAAQS of 40 µg/m^3 (Figure 27 and Table 22). At the point of maximum ground-level impact, the predicted 99th percentile 24-hour concentration for PM_{10} is 5 µg/m^3, which is well below 2015 the NAAQS of 75 µg/m^3 (Figure 28 and Table 22).

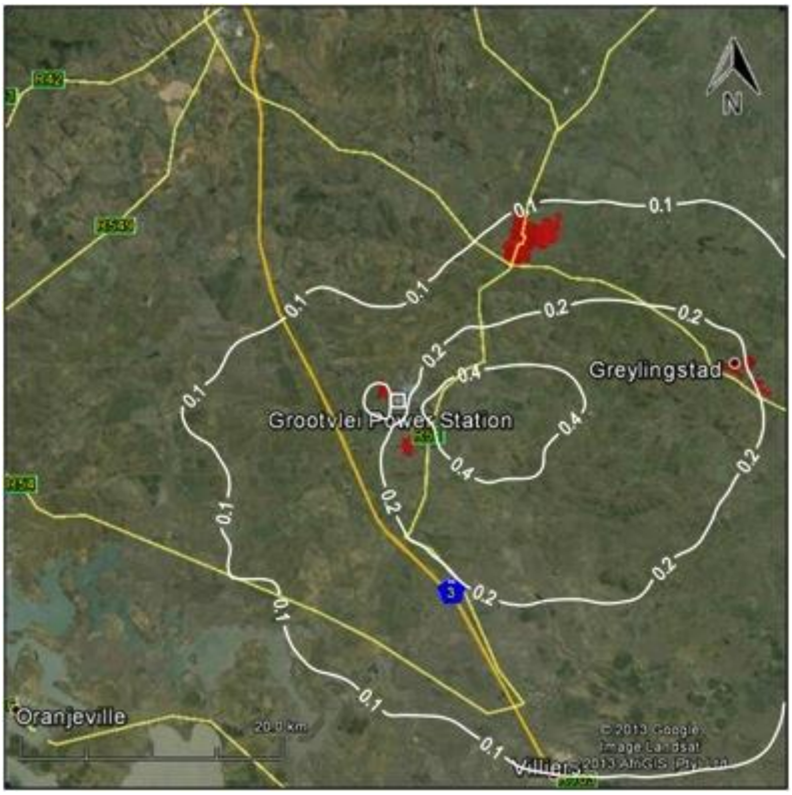


Figure 27: Predicted annual average PM_{10} concentrations (µg/m^3) resulting from requested emission limits from Grootvlei Power Station (Scenario 2b)

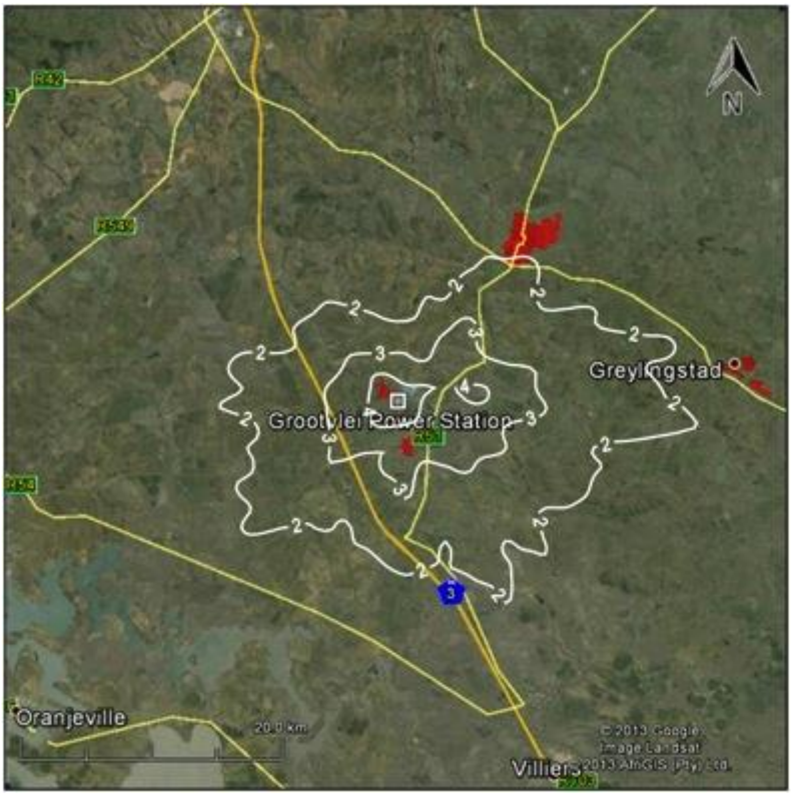


Figure 28: 99th percentile of the predicted 24-hour PM_{10} concentrations (µg/m^3) resulting from requested emission limits from Grootvlei Power Station (Scenario 2b)

5.4.5 Scenario 2c: Requested emission limits: PM_{10}: after FFP optimisation from 1 April 2020 onwards

For requested emission limits at Grootvlei Power Station from 1 April 2020 onwards, the predicted annual average PM_{10} concentration (which is 0.5 µg/m^3 at the point of highest impact in the domain) is again lower than for earlier requested limits and significantly less than the 2015 PM_{10} NAAQS of 40 µg/m^3 (Figure 29 and Table 22). At the point of maximum ground-level impact, the predicted 99th percentile 24-hour concentration for PM_{10} is 4 µg/m^3, which is well below the 2015 NAAQS of 75 µg/m^3 (Figure 30 and Table 22).

Figure 29: Predicted annual average PM_{10} concentrations (µg/m^3) resulting from requested emission limits from Grootvlei Power Station (Scenario 2c)

Figure 30: 99th percentile of the predicted 24-hour PM_{10} concentrations (µg/m^3) resulting from requested emission limits from Grootvlei Power Station (Scenario 2c)

5.5 Analysis of Emissions' Impact on Human Health

5.5.1 Potential health effects

As previously described the key atmospheric emissions from coal combustion at Grootvlei Power Station are SO_2, NO_X and particulates and the NAAQS for these pollutants have already been presented (see Section 1.3.2). The potential effect of these pollutants is described in the section that follows.

Sulphur dioxide (SO_2)

On inhalation, most SO_2 only penetrates as far as the nose and throat, with minimal amounts reaching the lungs, unless the person is breathing heavily, breathing only through the mouth, or if the concentration of SO_2 is high (CCINFO, 1998). The acute response to SO_2 is rapid, within 10 minutes in people suffering from asthma (WHO, 2005). Effects such as a reduction in lung function, an increase in airway resistance, wheezing and shortness of breath, are enhanced by exercise that increases the volume of air inspired, as it allows SO_2 to penetrate further into the respiratory tract (WHO, 1999). SO_2 reacts with cell moisture in the respiratory system to form sulphuric acid. This can lead to impaired cell function and effects such as coughing, broncho-constriction, exacerbation of asthma and reduced lung function.

Nitrogen dioxide (NO_2)

Exposure to NO_2 is typically inhalation and the seriousness of the effects depend more on the concentration than on the length of exposure. The site of deposition for NO_2 is the distal lung where NO_2 reacts with moisture in the fluids of the respiratory tract to form nitrous and nitric acids. About 80 to 90% of inhaled nitrogen dioxide is absorbed through the lungs (CCINFO, 1998). Nitrogen dioxide (present in the blood as the nitrite ion) oxidises unsaturated membrane lipids and proteins, which then results in the loss of control of cell permeability. Nitrogen dioxide caused decrements in lung function, particularly increased airway resistance. People with chronic respiratory problems and people who work or exercise outside will be more at risk to NO_2 exposure (EAE, 2006).

Particulate Matter

Particulate Matter (PM) is a broad term used to describe the fine particles found in the atmosphere, including soil dust, dirt, soot, smoke, pollen, ash, aerosols and liquid droplets. With PM, it is not just the chemical composition that is important but also the particle size. Particle size has the greatest influence on the behaviour of PM in the atmosphere with smaller particles tending to have longer residence times than larger ones. PM is categorised, according to particle size, into TSP, PM_{10} and $PM_{2.5}$.

Total suspended particulates (TSP) consist of all sizes of particles suspended within the air smaller than 100 micrometres (µm). TSP is useful for understanding nuisance effects of PM, e.g. settling on houses, deposition on and discolouration of buildings, and reduction in visibility.

PM_{10} describes all particulate matter in the atmosphere with a diameter equal to or less than 10 µm. Sometimes referred to simply as coarse particles, they are generally emitted from motor vehicles (primarily those using diesel engines), factory and utility smokestacks, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood. Natural sources include sea spray, windblown dust and volcanoes. Coarse particles tend to have relatively short residence times as they settle out rapidly and PM_{10} is generally found relatively close to the source except in strong winds.

$PM_{2.5}$ describes all particulate matter in the atmosphere with a diameter equal to or less than 2.5 µm. They are often called fine particles, and are mostly related to combustion (motor vehicles, smelting, incinerators), rather than mechanical processes as is the case with PM_{10}. $PM_{2.5}$ may be suspended in the atmosphere for long periods and can be transported over large distances. Fine particles can form in the atmosphere in three ways: when particles form from the gas phase, when gas molecules aggregate or cluster together without the aid of an existing surface to form a new particle, or from reactions of gases to form vapours that nucleate to form particles.

Particulate matter may contain both organic and inorganic pollutants. The extent to which particulates are considered harmful depends on their chemical composition and size, e.g. particulates emitted from diesel vehicle exhausts mainly contain unburned fuel oil and hydrocarbons that are known to be carcinogenic. Very fine particulates pose the greatest health risk as they can penetrate deep into the lung, as opposed to larger particles that may be filtered out through the airways' natural mechanisms.

In normal nasal breathing, particles larger than 10 µm are typically removed from the air stream as it passes through the nose and upper respiratory airways, and particles between 3 µm and 10 µm are deposited on the mucociliary escalator in the upper airways. Only particles in the range of 1 µm to 2 µm penetrate deeper where deposition in the alveoli of the lung can occur (WHO, 2003). Coarse particles (PM_{10} to $PM_{2.5}$) can accumulate in the respiratory system and aggravate health problems such as asthma. $PM_{2.5}$, which can penetrate deeply into the lungs, are more likely to contribute to the health effects (e.g. premature mortality and hospital admissions) than coarse particles (WHO, 2003).

A key consideration in assessing the air quality implications of the postponement applications is the chemical transformation of both SO_2 and NO_x into sulphates and nitrates, respectively. The importance of that transformation lies in the fact that the sulphates and nitrates manifest as particulates in the size range of < 2,5 micron. In the course of the assessment it has not been possible to deal satisfactorily with the issue of $PM_{2,5.}$ Only limited $PM_{2.5}$ data is available from the monitoring stations and the data that is available is not consistent, so is not useable. It has been argued earlier that there is no material increase in PM_{10} concentrations when the SO_2 concentrations peak suggesting that there is no additional PM load when the power station plume comes to ground. It is recognized, however, that assessing $PM_{2.5}$ concentrations and understanding the role of SO_2 and NO_x in contributing to the ambient concentrations, is a good deal more complex. Accordingly it is recommended that if the postponement be granted, that Eskom be obliged to conduct a detailed source apportionment study aimed at quantifying Eskom's contribution to ground level concentrations of PM_{10} and $PM_{2,5.}$

5.5.2 Analysis

The potential impacts on human health have been assessed in this report only by comparing the measured and predicted ambient air quality with the published NAAQS It can be seen from the measured ambient air quality measurements that SO_2, NO_2 and comply with the NAAQS for the various averaging periods, but the PM_{10} does not comply with the NAAQS. Ambient air quality concentrations resulting from Grootvlei's operations predicted using a dispersion model are seen to comply completely with the NAAQS for SO_2, NO_2 and PM_{10} concentrations. Drawing conclusions about the potential human health effects of these concentrations is not straight forward but the following can be stated with a reasonable degree of confidence:

Particulate Matter (PM)

Predicted ambient PM_{10} concentrations are seen to be fully compliant with the NAAQS and so while it cannot be argued that there is no health risk, the health risk posed by PM_{10} emissions must be considered permissible. The contribution of the power station to that health risk is negligible at worst. NO_x and SO_2 emissions from the power station contribute to the overall PM_{10} load as they are converted to particulate form in the atmosphere, but the diurnal patterning of ambient PM_{10} concentrations indicates that by far the dominant contribution to PM_{10} peak concentrations is low (ground) level sources such as domestic fuel use, motor vehicle emissions, biomass burning and others. This finding is in line with the FRIDGE study that was completed in 2004, which included estimates that the relative percentage health impact was between 64 and 69% as a result of domestic fuel use, versus some 4% from coal fired boilers. Thus, the Eskom requested PM emissions limits will not result in the material reduction in ambient air quality in the areas potentially impacted upon by the emissions, and neither will full compliance with the PM MES, result in a material reduction in the prevailing health risk.

Nitrogen oxides

Both measured and predicted ambient NO_2 concentrations are seen to be fully compliant with the NAAQS and so while it cannot be argued that there is no health risk, the health risk posed by NO_x emissions must be considered permissible. Thus, the requested NO_x emission limits will not result in the material deterioration of the ambient air quality that prevails currently. Full compliance with the MES would see a reduction in health risk simply by virtue of reducing the NO_x load, but the actual ambient concentrations are so far below the limit value of the standard that it seems unlikely that this reduction in health risk would be in any way significant.

Sulphur dioxide

Measured ambient concentrations of SO_2 are seen to be fully compliant with the NAAQS. Again, this compliance cannot be argued to imply no health risk, but it has to be accepted as being a permissible health risk. The predicted ambient concentrations of SO_2 as a function of current emissions and requested emissions from the power station indicate full compliance with the NAAQS in all populated areas. Areas of full compliance with the SO_2 NAAQS are again deemed not to be free of health risks necessarily but the health risks are considered to be permissible.

5.6 Analysis of Emissions' Impact on the Environment

In terms of impact on the environment, the pollutants in question pose the risk of a variety of potential non-health impacts. Of these impacts dry and wet acid deposition is considered to be the most significant but there are also concerns around potential impacts on vegetation and fauna. The most challenging part of assessing such impacts is the absence of defined damage thresholds (i.e. defined concentrations at which damage is known to occur) especially in a regulatory sense. As a result the assumption that is made here is that if there is compliance with the NAAQS that the damage risk will be considered permissible.

Various investigations have been conducted on regional acidification in both the Mpumalanga Highveld and escarpment areas, without any clear evidence emerging of significant negative impacts. These various investigations are cited in Josipovic (2009) who proceeded to investigate whether '*the impacts of emitted pollutants and relationally accumulated deposition of acidic air pollutants eventually exceed the carrying capacity of the natural environment'*. He further goes on to argue that: [bearing in mind the stated uncertainties][1] '*acidic pollution originating from the central industrial Highveld is not a current environmental threat to the environment in remote areas of South Africa, specifically the Mpumalanga Escarpment and forestry areas, and by implication neither is it a threat to adjacent countries. However, zones within north-west Mpumulanga and south to south east of the Witbank industrial area have indicated as areas exceeding critical loads of acidification, due also to local districts of sensitive soils. Although not extensive in spatial distribution, with one area only showing the highest exceedance level, these results indicate that areas in the vicinity of the central industrial zone that have susceptible soils are at risk of exceeding critical loads.'*

It is therefore clear that long-term emissions of acidic gases such as SO_2 and NO_2 pose a risk of acidification, but principally in areas of sensitive soils. Given the long-term nature of the effect it must be recognized that there will be an overall reduction in SO_2 and NO_2 emissions in the longer term across the fleet, as the RTS and older power stations are progressively decommissioned. In addition the significance of the acidification risk has not been presented so it is not possible to assess the potential consequences (biodiversity loss, reductions in land potential and so forth) in any meaningful way. More importantly perhaps it is simply not possible to weigh up the benefits of reduced acid gas emissions (that would occur if there was full compliance with the MES) against the financial and non-financial costs of full MES compliance. Decision-makers should recognize the acidification risk that would be associated with approving the applications for postponement, recognizing the longer-term reduction in acid load as power stations are decommissioned across the fleet.

6. Complaints

Grootvlei Power Stations does maintain a Complaints register. Any complaints that are received by the power station are recorded in this register. Complaints are presented in Table 23.

Table 23: Complaints register for Grootvlei Power Station

Date	Nature of the complaint	Source of the complaint	Response measures taken
2013/04/25	High Stack Emissions	Andre Kuse	Response letter was sent to the complainant on 25/04/2013
11/10/2013	High Stack Emissions & Noise	Mr Vermaak	Response letter was sent to the complainant

[1] As described in the PhD Thesis.

7. Current or planned air quality management interventions

Section 3.2 details the current air quality management interventions implemented at the Grootvlei Power Station. Plans are underway to reduce Particulate Matter (PM) through Fabric Filter Plant (FFP) retrofits so that Grootvlei will eventually comply with the existing plant limits.

8. Compliance and Enforcement History

No compliance and enforcement actions have been undertaken against Eskom's Grootvlei Power Station within the last five years.

9. Additional Information

No additional information is necessary.

10. Summary and conclusion

Eskom's coal-fired Grootvlei Power Station in Mpumalanga Province has a total installed capacity of 1 150 MW. Grootvlei. Power generation is a Listed Activity in terms of Section 21 of the NEMAQA and Grootvlei should comply with the prescribed Minimum Emission Standards (MES) for existing plants by 2015 and for new plants by 2020. Grootvlei currently does not comply with any of the 'existing plant' or 'new plant' MES limits. Due to water resource, financial and electricity supply capacity constraints (presented in more detail in this document and supporting Annexures), Eskom's Grootvlei Power Station will not be able to comply with either the 'new plant' or continuously with the 'existing plant' MES for Sulphur dioxide (SO_2) nor for Nitrogen oxides (NO_x). Grootvlei Power Station will also not be able to comply with the 'new plant' MES for Particulate Matter (PM), however it will be able to comply with the 'existing plant' limit once the Fabric Filter Plant (FFP) retrofit is complete. This will not be completed by the April 2015 timeframe stipulated in the MES, however. The inability to comply with the MES exists despite the transitional provisions contained in GNR 893 and is unlikely to change in the foreseeable future. As such, Eskom with this Application is applying for postponement of MES limits for NO_x, SO_2, and PM, and proposed alternative emissions limits that are achievable but less stringent than the 'new plant' standards. The purpose of this AIR has been to assess the likely implications of the postponement and the requested alternative emissions limits for human health and the environment.

An assessment of monitored ambient air quality data at the Grootvlei monitoring station reveals that although SO_2 loading is elevated, there is compliance with the National Ambient Air Quality Standards (NAAQS). Although there are exceedances of the hourly ambient limit value for SO_2, there is still compliance with the SO_2 NAAQS. Exceedances of the ten-minute limit values may have occurred, but 10-minute data is not logged. Ambient daily PM_{10} concentrations indicate sustained high loading and exceedance of the daily average NAAQS. Analysis of diurnal data shows that the Grootvlei Power Station does not contribute significantly to ambient PM_{10} and that the exceedances derive from ground level emissions such as domestic fuel use. Maximum hourly ambient NO_2 averages are seen to be well below the hourly limit and the annual averages are also seen to be well below the NAAQS.

Dispersion modelling indicates that Eskom's requested emission limits for NO_X for Grootvlei Power Station pose no risk of exceedance of the NAAQS. There is also predicted to be no risk of non-compliance as a result of Eskom's requested emission limits for SO_2 over most of the domain, although predicted marginal non-compliance with the daily SO_2 NAAQS is predicted in the immediate vicinity of Grootvlei Power Station, if Grootvlei emits continuously at the requested emission limit. In all probability this will not occur, however, as actual SO_2 emissions in future will be similar to current emission levels, an average 30-40% below the requested emission limit. It is thus likely that there will still be compliance with the SO_2 NAAQS if Grootvlei operates according to the requested SO_2 emission limit. Current and future Particulate emissions from the power station contribute only marginally to the measured ambient concentrations.

The implication is that areas of full compliance with the SO_2, NO_x and PM_{10} NAAQS are deemed not to be free of health risks necessarily but the health risks are considered to be permissible.

11. References

CCINFO, (1998 and 2000): The Canadian Centre for Occupational Health and Safety database. http://ccinfoweb.ccohs.ca visited on 21 July 2003.

DEA, (2007): Declaration of The Highveld Priority Area in Terms Of Section 18(1) of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004), Notice 1123 of 2007, Government Gazette, 23 November 2007, No. 30518.

DEA, (2008): Proposed Regulations regarding the form of the Atmospheric Impact Report, as contemplated in Section 30 of the National Environmental Management: Air Quality Act, (Act No. 39 of 2004), Notice 619 of 2008, Government Gazette, 6 June 2008, No. 31107.

DEA, (2009): National Ambient Air Quality Standards, Government Gazette, 32861, Vol. 1210, 24 December 2009.

DEA, (2012a): National Ambient Air Quality Standard for Particulate Matter of Aerodynamic Diameter less than 2.5 micometers, Notice 486, 29 June 2012, Government Gazette, 35463.

DEA, (2012b): Air Quality Management Plan for the Highveld Priority Area, Notice 144 of 2012, Government Gazette, 2 March 2012, No. 35072.

DEA, (2012c): Guideline to Air Dispersion Modelling for Air Quality Management in South Africa, draft regulation.

DEA, (2013): Listed activities and associated minimum emission standards identified in terms of Section 21 of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004), Government Gazette Notice No. 893 of 22 November 2013.

EAE, (2006): Encyclopaedia of the Atmospheric Environment, 2006, Nitrogen [Online], http://www.ace.mmu.ac.uk/eae/Air_Quality/Older/Nitrogen_Dioxide.html

FRIDGE (Fund for Research into Industrial Development Growth and Equity), (2004). Study to examine the potential socio-economic impact of measures to reduce air pollution from combustion. Trade and Industry Chamber, 114pp.

Hurley, P. (2000): Verification of TAPM meteorological predictions in the Melbourne region for a winter and summer month. Australian Meteorological Magazine, 49, 97-107.

Hurley, P.J., Blockley, A. and Rayner, K. (2001): Verification of a prognostic meteorological and air pollution model for year-long predictions in the Kwinana industrial region of Western Australia. Atmospheric Environment, 35(10), 1871-1880.

Hurley, P.J., Physick, W.L. and Ashok, K.L. (2002): The Air Pollution Model (TAPM) Version 2, Part 21: summary of some verification studies, CSIRO Atmospheric Research Technical Paper No. 57, 46 p.

Josipovic, M. (2009): Acidic deposition emanating from the South African highveld – a critical levels and critical loads assessment, Unpublished PhD thesis, University of Johannesburg.

Raghunandan, A., Scott, G., Zunckel, M. and Carter, W. (2007): TAPM verification in South Africa: modelling surface meteorology at Alexander Bay and Richards Bay. South African Journal of Science, in prep.

Schulze, B. R. (1980): Climate of South Africa. Part 8. General Survey, WB 28, Weather Bureau, Department of Transport, Pretoria, 330 pp.

uMoya-NILU (2013): Plan of Study Report, in support of Eskom's application for exemption from the Minimum Emission Standards and/or extension of the Minimum Emission Standards compliance timeframes.

WHO, (1999): Guidelines for Air Quality, World Health Organisation, http://www.who.int/peh/air/Airqualitygd.htm

WHO, (2000): Air Quality Guidelines for Europe, 2nd Edition, World Health Organisation, ISBN 92 890 1358 3.

WHO (2003): Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide. Report on a WHO Working Group Bonn, Germany 13-15 January 2003, WHO Geneva.

12. Formal Declarations