ATMOSPHERIC IMPACT REPORT
in support of
the EIA for the proposed Tshivhaso Coal-Fired Power Plant near Lephalale, Limpopo Province

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EXECUTIVE SUMMARY

Cennergi is a joint venture formed between Exxaro, the second largest producer of coal in South Africa, and Tata Power, India's largest integrated power company. Cennergi is evaluating the potential of establishing the Tshivhaso Coal-Fired Power Plant in the Lephalale Local Municipality, Limpopo, South Africa. The power station would have a capacity of up to 600MW during Phase 1 of installation, and would reach a maximum capacity of 1200MW during Phase 2. Various options regarding siting of the power station and associated infrastructure are being investigated. Coal is proposed to be sourced from Exxaro Coal's Thabametsi Coal-Mine development which is to be located in the vicinity of the sites under investigation. The electricity generated from the power station will be fed into the national electricity grid.

Savannah Environmental has been appointed to conduct an EIA for the proposed Tshivhaso Coal-fired Power Plant. uMoya-NILU has been sub-contracted to undertake the air quality specialist assessment. Power Generation is a Listed Activity in terms of the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (DEA, 2009). The environmental authorisation for the project must therefore be supported by a specialist air quality assessment. This assessment report meets all the requirements of an Atmospheric Impact Report (AIR), specified by the DEA (2013).

The combustion of solid fuels for the purpose of steam raising or electricity generation at facilities with a generation capacity of more than 50 MW heat output per unit is classified as a Listed Activity under Category 1, sub-category 1.1. With a proposed generation capacity of up to 1200 MW, the Tshivhaso coal-fired plant power plant is therefore a Listed Activity. The Listed Activity forms part of a matter declared as a national priority and the licensing authority is the National Air Quality Officer, Dr Thuli Mdluli.

The Proposed Tshivhaso Coal-Fired Power Station development falls within the Lephalale Local Municipality (LM) which is a part of a National Priority Area. The Minister declared the Waterberg–Bojanala Priority Area (WBPA) on 15 June 2012 as the third National Priority Area (DEA, 2012a), crossing the North West and Limpopo provincial borders. The WBPA covers an area of 67 837 km^2, bordering with Botswana. It includes the Waterberg District Municipality (WDM) in Limpopo Province and parts of the Bojanala Platinum District Municipality (BPDM) in the North West Province, with nine Local Municipalities.

Winters are mild, with average maximum temperatures dropping to between 26°C and 24 ºC between May and August, but are relatively cold at night dropping below 7°C. Summers are hot, and the average maximum temperature exceeds 30°C from October to March, with temperatures reaching more than 33°C in January. Lephalale receives an average of 435 mm of rainfall annually, with 88% of the rainfall occurring in the summer months from October to March. Rainfall seldom occurs in winter between April and September.

The Lephalale area is relatively flat with little influence by topography on the wind flow. The prevailing winds are northeasterly to easterly. The communities of concern are situated up-wind from the proposed power station, causing pollution emitted by the power station to be blown away from the main residential areas.

At Lephalale, the dispersion potential is expected to be relatively good during the day in both winter and summer as a result of hot daytime temperatures and a relatively high frequency of moderate winds. Dispersion potential will be better in summer than winter for several reasons. Firstly, rainfall in summer is an important removal mechanism for air pollutants. Secondly, the thermal mixing is stronger and the night-time temperature

inversions are weaker and break up earlier and establish later in the day. Thirdly, there is a higher frequency of stronger winds in summer than in winter.

The DEA established an ambient monitoring station in Lephalale, with monitoring commencing in February 2013 (www.saaqis.org.za). The station is well removed from industrial sources and from the influence of residential fuel burning. It is located near a busy road, but is classified as an urban background site. The average 1-hour ambient NO_2 concentration at the site since monitoring started is 16 μg/m^3 which is significantly below the national ambient air quality standard of 200 μg/m^3. The average 24-hour SO_2 concentration is 7 μg/m^3 which is also well below the ambient air quality standard of 125 μg/m^3. The average 24-hour PM_{10} concentration is 34 μg/m^3. This background concentration is relatively high compared to the 2015 ambient standard of 75 μg/m^3, equivalent to nearly 50% of the standard.

In coal-fired power plants, crushed coal is burnt to generate heat, which in turn is used to heat water and generate steam. The steam then drives turbines that generate electricity. The combustion of coal results in emissions of numerous pollutants into the atmosphere. The major pollutants emitted from coal combustion at the Tshivhaso Power Station are SO_2, NO_X and particulates; and dust from the coal stockpile and ash dump. Maximum permissible hourly release rates for SO_2, NO_X and particulates are specified for these pollutants (DEA, 2013a). The potential effect of these pollutants is described here.

Known human health impacts of exposure to SO_2 and NO_2 are mainly respiratory effects such as narrowing of the airways, exacerbation of asthma and an influence on lung function. The effects of PM depend on the size and chemical composition of the particles. Particles with a diameter smaller than 10 μm (including PM_{10} and $PM_{2.5}$) that are inhaled may result in respiratory effects as well as cardiovascular effects.

The Tshivhaso Power station will utilise Circulating Fluidised Bed (CFB) combustors (boilers) which have the advantage that sulphur trapping can take place with the sorbent bed (limestone) in these boilers. This ensures a plant with relatively low emissions. In addition, the power station will utilise dry cooling technology and dry ashing due to water availability constraints.

Dispersion Modelling and Impact Assessment methodology

This assessment is considered to be a level 2 assessment, according to the definition on the dispersion modelling guideline (DEA, 2012b). The CALPUFF suite of models (http://www.src.com/calpuff/calpuff1.htm) were 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.

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.

The assessment considers the impacts associated with:

- Construction;
- Operations;
- Cumulative effects and
- Decommissioning.

The assessment of the potential impacts associated with the scenarios presented above is based on the comparison of predicted ambient concentrations of relevant pollutants with the South African ambient air quality standards to assess the level of compliance and the significance of the potential impact. The predicted annual average, 99th percentile 24-hour and 99th percentile 1-hour concentrations of nitrogen dioxide (NO_x), SO_2 and PM_{10} are presented as isopleth maps on a base map of the area for each scenario and each alternative. The frequency of exceedance of the ambient 1-hour and 24-hour air quality standards are also presented spatially. Populated areas, or sensitive receptors, are considered in the designation of significance.

The additive, or cumulative effects, of emissions from the project to the existing ambient concentrations are not modelled. Rather typical background concentrations of respective pollutants are considered when assessing modelled concentrations resulting from the Tshivhaso Power Station in isolation.

This assessment is conducted in terms of the significance of direct, indirect and additive air quality impacts from the proposed modifications. The assessment considers the nature, extent, duration, probability and severity of air quality impacts, which leads to the determination of the significance of the impacts.

Modelled operational scenarios

Four operational scenarios are assessed for Tshivhaso power plant generating the maximum output of 1 200 MW. These scenarios are:

Scenario 1: The Tshivhaso Power Station in isolation with ash dump option 1
Scenario 2: The Tshivhaso Power Station in isolation with ash dump option 2
Scenario 3: The additive effect of the Tshivhaso Power Station with existing sources (Matimba Power Station)
Scenario 4: The cumulative effect of future sources in relatively close proximity to the Tshivhaso plant (e.g. Medupi and Thabametsi)

The results of the change in the location of the ash dump in Scenario 2 are only applicable to PM_{10} concentrations.

Annual and 99th percentile concentrations

The 99th percentile predicted ambient SO_2, NO_2, PM_{10} and benzene concentrations from the dispersion modelling for the plant using coal are presented as isopleth maps over the modelling domain. The DEA (2014) recommends the 99th percentile concentrations for short-term assessment with the National Ambient Air Quality Standards (NAAQS) since the highest predicted ground-level concentrations can be considered outliers due to complex variability of meteorological processes. In addition, the limit value in the NAAQS is the 99th percentile.

The impact assessment then compares the predicted 99th percentile concentrations with the respective ambient air quality standards (limit values and the permitted frequency of exceedance) 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 Actual Emissions and Requested Limits Scenarios were determined and are presented in Table A.

Table A: Maximum predicted annual average concentration and the highest 99th percentile concentration at the points of maximum ground-level impact

	SO_2 (µg/m^3)			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
1-hour	**246**	**246.44**	**322.79**	**759.71**
24-hour	**98**	**97.717**	**154.15**	**318.76**
Annual	**7.5**	**7.5078**	**12.638**	**36.362**
	NO_2 (µg/m^3)			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
1-hour	**105.69**	**105.69**	**113.21**	**211.39**
Annual	**3.2197**	**3.2197**	**3.8182**	**10.43**
	PM_{10} (µg/m^3)			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
24-hour	**3.6541**	**3.6541**	**3.7831**	**4.2293**
Annual	**0.35**	**0.35014**	**0.40442**	**0.5161**

Impact assessment

Impacts can generally be categorised as direct, indirect or cumulative. Direct impacts are impacts that are caused directly by the project or activity in isolation of other sources and generally occur at the same time and place as the activity. Indirect impacts are indirect or induced changes that may occur as a result of the activity. These types of impacts include all the potential impacts that do not manifest immediately when the activity is undertaken or which occur at a different place as a result of the activity. Cumulative impacts are impacts that result from the incremental impact of the proposed activity on a common resource when added to the impacts of other past, present or reasonably foreseeable future activities.

For this study, direct impacts will result from the inhalation of NO_2, SO_2 and particulates (PM_{10}) emitted during the operational life of the Tshivhaso Power Station. Direct impacts will also result from exposure to dust generated from the coal stockpiles, ash dump; and from the construction of the Tshivhaso Power Station and decommissioning activities. Indirect impacts resulting from emissions of SO_2 and NO_2 from coal-fired power plants include their contribution to acidification in both dry and wet (acid rain) deposition. Further indirect effects are associated emissions of CO and CO_2. CO_2 is a Greenhouse Gas (GHG), adding to the global concentrations. CO is not considered a GHG, but is a strong precursor in the formation of ozone in the troposphere. The global warming potential of tropospheric ozone is equivalent to between 918-1022 tons of CO_2.

The Tshivhaso Power Station is proposed to be constructed on agricultural land, and is surrounded by vast tracts of agricultural land. There is a high concentration of large scale mining activities in the area (Grootgeluk and Grootestryd mine dump and Matimba ash dump). Eskom's Matimba Power Station is located to the south.

With respect to cumulative impacts, mining and agricultural activities, ash dumps, and domestic fuel burning in the area are identified as existing sources of dust. There will be a cumulative impact with dust generated during construction and decommissioning of the Tshivhaso Power Station, as well as during normal operations of the proposed coal stockpile and ash dump at the Tshivhaso Power Station.

The Tshivhaso Power Station is located in an area where there are no notable sources of dust, PM_{10}, NO_2 and SO_2 in the immediate vicinity of the site, i.e. within a 5 km radius. Motor vehicle traffic on the R510, R572, R518 and surrounding roads will have some influence on ambient air quality as will domestic fuel burning. The Matimba (existing), Medupi (under construction) and Thabametsi (authorised) Power Stations are located within a 15 km radius from the Tshivhaso Power Station and are important sources of NO_2, SO_2 and PM_{10} in the locality. It is therefore expected that there will be compounding of effects and hence cumulative impacts during operation of the Tshivhaso Power Station.

Average ambient concentrations measured at the DEA's monitoring site at Lephalale are considered representative of background concentrations. Predicted ambient concentrations resulting from emissions from the Tshivhasoi Power Station are relatively localised and are indicated as very low for all modelled operational scenarios. The contribution to ambient concentrations beyond the immediate vicinity of the power station will be small. It is highly unlikely that they will result in exceedances of the national ambient air quality standards at the Lephalale monitoring site, and elsewhere in the area. A summary of air quality impacts is presented in Table B.

Table B: Summary of air quality impacts during operation of the Tshivhaso Power Station – applicable to all operational scenarios:

Nature: Air quality impacts are caused by the inhalation of NO_2, SO_2 and particulates (PM_{10}), which are contained in emissions from the Tshivhaso Power Station. The inhalation of the NO_2, SO_2 and PM_{10} at concentrations exceeding health-based air quality standards; and which are greater than the permitted number of exceedances per year, will result in negative health impacts.	
Extent	Local/municipal extending only as far as the local community or urban area (4)
Duration	Long-term (4)
Magnitude	Moderate (6)
Probability	High (4)
Significance (positive or negative)	medium (56) and negative
Reversibility	Yes
Irreplaceable loss of resources?	No
Can impacts be mitigated?	Yes
Mitigation: Plant engineers and operators are to ensure that the abatement technology that is to be installed is always in working order and maintained on a regular basis as per standard operating procedures.	
Cumulative Impacts: The Matimba (existing), Medupi (under construction) and Thabametsi (authorised) Power Stations are located approximately 15 km from the Tshivhaso Power Station and are important sources of NO2, SO2 and PM10 in the locality. It is therefore expected that there will be compounding of effects and hence cumulative impacts during operation of the Tshivhaso Power Station.	
Residual Impacts: No	

The main findings of the air quality specialist study are:

Construction and decommissioning of infrastructure for the project

Impacts due to construction and decommissioning on ambient air quality concern particulate matter only and is expected to be of a temporary nuisance nature. Impacts will be limited to less than 1 km from the source and may impact on the property on which the site is to be constructed. These impacts are expected to have a low significance.

PM_{10} from the coal stockpile and ash dump at the Tshivhaso Power Station

The predicted 99th percentile 24-hour and annual average PM10 concentrations resulting from the coal stockpile and ash dump are also assessed in isolation to show their individual contribution in the ambient environment; and together to show the cumulative impact under normal operating conditions. A worst case cumulative impact considers the coal stockpile and ash dump where 100% of both areas are exposed to wind erosion. Two scenarios were assessed, where two different sites were used as the location of the ash dump. In all cases considered, predicted ambient concentrations resulting from the Tshivhaso Power Station are compliant with the current and future national ambient standards. The impacts associated with PM_{10} from the coal stockpile and ash dump have a low significance.

PM_{10} from the coal stockpile, ash dump and stacks at the Tshivhaso Power Station

When assessing PM_{10} from all sources at the Tshivhaso Power Station, (i.e. the four stacks, the coal stockpile and the ash dump in combination), it is assumed that 100% of the area for both the coal stockpile and ash dump is exposed to wind erosion. This constitutes a worst case scenario. The predicted 99th percentile 24-hour and annual average PM_{10} are assessed and predicted ambient concentrations resulting from the Tshivhaso Power Station are compliant with the current and future national ambient standards.

There is very little difference in ambient concentrations between the two different locations proposed for the ash dump. It is therefore concluded that the contribution of PM_{10} in the ambient environment are not dominated by the coal stockpile and ash dump, which are low level sources. The impacts associated with PM10 are attributed primarily to the stacks and have a low significance.

NO_2 from the stacks at the Tshivhaso Power Station

The predicted 99th percentile 1-hour and annual average NO_2 concentrations are assessed. Predicted ambient concentrations resulting from the Tshivhaso Power Station are compliant with national ambient standards and no exceedance of the standard is predicted within the Tshivhaso Power Station site or in residential areas around the site. The impacts associated with NO_2 have a low significance.

SO_2 from the stacks at the Tshivhaso Power Station

For SO_2 the predicted 99th percentile 1-hour, 24-hour and annual average concentrations complies with the national ambient standard for SO_2 and no exceedance of the standard is predicted within the Tshivhaso Power Station site or in residential areas around the site. The impacts associated with SO_2 have a low significance.

Indirect impacts at the Tshivhaso Power Station

Indirect impacts associated with the SO_2 and NO_2 emissions relate to acidification, and those associated with CO and CO_2 relate to global warming. The magnitude of indirect impacts associated with the operational scenarios relates to the relative contribution to acidification and global warming. While quantification of the relative contribution of the Tshivhaso Power Station is difficult, the contribution is considered to be relatively small in the national and global context. It should be noted that a separate climate change assessment is being undertaken. However, for the puposes of this assessment the significance of the indirect impacts is deemed low for all operational scenarios.

Cumulative impacts at the Tshivhaso Power Station

With respect to cumulative impacts, mining and agricultural activities, tailings dams, domestic fuel burning and vehicles on dirt roads in the area are identified as existing sources of dust. There will thus be a cumulative impact with dust generated during construction and decommissioning of the Tshivhaso Power Station, as well as during normal operations of the proposed coal stockpile and ash dump at the Tshivhaso Power Station.

The Matimba and Medupi Power Stations, operated by Eskom, and the proposed Thabametsi Power Station are located approximately 15 km to the north to the southeast of the Tshivhaso Power Station and is an important source of NO_2, SO_2 and PM_{10} at that locality. While the predicted ambient concentrations resulting from emissions from the Tshivhaso Power Station comply with ambient air quality standards, the cumulative effect of these emissions with those from Eskom's Matimba Power Station and the new Medupi and Thabametsi Power Stations are likely to result in exceedances of the ambient standards (uMoya-NILU, 2013).

The AQMP for the Waterberg-Bojanala Priority Area includes emission reduction requirements. It is important that an emission control and reduction strategy for dust is designed and implemented, ensuring that the contribution to ambient concentrations is minimised (DEA, 2015). This can be achieved through the implementation of appropriate mitigation measures for all projects.

The probability of direct and cumulative impacts from dust, PM_{10}, NO_2 and SO_2, emitted during normal operation of the Tshivhaso Power Station, is considered to be high for all scenarios. The predictive modelling provides maximum expected ambient concentrations for each pollutant based on a worst-case meteorological scenario. These results show that predicted concentrations comply with the national ambient standard throughout the study domain. Despite this, some risk to health remains and the probability of direct and cumulative air quality impacts during the operation of Tshivhaso Power Station is considered to be high.

Employing the generic design parameters provided for the project, it is predicted that the site operations will generate low emissions, low ambient concentrations, and low air quality impacts overall. Mitigation measures are recommended for construction and decommissioning activities and during the operational lifespan of the facility. It is a reasonable opinion that the project should be authorised considering the outcomes of this impact assessment.

LIST OF ACRONYMS

AEL	Atmospheric Emission Licence
AIR	Atmospheric Impact Report
AQO	Air Quality Officer
CCGT	Combined Cycle Gas Turbine
C_6H_6	Benzene
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
EIA	Environmental Impact Assessment
ECO	Emission Control Officer
GHG	Greenhouse Gases
HRSG	Heat recovery steam generator
IDP	Integrated Development Plan
IPP	Independent Power Producer
NAAQS	National Ambient Air Quality Standards
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NEM: AQA	National Environmental Management: Air Quality Act (Act No. 39 of 2004)
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen (NO_X = NO + NO_2)
PM_{10}	Particulate matter with a diameter less than 10 microns
$PM_{2.5}$	Particulate matter with a diameter less than 2.5 microns
SAAQIS	South African Air Quality Information System
SAWB	South African Weather Bureau
SAWS	South African Weather Service
SO_2	Sulphur dioxide
μm	Micro meters (1 μm = 10^{-6} m)
US-EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
WHO	World Health Organisation

DECLARATION

Atmospheric Impact Report in support of the EIA for the proposed Tshivhaso Coal-Fired Power Plant near Lephalale, Limpopo Province

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I, MARK ZUNCKEL, declare that –
I act as the independent specialist in this matter;
I do not have and will not have any vested interest (either business, financial, personal or other) in the undertaking of the proposed activity, other than remuneration for work performed in compiling the Atmospheric Impact Report;
That there are no circumstances that may compromise my objectivity in performing the work;
I have expertise in compiling the Air Quality Specialist Study, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the Atmospheric Impact Report by the competent authority;
All the particulars furnished by me in Atmospheric Impact Report are true and correct; and
I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

Name of company: uMoya-NILU Consulting (Pty) Ltd
Date: 26 April 2016

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1. Introduction

Cennergi is a joint venture formed between Exxaro, the second largest producer of coal in South Africa, and Tata Power, India's largest integrated power company. Cennergi is evaluating the potential of establishing the Tshivhaso Coal-Fired Power Plant in the Lephalale Local Municipality, Limpopo, South Africa. The power station would have a capacity of up to 600MW during Phase 1 of installation, and would reach a maximum capacity of 1200MW during Phase 2. Various options regarding siting of the power station and associated infrastructure are being investigated (Figure 1-1). Coal is proposed to be sourced from Exxaro Coal's Thabametsi Coal-Mine development which is to be located in the vicinity of the sites under investigation. The electricity generated from the power station will be fed into the national electricity grid.

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The terms of reference for the study includes:

II. The drafting of air quality input to the Scoping Report, including the description of the current state of the receiving atmospheric environment in Lephalale, a legal review and potential air quality constraints. No primary information will be collected, rather information contained in the Baseline Air Quality Assessment for the Waterberg-Bojanala Priority Area (WBPA) will be used;

III. The development of the emission inventory for the TshivhasoPower Station and its supporting infrastructure;

IV. The prediction of ambient concentrations of pollutants resulting from emissions from the Tshivhaso Power Station operation using the DEA recommended CALPUFF dispersion model with three-year local meteorological data (2012, 2013, 2014), according to the DEA guideline for dispersion modelling (DEA, 2012) .

Dispersion modelling will be done for:

a) The Tshivhaso Power Station in isolation,
b) The additive effect of the Tshivhaso Power Station with existing sources (Matimba Power Station)
c) Future sources in relative close proximity to the Tshivhaso plant (e.g. Medupi and Thabametsi); and
d) include the compilation of a draft report AIR for submission to Savannah Environmental and Cennergi for review, including the assessment of air quality impacts of the proposed operation and the cumulative effects by evaluating predicted ambient concentrations of pollutants

1.1 Enterprise Details

Entity details for Tshivhaso Coal Fired Power are listed in Table 1-1.
Please note that this information has been requested.

Table 1-1: Entity details

Entity Name:	Tshivhaso Coal Fired Power Plant
Trading as:	Cennergi
Type of Entity, e.g. Company/Close Corporation/Trust, etc.:	Company
Company/Close Corporation/Trust Registration Number (Registration Numbers if Joint Venture):	
Registered Address:	
Postal Address:	
Telephone Number (General):	
Fax Number (General):	
Company Website:	
Industry Type/Nature of Trade:	Power generation
Name of the Landowner/s or Landlord/s:	Exxaro
Name of Mortgage Bondholder/s (if any):	
Deeds Office Registration Number of Mortgage Bond:	
Land Use Zoning as per Town Planning Scheme:	
Land Use Rights if outside Town Planning Scheme:	

1.2 Location and extent

Site information is provided in Table 1-2. Receptors within a 5 and 15 km radius of the proposed plant are shown in Figure 1-2. The Proposed Tshivhaso Coal-Fired Power Station development falls within the Lephalale Local Municipality (LM). The name "Lephalale Town" is inclusive of the town of Lephalale (previously Ellisras) as well as the Onverwacht and Marapong residential areas (Figure. 1.1). The majority of people in Lephalale LM live in scattered settlements, which puts a burden on provision of services including water, electricity and refuge removal.

Provision of electricity and water is a concern in the Lephalale LM. Although 85% of households have access to electricity (StatSA, 2011), the Waterberg substation has no spare capacity (Lephalale IDP, 2012/13) and already the demand for water cannot be met by the available water resources in the area (Schachtschneider et al., 2010).

Considering a population of 115 767 (StatSA, 2011) in an area of 20 000 km^2, the calculated population density for Lephalale LM is 5.8 individuals per km^2. The Lephalale LM household size is smaller than that of the Waterberg District Municipality (DM) (3.4) and Provincial (3.7) averages (StatsSA, 2011). It is speculated that this relatively low figure could be attributed to the fact that many households consist of migrant workers who came to the area as contract workers without their families (IDP, 2009/10).

About 26.2% of the population in Lephalale LM was below 15 years and 4.1% above 65 years during the last census (StatsSA, 2011), thus 30.3% of the population may be considered vulnerable as far as their age is concerned, including to environmental pollution. This vulnerable portion is slightly lower than that of the Waterberg DM, which had 35.7% vulnerable people and the province, which had 40.3%.

The population in the Limpopo province has grown by 0.8% between 2001 and 2011 and the population in the Waterberg DM by 2.1%, the highest growth rate of all DMs in the province. The population growth in Lephalale LM over the same period was 3.1%, the highest of all LMs in the province (StatsSA, 2011). It is speculated that this elevated growth rate is because of the influx of construction workers and job seekers due to development in the area.

Socio-economic status is a reliable predictor of quality of life, burden of disease, access to basic amenities, education, employment and uptake of basic government services. The deprivation index gives an indication of whether a community, area or country is deprived of material assets, employment and education as well as care and adequate housing. An index of 1 means that a community is not deprived, but the higher the index, the worse off the community is.

The deprivation index of Lephalale LM is 2.96, the second highest in the District Municipality (DM) (SAHR 2008). More than 4 300 households (15.5% of households) in Lephalale do not have any income, in 2010 about 78 000 (70%) people lived in poverty (Lephalale IDP, 2012/13) and 41% of the population receive grants (Lephalale IDP, 2012/13). However, there was an improvement in the education of people in Lephalale LM since 2001, when 24.6% had no schooling, compared to 9.9% of those above 20 who indicated they have no schooling in the 2010 census (StatsSA, 2011).

Table 1-2: Site information

Physical Address of the Licenced Premises:	
Description of Site (Where No Street Address):	Graafwater 456/ Goedehoop
Property Registration Number (Surveyor-General Code):	
Coordinates (latitude, longitude) of Approximate Centre of Operations (Decimal Degrees):	-23.611286° 27.522755°
Coordinates (UTM) of Approximate Centre of Operations:	553329.00 m E 7388711.00 m S
Extent (km²):	
Elevation Above Mean Sea Level (m)	36.48
Province:	Limpopo
District/Metropolitan Municipality:	Waterberg District Municipality
Local Municipality:	Lephalale Local Municipality
Designated Priority Area (if applicable):	Waterberg-Bojonala Priority Area

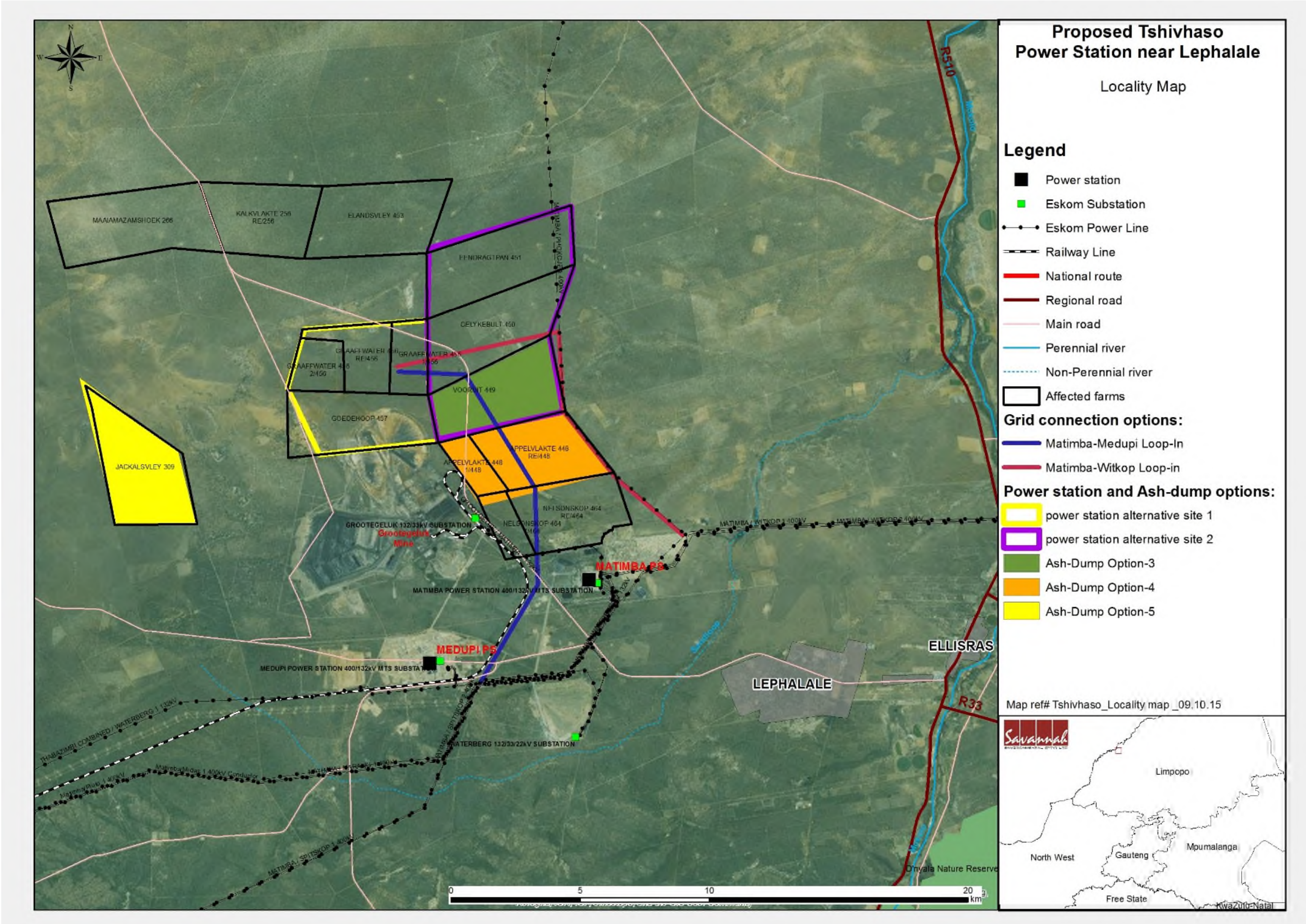
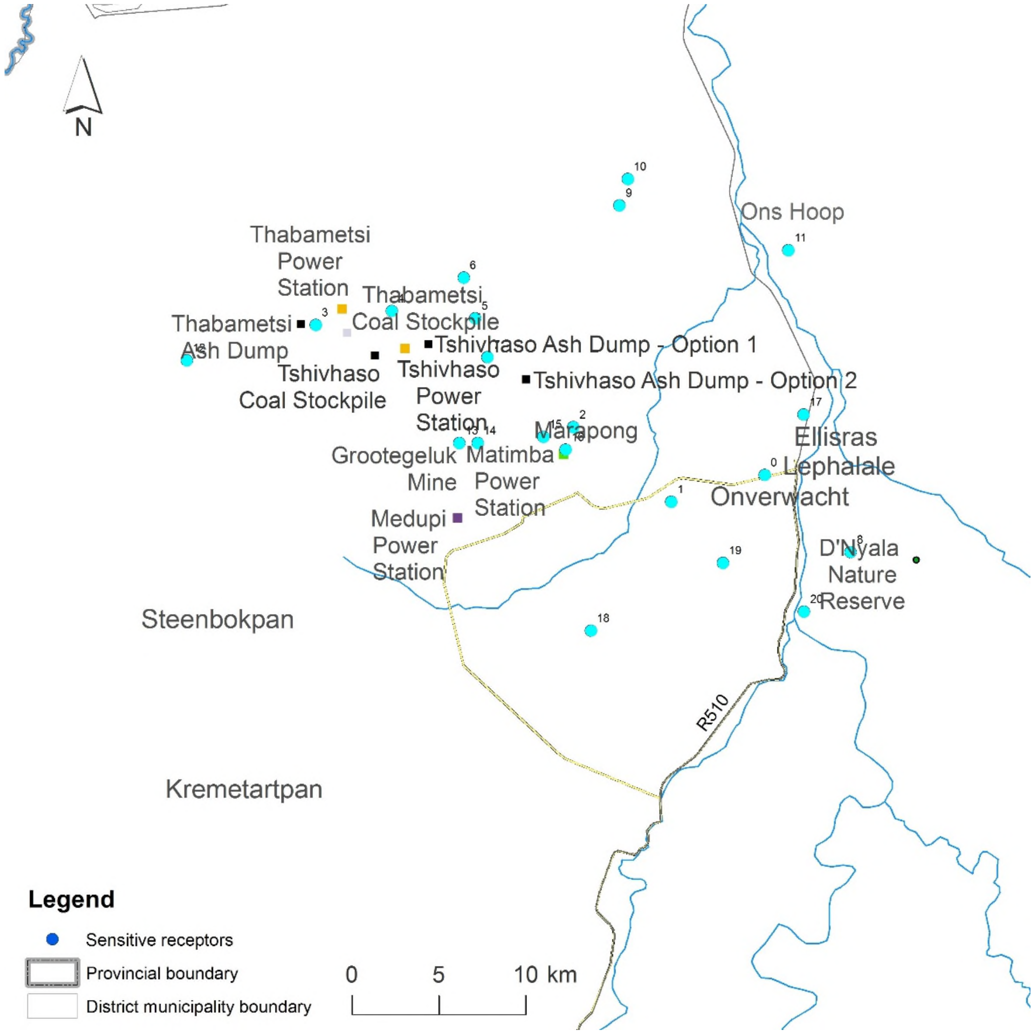


Figure 1-1: Proposed location of the Tshivhaso power plant in the Lephalale Municipality



Lephalale	0
Onverwacht	1
Marapong	2
Onbelyk	3
Gelykebult 450	4
Gelykebult 455	5
Eendragtpan 451	6
Vooruit 449	7
D'Nyala Nature Reserve	8
Settlement 1	9
Settlement 2	10
Settlement 3	11
Settlement 4	12
Settlement 5	13
Settlement 6	14
Settlement 7	15
Settlement 8	16
Settlement 9	17
Settlement 10	18
Settlement 11	19
Settlement 12	20

Figure 1-2: Receptors within 5 km from the proposed power plant in the Lephalale Local Municipality

1.3 Nature of the Process

1.3.1 Overview

The power station will utilise Circulating Fluidised Bed (CFB) combustors (boilers) which have the advantage that sulphur trapping can take place with the sorbent bed (limestone) in these boilers. This ensures a plant with relatively low emissions. In addition, the power station will utilise dry cooling technology and dry ashing due to water availability constraints. The process is shown schematically in Figure 1-3.

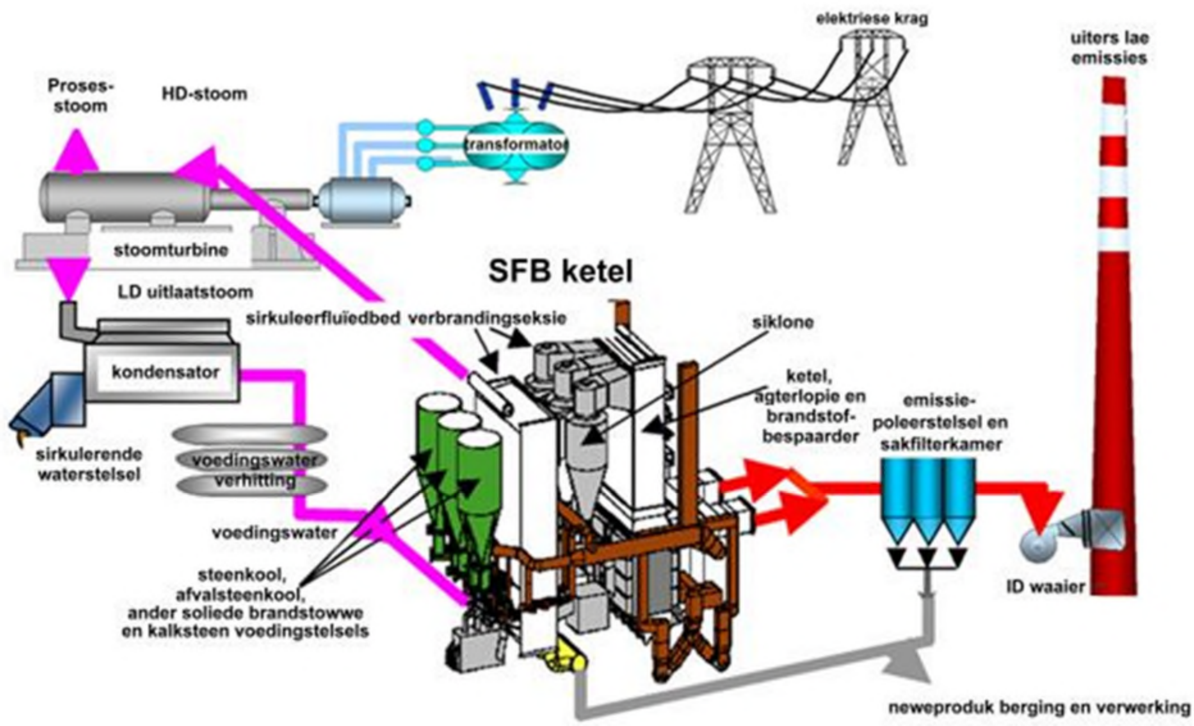


Figure 1-3: Mode of operation*

*Text in Afrikaans, as received from Savannah Environmental

1.3.2 Air pollutants resulting from power generation

In coal-fired power plants, crushed coal is burnt to generate heat, which in turn is used to heat water and generate steam. The steam then drives turbines that generate electricity. The combustion of coal results in emissions of numerous pollutants into the atmosphere. These include particulate matter (including trace metals), gases (including sulphur dioxide (SO_2), nitrogen oxides ($NOx = NO + NO_2$) and carbon monoxide (CO), organics (volatile organic compounds, polycyclic organic matter (PAH, PCDD, etc.) and trace elements (mercury, arsenic, etc). The resultant pollutants are a function of the coal properties, operating temperature, oxygen mixing and sufficient time for complete combustion. Greenhouse gases (GHG) emitted during coal combustion include carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O). Dust emissions may emanate from the following processes: the coal transfer house, strategic stockpile, working stockyard, silos and conveyor operations, limestone rail/road offloading, storage, ash-handling conveyors, silos, disposal and dump facility operations.

Known human health impacts of exposure to SO_2 and NO_2 are mainly respiratory effects such as narrowing of the airways, exacerbation of asthma and an influence on lung function. The effects of PM depend on the size and chemical composition of the particles. Particles with a diameter smaller than 10 µm (including PM_{10} and PM2.5), that are inhaled may result in respiratory effects as well as cardiovascular effects. The health effects of volatile organic compounds (VOC) such as benzene, toluene, ethyl-benzene and xylene, associated with fossil fuel burning, include acute neurological effects such as headaches and dizziness when exposed to relatively high concentrations. Some VOCs may also cause cancer, for example benzene.

1.4 Emission Control Officer

The project is a proposed development. An Emission Control Officer (ECO) has not yet been appointed.

1.5 Authorisation Details

No existing authorisations are in place for the activity, as it is a new activity.

1.6 Modelling contractor

The dispersion modelling for the AIR for the proposed TSHIVHASO power plant in Lephalale Municipality is conducted by:

Company:	uMoya-NILU Consulting (Pty) Ltd
Modellers:	Dr Mark Zunckel and Atham Raghunandan
Contact details:	Tel: 031 262 3265
	Cell: 083 690 2728
	Email: mark@umoya-nilu.co.za or atham@umoya-nilu.co.za

Dr Zunckel's curriculum vita is included in Appendix 1.

2. Legal requirements

2.1 National Environmental Management Act

Section 28 of the National Environmental Management Act (NEMA) (Act No. 107 of 1998) addresses the duty of care and remediation of environmental damage. Sub-section 1 and 3 apply to the Tshivhaso power plant and air quality management. These are:

Sub-section 1: Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment.

Sub-section 3: The measures required in terms of the above may include the following:

i) Investigate, assess and evaluate the impact on the environment;

ii) Inform and educate employees about the environmental risks of their work and the manner in which their tasks must be performed in order to avoid causing significant pollution or degradation of the environment;
iii) Cease, modify or control any act, activity or process causing the pollution or degradation;
iv) Contain or prevent the movement of pollutants or the cause of degradation;
v) Eliminate any source of the pollution or degradation;
vi) Remedy the effects of the pollution or degradation.

Considering the requirements of Section 28 of the NEMA, Cennergi is proactive in investigating, assessing and evaluating the impact of their emissions on ambient air quality through ambient monitoring and assessment studies.

2.2 The Air Quality Act

2.2.1 Listed activities and Minimum Emission Standards

Listed Activities are activities that the Minister (or MEC) reasonably believes have or may have a significant detrimental effect on the environment (Section 21(1)(a) of the NEM: AQA). Minimum emission standards have been set for most Listed Activities. Combustion installations used primarily for steam raising or electricity generation are Listed Activities (Category 1) in term of Section 21 of the NEM: AQA.

The combustion of solid fuels for the purpose of steam raising or electricity generation at facilities with a generation capacity of more than 50 MW heat output per unit is a Listed Activity (Category 1, sub-category 1.1). With a proposed generation capacity of up to 1200 MW, the Tshivhaso coal-fired plant power plant is therefore a Listed Activity.

2.2.2 Atmospheric Emission Licence (AEL)

The consequence of listing an activity is described in Section 22 of the NEM: AQA, i.e. that no person may conduct a Listed Activity without a provisional Atmospheric Emission Licence or an Atmospheric Emission Licence (AEL). The AEL application process is described in Section 37 of the NEM: AQA and in the National Environmental Management: Air Quality Amendment Act, (Act No. 20 of 2014).

In cases where the Listed Activity forms part of a matter declared as a national priority, the licensing authority is the National Air Quality Officer, Dr Thuli Mdluli (refer to the National Environmental Management: Air Quality Amendment Act, Act No. 20 of 2014) (Tel: 012 399 9188, email: TNMdluli@environment.gov.za)

The consequence of listing an activity is described in Section 22 of the NEM: AQA, that no person may conduct a Listed Activity without a provisional Atmospheric Emission Licence or and Atmospheric Emission Licence (AEL).

Regulations prescribing the AEL processing fee were gazetted on 11 March 2016 (DEA, 2016). The processing fee for new Listed Activities of R10 000 per Listed Activity should be paid on or before the date of the submission of the application.

2.2.3 Ambient air quality standards

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 level 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 established national ambient air quality standards for the criteria pollutants, i.e. SO_2, nitrogen dioxide (NO_2), carbon monoxide (CO), respirable particulate matter (PM_{10}), ozone (O_3), lead (Pb), benzene (C_6H_6) (DEA, 2009) and $PM_{2.5}$ (DEA, 2012a). The National Ambient Air Quality Standards for SO_2, NO_2, PM_{10} and $PM_{2.5}$, CO and benzene are listed in Table 2-2.

The national ambient air quality standard consists of a limit value and a permitted frequency of exceedance as shown in Table 2-2. The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant. The permitted frequency of exceedance represents the tolerated exceedance of the limit value and is equivalent to the 99th percentile, accounting for outliers in the data. 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 is acceptable and poses little or no risk to human health; while exposure to ambient concentrations above the standard implies that there is a risk to human health.

Table 2-1: National ambient air quality standards (DEA, 2009; DEA, 2012a)

Pollutants	Averaging period	Limit value (µg/m³)	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	75	4
	Calendar year	40	0
$PM_{2.5}$	24-hour	40 (25)[2]	0
	Calendar year	20 (15)[2]	0
Benzene	Calendar year	5	0
CO	1 hour	30	88
	8 hours	10	11

[2]: Implementation date 1 January 2030

2.3 AQMP for the Waterberg Bojanala Priority Area

The Minister declared the Waterberg–Bojanala Priority Area (WBPA) on 15 June 2012 as the third National Priority Area (DEA, 2012a), crossing the North West and Limpopo provincial borders. The WBPA covers an area of 67 837 km², bordering with Botswana. It includes the Waterberg District Municipality (WDM) in Limpopo Province and parts of the

Bojanala Platinum District Municipality (BPDM) in the North West Province, with nine Local Municipalities (LM) (Table 2-3).

Table 2-2: Municipalities within WBPA

Province	District Municipality	Local Municipality
Limpopo	Waterberg	Thabazimbi
		Modimolle
		Mogalakwena
		Bela-Bela
		Mookgopong
		Lephalale
North West	Bojanala Platinum	Moses Kotane
		Rustenburg
		Madibeng

The WDM and Botswana have significant coal reserves that are largely unexploited, with the Matimba Power Station and Morupule Power Station currently in operation. The National Development Plan 2030 acknowledges that the lack of stable power to meet the energy demands is an impediment to economic growth in the region, proposing Strategic Infrastructure Projects (SIPs) to accelerated growth and development in the WDM. In addition, the Government of Botswana requires that the energy sector be augmented through the development of new coal-fired power plant generation capacity. The energy-based development initiatives in South Africa and Botswana pose a threat to the current state of ambient air quality in the region. Management planning in the WBPA therefore needs to consider the current and future threats to air quality.

uMoya-NILU Consulting (Pty) Ltd was appointed by the Department of Environmental Affairs (DEA) to develop the Air Quality Management Plan (AQMP) for the WBPA.

The AQMP for the WBPA aims to address the gaps and issues identified in the baseline characterisation, and to address the challenges posed to air quality and the managementthereof by the planned development of energy-based projects in the region. The overall objective of the WBPA AQMP recognises that ambient air quality currently does not comply with NAAQS throughout the Priority Area, and the proposed expansion of energy based projects in the WDM and Botswana poses a risk to future air quality.

It states that:Ambient air quality in the Waterberg Bojanala Priority Area is brought into full compliance with national ambient air quality standards by 2020 and the state is maintained as the region develops.

The Overall Objective of the WBPA AQMP is to be realised through the attainment of five related goals. These are:

Goal 1

Cooperative governance in the WBPA promotes the implementation of the AQMP. This goal aims to address the shortcomings in cooperative governance by ensuring the appropriate structures and mechanisms are in place at the respective levels of governance for effective implementation of the AQMP

Goal 2

Air quality management in the WBPA is supported by effective systems and tools. This goal aims to improve the systems and tools required for effective air quality management in the WBPA, including emission inventories, ambient monitoring and modelling, and enforcement

Goal 3
Ambient concentrations of air pollutants comply with the NAAQS in the WBPA as a result of emission reductions. This goal focuses on emission control and reduction across all sectors to ensure that there is compliance with the NAAQS in the WBPA

Goal 4
Air quality decision making in the WBPA is informed by sound research. This goal aims to ensure appropriate research establishes the health baseline, which improves the Threat Assessment and prioritises emission reduction interventions to inform air quality management and planning in the WBPA

Goal 5
Knowledge and the understanding of air quality amongst stakeholders in the WBPA is enhanced. This goal aims to improve communication and current levels of knowledge of air quality amongst stakeholders in the WBPA

A number of outcomes-based objectives are set for each of the goals to steer the implementation of the WBPA AQMP. Activities are then defined, which upon their completion will ensure that the objectives are realised, and in turn, the goal is realised.

An Implementation Plan accompanies the AQMP. It includes the responsibility of executing the work required in each activity through assigning mandatory and participatory roles. The implementation of the WBPA commences when the AQMP has been accepted by the Minister and has been published in the Government Gazette. The implementation of the WBPA AQMP recognises the existing provincial and municipal AQMPs, their implementation and the current roles and responsibilities of the incumbent officials. The monitoring of progress with implementation of the WBPA AQMP is an on-going process that assesses all aspects of the plan. Monitoring allows issues to be addressed timeously so that implementation is not hindered and aspects do not lag, and are reported routinely to the Minister. Evaluation aims to measure the success of the WBPA AQMP implementation with an annual evaluation coinciding with the NAQO State of Air Report to the Minister. A mid-term review of the WBPA AQMP is recommended after 2 years to examine the successes and failures of implementation.

3. Process summary

A summary of the different unit processes is provided in Table 3-1. A schematic of process flow is illustrated and relative location of the process units is shown in Figure 3-1. *The process flow diagram has been requested from the client and is a requirement for an AIR (DEA,2013).

Table 3-1: Unit processes

Unit Process	Function of Unit Process	Batch or Continuous Process
Unit 1	Power generation process	Continuous
Unit 2	Power generation process	Continuous
Unit 3	Power generation process	Continuous
Unit 4	Power generation process	Continuous

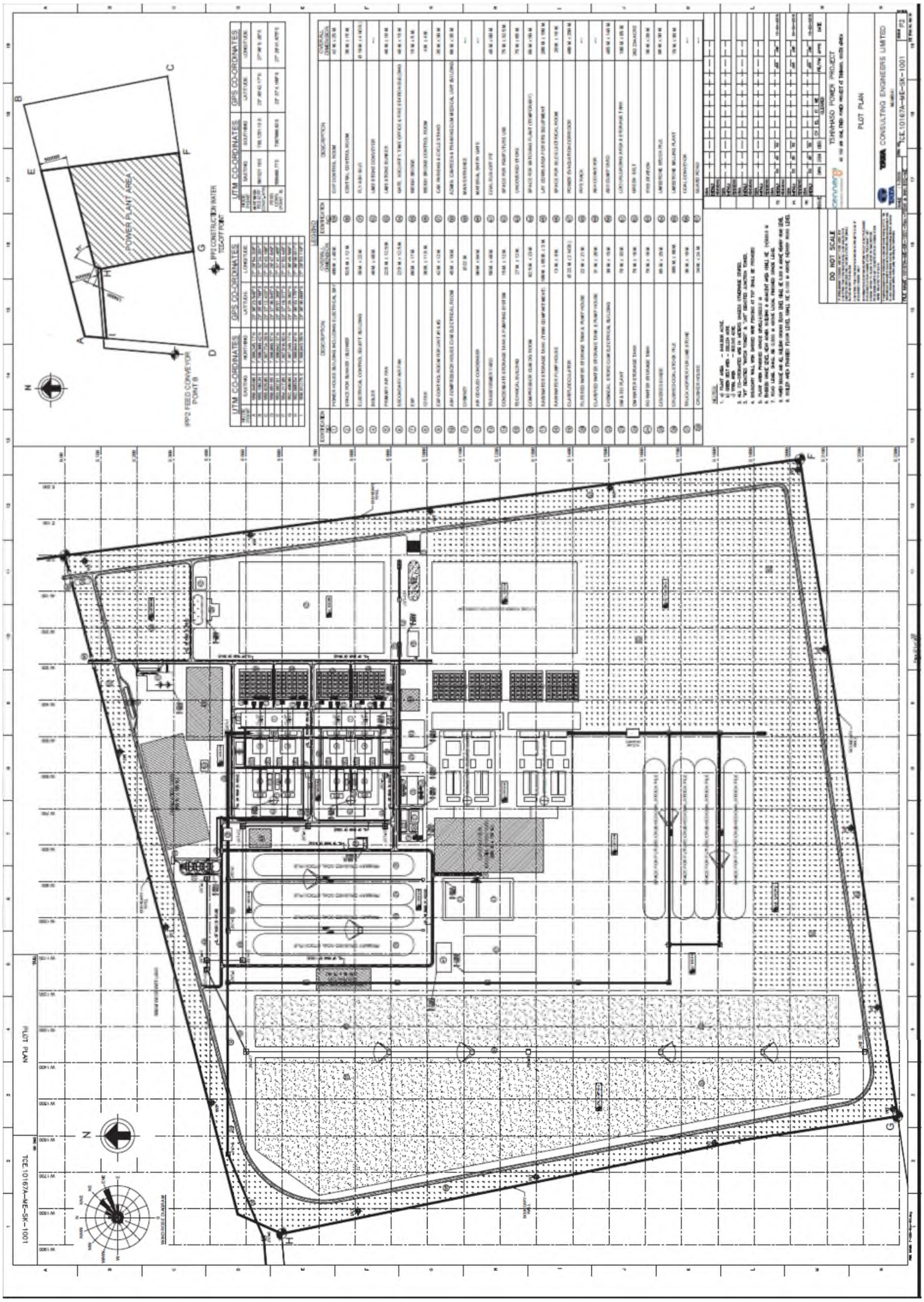


Figure 3-1: Relative location of the different process units

4. *Raw materials and products*

The raw materials consumption and electricity production rates at the Tshivhaso power plant are listed in Tables 4-1 and Table 4-2.

Table 4-1: Raw material used at the Tshivhaso power plant

Raw material	Maximum consumption rate	Units (quantity / period)
Coal	5 256 000	tons/annum

Table 4-2: Production rates

Product/by-product	Maximum Production capacity permitted (Volume)	Units (quantity / period)
Electricity	1 200	MW

5. *Atmospheric emissions*

5.1.1 Pollutants emitted at the Tshivhaso Power Station

The major pollutants emitted from coal combustion at the Tshivhaso Power Station will be SO_2, NO_X and particulates; and dust from the coal stockpile and ash dump. Maximum permissible hourly release rates for SO_2, NO_X and particulates are specified for these pollutants in DEA (2013a) (Table 5.1). The potential effect of these pollutants is described here.

Sulphur dioxide

Dominant sources of SO_2 include fossil fuel combustion from industry and power plants. SO_2 is emitted when coal is burnt for energy. The combustion of fuel oil also results in high SO_2 emissions. Domestic coal or kerosene burning can thus also result in the release of SO_2. Motor vehicles also emit SO_2, in particular diesel vehicles due to the higher sulphur content of diesel fuel. Smelting of mineral ores can also result in the production of SO_2, because metals usually exist as sulphides within the ore.

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

Nitrogen dioxide (NO_2) and nitric oxide (NO) are formed simultaneously in combustion processes and other high temperature operations such as metallurgical furnaces, blast furnaces, plasma furnaces, and kilns. NO_X is a term commonly used to refer to the combination of NO and NO_2. NO_X can also be released from nitric acid plants and other types of industrial processes involving the generation and/or use of nitric acid. NO_X also forms naturally through denitrification by anaerobic bacteria in soils and plants. Lightning is also a source of NO_X.

The route of exposure to NO_2 is 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 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. The most distinguishing characteristic of PM is the particle size and the chemical composition. 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 PM2.5.

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.

PM2.5 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}. PM2.5 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 be 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 PM2.5) can accumulate in the respiratory system and aggravate health problems such as asthma. PM2.5, 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).

5.1.2 Point source emissions

The physical data for the stacks at the power plant and additional sources are listed in Table 5-1. Emission concentrations and emission rates for maximum generation using coal are shown in Table 5-2.

Table 5-1: Point sources at the Tshivhaso coal-fired power station and additional sources, Matimba, Medupi and Thabametsi power stations

Power station	Source ID	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
Tshivhaso	Stack 1	150	11.5	18.29	418.6
Tshivhaso	Stack 2	150	11.5	18.29	418.6
Tshivhaso	Stack 3	150	11.5	18.29	418.6
Tshivhaso	Stack 4	150	11.5	18.29	418.6
Matimba	Stack 1	250	12.82	27.9	405
Matimba	Stack 2	250	12.82	27.9	405
Medupi	Stack 1	220	15.54	17.4	413
Medupi	Stack 2	220	15.54	17.4	413
Thabametsi	Stack 1	150	11.5	18.29	418.6
Thabametsi	Stack 2	150	11.5	18.29	418.6
Thabametsi	Stack 3	150	11.5	18.29	418.6
Thabametsi	Stack 4	150	11.5	18.29	418.6

Stack emission testing is generally considered to be the most accurate method for estimating emissions, as it entails the direct measurement of pollutant concentrations. In the absence of emission testing data, the alternate method is to use fuel consumption data and apply appropriate emission factors to estimate emissions. This section describes the methodology used to estimate emission rates of SO_2, NO_X, PM_{10} from each of the scenarios.

An emissions factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kg of particulate emitted per ton of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category.

The general equation for emissions estimation is: $E = A \times EF \times (1-ER/100)$, where:

E = emissions;
A = activity rate;
EF = emission factor; and
ER = overall emission reduction efficiency (%)

Table 5-2: Emission rates for the modelled stacks

Power station	Source ID	Scenario 1			Scenario 2			Scenario 3			Scenario 4		
		NO_X	SO_2	PM_{10}	NO_X	SO_2	PM_{10}	NO_X	SO_2	PM_{10}	NO_X	SO_2	PM_{10}
Tshivhaso	Stack 1	**12 066.**	**22 510**	**816**	**12066.85**	**22510**	**816**	**12067**	**22 510**	**816**	**12 067**	**22 510**	**816**
	Stack 2	**12 066**	**22 510**	**816**	**12066.85**	**22510**	**816**	**12067**	**22 510**	**816**	**12 067**	**22 510**	**816**
	Stack 3	**12 066**	**22 510**	**816**	**12066.85**	**22510**	**816**	**12067**	**22 510**	**816**	**12 067**	**22 510**	**816**
	Stack 4	**12 066**	**22 510**	**816**	**12066.85**	**22510**	**816**	**12067**	**22 510**	**816**	**12 067**	**22 510**	**816**
Matimba	Stack 1							33796	154 630	2 452	33 796	154 630	2 452
	Stack 2							33796	154 630	2 452	33 796	154 630	2 452
Medupi	Stack 1										46 019	245 440	3 068
	Stack 2										46 019	245 440	3068
Thabametsi	Stack 1										25 946	53 779	162
	Stack 2										25 946	53 779	162
	Stack 3										25 946	53 779	162
	Stack 4										25 946	53 779	162

Note that Tshivhaso power plant complies with the Minimum Emission Standards for existing and new facilities for NO_X (Table 3). NO_X is therefore not assessed in this AIR.

5.1.3 Fugitive emissions

Fugitive emissions of particulate matter at Tshivhaso power plant result from materials handling and wind erosion of the coal stockpiles and ash dumps. These are shown in Table 5-3 and Table 5-4. Fugitive emissions were also estimated for these sources at the proposed Thabametsi power station.

Table 5-3: Area sources at the Tshivhaso coal-fired power station and additional sources, Thabametsi power station

Power station	Source ID	Base Elevation	Height	Latitude of centre (UTM)	Longitude of centre (UTM)
Tshivhaso Power Station	Coal stockpile	932	12	551427	7388534
	Ash dump option 1	932	40	553941	7389551
	Ash dump option 2	932	40	559266	7386961
Thabametsi Power Station	Coal stockpile	932	12	549715	7390002
	Ash dump	923	50	545884	7391107

Table 5-4: PM_{10} emission rates for the area sources at the Tshivhaso power plant and the Thabametsi power station (in $t/m^2/a$)

Power station	Source ID	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Tshivhaso Power Station	Coal stockpile	1.04E-06	1.04E-06	1.04E-06	1.04E-06
	Ash dump option 1	1.72E-06	1.72E-06	1.72E-06	1.72E-06
	Ash dump option2	1.72E-06	1.72E-06	1.72E-06	1.72E-06
Thabametsi Power Station	Coal stockpile				7.720E-03
	Ash dump				4.360E-02

6. Receiving environment

6.1 Climatic conditions

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 Tshivhaso Power Station is located at approximately 23°35'26"S and 27°29'18"E, and approximately 945 m above sea level. It experiences a northern steppe climate according to the Köppen Climate Classification system (Schulze, 1965). Temperature and rainfall at Lephalale are best illustrated by the long-term measurements at the South African Weather Service's meteorological station (Figure 6-1).

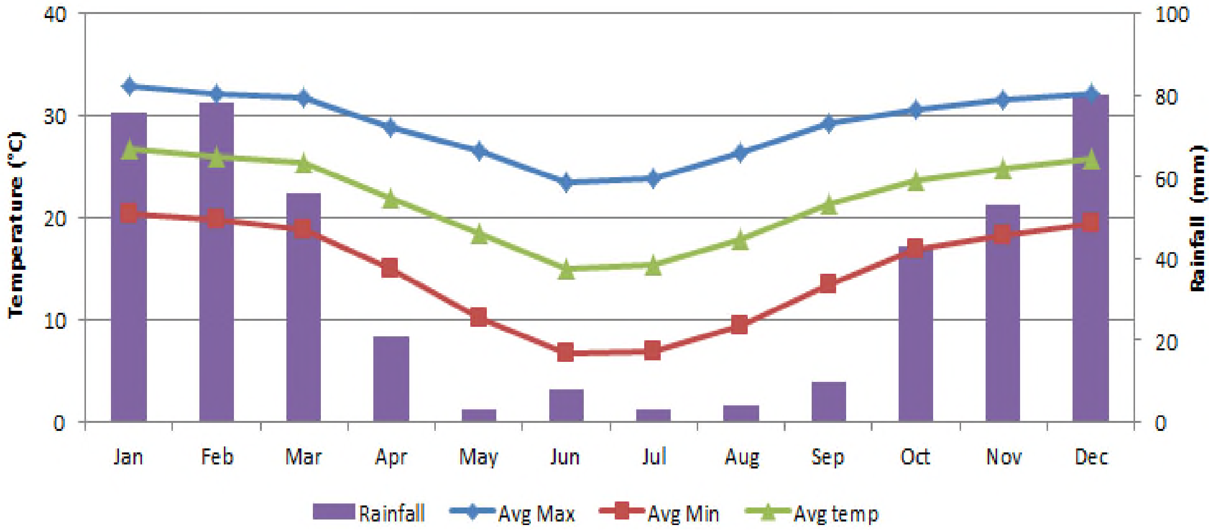


Figure 6-1: Average monthly maximum and minimum temperature, and average monthly rainfall at Lephalale from 1982 to 1990 (SAWS, 1992).

Winters are mild with average maximum temperatures dropping between 26°C and 24 ºC between May and August, but are relatively cold at night dropping below 7°C (Figure 6-1). Summers are hot and the average maximums exceed 30°C from October to March, with extremes reaching more than 33°C in January.

Lephalale receives an average of 435 mm of rainfall annually, with 88% of the rainfall occurring in the summer months from October to March (Figure 6-1). Rainfall seldom occurs in winter between April and September.

The Lephalale 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 6-2. The communities of concern are situated up-wind from the power station, causing pollution emitted by the power station to be blown away from the main residential areas. 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.

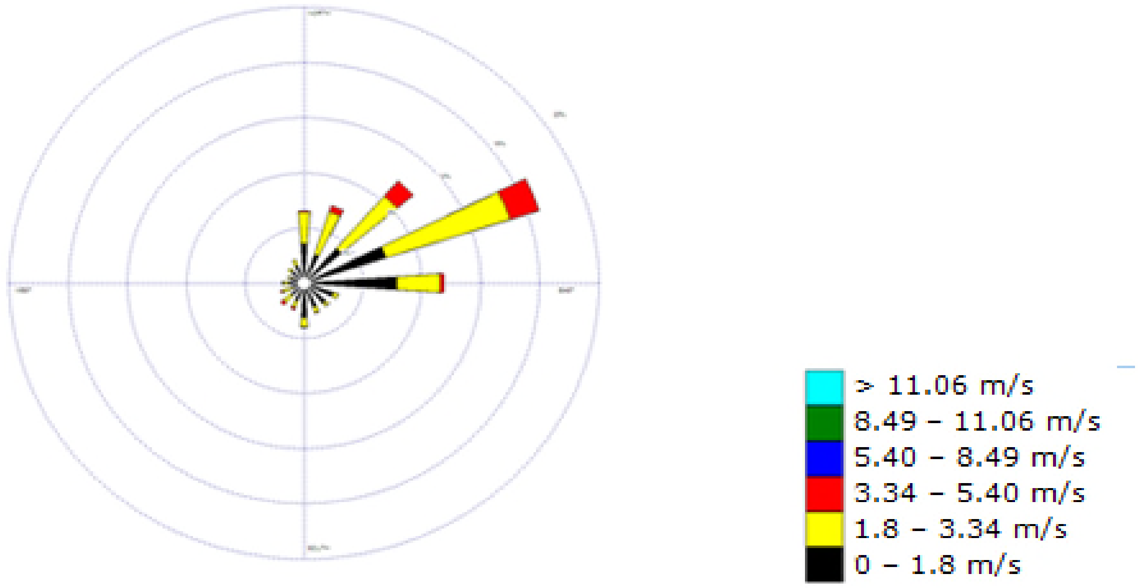


Figure 6-2: Annual windrose for 2010 to 2012 at Lephalale

6.2 Ambient air quality

The air pollution dispersion of an area refers to the ability of atmospheric processes, or meteorological mechanisms, to disperse and remove pollutants from the atmosphere. Dispersion comprises both vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines the rate of downwind transport and wind direction and the variability in wind direction determines the general path of pollutant. Atmospheric stability, or instability, determines the ability of the atmosphere to mix and dilute pollutants. Stability is a function of solar radiation (thermal turbulence) and wind speed and surface roughness which induce mechanical turbulence. The dispersion potential of an area therefore experiences diurnal and seasonal changes.

By day with strong insolation (incoming solar radiation) and stronger winds the dispersion potential is generally efficient through vertical dilution and horizontal dispersion. The dispersion potential is generally better on summer days than winter days. At night as the surface temperature inversion develops the lowest layer of the atmosphere becomes more and more stable, reaching a maximum at sunrise. As a result, the dispersion potential typically becomes less efficient during the night and the poorest conditions generally occur at sunrise. Thermal turbulence disappears when the sun sets, and mechanical turbulence decreases as the wind speed drops at night. Pollutants tend to accumulate near the point of release under these conditions, particularly if these are released close to ground level. The dispersion potential is generally poorer during winter nights than summer nights.

At Lephalale, the dispersion potential is expected to be relatively good during the day in the winter and summer as a result of hot daytime temperatures and a relatively high frequency of moderate winds. Dispersion potential will be better in summer than winter for several reasons. Firstly, rainfall in summer is an important removal mechanism for air pollutants. Secondly, the thermal mixing is stronger and the night-time temperature inversions are weaker and break up earlier and establish later in the day. Thirdly, there is a higher frequency of stronger winds in summer than in winter.

The rich coal reserves in the Lephalale area have led to the previous establishment of the Matimba Power Station and the current construction of the Medupi Power Station. Amongst others, development plans for the area include a new coal mine by Exxaro Resources Ltd. and the possibility of additional coal-fired power generation in the area. Mining and coal-fired power stations in Botswana are within 100 km of the Lephalale area. Other sources of air pollution in the Lephalale area include the existing Grootgeluk coal mine, vehicle emissions and the burning of domestic fuels and waste in Marapong and other residential areas. Lephalale Local Municipality (LM) contributes about 20% to emissions from domestic fuel use, and 24% to motor vehicle emissions, which, in each case, is the second highest of all LMs in the District Municipality (DM) (WBDM, 2009).

The DEA established an ambient monitoring station in Lephalale, with monitoring commencing in February 2013 (www.saaqis.org.za). The station is well removed from industrial sources and from the influence of residential fuel burning. It is located near a busy road, but is classified as an urban background site. The average 1-hour ambient NO2 concentration at the site since monitoring started is 16 μg/m^3 which is significantly below the national ambient air quality standard of 200 μg/m^3. The average 24-hour SO_2 concentration is 7 μg/m^3 which is also well below the ambient air quality standard of 125 μg/m^3. The average 24-hour PM_{10} concentration is 34 μg/m^3. This background concentration is relatively high compared to the ambient standard of 75 μg/m^3, equivalent to nearly 50% of the standard.

7. Dispersion modelling methodology

The approach to the dispersion modelling in this assessment is based on the requirements of the DEA guideline for dispersion modelling (DEA, 2012b). The dispersion modelling approach for Tshivhaso power plant is provided here.

7.1 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 to be a level 2 assessment, according to the definition on the dispersion modelling guideline (DEA, 2012b). The CALPUFF suite of models (http://www.src.com/calpuff/calpuff1.htm) were 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.

7.2 Model parameterisation

The parameterisation of key variables that are applied in CALMET and CALPUFF are indicated in Figure 7-1 and Table 7-1 and Table 7-2.

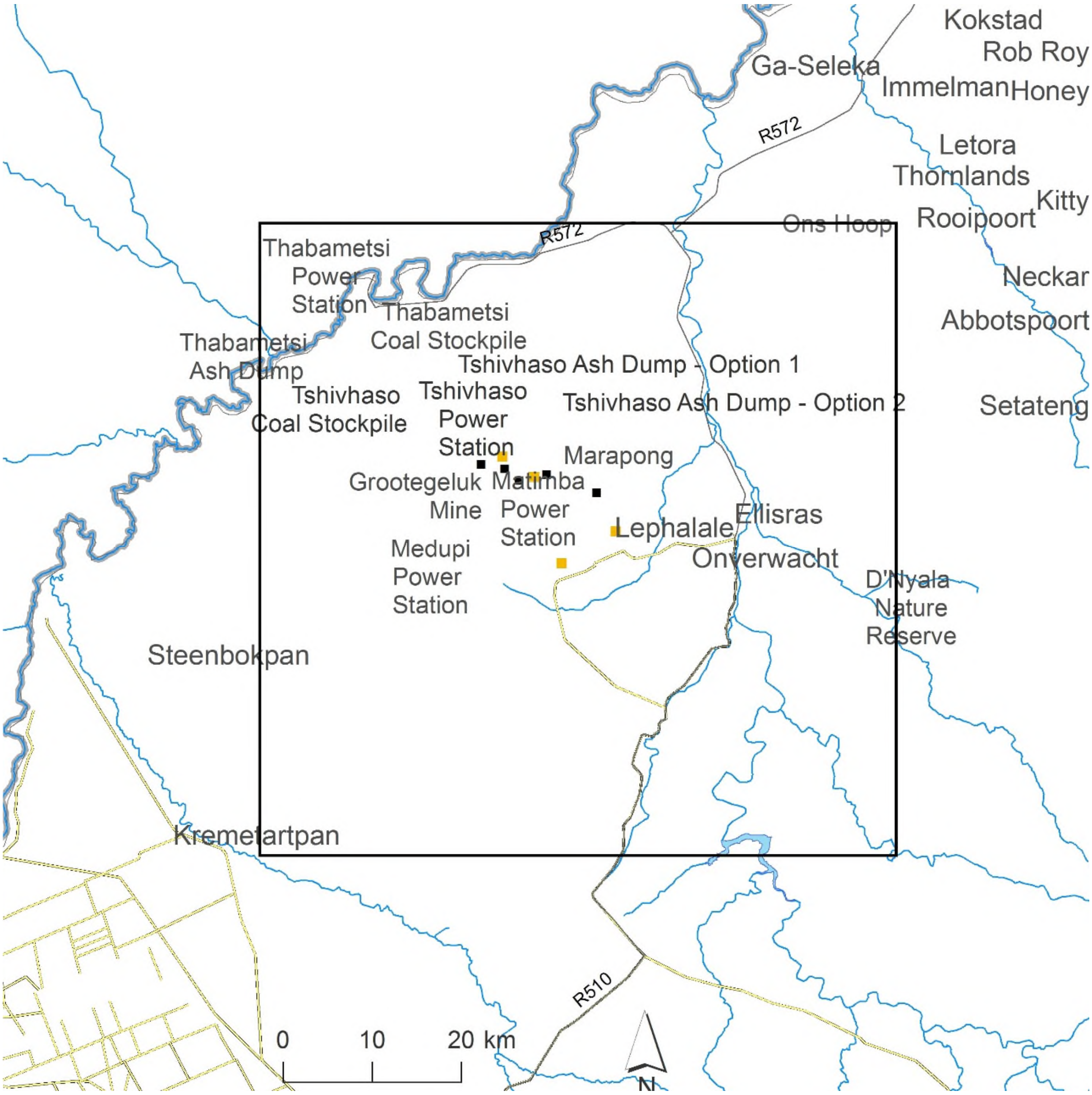


Figure 7-1: TAPM and CALPUFF modelling domains for the project

Table 7-1: 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	200

Parameter	Model value
through which lapse rate is computed (m)	
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

Table 7-2: 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

7.3 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 the Tshivhaso power plant, 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;
- Using representative emission data;
- Applying representative background concentrations to include the contribution of other sources; and
- Using a competent modelling team with considerable experience using CALPUFF.

8. Assessment of impacts

8.1 Assessment of air quality impacts

The assessment considers the impacts associated with:

- Construction – qualitative;
- Operations - quantitative
- Cumulative – quantitative;
- Decommissioning – qualitative.

The assessment of the potential impacts associated with the scenarios presented above is based on the comparison of predicted ambient concentrations of relevant pollutants with the South African ambient air quality standards to assess the level of compliance and the significance of the potential impact. The predicted annual average, 99^{th} percentile 24-hour and 99^{th} percentile 1-hour concentrations of nitrogen dioxide (NO_2), SO_2 and PM_{10} are presented as isopleth maps on a base map of the area for each scenario. The frequency of exceedance of the ambient 1-hour and 24-hour air quality standards are also presented spatially. Populated areas, or sensitive receptors, are considered in the designation of significance.

This assessment is conducted in terms of the significance of direct, indirect and additive air quality impacts from the proposed modifications. The assessment considers the nature, extent, duration, probability and severity of air quality impacts, which leads to the determination of the significance of the impacts.

The nature of impacts examines what causes the effect, what is affected and how it is affected. The extent of impacts involves determining whether the impacts are local or regional and scoring the impacts accordingly from 1 to 5. The duration of impacts considers the lifetime of the impacts, allocating scores from 1 to 5 for very short (0 - 1 years), short (2 – 5 years), medium-term (5 – 15 years), long-term (> 15 years) and permanent. The magnitude of impacts are rated on a scale of 0 to 10, and examines the magnitude of the impacts as no effect (0), minor effect, low effect, moderate effect, high effect and very high effect (10). The probability of occurrence examines the likelihood of the impact actually occurring. Probability is also estimated on a scale of 1 to 5, where 1 is very improbable, 2 is improbable, 3 is probable, 4 is highly probable, and 5 is definite.

The significance of impacts is derived from an assessment of all of the above and is categorised as low, medium or high.

8.2 Modelled operational scenarios

Four operational scenarios are assessed for Tshivhaso power plant generating the maximum output of 1 200 MW. These scenarios are:

Scenario 1: The Tshivhaso Power Station in isolation with ash dump option 1
Scenario 2: The Tshivhaso Power Station in isolation with ash dump option 1
Scenario 3: The additive effect of the Tshivhaso Power Station with existing sources (Matimba Power Station)
Scenario 4: The cumulative effect of future sources in relative close proximity to the Tshivhaso plant (e.g. Medupi and Thabametsi);

The results of the change in the location of the ash dump in Scenario 2 are only applicable to PM_{10} concentrations, therefore the isopleth plots for Scenario 2 are only presented for PM_{10}.

8.3 Annual and 99th percentile concentrations

The 99th percentile predicted ambient SO_2, NO_2, PM_{10} and benzene concentrations from the dispersion modelling for the plant using coal are presented as isopleth maps over the modelling domain. The DEA (2014) recommends the 99th percentile concentrations for short-term assessment with the NAAQS since the highest predicted ground-level concentrations can be considered outliers due to complex variability of meteorological processes. In addition, the limit value in the NAAQS is the 99th percentile.

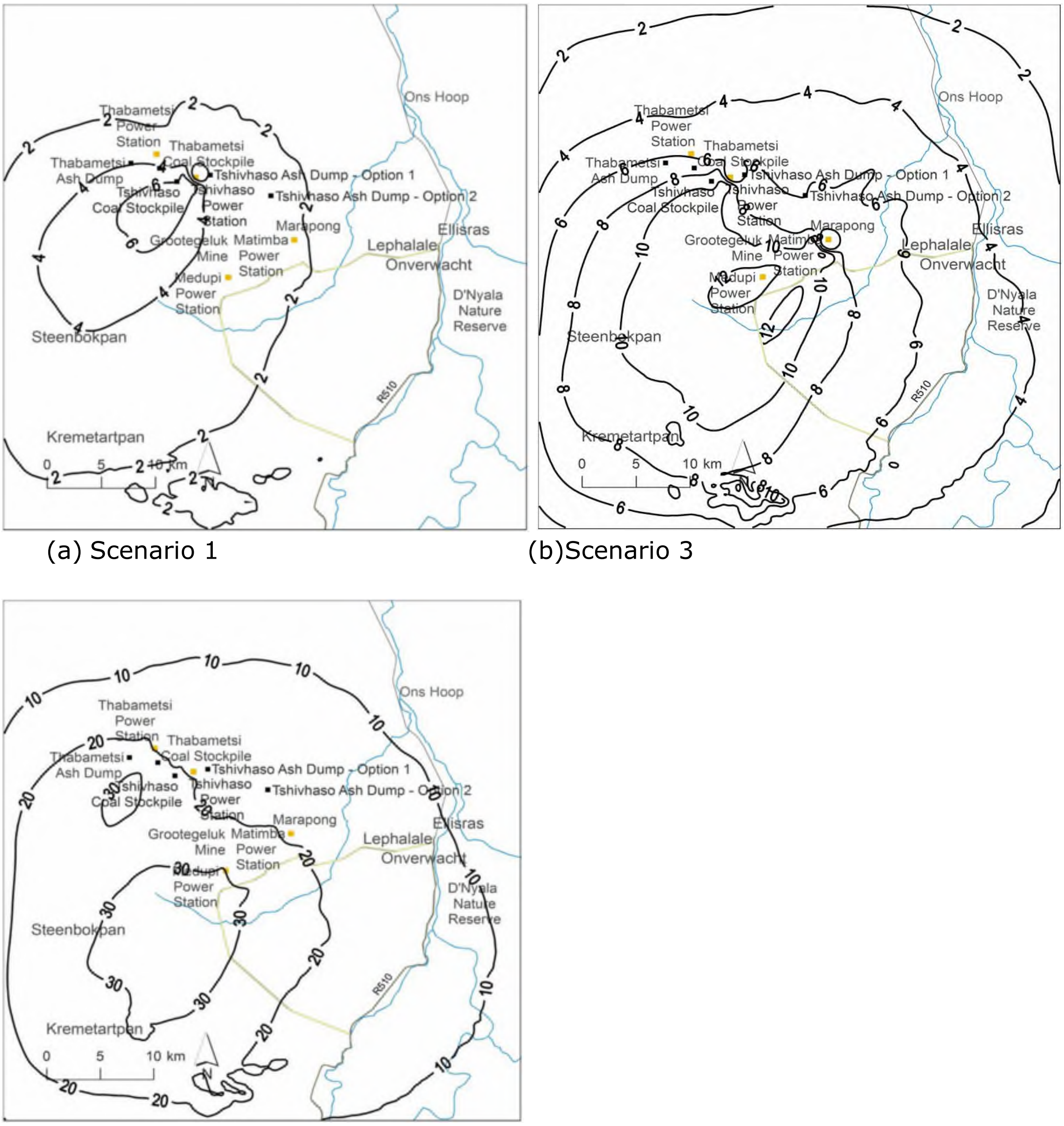
The impact assessment then compares the predicted 99th percentile concentrations with the respective ambient air quality standards (limit values and the permitted frequency of exceedance) with consideration of populated areas in the modelling domain. These are shown in Table 8-1 below.

Table 8-1: Maximum predicted annual average concentration and the highest 99th percentile concentration at the points of maximum ground-level impact

	SO_2 (µg/m^3)			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
1-hour	246	246	323	760
24-hour	97	98	154	319
Annual	7.5	7.5	12.6	36.3
	NO_2 (µg/m^3)			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
1-hour	106	105	113	211
Annual	3.2	3.2	3.8	10
	PM_{10} (µg/m^3)			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
24-hour	3.6	3.6	3.8	4.2
Annual	0.35	0.35	0.40	0.51

8.3.1 Predicted SO_2 concentrations

Predicted annual average SO_2 concentrations for Scenarios 1, 3 and 4 are shown as isopleths in Figure 8.1, and compared to the NAAQS of 50 µg/m^3. The predicted 99th percentile 24-hour and 1-hour SO_2 concentrations are also presented as isopleths on Figure 8.2 and Figure 8.3 respectively, and compared with the NAAQS of 125 µg/m^3 and 350 µg/m^3 respectively. Exceedances of the respective NAAQS are shown by red isopleth lines. Exceedance plots, if relevant, are presented next to the accompanying isopleth plot.



(a) Scenario 1 (b)Scenario 3

(c) Scenario 4

Figure 8-1 Predicted Annual Average SO_2 concentrations for Scenario 1, 3 and 4

The predicted annual average SO_2 concentrations are well below the NAAQS for Scenarios 1, 3 and 4, with a maximum concentration of 7.5078 µg/m^3, 12.638µg/m^3 and 36.362

µg/m³ respectively. In Scenario 4, the predicted SO_2 concentrations are significantly higher compared to Scenarios 1 and 3. The resultant SO_2 concentration for each scenario is directly related to cumulative emissions from Matimba, Medupi and Thabametsi. The maximum concentration in each scenario occurs close to the respective power station sites.

(a) Scenario 1

(b) Scenario 3

(c) Scenario 4

Figure 8-2 Predicted 24-hour SO_2 for Scenario 1,3 and 4

The 99th percentile of the predicted 24-hour SO_2 concentrations are below the NAAQS for Scenarios 1 and 3, with a maximum concentration of 97.717 µg/m³ and 154.15 µg/m³ respectively. In Scenario 4, the predicted SO_2 concentrations are significantly higher with a maximum of 759.71 µg/m³ compared to Scenarios 1 and 3. Exceedances are evident for Scenario 3 and 4 in the isopleths, but these are below the exceedance threshold (in compliance). The NAAQS permits 4 exceedances of the 24-hour limit value per annum, so-called tolerance, implying 12 permitted exceedances in the three-year modelling period. Exceedance plots are therefore not plotted for these cases. The resultant SO_2 concentration for Scenario 3 and 4 is directly related to cumulative emissions from Matimba, Medupi and Thabametsi. The maximum concentration in each scenario occurs close to the respective power station sites.

(a) Scenario 1

(b) Scenario 3

(c) Scenario 4

Figure 8-3 Predicted 1-hour SO_2 concentrations for Scenario 1, 3 and 4

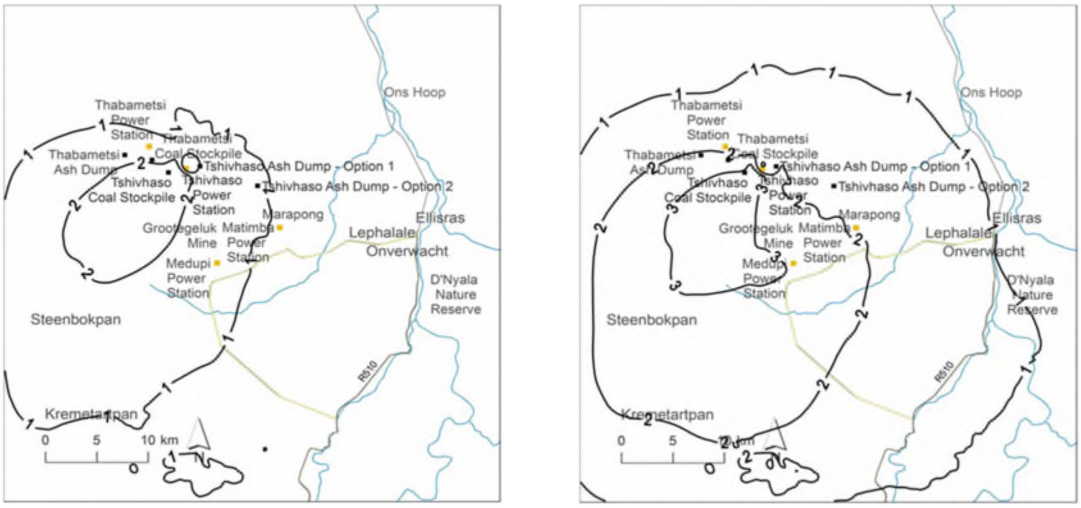
The 99th percentile of the predicted 1-hour SO_2 concentrations are well below the NAAQS for Scenarios 1 and 3, with a maximum concentration of 246.44 µg/m^3 and 322.79 µg/m^3 respectively. In Scenario 4, the predicted SO_2 concentrations are higher compared to Scenarios 1 and 3, with a maximum concentration of 759.71.

In Scenario 4, exceedances of the NAAQS occur near the respective power stations. The NAAQS permits 88 exceedances of the 1-hour limit value per annum, implying 264 permitted exceedances in the three-year modelling period. There are no areas where the permitted tolerance is exceeded. The predicted 1-hour SO_2 concentrations in these areas therefore comply with the NAAQS for this scenario. Exceedance plots are therefore not plotted for these cases. The maximum concentration in each scenario occurs close to the power station sites.

8.3.2 Predicted NO_2 concentrations

Ambient concentrations of NO_2 are predicted from emissions of NO_X (NO_X=NO+NO_2). Emissions from combustion processes are dominated by NO_2, and furthermore, NO converts rapidly to NO_2 in the presence of nitrogen in the atmosphere. Comparing the predicted concentrations of NO_2 to the NAAQS is therefore conservative.

Predicted annual average NO_2 concentrations for Scenarios 1, 3 and 4 are shown as isopleths in Figure 8.4 for the NO_X emissions and compared to the NAAQS of 40 µg/m^3. The predicted annual average NO_2 concentrations for Scenario 4 are higher than Scenarios 1 and 3 and has a maximum concentration of 10.43 µg/m^3.



(a) Scenario 1 (b)Scenario 3

(c) Scenario 4

Figure 8-4: ***Predicted annual average NO_2 concentrations (in µg/m³) for Scenarios 1, 3 and 4***

The predicted 99th percentile 1-hour NO_2 concentrations are also presented as isopleths in Figure 8.6 for the NO_X emissions; and compared with the NAAQS of 200 µg/m³. Exceedances of the respective NAAQS are shown by red isopleth lines. Exceedances are evident for Scenario 4 with a maximum value of 211.39 µg/m³ but these are below the exceedance threshold (in compliance).

(a) Scenario 1

(b)Scenario 3

(

c)Scenario 4

Figure 8-5: *99th percentile of the predicted 1-hour NO_2 concentrations ($\mu g/m^3$) resulting for Scenario 1, 3 and 4.*

8.3.3 Predicted PM_{10} concentrations

Predicted annual average PM_{10} concentrations for Scenarios 1, 2, 3 and 4 are shown as isopleths in Figure 8.7, and compared to the NAAQS of 40 $\mu g/m^3$. The predicted 99th percentile 24-hour concentrations are also presented as isopleths in Figure 8.8, and compared with the NAAQS of 75 $\mu g/m^3$.

The predicted annual average PM_{10} concentrations are well below the NAAQS for Scenario 1, 2, 3 and 4. The PM_{10} concentrations predicted in Scenario 1 and 2 are similar as the change in the location of the stockpile does not significantly affect PM_{10} dispersion, with a maximum concentration of 0.2 $\mu g/m^3$. While the PM_{10} concentrations predicted in Scenario 4 are comparatively higher, with a maximum concentration of 0.52 μg/m3 .

(a)Scenario 1

(b) Scenario 2

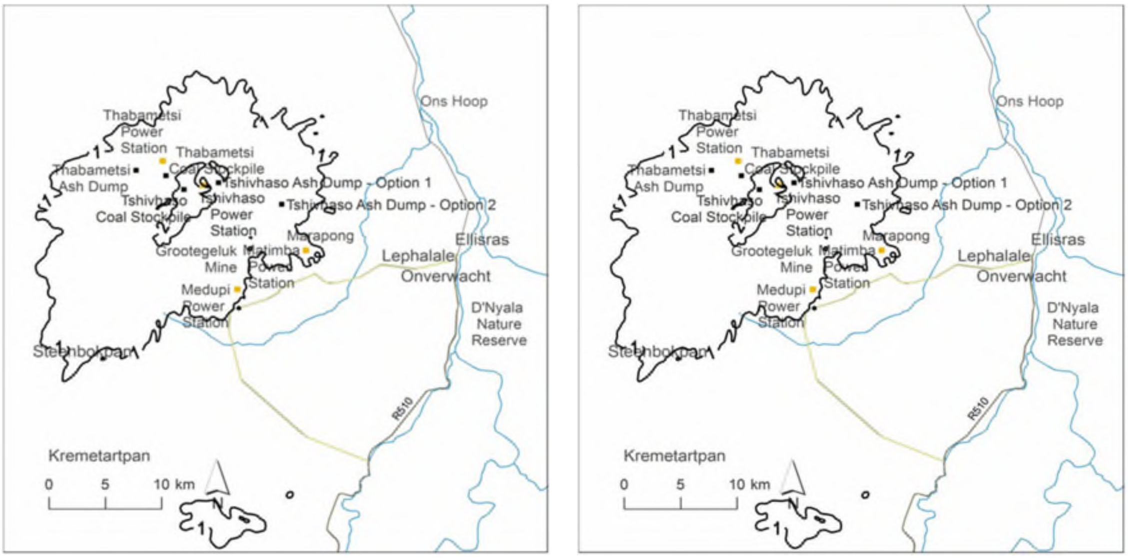
(c) Scenario 3

(d) Scenario 4

Figure 8-6*: Predicted annual average PM_{10} concentrations (μg/m^3) resulting from emissions from Scenario 1 , 2, 3 & 4*

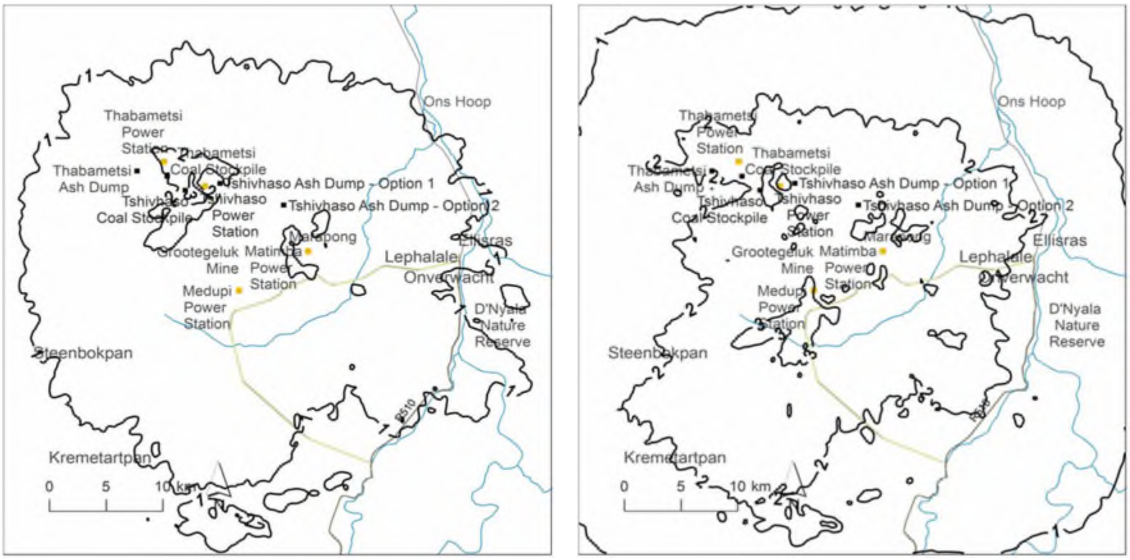
The 99th percentile of the predicted 24-hour PM_{10} concentrations for Scenario 1, 2, 3 and 4 are below the NAAQS with maximum predicted concentration of 3.7 μg/m^3, 3.7 μg/m^3, 3.7831 μg/m^3 and 4.2293 μg/m^3 respectively. The PM_{10} concentrations predicted in Scenario 1 and 2 are lower than Scenario 3 and 4. The maximum concentration in each scenario occurs close to the sites of the power stations.

The WHO ambient air quality 24-hour guideline of 50 μg/m^3 is less stringent than the NAAQS of 75 μg/m^3. The predicted 24-hour PM_{10} concentrations for all scenarios are well below the WHO guideline. The change in the location of the ash dump to Option 2 (Figure 8-7) does not affect the dispersion of PM_{10}.



(a)Scenario 1

(b) Scenario 2



(c) Scenario 3 (d) Scenario 4

Figure 8-7 *: Predicted 24 hour average PM_{10} concentrations (µg/m^3) resulting from emissions from Scenario 1 , 2, 3 & 4*

8.4 Impact assessment

Impacts can generally be categorised as direct, indirect or cumulative. Direct impacts are impacts that are caused directly by the project or activity in isolation of other sources and generally occur at the same time and place as the activity. Indirect impacts are indirect or induced changes that may occur as a result of the activity. These types of impacts include all the potential impacts that do not manifest immediately when the activity is undertaken or which occur at a different place as a result of the activity. Cumulative impacts are impacts that result from the incremental impact of the proposed activity on a common resource when added to the impacts of other past, present or reasonably foreseeable future activities.

For this study, direct impacts will result from the inhalation of NO_2, SO_2 and particulates (PM10) emitted during the operational life of the Tshivhaso Power Station. Direct impacts will also result from exposure to dust generated from the coal stockpiles, ash dump; and from the construction of the Tshivhaso Power Station and decommissioning activities. Indirect impacts resulting from emissions of SO_2 and NO_2 from coal-fired power plants include their contribution to acidification in both dry and wet (acid rain) deposition. Further indirect effects are associated emissions of CO and CO_2. CO_2 is a GHG, adding to the global concentrations. CO is not considered a GHG, but is a strong precursor in the formation of ozone in the troposphere. The global warming potential of tropospheric ozone is equivalent to between 918 - 1 022 tons of CO_2.

The Tshivhaso Power Station is proposed to be constructed on agricultural land, and is surrounded by vast tracts of agricultural land. There is a high concentration of large scale mining activities (Grootgeluk and Grootestryd mine dump and Matimba ash dump). Eskom's Matimba Power is located to the south.

With respect to cumulative impacts, mining and agricultural activities, ash dumps, domestic fuel burning in the area are identified as existing sources of dust. There will thus be a cumulative impact with dust generated during construction and decommissioning of the Tshivhaso Power Station, as well as during normal operations of the proposed coal stockpile and ash dump at the Tshivhaso Power Station.

The Tshivhaso Power Station is located in an area where there are no notable sources of dust, PM_{10}, NO_2 and SO_2 in the immediate vicinity of the site, i.e. within a 5 km radius. Motor vehicle traffic on the R510, R572, R518 and surrounding roads will have some influence on ambient air quality as will domestic fuel burning. Eskom's Matimba and Medupi Power Stations, as well as the Thabametsi Power Station are located in a 15 km radius of the Tshivhaso Power Station and are an important source of NO_2, SO_2 and PM_{10} at that locality. It is therefore expected that there will be compounding of effects and hence cumulative impacts during operation of the Tshivhaso Power Station, as it is also coal-fired.

Average ambient concentrations measured at the DEA's monitoring site at Lephalale are considered representative of background concentrations. Predicted ambient concentrations resulting from emissions from the Tshivhaso Power Station are relatively localised and are indicated as very low for all modelled operational scenarios. The contribution to ambient concentrations beyond the immediate vicinity of the power station will be small. It is highly unlikely that they will result in exceedances of the national ambient air quality standards at the Lephalale monitoring site, and elsewhere in the area.

Scenarios 1, 3 and 4 were considered in the Impact Assessment as the change in the location of the ash dump in Scenario 2 (Figure 8-7) does not affect the dispersion of PM_{10}.

Extent of Impacts

The extent of impacts are assessed in accordance with the following scoring criteria:
0 – No effect
1 - Limited to the site and its immediate surroundings
2 - Local/municipal extending only as far as the local community or urban area
3 - Provincial/regional
4 - National i.e. South Africa
5 - Across international borders

PHASE	EXTENT OF IMPACTS			IMPACT OF TSHIVHASO POWER STATION
	DIRECT	INDIRECT	CUMULATIVE	
Construction and decommissioning	1	0	1	NEGATIVE
Scenario 1: Tshivhaso Power Station	1	1	2	NEGATIVE
Scenario 3: Tshivhaso Power Station with existing sources (Matimba Power Station)	2	2	2	NEGATIVE
Scenario 4:	2	2	2	NEGATIVE

Tshivhaso Power Station with existing/future sources Tshivhaso(Matimba, Medupi and Thabametsi)	

Construction and decommissioning activities will result in the emission of low quantities of terrestrial and construction dust, and are not expected to pose a health risk. Furthermore, dust emissions will not travel over vast distances, but will most likely settle within 100 m to 1 km of the Tshivhaso Power Station. A temporary nuisance impact may be experienced in parts of the property on which the site is to be constructed. The extent of direct and cumulative dust impacts during construction and decommissioning are also considered to be limited to the site and its immediate surroundings and be of a nuisance nature only.

For the operational scenarios, the extent of direct impacts resulting from SO_2, NO_2 and PM_{10} are limited to the local/municipal area extending only as far as the local community or urban area. For the cumulative effect, limit values for SO_2 and NO_2 are exceeded over a small area around the power station site, when emissions from current and future sources are considered. However, it must be noted that these exceedances do occur over an area that has been identified as a sensitive area, of medium ecological sensitivity. However, no exceedances are predicted at the Tshivhaso Power Station in isolation. The extent of indirect impacts associated are local/municipal extending only as far as the local community or urban area.

Duration of Impacts

The duration of impacts are assessed in accordance with the following scoring criteria:
0 – None (impact will not occur)
1 - Immediate (less than 1 year)
2 - Short term (1-5 years)
3 - Medium term (6-15 years)
4 - Long term (the impact will cease after the operational life span of the project)
5 - Permanent (no mitigation measures of natural process will reduce the impact after construction)

PHASE	**DURATION OF IMPACTS**			**IMPACT OF TSHIVHASO POWER STATION**
	DIRECT	**INDIRECT**	**CUMULATIVE**	
Construction and decommissioning	1	0	1	NEGATIVE
Scenario 1: Tshivhaso Power Station	4	4	4	NEGATIVE
Scenario 3: Tshivhaso Power Station with existing sources (Matimba Power Station)	4	4	4	NEGATIVE
Scenario 4: Tshivhaso Power Station with existing/future sources	4	4	4	NEGATIVE

Tshivhaso(Matimba, Medupi and Thabametsi)

Construction and decommissioning impacts will last for a relatively short period as these activities occur for the duration of these activities only. Direct and cumulative impacts from construction and decommissioning are therefore expected to have an immediate duration.

Impacts in terms of predicted concentrations of NO_2, SO_2 and PM_{10} from operations will however last for the full period of operation of the Tshivhaso Power Station. The duration of direct, indirect and cumulative impacts from operation are therefore expected to be long-term.

Magnitude of Impacts

The magnitude of impacts may be assessed in accordance with the following scoring criteria:
0 - None (where the aspect will have no impact on the environment)
2 - Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
4 - Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
6 - Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
8 - High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
10 - Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).

PHASE	**MAGNITUDE OF IMPACTS**			**IMPACT OF TSHIVHASO POWER STATION**
	DIRECT	**INDIRECT**	**CUMULATIVE**	
Construction and decommissioning	2	0	2	NEGATIVE
Scenario 1: Tshivhaso Power Station	4	2	6	NEGATIVE
Scenario 3: Tshivhaso Power Station with existing sources (Matimba Power Station)	4	2	6	NEGATIVE
Scenario 4: Tshivhaso Power Station with existing/future sources Tshivhaso(Matimba, Medupi and Thabametsi)	6	4	6	NEGATIVE

The magnitude of impacts provides an indication of how serious the impacts are. From an air quality perspective, this relates to the potential health impacts to humans through exposure to ambient concentrations that exceed the standard set for the protection of human health.

No direct health impacts are expected from dust generated during construction and decommissioning activities for the Tshivhaso Power Station. There may be temporary nuisance impact through dust deposition in parts of the farm the power station will be located on during these periods. As a result, the magnitude of these impacts is considered to be low. Cumulative impacts may result from the dust combining with that from other sources such as the mining and agricultural activities, tailings dams and domestic fuel burning in the area. The cumulative impact of dust emission is therefore considered to be moderate.

Predicted ambient concentrations of SO_2, NO_2 and PM_{10} during the operational scenarios of the Tshivhaso Power Station are well below health-based air quality standards, with the exception of exceedances for the short term 1-hour and 24-hour limit values for SO_2, and NO_x for Scenario 3 and 4. However, as noted in Section 7, no exceedances of the permitted tolerance for the number of exceedances are predicted. The overall magnitude of direct impacts during operation is therefore considered to be low for all operational scenarios. For the cumulative impacts, emissions from Tshivhaso Power Station increase the existing ambient concentrations of all pollutants in the immediate vicinity and the surrounding areas, but marginally so. The overall magnitude of cumulative impacts during operation is therefore considered vary for all operational scenarios.

The magnitude of indirect impacts associated with the operational scenarios relates to the relative contribution to acidification and global warming. Quantification of the relative contribution of Tshivhaso Power Station is not possible, but it is considered to be relatively small in the national and global context. The overall magnitude of the indirect impacts is anticipated to be low for all these scenarios.

Probability of Impacts

The probability of impacts are assessed in accordance with the following scoring criteria:
0 - None (impact will not occur)
1 - Improbable (the possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures)
2 - Low probability (there is a possibility that the impact will occur)
3 - Medium probability (the impact may occur)
4 - High probability (it is most likely that the impact will occur)
5 - Definite / do not know (the impact will occur regardless of the implementation of any prevention or corrective actions or if the specialist does not know what the probability will be based on too little published information)

PHASE	**PROBABILITY OF IMPACTS**			**IMPACT OF TSHIVHASO POWER STATION**
	DIRECT	**INDIRECT**	**CUMULATIVE**	
Construction and decommissioning	3	0	3	NEGATIVE
Scenario 1:	4	3	4	NEGATIVE

Tshivhaso Power Station				
Scenario 3: Tshivhaso Power Station with existing sources (Matimba Power Station)	4	3	4	NEGATIVE
Scenario 4: Tshivhaso Power Station with existing/future sources Tshivhaso(Matimba, Medupi and Thabametsi)	4	3	4	NEGATIVE

The probability of direct impacts is considered to be medium for construction and decommissioning. Dust emissions from construction and decommissioning will be present on the farm that the Tshivhaso Power Station will be located on. There is a medium probability of direct dust nuisance impacts from construction and decommissioning activities. However, there is a high probability of cumulative dust impacts due to the existence of other dust sources in the vicinity of the Tshivhaso Power Station.

The probability of direct and cumulative impacts from dust, PM_{10}, NO_2 and SO_2 emitted during normal operation of the Tshivhaso Power Station, is considered to be high for all scenarios. The predictive modelling provides maximum expected ambient concentrations for each pollutant based on a worst-case meteorological scenario. These results show that predicted concentrations comply with the national ambient standard throughout the study domain. Despite this, some risk to health remains and the probability of direct and cumulative air quality impacts during the operation of Tshivhaso Power Station is considered to be high.

The probability of indirect impacts occurring with the operational scenarios relates to the relative contribution to acidification and global warming. Quantification of the relative contribution of Tshivhaso Power Station is difficult, but it is considered to be relatively small in the national and global context, and somewhat less for the co-fired option. Despite this, the probability of indirect impacts occurring is medium.

Significance of Impacts

The significance of impacts is determined through the following equation:

Significance = (Extent + Duration + Magnitude) x Probability

A score of less than 30 implies that impacts are of a low significance, a score of between 30 and 60 implies a medium significance, whereas a score of greater than 60 implies a high significance. For the current proposed Tshivhaso Power Station, the significance is:

PHASE	SIGNIFICANCE OF IMPACTS		
	DIRECT	INDIRECT	CUMULATIVE
Construction and decommissioning	(1+1+2) x 3= 12	(0+0+0)x0=0	(1+1+2)x3=12
Scenario 1: Tshivhaso Power Station	(1+4+4)x4=26	(1+4+2)x3=21	(2+4+6)x4=48
Scenario 3: Tshivhaso Power Station with existing sources (Matimba Power Station)	(2+4+4)x4=40	(2+4+4)x3=30	(2+4+6)x4=48
Scenario 4: Tshivhaso Power Station with existing/future sources Tshivhaso(Matimba, Medupi and Thabametsi)	(2+4+6)x4=48	(2+4+4)x3=30	(2+4+6)x4=48

From the scoring above, it is predicted that the significance of all impacts during construction and decommissioning phase is low. The significance of these impacts for all operational scenarios is medium.

In summarising the impacts, the highest score in each category described above is selected. (Table 8-2).

Table 8-2 Summary of air quality impacts during construction of infrastructure and decommissioning of the Tshivhaso Power Station

Nature: Cumulative air quality impacts are caused by exposure to dust generated during construction activities and decommissioning of the Tshivhaso Power Station and by other existing sources in the vicinity of the power station. Dust has a nuisance impact and negatively affects quality of life by causing soiling, contamination, structural corrosion and damage to precision equipment, machinery and computers.		
	Without mitigation	**With mitigation**
Extent	Limited to site and immediate surroundings (2)	Limited to site and immediate surroundings (1)
Duration	Immediate (1)	Immediate (1)
Magnitude	Moderate (2)	Low (2)
Probability	High (3)	Low (2)
Significance (positive or negative)	**Low (24) and negative**	**Low (12) and negative**
Reversibility	Yes	Yes
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	N/A
Mitigation: Compile and implement an appropriate Dust management plan for all projects in the area.		

Cumulative Impacts: Yes	
Residual Impacts: No	

Although the significance of impacts during construction and decommissioning is low, a basic dust management plan is required to ensure the nuisance impacts are mitigated. This can be achieved by addressing dust management in the Environmental Management Plan for the Tshivhaso Power Station.

Impacts in terms of the predicted ambient concentrations of PM_{10}, SO_2 and NO_2 for all scenarios are summarised below.

Table 8-3 Summary of air quality impacts during operation of the Tshivhaso Power Station – applicable to all operational scenarios

Nature: The inhalation of NO_2, SO_2 and particulates (PM_{10}), which are contained in emissions from the Tshivhaso Power Station will result in health impacts as a result of air quality impacts. The inhalation of the NO_2, SO_2 and PM_{10} at concentrations exceeding health-based air quality standards; and which are greater than the permitted number of exceedances per year, will result in negative health impacts.	
Extent	Local/municipal extending only as far as the local community or urban area (4)
Duration	Long-term (4)
Magnitude	Moderate (6)
Probability	High (4)
Significance (positive or negative)	**medium (48) and negative**
Reversibility	Yes
Irreplaceable loss of resources?	No
Can impacts be mitigated?	Yes
Mitigation: Plant engineers and operators are to ensure that the abatement technology that is to be installed is always in working order and maintained on a regular basis as per standard operating procedures.	
Cumulative Impacts: Yes	
Residual Impacts: No	

Proposed operational emission mitigation at the Tshivhaso Power Station is for particulates only, and SO_2 and NO_2 emissions are further reduced through the utilisation of the CFB technology. This situation leads to a medium impact rating for the magnitude of the indirect impacts, associated with regional scale acidification. SO_2 and NO_2 abatement will result in the rating decreasing to low during the operational phase for all scenarios, as discussed in the mitigation section.

8.5 Mitigation

The predicted ambient concentrations resulting from emissions from the Tshivhaso Power Station comply with ambient air quality standards. The cumulative effect of these emissions with those from the Matimba Power Station and the proposed Medupi and Thabametsi Power Stations are likely to result in exceedances of the ambient standards (uMoya-NILU, 2013). The AQMP for the Waterberg-Bojanala Priority Area includes emission reduction requirements to further address this situation.

Recommendations made to control/mitigate dust missions during construction and decommissioning are included in Table 8-4 for consideration in the EMP.

Table 8-4 Dust mitigation plan to be included in EMP

Mitigation: Action/control	Responsibility	Timeframe
Roads should be tarred or traffic control measures implemented to limit vehicle-entrained dust from unpaved roads e.g. by limiting vehicle speeds and by restricting traffic volumes. Unpaved road surfaces should be sprayed with a surfactant to ensure high moisture content which will bind the silt.	Site Manager	During operations
The sidewalls of the ash dump should be vegetated as they rise, and the vegetation cover should be maintained to reduce the exposed area and limit wind entrainment. The top of the ash dump must be kept moist to bind the surface dust and prevent wind entrainment of dust.	Site manager	During operations
Stabilise open areas with dust palliative, gravel or similar	Construction Project Manager	During construction

8.6 Management & Monitoring

The operation of the power station is a Listed Activity in terms of the NEM: AQA. Requirements for environmental management will be dictated by the conditions in the Atmospheric Emission Licence (AEL). These are likely to include:

i. Annual emission measurements to assess compliance with the Minimum Emission Standards for Listed Activities (Government Gazette 37054, Notice No. 893 of 22 November 2013);
ii. The maintenance of an emission inventory with registration on the National Atmospheric Emission Inventory System (NAEIS) and annual reporting of emissions to the NAEIS (Government Gazette 38633, Notice No. R 283 of 2 April 2015).

Further environmental management requirements should address the control of emissions during operations through routine maintenance and operation according to specification.

8.7 Conclusions

Cennergi is a joint venture formed between Exxaro, the second largest producer of coal in South Africa, and Tata Power, India's largest integrated power company. Cennergi is evaluating the potential of establishing the Tshivhaso Coal-Fired Power Plant in the Lephalale Local Municipality, Limpopo, South Africa. The power station would have a capacity of up to 600MW during Phase 1 of installation, and would reach a maximum capacity of 1200MW during Phase 2. Savannah Environmental (Pty) Ltd has been appointed as an independent consultant to conduct the Environmental Impact Assessment for the proposed project.

The main findings of the air quality specialist study are:

Construction and decommissioning of infrastructure for the project

Impacts due to construction and decommissioning on ambient air quality concern particulate matter only and is expected to be of a temporary nuisance nature. Impacts will be limited to less than 1 km from the source and may impact on the property on which the site is to be constructed. These impacts are expected to have a low significance.

PM_{10} from the coal stockpile and ash dump at the Tshivhaso Power Station

The predicted 99th percentile 24-hour and annual average PM_{10} concentrations resulting from the coal stockpile and ash dump are also assessed in isolation to show their individual contribution in the ambient environment; and together to show the cumulative impact under normal operating conditions. A worst case cumulative impact considers the coal stockpile and ash dump where 100% of both areas are exposed to wind erosion. Two scenarios were assessed, where two different sites were used as the location of the ash dump. In all cases considered, predicted ambient concentrations resulting from the Tshivhaso Power Station are compliant with the current and future national ambient standards. The impacts associated with PM_{10} from the coal stockpile and ash dump have a low significance.

PM_{10} from the coal stockpile, ash dump and stacks at the Tshivhaso Power Station

When assessing PM_{10} from all sources at the Tshivhaso Power Station, (i.e. the four stacks, the coal stockpile and the ash dump in combination), it is assumed that 100% of the area for both the coal stockpile and ash dump is exposed to wind erosion. This constitutes a worst case scenario. The predicted 99th percentile 24-hour and annual average PM_{10} are assessed and predicted ambient concentrations resulting from the Tshivhaso Power Station are compliant with the current and future national ambient standards.

There is very little difference in ambient concentrations between the two different locations proposed for the ash dump. It is therefore concluded that the contribution of PM_{10} in the ambient environment are not dominated by the coal stockpile and ash dump, which are low level sources. The impacts associated with PM_{10} are attributed primarily to the stacks and have a low significance.

NO_2 from the stacks at the Tshivhaso Power Station

The predicted 99th percentile 1-hour and annual average NO_2 concentrations are assessed. Predicted ambient concentrations resulting from the Tshivhaso Power Station are compliant with national ambient standards and no exceedance of the standard is predicted within the Tshivhaso Power Station site or in residential areas around the site. The impacts associated with NO_2 have a low significance.

SO_2 from the stacks at the Tshivhaso Power Station

For SO_2 the predicted 99th percentile 1-hour, 24-hour and annual average concentrations complies with the national ambient standard for SO_2 and no exceedance of the standard is predicted within the Tshivhaso Power Station site or in residential areas around the site. The impacts associated with SO_2 have a low significance.

Indirect impacts at the Tshivhaso Power Station

Indirect impacts associated with the SO_2 and NO_2 emissions relate to acidification, and those associated with CO and CO_2 relate to global warming. The magnitude of indirect impacts associated with the operational scenarios relates to the relative contribution to acidification and global warming. While quantification of the relative contribution of the Tshivhaso Power Station is difficult, the contribution is considered to be relatively small in the national and global context. The significance of the indirect impacts is therefore anticipated to be low for all operational scenarios.

Cumulative impacts at the Tshivhaso Power Station

With respect to cumulative impacts, mining and agricultural activities, tailings dams, domestic fuel burning and vehicles on dirt roads in the area are identified as existing sources of dust. There will thus be a cumulative impact with dust generated during construction and decommissioning of the Tshivhaso Power Station, as well as during normal operations of the proposed coal stockpile and ash dump at the Tshivhaso Power Station.

The Matimba,Medupi and Thabametsi Power Stations are located within a 15 km radius of the Tshivhaso Power Station and are important sources of NO_2, SO_2 and PM_{10} at that locality. While the predicted ambient concentrations resulting from emissions from the Tshivhaso Power Station comply with ambient air quality standards, the cumulative effect of these emissions with those from the Matimba Power Station, and the new Medupi and Thabametsi Power Stations are likely to result in exceedances of the ambient standards (uMoya-NILU, 2013).

The AQMP for the Waterberg-Bojanala Priority Area includes emission reduction requirements to address this situation. It is important that an emission control and reduction strategy for dust is designed and implemented, ensuring that the contribution to ambient concentrations is minimised.

The probability of direct and cumulative impacts from dust, PM_{10}, NO_2 and SO_2, emitted during normal operation of the Tshivhaso Power Station, is considered to be high for all scenarios. The predictive modelling provides maximum expected ambient concentrations for each pollutant based on a worst-case meteorological scenario. These results show that predicted concentrations comply with the national ambient standard throughout the study domain. Despite this, some risk to health remains and the probability of direct and cumulative air quality impacts during the operation of Tshivhaso Power Station is considered to be high.

Employing the generic design parameters provided for the project, it is predicted that the site operations will low generate emissions, low ambient concentrations, and low environmental impacts overall. Mitigation measures are recommended for construction and decommissioning activities and during the operational lifespan of the facility. It is a reasonable opinion that the project should be authorised considering the outcomes of this impact assessment.

9. References

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APPENDIX 1: CURRICULUM VITAE

MARK ZUNCKEL

Firm	:	uMoya-NILU (Pty) Ltd
Profession	:	Air quality consultant
Specialization	:	Air quality assessment, air quality management planning, air dispersion modelling, boundary layer meteorology, project management
Position in Firm	:	Managing director and senior consultant
Years with Firm	:	New firm started on 1 August 2007
Nationality	:	South African
Year of Birth	:	1959
Language Proficiency	:	English and Afrikaans

EDUCATION AND PROFESSIONAL STATUS

Qualification	Institution	Year
National Diploma (Meteorology)	Technikon Pretoria	1980
BSc (Meteorology)	Univ. of Pretoria	1984
BSc Hons (Meteorology)	Univ. of Pretoria	1988
MSc	Univ. of Natal	1992
PhD	Univ. Witwatersrand	1999

Registered Natural Scientist: South African Society for Natural Scientific Professionals

Council Member: National Association for Clean Air
Member: African Meteorological Society
Member: Air and Waste Management Association

EMPLOYMENT AND EXPERIENCE RECORD

Period	Organisation details and responsibilities/roles
1976 – May 1992	*South African Weather Bureau :* Observer, junior forecaster, senior forecast, researcher, assistant director
June 1992 – July 2007	*CSIR:* Consultant and researcher, Research group Leader: Atmospheric Impacts
August 2007 to present	*uMoya-NILU Consulting:* Managing Director and senior air quality consultant

Key and Recent Project Experience:

1996	Project leader & Principal researcher: Atmospheric impact assessment for the proposed Mozal aluminium smelter in Maputo, Mozambique.
1996	Project leader & Principal researcher: Dry sulphur deposition during the Ben MacDhui High Altitude Trace Gas and Transport Experiment (BATTEX) in the Eastern Cape.
1997	Project leader & Principal researcher: Atmospheric impact assessment of the proposed capacity expansion project for Alusaf in Richards Bay.
1997	Project leader & Principal researcher: The Uruguayan ambient air quality project with LATU.

1997	Principal researcher on the Air quality specialist study for the Strategic Environmental Assessment on the industrial and urban hinterland of Richards Bay.
1997	Project leader & Principal researcher: Feasibility study for the implementation of a fog detection system in the Cape Metropolitan area: Meteorological aspects.
2001	Project leader & Principal researcher: Air quality specialist study for the Environmental Impact Assessment for the proposed expansion of the Hillside Aluminium Smelter, Richards Bay.
2001-2003	Researcher: The Cross Border air Pollution Impact (CAPIA) project. A 3-year modelling and impacts study in the SADC region.
2002	Project leader & Principal researcher: Air quality assessment specialist study for the proposed Pechiney Smelter at Coega.
2002	Project leader & Principal researcher: Air quality assessment specialist study for the proposed N2 Wild Coast Toll Road.
2002-2005	Project leader on the NRF project – development of a dynamic air pollution prediction system
2004	Project leader on the specialist study for expansion at the Natal Portland Cement plant at Simuma, KwaZulu-Natal.
2004-2005	Researcher: National Air Quality Management Plan implementation project for Department Environmental Affairs and Tourism.
2005	Researcher in the assessment of air quality impacts associated with the expansion of the Natal Portland Cement plant at Port Shepstone.
2005	Technical assistance to the Department of Environment Affairs and Tourism in the implementation of the Air Quality Act
2006-2007	Project team leader of a multi-national team to develop the National Framework for Air Quality Management for the Department of Environment Affairs and Tourism
2007	Air quality assessment for Mutla Early Production System in Uganda for ERM Southern Africa on behalf of Tullow Oil.
2007-2010	Lead consultant on the development of a dust mitigation strategy fro the Bulk Terminal Saldanha and an ambient guideline for Fe_2O_3 dust for Transnet Projects and on-going monitoring.
2008	Lead consultant on the Air quality status quo assessment and scoping for the EIA for the Sonangol Refinery
2008-09	Lead consultant on the development of the air quality management plan for the Western Cape Provincial. Department of Environmental Affairs and Development Planning.
2008-10	Lead consultant on the development of the Highveld Priority Area air quality management plan for the Department of Environmental Affairs and Tourism.
2008	Lead consultant in the development of an odour management and implementation strategy for eThekwini.
2008 & 2010	Lead consultant on the Air Quality Specialist Study for the EIA for the proposed Kalagadi Manganese Smelter at Coega
2008	Lead consultant on the Air Quality Assessment for the Proposed Construction and Operation of a Second Cement Mill at NPC-Cimpor, Simuma near Port Shepstone.
2008	Lead consultant on the Air Quality Specialist Study Report for the New Multi-Purpose Pipeline Project (NMPP) for Transnet Pipelines.
2008	Lead consultant on the Air quality assessment for the proposed UTE Power Plant and RMDZ coal mine at Moatize, Mozambique for Vale.
2009	Lead consultant on the Air quality assessment for the development of the ETA STAR coal mine at Moatize, Mozambique for Impacto.
2008-09	Lead consultant on the Dust source apportionment study for the Coedmore region in Durban for NPC-Cimpor.
2009	Consultant on the Air quality specialist study for the upgrade of the Kwadukuza Landfill, KwaZulu-Natal

2009-10	Lead consultant on the Audit of ambient air quality monitoring programme and air quality training for air quality personnel at PetroSA
2010	Lead consultant on the Qualitative assessment of impact of dust on solar power station at Saldanha Bay
2010	Lead consultant on the Air quality specialist study for the EIA for the Kalagadi Manganese Smelter at Coega
2010	Lead consultant on the Qualitative air quality assessment for the EIA for the Sechaba Aphalt plant, Ferrobank
2009 – 2010	Lead consultant on the Air quality specialist study for the Environmental Management Framework for the Port of Richards Bay
2010	Lead consultant on the Air quality status quo assessment and abatement planning at Idwala Carbonates, Port Shepstone
2010	Lead consultant on the Air quality status quo assessment and abatement planning at Sappi Tugela, Mandeni
2010 – 2011	Air quality status quo assessment and revision of the Air Quality Management Plan for City of Johannesburg
2010	Lead consultant on the Air quality status quo assessment and abatement planning at First Quantum Mining's Bwana Mkubwa and Kansanshi mines, Zambia
2010 – 2011	Lead consultant on the Air quality specialist study for the EIA for the Alternative Fuel and Resources Project at Simuma, Port Shepstone
2010 – 2011	Lead consultant on the Air quality specialist study for the EIA for the Coke Oven re-commissioning at ArcelorMittal Newcastle
2010	Qualitative air quality assessment for the EIA for the Mozpel sugar to ethanol project , Mozambique
2011	Development of the South African Air Quality Information System – Phase II The National Emission Inventory
2011	Ambient baseline monitoring for Riversdale's Zambeze Coal Project in Tete, Mozambique
2010 - 2011	Ambient quality baseline assessment for the Ncondeze Coal Project, Tete Mozambique
2011-12	Air quality assessment for the mining and processing facilities at Longmin Platinum in Marikana
2012	Air quality assessment for the proposed LNG and OLNG plants in Mozambique
2012	Modelling study in Abu Dhabi for the transport and deposition of radio nuclides
2012	Air quality assessment for the proposed manganese ore terminal at the Ngqura Port
2012-13	Air quality management plan development for Stellenbosch Municipality
2012-12	Air quality management plan development for the Eastern Cape Province
2013	Air quality specialist for Tullow Oil Waraga-D and Kinsinsi environmental audit
2013	Air quality specialist study for the EIA for the Thabametsi IPP station
2013	Air quality specialist study for the EIA for the Mamathwane Common User facility
2013	Air quality management plan for the Ugu District Municipality
2013-14	Air quality specialist study for the application for postponement of the minimum emission standards for 9 Eskom power stations
2014	Air quality specialist study for the application for postponement of the minimum emission standards for the Engen Refinery in Merebank, Durban
2014-15	Baseline assessment and AQMP development for the uThungulu District Municipality
2013-15	Baseline assessment and air quality management plan for the Waterberg-Bojanala Priority Area
2014-15	AQMP review for eThekwini Municipality
2014-14	Dispersion modelling study for Richards Bay Minerals
2015	Air quality assessment for Rainbow Chickens at Hammersdale

2015	Air quality status quo assessment and planning for TNPA managed ports in South Africa

PUBLICATIONS

Author and co-author of 34 articles in scientific journals, chapters in books and conference proceedings. Author and co-author of more than 100 technical reports and presented 47 papers at local and international conferences. A full publications list is available on request.