TITLE AND DESCRIPTIVE ABSTRACT

AGES (PTY) LTD

REPORT 0815-P002-AGE

AMBIENT AIR QUALITY IMPACT STUDY IN SUPPORT OF A PROPOSED THERMAL POWER PLANT NEAR SALDANHA BAY IN THE WESTERN CAPE

This document provides the findings of a study investigating the impact of atmospheric emissions from a proposed thermal power plant on a portion of the remainder of the Farm Langeberg 188, Malmesbury Road, Saldanha Bay Local Municipality, West Coast District Municipality, Western Cape Province.

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TECHNICAL VERIFICATION

All results and related data have been obtained through careful and precise execution of recognised methods of evaluation and are related only to the scope of work covered in this report and of prevailing conditions at the time of the assessment. The opinions and interpretations are embraced through judgment, discernment and comprehension to the best of available knowledge.

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28 February 2016

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TABLE OF CONTENTS

1. *INTRODUCTION*

Environmental and Health Risk Consulting (Pty) Ltd (EHRCON) was retained by AGES Limpopo (AGES) to assess the impact of atmospheric emissions from a new thermal power project proposed by Vortum Energy (Pty) Ltd on a portion of the remainder of the Farm Langeberg 188, Malmesbury Road, Saldanha Bay (Vortum Thermal Power Plant).

The national priority for new power generation capacity determined the Vortum Thermal Power Plant to initially operate as an Open Cycle Gas Turbine (OCGT) power plant. During the second phase of the project, steam turbine units will be added to the OCGT configuration in order to function as a Combined Cycle Gas Turbine (CCGT) power plant.

In a CCGT power plant a Rankine cycle (steam cycle) is added to a Brayton cycle (gas cycle). The combination of the two thermodynamic cycles result in an overall thermal efficiency improvement of more than 20% through the use of heat recovery steam generators (HRSGs) which produce additional energy from the gas cycle waste heat.

The plant will initially operate as a peak power plant using diesel fuel imported from the oil pier at the Port of Saldanha, delivered to site by means of an underground pipeline. Oil tank trucks will be used until commissioning of the pipeline.

During the second phase of the development, natural gas will be imported via underground pipeline from the Port of Saldanha Liquid Natural Gas (LNG) Import and Re-gas Facility currently being considered by the Department of Energy.

The rated capacity of the Vortum Thermal Power Plant will increase from 800 MW_{el} during the OCGT phase, to 1 200 MW_{el} during the CCGT phase.

The scope of the investigation was based on specific conditions outlined by Ms Engela Grobler of AGES.

The objectives of this study were to describe the atmospheric emissions from the electricity generation process and to assess the impact on the health of the receiving community. The findings of the study are aimed at providing Vortum Energy (Pty) Ltd, the Saldanha Bay Local Municipality and other stakeholders with scientific reference data to support future air quality management systems.

1.1. TERMS OF REFERENCE

The study area (5 km radius around the project site) is located in the Saldanha Bay Local Municipality, one of five municipalities comprising the West Coast District Municipality. Current land use in the area includes industrial, commercial, agricultural and residential (See **Figure 1**).

The project site is located 9 kilometre (km) north east of the Port of Saldanha Bay, in an area earmarked for industrial use. Other major industrial processes nearby include the Namakwa Sands smelter complex of Tronox, located approximately 2.3 km west south-west, the Saldanha Steel operations of ArcelorMittal approximately 4.4 km south west and the PetroSA SFF Terminal approximately 4.7 km south west.

The R27 regional road borders the eastern side of the process site and bisects the study area along a north north-west to south south-east axis.

A number of small commercial businesses, hospitality and leisure establishments and isolated residences are scattered throughout the study area. The residential area of the Air Force Base Langebaanweg falls just outside the eastern boundary of the study area.

Figure 1: Vortum Thermal Power Plant site location (red polygon) and study area (5km radius)

The assessment of emissions from the electricity generation process comprised the following terms of reference:

- A review of relevant health criteria, ambient air quality guidelines and standards.
- The compilation of a process emissions inventory, based on current emission factors.
- Compilation of a meteorology database.

- An assessment of impact based on dispersion simulation.
- Evaluation of the potential for human health and environmental impacts based on comparisons of modelled pollutant concentrations with relevant guidelines and standards.

1.2. METHODOLOGICAL OVERVIEW

The establishment of an emissions inventory formed the basis for assessing the impact from the proposed electricity generation process. This comprised the identification of sources of emission and the quantification of each source's contribution to ambient air concentrations.

In the emissions inventory, dispersion simulation and impact assessment, reference was made to routine emissions from production processes.

Process emission rates were obtained from emission factors which associate the quantity of a pollutant to the activity associated with its release. Due to the absence of locally generated emission factors, the comprehensive set of emission factors published by the United States Environmental Protection Agency (US-EPA) in its AP-42 document *Compilation of Pollution Emission Factors*, was used.

The simulation of emissions was performed through the application of the ISC-AERMOD View Model. AERMOD is a steady-state plume model, applicable to rural and urban areas, flat and complex terrain, surface and elevated releases, and multiple sources (including, point, area and volume sources). In the stable boundary layer (SBL), the concentration distribution is assumed to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function. Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate.

The dispersion simulations of emissions facilitated a preliminary or screening study of the potential for human health impacts. In order to assess the health implications, the simulated concentrations were compared to ambient air quality guidelines and standards.

1.3. KEY FINDINGS

The study, aimed at describing emissions from the proposed Vortum Thermal Power Plant near Saldanha Bay, concludes the following:

- Primary combustion emissions will be the dominant source of ambient pollution, discharging more than 95% of the total emission load. Less than 5% of the atmospheric pollution load will be attributed to fugitive emissions from support processes, fuel handling and vehicle movement.
- Dispersion of emissions from the facility was modelled using the ISC-AERMOD View model based on the standard Gaussian solution.
- The results present the spectrum from maximum ground level concentration to maximum impact area, and accounts for hourly, daily and annual averages.
- Average ground level concentrations were predicted for atmospheric conditions based on local meteorological data for the period January 2010 to December 2015.
- Annual PM_{10} emissions could potentially contravene the national standard of 40µg/m^3 up to a maximum distance of 450m beyond the north eastern and western process boundaries. Daily contraventions as a result of the process, should not exceed one per annum at the nearest sensitive receiver, north west of the plant.
- It is unlikely that the process independently, would result in average PM_{10} concentrations above current background concentrations at the nearest residential receivers.
- NO_2 emissions from the process could potentially contravene the hourly standard of 350µg/m^3 up to a distance of 5km in all directions from the process. These contraventions will mostly like occur during upset process situations combined with poor atmospheric dispersion conditions. It is unlikely that these contraventions will exceed 10% of the number of permitted annual contraventions.
- Annual average NO_2 concentrations will probably remain below 10% of the standard beyond the process boundary.

- The NO_2 predictions are based on the implementation of Dry Low NOx (DNL) technology during both phases of the project.
- SO_2 emissions could potentially contravene the short-term reference standards in isolated areas, up to a distance of 5km from the process. It is unlikely that these contraventions will exceed 10% of the number of permitted annual contraventions.
- Annual average SO_2 concentrations as a result of the process will be most significant in the north north-easterly and south south-westerly directions from the plant. Concentrations are not expected to exceed current background levels.
- Ground level concentrations for all volatile organic compounds, other hazardous air pollutants and metallic pollutants are predicted to remain below 5% of the relevant standard, for all reference periods.
- Controlled emissions can be effectively mitigated through application of best available industrial control measures and sound environmental management principles. A reduction in emissions of up to 98% can be achieved.
- Process emission testing will assist effective air quality management and open communication to all stakeholders (see **Section 2.2**).

2. AIR QUALITY ASSESSMENT CRITERIA

2.1. AIR QUALITY DESCRIPTORS

It is assumed that the reader is familiar with most commonly used air quality terminology. The following words or expressions form the basis of the Act, existing guidelines and SANS standards and will be used in this report-

a) **acceptable** to the authority administering this standard or to the parties concluding the purchase contract, as relevant.

b) **air pollution** means any change in the composition of the air, caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.

c) **air quality standard** comprises limit values based on health risk or environmental risk (or both) and associated averaging periods indicative of exposure durations, in addition to the following criteria:
   - monitoring and data management protocols for air quality assessment and reporting;
   - permissible frequencies of exceeded limit values within defined time frames; and
   - time frames for achieving compliance in non-attainment areas

d) **agglomeration** area with a population of 250 000 or more inhabitants or, where the population is less than 250 000 inhabitants, a population density per square kilometre that justifies the need for ambient air quality to be assessed and managed.

e) **alert threshold** level beyond which there is a risk to human health from brief exposure and for which priority action is required.

f) **ambient air** means outdoor air in the troposphere, excluding work places, were air quality is determined in accordance with SANS 1929:2005.

g) **assessment** method used to measure, calculate, predict or estimate the level of a pollutant in the ambient air.

h) **assessment threshold**
   - **lower assessment threshold** level below which modelling or objective estimation techniques alone may be used to assess ambient air quality; and

- **upper assessment threshold** level above which monitoring is mandatory, and below which a combination of measurements and modelling techniques may be used to assess ambient air quality.

i) **atmospheric emission** or **emission** means any emission or entrainment process emanating from a point, non-point or mobile source that result in pollution.

j) **national** authority national authority responsible for air quality.

k) **provincial authority** provincial government department tasked with air quality management under the National Environmental Management: Air Quality Act.

l) **local authority** local government department tasked with air quality management under the National Environmental Management: Air Quality Act.

m) **averaging period** over which average value is determined.

n) **level** concentration of a pollutant in ambient air or the deposition thereof over a given time.

o) **limit value** level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health or the environment as a whole (or both), to be attained within a given period and not to be exceeded once attained.

p) **margin of tolerance** percentage of the limit value by which this value may be exceeded, subject to the conditions laid down in SANS 69:2004.

q) **natural events** geothermal activities, bush fires, high winds or the atmospheric re-suspension or transport of natural particles from dry regions.

r) **pollutant** substance introduced directly or indirectly by man into the ambient air and likely to have harmful effects on human health or the environment as a whole (or both).

s) **priority area** identified and proclaimed as a priority area by the Minister of Environmental Affairs and Tourism or any member of the executive committee (MEC), by notice in the Gazette and after consultation with relevant stakeholders, where he/she is of the opinion that:

- ambient air quality limits or values are being, or are likely to be exceeded; or
- any other harmful situation exists; and
- the limits or values being exceeded are causing, or may cause, a significant negative impact on the environment or health.

t) **PM10** particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 10µm aerodynamic diameter.

u) **target value** level fixed with the aim of avoiding more long-term harmful effects on human health and the environment as a whole, to be attained where possible over a given period.

v) **zone** area designated by the national authority in which limit values for a specific pollutant are exceeded owing to the concentrations of that pollutant in ambient air due to natural sources.

2.2. MINISTRY OF ENVIRONMENTAL AFFAIRS

National Environmental Management: Air Quality Act

The Department of Environmental Affairs (DEA) have brought into effect the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (AQA) on 11 September 2005 as part of a broad programme of air quality management reform. Sections 21 and 22 of AQA read as follows:

(1) The Minister must, or the MEC may, by notice in the Gazette -

(a) publish a list of activities which result in atmospheric emissions and which the Minister or MEC reasonably believes have or many have significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage, and

(b) when necessary, amend the list by-

(i) adding to the list activities in addition to those contemplated in paragraph (a);

(ii) removing activities from the list; or

(iii) making other changes to particulars in the list.

(2) A list published by the Minister applies nationally and a list published by the MEC applies to the relevant province only.

(3) A notice referred to in subsection (1) -

(a) must establish minimum emission standards in respect of a substance or mixture of substances resulting from a listed activity and identified in the notice, including-

(i) the permissible amount, volume, emission rate or concentration of that substance or mixture of substances that may be emitted, and

(ii) the manner in which measurements of much emissions must be carried out;

(b) may certain transitional and other special arrangements in respect of activities which are carried out at the time of their listing; and

(c) must determine the date on the notice takes effect.

(4)(a) Before publishing a notice in terms of subsection (1) or any amendment to the notice, the Minister or MEC must follow a consultative process in accordance with sections 56 and 57.

(b) Paragraph (a) need not be complied with if the notice is amended in non–substantive way.

No person may without a provisional atmospheric emission license or an atmospheric emission license conduct any activity –

(a) listed on the national list anywhere in the Republic; or

(b) listed on the list applicable in the province anywhere in that province.

These sections of the AQA make the publication of a list of activities, together with emission limits for these activities and the method by which emissions shall be tested mandatory, on at least the Minister.

Listed activity and minimum emission standards

A list of activities associated minimum emission standards are set out in *National Environmental Management: Air Quality Act (ACT 39 of 2004): List of activities which result in atmospheric emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage - GN 893 of 22 November 2013.*

The standards given below shall apply only to the activities listed with the proviso that "Existing Plant" standards shall apply from the date eight years after the publication date of these regulations to all plant in operation on the final publication date and plant put into operation within three years of the final publication date of these regulations and "New Plant" standards shall apply to all plant put into operation later than three years after final publication date of these regulations.

The minimum emission standards applicable to the Vortum Thermal Power Plant project are summarised in **Table 1** on the next page.

The owner or operator of a facility in which listed activities are operated shall submit an annual emission report to the licensing authority in terms of section 36 of the Act within a year after first date of issue of license to the facility, and annually thereafter not longer than 13 months after submission of the previous report, for each activity operated within the facility which is listed in this regulation, whether such activity was operated for the full period or not. The emission report shall be in an electronic format approved by the National Air Quality Officer.

Table 1a:

Minimum emission standards for new liquid fuel combustion installations

Substance or mixture of substances		mg/m^3 under normal conditions of 273 Kelvin and 101.3kPa
Common name	**Chemical symbol**	
Particulate matter	n.a.	50
Sulphur dioxide	SO_2	500
Oxides of nitrogen	NO_x expressed as NO_2	250

Notes:

Category	:	Category 1: Combustion Installations. Subcategory 1.2: Liquid Fuel Combustion Installations.
Description	:	Installations used primarily for steam raising or electricity generation.
Application	:	All installations with a design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used.
Special Arrangement	:	Reference conditions for gas turbines shall be 15% O_2, 273K and 101.3kPa. Continuous emission monitoring of PM, SO_2 and NO_x is required, however, Installations less than 100 MW heat input per unit must adhere to periodic emission monitoring as stipulated in Part 2 of the Notice.

Table 1b:

Minimum emission standards for new gas combustion installations

Substance or mixture of substances		mg/m^3 under normal conditions of 273 Kelvin and 101.3kPa
Common name	**Chemical symbol**	
Particulate matter	n.a.	10
Sulphur dioxide	SO_2	400
Oxides of nitrogen	NO_x expressed as NO_2	50

Notes:

Category	:	Category 1: Combustion Installations. Subcategory 1.4: Gas (including natural gas) Combustion Installations.
Description	:	Installations used primarily for steam raising or electricity generation.
Application	:	All installations with a design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used.
Special Arrangement	:	Reference conditions for gas turbines shall be 15% O_2, 273K and 101.3kPa.

In terms of *Subcategory 2.4: Storage and Handling of Petroleum Products*, all permanent immobile liquid storage facilities at a single site with a combined storage capacity of greater than 1 000m^3 shall at least be fixed roof, free atmospheric vent type installations for the storage of raw materials, intermediate and final products with a true vapour pressure of up to 14kPa at operating temperature. Alternative control measures that can achieve the same or better results may be used.

No special requirements are applicable for the handling of raw materials, intermediate and final products with a true vapour pressure of up to 14kPa at operating temperature.

Each report shall include all of the following:

a) The name and description of the facility and of the listed activity as on the emission license for the facility.
b) The name and address of the accredited measurement authority that carried out the emission test.
c) The date and time on which the emission test was carried out. The emission test shall be carried out at least once during the reporting period, unless specified otherwise for the specific activity.

d) A declaration to the effect that normal operating conditions were maintained during the emission tests.

e) The total volumetric flow of gas, expressed in normal cubic meters (Nm^3) per unit time and mass flow (kg per unit time) being emitted by the listed activity or activities measured during the emission test, as the average of at least two measurements.

f) The concentration or mass of pollutant for which emissions standards have been set in this schedule emitted by each listed activity within the facility, as the average of at least two measurements.

g) The method or combination of methods used for determining the flow rate and concentration, selected from the reference list of methods. Where a reference method was not used, the reason shall be provided, as well as a description of the method used and documentary proof of equivalence to a reference method.

h) Where continuous emission measurement is prescribed, the report should include results of correlation tests, which should be carried out at least annually, and the availability of the continuous measurement in terms of the number of full hours per annum that valid results were obtained.

i) Remediation measures with an implementation schedule where
   - the average values under (f) above exceed the prescribed standard or
   - in the case where continuous emission measurement is prescribed, results were available for less than 90% of the total hours during the reporting period and/or
   - measurement results exceeded the standard given for that activity for more than 5% of the time that measurements are available.

Ambient Air Quality Limits

The exclusive use of source-based controls (e.g. emission limits) as an air quality management tool has been found to have important short-comings. Emission limits do not take the unique characteristics of the receiving environment into account, such as the dispersion potential, existence of other sources, existing ambient pollutant concentrations, and the sensitivity of the receiving environment. Such limits therefore provide no insurance that ambient air quality objectives will be achieved and that there will be no adverse effects on human health and welfare.

There has been a strong shift from air pollution control based exclusively on source-based methods (e.g. emission limits) to air quality management based on an effects-based approach (e.g. air quality objectives). An effects-based approach requires the setting of ambient air quality guidelines and standards. Ambient air quality guidelines and standards are laid down by various countries, including South Africa, for the regulation of air concentrations of various criteria pollutants (e.g. sulphur dioxide, particulate matter, nitrogen oxides and lead). Such ambient guideline and standards define satisfactory air quality to ensure human health and welfare, thus providing objectives for air quality management.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the receptor. These guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout the individual's entire lifetime. Air quality guidelines and standards are normally given for specific averaging periods, i.e. the duration over which the standard or guideline is applicable. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average and annual average.

DEA have brought into effect the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (NEMAQA) on 11 September 2005 as part of a broad programme of air quality management reform. The publication in May 2000 of government's Integrated Pollution and Waste Management Policy (IP & WM Policy) marked a turning point for pollution and waste governance in South Africa. The National Air Quality Management Plan (NAQMP), borne from the IP & WM Policy, has as its definition the NEMAQA.

Government's vision with respect to the NAQMP is that the programme will develop, implement and maintain an air quality management regime that contributes to sustainable development and a measurable improvement in the quality of life of all, by harnessing the energy and commitment of all South Africans for the effective prevention, minimisation and control of atmospheric pollution.

DEA is responsible for establishing a national framework for achieving the objectives of NEMAQA, which includes –

a) mechanisms, systems and procedures to attain compliance with ambient air quality standards;
b) mechanisms, systems and procedures to give effect to the Republic's obligations in terms of international agreements;
c) national norms and standards for the control of emissions from point and non-point sources;
d) national norms and standards for air quality monitoring;
e) national norms and standards for air quality management planning;
f) national norms and standards for air quality information management; and
g) any other matter which the Minister considers necessary for achieving the objectives of the Act.

The establishment of national ambient air quality standards is achieved through NEMAQA and the South African Bureau of Standards (SABS) standard setting initiative. The National Ambient Air Quality Standards (NAAQS) have subsequently been published in the Government Gazette of 24 December 2009 and 29 June 2012. The standards are summarised in **Table 2** below.

Table 2:

Ambient air quality standards (@ 25°C and 101.3 kPa)

Substance	Time-weighted average (µg/m³)				
	10-minutes	1-hour	8-hour	24-hour	Annual
Ozone (O_3)	n.a.	n.a.	120[1]	n.a.	n.a.
Nitrogen dioxide (NO_2)	n.a.	200[2]	n.a.	n.a.	40
Sulphur dioxide (SO_2)	500[3]	350[2]	n.a.	125[4]	50
Lead (Pb)	n.a.	n.a.	n.a.	n.a.	0.5
Particulate matter (PM_{10})	n.a.	n.a.	n.a.	75[4]	40
Particulate matter ($PM_{2.5}$)	n.a.	n.a.	n.a.	40[4] 25[4]*	20 15*
Carbon monoxide (CO)	n.a.	30 000[2]	10 000[1]	n.a.	n.a.
Benzene (C_6H_6)	n.a.	n.a.	n.a.	n.a.	10 5*

Note:

µg/m³	:	microgram per cubic meter air
DEA	:	Department of Environmental Affairs
1	:	Not to be exceeded more than 11 times per annum.
2	:	Not to be exceeded more than 88 times per annum.
3	:	Not to be exceeded more than 526 times per annum.
4	:	Not to be exceeded more than 4 times per annum.
5	:	Not to be exceeded more than 4 times per annum.
*	:	All standards are to be complied with immediately. Standards with one asterisk are to be complied with as from 1 January 2030.

2.3. WEST COAST DISTRICT MUNICIPALITY

Air Quality Management By-Law

The Council of the West Coast District Municipality (WCDM) acting in terms of the section 156(2) of the Constitution of the Republic of South Africa Act, 1996. Read with section 13(a) of the Local Government Municipal Systems Act, 2000 (Act No. 32 of 2000) and section 11(1) of the National

Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) enacted the WCDM Air Quality Management By-Law on 6 September 2013.

The WCDM seeks to ensure management of air quality and the control of air pollution within the area of jurisdiction and to ensure that air pollution is avoided or, where it cannot be altogether avoided, is minimized and remedied.

This By-Law applies to all properties or premises from where listed activities and controlled emitters identified in terms of Section 21 and 23 of the Air Quality Act are conducted within the area of jurisdiction of the WCDM that include the five local municipalities.

The By-Law give effect to the right contained in Section 24 of the Constitution by regulating air pollution within the area of the municipality's jurisdiction in a cooperative manner between the District and Local Municipalities taking cognisance of the respective air quality management plans. In conjunction with other applicable laws, the By-Law provides an effective legal and administrative framework within which the WCDM can manage and regulate activities that have potential to adversely impact on the environment, public health and well being.

3. BACKGROUND

3.1. PROCESS OVERVIEW

Background

The idea of combined cycles has grown out of the need to improve the simple Joule-cycle efficiency by utilising the waste heat in the turbine exhaust gas. This is a natural solution because the gas turbine is a relatively high temperature machine and the steam turbine a relatively low temperature machine.

The use of gas turbines by utility companies is now well established recognised industrially. The waste flue-gas temperature at the gas turbine outlet is about 500°C or more. This temperature creates the possibility to apply an additional steam cycle process. Such system combination optimises the gas and steam processes to increase the overall electric or mechanical efficiency. Combined cycle principles may also be applicable to combustion engines.

Combined cycle gas turbines operate at maximum electrical efficiency at full load. At 10 to 20% supplementary firing of the heat recovery steam generator (HRSG), the overall efficiency starts to decrease but still remains higher than electricity produced by only a boiler in combination with a steam turbine. For this reason supplementary firing of a HRSG is often used for small scale peak load heat operation in industrial and district heating. This application is often used to improve the cost-effectiveness and flexibility of combined cycle power plants. In addition the incremental pollution of NO_x is very low, due to the lower oxygen content of the combusted flue-gas. The use of a pre-mix burner ensures this low level of emissions.

Few combined cycle systems are used in the natural gas transmission system, because their high investment is only reasonable if the use of compressors is on a high yearly basis (e.g. > 6 000h/yr).

The Vortum Power Plant

In a CCGT power plant a Rankine cycle (steam cycle) is added to a Brayton cycle (gas cycle). The combination of the two thermodynamic cycles result in improved overall efficiency because heat from the gas cycle is utilised to produce steam to generate additional electricity via steam turbine units, enhancing the efficiency of overall electricity generation. The thermal efficiency of a CCGT power plant is up to 62%, 20% more than an OCGT plant.

A CCGT power plant consists of gas turbine units coupled with steam turbine units: the "waste" heat from each gas turbine is sent to HRSGs to generate high pressure steam; the steam from the HRSG drives steam turbines coupled with generators, in order to generate electricity increasing the efficiency of the power plant.

The Vortum Thermal Power Plant will consist of the following components:

- up to 5 gas turbine units with a capacity up to 400 MW_{el} each and an overall capacity up to 800 MW_{el};
- heat recovery steam generators (HRSG) to generate steam;
- up to 5 steam turbine units with a capacity up to 400 MW_{el} each and an overall capacity up to 400 MW_{el}.
- up to 5 electrical generators, which convert the mechanical energy of the gas and steam turbine units to electricity;
- gas compressors and combustors with Dry Low NOx (DNL) technology, for the gas cycle;
- water pumps and pressurisers, for the steam cycle;
- dry cooled condensers, in order to condensate the steam to water;
- a control room with offices;
- warehouses;
- up to 6 fuel (diesel) storage tanks of 5,400 m^3 each, required during the first phase of the project, until gas is available;
- an underground liquid fuel (diesel) pipeline approximately 12 km long and with a throughput capacity up to 2327 m^3/day, from the Saldanha Port to the on-site fuel storage tanks;

- an underground natural gas pipeline approximately 12 km long and with a throughput capacity up to 3171 ton/day, from the Saldanha Port to the project site;
- one on-site high voltage substation;
- up to three 400 kV power lines, for the connection to the Eskom Aurora substation;
- a water supply pipeline;
- water tanks with an overall storage capacity up to 10,000 m^3;
- firefighting system;
- water treatment system (Reverse Osmosis Plant);
- compressed air system;
- exhaust system with flares, for exhaust gas.

Each steam turbine can be coupled to one or more gas turbines (single-shaft or multi-shaft arrangement), depending on design requirements. The number and size (capacity) of the gas and steam turbine units has not been finalised yet and will depend on the cost-effective curve of gas and steam turbines at the time of the commissioning.

The final generation capacity (up to 1200 MW_{el}) and the timeframe of the OCGT phase and CCGT phase will depend on:

- Gas availability: the future gas availability at Saldanha depends on the LNG Import Terminal planned at Saldanha Bay by the Department of Energy (DoE). At this stage, the import capacity of this terminal is not finalised yet;
- the requirements of the RFP of Gas-to-Power IPP Procurement Programme (not been published yet by the DoE), which may establish a threshold for the maximum generation capacity of IPP's power plants allowed to participate in the tender.

The final CCGT power plant may comprise the following:

- 2 gas turbines units of 400 MW_{el} each + one or more steam turbines units with an overall installed capacity of 400 MW_{el} (overall installed capacity: 1200 MW_{el}); or (*e.g.*)
- 5 gas turbines units of 160 MW_{el} each + one or more steam turbines units with an overall installed capacity of 400 MW_{el} (overall installed capacity: 1200 MW_{el}); or (*e.g.*)

- a combination of different sizes of gas and steam turbine units.

The final configuration will be defined at the commissioning time, on the basis of the best cost-effective gas and steam turbine generators available on the market.

The overall installed capacity will nevertheless be up to 1 200 MW_{el} during the second phase and up to 800 MW_{el} during the first phase.

Fuel Handling and Storage

During the first phase of the development, diesel will be imported from the oil pier of the Port of Saldanha and delivered to the Vortum Thermal Power Plant by means of an underground pipeline. Road transport tank trucks will be used to support diesel delivery to site until commissioning of the pipeline. The onsite diesel storage capacity of 32 400m^3 will be in the form of six fixed roof, vertical storage tanks.

No onsite natural gas storage facility is planned for the CCGT phase of the Vortum Thermal Power Plant as natural gas will be delivered directly via an underground pipeline from the planned DoE import/re-gas facility in the Port of Saldanha.

3.2. EMISSIONS INVENTORY

3.2.1 Gas Turbines

Combustion Emissions

The primary pollutants from gas turbine engines are nitrogen oxides (NO_X), carbon monoxide (CO), and to a lesser extent, volatile organic compounds (VOC). Particulate matter (PM) is also a primary pollutant for gas turbines using liquid fuels. Nitrogen oxide formation is strongly dependent on the high temperatures developed in the combustor. Carbon monoxide, VOC, hazardous air pollutants (HAP), and PM are primarily the result of incomplete combustion. Trace to low amounts of HAP and sulphur dioxide (SO_2) are emitted from gas turbines. Ash and metallic additives in the fuel may

also contribute to PM in the exhaust. Oxides of sulphur (SO_X) will only appear in a significant quantity if heavy oils are fired in the turbine. Emissions of sulphur compounds, mainly SO_2, are directly related to the sulphur content of the fuel.

Available emissions data indicate that the turbine's operating load has a considerable effect on the resulting emission levels. Gas turbines are typically operated at high loads (greater than or equal to 80 percent of rated capacity) to achieve maximum thermal efficiency and peak combustor zone flame temperatures. With reduced loads (lower than 80 percent), or during periods of frequent load changes, the combustor zone flame temperatures are expected to be lower than the high load temperatures, yielding lower thermal efficiencies and more incomplete combustion.

Gas turbines firing diesel may emit trace metals carried over from the metals content of the fuel. If the fuel analysis is known, the metals content of the fuel ash should be used for flue gas emission factors assuming all metals pass through the turbine.

Nitrogen oxides (NO_X) – NO_X formation occurs by three fundamentally different mechanisms. The principal mechanism with turbines firing gas or diesel fuel is thermal NO_X, which arises from the thermal dissociation and subsequent reaction of nitrogen (N_2) and oxygen (O_2) molecules in the combustion air. Most thermal NO_X is formed in high temperature stoichiometric flame pockets downstream of the fuel injectors where combustion air has mixed sufficiently with the fuel to produce the peak temperature fuel/air interface.

The second mechanism, called prompt NO_X, is formed from early reactions of nitrogen molecules in the combustion air and hydrocarbon radicals from the fuel. Prompt NO_X forms within the flame and is usually negligible when compared to the amount of thermal NO_X formed. The third mechanism, fuel NO_X, stems from the evolution and reaction of fuel-bound nitrogen compounds with oxygen. Natural gas has negligible chemically-bound fuel nitrogen (although some molecular nitrogen is present). Essentially all NO_X formed from natural gas combustion is thermal NO_X. Diesel have low levels of fuel-bound nitrogen. Fuel NO_X from diesel-fired turbines may become significant in turbines equipped with a high degree of thermal NO_X controls. Otherwise, thermal NO_X is the predominant NO_X formation mechanism in diesel-fired turbines.

The maximum thermal NO_X formation occurs at a slightly fuel-lean mixture because of excess oxygen available for reaction. The control of stoichiometry is critical in achieving reductions in thermal NO_X. Thermal NO_X formation also decreases rapidly as the temperature drops below the adiabatic flame temperature, for a given stoichiometry. Maximum reduction of thermal NO_X can be achieved by control of both the combustion temperature and the stoichiometry. Gas turbines operate with high overall levels of excess air, because turbines use combustion air dilution as the means to maintain the turbine inlet temperature below design limits. In older gas turbine models, where combustion is in the form of a diffusion flame, most of the dilution takes place downstream of the primary flame, which does not minimize peak temperature in the flame and suppress thermal NO_X formation.

Diffusion flames are characterized by regions of near-stoichiometric fuel/air mixtures where temperatures are very high and significant thermal NO_X is formed. Water vapour in the turbine inlet air contributes to the lowering of the peak temperature in the flame, and therefore to thermal NO_X emissions. Thermal NO_X can also be reduced in diffusion type turbines through water or steam injection. The injected water-steam acts as a heat sink lowering the combustion zone temperature, and therefore thermal NO_X. Newer model gas turbines use lean, premixed combustion where the fuel is typically premixed with more than 50 percent theoretical air which results in lower flame temperatures, thus suppressing thermal NO_X formation.

Ambient conditions also affect emissions and power output from turbines more than from external combustion systems. The operation at high excess air levels and at high pressures increases the influence of inlet humidity, temperature, and pressure. Variations of emissions of 30 percent or greater have been exhibited with changes in ambient humidity and temperature. Humidity acts to absorb heat in the primary flame zone due to the conversion of the water content to steam. As heat energy is used for water to steam conversion, the temperature is the flame zone will decrease resulting in a decrease of thermal NO_X formation. For a given fuel firing rate, lower ambient temperatures lower the peak temperature in the flame, lowering thermal NO_X significantly. Similarly, the gas turbine operating loads affect NO_X emissions. Higher NO_X emissions are expected for high operating loads due to the higher peak temperature in the flame zone resulting in higher thermal NO_X.

Carbon Monoxide (CO) and Volatile Organic Compounds (VOCs) – CO and VOC emissions both result from incomplete combustion. CO results when there is insufficient residence time at high temperature or incomplete mixing to complete the final step in fuel carbon oxidation. The oxidation of CO to CO_2 at gas turbine temperatures is a slow reaction compared to most hydrocarbon oxidation reactions. In gas turbines, failure to achieve CO burnout may result from quenching by dilution air. With liquid fuels, this can be aggravated by carryover of larger droplets from the atomizer at the fuel injector. Carbon monoxide emissions are also dependent on the loading of the gas turbine. For example, a gas turbine operating under a full load will experience greater fuel efficiencies which will reduce the formation of carbon monoxide. The opposite is also true, a gas turbine operating under a light to medium load will experience reduced fuel efficiencies (incomplete combustion) which will increase the formation of carbon monoxide.

The pollutants commonly classified as VOC can encompass a wide spectrum of volatile organic compounds some of which are hazardous air pollutants. These compounds are discharged into the atmosphere when some of the fuel remains unburned or is only partially burned during the combustion process. With natural gas, some organics are carried over as unreacted, trace constituents of the gas, while others may be pyrolysis products of the heavier hydrocarbon constituents. With liquid fuels, large droplet carryover to the quench zone accounts for much of the unreacted and partially pyrolized volatile organic emissions.

Similar to CO emissions, VOC emissions are affected by the gas turbine operating load conditions. Volatile organic compounds emissions are higher for gas turbines operating at low loads as compared to similar gas turbines operating at higher loads.

Particulate Matter (PM) – PM emissions from turbines primarily result from carryover of non-combustible trace constituents in the fuel. PM emissions are negligible with natural gas firing and marginally significant with diesel firing because of the low ash content. PM emissions can be classified as "filterable" or "condensable" PM. Filterable PM is that portion of the total PM that exists in the stack in either the solid or liquid state and can be measured on filter. Condensable PM is that portion of the total PM that exists as a gas in the stack but condenses in the cooler ambient air to form particulate matter. Condensable PM exists as a gas in the stack and so it passes through a filter. Condensable PM is composed of organic and inorganic compounds and is generally considered to be all less than 1.0 micrometers in aerodynamic diameter.

Greenhouse Gases – Carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions are all produced during natural gas and distillate oil combustion in gas turbines. Nearly all of the fuel carbon is converted to CO_2 during the combustion process. This conversion is relatively independent of firing configuration. Methane (CH_4) is also present in the exhaust gas and is thought to be unburned fuel in the case of natural gas or a product of combustion in the case of diesel.

Although the formation of CO acts to reduce CO_2 emissions, the amount of CO produced is insignificant compared to the amount of CO_2 produced. The majority of the fuel carbon not converted to CO_2 is due to incomplete combustion.

Formation of N_2O during the combustion process is governed by a complex series of reactions and its formation is dependent upon many factors. However, the formation of N_2O is minimized when combustion temperatures are kept high (above 800°C) and excess air is kept to a minimum (<1%).

Hazardous Air Pollutants (HAP) – Available data indicate that emission levels of HAP are lower for gas turbines than for other combustion sources. This is due to the high combustion temperatures reached during normal operation. The emissions data also indicate that formaldehyde is the most significant HAP emitted from combustion turbines. For natural gas fired turbines, formaldehyde accounts for about two-thirds of the total HAP emissions. Polycyclic aromatic hydrocarbons (PAH), benzene, toluene, xylenes, and others account for the remaining one-third of HAP emissions. For Diesel-fired turbines, small amount of metallic HAP are present in the turbine's exhaust in addition to the gaseous HAP identified under gas fired turbines. These metallic HAP are carried over from the fuel constituents. The formation of carbon monoxide during the combustion process is a good indication of the expected levels of HAP emissions. Similar to CO emissions, HAP emissions increase with reduced operating loads. Typically, combustion turbines operate under full loads for greater fuel efficiency, thereby minimizing the amount of CO and HAP emissions.

Emission Control Technologies

There are three generic types of emission controls in use for gas turbines, wet controls using steam or water injection to reduce combustion temperatures for NO_X control, dry controls using advanced combustor design to suppress NO_X formation and/or promote CO burnout, and post-combustion

catalytic control to selectively reduce NO_X and/or oxidize CO emission from the turbine. Other recently developed technologies promise significantly lower levels of NO_X and CO emissions from diffusion combustion type gas turbines. These technologies are currently being demonstrated in several installations.

Water Injection – Water or steam injection is a technology that has been demonstrated to effectively suppress NO_X emissions from gas turbines. The effect of steam and water injection is to increase the thermal mass by dilution and thereby reduce peak temperatures in the flame zone. With water injection, there is an additional benefit of absorbing the latent heat of vaporization from the flame zone. Water or steam is typically injected at a water-to-fuel weight ratio of less than one.

Depending on the initial NO_X levels, such rates of injection may reduce NO_X by 60 percent or higher. Water or steam injection is usually accompanied by an efficiency penalty (typically 2 to 3 percent) but an increase in power output (typically 5 to 6 percent). The increased power output results from the increased mass flow required to maintain turbine inlet temperature at manufacturer's specifications. Both CO and VOC emissions are increased by water injection, with the level of CO and VOC increases dependent on the amount of water injection.

Dry Controls – Since thermal NO_X is a function of both temperature (exponentially) and time (linearly), the basis of dry controls are to either lower the combustor temperature using lean mixtures of air and/or fuel staging, or decrease the residence time of the combustor. A combination of methods may be used to reduce NO_X emissions such as lean combustion and staged combustion (two stage lean/lean combustion or two stage rich/lean combustion).

Lean combustion involves increasing the air-to-fuel ratio of the mixture so that the peak and average temperatures within the combustor will be less than that of the stoichiometric mixture, thus suppressing thermal NO_X formation. Introducing excess air not only creates a leaner mixture but it also can reduce residence time at peak temperatures.

Two-stage lean/lean combustors are essentially fuel-staged, premixed combustors in which each stage burns lean. The two-stage lean/lean combustor allows the turbine to operate with an extremely lean mixture while ensuring a stable flame. A small stoichiometric pilot flame ignites the premixed gas

and provides flame stability. The NO_X emissions associated with the high temperature pilot flame are insignificant. Low NO_X emission levels are achieved by this combustor design through cooler flame temperatures associated with lean combustion and avoidance of localized "hot spots" by premixing the fuel and air.

Two stage rich/lean combustors are essentially air-staged, premixed combustors in which the primary zone is operated fuel rich and the secondary zone is operated fuel lean. The rich mixture produces lower temperatures (compared to stoichiometric) and higher concentrations of CO and H_2, because of incomplete combustion. The rich mixture also decreases the amount of oxygen available for NO_X generation. Before entering the secondary zone, the exhaust of the primary zone is quenched (to extinguish the flame) by large amounts of air and a lean mixture is created. The lean mixture is pre-ignited and the combustion completed in the secondary zone. NO_X formation in the second stage are minimized through combustion in a fuel lean, lower temperature environment. Staged combustion is identified through a variety of names, including Dry-Low NOx (DLN), Dry-Low Emissions (DLE), or SoLoNOx.

Catalytic Reduction Systems – Selective catalytic reduction (SCR) systems selectively reduce NO_X emissions by injecting ammonium (NH_3) into the exhaust gas stream upstream of a catalyst. Nitrogen oxides, NH_3, and O_2 react on the surface of the catalyst to form N_2 and H_2O. The exhaust gas must contain a minimum amount of O_2 and be within a particular temperature range (typically 230°C to 450°C) in order for the SCR system to operate properly.

The temperature range is dictated by the catalyst material which is typically made from noble metals, including base metal oxides such as vanadium and titanium, or zeolite-based material. The removal efficiency of an SCR system in good working order is typically from 65 to 90 percent. Exhaust gas temperatures greater than the upper limit (450°C) cause NO_X and NH_3 to pass through the catalyst unreacted. Ammonia emissions, called NH_3 slip, may be a consideration when specifying an SCR system.

Ammonia, either in the form of liquid anhydrous ammonia, or aqueous ammonia hydroxide is stored on site and injected into the exhaust stream upstream of the catalyst. Although an SCR system can operate alone, it is typically used in conjunction with water-steam injection systems or lean-premix

system to reduce NO_X emissions to their lowest levels (less than 10 ppm at 15 percent oxygen for SCR and wet injection systems).

The catalyst and catalyst housing used in SCR systems tend to be very large and dense (in terms of surface area to volume ratio) because of the high exhaust flow rates and long residence times required for NO_X, O_2, and NH_3, to react on the catalyst. Most catalysts are configured in a parallel-plate, "honeycomb" design to maximize the surface area-to-volume ratio of the catalyst. Some SCR installations incorporate CO catalytic oxidation modules along with the NOX reduction catalyst for simultaneous CO/NOX control.

Carbon monoxide oxidation catalysts are typically used on turbines to achieve control of CO emissions, especially turbines that use steam injection, which can increase the concentrations of CO and unburned hydrocarbons in the exhaust. CO catalysts are also being used to reduce VOC and organic HAPs emissions. The catalyst is usually made of a precious metal such as platinum, palladium, or rhodium. Other formulations, such as metal oxides for emission streams containing chlorinated compounds, are also used. The CO catalyst promotes the oxidation of CO and hydrocarbon compounds to carbon dioxide (CO_2) and water (H_2O) as the emission stream passes through the catalyst bed. The oxidation process takes place spontaneously, without the requirement for introducing reactants. The performance of these oxidation catalyst systems on combustion turbines results in 90-plus percent control of CO and about 85 to 90 percent control of formaldehyde. Similar emission reductions are expected on other HAP pollutants.

Other Catalytic Systems – New catalytic reduction technologies have been developed and are currently being commercially demonstrated for gas turbines. Such technologies include, but are not limited to, the SCONOX and the XONON systems, both of which are designed to reduce NO_X and CO emissions. The SCONOX system is applicable to natural gas fired gas turbines. It is based on a unique integration of catalytic oxidation and absorption technology. CO and NO are catalytically oxidized to CO_2 and NO_2. The NO_2 molecules are subsequently absorbed on the treated surface of the SCONOX catalyst. The system manufacturer guarantees CO emissions of 1 ppm and NO_X emissions of 2 ppm. The SCONOX system does not require the use of ammonia, eliminating the potential of ammonia slip conditions evident in existing SCR systems. Only limited emissions data were available for a gas turbine equipped with a SCONOX system. This data reflected HAP emissions and was not sufficient to verify the manufacturer's claims.

The XONON system is applicable to diffusion and lean-premix combustors and is currently being demonstrated with the assistance of leading gas turbine manufacturers. The system utilizes a flameless combustion system where fuel and air reacts on a catalyst surface, preventing the formation of NO_X while achieving low CO and unburned hydrocarbon emission levels. The overall combustion process consists of the partial combustion of the fuel in the catalyst module followed by completion of the combustion downstream of the catalyst. The partial combustion within the catalyst produces no NO_X, and the combustion downstream of the catalyst occurs in a flameless homogeneous reaction that produces almost no NO_X. The system is totally contained within the combustor of the gas turbine and is not a process for clean-up of the turbine exhaust. Note that this technology has not been fully demonstrated as of the drafting of this section. The catalyst manufacturer claims that gas turbines equipped with the XONON Catalyst emit NO_X levels below 3 ppm and CO and unburned hydrocarbons levels below 10 ppm.

3.2.2 Cooling Towers

Because wet cooling towers provide direct contact between the cooling water and the air passing through the tower, some of the liquid water may be entrained in the air stream and be carried out of the tower as "drift" droplets. Therefore, the particulate matter constituent of the drift droplets may be classified as an emission.

The magnitude of drift loss is influenced by the number and size of droplets produced within the cooling tower, which in turn are determined by the fill design, the air and water patterns, and other interrelated factors. Tower maintenance and operation levels also can influence the formation of drift droplets. For example, excessive water flow, excessive airflow, and water bypassing the tower drift eliminators can promote and/or increase drift emissions.

Because the drift droplets generally contain the same chemical impurities as the water circulating through the tower, these impurities can be converted to airborne emissions. Large drift droplets settle out of the tower exhaust air stream and deposit near the tower. This process can lead to wetting, icing, salt deposition, and related problems such as damage to equipment or to vegetation. Other drift droplets may evaporate before being deposited in the area surrounding the tower, and they also can produce PM_{10} emissions. PM_{10} is generated when the drift droplets evaporate and leave fine

particulate matter formed by crystallization of dissolved solids. Dissolved solids found in cooling tower drift can consist of mineral matter, chemicals for corrosion inhibition, etc.

To reduce the drift from cooling towers, drift eliminators are usually incorporated into the tower design to remove as many droplets as practical from the air stream before exiting the tower. The drift eliminators used in cooling towers rely on inertial separation caused by direction changes while passing through the eliminators. Types of drift eliminator configurations include herringbone (blade-type), wave form, and cellular (or honeycomb) designs. The cellular units generally are the most efficient. Drift eliminators may include various materials, such as ceramics, fibre reinforced cement, fiberglass, metal, plastic, and wood installed or formed into closely spaced slats, sheets, honeycomb assemblies, or tiles. The materials may include other features, such as corrugations and water removal channels, to enhance the drift removal further.

3.2.3 Diesel Fuel Handling and Storage

Loading losses

Loading losses are the primary source of evaporative emissions from road transport tankers. Loading losses occur as organic vapours in "empty" cargo tanks are displaced to the atmosphere by the liquid being loaded into the tanks. These vapours are a composite of (1) vapours formed in the empty tank by evaporation of residual product from previous loads, (2) vapours transferred to the tank in vapour balance systems as product is being unloaded, and (3) vapours generated in the tank as the new product is being loaded. The quantity of evaporative losses from loading operations is, therefore, a function of the following parameters:

- Physical and chemical characteristics of the previous cargo;
- Method of unloading the previous cargo;
- Operations to transport the empty carrier to a loading terminal;
- Method of loading the new cargo; and
- Physical and chemical characteristics of the new cargo.

The principal methods of cargo carrier loading are illustrated in **Figure 2**.

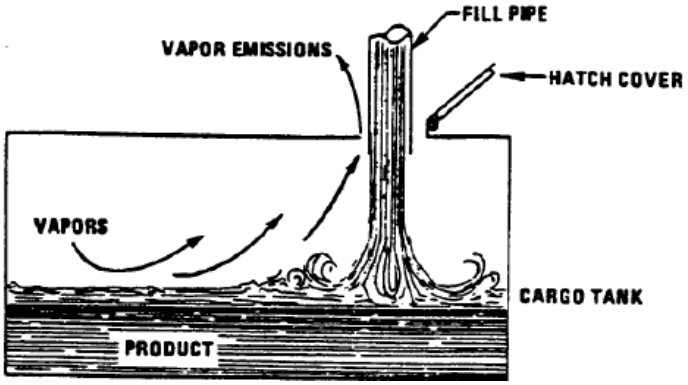


Figure 2a: Splash loading method

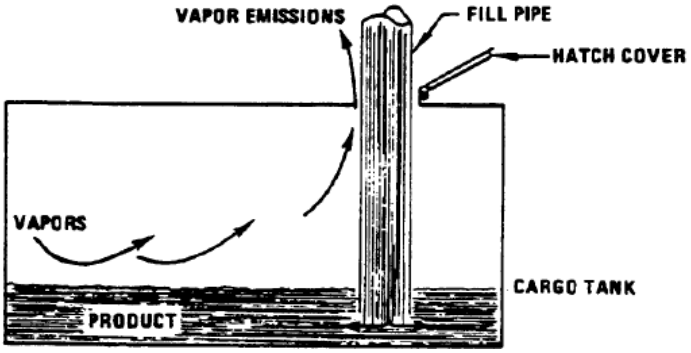


Figure 2b: Submerged fill pipe loading method

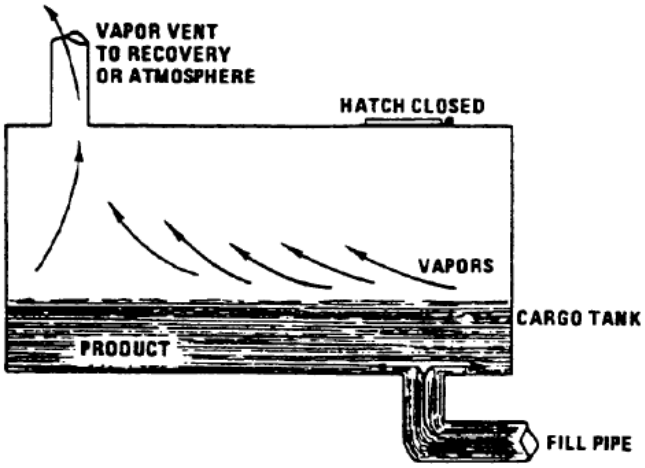


Figure 2c: Bottom loading method

In the splash loading method, the fill pipe dispensing the cargo is lowered only part way into the cargo tank. Significant turbulence and vapour/liquid contact occur during the splash loading operation, resulting in high levels of vapour generation and loss. If the turbulence is great enough, liquid droplets will be entrained in the vented vapours.

A second method of loading is submerged loading. Two types are the submerged fill pipe method and the bottom loading method. In the submerged fill pipe method, the fill pipe extends almost to the bottom of the cargo tank. In the bottom loading method, a permanent fill pipe is attached to the cargo tank bottom.

During most of submerged loading by both methods, the fill pipe opening is below the liquid surface level. Liquid turbulence is controlled significantly during submerged loading, resulting in much lower vapour generation than encountered during splash loading.

The recent loading history of a cargo carrier is just as important a factor in loading losses as the method of loading. If the carrier has carried a non-volatile liquid such as fuel oil, or has just been cleaned, it will contain vapour-free air. If it has just carried petrol and has not been vented, the air in the carrier tank will contain volatile organic vapours, which will be expelled during the loading operation along with newly generated vapours.

Cargo carriers are sometimes designated to transport only one product, and in such cases are practicing "dedicated service". Dedicated petrol cargo tanks return to a loading terminal containing air fully or partially saturated with vapour from the previous load. Cargo tanks may also be "switch loaded" with various products, so that a non-volatile product being loaded may expel the vapours remaining from a previous load of a volatile product such as petrol. These circumstances vary with the type of cargo tank and with the ownership of the carrier, the petroleum liquids being transported, geographic location, and season of the year.

Plant losses

Fugitive emission sources include valves of all types, flanges, pump and compressor seals, process drains, cooling towers, and oil/water separators. Fugitive emissions are attributable to the evaporation of leaked or spilled petroleum liquids. Normally, control of fugitive emissions involves minimizing leaks and spills through equipment changes, procedure changes, and improved monitoring, housekeeping, and maintenance practices.

The size of valves, flanges, pump seals, compressor seals, relief valves, and process drains does not affect their leak rates. The emission factors are independent of process unit or refinery throughput. Valves, because of their number and relatively high emission factor, are the major plant emission source.

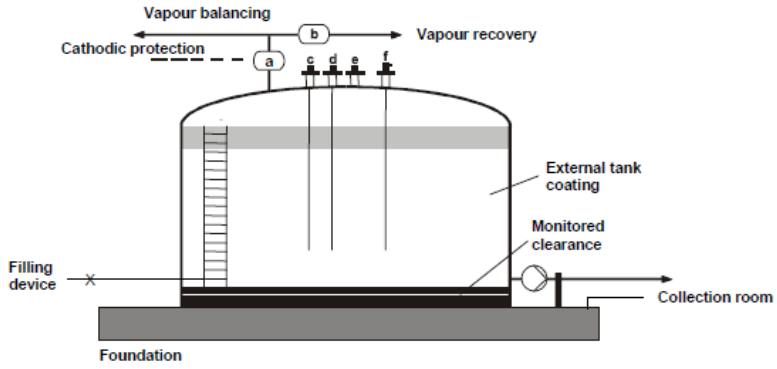
Storage losses

Emissions from storage represent more than 40% of the total emissions and are normally the biggest emitter at a fuel depot. Emissions from hydrocarbon liquids in storage occur because of evaporative loss of the liquid during storage and as a result of changes in the liquid level. Moreover, fugitive emissions in storage systems are mainly from imperfect seals or from tank fittings. However, it is generally the case that the amount of emissions depends much more on the vapour pressure of the product than on the type of tank.

Vertical fixed roof tanks are the storage tanks of choice at the Vortum Thermal Power Plant.

A typical vertical fixed roof tank is shown in **Figure 3**. This type of tank consists of a cylindrical steel shell with a permanently affixed roof, which may vary in design from cone- or dome shaped to flat. Losses from fixed roof tanks are caused by changes in temperature, pressure, and liquid level.

Fixed roof tanks are either freely vented or equipped with a pressure/vacuum vent. The latter allows the tanks to operate at a slight internal pressure or vacuum to prevent the release of vapours during very small changes in temperature, pressure, or liquid level. Of current tank designs, the fixed roof tank is the least expensive to construct and is generally considered the minimum acceptable equipment for storing organic liquids.



Key:
a=Flame arrester
b= Pressure/vacuum valve
c= Level measurement
d= Temperature monitoring (optional)
e= Pressure monitoring (optional)
f= Overfill protection

Figure 3: Vertical fixed roof tank with some emission control equipment installed

3.2.4 Emissions from paved surfaces

Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking area. Particulate emissions from paved roads are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions and resuspension of loose material on the road surface. In general terms, resuspended particulate emissions from paved roads originate from, and result in the depletion of, the loose material present on the surface (i.e., the surface loading). In turn, that surface loading is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and track-out from unpaved roads and staging areas.

In the absence of continuous addition of fresh material, paved road surface loading should reach an equilibrium value in which the amount of material re-suspended matches the amount replenished. The equilibrium surface loading value depends upon numerous factors. The most important factors are; mean speed of vehicles traveling on site; the average daily traffic volume, the fraction of heavy vehicles and the presence/absence of curbs, storm sewers and marshalling areas.

Emission rates

Due to the absence of locally generated emission factors, use was made of the comprehensive set of emission factors published by the United States Environmental Protection Agency (US-EPA) in its AP-42 document *Compilation of Pollution Emission Factors*, the reference document *Best Available*

Techniques Reference Document for Large Combustion Plants published by the European Integrated Pollution Prevention and Control Bureau.

Reference is also made to fugitive emission rates obtained from ambient air quality monitoring and stack emission monitoring data conducted by EHRCON on similar and other processes over the past ten years. **Table 3** below summarizes emission rates for the Vortum Thermal Power Plant.

Table 3a:

Vortum Thermal Power Plant – Gas Turbine Emission Factors and Emission Rates

Pollutant	Natural Gas [a]		Diesel [b]	
	Emission Factor (kg/MMBtu)	Emission Rate (g/s)	Emission Factor (kg/MMBtu)	Emission Rate (g/s)
PM_{10}	2.989E-3	5.666	5.436E-3	10.846
Nitrogen oxides	0.144	272.971	0.398	794.124
Sulphur dioxide	1.540E-3	2.919	0.228	454.925
Carbon monoxide	0.037	70.138	1.494E-3	2.980
Carbon dioxide	49.830	94 459.454	71.121	141 906.78
Volatile organic compounds	9.513E-4	1.803	1.857E-4	0.370
Methane	3.895E-3	7.383	n.d.	n.d.
Nitrous oxide	1.359E-3	2.576	n.d.	n.d.
Polycyclic aromatic hydrocarbons	9.966E-7	0.002	1.812E-5	0.036
Formaldehyde	3.216E-4	0.609	1.268E-4	0.253
Benzene	5.436E-6	0.010	2.491E-5	0.049
Toluene	5.889E-5	0.112	n.d.	n.d.
Ethylbenzene	1.449E-5	0.027	n.d.	n.d.
Xylenes	2.899E-5	0.055	n.d.	n.d.
Arsenic, Beryllium, Cadmium, Chromium, Lead, Manganese, Mercury, Nickel and Selenium	n.d.	n.d.	3.904E-4	0.778

Notes:

kg/MMBtu : Kilogram per Million British Thermal Units
g/s : Gram per second
n.d. : No data
a : *Emission Factor Documentation of AP-42 Section 3.1,*

Stationary Combustion Turbines, EPA, April 2000.
Uncontrolled emission rate based on an annual energy consumption of 57 600 TJ or 54 594 266 MMBtu

b : *Emission Factor Documentation of AP-42 Section 3.1, Stationary Combustion Turbines*, EPA, April 2000.
Uncontrolled emission rate based on an annual energy consumption of 30 314 TJ or 28 732 128 MMBtu

Table 3b:

Vortum Thermal Power Plant – Wet Cooling Tower Emission Factor and Emission Rate

Activity	Emission factor kg/litre		Emission rate (g/s)	
	Total Liquid Drift	PM_{10}	Total Liquid Drift	PM_{10}
Induced draft wet cooling tower [a]	2.034E-5	2.273E-7	5.424	0.061

Notes:

kg/Litre : Kilogram per litre
g/s : Gram per second
a : *Emission Factor Documentation of AP-42 Section 13.4, Wet Cooling Towers*, EPA, April 2000.
Uncontrolled emission rate based on a water consumption rate of 16 000 litres per minute.

Table 3c:

Vortum Thermal Power Plant – Diesel road transport delivery emission factors and rates

Activity	TVOCs emission factor (g/L) [a]	TVOCs emission rate (g/s) [b]
Submerged loading of vertical fixed roof storage tanks	1.17E-3	$6.302E^{-5}$

Notes:

a : *Emission Factor Documentation of AP-42 Section 5.2, Transportation and Marketing of Petroleum Products*, EPA, April 2000.
Gram total volatile organic compounds (TVOCs) emitted per litre (L) diesel transferred.

b : Gram total volatile organic compounds (TVOCs) emitted per second.
Uncontrolled emission rate based on a diesel delivery rate of 78 road tank trucks per day or 2 327 m^3 per day.

Table 3d:

Vortum Thermal Power Plant – Diesel handling fugitive emission factors and rates

Source	TVOCs emissions [a]	
	Emission factor (kg/m^3) [a]	Emission rate (g/s) [b]
1. Valves	0.030	7.912E-4
2. Flanges	$2.86E^{-3}$	7.679E-5
3. Pump seals	0.006	1.513E-4
4. Compressor seals	$4.76E^{-3}$	2.052E-4
5. Relief valves	$1.91E^{-3}$	5.119E-5
6. Drains/separator	$4.28E^{-3}$	1.154E-4
7. All sources	0.049	1.396E-3

Notes:

a : *Emission Factor Documentation of AP-42 Section 5.2, Transportation and Marketing of Petroleum Products*, EPA, April 2000. Gram total volatile organic compounds (TVOCs) emitted per litre (L) diesel transferred.

b : Gram total volatile organic compounds (TVOCs) emitted per second. Uncontrolled emission rate based on a facility throughput of 2 327 m^3 per day.

Table 3e:

Vortum Thermal Power Plant – Diesel storage fugitive emission factors and rates

Source	TVOCs emission rate (g/s) [a]
Six 5 888m^3 vertical LCO storage tanks	0.037

Notes:

a : *Emission Factor Documentation of AP-42 Section 7.1, Organic Liquid Storage Tanks*, EPA, April 2000. Gram total volatile organic compounds (TVOCs) emitted per second. Emission rate calculation for working and standing losses.

Table 3f:

Vortum Thermal Power Plant – Diesel handling emission summary

Pollutant	Emission rate (g/s) [a]
1. Total volatile organic compounds	0.033
2. Benzene	$5.17E^{-6}$
3. Toluene	$3.38E^{-5}$
4. Ethylbenzene	$2.34E^{-5}$
5. Xylenes (*o*-, *m*- and *p*-isomers)	$1.43E^{-4}$
6. Total BTEX	$2.12E^{-4}$

Notes:

a : *Emission Factor Documentation of AP-42 Section 7.1, Organic Liquid Storage Tanks*, EPA, April 2000.
Gram emission per second.

Table 3g:

Vortum Thermal Power Plant – Vehicle entrained particulate emission factors and emission rates

Activity	Emission factor		Emission rate (g/s)	
	TSP	PM_{10}	TSP	PM_{10}
Vehicle movement [a]	3.402 kg/VKT	1.800 kg/VKT	3.934	1.946

Notes:

kg/Mg : Kilogram per mega gram
kg/VKT : Kilogram per vehicle kilometre travelled
g/s : Gram per second
a : US EPA, AP42, Volume I, 5 Edition, Chapter 13.2.1
Calculated for a road surface silt loading of 9.7 g/m^2,
a mean vehicle weight of 21 tons and 1 000 kilometres travelled on site per day.

3.3. METEOROLOGY

Once pollutants are emitted into the atmosphere they move away from the source and disperse. The ability of the atmosphere to disperse pollutants varies both geographically and temporally. Conditions that promote dispersion result in lower concentrations of pollution whereas those that inhibit dispersion cause pollutants to accumulate near the source, increasing pollution concentrations. Therefore knowledge of how the atmosphere behaves assists in understanding the movement of pollutants and hence in determining concentrations at particular locations. Vertical and horizontal movement of pollutants is governed by atmospheric stability and wind characteristics respectively; while chemical transformation of pollutants is dependent on solar radiation and moisture; and the removal of pollutants from the atmosphere results from precipitation. Thus air pollution meteorology forms the basis of understanding air dispersion. This section provides an overview of the macro scale and meso scale atmospheric circulations influencing airflow and the subsequent dispersion and dilution of pollutants in the study area.

Macro Scale Circulations

Vertical dispersion is governed by atmospheric stability. An unstable atmosphere is conducive to vertical movement which results in lower pollution concentrations as it is dispersed over a larger volume of air, whereas a stable atmosphere inhibits this movement and causes higher ground level concentrations. In the case of a neutral atmosphere pollution will remain at the height it is released. Unstable conditions are created when a parcel of air is warmer than the surrounding air it is released into. The parcel is less dense and therefore will rise until it reaches the same temperature and density of the surrounding air. In stable conditions the parcel is cooler and denser and therefore will sink. The vertical temperature structure of the ambient air determines whether the atmosphere is stable or not. Generally, inversion (increasing temperature with height) or isothermal (constant temperature with height) are representative of stable atmospheric conditions while lapse conditions (decreasing temperature with height) is unstable (**Figure 4**). Temperature inversions are often cited as the cause or poor air quality; however it is also possible to have a stable atmosphere even under lapse conditions since stability is ultimately determined by the difference in temperature of the parcel of air and that of the ambient air at the same height.

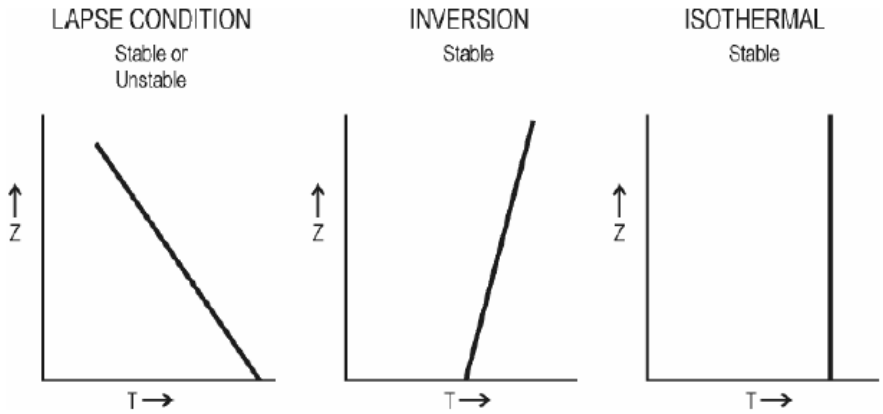


Figure 4: Variations of the environmental lapse rate (DEA, 2009).

The temperature structure of the atmosphere is directly linked to the diurnal heating cycle. During the day, solar heating of the earth's surface results in lapse conditions whereas inversions are caused by surface cooling as a result of infrared radiative transfer at night. Surface inversions are also common in valleys where cold air collects. As the surface is heated after sunrise the temperature of the lowest atmospheric layer increases causing the inversion that formed the night before to dissipate. With continued heating the inversion dissipates completely and a lapse profile forms. Around sunset, a surface inversion starts to form due to surface cooling and deepens throughout the night (**Figure 5**). This cycle is repeated daily and favours clear skies and calm conditions and will best develop over mid-summer and mid-winter.

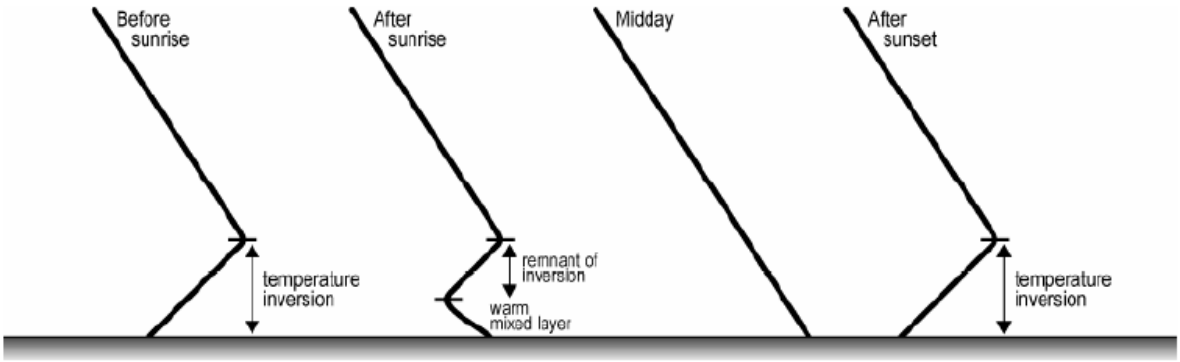


Figure 5: Change in the environmental lapse rate as a function of diurnal temperature differences (DEA, 2009).

Horizontal air movement is a function of wind speed and direction. Higher wind speeds have greater pollution dispersion potential while direction governs the impact area since it determines where the pollution is being dispersed. Wind is generated as a result of a pressure gradient in the atmosphere. Wind is produced on a range of scales (i.e. global/large scale or local/small scale). Smaller scale systems are embedded within larger ones and the effects differ depending on the interactions between them. On a global scale a series of wind belts and semi-permanent high and low pressure belts govern climates around the planet. In terms of pollution they produce areas that either favour or inhibit dispersion. Southern Africa is dominated by three semi-permanent subtropical high pressure cells which together with the influence of easterlies in the north and westerlies in the south control the overall climate of South Africa.

The anticyclone belt centred over the subcontinent is characterised by light winds that are not conducive to wind dispersion. High pressure systems are also accompanied by stable atmospheric conditions due to subsiding air which is intensified during winter months, resulting in less dispersion potential and increased pollution concentrations. Over the interior plateau, three stable layers occur at 700 hPa, 500 hPa and 300 hPa, with another layer at 800 hPa between the escarpment and the coast. On days when these stable layers occur, dense haze layers are evident. These stable layers encourage the formation of surface inversions due to nocturnal cooling, preventing the vertical dispersion of pollutants in the atmosphere reducing early morning visibility. Day time heating causes the stable boundary layer to erode allowing pollutants to disperse.

Travelling high and low pressure systems have associated weather characteristics which impact daily weather patterns. For example low pressure systems are characterised by strong winds and instability whereas high pressures systems are associated with light winds and stable conditions. The passage of these systems across South Africa is governed by the westerly wind belt situated to the south of the landmass, bringing frequent changes in stability and wind conditions, particularly for coastal regions. Cold fronts resulting from such circulations are frequent during winter months. Cold fronts are preceded by warm, clear and stable conditions as a result of subsistence while behind the front low-level convergence causes cool conditions and rain. Along with changes in wind direction, cold fronts are responsible for most winter rainfall in the Western Cape which assists in cleansing the atmosphere of accumulated pollutants.

Meso Scale Circulations

At a more localised level, circulations resulting from pressure gradients driven by temperature differences associated with uneven surface heating and topography also play a significant role in the dispersion and transportation of pollutants. Examples of these circulations are land and sea breezes along coastal regions while topographically induced winds result from complex terrain.

Differences in thermal properties between water and land surfaces produce land and sea breezes. During the day, land heats faster than a water mass, while at night water retains heat better than a land mass. The diurnal temperature differences of the two surfaces results in a pressure gradient driving localised air circulation which changes direction with the time of day (**Figure 6**). Sea breezes blow from the sea onto land and cause turbulence and atmospheric instability favouring the vertical dispersion of pollutants. Land breezes occur at night, blow from land to sea and are characterised by stable conditions with light winds which can transport pollution over long distances as a narrow plume. Land and sea breezes develop better during winter when nocturnal cooling is greater.

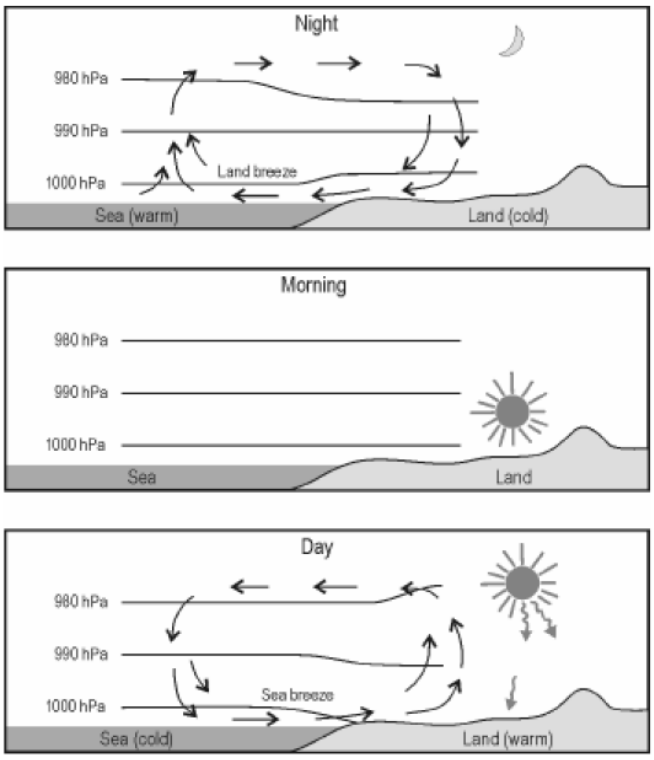


Figure 6: Diagrammatic sketch of land and sea circulations (DEA, 2009).

Topography plays an important role in air flow. Hills and valleys cause air to move in a number of ways but mostly inducing changes in direction, speed and turbulence. Other topographically induced wind circulations include *slope winds*, *valley winds* and regional *mountain-plain winds*. Slope winds flow up and down the sides of a valley as a result of differential heating and cooling between the valley floor and the valley sides. By day these wind flow upslope (anabatic winds) while at night the circulation is reversed and winds flow downslope (katabatic winds). Valley winds travel up and down the longitudinal section of a valley, flowing up the valley by day (valley winds) and down the valley by night (mountain winds). **Figure 7** illustrates this. The formation of frost hollows and the accumulation of fog and pollutants are associated with katabatic and mountain winds.

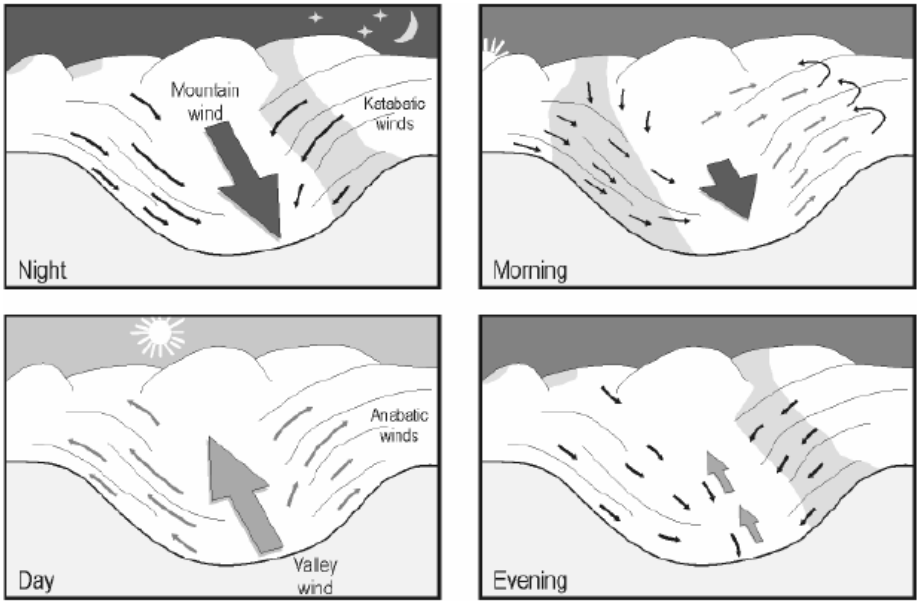


Figure 7: Diagrammatic sketch of slope and valley circulations (DEA, 2009).

In areas of fragmented topography especially where valleys lie adjacent to each other, valley/mountain winds may spill over to the surrounding terrain resulting a widespread sheet of air which travels across an entire region. These winds are known as plain-mountain winds during the day and mountain-plain winds at night.

There are no significant topographical features associated with the Vortum Thermal Power Plant project.

Wind Field

Period, day-time, evening, night-time, and seasonal wind roses for the process location for the period 1 January 2010 to 31 December 2015 are reflected in **Figure 8**. Wind roses comprise 16 spokes, which represents the directions from which winds blew during the period. The colours used in the wind roses reflect the different categories of wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The value given in the centre of the circle describe the frequency with which calms occurred, i.e. periods during which the wind speed was below 1m/s.

Dispersion comprises vertical and horizontal components of motion. The wind field largely determines the horizontal dispersion of pollution in the atmospheric boundary layer. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume stretching. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction and the variability in wind direction, determine the general path pollutants will follow, and the extend of cross-wind spreading.

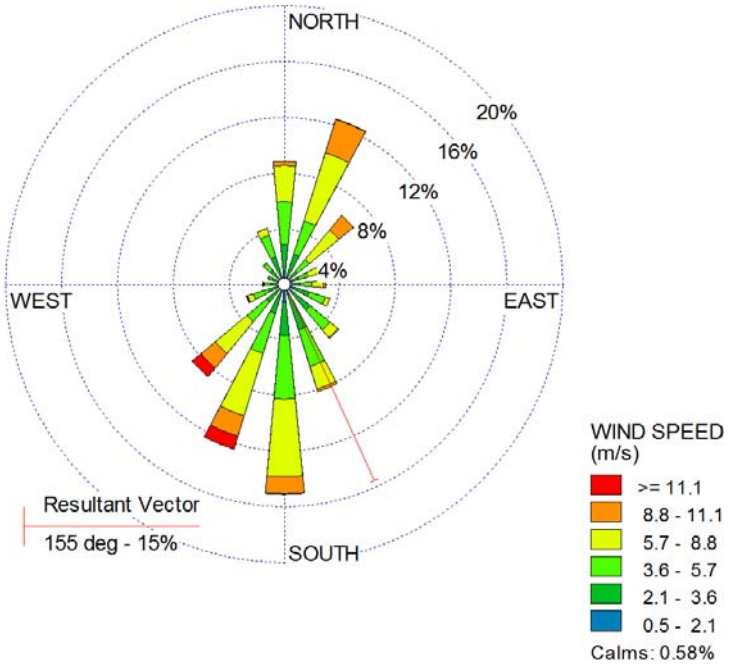


Figure 8a: Period wind rose – Vortum Thermal Power Plant

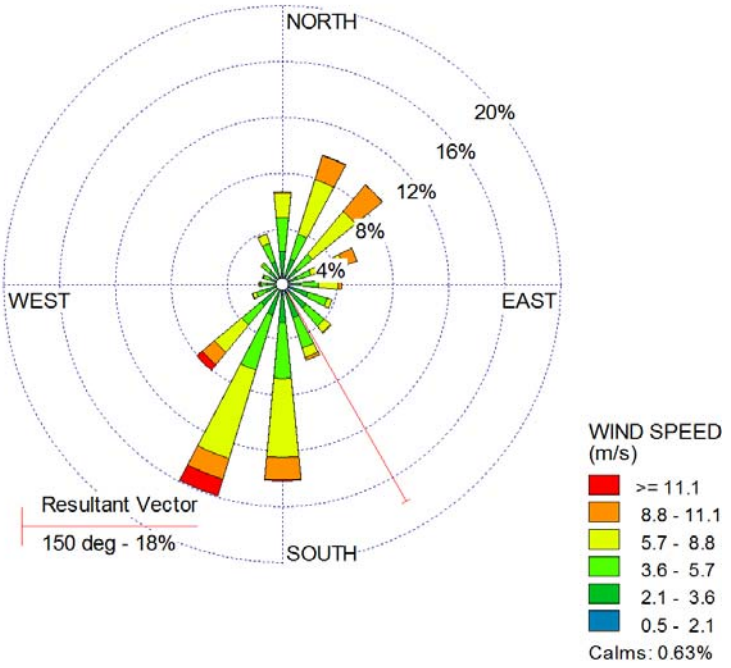


Figure 8b: Day-time wind rose – Vortum Thermal Power Plant

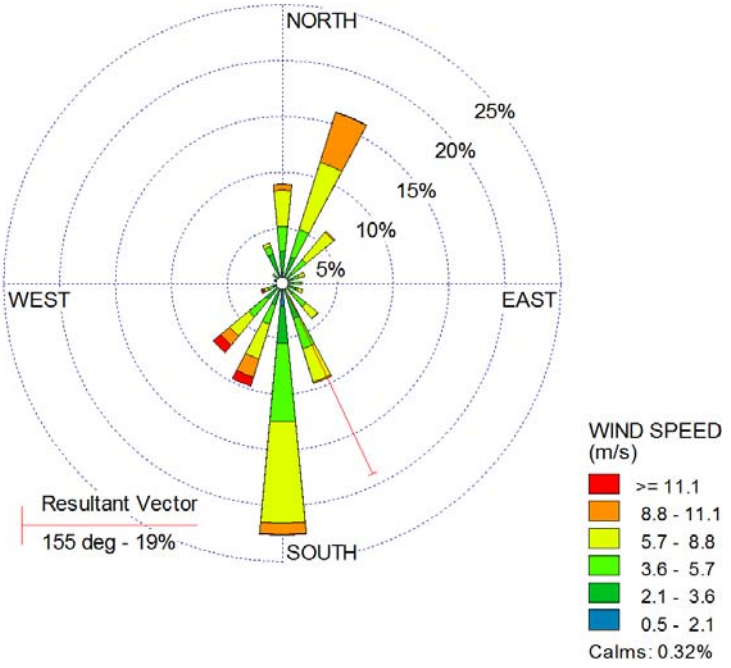


Figure 8c: Evening wind rose – Vortum Thermal Power Plant

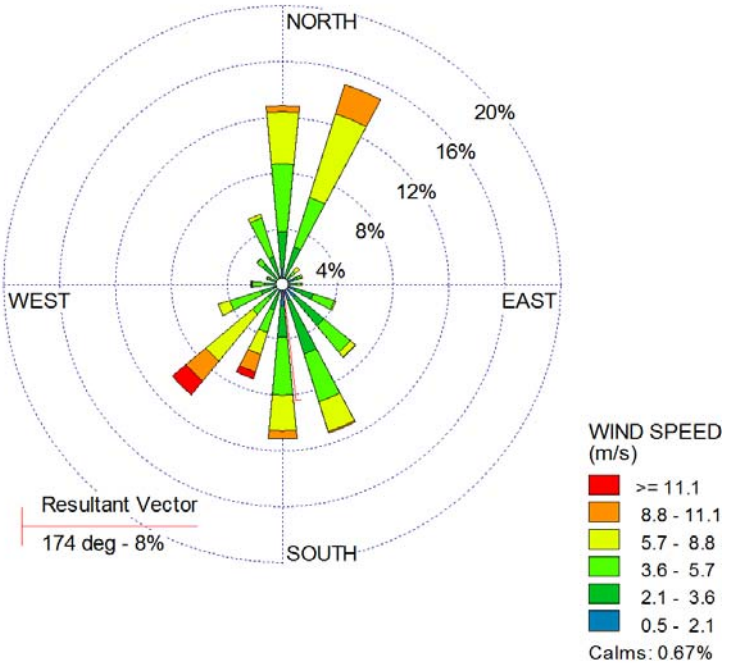


Figure 8d: Night-time wind rose – Vortum Thermal Power Plant

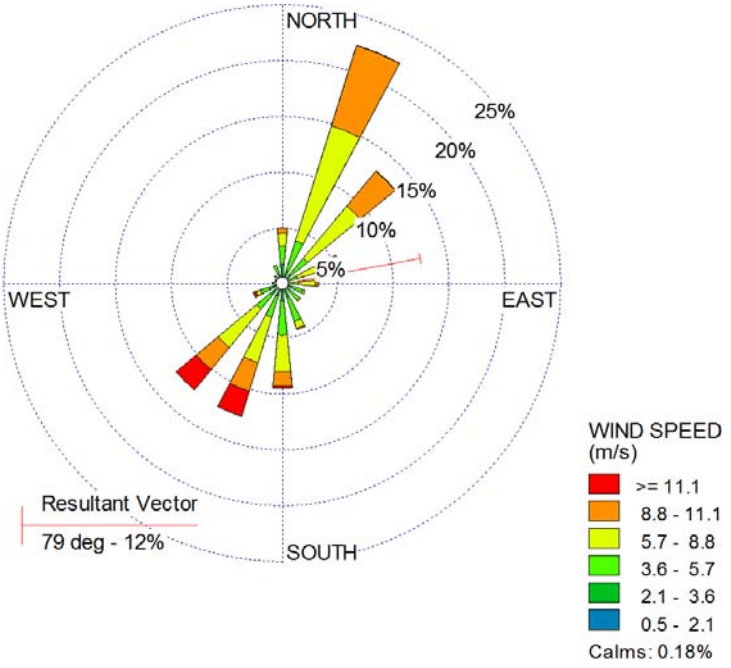


Figure 8e: Spring wind rose – Vortum Thermal Power Plant

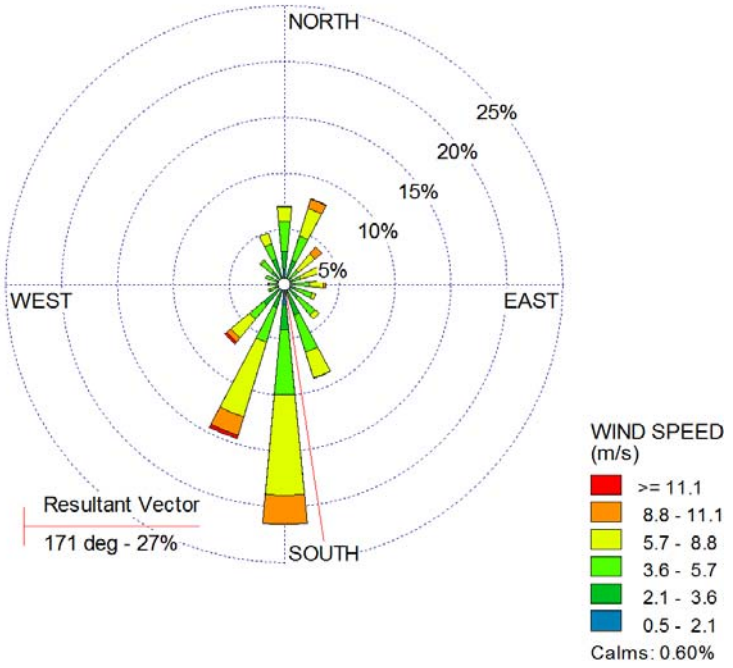


Figure 8f: Summer wind rose – Vortum Thermal Power Plant

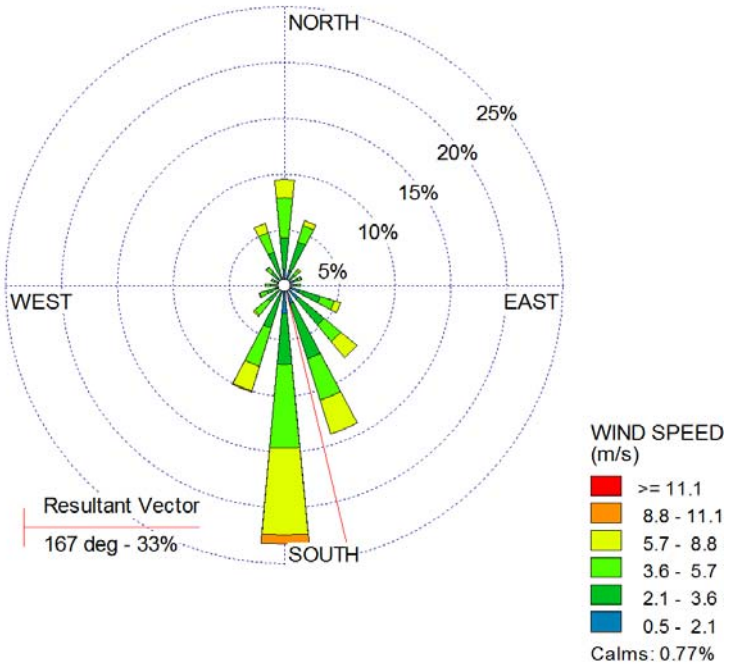


Figure 8g: Autumn wind rose – Vortum Thermal Power Plant

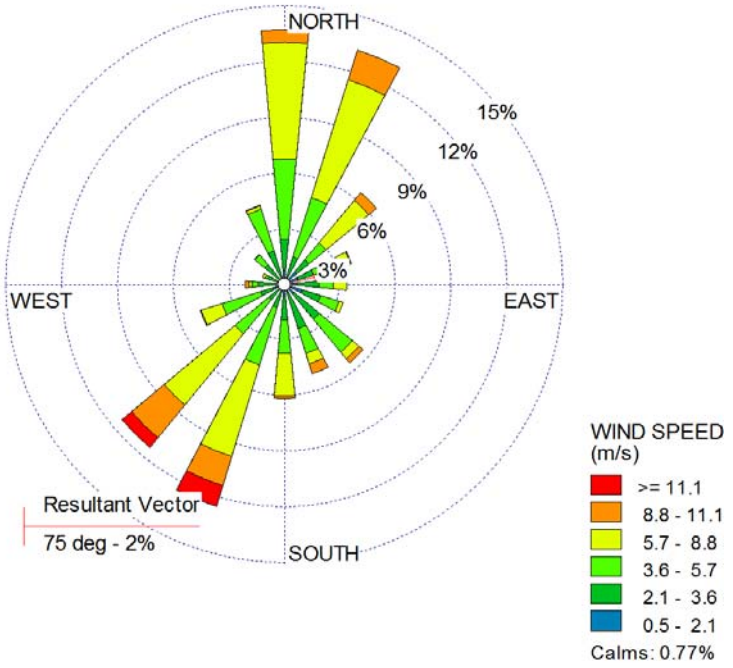


Figure 8h: Winter wind rose – Vortum Thermal Power Plant

Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of mixing and inversion layers.

Long-term average maximum, minimum and mean temperatures for Malmesbury are given in **Figure 9**. Average maximum temperatures range from 31 °C in February to 12 °C in July with average minimums ranging from 14.9 °C in February to 5.8 °C in July.

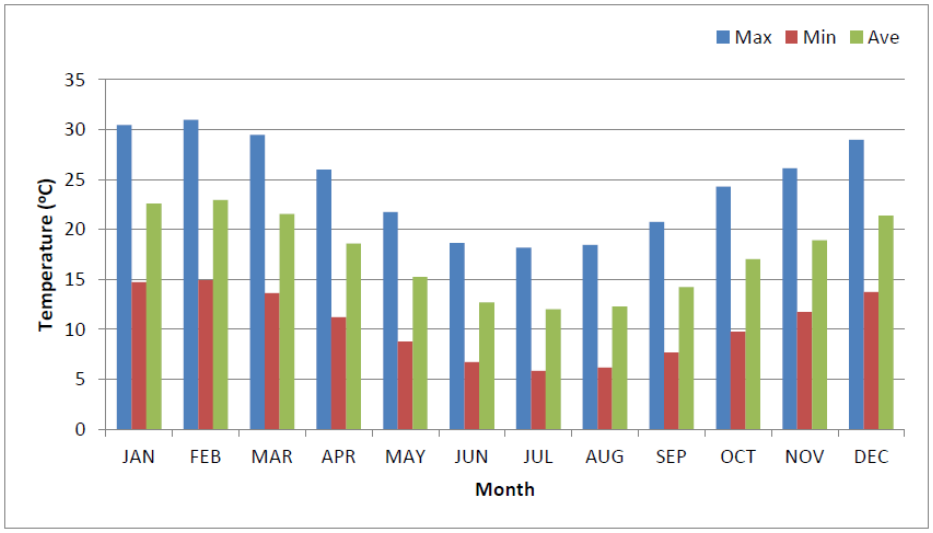


Figure 9: Long term temperature (°C) for Malmesbury for the period 1990 – 2009.

Precipitation

The West Coast District experiences a marked seasonality of precipitation with cool, wet winters and warm, dry summers, characteristic of a Mediterranean climate. Winter precipitation is mainly from a westerly direction due to cold fronts crossing the South Atlantic and Southern Oceans. Monthly rainfall averages for Malmesbury (**Figure 10**) measured over a period of 44 years, varied between 78 mm in June and 9.9 mm in January.

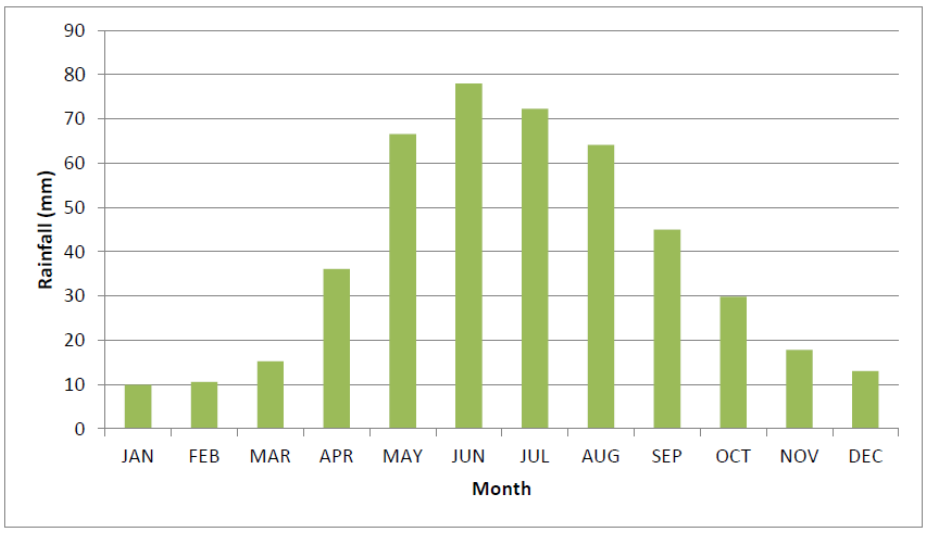


Figure 10: Average monthly rainfall (mm) for Malmesbury for the period 1966 – 2010.

4. AIR QUALITY IMPACT ASSESSMENT

4.1. EXISTING AIR QUALITY

The outdoor sources of air pollution resulting from human activities comprise three broad categories.

Stationary sources, which can be subdivided into; rural area sources, e.g. agriculture, mining and quarrying and industrial point and area sources, e.g. manufacturing of chemicals, non-metallic mineral products, basic metal industries and power generation.

Community sources, e.g. heating of homes and buildings, municipal waste and sewage sludge incinerators, fireplaces, cooking facilities, laundry services and cleaning plants.

Mobile sources, such as combustion-engine vehicles, e.g. light duty petrol-powered cars, light and heavy-duty diesel-powered vehicles, motorcycles, aircraft and line sources such as fugitive emissions from vehicle traffic.

Air pollutants are traditionally classified into suspended particulate matter (dusts, fumes, mists and smokes), gaseous pollutants (gases and vapours) and odours.

Particulate matter suspended in air includes total suspended particles (TSP), PM_{10} (SPM with an aerodynamic diameter of less than 10µm), $PM_{2.5}$ (SPM with an aerodynamic diameter of less than 2.5µm), fine and ultra-fine particles, diesel exhaust, coal fly-ash, mineral dusts (e.g. coal, asbestos, limestone and cement), metal dusts and fumes (e.g. zinc, copper, iron, lead), acid mists (e.g. sulphuric acid), fluoride particles, paint pigments, pesticide mists, carbon black, oil smoke and many others.

Gaseous pollutants include sulphur compounds (e.g. sulphur dioxide and sulphur trioxide), carbon monoxide, nitrogen compounds (e.g. nitric oxide, nitrogen oxide and ammonia), organic compounds (e.g. hydrocarbons, volatile organic compounds, polycyclic aromatic hydrocarbons and halogen derivatives, aldehydes etc.), halogen compounds (e.g. HF and HCL) and odorous substances.

Secondary pollutants may be formed from gaseous pollutants by thermal, chemical or photochemical reactions. For example, by thermal action sulphur dioxide can be oxidised to sulphur trioxide which, dissolved in water, gives rise to the formation of sulphuric acid mist. Photochemical reactions

between nitrogen oxides and reactive hydrocarbons can produce ozone, formaldehyde and peroxyacetyl nitrate; reactions between hydrochloric acid and formaldehyde can form bischloromethyl ether.

While some odours are known to be caused by specific chemical agents such as hydrogen sulphide, carbon disulphide and mercaptans, others are difficult to define chemically.

Ambient Air Quality Monitoring Information for the WCDM

Continuous ambient air quality monitoring campaigns in the WCDM are mostly run by industry. The Western Cape Provincial Government also operates an ambient network of four mobile stations where NO_2, SO_2, O_3, PM_{10}, CO and CO_2 levels are measured. One station was situated at Vredenburg and has recently been relocated to Malmesbury. The other three are located outside the West Coast District. A map indicating the locations of the air quality monitoring stations is included below.

Figure 11: Air Quality Monitoring Stations in the WCDM

Below are graphs of available data for Vredenburg and Saldanha Bay. These areas also have the most industrial operations. Although the data only portray sections of the overall air quality monitoring data, no exceedances are visible. This shows that the air quality in the most industrialised areas within the WCDM is still well within the national standards.

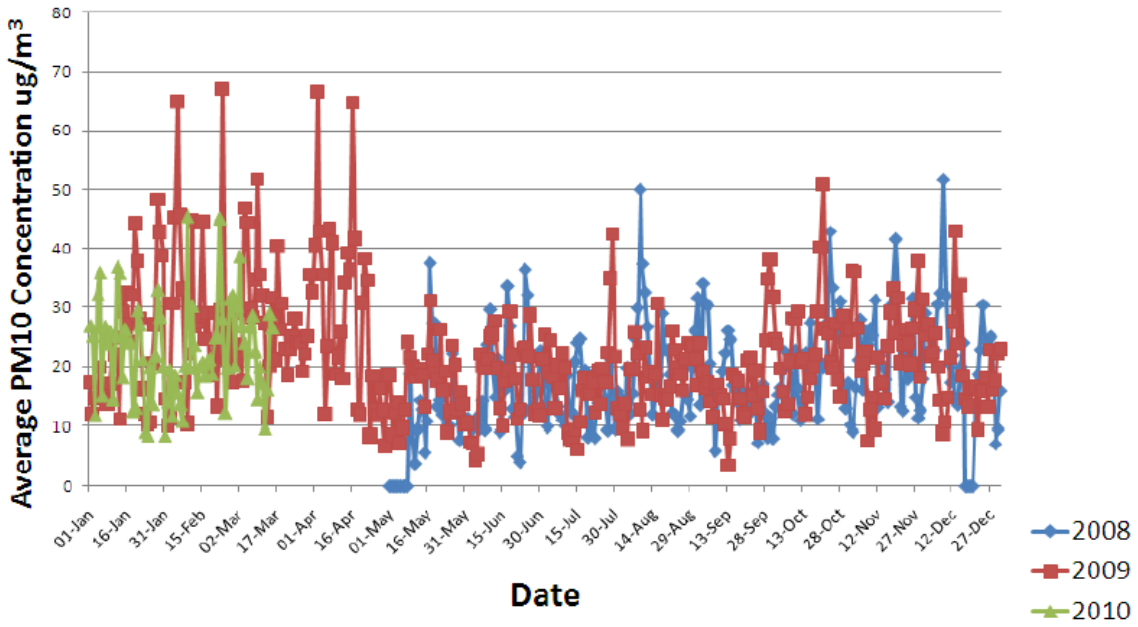


Figure 12: Daily average PM_{10} Concentration for the Vredenburg Monitoring Station 2008-2010

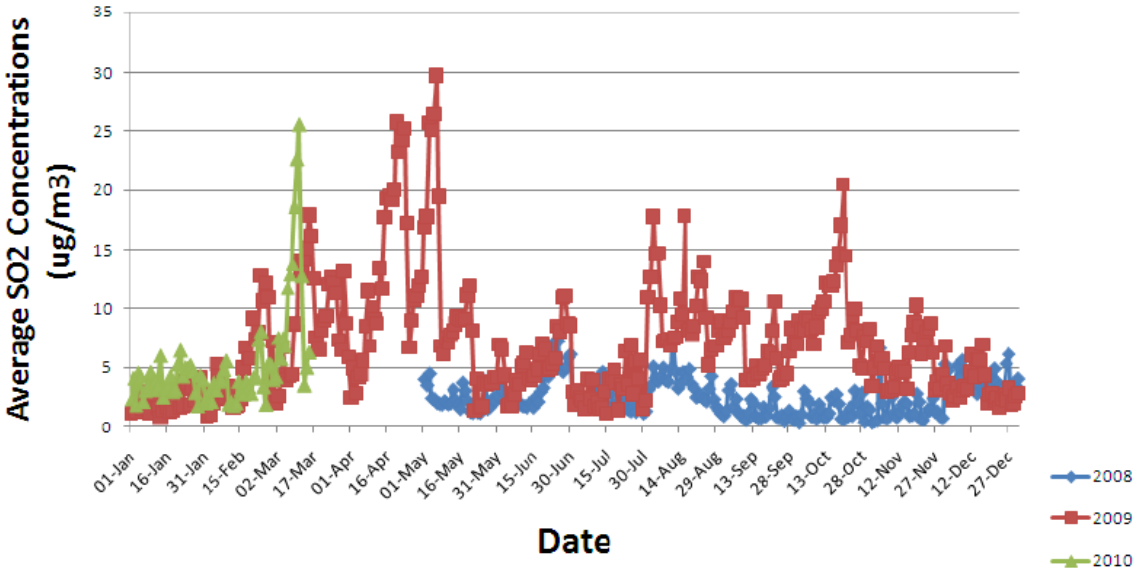


Figure 13: Daily average SO_2 Concentration for the Vredenburg Monitoring Station 2008-2010

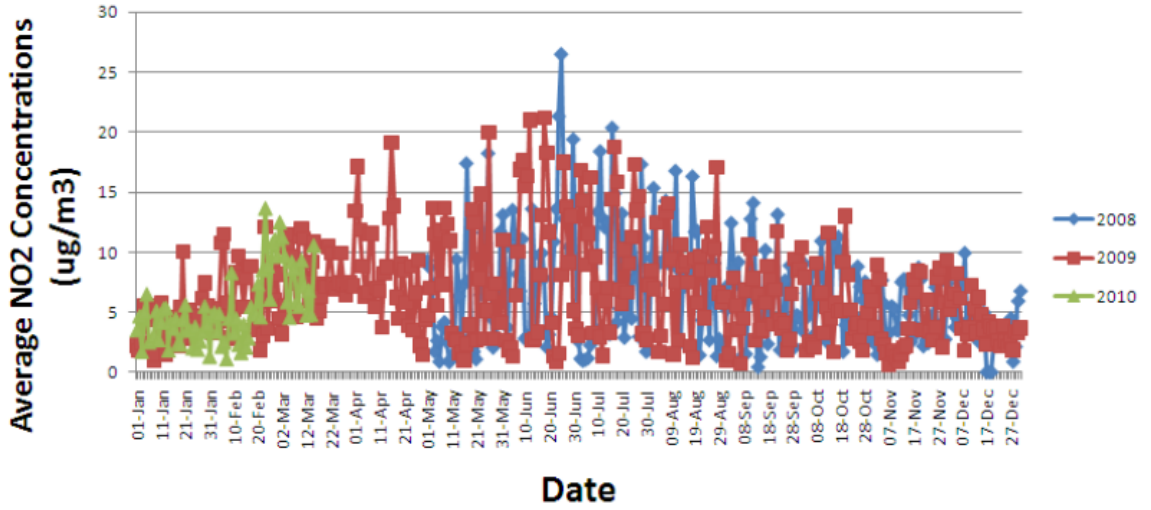


Figure 14: Daily average NO_2 Concentration for the Vredenburg Monitoring Station 2008-2010

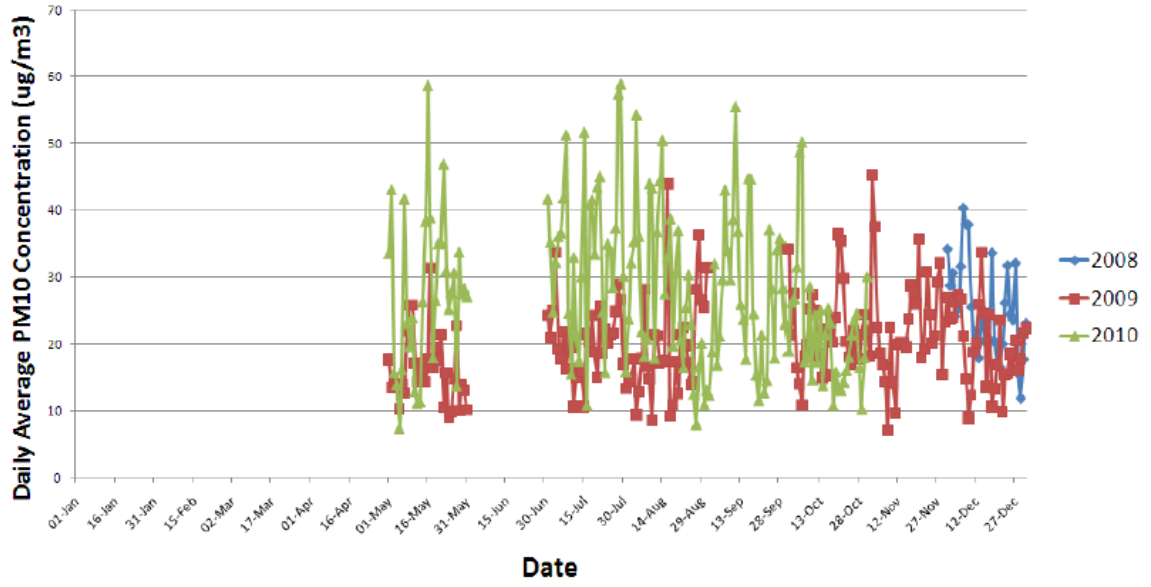


Figure 15: Daily average PM_{10} Concentration for the Bluewater Bay (Port of Saldanha) 2008-2010

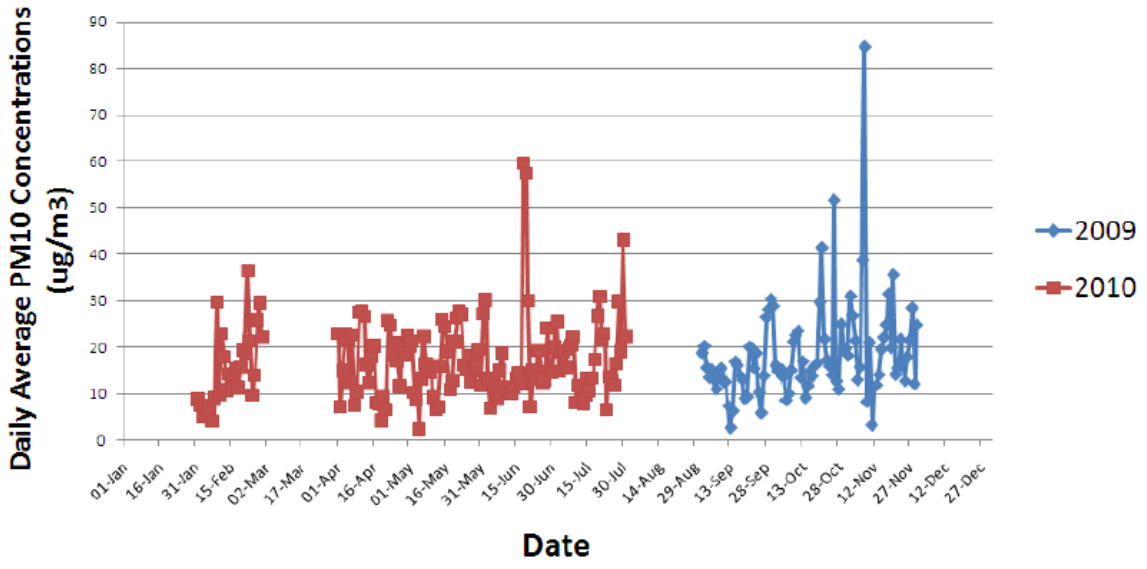


Figure 16: Daily average PM_{10} Concentration for Vredenburg Hills (Port of Saldanha) 2009-2010

Sulphur dioxide

SO_2 is a colourless pungent, irritating, water-soluble and reactive gas. In most cities of developed countries the annual mean concentrations of SO2 in residential areas range between 20 and 40µg/m^3.

However, in developing countries the annual mean concentration of SO_2 in ambient air may be as high as 300µg/m^3. High concentrations are especially evident in cities with cold winters, under conditions of poor atmospheric dispersion such as inversions or when emission from a major source are brought to ground by certain atmospheric conditions.

Due to its reactivity, SO_2 has a highly non-uniform dose distribution along the conductive airways of the respiratory tract. For low to moderate tidal volumes and nasal breathing, the penetration into the lungs is negligible. For larger tidal volumes and oral inhalation, doses of interest may extend into the segmental bronchi. SO_2 can only reach the gas-exchange region of the lungs after adsorption onto particulate matter.

Another special consideration for SO_2 is that there is great variation in susceptibility to bronchoconstrictive responses. Persons having asthma or atopy can be about ten times more responsive than healthy subjects.

Nitrogen oxides

Ambient concentrations of NO_2 in air are highly variable. Natural background concentrations can range from less than 1µg/m^3 to more than 9µg/m^3. In cities, ambient annual mean concentrations can range from 20-90µg/m^3 with hourly maximum concentrations from 75-1 000µg/m^3.

Ambient NO_2 concentrations are low throughout the Vaal Triangle and do not exceed the ambient air quality guidelines. A distinct seasonal trend in ambient NO_2 concentrations is observed, with elevated concentrations during the winter months. The regional scale impact of NO_2 concentrations within the Vaal Triangle is evident in the diurnal trends recorded, indicative of a regional source influence and prevailing meteorological conditions.

NO_2 is a relatively water-insoluble gas and appreciable amounts of inhaled NO_2 can penetrate to, and elicit biological responses in small lung airways. As with SO_2 there is much greater susceptibility to bronchoconstrictive responses in individuals with asthma.

Carbon monoxide

Natural ambient concentrations of CO range between 0.01 and 0.23mg/m^3. In urban environments, mean concentrations over eight hours are usually less than 20mg/m^3, and one-hour peak levels are usually less than 60mg/m^3. Highest concentrations are usually measured near major roads, as vehicles are the major source of CO.

CO exerts its toxic effects after binding with haemoglobin in the capillaries of the lungs.

Ozone

Background one-hour average concentrations of O_3 in remote and relatively unpolluted parts of the world are often in the range of 40 to 70µg/m^3. In cities maximum mean hourly concentrations can be as high as 300 to 400µg/m^3. High O_3 concentrations can persist for 8 to 12 hours per day for several days, when atmospheric conditions favour O_3 formation and poor dispersion conditions exists.

O_3 is a relatively water-insoluble gas. It reacts and produces toxic effects on the small airway surfaces. The dose-delivery is greatest in terminal and respiratory bronchioles. Unlike NO_2 and SO_2, there is very little difference in lung function responsiveness between asthmatics and healthy subjects. These is, however great variability in individual responsiveness that is not yet fully understood.

Lead

Levels of lead found in air, food, water and soil/dust vary widely throughout the world and depend on the degree of industrial development, urbanization and other lifestyle factors. In cities of developing countries traffic-related lead levels range between 0.3 and 1µg/m^3 with extreme annual mean values between 1.5-2µg/m^3.

Lead is inhaled as fine particles and deposited in the lungs. Since lead uptake by blood is dependent on deposition pattern and solubility, total lead content is only a surrogate for the biologically effective dose.

Particulate Matter

In Western Europe and North America efforts to control emissions of particulate matter have generally resulted in positive trends. In many cities the annual ambient average concentrations of PM_{10} are in the range of 20 to 50µg/m^3.

However, annual average concentrations in some cities in Eastern Europe and in most developing countries can be well above 100µg/m^3. Concentrations of $PM_{2.5}$ are usually about 45 to 65% of the concentrations of PM_{10}.

Particle size is a critical factor in internal dose distribution. The location of initial deposition in the airways depends on particle size, with coarse particles being deposited in the upper respiratory tract and fine particles being transported to the lower respiratory tract. The smaller particles contain the secondarily formed aerosols (gas to particle conversion), combustion particles and condensed organic vapours and metal fumes.

Irritant effects from inhaled particles may result in increased airway constriction, altered mucociliary transport, and changes in alveolar macrophage activity. These effects apply across a wide range of inhaled particles, acting alone or together with common gaseous air pollutants, such as SO_2, NO_x or Ozone. Other toxic effects are more chemical specific and, depending on the nature of the chemical, may include organs outside the respiratory tract.

Bronchi constriction, arising from chemical and/or mechanical stimulation of irritant neural receptors in the bronchi, has been reported as a response to exposure to inert dusts, as well as acid and alkaline aerosols. Individuals with asthma or emphysema and other respiratory diseases may have increased particle deposition due to altered breathing patterns or airway structural changes, which may then contribute in a cascading effect to even more bronchi constriction and particle deposition.

4.2. DISPERSION SIMULATION

Dilution of air contaminants in the atmosphere is an important process in preventing undesirable levels of pollutants in the ambient air. Atmospheric dispersion of air contaminants is the result of ventilation, atmospheric turbulence and molecular diffusion. However, gaseous and particulate air contaminants are primarily dispersed into the ambient air through wind action and atmospheric turbulence, much of it on the micro scale level. Depending on the relevant environmental and adiabatic lapse rates, various plume formation can be predicted. These include, looping, neutral, coning, fanning, lofting, fumigating and trapping.

Moisture content and form in the atmosphere can have a profound effect upon the air quality. The presence and amount of water vapour in the atmosphere affects the amount of solar radiation received and reflected by the earth.

Several dispersion models have been developed and are the mathematical description of the meteorological transport and dispersion of air contaminants. In order to describe the position of the place where the concentration of contaminants will be estimated, relative to both the source and the ground, a standard Cartesian (x, y, z) co-ordinate system is used in which:

- the physical source is located at the origin,

- the x-axis lies along the mean wind direction,
- x is the distance from the source,
- y is the lateral distance from the mean wind direction,
- z is the height above ground level,
- h is the physical height of the source,
- Δh is the additional height by which the plume rises due to its buoyancy and/or momentum,
- $H = h + \Delta h$ is the effective (plume) height of the release, and
- u is the mean wind speed at plume height.

Most models in use today assume Gaussian distribution of emission pollutants, horizontally and vertically downwind of the source. With the assumption that the distributions in the y and z directions are normal with a standard deviation of σ_i, the concentration of a gas or aerosol (<20μm diameter particles) can be calculated at ground level for a distance downwind of the source:

$$C_{x,y} = \frac{Q}{\pi u \sigma_z \sigma_y} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where $C_{x,y}$ = pollutant concentration in g/m^3 with a maximum ground level concentration where $\sigma_z = 0.707H$,

Q = pollutant emission rate in g/s

π = constant pi = 3.14159

u = mean wind speed in m/s

σ_y = standard deviation of horizontal plume concentration at distance x in m,

σ_z = standard deviation of vertical plume concentration at distance x in m,

exp = base of natural logarithm = 2.71828183

H = effective stack height in m,

x = downwind distance along plume mean centreline from point source in m, and

y = crosswind distance from centreline of plume in m

The Gaussian equation contains explicit references to y and z, and also implicit references to x (since σ_y and σ_z are themselves functions of x). Empirical studies resulted in graphs where values for these constants could be obtained for different Pasquill stability categories. However, these graphs were inaccurate by nature and equations for the variation of σ_y and σ_z with stability class have been developed and are shown in the table on the next page.

Table 4:

Equations for the variation of σ_y and σ_z

Pasquill stability class	σ_y	σ_z
A	$0.22x(1+0.0001x)^{-0.5}$	$0.20x$
B	$0.16x(1+0.0001x)^{-0.5}$	$0.12x$
C	$0.11x(1+0.0001x)^{-0.5}$	$0.08x(1+0.0002x)^{-0.5}$
D	$0.08x(1+0.0001x)^{-0.5}$	$0.06x(1+0.0015x)^{-0.5}$
E	$0.06x(1+0.0001x)^{-0.5}$	$0.03x(1+0.0003x)^{-1}$
F	$0.04x(1+0.0001x)^{-0.5}$	$0.016x(1+0.0001x)^{-1}$

Industrial plant stacks normally have exit velocity and buoyancy due to the temperature and density difference with the surrounding air that carries them up into the air. This would result in the effective plume height being greater than the physical stack height as presented below.

$$H = h + \Delta h$$

where H = effective stack height in m,
h = height of the stack in m, and
Δh = plume rise in m.

One of the popular equations for the distance the flue gas rises before levelling out is Holland's empirical equation.

$$\Delta h = \frac{v_s d}{u}\left[1.5 + \left(2.68x10^{-3} p \frac{\Delta T d}{T_s}\right)\right]$$

where Δh = rise of plume above the stack in m,

v_s = stack gas velocity in m/s,

d = inside stack diameter in m,

u = mean wind speed in m/s,

p = atmospheric pressure in millibars

ΔT = stack gas temperature minus air temperature in K, and

T_s = stack gas temperature

The above equation is suitable for neutral conditions. For unstable conditions, Δh should be increased by a factor of 1.1 to 1.2 and decreased by a factor of 0.8 to 0.9 for stable conditions. Holland's equation frequently underestimates the effective stack height, giving a conservative figure for design purposes. Although more complex models are available to determine the upward driving force in terms of a buoyancy flux, Holland's equation will suffice when insufficient information with regards the properties of the source is known.

The simplest Gaussian solution assumes that the plume is free to expand in all directions without constraint. In the usual situation of an elevated source at some height above the ground, downwind dispersion is always limited by the presence of the ground, while upward dispersion may be limited by an elevated inversion. Assuming that no pollutant is absorbed by the ground, any pollutant that reaches the ground is available for upward dispersion and the following equation takes into account reflection at the ground:

$$C_{x,y} = \frac{Q}{2\pi u \sigma_z \sigma_y} \exp\frac{-y^2}{2\sigma_y^2}\left[\exp -\frac{1}{2}\left(\frac{z-H}{\sigma_z^2}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z^2}\right)^2\right]$$

Results

This section contains the results of the predicted maximum and average ground level concentrations generated through the ISC-AERMOD VIEW model.

Concentration and deposition isopleths illustrated in **Figure 17** to **19** reflect interpolated values for each receptor grid point for various averaging periods. It has generally been found that the accuracy of dispersion models improve with increased averaging periods. The prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the process and location. For this reason concentrations resulting from routine releases are given for at least three averaging periods, viz. highest hourly, daily and annual averages.

The results presented in **Figure 17** to **19** reflect the spectrum from maximum ground level concentrations, occurring during very stable conditions with low wind speeds, to high wind speeds during very unstable conditions resulting in maximum impact area.

Dispersion results are presented under the following subsections:

- Annual average PM_{10} concentration – OCGT diesel combustion and CCGT natural gas combustion (**Figure 17**)
- Hourly and annual average NO_2 concentration – OCGT and CCGT with DNL emission control technology (guaranteed 12ppm) (**Figure 18**)
- Hourly, daily and annual average SO_2 concentration – OCGT diesel combustion (**Figure 19**)

The dispersion of emissions from the Vortum Thermal Power Plant was modelled using the following inputs:

- Source emission rates contained in **Table 3**.
- Stack parameters; height 50m, diameter 6.5m, exit velocity 40m/s and exit temperature 500°C.
- A Uniform Cartesian grid with a resolution of 500m by 500m.

- Meteorological data obtained from the South African Weather Bureau, modelled to the exact process location for the period 1 January 2010 to 31 December 2015.
- Average annual background PM_{10} concentration of 20µg/m^3 for cumulative assessment.
- Average annual background SO_2 concentration of 15µg/m^3 for cumulative assessment.
- Average annual background NO_2 concentration of 10µg/m^3 for cumulative assessment.

Please note that only modelling outcomes showing little or more impact (>10% of the standard) were reflected in the report.

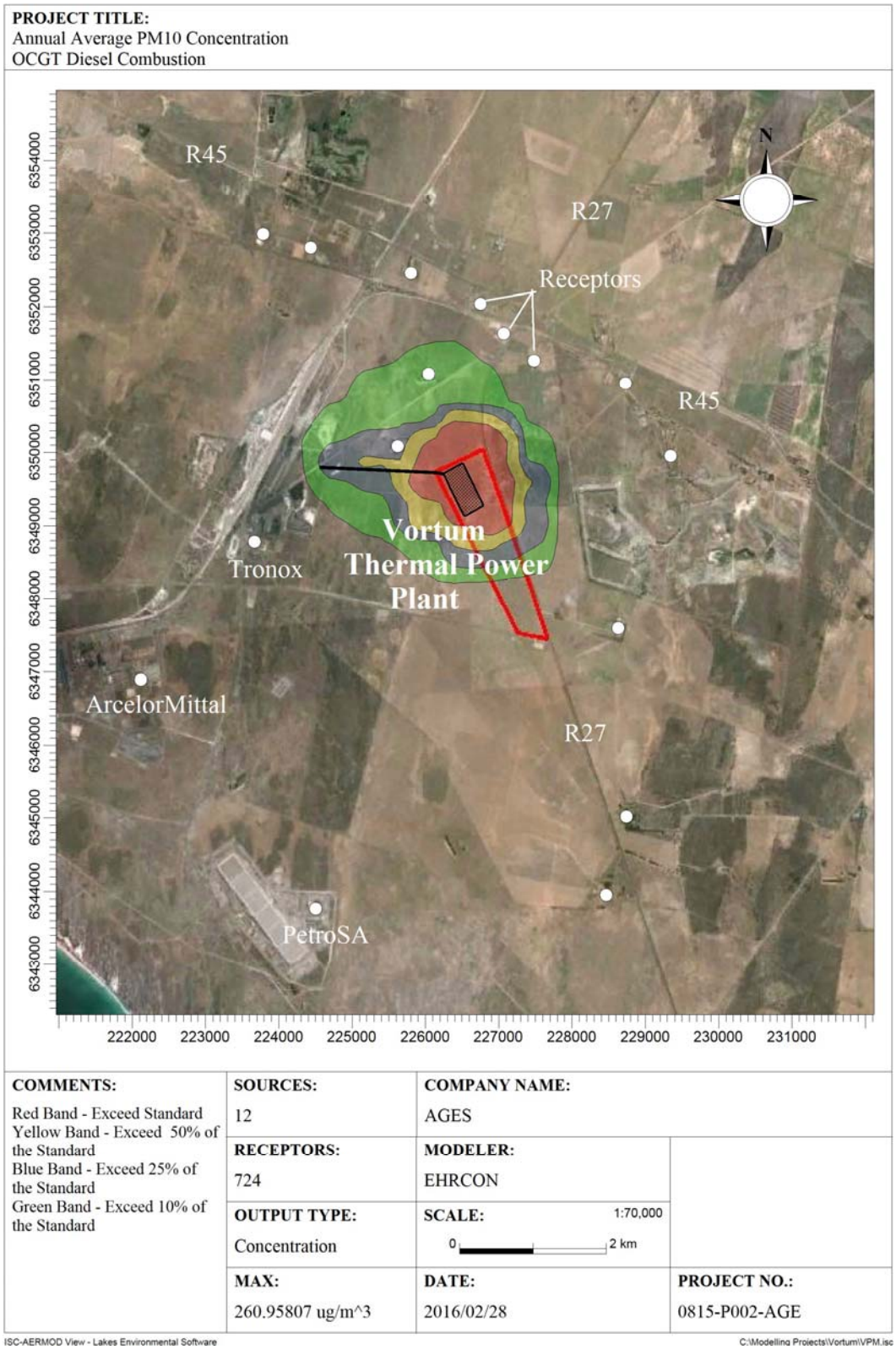


Figure 17a: Cumulative annual average PM_{10} concentration

(National air quality standard – 40µg/m^3)

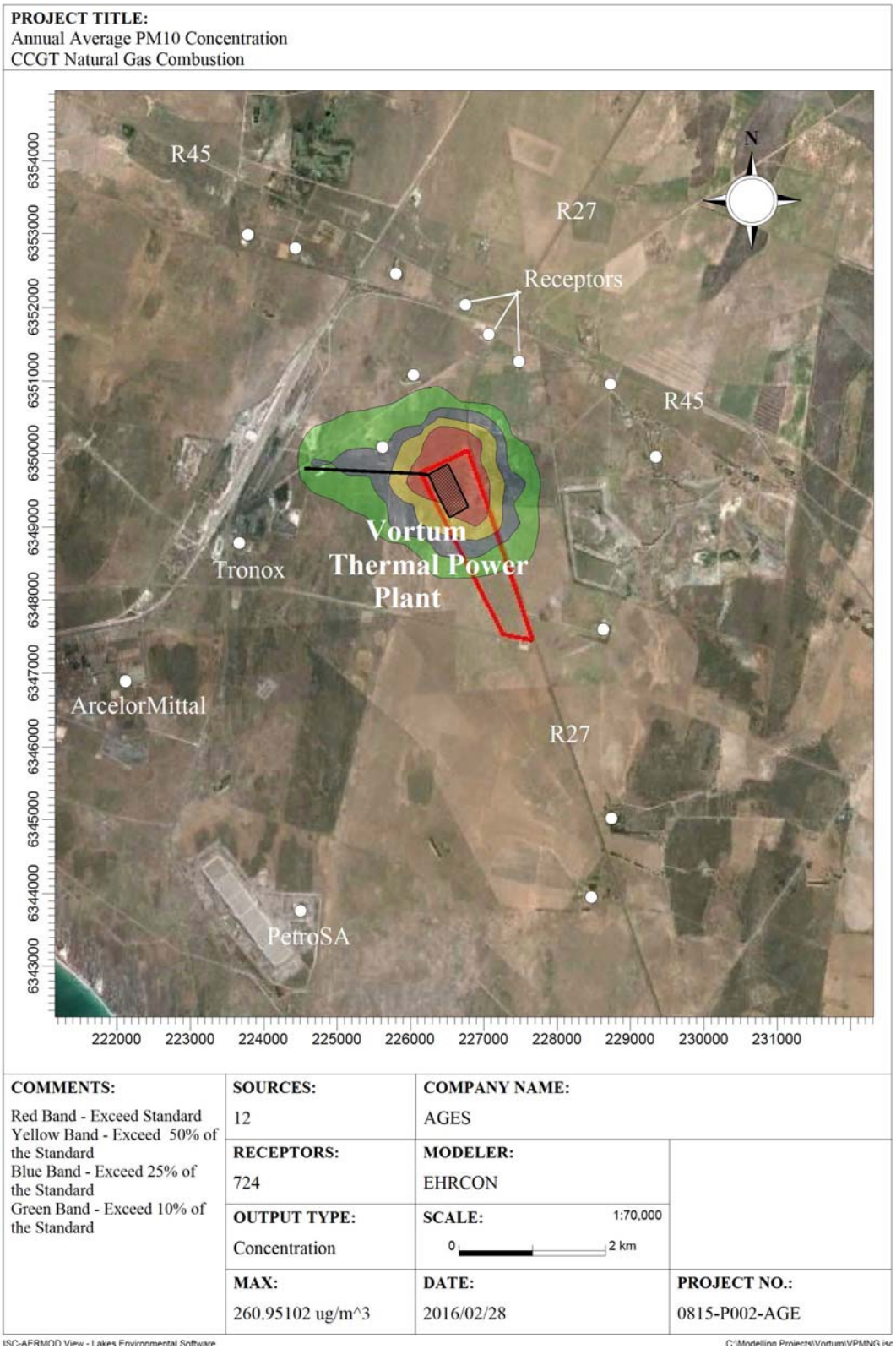


Figure 17b: Cumulative annual average PM_{10} concentration

(National air quality standard – 40µg/m^3)

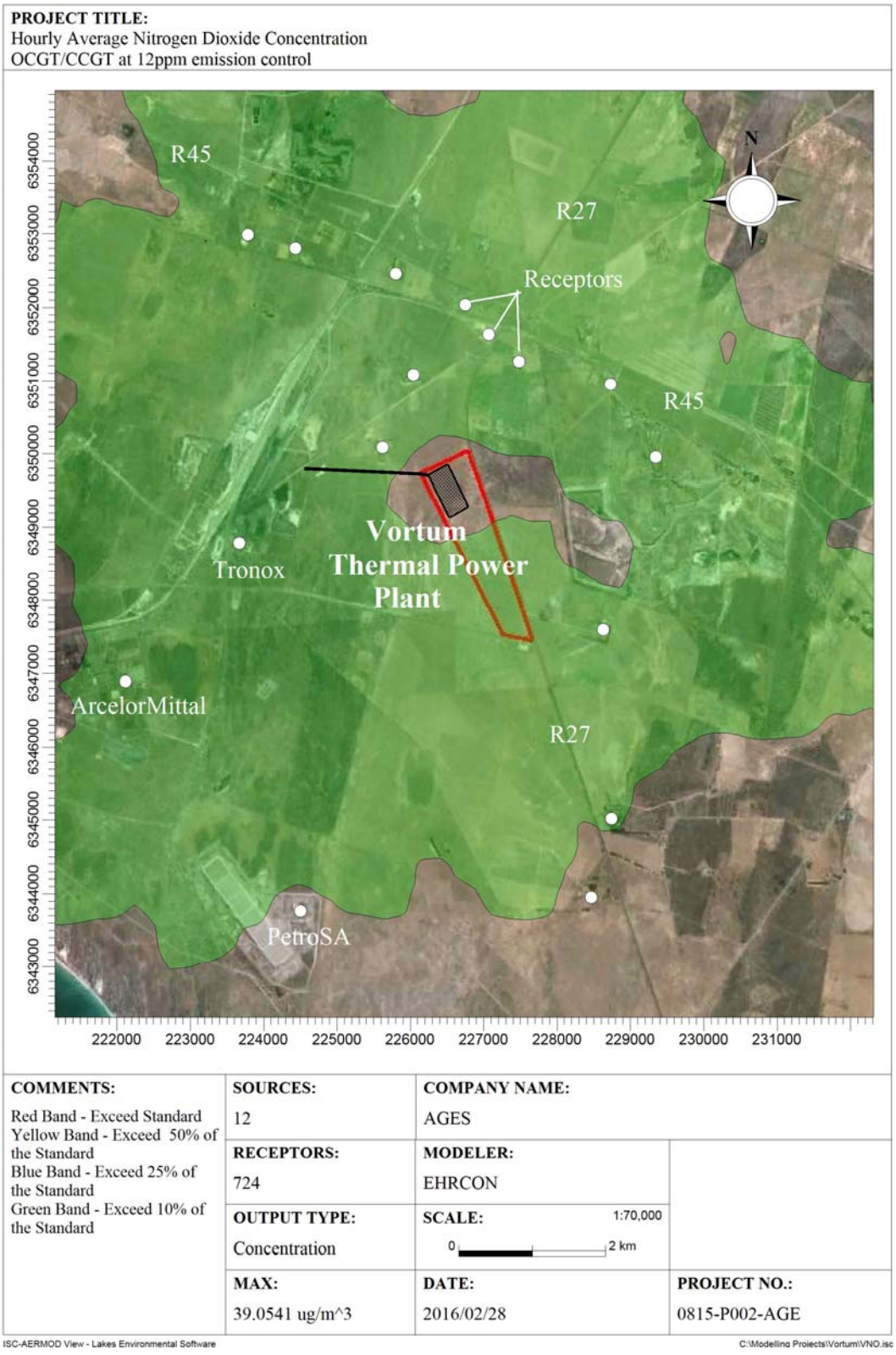


Figure 18a: Hourly average NO_2 standard contraventions

(National air quality standard – 200µg/m^3 not more than 88 times per annum)

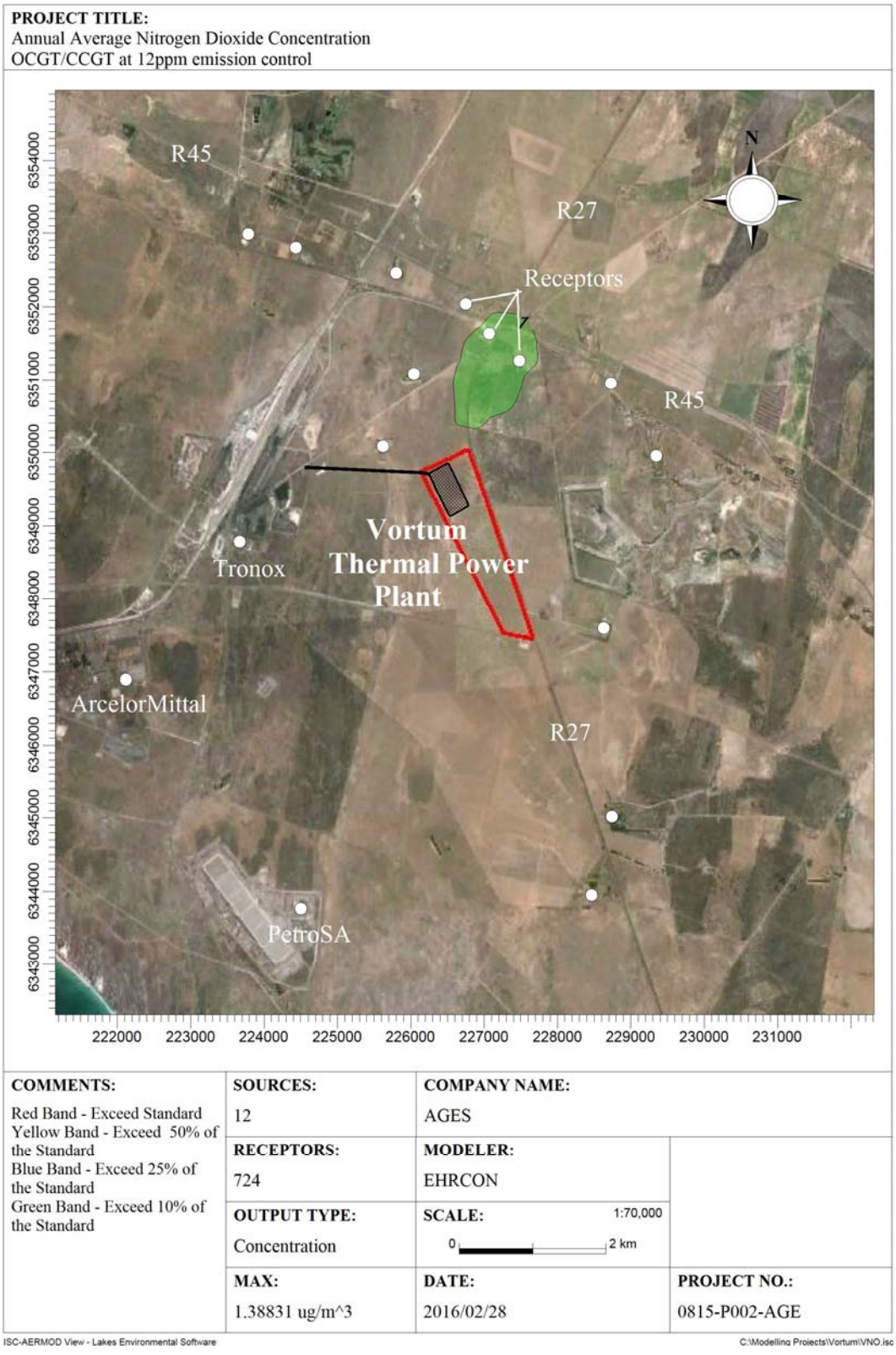


Figure 18b: Cumulative annual average NO_2 concentration

(National air quality standard – 40µg/m^3)

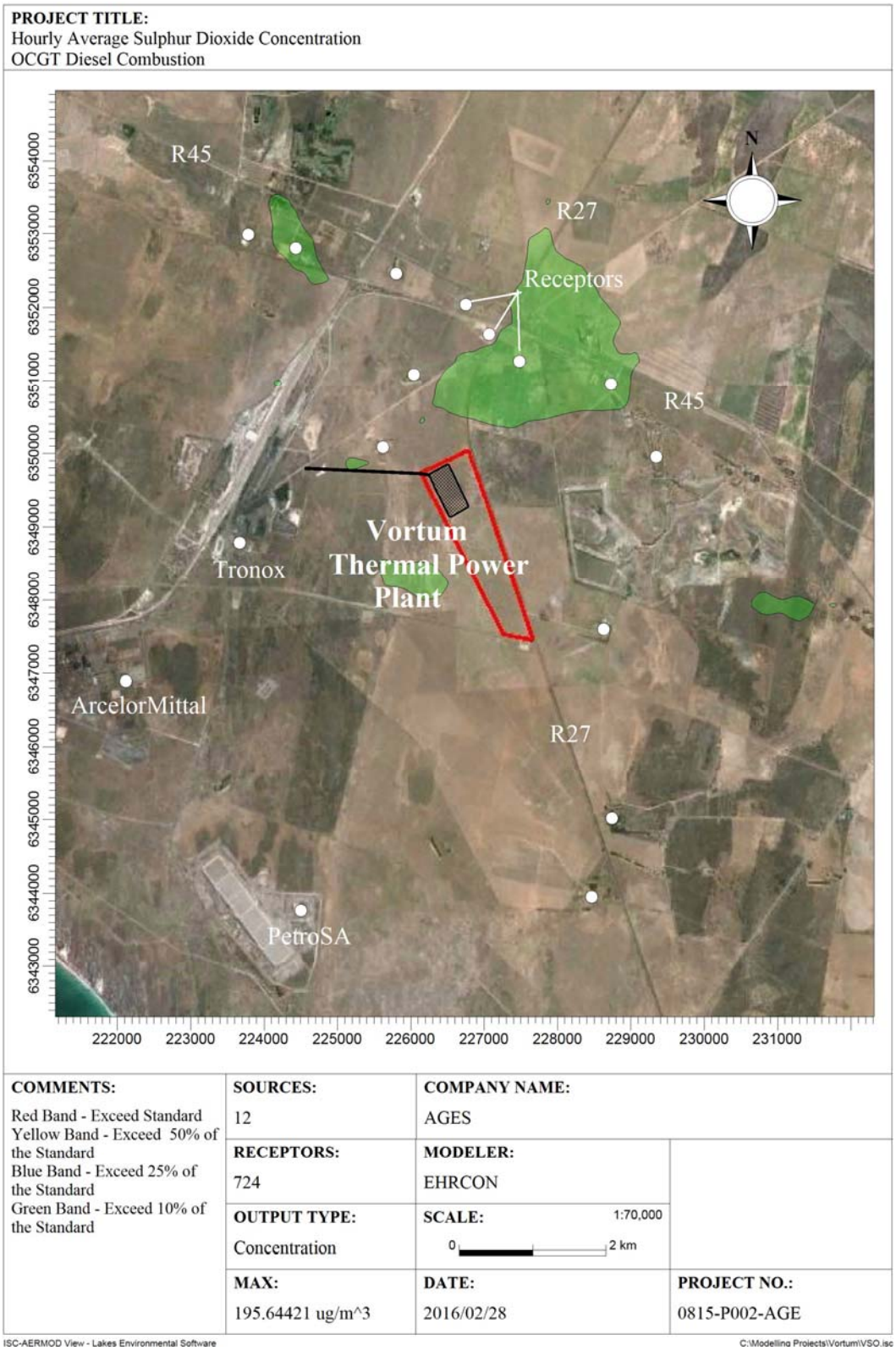


Figure 19a: Hourly average SO_2 standard contraventions

(National air quality standard – 350µg/m^3 not more than 88 times per annum)

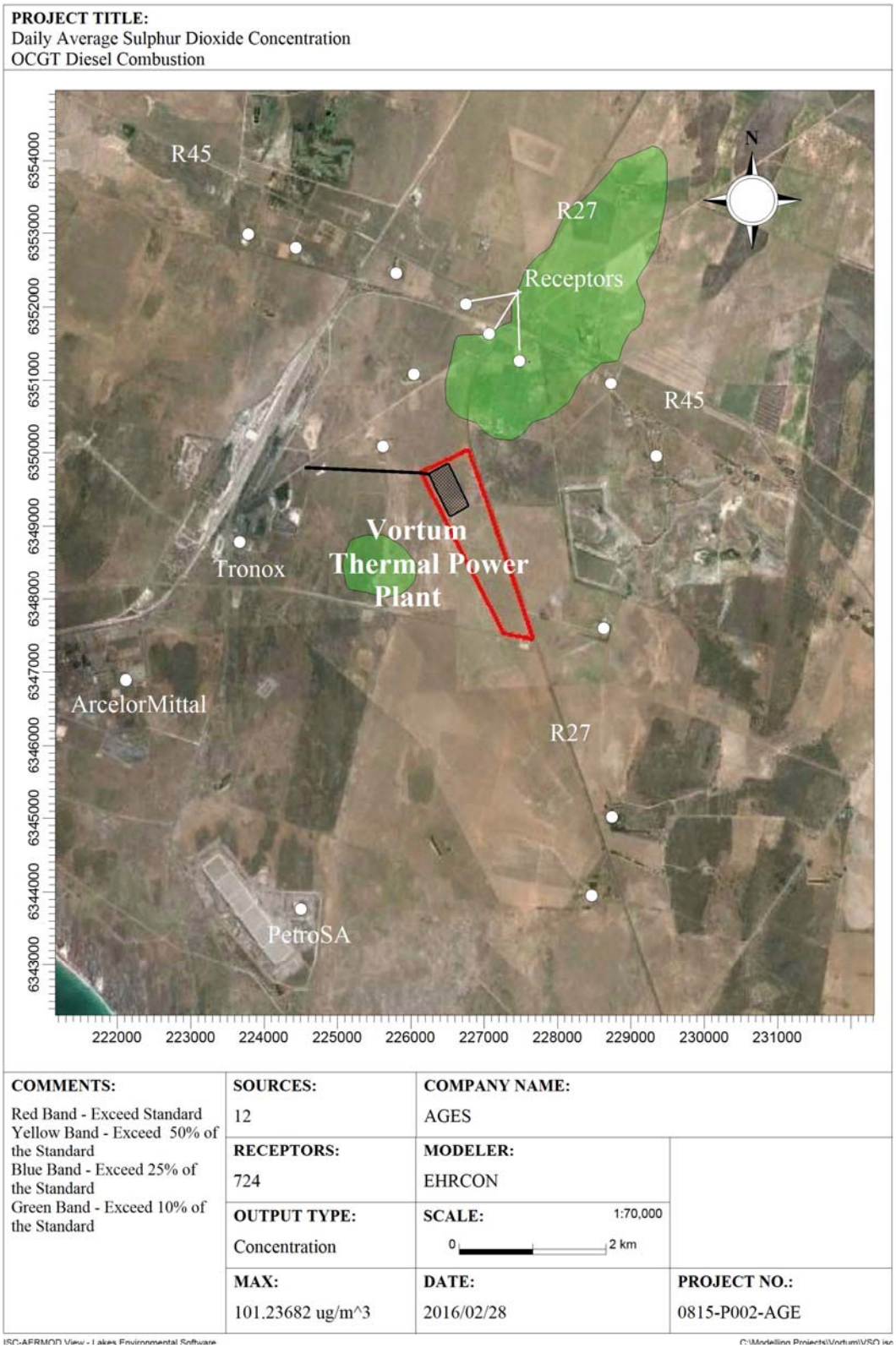


Figure 19b: Daily average SO_2 standard contraventions

(National air quality standard – 125µg/m^3 not more than 4 times per annum)

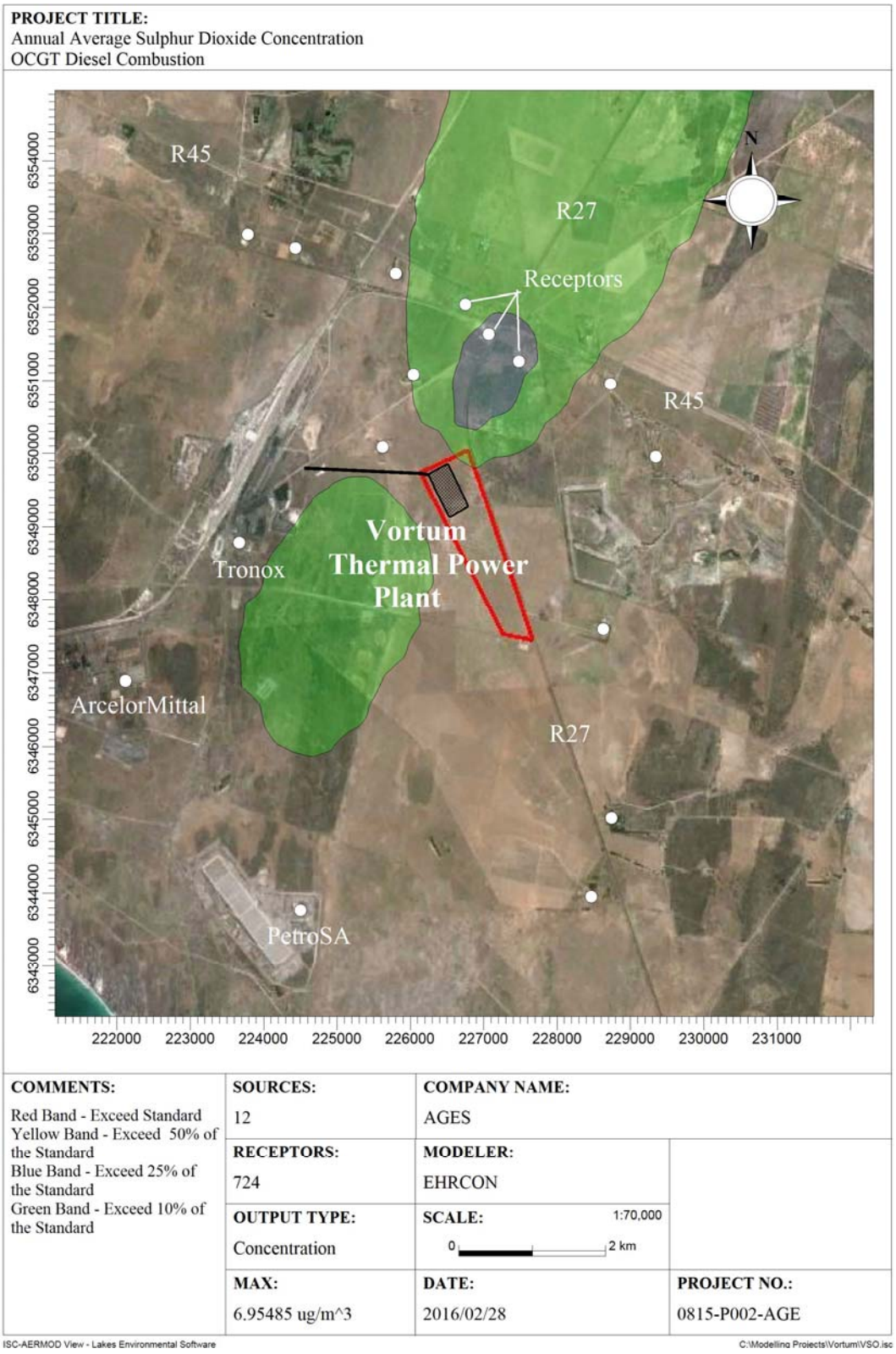


Figure 19c: Cumulative annual average SO_2 concentration

(National air quality standard – 50µg/m^3)

4.3. DISCUSSION

Prior to an analysis of the simulation results it is recommendable to briefly review areas of uncertainty which needs to be taken into account in the interpretation of the results. The range of uncertainty of the Gaussian plume model is given by the US-EPA as being in the range of -50% to +200% when used under the recommended conditions. Uncertainties are, however, not only associated with the mathematical model itself, but also with the generation of the meteorological and source data used as input data. It is well known that wind data errors are the major cause of poor agreement, especially for short-term predictions and long down-wind distances. The selection of a suitable meteorological data set for use in the simulation analysis is fundamental to the accuracy of the results. Errors in source strengths translate directly into errors of similar magnitudes in the model prediction.

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

The impact evaluation consists of a comparison of modelled results to ambient air quality guidelines and a significance rating of the predicted impacts.

4.3.1. PM10

Annual PM_{10} emissions from the proposed electricity generation process could potentially contravene the national standard of 40µg/m^3 up to a maximum distance of 450m beyond the north eastern and western process boundaries. Daily contraventions as a result of the process, should not exceed one per annum at the nearest sensitive receiver, north west of the plant.

It is unlikely that the process independently, would result in average PM_{10} concentrations above current background concentrations at the nearest residential receivers.

Although the particulate emission rates from the CCGT primary stacks are calculated to be significantly lower compared with the OCGT phase, the overall PM_{10} impact of the two phases remains similar. This can be attributed to other prominent PM_{10} emissions sources i.e. wet cooling towers and road vehicle traffic and the associated building down-wash effects from the major structures on site.

Linear relationships between fine particulate concentrations and human health risks are published by organisations such as the WHO. Relatively low PM_{10} concentrations have been associated with various health effects including; increased respiratory hospital admissions, respiratory system exacerbation, cough and in some cases mortality.

Current PM_{10} concentrations in the study are above the lowest level at which statistically significant health effects have been noted to occur (i.e. 20 to 25µg/m^3). Ambient PM_{10} limits are not based on any safe level but rather constitute an acceptance of risk (i.e. acceptance of an additional one hospital admission for respiratory ailment per million persons exposed).

4.3.2. Nitrogen dioxide

NO_2 emissions from the process could potentially contravene the hourly standard of 350µg/m^3 up to a distance of 5km in all directions from the process. These contraventions will mostly like occur during upset process situations combined with poor atmospheric dispersion conditions. It is unlikely that these contraventions will exceed 10% of the number of permitted annual contraventions.

Annual average NO_2 concentrations will probably remain below 10% of the standard beyond the process boundary.

The NO_2 predictions are based on the implementation of Dry Low NOx (DNL) technology during both phases of the project.

4.3.3 Sulphur dioxide

SO_2 emissions could potentially contravene the short-term reference standards in isolated areas, up to a distance of 5km from the process. It is unlikely that these contraventions will exceed 10% of the number of permitted annual contraventions.

Annual average SO_2 concentrations as a result of the process will be most significant in the north north-easterly and south south-westerly directions from the plant. Concentrations are not expected to exceed current background levels.

4.3.4 Minor Pollutants

Ground level concentrations for all volatile organic compounds, other hazardous air pollutants and metallic pollutants are predicted to remain below 5% of the relevant standard, for all reference periods.

4.3.5. Health Impact Assessment

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human activities related to alternatives under study for meeting a project need.

The significance of the aspects/impacts of the Vortum Thermal Power Plant were rated by using a matrix derived from Plomp (2004) and adapted to some extent to fit this process. These matrixes use the consequence and the likelihood of the different aspects and associated impacts to determine the significance of the impacts. The significances of the impacts were determined through a synthesis of the criteria explained below.

Probability – This describes the likelihood of the impact actually occurring.

Improbable	The possibility of the impact occurring is very low, due to the circumstances, design or experience.
Probable	There is a probability that the impact will occur to the extent that provision must be made therefore.
Highly Probable	It is most likely that the impact will occur at some stage of the development.
Definite	The impact will take place regardless of any prevention plans, and there can only be relied on mitigatory actions or contingency plans to contain the effect.

Duration – The lifetime of the impact.

Short term	The impact will either disappear with mitigation or will be mitigated through natural processes in a time span shorter than any of the phases.
Medium term	The impact will last up to the end of the phases, where after it will be negated.
Long term	The impact will last for the entire operational phase of the project but will be mitigated by direct human action or by natural processes thereafter.
Permanent	Impact that will be non-transitory. Mitigation either by man or natural processes will not occur in such a way or in such a time span that the impact can be considered transient.

Scale – The physical and spatial size of the impact.

Local	The impacted area extends only as far as the activity, e.g. footprint
Site	The impact could affect the whole, or a measurable portion of the above mentioned properties.
Regional	The impact could affect the area including the neighboring residential areas.

Magnitude/ Severity – Does the impact destroy the environment, or alter its function?

Low	The impact alters the affected environment in such a way that natural processes are not affected.
Medium	The affected environment is altered, but functions and processes continue in a modified way.
High	Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.

Significance – This is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required.

Negligible	The impact is non-existent or unsubstantial and is of no or little importance to any stakeholder and can be ignored.
Low	The impact is limited in extent, has low to medium intensity; whatever its probability of occurrence is, the impact will not have a material effect on the decision and is likely to require management intervention with increased costs.
Moderate	The impact is of importance to one or more stakeholders, and its intensity will be medium or high; therefore, the impact may materially affect the decision, and management intervention will be required.
High	The impact could render development options controversial or the project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor in mitigation.

The following weights were assigned to each attribute:

Aspect	Description	Weight
Probability	Improbable	1
	Probable	2
	Highly Probable	4
	Definite	5
Duration	Short term	1
	Medium term	3
	Long term	4
	Permanent	5
Scale	Local	1
	Site	2
	Regional	3
Magnitude/Severity	Low	2
	Medium	6
	High	8
Significance	**Sum(Duration, Scale, Magnitude) x Probability**	
	Negligible	<20
	Low	<40
	Moderate	<60
	High	>60

The significance of the major impacts was rated without mitigation measures (WOM) and with mitigation (WM) measures.

Significance	**Without mitigation measures**
Negligible	The impact is not substantial and does not require any mitigation action.
Low	The impact is of little importance, but may require limited mitigation.
Moderate	The impact is of importance and is therefore considered to have a negative impact. Mitigation is required to reduce the negative impacts to acceptable levels.
High	The impact is of major importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.
Significance	**With mitigation measures**
Negligible	The impact will be mitigated to the point where it is regarded as insubstantial.
Low	The impact will be mitigated to the point where it is of limited importance.
Low to Moderate	The impact is of importance, however, through the implementation of the correct mitigation measures such potential impacts can be reduced to acceptable levels.
Moderate	Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.
Moderate to High	The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels.
High	The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance after mitigation could render the entire development option or entire project proposal unacceptable.

Table 5 contains a summary of the potential future impact on human health posed by the Vortum Thermal Power Plant based on predicted process conditions.

Table 5a:

PM_{10} impact assessment

Nature of Impact					
PM_{10} impact from normal operations					
Attribute	**Background**	**With Process**			
		No Mitigation	**With Mitigation @ 550m NW**	**With Mitigation @ 1.5km NNE**	**With Mitigation @ 1.3km NE**
Duration	Long term (4)	Long term (4)	Long term (4)	Long term (4)	Long term (4)
Scale	Local (1)	Regional (3)	Local (1)	Local (1)	Local (1)
Severity	Medium (6)	Medium (6)	Medium (6)	Medium (6)	Medium (6)
Probability	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)
Significance	Moderate (44)	Moderate (52)	Moderate (44)	Moderate (44)	Moderate (44)

Mitigation:

No specific particulate control measures currently specified for the OCGT and CCGT phases and the cooling towers.

The site will be paved and all access roads will either be paved or asphalt sealed. Vehicle traffic on site must be well controlled.

Please refer to additional control measures discussed in **Section 3.2** and **4.4**.

Cumulative impacts:

Short term and annual average background concentrations currently below the national air quality standards. The process could potentially further increase ambient concentrations at the nearest receivers.

Residual impacts:

Impact from process can be further reduced by applying best available industry techniques. Dry cooling technology should be favoured above wet cooling.

Table 5b:

Nitrogen dioxide impact assessment

Nature of Impact					
Nitrogen dioxide impact from normal operations					
Attribute	**Background**	**With Process**			
		No Mitigation	**With Mitigation @ 550m NW**	**With Mitigation @ 1.5km NNE**	**With Mitigation @ 1.3km NE**
Duration	Long term (4)	Long term (4)	Long term (4)	Long term (4)	Long term (4)
Scale	Local (1)	Regional (3)	Regional (3)	Regional (3)	Regional (3)
Severity	Low (2)	High (8)	Moderate (2)	Moderate (6)	High (8)
Probability	Highly Probable (4)	Definite (5)	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)
Significance	Low (28)	High (75)	Low (36)	Moderate (52)	Moderate (52)

Mitigation:

Process design specification provides for Dry Low NOx (DNL) emission control technology for the OCGT and CCGT phases of the project. This technology can potentially reduce process emissions to 9 parts per million (PPM) which will be sufficient compared to the findings of this study i.e. 12ppm.

Please refer to additional control measures discussed in **Section 3.2** and **4.4**.

Cumulative impacts:

Short term and annual average background concentrations currently below the national air quality standards. The process could potentially further increase ambient concentrations at the nearest receivers.

Residual impacts:

Impact from process can be further reduced by applying additional best available industry techniques, such as Selective Catalytic Reduction (SCR), in combination with DNL emission control.

Table 5c:

Sulphur dioxide impact assessment

Nature of Impact					
Sulphur dioxide impact from normal operations					
Attribute	**Background**	**With Process**			
		No Mitigation	**With Mitigation @ 550m NW**	**With Mitigation @ 1.5km NNE**	**With Mitigation @ 1.3km NE**
Duration	Long term (4)	Long term (4)	Long term (4)	Long term (4)	Long term (4)
Scale	Local (1)	Regional (3)	Local (1)	Regional (3)	Regional (3)
Severity	Low (2)	Moderate (6)	Low (2)	Moderate (6)	Moderate (6)
Probability	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)	Highly Probable (4)
Significance	Low (28)	Moderate (52)	Low (28)	Moderate (52)	Moderate (52)

Mitigation:

No specific sulphur dioxide control measures currently specified for the OCGT phase of the project.

Please refer to additional control measures discussed in **Section 3.2** and **4.4**.

Cumulative impacts:

Short term and annual average background concentrations currently below the national air quality standards. The process could potentially further increase ambient concentrations at the nearest receivers.

Residual impacts:

Impact from process should be further reduced by applying additional best available industry techniques in combination with ultra-low sulphur diesel.

4.4. RECOMMENDATIONS

Ambient air quality assessment

According to SANS 1929:2009 the concentrations of specific pollutants within an area shall be evaluated against the following thresholds to determine applicable assessment methods:

a) upper assessment threshold, i.e. the 99th percentile pollutant levels represent a pollutant value exceeding 70% of a limit value (taking into account limit values for all periods which have been used to derive averages).
b) lower assessment threshold, i.e. the 99th percentile pollutant levels represent a pollutant value below 50% of all limit values (taking into account limit values for all periods which have been used to derive averages).

Provision should be made for three air pollutant concentration assessment methods, based on the classification pollutant concentrations relative to the upper and lower assessment thresholds. These methods are:

a) mandatory monitoring, which may be supplemented by modelling techniques to provide an adequate level of information on ambient air quality. This method should be implemented where the upper assessment threshold for a specific pollutant is exceeded;
b) a combination of measurement and modelling techniques should be implemented in areas and for pollutants for which concentrations are between the upper and lower assessment thresholds; and
c) the sole use of modelling or objective estimation techniques is permissible for pollutant concentrations below the lower assessment threshold.

The classification to determine applicable assessment methods should be based on air pollutant concentrations recorded during the previous five years where data is available. Results from measurement campaigns of short duration during the period of a year and at locations likely to be typical of the highest pollution levels may be combined with information from emission inventories and modelling to provide the concentration data required. Classification should be reviewed earlier

than every five years in the event of significant changes in activities relevant to ambient air pollutant concentrations.

In view of the potential impact resulting from emissions from the Vortum Thermal Power Plant, it is recommended that continuous ambient PM_{10}, NO_2, SO_2 and VOC monitoring be conducted at the collection of sensitive receivers, approximately 1.5km north north-west of the plant, for the operational life of the project. Monitoring should commence at least one year before the construction phase of the project.

All primary process should be fitted with continuous monitoring equipment, in line with the requirements for listed activities (see **Section 2.2**).

The ultimate purpose of monitoring is not merely to collect data, but to provide information necessary to make informed decisions on managing and improving the environment. Monitoring fulfils a central role in this process, providing the necessary sound scientific basis for policy and strategy development, objective setting, compliance measurement against targets and enforcement action.

However, the limitations of monitoring should be recognised. In many circumstances, measurements alone may be insufficient, or impractical for the purpose of fully defining population exposure. No monitoring programme, however well-funded and designed, can hope to comprehensively quantify patterns of air pollution in both space and time. At best monitoring provides an incomplete, but useful, picture of current environmental air quality. Monitoring often needs to be used in conjunction with other objective assessment techniques, including modelling, emission measurement and inventories, interpolation and mapping.

Air quality management objectives

The relationship between data collected and the information to be derived from it is essential in compiling an effective air quality management programme. The air quality management programme for the Vortum Thermal Power Plant should ideally focus on the following key objectives:

- Determining population exposure and health impact assessment.
- Informing the public about air quality and raising awareness.
- Identifying threats to natural ecosystems.
- Determining compliance with national and international standards.
- Providing objective inputs to management.
- Source apportionment and identification.
- Policy development and prioritisation of management actions.
- Development/validation of management tools such as models and inventories.
- Assessing source impacts.
- Trend qualification, to identify future problems or progress against management actions.
- Application of air quality permits in terms of the new requirements for listed activities as stipulated by AQA.

The setting of clear objectives enables the definition of objectives for data quality. These requirements must be met to ensure that the overall objectives are achieved. This may include the following:

- Measurement accuracy and precision.
- Traceability to metrology standards.
- Temporal completeness (data capturing).
- Spatial representation and coverage.
- Consistency from site to site and over time.
- International comparability/harmonisation.

Monitoring, modelling and emission measurements should be regarded as complementary components in any integrated approach to air quality management.

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