Project Done on Behalf of
Synergistics Environmental Services (Pty) Ltd

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED KOMATI POWER STATION ASH DAM EXTENSION, MPUMALANGA

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EXECUTIVE SUMMARY

Airshed Planning Professionals (Pty) Limited was appointed by Synergistics Environmental Services (Pty) Ltd to compile an air quality impact assessment for the proposed ash dam extension at Komati Power Station on the surrounding environment and human health. Particulate matter was the main pollutant of concern associated with the extension of the existing ash dam. Pollutants included in the study were particulate matter (PM10). The air quality study comprised of two main components, viz. baseline characterisation and compliance assessment. The baseline characterisation included the review of the site-specific atmospheric dispersion potential, relevant air quality limits and existing ambient air quality in the region. Use was made of site specific meteorological data extracted from Calmet and air quality data recorded for the region in the characterisation of the baseline condition.

In order to determine compliance with ambient air quality limits due to the proposed ash dam extension at Komati Power Station, an emissions inventory was compiled, atmospheric dispersion simulations undertaken and predicted concentrations evaluated.

The evaluation of simulated air pollutant concentrations was based on pertinent local ambient air quality limits, viz. the Department of Environmental Affairs and Tourism (DEAT) standards, recently included in the National Environmental Management: Air Quality Act and limits published by the South African Bureau of Standards (SABS).

Description of Proposed Project

Komati Power Station operations involve the production of fine and coarse ash. The ash is pumped as a dilute slurry to the ash dam complex. This complex consists of three existing dams, one of which, Dam 1 is to be recomissioned. Dam 2 and 3 are capped with topsoil and are vegetated. Dam 1 is to be extended (Extension 3) to accommodate a shortfall in deposition capacity. Extension 3 will partially cover Dam 3. The ash will be deposited on the ash dams in a cyclical fashion. Supernatant and storm water are to be decanted via gravity penstocks to an Ash Water Return Dam located on Ash Dam 1. The water will then gravitate back to the power station for re-use in the ashing circuit.

The terms of reference for the study comprised of two main components, viz, (i) a baseline assessment, and (ii) and air quality impact assessment.

The baseline assessment included the following

- Regional climate and site-specific atmospheric dispersion potential;
- Preparation of hourly average meteorological data;
- Identification of existing sources of emission and characterisation of ambient air quality within the region based on observational data;
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and threshold value, and dust fallout classifications with specific reference to new National Environmental Management : Air Quality Act;
- Quantification of existing sources of emissions;

- Dispersion modelling of existing sources of emissions.
- Health screening assessment based on the dispersion modelling results.

The air quality impact assessment comprises the following;

- Identification and quantification of all sources of atmospheric emissions associated with the ash dam extension.
- Simulation of ground level PM10 concentrations and dust fallout for the ash dam extension.
- Analysis of dispersion modelling results, including:
    - Determine zones of maximum incremental ground level impacts (concentrations and dust fallout from each source); and,
    - Determine zones of maximum predicted cumulative ground level impacts (concentrations and dust fallout from all sources).
- Evaluation of potential for human health and environmental impacts; and'
- Develop a Dust Management Plan (DMP) for the Power Station dust sources, including
    - Rank main contributing sources;
    - Determine control efficiencies for main contributing sources;
    - Identify feasible and cost effective mitigation options;
    - Develop operating and monitoring procedures for significant sources
    - Key performance indicators for compliance assessment; and,
    - External and internal reporting

Assumptions and Limitations

- The impact assessment focused primarily on particulate emissions, these having been identified as the primary pollutants associated with the proposed ash dam extension activities. Although gases will be emitted by exhausts from vehicles, such vehicle activity and hence the associated emissions would be limited and the potential for ambient air pollutant concentrations considered negligible.

- Particle size distributions for topsoil and unpaved road surfaces were not available and therefore particle sizes from similar operations were utilised for the purposes of the study.

Based on the detail of the process description, the following dust generating sources were included:

- Material transfer of scrapped topsoil to topsoil stockpiles.
- Vehicle dust entrainment (removal of topsoil at the proposed ash dam extension site)
- Wind erosion of exposed areas (ash dams).

The impact assessment was limited to airborne particulates in general only. No chemical speciation was available to quantify specific airborne metal concentrations and fallout rates.

The following qualifications apply to this study:

- The dispersion model cannot compute real time mining processes, therefore *average* process throughputs were utilised.

- Meteorological data observed in Middelburg, Witbank, Lydenburg, Groblersdal and Steelpoort were used as input into a wind-field simulation model- CALMET (CALMET is a US Environmental Protection Agency (US-EPA) approved model for use together with the CALPUFF dispersion model.

METHODOLOGY

The air quality baseline study included the specific atmospheric dispersion potential, relevant air quality guidelines and limits and existing ambient air quality in the region. In the characterisation of the baseline conditions, use was made of simulated meteorological data for the site. Reference was also made to studies focusing on the existing air quality in the region. The ambient air quality impact assessment comprised the establishment of an emissions inventory for the proposed ash dam extension activities at Komati Power Station. The simulation of ambient air pollutant concentrations and dust fallout rates occurring due to the construction and operational phases and the baseline were also assessed. Lastly, the resultant potential for impacts and non-compliance was evaluated. An air quality management plan comprising of possible mitigation and management measures for significant sources was developed.

The following emission sources were identified as possible sources of air emissions:

- Material transfer onto topsoil stockpiles;
- Scrapping activities during the construction phase
- Wind erosion of
    - Exposed areas

The expected pollutants associated with the proposed activities included:

- Airborne Particulates:
    - Inhalable particulates, with aerodynamic diameters less than or equal to 10 micron (PM10) from all mining sources;
    - Total suspended particulates (TSP), which includes all particle sizes (generally only up to about 100 µm) from all mining sources;
    - Diesel particulate matter (DM), being emitted from haul trucks and earthmoving equipment;
- Gaseous emissions from vehicles including
    - Oxides of nitrogen (NO and NO_2, collectively known as NO_x);
    - Sulphur dioxide (SO_2);

    - Carbon monoxide (CO);
- Organic compounds from vehicle exhausts and evaporation; the most significant including benzene, formaldehyde, and 1,3-butadiene. (Petrol engines emit significantly more volatile organic emissions, such as toluene, xylene, ethylbenzene, and many more, in addition to these organic compounds.)

However, as discussed earlier, the impact assessment was limited to airborne particulates since these were considered the most significant air pollutant. Emission rates were calculated using internationally accepted methodologies, sourced primarily from the United States Environmental Protection Agency (US EPA AP42).

The US-EPA approved dispersion model, AERMOD, was used to simulate the atmospheric dispersion process. This model was developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective was to include state-of the-art science in regulatory models The AERMOD is a dispersion modeling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. However, given the relatively uncomplicated topography, the predictions are not expected to be compromised by this limitation. The range of uncertainty of the model predictions is between -50% to 200%. The US-EPA considers this range acceptable for their regulatory models, including AERMOD. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

To determine the impacts of the proposed ash dam extension activities at Komati Power Station, the following modelling scenarios were used in the study:

Baseline Scenario

Existing Ash Dam 1 wind erosion sources without mitigation.

Construction Phase:

Scenario 1-Proposed construction activities for ash dam extension without mitigation.

Scenario 2- Proposed construction activities for ash dam extension with mitigation.

Operational Phase Scenario

Existing Ash Dam 1 and Extension 3 wind erosion sources without mitigation.

Conclusions

Baseline Characterisation: Meteorology

Over the one year period (2006), predominant winds were from the north-east and north, with frequencies of up to 10%, with strong wind speeds of up to 15m/s. Calm conditions (wind speeds below 1 m/s) occurred 7.2% of the time. During day-time conditions, the predominant winds were from the north-westerly, northerly and easterly sectors, with an increase in the frequency of winds from the north-westerly sector. Night-time conditions were characterised by winds from the north-easterly and south–easterly sectors. The frequency of occurrence of the winds from the north-easterly sector was 12% and that of the south-easterly sector was 14%. The seasonal variability in the wind field for the Komati Power Station site for 2006 indicated the dominancy of winds from the easterly, south easterly and northerly sectors, with stronger winds of up to 15 m/s occurring in all sectors. During autumn, strong winds of up to 7.5 m/s blew more frequently from the north-westerly, south easterly and north easterly sectors with frequencies of up to 8%. The winter months reflected dominancy of winds from the northerly, south-easterly and westerly sectors although there was a noticeable decrease in the frequency of winds from the northerly sector compared to the summer months. In spring, the predominant winds were from the northerly, westerly and easterly sectors.

The Mpumalanga Highveld (formerly known as the Eastern Transvaal Highveld) has been noted to have increased air pollution concentrations and various elevated sources of emissions located in this region have been associated with the long-range transportation of pollutants and with the potential for impacting on the air quality of the adjacent and more distant regions. Criteria pollutants identified as of major concern in the region include particulates, sulphur dioxide (SO_2) and nitrogen oxides (NO_x).

Impact Assessment: Construction Phase

<u>Construction Phase Scenario 1: PM10 and Dust fallout (Unmitigated)</u>

- The predicted unmitigated highest daily average ground level concentrations for the proposed construction activities exceeded the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and sensitive receptor site of Komati. These standards were however, not exceeded at the sensitive receptor sites of Koornfontein and Blinkpan. This could be attributed to the fact that these sensitive receptors are located further away from the Komati Power Station while the sensitive receptor area of Komati is located closer to the power station.

- The predicted unmitigated maximum daily dust deposition rates for the proposed construction activities did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

<u>Construction Phase Scenario 2: PM10 and Dust fallout (Mitigated)</u>

- The predicted mitigated highest daily average ground level concentrations for the proposed construction activities did not exceed the daily SA standard of 180 µg/m³ at the site boundary and sensitive receptor site of Komati, but exceeded the proposed SA standard of 75 µg/m³ at both sites. These standards were however, not exceeded at the sensitive receptor sites of Koornfontein and Blinkpan.

- o The predicted mitigated maximum daily dust deposition rates for the proposed construction activities did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

Dust concentrations and deposition rates due to the construction phase of the proposed extension activities are unlikely to be of high significance given the short duration over which construction operations occur. It is however recommended that effective dust control measures be implemented in line with good practice. The implementation of effective controls during this phase would also serve to set the president for mitigation during the operational phase. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed through the use of windbreaks and source enclosures. Emission control efficiencies of 50% can readily be achieved through the implementation of effective watering programmes for unpaved roads and material handling points.

Impact Assessment: Baseline Scenario

<u>Baseline scenario</u>

- o The predicted unmitigated highest daily average ground level concentrations for the baseline did not exceed the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and all the sensitive receptor sites.

- o The predicted unmitigated maximum daily dust deposition rates for the baseline did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

Impact Assessment: Operational Phase

<u>Operational Phase Scenario</u>

- o The predicted unmitigated highest daily average ground level concentrations for the operational phase did not exceed the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and all the sensitive receptor sites.
- o The predicted unmitigated maximum daily dust deposition rates for the for the operational phase did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

The current highest daily PM10 concentrations in the region are already between 25-75 µg/m³ and these background concentrations will increase the predicted PM10 concentrations. It is therefore likely that without appropriate mitigation measures, the predicted highest daily concentrations could exceed the SANS and proposed SA standard of 75 µg/m³ at the site boundary and at all the sensitive receptor sites. Similarly, the annual values are expected to be higher due to the current PM10 levels (~10 µg/m³).

Recommendations

Mitigation Recommendations

- Due to the generally high existing background levels of particulate air concentrations in the region, it is highly recommended to control major contributing sources such as wind erosion. Wind erosion of exposed areas should be kept to a minimum through watering programs and avoiding unnecessary disturbance of stabilised areas.

Monitoring Recommendations

Dust fallout monitoring should be carried out close to the sensitive receptors around the power station, especially the sensitive receptor area of Komati as it is located closer to the ash dumps. It is recommended that dust deposition monitoring be confined to sites within and in close proximity (<2 km) to the proposed operations.

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1. INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Synergistics Environmental Services (Pty) Ltd to compile an air quality impact assessment for the proposed ash dam extension at Komati Power Station. Komati Power Station is located within the Mpumalanga Province (Figure 1-1). The air quality study comprises of two main components, viz. baseline characterisation and compliance assessment. The baseline characterisation includes the review of site-specific atmospheric dispersion potential, relevant air quality limits and existing ambient air quality in the region. Use is made of site specific meteorological data extracted from Calmet and air quality data recorded for the region in the characterisation of the baseline condition.

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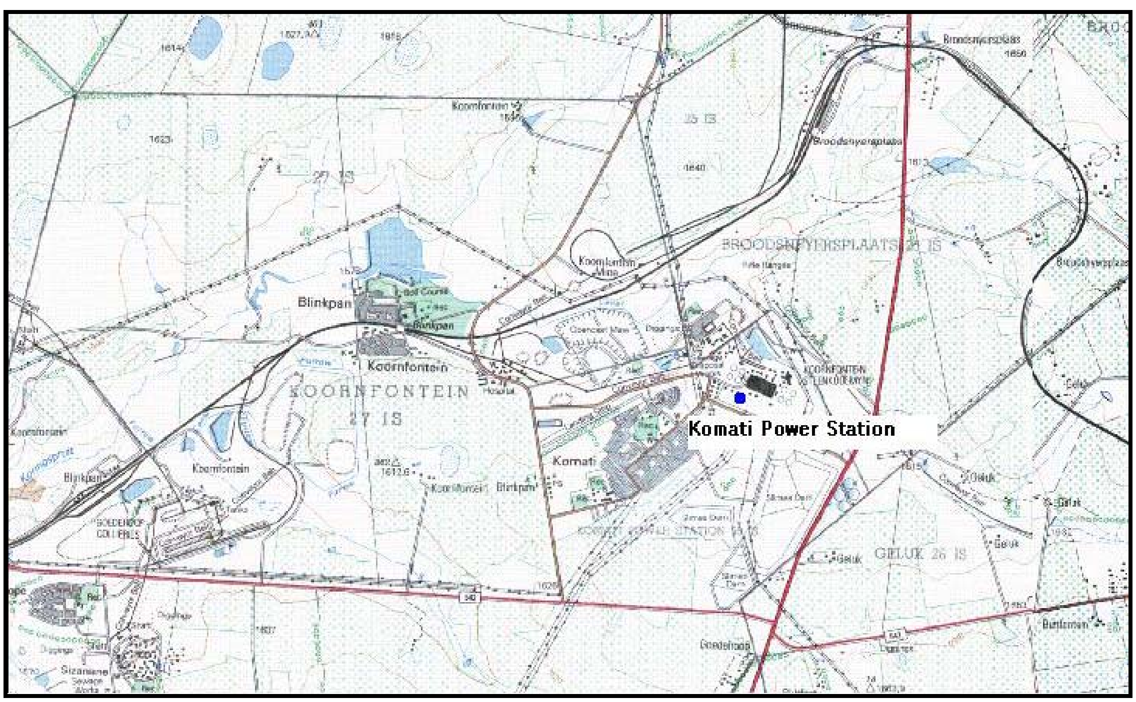

Figure 1-1: Komati Power Station location and closely situated surrounding areas.

1.1 Description of Proposed Project

Komati Power Station operations involve the production of fine and coarse ash. The ash is pumped as a dilute slurry to the ash dam complex (Figure 1-2). This complex consists of three existing dams, one of which, Dam 1 is to be recomissioned. Dam 2 and 3 are capped with topsoil and are vegetated. Dam 1 is to be extended (Extension 3) to accommodate a shortfall in deposition capacity. Extension 3 will partially cover Dam 3. The ash will be deposited on the ash dams in a cyclical fashion. Supernatant and storm water are to be decanted via gravity penstocks to an Ash Water Return Dam located on Ash Dam 1. The water will then gravitate back to the power station for re-use in the ashing circuit.

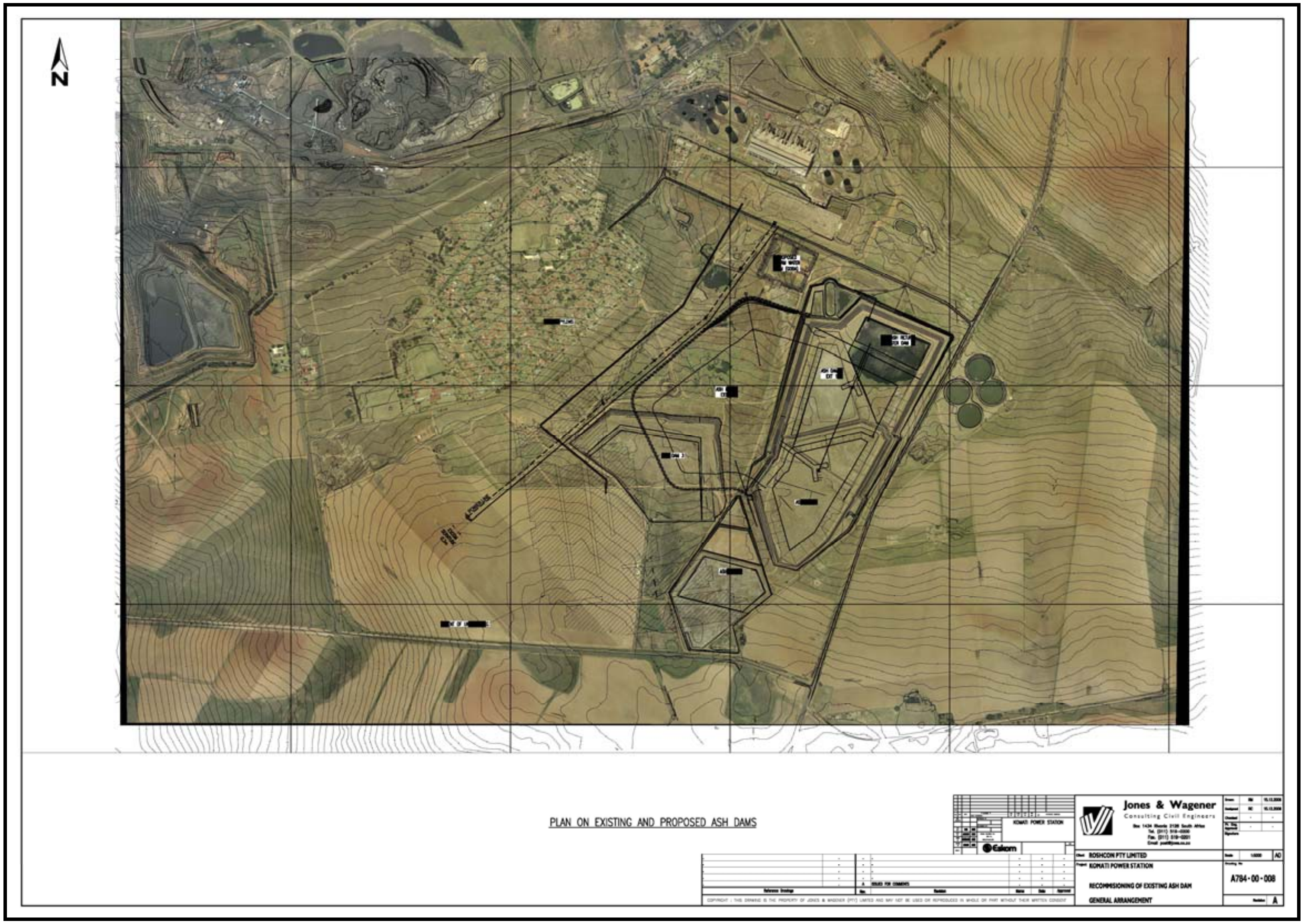

Figure 1-2: Komati Ash Dam Extension Layout

1.2 Sensitive Receptors

Sensitive receptors close to the Komati Power Station include the town of Komati (located approximately 700 m south west), and the settlements of Koornfontein (located approximately 3km west) and Blinkpan (located approximately 4 km west) (Figure 1-3).

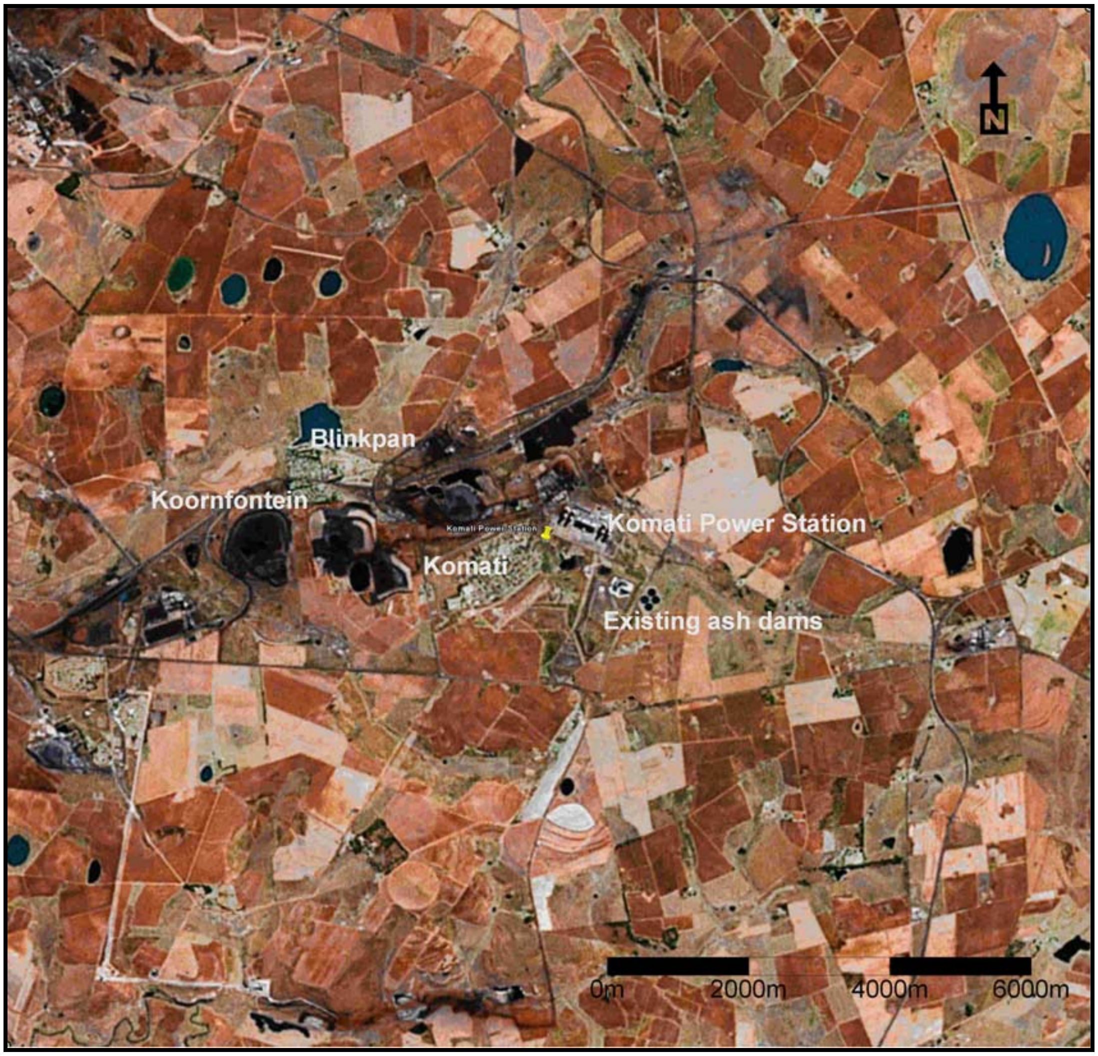

Figure 1-3: **Location of the sensitive receptors around Komati Power Station**

1.3 Terms of Reference

The terms of reference for the study comprised of two main components, viz, (i) a baseline assessment, and (ii) and air quality impact assessment.

The baseline assessment included the following

- Regional climate and site-specific atmospheric dispersion potential;
- Preparation of hourly average meteorological data;

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1.5 Report Structure

Chapter 2 comprises a description of the legislative overview and the guidelines and standards to which the results are referenced. The methodology and approach utilised in this study is outlined in Chapter 3, while Chapter 4 comprises a description of the atmospheric dispersion potential of the region, with a more detailed discussion on the macro dispersion potential attached for further perusal in Appendix B. A baseline assessment incorporating identified sources of emissions in the project area as well as the presentation of available air quality data is discussed in this Chapter.

The impact assessment for the construction phase is presented in Chapter 5 and the impact assessment related to the baseline and operational phases of the project are presented in Chapters 6. Chapter 7 provides recommended mitigation measures.

2. POLICY AND REGULATORY CONTEXT

Prior to assessing the impact of the proposed ash dam extension at Komati Power Station, reference need be made to the environmental regulations and guidelines governing the emissions and impact of such operations.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average. The application of these standards varies, with some countries allowing a certain number of exceedances of each of the standards per year.

2.1 Review of the Current Air Pollution Legislative Context

Under the Air Pollution Prevention Act (Act No 45 of 1965) (APPA) the focus is mainly on sourced based control with permits issued for Scheduled Processes. Scheduled processes, referred to in the Act, are processes which emit more than a defined quantity of pollutants per year, including combustion sources, smelting and inherently dusty industries. Best Practical Means (BPM), on which the permits are based, represents an attempt to restrict emissions while having regard to local conditions, the prevailing extent of technical knowledge, the available control options, and the cost of abatement. The Department of Environmental Affairs and Tourism (DEAT) is responsible for the administration of this Act with the implementation thereof charged to the Chief Air Pollution Control Officer (CAPCO).

The APPA is outdated and not in line with international best practice. It also proves inadequate to facilitate the implementation of the principles underpinning the National Environmental Management Act (NEMA) and the Integrated Pollution and Waste Management (IP&WM) white paper. In this light, the National Environmental Management: Air Quality Act (Act no. 39 of 2004) was drafted, shifting the approach from source based control to decentralised air quality management through an effects-based approach.

Although emission limits and ambient concentration guidelines are published by the Department of Environmental Affairs and Tourism (DEAT), no provision was made under the APPA for ambient air quality standards or emission standards. The decision as to what constitutes the best practicable means for each individual case was reached following discussions with the industry. A registration certificate, containing maximum emission limits specific to the industry, was then issued.

The new National Environmental Management Air Quality Act has shifted the approach of air quality management from source-based control only to the control of the receiving environment.

The act has also placed the responsibility of air quality management on the shoulders of local authorities that will be tasked with baseline characterisation, management and operation of ambient monitoring networks, licensing of listed activities, and emissions reduction strategies. The main objective of the act is to ensure the protection of the environment and human health through reasonable measures of air pollution control within the sustainable (economic, social and ecological) development framework.

The Air Quality Act (AQA) makes provision for the setting of ambient air quality standards and emission limits on National level, which provides the objective for air quality management. More stringent ambient standards may be implemented by provincial and metropolitan authorities. Listed activities will be identified by the Minister and will include all activities regarded to have a significant detrimental effect on the environment, including health. Emission limits will be established on National level for each of these activities and an atmospheric emission licence will be required in order to operate. With the decentralisation of power down to provincial and local authority level, district and metropolitan municipalities will be responsible for the issuing of licences for listed activities. In addition, the Minister may declare priority pollutants for which an industry emitting this substance will be required to implement air pollution prevention plans. An air quality officer appointed by local authorities and responsible for the issuing of atmospheric emission licences, may also require from a company (or person) to submit atmospheric impact reports in order to demonstrate compliance.

The AQA commenced on the 11th of September 2005[1] with the exclusion of certain sections. These sections pertain to the listing of activities and the issuing of atmospheric emissions licences. Thus, for all Scheduled Processes the conditions as stipulated under the APPA prevails until these sections are appealed by the AQA. It is expected that the Listed Activities under the AQA will as a minimum include the current Scheduled Processes.

2.1.1 Legal requirements according to the new Air Quality Act No.39 of 2004.

The minister must, within two years of the date on which this section took effect, establish a national framework for achieving the object of this Act. This needs to include mechanisms, systems and procedures to attain compliance with ambient air quality standards, to give effect to the Republic's responsibility to international agreements and to control emissions from point and non-point sources. In addition, national norms and standards needs to be set for air quality - monitoring; -management planning, - information management, and any other matter which the Minister considers necessary for achieving the object of this Act.

Chapter 2 states that substances and mixtures of substances that present a threat to health, well-being or the environment must be identified and national standards be established (including the permissible amount or concentration of each such substance or mixture of substances in ambient air). In addition, emission standards need to be established for each of these substances and mixtures of substances from point, non-point or mobile sources.

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

Chapter 4 of the Air Quality Act focuses on Air Quality Management Measures. Section 21 of this chapter states that the Minister must, or MEC of a province may publish a list of activities which he/she thinks might have a negative effect on the environment (including health, social conditions, economic conditions, ecological conditions or cultural heritage) and this list can be amended from time to time by adding or removing activities. In addition, if an activity is listed, emission standards need to be set for pollutants emanating from such an activity.

Section 32 of Chapter 4 states that the Minister or MEC may prescribe ***measures for the control of dust in specified places or areas***, steps that must be taken to prevent nuisance by dust; or other measures aimed at the control of dust. In Section 33 reference is made to the ceasing of mining operations where a mine has to notify the Minister 5 years prior to closure, clearly stating plans for rehabilitation and prevention of pollution of the atmosphere by dust after those operations have stopped.

Section 60 of the Air Quality Act lists the ambient air quality standards which are discussed under subsection 2.3. It is important to note that the Air Quality Act makes provision for listed activities which will be regulated by District and Metropolitan Municipalities. The sections however pertaining to listed activities and license specifications were excluded from the implementation of the AQA. Subsequently, the current specifications for Scheduled Processes as stipulated under the APPA prevail. This is discussed in subsection 2.2.

2.1.2 Role Out of the Air Quality Act

Given the specific requirements of the Air Quality Act various projects had to be initiated to ensure these requirements are met. The following provides a brief description of the projects that would have an influence on the proposed town planning.

- *National Framework for Air Quality Management* – according to the Air Quality Act, the Minister must within two years of the date on which this section took effect, establish a national framework for achieving the object of the Act. The project provides the norms and standards to guide air quality management initiatives at national, provincial and local government levels throughout the country. The National Framework is a medium- to long term plan on how to implement the Air Quality Act to ensure the objectives of the act are met. The plan was published in the Government Gazette on the 11th of September 2007.

- *Listed Activities and Minimum Emissions Standard Setting Project* – the minister must in accordance to the act publish a list of activities which result in atmospheric emissions and which is believed to have significant detrimental effects on the environment and human health and social welfare. The project aims to establish minimum emission limits for all the listed activities identified through a consultative process at several forums. All current scheduled processes as stipulated under the APPA would automatically become listed activities with additional activities being added to the list. An initial list of activities forms part of the National Framework. The final lists and limits will be published by mid 2008.

The initial list of activities, as published in the National Framework for Air Quality Management 2007 (Table 26), Combustion Installations is included as proposed listed activities Category 1. This implies that minimum national emission limits will be stipulated for all sources associated with Combustion Installations and an Atmospheric Emissions License will be a legal requirement. It is likely that for fugitive dust sources, dust fallout monitoring and mitigation measures will be a requirement.

- *Highveld Airshed Priority Area Air Quality Management Plan* – the Highveld Airshed was declared the second priority area by the minister on Friday, 23 November 2007. This requires that an Air Quality Management Plan for the area be developed. The plan includes the establishment of an emissions reduction strategies and intervention programmes based on the findings of a baseline characterisation of the area. The implication of this is that all contributing sources in the area will be assessed to determine the emission reduction targets to be achieved over the following few years.

Komati Power Station falls within the Highveld priority area. Emission reduction strategies will be included for all significant sources of pollution in the area with specific targets associated with it.

2.2 Ambient Air Quality Criteria

The Department of Environmental Affairs and Tourism (DEAT) have issued ambient air quality guidelines to support receiving environment management practices. A detailed discussion on the establishment of guidelines and standards follows in Appendix A.

2.2.1 National Standards and International Criteria

Air quality limits issued locally by South Africa and SABS (South African Bureau of Standards) are reflected in the tables together with limits published by the WHO (World Health Organisation), EC (European Community) and US-EPA (United States Environmental Protection Agency).

The SABS was engaged to assist DEAT in the facilitation of the development of ambient air quality standards. A technical committee was established to oversee the development of standards. Three working groups were established by this committee for the drafting of ambient air quality standards for (i) sulphur dioxide, particulates, oxides of nitrogen and ozone, (ii) lead and (iii) volatile organic compounds, specifically benzene. Two documents were produced during the process, viz.:

SANS 69 - South African National Standard - Framework for setting & implementing national ambient air quality standards

SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants

The latter document includes air quality limits for particulate matter less than 10 μm in aerodynamic diameter (PM10), dustfall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene. The SANS documents were approved by the technical committee for gazetting for public comment and were finalized and published in November 2004. DEAT raised concerns regarding certain policy issues having been addressed in the documents. Although the SANS documents have been finalised, it is currently uncertain whether these standards will be adopted by DEAT. The current, primarily outdated DEAT air quality guidelines have been included in the South African Air Quality Act (National Environmental Management: Air Quality Act No.39 of 2004) (to be referred to as SA standard in the current report).
The Department of Environmental Affairs and Tourism (DEAT) issued ambient air quality guidelines for several criteria pollutants, including particulates, sulphur dioxide, oxides of nitrogen, lead, ozone and carbon monoxide. The National Environmental: Air Quality Act, which commenced with on the 11th of September 2005, adopted these guidelines as national standards. The SANS limit values are now proposed to replace these standards as national ambient standards. This was published for public comment in the Government Gazette of 9 June 2006. In the notice the minister indicates that margins of tolerance, compliance timeframes and permissible frequencies of exceedance will be included in the regulations or the national framework to be established in terms of Section 7 of the Act.

2.2.1.1 Suspended Particulates

The impact of particles on human health is largely depended on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 μm) and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 μm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, an effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung. PM10 limits and standards issued nationally and abroad are documented in Table 2-1.

Table 2-1: Air quality guidelines and standards for inhalable particulates (PM10) and total suspended particulates (TSP).

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	180(a)	60
SANS limits & Proposed standards	75(b) 50(c)	40(d) 30(e)
Australian standards	50(f)	-
European Community (EC)	50(g)	30(h) 20(i)
World Bank (General Environmental Guidelines)	70(j)	50(j)
World Bank (Thermal Power Guidelines)	150(k)	50(k)
United Kingdom	50(l)	40(m)
United States EPA	150(n)	50(o)
World Health Organisation	(p)	(p)

Notes:
(a) Not to be exceeded more than three times in one year.
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Target value. Permissible frequencies of exceedance and date by which limit value should be complied with not yet set.
(d) Limit value. Margin of tolerance and date by which limit value should be complied with not yet set.
(e) Target value. Date by which limit value should be complied with not yet set.
(f) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 5 days per year. Compliance by 2008.
(g) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.)
(h) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005
(i) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010
(j) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(k) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air quality in Thermal Power Plants.
(l) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Not to be exceeded more than 35 times per year. Compliance by 31 December 2004
(m) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Compliance by 31 December 2004
(n) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(o) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). To attain this standard, the 3-year average of the weighted annual mean PM10 concentration at each monitor within an area must not exceed 50 µg/m³.
(p) WHO (2000) issued linear dose-response relationships for PM10 concentrations and various health endpoints with no specific guideline provided. WHO (2005) made available during early 2006 proposes several interim target levels (see Table 2-

2 and 2-3).

In addition to the PM10 standards published in schedule 2 of the Air Quality Act, the Act also includes standards for TSP, viz. a 24-hour average maximum concentration of 300 μg/m³ not to be exceeded more than three times in one year and an annual average of 100 μg/m³.

During the 1990s the WHO stated that no safe thresholds could be determined for particulate exposures and responded by publishing linear dose-response relationships for PM10 and PM2.5 concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document contain guidelines that define concentrations which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. These guidelines would provide air quality managers and policy makers with an explicit objective when they were tasked with setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO air quality guidelines (AQGs), the Working Group also proposed interim targets (IT) levels, in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2-2 and 2-3.

Table 2-2: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)

Annual Mean Level	PM10 (μg/m³)	PM2.5 (μg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1
WHO interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO Air Quality Guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred.

Table 2-3: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Daily Mean Level	PM10 ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)	Basis for the selected level
WHO interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG)
WHO interim target-2 (IT-2)*	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG)
WHO interim target-3 (IT-3)**	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG)
WHO Air Quality Guideline (AQG)	50	25	Based on relation between 24-hour and annual levels

* 99th percentile (3 days/year)

** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

The United Kingdom Department of Environment classifies air quality on the basis of concentrations of fine particulates as follows (based on 24-hour average concentrations):

< 50 $\mu g/m^3$	=	Low
50 - 74 $\mu g/m^3$	=	Moderate
75 - 99 $\mu g/m^3$	=	High
> 100 $\mu g/m^3$	=	Very high

Dust Deposition Limits

No criteria for the evaluation of dust fallout levels are available for the US-EPA, EU, WHO, or the WB. Dust deposition may be gauged according to the criteria published by the South African Department of Environmental Affairs and Tourism (DEAT). In terms of these criteria dust deposition is classified as follows:

SLIGHT	-	less than 250 $mg/m^2/day$
MODERATE	-	250 to 500 $mg/m^2/day$
HEAVY	-	500 to 1200 $mg/m^2/day$
VERY HEAVY	-	more than 1200 $mg/m^2/day$

The South African Department of Minerals and Energy (DME) uses the 1 200 $mg/m^2/day$ threshold level as an action level. In the event that on-site dustfall exceeds this threshold, the specific causes of high dustfall should be investigated and remedial steps taken.

A perceived weakness in the current dust-fall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, VERY HEAVY). On the basis of the cumulative South African experience of dustfall measurements, a modified set of dustfall standards is proposed, within the overall framework of the new Clean Air Legislation.

Dustfall will be evaluated against a four-band scale as presented in Table 2-4 and Table 2-5.

Table 2-4: Bands of dustfall rates proposed for adoption

BAND NUMBER	BAND DESCRIPTION LABEL	DUST-FALL RATE (D) ($mg/m^{-2}/day^{-1}$,30-day average)	COMMENT
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial
2	INDUSTRIAL	600 < D < 1 200	Permissible for heavy commercial and industrial
3	ACTION	1 200 < D < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	ALERT	2 400 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Table 2-5: Target, action and alert thresholds for ambient dustfall

LEVEL	DUST-FALL RATE (D) (mg m-2 day-1,30-day average)	AVERAGING PERIOD	PERMITTED FREQUENCY OF EXCEEDANCES
TARGET	300	Annual	
ACTION RESIDENTIAL	600	30 days	Three within any year, no two sequential months.
ACTION INDUSTRIAL	1 200	30 days	Three within any year, not sequential months.
ALERT THRESHOLD	2 400	30 days	None. First exceedance requires remediation and compulsory report to authorities.

3. METHODOLOGY

In assessing atmospheric impacts from the proposed ash dam extension activities, an emissions inventory was undertaken, atmospheric dispersion modelling conducted and predicted air pollutant concentrations evaluated.

The phases undertaken in the impact assessment are described in the following subsections.

3.1 Baseline Assessment

The baseline assessment includes the review of site-specific atmospheric dispersion potentials, and existing ambient air quality in the region, in addition to the identification of potentially sensitive receptors. No ambient monitored data exist for the Komati Power Station and the nearest Eskom monitoring station is Elandsfontein located approximately 18 km to the southwest. The dispersion model requires at least one year of meteorological data as input, including as a minimum hourly average wind speed, wind direction and temperature data. Mixing heights need to be estimated for each hour, based on prognostic equations, while night-time boundary layers will be calculated from various diagnostic approaches.

Airshed conducted a cumulative ambient air quality impact assessment for Eskom in 2006 for various scenarios. All sources of emissions within the Mpumalanga Highveld were accounted for including industrial sources, vehicle emissions, mining operations, domestic fuel burning etc. The dispersion model utilized for modeling such a vast terrain was the US.EPA approved CALMET/CALPUFF suit of models. CALMET simulates a three dimensional meteorological profile for the study area using more than one surface weather station and upper air data. Hourly average meteorological data, including wind speed, wind direction and temperature was used, and mixing heights were estimated for each hour, based on prognostic equations, while night-time boundary layers were calculated from various diagnostic approaches. Wind speed and solar radiation were used to calculate hourly stability classes. The following meteorological surface stations' hourly data for 2006 were used for the CALMET model:

- South African Weather Services Station in Witbank
- South African Weather Services Station in Groblersdal
- Columbus Stainless Steel meteorological station in Middelburg
- Xstrata Project Lion meteorological station in Steelpoort
- Xstrata Lydenburg meteorological station in Lydenburg

The CALMET results for the period 2006 were used to extract meteorological data for a specific point representative of the Komati Power Station. This dataset was then used for the assessment of the dispersion potential of the site and for use in the dispersion model for the proposed ash dam extension. The results from the Calpuff model was used as indication of the background particulate concentrations in the area due to the lack of ambient PM10 monitored data.

3.2 Emissions Inventory

An emissions inventory was established and comprised emissions for the proposed operations with unmitigated and mitigated emissions for the construction activities and unmitigated emissions for the current and proposed operational activities. The establishment of an emissions inventory is necessary to provide the source and emissions data required as input to the dispersion simulations. The release of particulates represents the most significant emission and is the focus of the current study.

In the quantification of emissions, use was made of predictive emissions factor equations published by the US-EPA (EPA, 1996). An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.

3.3 Selection of dispersion model

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

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The most widely used Gaussian plume model is the US-EPA Industrial Source Complex Short Term model (ISCST3).

The AERMET/AERMOD dispersion model suite was chosen for the current study as it is the new regulatory model that has replaced the US-EPA Industrial Source Complex Model (ISC Version 3) Gaussian plume model. AERMET uses more comprehensive meteorological data sets including upper air data. The model also has a terrain pre-processor (AERMAP) for including a large topography into the model. The AERMET/AERMOD suite was developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models.

The dispersion modelling domain (for the Komati Power Station Ash Dam Extension Study) included an area covering 15 km by 15 km. This area was further divided into a receptor grid matrix with a resolution of 150m for the purposes of the AERMOD dispersion model. The annual and the highest daily averages were predicted for each of these receptor locations.

- AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources (Trinity Consultants, 2004). AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature, but retains the single straight line trajectory limitation of ISCST3 (Hanna *et al*).

- AERMET is a meteorological preprocessor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters.
- AERMAP is a terrain preprocessor designed to simplify and standardize the input of terrain data for AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. Output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

Similar to the ISCST3 a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Also, the range of uncertainty of the model predictions could to be -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

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

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

Input data types required for the AERMOD model include: source data, meteorological data (pre-processed by the AERMET model), terrain data and information on the nature of the receptor grid

3.4 Meteorological data requirements

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database). Since the model was designed for the USA environment, various difficulties are found compiling the required dataset for the South African environment. The main data shortfalls include the following:

- The national meteorological database does not accommodate all the parameters required by AERMET.
- Upper air measurements are taken at only 5 locations in South Africa. The South African Weather Services has modelled upper air data for the entire country on a half degree interval.
- Surface meteorological stations seldom measure all the required parameters (such as solar radiation, cloud cover, humidity).
- The meteorological data extracted from CALMET includes hourly wind speed, wind direction and temperature data for 2006.

3.5 Preparation of source data

AERMOD is able to model point, area, volume and line sources. Wind erosion sources were modelled as area sources. Hourly files incorporating meteorological data were prepared for the wind erosion sources.

3.6 Preparation of receptor grid

For the study, the dispersion of pollutants was modelled for an area covering 15 km (north-south) by 15 km (east-west). AERMOD simulates ground-level concentrations for each of the receptor grid points. The nearby settlements of Komati, Koornfontein and Blinkpan were included as discrete receptors.

3.7 Model input and execution

Input into the dispersion model includes prepared upper air and surface meteorological data, source data, information on the nature of the receptor grid and emissions input data. The model inputs were verified before the model was executed.

3.8 Plotting of model outputs

Simulated outputs for PM10 (daily and annual) and TSP (average and maximum daily) were plotted.

4. BASELINE CHARACTERISATION

The characterisation of the baseline environment comprises the description of the atmospheric dispersion potential, the regulatory context and the existing air quality of the study region. The atmospheric dispersion potential impacts on the way in which emissions from the proposed Komati Power Station extension activities accumulate, disperse and are removed in the atmosphere. Information on existing air pollution concentrations is crucial to the quantification of cumulative air pollution impacts. Regulatory requirements, specifically permissible air quality limits, facilitate the assessment of the acceptability of measures and predicted air pollutant concentrations.

4.1 Atmospheric Dispersion Potential

A description of the regional climate and macro-scale dispersion potential is given in Appendix A. The meso-scale meteorology is discussed in this section.

4.1.1 Meso-Scale Wind Field

Following the modelling of the three dimensional meteorological field over the study region, modelled wind field results were extracted from nine points to facilitate the generation of period average and diurnal wind roses at surface and upper air levels (Figure 3-1).

Wind roses represent wind frequencies for the 16 cardinal wind directions. Wind frequencies are indicated by the length of the shaft when compared to the circles drawn to represent a 5% frequency of occurrence. Wind speed classes are assigned to illustrate the frequencies of high and low wind for each wind vector. The frequencies of calm periods, defined as periods for which wind speeds are below 1 m/s, are indicated in the centre of the wind rose

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. In order to understand the potential for dispersion at a given site, it is preferred to have an on-site meteorological station. No meteorological station is in place at or near Komati Power Station and to overcome this problem, it was decided to make use of meteorological data extracted from the US-EPA CALMET model (which forms part of the CALPUFF suit of models) for the region.

The CALMET meteorological model contains a diagnostic wind field module that includes parameterised treatments of terrain effects, including slope flows, terrain channelling and kinematic effects, which are responsible for highly variable wind patterns. CALMET uses a two-step procedure for computing wind fields. An initial guess wind field is adjusted for terrain effects to produce a Step 1 wind field. The user specifies the vertical layers through which the domain wind is averaged and computed, and the upper air and surface meteorological stations to be included in the interpolation to produce the spatially varying guess field. The Step 1 (initial guess) field and wind observational data are then weighted through an objective analysis procedure to produce the final (Step 2) wind field. Weighting is undertaken through assigning a radius of influence to stations, both within the surface layer and layers aloft. Observational data are excluded from the interpolation if the distance between the station and a particular grid point exceeds the maximum radius of influence specified (EPA, 1995b; Scire and Robe, 1997; Robe and Scire, 1998).

CALMET was used to simulate the wind field and stability regime within the study region. A meteorological modelling terrain was chosen to include the complex features of the study area. The modelling domain covers an area of 150 km (east-west) by 166 km (north-south), with grid intervals of 1 km calculated on seven vertical levels. Meteorological data from five surface stations and two upper air station were obtained for inclusion in the simulations. The following meteorological surface stations' data were used:

- South African Weather Service Station in Witbank
- South African Weather Service Station in Groblersdal
- Columbus Stainless' meteorological station in Middelburg
- Xstrata Project Lion meteorological station in Steelpoort
- Xstrata Lydenburg meteorological station in Lydenburg

Upper air data required by CALMET includes pressure levels, geo-potential height, temperature, wind direction and wind speed for various levels. Eight daily data points for various pressure levels (800 hPa, 750 hPa, 700 hPa, 650 hPa, 600 hPa, 550 hPa and 500 hPa) were included in the meteorological simulations. The initial guess field in CALMET will therefore be determined as a combined weighing of surface winds at the nine surface weather stations, vertically extrapolated using Similarity Theory (Stull, 1997) and the upper air winds.

The CALMET meteorological model requires hourly average surface data as input, including wind speed, wind direction, mixing depth, cloud cover, temperature, relative humidity, pressure and precipitation. The mixing depth is not measured and needs to be calculated based on readily available data, viz. temperature and predicted solar radiation. The daytime mixing heights are calculated with the prognostic equations of Batchvarova and Gryning (1990), while night-time boundary layer heights are calculated from various diagnostic approaches for stable and neutral conditions.

A three-dimensional meteorological data set for the region was simulated by the CALMET. This data set parameterised the spatial (horizontal and vertical) and temporal variations of parameters required to model the dispersion and removal of pollutants, including: wind speed, wind direction, temperature, mixing depths over land, atmospheric stability, (etc.). A meteorological data set was generated for the year 2006.

The geophysical data required as input to CALMET includes land use type, elevations and various surface parameters. The land use and elevation data are entered as gridded fields. Due to the extent of the modelling domain (24800 km²), a grid resolution of 1 km was used in CALMET to characterise the terrain. In the vertical, four levels of ceiling heights of 20 m, 200 m, 500 m and 1 500 m above the ground were used. This vertical structure allows for levels completely within the valleys, transitional levels and layers above most of the terrain.

Figure 4-1 shows the local wind field for Komati Power site based on the meteorological data extracted from CALMET.

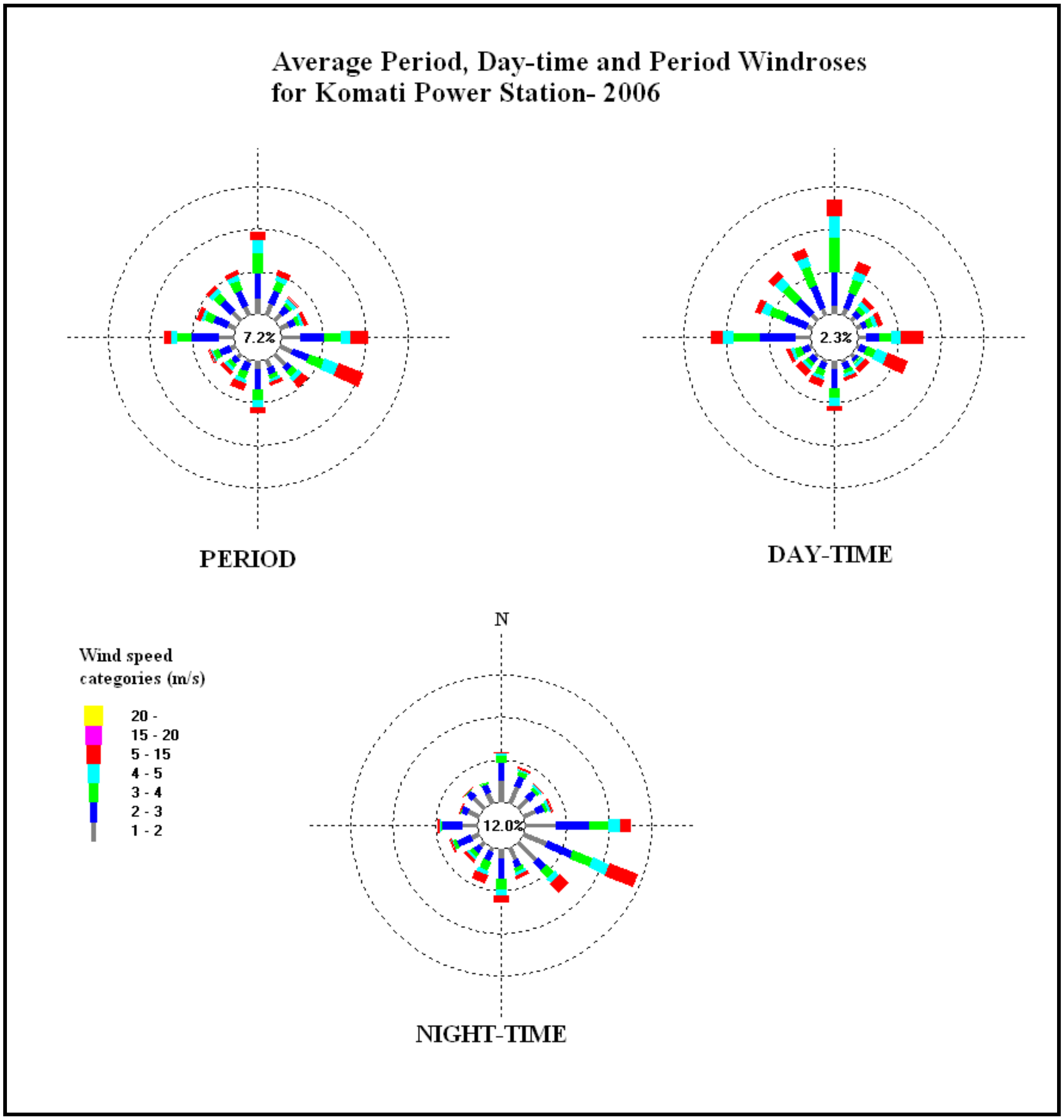

Figure 4-1: Wind roses for Komati Power Station site for 2006

Over the one year period assessed predominant winds are from the north-east and north, with frequencies of up to 10%, with strong wind speeds of up to 15m/s. Calm conditions (wind speeds below 1 m/s) occur 7.2% of the time. During day-time conditions, the predominant winds are from the north-westerly, northerly and easterly sectors, with an increase in frequency of winds from the north-westerly sector. Night-time conditions are characterised by winds from the north-easterly and south–easterly sectors. The frequency of occurrence of the winds from the north-easterly sector is 12% and that of the south-easterly sector is 14%.

The seasonal variability in the wind field for the Komati Power Station site for 2006 is shown in Figure 4-2. During the summer months, winds from the easterly, south easterly and northerly sectors dominate, with stronger winds of up to 15 m/s occurring in all sectors. During autumn, strong winds of up to 7.5 m/s blow more frequently from the north-westerly, south easterly and north easterly sectors with frequencies of up to 8%. The winter months reflect dominancy of winds from the northerly, south-easterly and westerly sectors although there is a noticeable decrease in the frequency of winds from the northerly sector compared to the summer months. In spring, wind flow is predominant from the northerly, westerly and easterly sectors.

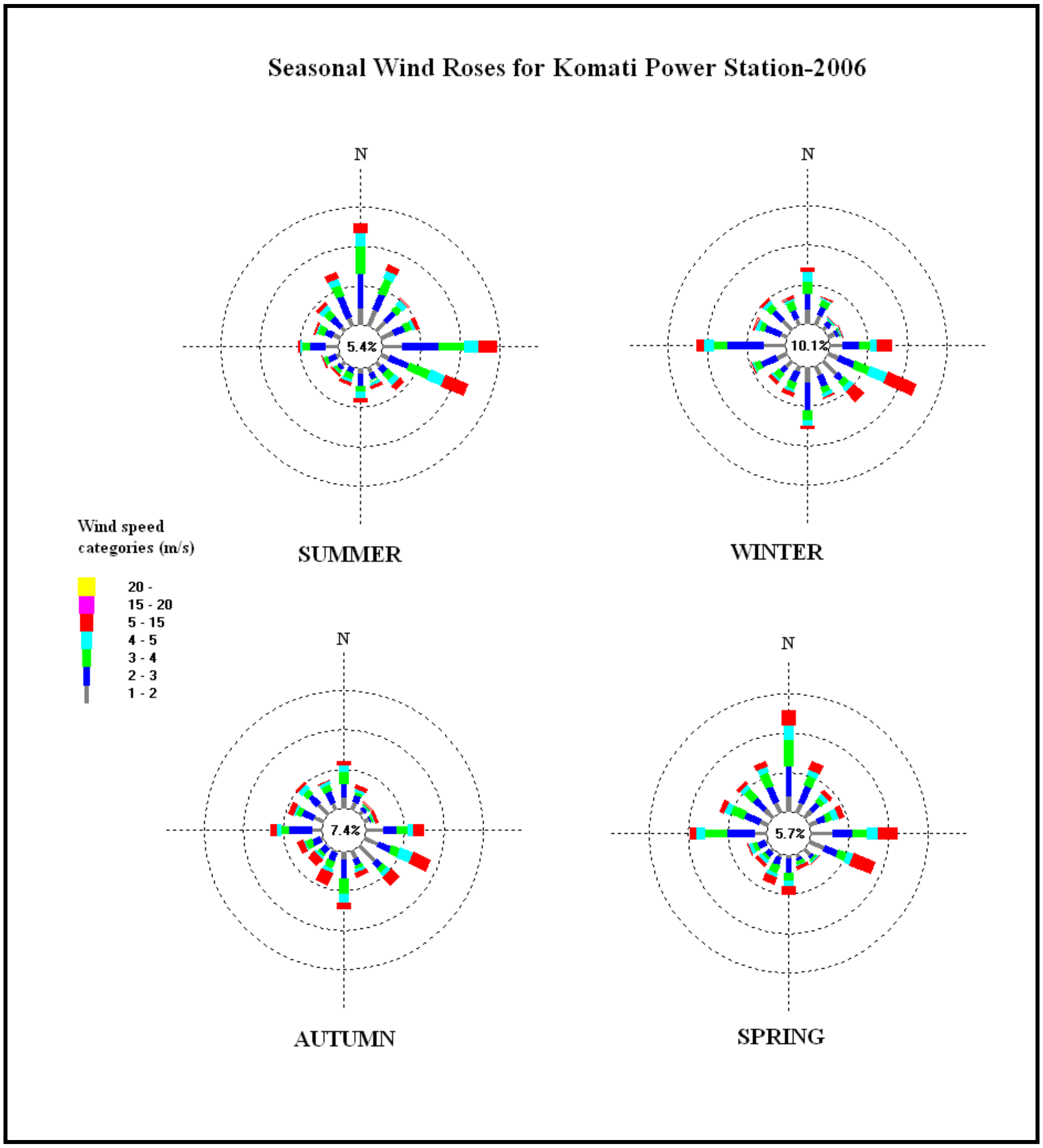

Figure 4-2: Seasonal wind roses for Komati Power Station site for the period 2006.

4.1.2 Air 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 the mixing and inversion layers. The temperature trends for Komati Power Station for the year 2006 are presented in Figure 4-3.

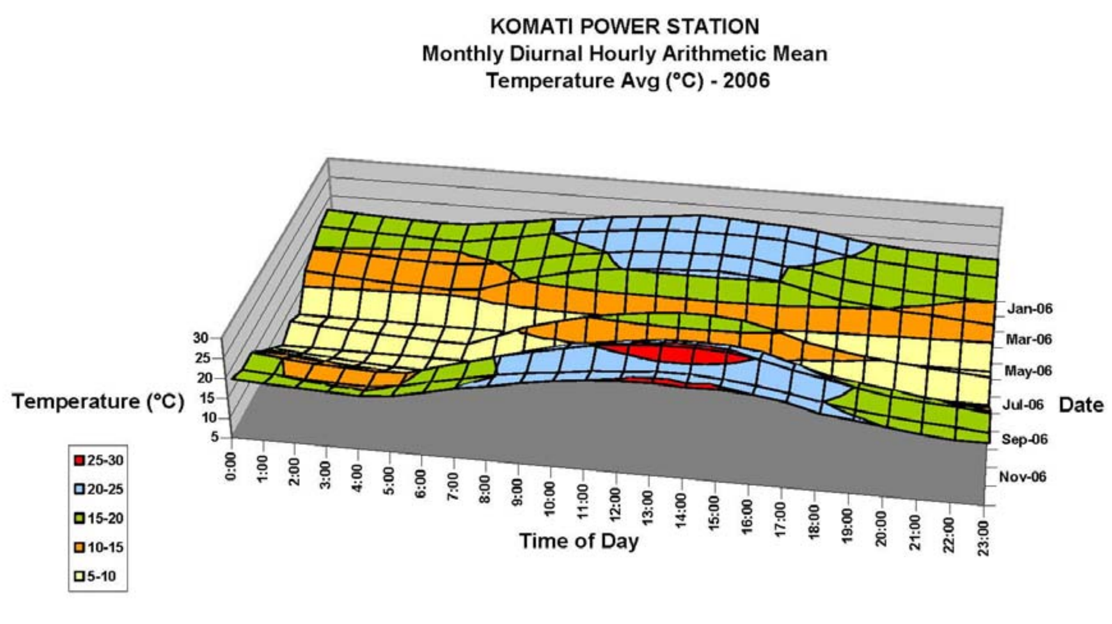

Figure 4-3: Air temperature trends for Komati Power Station for the year 2006.

Since no long term data was available for the Komati Power Station and Witbank areas, reference was made to long term climate data for Middelburg. The long term temperature trends recorded for Middelburg from 1925-1950 are presented in Table 3-1. Minimum long-term temperatures have been recorded as ranging from -1.8°C to 13.7°C with maximum temperatures ranging between 18.4°C and 27.1°C, as presented in Table 4-1. Mean temperatures, recorded over the long-term, ranged between 8.3°C and 20.5°C.

Table 4-1: Long-term minimum, maximum and mean temperature for Middelburg - 1925-1950 (Schulze, 1986)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Middelburg	Maximum	27.2	26.8	26.0	23.9	21.3	18.5	18.4	21.4	24	26	26.2	27.1
	Mean	20.5	20.1	18.7	15.7	11.7	8.3	8.3	11.1	14.7	18.0	19.0	20.1
	Minimum	13.7	13.4	11.4	7.4	2.2	-1.8	-1.7	0.8	5.3	10.1	11.8	13.2

4.1.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Long-term monthly average rainfall data for Middelburg is shown in Table 4-2 and Figure 4-4. No data for hail, snow and fog days observed to occur at Middelburg during the period 1904-1950 was available. The average total annual rainfall is ~735 mm. Rain falls mainly in summer from October to April, with the peak being in January for the region (Weather Bureau, 1986).

Table 4-2: Long-term *average* monthly rainfall figures (mm) for Middelburg (Schulze, 1986)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Middelburg (1904 – 1950)	132	103	88	42	19	7	9	8	22	63	124	118	735

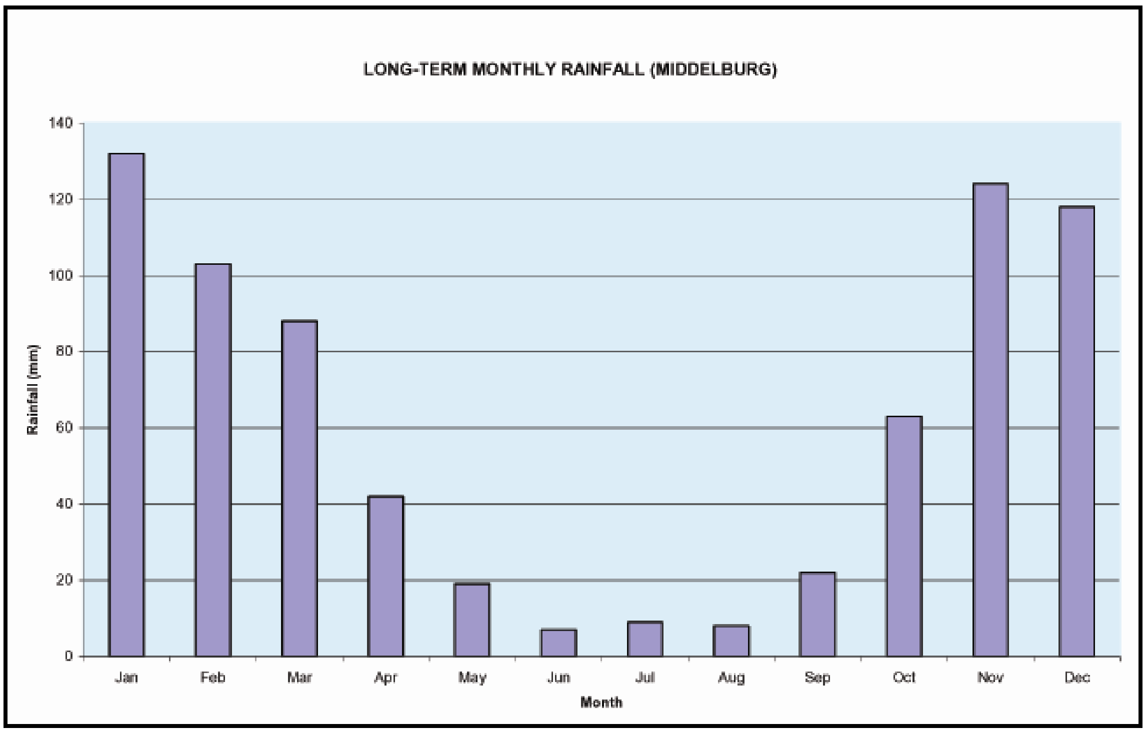

Figure 4-4: Long term average monthly rainfall for Middelburg

4.1.4 Atmospheric Stability and Mixing Depth

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

The mixed layer ranges in depth from a few metres (i.e. a stable or neutral layers) during nighttimes to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons, and on some occasions as many as five may occur in the first 1000 m above the surface. The lowest-level elevated inversion is located at a mean height above ground of 1 550 m during winter months with a 78 % frequency of occurrence. By contrast, the mean summer subsidence inversion occurs at 2 600 m with a 40% frequency.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 4-3.

Table 4-3: Atmospheric stability classes

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

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

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

4.2 Baseline Air Quality

The objective of the baseline assessment is to understand the extent of air pollution levels in the region and to identify the main contributing sources to such levels. In the baseline air quality characterisation use was made of previous dispersion modelling results from Eskom. Eskom undertook ambient sulphur dioxide concentration and meteorological monitoring in the vicinity of the Komati Power Station during the January 1984 to December 1988 period, during which time the power station was operational. No ambient PM10 concentrations were recorded.

4.2.1 Sources of Atmospheric Emissions in the Region

Sources of SO_2 and NO_x that occur in the region include Eskom power stations, industrial emissions, blasting operations at mines and spontaneous combustion of discard at coal mines, veld burning, vehicle exhaust emissions and household fuel burning. The highest ground level concentrations due to the Eskom Power Station stack emissions are expected to occur during unstable conditions when the plume is forced to ground in relatively close proximity to the power station.

Various local and far-a-field sources are expected to contribute to the suspended fine particulate concentrations in the region with the Eskom Power Stations predicted to contribute only marginally to such concentrations. Local sources include wind erosion from exposed areas, fugitive dust from agricultural and mining operations, particulate releases from industrial operations, vehicle entrainment from roadways and veld burning. Household fuel burning also constitutes a significant local source of low-level emissions. Long-range transport of particulates, emitted from remote tall stacks and from large-scale biomass burning in countries to the north of South Africa, has been found to contribute significantly to background fine particulate concentrations over the interior (Andrea *et al.*, 1996; Garstang *et al*., 1996; Piketh, 1996).

4.2.2 Existing Air Quality within the Region

The Mpumalanga Highveld (formerly known as the Eastern Transvaal Highveld) has frequently been the focus of air pollution studies for two reasons. Firstly, elevated air pollution concentrations have been noted to occur in the region itself. Secondly, various elevated sources of emission located in this region have been associated with the long-range transportation of pollutants and with the potential for impacting on the air quality of the adjacent and more distant regions (Piketh, 1994). Criteria pollutants identified as of major concern in the region include particulates, sulphur dioxide and nitrogen oxides. (Scorgie *et al*, 2006).

The predicted highest and annual average concentrations of particulates in the study region for all the sources according to a cumulative study conducted for Eskom in 2006 in the study region are shown in Figures 4-6 and 4-7. The study led to the conclusion that elevated PM10 concentrations were predicted to occur in the study region.

Background maximum daily concentrations were estimated to be between 25 µg/m³ and 75µg/m³ in the region. Annual average concentrations are estimated to be about 10 µg/m³.

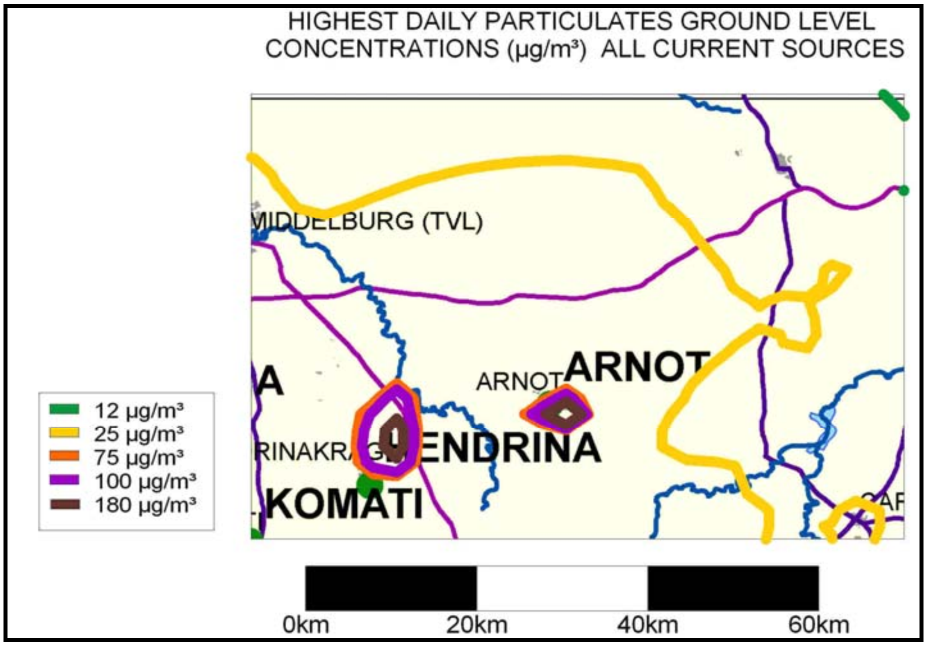

Figure 4-5: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources in the study region due for the current operations (Eskom Mpumalanga Cumulative Scenario Planning Study, Scorgie *et al, 2006*)

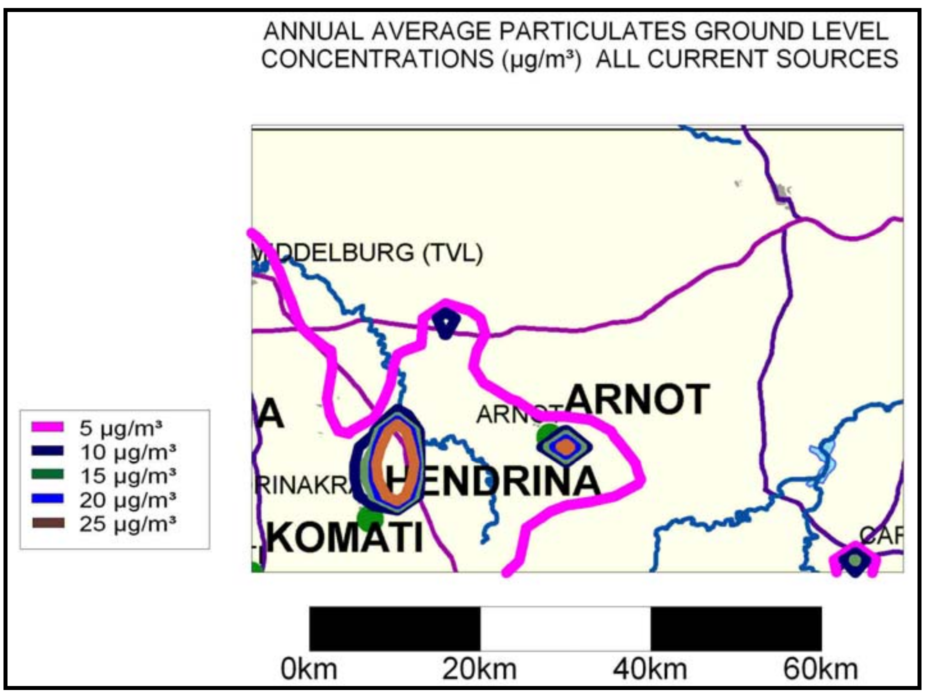

Figure 4-6: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources in the study region due to current operations. (Eskom Mpumalanga Cumulative Scenario Planning Study, Scorgie *et al, 2006).*

5. IMPACT ASSESSMENT: CONSTRUCTION PHASE

The construction phase for the proposed ash dam extension at Komati Power Station will comprise various activities. Activities associated with this phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction and most of these activities will be carried out during the construction of unpaved roads which will provide access to the ash dam. Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. Aspects associated with the construction phase in terms of air quality are outlined in Table 5-1.

Table 5-1: Environmental impacts and associated activities during the construction phase

Impact	Source	Activity
	Unpaved roads	Vehicle entrainment on unpaved roads surface
		Clearing and levelling of roads
	Ash dam site	Clearing of groundcover
		Materials handling (loading and hauling of topsoil)
		Wind erosion from exposed areas
		Vehicle entrainment on unpaved road surfaces
Gases and particulates	Vehicles	Tailpipe emissions from construction vehicles at the site.

5.1 PM10 Concentrations and Dust Fallout due to Construction Phase Activities

PM10 concentrations and dust fallout were simulated for two scenarios and the description is outlined in Table 5- 2.

Table 5-2: Scenarios simulated for the PM10 concentrations during the construction phase.

Scenario 1	o Construction activities during the extension of the ash dams were simulated to determine the unmitigated impacts of the proposed ash dam extension operations. o No mitigation measures were applied to the construction activities.
Scenario 2	o Construction activities during the extension of the ash dams were simulated to determine the mitigated impacts of the proposed ash dam extension operations. o Mitigation measures were applied to the construction activities (50% control efficiency).

5.2 Quantification of Environmental Aspects

5.2.1 Estimation of Emissions

In the quantification of fugitive dust releases and gaseous emissions from the proposed ash dam extension 3 activities, use was made of the predictive emission factor equations published by the US-EPA (EPA, 1996). Fugitive dust emission rates were estimated for PM10 (i.e. particles <10 μm) and total suspended particulate (TSP). Ambient PM10 concentrations were simulated on the basis of the emission rates estimated to determine potential health impacts. TSP emissions were required for the simulation of dustfall levels.

5.2.1.1 Topsoil removal by Scraper

The US.EPA in their AP42 document on Western Surface Coal mining has a single values emission factor to quantify the amount of fugitive dust deriving from topsoil removal by scraper. The units are in kg per Mg.

$$E_{TSP} \quad = 0.029 \text{ kg of dust / tonne of topsoil removed}$$

The PM10 fraction was assumed to be 52% of the TSP.

Scraping of topsoil takes place during the construction of the unpaved road networks for the proposed ash dam extension activities.

5.2.1.2 Construction activities during the Ash Dam Extension Activities

If detailed information regarding the construction phase of the proposed ash dam extension at Komati Power Station had been available, the construction process would have been broken down into component operations as shown in Table 6-1, for emissions quantification and dispersion simulations. Due to the lack of detailed information (e.g. number of scrappers, dozers to be used, size and locations of temporary stockpiles and temporary roads, rate of on-site vehicle activity), emissions were instead estimated on an area wide basis. The quantity of dust emissions was assumed to be proportional to the area of land being worked and the level of construction activity.

The US-EPA documents emission factors that aim to provide a general rule-of–thumb as to the magnitude of emissions, which may be anticipated from construction operations. Based on field measurements of total suspended particulate, the approximate emission factors for construction activity operations are given as:

$$E = 2.69 \text{Mg/ hectare/ month of activity } (269 \text{g/ m}^2\text{/ month})$$

The Midwest Research Institute (1999), provide a construction emission factor for PM10. The approximate emission factor for construction activity operations for inhalable particulate is given as:

E= 0.42 Mg/ acre/ month of activity (103.8g/ m²/ month)

The PM10 fraction is given as ~39% of the US-EPA total suspended particulate factor. It is applicable to construction operations with active large –scale earth moving operations. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semi-arid climates. The emission factor for TSP considers 42 hours of work per week of construction activity.

5.2.1.3 Dispersion Simulation Results

Simulations were undertaken to determine inhalable particulate (PM10) concentrations and dustfall rates. PM10 concentrations were simulated to determine highest daily average levels. This averaging period was selected to facilitate comparisons between predicted concentrations and ambient air quality guidelines and standards. Maximum total daily dustfall was similarly modelled to allow for the categorisation of predicted dust deposition rates based on the SA standards and SANS (proposed SA standards). dustfall classification criteria. Annual average PM10 concentrations and average daily dust deposition rates were simulated for the construction phase as the worst case scenario in case the duration of this phase exceeded 1 year. Isopleth plots illustrating spatial distributions of predicted pollutant concentrations and dust deposition rates are presented in Figures 5-1 to 5-8 as shown in Table 5-3 below.

Table 5-3: Figure numbers for the construction phase isopleths plots

Pollutant and Averaging Period	Figure No.
Highest daily and annual PM10 concentrations	Figure 5-1 to 5-4
Maximum total daily dustfall	Figure 5-5 to 5-8

Construction Phase Scenario 1: PM10 and Dust fallout (Unmitigated)

- The predicted unmitigated highest daily average ground level concentrations for the proposed construction activities exceed the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and sensitive receptor site of Komati (Table 5-4). These standards are however, not exceeded at the sensitive receptor sites of Koornfontein and Blinkpan. This could be attributed to the fact that these sensitive receptors are located further away from the Komati Power Station while the town of Komati is located closer to the power station and in the direction of the prevailing easterly winds.

- The predicted unmitigated maximum daily dust deposition rates for the proposed construction activities do not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites (Table 5-4).

Construction Phase Scenario 2: PM10 and Dust fallout (Mitigated)

- The predicted mitigated highest daily average ground level concentrations for the proposed construction activities do not exceed the daily SA standard of 180 µg/m³ at the site boundary and sensitive receptor site of Komati, but exceed the proposed SA standard of 75 µg/m³ at both sites (Table 5-5). These standards are however, not exceeded at the sensitive receptor sites of Koornfontein and Blinkpan.

- The predicted mitigated maximum daily dust deposition rates for the proposed construction activities do not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites (Table 5-5).

Isopleth plots reflecting daily averaging periods contain only the highest predicted ground level concentrations/deposition levels for that averaging period, over the entire period for which simulations were undertaken. *It is therefore possible that even though a high daily concentration or dustfall rate is predicted to occur at certain locations, that this may only be true for one day during the entire period of operation.*

Maximum PM10 concentrations and dustfall rates predicted to occur within the immediate vicinity of the mine and off-site at the closest sensitive receptor due to the proposed construction activities are summarised in Table 5-4.

Table 5-4: Maximum PM10 concentrations and dustfall rates due to the proposed extension construction activities without mitigation (i) close to the sensitive receptors (Komati, Koornfontein and Blinkpan) (ii) off-site (at the site boundary).

Highest Daily Average PM10 Concentrations (µg/m³)				Maximum Total Daily Dustfall (mg/m²/day)			
At Site Boundary	Komati	Koornfontein	Blinkpan	At Site	Komati	Koornfontein	Blinkpan
320	287	64.8	41.2	250	105	12.5	11

Table 5-5: Maximum PM10 concentrations and dustfall rates due to the proposed extension construction activities with mitigation (i) close to the sensitive receptors (Komati, Koornfontein and Blinkpan) (ii) off-site (at the site boundary).

Highest Daily Average PM10 Concentrations (µg/m³)				Maximum Total Daily Dustfall (mg/m²/day)			
At Site Boundary	Komati	Koornfontein	Blinkpan	At Site	Komati	Koornfontein	Blinkpan
150	143	32.6	19	122	52.6	6	5

Dust concentrations and deposition rates due to the construction phase of the proposed extension activities are unlikely to be of high significance given the short duration over which construction operations occur. It is however recommended that effective dust control measures be implemented in line with good practice. Effective dust control measures during the construction phase will lead to significant reductions in predicted impacts at the sensitive receptor areas. The implementation of effective controls during this phase would also serve to set the president for mitigation during the operational phase.

Dust control measures that may be implemented during the construction phase are outlined in Table 5-6. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed through the use of windbreaks and source enclosures. Emission control efficiencies of 50% can readily be achieved through the implementation of effective watering programmes for unpaved roads and material handling points. In the dispersion simulations an emission scenario comprising a 50% control efficiency on construction phase emissions was therefore included.

Table 5-6: Dust control measures implementable during construction activities

Construction Activity	Recommended Control Measure(s)
Debris handling	Wind speed reduction through sheltering Wet suppression
Truck transport and road dust entrainment	Wet suppression or chemical stabilization of unpaved roads Reduction of mud/dirt carry-out onto paved roads Reduction of unnecessary traffic Require haul trucks to be covered Wet material being hauled Strict speed control
Materials storage, handling and transfer operations	Wet suppression
Earthmoving and dozing operations	Wet suppression
General construction	Wind speed reduction Wet suppression Phasing of earthmoving activities to reduce source size Early paving of permanent roads
Open areas (wind-blown emissions)	Reduction of extent of open areas Reduction of frequency of disturbance Early revegetation Compaction and stabilization (chemical or vegetative) of disturbed soil

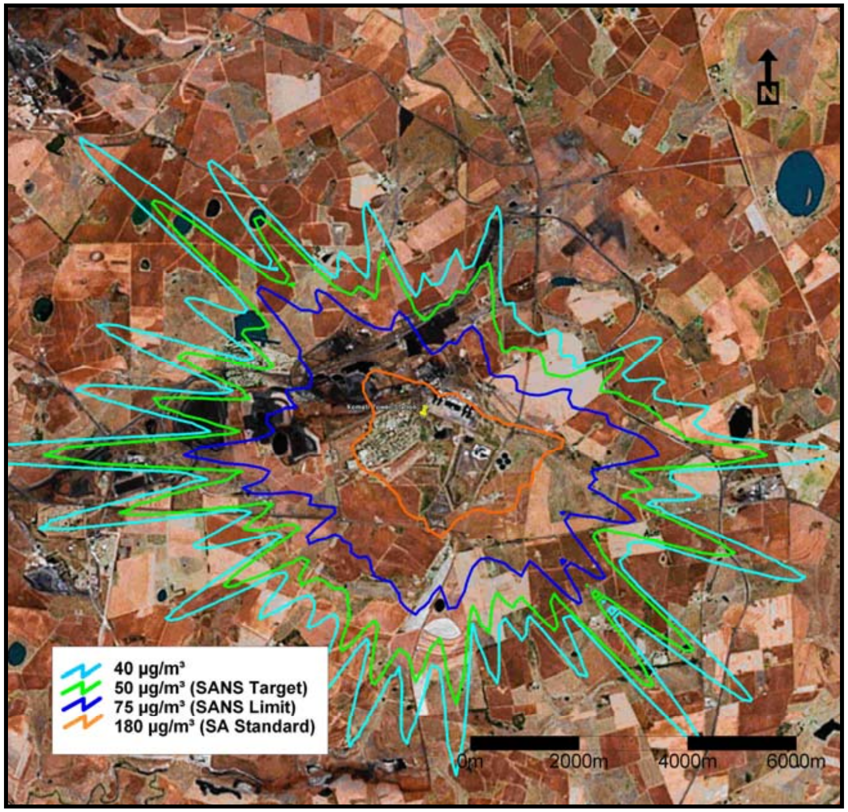

Figure 5-1: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to uncontrolled construction phase emissions for the proposed operations at Komati Power Station (Scenario 1)

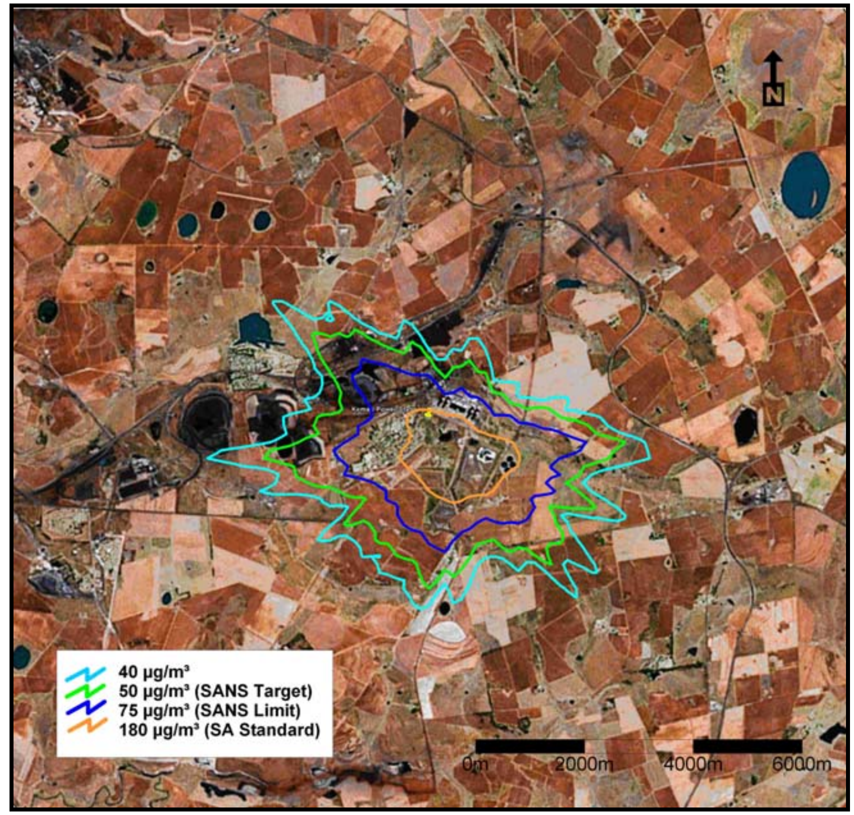

Figure 5-2: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially controlled construction phase emissions for the proposed operations at Komati Power Station (Scenario 2).

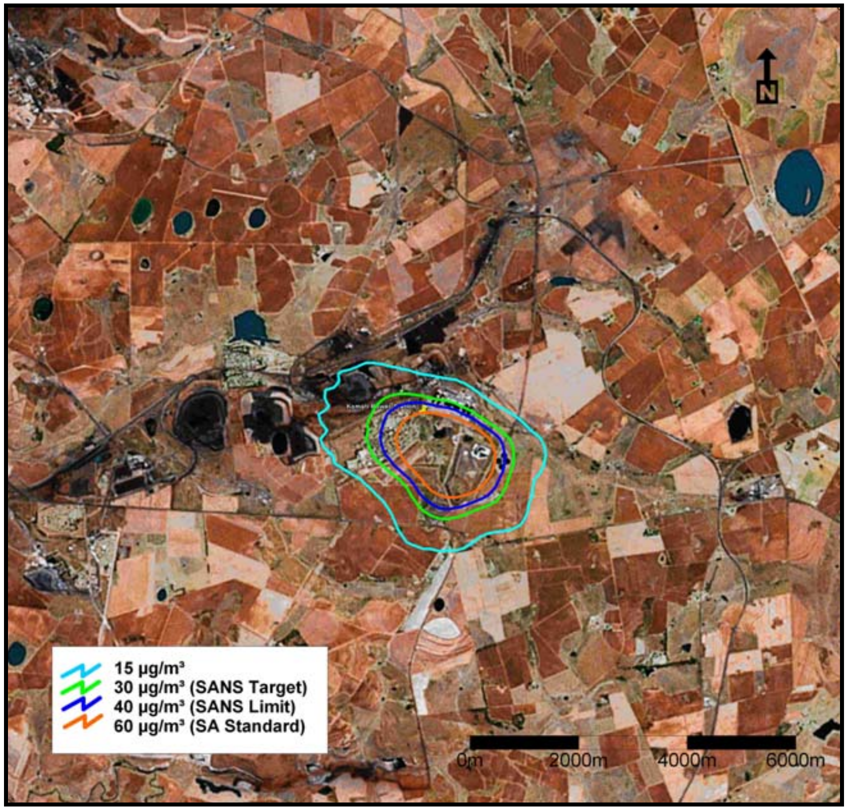

Figure 5-3: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to uncontrolled construction phase emissions for the proposed operations at Komati Power Station (Scenario 1)

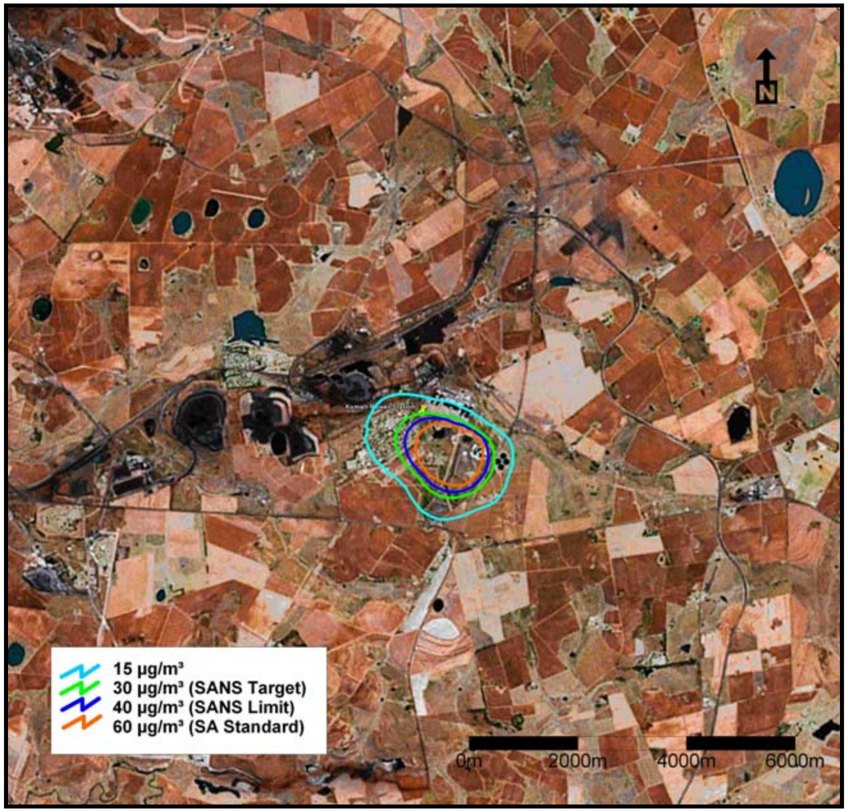

Figure 5-4: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially controlled construction phase emissions for the proposed operations at Komati Power Station (Scenario 2)

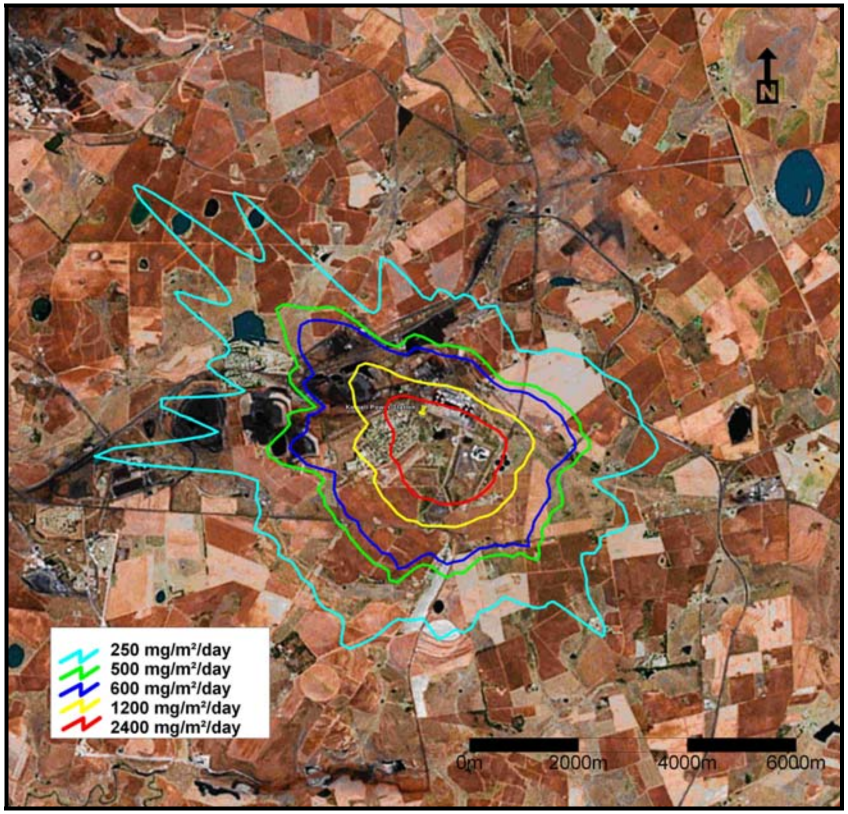

Figure 5-5: Maximum daily dust deposition rates (mg/m²/day) for all sources due to uncontrolled construction phase emissions during the proposed Komati operations (Scenario1)

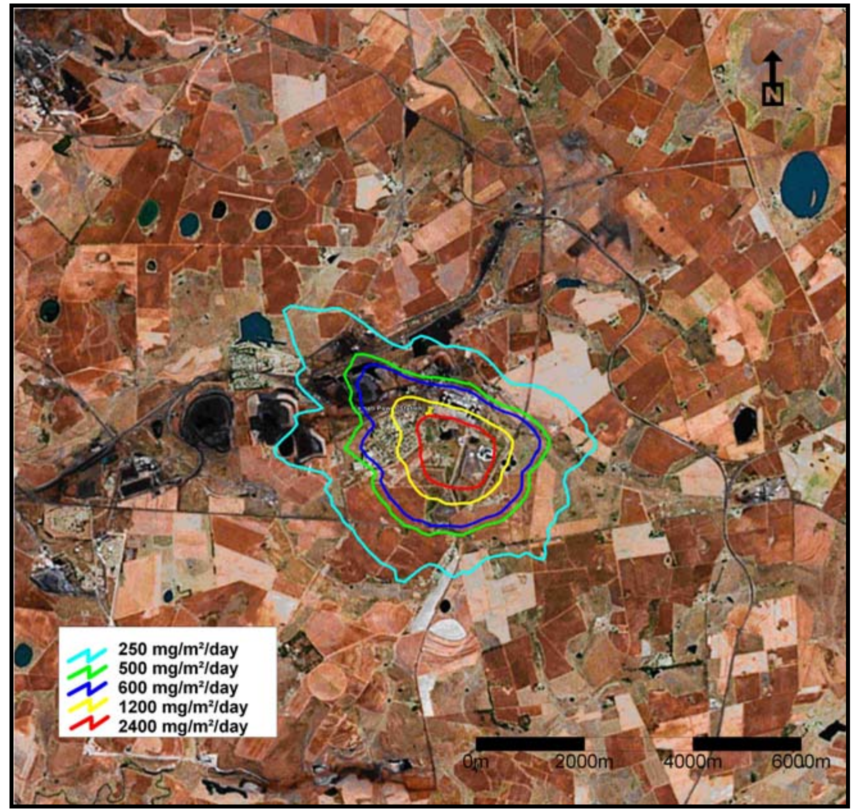

Figure 5-6: Maximum daily dust deposition rates (mg/m²/day) for all sources due to partially controlled construction phase emissions during the proposed Komati operations (Scenario 2).

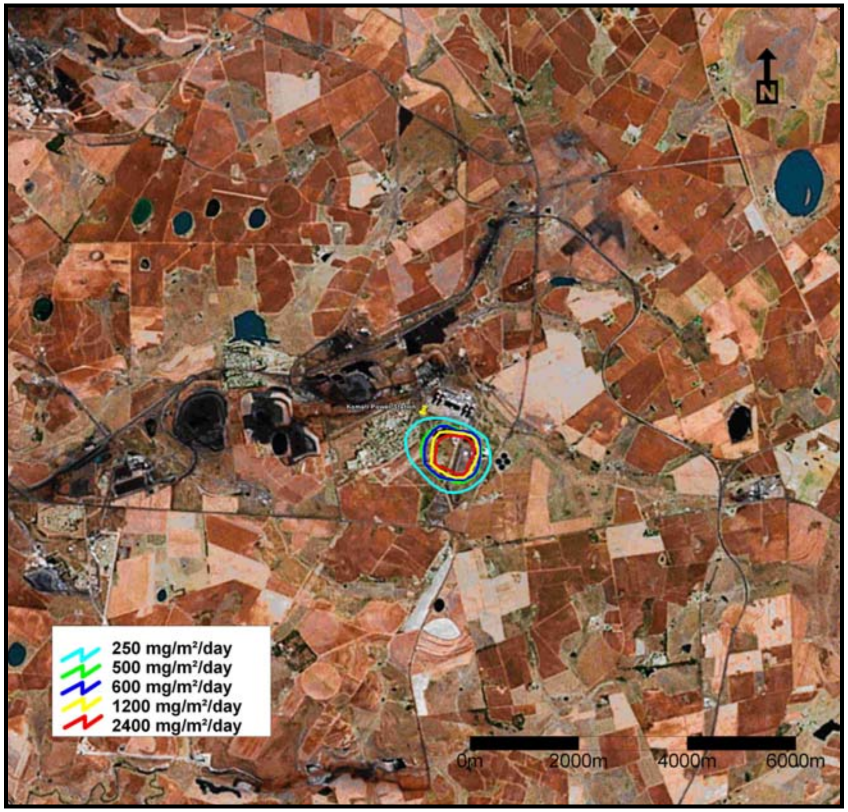

Figure 5-7: Average daily dust deposition rates (mg/m²/day) for all sources due to uncontrolled construction phase emissions during the proposed Komati operations (Scenario1)

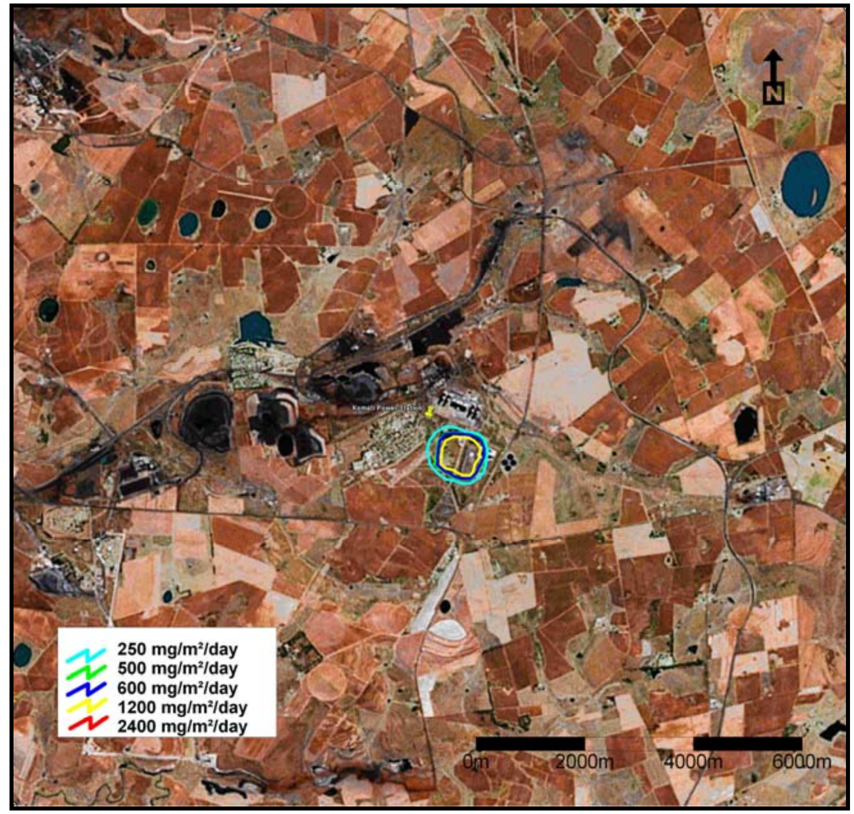

Figure 5-8: Average daily dust deposition rates (mg/m²/day) for all sources due to partially controlled construction phase emissions during the proposed Komati operations (Scenario1)

6. IMPACT ASSESSMENT: OPERATIONAL PHASE

6.1 Emissions Inventory

An emissions inventory is necessary to provide the source and emissions data required as input to the atmospheric dispersion simulations. The establishment of an emissions inventory comprises the following: (i) identification of sources of emission; (ii) identification of types of pollutants being released; (iii) determination of pertinent source parameters (e.g. stockpile height and width); and (iv) quantification of each source's emissions. The activities and aspects identified for the construction and operational phases of Komati Power Station's proposed ash dam extension are depicted in Table 6-1.

Table 6-1: Activities and aspects identified for the construction and operational phases of Komati Power Station proposed ash dam extension activities.

Impact	Source	Activity
Particulates	Materials handling operations	Tipping of topsoil into haul trucks after scrapping activities on the proposed ash dam extension area.
		Tipping of topsoil to topsoil stockpiles by the haul trucks.
	Wind Erosion	Exposed ash dam areas
	Vehicle Activity on unpaved roads	Scrappers and bulldozers activity during the construction of the unpaved roads to be utilised during the proposed ash dam extension activities and operational phase
Gases and particles	Vehicle activity	Tailpipe emissions from haul trucks and scrappers/bulldozers
		Tailpipe emissions from further transport mediums (private motor vehicles, mine personnel movement etc

Notes:
1. Gases and particulates resultant from the listed vehicle activity were not simulated

6.1.1 Wind erosion from Exposed Areas

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

Topsoil and overburden stockpiles were identified to be sources that are significantly prone to wind erosion.

The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface. Equations used for calculating emission rates from wind erosion sources are shown below. The equations used are as follows:

$$E_i = G_i 10^{(0.134C-6)}$$

where,

$$G_i = 0.261 \frac{\rho_a}{g} U_*^3 (1+R_i)(1-R_i^{\ 2})$$

$$R_i = \frac{U_{t*i}}{U_*}$$

and,

E_i = Emission rate (size category i)
C = clay content (%)
ρ_a = air density
g = gravitational acceleration
U_* = frictional velocity
U_{t*i} = threshold frictional velocity (size category i)

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure 6-1.

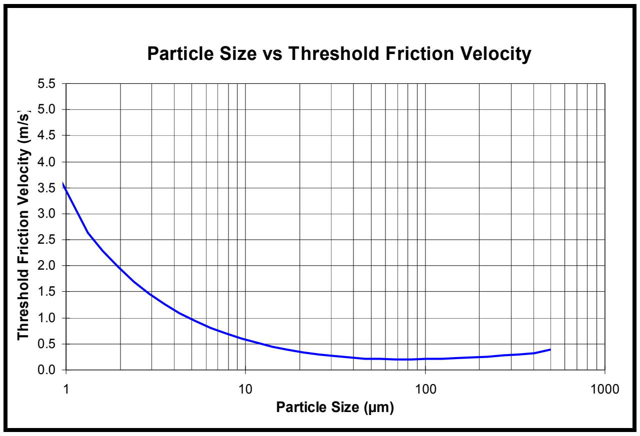

Figure 6-1: Relationship between particle sizes and threshold friction velocities using the calculation methods proposed by Marticorena and Bergametti (1995)

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (EPA, 1996):

$$U^* = 0.053U_{10}^+$$

(This equation assumes a typical roughness height of 0.5 cm for open terrain, and is restricted to large relatively flat piles or exposed areas with little penetration into the surface layer.)

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

Information pertaining to the exposed ash dam areas is listed in Table 6-2. The parameters used for the calculation of emissions from the ash dams are shown in Table 6-3, while those used in the calculation of emissions from topsoil scrapping activities are shown in Table 6-4.

Table 6-2: Information Input into the AERMOD and ADDAS Models for the Proposed and Existing Ash Dams at Komati Power Station during the Operational Phase

Source	Height (m)	Area (m²)	x-length (m)	y-length (m)	Particle density (g/cm3)	Bulk density (kg/m3)	Moisture (%)
Ash dam 1	10	690 000	831	831	1.4	771	13.5
Ash dam 3	10	522 500	550	950	1.4	771	13.5

Table-6-3: Particle Size Distribution Used for the Proposed and Existing Ash Dams at Komati Power Station during the Operational Phase

Source	Particle Size Fraction (%)									
	68µm	56µm	46 µm	38 µm	31 µm	25 µm	17 µm	14 µm	8 µm	4 µm
Ash Dam	0.15	0.13	0.12	0.11	0.1	0.08	0.13	0.1	0.06	0.02

Table 6-4: Particle Size Distribution Used for Topsoil Scrapping Activities During the Construction Phase.

Source	Particle Size Fraction (%)							
	75µm	45µm	30µm	15µm	10µm	5µm	2.5µm	4 µm
Topsoil	0.12	0.14	0.21	0.09	0.14	0.1	0.13	0.07

6.2 Dispersion Modelling Results

Dispersion simulations were executed incorporating various scenarios including:

- Baseline: existing ash dam operations (Ash Dam 1);
- Operational phase: existing ash dam operations and Extension 3 (proposed ash dam extension operations).

6.2.1 Baseline: Existing Ash Dam Operations (Ash Dam 1)

The PM10 concentrations and dust deposition rates were simulated for one scenario and the description is outlined in Table 6-5.

Table 6-5: Scenario simulated for baseline PM10 concentrations and dust fallout

Baseline scenario	o Existing Ash Dam 1 wind erosion sources were modelled. o No mitigation measures were applied

This section focuses on potential impacts at the closest human sensitive receptor sites. These include the various settlements of Komati, Koornfontein and Blinkpan, which are located close to the Komati Power Station.

Baseline scenario

- The predicted unmitigated highest daily average ground level concentrations for the baseline do not exceed the daily SA standard of 180 μg/m³ and the proposed SA standard of 75 μg/m³ at the site boundary and all the sensitive receptor sites (Table 6-6) and Figure 6-2).

- The predicted unmitigated maximum daily dust deposition rates for the baseline do not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites (Table6-6 and Figure 6-4).

Table 6-6: Maximum PM10 concentrations and dustfall rates for the baseline without mitigation (i) close to the sensitive receptors (Komati, Koornfontein and Blinkpan) (ii) off-site (at the site boundary).

Highest Daily Average PM10 Concentrations (μg/m³)				Maximum Total Daily Dustfall (mg/m²/day)			
At Site Boundary	**Komati**	**Koornfontein**	**Blinkpan**	**At Site**	**Komati**	**Koornfontein**	**Blinkpan**
5	2	0.5	0.5	120	111	23	22

The current highest daily PM10 concentrations in the region are already between 25-75 μg/m³ and these background concentrations will increase the predicted PM10 concentrations for this scenario. It is therefore likely that without appropriate mitigation measures, the predicted highest daily concentrations could exceed the SANS and proposed SA standard of 75 μg/m³ at the site boundary and at all the sensitive receptor sites. Similarly, the annual values are expected to be higher due to the current PM10 levels (~10 μg/m³).

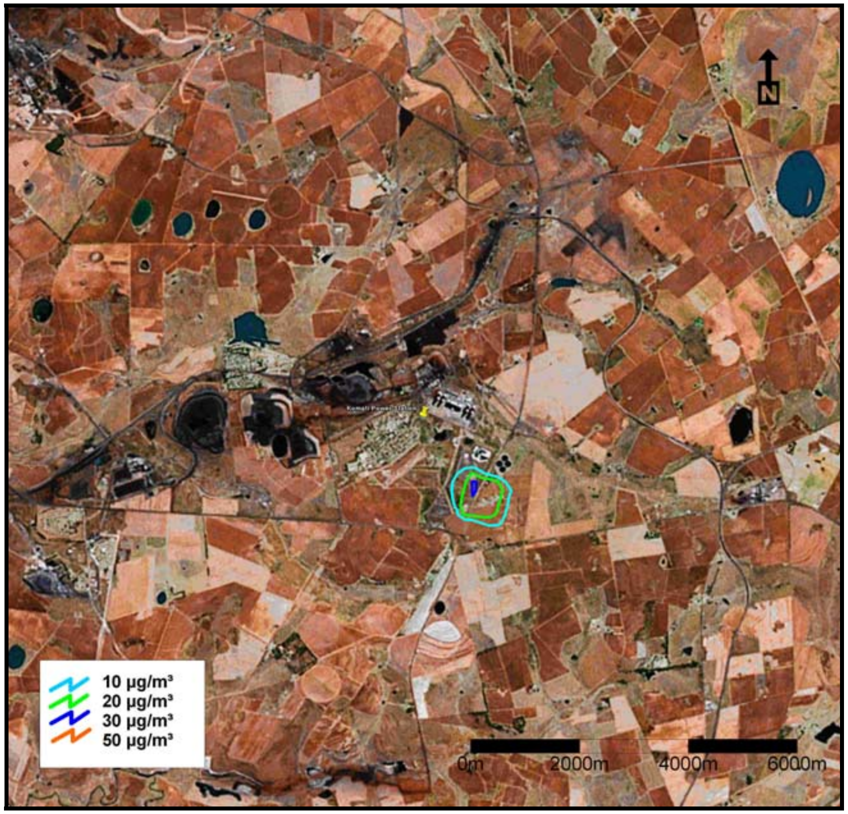

Figure 6-2: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to uncontrolled emissions (Baseline).

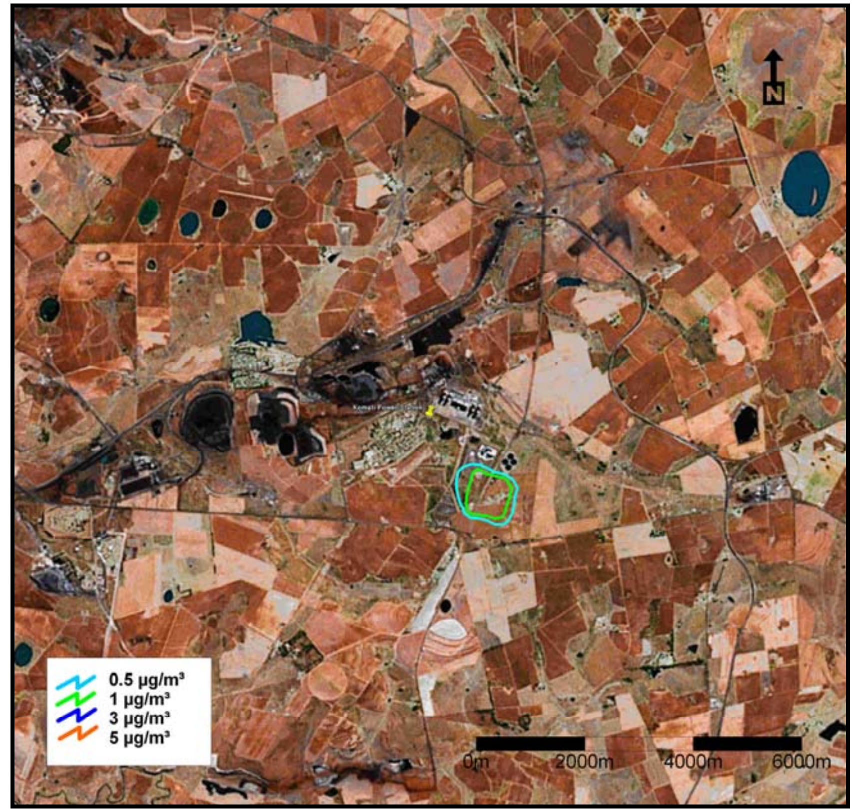

Figure 6-3: Annual average predicted PM10 ground level concentrations (µg/m³) due to partially controlled emissions (Baseline).

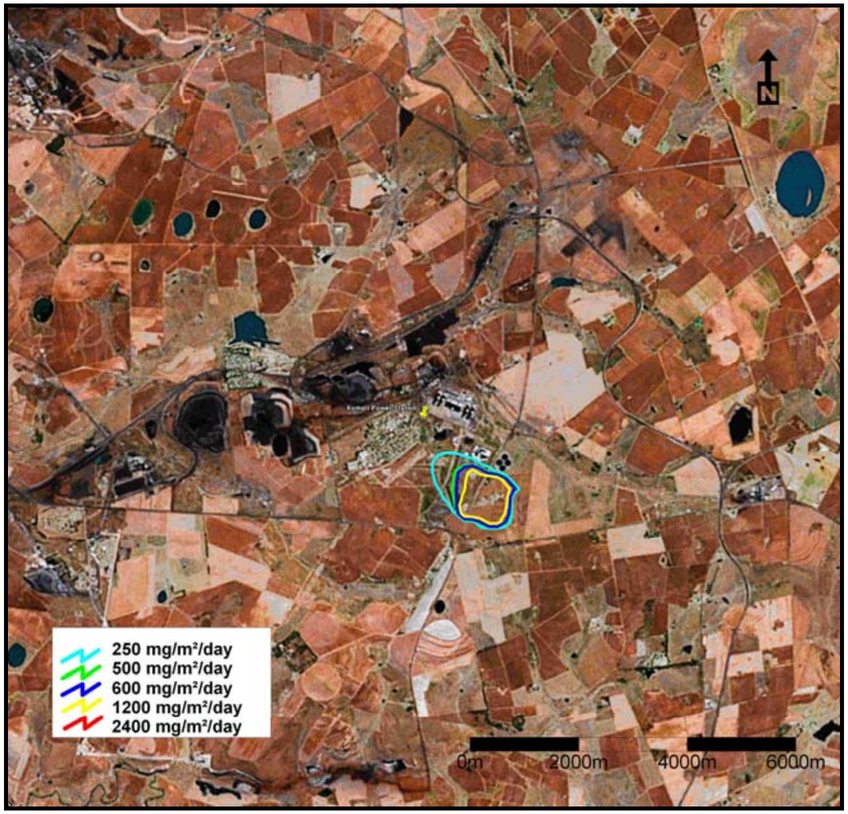

Figure 6-4: Maximum daily dust deposition rates (mg/m²/day) due to uncontrolled emissions (Baseline).

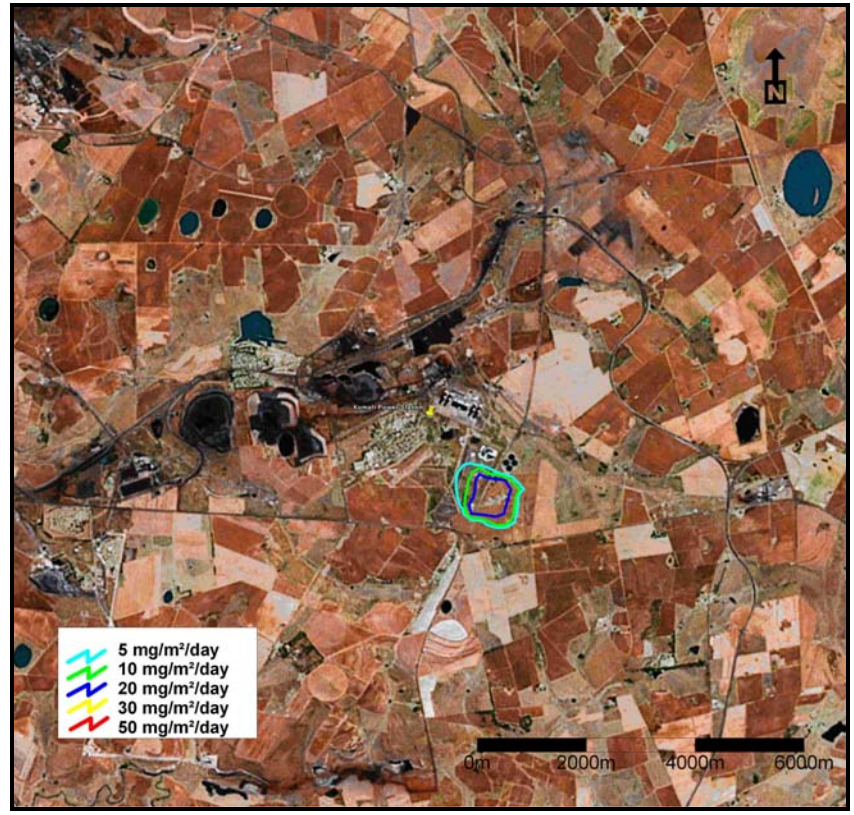

Figure 6-5: Maximum daily dust deposition rates (mg/m²/day) due to partially controlled emissions (Baseline).

6.3 Operational Phase PM10 Concentrations and Dust Fallout

The PM10 concentrations and dust fallout rates were simulated for one scenario and the description is outlined in Table 6-7.

Table 6-7: Scenario simulated for baseline PM10 concentrations and dust fallout rates

Operational Phase scenario	o Existing ash dam 1 and extension 3 wind erosion sources were modelled. o No mitigation measures were applied

Operational Phase scenario

- o The predicted unmitigated highest daily average ground level concentrations for the operational phase do not exceed the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and all the sensitive receptor sites (Table 6-8) and Figure 6-6).
- o The predicted unmitigated maximum daily dust deposition rates for the operational phase do not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites (Table 6-8) and Figure 6-8).

Table 6-8: Maximum PM10 concentrations and dustfall rates during the operational phase without mitigation (i) close to the sensitive receptors (Komati, Koornfontein and Blinkpan) (ii) off-site (at the site boundary).

Highest Daily Average PM10 Concentrations ($\mu g/m^3$)				Maximum Total Daily Dustfall ($mg/m^2/day$)			
At Site Boundary	Komati	Koornfontein	Blinkpan	At Site	Komati	Koornfontein	Blinkpan
6	4.2	0.77	0.8	260	229	32	35

The predicted PM10 concentrations and deposition rates due to the operational phase of the proposed extension activities are predicted to be of medium significance. It is therefore recommended that effective mitigation measures be implemented in order for the impacts to be of low significance. Even so, it should be noted that the predicted impacts are reported for daily averages (health risk) and do not affect short-term impacts due to the wind gusts. During such events, large amounts of dust can result from the ash dams which are typically associated with nuisance impacts. Nuisance dust, even though not posing health risk, is perceived by people as an issue.

As already stated, the current highest daily PM10 concentrations in the region are already between 25-75 µg/m³ and these background concentrations will increase the predicted PM10 concentrations for the operational phase. Without mitigation measures, it is highly likely that the predicted highest daily PM10 concentrations could exceed the SANS and proposed SA standard of 75 μg/m³. Similarly, the annual values are expected to be higher due to the current PM10 levels (~10 μg/m³).

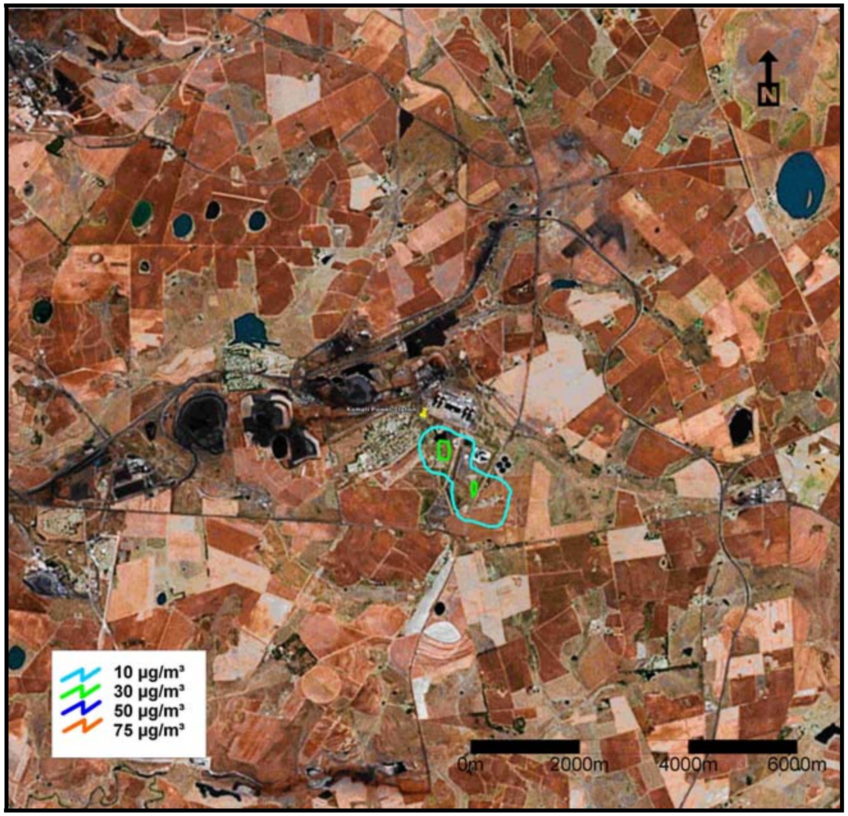

Figure 6-6: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to uncontrolled emissions during the operational phase.

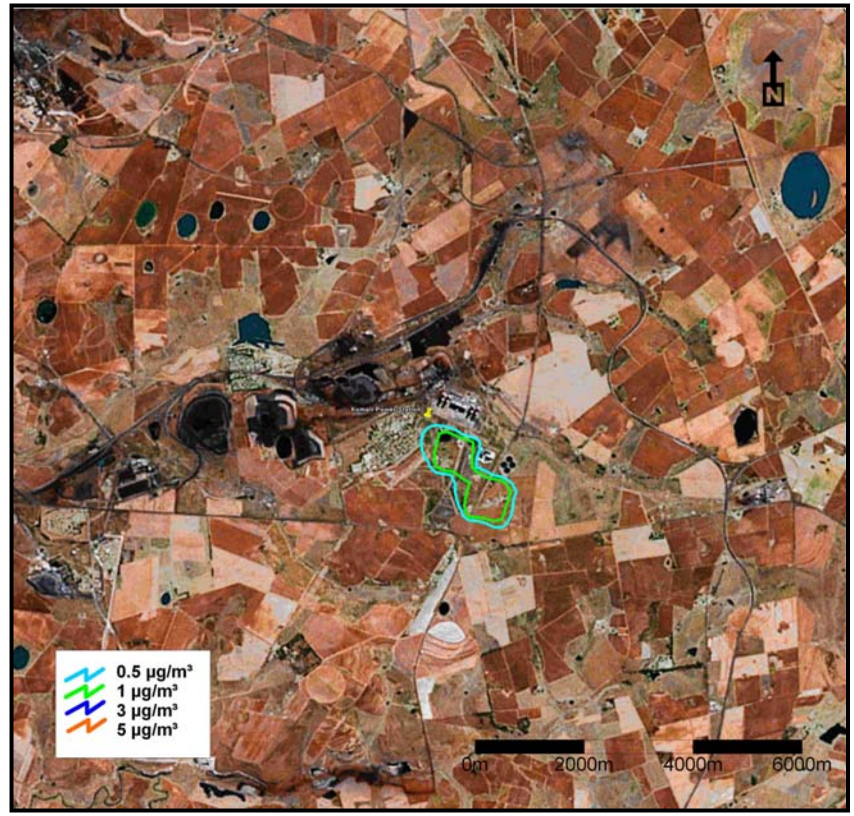

Figure 6-7: Annual average predicted PM10 ground level concentrations (µg/m³) due to partially controlled emissions during the operational phase.

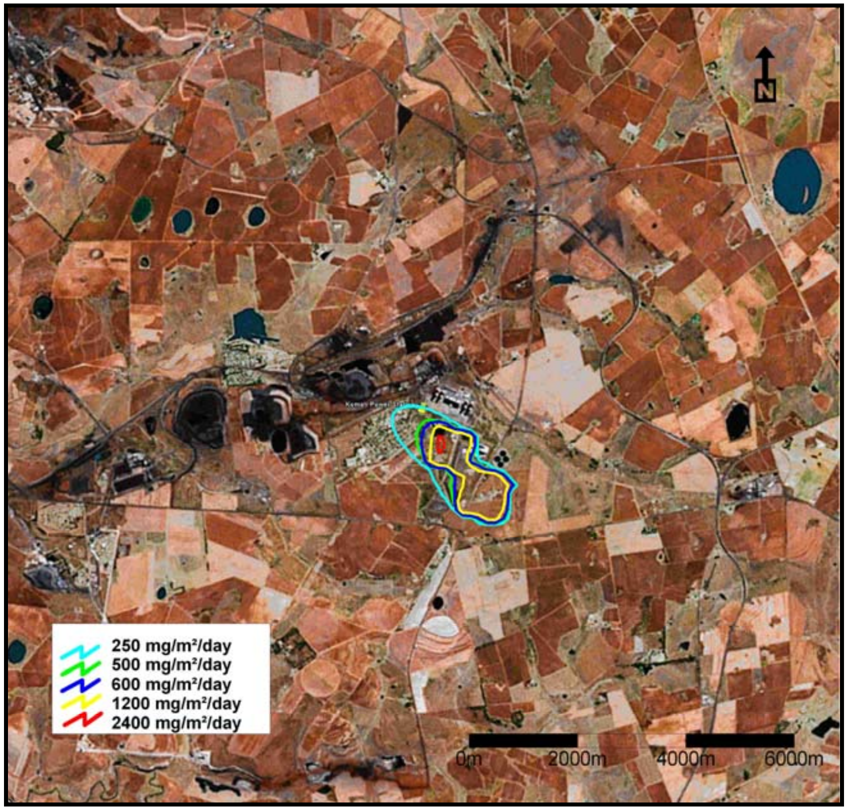

Figure 6-8: Maximum daily dust deposition rates (mg/m²/day) due to uncontrolled emissions during the operational phase.

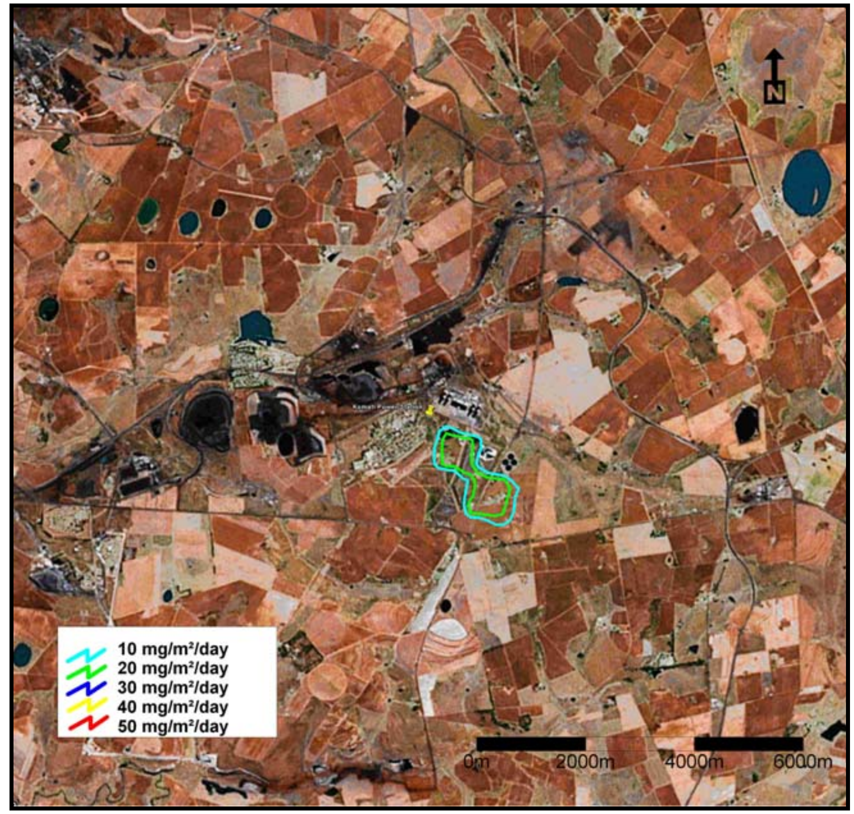

Figure 6-9: Average daily dust deposition rates (mg/m²/day) due to partially controlled emissions during the operational; phase.

7. AIR QUALITY MANAGEMENT PLAN FOR THE PROPOSED KOMATI ASH DAM EXTENSION

An air quality impact assessment was conducted for the proposed Komati ash dam extension operations as part of an Environmental Impact Assessment. The main objective of this study was to determine the significance of the predicted impacts from the proposed operations on the surrounding environment and on human health.

To achieve this objective, the local climate was characterised and existing ambient air quality data and dust fallout information evaluated, albeit only qualitatively. Particulates were identified to be the main pollutant of concern resulting from the proposed operations and all potential sources of fugitive dust have been identified and quantified. Dispersion simulations were undertaken to reflect both incremental (separate sources) and cumulative (all sources combined) impacts for the operational and construction phases and baseline.

The comparison of predicted pollutant concentrations to ambient air quality guidelines and standards facilitated a preliminary screening of the potential human health impacts. The sensitive receptors identified to be included in the assessment were the various settlements located around Komati Power Station.

7.1 Conclusions

7.1.1 Baseline Characterisation: Meteorology

Over the one year period (2006), predominant winds were from the north-east and north, with frequencies of up to 10%, with strong wind speeds of up to 15m/s. Calm conditions (wind speeds below 1 m/s) occurred 7.2% of the time. During day-time conditions, the predominant winds were from the north-westerly, northerly and easterly sectors, with an increase in the frequency of winds from the north-westerly sector. Night-time conditions were characterised by winds from the north-easterly and south–easterly sectors. The frequency of occurrence of the winds from the north-easterly sector was 12% and that of the south-easterly sector was 14%. The seasonal variability in the wind field for the Komati Power Station site for 2006 indicated the dominancy of winds from the easterly, south easterly and northerly sectors, with stronger winds of up to 15 m/s occurring in all sectors. During autumn, strong winds of up to 7.5 m/s blew more frequently from the north-westerly, south easterly and north easterly sectors with frequencies of up to 8%. The winter months reflected dominancy of winds from the northerly, south-easterly and westerly sectors although there was a noticeable decrease in the frequency of winds from the northerly sector compared to the summer months. In spring, the predominant winds were from the northerly, westerly and easterly sectors.

The Mpumalanga Highveld (formerly known as the Eastern Transvaal Highveld) has been noted to have increased air pollution concentrations and various elevated sources of emissions located in this region have been associated with the long-range transportation of pollutants and with the potential for impacting on the air quality of the adjacent and more distant regions. Criteria pollutants identified as of major concern in the region include particulates, sulphur dioxide (SO_2) and nitrogen oxides (NO_x). The simulated background concentrations for the Komati Power Station ranged between 25-75 µg/m³. This was based on all sources of particulate emissions within the Mpumalanga region as taken from the Eskom Report (2006).

7.1.2 Impact Assessment: Construction Phase

<u>Construction Phase Scenario 1: PM10 and Dust fallout (Unmitigated)</u>

- The predicted unmitigated highest daily average ground level concentrations for the proposed construction activities exceeded the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and sensitive receptor site of Komati. These standards were however, not exceeded at the sensitive receptor sites of Koornfontein and Blinkpan. This could be attributed to the fact that these sensitive receptors are located further away from the Komati Power Station while the sensitive receptor area of Komati is located closer to the power station.

- The predicted unmitigated maximum daily dust deposition rates for the proposed construction activities did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

<u>Construction Phase Scenario 2: PM10 and Dust fallout (Mitigated)</u>

- The predicted mitigated highest daily average ground level concentrations for the proposed construction activities did not exceed the daily SA standard of 180 µg/m³ at the site boundary and sensitive receptor site of Komati, but exceeded the proposed SA standard of 75 µg/m³ at both sites. These standards were however, not exceeded at the sensitive receptor sites of Koornfontein and Blinkpan.

- The predicted mitigated maximum daily dust deposition rates for the proposed construction activities did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

Dust concentrations and deposition rates due to the construction phase of the proposed extension activities are unlikely to be of high significance given the short duration over which construction operations occur. It is however recommended that effective dust control measures be implemented in line with good practice. The implementation of effective controls during this phase would also serve to set the president for mitigation during the operational phase. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed through the use of windbreaks and source enclosures. Emission control efficiencies of 50% can readily be achieved through the implementation of effective watering programmes for unpaved roads and material handling points.

7.1.3 Impact Assessment: Baseline Scenario

<u>Baseline scenario</u>

- o The predicted unmitigated highest daily average ground level concentrations for the baseline did not exceed the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and all the sensitive receptor sites.

- o The predicted unmitigated maximum daily dust deposition rates for the baseline did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

7.1.4 Impact Assessment: Operational Phase

<u>Operational Phase Scenario</u>

- o The predicted unmitigated highest daily average ground level concentrations for the operational phase did not exceed the daily SA standard of 180 µg/m³ and the proposed SA standard of 75 µg/m³ at the site boundary and all the sensitive receptor sites.
- o The predicted unmitigated maximum daily dust deposition rates for the for the operational phase did not exceed the SANS residential dust fallout limit of 600 mg/m²/day at the site boundary and at all the sensitive receptor sites.

The current highest daily PM10 concentrations in the region are already between 25-75 µg/m³ and these background concentrations will increase the predicted PM10 concentrations. It is therefore likely that without appropriate mitigation measures, the predicted highest daily concentrations could exceed the SANS and proposed SA standard of 75 µg/m³ at the site boundary and at all the sensitive receptor sites. Similarly, the annual values are expected to be higher due to the current PM10 levels (~10 µg/m³).

7.2 Site Specific Management Objectives

The main objective of Air Quality Management measures for the proposed operations at Komati Power Station is to ensure that all operations will be in compliance with the requirements of the Air Quality Act. In order to define site specific management objectives, the main sources of pollution needed to be identified. Sources can be ranked based on source strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

The main pollutants of concern identified during the impact assessment were particulates (PM10 and TSP).

7.2.1 Source Ranking by Emissions

7.2.1.1 Construction Phase

During the proposed extension activities, implementation of standard mitigation measures such as water sprays can be done to reduce the overall emissions (both TSP and PM10). Also, the implementation of dust abatement measures would restrict dustfall rates to within the “moderate’ to “low” range, whilst ensuring off-site dust-deposition is within the ‘slight’ class.

The tonnes per annum for PM10 and TSP for the construction phase are depicted in Table 8-1. The tonnes per annum were calculated using the construction equation.

Table 7-1: Unmitigated construction activities contribution to PM10 and TSP tonnes per annum for the baseline and operational phase

Source	Scenario	PM10 (tpa)	TSP (tpa)
All construction activities	Construction (unmitigated)	537	1517
	Construction (mitigated)	269	759

7.2.1.2 Baseline and Operational Phase

The primary source of emissions modelled for the baseline and operational phases is wind erosion of the exposed ash dams with PM10 and TSP tonnages shown in Table 8-2.

Table 7-2: Wind erosion contribution to PM10 and TSP tonnes per annum for the baseline and operational phase

Source	Scenario	PM10 (tpa)	TSP (tpa)
Wind erosion	Baseline (ash dam 1)	11.4	107.4
	Operational (ash dam 1 and ash dam extension 3)	15.1	141.8

7.2.2 Target Control Efficiencies

Based on the impact assessment, the following target control efficiencies for the main sources of emissions were determined.

7.2.2.1 Construction Phase

- Wind erosion from stockpiles and open areas – 50% control efficiency through effective vegetation cover and use of water sprays.

7.2.2.2 Operational Phase

- Vehicle entrainment on unpaved roads – 75% control efficiency through effective water sprays on haul roads.
- Wind erosion from stockpiles and open areas – 50% control efficiency through effective vegetation cover.

7.3 Project-specific Management Measures

It is recommended that the project proponent commits to air quality management planning throughout the various operations of the power station. It is recommended that an Air Pollution Control System (APCS) be developed for to reduce and control all main contributing sources. This APCS includes detailed management plans, mitigation measures and monitoring and operational procedures developed for each significant source of emissions to ensure emissions reductions will occur. The APCS must be implemented and revised on an on-going basis.

7.3.1 Identification of Suitable Pollution Abatement Measures

7.3.1.1 Vehicle Entrainment on Unpaved Haul Roads

Although vehicle entrained dust from unpaved road surfaces was not modelled for all the scenarios, it is recommended that mitigation measures be considered on all unpaved haul roads

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (EPA, 1987; Cowhert *et al.*, 1988; APCD, 1995).

7.3.1.2 Wind Erosion

Wind Erosion

The largest impacting source would be wind erosion from the ash dump. With no controls on the slopes and on the surfaces of the ash dump, impacts could be higher than predicted. Thus to ensure impacts of low significance, it is recommended that the walls of the ash dump be vegetated or covered up to 1 m from the top throughout the life of mine. The vegetation cover should be such to ensure at least 80% control efficiency for the walls. The surface areas should be kept wet, if feasible. A water spraying system could be implemented on the surface of the ash dump covering the outer perimeter of the dump, spraying water when wind exceeds 4 m/s. Experience has shown that the threshold wind velocity of local gold mine tailings impoundments generally accords with a wind speed of ~4.5 m/s (Mitzelle *et al.*, 1995), which corresponds with a threshold friction velocity of ~0.24 m/s. Thus it was assumed that similar principles would apply to the wind erodibility of ash dumps. In addition, screens could be installed on the crest of the ash dump walls mainly to act as wind breaks and to reduce the potential for dust deposition on the vegetated side walls, hence curbing the growth of the grass. The workable surface (disturbed surface) of the ash dump should be kept as small as possible to reduce the exposed surface.

It should be noted that the wind erosion equations are very sensitive to clay percentage, moisture content and particle size distribution of the material. It is therefore recommended that samples be taken and analysed for clay and moisture content, and particle size distribution as soon as the mine and power plant is in operation. The emissions should then be re-quantified and the simulation redone for inclusion into the management plan.

7.3.2 Monitoring Requirements

7.3.2.1 Performance Indicators

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of wind erosion exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below 250 mg/m^2/day represents an impact- or receptor-based performance indicator. Source-based performance indicators have been included in regulations abroad. The ambient air quality guidelines and standards given for respirable and inhalable particulate concentrations by various countries, including South Africa, represent receptor-based objectives. The dustfall categories issued by the Department of Environmental Affairs and Tourism, which have been accepted by the DME as the reference levels for dust deposition for the purposes of EMPs, also represent receptor-based targets.

7.3.3 Specification of Source Based Performance Indicators

It is recommended that dust fallout in the immediate vicinity should be less than 1 200 mg/m^2/day for unpaved roads associated with on-site activities.

The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dustfall in the immediate vicinity of various sources should be less than 1 200 mg/m^2/day. Dustfall levels from the proposed activities should not exceed 600 mg/m^2/day off-site.

7.3.4 Receptor based Performance Indicators

Based on the impacts predicted from the proposed operations on the surrounding environment and the limitations associated with the data used, it is recommended that the following be implemented:

- Establishment of a dust fallout network

Dust fallout monitoring network

It is advisable that a dust fallout monitoring network be set up once the proposed ash dams are in operation. This would provide management with an indication of what the fugitive dust levels are. In addition, a dust fallout network can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal trend analysis;
- Spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

A dust fallout monitoring network may include placing a dust fallout bucket west of the ash dams and the sensitive receptor area of Komati. Another single dust fallout bucket can be placed to the north of the ash dams as this is also the direction of the prevailing winds (Figure 7-1).

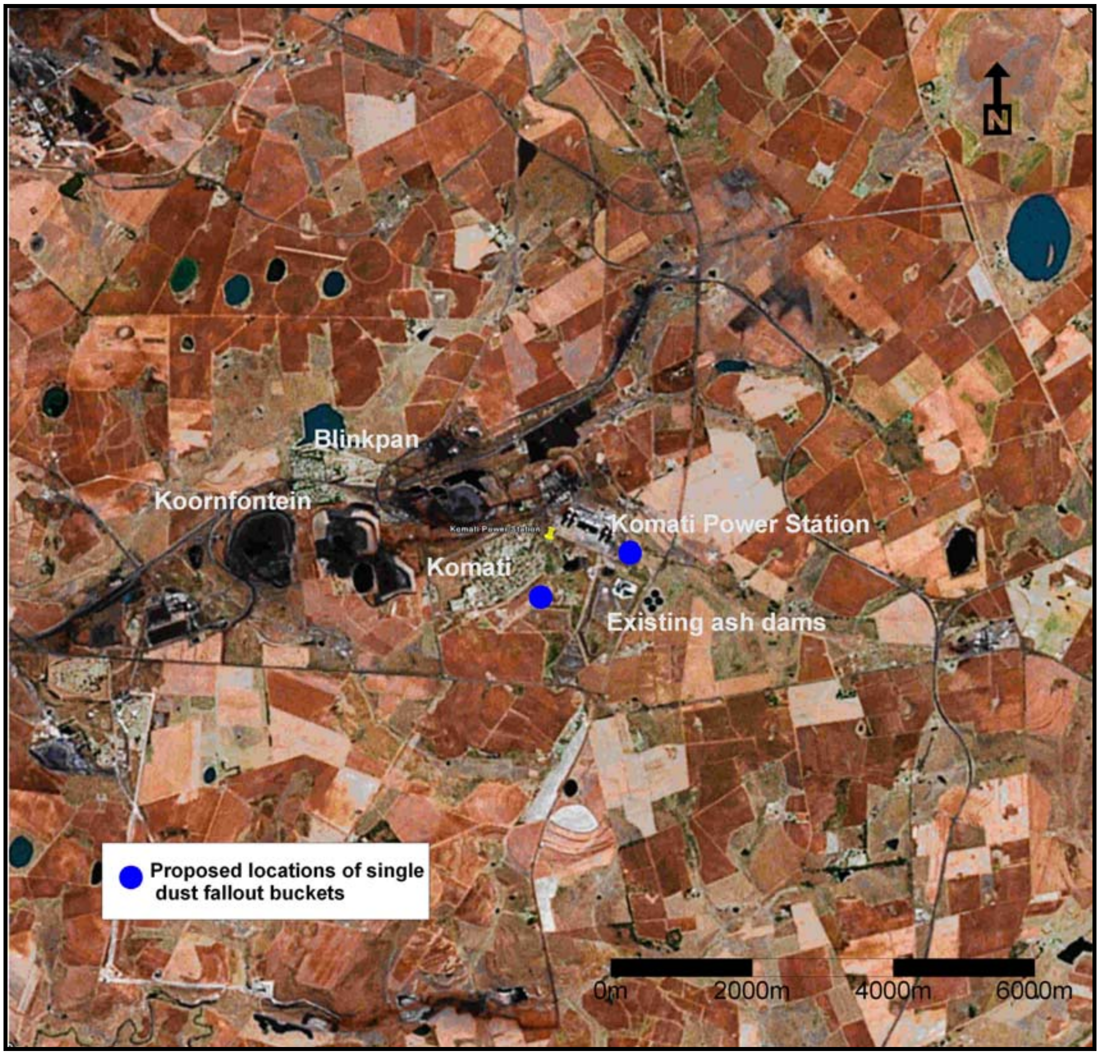

Figure 7-1: Proposed dust bucket locations for the proposed ash dam operations at Komati Power Station.

7.4 Environmental Reporting and Community Liaison

7.4.1 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. EMPs should stipulate specific intervals at which forum meetings will be held, and provide information on how people will be notified of such meetings.

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APPENDIX A

REGIONAL CLIMATE AND ATMOSPHERIC DISPERSION POTENTIAL FOR THE MPUMALANGA HIGHVELD STUDY REGION

The macro-ventilation characteristics of the region are determined by the nature of the synoptic systems which dominate the circulation of the region, and the nature and frequency of occurrence of alternative systems and weather pertubations over the region.

A.1 Regional Climate

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

Five major synoptic scale circulation patterns dominate (Figure A-1) (Vowinckel, 1956; Schulze, 1965; Taljaard, 1972; Preston-Whyte and Tyson, 1988). The most important of these is the semi-permanent, subtropical continental anticyclones which are shown by both Vowinckel (1956) and Tyson (1986) to dominate 70 % of the time during winter and 20 % of the time in summer. This leads to the establishment of extremely stable atmospheric conditions which can persist at various levels in the atmosphere for long periods.

Seasonal variations in the position and intensity of the HP cells determine the extent to which the tropical easterlies and the circumpolar westerlies impact on the atmosphere over the subcontinent. The tropical easterlies, and the occurrence of easterly waves and lows, affect most of southern Africa throughout the year. In winter, the high pressure belt intensifies and moves northward, the upper level circumpolar westerlies expand and displace the upper tropical easterlies equatorward. The winter weather of South Africa is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or anticyclones moving eastwards around the coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards, allowing the tropical easterly flow to resume its influence over South Africa. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic winter-time circulation (Schulze, 1986; Preston-Whyte and Tyson, 1988).

Anticyclones situated over the subcontinent are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions with little or no rainfall, and light variable winds occur as a result of such widespread anticyclonic subsidence. Anticyclones occur most frequently over the interior during winter months, with a maximum frequency of occurrence of 79 percent in June and July. During December such anticyclones only occur 11 percent of the time. Although widespread subsidence dominates the winter months, weather occurs as a result of uplift produced by localized systems.

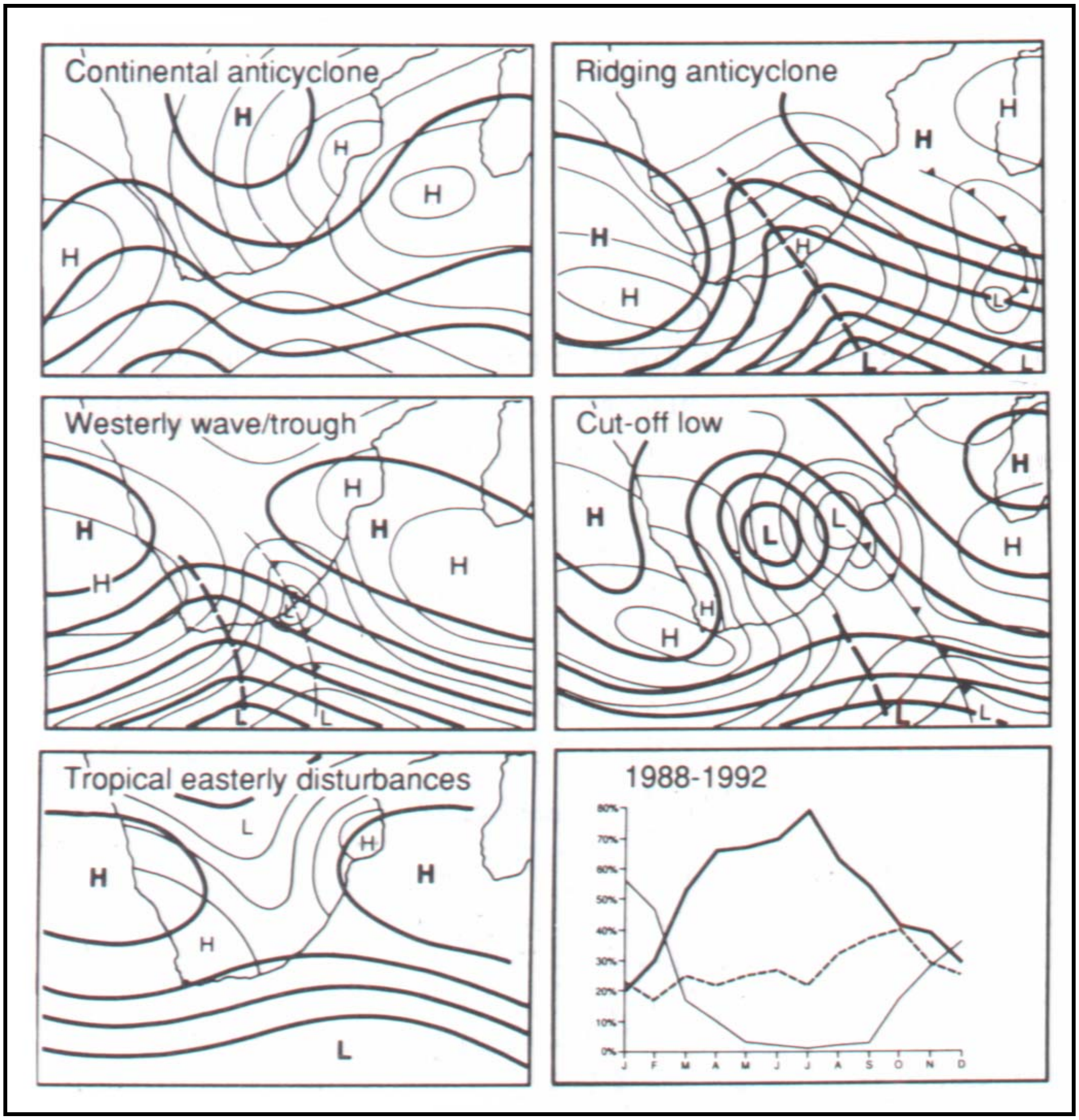

Figure A-1. Major synoptic circulation types affecting southern Africa and their monthly frequencies of occurrence over a five year period (after Preston-Whyte and Tyson, 1988 and Garstang *et al.,* 1996a).

Tropical easterly waves give rise to surface convergence and upper air (500 hPa) divergence to the east of the wave resulting in strong uplift, instability and the potential for precipitation. To the west of the wave, surface divergence and upper-level convergence produces subsidence, and consequently fine clear conditions with no precipitation. Easterly lows are usually deeper systems than are easterly waves, with upper-level divergence to the east of the low occurring at higher levels resulting in strong uplift through the 500 hPa level and the occurrence of copious rains. Easterly waves and lows occur almost exclusively during summer months, and are largely responsible for the summer rainfall pattern and the northerly wind component which occurs over the interior.

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

A.2 Regional Atmospheric Dispersion Potential

The impact of various synoptic systems and weather disturbances on the dispersion potential of the atmosphere largely depends on the effect of such systems on the height and persistence of elevated inversions. Elevated inversions suppress the diffusion and vertical dispersion of pollutants by reducing the height to which such pollutants are able to mix, and consequently result in the concentration of pollutants below their bases. Such inversions therefore play an important role in controlling the long-range transport, and recirculation of pollution.

Subsidence inversions, which represent the predominant type of elevated inversion occurring over South Africa, result from the large-scale anticyclonic activity which dominates the synoptic circulation of the subcontinent. Subsiding air warms adiabatically to temperatures in excess of those in the mixed boundary layer. The interface between the subsiding air and the mixed boundary layer is thus characterised by a marked elevated inversion. Protracted periods of anticyclonic weather, such as characterize the plateau during winter, result in subsidence inversions which are persistent in time, and continuous over considerable distances. The fairly constant afternoon mixing depths, with little diurnal variation, associated with the persistence of subsidence inversions, are believed to greatly reduce the dispersion potential of the atmosphere over the plateau, resulting in the accumulation of pollutants over the region.

Multiple elevated inversions occur in the middle to upper troposphere as a result of large-scale anticyclonic subsidence. The mean annual height and depth of such absolutely stable layers are illustrated in Figure A-2. Three distinct elevated inversions, situated at altitudes of approximately 700 hPa (~3 km), 500 hPa (~5 km) and 300 hPa (~7 km), were identified over southern Africa. The height and persistence of such elevated inversions vary with latitudinal and longitudinal position. During winter months the first elevated inversion is located at an altitude of around 3 km over the plateau. In summer this inversion is known to increase in to 4 to 5 km over the plateau (Diab, 1975; Cosijn, 1996).

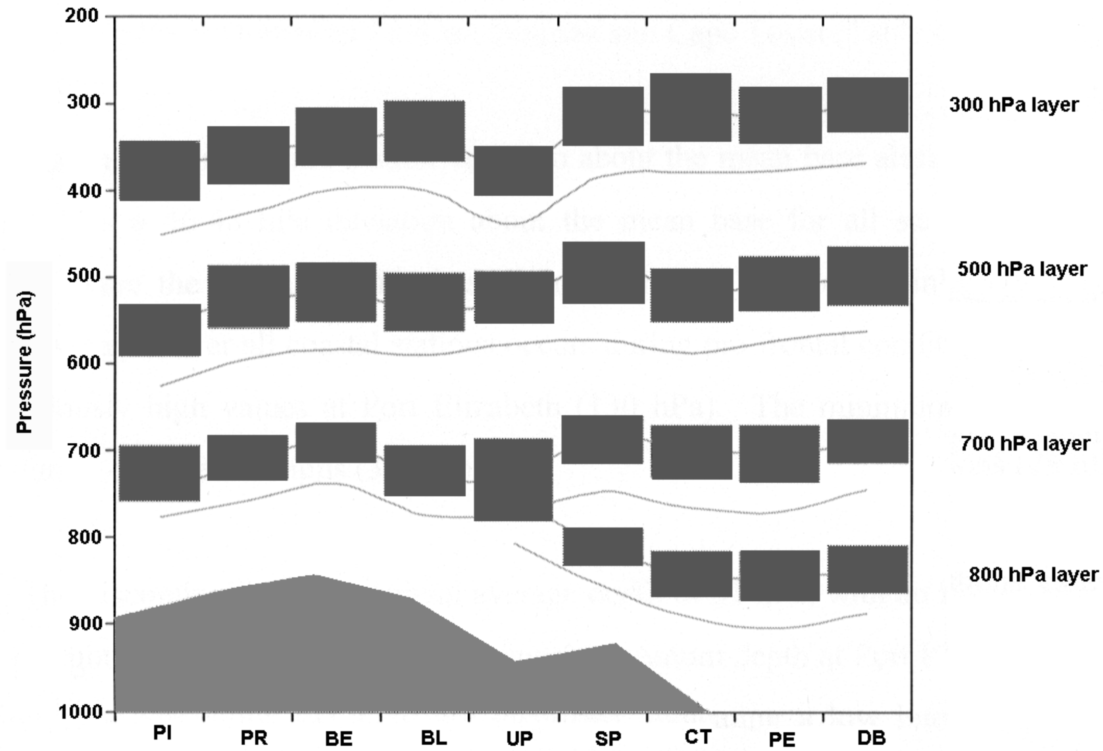

Figure A-2. Mean annual stable layers (shaded) over Pietersburg (PI), Pretoria (PR), Bethlehem (BE), Bloemfontein (BL), Upington (UP), Springbok (SP), Cape Town (CT), Port Elizabeth (PE) and Durban DB). Upper and lower 95% confidence limits for the base heights of the layers are shown in each case (after Cosijn, 1996).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the formation of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, either destroy, weaken, or increase the altitude of, elevated inversions. Although cyclonic disturbances are generally associated with the dissipation of inversions, pre-frontal conditions tend to lower the base of the elevated inversion, so reducing the mixing depth. Pre-frontal conditions are also characterised by relatively calm winds. Over the interior due to the passage of a cold front, there is a tendency for the lowest mixing depths to coincide with the coldest air temperatures and rising pressure. Following the passage of the front, a gradual rise in the mixing depth occurs over the interior (Cosijn, 1996; Preston-Whyte and Tyson, 1988).

APPENDIX B

AMBIENT AIR QUALITY EVALUATION CRITERIA

Air quality standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. Ambient air quality guideline values are intended to indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality standards are normally given for specific averaging periods.

Ambient air quality standards for particulate matter, sulphur dioxide and oxides of nitrogen are discussed in Sections B.1 and Section B.2.

B.1 Ambient Air Quality Criteria for Suspended Particulates

The impact of particles on human health is largely depended on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (Figure B-1) (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 μm), and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 μm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 μm, and effective upper limit of 30 μm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung.

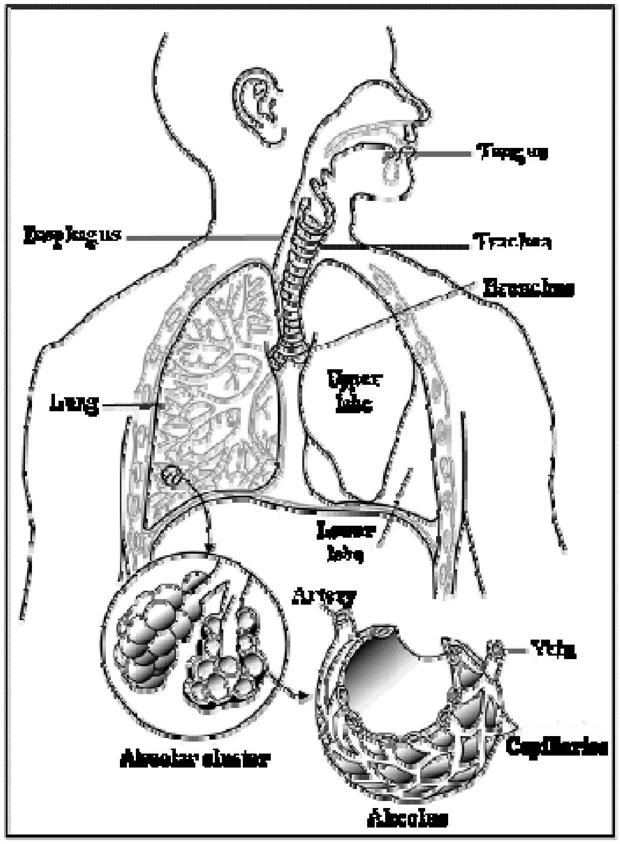

Figure B-1: Schematic diagram indicating the trachea, bronchus and alveolar regions (NCOH, 1992).

B.1.1 Air Quality Guidelines and Standards for Suspended Particulates

Ambient air quality guidelines were initially given in South Africa by the Department of Health for TSP. TSP guidelines were given as 300 $\mu g/m^3$ for maximum daily averages and 100 $\mu g/m^3$ for annual averages. During the mid 1990s, the Department of Environmental Affairs and Tourism (DEAT), which had taken over responsibility for air quality management from the Department of Health, issued air quality guidelines for PM10. The UK and EC air quality criteria presented in Table B-1 represent objectives/standards to be achieved by the year 2004/2005 and are designed primarily to protect human health. The South African standards are significantly less stringent than the recently issued UK objectives, WB guidelines and EC standards. It is however currently proposed that the South African limits be brought in line with such international criteria. The recently issued SANS limits reflect this (Table B-1).

Table B-1: Air quality guidelines and standards for inhalable particulates (PM10)

Country / Organisation	Inhalable Particulates (PM10)	
	Maximum 24-hour Concentrations ($\mu g/m^3$)	Annual Average Concentrations ($\mu g/m^3$)
South Africa - current standards	180(1)	60(2)
South Africa - SANS limits	75(11) 50(12)	40(11) 30(12)
United States EPA (US-EPA)	150(3)	50(2)(4)
European Community (EC) Standards	50(5)	30(6) 20(7)
UK National Air Quality Objectives	50(8)	40(9)
World Bank (WB)	70(10)	50(10)

Notes:

(1) Not to be exceeded more than three times per year.

(2) Represents the arithmetic mean.

(3) Not to be exceeded more than once per year.

(4) Requires that the *three-year* annual average concentration be less than this limit.

(5) Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.)

(6) Compliance by 1 January 2005.

(7) Compliance by 1 January 2010.

(8) 24-hour mean, not to be exceeded more than 35 times a year. Compliance by 31 December 2004.

(9) Annual mean, with compliance required by 31 December 2004.

(10) Pollutant concentration limit at property boundary (World Bank 1998).

(11) South African limit values, reference: *SANS 1929 - Ambient air quality - Limits for common pollutants (draft document).*

(12) South African target values, reference: *SANS 1929 - Ambient air quality - Limits for common pollutants (draft document).*

An eight-year study of over 550,000 adults living in 151 different U.S. urban areas showed that residents of the most polluted cities lose one to three years of life expectancy. The researchers controlled for physical differences in the adults such as age, gender and smoking habits, and found that particulate pollution caused a significant number of deaths from lung cancer and heart disease (Pope III *et al*, 1995). A 15-year study of 8,000 people showed that those living in areas with higher levels of particulate pollution have a 26% higher risk of early death (Dockery and Pope III, 1993). A Utah study showed that increases in particulate pollution resulted in a 40% increase in overall absences from school by children (Pope III *et al*, 1992).

Based on these scientific data, the US EPA has recently proposed a supplementary sub-standard for PM2.5 (i.e. particulates < 2.5 µm). The PM2.5 standard is given as:

Maximum 24 hr average	-	65 $\mu g/m^3$
Annual average	-	15 $\mu g/m^3$

An exceedance of the maximum daily average limit by the three-year average 98th percentile of 24-hour concentrations would constitute a violation of this standard. The PM2.5 three-year annual average needs to be less than the 15 μg/m^3 limit in order to demonstrate compliance with the annual standard (Chow and Watson, 1998).

B.1.2 Dose Response Relationships for Suspended Particulate Exposures

The World Health Organisation (WHO) no longer supports air quality threshold levels for particulates. The WHO stated that the development of a new procedure for the assessment of health impacts occurring due to airborne particulates was necessary since the threshold for the onset of health effects could not be detected (WHO, 2000). The new approach adopted by the WHO is comparable to that for carcinogenic compounds, with linear relationships between PM10 or PM2.5 concentrations and various types of health effects being established. Such linear relationships are presented in Figures B-2 to B-4 for increases in daily mortality rates, hospital admissions and various health endpoints such as bronchodilator use, cough and symptom exacerbation (WHO, 2000).

The WHO recommends that reference be made to the linear relationship of PM10 and PM2.5 with various health effect indicators in determining acceptable levels of risk. In determining 'acceptable' airborne particulate concentrations, a decision-maker will be faced with the following controversial decisions:

- selection of the curve to be used for deriving an acceptable ambient particulate concentration (i.e. decide from which health effect the population is to be protected);

- determine the population or sensitive groups to be protected from air pollution effects. For example, the use of the bronchodilator application curve would imply that asthmatics are a sensitive group to be protected by the chosen standard; and

- set a fixed value for the acceptable risk in a population so that a single value for a given exposure period may be defined (Junker and Schwela, 1998; Schwela, 1998).

The graphs given in Figures B-2 to B-4 were not intended for use for PM10 concentrations below 20 μg/m^3, or above 200 μg/m^3; or for PM2.5 concentrations below 10 μg/m^3 or above 100 μg/m^3. This caution is required as mean 24-hour concentrations outside of these ranges were not used for the risk assessment and extrapolations beyond these ranges would therefore be invalid.

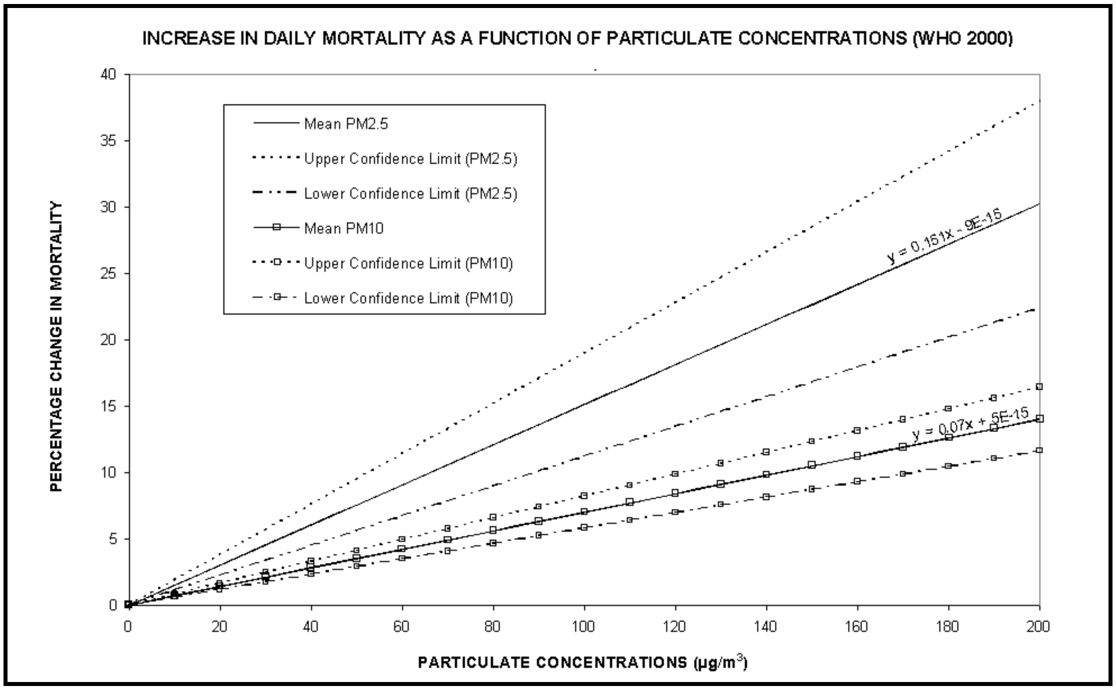

Figure B-2: Increases in daily mortality as a function of increases in PM10 and PM2.5 concentrations (after WHO, 2000).

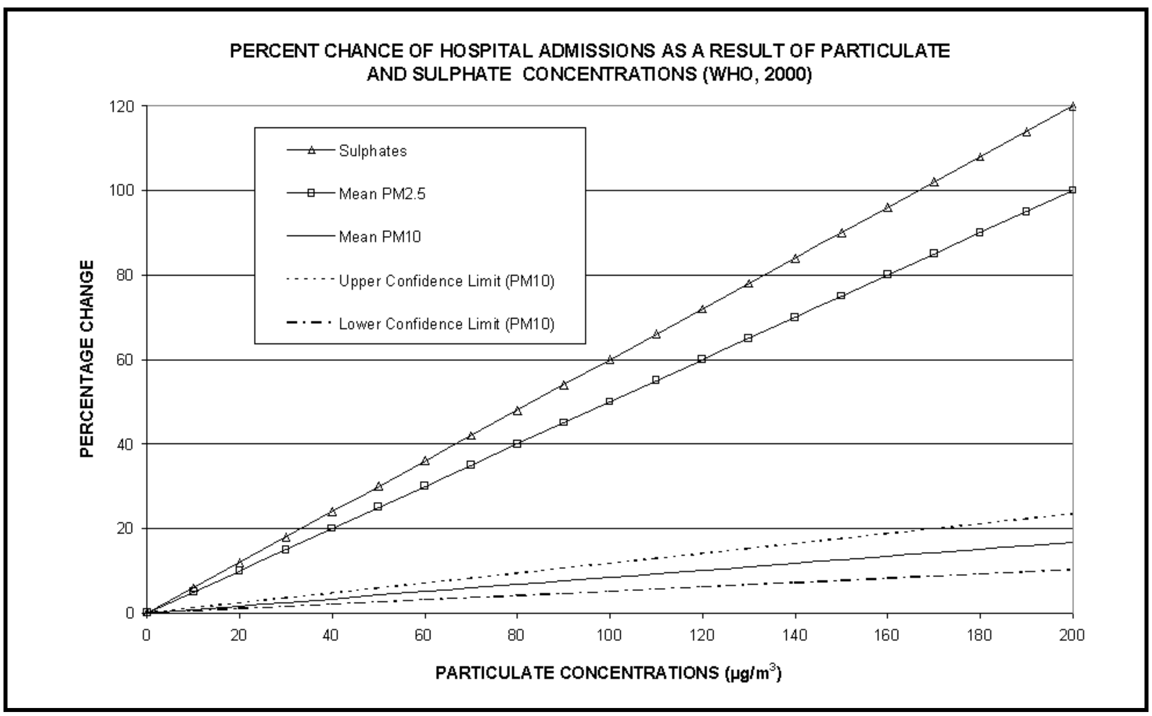

Figure B-3: Increases in hospital admissions as a result of increased PM10, PM2.5 and sulphate concentrations (WHO, 2000).

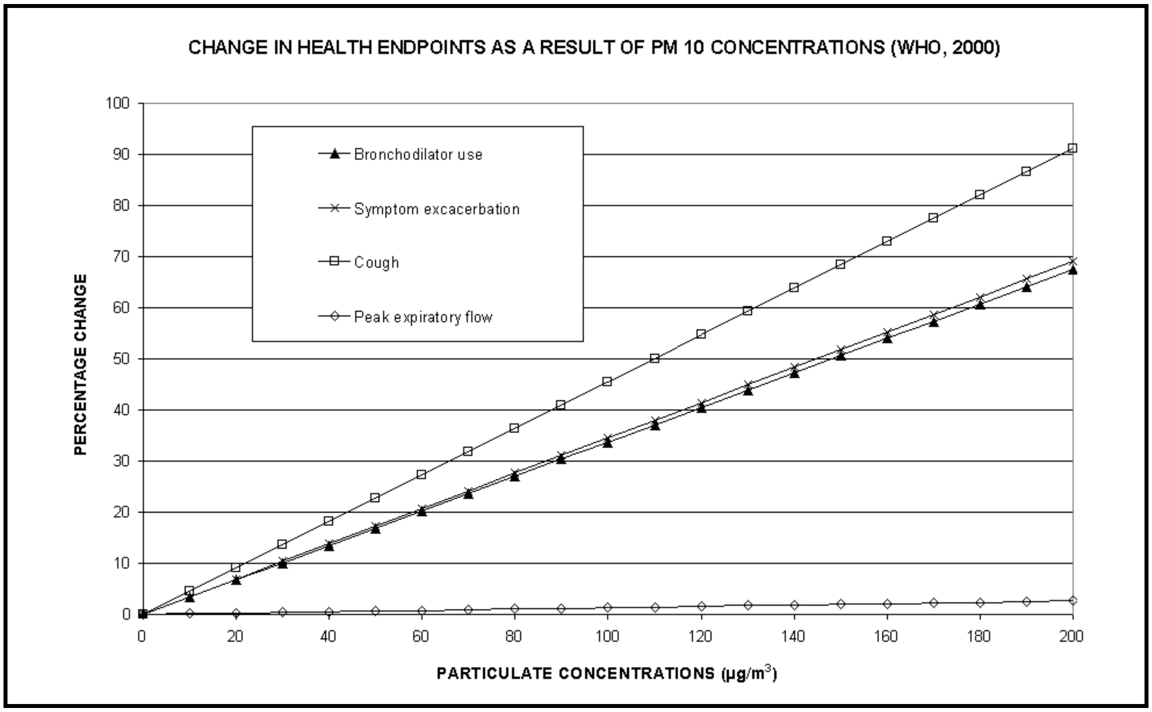

Figure B-4: Percentage change in the occurrence of various health endpoints as a result of changes in ambient PM10 concentrations (WHO, 2000).

The Canadian Environmental Protection Agency (CEPA) has recently undertaken an extensive review of epidemiological studies conducted throughout the world with regard to the relationship between particulate concentrations and human health. The conclusion reached was that daily or short-term variations in particulate matter, as PM10 or PM2.5, were significantly associated with increases in all-cause mortality in 18 studies carried out in 20 cities across North and South America, England, and Europe. The association between particulate concentrations and acute mortality could not be explained by the influence of weather, season, yearly trends, diurnal variations, or the presence of other pollutants such as SO_2, CO, NO_x and O_3 (CEPA/FPAC Working Group, 1998).

In its review, the CEPA could find no evidence of a threshold in the relationship between particulate concentrations and adverse human health effects, with estimates of mortality and morbidity increasing with increasing concentrations. As for the relationship expressed by the WHO, the lack of an apparent threshold suggests that it is problematic to select a level at which no adverse effects would be expected to occur as a result of exposure to particulate matter. The relative risk for PM10 was given by the CEPA as varying between 0.4% and 1.7% per 10 µg/m^3 increase, with an unweighted mean of 0.8% and a weighted mean of 0.5% per 10 µg/m^3 increase. In what the CEPA termed the "best-conducted study" which examined PM2.5, a mean increase in mortality of 1.5% per 10 µg/m^3 was observed (CEPA/FPAC Working Group, 1998) (Figure B-5).

The CEPA recommended that the reference levels for PM10 and PM2.5, for a *daily* averaging period, be 25 µg/m^3 and 15 µg/m^3, respectively. These levels are estimates of the lowest ambient particulate concentrations at which statistically significant increases in health responses can be detected based upon available data and current technology. The CEPA emphasises that the reference levels should not be interpreted as thresholds of effects, or levels at which impacts do not occur (CEPA/FPAC Working Group, 1998).

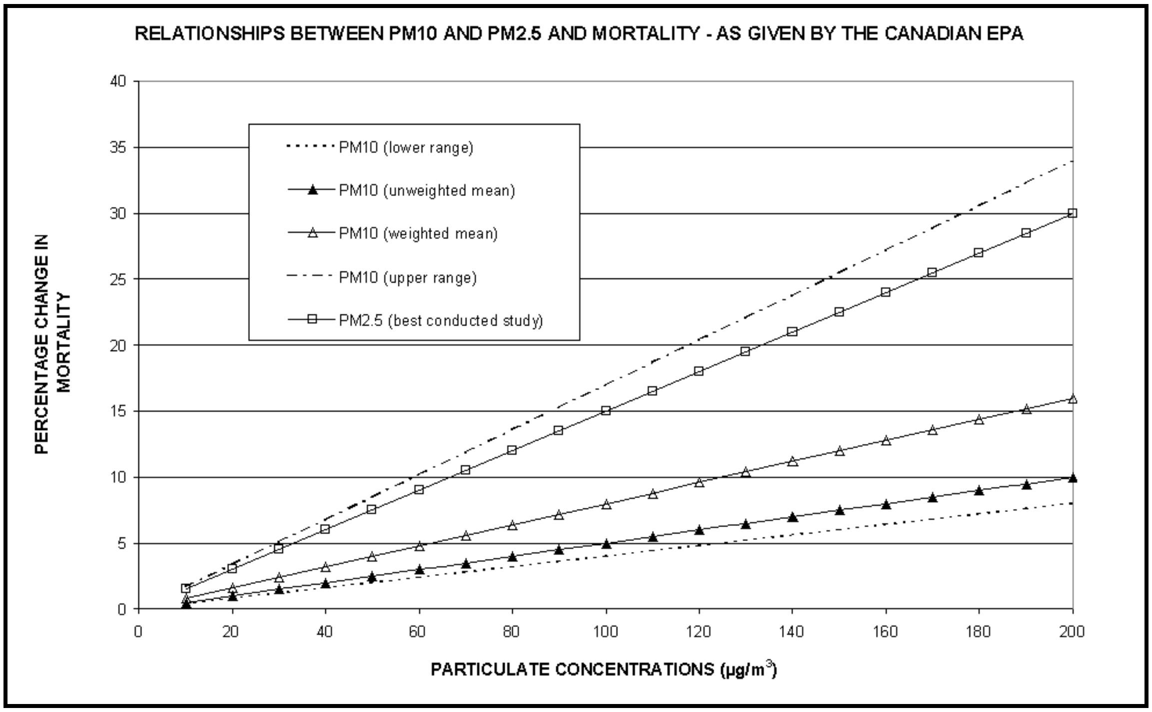

Figure B-5: Relationships between PM10 and PM2.5 and mortality indicated by the Canadian EPA (CEPA/FPAC Working Group, 1998).

A fairly recent review was prepared by CONCAWE (Hext *et al.* 1999) of the health effects of exposure to PM2.5 particles, including the so-called ultra fine particles with aerodynamic diameter of <0.1 µm. The following conclusions were presented in their report:

- *Dosimetric consideration of inhaled PM2.5 suggests that asymmetric deposition patterns in some individuals with obstructive lung diseases might result in localised doses from near ambient concentrations that might enhance the already existing conditions.*

- *Particles of low solubility pose a limited risk to health but animal experiments imply that trace metals and adsorbed components associated with some particle types may enhance pulmonary responses.*

- *Many of the experimental studies have been conducted at high concentrations and used the rat as experimental species. It is now evident that the rat lung may over-respond to the presence of particles in the lung, especially at high doses, and thus results in this species and their extrapolation to man may need to be interpreted with caution.*

- *Ambient acidic particles probably pose the greatest risk to health and there is a suggestion from epidemiological studies that acidity is an important aspect of air pollution with respect to respiratory symptoms.*

- *There is no effect of concern on pulmonary function in normal healthy individuals at concentrations of acidic aerosols as high as 1000 µg/m^3. Effects that may have biological significance may occur at concentrations below 100 µg/m^3 in the most sensitive asthmatic individuals.*

- *There is evidence to suggest that acidic particles may enhance in a synergistic manner the effects of gaseous components of air pollution such as O_3, adding support to the view that health effects associated with episodic increases in urban airborne pollutants arise from an additive or synergistic combination of exposure to both the particulate phase and the gaseous phase.*

- *Ultra fine particles (particles < 100 nm diameter) may pose a greater health risk due to higher particle numbers and deposition efficiencies in the lung and greater biological reaction potential, but further studies or evidence will be required for a full evaluation to be made.*

- *There is a limited number of epidemiological studies that have specifically addressed PM2.5. These appear to provide limited evidence of an association between PM2.5 levels and acute and chronic mortality available at present. However, this is not convincing for several reasons including study design, lack of robust correlation between environmental data and reported exposed population, and inability of identifying or selecting out one individual harmful component (PM2.5) from an ambient mixture of a number of potentially harmful components.*

- *The overall pattern that emerges is that PM2.5, at normal ambient levels or those seen during episodic pollutant increases, poses limited risk, if any, to normal healthy subjects. Individuals suffering already from cardio-respiratory disease or pre-disposed to other respiratory diseases such as asthma may be at risk of developing adverse responses to exposure to increased ambient levels of PM2.5 but more robust evidence is required to substantiate this.*

Dose-response coefficients for PM10 used by the UK Department of Environment, Transport and the Regions in a recent study were given as follows (Stedman *et al,* 1999):

Health Outcome:		**Dose-Response Coefficient:**
Deaths brought forward (all causes)	-	+0.75% per 10 µg/m^3 (24 hr mean)
Respiratory hospital admissions	-	+0.8% per 10 µg/m^3 (24 hr mean)

The United Kingdom Department of Environment classifies air quality on the basis of concentrations of fine particulates as follows (based on 24-hour average concentrations):

< 50 µg/m^3	=	Low
50 – 74 µg/m^3	=	Moderate
75 – 99 µg/m^3	=	High

> 100 μg/m³ = Very high

In estimating the health costs due to road traffic-related air pollution, the WHO Ministerial Conference on Environment and Health used chronic exposure levels (Seethaler, 1999) in three countries namely Austria, France and Switzerland to derive increased frequencies of health outcomes. Seven air pollution related health outcomes were considered. These and the Effect Estimate Relative Risk are summarised in Table B-2.

Table B-2: Additional health cases for exposure to 10 μg/m³ PM10 increments (Seethaler 1999).

Health Outcome	Age	Effect Estimate Relative Risk (1)
Total Mortality	Adults (≥ 30 years)	1.043 (Range: 1.026 –1.061)
Respiratory Hospital Admissions	All Ages	1.0131 (Range: 1.001 –1.025)
Cardiovascular Hospital Admissions	All Ages	1.0125 (Range: 1.007 –1.019)
Chronic Bronchitis Incidence	Adults (≥ 25 years)	1.098 (Range: 1.009 –1.194)
Acute Bronchitis	Children (< 15 years)	1.306 (Range: 1.135 –1.502)
Restricted Activity Days (2)	Adults (≥ 30 years)	1.094 (Range: 1.079 –1.109)
Asthmatics: Asthma Attacks (3)	Children (< 15 years)	1.044 (Range: 1.027 –1.062)
Asthmatics: Asthma Attacks (3)	Adults (≥ 15 years)	1.039 (Range: 1.019 –1.059)

Notes:
(1) Calculated expectancy frequency at the reference level of 7.5 μg/m³ PM10 (±95% confidence interval)
(2) Restricted activity days: total person-days per year
(3) Asthma attacks: total person days with asthma attacks

It is important to note that the linear relationships depicted by the WHO, CEPA and UK Department of Environment, Transport and the Regions are based on *epidemiological* studies. Causal relationships based on *clinical* studies have not yet been established to support such linear relationships. Clinical studies involve controlled human exposure investigations, whereas epidemiological studies are observational in nature. In epidemiological studies, the investigator has no control over exposure or treatment of subjects, but rather examines the statistical relationship between dose and response.

B.2 Ambient Air Quality Criteria for Gaseous Pollutants

B.2.1 Air Quality Guidelines and Standards for Sulphur Dioxide (SO_2)

SO_2 is an irritating gas that is absorbed in the nose and aqueous surfaces of the upper respiratory tract, and is associated with reduced lung function and increased risk of mortality and morbidity. Adverse health effects of SO_2 include coughing, phlegm, chest discomfort and bronchitis.

Short-period exposures (less than 24 hours): Most information on the acute effects of SO_2 comes from controlled chamber experiments on volunteers exposed to SO_2 for periods ranging from a few minutes up to one hour (WHO, 2000). Acute responses occur within the first few minutes after commencement of inhalation. Further exposure does not increase effects. Effects include reductions in the mean forced expiratory volume over one second (FEV_1), increases in specific airway resistance, and symptoms such as wheezing or shortness of breath. These effects are enhanced by exercise that increases the volume of air inspired, as it allows SO_2 to penetrate further into the respiratory tract. A wide range of sensitivity has been demonstrated, both among normal subjects and among those with asthma. People with asthma are the most sensitive group in the community. Continuous exposure-response relationships, without any clearly defined threshold, are evident.

Sub-chronic exposure over a 24-hour period: Information on the effects of exposure averaged over a 24-hour period is derived mainly from epidemiological studies in which the effects of SO_2, suspended particulate matter and other associated pollutants are considered. Exacerbation of symptoms among panels of selected sensitive patients seems to arise in a consistent manner when the concentration of SO_2 exceeds 250 µg/m^3 in the presence of suspended particulate matter. Several more recent studies in Europe have involved mixed industrial and vehicular emissions now common in ambient air. At low levels of exposure (mean annual levels below 50 µg/m^3; daily levels usually not exceeding 125 µg/m^3) effects on mortality (total, cardiovascular and respiratory) and on hospital emergency admissions for total respiratory causes and chronic obstructive pulmonary disease (COPD), have been consistently demonstrated. These results have been shown, in some instances, to persist when black smoke and suspended particulate matter levels were controlled, while in others no attempts have been made to separate the pollutant effects. In these studies no obvious threshold levels for SO_2 have been identified.

Long-term exposure: Earlier assessments, using data from the coal-burning era in Europe judged the lowest-observed-adverse-effect level of SO_2 to be at an annual average of 100 µg/m^3, when present with suspended particulate matter. More recent studies related to industrial sources of SO_2, or to the changed urban mixture of air pollutants, have shown adverse effects below this level. There is, however, some difficulty in finding this value.

Based upon controlled studies with asthmatics exposed to SO_2 for short periods, the WHO (WHO, 2000) recommends that a value of 500 µg/m^3 (0.175 ppm) should not be exceeded over averaging periods of 10 minutes. Because exposure to sharp peaks depends on the nature of local sources, no single factor can be applied to estimate corresponding guideline values over longer periods, such as an hour. Day-to-day changes in mortality, morbidity, or lung function related to 24-hour average concentrations of SO_2 are necessarily based on epidemiological studies, in which people are in general exposed to a mixture of pollutants; and guideline values for SO_2 have previously been linked with corresponding values for suspended particulate matter. This approach led to a previous guideline 24-hour average value of 125 µg/m^3 (0.04 ppm) for SO_2, after applying an uncertainty factor of two to the lowest-observed-adverse-effect level. In more recent studies, adverse effects with significant public health importance have been observed at much lower levels of exposure. However, there is still a large uncertainty with this and hence no concrete basis for numerical changes of the 1987-guideline values for SO_2.

Ambient air quality guidelines and standards issued for various countries and organisations for sulphur dioxide are given in Table B-3. The EC's air quality criteria represent standards to be achieved by the year 2005, and would supersede the EU standards. The ambient air quality standards of the US-EPA are based on clinical and epidemiological evidence.

Table B-3: Ambient air quality guidelines and standards for sulphur dioxide for various countries and organisations

Averaging Period	South Africa (SA standards/SANS)		World Bank (2002)		World Health Organisation (1999)		US-EPA		European Community	
	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm
Annual Average	50(7)	0.019(7)	50	0.019	50(3) 10-30(10)	0.019(3) 0.004-0.01(10)	80(1)	0.03(1)	20(2)	0.008(2)
Max. 24-hour Ave	125(7)	0.048(7)	125	0.048	125(3)	0.048(3)	365(4)	0.14(4)	125(5)	0.048(5)
Max 1-hour Ave	-	-	-	-	350(9)	0.133(9)	-	-	350(6)	0.133(6)
Instantaneous Peak	500(7)(8)	0.191(7)(8)	-	-	500(3)(8)	0.191(3)(8)	-	-	-	-

Notes:

(1) Arithmetic mean.
(2) Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.
(3) Air Quality guidelines (issued by the WHO for Europe) for the protection for human health (WHO, 2000).
(4) Not to be exceeded more than 1 day per year.
(5) Limit to protect health, to be compiled with by the 1 January 2005 (not to be exceeded more than 3 times per calendar year).
(6) Limit to protect health, to be compiled with by the 1 January 2005 (not to be exceeded more than 4 times per calendar year).
(7) Recommended interim guidelines for South Africa by DEAT (Government Gazette, 21 Dec. 2001). These limits are also supported by SANS (SANS, 2004).
(8) 10 minute average.
(9) WHO 1994.
(10) Represents the critical level of ecotoxic effects (issued by WHO for Europe); a range is given to account for different sensitivities of vegetation types.

These standards were established by determining concentrations with the lowest-observed-adverse effect, adjusted by an arbitrary margin of safety factor to allow for uncertainties in extrapolating from animals to humans and from small groups of humans to larger populations. The standards of the US-EPA also reflect the technological feasibility of attainment.

Dose-response coefficients for SO_2 used by the UK Department of Environment, Transport and the Regions in a recent study were given as follows (Stedman et al., 1999):

Health Outcome:		Dose-Response Coefficient:
Deaths brought forward (all causes)	-	+0.6% per 10 μg/m^3 (24 hr mean)
Respiratory hospital admissions	-	+0.5% per 10 μg/m^3 (24 hr mean)

In the formulation of the WHO goals, the lowest observed level at which adverse health effects are observed to occur as a result of a particular pollutant is identified and a margin of safety added. Margins of safety are included to account for uncertainties in, for example, extrapolating health effects from animals to humans or from small human sample group to entire populations. The observed effect level and uncertainty factor identified by the WHO for sulphur dioxide are indicated in Table B-4 for each averaging period. From the values given in Table B-4 it is apparent that an exceedance of a WHO goal would not necessarily result in the occurrence of health effects.

Table B-4: Comparison of observed effect levels and WHO SO_2 guidelines (WHO, 2000).

Averaging Period	Observed Effect Level (μg/m³)	Uncertainty Factor	WHO Guideline Value (μg/m³)
10 minutes	1000	2	500
24-hour	250	2	125
Annual average	100	2	50

B.2.2 Air Quality Guidelines and Standards for Oxides of Nitrogen

NO_x is one of the primary pollutants emitted by motor vehicle exhausts. NO_2 is formed through oxidation of these oxides once released in the air. NO_2 is an irritating gas that is absorbed into the mucous membrane of the respiratory tract. The most adverse health effect occurs at the junction of the conducting airway and the gas exchange region of the lungs. The upper airways are less affected because NO_2 is not very soluble in aqueous surfaces. Exposure to NO_2 is linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics and decreased pulmonary function.

Available data from animal toxicology experiments indicate that acute exposure to NO_2 concentrations of less than 1 880 μg/m^3 (1 ppm) rarely produces observable effects (WHO, 2000). Normal healthy humans, exposed at rest or with light exercise for less than two hours to concentrations above 4 700 μg/m^3 (2.5 ppm), experience pronounced decreases in pulmonary function; generally, normal subjects are not affected by concentrations less than 1 880 μg/m^3 (1.0 ppm). One study showed that the lung function of subjects with chronic obstructive pulmonary disease is slightly affected by a 3.75-hour exposure to 560 μg/m^3 (0.3 ppm) (WHO, 2000).

Asthmatics are likely to be the most sensitive subjects, although uncertainties exist in the health database. The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30 to 110 minutes to 565 $\mu g/m^3$ (0.3 ppm) NO_2 during intermittent exercise. However, neither of these laboratories was able to replicate these responses with a larger group of asthmatic subjects. NO_2 increases bronchial reactivity, as measured by the response of normal and asthmatic subjects following exposure to pharmacological broncho-constrictor agents, even at levels that do not affect pulmonary function directly in the absence of a broncho-constrictor.

Some, but not all, studies show increased responsiveness to broncho-constrictors at NO_2 levels as low as 376-565 $\mu g/m^3$ (0.2 to 0.3 ppm); in other studies, higher levels had no such effect. Because the actual mechanisms of effect are not fully defined and NO_2 studies with allergen challenges showed no effects at the lowest concentration tested (188 $\mu g/m^3$; 0.1 ppm), full evaluation of the health consequences of the increased responsiveness to broncho-constrictors is not yet possible.

Studies with animals have clearly shown that several weeks to months of exposure to NO_2 concentrations of less than 1 880 $\mu g/m^3$ (1 ppm) causes a range of effects, primarily in the lung, but also in other organs such as the spleen and liver, and in blood. Both reversible and irreversible lung effects have been observed. Structural changes range from a change in cell type in the tracheobronchial and pulmonary regions (at a lowest reported level of 640 $\mu g/m^3$), to emphysema-like effects. Biochemical changes often reflect cellular alterations, with the lowest effective NO_2 concentrations in several studies ranging from 380-750$\mu g/m^3$. NO_2 levels of about 940 $\mu g/m^3$ (0.5 ppm) also increase susceptibility to bacterial and viral infection of the lung. Children of between 5-12 years old are estimated to have a 20% increased risk for respiratory symptoms and disease for each increase of 28 $\mu g/m^3$ NO_2 (2-week average), where the weekly average concentrations are in the range of 15-128 $\mu g/m^3$ or possibly higher. However, the observed effects cannot clearly be attributed to either the repeated short-term high-level peak, or to long-term exposures in the range of the stated weekly averages (or possibly both). The results of outdoor studies consistently indicate that children with long-term ambient NO_2 exposures exhibit increased respiratory symptoms that are of longer duration, and show a decrease in lung function.

Table B-5: Ambient air quality guidelines and standards for NO_2

Averaging Period	South Africa (SA standards)		South Africa (SANS limits)		World Health Organisation (1994)		US-EPA		European Union	
	µg/m³	ppb	µg/m³	ppb	µg/m³	ppb	µg/m³	ppb	µg/m³	ppb
Annual Average	96	50	40	21	40	21	100(1)	53(1)	40(2)	21(2)
Max. 1-month Ave	153	80	-	-	-	-	-	-	-	-
Max. 24-hour Ave	191	100	-	-	150	80	-	-	-	-
Max. 1-hour Ave	382	200	200	100	200	100	-	-	200(3)	100(3)
Instantaneous Peak	955	500	-	-	-	-	-	-	-	-

Notes:
(1) Annual arithmetic mean.
(2) Annual limit value for the protection of human health, to be complied with by 1 January 2010.
(2) Averaging times represent 98th percentile of averaging periods; calculated from mean values per hour or per period of less than an hour taken through out year; not to be exceeded more than 8 times per year. This limit is to be complied with by 1 January 2010.

Table B-6: South African air quality standards for oxides of nitrogen(1)

Averaging Period	South African NO Standards		South African NO_2 Standards		South African NO_x Standards	
	µg/m³	ppb	µg/m³	ppb	µg/m³	ppb
Annual Average	188	150	96	50	283	200
Max. 1-month Ave	250	200	153	80	403	300
Max. 24-hour Ave	375	300	191	100	566	400
Max. 1-hour Ave	750	600	382	200	1132	800
Instantaneous Peak	1125	900	955	500	2080	1400

Note:
(1)Although the standards are given by the DEAT in ppb, the equivalent values in µg/m³ were calculated for NO_2 and NO based on the molecular weights of these constituents and the assumption of ambient conditions comprising an ambient temperature of 20°C and a pressure of 1 atmosphere. NO_x concentration limits in µg/m³ were calculated by summing the NO and NO_2 limits.

The standards and guidelines of most countries and organisations are given exclusively for NO_2 concentrations. South Africa's NO_2 standards are compared to various widely referenced foreign standards and guidelines in Table B-5. In addition, South Africa also publishes standards for oxides of nitrogen (NO_x) and nitrous oxide (NO). The standards for NO and NO_x are presented in Table B-6.