Project done on behalf of
Zitholele Consulting (Pty) Ltd

KUSILE RAILWAY PROJECT:
AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED RAILWAY LINE FROM THE EXISTING PRETORIA-WITBANK RAILWAY (PARALLEL TO THE N4) TO THE KUSILE POWER STATION

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REPORT DETAILS

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Prepared by	Reneé von Gruenewaldt (*Pr. Sci. Nat.*), MSc (University of Pretoria)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighborhood concerns to regional air pollution impacts. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
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Executive Summary

Introduction

Airshed Planning Professionals (Pty) Ltd was appointed by Zitholele Consulting (Pty) Ltd to undertake the specialist air quality study for the proposed railway line from the existing Pretoria-Witbank Railway to the Kusile Power Station (Kusile Railway Project).

Assumptions and Limitations

The assumptions and limitations of the investigation are as follows:

- No ambient air quality measurements are available along the proposed railway routes. This is a limitation to this study. Some activities do occur (i.e. farming operations and vehicle activity) which may impact air quality.
- No on-site meteorological data was available and use was made of the closest meteorological station (Kendal 2) which is operated by Eskom. This meteorological station is ~18km southeast of the southern point of the proposed railway lines. Eskom also operate a second meteorological station in the area (Kendal B) but the data is of a shorter time period.
- Measured upper data was not available close to the study site. Use was therefore made of calculated ETA data obtained from the South African Weather Services.
- The moisture content, silt loading and silt content for the road material was unknown for the current study. Use was therefore made of typical values obtained from the United States Environmental Protection Agency (US-EPA).
- The sorbent material to be transported will be between 1 mm and 18 mm in size. Predictably a small percentage of this material will be fine matter. Detailed information on the particle size distribution for the sorbent material to be transported via rail was not available for the current study. Use was therefore made of particle size distribution of sorbent material in fly ash after circulating fluidised bed combustion (with attrition) (Montagnaro *et al*, 2009). This information was taken to be a conservative approach as the particle size distribution of the sorbent is likely to be finer after circulating fluidised bed combustion.

- Fugitive emission rates from vehicle entrainment were estimated using emission factors. For this purpose, the US-EPA factors were employed.

- The impact assessment was limited to airborne particulates (including total suspended particulates (TSP) and inhalable particulate matter (PM10)). Although the proposed activities would also emit other gaseous pollutants, primarily by vehicle exhaust releases during construction, the impact of these compounds was regarded to be low and was omitted from this study. If the sorbent were to be transported solely by road, the gaseous emissions as well as fugitive emissions from vehicle activity would increase. The assessment of this scenario, however, did not form part of the scope of study.

Methodology

The following methodology was followed:

- Preparation of an emissions inventory for construction and operation activities:
    - Three routes were provided for the current assessment.
    - Information pertaining to proposed construction activities (vehicle activities) were provided and used to calculate the expected air pollution rates from all significant sources.
    - The emission inventory included ambient air particulates.
- Impact analysis:
    - Comparison of predicted air concentrations to current and proposed SA standards.
    - Recommended mitigation measures.

Conclusions

The main objective of this investigation was to determine ground level particulate concentrations due to construction and operation activities from the proposed Kusile Railway Project.

Pollutants of concern for the current study consisted of particulate matter (including inhalable particulates (PM10) and total suspended particulates (TSP).

The main conclusions from the current assessment are summarised as follows:

- For construction activities the predicted PM10 concentrations due to vehicle entrainment on paved and unpaved road surfaces were well within current and proposed SA standards for all averaging periods (with the conservative approach of assuming no control efficiencies on road surfaces).

- Due to the transportation of sorbent material in open wagons during the operational phase, the highest daily and annual predicted PM10 concentrations were within the current and proposed SA standards (with the conservative approach of assuming no covering of rail wagons). The impacts due to not covering the sorbent during transportation are therefore low.

Recommendation

As the proposed PM10 impacts due to the construction and operational activities from the Kusile Project are within the current and proposed SA standards for all averaging periods, it is recommended that Kusile Project be implemented as specified for the current assessment (i.e. 1 train entering and leaving the Kusile premises per day with 50 wagons per train, etc). The impacts transported via rail is expected to have lower impacts that if the sorbent were transported via road. It therefore recommended that this mode of transport (rail) be implemented.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KUSILE RAILWAY PROJECT:

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED RAILWAY LINE FROM THE EXISTING PRETORIA-WITBANK RAILWAY (PARALLEL TO THE N4) TO THE KUSILE POWER STATION

1 INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was appointed by Zitholele Consulting (Pty) Ltd to undertake the specialist air quality study for the proposed railway line from the existing Pretoria-Witbank Railway to the Kusile Power Station (hereafter referred to as the Kusile Railway Project).

1.1 Background

The growing demand for electricity is placing increasing pressure on Eskom's existing power generation and transmission capacity. Eskom is committed to implementing a Sustainable Energy Strategy that complements the policies and strategies of National Government. Eskom aims to improve the reliability of electricity supply to the country. For this reason, Eskom obtained environmental authorization to construct the new Kusile Power Station between Bronkhorstspruit and Witbank in 2007. Construction of this power station has already commenced.

The new Kusile Power Station requires the delivery of sorbent to the plant as a reagent in the air quality abatement technologies (flue gas desulphurisation) of the power generation process. It is anticipated that this delivery will be best suited to rail transport. This proposed project is to construct a new railway line from the existing Bronkhorstspruit – Emahlahleni railway line to the Kusile Power Station.

For the current assessment, three railway alternative corridor routes are investigated (Figure 1-1).

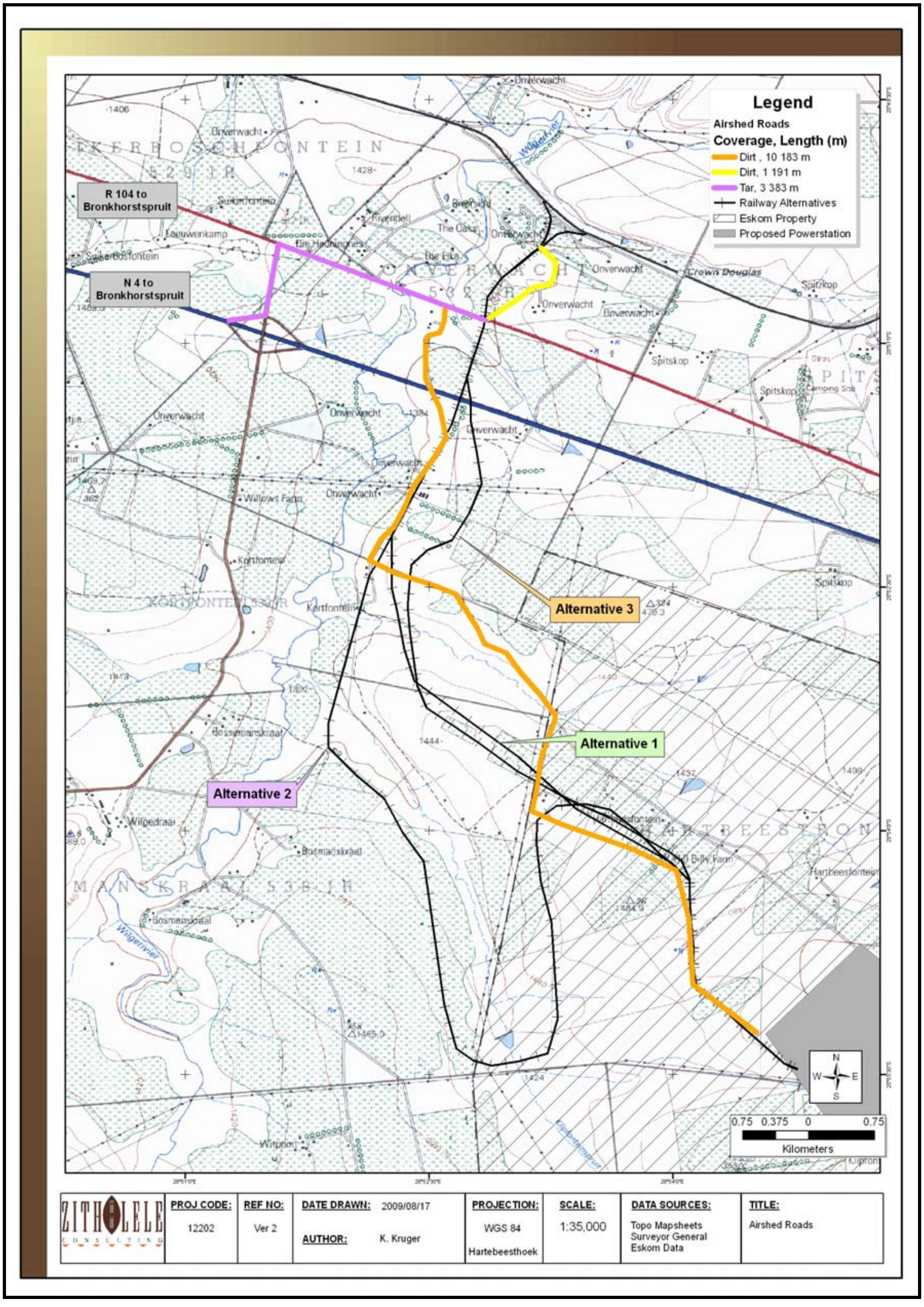

Figure 1-1: Three proposed alternative railway corridor routes considered for the current assessment.

1.2 Terms of Reference

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

- Characterisation of the site-specific atmospheric dispersion potential;
- Identification of the potential sensitive receptors within the vicinity of the proposed study area;
- The legislative and regulatory context, including ambient air quality guidelines and dustfall classifications.

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

- Compilation of an emissions inventory, comprising the identification and quantification of all potential routine sources of emission from the construction activities and proposed transportation;
- Dispersion simulations of particulate matter from the proposed transportation activities;
- Analysis of dispersion modelling results;
- Evaluation of potential for human health and environmental impacts.

1.3 Assumptions and Limitations

The assumptions and limitations of the investigation are as follows:

- No ambient air quality measurements are available along the proposed railway routes. This is a limitation to this study. Some activities do occur (i.e. farming operations and vehicle activity) which may impact air quality.
- No on-site meteorological data was available and use was made of the closest meteorological station (Kendal 2) which is operated by Eskom. This meteorological station is ~18km southeast of the southern point of the proposed railway lines. Eskom also operate a second meteorological station in the area (Kendal B) but the data is of a shorter time period.

- Measured upper data was not available close to the study site. Use was therefore made of calculated ETA data obtained from the South African Weather Services.

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1.4 Outline of Report

The meso-scale ventilation and site specific dispersion potential of the area are discussed in Section 2. The ambient air quality criteria applicable for the current study are presented in Section 3. Section 4 provides the impact assessment. Recommendations and conclusions are presented in Section 5.

2 MESO-SCALE VENTILATION AND SITE SPECIFIC DISPERSION POTENTIAL

The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the ventilation potential of the site (which is the ability for air to move in and out of an area), and to provide the input requirements for the dispersion simulations. A comprehensive data set for at least one year of detailed hourly average wind speed, wind direction, temperature, relative humidity and cloud cover data are needed for the dispersion simulations. Surface meteorological data were obtained from the Kendal 2 monitoring station operated by Eskom for the period 2004 – 2007. The period 2006 was selected for dispersion modelling purposes as this period had the most comprehensive data set.

2.1 Local wind field

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

Wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours reflected the different categories of wind speeds with the dotted circles indicating the frequency of occurrence, and each circle representing a 5% frequency of occurrence. The figure given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

The predominant wind field for the period 2004 – 2007 is from the west-northwest (~12% frequency of occurrence) with frequent moderate wind speeds of 5-10 m/s (Figure 2-1). A diurnal variation wind shift is clearly evident in the study area. During day-time conditions, the frequency of winds from the west-northwestern sector increases (>15% frequency of occurrence) with calm conditions of 3.7%. During night-time conditions, the winds from the east and east-northeast increase in occurrence with an increase in calm conditions (12.4%) as is typical of more stable conditions.

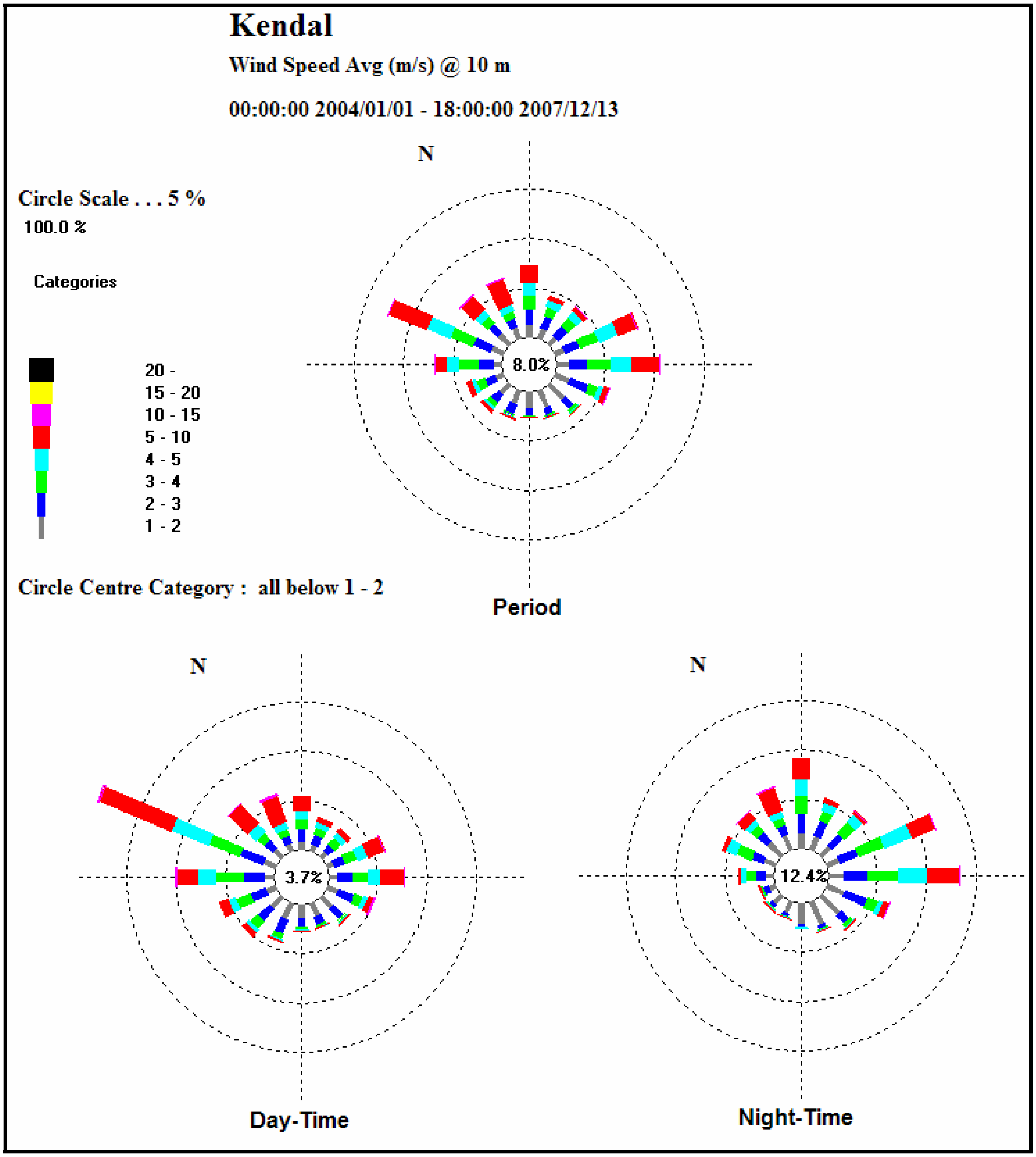

Figure 2-1: Period, day- and night-time wind roses for the Kendal 2 Monitoring Station (2004 – 2007).

2.2 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.

Temperature provides an indication of the intensity of insolation, and therefore of the rate of development and dissipation of the mixing layer. The monthly diurnal temperature trend for Kendal 2 monitoring station for the year 2006 is presented in Figure 2-2. Ambient average temperatures were recorded to range between 9.6°C and 21.6°C (Table 2-1).

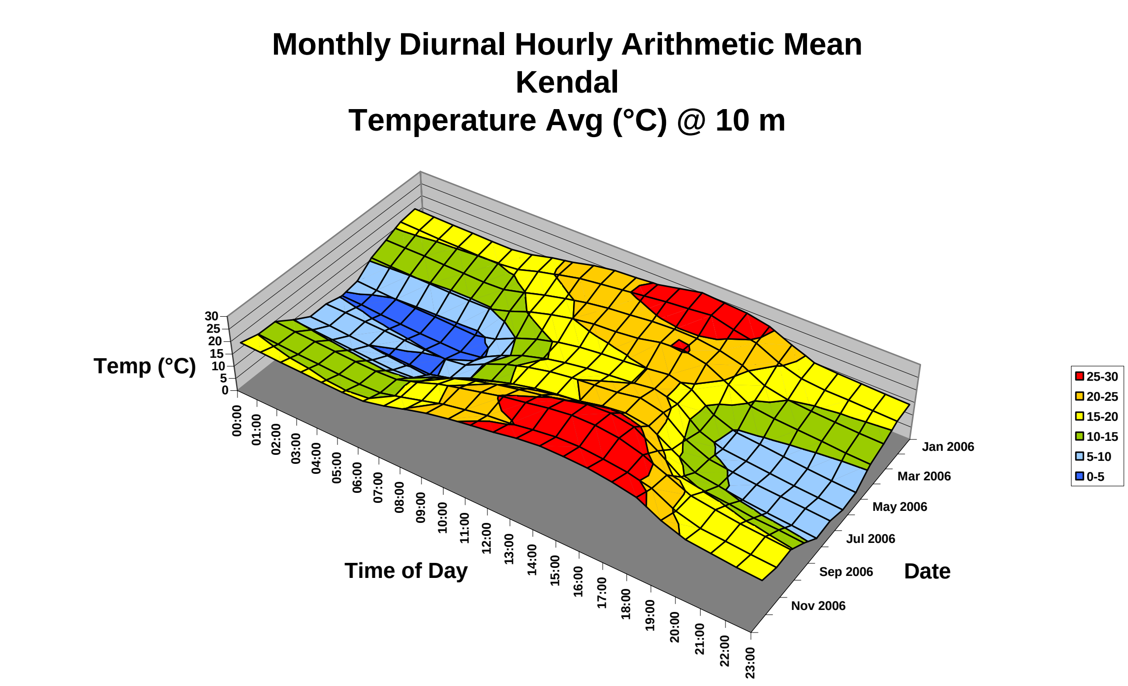

Figure 2-2: Air temperature trends for Kendal 2 monitoring station for the period 2006.

Table 2-1: Maximum, minimum and mean monthly temperatures (°C) for Kendal 2 monitoring station for the period 2006.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	15.9	15.0	12.3	9.7	4.0	2.5	5.0	4.1	7.8	12.8	13.1	15.5
Mean	20.8	20.1	17.2	15.4	10.5	9.6	11.6	11.4	16.2	20.0	19.3	21.6
Max	28.7	28.4	24.7	25.3	21.1	21.2	23.2	23.1	28.8	30.1	27.6	30.3

3 LEGAL REQUIREMENTS AND HUMAN HEALTH CRITERIA

Prior to assessing the impact of the proposed Kusile Railway Project, 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.

3.1 Review of the Current Air Pollution Legislative Context

The National Environmental Management: Air Quality Act (Act no.39 of 2004) (AQA) came into effect on the 11 of September 2005 as published in the Government Gazette on the 9 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. Schedule 2 of the AQA provides ambient air quality standards that were based on the previously adopted Department of Environmental Affairs (DEA) guidelines (the "1st generation ambient air quality standards"). These are currently being revised with the publication of the new ambient air quality standards (*Government Gazette No. 31987, 13 March 2009*) for public comment ("the 2nd generation ambient air quality standards"). These standards are based on those issued by the South African National Standards (SANS) during 2004.

The AQA was developed to reform and update air quality legislation in South Africa and is intended to reflect the overarching principles within the National Environmental Management Act (Act no. 107 of 1998) (NEMA) and general environmental policy and to bring legislation in line with local and international good practices as they pertain to air quality management.

With the shift of the new AQA from source control to the impacts on the receiving environment, the responsibility to achieve and manage sustainable development has reached a new dimension. The National Framework states that aside from the various spheres of government responsibility towards good air quality, industry too has a responsibility not to impinge on everyone's right to air that is not harmful to health and well-being. Industries therefore should take reasonable measures to prevent such pollution order degradation from occurring, continuing or recurring.

In terms of the AQA, certain industries have further responsibilities, including:

- Taking reasonable steps to prevent the emission of any offensive odour caused by any activity on their premises.
- Compliance with any relevant national standards for emissions from point, non-point or mobile sources in respect of substances or mixtures of substances identified by the Minister, MEC or municipality.
- Compliance with the measurements requirements of identified emissions from point, non-point or mobile sources and the form in which such measurements must be reported and the organs of state to whom such measurements must be reported.
- Compliance with relevant emission standards in respect of controlled emitters if an activity undertaken by the industry and/or an appliance used by the industry is identified as a controlled emitter.
- Compliance with any usage, manufacture or sale and/or emissions standards or prohibitions in respect of controlled fuels if such fuels are manufactured, sold or used by the industry.
- Comply with the Minister's requirement for the implementation of a pollution prevention plan in respect of a substance declared as a priority air pollutant.
- Comply with an Air Quality Officer's legal request to submit an atmospheric impact report in a prescribed form.
- Furthermore, industries identified as Listed Activities (see Section 2.2.3) have further responsibilities, including:
    - Making application for an Atmospheric Emission License (AEL) and complying with its provisions.
    - Compliance with any minimum emission standards in respect of a substance or mixture of substances identified as resulting from a listed activity.
    - Designate an Emission Control Officer if required to do so.

Compliance of the operation is screened against the newly proposed AQA standards ("the 2nd generation ambient air quality standards"), which have been based on the SANS limit values (SANS 1929), which are more in line with international trends.

3.2 Ambient Air Quality Standards

The Department of Environmental Affairs have issued ambient air quality guidelines to support receiving environment management practices.

As of **April 30, 2007**, new versions of the World Bank Group Environmental, Health, and Safety Guidelines (known as the 'EHS Guidelines') are now in use. They replace those documents previously published in Part **III** of the Pollution Prevention and Abatement Handbook and on the IFC website.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent.

Although there are a number of ambient air pollutants in the vicinity of the proposed Kusile Railway Project, the pollutants of concern due to the construction and operation activities will consist of particulate matter. This pollutant will thus be the focus of this section.

3.2.1 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 (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 are documented in Table 3-1. In addition to the PM10 standards published in schedule 2 of the Air Quality Act (Act no. 107 of 1998), the Act also includes standards for total suspended particulates (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.

Table 3-1: National air quality standard for inhalable particulates (PM10)

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	180	60
Proposed SA Standards (Government Gazette No.: 31987)	75(a)	40

Notes:
(a) Proposed Standard. Permissible frequency of exceedance is 4 days per year to be complied with immediately once the proposed standards have been adopted.

PM10 limits and standards issued for various other countries are documented in Table 3-2.

During the 1990s the World Health Organisation (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 3-3 and 3-4.

Table 3-2: Air quality standards from other countries for inhalable particulates (PM10)

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
World Bank Group	(a)	(a)
World Health Organisation	50(b)	20(b)
European Community (EC)	50(c)	40(d)
United Kingdom	50(e)	40(f)
United States EPA	150(g)	50(h)

Notes:

(a) World Bank Group, 2007. EHS Guidelines (http://www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines). Guidelines state that pollutant concentrations do not reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources.

(b) 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).

(c) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005. Not to be exceeded more than 35 times per calendar year.

(d) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005.

(e) UK Air Quality Standard. (http://www.defra.gov.uk/environment/airquality/regulations.htm. Not to be exceeded more than 35 times per year.

(f) UK Air Quality Standard. (http://www.defra.gov.uk/environment/airquality/regulations.htm.

(g) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year on average over three years.

(h) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). The annual standard revoked, effective 17 December 2006.

Table 3-3: 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 3-4: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Daily Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	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

3.3 Pollution Management Intervention Criteria

The following system for the use of these in the management of ambient air quality is recommended by SANS 1929:

Levels below 50% of the NEMAQA guidelines	:	No current significant impact
Levels above 50% of the NEMAQA guidelines	:	Ongoing monitoring of certain pollutants may be required
Levels of certain pollutants at 80% or more of the guidelines	:	Some air pollution management intervention in the area required and careful assessment of any new facilities in the area
Levels above the guidelines	:	Potential for air pollution health impacts in the area and any new plants in the area could make things worse

4 IMPACT ASSESSMENT FOR PROPOSED KUSILE RAILWAY PROJECT

4.1 Potentially Sensitive Receptors

The proposed routes traverse only cultivation / unimproved grassland land uses and certain water bodies. Water bodies are thus the only land use regarded as sensitive (Zitolele, 2009)[1].

4.2 Railway Corridor Routes Considered for the Current Assessment

Three alternative railway corridor routes have been considered for the current assessment (Figure 1-1) (Zitholele, 2009):

- The **Alternative 1 route** alignment, which starts at the existing Pretoria-Witbank railway line, heads in a south westerly direction and crosses the N4 highway. Thereafter the route follows the course of the Wilge River. This route then heads in a south easterly direction and crosses an unnamed tributary of the Wilge River continuing for six kilometres into the Kusile Power Station. This route is approximately 12 km in length.

- The **Alternative 2 route** alignment follows the same initial alignment as Alternative 1, but after crossing the N4 highway the alignment continues in a south westerly direction for approximately 4.5 kilometres. Thereafter the route crosses over the Klipfonteinspruit river and turns in a south easterly direction for approximately two kilometres. The route then turns south south east for 2.5 kilometres, turns eastward and crosses the Klipfonteinspruit river a second time and then turns to run in a northerly direction for three kilometres before meeting up with alternative 1 approximately 3 kilometres from the Kusile Power Station). This route is estimated at 18 km in length.

- The **Alternative 3 route** alignment follows the same initial alignment as Alternative 1 (AF) but it crosses the N4 highway 500 metres eastward of the Alternative 1 and 2 crossing (avoiding the farmstead complexes) (FCDE). The alternative rejoins

[1] Screening Phase: Proposed Kusile Power Station Railway Line Route Alternatives, Project 12202, April 2009.

alternative 1 for approximately seven kilometres before entering the Kusile Power Station. This route is very similar to Alternative 1, with some minor deviations 12.2 km.

4.3 Construction Phase

During construction operations, the main activity of concern in terms of Air Quality was identified to be fugitive emissions from vehicle activity and earthworks. The roads that are proposed to be used during the construction phase are provided in Figure 1-1. These roads will only be used during the construction phase with the roads crossing through the farmlands being rehabilitated after this phase is completed.

4.3.1 Emissions Inventory

For proposed construction operations for the Kusile Railway Project, the following vehicle activities were provided: 3 Dozers, 4 Graders, 10 Tippers (10 ton each), 4 Compaction machines, 6 water Bowzers, 2 front end loaders, 3 excavators, 10 light duty vehicle's, 4 lorries (8 tonnes) with cranes. The proposed construction operations were given to take place for 9 hours per day (07:00 to 17:00) for 5 days per week over a 22 month period.

4.3.1.1 Earthworks

The construction phase will comprise land clearing and site development operations at the site. In order to determine the significance of the potential for impacts it is necessary to quantify atmospheric emissions and predicted airborne pollutant concentrations and dustfall rates occurring as a result of such emissions.

The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity.

The US-EPA documents emissions factors which 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:

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

These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates.

PM10 was assumed to represent ~35% of the TSP emissions given that this is the approximate PM10 component of vehicle-entrainment releases and such releases are anticipated to represent the most significant source of dust during construction operations.

4.3.1.2 Vehicle-Entrained Emissions from Unpaved Roads

Vehicle-entrained dust emissions from unpaved haul roads represent a significant source of fugitive dust. The force of the wheels of vehicles travelling on unpaved roadways causes pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to affect the road surface once the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic, including average vehicle speed, mean vehicle weight, silt content of road material and road surface moisture (EPA, 2006).

Vehicle-entrained dust emissions from the proposed access road from the proposed railway line from the existing Pretoria-Witbank Railway to the Kusile Power Station represents a relatively significant source of fugitive dust.

The unpaved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}$$

where,

E = emissions in lb of particulates per vehicle mile travelled (lb/VMT) – 1 lb/VMT = 281.9 g/VKT (vehicle kilometres travelled)
k = particle size multiplier (dimensionless)
s = silt content of road surface material (%)
W = mean vehicle weight (tonnes)

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 1.5 for PM10 and 4.9 for total suspended particulates (TSP). a and b are given as 0.9 and 0.45 respectively for PM10 and as 0.7 and 0.45 respectively for TSP.

The silt content should preferably be measured to reflect site-specific conditions. As the silt content could not be determined for the current study, generic US-EPA silt loadings were used:

Silt Content Range	Average Silt Content
4.9% to 5.3%	5.1%

The average silt content (5.1%) was used in the emission estimates. The US-EPA recommends a moisture content of 0.2% for dry uncontrolled conditions which was used in the current assessment.

Annual average ground level concentrations were assessed with the assumption that the US-EPA natural dust control (rainfall) on unpaved road surfaces:

$$E_x = E\left[{(365 - P)}\big/{365}\right]$$

Where,

E_x	=	Emission rate
E	=	Unmitigated emission rate
P	=	number of days in a year with at least 0.254 mm of precipitation.

Assuming that the vehicles move over the access road surfaces at least once per day during construction activities, the calculated emissions due to vehicle entrainment on unpaved road surfaces is 22.9 tpa (TSP) and 6 tpa (PM10).

As a conservative approach, no control efficiencies were applied to the unpaved road surfaces in order to predict “worst case” particulate matter impacts.

4.3.1.3 Vehicle Entrained Emissions from Paved Roads

Particulate emissions will result from the entrainment of loose material from the paved road surface due to vehicle traffic (Cowhert and Engelhart, 1984, 1985; Jones and Tinker, 1984). The extent of particulate emissions from paved roads is a function of the "silt loading" present on the road surface. In return, the silt loading is affected by the mean speed of vehicles on the road, the average daily traffic, the number of lanes and to a lesser extent of the average weight of vehicles travelling on the road (Cowhert and Engelhart, 1985; EPA, 2006). Silt loading (sL) refers to the mass of silt-size material (i.e. equal to or less than 75 microns in diameter) per unit area of the travel surface.

The quantity of dust emitted from vehicle traffic on paved roads was estimated based on the following equation (EPA, 2006):

$$E = k(\frac{sL}{2})^{0.65}(\frac{W}{3})^{1.5} - C$$

where,

E = particulate emission factor in grams per vehicle km travelled (g/VKT)

K = basic emission factor for particle size range and units of interest

sL = road surface silt loadings (g/m^2)

W = average weight (tons) of the vehicles travelling the road

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

The particle size multiplier (k) is given as 4.6 for PM10, and as 24 for TSP. The emission factor (C) is given as 0.1317 g/VKT for PM10 and TSP. Generally, roads with a higher traffic volume tend to have lower surface silt loading (sL). The surface silt loading should preferably be measured to reflect site-specific conditions. As the silt loading was unknown for the current study, recommended US-EPA silt loading of 0.2 g/m^3 was used. This value was obtained from the US-EPA AP-42 Section 13.2.1 (2006) recommended for normal conditions 500-5000 vehicles per day.

Ground level concentrations were assessed with the assumption that the US-EPA natural dust control (rainfall) on paved road surfaces:

$$E_x = E\left[1 - {(1.2 * P)}\big/{8760}\right]$$

Where,

$\boldsymbol{E_x}$	=	Emission rate
E	=	Unmitigated emission rate
P	=	number of hours in a year with at least 0.254 mm of precipitation.

The calculated emissions due to vehicle entrainment on paved road surfaces from construction activities only is 0.34 tpa (TSP) and 0.06 tpa (PM10).

4.3.2 Dispersion Simulations

The dispersion simulations were undertaken using an analytically derived line source Gaussian dispersion model (Huang, 1979). The model was derived from the classic Advection-Diffusion equation and assumed power law expressions for the mean wind speed and vertical eddy diffusivity. For a summary of this model refer to Seinfeld & Pandis (1997).

The source release height and receptor (“flag”) heights were simulated as being 0.5 m and 1.5 m, respectively. Air concentrations at the flag height were calculated at increasing distances, up to 1 000m, from the vehicle source.

Impacts from the vehicles were assessed with the various stability and average wind speed categories as obtained from the Eskom operated Kendal 2 monitoring station.

4.3.3 Predicted Impacts

The predicted impacts provided for the relevant pollutants of concern due to the vehicle entrainment releases and earthworks are given in Figure 4-1 to Figure 4-4.

The predicted PM10 ground level concentrations due to vehicle entrainment on unpaved and paved road surfaces as well as earthworks as a result of proposed construction activities, were well within the proposed daily and annual PM10 SA standards of 75 µg/m³ and 40 µg/m³ respectively.

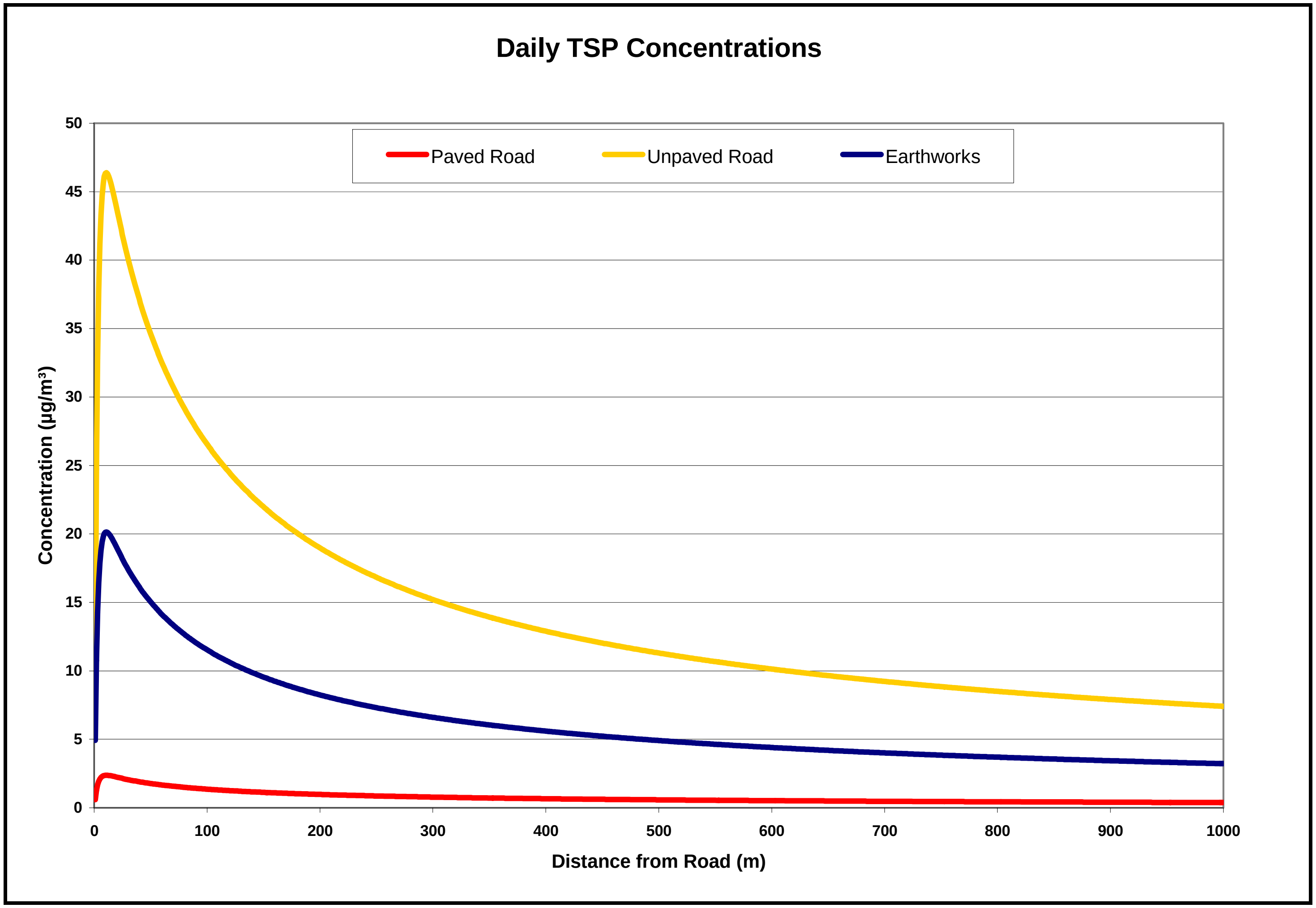

Figure 4-1: Daily TSP concentrations due to vehicle entrainment on paved and unpaved road surfaces as well as earthworks for proposed construction operations.

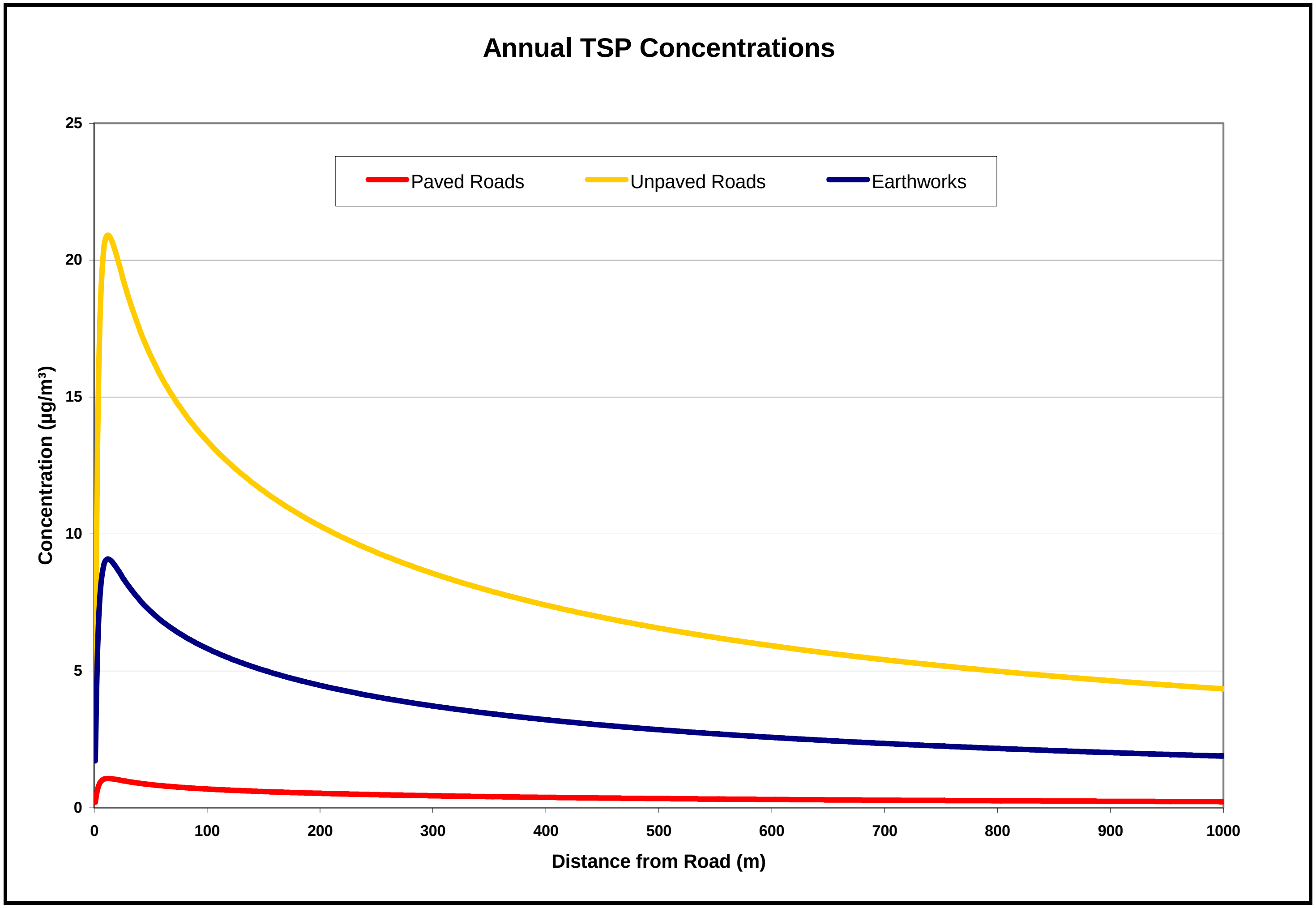

Figure 4-2: Annual average TSP concentrations due to vehicle entrainment on paved and unpaved road surfaces as well as earthworks for proposed construction operations.

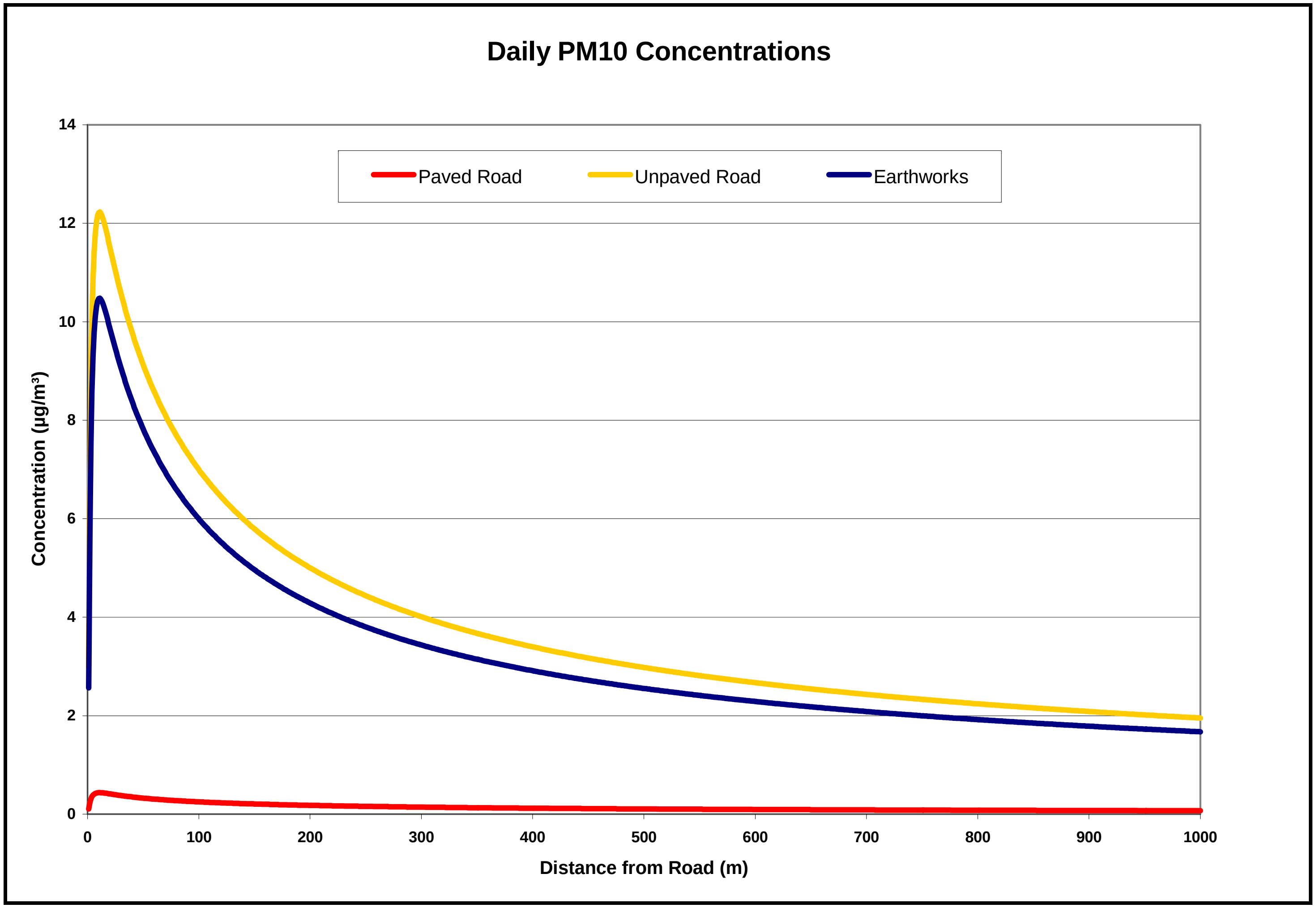

Figure 4-3: Daily PM10 concentrations due to vehicle entrainment on paved and unpaved road surfaces as well as earthworks for proposed construction operations.

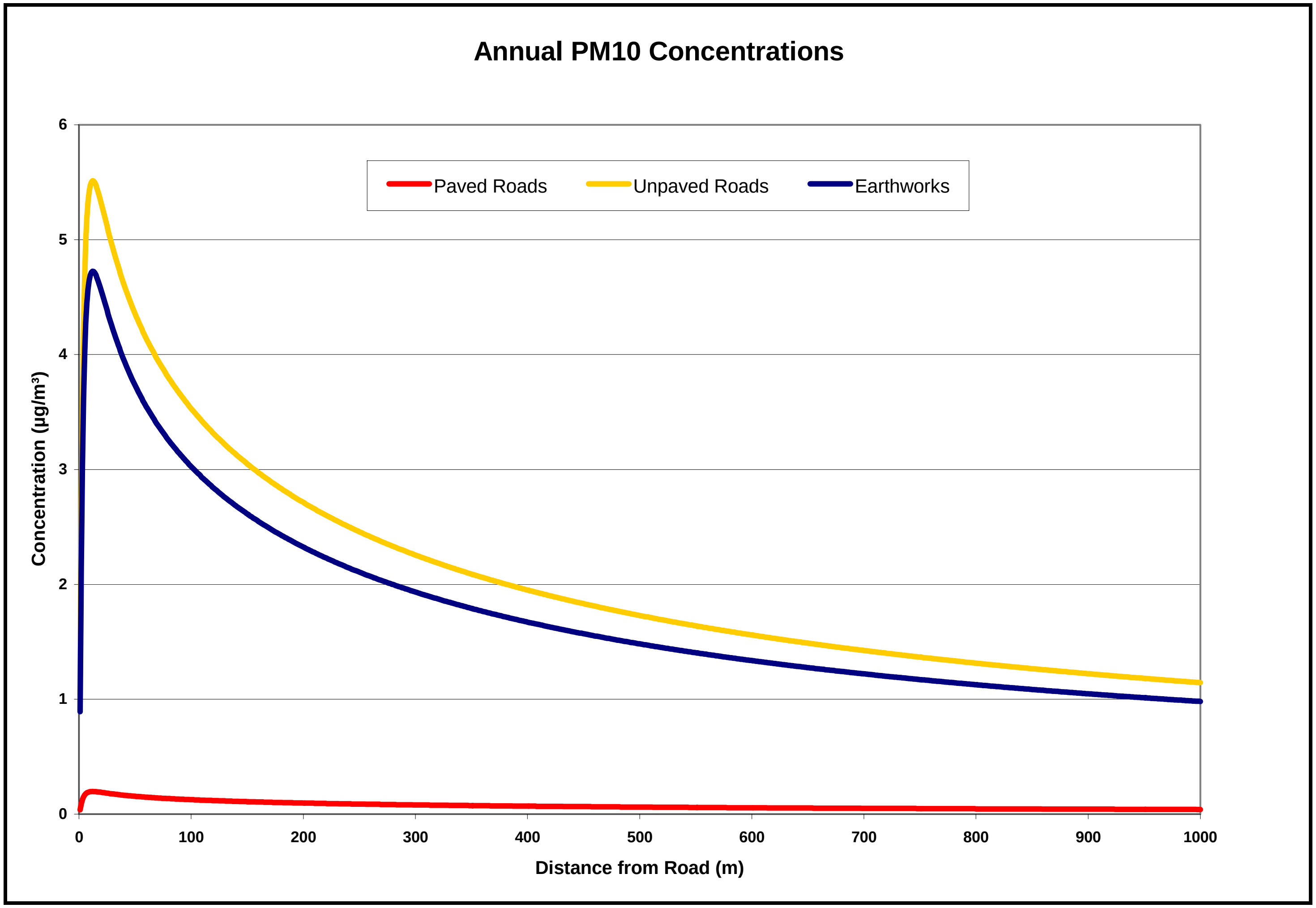

Figure 4-4: Annual average PM10 concentrations due to vehicle entrainment on paved and unpaved road surfaces as well as earthworks for proposed construction operations.

4.3.4 Mitigation Measures

Dust Control Options for Unpaved 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, gravel surface), (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).

The control efficiencies achievable through paving unpaved roads may be estimated by comparing emission factors for unpaved and paved roads, in the particle size range of interest. Control efficiencies of 70% to 90% may be achieved through effective application of chemical surfactants or through the surfacing of roadways. It should, however, be noted that the paving of roads will only be effective if the dust loading on the road is controlled. Control programs aimed at reducing the particulate loading may consist of either preventative or mitigative measures, or a combination of both. Preventative measures impede the deposition of materials onto the travel surface, whereas mitigative measures remove that which has been deposited.

The control efficiency obtained by speed reduction can be calculated by varying the vehicle speed input parameter in the predictive emission factor equation given for unpaved roads. An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted.

Permanent improvements in travel surfaces, such as the paving of a road, results in continuous control efficiencies. The control efficiencies obtained by wet suppression and the use of chemical stabilizers are, however, cyclic rather than continuous by nature as indicated previously.

Watering represents a commonly used, relatively inexpensive option, but provides only temporary dust control. Although the chemical treatment of exposed surfaces is more expensive, it provides for longer dust suppression. The use of chemicals may, however, have adverse effects on the receiving biophysical environment if not carefully selected and properly applied (Cowherd et al., 1988; EPA, 1996).

The efficiency afforded by the application of water or chemicals decays over time, requiring periodic reapplication to maintain the desired average efficiency (Cowherd et al., 1988).

4.4 Operational Phase

During the operational phase, the main activity of concern in terms of Air Quality was identified to be fugitive emissions from the railway due to the transportation of sorbent. The sorbent material in the rail wagons should be covered during transportation. However, as a conservative approach the rail wagons were assumed to be uncovered in order to quantify the maximum impacts due to this activity.

4.4.1 Emissions Inventory

In order to quantify the fugitive emissions from sorbent material in open wagons on a train in transit, a wind erosion calculation method was applied to account for the variability in source erodibility through the parameterisation of the erosion thresholds based on the particle size distribution of the source.

With the ADDAS model threshold friction velocities for each of a number of particle size categories are calculated. Mobilisation of each particle size can then be determined to finally obtain a vertically integrated horizontal dust flux. The horizontal dust flux is subsequently used to quantify the vertical dust flux, i.e. the suspended fraction of airborne particulates. Under normal wind conditions, the maximum suspended particles size is seldom more than 100 micron. However, with a train speed of 30-70 km/hr, larger particles could possibly remain airborne. These particles would however, be deposited within the first 100 - 200 m.

The ADDAS model is discussed in more detail in the Appendix A. The sorbent material will mainly range from 1 mm to 18 mm in size with a small fraction of the material being fine. The fine particle size distribution of the solvent (Table 4-1) was obtained from a study undertaken for solvent material after circulating fluidised bed combustion (Montagnaro *et al*, 2009) as no detailed particle size distribution information on the proposed sorbent to be used was available for the current study. The parameters used in the calculation of emissions from the open wagons are given in Table 4-2. Emission rates were calculated for various wind speeds, ranging from 2 to 19.4 m/s. It is assumed that the material on the surface will become dryer as the train increases speed. Three variations in material moisture were assessed in the emission calculations (i.e. 8%, 6% and 4%). The three scenarios however provided similar impacts.

Table 4-1: Particle size distribution of sorbent used in the wind erosion estimation method.

Particle diameter (µm)	Mass Fraction
2000	0.0502
1000	0.1172
300	0.2680
150	0.1340
100	0.1675
75	0.0502
50	0.1273
30	0.0670
10	0.0167
5	0.0017
1	0.0002

Table 4-2: Parameters used to calculate the particulate emissions from the open rail wagons

Parameter		Information
Ore Wagon Dimensions	Length [(1)]	12.6 m
	Width [(1)]	3.3 m
	Height [(1)]	3.35 m
	Height above rail level [(1)]	3.35 m
Average Speed of Loaded Train		30 km/hr
Maximum Speed of Loaded Train		70 km/hr
Wagons per train		50
Solvent load per wagon		80 t
Trains entering Kusile Power Station site per day		1
Trains exiting Kusile Power Station site per day		1

Note:

(1) Assumptions

4.4.2 Dispersion simulation

The dispersion simulations were done using an analytically derived line source Gaussian dispersion model (Huang, 1979). The model was derived from the classic Advection-Diffusion equation and assumed power law expressions for the mean wind speed and vertical eddy diffusivity. For a summary of this model refer to Seinfeld & Pandis (1997).

The source release height and receptor (“flag”) heights were simulated as being 3.35 and 1 m, respectively. Air concentrations at the flag height were calculated at increasing distances, up to 1 000m, from the rail track.

Maximum and average daily and annual impacts from the railway wagons were assessed with the various site specific stability and average daily wind speed categories.

4.4.3 Predicted Impacts

The predicted daily PM10 and TSP concentrations for sorbent material are presented in Figure 4-5 to Figure 4-8. As the various moisture contents of the sorbent material (i.e. 8%, 6% and 4%) provided similar impacts, the prediction ground level concentration for sorbent at 8% moisture content was illustrated only.

The predicted PM10 ground level concentrations due to wind-blown sorbent material from the moving rail carts were well within the proposed daily and annual PM10 SA standards of 75 µg/m³ and 40 µg/m³ respectively.

4.4.4 Mitigation Measures

Effective mitigation measures for the rail transportation of sorbent material would be to cover the wagons. This will eliminate the impacts of wind blown sorbent material.

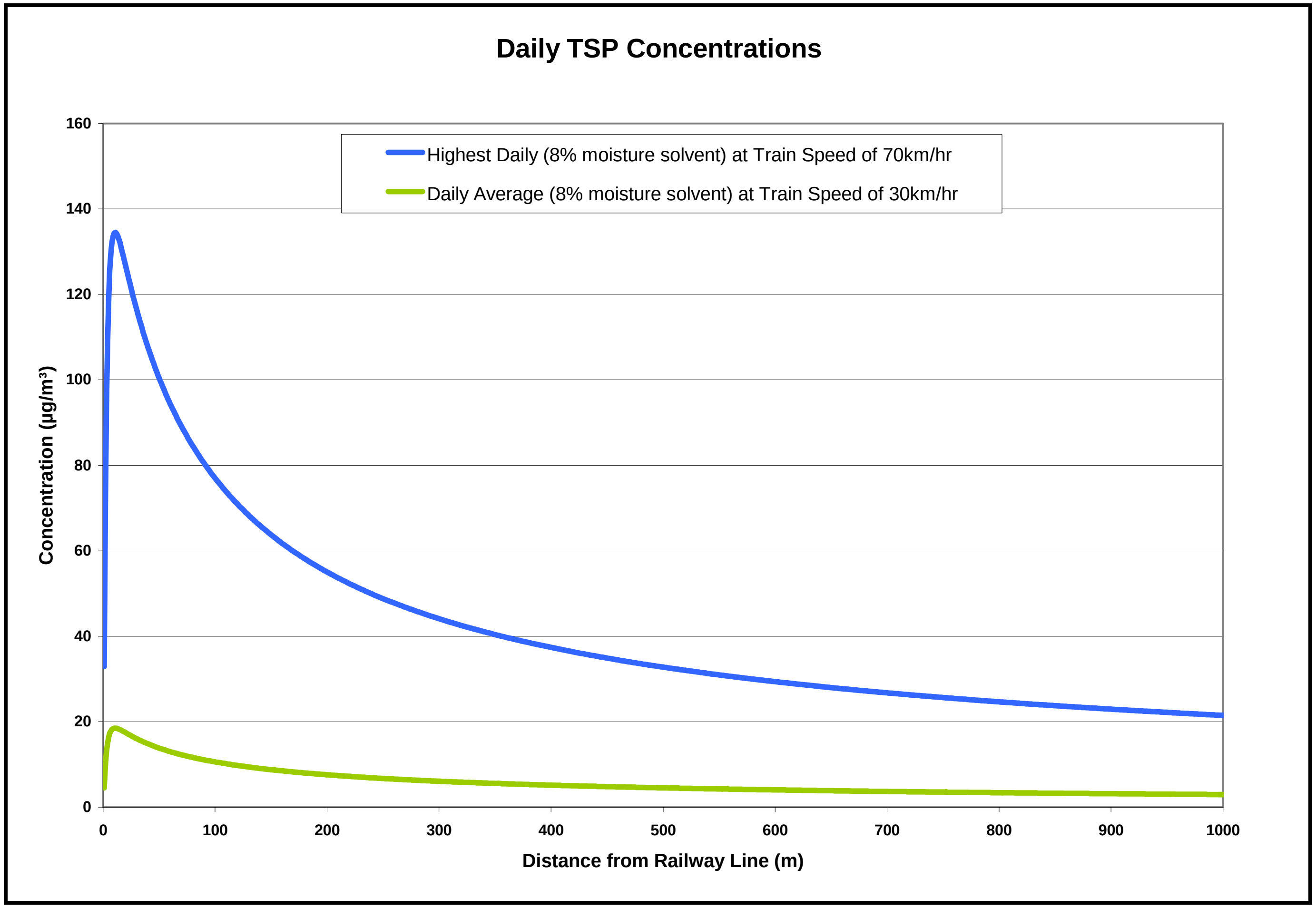

Figure 4-5: Daily TSP concentrations due to wind-blown sorbent material from moving rail carts during operational activities.

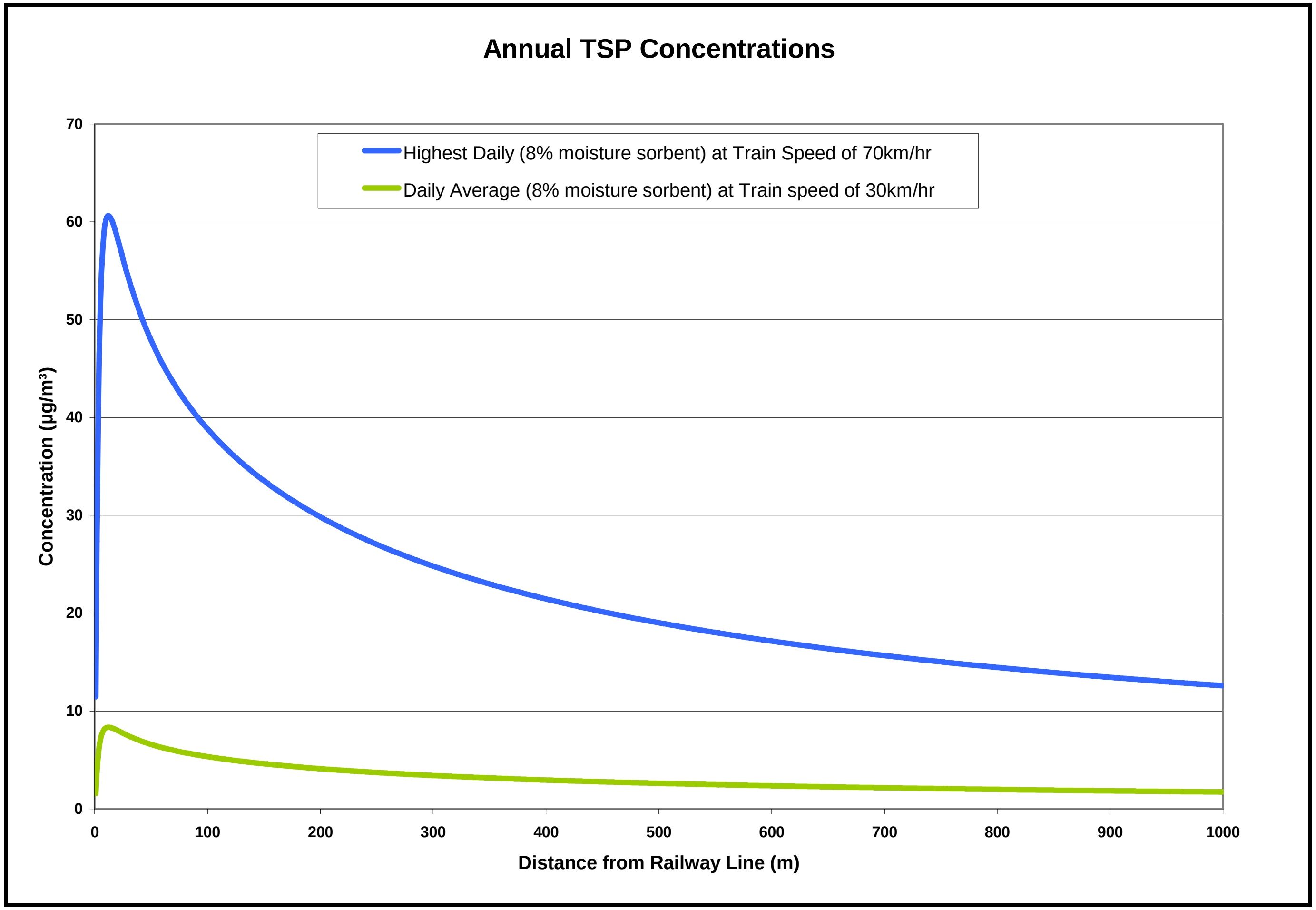

Figure 4-6: Annual TSP concentrations due to wind-blown sorbent material from moving rail carts during operational activities.

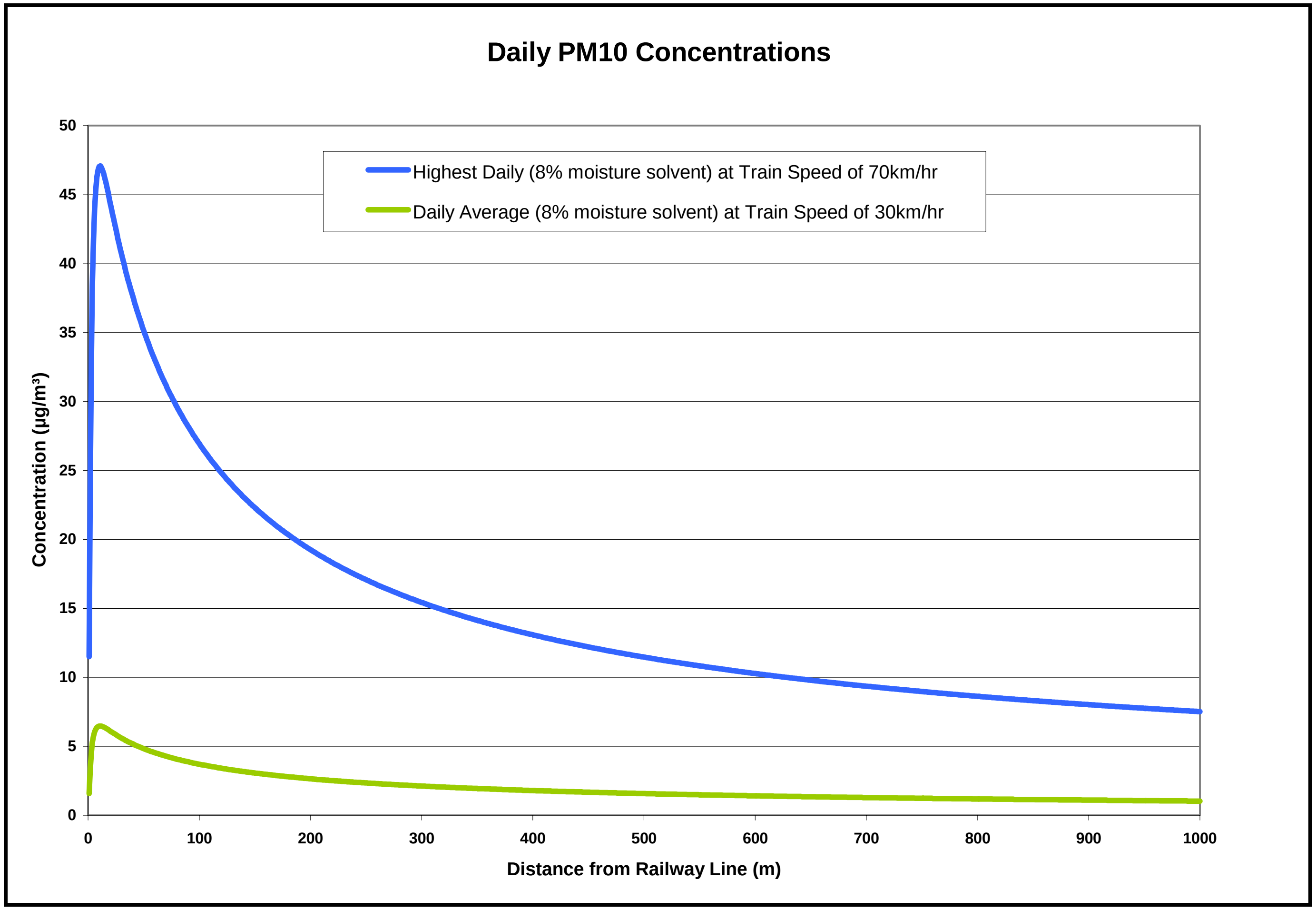

Figure 4-7: Daily PM10 concentrations due to wind-blown sorbent material from moving rail carts during operational activities.

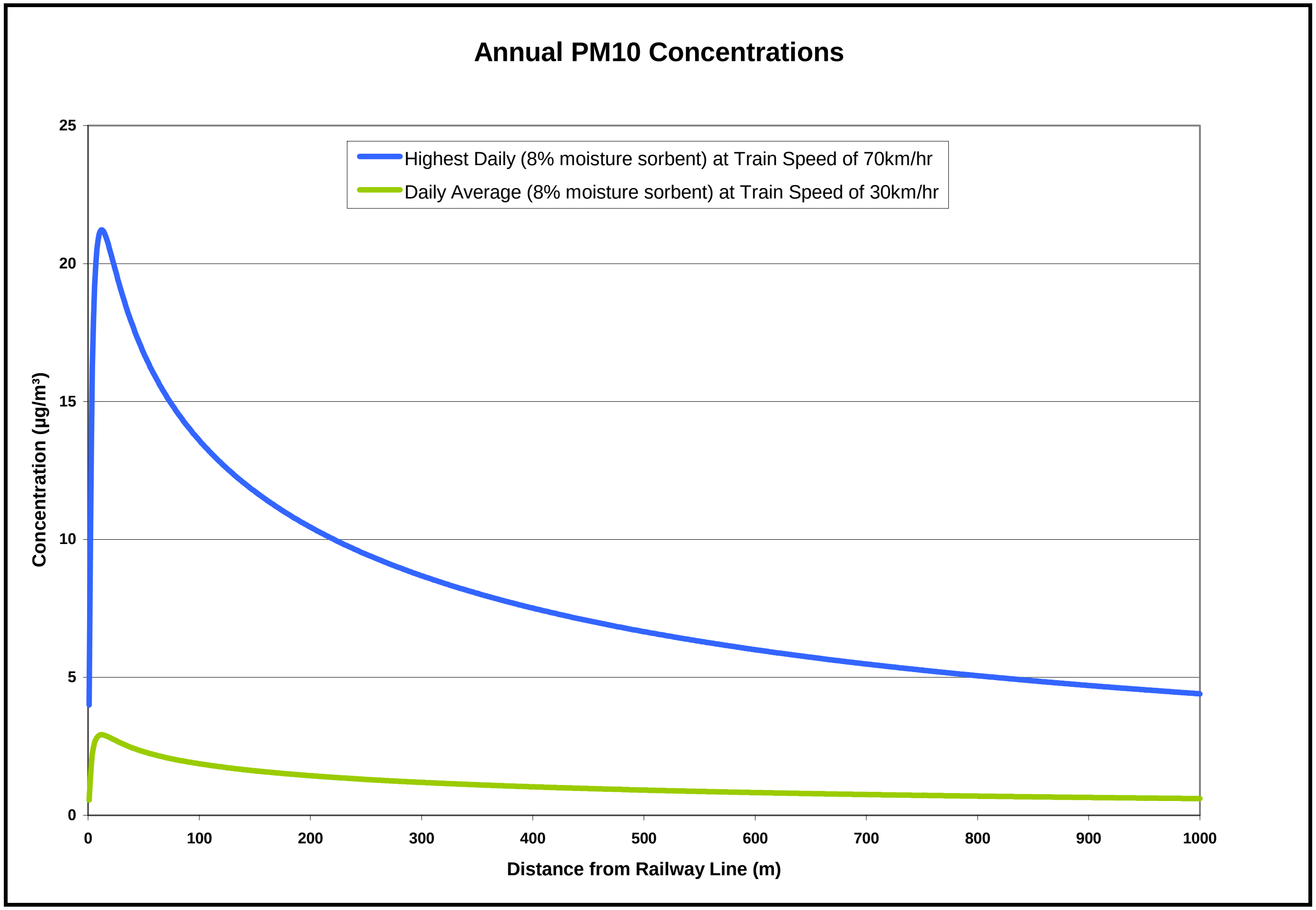

Figure 4-8: Annual PM10 concentrations due to wind-blown sorbent material from moving rail carts during operational activities.

5 CONCLUSIONS AND RECOMMENDATIONS

The main objective of this investigation was to determine ground level particulate concentrations due to construction and operation activities from the proposed Kusile Railway Project.

Pollutants of concern for the current study consisted of particulate matter (including inhalable particulates (PM10) and total suspended particulates (TSP).

The main conclusions from the current assessment are summarised as follows:

- For construction activities the predicted PM10 concentrations due to vehicle entrainment on paved and unpaved road surfaces were well within current and proposed SA standards for all averaging periods (with the conservative approach of assuming no control efficiencies on road surfaces).

- Due to the transportation of sorbent material in open wagons during the operational phase, the highest daily and annual predicted PM10 concentrations were within the current and proposed SA standards (with the conservative approach of assuming no covering of rail wagons). The impacts due to not covering the sorbent during transportation are therefore low.

Recommendation

As the proposed PM10 impacts due to the construction and operational activities from the Kusile Project are within the current and proposed SA standards for all averaging periods, it is recommended that Kusile Project be implemented as specified for the current assessment (i.e. 1 train entering and leaving the Kusile premises per day with 50 wagons per train, etc). The impacts transported via rail is expected to have lower impacts that if the sorbent were transported via road. It therefore recommended that this mode of transport (rail) be implemented.

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APPENDIX A:

Fugitive Dust Emissions – 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, cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and cover similarly reduces the potential for dust generation. The shape of an erodible area 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).

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

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

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

for

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

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

where,

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

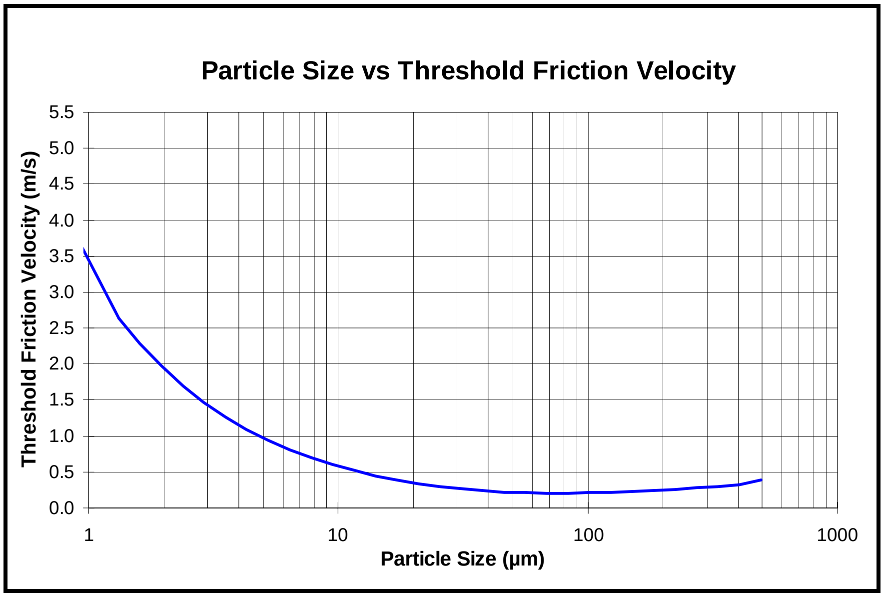

Figure A-1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995).

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

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, 1998):

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

(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.)