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GROOT LETABA RIVER WATER DEVELOPMENT PROJECT (GLeWaP)

Environmental Impact Assessment

(DEAT Ref No 12/12/20/978)

ANNEXURE F: AIR QUALITY IMPACT ASSESSMENT

MARCH 2010

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DECLARATION OF CONSULTANTS' INDEPENDENCE

Airshed Planning Professionals (Pty) Ltd, who are an air quality specialists, are independent consultants to ILISO (Pty) Ltd Consultants (for the Department of Water Affairs and Forestry), i.e. they have no business, financial, personal or other interest in the activity, application or appeal in respect of which they were appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of these specialists performing such work.

REPORT DETAILS PAGE

Project name:	***Groot Letaba River Development Project***
Report Title:	***Environmental Impact Assessment Appendix J: Air Quality Impact Assessment***
Author:	***RG Thomas***
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SPECIALIST
Approved for Specialist Study by:

12/03/2009

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Project Director

EXECUTIVE SUMMARY

Airshed Planning Professionals (Pty) Ltd was appointed by ILISO Consulting (Pty) Ltd to undertake an air quality impact assessment for the fugitive emissions that would emanate from the raising the Tzaneen Dam, the construction of a storage dam in the Groot Letaba River and associated bulk water infrastructure.

The aim of the investigation was to quantify the possible impacts resulting from fugitive sources on the surrounding environment and human health. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

The investigation followed the methodology required for a specialist report, comprising the baseline characterisation and the impact assessment study.

Baseline Assessment

The baseline study encompassed the analysis of meteorological data recorded at the Weather Service Station of Grenshoek Tzaneen (~42 km west from the proposed Nwamitwa Dam). Hourly average wind field, temperature and relative humidity data for the period January 2003 to May 2006 was used to determine wind field and temperature profiles for the region. This hourly average data was used for the dispersion simulations for the proposed project. Upper air data was obtained from the closest calculated ETA data point, obtained from the South African Weather Services.

Impact Assessment Criteria

Particulates represented the main pollutant of concern given the nature of the operations. Particulate matter is classified as a criteria pollutant, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of this pollutant. Air quality guidelines and standards for particulates are given for various particle size fractions, including Total Suspended Particulates (TSP) and respirable particulates or PM10 (i.e. particulate matter with an aerodynamic diameter of < 10 µm).

Emissions Inventory

Emissions inventories provide the source input required for the simulation of ambient air concentrations. Fugitive emissions from the construction activities were quantified for the current assessment.

Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important limitations and assumptions of the air quality impact assessment are summarised as follows:

- *Ambient monitored data could not be obtained for the current study. The baseline ambient air quality and thus cumulative ground level impacts could therefore not be assessed.*
- *Measured upper data was not available close to the study site. Use was therefore made of calculated ETA data obtained from the Weather Services (~25 km south of the proposed dam).*
- *No on-site meteorological data was available for the current study. Use was therefore made of the closest Weather Service Station at Grenshoek Tzaneen at 23°46'12"S; 30°04'12"E (~42km west of the proposed Nwamitwa Dam) for the impact assessment.*
- *The Weather Service Station at Grenshoek Tzaneen was decommissioned in June 2006. Use was therefore made of data for the period January 2003 to May 2006.*
- *Due to the lack of detailed information available for the construction activities, use was made of the construction emission factors provided by the US-EPA.*
- *The width of the weir to be constructed was assumed to be 100 m.*
- *The moisture content of the material handled and transported was assumed to be 2 %.*
- *The silt loading on the public roads (which will be used to transport the material from the borrow areas to the construction sites) was not available for the current study. Use was therefore made of typical values.*

- *The empty weight of the trucks used to transport the material from the borrow sites and concrete batching plant was assumed to be 10t.*

- *Particle and bulk density for the material transported was not available for the current study. Use was therefore made of typical values.*

- *No information was available for the cement batching plant and bitumen plant process. The impacts from these processes, however, are expected to be localised.*

- *Detailed information of activities (i.e. vehicle movements, stockpiles, etc.) at the borrow pit was not available for the current assessment. Emissions quantification at these sources was therefore limited to materials handling operations.*

Impact Prediction Study

Particulate concentrations and deposition rates due to the proposed project was simulated using the US-EPA approved AERMET/AERMOD dispersion modelling suite. Ambient concentrations were simulated to ascertain highest daily and annual averaging levels occurring as a result of the proposed activities.

CONCLUSIONS

The following conclusions were reached:

Baseline Assessment

- *The prevailing wind field for the area is from the east (~10 % of the time), the west (~6.5 %) and the south (6 %).*

- *No ambient monitored data were available for the area. Cumulative impacts due to the proposed project could therefore not be assessed.*

Impact Assessment

- *The highest daily and annual average PM10 ground level concentrations at the sensitive receptor of Tzaneen due to the proposed raising of the dam wall with no control efficiency was predicted to be 0.59 µg/m³ and 0.04 µg/m³ respectively (well within all relevant standards and guidelines).*

- *The predicted maximum deposition due to the raising of the Tzaneen Dam was predicted to be 0.98 mg/m²/day at the sensitive receptor of Tzaneen (well within the SANS target of 600 mg/m²/day for residential areas).*

- *For construction activities at the Nwamitwa Dam and road realignment, the highest daily and annual predicted PM10 ground level concentrations at the closest sensitive receptor of Nkamboko were 345 µg/m³ and 30 µg/m³ respectively (assuming no dust control). The highest daily ground level concentrations exceeded the current SA standards as well as the stricter SANS and EC limits. The predicted maximum deposition at the closest sensitive receptor of Ka-Mswazi is predicted to be 107 mg/m²/day (within SANS target of 600 mg/m²/day for residential areas).*

- *For the construction of the reservoirs and pump houses, the highest predicted daily and annual average PM10 ground level concentrations at the closest sensitive receptor of Serolorolo was 66 µg/m³ and 9 µg/m³ respectively. The highest daily ground level concentrations are within the SA standards and in line with the SANS limits, but exceeded the EC limits by 33 %. During this construction phase (assuming uncontrolled emissions), the predicted maximum deposition at the closest sensitive receptor of Ka-Mswazi was predicted to be 107 mg/m²/day (within SANS target of 600 mg/m²/day for residential areas).*

- *The highest daily and annual average ground level concentrations due to borrow pit activities were well within the SA standards, SANS and EC limits.*

- *For highest daily PM10 concentrations due to vehicle entrainment from the transportation of various materials, the SANS (75 µg/m³) and EC limits (50 µg/m³) were exceeded for 50m (transportation of earthfill material) from the road as the vehicle passes. For annual average PM10 concentrations, the SANS and EC limits of 40 µg/m³ are exceeded for 40 m (transportation of earthfill material) from the source. The predicted maximum deposition, exceeded the SANS industrial (1 200 mg/m²/day) and residential targets*

(600 mg/m^2/day) for 50 m with the transportation of earthfill material. With the transportation of concrete and concrete coarse aggregate, the SANS residential target of 600 mg/m^2/day is exceeded for 50m from the source.

- *The predicted ground level concentrations for SO2 (<0.3 %), 1,3 butadiene (<1.1 %), CO (<0.03 %), NO2 (<2.8 %), diesel particulates (<5.9 %) and benzene (<0.05 %) are well below the applicable guidelines/ standards given in Section 7 as well as the strictest effect screening levels. The predicted cancer risk (using the US-EPA unit risk factors) due to 1,3 butadiene and benzene is predicted to be less than 8 in 10 million (10 m from the vehicle source), well below the acceptable limit of 1 in 1 million given by the US-EPA.*

- *The predicted daily PM10 concentrations and dust deposition for the trenching and covering of the pipeline path exceeded the SANS limit of 75 µg/m^3 and EC limit of 50 µg/m for a distance of 10 m and 20 m from the source respectively. For annual average PM10 concentrations, the SA standard of 60 µg/m^3 was exceeded for 10 m from the source, and the SANS and EC limits of 40 µg/m^3 was exceeded for 20 m from the source. The predicted maximum deposition, exceeded the SANS industrial (1200 mg/m^2/day) and residential (600 mg/m^2/day) targets for 10 m and 20 m from the source respectively.*

- *The significance rating without mitigation was* ***Medium*** *for the construction activities at the Nwamitwa Dam and road realignment and the construction of the reservoirs due to short-term PM10 exposure For the transportation of material, laying down of the pipeline, raising of the Tzaneen Dam and activities at the borrow pits, the significance rating was* ***Low****.*

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ABBREVIATIONS

AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMOD	AERMIC dispersion model
AERMAP	AERMOD terrain pre-processor
AERMET	AERMOD meteorological pre-processor
APCS	Air Pollution Control System
AQGs	Air Quality Guidelines
CO	Carbon monoxide
CO_2	Carbon dioxide
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DWAF	Department of Water Affairs and Forestry
EC	European Community
EIA	Environmental Impact Assessment
EMS	Environmental Management System
GLeWaP	Groot Letaba River Water Development Project
HC	Hydrocarbon
HP	High Pressure
ISCST	Industrial Sources Complex Short-Term Model
IT	Interim Targets

NEMA	National Environmental Management Act
NO	Nitrous oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
OA	Options Analysis
PAH	Polycyclic aromatic hydrocarbons
PCMT	Project Co-ordination and Management Team
PM2.5	Particulate matter with diameter of 2.5 µm
PM10	Particulate matter with diameter of 10 µm
PSP	Professional Service Provider
SA	South African
SABS	South African Bureau of Standards
SO_2	Sulphur dioxide
TSP	Total Suspended Particulates
UK	United Kingdom
USA	United States of America
US EPA	United States Environmental Protection Agency
WB	World Bank
WHO	World Health Organisation

1. STUDY INTRODUCTION

1.1 BACKGROUND TO PROJECT

The Department of Water Affairs and Forestry (DWAF) has commissioned an Environmental Impact Assessment (EIA) to investigate the environmental feasibility of raising the Tzaneen Dam, the construction of a storage dam in the Groot Letaba River and associated bulk water infrastructure (water treatment, pipelines, pump stations, off-takes and reservoirs) in the Limpopo province (**Figure 1.1**). The EIA is being undertaken by ILISO Consulting with Zitholele Consulting providing the public participation support. The EIA is being undertaken according to the EIA Regulations under Section 24 (5) of the National Environmental Management Act (NEMA), (Act No 107 of 1998) as amended in Government Notice R385, 386, 387 – Government Gazette No. 28753 of 21 April 2006.

ILISO Consulting has appointed Airshed Planning Professionals (Pty) Ltd. to undertake the Air Quality Impact Assessment as part of the EIA.

1.2 STRUCTURE OF THIS REPORT

This specialist study will be undertaken in compliance with regulation 33(2) of GN385. **Table 1.1** indicates how Regulation 33 of GN385 has been fulfilled in this report.

Table 1.1: Indication of compliance with Regulation 33 in this report

Regulatory Requirements	Section of Report
(a) The person who prepared the report; and the expertise of that person to carry out the specialist study or specialised process.	Chapter 2
(b) a declaration that the person is independent	Page i
(c) an indication of the scope of, and the purpose for which, the report was prepared	Chapter 3
(d) a description of the methodology adopted in preparing the report or carrying out the specialised process	Chapter 4
(e) a description of any assumptions made and any uncertainties or gaps in knowledge	Chapter 5

Regulatory Requirements	Section of Report
(f) a description of the findings and potential implications of such findings on the impact of the proposed activity on the environment	Chapter 8
(g) recommendations in respect of any mitigation measures that should be considered by the applicant and the competent authority	Chapter 10
(h) a description of any consultation process that was undertaken during the course of carrying out the study	Chapter 11
(i) a summary and copies of any comments that were received during any consultation process	Chapter 12
(j) any other information requested by the competent authority.	Chapter 13

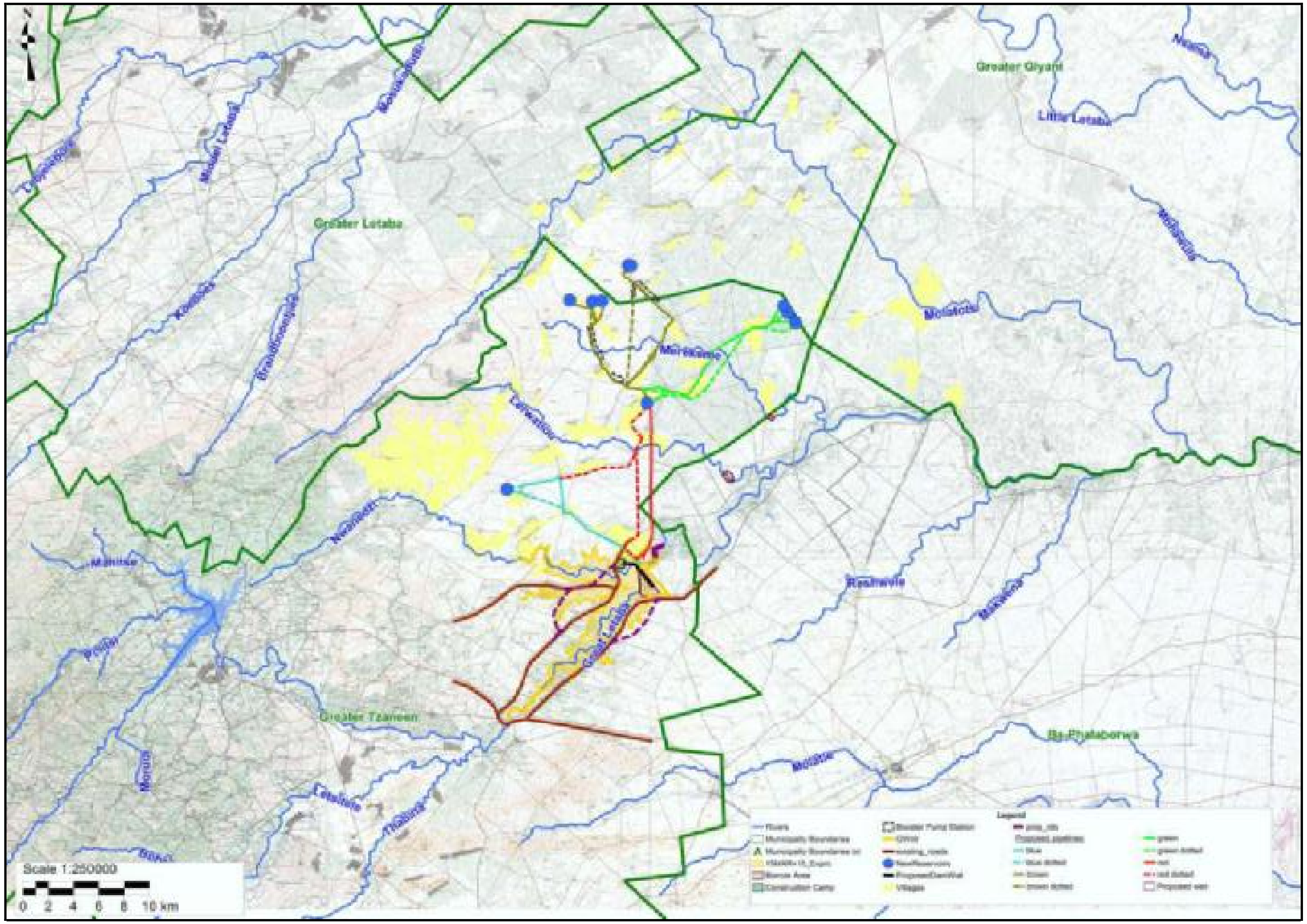


Figure 1.1: The study area

2. PROJECT TEAM

Reneé Thomas of Airshed Planning Professionals (Pty) Ltd. will undertake the air quality impact assessment. She has six years of experience in the field of air pollution impact assessment and air quality management. She was part of the Highveld Boundary Layer Wind Research Group based at the University of Pretoria. At Airshed Planning Professionals (previously Environmental Management Services) she has undertaken numerous air pollution impact studies and has provided extensive guidance to both industry and government on air quality management practices. She is currently completing her masters in micrometeorology. She has experience in conducting air quality impact assessments for a wide range of industries including: pulp and paper industries, pelletizer operations, refineries, cement operations, incinerators, chromium chemical operations, power stations, iron and steel industries, platinum industry, mining, cement industries, chlorine industries, ferro-silicon industries and fertilizer plants. She is a member of NACA, the National Association for Clean Air.

3. PURPOSE OF REPORT AND SCOPE OF WORK

The aim of the investigation is to quantify the possible impacts resulting from the proposed raising the Tzaneen Dam, the construction of a storage dam in the Groot Letaba River and associated bulk water infrastructure. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

Typical of specialist investigations conducted, the air quality investigation comprises both a baseline study and an impact assessment. The baseline study 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.

Particulates represent the main pollutant of concern in the assessment of construction activities from the project. Particulate matter is classified as *criteria pollutant*, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of this pollutant. Particulates in the atmosphere may contribute to visibility reduction, pose a threat to human health, or simply be a nuisance due to their soiling potential.

3.1 SCOPE OF WORK

The following tasks will be undertaken:

Baseline Characterisation

Determine the regional climate and site-specific atmospheric dispersion potential, including:

- Analysis of meteorological data (from the nearest weather station to the site);
- Characterisation of ambient air quality and dustfall levels in the region based on available data recorded to date in the region (if available);
- Identification of the potential sensitive receptors within the vicinity of the proposed site;

- Identification of existing sources of dust emissions in area;
- The legislative and regulatory context for South Africa (also likely to include reference to the World Bank guidelines, the World Health Organisation and the European Community).

Impacts Assessment

The impacts assessment will include:

Construction Phase:

- Compilation of an emissions inventory, comprising the identification and quantification of sources of emission;
- Dispersion simulations of ambient respirable particulate concentrations and dust fallout from the construction activities for the proposed dam;
- Analysis of dispersion modelling results from both construction phases of the proposed dam, will include:
  - Determine zones of maximum incremental ground level impacts (concentrations and dust fallout); and,
  - Evaluation of potential for human health and environmental impacts.

Operational Phase:

A qualitative assessment of the proposed air quality due to the operation of the proposed dam.

Dust Management Plan:

Development of a dust management planning component for the construction phase comprising of the following:

- Source prioritisation based on source contributions to total emissions and air quality related impact potentials;
- Identification of cost-optimised mitigation and management measures for priority sources;
- Determination of suitable timeframes, responsibilities, performance indicators and targets for selected mitigation and management measures;
- Development of a suitable ambient monitoring network, to fulfil the following functions:
  - On-going characterisation of ambient air quality levels;
  - Demonstrate the level of compliance with relevant air quality guidelines and standards, and deposition levels;
  - Track progress of emission reductions measures being implemented; and,
  - Provide early warning of adverse external impacts.
- Recommendation of emission controls and management measures to be taken into account in the project design phase in order to minimise the potential for air quality impacts.

4. METHODOLOGY

4.1 ATMOSPHERIC DISPERSION MODEL

4.1.1 Atmospheric Dispersion Model Selection

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.

It was decided to employ the most recently US Environmental Protection Agency's (US EPA) approved regulatory model. The most widely used US EPA model has been the Industrial Source Complex Short Term model (ISCST3). This model is based on a Gaussian plume model. However this model has been replaced by the new generation AERMET/AERMOD suite of models. AERMOD is a dispersion model, which was developed under 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 (Hanna et al., 1999). The AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

- 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 however retains the single straight line trajectory limitation of ISCST3 (Hanna et al, 1999).

- AERMET is a meteorological pre-processor for the AERMOD model. 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 pre-processor designed to simplify and standardize the input of terrain data for the AERMOD model. 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.

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 even associated with the mathematical models themselves.

Similar to the ISC model, a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Although the model has been shown to be an improvement on the ISC model, especially short-term predictions, the range of uncertainty of the model predictions is -50 % to 200 %. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

Input data types required for the AERMOD model include: meteorological data, source data, and information on the nature of the receptor grid. Each of these data types will be described below.

4.1.2 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). Surface meteorological data, for the period January 2003 to May 2006, was obtained from the closest Weather Service Station (Grenshoek Tzaneen) to the proposed Nwamitwa dam. Upper air data was obtained from the calculated ETA modelled data from the South African Weather Services for the point 30°30'E; 24°00'S (**Figure 4.1**).

4.1.3 Source Data Requirements

The AERMOD model is able to model point, area and volume sources. The vehicle entrainment sources, pipeline trenching and construction sites were modelled as area sources.

4.1.4 Modelling Domain

The dispersion of pollutants was modelled for an area covering ~38 km (north-south) by ~55 km (east-west). This area was divided into 6 study sites, where maximum impact potential would be expected due to the proposed construction operations (**Figure 4.2**).

4.1.5 Topography

Topography was included for dispersion modelling purposes (**Figure 4.3**).

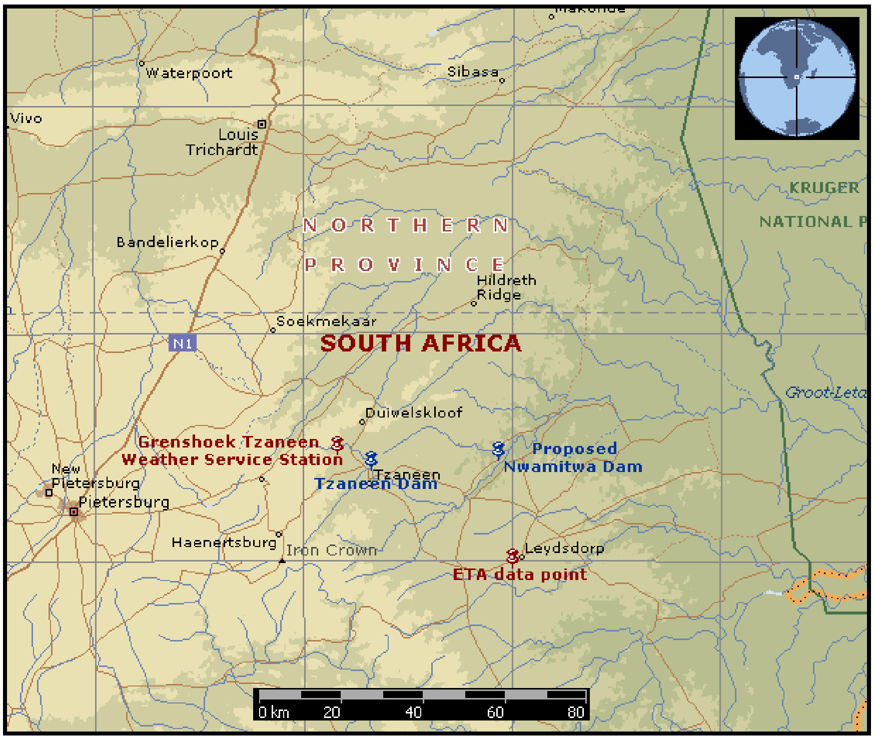


Figure 4.1: Location of the surface meteorological station and the calculated upper air ETA data point.

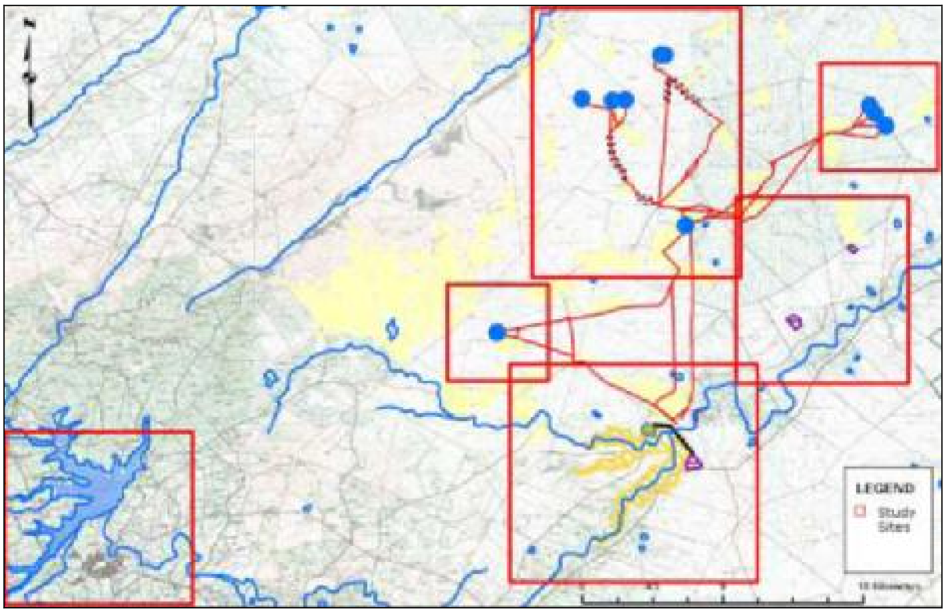


Figure 4.2: Study sites.

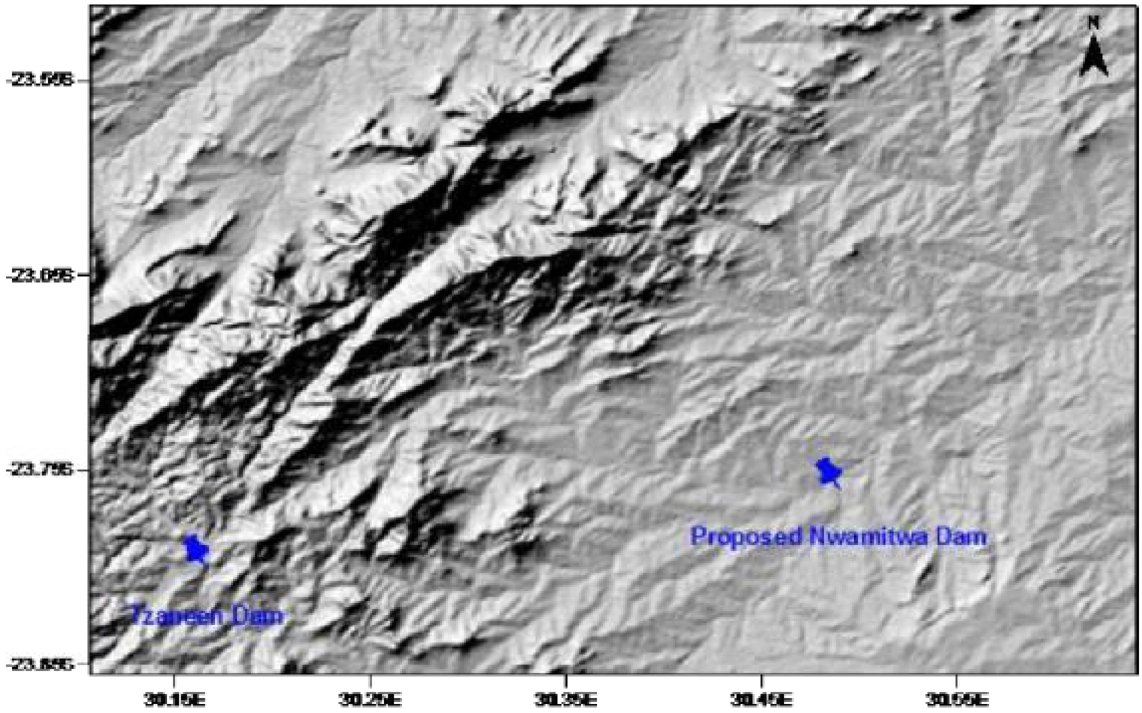


Figure 4.3: Shaded relief profile of the study area.

4.2 SIGNIFICANCE RATING

The key issues identified during the Scoping Phase informed the terms of references of the specialist studies. Each issue consists of components that on their own or in combination with each other give rise to potential impacts, either positive or negative and from the project onto the environment or from the environment onto the project. In the EIA the significance of the potential impacts will be considered before and after identified mitigation is implemented.

A description of the nature of the impact, any specific legal requirements and the stage (construction/decommissioning or operation) will be given. Impacts are considered to be the same during construction and decommissioning.

The following criteria will be used to evaluate significance:

Nature

The nature of the impact will be classified as positive or negative, and direct or indirect.

Extent and location

Magnitude of the impact and is classified as:

- **Local**: the impacted area is only at the site – the actual extent of the activity
- **Regional**: the impacted area extends to the surrounding, the immediate and the neighbouring properties.
- **National**: the impact can be considered to be of national importance.

Duration

This measures the lifetime of the impact, and is classified as:

- **Short term**: the impact will be for 0 – 3 years, or only last for the period of construction.
- **Medium term**: three to ten years.
- **Long term**: longer than 10 years or the impact will continue for the entire operational lifetime of the project.
- **Permanent**: this applies to the impact that will remain after the operational lifetime of the project.

Intensity

This is the degree to which the project affects or changes the environment, and is classified as:

- **Low**: the change is slight and often not noticeable, and the natural functioning of the environment is not affected.
- **Medium**: The environment is remarkably altered, but still functions in a modified way.
- **High**: Functioning of the affected environment is disturbed and can cease.

Probability

This is the likelihood or the chances that the impact will occur, and is classified as:

- **Low**: during the normal operation of the project, no impacts are expected.
- **Medium**: the impact is likely to occur if extra care is not taken to mitigate them.
- **High**: the environment will be affected irrespectively; in some cases such impact can be reduced.

Confidence

This is the level knowledge/information, the environmental impact practitioner or a specialist had in his/her judgement, and is rated as:

- **Low**: the judgement is based on intuition and not on knowledge or information.
- **Medium**: common sense and general knowledge informs the decision.
- **High**: Scientific and or proven information has been used to give such a judgement.

Significance

Based on the above criteria the significance of issues will be determined. This is the importance of the impact in terms of physical extent and time scale, and is rated as:

- **Low**: the impacts are less important, but may require some mitigation action.
- **Medium**: the impacts are important and require attention; mitigation is required to reduce the negative impacts
- **High**: the impacts are of great importance. Mitigation is therefore crucial.

Cumulative Impacts

The possible cumulative impacts will also be considered.

Mitigation

Mitigation for significant issues will be incorporated into the EMP for construction.

Table 4.1: Example of Impact Assessment Table

Description of potential impact		
Nature of impact		
Legal requirements		
Stage	Construction and decommissioning	Operation
Nature of Impact		
Extent of impact		
Duration of impact		
Intensity		
Probability of occurrence		
Confidence of assessment		
Level of significance before mitigation		
Mitigation measures (EMP requirements)		N/A
Level of significance after mitigation		N/A
Cumulative Impacts		
Comments or Discussion		

5. ASSUMPTIONS, UNCERTAINTIES AND GAPS IN KNOWLEDGE

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important limitations and assumptions of the air quality impact assessment are summarised as follows:

- Ambient monitored data could not be obtained for the current study. The baseline ambient air quality and thus cumulative ground level impacts could therefore not be assessed.

- Measured upper data was not available close to the study site. Use was therefore made of calculated ETA data obtained from the Weather Services (~25km south of the proposed dam).

- No on-site meteorological data was available for the current study. Use was therefore made of the closest Weather Service Station at Grenshoek Tzaneen at 23°46'12"S; 30°04'12"E (~42km west of the proposed Nwamitwa Dam) for the impact assessment.

- The Weather Service Station at Grenshoek Tzaneen was decommissioned in June 2006. Use was therefore made of data for the period January 2003 to May 2006.

- Due to the lack of detailed information available for the construction activities, use was made of the construction emission factor provided by the US-EPA.

- The width of the weir to be constructed was assumed to be 100 m.

- The moisture content of the material handled and transported was assumed to be 2 %.

- The silt loading on the public roads (which will be used to transport the material for the borrow areas to the construction sites) was not available for the current study. Use was therefore made of typical values.

- The empty weight of the trucks used to transport the material from the borrow sites and concrete batching plant was assumed to be 10 tonne.

- Particle and bulk density for the material transported was not available for the current study. Use was therefore made of typical values.

- No information was available for the cement batching plant and bitumen plant process. The impacts from these processes, however, are expected to be localised.

- Detailed information of activities (i.e. vehicle movements, stockpiles, etc.) at the borrow pit was not available for the current assessment. Emissions quantification at these sources was therefore limited to materials handling operations.

6. EXISTING ENVIRONMENT

6.1 SENSITIVE RECEPTORS

The proposed project consists of numerous residential areas **(Figure 6.1),** with residential areas in the immediate vicinity of the proposed construction sites consisting of Mothomeng, Mabyepelong, Hlohlokwe, Mookgo 6, Mookgo 7, Mawa 8, Mawa 12, Gamokgwathi, Ga-Wale, Serolorolo, Ka-Xihoko, Nkamboko, Ka-Mswazi, Mugwazini, Musiphana East, Musiphana West, Babanana and Jopi. The closest residential area to the Tzaneen dam is Tzaneen.

Residential areas represent the primary sensitive receptors in various study regions, given the potential for dust impacts associated with the proposed project.

6.2 REGIONAL CLIMATE AND ATMOSPHERIC DISPERSION POTENTIAL

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field.

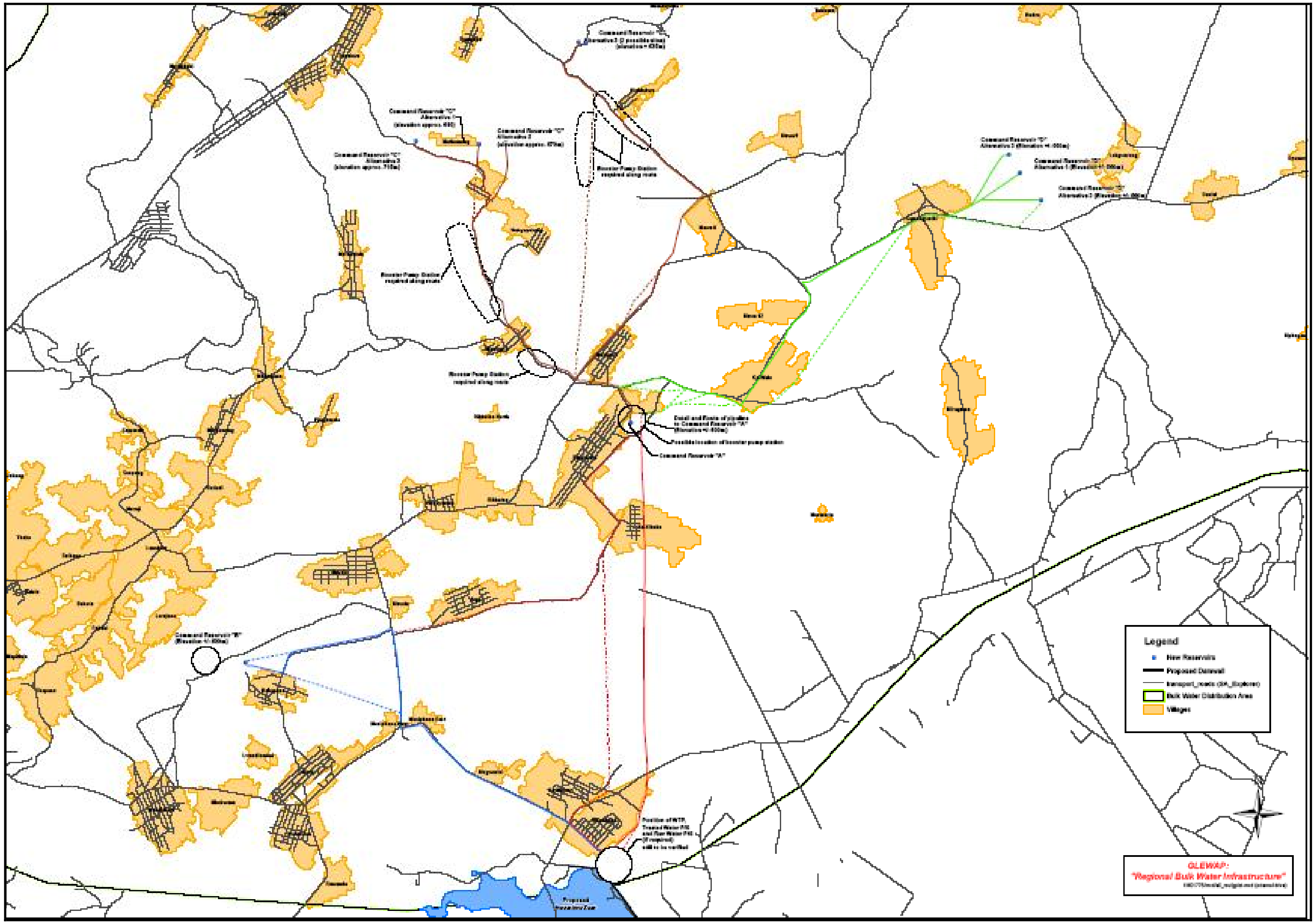


Figure 6.1: Sensitive receptors within the study area.

Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales therefore need be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic systems determining the macro-ventilation potential of the region may be provided based on the review of pertinent literature. Meso-scale systems may be investigated through the analysis of meteorological data observed for the region.

6.3 SYNOPTIC-SCALE CIRCULATIONS AND REGIONAL ATMOSPHERIC DISPERSION POTENTIAL

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 temperate latitudes. The mean circulation of the atmosphere over the subcontinent is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic High Pressure (HP), the South Indian HP off the east coast, and the continental HP over the interior.

Seasonal variations in the positioning and intensity of the HP cells determine the extent to which the circumpolar westerlies impact on the atmosphere over the region. In winter, the high-pressure belt intensifies and moves northward and the upper level circumpolar westerlies are able to impact significantly on the region. The winter weather of the region is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or ridging anticyclones moving eastwards around the South African coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards and the influence of the circumpolar westerlies diminishes. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic wintertime circulation (Preston-Whyte and Tyson, 1988; Schulze, 1980).

The general circulation of the atmosphere over southern Africa as a whole is anticyclonic throughout the year above the 700 hPa level (i.e. altitude of ~3 000 m). Anticyclones 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 and little to no rainfall occur as a result of such airflow. The climatology of the highveld region has been studied extensively in the past, where the frequency of anticyclonic conditions reaches a maximum in winter. The dominant effect of the winter subsidence is that, averaged over the year, the mean vertical motion is downward. The clear, dry air and light winds, often associated with anticyclonic circulation are ideal for surface radiation inversions of temperature, responsible for limited dispersion of especially low level pollution emissions (e.g. domestic coal fires). Surface inversions increase in frequency during nighttime and varies in depth between ~300 m to more than 500 m. The mean inversion strength during the winter is about 5°C – 6°C, whereas, in summer the strength is less than 2°C.

Circumpolar westerly waves are characterised by concomitant surface convergence and upper-level divergence that produce sustained uplift, cloud and the potential for precipitation. Cold fronts, which are associated with westerly waves, occur predominantly during winter when the amplitude of such disturbances is greatest. The passage of a cold front is characterised by distinctive cloud bands and pronounced variations in wind direction, wind speed, temperature, humidity, and surface pressure. Airflow ahead of a front passing over has a distinct north-northeasterly component and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. Following the passage of the cold front the north-easterly wind is replaced by winds with a distinct southerly component. The low-level convergence in the south-westerly airflow to the rear of the front produce favourable conditions for convection. Temperature decreases 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 radiation cooling due to the absence of cloud cover, and the advection of cold southerly air combining to produce the lowest temperatures

The tropical easterlies, and the occurrence of easterly waves and lows affect most of southern Africa throughout the year, but occur almost exclusively during summer months. The easterly waves and lows are largely responsible for the summer rainfall pattern and the northeasterly wind component that occurs over the region (Schulze, 1986; Preston-Whyte and Tyson, 1988).

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the persistence of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, destroy, weaken, or increase the altitude of elevated inversions. Easterly and westerly wave disturbances therefore facilitate the dispersion and dilution of accumulated atmospheric pollution.

6.4 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, 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 Weather Service Station in Grenshoek Tzaneen for the period January 2003 – May 2006.

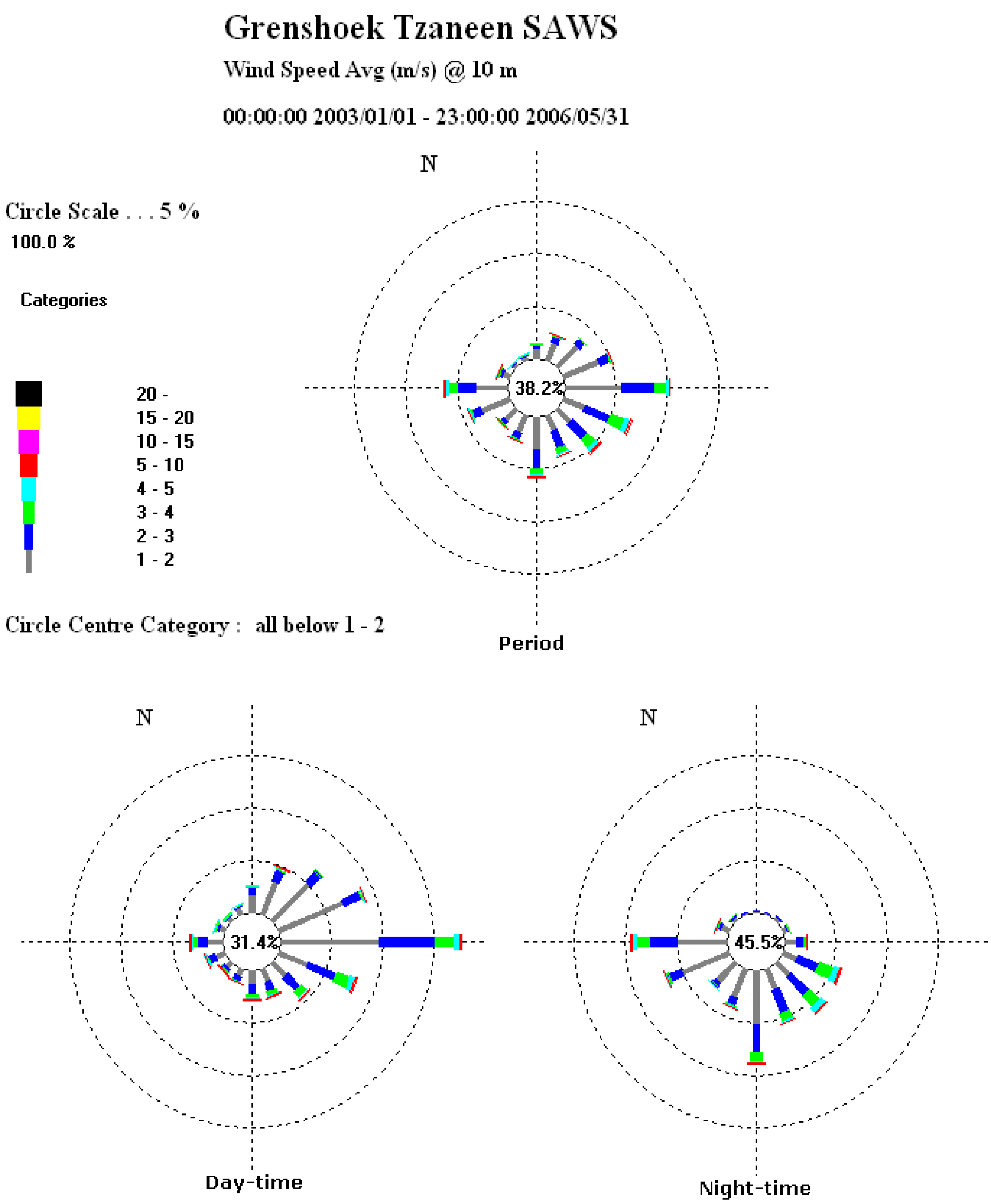
6.4.1 Local Wind Field

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.

As an average, the predominant wind field for the region is from the east (~10% frequency of occurrence) **(Figure 6.2).** A diurnal variation wind shift is clearly evident in the study area. During day-time conditions, the frequency of winds from the east increases (>15% occurrence) with calm conditions of 31.4%. During night-time conditions, the winds from the west and south increase in occurrence with an increase in calm conditions (45.5%) as is typical of more stable conditions.

Figure 6.2: Period, day- and night-time wind roses for the Grenshoek Tzaneen Weather Service Station (January 2003 – May 2006).



6.4.2 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 extent of insolation, and therefore of the rate of development and dissipation of the mixing layer. The monthly diurnal temperature trend for Grenshoek Tzaneen for the year 2005 is presented in **Figure 6.3**. Ambient temperatures were recorded to range between 13°C and 29°C.

Long-term average maximum, mean and minimum temperatures for Tzaneen (1979-1984) are shown in **Table 6.1** (Schulze, 1986). An annual mean temperature for Tzaneen is given as 14.0°C, based on the long-term record.

Table 6.1: Long-term maximum, minimum and mean monthly temperatures (°C) for various stations within the Tzaneen region for the period 1979 – 1984 (Schulze, 1986).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Max	29.6	29.1	28.0	27.1	25.3	23.1	22.6	23.9	26.1	26.3	27.9	28.9	26.5
Min	19.2	18.8	17.3	14.5	11.1	7.7	8.0	9.7	12.1	14.5	17.0	18.4	14.0
Mean	24.4	24.0	22.6	20.8	18.2	15.4	15.3	16.8	19.1	20.4	22.4	23.8	20.3

6.4.3 Evaporation

As shown in **Table 6.2**, the annual monthly maximum, minimum and mean monthly evaporation rates for the Limpopo Province are 219 mm, 149 mm and 185 mm, respectively. The highest monthly maximum evaporation (294 mm) occurs in October. The rate decreases significantly down to 101 mm in June. The monthly minimum evaporation ranges between 187 mm in October and 101 mm in June.

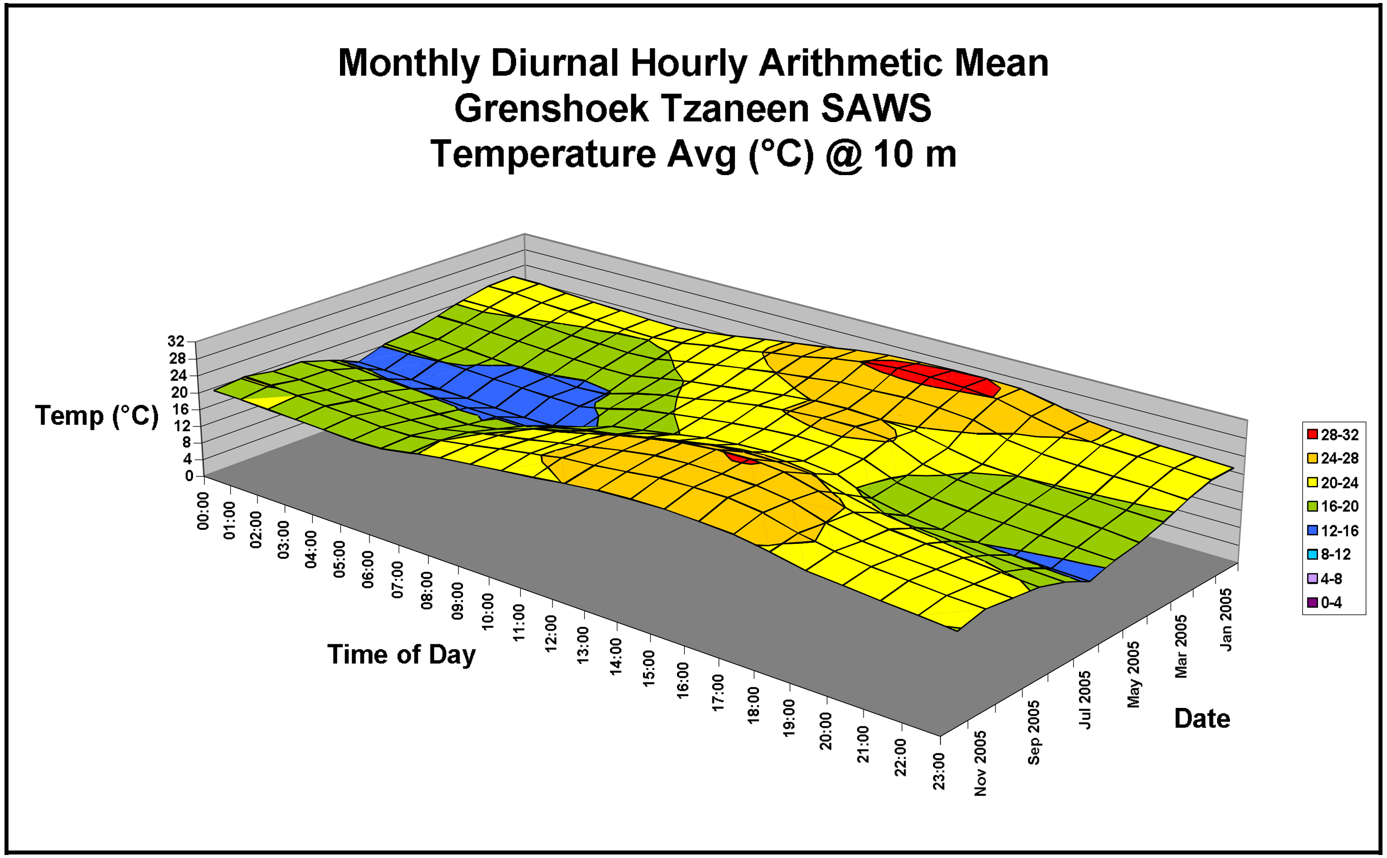


Figure 6.3: Air temperature trends for the study area for the period 2005.

Table 6.2: Maximum, minimum and mean monthly evaporation for the Limpopo Province (Schulze, 1997).

Evaporation mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	292	238	222	165	152	128	136	181	239	294	287	288	219
Monthly Min.	168	146	159	132	120	101	112	142	166	187	179	175	149
Monthly Mean	237	193	191	152	135	114	125	164	202	233	239	234	185

6.4.4 Evapotranspiration

As shown in **Table 6.3**, the annual monthly maximum, minimum and mean monthly evapotranspiration rates for the Limpopo Province are 158 mm, 104 mm and 134 mm, respectively. The highest monthly maximum evapotranspiration (222 mm) occurs for January. The rate decreases to 85 mm in June. The monthly minimum evapotranspiration ranges between 133 mm in October and 62 mm in June.

Table 6.3: Maximum, minimum and mean monthly evapotranspiration for the Limpopo Province (Schulze, 1997).

Evapotranspiration mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	222	181	167	122	104	85	92	125	164	209	212	216	158
Monthly Min.	124	110	116	94	77	62	68	92	115	133	131	128	104
Monthly Mean	181	148	145	110	91	74	81	110	140	169	179	178	134

6.4.5 Relative Humidity

The data in **Table 6.4** is representative of the relative humidity for the Limpopo region. The annual monthly maximum, minimum and mean relative humidity is given as 72.5 %, 57.4 % and 64.1 %, respectively. The daily maximum relative humidity remains above 50 % throughout the year, and ranges from 76 % in summer (February) to 69.1 % in winter (July). The daily minimum relative humidity ranges from 64.1 % in February to 49.7 in August.

Table 6.4: Maximum, minimum and mean monthly relative humidity for the Limpopo Province (Schulze, 1997).

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Daily Max.	74.8	76.0	75.9	74.0	71.2	69.9	69.1	68.9	70.4	71.2	73.5	75.1	72.5
Daily Min.	63.5	64.1	62.9	58.8	52.1	50.2	49.8	49.7	54.5	58.4	61.6	63.3	57.4
Daily Mean	69.3	70.0	69.2	65.3	59.7	57.6	57.1	57.7	61.3	64.9	67.5	69.2	64.1

6.4.6 Incoming Solar Radiation (Insolation)

As shown in **Table 6.5**, the annual monthly maximum, minimum and mean monthly solar radiation rates for the Limpopo Province are 27.2 MJ/m²/day, 20.5 MJ/m²/day and 24.5 MJ/m²/day, respectively. The monthly maximum solar radiation ranges from 32.9 MJ/m²/day in December to 19.3 MJ/m²/day in June. The monthly minimum solar radiation ranges between 25 MJ/m²/day in November to 14.5 MJ/m²/day in June.

Table 6.5: Maximum, minimum and mean monthly solar radiation for the Limpopo Province (Schulze, 1997).

Solar radiation (MJ/m²/day)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	32.6	30.5	27.6	24.2	21.1	19.3	20.3	24.5	28.4	31.6	32.8	32.9	27.2
Monthly Min.	24.8	22.9	20.6	18.4	16.1	14.5	15.3	18.1	21.3	23.8	25.0	24.6	20.5
Monthly Mean	28.8	27.1	24.7	22.3	19.7	18.0	18.9	22.4	25.8	28.2	29.1	29.0	24.5

6.5 EXISTING AIR QUALITY WITHIN THE STUDY AREA

The identification of existing sources of emission in the region, and the characterisation of ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the proposed operation and its associated emissions.

A comprehensive emissions inventory has not been completed for the region to date. The establishment of such an inventory is not within the scope of the current study. Instead source types present in the area and the pollutants associated with such source types are noted with the aim of identifying pollutants, which may be of importance in terms of cumulative impact potentials.

The study area is mainly utilised by agricultural activities and numerous small villages (which use the land for informal cultivation and grazing). Source types include:

- Vehicle tailpipe emissions;
- Household fuel combustion (particularly coal and wood used by smaller communities/settlements);
- Biomass burning (veld fires in agricultural areas within the region); and,
- Various miscellaneous fugitive dust sources (agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads).

6.5.1 Vehicle tailpipe emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbons (HCs), sulphur dioxide (SO_2), oxides of nitrogen (NO_x), particulates and lead. Secondary pollutants include: nitrogen dioxide (NO_2), photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses. The main roads in the vicinity of the proposed Nwamitwa Dam area is the R529, R71 and P43/3. In the vicinity of the Tzaneen dam, the main roads are the R528 and the R36. In addition, numerous smaller paved and unpaved roads that carry local residential traffic are contained in the project area.

6.5.2 Household fuel combustion

It is likely that certain households within local communities/settlements are likely to use coal or wood for space heating and/or cooking purposes. Pollutants arising due to the combustion of wood include respirable particulates, carbon monoxide and sulphur dioxide with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, total and respirable particulates including heavy metals and inorganic ash, CO, polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene, NO_2 and various toxins. Pollutants from wood burning include respirable particulates, NO_2, CO, PAHs (benzo(a)pyrene and formaldehyde). Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons. Small residential developments that are within the project area is given in **Figure 6.1.**

6.5.3 Biomass burning

Crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. Biomass burning is an incomplete combustion process with carbon monoxide, methane and nitrogen dioxide being emitted during the process. About 40 % of the nitrogen in biomass is emitted as nitrogen, 10 % remains in the ashes and it is assumed that 20 % of the nitrogen is emitted as higher molecular weight nitrogen compounds. The visibility of smoke plumes from vegetation fires is due to their aerosol content.

6.5.4 Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g. tilling). The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways. The extent, nature and duration of agricultural activities and the moisture and silt content of soils is required to be known in order to quantify fugitive emissions from this source. The quantity of wind blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

The pollutants listed above are released directly by sources and are therefore termed 'primary pollutants'. 'Secondary pollutants' which form in the atmosphere as a result of chemical transformations and reactions between various compounds include: NO_2, various photochemical oxidants (e.g. ozone), hydrocarbon compounds, sulphur acid, sulphates, nitric acid and nitrate aerosols.

6.5.5 Monitored Ambient Air Quality

No ambient air quality data exists for the proposed project study area. The background concentrations/fallout for the area could therefore not be assessed.

7. LEGAL REQUIREMENTS AND HUMAN HEALTH CRITERIA

Prior to assessing the impact of the proposed fugitive dust due to activities at the Proposed 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 limits 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. Such limits are given for one or more specific averaging periods, typically 10 minutes, 1-hour average, 24-hour average, 1-month average, and/or annual average.

The ambient air quality guidelines and standards for pollutants relevant to the current study are presented in subsequent subsections. Air quality limits issued nationally by the Department of Environmental Affairs and Tourism (DEAT) and South African Bureau of Standards (SABS)[(1)] are reflected together with limits published by the World Health Organisation (WHO), European Community (EC), World Bank (WB), United Kingdom (UK), and the United States Environmental Protection Agency (US EPA).

[1] The SABS was initially engaged to assist DEAT in the facilitation of the development of ambient air quality standards. This process resulted in the publication of: (a) SANS 69 - South African National Standard - Framework for setting & implementing national ambient air quality standards, and (b) 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, were made available for public comment during the May/June 2004 period and were finalized and published during the last quarter of 2004. Although the SANS documents have been finalised, it was decided by the DEAT not to adopt these limits but rather to include the previous CAPCO guidelines as standards in the second schedule of the new Air Quality Act with a view of replacing these with alternative thresholds in the future. Although the threshold levels to be selected for future air quality standards are not currently known it is expected that such thresholds will be more stringent than the initial standards included in the Act and more in line with the SANS limits.

7.1 SUSPENDED PARTICULATE MATTER

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, 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.

PM10 limits and standards issued nationally and abroad are documented in **Table 7.1**. In addition to the PM10 standards published in schedule 2 of the Air Quality Act, the Act also includes standards for total suspended particulates (TSP), viz. a 24-hour average maximum concentration of 300 µg/m^3 not to be exceeded more than three times in one year and an annual average of 100 µg/m^3.

Table 7.1: 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
RSA SANS limits (SANS:1929,2004)	75(a) 50(b)	40(c) 30(d)
Australian standards	50(e)	-
European Community (EC)	50(f)	40(g) 20(h)
World Bank (General Environmental Guidelines)	70(i)	50(i)
United Kingdom	50(j)	40(k)
United States EPA	150(l)	50(m)
World Health Organisation	(n)	(n)

Notes:
(a) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(b) Target value. Permissible frequencies of exceedance and date by which limit value should be complied with not yet set.
(c) Limit value. Margin of tolerance and date by which limit value should be complied with not yet set.
(d) Target value. Date by which limit value should be complied with not yet set.
(e) 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.
(f) 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 35 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.)
(g) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005
(h) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010
(i) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(j) 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
(k) UK Air Quality Objectives. www.airquality.co.uk/archive/standards/php. Compliance by 31 December 2004
(l) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(m) 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.
(n) WHO (2000) issues linear dose-response relationships for PM10 concentrations and various health endpoints. No specific guideline given.

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, 2000). 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 7.2 and 7.3**.

Table 7.2: 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 7.3: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Annual 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

7.2 DUST DEPOSITION LIMITS

Foreign dust deposition standards issued by various countries are given in **Table 7.4.** It is important to note that the limits given by Argentina, Australia, Canada, Spain and the USA are based on annual average dustfall. The standards given for Germany are given for maximum monthly dustfall and therefore comparable to the dustfall categories issued locally. Based on a comparison of the annual average dustfall standards it is evident that in many cases a threshold of ~200 mg/m^2/day to ~300 mg/m^2/day is given for residential areas.

Table 7.4: Dust deposition standards issued by various countries

Country	Annual Average Dust Deposition Standards (based on monthly monitoring) (mg/m²/day)	Maximum Monthly Dust Deposition Standards (based on 30 day average) (mg/m²/day)
Argentina	133	
Australia	133 (onset of loss of amenity)	

	333 (unacceptable in New South Wales)	
Canada Alberta: Manitoba:	179 (acceptable) 226 (maximum acceptable) 200 (maximum desirable)	
Germany		350 (maximum permissible in general areas) 650 (maximum permissible in industrial areas)
Spain	200 (acceptable)	
USA: Hawaii Kentucky New York Pennsylvania Washington Wyoming	 200 175 200 (urban, 50 percentile of monthly value) 300 (urban, 84 percentile of monthly value) 267 183 (residential areas) 366 (industrial areas) 167 (residential areas) 333 (industrial areas)	

Locally dust deposition is evaluated 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 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.

"Slight" dustfall is barely visible to the naked eye. "Heavy" dustfall indicates a fine layer of dust on a surface, with "very heavy" dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of > 2000 mg/m^2/day constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers.

A perceived weakness of the current dustfall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, VERY HEAVY). It has recently been proposed (as part of the SANS air quality standard setting processes) that dustfall rates be evaluated against a four-band scale, as presented in **Table 7.5**. Proposed target, action and alert thresholds for ambient dust deposition are given in **Table 7.6.**

According to the proposed dustfall limits an enterprise may submit a request to the authorities to operate within the Band 3 ACTION band for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 ALERT.

Table 7.5: 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 7.6: 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.

7.3 SULPHUR DIOXIDE

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 (FEV1), 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 for, while in others no attempts have been made to separate the pollutant effects. In these studies no obvious threshold levels for SO_2 has 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 7.7**.

Table 7.7 : Ambient air quality guidelines and standards for sulphur dioxide for various countries and organisations

Authority	Maximum 10-minute Average (µg/m³)	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Annual Average Concentration (µg/m³)
South African Standards (Air Quality Act)	500(a)	-	125(a)	50
RSA SANS limits (SANS:1929,2004)	500(b)	-	125(b)	50
Australian standards	-	524(c)	209(c)	52
European Community (EC)	-	350(d)	125(e)	20(f)
World Bank	-	-	125(g)	50(g)
United Kingdom	266(h)	350(i)	125(j)	20(k)
United States EPA	-	-	365(l)	80
World Health Organisation (2000)	500(m)		125(m)	50(m) 10-30(m)
World Health Organisation (2005)	500(o)		20(o)	(o)

NOTES:
(a) No permissible frequencies of exceedance specified
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.
(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).
(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).

(f) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.
(g) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(h) UK Air Quality Objective for 15-minute averaging period (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 35 times per year. Compliance by 31 December 2005.
(i) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 24 times per year.
(j) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 3 times per year.
(k) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php).
(l) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(m) WHO Guidelines for the protection of human health (WHO, 2000).
(n) Represents the critical level of ecotoxic effects (issued by WHO for Europe); a range is given to account for different sensitivities of vegetation types (WHO, 2000).
(o) WHO Air Quality Guidelines, Global Update, 2005 – Report on a Working Group Meeting, Bonn, Germany, 18-20 October 2005. Documents new WHO guidelines primarily for the protection of human health. The 10-minute guideline of 500 µg/m³ published in 2000 remains unchanged but the daily guideline is significantly reduced from 125 µg/m³ to 20 µg/m³ (in line with the precautionary principle). An annual guideline is given at not being needed, since "compliance with the 24-hour level will assure lower levels for the annual average".

It is important to note that the WHO air quality guidelines (AQGs) published in 2000 for sulphur dioxide have recently been revised (WHO, 2005). Although the 10-minute AQG of 500 µg/m³ has remained unchanged, the previously published daily guideline has been significantly reduced from 125 µg/m³ to 20 µg/m³. The previous daily guideline was based on epidemiological studies. WHO (2005) makes reference to more recent evidence which suggests the occurrence of health risks at lower concentrations. Although WHO (2005) acknowledges the considerable uncertainty as to whether sulphur dioxide is the pollutant responsible for the observed adverse effects (may be due to ultra-fine particles or other correlated substances), it took the decision to publish a stringent daily guideline in line with the precautionary principle.

The WHO (2005) stipulates an annual guideline is not needed for the protection of human health, since compliance with the 24-hour level will assure sufficiently lower levels for the annual average. Given that the 24-hour WHO AQG of 20 µg/m³ is anticipated to be difficult for some countries to achieve in the short term, the WHO (2005) recommends a stepped approach using interim goals as shown in **Table 7.8**.

Table 7.8 : WHO air quality guidelines and interim guidelines for sulphur dioxide (WHO, 2005)

	24-hour Average Sulphur Dioxide (µg/m³)	10-minute Average Sulphur Dioxide (µg/m³)
WHO interim target-1 (IT-1) (2000 AQF level)	125	
WHO interim target-2 (IT-2)	50(a)	
WHO Air Quality Guideline (AQG)	20	500

NOTE:
Intermediate goal based on controlling either (i) motor vehicle (ii) industrial emissions and/or (iii) power production; this would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvements that would justify further improvements (such as aiming for the guideline).

7.4 Oxides of Nitrogen

NO_x, primarily in the form of NO, is one of the primary pollutants emitted during combustion. 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 µg/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 bronchoconstrictor agents, even at levels that do not affect pulmonary function directly in the absence of a bronchoconstrictor. Some, but not all, studies show increased responsiveness to bronchoconstrictors at NO_2 levels as low as 376-565 µg/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 µg/m^3; 0.1 ppm), full evaluation of the health consequences of the increased responsiveness to bronchoconstrictors 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 µg/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 µg/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 µg/m^3. NO_2 levels of about 940 µg/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 µg/m^3 NO_2 (2-week average), where the weekly average concentrations are in the range of 15-128 µg/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.

The standards and guidelines of most countries and organisations are given exclusively for NO_2 concentrations (**Table 7.9**).

Table 7.9 : Ambient air quality guidelines and standards for nitrogen dioxide for various countries and organisations

Authority	Instantaneous Peak (µg/m³)	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Maximum 1-month Average (µg/m³)	Annual Average Concentration (µg/m³)
South African Standards (Air Quality Act) [(a)]	940	376	188	150	94
RSA SANS limits (SANS:1929,2004)	-	200[(b)]	-	-	40[(b)]
Australian standards		226[(c)]			56
European Community (EC)	-	200[(d)]	-	-	40[(e)]
World Bank	-	-	150 (as NO_x)[(f)]	-	-
United Kingdom	-	200[(g)]	-	-	40[(h)] 30[(i)]
United States EPA	-	-	-	-	100[(j)]
World Health Organisation (2000, 2005)	-	200[(k)]		-	40[(k)]

NOTES :
(a) On 9 June 2006 the Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (90 day comment period given). The proposed NO_2 standards are given as 200 µg/m³ for highest daily and 40 µg/m³ for annual averages (in line with the SANS limits) (Government Gazette No. 28899, 9 June 2006). No permissible frequencies of exceedance specified
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year. Compliance by 2008.
(d) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Averaging times represent the 98th percentile of averaging periods; calculated from mean values per hour or per period of less than an hour taken throughout the year; not to be exceeded more than 18 times per year. This limit is to be complied with by 1 January 2010.
(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Annual limit value for the protection of human health, to be complied with by 1 January 2010.
(f) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(g) UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 18 times per year.
(h) UK Air Quality Provisional Objective for NO_2 (www.airquality.co.uk/archive/standards/php).
(i) UK Air Quality Objective for NOx for protection of vegetation (www.airquality.co.uk/archive/standards/php).
(j) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html).
(k) WHO Guidelines for the protection of human health (WHO, 2000). AQGs remain unchanged according to WHO (2005).

7.5 CARBON MONOXIDE

Carbon monoxide absorbed through the lungs reduces the blood's capacity to transport available oxygen to the tissues. Approximately 80-90 % of the absorbed CO binds with haemoglobin to form carboxyhaemoglobin (COHb), which lowers the oxygen level in blood. Since more blood is needed to supply the same amount of oxygen, the heart needs to work harder. These are the main causes of tissue hypoxia produced by CO at low exposure levels. At higher concentrations, the rest of the absorbed CO binds with other heme proteins such as myoglobin and with cytochrome oxidase and cytochrome P-450. CO uptake impairs perception and thinking, slows reflexes, and may cause drowsiness, angina, unconsciousness, or death. The ambient air quality guidelines and other standards issued for various countries and organisations for carbon monoxide are given in **Table 7.10**.

Table 7.10 : Ambient air quality guidelines and standards for carbon monoxide for various countries and organisations

Authority	Maximum 1-hourly Average(μg/m³)	Maximum 8-hour Average (μg/m³)
South African Guideline[(a)]	40 000	10 000
SA SANS limits (SANS:1929,2004)	30 000[(b)]	10 000[(b)]
Australian standards	-	10 000[(c)]
European Community (EC)	-	10 000[(d)]
World Bank	-	-
United Kingdom	-	10 000[(e)]
United States EPA	40 000[(f)]	10 000[(f)]
World Health Organisation	30 000[(g)]	10 000[(g)]

NOTES:
(a) Issued in 1990s by CAPCO. No air quality standards for CO were included in the National Environmental Management: Air Quality Act.
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 1 day per year.
(d) EC Second Daughter Directive, 2000/69/EC (http://europa.eu.int/comm/environment/air/ambient.htm).
(e) UK Air Quality Objective (www.airquality.co.uk/archive/standards/php). Maximum daily running 8-hourly mean. Compliance by 31 December 2003.
(f) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than one per year.
(g) WHO Guidelines for the protection of human health (WHO, 2000).

7.6 DIESEL PARTICULATE MATTER

Diesel particulate has been classified by the US-EPA as a compound with non-cancer chronic inhalation risk for which a reference concentration (RfC) is given. Reference concentrations are derived from clinical studies. An uncertainty factor is applied to the No Observed Adverse Effect Level (NOAEL) from these studies, allowing (for instance) for application of results of animal studies to human health risks. Concentration values below the RfC imply that no risk has been identified; above the RfC does not necessarily imply risk, but further investigation might be warranted. The USA EPA IRIS database gives an RfC value of 5 $\mu g/m^3$ for annual exposure, and this value will be used for the preliminary health screening.

In addition, diesel engines emit benzene and 1,3-butadiene which have both been classified as carcinogens. Standards for carcinogens are not set using the same methodology as for non-carcinogens, as they have no lower threshold for adverse effects. However, using an appropriate acceptable risk level, annual average concentration standards may be derived. In South Africa, the proposed SANS standard for benzene is 5 $\mu g/m^3$ (annual average). Using the relative toxicity of 1,3 butadiene to benzene (as indicated by the relative US EPA unit risk factors) the standard for 1.3 butadiene on the same basis would be 1.3 $\mu g/m^3$. However, the rate of emissions of the benzene and 1,3 butadiene from diesel engines is approximately 1% of the emission rate of particulates (California ARB 2002). Screening for diesel particulate as an indicator of transport-related emissions therefore provides a conservative screening value for the carcinogens mentioned above.

7.7 NON-CRITERIA POLLUTANTS

Reference has been made to various effects screening and health risk criteria to ensure that the potential for risks due to all pollutants being considered could be gauged. (Effect screening levels are generally published for a much wider range of pollutants compared to health risk criteria.)

7.7.1 Health Thresholds (non-carcinogenic effects)

Risk Assessment Information System (RAIS) inhalation reference and the Office of Environmental Health Hazard Assessment (OEHHA) concentrations were considered (**Table 7.11**). Where various effect screening and health risk thresholds are available for one pollutant, the most stringent threshold is used in the screening of predicted pollutant concentrations.

7.7.2 Health Thresholds for Carcinogenic Exposures

Unit risk factors are applied in the calculation of carcinogenic risks. These factors are defined as the estimated probability of a person (60-70 kg) contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m³ over a 70-year lifetime. In the generic health risk assessment undertaken as part of the current study, maximum possible exposures (24-hours a day over a 70-year lifetime) are assumed for all areas beyond the boundary of the proposed development site. Unit risk factors were obtained from the WHO (2000) and from the US-EPA IRIS database (accessed May 2005). Unit Risk Factors for compounds of interest in the current study are given in **Table 7.12**.

(a) Evaluation of Cancer Risk Acceptability

The definition of what is deemed to be an acceptable risk remains one of the most controversial aspects of risk characterisation studies. An important point to be borne in mind is the crucial distinction between voluntary and involuntary risks. The risk to which a member of the public is exposed from an industrial activity is an involuntary one. In general, people are prepared to tolerate higher levels of risk for hazards to which they exposure themselves voluntarily.

There appears to be a measure of uncertainty as to what level of risk would be acceptable to the public. Pollutants are often excluded from further assessment when they contribute an individual risk of less than 1×10^{-7}. (A carcinogenic risk of 1×10^{-7} corresponds to a one-in-ten-million chance of an individual developing cancer during their lifetime.) The US-EPA adopts a 1 in a million chance for cancer risks (i.e. 1×10^{-6}), applied to a person being in contact with the chemical for 70 years, 24-hours per day. Although a risk of 10^{-7} (1 in 10 million) would be desirable, and a risk of less than 10^{-6} (1 in 1 million) acceptable in terms of US regulations, some authors (Kletz, 1976; Lees, 1980; Travis et al., 1987) suggest that a risk level of between 10^{-5} and 10^{-6} per year (i.e. 1:100 000 and 1: 1000 000) could still be acceptable. Further work by Travis et al. (1987) indicated that for small populations, risks of less than 10^{-4} (1 in 10 000) may also potentially be acceptable, whereas risks greater than 10^{-4} are likely to prompt action.

Locally the Department of Environmental Affairs and Tourism (DEAT) has only been noted to give an indication of cancer risk acceptability in the case of dioxin and furan exposures. According to the DEAT, emissions of dioxins and furans from a hazardous waste incinerator may not result in an excess cancer risk of greater than 1: 100 000 on the basis of annual average exposure (DEAT, 1994). Excess cancer risks of less than 1:100 000 appear therefore to be viewed as acceptable to the DEAT.

Table 7.11: Health risk criteria for non-carcinogenic exposures via the inhalation pathway (as downloaded February 2006 for RAIS, OEHHA and ATSDR).

Constituent	WHO Guidelines (2000)		RAIS Inhalation Reference Concentrations		Californian OEHHA (adopted as of August 2003)		US ATSDR Maximum Risk Levels (MRLs)		
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Benzene				30 (a)	1300 (6 hrs)	60	160	13	
1,3-Butadiene				2		20			

Notes:

Abbreviations:

- WHO – World Health Organisation
- RAIS – Risk Assessment Information System
- OEHHA – Office of Environmental Health Hazard Assessment
- US ATSDR – US Federal Agency for Toxic Substances and Disease Registry
- TC – tolerable concentration
- GV – guideline value
- RfC – inhalation reference concentration
- MRL – maximum risk level
- REL – reference exposure level

(a) Source: Integrated Risk Information System (IRIS)

Table 7.12 : Unit risk factors from California EPA, US-EPA Integrated Risk Information System (IRIS) (February 2006) and WHO risk factors (2000)

Chemical	Californian EPA Unit Risk Factor (µg/m³)	WHO Inhalation Unit Risk (µg/m³)	US-EPA IRIS Unit Risk Factor (µg/m³)	IARC Cancer Class	US-EPA Cancer Class (a)
Benzene	2.9×10^{-5}	4.4×10^{-6} to 7.5×10^{-6}	2.2×10^{-6} to 7.8×10^{-6}	1	A
1,3 - butadiene	1.7×10^{-4}		3×10^{-5}	2A	B2

(a)EPA cancer classifications:

A--human carcinogen; B--probable human carcinogen. There are two sub-classifications: B1--agents for which there is limited human data from epidemiological studies. B2--agents for which there is sufficient evidence from animal studies and inadequate or no evidence from human epidemiological studies. C--possible human carcinogen. D--not classifiable as to human carcinogenicity. E--evidence of non-carcinogenicity for humans.

8. IMPACT DUE TO PROPOSED PROJECT ACTIVITIES

8.1 EMISSIONS INVENTORY

An emissions inventory comprises the identification and quantification of sources of emissions. An emissions inventory forms the basis for assessing the impact of pollutants from operations on the receiving environment.

The nature and significance of air quality impacts associated with activities at the proposed project area forms the focus of the current section. The approach typically followed includes:

- Identification of sources of emissions;
- Identification of types of pollutants being released;
- Determination of pertinent source parameters; and,
- Quantification of each source's emissions.

The main source of concern was identified to be fugitive dust emanating from the construction activities. Releases are mainly restricted to particulate matter (PM10) and dust fallout (TSP) from these fugitive sources.

8.1.1 Construction Phase

(a) Construction Operations

The construction phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). 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. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Should detailed information regarding the construction sites be available, the construction process would have been broken down into component operations for emissions quantification and dispersion simulations. Due to the lack of detailed information, 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 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:

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

These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. Estimated emissions during the construction phase are given in **Table 8.1**.

Table 8.1 : Emissions rates and parameters used in the current assessment per construction site.

Construction Areas	Operating hours per day	Duration (months)	Area (m²)	Emission Rate (tpa)	
				TSP	PM10
Nwamitwa Dam + office buildings + borrow pit	8	60	2466250	3317	1161
Weir	8	24	150000	968	339
Tzaneen Dam	8	24	18375	119	42
10 x Resevoirs	8	24	5000	32	11
4 x Pump Stations	8	24	5000	32	11
Road realignment	8	36	125000	1211	424

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.

(b) Fugitive Dust from Materials Handling Operations

The following predictive US-EPA equation was used to estimate emissions from materials handling operations:

$$E_{TSP} = k\left(0.0016\frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}\right)$$

where,

E_{TSP} = Total Suspended Particulate emission factor (kg dust / t transferred)

U = mean wind speed (m/s)

M = material moisture content (%)

k = particle size multiplier (dimensionless)

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74 %, with 35 % of TSP given to be equal to PM10, and the PM2.5 fraction is 11 % of TSP (EPA, 1998). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations.

Materials handling emissions were calculated for the trenching and filling activities for the laying down of the pipeline, as well from the borrow pits. The parameters used for the calculation of emissions from the borrow pits is given in **Table 8.2**.

Table 8.2: Parameters used to calculate the materials handling emissions from the borrow pits.

Parameter	Earthfill materials	Filter materials	Concrete sand
Path	Borrow area to embankment	Sand borrow area to embankment	Sand borrow area to embankment
Volume (m³)	700 000	30 000	260 000
Months to remove	18	18	24
hours/day	10	10	10
days/week	5	5	5
Amount of material per hour (m³/hr)	14.96	0.64	4.17
Bulk Density (t/m³)	1.22	1.60	2.31
Throughput (t/h)	18.22	1.03	9.62

Emissions from two borrow pits were quantified: (i) the borrow pit along the Lerwatlou river (~375 000 m²) and (ii) the borrow pit along the Merekome River (~125 000 m²). The calculated PM10 and TSP emissions were 0.013 tpa and 0.038 tpa from the Lerwatlou borrow pit area and 0.004 tpa and 0.013 tpa from the Merekome borrow pit areas respectively. Emissions from the proposed borrow pit at the Nwamitwa dam was incorporated in the construction emission quantification of the area.

The parameters used for the calculation of emissions from the materials handling operations per day at the pipeline are given in **Table 8.3.**

Table 8.3: Parameters used to calculate the materials handling emissions form the pipeline area.

Parameter	Quanity
length (m)	300
depth (m)	3.5
width (m)	2.5
volume (m³)	2 625

Parameter	Quanity
Moisture (%)	2
Bulk Density (t/m³)	1.22
Material handled (t/day)	3 197.64
Material handled (t/hr)	3 19.76

The calculated PM10 and TSP emissions from the proposed pipeline area are calculated to be 0.81 tpa and 2.32 tpa respectively, assuming they operate 10 hours per day and 5 days per week.

(c) Vehicle Entrainment

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 traveling on the road (Cowhert and Engelhart, 1985; EPA, 1997). 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, 1997):

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

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/m²)

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 routs that would be taken and the silt loading was unknown for the current study, generic US-EPA silt loading of 0.6 g/m² (public roads with an average daily traffic of less than 500 vehicles) was used.

The parameters used for the calculation of the vehicle entrainment emissions is given in **Table 8.4**

Table 8.4: Parameters used to calculate the vehicle entrainment emissions

Parameters	Earthfill materials	Filter materials	Concrete sand	Rockfill materials	Concrete coarse aggregates
Path	Borrow area to embankment	Sand borrow area to embankment	Sand borrow area to embankmen t	Quarry to embankment	Quarry to embankment
Volume of material transported (m³)	700000	30000	260000	70000	300000
Months to remove	18	18	24	18	24
hours/day	10	10	10	10	10
days/week	5	5	5	5	5
Amt of trucks to remove material per day	602.93	25.84	167.96	60.29	193.80
Bulk Density	1.22	1.60	2.31	1.31	1.31

Parameters	Earthfill materials	Filter materials	Concrete sand	Rockfill materials	Concrete coarse aggregates
(t/m³)					
Weight of material per load (t)	3.65	4.81	6.92	3.94	3.94
Ave weight of vehicle (t)	11.83	12.40	13.46	11.97	11.97

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

$$E_{ext} = E\left(1 - \frac{P}{4N}\right)$$

Where,

E_{ext} = Annual or long-term emission factor

E = Unmitigated emission rate

P = number of days in an averaging period with at least 0.254 mm of precipitation.

N = number of days in an averaging period.

The calculated emissions per material transported, is given in **Table 8.5**.

Table 8.5: Emissions calculated for vehicle entrainment.

Material	Emissions (tpa)	
	TSP	PM10
Earthfill materials	24.70	4.23

Material	Emissions (tpa)	
	TSP	PM10
Filter materials	1.14	0.20
Concrete sand	8.39	1.47
Rockfill materials	2.52	0.43
Concrete coarse aggregates	8.09	1.39

(d) Tailpipe Emissions

To quantify the exhaust emissions from the vehicles, use was made of the Copert emission factors.

The emissions from diesel exhaust are given in **Table 8.6**. The NO_2 emissions were taken to be 20 % of total NO_x emissions (Heywood, 1988).

Table 8.6: Emissions from vehicle exhaust (g/s/m²)

Pollutant	Material Transported				
	Earthfill materials	Filter materials	Concrete sand	Rockfill materials	Concrete coarse aggregates
CO	1.14E-06	4.9E-08	3.18E-07	1.14E-07	3.67E-07
NO_2	5.82E-07	2.49E-08	1.62E-07	5.82E-08	1.87E-07
VOC	5.4E-07	2.31E-08	1.5E-07	5.4E-08	1.74E-07
Diesel PM	2.56E-07	1.1E-08	7.12E-08	2.56E-08	8.22E-08
CO_2	0.000403	1.73E-05	0.000112	4.03E-05	0.000129
SO_2	1.28E-07	5.5E-09	3.58E-08	1.28E-08	4.13E-08
Methane	1.62E-08	5.98E-10	3.89E-09	1.62E-09	5.21E-09
NMVOC	6.11E-07	2.25E-08	1.47E-07	6.11E-08	1.96E-07
1,3-butadiene	2.01E-08	8.63E-10	5.61E-09	2.01E-09	6.48E-09
Benzene	1.22E-08	4.51E-10	2.93E-09	1.22E-09	3.92E-09

The predicted average carbon dioxide (CO_2) direct emissions from vehicle exhaust is ~6.8 million metric tons per year. This should be seen in the perspective of the annual South Africa, Africa and global emission rate of green house gases (GHG), which is approximately 365 million metric tons, 861 million metric tonnes and 26,778 million metric tonnes, respectively expressed as carbon dioxide equivalent (Marland et al, 2006). The CO_2 emissions therefore contribute approximately 1.9% of the South Africa GHG emissions and 0.8% percent of Africa's total GHG emissions. This would only be 0.03% of the global GHG emissions.

(e) Concrete Batching, Bitumen and Water Treatment Plants

No information on the activities and sources of emissions at the concrete batching, bitumen and water treatment plants was available for the current study and thus could not be quantified for the assessment.

Particulate matter, consisting primarily of cement and pozzolan dust but including some aggregate and sand dust emissions, is the primary pollutant of concern at cement batching plants. In addition, there are emissions of metals that are associated with this particulate matter. Fugitive sources of emissions include the transfer of sand and aggregate, truck loading, mixer loading, vehicle traffic, and wind erosion from sand and aggregate storage piles. The amount of fugitive emissions generated during the transfer of sand and aggregate depends primarily on the surface moisture content of these materials. The emissions from these sources, however are expected to be localised.

Most emissions of listed substances from bitumen plants arise from coincidental activities, such as fuel combustion. Bituminous materials in turn give off volatile organic compounds (VOCs). The bitumen plant will be mobile and will move as the construction of the alternative routes progresses. Therefore, these emissions are expected to be of a temporary nature at any given location.

Chlorine and ammonia are the most likely substances to be lost fugitively to air from a water treatment facility. Other substances, such as fluoride, chlorine dioxide and hydrochloric acid, may also be emitted in smaller volumes. Water treatment processes vary from one facility to the next and each reporting facility may handle a different range of substances on the reporting list.

(f) Demolition of the Construction Camp before Operation Phase

Before the operational phase of the proposed Nwamitwa Dam commences, the temporary construction camp will be demolished. The construction camp however will consist of prefab materials and will be disassembled, with minimal dust occurring during this phase of the project.

8.1.2 Operation Phase

During the operational phase the proposed Nwamitwa dam will be fully in operation. The Tzaneen dam would also have been raised and the pump houses and reservoirs in use. It is assumed that the transportation of material from the borrow pits and the operations from the cement batching and bitumen plants would have ceased. Thus the air emissions during the operational phase will be minimal and localised, with emissions limited to vehicle entrainment and tailpipe emissions from staff vehicles, and exhaust fumes from the pump houses.

8.1.3 Closure and Post-Closure Phase

The emissions from closure operations are assumed to consist of the demolition of structures (i.e. dams, reservoirs, etc.) and the removal of the pipeline. The emissions are thus expected to be similar to that of construction operations.

8.2 DISPERSION SIMULATION RESULTS

Simulations were undertaken to determine particulate matter (PM10) concentrations and total daily dust deposition from proposed construction activities (identified to be the main impact phase of the project). PM10 concentrations were simulated to determine highest daily and annual average levels. Impact due to the operation phase was not assessed as these sources would be localised. Impacts due to the closure phase are assumed to be similar to impacts due to construction activities and were also not assessed.

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

The plots provided for the relevant pollutants of concern during the construction phase are given in **Table 8.7.**

Table 8.7: Isopleth plots presented in the current section

Scenario	Pollutant	Averaging Period	Guideline/Standard	Figure
Raising of the Tzaneen Dam	PM10	Highest daily	$180\mu g/m^3$ (1), $75\mu g/m^3$ (2), $50\mu g/m^3$ (3)	8.1
		Annual Average	$60\mu g/m^3$ (1), $40\mu g/m^3$ (2), $40\mu g/m^3$ (3)	8.2
	Dust deposition	Maximum Daily	$600 mg/m^2/day$ (4)	8.3
Construction of the Nwamitwa Dam	PM10	Highest daily	$180\mu g/m^3$ (1), $75\mu g/m^3$ (2), $50\mu g/m^3$ (3)	8.4
		Annual Average	$60\mu g/m^3$ (1), $40\mu g/m^3$ (2), $40\mu g/m^3$ (3)	8.5
	Dust deposition	Maximum Daily	$600 mg/m^2/day$ (4)	8.6
Construction of the reservoirs and pump houses	PM10	Highest daily	$180\mu g/m^3$ (1), $75\mu g/m^3$ (2), $50\mu g/m^3$ (3)	8.7
		Annual Average	$60\mu g/m^3$ (1), $40\mu g/m^3$ (2), $40\mu g/m^3$ (3)	8.8
	Dust deposition	Maximum Daily	$600 mg/m^2/day$ (4)	8.9
Activities at the borrow pits	PM10	Highest daily	$180\mu g/m^3$ (1), $75\mu g/m^3$ (2), $50\mu g/m^3$ (3)	8.10
		Annual Average	$60\mu g/m^3$ (1), $40\mu g/m^3$ (2), $40\mu g/m^3$ (3)	8.11
	Dust deposition	Maximum Daily	$600 mg/m^2/day$ (4)	8.12
Vehicle entrainment from the transportation of material	PM10	Highest daily	$180\mu g/m^3$ (1), $75\mu g/m^3$ (2), $50\mu g/m^3$ (3)	8.13
		Annual Average	$60\mu g/m^3$ (1), $40\mu g/m^3$ (2), $40\mu g/m^3$ (3)	8.14
	Dust deposition	Maximum Daily	$600 mg/m^2/day$ (4)	8.15
Impact due to vehicle exhaust	CO	Highest hourly	$40\,000\mu g/m^3$ (1), $30\,000\mu g/m^3$ (2)	8.16
	NO_2	Highest hourly	$376\mu g/m^3$ (1), $200\mu g/m^3$ (2)(3)	8.17
		Highest daily	$188\mu g/m^3$ (1)	8.18
		Annual average	$94\mu g/m^3$ (1), 40(2)(3)	8.19
	Diesel PM	Annual average	-	8.20
	SO_2	Highest hourly	$350\mu g/m^3$ (2)(3)	8.21
		Highest daily	$125\mu g/m^3$ (1)(2)(3)	8.22
		Annual average	50(1)(2)(3)	8.23
	1,3 Butadiene	Annual average	-	8.24

Scenario	Pollutant	Averaging Period	Guideline/Standard	Figure
	Benzene	Annual average	-	8.25
Impact due to the laying down of the pipeline	PM10	Highest daily	180µg/m³ (1), 75µg/m³ (2), 50µg/m³ (3)	8.26
		Annual Average	60µg/m³ (1), 40µg/m³ (2), 40µg/m³ (3)	8.27
	Dust deposition	Maximum Daily	600 mg/m²/day(4)	8.28

Notes:

(1) SA standards

(2) Proposed SA standards (SANS limits)

(3) EC limits

(4) SANS residential target level

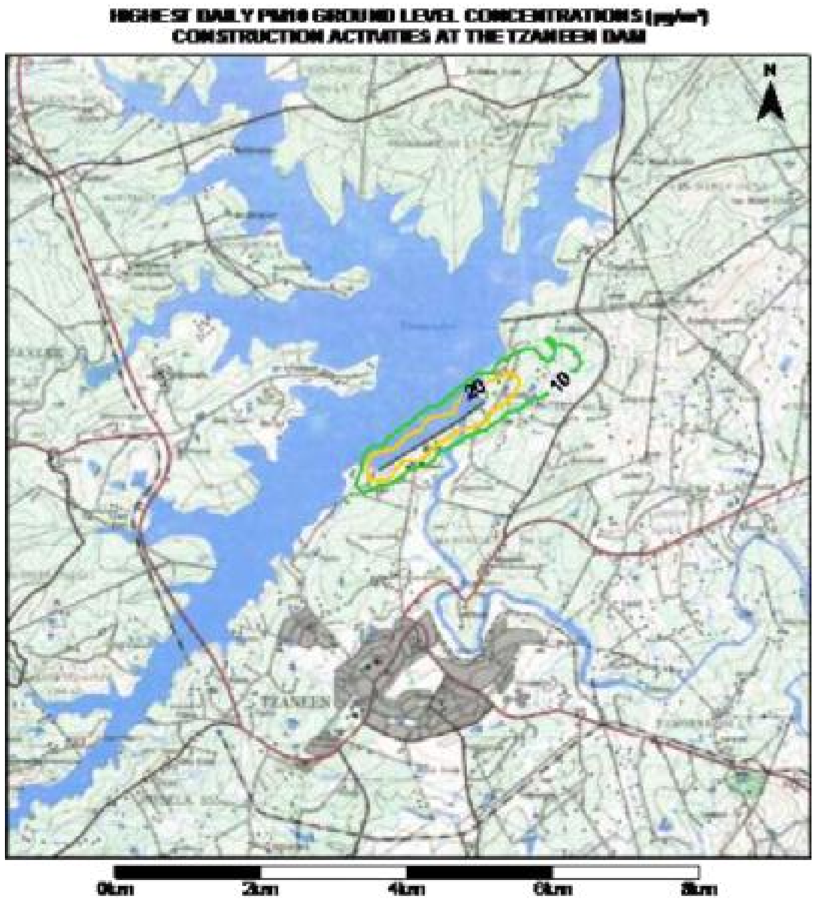


Figure 8.1: *Raising of the Tzaneen Dam* – highest daily PM10 ground level concentrations (µg/m³) (unmitigated).

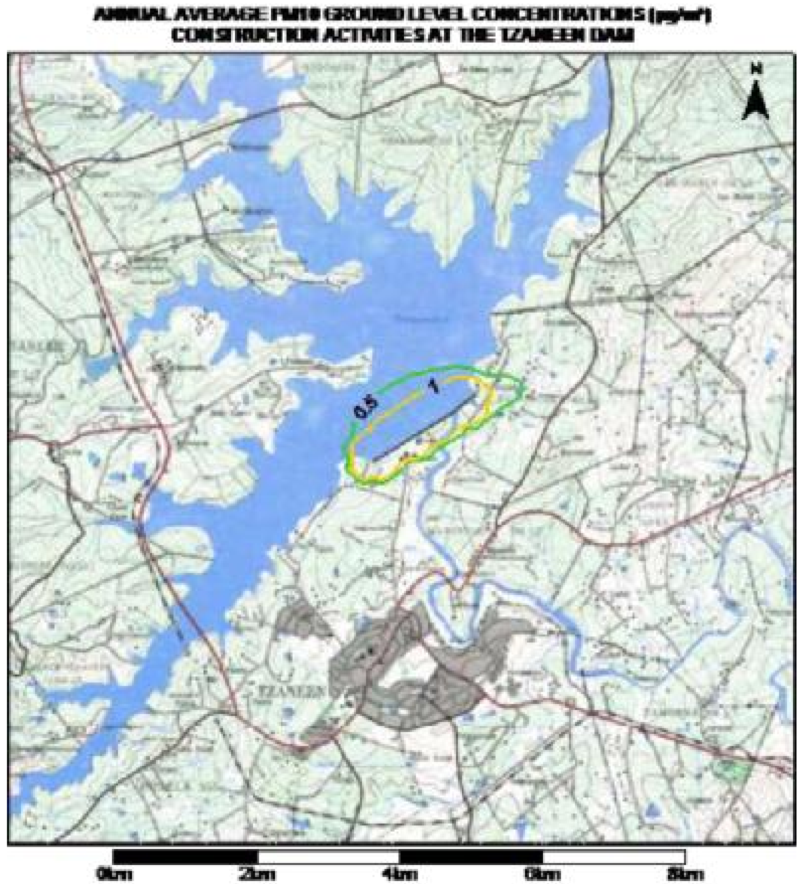


Figure 8.2: *Raising of the Tzaneen Dam* – annual average PM10 ground level concentrations (µg/m³) (unmitigated).

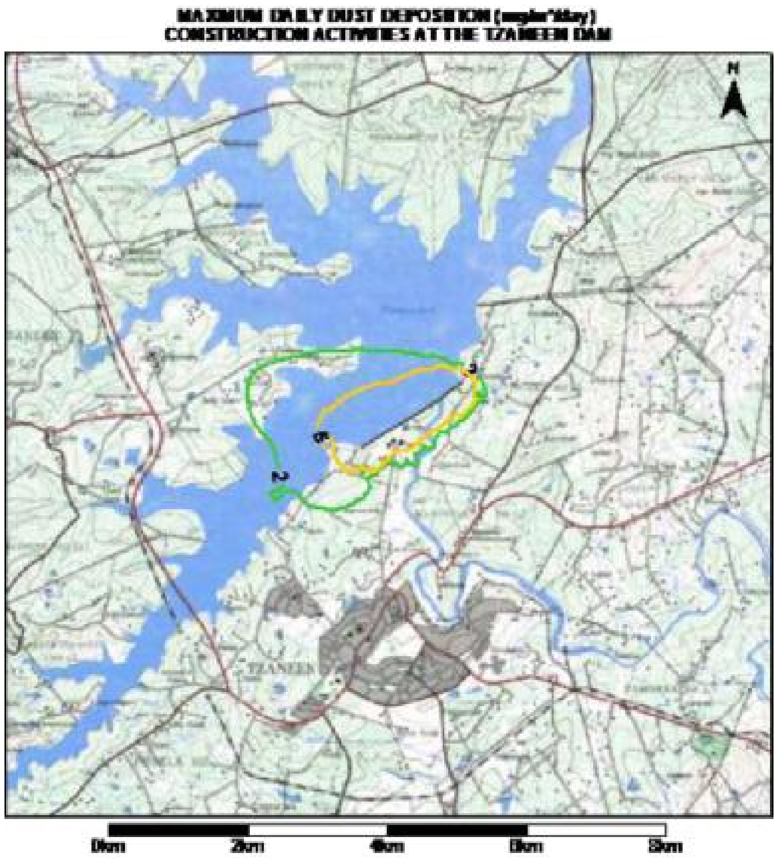


Figure 8.3: ***Raising of the Tzaneen Dam*** **– maximum daily dust deposition (mg/m²/day) (unmitigated).**

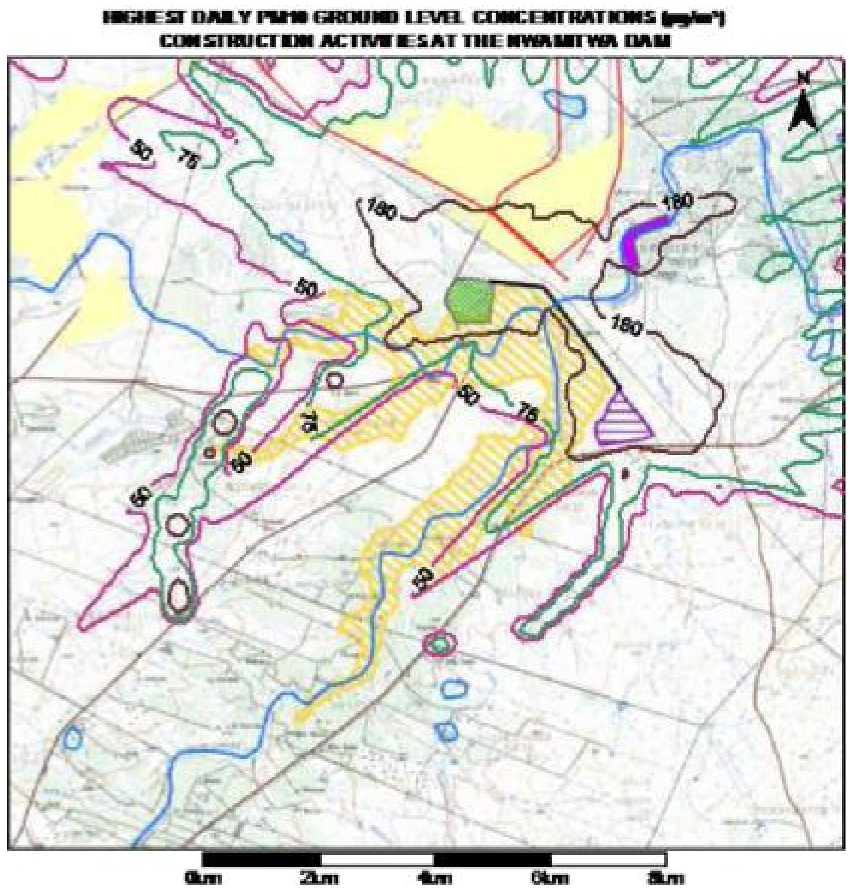


Figure 8.4: ***Construction of Nwamitwa dam, weir and construction camp*** **– highest daily PM10 ground level concentrations (µg/m³) (unmitigated).**

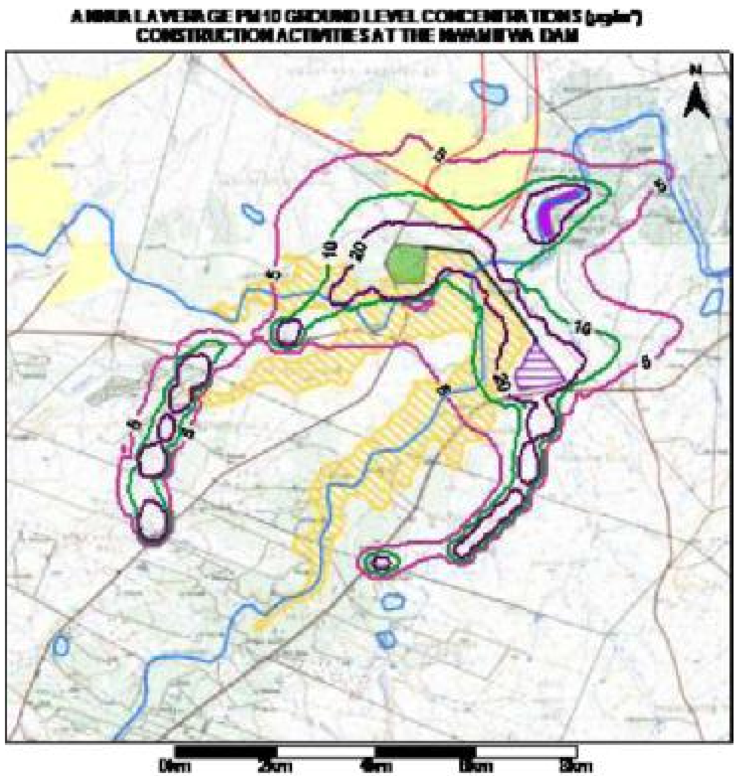


Figure 8.5: Construction of Nwamitwa Dam weir, construction camp- annual average PM 10 ground level concentrations ((µg/m³)(unmitigated)

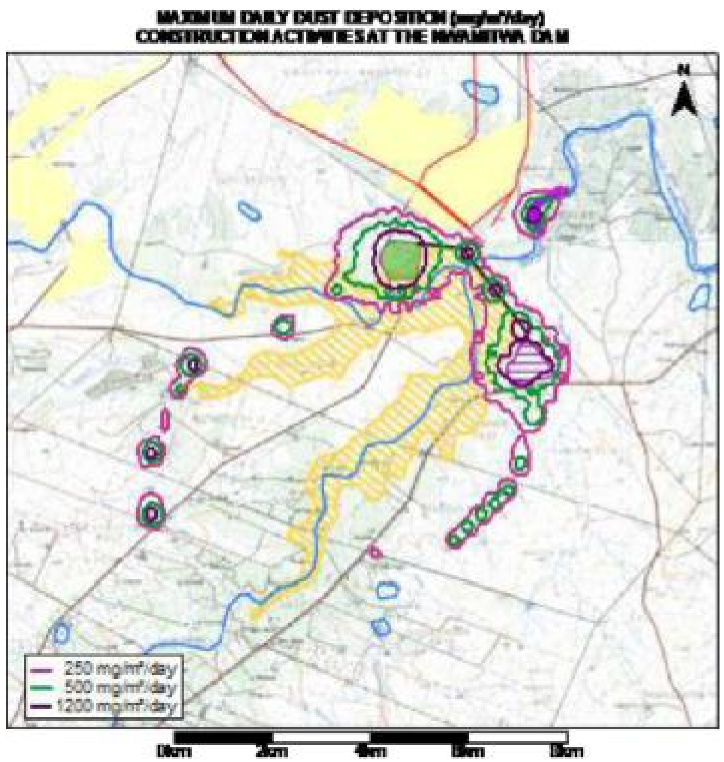


Figure 8.6: *Construction of Nwamitwa dam, weir and construction camp* – maximum daily dust deposition (mg/m²/day) (unmitigated).

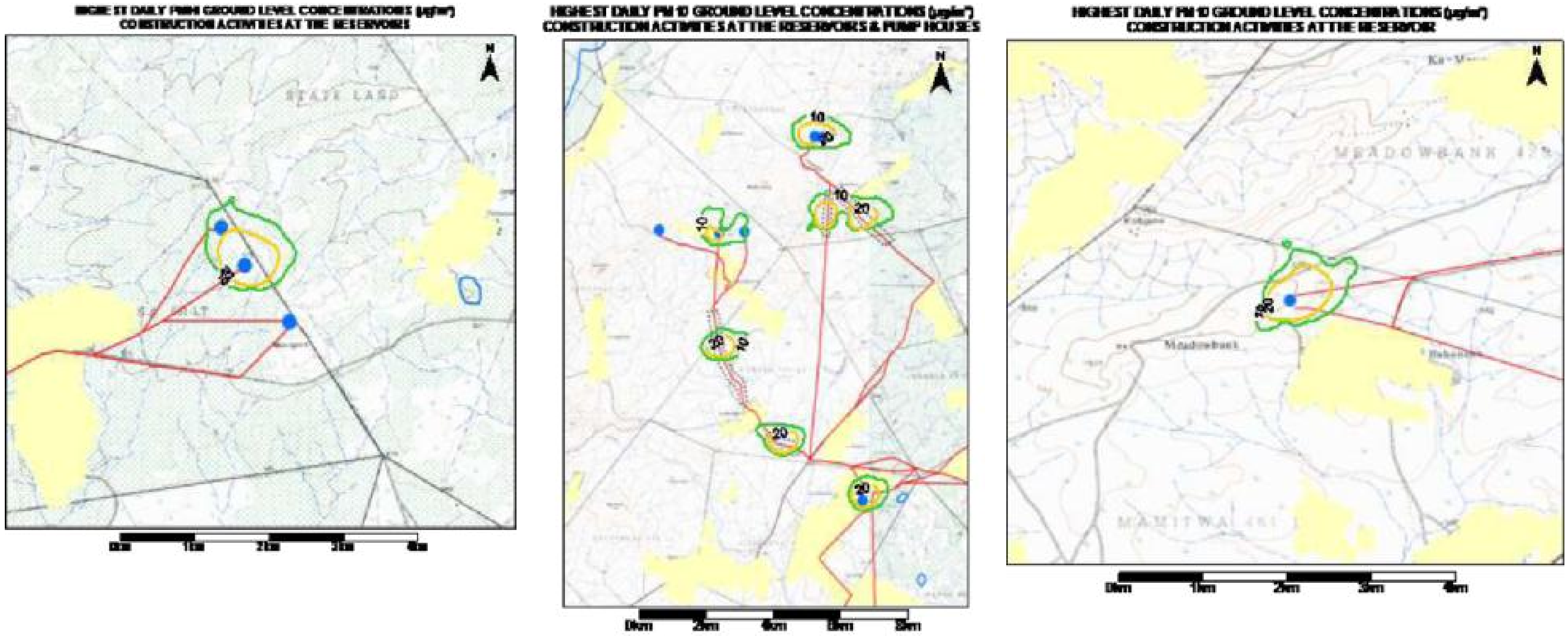


Figure 8.7: ***Construction of reservoirs and pump houses*** **– highest daily PM10 ground level concentrations (µg/m³) (unmitigated).**

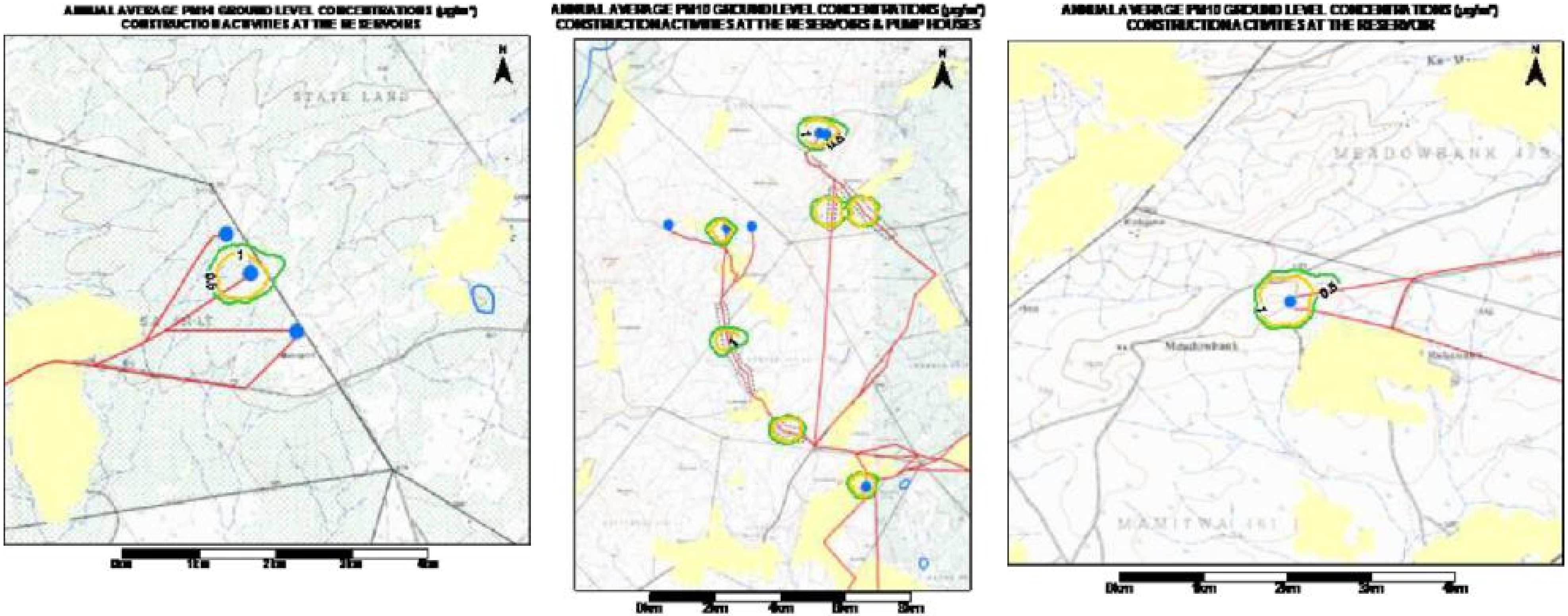


Figure 8.8: ***Construction of reservoirs and pump houses*** **– annual average PM10 ground level concentrations (µg/m³) (unmitigated).**

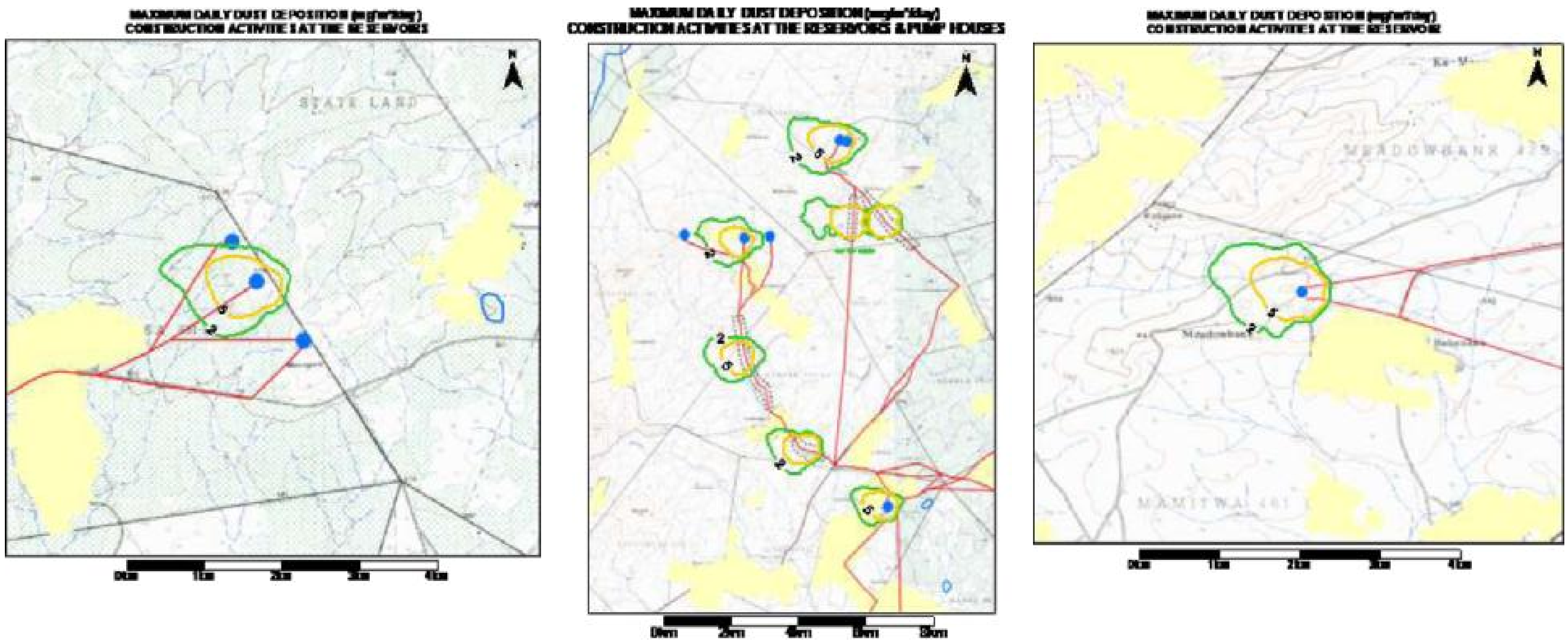


Figure 8.9: ***Construction of reservoirs and pump houses*** **– maximum daily dust deposition (mg/m²/day) (unmitigated).**

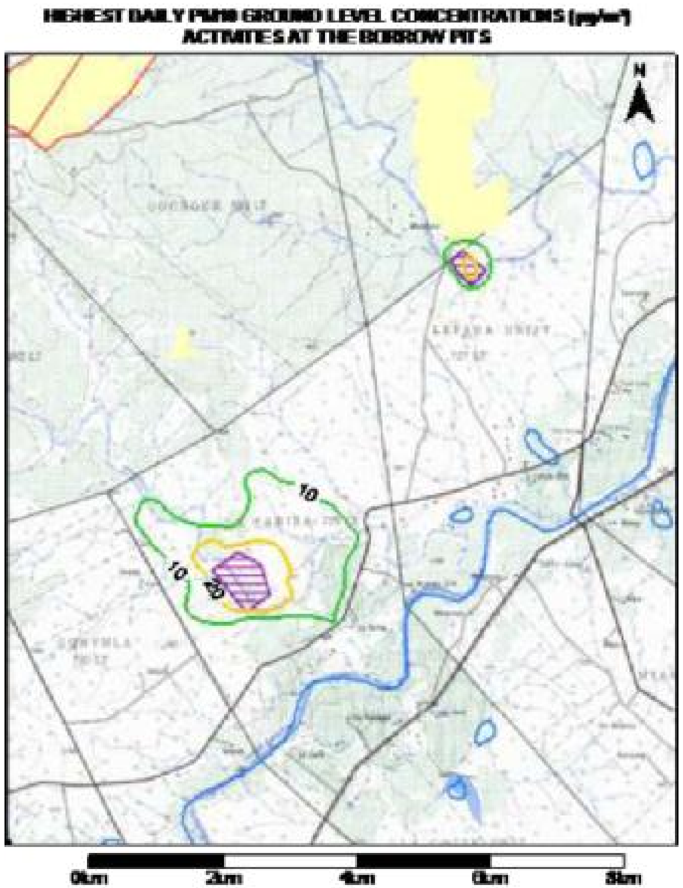


Figure 8.10: *Activities at the borrow pits* – highest daily PM10 ground level concentrations (µg/m³) (unmitigated).

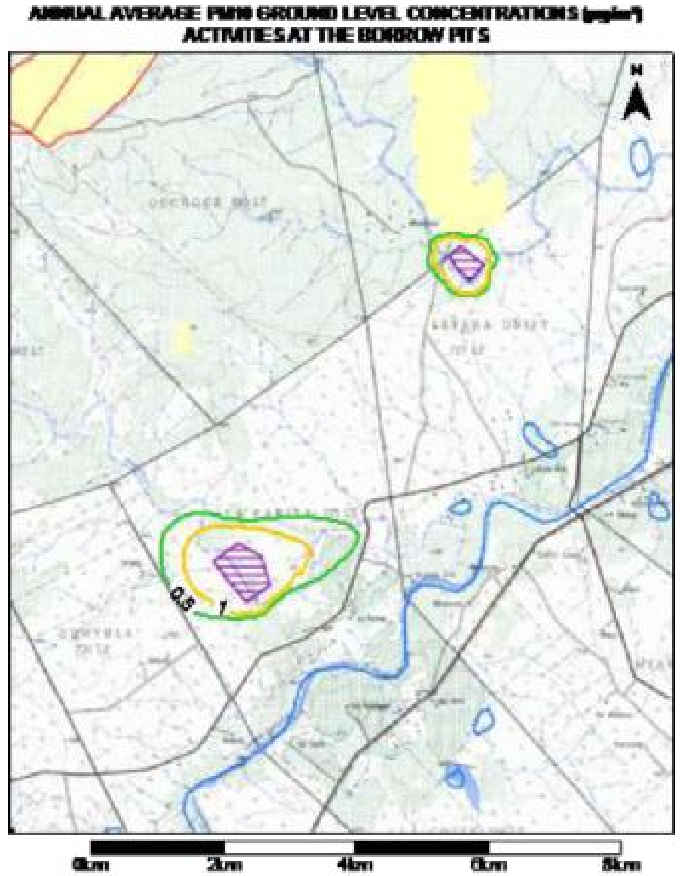


Figure 8.11: *Activities at the borrow pits* – annual average PM10 ground level concentrations (µg/m³) (unmitigated).

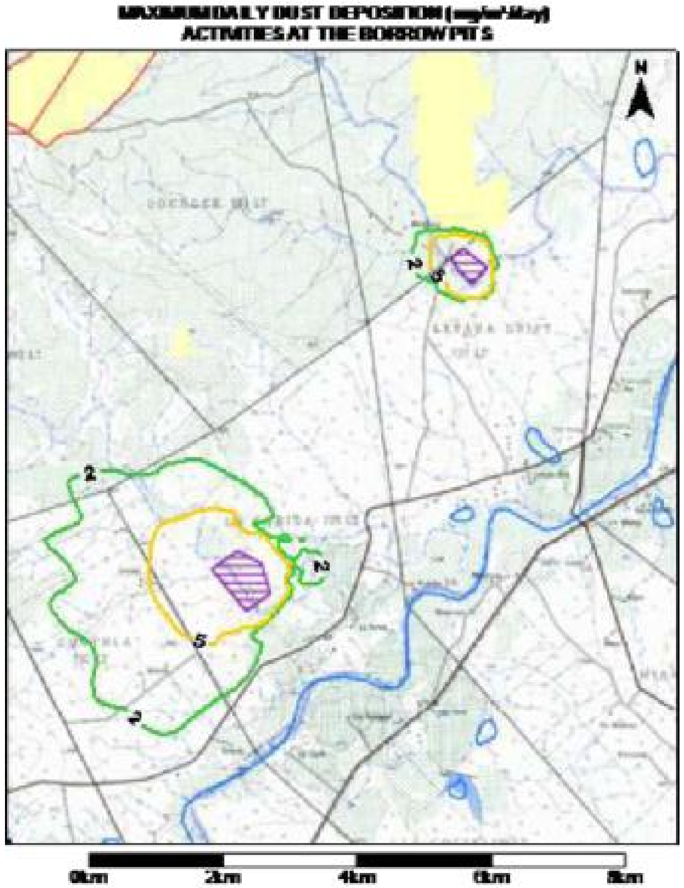


Figure 8.12: ***Activities at the borrow pits*** **– maximum daily dust deposition (mg/m²/day) (unmitigated).**

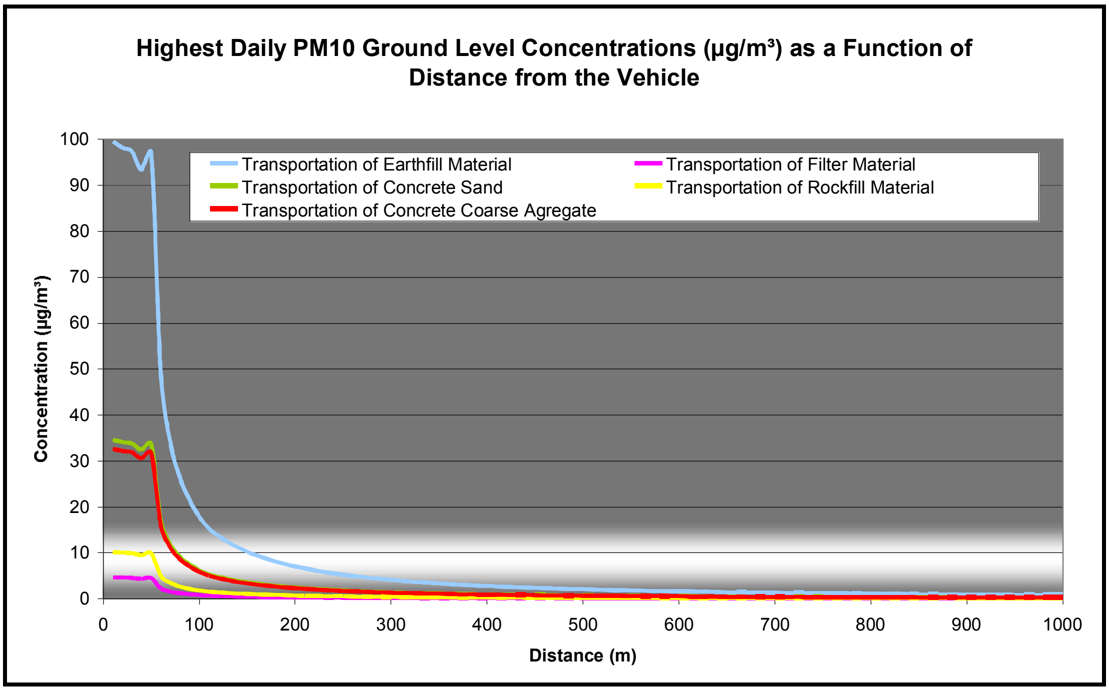


Figure 8.13: ***Vehicle entrainment from the transportation of material* – highest daily PM10 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

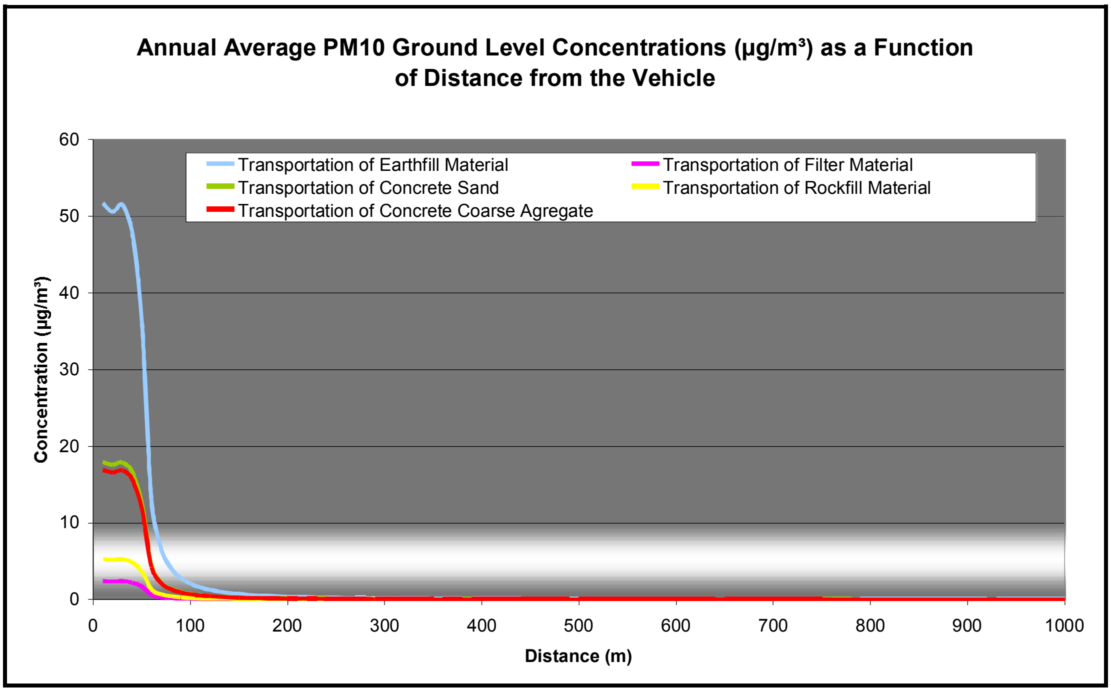


Figure 8.14: ***Vehicle entrainment from the transportation of material* – annual average PM10 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

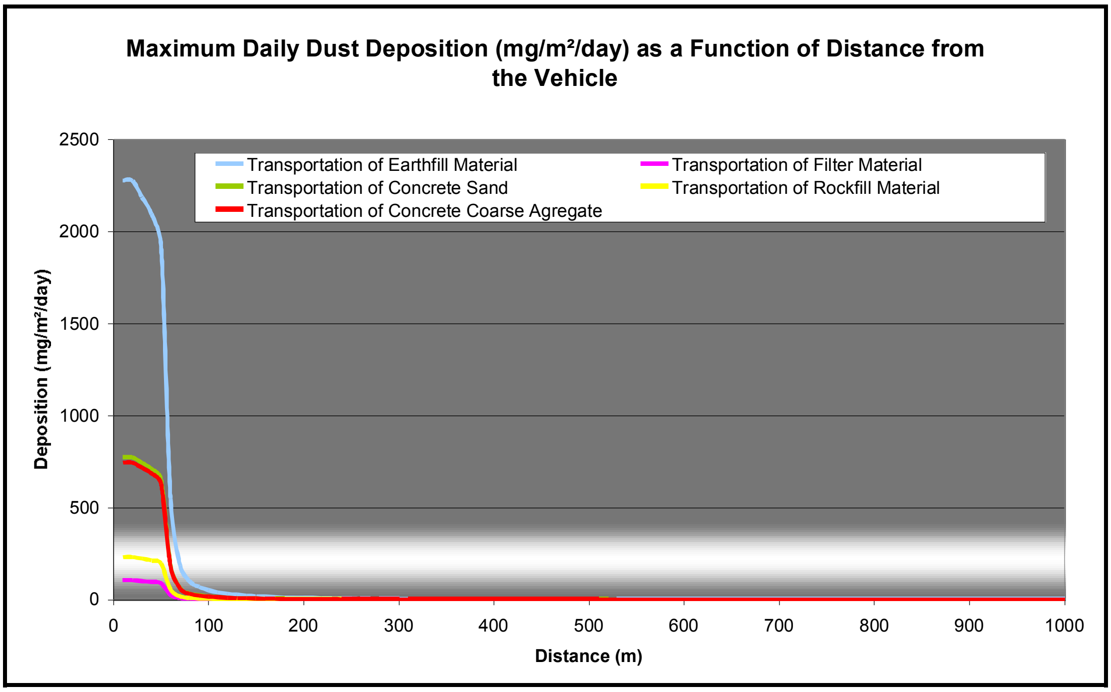


Figure 8.15: ***Vehicle entrainment from the transportation of material* – maximum daily dust deposition (mg/m²/day) as a function of distance from the emission source (unmitigated).**

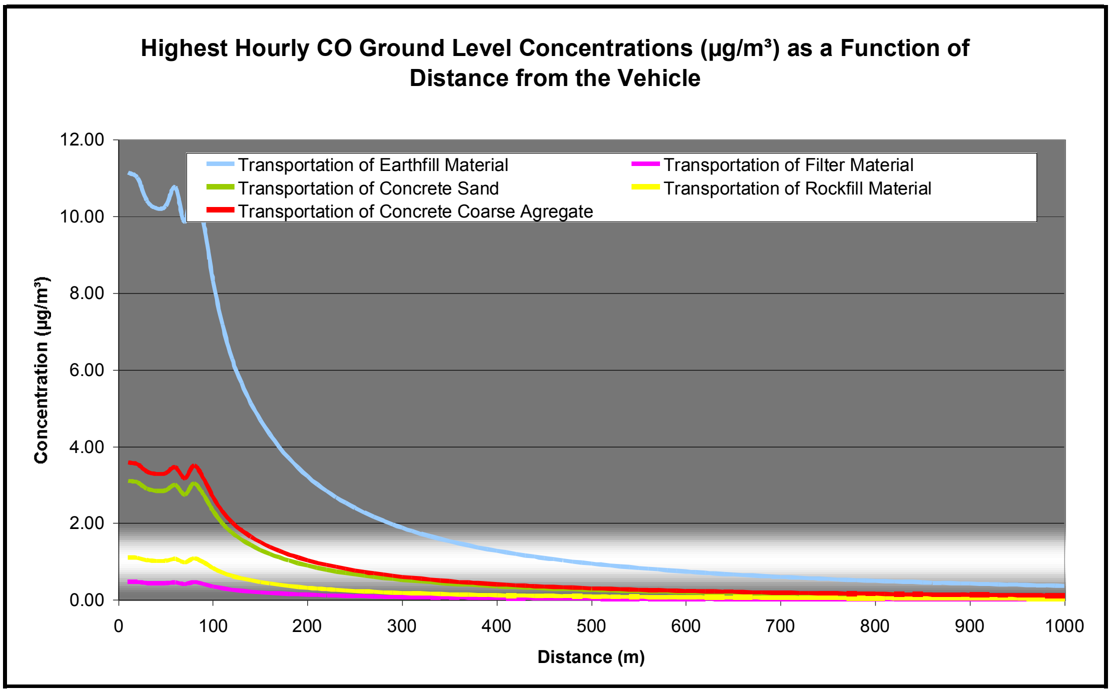


Figure 8.16: ***Vehicle exhaust from the transportation of material* – highest hourly CO ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

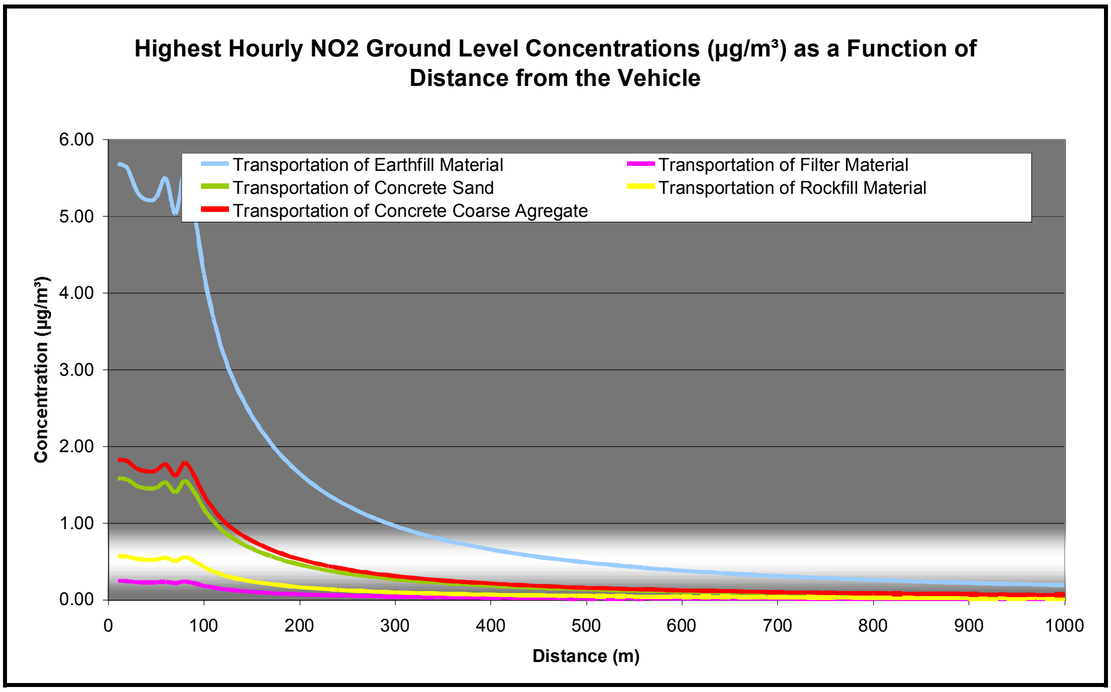


Figure 8.17: ***Vehicle exhaust from the transportation of material*** **– highest hourly NO_2 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

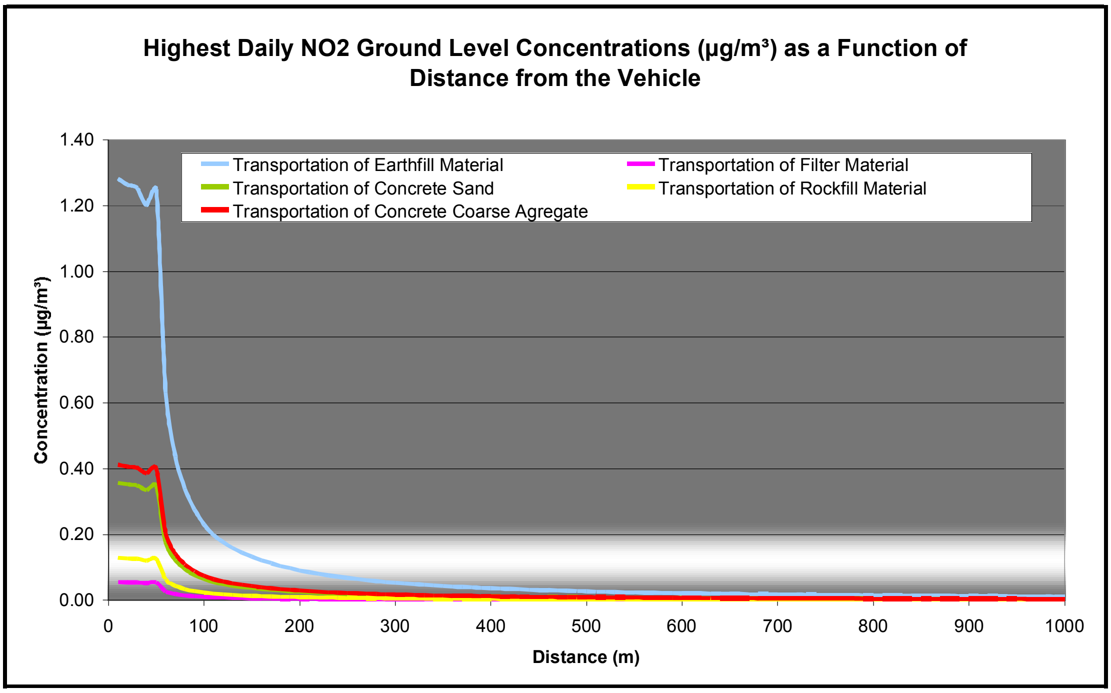


Figure 8.18: ***Vehicle exhaust from the transportation of material*** **– highest daily NO_2 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

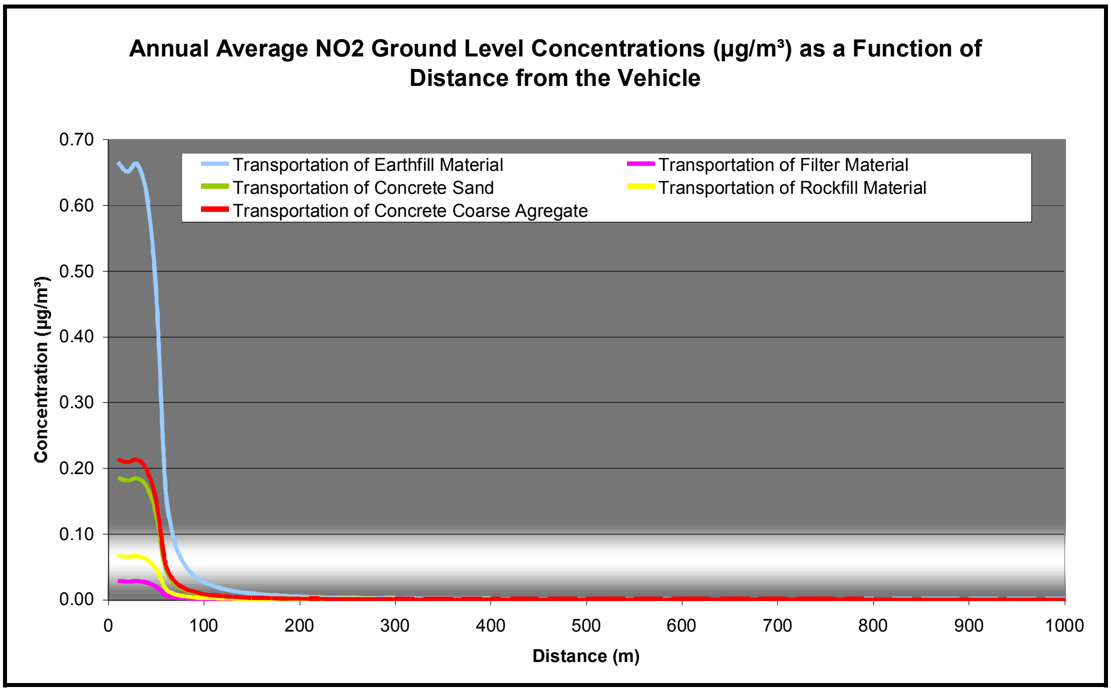


Figure 8.19: ***Vehicle exhaust from the transportation of material*** **– annual average NO_2 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

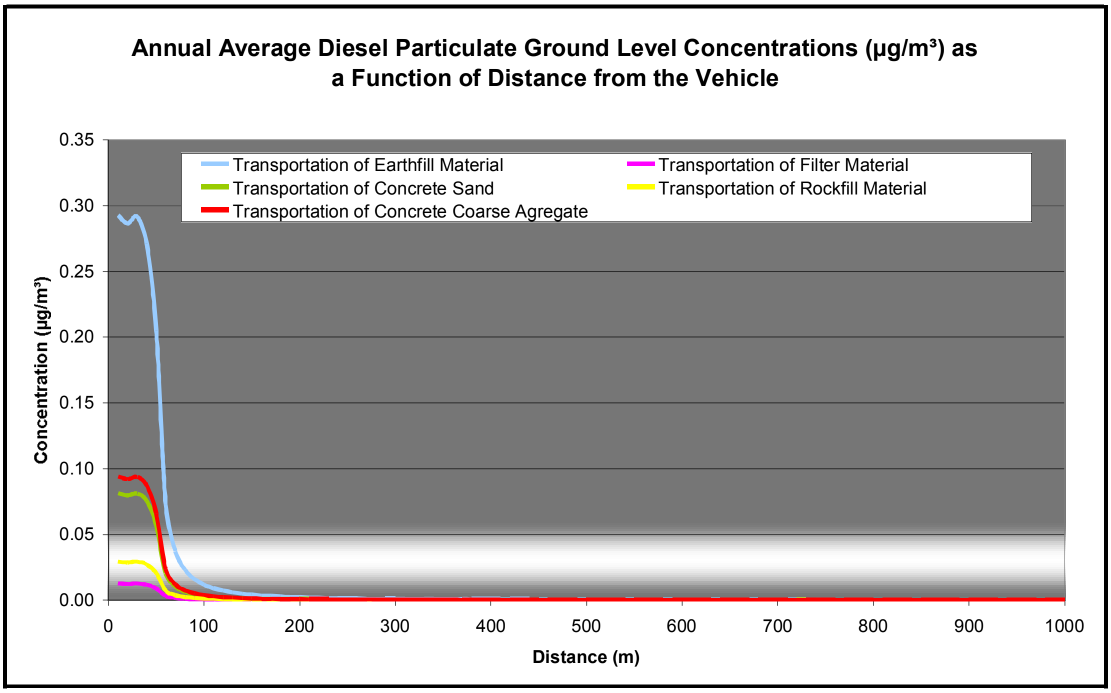


Figure 8.20: ***Vehicle exhaust from the transportation of material*** **– annual average diesel particulate ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

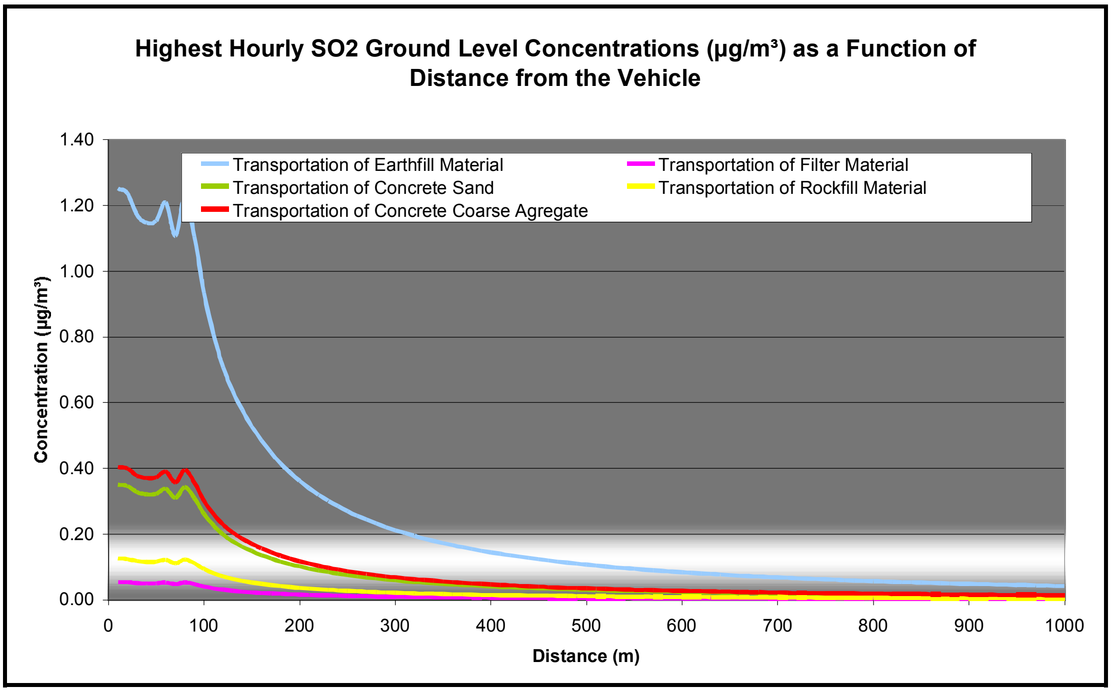


Figure 8.21: ***Vehicle exhaust from the transportation of material*** **– highest hourly SO_2 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

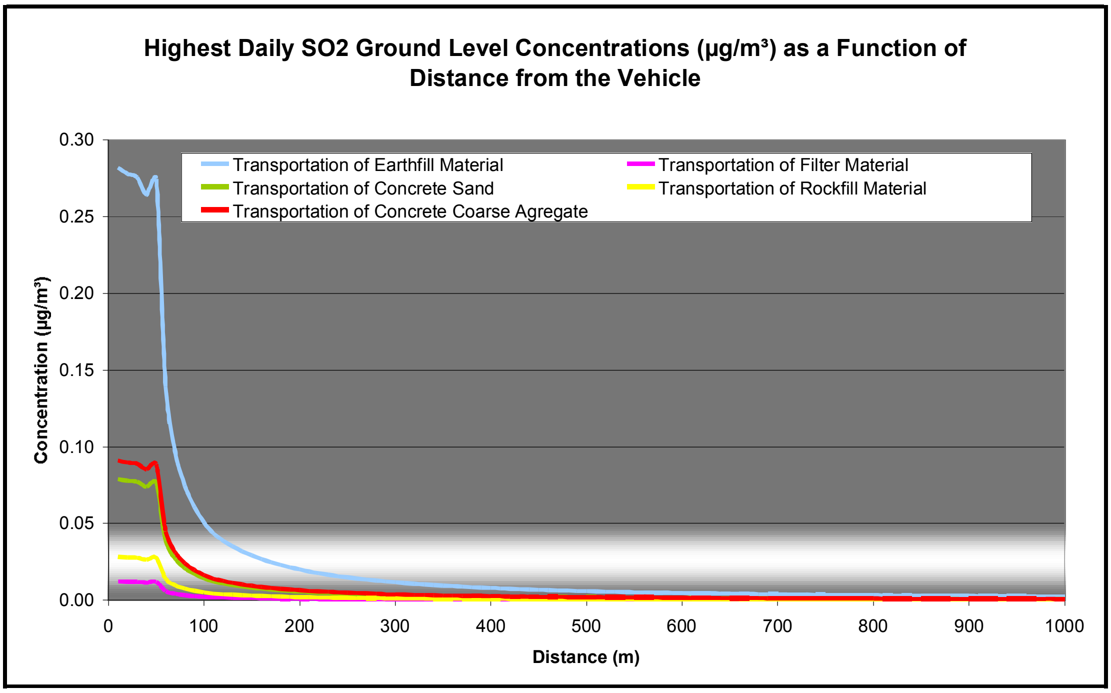


Figure 8.22: ***Vehicle exhaust from the transportation of material*** **– highest daily SO_2 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

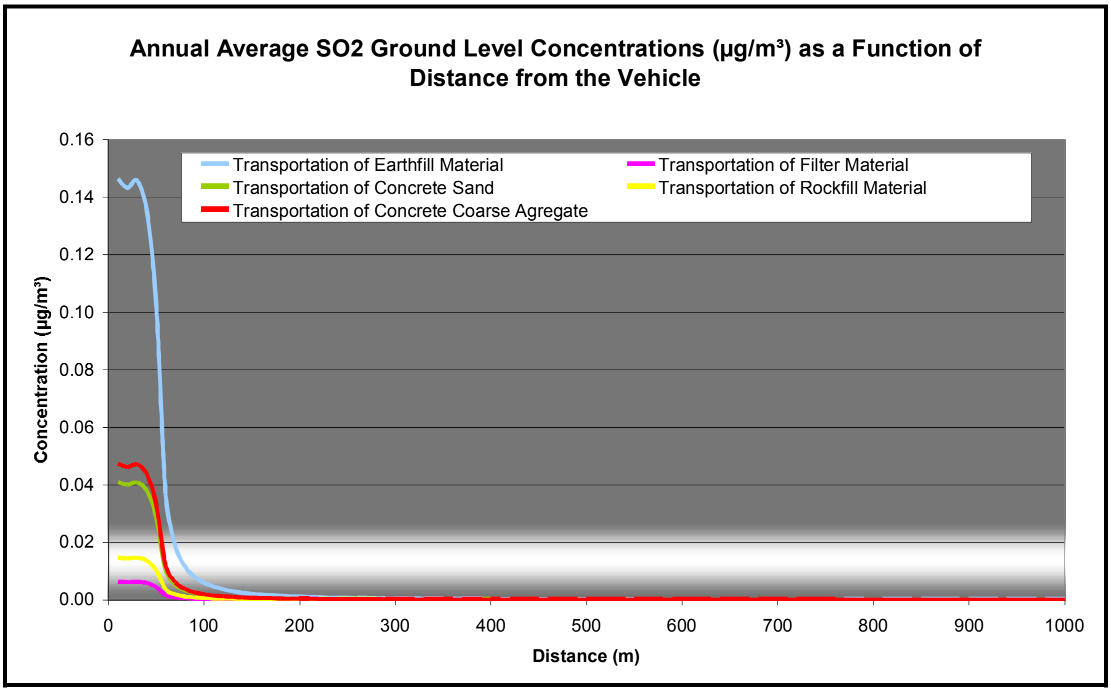


Figure 8.23: ***Vehicle exhaust from the transportation of material*** **– annual average SO_2 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

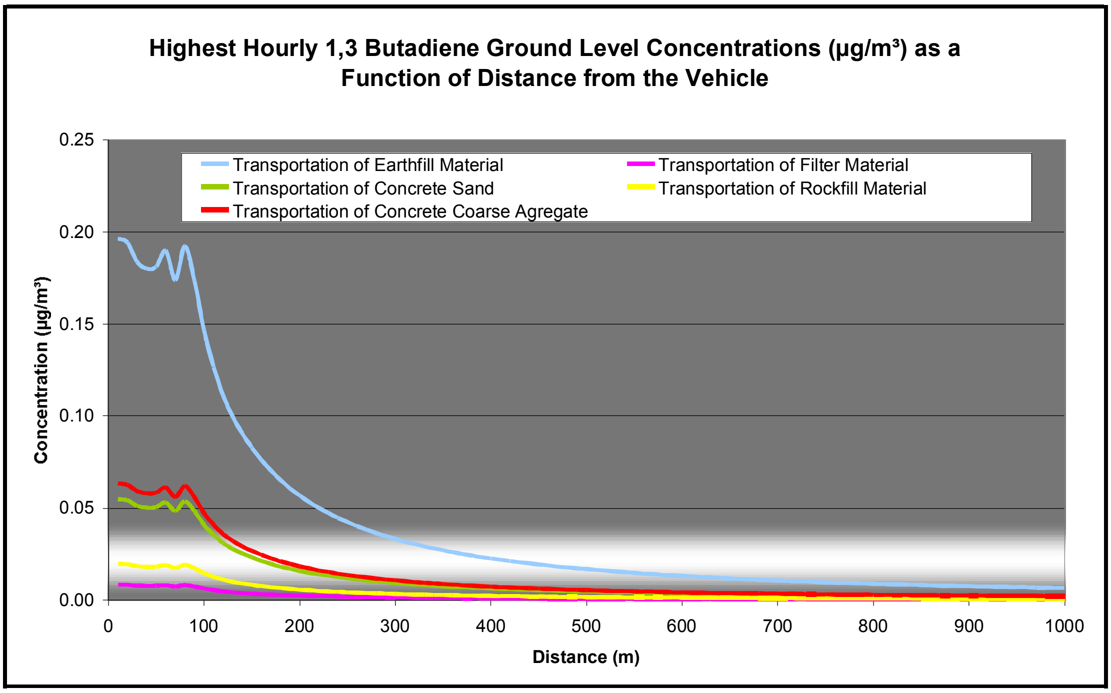


Figure 8.24: ***Vehicle exhaust from the transportation of material*** **– annual average 1,3 Butadiene ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

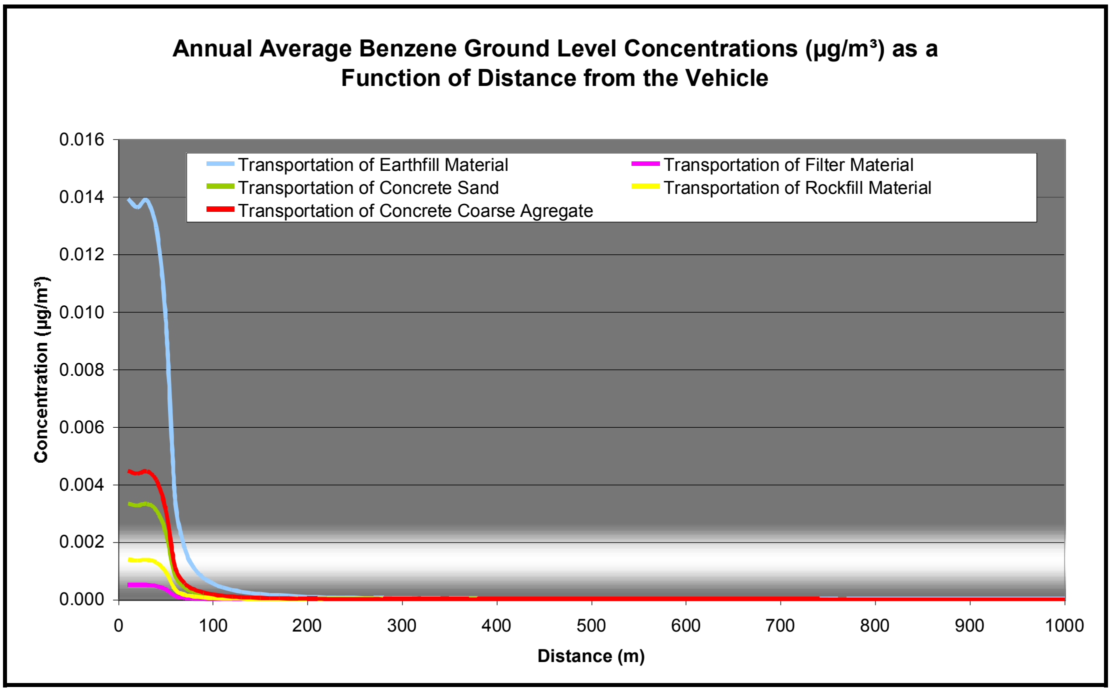


Figure 8.25: ***Vehicle exhaust from the transportation of material*** **– annual average benzene ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

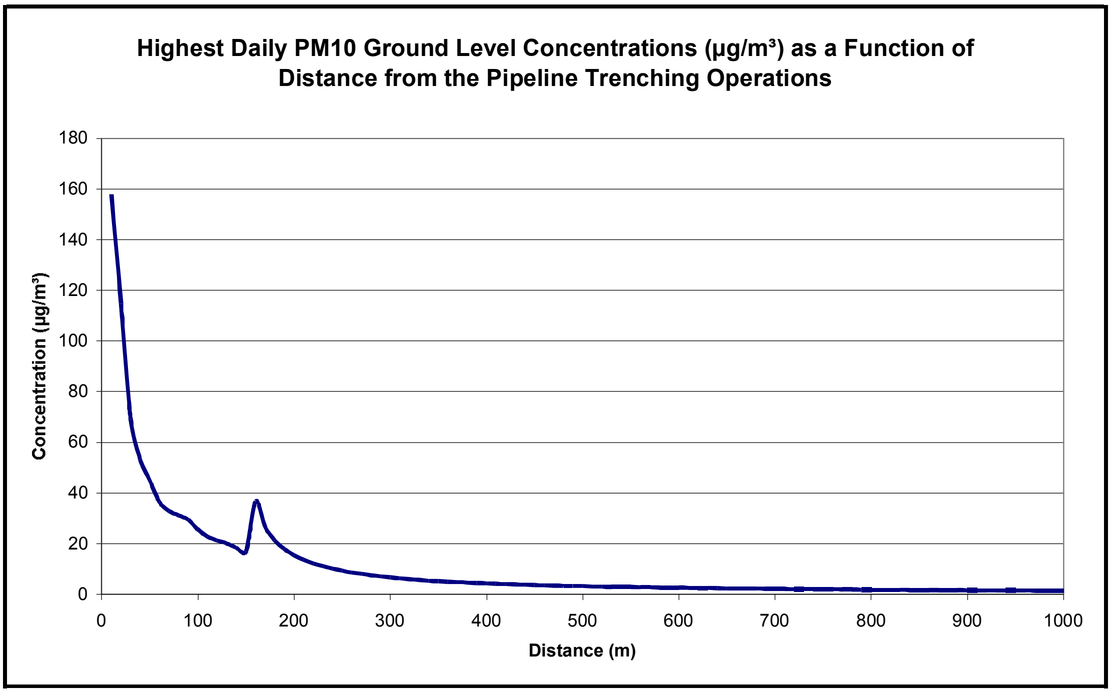


Figure 8.26: ***Impact due to the laying down of the pipeline*** **– highest daily PM10 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

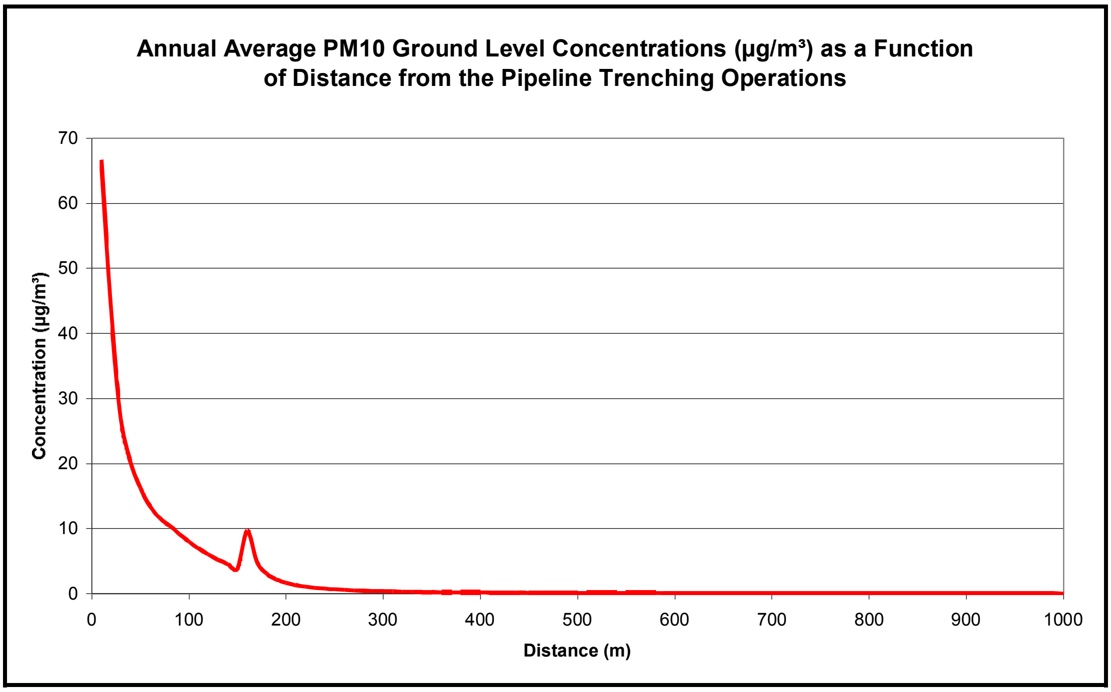


Figure 8.27: ***Impact due to the laying down of the pipeline*** **– annual average PM10 ground level concentrations (µg/m³) as a function of distance from the emission source (unmitigated).**

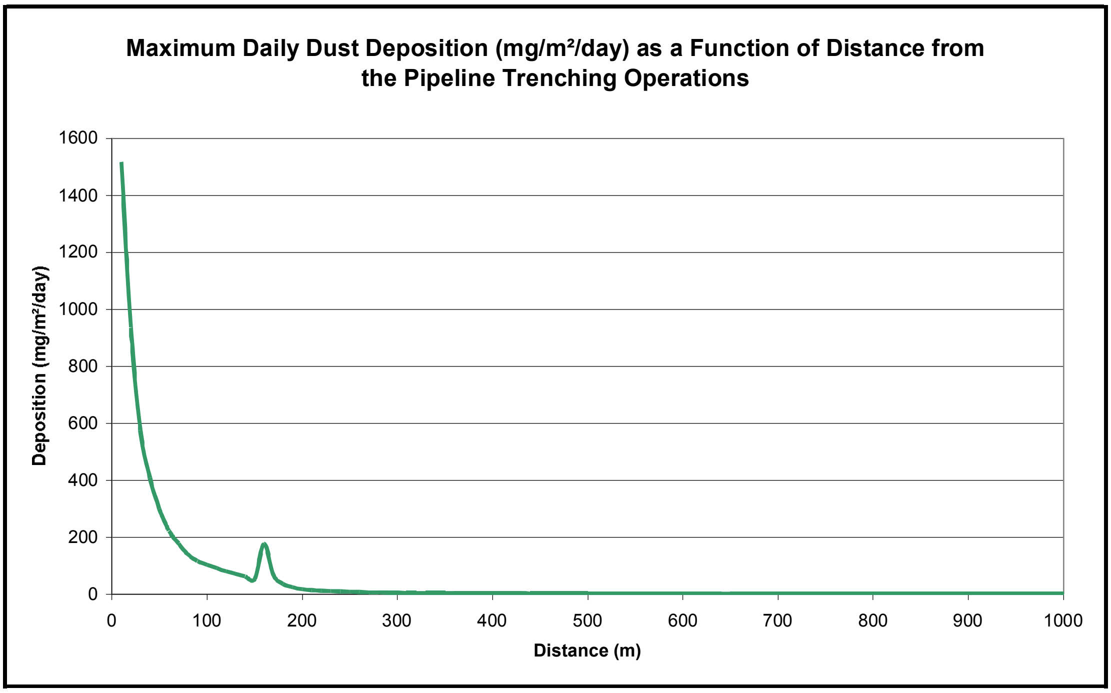


Figure 8.28: ***Impact due to the laying down of the pipeline*** **– maximum daily dust deposition (mg/m²/day) as a function of distance from the emission source (unmitigated).**

8.3 COMPLIANCE ASSESSMENT

The predicted PM10 ground level at the nearest sensitive receptors due to various construction activities is given in **Table 8.7.**

Table 8.8: Highest predicted PM10 concentrations off-site at the closest sensitive receptor (4).

Scenarion	Highest daily			Annual Average		
	Predicted Conc μg/m³	Guideline μg/m³	Fraction of Guideline	Predicted Conc μg/m³	Guideline μg/m³	Fraction of Guideline
Raising of the Tzaneen Dam	0.59 (5)	180(1) 75(2) 50(3)	<0.01 <0.01 0.01	0.04 (5)	60(1) 40(2)(3)	<0.01 <0.01
Construction of the Nwamitwa Dam, weir, and construction camp	345.0 (6)	180(1) 75(2) 50(3)	**1.9** **4.6** **6.9**	29.6 (6)	60(1) 40(2)(3)	0.5 0.7
Construction of the reservoirs and pump houses	66.3 (7)	180(1) 75(2) 50(3)	0.4 0.9 **1.3**	8.6 (7)	60(1) 40(2)(3)	0.1 0.2
Activities at the borrow pits	12.5 (8)	180(1) 75(2) 50(3)	0.07 0.2 0.3	1.2 (8)	60(1) 40(2)(3)	0.02 0.03

Note: (1) SA Standard
(2) SANS limit
(3) EC limit
(4) Exceedance of the guideline is provided in bold
(5) Sensitive receptor of Tzaneen
(6) Sensitive receptor of Nkamboko
(7) Sensitive receptor of Serolorolo
(8) Sensitive receptor of Miragoma

(a) Raising of the Tzaneen Dam

The highest daily and annual average PM10 ground level concentrations at the sensitive receptor of Tzaneen due to the proposed raising of the dam wall with no control efficiency is predicted to be 0.59 µg/m³ and 0.04 µg/m³ respectively. The highest daily and annual average ground level concentrations are well within the SA standards (180 µg/m³), SANS daily limits (75 µg/m³) for the protection of human health and the EC limit/SANS target of 50 µg/m³ (**Table 8.7**).

The predicted maximum deposition during this project phase, due to uncontrolled emissions, is predicted to be 0.98 mg/m²/day at the sensitive receptor of Tzaneen (well within the SANS target of 600 mg/m²/day for residential areas).

(b) Construction of the Nwamitwa Dam, Weir, Construction Camp and Road Realignment

For construction activities at the Nwamitwa Dam, the highest daily and annual predicted PM10 ground level concentrations at the closest sensitive receptor of Nkamboko are 345 µg/m³ and 30 µg/m³ respectively (assuming no dust control). The highest daily ground level concentrations exceed the current SA standards as well as the stricter SANS and EC limits. The annual average ground level concentrations are within the SA standards, SANS and EC limits.

Currently the SA standards do not have frequency of exceedance. However, the EC daily PM10 limit allows for 35 exceedances in a calendar year. A maximum frequency of exceedance of 36 days for the proposed operations was predicted at the nearest sensitive receptors (higher than the allowable EC limit).

During this construction phase (assuming uncontrolled emissions), the predicted maximum deposition at the closest sensitive receptor of Ka-Mswazi is predicted to be 107 mg/m²/day (within SANS target of 600 mg/m²/day for residential areas).

(c) Construction of the Reservoirs and Pump Houses

For the construction of the reservoirs and pump houses, the highest predicted daily and annual average PM10 ground level concentrations at the closest sensitive receptor of Serolorolo is 66 µg/m³ and 9 µg/m³ respectively. Impacts from the construction of the other reservoirs (further from Serolorolo) do not exceed the health guidelines/ standards at the residential receptors. The highest daily ground level concentrations are within the SA standards and in line with the SANS limits, but exceed the EC limits by 33 %. The annual average ground level concentrations are within all standards and limits.

A maximum frequency of exceedance of 4 days for the proposed operations was predicted at the nearest sensitive receptors (within the allowable EC limit).

During this construction phase (assuming uncontrolled emissions), the predicted maximum deposition at the closest sensitive receptor of Ka-Mswazi is predicted to be 107 mg/m²/day (within SANS target of 600 mg/m²/day for residential areas).

(d) Activities at the Borrow Pits

The highest daily and annual average PM10 ground level concentrations at the closest sensitive receptor of Miragoma due to the proposed activities at the borrow pits (assuming uncontrolled emissions) is predicted to be 12.5 µg/m³ and 1.2 µg/m³ respectively. The highest daily and annual average ground level concentrations are well within the SA standards, SANS and EC limits.

The predicted maximum deposition during this project phase, due to uncontrolled emissions, is predicted to be 13 mg/m²/day at the sensitive receptor of Miragoma (well within the SANS target of 600 mg/m²/day for residential areas).

(e) Vehicle Entrainment from the Transportation of Material

The predicted PM10 concentrations and dust deposition for the transportation of various materials are given in **Figure 8.13 to Figure 8.15.**

For highest daily PM10 concentrations, the SANS (75 µg/m³) and EC limits (50 µg/m³) are exceeded for 50 m (transportation of earthfill material) from the road as the vehicle passes. For annual average PM10 concentrations, the SANS and EC limits of 40 µg/m³ are exceeded for 40 m (transportation of earthfill material) from the source.

The predicted maximum deposition, exceeds the SANS industrial (1200 mg/m²/day) and residential targets (600 mg/m²/day) for 50m with the transportation of earthfill material. With the transportation of concrete and concrete coarse aggregate, the SANS residential target of 600 mg/m²/day is exceeded for 50m from the source.

(f) Vehicle Exhaust from the Transportation of Material

The predicted CO, NO_2, diesel particulates, SO_2, 1,3 butadiene and benzene concentrations from vehicle exhaust for the transportation of various materials are given in **Figure 8.16 to Figure 8.25.**

The predicted ground level concentrations for SO_2 (<0.3%), 1,3 butadiene (<1.1%), CO (<0.03%), NO_2 (<2.8%), diesel particulates (<5.9%) and benzene (<0.05%) are well below the applicable guidelines/ standards given in Section 7 as well as the strictest effect screening levels. The predicted cancer risk (using the US-EPA unit risk factors) due to 1,3 butadiene and benzene is predicted to be less than 8 in 10 million (10 m from the vehicle source), well below the acceptable limit of 1 in 1 million given by the US-EPA.

(g) Impacts due to the Laying Down of the Pipeline

The predicted PM10 concentrations and dust deposition for the trenching and covering of the pipeline path are given in **Figure 8.16 to Figure 8.18.**

For highest daily PM10 concentrations, the SANS limit of 75 µg/m³ and EC limit of 50 µg/m³ is exceeded for a distance of 10 m and 20 m from the source respectively. For annual average PM10 concentrations, the SA standard of 60 µg/m³ is exceeded for 10 m from the source, and the SANS and EC limits of 40 µg/m³ are exceeded for 20 m from the source.

The predicted maximum deposition, exceeds the SANS industrial (1200 mg/m²/day) and residential (600 mg/m²/day) targets for 10 m and 20 m from the source respectively.

8.4 SIGNIFICANCE RATING

The significance rating was done on the basis of the ILISO definitions (Section 4.2). The significance rating is shown in **Table 8.8 to Table 8.16.** The significance rating without mitigation is **Medium** for the construction activities at the Nwamitwa Dam and road realignment and the construction of the reservoirs due to short-term PM10 exposure. For the transportation of material, laying down of the pipeline, raising of the Tzaneen Dam and activities at the borrow pits, the significance rating is **Low**.

Table 8.9: The impact significance rating for the proposed raising of the Tzaneen Dam

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	Negative, direct
Extent of impact	Regional	Local
Duration of impact	Short-term	Long-term
Intensity	Low	Low
Probability of occurrence	High	High
Confidence of assessment	High	Medium
Level of significance before mitigation	Low	Low
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed
Comments or Discussion: Intensity and level of significance based on the exceedance of the "stricter" PM10 EC limits.		

Table 8.10: The impact significance rating for the proposed construction of the Nwamitwa Dam, weir, and construction camp

Impact Assessment Criteria	Rating
Description of potential impact	Fugitive Dust
Nature of impact	Negative, direct
Legal requirements	To be within SA ambient air quality standards

Impact Assessment Criteria	Rating	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	Negative, direct
Extent of impact	Regional	Local
Duration of impact	Short-term	Long-term
Intensity	Medium	Low
Probability of occurrence	High	High
Confidence of assessment	High	Medium
Level of significance before mitigation	Medium	Low
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed
Comments or Discussion: Intensity and level of significance based on the exceedance of the "stricter" PM10 EC limits.		

Table 8.11: The impact significance rating for the proposed construction of the reservoirs and pump houses

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	Negative, direct
Extent of impact	Regional	Local
Duration of impact	Short-term	Long-term
Intensity	Medium	Low
Probability of occurrence	High	High
Confidence of assessment	High	Medium
Level of significance before mitigation	Medium	Low
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed
Comments or Discussion: Intensity and level of significance based on the exceedance of the “stricter” PM10 EC limits.		

Table 8.12: The impact significance rating for the proposed activities at the borrow pits

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	N/A
Extent of impact	Regional	N/A
Duration of impact	Short-term	N/A
Intensity	Low	N/A
Probability of occurrence	High	N/A
Confidence of assessment	High	N/A
Level of significance before mitigation	Low	N/A
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed
Comments or Discussion: Intensity and level of significance based on the exceedance of the “stricter” PM10 EC limits.		

Table 8.13: The impact significance rating for the proposed vehicle entrainment from the transportation of material

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	N/A
Extent of impact	Regional	N/A
Duration of impact	Short-term	N/A
Intensity	Low	N/A
Probability of occurrence	High	N/A
Confidence of assessment	High	N/A
Level of significance before mitigation	Low	N/A
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed
Comments or Discussion: Intensity and level of significance based on the exceedance of the “stricter” PM10 EC limits.		

Table 8.14: The impact significance rating for the proposed vehicle exhaust from the transportation of material

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	N/A
Extent of impact	Regional	N/A
Duration of impact	Short-term	N/A
Intensity	Low	N/A
Probability of occurrence	High	N/A
Confidence of assessment	High	N/A
Level of significance before mitigation	Low	N/A
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed

Table 8.15: The impact significance rating for the proposed pipeline.

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	N/A
Extent of impact	Regional	N/A
Duration of impact	Short-term	N/A
Intensity	Low	N/A
Probability of occurrence	High	N/A
Confidence of assessment	High	N/A
Level of significance before mitigation	Low	N/A
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed
Comments or Discussion: Intensity and level of significance based on the exceedance of the “stricter” PM10 EC limits.		

Table 8.16: The impact significance rating for the proposed demolition of the construction camp.

Impact Assessment Criteria	Rating	
Description of potential impact	Fugitive Dust	
Nature of impact	Negative, direct	
Legal requirements	To be within SA ambient air quality standards	
Stage	Construction and decommissioning	Operation
Nature of Impact	Negative, direct	N/A
Extent of impact	Regional	N/A
Duration of impact	Short-term	N/A
Intensity	Low	N/A
Probability of occurrence	High	N/A
Confidence of assessment	High	N/A
Level of significance before mitigation	Low	N/A
Mitigation measures (EMP requirements)	(see Section 9)	N/A
Level of significance after mitigation	Low	N/A
Cumulative Impacts	Could not be assessed	Could not be assessed

9. AIR QUALITY MANAGEMENT MEASURES FOR THE PROPOSED CONSTRUCTION PHASE OF THE PROJECT

An air quality impact assessment was conducted for the proposed construction operations at Nwamitwa Dam and associated bulk water infrastructure. The main objective of this study was to determine the significance of the predicted impacts from the proposed fugitive emissions on the surrounding environment and on human health.

To achieve this objective, the local climate was characterised and existing sensitive receptors identified. Particulates were identified to be the main pollutant of concern resulting from the construction operations. The most significant source of fugitive emissions is from the proposed Nwamitwa Dam construction site. Dispersion simulations were undertaken to reflect construction conditions.

The comparison of predicted pollutant concentrations to ambient air quality guidelines and standards facilitated a preliminary screening of the potential, which exists for human health impacts. The sensitive receptors identified in the area consisted of informal settlements surrounding the proposed facility.

The main pollutant of concern is particulate matter (TSP, PM10 and PM2.5). Operations from the cement batching plant and bitumen plant could give rise to heavy metal and VOC emissions and emissions from the cement batching and bitumen plants respectively. The emissions most likely from a water treatment plant are chlorine and ammonia. Information was only available for particulate matter (TSP, PM10).

9.1 TARGET CONTROL EFFICIENCIES

Vehicle entrainment on unpaved roads (of 75% control efficiency (i.e. reducing emissions by 75%) can be achieved through effective water sprays. Construction of plant areas and roads can obtain a 62% control efficiency through effective water sprays. Wind erosion from the storage piles can be reduced through the implementation of wind breakers on the windward side of the pile.

9.2 SITE-SPECIFIC MANAGEMENT OBJECTIVES

The main objective of Air Quality Management measures for the raising of the Tzaneen Dam, the construction of a storage dam in the Groot Letaba River and associated bulk water infrastructure is to ensure that all operations will be within compliance with the requirements of Air Quality Act.

It is recommended that the project proponent commits to air quality management planning throughout the various operations of the construction phase of the project. It is recommended that an Air Pollution Control System (APCS) be developed for the project to reduce and control emissions from the construction activities. This APCS includes detailed management plans, mitigations measures and monitoring and operational procedures developed to ensure emissions reductions will occur. The APCS must be implemented and revised by on-site personnel on an on-going basis. This APCS can be incorporated into the EMS (Environmental Management System) for the project.

9.2.1 Source Ranking by Emissions

The primary sources during construction were identified as the construction of the Nwamitwa dam and construction village, weir and road realignment. For TSP emissions from the Nwamitwa dam and construction village, weir and road realignment was calculated to be 3317 tpa, 968 tpa and 1211 tpa respectively. For PM10 the emissions were calculated to be 1161 tpa (Nwamitwa dam and construction village), 339 tpa (weir) and 424 tpa (road realignment).

9.2.2 Source Ranking by Impacts

By taking all construction sources into account, predicted PM10 highest daily concentrations exceeded the SA standards at the sensitive receptor of Nkomboko. The frequency of exceedance was predicted to be 39 times at the closest sensitive receptor (exceeding the allowable EC limit).

The main sources of particulates resulting in off-site impacts at this sensitive receptor (both for PM10 and TSP) during the construction phase includes the construction of the Nwamitwa Dam and construction camp, road realignment and construction of the weir.

9.3 PROJECT-SPECIFIC MANAGEMENT MEASURES

9.3.1 Identification of Suitable Pollution Abatement Measures

Dust control measures which may be implemented during the construction phase are outlined in **Table 9.1.** Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed though the use of windbreaks and source enclosures.

Table 9.1: Dust control measures implementable during construction activities

Construction Activity	Recommended Control Measure(s)
Truck transport and road dust entrainment	Where possible and for high risk sites, pave all major haul routes. Paving is highly effective but is expensive and unsuitable for surfaces used by very heavy vehicles or subject to spillage of material in transport. In addition, dust control measures will usually still be required on the paved surfaces. The use of gravel or slag can be moderately effective, but repeated additions will usually be required.
	Set speed limits of 35 km/hr or less for site traffic on paved roads and 10-15 km/hr on unpaved surfaces. Speed controls on vehicles have an approximately linear effect on dust emissions. Thus by reducing the speed from 30 km/hr to 15 km/hr dust emissions can be reduced by 50%.
	Wet suppression of unpaved areas should be applied during dry windy periods, using a water cart and/or fixed sprinklers.
	Chemical suppression can also be used in conjuction with wet suppression. This involves the use of chemical additives in the water, which help to form a crust on the surface and bind the dust particles together. Chemical stabilisation reduces watering requirements, but any savings can be offset by the cost of the additives. Repeat treatments are usually required at intervals of 1-4 weeks. The method is best suited to permanent site roads and usually not cost-effective on temporary roads, which are common in construction sites.
	Inspect haul roads for integrity and repair if required.
	Provide hard-standing areas for vehicles and regularly inspect and clean these areas.
	Reduce mud/dirt carry-out onto paved roads.
	Reduce unnecessary traffic.
	Cover loads with tarpaulins to prevent dust re-entrainment from trucks.
	Limit load size to reduce spillage.
	Minimise travel distances through appropriate site layout and design.

Construction Activity	Recommended Control Measure(s)
	Use wheel and truck wash facilities at site exits.
Excavation and earthworks	Re-vegetate dry, exposed areas to stabilise surfaces. Only remove secure covers in small areas and not all at once. All activities must be damped down, especially during dry weather.
Stockpiles and storage mounds	Limit the height and slope of the stockpiles to reduce wind entrainment. For example, a flat shallow stockpile will be subject to less wind turbulence than one with a tall conical shape.
	Keep stockpiles or mounds away from the site boundary, sensitive receptors and watercourses. If necessary, take into account the predominant wind direction to reduce the likelihood of affecting sensitive receptors.
	Make sure the stockpiles are maintained for the shortest possible time.
	Seed, re-vegetate or turf long term stockpiles to stabilise surfaces or use surface binding agents.
	Where possible, enclose stockpiles or keep them securely sheeted.
	Erect fences of similar height and size to the stockpile to act as wind barriers and keep these clean using wet methods. Porous fences or hedges often make the most suitable shelter.
	Store fine material (under 3 mm in size) inside buildings or enclosures.
	Minimise drop heights to control the fall of materials.

Types of controls used at cement batching plants may include water sprays, enclosures, hoods, curtains, shrouds, movable and telescoping chutes, central duct collection systems, and the like. A major source of potential emissions, the movement of heavy trucks over unpaved or dusty surfaces in and around the plant, can be controlled by good maintenance and wetting of the road surface.

9.3.2 Monitoring Requirements

(a) 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.

9.3.2.a.1 Specification of Source Based Performance Indicators

Source based performance indicators for the proposed construction operations would include the following:

- Maximum dustfall immediately downwind of the construction activities to be <1 200 mg/m^2/day.
- From all activities associated with the construction phase of the project, dustfall in close proximity to sensitive receptors should not exceed 600 mg/m^2/day.

9.3.2.a.2 Receptor based Performance Indicators

Based on the impacts predicted from the construction operations it is recommended that a dust fallout monitoring network be implemented.

A dust fallout network for the proposed project should be implemented even before the construction phase commences. This would provide management with an indication of what the increase in fugitive dust levels are once construction operations commence and would bring the construction operations in line with the new Air Quality Act (no.39 of 2004).

- ***Dust fallout monitoring network***

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.

It is therefore recommended that a dust fallout network comprising of ~3 single dust fallout buckets be implemented. The proposed locations of the dust buckets are indicated in Figure 9.1 and are selected in terms of maximum zones of impact due to the construction activities, with the additional aspect of exposure potential.

The analysis of the single dust fallout buckets should be presented as total daily dustfall over a month (28 to 32 days) as set out by the DEAT dust fallout categories. Monitoring procedures and reporting protocol are provided in **Table 9.2**.

Figure 9.1: Proposed dust fallout monitoring network for the proposed construction phase of the Project.

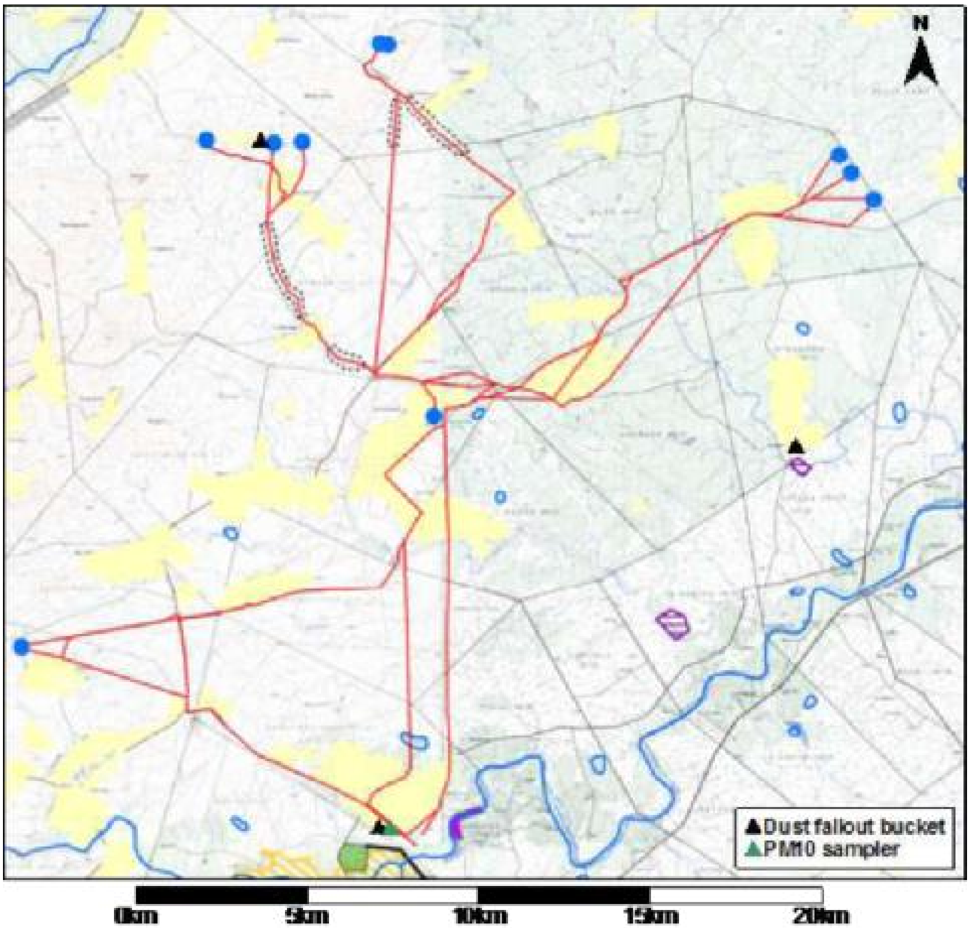


Table 9.2: Ambient air monitoring, performance assessment and reporting programme.

Monitoring Strategy Criteria	Dustfall Monitoring
Monitoring objectives	- Assessment of compliance with dustfall limits within the main impact zone of the operation. - Facilitate the measurement of progress against environmental targets within the main impact zone of the operation. - Temporal trend analysis to determine the potential for nuisance impacts within the main impact zone of the operation. - Tracking of progress due to pollution control measure implementation within the main impact zone of the operation. - Informing the public of the extent of localised dust nuisance impacts occurring in the vicinity of

Monitoring Strategy Criteria	Dustfall Monitoring
	the project.
Monitoring location(s)	Figure 9.1. Dustfall to be recorded by dustfall monitoring network comprising 10 single buckets.
Sampling techniques	Single Bucket Dust Fallout Monitors Dust fallout sampling measures the fallout of windblown settleable dust. Single bucket fallout monitors to be deployed following the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739). This method employs a simple device consisting of a cylindrical container half-filled with de-ionised water exposed for one calendar month (30 days, ±3 days). The water is treated with an inorganic biocide to prevent algae growth in the buckets. The bucket stand comprises a ring that is raised above the rim of the bucket to prevent contamination from perching birds. Once returned to the laboratory, the content of the bucket are filtered and the residue dried before the insoluble dust is weighed.
Accuracy of sampling technique	Margin of accuracy given as ±200 mg/m^2/day.
Sampling frequency and duration	On-going, continuous monitoring to be implemented facilitating data collection over 1-month averaging period.
Commitment to QA/QC protocol	Comprehensive QA/QC protocol implemented.
Interim environmental targets (i.e. receptor-based performance indicator)	Maximum total daily dustfall (calculated from total monthly dustfall) of not greater than 600 mg/m^2/day for residential areas. Maximum annual average dustfall to be less than 1,200 mg/m^2/day on-site.
Frequency of reviewing environmental targets	Annually (or may be triggered by changes in air quality regulations).
Action to be taken if targets are not met	(i) Source contribution quantification. (ii) Review of current control measures for significant sources (implementation of contingency measures where applicable).
Procedure to be followed in reviewing environmental targets and other elements of the monitoring strategy (e.g. sampling technique, duration, procedure)	Procedure to be drafted in liaison with I&APs through the proposed community liaison forum. Points to be taken into account will include, for example: (i) trends in local and international ambient particulate guidelines and standards and/or compliance monitoring requirements, (ii) best practice with regard to monitoring methods, (iii) current trends in local air quality, i.e. is there an improvement or deterioration, (iv) future development plans within the airshed (etc.)
Progress reporting	At least twice annually to the necessary authorities and community forum.

PM10 ambient monitor

In addition to the dust fallout buckets, it is recommended that a PM10 sampler be located at the sensitive receptor of Nkamboko due to the modelled exceedances of the daily PM10 SA standards during the proposed construction activities of the Nwamitwa Dam, weir and road realignment.

9.3.3 Record-keeping, Environmental Reporting and Community Liaison

(a) Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes.

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during construction operations, with annual environmental audits being conducted. Annual environmental audits forms part of an APCS and should be initiated. Results from site inspections and off-site monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

(b) 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 forums will be held, and provide information on how people will be notified of such meetings. For operations for which construction activities will impound on residential areas, it is recommended that such meetings be scheduled to be held at least on a quarterly basis. This, for example would be applicable to the project, the surrounding residents and all the surrounding land owners.

9.3.4 Financial Provision (Budget)

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to construction activities. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and I&AP liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures.

The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

10. RECOMMENDED MITIGATION MEASURES

Dust control measures which may be implemented during the construction phase are outlined in Table 9.1. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed though the use of windbreaks and source enclosures.

Table 10.1: Dust control measures implementable during construction activities

Construction Activity	Recommended Control Measure(s)
Truck transport and road dust entrainment	Where possible and for high risk sites, pave all major haul routes. Paving is highly effective but is expensive and unsuitable for surfaces used by very heavy vehicles or subject to spillage of material in transport. In addition, dust control measures will usually still be required on the paved surfaces. The use of gravel or slag can be moderately effective, but repeated additions will usually be required.
	Set speed limits of 35 km/hr or less for site traffic on paved roads and 10-15 km/hr on unpaved surfaces. Speed controls on vehicles have an approximately linear effect on dust emissions. Thus by reducing the speed from 30 km/hr to 15 km/hr dust emissions can be reduced by 50%.
	Wet suppression of unpaved areas should be applied during dry windy periods, using a water cart and/or fixed sprinklers.
	Chemical suppression can also be used in conjuction with wet suppression. This involves the use of chemical additives in the water, which help to form a crust on the surface and bind the dust particles together. Chemical stabilisation reduces watering requirements, but any savings can be offset by the cost of the additives. Repeat treatments are usually required at intervals of 1-4 weeks. The method is best suited to permanent site roads and usually not cost-effective on temporary roads, which are common in construction sites.
	Inspect haul roads for integrity and repair if required.
	Provide hard-standing areas for vehicles and regularly inspect and clean these areas.
	Reduce mud/dirt carry-out onto paved roads.
	Reduce unnecessary traffic.
	Cover loads with tarpaulins to prevent dust re-entrainment from trucks.
	Limit load size to reduce spillage.
	Minimise travel distances through appropriate site layout and design.

Construction Activity	Recommended Control Measure(s)
	Use wheel and truck wash facilities at site exits.
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Stockpiles and storage mounds	Limit the height and slope of the stockpiles to reduce wind entrainment. For example, a flat shallow stockpile will be subject to less wind turbulence than one with a tall conical shape.
	Keep stockpiles or mounds away from the site boundary, sensitive receptors and watercourses. If necessary, take into account the predominant wind direction to reduce the likelihood of affecting sensitive receptors.
	Make sure the stockpiles are maintained for the shortest possible time.
	Seed, re-vegetate or turf long term stockpiles to stabilise surfaces or use surface binding agents.
	Where possible, enclose stockpiles or keep them securely sheeted.
	Erect fences of similar height and size to the stockpile to act as wind barriers and keep these clean using wet methods. Porous fences or hedges often make the most suitable shelter.
	Store fine material (under 3 mm in size) inside buildings or enclosures.
	Minimise drop heights to control the fall of materials.

Types of controls used at cement batching plants may include water sprays, enclosures, hoods, curtains, shrouds, movable and telescoping chutes, central duct collection systems, and the like. A major source of potential emissions, the movement of heavy trucks over unpaved or dusty surfaces in and around the plant, can be controlled by good maintenance and wetting of the road surface.

11. CONSULTATION PROCESS

Engagement with Interested and Affected Parties (I&APs) forms an integral component of the EIA process. I&APs have an opportunity at various stages throughout the EIA process to gain more knowledge about the proposed project, to provide input into the process and to verify that their issues and concerns have been addressed.

The proposed project was announced in July 2007 to elicit comment from and register I&APs from as broad a spectrum of public as possible. The announcement was done by the following means:

- the distribution of Background Information Documents (BIDs) in four languages,
- placement of site notices in the project area,
- placement of advertisements in regional and local newspapers,
- placement of information on the DWAF web site,
- announcement on local and regional radio stations; and
- the hosting of five focus group meetings in the project area.

Comments received from stakeholders were captured in the Issues and Response Report (IRR) which formed part of the Draft Scoping Report (DSR). The DRS was made available for public comment in October 2007. A summary of the DSR (translated into four languages) was distributed to all stakeholders and copies of the full report at public places. Two stakeholder meetings were held in October to present and discuss the DSR. The Final Scoping Report was made available to stakeholders in December 2007.

The availability of the Draft Environmental Impact Assessment Report, its summary (translated in four languages), the various specialist studies, the Environmental Management Plans and Programmes will be announced by way of personalized letters to stakeholders and the placement of advertisements in regional and local newspapers. The draft documents will be made available to I&APs for the inputs and comments. Two stakeholder meetings are planned to present the contents of the documents and to discuss the findings of the study.

The Draft Environmental Impact Assessment Report, its summary (translated in four languages), the various specialist studies, the Environmental Management Plans and Programmes were made available for a period of thirty (30 days) for stakeholders to comment. Stakeholder comments were taken into consideration with the preparation of the final documents. The availability of the final documents will be announced prior to submission to the decision-making authority.

12. CONCLUSIONS

An air quality impact assessment was conducted for the construction operations of the proposed project. The main objective of this study was to determine the significance of the predicted impacts from fugitive emissions on the surrounding environment and on human health.

Emission rates were quantified for the fugitive sources and dispersion modelling executed. Ground level concentrations and depositions levels were screened against existing SA standards, SANS and EC limits pertaining to health risk. Nuisance dust (dust deposition) was assessed by comparison to the SANS (proposed SA) target levels for residential areas.

The following conclusions were reached:

Baseline Assessment

- The prevailing wind field for the area is from the east (~10% of the time), the west (~6.5%) and the south (6%).

- No ambient monitored data were available for the area. Cumulative impacts due to the proposed project could therefore not be assessed.

Impact Assessment

- The highest daily and annual average PM10 ground level concentrations at the sensitive receptor of Tzaneen due to the proposed raising of the dam wall with no control efficiency was predicted to be 0.59 µg/m³ and 0.04 µg/m³ respectively (well within all relevant standards and guidelines).

- The predicted maximum deposition due to the raising of the Tzaneen Dam was predicted to be 0.98 mg/m²/day at the sensitive receptor of Tzaneen (well within the SANS target of 600 mg/m²/day for residential areas).

- For construction activities at the Nwamitwa Dam and road realignment, the highest daily and annual predicted PM10 ground level concentrations at the closest sensitive receptor of Nkamboko were 345 µg/m³ and 30 µg/m³ respectively (assuming no dust control). The highest daily ground level concentrations exceeded the current SA standards as well as the stricter SANS and EC limits. The predicted maximum deposition at the closest sensitive receptor of Ka-Mswazi is predicted to be 107 mg/m²/day (within SANS target of 600 mg/m²/day for residential areas).

- For the construction of the reservoirs and pump houses, the highest predicted daily and annual average PM10 ground level concentrations at the closest sensitive receptor of Serolorolo was 66 µg/m³ and 9 µg/m³ respectively. The highest daily ground level concentrations are within the SA standards and in line with the SANS limits, but exceeded the EC limits by 33%. During this construction phase (assuming uncontrolled emissions), the predicted maximum deposition at the closest sensitive receptor of Ka-Mswazi was predicted to be 107 mg/m²/day (within SANS target of 600 mg/m²/day for residential areas).

- The highest daily and annual average ground level concentrations due to borrow pit activities were well within the SA standards, SANS and EC limits.

- For highest daily PM10 concentrations due to vehicle entrainment from the transportation of various materials, the SANS (75 µg/m³) and EC limits (50 µg/m³) were exceeded for 50 m (transportation of earthfill material) from the road as the vehicle passes. For annual average PM10 concentrations, the SANS and EC limits of 40 µg/m³ are exceeded for 40 m (transportation of earthfill material) from the source. The predicted maximum deposition, exceeded the SANS industrial (1200 mg/m²/day) and residential targets (600 mg/m²/day) for 50m with the transportation of earthfill material. With the transportation of concrete and concrete coarse aggregate, the SANS residential target of 600 mg/m²/day is exceeded for 50m from the source.

- The predicted ground level concentrations for SO_2 (<0.3%), 1,3 butadiene (<1.1%), CO (<0.03%), NO_2 (<2.8%), diesel particulates (<5.9%) and benzene (<0.05%) are well below the applicable guidelines/ standards given in Section 7 as well as the strictest effect screening levels. The predicted cancer risk (using the US-EPA unit risk factors) due to 1,3 butadiene and benzene is predicted to be less than 8 in 10 million (10 m from the vehicle source), well below the acceptable limit of 1 in 1 million given by the US-EPA.

- The predicted daily PM10 concentrations and dust deposition for the trenching and covering of the pipeline path exceeded the SANS limit of 75 µg/m³ and EC limit of 50 µg/m for a distance of 10 m and 20 m from the source respectively. For annual average PM10 concentrations, the SA standard of 60 µg/m³ was exceeded for 10 m from the source, and the SANS and EC limits of 40 µg/m³ was exceeded for 20 m from the source. The predicted maximum deposition, exceeded the SANS industrial (1200 mg/m²/day) and residential (600 mg/m²/day) targets for 10 m and 20 m from the source respectively.

- The significance rating without mitigation was **Medium** for the construction activities at the Nwamitwa Dam and road realignment and the construction of the reservoirs due to short-term PM10 exposure. For the transportation of material, laying down of the pipeline, raising of the Tzaneen Dam and activities at the borrow pits, the significance rating was **Low**. The effectiveness of control measures in unpaved roads through effective water spraying can result in 75% control efficiency. Similarly, for material handling a control efficiency of 62% can be achieved if the moisture content of the material is doubled.

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