# Air Quality Specialist Impact Assessment Report for the Bakubung Platinum Mine

Project done on behalf of **SLR Consulting (Africa) (Pty) Ltd**

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**Report No:** 15SLR14 Final | **Date:** February 2016

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# Report Details

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| Status | Final |
| Report Title | Air Quality Specialist Impact Assessment Report for the Bakubung Platinum Mine |
| Date | February 2016 |
| Client | SLR Consulting (Africa) (Pty) Ltd |
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# Author Description

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Natasha holds a BSc Honours degree in Meteorology from the University of Pretoria and is currently employed at Airshed Planning Professionals. Natasha's main focus is air quality impact studies. She has been an Air Quality Consultant for 4 years and as such has been focused primarily on air quality management and impact assessment. Natasha has worked on air quality impact assessments and management plans in South Africa, Botswana, Burkina Faso, Mozambique, Zimbabwe, Zambia, Namibia and Madagascar.

# Revision Record

| Revision Number | Date | Reason for Revision |
|---|---|---|
| Draft | February 2016 | For Client Review |
| Final | March 2016 | With Client Comments Addressed |

# Consultation Process

No specific consultation was undertaken or deemed necessary as part of this study. Comments received by SLR as part of the EIA were considered in the undertaking of this study.

# Specialist report requirements

| | **A specialist report prepared in terms of the Environmental Impact Regulations of 2014 must contain:** | **Section in report (air)** |
|---|---|---|
| **a** | details of-<br>(i) the specialist who prepared the report; and<br>(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae; | Report details and author description<br>(page i)<br>Appendix F |
| **b** | a declaration that the specialist is independent in a form as may be specified by the competent authority; | Report details<br>(page i) |
| **c** | an indication of the scope of, and the purpose for which, the report was prepared; | Section 1.1 – Scope of Work<br>(Page 1-2) |
| **d** | the date and season of the site investigation and the relevance of the season to the outcome of the assessment; | Section 1.3.1 - Project Site Investigation<br>(Page 1-4) |
| **e** | a description of the methodology adopted in preparing the report or carrying out the specialised process; | Section 1.3. – Approach and Methodology<br>(Page 1-3) |
| **f** | the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure; | Section 3.1.<br>(Page 3-1) |
| **g** | an identification of any areas to be avoided, including buffers; | NA |
| **h** | a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers; | Figure 1-1: Location and layout of the BPM<br>(Page 1-1) |
| **i** | a description of any assumptions made and any uncertainties or gaps in knowledge; | Section 1.4 – Assumptions, Exclusions and Limitations<br>(Page 1-5) |
| **j** | a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment; | Section 6 –<br>Conclusions and Recommendations<br>(Page 6-1) |
| **k** | any mitigation measures for inclusion in the EMPr; | |
| **l** | any conditions for inclusion in the environmental authorisation; | |
| **m** | any monitoring requirements for inclusion in the EMPr or environmental authorisation; | None |
| **n** | a reasoned opinion-<br>(I) as to whether the proposed activity or portions thereof should be authorised; and<br>(ii) if the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan; | Section 6 –<br>Conclusions and Recommendations<br>(Page 6-1) |
| **o** | a description of any consultation process that was undertaken during the course of preparing the specialist report; | Consultation Process<br>(page i) |
| **p** | a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and | NA |

| | | |
|---|---|---|
| **q** | any other information requested by the competent authority. | NA |

# Abbreviations

| | |
|---|---|
| **AERMIC** | AMS/EPA Regulatory Model Improvement Committee |
| **Airshed** | Airshed Planning Professionals (Pty) Ltd |
| **AMS** | American Meteorological Society |
| **AQG(s)** | Air Quality Guideline(s) |
| **AQSR(s)** | Air Quality Sensitive Receptor(s) |
| **ASG** | Atmospheric Studies Group |
| **AST** | Anemometer Starting Threshold |
| **ASTM** | American Society for Testing and Materials |
| **BPM** | Bakubung Platinum Mine |
| **CALEPA** | California Environmental Protection Agency |
| **CE** | Control Efficiency |
| **CEPA** | Canadian Environmental Protection Agency |
| **CPVs** | Cancer Potency Values |
| **DEA** | Department of Environmental Affairs |
| **DEAT** | Department of Environmental Affairs and Tourism |
| **EETM(s)** | Emission Estimation Technique Manual(s) |
| **EMS** | Environmental Management Systems |
| **FOE** | Frequency of Exceedence |
| **GLC(s)** | Ground Level Concentration(s) |
| **GLCC** | Global Land Cover Characterisation |
| **I&APs** | Interested and Affected Parties |
| **IRIS** | Integrated Risk Information System |
| **LPG** | Liquefied Petroleum Gas |
| **mamsl** | Meters above mean sea level |
| **MEI** | Maximally Exposed Individual |
| **NAAQ** | National Ambient Air Quality |
| **NAAQS** | National Ambient Air Quality Standard(s) |
| **NDCR(s)** | National Dust Control Regulation(s) |
| **NEM:AQA** | National Environmental Management: Air Quality Act 2004 |
| **NPI** | National Pollutant Inventory |
| **PM** | Particulate Matter |
| **PSD** | Particle Size Distribution |
| **RELs** | Reference Exposure Levels |
| **RfC(s)** | Reference Concentration(s) |
| **SA** | South African |
| **SABS** | South African Bureau of Standards |
| **SANS** | South African National Standards |
| **SLR** | SLR Environmental Consulting (Africa) (Pty) Ltd |

| | |
|---|---|
| **SRTM** | Shuttle Radar Topography Mission |
| **TCEQ** | Texas Commission on Environmental Quality |
| **tpa** | Tonnes per annum |
| **TSF** | Tailings Storage Facility |
| **TSP** | Total Suspended Particulates |
| **URFs** | Unit Risk Factors |
| **US EPA** | United States Environmental Protection Agency |
| **USGS** | United States Geological Survey |
| **VKT** | Vehicle Kilometers Travelled |
| **WHO** | World Health Organisation |
| **WRD** | Waste Rock Dump |

# Glossary

| | |
|---|---|
| **Air pollution**[a] | The presence of substances in the atmosphere, particularly those that do not occur naturally |
| **Dispersion**[a] | The spreading of atmospheric constituents, such as air pollutants |
| **Dust**[a] | Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size |
| **Instability**[a] | A property of the steady state of a system such that certain disturbances or perturbations introduced into the steady state will increase in magnitude, the maximum perturbation amplitude always remaining larger than the initial amplitude |
| **Mechanical mixing**[a] | Any mixing process that utilizes the kinetic energy of relative fluid motion |
| **Oxides of nitrogen ($NO_x$)** | The sum of nitrogen oxide (NO) and nitrogen dioxide ($NO_2$) expressed as nitrogen dioxide ($NO_2$) |
| **Particulate matter (PM)** | Total particulate matter, that is solid matter contained in the gas stream in the solid state as well as insoluble and soluble solid matter contained in entrained droplets in the gas stream |
| **$PM_{2.5}$** | Particulate Matter with an aerodynamic diameter of less than 2.5 µm |
| **$PM_{10}$** | Particulate Matter with an aerodynamic diameter of less than 10 µm |
| **Stability**[a] | The characteristic of a system if sufficiently small disturbances have only small effects, either decreasing in amplitude or oscillating periodically; it is asymptotically stable if the effect of small disturbances vanishes for long time periods |

**Notes:**

(a) Definition from American Meteorological Society's glossary of meteorology (AMS, 2014)

# Symbols and Units

| | |
|---|---|
| **°C** | Degree Celsius |
| **C** | Carbon |
| **$CH_4$** | Methane |
| **$C_6H_6$** | Benzene |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **DPM** | Diesel particulate matter |
| **g** | Gram(s) |
| **$g/cm^3$** | Gram(s) per cubic centimetre |
| **ha** | Hectare |
| **1 ha** | 10 000 $m^2$ |
| **HC(s)** | Hydrocarbon(s) |
| **$H_2S$** | Hydrogen sulfide |
| **kg** | Kilograms |
| **1 kilogram** | 1 000 grams |
| **kg/l** | Kilogram(s) per litre |
| **kg/kWh** | Kilogram(s) per kilowatt hour |
| **$kg/m^3$** | Kilogram(s) per cubic metre |
| **kW** | 1 000 Watts |
| **km** | Kilometre(s) |
| **$km^2$** | Square kilometre(s) |
| **km/h** | Kilometre per hour |
| **m** | Meter(s) |
| **$m^2$** | Square meter(s) |
| **m/s** | Meters per second |
| **µg** | $1x10^{-6}$ grams |
| **$µg/m^3$** | Micrograms per square meter |
| **mg** | 0.001 grams |
| **$mg/m^2/day$** | Milligrams per square metre per day |
| **$mg/Nm^3$** | Milligrams per normal cubic metre |
| **$m^2$** | Square meter |
| **µm** | Micrometre |
| **1 µm** | $1x10^{-6}$ metres |
| **mm** | Millimetres |
| **1 mm** | 0.001 metres |
| **Mg** | Megagram = tonne |
| **$N_2$** | Nitrogen |
| **$N_2O$** | Nitrous oxide |
| **NO** | Nitrogen oxide |
| **$NO_2$** | Nitrogen dioxide |

| | |
|---|---|
| **$NO_x$** | Oxides of nitrogen |
| **$Nm^3/h$** | Normal cubic metre per hour |
| **$O_3$** | Ozone |
| **PAH** | Polycyclic aromatic hydrocarbons |
| **Pb** | Lead |
| **$PM_{2.5}$** | Inhalable particulate matter |
| **$PM_{10}$** | Thoracic particulate matter |
| **$SO_2$** | Sulphur dioxide |
| **1 tonne** | 1 000 000 grams |
| **VOC(s)** | Volatile organic compound(s) |

# Executive Summary

The Bakubung Platinum Mine (BPM) is located 30 km north of Rustenburg in the North West Province of South Africa. The R556 road runs north of the mine area and the R565 road runs through the mine area.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by SLR Consulting (Africa) (Pty) Ltd (SLR) to conduct an air quality specialist study for the BPM including the proposed concentrator and tailings storage facility (TSF). The main objective of the air quality study was to determine potential air quality related impacts associated with all BPM activities on the surrounding environment and human health.

As is typical of an air quality impact assessment, the study included: a **review** of activities in order to identify sources of emissions and associated pollutants emitted; a study of **regulatory requirements and health thresholds** for identified key pollutants; a study of the **receiving environment** in the vicinity of the project; the compilation of a comprehensive **emissions inventory** for the operational phase of the project, **atmospheric dispersion modelling** to simulate ambient air pollutant concentrations and dustfall rates as a result of the BPM, a **screening** assessment to determine compliance with air quality criteria; and the compilation of a **comprehensive air quality specialist report** detailing the study approach, limitations, assumption, results and recommendations of mitigation and management of air quality impacts.

Pollutants included in the assessment are particulate matter (PM), diesel particulate matter (DPM), carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$) and volatile organic compounds (VOCs). Impacts associated with emissions were quantified, taking into account: unmitigated operations and mitigation measures that form part of the BPM design.

The main conclusion is that the unmitigated future BPM operations are likely to result in exceedances of the NAAQS for $PM_{2.5}$ and $PM_{10}$ at nearby sensitive receptor areas. Assessing the unmitigated cumulative impacts, there is the possibility of exceedances of the NAAQS outside the project boundary and at the sensitive receptor areas due to possible elevated concentrations from current and future sources at the mine. With mitigation measures in place – waters sprays on unpaved roads and at materials handling points, and enclosure of crushers and screens with fabric filters – ambient pollutant concentrations as a result of the BPM operations will reduce significantly although cumulative $PM_{2.5}$ concentrations are still likely to be in exceedance at the mine housing. There is the possibility of $NO_2$ hourly NAAQS being exceeded on a cumulative basis as the ambient hourly $NO_2$ is already in exceedance of the NAAQ limit during multiple months.

The environmental significance of the future operations is “medium” for fine particulates and “low” for dustfall, SO2, NO2, CO, DPM and VOCs without mitigation applied; and, “medium to low” for PM2.5 and “low” for PM10 and dustfall with design mitigation applied.

It is recommended that the proposed management and mitigation measures as set out in Section 5 be implemented. These include:

- Reduction of emissions from ventilation shafts through effective mitigation of underground activities (water sprays on roads, at materials handling points and drilling)
- Continuation of dustfall and ambient $SO_2$, $NO_2$ and $PM_{10}$ sampling;
- Addition of $PM_{2.5}$ sampling; and
- Continuation of meteorological recordings.

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# 1 INTRODUCTION

The Bakubung Platinum Mine (BPM) is located 30 km north of Rustenburg in the North West Province of South Africa. The R556 road runs north of the mine area and the R565 road runs through the mine area (Figure 1-1). Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by SLR Consulting (Africa) (Pty) Ltd (SLR) to conduct an air quality specialist study for the BPM including both the current/approved operations and the amendment operations. An environmental impact assessment/ environmental management plan (EIA/EMP) was compiled in 2007/2008. Under the Mineral and Petroleum Resources Development Act No. 28 of 2002 (MPRDA) the EIA/EMP was approved in May 2009. Under the National Environmental Management Act: Environmental Impact Assessment (NEMA:EIA) Listed Activities (April 2006), the EIA/EMP was approved in November 2008. Since completion of the Definitive Feasibility Study (DFS) there have been some changes made to the “approved” design of the concentrator and tailings storage facility (TSF). The changes in design warrant the compilation and submission of an EMP Amendment under the current MPRDA. The main objective of the air quality study was to determine potential air quality related impacts associated with all future BPM activities on the surrounding environment and human health for purpose of inclusion into an EIA/EMP.

As part of the previous EIA/EMP an air quality study was conducted by Airshed in 2008 (Burger and Mashilo, 2008). There are a few similarities and a few differences in the two studies that will have an impact on the outcome of the air quality studies. Similarities in the two studies include the underground mining, waste rock dump (WRD) and access road. The differences include:

- crushing and screening undertaken underground (2008 study) versus crushing and screening at the surface plant infrastructure (current study);
- smaller TSF area (2008 study) versus larger TSF area (current study)
- 230 kilotonne per month (ktpm) concentrator plant (2008 study) versus 265 000 ktpm concentrator plant (current study)
- smaller stockpile areas (2008 study) versus larger stockpile areas (current study)

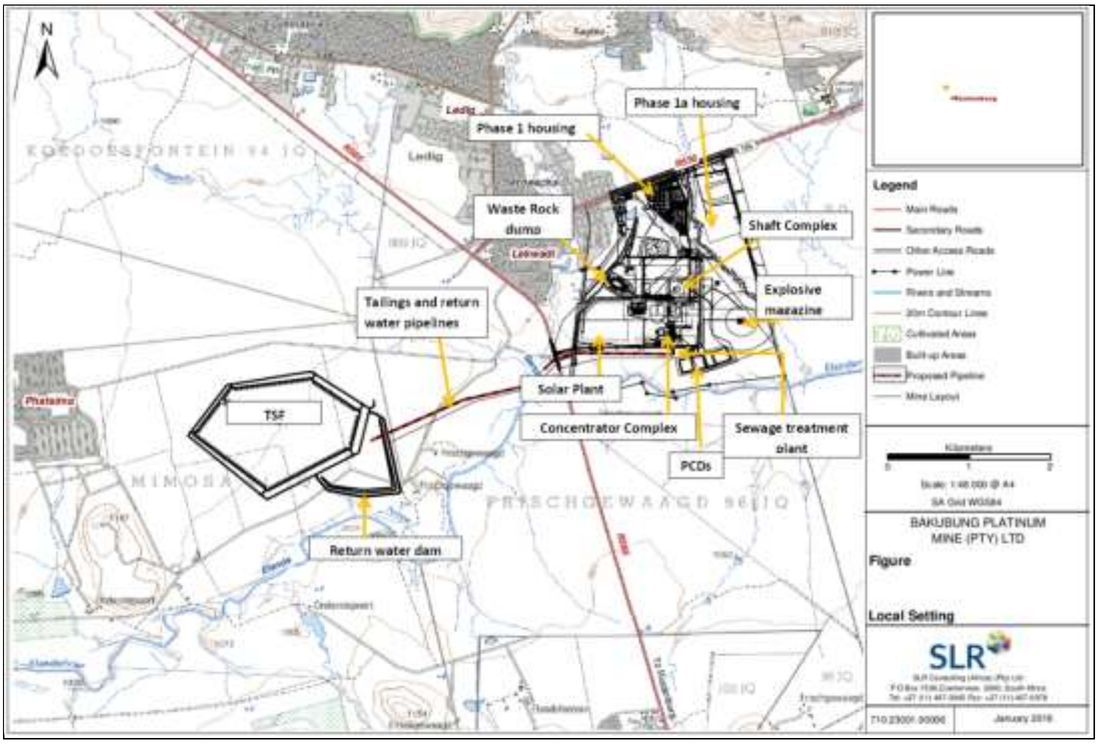


Figure 1-1: Location and layout of the BPM

## 1.1 Scope of Work

As is typical of an air quality impact assessment, the following tasks were included in the study:

- A **review** of future operational activities in order to identify sources of emission and associated pollutants emitted.
- A study of **regulatory requirements and inhalation thresholds** for identified key pollutants against which compliance need to be assessed and health risks screened.
- A study of the **receiving environment** in the vicinity of the project; including:
    - The identification of potential air quality sensitive receptors (AQSRs);
    - A study of the atmospheric dispersion potential of the area taking into consideration local meteorology, land-use and topography; and
    - The analysis of all available ambient air quality information/data to determine ambient pollutant levels and dustfall rates.
- The compilation of a comprehensive **emissions inventory** which included:
    - Fugitive dust emissions; and
    - Combustion emissions (particulate matter (PM) and gaseous pollutants).
- **Atmospheric dispersion modelling** to simulate ambient air pollutant concentrations and dustfall rates.
- A **screening** assessment to determine:
    - Compliance of simulated criteria pollutant concentrations with ambient air quality standards;
    - The potential for health impacts as a result of exposure to non-criteria pollutants; and
    - Nuisance dustfall.
- The compilation of a comprehensive air quality specialist report detailing the study approach, limitations, assumption, results and recommendations of mitigation and management of air quality impacts.

## 1.2 Description of Bakubung Platinum Mine's Activities from an Air Quality Perspective

The BPM is currently in construction phase and will consist of an underground mine. Mining activities will include the removal of waste rock and ore, loading of ore and waste rock onto haul trucks, transportation of ore and waste along underground unpaved roads, as well as transportation of waste and ore to the surface.

The underground mining will broadly encompass the following unit operating processes that may result in atmospheric emissions:

- drilling and blasting of ore and waste rock;
- excavation of ore and waste rock;
- transportation of ore and waste rock; and
- handling of ore and waste rock.

At the surface, ore will be transported to the proposed 265 ktpm concentrator plant via conveyors, while waste generated will be transported via truck to the WRD. At the concentrator plant ore will be fed to the crushers and screens before being milled. Operations after the feeding of crushed ore to the primary mill will be wet process steps, likely to result in negligible atmospheric emissions. The concentrate will be transported via tankers in the form of slurry to a nearby smelter. The tailings will be transported via pipeline to the proposed TSF.

The approved and proposed surface operations broadly encompass the following unit operating processes that may result in atmospheric emissions:

- ore handling;

- waste handling and transportation;
- crushing and screening of ore;
- processing of ore;
- concentrate handling and storage;
- concentrate (slurry) transportation; and
- erosion of stockpiles, WRD and TSF.

The layout for the BPM is shown in Figure 1-1. The potential air emissions that may result from operations are dependent on the nature of the source material itself (Table 1-1 and Table 1-2).

**Table 1-1: Air emissions and pollutants associated with approved underground mining**

| Details | Activities | Pollutants |
|---|---|---|
| Drilling of ore and waste rock | Drilling | Total suspended particulates (TSP), particulate matter with an aerodynamic diameter of less than 10 µm ($PM_{10}$) and particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) |
| Blasting of ore and waste rock | Blasting | Mainly TSP, $PM_{10}$ and $PM_{2.5}$, but also oxides of nitrogen ($NO_x$), carbon dioxide ($CO_2$), carbon monoxide (CO), sulphur dioxide ($SO_2$), methane ($CH_4$), hydrogen sulphide ($H_2S$). |
| Excavation of ore and waste rock | Excavation | TSP, $PM_{10}$ and $PM_{2.5}$ |
| Ore and waste rock transport along underground unpaved roads | Wheel entrainment and exhaust gas | Mainly TSP, $PM_{10}$ and $PM_{2.5}$, but vehicle tailpipe emissions including $NO_x$, $CO_2$, CO, $SO_2$, $CH_4$, nitrous oxide ($N_2O$), volatile organic compounds (VOCs) and particulates including diesel particulate matter (DPM) |
| Ore and waste rock handling | Offloading, reclaiming and other tipping operations | TSP, $PM_{10}$ and $PM_{2.5}$ |

**Table 1-2: Air emissions and pollutants associated with approved and proposed surface operations**

| Details | Activities | Pollutants |
|---|---|---|
| Ore and waste rock handling | Offloading, reclaiming and other tipping operations | TSP, $PM_{10}$ and $PM_{2.5}$ |
| Crushers and screens | Primary and secondary crushing and screening | TSP, $PM_{10}$ and $PM_{2.5}$ |
| Concentrate handling | Offloading and reclaiming | TSP, $PM_{10}$ and $PM_{2.5}$ |
| Waste rock and concentrate (slurry) transport | Wheel entrainment and exhaust gas | Mainly TSP, $PM_{10}$ and $PM_{2.5}$, but vehicle tailpipe emissions including $NO_x$, $CO_2$, CO, $SO_2$, methane, $N_2O$, VOCs and particulates including diesel particulate matter (DPM) |
| Ore, concentrate, waste rock and tailings storage | Wind erosion | TSP, $PM_{10}$ and $PM_{2.5}$ |

## 1.3 Approach and Methodology

The approach to, and methodology followed in the completion of tasks included in the scope of work are discussed in this section.

### *1.3.1 Project Site Investigation*

No site investigation was undertaken for air quality as all necessary site specific information was made available by Wesizwe Platinum Limited (Wesizwe) through SLR or was included in the previous study (Burger and Mashilo, 2008).

### *1.3.2 Project Information and Activity Review*

All project/process related information referred to in this study was provided by Wesizwe through SLR.

### *1.3.3 The Identification of Regulatory Requirements and Screening Criteria*

In the evaluation of ambient air quality impacts and dustfall rates reference was made to:

- South African National Ambient Air Quality Standards (SA NAAQS) as set out in the National Environmental Management: Air Quality Act (Act No. 39 of 2004) (NEM:AQA) and National Dust Control Regulations (SA NDCR); and,
- Health risk screening levels for non-criteria pollutants published by the various internationally recognised regulatory authorities.

### *1.3.4 Study of the Receiving Environment*

Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology. Existing pre-development ambient air quality in the study area is also considered. Readily available terrain and land cover data was obtained from the Atmospheric Studies Group (ASG) via the United States Geological Survey (USGS) web site (ASG, 2011). Use was made of Shuttle Radar Topography Mission (SRTM) (90 m, 3 arc-sec) data and Global Land Cover Characterisation (GLCC) data for Africa.

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. There was at least one year of on-site hourly sequential meteorological data with high data availability (required for atmospheric dispersion modelling). Use was made of this data for a period between 1 October 2014 and 31 October 2015. On-site data used for modelling are evaluated and discussed in this report.

### *1.3.5 Determining the Impact of BPM on the Receiving Environment*

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from BPM's emissions on the receiving environment. In the quantification of emissions, use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. Emissions were calculated emission factors and equation such as those published by the United States Environmental Protection Agency (US EPA) and Australian Environment in their National Pollutant Inventory (NPI) Emission Estimation Technique Manuals (EETMs).

In the simulation of ambient air pollutant concentrations and dustfall rates use was made of the US EPA AERMOD atmospheric dispersion modelling suite. AERMOD is a Gaussian plume model best used for near-field applications where the steady-state meteorology assumption is most likely to apply. AERMOD is a model developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). 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).

### *1.3.6 Compliance Assessment and Health Risk Screening*

Compliance was assessed by comparing simulated ambient criteria pollutant concentrations (CO, nitrogen dioxide ($NO_2$), $PM_{2.5}$, $PM_{10}$ and $SO_2$) and dustfall rates to NAAQS and NDCRs, respectively. Health risk screening was done through the comparison of simulated non-criteria pollutant concentrations (DPM and VOCs) to selected inhalation screening levels.

### *1.3.7 The Development of an Air Quality Management Plan*

The findings of the above components informed recommendations of air quality management measures, including mitigation and monitoring.

## 1.4 Assumptions, Exclusions and Limitations

A number of assumptions had to be made resulting in certain limitations associated with the results. The most important assumptions and limitations of the air quality impact assessment are:

- Emissions were based on the process description and layout plan as provided by Wesizwe through SLR.
- This study only considered atmospheric emissions and impacts associated with the underground mining, concentrator plant, WRD and TSF at BPM.
- Site specific particle size fraction, moisture or silt content data were not available for all sources and use was made of US EPA default values and values from similar operations in South Africa.
- Only routine emissions from operations were simulated.
- Dispersion models do not contain all the features of a real environmental system but contain the feature of interest for the management issue or scientific problem to be solved (MFE, 2001). Gaussian plume models are generally regarded to have an uncertainty range between -50% to 200%. It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location.
- The selected dispersion model, AERMOD, cannot compute real time processes; average process throughputs were therefore used, though the nature of operations may change over the life of operations.
- Gaseous emissions would result from vehicle exhaust and blasting. Emissions from blasting underground is expected to be intermittent and minimal. Emission rates for combustion sources are dependent on the amount of fuel used, type and size of vehicles used. The fuel use amount for plant vehicles was supplied and the main underground vehicles' type and size were available. Only vehicle exhaust emissions at the plant and underground were estimated and modelled.
- NO is rapidly converted in the atmosphere into the much more toxic $NO_2$. The rate of this conversion process is determined by the rate of the physical processes of dispersion and mixing of the plume and the chemical reaction rates as well as the local atmospheric ozone ($O_3$) concentration. 20% of $NO_x$ emissions from vehicle exhaust were assumed to be to $NO_2$ (Howard, 1988).
- The construction, decommissioning and closure phases of the proposed additions to BPM are assessed qualitatively. It was assumed that all processing operations will have ceased by the closure phase. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during decommissioning and on features which will remain. Information regarding the extent of demolition and/or

rehabilitation procedures were limited and therefore not included in the emissions inventory or the dispersion modelling.

# 2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

## 2.1 Ambient Air Quality Standards for Criteria Pollutants

### *2.1.1 National*

The South African Bureau of Standards (SABS) was engaged to assist the Department of Environmental Affairs (DEA, then known as the Department of Environmental Affairs and Tourism or DEAT) in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. Standards were determined based on international best practice for $PM_{10}$, $PM_{2.5}$, dustfall, $SO_2$, $NO_2$, ozone ($O_3$), CO, lead (Pb) and benzene ($C_6H_6$).

The final revised NAAQS were published in the Government Gazette on 24 of December 2009 and included a margin of tolerance (i.e. frequency of exceedance) and implementation timelines linked to it. NAAQS for $PM_{2.5}$ were published on 29 July 2012. NAAQS are given in Table 2-1.

**Table 2-1: National assessment criteria for criteria pollutants**

| Pollutant | Averaging Period | Limit Values | Frequency of Exceedance | Compliance Date |
|---|---|---|---|---|
| | | Concentration (µg/m³) | Occurrences per Year | |
| $NO_2$ | 1 hour | 200 | 88 | Immediate |
| | 1 year | 40 | n/a | Immediate |
| $PM_{2.5}$ | 24 hour | 40 | 4 | 1 January 2016 – 31 December 2029 |
| | 24 hour | 25 | 4 | 1 January 2030 |
| | 1 year | 25 | n/a | 1 January 2016 – 31 December 2029 |
| | 1 year | 20 | n/a | 1 January 2030 |
| $PM_{10}$ | 24 hour | 75 | 4 | 1 January 2015 |
| | 1 year | 40 | n/a | 1 January 2015 |
| $SO_2$ | 1 hour | 350 | 88 | Immediate |
| | 24 hour | 125 | 4 | Immediate |
| | 1 year | 50 | n/a | Immediate |
| $O_3$ | 8 hours (running) | 120 | 11 | Immediate |
| $C_6H_6$ | 1 year | 5 | n/a | 1 January 2015 |
| Pb | 1 year | 0.5 | n/a | Immediate |
| CO | 1 hour | 30 000 | 88 | Immediate |
| | 8 hour (calculated on 1 hourly averages) | 10 000 | 11 | Immediate |

**Notes:**

(a) n/a – not applicable

### 2.2 Inhalation Health Criteria and Unit Risk Factors for Non-criteria Pollutants

The potential for health impacts associated with non-criteria pollutants emitted from mobile diesel combustion sources are assessed according to guidelines published by the following institutions:

- Inhalation reference concentrations (RfCs) and URFs published by the US EPA Integrated Risk Information System (IRIS)
- Reference Exposure Levels (RELs) and Cancer Potency Values (CPVs) published by the California Environmental Protection Agency (CALEPA)
- The Texas Commission on Environmental Quality (TCEQ)

Chronic inhalation criteria and URFs/CPVs for pollutants considered in the study are summarised in Table 2-2. Increased lifetime cancer risk is conservatively calculated by applying the unit risk factors to predicted long term (annual average) pollutant concentrations.

**Table 2-2: Chronic and acute inhalation screening criteria and cancer unit risk factors**

| Pollutant | Chronic Screening Criteria ($\mu g/m^3$) | Acute Screening Criteria ($\mu g/m^3$) | Inhalation URF/CPV $(\mu g/m^3)^{-1}$ |
|---|---|---|---|
| Diesel Exhaust as DPM | 5 (US EPA IRIS) | Not Specified | $3x10^{-04}$ (CALEPA) |
| VOC (*Diesel fuel* used as indicator) | 100 (TCEQ) | Not Specified | Not Specified |

The identification of an acceptable cancer risk level has been debated for many years and it possibly will still continue as societal norms and values change. Some people would easily accept higher risks than others, even if it were not within their own control; others prefer to take very low risks. An acceptable risk is a question of societal acceptance and will therefore vary from society to society. In spite of the difficulty to provide a definitive "acceptable risk level", the estimation of a risk associated with an activity provides the means for a comparison of the activity to other everyday hazards, and therefore allowing risk-management policy decisions. Technical risk assessments seldom set the regulatory agenda because of the different ways in which the non-technical public perceives risks. Consequently, science does not directly provide an answer to the question.

Whilst it is perhaps inappropriate to make a judgment about how much risk should be acceptable, through reviewing acceptable risk levels selected by other well-known organizations, it would appear that the US EPA's application is the most suitable, i.e. *"If the risk to the maximally exposed individual (MEI) is no more than $1x10^{-6}$, then no further action is required. If not, the MEI risk must be reduced to no more than $1x10^{-4}$, regardless of feasibility and cost, while protecting as many individuals as possible in the general population against risks exceeding $1x10^{-6}$".*Some authorities tend to avoid the specification of a single acceptable risk level. Instead a "risk-ranking system" is preferred. For example, the New York State Department of Health produced a qualitative ranking of cancer risk estimates, from very low to very high (Table 2-3). Therefore if the qualitative descriptor was "low", then the excess lifetime cancer risk from that exposure is in the range of greater than one per million to less than one per ten thousand.

**Table 2-3: Excess Lifetime Cancer Risk (as applied by New York State Department of Health)**

| Risk Ratio | Qualitative Descriptor |
|---|---|
| Equal to or less than one in a million | Very low |
| Greater than one in a million to less than one in ten thousand | Low |
| One in ten thousand to less than one in a thousand | Moderate |
| One in a thousand to less than one in ten | High |

| Risk Ratio | Qualitative Descriptor |
|---|---|
| Equal to or greater than one in ten | Very high |

## 2.3 Dust Control Regulations

South Africa has published the NDCRs in November 2013 (Government Gazette No. 36974) with the purpose to prescribe general measures for the control of dust in all areas including residential and light commercial areas. The acceptable dustfall rates as measured using the American Society of Testing and Materials (ASTM) D1739:1970 (ASTM International, 1998) or equivalent at and beyond the boundary of the premises where dust originates are given in Table 2-4. It is important to note that **dustfall is assessed for nuisance impact** and not inhalation health impact.

**Table 2-4: South African National Dust Control Regulations.**

| Restriction Area | Dustfall Rate (mg/m2-day) | Permitted Frequency of Exceedence |
|---|---|---|
| Residential area | D < 600 | Two within a year, not sequential months |
| Non-residential area | 600 < D < 1 200 | Two within a year, not sequential months |

### *2.3.1 Dust fallout limits (prior to 2013)*

This has been included for comparison to the ambient dustfall measured in 2011 and 2012. In the South African context, widespread dust deposition impacts occur as a result of windblown mine tailings material and other fugitive dust sources. It is for this reason that the SABS Technical Committee on air quality standards has recommended the establishment of target levels and alert thresholds for dustfall. The South African National Standards (SANS) four-band scale is presented in Table 2-5. Target, action and alert thresholds for ambient dust deposition are given in Table 2-6. No margin of tolerance is granted for operations that result in dust fall rates in Band 4 ALERT.

**Table 2-5: Bands of dustfall rates proposed for adoption**

| Band Number | Band Description Label | 30 Day Average Dustfall Rate (mg/m$^2$-day) | Comment |
|---|---|---|---|
| 1 | RESIDENTIAL | D < 600 | Permissible for residential and light commercial |
| 2 | INDUSTRIAL | 600 < D < 1 200 | Permissible for heavy commercial and industrial |
| 3 | ACTION | 1 200 < D < 2 400 | Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year. |
| 4 | ALERT | 2 400 < D | Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority. |

**Table 2-6: Target, action and alert thresholds for ambient dustfall**

| Level | Dustfall Rate (mg/m$^2$-day) | Averaging Period | Permitted Frequency of Exceedence |
|---|---|---|---|
| TARGET | 300 | Annual | |
| ACTION RESIDENTIAL | 600 | 30 days | Three within any year, no two sequential months. |

| Level | Dustfall Rate (mg/m$^2$-day) | Averaging Period | Permitted Frequency of Exceedence |
|---|---|---|---|
| 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. |

### 2.4 Screening criteria for animals and vegetation

The impact of dust on vegetation and grazing quality may be a concern to interested and affected parties (I&APs). While there is little direct evidence of what the impact of dust fall on vegetation is under a South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dust fall rates greater than 400 mg/m²/day (Farmer, 1993). This is discussed in more detail in Appendix A.

# 3 DESCRIPTION OF THE RECEIVING/BASELINE ENVIRONMENT

## 3.1 Air Quality Sensitive Receptors

The BPM is situated near Ledig and Sun City. Current land uses within the vicinity of the BPM area are farming, residential and tourism. There are a number of residences in the vicinity of BPM. The nearest residential areas or homesteads were identified as air quality sensitive receptors (AQSRs). These AQSRs, including the mine housing, are shown in Figure 3-1.

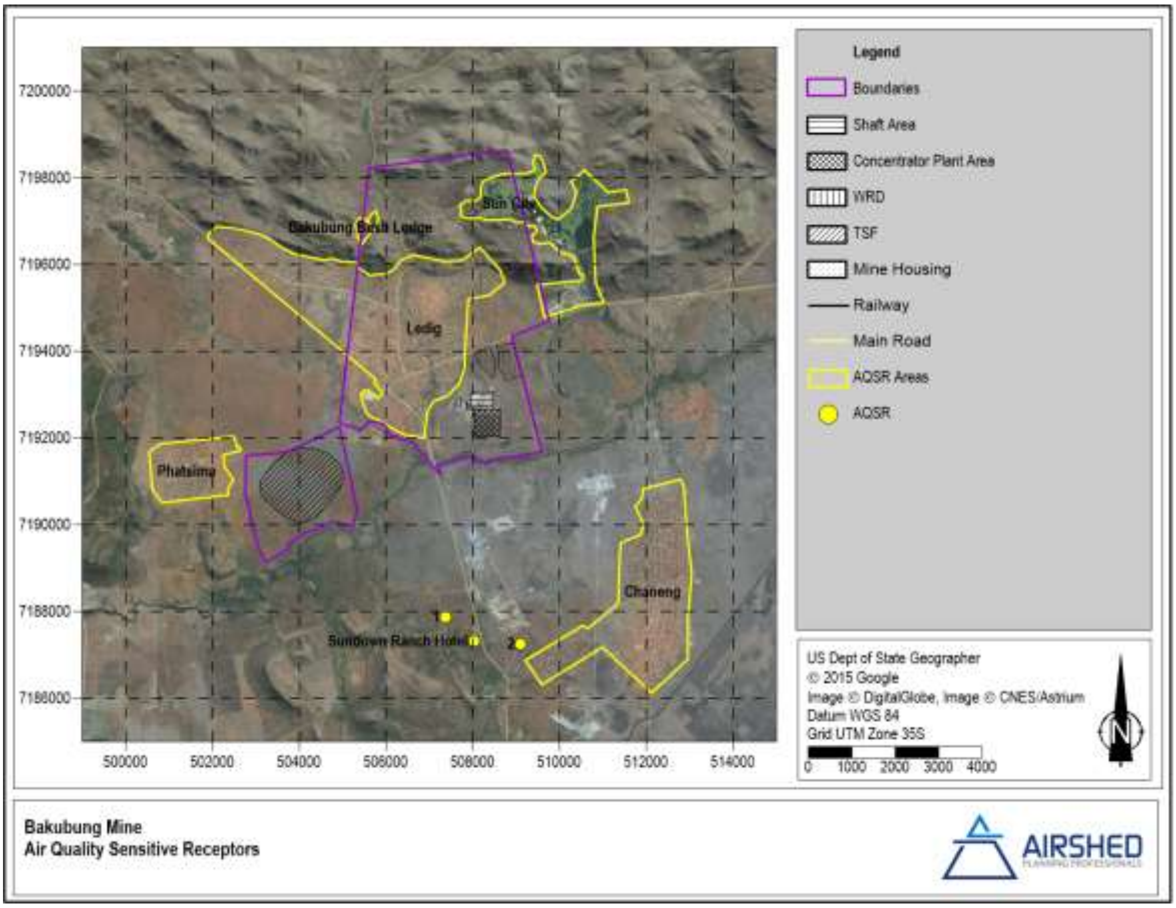


**Figure 3-1: Nearby AQSRs**

**Table 7: Individual AQSR locations**

| ID | Latitude | Longitude |
|---|---|---|
| 1 | -25.4261072° | 27.0733978° |
| 2 | -25.4316406° | 27.090551° |
| Sundown Ranch Hotel | -25.431119° | 27.0797957° |

## 3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. Parameters useful in describing the dispersion and dilution potential of the site i.e. wind speed, wind direction, temperature and atmospheric stability, are subsequently discussed.

An on-site meteorological station was installed (Figure 3-2) to record hourly average wind speed, wind direction and temperature, amongst other parameters. At the time of report compilation, data was available from the 22nd of May 2014 to the 6th of October 2015, hence, one year of data covering the period 7th of October 2014 to the 6th of October 2015 was utilized for dispersion simulation.

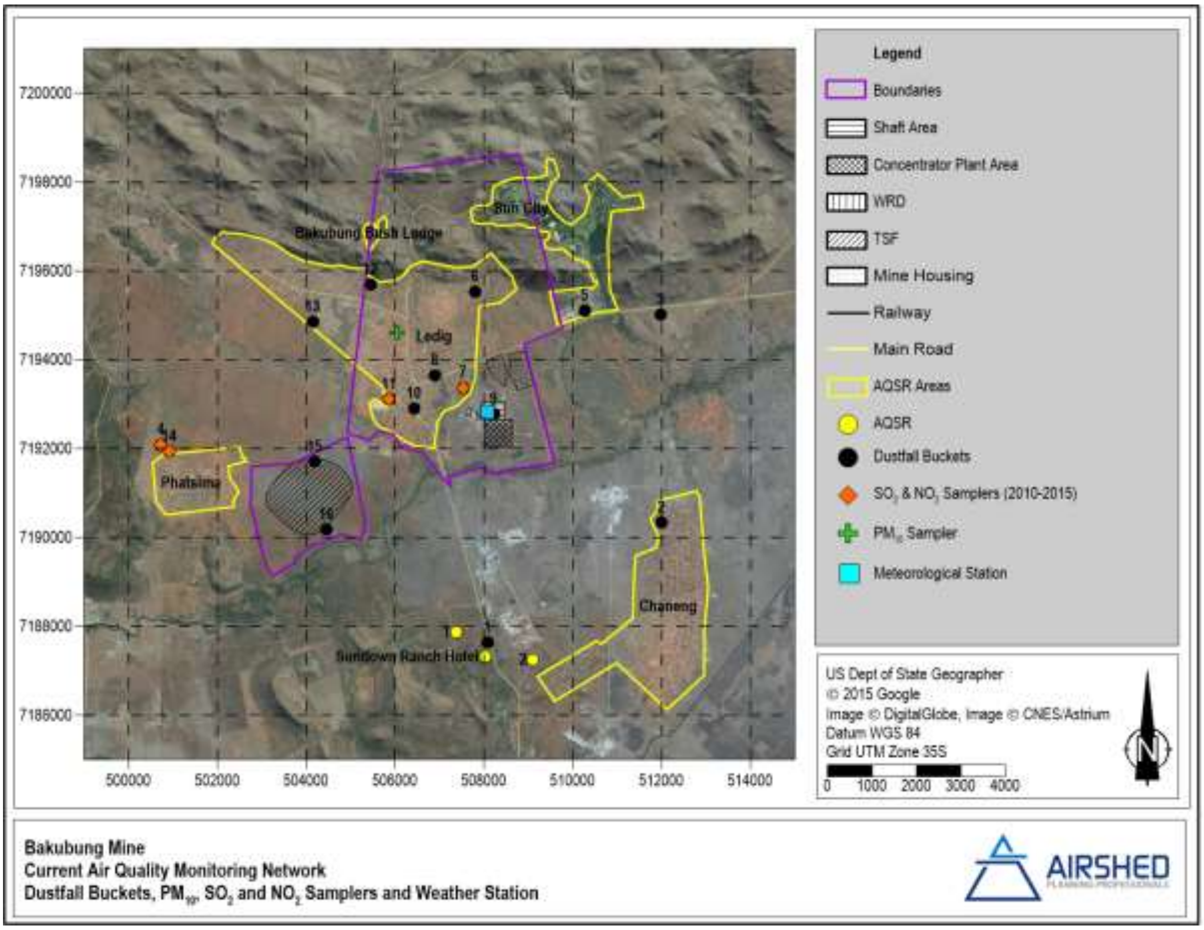


**Figure 3-2: Current air quality monitoring network including meteorological station location**

### *3.2.1 Topography and Land-use*

The terrain of the study area is shown in Figure 3-3. The area ranges in height between 1 017 and 1 470 meters above mean sea level (mamsl). Terrain was included in the dispersion model. Topographical data used was SRTM (90m, 3 arc sec) obtained from the USGS.

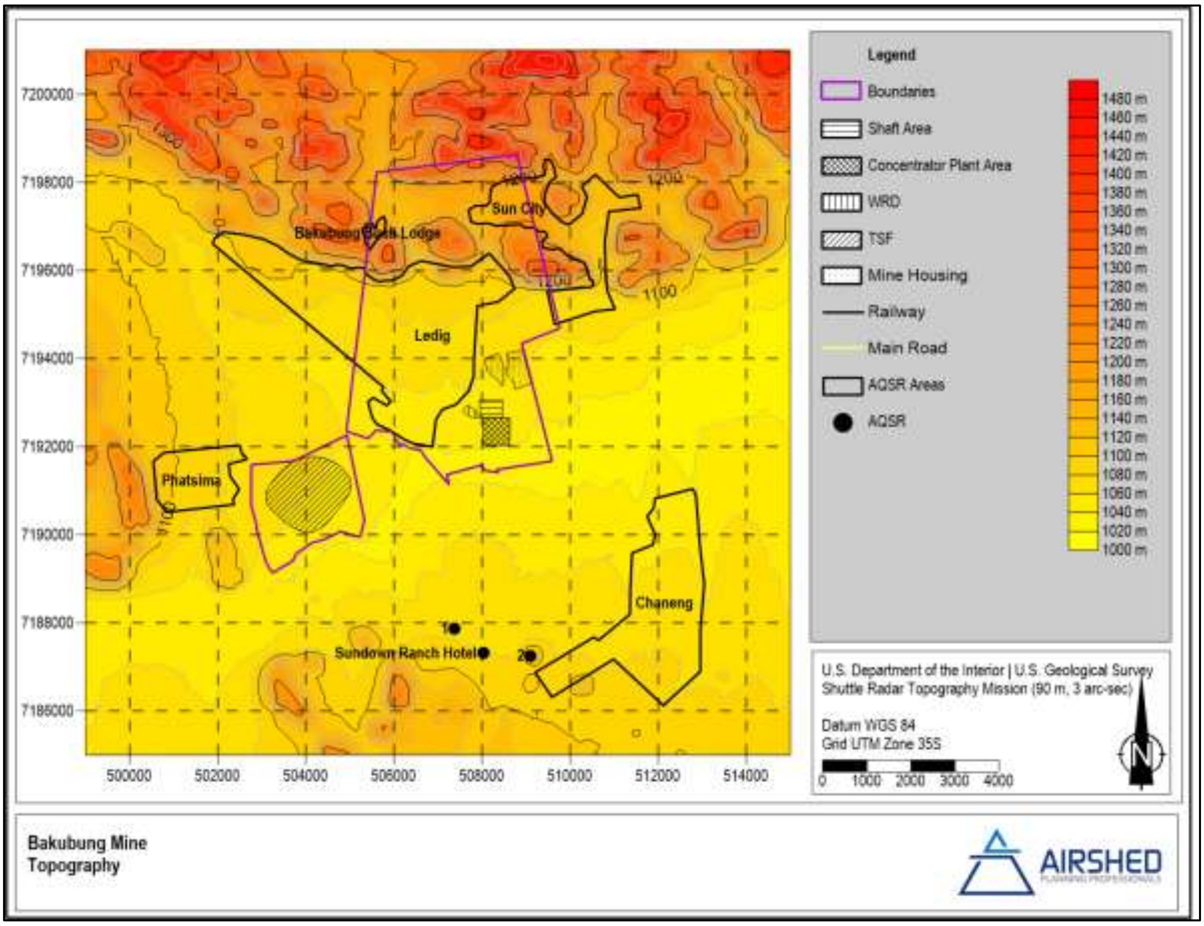


Figure 3-3: Topography of the area surrounding the BPM

### *3.2.2 Surface Wind Field*

The wind field determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is a function of the wind speed, in combination with the surface roughness. The wind field for the study area is described with the use of wind roses. Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 5 and 6 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

To avoid the overly conservative concentration estimates being made by AERMOD, it is suggested that all wind speeds greater than/equal to the anemometer starting threshold (AST) and less than 1 m/s be replaced with the value of 1 m/s. This approach was undertaken and 27% of the wind speeds were replaced with 1 m/s.

The wind rose for the period 7th of October 2014 to 6th of October 2015 is shown in Figure 3-4. Day-time and night-time wind roses are provided in Figure 3-5.

The wind field was dominated by winds from the west-north-west and west. Calm conditions occurred approximately 3% of the time. During the day, frequent winds occurred from the west-north-westerly and westerly sectors with almost 3% calm conditions. Night-time airflow had less frequent winds from the east-south-easterly sector than the day-time and lower wind speeds. Night-time winds most frequently occurred from the west-north-westerly and westerly sectors. The percentage calm conditions increased to almost 4%.

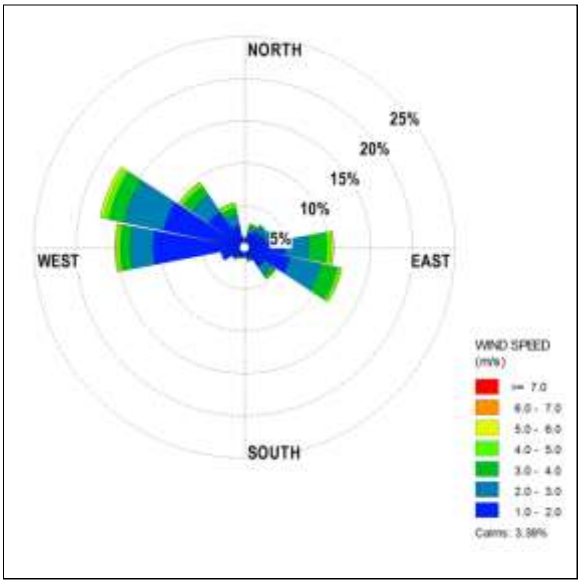


Figure 3-4: Period average wind rose (on-site data, October 2014 to October 2015)

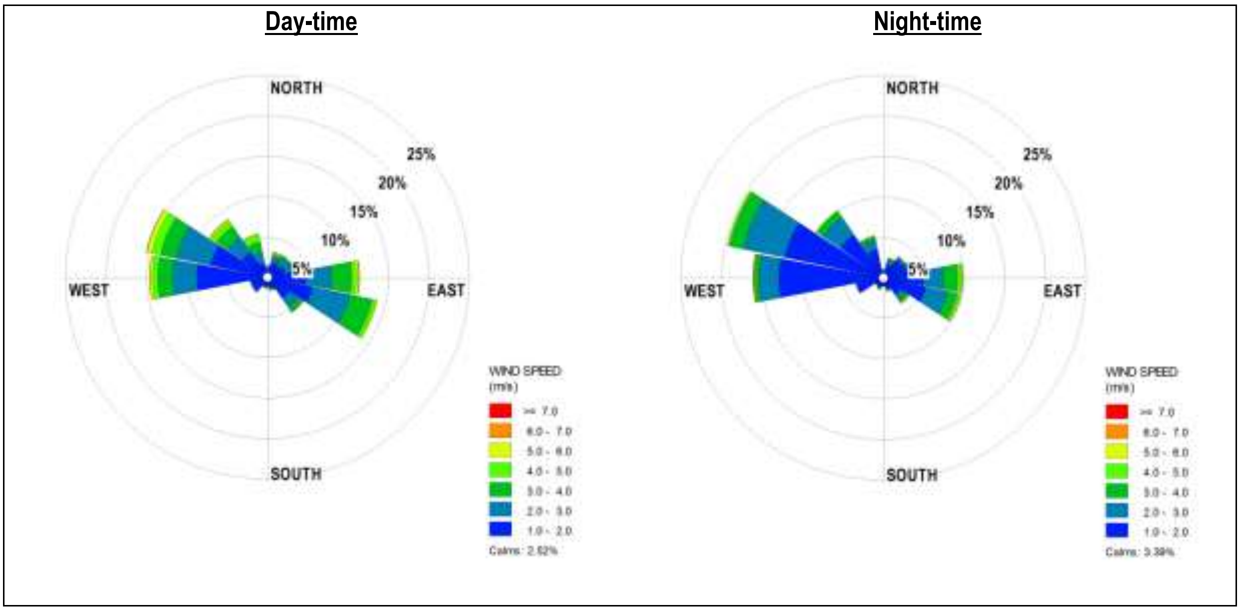


Figure 3-5: Day-time and night-time wind roses (on-site data, October 2014 to October 2015)

### *3.2.3 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 a pollution plume is able to rise), and determining the development of the mixing and inversion layers.

Minimum, maximum and mean temperatures for the project area, as obtained from on-site data, are shown in Table 3-8. Diurnal monthly average temperatures are shown in Figure 3-6.

Maximum, minimum and average temperatures were 36.8°C, -2.3°C and 19.9°C, respectively. The month of June had the lowest temperature of -2.3°C while the maximum temperature of 36.8°C occurred in February. Temperatures reached their minimum just before sunrise and their maximum between midday and sunset.

**Table 3-8: Minimum, maximum and average temperatures (measured data, October 2014 to October 2015)**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 24.8 | 25.7 | 23.6 | 20.0 | 17.3 | 12.0 | 12.9 | 17.1 | 20.9 | 24.1 | 22.2 | 23.7 |
| Maximum | 35.7 | 36.8 | 35.0 | 30.7 | 31.8 | 24.4 | 25.7 | 32.3 | 35.7 | 36.1 | 35.0 | 35.7 |
| Minimum | 15.7 | 13.3 | 14.4 | 9.4 | 3.9 | -1.1 | -1.1 | -2.3 | 6.8 | 12.3 | 11.1 | 13.9 |

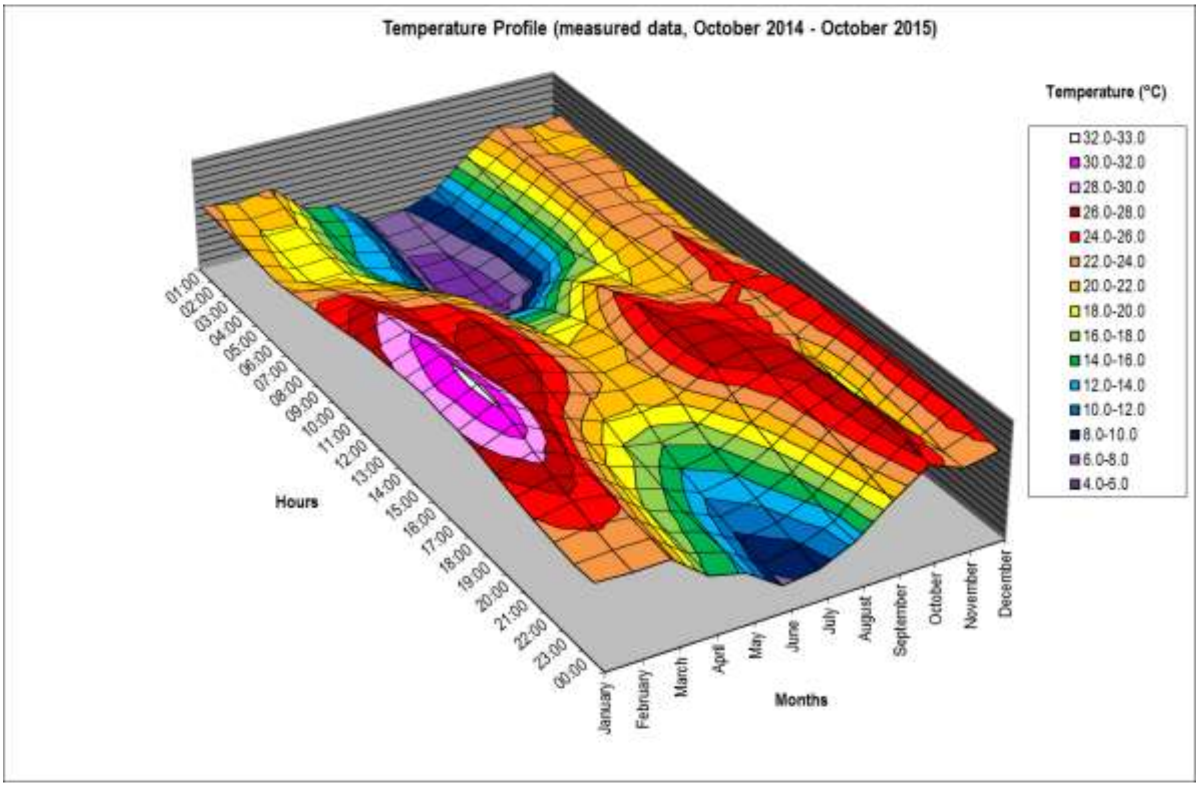


**Figure 3-6: Diurnal monthly average temperature profile (measured data, October 2014 to October 2015)**

### *3.2.4 Rainfall*

Rainfall represents an effective removal mechanism of atmospheric pollutants and is therefore frequently considered during air pollution studies. Dust is generated by strong winds that sometimes accompany storms. This dust generally occurs in areas with dry soils and sparse vegetation.

The study area experience rainfall mostly between September and January, with maximum monthly rainfall occurring in December (Figure 3-7).

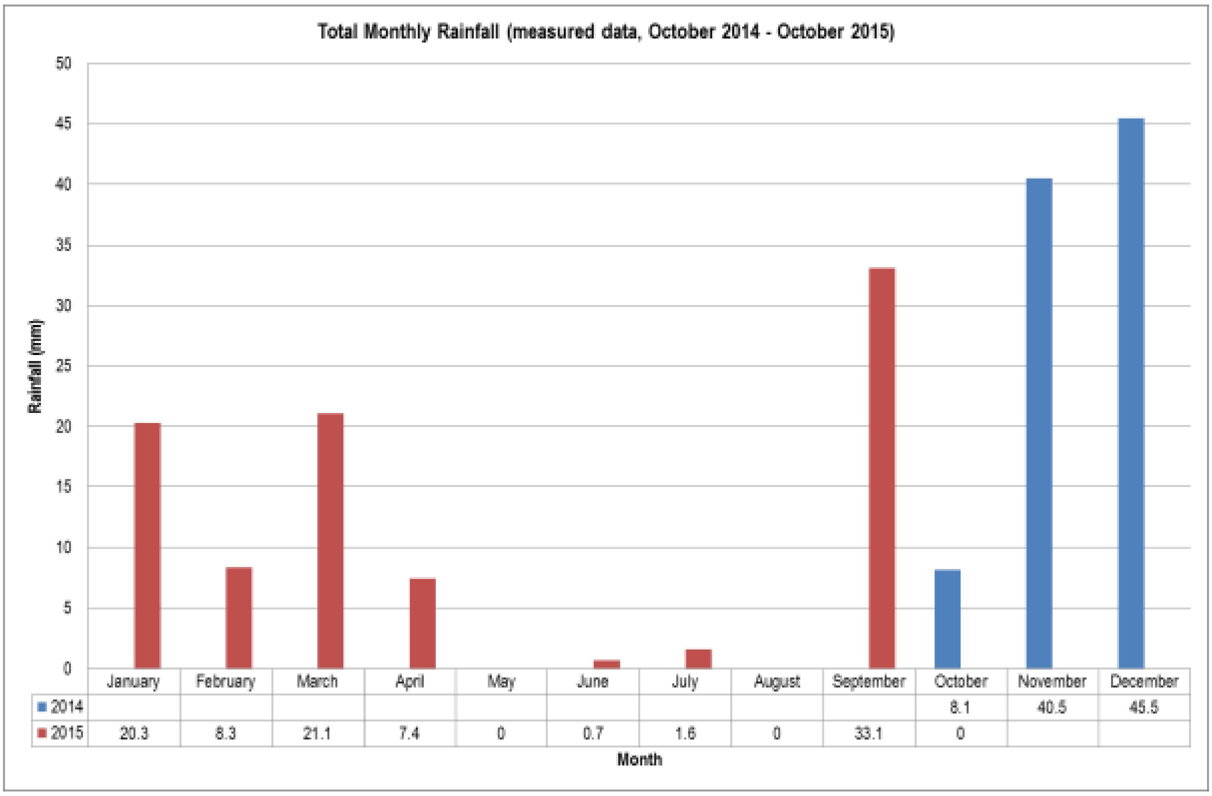


Figure 3-7: Monthly rainfall (measured data, October 2014 to October 2015)

### *3.2.5 Atmospheric Stability and Mixing Depth*

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class.

The Monin-Obukhov length ($L_{Mo}$) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

Diurnal variation in atmospheric stability, as calculated from measured data, and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 3-8. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning*. Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Tiwary & Colls, 2010). For ground level releases the highest ground level concentrations occur during stable night-time conditions.

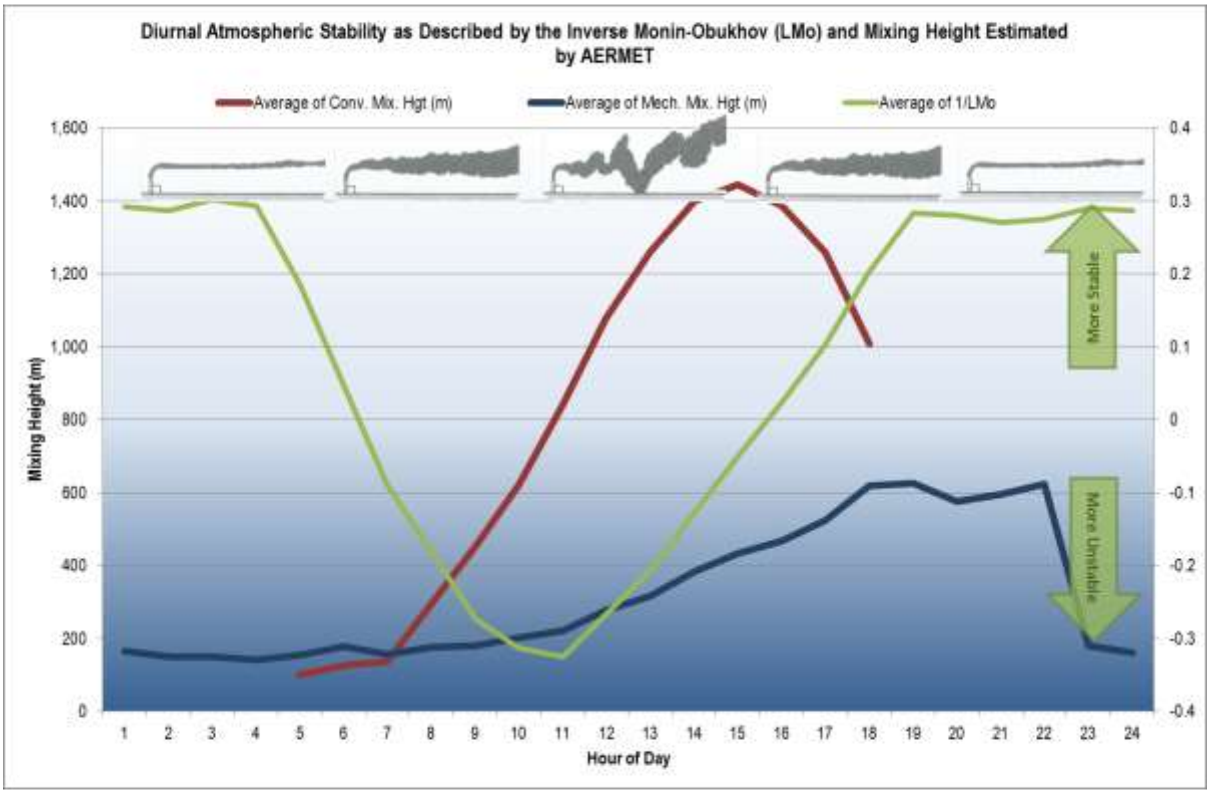


**Figure 3-8: Diurnal atmospheric stability (measured data, October 2014 to October 2015)**

## 3.3 Existing Sources of Air Pollution in the Area

Land use in the region includes farming, residential and tourism. Expected sources of atmospheric emissions include:

- Miscellaneous fugitive dust sources including vehicle entrainment on roads and wind-blown dust from open areas;
- Gaseous and particulate emissions from vehicle exhaust emissions;
- Gaseous and particulate emissions from household fuel burning; and
- Gaseous and particulate emissions from biomass burning (e.g. wild fires).

### *3.3.1 Miscellaneous Fugitive Dust Sources*

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, and wind erosion from open or sparsely vegetated areas. 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 road-use activity and the moisture and silt content of soils are 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

### *3.3.2 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 vehicles include $CO_2$, CO, hydrocarbons (HCs), $SO_2$, $NO_x$, DPM and Pb. Secondary pollutants include: $NO_2$, photochemical oxidants (e.g. $O_3$), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. 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. Vehicle tailpipe emissions are localised sources and unlikely to impact far-field.

### *3.3.3 Household Fuel Burning*

Energy use within the residential sector is given as falling within three main categories, viz.: (i) traditional - consisting of wood, dung and bagasse, (ii) transitional - consisting of coal, paraffin and liquefied petroleum gas (LPG), and (iii) modern - consisting of electricity (increasingly this includes the use of renewable energy). The typical universal trend is given as being from (i) through (ii) to (iii).

### *3.3.4 Biomass Burning*

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity wild fires may therefore represent a source of combustion-related emissions. Biomass burning is an incomplete combustion process, with CO, methane and $NO_2$ gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen ($N_2$), 10% is left is the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the project, long-range transported emissions from this source can further be expected to impact on the air quality. It is impossible to control this source of atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

## 3.4 Status Quo Ambient Air Quality

Ambient air quality data was available to establish current and past pollutant concentrations and dustfall rates. The main pollutants of concern, from an air quality perspective, associated with BPM activities are $PM_{10}$, $NO_2$ and $SO_2$. These pollutants pose an important health risk to the surrounding communities. Dustfall (TSP) is of concern due to its nuisance effects.

The ambient air quality monitoring network (Figure 3-2) comprises of 16 ASTM D1739-98 compliant samplers, one $PM_{10}$ sampler, four $SO_2$ samplers and four $NO_2$ samplers.

### *3.4.1 Dustfall Results*

Average annual dustfall rates for the period January 2011 to August 2015 are presented in Table 3-9. The monthly dustfall rates are illustrated in Figure 3-9 to Figure 3-24.

Dustfall rates are generally below the relevant legislation for the period January 2011 to August 2015 with exception of October 2012 at Kagiso; March 2012, August 2012, October 2012 and November 2014 at Lekwadi Section; October 2012 at Bakgofa Primary School; July 2012 at tailings dam and November 2012 at tailings north. The average annual dustfall rates show an annual decrease in dustfall rates from 2011 to 2015 at Amtel, Kagiso, explosive magazine and Ledig East; this would suggest that mitigation of sources in the vicinity of these dustfall buckets are effective.

**Table 3-9: Average annual dustfall rates per sampling location (2011-2015)**

| Map ID | Description | Type | Average Annual Dustfall Rates (mg/m²/day) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 2011 | 2012 | 2013 | 2014 | 2015 |
| 1 | Amtel | Industrial/Non Residential | 118 | 169 | 131 | 117 | 78 |
| 2 | Tshaneng | Residential | 89 | 163 | 46 | 81 | 68 |
| 3 | Sun City | Industrial/Non Residential | 81 | 136 | 29 | 38 | 36 |
| 4 | Frisch Gewaagd | Industrial/Non Residential | 47 | 120 | 36 | 45 | 79 |
| 5 | Opposite Sun City Sewage | Industrial/Non Residential | 51 | 110 | 29 | 27 | 41 |
| 6 | Kagiso | Residential | 107 | 110 | 81 | 76 | 60 |
| 7 | Explosive Magazine | Industrial/Non Residential | 106 | 391 | 165 | 143 | 45 |
| 8 | Ledig East | Residential | 100 | 194 | 82 | 81 | 73 |
| 9 | Main Shaft | Industrial/Non Residential | 69 | 200 | 160 | 44 | 78 |
| 10 | Lekwadi Section | Residential | 237 | 492 | 228 | 258 | 120 |
| 11 | Moses Kotane Hospital | Residential | 102 | 243 | 101 | 115 | 108 |
| 12 | House 1492 | Residential | 95 | 179 | 81 | 85 | 32 |
| 13 | Bakgofa Primary School | Residential | 146 | 284 | 53 | 98 | 52 |
| 14 | Kayalethu H. School | Residential | 132 | 166 | 85 | 95 | 42 |
| 15 | Tailings Dam | Industrial/Non Residential | 123 | 538 | 172 | 203 | 213 |
| 16 | Tailings North | Industrial/Non Residential | 113 | 398 | 105 | 137 | 262 |

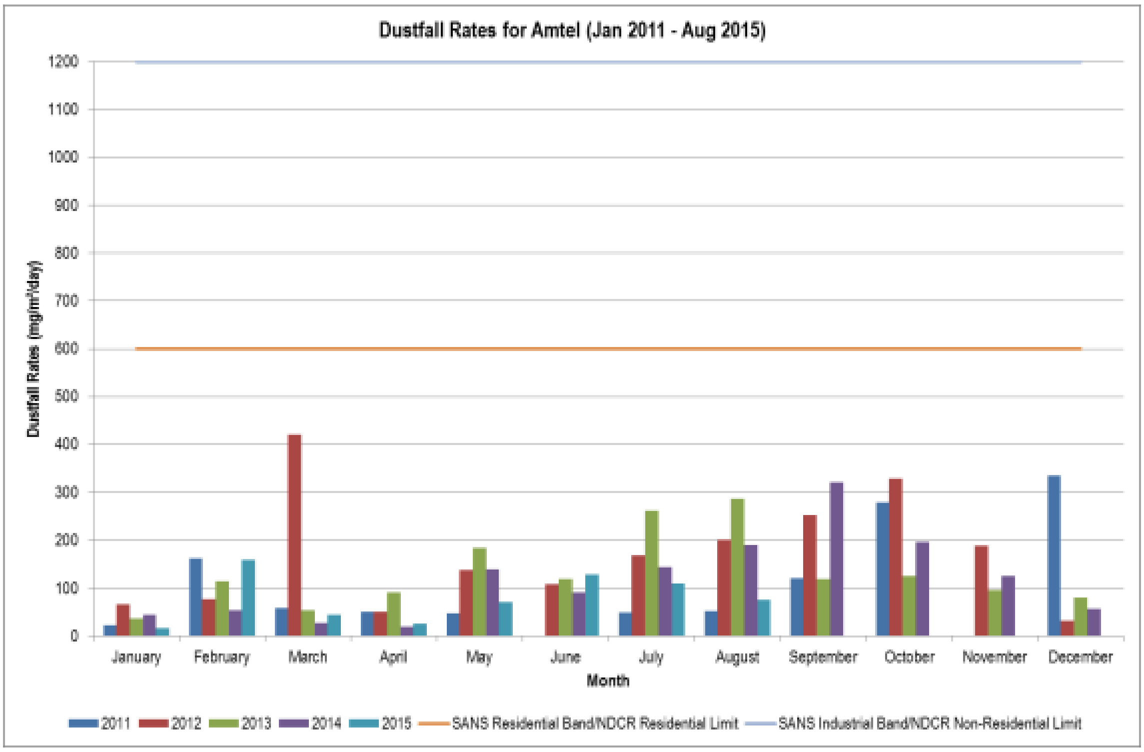


Figure 3-9: Monthly dustfall rates for Amtel (January 2011 to August 2015)

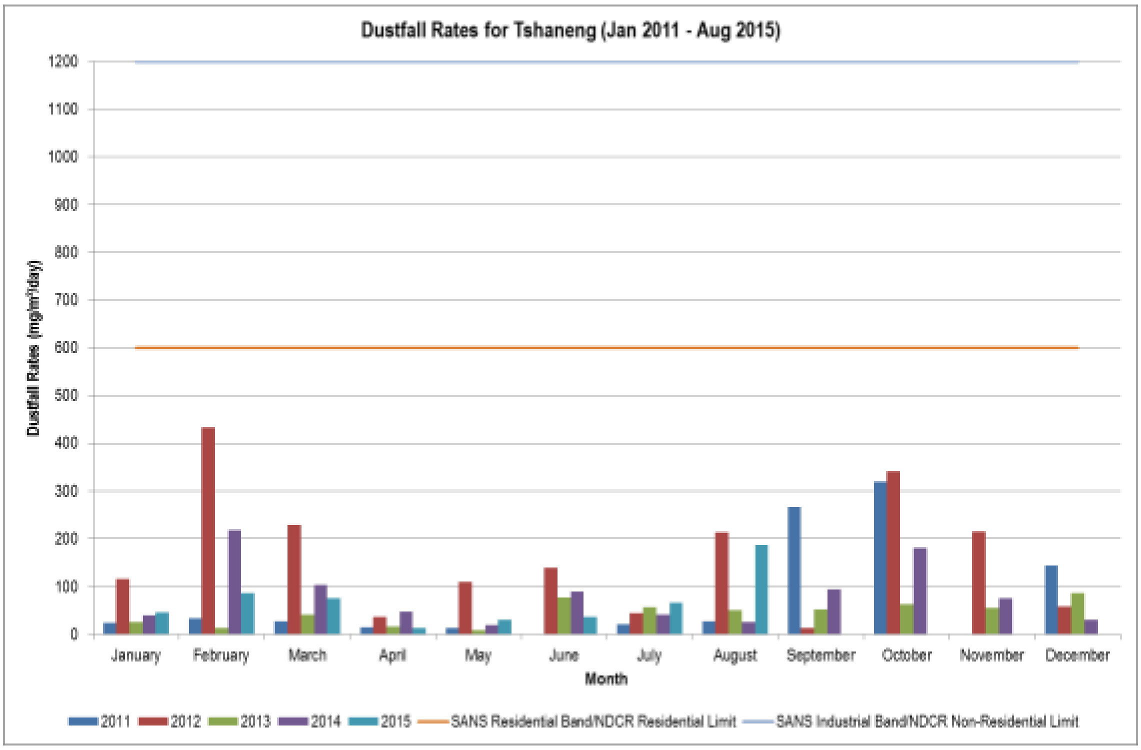


Figure 3-10: Monthly dustfall rates for Tshaneng (January 2011 to August 2015)

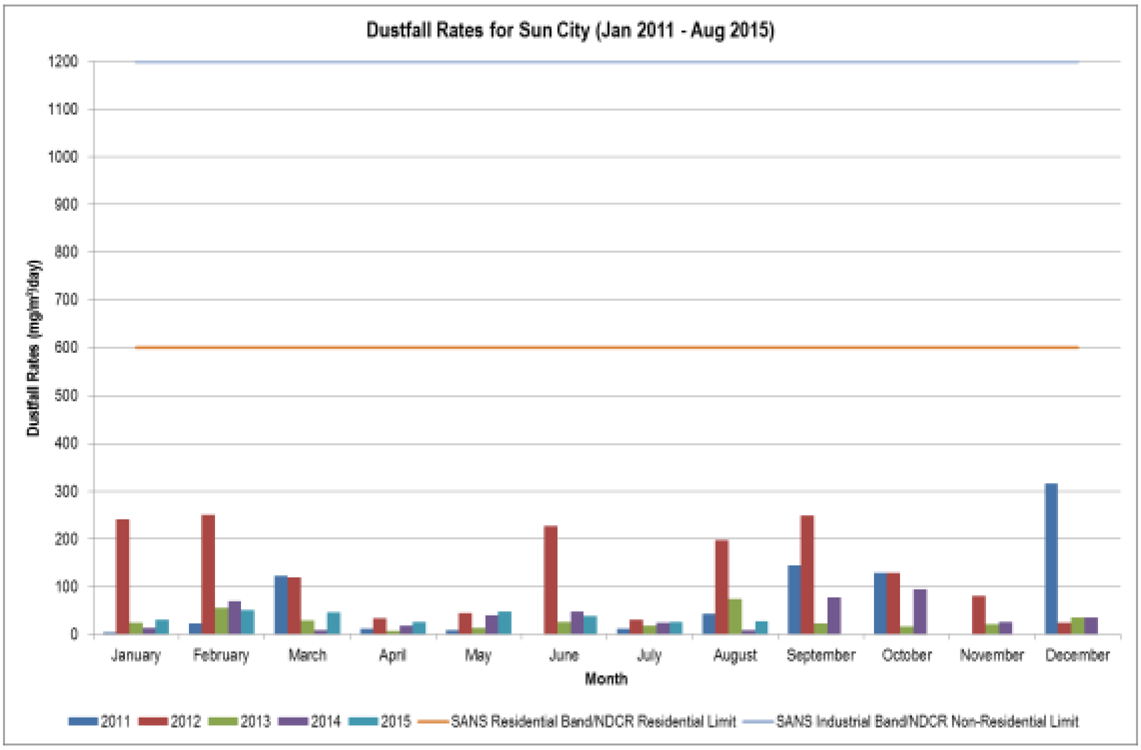


Figure 3-11: Monthly dustfall rates for Sun City (January 2011 to August 2015)

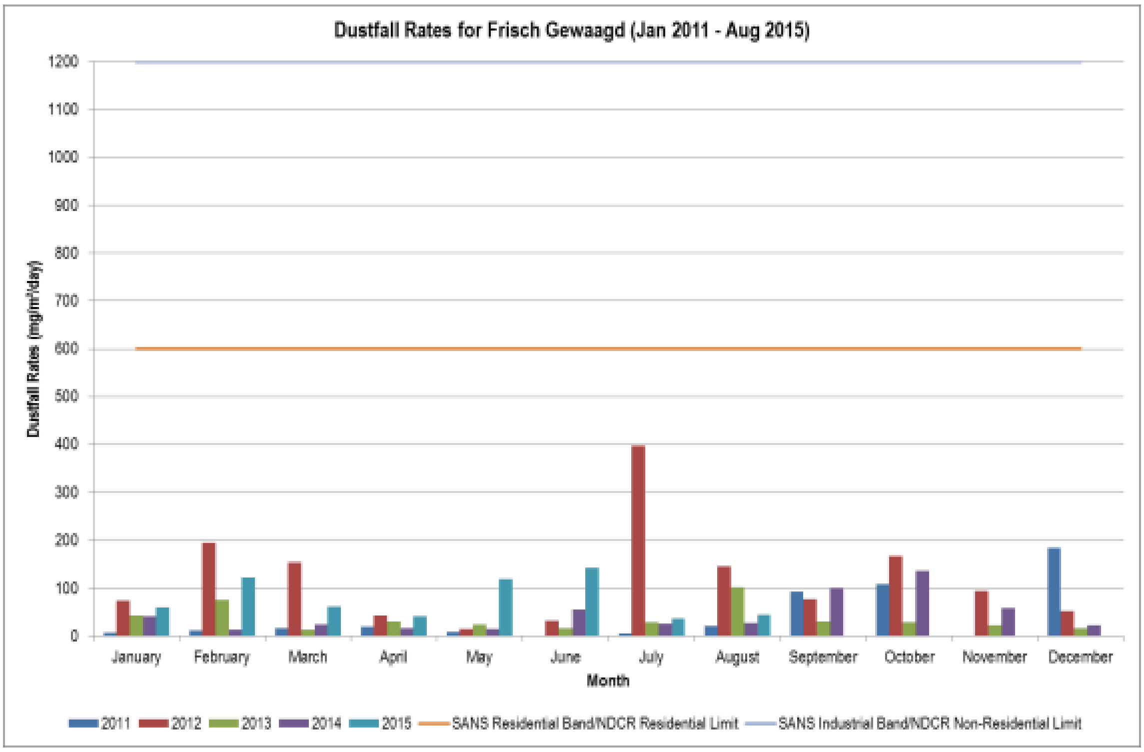


Figure 3-12: Monthly dustfall rates for Frisch Gewaagd (January 2011 to August 2015)

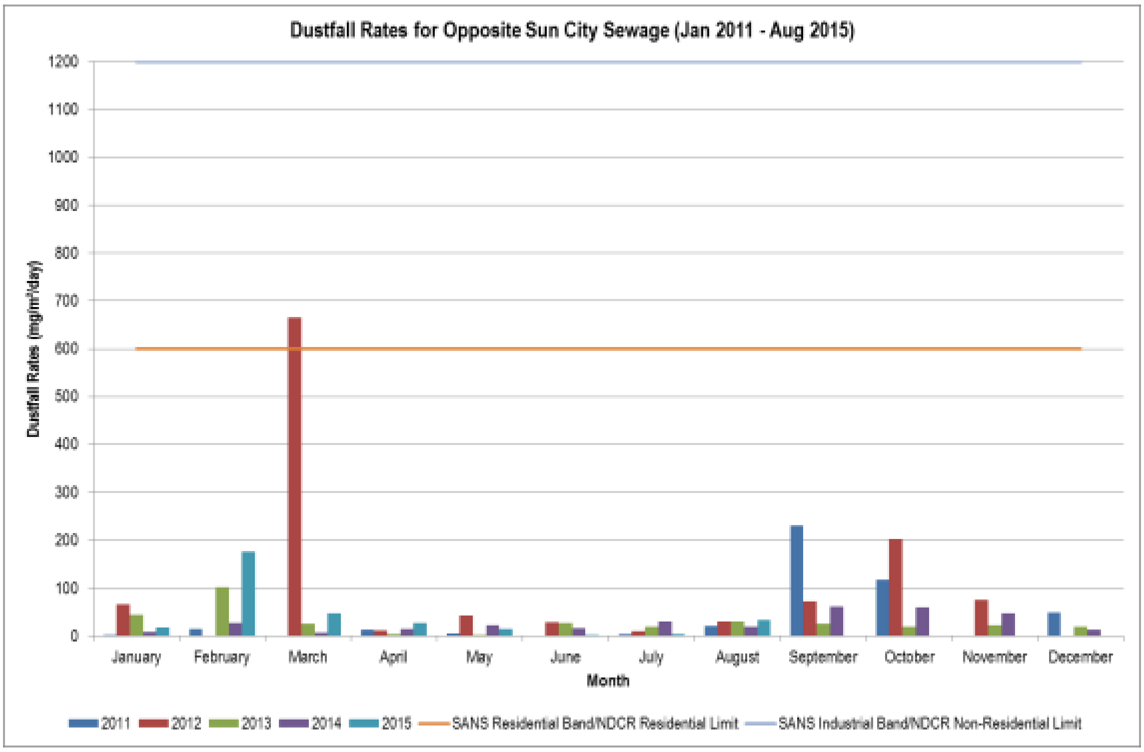


Figure 3-13: Monthly dustfall rates for opposite Sun City Sewage (January 2011 to August 2015)

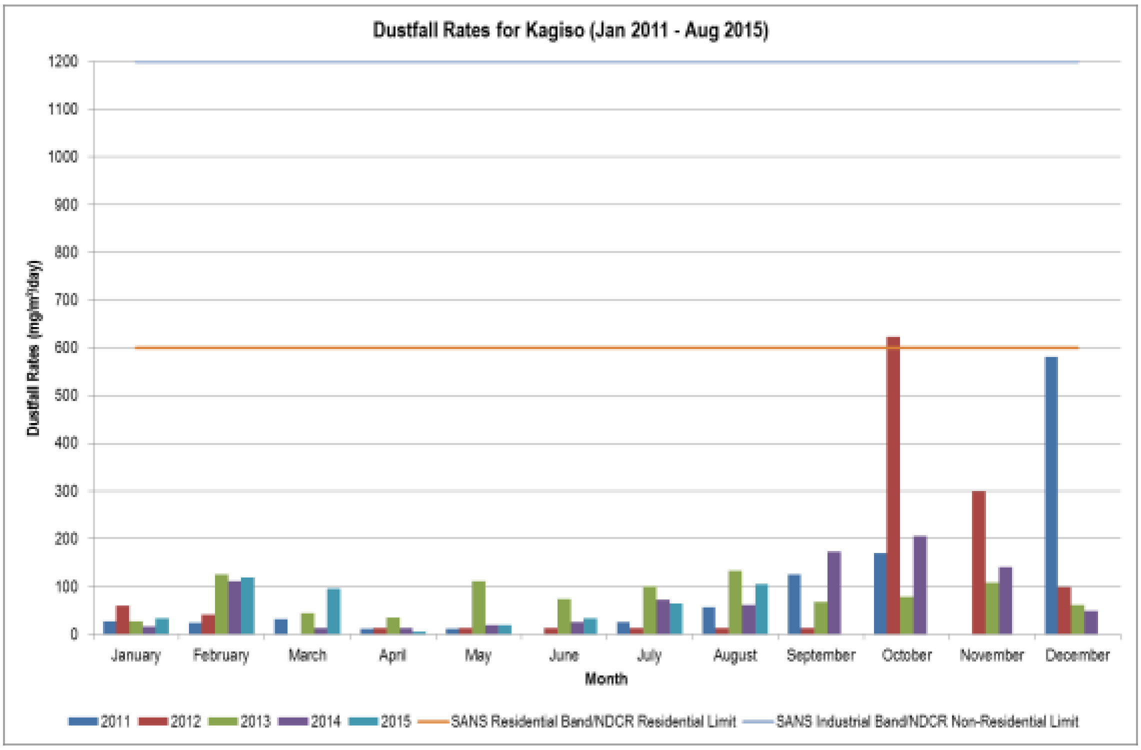


Figure 3-14: Monthly dustfall rates for Kagiso (January 2011 to August 2015)

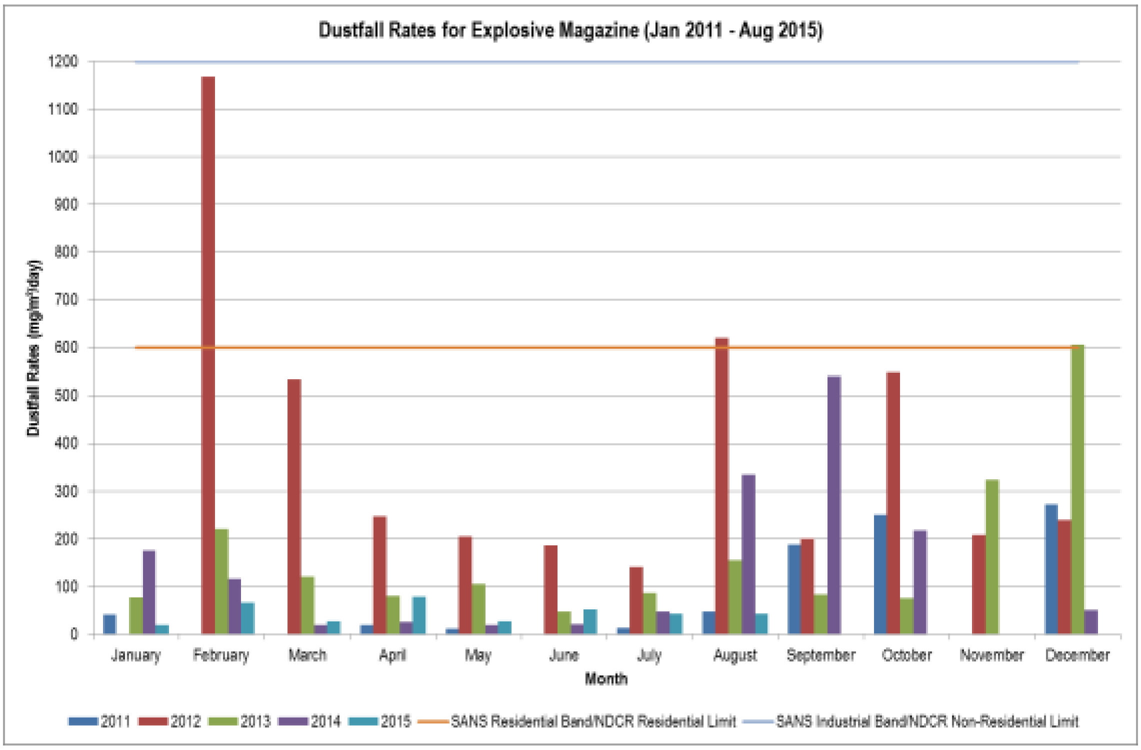


Figure 3-15: Monthly dustfall rates for explosive magazine (January 2011 to August 2015)

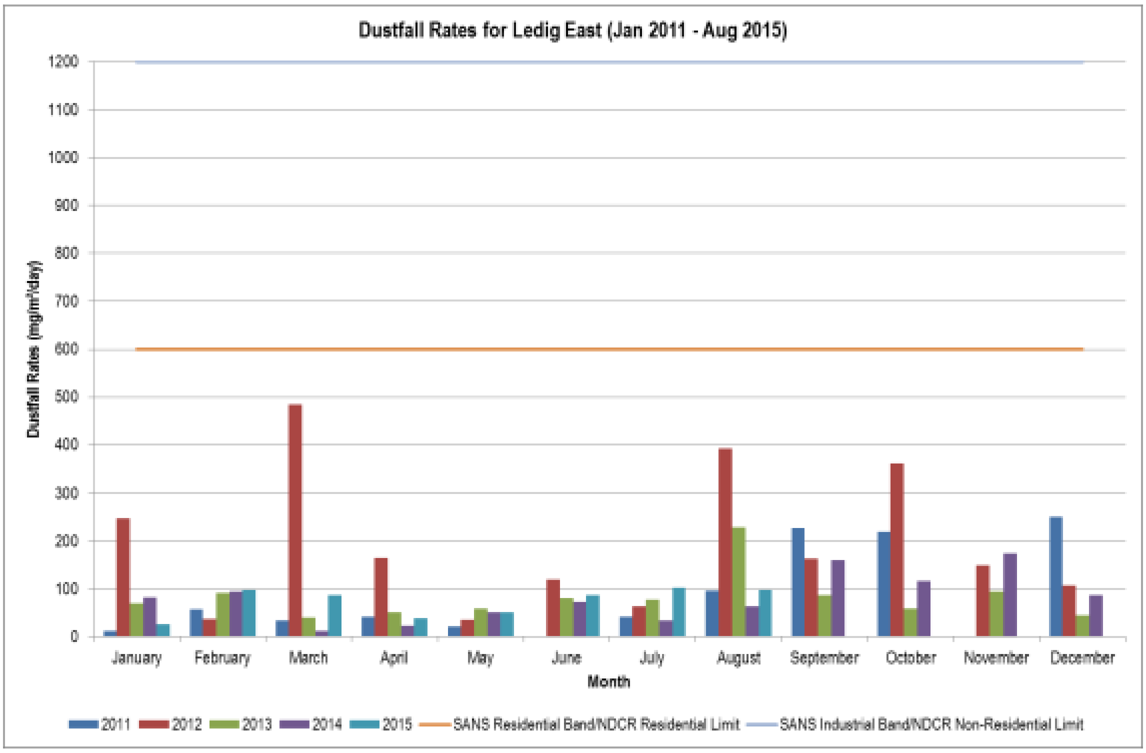


Figure 3-16: Monthly dustfall rates for Ledig East (January 2011 to August 2015)

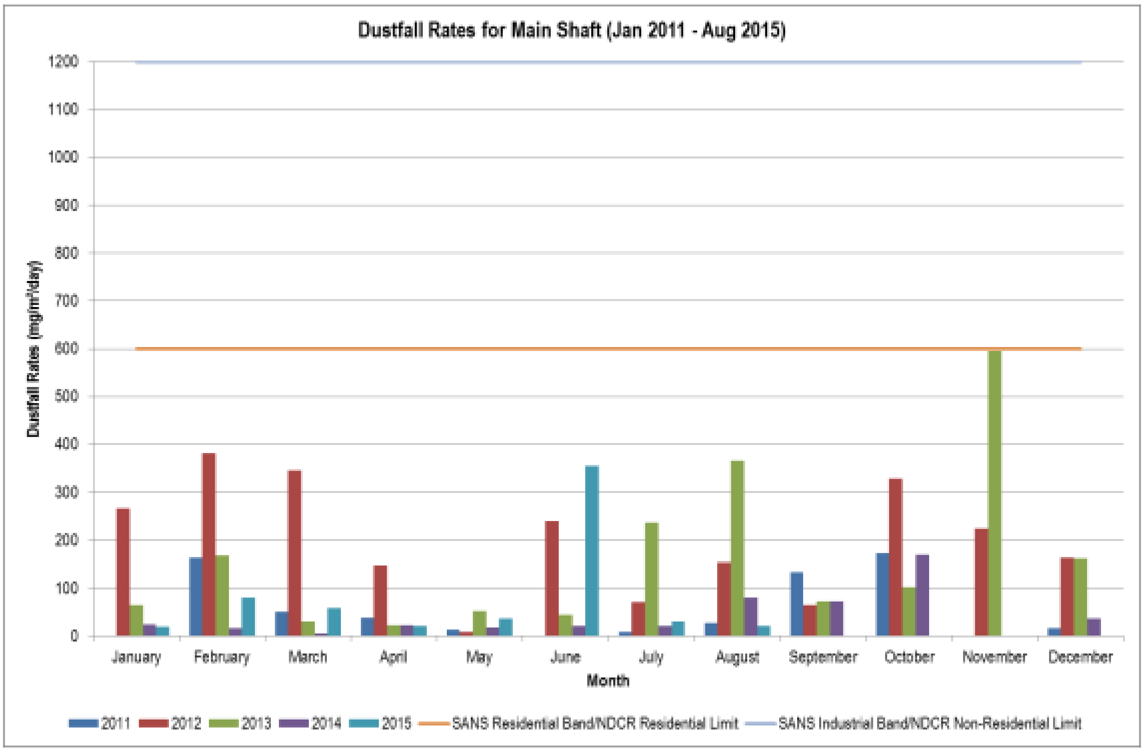


Figure 3-17: Monthly dustfall rates for main shaft (January 2011 to August 2015)

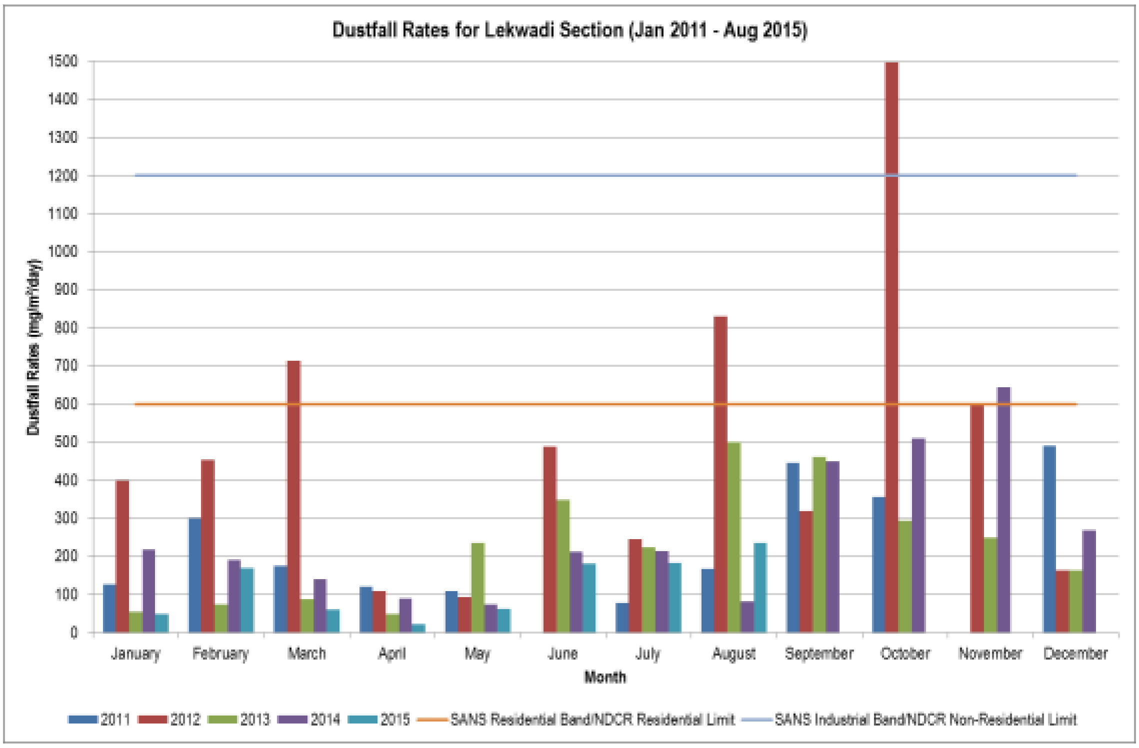


Figure 3-18: Monthly dustfall rates for Lekwadi Section (January 2011 to August 2015)

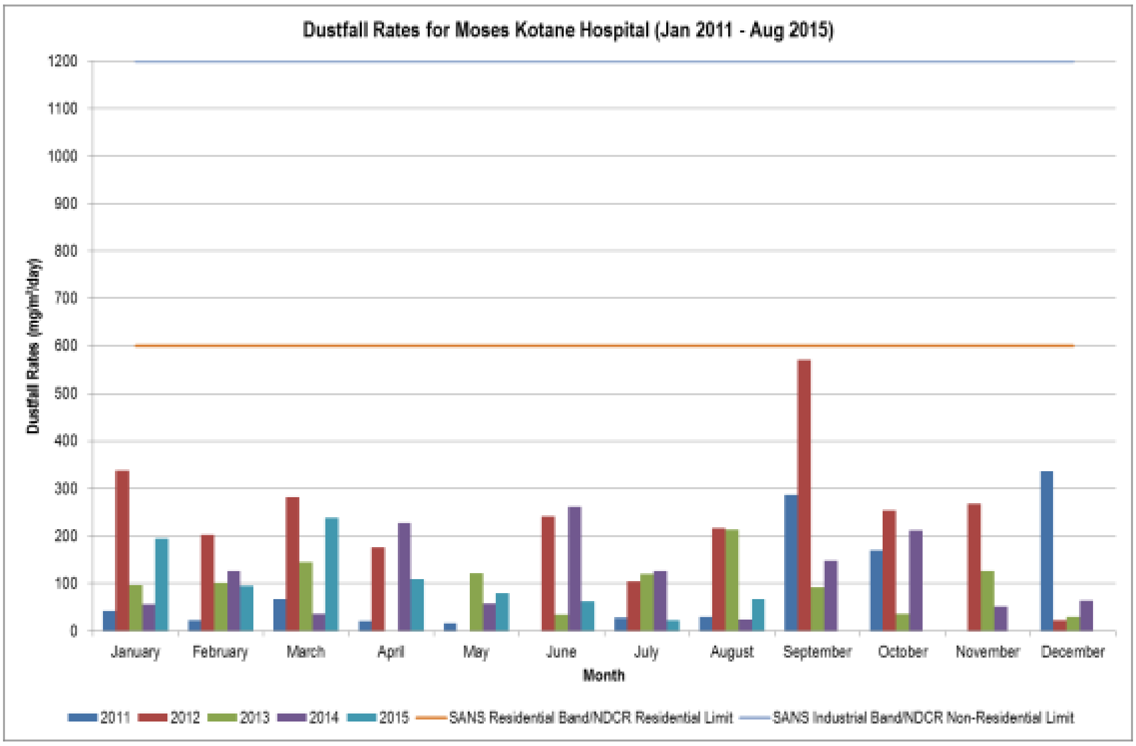


Figure 3-19: Monthly dustfall rates for Moses Kotane Hospital (January 2011 to August 2015)

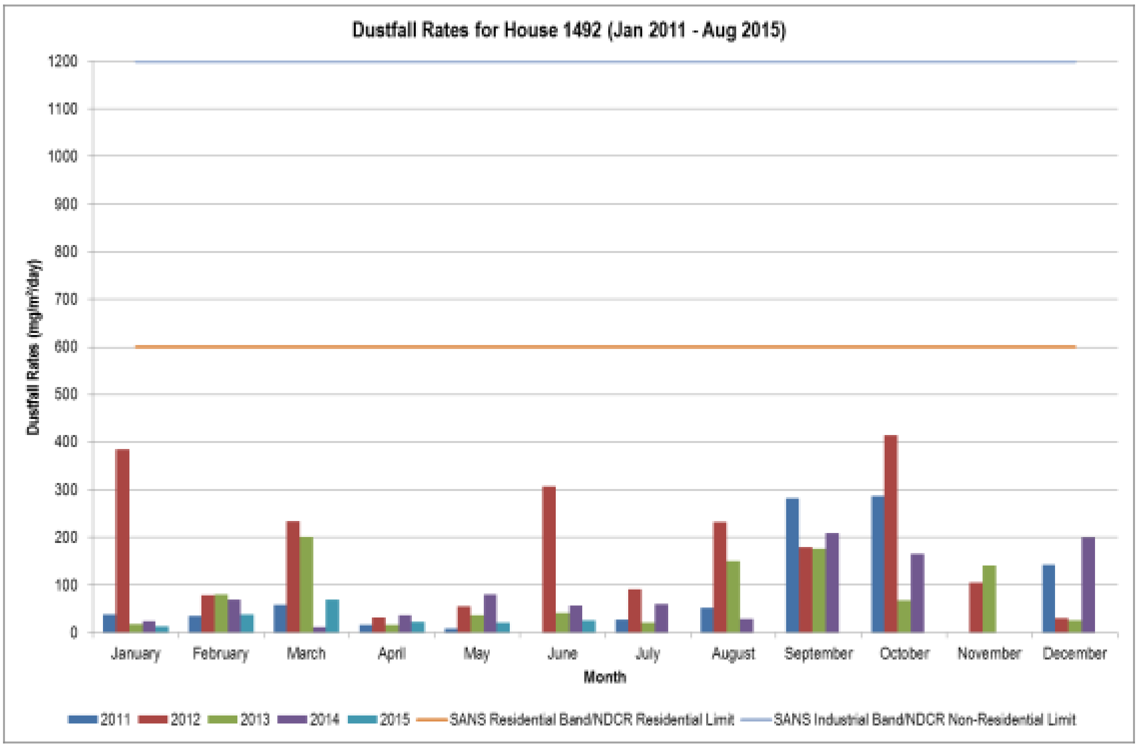


Figure 3-20: Monthly dustfall rates for House 1492 (January 2011 to August 2015)

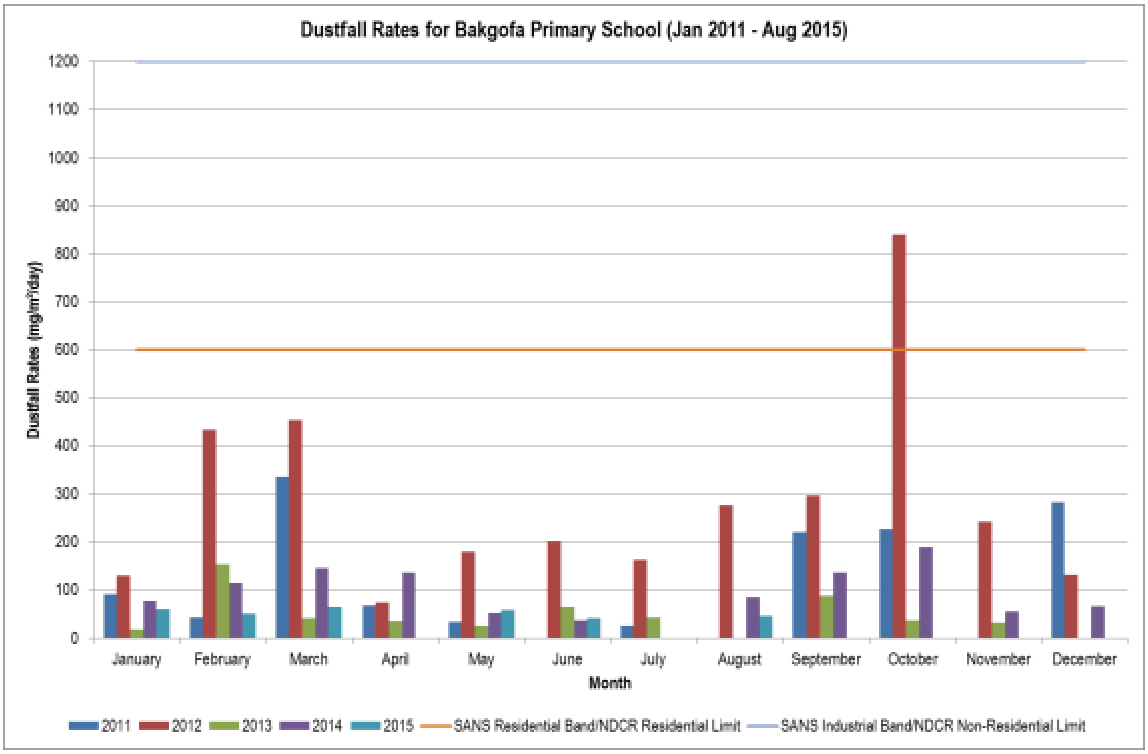


Figure 3-21: Monthly dustfall rates for Bakgofa Primary School (January 2011 to August 2015)

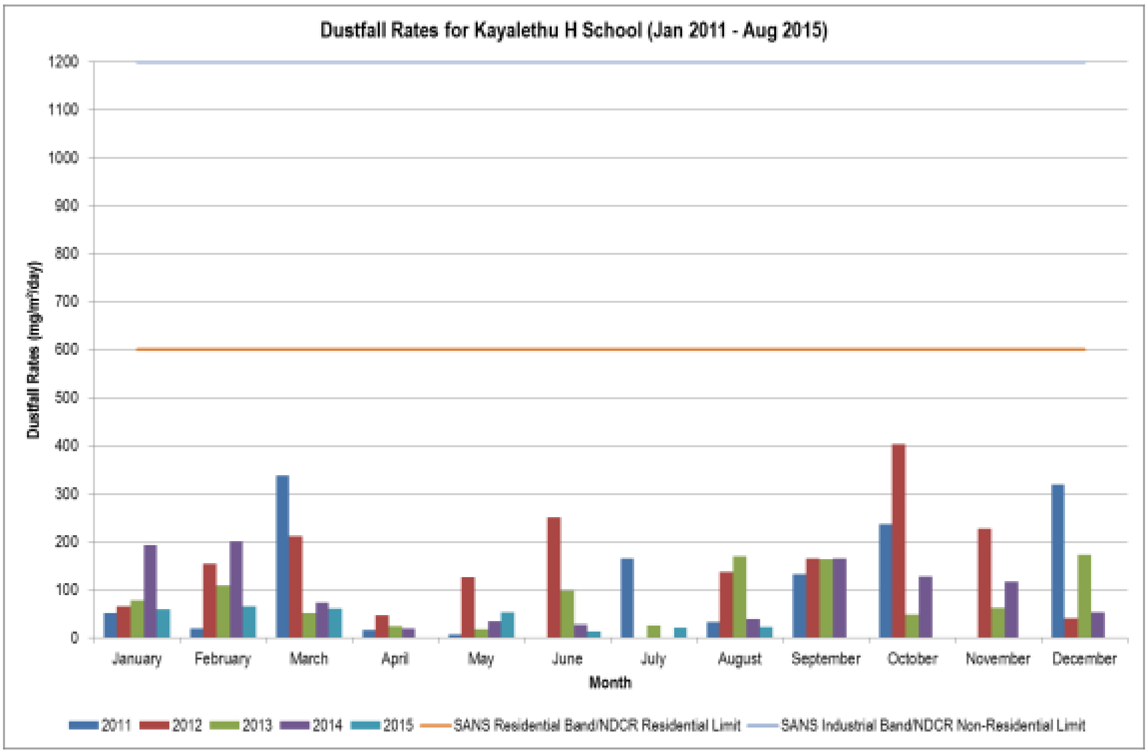


Figure 3-22: Monthly dustfall rates for Kayalethu H School (January 2011 to August 2015)

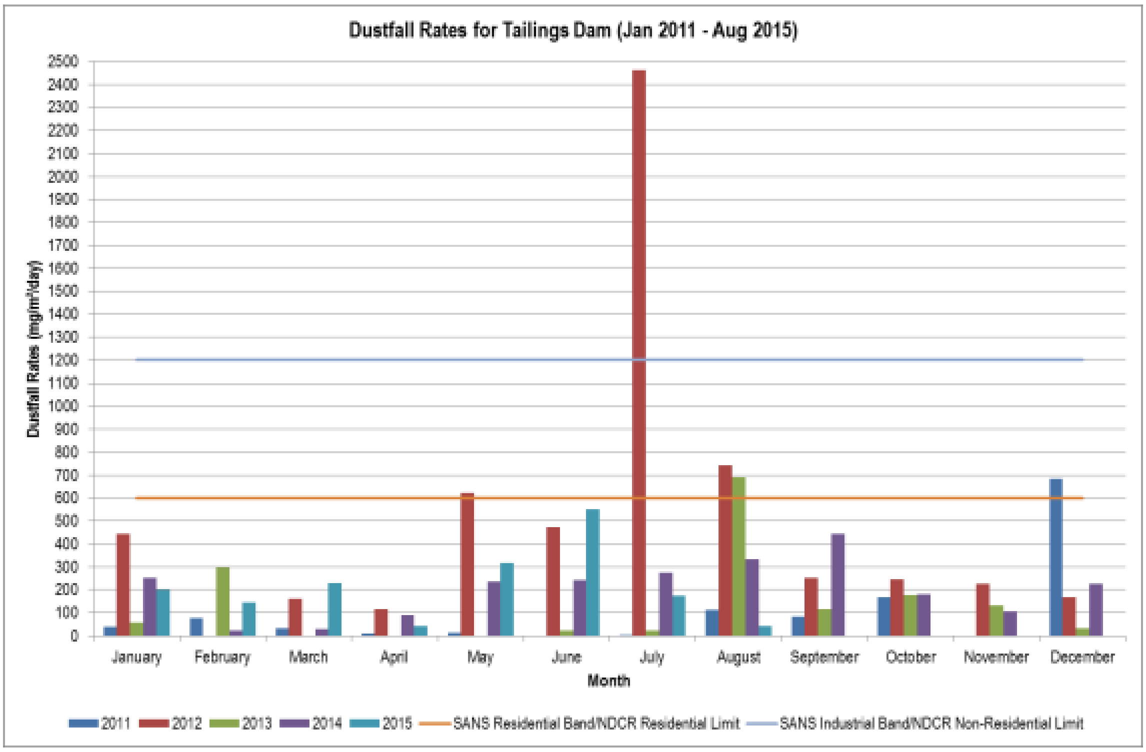


Figure 3-23: Monthly dustfall rates for tailings dam (January 2011 to August 2015)

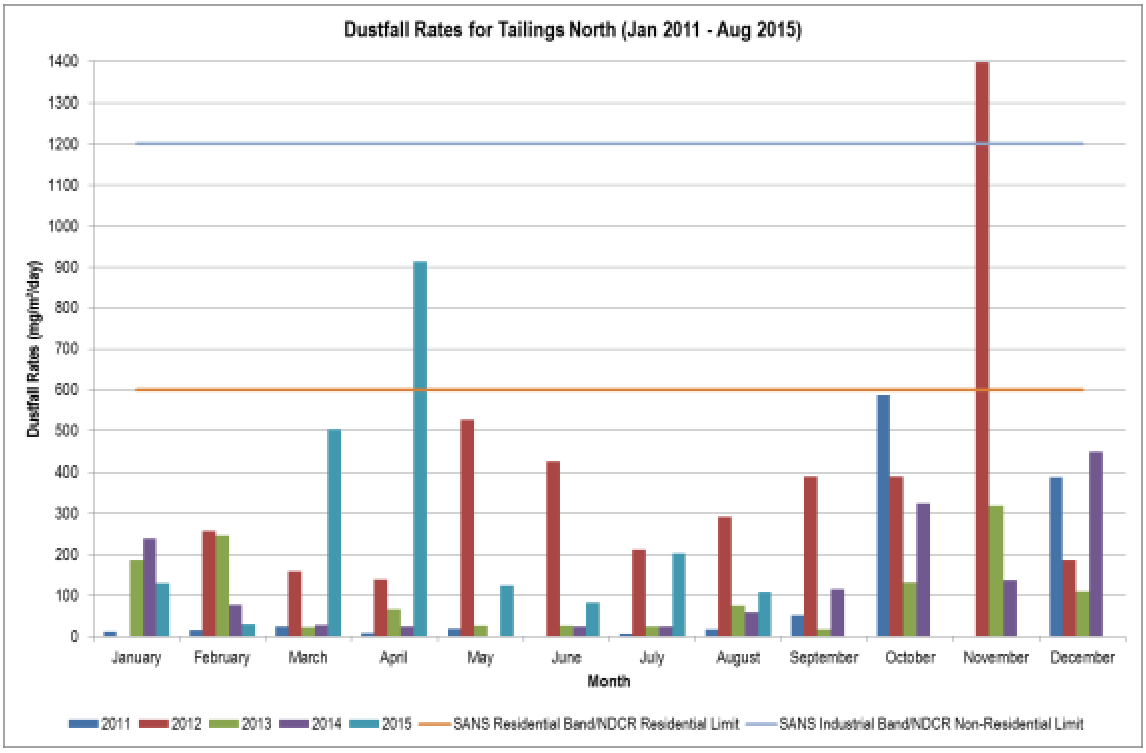
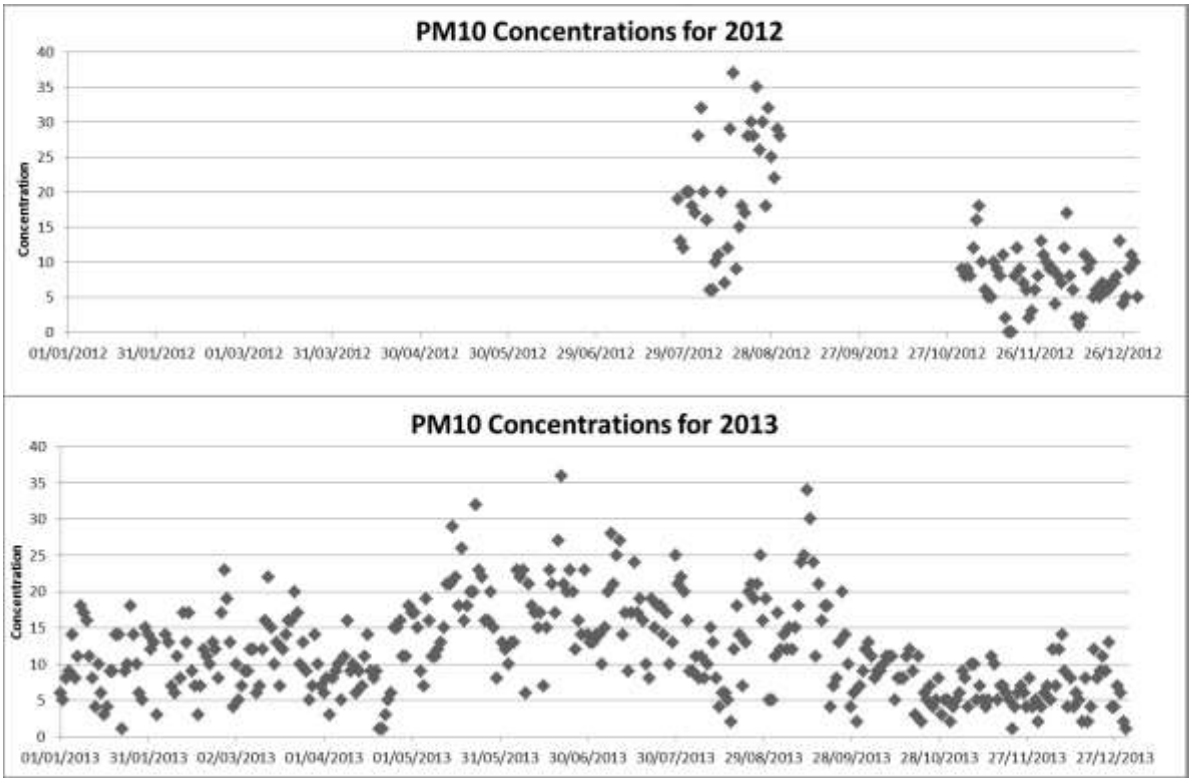


Figure 3-24: Monthly dustfall rates for tailings north (January 2011 to August 2015)

### *3.4.2 $PM_{10}$ Results*

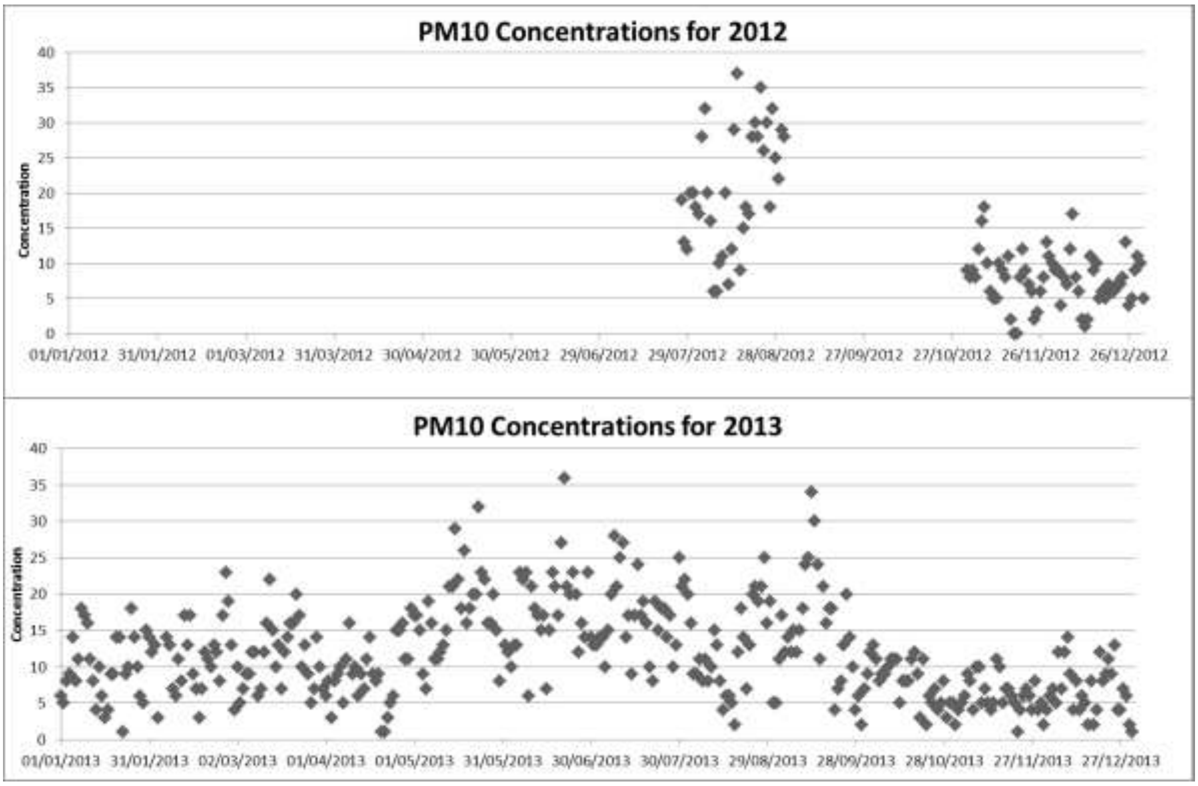
Daily $PM_{10}$ results from the particulate monitor for the period 27 July 2012 to 30 June 2015 are depicted in Figure 3-25 and Figure 3-26. 2013 had the best data availability of all the years; the other years had several months of missing data.

The 24-hour NAAQS limit value for $PM_{10}$ of 75 µg/m³ (Table 2-1) was not exceeded for over the sampling period, equating to 0% exceedances.


PM10 Concentrations for 2012

PM10 Concentrations for 2013

**Figure 3-25: $PM_{10}$ concentrations (27 July 2012 – 31 December 2013)**


PM10 Concentrations for 2012

PM10 Concentrations for 2013

**Figure 3-26: $PM_{10}$ concentrations (1 January 2014 to 30 June 2015)**

### *3.4.3 $SO_2$ Results*

$SO_2$ sampling data available was for the period October 2010 to August 2015. There were no exceedences of the 1-year or 24-hour average NAAQS of 50 µg/m³ and 125 µg/m³ at any of the sites. Extrapolated hourly concentrations exceeded the NAAQ limit of 350 µg/m³ at FrischGewaagd and Khayalethu H.School during January 2011 and at the explosive magazine in January 2011 and May 2015. Since samples are collected on a monthly basis (i.e. 30 day exposure periods) there is the possibility of multiple exceedances of the hourly NAAQS limit during these months at these locations. It is suggested by the sampler manufacturer (Radiello®) that a maximum exposure period of 15 days is feasible.

### *3.4.4 $NO_2$ Results*

$NO_2$ sampling data available was conducted for the period October 2010 to August 2015. There were no exceedences of the 1-year average NAAQS of 40 µg/m³ at any of the sites. Extrapolated hourly concentrations exceeded the NAAQ limit of 200 µg/m³ at all sites during the sampling period. The highest amount of exceedences occurred during 2011 and 2013. This would suggest elevated $NO_2$ during 2011 and 2013. Since samples are collected on a monthly basis (i.e. 30 day exposure periods) there is the possibility of multiple exceedances of the hourly NAAQS limit during these months at these locations. It is suggested by the sampler manufacturer (Radiello®) that a maximum exposure period of 15 days is feasible.

# 4 IMPACT OF BPM ON THE RECEIVING ENVIRONMENT

## 4.1 Atmospheric Emissions

### *4.1.1 Construction Phase*

The approved BPM infrastructure is currently under construction. Construction of the additional concentrator plant facilities, additional roads and the additional TSF area will add to emissions from existing construction operations. Specific activities likely to result in air emissions are listed in Table 4-1.

**Table 4-1: Typical fugitive dust impacts and associated activities during construction**

| Impact | Source | Activity |
|---|---|---|
| TSP, $PM_{10}$ and $PM_{2.5}$ | Dust generation from earthworks | Drilling and blasting activities |
| | | Clearing and grubbing and bulldozing activities |
| | | Soil excavation |
| | | Stockpiling of topsoil and other material |
| | | Disposal and treatment of contaminated soil |
| | Dust generation from site development | Clearing of vegetation and topsoil |
| | Vehicle entrained dust | Construction and use of new on-site roads, clearing of areas |
| | | Operation and movement of construction vehicles and machinery |
| Gases and particles | Vehicle and construction equipment activity | Tailpipe emissions from vehicles and construction equipment such as graders, scrapers and dozers |

These activities normally comprise a series of different operations including land clearing, topsoil removal, road grading, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has their own duration and potential for dust generation. It is anticipated 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. Due to the lack of detailed information, emissions from the construction activities would be estimated on an area wide basis. This approach estimates construction emissions for the entire affected area without regard to the actual plans of the individual construction project.

In the quantification of releases from the construction phase, emission factors published by the US EPA (US EPA, 1996) were utilized. The approximate emission factor for construction is given as:

$$E_{TSP} = 2.69 \text{ megagrams(Mg)/hectare(ha)/month of activity}$$

This emission factor is most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semi-arid climates and applies to TSP. Thus, it will result in conservatively high estimates when applied to $PM_{10}$. Also, because the derivation of the factor assumes that construction activity occurs 30 days per month, it is regarded as conservatively high for TSP as well (US EPA, 1995). The emission factor does not provide an indication of which type of activity during construction would result in the highest impacts thus not providing information to develop an effective dust control plan. For example, secondary dust sources during construction might be far more significant than the actual on-site construction operations. Such secondary sources may include vehicle activity on off-site roads, quarry operations and stockpiles located away from the actual site (US EPA, 1995). The calculated emissions from construction of the concentrator and TSF are shown in Table 4-2 (excluding additional roads).

Mitigation measures to consider during the construction phase include water sprays (50% efficiency) on all cleared and graded areas; ensure the distances between the topsoil removal and topsoil stockpiles are kept at a minimum and topsoil stockpiles vegetated. The recommended mitigation measures are provided in Section 5.

**Table 4-2: Emissions from unmitigated and mitigated construction activities**

| Pollutant | Unmitigated (tpa) | Mitigated (tpa) |
|---|---|---|
| $PM_{2.5}$ | 384 | 192 |
| $PM_{10}$ | 769 | 384 |
| TSP | 2 196 | 1 098 |

### *4.1.2 Operational Phase*

The main environmental impacts associated with the operations are underground mining, loading and off-loading of trucks, conveyor transfer points, crushing and screening and unpaved roads. These all contribute to dust emissions. An emissions inventory was completed for unmitigated and design mitigated operations.

Sources of atmospheric emission associated with BPM are listed in Table 4-3 with relevant information as used in the emissions calculations included. The emission factors and equations are provided in Appendix B and a summary of the emission rates are provided in Table 4-5 to Table 4-7. Where specific mitigation measures were stipulated for specific sources, the efficiencies of such measures were applied in calculations. Particle size distributions for the TSF and WRD are provided in Table 4-4.

#### *4.1.2.1 Emissions inventory summary - PM emissions*

*Unmitigated*

Source group contributions to total emissions are shown in Table 4-5. The most significant source of $PM_{2.5}$ and $PM_{10}$ emissions are the ventilation shafts contributing 73% and 51% to the overall $PM_{2.5}$ and $PM_{10}$ emissions, respectively. The most significant sources of TSP emissions are crushing and screening, contributing 49% to the overall TSP emissions. The second most significant source of $PM_{2.5}$ and $PM_{10}$ emissions is crushing and screening. The second most significant source of TSP emissions are the ventilation shafts. The least significant source of $PM_{2.5}$, $PM_{10}$ and TSP emissions is surface vehicle exhausts. The only source of DPM are the ventilation shafts (underground vehicle exhaust). Without mitigation in place, overall TSP emissions are 290 tpa, with $PM_{10}$ at 163 tpa, $PM_{2.5}$ at 114 tpa and DPM at 10 tpa.

*Design-Mitigated*

The source group contributions to total emissions are shown in Table 4-6. The most significant source of $PM_{2.5}$, $PM_{10}$ and TSP emissions is ventilation shafts contributing 93%, 80% and 62% to the overall $PM_{2.5}$, $PM_{10}$ and TSP emissions, respectively. The second most significant source of $PM_{2.5}$, $PM_{10}$ and TSP emissions is crushing and screening. The least significant source of $PM_{2.5}$, $PM_{10}$ and TSP emissions is surface vehicle exhausts. The only source of DPM is ventilation shafts (underground vehicle exhausts). With design mitigation in place the overall TSP emissions are 134 tpa, with $PM_{10}$ at 104 tpa, $PM_{2.5}$ at 89 tpa and DPM at 10 tpa.

**Table 4-3: Summary of information used in the estimation of emissions**

| Aspect | Source | Activity | Comments/Assumptions/Mitigation |
|---|---|---|---|
| Fugitive dust (TSP, $PM_{10}$ and $PM_{2.5}$ ) and gases | Ventilation shafts – underground emissions | Drilling and blasting<br>Waste removal and handling<br>Ore removal and handling<br>Vehicle entrained dust and exhaust emissions from vehicle travelling on unpaved roads | Based on 24 hours, 7 days a week.<br>Main vehicles: 23 load, haul, dump machines (LHDs) and 22 trucks at 158 kW and 354 kW, respectively.<br>V1<br>Release height: 8.5 m<br>Ventilation shaft diameter: 6.1 m<br>Temperature: 24.2 °C<br>Volumetric flow rate: 2 034 000 $Nm^3/h$<br>PM emissions: 2.5 $mg/Nm^3$<br>V2<br>Release height: 8.5 m<br>Ventilation shaft diameter: 6.1 m<br>Temperature: 25 °C<br>Volumetric flow rate: 1 778 400 $Nm^3/h$<br>PM emissions: 2.5 $mg/Nm^3$ |
| | Materials handling operations | Loading waste onto trucks and tipping at WRD<br>Loading ore onto conveyor at incline shaft<br>Processed ore to stockpiles<br>Conveyor transfer points | Based on 24 hours, 7 days a week.<br>Average wind speed from measured data = 1.9 m/s.<br>Moisture content of ore = 4%.<br>Moisture content of waste = 4%.<br>Moisture content of crushed ore = 5%.<br>Moisture content of processed ore = 5%.<br>Mitigation measures will include water sprays at all materials handling points (assumed 50% control efficiency (CE)). |
| | Crushing and screening | Primary, secondary and tertiary crushing of ore at plant<br>Primary and secondary screening of ore at plant | Based on 24 hours, 7 days a week.<br>Moisture content of ore at crushers and screens = 5%.<br>Mitigation measures will include enclosure with fabric filters (assumed 83% CE). |
| | Vehicle activity on surface unpaved roads | Transportation of waste<br>Vehicle exhaust emissions from vehicle travelling on unpaved haul roads | Based on 24 hours, 7 days a week.<br>Silt content for haul roads is 8.4% – previous study.<br>Width of road = 3 m.<br>30 tonne capacity haul trucks for waste (36.3 tonne average weight). |

| Aspect | Source | Activity | Comments/Assumptions/Mitigation |
|---|---|---|---|
| | | | Mitigation measures will include water sprays on unpaved roads (assumed 75% CE). |
| | Vehicle activity on paved roads | Transportation of concentrate (slurry) in tankers.<br>Transportation of workers in buses.<br>Vehicle exhaust emissions from vehicle travelling on unpaved haul roads | Based on 24 hours, 7 days a week.<br>Silt loading for haul roads is 0.6 g/m² – US EPA default.<br>Width of road = 6 m.<br>40.5 tonne average weight tankers for concentrate (slurry).<br>26.4 tonne average weight buses.<br>7 000 litres/year/vehicle at plant (15 vehicles). |
| | Wind erosion | Wind erosion at stockpiles, WRD and TSF | Due to the moisture content and size of particles at stockpiles erosion is likely to be negligible.<br>Particle size distribution (PSD) for WRD from similar projects in area, assumed 100% of the area is erodible.<br>Particle size distribution (PSD) for TSF from similar projects in area, assumed 100% of the area is erodible.<br>Moisture content of 1.2% for WRD (assuming waste rock will dry out on dump), from similar projects in area.<br>Moisture content of 0.1% for TSF (assuming top of TSF will dry out).<br>Particle density of 2.8 g/cm³ for WRD, information provided.<br>Particle density of 3 402 kg/m³ for UG2 tailings and 3 076 kg/m³ for Merensky tailings.<br>Wind erosion at WRD was determined to be negligible. |

**Table 4-4: PSD for WRD and TSF**

| Particle size (µm) | % for WRD | % for TSF |
|---|---|---|
| 5000 | 0.00% | 0.00% |
| 4000 | 52.07% | 55.24% |
| 2000 | 11.64% | 6.54% |
| 555.71 | 2.10% | 0.49% |
| 301.68 | 5.57% | 2.67% |
| 190.8 | 6.62% | 5.30% |
| 103.58 | 2.37% | 3.11% |

| Particle size (µm) | % for WRD | % for TSF |
|---|---|---|
| 76.32 | 1.99% | 3.28% |
| 56.23 | 1.80% | 3.19% |
| 41.43 | 1.73% | 2.88% |
| 30.53 | 2.54% | 3.67% |
| 19.31 | 3.28% | 3.97% |
| 10.48 | 3.55% | 3.95% |
| 4.88 | 4.04% | 4.50% |
| 1.06 | 0.70% | 1.23% |

**Table 4-5: Summary of estimated annual particulate emission rates**

| Source Group | $PM_{2.5}$ | $PM_{10}$ | TSP | DPM | $PM_{2.5}$ | $PM_{10}$ | TSP | DPM | Mitigation Applied |
|---|---|---|---|---|---|---|---|---|---|
| | **tpa** | **tpa** | **tpa** | **tpa** | **%** | **%** | **%** | **%** | |
| **Unmitigated** | | | | | | | | | |
| Ventilation shafts | 83 | 83 | 83 | 10 | 73% | 51% | 29% | 100% | |
| Materials handling | 1 | 6 | 12 | - | 1% | 3% | 4% | - | |
| Crushing and screening | 29 | 57 | 143 | - | 25% | 35% | 49% | - | |
| Unpaved roads | 1 | 11 | 40 | - | 1% | 7% | 14% | - | |
| Paved roads | 0.1 | 1 | 3 | - | 0% | 0% | 1% | - | |
| Surface vehicle exhaust | 0.1 | 0.1 | 0.1 | - | 0% | 0% | 0% | - | |
| Wind erosion | 0.2 | 5 | 9 | - | 0% | 3% | 3% | - | |
| **Total** | **114** | **163** | **290** | **10** | **100%** | **100%** | **100%** | **100%** | |

**Table 4-6: Summary of estimated annual particulate emission rates**

| Source Group | $PM_{2.5}$ | $PM_{10}$ | TSP | DPM | $PM_{2.5}$ | $PM_{10}$ | TSP | DPM | Mitigation Applied |
|---|---|---|---|---|---|---|---|---|---|
| | tpa | tpa | tpa | tpa | % | % | % | % | |
| **Design mitigated** | | | | | | | | | |
| Ventilation shafts | 83 | 83 | 83 | 10 | 93% | 80% | 62% | 100% | |
| Materials handling | 0 | 3 | 6 | - | 0% | 3% | 4% | - | Water sprays (50% CE) |
| Crushing and screening | 5 | 10 | 24 | - | 5% | 9% | 18% | - | Enclosure with fabric filters (83% CE) |
| Unpaved roads | 0.3 | 3 | 10 | - | 0% | 3% | 7% | - | Water sprays (75% CE) |
| Paved roads | 0.1 | 0.2 | 1 | - | 0% | 0% | 1% | - | |
| Surface vehicle exhaust | 0.1 | 0.1 | 0.1 | - | 0% | 0% | 0% | - | |
| Wind erosion | 0.2 | 5 | 9 | - | 0% | 5% | 7% | - | |
| **Total** | **89** | **104** | **134** | **10** | **100%** | **100%** | **100%** | **100%** | |

#### *4.1.2.2 Emissions inventory summary - Gaseous emissions*

Gaseous emissions from vehicle exhausts at the plant and underground were estimated (Table 4-7). Overall, $SO_2$ emissions are 0.5 tpa, with $NO_x$ at 208 tpa, CO at 392 tpa and VOCs at 79 tpa.

**Table 4-7: Summary of estimated gaseous emission rates for the future operational phase**

| Source Group | $SO_2$ | $NO_x$ | CO | VOC |
|---|---|---|---|---|
| | tpa | tpa | tpa | tpa |
| Ventilation shaft (underground vehicle exhausts) | 0.4 | 206 | 341 | 77 |
| Surface vehicle exhausts | 0.04 | 1 | 51 | 2 |
| **Total** | **0.5** | **208** | **392** | **79** |

### *4.1.3 Closure Phase*

It is assumed that all operations will have ceased by the closure phase. It is expected that all surface infrastructure will be demolished and removed and access roads closed off. It is also expected that the surface will be covered with topsoil and vegetated.

The potential for air quality impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure and on features which will remain. Aspects and activities associated with the closure phase of the operations are listed in Table 4-8.

**Table 4-8: Activities and aspects identified for the closure phase of operations**

| Impact | Source | Activity |
|---|---|---|
| TSP, $PM_{10}$ and $PM_{2.5}$ | Topsoil stockpiles | Topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings |
| | Processing Plant | Infrastructure removal at processing plant site |
| | Unpaved and paved roads | Vehicle entrainment on unpaved and paved road surfaces during rehabilitation. Once that is done, vehicle activity should cease |
| Gases and particles | Blasting | Demolition of infrastructure may necessitate the use of blasting |
| | Vehicles | Exhaust emissions from vehicles utilised during the closure phase. Once that is done, vehicle activity should cease. |

### *4.1.4 Post Closure Phase*

No emissions are expected post-closure.

## 4.2 Screening of Simulated Human Health Impacts (Incremental and Cumulative)

### *4.2.1 Construction Phase*

Impacts associated with the construction of the BPM approved and additional infrustructure are expected to be less significant than overall operational activities given the temporary nature of construction related activities.

### *4.2.2 Operational Phase*

#### *4.2.2.1 $PM_{2.5}$*

- Simulated ***unmitigated*** $PM_{2.5}$ daily frequency of exceedance and annual GLCs are shown in Figure 4-1 and Figure 4-2 respectively. Daily average concentrations exceed the NAAQS limit of 40 µg/m³ more than 4 days per year at Ledig, mine housing and off-site Over an annual average, simulated GLCs do not exceed the NAAQS of 20 µg/m³ at any of the sensitive receptor areas or off-site.
- Simulated ***design-mitigated*** $PM_{2.5}$ annual GLCs and daily frequency of exceedance are shown in Figure 4-4 and Figure 4-3 respectively. Daily average concentrations exceed the NAAQS limit of 40 µg/m³ more than 4 days per year at the mine housing and slightly off-site. Over an annual average, the simulated GLCs do not exceed the NAAQS of 20 µg/m³ at any of the sensitive receptor areas or off-site (Figure 4-4).
- The main contributing sources to the ***unmitigated*** $PM_{2.5}$ concentrations are crushing and screening followed by ventilation shafts. The main contributing source to the ***design-mitigated*** $PM_{2.5}$ concentrations are ventilation shafts followed by crushing and screening. The source that contributes the least to the ***unmitigated*** and ***design-mitigated*** $PM_{2.5}$ simulated concentrations is surface (plant) vehicles.
- Due to the absence of ambient air quality data, cumulative (baseline concentrations and future BPM GLCs) $PM_{2.5}$ concentrations could not be determined. It is likely that cumulatively, there will be exceedances of the NAAQS at Ledig and the mine housing for ***unmitigated*** operations. It is also likely that cumulatively, there will be exceedances of the selected criteia at the mine housing for ***design-mitigated*** future operations.

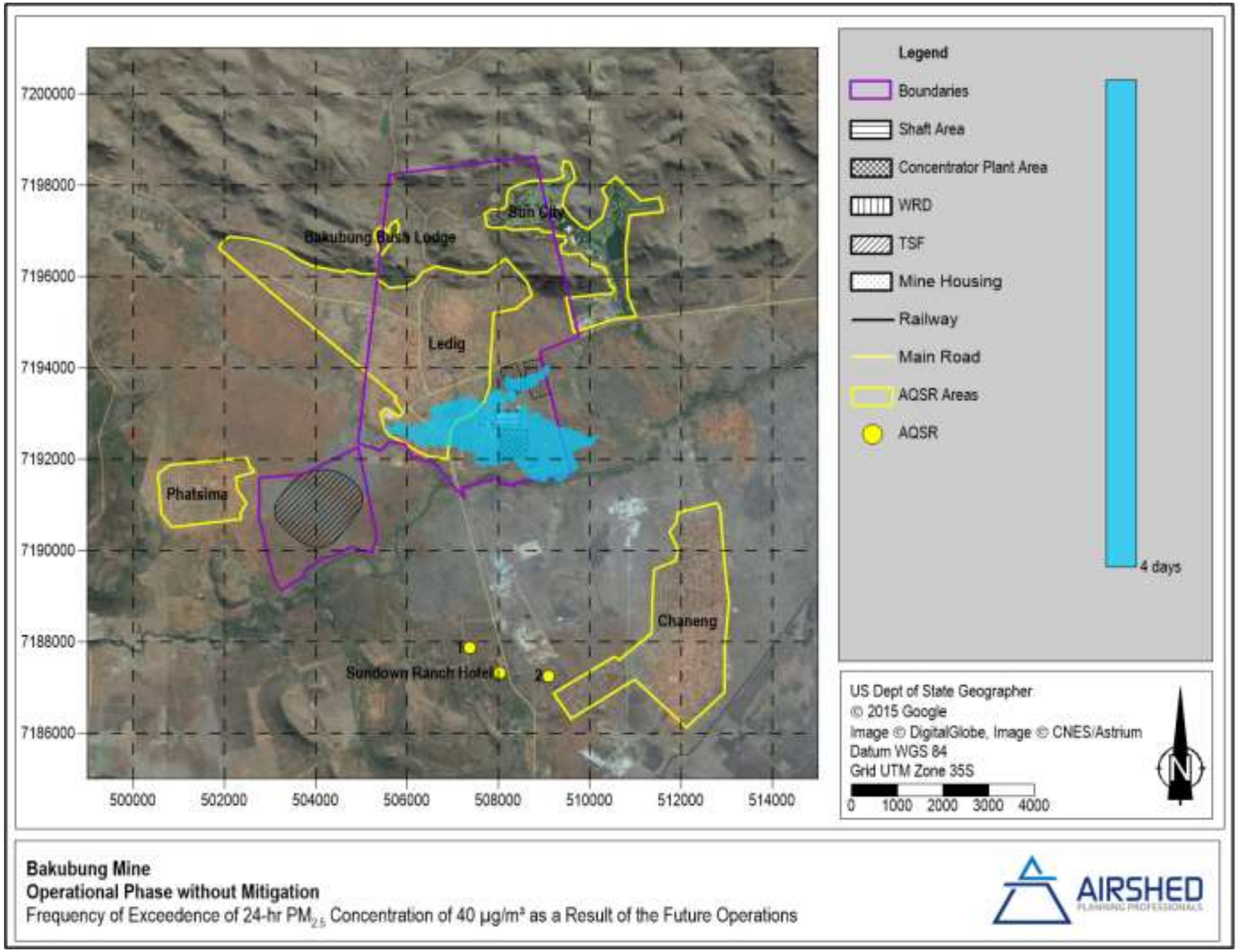


**Figure 4-1: Unmitigated operational phase - Area of exceedance of the NAAQS for daily average $PM_{2.5}$ concentrations**

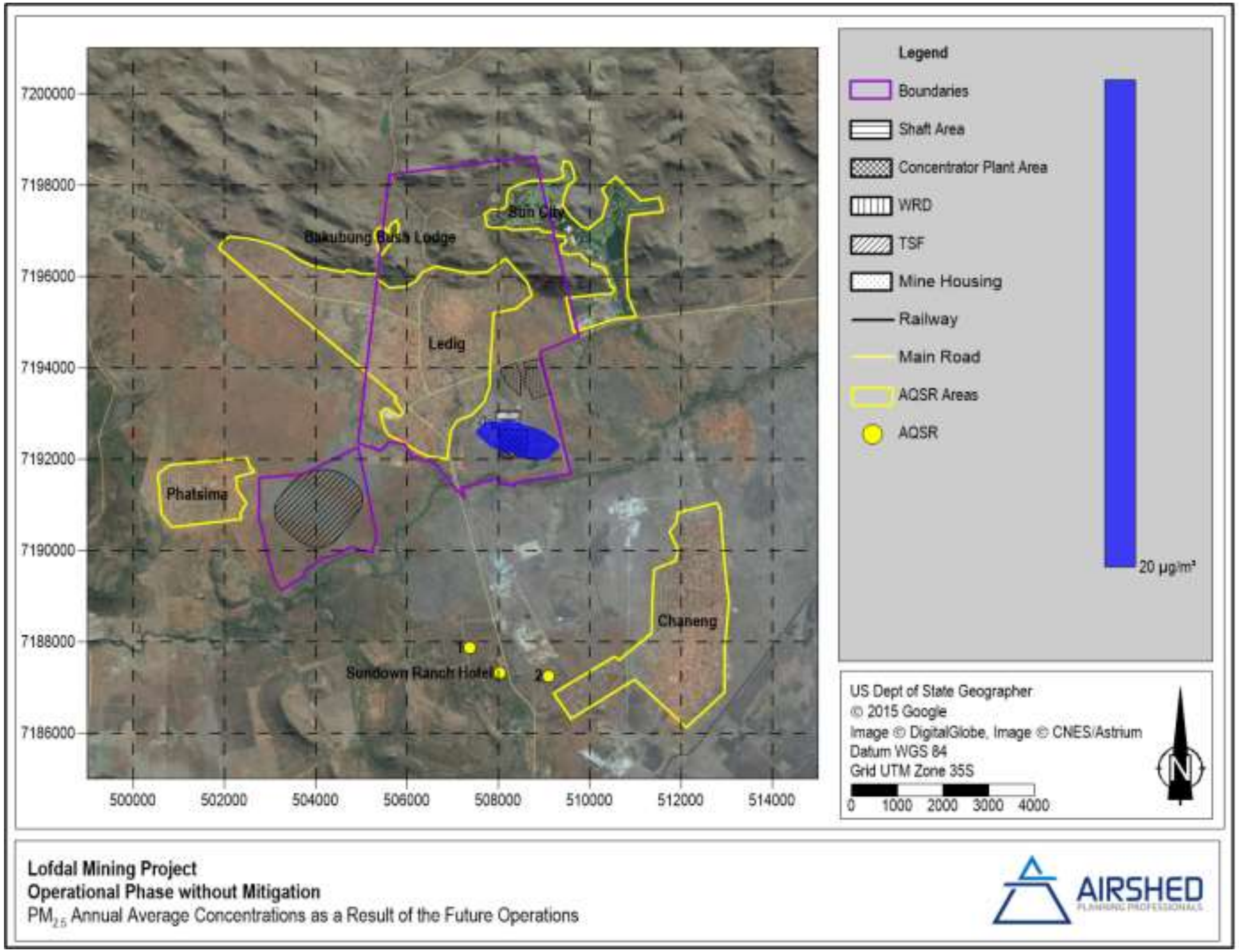


**Figure 4-2: Unmitigated operational phase - Area of exceedance of the NAAQS for annual average $PM_{2.5}$ concentrations**

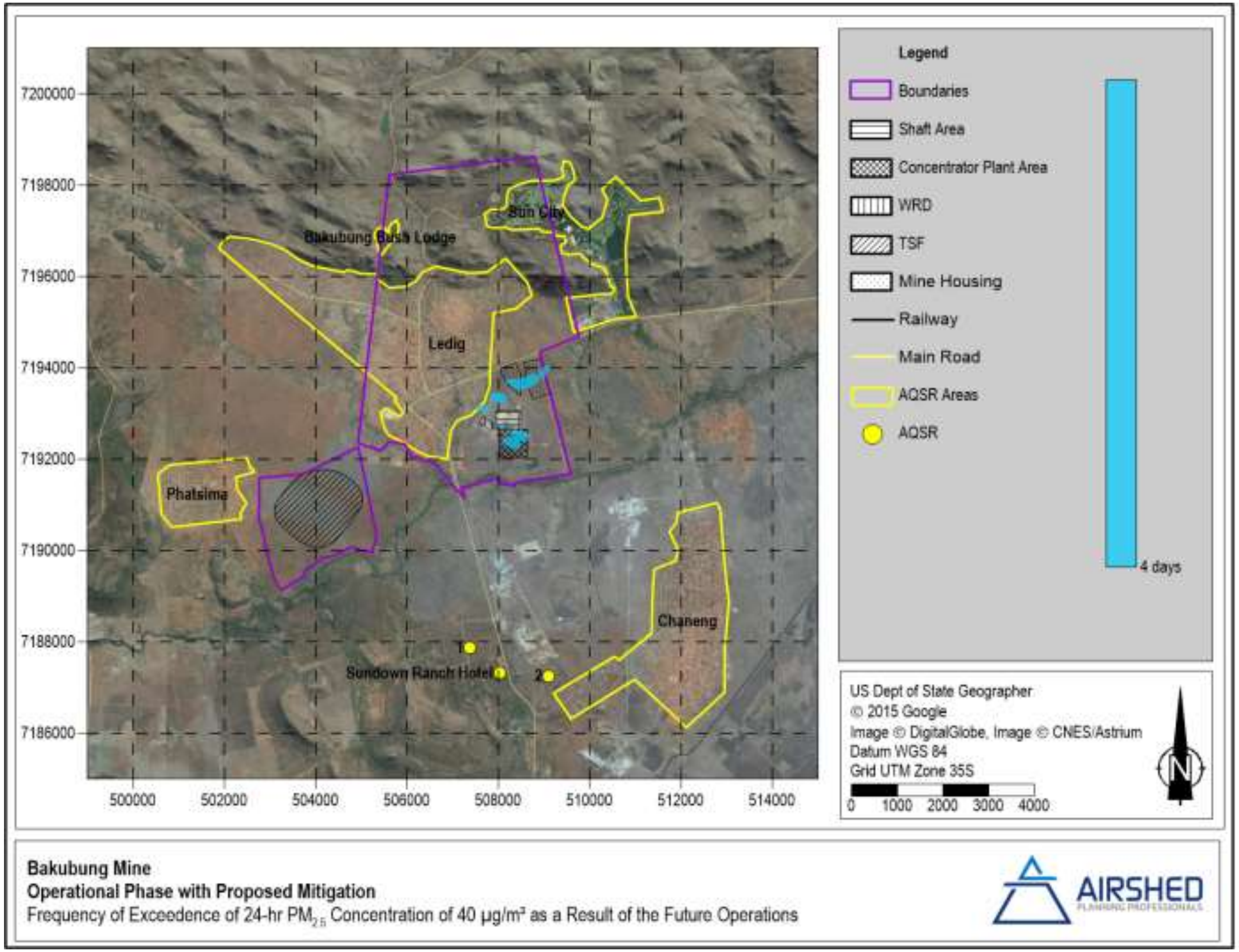


**Figure 4-3: Design mitigated operational phase - Area of exceedance of the NAAQS for daily average $PM_{2.5}$ concentrations**

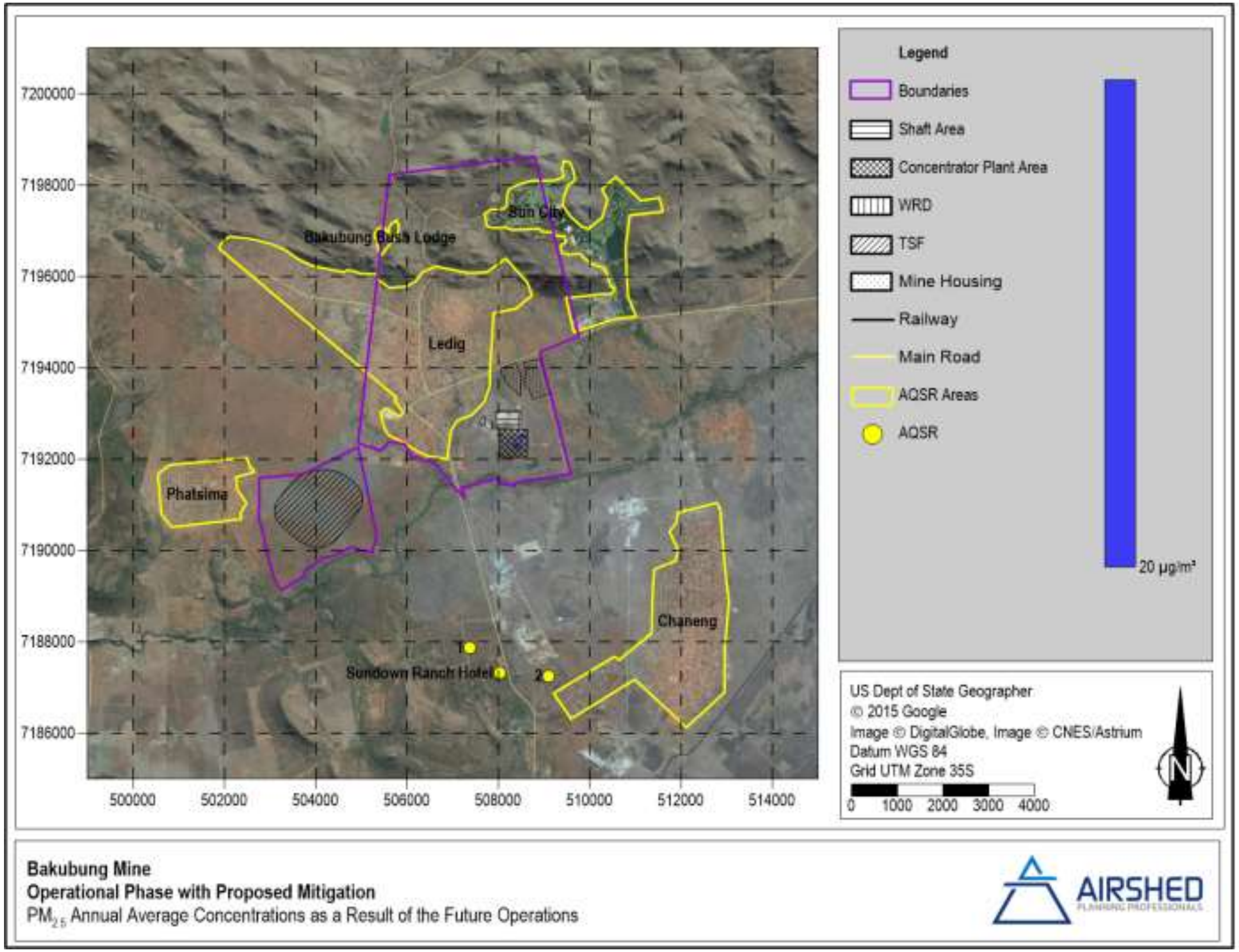


Figure 4-4: Design mitigated operational phase - Area of exceedance of the NAAQS for annual average $PM_{2.5}$ concentrations

#### *4.2.2.2 $PM_{10}$*

- Simulated ***unmitigated*** $PM_{10}$ daily frequency of exceedance and annual GLCs are shown in Figure 4-5 and Figure 4-6 respectively. Over a daily average, the concentrations exceed the NAAQ limit of 75 µg/m³ more than 4 days per year at Ledig and off-site. Over an annual average, the simulated GLCs do not exceed the NAAQS of 40 µg/m³ at any of the sensitive receptor areas or off-site.

- Simulated ***design mitigated*** $PM_{10}$ daily frequency of exceedance and annual GLCs are shown in Figure 4-7 Figure 4-8 respectively. Daily average concentrations do not exceed the NAAQ limit of 75 µg/m³ more than 4 days per year at any of the sensitive receptors or off-site. Over an annual average, simulated GLCs do not exceed the NAAQS of 40 µg/m³ at any of the sensitive receptors areas or off-site.

- The main contributing sources to the ***unmitigated*** $PM_{10}$ concentrations are crushing and screening followed by vehicles travelling on unpaved roads. The main contributing sources to the ***design mitigated*** $PM_{10}$ concentrations are vehicles travelling on unpaved roads followed by crushing and screening.

- The on-site measured data show no exceedances of the $PM_{10}$ NAAQS limit value. Note that measured data includes $PM_{10}$ concentrations as a result of background sources as well as current operations at BPM. It is likely that cumulatively, there will be exceedances of the daily and annual NAAQS at Ledig for ***unmitigated*** future operations. It is likely that cumulatively, there will be no exceedances of the NAAQS at any of the sensitive receptor areas for ***design mitigated*** future operations.

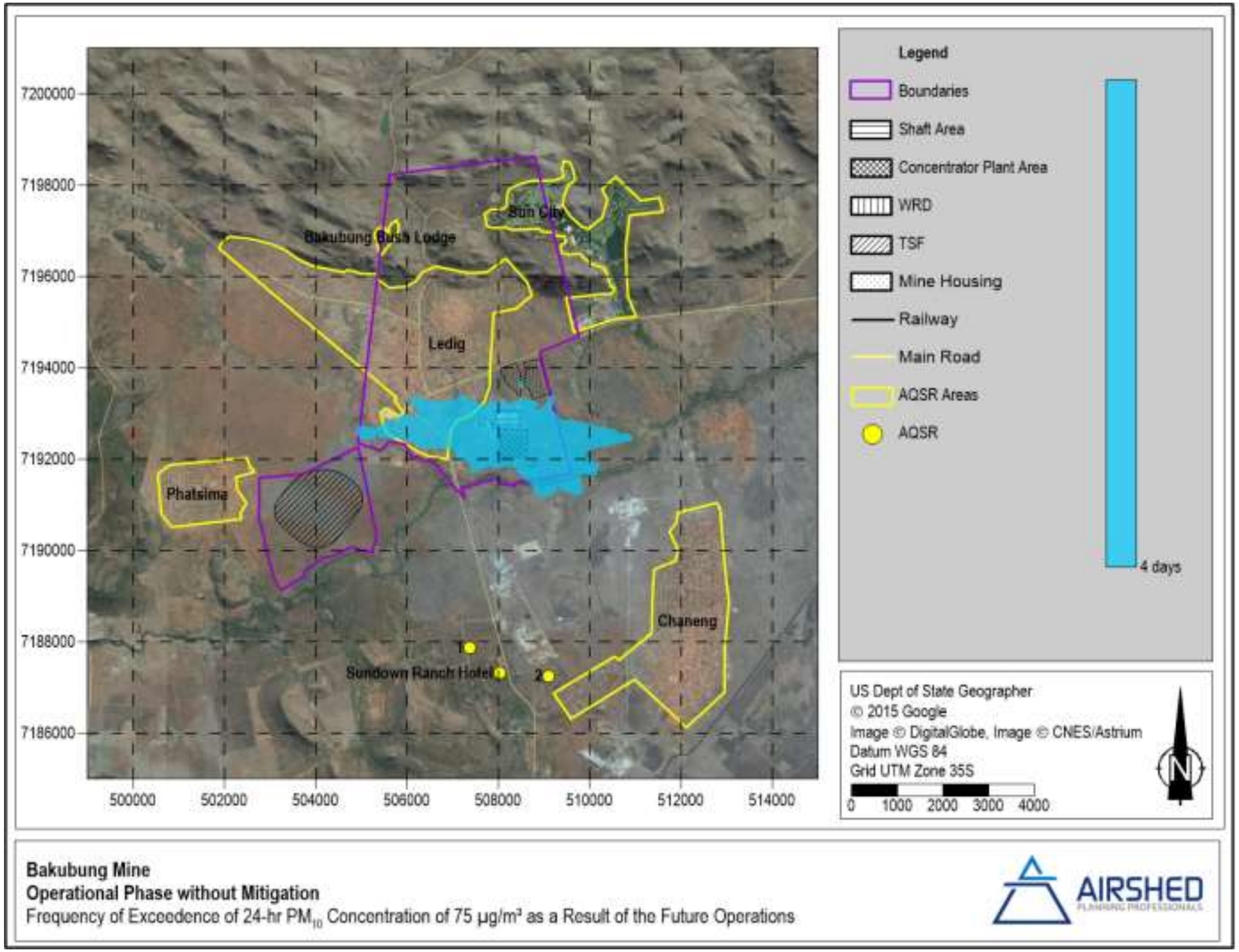


**Figure 4-5: Unmitigated operational phase - Area of exceedance of the NAAQS for daily average $PM_{10}$ concentrations**

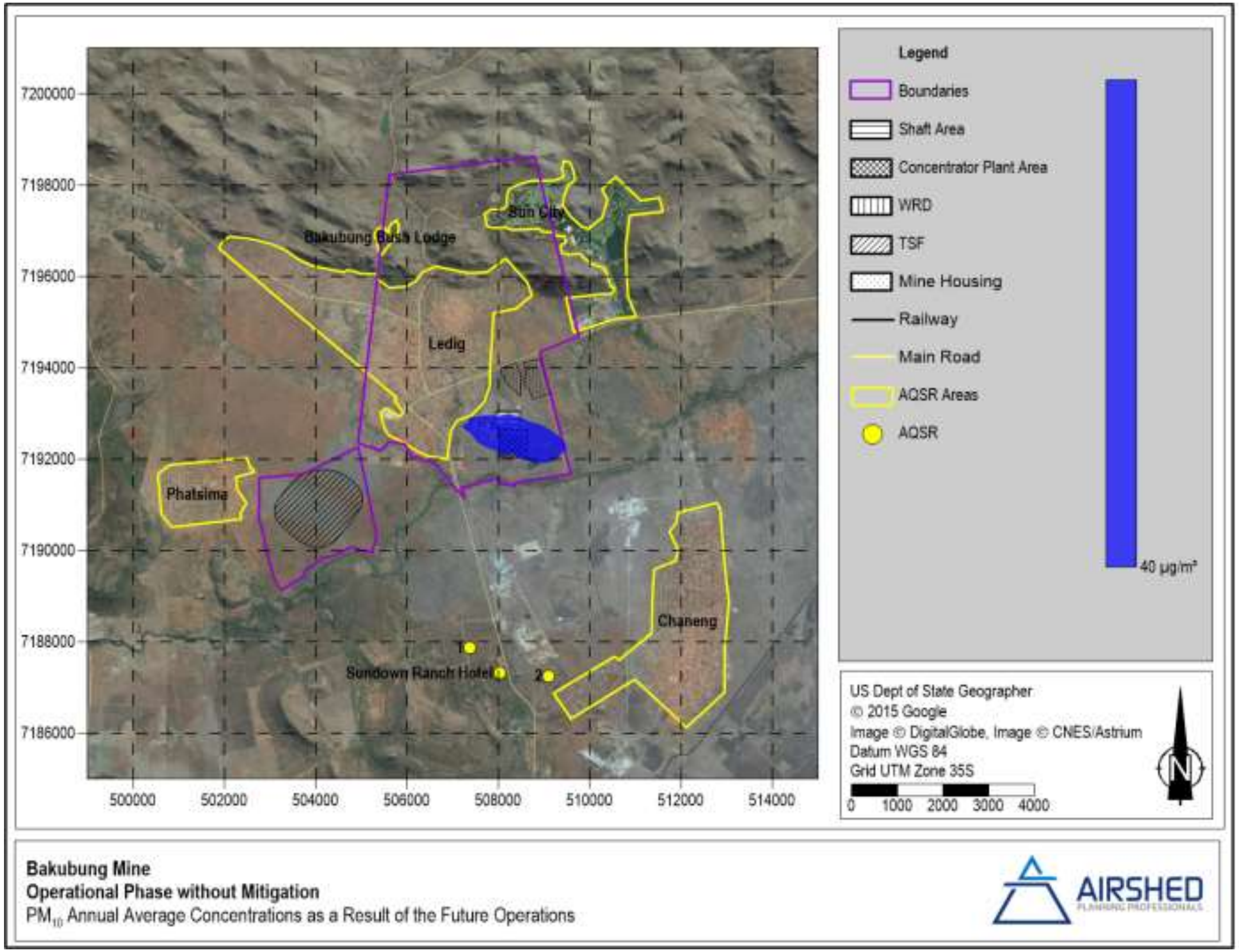


**Figure 4-6: Unmitigated operational phase - Area of exceedance of the NAAQS for annual average $PM_{10}$ concentrations**

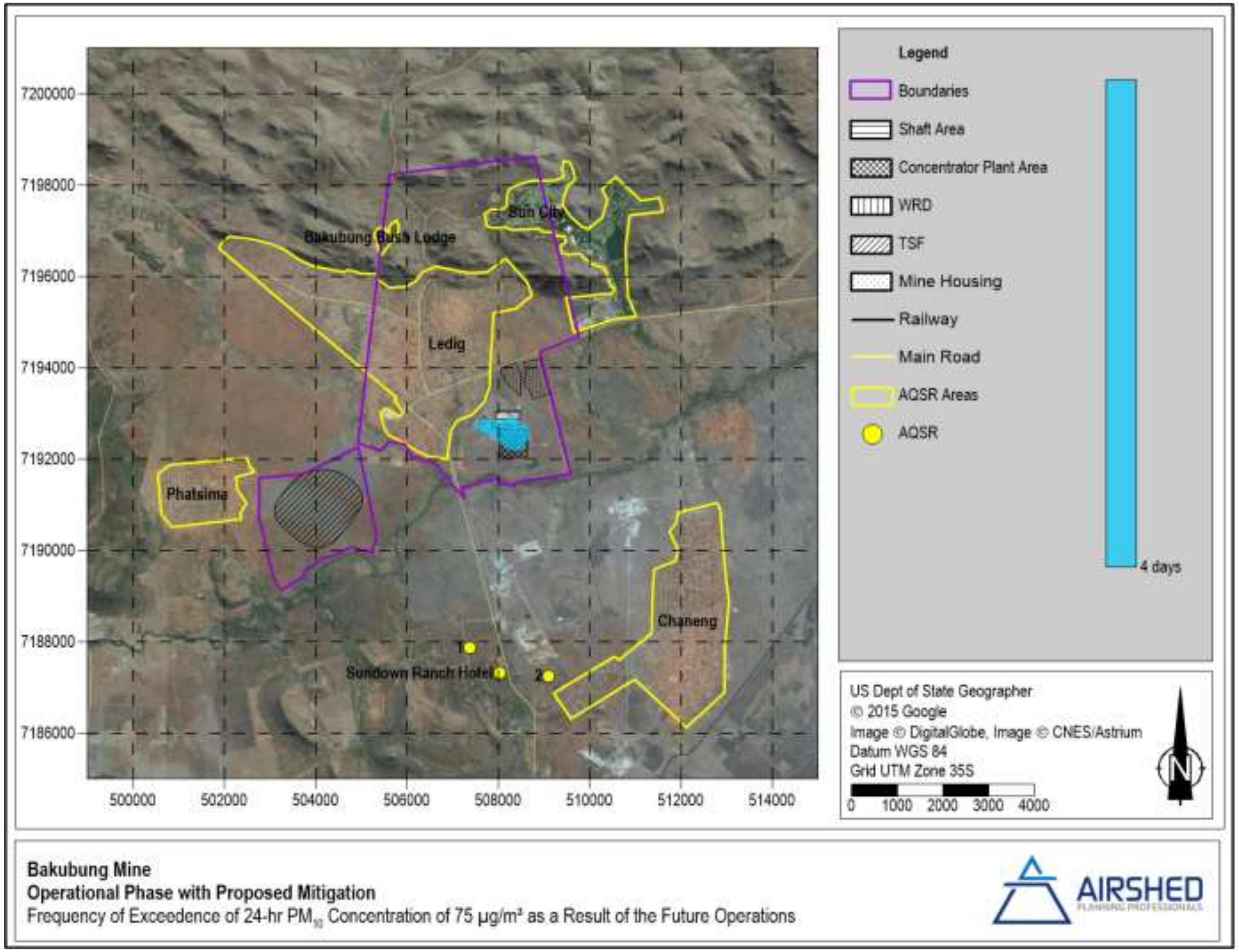


**Figure 4-7: Design mitigated operational phase - Area of exceedance of the NAAQS for daily average $PM_{10}$ concentrations**

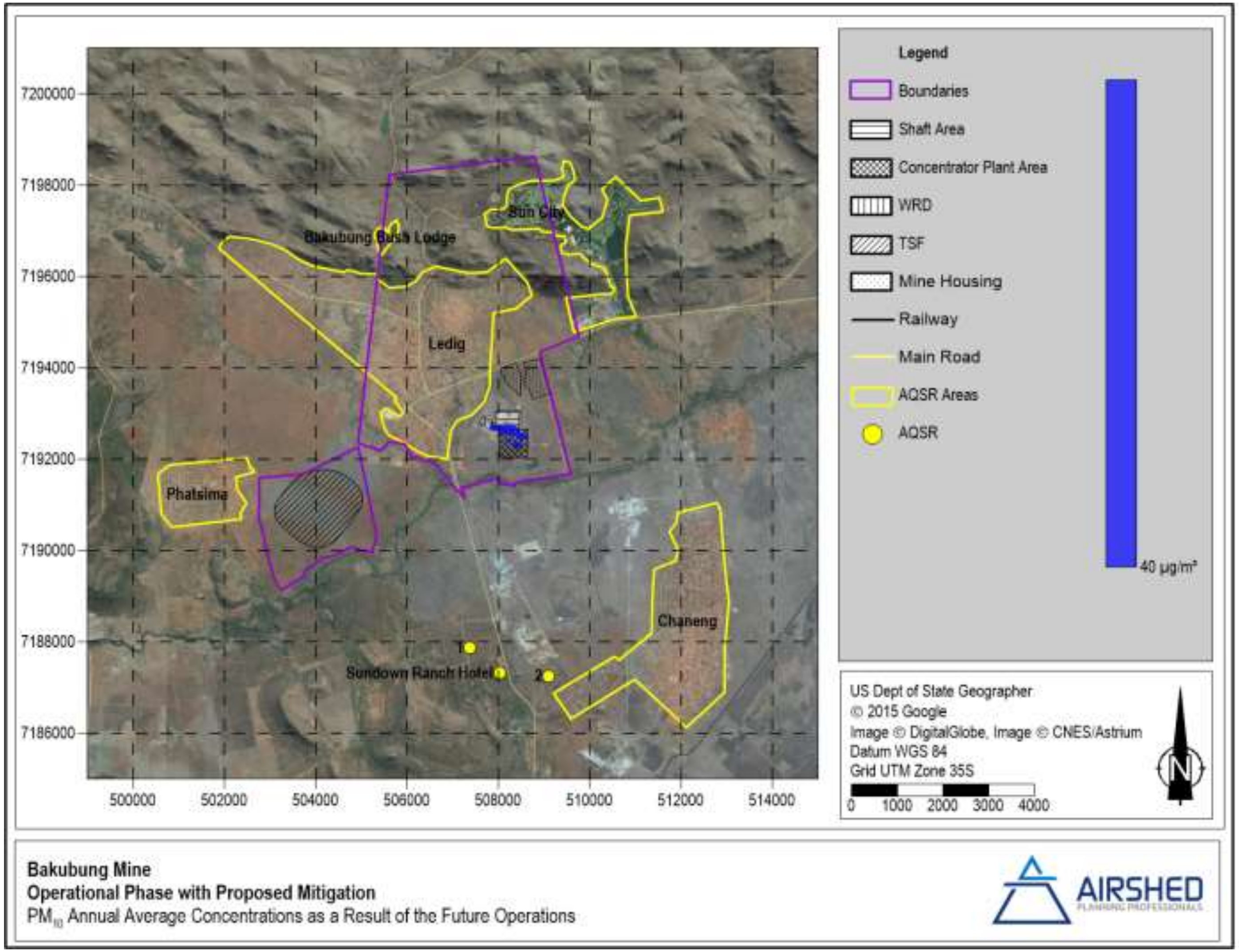


Figure 4-8: Design mitigated operational phase - Area of exceedance of the NAAQS for annual average $PM_{10}$ concentrations

#### *4.2.2.3 DPM*

- Simulated incremental DPM concentrations as a result of underground vehicle exhaust emissions are low and do not exceed the selected annual evaluation criterion of 5 µg/m³ on-site, at any of the sensitive receptor or off-site.
- Due to the absence of ambient air quality data, cumulative (baseline concentrations and future BPM GLCs) DPM concentrations could not be determined.
- Increased lifetime cancer risk as a result of chronic exposure to DPM is considered ‘low’ (between 1 in 1 million and 1 in 10 000) at sensitive receptors.

#### *4.2.2.4 CO*

- Simulated incremental CO concentrations as a result of underground and plant vehicle exhaust emissions are low and do not exceed the selected evaluation criterion of 30 000 µg/m³ more than 88 hours per year.
- Due to the absence of ambient air quality data, cumulative CO concentrations could not be determined.

#### *4.2.2.5 $NO_2$*

As a conservative measure, and in the absence of accurate $O_3$ concentrations, it was assumed that 20% of all $NO_x$ emitted from underground and plant vehicle exhausts will be in the form of $NO_2$. According to literature, between 10% and 20% of $NO_x$ emissions from vehicle combustion will be $NO_2$ (Howard, 1988).

- Simulated $NO_2$ concentrations as a result of underground and plant vehicle exhaust emissions do not exceed the annual or hourly NAAQSs on or off-site.
- Taking into account the ambient air quality data, cumulative $NO_2$ hourly concentrations could exceed the NAAQ limit of 200 µg/m³ more than 88 hours per year on-site, at sensitive receptor areas or off-site. Over an annual average, the cumulative $NO_2$ GLCs are not likely to exceed the NAAQS of 40 µg/m³ on-site, at any of the sensitive receptors or off-site.

#### *4.2.2.6 $SO_2$*

- Simulated hourly $SO_2$ concentrations as a result of underground and plant vehicle exhaust emissions do not exceed the annual, daily or hourly NAAQSs on or off-site.
- Taking into account the ambient air quality data, cumulative $SO_2$ concentrations are not likely to exceed NAAQS either.

#### *4.2.2.7 VOC*

- Simulated incremental VOC concentrations as a result of underground and plant vehicle exhaust emissions do not exceed the selected annual evaluation criteria of 100 µg/m³ on-site, at any sensitive receptors or off-site.
- Due to the absence of ambient air quality data, cumulative VOC concentrations could not be determined.

- Increased lifetime cancer risk as a result of chronic exposure to VOCs is considered 'low' (between 1 in 1 million and 1 in 10 000) at sensitive receptors.

### *4.2.3 Closure Phase*

Dispersion modelling was not possible due to limited information on the closure schedule. It is anticipated that the closure phase activities would result in low off-site $PM_{2.5}$, $PM_{10}$, DPM, $NO_2$, CO, $SO_2$ and VOCs GLCs.

### *4.2.4 Post Closure Phase*

No $PM_{2.5}$, $PM_{10}$, DPM, $NO_2$, CO, $SO_2$ and VOC emissions or impacts due to the BPM are expected post-closure.

## 4.3 Analysis of Emissions' Impact on the Environment (Dustfall) (Incremental and Cumulative)

### *4.3.1 Construction Phase*

Impacts associated with construction are expected to be less significant than overall operational activities given the temporary nature of construction related activities.

### *4.3.2 Operational Phase*

- Incremental dustfall rates for ***unmitigated*** operations are below the SA NDCR limit of 600 mg/m²/day for residential areas at all of the sensitive receptor areas and off-site (Figure 4-9).
- Incremental dustfall rates for ***design mitigated*** operations are below the SA NDCR limit of 600 mg/m²/day for residential areas at all of the sensitive receptor areas and off-site (Figure 4-10).
- The main contributing sources to the ***unmitigated*** and ***design mitigated*** dustfall rates is materials handling followed by crushing and screening.
- Based on the ambient dustfall rates which include background sources and current BPM operations, cumulative (ambient and future BPM) dustfall rates not likely to be in exceedance of the SA NDCR limit of 600 mg/m²/day for residential areas, exceedences of the 400 mg/m²/day at the reserve are also not likely.

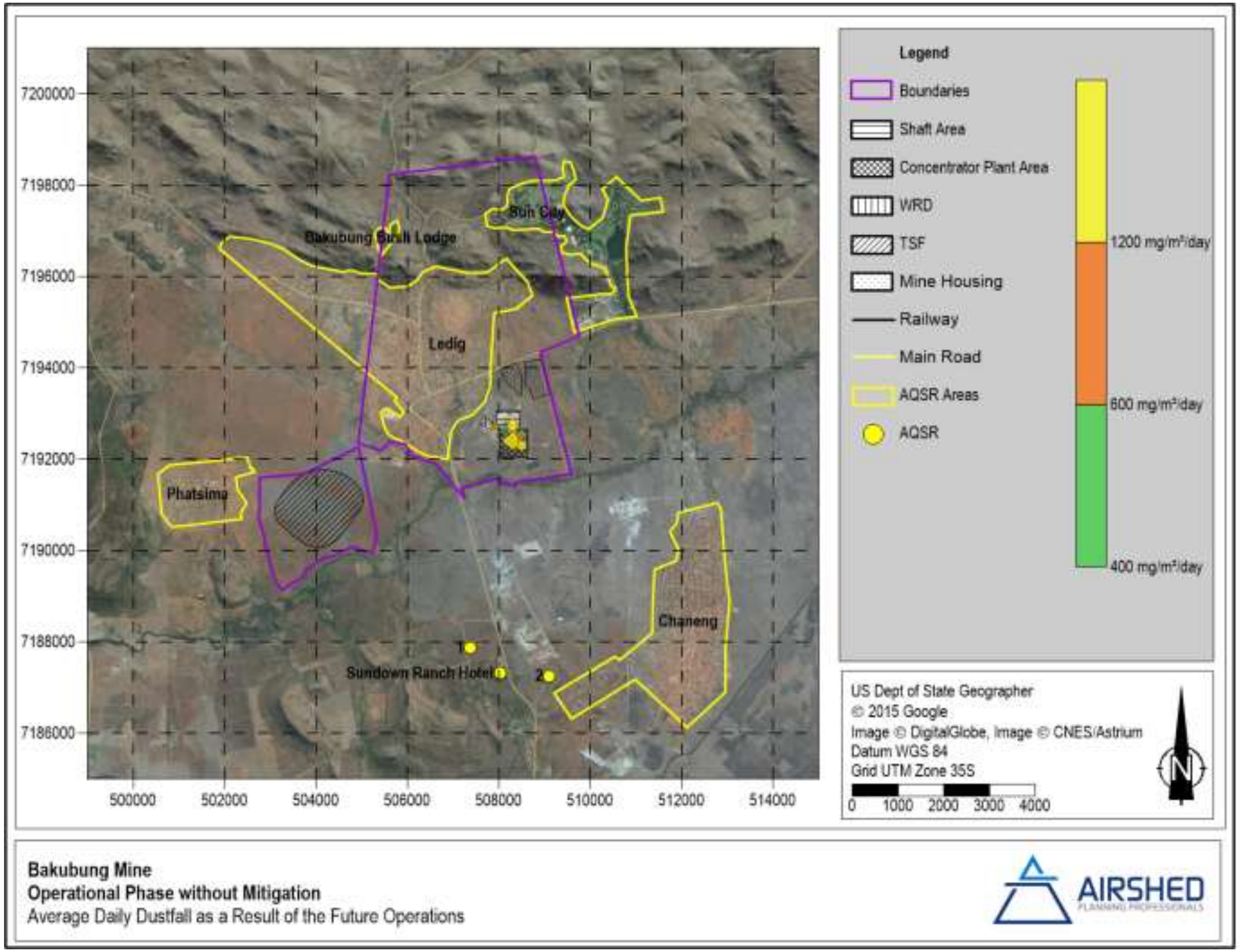


**Figure 4-9: Predicted unmitigated daily dustfall rates (SA NDCR residential limit is 600 mg/m²/day)**

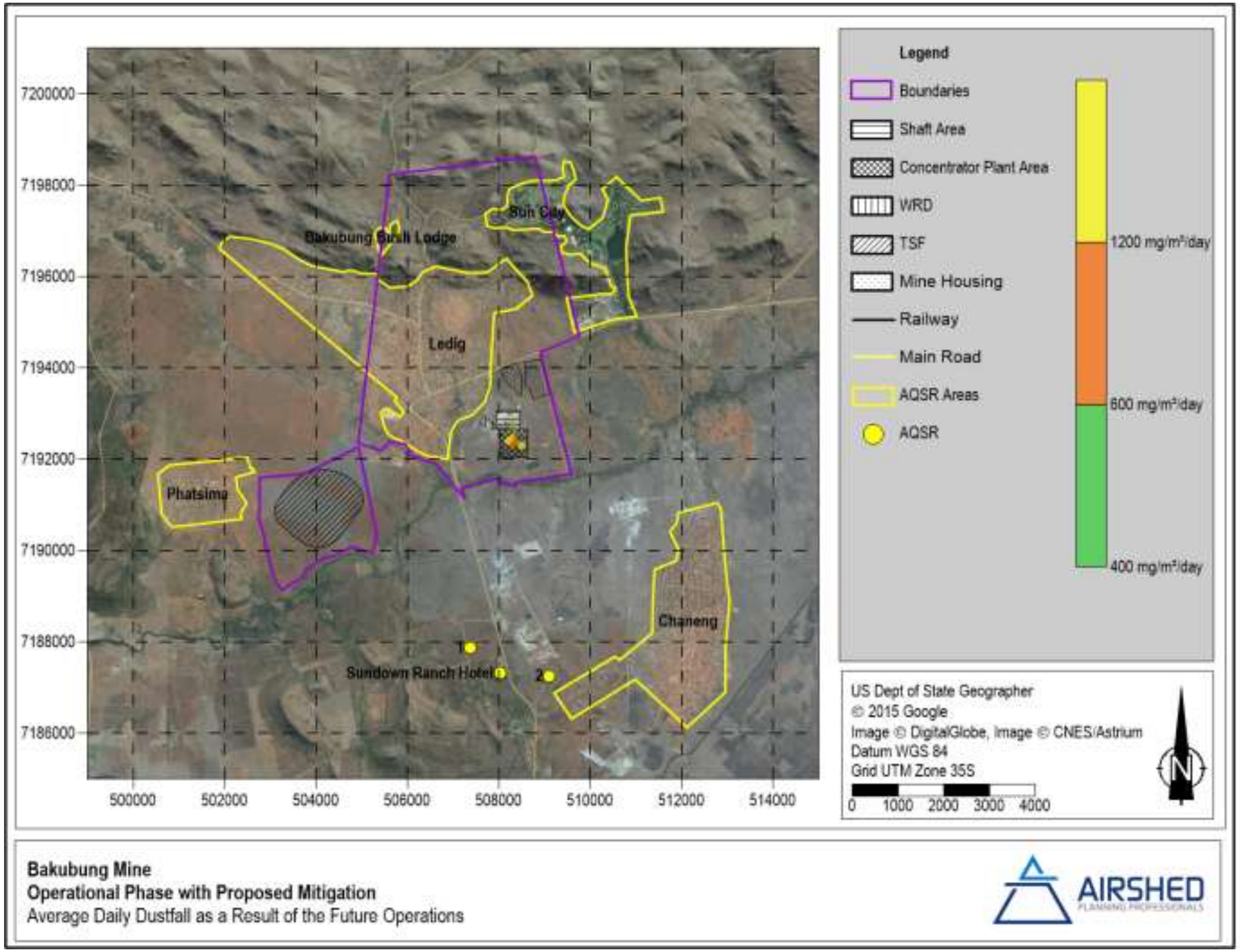


**Figure 4-10: Predicted design mitigated daily dustfall rates (SA NDCR residential limit is 600 mg/m²/day)**

### *4.3.3 Closure Phase*

It is anticipated that the various closure activities would result in low off-site dustfall rates.

### *4.3.4 Post Closure Phase*

No dustfall impacts due to the BPM are expected post-closure.

## 4.4 Impact Significance Rating

The impact assessment is summarised in the subsequent tables for the different phases. Table 4-9 provides the significance rating for the construction phase with the evaluation of the operational phase provided in Table 4-10. The significance rating for the closure phase is provided in Table 4-11. The methodology is discussed in Appendix D.

### *4.4.1 Construction Phase*

**ISSUE: REDUCTION IN AIR QUALITY IN THE AREA DUE TO CONSTRUCTION ACTIVITIES**

**Rating of Impact – Unmitigated Construction**

Severity / nature

The severity of unmitigated construction activities is expected to have moderate/ measurable deterioration (discomfort) for $PM_{2.5}$ and $PM_{10}$ as the recommended level (daily NAAQ limit) will occasionally be violated. There is only likely to be widespread complaints in Ledig and at the mine housing after a significant duration of time. The severity of unmitigated construction activities is expected to have minor deterioration (nuisance or minor deterioration) for dustfall as the change in dustfall rates will remain in the current range. The recommended level (NDCR residential limit) will likely never be violated off-site or at sensitive receptor areas. There is likely to be sporadic complaints.

Duration

The duration of unmitigated construction activities is short term as it is less than the project life, probably 3 years.

Spatial scale / extent

The spatial scale / extent for $PM_{2.5}$ and $PM_{10}$ due to construction is likely to be fairly widespread but local as exceedences of the daily NAAQS are likely to reach beyond the site boundary and occur at sensitive receptor areas.

The spatial scale / extent for dustfall due to unmitigated construction activities is likely to be localised as exceedences of the NDCR limit for residential areas is likely to occur within the site boundary and not off-site or at any of the sensitive receptor areas.

Probability

The probability of exceedences of the selected criteria off-site and at sensitive receptor areas due to unmitigated construction activities is “possible”.

**Rating of Impact – Mitigated Construction**

Severity / nature

The severity of mitigated construction activities is expected to have minor deterioration (nuisance or minor deterioration) as the change in dustfall rates and $PM_{2.5}$ and $PM_{10}$ concentrations will remain in the current range. The recommended levels will likely never be violated off-site or at sensitive receptor areas. There is likely to be sporadic complaints.

Duration

The duration of mitigated construction activities is short term as it is less than the project life, probably 3 years.

Spatial scale / extent

The spatial scale / extent due to mitigated construction activities is likely to be localised as exceedences recommended levels is likely to occur within the site boundary and not off-site or at any of the sensitive receptor areas.

Probability

The probability of exceedences of the selected criteria off-site and at sensitive receptor areas due to mitigated construction activities is "possible".

### *4.4.2 Future Operational Phase*

**ISSUE: REDUCTION IN AIR QUALITY IN THE AREA DUE TO FUTRE OPERATIONAL ACTIVITIES**

**Rating of Impact – Unmitigated Future Operations**

Severity / nature

The severity of unmitigated future operational activities is expected to have substantial deterioration (death, illness or injury) for $PM_{2.5}$ and $PM_{10}$ as the recommended level (daily NAAQ limit) will often be violated. There is likely to be vigorous community action in Ledig and at the mine housing after a significant duration of time.

The severity of unmitigated future operational activities is expected to have minor deterioration (nuisance or minor deterioration) for dustfall, $SO_2$, $NO_2$, CO, DPM and VOCs as the change in dustfall rates and $SO_2$, $NO_2$, CO, DPM and VOC concentrations will remain in the current range. The recommended levels will likely never be violated off-site or at sensitive receptor areas. There is likely to be sporadic complaints.

Duration

The duration of unmitigated future operational activities is "medium term" as it is the project life.

Spatial scale / extent

The spatial scale / extent for $PM_{2.5}$ and $PM_{10}$ due to future operational activities is likely to be fairly widespread but local as exceedences of the daily NAAQS are likely to reach beyond the site boundary and occur at sensitive receptor areas.

The spatial scale / extent for dustfall, $SO_2$, $NO_2$, CO, DPM and VOCs due to unmitigated future operational activities is likely to be localised as exceedences of the selected criteria is likely to occur within the site boundary and not off-site or at any of the sensitive receptor areas.

Probability

The probability of exceedences of the selected criteria off-site and at sensitive receptor areas due to unmitigated future operational activities is possible. Possible has been selected due to the inherent error in the model.

**Rating of Impact – Mitigated Future Operations**

Severity / nature

The severity of mitigated future operational activities is expected to have substantial deterioration (death, illness or injury) for $PM_{2.5}$ as the recommended level (daily NAAQ limit) will often be violated. There is likely to be vigorous community action in at the mine housing after a significant duration of time.

The severity of unmitigated future operational activities is expected to have minor deterioration (nuisance or minor deterioration) for $PM_{10}$ and dustfall as the change in dustfall rates and $PM_{10}$ concentrations will remain in the current range.

The recommended levels will likely never be violated off-site or at sensitive receptor areas. There is likely to be sporadic complaints.

Duration

The duration of unmitigated future operational activities is "medium term" as it is the project life.

Spatial scale / extent

The spatial scale / extent for $PM_{2.5}$ due to mitigated future operational activities is likely to be fairly widespread but local as exceedences of the daily NAAQS are likely to reach beyond the site boundary and occur at sensitive receptor areas.

The spatial scale / extent for $PM_{10}$ and dustfall due to mitigated future operational activities is likely to be localised as exceedences of the selected criteria is likely to occur within the site boundary and not off-site or at any of the sensitive receptor areas.

Probability

For $PM_{2.5}$ the probability of exceedences of the selected criteria off-site and at sensitive receptor areas due to mitigated operational phase activities is "possible" to "unlikely", as the ventilation shaft emissions which are the contributor to exceedences off-site and at the mine housing are not likely to be the same as the total PM emissions as has been assumed.

For $PM_{10}$ and dustfall the probability of exceedences of the selected criteria off-site and at sensitive receptor areas due to mitigated future operational activities is possible. Possible has been selected due to the inherent uncertainty in the model.

### *4.4.3 Closure Phase*

**ISSUE: REDUCTION IN AIR QUALITY IN THE AREA DUE TO DECOMMISSIONING ACTIVITIES**

**Rating of Impact – Decommissioning**

Severity / nature

The severity of unmitigated decommissioning activities is expected to have moderate/ measurable deterioration (discomfort) for $PM_{2.5}$ and $PM_{10}$ as the recommended level (daily NAAQ limit) will occasionally be violated. There is only likely to be widespread complaints in Ledig and at the mine housing after a significant duration of time.

The severity of unmitigated closure activities is expected to have minor deterioration (nuisance or minor deterioration) for dustfall as the change in dustfall rates will remain in the current range. The recommended levels will likely never be violated off-site or at sensitive receptor areas. There is likely to be sporadic complaints.

Duration

The duration of unmitigated decommissioning activities is short term as it is less than the project life.

Spatial scale / extent

The spatial scale / extent for $PM_{2.5}$ and $PM_{10}$ due to unmitigated decommissioning is likely to be fairly widespread as exceedences of the daily NAAQS will likely reach beyond the site boundary and sensitive receptor areas during decommissioning operations.

The spatial scale / extent for dustfall due to unmitigated decommissioning activities is likely to be localised as exceedences of the NDCR limit for residential areas is likely to occur within the site boundary and not off-site or at any of the sensitive receptor areas.

Probability

The probability of exceedences of the selected criteria off-site and at sensitive receptor areas due to unmitigated decommissioning activities is "possible".

**Table 4-9: Impact assessment summary table for the construction phase**

| Scenario | Impact | Severity/ Nature of Impact | Duration of Impact[a] | Spatial Scale of Impacts[b] | Consequence | Probability[c] | SIGNIFICANCE | Mitigation Measures |
|---|---|---|---|---|---|---|---|---|
| Construction - Unmitigated | $PM_{2.5}$ | M | L | M | M | M | Medium | None |
| | $PM_{10}$ | M | L | M | M | M | Medium | |
| | Dustfall | L | L | L | L | M | Low | |
| Construction - Mitigated | $PM_{2.5}$ | L | L | L | L | M | Low | Use of water sprays.<br>Minimise travel distances.<br>Freshly graded areas to be kept to a minimum. |
| | $PM_{10}$ | L | L | L | L | M | Low | |
| | Dustfall | L | L | L | L | M | Low | |

**Notes:**

(a) For construction period only

(b) Not entire area will be constructed at once, it was assumed that approximately 25% of infrastructure area will be constructed per month thus the$PM_{2.5}$ and $PM_{10}$ impacts are widespread but local for times when the construction occurs near the AQSRs/boundary and will become localised with mitigation applied.

**Table 4-10: Impact assessment summary table for the operational phase**

| Scenario | Impact | Severity/ Nature of Impact | Duration of Impact | Spatial Scale of Impacts | Consequence | Probability | SIGNIFICANCE | Mitigation Measures |
|---|---|---|---|---|---|---|---|---|
| Operational - Unmitigated | $PM_{2.5}$ | H | M | M | M | M | Medium | None |
| | $PM_{10}$ | H | M | M | M | M | Medium | |
| | Dustfall | L | M | L | L | M | Low[a] | |
| | $SO_2$ | L | M | L | L | M | Low[a] | |

| Scenario | Impact | Severity/ Nature of Impact | Duration of Impact | Spatial Scale of Impacts | Consequence | Probability | SIGNIFICANCE | Mitigation Measures |
|---|---|---|---|---|---|---|---|---|
|  | $NO_2$ | L | M | L | L | M | Low[(a)] |  |
|  | CO | L | M | L | L | M | Low[(a)] |  |
|  | DPM | L | M | L | L | M | Low[(a)] |  |
|  | VOC | L | M | L | L | M | Low[(a)] |  |
| Operations – Design Mitigated | $PM_{2.5}$ | H | M | M | M | M - L | Medium - Low | Water sprays on unpaved roads and at materials handling points.<br>Enclosure with fabric filters at crushers and screens |
|  | $PM_{10}$ | L | M | L | L | L[(a)] | Low |  |
|  | Dustfall | L | M | L | L | L[(a)] | Low |  |

**Notes:** (a) The GLCs are low and the selected criteria are not exceeded at any of the sensitive receptors or off-site thus from an air quality perspective the probability is likely to be low.

**Table 4-11: Impact assessment summary table for the closure phase**

| Scenario | Impact | Severity/ Nature of Impact | Duration of Impact[(a)] | Spatial Scale of Impacts | Consequence | Probability | SIGNIFICANCE |
|---|---|---|---|---|---|---|---|
| Closure - Unmitigated | $PM_{2.5}$ | M | L | M | M | M | Medium |
|  | $PM_{10}$ | M | L | M | M | M | Medium |
|  | Dustfall | L | L | L | L | M | Low |

**Notes:** (a) For closure period only

# 5 RECOMMENDED AIR QUALITY MANAGEMENT MEASURES

It is recommended that the project proponent commit itself to air quality management planning throughout the life of the operations. This section expands on the air quality management plan for the future BPM operations.

## 5.1 Air Quality Management Objectives

It is recommended that air quality management planning forms part of the construction, operational phase and decommissioning/closure of BPM. The air quality management plan provides options on the control of dust at the main sources with the monitoring network designed as such to track the effectiveness of the mitigation measures. The sources need to be ranked according to sources strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

In places of constant human occupation pollutant concentrations should not exceed the selected criteria and dustfall rates should be below the SA NDCR residential limit of 600 mg/m²/day. In the places of vegetation growing within the communities and the game reserves dustfall rates should be below 400 mg/m²/day. On-site dustfall rates should be below the SA NDCR non-residential limit of 1 200 mg/m²/day.

## 5.2 Source Ranking

Source ranking focuses on the operational phase since the construction phase and decommissioning and closure phase were not assessed in detail. The ranking of sources serves to determine the significance of specific sources and to evaluate the emission reduction potentials required for each. Sources of emissions during the unmitigated and design mitigated future operational phase of the BPM may be ranked based on emissions and impacts.

### *5.2.1 Ranking of Sources by Emissions*

*Unmitigated*

The most significant source of $PM_{2.5}$ and $PM_{10}$ emissions are the ventilation shafts – this mainly due to the conservative assumption that all the particulate matter measured is $PM_{2.5}$. The most significant source of TSP emissions is crushing and screening. The second most significant source of $PM_{2.5}$ and $PM_{10}$ emissions is crushing and screening. The second most significant source of TSP emissions is ventilation shafts. The only source of DPM is ventilation shafts (underground vehicle exhausts). The greatest source of $NO_2$, $SO_2$, CO and VOCs emissions is ventilation shafts (underground vehicle exhausts).

*Design mitigated*

With design mitigation in place, the main contributor to $PM_{2.5}$, $PM_{10}$ and TSP emissions is the ventilation shafts followed by crushing and screening. The only source of DPM is ventilation shafts (underground vehicle exhausts). The greatest source of $NO_2$, $SO_2$, CO and VOCs emissions is ventilation shafts (underground vehicle exhausts).

### *5.2.2 Ranking of Sources by Impact*

- The main contributing sources to the unmitigated $PM_{2.5}$ simulated concentrations is the crushing and screening. The main contributing sources to the design mitigated $PM_{2.5}$ simulated concentrations are the ventilation shafts. The source that contributes the least to the unmitigated and design mitigated $PM_{2.5}$ simulated concentrations was surface (plant) vehicle exhausts.

- The main contributing sources to the unmitigated $PM_{10}$ simulated concentrations were crushing and screening. The main contributing sources to the design mitigated $PM_{10}$ simulated concentrations were vehicles travelling on unpaved roads. The source that contributes the least to the unmitigated and design mitigated $PM_{10}$ simulated concentrations was the surface (plant) vehicle exhausts.
- The main contributing sources to the unmitigated and design mitigated simulated dustfall is the materials handling. The source that contributes the least to the unmitigated and design mitigated simulated dustfall is the surface (plant) vehicle exhausts.

## 5.3 Source Specific Recommended Management and Mitigation Measures

The minimum mitigation measures must be achieved; it is not necessary that additional mitigation measures be considered. The mitigation measures are briefly discussed below (Table 5-1 for construction phase, Table 5-2 for the operational phase and Table 5-3 for decommissioning and closure phase) (in more detail in Appendix E).

**Table 5-1: Air Quality Management Plan: construction phase of the BPM additions**

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Land clearing activities such as bulldozing and scraping of road and blasting | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Water sprays at area to be cleared.<br>Moist topsoil will reduce the potential for dust generation when tipped onto stockpiles.<br>Ensure travel distance between clearing area and topsoil piles to be at a minimum. | Contractor(s)<br>BPM Environmental Manager | During construction |
| Road construction activities such as road grading | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Water sprays at area to be graded.<br>Freshly graded areas to be kept to a minimum.<br>During construction operations monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |
| Wind erosion from exposed areas | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Ensure exposed areas remain moist through regular water spraying during dry, windy periods.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |

**Notes:**

(a) SA NDCR residential limit of 600 mg/m²/day

(b) SA NDCR non-residential limit of 1 200 mg/m²/day

**Table 5-2: Air Quality Management Plan: operational phase of the BPM**

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Ventilation shafts (underground mining emissions) | $PM_{10}$, $PM_{2.5}$, $NO_2$, $SO_2$, CO and DPM concentrations and dustfall rates | It is recommended that a mitigation measure of water sprays on underground roads resulting in 75% CE.<br>Shorter haul routes would reduce emissions.<br>It is recommended that a mitigation measure of water sprays at underground materials handling points resulting in 50% CE.<br>It is recommended that a mitigation measure of water sprays at underground drilling resulting in 70% CE.<br>Vehicle exhausts – vehicle inspection and maintenance programs.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | BPM Environmental Manager | On-going during operational phase |
| Vehicle activity on unpaved roads | $PM_{10}$, $PM_{2.5}$, $NO_2$, $SO_2$, CO and DPM concentrations and dustfall rates | A minimum mitigation measure of water sprays resulting in 75% CE.<br>Shorter haul routes would reduce emissions.<br>Speed limits on all the BPM roads.<br>Vehicle exhausts – vehicle inspection and maintenance programs.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |
| Vehicle activity on paved roads | $PM_{10}$, $PM_{2.5}$, $NO_2$, $SO_2$, CO and DPM concentrations and dustfall rates | Shorter haul routes would reduce emissions.<br>Speed limits on all the BPM roads.<br>Vehicle exhausts – vehicle inspection and maintenance programs.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |
| Materials handling | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | A minimum mitigation measure of water sprays resulting in 50% CE.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |
| Crushing and screening | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | A minimum mitigation measure of enclosure with fabric filters resulting in 83% CE.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |
| Wind erosion | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Keep active TSF and WRD surfaces to a minimum.<br>Monthly dustfall rates should not exceed 600 mg/m²/day(a) at residential dustfall bucket locations and 1 200 mg/m²/day(b) at non-residential dustfall bucket locations. | | |

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| General | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Monthly dustfall rates should not exceed 600 mg/m²/day[(a)] at residential dustfall bucket locations and 1 200 mg/m²/day[(b)] at non-residential dustfall bucket locations.<br>$PM_{2.5}$ and $PM_{10}$ ambient samplers with no exceedences of the selected criteria.<br>$SO_2$ and $NO_2$ ambient samplers with no exceedences of the selected criteria. | | |

**Notes:**

(a) SA NDCR residential limit of 600 mg/m²/day.

(b) SA NDCR non-residential limit of 1 200 mg/m²/day

**Table 5-3: Air Quality Management Plan: decommissioning and closure phase (rehabilitation activities) for the BPM**

| Aspect | Impact | Management Actions/Objectives | Responsible Person(s) | Target Date |
|---|---|---|---|---|
| Wind erosion from exposed areas | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Demolition of infrastructure to have water sprays where a lot of vehicle activity is required.<br>Ensure site is restored to pre-mining conditions. | Contractor(s)<br>BPM Environmental Manager | Post-operational, can cease once rehabilitation is in place |

## 5.4 Performance Indicators

Increasingly, environmental indicators are used in Environmental Land Use Planning and Management to simplify environmental assessments.

Indicators are defined as a single measure of a condition of an environmental element that represents the status or quality of that element. An index is a combination of a group of indicators to measure the overall status of an environmental element, and a threshold is the value of an indicator or index. For example, ambient $PM_{10}$ concentrations monitored within a specific area will be the indicator, with the NAAQS being the threshold.

It is recommended that the selected criteria as listed in Section 2 be adopted as indicators for the BPM.

### *5.4.1 Performance Indicators*

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

Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of wind erosion exists represents an example of a source-based indicator, whereas maintaining off-site and receptor dustfall rates to below 600 mg/m$^2$/day represents an impact- or receptor-based performance indicator. Criteria for pollutant concentrations and dustfall rates have been published as indicated in Section 2. The adopted evaluation criteria discussed in Section 2 should not be exceeded.

### *5.4.2 Specification of Source Based Performance Indicators*

The absence of visible dust plume at all tipping points, crushers and screens would be the best indicator of effective control equipment in place. In addition, the dustfall rates in the immediate vicinity of various sources should be less than 1 200 mg/m$^2$/day. Dustfall rates from all activities associated with the BPM should not exceed 600 mg/m$^2$/day off-site or at sensitive receptors. If blasting takes place during construction it would always result in significant dust generation but the impacts need to be controlled by ensuring blasting only occurs during midday when there is no inversion layer and for as short durations as possible. In addition the dust fallout in the immediate vicinity of where the blasting occurs should be less than 1200 mg/m$^2$/day.

### *5.4.3 Receptor based Performance Indicators*

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

- Dustfall monitoring should continue to be conducted. Monitoring should be undertaken using the American Society for Testing and Materials standard test method for the collection and analysis of dustfall (ASTM D-1739) (ASTM D1739-98 , 2004). Log sheets should be kept providing information on the surrounding conditions (such as construction activities), sampling date and duration. This is essential for reporting on the dustfall rates.
- It is recommended that the meteorological station be kept in good working order.

- It is recommended that $SO_2$ and $NO_2$ sampling continue to be conducted at the current sites. Log sheets should be kept providing information on the surrounding conditions (such as construction activities), sampling date, duration and filter number. This is essential for reporting on the $SO_2$ and $NO_2$ concentrations.
- It is recommended that $PM_{10}$ sampling continue to be conducted at the current site. Log sheets should be kept providing information on the surrounding conditions (such as construction activities), sampling date, duration, flow rate and filter number. This is essential for reporting on the $PM_{10}$ concentrations.
- It is further recommended that $PM_{2.5}$ sampling be conducted near the current $PM_{10}$ sampling site. Log sheets should be kept providing information on the surrounding conditions (such as construction activities), sampling date, duration, flow rate and filter number. This is essential for reporting on the $PM_{2.5}$ concentrations.

## 5.5 Monitoring

### *5.5.1 Source Monitoring*

No additional monitoring at sources is necessary.

### *5.5.2 Ambient Air Quality Monitoring*

- Dustfall collection provides a useful and cost effective tool to track the success of mitigation measures and overall dust generation from the BPM. It is recommended that the proposed mine continues with monthly dustfall monitoring as well as ambient $SO_2$, $NO_2$ and $PM_{10}$ monitoring.
- It is recommended that $PM_{2.5}$ sampling be conducted to determine if there are significant $PM_{2.5}$ concentrations. The recommended location for the $PM_{2.5}$ sampling would be close to the current $PM_{10}$ sampling site.
- It is recommended that the on-site meteorological monitoring remain where it is located (Figure 3-2) and be kept in good working order. The meteorological station must be calibrated at least once a year with regular span checks and data validation carried out to ensure the data reported are correct.

## 5.6 Record-keeping, Environmental Reporting and Community Liaison

### *5.6.1 Periodic Inspections and Audits*

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during operations, with annual environmental audits being conducted. Annual environmental audits form part of the overall environmental management systems (EMS) at the mine. 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.

### *5.6.2 Liaison Strategy for Communication with I&APs*

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

# 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Main Conclusions

The main conclusion is that the unmitigated future BPM operations are likely to result in exceedances of the NAAQS for $PM_{2.5}$ and $PM_{10}$ at nearby sensitive receptor areas. Assessing the unmitigated cumulative impacts, there is the possibility of exceedances of the NAAQS outside the project boundary and at the sensitive receptor areas due to possible elevated concentrations from current and future sources at the mine. With mitigation measures in place – waters sprays on unpaved roads and at materials handling points, and enclosure of crushers and screens with fabric filters – ambient pollutant concentrations as a result of the future BPM operations will reduce significantly although cumulative $PM_{2.5}$ concentrations are still likely to be in exceedance at the mine housing. There is the possibility of $NO_2$ hourly NAAQS being exceeded on a cumulative basis as the ambient hourly $NO_2$ is already in exceedance of the NAAQ limit during multiple months.

Although there are no exceedences of the NAAQS and NDCRs at and surrounding the TSF there is still likely to be dust generated from the TSF during period of high wind speeds.

The environmental significance of the future operations is “medium” for fine particulates and “low” for dustfall, $SO_2$, $NO_2$, CO, DPM and VOCs without mitigation applied; and, “medium to low” for $PM_{2.5}$ and “low” for $PM_{10}$ and dustfall with design mitigation applied.

## 6.2 Recommendations

It is recommended that the proposed management and mitigation measures as set out in Section 5 be implemented. These include:

- Reduction of emissions from ventilation shafts through effective mitigation of underground activities (water sprays on roads, at materials handling points and drilling)
- Continuation of dustfall and ambient $SO_2$, $NO_2$ and $PM_{10}$ sampling;
- Addition of $PM_{2.5}$ sampling; and
- Continuation of meteorological recordings.

Based on these conclusions and provided the recommended measures are in place, it is the specialist opinion that the project may be authorised.

# 7 REFERENCES

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# 8 APPENDIX A: DUST EFFECTS ON VEGETATION AND ANIMALS

## 8.1 Dust Effects on Vegetation

Suspended particulate matter can produce a wide variety of effects on the physiology of vegetation that in many cases depend on the chemical composition of the particle. Heavy metals and other toxic particles have been shown to cause damage and death of some species as a result of both the phytotoxicity and the abrasive action during turbulent deposition (Harmens et al, 2005). Heavy loads of particle can also result in reduced light transmission to the chloroplasts and the occlusion of stomata (Harmens et al, 2005; Naidoo and Chirkoot, 2004), decreasing the efficiency of gaseous exchange (Harmens et al, 2005; Naidoo and Chirkoot, 2004, Ernst, 1981) and hence water loss (Harmens et al, 2005). They may also disrupt other physiological processes such as budbreak, pollination and light absorption/reflectance (Harmens et al, 2005). The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH (Spencer, 2001).

To determine the impact of dust deposition on vegetation, two factors are of importance: (i) Does dust collect on vegetation and if it does, what are the factors influencing the rate of deposition (ii) Once the dust has deposited, what is the impact of the dust on the vegetation?

Regarding the first question, there is adequate evidence that dust does collect on all types of vegetation. Any type of vegetation causes a change in the local wind fields, with an increase in turbulence which enhances the collection efficiency. The characteristics of the vegetation influences the rate; the larger the “collecting elements” (branches and leaves), the lower the impaction efficiency per element. This would seem to indicate that, for the same volume of tree/shrub canopy, finer leaves will have a better collection efficiency. However, the roughness of the leaves themselves and particularly the presence of hairs on the leaves and stems plays a significant role, with veinous surfaces increasing deposition of 1-5 micron particles by up to seven times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; for moderate wind speeds wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size (Tiwary and Colls 2010). In wind tunnel studies , windbreaks or “shelter belts” of three rows of trees has shown a decrease in 35 to 56% in the downwind mass transport of inorganic particles.

On the effect of particulate matter once it is deposited on vegetation, this depends on the composition of the dust. Internationally it is recognised that there are major differences in the chemical composition of the fine PM (the fraction between 0 and 2.5 µm in aerodynamic diameter) and coarse PM (the fraction between 2.5 µm and 10 µm in aerodynamic diameter). The former is often the result of chemical reactions in the atmosphere and may have a high proportion of black carbon, sulphate and nitrate, whereas the latter often consist of primary particles resulting from abrasion, crushing, soil disturbances and wind erosion (Grantz et al. 2003). Sulphate is however often hygroscopic and may exist in significant fractions in coarse PM. Alade 2010. Grantz *et al* (*op .cit.*) do however indicate that sulphate is much less phototoxic than gaseous sulphur dioxide and that “it is unusual for injurious levels of particular sulphate to be deposited upon vegetation”.

Naidoo and Chirkoot conducted a study during the period October 2001 to April 2002 to investigate the effects of coal dust on Mangroves in the Richards Bay harbour. The investigation was conducted at two sites where 10 trees of the Mangrove species: *Avicennia Marina* were selected and mature, fully exposed, sun leaves tagged as being covered or uncovered with coal dust. From the study it was concluded that coal dust significantly reduced photosynthesis of upper and lower leaf surfaces. The reduced photosynthetic performance was expected to reduce growth and productivity. In addition, trees in close proximity to the coal stockpiles were in poorer health than those further away. Coal dust particles, which are composed predominantly of carbon were found not to be toxic to the leaves; neither wasit found that it occlude stomata as these particles were larger than fully open stomatal apertures (Naidoo and Chirkoot, 2004).

In general, according to the Canadian Environmental Protection Agency (CEPA), air pollution adversely affects plants in one of two ways. Either the quantity of output or yield is reduced or the quality of the product is lowered. The former (invisible) injury results from pollutant impacts on plant physiological or biochemical processes and can lead to significant loss of growth or yield in nutritional quality (e.g. protein content). The latter (visible) may take the form of discolouration of the leaf surface caused by internal cellular damage. Such injury can reduce the market value of agricultural crops for which visual appearance is important (e.g. lettuce and spinach). Visible injury tends to be associated with acute exposures at high pollutant concentrations whilst invisible injury is generally a consequence of chronic exposures to moderately elevated pollutant concentrations. However given the limited information available, specifically the lack of quantitative dose-effect information, it is not possible to define a Reference Level for vegetation and particulate matter (CEPA, 1998).

Exposure to a given concentration of airborne PM may therefore lead to widely differing phytotoxic responses, depending on the mix of the deposited particles. The majority of documented toxic effects indicate responses to the chemical composition of the particles. Direct effects have most often been observed around heavily industrialised point sources, but even there, effects are often associated with the chemistry of the particulate rather than with the mass of particulate.

### 8.2 Dust Effects on Animals

Most of the literature regarding air quality impacts and animals, specifically cattle, refers to the impacts from feedlots on the surrounding environment, hence where the feedlot is seen as the source of pollution. This mainly pertains to odours and dust generation. The US EPA has recently started to focus on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter (Horzinek and Lutz, 2001). The National Cattle Beef Association in the USA in response has disputed this decision based on the lack of evidence on health impacts associated with coarse dust (TSP) concentrations.

A study was conducted by the State University of IOWA on the effects of air contaminants and emissions on animal health in swine facilities. Air pollutants included gases, particulates, bioaerosols, and toxic microbial by-products. The main findings were that ammonia is associated with lowered average number of pigs weaned, arthritis, porcine stress syndrome, muscle lesions, abscesses, and liver ascarid scars. Particulates are associated with the reduction in growth and turbine pathology, and bioaerosols could lower feed efficiency, decrease growth, and increase morbidity and mortality. The study concurred the lack of information on the health effects and productivity problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulphide are regarded the two most important inorganic gases affecting the respiratory system of cattle raised in confinement facilities, affecting the mucociliary transport and alveolar macrophage functions. With regard to particulates, it was found that it is the fine inhalable fraction that is mainly deriving from dried faecal dust (Holland et al., 2002). Another study conducted by DSM Nutritional Products North America indicated that calves exposed to a dust-stress environment continued to have lower serum vitamin E concentrations.

Inhalation of confinement house dust and gases produces a complex set of respiratory responses. An individual's response depends on characteristics of the inhaled components (such as composition, particle size and antigenicity) and of the individual's susceptibility, which is tempered by extant respiratory conditions. Most of the studies concurred that the main implication of dusty environments are causing animal stress which is detrimental to their health. However, no threshold levels exist to indicate at what levels these are having a negative effect. In this light it was decided to use the same screening criteria applied to human health, i.e. international standards and SA NDCR values.

# 9 APPENDIX B: EMISSIONS QUANTIFICATION METHODOLOGY

In the quantification of fugitive emissions such as fugitive dust releases from wind entrainment, vehicle entrainment, materials handling and crushing and screening it is recommended that use be made of emission equations and emission factors. Given that no local emission equations and emission factors are available it is proposed that reference be made to factors that are widely used internationally. The US EPA AP-42 Emission Data Base is widely used for the quantification of fugitive and diffuse sources. Although this data base does not separately address processing operations it provides a comprehensive list of emission factors for use in mining and industrial processes. Separate emission equations and emission factors are given for specific particle size ranges, viz. fine particulates ($PM_{10}$ and $PM_{2.5}$) and TSP. TSP is quantified for the purpose of assessing dust nuisance impact potentials, whereas $PM_{2.5}$ and $PM_{10}$ are of concern due to the potential for human health risks associated with these inhalable fractions.

## 9.1 Ventilation Shaft Emissions

Information on the equipment operated underground was available and thus vehicle exhaust emissions could be calculated. Blasting is an intermittent source. It was decided to use the calculated vehicle exhaust emission as the emission for the ventilation shafts' DPM, CO, $NO_x$, $SO_2$ and VOC. The total particulate emission from the ventilation shafts was provided. This was used as the $PM_{2.5}$, $PM_{10}$ and TSP emission rate.

DPM ($PM_{2.5}$), CO, $NO_x$, $SO_2$ and VOC emission factors published by the NPI (NPI, 2008) for diesel vehicles are provided in Table 9-3. The diesel $SO_2$ emission factor is based on 10 ppm sulphur content.

**Table 9-1: Diesel vehicle exhaust emission factors**

| Mobile Equipment Type | Unit | $PM_{2.5}$ | $PM_{10}$ | CO | $NO_x$ | $SO_2$ | VOCs |
|---|---|---|---|---|---|---|---|
| Diesel Vehicle Exhaust Emissions (miscellaneous industrial vehicle) | kg/kWh | $1.10x10^{-03}$ | $1.20x10^{-03}$ | $6.20x10^{-03}$ | $1.50x10^{-02}$ | $8.00x10^{-06}$ | $1.40x10^{-03}$ |

## 9.2 Fugitive Dust Emission Estimation

In the quantification of fugitive dust emissions such as materials handling operations and vehicle entrainment on unpaved roads use was primarily made of US EPA and NPI emission estimation factors and protocols.

### *9.2.1 Vehicle entrained dust from unpaved roads*

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from mining operations. The force of the wheels of vehicles travelling on the on-site unpaved roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

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

$$E = k*(s/12)^{a}*(W/3)^{b}*281.9 \qquad (1)$$

where,

***E*** = *emissions in g of particulates per vehicle kilometre travelled (g/VKT)*

***k*** = *particle size multiplier (dimensionless);*

**S** = *silt content of road surface material (%);*
**W** = *mean vehicle weight (tons)*

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 0.15 for $PM_{2.5}$, 1.5 for $PM_{10}$ and 4.9 for TSP. The constants a and b are given as 0.9 and 0.45 respectively for $PM_{2.5}$, 0.9 and 0.45 respectively for $PM_{10}$ and as 0.7 and 0.45 respectively for TSP.

### 9.2.2 Vehicle entrained dust from paved roads

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

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

$$E = k*(sL)^{0.91}*(W)^{1.02} \qquad (2)$$

Where,

*E* = *emissions in g of particulates per vehicle kilometre travelled (g/VKT)*
*K* = *particle size multiplier (dimensionless);*
*sL* = *silt loading of road surface material (g/m²);*
*W* = *mean vehicle weight (tonnes)*

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 0.15 for $PM_{2.5}$, 0.62 for $PM_{10}$ and 3.23 for TSP.

### 9.2.3 Materials handling

The quantity of dust that will be generated from miscellaneous materials handling operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles. The following US EPA AP42 predictive equation was used to estimate emissions from material transfer operations:

$$E = k*0.0016*(U/2.3)^{1.3}*(M/2)^{1.4} \qquad (3)$$

where,

**E** = *emissions in kg of particles per ton of material transferred*
**U** = *mean wind speed (m/s)*
**M** = *material moisture content (%)*
**k** = *particle size multiplier* ($k_{PM2.5} = 0.053$; $k_{PM10} = 0.35$; $k_{TSP} = 0.74$)

### 9.2.4 Crushing and screening

Crushing and screening operations can be a significant dust-generating source if uncontrolled. Dust fallout in the vicinity of crushers also give rise to the potential for re-entrainment of dust by vehicles or by wind at a later date. The large percentage of fines in the deposited material enhances the potential for it to become airborne.

Primary crushing, secondary crushing and screening will occur at the mine. Fugitive dust emissions due to the crushing and screening operations for mine were quantified using the NPI single valued emission factors for such operations. Emissions factors are provided for high moisture ore (moisture in excess of 4%) and low moisture ore (moisture less than 4%) (Table 9-2).

The crushing emission factors include emissions from the loading of crusher hoppers, crushing and unloading of crushers. The $PM_{2.5}$ emission factor is assumed to be 50% of the $PM_{10}$ emission factor.

**Table 9-2: Emission factors for metallic minerals crushing and screening**

| Source | Emission Factor (kg/ton material processed) | | | |
|---|---|---|---|---|
| | Low Moisture Material[(a)] | | High Moisture Material[(b)] | |
| | $PM_{10}$ | TSP | $PM_{10}$ | TSP |
| Primary crushing | 0.02 | 0.2 | 0.004 | 0.01 |
| Secondary crushing | 0.04 | 0.6 | 0.012 | 0.03 |
| Tertiary crushing | 0.08 | 1.40 | 0.01 | 0.03 |
| Screening | 0.06 | 0.06 | - | - |

Notes:

(a) Moisture content of 4% or less

(b) Moisture content more than 4%

### *9.2.5 Wind Erosion*

Wind erosion is a complex process, including three different phases of particle entrainment, transport and deposition. It is primarily influenced by atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) and land-use practice (e.g. farming, grazing and mining) (Shao, 2008).

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface, is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008).

Saltation and suspension are the two modes of airborne particles in the atmosphere. The former relates to larger sand particles that hop and can be deposited as the wind speed reduces or changes. Suspension refers to the finer dust particles that remain suspended in the atmosphere for longer and can disperse and be transported over large distances. It should be noted that wind erosion involves complex physics that is not yet fully understood (Shao, 2008).

Airshed has developed an in-house wind erosion model called ADDAS (Burger et al., 1997; Burger, 2010). This model, developed for specific use by Eskom in the quantification of fugitive emissions from its ash dumps, is based on the dust emission models proposed by Marticorena and Bergametti (1995) and more recently the one by Shao (2008). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface. In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate).

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

$$E_i = G_i 10^{(0.134C-6)} \tag{4}$$

where,

$$G_i = 0.261 \frac{\rho_a}{g} U_*^3 (1+R_i)(1-R_i^{\,2}) \tag{5}$$

$$R_i = \frac{U_{t*i}}{U_*} \tag{6}$$

and,

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

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure 10-1.

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (US EPA, 2006b):

$$U^* = 0.053 U_{10}^{+} \tag{7}$$

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

Equivalent friction velocity can also be calculated using a re-arrangement of the logarithmic distribution of the wind speed profile in the surface boundary (US EPA, 2006b):

$$U^* = \frac{KU_{10}}{\ln\left(\frac{Z}{Z_0}\right)} \tag{8}$$

where,

$U^*$ = friction velocity (m/s)
$K$ = von Karma’s constant (0.41)
$Z$ = wind speed height (in this case 10 m)
$Z_0$ = wind speed height (in this case 10 m)

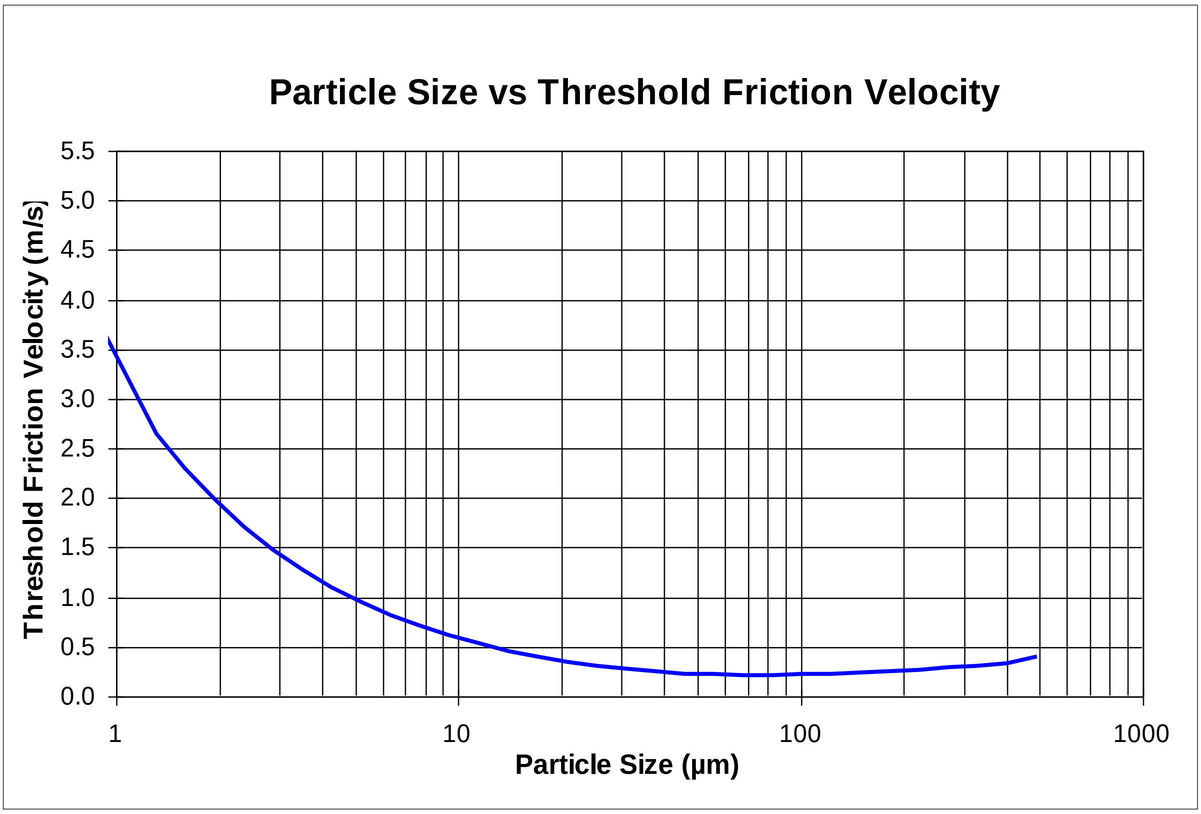


**Figure 9-1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995).**

The wind speed variation over the dump was based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed ($u_s$) to approach wind speed ($u_r$), derived from wind tunnel studies for two representative pile shapes, are indicated in Figure 9-2 (viz. a conical pile, and an oval pile with a flat top and 37° side slope. The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow. (The higher the ratio, the greater the wind exposure potential).

Particle size distribution data were taken from similar operations. The particle size distribution was taken into account both in the estimation of emissions and in the simulation of resultant dust fall and ambient $PM_{10}$ concentrations.

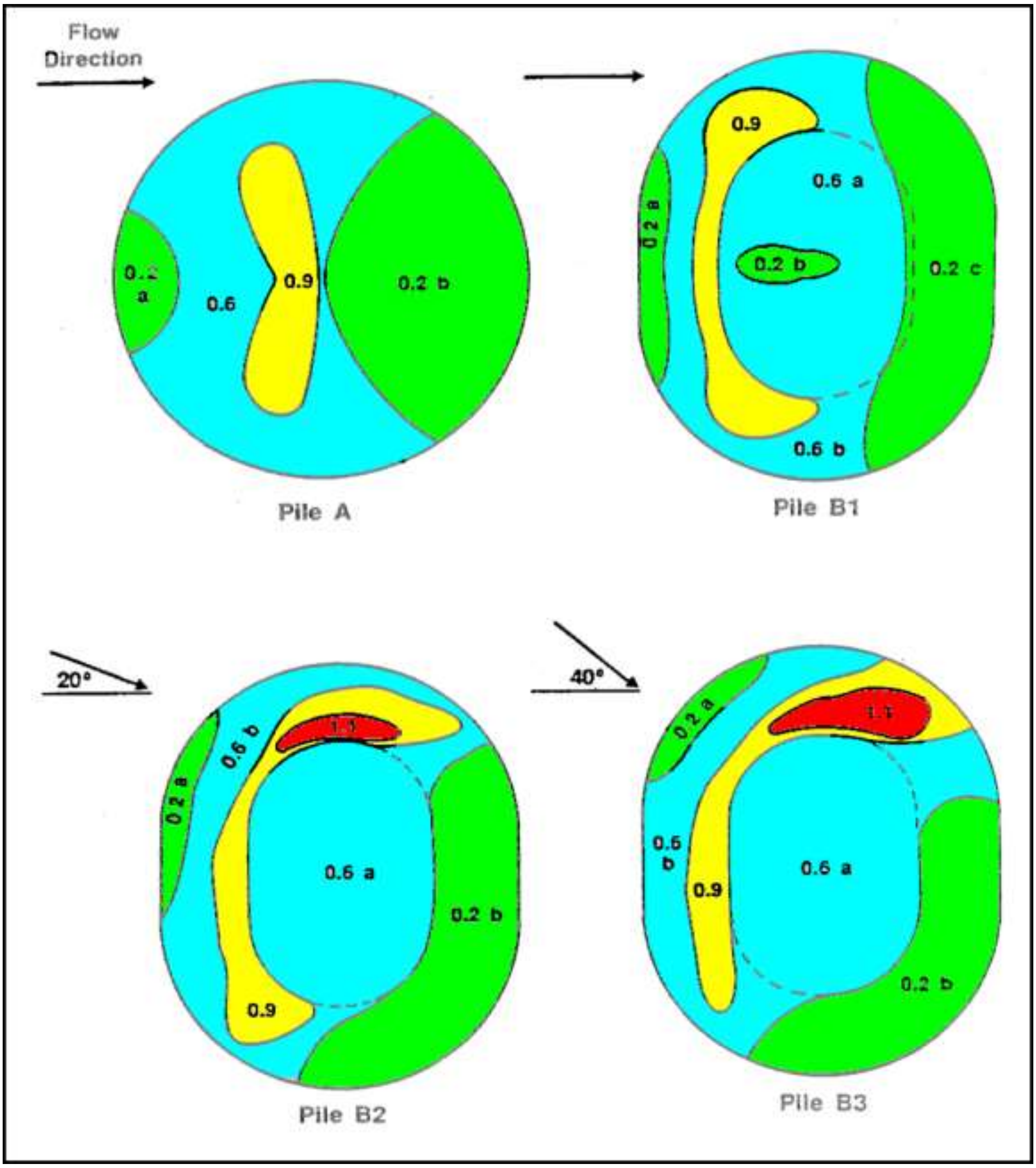


**Figure 9-2: Contours of normalised surface wind speeds (i.e. surface wind speed/ approach wind speed) (after US EPA, 1996).**

### 9.3 Surface Vehicle Exhausts

$PM_{2.5}$, $PM_{10}$, CO, $NO_x$ and $SO_2$ emission factors published by the NPI (NPI, 2008) for petrol vehicles are provided in Table 9-3. The petrol $SO_2$ emission factor is based on 150 ppm sulphur content. The fuel use for plant vehicles was available.

**Table 9-3: Vehicle exhaust emission factors**

| Mobile Equipment Type | Unit | $PM_{2.5}$ | $PM_{10}$ | CO | $NO_x$ | $SO_2$ | VOCs |
|---|---|---|---|---|---|---|---|
| Petrol Vehicle Exhaust Emissions (miscellaneous vehicle) | kg/l | $6.84x10^{-04}$ | $7.38x10^{-04}$ | $4.86x10^{-01}$ | $1.17x10^{-02}$ | $3.60x10^{-04}$ | $1.57x10^{-02}$ |

# 10 APPENDIX C: AIR QUALITY SENSITIVE RECEPTOR RESULTS TABLES

| Receptor | Unmitigated | | Design mitigated | |
|---|---|---|---|---|
| | PM$_{2.5}$ Annual (µg/m$^3$) | PM$_{2.5}$ FOE (days) | PM$_{2.5}$ Annual (µg/m$^3$) | PM$_{2.5}$ FOE (days) |
| Ledig | 15 | **30** | 4 | <4 |
| Phatsima | 0.5 | <4 | 0.2 | <4 |
| Chaneng | 3 | <4 | 2 | <4 |
| Sun City | 1 | <4 | 0.5 | <4 |
| Bakubung Bush Lodge | 0.1 | <4 | 0.1 | <4 |
| 1 | 0.2 | <4 | 0.2 | <4 |
| 2 | 0.1 | <4 | 0.1 | <4 |
| Sundown Ranch Hotel | 0.1 | <4 | 0.1 | <4 |
| Mine Housing | 5 | **5** | 4 | **9** |

| Receptor | Unmitigated | | Design mitigated | |
|---|---|---|---|---|
| | PM$_{10}$ Annual (µg/m$^3$) | PM$_{10}$ FOE (days) | PM$_{10}$ Annual (µg/m$^3$) | PM$_{10}$ FOE (days) |
| Ledig | 37 | **48** | 10 | <4 |
| Phatsima | 1 | <4 | 0.5 | <4 |
| Chaneng | 7 | <4 | 3 | <4 |
| Sun City | 1 | <4 | 0.5 | <4 |
| Bakubung Bush Lodge | 0.1 | <4 | 0.1 | <4 |
| 1 | 0.3 | <4 | 0.2 | <4 |
| 2 | 0.1 | <4 | 0.1 | <4 |
| Sundown Ranch Hotel | 0.1 | <4 | 0.1 | <4 |
| Mine Housing | 9 | **4** | 4 | <4 |

| Receptor | Unmitigated | Design mitigated |
|---|---|---|
| | Average Daily Dustfall (mg/m$^2$/day) | Average Daily Dustfall (mg/m$^2$/day) |
| Ledig | 15 | 3 |
| Phatsima | 1 | 1 |
| Chaneng | 2 | 0.5 |
| Sun City | 0.5 | 0.1 |
| Bakubung Bush Lodge | 0.2 | 0.1 |
| 1 | 0.3 | 0.1 |
| 2 | 0.2 | 0.1 |
| Sundown Ranch Hotel | 0.2 | 0.1 |
| Mine Housing | 3 | 1 |

# 11 APPENDIX D: IMPACT SIGNIFICANCE METHODOLOGY

**Table 11-1: Criteria for assessment of impacts**

| PART A: DEFINITION AND CRITERIA* | | |
|---|---|---|
| **Definition of SIGNIFICANCE** | | **Significance = consequence x probability** |
| **Definition of CONSEQUENCE** | | **Consequence is a function of severity, spatial extent and duration** |
| **Criteria for ranking of the SEVERITY of environmental impacts** | **H** | Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. |
| | **M** | Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. |
| | **L** | Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. |
| | **L+** | Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. |
| | **M+** | Moderate improvement. Will be within or better than the recommended level. No observed reaction. |
| | **H+** | Substantial improvement. Will be within or better than the recommended level. Favourable publicity. |
| **Criteria for ranking the DURATION of impacts** | **L** | Quickly reversible. Less than the project life. Short term |
| | **M** | Reversible over time. Life of the project. Medium term |
| | **H** | Permanent. Beyond closure. Long term. |
| **Criteria for ranking the SPATIAL SCALE of impacts** | **L** | Localised - Within the site boundary. |
| | **M** | Fairly widespread – Beyond the site boundary. Local |
| | **H** | Widespread – Far beyond site boundary. Regional/ national |

| PART B: DETERMINING CONSEQUENCE | | | | | |
|---|---|---|---|---|---|
| | | | **SEVERITY = L** | | |
| **DURATION** | Long term | **H** | **Medium** | **Medium** | **Medium** |
| | Medium term | **M** | **Low** | **Low** | **Medium** |
| | Short term | **L** | **Low** | **Low** | **Medium** |
| | | | **SEVERITY = M** | | |
| **DURATION** | Long term | **H** | **Medium** | **High** | **High** |
| | Medium term | **M** | **Medium** | **Medium** | **High** |
| | Short term | **L** | **Low** | **Medium** | **Medium** |
| | | | **SEVERITY = H** | | |
| **DURATION** | Long term | **H** | **High** | **High** | **High** |
| | Medium term | **M** | **Medium** | **Medium** | **High** |
| | Short term | **L** | **Medium** | **Medium** | **High** |
| | | | **L** | **M** | **H** |
| | | | Localised<br>Within site boundary<br>Site | Fairly widespread<br>Beyond site boundary<br>Local | Widespread<br>Far beyond site boundary<br>Regional/ national |
| | | | **SPATIAL SCALE** | | |

| PART C: DETERMINING SIGNIFICANCE | | | | | |
|---|---|---|---|---|---|
| **PROBABILITY (of exposure to impacts)** | Definite/ Continuous | **H** | **Medium** | **Medium** | **High** |
| | Possible/ frequent | **M** | **Medium** | **Medium** | **High** |
| | Unlikely/ seldom | **L** | **Low** | **Low** | **Medium** |
| | | | **L** | **M** | **H** |
| | | | **CONSEQUENCE** | | |

| PART D: INTERPRETATION OF SIGNIFICANCE | |
|---|---|
| **Significance** | **Decision guideline** |
| High | It would influence the decision regardless of any possible mitigation. |
| Medium | It should have an influence on the decision unless it is mitigated. |
| Low | It will not have an influence on the decision. |

***H = high, M= medium and L= low and + denotes a positive impact.**

# 12 APPENDIX E: DESCRIPTION OF SUITABLE POLLUTION ABATEMENT MEASURES

## 12.1 General

The plan provided indicate the majority of dust generating sources within a specific boundary. Adherence to this plan will limit the potential for off-site impacts. Drastic changes to the proposed plan could have adverse effects on the off-site $PM_{2.5}$ and $PM_{10}$ concentrations and dustfall rates.

## 12.2 Vehicle Entrainment Dust from Unpaved Roads

There are three types of measures that can be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (Cowherd *et al.*, 1988; APCD, 1995).
The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds
- Number of wheels per vehicle
- Traffic volumes
- Particle size distribution of the aggregate
- Compaction of the surface material
- Surface moisture
- Climate

When quantifying emissions from unpaved road surfaces, most of these factors are accounted for. Vehicle speed is one of the significant factors influencing the amount of fugitive dust generated from unpaved roads surfaces. The control efficiency obtained by speed reduction can be calculated by varying the vehicle speed input parameter in the predictive emission factor equation given for unpaved roads. An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads. Thus, by increasing the payload of the truck, fewer trips will be required to transport the same amount of material.

The mitigation measure proposed to be implemented at the mine is the use of water sprays on unpaved haul roads. It is the most common means of suppressing fugitive dust due to vehicle entrainment at mines, but it is not necessarily the most efficient means (Thompson & Visser, 2000). Thompson and Visser (2000) developed a model to determine the cost and management implications of dust suppression on mine haul roads using water or other chemical palliatives. The study was undertaken at 10 mine sites in Southern Africa. The model was first developed looking at the re-application frequency of water required for maintaining a specific degree of dust palliation. From this the cost effectiveness of water spray suppression could be determined and compared to other strategies. Factors accounted for in the model included climate, traffic, vehicle speed and the road aggregate material. A number of chemical palliative products, including hygroscopic salts, lignosulponates, petroleum resins, polymer emulsions and tar and bitumen products were assessed to benchmark their performance and identify appropriate management strategies. Cost elements taken into consideration included amongst others capital equipment, operation and maintenance costs, material costs and activity related costs. The main findings were that water-based spraying is the cheapest dust suppression option over the short term. Over the longer term however, the polymer-emulsion option is marginally cheaper with added benefits such as improved road surfaces during wet weather, reduced erosion and dry skid resistance (Thompson & Visser, 2000).

### 12.3 Crushing

The use of shrouds or enclosures for crushers can contain the dust so that a dust control system can operate more efficiently. The following measures are recommended:

- A crusher feed box with a minimum number of openings should be installed;
- Rubber curtains should be used to minimize dust escape and air flow;
- The crusher should be choke fed to reduce air entrainment and dust emission; and
- Dust escape at the crusher discharge end can be minimized by properly designed and installed transfer chutes.

Dust from crushers is normally controlled by water sprays and local exhaust ventilation from the crusher enclosure. The amount of water needed to do the job is hard to specify since it depends on the type of material crushed and the degree to which water will cause downstream handling problems. If the ore is dry a starting point would be to add a water quantity equivalent to 1% of the weight of the material being crushed. The nozzle pressure of sprays should avoid stirring the dust cloud and reducing the capture efficiency of the ventilation system.

The amount of air required for dust control depends on how much the crusher can be enclosed. Enough air should be exhausted from a plenum under the crusher to produce a strong in-draught around the crusher.

Emission reductions that can typically be afforded are as follows (NPI, 2012):

- 65% for hooding with cyclones
- 75% for hooding with scrubbers
- 83% for hooding with fabric filters (proposed to be implemented at BPM)

### 12.4 Materials handling

Materials handling operations including various material transfer points resulted in significant near source ground level impacts over the long term. Australian NPI indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. According to the Australian NPI, water sprays (the proposed mitigation measure at BPM) can have up to 50% control efficiency, and hoods with scrubbers up to 75%. If in addition, the scrubbers and screens were to be enclosed, up to 100% control efficiency can be achieved. With these control measures in place, the impacts would reduce to negligible levels. It is important that these control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met.

The control efficiency of pure water suppression can be estimated based on the US EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 12-1. From the relationship between moisture content and dust control efficiency it is apparent that by doubling the moisture content of the material an emission reduction of 62% could be achieved. Thus chemicals mixed into the water will not just save on water consumption but also improve the control efficiency of the application even further.

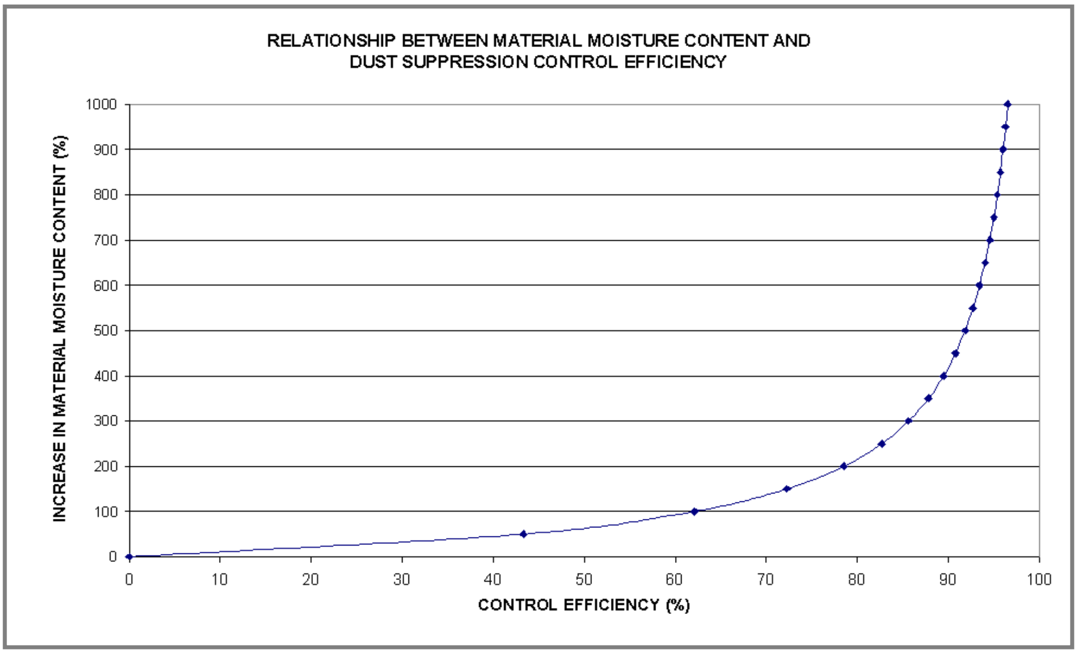
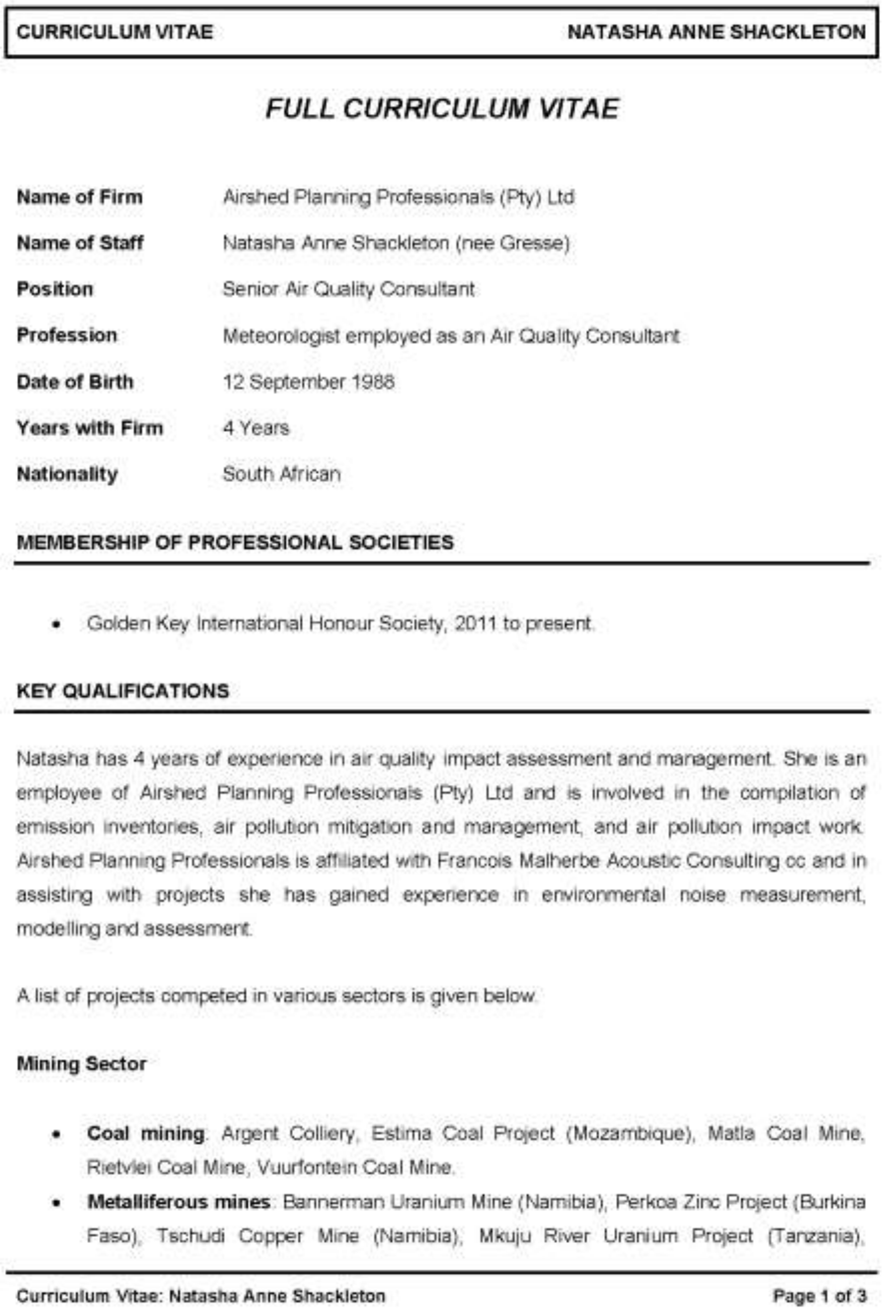


**Figure 12-1: Relationship between the moisture content of the material handled and the dust control efficiency (calculated based on the US-EPA predictive emission factor equation for continuous and batch drop operations)**

# 13 APPENDIX F: AUTHOR'S CURRICULUM VITAE



## *FULL CURRICULUM VITAE*

| | |
|---|---|
| **Name of Firm** | Airshed Planning Professionals (Pty) Ltd |
| **Name of Staff** | Natasha Anne Shackleton (nee Gresse) |
| **Position** | Senior Air Quality Consultant |
| **Profession** | Meteorologist employed as an Air Quality Consultant |
| **Date of Birth** | 12 September 1988 |
| **Years with Firm** | 4 Years |
| **Nationality** | South African |

### MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Golden Key International Honour Society, 2011 to present.

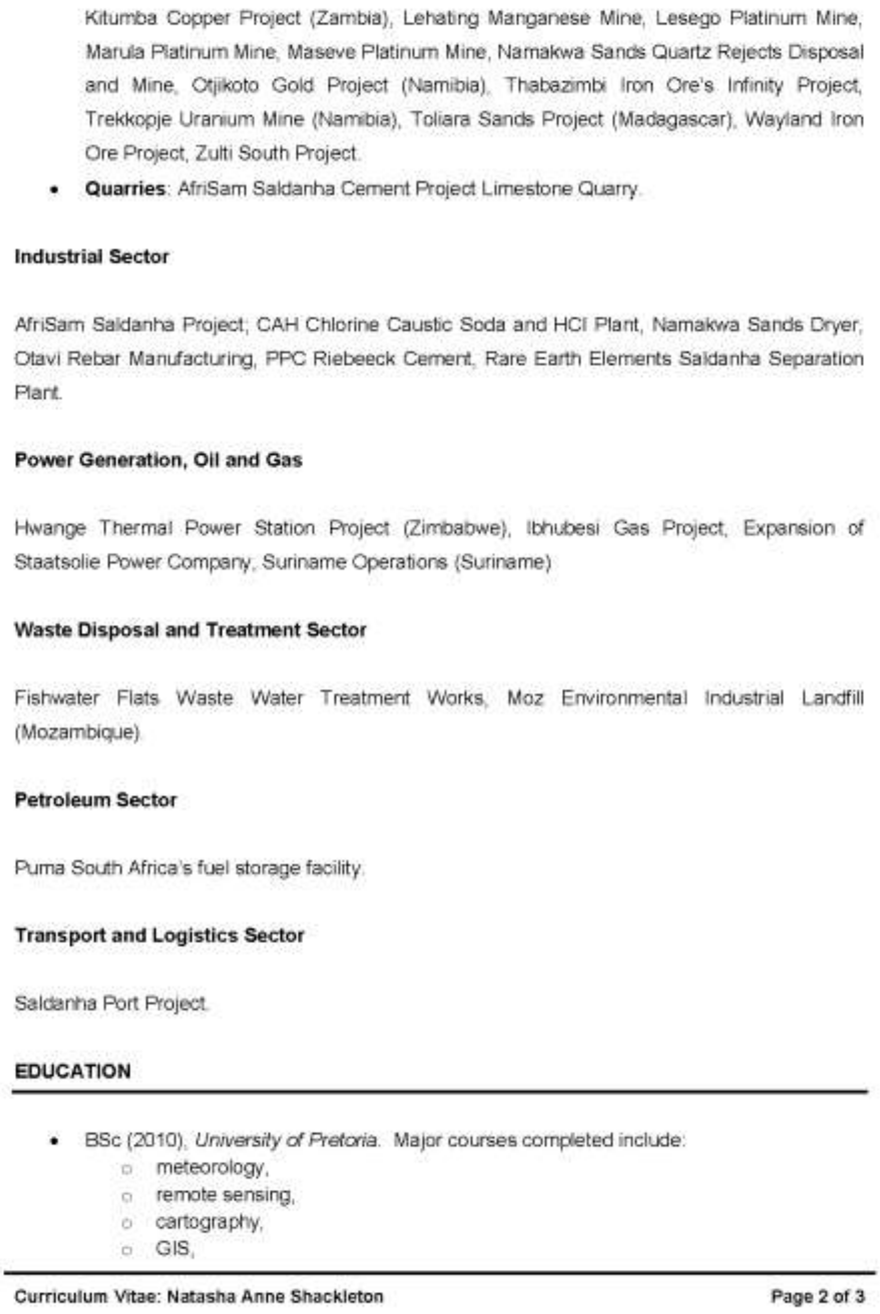
### KEY QUALIFICATIONS

Natasha has 4 years of experience in air quality impact assessment and management. She is an employee of Airshed Planning Professionals (Pty) Ltd and is involved in the compilation of emission inventories, air pollution mitigation and management, and air pollution impact work. Airshed Planning Professionals is affiliated with Francois Malherbe Acoustic Consulting cc and in assisting with projects she has gained experience in environmental noise measurement, modelling and assessment.

A list of projects competed in various sectors is given below.

**Mining Sector**

- **Coal mining**: Argent Colliery, Estima Coal Project (Mozambique), Matla Coal Mine, Rietvlei Coal Mine, Vuurfontein Coal Mine.
- **Metalliferous mines**: Bannerman Uranium Mine (Namibia), Perkoa Zinc Project (Burkina Faso), Tschudi Copper Mine (Namibia), Mkuju River Uranium Project (Tanzania),



Kitumba Copper Project (Zambia), Lehating Manganese Mine, Lesego Platinum Mine, Marula Platinum Mine, Maseve Platinum Mine, Namakwa Sands Quartz Rejects Disposal and Mine, Otjikoto Gold Project (Namibia), Thabazimbi Iron Ore's Infinity Project, Trekkopje Uranium Mine (Namibia), Toliara Sands Project (Madagascar), Wayland Iron Ore Project, Zulti South Project.

- **Quarries**: AfriSam Saldanha Cement Project Limestone Quarry.

**Industrial Sector**

AfriSam Saldanha Project; CAH Chlorine Caustic Soda and HCl Plant, Namakwa Sands Dryer, Otavi Rebar Manufacturing, PPC Riebeeck Cement, Rare Earth Elements Saldanha Separation Plant.

**Power Generation, Oil and Gas**

Hwange Thermal Power Station Project (Zimbabwe), Ibhubesi Gas Project, Expansion of Staatsolie Power Company, Suriname Operations (Suriname).

**Waste Disposal and Treatment Sector**

Fishwater Flats Waste Water Treatment Works, Moz Environmental Industrial Landfill (Mozambique).

**Petroleum Sector**

Puma South Africa's fuel storage facility.

**Transport and Logistics Sector**

Saldanha Port Project.

## EDUCATION

- BSc (2010), *University of Pretoria*. Major courses completed include:
    - meteorology,
    - remote sensing,
    - cartography,
    - GIS,

  - land surveying,
  - mathematics, and
  - physics.
- BSc(Hons) Meteorology (2011), *University of Pretoria*. Major courses completed include:
  - dynamical meteorology,
  - remote sensing,
  - cloud dynamics,
  - cloud microphysics,
  - boundary layer meteorology,
  - numerical modeling applications, and
  - tropical and mesoscale meteorology.

## COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Namibia, Madagascar, Zimbabwe, Zambia, Botswana, Burkina Faso, Tanzania and Suriname.

## LANGUAGES

| | **Speak** | **Read** | **Write** |
|---|---|---|---|
| **English** | Excellent | Excellent | Excellent |
| **Afrikaans** | Good | Good | Good |

## CERTIFICCATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications and my experience.

23/02/2015