# Air Quality Impact Assessment for the proposed Fluorspar Mine at Doornhoek in the North West Province

Project done on behalf of **Exigo Sustainability (Pty) Ltd**

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# EXECUTIVE SUMMARY

## Introduction

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Exigo Sustainability (Pty) Ltd (Exigo) to undertake an air quality impact assessment for the proposed Fluorspar Mine at Doornhoek in the North West province (hereafter referred to the proposed project).

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

## Study Approach and Methodology

The investigation followed the methodology required for a specialist report as prescribed in the Environmental Impact Assessment EIA Regulations (Government Notice R.543 in Government Gazette 33306 of 18 June 2010).

### *Baseline Assessment*

The baseline study encompassed the analysis of meteorological data. Local meteorological data (including wind speed, wind direction and temperature) was obtained from MM 5 data for the period 2013 to 2015.

### Impact Assessment Criteria

Particulates represent the main pollutants of concern in the assessment of operations from the proposed project. Particulate matter is classified as a criteria pollutant, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of these pollutants. For the current study, the impacts were assessed against published National Ambient Air Quality Standards (NAAQS) and National Dust Control Regulations (NDCR).

### Emissions Inventory

Emissions inventories provide the source input required for the simulation of ambient air concentrations. Fugitive source emissions from vehicle entrainment, materials handling, crushing activities and wind erosion from the tailings facility were quantified.

### Impact Prediction Study

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

## Assumptions, Exclusions and Limitations

The main assumptions, exclusions and limitations consisted of the following:

- Use was made of modelled MM5 meteorological data for the project area.
- The quantification of sources of emission was restricted to the proposed project activities only.
- The construction and closure phases were assessed qualitatively due to the temporary nature of these operations, whilst the operational phase was assessed quantitatively.
- As no on-site ambient $PM_{2.5}$ (inhalable particulate matter with aerodynamic diameter of <2.5 µm) and $PM_{10}$ (inhalable particulate matter with aerodynamic diameter of <10 µm) baseline measurements were available for the assessment; cumulative impacts were assessed qualitatively.

## Findings

The main findings from the baseline assessment were as follows:

- The main sources likely to contribute to cumulative particulate impact are surrounding mining operations, agricultural activities as well as vehicle entrainment on unpaved road surfaces and household and biomass burning.
- The flow field is dominated by winds from the north-easterly sector. During day-time conditions, wind speeds are slightly higher and more frequently from the north and north-northeast, with winds from the east-northeast increasing at night.
- The closest residential area to the project area is the suburb of Zeerust (~10km to the north-west of the project area), Groot Marico (~15km to the north-east of the project area) and Ottoshoop (~10km to the west of the project area) with numerous individual homesteads located within and around the proposed project area.
- Annual $PM_{10}$ and $PM_{2.5}$ concentrations measured at the closest monitoring station (Mahikeng) to the site was 39 µg/m³ and 16 µg/m³ respectively for the period May 2015 to April 2016.

The main findings from the impact assessment due to proposed project operations were as follows:

- Crushing activities and vehicle entrained dust from unpaved road surfaces represented the highest impacting particulate sources from the proposed operations.
- The highest $PM_{2.5}$ concentrations due to proposed project operations (unmitigated) were in non-compliance with NAAQS at the closest sensitive receptors for all four layout options. When activities were mitigated (assuming 75% control efficiency on unpaved road surfaces and 50% control efficiency on crushing activities) the $PM_{2.5}$ concentrations were in compliance with NAAQS at the closest sensitive receptors.
- The highest $PM_{10}$ concentrations due to proposed project operations (unmitigated) were in non-compliance with NAAQS at the closest sensitive receptors for all four layout options. When activities were mitigated the $PM_{10}$ concentrations were still in non-compliance with NAAQS at the closest sensitive in the northern sector of operations. The non-compliance in the northern sector of operations was due to vehicle entrainment.

- Maximum daily dust deposition exceeded the NDCR for non-residential areas at the sensitive receptors to the north of operations (assuming unmitigated activities) due to vehicle entrainment on the haul road. With mitigation measures in place (assuming 75% control efficiency on the haul road) the dust deposition was within the NDCR for residential areas at all sensitive receptors.

### Recommendations

The following recommendations are made:

- It is recommended that a dust fallout monitoring network be implemented at the proposed project site as recommended in Section 6 in order to monitor the impacts from the proposed project activities.

- Due to the close proximity of sensitive receptors to the proposed project activities, it is recommended that mitigation measures on the main sources of fugitive dust (as recommended in Table 6-2) be implemented to minimise impacts as far as possible.

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| | |
|---|---|
| APCS | Air pollution control systems |
| AQA | Air Quality Act |
| °C | Degrees Celsius |
| $CH_4$ | Methane |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| CEPA | Canadian Environmental Protection Agency |
| DEA | Department of Environmental Affairs |
| EIA | Environmental Impact Assessment |
| $H_2S$ | Hydrogen sulphide |
| km | Kilometre |
| LMo | Monin-Obukhov length |
| $m^3$ | Cubic metre |
| $m^2$ | Square metre |
| NAAQS | National Ambient Air Quality Standards |
| NDCR | National Dust Control Regulations |
| $NH_3$ | Ammonia |
| $NO_x$ | Oxides of nitrogen |
| $NO_2$ | Nitrogen dioxide |
| NO | Nitrous oxide |
| $O_3$ | Ozone |
| Pb | Lead |
| PM | Particulate matter |
| $PM_{10}$ | Particulate Matter with an aerodynamic diameter of less than 10$\mu$m |
| $PM_{2.5}$ | Particulate Matter with an aerodynamic diameter of less than 2.5$\mu$m |
| SAAQIS | South African Air Quality Information System |
| SABS | South African Bureau of Standards |
| SANS | South African National Standards |
| $SO_2$ | Sulfur Dioxide |
| TSP | Total Suspended Particles |
| US-EPA | United States Environmental Protection Agency |
| VOCs | Volatile organic compounds |

# Air Quality Impact Assessment for the proposed Fluorspar Mine at Doornhoek in the North West Province

## 1 INTRODUCTION

### 1.1 Project Description

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Exigo Sustainability (Pty) Ltd (Exigo) to undertake an air quality impact assessment for the proposed Fluorspar Mine at Doornhoek in the North West province (hereafter referred to the proposed project).

Typical of specialist investigations conducted, the air quality investigation comprises both a baseline study and an impact assessment. The baseline study includes the review of site-specific atmospheric dispersion potentials, and existing ambient air quality in the region, in addition to the identification of potentially sensitive receptors.

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

### 1.2 Approach and Methodology

The methodology followed in the assessment to quantify the air quality impacts associated with the proposed project is discussed below. The general tasks included:

- The establishment of the baseline air quality (based on available information);
- Quantification of air emissions from the proposed project;
- Discussion of meteorological parameters required to establish the atmospheric dispersion potential;
- Calculation of the air concentrations and dust fallout using a suitable atmospheric dispersion model;
- Assessment of the significance of the impact through the comparison of simulated air concentrations (and fallout rates) with local standards (for compliance);
- Recommendations for mitigation and monitoring.

#### *1.2.1 Potential Air Emissions from the Proposed Project*

The air pollution associated with the proposed project activities includes the air emissions emitted during construction, operation and closure. During operational phase air emissions include drilling and blasting activity, crushing, vehicle activity, materials handling and wind erosion.

### 1.2.2 Regulatory Requirements and Assessment Criteria

In the evaluation of air emissions and ambient air quality impacts reference is made to National Ambient Air Quality Standards (NAAQS). These standards generally apply only to a number of common air pollutants, collectively known as criteria pollutants. Criteria pollutants typically include sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), inhalable particulate matter (including thoracic particulate matter with an aerodynamic diameter of equal to or less than 10 µm or $PM_{10}$ and Inhalable particulate matter with an aerodynamic diameter equal to or less than 2.5 µm or $PM_{2.5}$), benzene, ozone and lead.

Particulates represent the main pollutants of concern in the assessment of operations from the proposed project. For the current assessment, the impacts were assessed against published NAAQS and Dust Control Regulations (NDCR).

### 1.2.3 Description of the Baseline Environment

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. For this assessment use was made of a numerical weather prediction model (Mesoscale Model version 5 (MM5[1])).

### 1.2.4 Emissions Inventory

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from proposed operations. Proposed project operations result in fugitive particulate emissions. Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007).

In the quantification of fugitive dust, 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 using a comprehensive set of emission factors and equations as published by the United States Environmental Protection Agency (US EPA) and Australian National Pollutant Inventory (NPI).

### 1.2.5 Atmospheric Dispersion Modelling

In the calculation 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

[1] MM5 is a widely-used three-dimensional numerical meteorological model which contains non-hydrostatic dynamics, a variety of physics options for parameterizing cumulus clouds, microphysics, the planetary boundary layer and atmospheric radiation. MM5 has the capability to perform Four Dimensional Data Assimilation (FDDA), and are able to simulate a variety of meteorological phenomena such as tropical cyclones, severe convective storms, sea-land breezes, and terrain forced flows such as mountain valley wind systems.

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).

The dispersion of pollutants was modelled for an area covering 23.8 km (north-south) by 21.5 km (east-west). These areas were divided into a grid with a resolution of 238 m (north-south) by 215 m (east-west). AERMOD simulates ground-level concentrations for each of the receptor grid points.

#### *1.2.6 Management and Mitigation*

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

## 1.3 Limitations and Assumptions

The main assumptions, exclusions and limitations are summarised below:

- Meteorological data: Use was made of modelled MM5 meteorological data for the project area.
- Emissions:
    - The quantification of sources of emission was restricted to the proposed project activities only. Although other background sources were identified, such sources were not quantified.
    - Information required for the calculation of emissions from fugitive dust sources for the proposed project operations were provided. The assumption was made that this information was accurate and correct.
    - Routine emissions from the proposed operations were estimated and modelled. Atmospheric releases occurring as a result of accidents were not accounted for.
    - Vehicle exhaust emissions were not quantified as the impacts from these sources are localized and will not exceed NAAQS offsite.
- Impact assessment:
    - The construction and closure phases were assessed qualitatively due to the temporary nature of these operations, whilst the operational phase was assessed quantitatively.
    - As no on-site ambient $PM_{2.5}$ and $PM_{10}$ baseline measurements were available for the assessment; cumulative impacts were assessed qualitatively (were feasible).

## 1.4 Outline of Report

Assessment criteria applicable to the proposed project are presented in Section 2. The study area, atmospheric dispersion potential and the existing air quality for the area are discussed in Section 3. Dispersion model results are presented and the main findings of the air quality impact assessments documented in Section 4. The significance ranking for the proposed project is provided in Section 5. A dust management plan is provided in Section 6 and finding and recommendations provided in Section 7.

# 2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

The environmental regulations and guidelines governing the emissions and impact of the mining operations need to be considered prior to potential impacts and sensitive receptors are identified.

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

## 2.1 National Ambient Regulations

### *2.1.1 National Ambient Air Quality Standards*

The South African Bureau of Standards (SABS) assisted the Department of Environmental Affairs (DEA) in the development of ambient air quality standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for $PM_{2.5}$ $PM_{10}$, sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), carbon monoxide (CO), lead (Pb) and benzene. The NAAQS were published in the Government Gazette (no. 32816) on 24 December 2009 (Table 2-1). The pollutants of concern for the proposed project are provided in bold.

**Table 2-1: South African National Ambient Air Quality Standards (DEA, 2009) (DEA, 2012)**

| Substance | Molecular formula / notation | Averaging period | Concentration limit (µg/m³) | Frequency of exceedance[1] | Compliance date[2] |
|---|---|---|---|---|---|
| Sulfur dioxide | $SO_2$ | 10 minutes | 500 | 526 | Immediate |
| | | 1 hour | 350 | 88 | Immediate |
| | | 24 hours | 125 | 4 | Immediate |
| | | 1 year | 50 | - | Immediate |
| Nitrogen dioxide | $NO_2$ | 1 hour | 200 | 88 | Immediate |
| | | 1 year | 40 | - | Immediate |
| **Particulate matter** | $PM_{10}$ | 24 hour | 75 | 4 | Immediate |
| | | 1 year | 40 | - | Immediate |
| **Fine particulate matter** | $PM_{2.5}$ | 24 hour | 40 | | Immediate |
| | | | 25 | | 1 Jan 2030 |
| | | 1 year | 20 | | Immediate |
| | | | 15 | | 1 Jan 2030 |
| Ozone | $O_3$ | 8 hours (running) | 120 | 11 | Immediate |
| Benzene | $C_6H_6$ | 1 year | 5 | - | Immediate |
| Lead | Pb | 1 year | 0.5 | - | Immediate |
| Carbon | CO | 1 hour | 30 000 | 88 | Immediate |

| Substance | Molecular formula / notation | Averaging period | Concentration limit ($\mu g/m^3$) | Frequency of exceedance[1] | Compliance date[2] |
|---|---|---|---|---|---|
| monoxide | | 8 hour (calculated on 1 hour averages) | 10 000 | 11 | Immediate |
| [1]The number of averaging periods where exceedance of limit is acceptable.<br>[2]Date after which concentration limits become enforceable. | | | | | |

#### *2.1.2 National Regulations for Dust Deposition*

South Africa's Draft National Dust Control Regulations were published on the 27 May 2011 with the dust fallout standards passed and subsequently published on the 1st of November 2013 (Government Gazette No. 36974). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. SA NDCRs were published on the 1st of November 2013. Acceptable dustfall rates according to the regulation are summarised in Table 2-2.

**Table 2-2: Acceptable dustfall rates (DEA, 2011)**

| Restriction Area | Dustfall rate (D) (mg $m^{-2}$ $day^{-1}$, 30-day average) | Permitted frequency of exceeding dust fall rate |
|---|---|---|
| Residential | D < 600 | Two within a year, not sequential months. |
| Non-residential | 600 < D < 1 200 | Two within a year, not sequential months |

The regulation also specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

### 2.2 Effect of Dust on Vegetation, Animals and Susceptible Human Receptors

#### *2.2.1 Effects of Particular Matter 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, Mills, Hayes, Williams, & De Temmerman, 2005). Heavy particle loads can also result in reduced light transmission to the chloroplasts and the occlusion of stomata (Ricks & Williams, 1974) (Hirano, Kiyota, & Aiga, 1995) (Naidoo & Chirkoot, 2004) (Harmens, Mills, Hayes, Williams, & De Temmerman, 2005) and hence water loss (Harmens *et al.*, 2005). Disruption of other physiological processes such as budbreak, pollination and light absorption/reflectance may also result under heavy particulate loads (Harmens *et al.*, 2005). The chemical composition of the dust particles can also affect exposed plant tissue and have indirect effects on the soil pH (Spencer, 2001).

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To determine the impact of dust deposition on vegetation, two factors are of importance: (i) Does dust accumulate on vegetation surfaces and if it does, what are the factors influencing the rate of deposition (ii) Once the dust has been deposited, what is the impact of the dust on the vegetation? Regarding the first question, there is adequate evidence that dust does accumulate on all types of vegetation. Any type of vegetation causes a change in the local wind fields, increasing turbulence and enhancing the collection efficiency. Vegetation structure alters the rate of dust deposition such that the larger the "collecting elements" (branches and leaves), the lower the impaction efficiency per element. Therefore, for the same volume of tree/shrub canopy, finer leaves will have better collection efficiencies. However, the roughness of the leaves themselves, in particularly the presence of hairs on the leaves and stems, plays a significant role, with venous surfaces increasing deposition of 1-5 µm particles by up to seven-times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size for moderate wind speeds (Tiwary & Colls, 2010). Wind tunnel studies also show that windbreaks or "shelter belts" of three rows of trees have a decrease of between 35 and 56% of the downwind mass transport of inorganic particles.

After deposition onto vegetation, the effect of particulate matter depends on the composition of the dust. South African ambient standards are set in terms of $PM_{2.5}$ and $PM_{10}$ (particulate matter smaller than 2.5 µm and 10 µm aerodynamic diameter) but 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, sulfate and nitrate; whereas the latter often consists of primary particles as a result of abrasion, crushing, soil disturbances and wind erosion (Grantz, Garner, & Johnson, 2003). Sulfate is however often hygroscopic and may exist in significant fractions in coarse PM. This has been shown at the Elandsfontein Eskom air quality monitoring station where the $PM_{10}$ has been shown to vary between 15% (winter) and 49% (spring) sulfate (Alade, 2009). Grantz *et al.* (op. cit.) however indicate that sulfate is much less phototoxic than gaseous sulfur dioxide and that "it is unusual for injurious levels of particular sulfate to be deposited upon vegetation".

Naidoo and Chirkoot (2004) conducted a study to investigate the effects of coal dust on mangrove trees at two sites in the Richards Bay harbour. Mature fully-exposed sun leaves of 10 trees (*Avicennia marina)* were tagged as being covered or uncovered with coal dust and photosynthetic rates were measured. It was concluded that coal dust significantly reduced photosynthesis of upper and lower leaf surfaces and reduction in growth and productivity was expected. 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 not toxic to the leaves; neither did they occlude stomata as they were larger than fully open stomatal apertures (Naidoo and Chirkoot, 2004).

According to the Canadian Environmental Protection Agency (CEPA), generally 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/FPAC Working Group, 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. 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 $m^{-2}$ day. Little direct evidence of the effects of dust-fall on South African vegetation, including crops, exists.

### 2.2.2 Effects of Particulate Matter on Animals

As presented by the Canadian Environmental Protection Agency (CEPA/FPAC Working Group, 1998) studies using experimental animals have not provided convincing evidence of particle toxicity at ambient levels. Acute exposures (4-6 hour single exposures) of laboratory animals to a variety of types of particles, almost always at concentrations well above those occurring in the environment have been shown to cause:

- decreases in ventilatory lung function;
- changes in mucociliary clearance of particles from the lower respiratory tract (front line of defence in the conducting airways);
- increased number of alveolar macrophages and polymorphonuclear leukocytes in the alveoli (primary line of defence of the alveolar region against inhaled particles);
- alterations in immunologic responses (particle composition a factor, since particles with known cytotoxic properties, such as metals, affect the immune system to a significantly greater degree);
- changes in airway defence mechanisms against microbial infections (appears to be related to particle composition and not strictly a particle effect);
- increase or decrease in the ability of macrophages to phagocytize particles (also related to particle composition);
- a range of histologic, cellular and biochemical disturbances, including the production of proinflammatory cytokines and other mediators by the lungs alveolar macrophages (may be related to particle size, with greater effects occurring with ultrafine particles);
- increased electrocardiographic abnormalities (an indication of cardiovascular disturbance); and
- increased mortality.

Bronchial hypersensitivity to non-specific stimuli, and increased morbidity and mortality from cardio-respiratory symptoms, are most likely to occur in animals with pre-existing cardio-respiratory diseases. Sub-chronic and chronic exposure tests involved repeated exposures for at least half the lifetime of the test species. Particle mass concentrations to which test animals were exposed were very high (> 1 mg $m^{-3}$), greatly exceeding levels reported in the ambient environment. Exposure resulted in significant compromises in various lung functions similar to those seen in the acute studies, but including also:

- reductions in lung clearance;
- induction of histopathologic and cytologic changes (regardless of particle types, mass, concentration, duration of exposure or species examined);
- development of chronic alveolitis and fibrosis; and
- development of lung cancer (a particle and/or chemical effect).

The epidemiological finding of an association between 24-hour ambient particle levels below 100 µg $m^{-3}$ and mortality has not been substantiated by animal studies as far as $PM_{10}$ and $PM_{2.5}$ are concerned. At ambient concentrations, none of the other particle types and sizes used in animal inhalation studies result in acute effects, including high mortality, with exception of ultrafine particles (0.1 µm). The lowest concentration of $PM_{2.5}$ reported that caused acute death in rats with acute pulmonary inflammation or chronic bronchitis was 250 g $m^{-3}$ (3 days, 6 hour $day^{-1}$), using continuous exposure to concentrated ambient particles.

Most of the literature regarding air quality impacts on 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 recently focussed on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter. However, the link between particulates and public health is considered to be understudied (Sneeringer, 2009).

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 (Davidson, Phalen, & Solomon, 2005). Most studies concurred that the main implication of dusty environments is the stress caused to animals which is detrimental to their general 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. the South African Standards and SANS limit values.

### *2.2.3 Effect of Particulate Matter on Susceptible Human Receptors*

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

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. These larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. The smaller particles ($PM_{10}$) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Then particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998) (Dockery & Pope, 1994).

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

The World Health Organization states that the evidence on airborne particulates and public health consistently shows adverse health effects at exposures experienced by urban populations throughout the world. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending from children to adults including a number of large, susceptible groups within the general population. Long-term exposure to particulate matter has been found to have adverse effects on human respiratory health (Abbey, Ostro, & F, 1995). Respiratory symptoms in children resident in an industrialised city were found not to be associated with long-term exposure to particulate matter; however non-asthmatic symptoms and hospitalizations did increase with increased total suspended particulate concentrations (Hruba, Fabianova, Koppova, & Vandenberg, 2001). The epidemiological evidence shows adverse effects of particles after both short-term and long-term exposures. However, current scientific evidence indicates that guidelines cannot be proposed that will lead to complete protection against adverse health effects as thresholds have not been identified.

Many scientific studies have linked inhaled particulate matter to a series of significant health problems, including:

- aggravated asthma;
- increases in respiratory symptoms like coughing and difficult or painful breathing;
- chronic bronchitis;
- decreased lung function; and,
- premature death.

$PM_{10}$ is the standard measure of particulate air pollution used worldwide and studies suggest that asthma symptoms can be worsened by increases in the levels of $PM_{10}$, which is a complex mixture of particle types. $PM_{10}$ has many components and there is no general agreement regarding which component(s) could exacerbate asthma. However, pro-inflammatory effects of transition metals, hydrocarbons, ultrafine particles (due to combustion processes) and endotoxins - all present to varying degrees in $PM_{10}$ - could be important.

Exposure to motor traffic emissions can have a significant effect on respiratory function in children and adults. Studies show that children living near heavily travelled roadways have significantly higher rates of wheezing and diagnosed asthma. Epidemiologic studies suggest that children may be particularly susceptible to diesel exhaust. The adverse health effects from particulate matter exposure and susceptible populations is summarised in Table 2-3.

**Table 2-3: Summary of adverse health effects from particulate matter exposure and susceptible populations**

| Health Effects | Susceptible Groups | Notes |
|---|---|---|
| ***Acute (short-term) exposure*** | | |
| Mortality | Elderly, infants, persons with chronic cardiopulmonary disease, influenza or asthma | Uncertainty regarding how much life shortening is involved and how much is due to short-term mortality displacement. |
| Hospitalisation / other health care visits | Elderly, infants, persons with chronic cardiopulmonary disease, pneumonia, influenza or asthma | Reflects substantive health impacts in terms of illness, discomfort, treatment costs, work or school time lost, etc. |
| Increased respiratory symptoms | Most consistently observed in people with asthma, and children | Mostly transient with minimal overall health consequences, although for a few there may be short-term absence from work or school due to illness. |
| Decreased lung function | Observed in both children and adults | For most, effects seem to be small and transient. For a few, lung function losses may be clinically relevant. |
| ***Chronic (long-term) exposure*** | | |
| Increased mortality rates, reduced survival times, chronic cardiopulmonary disease, reduced lung function, lung cancer | Observed in broad-based cohorts or samples of adults and children (including infants). All chronically exposed are potentially affected. | Long-term repeated exposure appears to increase the risk of cardiopulmonary disease and mortality. May result in lower lung function. Average loss of life expectancy in highly polluted cities may be |

| Health Effects | Susceptible Groups | Notes |
|---|---|---|
| | | as much as a few years. |

Source: Adopted from Pope (2000) and Pope et al. (2002)

## 2.3 Regulations regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Regulations regarding Air Dispersion Modelling were promulgated in Government Gazette No. 37804 vol. 589; 11 July 2014, (DEA, 2014) and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

(a) in the development of an air quality management plan, as contemplated in Chapter 3 of the Air Quality Act (AQA);
(b) in the development of a priority area air quality management plan, as contemplated in section 19 of the AQA;
(c) in the development of an atmospheric impact report, as contemplated in section 30 of the AQA; and,
(d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the AQA.

The Regulations have been applied to the development of this report. The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives direction to the choice of the dispersion model most suited for the purpose. Chapter 2 of the Regulations present the typical levels of assessments, technical summaries of the prescribed models (SCREEN3, AERSCREEN, AERMOD, SCIPUFF, and CALPUFF) and good practice steps to be taken for modelling applications. The proposed operation falls under a Level 2 assessment – described as follows;

- The distribution of pollutants concentrations and depositions are required in time and space.
- Pollutant dispersion can be reasonably treated by a straight-line, steady-state, Gaussian plume model with first order chemical transformation. The model specifically to be used in the air quality impact assessment of the proposed operation is AERMOD.
- Emissions are from sources where the greatest impacts are in the order of a few kilometres (less than 50 km) downwind.

Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Chapter 3 of the Regulations prescribe the source data input to be used in the models. Dispersion modelling can typically be used in the:

- Apportionment of individual sources for installations with multiple sources. In this way, the individual contribution of each source to the maximum ambient predicted concentration can be determined. This may be extended to the study of cumulative impact assessments where modelling can be used to model numerous installations and to investigate the impact of individual installations and sources on the maximum ambient pollutant concentrations.
- Analysis of ground level concentration changes as a result of different release conditions (e.g. by changing stack heights, diameters and operating conditions such as exit gas velocity and temperatures).
- Assessment of variable emissions as a result of process variations, start-up, shut-down or abnormal operations.
- Specification and planning of ambient air monitoring programs which, in addition to the location of sensitive receptors, are often based on the prediction of air quality hotspots.

The above options can be used to determine the most cost-effective strategy for compliance with the NAAQS. Dispersion models are particularly useful under circumstances where the maximum ambient concentration approaches the ambient air quality limit value and provide a means for establishing the preferred combination of mitigation measures that may be required including:

- Stack height increases;
- Reduction in pollutant emissions through the use of air pollution control systems (APCS) or process variations;
- Switching from continuous to non-continuous process operations or from full to partial load.

Chapter 4 of the Regulations prescribe meteorological data input from onsite observations to simulated meteorological data. The chapter also gives information on how missing data and calm conditions are to be treated in modelling applications. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the diluting effect of the atmosphere. Therefore, it is important that meteorology is carefully considered when modelling.

Topography is also an important geophysical parameter. The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result. Thus the accurate determination of terrain elevations in air dispersion models is very important.

The modelling domain would normally be decided on the expected zone of influence; the latter extent being defined by the predicted ground level concentrations from initial model runs. The modelling domain must include all areas where the ground level concentration is significant when compared to the air quality limit value (or other guideline). Air dispersion models require a receptor grid at which ground-level concentrations can be calculated. The receptor grid size should include the entire modelling domain to ensure that the maximum ground-level concentration is captured and the grid resolution (distance between grid points) sufficiently small to ensure that areas of maximum impact adequately covered. No receptors however should be located within the property line as health and safety legislation (rather than ambient air quality standards) are applicable within the site.

Chapter 5 provides general guidance on geophysical data, model domain and coordinates system required in dispersion modelling, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air concentration data. The chapter also provides guidance on the treatment of $NO_2$ formation from oxides of nitrogen ($NO_x$) emissions, chemical transformation of sulfur dioxide into sulfates and deposition processes.

Chapter 7 of the Regulations outline how the plan of study and modelling assessment reports are to be presented to authorities.

# 3 RECEIVING ENVIRONMENT

## 3.1 Sensitive Receptors

Numerous individual homesteads are located within and around the proposed project area (Figure 3-1). Larger residential areas include Zeerust (~10km to the north-west of the project area), Groot Marico (~15km to the north-east of the project area) and Ottoshoop (~10km to the west of the project area).

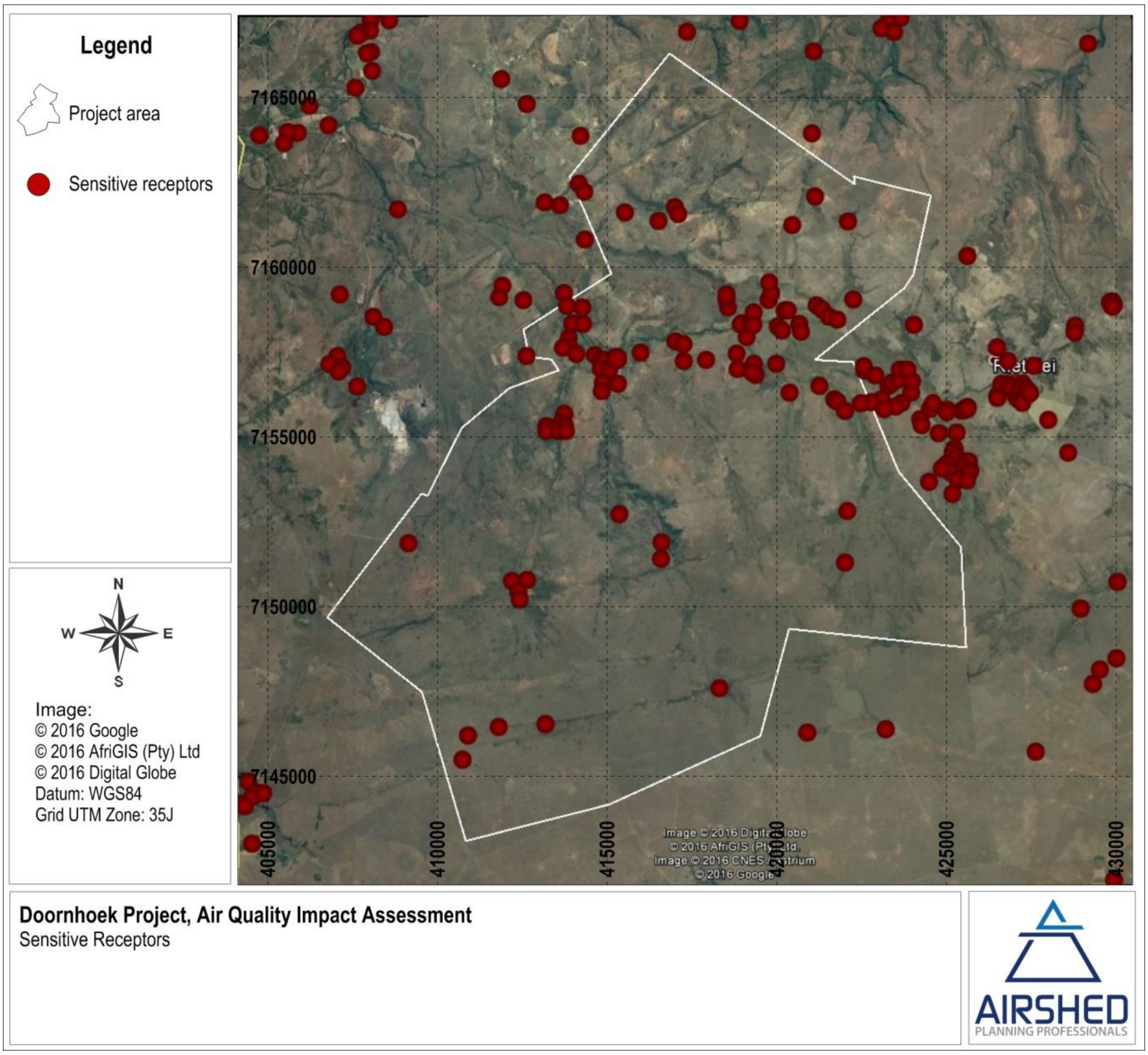


**Figure 3-1: Location of sensitive receptors to the proposed mining right area**

## 3.2 Climate and atmospheric dispersion potential

Meteorological mechanisms direct the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. This dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. The pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Tiwary & Colls, 2010).

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

Since no weather measurements are available from the proposed site, meteorological information was obtained from modelled MM5 data for the period 1 January 2013 to 31 December 2015.

### *3.2.1 Local Wind Field*

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness (Tiwary and Colls, 2010).

The 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 4 and 5 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.

The period wind field and diurnal variability in the wind field are shown in Figure 3-2. The wind regime for the area largely reflects the synoptic scale circulation with dominant north-easterly flow fields. Day-time and night-time flow fields are similar with winds predominating from the north-eastern sector.

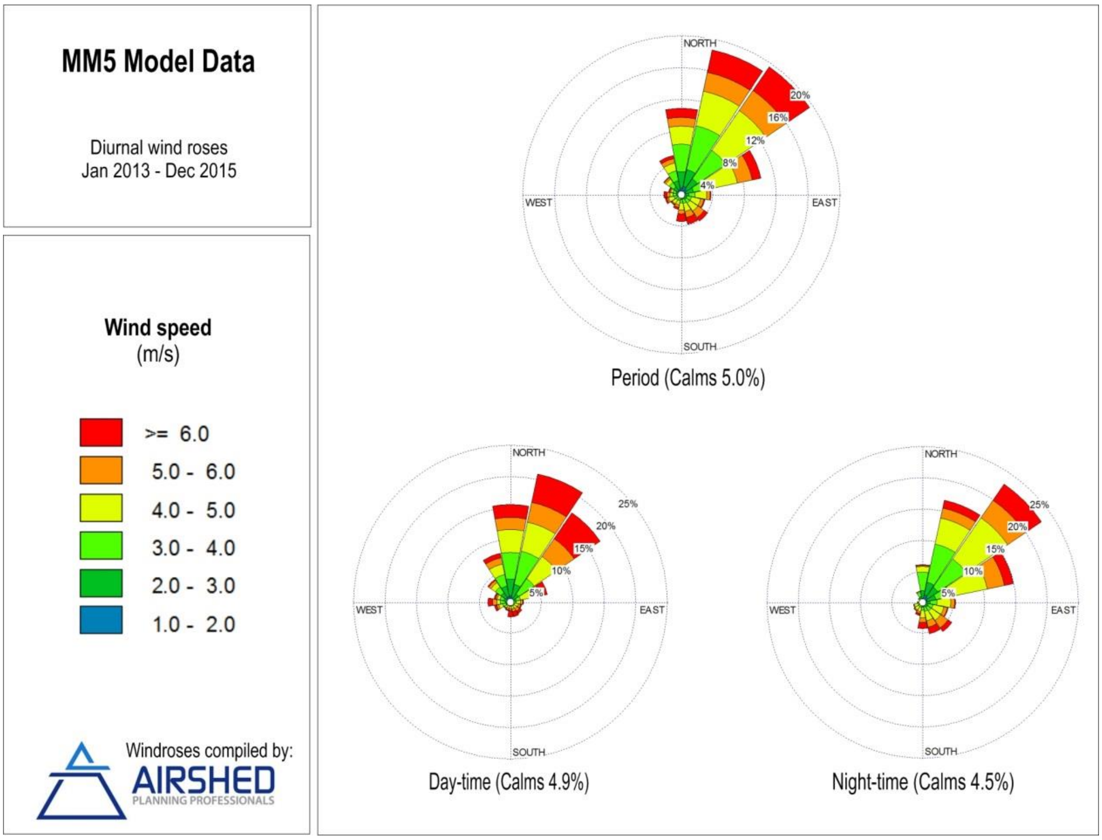


**Figure 3-2: Period, day-, and night-time wind roses (MM5 data, January 2013 to December 2015)**

### 3.2.2 *Ambient Temperature*

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

Monthly mean, maximum and minimum temperatures are given in Table 3-1. Diurnal temperature variability is presented in Figure 3-3. Monthly temperatures ranged between 6°C and 27.1°C. During the day, temperatures increase to reach maximum between 15:00 and 16:00 in the evening. Ambient air temperature decreases to reach a minimum at between 06:00 and 07:00.

**Table 3-1: Monthly temperature summary (MM5 data, January 2013 to December 2015)**

| Monthly Minimum, Maximum and Average Temperatures (°C) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| **Minimum** | 17.4 | 17.3 | 15.7 | 12.0 | 10.2 | 6.5 | 6.0 | 8.2 | 11.9 | 14.0 | 15.1 | 17.7 |
| **Average** | 22.6 | 22.3 | 20.3 | 16.4 | 13.8 | 10.1 | 9.6 | 12.4 | 16.5 | 19.0 | 20.7 | 22.7 |
| **Maximum** | 27.0 | 26.8 | 24.8 | 21.0 | 18.1 | 14.6 | 13.9 | 17.1 | 21.3 | 23.9 | 25.7 | 27.1 |

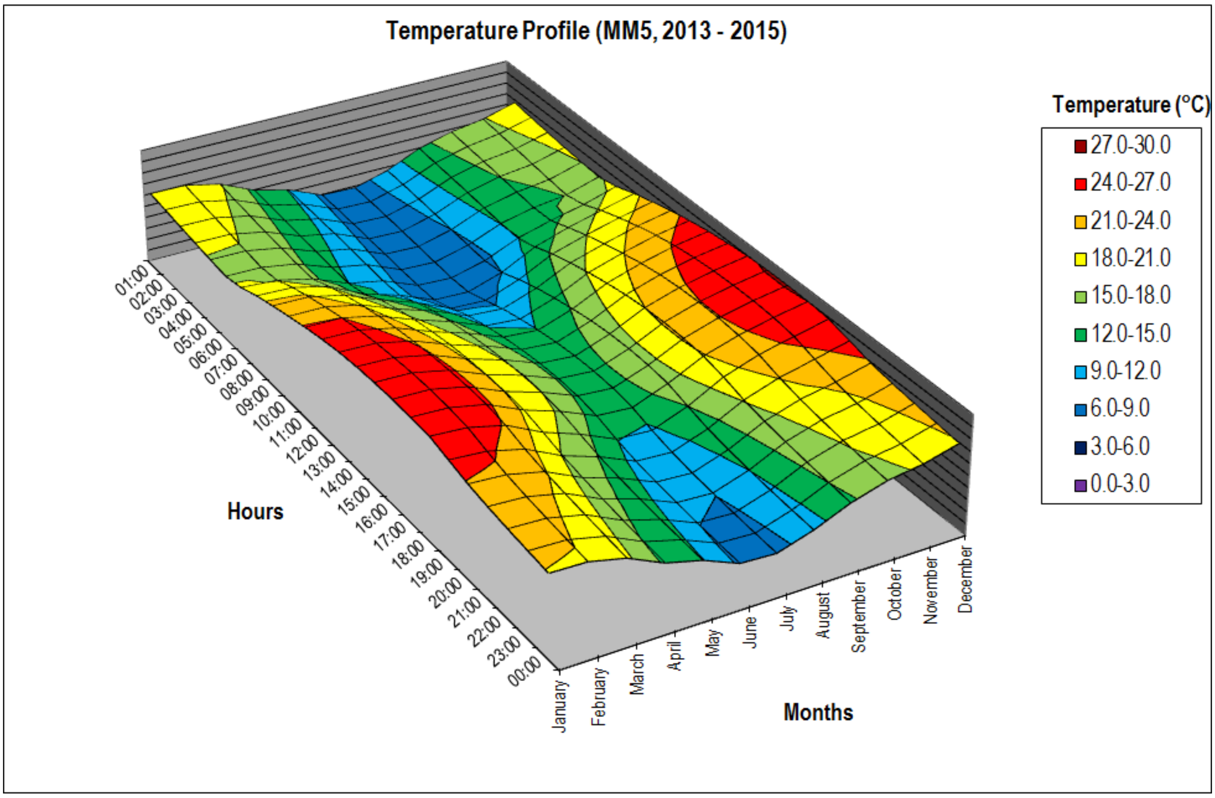


**Figure 3-3: Diurnal temperature profile (MM5 data, January 2013 to December 2015)**

### *3.2.3 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 (LMo) 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 the 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 less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral. For low level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions. Diurnal variation in atmospheric stability for the mine site is provided in Figure 3-4.

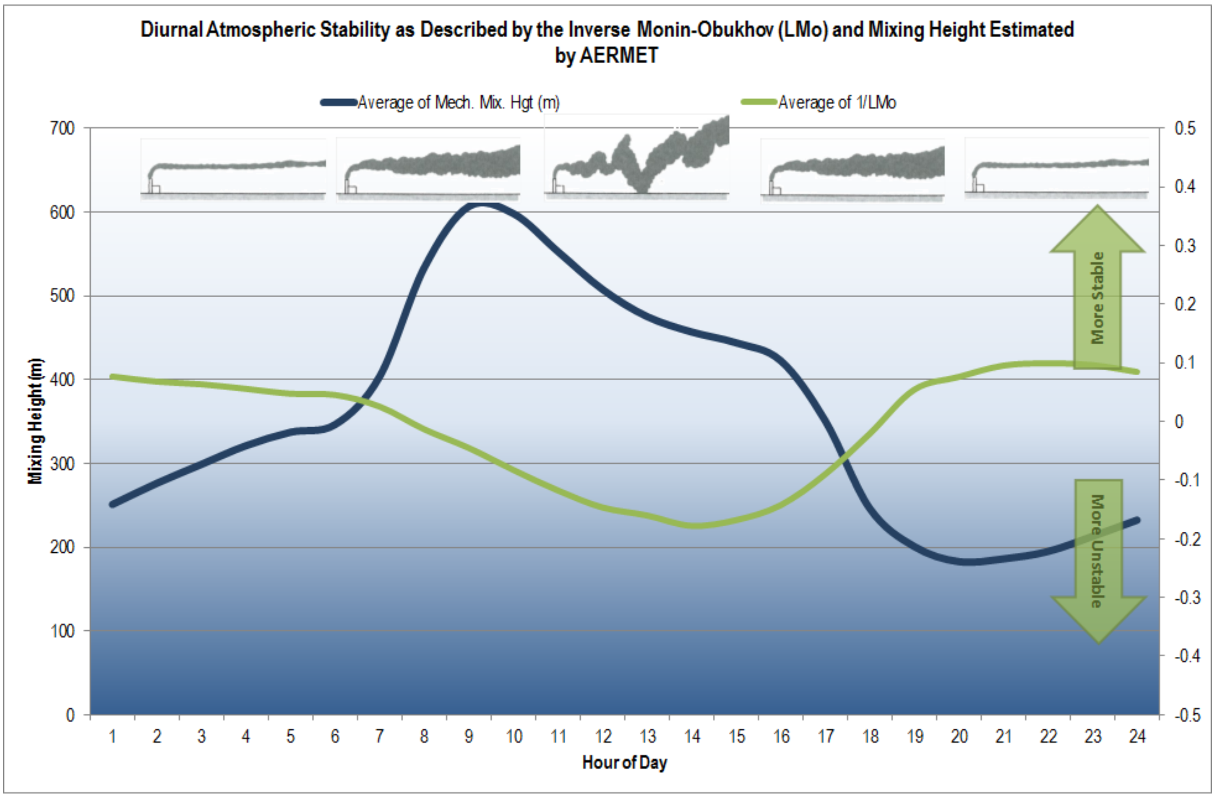


**Figure 3-4: Average diurnal atmospheric stability as calculated by Aermet from MM5 data for the period 2013 - 2015**

## 3.3 Measured Baseline Ambient Air Quality

Ambient air quality monitoring is conducted by the North West Provincial Government at Lichtenburg (~40km south of the proposed project) and at Mahikeng (~50 km west-southwest of the proposed project). No ambient particulate data is available at Mahikeng for the period 2015. Ambient particulate concentrations for Lichtenburg was obtained from the South African Air Quality Information System (SAAQIS) website (www.saaqis.org.za) as downloaded on 29 June 2016. The daily $PM_{10}$ and $PM_{2.5}$ concentrations for Lichtenburg are provided in Figure 3-5 and 3-6 respectively. Annual measured $PM_{10}$ and $PM_{2.5}$ concentrations at Lichtenburg for the period April 2015 to April 2016 was 39 µg/m³ and 16 µg/m³ respectively.

Exigo were subcontracted to undertake a baseline dustfall sampling campaign for the site for the period May 2013 to December 2014. Sampling was undertaken at eight sites. Valid monthly dustfall rates during this sampling period was below the NDCR for residential areas of 600 mg/m²/day (Exigo, 2015).

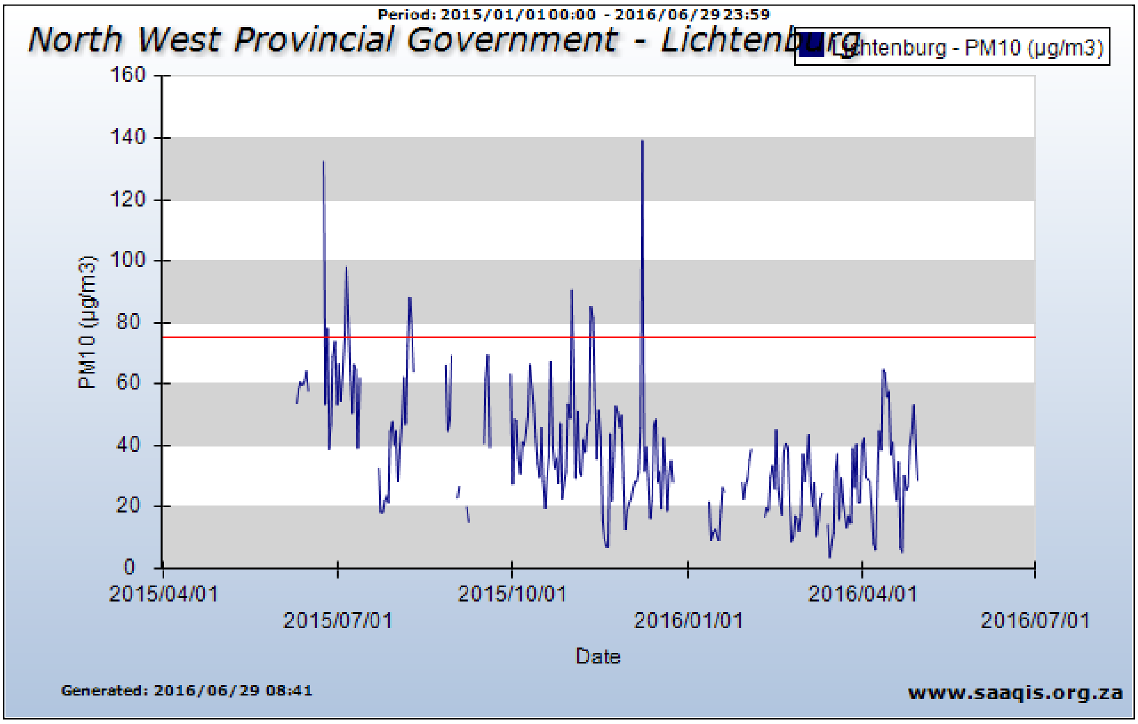


**Figure 3-5: Daily $PM_{10}$ ambient concentrations as measured at Lichtenburg for the period April 2015 to July 2016**

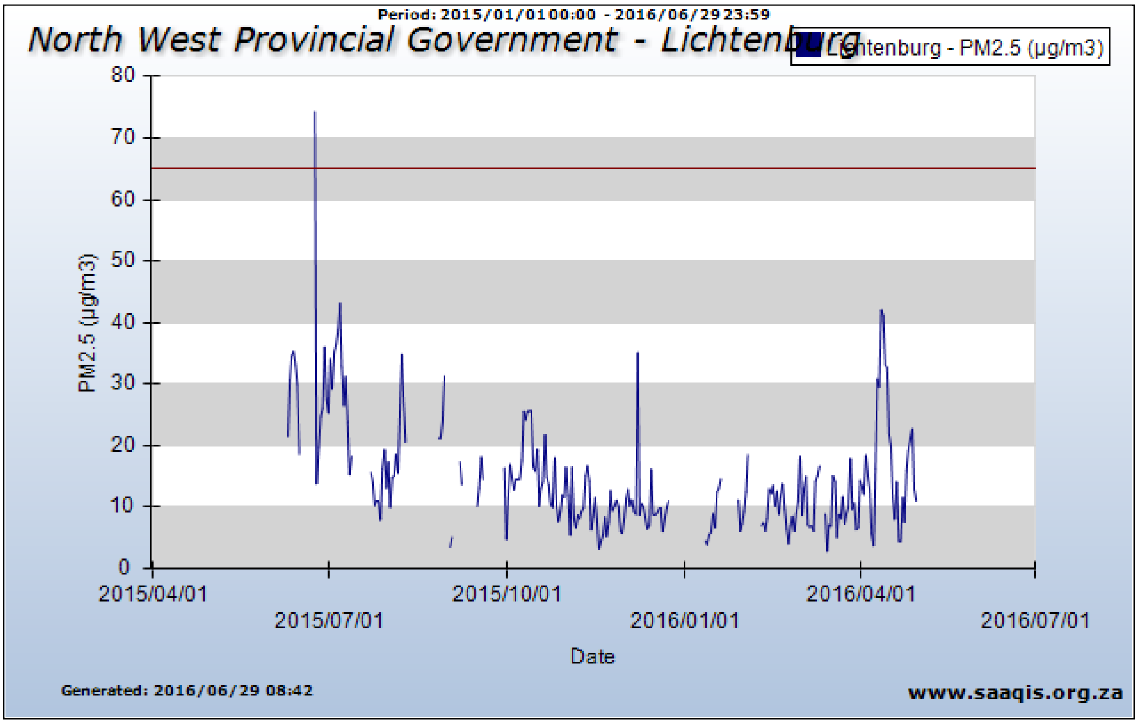


**Figure 3-6: Daily $PM_{2.5}$ ambient concentrations as measured at Lichtenburg for the period April 2015 to July 2016**

## 3.4 Existing Sources of Emissions near the Proposed Project

### *3.4.1 Vehicle Tailpipe Emissions*

Emissions resulting from motor vehicles can be grouped into primary and secondary pollutants. While primary pollutants are emitted directly into the atmosphere, secondary pollutants form in the atmosphere as a result of chemical reactions. Significant primary pollutants emitted by internal combustion engines include carbon dioxide ($CO_2$), CO, carbon (C), $SO_2$, oxides of nitrogen (mainly NO) and particulates. Secondary pollutants include $NO_2$, photochemical oxidants such as ozone, sulfur acid, sulfates, nitric acid, and nitrate aerosols (particulate matter). Vehicle (i.e. model-year, fuel delivery system), fuel (i.e. type, oxygen content), operating (i.e. vehicle speed, load), and environmental parameters (i.e. altitude, humidity) influence vehicle emission rates (Onursal & Gautam, 1997). The release of volatile organic compounds (VOCs) via vehicle emissions is likely to have localised impacts and be within ambient air quality standards and are considered to be a minor contributor to an emissions inventory.

### *3.4.2 Agricultural Sources*

Crop farming and livestock rearing occurs in the area.

Crop farming activities that may result in atmospheric emissions include land tilling operations, fertiliser and pesticide applications, and harvesting. By applying fertiliser and pesticides use are typically made of vehicles (tractors) driving on unpaved roads and exposed soil. Land tilling include dust entrainment on exposed surfaces, wind-blown dust and scraping and grading type activities resulting in fugitive dust releases. Both particulate matter (PM) and gaseous air emissions (mainly NO, $NO_2$, ammonia ($NH_3$), $SO_2$ and VOCs) are generated from the application of nutrients as fertilizers or manures. There are primarily three harvesting operations resulting in particulate emissions: (1) crop handling by the harvest machine, (2) loading of the harvested crop into trucks, and (3) transport by trucks in the field. Particulate matter, composed of soil dust and plant tissue fragments (chaff), may be entrained by wind (US EPA, 1995).

Livestock farms, especially cattle, are also significant sources of fugitive dust especially when feedlots are used and the cattle trample in confined areas. Pollutants associated with dairy production for instance include $NH_3$, hydrogen sulfide ($H_2S$), methane ($CH_4$), $CO_2$, $NO_x$ and odour related trace gasses. According to the US-EPA, cattle emit methane through a digestive process that is unique to ruminant animals called enteric fermentation. The calf-cow sector of the beef industry was found to be the largest emitter of methane emissions. Where animals are densely confined the main pollutants of concern include dust from the animal movements, their feed and their manure, $NH_3$ from the animal urine and manure, and $H_2S$ from manure pits.

Organic dust includes dandruff, dried manure, urine, feed, fungi, bacteria and endotoxins (produced by bacteria, and viruses). Inorganic dust is composed of numerous aerosols from building, materials and the environment. Since the dust is biological it may react with the defence system of the respiratory tract. Odours and VOCs associated with animal manure is also a concern when cattle are kept in feedlots. The main impact from methane is on the dietary energy due to the reduction of carbon from the rumen. Dust and gas levels are higher in winter or whenever animals are fed, handled or moved (http://www.cdc.gov/nasd/docs).

### 3.4.3 Fugitive Dust Sources

These sources are termed fugitive because they are not discharged to the atmosphere in a confined flow stream. Sources of fugitive dust identified to potentially occur in the study area include mining operations, paved and unpaved roads; agricultural tilling operations; and wind erosion of sparsely vegetated surfaces.

*Unpaved and paved roads*

Emissions from unpaved roads can constitute a substantial source of emissions to the atmosphere in the South African context. The force of the wheels of a vehicle traveling on an unpaved road, results in the pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads vary in relation to the vehicle traffic (including average vehicle speed, mean vehicle weight, average number of wheels per vehicle) and the silt loading on the roads.

Emissions from paved roads are significantly less than those originating from unpaved roads; however, they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface.

*Wind erosion of open areas*

Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface. Every time a surface is disturbed, its erosion potential is restored. Erodible surfaces may occur as a result of agriculture and/or grazing activities.

*Open Cast Mining*

Open cast mines are associated with significant dust emissions, sources of which include land clearing, blasting and drilling operations, materials handling, vehicle entrainment, crushing, screening (etc.).

### 3.4.4 Biomass Burning

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, wild fires (locally known as veld fires) may represent significant sources of combustion-related emissions (Maenhaut, Salma, Cafmeyer, Annegarn, & Andreae, 1996) (Galpin & Turner, 1999). The frequency of wildfires varies between annual and triennial (Tainton & Mentis, 1984).

Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held *et al.*, 1996). 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 proposed mining activity, long-range transported emissions from this source can be expected to impact on the air quality between the months August to October. 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.

# 4 IMPACTS FROM THE PROPOSED PROJECT ON THE RECEIVING ENVIRONMENT

## 4.1 Construction Phase

### *4.1.1 Identification of Environmental Aspects*

The construction phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle.

A list of all the potential dust generation activities expected during the construction phase is provided in Table 4-1. Unmitigated construction activities provide the potential for impacts on local communities, primarily due to nuisance and aesthetic impacts associated with fugitive dust emissions. On-site dustfall may also represent a nuisance to employees.

Impact due to the construction phase was not assessed as these sources would be of a relatively short-term duration and the impact would be near to site.

**Table 4-1: Typical sources of fugitive particulate emission associated with construction**

| Impact | Source | Activity |
|---|---|---|
| Gasses | Vehicle tailpipe | Transport and general construction activities |
| $PM_{10}$ and $PM_{2.5}$ | Stockpile areas and open pits | Clearing of groundcover |
| | | Levelling of area |
| | | Wind erosion from open areas |
| | | Materials handling |
| | Transport infrastructure | Clearing of vegetation and topsoil |
| | | Levelling of proposed transportation route areas |

### *4.1.2 Mitigation Measures Recommended*

Incremental $PM_{10}$ and $PM_{2.5}$ concentrations and deposition rates due to the Construction Phase of the proposed project will be of relatively short-term and of local impact. The implementation of effective controls, however, during this phase would also serve to set the president for mitigation during the operational phase.

Dust control measures which may be implemented during the construction phase are outlined in Table 4-2. Control techniques for fugitive dust sources generally involve watering, chemical stabilization, and the reduction of surface wind speed though the use of windbreaks and source enclosures.

**Table 4-2: Dust control measures that may be implemented during construction activities**

| Construction Activity | Recommended Control Measure(s) |
|---|---|
| Materials storage, handling and transfer operations | Wet suppression where feasible on stockpiles and materials handling activities |
| Open areas (windblown emissions) | Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil |

## 4.2 Operation Phase

### *4.2.1 Identification of Environmental Aspects*

The proposed project will consist of strip mining and simultaneous rehabilitation. The seam will be drilled and blasted, where after it will be loaded by means of excavator onto dump trucks for transport to the plant or stockpile. The ROM will be crushed and screened before moving through the plant.

In terms of air quality, atmospheric emissions represent the environmental aspects of concern for the assessment of the proposed project. The sources of these emissions were determined by first identifying the inputs and outputs to the various processes and secondly considering the disturbance to the environment by the proposed operations. Possible aspects associated with the proposed operations of relevance in terms of air quality impacts are listed in Table 4-3. Particulates present the main pollutant of concern from mining operations. Fugitive dust from materials handling operations, wind erosion, crushing and screening and vehicle entrainment on paved and unpaved roads are classified as routine emissions and are fairly constant throughout the year.

**Table 4-3: Potential air pollutants emitted from the proposed project**

| Operational phase | | |
|---|---|---|
| **Aspects** | **Source** | **Activities** |
| **Vehicle Entrainment** | | |
| Gaseous and particulate emissions; fugitive dust | Vehicle activity on paved and unpaved roads | Transportation of ROM from open pit to crusher plant<br>Transportation of product to rail siding |
| **Material handling** | | |
| Fugitive dust | Materials handling operations | Remove ROM from pit<br>Tip ROM at crusher<br>Tip from crusher to product stockpile<br>Reclaim from stockpile<br>Tipping of product at load-out area<br>Primary, secondary and tertiary crushing |
| **In-pit mining operations** | | |
| Fugitive dust | Mining operations within open pit | Topsoil removal<br>Drilling and blasting of seam<br>Removal of ROM by excavator and loading of haul trucks |

| Operational phase | | |
|---|---|---|
| **Aspects** | **Source** | **Activities** |
| | | Overburden replacement<br>Grading of covered pit areas |
| **Storage piles** | | |
| Fugitive dust | Wind erosion | Windblown dust from tailings, waste rock dump and storage piles |

### 4.2.2 Quantification of Environmental Aspects and Impact Classification

#### 4.2.2.1 Emissions Inventory

The operation phase is assessed quantitatively with the emissions provided in the current section. The emission factors and calculated emission rates are provided in Table 4-4.

**Table 4-4: Emission factors used to qualify the routine emissions from the operational phase for the proposed project**

| Activity | Emission Equation | Source | Information assumed/provided |
|---|---|---|---|
| Vehicle entrainment on unpaved surfaces | $E = k(s/12)^a(W/3)^b$<br><br>Where,<br>E = size-specific emission factor (lb/VKT)<br>s = surface material silt content (%)<br>W = mean vehicle weight (tons)<br><br>The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$, 1.5 for $PM_{10}$, and as 4.9 for TSP.<br>a is given as 0.9 for $PM_{2.5}$ and $PM_{10}$ and 0.7 for TSP.<br>a is given as 0.45 for $PM_{2.5}$, $PM_{10}$ and TSP. | US-EPA AP42 Section 13.2.2 | In the absence of site specific silt data, use was made of US EPA default mean silt content of 8.4 % for haul roads.<br><br>The capacity of the haul trucks to be used was given to be 100 tons.<br><br>The capacity of the interlink trucks to transport product was provided as 30 tons.<br><br>The maximum throughput of material for the first 5 years (Year 5) was provided as 500 000 tpa of ROM.<br><br>The maximum throughput of material (from Year 6) was provided as 1 500 000 tpa of ROM and 20 000 tpm product.<br><br>The same ratio of ROM to product as provided for mining operations from Year 6, was assumed for Year 5.<br><br>Location of all haul roads at the mine was provided. |
| Vehicle entrainment on paved surfaces | $E = k(sL)^{0.91}(W)^{1.02}$<br><br>Where,<br>E = size-specific emission factor (g/VKT)<br>sL = road surface silt loading (g/m²) | US-EPA AP42 Section 13.2.1 | In the absence of site specific silt data, use was made of US EPA default mean silt loading of 8.2 g/m².<br><br>The capacity of the interlink trucks to transport product was provided as 30 |

| Activity | Emission Equation | Source | Information assumed/provided |
|---|---|---|---|
| | W = mean vehicle weight (tons)<br><br>The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$, 0.62 for $PM_{10}$, and as 3.23 for TSP. | | tons.<br><br>The maximum throughput of material (from Year 6) was provided as 1 500 000 tpa of ROM and 20 000 tpm product.<br><br>The same ratio of ROM to product as provided for mining operations from Year 6, was assumed for Year 5.<br><br>Paved road network was provided. |
| Materials handling | $E = 0.0016 \frac{(U/_{2.2})^{1.3}}{(M/_{2})^{1.4}}$<br><br>Where,<br>E = Emission factor (kg dust / t transferred)<br>U = Mean wind speed (m/s)<br>M = Material moisture content (%)<br><br>The $PM_{2.5}$, $PM_{10}$ and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively. | US-EPA AP42 Section 13.2.4 | An average wind speed of 4 m/s was used based on the MM5 data for the period 2013 – 2015.<br><br>The maximum throughput of material for the first 5 years (Year 5) was provided as 500 000 tpa of ROM.<br><br>The maximum throughput of material (from Year 6) was provided as 1 500 000 tpa of ROM and 20 000 tpm product. |
| Drilling | $E_{TSP} = 0.59\ kg\ of\ dust\ /drill\ hole$<br><br>$PM_{10}$ is given as 52% of TSP emissions and $PM_{2.5}$ is assumed to be 3% of TSP emissions | NPI Section: Mining | Information provided:<br>Burden: 3.5 m<br>Spacing: 3.5 m |
| Blasting | $E_{TSP} = 0.00022\ x\ A^{1.5}$<br><br>Where,<br>A = area blasted in m²<br>$PM_{10}$ is given as 52% of TSP emissions and $PM_{2.5}$ is assumed to be 3% of TSP emissions | NPI Section: Mining | Information for blasting activities was not available for the assessment. It was assumed that blasting would take place once a week over a blast area of 50 m x 50 m. |
| Crushing and screening | Primary (for high moisture ore):<br>$E_{TSP} = 0.2\ kg/t\ material\ processed$<br>$E_{PM10} = 0.02\ kg/t\ material\ processed$<br>$E_{PM2.5} = 0.0037\ kg/t\ material\ processed$<br><br>Secondary (for high moisture ore):<br>$E_{TSP} = 0.6\ kg/t\ material\ processed$<br>$E_{PM10} = 0.06\ kg/t\ material\ processed$<br>$E_{PM2.5} = 0.0111\ kg/t\ material\ processed$<br><br>Tertiary (for high moisture ore):<br>$E_{TSP} = 1.4\ kg/t\ material\ processed$<br>$E_{PM10} = 0.08\ kg/t\ material\ processed$<br>$E_{PM2.5} = 0.0148\ kg/t\ material\ processed$<br><br>Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing | NPI Section: Mining | The maximum throughput of material for the first 5 years (Year 5) was provided as 500 000 tpa of ROM.<br><br>The maximum throughput of the ROM material (from Year 6) was provided as 1 500 000 tpa.<br><br>100% recovery of material was assumed to secondary and tertiary crusher.<br><br>The moisture of the ore was provided as <4% (low moisture ore)<br><br>Four plant layouts were considered for the assessment. |

| Activity | Emission Equation | Source | Information assumed/provided |
|---|---|---|---|
| Wind Erosion | $$E(i) = G(i)10^{(0.134(\%clay)-6)}$$ For $$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$ And $$R = \frac{u_*^{\ t}}{u^*}$$ where,<br>$E_{(i)}$ = emission rate (g/m²/s) for particle size class i<br>$P_a$ = air density (g/cm³)<br>$G$ = gravitational acceleration (cm/s³)<br>$u_*^t$ = threshold friction velocity (m/s) for particle size i<br>$u^*$ = friction velocity (m/s) | Marticorena & Bergametti, 1995 | Particle size distribution was obtained from similar processes for tailings material (Table 4-5).<br><br>Layout of the tailings facility was provided.<br><br>Hourly emission rate file was calculated and simulated.<br><br>Impacts form the waste rock dump and other stockpiles were not simulated as information on the particle size distribution of these sources was not available. The impacts from these sources however are expected to be localised and low in magnitude in comparison to the tailings facility.<br><br>Four layouts were considered for the assessment. |

**Table 4-5: Particle size distribution for the proposed tailings material**

| Particle size distribution (µm) | Mass Fraction (Tailings) |
|---|---|
| 120.67 | 0.014 |
| 76.32 | 0.140 |
| 35.56 | 0.322 |
| 19.31 | 0.113 |
| 10.48 | 0.053 |
| 4.88 | 0.066 |
| 3.09 | 0.018 |
| 1.95 | 0.038 |
| 1.06 | 0.236 |

#### 4.2.2.2 *Synopsis of Particulate Emissions from Various Sources at the Proposed Project due to Proposed Operational Activities*

In the quantification of emissions from the proposed mining operations the maximum total material movement of 500 000 tpa (first 5 years) and 1 500 000 tpa (from Year 6) ROM and 20 000 tpm (from Year 6) product was evaluated. Four plant and tailings facility positions were assessed.

The synopsis of particulate emissions was based on layout 1 for Year 6, providing an indication of source apportionment and where mitigation efforts need to be focused.

Particulate emissions calculated for various source types are given in Table 4-6. Both unmitigated and mitigated (applying 75% control efficiency on unpaved road surfaces and 50% control efficiency on crushing activities (control efficiency documented by Australia's National Pollution Inventory as being achievable through water sprayers)) conditions were assessed. For unmitigated operations, crushing and screening activities represent the most significant source of total particulate emissions. The second largest source of unmitigated total particulate emissions for operations is due to vehicle entrainment activities (Figure 4-1).

**Table 4-6: Particulate emissions due to routine operations for the proposed project**

| ACTIVITY | Emissions (tpa) | | | % Contribution | | | Rank |
|---|---|---|---|---|---|---|---|
| | TSP | $PM_{10}$ | $PM_{2.5}$ | TSP | $PM_{10}$ | $PM_{2.5}$ | TSP |
| ***Unmitigated*** | | | | | | | |
| Vehicle entrainment | 1 671.51 | 434.04 | 46.05 | 25.39 | 32.20 | 8.49 | 2 |
| Drilling and blasting | 8.60 | 4.47 | 0.26 | 0.13 | 0.33 | 0.05 | 5 |
| Materials handling | 36.58 | 17.30 | 2.62 | 0.56 | 1.28 | 0.48 | 4 |
| Crushing and screening | 3 300.00 | 240.00 | 44.40 | 50.12 | 17.81 | 8.18 | 1 |
| Wind erosion | 1 567.14 | 652.12 | 449.39 | 23.80 | 48.38 | 82.80 | 3 |
| **TOTAL** | **6 583.83** | **1 347.93** | **542.72** | **100.00** | **100.00** | **100.00** | |
| ***Mitigated: control efficiency of 75% applied to unpaved roads; 50% applied to crushing activities*** | | | | | | | |
| Vehicle entrainment | 490.74 | 122.50 | 14.90 | 13.14 | 13.49 | 3.05 | 3 |
| Drilling and blasting | 8.60 | 4.47 | 0.26 | 0.23 | 0.49 | 0.05 | 5 |
| Materials handling | 18.29 | 8.65 | 1.31 | 0.49 | 0.95 | 0.27 | 4 |
| Crushing and screening | 1 650.00 | 120.00 | 22.20 | 44.18 | 13.22 | 4.55 | 1 |
| Wind erosion | 1 567.14 | 652.12 | 449.39 | 41.96 | 71.84 | 92.08 | 2 |
| **TOTAL** | **3 734.77** | **907.73** | **488.06** | **100.00** | **100.00** | **100.00** | |

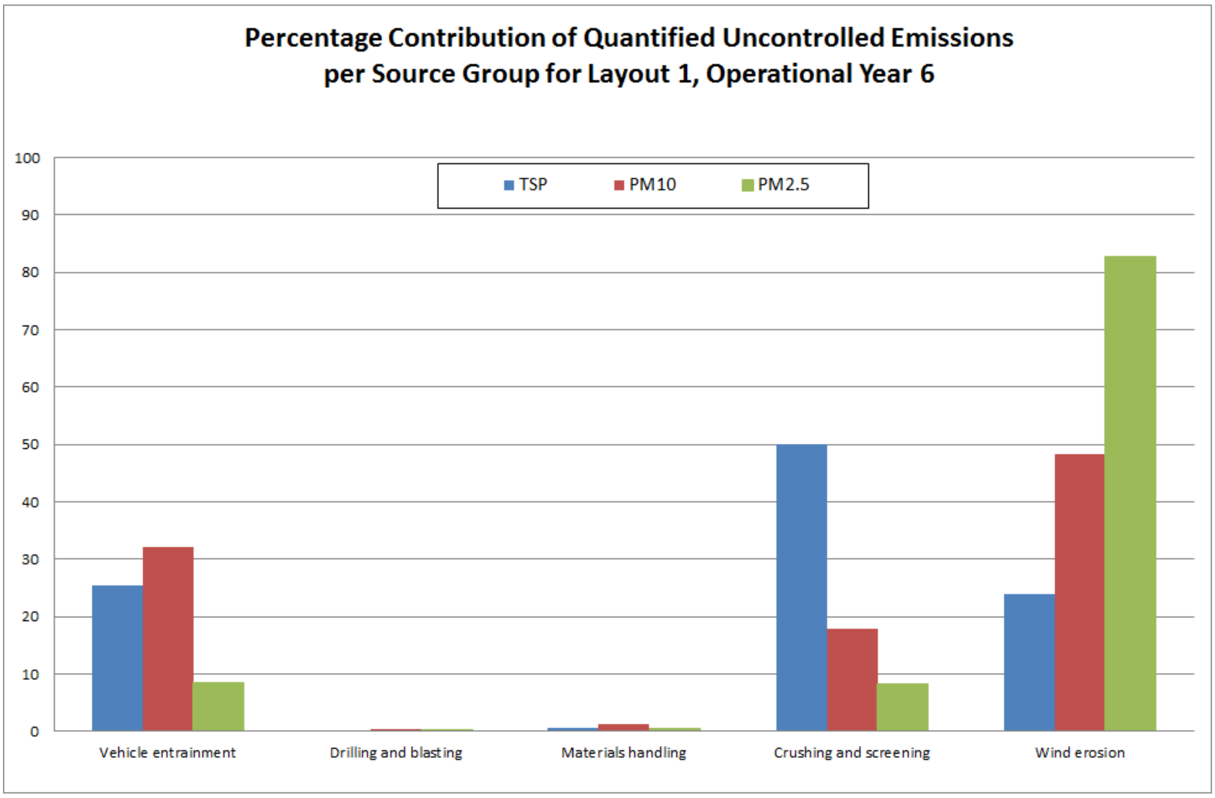


**Figure 4-1: Source contribution of particulate emissions due to unmitigated operations**

#### *4.2.2.3 Dispersion Simulation Results and Compliance Assessment*

Due to the fact that the mining activities are not stationary sources of emissions (i.e. pit activity, roads) and the fact that the sensitive receptors (viz. residential developments) may be in close proximity to mining operations (as they are located within the mining rights area) the total impact has been assessed for the life of the mine. For compliance, reference was made to NAAQS and NDCR.

Simulations were undertaken to determine particulate matter ($PM_{10}$ and $PM_{2.5}$) concentrations and total daily dust deposition from proposed project activities. The plots provided for the relevant pollutants of concern during the operational phase are given in Table 4-7. The plots present the potential impact from the entire life of operation.

**Table 4-7: Isopleth plots presented in the current section**

| Pollutant | Layout | Operating Conditions | Figure |
|---|---|---|---|
| $PM_{2.5}$ | 1 | Unmitigated operations | 4-2 |
| | | Mitigated operations | 4-3 |
| | 2 | Unmitigated operations | 4-4 |
| | | Mitigated operations | 4-5 |
| | 3 | Unmitigated operations | 4-6 |

| Pollutant | Layout | Operating Conditions | Figure |
|---|---|---|---|
| | | Mitigated operations | 4-7 |
| | 4 | Unmitigated operations | 4-8 |
| | | Mitigated operations | 4-9 |
| $PM_{10}$ | 1 | Unmitigated operations | 4-10 |
| | | Mitigated operations | 4-11 |
| | 2 | Unmitigated operations | 4-12 |
| | | Mitigated operations | 4-13 |
| | 3 | Unmitigated operations | 4-14 |
| | | Mitigated operations | 4-15 |
| | 4 | Unmitigated operations | 4-16 |
| | | Mitigated operations | 4-17 |
| TSP | 1 | Unmitigated operations | 4-18 |
| | | Mitigated operations | 4-19 |
| | 2 | Unmitigated operations | 4-20 |
| | | Mitigated operations | 4-21 |
| | 3 | Unmitigated operations | 4-22 |
| | | Mitigated operations | 4-23 |
| | 4 | Unmitigated operations | 4-24 |
| | | Mitigated operations | 4-25 |

The highest $PM_{2.5}$ concentrations due to proposed project operations (unmitigated) are in non-compliance with NAAQS at the closest sensitive receptors for all four layout options (Figure 4-2, Figure 4-4, Figure 4-6 and Figure 4-8). When activities are mitigated (assuming 75% control efficiency on unpaved road surfaces and 50% control efficiency on crushing activities) the $PM_{2.5}$ concentrations are in compliance with NAAQS at the closest sensitive receptors with 4 daily exceedances predicted at sensitive receptors in the northern sector of operations (Figure 4-3, Figure 4-5, Figure 4-7 and Figure 4-9).

The highest $PM_{10}$ concentrations due to proposed project operations (unmitigated) are in non-compliance with NAAQS at the closest sensitive receptors for all four layout options (Figure 4-10, Figure 4-12, Figure 4-14 and Figure 4-16). When activities are mitigated (assuming 75% control efficiency on unpaved road surfaces and 50% control efficiency on crushing activities) the $PM_{10}$ concentrations are still in non-compliance with NAAQS at the closest sensitive in the northern sector of operations (Figure 4-11, Figure 4-13, Figure 4-15 and Figure 4-17). The non-compliance in the northern sector of operations is due to vehicle entrainment. Due to the close proximity of sensitive receptors to the haul road, further mitigation on the haul road (i.e. chemical suppressant) may be necessary in order comply with NAAQS at these receptors.

Maximum daily dust deposition exceeds the NDCR for non-residential areas at the sensitive receptors to the north of operations (assuming unmitigated activities) due to vehicle entrainment on the haul road (Figure 4-18, Figure 4-20, Figure 4-22 and Figure 4-24). With mitigation measures in place (assuming 75% control efficiency on the haul road) the dust deposition is within the NDCR for residential areas at all sensitive receptors (Figure 4-19, Figure 4-21, Figure 4-23 and Figure 4-25).

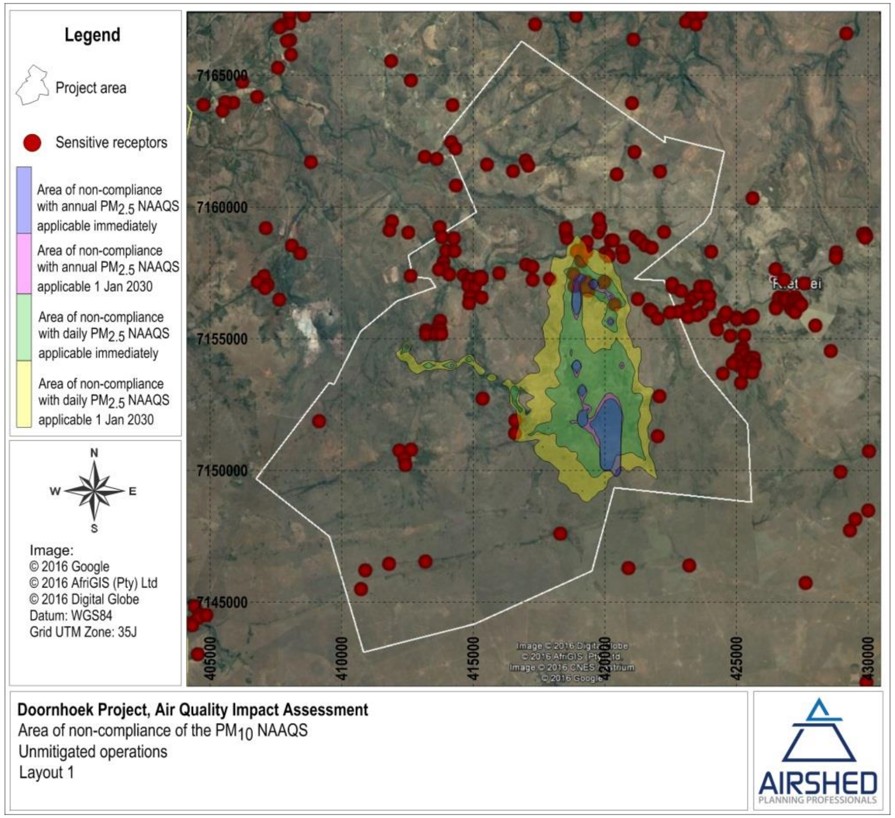


**Figure 4-2: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations assuming layout 1**

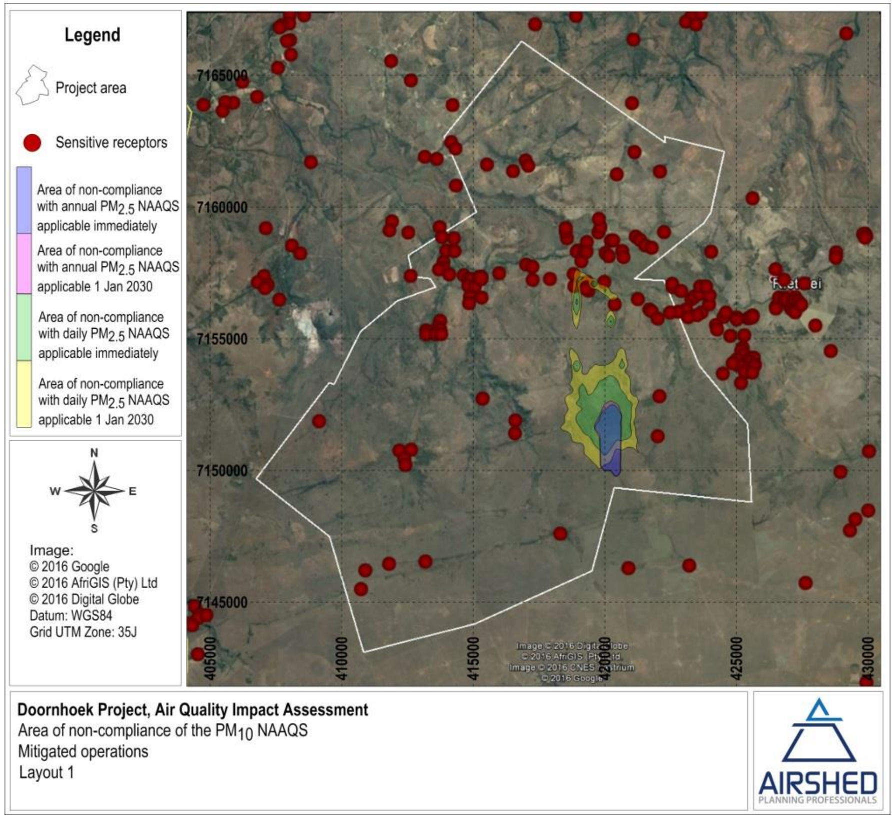


**Figure 4-3: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations assuming layout 1**

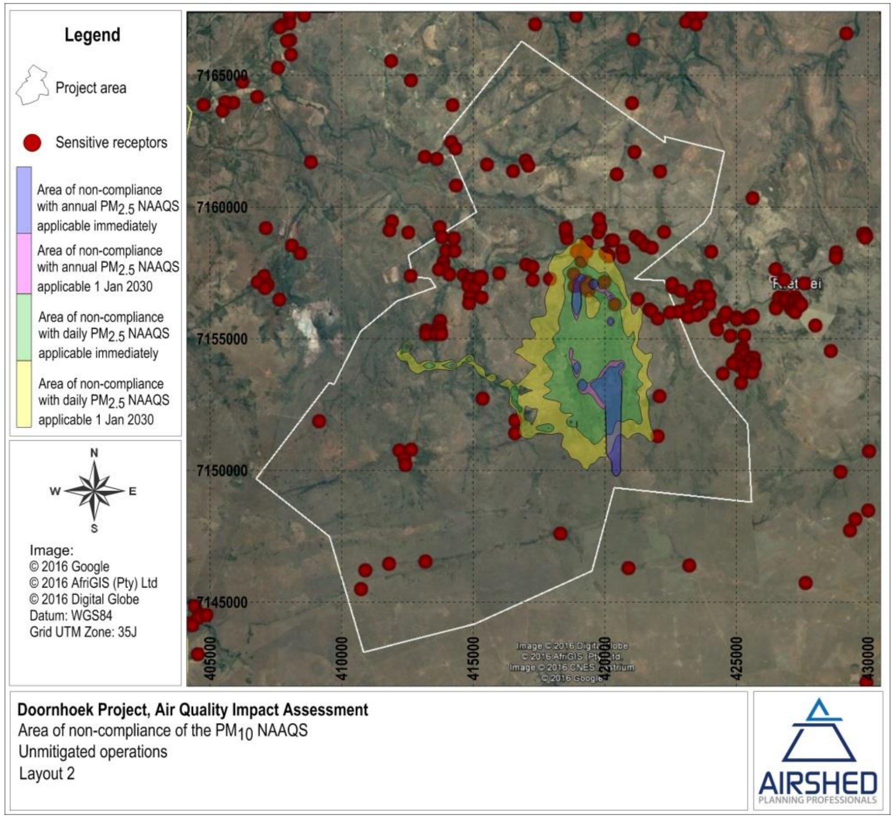


**Figure 4-4: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations assuming layout 2**

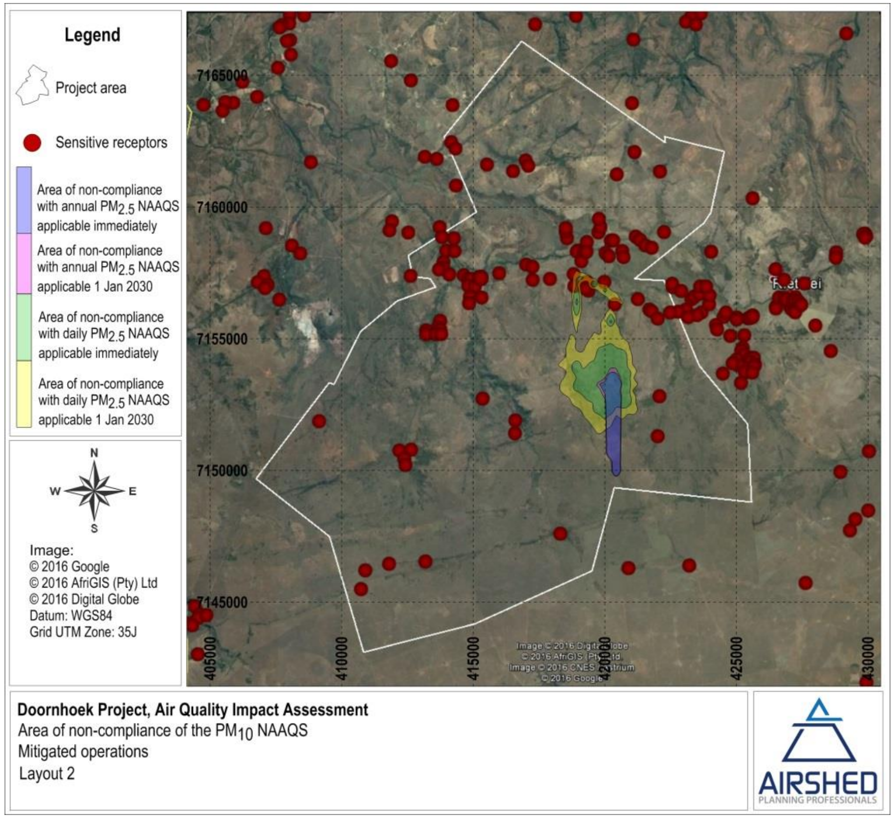


**Figure 4-5: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations assuming layout 2**

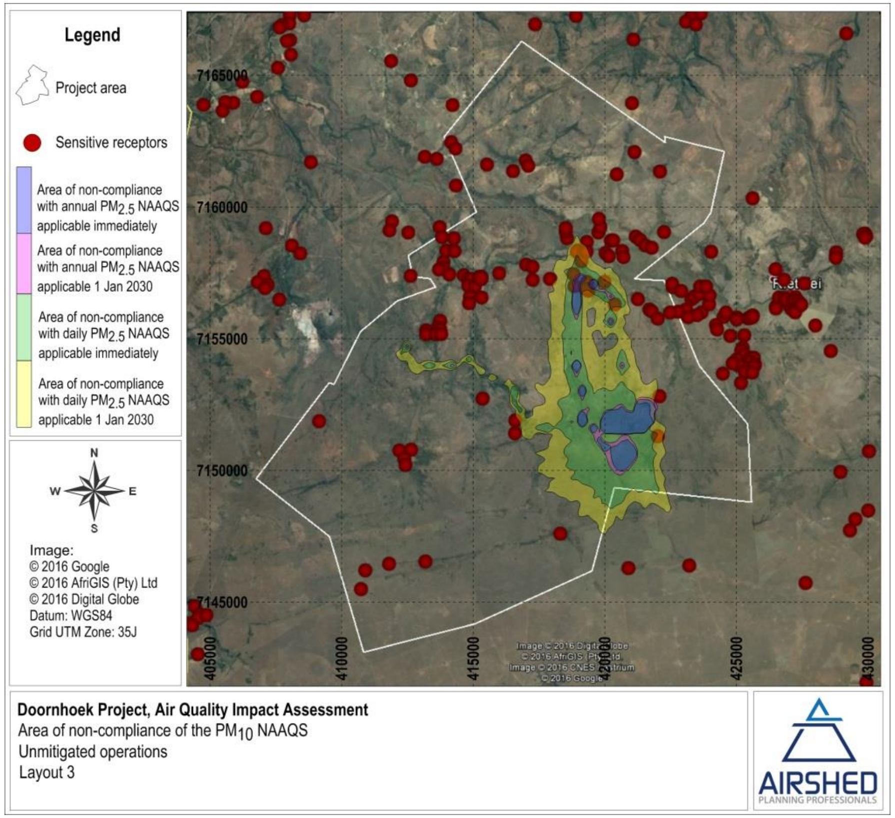


Figure 4-6: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations assuming layout 3

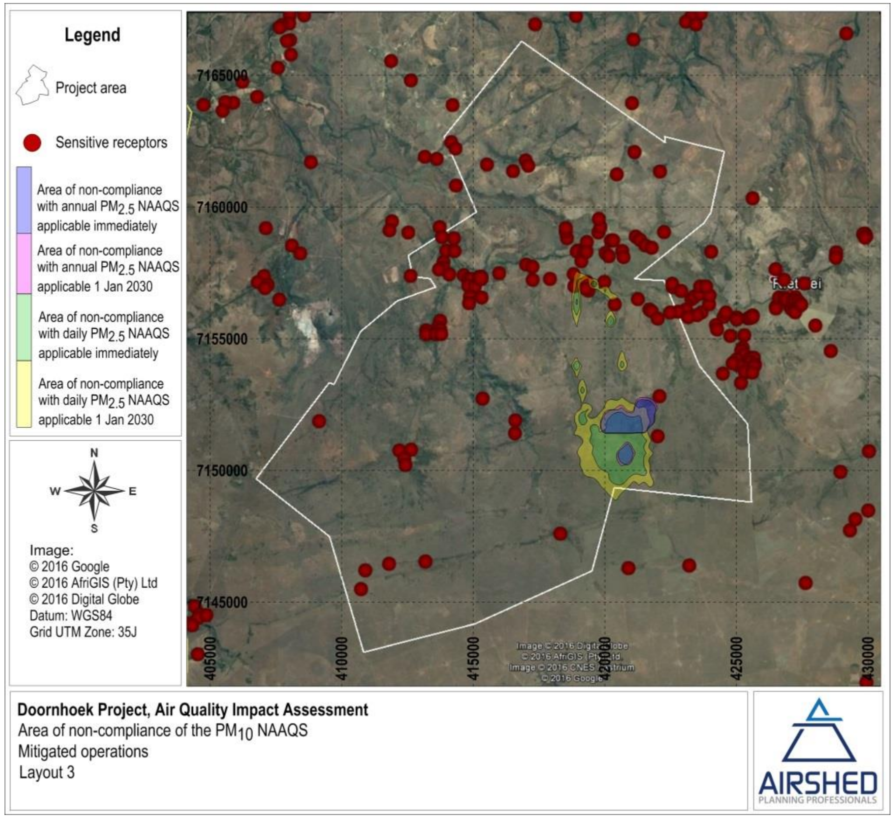


Figure 4-7: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations assuming layout 3

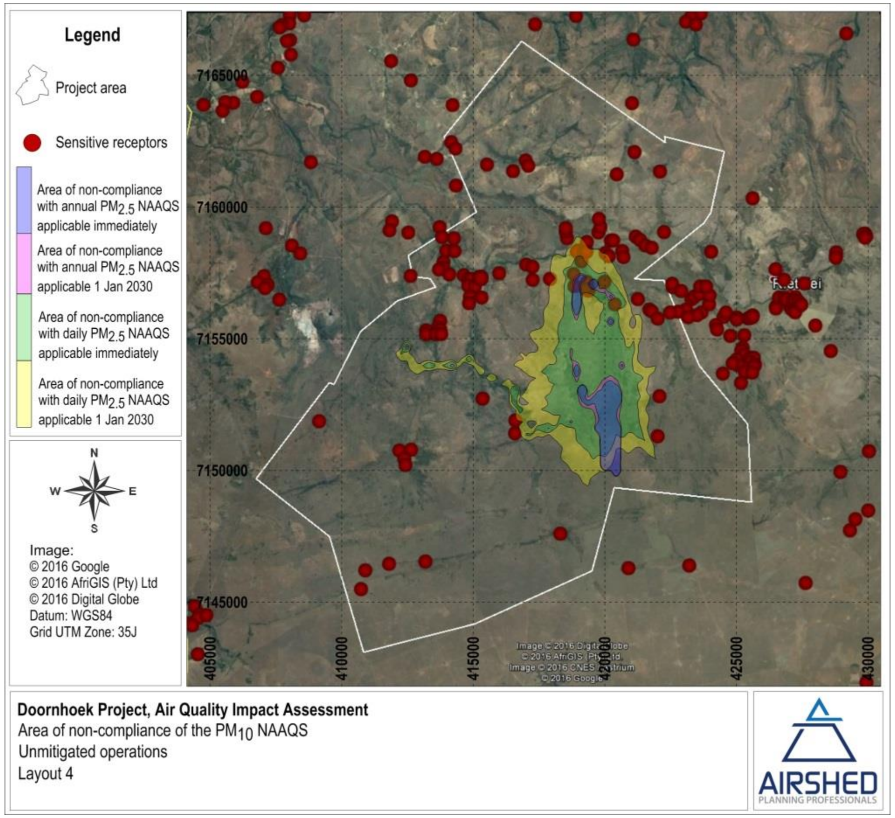


**Figure 4-8: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations assuming layout 4**

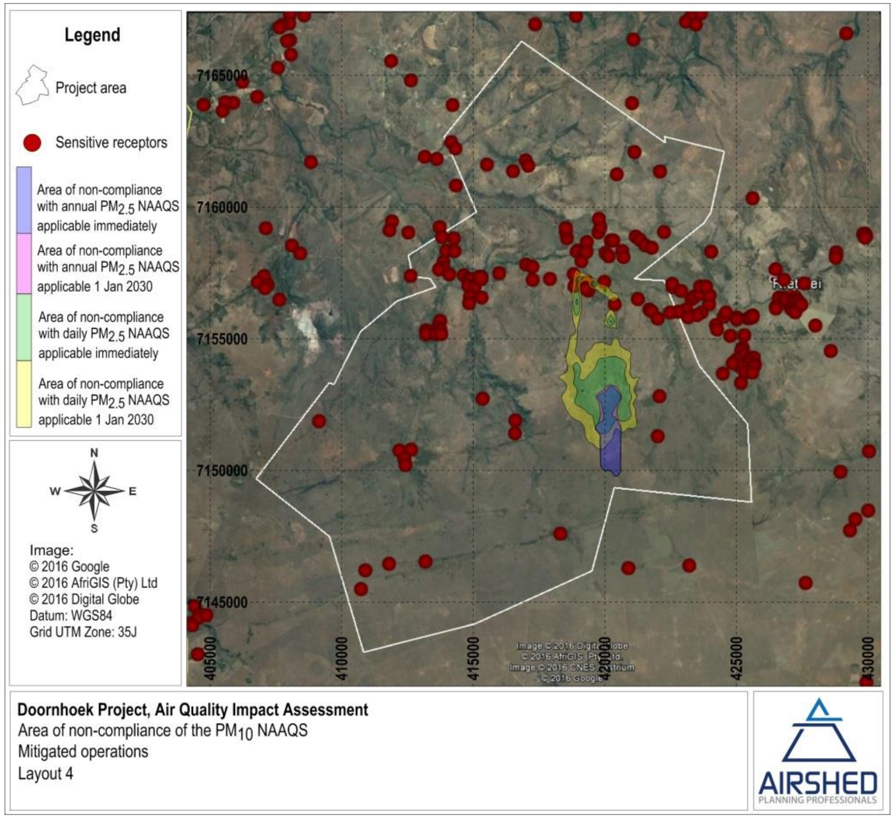


**Figure 4-9: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations assuming layout 4**

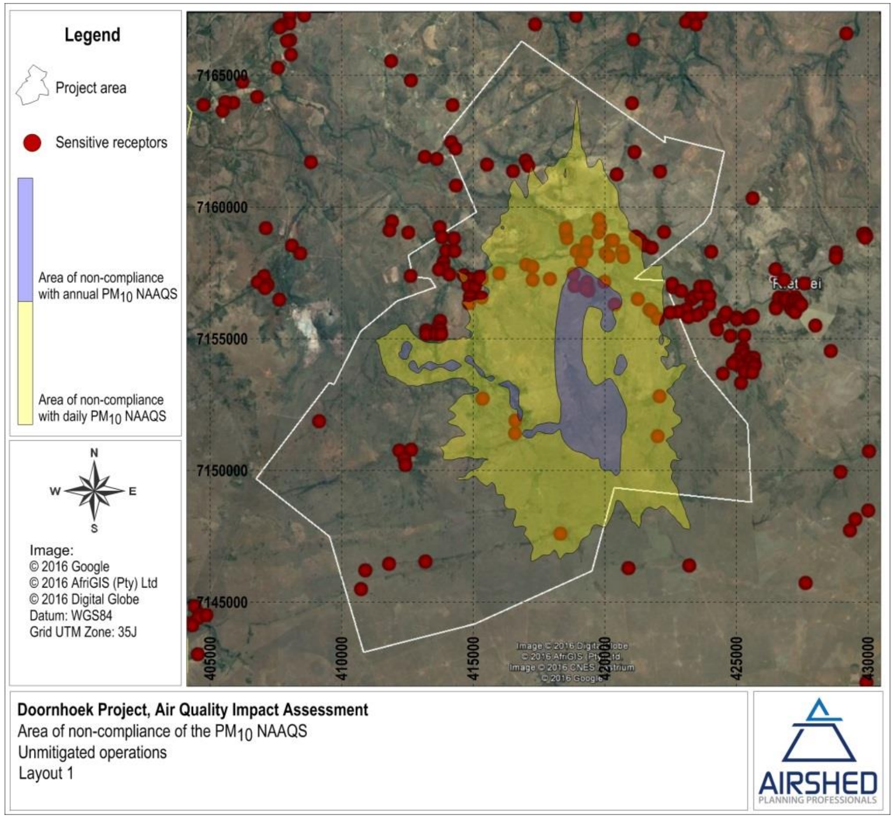


**Figure 4-10: Area of non-compliance of $PM_{10}$ NAAQS due to unmitigated operations assuming layout 1**

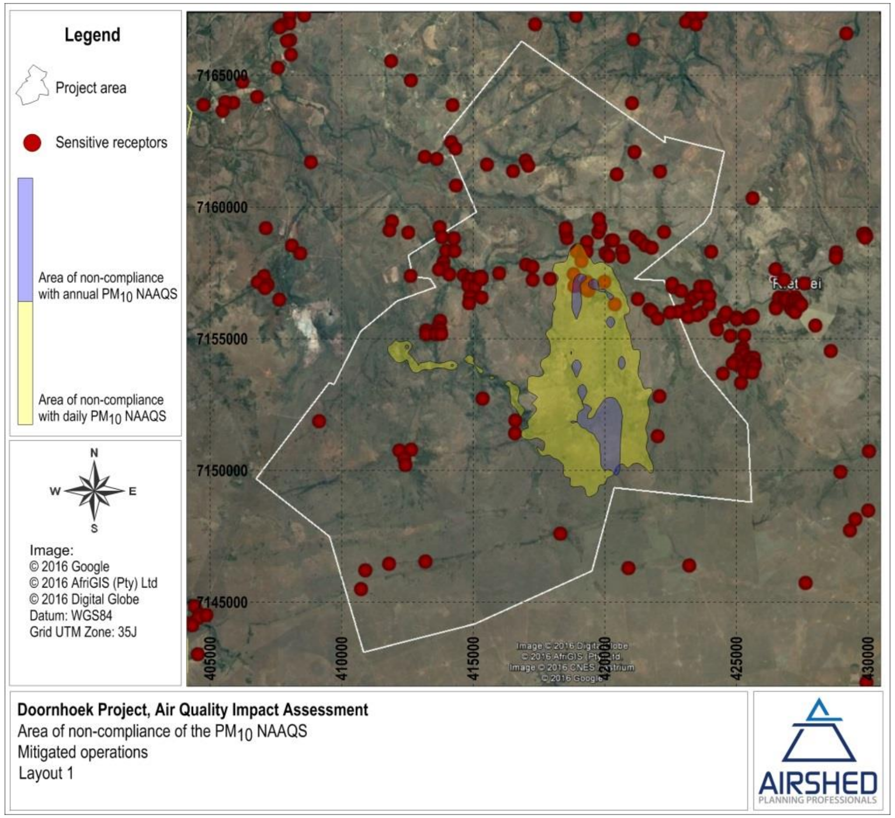


**Figure 4-11: Area of non-compliance of $PM_{10}$ NAAQS due to mitigated operations assuming layout 1**

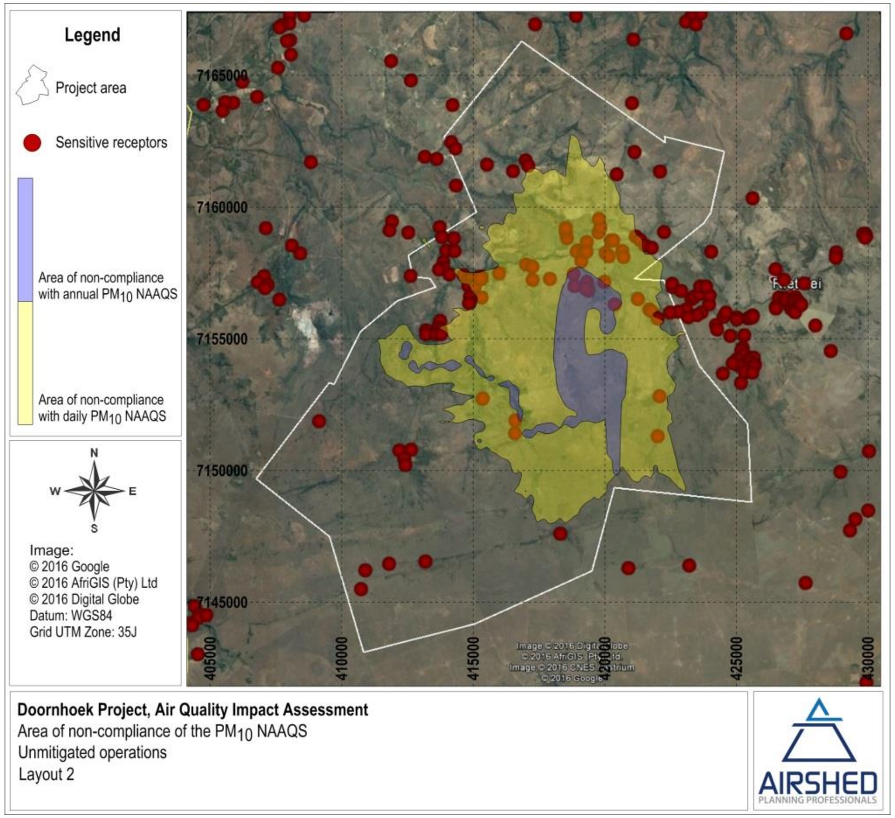


**Figure 4-12: Area of non-compliance of $PM_{10}$ NAAQS due to unmitigated operations assuming layout 2**

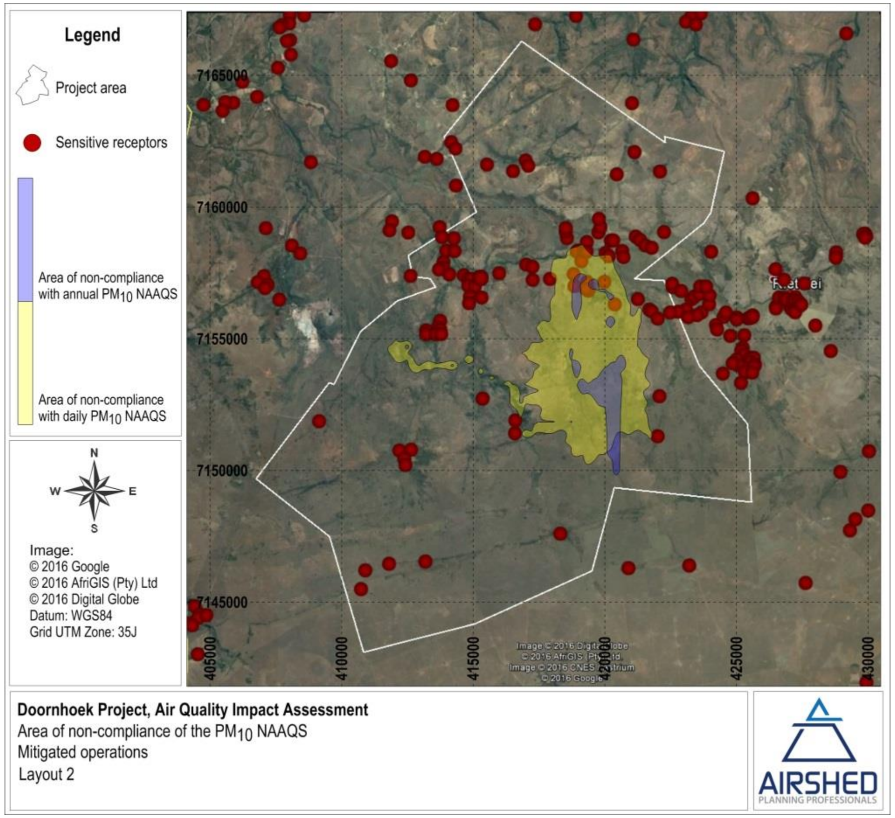


**Figure 4-13: Area of non-compliance of $PM_{10}$ NAAQS due to mitigated operations assuming layout 2**

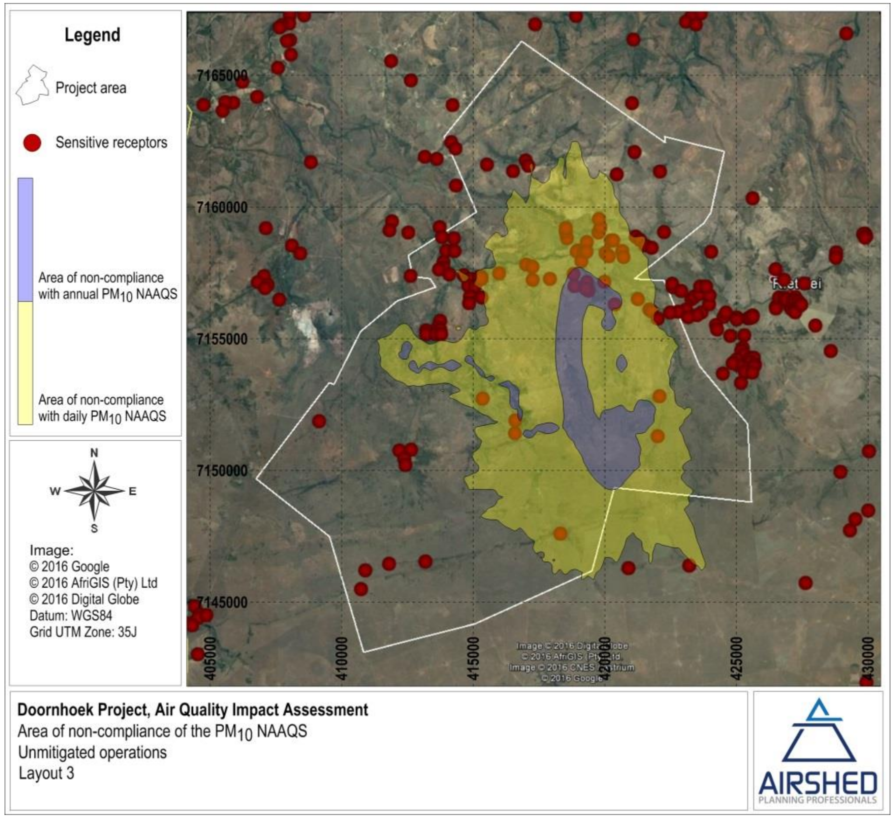


**Figure 4-14: Area of non-compliance of $PM_{10}$ NAAQS due to unmitigated operations assuming layout 3**

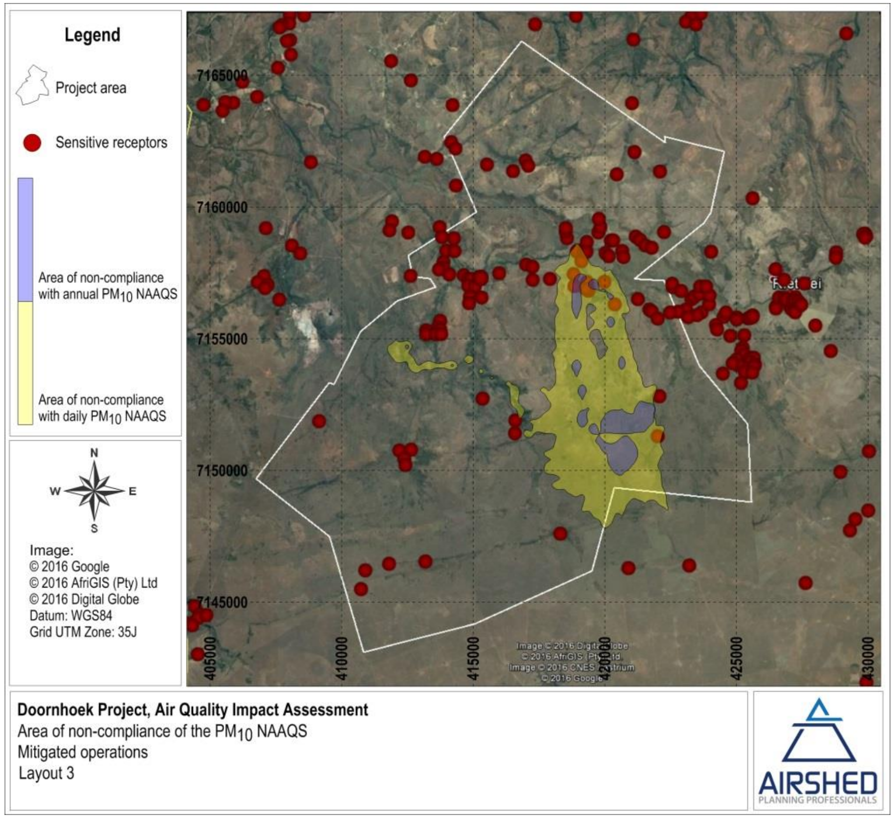


**Figure 4-15: Area of non-compliance of $PM_{10}$ NAAQS due to mitigated operations assuming layout 3**

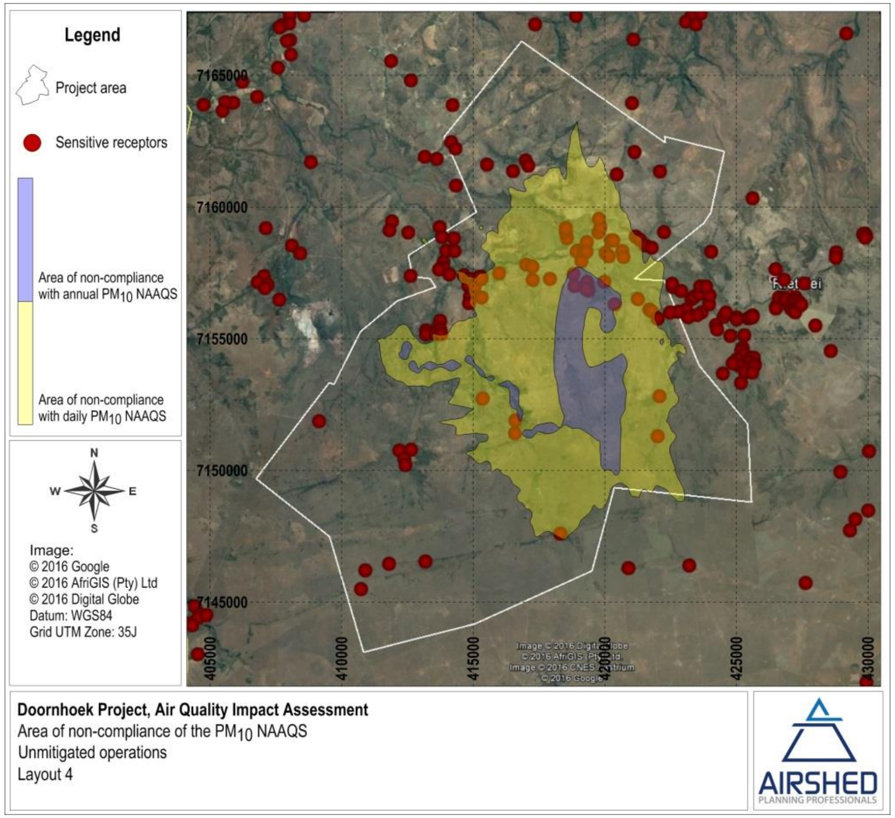


**Figure 4-16: Area of non-compliance of $PM_{10}$ NAAQS due to unmitigated operations assuming layout 4**

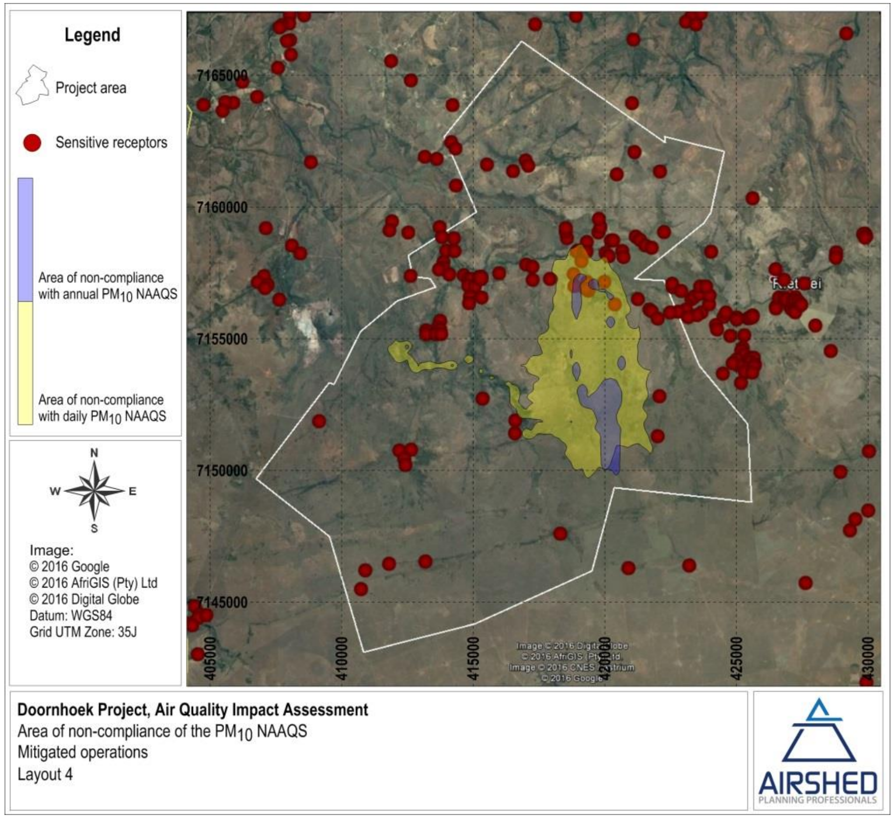


**Figure 4-17: Area of non-compliance of $PM_{10}$ NAAQS due to mitigated operations assuming layout 4**

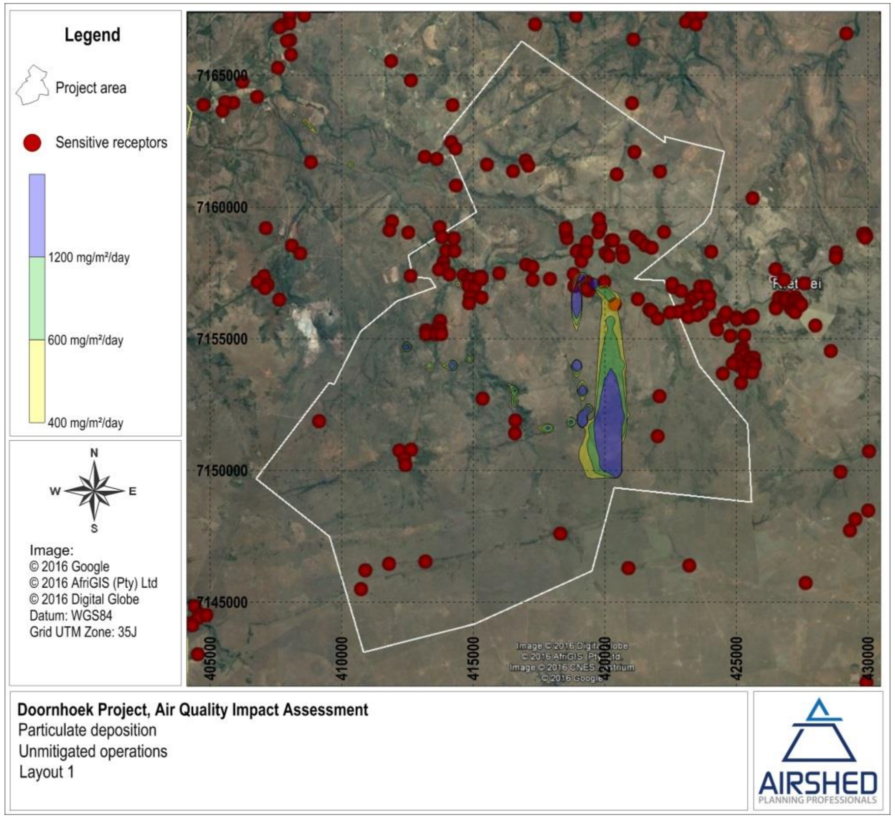


**Figure 4-18: Total particulate deposition due to unmitigated operations assuming layout 1**

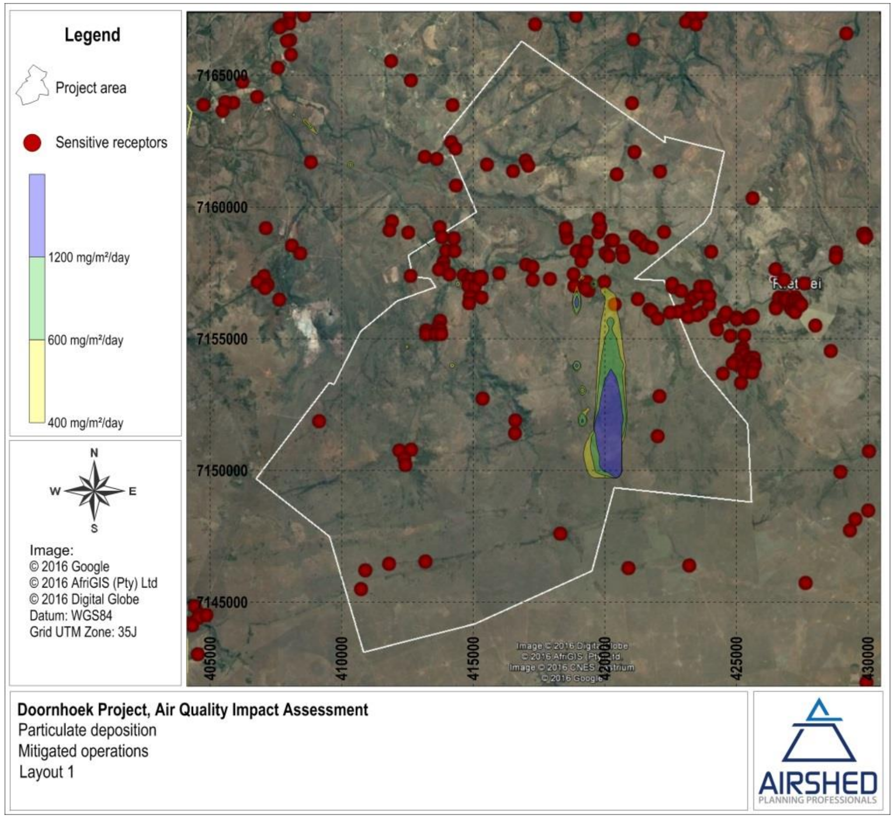


**Figure 4-19: Total particulate deposition due to mitigated operations assuming layout 1**

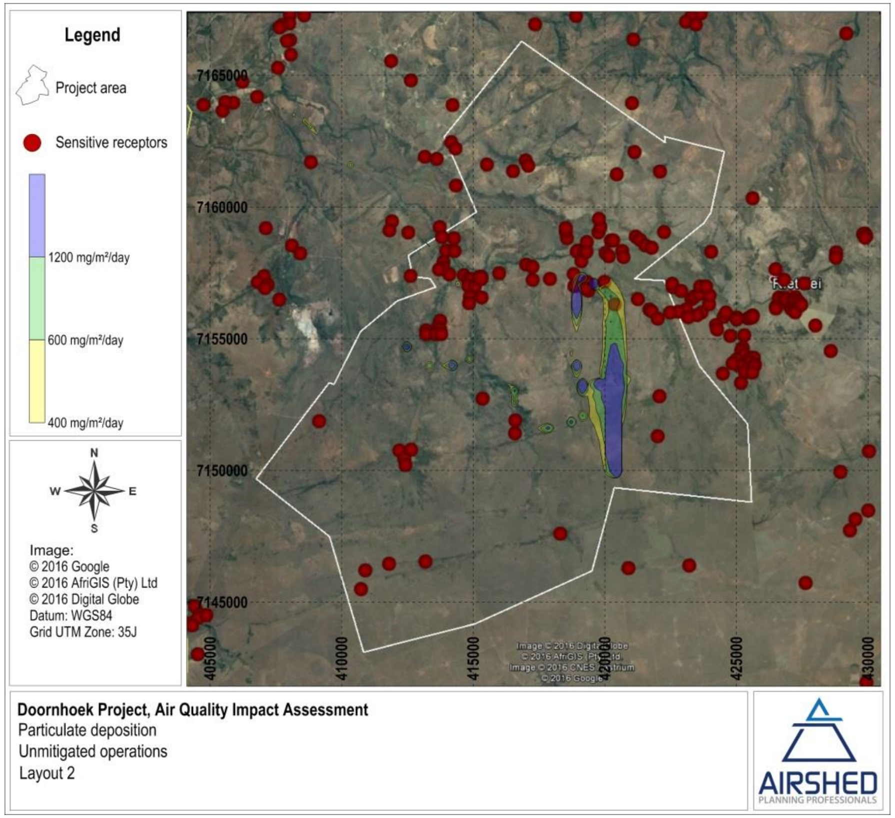


**Figure 4-20: Total particulate deposition due to unmitigated operations assuming layout 2**

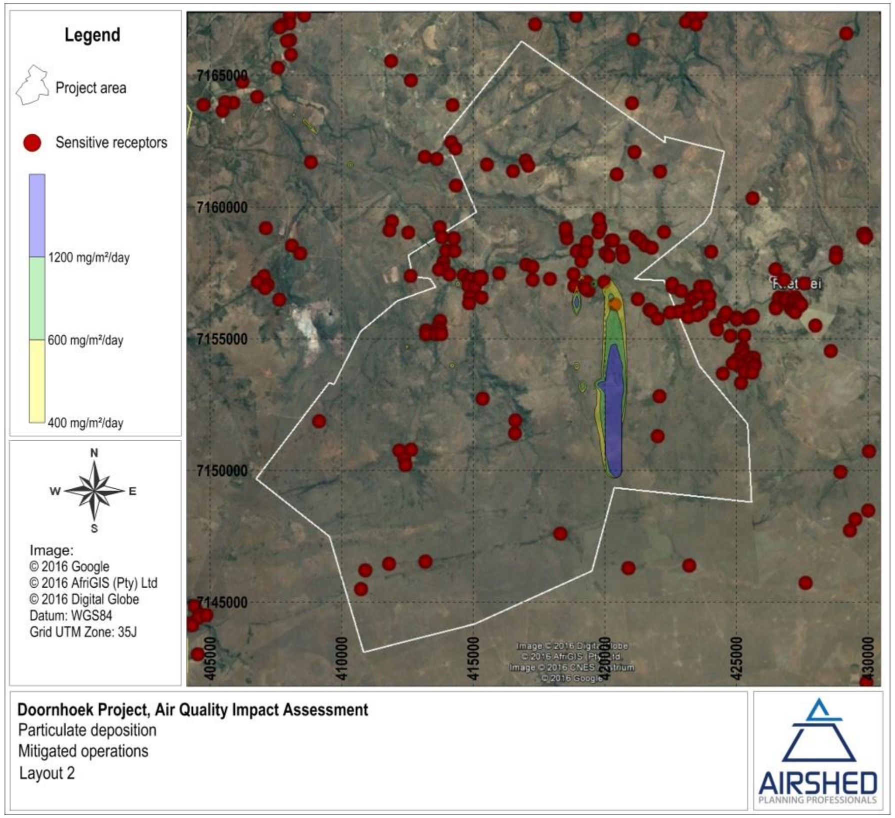


**Figure 4-21: Total particulate deposition due to mitigated operations assuming layout 2**

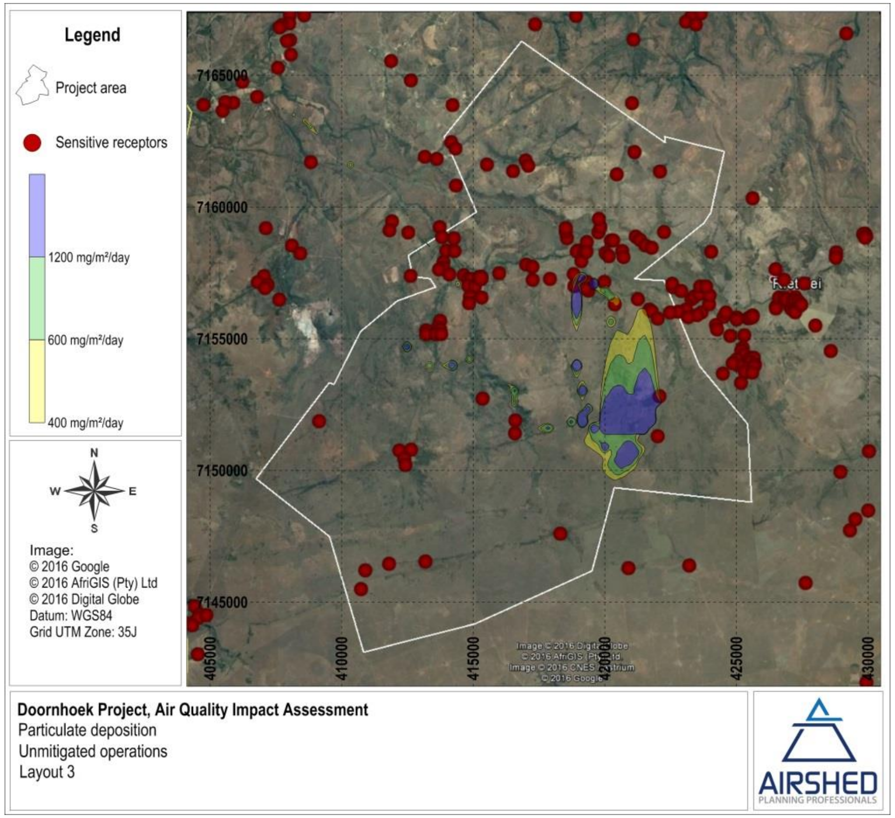


**Figure 4-22: Total particulate deposition due to unmitigated operations assuming layout 3**

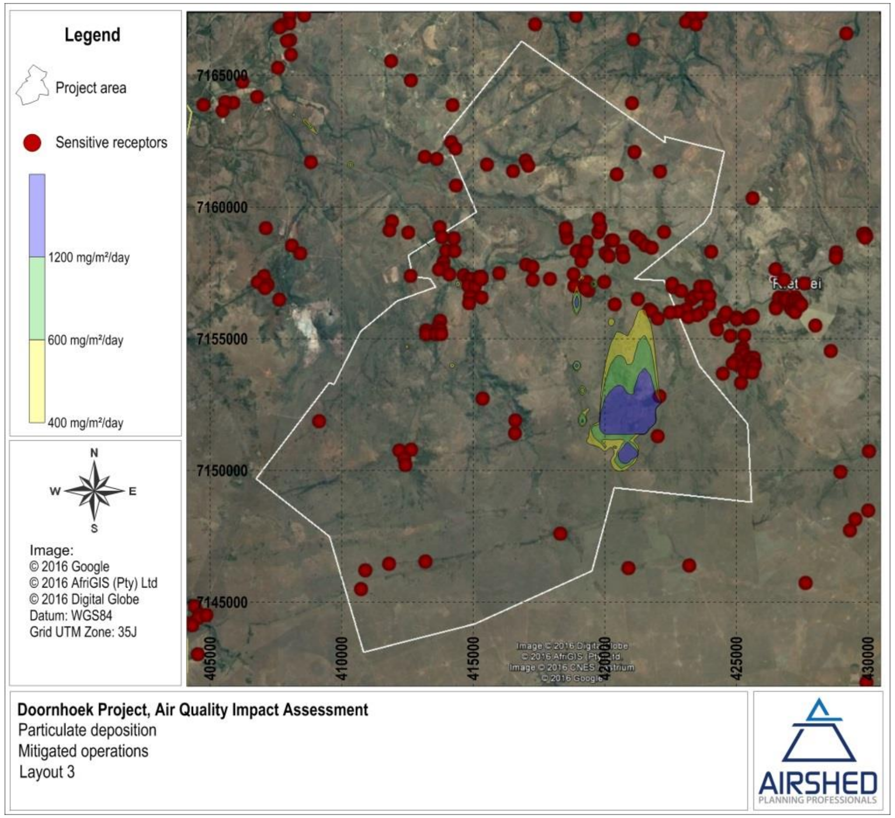


**Figure 4-23: Total particulate deposition due to mitigated operations assuming layout 3**

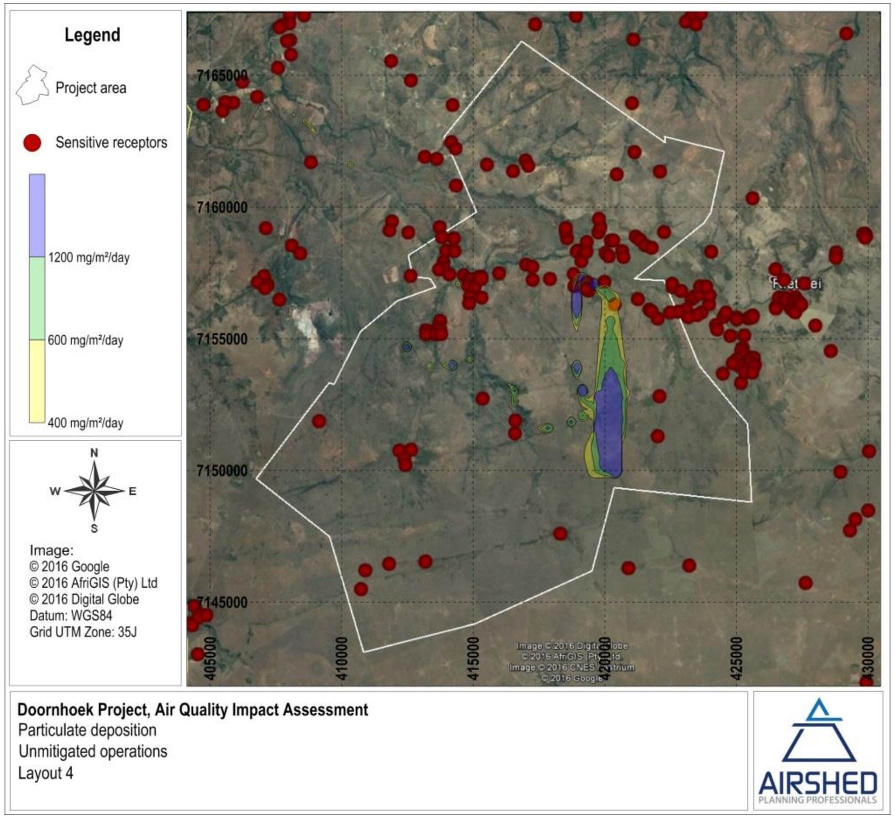


**Figure 4-24: Total particulate deposition due to unmitigated operations assuming layout 4**

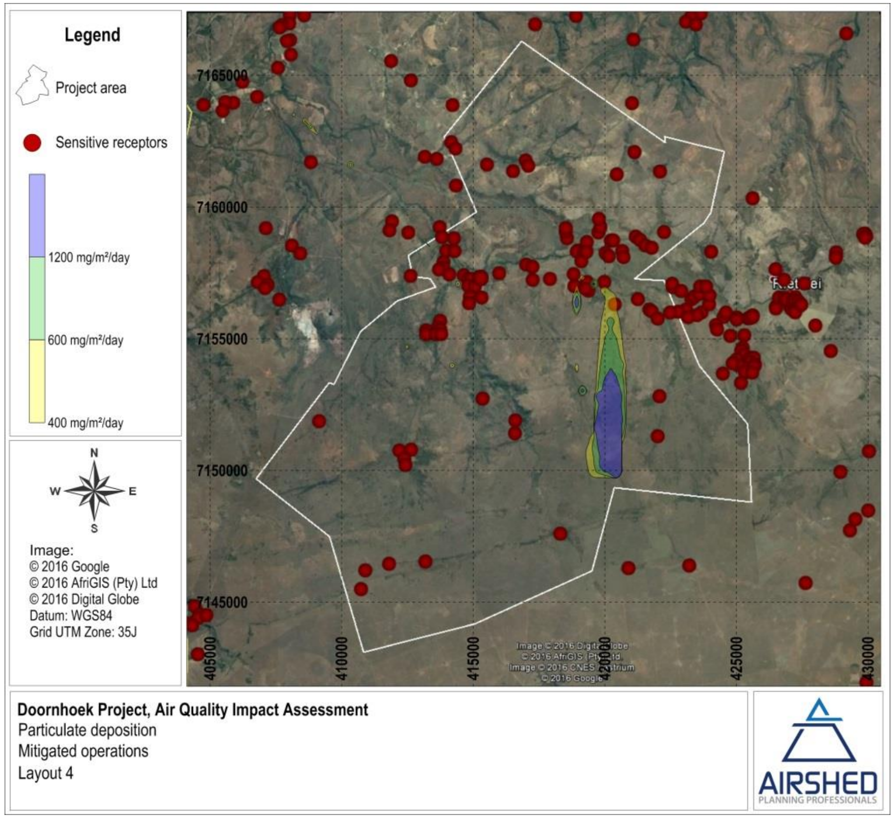


**Figure 4-25: Total particulate deposition due to mitigated operations assuming layout 4**

#### 4.2.2.4 Cumulative Impacts

Literature states that by adding the peak model concentrations to the background concentrations, this can result in sever overestimation of the source contribution and that a more realistic method is to add twice the annual mean background concentrations to the peak (or 99.9th percentile) (Ministry for the Environment, 2004). If the background $PM_{10}$ and $PM_{2.5}$ concentrations for Mahikeng (39 µg/m³ and 16 µg/m³ annual average respectively) are assumed to be representative of the mine and railway siding study areas, the annual and daily cumulative ground level concentrations may increase with a further 39 µg/m³ and 78 µg/m³ respectively for $PM_{10}$ and 16 µg/m³ and 32 µg/m³ respectively for $PM_{2.5}$.

#### 4.2.2.5 Predicted Impacts on Vegetation and Animals

No national ambient air quality standards or guidelines are available for the protection of animals and vegetation. In the absence of national ambient standards for animals, the standards used for the protection of human beings may be used to assess the impacts on animals. Areas of non-compliance of $PM_{10}$ and $PM_{2.5}$ NAAQS due to the proposed project operations are provided in Section 4.2.2.3.

While there is little direct evidence of what the impact of dustfall 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, 1991). The simulated dustfall rates due to the proposed project operations are provided in Section 4.2.2.3.

If more detailed information is required on the impact of particulate matter on vegetation and animals, it is recommended that the predicted PM concentrations and dust depositions be used in a more detailed biodiversity and/or health risk assessment study.

### 4.2.3 Mitigation Measures Recommended

Based on literature surveys, air pollution abatement measures were identified to be implemented at the main sources of fugitive dust. These mitigation measures are discussed in more detail in the following section. From the impact assessment for the Operation Phase it was predicted that impacts from the unpaved road surface and crushing and screening activities was significant.

#### 4.2.3.1 Dust Control Options for Unpaved Roads

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (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, Muleski, & Kinsey, 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

According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 10 miles per hour resulted in an increase in $PM_{10}$ emissions of between 1.5 and 3 times. A similar study conducted by Flocchini et.al. (1994) found a decrease in $PM_{10}$ emissions of 42±35% with a speed reduction from 40 km/hr to 24 km/hr (Stevenson, 2004). 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.

Water sprays on unpaved roads 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 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 and Visser, 2000).

An empirical model, developed by the US EPA (US EPA, 1996), can be used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account rainfall, evaporation rates and traffic.

Chemical suppressant has been proven to be affective due to the binding of fine particulates in the road surface, hence increasing the density of the surface material. In addition, dust control additives are beneficial in the fact that it also improves the compaction and stability of the road. The effectiveness of a dust palliative include numerous factors such as the application rate, method of application, moisture content of the surface material during application, palliative concentrations, mineralogy of aggregate and environmental conditions. Thus, for different climates and conditions you need different chemicals, one chemical might not be as effective as another under the same conditions and each product comes with various advantages and limitations of each own. In general, chemical suppressants are given to achieve a $PM_{10}$ control efficiency of 80% to 90% when applied regularly on the road surfaces (Stevenson, 2004).

There is however no cure-all solution but rather a combination of solutions. A cost-effective chemical control programme may be developed through establishing the minimum control efficiency required on a particular roadway, and evaluating the costs and benefits arising from various chemical stabilization practices. Appropriate chemicals and the most effective relationships between application intensities, reapplication frequencies, and dilution ratios may be taken into account in the evaluation of such practices.

Spillage and track-on from the surrounding unpaved areas may result in the deposition of materials onto the chemically treated or watered road resulting in the need for periodic "housekeeping" activities (Cowherd, Muleski, & Kinsey, 1988) (US EPA, 1996). In addition, the gradual abrasion of the chemically treated surface by traffic will result in loose material on the surface which would have to be controlled. The minimum frequency for the reapplication of watering or chemical stabilizers thus depends not only on the control efficiency of the suppressant but also on the degree of spillage and track-on from adjacent areas, and the rate at which the treated surface is abraded. The best way to avoid dust generating problems from unpaved roads is to properly maintain the surface by grading and shaping for cross sectional crowing to prevent dust generation caused by excessive road surface wear (Stevenson, 2004).

One of the main benefits of chemical stabilisation in conjunction with wet suppression is the management of water resources (MFE, 2001).

*In the assessment of mitigated operations, proposed project activities was simulated assuming 75% control efficiency for vehicle entrainment.*

#### *4.2.3.2 Crushing*

Enclosure of crushing operations is very effective in reducing dust. The 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 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. Hooding with fabric filters can result in control efficiencies of 83%. It is important that these control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met.

*In the assessment of mitigated operations, proposed project activities was simulated assuming 50% control efficiency on the crushing activities.*

## 4.3 Closure Phase

### *4.3.1 Identification of Environmental Aspects*

It is assumed that all the operations will have ceased by the closure phase of the project. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during closure. Aspects and activities associated with the closure phase of the proposed operations are listed in Table 4-8. Simulations of the closure phase were not included in the current study due to its temporary impacting nature.

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

| Impact | Source | Activity |
|---|---|---|
| Generation of $PM_{2.5}$ and $PM_{10}$ | Open surfaces | Dust generated during rehabilitation activities |

| Impact | Source | Activity |
|---|---|---|
| Generation of $PM_{2.5}$ and $PM_{10}$ | Offices and buildings | Demolition of the structure |
| Gas emissions | Vehicles | Tailpipe emissions from vehicles utilised during the closure phase |

### 4.3.2 Mitigation Measures Recommended

Dust control measures for open areas can consist of wet suppression, chemical suppressants, vegetation, wind breaks, etc. Wet suppressants and chemical suppressants are generally applied for short storage pile durations. For long-term control measures vegetation frequently represents the most cost-effective and efficient control.

Vegetation cover retards erosion by binding the soil with a root network, by sheltering the soil surface and by trapping material already eroded. Sheltering occurs by reducing the wind velocity close to the surface, thus reducing the erosion potential and volume of material removed. The trapping of the material already removed by wind and in suspension in the air is an important secondary effect. Vegetation is also considered the most effective control measure in terms of its ability to also control water erosion. In investigating the feasibility of vegetation types the following properties are normally taken into account: indigenous plants; ability to establish and regenerate quickly; proven effective for reclamation elsewhere; tolerant to the climatic conditions of the area; high rate of root production; easily propagated by seed or cuttings; and nitrogen-fixing ability. The long-term effectiveness of suitable vegetation selected for the site will be dependent on the nature of the cover.

# 5 SIGNIFICANCE RANKING

2014 EIA Regulations require that impacts be assessed in terms of the nature, significance, consequence, extent, duration and probability of the impacts including the degree to which these impacts can be reversed, may cause irreplaceable loss of resources, and can be avoided, managed or mitigated. The significance ranking methodology used in this assessment was provided by Exigo. The summary of significance ranking for the planning, construction, operation, closure and post-closure phases is provided in Table 5-1.

**Table 5-1: South African National Ambient Air Quality Standards (Government Gazette 32816, 2009)**

| Nr | Activity | Impact | Without or With Mitigation | Nature (Negative or Positive Impact) | Probability | | Duration | | Scale | | Magnitude/ Severity | | Significance | | Mitigation Measures | Mitigation Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Magnitude | Score | Magnitude | Score | Magnitude | Score | Magnitude | Score | Score | Magnitude | | |
| Planning Phase | | | | | | | | | | | | | | | | |
| 1 | Existing baseline ambient conditions | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Probable | 2 | Long term | 4 | Regional | 3 | High | 8 | 30 | Low | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Probable | 2 | Long term | 4 | Regional | 3 | Medium | 6 | 26 | Low | Best engineering practice to minimise impact on surrounding environment where feasible. | Can be avoided, managed or mitigated |
| Construction Phase | | | | | | | | | | | | | | | | |
| 2 | Transport and general construction activities | Gaseous and particulate emissions; fugitive dust | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Maintenance of vehicles and wet suppression or chemical treatment on unpaved road surfaces. | Can be avoided, managed or mitigated |
| 3 | Clearing of groundcover and levelling of area | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Wet suppression where feasible.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Can be avoided, managed or mitigated |
| 4 | Materials handling | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Wet suppression where feasible on materials handling activities and reducing drop height. | Can be avoided, managed or mitigated |
| 5 | Wind erosion from open areas | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Wet suppression where feasible.<br>Minimise extent of disturbed areas.<br>Reduction of frequency of disturbance.<br>Early re-vegetation<br>Stabilisation (chemical, rock cladding or vegetative) of disturbed soil. | Can be avoided, managed or mitigated |
| Operational Phase | | | | | | | | | | | | | | | | |
| 6 | Vehicle activity on paved and unpaved roads | Gaseous and particulate emissions; fugitive dust | WOM | Negative | Highly Probable | 4 | Long term | 4 | Site | 2 | High | 8 | 56 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Long term | 4 | Site | 2 | Medium | 6 | 48 | Moderate | Maintenance of vehicles and wet suppression or chemical treatment on unpaved road surfaces. | Can be avoided, managed or mitigated |
| 7 | Materials handling operations | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Long term | 4 | Site | 2 | High | 8 | 56 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Long term | 4 | Local | 1 | Medium | 6 | 44 | Moderate | Wet suppression where feasible on materials handling activities and reducing drop height. Enclosure or wet suppression on crushing | Can be avoided, managed or mitigated |

| Nr | Activity | Impact | Without or With Mitigation | Nature (Negative or Positive Impact) | Probability | | Duration | | Scale | | Magnitude/ Severity | | Significance | | Mitigation Measures | Mitigation Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Magnitude | Score | Magnitude | Score | Magnitude | Score | Magnitude | Score | Score | Magnitude | | |
| | | | | | | | | | | | | | | | activities. | |
| 8 | Mining operations within open pit | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Long term | 4 | Local | 1 | High | 8 | 52 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Long term | 4 | Local | 1 | Medium | 6 | 44 | Moderate | Wet suppression or chemical treatment on unpaved road surfaces. | Can be avoided, managed or mitigated |
| 9 | Wind erosion | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Long term | 4 | Local | 1 | Medium | 6 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Long term | 4 | Local | 1 | Low | 2 | 28 | Low | Wet suppression where feasible. Stabilisation (chemical, rock cladding or vegetative) of tailings facility. | Can be avoided, managed or mitigated |
| Closure and Decommissioning Phase | | | | | | | | | | | | | | | | |
| 10 | Dust generated during rehabilitation activities | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Wet suppression where feasible. | Can be avoided, managed or mitigated |
| 11 | Demolition of the structure | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Wet suppression where feasible. | Can be avoided, managed or mitigated |
| 12 | Tailpipe emissions from vehicles utilised during the closure phase | Gaseous and particulate emissions; fugitive dust | WOM | Negative | Highly Probable | 4 | Short term | 1 | Site | 2 | High | 8 | 44 | Moderate | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Highly Probable | 4 | Short term | 1 | Local | 1 | Medium | 6 | 32 | Low | Maintenance of vehicles and wet suppression on unpaved road surfaces. | Can be avoided, managed or mitigated |
| Post-Closure Phase | | | | | | | | | | | | | | | | |
| 13 | Wind erosion from open areas | $PM_{10}$ and $PM_{2.5}$ | WOM | Negative | Probable | 2 | Medium term | 3 | Site | 2 | Medium | 6 | 22 | Low | | Can be avoided, managed or mitigated |
| | | | WM | Negative | Probable | 2 | Medium term | 3 | Local | 1 | Low | 2 | 12 | Negligible | Vegetation of open areas. | Can be avoided, managed or mitigated |

# 6 DUST MANAGEMENT PLAN

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

## 6.1 Site Specific Management Objectives

The main objective of Air Quality Management measures for the proposed project is to ensure that all operations are within ambient air quality criteria. In order to define site specific management objectives, the main sources of pollution needed to be identified. Sources can be ranked based on source strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

Particulates were identified as the main pollutant of concern from the proposed project operations.

The ranking of sources serves to confirm or, where necessary revise, the current understanding of the significance of specific sources, and to evaluate the emission reduction potentials required for each. Sources of emissions for the proposed project may be ranked based on:

- emissions - based on the comprehensive emissions inventory established for the operations, and,
- impacts - based on the predicted dustfall levels and ambient inhalable and respirable particulate concentrations.

Source ranking based on emissions was undertaken for source groups reflecting proposed operations with no control measures. Ranking of uncontrolled sources provides an indication of the relative significance of each source. This also allows the assessment of the suitability of controls. Ranking according to emissions and impacts facilitates the identification of sources requiring further controls.

### *6.1.1 Ranking of Sources by Emissions*

Quantified particulate emissions due to the proposed project operations were provided in Section 4.2.2.2. The emissions were divided into TSP, $PM_{10}$ and $PM_{2.5}$ per operation category.

The largest contribution of total particulate emissions due to proposed unmitigated operations is crushing operations. The subsequent highest emissions are due to vehicle entrainment. Windblown dust from the tailings facility also contributes significantly to the particulate emissions.

### *6.1.2 Ranking of Sources by Impact*

In the assessment of the significance of the main source categories in terms of their impacts, reference is made to the inhalable particulate concentrations and dustfall results. NAAQS are applicable to the assessment of community exposures.

Prior to the analysis of these results, careful consideration should be given to the assumptions with regard to the temporal variations in emissions for the purpose of the dispersion modelling. Given that annual tonnages of materials (i.e. ROM and product) handled were available it was necessary to assume a constant hourly rate of emissions from such sources. Wind-blown dust was, however, calculated for each hour on the basis of wind speed and atmospheric stabilities occurring during that hour. Peaks in wind-blown emissions were therefore accounted for in the dispersion simulations, whereas peaks in materials handling emissions due to intermittent high tonnage handling periods were not accounted for.

Given that vehicle-entrained dust is not directly dependent on the wind field, such sources are estimated to have the greatest impact under relatively stable atmospheric conditions characterised by low wind speeds. With control measures in place on the haul roads (i.e. Water Carts), these emissions may reduce by 75%. On windy days, impacts due to wind-blown dust from stockpiles and open areas are expected to be high but daily estimations over annual averages indicated ground level concentrations within relevant ambient air quality criteria.

From the impact assessment, the main sources of concern due to the close proximity of sensitive receptors were identified to be the vehicle entrainment on unpaved roads and crushing operations.

## 6.2 Project-Specific Management Measures

The proposed operations have been assessed during this study with all emissions quantified and dispersion simulations executed. As a result of the air quality assessment, it is found that the acceptability of proposed operations in terms of NAAQS and NDCR necessitates the implementation of an effective local dust management plan.

Given the potential dust impacts from operations it is considered imperative that dust control measures be implemented throughout the life of the project and it is recommended that the project proponent commit itself to dust management planning.

The main contributing sources of particulate emissions have been identified and quantified. Due to the focus of the current section on the provision of a proposed monitoring system for the project (once mining has commenced), the dust management plan will focus on the proposed sources.

### *6.2.1 Estimation of Dust Control Efficiencies*

The main sources of fugitive dust emissions from the proposed project were identified to be:

- Vehicle entrainment from unpaved haul roads
- Crushing and screening activities

From the impact assessment, crushing and screening as well as vehicle entrainment were also identified as the main impacting sources.

The impacts from vehicle entrainment are directly linked to the vehicle activity. The impacts from unpaved road surfaces may be mitigated with water sprayers (assuring ~75% control efficiency). However, due to the close proximity of sensitive receptors (within the mining rights area) to the proposed activities, it is recommended that chemical suppressants be applied to unpaved roads that are in close proximity to the sensitive receptors to reduce the impacts from this source with more than 75% control efficiency in these sensitive areas.

The crushing operations are shown to be a significant source of emissions if unmitigated. It is recommended that mitigation by means of water sprayers (providing a 50% control efficiency) at the crushing and screening plant be implemented to minimise impacts from this source.

### *6.2.2 Identification of Suitable Pollution Abatement Measures*

Suitable abatement measures have been discussed in detail in Section 4.2.3.

### *6.2.3 Performance Indicators*

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

Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of wind erosion exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below 600 mg/m²/day represents an impact- or receptor-based performance indicator. The NAAQS for particulate matter and NDCR represent receptor-based objectives.

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

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

- Unpaved roads: For unpaved roads on-site of the mine it is recommended that dustfall in the immediate vicinity be <1 200 mg/m²/day and dustfall at sensitive receptors to be <600 mg/m²/day. $PM_{10}$ and $PM_{2.5}$ concentrations at the closest sensitive receptor should be within NAAQS.
- Crushing and screening plant: The absence of visible dust plume at all tipping points and outside the crushers during crushing operations would be the best indicator of effective control equipment in place. In addition the dustfall in the immediate vicinity of various sources should be <1 200 mg/m²/day and dustfall at sensitive receptors to be <600 mg/m²/day. $PM_{10}$ and $PM_{2.5}$ concentrations at the closest sensitive receptor should be within NAAQS.

#### *6.2.3.2 Receptor based Performance Indicators*

*Dustfall Network*

Based on the impacts from the proposed project it is recommended that a dust fallout monitoring network be implemented.

A dust fallout network provides management with an indication of what the increase in fugitive dust levels are. In addition, a dust fallout network can serve to meet various objectives, such as:

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

It is therefore recommended that a dust fallout network comprising of ~8 single dust fallout buckets be implemented at the mine as follows:

- Placement of a dust bucket downwind of the plant (Bucket 1);
- Placement of a dust bucket along main unpaved haul road (Bucket 2);
- Placement of a dust bucket downwind of active mining pit (Bucket 3);
- Placement of a dust buckets at the closest sensitive receptors to the north, south, east and west of the proposed plant operations (Buckets 4, Bucket 5, Bucket 6 and Bucket 7).
- Placement of a dust buckets at the closest sensitive receptors to the active haul road (Buckets 8).

The location of the dust buckets may change due to the location of active mining area, layout, etc.

A dust fallout network comprising of ~2 single dust fallout buckets is recommended at the railway siding:

- Placement of a dust bucket at closest sensitive receptor to the railway siding (Bucket 1);
- Placement of a dust bucket along access road to the rail siding (Bucket 2).

The recommended performance assessment and reporting programme for ambient air monitoring is given in Table 6-1.

**Table 6-1: Ambient air monitoring, performance assessment and reporting programme**

| Monitoring Strategy Criteria | Dustfall Monitoring |
|---|---|
| *Monitoring objectives* | - Assessment of compliance with dustfall limits within the main impact zone of the operation.<br>- Facilitate the measurement of progress against environmental targets within the main impact zone of the operation.<br>- Temporal trend analysis to determine the potential for nuisance impacts within the main impact zone of the operation.<br>- Tracking of progress due to pollution control measure implementation within the main impact zone of the operation.<br>- Informing the public of the extent of localised dust nuisance impacts occurring in the vicinity of the mine operations. |
| *Monitoring location(s)* | It is recommended to implement a dust fallout monitoring network consisting of 8 single dust buckets at the proposed mine and 2 single dust buckets at the railway siding. |
| *Sampling techniques* | *Single Bucket Dust Fallout Monitors*<br>Dust fallout sampling measures the fallout of windblown settle able dust. Single bucket fallout monitors to be deployed following the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739). This method employs a simple device consisting of a cylindrical container exposed for one calendar month (30 days, ±2 days). |

| Monitoring Strategy Criteria | Dustfall Monitoring |
|---|---|
| *Accuracy of sampling technique* | Margin of accuracy given as ±200 $mg/m^2/day$. |
| *Sampling frequency and duration* | On-going, continuous monitoring to be implemented facilitating data collection over 1-month averaging period. |
| *Commitment to QA/QC protocol* | Comprehensive QA/QC protocol implemented. |
| *Interim environmental targets (i.e. receptor-based performance indicator)* | Maximum total daily dustfall (calculated from total monthly dustfall) of not greater than 600 $mg/m^2/day$ for residential areas. Maximum total daily dustfall to be less than 1 200 $mg/m^2/day$ on-site (non-residential areas). |
| *Frequency of reviewing environmental targets* | Annually (or may be triggered by changes in air quality regulations). |
| *Action to be taken if targets are not met* | (i) Source contribution quantification.<br>(ii) Review of current control measures for significant sources (implementation of contingency measures where applicable). |
| *Procedure to be followed in reviewing environmental targets and other elements of the monitoring strategy (e.g. sampling technique, duration, procedure)* | Procedure to be drafted in liaison with I&APs through the proposed community liaison forum. Points to be taken into account will include, for example: (i) trends in local and international ambient particulate guidelines and standards and/or compliance monitoring requirements, (ii) best practice with regard to monitoring methods, (iii) current trends in local air quality, i.e. is there an improvement or deterioration, (iv) future development plans within the airshed (etc.) |
| *Progress reporting* | At least annually to the necessary authorities and community forum. |

*$PM_{10}$ Sampling*

It is recommended that $PM_{10}$ sampling campaign be undertaken at the receptors in the northern operational area once the haul road in the vicinity is active in order to ensure that NAAQS are being met.

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

#### 6.2.4.1 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during rehabilitation, with annual environmental audits being conducted. Annual environmental audits should be continued at least until closure. Results from site inspections and 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.

The criteria to be taken into account in the inspections and audits must be made transparent by way of minimum requirement checklists included in the Environmental Management Plan.

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.

#### 6.2.4.2 Liaison Strategy for Communication with Interested and Affected Parties (I&APs)

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. EMPs should stipulate specific intervals at which forums will be held, and provide information on how people will be notified of such meetings. For operations for which un-rehabilitated or party rehabilitated impoundments are located in close proximity (within 3 km) from residential areas, it is recommended that such meetings be scheduled and held at least on a bi-annual basis.

#### 6.2.4.3 Financial Provision (Budget)

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

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

### 6.3 Summary of Dust Management Plan

Based on the evaluation of the proposed project, a summary of the air quality management objectives are provided in Table 6-2. The management and monitoring of all operations at the mine and railway siding should be evaluated on a daily basis and appropriate actions taken to minimise dust generation and impacts.

**Table 6-2: Air Quality Management Plan for the proposed project operations**

| Aspect | Impact | Management Actions/Objectives | Target Date |
|---|---|---|---|
| Vehicle entrainment on unpaved road surfaces | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Various management measures may be implemented including:<br>Water sprayers providing ~75% control efficiency<br>Chemical suppressants providing 80%-90% control efficiency.<br><br>Due to the close proximity of sensitive receptors (within the mining rights area) to the proposed project activities, it is recommended that chemical suppressants be applied to unpaved roads that are in close proximity to the sensitive receptors to reduce the impacts from this source by 80%-90% control efficiency in these sensitive areas. | Duration of operations |
| Crushing operations | $PM_{10}$ and $PM_{2.5}$ concentrations and dustfall rates | Various management measures may be implemented including:<br>Telescopic chute with water sprays providing ~75% control efficiency<br>Water sprayers on crushing activities providing ~50% control efficiency<br>Hoods with scrubbers providing up to 75% control efficiency<br>Enclosure of scrubbers and screens would provide up to 100% control efficiency<br>Hooding with fabric filters can result in control efficiencies of 83%.<br><br>As a minimum, water sprayers on the crushing activities should be implemented. | Duration of operations |
| Wind erosion from | $PM_{10}$ and $PM_{2.5}$ | Progressive backfilling and rehabilitation efforts during operation and | On-going and |

| Aspect | Impact | Management Actions/Objectives | Target Date |
|---|---|---|---|
| exposed mining surfaces | concentrations and dustfall rates | closure of the mine. | post-operational phase |
| Ambient Monitoring | Dustfall rates | Establish a dust fallout monitoring network (consisting of 8 single dust buckets at the mine site and 2 single dust buckets at the railway siding), as recommended in Section 6.2.3. Dust fallout rates to be below 1200 mg/m²/day in non-residential areas and 600 mg/m²/day in residential areas, averaged over 30 days. | Duration of operations |

# 7 FINDINGS AND RECOMMENDATIONS

## 7.1 Findings

An air quality impact assessment was conducted for the proposed operations at the Doornhoek Fluorspar mine and associated railway siding. The main objective of this study was to determine the significance of the predicted impacts from the proposed project operations on the surrounding environment and on human health. Emission rates were quantified for the proposed activities and dispersion modelling executed.

The main findings from the baseline assessment were as follows:

- The main sources likely to contribute to cumulative particulate impact are surrounding mining operations, agricultural activities as well as vehicle entrainment on unpaved road surfaces and household and biomass burning.

- The flow field is dominated by winds from the north-easterly sector. During day-time conditions, wind speeds are slightly higher and more frequently from the north and north-northeast, with winds from the east-northeast increasing at night.

- The closest residential area to the project area is the suburb of Zeerust (~10km to the north-west of the project area), Groot Marico (~15km to the north-east of the project area) and Ottoshoop (~10km to the west of the project area) with numerous individual homesteads located within and around the proposed project area.

- Annual $PM_{10}$ and $PM_{2.5}$ concentrations measured at the closest monitoring station (Mahikeng) to the site was 39 µg/m³ and 16 µg/m³ respectively for the period May 2015 to April 2016.

The main findings from the impact assessment due to proposed project operations were as follows:

- Crushing activities and vehicle entrained dust from unpaved road surfaces represented the highest impacting particulate sources from the proposed operations.

- The highest $PM_{2.5}$ concentrations due to proposed project operations (unmitigated) were in non-compliance with NAAQS at the closest sensitive receptors for all four layout options. When activities were mitigated (assuming 75% control efficiency on unpaved road surfaces and 50% control efficiency on crushing activities) the $PM_{2.5}$ concentrations were in compliance with NAAQS at the closest sensitive receptors.

- The highest $PM_{10}$ concentrations due to proposed project operations (unmitigated) were in non-compliance with NAAQS at the closest sensitive receptors for all four layout options. When activities were mitigated the $PM_{10}$ concentrations were still in non-compliance with NAAQS at the closest sensitive in the northern sector of operations. The non-compliance in the northern sector of operations was due to vehicle entrainment.

- Maximum daily dust deposition exceeded the NDCR for non-residential areas at the sensitive receptors to the north of operations (assuming unmitigated activities) due to vehicle entrainment on the haul road. With mitigation measures in place (assuming 75% control efficiency on the haul road) the dust deposition was within the NDCR for residential areas at all sensitive receptors.

## 7.2 Recommendations

The following recommendations are made:

- It is recommended that a dust fallout monitoring network be implemented at the proposed project site as recommended in Section 6 in order to monitor the impacts from the proposed project activities.

- Due to the close proximity of sensitive receptors to the proposed project activities, it is recommended that mitigation measures on the main sources of fugitive dust (as recommended in Table 6-2) be implemented to minimise impacts as far as possible.

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