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Air Quality Impact Assessment for the Vlakvarkfontein Colliery

Project done on behalf of **Environmental Impact Management Services (Pty) Ltd**

Project Compiled by:

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Report Details

Status	Revision 0.2
Report Title	Air Quality Impact Assessment for the Vlakvarkfontein Colliery
Report Number	17EIM07
Date	December 2017
Client	Environmental Impact Management Services (Pty) Ltd
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Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts as well as noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
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Revision Record

Revision Number	**Date**	**Reason for Revision**
Draft	November 2017	For client review
Rev 0.1	December 2017	Additional information provided on measured dust fallout results
Rev 0.2	December 2017	Change in writeup of dust fallout measurements
Rev 0.3	February 2018	Grammatical changes

EXECUTIVE SUMMARY

Introduction

Vlakvarkfontein coal mine is planning to extend their opencast mining area to include an additional ~100 hectares within the existing mining right boundary. As such a S102 amendment process is being undertaken by the mine, as well an EA process, including an EIA to assess any new impacts associated with the change in the extent of the approved mining area. The operations at the Vlakvarkfontein Mine is hereafter referred to as the project. Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd to undertake an Air Quality Impact Assessment for the project.

The aim of the investigation is to quantify the possible impacts resulting from the 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 Gazette 40772 of 7 April 2017).

Baseline Assessment

The baseline study encompassed the analysis of meteorological data. Local meteorological data (including wind speed, wind direction and temperature) was obtained from the Eskom operation station at Kendal for the period January 2012 to March 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 drilling and blasting activities, vehicle entrainment, materials handling, crushing activities and wind erosion from stockpiles were quantified.

Impact Prediction Study

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

Assumptions, Exclusions and Limitations

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

- Meteorological data: As no onsite meteorological data was available, use was made of measured meteorological data from the closest Eskom monitoring station located south of the Kendal Power Station (~9km southeast of the current Vlakvarkfontein opencast mining area) for the period January 2012 to March 2015. Due to the relatively flat terrain, the distance is not expected to have a material impact on the dispersion modelling results and the conclusions reached.
- Emissions:
    - The quantification of sources of emission was restricted to the project activities only. Although other background sources were identified in the study area, such sources were not quantified as this did not form part of the scope of this assessment.
    - Information required for the calculation of emissions from fugitive dust sources for the proposed project operations was provided by the client. 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 non-routine operations or 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 could only be 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 agricultural activities, mining and industrial activities as well as vehicle entrainment on unpaved road surfaces and biomass burning.

- The wind field is dominated by winds from the north-west and east.

- Numerous individual homesteads are located around the project area. Larger residential areas include a settlement directly north of the mine.

- Measured PM_{10} ground level concentrations at Kendal (Eskom monitoring station) exceed NAAQS during the sampling period of 2012 to 2014.

- The dust fallout measured at the Vlakvarkfontein sampling network (directional buckets) for the period March to August 2017 were provided for five sites with the geometric mean ranging from 527 mg/m²/day to 70 mg/m²/day.

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

- Vehicle entrainment on unpaved surfaces and, to a lesser extent, crushing activities represented the highest impacting particulate sources from the current and proposed project operations.

- The highest simulated ground level PM_{10} concentrations due to current unmitigated project operations were in non-compliance with daily NAAQS at sensitive receptors within the study area. When activities were mitigated (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities), the impacts reduced significantly with exceedances of the NAAQS only at the closest sensitive receptors directly north of the mine. The extent of the PM_{10} impacts increase with proposed operations with exceedances of the NAAQS (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities) at residential area north of the mine and individual homesteads north and northwest of the mine.

- The highest simulated $PM_{2.5}$ concentrations due to current unmitigated project operations were in non-compliance with daily NAAQS at the residential area north of the mine and an individual homestead northwest of the mine. When activities were mitigated (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities), the impacts reduced significantly with no exceedances of the NAAQS at the closest sensitive receptors. The extent of the $PM_{2.5}$ impacts increase with proposed operations but are within NAAQS with mitigated operations (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities).

- Maximum daily dust deposition due to unmitigated and mitigated operations exceeded the NDCR for residential areas at the closest sensitive receptors (residential area) to the north of the mine.

Recommendations

The following recommendations are made:

- It is recommended that ambient sampling, as outlined in Section 6.2.3.2, be undertaken 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 extensive 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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LIST OF ACRONYMS AND SYMBOLS

APCS	Air pollution control systems
AQA	Air Quality Act
AQM	Air Quality Management
°C	Degrees Celsius
CE	Control efficiency
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CEPA	Canadian Environmental Protection Agency
DEA	Department of Environmental Affairs
EIA	Environmental Impact Assessment
GHG	Greenhouse gas
GJ	Giga joule
GWP	Global warming potential
HPA	Highveld priority area
I&AP	Interested and affected parties
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
LMo	Monin-Obukhov length
m^3	Cubic metre
m^2	Square metre
NAAQS	National Ambient Air Quality Standards
NACA	National Association for Clean Air
NDCR	National Dust Control Regulations
NH_3	Ammonia
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
NO	Nitrogen oxide
NPI	National pollution inventory
O_3	Ozone
Pb	Lead
PM	Particulate matter
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10μm
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5μm
QA	Quality assessment
QC	Quality control
ROM	Run of Mine
SA	South Africa
SACNASP	South African Council for Natural Scientific Professions
SANS	South African National Standards
SO_2	Sulfur Dioxide
tCO_2eq	Tonnes carbon dioxide equivalent
TJ	Terra joule
TSP	Total Suspended Particles
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometre travelled
VOC	Volatile organic compound

Note:

1. The spelling of "sulfur" has been standardised to the American spelling throughout the report. The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, in 1990 published a list of standard names for all chemical elements. It was decided that element 16 should be spelled "sulfur". This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: http://goldbook.iupac.org (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.doi: 10.1351/goldbook)"

Air Quality Impact Assessment for the Vlakvarkfontein Colliery

1 INTRODUCTION

1.1 Purpose/ Objectives

Vlakvarkfontein coal mine is planning to extend their opencast mining area to include an additional ~100 hectares within the existing mining right boundary. As such a S102 amendment process is being undertaken by the mine, as well an Environmental Impact Assessment (EIA) to assess any new impacts associated with the change in the extent of the approved mining area. The operations at the Vlakvarkfontein Mine is hereafter referred to as the project. Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd to undertake an Air Quality Impact Assessment for the project.

The main objective of this study is to determine the significance of the predicted impacts from the project operations on the surrounding environment and on human health.

1.2 Terms of Reference/Scope of Work

The terms of reference for the assessment are as follows:

1. **Baseline**
    - Identification of existing air pollution sources;
    - Identification of air quality-sensitive receptors, including any nearby residential dwellings in the vicinity of the project;
    - Collection of local weather conditions form the closest meteorological monitoring station;
        - Preparation of three years of raw meteorological data. The required meteorological data includes hourly average wind speed, wind direction and temperature data.
        - Simulation of wind field, mixing depth and atmospheric stability.
    - The legislative and regulatory context, including ambient air quality standards.
    - Assessment of baseline air pollutant measurements (from available information).

2. **Impact Assessment**
    - Quantification of all sources of atmospheric emissions associated with the project.
    - Formatting of meteorological data for input to the dispersion.
    - Obtain and process topographical data for input into the dispersion model (if required).
    - Dispersion simulations of ground level pollutants, due to routine emissions from the project, reflecting highest daily and annual average concentrations. The United States Environmental Protection Agency (US EPA) approved AERMOD model to be used.
    - Analysis of dispersion modelling results.
    - Evaluation of potential for human health and environmental impacts.
    - Quantification of greenhouse gas (GHG) emissions.

3. **Air Quality Management Plan**
    - Recommended mitigation measures and monitoring program for the site.

1.3 Deliverables

At the core of the study is the provision of a mathematical tool (i.e. the dispersion model) that credibly describes the fluxes and dispersion of air emissions from the project through the incorporation of meteorological and emission configuration complexities.

The final deliverables are ground level particulate air concentration and total dust deposition predictions provided as isopleths superimposed on base maps of the study area.

1.4 Specialist Details

1.4.1 Statement of Independence

Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.

1.4.2 Competency Profiles

1.4.2.1 RG von Gruenewaldt (MSc (Meteorology), BSc, Pr. Sci Nat.)

Reneé von Gruenewaldt is a Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP) and a member of the National Association for Clean Air (NACA).

Following the completion of her bachelor's degree in atmospheric sciences in 2000 and honours degree (with distinction) with specialisation in Environmental Analysis and Management in 2001 at the University of Pretoria, her experience in air pollution started when she joined Environmental Management Services (now Airshed Planning Professionals) in 2002. Reneé von Gruenewaldt later completed her Master's Degree (with distinction) in Meteorology at the University of Pretoria in 2009.

Reneé von Gruenewaldt became partner of Airshed Planning Professionals in September 2006. Airshed Planning Professionals is a technical and scientific consultancy providing scientific, engineering and strategic air pollution impact assessment and management services and policy support to assist clients in addressing a wide variety of air pollution related risks and air quality management challenges.

She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Reneé has been the principal air quality specialist and manager on several Air Quality Impact Assessment projects between 2006 to present and her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality.

A comprehensive curriculum vitae of Reneé von Gruenewaldt is provided in Appendix A.

The declaration of independence for Reneé von Gruenewaldt is provided in Appendix B.

1.5 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 project;
- Discussion of meteorological parameters required to establish the atmospheric dispersion potential;
- Simulation of the ambient 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.

1.5.1 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 demolition/closure. During operational phase air emissions include those from vehicle entrainment, drilling, blasting, crushing, materials handling and wind erosion.

1.5.2 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 project. For the current assessment, the impacts were assessed against published NAAQS and Dust Control Regulations (NDCR).

1.5.3 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 measured meteorological data from the Eskom monitoring station located south of the Kendal Power Station.

1.5.4 Alternatives Considered for the Assessment

The following alternatives are looked at in terms of air quality:

- Regarding the filter cake (fines): both the option to stockpile on site for use as non-select product (Alternative P2a) as well as the option for disposal (Alternative P2b).
- For the disposal of carboniferous wastes (wash plant waste rock and possibly filter cake), the option of disposal of to pit (Alternative P3d) appears to be most suitable because no new dump on surface will be required. Disposal to a surface waste disposal facility located on old rehabilitated mine area (Alternative P3a) is however also assessed if in pit disposal in not feasible. In the event that designing the dumps on rehabilitated areas becomes problematic, the option of disposal to a surface waste disposal facility located on un-mined area (Alternative P3b) is to be considered.

The emissions from these alternatives would result from vehicle entrainment for the transport of the fines and wash plant waste rock with limited emissions as a result of windblown dust due to the nature of the material. These alternatives are assessed qualitatively, and their significance rated in Section 5.

1.5.5 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 with 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).

1.5.6 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 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 PM_{10}, $PM_{2.5}$ and total suspended particulates (TSP) was modelled for an area covering 14.7 km (north-south) by 14.7 km (east-west). These areas were divided into a grid with a resolution of 147 m (north-south) by 147 m (east-west) for the modelling of concentrations and a grid with a resolution of 210 m (north-south) by 210 m (east-west) for the modelling of deposition. AERMOD simulates ground-level concentrations for each of the receptor grid points. AERMOD executable version 16216 was used for the assessment.

1.5.7 Management and Mitigation

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

1.6 Assumptions and Limitations

The main assumptions, exclusions and limitations are summarised below:

- Meteorological data: As no onsite meteorological data was available, use was made of measured meteorological data from the closest Eskom monitoring station located south of the Kendal Power Station (~9km southeast of the current Vlakvarkfontein opencast mining area) for the period January 2012 to March 2015. Due to the relatively flat terrain, the distance is not expected to have a material impact on the dispersion modelling results and the conclusions reached.
- Emissions:
    - The quantification of sources of emission was restricted to the project activities only. Although other background sources were identified in the study area, such sources were not quantified as this did not form part of the scope of this assessment.
    - Information required for the calculation of emissions from fugitive dust sources for the proposed project operations was provided by the client. 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 non-routine operations or 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 could only be assessed qualitatively.

1.7 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 findings and recommendations provided in Section 7. The quantification of GHG emissions is provided in Section 8.

2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

The environmental regulations and guidelines governing the emissions and impact of the project need to be considered prior to potential impacts and sensitive receptors being 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 standards 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.

2.1 National Ambient Air Quality Standards

NAAQS are available for $PM_{2.5}$ (gazetted on 29 June 2012 (Government Gazette no. 35463)) as well as, PM_{10}, SO_2, NO_2 ozone (O_3), CO, lead (Pb) and benzene gazetted on 24 December 2009 (Government Gazette 32816). The NAAQS are provided in Table 2-1 with the pollutants of concern for the project provided in bold text.

Table 2-1: South African National Ambient Air Quality Standards

Substance	Molecular formula / notation	Averaging period	Concentration limit (µg/m³)	Frequency of exceedance	Compliance date
Sulfur dioxide	SO_2	10 minutes	500	526	Immediate
		1 hour	350	88	Immediate
		24 hours	125	4	Immediate
		1 year	50	0	Immediate
Nitrogen dioxide	NO_2	1 hour	200	88	Immediate
		1 year	40	0	Immediate
Particulate matter	**PM_{10}**	**24 hour**	**75**	**4**	**Immediate**
		1 year	**40**	**0**	**Immediate**
Fine particulate matter	**$PM_{2.5}$**	**24 hour**	**40**	**4**	**Immediate**
			25	**4**	**1 Jan 2030**
		1 year	**20**	**0**	**Immediate**
			15	**0**	**1 Jan 2030**
Ozone	O_3	8 hours (running)	120	11	Immediate
Benzene	C_6H_6	1 year	5	0	1 Jan 2015
Lead	Pb	1 year	0.5	0	Immediate
Carbon monoxide	CO	1 hour	30 000	88	Immediate
		8 hour (calculated on 1 hour averages)	10 000	11	Immediate

2.2 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 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. South African (SA) NDCRs that were published on the 1st of November 2013. Acceptable dustfall rates according to the regulation are summarised in Table 2-2. These regulations are only applicable to a facility (including mining) that has been identified as a potential source of nuisance dust by a local air quality officer.

Table 2-2: Acceptable dustfall rates

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.

2.3 Effect of Dust on Vegetation, Animals and Susceptible Human Receptors

2.3.1 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 et al., 2005). Heavy particle loads can also result in reduced light transmission to the chloroplasts and the occlusion of stomata (Ricks and Williams, 1974, Hirano et al., 1995; Naidoo and Chirkoot; 2004; Harmens et al., 2005), decreasing the efficiency of gaseous exchange (Ernst, 1981; Naidoo and Chirkoot, 2004; Harmens et al., 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).

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 and 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 particulate matter (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 et al., 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, 2010). 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, 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/m²/day. Little direct evidence of the effects of dust-fall on South African vegetation, including crops, exists.

2.3.2 Effects of Particulate Matter on Animals

As presented by the Canadian Environmental Protection Agency (CEPA, 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/m³ 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/m³ (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).

A study was conducted by the State University of Iowa on the effects of air contaminants and emissions on animal health in swine facilities. Air pollutants included gases, particulates, bioaerosols, and toxic microbial by-products. The main findings were that ammonia is associated with lowered average number of pigs weaned, arthritis, porcine stress syndrome, muscle lesions, abscesses, and liver ascarid scars. Particulates are associated with the reduction in growth and turbine pathology, and bioaerosols could lower feed efficiency, decrease growth, and increase morbidity and mortality. The authors highlighted the general lack of information on the health effects and productivity-problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulfide are regarded the two most important inorganic gases affecting the respiratory system of cattle raised in confinement facilities, affecting the mucociliary transport and alveolar macrophage functions. Holland et al., (2002) found that the fine inhalable particulate fraction is mainly derived from dried faecal dust.

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 et al., 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.

2.3.3 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, 1998; Dockery and Pope, 1994).

The air quality guidelines for particulates are given for various particle size fractions, including TSP, thoracic particulates or PM_{10}, and respirable particulates or $PM_{2.5}$. 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 et al., 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 et al., 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)

2.4 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) is 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 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.

2.5 Regulations Regarding Report Writing

This report complies with the requirements of the National Environmental Management Act, 1998 (NEMA, No 107 of 1998) and the environmental impact assessment (EIA) regulations (GNR 982 of 2014), as amended. The table below provides a summary of the requirements, with cross references to the report sections where these requirements have been addressed.

Table 2-4: Specialist report requirements in terms of Appendix 6 of the EIA Regulations (2014), as amended

A specialist report prepared in terms of the Environmental Impact Regulations of 2014 must contain:	Relevant section in report
Details of the specialist who prepared the report	Section 1.4
The expertise of that person to compile a specialist report including a curriculum vitae	Section 1.4.2 Appendix A
A declaration that the person is independent in a form as may be specified by the competent authority	Section 1.4.1 Appendix B
An indication of the scope of, and the purpose for which, the report was prepared	Section 1.2
An indication of the quality and age of base data used for the specialist report;	Section 3.2 Section 3.3
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 4
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3.2 Section 4.2
A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 1.5
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternative;	Section 3.1
An identification of any areas to be avoided, including buffers	Section 3.1
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 4.2
A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 1.6
A description of the findings and potential implications of such findings on the impact of the proposed activity or activities	Section 4.2
Any mitigation measures for inclusion in the EMPr	Section 4.1.2 Section 4.2.3 Section 4.3.2
Any conditions for inclusion in the environmental authorisation	Section 6.2 Section 7.2
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 6.2.3
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	Section 7.2
Regarding the acceptability of the proposed activity or activities; and	Section 4.2
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 4.1.2 Section 4.2.3 Section 4.3.2 Section 6.2.2 Section 7.2
A description of any consultation process that was undertaken during the course of carrying out the study	Not applicable
A summary and copies if any comments that were received during any consultation process	Not applicable
Any other information requested by the competent authority.	Not applicable

2.6 Highveld Priority Area

The Highveld Airshed Priority Area (HPA) was declared by the Minister of Environmental Affairs at the end of 2007, requiring the development of an Air Quality Management Plan for the area. The plan (HPA, 2011) includes the establishment of emissions reduction strategies and intervention programmes based on the findings of a baseline characterisation of the area. The implication of this is that all contributing sources in the area will be assessed to determine the emission reduction targets to be achieved over the following few years.

The project is within the footprint of the Highveld Priority Area. Emission reduction strategies are included for the numerous operations in the area with specific associated targets. Included in this management plan are seven goals, each of which has a further list of objectives that has to be met. The seven goals for the Highveld Priority Area are as follows:

- **Goal 1:** By 2015, organisational capacity in government is optimised to efficiently and effectively maintain, monitor and enforce compliance with ambient air quality standards
- **Goal 2:** By 2020, industrial emissions are equitably reduced to achieve compliance with ambient air quality standards and dust fallout limit values
- **Goal 3:** By 2020, air quality in all low-income settlements is in full compliance with ambient air quality standards
- **Goal 4:** By 2020, all vehicles comply with the requirements of the National Vehicle Emission Strategy
- **Goal 5:** By 2020, a measurable increase in awareness and knowledge of air quality exists
- **Goal 6:** By 2020, biomass burning, and agricultural emissions will be 30% less than current
- **Goal 7:** By 2020, emissions from waste management are 40% less than current.

Goal 2 applies directly to the proposed project, the objectives associated with this goal include:

- Emissions are quantified from all sources.
- Gaseous and particulate emissions are reduced.
- Fugitive emissions are minimised.
- Emissions from dust generating activities are reduced.
- Incidences of spontaneous combustion are reduced.
- Abatement technology is appropriate and operational.
- Industrial Air Quality Management (AQM) decision making is robust and well-informed, with necessary information available.
- Clean technologies and processes are implemented.
- Adequate resources are available for AQM in industry.
- Ambient air quality standard and dust fallout limit value exceedances as a result of industrial emissions are assessed.
- A line of communication exists between industry and communities.

Each of these objectives is further divided into activities, each of which has a timeframe, responsibility and indicator. Refer to the Highveld Priority Management Plan for further details (HPA, 2011).

3 RECEIVING ENVIRONMENT

3.1 Air Quality Sensitive Receptors

The NAAQS (Section 2.1) are based on human exposure to specific criteria pollutants and as such, possible sensitive receptors were identified where the public is likely to be unwittingly exposed. NAAQS are enforceable where Occupational Health and Safety Standards are not applicable and therefore a number of sensitive receptors have been identified in the study area (Figure 3-1). These sensitive receptors are small residential communities, individual residences, and farmsteads in the vicinity of the project. Potential impacts from the project will be assessed at these sensitive receptors and screened against NAAQS.

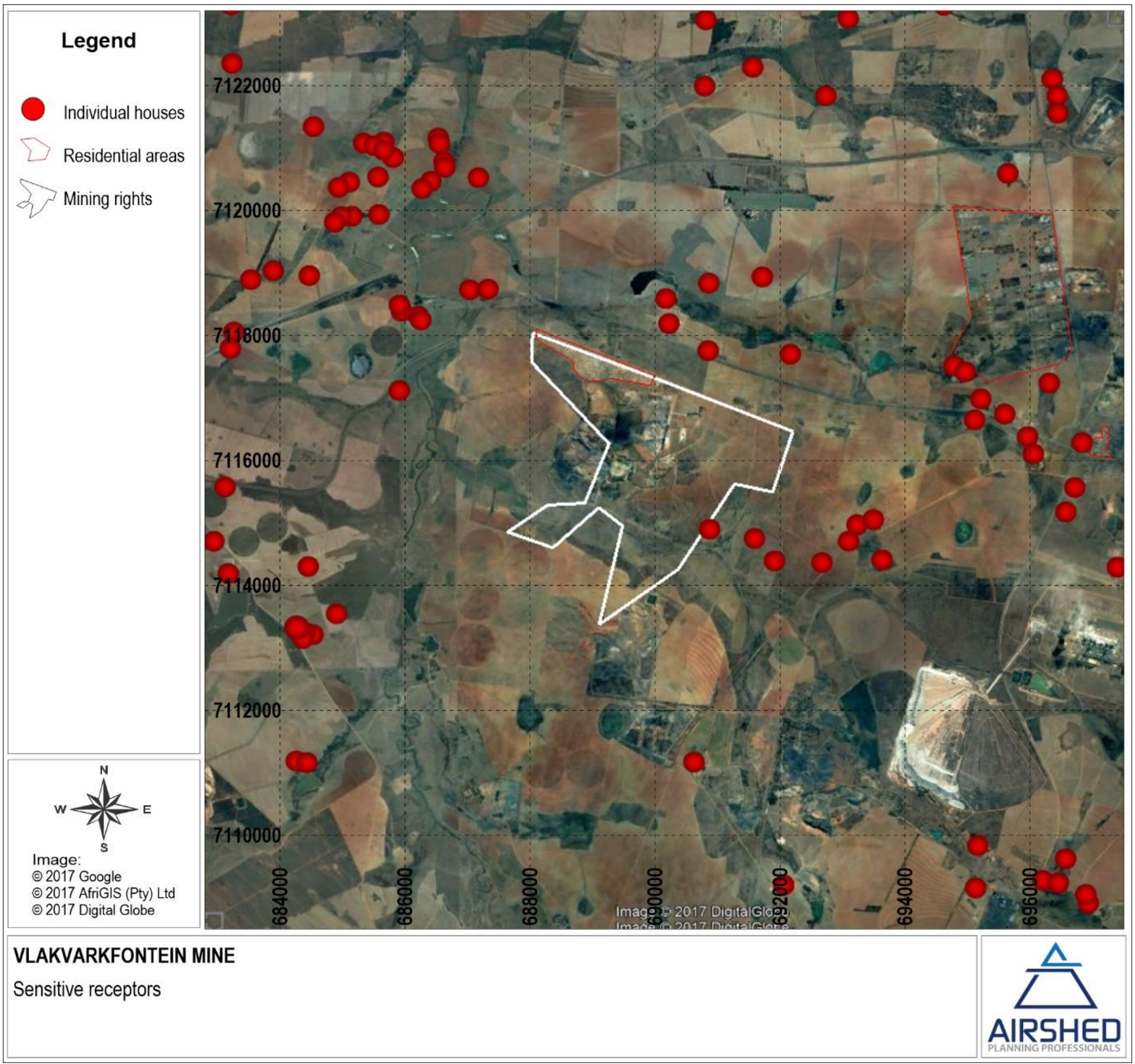

Figure 3-1: Location of potentially sensitive receptors in relation to the project

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 and 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 and 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 project site, meteorological information was obtained from the Eskom station south of the Kendal Power Station for the period January 2012 to March 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, which illustrate and summarise wind field information, comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 5 and 7 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 co-dominant wind directions (Figure 3-2), during the period under investigation, are north-west and east with a frequency of occurrence of approximately 10%. Winds from the south-westerly sector occur relatively infrequently (<4% of the total period). Calm conditions (wind speeds <1 m/s) occur 9.3% of the time. A frequent north-westerly flow dominates day-time conditions with >12% frequency of occurrence. At night, an increase in easterly flow is observed (~11% frequency).

During summer months, winds from the east become more frequent (Figure 3-3). There is an increase in the frequency of calm periods (i.e. wind speeds <1 m/s) during the autumn (10.8%) and winter months (9.9%). The predominant wind direction in winter is from the north-west. During spring-time, winds are more likely to exceed 5.0 m/s, with calm conditions only 3.6% of the time.

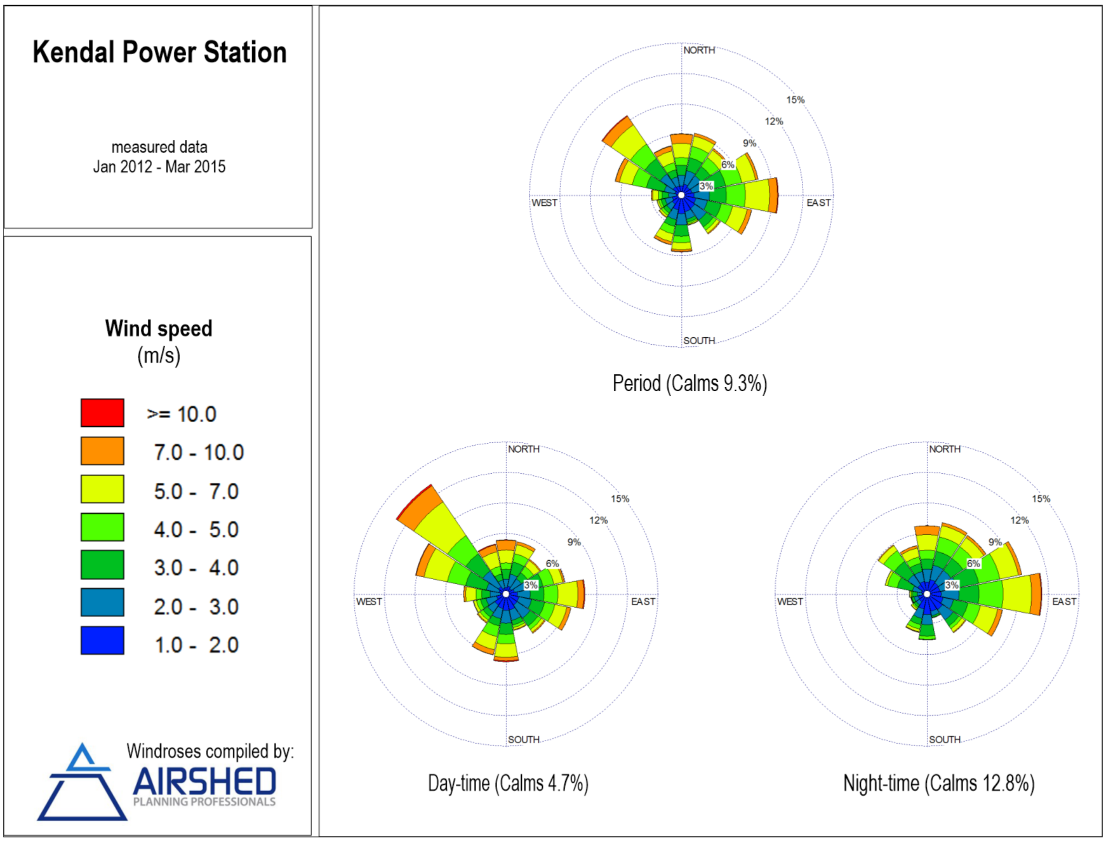

Figure 3-2: Period average, day-time and night-time wind roses (measured data; January 2012 to March 2015)

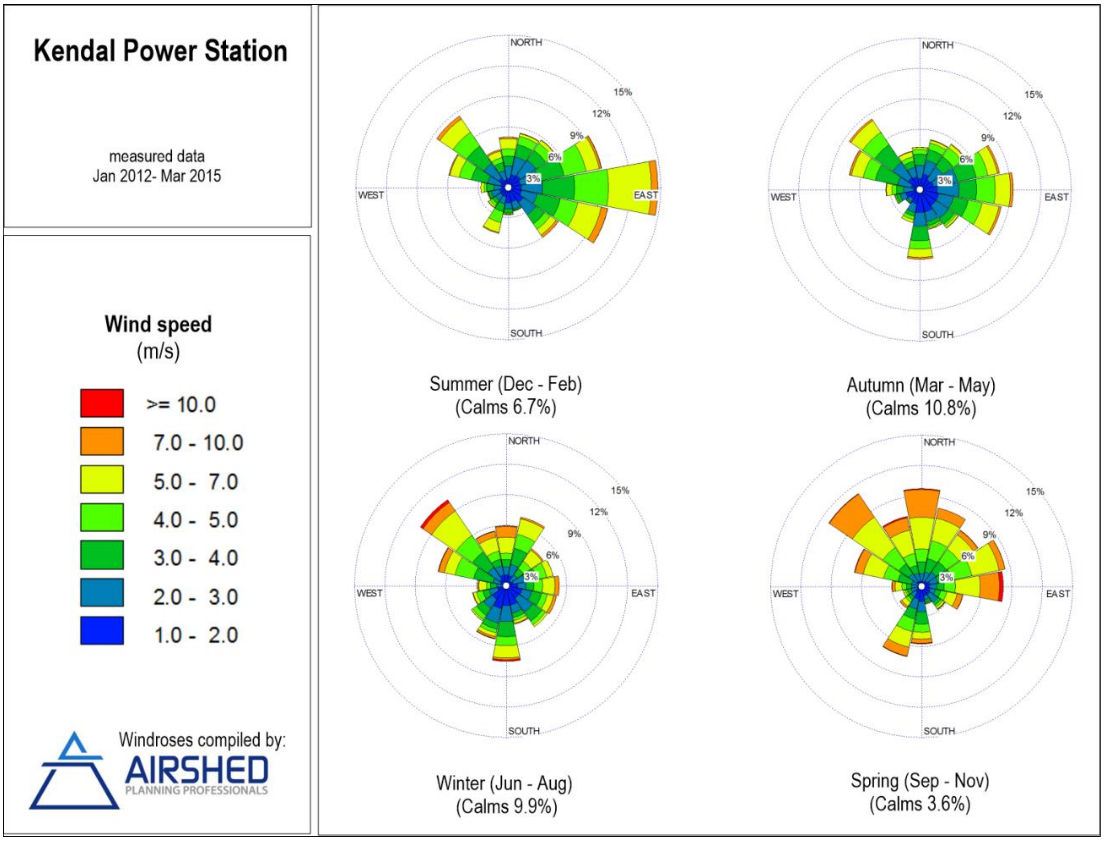

Figure 3-3: Seasonal wind roses (measured data; January 2012 to March 2015)

3.2.2 Ambient Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher a pollution plume rises), and determining the development of the mixing and inversion layers. The monthly temperature pattern is shown in Figure 3-4. Average daily maximum, minimum and mean temperatures for the site are given as 31.1°C, 3.2°C and 16.8°C, respectively, based on the measured data at Eskom's Kendal ambient air quality monitoring station for the period January 2012 – March 2015. Maximum temperatures range from 43.6°C in January to 27.3°C in July, with daily minima ranging from 11.0°C in December to –5.0°C in June.

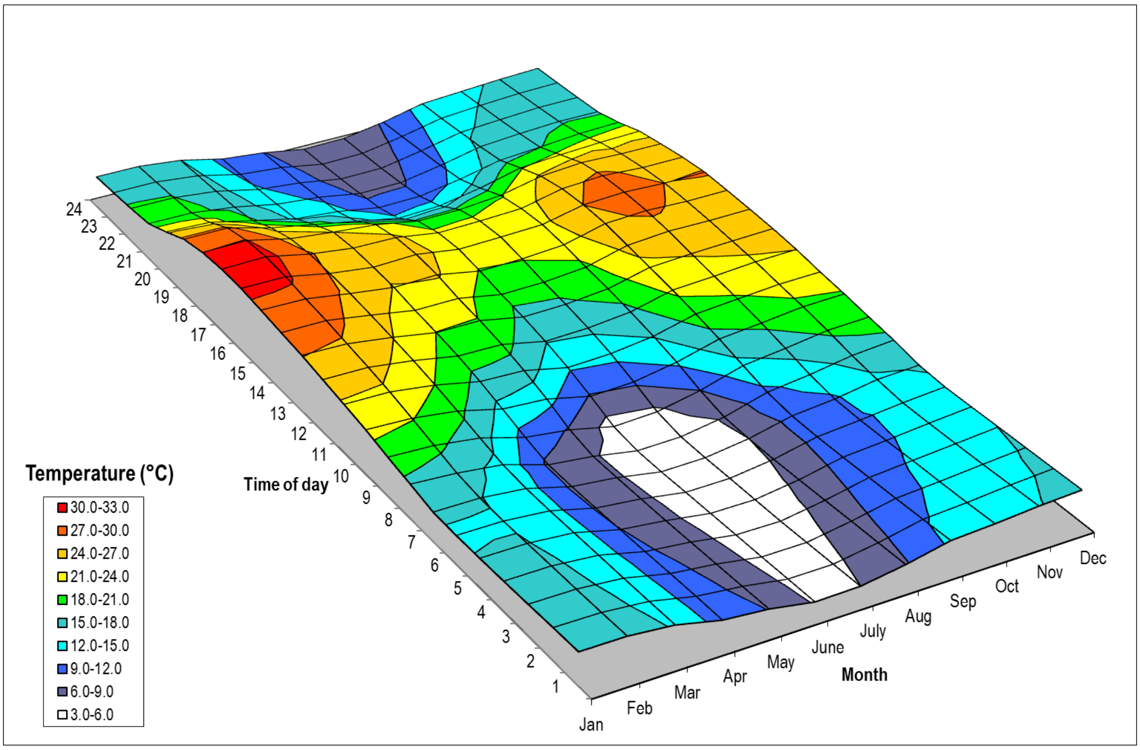

Figure 3-4: Monthly temperature profile (measured data; January 2012 to March 2015)

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 is 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.

3.3 Ambient Air Quality within the Region

3.3.1 Eskom Kendal Monitoring Station

PM_{10} monitored at the Eskom Kendal monitoring station during the period January 2012 and December 2014 recorded more than four days per year when the PM_{10} concentration exceeded the NAAQ limit concentration (Table 3-1 and Figure 3-5). Annual average concentrations at this station were in non-compliance with the annual NAAQS during 2012, 2013, and 2014 (Table 3-1).

An analysis of the observed PM_{10} concentrations at the Kendal monitoring station involved categorising the concentration values into wind speed and direction bins for different concentrations. The information is most easily visualised as polar plots, where the centre of the polar plot refers to the location of the monitoring station (Figure 3-6). Polar plots (Carslaw and Ropkins, 2012; Carslaw, 2013) provide an indication of the directional contribution as well as the dependence of concentrations on wind speed. The directional display is fairly obvious, i.e. when higher concentrations are shown to occur in a certain sector, e.g. northerly for PM10 at Kendal (Figure 3-6), it is understood that most of the high concentrations occur when winds blow from that sector. The almost symmetrical around the centre of the plot is an indication that the contributions are near-equally distributed and occur under calm-wind conditions (PM_{10} concentrations between 40 to 60 µg/m³). Sources to the north of the monitoring station contribute at wind speeds above 5 m/s and result in PM_{10} concentrations exceeding 75 µg/m³.

The Kendal monitoring station is located to the south-east of the Kendal Power Station and reflects contributions from the power station, ash disposal facility, coal mining, agriculture, and residential fuel use. This is evident from the station data when a time variation plot is used to understand temporal changes in concentration (Carslaw and Ropkins, 2012; Carslaw, 2013). Elevated PM_{10} concentrations occur between May and October (Figure 3-7), when household fuel use for heating is likely to increase in winter. Similarly, veld fires and fallow fields would be sources of particulates during the dry winter and during high wind speed events in spring. The Kendal Power Station ash disposal facility would similarly contribute to ambient particulate concentrations from exposed areas, especially during operations and high wind speed events.

Table 3-1: Daily and annual average PM_{10} concentration at the Eskom Kendal monitoring station (January 2012 to March 2015)

Year	Daily NAAQ limit	Number of valid daily records	Frequency of Exceedance	Annual average* (µg/m³)
2012	120	121	**9**	**60.6**
2013	120	300	**15**	**58.9**
2014	120	324	**5**	**53.2**
2015	75	22	0	(data set incomplete)
Note: * Bold text indicates non-compliance with NAAQS				

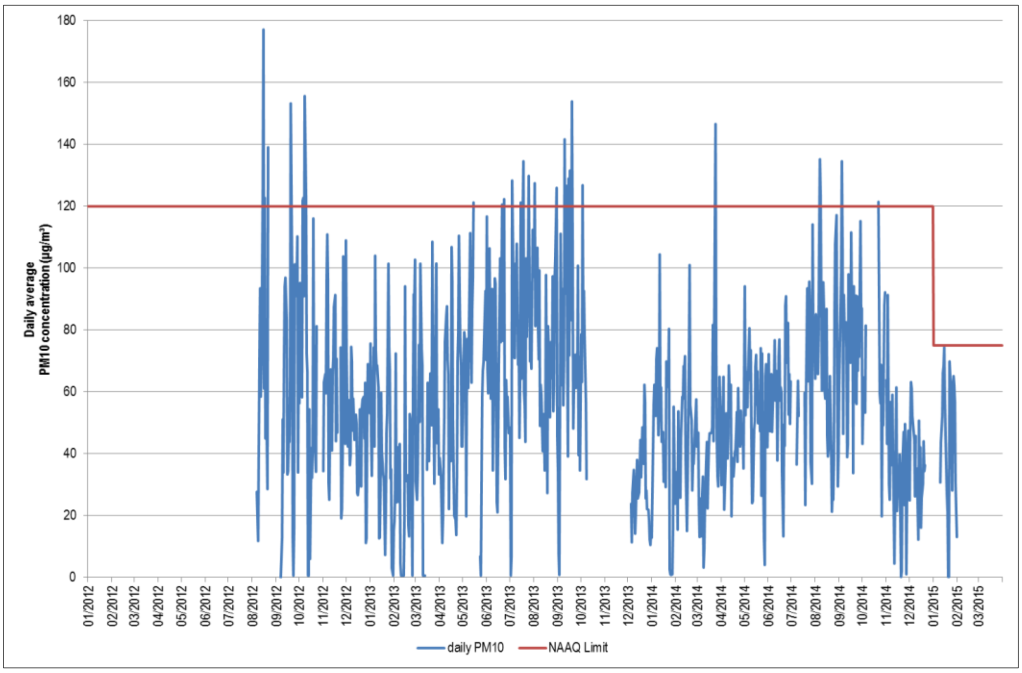

Figure 3-5: Daily average PM_{10} concentrations at the Eskom Kendal Power Station (2012 to 2015)

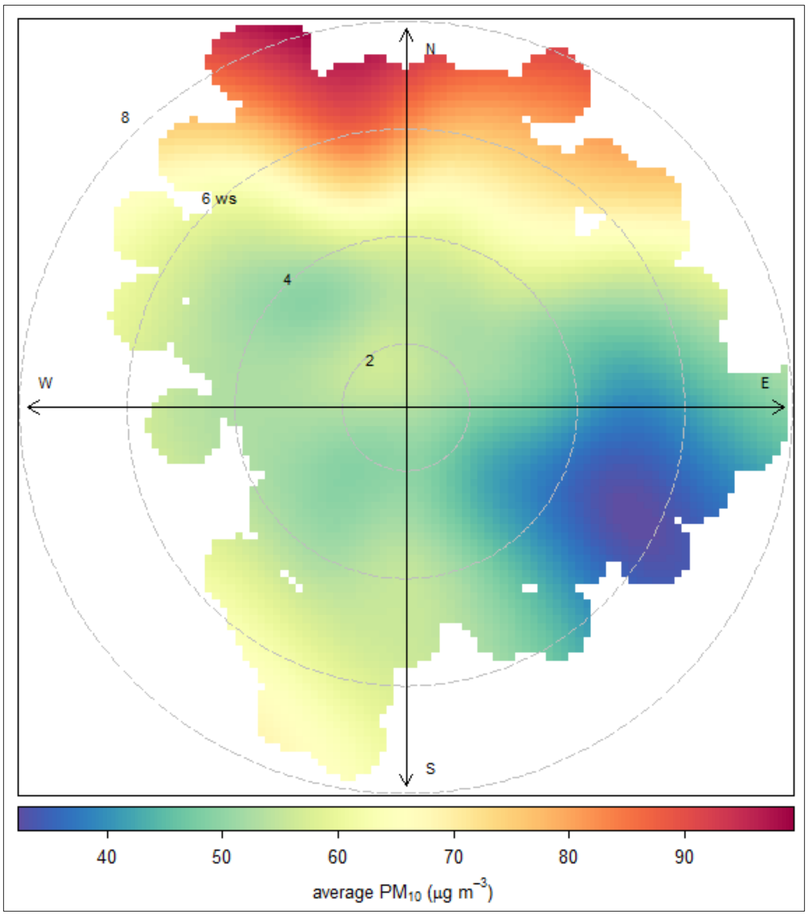

Figure 3-6: Polar plot of daily PM_{10} measured at the Eskom Kendal monitoring station

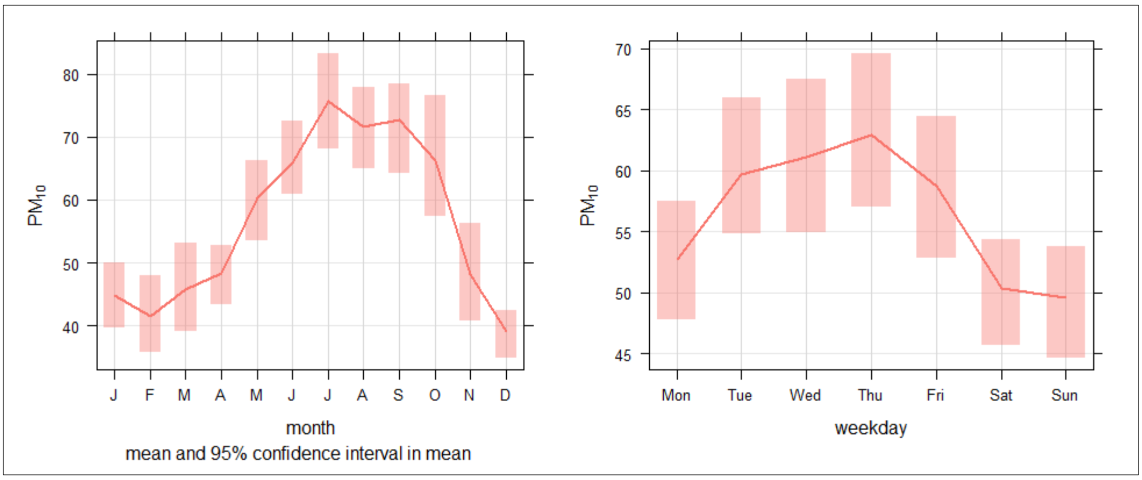

Figure 3-7: Time variation of PM_{10} at the Eskom Kendal monitoring station (January 2012 - March 2015)

3.3.2 Dust Fallout Monitoring

The Vlakvarkfontein Mine have a dust fallout monitoring network onsite consisting of 5 directional buckets (Figure 3-8 and Table 3-2). The dust deposition levels for the period March to August 2017 were provided for the current assessment and is summarised in Table 3-3.

It should be noted that the NDCR 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. The method uses a simple non-directional bucket of at least 150 mm diameter and at least twice as deep as the diameter with the top of the bucket at 2 m above ground level. Samples are exposed for 30 ± 3 days, and results reported as a dustfall rate in units (mg/m²/day), 30-day average.

The dustfall rates as specified in the NDCR (600 mg/m²/day for residential areas and 1200 mg/m²/day for non-residential areas) are applicable for dust fallout measured by the ASTM D1739 method. As the dust fallout for the Vlakvarkfontein network are measured by directional buckets, the fallout rates should be used as directional indicators only and not compared to the NDCR. For regulatory purposes, these samplers should thus be replaced or co-located with the single dust bucket sampler.

From studies done though (Kornelius, Loans, & Ramsuchit, 2017) the average from the directional buckets was looked at to understand its relation to single buckets (ASTM D1739 method). Averages were calculated in two ways: geometric average and arithmetic average. For low values, the directional fallout per bucket (geometric average) was close to the value obtained from single buckets. The geometric mean dust fallout for the directional buckets is provided in Figure 3-9.

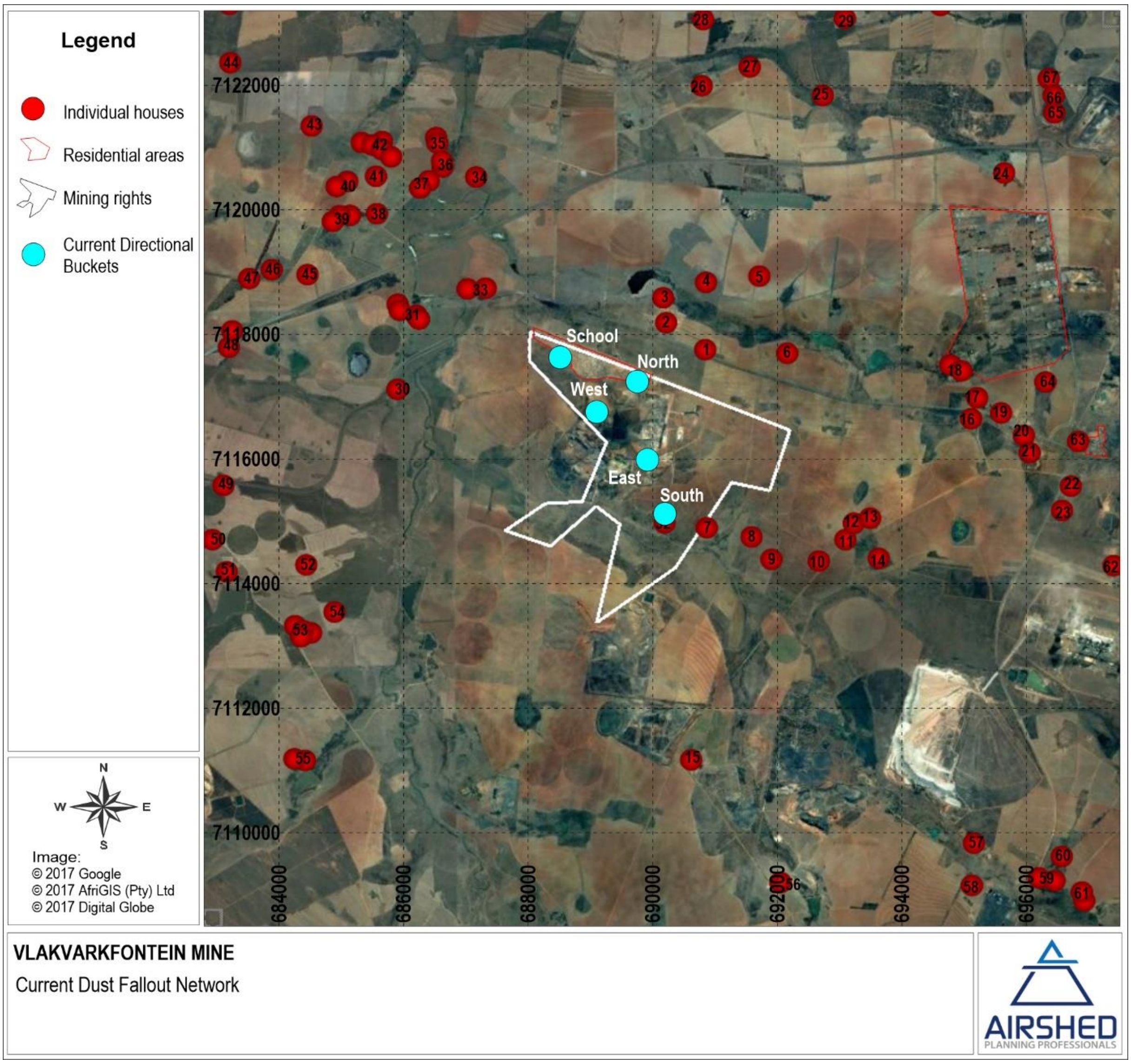

Figure 3-8: The position of the current dust fallout network for the Vlakvarkfontein Mine

Table 3-2: The co-ordinates of the current dust fallout network for the Vlakvarkfontein Mine

Description	Latitude	Longitude
School	-26.048141	28.884462
West - Behind Workshop	-26.056314	28.890238
North - Towards Community	-26.052399	28.896695
East - Maize Field	-26.063334	28.898229
South - Farm House	-26.071784	28.901206

Table 3-3: The measured dust fallout rates for the period March to August 2017

Period	School	West - Behind Workshop	North - Towards Community	East - Maize Field	South - Farm House
Total Deposition					
Mar-17	963	1750	2146	0	492
Apr-17	1210	1124	1458	0	300
May-17	278	945	680	2519	192
Jun-17	1223	795	710	705	472
Jul-17	1109	1501	1248	900	431
Aug-17	881	1316	1023	1047	885
Arithmetic Mean					
Mar-17	241	438	537	0	123
Apr-17	303	281	365	0	75
May-17	70	236	170	630	48
Jun-17	306	199	178	176	118
Jul-17	277	375	312	225	108
Aug-17	220	329	256	262	221
Geometric Mean					
Mar-17	197	295	527	0	118
Apr-17	298	278	359	0	70
May-17	ISD	ISD	ISD	ISD	ISD
Jun-17	292	196	177	0	107
Jul-17	276	374	307	194	104
Aug-17	ISD	ISD	ISD	ISD	ISD

ISD: Insufficient data available for the calculation of the geometric mean

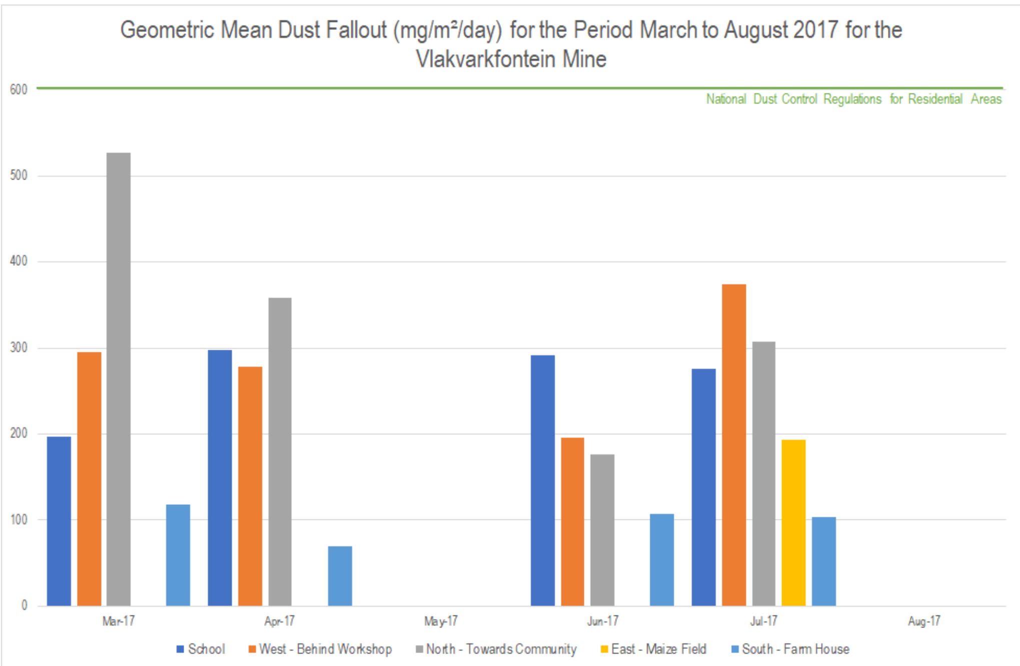

Figure 3-9: The geometric mean dust fallout rates calculated from measured data for the period March to August 2017

3.4 Existing Sources of Emissions near the 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 nitrogen monoxide (NO)) and particulates. Secondary pollutants include NO2, 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 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 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).

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, or as a result of drying of fine material such as slimes.

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.

3.4.5 Industrial Emissions

The proposed project is within the Mpumalanga province which consists of several industrial activities:

- Emissions from coal combustion by power generation, metallurgical and petrochemical industries represent the largest contribution to total emissions from the industrial / institutional / commercial fuel use sector within the Mpumalanga region.
- The metallurgical group is estimated to be responsible for at least ~50% of the particulate emissions from this sector. This group includes iron and steel, ferro-chrome, ferro-alloy and stainless-steel manufacturers (includes Ferrometals, Columbus Stainless, Transalloys, Middelburg Ferrochrome).
- Petrochemical and chemical industries are primarily situated in Secunda (viz. Sasol Synfuels). The use of coal for power generation and the coal gasification process represent significant sources of sulphur dioxide emissions. (Particulate emissions are controlled through the implementation of stack gas cleaning equipment.)
- Other industrial sources include: brick manufacturers which use coal (e.g. Witbank Brickworks, Quality Bricks, Corobrik, Hoeveld Stene, Middelwit Stene) and woodburning and wood drying by various sawmills (Bruply, Busby, M&N Sawmills) and other heavy industries (using coal and to a lesser extent heavy fuel oil (HFO) for steam generation). The contribution of fuel combustion (primarily coal) by institutions such as schools and hospitals to total emissions is relatively minor due to the extent of emissions from other groups.

The closest industrial activity within the immediate vicinity of the project includes Kendal Power Station located ~8 km southeast of the Vlakvarkfontein mining operations.

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 areas	Clearing of groundcover
		Levelling of area
		Wind erosion from open areas
		Materials handling
	Transport infrastructure	Clearing of vegetation and topsoil
		Levelling of 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 precedent 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. Reduction of frequency of disturbance. Early re-vegetation Stabilisation (chemical, rock cladding or vegetative) of disturbed soil

4.2 Operational Phase

4.2.1 Identification of Environmental Aspects

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 vehicle entrainment, materials handling operations, wind erosion and crushing and screening 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 Run of Mine (ROM) from open pit to crusher plant Transportation of overburden Transportation of product
Material handling		
Fugitive dust	Materials handling operations	Remove ROM from pit Tip ROM at crusher Tip from crusher to product stockpile Reclaim from stockpile Tipping of product at load-out area Primary and secondary crushing
In-pit mining operations		
Fugitive dust	Mining operations within open pit	Topsoil removal Drilling and blasting of seam Removal of ROM by excavator and loading of haul trucks Overburden replacement Grading of covered pit areas
Storage piles		

Operational phase		
Aspects	**Source**	**Activities**
Fugitive dust	Wind erosion	Windblown dust from 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 project

Activity	Emission Equation	Source	Information assumed/provided
Vehicle entrainment on unpaved surfaces	$E = k(s/12)^a(W/3)^b$ Where, E = size-specific emission factor (lb/VKT) s = surface material silt content (%) W = mean vehicle weight (tons) 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. A is given as 0.9 for $PM_{2.5}$ and PM_{10} and 0.7 for TSP. 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 loading of 8.4 % for haul roads. The capacity of the haul trucks to be used was provided as 60t. The product will be transported by 34 t interlink trucks. The throughput of the ROM material and overburden was provided for current and proposed operations. An average throughput for the period July 2017 to November 2018 was assumed for current operations (as the throughput decreases after this period). The throughput provided for the period 2022 was assumed for proposed operations (as this period had the highest ROM throughput for proposed activities). *75% and 90% control efficiency were assumed for the mitigated scenario.*
Materials handling	$E = 0.0016\frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}$ Where, E = Emission factor (kg dust / t transferred) U = Mean wind speed (m/s) M = Material moisture content (%) The $PM_{2.5}$, PM_{10} and TSP fraction of the emission	US-EPA AP42 Section 13.2.4	An average wind speed of 3.4 m/s was used based on the Eskom Kendal data for the period January 2012 to March 2015. The throughput of the material was provided.

Activity	Emission Equation	Source	Information assumed/provided
	factor is 5.3%, 35% and 74% respectively.		
Crushing and screening	Primary (for high moisture ore): $E_{TSP} = 0.01\ kg/t\ material\ processed$ $E_{PM10} = 0.004\ kg/t\ material\ processed$ $E_{PM2.5} = 0.00074\ kg/t\ material\ processed$ Secondary (for high moisture ore): $E_{TSP} = 0.03\ kg/t\ material\ processed$ $E_{PM10} = 0.012\ kg/t\ material\ processed$ $E_{PM2.5} = 0.00222\ kg/t\ material\ processed$ Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing	NPI Section: Mining	*50% control efficiency was assumed for the mitigated scenario.*
Drilling	$E_{TSP} = 0.59\ kg\ of\ dust\ /drill\ hole$ PM_{10} is given as 52% of TSP emissions and $PM_{2.5}$ is assumed to be 3% of TSP emissions	NPI Section: Mining	A blast area of 40 m x 120 m was provided. *99% control efficiency was assumed for the mitigated scenario.*
Blasting	$E_{TSP} = 0.00022\ x\ A^{1.5}$ Where, A = area blasted in m² PM_{10} is given as 52% of TSP emissions and $PM_{2.5}$ is assumed to be 3% of TSP emissions	NPI Section: Mining	A blast area of 40 m x 120 m was provided. *As blasting activities are intermittent and not a continuous operation, the emissions from this activity was quantified but not modelled.*
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, $E_{(i)}$ = emission rate (g/m²/s) for particle size class i P_a = air density (g/cm³) G = gravitational acceleration (cm/s³) u_*^t = threshold friction velocity (m/s) for particle size i u^* = friction velocity (m/s)	Marticorena & Bergametti, 1995	Particle size distribution was obtained from similar processes (Table 4-5). Layout of all storage piles were provided. Hourly emission rate file was calculated and simulated.

Table 4-5: Particle size distribution for the ROM and product material

Particle size (µm)	Fraction	
	ROM	Product
4750	0.188	0.234
3375	0.205	0.352
2850	0.144	0.092
477.01	0.001	0
409.45	0.002	0.002
351.46	0.002	0.004
301.68	0.004	0.007
258.95	0.004	0.005
222.28	0.004	0.003
190.8	0.005	0.003
163.77	0.004	0.004
140.58	0.005	0.007
120.67	0.006	0.009
103.58	0.005	0.007
88.91	0.004	0.005
76.32	0.005	0.006
65.51	0.006	0.009
56.23	0.006	0.01
48.27	0.005	0.009
41.43	0.003	0.008
35.56	0.003	0.008
30.53	0.003	0.008
26.2	0.003	0.008
22.49	0.003	0.007
19.31	0.003	0.007
16.57	0.003	0.006
14.22	0.003	0.006
12.21	0.003	0.005
10.48	0.002	0.005
9	0.002	0.005
7.72	0.003	0.005
6.63	0.004	0.005
5.69	0.004	0.005
4.88	0.002	0.004
4.19	0	0.002
3.6	0.001	0.002
3.09	0.001	0.002
2.65	0.001	0.002

Particle size (µm)	Fraction	
	ROM	Product
2.28	0.001	0.001
1.95	0.001	0
1.68	0.002	0
1.44	0.003	0
1.24	0.003	0
0.42	0.003	0
0.36	0.038	0
0.31	0.128	0
0.27	0.128	0
0.23	0.038	0
0.2	0.003	0
0.13	0	0.002
0.11	0	0.005
0.09	0	0.013
0.08	0	0.025
0.07	0	0.039
0.06	0	0.048

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

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. A further mitigated scenario was assessed where 90% control efficiency on unpaved roads (achieved through chemical suppressants or paving surfaces), 50% control efficiency on crushing activities and 99% control efficiency on drilling activities (achieved through fabric filters) was assumed. For unmitigated operations, vehicle entrainment on unpaved surfaces represents the most significant source of particulate emissions. The second largest source of unmitigated emissions for mining operations is due to windblown dust and crushing activities (Figure 4-1 and Figure 4-2).

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

ACTIVITY	Emissions (tpa)			% Contribution			Rank
	TSP	PM10	PM2.5	TSP	PM10	PM2.5	TSP
Current Vlakvarkfontein operations							
Unmitigated							
Vehicle entrainment	2 774.70	790.92	79.09	95.73	92.92	78.87	1
Drilling and blasting	21.18	11.01	0.64	0.73	1.29	0.63	4
Materials handling	15.62	7.39	1.12	0.54	0.87	1.12	5
Crushing and screening	57.04	22.81	4.22	1.97	2.68	4.21	2
Wind erosion	29.99	19.07	15.22	1.03	2.24	15.18	3
TOTAL	**2 898.53**	**851.20**	**100.29**	**100.00**	**100.00**	**100.00**	
Mitigated: control efficiency of 75% applied to unpaved roads; 50% applied to crushing activities; 99% on drilling activities							
Vehicle entrainment	693.68	197.73	19.77	89.44	82.52	51.42	1
Drilling and blasting	7.74	4.03	0.23	1.00	1.68	0.60	5
Materials handling	15.62	7.39	1.12	2.01	3.08	2.91	4
Crushing and screening	28.52	11.41	2.11	3.68	4.76	5.49	3
Wind erosion	29.99	19.07	15.22	3.87	7.96	39.58	2
TOTAL	**775.55**	**239.62**	**38.46**	**100.00**	**100.00**	**100.00**	
Mitigated: control efficiency of 90% applied to unpaved roads; 50% applied to crushing activities; 99% on drilling activities							
Vehicle entrainment	277.47	79.09	7.91	35.78	33.01	20.57	1
Drilling and blasting	7.74	4.03	0.23	1.00	1.68	0.60	5
Materials handling	15.62	7.39	1.12	2.01	3.08	2.91	4
Crushing and screening	28.52	11.41	2.11	3.68	4.76	5.49	3
Wind erosion	29.99	19.07	15.22	3.87	7.96	39.58	2
TOTAL	**359.34**	**120.98**	**26.59**	**46.33**	**50.49**	**69.15**	
Proposed Vlakvarkfontein operations							
Unmitigated							
Vehicle entrainment	4 033.32	1 149.68	114.97	96.29	94.02	83.01	1
Drilling and blasting	21.18	11.01	0.64	0.51	0.90	0.46	4
Materials handling	18.29	8.65	1.31	0.44	0.71	0.95	5
Crushing and screening	85.99	34.39	6.36	2.05	2.81	4.59	2
Wind erosion	29.99	19.07	15.22	0.72	1.56	10.99	3
TOTAL	**4 188.77**	**1 222.81**	**138.50**	**100.00**	**100.00**	**100.00**	
Mitigated: control efficiency of 75% applied to unpaved roads; 50% applied to crushing activities; 99% on drilling activities							
Vehicle entrainment	1 008.33	287.42	28.74	91.06	85.45	59.03	1
Drilling and blasting	7.74	4.03	0.23	0.70	1.20	0.48	5
Materials handling	18.29	8.65	1.31	1.65	2.57	2.69	4
Crushing and screening	42.99	17.20	3.18	3.88	5.11	6.53	2
Wind erosion	29.99	19.07	15.22	2.71	5.67	31.26	3
TOTAL	**1 107.35**	**336.37**	**48.69**	**100.00**	**100.00**	**100.00**	
Mitigated: control efficiency of 90% applied to unpaved roads; 50% applied to crushing activities; 99% on drilling activities							
Vehicle entrainment	403.33	114.97	11.50	36.42	34.18	23.61	1
Drilling and blasting	7.74	4.03	0.23	0.70	1.20	0.48	5
Materials handling	18.29	8.65	1.31	1.65	2.57	2.69	4
Crushing and screening	42.99	17.20	3.18	3.88	5.11	6.53	2
Wind erosion	29.99	19.07	15.22	2.71	5.67	31.26	3
TOTAL	**502.35**	**163.91**	**31.44**	**45.37**	**48.73**	**64.58**	

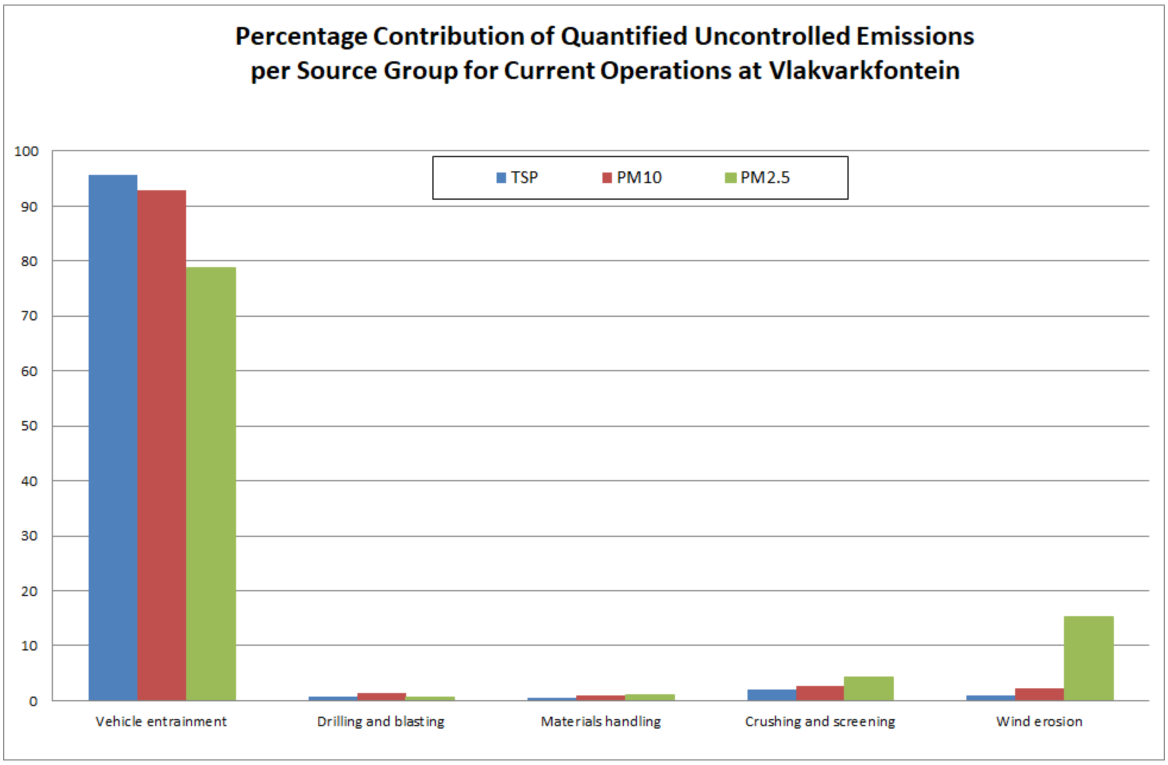

Figure 4-1: Percentage contribution of particulate emissions due to current routine unmitigated operations for the project

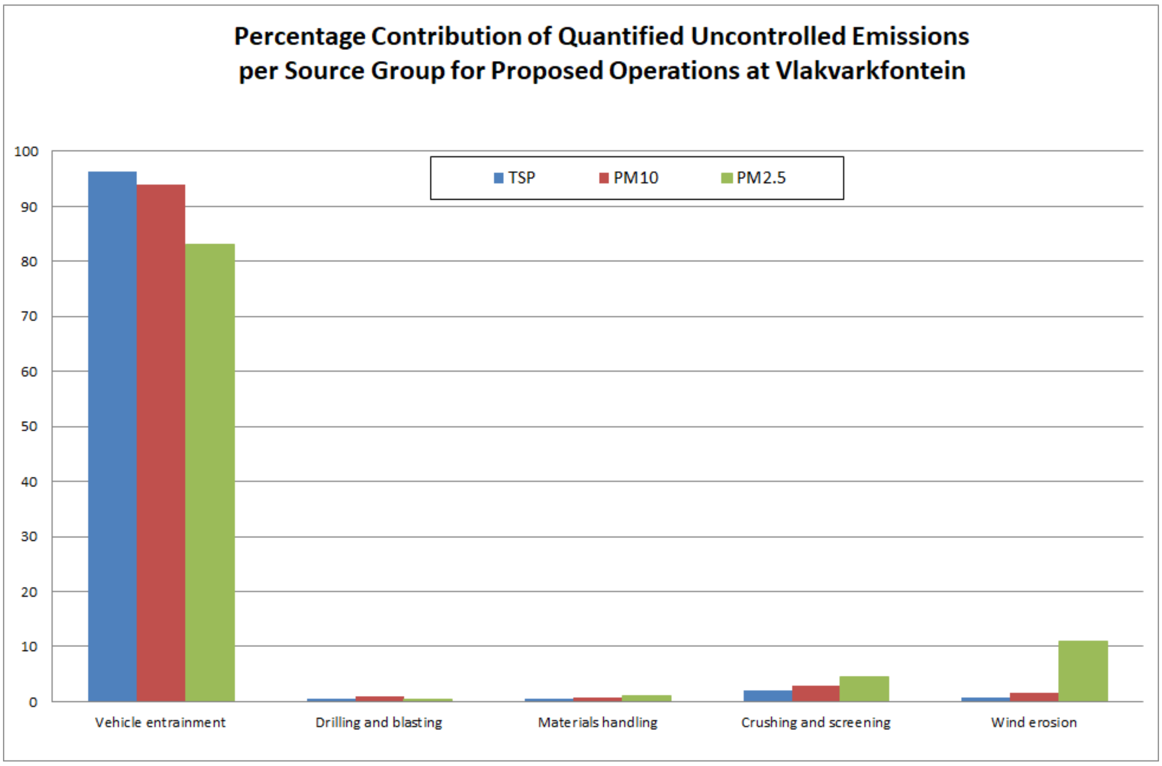

Figure 4-2: Percentage contribution of particulate emissions due to proposed routine unmitigated operations for the project

4.2.2.3 Dispersion Simulation Results and Compliance Assessment

Simulations were undertaken to determine particulate matter (PM_{10} and $PM_{2.5}$) concentrations and total daily dust deposition from project activities. For compliance, reference was made to NAAQS and NDCR. The plots provided for the relevant pollutants of concern during the operational phase are given in Table 4-7.

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

Pollutant	Scenario	Operating Conditions	Figure
PM_{10}	Current operations	Unmitigated operations	4-3
		Mitigated operations (assuming 75% control efficiency (CE) on unpaved roads and 50% CE on crushing activities)	4-4
		Mitigated operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)	4-5
	Proposed operations	Unmitigated operations	4-6
		Mitigated operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)	4-7
		Mitigated operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)	4-8
$PM_{2.5}$	Current operations	Unmitigated operations	4-9
		Mitigated operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)	4-10
		Mitigated operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)	4-11
	Proposed operations	Unmitigated operations	4-12
		Mitigated operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)	4-13
		Mitigated operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)	4-14
TSP	Current operations	Unmitigated operations	4-15
		Mitigated operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)	4-16
		Mitigated operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)	4-17
	Proposed operations	Unmitigated operations	4-18
		Mitigated operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)	4-19
		Mitigated operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)	4-20

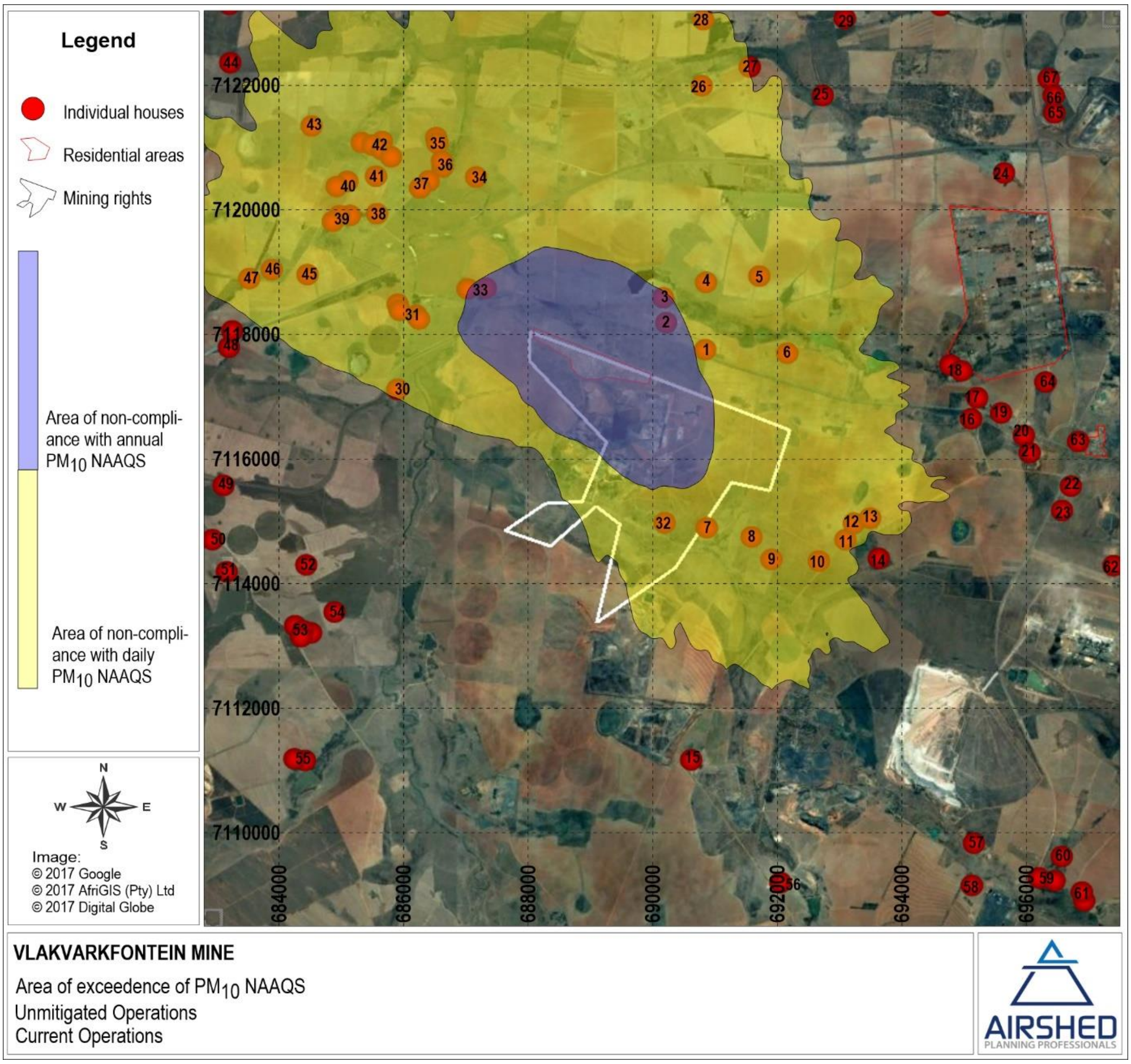

Figure 4-3: Area of non-compliance of PM_{10} NAAQS due to current unmitigated project operations

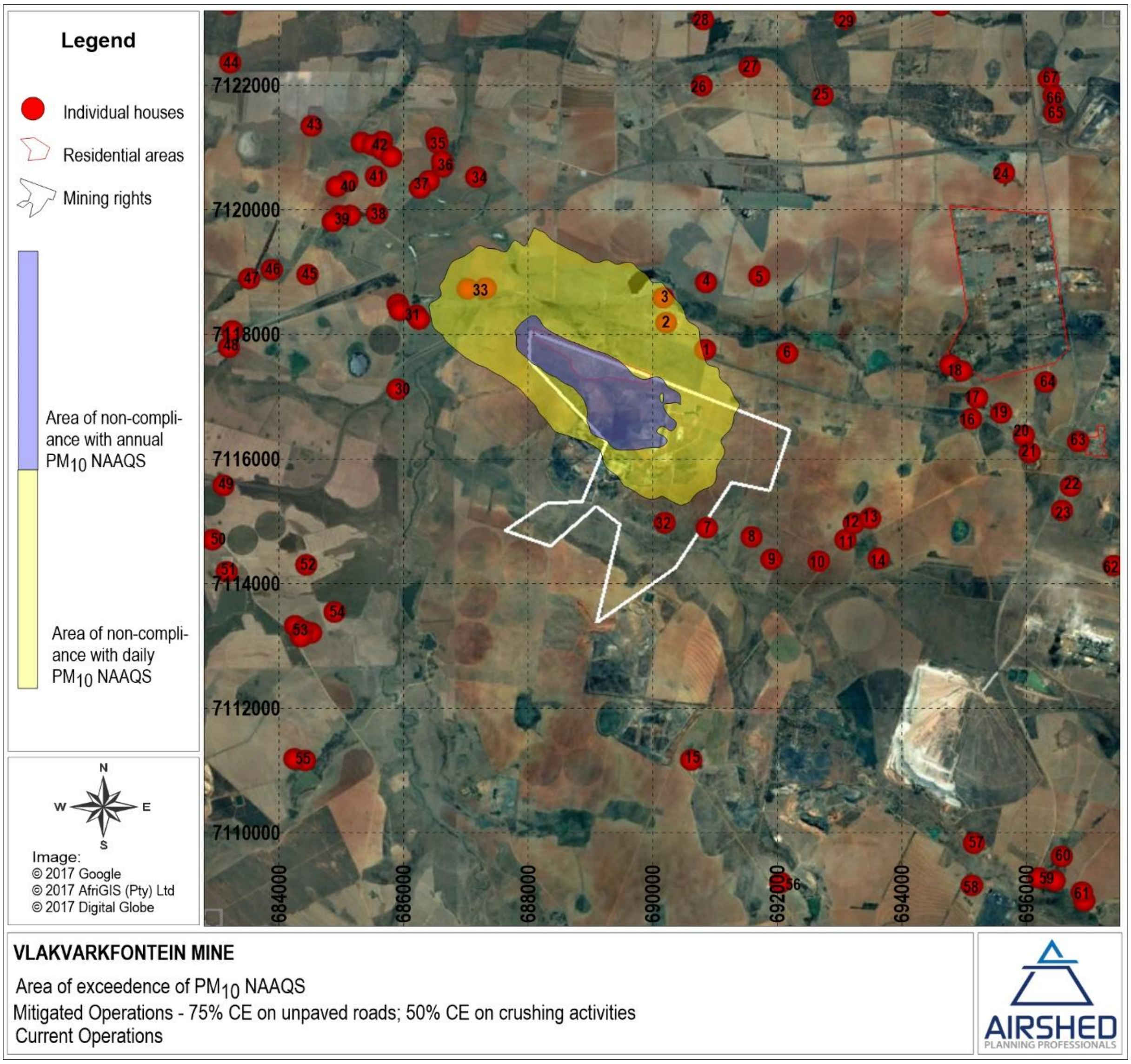

Figure 4-4: Area of non-compliance of PM_{10} NAAQS due to current mitigated project operations (assuming 75% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

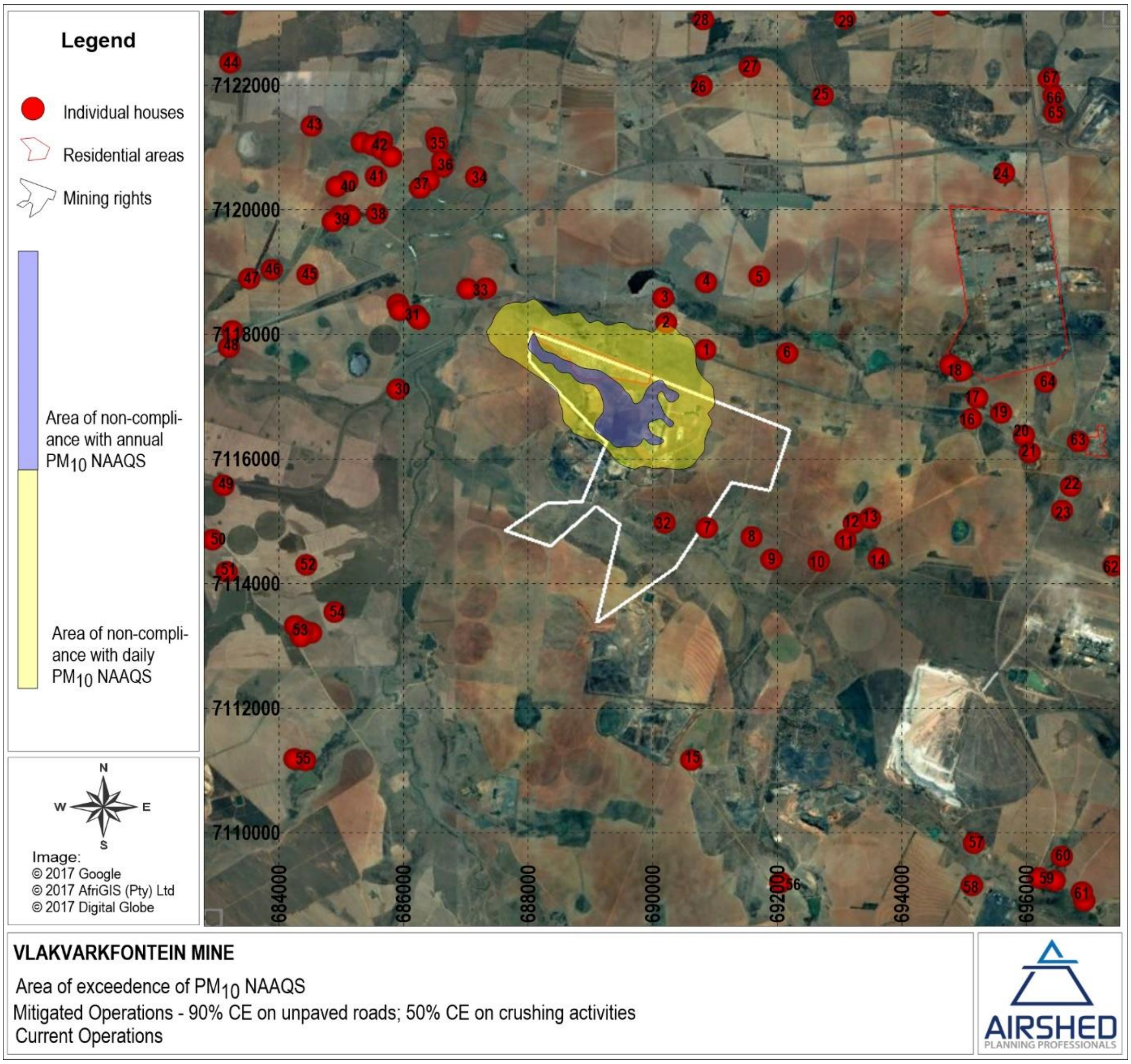

Figure 4-5: Area of non-compliance of PM_{10} NAAQS due to current mitigated project operations (assuming 90% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

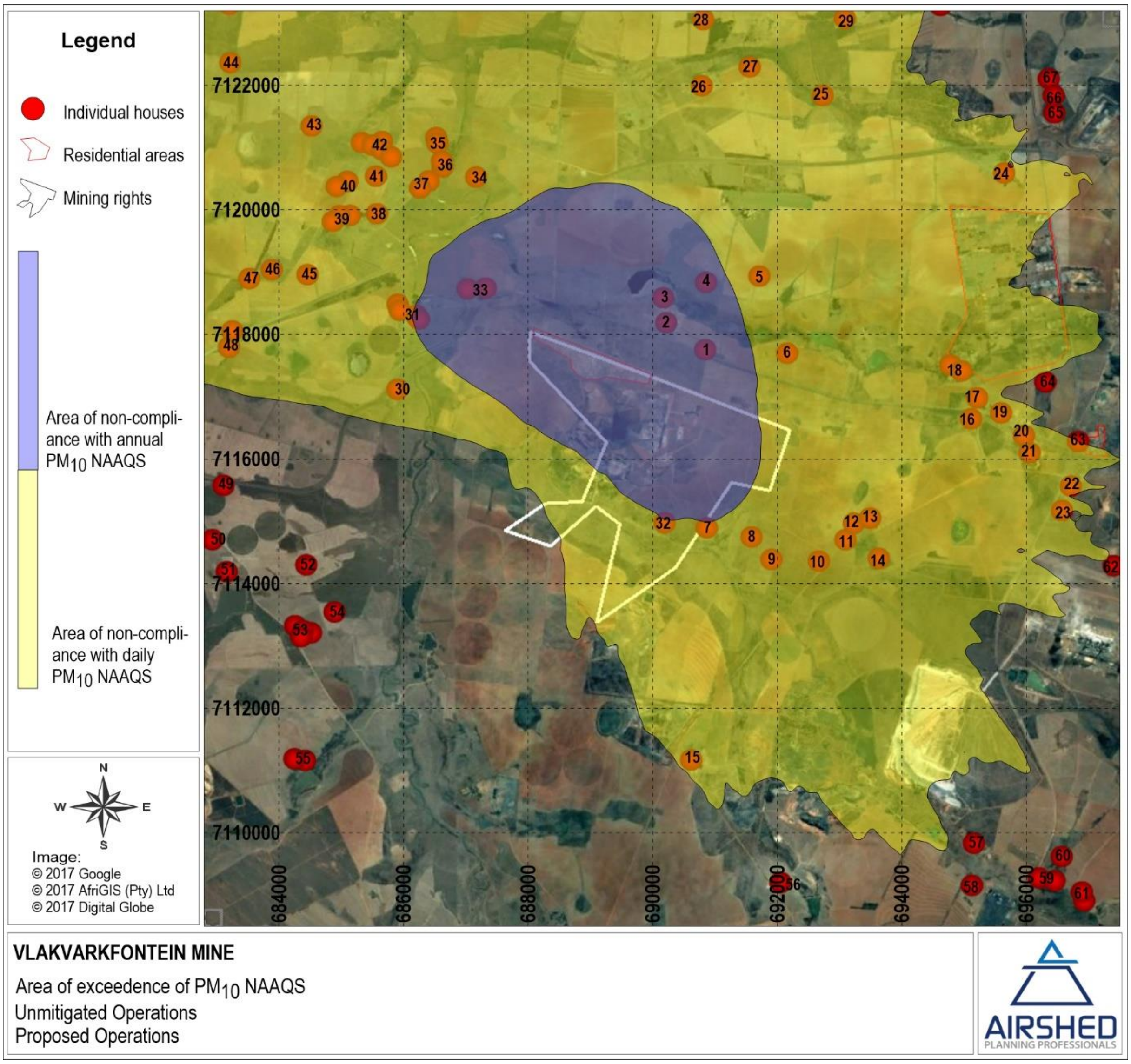

Figure 4-6: Area of non-compliance of PM_{10} NAAQS due to proposed unmitigated project operations

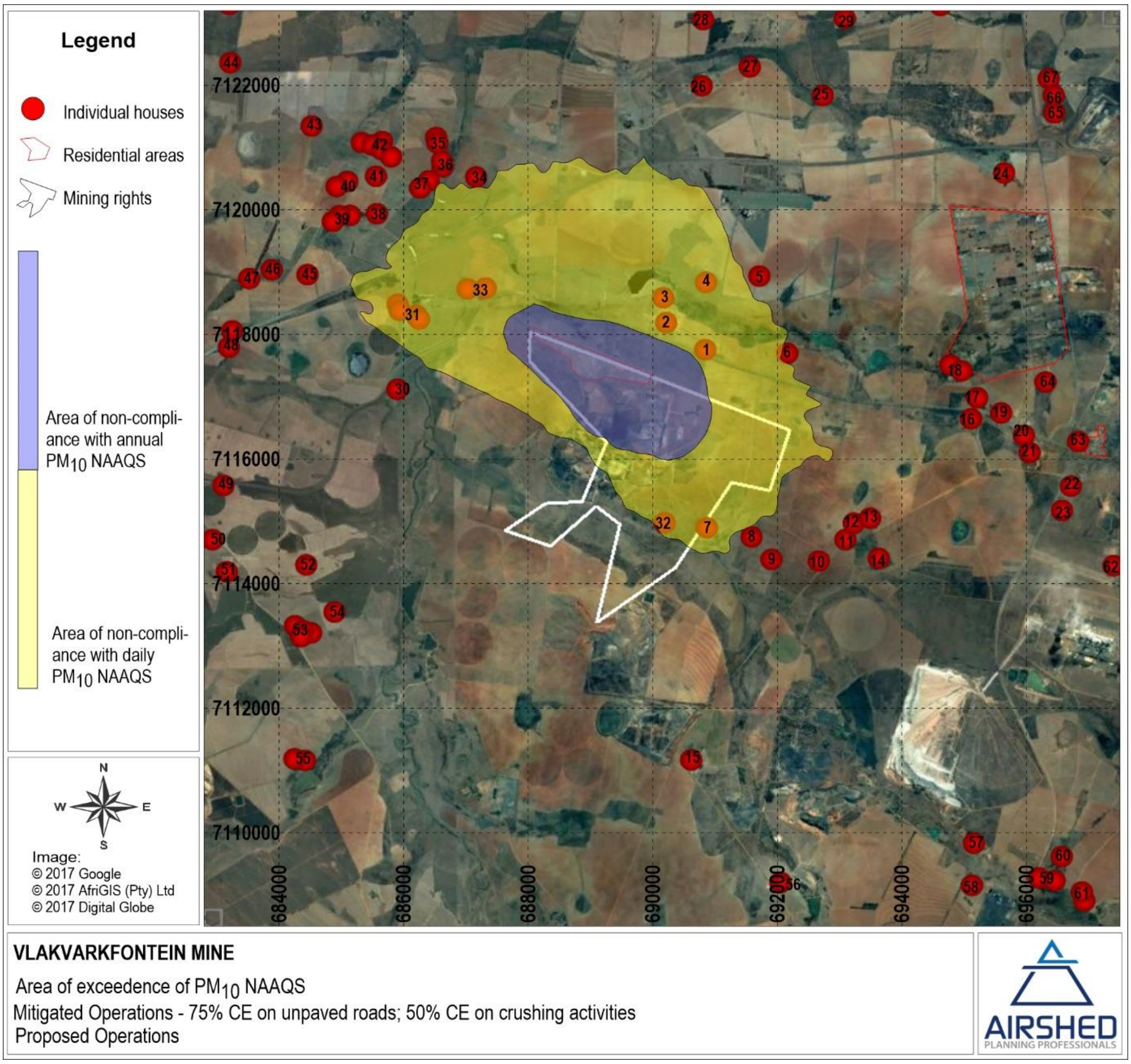

Figure 4-7: Area of non-compliance of PM_{10} NAAQS due to proposed mitigated project operations (assuming 75% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

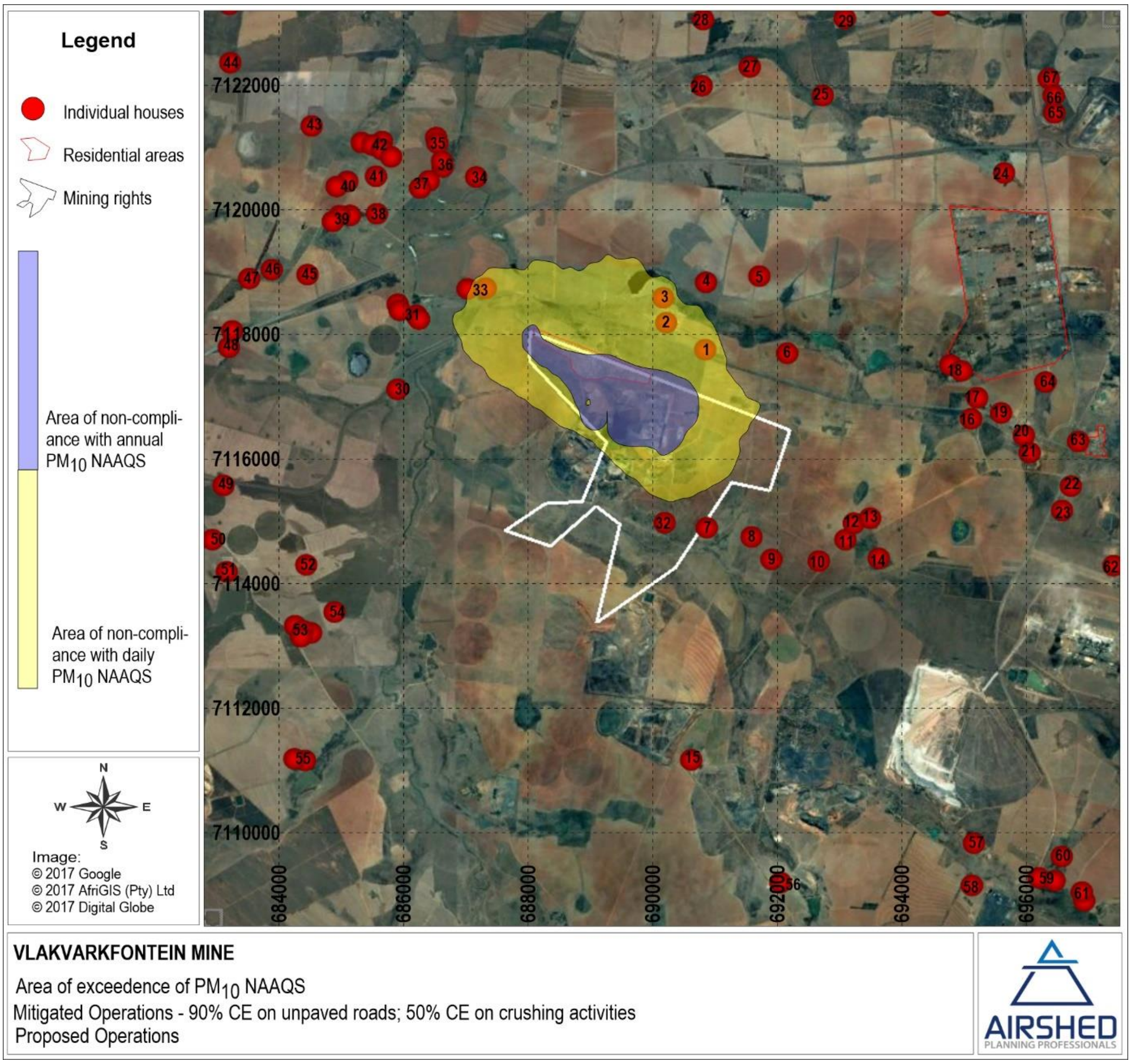

Figure 4-8: Area of non-compliance of PM_{10} NAAQS due to proposed mitigated project operations (assuming 90% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

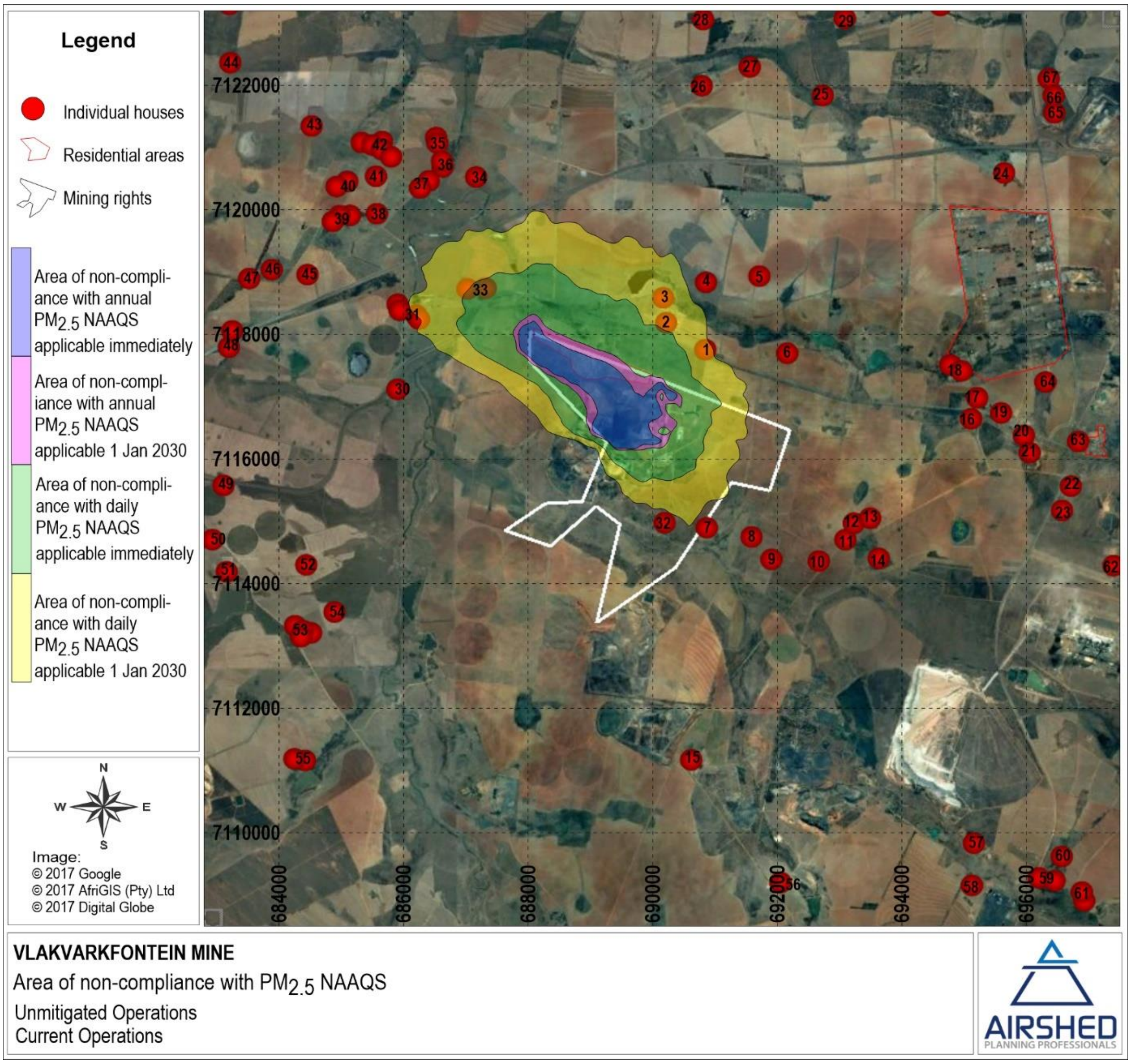

Figure 4-9: Area of non-compliance of $PM_{2.5}$ NAAQS due to current unmitigated project operations

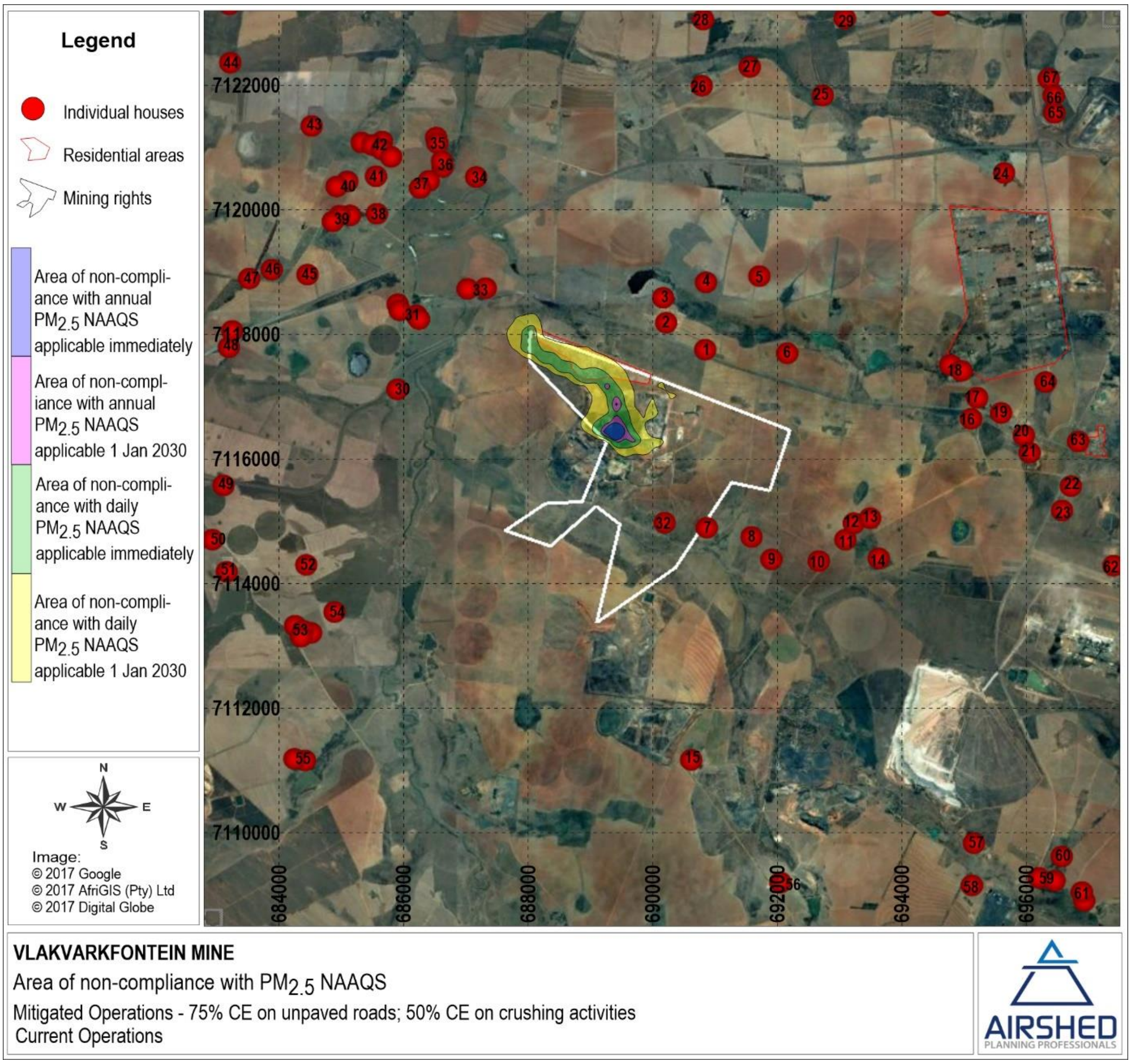

Figure 4-10: Area of non-compliance of $PM_{2.5}$ NAAQS due to current mitigated project operations (assuming 75% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

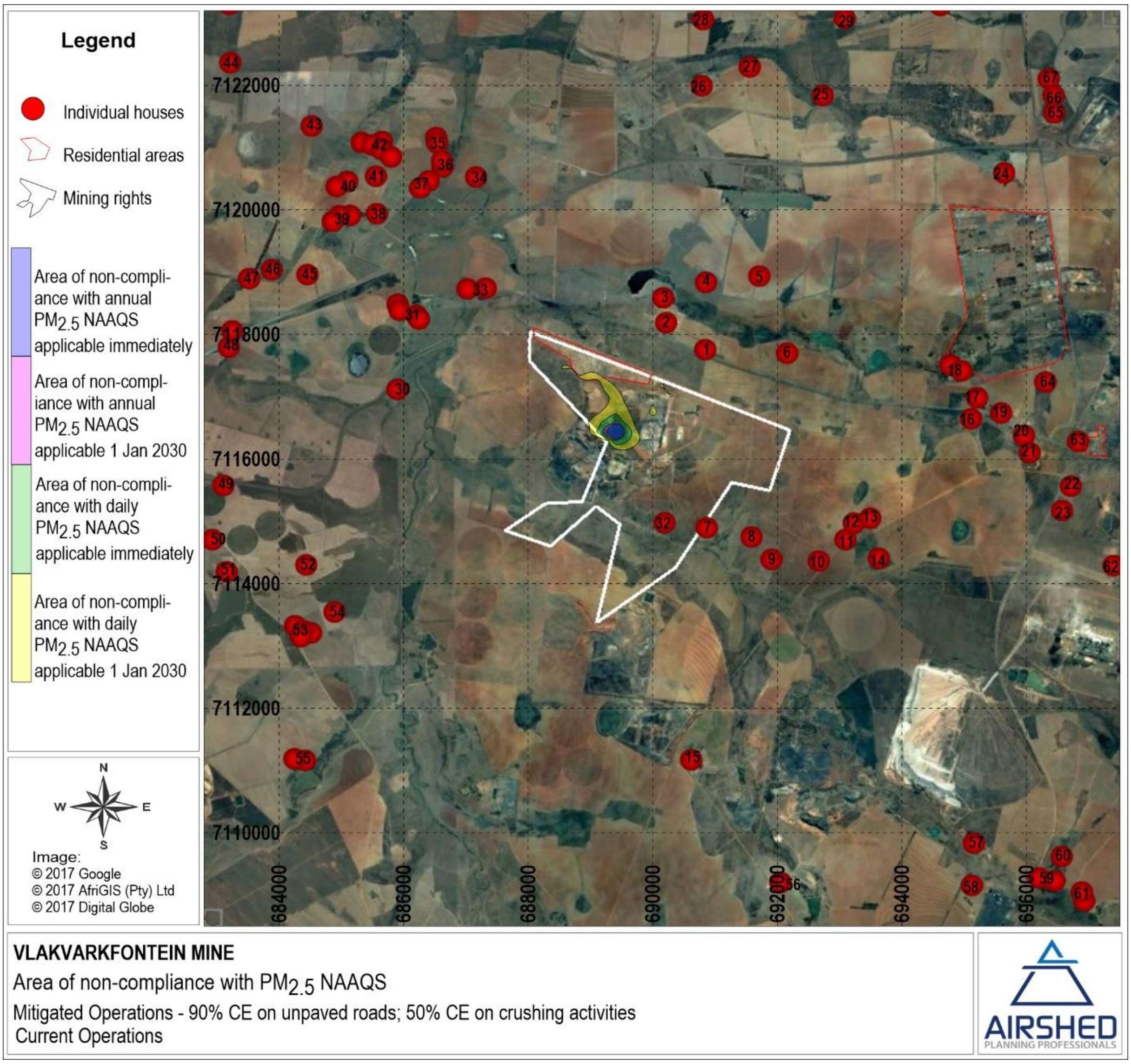

Figure 4-11: Area of non-compliance of $PM_{2.5}$ NAAQS due to current mitigated project operations (assuming 90% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

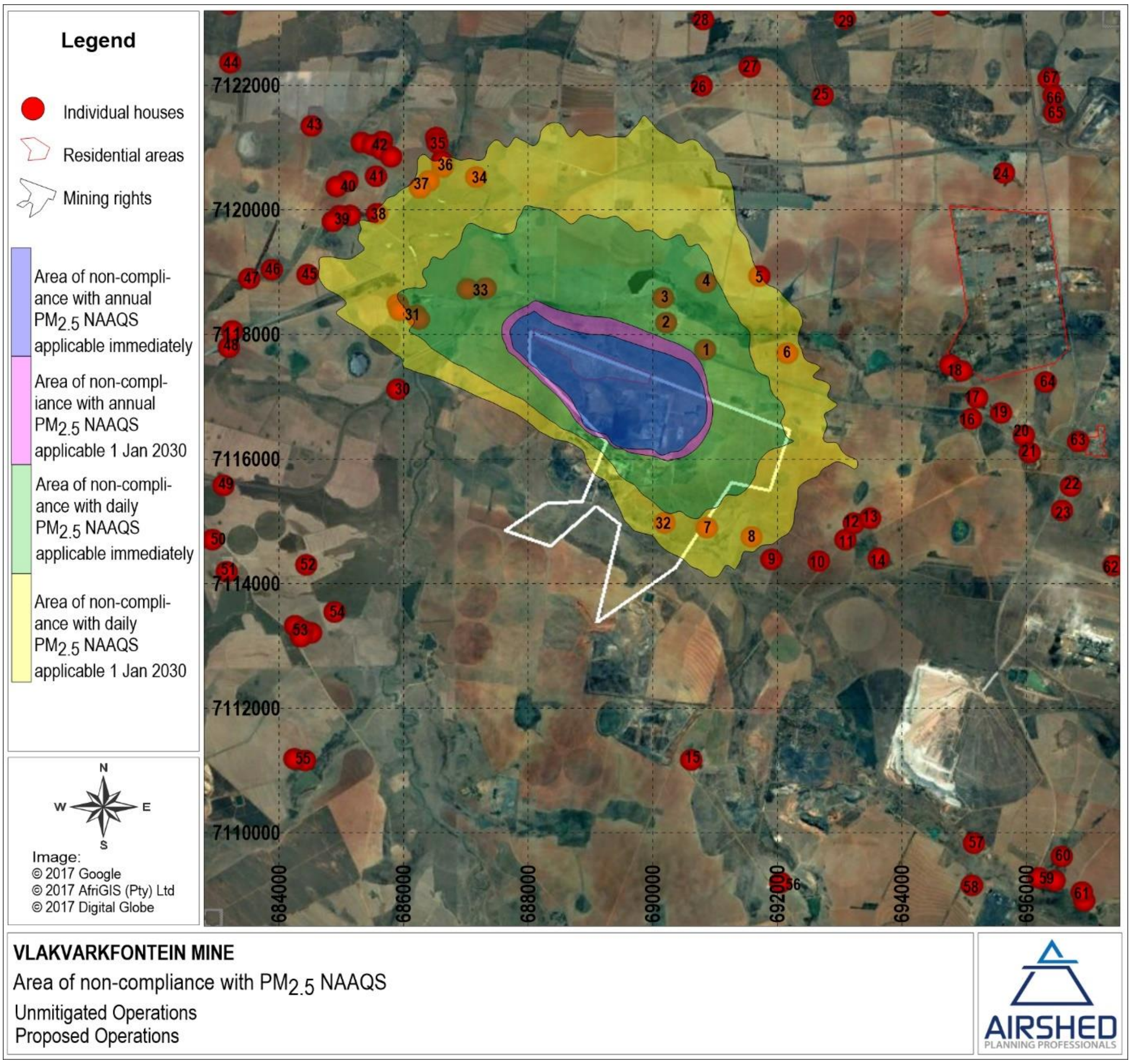

Figure 4-12: Area of non-compliance of $PM_{2.5}$ NAAQS due to proposed unmitigated project operations

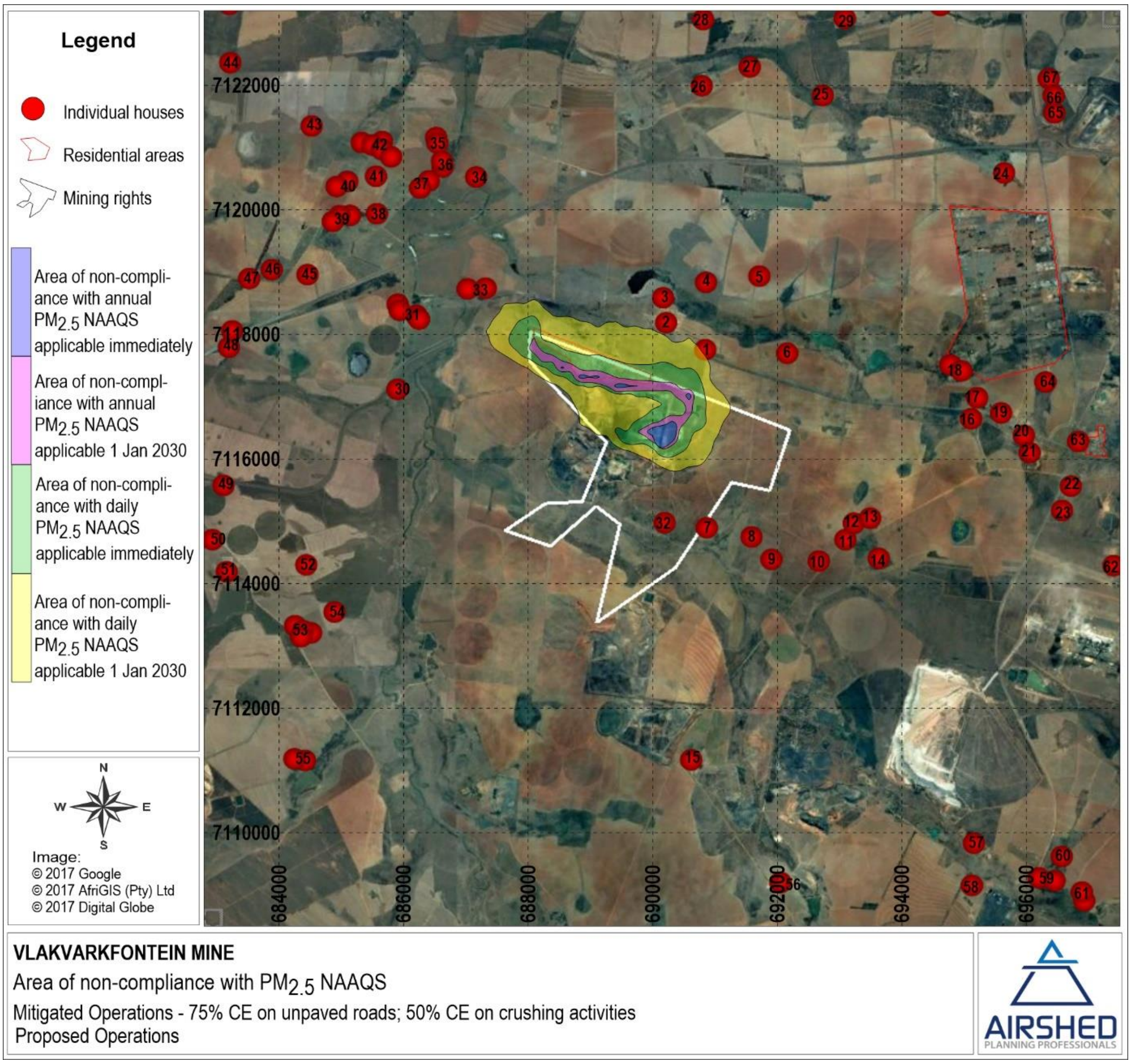

Figure 4-13: Area of non-compliance of $PM_{2.5}$ NAAQS due to proposed mitigated project operations (assuming 75% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

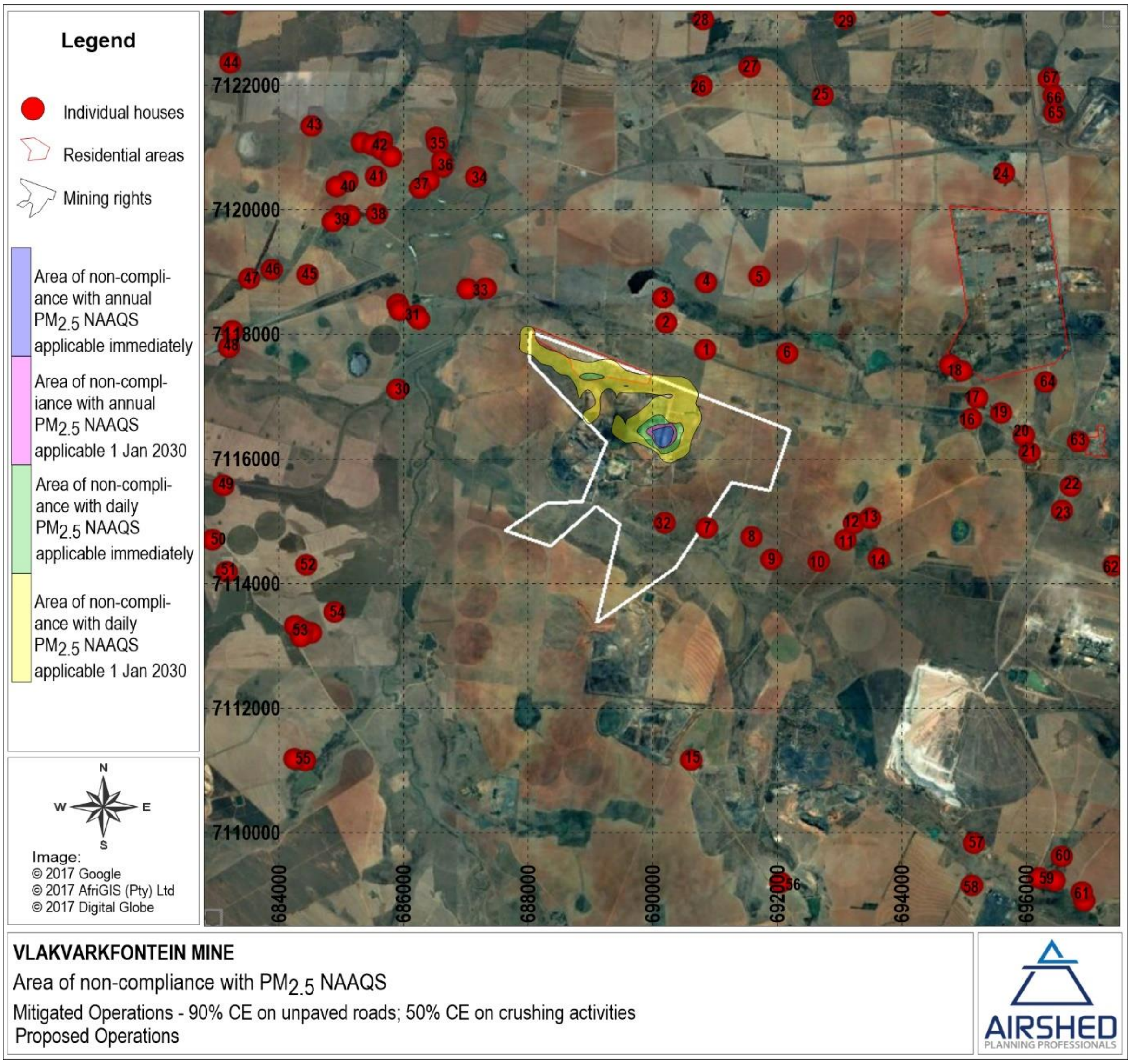

Figure 4-14: Area of non-compliance of $PM_{2.5}$ NAAQS due to proposed mitigated project operations (assuming 90% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

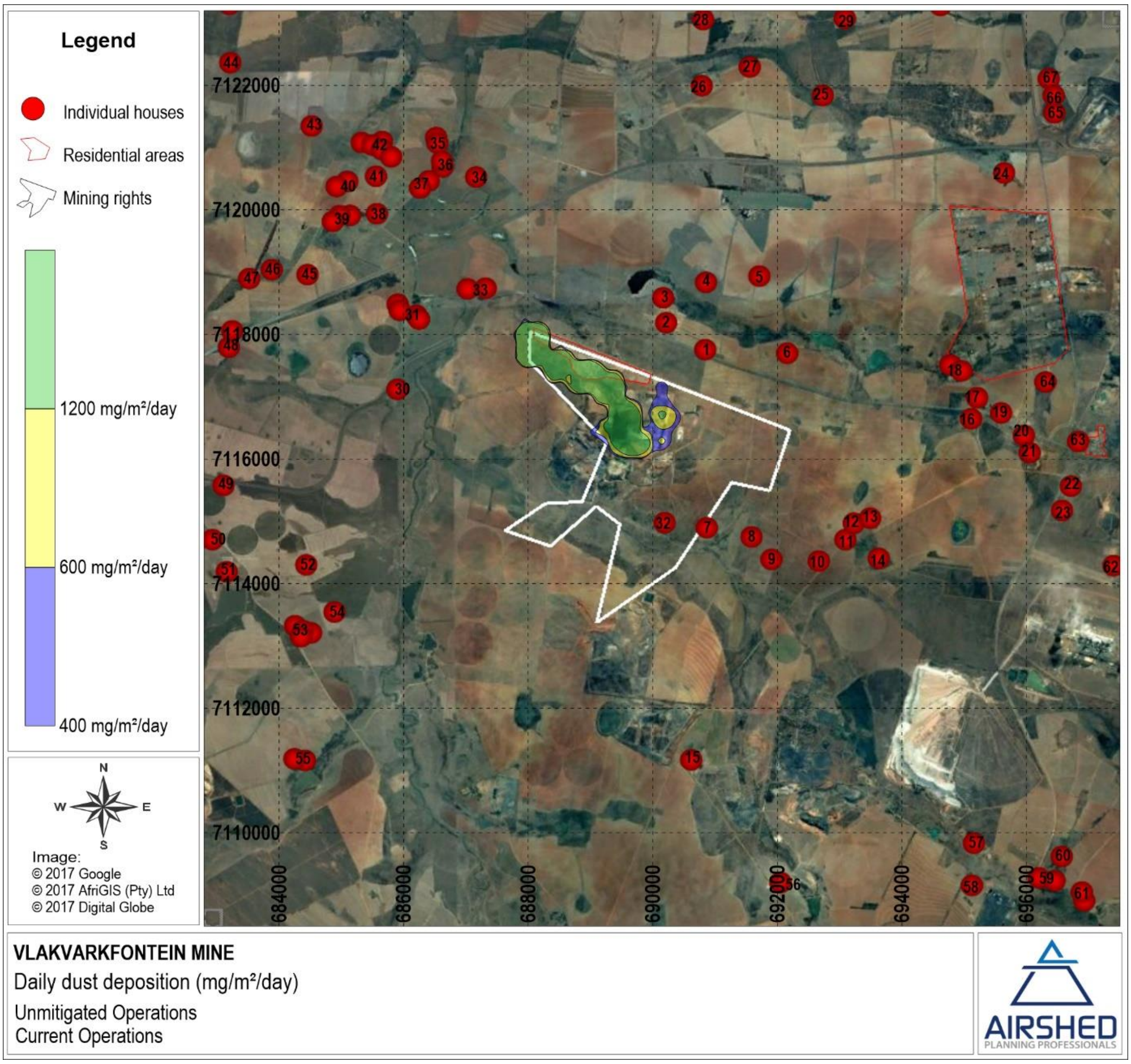

Figure 4-15: Total particulate deposition due to current unmitigated project operations

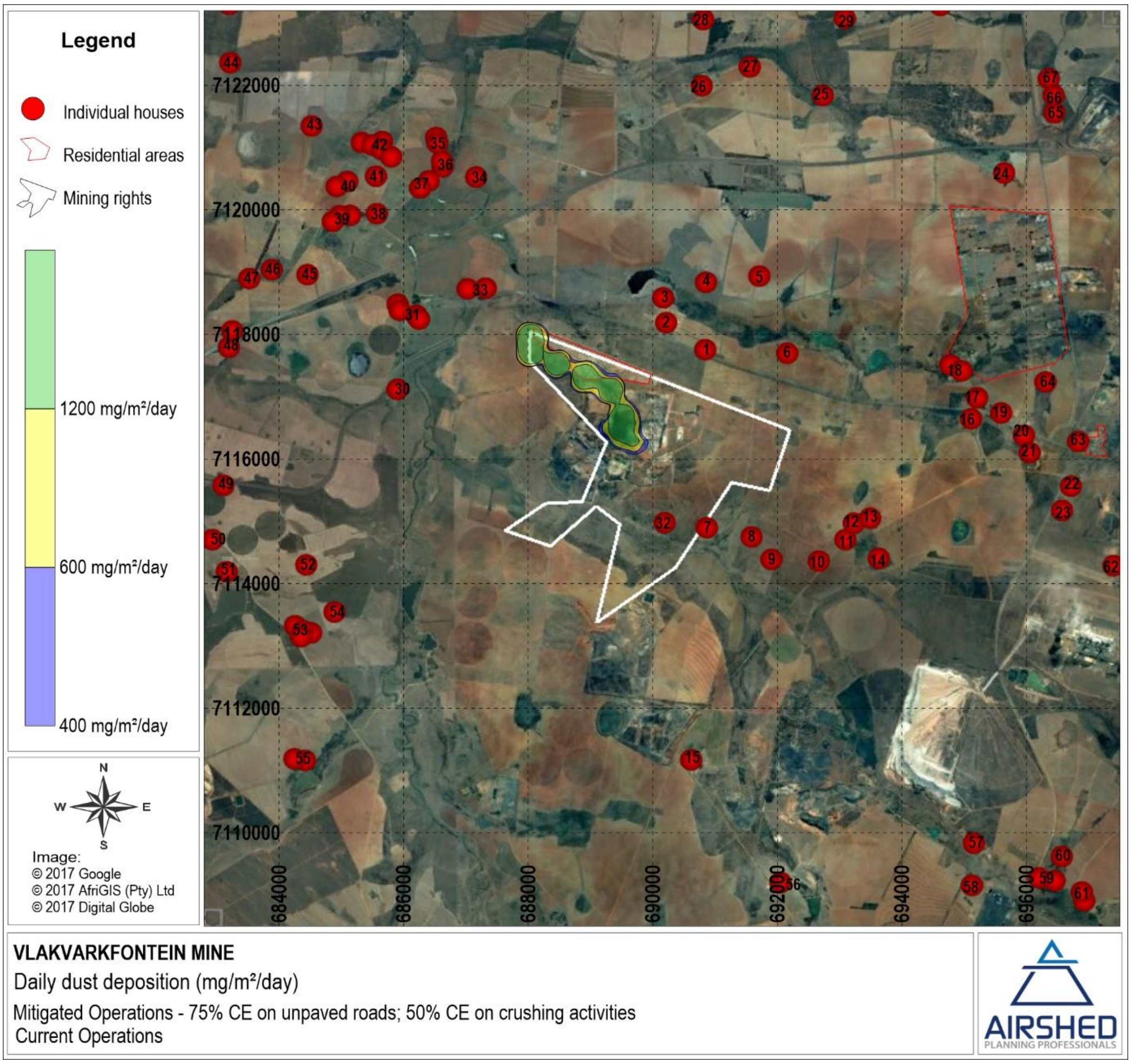

Figure 4-16: Total particulate deposition due to current mitigated project operations (assuming 75% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

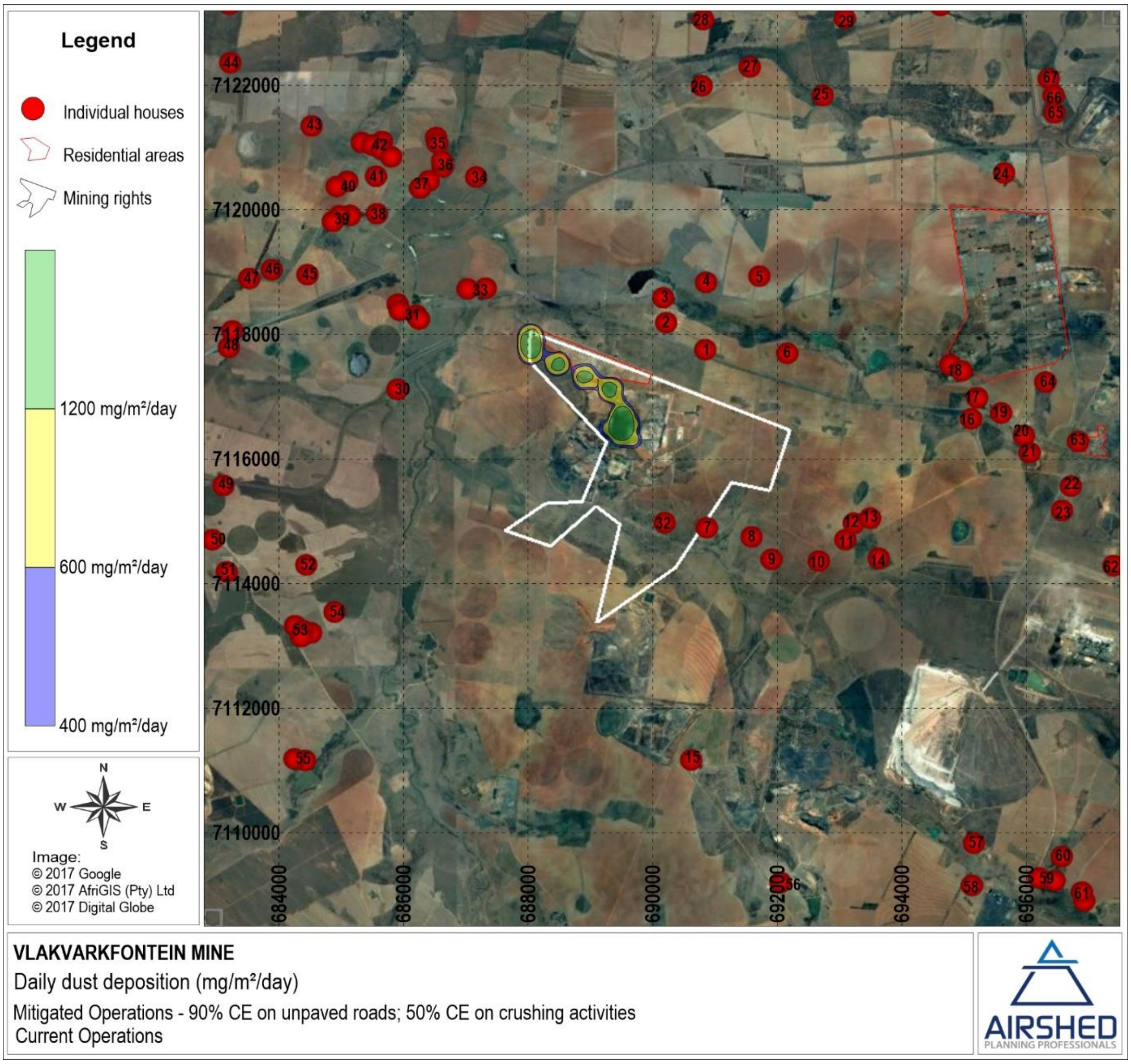

Figure 4-17: Total particulate deposition due to current mitigated project operations (assuming 90% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

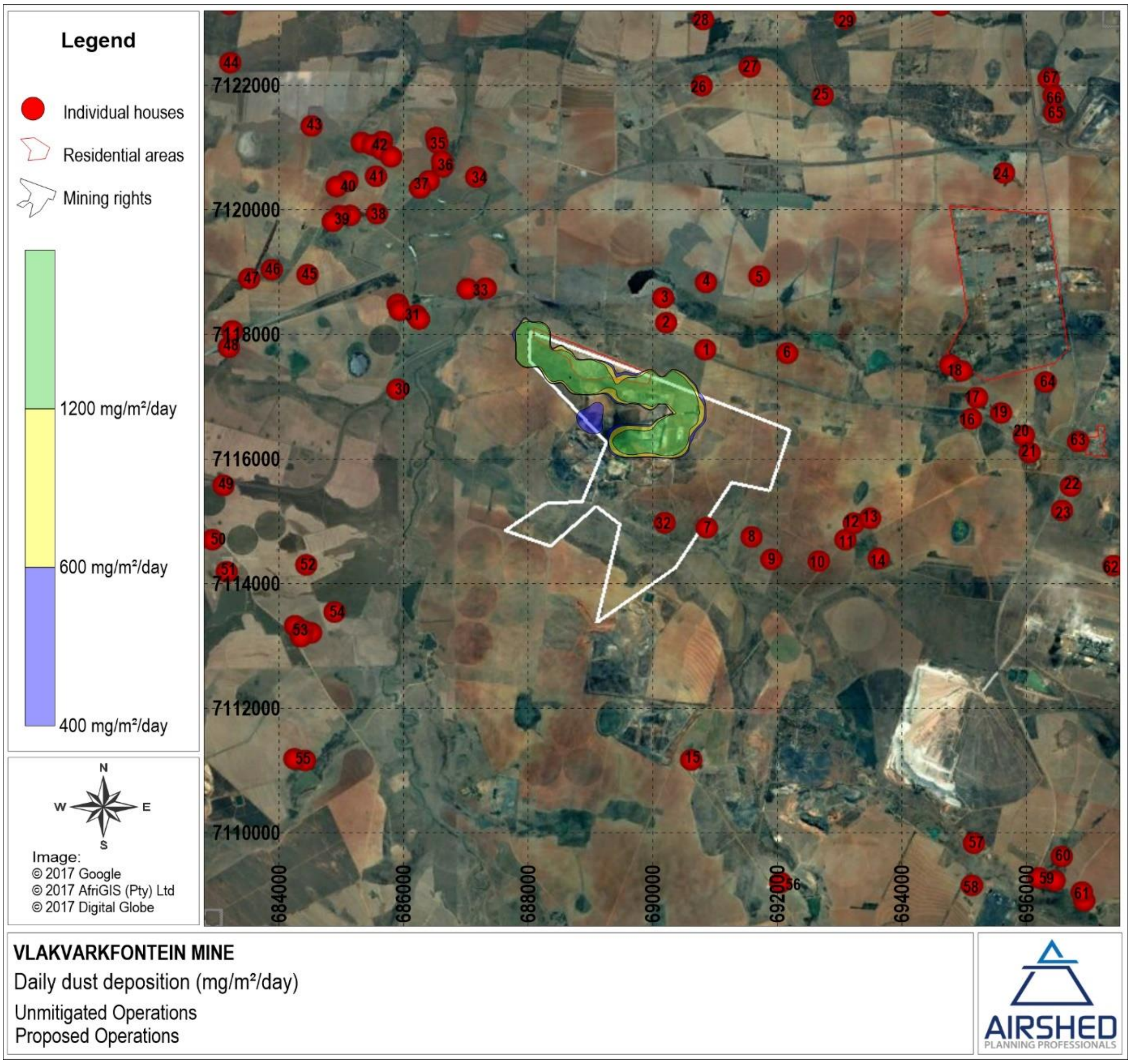

Figure 4-18: Total particulate deposition due to proposed unmitigated project operations

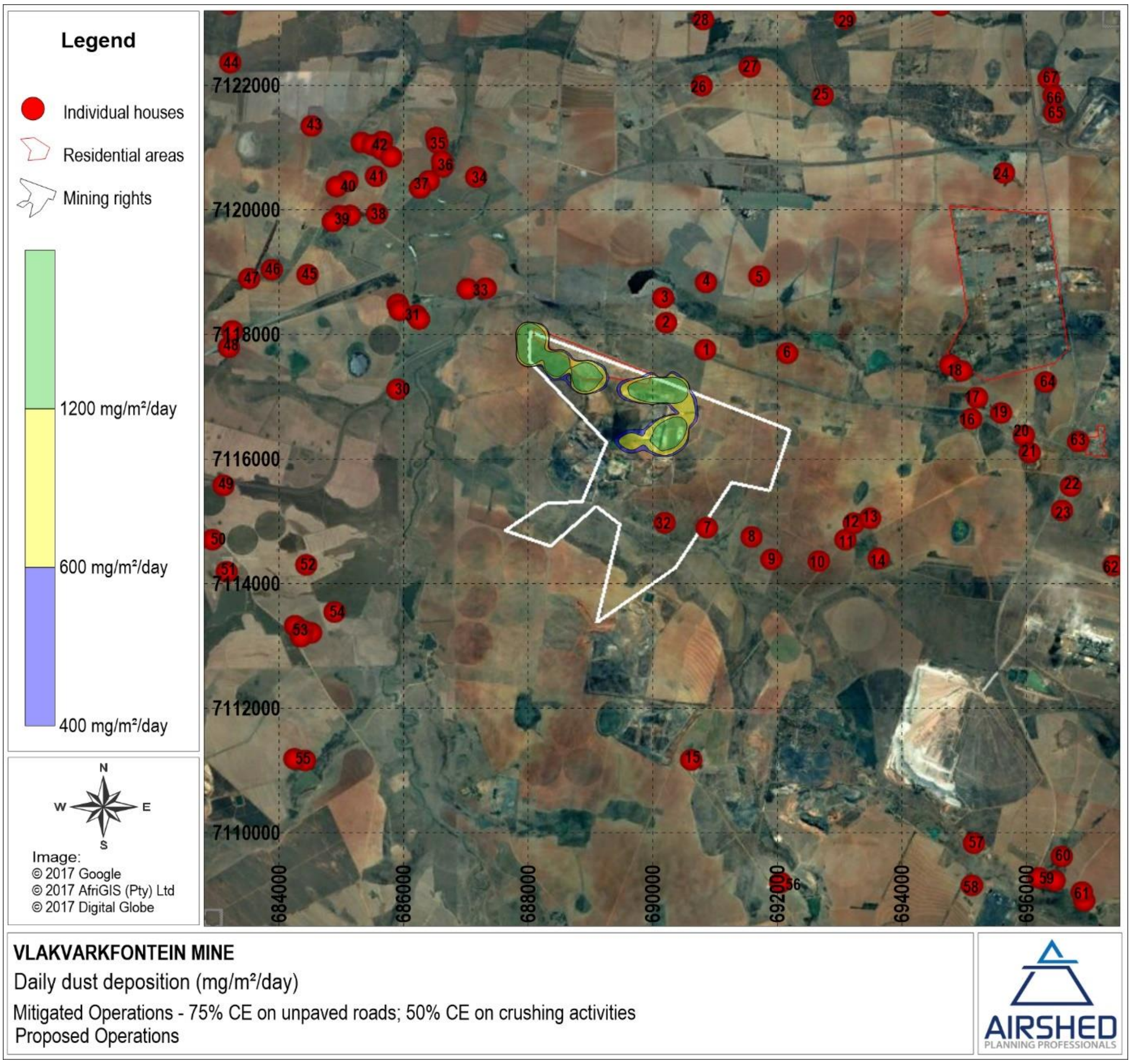

Figure 4-19: Total particulate deposition due to proposed mitigated project operations (assuming 75% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

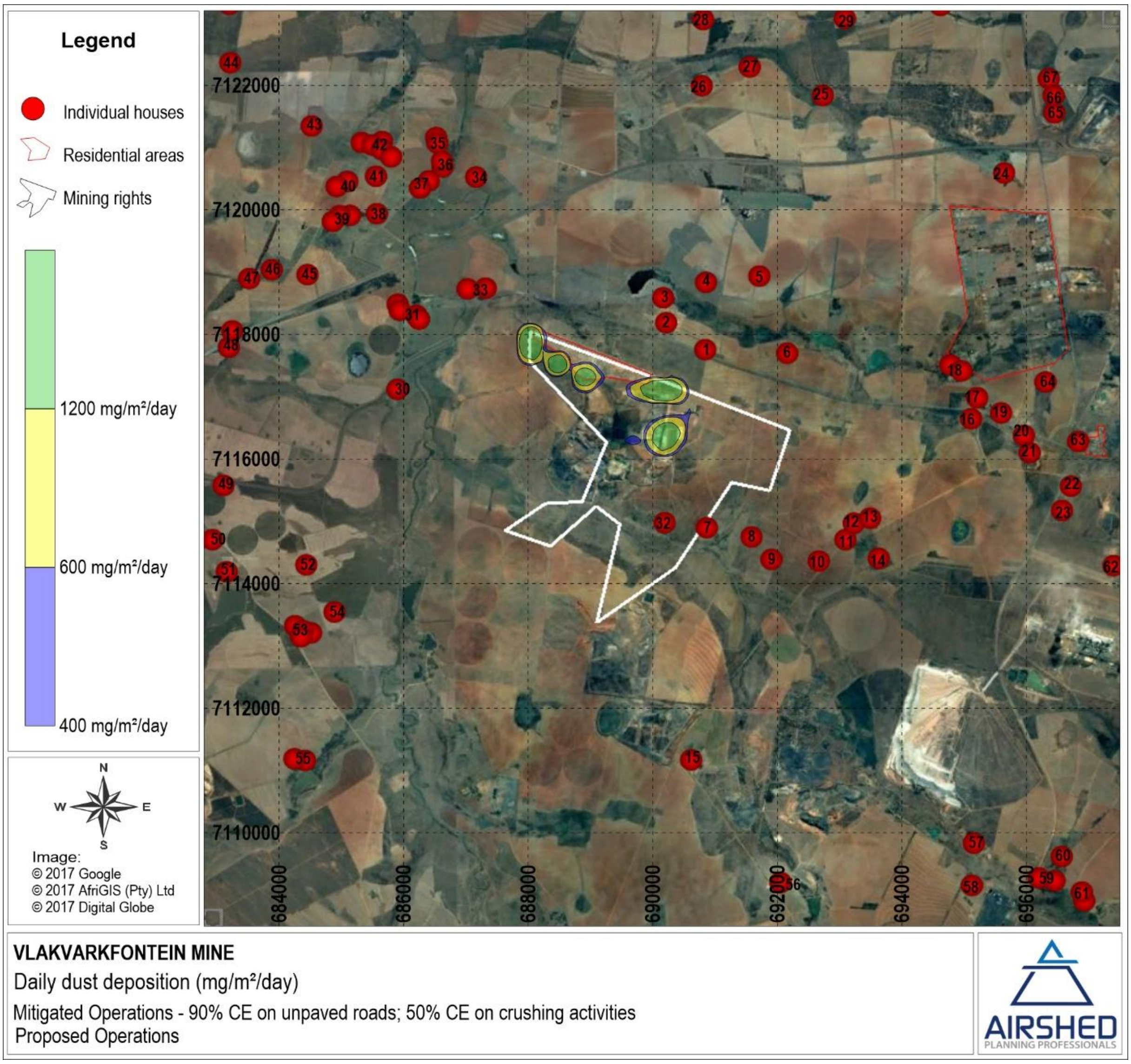

Figure 4-20: Total particulate deposition due to proposed mitigated project operations (assuming 90% control efficiency on unpaved roads, 50% control efficiency on crushing activities and 99% control efficiency on drilling activities)

Compliance of $PM_{2.5}$ and PM_{10} concentrations with NAAQS and total particulate deposition with NDCR at selected sensitive receptors in the study area, is provided in Table 4-8 and Table 4-9 for current and proposed operations respectively.

Table 4-8: Compliance of simulated $PM_{2.5}$ and PM_{10} ground level concentrations due to current operations with NAAQS and dust deposition with NDCR for residential areas at the closest sensitive receptors within the study area

Receptor	Current Unmitigated Operations					Current Mitigated Operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)					Current Mitigated Operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)				
	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)
Residential area directly north of operations	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✓	✓	✗
Residential area ~3km east of operations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Residential area ~5km east of operations (next to R63)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R1	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R2	✗	✗	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
R3	✗	✗	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
R4	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R5	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R6	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R7	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R8	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R9	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R10	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R11	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R12	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R13	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R15	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R16	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R17	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R19	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R21	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R22	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R23	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R24	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R25	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R26	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R27	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R28	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R29	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R30	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R31	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R32	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Receptor	Current Unmitigated Operations					Current Mitigated Operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)					Current Mitigated Operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)				
	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)
R33	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
R34	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R35	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R36	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R37	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R38	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R39	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R40	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R41	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R42	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R43	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R44	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R45	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R46	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R47	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R48	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R49	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R51	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R52	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R53	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R54	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R55	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R56	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R57	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R58	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R59	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R60	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R61	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R62	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R63	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R64	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R65	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R66	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R67	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 4-9: Compliance of simulated $PM_{2.5}$ and PM_{10} ground level concentrations due to proposed operations with NAAQS and dust deposition with NDCR for residential areas at the closest sensitive receptors within the study area

Receptor	Proposed Unmitigated Operations					Proposed Mitigated Operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)					Proposed Mitigated Operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)				
	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)
Residential area directly north of operations	×	×	×	×	×	×	×	×	✓	×	×	×	✓	✓	×
Residential area ~3km east of operations	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Residential area ~5km east of operations (next to R63)	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R1	×	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓
R2	×	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓
R3	×	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓
R4	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
R5	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R6	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R7	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
R8	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R9	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R10	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R11	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R12	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R13	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R14	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R15	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R16	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R17	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R18	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R19	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R20	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R21	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R22	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R23	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R24	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R25	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R26	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R27	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R28	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R29	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R30	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R31	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
R32	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓

Receptor	Proposed Unmitigated Operations					Proposed Mitigated Operations (assuming 75% CE on unpaved roads and 50% CE on crushing activities)					Proposed Mitigated Operations (assuming 90% CE on unpaved roads and 50% CE on crushing activities)				
	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)	Compliance with daily PM10 NAAQS	Compliance with annual PM10 NAAQS	Compliance with daily PM2.5 NAAQS	Compliance with annual PM2.5 NAAQS	Within Daily dust deposition of 600 mg/m²/day (for residential areas)
R33	✗	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓
R34	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R35	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R36	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R37	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R38	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R39	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R40	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R41	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R42	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R43	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R44	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R45	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R46	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R47	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R48	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R49	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R51	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R52	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R53	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R54	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R55	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R56	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R57	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R58	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R59	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R60	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R61	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R62	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R63	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R64	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R65	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R66	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R67	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The highest simulated PM_{10} concentrations due to current unmitigated project operations are in non-compliance with daily NAAQS at sensitive receptors within the study area (Figure 4-3). The area of non-compliance extends ~6km northwest to ~3km southeast from the mine boundary. When activities are mitigated (assuming 50% control efficiency on crushing activities and 75% control efficiency on unpaved roads) the PM_{10} concentrations reduce notably in magnitude and spatial distribution with exceedances of daily NAAQS at the closest sensitive receptors surrounding the mine (i.e. residential area to the north of mining operations, R2, R3 and R33) (Figure 4-4). When further mitigation is applied (90% control efficiency on unpaved roads), the impacts reduce further with exceedances of the NAAQS at the closest sensitive receptors directly north of the mine (Figure 4-5).

The highest simulated ground level PM_{10} concentrations due to proposed unmitigated project operations are in non-compliance with daily NAAQS at sensitive receptors within the study area extending ~7km northwest and north and ~5.5km southeast and east (Figure 4-6). When activities are mitigated (assuming 50% control efficiency on crushing activities and 75% control efficiency on unpaved roads) the PM_{10} concentrations reduce notably in magnitude and spatial distribution with exceedances of daily NAAQS at the closest sensitive receptors surrounding the mine (i.e. residential area to the north of mining operations, R1, R2, R3, R4, R7, R31, R32, R33) (Figure 4-7). When further mitigation is applied (90% control efficiency on unpaved roads), the impacts reduce further with exceedances of the NAAQS only at the closest sensitive receptors directly north of the mine (residential area, R1, R2 and R3) and northwest of the mine (R33) (Figure 4-8).

The highest $PM_{2.5}$ concentrations due to current unmitigated project operations are in non-compliance with daily NAAQS at sensitive receptors north of the mine (i.e. residential area) and northwest of the mine (R33) (Figure 4-9). When activities are mitigated (assuming 50% control efficiency on crushing activities and 75% control efficiency on unpaved roads) the $PM_{2.5}$ concentrations reduce notably in magnitude and spatial distribution with exceedances of daily NAAQS at the closest sensitive receptors surrounding the mine (i.e. residential area to the north of mining operations) (Figure 4-10). When further mitigation is applied (90% control efficiency on unpaved roads), the impacts reduce further with no exceedances of the NAAQS at the closest sensitive receptors within the study area (Figure 4-11).

The highest $PM_{2.5}$ concentrations due to proposed unmitigated project operations are in non-compliance with daily NAAQS at sensitive receptors north of the mine (i.e. residential area, R1, R2, R3 and R4) and northwest of the mine (R33) (Figure 4-12). When activities are mitigated (assuming 50% control efficiency on crushing activities and 75% control efficiency on unpaved roads) the $PM_{2.5}$ concentrations reduce notably in magnitude and spatial distribution with exceedances of daily NAAQS at the closest sensitive receptors surrounding the mine (i.e. residential area to the north of mining operations) (Figure 4-13). When further mitigation is applied (90% control efficiency on unpaved roads), the impacts reduce further with no exceedances of the NAAQS at the closest sensitive receptors within the study area (Figure 4-14).

Maximum daily dust deposition due to unmitigated and mitigated current and proposed operations are within the NDCR for residential areas at all sensitive receptors within the study area with the exception of the residential area to the north of mining operations (Figure 4-15 to Figure 4-20).

4.2.2.4 Cumulative Impacts

Literature states that by adding the peak model concentrations to the background concentrations, this can result in severe 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} concentrations for Kendal (57.6 µg/m³ annual average for the period 2012 to 2014) are assumed to be representative of the project area, the annual and daily cumulative ground level concentrations may increase with a further 57.6 µg/m³ and 115 µg/m³ respectively.

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 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, to a lesser extent, crushing and screening activities was significant.

The modelled impacts from materials handling activities and windblown dust from the storage piles did not exceed the relevant particulate NAAQS at sensitive receptors in the study area. Although there will be incidences of high particulate concentrations during high wind speed episodes from these sources (duration from a few minutes to hours), the NAAQS for particulate matter is for daily and annual averages.

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 (Cowhert et al., 1988; APCD, 1995).

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds
- Number of wheels per vehicle
- Traffic volumes
- Particle size distribution of the aggregate

- Compaction of the surface material
- Surface moisture
- Climate

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 and 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 (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 et al., 1988; 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 were simulated assuming 75% and 90% 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 this 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 were simulated assuming 50% control efficiency on the crushing activities.

4.2.3.3 Stockpiles

The stockpiles that are positioned between the mining activities to the south and the residential area to the north can be used as a buffer reducing the impacts from the project activities on the sensitive receptors. The stockpiles will need to be mitigated, however, so they do not pose their own impacts (i.e. through wind erosion) on the sensitive receptors.

Dust control measures for the stockpiles for long-term duration consists mainly of vegetation (for topsoil stockpiles) and rock-cladding (for waste material).

4.3 Decommissioning and 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 decommissioning phase of the proposed operations are listed in Table 4-10. The same mitigation measures for construction phase can be implemented for the decommissioning phase. For long-term rehabilitation, mitigation measures are provided in

Section 4.3.2. Simulations of the decommissioning and closure phases were not included in the current study due to its temporary impacting nature.

Table 4-10: Activities and aspects identified for the decommissioning phase

Impact	Source	Activity
Generation of $PM_{2.5}$ and PM_{10}	Open surfaces	Dust generated during rehabilitation activities
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 scoping report is provided in Appendix C.

The following alternatives were considered:

- Regarding the filter cake (fines): both the option to stockpile on site for use as non-select product (Alternative P2a) as well as the option for disposal (Alternative P2b).
- For the disposal of carboniferous wastes (wash plant waste rock and possibly filter cake), the option of disposal of to pit (Alternative P3d) appears to be most suitable because no new dump on surface will be required. Disposal to a surface waste disposal facility located on old rehabilitated mine area (Alternative P3a) is however also assessed if in pit disposal in not feasible. In the event that designing the dumps on rehabilitated areas becomes problematic, the option of disposal to a surface waste disposal facility located on un-mined area (Alternative P3b) is to be considered.

The decline in ambient air quality was the same for all alternatives assessed as the impacts would result from vehicle entrainment from the transport of material which would all be similar as the roads used would be relative to the operations. The significance ranking for all alternatives (including proposed project operations) is provided in Table 5-1 to Table 5-4 and provides a low significance ranking for construction, decommissioning and closure phases and a moderate significance ranking for operation phase.

Table 5-1: Significance ranking due to proposed project construction activities

Impact Name	**Decline in Ambient Air Quality**				
Alternative	**Alternative P2a, P2b, P3a, P3b and P3d**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	2	2	Reversibility of Impact	2	1
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-9.00
Mitigation Measures					
See Section 4.1.2					
Environmental Risk (Post-mitigation)					-8.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-9.33

Table 5-2: Significance ranking due to proposed project operation activities

Impact Name	Decline in Ambient Air Quality				
Alternative	Alternative P2a, P2b, P3a, P3b and P3d				
Phase	Operation				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	4	3	Reversibility of Impact	3	1
Duration of Impact	4	4	Probability	4	4
Environmental Risk (Pre-mitigation)					-14.00
Mitigation Measures					
See Section 4.2.3					
Environmental Risk (Post-mitigation)					-11.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-12.83

Table 5-3: Significance ranking due to proposed project decommissioning activities

Impact Name	Decline in Ambient Air Quality				
Alternative	Alternative P2a, P2b, P3a, P3b and P3d				
Phase	Decommissioning				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	2	Reversibility of Impact	3	1
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
See Section 4.1.2					
Environmental Risk (Post-mitigation)					-8.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-8.00

Table 5-4: Significance ranking due to proposed project closure and rehabilitation activities

Impact Name	**Decline in Ambient Air Quality**				
Alternative	**Alternative P2a, P2b, P3a, P3b and P3d**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	2	2	Reversibility of Impact	3	1
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-10.00
Mitigation Measures					
See Section 4.3.2					
Environmental Risk (Post-mitigation)					-8.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-8.00

6 DUST MANAGEMENT PLAN

An air quality impact assessment was conducted for the project operations. The main objective of this study was to determine the significance of the predicted impacts from the current and 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 vehicle entrainment and then crushing activities and windblown dust.

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. Constant emissions were assumed for material handling operations and vehicle entrainment. 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.

From the impact assessment, the main sources of concern were identified to be the vehicle entrainment and, to a lesser extent, 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 "good practice" 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 potential expansion of the monitoring system for the project, 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 on unpaved road surfaces
- Crushing and screening activities

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 to the proposed activities, it is recommended that chemical suppressants be applied to unpaved haul roads and access roads to reduce the impacts from this source with **90% control efficiency**.

The crushing operations are shown to be a potentially significant source of emissions if unmitigated. It is recommended that mitigation by means of **water sprayers (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:

- Dustfall immediately downwind of the product storage piles to be < 1200 mg/m²/day and dustfall at sensitive receptors to be < 600 mg/m²/day.
- 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.

6.2.3.2 Receptor Based Performance Indicators

Dustfall Network

Based on the impacts from the proposed project it is recommended that the current dust fallout sampling undertaken at the mine be continued during proposed operations to ensure management measures implemented are effective and ambient air quality levels are not significantly different to baseline levels.

A recommended dust fallout network comprising of single dust buckets is provided in Table 6-1. The recommended performance assessment and reporting programme for ambient air sampling is given in Table 6-2.

Table 6-1: Recommended dust fallout and PM_{10} sampling for the proposed project

Sampler	Latitude	Longitude	Description
Dust bucket 1	-26.048141	28.884462	At closest sensitive receptor to north of operations – School (location of current sampler)
Dust bucket 2	-26.071784	28.901206	At closest sensitive receptor to south of operations
Dust bucket 3	-26.059648	28.897870	Downwind of proposed plant activities
Dust bucket 4	-26.042746	28.901439	At sensitive receptor to north of mine boundary
PM_{10} sampler	-26.048141	28.884462	At closest sensitive receptor to north of operations – School

Table 6-2: Ambient air monitoring, performance assessment and reporting programme

Monitoring Strategy Criteria	Dustfall Monitoring
Monitoring objectives	- Assessment of compliance with dustfall limits within the main impact zone of the operation. - Facilitate the measurement of progress against environmental targets within the main impact zone of the operation. - Temporal trend analysis to determine the potential for nuisance impacts within the main impact zone of the operation. - Tracking of progress due to pollution control measure implementation within the main impact zone of the operation. - Informing the public of the extent of localised dust nuisance impacts occurring in the vicinity of the mine operations.
Monitoring location(s)	It is recommended that a dust fallout network be implemented consisting of four dust buckets (Figure 6-1).
Sampling techniques	*Single Bucket Dust Fallout Monitors* 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).
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 Quality Assessment/ Quality Control (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. (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.

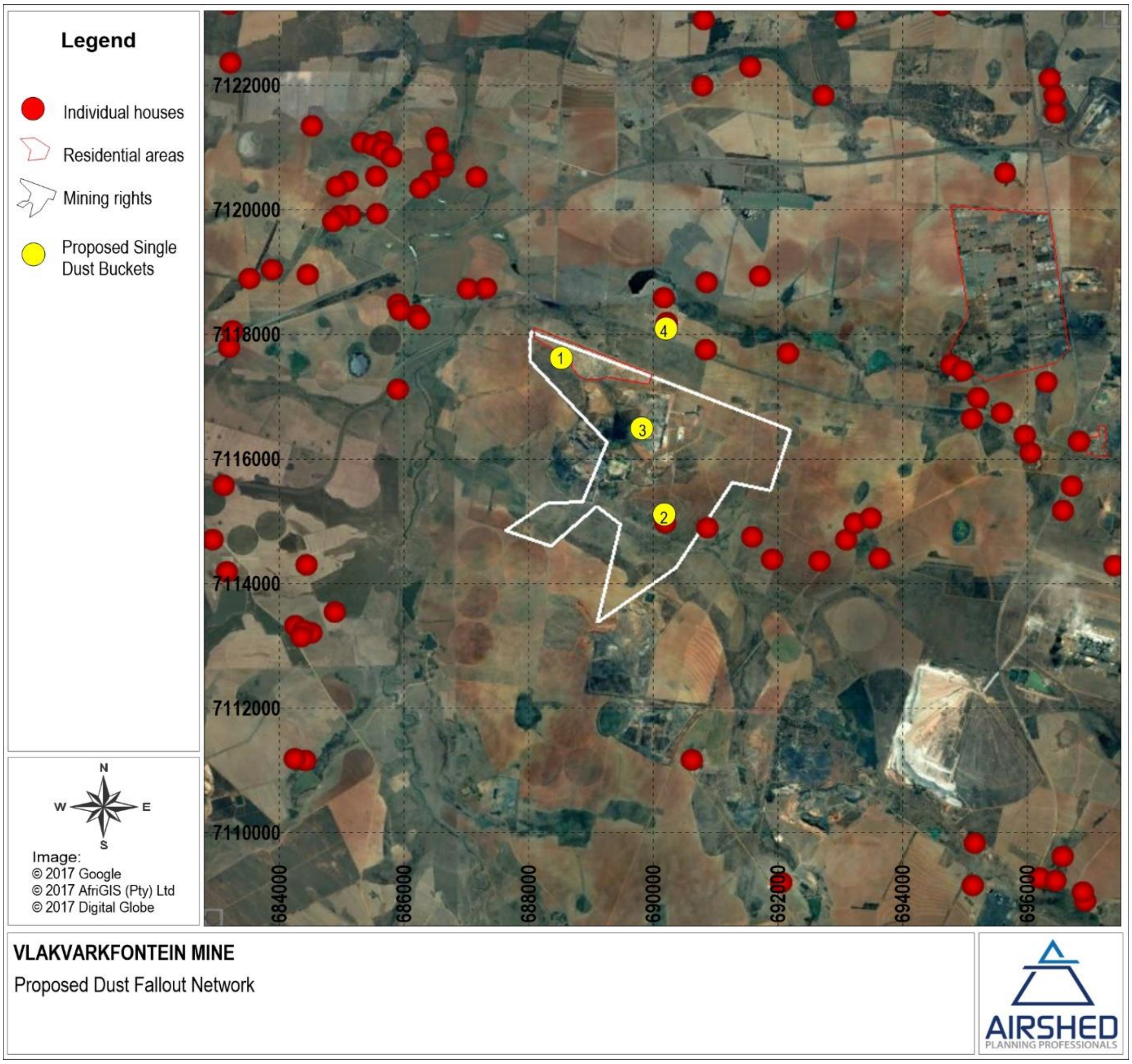

Figure 6-1: Proposed dust fallout network for the proposed project operations

PM_{10} Sampling

It is recommended that PM_{10} sampling campaign of 12 months be undertaken (to obtain daily PM_{10} concentration averages) at the closest receptors to the north of mining operations before operations commence to understand the baseline ambient concentrations. It is suspected that baseline ambient PM_{10} concentrations at the closest sensitive receptors north of the project exceed NAAQS. Once proposed mitigated operations commence, a PM_{10} sampling campaign of 12 months needs to be undertaken in order to ensure that baseline levels are not further compromised by the projects proposed operations and if possible, to reduce ambient particulate concentrations to within NAAQS. The PM_{10} sampling can be undertaken by inexpensive sampling equipment such as a MiniVol or EBam or more expensive equipment such as a TEOM.

It is recommended that the placement of the PM_{10} sampler be co-located with a close sensitive receptor (i.e. at dust bucket 2 or dust bucket 4) in order to understand the change in baseline of ambient PM_{10} concentrations once proposed operations commence. If this is not possible due to security reasons, then the PM_{10} sampling should not be undertaken as placement inside the mining boundary will not meet the same objective.

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 interested and affected parties (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 6-3. The management and monitoring of all operations at the mine should be evaluated on a daily basis and appropriate actions taken to minimise dust generation and impacts.

Table 6-3: 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: Water sprayers providing ~75% control efficiency Chemical suppressants providing 80%-90% control efficiency. *Due to the proximity of sensitive receptors to the proposed project activities, it is recommended that chemical suppressants be applied to unpaved haul and access roads to reduce the impacts from this source by 90% control efficiency.*	Duration of operations
Crushing operations	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	Various management measures may be implemented including: Telescopic chute with water sprays providing ~75% control efficiency Water sprayers on crushing activities providing ~50% control efficiency Hoods with scrubbers providing up to 75% control efficiency Enclosure of scrubbers and screens would provide up to 100% control efficiency Hooding with fabric filters can result in control efficiencies of 83%. *Water sprayers on the crushing activities should be implemented to control the emission of this source by 50%.*	Duration of operations
Ambient Monitoring	PM_{10} concentrations and dustfall rates	A proposed dust fallout sampling network (comprising of four single dust buckets), as provided in Section 6.2.3, is recommended. 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. Two PM_{10} sampling campaigns are recommended at the closest sensitive receptors (north of operations) before proposed operations commence and once proposed mitigated operations take place in order to ensure minimum impacts from the project on the surrounding communities.	Duration of operations

7 FINDINGS AND RECOMMENDATIONS

7.1 Findings

An air quality impact assessment was conducted for the project operations. The main objective of this study was to determine the significance of the predicted impacts from the project operations on the surrounding environment and on human health. Emission rates were quantified for the current and 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 agricultural activities, mining and industrial activities as well as vehicle entrainment on unpaved road surfaces and biomass burning.
- The wind field is dominated by winds from the north-west and east.
- Numerous individual homesteads are located around the project area. Larger residential areas include a settlement directly north of the mine.
- Measured PM_{10} ground level concentrations at Kendal (Eskom monitoring station) exceed NAAQS during the sampling period of 2012 to 2014.
- The dust fallout measured at the Vlakvarkfontein sampling network (directional buckets) for the period March to August 2017 were provided for five sites with the geometric mean ranging from 527 mg/m²/day to 70 mg/m²/day.

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

- Vehicle entrainment on unpaved surfaces and, to a lesser extent, crushing activities represented the highest impacting particulate sources from the current and proposed project operations.
- The highest simulated ground level PM_{10} concentrations due to current unmitigated project operations were in non-compliance with daily NAAQS at sensitive receptors within the study area. When activities were mitigated (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities), the impacts reduced significantly with exceedances of the NAAQS only at the closest sensitive receptors directly north of the mine. The extent of the PM_{10} impacts increase with proposed operations with exceedances of the NAAQS (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities) at residential area north of the mine and individual homesteads north and northwest of the mine.
- The highest simulated $PM_{2.5}$ concentrations due to current unmitigated project operations were in non-compliance with daily NAAQS at the residential area north of the mine and an individual homestead northwest of the mine. When activities were mitigated (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities), the impacts reduced significantly with no exceedances of the NAAQS at the closest sensitive receptors. The extent of the $PM_{2.5}$ impacts increase with proposed operations but are within NAAQS with mitigated operations (assuming 90% control efficiency on unpaved roads and 50% control efficiency on crushing activities).

- Maximum daily dust deposition due to unmitigated and mitigated operations exceeded the NDCR for residential areas at the closest sensitive receptors (residential area) to the north of the mine.

7.2 Recommendations

It is of the authors opinion that the project be authorised provided that the following recommendations are followed:

- It is recommended that ambient sampling, as outlined in Section 6.2.3.2, be undertaken 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 extensive mitigation measures on the main sources of fugitive dust (as recommended in Table 6-2) be implemented to minimise impacts as far as possible.

8 GREENHOUSE GAS QUANTIFICATION

The South African mandatory reporting guidelines for GHG focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

The National Air Quality Act, 2004 (Act No.39 of 2004) and the National Greenhouse Gas Emissions Reporting Regulations (NGERs) under that Act establish the legislative framework for a national GHG reporting system.

The South African Technical Guidelines (DEA, 2017) embody the latest methods for estimating emissions and are based on the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for compilation of National Greenhouse Gas inventories.

Sources of GHGs at the Vlakvarkfontein Mine include the liberation of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) during fossil fuel combustion from mining. This section will include the following:

- Detail and determine the direct carbon footprint of the mine;
- Determination of the type and volumes GHG emissions arising from the mines direct operations; and
- Determination of the carbon tax to be levied on the mine as a result of its direct operations once the carbon emissions tax is promulgated.

8.1 Greenhouse Gas Emissions Inventory

The Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry (DEA, 2017) state methods for determining greenhouse gas emissions as required by the IPCC. The following methods are given:

- Tier 1: A bare minimum method using readily available statistical data on the intensity of processes (activity data) and default emission factors. This method is the simplest method and has the highest level of uncertainty;
- Tier 2: Similar to Tier 1 but uses technology or country specific emission factors. Tier 2 methods reduce the level of uncertainty;
- Tier 3: Defined as any methodology more detailed than Tier 2 and might include amongst others, process models and direct measurements. Tier 3 methods have the lowest level of uncertainty.

Mining is a key category for South Africa and thus reporting of emissions on either Tier 2 or Tier 3 is required. Mining has a specific stationary combustion category within the IPCC Regulations (1A2i Mining and Quarrying). However, emissions produced by a mining company are not all unique to this category of emissions. All stationary combustion emissions should be reported in this sector.

Table 8-1: IPCC classification of emissions for mining and quarrying

Sector	Relevant IPCC code/s	Definition	Relevant IPCC Gases	Tier	Transitional arrangements
Mining and Quarrying	1A2i	Emissions from the mining operation and processing plants.	CO_2	2 or 3	Yes
			CH_4	1, 2 or 3	No
			N_2O	1, 2 or 3	No

For diesel emissions, only tier 1 emission factors are available. A summary of all direct GHG emissions from the Vlakvarkfontein Mine for current and proposed operations (based on diesel usage provided) (assuming the tier 1 approach) is given in Table 8-2 (this includes CO_2, CH_4 and N_2O expressed as tonne CO_2 equivalent or tCO_2eq). CO_2eq is a term for describing different GHG in a common unit. For any quantity and type of GHG, CO_2eq signifies the amount of CO_2 which would have the equivalent global warming impact. A quantity of GHG can be expressed as CO_2eq by multiplying the amount of the GHG by its global warming potential (GWP) (e.g. if 1kg of CH_4 is emitted, this can be expressed as 23 kg of CO_2eq (1kg CH_4 * 23 = 23kg CO_2eq) and 1kg of N_2O is expressed as 296 kg of CO_2eq (1kg N_2O* 296 = 296kg CO_2eq) based on a time horizon of 100 years).

Table 8-2: Greenhouse Gas Emissions Inventory at the Vlakvarkfontein Mine

Emission Source	Description	Quantity	Units	Emission Factor	CO_2 Emission Rate (tpa)	CH_4 Emission Rate (tpa)	N_2O Emission Rate (tpa)	CO_2eq Emission Rate (tpa)
Fuel Use for current operations (October 2016 to September 2017)	Diesel fuel use	3 627 502 (138 207)	l/a (GJ/a)	74 100 kg CO_2/TJ fuel 3 kg CH_4/TJ fuel 0.6 kg N_2O/TJ fuel	10 241	0.41	0.08	10 275
Fuel Use for proposed operations	Diesel fuel use	4 173 324 (159 004)	l/a (GJ/a)	74 100 kg CO_2/TJ fuel 3 kg CH_4/TJ fuel 0.6 kg N_2O/TJ fuel	11 782	0.48	0.10	11 821

8.2 Estimated Carbon Tax

According to the Coaltech report (Cook, 2013) it is the responsibility of the DEA to collate all the GHG emissions data and compile the National Inventory. This includes data from all industries and other sources, including the mining emissions. This inventory will also form the basis for possible emissions taxation, and all measured emissions must be included in the National Inventory, including the emissions for mining. However, if the measuring methodology is not approved or accepted by the IPCC as an international standard, no matter how robust and repeatable the methodology is, any emissions so measured, cannot be included by SARS for emissions tax purposes as they cannot be internationally verified. The IPCC approved factor used in this assessment can be used for tax purposes.

The Carbon Tax Policy Paper (Department of National Treasury, 2013) stated that the proposed basic tax-free threshold of 60 per cent, the additional tax-free threshold for process emissions for trade-exposed sectors, and the maximum offset percentages of 5 and 10 per cent for the different sectors will remain fixed during the first phase of the introduction of the carbon tax (2015–19). The percentage tax-free thresholds will be reduced during the second phase (2020–25) and may be replaced with absolute emissions thresholds thereafter. In this paper the government proposed that a carbon tax be introduced at R120 per tCO_2eq above the tax-free thresholds (including the proposed offsets) on 1 January 2015. The effective tax rate will be substantially below the rate of R120 per tCO_2eq (and as adjusted over time) during the first five-year period if the tax-free thresholds are taken into account. However, the R120 per tCO_2eq will provide an important price signal for mitigation potential on the margin.

Based on the assumption of R120 per tCO_2eq from the carbon tax bill (2017 – final for comment), with a 70% tax-free threshold for emissions from other operations (60% basic tax-free allowance and 10% offset allowance), the proposed tax would then be in the region of R369 910 per year for current operations and R425 570 for proposed operations. After the first five-year period of implementation the tax-free thresholds will be reduced, but the figures are unknown at this stage.

Table 8-3: Carbon tax estimation

Operations	tCO_2eq (total)	Tax-free threshold for coal mining (%)	tCO_2eq (applicable to be taxed – assuming 70% tax-free)	Tax due (R120/ tCO_2eq) per year
Current Vlakvarkfontein operations	10 275	70	3 082	R369 910
Proposed Vlakvarkfontein operations	11 821	70	3 546	R425 570

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APPENDIX A - COMPREHENSIVE CURRICULUM VITAE OF THE AUTHOUR OF THE CURRENT ASSESSMENT

CURRICULUM VITAE	RENEÉ VON GRUENEWALDT

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Reneé von Gruenewaldt (*nee* Thomas)
Profession	Air Quality Scientist
Date of Birth	13 May 1978
Years with Firm	More than 15 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP)
- Member of the National Association for Clean Air (NACA)

KEY QUALIFICATIONS

Reneé von Gruenewaldt (Air Quality Scientist): René joined Airshed Planning Professionals (Pty) Ltd (previously known as Environmental Management Services cc) in 2002. She has, as a Specialist, attained over fifteen (15) years of experience in the Earth and Natural Sciences sector in the field of Air Quality and three (3) years of experience in the field of noise assessments. As an environmental practitioner, she has provided solutions to both large-scale and smaller projects within the mining, minerals, and process industries.

She has developed technical and specialist skills in various modelling packages including the AMS/EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff based model (CALPUFF and CALMET), puff based HAWK model and line based models. Her experience with emission models includes Tanks 4.0 (for the quantification of tank emissions), WATER9 (for the quantification of waste water treatment works) and GasSim (for the quantification of landfill emissions). Noise propagation modelling proficiency includes CONCAWE, South African National Standards (SANS 10210) for calculating and predicting road traffic noise.

Having worked on projects throughout Africa (i.e. South Africa, Mozambique, Malawi, Kenya, Angola, Democratic Republic of Congo, Namibia, Madagascar and Egypt) René has developed a broad experience base. She has a good understanding of the laws and regulations associated with ambient air quality and emission limits in South Africa and various other African countries, as well as the World Bank Guidelines, European Community Limits and World Health Organisation.

RELEVANT EXPERIENCE

Mining and Ore Handling

Reneé has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite, manganese and mineral sands mines. These include: compilation of emissions databases for Landau and New Vaal coal collieries (SA), impact assessments and management plans for numerous mines over Mpumalanga (viz. Schoonoord, Belfast, Goedgevonden, Mbila, Evander South, Driefontein, Hartogshoop, Belfast, New Largo, Geluk, etc.), Mmamabula Coal Colliery (Botswana), Moatize Coal Colliery (Mozambique), Revuboe Coal Colliery (Mozambique), Toliera Sands Heavy Minerals Mine and Processing (Madagascar), Corridor Sands Heavy Minerals Mine monitoring assessment, El Burullus Heavy Minerals Mine and processing (Egypt), Namakwa Sands Heavy Minerals Mine (SA), Tenke Copper Mine and Processing Plant (DRC), Rössing Uranium (Namibia), Lonmin platinum mines including operations at Marikana, Baobab, Dwaalkop and Doornvlei (SA), Impala Platinum (SA), Pilannesburg Platinum (SA), Aquarius Platinum, Hoogland Platinum Mine (SA), Tamboti PGM Mine (SA), Sari Gunay Gold Mine (Iran), chrome mines in the Steelpoort Valley (SA), Mecklenburg Chrome Mine (SA), Naboom Chrome Mine (SA), Kinsenda Copper Mine (DRC), Kassinga Mine (Angola) and Nokeng Flourspar Mine (SA), etc.

Mining monitoring reviews have also been undertaken for Optimum Colliery's operations near Hendrina Power Station and Impunzi Coal Colliery with a detailed management plan undertaken for Morupule (Botswana) and Glencor (previously known as Xstrata Coal South Africa).

Air quality assessments have also been undertaken for mechanical appliances including the Durban Coal Terminal and Nacala Port (Mozambique) as well as rail transport assessments including BHP-Billiton Bauxite transport (Suriname), Nacala Rail Corridor (Mozambique and Malawi), Kusile Rail (SA) and WCL Rail (Liberia).

Metal Recovery

Air quality impact assessments have been carried out for Highveld Steel, Scaw Metals, Lonmin's Marikana Smelter operations, Saldanha Steel, Tata Steel, Afro Asia Steel and Exxaro's Manganese Pilot Plant Smelter (Pretoria).

Chemical Industry

Comprehensive air quality impact assessments have been completed for NCP (including Chloorkop Expansion Project, Contaminated soils recovery, C3 Project and the 200T Receiver Project), Revertex Chemicals (Durban), Stoppani Chromium Chemicals, Foskor (Richards Bay), Straits Chemicals (Coega), Tenke Acid Plant (DRC), and Omnia (Sasolburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for Sasol (including the postponement/exemption application for Synfuels, Infrachem, Natref, MIBK2 Project, Wax Project, GTL Project, re-commissioning of boilers at Sasol Sasolburg and Ekandustria), Engen Emission Inventory Functional Specification (Durban), Sapref refinery (Durban), Sasol (at Elrode) and Island View (in Durban) tanks quantification, Petro SA and Chevron (including the postponement/exemption application).

Pulp and Paper Industry

Air quality studies have been undertaken or the expansion of Mondi Richards Bay, Multi-Boiler Project for Mondi Merebank (Durban), impact assessments for Sappi Stanger, Sappi Enstra (Springs), Sappi Ngodwana (Nelspruit) and Pulp United (Richards Bay).

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the ash expansion projects at Kusile, Kendal, Hendrina, Kriel and Arnot; Fabric Filter Plants at Komati, Grootvlei, Tutuka, Lethabo and Kriel Power Stations; the proposed Kusile, Medupi (including the impact assessment for the Flue Gas Desulphurization) and Vaal South Power Stations. René was also involved and the cumulative assessment of the existing and return to service Eskom power stations assessment and the optimization of Eskom's ambient air quality monitoring network over the Highveld.

In addition to Eskom's coal fired power stations, various Eskom nuclear power supply projects have been completed including the air quality assessment of Pebble Bed Modular Reactor and nuclear plants at Duynefontein, Bantamsklip and Thyspunt.

Apart from Eskom projects, power station assessments have also been completed in Kenya (Rabai Power Station) and Namibia (Paratus Power Plant).

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the Waste Water Treatment Works in Magaliesburg, proposed Waterval Landfill (near Rustenburg), Tutuka Landfill, Mogale General Waste Landfill (adjacent to the Leipardsvlei Landfill), Cape Winelands District Municipality Landfill and the Tsoeneng Landfill (Lesotho). Air quality impact assessments have also been completed for the BCL incinerator (Cape Town), the Ergo Rubber Incinerator and the Ecorevert Pyrolysis Plant.

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the Holcim Alternative Fuels Project (which included the assessment of the cement manufacturing plants at Ulco and Dudfield as well as a proposed blending platform in Roodepoort).

Management Plans

Reneé undertook the quantification of the baseline air quality for the first declared Vaal Triangle Airshed Priority Area. This included the establishment of a comprehensive air pollution emissions inventory, atmospheric dispersion modelling, focusing on impact area "hotspots" and quantifying emission reduction strategies. The management plan was published in 2009 (Government Gazette 32263).

Reneé has also been involved in the Provincial Air Quality Management Plan for the Limpopo Province.

Other Experience (2001)

Research for B.Sc Honours degree was part of the "Highveld Boundary Layer Wind" research group and was based on the identification of faulty data from the Majuba Sodar. The project was THRIP funded and was a joint venture with the University of Pretoria, Eskom and Sasol (2001).

EDUCATION

M.Sc Earth Sciences	University of Pretoria, RSA, Cum Laude (2009) Title: *An Air Quality Baseline Assessment for the Vaal Airshed in South Africa*
B.Sc Hons. Earth Sciences	University of Pretoria, RSA, Cum Laude (2001) Environmental Management and Impact Assessments
B.Sc Earth Sciences	University of Pretoria, RSA, (2000) Atmospheric Sciences: Meteorology

ADDITIONAL COURSES

CALMET/CALPUFF	Presented by the University of Johannesburg, RSA (March 2008)
Air Quality Management	Presented by the University of Johannesburg, RSA (March 2006)
ARCINFO	GIMS, Course: Introduction to ARCINFO 7 (2001)

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Malawi, Liberia, Kenya, Angola, Democratic Republic of Congo, Namibia, Madagascar, Egypt, Suriname and Iran.

EMPLOYMENT RECORD

January 2002 - Present

Airshed Planning Professionals (Pty) Ltd, (previously known as Environmental Management Services cc until March 2003), Principal Air Quality Scientist, Midrand, South Africa.

2001

University of Pretoria, Demi for the Geography and Geoinformatics department and a research assistant for the Atmospheric Science department, Pretoria, South Africa.

Department of Environmental Affairs and Tourism, assisted in the editing of the Agenda 21 document for the world summit (July 2001), Pretoria, South Africa.

1999 - 2000

The South African Weather Services, vacation work in the research department, Pretoria, South Africa.

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Topographical Effects on Predicted Ground Level Concentrations using AERMOD, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2011.
- Emission Factor Performance Assessment for Blasting Operations, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2009.
- Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007.
- A High Resolution Diagnostic Wind Field Model for Mesoscale Air Pollution Forecasting, R.G. Thomas, L.W. Burger, and H Rautenbach. National Association for Clean Air (NACA) conference, September 2005.
- Emissions Based Management Tool for Mining Operations, R.G. Thomas and L.W. Burger. National Association for Clean Air (NACA) conference, October 2004.
- An Investigation into the Accuracy of the Majuba Sodar Mixing Layer Heights, R.G. Thomas. Highveld Boundary Layer Wind Conference, November 2002.

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Fair	Good	Good

CERTIFICATION

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

Signature of staff member

10/05/2017

Date (Day / Month / Year)

Full name of staff member: René Georgeinna von Gruenewaldt

APPENDIX B - DECLARATION OF INDEPENDENCE

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: René von Gruenewaldt

Name of Registration Body: South African Council for Natural Scientific Professions

Professional Registration No.: 400304/07

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of section 30 of the Act.

I, René von Gruenewaldt, declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The additional information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at Midrand on this 7th day of December 2017

AIRSHED PLANNING PROFESSIONALS

SIGNATURE

Principal Air Quality Scientist

CAPACITY OF SIGNATORY

APPENDIX C – EIMS ENVIRONMENTAL IMPACT ASSESSMENT SIGNIFICANCE RATING METHODOLOGY

THE IMPACT ASSESSMENT METHODOLOGY

Method of Assessing Impacts:

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). Please note that the impact assessment must apply to the identified Sub Station alternatives as well as the identified Transmission line routes.

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER).

The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C= (E+D+M+R) \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 1.

Table 1: Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	-1	Likely to result in a negative/ detrimental impact
	1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),

Aspect	Score	Definition
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table 2.

Table 2: Probability Scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table 3: Determination of Environmental Risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 4.

Table 4: Significance Classes

Environmental Risk Score	
Value	**Description**
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 5: Criteria for Determining Prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 7. The impact priority is therefore determined as follows:

Priority = PR + CI + LR

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (refer to Table 6).

Table 6: Determination of Prioritisation Factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 7: Final Environmental Significance Rating

Environmental Significance Rating	
Value	**Description**
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).