Air Quality Impact Assessment for the Glencore Mines Near Lydenburg

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

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Draft	February 2018	For client review
Rev 0.1	March 2018	Grammatical changes
Rev 0.2	March 2018	Grammatical changes after client review

EXECUTIVE SUMMARY

Introduction

Glencore Eastern Mines near Lydenburg proposes to extend their operations with a Waste Rock Dump (WRD) at the Helena Mine and a new Tailings Storage Facility (TSF), WRD and Pollution Control Dam (PCD) at the Thorncliffe Mine. Two additional vent shafts are also proposed. Glencore will also extend their underground mining operations onto the farms of Richmond 370 KT and St George 2 JT. No surface infrastructure is planned on these farms. The operations at the Glencore Mines described above are hereafter referred to as the project. Airshed Planning Professionals (Pty) Ltd was appointed by Exigo Sustainability (Pty) Ltd to undertake an Air Quality Impact Assessment for the project.

The aim of the investigation is to quantify the possible air quality 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. Use was made of MM5 data for the period 2013 to 2015

Impact Assessment Criteria

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

Emissions Inventory

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

- Meteorological data: As no onsite meteorological data was available, use was made of MM5 data for the period 2013 to 2015. The modelling guidelines stipulate that three years of off-site meteorological data should be used from a period no older than five years to the year of assessment. As the onset of the Air Quality Assessment was in January 2017, meteorological data for the period 2013 – 2015 was used. Presently a few months of the data set falls outside of the last five-year period. This limitation is not found to be significant, however, as the meteorological conditions within the study area have not shown any significant historical changes.
- 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.
  - There are no on-site ambient $PM_{2.5}$ (inhalable particulate matter with aerodynamic diameter of <2.5 µm) and PM_{10} (inhalable particulate matter with aerodynamic diameter of <10 µm) baseline measurements available. In addition, no Department of Environmental Affairs operated monitoring stations is available in the vicinity to indicate baseline ambient air quality levels. It was therefore not possible to assess the cumulative impacts.

Findings

The main findings from the baseline assessment were as follows:

- The wind field is dominated by winds from the south-easterly sectors. During day-time conditions, winds from the north increase in frequency, with winds from the south-easterly sector increasing at night.

- The closest residential developments to the proposed project consist of Leshaba (~1 km east), Ga-Masha (~12 km northwest) and Steelpoort (~15 km north-northeast). Individual farmsteads also surround the Glencore mine area.

- Measured dust fallout at Helena Mine and Thorncliffe Mine is below the NDCR for non-residential areas (1 200 mg/m²/day) and residential areas (600 mg/m²/day) for the period 2016.

- Exceedances of the NDCR residential standard of 600 mg/m²/day (which allows for two exceedances in a year, not sequential months) was measured at the S23 sampling site at Magareng Mine during the period January to April 2016 and in August 2016. The NDCR non-residential standard of 1200 mg/m²/day (which allows for two exceedances in a year, not sequential months) was reached at sampling site S23 but not exceeded.

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

- Crushing activities and windblown dust from the TSFs represented the highest impacting particulate sources from the current and proposed project operations.

- The highest $PM_{2.5}$ and PM_{10} concentrations due to proposed project operations (unmitigated) were in compliance with NAAQS at the closest sensitive receptors for all scenarios. When activities were mitigated (assuming 50% control efficiency on crushing activities) the $PM_{2.5}$ and PM_{10} concentrations reduced notably in magnitude and spatial distribution.

- Maximum daily dust deposition was within with the NDCR for residential areas at the closest sensitive receptors for all modelled scenarios.

Recommendations

The following recommendations are made:

- It is recommended that ambient sampling, as outlined in Section 6.2.3.2, be undertaken to monitor the impacts from the proposed project activities.

- Due to the proximity of sensitive receptors to the proposed project activities, it is recommended that mitigation measures on the main sources of fugitive dust be implemented to minimise impacts as far as possible. These include:

    - Water sprayers on the crushing activities to control the emission of this source by 50%.

    - Vegetation on sidewalls of tailings facilities and reducing top-surface area to wind erosion if feasible.

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LIST OF ACRONYMS AND SYMBOLS

APCS	Air pollution control systems
AQA	Air Quality Act
ASTM	American Society for Testing and Materials standard
°C	Degrees Celsius
CE	Control efficiency
CO	Carbon monoxide
DEA	Department of Environmental Affairs
EIA	Environmental Impact Assessment
FDDA	Four Dimensional Data Assimilation
I&AP	Interested and affected parties
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
NO_2	Nitrogen dioxide
NPI	National pollution inventory
O_3	Ozone
Pb	Lead
PCD	Pollution control dam
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
TSF	Tailings storage facility
TSP	Total Suspended Particles
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WM	With mitigation
WOM	Without mitigation
WRD	Waste rock dump

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 Glencore Mines Near Lydenburg

1 INTRODUCTION

1.1 Purpose/ Objectives

Glencore Eastern Mines near Lydenburg proposes to extend their operations with a Waste Rock Dump (WRD) at the Helena Mine and a new Tailings Storage Facility (TSF), WRD and Pollution Control Dam (PCD) at the Thorncliffe Mine. Two additional vent shafts are also proposed. Glencore will also extend their underground mining operations onto the farms of Richmond 370 KT and St George 2 JT. No surface infrastructure is planned on these farms. The operations at the Glencore Mines described above are hereafter referred to as the project. Airshed Planning Professionals (Pty) Ltd was appointed by Exigo Sustainability (Pty) Ltd (Exigo) to undertake an Air Quality Impact Assessment for the project.

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

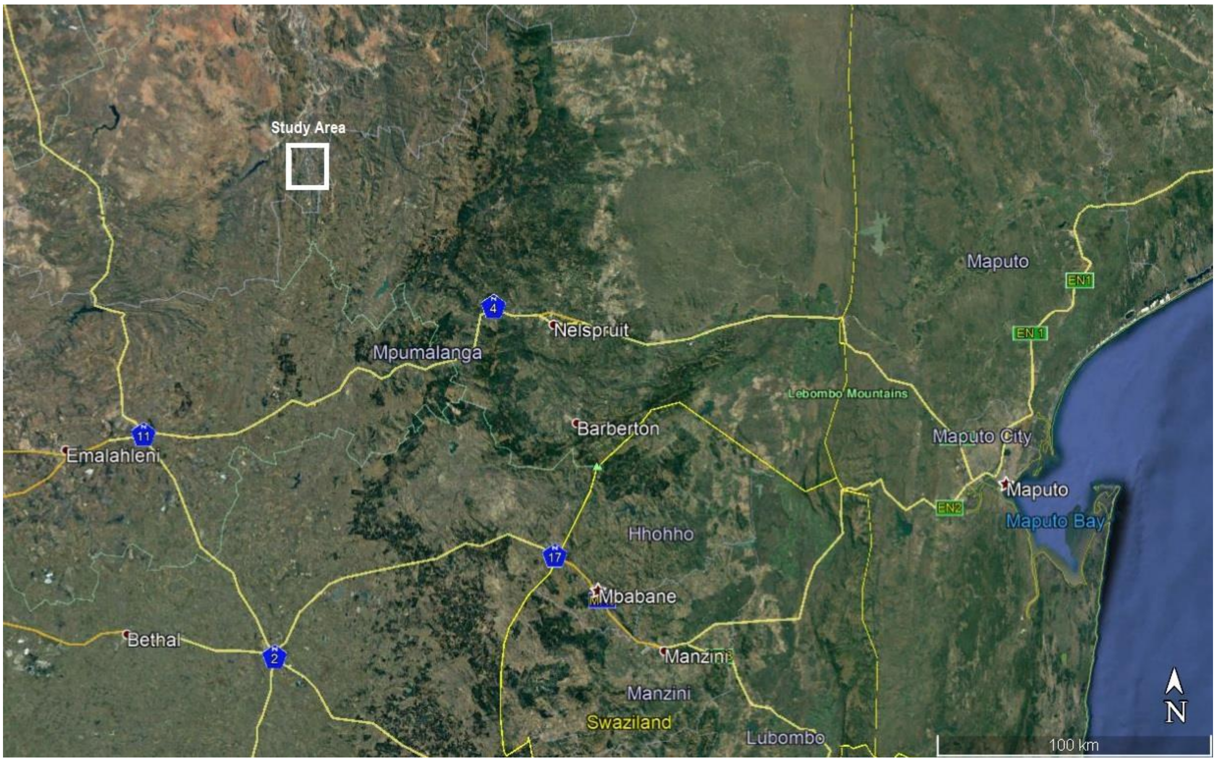


Figure 1-1: Location of study area

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 from the closest meteorological monitoring station or, if absent, from modelled meteorological data;
     - 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.

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 vents, vehicle entrainment, 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 a numerical weather prediction model (Mesoscale Model version 5 (MM5[1])) for the period 2013 to 2015.

1.5.4 Alternatives Considered for the Assessment

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

- The transport of tailings material from the existing Helena Tailings Storage Facility (TSF) to Thorncliffe via haul truck.
- The transport of tailings material from the existing Helena Tailings Storage Facility (TSF) to Thorncliffe via pipeline.

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

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 16 km (north-south) by 16 km (east-west). These areas were divided into a grid with a resolution of 160 m (north-south) by 160 m (east-west). AERMOD simulates ground-level concentrations for each of the receptor grid points. AERMOD executable version 09292 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 MM5 data for the period 2013 to 2015. The modelling guidelines stipulate that three years of off-site meteorological data should be used from a period no older than five years to the year of assessment. As the onset of the Air Quality Assessment was in January 2017, meteorological data for the period 2013 – 2015 was used. Presently a few months of the data set falls outside of the last five-year period. This limitation is not found to be significant, however, as the meteorological conditions within the study area have not shown any significant historical changes.
- 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.
  - There is no on-site ambient $PM_{2.5}$ (inhalable particulate matter with aerodynamic diameter of <2.5 µm) and PM_{10} (inhalable particulate matter with aerodynamic diameter of <10 µm) baseline measurements available. In addition, no Department of Environmental Affairs operated monitoring stations is available in the vicinity to indicate baseline ambient air quality levels. It was therefore not possible to assess the cumulative impacts.

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.

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

Since plants are constantly exposed to air, they are the primary receptors for both gaseous and particulate pollutants of the atmosphere. In terrestrial plant species, the enormous foliar surface area acts as a natural sink for pollutants especially the particulate ones. Vegetation is an effective indicator of the overall impact of air pollution particularly in context of particulate matter (PM) (Rai, 2016).

There are two main types of direct injury that PM pollution can cause on plants: acute and chronic injury. Acute injury results from exposure to a high concentration of gas for a relatively short period and is manifested by clear visible symptoms on the foliage, often in the form of necrotic lesions. While this type of injury is very easy to detect (although not necessarily to diagnose), chronic injury is subtler: it results from prolonged exposure to lower gas concentrations and takes the form of growth and/or yield reductions, often with no clear visible symptoms. Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. It reported that depending on their sensitivity level, plants show visible changes which would include alteration in the biochemical processes or accumulation of certain metabolites (Rai, 2016). Pollutants can cause leaf injury, stomatal damage (Ricks and Williams, 1974, Hirano et al., 1995; Naidoo and Chirkoot; 2004; Harmens et al., 2005), premature senescence, decrease photosynthetic activity, disturb membrane permeability (Ernst, 1981; Naidoo and Chirkoot, 2004; Harmens et al., 2005) and reduce growth and yield in sensitive plant species. The long term, low-concentration exposures of air pollution produces harmful impacts on plant leaves without visible injury. Several studies have been conducted to assess the effects of pollution on different aspects of plant life such as overall growth and development, foliar morphology, anatomy, and bio chemical changes (Rai, 2016).

Plant leaves are the primary receptors for both gaseous and PM pollutants of the atmosphere. Before these pollutants enter the leaf tissue, they interact with foliar surface and modify its configuration. Dust deposition on leaf surface, consisting of ultra-fine and coarse particles, showed reduction in plant growth through its effect on leaf gas exchange, flowering and reproduction of plants, number of leaves and leaf area, one of the most common driving variables in growth analyses. Reduction in leaf area and leaf number may be due to decreased leaf production rate and enhanced senescence (Rai, 2016).

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 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 pollutant concentrations and deposition 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 3.3 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

A specialist report prepared in terms of the Environmental Impact Regulations of 2014 must contain:	Relevant section in report
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

3 RECEIVING ENVIRONMENT

3.1 Air Quality Sensitive Receptors

The closest residential developments to the proposed project consist of Leshaba (~1 km east), Ga-Masha (~12 km northwest) and Steelpoort (~15 km north-northeast). Individual farmsteads also surround the Glencore mine area (Figure 3-1 as identified from Google Earth).

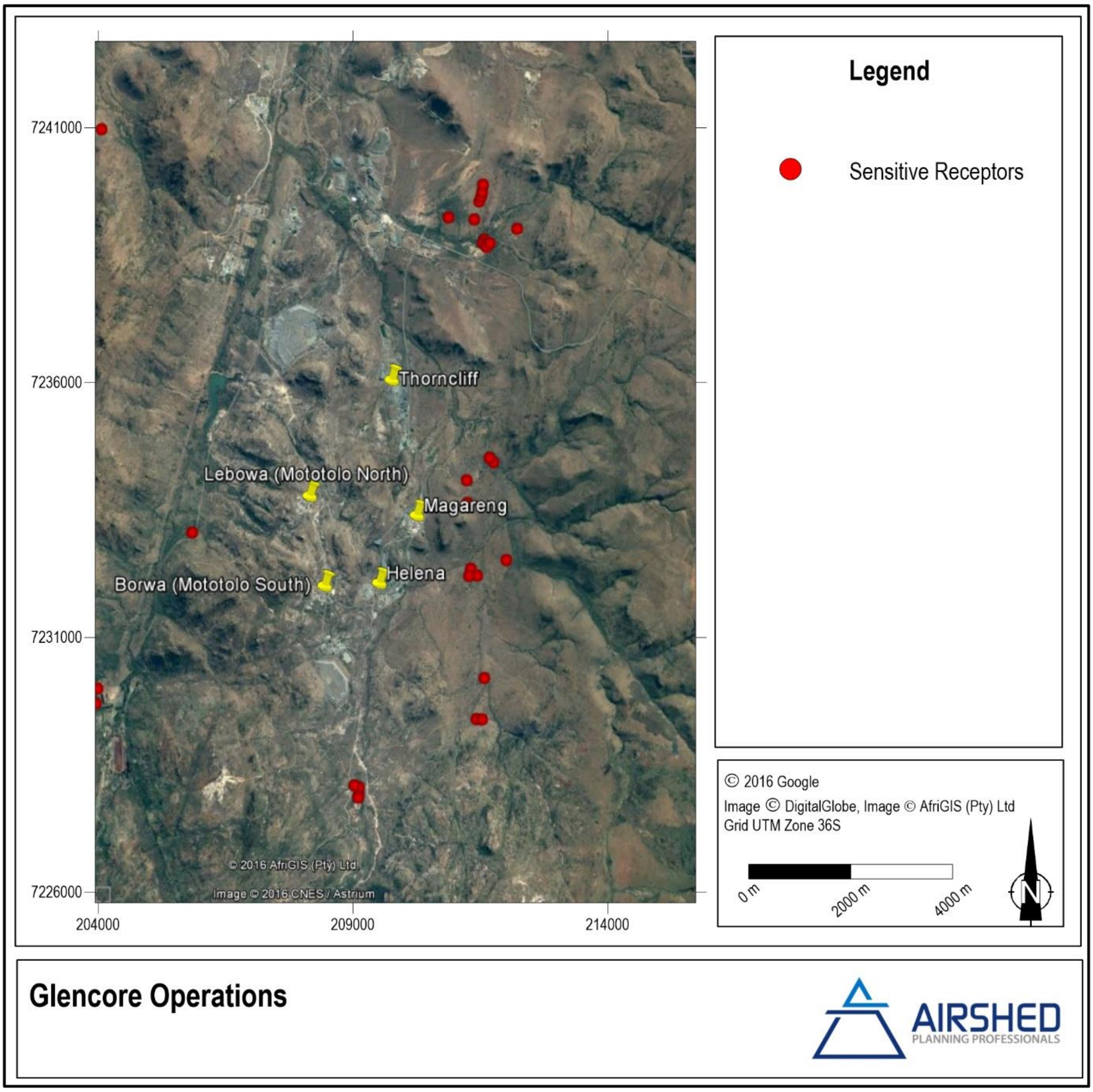


Figure 3-1: Location of potentially sensitive receptors in relation to the project

3.2 Terrain

Readily available terrain data was obtained from the United States Geological Survey (USGS) web site (https://earthexplorer.usgs.gov/). A study was made of Shuttle Radar Topography Mission (STRM) 1 arc-sec data. The topography for the study area is provided in Figure 3-2.

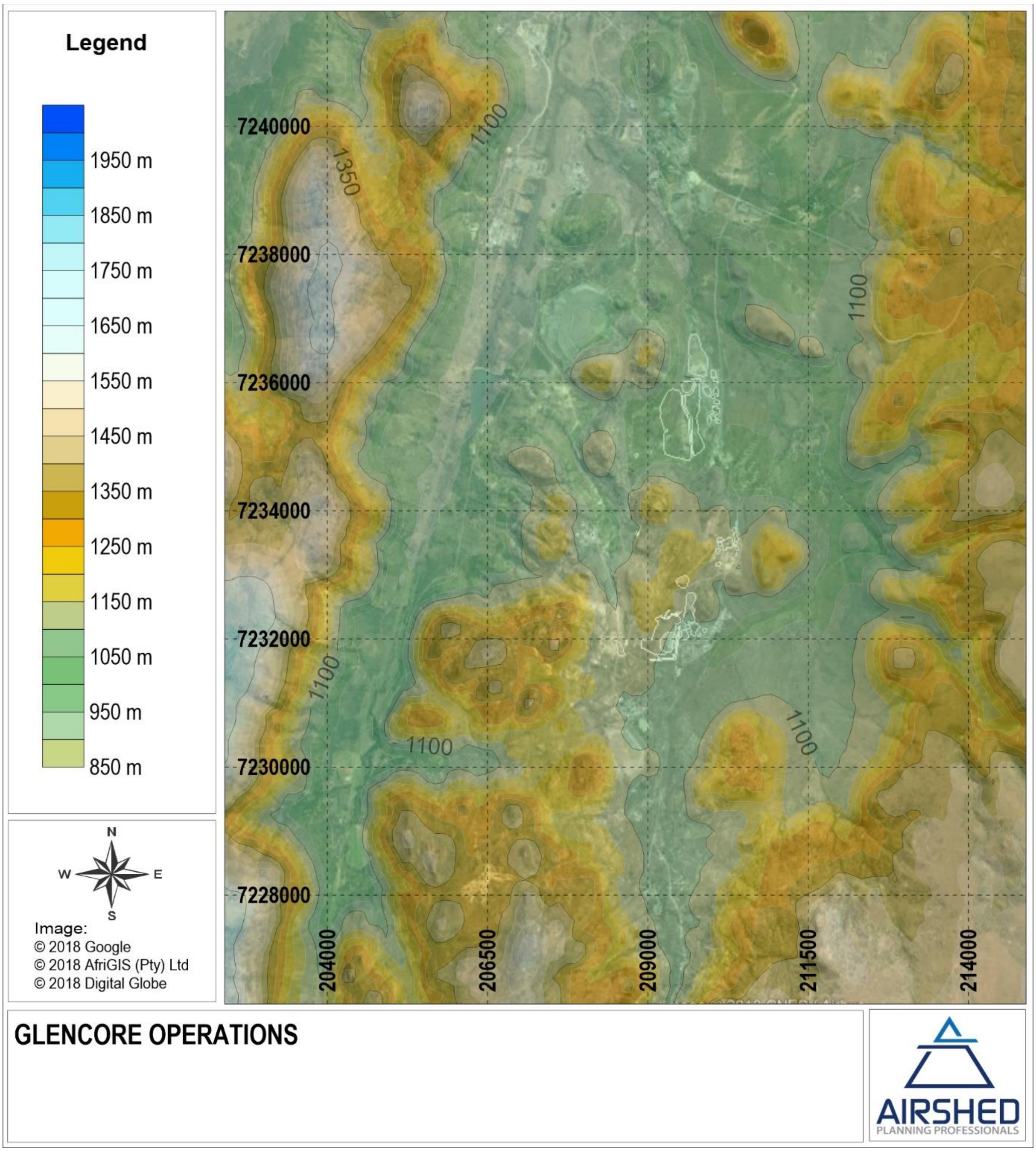


Figure 3-2: Terrain elevation over the study area

3.3 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.

A weather station is operational at the Helena Mine and measurements for the period 2016 was provided for the assessment. The wind data, however, had a very high percentage of recorded calms (more than 70%) with very low wind speeds. This is unusual for the area, given the proximity to elevated terrain. Meteorological information was therefore sourced from MM5 modelled data for the period 2013 to 2015. A comparison of the measured meteorological data recorded at Helena and the modelled MM5 data is provided in Appendix C.

3.3.1 Local Wind Field

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

The wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 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 period wind field and diurnal variability in the wind field are shown in Figure 3-3, while the seasonal variations are shown in Figure 3-4. The wind regime for the area is dominated by south-easterly flow fields. The northerly wind flow is more dominant during day-time conditions, with south-easterly wind flow more dominant during the night. Calm conditions occurred 2.85 % of the period summarised.

During the summer months, wind from the southeast sector dominates, with stronger winds of more than 6 m/s occurring. Infrequent but strong winds occur from the northerly and north-easterly sectors. During autumn, the winds are more frequent from the south-easterly sector. Winter months reflect an increase in flow from the south. During the Spring wind flow is still predominant from the south-easterly with an increase in winds from the northern sector.

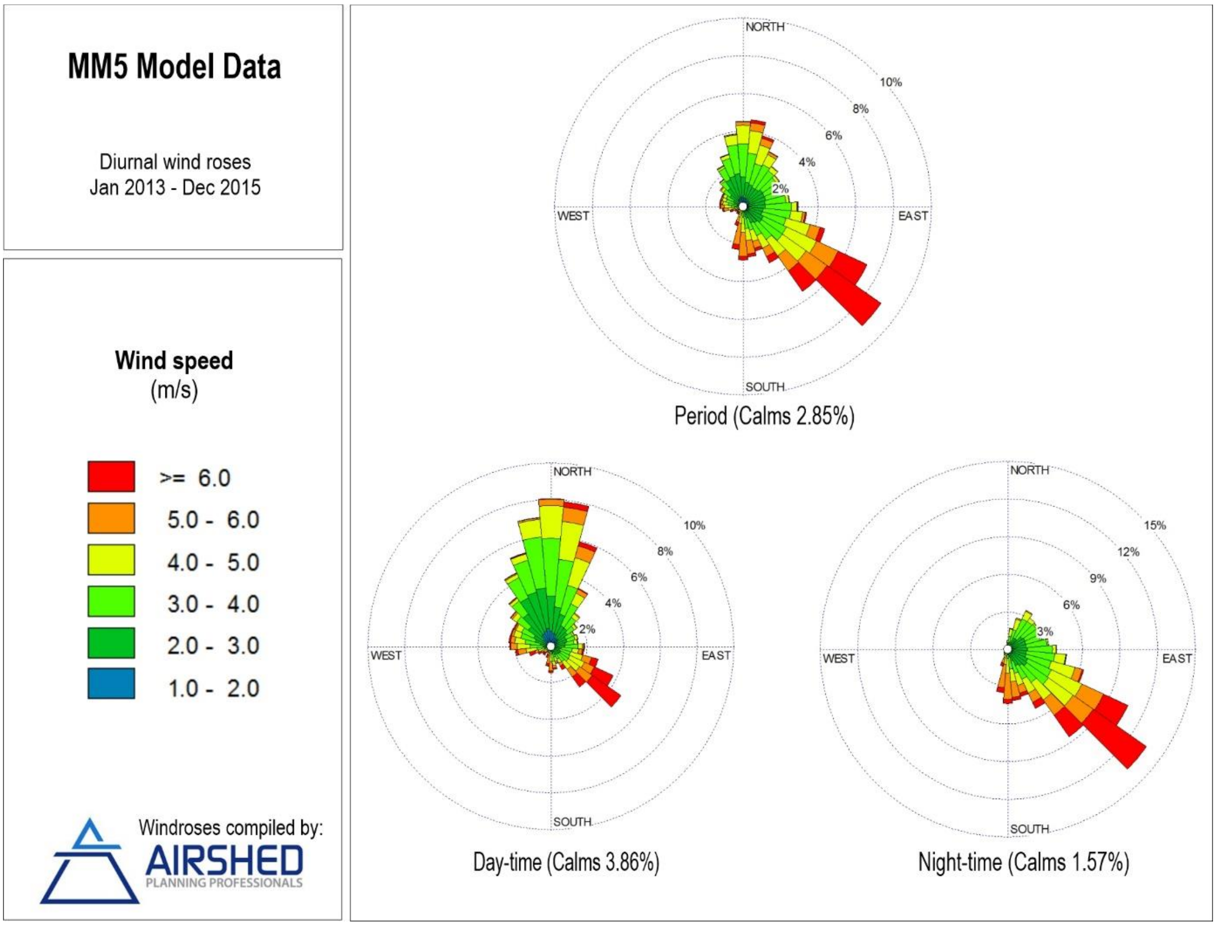


Figure 3-3: Period, day- and night-time wind rose (MM5 data for the period 2013 – 2015)

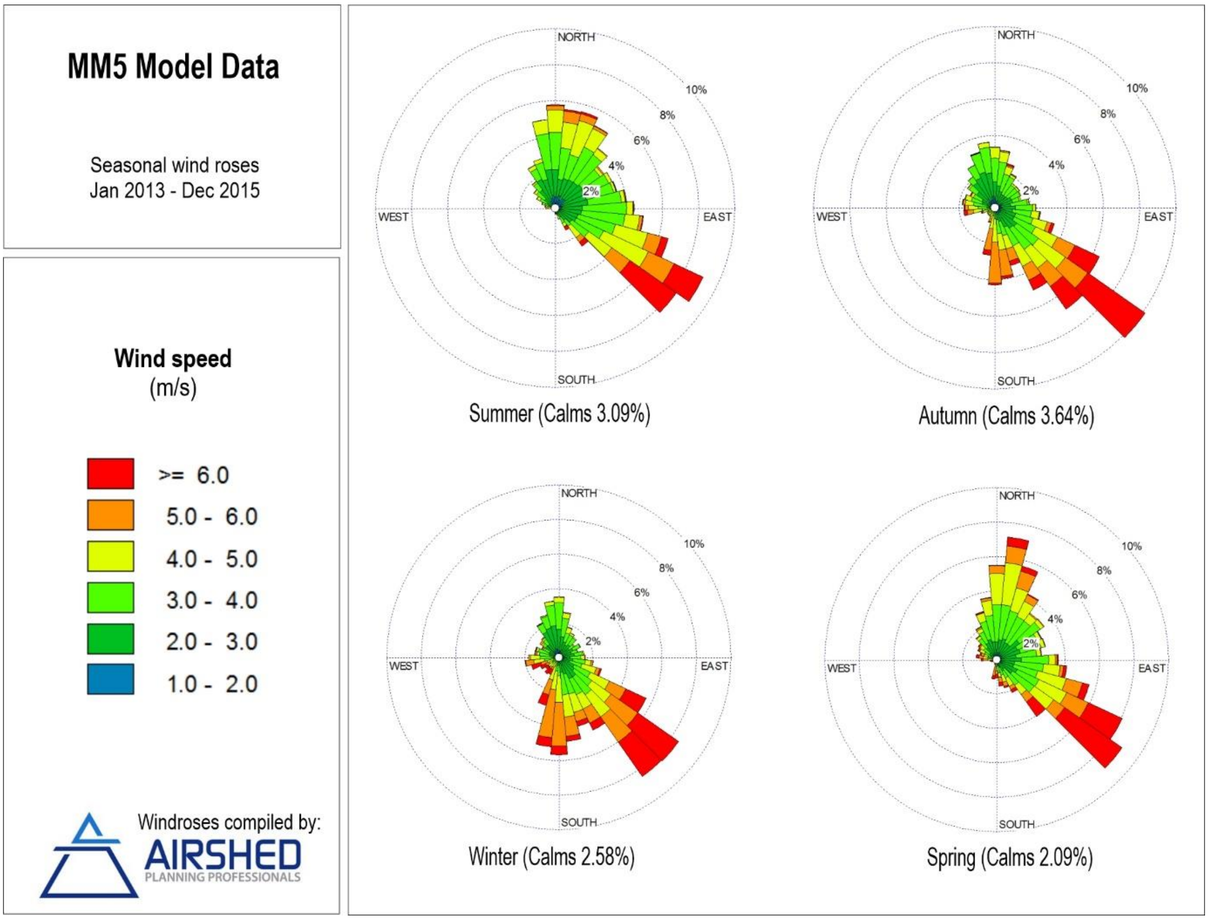


Figure 3-4: Seasonal wind rose (MM5 data for the period 2013 – 2015)

3.3.2 Ambient Temperature

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

Monthly mean, maximum and minimum temperatures are given in Table 3-1. Diurnal temperature variability is presented in Figure 3-5. Temperatures ranged between 8.5°C and 26.2°C. During the day, temperatures increase to reach maximum at about 15:00 in the late afternoon. Ambient air temperature decreases to reach a minimum at between 06:00 and 07:00.

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

Monthly Minimum, Maximum and Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	16.2	15.8	15.0	12.8	11.3	9.2	8.5	10.2	12.9	13.2	14.7	16.4
Average	20.7	20.6	19.1	16.6	14.8	12.4	11.8	13.7	16.5	17.4	19.2	20.5
Maximum	26.0	26.2	24.2	21.6	19.4	17.1	16.4	18.7	21.5	22.7	24.4	25.4

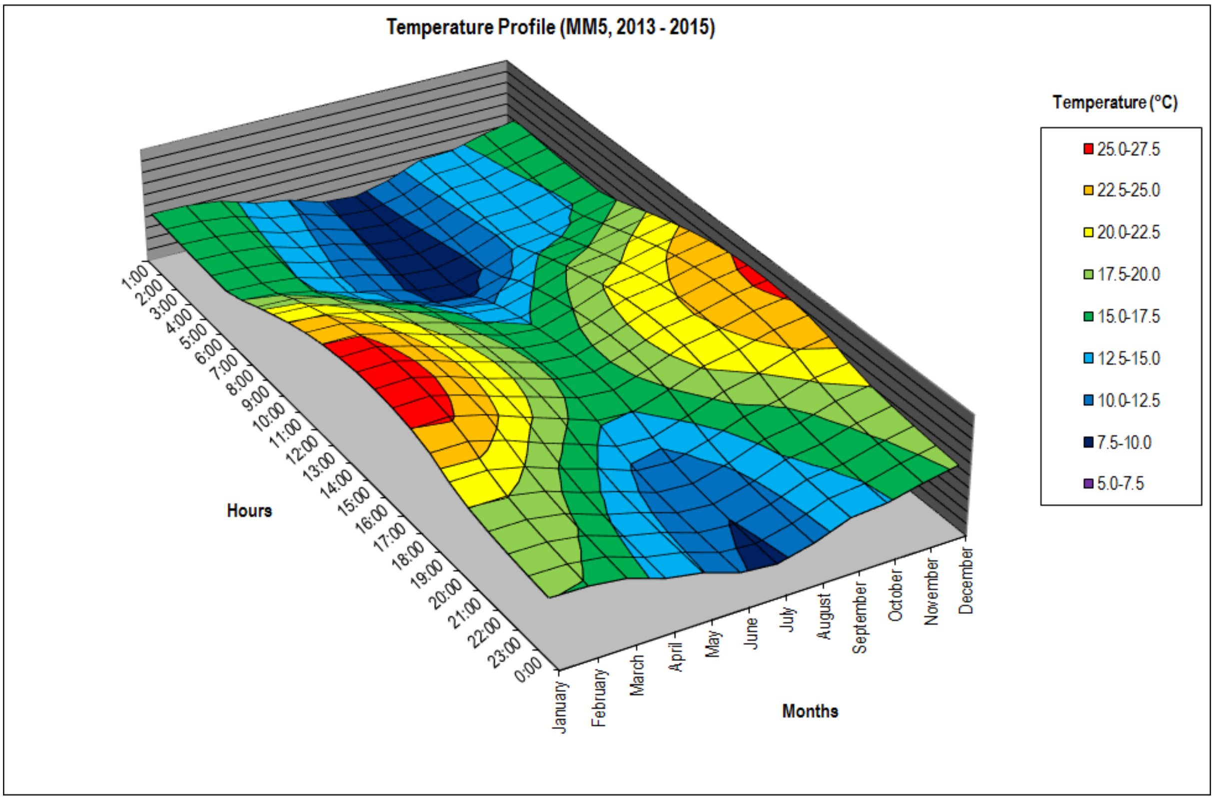
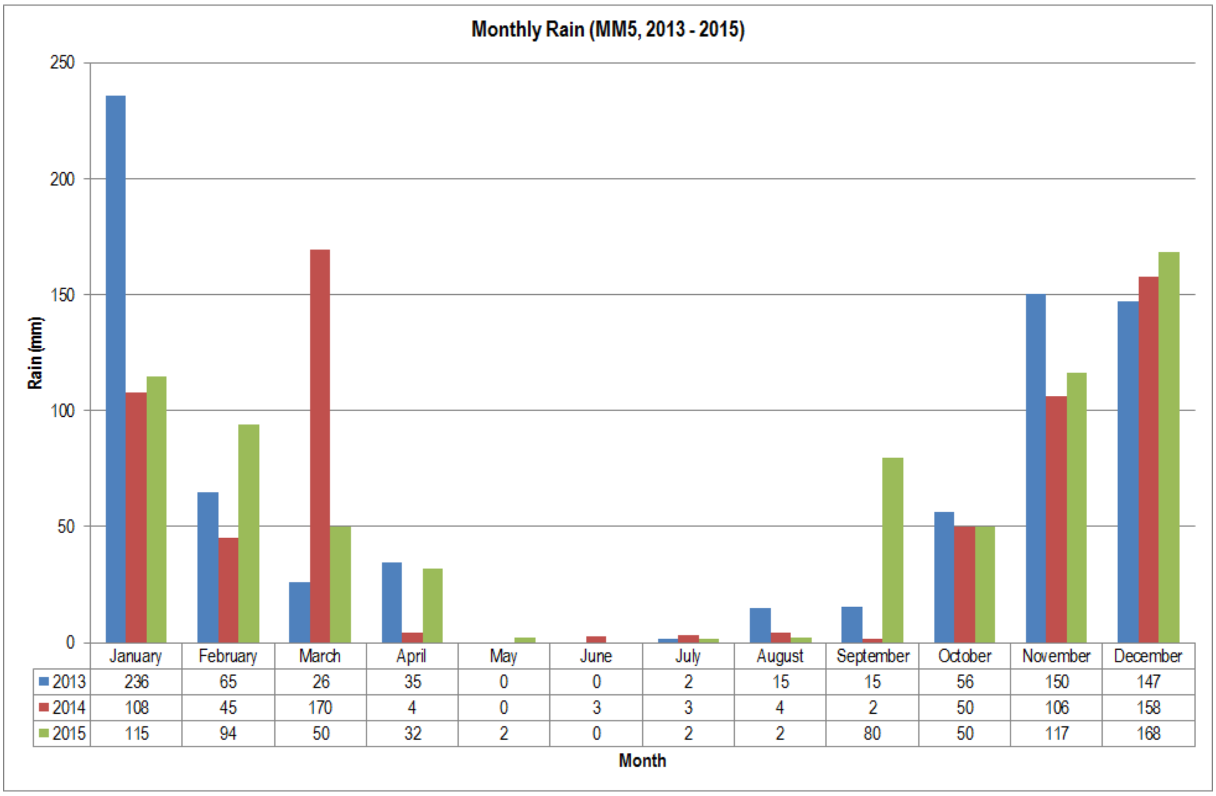


Figure 3-5: Diurnal temperature profile (MM5 data, January 2013 to December 2015)

3.3.3 Precipitation

Precipitation represents an effective removal mechanism of atmospheric pollutants. Precipitation reduces wind erosion potential by increasing the moisture content of materials. Rain-days are defined as days experiencing 0.1 mm or more rainfall. The rainfall provided by the MM5 data set for the period 2013 to 2015 ranged between 652 and 746 mm per year.



	January	February	March	April	May	June	July	August	September	October	November	December
2013	236	65	26	35	0	0	2	15	15	56	150	147
2014	108	45	170	4	0	3	3	4	2	50	106	158
2015	115	94	50	32	2	0	2	2	80	50	117	168

Figure 3-6: Monthly rainfall as obtained from the MM5 data for the area (2013-2015)

3.3.4 Atmospheric Stability and Mixing Depth

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class. The Monin-Obukhov length (LMo) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral. For low level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions. Diurnal variation in atmospheric stability for the site is provided in Figure 3-7.

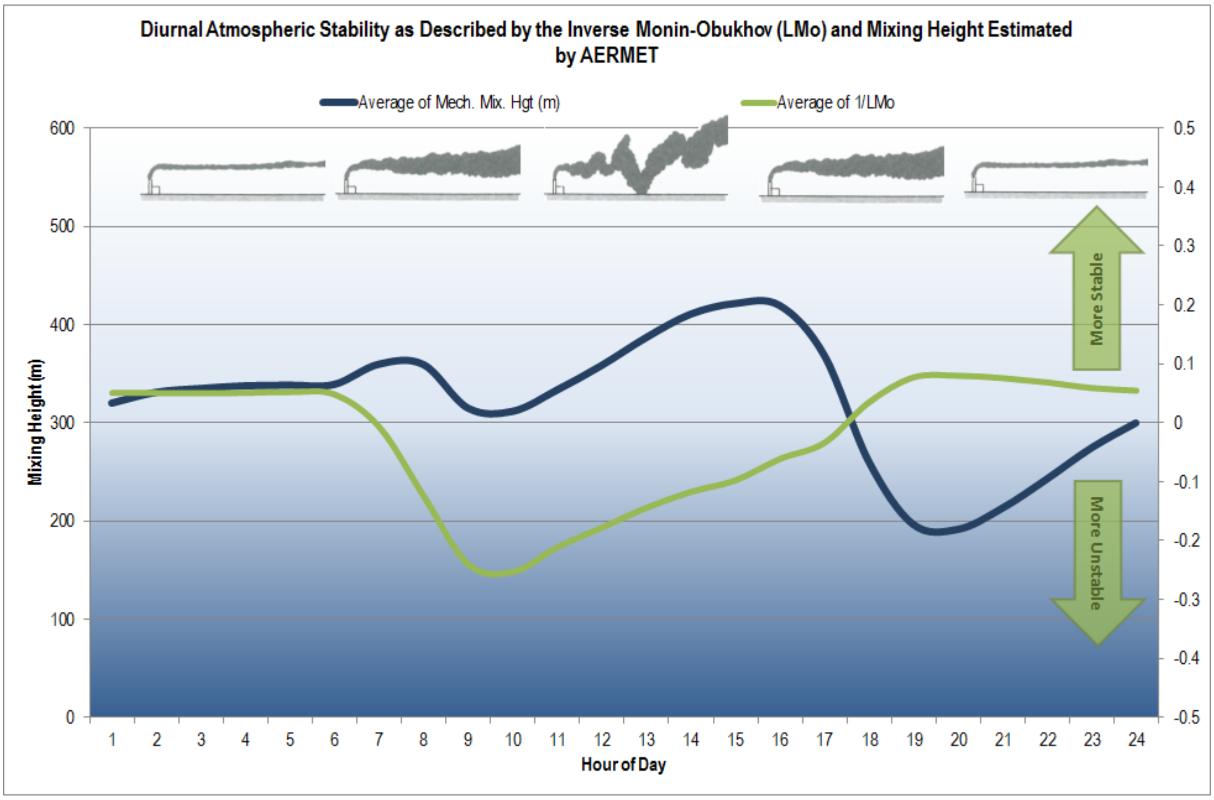


Figure 3-7: Average diurnal atmospheric stability as calculated by Aermet from MM5 data for the period 2013 – 2015

3.4 Ambient Air Quality within the Region

Glencoree have three chrome mines near Lydenburg (i.e. Helena Mine, Magareng Mine and Thorncliffe mine). The three chrome mines operate a dustfall sampling network consisting of 11 single dust fallout buckets (Figure 3-8). Measured dustfall from the three mines for the period 2016 was provide for this assessment (Table 3-2, Table 3-3, Table 3-4 and Figure 3-9, Figure 3-10, Figure 3-11). Dust fallout was also provided for Mototolo (Glencore's platinum mines to the west) for the period January 2016 to December 2017 (Table 3-5 and Figure 3-12). The Mototolo dust fallout network consists of nine single dust buckets.

In accordance with the NDCR the dust buckets should be setup, operated and analysed according to the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739-98). The ASTM method covers the procedure of collection of dustfall and its measurement and employs a simple device consisting of a cylindrical container (not less than 150 mm in diameter) exposed for one calendar month (30 ±2 days). From the measured dustfall provided for this assessment, samples for the period April 2016, December 2016, February 2017, April 2017 August 2017 and October 2017 were exposed slightly longer than the acceptable range of 28 to 32 days (refer to Table 3-2, Table 3-3, Table 3-4 and Table 3-5). This should be kept in mind when assessing the measurements.

From the dustfall sampled during the period 2016 (Helena Mine, Magareng Mine and Thorncliffe mines), no exceedances of the NDCR non-residential standard of 1200 mg/m²/day and residential standard of 600 mg/m²/day was measured at the Helena Mine or the Thorncliffe Mine. Exceedances of the NDCR residential standard of 600 mg/m²/day (which allows for two exceedances in a year, not sequential months) was measured at the sampling site 23 at Magareng Mine during the period

January to April and in August. The NDCR non-residential standard of 1200 mg/m²/day (which allows for two exceedances in a year, not sequential months) was reached at sampling site 23 but not exceeded (Figure 3-10). The NDCR for non-residential standard was exceeded at Mototolo - site 12 during the period January to February 2016, April to May 2016 and January to March 2017 and at site 13 during the period October to November 2017.

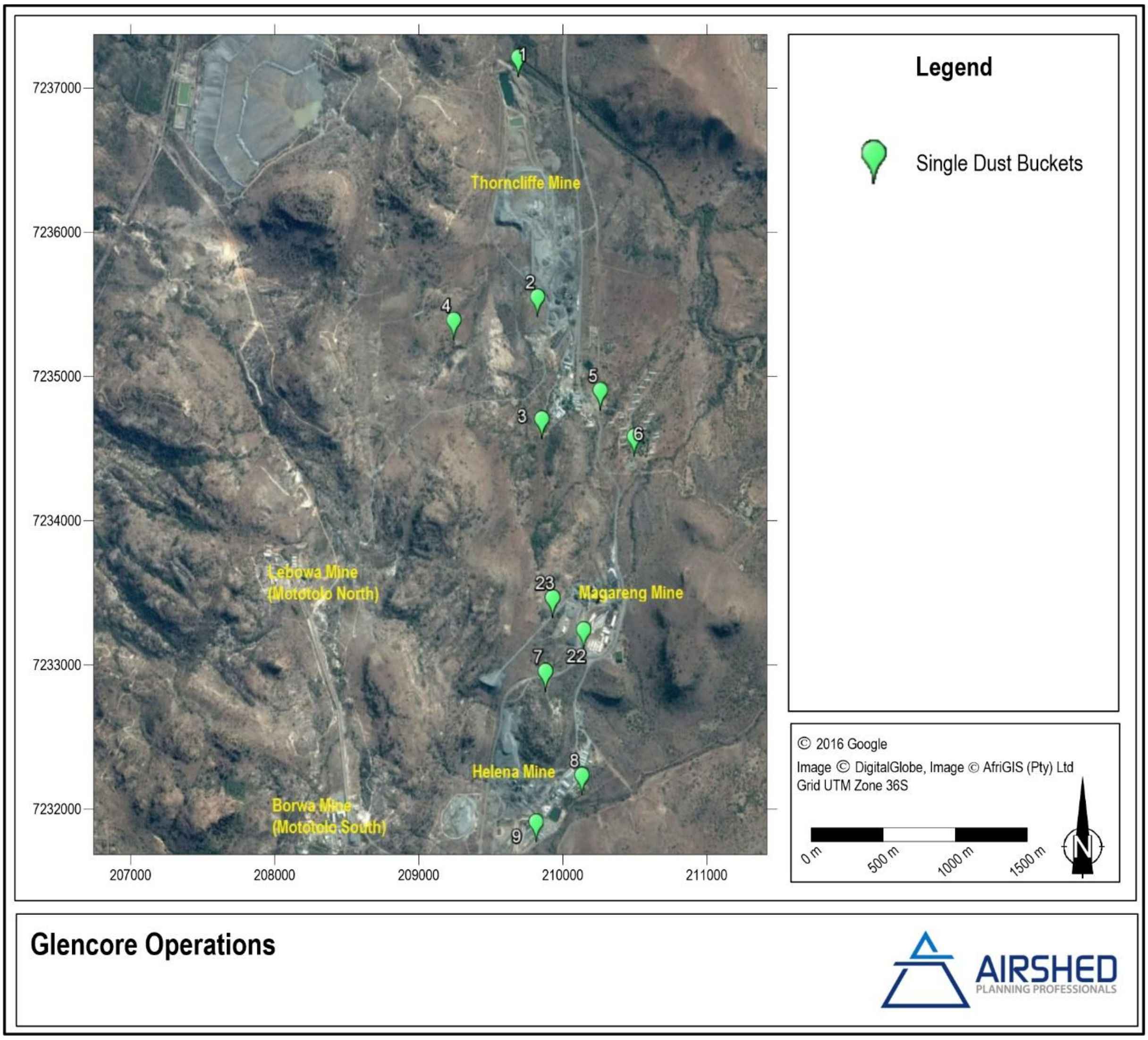


Figure 3-8: Location of the dust fallout network for Glencore chrome mines

Table 3-2: Measured dust fallout at Helena for the period 4 January to 1 December 2016

Sampling period		Days exposed	Dustfall levels (mg/m²/day)		
			7	8	9
Start date	End Date		CMO Offices	Helena eastern border next to river	Helena Vent Shaft
			24°59'33.31"S; 30°7'34.19"E	24°59'57.03"S; 30°7'43.72"E	25°0'7.53"S; 30°7'31.84"E
04-Jan-16	02-Feb-16	29	149	173	149
02-Feb-16	02-Mar-16	29	164	88	246
02-Mar-16	01-Apr-16	30	140	142	192
01-Apr-16	05-May-16	**34**	185	160	156
05-May-16	03-Jun-16	29	202	172	166
03-Jun-16	04-Jul-16	31	139	141	179
04-Jul-16	02-Aug-16	29	109	114	169
02-Aug-16	02-Sep-16	31	205	263	364
02-Sep-16	03-Oct-16	31	306	390	187
03-Oct-16	01-Nov-16	29	129	159	217
01-Nov-16	01-Dec-16	30	104	100	89

Table 3-3: Measured dust fallout at Magareng for the period 4 January to 1 December 2016

Sampling period		Days exposed	Dustfall levels (mg/m²/day)	
			22	23
Start date	End Date		Opencast	Opencast
			24°59'24"S; 30°7'44"E	24°59'16.69"S; 30°7'35.97"E
04-Jan-16	02-Feb-16	29	991	908
02-Feb-16	02-Mar-16	29	124	1269
02-Mar-16	01-Apr-16	30	458	1126
01-Apr-16	05-May-16	**34**	487	1713
05-May-16	03-Jun-16	29	391	558
03-Jun-16	04-Jul-16	31	282	553
04-Jul-16	02-Aug-16	29	532	387
02-Aug-16	02-Sep-16	31	353	849
02-Sep-16	03-Oct-16	31	453	268
03-Oct-16	01-Nov-16	29	221	260
01-Nov-16	01-Dec-16	30	178	186

Table 3-4: Measured dust fallout at Thorncliffe for the period 4 January to 1 December 2016

Sampling period		Days exposed	Dustfall levels (mg/m²/day)					
			1	2	3	4	5	6
			Thorncliffe waste dump	Thorncliffe on top of hill behind plant	Thorncliffe up cast shaft behind stores	Thorncliffe up cast shaft 2	Thorncliffe next to shop	Chicken farm
Start date	End Date		24°57'13.92"S; 30°7'27.35"E	24°58'8.84"S; 30°7'32.27"E	24°58'36.62"S; 30°7'33.32"E	24°58'14.13"S; 30°7'10.47"E	24°58'30.08"S; 30°7'48.57"E	24°58'40.58"S; 30°7'57.33"E
04-Jan-16	02-Feb-16	29	122	222	114	195	256	203
02-Feb-16	02-Mar-16	29	225	245	147	148	285	155
02-Mar-16	01-Apr-16	30	128	278	142	225	346	170
01-Apr-16	05-May-16	**34**	109	258	108	245	328	180
05-May-16	03-Jun-16	29	146	215	131	285	387	178
03-Jun-16	04-Jul-16	31	114	36	170	75	332	157
04-Jul-16	02-Aug-16	29	178	151	104	123	379	117
02-Aug-16	02-Sep-16	31	125	205	164	251	331	258
02-Sep-16	03-Oct-16	31	136	267	177	144	286	282
03-Oct-16	01-Nov-16	29	85	131	84	190	292	220
01-Nov-16	01-Dec-16	30	56	74	63	43	29	84

Table 3-5: Measured dust fallout at Mototolo for the period 4 January 2016 to 6 December 2017

Sampling period		Days exposed	Sampling month	Dustfall levels (mg/m²/day)								
Start date	End Date			12	13	14	15	16	17	18	19	20
2016-01-04	2016-02-02	29	Jan-16	2147	407	169	150	202	110	264	160	164
2016-02-02	2016-03-02	29	Feb-16	1471	253	201	166	134	148	282	406	258
2016-03-02	2016-04-01	30	Mar-16	736	228	141	99	187	126	115	93	122
2016-04-01	2016-05-05	**34**	Apr-16	2078	413	152	153	172	134	171	141	175
2016-05-05	2016-06-03	29	May-16	1098	347	131	134	134	120	224	163	189
2016-06-03	2016-07-04	31	Jun-16	662	248	182	148	92	134	248	80	154
2016-07-04	2016-08-02	29	Jul-16	416	306	112	177	118	102	138	216	183
2016-08-02	2016-09-02	31	Aug-16	612	270	130	145	132	115	213	181	256
2016-09-02	2016-10-03	31	Sep-16	398	212	160	121	219	206	264	184	190
2016-10-03	2016-11-01	29	Oct-16	376	339	113	265	207	151	150	134	
2016-11-01	2016-12-01	30	Nov-16	226	32	59	66	141	63	62	75	115
2016-12-01	2017-01-05	**35**	Dec-16	29	79	49	113	79	60	44	45	30
2017-01-05	2017-02-01	27	Jan-17	1282	548	76	345	337	142	269	281	461
2017-02-01	2017-03-07	**34**	Feb-17	637	403	122	125	130	109	141	97	143
2017-03-07	2017-04-05	29	Mar-17	738	286	72	806	207	35	105	12	138
2017-04-05	2017-05-08	**33**	Apr-17	258	114	28	41	64	2	2	22	52
2017-05-08	2017-06-06	29	May-17	58	147	52	120	138	216	122	76	103
2017-06-06	2017-07-05	29	Jun-17	177	149	23	27	19	17	91	34	77
2017-07-05	2017-08-02	28	Jul-17	24	207	1	7	13	142	71	3	71

Sampling period		Days exposed	Sampling month	Dustfall levels (mg/m²/day)								
Start date	End Date			12	13	14	15	16	17	18	19	20
2017-08-02	2017-09-04	**33**	Aug-17	228	423	25	41	59	10	120	36	80
2017-09-04	2017-10-04	30	Sep-17	126	563	36		103	26	96	84	106
2017-10-04	2017-11-06	**33**	Oct-17	204	1880	71	141	91	69	183	98	138
2017-11-06	2017-12-06	30	Nov-17	410	4940	182	248	309	88	148	159	152
2017-12-06	2018-01-08	**33**	Dec-17	220	2320	78	279		132	92	310	187

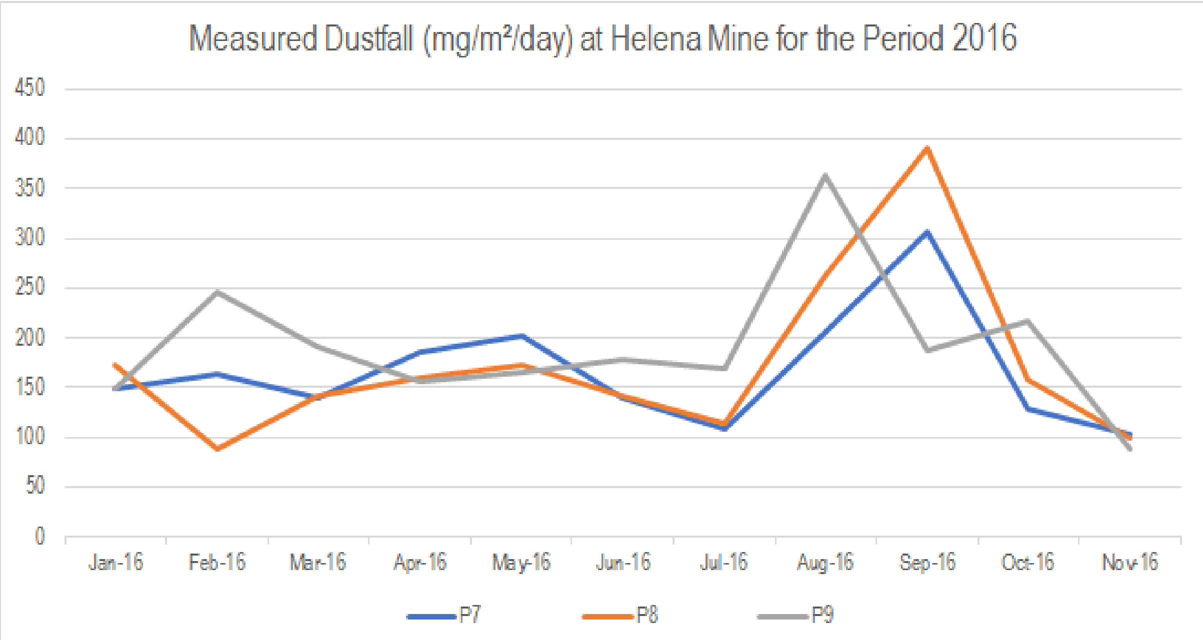


Figure 3-9: Measured dust fallout at Helena for the period 4 January to 1 December 2016

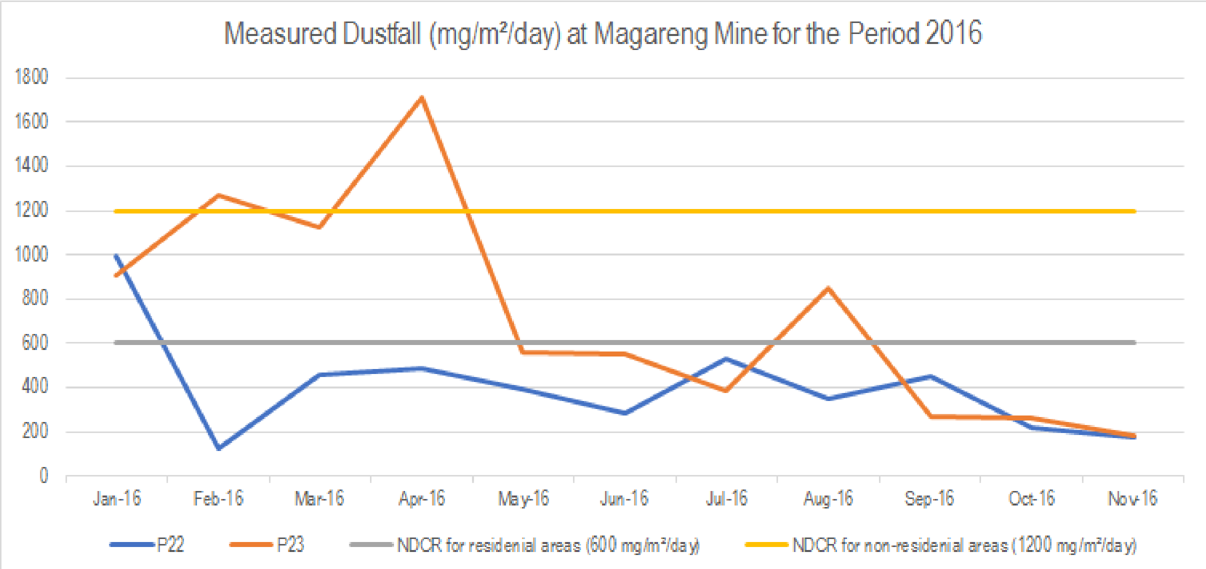


Figure 3-10: Measured dust fallout at Magareng for the period 4 January to 1 December 2016

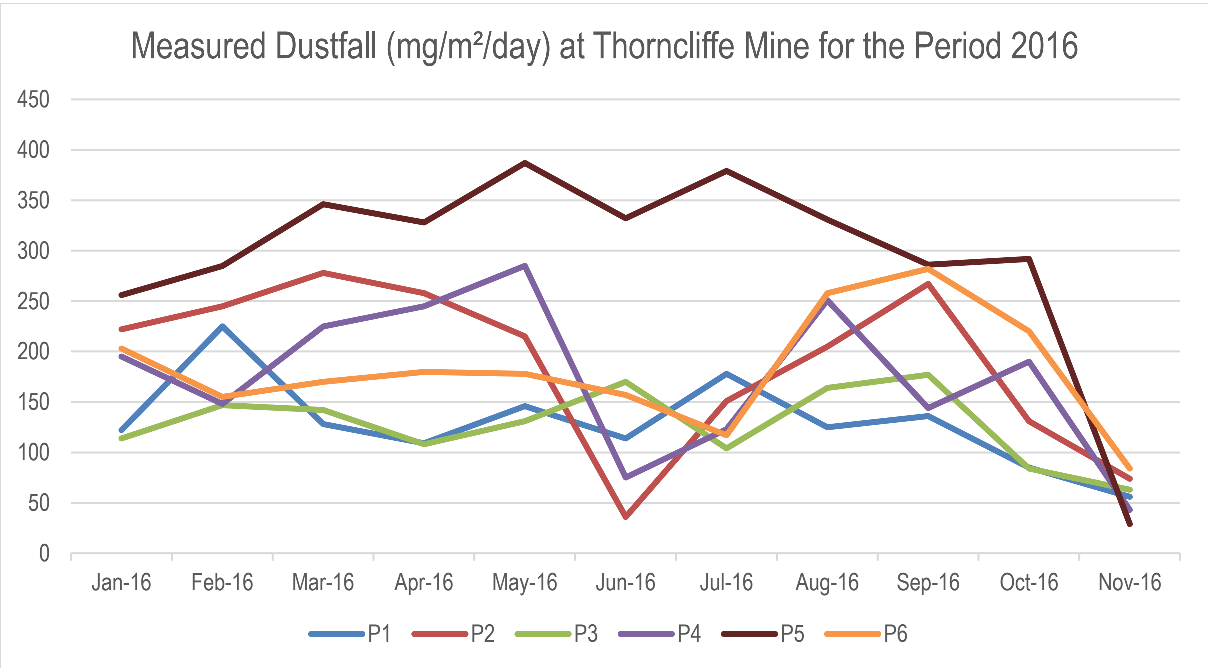


Figure 3-11: Measured dust fallout at Thorncliffe for the period 4 January to 1 December 2016

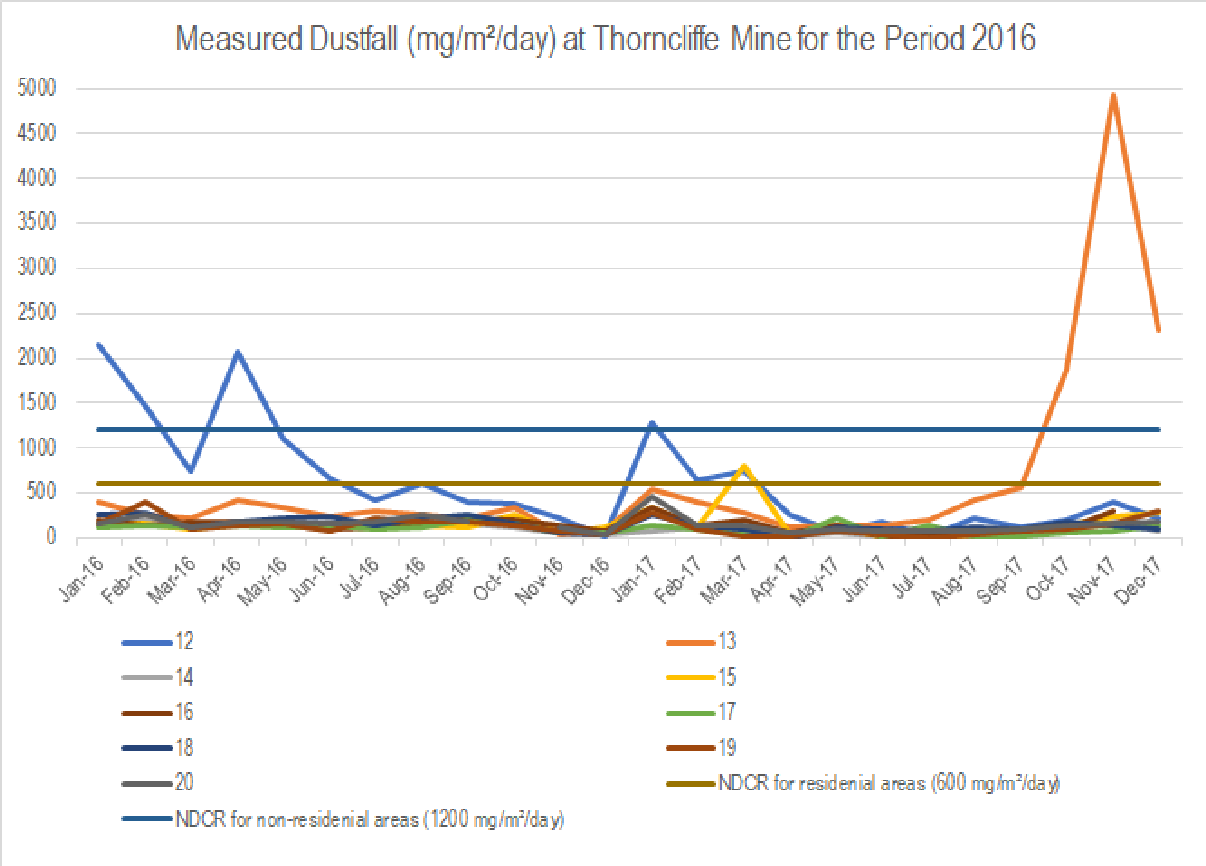


Figure 3-12: Measured dust fallout at Thorncliffe for the period 4 January 2016 to 6 December 2017

3.5 Existing Sources of Emissions near the Proposed Project

The sources of SO_2 and oxides of nitrogen (NO_x) that occur in the region include blasting operations at mines, veld burning, vehicle exhaust emissions and household fuel burning.

Various local and far-a-field sources are expected to contribute to the suspended fine particulate concentrations (which would include PM_{10} and $PM_{2.5}$) in the region. Local sources include wind erosion from exposed areas, fugitive dust from agricultural and mining operations, vehicle entrainment from roadways and veld burning. Long-range transport of particulates, emitted from remote tall stacks and from large-scale biomass burning in countries to the north of South Africa, has been found to contribute significantly to background fine particulate concentrations over the interior (Andreae, et al., 1996) (Garstang, et al., 1996) (Piketh, et al., 1996).

3.5.1 Materials handling

Materials handling operations associated with mining activities in the area include the transfer of material by means of tipping, loading and off-loading of trucks. The quantity of dust that will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled.

3.5.2 Household Fuel Burning

Despite the intensive national electrification program, a large number of households continue to burn fuel to meet all or a portion of their energy requirements. The main fuels with air pollution potentials used by households within the study region are coal, wood and paraffin.

Coal burning emits a large amount of gaseous and particulate pollutants including sulfur dioxide, heavy metals, total and respirable particulates including heavy metals and inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, and benzo(a)pyrene. Polyaromatic hydrocarbons are recognised as carcinogens. Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a)pyrene and formaldehyde. The main pollutants emitted from the combustion of paraffin are NO_2, particulates carbon monoxide and polycyclic aromatic hydrocarbons.

3.5.3 Biomass Burning

The biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, crop-residue burning and wild fires (locally known as veld fires) may represent significant sources of combustion-related emissions.

The biomass burning is an incomplete combustion process, with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left is 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.

3.5.4 Vehicle Exhaust Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include carbon dioxide (CO_2), CO, hydrocarbon compounds (HC), SO_2, NO_x and particulate matter (PM). Secondary pollutants include NO_2, photochemical oxidants (e.g. ozone), HC, sulfur acid, sulfates, nitric acid and nitrate aerosols.

3.5.5 Fugitive Dust Emissions from Open Cast Mining

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

Glencor Eastern Mines do not consist of opencast operations, however opencast mining activities in the area include the Der Brochen Mine and Northam's Booysendal Mine to the south. In addition, the Mareesburg Platinum Joint Venture is adjacent to Mareesburg farm to the southeast.

It should be noted that Der Brochen Mine have a TSF located to the east of the closest sensitive receptors to Helena Mine (to the east). This should be kept in mind when assessing the impacts on these receptors.

3.5.6 Other Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g. tilling) and mining. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and, on the silt loading on the roadways.

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne, its erosion potential has to be restored; that is, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity. Every time a surface is disturbed, its erosion potential is restored (US EPA, 2004). Erodible surfaces may occur as a result of agriculture and/or grazing activities.

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

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 underground mines to crusher plant Transportation of product
Material handling		
Fugitive dust	Materials handling operations	Remove ROM from underground mining areas Tip ROM at crusher Tip from crusher to plant Crushing Conveyor operations
Vents		
Gaseous and particulate emissions	Vent point sources	Underground mining operations will result in gaseous and particulate emissions that will need to be released to atmosphere. This is done by means of vents.
Storage piles		
Fugitive dust	Wind erosion	Windblown dust from TSF, WRD and ROM stockpiles

4.2.2 Quantification of Environmental Aspects and Impact Classification

The following scenarios were assessed:

- **Scenario 1:** Current operations. This consists of the following:
  - All existing storage piles including ROM, WRDs and TSFs
  - The transport of concentrate from Helena and Magareng mines offsite
  - The underground mines and associated conveyors and vent shafts
  - Crushing activities at Helena, Magareng, Thorncliffe and Mototolo mines
- **Scenario 2:** Current and proposed operations assuming the following:
  - Transport of TSF material from Helena Mine to Thorncliffe Mine via paved road;
  - The TSF at Helena Mine is 100% exposed to wind erosion.
  - Closing of the eastern most shaft and the opening of the two additional shafts to the west of operations
- **Scenario 3:** Current and proposed operations assuming the following:
  - Transport of TSF material from Helena Mine to Thorncliffe Mine via pipe;
  - The TSF at Helena Mine is 100% exposed to wind erosion.
  - Closing of the eastern most shaft and the opening of the two additional shafts to the west of operations
- **Scenario 4:** Current and proposed operations assuming the following:
  - TSF at Helena Mine no longer exists;
  - New WRD at Helena Mine.
  - Closing of the eastern most shaft and the opening of the two additional shafts to the west of operations.

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 paved surfaces	$E = k(sL)^{0.91}(W)^{1.02}$ Where, E = size-specific emission factor (lb/VKT) sL = surface material silt loading (g/m²) W = mean vehicle weight (tons) The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$, 0.62 for PM_{10}, and as 3.23 for TSP.	US-EPA AP42 Section 13.2.1	In the absence of site specific silt data, use was made of US EPA default mean silt loading of 8.2 g/m². The capacity of the haul trucks to be used was given to be 30 tons for the transport of tailings material and 45 tons for the transport of concentrate.

Activity	Emission Equation	Source	Information assumed/provided
Materials handling	$$E = 0.0016\frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$ 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 factor is 5.3%, 35% and 74% respectively.	US-EPA AP42 Section 13.2.4	An average wind speed of 3.6 m/s was used based on the modelled MM5 data for the period 2013 to 2015. The throughput of the ROM material was provided as follows: Helena Mine = 1 284 764 tpa Magareng Mine = 1 347 360 tpa Thorncliffe Mine = 1 451 355 tpa Mototolo (Borwa) Mine = 832 819 tpa Mototolo (Lebowa) Mine = 975 168 tpa The moisture of the ROM was assumed to be 3%.
Crushing and screening	<u>Primary (for low moisture ore):</u> $$E_{TSP} = 0.2\ kg/t\ material\ processed$$ $$E_{PM10} = 0.02\ kg/t\ material\ processed$$ $$E_{PM2.5} = 0.0037\ kg/t\ material\ processed$$ Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing	NPI Section: Mining	It was provided that primary crushing takes place at Helena, Magareng, Thorncliffe, Mototolo Borwa and Mototolo Lebowa mines. *50% control efficiency was assumed for the mitigated scenario.*
Vents	Occupational exposure limits PM_{10} = 10 mg/m³ $PM_{2.5}$ = 5 mg/m³	ACGIH TLVs 1996 – Occupational Guidelines	Parameters assumed: - Diameter: 5 m - Exit velocity: 17 m/s - Height: 21 m
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 (provided as a fraction) for the storage pile material

Size Distribution (µm)	TSF	ROM	Waste
>2000	0.009	0.800	0.800
2000 - 301.68	0.046	0.009	0.100
301.68 - 190.8	0.099	0.020	0.010
190.8 - 103.58	0.224	0.045	0.024
103.58 - 76.32	0.110	0.022	0.012
76.32 - 65.51	0.050	0.010	0.005
65.51 - 48.27	0.095	0.019	0.010
48.27 - 30.53	0.087	0.018	0.009
30.53 - 16.57	0.071	0.014	0.008
16.57 - 10.48	0.032	0.006	0.003
10.48 - 4.88	0.008	0.002	0.001
4.88 - 1.95	0.001	0.000	0.000
1.95 - 1.24	0.168	0.034	0.018

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 50% control efficiency on crushing activities (control efficiency documented by Australia's National Pollution Inventory as being achievable through water sprayers)) conditions were assessed. For unmitigated operations, crushing activities represents the most significant source of particulate emissions (Figure 4-1).

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

ACTIVITY	Emissions (tpa)			% Contribution			Rank
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP
Scenario 1: Current Glencore Mining Operations							
Unmitigated							
Vehicle entrainment	532.98	102.31	24.75	18.83	7.89	4.20	3
Materials handling	8.79	4.16	0.63	0.31	0.32	0.11	5
Crushing and screening	1 178.29	117.83	21.80	41.64	9.09	3.70	1
Wind erosion	57.22	19.27	15.74	2.02	1.49	2.67	4
Vents	1 052.65	1 052.65	526.33	37.20	81.21	89.32	2
TOTAL	***2 829.94***	***1 296.22***	***589.25***	***100.00***	***100.00***	***100.00***	
Mitigated: control efficiency of 50% applied to crushing activities							
Vehicle entrainment	532.98	102.31	24.75	23.79	8.27	4.28	3
Materials handling	8.79	4.16	0.63	0.39	0.34	0.11	5
Crushing and screening	589.15	58.91	10.90	26.29	4.76	1.88	2
Wind erosion	57.22	19.27	15.74	2.55	1.56	2.72	4
Vents	1 052.65	1 052.65	526.33	46.98	85.08	91.01	1
TOTAL	***2 240.79***	***1 237.30***	***578.35***	***100.00***	***100.00***	***100.00***	
Scenario 2: Proposed Glencore Mining Operations (assuming the TSF material from Helena is transported to Thorncliffe via road)							
Unmitigated							
Vehicle entrainment	565.56	108.56	26.26	18.44	7.53	3.92	3
Materials handling	8.79	4.16	0.63	0.29	0.29	0.09	5

ACTIVITY	Emissions (tpa)			% Contribution			Rank
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP
Crushing and screening	1 178.29	117.83	21.80	38.41	8.17	3.25	1
Wind erosion	157.04	52.88	43.20	5.12	3.67	6.44	4
Vents	1 157.92	1 157.92	578.96	37.75	80.34	86.30	2
TOTAL	***3 067.60***	***1 441.35***	***670.85***	***100.00***	***100.00***	***100.00***	
Mitigated: control efficiency of 50% applied to crushing activities							
Vehicle entrainment	565.56	108.56	26.26	22.82	7.85	3.98	3
Materials handling	8.79	4.16	0.63	0.35	0.30	0.10	5
Crushing and screening	589.15	58.91	10.90	23.77	4.26	1.65	2
Wind erosion	157.04	52.88	43.20	6.34	3.83	6.55	4
Vents	1 157.92	1 157.92	578.96	46.72	83.76	87.73	1
TOTAL	***2 478.45***	***1 382.43***	***659.95***	***100.00***	***100.00***	***100.00***	
Scenario 3: Proposed Glencore Mining Operations (assuming the TSF material from Helena is transported to Thorncliffe via pipe)							
Unmitigated							
Vehicle entrainment	532.98	102.31	24.75	17.56	7.13	3.70	3
Materials handling	8.79	4.16	0.63	0.29	0.29	0.09	5
Crushing and screening	1 178.29	117.83	21.80	38.82	8.21	3.26	1
Wind erosion	157.04	52.88	43.20	5.17	3.69	6.45	4
Vents	1 157.92	1 157.92	578.96	38.15	80.69	86.50	2
TOTAL	***3 035.02***	***1 435.10***	***669.33***	***100.00***	***100.00***	***100.00***	
Mitigated: control efficiency of 50% applied to crushing activities							
Vehicle entrainment	532.98	102.31	24.75	21.79	7.43	3.76	3
Materials handling	8.79	4.16	0.63	0.36	0.30	0.10	5
Crushing and screening	589.15	58.91	10.90	24.09	4.28	1.66	2
Wind erosion	157.04	52.88	43.20	6.42	3.84	6.56	4
Vents	1 157.92	1 157.92	578.96	47.34	84.14	87.93	1
TOTAL	***2 445.88***	***1 376.18***	***658.44***	***100.00***	***100.00***	***100.00***	
Scenario 4: Proposed Glencore Mining Operations (assuming all TSF material from Helena is completely removed and WRD is in its stead)							
Unmitigated							
Vehicle entrainment	532.98	102.31	24.75	17.66	7.16	3.73	3
Materials handling	8.79	4.16	0.63	0.29	0.29	0.09	5
Crushing and screening	1 178.29	117.83	21.80	39.05	8.24	3.28	1
Wind erosion	139.27	46.90	38.31	4.62	3.28	5.77	4
Vents	1 157.92	1 157.92	578.96	38.38	81.02	87.13	2
TOTAL	***3 017.25***	***1 429.11***	***664.45***	***100.00***	***100.00***	***100.00***	
Mitigated: control efficiency of 50% applied to crushing activities							
Vehicle entrainment	532.98	102.31	24.75	21.95	7.47	3.79	3
Materials handling	8.79	4.16	0.63	0.36	0.30	0.10	5
Crushing and screening	589.15	58.91	10.90	24.26	4.30	1.67	2
Wind erosion	139.27	46.90	38.31	5.74	3.42	5.86	4
Vents	1 157.92	1 157.92	578.96	47.69	84.51	88.59	1
TOTAL	***2 428.11***	***1 370.20***	***653.55***	***100.00***	***100.00***	***100.00***	

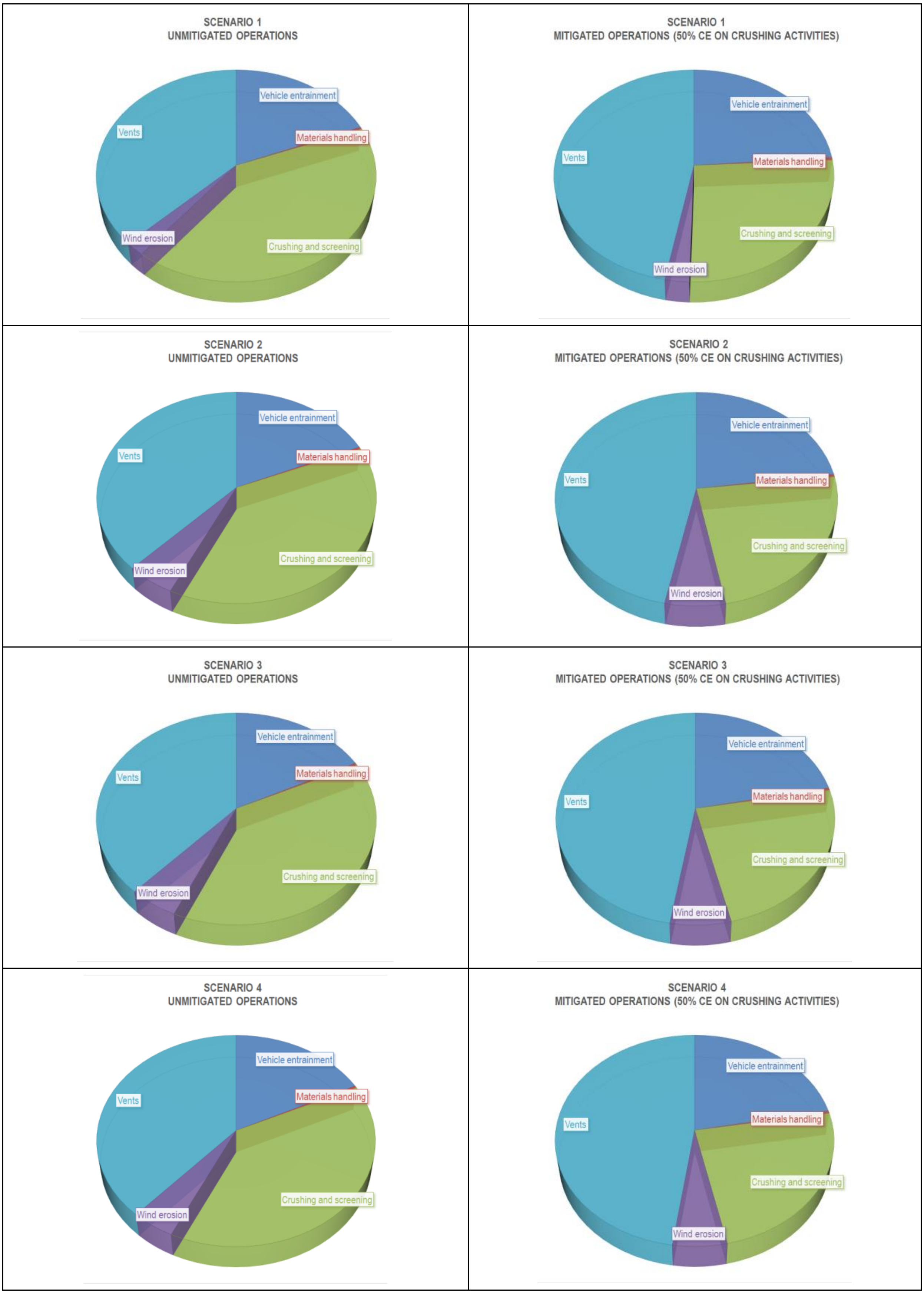


Figure 4-1: Percentage contribution of TSP emissions due to project operations

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
$PM_{2.5}$	1	Unmitigated operations	4-2
		Mitigated operations	4-3
	2	Unmitigated operations	4-4
		Mitigated operations	4-5
	3	Unmitigated operations	4-6
		Mitigated operations	4-7
	4	Unmitigated operations	4-8
		Mitigated operations	4-9
PM_{10}	1	Unmitigated operations	4-10
		Mitigated operations	4-11
	2	Unmitigated operations	4-12
		Mitigated operations	4-13
	3	Unmitigated operations	4-14
		Mitigated operations	4-15
	4	Unmitigated operations	4-16
		Mitigated operations	4-17
TSP	1	Unmitigated operations	4-18
		Mitigated operations	4-19
	2	Unmitigated operations	4-20
		Mitigated operations	4-21
	3	Unmitigated operations	4-22
		Mitigated operations	4-23
	4	Unmitigated operations	4-24
		Mitigated operations	4-25

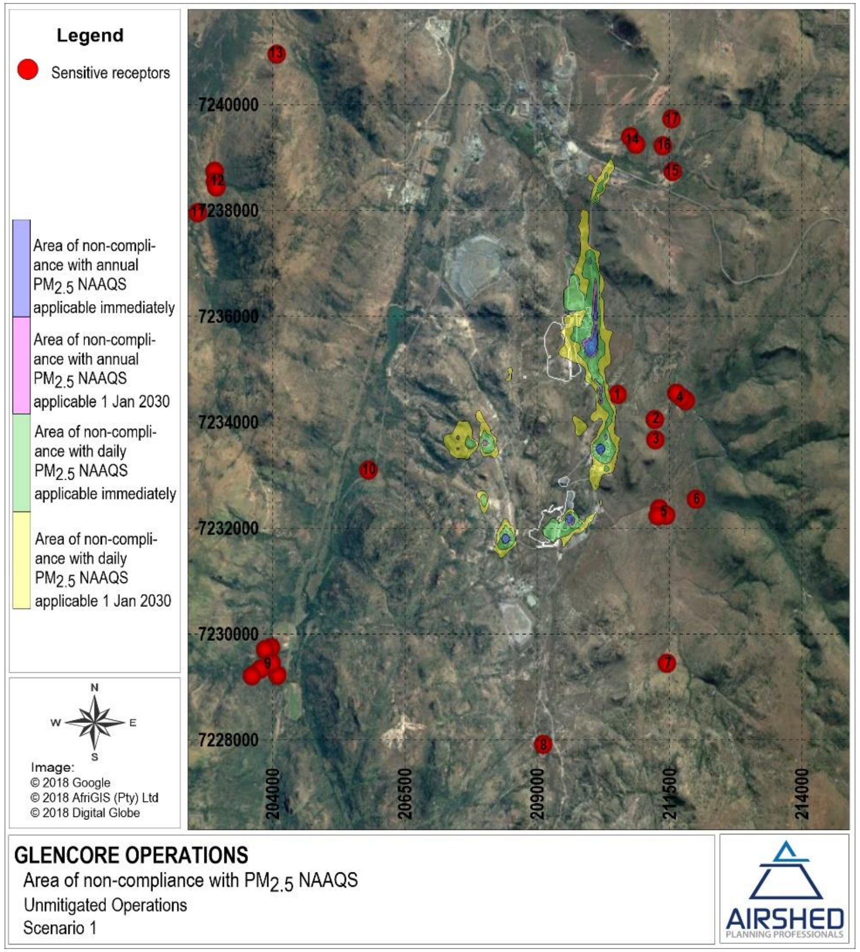


Figure 4-2: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations for Scenario 1

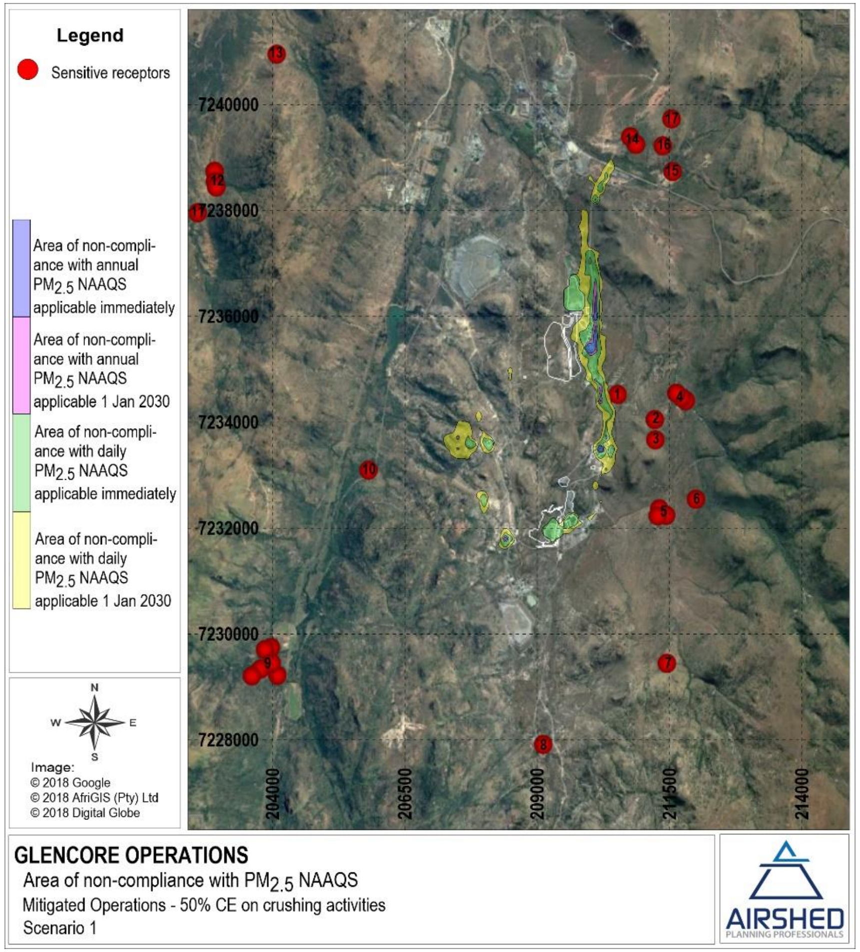


Figure 4-3: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations for Scenario 1

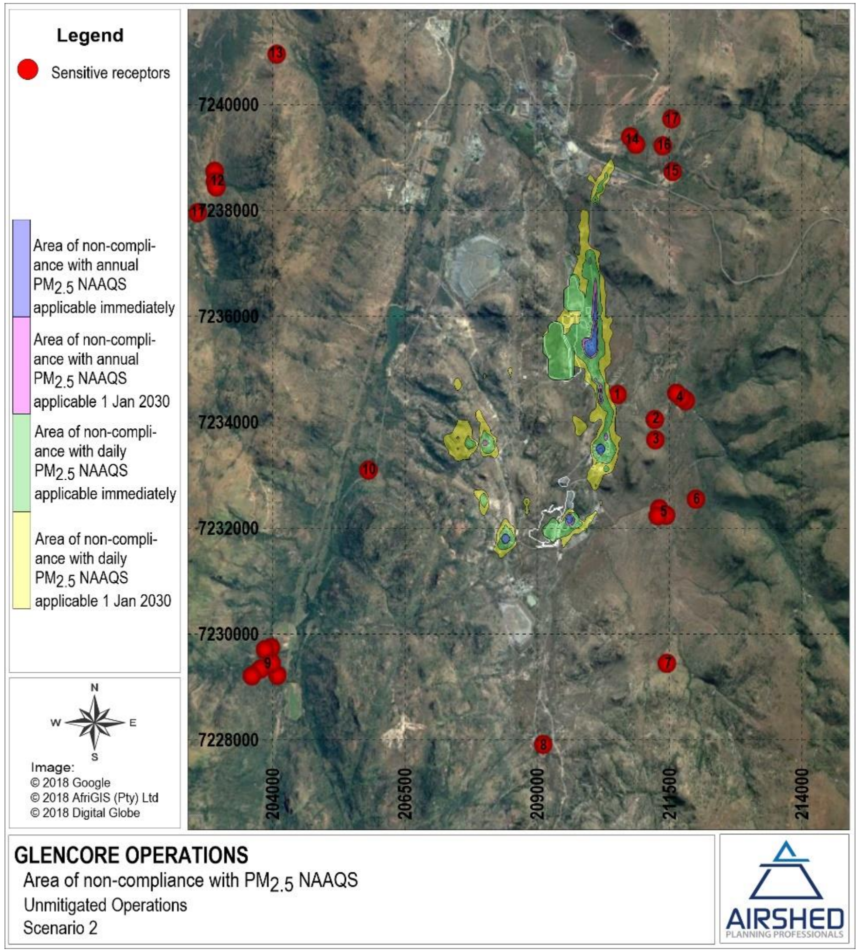


Figure 4-4: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations for Scenario 2

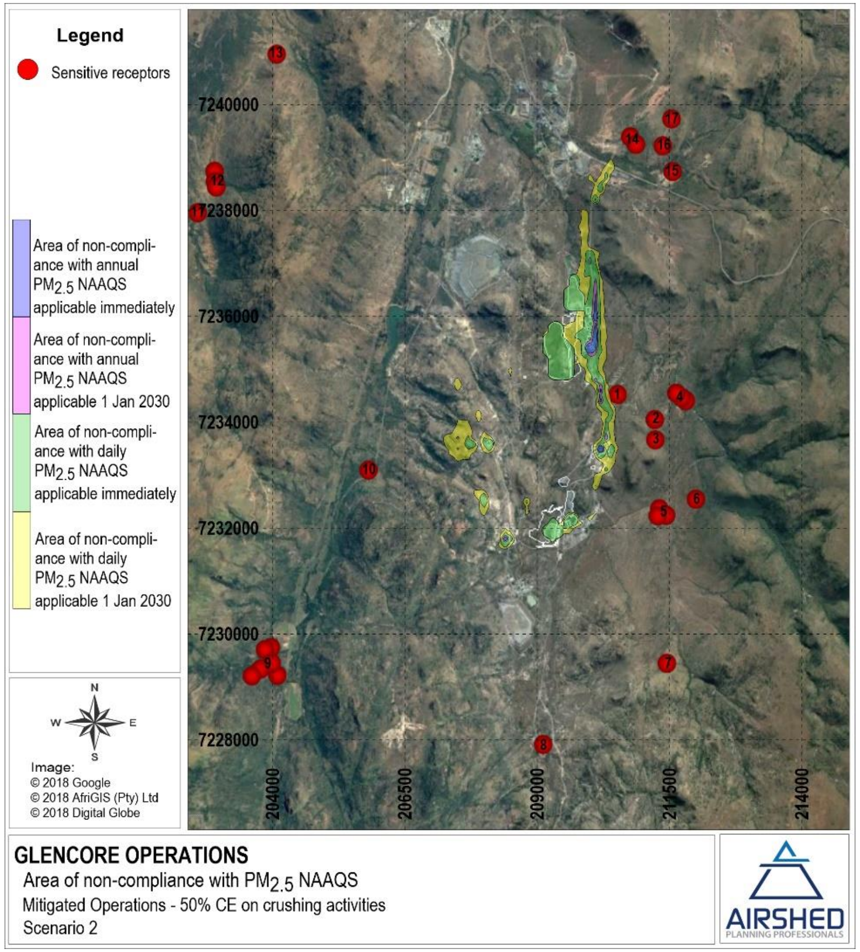


Figure 4-5: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations for Scenario 2

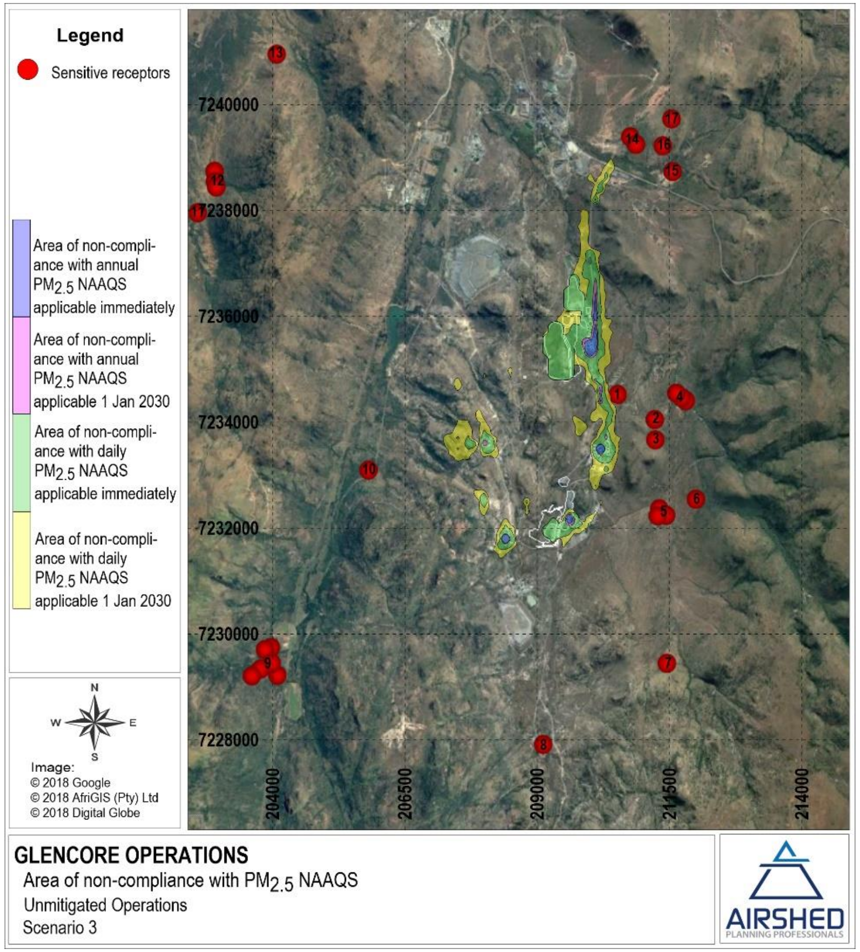


Figure 4-6: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations for Scenario 3

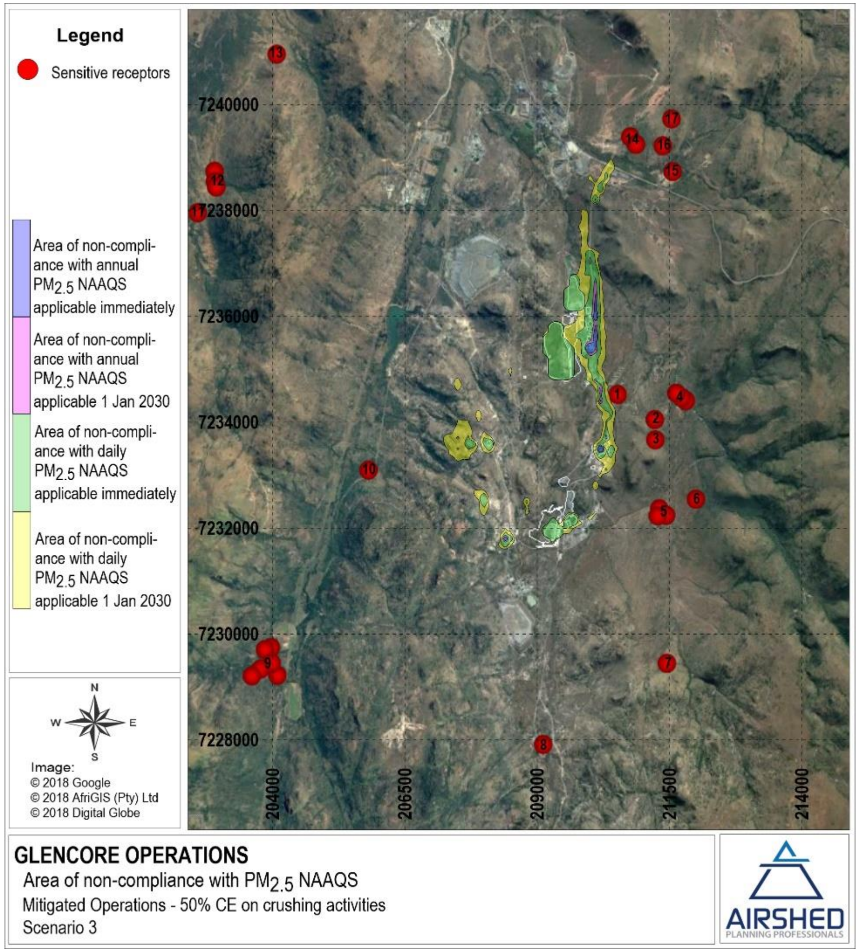


Figure 4-7: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations for Scenario 3

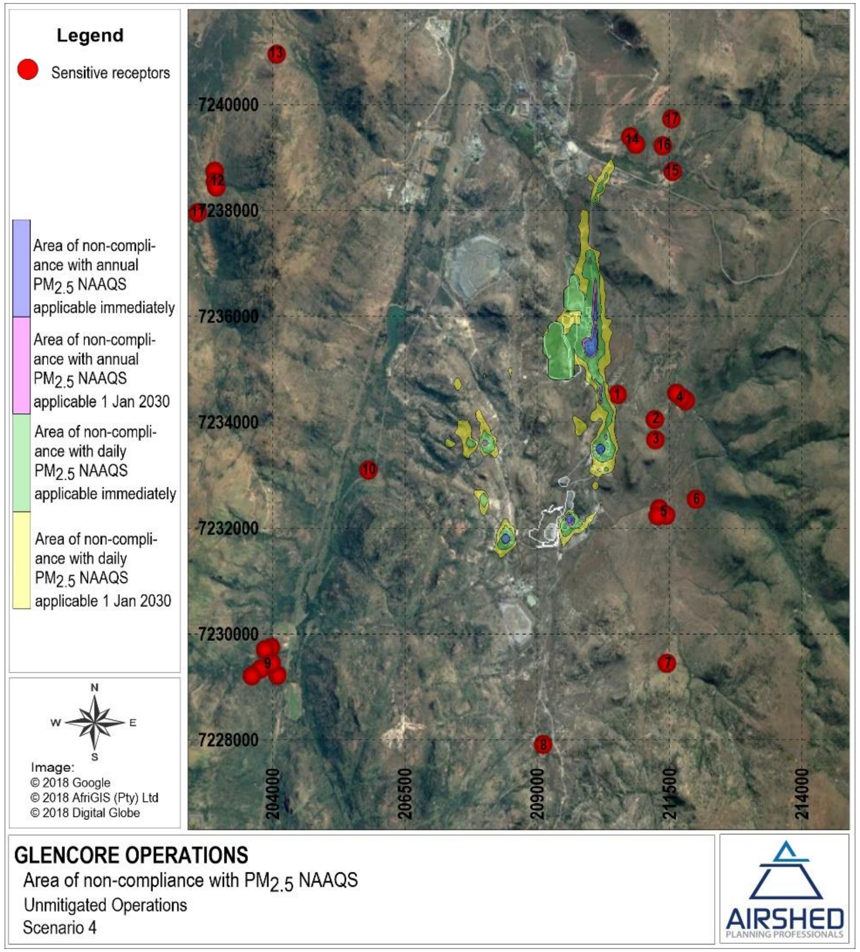


Figure 4-8: Area of non-compliance of $PM_{2.5}$ NAAQS due to unmitigated operations for Scenario 4

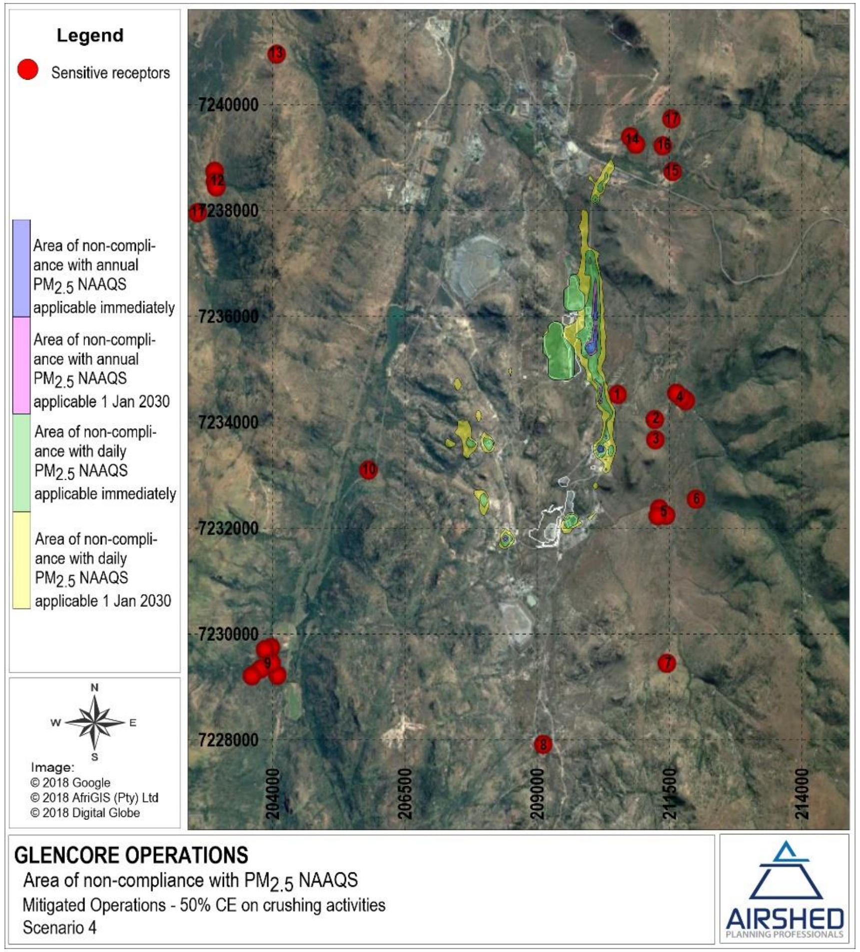


Figure 4-9: Area of non-compliance of $PM_{2.5}$ NAAQS due to mitigated operations for Scenario 4

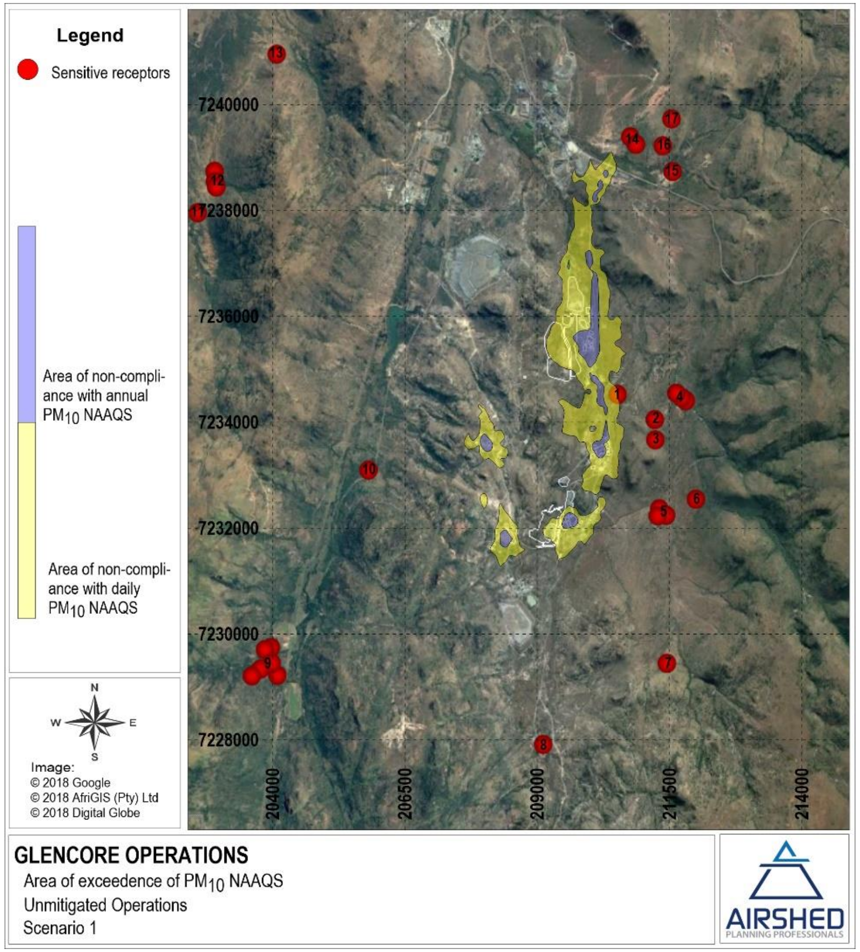


Figure 4-10: Area of non-compliance of PM_{10} NAAQS due to unmitigated operations for Scenario 1

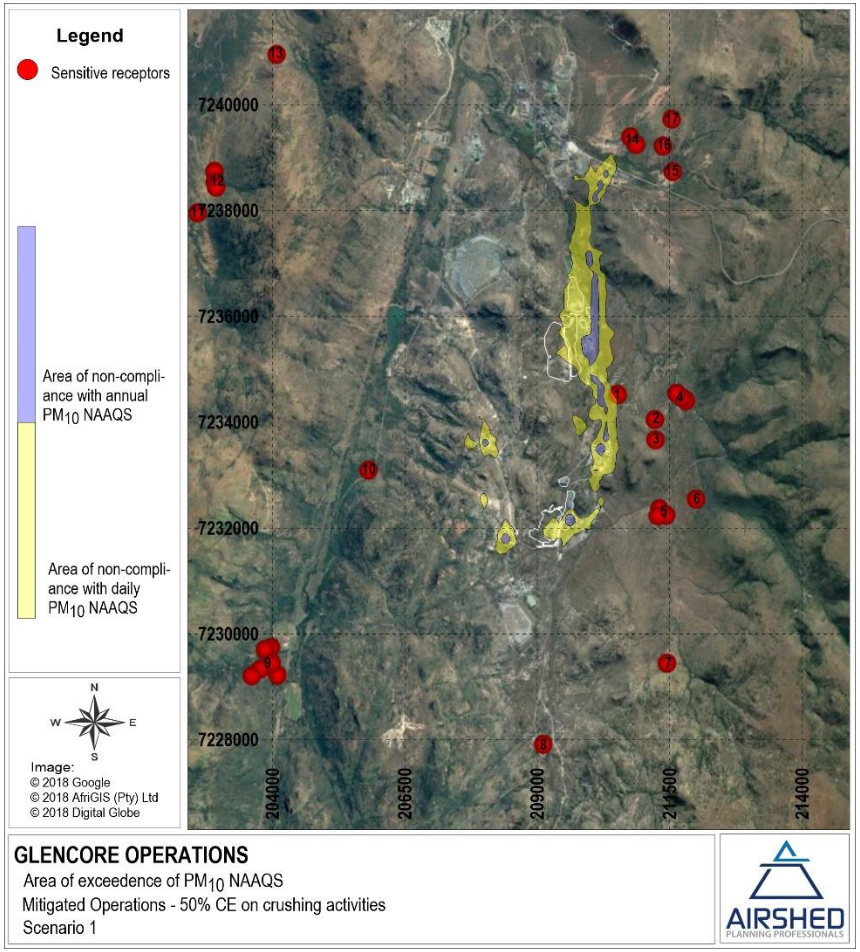


Figure 4-11: Area of non-compliance of PM_{10} NAAQS due to mitigated operations for Scenario 1

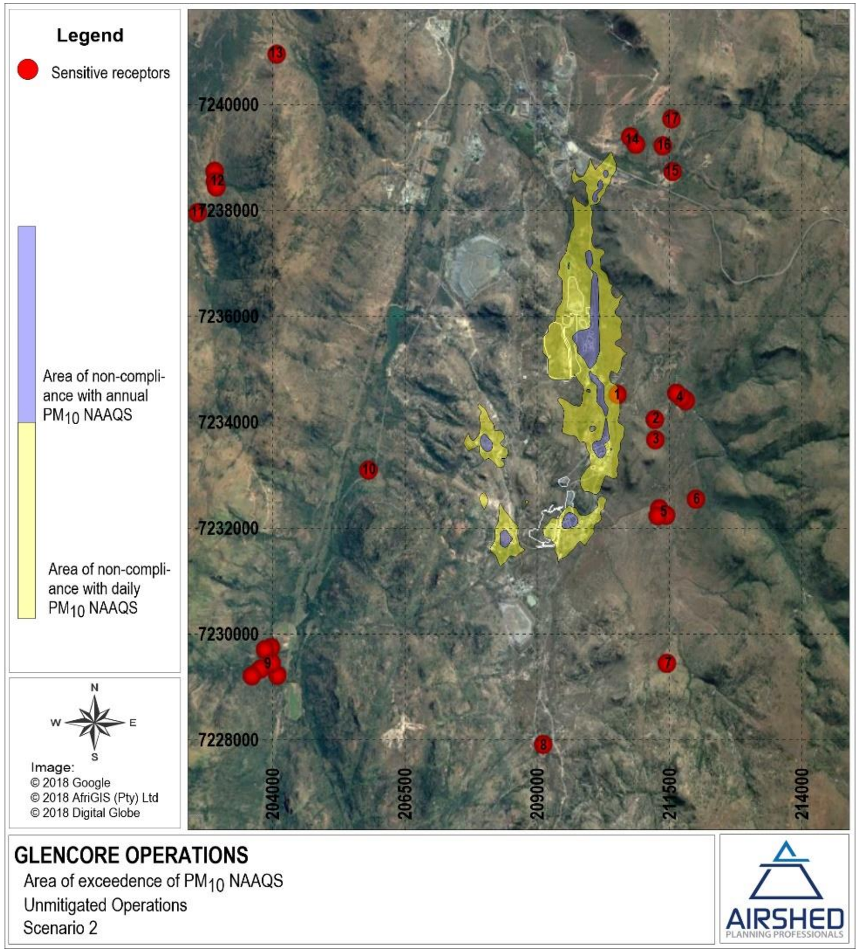


Figure 4-12: Area of non-compliance of PM_{10} NAAQS due to unmitigated operations for Scenario 2

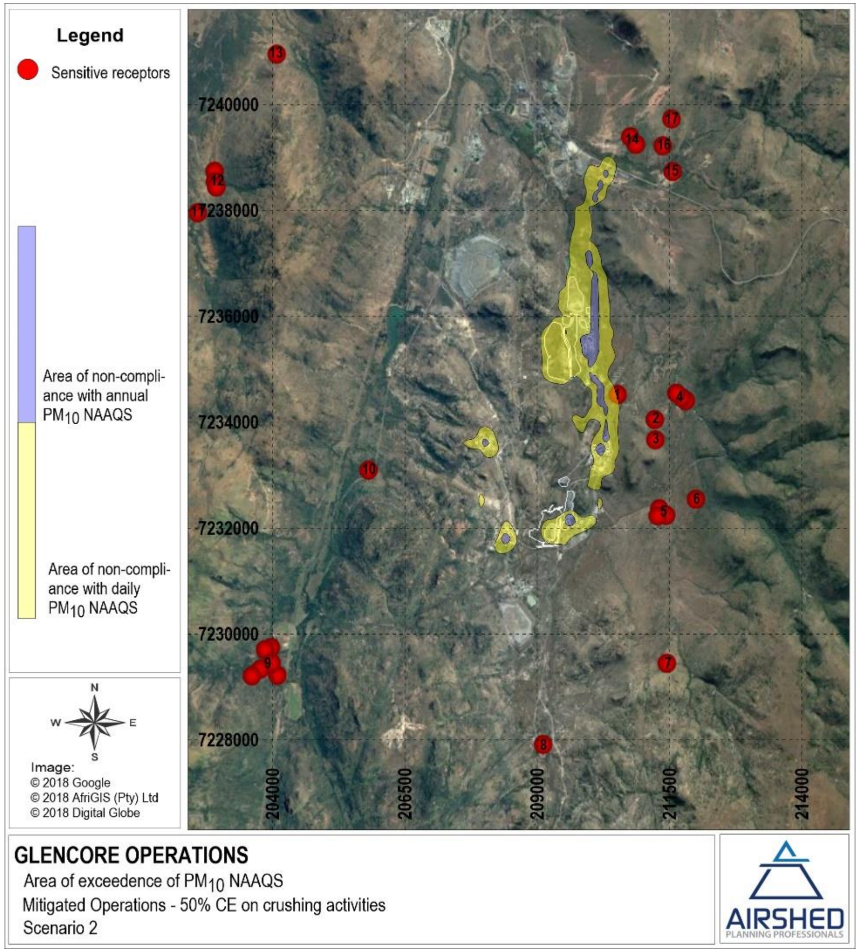


Figure 4-13: Area of non-compliance of PM_{10} NAAQS due to mitigated operations for Scenario 2

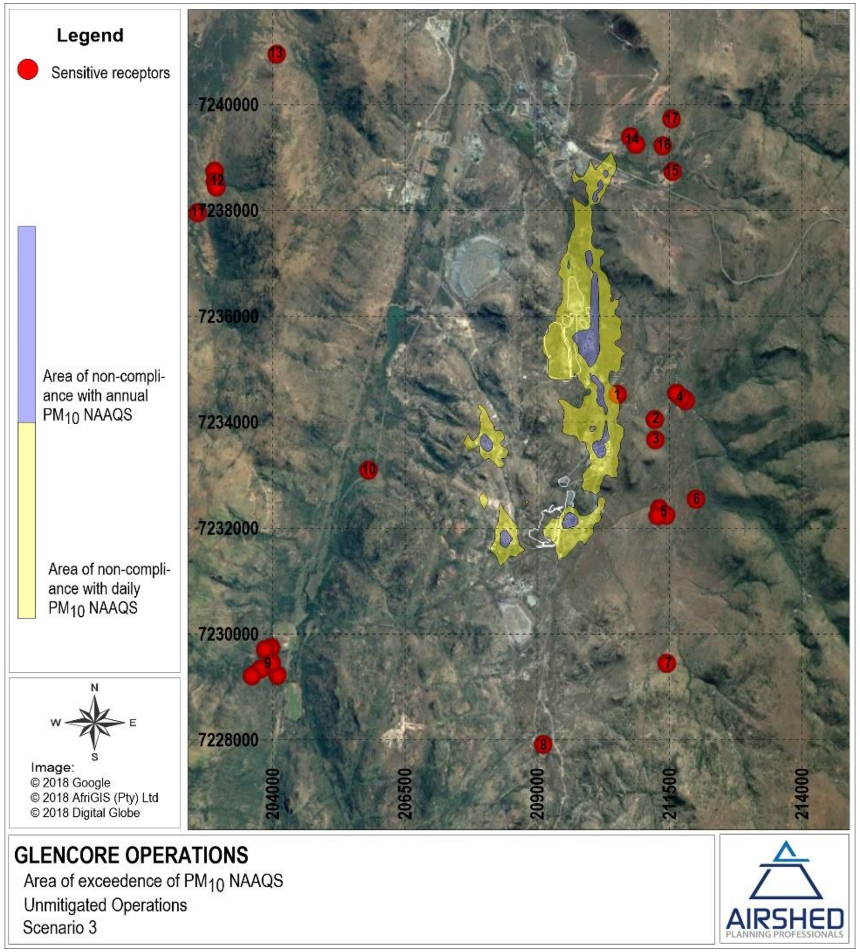


Figure 4-14: Area of non-compliance of PM_{10} NAAQS due to unmitigated operations for Scenario 3

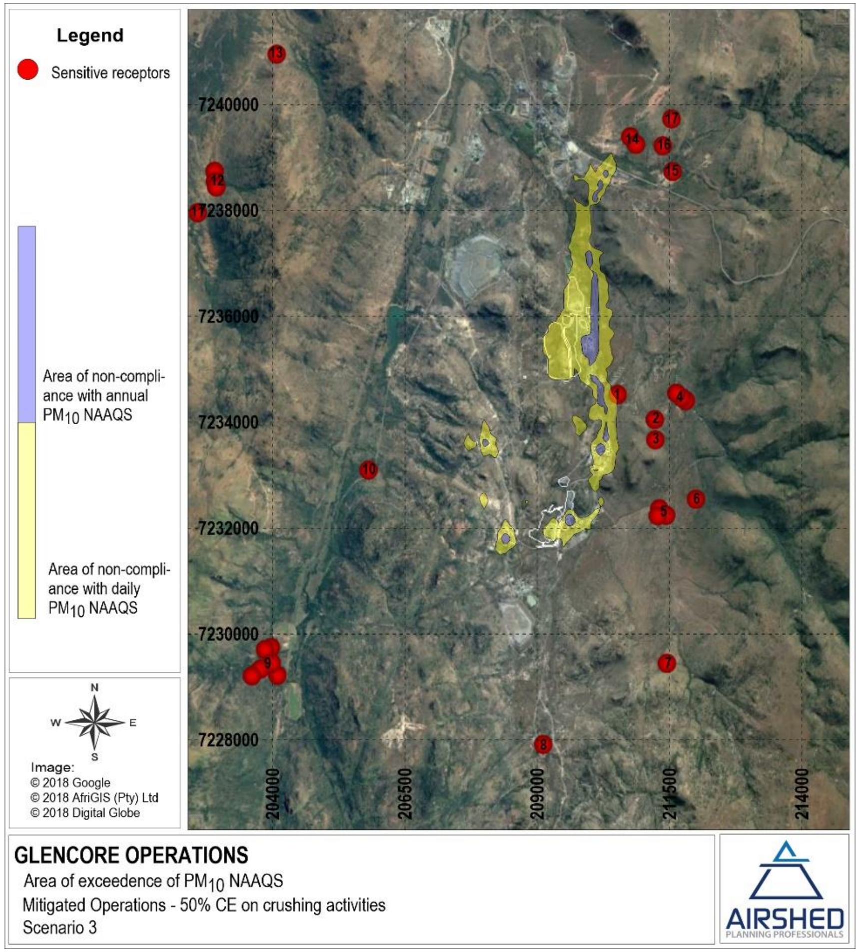


Figure 4-15: Area of non-compliance of PM_{10} NAAQS due to mitigated operations for Scenario 3

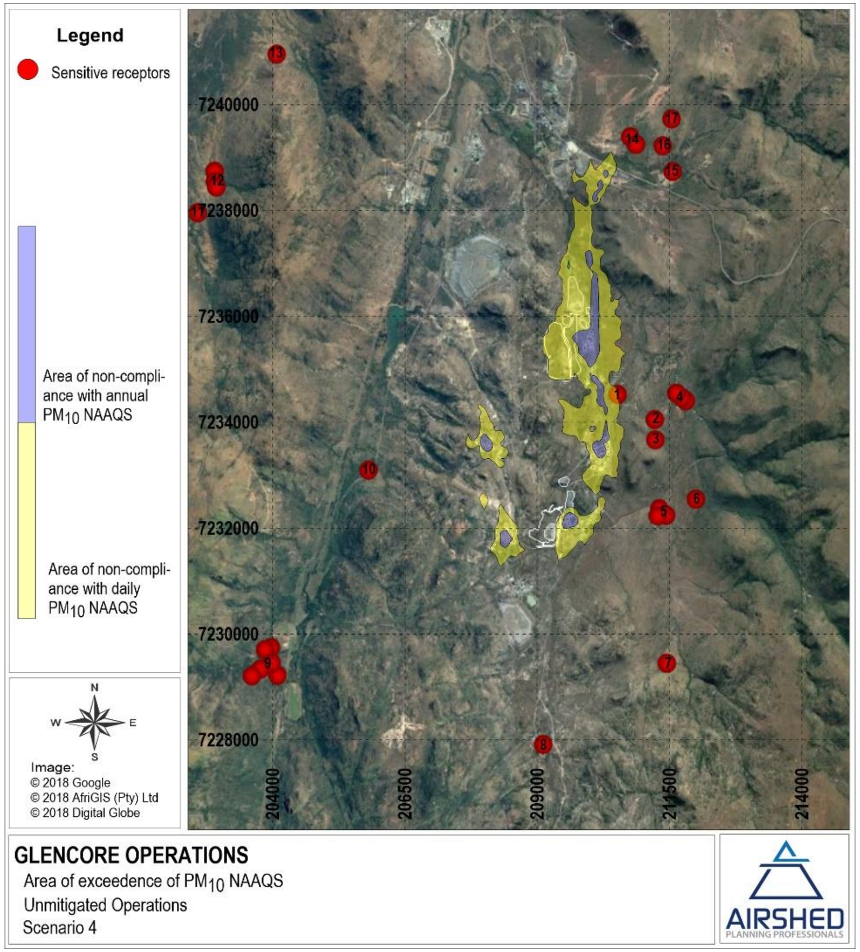


Figure 4-16: Area of non-compliance of PM_{10} NAAQS due to unmitigated operations for Scenario 4

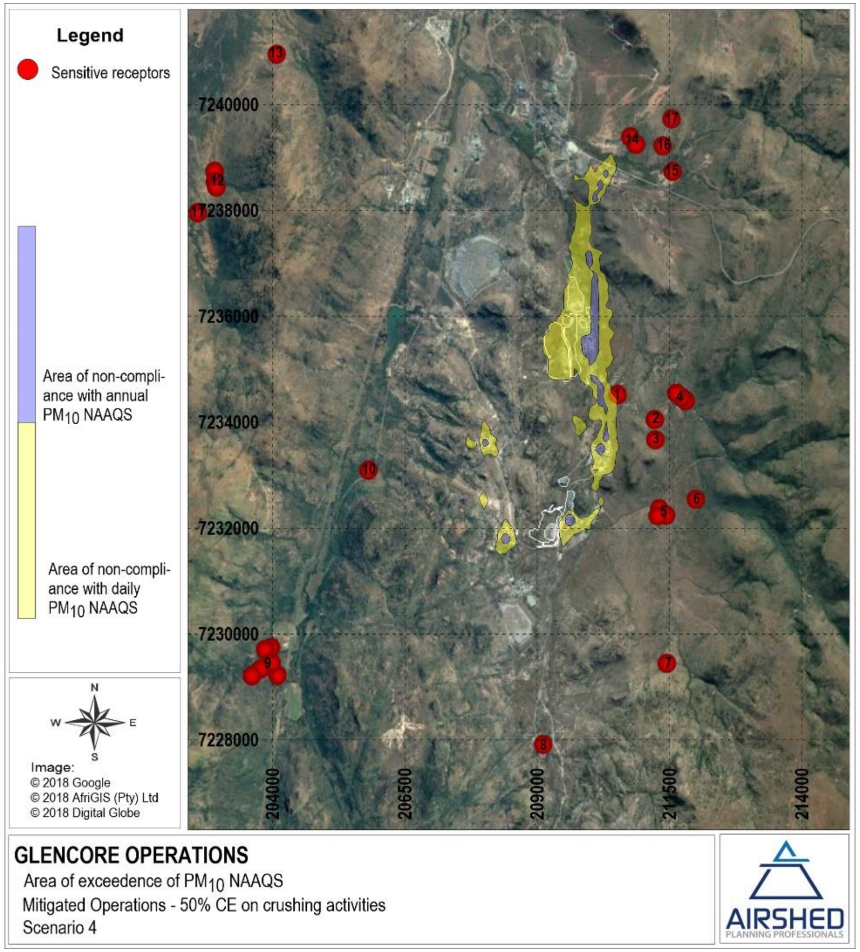


Figure 4-17: Area of non-compliance of PM_{10} NAAQS due to mitigated operations for Scenario 4

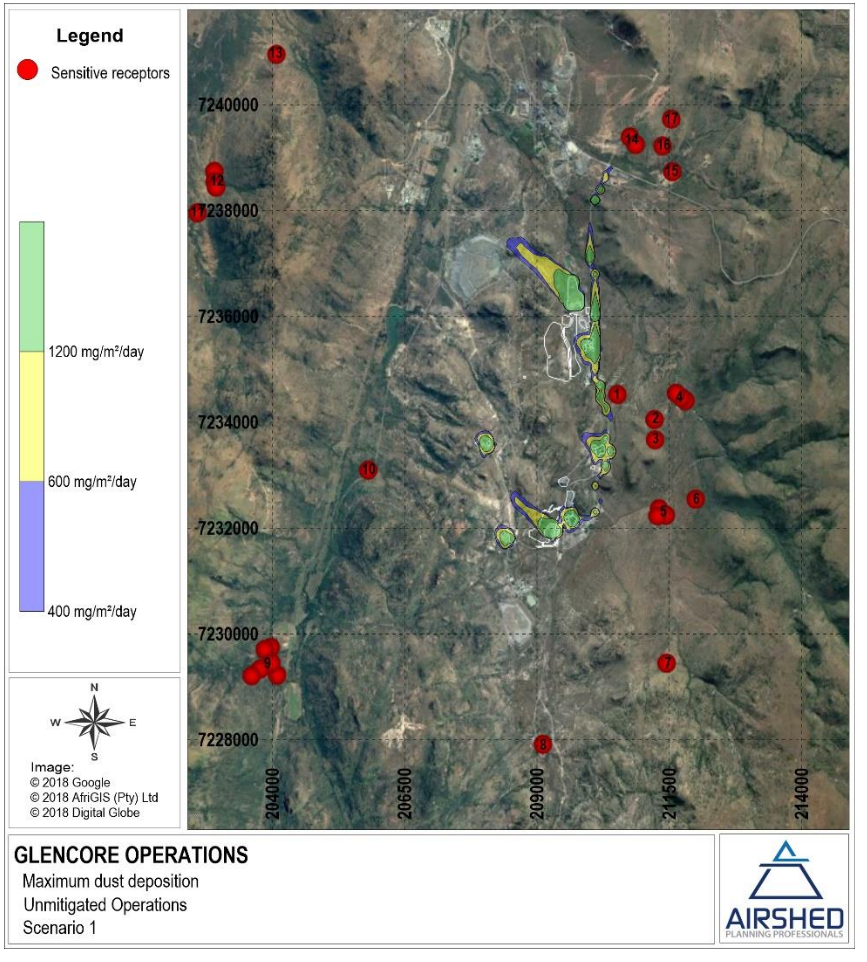


Figure 4-18: Total particulate deposition due to unmitigated operations for Scenario 1

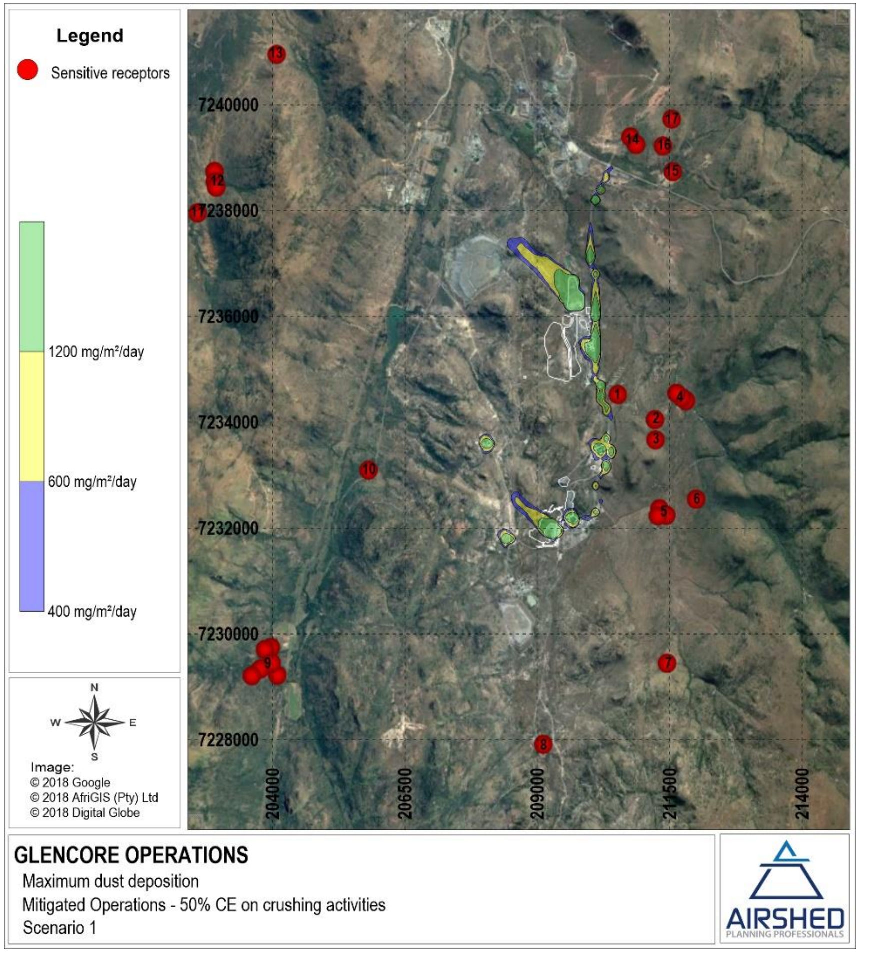


Figure 4-19: Total particulate deposition due to mitigated operations for Scenario 1

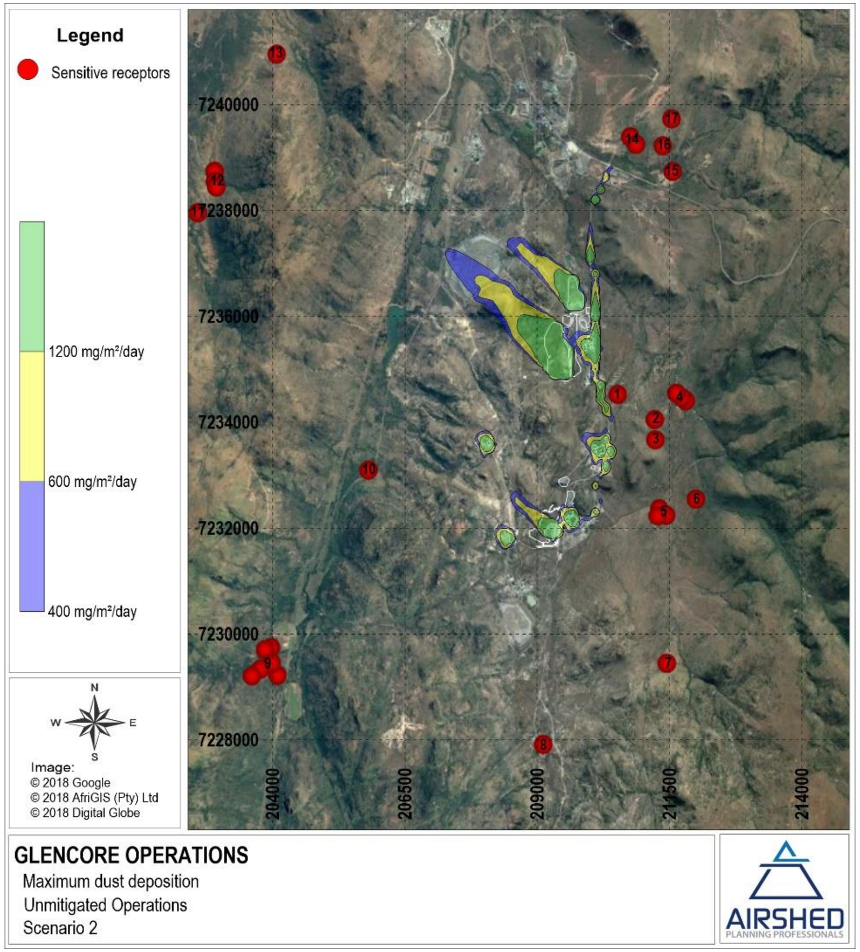


Figure 4-20: Total particulate deposition due to unmitigated operations for Scenario 2

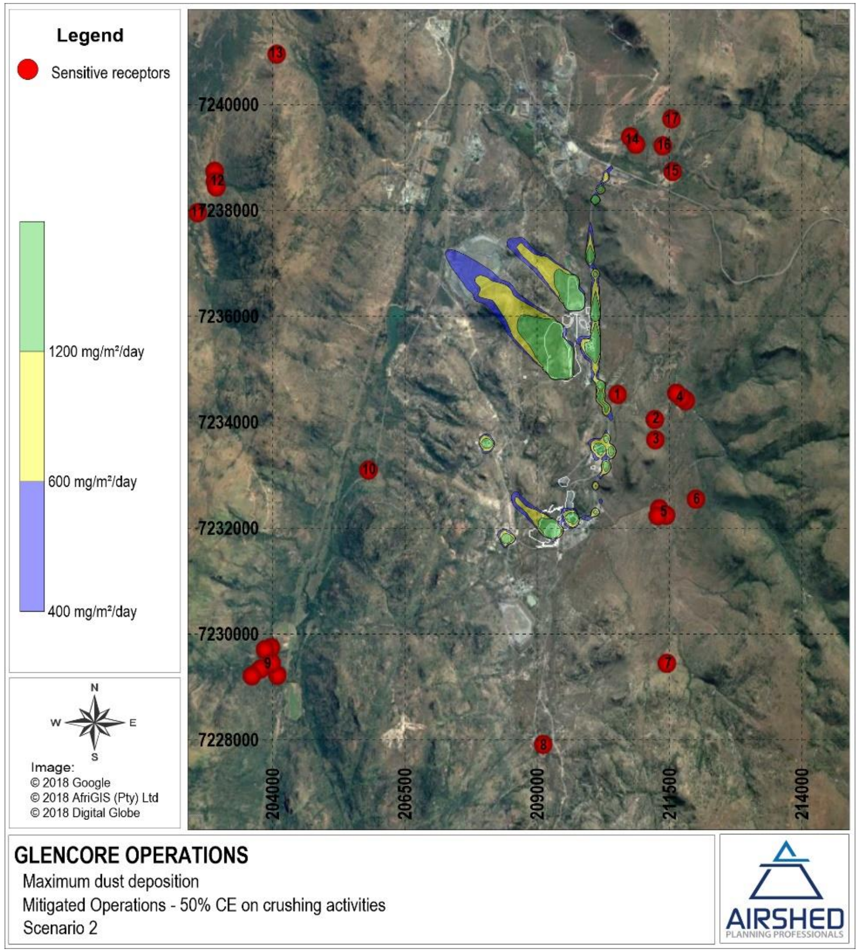


Figure 4-21: Total particulate deposition due to mitigated operations for Scenario 2

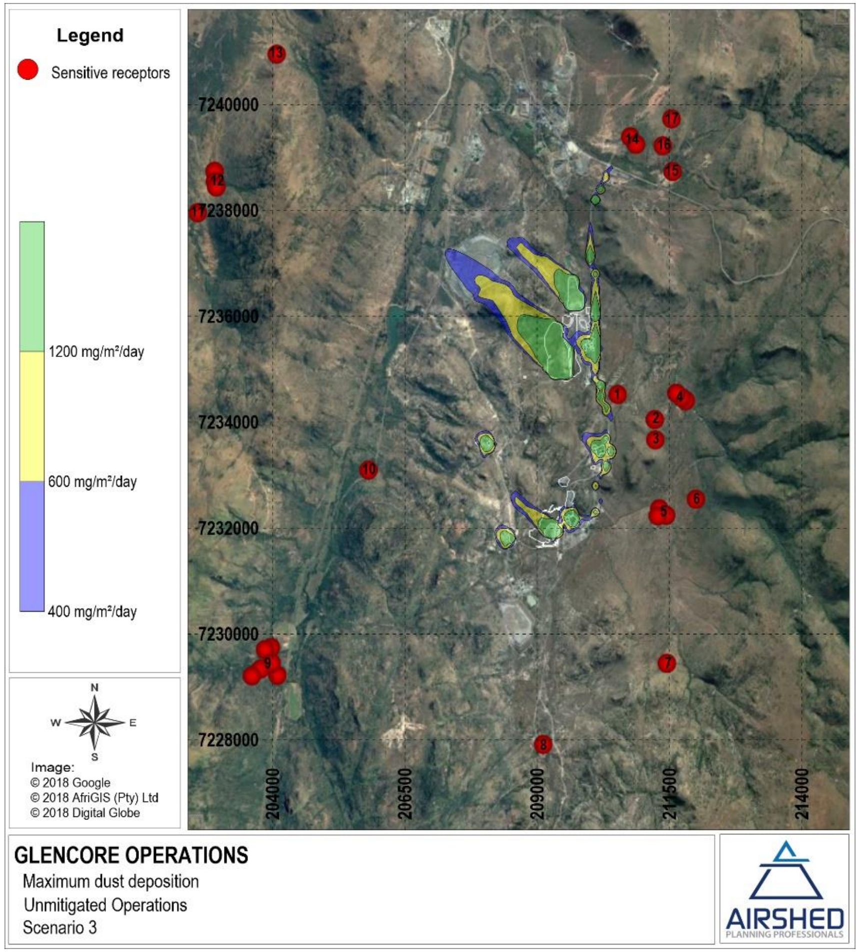


Figure 4-22: Total particulate deposition due to unmitigated operations for Scenario 3

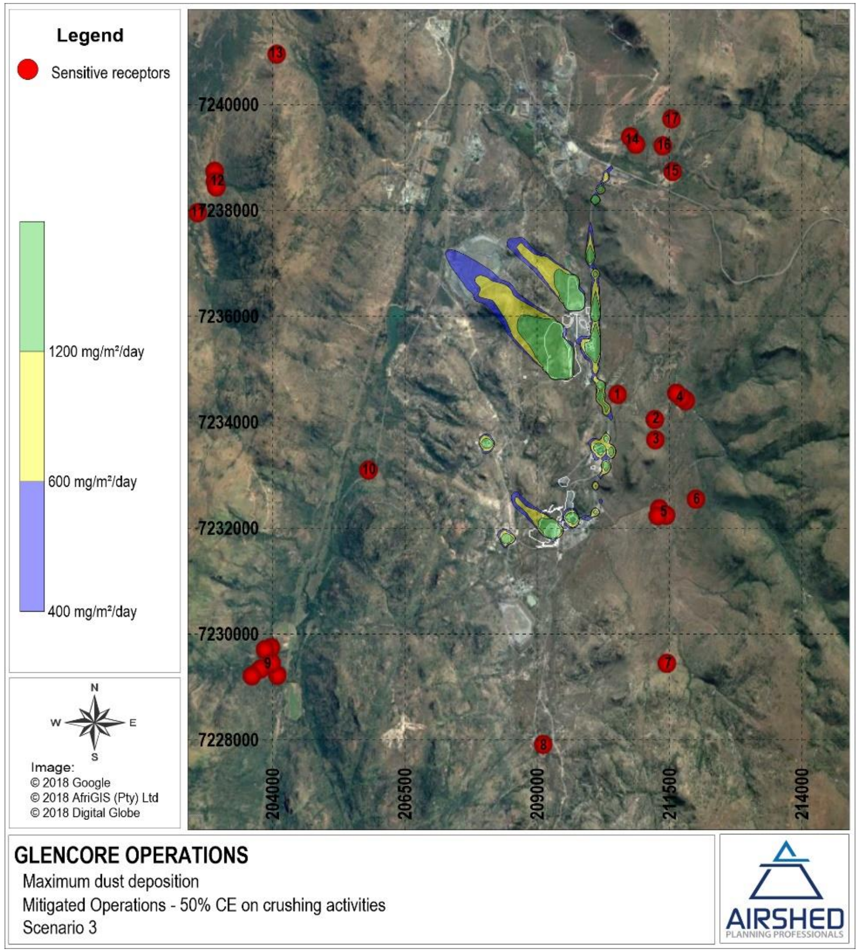


Figure 4-23: Total particulate deposition due to mitigated operations for Scenario 3

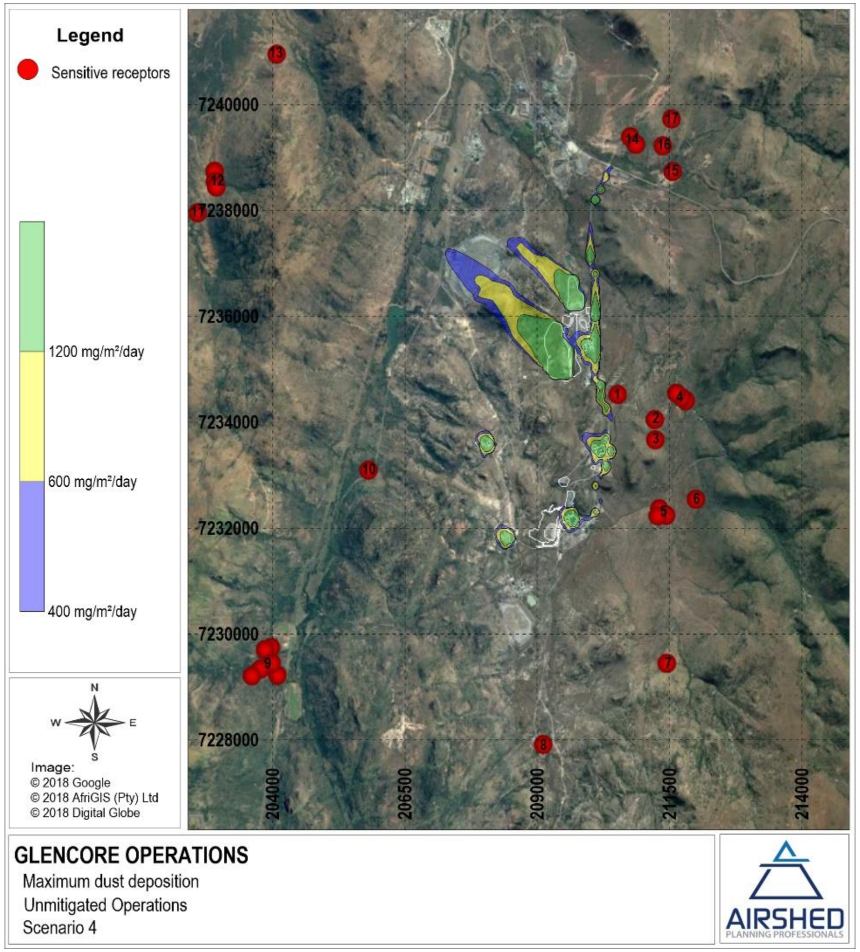


Figure 4-24: Total particulate deposition due to unmitigated operations for Scenario 4

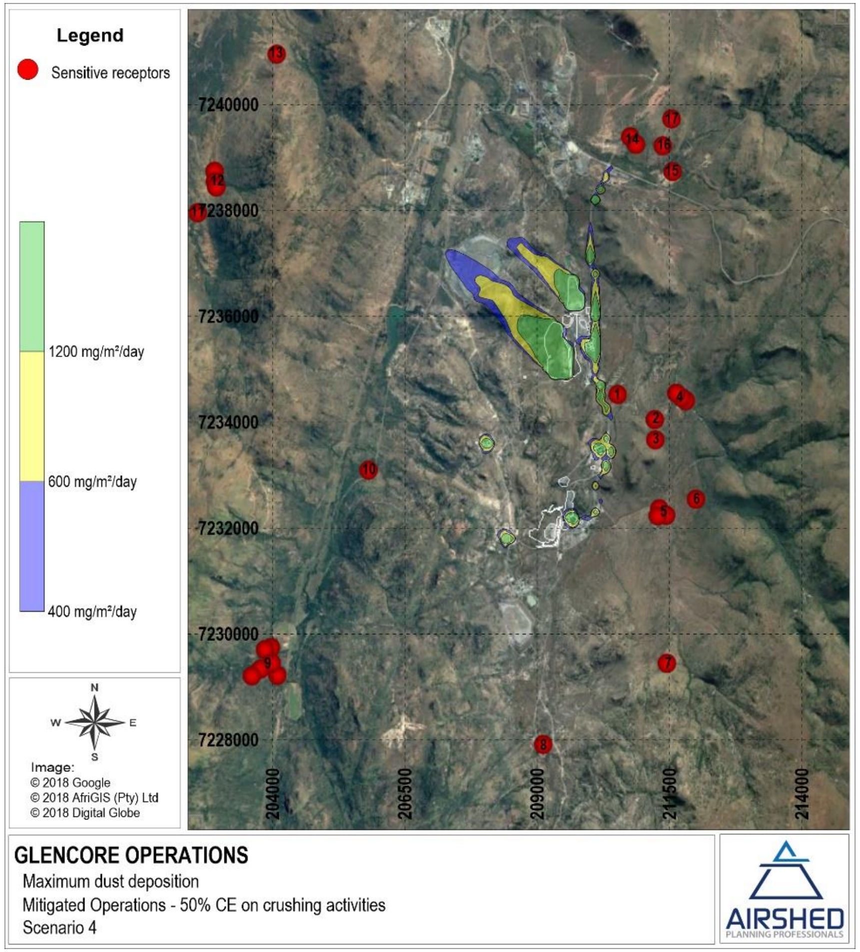


Figure 4-25: Total particulate deposition due to mitigated operations for Scenario 4

The highest $PM_{2.5}$ concentrations due to proposed project operations (unmitigated) are in compliance with NAAQS at the closest sensitive receptors for all four scenarios. When activities are mitigated (assuming 50% control efficiency on crushing activities) the $PM_{2.5}$ concentrations reduce in spatial distribution (Figure 4-2 to Figure 4-9).

The highest PM_{10} concentrations due to proposed project operations (unmitigated) are in compliance with NAAQS at the closest sensitive receptors for all four scenarios reducing in magnitude and spatial distribution with mitigation (assuming 50% control efficiency on crushing activities) (Figure 4-10 to Figure 4-17).

Maximum daily dust deposition is within with the NDCR for residential areas at the closest sensitive receptors for all modelled scenarios (Figure 4-18 to Figure 4-25).

4.2.2.4 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 crushing and screening activities and windblown dust from the tailings facilities were significant.

4.2.3.1 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.

4.2.3.2 Wind Erosion

A potentially significant impacting source may be wind erosion from the TSFs during periods of high winds (>9m/s). It is recommended that the sidewalls of the tailings dam be vegetated or rock cladded. The vegetation cover or rock cladding should be such to ensure at least 80% control efficiency. The top surface area should have 40% wet area (if feasible). Other control measures that may be implemented (depending on the practicality) is to introduce a water spraying system on the surface of the tailings dam covering the outer perimeter of the dam, spraying water when wind exceeds 4 m/s.

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 4-8. 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 4-8: 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 was provided by Exigo.

The significance ranking for all project phases is provided in Table 5-1 and provides the following significance ranking:

- Planning Phase: low;
- Construction phase: moderate to low for unmitigated activities and low for mitigated activities;
- Operation phase: moderate for unmitigated activities and low for mitigated activities;
- Closure and decommissioning phase: moderate to low for unmitigated activities and low for mitigated activities;
- Post-closure phase: low for unmitigated activities and negligible for mitigated activities.

Table 5-1: Significance ranking due to project activities

Activity	Impact	Without or With Mitigation	Nature (Negative or Positive Impact)	Probability		Duration		Scale		Magnitude/ Severity		Significance		Typical Mitigation Measures
				Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Score	Magnitude	
Planning Phase														
Existing baseline ambient conditions	PM_{10} concentrations, ambient $PM_{2.5}$ concentrations	WOM	Negative	Probable	2	Long term	4	Regional	3	High	8	30	Low	Best Engineering practice to minimise impact on surrounding environmental where feasible
		WM	Negative	Probable	2	Long term	4	Regional	3	High	8	30	Low	
Construction Phase														
Transport and general construction activities	Gaseous and particulate emissions; fugitive dust	WOM	Negative	Highly Probable	4	Short term	1	Site	2	High	8	44	Moderate	Maintenance of vehicles and wet suppression or chemical treatment on unpaved road and surfaces
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	
Clearing of groundcover and levelling of area	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Short term	1	Site	2	High	8	44	Moderate	Wet suppression where feasible. Minimise extent of disturbed areas. Reduction of frequency of disturbance. Early re-vegetation Stabilisation (chemical, rock cladding or vegetative) of disturbed soil.
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	
Materials handling	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Short term	1	Local	1	High	8	40	Low	Wet suppression where feasible on materials handling activities and reducing drop height.
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	

Activity	Impact	Without or With Mitigation	Nature (Negative or Positive Impact)	Probability		Duration		Scale		Magnitude/ Severity		Significance		Typical Mitigation Measures
				Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Score	Magnitude	
Wind erosion from open areas	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Short term	1	Site	2	High	8	44	Moderate	Wet suppression where feasible. Minimise extent of disturbed areas. Reduction of frequency of disturbance. Early re-vegetation Stabilisation (chemical, rock cladding or vegetative) of disturbed soil.
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	
Operational Phase														
Vehicle activity on paved roads	Gaseous and particulate emissions; fugitive dust	WOM	Negative	Highly Probable	4	Long term	4	Local	1	Medium	6	44	Moderate	Maintenance of vehicles and wet suppression or chemical treatment on unpaved road surfaces
		WM	Negative	Highly Probable	4	Long term	4	Local	1	Low	2	28	Low	
Materials handling operations	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Long term	4	Local	1	High	8	52	Moderate	Wet suppression where feasible on materials handling activities and reducing drop height. Enclosure or wet suppression on crushing activities.
		WM	Negative	Highly Probable	4	Long term	4	Local	1	Low	2	28	Low	
Wind erosion	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Long term	4	Site	2	High	8	56	Moderate	Wet suppression where feasible. Stabilisation (chemical, rock cladding or vegetative) of tailings facility.
		WM	Negative	Highly Probable	4	Long term	4	Local	1	Low	2	28	Low	

Activity	Impact	Without or With Mitigation	Nature (Negative or Positive Impact)	Probability		Duration		Scale		Magnitude/ Severity		Significance		Typical Mitigation Measures
				Magnitude	Score	Magnitude	Score	Magnitude	Score	Magnitude	Score	Score	Magnitude	
Closure and Decommissioning Phase														
Dust generated during rehabilitation activities	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Short term	1	Site	2	High	8	44	Moderate	Wet suppression where feasible
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	
Demolition of the structure	PM_{10} and $PM_{2.5}$	WOM	Negative	Highly Probable	4	Short term	1	Site	2	High	8	44	Moderate	
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	
Tailpipe emissions from vehicles utilised during the closure phase	Gaseous and particulate emissions; fugitive dust	WOM	Negative	Highly Probable	4	Short term	1	Local	1	High	8	40	Low	Maintenance of vehicles and wet suppression on unpaved road surfaces.
		WM	Negative	Highly Probable	4	Short term	1	Local	1	Medium	6	32	Low	
Post-Closure Phase														
Wind erosion from open areas	PM_{10} and $PM_{2.5}$	WOM	Negative	Probable	2	Long term	4	Regional	3	Medium	6	26	Low	Vegetation of open areas.
		WM	Negative	Probable	2	Long term	4	Regional	3	Low	2	18	Negligible	

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 unmitigated operations is crushing activities.

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 were identified to be the crushing operations and the windblown dust.

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 source of continuous fugitive dust emissions from the proposed project were identified to be crushing and screening activities.

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 TSFs 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

The current dust fallout network from the Glencore chrome mines consists of 11 single buckets. It is recommended that the dust fallout as currently sampled be continued during proposed operations. The only site that may need to be moved is Site 4, when the proposed tailings facility of Thorncliffe reaches full capacity (if it is in the way of the TSF footprint). The recommended performance assessment and reporting programme for ambient air sampling is given in Table 6-1.

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

Monitoring Strategy Criteria	Dustfall Monitoring
Monitoring objectives	- Assessment of compliance with dustfall limits within the main impact zone of the operation. - 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 the current dust fallout network comprising of 11 single dust buckets, be continued (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/m²/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.

Monitoring Strategy Criteria	Dustfall Monitoring
Interim environmental targets (i.e. receptor-based performance indicator)	Maximum total daily dustfall (calculated from total monthly dustfall) of not greater than 600 mg/m²/day for residential areas. Maximum total daily dustfall to be less than 1 200 mg/m²/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.

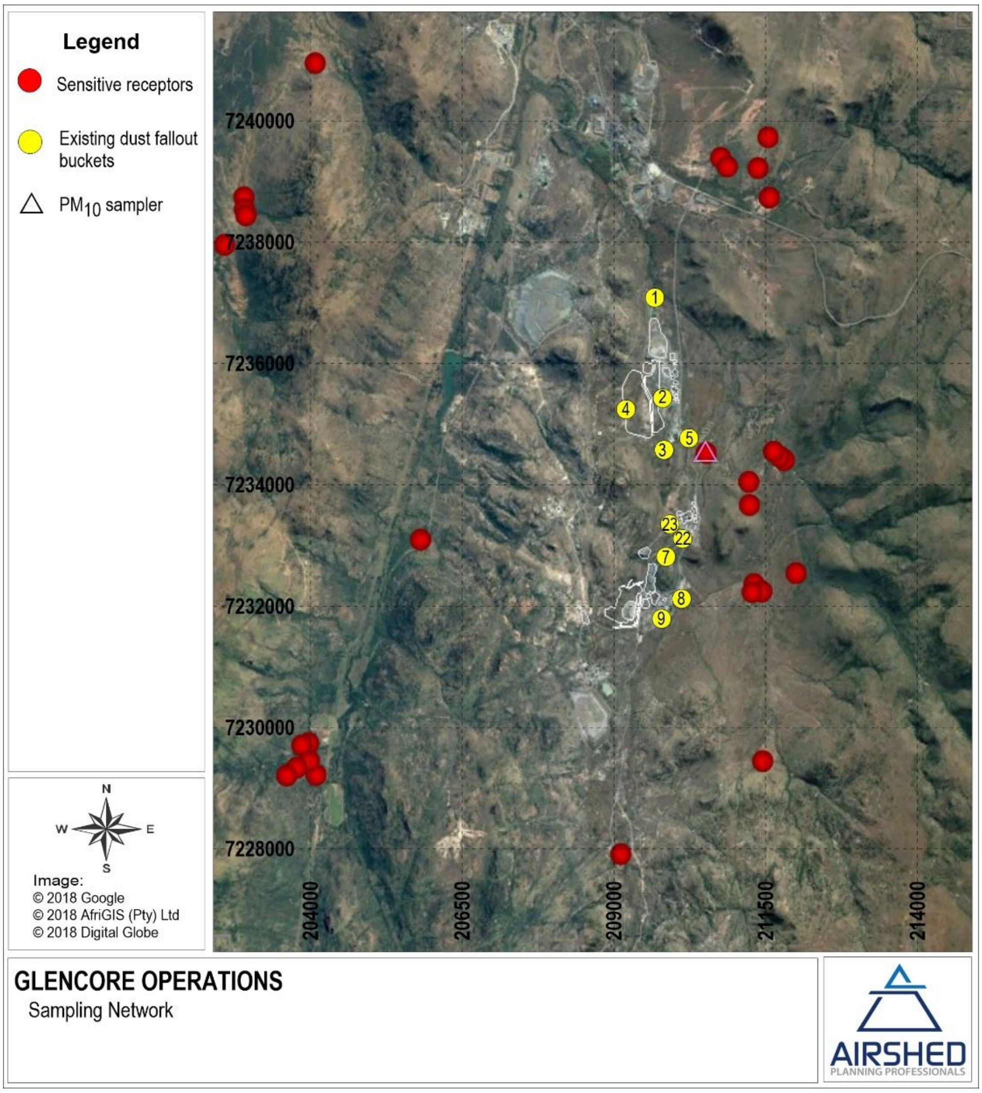


Figure 6-1: Sampling network for the project

PM_{10} Sampling

It is recommended that two PM_{10} sampling campaigns of 12 months be undertaken (to obtain daily PM_{10} concentration averages) prior to proposed operations (to understand the baseline PM_{10} concentrations – with the impacts of the Der Brochen TSF further east of Glencores operations) and once the proposed operations commence to ensure that NAAQS are being met (or at least not significantly altered from baseline conditions). 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. to the east of operations) to understand the operations impacts on surrounding sensitive receptors. 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 is provided in Table 6-2. 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 6-2: Air Quality Management Plan for the proposed project operations

Aspect	Impact	Management Actions/Objectives	Target Date
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
Wind erosion from the TSFs	PM_{10} and $PM_{2.5}$ concentrations and dustfall rates	It is recommended that the sidewalls of the tailings dam be vegetated. The vegetation cover should be such to ensure at least 80% control efficiency. The top surface area should have 40% wet area (if feasible). Other control measures that may be implemented (depending on the practicality) is to introduce a water spraying system on the surface of the tailings dam covering the outer perimeter of the dam, spraying water when wind exceeds 4 m/s. Exposed surface area should be kept to a minimum (if feasible).	On-going and post-operational phase
Ambient Monitoring	PM_{10} concentrations and dustfall rates	It is recommended that the current dust fallout network consisting of 11 dust buckets be continued during the proposed operations. Dust fallout rates should 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 receptor (east of operations) prior to proposed operations to understand baseline levels and once proposed mitigated operations take place in order to ensure the impacts from the project are kept to a minimum at sensitive receptors.	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 flow field is dominated by winds from the south-easterly sectors. During day-time conditions, winds from the north increase in frequency, with winds from the south-easterly sector increasing at night.

- The closest residential developments to the proposed project consist of Ga-Masha (~12 km northwest) and Steelpoort (~15 km north-northeast). Individual farmsteads also surround the Glencore mine area.

- Measured dust fallout at Helena Mine and Thorncliffe Mine is below the National Dust Control Regulation (NDCR) for non-residential areas (1 200 mg/m²/day) and residential areas (600 mg/m²/day) for the period 2016.

- Exceedances of the NDCR residential standard of 600 mg/m²/day (which allows for two exceedances in a year, not sequential months) was measured at the S23 sampling site at Magareng Mine during the period January to April and in August. The NDCR non-residential standard of 1200 mg/m²/day (which allows for two exceedances in a year, not sequential months) was reached at sampling site S23 but not exceeded.

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

- Crushing activities and windblown dust from the TSFs represented the highest impacting particulate sources from the current and proposed project operations.

- The highest $PM_{2.5}$ and PM_{10} concentrations due to proposed project operations (unmitigated) were in compliance with NAAQS at the closest sensitive receptors for all scenarios. When activities were mitigated (assuming 50% control efficiency on crushing activities) the $PM_{2.5}$ and PM_{10} concentrations reduced notably in magnitude and spatial distribution.

- Maximum daily dust deposition was within with the NDCR for residential areas at the closest sensitive receptors for all modelled scenarios.

7.2 Recommendations

It is 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 mitigation measures on the main sources of fugitive dust (as recommended in Table 6-4) be implemented to minimise impacts as far as possible.

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

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	René 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

René 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

René 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

René 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).

René 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, Lesotho, 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

- Understanding the Synoptic Systems that lead to Strong Easterly Wind Conditions and High Particulate Matter Concentrations on The West Coast of Namibia, H Liebenberg-Enslin, R von Gruenewaldt, H Rauntenbach and L Burger. National Association for Clean Air (NACA) conference, October 2017.
- 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.

______________________	22/11/2017
Signature of staff member	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: Reneé 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 2nd day of March 2018

SIGNATURE

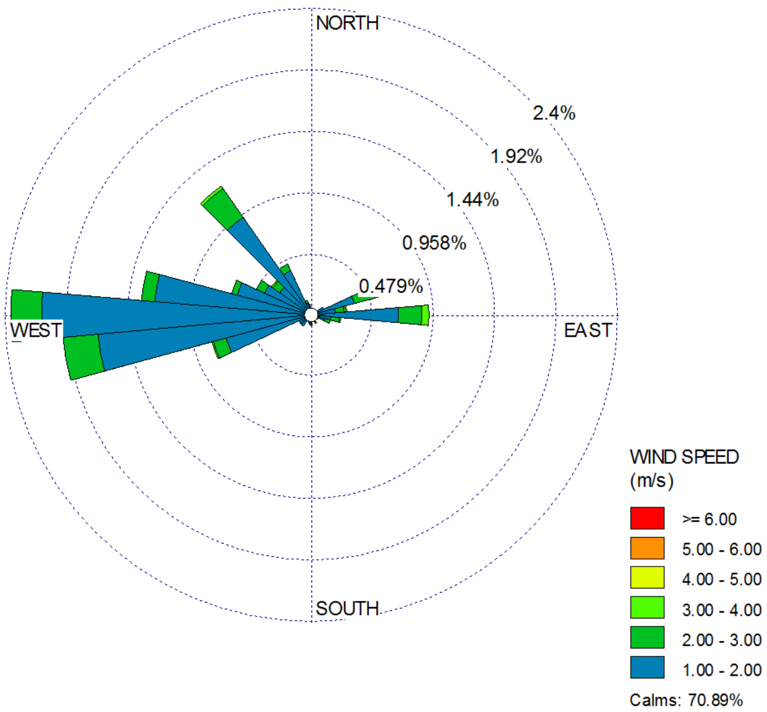
Principal Air Quality Scientist

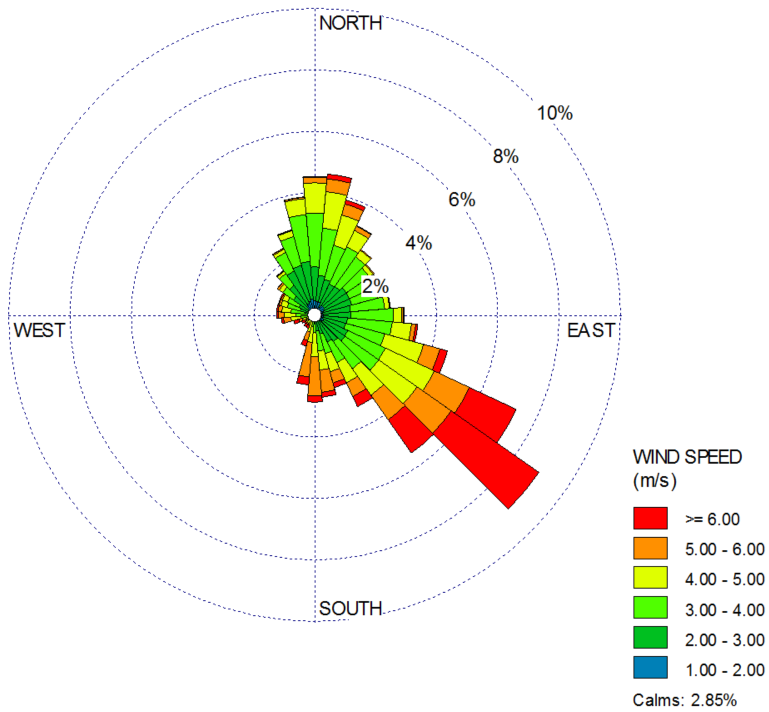
CAPACITY OF SIGNATORY

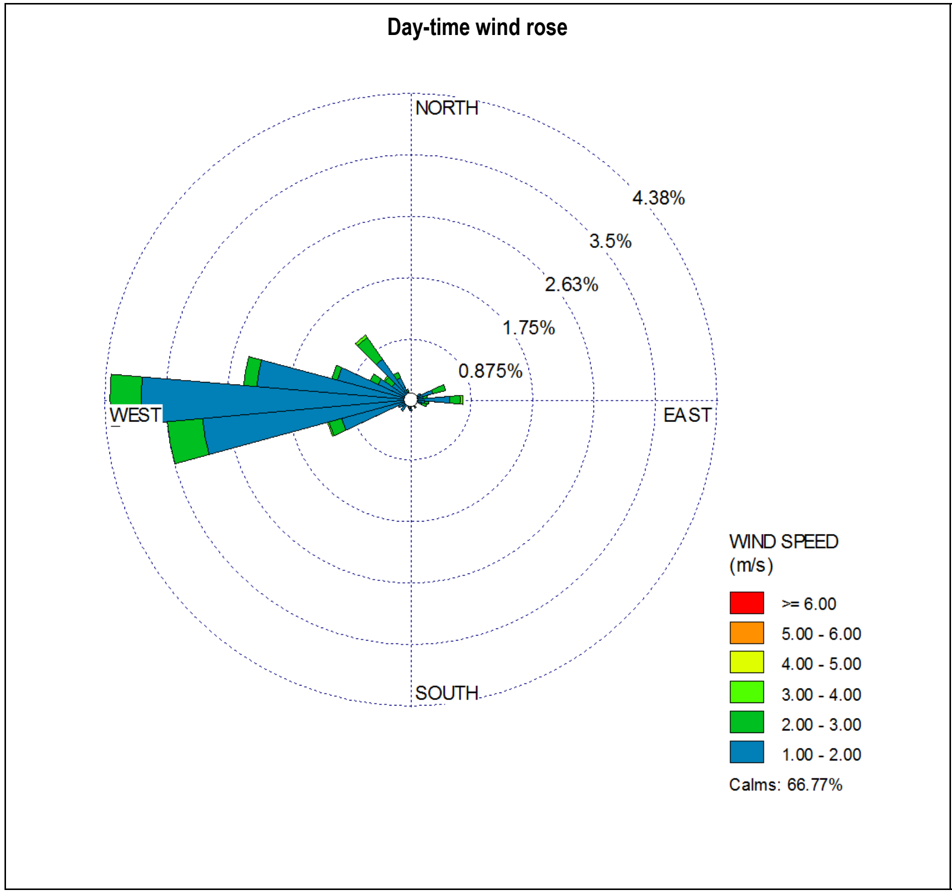
APPENDIX C – COMPARISON OF MEASURED WIND DATA AT HELENA MINE TO MODELLED MM5 METEOROLOGICAL DATA

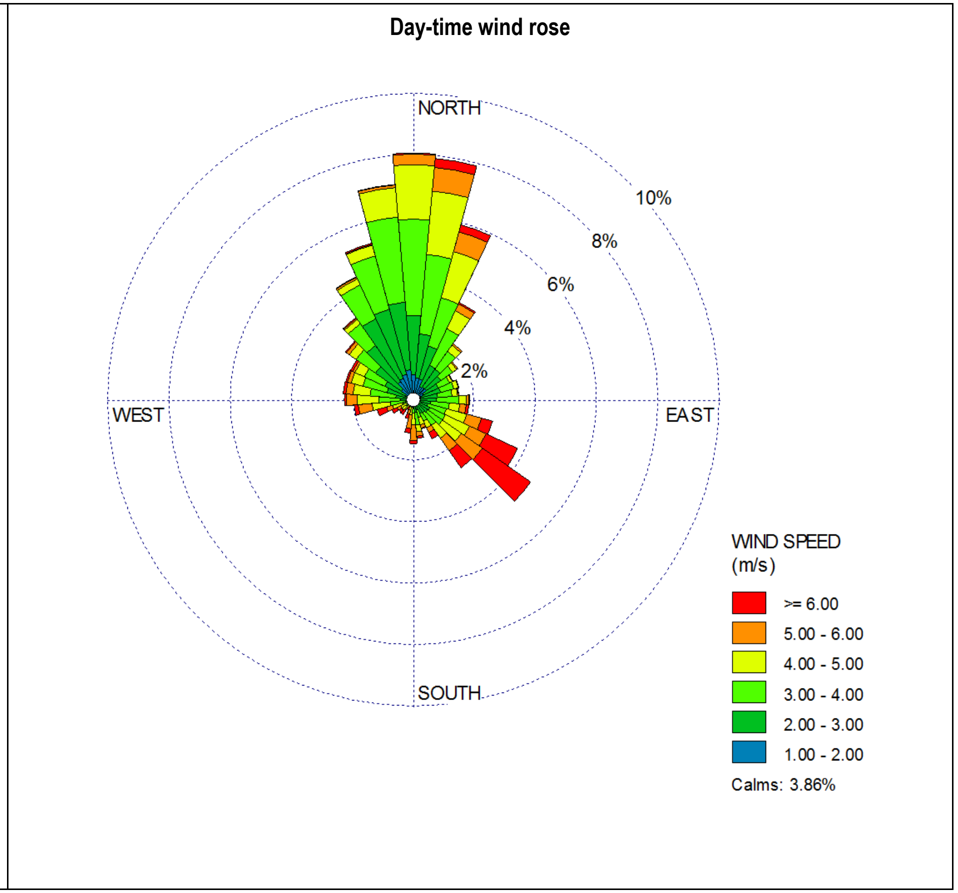
COMPARISON OF WIND DATA

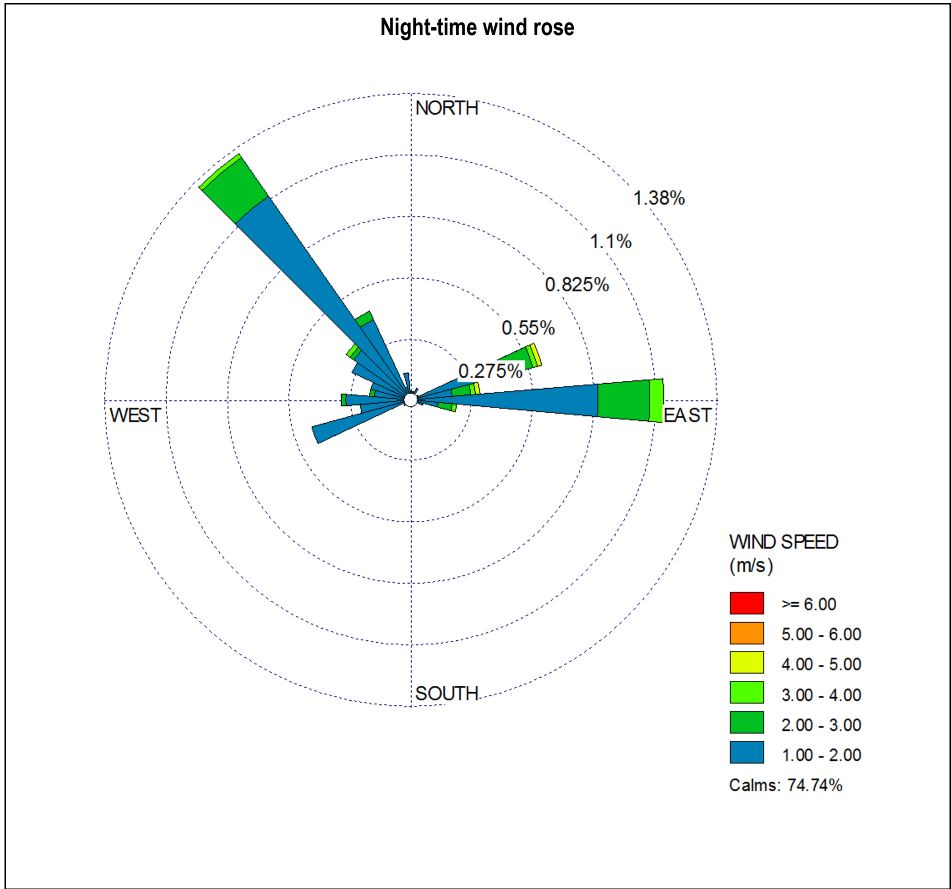
Meteorological Data Measured at Helena Mine	Modelled MM5 data
Period wind rose	**Period wind roses**

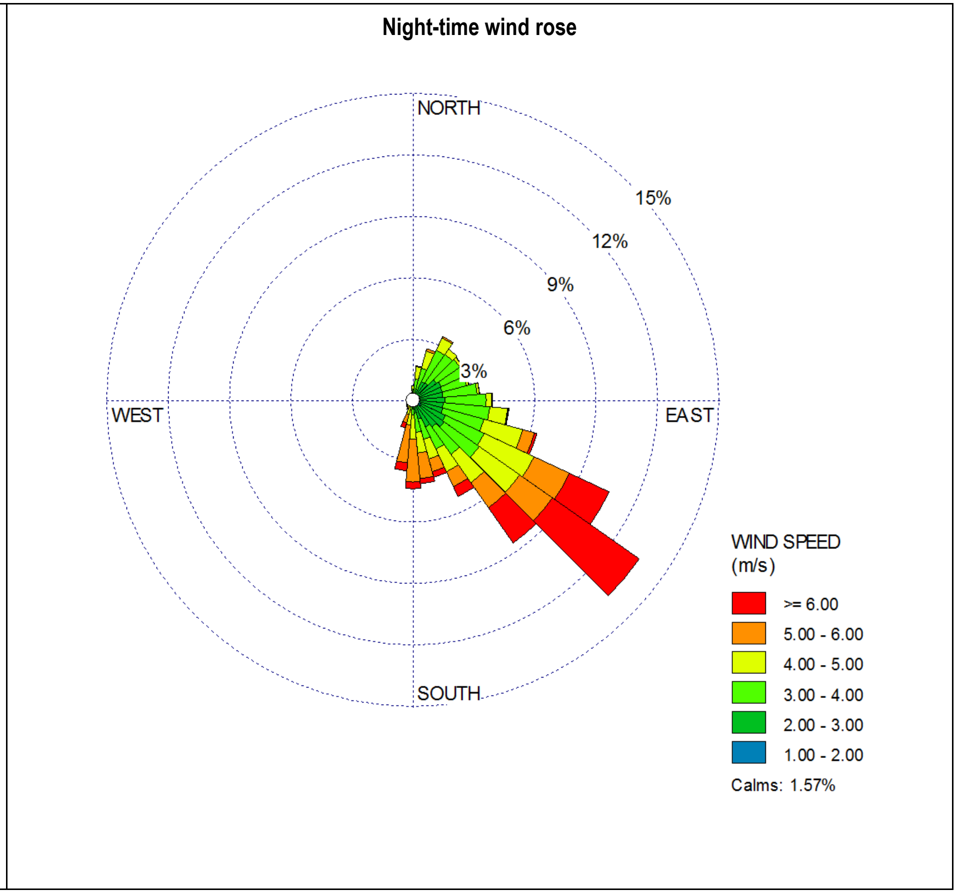





Day-time wind rose
NORTH
SOUTH
EAST
WEST
4.38%
3.5%
2.63%
1.75%
0.875%
WIND SPEED
(m/s)
>= 6.00
5.00 - 6.00
4.00 - 5.00
3.00 - 4.00
2.00 - 3.00
1.00 - 2.00
Calms: 66.77%


Day-time wind rose
NORTH
SOUTH
EAST
WEST
10%
8%
6%
4%
2%
WIND SPEED
(m/s)
>= 6.00
5.00 - 6.00
4.00 - 5.00
3.00 - 4.00
2.00 - 3.00
1.00 - 2.00
Calms: 3.86%





The concern with the measured data at Helena Mine is the high percentage calms and low wind speed for the entire period. Given the location of the station to prominent topographical features in the area, higher wind speeds and low calm conditions are expected with anabatic/katabatic flows and mountain/valley flows. There is also little to no wind observed from the south and north for period as well as day- and night-time conditions. It is suspected that this station may be sited incorrectly where flow is being blocked or reduced due to man-made structures.