Air Quality Specialist Report for the Proposed Heuningkranz Project

Project done for EXM Advisory Services (Pty) Ltd

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Report No: 17EXM01 | **Version:** Final | **Date:** February 2018

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Report Details

Project Number	17EXM01
Status	Final
Report Title	Air Quality Specialist Report for the Proposed Heuningkranz Project
Date	February 2018
Client	EXM Advisory Services (Pty) Ltd
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Revision Record

Revision Number	Date	Reason for Revision
Final	8 March	-

Abbreviations

AEL	Atmospheric Emission License
AERMIC	AMS/EPA Regulatory Model Improvement Committee
Airshed	Airshed Planning Professionals (Pty) Ltd
APPA	Air Pollution and Prevention Act
AQSR	Air Quality Sensitive Receptor
ASTM	American Society for Testing and Materials
DEA	Department of Environmental Affairs (South Africa)
IFC	International Finance Corporation
LoM	Life of Mine
NAAQS	National Ambient Air Quality Standards (South Africa)
NEMAQA	National Environmental Management Air Quality Act
NDCR	National Dust Control Regulation
NMES	National Minimum Emission Standard
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NPI	National Pollutant Inventory (Australia)
PM	Particulate matter
PM_{10}	Thoracic particulate matter with an aerodynamic diameter of less than 10 μm
$PM_{2.5}$	Inhalable particulate matter with an aerodynamic diameter of less than 2.5 μm
RoM	Run of Mine
SA	South Africa(n)
SO_2	Sulphur dioxide
TSP	Total Suspended Particulates
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled

Executive Summary

An air quality impact assessment was conducted for activities planned for the Heuningkranz Mine near Postmasburg in the Northern Cape. The main objective of this study was to quantify the extent to which existing ambient pollutant levels will change as a result of the mine. The impact study then informed the air quality management and mitigation measures recommended as part of the Air Quality Management Plan (AQMP).

The air quality impact assessment included a study of the receiving environment and the quantification and assessment of the impact of Heuningkranz Mine on human health and the environment. The receiving environment was described in terms of local atmospheric dispersion potential, the location of potential quality sensitive receptors (AQSRs) in relation to proposed activities as well as ambient pollutant levels and dustfall rates. The following was found:

- The study area is dominated by winds from the north-northwest. Long term air quality impacts are therefore expected to the most significant to the south-east of the operations.
- Several farm houses or farmsteads are situated within a few hundred meters from proposed activities. The nearest residential area is Postmasburg which lies 18 km south-east of the project.
- Current ambient air quality monitoring for the Heuningkranz mine area indicated ambient PM_{10} and $PM_{2.5}$ levels in compliance with the National Ambient Air Quality Standards (NAAQSs) but dustfall rates in exceedance of the National Dust Control Regulations (NDCR).

A comprehensive atmospheric emissions inventory was then compiled for the project. Pollutants quantified included those most commonly associated with mining i.e. particulate matter (PM) (TSP, PM_{10}, and $PM_{2.5}$).

Estimated emissions along with information on the receiving environment were used as input to an atmospheric dispersion model which simulated ground level pollutant concentrations and dustfall rates. Simulated ground level pollutant concentrations and dustfall rates were screened against NAAQSs and NDCR. The main findings of the impact study are listed below.

- Operational phase PM emissions ($PM_{2.5}$, PM_{10} and TSP) were quantified and used in simulations.
- Simulated ground level $PM_{2.5}$ and PM_{10} concentrations were compliant with air quality criteria at the identified AQSRs.
- Simulated ground level dustfall rates were compliant with NDCR at the identified AQSRs.
- The proposed Heuningkranz project has a moderate significance ranking.

To ensure the lowest possible impact on AQSRs and environment it is recommended that the air quality management plan as set out in this report should be adopted. In summary, this includes:

- The mitigation of sources of emission. Special attention should be paid to the mitigation of dust from unpaved haul roads; and
- Continued ambient air quality monitoring, including:
  - Gravimetric sampling of PM_{10} and $PM_{2.5}$ concentrations.
  - Continued dustfall sampling around operations with an additional 2 locations proposed.

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1 INTRODUCTION

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by EXM Advisory Services (Pty) Ltd (EXM) to conduct the air quality impact specialist study for the Proposed Heuningkranz Project (the project) in the Northern Cape approximately 20 km north-west of Postmasburg.

The following tasks, typical of an air quality impact assessment, were included in the scope of work:

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

1.1 Description of Project Activities from an Air Quality Perspective (EXM, 2017)

The Sishen Iron Ore Company (Pty) Ltd is proposing to incorporate the Heuningkranz Section into the existing Kolomela Mine mining right. The Heuningkranz Section includes the Farm 364 (Heuningkranz) and Farm 432 (Langverwacht), Portion 1, located approximately 18 km north west of Postmasburg, in the Tsantsabane Local Municipal area, and 18 km north north west of the main infrastructure area at Kolomela Mine.

The construction of infrastructure and the stripping of overburden is scheduled to commence at Heuningkranz in 2031, with the first ore being mined and processed in 2034. The inclusion of the Heuningkranz Section, will extend the life of Kolomela Mine by an additional 14 years, until 2048.

Mining at the Heuningkranz Section will be from 2 open pits, the Heuningkranz North and Heuningkranz South Pits. Overburden and waste rock originating from the Heuningkranz North and South Pits will be placed on surface to create waste rock dumps. It is planned that 6 million tonnes per annum (Mtpa) of iron ore will be processed by using ultra high dense media separation (UHDMS) at a new processing plant to be developed at Heuningkranz. Mineral waste from processing by UHDMS will be managed into two mine residue facilities: a discard dump and slimes dam, that will be developed at Heuningkranz. A further 4.2 Mtpa of high grade ore will be railed to Kolomela Mine, for processing at the existing Kolomela direct shipping ore (DSO) plant. Primary and secondary crushing of this ore will take place at Heuningkranz. A rail link will be developed at Heuningkranz both for the export of product directly from Heuningkranz as well as the transport of DSO material to Kolomela via the existing iron ore rail line for processing. The total maximum production from Heuningkranz will be 10.2 Mtpa.

Conventional open cast mining methods will be employed where ore and waste rock is drilled and blasted, loaded to haul trucks for transport either to waste rock dumps or the beneficiation plant. At the beneficiation plants (2 plants operational at any time - the DSO plant and the DMS plant), ore will be stockpiled, crushed and screened before being hauled to a nearby rail siding for rail transport.

Airborne emissions may occur during all phases of the mining cycle. The most notable sources of fugitive PM include drilling, blasting, ore and waste rock handling, windblown dust from exposed surfaces such as stockpiles as well as traffic on haul routes. 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 discussion, regulation and estimation of PM emissions and impacts a distinction is made between different particle size fractions, viz. TSP, PM_{10} and $PM_{2.5}$. PM_{10} is defined as particulate matter with an aerodynamic diameter of less than 10 µm and is also referred to as thoracic particulates. Inhalable particulate matter, $PM_{2.5}$, is defined as particulate matter with an aerodynamic diameter of less than 2.5 µm. Whereas PM_{10} and $PM_{2.5}$ fractions are taken into account to determine the potential for human health risks, total suspended particulate matter (TSP) is included to assess nuisance dustfall.

1.2 Approach and Methodology

The approach to, and methodology followed in the completion of tasks completed as part of the scope of work are discussed.

1.2.1 The Identification of Regulatory Requirements and Health Thresholds

In the evaluation air emissions and ambient air quality impacts reference was made to:

- National Minimum Emission Standards (NMES), National Ambient Air Quality Standards (NAAQS) and National Dust Control Regulations (NDCR) as set out in the National Environmental Management Air Quality Act (Act No. 39 of 2004) (NEMAQA)

1.2.2 Study of the Receiving Environment

Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology. Existing ambient air quality in the study area was also considered.

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. Use was made of on-site meteorological data, for the period between May 2015 to August 2017. According to the regulations regarding air dispersion modelling, a minimum of 1-year on-site specific data or at least three years of appropriate off -site data must be used for Level 2 assessments. As this is on-site data, this meets the regulations.

1.2.3 Determining the Impact of the Project on the Receiving Environment

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's emissions on the receiving environment. In the quantification of emissions, use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. Emissions were calculated using comprehensive sets of emission factors and equations as published by the United States Environmental Protection Agency (US EPA) and Australian National Pollutant Inventory (NPI).

The following emission scenario was identified (Table 1-1):

- Scenario: 2035 (year with maximum quantities of ROM, and the ROM coming from the pit closest to the sensitive receptors, i.e. the north pit – 10.8 Mtpa ore and 65 Mtpa waste – 75.8 Mtpa to be handled and transported, with all the ore and waste coming from the North pit)

Table 1-1: Scenario selected for the dispersion modelling

Selected Year	North pit waste (Mtpa)	South pit waste	Total waste (Mtpa)	North pit ore (Mtpa)	South pit ore	Total ore (Mtpa)
2035	65	-	65	10.8	-	10.8

In the simulation of ambient air pollutant concentrations and dustfall rates use was made of the US EPA AERMOD atmospheric dispersion modelling suite. The Department of Environmental Affairs (DEA) prescribes the use of AERMOD for regulatory purposes. It is a Gaussian plume model best used for near-field applications where the steady-state meteorology assumption is most likely to apply. AERMOD is a model developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC dispersion model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

1.2.4 Compliance Assessment and Health Risk Screening

Compliance was assessed by comparing simulated ambient criteria pollutant concentrations ($PM_{2.5}$, PM_{10}) and dustfall rates to NAAQS's and NDCR's. In addition, Anglo American Limited has developed internal air quality performance requirements which are discussed in Section 2.3 and are also followed in this assessment.

1.2.5 The Development of an Air Quality Management Plan

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

1.3 Assumptions, Exclusions and Limitations

Several assumptions regarding the mine plan and process had to be made in the study. These, along with other limitations are listed below and should be noted when interpreting the outcomes of the study:

- The quantification of sources of emission was restricted to proposed operations at Heuningkranz.
- Project information required to calculate emissions for operations were provided by EXM. Where necessary, assumptions were made based on the specialist's experience.
- Only routine operational phase emissions were estimated and simulated.
- The impact assessment was limited to airborne particulates (including TSP, PM_{10} and $PM_{2.5}$).
- Information pertaining to fuel use and storage was limited. Diesel storage VOC emissions could therefore not be quantified. Even though the storage of diesel on-site is considered a listed activity under NEMAQA if total storage capacity exceeds 1 000 m^3, VOC emissions from such operations are negligible.

- Construction and decommissioning/closure phase impacts were not quantified. Impacts associated with this phase are highly variable and generally less significant than operational phase impacts. Mitigation and management measures recommended for the operational phase are however also applicable to the construction/closure phase.

2 Regulatory Requirements and Assessment Criteria

Prior to assessing the impact of proposed activities at Heuningkranz on human health and the environment, reference needs to be made to the environmental regulations governing the impact of such operations i.e. emission standards, ambient air quality standards and dust control regulations.

Emission standards are generally provided for point sources and specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment.

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 and guideline values 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 or exposure periods.

This section summarises national legislation for criteria pollutants relevant to the current study and dustfall.

2.1 Anglo Air Quality Performance Standard

Anglo American has developed internal air quality performance requirements to ensure that all Anglo American projects and managed operations implement management measures to avoid or minimise potential adverse impacts on ambient air quality.

These Performance Requirements and supporting documentation contains additional minimum requirements for responsible management of air quality and applies to all on-site and off-site activities managed by Anglo American during the entire mining lifecycle, including exploration, evaluation, operation and closure.

A summary of the Air Quality Performance Requirement is provided below.

2.1.1 General Requirements

2.1.1.1 Environmental aspects

Where there is the potential for significant adverse impacts on air quality:

- Establish an inventory of emissions to air, which includes: the location of all point and fugitive sources; types of pollutant and concentrations emitted; stack heights and control measures;
- Characterise the receiving environment, including the sensitivity, proximity and direction; and
- Identify all significant pollutants.

2.1.1.2 Legal and Other Requirements

Use the following legislation and standards as a basis when conducting impact assessments for criteria pollutants:

- Host country standards for ambient air quality and emissions to air, as a minimum.
- European Community (EC) Limit Values, where there are no host country standards.
- EC ambient air quality target values for Arsenic, Cadmium or Nickel, unless there are specific host country standards.

Use the following guidelines as a basis for screening when conducting impact assessments for non-criteria pollutants:

- The World Health Organisation (WHO) guideline values for non-carcinogens and unit risk factor guidelines for carcinogens.
- The US-EPA's Integrated Risk Information System (IRIS) guidelines for chronic and sub-chronic inhalation reference concentrations and cancer unit risk factors.
- The Texas Natural Resource Conservation Commission Toxicology and Risk Assessment (TARA) Division guidelines for acute, sub-acute and chronic effect screening levels.
- The Californian Office of Environmental Health Hazard Assessment (OEHHA) guidelines for reference exposure levels.
- The US Federal Agency for Toxic Substances and Disease Registry (ATSDR) guidelines for minimum risk levels.

Assessments need to take into account trans-boundary pollution and the implications thereof where applicable.

2.1.1.3 Risk/Impact Assessment

Assess potential impacts on air quality by using dispersion modelling. This shall be undertaken in relation to applicable legal standards as well as the targets as described in the performance requirement. Impacts and risks are to be stated in terms of the pollutant maximum predicted concentrations, the percentage contribution to the standard, the frequency of exceedence and the margin by which any such standards are exceeded.

2.1.1.4 Objectives and Targets

Set as the internal air quality target the EC Limit Values, in cases where the host country standard is less stringent than that of the EC Limit Values.

Set out to contribute no more than 70% of the EC Limit Value, not to exceed this contribution to ambient air levels by more than a pre-determined frequency corresponding to that of the EC Limit Values.

Apply the target to all locations where members of the public may be exposed at a frequency or duration which could influence the exposure averaging periods of the EC Limit Values (e.g. 24-hours, annual). Apply host-country standards to all other locations.

2.1.1.5 Plan/Design Environmental Programmes and Operation Controls

Where there is the potential for significant adverse impacts on air quality:

- Evaluate appropriate emission abatement technology/equipment and incorporate this into the scope of work in order to ensure that air pollution impacts do not exceed the internal targets;
- Develop management measures that incorporate, as a minimum, controls to reduce air quality risks/impacts to as low as reasonable practicable or to levels which achieve the internal air quality target; and
- Record this process in an Air Quality Management Plan.

2.1.1.6 Monitoring

Establish a regular and up-to-date monitoring programme for significant emissions (point and fugitive) arising from the operations activities, products and services.

2.1.1.7 Communication and Stakeholder Engagement

Where there is the potential for significant adverse impacts on air quality, ensure that communities are made aware of the significant pollutants emitted from the operation (including their concentration and distribution).

2.1.2 Specific Requirements with regard to the Project

2.1.2.1 Evaluation Stage: Projects

All projects shall:

- Conduct screening-level dispersion modelling during the Pre-feasibility phase based on the monitoring data received from the exploration/ prospecting stage. Identify pollutants which may be significant by having a detailed understanding of the chemistry and constituents of the materials which will be processed.
- Conduct advanced dispersion modelling during the Feasibility phase, for pollutants that the screening-level dispersion model indicated have the potential for significant adverse impacts on air quality or receiving soil and water bodies.
- Identification of specific legal and other requirements needs to be done at this stage. Taking into account the timing of the project all legal and other authorization need to be achieved before the Feasibility phase is complete.

Air pollution significance is based on any of the following:

- It exceeds 70% of the emission rate allowed in the emission license.
- It contributes more than 25% to the European Union (EU) air quality standards.
- More than 50 tpa PM_{10} or 500 tpa NO_x or SO_2 are emitted from an operation.
- Communities perceive there to be unacceptable levels of pollution, or consequent health impacts.
- Emissions, other than PM_{10}, NO_x or SO_2 exceed reporting or significance thresholds of the E-PRTR (Europe), or the equivalent relevant reporting threshold in the host country.
- The result in ambient air concentrations, either predicted or measured, which exceed health risk criteria for elements or compounds as listed in the WHO Guidelines, Integrated Risk Information System (IRIS) Inhalation reference concentrations, California OEHHA, US ATSDR Maximum Risk Levels, or TARA effect screening levels.
- Carcinogens which, when assessed against Unit risk factors of the US-EPA IRIS result in cancer risks of greater than 1 in a million, applied to a person being in contact with the substance for 70 years, 24 hours a day.

2.2 National Minimum Emission Standards

The minister must in accordance with the NEMAQA (Act No. 39 of 2004) publish a list of activities which result in atmospheric emissions and which is believed to have significant detrimental effects on the environment and human health and social welfare. All scheduled processes as previously stipulated under the Air Pollution Prevention Act (APPA) are included as listed activities with additional activities being added to the list. The most recent Listed Activities and NMES's were published on the 22nd of November 2013 (Government Gazette No. 37054).

Only the on-site storage of diesel may be considered a listed activity. Subcategory 2.4, *'the storage and handling of petroleum products'*, are however only applicable to permanent immobile liquid storage facilities at a single site with a combined storage capacity of more than 1 000 m^3, and an AEL is required for installations exceeding that storage volume.

2.3 National Ambient Air Quality Standards for Criteria Pollutants

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. South African NAAQS for CO, NO_2, PM_{10} and SO_2 were published on the 13th of March 2009 (Government Gazette, 2009). On the 24th of December 2009 standards for $PM_{2.5}$ were also published (Government Gazette, 2012). These standards are listed in Table 2-1.

Table 2-1: South African NAAQS for criteria pollutants

Pollutant	Averaging Period	Limit Value (µg/m³)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
$PM_{2.5}$	24 hour[(a)]	40	-	4	1 Jan 2016 – 31 Dec 2029
	24 hour	25	-	4	1 Jan 2030
	1 year[(a)]	20	-	0	1 Jan 2016 – 31 Dec 2029
	1 year	15	-	0	1 Jan 2030
PM_{10}	24 hour	75	-	4	Immediate
	1 year	40	-	0	Immediate

Notes:

(a) Used in this assessment.

2.4 International Ambient Air Quality Standards for Criteria Pollutants

The EC limit values for the protection of human health (as obtained from the EC Directive, 2008/50/EC are provided in Table 2-2 for pollutants of concern for the current assessment. These are included as the Anglo Air Quality Performance Standard sets internal targets for Anglo Projects based on the EC limit values.

Table 2-2: EC limit values for criteria pollutants

Pollutant	Averaging Period	Limit Value (µg/m³)	Frequency of Exceedance	Compliance Date
PM_{10}	24 hour	50	35	Immediate
	1 year	40	0	Immediate

2.5 National Dust Control Regulations

NDCRs were published on the 1st of November 2013 (Goverment Gazette, 2013). Acceptable dustfall rates according to the Regulation are summarised in Table 2-3.

Table 2-3: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m²-day over a 30 day average	Permitted frequency of exceedance
Residential areas	D < 600	Two within a year, not sequential months.
Non-residential areas	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. It should be noted that the requirements of the regulations only become applicable to a specific installation or site after a written notice has been given to the site/installation by the local Air Quality Officer.

3 DESCRIPTION OF THE RECEIVING ENVIRONMENT

3.1 Air Quality Sensitive Receptors

A study area, determined from the expected impact area, of 15 km east-west by 15 km north-south with the project located centrally was included. The study area is shown in Figure 3-1 and Table 3-1 with identified scattered AQSRs indicated. AQSRs generally include places of residence and areas where members of the public may be affected by atmospheric emissions generated by mining/industrial activities. The nearest residential area is Postmasburg which lies 17 km south-east of the project.

The land use in the area comprises primarily of agricultural activities and open natural areas.

Table 3-1: AQSRs

Number	Farm	Name
SR1	Broomlands	Bennie Bredenkamp
SR2	Lucasdam	John Daniel
SR3	Blinklip	
SR4	Putjie	Sante Maritz
SR5	Lynput	Chris Claassens
SR6	Makganyene	Bok Wessels
SR7		
SR8		
SR9	Mogoloring	J.J. Claassens
SR10	Aarkop	J.J. Claassens
SR10A		
SR11	Maartahspoort	C.C. Claassens
SR12	Aucampsrus	
SR13	Kameelhoek	Rassie Erasmus
SR14	Kameelhoek	Rudie Erasmus
SR15		

3.2 Atmospheric Dispersion Potential

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

3.2.1 Land Use and Topography

The topography is characterised by failrly flat terrain ranging from 1380 (south east of the mine boundary) to 1240 (western boundary) metres above mean sea level (mamsl). No topography was included in dispersion simulations.

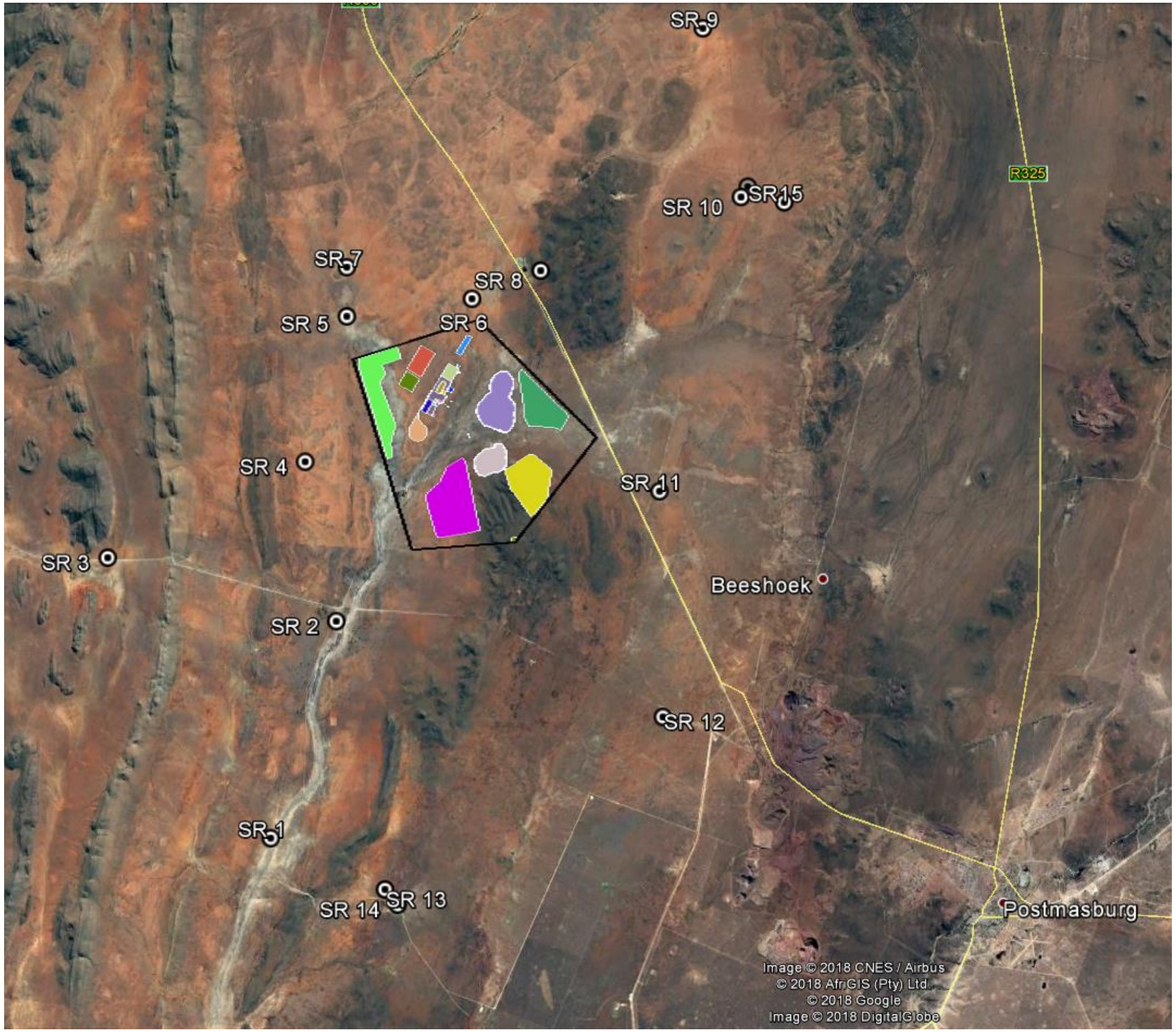


Figure 3-1: Mining boundary and AQSRs

3.2.2 Surface Wind Field

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; for example, dark green representing winds in between 3 and 4 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind field and diurnal variability in the wind field are shown in Figure 3-2. During the 2015 to 2017 period, the wind field was dominated by winds from the north-northwest, the north and the south. Calm conditions occurred less than 1% of the time, with the average wind speed over the period calculated as 5.2 m/s.

There was a shift from the night to the daytime wind field, with predominantly north-north-westerly winds during the day. Wind speeds increased during the day-time conditions.

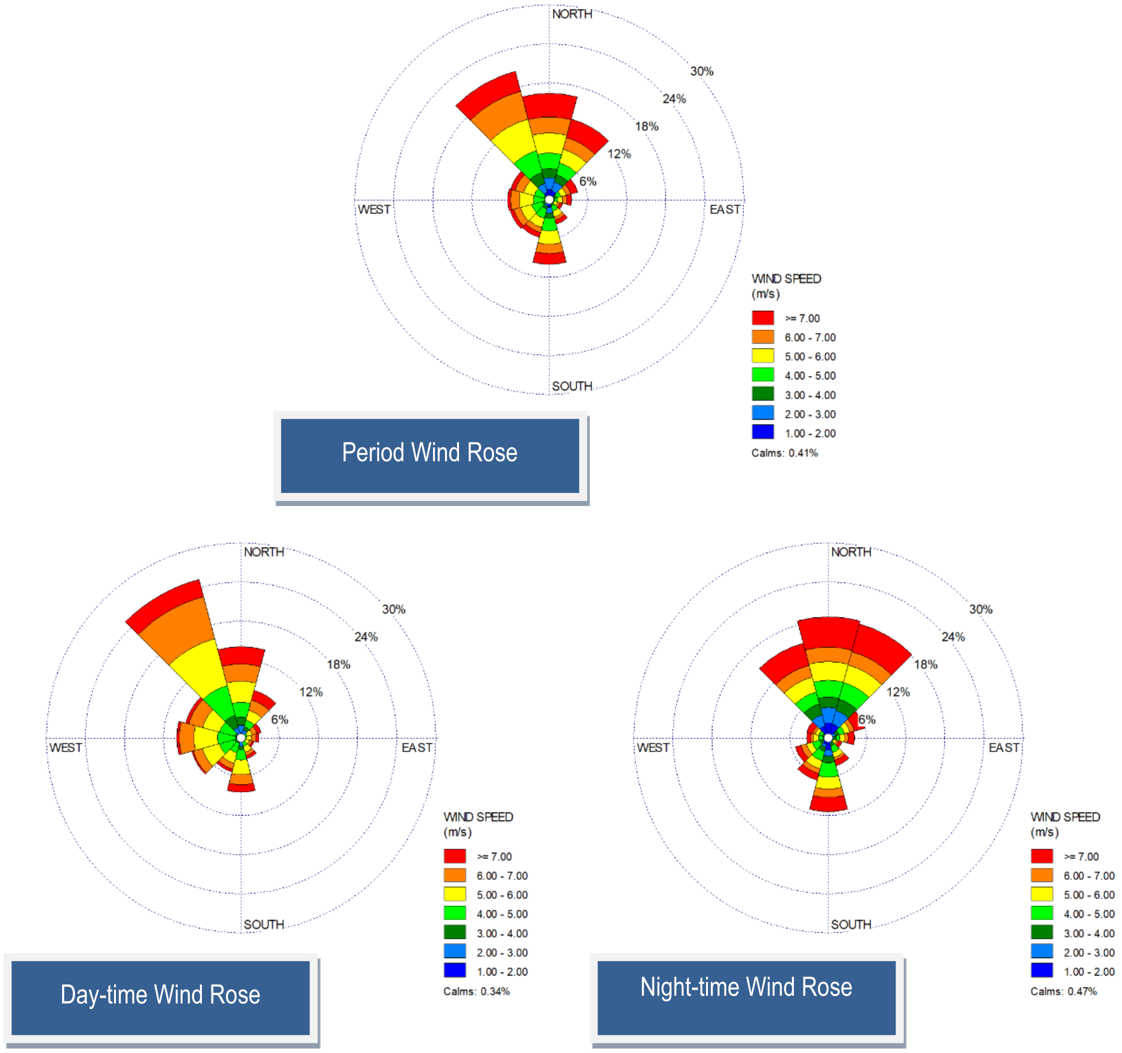


Figure 3-2: Period, day- and night-time wind roses (on-site data, May 2015 to August 2017)

3.2.3 *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 and hourly maximum and minimum temperatures are given in Table 3-2. Temperatures ranged between -8.1 °C and 41.4 °C. The highest temperatures occurred in December and the lowest in July. During the day, temperatures increase to reach maximum at around 14:00 in the afternoon. Ambient air temperatures decrease to reach a minimum at around 06:00 i.e. just before sunrise.

Table 3-2: Monthly temperature summary

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	10.0	9.4	3.6	2.0	-1.1	-5.1	-8.1	-6.3	-0.8	1.8	4.8	10.9
Maximum	41.4	37.4	35.7	34.1	28.1	26.3	26.9	31.7	35.9	39.0	39.3	39.5
Average	25.0	24.5	22.1	18.0	14.0	10.7	10.1	13.9	17.3	22.2	23.8	27.1

3.2.4 *Rainfall*

Precipitation is important to air pollution studies since it represents an effective mechanism of removing pollutants from the environment. On its way to the surface rain water combines with lots of pollutants in atmosphere; this process may alter the composition of rain by making it acidic but this also means that the pollutants are removed from the atmosphere which may reduce the impacts on human health. There is no ambient rainfall data available for the Heuningkranz station.

3.3 Ambient Air Pollutant Concentrations and Dustfall Rates

The region is characterised by being a relatively dry, arid and dusty region. It is expected that various local and far-a-field sources will contribute to suspended fine particulate ($PM_{2.5}$ and PM_{10}) concentrations in the region. Local sources include wind erosion from exposed areas, fugitive dust from agricultural activities and mining activities, vehicle entrainment from roadways and veld burning. Long range particulates can result from remote tall stack emissions and from large scale biomass burning in countries to the north of South Africa. These have been found to contribute significantly to background fine particulate concentrations over the interior of South Africa ((Andreae, 1996), (Garstang, 1996), (Piketh, Annegarn, & Kneen, 1996)).

Kumba Iron Ore installed a continuous monitor and meteorological station at Heuningkranz, which began recording data in May 2015. The data recorded includes hourly PM_{10} and $PM_{2.5}$. A dust monitoring network has been installed since July 2013. Data available for this ambient air quality range from May 2015 to August 2017, approximately 2 years' worth of data. Both PM_{10} and $PM_{2.5}$ are screened against NAAQS while dustfall is screened against the NDCR.

3.3.1 *Ambient PM_{10} and $PM_{2.5}$*

The results of PM_{10} and $PM_{2.5}$ monitoring are represented in Table 3-3 and Table 3-4 as well as Figure 3-3 and Figure 3-4.

The annual average PM_{10} concentration recorded at Heuningkranz for 2015, 2016 and 2017 were 22 µg/m³, 14 µg/m³ and 17 µg/m³ respectively. The annual NAAQS for PM_{10} is 40 µg/m³. The highest daily concentration recorded was 113 µg/m³ during 2015. The frequency of exceedence (NAAQs = 4 days allowed at 75 µg/m³) recorded for 2015,2016 and 2017 are 2 days, 1 day and 0 days respectively.

Currently, the ambient air quality in the vicinity of Heuningkranz is in compliance with the NAAQS for PM_{10}. The ambient air quality also meets the Anglo internal air quality target as it contributes no more than 70% of the EC Limit Value.

The annual average $PM_{2.5}$ concentration recorded at Heuningkranz for 2015, 2016 and 2017 were 8 µg/m³, 6 µg/m³ and 6 µg/m³ respectively. The current annual NAAQS for $PM_{2.5}$ is 20 µg/m³. The highest daily concentration recorded was 31 µg/m³ during 2016. No exceedences of the daily limit value were recorded for $PM_{2.5}$ daily concentrations (NAAQs = 4 days allowed at 40 µg/m³).

Currently, the ambient air quality in the vicinity of Heuningkranz is in compliance with the NAAQS for $PM_{2.5}$.

Table 3-3: Summary of PM_{10} concentrations for the Heuningkranz station

Year	Data availability	Annual average (µg/m³)	Highest daily average (µg/m³)	Number of exceedences of 75 µg/m³
2015	59%	22	113	2
2016	81%	14	112	1
2017	62%	17	65	0

Table 3-4: Summary of $PM_{2.5}$ concentrations for the Heuningkranz station

Year	Data availability	Annual average (µg/m³)	Highest daily average (µg/m³)	Number of exceedences of 40 µg/m³
2015	59%	8	25	0
2016	81%	6	31	0
2017	62%	6	22	0

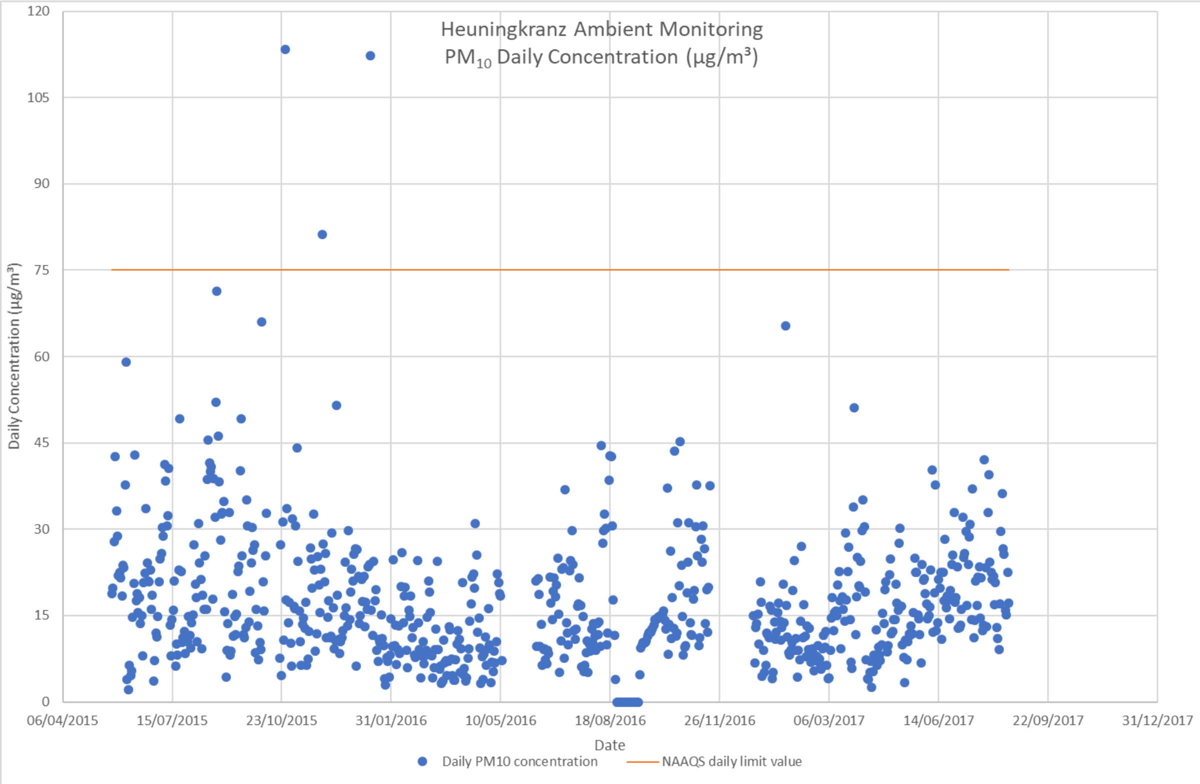


Figure 3-3: PM_{10} daily concentrations

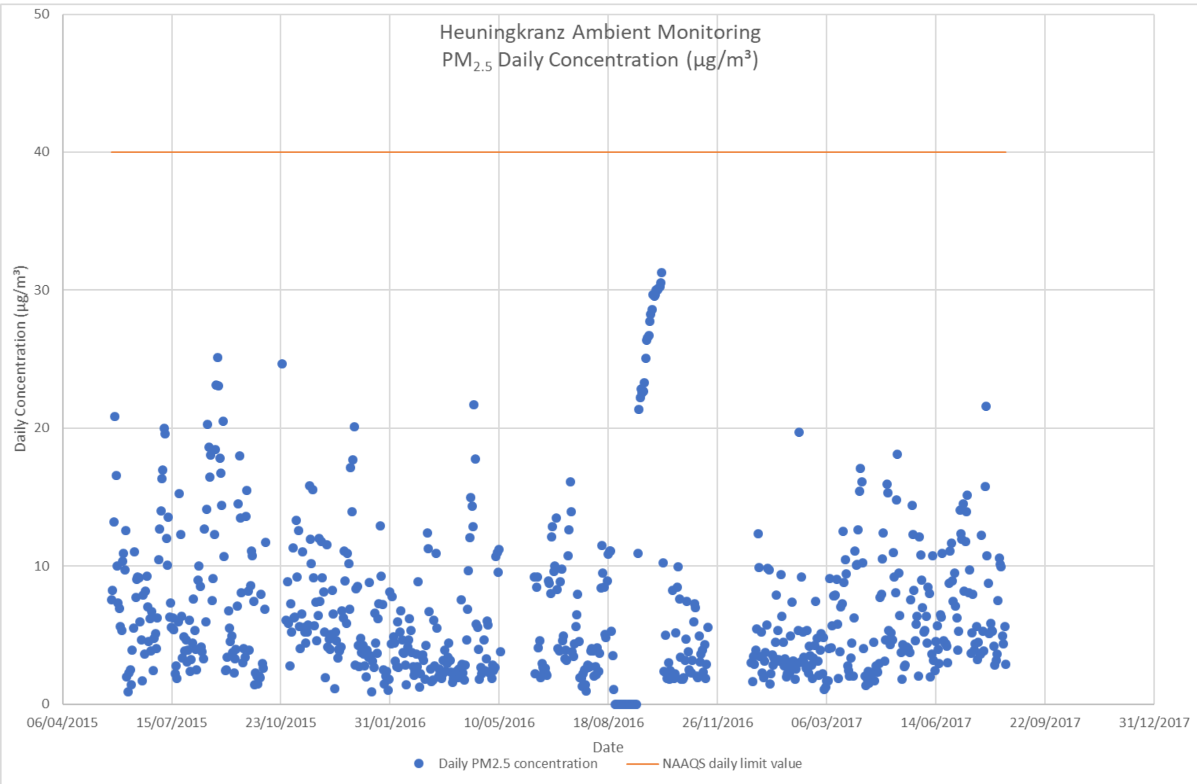


Figure 3-4: $PM_{2.5}$ daily concentrations

Concentration values have been compared to wind speed and direction recorded. This information is most easily visualised as a polar plot (Carslaw & Ropkins, 2012), with the results provided in Figure 3-5 and Figure 3-6. Figure 3-7 and Figure 3-8 provides a time series plot for the PM_{10} and $PM_{2.5}$ measured. From both the polar plots it can be seen that there is a distinct source of PM_{10} and $PM_{2.5}$ that results in higher concentrations under wind speeds of ~ 4 m/s (i.e. are further away from the station). This source is located north of the station. The source located north of the station is unknown but may be due to traffic on the unpaved roads.

The time series plot indicates peak PM_{10} and $PM_{2.5}$ concentrations during the mornings (around 09h00). Increased PM_{10} and $PM_{2.5}$ concentrations are shown during the windy spring months.

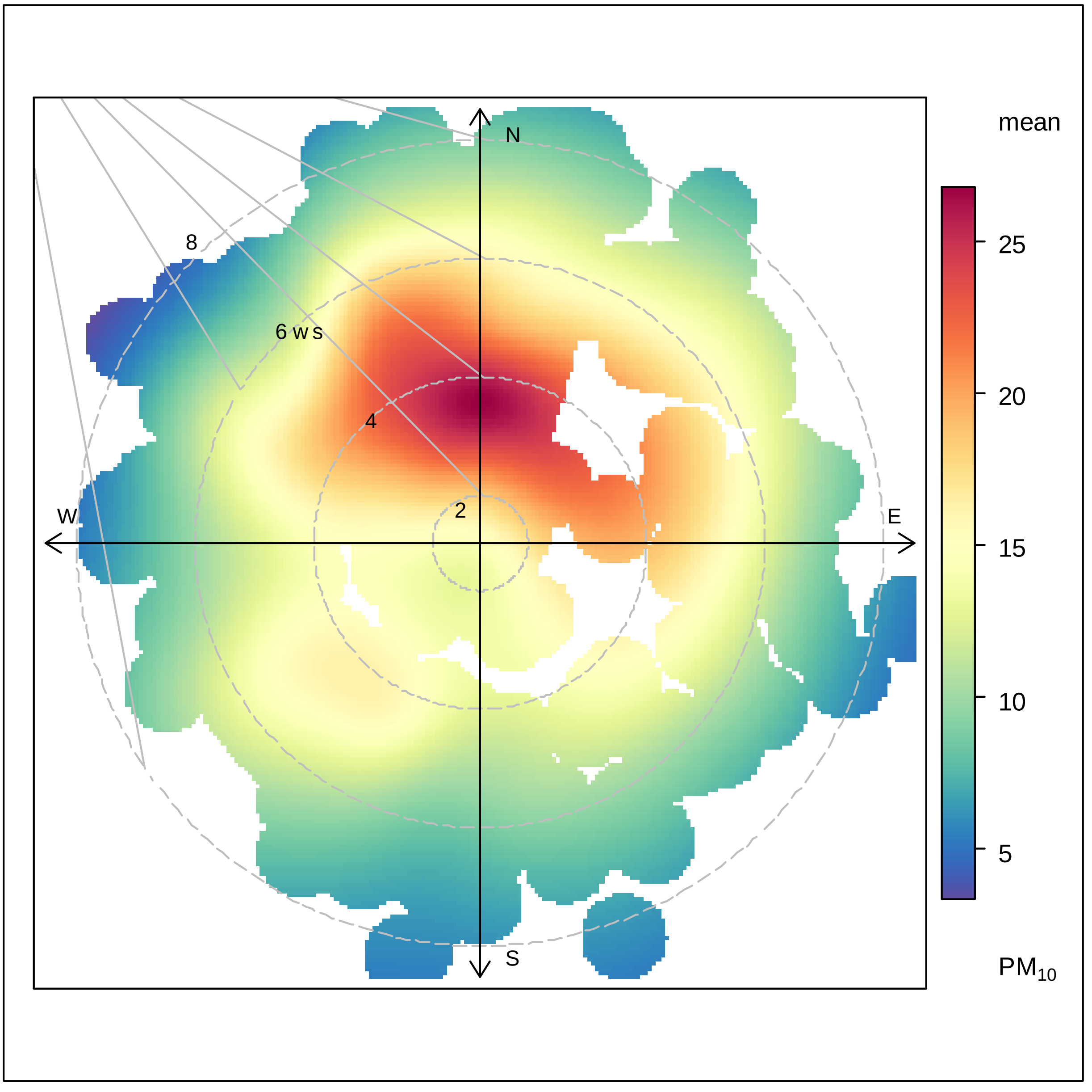


Figure 3-5: PM_{10} daily average polar plots for the Heuningkranz Station

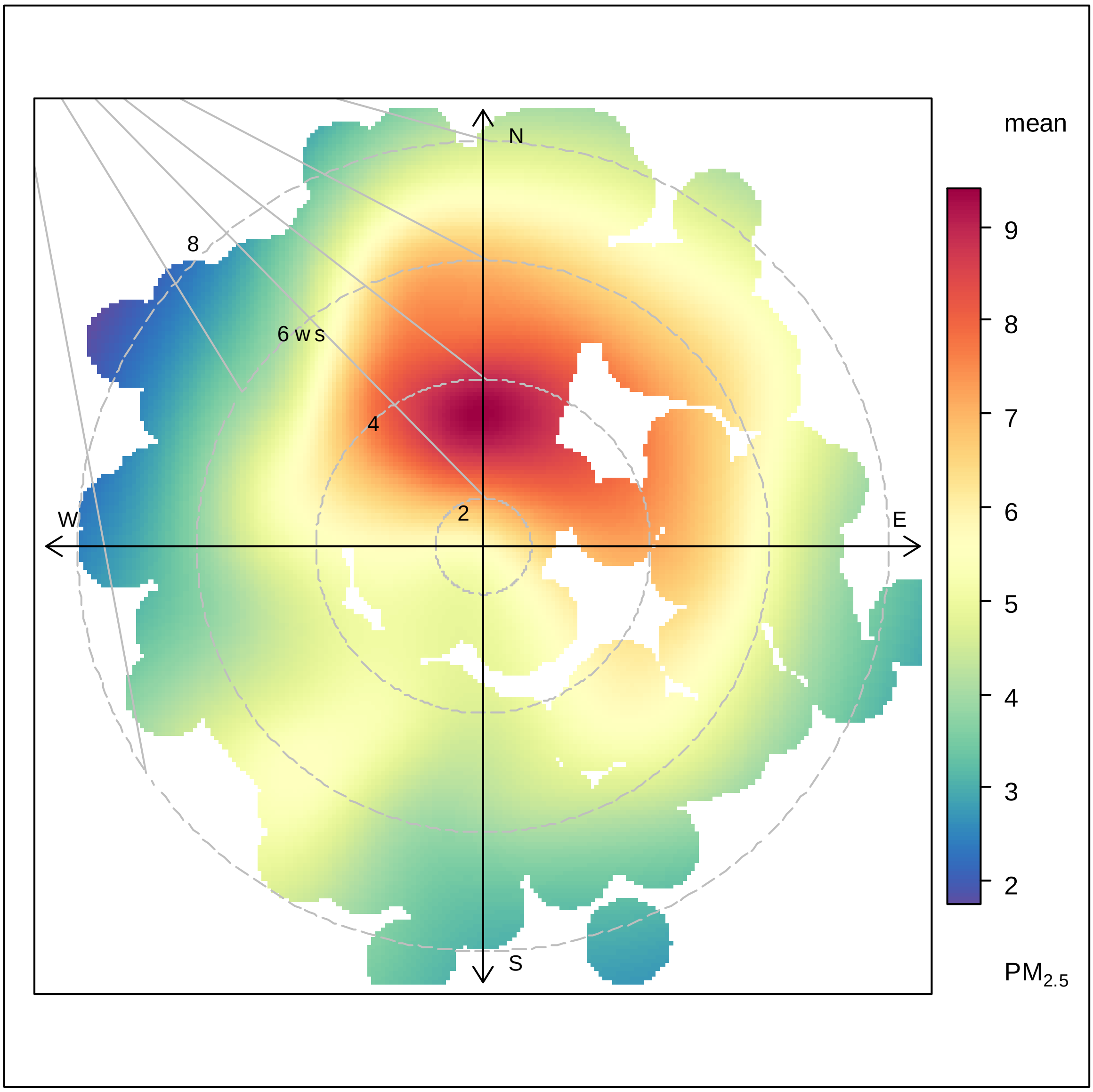


Figure 3-6: $PM_{2.5}$ daily average polar plots for the Heuningkranz Station

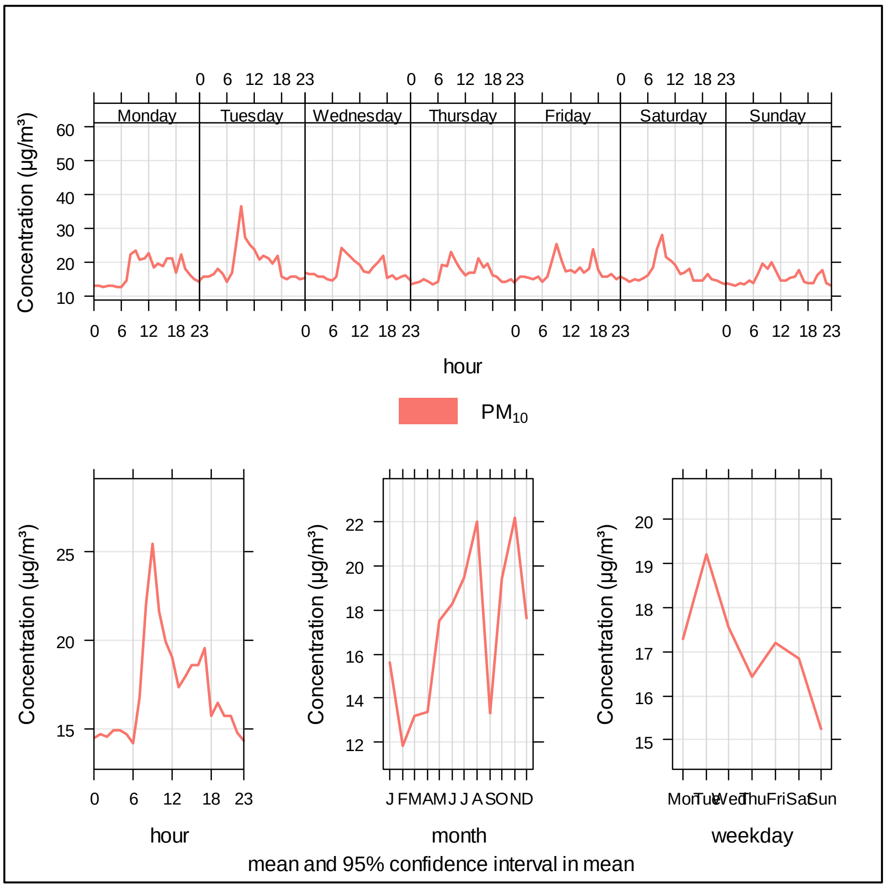


Figure 3-7: Time series data for the Heuningkranz Station – PM_{10}

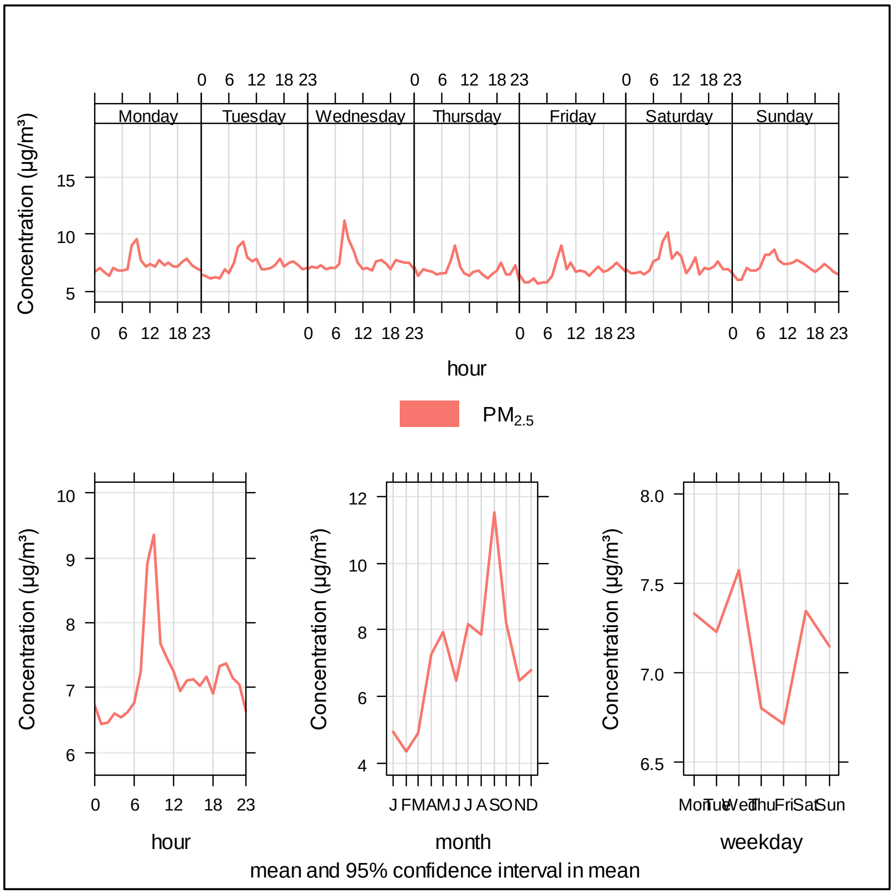


Figure 3-8: Time series data for the Heuningkranz Station – $PM_{2.5}$

3.3.2 Dustfall Sampling

A sampling campaign for the capture of dustfall has been in operation since 2013 (including both single buckets as well as directional buckets). The location of the single buckets is shown in Figure 3-9. The results were taken from the DustWatch reports (Figure 3-10). DustWatch currently performs the dustfall sampling. Only the single bucket results are reported here, as the directional buckets can't be used for comparison to NDCR.

Figure 3-9: Dustfall monitoring network locations of single buckets

From the results of the monitoring campaign, it can be seen that dustfall at the following dust bucket locations are non-compliant with the NDCR for non-residential areas (exceed 1200 mg/m²/day either more than twice per year or in two consecutive months);

- 2013 – Lukas Dam
- 2014 – Lukas Dam and Putjie
- 2015 – Lukas Dam and Putjie
- 2016 – Lukas Dam and Putjie
- 2017 – Lukas Dam, Putjie and Langverwacht.

Both the buckets at Lukas Dam and Putjie are located next to gravel roads, and traffic along the road will contribute to elevated dustfall levels.

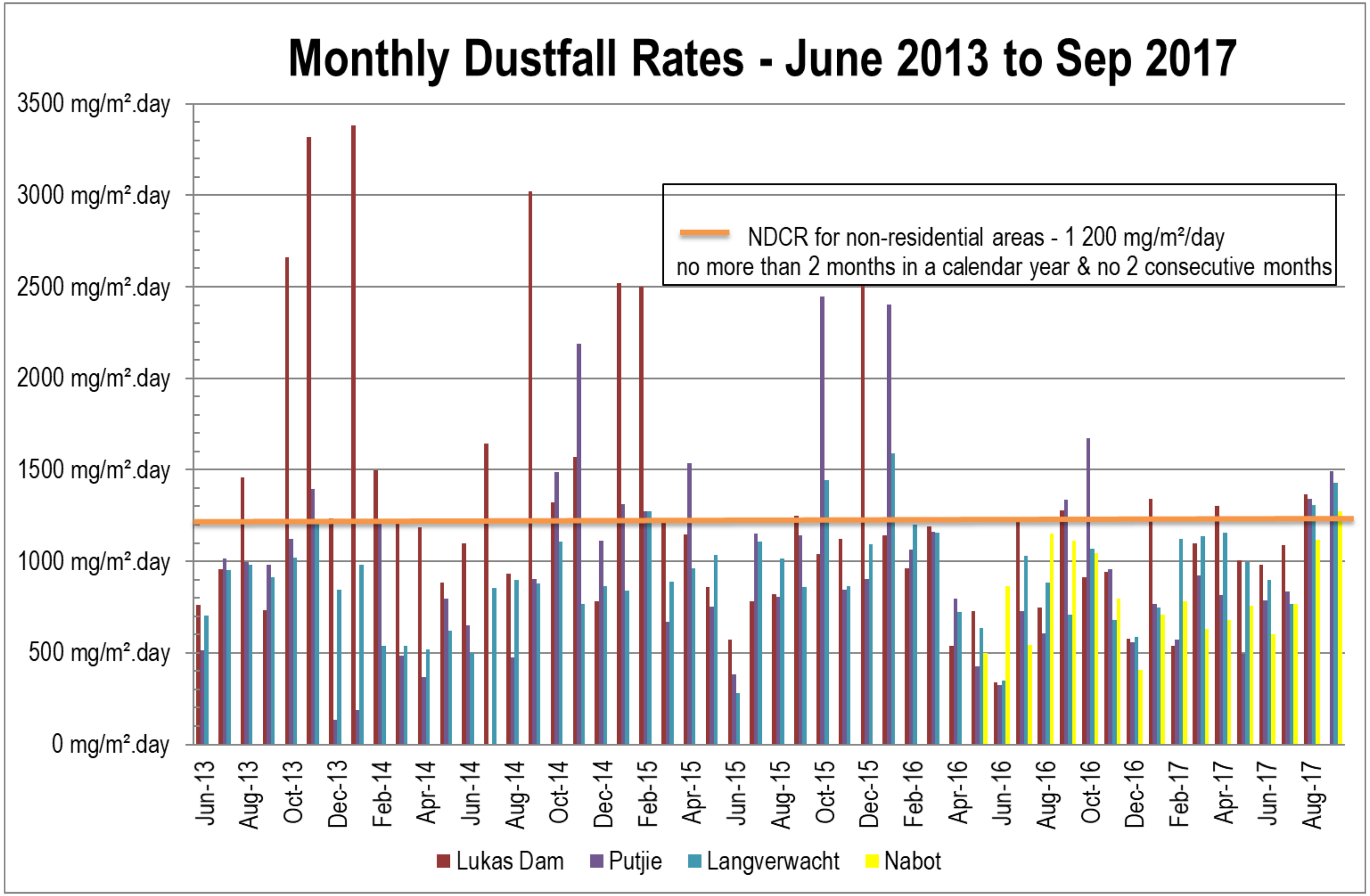


Figure 3-10: Results of the dustfall monitoring campaign – off-site dust buckets

4 IMPACT OF PROPOSED PROJECT ON THE RECEIVING ENVIRONMENT

4.1 Atmospheric Emissions

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's operations on the receiving environment.

Sources of emission and associated pollutants considered in the emissions inventory included:

- Crushing and Screening RoM at the DSO and DMS plant – $PM_{2.5}$, PM_{10} and TSP
- Drilling – $PM_{2.5}$, PM_{10} and TSP
- Handling of RoM, waste rock and product ore – $PM_{2.5}$, PM_{10} and TSP
- Transport of RoM, product ore and waste rock – $PM_{2.5}$, PM_{10} and TSP
- Windblown dust from the stockpile areas – $PM_{2.5}$, PM_{10} and TSP

All emissions were determined through the application of emission factors published by the US EPA and the Australian NPI. A summary of fugitive dust sources quantified, emissions estimation techniques applied, and source input parameters is given in Table 4-1. Estimated annual average emissions, per source group and scenario, are presented in Table 4-2.

The following is noted with regards to the emissions inventory:

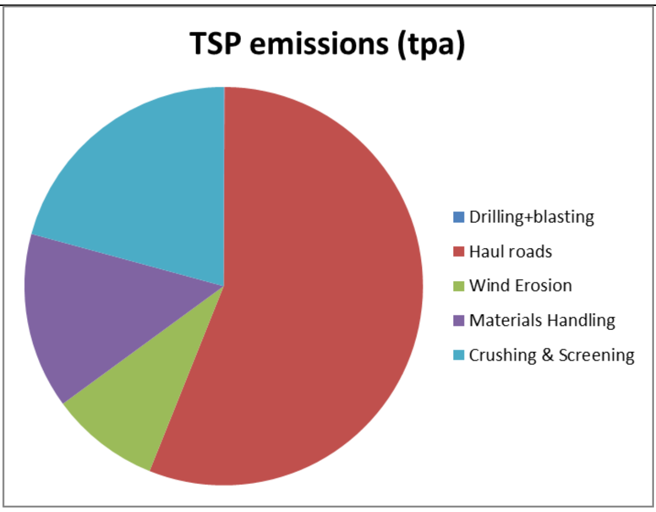
- Operational phase PM emissions amount to 6 146 t/a TSP, 2 262 t/a PM_{10} and 673 t/a $PM_{2.5}$.
- Maximum TSP emissions result mostly from unpaved roads and crushing (Figure 4-1 (a)).
- The top contributors to PM_{10} are unpaved roads and wind erosion (Figure 4-1 (b)).
- $PM_{2.5}$ emissions result mostly from wind erosion and unpaved roads (Figure 4-1 (c)).

Table 4-1: Emission estimation techniques and parameters

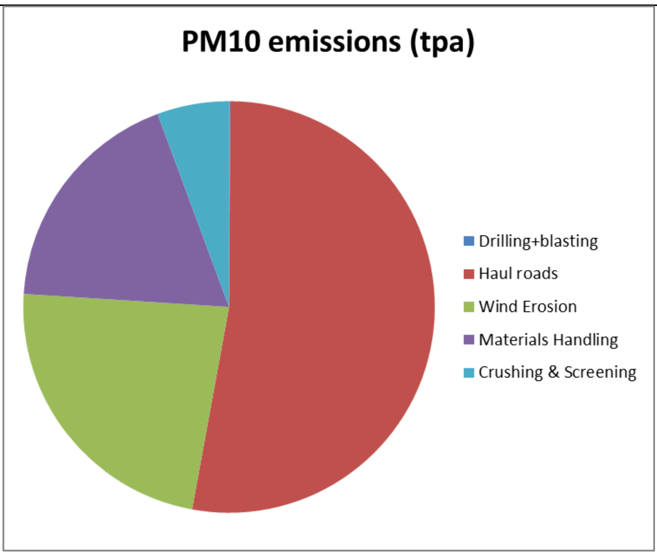
Source Group	Emission Estimation Technique	Input Parameters
Crushing	Use was made of NPI single valued emission factors for primary crushing of low moisture (<4%) ore (NPI, 2012): • TSP – 0.2 kg/tonne • PM_{10} – 0.02 kg/tonne • $PM_{2.5}$ – *assumed* to be 0.01 kg/tonne Use was made of NPI single valued emission factors for secondary crushing of low moisture (<4%) ore (NPI, 2012): • TSP – 0.6 kg/tonne • PM_{10} – 0.06 kg/tonne • $PM_{2.5}$ – *assumed* to be 0.03 kg/tonne Use was made of NPI single valued emission factors for tertiary crushing of low moisture (<4%) ore (NPI, 2012): • TSP – 1.4 kg/tonne • PM_{10} – 0.08 kg/tonne • $PM_{2.5}$ – *assumed* to be 0.04 kg/tonne	Primary crushing of RoM at the following rate: 479 t/h (at the DSO plant – 4.2 Mtpa) and 685 t/h (at the DMS plant – 6 Mtpa) Secondary crushing of RoM at the following rate: 479 t/h (at the DSO plant – 4.2 Mtpa) and 685 t/h (at the DMS plant – 6 Mtpa) Tertiary crushing of RoM at the following rate: 685 t/h (at the DMS plant – 6 Mtpa) Hours of operation: 7 days per week, 24 hours per day Mitigation: assumed for primary and secondary 62% due to water suppression; assumed for tertiary 98% due to being enclosed
Drilling	NPI emission factor (NPI, 2012): • TSP – 0.59 kg/hole • PM_{10} – 0.31 kg/hole • $PM_{2.5}$ – *assumed* to be 0.04231 kg/hole	~7 500 holes drilled per year: Hours of operation: 7 days per week, 24 hours per day Mitigation: None
Materials Handling	US EPA emission factor equation (US EPA, 2006) $EF = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$ Where EF is the emission factor in kg/tonne material handled k is the particle size multiplier (k_{TSP} – 0.74, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.053) U is the average wind speed in m/s M is the material moisture content in %	RoM, product ore and waste rock loading and off-loading points were included. The number of transfer points and rates used in the estimation of emissions are: • Product ore, rate 1 233 tonnes/hour • Waste rock, rate 7 420 tonnes/hour An average wind speed of 5.2 m/s was determined from the on-site data set. A moisture content of 1.5% was assumed. Hours of operation: 7 days per week, 24 hours per day. Mitigation: None
Vehicle Entrained Dust from Unpaved Roads	US EPA emission factor equation (US EPA, 2006) $E = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{0.45} \cdot 281.9$ Where EF is the emission factor in g/vehicle kilometer travelled (VKT) k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) s is the road surface material silt content in % W is the average weight vehicles in tonnes	Transport activities include the transport of RoM to the beneficiation plant, waste rock to waste rock dumps. VKT were calculated from road lengths, truck capacities and the number of trips required transporting RoM and waste rock. A road surface silt content of 22.4% was applied in calculations (based on Kolomela mine) Hours of operation: 7 days per week, 24 hours per day Mitigation: 75% with water sprays on roads within the pit and 90% with DAS on haul roads.
Windblown Dust	Airshed addas program	Hours of operation: Continuous

Table 4-2: Estimated annual average emission rates per source group

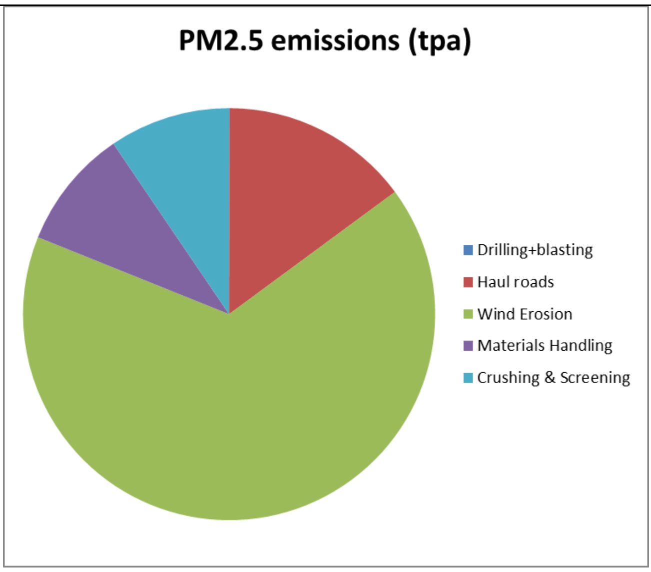
Source Group	TSP	PM_{10}	$PM_{2.5}$
Drilling and blasting	4	2	0.3
Vehicle Entrained Dust	3 441	1 193	100
Windblown Dust	546	523	445
Materials Handling	878	415	63
Crushing	1 277	128	64
Total Emissions	6 146	2 262	673



a) TSP emissions



b) PM_{10} emissions



c) $PM_{2.5}$ emissions

Figure 4-1: Source group contributions to estimated maximum annual particulate matter emissions

4.2 Atmospheric Dispersion Modelling

The assessment of the impact of the project's operations on the environment is discussed in this Section. To assess impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 2);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates.

The potential impact on human health as a result of $PM_{2.5}$ and PM_{10} emissions from proposed operations are discussed in Section 4.3. The impact of dustfall on the environment, as a result of TSP emissions, is discussed in Section 4.4. The impact of operations on the atmospheric environment was determined through the simulation of dustfall rates and ambient pollutant concentrations. Simulated air quality impacts represent those associated with the project's operations only.

Dispersion models simulate ambient pollutant concentrations and dustfall rates as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

4.2.1 Dispersion Model Selection

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. One of the most widely used Gaussian plume model is the US EPA AERMOD model that was used in this study. AERMOD is a model developed with the support of 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).

AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources. AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature however retains the single straight line trajectory limitation. AERMET is a meteorological pre-processor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters. AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. The output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model include: source data, meteorological data (pre-processed by the AERMET model), terrain data, information on the nature of the receptor grid and pre-development or background pollutant concentrations or dustfall rates.

Version 7.12 of AERMOD and its pre-processors were used in the study.

4.2.2 Meteorological Requirements

For the purpose of the study use was made of hourly on-site data from Heuningkranz for the period May 2015 to August 2017 (Section 3.2).

4.2.3 Source Data Requirements

The AERMOD model is able to model point, jet, area, line and volume sources. Potential sources at Heuningkranz were modelled as follows:

- Crushing and materials handling – modelled as volume sources;
- Activities in the pit – modelled as open pit sources;
- Unpaved roads and windblown dust – modelled as area sources.

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 15 km (east-west) by 15 km (north-south). The area was divided into a grid matrix with a resolution of 150 m, with the mine located centrally. The residences were included as AQSR (Figure 3-1). AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor point.

4.2.5 Presentation of Results

Dispersion modelling was undertaken to determine highest hourly, highest daily and annual average ground level concentrations and dustfall rates for each of the pollutants considered in the study. Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations.

Results are primarily provided in tabular form as discrete values simulated at specific AQSR receptor locations. Selective use is also made of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified.

It should be noted that ambient air quality criteria applies to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site. Section 4.3 deals with impacts on human health. Dustfall is assessed for nuisance impact on the environment (Section 4.4) and not inhalation health impact.

4.3 Screening of Simulated Human Health Impacts

4.3.1 *Simulated Ambient PM_{10} Concentrations*

Simulated ambient PM_{10} concentrations as a result of the operational phase of Heuningkranz Mine are within annual and daily NAAQS at all AQSRs (Table 4-3). Exceedances of criteria are only expected in close proximity to areas of operation (Figure 4-3 and Figure 4-4).

Overall source group contributions to simulated ground level PM_{10} concentrations are shown in Figure 4-2. As expected, dust generated by vehicles travelling on unpaved haul roads is the most notable contributor to ground level PM_{10} concentrations.

Table 4-3: Simulated PM_{10} concentrations

Receptor	Annual Average Conc. (µg/m³)	Days of Exceedance of 75 µg/m³
SR1	0.09	0
SR2	0.22	0
SR3	0.03	0
SR4	0.15	0
SR5	0.11	0
SR6	1.11	0
SR7	0.09	0
SR8	0.85	0
SR9	0.05	0
SR10	0.07	0
SR10A	0.07	0
SR11	0.17	0
SR12	0.18	0
SR13	0.10	0
SR14	010	0
SR15	0.06	0
NAAQS	40	4

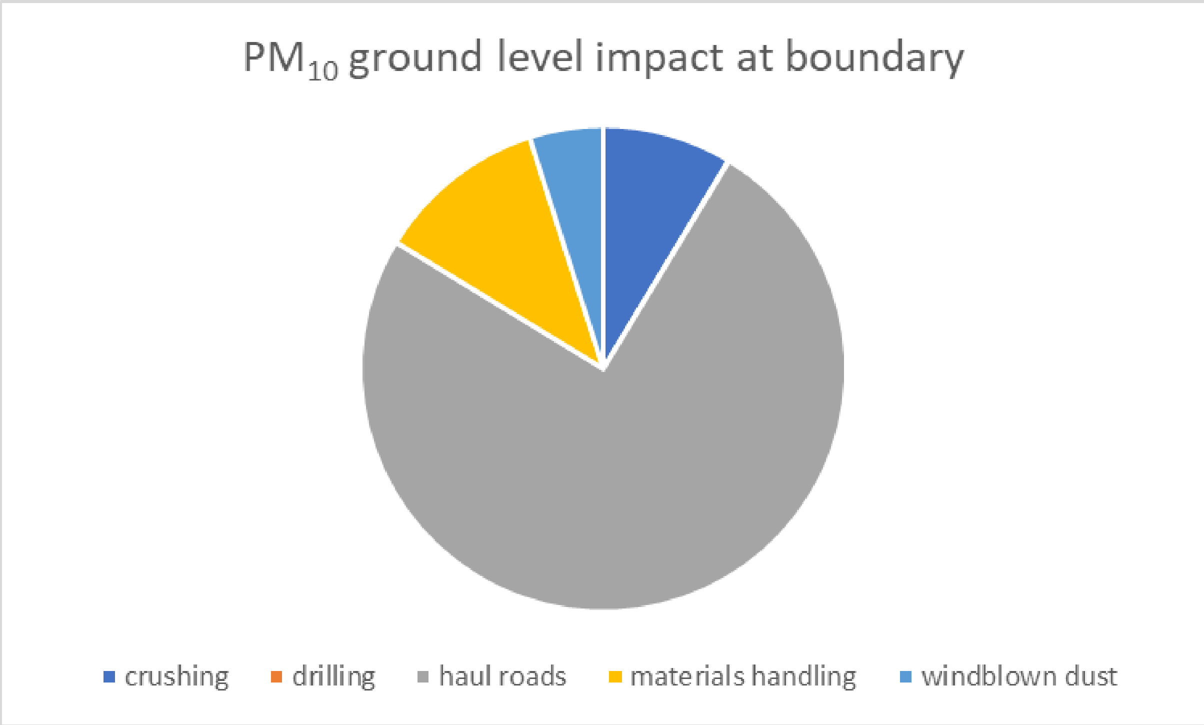


Figure 4-2: Source group contribution to simulated annual average PM_{10} concentrations

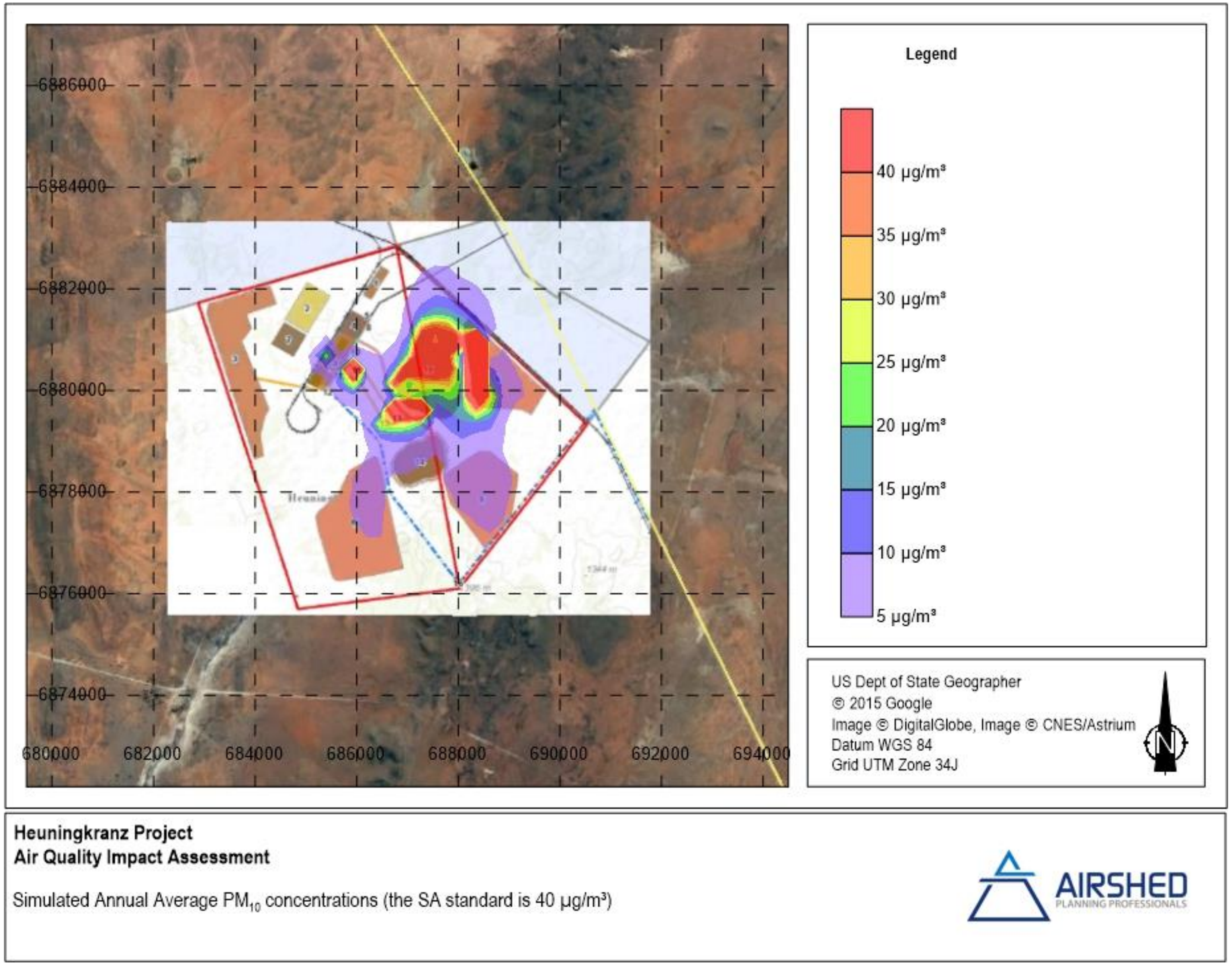


Figure 4-3: Simulated annual average PM_{10} concentrations

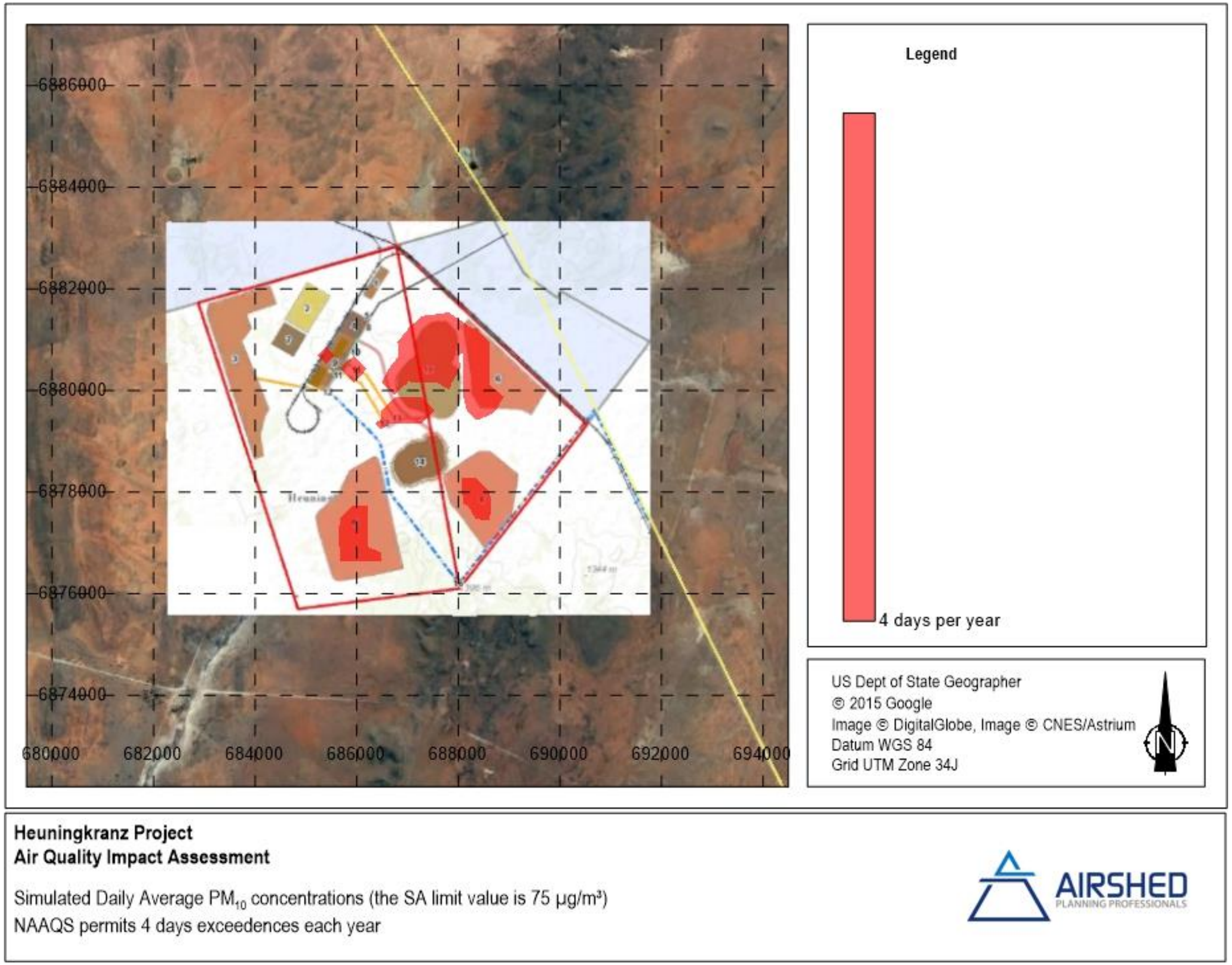


Figure 4-4: Simulated no. of days of exceedance of the PM_{10} NAAQS limit value of 75 µg/m^3

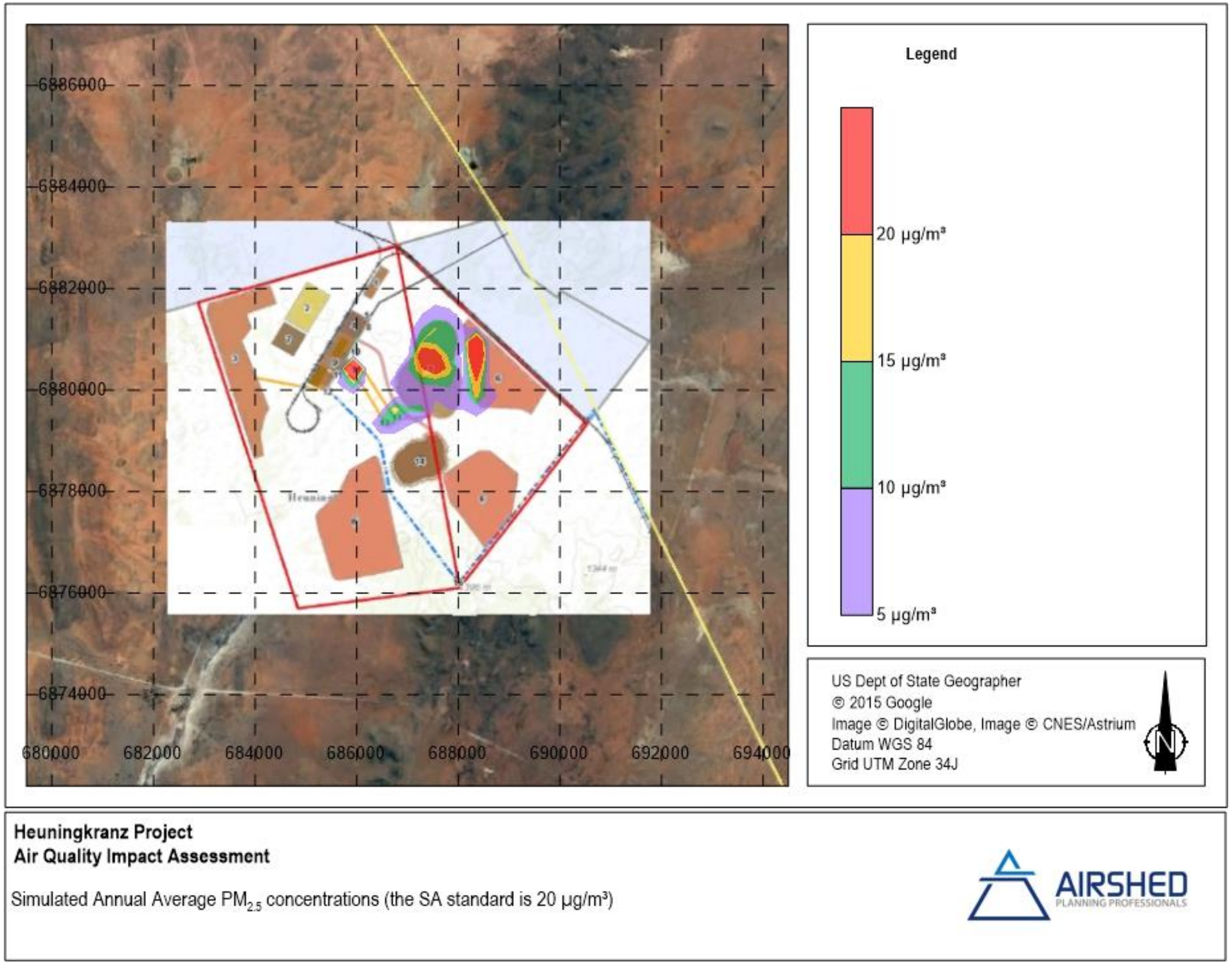


Figure 4-5: Simulated annual average $PM_{2.5}$ concentrations

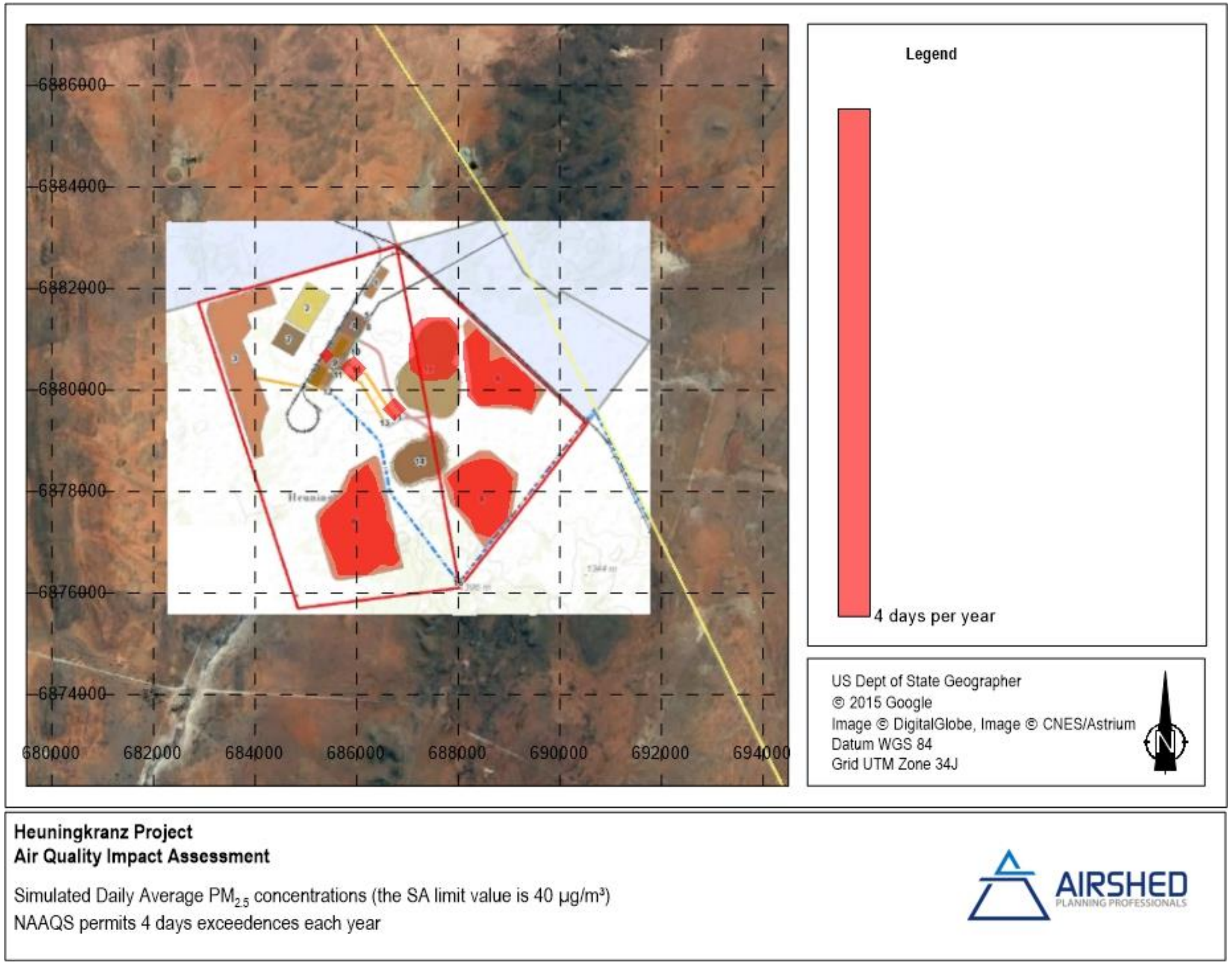


Figure 4-6: Simulated no. of days of exceedance of the $PM_{2.5}$ NAAQS limit value of 40 µg/m^3

4.3.2 *Simulated Ambient $PM_{2.5}$ Concentrations*

Simulated ambient $PM_{2.5}$ concentrations as a result of the operational phase of Heuningkranz Mine are within annual and daily NAAQS at all AQSRs (Table 4-4). Exceedances of criteria are only expected in close proximity to areas of operation (Figure 4-5 and Figure 4-6).

Overall source group contributions to simulated ground level $PM_{2.5}$ concentrations are shown in Figure 4-7. As expected, dust generated by vehicles travelling on unpaved haul roads is the most notable contributor to ground level $PM_{2.5}$ concentrations.

Table 4-4: Simulated $PM_{2.5}$ concentrations

Receptor	Annual Average Conc. (µg/m³)	Days of Exceedance of 40 µg/m³
SR1	0.03	0
SR2	0.08	0
SR3	0.01	0
SR4	0.05	0
SR5	0.04	0
SR6	0.37	0
SR7	0.03	0
SR8	0.26	0
SR9	0.02	0
SR10	0.02	0
SR10A	0.02	0
SR11	0.06	0
SR12	0.06	0
SR13	0.04	0
SR14	0.03	0
SR15	0.02	0
NAAQS	20	4

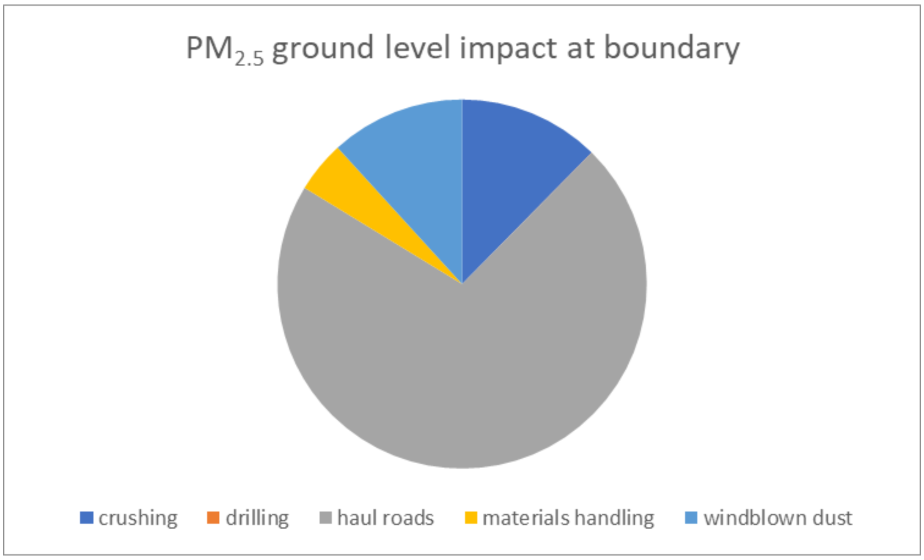


Figure 4-7: Source group contribution to simulated annual average $PM_{2.5}$ concentrations over all scenarios

4.4 Analysis of Emissions' Impact on the Environment

4.4.1 Simulated Dustfall Rates

Simulated dustfall rates at Heuningkranz Mine are low and within the NDCR for residential areas at all AQSRs (Table 4-5). Although incremental dustfall rates are below NDCRs at AQSRs, exceedances of criteria are expected in close proximity to areas of operation (Figure 4-8).

Table 4-5: Simulated dustfall rates

Receptor	Highest Daily Dustfall (mg/m^2-day)
SR1	6
SR2	12
SR3	2
SR4	11
SR5	11
SR6	57
SR7	9
SR8	44
SR9	5
SR10	9
SR10A	8
SR11	13
SR12	15
SR13	7
SR14	6
SR15	10
Residential NDCR	600

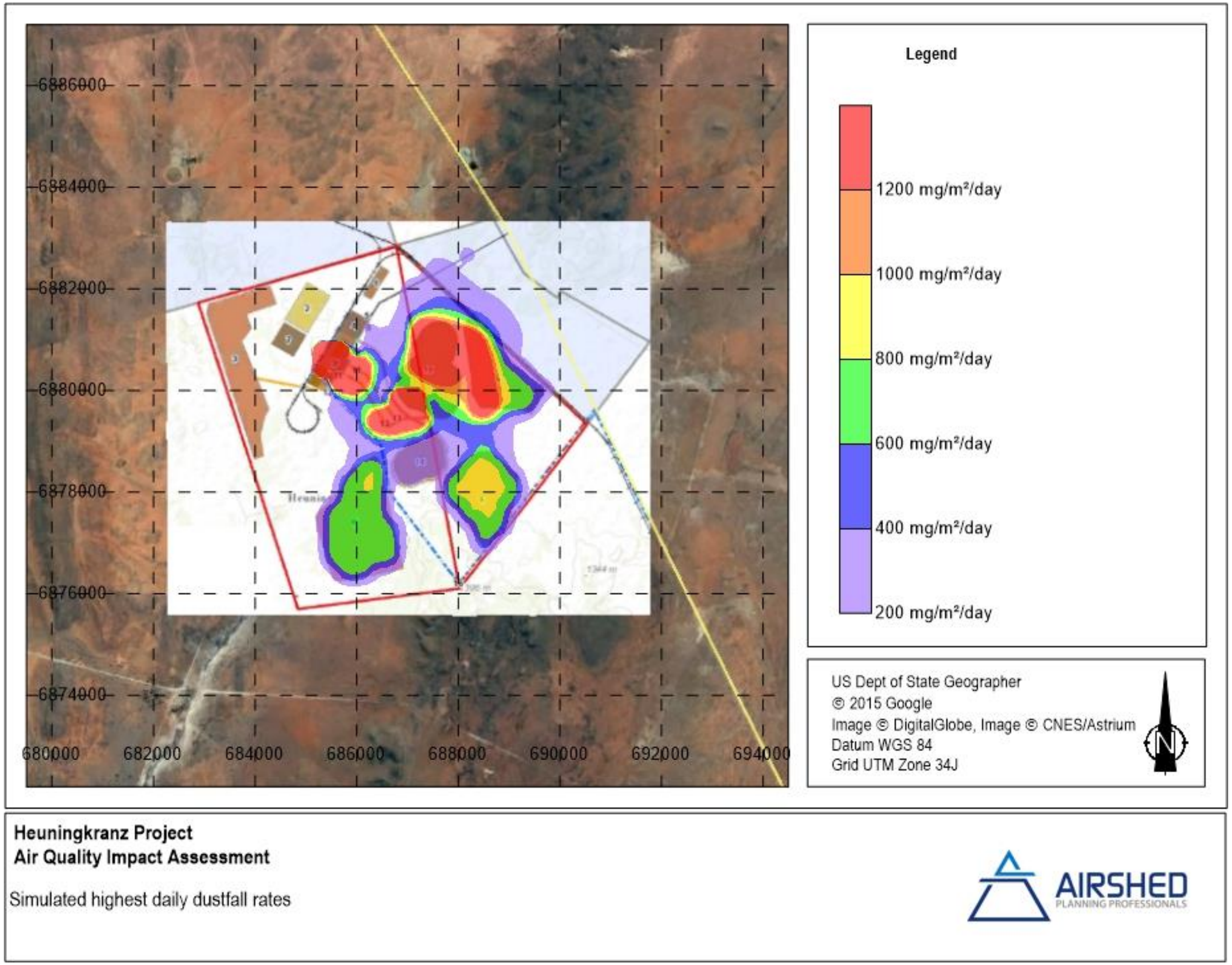


Figure 4-8: Simulated highest daily dustfall rates

4.5 Internal Air Quality Targets

Anglo American Air Quality Performance Requirements stipulate that the objectives and targets to be met must look at the following criteria:

a) Set as the internal air quality target the EC Limit Values, in cases where the host country standard is less stringent than that of the EC Limit Values.
b) Set out to contribute no more than 70% of the EC Limit Value, not to exceed this contribution to ambient air levels by more than a pre-determined frequency corresponding to that of the EC Limit Values.
c) Apply the target to all locations where members of the public may be exposed at a frequency or duration which could influence the exposure averaging periods of the EC Limit Values (e.g. 24-hours, annual). Apply host-country standards to all other locations.

The areas of exceedences for 70% of the EC limit value for PM_{10} is provided in Figure 4-9. When compared to areas of exceedences of NAAQS for PM_{10}, the EC annual target is similar to the NAAQS criteria. Using this as a criterion, together with 70% of the EC Limit, the Anglo American internal targets according to their Air Quality Performance Requirements are assessed in Table 4-7.

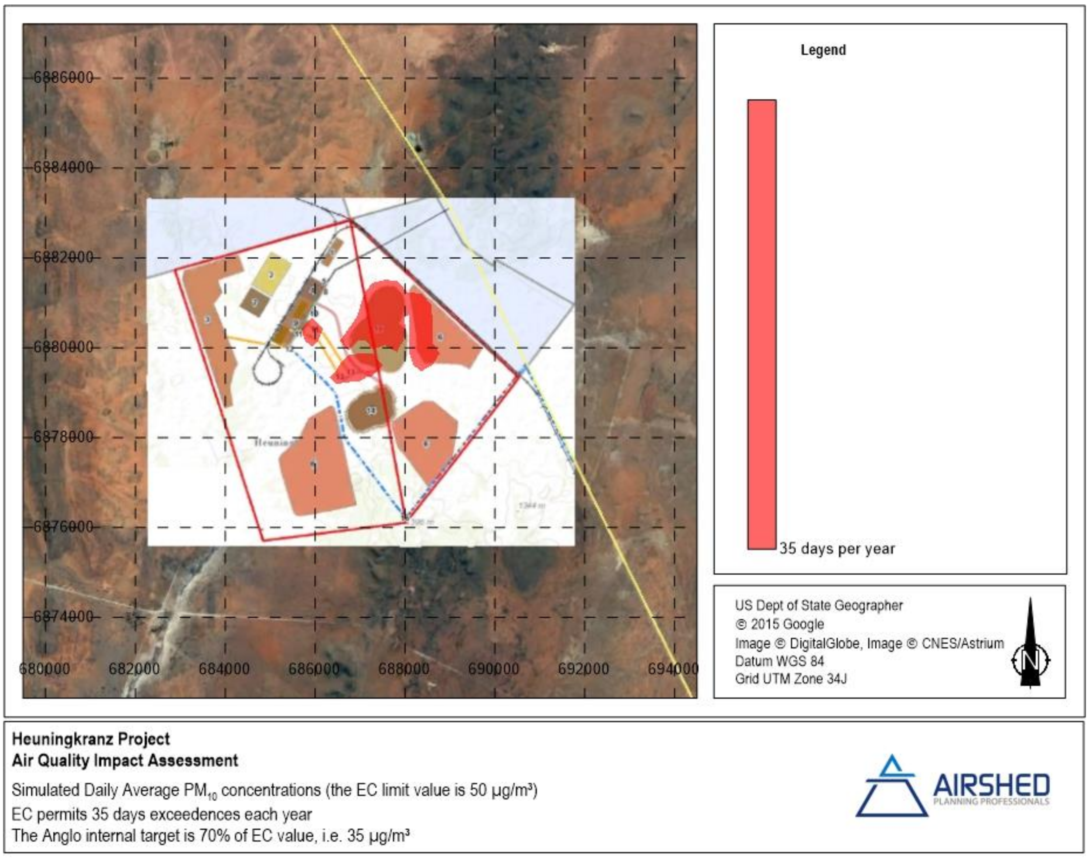


Figure 4-9: Simulated no. of days of exceedance of 70% of the PM_{10} EC limit value of 50 µg/m³, i.e. 35 µg/m³

The internal targets were met for the proposed Project.

Table 4-6: Simulated PM_{10} ground level concentrations at the nearest sensitive receptors to assess whether internal targets are met [(a)]

Assessment Criteria	Boundary
Frequency of exceedence of 70% of daily EC limit	0 (baseline) 0 (Heuningkranz)
Frequency of exceedence of daily NAAQ limit applicable immediately)	0 (baseline) 0 (Heuningkranz)
Annual average concentrations (µg/m³)	18 (baseline) 10 (Heuningkranz)
Within Internal Air Quality Targets	yes (baseline) yes (Heuningkranz)

a) The NAAQS for PM_{10} and 70% of the EC limit has to be met in order for the internal target to be met.

4.6 Significance of Impact on the Environment

The methodology used for assessing the significance of the impact was obtained from EXM (EXM, 2017). The significance of the impact is dependent on the consequence and the probability that the impact will occur.

impact significance = (consequence x probability)

Where:

consequence = (severity + extent)/2

and

severity = [intensity + duration]/2

Each criterion is given a score from 1 to 5 based on the definitions given in Table 4-7 to Table 4-9. Although the criteria used for the assessment of impacts attempts to quantify the significance, it is important to note that the assessment is generally a qualitative process and therefore the application of this criteria is open to interpretation. The process adopted will therefore include the application of scientific measurements and professional judgement to determine the significance of environmental impacts associated with the project. The assessment thus largely relies on experience of the environmental assessment practitioner (EAP) and the information provided by the specialists appointed to undertake studies for the EIA.

Where the consequence of an event is not known or cannot be determined, the "precautionary principle" will be adhered to and the worst-case scenario assumed. Where possible, mitigation measures to reduce the significance of negative impacts and enhance positive impacts will be recommended. The detailed actions, which are required to ensure that mitigation is successful, will be provided in the EMPR, which will form part of the EIA report. Consideration will be given to the phase of the project during which the impact occurs. The phase of the development during which the impact will occur will be noted to assist with the scheduling and implementation of management measures.

Table 4-7: Criteria for Assessing the Impact Significance (Severity Criteria)

INTENSITY = MAGNITUDE OF IMPACT	RATING
Insignificant: impact is of a very low magnitude	1
Low: impact is of low magnitude	2
Medium: impact is of medium magnitude	3
High: impact is of high magnitude	4
Very high: impact is of highest order possible	5
DURATION = HOW LONG THE IMPACT LASTS	RATING

Very short-term: impact lasts for a very short time (less than a month)	1
Short-term: impact lasts for a short time (months but less than a year)	2
Medium-term: impact lasts for the for more than a year but less than the life of operation	3
Long-term: impact occurs over the operational life of the proposed extension	4
Residual: impact is permanent (remains after mine closure)	5
EXTENT = SPATIAL SCOPE OF IMPACT/ FOOTPRINT AREA / NUMBER OF RECEPTORS	RATING
Limited: impact affects the mine site	1
Small: impact extends to the whole farm portion	2
Medium: impact extends to neighbouring properties	3
Large: impact affects the surrounding community	4
Very Large: The impact affects an area larger the municipal area	5

Table 4-8: Criteria for Assessing the Impact Significance (Probability)

PROBABILITY = LIKELIHOOD THAT THE IMPACT WILL OCCUR	RATING
Highly unlikely: the impact is highly unlikely to occur	0.2
Unlikely: the impact is unlikely to occur	0.4
Possible: the impact could possibly occur	0.6
Probable: the impact will probably occur	0.8
Definite: the impact will occur	1.0

Table 4-9: Criteria for Assessing the Impact Significance (Impact Significance)

Negative Impacts		
≤ 1	Very Low	Impact is negligible. No mitigation required.
> 1 ≤ 2	Low	Impact is of a low order. Mitigation could be considered to reduce impacts. But does not affect environmental acceptability.
> 2 ≤ 3	Moderate	Impact is real but not substantial in relation to other impacts. Mitigation should be implemented to reduce impacts.
> 3 ≤ 4	High	Impact is substantial. Mitigation is required to lower impacts to acceptable levels.
> 4 ≤ 5	Very High	Impact is of the highest order possible. Mitigation is required to lower impacts to acceptable levels. Potential Fatal Flaw.
Positive impacts		
≤ 1	Very Low	Impact is negligible.
> 1 ≤ 2	Low	Impact is of a low order.
> 2 ≤ 3	Moderate	Impact is real but not substantial in relation to other impacts.
> 3 ≤ 4	High	Impact is substantial.
> 4 ≤ 5	Very High	Impact is of the highest order possible.

Applying the criterion given above, the significance for the proposed Heuningkranz project is given in Table 4-10, and the cumulative ranking in Table 4-11 . The proposed Heuningkranz project has a moderate significance ranking and taking into account background ambient concentrations the cumulative significance ranking is also moderate. The mine needs to mitigate to reduce to a low significance ranking to ensure particulate matter levels are as low as possible.

Table 4-10: Proposed Heuningkranz Project Significance Ranking

Significance	RATING
Intensity = Medium: impact is of medium magnitude	3
Duration = Long-term: impact occurs over the operational life of the proposed extension	4
Extent = Small: impact extends to the whole farm portion	2
Severity = (intensity + duration) / 2	3.5
Consequence = (severity + extent) / 2	2.75
Probability = Probable: the impact will probably occur	0.8
Impact significance = (consequence x probability) = Moderate	2.2

Table 4-11: Proposed cumulative Significance Ranking

Significance	RATING
Intensity = Medium: impact is of medium magnitude	3
Duration = Long-term: impact occurs over the operational life of the proposed extension	4
Extent = Medium: impact extends to neighbouring properties	3
Severity = (intensity + duration) / 2	3.5
Consequence = (severity + extent) / 2	3.25
Probability = Probable: the impact will probably occur	0.8
Impact significance = (consequence x probability) = High	2.6

5 Recommended Air Quality Management Measures

5.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the project is to ensure that operations at Heuningkranz Mine result in ambient air concentrations (specifically PM_{10}) and dustfall rates that are within the relevant ambient air quality standards off-site. In order to define site specific management objectives, the main sources of pollution needed to be identified. Sources area ranked based on source strengths (emissions) and impacts (concentrations).

5.2 Source Ranking

The ranking of sources serves to confirm the understanding of the significance of specific sources, and to evaluate the emission reduction potentials required for each. Sources of emissions at the Heuningkranz Mine operations are ranked based on:

- Emissions; based on the comprehensive emissions inventory established for the operations, and,
- Impacts; based on the predicted dustfall levels and particulate concentrations.

5.2.1 Ranking of Sources by Emissions

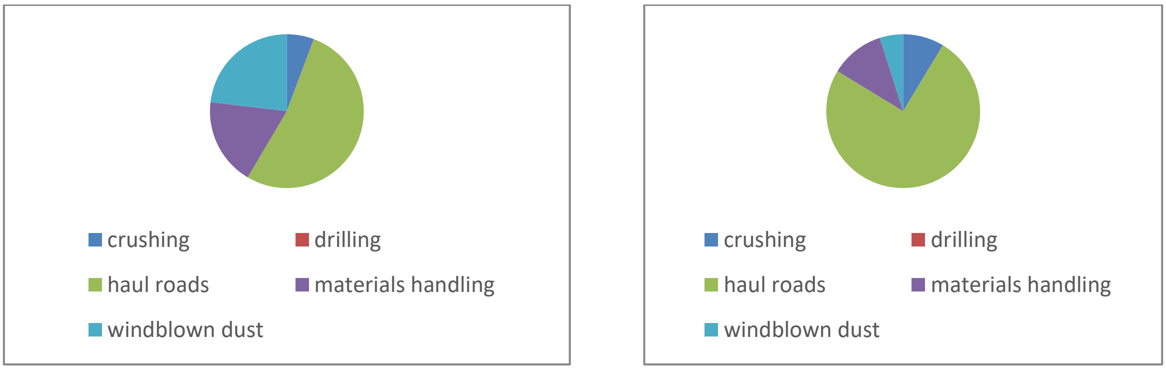
On average, sources of emission are ranked as follows from most to least significant (Figure 5-1 (a)):

1. Vehicle entrained dust from unpaved haul roads
2. Windblown dust
3. Materials Handling
4. Crushing
5. Drilling & blasting

5.2.2 Ranking of Sources by Impact

On average, sources of impact are ranked as follows from most to least significant (Figure 5-1 (b)):

1. Vehicle entrained dust from unpaved haul roads
2. Materials Handling
3. Crushing
4. Windblown dust
5. Drilling & blasting



(a) Emission ranking (b) Impact ranking

Figure 5-1: Average source group contribution to overall PM_{10} emissions and simulated impacts

5.2.3 Conclusion with Regards to Source Ranking

From the preceding it can be concluded that measures aimed at reducing emissions from unpaved roads, materials handling, and crushing must be considered to most significantly reduce impacts on the environment. In the following section, source specific management and mitigation measures are recommended specifically for unpaved roads. Other sources of emission are also addressed in general.

5.3 Source Specific Recommended Management and Mitigation Measures

5.3.1 Dust Control Options for Unpaved Haul Roads

Three types of measures may be taken to reduce emissions from unpaved roads:

- Measures aimed at reducing the extent of unpaved roads, e.g. paving;
- Traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds; and
- Measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (Cowherd, Muleski, & Kinsey, 1988).

The main dust generating factors on unpaved road surfaces include:

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

According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 10 miles per hour resulted in an increase in PM_{10} emissions of between 1.5 and 3 times. A similar study conducted by Flocchini (Flocchini, Cahill, Matsumura, Carvacho, & Lu, 1994) found a decrease in PM_{10} emissions of 42±35% with a speed reduction from 40 km/hr to 24 km/hr (Stevenson, 2004). The control efficiency obtained by speed reduction can be calculated by varying the vehicle speed input parameter in the predictive emission factor equation given for unpaved roads. An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads.

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

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

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

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

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

5.3.2 Options for Reducing Windblown Dust Emissions

The main techniques adopted to reduce windblown dust potential include source extent reduction, source improvement and surface treatment methods:

- Source extent reduction:
    - Disturbed area reduction.
    - Disturbance frequency reduction.
    - Dust spillage prevention and/or removal.
- Source Improvement:
    - Disturbed area wind exposure reduction, e.g. wind fences and enclosure of source areas.
- Surface Treatment:
    - Wet suppression
    - Chemical stabilisation

    - Covering of surface with less erodible aggregate material
    - Vegetation of open areas

The suitability of the dust control techniques indicated will depend on the specific source to be addressed, and will vary between dust spillage, material storage and open areas. The NPI recommends the following methods for reducing windblown dust:

- Primary rehabilitation - 30%
- Vegetation established but not demonstrated to be self-sustaining. Weed control and grazing control - 40%
- Secondary rehabilitation - 60%
- Re-vegetation - 90%
- Fully rehabilitated (release) vegetation - 100%

5.3.3 Materials Handling Dust Control Options

Control techniques applicable to materials handling are generally classifiable as source extent reduction, source improvement related to work practices and transfer equipment, and surface treatment. These control options may be summarised as follows:

- Source extent reduction:
    - Mass transfer reduction
- Source improvement:
    - Drop height reduction
    - Wind sheltering
    - Moisture retention
- Surface treatment:
    - Wet suppression
    - Air atomising suppression

The efficiency of these controls may be estimated through the relationships between climatic parameters, material properties and quantities of material transferred demonstrated in the predictive emission factor equation.

Good operational practices frequently represent the most cost effective and efficient means of reducing emissions. The variation of the height from which stacking occurs to suit the height of the storage pile would limit drop heights and therefore reduce the potential for the entrainment of fines by the wind.

Wet suppression systems use either liquid sprays or foam to suppress the formation of airborne dust. Emissions are prevented through agglomerate formation by combining fine particulates with larger aggregate or with liquid droplets. The key factors which affect the extent of agglomeration and therefore the efficiency of the system are the coverage of the material by the liquid and the ability of the liquid to "wet' small particles. The only wet suppression systems considered in this section is liquid sprays.

Liquid spray suppression systems may use only water or a combination of water and a chemical surfactant as the wetting agent. Surfactants reduce the surface tension of the water thus allowing particles to more easily penetrate the water particle and reducing the quantity of water needed to achieve the control efficiency required. General engineering guidelines which have been shown to be effective in improving the control efficiency of liquid spray systems are as follows:

- of the various nozzle types, the use of hollow cone nozzles tend to afford the greatest control for bulk materials handling applications whilst minimising clogging;

- optimal droplet size for surface impaction and fine particle agglomeration is about 500 µm; finer droplets are affected by drift and surface tension and appear to be less effective; and,
- application of water sprays to the underside of conveyor belts has been noted by various studies to improve the efficiency of water suppression systems and belt-to-belt transfer points.

The control efficiency of pure water suppression can be estimated based on the US EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 5-2.

It is important to note that the improvements in dust control efficiencies are marginal following increases in material moisture contents by 400%. To obtain control efficiencies of greater than 90%, it would be more feasible and cost effective to consider either alternative systems (e.g. foam suppression) or supplementary methods (e.g. addition of chemical surfactants to water).

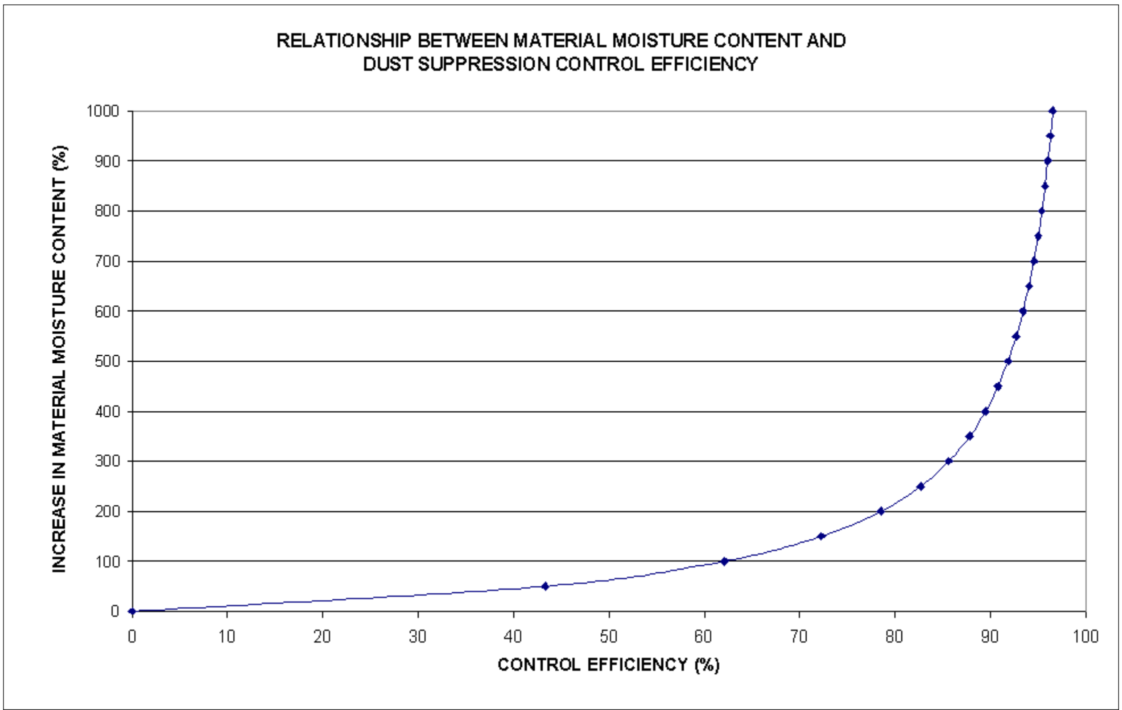


Figure 5-2: Relationship between the moisture content and the dust control efficiency

Wind sheltering techniques are widely applied for dust minimization during stacking and loading operations, particularly in cases where the application of wet suppression is not a viable alternative. The application of transfer chutes represents one of the most common of such wind sheltering methods.

Transfer chutes can be used at belt-to-belt transfer points. Chutes provide the potential for dust control due to wind sheltering, and prevention of spillages, which could give rise to dust emissions through wind or vehicle entrainment. Spillage, material degradation, conveyor belt damage, blockage and high maintenance costs have been noted as commonly re-occurring problems at transfer chute operating sites. Considerable improvements on conventional transfer chute design over the past few years have, however, resulted in solutions to many of these problems.

As an example, the South African developed Weba Chute is reported by its developer, M & J Engineering (Pty) Ltd, to have been installed in dolomite, iron ore, coal, manganese, kimberlite, phosphate and agricultural product operations. This transfer chute technology is described as being able to be applied in transfer of lumpy, sticky, and slightly wet materials.

Spillage avoidance, dust minimization and noise abatement represent the main environmental benefits of the Weba Chute. Examples of Weba chutes are given in Figure 5-3.

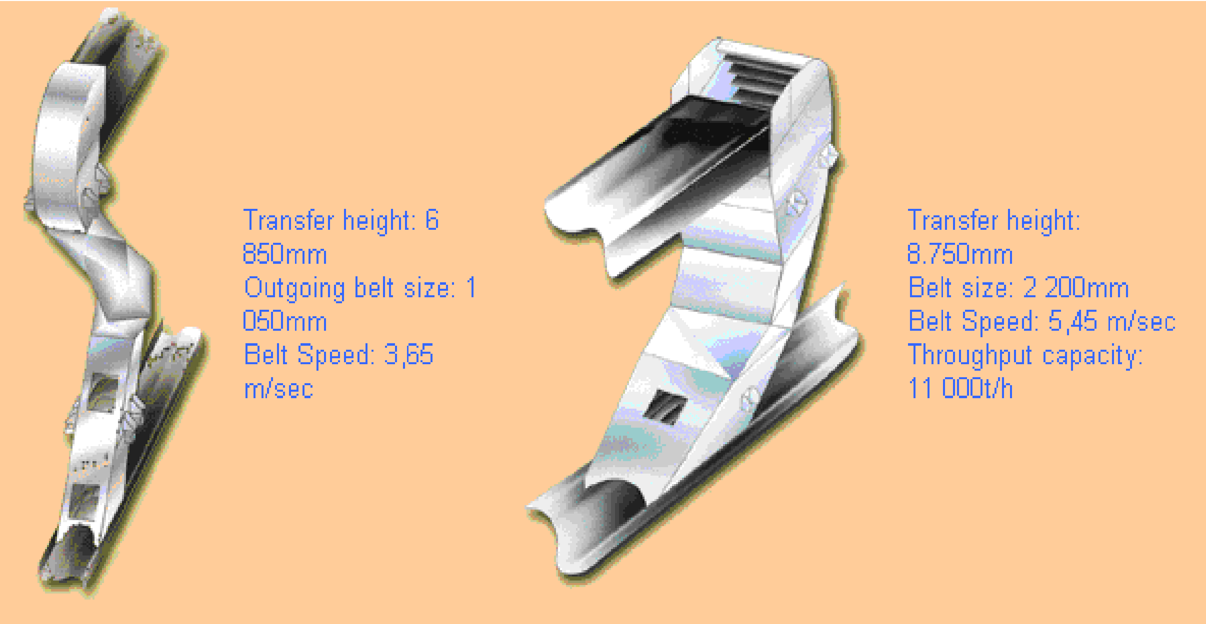


Figure 5-3: Examples of Weba chutes, developed by M & J Engineering (M&J Engineering, 2011)

Significant developments have been made in the field of air atomising spray systems. These systems use water and compressed air to produce micron sized droplets that are able to suppress respirable dust without adding any detectable moisture to the process. As such, such systems may be suitable for implementation at transfer points beyond the sampling plant. No information could be obtained on the control efficiency of such spray systems.

5.4 Performance Indicators

Key performance indicators against which progress of implemented mitigation and management measures 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 (source monitoring) and the impact on the receiving environment (ambient air quality monitoring). Ensuring that no visible evidence of windblown dust 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.

Except for vehicle/equipment emission testing, source monitoring at mining activities can be challenging due to the fugitive and wind-dependant nature of particulate emissions. The focus is therefore rather on receptor based performance indicators i.e. compliance with ambient air quality standards and dustfall regulations. It is recommended that NAAQS listed in Table 2-1 and dustfall regulations in Table 2-3, be adopted by Heuningkranz Mine as receptor-based objectives.

5.4.1 Ambient Air Quality Monitoring

Ambient air quality monitoring can serve to meet various objectives, such as:

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

It is recommended that, as a minimum dustfall, PM_{10} and $PM_{2.5}$ as well as meteorology monitoring continue at Heuningkranz as part of the project's air quality management plan. Additional recommended sampling locations are shown in Figure 5-4. These locations were selected for the reasons given in
Table **5-1**.

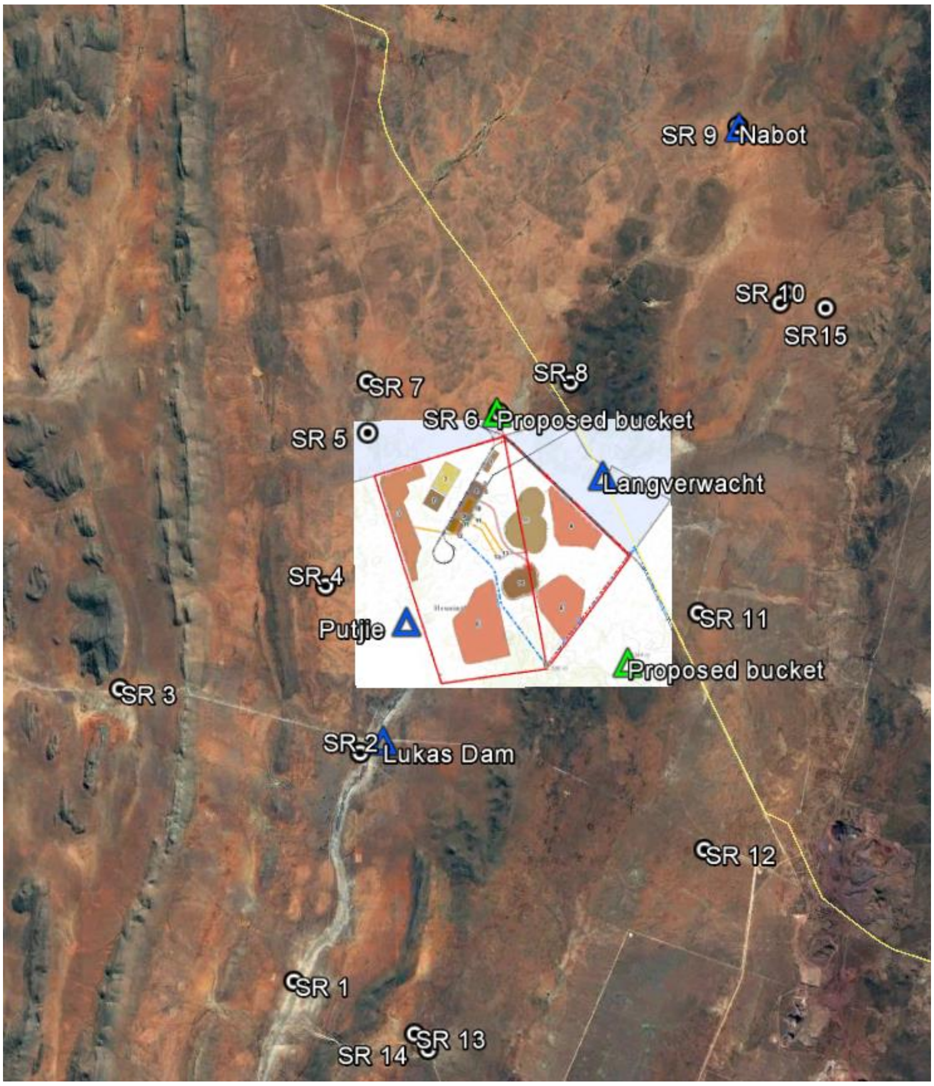


Figure 5-4: Recommended additional sampling locations

Table 5-1: Additional sampling locations and parameters

No.	Description	Parameter to be Sampled
A	Just off south-eastern boundary and downwind of all operations	Dustfall
B	Northern boundary	Dustfall

The following cost effective sampling methods are recommended:

- For dustfall, the NDCR specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. There are currently other directional buckets also being used, but these can't be used for comparison to NDCR.
- For PM_{10} and $PM_{2.5}$ the method as set out by British Standards (BS EN 12341) is recommended.

5.5 Record-keeping, Environmental Reporting and Community Liaison

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), 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 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.

5.5.1 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans 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 community areas, it is recommended that such meetings be scheduled and held at least on a bi-annual basis.

5.5.2 Financial Provision

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

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