Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province

Air Quality Assessment

Project Number:

VMC3049

Prepared for:

Pamish Investments No. 39 (Pty) Ltd

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Project Name:	**Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province**
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EXECUTIVE SUMMARY

Project Outline

Pamish Investments appointed Digby Wells Environmental to conduct an Environmental Impact Assessment (EIA) to support their application for various environmental authorisations. The study comprises a number of specialist studies of which Air Quality Impact Assessment (AQIA) forms an integral component. The overall aim of this AQIA is to identify the potential air quality concerns, and develop management measures to optimise the project benefits and minimise any adverse impacts that may result from the proposed Magnetite Mine. This study was compiled taking cognisance of the various South African national standards in order to evaluate impacts and assess environmental risks from the proposed project.

This AQIA study was conducted in accordance with the International Finance Corporation (IFC) Performance Standards, as well as the Equator Principles (EPs), a framework accepted among international project financiers for managing Environmental and Social Risks (Equator Principle 2006, 2007; Steve et al., 2008).

Knowledge Gaps

The air quality and climate assessment was carried out as a desktop study, using modelled meteorological data, as site specific information was not available. Background monitoring of dust deposition rates and ambient monitoring of PM_{10} and $PM_{2.5}$ are not undertaken at the moment by the proposed Magnetite Mine. These pollutants are regulated and likely to be impacted by the day-to-day operations of the mine.

Baseline Assessment

In the baseline assessment, a modelled meteorological data set from Lakes Environmental was analysed. Meteorological parameters such as rainfall, relative humidity, temperature and wind speed for the area were assessed. The predominant winds are from the northeast and east northeast. The annual mean temperature for the proposed mining area is 19.2°C. The annual mean relative humidity and annual total rainfall estimated were 63.9% and 798 mm respectively. The highest monthly maximum precipitation (224.8 mm) was observed in January. Baseline data from Mokopane Ambient Air Quality monitoring station located at Mahwelereng Police Station in Mokopane. The following pollutants were assessed: Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Particular Matter (PM_{10}, $PM_{2.5}$), Ozone (O_3), and Carbon monoxide (CO). This assessment confirmed few exceedances for PM_{10} and $PM_{2.5}$ but the gaseous pollutants were generally within the South African standard National Ambient Air Quality Act (2004). With regards to World Health Organisation's ambient air quality guidelines for PM_{10}, $PM_{2.5,}$ NO_2 and SO_2 were all exceeded World Health Organization (2005).

Impact Assessment

A domain of 20x20 km was defined, with a reference mid-point within the future project area. This domain, defined as the zone of potential impact due to air pollution emanating from the proposed Magnetite Mine stretches 10 kilometres north, south, east and west from the reference point. This zone of impact encompasses nearby communities in the area.

An emissions inventory was established comprising emissions for the operational phase of the proposed Magnetite Mine. Data from the emission inventory analysis ensures inputs data are available for dispersion model simulations. This inventory quantified emissions of total suspended particulate (TSP), PM_{10} and $PM_{2.5}$ from the material handling processes, topsoil and overburden stockpile, run-off-mine (ROM), tailings storage facility (TSF) and roads.

A multi-tier grid was utilised with a total of 3281 grid points each of the grid points has x and y (Cartesian co-ordinates) values in metres. Terrain effects were imported from NASA Shuttle Topography Radar Mission (STRM3) global database with ~90 m accuracy. The 24-hour and annual averaging times have been used for consistency. Predicted concentrations and deposition rates obtained are attributed to mine operations only.

Results

The AQIA study conducted shows that particulate pollution from the proposed Magnetite Mine operation can exert impact on current ambient air quality of the area. Pollutants were assessed at the boundary and at the sensitive receptors. A summary of the results are presented below:

- The highest level of PM_{10} anticipated at any point on the mine boundary over a 24 hour reached 138 µg/m³. This exceeds the current South African National Ambient Air Quality limit of 75 µg/m³. The highest PM_{10} annual recorded at the boundary of 26 µg/m³ is within the South African standard of 40 µg/m³. The WHO (IFC) guidelines for both daily (50 µg/m³) and annual (20 µg/m³) were exceeded.
- The predicted daily $PM_{2.5}$ levels at the mine boundary of 22 µg/m³ and the highest annual of 4 µg/m³, are below the daily and annual South African National Ambient Air Quality limits of 65 µg/m³ and 25 µg/m³ respectively. The WHO (IFC) guidelines for both daily (25 µg/m³) and annual (10 µg/m³) were not exceeded at any point on the mine boundary.
- The predicted dust fallout rates at the mine boundary reach a high of 2000 mg/m²/day (without mitigation). When mitigation measures were applied, the predicted level decreased 700 mg/m²/day. It is recommended to start monitoring for dust fallout around the communities to determine the levels of dust fallout prior to the construction of the mine and also continue monitoring after the mining has commenced. With no IFC standard for dust fallout, the highest deposition rates predicted at the mine boundary is higher than the 1 200 mg/m²/day stipulated by the National Dust Control Regulation (NDCR, 2013) for non-residential areas.

Conclusion

In this report, site specific meteorological data, dust deposition records and PM_{10} and $PM_{2.5}$ data were not available to assess background conditions. However, data from Mokopane Ambient Air Quality Monitoring Station were used to establish ambient scenario in the area. The AQIA confirms that the fallout dust, PM_{10} and $PM_{2.5}$ has the potential to have significant impacts during the operational phase of the mine. However, with adequate mitigation measures in place coupled with monitoring, the impacts can be reduced to within regulatory standards according to South African National Ambient Air Quality Standards (NAAQS)

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1 Introduction

Pamish Investments have appointed Digby Wells Environmental to conduct an Environmental Impact Assessment (EIA) study to support the Mining Right Application for the construction of a magnetite mine and associated infrastructure. In the suite of environmental studies needed to compile the EIA, an Air Quality Impact Assessment (AQIA) for the proposed open pit magnetite mine is required.

The AQIA study will include an air emission inventory that will take into account the relevant sources of air pollution associated with the proposed project and dispersion modelling to determine the spread of airborne pollutants from sources across the mining landscape. The predicted model results will be compared against relevant regulatory standards to appraise compliance and impacts on ambient environment.

The AQIA will use the impact assessment matrix developed in-house to evaluate potential implications of the activities identified for the three phases of the mine life and recommend appropriate mitigation measures to ameliorate impacts.

1.1 Project Background

The proposed project area is located in the Mogalakwena Local Municipality of the Mokopane District within the Waterberg District Municipality of the Limpopo Province. It is 45 km north-northwest of Mokopane and 65 km west of Polokwane. Figure 1-1 and Figure 1-2 shows the regional and local setting of the proposed project area. It is located in the Waterberg - Bojanala Priority Area (WBPA).

Some of the surrounding sensitive receptor (residential) areas include:

- Sepharane in the proposed project boundary;
- Ditlotswana – approximately 0.5 km to the east;
- Rooival – approximately 3 km to the north east;
- Ramorulane approximately 3.5 km to the south; and
- Pudia – approximately 1.5 km to the northwest.

1.2 Waterberg- Bojanala Priority Area (WBPA)

The proposed magnetite mine is located within the footprint demarcated as the Waterberg air quality Priority Area. The Waterberg-Bojanala Priority Area (WBPA) was declared the third priority area by the Minister in terms of GNR 495 on 15 June 2012 (Figure 1-3). The WBPA is comprises of the Waterberg District in Limpopo Province and the Bojanala Platinum District in the North West.

The Waterberg district has three forms of settlements which are villages, informal settlements and farms. The mining activities are located around the periphery, while tourism and game farming are located around the centre of the District. There are various developments at present and some proposed operations. Hence there was an urgency to be proactive and to take precautionary measures prior to these developments to ensure that the ambient air quality standards are met (DEA, 2012). The current air pollution sources of concern in the Waterberg District are:

- Dust from mines, quarries, brickworks, spoil/overburden heaps and heavy vehicles using gravel roads;
- Burning of solid waste at waste disposal sites, informal waste dumps;.
- Tailpipe emissions from vehicles;
- Power plants;
- Dust from vehicle entrainment on dirt roads; and
- Dust from wind erosion of open areas.

The Bojanala Platinum District covers 5 local municipalities which are Moses Kotane, Rustenburg, Madibeng, Moretele and Kgetlengrivier (C&M Consulting Engineers, 2013). This district has several sources of pollution such as heavy industry, refinery, power station, motor vehicles, small industries and household consumption of coal for cooking and space heating.

In view of the growing sources of air pollution in the area, on 15 June 2012, the Minister of Water and Environmental Affairs published a notice in the national gazette declaring the Waterberg-Bojanala an air quality priority area. The overall aim was to regulate and to ensure future sustainable development in the area and maintain national ambient air quality standards.

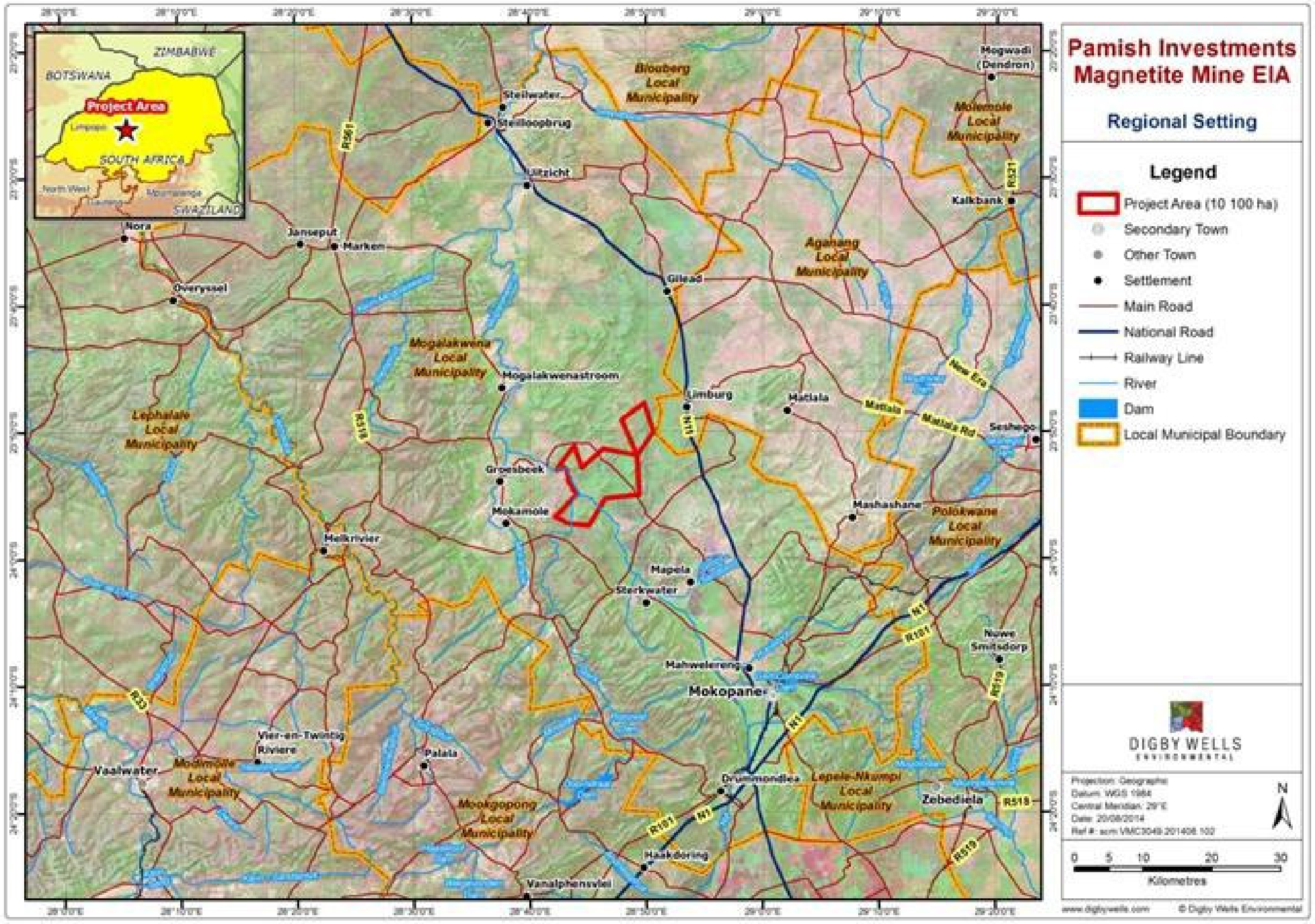

Figure 1-1: Pamish Investments Magnetite Mine Regional Setting

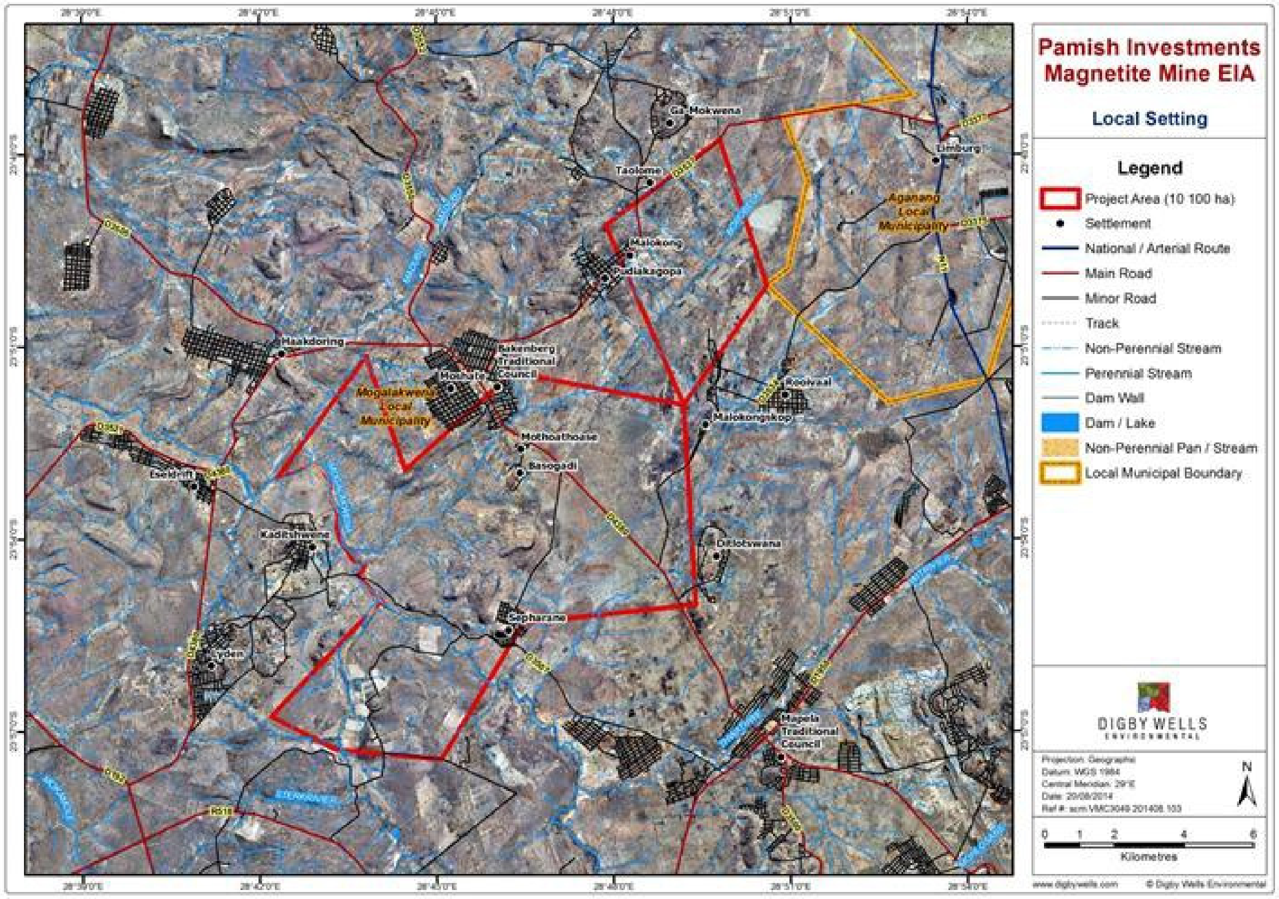

Figure 1-2: Pamish Investments Magnetite Mine Local Setting

Currently, the Department of Environmental Affairs operates four ambient monitoring stations in the priority area which are referred to as the Waterberg-Bojanala Ambient Air Quality Monitoring Network. This network previously comprised of three air quality monitoring stations bought by the Department of Environmental Affairs situated at various locations: Lephalale, Thabazimbi and Mokopane. The fourth station which was recently installed is located in Brits. The following parameters are measured at each station: PM_{10}, $PM_{2.5}$, sulphur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), benzene (C_6H_6), toluene and xylene. In addition to the above, meteorological parameters i.e. wind speed; wind direction, ambient temperature, relative humidity, rainfall, solar radiation and barometric pressure are also measured.

Figure 1-3: Waterberg- Bojanala Priority Area (DEA, 2012)

1.3 Terms of Reference

Tasks associated with the air quality scope of work are outlined below:

- Baseline assessment;
  - Evaluation of site specific meteorology;
  - Evaluation of background ambient air quality data (if available); and
  - Review of possible health and environmental implications of potential pollutants.
- Emissions inventory compilation;
- Dispersion modelling;
- Impact assessment; and
- Recommendation of mitigation measures incorporating Best Practicable Environmental Option.

This study was conducted in accordance with the International Finance Corporation (IFC) Performance Standards, as well as the Equator Principles (EPs), a framework accepted among international project financiers for managing Environmental and Social Risks associated with projects (Equator Principle 2006, 2007; Steve et al., 2008).

2 Details of the Specialist

Winnie Ngara completed her B.Sc (Hons) degree at the National University of Science and Technology, Bulawayo, Zimbabwe; and M.Sc in Environmental Science from the University of Johannesburg. She has been in the Atmospheric Science field for 3 years. She has conducted a number of air quality impact assessment studies and is conversant with the dispersion modelling packages AERMOD and CALPUFF.

Matthew Ojelede completed his BSc (Hons) degree at the University of Benin, Edo State, Nigeria; an MSc in Environmental Science (Wits University) and a PhD in Environmental Management from the University of Johannesburg. He has been in the Atmospheric Research field since 2005 and now actively involved in air pollution research, associated impacts and application of regulatory requirements. Authored and co-authored research articles in peer Reviewed Journals and Dispersion Modelling Impact Assessments Reports. He has attended specialised courses in atmospheric dispersion modelling (AERMOD and CALPUFF).

3 Aims and Objectives

The overall objective of this AQIA is to identify the potential concerns, and develop management measures to optimise the project benefits and minimise any adverse impacts that may result from the proposed Magnetite Mine operations. To achieve this aim, several objectives were identified:

- Establish baseline condition;
- Conduct an emission inventory of polluting sources attributed to the proposed Magnetite Mine operations;
- Assess impacts of quantified emission on the environment and surrounding receptors; and
- To provide suitable mitigation and monitoring measures to manage impacts associated with the development.

4 Literature Review and Desktop Assessment

4.1 Legal Context

4.1.1 South African Legislation

The prevailing legislation in the Republic of South Africa with regards to the air quality field is the National Environment Management: Air Quality Act (Act No. 39 of 2004) (NEM: AQA). The NEM: AQA repealed the Atmospheric Pollution Prevention Act (Act No.45 of 1965) (APPA).

According to NEM: AQA, the then Department of Environment Affairs and Tourism (now the Department of Environmental Affairs) (DEA), the provincial environmental departments and local authorities (district and local municipalities) are separately and jointly responsible for the implementation and enforcement of various aspects of NEM: AQA. Each of these spheres of government is obliged to appoint an air quality officer and to co-operate with each other and co-ordinate their activities through mechanisms provided for in the National Environment Management Act, 1998 (Act No.107 of 1998) (NEMA).

The purpose of NEM: AQA is to set norms and standards that relate to:

- Institutional frameworks, roles and responsibilities;
- Air quality management planning;
- Air quality monitoring and information management;
- Air quality management measures; and
- General compliance and enforcement.

Amongst other things, it is intended that the setting of norms and standards will achieve the following:

- The protection, restoration and enhancement of air quality in South Africa;
- Increased public participation in the protection of air quality and improved public access to relevant and meaningful information about air quality; and
- The reduction of risks to human health and the prevention of the degradation of air quality.

Section 24 in Chapter 2 (Bill of Rights) of the Constitution of the Republic of South Africa, 1996 dealing with the Environment states that:

Everyone has the right:

- to an environment that is not harmful to their health or well-being; and
- to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
  - prevent pollution and ecological degradation;
  - promote conservation; and
  - secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

It is this constitutional imperative that underpins the environmental laws such as NEM: AQA.

A fundamental aspect of the new approach to the air quality regulation, as reflected in the NEM: AQA, is the establishment of National Ambient Air Quality Standards (NAAQS). These standards provide the goals for air quality management plans and also provide the benchmark by which the effectiveness of these management plans is measured. The NEM: AQA provides for the identification of priority pollutants and the setting of ambient standards with respect to these pollutants.

The Act ensures that air quality planning is integrated with existing activities. The implications of this are that plans that are required in terms of the NEMA must incorporate consideration of air quality. In addition, Integrated Development Plans (IDP's) developed by local and district municipalities, also have to take air quality into account.

The Act describes various regulatory tools that should be developed to ensure the implementation and enforcement of air quality management plans.

These include:

- *Priority Areas*, which are air pollution 'hot spots';
- *Listed Activities and Minimum Emission Standards*[1], under Section 21 of the NEM: AQA which are 'problem' processes that require an Atmospheric Emission Licence (AEL) in order to operate;
- *Controlled Emitters*, which includes the setting of emission standards for 'classes' of emitters, such as motor vehicles, incinerators, etc., as well as controlled fuels;
- Control of Dust;
- Control of Noise; and
- Control of Odours.

In order to facilitate implementation of and compliance with the NEM: AQA, the Act provides for government to turn down AEL applications from applicants who have a problematic record of air quality management practices. It also provides for government to demand that 'problem' industries appoint qualified air quality practitioners.

The Act also deals with South Africa's international obligations in terms of air quality management. Provision is made for the control of processes impacting on South Africa's neighbours and the global atmosphere in general, as well as trans-boundary air pollution.

The Act further regulates the establishment of the National Framework for Air Quality Management (NFAQM). The 2007 framework was amended on the 29 November 2013.

The Act as a whole is defined by the adoption of a comprehensive approach to the management of offences and penalties, which includes the provision of transitional arrangements. The Act provides for flexibility and proactive approach, so that permissible emission limits can be amended on a progressive basis in order to achieve set air quality standards. As a consequence, the NEM: AQA came into full effect only on 1 April 2010. Certain sections of the Act came into force on 11 September 2005, but the Minister excluded other sections until such time as local authorities had the capacity and skills to deal with the implementation of the legislation. Significantly, many of the excluded sections related to listed activities and licensing of listed activities. The excluded sections were brought into effect on 31 March 2010, and the old APPA of 1965 was fully repealed on the same date.

[1]Minimum Emission Standards are the highest emission standards at which a Listed Activity will be allowed to operate under normal working conditions. If a definition of the process operated on the plant is matching the process description under established Listed Activities, the plant operates a Listed Activity and it must then be in possession of an Atmospheric Emission Licence indicating the specific Listed Activity(s) operated on the facility. Not only must the plant be in possession of an Atmospheric Emission Licence, it must also comply with the conditions within the licence to comply with NEM: AQA.

The NEM: AQA Act also required the Minister or the Member of Executive Council (MEC) to identify and publish activities which result in atmospheric emissions that require an Atmospheric Emission Licence before they can operate. On 31 March 2010 under GNR248 the list of activities which result in atmospheric emissions which may have a significant detrimental effect on the environment were published. 1 April 2010 also marked the date when the new list of activities requiring Atmospheric Emissions Licenses to operate was promulgated and, with this, the levelling of the atmospheric emission “playing field” through the setting of minimum emissions standards for all these listed activities was implemented.

On 22 November 2013 the Minister repealed the listed activities promulgated on 31 March 2010 and introduced a new list of activities under GNR 893 promulgated on 22 November 2013. Government Notice 893 (GN893:2013) established and identified activities which result in atmospheric emissions for which an Atmospheric Emission Licence must be obtained before operation can take place.

GN893:2013 lists the ten main categories, each with its associated subcategories (more detailed description of the exact activities and minimum emission standards), for which an Atmospheric Emission Licence needs to be obtained. The main categories include:

- Combustion Installations;
- Petroleum Industry;
- Carbonization and Coal Gasification;
- Metallurgical Industry;
- Mineral Processing, Storage and Handling;
- Organic Chemicals Industry;
- Inorganic Chemicals Industry;
- Disposal of Hazardous and General Waste;
- Pulp and Paper Manufacturing Activities; and
- Animal Matter Processing.

The Notice further states that the minimum emission standards will be applicable to both permanently operating plants and for experimental (pilot) plants with a design capacity equivalent to a listed activity. Treatment of titano-magnetite slag by salt roasting will trigger: and AEL in terms of NEM:AQA. Minimum standards are applicable under normal working conditions, and any normal start-ups, maintenance, upset and shut-down conditions that exceed a period of 48 hours will be subject to Section 30 of the NEM:AQA, which deals with control of emergency incidents. Upset conditions means any temporary failure of air pollution control equipment or failure of a process to operate in a normal or usual manner that leads to an emission standard being exceeded. This list of activities has been amended and a revised version released in November 2013.

Any new plant must comply with the new plant minimum emission standards as contained in Part 3 of the Notice (which gives detailed account of minimum emission standards) on the date of publication of the notice, which was 31 March 2010.

DEA has established the National Ambient Air Quality Standards for the criteria pollutants in the Government Notice - GN1210:2009 – for gases and particulates. Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm) (Harrison and van Grieken, 1998). The fine particles contain the secondarily formed aerosols such as sulphates and nitrates, combustion particles and recondensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dust from roads and industries (Fenger, 2002).

Table 4-1 gives an overview of the established NAAQS, as well reference methods and compliance dates for criteria pollutants.

Table 4-1: National Ambient Air Quality Standards as of 24 December 2009

National Ambient Air Quality Standard for Sulphur Dioxide (SO_2)				
Averaging Period	**Limit Value (µG/M3)**	**Limit Value (PPB)**	**Frequency Of Exceedance**	**Compliance Date**
10 Minutes	500	191	526	Immediate
1 hour	350	134	88	Immediate
24 hours	125	48	4	Immediate
1 year	50	19	0	Immediate
The reference method for the analysis of SO_2 shall be ISO 6767.				
National Ambient Air Quality Standard for Nitrogen Dioxide (NO2)				
Averaging Period	**Limit Value (µG/M3)**	**Limit Value (PPB)**	**Frequency Of Exceedance**	**Compliance Date**
1 hour	200	106	88	Immediate
1 year	40	21	0	Immediate
The reference method for the analysis of NO_2 shall be ISO 7996.				

National Ambient Air Quality Standard for Particulate Matter (PM_{10})			
Averaging Period	**Limit Value (µG/M3)**	**Frequency Of Exceedance**	**Compliance Date**
24 hour	120	4	Immediate – 31 December 2014
24 hour	75	4	1 January 2015
1 year	50	0	Immediate – 31 December 2014
1 year	40	0	1 January 2015
The reference method for the determination of the PM_{10} fraction of suspended particulate matter shall be EN 12341.			

National Ambient Air Quality Standard for Ozone (O_3)				
Averaging Period	**Limit Value**	**Limit Value**	**Frequency Of**	**Compliance Date**

	(µG/M3)	(PPB)	Exceedance	
8 hours (running)	120	61	11	Immediate
The reference method for the analysis of ozone shall be the UV photometric method as described in SANS 13964.				
National Ambient Air Quality Standard for Benzene (C_6H_6)				
Averaging Period	**Limit Value (µG/M3)**	**Limit Value (PPB)**	**Frequency Of Exceedance**	**Compliance Date**
1 year	10	3.2	0	Immediate – 31 December 2014
1 year	5	1.6	0	1 January 2015
The reference methods for the sampling and analysis of benzene shall either be EPA compendium method TO-14 A or method TO-17.				
National Ambient Air Quality Standard for Lead (Pb)				
Averaging Period	**Limit Value (µG/M3)**	**Limit Value (PPB)**	**Frequency Of Exceedance**	**Compliance Date**
1 year	0.5		0	Immediate
The reference method for the analysis of lead shall be ISO 9855.				
National Ambient Air Quality Standard for Carbon Monoxide (CO)				
Averaging Period	**Limit Value (µG/M3)**	**Limit Value (PPB)**	**Frequency Of Exceedance**	**Compliance Date**
1 hour	30	26	88	Immediate
8 hour (calculated on 1 hourly averages)	10	8.7	11	Immediate
The reference method for analysis of CO shall be ISO 4224.				

The Minister of Water and Environmental Affairs, in terms of section 9 (1) of the NEM: AQA established the National Ambient Air Quality Standard for particulate matter of aerodynamic diameter less than 2.5 micron metre ($PM_{2.5}$), published in GN R 486 in GG 35463 of 29 June 2012 (Table 4-2).

Table 4-2: National Ambient Air Quality Standard for Particulate Matter $PM_{2.5}$

National Ambient Air Quality Standard for Particulate Matter ($PM_{2.5}$)			
Averaging Period	**Concentration**	**Frequency Of Exceedance**	**COMPLIANCE DATE**
24 hours	65 µg/m^3	4	Immediate – 31 December 2015
24 hours	40 µg/m^3	4	1 January 2016 – 31 December 2029
24 hours	25 µg/m^3	4	1 January 2030
1 year	25 µg/m^3	0	Immediate – 31 December 2015
1 year	20 µg/m^3	0	1 January 2016 – 31 December

			2029
1 year	15 µg/m^3	0	1 January 2030
The reference method for the determination of the $PM_{2.5}$ fraction of suspended particulate matter shall be EN 14907.			

In line with NEM: AQA, and on the basis of the cumulative South African experience of dust fall-out measurements, the National Department of Environmental Affairs has published important National Dust Control Regulations in Government Notice 827 in Gazette 36974 on 1 November 2013.

Terms such as “target”, “action” and “alert thresholds” were omitted. Another notable observation was the reduction of the permissible frequency from three to two incidences within a year. The standard actually adopted a more stringent approach than previously, and requires dedicated mitigation plans, and this is in force.

The National Dust fallout standard is given in Table 4-3 below.

Table 4-3: Acceptable Dust Fall Rates as Measured (using ASTM D1739:1970 or Equivalent) (National Dust Control Regulation, 2013)

Restriction Areas	Dust fall rate (mg/m^2/day, 30-days average)	Permitted Frequency of exceeding dust fall rate
Residential Area	D < 600	Two within a year, not sequential months
Non-Residential Area	600 < D < 1200	Two within a year, not sequential months

4.1.2 Equator Principles and IFC Performance Standards

The IFC EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP). The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account (IFC, 2007).

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

4.1.2.1 International Guidelines and Standards

The IFC subscribe to the World Health Organization guidelines and standards (Table 4-4) for the general environmental health and safety, air emissions and ambient air quality

Table 4-4: World Health Organization Ambient Air Quality Guidelines (as used by IFC)

WHO Ambient Air Quality Guidelines[23]		
Pollutant	**Averaging Period**	**Guideline value in µg/m^3**
Sulfur dioxide (SO_2)	24-hour	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)
Sulfur dioxide (SO_2)	10 minute	500 (guideline)
Nitrogen dioxide (NO_2)	1-year	40 (guideline)
Nitrogen dioxide (NO_2)	1-hour	200 (guideline)
Particulate Matter PM_{10}	1-year	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline)
	24-hour	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)
Particulate Matter $PM_{2.5}$	1-year	35 (Interim target-1) 25 (Interim target-2) 15 (Interim target-3) 10 (guideline)
	24-hour	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)
Ozone	8-hour daily maximum	160 (Interim target-1) 100 (guideline)

4.2 Health Effects of Identified Pollutants

4.2.1 Particulates

The main pollutant of concern identified as a result of the construction and operational phases of the mining development will be the particulate matter, whether in the form of total suspended particulates (TSP), PM_{10} or $PM_{2.5}$.

In terms of health effects, particulate air pollution is associated with complaints of the respiratory system (WHO, 2000). Particle size is important for health because it controls where in the respiratory system a given particle deposits. Fine particles are thought to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extrathoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

PM is a type of air pollution that is present wherever people live. It is generated mainly by human activities: transport, energy production, domestic fuel combustion and by a wide range of industries. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur.

The range of adverse health effects of PM is broad, involving respiratory and cardiovascular systems in children and adults. Both short- and long-term exposures lead to adverse health effects. Very young children, probably including unborn babies, are particularly sensitive to the adverse effects of PM. The evidence is sufficient to infer a causal relationship between exposure to PM and deaths from respiratory diseases in the post-neonatal period. Adverse effects of PM on lung development include reversible deficits of lung function as well as chronically reduced lung growth rate and long-term lung function deficit. The available evidence is also sufficient to assume a causal relationship between exposure to PM and aggravation of asthma, as well as cough and bronchitis symptoms. Daily mortality and hospital admissions have been linked with short term variation of PM levels. Increased mortality from cardiovascular and respiratory diseases and from lung cancer has been observed in residents of more polluted areas.

Based on the existing evidence of adverse health effects at low levels of exposure, the WHO revised its Air Quality Guidelines (AQG) for PM in 2005. For $PM_{2.5}$, the new AQG values are 10 µg/m^3 for the annual average and 25 µg/m^3 for the 24-hour mean (not to be exceeded for more than 3 days/year). The corresponding guidelines for PM_{10} were set as 20 µg/m^3 and 50 µg/m^3.

Ambient PM_{10} concentrations are a good approximation of population exposure to PM from outdoor sources. Numerous epidemiological studies conducted in Europe and in other parts of the world have shown adverse health effects of exposure to PM_{10} and $PM_{2.5}$ at concentrations that are currently observed in Europe and the rest of the world. WHO estimated that approximately 700 annual deaths from acute respiratory infections in children aged 0–4 years could be attributed to PM_{10} exposure in the WHO European Region in the late 1990s alone. Population health effects of exposure to PM in adults are dominated by mortality associated with long-time exposure to fine PM ($PM_{2.5}$). Short-term and long-term health effects associated with exposure to particulate matter are presented in Table 4-5.

4.2.1.1 Short-Term Exposure

Recent studies suggest that short-term exposure to particulate matter is associated with health effects, even at low concentrations of exposure. Various studies undertaken during the 1980s and early 1990s have looked at the relationship between daily fluctuations in particulate matter and mortality at low levels of exposure. Pope *et al* (1992) studied daily mortality in relation to PM_{10} concentrations in Utah Valley during the period 1985 - 1989. A maximum daily average concentration of 365 µg/m^3 was recorded with effects on mortality observed at concentrations of < 100 µg/m^3. The increase in total daily mortality was 13% per 100 µg/m^3 increase in the 24 hour average. Studies by Schwartz (1993) in Birmingham recorded daily concentrations of 163 µg/m^{3}and noted that an increase in daily mortality was experienced with an increase in PM_{10} concentrations. Relative risks for chronic lung disease and cardiovascular deaths were higher than deaths from other causes.

However, in the past, daily particulate concentrations were in the range 100 – 1000 µg/m^3 whereas in more recent times, daily concentrations are between 10 – 100 µg/m^3. Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (WHO, 2000).

Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function. Pope and Dockery (1992) studied panels of children in Utah Valley in winter during the period 1990 – 1991. Daily PM_{10} concentrations ranged between 7 – 251 µg/m^3. Peak Expiratory Flow (PEF) was decreased and respiratory symptoms increased when PM_{10} concentrations increased. Pope and Kanner (1993) utilised lung function data obtained from smokers with mild to moderate chronic obstructive pulmonary disease in Salt Lake City. The estimated effect was a 2% decline in FEV_1 (Forced Expiratory Volume over one second) for each 100 µg/m^3 increase in the daily PM_{10} average.

4.2.1.2 Long-Term Exposure

Long-term exposure to low concentrations (~10 µg/m^3) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000).The short term and long term effects associated with particulate matter are depicted in Table 4-5.

Studies have indicated an association between lung function and chronic respiratory disease and airborne particles. Older studies by Chestnut *et al* (1991) found that Forced Vital Capacity decreases with increasing annual average particulate levels with an apparent threshold at 60 µg/m^3. Using chronic respiratory disease data, Schwartz (1993) determined that the risk of chronic bronchitis increased with increasing particulate concentrations, with no apparent threshold.

Few studies have been undertaken documenting the morbidity effects of long-term exposure to particulates. Recently, the Harvard Six Cities Study showed increased respiratory illness rates among children exposed to increasing particulate, sulphate and hydrogen ion concentrations. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10 µg/m^3 increase in annual average particulate concentrations.

Table 4-5: Short-Term and Long-Term Health Effects associated with Exposure to PM (after WHO 2004)

Pollutant	Short-Term Exposure	Long-Term Exposure
Particulate matter	▪ Lung inflammatory reactions ▪ Respiratory symptoms ▪ Adverse effects on the cardiovascular system ▪ Increase in medication usage ▪ Increase in hospital admissions ▪ Increase in mortality	▪ Increase in lower respiratory symptoms ▪ Reduction in lung function in children ▪ Increase in chronic obstructive pulmonary disease ▪ Reduction in lung function in adults ▪ Reduction in life expectancy ▪ Reduction in lung function development

5 Assumptions and Limitations

Data limitations and assumptions associated with this study are listed below:

- This impact assessment is limited to particulates $PM_{2.5}$, PM_{10}, and dust fallout and based solely on the infrastructure plan provided by the client. No long-term monitoring data is available for the proposed site;
- This assessment did not include emissions from onsite generator and tail pipe emissions from vehicles. However, the Green House Gas study compiled an emission inventory including the aforementioned sources; and
- US-EPA and NPi emission factors for mining will be utilised in this assessment due to the unavailability of local emission factors.

6 Baseline Environment

6.1 Regional Climate and Factors Influencing Air Dispersion

6.1.1 Topography

The Magnetite Mine project area is comprised of a relatively undulating topography, with features such as ridgelines in places. The elevation in the area ranges between 965 to 1089 m above mean sea level (amsl).

6.1.2 Vegetation and Land Use

The regional natural vegetation cover is Savanna Biome, within the Makhado Sweet Bushveld and Central Sandy Bushveld regional vegetation types. Agriculture is not a significant feature, except on the north western corner of the proposed site with visible agricultural areas and associated irrigation.

6.2 Climate and Local Meteorological Overview

Southern Africa is influenced by two major high pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperate latitudes. The mean circulation of the atmosphere over Southern Africa is anticyclonic throughout the year (except near the surface) due to the dominance of the three high pressure cells, namely South Atlantic High Pressure Cell, off the west coast, the South Indian High Pressure Cell off the east coast and the Continental High Pressure Cell over the interior. It is these climatic conditions and circulation movements that are responsible for the distribution and dispersion of air pollutants within and around the Mokopane area, neighbouring provinces and countries bordering South Africa.

South Africa is located in the sub-tropics where high pressures and subsidence dominate. However, the southern part of the continent can also serve as a source of hot air that intrudes sub-tropics, and that sometimes lead to convective movement of air masses. On average, a low pressure will develop over the southern part of the continent, while the normal high pressures will remain over the surrounding oceans. These high pressures are known as Indian High Pressure Cell and Atlantic High Pressure Cell. The intrusion of continents will allow for the development of circulation patterns that will draw moisture (rain) from either tropics (hot air masses over equator) or from the mid-latitude and temperate latitudes.

Limpopo province experiences warm wet summers and dry winters. Summer rainfall aids in removing pollutants through wet deposition. In summer, unstable atmospheric conditions result in mixing of the atmosphere and rapid dispersion of pollutants. In contrast, winter is characterised by atmospheric stability caused by a persistent high pressure system over South Africa. Preston-Whyte and Tyson (1988) describe the atmospheric conditions in the winter months as highly unfavourable for the dispersion of atmospheric pollutants.

Precipitation reduces erosion potential by increasing the moisture content of materials. This represents an effective mechanism for removal of atmospheric pollutants and is therefore considered during air pollution studies. Rain-days are defined as days experiencing 0.2 mm or more rainfall.

There are temperature variations throughout the year. These vary greatly within the daily cycle and according to location, vegetation cover, wind reach, and the presence of any large water bodies. The austral winter in southern Africa is characterised by the presence of pronounced atmospheric inversion layer, which, combined with a regional high-pressure system, can trap the pollutants in the lower atmosphere in a large anti-cyclonic vortex covering the interior of southern Africa. This usually results in reduced dispersion and a poorer ambient air quality during the winter period. Preston-Whyte and Tyson (1988) describe the atmospheric conditions in the winter months as highly unfavourable for the dispersion of atmospheric pollutants.

Site specific (meso-scale model) MM5 modelled meteorological data set for the period 2011 – 2013 was obtained from Lakes Environmental Consultants in Canada to determine local prevailing weather conditions. This dataset consists of surface data, as well as upper air meteorological data that is required to run the dispersion model. It is required if site specific surface and upper air meteorological data is not available. The Pennsylvania State University / National Centre for Atmospheric Research (PSU/NCAR) MM5 is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict meso-scale atmospheric circulation (Lakes Environmental Software, 2015).

This data has been tested extensively and has been found to be extremely accurate. Modelled meteorological data for the period January 2011 to December 2013 was obtained for the project area (23.897667 S, 28.801219 E). Data availability was 100%.

Generally, a data set of greater than 90% (taken to be the same as that stipulated for pollutant data availability (SANS, 2005) is required in order for that month/year to be considered representative of the assessed area (SANS, 2005).

Dispersion of atmospheric pollutants is a function of the prevailing wind characteristics at any site. 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 (Jacobson, 2005)

The amount of particulate matter (PM) generated by wind is highly dependent upon the wind speed. Below the wind speed threshold for a specific particle type, no PM is liberated, while above the threshold, PM liberation tends to increase with the wind speed. The amount of PM generated by wind is also dependent on the material's surface properties. This includes whether the material is crusted, the amount of non-erodible particles and the particle size distribution of the material (Fryrear *et al*., 1991)

Wind roses generally comprise of 16 spokes which represent the directions from which winds blew during the period. The colours reflect the different categories of wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The figure given at the bottom of the legend described the frequency with which calms occurred, i.e. periods during which the wind speed was below 0.5 m/s.

The spatial and annual variability in the wind field for the project area modelled data is clearly evident in Figure 6-1. The predominant wind direction is from the north east, east northeast and south east. Over the three year period, frequency of occurrence was 11.1% from the north easterly sector, 10.9% east north east, 9.5% south east. Calm conditions (wind speeds < 0.5 m/s) occurred for 9% of the time. Wind class frequency distribution per sector is given in Table 6-1 and Figure 6-4.

There is some diurnal variation in the modelled meteorological data as shown in Figure 6-2. The predominant wind direction is from the north east and south east throughout the day except for the afternoon when the predominant wind direction is from the northwest. The morning and evening wind roses are similar to the period wind rose with calm periods of 14% and 3% respectively. The afternoon experiences the calmest period of 16% (Figure 6-2)

The wind roses for the four seasons are shown in Figure 6-3. The predominant wind direction in spring and summer is from the north east and east north east. In autumn and winter the predominant wind direction is from the south east and south southeast. The highest calm periods of 11% are experienced in summer and autumn.

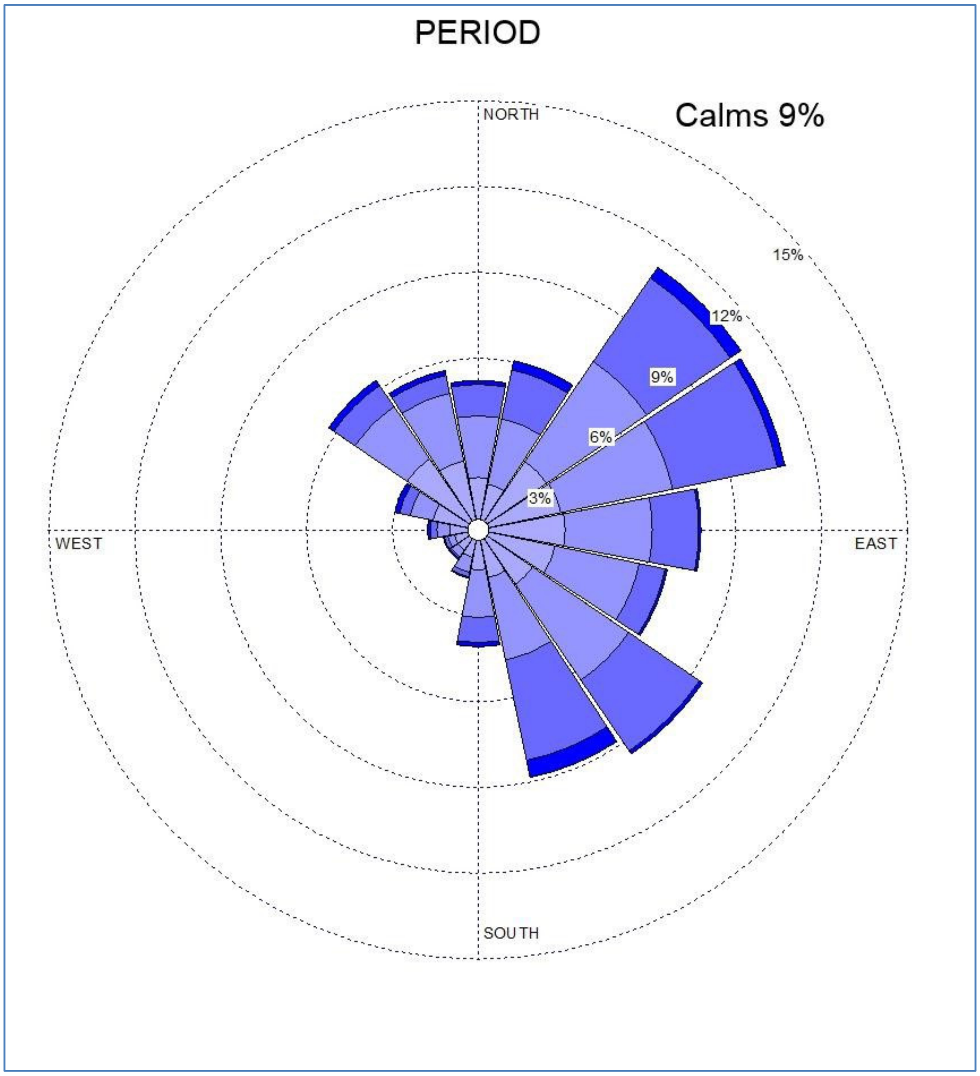

Figure 6-1: Period Surface Wind Rose for Project Area

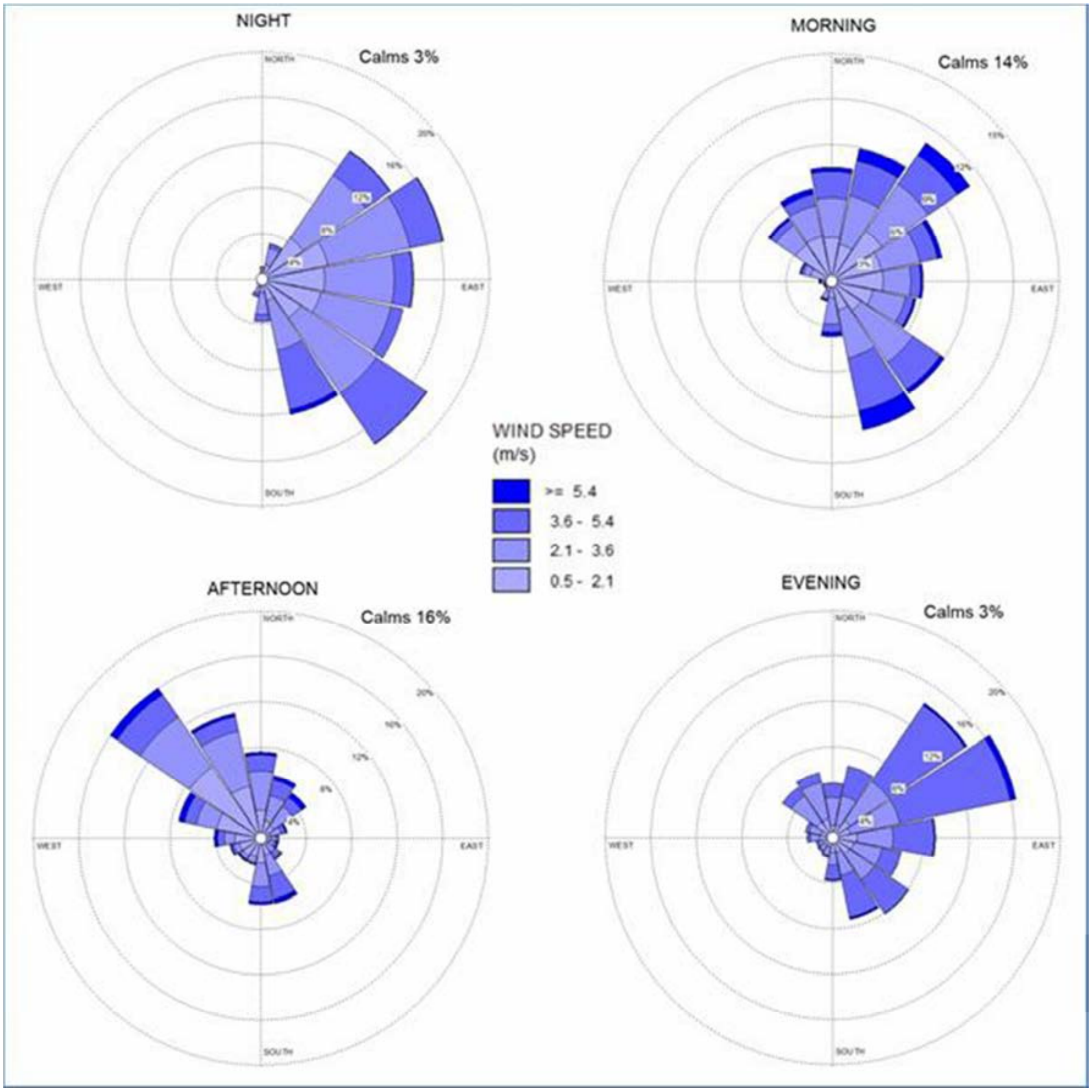

Figure 6-2: Diurnal Variation of Wind Directions for the Project Area Modelled Data (01 January 2011 - 31 December 2013): night 00:00 – 06:00 (top left), morning 06:00 – 12:00 (top right), afternoon 12:00 – 18:00 (bottom left) and evening 18:00 – 23:00 (bottom right)

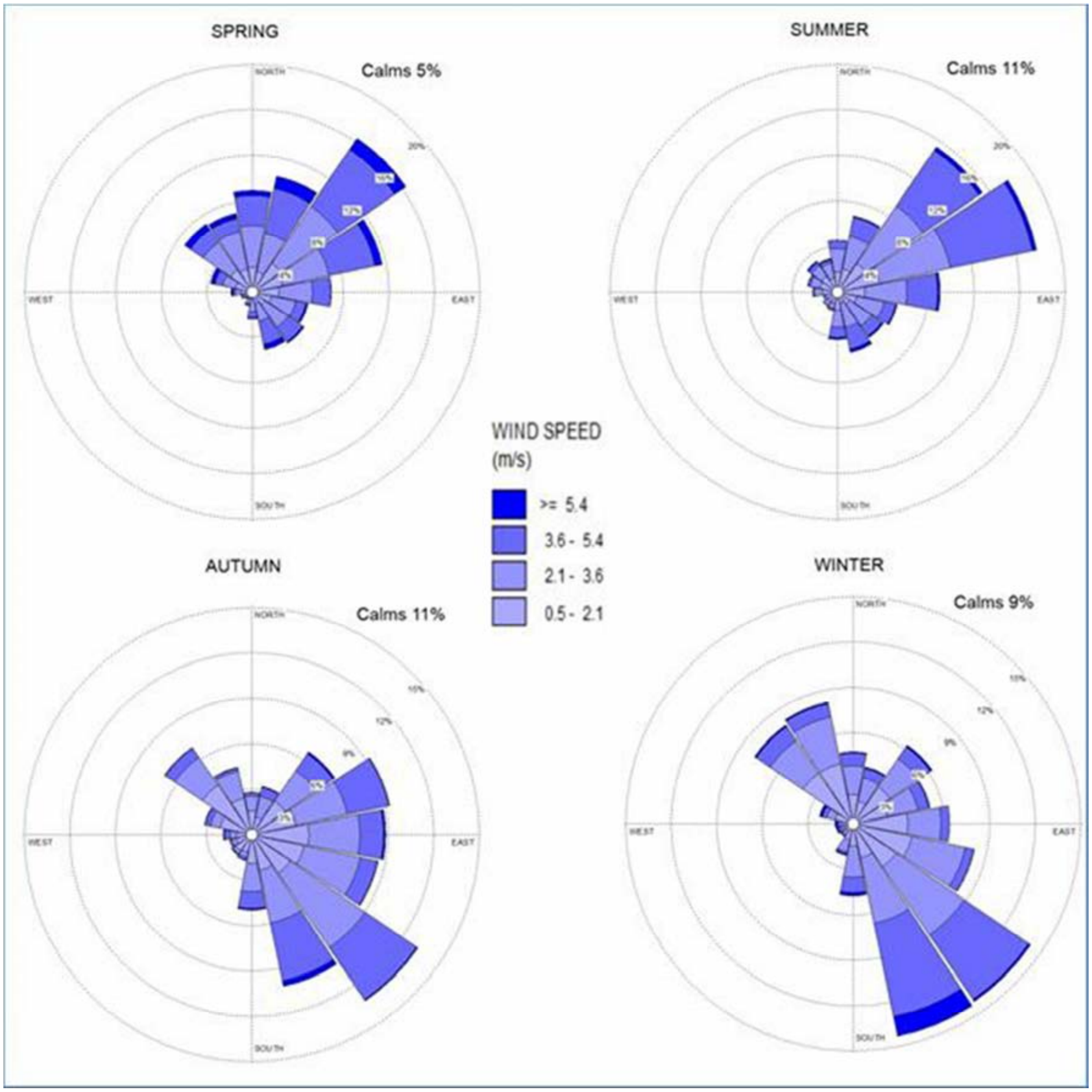

Figure 6-3: Seasonal Surface Wind Roses for Project Area Spring (September – November), summer (December – February); autumn (March – May); winter (June – August)

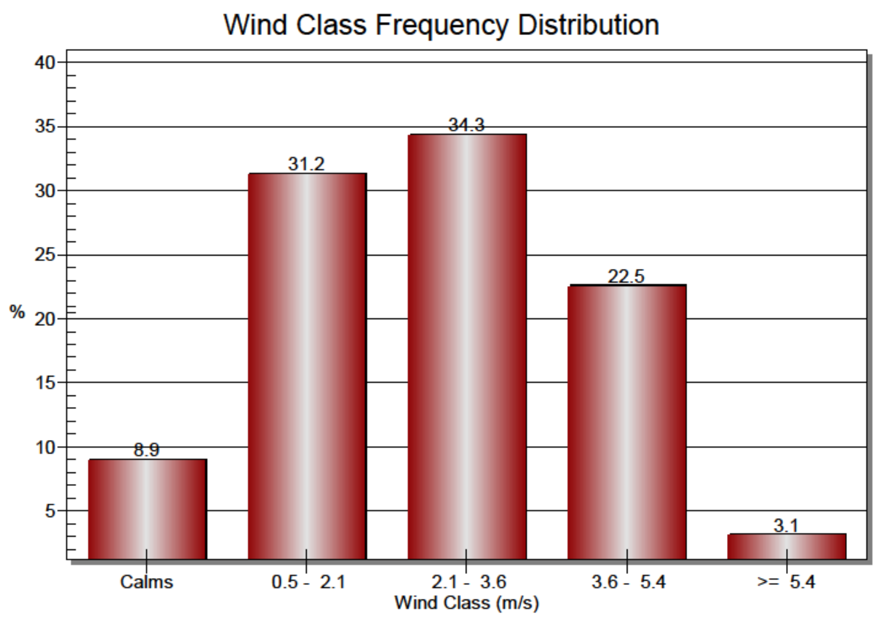

Figure 6-4: Wind Class Frequency Distribution

Table 6-1: Wind Class Frequency Distribution per Direction

Direction		Wind classes (m/s)				
		0.5 - 2.1	2.1 - 3.6	3.6 - 5.4	>5.4	Total (%)
1	N	1.8	2.2	1.1	0.1	5.2
2	NNE	1.6	2.3	1.7	0.3	6.0
3	NE	2.9	4.2	3.5	0.5	11.1
4	ENE	2.9	4.0	3.7	0.3	10.9
5	E	3.0	3.0	1.6	0.1	7.8
6	ESE	2.7	3.0	0.9	0.1	6.7
7	SE	2.3	4.0	3.0	0.1	9.5
8	SSE	1.7	2.9	3.6	0.6	8.8
9	S	1.4	1.7	0.9	0.1	4.1
10	SSW	1.0	0.5	0.2	0.0	1.7
11	SW	0.9	0.3	0.1	0.0	1.3
12	WSW	0.9	0.2	0.1	0.0	1.3
13	W	1.0	0.4	0.2	0.1	1.8
14	WNW	1.6	0.8	0.4	0.2	3.0

Direction		Wind classes (m/s)				
		0.5 - 2.1	**2.1 - 3.6**	**3.6 - 5.4**	**>5.4**	**Total (%)**
15	NW	3.0	2.2	0.9	0.2	6.3
16	NNW	2.5	2.4	0.6	0.2	5.7
	Sub-Total	31.2	34.3	22.5	3.1	91.1
	Calms					8.9
	Missing/Incomplete					0.0
	Total					**100.0**

6.2.1 Temperature

Three-year average maximum, minimum and mean temperatures for the project area are shown in Figure 6-5 and Table 6-2. Annual mean temperature is 19.7°C. The average monthly maximum temperatures range from 13.2°C in July to 23.8°C in January and December, with daily minima ranging from 11.6°C in July to 23.8°C in January. This pattern followed the seasonal variations, with highest temperatures during summer months and lowest during winter.

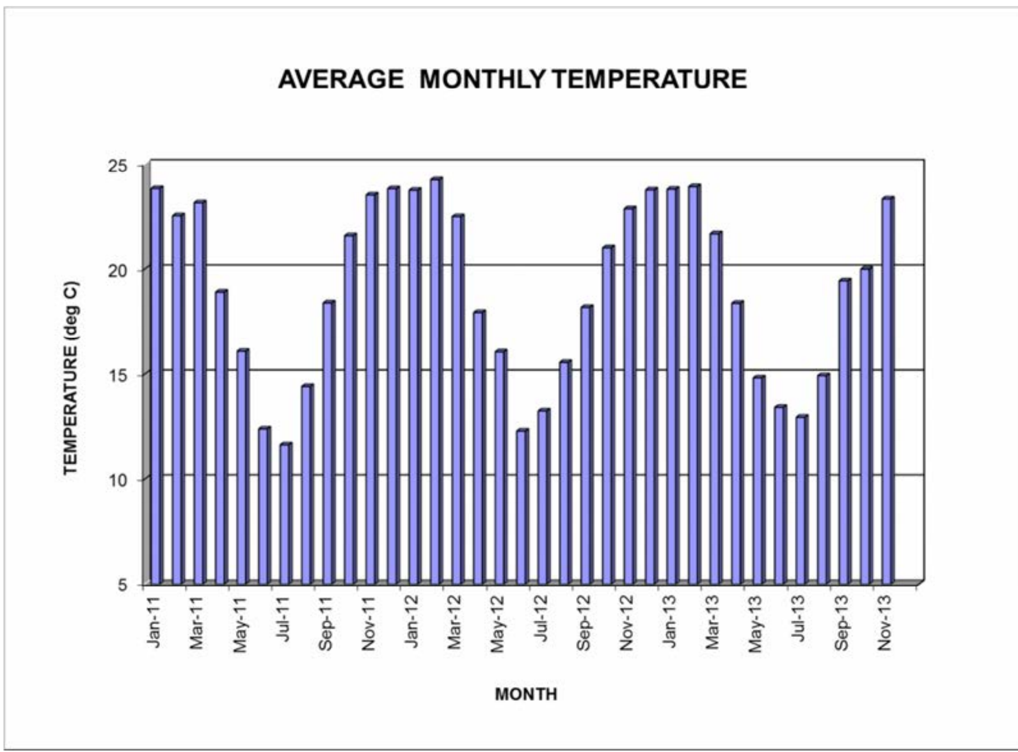

Figure 6-5: Monthly Average Temperature

Table 6-2: Monthly Temperature Values

Temperature (deg °C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann. Ave
Monthly Max	23.8	24.2	23.2	18.9	16.1	13.4	13.2	15.6	19.4	21.6	23.5	23.8	19.7
Monthly Min	15.2	22.5	21.7	17.9	14.8	12.3	11.6	14.4	18.2	20.0	22.9	23.4	18.6
Monthly Mean	17.8	23.6	22.4	18.4	15.7	12.7	12.6	15.0	18.7	20.9	23.2	23.6	19.2

6.2.2 Relative Humidity

Figure 6-6 and Table 6-3 depict the relative humidity for the project area. The annual values for maximum, minimum and mean relative humidity are given as 63.9%, 60.4% and 62.2%, respectively. For the entire three years, maximum relative humidity of 69.3% in July and the lowest of 57.6% was calculated for November.

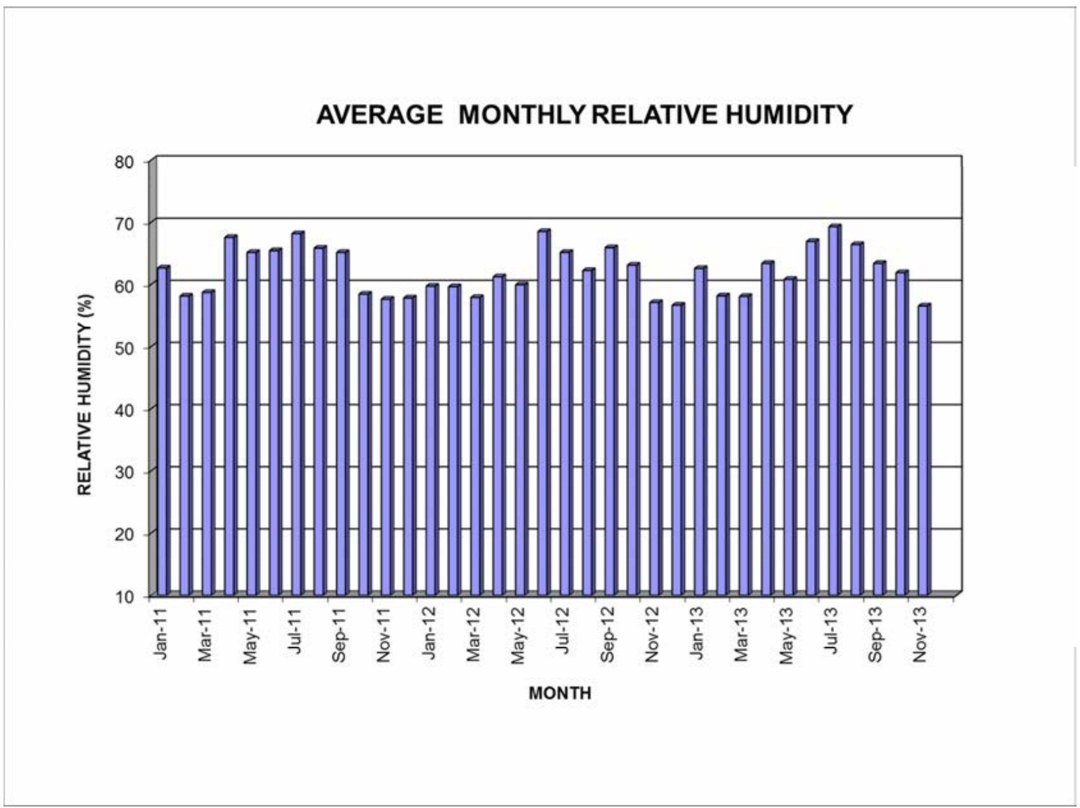

Figure 6-6: Monthly Average Relative Humidity

Table 6-3: Monthly Relative Humidity Values

Relative Humidity (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max	62.7	59.6	58.7	67.6	65.2	68.5	69.3	66.4	65.9	63.1	57.6	62.2	63.9
Monthly Min	59.7	58.1	57.9	61.2	60.0	65.4	65.2	62.2	63.4	58.4	56.5	56.7	60.4
Monthly Mean	61.7	58.6	58.2	64.1	62.0	67.0	67.5	64.8	64.8	61.2	57.1	58.9	62.2

6.2.3 Rainfall

Figure 6-7 shows the total monthly rainfall (maximum) and the average total monthly precipitation for the project area. As shown in Table 6-4, the annual total and average monthly rainfall of 798 mm and 44 mm were estimated. The highest monthly maximum precipitation of 224.8 mm was recorded in January.

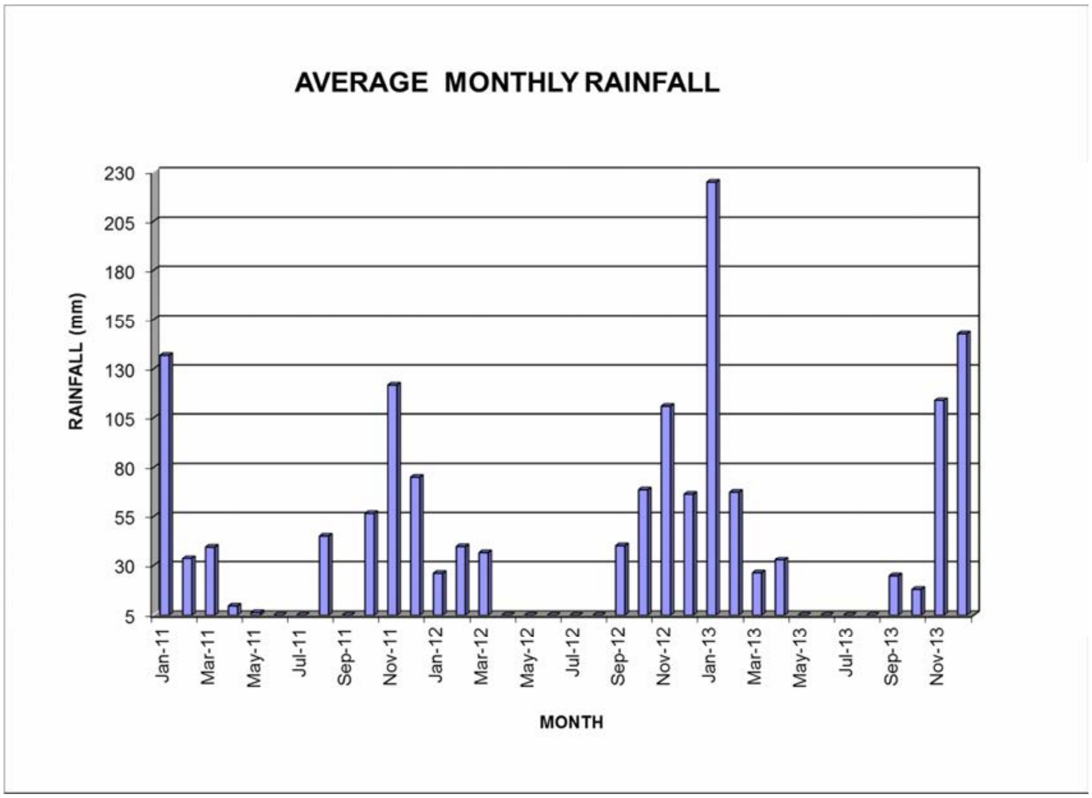

Figure 6-7: Monthly Average Precipitation

Table 6-4: Monthly Precipitation Values

Precipitation (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Tot
Total Monthly Rainfall (Max)	224.8	67.3	39.6	33.0	6.4	0.3	3.0	45.2	40.4	68.6	121.9	147.8	798.3
Average Total Monthly Rainfall	129.3	47.0	34.3	14.4	2.3	0.2	1.5	15.5	22.0	47.8	115.7	96.4	43.9

6.2.4 Evaporation

As shown in Table 6-5, the annual maximum, minimum and mean monthly evaporation rates for the Potgietersrus (Mokopane) area for the period 1957-1987 are 244 mm, 130 mm and 178 mm, respectively. The highest monthly maximum evaporation (332.2 mm) occurred in November. The rate decreases significantly down to 121.6 mm in June. The monthly minimum evaporation ranges between 200.7 mm in December and 69.9 mm in June.

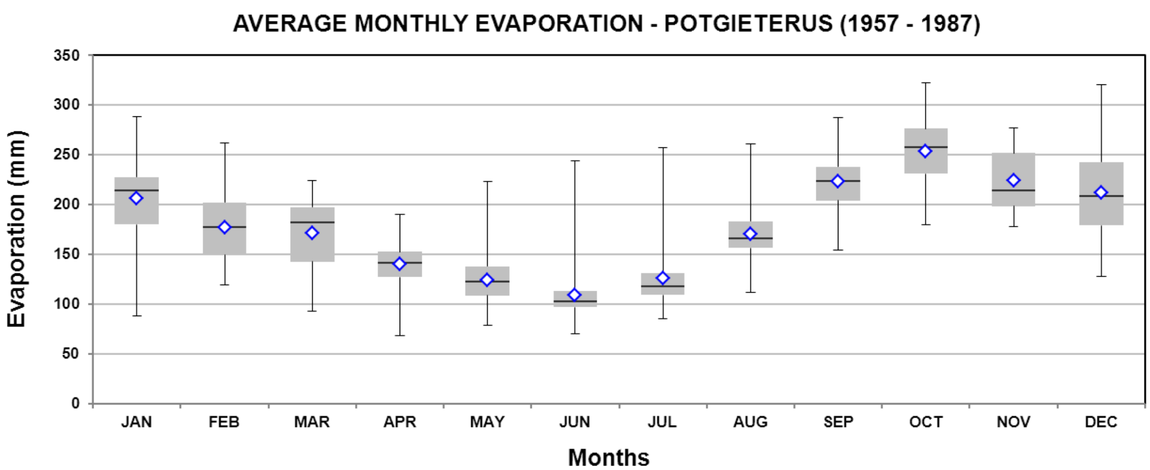

Figure 6-8: Average Monthly Evaporation for Potgieterus (Mokopane) S-Pan Evaporation Station (1957 – 1987)

(Source: South African Weather Service)

Table 6-5: Maximum, Minimum and Mean Monthly Evaporation Rates for the Potgietersrus(Mokopane)Symon's Pan) S-Pan evaporation station for 1957-1987 period (South African Weather Service)

Evaporation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	289	262	224	190	223	244	257	261	288	322	277	320	289
Monthly Min.	88	120	93	68	79	70	85	111	155	180	178	128	88
Monthly Mean	206	177	171	141	124	109	126	170	224	253	224	212	206

6.2.5 Boundary Layer Properties and Atmospheric Stability

The region of the atmosphere governing transport and dispersion of the majority of the pollutants is the planetary boundary layer. This layer is defined as the layer where the wind structure is influenced by the surface of the Earth.

The height of the planetary boundary layer varies with the atmospheric stability and this is important for the concentrations of pollutants in the air because the majority of the pollutant mass typically is confined within this layer. During night-time when conditions in most cases are stable, the planetary boundary layer is shallow, down to 20-50 metres and the surface concentration of pollutants can therefore be quite high, especially close to emission sources that are active during the night. Under unstable conditions the planetary boundary layer can be as high as 2 kilometres and pollutants are in this case distributed in the air column mainly by convective turbulence. In the vicinity of the top of the boundary layer, the horizontal winds are typically stronger and the pollutants that end up at these higher levels may be transported far away from the emission sources. In neutral conditions emitted pollutants are quickly mixed in the air by mechanical turbulence and the surface concentration is not particularly high. During neutral conditions the strong horizontal wind speeds can transport pollutants across large distances.

The atmospheric conditions may be divided into three broad classes in terms of stability: neutral, stable and unstable conditions. These major three categories are characterised by the following:

- *Neutral* conditions where the temperature is homogeneous throughout the boundary layer. This situation typically occurs in the transition from day to night and is characterised by strong winds and clouds and large amounts of mechanical turbulence;
- *Stable* conditions where the temperature is lowest close to the surface and increases towards the top of the boundary layer. This situation typically occurs during night-time or in winter situations and is characterised by little turbulence and a strong stratification of the planetary boundary layer which is quite shallow. This class can be further divided into stable and very stable classes; and
- *Unstable* conditions where the temperature of the air closest to the surface is higher than the temperature of the air above it. This situation typically occurs during daytime at summer when the sun is shining and it is characterised by large amounts of convective turbulence usually resulting in the formation of cumulus clouds during the day. This class can be further divided into very unstable, moderately unstable and unstable classes.

The refined classes of atmospheric stability classes are further defined in the Table 6-6 and Table 6-7.

Table 6-6: Atmospheric Stability Classes

Designation	Stability Class	Atmospheric Condition
A	Very unstable	Calm wind, clear skies, hot daytime conditions
B	Moderately unstable	Clear skies, daytime conditions
C	Unstable	Moderate wind, slightly overcast daytime conditions
D	Neutral	High winds or cloudy days and nights
E	Stable	Moderate wind, slightly overcast night-time conditions
F	Very stable	Low winds, clear skies, cold night-time conditions

Table 6-7: Meteorological conditions that define the Pasquill stability classes

Surface Wind Speed	Daytime Incoming Solar Radiation			Night Time Cloud Cover	
m/s	Strong	Moderate	Slight	> 50%	< 50%
< 2	A	A – B	B	E	F
2 – 3	A – B	B	C	E	F
3 – 5	B	B – C	C	D	E
5 – 6	C	C – D	D	D	D
> 6	C	D	D	D	D

*Note: Class D applies to heavily overcast skies, at any wind speed day or night.

7 Baseline Assessment

Baseline monitoring and assessment of atmospheric pollutants was appraised using data hosted at SAAQIS database from the Air Quality Monitoring Station in Mokopane, owned by the Department of Environmental Affair. The database contains measurement for known priority pollutants, recording data based on the recommended averaging period. Archived measurements from January 2013 to date are used to assess background levels of pollutants.

7.1 Sulphur dioxide (SO_2)

The daily level of SO_2 at the station was below the South African standard of 48 ppb (125 µg/m^3) during the monitoring period. September 2013 had the highest level of SO_2, exceeding 30 ppb (Figure 7-1) with the lowest levels being in January 2014. In comparison to the WHO guideline of 125 µg/m^3 (48ppb) the ambient concentration are not exceeded.

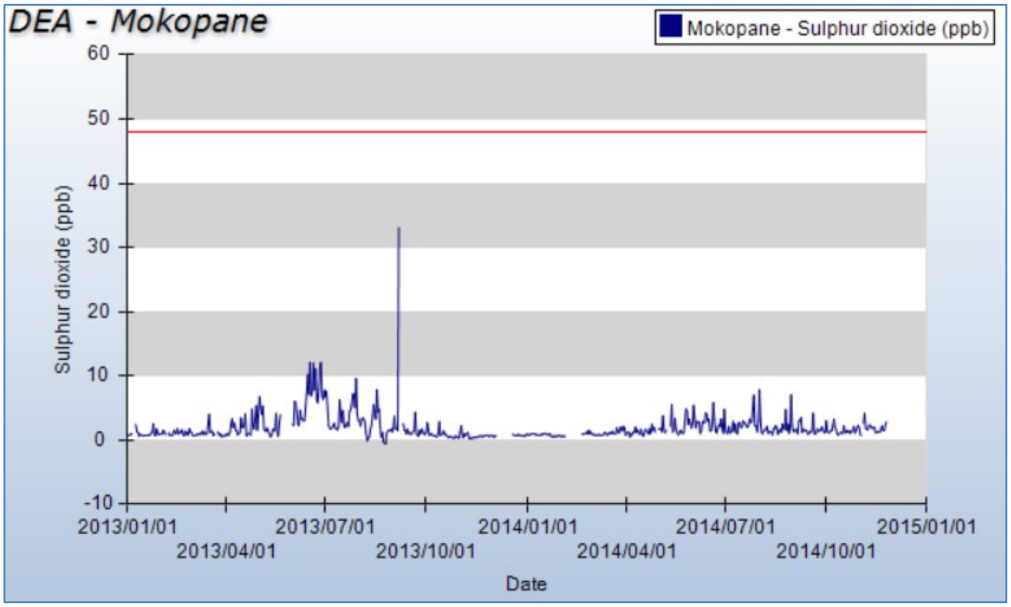

Figure 7-1: Daily SO_2 at Mokopane Station 2013- 2015 (SAAQIS, 2015)

7.2 Nitrogen Dioxide (NO_2)

Figure 7-2 shows the hourly NO_2 recorded at the Mokopane station. The NO_2 records are below the South African Standard of 106 ppb (200 µg/m^3). The NO_2 increase from July and begin to decline after October. Data gaps are observed in 2013 and 2014 respectively. It is believed that the increase observed in the level of NO_2 is a result of the weak wind speed and the low surface temperature during this period, as both conditions do not favour the dispersion of pollutants. The NO_2 levels are below the IFC standard of 106 ppb (200 µg/m^3).

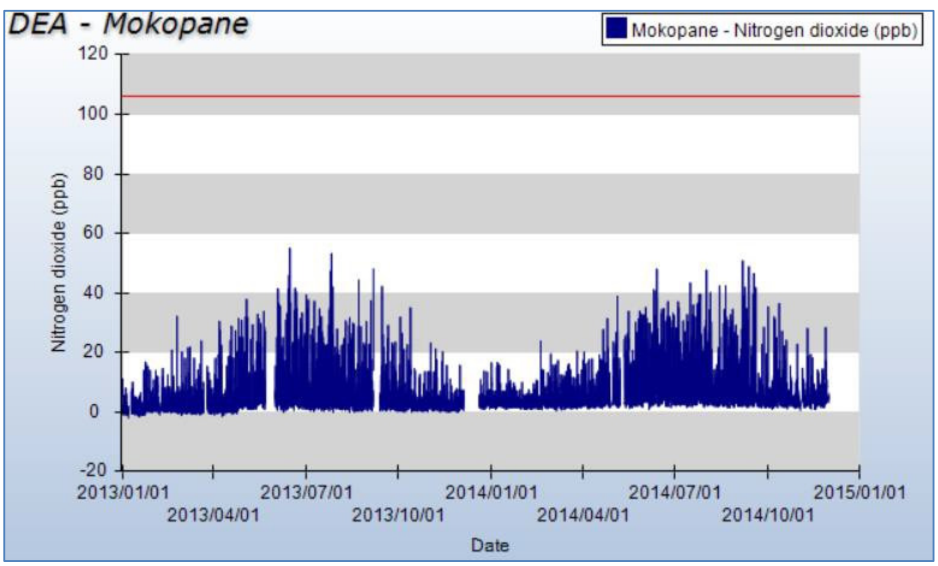

Figure 7-2: Hourly NO_2 at Mokopane Station 2013- 2015 (SAAQIS, 2015)

7.3 Particulate Matter (PM_{10})

The daily PM_{10} concentrations measured at the station (Figure 7-3) show that the South African Standard 75 µg/m^3 is exceeded four times during the period under review. The highest daily PM_{10} concentration measures reached ~150 µg/m^3 in September 2014. The lowest of PM_{10} are experienced around January 2013. The highest ambient concentration observed is twice the current standard. The WHO guideline that IFC subscribes to 50 µg/m^3 is exceeding on several occasions as observed in Figure 7-3.

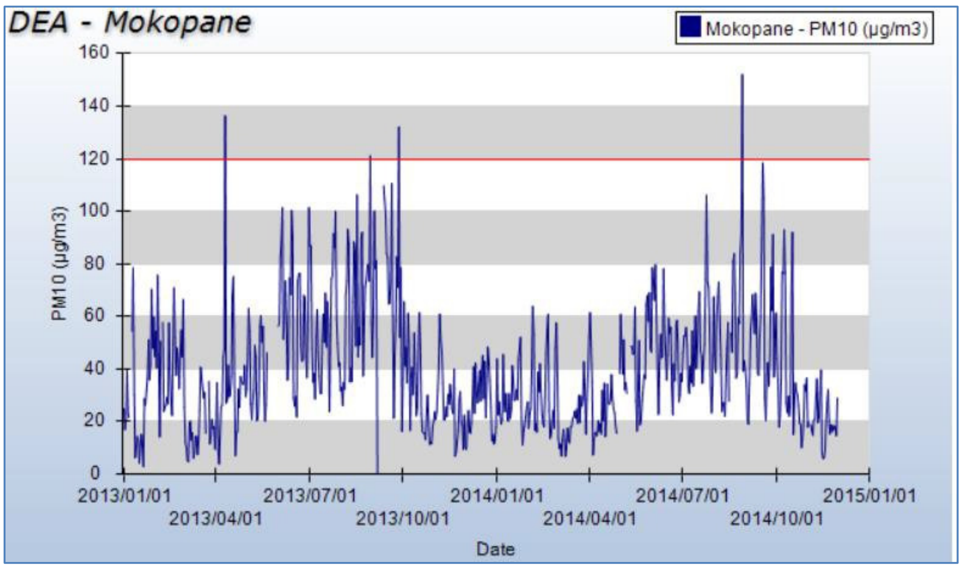

Figure 7-3: Daily PM_{10} at Mokopane Station 2013- 2015 (SAAQIS, 2015)

7.4 Particulate Matter ($PM_{2.5}$)

Figure 7-4 shows the $PM_{2.5}$ levels recorded at the station from 2013 to 2015. From July to October 2013 the recorded levels exceeded the current limit is 65 µg/m^3 and began to decline with the lowest recorded in February and March 2014. The wind speed usually peaks during the months of July, August and September. This might explain why ambient concentrations are higher during those months. The future limit (1January 2016 – 31 December 2029) will be 40 µg/m^3. The ambient $PM_{2.5}$ levels are observed to have exceeded the WHO guideline that IFC subscribes of 25 µg/m^3 especially during the months of May through to August of 2013 and 2014 respectively (Figure 7-3).

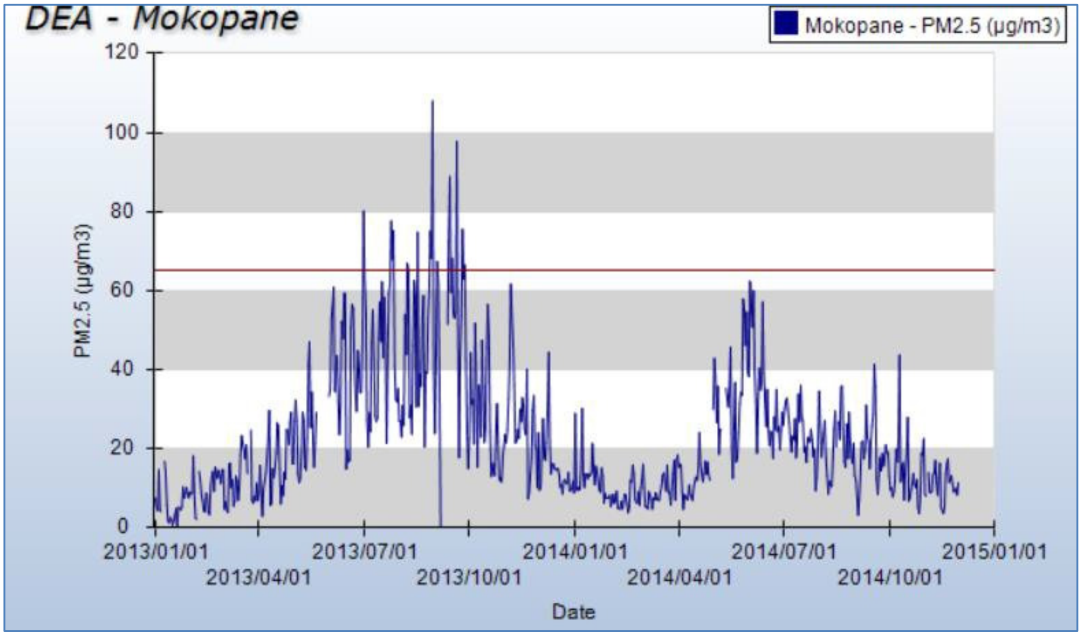

Figure 7-4: Daily $PM_{2.5}$ at Mokopane Station 2013- 2015 (SAAQIS, 2015)

7.5 Ozone O_3 (ppb)

Figure 7-5 shows the 8 hourly running average data recorded for O_3. No data was recorded before November 2013. The data recorded in December 2013 was below the limit of 61 ppb. It is worth mentioning that the available data is not sufficient to accurately assess background conditions of this pollutant in the area. At the time of the assessment, this was the data available.

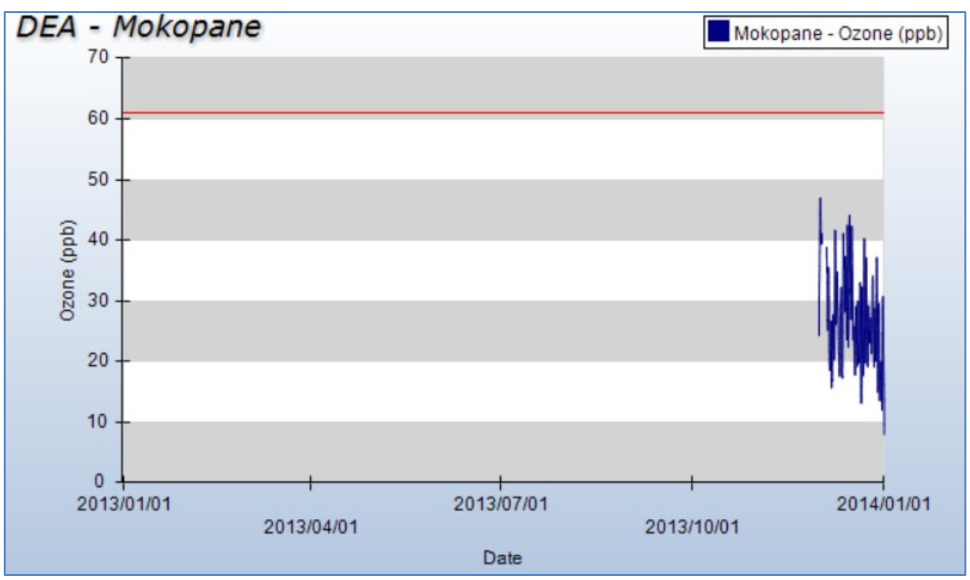

Figure 7-5: 8 Hour Running O_3 at Mokopane Station 2013- 2015 (SAAQIS, 2015)

7.6 Carbon Monoxide (CO)

Figure 7-6 shows the hourly CO concentration measured at the station. Throughout the period under review, the levels were below the South African Standard of 26 ppm. The highest concentration of 5 ppm measured in the month of June 2013 might be attributed to a once off incident, because the general background levels are below 3 ppm.

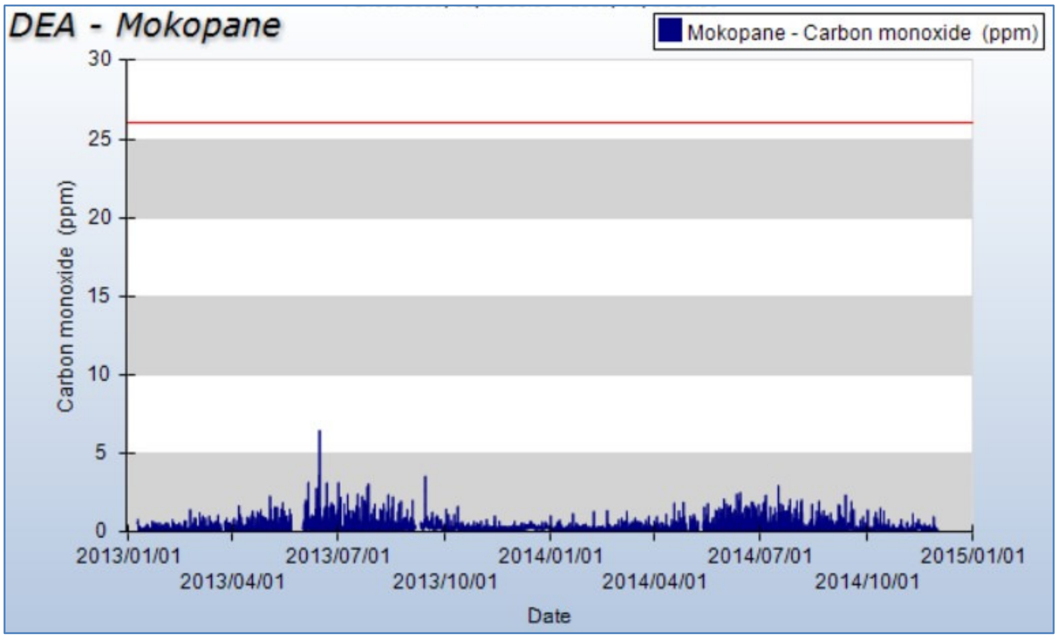

Figure 7-6: Hourly CO at Mokopane Station 2013- 2015 (SAAQIS, 2015)

8 Methodology

8.1 Emission Inventory

The establishment of an emissions inventory forms the basis for any air quality impact assessment. Air pollution emissions may typically be obtained using actual sampling at the point of emission, or estimating it from mass and energy balances or emission factors which have been established at other, similar operations. The method adopted here is the latter. Emission factors published by the US-EPA in its AP-42 document Compilation of Air Pollution Emission Factors and Australian National Pollutant Inventory Emission Estimation Technique Manuals (Common Wealth Australia 2012).

There are various sources of emissions anticipated from the proposed Magnetite Mine operational and decommissioning phases. Typical emissions from a Magnetite Mine include:

- Inhalable particulates, with aerodynamic diameters less than or equal to 10 micron (PM_{10}) and $PM_{2.5}$ from all mining sources; and
- TSP from all mining sources.

An emission factor is a representative value that attempts to relate an activity associated with the release of a pollutant to the quantity of that pollutant released into the atmosphere. Emission factors and emission inventories are fundamental tools for air quality management. The emission factors are frequently the best or only method available for estimating emissions produced by varying sources. Emission estimates are important, amongst others, for developing emission control strategies; determining applicability of permitting and control programmes; and ascertaining the effects of sources and appropriate mitigation measures.

In order to determine the significance of the potential for impacts, it is necessary to quantify atmospheric emissions and predicted airborne pollutant concentrations occurring as a result of each emission source. Empirically derived *predictive emission factor equations* are available for the quantification of TSP, PM_{10} and $PM_{2.5}$, for sources such as aeolian erosion from open areas with no vegetation cover.

The State Pollution Control Commission of New South Wales, Australia (SPCC, 1983) published a number of emission factors i.e. the average value for wind erosion from open areas is 0.4 kg/ha/h (3,504 kg/ha/year). It is suggested that this value be adopted as a default in the absence of other information. The same applies to all other activities with inadequate information to assess associated pollution load.

AP-42 (USEPA, 1998) states that 50% of the TSP is actually in lower PM_{10} fraction. Therefore, the default emission factor for PM_{10} is 0.2 kg/ha/h and 0.4 kg/ha/h for TSP respectively. For the fine dust component of particulate emissions from industrial wind erosion, a $PM_{2.5}/PM_{10}$ ratio of 0.15 is recommended. Industrial wind erosion is associated with crushed aggregate materials, such as coal or metallic ore piles. Examples would include open storage piles at mining operations (USEPA, 2006). A pit retention factor of 50% for TSP and 5% for PM_{10} was applied to the pit.

Significant emissions can arise due to the mechanical disturbance of granular material from open areas and stockpile. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture content, whether due to precipitation or deliberate wetting, promotes the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition which may be anticipated.

Dust emissions due to the erosion of open stockpile and exposed areas occur when the threshold wind speed (>5.4 m/s) is exceeded (Cowherd *et al.*, 1988; USEPA, 1995). The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). Studies have shown that when the threshold wind speeds are exceeded, particulate emission rates tend to decay rapidly due to the reduced availability of erodible material (Cowherd *et al.*, 1988).

It is anticipated that significant amounts of dust will be eroded from the crusher under wind speeds of greater than 5.4 m/s (i.e. threshold friction velocity of 0.26 m/s). Fugitive dust generation resulting from wind erosion under high winds (i.e. > 5.4 m/s) is directly proportional to the elevated dust levels. Wind speeds of 5.4 m/s and stronger occur in the area some 9% of the time. An average wind speed of 2.5 m/s was calculated for the proposed Magnetite Mine project area.

The establishment of this emissions inventory is necessary to provide the source and emissions data required as input to the dispersion model simulations. Emissions from the construction operation were not considered in this emission inventory as this was considered short-term and negligible. Some of the activities associated with the mining operation are discussed.

8.1.1 Material Handling Operations

Material handling focuses on the loading and offloading of ore, tipping and storage / conveyors. These emissions depend on various factors such as wind speed, wind direction and precipitation. The higher the moisture content of the material, the less fugitive dust will be released during the process. To calculate the emissions from the material handling operations, equations from USEPA AP-42 and Australian NPI emission factors were utilised.

8.1.2 Vehicle Activity on Haul Roads

Articulate vehicles that will be used for the proposed magnetite operations include 25 tonne ADT trucks to transfer the ore to the crusher and the waste to the designated waste rock dump.

8.1.3 Wind Erosion from Stockpiles

Wind erosion from various stockpiles was calculated and the following stockpiles were considered in this assessment:

- Low grade stockpiles 1 and 2;
- Lower grade stockpiles 1 and 2;
- TSF;
- Topsoil stockpiles 1 and 2; and
- Waste rock dumps.

8.1.4 Crushing

Primary, secondary and tertiary crushers will be utilised at the proposed Magnetite Mine. The crushers are anticipated to be working the same number of hours as the mine operations of 2 shifts of 9 hours on a daily basis.

8.2 Dispersion Modelling

Dispersion models are used to predict the ambient concentration in the air of pollutants emitted to the atmosphere from a variety of processes (South African National Standards - SANS 1929:2011). Dispersion models compute ambient concentrations 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 due to emissions from various mine 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.

All emission scenarios have been simulated using the USA Environmental Protection Agency's Preferred/Recommended Models: AERMOD modelling system (as of December 9, 2006, AERMOD is fully promulgated as a replacement to ISC3 model).

The AERMOD modelling system incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

There are two input data processors that are regulatory components of the AERMOD modelling system: AERMET, a meteorological data pre-processor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP, a terrain data pre-processor that incorporates complex terrain using USGS Digital Elevation Data. Other non-regulatory components of this system include: AERSCREEN, a screening version of AERMOD; AERSURFACE, a surface characteristics pre-processor, and BPIPPRIME, a multi-building dimensions program incorporating the GEP technical procedures for PRIME applications.

AERMOD model is capable of providing ground level concentration estimates of various averaging times, for any number of meteorological and emission source configurations (point, area and volume sources for gaseous or particulate emissions), as well dust deposition estimates.

The effect of complex terrain is modelled by changing the plume trajectory and dispersion to account for disturbances in the air flow due to the terrain. This may increase or decrease the concentrations calculated. The influence of the terrain will vary with the source height and position and the local meteorology.

8.2.1 Modelled Domain

The modelled scenario in this project took cognizance of the mining and hauling of ore to the respective stockpiles and to the crusher alongside tipping and wind erosion. The multi-tier grid used in settings up the model is shown in Table 8-1. It is assumed the mine's operations are 2 shifts of 9 hours each day for 238 days a year. The pollutants modelled were PM_{10}, $PM_{2.5}$ and TSP. For TSP, two scenarios were modelled, deposition without mitigation and deposition with mitigation.

A rectangular receptor grid of 20 km x 20 km was utilised as the modelling domain. The multi-tier grid mesh was utilised. Multi-tier grid combines coarse and fine grids to ensure that maximum impacts from sources are captured. Table 8-1 shows the grid spacing utilised for the dispersion modelling at the proposed magnetite mine.

Table 8-1: Grid Spacing for Receptor Grids at the proposed Magnetite Mine

Tier	Distance from Centre (m)	Tier Spacing (m)
1	1000	100
2	5000	250
3	10000	500

A total of 3281 grid points were generated. Each of the grid points has x and y (Cartesian co-ordinates) values in metres. Terrain effects were imported from NASA Shuttle Radar Topography Mission (SRTM3) global database with ~90 m accuracy and processed by the AERMAP module of AERMOD.

This receptor grid has been chosen to include the nearest sensitive receptors (these are mainly surrounding farms and residential dwellings) and provide an indication of the extent of any air pollution impacts. The 24-hour and annual averaging times have been used for consistency. The modelling has been performed using the meteorological data discussed in previous section and the gaseous, particulate and deposition emissions calculations explained in the emissions inventory section.

Table 8-2 gives an overview of meteorological parameters and basic setup options for the AERMOD model runs.

Table 8-2: Summary of Meteorological and AERMET Parameters Utilised

Years of analysis	Jan 2011 to Dec 2013
Centre of analysis	23.897667S, 28.801219E
Meteorological grid domain	12 km (east-west) x 12 km (south-north)
Meteorological grid cell resolution	12 km x 12 km
Station Base Elevation	1048 mamsl

MM5-Processed Grid Cell (Grid Cell Centre)	23.897667S, 28.801219E
Anemometer Height	14 m
Surface meteorological stations	1 site at the proposed operations using data generated by AERMET
Upper air meteorological stations	1 site at the proposed operations using data generated by AERMET
Simulation length	26280 hours (Jan 2011 to Dec 2013)
Sectors	The surrounding area land use type was considered to be *grassland and residential*
Albedo	0.29 (generated with the AERMOD Model – when the land use types are specified)
Surface Roughness	0.04025
Bowen Ratio	0.925
Terrain Option	Elevated (The regional setting showed some ridges in the area)

8.2.2 Sensitive Receptors

Discrete receptors were identified as the houses and developments located around and within the 20km by 20km dispersion modelling domain (Table 8-3). These were categorised as sensitive receptors prone to be impacted by air emissions from the proposed Magnetite Mine operations. The level of exposure to each of the pollutants is dependent on the proximity of the receptors to the mine operations and the wind direction.

Table 8-3: Sensitive Receptor Locations

Identified Receptor	UTM Easting coordinate (m)	UTM Northing coordinate (m)
Mine boundary	6803889	7360502
Rooival	688158	7359570
Malokongskop	686262	7359991
Ditlotswana	6857667	7354940
Sepharane	680648	7353425
Kaditshwene	674360	7355373
Mosate	678954	7359968
Pudiakagopa	682986	7363085

8.2.3 Source Data Requirements

The infrastructure layout utilised during the dispersion model was provided by the client as shown in Figure 8-1. AERMOD can model area, volume and point sources. Input into the dispersion model includes prepared meteorological data, source data, information on the nature of the receptor grid and emissions input data. Model inputs were verified before the model was executed.

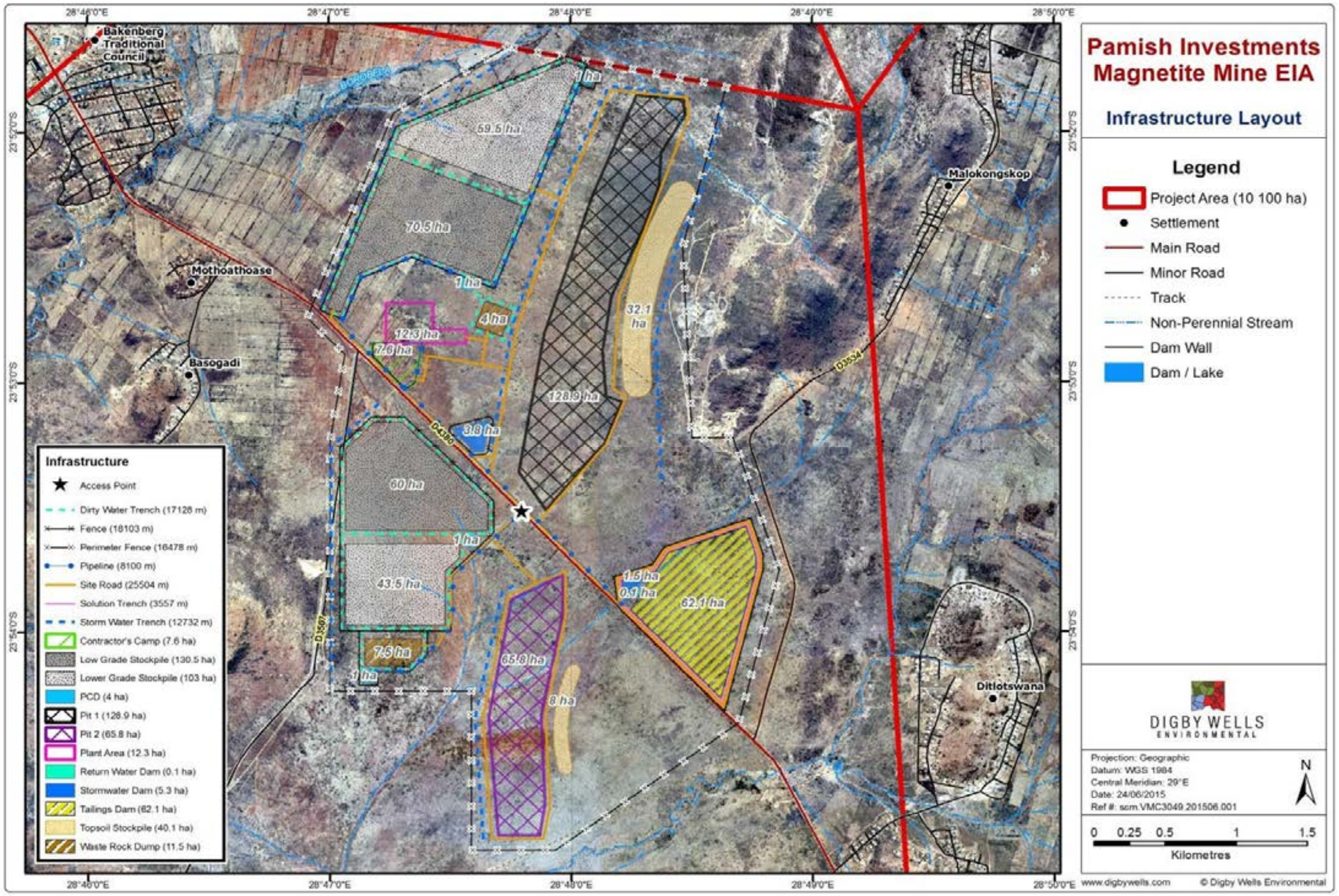

Figure 8-1: Pamish Investments Infrastructure Layout (dated 24June 2015)

8.3 Impact Assessment

The AERMOD model predicts the one-hour average concentration at each receptor specified, for each hour of the year's meteorological data. The highest ground level concentration is established for each hour and is referred to as the peak hourly concentration.

The daily values option controls the output options for tables of concurrent values summarised by receptor for each day processed. For each averaging period for which the daily values option is selected, the model will print in the main output file the concurrent averages for all receptors for each day of data processed. Results are output for each source group.

In general, the predicted concentrations of pollutants follow closely the main wind directions (the wind rose generated for the site is presented in Figure 6-1). Numerical values of maximum depend on the emission rate and the meteorological data used. Simulations were undertaken to determine concentrations of particulate matter with a particle size of less than 10 microns (µm) in size (PM_{10}), particle size of less than 2.5 microns (µm) in size ($PM_{2.5}$), and of deposition of total suspended particulates (TSP) all operations at the proposed magnetite mine.

8.3.1 Isopleth Plots and Evaluation of Modelling Results

A summary of isopleth plots generated in the current section are presented in Table 8-4.

Table 8-4: Evaluation of Results at the Mine Boundary for Particulate Matter and Deposited Nuisance Dust during the Operational Phase

Pollutant	Averaging period	Guideline (µg/m³)	Predicted concentrations based on Pamish Investments operations (µg/m³)	Figure number
Unmitigated concentrations				
PM_{10}	24 Hours 1 Year	75 (2) 40(2)	**138** 26	10-2 10-3
$PM_{2.5}$	24 Hours 1 Year	65(2) 40(3) 25(2) 20(3)	22 4	10-4 10-5
Dust deposition	Maximum 24 Hours	600/1200(4)	**2000**	10-5
Mitigated concentrations				
Dust Deposition	Maximum 24 Hours	600/1200(4)	**700**	10-6

- South African - 1 January 2015 National Ambient Air Quality Standards (NAAQS)

- South African- Proposed current National Ambient Air Quality Standards (NAAQS)
- South African- Proposed future (from 1 January 2016) National Ambient Air Quality Standards (NAAQS)
- South African- National Ambient Air Quality Standards (NAAQS) – National Dust Control Regulation 2013

8.3.2 PM_{10} Predicted Impacts

The predicted 99th percentile 24-hour (daily) concentration of PM_{10} attributed to the proposed Magnetite Mine operation reached a maximum of 2 403 µg/m³ and minimum of 24 µg/m³. The predicted maximum concentration at the northern section of the mine boundary of 137.6 µg/m³ exceeds the current ambient air quality standard of 75 µg/m³ at the northern sections (Figure 8-2). This isopleth plot predicted plant boundary daily values from the stockpiles, haul roads, crushers, material handling processes without mitigation measures. Ambient PM_{10} levels predicted for nearby sensitive receptors are presented in Table 8-5. The concentration predicted at the northern section of the mine boundary is found to exceed the WHO guideline of 50 µg/m³.

The predicted concentrations are the likely additions to background levels of pollutants anticipated from the proposed mining operation and not cumulative impact from all the existing sources in the area (refer to plots).

Table 8-5: Predicted 24 Hour Average PM_{10} Concentrations at Sensitive Receptors

Receptor modelled	PM_{10} concentrations (µg/m³) NEM:AQA Standard (75 µg/m³)
Mine boundary	**137.6**
Rooival	8.5
Malokongskop	25.0
Ditlotswana	42.5
Sepharane	66.6
Kaditshwene	36.22
Mosate	55.4
Pudiakagopa	25.2

The predicted annual concentration of PM_{10} anticipated from the proposed Magnetite Mine operations is presented in Figure 8-3. The predicted annual highest ground level concentration of this pollutant arrived at 757 µg/m³ and minimum of 7.5 µg/m³. The predicted concentration at any point on the mine boundary of 25.8 µg/m³ is within the current South African ambient air quality standard of 40 µg/m³ (this is without mitigation measures). Ambient PM_{10} levels predicted for nearby sensitive receptors are presented in Table 8-6. When compared against the WHO guideline of 20 µg/m³, the predicted concentration exiting the mine boundary exceeded the guideline.

Table 8-6: Predicted Annual Average PM_{10} Concentrations at Sensitive Receptors

Annual average PM_{10} concentrations (µg/m^3)	
Receptor modelled	**PM_{10} concentrations (µg/m^3) NEM:AQA Standard (40 µg/m^3)**
Mine boundary	25.8
Rooival	0.6
Malokongskop	0.9
Ditlotswana	3.6
Sepharane	11.7
Kaditshwene	5.5
Mosate	9.8
Pudiakagopa	2.3

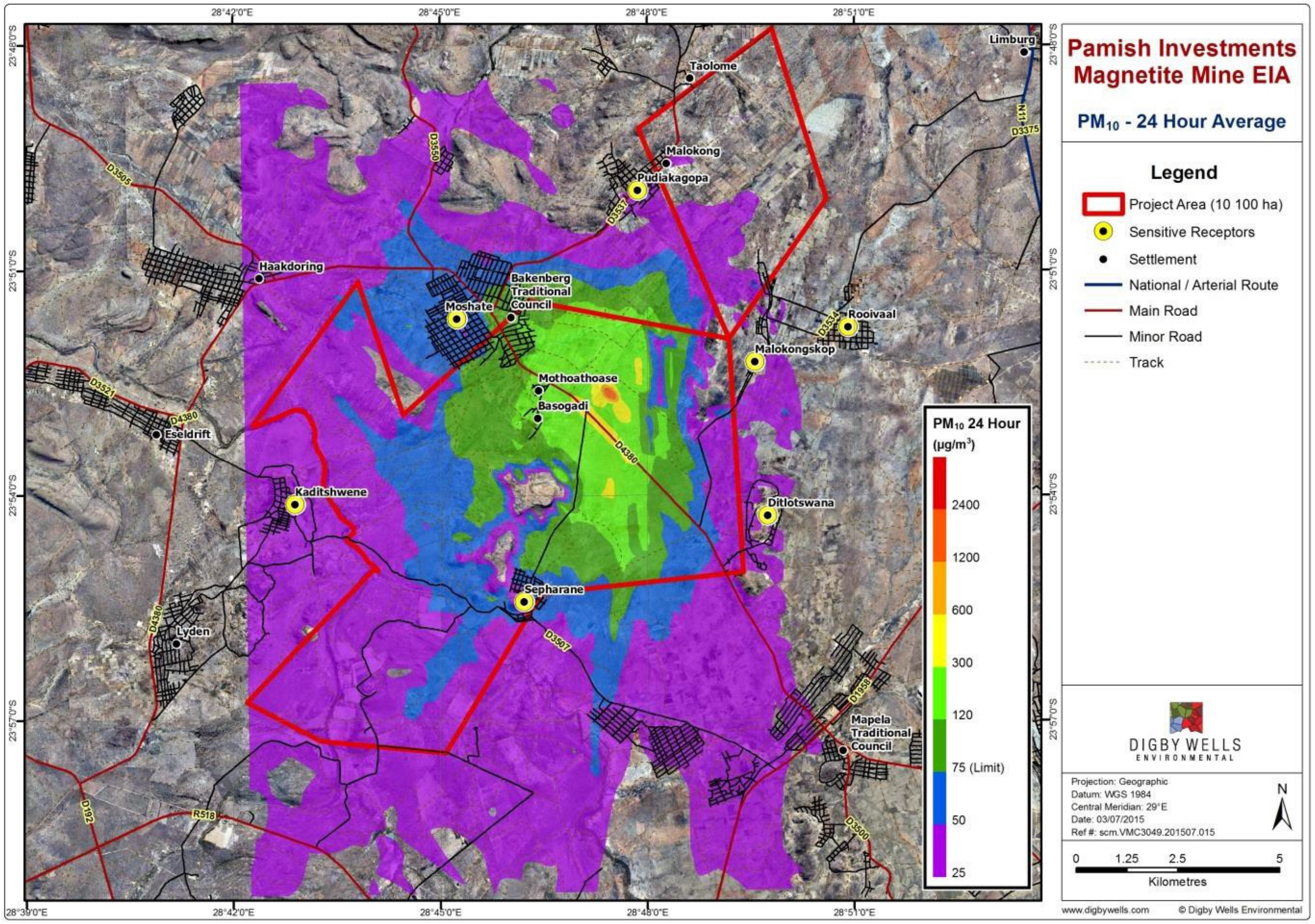

Figure 8-2: Predicted 99th Percentile 24 Hour Average PM_{10} Concentrations (µg/m³)

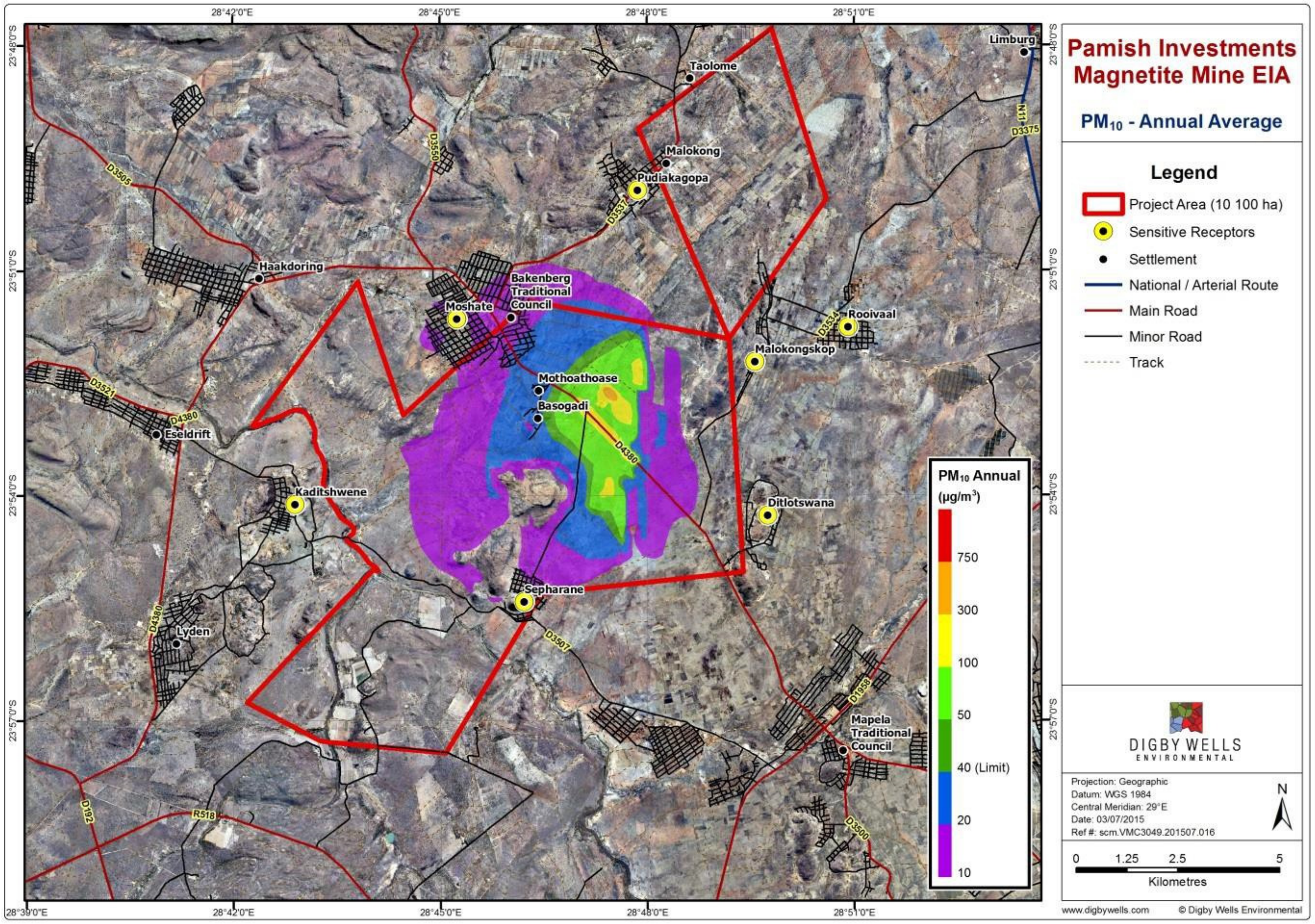

Figure 8-3: Predicted 1st Highest (100th percentile) Annual Average PM_{10} Concentrations (µg/m^3)

8.3.3 $PM_{2.5}$ Predicted Impacts

Isopleth plot of predicted 99th percentile highest daily values for $PM_{2.5}$ generated by the proposed Magnetite Mine operations is given in Figure 8-4. Daily highest predicted ground level concentration of 363 µg/m³ was predicted and minimum of 3.6 µg/m³. The predicted $PM_{2.5}$ impacts at the mine boundary do not exceed the current 24-hours $PM_{2.5}$ ambient air quality standard of 65 µg/m³ and future limit 40 µg/m³ (comes into effect 1st January 2016 to 31 December 2029). Predicted concentrations at the selected sensitive receptors are presented Table 8-7. The WHO daily guideline was not exceeded as the concentration predicted at the mine boundary of 21 µg/m³ is below the WHO guideline of 25 µg/m³.

Table 8-7: Predicted 24 Hour Average $PM_{2.5}$ Concentrations at Sensitive Receptors

Receptor modelled	$PM_{2.5}$ concentrations (µg/m³) NEM:AQA Standard (65 µg/m³)
Mine boundary	21.7
Rooival	1.4
Malokongskop	3.9
Ditlotswana	5.6
Sepharane	15.6
Kaditshwene	6.4
Mosate	10.0
Pudiakagopa	5.1

Isopleth plot showing the predicted highest annual $PM_{2.5}$ generated by the proposed Magnetite Mine operation is presented in Figure 8-5, with annual highest ground level concentration of 128 µg/m³ and minimum of 1.3 µg/m³. The mine boundary is predicted to receive an annual concentration that is below 4.2 µg/m³. The predicted $PM_{2.5}$ impacts at the mine boundary do not exceed the current $PM_{2.5}$ ambient air quality standard of 25 µg/m³ and the future limit of 20 µg/m³ (which comes into effect from the 1st of January 2016 to 31 December 2029). The concentrations of the respective sensitive receptors are given below. The annual $PM_{2.5}$ concentration predicted at the mine boundary is within the WHO guideline of 10 µg/m³.

Table 8-8: Predicted Annual Average $PM_{2.5}$ Concentrations at Sensitive Receptors

Annual average $PM_{2.5}$ concentrations ($\mu g/m^3$)	
Receptor modelled	**$PM_{2.5}$ concentrations ($\mu g/m^3$) NEM:AQA Standard (25 $\mu g/m^3$)**
Mine boundary	4.19
Rooival	0.09
Malokongskop	0.15
Ditlotswana	0.58
Sepharane	2.39
Kaditshwene	0.99
Mosate	1.65
Pudiakagopa	0.35

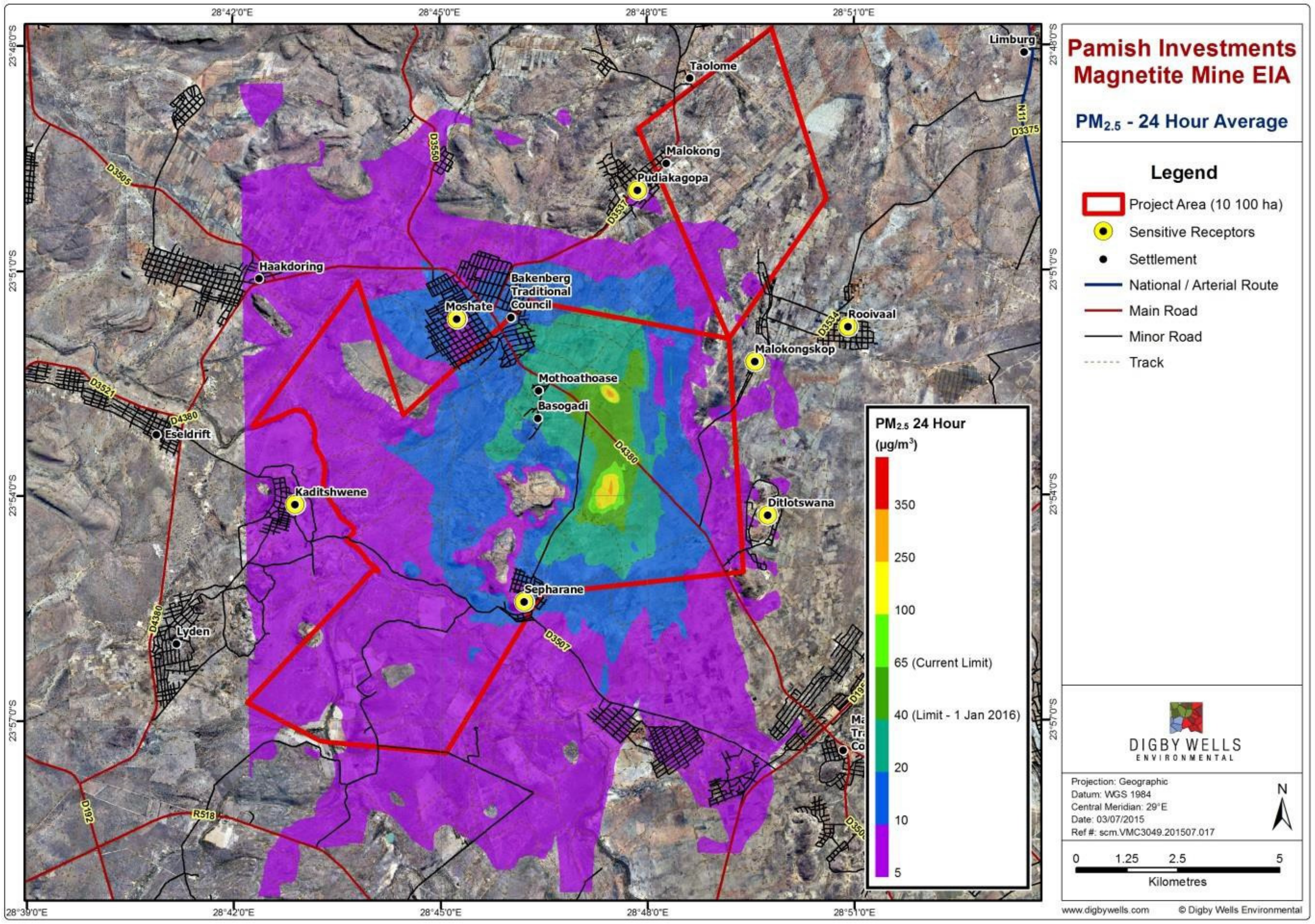

Figure 8-4: Predicted 99th Percentile 24 Hour Average $PM_{2.5}$ Concentrations (µg/m^3)

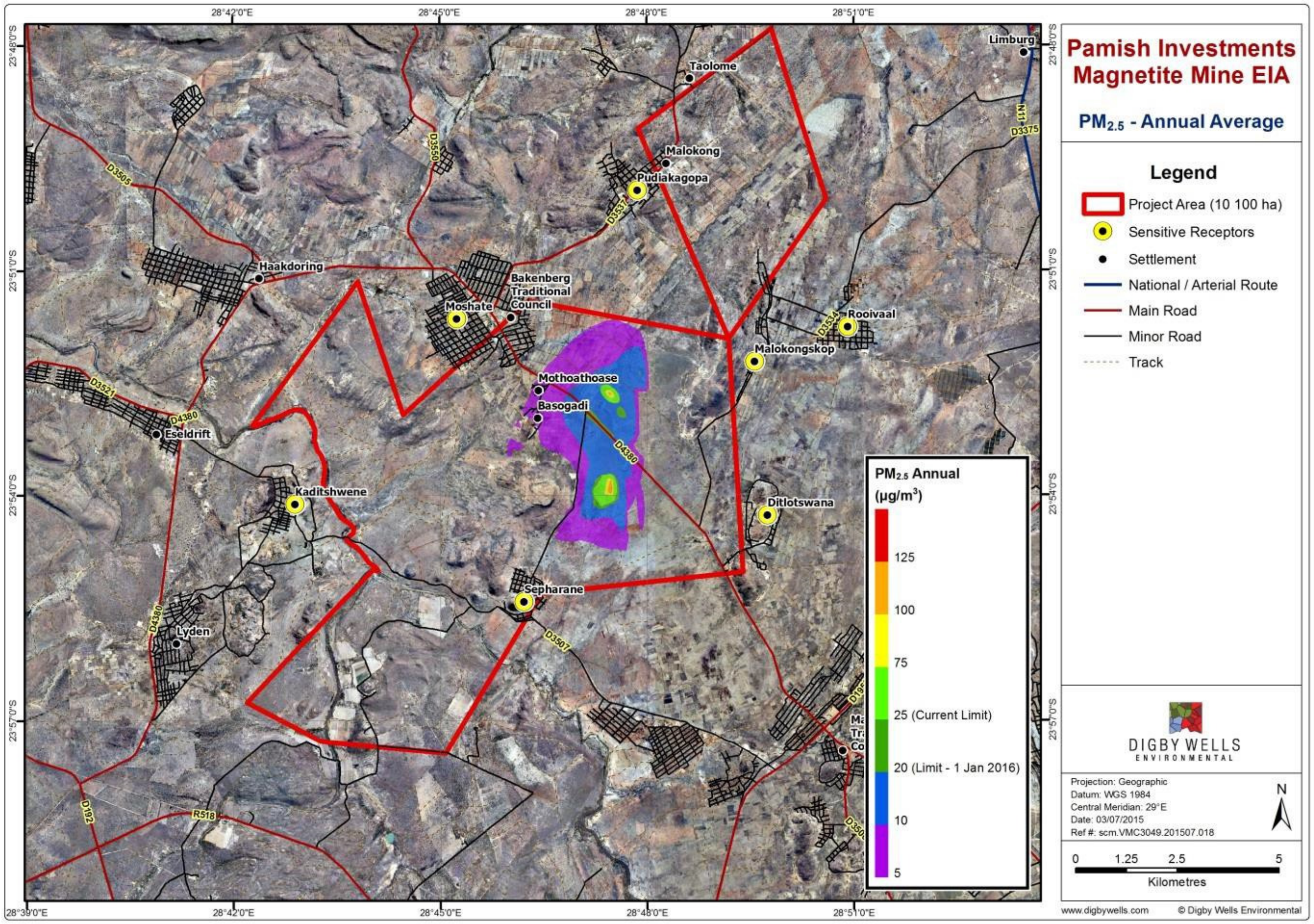

Figure 8-5: Predicted 1st Highest (100th percentile) Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$)

8.3.4 Dust Deposition Predicted Impacts

The predicted highest dust fallout rate at any point on the mine boundary arrived ~ 2000 mg/m²/day before mitigation. The predicted dust fallout rate exceeds the current NDCR 2013 standard for residential areas and non-residential (i.e. 600 mg/m²/day and 1 200 mg/m²/day). Dust deposition rates at the selected sensitive receptors are presented in Table 8-9.

Table 8-9: Predicted 30 Day Average Dust Deposition (mg/m^2/day)-No Mitigation

Receptor modelled	Dust deposition (mg/m2/day) NDCR, 2013 (600 mg/m^2/day)
Mine boundary	2000
Rooival	52
Malokongskop	82
Ditlotswana	339
Sepharane	659
Kaditshwene	199
Mosate	608
Pudiakagopa	169

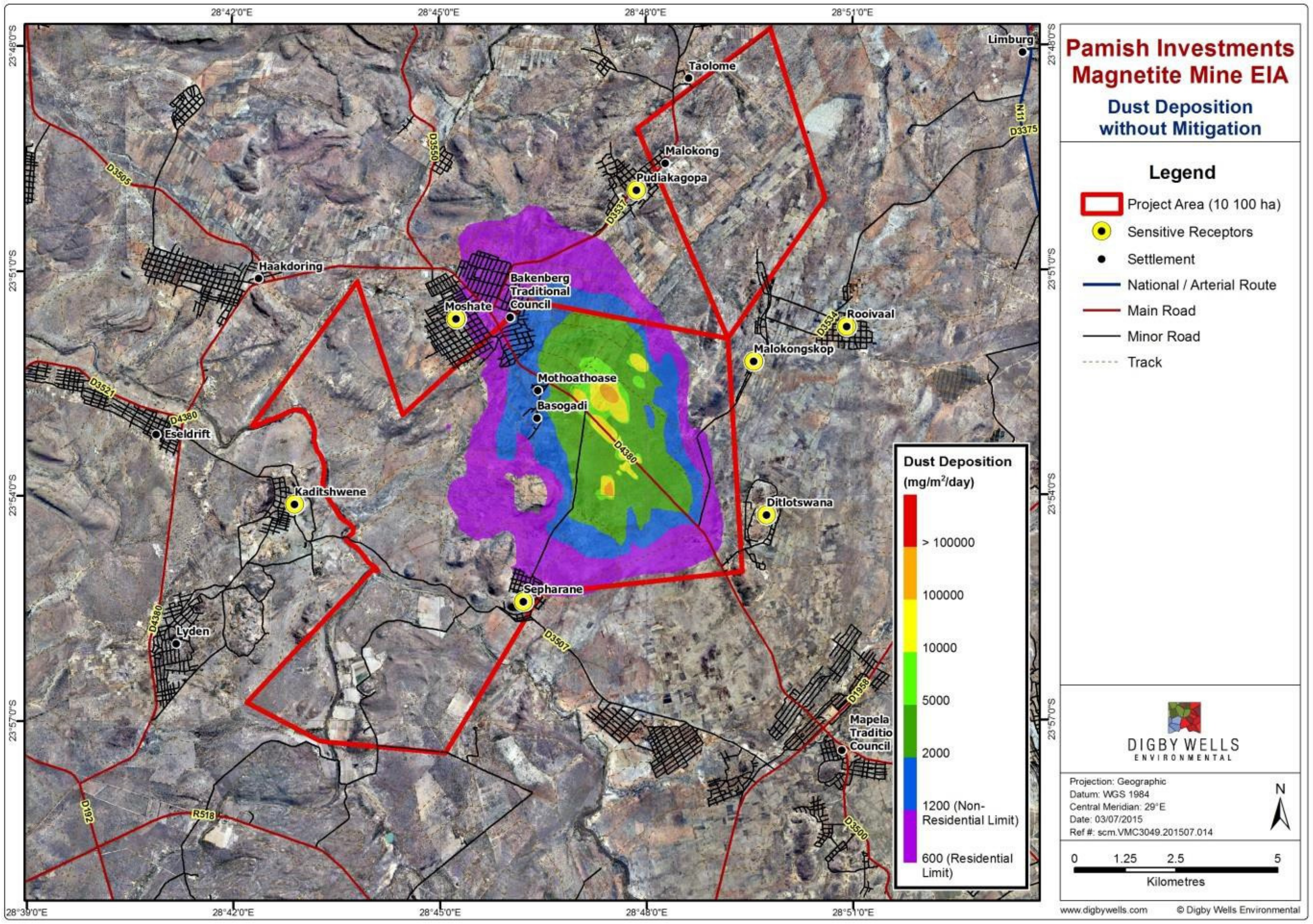

Figure 8-6: Predicted 30-Days Average (100th percentile) Dust Deposition (mg/m²/day) – No Mitigation

8.3.5 Mitigated Dust Deposition Predicted Impacts

To reduce the predicted dust deposition impacts, mitigation measures are implemented on various processes within the operations. The following were the mitigation measures with control factors implemented in the dispersion model runs to ameliorate emission from sources.

Table 8-10: Estimated Control Factors for the proposed Magnetite Operations

Operation / Activity	Control method and emission reduction
Haul roads	75% for level 1 watering (2 litres/m^2/h)
Materials handling	70% for water sprays
Unloading stockpiles	50% for water sprays
Crushers	75% enclosure

*Source Australian NPI (2012) Version 3.1

After the above measures were implemented, the model predicted a reduction in the dust deposition rates. After mitigation, the maximum dust deposition rates predicted at the mine boundary decreased to 700 mg/m^2/day. Despite the substantial reduction predicted, deposition rate is in exceedance of the current NDCR 2013 standard for residential areas i.e. 600 mg/m^2/day. The maximum impact after mitigation is limited to within the mine boundary, classified as non-residential (with a standard of - 1 200 mg/m^2/day). When mitigation measures are implemented, the dust deposition rates predicted at the selected receptors was reduced (Table 8-11). It is worth mentioning that prior to mitigation, residential areas as Sepharane (659 mg/m^2/day) and Mosate (608 mg/m^2/day) were in exceedance of the residential limit. After mitigation, predicted deposition rates at these communities decrease to less than 230 mg/m^2/day.

It should be noted that isopleth plots reflecting daily averaging periods contain only the highest predicted ground level dust deposition rates for that averaging period, over the entire period for which simulations were undertaken. These isopleths are likely concentrations that the proposed magnetite mine activities would have on ambient air quality and not cumulative impact from all the sources. *It is therefore possible that even though a high daily deposition rate is predicted to occur at certain locations, that this may only be true for one day during the entire period.*

Table 8-11: Predicted 30 Day Average Dust Deposition ($mg/m^2/day$) with Mitigation for Sensitive Receptors

Receptor modelled	Dust deposition ($mg/m^2/day$) NDCR, 2013 (600 $mg/m^2/day$)
Mine boundary	700
Rooival	19
Malokongskop	27
Ditlotswana	106
Sepharane	229
Kaditshwene	105
Mosate	224
Pudiakagopa	54

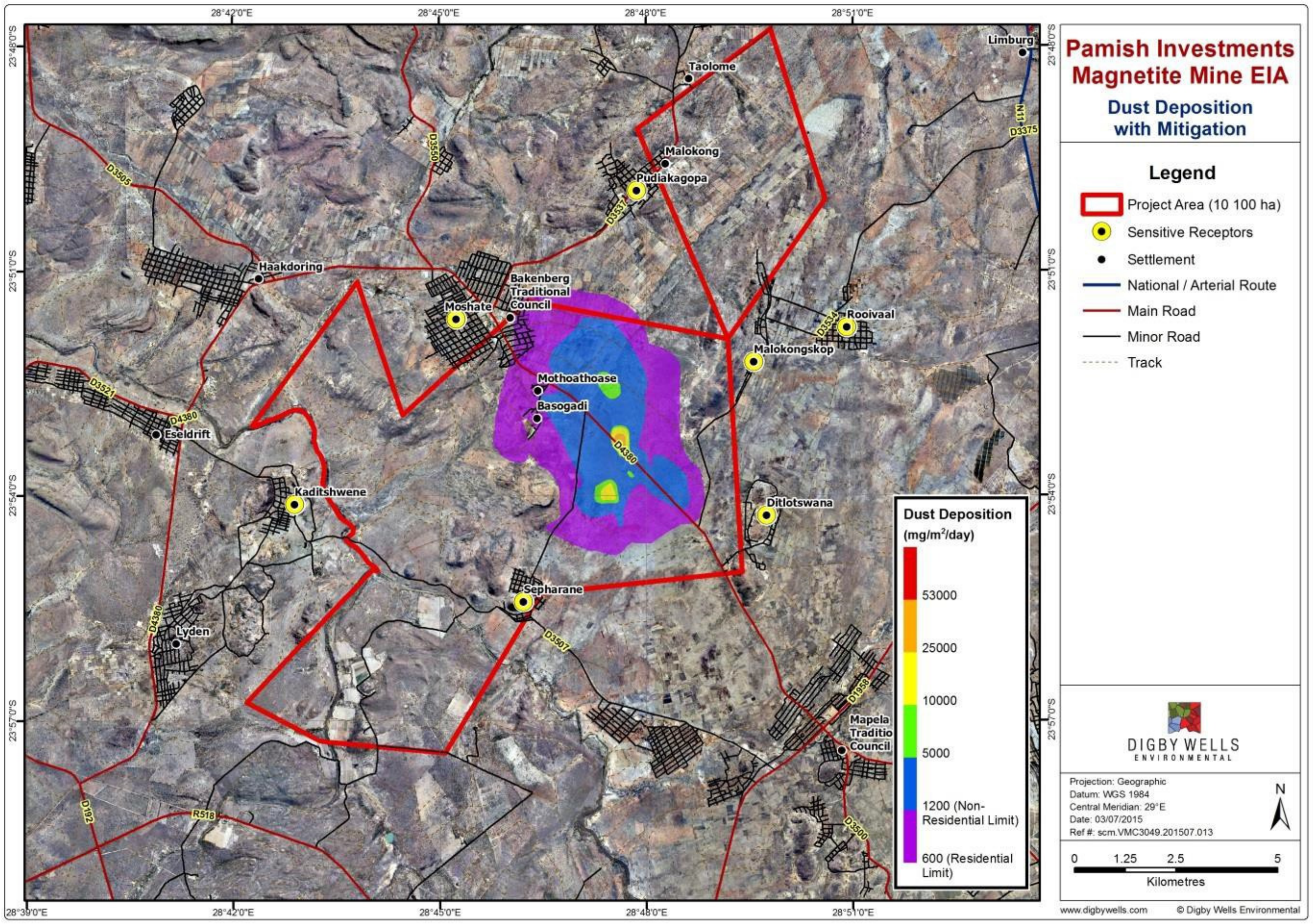

Figure 8-7: Predicted 30-Days Average (100th percentile) Dust Deposition (mg/m²/day) – With Mitigation

9 Sensitivity Analysis and No-Go Areas

Wind-blown dust from tailings storage facilities on the Witwatersrand have been studied extensively (Ojelede et al, 2009). Ambient aerosol concentrations during storm episodes, especially at high wind speed (>10 m/s) can impact receptors up to 2 km downwind. For the magnetite tailings (with 80% of the particles less than 75µm), maybe heavier and less amenable to erosion. A sensitivity map is presented below showing buffers of 1 km and 2 km from the edges of the stockpiles.

From Figure 9-1 below, sensitive areas such as Sepharane, Ditloswana, Malokonskop Basogadi and Mathoathoase which are between 1 – 2 km buffers can be impacted. However, the farther away from the mine operation the lower the concentration residents are exposed to and the associated health risk. Hence, it is recommended that the current buffers be maintained and concerted efforts must be made to prevent proliferation of formal or informal settlements within the current buffer.

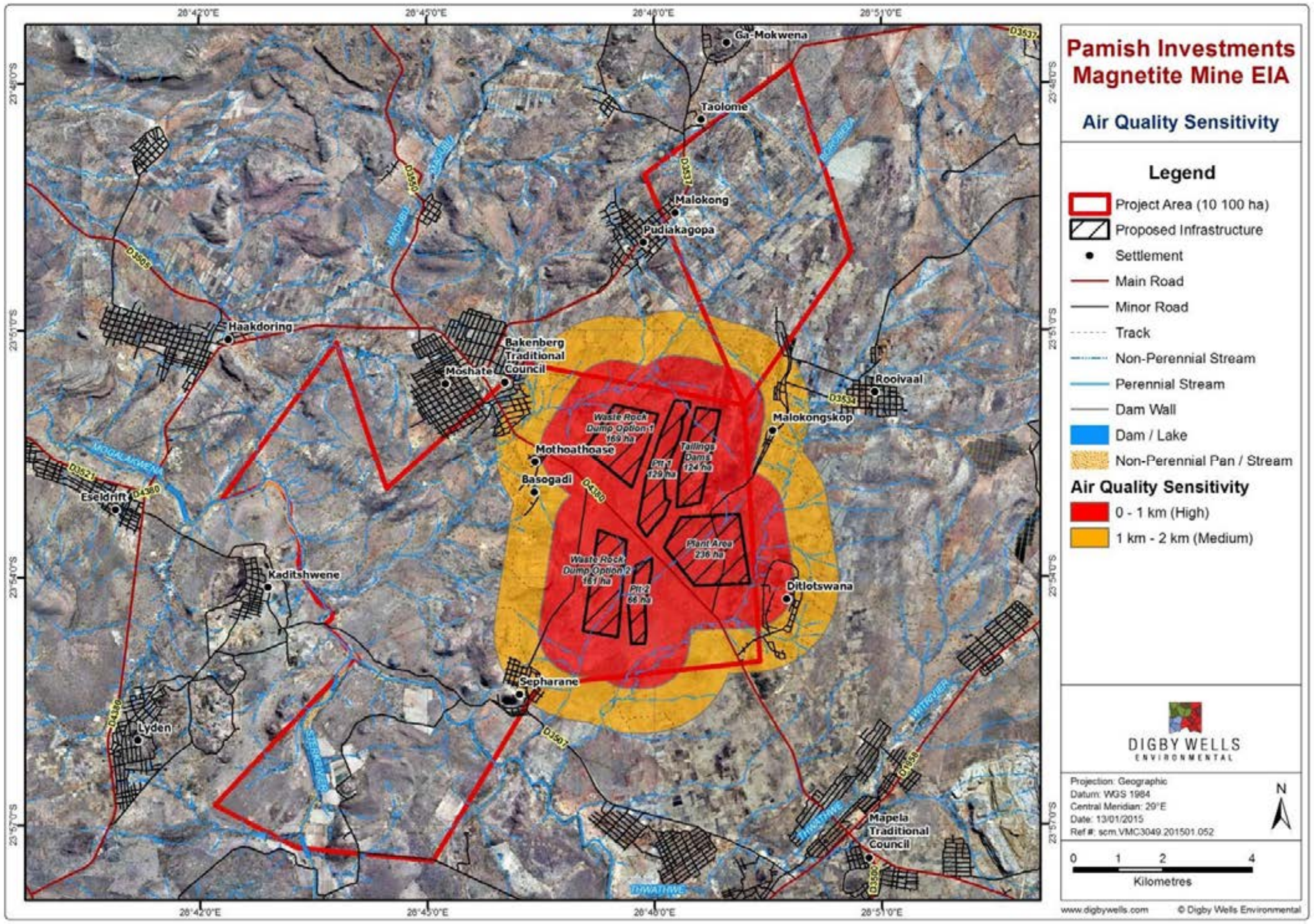

Figure 9-1: Air Quality Sensitive Map

10 Impact Assessment Matrix

10.1 Overview

Impacts are broadly assessed based on magnitude and receptor sensitivity. This permits the assessment practitioner to determine impact significance and mitigation.

Based on international guidelines and South African legislation, the following criteria were taken into account when examining potentially significant impacts:

- Nature of impacts (induced/direct/indirect, positive/negative);
- Duration (short/medium/long-term, permanent(irreversible) / temporary (reversible), frequent/seldom);
- Extent (geographical area, size of affected population/habitat/species);
- Intensity (minimal, severe, replaceable/irreplaceable);
- Probability (high/medium/low probability); and
- Mitigation (as per mitigation hierarchy: avoid, mitigate or offset significant adverse impacts).

10.2 Methodology - Impact Rating in terms of its Nature, Extent, Duration, Probability and Significance

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = intensity + extent + duration

And

Probability = likelihood of an impact occurring

And

Nature = positive (+1) or negative (-1) impact

The matrix calculates the rating out of 147, whereby intensity, extent, duration and probability are each rated out of seven as indicated in Table 10-1. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation has been applied; post-mitigation is referred to as the residual impact. The significance of an impact is determined and categorised into one of seven categories (The descriptions of the significance ratings are presented in Table 10-3).

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, (i.e., there may already be some mitigation included in the engineering design). If the specialist determines the potential impact is still too high, additional mitigation measures are proposed.

Table 10-1: Impact Assessment Parameter Ratings

Rating	Intensity/Replace ability		Extent	Duration/reversibility	Probability
	Negative impacts (nature = -1)	**Positive impacts (nature = +1)**			
7	Irreplaceable loss or damage to biological or physical resources or **highly** sensitive environments. Irreplaceable damage to **highly sensitive** cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: the impact is irreversible, even with management, and will remain after the life of the project.	Definite: there are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or **moderate to highly** sensitive environments. Irreplaceable damage to cultural/social resources of **moderate to highly** sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: the impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / highly probable: it is most likely that the impact will occur. <80% probability.

Rating	Intensity/Rep lace ability		Extent	Duration/reversibility	Probability
	Negative impacts (nature = -1)	**Positive impacts (nature = +1)**			
5	Serious loss and/or damage to physical or biological resources or **highly** sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ region Will affect the entire province or region.	Project life (>15 years): the impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: the impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or **moderately** sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/Rep lace ability		Extent	Duration/reversibility	Probability
	Negative impacts (nature = -1)	Positive impacts (nature = +1)			
3	Moderate loss and/or damage to biological or physical resources of **low to moderately** sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	**Minor loss and/or effects** to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: less than 1 year and is reversible.	Rare / improbable: conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/Rep lace ability		Extent	Duration/reversibility	Probability
	Negative impacts (nature = -1)	Positive impacts (nature = +1)			
1	**Minimal to no loss** and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/isolated Limited to specific isolated parts of the site.	Immediate: less than 1 month and is completely reversible without management.	Highly unlikely / none: expected never to happen. <1% probability.

Table 10-2: Probability/Consequence Matrix

Probability	Significance																																					
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Consequence																																					

Table 10-3: Significance Rating Description[4]

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	An positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

11 Impact Assessment Format

11.1 Construction Phase

11.1.1 Site Clearance and Vegetation Removal

Interaction	Impact
Site clearing and vegetation removal	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ from site clearance and removal of vegetation that holds the soil together through the use of earthmoving equipment.
	Emission from vehicle exhausts can lead to increased particulate matter (PM) loading and oxides of nitrogen (NO_X).
	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ from excavation and compaction activities.

Activity and Interaction			
Dimension	**Rating**	**Motivation**[5]	**Significance**
Impact Description: During the process of site clearance and the removal of vegetation the soil is disturbed which leads to the generation of fugitive dust (TSP), PM10 and PM2.5.			
Prior to Mitigation/ Management			
Duration	Medium term (3)	The removal of vegetation is anticipated to lead to generation of TSP, PM_{10} and $PM_{2.5}$ only during the construction phase	Minor (negative) – 40
Extent	Limited (2)	Vegetation removal and dust generation is limited to the specific area of the site clearances.	
Intensity x type of impact	Moderate loss (-3)	Dependent on sensitivity.	
Probability	Likely (5)	It is likely that vegetation removal which leads to dust generation will occur during the course of the construction phase	
Mitigation / Management Actions[6]			
▪ Clearing should be conducted in phases ▪ Limit vegetation removal only to the areas being worked on ▪ Water the areas which are being worked on to supress erosion			

Activity and Interaction			
Dimension	**Rating**	**Motivation**[5]	**Significance**
Post-Mitigation			
Duration	Short term (2)	Vegetation removal effects will be reversed within 1 year	Negligible (negative) – 24
Extent	Limited (2)	Vegetation removal will occur within and immediately around the Project site.	
Intensity x type of impact	Minor loss and/or effects (-2)	Dependent on sensitivity etc.	
Probability	Probable (4)	It is probable that some dust will still be generated.	

11.1.2 Topsoil and Softs Removal and Stockpiling

Interaction	Impact
Topsoil and softs removal and stockpiling	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ from the stockpiling processes through the use of heavy earthmoving equipment will occur.
	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ as the topsoil and the softs are deposited on the respective stockpiles.

Activity and Interaction			
Dimension	**Rating**	**Motivation**[7]	**Significance**
Impact Description: Topsoil removal using heavy equipment and stockpiling. This activity will results in the generation of fugitive dust (TSP), PM10 and PM2.5			
Prior To Mitigation / Management			
Duration	Medium term (3)	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ from the stockpiling processes, especially hauling using dirt roads by heavy earthmoving equipment	Minor (negative) – 40
Extent	Limited (2)	Emission is limited to the respective stockpile area.	
Intensity x type of impact	Moderate loss (-3)	Dependent on sensitivity.	
Probability	Likely (5)	It is likely that the stockpiling will lead to generation of fugitive dust	

Activity and Interaction			
Dimension	**Rating**	**Motivation[7]**	**Significance**
Mitigation / Management Actions[8]			
▪ Use of water sprays and/or bowsers ▪ Use of windbreaks for the duration of the stockpiling. Trees can be planted along the edges of the stockpile i.e. few meters from the base of the stockpile. ▪ Reduce vehicle speed on haul roads			
Post-Mitigation			
Duration	Short term (2)	Topsoil stockpiling effects will be reversed within 1 year	Negligible (negative) – 21
Extent	Limited (2)	Impact will be limited to the stockpile area	
Intensity x type of impact	Minor loss and/or effects (-2)	Dependent on sensitivity etc.	
Probability	Probable (4)	It is probable that some dust will still be generated.	

11.1.3 Development of Access and Haul Roads

Interaction	Impact
Development of access and haul roads	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ land clearance to construct access and haul roads through the use of heavy earthmoving equipment.
	Generation of fugitive dust, PM_{10} and $PM_{2.5}$ from trucks moving along the roads.

Activity and Interaction			
Dimension	**Rating**	**Motivation[9]**	**Significance**
Impact Description: During the process of development access and haul roads there will be generation of fugitive dust (TSP), PM10 and PM2.5.			
Prior To Mitigation / Management			
Duration	Medium term (3)	The development of access and haul roads will occur throughout the construction phase.	Minor (negative) – 45
Extent	Local (3)	The development of access and haul roads will be extending only as far as the development site area.	

Activity and Interaction			
Dimension	**Rating**	**Motivation**[9]	**Significance**
Intensity x type of impact	Moderate loss (-3)	Moderate loss and/or damage to biological or physical resources of **low to moderately** sensitive environments and, limiting ecosystem function.	
Probability	Likely (5)	It is likely that vegetation removal which leads to dust generation will occur during the course of the construction phase	
Mitigation / Management Actions[10]			
▪ Use of water sprays during the development ▪ Use of surfactants to seal the roads ▪ Phase approach during road construction			
Post-Mitigation			
Duration	Medium term (3)	The development of access and haul roads will occur throughout the construction phase.	Negligible (negative) – 32
Extent	Limited (2)	Emissions will be limited to the construction area i.e. Immediate surroundings.	
Intensity x type of impact	Moderate loss (-3)	Moderate damage to the biophysical resources.	
Probability	Probable (4)	It is unlikely that compaction will have an effect after rehabilitation	

11.2 Operational Phase

Interaction	Impact
Development of two open pits by drilling and blasting, truck and shovel methods (129 ha and 69 ha footprints)	Drilling and blasting generates fugitive dust i.e. TSP, PM_{10} and $PM_{2.5}$
	Generation of fugitive dust, PM10 and PM2.5 from the onsite truck and shovel traffic

11.2.1 Development of Two Open Pits by Drilling and Blasting, Truck and Shovel Methods (129 ha and 69 ha Footprints)

Activity and Interaction			
Dimension	**Rating**	**Motivation**[11]	**Significance**
Impact Description: The process of drilling and blasting leads to the generation of fugitive dust TSP, PM_{10} and $PM_{2.5}$. Gaseous emissions from drilling and blasting will be assess in the blasting and vibration report			

Activity and Interaction			
Dimension	**Rating**	**Motivation**[11]	**Significance**
Prior To Mitigation / Management			
Duration	Project life (5)	The drilling and blasting process will take place for the duration of the mine, these processes lead to the generation of TSP, PM_{10} and $PM_{2.5}$.	Minor (negative) – 72
Extent	Local (3)	The dust emissions from the drilling and blasting and the truck and shovel will extend only as far as the development site.	
Intensity x type of impact	Serious loss (-4)	There will be damage to the physical and biological resources	
Probability	Highly probable (6)	It is almost certain that the drilling and blasting will generate dust, PM_{10} and $PM_{2.5}$	
Mitigation / Management Actions[12]			
▪ Water sprays ▪ Mitigation measures are in the blasting and vibration report			
Post-Mitigation			
Duration	Project life (5)	The emissions from the drilling and blasting and the use of the truck and shovel will continue for the duration of the mine.	Minor (negative) – (40)
Extent	Limited (2)	Emissions will be limited to the pits and the immediate surroundings.	
Intensity x type of impact	Moderate (-3)	Moderate damage to the biophysical resources.	
Probability	Likely (4)	It is likely that there will still be some emissions post mitigation	

11.2.2 Development of the Waste Rock Dump

Interaction	**Impact**
Development of the waste rock dump	PM_{10} and $PM_{2.5}$ generated during the dumping of material onto the dump.

Activity and Interaction			
Dimension	**Rating**	**Motivation**[13]	**Significance**
Impact Description: During the development of the dump, the generation of fugitive emissions TSP, PM_{10} and $PM_{2.5}$ occurs.			
Prior To Mitigation / Management			
Duration	Medium term (3)	The dumping of the materials is anticipated to be less than 5 years as some of the materials will be deposited into the pits.	Negligible (negative) – 35
Extent	Limited (2)	The dumping process is anticipated to be limited to the specific area of the site clearances.	
Intensity x type of impact	Minor loss (-2)	Minor loss is anticipated on the specific areas with the dumps	
Probability	Likely (5)	It is likely that as finer materials are deposited some dust will be generated.	
Mitigation / Management Actions[14]			
▪ Water sprays during unloading			
Post-Mitigation			
Duration	Medium term (3)	The dumping of the materials is anticipated to be less than 5 years as some of the materials will be deposited into the pits.	Negligible (negative) – 28
Extent	Limited (2)	The dumping process is anticipated to be limited to the specific area of the site clearances.	
Intensity x type of impact	Minor loss (-2)	Minor loss is anticipated on the specific areas with the dumps	
Probability	Probable (4)	It is unlikely that some dust will be generated	

11.2.3 Concentrator Plant including Conveyor, Crushing, Grinding and Screening

Interaction	Impact
Concentrator plant including crushing, grinding and screening	PM_{10} and $PM_{2.5}$ generated are released during the crushing of the ore.
	The screening process also leads to the release of fugitive dust.

Interaction	Impact
	PM_{10} and $PM_{2.5}$ are release when the haul truck dumps into the crusher and the convey (at the tipping point)

Activity and Interaction			
Dimension	**Rating**	**Motivation**[15]	**Significance**
Impact Description: Crushing and grinding of the materials to reduce the size for further processing leads to fugitive dust emissions TSP, PM_{10} and $PM_{2.5}$.			
Prior To Mitigation / Management			
Duration	Project life (5)	Crushing of the materials generates TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine.	Moderate (negative) – 84
Extent	Local (3)	Emissions from the crushers will extend as far as the development site	
Intensity x type of impact	Serious loss (-4)	Serious damage to the biological and physical resources.	
Probability	Definite (7)	It is certain that the crushing process will generate TSP, PM_{10} and $PM_{2.5}$	
Mitigation / Management Actions[16]			
▪ Watering sprays ▪ Total enclosure			
Post-Mitigation			
Duration	Project life (5)	Crushing of the materials generates TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine.	Minor (negative) – 40
Extent	Limited (2)	Emissions are only limited to the immediate surroundings.	
Intensity x type of impact	Moderate loss (-3)	Moderate damage to the resources	
Probability	Probable (4)	Mitigation is likely to reduce emissions from this source.	

11.2.4 Hauling of Waste Rock

Interaction	Impact
Hauling of waste rock	The hauling of ore and waste rock using dirt road will lead to the generation of TSP, PM_{10} and $PM_{2.5}$ due the action of vehicle wheels on dirt road.

Activity and Interaction			
Dimension	**Rating**	**Motivation**[17]	**Significance**
Impact Description: During hauling of the waste rock, the action of wheels on dirt roads leads to the particulate matter entrainment and the generation of fugitive dust TSP, PM_{10} and $PM_{2.5}$			
Prior To Mitigation / Management			
Duration	Project life (5)	Hauling of the waste rock generates TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine.	Moderate (negative) – 78
Extent	Local (3)	Emissions will be heavy near the vehicle route and can be dispersed laterally to nearby receptors.	
Intensity x type of impact	Serious loss (-5)	Dependent on sensitivity of the ecosystem however moderate loss is anticipated.	
Probability	Almost certain (6)	It is almost certain that fugitive emissions will occur during hauling.	
Mitigation / Management Actions[18]			
▪ Watering the roads			
Post-Mitigation			
Duration	Project life (5)	Even after mitigation, hauling of the waste is anticipated to generate TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine.	Minor (negative) – 44
Extent	Local (3)	Emissions will be limited to the vehicle route	
Intensity x type of impact	Moderate loss and/or effects (-3)	Moderate damage to the physical and biological resources.	
Probability	Probable (4)	Mitigation will surely results in a reduction of fugitive emissions.	

11.2.5 Tailings Storage Facility (TSF)

Interaction	Impact
Tailings Storage Facility (TSF)	TSP, PM_{10} and $PM_{2.5}$ generated when the TSF is dry and uncared for i.e. vegetation.
	The 6m wide waste rock road will generate dust, PM_{10} and $PM_{2.5}$ during vehicle entrainment.

Activity and Interaction			
Dimension	**Rating**	**Motivation**[19]	**Significance**
Impact Description: Emissions will be generated from the waste rock road at the perimeter of the TSF as well as dust generation when the tailings are dry generating suspended particulates (TSP), PM10 and PM2.5			
Prior To Mitigation / Management			
Duration	Project life (5)	Vehicle entrainment and wind erosion at the TSF will generate TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine. Emissions are likely during wind erosion	Moderate negative (-)84
Extent	Local (3)	Emissions will extend as far beyond the boundary of the TSF	
Intensity x type of impact	Serious loss (-4)	Impact to human receptors is anticipated.	
Probability	Definite (7)	It is likely that the wind erosion from the TSF leads to dust generation will occur during the course of the mining operations	
Mitigation / Management Actions[20]			
▪ Periodic wetting ▪ Use of windrows			
Post-Mitigation			
Duration	Project life (5)	Vehicle entrainment and wind erosion at the TSF will generate TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine.	Minor (negative) – 44
Extent	Limited (2)	Wind erosion will occur within and immediately around and beyond the Project site.	
Intensity x type of impact	Serious loss (-4)	Minor impact to exposed human receptors	

Activity and Interaction			
Dimension	**Rating**	**Motivation**[19]	**Significance**
Probability	Probable (4)	It is likely that wind erosion may still occur even after mitigation measures are implemented.	

11.2.6 Use of Heavy Machinery (Haul trucks, FEL, Excavators, etc.)

Interaction	Impact
Use of heavy machinery (Haul trucks, FEL, Excavators etc.)	TSP, PM and $PM_{2.5}$ generated during vehicle entrainment

Activity and Interaction			
Dimension	**Rating**	**Motivation**[21]	**Significance**
Impact Description: The use of haul truck on the unpaved roads generates TSP, PM10, PM2.5			
Prior To Mitigation / Management			
Duration	Project life (5)	Vehicle entrainment will generate TSP, PM_{10} and $PM_{2.5}$ for the duration of the mine.	Moderate (negative) – 84
Extent	Local (3)	Dust generation is limited to the specific routes that will be used by the haul truck, FEL and excavators.	
Intensity x type of impact	Moderate loss (-4)	Exposed resident, especially children and the elderly will experience some impacts due to the dust generation	
Probability	Definite (7)	It is definite that the use of haul trucks on the unpaved roads generates TSP, PM_{10} and $PM_{2.5}$	
Mitigation / Management Actions[22]			
▪ Water the roads frequently ▪ Use of suppressants such as dust a side			
Post-Mitigation			
Duration	Project life (5)	TSP, PM_{10} and $PM_{2.5}$ will be generated for the duration of the mine.	Minor (negative) – 36
Extent	Limited (2)	Dust will be generated within and immediately around the Project site.	
Intensity x type of impact	Minor loss and/or effects (-2)	Minor loss anticipated	

Activity and Interaction			
Dimension	**Rating**	**Motivation**[21]	**Significance**
Probability	Probable (4)	It is likely some dust will be generated	

11.3 Closure and Rehabilitation

11.3.1 Rehabilitation of Disturbed Areas including Stockpile Dumps and Pits etc.

Interaction	Impact
Rehabilitation of disturbed areas including stockpile dumps and pits etc.	TSP, PM_{10} and $PM_{2.5}$ generated during vehicle entrainment

Activity and Interaction			
Dimension	**Rating**	**Motivation**[23]	**Significance**
Impact Description: During the rehabilitation of various areas, haul trucks will be utilised to transport materials and offloading, resulting in the generation of fugitive dust TSP, PM_{10} and $PM_{2.5}$.			
Prior To Mitigation / Management			
Duration	Medium term (3)	The rehabilitation is anticipated to take place over 1- 5 years generation of TSP, PM_{10} and $PM_{2.5}$ during the rehabilitation phase only	Minor (negative) – 50
Extent	Limited (2)	Dust generation is limited to the specific area of rehabilitation.	
Intensity x type of impact	Moderate loss (-3)	Low to moderately impacts on exposed residents in nearby communities.	
Probability	Probable (4)	It is probable that emissions will be generated	
Mitigation / Management Actions[24]			
▪ Water the areas which are being worked on			
Post-Mitigation			
Duration	Medium term (3)	The rehabilitation is anticipated to take place over 1- 5 years generation of TSP, PM_{10} and $PM_{2.5}$ during the rehabilitation phase only	Negligible (negative) – 28
Extent	Limited (2)	Dust generation will only occur within and immediately around the Project site.	

Activity and Interaction			
Dimension	**Rating**	**Motivation**[23]	**Significance**
Intensity x type of impact	Minor loss and/or effects (-2)	Minor loss anticipated	
Probability	Probable (4)	It is unlikely that compaction will have an effect after rehabilitation	

12 Cumulative Impacts

As discussed previously, the proposed Magnetite Mine is located within the footprint demarcated as the Waterberg Air Quality Priority Area. Industrial sources in the area are the highest contributors of SO_2, NOx and CO, with mining as the highest contributor of PM10. The surrounding communities in the area that rely on biomass (firewood) for cooking and space heating are associated with fine particulate emissions from combustion.

The real and future threats to the ambient air quality of the area are attributed to the planned expansion of energy-based projects and coal mining in Waterberg District Municipality. This future rise in emissions will exacerbate ambient concentration of pollutants with potential increase in exposure and impacts on human and surrounding environment.

Findings from this study confirm the proposed Magnetite Mine will add to background pollutants load and hence requires mitigation measures to ameliorate associated emissions. With the new National Atmospheric Emission Reporting Regulation (May 2015), the mine should ensure adequate facilities are in place to conduct routine monitoring of all its sources, embark on a detailed emission inventory and final reporting to an internet-based emission reporting system. In addition to the aforementioned, the mine management should establish a community communication strategy that facilitates reporting of environmental efforts, concerns and mitigation measures adopted in its day-to-day to the air quality officer at the Mogalakwena Local Municipality and community members. Also, they must endeavour to work along with existing forums in the area aimed at improving air quality. More especially, its operation must be aligned to the goals of the Waterberg District Municipality in ensuring good ambient air quality management in the region.

13 Unplanned Events and Low Risks

Low risks can be monitored to gauge if the increased level of pollutants represent greater impacts and if the adopted mitigation measures are effective. Often, unplanned events occur at any point in a project life time, and adequate measures should be in place to address such. Table 13-1 shows some unplanned events associated with air quality and possible mitigation measures to apply.

Table 13-1: Unplanned Events, Low Risks and their Management Measures

Unplanned event	Potential impact	Mitigation/ Management/ Monitoring
Hydrocarbon spillage	Odour	Vehicles must only be serviced within designated service bays. Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place. Training for onsite personnel.
Increased SO_2 levels	Air pollution	Use of low sulphur fuels
Storm episode	Air pollution	Vegetation of stockpiles and exposed areas.

14 Mitigation Measures and Environmental Management Plan

The main sources of emissions are identified to be materials haul roads, handling, crushers and stockpiles. Mitigation and management measures detailed below will reduce emission of particulate matter from these sources.

14.1 Material Handling Operations

As the crusher is one of the main sources of emissions it is advised that the following be performed. Use of fan sprays nozzles to minimise the volume of water utilised. Have a spray at the beginning of a dust sources, in this case the stockpile. Elimination of dust generation at transfer points is not feasible; however, it is advised to control dust. An enclosure at the transfer points is necessary to control emissions. Fall heights of the transfer points should be reduced though the use of spiral chutes. Load profiling creates a consistent surface of ore in each truck, which would be implemented at the mine.

The magnitude of ore dust emissions from transport of ore in trucks will depend on a number of factors, such as the level of exposure of the open surface to air moving at high speeds and the inherent dustiness of the material. Measures that can be applied include: potential modifications to trucks to reduce wind contact with ore during transport, employ water or air blow-down to reduce parasitic loads on trucks exiting load-out. Dust can be mitigated using water and having an enclosure on the crushers. To manage the fugitive dust, the feed side of the crusher must be enclosed. (USBM, 1974).

14.2 Haul Roads

The fugitive dust from haul roads reduces visibility. Proper road construction is required to manage the fugitive dust from roads. Proper road construction has high initial costs, but there will be less road maintenance costs incurred in the long run. Effective dust management measures reduce fugitive dust from haul roads. Dust suppressants on roads work by forming a layer over the top of the roads, these can be i.e. Dust-A-side. Midwest Research Institute (1981) advises that road construction should have the following properties: resistance to wear, soundness, maximum size, particle shape and gradation.

14.2.1 Speed Control

Reducing speed on haul roads is an effective way to manage fugitive dust. However, reducing speed may lower the production of mines. Studies by Watson et al., 1996 showed that reducing speed reduces the generation of particles less than 10 micro meters by about 58% when speed controls are reduced from 25 mph (40 km/h) to 15 mph (24 km/h). Reducing the volume of traffic on the haul roads reduces the impacts of dust entrainment.

14.2.2 Load Covers

When loads are covered by tarps, the loaded material is prevented from being airborne. Chepil (1958) shows that entrainment may occur when air flow comes into contact with materials exceed 21 km/h for small material (0.1 mm) large materials require high velocities. Wetting of the loaded materials can be done to reduce the dust generated.

15 Monitoring Programme

15.1 Dust Monitoring Programme

The proposed magnetite operations should begin dust monitoring programme during the project life in order to amass historical dust deposition data that will feed into management practices aimed at reducing impacts from the construction, operation and closure phases of the project

As the area exposed is directly proportional to the amount of dust generated and transported, it is advised that construction activities be limited during the windy periods of August, September and October. If construction has to be done during this period, it is advised to disturb a small area at a time. As trucks are a major source of dust, reducing speed of trucks in haul roads will reduce dust immensely.

In order to determine the wind speed for each particular day, a wind anemometer installed on site should be utilised. Wind speed is recorded daily and when it exceeds 5.4 m/s (this is the threshold for transporting particles) extra dust control measures need to be carried out. During dust generating periods, sprinkling of the area until it is moist is ideal for haul roads and traffic routes (Smolen *et al*., 1988). It must be noted however that excessive sprinkling to manage dust may result in runoff from the site.

15.2 Particulate Matter Monitoring

Pamish Investments must implement ambient air quality monitoring programme which should include at an instrument to monitor PM_{10} and $PM_{2.5}$. It will be much better if the is housed with a weather station to record meteorological parameters. It is advised to install the unit at least one year prior to the construction phase to allow for the collection of an ambient air quality baseline data set.

16 Consultation Undertaken

Consultation was undertaken during site visit with the villagers who reside near the proposed mine area. A brief tour around and discussion with the villagers gave some insight and understanding of the activities that are likely to impact ambient air quality conducted in the communities.

The project may result in air pollution.	Abel Kotzé & Stephanus Kotzé	Trekdrift Boerdery BK (Bellevue Pt. 5)	26 March 2015	Registration & Comment Form	An Air Quality study was undertaken as part of the Environmental Impact Assessment (EIA). In the air quality assessment considered PM_{10}, $PM_{2.5}$ and dust deposition. The maximum PM_{10} concentration observed at the four compass mine boundary were within the standard of 75 µg/m^3, except the northern boundary with 138 µg/m^3 prior to mitigation. With Moshate impacted the most, levels predicted at the surrounding residential receptors were all within Standard. The maximum annual PM_{10} concentrations predicted at any point on the mine boundary were below 10 µg/m^3. Hence, levels at the surrounding residential receptors were within the current standard (40 µg/m^3). $PM_{2.5}$ concentrations at the four compass points around the MRA were all below 5 µg/m^3 for both daily and annul respectively. Hence, the surrounding residential receptors are all within the daily and annual standard of 65 µg/m^3 and 25 µg/m^3 respectively. Predicted dust deposition rates at Moshate and Sepharane were slightly above the residential standard 600 mg/m2/day prior to mitigation. After mitigation, the predicted dust deposition rates at the four compass points around the proposed mine were all below 600 mg/m^2/day. Hence, deposition rates at the surrounding residential receptors are within the recommended standard (600 mg/m^2/day). Detailed assessment of findings is presented in the EIA Report.

Uncertain how dust will affect game farming. All the farmers rely on tourism.	AJ Kotze	Bellevue farmer / owner	26 March 2015	Commercial Farmers Meeting	An Air Quality study was undertaken as part of the Environmental Impact Assessment (EIA). In the air quality assessment considered PM_{10}, $PM_{2.5}$ and dust deposition. The maximum PM_{10} concentration observed at the four compass mine boundary were within the standard of 75 µg/m^3, except the northern boundary with 138 µg/m^3 prior to mitigation. With Moshate impacted most. Levels predicted at the surrounding residential receptors were all within Standard. The maximum annual PM_{10} concentrations predicted at any point on the mine boundary were below 10 µg/m^3. Hence, levels at the surrounding residential receptors were within the current standard (40 µg/m^3). $PM_{2.5}$ concentrations at the four compass points around the MRA were all below 5 µg/m^3 for both daily and annul respectively. Hence, the surrounding residential receptors are all within the daily and annual standard of 65 µg/m^3 and 25 µg/m^3 respectively. Predicted dust deposition rates at Moshate and Sepharane were slightly above the residential standard 600 mg/m2/day prior to mitigation. After mitigation, the predicted dust deposition rates at the four compass points around the proposed mine were all below 600 mg/m^2/day. Hence, deposition rates at the surrounding residential receptors are within the recommended standard (600 mg/m^2/day). Detailed assessment of findings is presented in the EIA Report.

17 Conclusion and Recommendation

Background data from the DEA Ambient Air Quality Station in Mokopane have been used to assess background. Modelled meteorological data were combined with the Magnetite Mine's mining operational parameters to assess potential implications on ambient air quality of the area.

Findings are summarized:

- Background levels indicate that gaseous pollutants, such as SO_2, NO_2, O_3 and CO were all within the South African National Standard. Particulate PM_{10} and $PM_{2.5}$ were observed to have exceeded the standard during the period under review.

- The highest level of PM_{10} anticipated at the boundary over a 24 hour period is 138 µg/m³ exceeded the limit of 75 µg/m³. The highest PM_{10} annual limit is 26 µg/m³ which is below the South African standard of 40 µg/m³. The predicted levels of this pollutant at the mine boundary are higher than the WHO daily and annual guidelines of 50 µg/m³ and 20 µg/m³.
- $PM_{2.5}$ was below the limits of both the 24 hour and annual limit of 65 µg/m³ and 25 µg/m³. The anticipated emission at the boundary for $PM_{2.5}$ over a 24 hour period is 22 µg/m³ and the highest annual at the boundary is 4 µg/m³. The predicted levels of this pollutant at the mine boundary lower than the WHO daily and annual guideline values of 25 µg/m³ and 10 µg/m³ respectively.
- In terms of dust fallout, the predicted level at any point on the mine reached 2000 mg/m²/day before mitigation. After mitigation measures were applied, the highest dust deposition rate at any point on the mine boundary decreased to 700 mg/m²/day.

The predicted outcome of this air quality impact assessment shows that particulate pollution has the potential to exacerbate ambient air quality during the operational phase of the mine. Mitigations measures have been proposed to ameliorate emissions, which will reduce impacts to within current and anticipated air quality standards.

The following recommendations should be applied during the course of mining based on the results predicted in the AQIA report:

- It is recommended that a dust monitoring programme be initiated. Data collected will assist in management decision making process in reducing emissions.
- Commission a particulate monitoring programme - PM_{10} and $PM_{2.5}$ downwind of the proposed Magnetite Mine operation.
- Designate a qualified person to act as the Air Quality Officer as required in terms of the Air Quality Act.
- Integrate the air quality data into the environmental management information system.
- Establish a community communication strategy that facilitates reporting of environmental concerns by community members to the mine management.
- Procure and operate Dust-A-Side or something similar on haul road.
- Invest in fixed water sprays and enclosure at the crusher, tipping and transfer points in line with current best engineering practice. Housing of crushers and screens to contain emissions.
- Demarcate roadways and boundaries of dormant areas not to be used by vehicles.
- Establish **codes of practice** for good housekeeping with respect to dust management and mitigation.

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Appendix A: Declaration of Independence

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I, Winnie Ngara as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Pamish Investments, other than fair remuneration for work performed, specifically in connection with the proposed Open pit Magnetite Mine, Limpopo Province.

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