AIR QUALIY IMPACT ASSESSMENT FOR DE GROOTE BOOM MINING PERMIT APPLICATION

AIR QUALITY

Project Number:

AUR2967

Prepared for:

DE GROOTE BOOM MINERAL (PTY) LTD

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DIGBY WELLS
ENVIRONMENTAL

This document has been prepared by Digby Wells Environmental.

Report Type:	**AIR QUALITY**
Project Name:	**AIR QUALIY IMPACT ASSESSMENT FOR DE GROOTE BOOM MINING PERMIT APPLICATION**
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Name	**Responsibility**	**Signature**	**Date**
Matthew Ojelede	Report Writer		May 2015
Danie Otto	Report Reviewer		May 2015

EXECUTIVE SUMMARY

OUTLINE OF THE PROJECT

Digby Wells Environmental (hereafter Digby Wells) was been requested by De Groote Boom Minerals (Pty) Ltd (hereafter De Groote Boom), to compile and submit an Environmental Management Plan (EMP), pursuant to an application for a mining permit, in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) to the Limpopo Department of Mineral Resources (DMR). The study area is situated on the farm De Groote Boom 373 KT, near the town of Steelpoort situated in the Limpopo Province.

The Mining Permit Application has been accepted by the Regional Manager, Limpopo Region, of the DMR under Reference LP 10656 MR and De Groote Boom has been instructed to prepare an EMP, encompassing several specialist investigations of which an Air Quality Impact Assessment (AQIA) forms an integral component.

This AQIA study was compiled taking cognisance of the various South African National Standards (SANS) in order to evaluate impacts and assess environmental risks from the proposed De Groote Boom project.

KNOWLEDGE GAPS

Monitoring of ambient PM_{10} and $PM_{2.5}$ is not undertaken at the moment in the vicinity of the proposed De Groote Boom study area. These pollutants are regulated and monitoring is deemed essential i.e. Best Practice to establish background concentrations prior to mining. This will most likely continue during mining as the day to day activities from the proposed De Groote Boom operation will exact some level of impacts on the ambient air quality of the area.

Background air quality assessment is limited to the proposed dust monitoring network which will be commissioned towards the end of May 2015,. The data will be used to determine current dust deposition rates in the area. Once this is available, the EMP will be updated accordingly. The air quality and climate assessment was carried out as a desktop study – using modelled meteorological data, because site specific information was not available.

BASELINE ASSESSMENT

In the baseline assessment, 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 wind direction is from the east southeast accounting for about 15.5% of the time, and wind speed greater than 5.4 m/s occurring for 11% throughout the period. Secondary wind speeds were also observed from the southeast (14%) and east (~10%). Over the three year period, winds capable of generating dust occurred for some 93 days. Calm conditions (wind speeds < 0.5 m/s) occurred for 0.25% of the time.

Annual total rainfall maximum and average rainfall for the De Groote Boom site are 1,249 mm and 788 mm respectively. The highest total monthly precipitation of 488 mm was observed in January. The rate decreases down to 1 mm of rainfall in May.

IMPACT ASSESSMENT

A domain of 20 x 20 km was defined, with a reference mid-point within the future study area. This domain, defined as the zone of potential impact due to air emissions anticipated from the proposed De Groote Boom operation stretches 10 kilometres North, South, East and West from the reference point. This zone of impact encompasses sensitive receptors in the vicinity, including scattered farm houses and existing mining operations to the west and north west sections.

An emissions inventory was established comprising emissions from construction and operation of the proposed mine at De Groote Boom, which served as inputs data for the dispersion model simulations. This inventory calculated emissions of total suspended particulate (TSP), PM_{10} and $PM_{2.5}$ from the material handling (tipping) processes, topsoil erosion and waste stockpile, run-off-mine (ROM), roads as well as drilling and blasting operations. It was assumed that the mine will use electricity from the national grid, and no on-site power generators (emission considered negligible from the standby generator which is always available), hence emissions from this source was not qualified.

The grid mesh was 250 metres resulting in a total of 6 561 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 and processed by the AERMAP module of AERMOD. The operating hours at the mine is assumed to be 24 hours per day and 329 days a year. The 24-hour and annual averaging times have been used for consistency. Predicted concentrations and deposition rates obtained are attributed to mine operation only.

RESULTS

The daily highest ground level concentration predicted for the area was 177 µg/m³. The highest concentration predicted at the boundary of the study area was 78 µg/m³ (in the northwest boundary). This predicted ground level concentration at the boundary is in exceedance of the current daily limit of 75 µg/m³ without mitigation. The *major contributors are road, wind erosion*). Ambient concentrations at the identified receptors within the project boundary are in compliance, as the model predicted concentrations below 1 µg/m³. The annual highest ground level concentration of this pollutant predicted was 65 µg/m³. The predicted concentration at the mine boundary was 20 µg/m³. Although the highest ground level concentration predicted from this operation is in exceedance of the current standard of 40 µg/m³, levels at the mine boundary are within compliance.

For $PM_{2.5}$, the 4th highest daily concentration predicted for the was 37 µg/m³. This predicted maximum daily values for $PM_{2.5}$ represented emissions from all sources within the proposed mine without mitigation measures in place. The concentration predicted is within the current daily limit of 65 µg/m³ and the future limit of 40 µg/m³. The predicted $PM_{2.5}$ concentrations at the mine boundary arrived at 10 µg/m³. The 1st highest annual ground level concentrations for $PM_{2.5}$ anticipated from the proposed De Groote Boom Mine arrived 13 µg/m³, with concentrations of 5 µg/m³ predicted at the mine boundary.

The predicted dust deposition rates are confirming that dust levels will be a course for concern. The predicted maximum concentration at the mine boundary is 2 188 mg/m^2/day. Exposure will be higher at the northwestern section, reasons being that the area is downwind and the pollution plume travel in that direction. Major contributions are coming from hauling of ore and waste to product and waste stockpiles respectively. Deposition rates at the selected sensitive receptors (20 mg/m^2/day) are within the recommended standards.

CONCLUSION

The conclusion reached in this reported is informed by modelled data and predicted results. An air quality impact assessment study was undertaken for the De Groote Boom proposed mine area. Pollutants assessed in the study includes: TSP, PM10 and $PM_{2.5}$. Other pollutants common to mining operation of this nature i.e. gaseous pollutant were not assessed.

The predicted highest PM_{10} daily (177 µg/m³) and annual average (65 µg/m³) without mitigation were in exceedance of the current South African standards of 75 µg/m³ and 40 µg/m³ respectively. However, concentrations predicted at the boundary and selected receptors are within compliance, except for PM10 (78 µg/m³ which can be reduce to within limit once mitigation measures are applied).

The predicted highest $PM_{2.5}$ daily (37 µg/m³) without mitigation is below the current South African standards of 65 µg/m³. The annual average (13 µg/m³) is within the current standard of 25 µg/m³, with concentrations predicted at the boundary and selected sensitive receptors all within compliance.

The findings from this study should assist mine management in deciding on the monitoring protocol and mitigation measures to adopt if they are to commence and operate within compliance of current regulatory standards.

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LIST OF ABBREVATIONS

AQG	Air Quality Guidelines
APPA	Atmospheric Pollution Prevention Act
AQIA	Air Quality Impact Assessment
ASTM	American Society for Testing and Materials
^{o}rc	Degrees Celsius
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
km	Kilometre
km^2	Kilometre squared
m	Metre
m^2	Metre squared
mg	Milligram
mm	Millimetre
MM5	Mesoscale model - Fifth generation
MPRDA	Mineral and Petroleum Resource Development Act
NDCR	National Dust Control Regulation
NEM:AQA	National Environmental Management: Air Quality Act
NEMA	National Environmental Management Act
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
PM_{10}	Particulate Matter less than 10 microns in diameter
PSU/NCAR	Pennsylvania State University / National Center for Atmospheric Research
ROM	Run of Mine

SANS	South African National Standards
SAWS	South African Weather Service
TSP	Total Suspended Particulates
WHO	World Health Organisation

1 INTRODUCTION

Digby Wells Environmental (hereafter Digby Wells) has been requested by De Groote Boom Minerals (Pty) Ltd (hereafter De Groote Boom), to compile and submit an Environmental Management Plan (EMP), pursuant to an application for a mining permit, in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) to the Limpopo Department of Mineral Resources (DMR).

The study area is situated on the farm De Groote boom 373 KT, near the town Teleport situated in the Limpopo Province.

The Mining Permit Application has been accepted by the Regional Manager, Limpopo Region, of the DMR under Reference LP 10656 MR and De Groote Boom has been instructed to prepare an EMP, which will include various specialist investigations, which includes an Air Quality Impact Assessment (AQIA) study.

As a prelude to the AQIA – the baseline conditions i.e. the background levels of ambient pollutant concentrations pre-mining operations, current pollution sources and their locations, detailed description of the meteorology and climatology, local topography and physical conditions affecting pollutants dispersion, and sensitive receptors in the vicinity of the propose mining area likely to be impacted will be identified.

In the AQIA, several activities associated with mining operations such as: drilling, blasting, loading and offloading of trucks, transport, crushing and screening of ore and the milling of materials, which are all known sources of dust will be assessed. Emissions from other sources such product stockpiles, Run of Mine (ROM) stockpile, processing plant, waste rock dumps and discard dumps will be assessed alongside the former due to the implication on ambient air quality. Environmental impacts results from the release of gaseous and particulate matter from the different activities taking place from construction to operation to decommissioning.

The overall objective of AQIA is to establish the nature of current ambient air quality, for which future changes and management measures can be compared, in order to optimise the project benefits and minimise or avoid any adverse impacts that may result.

2 TERMS OF REFERENCE

As a vital component of the whole, an AQIA study have been conducted to predict impacts from the proposed De Groote Boom operation on surrounding air quality coupled with recommendations for mitigation.

The terms of reference for the AQIA characterisation included:

- Identification of sensitive receptors based on the area that could potentially be affected by the proposed project;
- Assessment of current ambient air quality scenario, using available air quality data and climatic modelled data and published reports;

- Identification of significant information gaps; and
- Compilation of an air quality impact assessment report employing.

2.1 Background and Context

De Groote Boom currently holds an approved Prospecting Right valid for three years and it now proposes to mine primarily Chromite (Chrome ore, and associated minerals) covering the farm De Groote Boom 373 KT (refer to local setting plan). It is possible that after completing work under the mining permit, De Groote Boom will commence with full scale mining in terms of a mining right that would be applied for at that stage. Mining will be undertaken by open cut methods and the ore will be transported to a portable plant for crushing and screening. The ore will be stockpiled until transported off site by truck. The mining permit area is adjacent to the operational and related infrastructure areas are depicted on the infrastructure plan. The project entails a construction phase, operational phase and possibly a decommissioning phase.

3 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations were identified:

- Adequate ambient air quality monitoring data does not exist to evaluate the baseline air quality situation in the vicinity of the proposed De Groote Boom opencast study area. Hence, dust monitoring units are being installed to collect background dust deposition rates in the area
- South Africa Weather Service (SAWS) do not have an Automatic Weather Station nearby, with the closest more than 45 km to the southeast. Hence, use will be made of modelled site-specific meteorological data for the baseline assessment; and
- Data input into the model has been based on information provided by the Client. It is assumed that the information provided is accurate and complete.

4 STUDY AREA

The proposed site for the De Groote Boom opencast operation is located approximately 15 km southwest of Steelpoort, a small settlement in the Greater Tubatse Local Municipality, Greater Sekhukhune District Municipality, Limpopoa Province.

5 EXPERTISE OF THE SPECIALIST

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 is now actively involved in Atmospheric dispersion modelling and emissions inventories compilation. He has authored and co-authored research articles in peer reviewed Journals and Dispersion Modelling Impact Assessments Reports. He has attended specialized courses in atmospheric dispersion modelling (AERMOD and CALPUFF). A detailed Curriculum Vitae (CV) is attached as Appendix A.

6 REGIONAL CLIMATE AND FACTORS INFLUENCING AIR DISPERSION

6.1 Regional Climate

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.

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, off the west coast, the South Indian high pressure off the east coast and the continental high pressure over the interior.

It is these climatic conditions and circulation movements that are responsible for the distribution and dispersion of air pollutants within proposed De Groote Boom opencast area and between neighbouring provinces and countries bordering South Africa.

6.2 Topography

The proposed De Groote Boom Mining Development will be located in an area characterised by undulating escarpments that range between 1,613 m and 907 m above mean sea level. There are significant topographical features like ridgelines and mountain peaks that are prominent features in the landscapes.

6.3 Vegetation

There is a limited amount of natural vegetation, comprising indigenous trees, grasses, shrubs and flowering plants on the rocky areas of the site. The indigenous grassland is classified as North-Eastern Mountain Grassland and falls within the grassland biome and is typical of the grassland of the mountains and plateau.

6.4 Climate and Meteorological Overview

The study area falls within the escarpment. The climate of the area is described as temperate interior according to SANS 204. There is no weather station on site and the closest SAWS Automated Weather Stations are in Mashishing (Lydenburg), about 45 km to the southeast, and in Graskop (about 75km east-southeast). Although a series of parallel ridges are observed between Lydenburg and the proposed De Groote Boom Mining Area, which could have an effect on the airflow and dispersal of pollutants. In order to get the prevailing conditions, set of site specific modelled meteorological data was ordered from Lakes Environmental Consultants in Canada, which covered three calendar years (2012 – 2014).

Ambient air quality in this region of South Africa is strongly influenced by regional atmospheric movements, together with local climatic and meteorological conditions. The most important of these atmospheric movement routes are the direct transport towards the Indian Ocean and the recirculation over the sub-continents.

The country experiences distinct weather patterns in summer and winter that affect the dispersal of pollutants in the atmosphere. In summer, unstable atmospheric conditions result in mixing of the atmosphere and rapid dispersion of pollutants. Summer rainfall also aids in removing pollutants through wet deposition. In contrast, winter is characterised by atmospheric stability caused by a persistent high pressure system over South Africa. This dominant high pressure system results in subsidence, causing clear skies and a pronounced temperature inversion over the Highveld. This inversion layer traps the pollutants in the lower atmosphere, which results in reduced dispersion and a poorer ambient air quality. 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 0.1 mm or more rainfall.

Site specific MM5 modelled meteorological data set for full three calendar years (2012 – 2014) was obtained from the 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 Center for Atmospheric Research (PSU/NCAR) meso-scale model (known as MM5) is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict meso-scale atmospheric circulation. This data has been tested extensively and has been found to be extremely accurate.

Modelled meteorological data for the period January 20112 to December 2014 was obtained for a point in the proposed De Groote Boom open pit site (24.941561 S, 30.150786 E). Data availability was 100%.

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.

The amount of particulate matter generated by wind is highly dependent upon the wind speed. Below the wind speed threshold for a specific particle type, no particulate matter is liberated, while above the threshold, particulate matter liberation tends to increase with the wind speed. The amount of particulate matter 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.

Wind roses comprise 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 De Groote Boom area modelled data is clearly evident in Figure 6-1. The predominant wind direction is from the east southeast accounting for about 15.5% of the time, and wind speed greater than 5.4 m/s occurring for 11% throughout the period. Secondary wind speeds were also observed from the southeast (14%) and east (~10%). Over the three year period, winds capable of generating dust occurred for some 93 days. Calm conditions (wind speeds < 0.5 m/s) occurred for 0.25% of the time. Wind class frequency distribution per sector is given in Figure 6-4 and Table 6-1. During the last three years, strong winds greater than 8.8 m/s occurred for approximately 1% of the time. This equates to 11 days throughout the entire three year period.

The diurnal patterns during the night, showed winds coming from the ESE (30%) and SE (28%) dominating, while the morning, afternoon and evening experienced predominant winds from the ESE (14%), N (16%) and E (16%) sectors respectively (Figure 6-2).

Calm conditions in the morning, afternoon, evening and night time were: 0.76%, 0.17%, 0.03% and 0.05%. Average wind speeds were 3.16 m/s (morning), 3.37 m/s (afternoon), 3.78 m/s (evening) and 4.20 m/s (night time).

The seasonal patterns show spring has been dominated by winds from the ESE (17%) and E (13%) respectively. Wind speed greater than 5.4 m/s was observed 14% of the time. Average wind speed was 3.97 m/s and calm 0.15%. Summer was dominated by winds from the ESE (19%) and E (16%), and winds greater than 5.4 m/s was observed 7.6% of the time in summer. In autumn, winds from the SE (20%), and ESE (15%) dominated. Wind greater than 5.4 m/s capable of generating dust occurred some ~10% of the time. Winter was dominated by winds from SE (19%) and ESE (12%) with winds greater than 5.4 m/s occurring some 11% of the time.

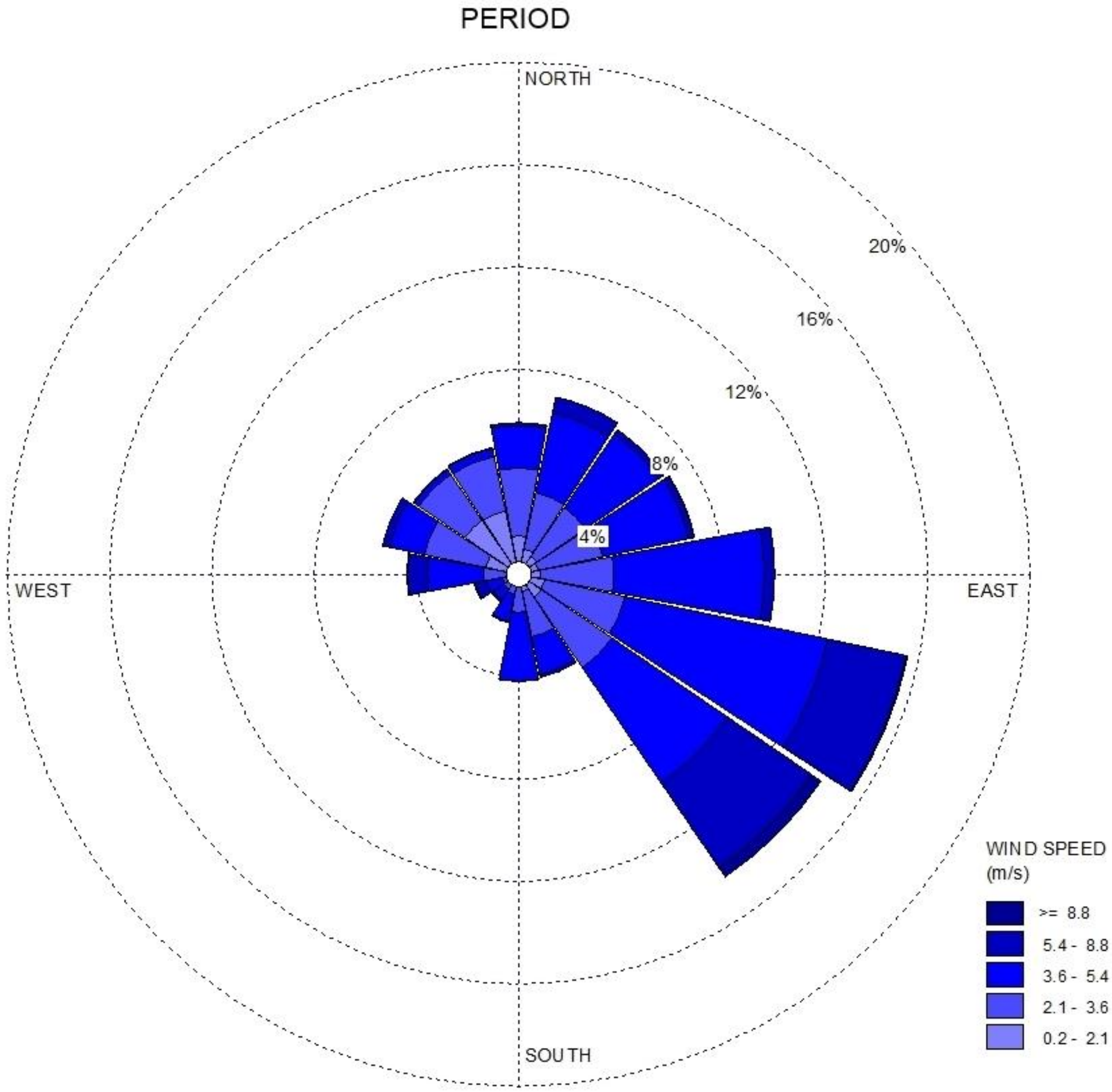

Figure 6-1: Surface wind rose for De Groote Boom modelled data, 01 January 2012 – 31 December 2014

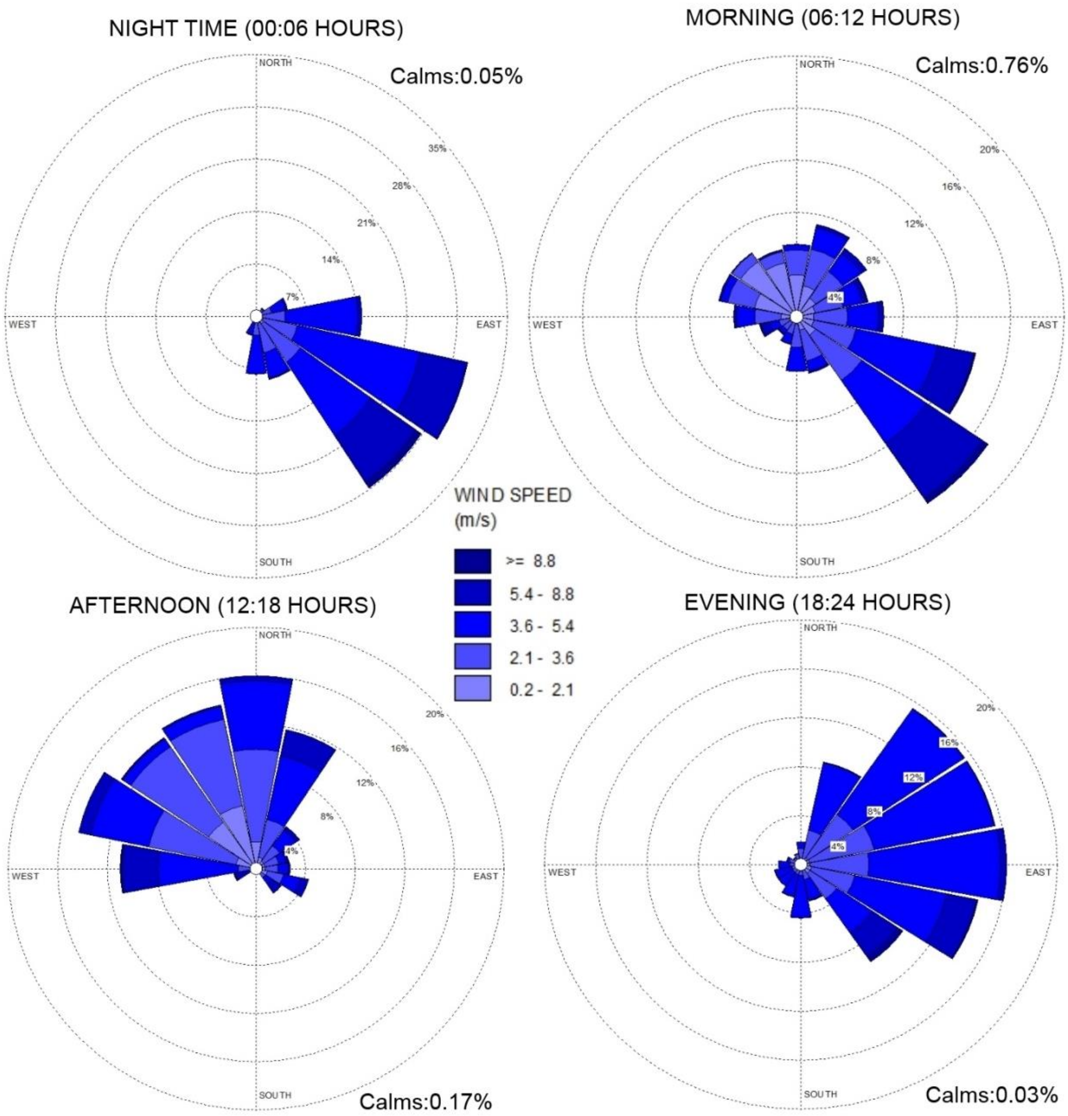

Figure 6-2: Diurnal variation of winds between Morning 06:00 – 12:00 (top right), Afternoon 12:00 – 18:00 (bottom right), Evening 18:00 – 24:00 (bottom right) and Night time 00:00 – 06:00 (top left) (01 January 2012 – 31 December 2014)

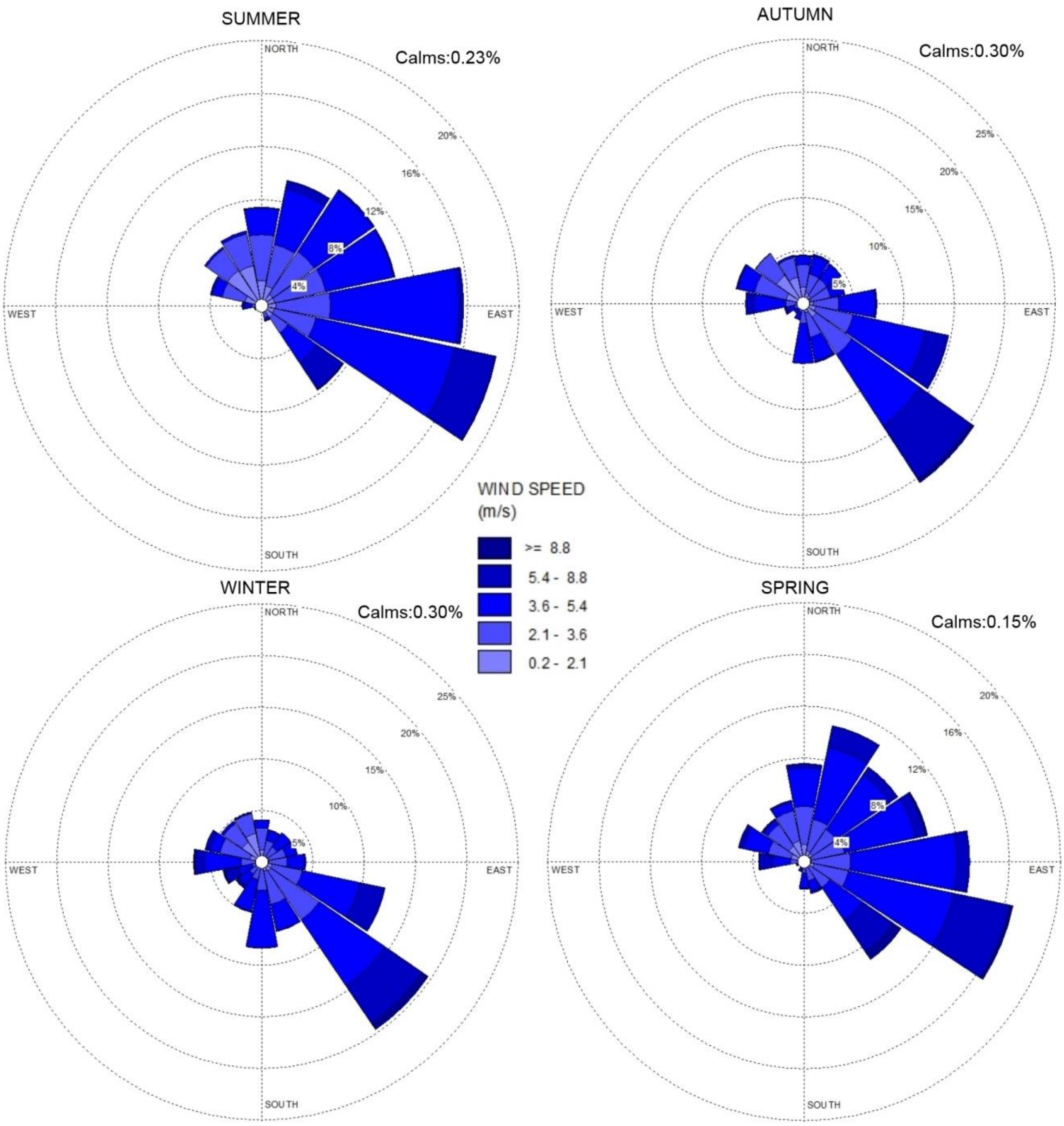

Figure 6-3: Seasonal variation of winds in spring season (September – November) (bottom right), summer season (December - February) (top left), autumn season (March – May) (top right) and winter season (June – August) (bottom left) (01 January 2012 – 31 December 2014)

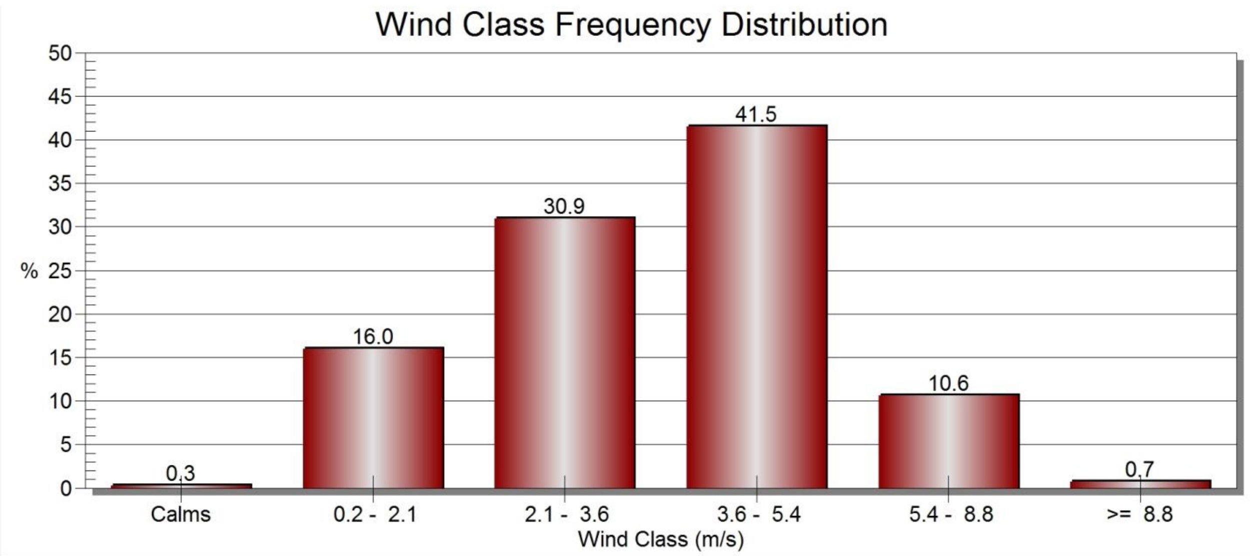

Figure 6-4: Wind Class Frequency Distribution for De Groote Boom opencast pit modelled data, 01 January 2012 – 31 December 2014

Table 6-1: Wind Class Frequency Distribution per Direction for De Groote Boom modelled data, 01 January 2012 – 31 December 2014

Directions		Wind Classes (m/s)					
		0.2 - 2.1	**2.1 - 3.6**	**3.6 - 5.4**	**5.4 - 8.8**	**>= 8.8**	**Total (%)**
1	N	0.36	0.94	0.53	0.00	0.00	1.84
2	NNE	0.40	2.46	5.60	0.09	0.00	8.55
3	NE	0.65	4.29	10.40	0.09	0.00	15.43
4	ENE	0.71	5.11	9.53	0.08	0.00	15.43
5	E	0.71	4.58	10.22	0.50	0.00	16.01
6	ESE	0.87	3.42	7.28	2.42	0.09	14.08
7	SE	0.87	2.52	3.35	2.37	0.50	9.61
8	SSE	0.52	0.75	1.69	0.09	0.02	3.06
9	S	0.36	0.53	3.47	0.02	0.00	4.38
10	SSW	0.20	0.62	1.86	0.05	0.00	2.72
11	SW	0.26	0.52	1.34	0.02	0.00	2.13
12	WSW	0.23	0.49	1.37	0.03	0.00	2.11
13	W	0.29	0.58	0.87	0.02	0.00	1.75
14	WNW	0.38	0.55	0.23	0.02	0.00	1.17
15	NW	0.36	0.30	0.05	0.03	0.00	0.75
16	NNW	0.43	0.46	0.06	0.00	0.00	0.94
	Sub-Total	7.60	28.12	57.83	5.81	0.61	99.97
	Calms						0.03
	Missing/Incomplete						0
	Total						100

6.4.1 Temperature

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

Three-year average maximum, mean and minimum temperatures for De Groote Boom area are given in Table 6-2. The average monthly maximum temperatures range from 18°C in July to 30°C in January, with monthly minima ranging from 0°C in July to 13°C in February and December respectively (Figure 6-5). Annual mean temperature for De Groote Boom area is given as 25°C. It is worth mentioning that the highest temperature recorded was 30°C and a lowest of 0 C in the area.

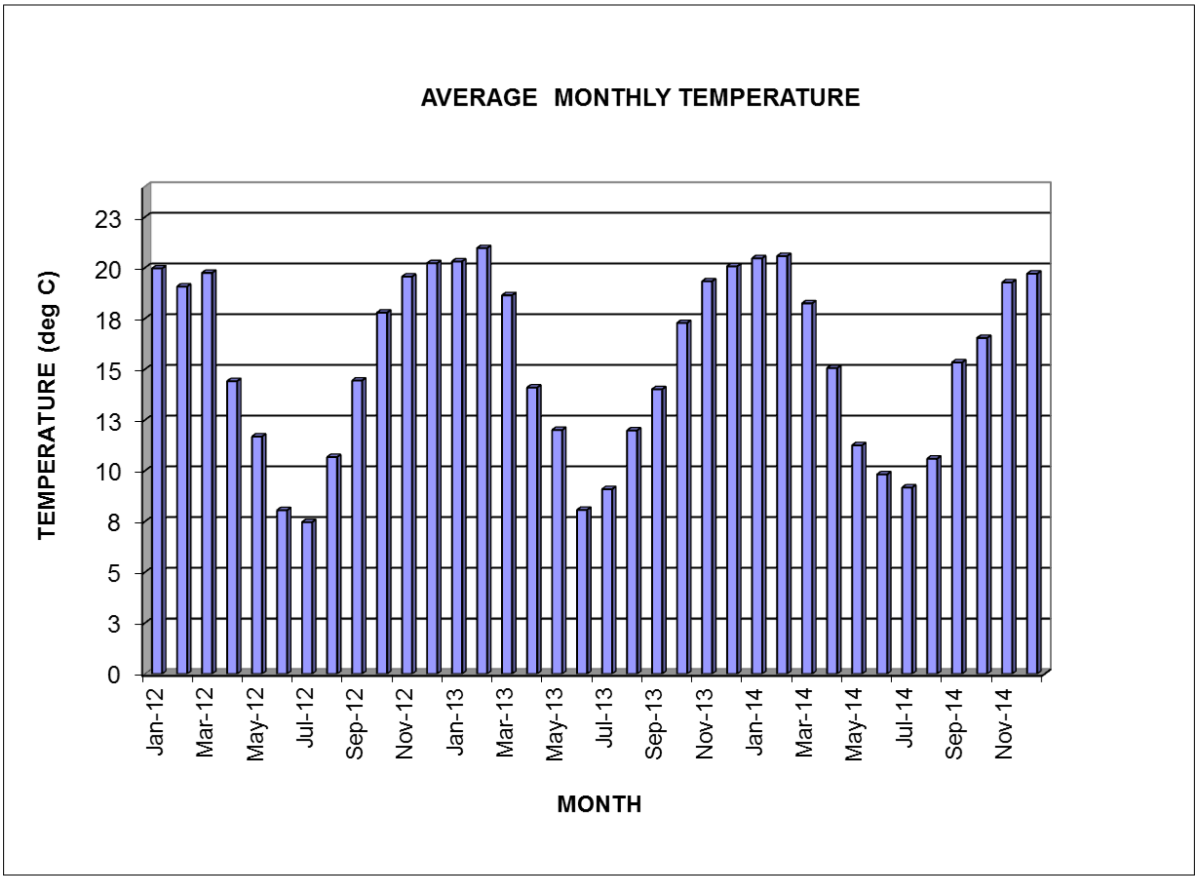

Figure 6-5: Average monthly temperature derived from the De Groote Boom modelled data (2012-2014)

Table 6-2: Average monthly minimum, maximum and mean temperature values derived from the De Groote Boom modelled data (2012-2014)

Temp(°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	30	29	27	25	19	19	18	20	25	27	28	29	25
Monthly Min.	11	13	10	7	2	1	0	2	2	7	10	13	6
Monthly Mean	20	21	18	15	11	10	9	11	15	17	19	20	16

Temperature data from the Lydenburg Weather Stations covering a 29 years monitoring period was used in the baseline report (Table 6-3). Data provided shows that summers are warm, temperatures rarely exceed 30°C, and winters are mild.

Table 6-3: Temperatures recorded in the region of the Project - Lydenburg SAWS weather station (1961 to 1990)

Month	Mean daily (°C)			Extremes (°C)	
	Maximum	Minimum	Average	Highest	Lowest
January	25.9	14.7	20.3	33.5 (1983/11)	15.8 (1972/23)
February	25.5	14.2	19.8	34.5 (1983/27)	14.9 (1967/19)
March	24.8	12.9	18.8	34.0 (1984/02)	13.6 (1975/18)
April	22.6	10.0	16.3	31.3 (1987/04)	12.8 (1974/03)
May	20.8	6.0	13.4	28.0 (1979/08)	9.0 (1972/13)
June	18.3	2.8	10.6	25.3 (1962/28)	5.9 (1968/03)
July	18.8	2.7	10.7	26.4 (1983/15)	8.0 (1967/15)
August	20.9	4.8	12.8	28.5 (1979/08)	6.2 (1977/24)
September	23.6	8.1	15.9	33.5 (1983/29)	6.4 (1974/04)
October	24.0	10.8	17.4	33.5 (1961/24)	9.3 (1965/19)
November	24.2	12.7	18.4	33.3 (1981/06)	9.0 (1968/11)
December	25.2	14.1	19.6	31.8 (1972/30)	15.2 (1966/17)
Annual	**22.9**	**9.5**	**16.2**	**34.5 (1983/27)**	**5.9 (1968/03)**

The long term data of temperature recorded at the Lydenburg Weather Station is in agreement with the modelled Lakes Software data used in the baseline.

6.4.2 Wind Speed

The data in Table 6-5 is representative of the wind speed for the De Groote Boom mining area. The monthly maximum and minimum wind speed is reported. For the period under survey, 2012– 2014 the highest wind speed observed in the area was 12.3 m/s. Wind speed greater than 5.4 m/s occurred some 11% throughout the period, accounting for 93 day (~31 days each year). The potential is there for wind erosion in the proposed De Groote Boom mining area.

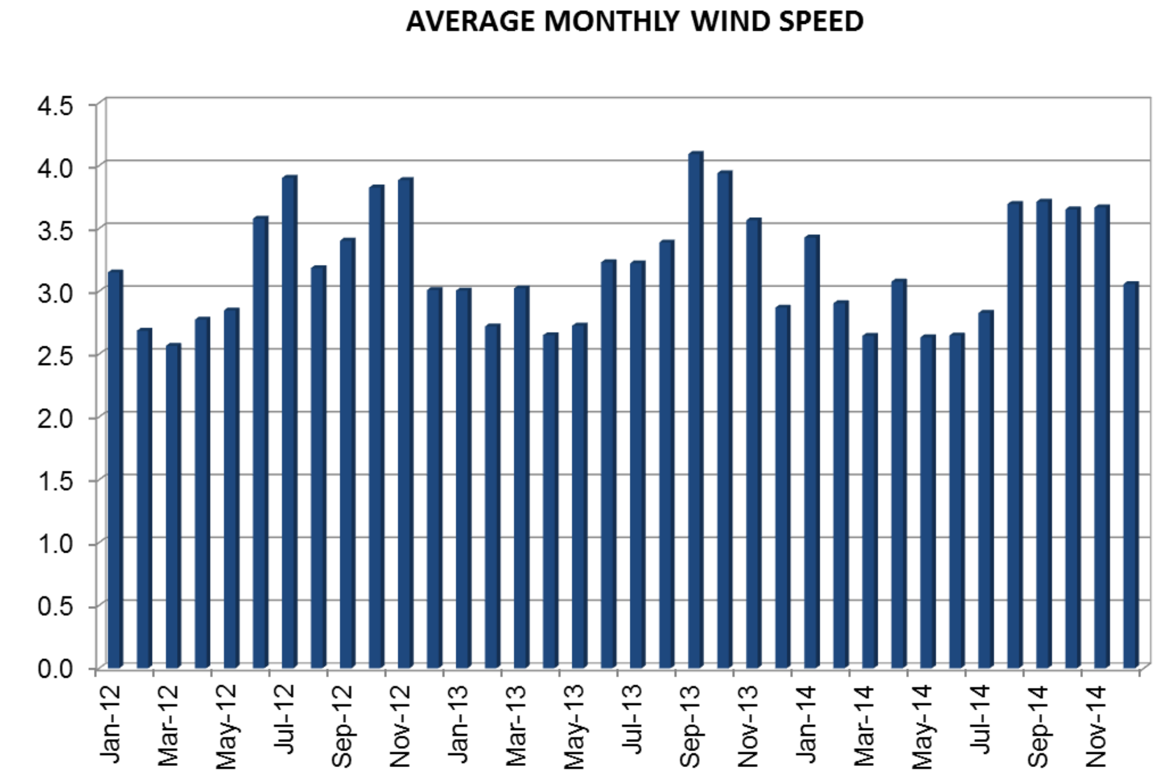

Figure 6-6: Average Monthly Wind Speed derived from the De Groote Boom modelled data (2012-2014)

Table 6-4: Average Monthly Wind Speed derived from the De Groote Boom modelled data (2012-2014)

Wind Speed (m/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	9.1	8.9	8.2	8.3	8.8	10.5	9.3	11.2	12.3	11.4	9.2	9.9	9.76
Monthly Min.	3.2	2.8	2.8	2.8	2.7	3.1	3.3	3.4	3.7	3.8	3.7	3.0	3.20

6.4.3 Relative Humidity

The data in Table 6-5 is representative of the relative humidity for the De Groote Boom mining area. The monthly maximum, minimum and mean relative humidity reported on. The monthly maximum relative humidity remains above 99.9 % for the year. The monthly minimum relative humidity recorded range between 18 % (March) and 36 % in June.

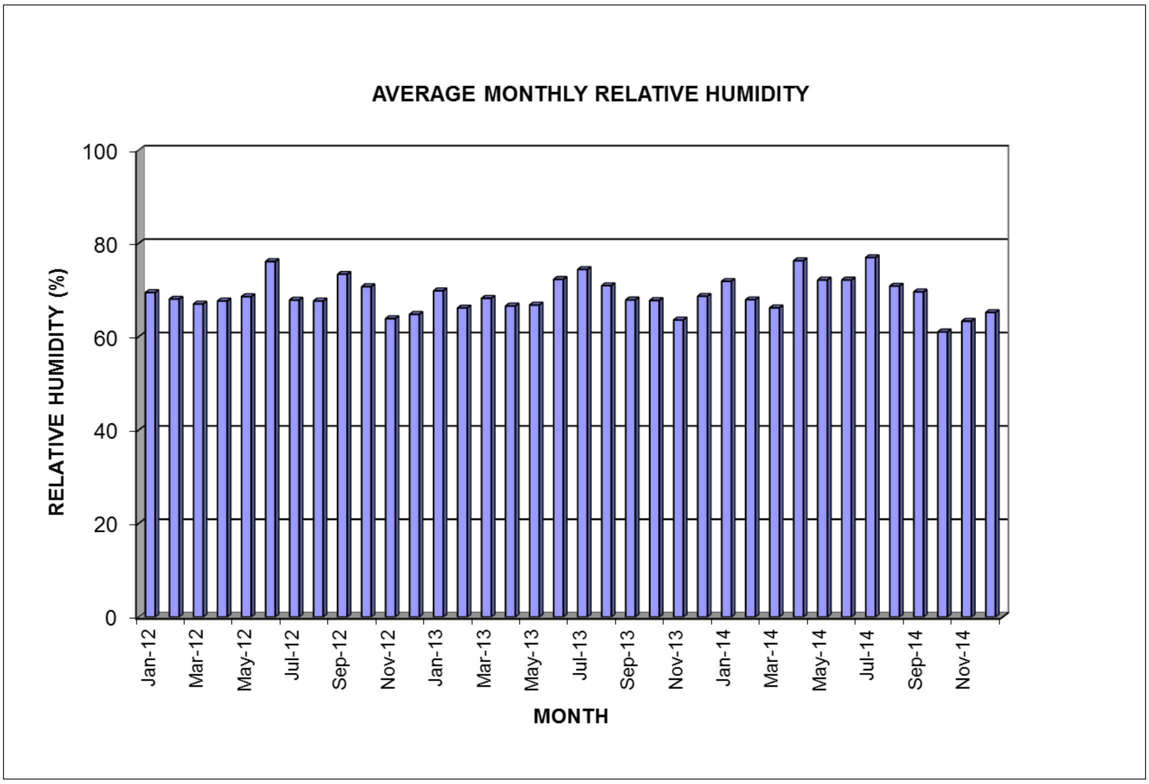

Figure 6-7: Average Monthly Relative Humidity derived from the De Groote Boom modelled data (2012-2014)

Table 6-5: Average Monthly Relative Humidity derived from the De Groote Boom modelled data (2012-2014)

Relative Humidity (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Monthly Min.	20.0	22.0	18.0	23.0	28.0	36.0	27.0	22.0	27.0	24.0	18.0	23.0	24.0
Monthly Mean	70.1	65.7	68.3	66.1	66.8	72.7	74.4	71.0	67.9	68.0	63.6	68.5	68.6

6.4.4 Precipitation

As shown in Table 6-7 below, the three year (2012-2014) annual total rainfall maximum and average for the De Groote Boom site are 1,249 mm and 788mm respectively. The highest total monthly precipitation (488 mm) was observed in January. The rate decreases down to1 mm in May. The maximum total rainfall and averages observed for each month over the three year period under survey are depicted in Figure 6-8 below.

Historical monthly rainfall statistics in the vicinity of proposed mining development were obtained from Lydenburg weather stations that had records 40 years rainfall data. The Lydenburg Weather Station (WD 0554816), located 45 km east of the study area at 25˚00' South and 30˚28' East. A summary of the mean monthly and mean annual rainfall at the Lydenburg stations is given in Table 6-6.

Table 6-6: Average monthly rainfall in the region of the project at the nearest SAWS stations

STATIONS	
Station name	**Lydenburg**
SAWS Station No.	0554816 W
Latitude	25°06’ S
Longitude	30°28’ E
Altitude (m)	1412
Length of record	1960 – 2000
RAINFALL (mm)	
January	137.8
February	78.1
March	75.0
April	47.5
May	16.0
June	5.9
July	5.5
August	10.1
September	24.6
October	66.1
November	126.3
December	118.4
Annual	**711.3**

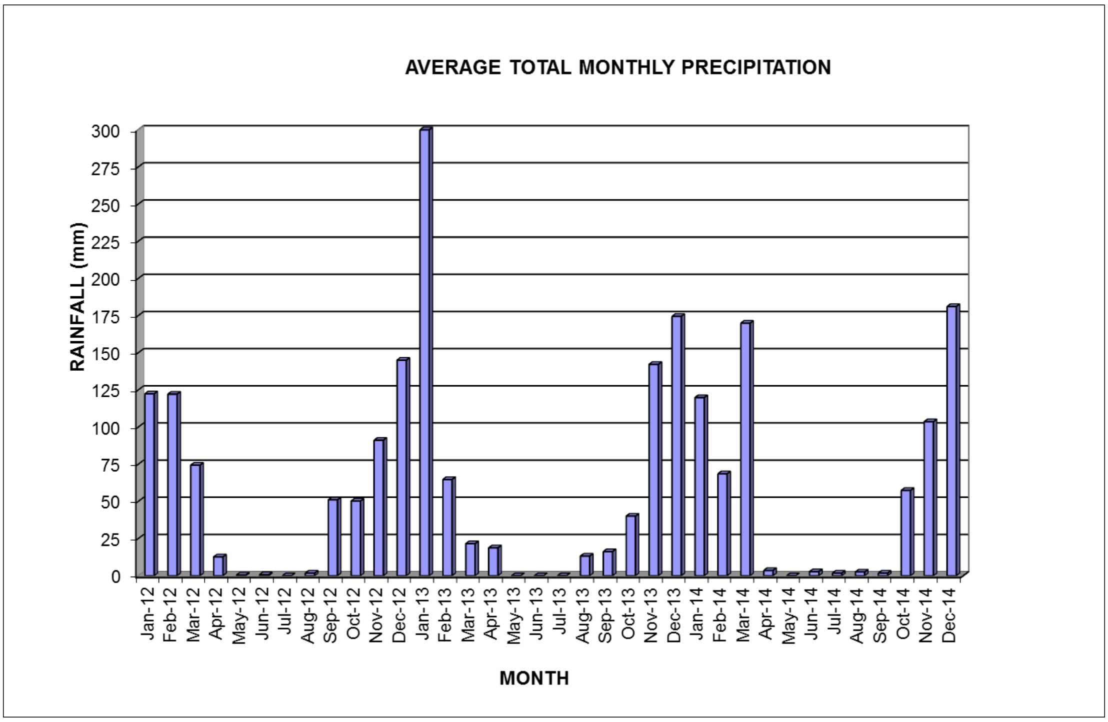

Figure 6-8: Average Monthly Precipitation derived from the De Groote Boom modelled data (2012-2014)

Table 6-7: Average Monthly Precipitation derived from the De Groote Boom modelled data (2012-2014)

Precipitation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Total Monthly Rainfall (Max).	488	122	170	19	1	3	2	13	51	57	142	181	1249
Average Total Monthly Rainfall	244	85	89	12	0	1	1	6	23	49	112	167	788

6.4.5 Evaporation

The South African Weather Station in Lydenburg is the only station with evaporation data in the surrounding area. Mean monthly S-pan evaporation data shows that the evaporation exceeds precipitation. It was assumed that the evaporation statistics for the SAWS Lydenburg Weather Station is similar to that at the proposed mining development. The 25 years of evaporation data generated for the SAWS Lydenburg Weather Station is displayed below (Table 6-6).

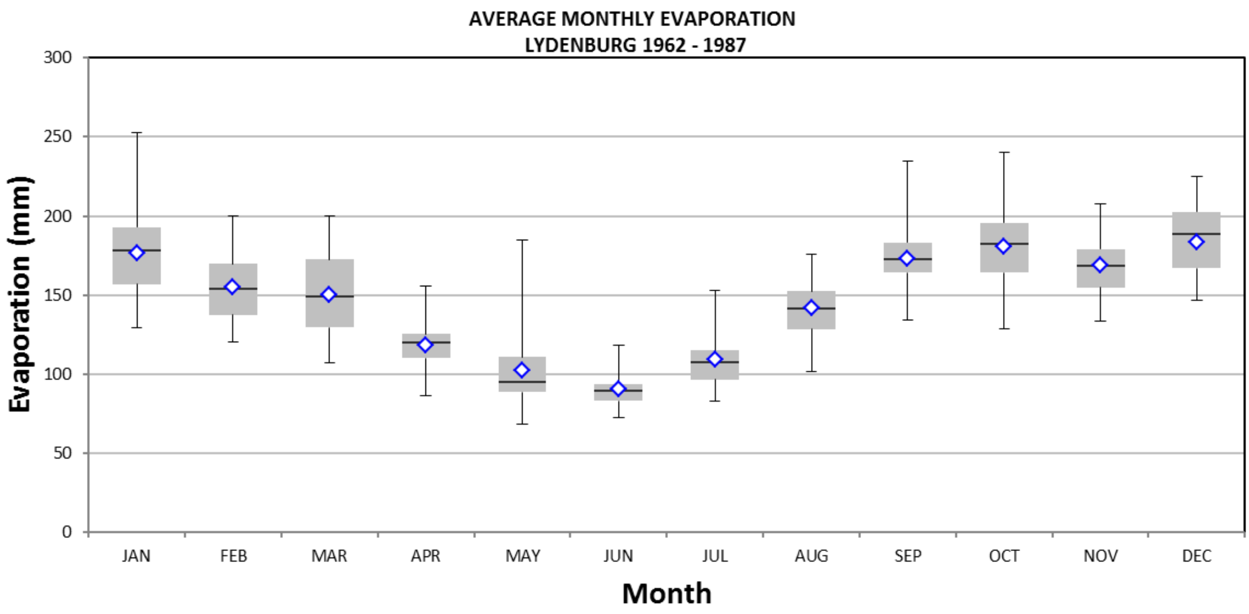

Figure 6-9: Average Monthly Evaporation for Bethal S-Pan Evaporation Station (1963 – 1987) (Source: South African Weather Service)

Table 6-8: Maximum, minimum and mean monthly evaporation rates for the Bethal (Symon's Pan) S-Pan evaporation station for 1963-1987 period (South African Weather Service)

Evaporation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly Max.	253	200	200	155	185	118	153	176	235	240	208	225	196
Monthly Min.	129	121	107	87	69	73	83	102	134	129	134	146	109
Monthly Mean	177	155	150	118	102	90	109	142	173	180	169	183	146

6.4.6 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.
- *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 6-9 and Table 6-10.

Table 6-9: 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 6-10: 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 LEGAL CONTEXT

Guidelines provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants of air that are known or likely to be hazardous to human health and wellbeing World Health Organization (WHO, 2000). Once the guidelines are adopted as standards, they become legally enforceable. These standards prescribe the allowable ambient concentrations of pollutants which are not to be exceeded during a specified time period in a defined area. If the air quality guidelines/standards are exceeded, the ambient air quality is poor and the potential for health effects is greatest.

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 serves to repeal the Atmospheric Pollution Prevention Act (45 of 1965) (APPA) and various other laws dealing with air pollution.

According to the Act, 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 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.

The Minister of Water and Environmental Affairs, released on the 01 November 2013 the National Dust Control Regulation, in terms of Section 53, read with Section 32 of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004). The National Dust Control Regulation published the acceptable dust fallout rates in residential and non-residential areas.

The National Dust Standard is given in the Table 7-1 below.

Table 7-1: Acceptable dust fall rates as measured (NEMAQA - NDCR, 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

Dustfalls that exceed the specified rates but that can be shown to be the result of some extreme weather or geological event shall be discounted for the purpose of enforcement and control. Such an event might typically result in excessive dustfall rates across an entire metropolitan region, and not be localized to a particular operation. Natural seasonal variations, for example the naturally windy months each year, will not be considered extreme events for this definition (SANS 1929:2011).

Any person who conducts any activity in such a way as to give rise to dust in quantities and concentrations that may exceed the dustfall standard (Table 7-1) set out in regulation 3 must, upon receipt of a notice from an air quality officer, implement a dustfall monitoring programme (NEMAQA-NDCR, 2013).

In the National Dust Control Regulation, terms like target, action and alert thresholds have been omitted. Another notable observation was the reduction of the *margin of tolerance* from the usual three to two incidences within a year (NEMAQA-NDCR, 2013). The National Dust Control Regulation actually adopted a more stringent approach than the previous standard, and would require dedicated mitigation plans now that it is in force.

Also, the DEA has established National Ambient Air Quality Standards for PM_{10} (Table 7-2), particulate matter of aerodynamic diameter less than 2.5 µm since June 2012 (GN486: 2012) and some criteria pollutants as depicted in Table 7-3.

Table 7-2: National Ambient Air Quality Standards as of 24 December 2009

National Ambient Air Quality Standards for Sulphur Dioxide (SO_2)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**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 Standards for Nitrogen Dioxide (NO_2)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**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 Standards for Particulate Matter (PM_{10})			
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
24 hour	75	4	1 January 2015
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 Standards for Ozone (O_3)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
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 Standards for Benzene (C_6H_6)

AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	LIMIT VALUE (ppb)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
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 ($\mu g/m^3$)	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 Standards for Carbon Monoxide (CO)				
AVERAGING PERIOD	LIMIT VALUE (mg/m^3)	LIMIT VALUE (ppm)	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.				

Table 7-3: Established National Ambient Air Quality Standards for Particulate Matter ($PM_{2.5}$) as of 29 June 2012

National Ambient Air Quality Standards for Particulate Matter ($PM_{2.5}$)			
AVERAGING PERIOD	LIMIT VALUE ($\mu g/m^3$)	FREQUENCY OF EXCEEDANCE	COMPLIANCE DATE
24 hours	65	0	Immediate – 31 December 2015
24 hours	40	0	1 January 2016 – 31 December 2029
24 hours	25	0	01 January 2030
1 year	25	0	Immediate – 31 December 2015
1 year	20	0	1 January 2016 – 31 December 2029
1 year	15	0	01 January 2030
The reference method for the determination of PM2.5 fraction of suspended particulate matter shall be EN 14907.			

8 HEALTH EFFECTS OF THE IDENTIFIED POLLUTANTS

8.1 Particulates

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

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). Other pollutants, i.e. fine particles contain the secondarily formed aerosols such as sulphates and nitrates, combustion particles and re-condensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dust from roads and industries (Fenger, 2002).

In terms of health effects, particulate air pollution is associated with complaints of the respiratory system (WHO, 2000). The size of the particulate matter is crucial as it determines the 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 extra-thoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

Particulate matter (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, 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 8-1.

8.1.1 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; 2002).

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 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 Forced Expiratory Volume over one second for each 100 µg/m^3 increase in the daily PM_{10} average.

8.1.2 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;2002).

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 (Table 8-1). 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 8-1: 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

9 BASELINE ASSESSMENT

Major atmospheric pollutants in the proposed De Groote Boom Study area will be influenced by local and regional pollutants signature, which include:

- Operational opencast and underground mines in the immediate vicinity, with numerous area and point sources;
- Agricultural activities, which is not dominant in the area.

In terms of air quality, the main pollutants of concern will be associated with dust generated from mining operations i.e. erosion of stockpiles, vehicular movement on unpaved, dry and dusty roads and material handling process.

9.1 Dust Fallout Baseline

Dust deposition data is crucial as it shows monthly, seasonal, and inter-annual variability in dust fallout rates – pre and during mining scenarios. The amount of dust collected at any given time is a function of the rate of deposition, which may vary widely depending on meteorological factors such as wind speed and direction, variations in the number of sources and mitigation measures adopted, and the background level of pollutants. The dust monitoring network will be commissioned towards the end of May 2015. Sampling will be conducted for an initial period of six months. The dust fallout sampling, analyses, comparison and interpretation will be conducted according to the recommended SANS 1929:2011 (adapted from ASTM1739-98).

The deposition results will be illustrated by means of tables and graphs expressed in the units of $mg/m^2/day$ averaged over a 30-day period. South African Bureau of Standards (SANS 1929:2011) has published an important standard in terms of air quality underlying limits for dust fallout rates. In terms of dust deposition standards, a four-band scale use to apply – with target, action and alert thresholds clearly spelt out, with three permissible frequencies of excesses.

Since November of 2013, the National Dust Control Regulation (NDCR) dust fallout rates in residential and non-residential areas now apply (Table 7-1). Pre mining dust deposition rates measured in the in and around the proposed site will be compared to the NDCR 2013.

9.2 Particulate and Gaseous Pollutants Baseline

Particulate matter - 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) are of health significance (Harrison and van Grieken, 1998). Data for both sets of pollutants were not available for assessment. This is considered a data gap, since mining operation often impacts on the ambient particulate loading of these pollutants in any airshed.

As a result of the latter, acquisition of site specific information for these criteria pollutants is imperative. These pollutants are regulated, as such measurement should be prioritised before the project commences to establish baseline conditions prior to mining by De Groote Boom.

10 IMPACT ASSESSMENT

11 Methodology

11.1 Emissions 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 (EET)" manuals have been used.

There are various sources of emissions anticipated from any mining operation, from the construction, operational and decommissioning phases. Envisaged emissions from the proposed mining operation include:

- Inhalable fraction (airborne material that enters the nose and mouth during breathing, which can be deposited anywhere in the respiratory tract - aerodynamic diameters less than or equal to 10 µm). While the respirable fraction encompasses the airborne material that penetrates the lower gas exchange region of the lungs (aerodynamic diameters less than or equal to 2.5 µm));
- Total suspended particulates (TSP);
- Diesel particulate matter (DM), being emitted from haul trucks and diesel generators;
- Gaseous emissions from haul trucks and off road mine vehicles i.e. oxides of nitrogen (NO and NO_2, jointly known as NO_x);
- Sulphur dioxide (SO_2) from mine vehicles;
- Carbon monoxide (CO) from haul trucks and mine vehicles.

An emissions inventory was established comprising emissions from construction and operational activities at the proposed De Groote Boom Project. Some activities associated with the operation are highlighted (Table 11-1). The establishment of this emissions inventory is necessary to provide the source and emissions data required as input to the dispersion simulations. It was assumed that the mine will rely solely on the national grid for power, hence emissions from diesel generators on-site were not quantified. The operation of the latter will be intermittent and resulting emissions will be negligible.

Table 11-1: Activity and source of of emmissions for the proposed De Groote Boom project

Source	Activity
Construction	
	Site clearing
	Mine fleet heavy equipment
Operational	
Material handling	Tipping from excavator to haul truck
	Tipping from haul truck to ROM stockpile and Waste Rock Dump

Source	Activity
	Tipping from front end loader to truck
	Tipping from truck to crusher
	Tipping from crusher to product stockpile
	Tipping from front end loader to truck
Vehicle activity on haul roads	Trucks from pit to ROM and Waste Rock Dump
Wind erosion	Haul roads
	Topsoil storage pile
	Waste Rock Dump
	ROM stockpile
Screening and Crushing	Crushing

Emission factors from the US EPA AP42 database were used for the purposes of predicting vehicle wheel entrainment emissions from haul roads. It must be noted that these factors are known to conservatively overestimate particulate emission rates from unpaved roads. It is worth mentioning that emissions quantification for the study was informed by vehicle data from similar studies, and the same applies to surface particle size distribution data.

11.1.1 Construction Phase

11.1.1.1 Mine Fleet Equipment (Road Dust Emissions)

During the construction phase, clearing of vegetation and stripping of soil, excavation and loading of topsoil onto trucks or stockpiles will occur accompanied by removal of topsoil, erosion and suspension of loose dust particulate matter. Although this phase will be short-term, quantification of emissions have been conducted for fugitive dust generation from dirt roads and cleared areas using known emission factors from the USEPA 2006.

Movement of construction vehicles such as bulldozers, graders and a host of machineries lead to dust generation. Road dust emissions from construction vehicles during clearing were estimated. For this activity, 10 working hours per day was assumed for the dusty construction works. Emission factors from the United States Environmental Protection Agency (U.S EPA) AP-42 factor for heavy construction vehicle of 2.69 Mg/hectare/year were used. A summary of the emission burden from heavy construction vehicles is presented below (Table 11-2).

Table 11-2: Summary of particulate matter from construction vehicles on dirt roads

Pollutant	Emissions (t/y)
PM2.5	0.68

PM10	3.25
TSP	6.5

In our calculation of erosion from cleared areas, we assumed that the entire surface area for the PCD, workshop offices and WRD will be cleared at the same time. Emissions from construction were modelled in accordance with best practice as recommended by USEPA AP-42 manual.

11.1.2 Operational Phase

Emissions associated with the operational phase encompass those from a variety of sources: drilling and blasting, excavation, material handling, emissions from dirt road, and wind erosion from stockpiles. To quantify emissions, the specifications and dimension of the various sources, the meteorology of the area and the particle size distribution materials were used as input parameters. Emphasis is often placed on particulate matter emissions two primary sources; wind erosion from exposed surfaces, and dust generated from haul roads. Wind generated erosions is expected to be exacerbated during the dry and windy season. Gaseous emissions from the mine fleet of vehicles and other mine machineries (i.e. were not appraised).

11.1.2.1 Material handling operations

This process includes the transfer of ore from the pits to the ROM stockpile, front end loader to trucks, trucks to crusher, and from crushers to product stockpile. The crusher will reduce the size of the ore which is then transferred via the conveyor belt to the product stockpile and then trucked out of site to the Plant. The tipping process and crushing are associated with fugitive emissions, which depend on various factors such as wind speed, wind direction and precipitation. The higher the moisture content of the material, the less fugitive dust released during the process. To calculate the emissions from the material handling operations, equations from US EPAP-42 emission factors were utilised. The throughput of 180 000 tonnes annually was used in our assessment, which translates to 23 tonnes per hour (Table 11-3). The latter will apply if the mine operates for 90 percent of the time (328 days in year).

Table 11-3: Throughput from material handling operations

Operation	Throughput t/hour
Tipping from truck to crusher	23
Tipping crusher to product stockpile	23
Tipping product stockpile to truck	23

11.1.2.2 Vehicle activity on haul roads

CAT® 777G trucks with rated payload of 100 tonnes are assumed to be employed in transporting excavated materials from the pits. This emission inventory calculated emissions from the pits through the haul road to ROM stockpile and waste rock dumps. The estimate took into cognisance the annual tonnage and hauling of ore and waste rock and the travel distances to and fro on the 4.5 kilometre length of road (Table 11-4). Emission factor was estimated, which served as input data used in the dispersion model.

Table 11-4: Parameters of the unpaved haul road for the proposed operations

Road	Length (m)	Width (m)
Road	4500	10

11.1.2.3 Wind erosion from topsoil stockpile, ROM stockpile and waste rock dump

There are two main types of stockpiles: long term and short term. The waste rock dump (WRD) facility and the topsoil stockpile are both considered long term stockpiles. The latter will be vegetated and not disturbed for a long period, only utilised during the reclamation of the mine. A ROM stockpile will be a short term stockpile, as there will be constant offload and removal of ore from the stockpile. The following are the specifications of the significant sources of the wind erosion used in the dispersion modelling (Table 11-5).

Table 11-5: Parameters for the topsoil, ROM and WRD stockpiles

Source	Height (m)	Area (m^2)	X length (m)	Y length (m)	Moisture content (%)
Waste	20	69 075	225	307	6.9
Topsoil stockpile	1	10 000	100	100	6.9
ROM	5	13 920	116	120	6.9

An emission factor is a representative value that attempts to relate an activity with the release of pollutant (s) to 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.

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 various sources. These derived emission factors served as input data for our dispersion model, to predict the ground level concentrations and pollutant spread from the study area.

For the fine dust component of particulate emissions from industrial wind erosion, a $PM_{2.5}/PM_{10}$ ratio of 0.15 is recommended. However, a ratio of 0.21 was used in our estimate based on findings from literature survey. Industrial wind erosion is associated with crushed aggregate materials or ore piles. Examples would include open storage piles at mining operations (USEPA, 2006). The parameters used in the calculations of the emissions associated with wind erosion are given below (Table 11-6).

Table 11-6: Wind erosion from exposed areas and derived emission factors without mitigation

Activity	Unit	TSP emission factors	PM_{10} emission factors	$PM_{2.5}$ emission factors
Waste rock	$g/m^2/s$	5.2E-06	2.6E-06	5.4E-07
Pit	$g/m^2/s$	5.2E-06	2.6E-06	5.4E-07
Topsoil stockpile	$g/m^2/s$	7.8E-06	3.9E-06	8.2E-07
ROM	$g/m^2/s$	5.2E-06	2.6E-06	5.4E-07
Unpaved roads erosion (ore)	g/s	0.216	0.056	0.011

Significant emissions can arise due to the mechanical disturbance of granular material from open areas and storage piles. 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 from the surface, the nature of dispersion of the dust plume, and the rate of deposition.

Dust emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed 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 speed is exceeded, erosion rates tend to increase rapidly (Cowherd *et al.*, 1988).

It is anticipated that dust will be eroded from identified sources at the proposed De Groote Boom mining area at 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 wind speed. Wind speeds of 5.4 m/s and stronger occur in the area 9 % of the time. An average wind speed of xx m/s was calculated from the De Groote Boom modelled data.

Wind erosion is generally a selective material-loss process, which moves particles of various size fractions at different mass-flow rates. One also needs to understand how the particle-size distribution (PSD) is related to material properties of the eroded material.

PSD is the key parameter, determining the entire process of wind erosion, from entrainment through transport to deposition. Table 11-7 gives PSD as adopted from a similar opencast operation. These values were used as input parameters into the model for dust deposition.

Table 11-8 gives an overview of annual emissions from ROM stockpile, topsoil stockpile, tipping and unpaved roads.

Table 11-7: Particle size distribution for proposed mining activities

SOURCE	PARTICLE SIZE FRACTION (%)			
	75µm	30 µm	10 µm	2.5 µm
Topsoil stockpile	0.26	0.30	0.24	0.20
Run of Mine (ROM)	0.49	0.27	0.14	0.10
Waste dump (WRD)	0.44	0.27	0.15	0.14

Table 11-8: Estimated annual emissions for the wind erosion sources

Activity	Annual emissions (t/year)		
	TSP	PM_{10}	$PM_{2.5}$
Waste dump	11.29	5.64	1.19
Pit	3.68	1.84	0.39
Topsoil stockpile	2.45	1.23	0.26
ROM	2.28	1.14	0.24
Crusher	0.13	0.02	0.001
Tipping	2.5	1.2	0.24
Total emissions	**22.33**	**11.07**	**2.321**

11.1.2.4 Screens and Crushers

Crushers are used to reduce the size of the ore for ease of processing. In most cases this is a significant source of fugitive dust with large quantities of respirable fractions of dust produced. The crushers will be working for 6560 hours per year. The parameters used in the calculations of the emissions are given below (Table 11-9).

Table 11-9: Tonnes of material and moisture content feed to the Crushers

Source	Tonnes per annum	Moisture content (%)
Primary Crusher	180,000	6.9
Secondary Crusher	180,000	6.9

11.1.2.5 Gaseous emissions from generators

Emission rates from standby diesel generator with the subsequent releases of such as: NOx, CO, HC were not quantified. The assumption is that the mine will rely solely on power from the national grid. Standby generator will be used sparingly and associated emissions will be very low.

12 Methodology, Results and Discussion for Dispersion Modelling

12.1 Dispersion Modelling

Atmospheric dispersion modelling is the mathematical simulations of how airborne pollutants disperse in the ambient atmosphere, making use of algorithms that mimic the dispersion and transformation of pollutants in the natural atmosphere. With the latter, downwind concentration of air pollutants emitted from various sources can be predicted. Isopleths of pollutants concentration generation are then used to assist in the design and assessment of various control strategies and abatement technologies for emission reductions.

The mathematical equations employed in these models, attempt to describe processes observed in nature, which enables scientists to create replicas of natural systems with a computer, so that the causes and effects of system behaviour may be better understood. The primary focus of dispersion modelling is to estimate the ambient concentrations of primary pollutants that have been emitted in the atmosphere. There are a number of dispersion models that have been developed around the world. The widely used AERMOD dispersion model is one such example.

12.1.1 AERMOD Suite of Models

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 arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

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. Table 12-1 gives an overview of meteorological parameters and basic setup options for the AERMOD model runs.

Table 12-1: Summary of meteorological and AERMET parameters used for this study

Number of grids (spacing)	1 (250 m)
Number of grids points	81x81
Years of analysis	Jan 2012 to Dec 2014
Centre of analysis	(24.941561 S, 30.150786 E)
Meteorological grid domain	20 km (east-west) x 20 km (south-north)
Meteorological grid cell resolution	20 km x 20 km
Station Base Elevation	1262 m

MM5-Processed Grid Cell (Grid Cell Centre)	(24.941561 S, 30.150786
Anemometer Height	14 m
Surface meteorological stations	1 site at the proposed De Groote Boom site using data generated by AERMET
Upper air meteorological stations	1 site at the proposed De Groote Boom site using data generated by AERMET
Simulation length	2561 hours (Jan 2012 to Dec 2014)
Sectors	The surrounding area land use type was considered to be *grassland land*
Albedo	0.28 (generated with the AERMOD Model – when the land use types are specified)
Surface Roughness	0.0725
Bowen Ratio	0.75
Terrain Option	Elevated (The regional setting showed some ridges in the area)

12.1.2 Geophysical Model Input Data

Geophysical data requirements include land use type and terrain elevation. Land use categories and terrain of the surrounding region are defined when processing AERMET and AERMAP respectively. Often, the in-built land use classification type and the terrain heights derived from the 90m SRTM DEM product are employed. The aforementioned parameters exact strong influence on wind speed and turbulence, which are key components for dispersion. AERMOD model system and for this study include: emissions source data, meteorological data and information on the nature of the receptor grid. Parameters required depend on the source type (point, line, area or volume).

Meteorological data is crucial as this principal factor to the dispersion of pollutants in the atmosphere i.e. vertical profiles of wind speed and direction, atmospheric turbulence and ambient air temperature. It is worth mentioning that topography plays a significant role in dispersion of emissions from source. Topographic features create mechanical drag, inducing turbulence and the subsequent dispersion of pollutants and atmospheric mixing / dilution. The surrounding topography is ridgelines and mountain peaks prominent in the landscapes of the proposed De Groote Boom study area, an average height of mamsl.

12.2 Impact Assessment Summary

All relevant averaging periods were modelled for pollutants of concern. In all instances the worst case scenario has been presented to demonstrate the highest predicted impact. It is important to note that highest period-averages (i.e. highest hourly-average and highest 24-

hour-average) presented in the maps are indicative of the highest expected concentrations for the period-average for the modelled year at each position in the modelled domain, and must not be interpreted as being representative of general conditions. The intent of the maps is to conservatively present the worst case scenario for those averaging periods.

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 ground level concentrations follow closely the main wind directions (wind roses generated for the site). Numerical values of maximum depend on the emission rate and the prevailing meteorological condition of the area. Simulations were undertaken to determine concentrations of particulate matter with a particle size of less than 10 µm in size (PM_{10}), particle size of less than 2.5 µm in size ($PM_{2.5}$) and for dust deposition (≥ 30 µm). These simulations were undertaken to determine concentrations without-mitigation.

Isopleth plots of predicted concentrations of pollutants: PM_{10}, $PM_{2.5}$, and dust deposition for the worst case scenario (where mitigation measures are not applied for topsoil, overburden dumps and activities like tipping and haulage) were predicted for the respective averaging periods).

The hourly and daily average concentrations were calculated as the 4th highest value (99th percentile). Annual mean values were shown as the highest values (100th percentile) according to the NEM: AQA Air Dispersion Regulation (2012). IFC General EHS Guidelines: Environmental Air Emissions and Ambient Air Quality also stipulate that PM 24-hour value is the 99th percentile, and this was applied to all the pollutants.

Isopleths of ground level concentrations generated for the different pollutants associated with the proposed De Groote Boom are presented (Appendix C to G).

Simulations were undertaken to determine concentrations of particulate matter with aerodynamic size of 10 µm or less (PM_{10}), aerodynamic size of 2.5 µm or less ($PM_{2.5}$), and of deposition of total suspended particulates (TSP) ≥ 30 µm from the operations of the proposed De Groote Boom project.

12.2.1 Isopleth Plots and Evaluation of Modelling Results

12.2.1.1 PM_{10} predicted impacts

Isopleth plot of predicted 4th highest daily concentration of PM_{10} attributed to the proposed De Groote Boom operation is given in Appendix C. The daily highest ground level concentration predicted was 177 µg/m^3. The highest concentration predicted at the project boundary was 78 µg/m^3, which extended outside the proposed study area (in the northwest boundary). The predicted ground level concentration at the mine boundary is in exceedance of the current daily limit of 75 µg/m³ without mitigation. The *major contributors are road, wind erosion*). In terms of spatial impact, much of the area impacted is outside the study area. Ambient concentrations at the identified receptors within the boundary are in compliance, as the model predicted concentrations below 1 µg/m³.

The predicted concentrations are the likely additions that can be anticipated from the proposed De Groote Boom Mine on ambient air quality and not cumulative impact from all the existing sources in the area. *It is therefore possible that the highest daily concentration predicted to occur at a certain locations, this may only be true for one day during the entire period.*

The predicted 1st highest annual values for PM_{10} anticipated from the proposed De Groote Boom mining operations are given in Appendix D. The annual highest ground level concentration of this pollutant predicted was 65 µg/m³. The predicted concentration at the mine boundary was 20 µg/m³. Although the highest ground level concentration predicted for this operation is in exceedance of the current standard of 40 µg/m³, levels at the mine boundary are within compliance. The ambient concentrations at identified sensitive receptors are below 1 ug/m^3.

12.2.1.2 $PM_{2.5}$ Predicted impacts

Isopleth plot of predicted 4th highest daily values for $PM_{2.5}$ generated by the proposed De Groote Boom Mine is given in Appendix E, the maximum ground level concentration of 37 µg/m³ was predicted. This isopleth plot of predicted maximum daily values for $PM_{2.5}$ from all sources without mitigation measures predicted is within the current daily limit of 65 µg/m³ and the future limit of 40 µg/m³. The predicted $PM_{2.5}$ concentrations at the mine boundary arrived at 10 µg/m³. The identified sensitive receptors are exposed to concentration below 1 µg/m³.

The isopleth depicting the predicted 1st highest annual ground level concentrations for $PM_{2.5}$ that will be generated by the proposed De Groote Boom Mine is presented Appendix F). The predicted annual maximum ground level concentration of 13 µg/m³ was obtained, with concentrations at the mine boundary of 5 µg/m³ generated. The concentrations at the selected sensitive receptors were all below 1 µg/m³.

12.2.1.3 Dust deposition predicted impacts

The predicted dust deposition rates anticipated from the proposed De Groote Boom project is confirming that dust levels will be a course for concern. The predicted maximum concentration at the mine boundary is 2 188 mg/m^2/day. Exposure will be higher at the northwestern sector, reason being that the predominant wind is from the southeast (Appendix G). Major contributions are coming from hauling of ore and waste to product and waste stockpiles respectively. Deposition rates at the selected sensitive receptors (20 mg/m^2/day) are within the NDCR 2013 recommended standard for both residential and industrial areas (i.e. 600 mg/m²/day and 1200 mg/m²/day).

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

These isopleth plots and concentrations are generated without mitigation measures in place. Once mitigation measures are applied the predicted footprints of the different pollutants are likely to decrease considerably. Summary of isopleth plots generated in the current section are presented in Table 12-2.

Table 12-2: Evaluation of results for particulate matter and deposited nuisance dust for the operational phase of De Groote Boom.

Pollutant	Averaging period	Standard (µg/m³)	Figure
	Unmitigated concentrations		
PM_{10}	24 Hours	75 (1)	Figure 12-1
	Annual	40(1)	Figure 12-2
$PM_{2.5}$	24 Hours	65(1) 40(2)	Figure 12-3
	Annual	25(1) 20(2)	Figure 12-4
Dust Deposition	Monthly	600(3)	Figure 12-5

(1) South African- Current National Ambient Air Quality Standards (NAAQS)
(2) South African- Proposed future (from 1 January 2016) National Ambient Air Quality Standards (NAAQS)
(3) National Dust Control Regulation 2013: "Dust fallout Standards"

12.3 Discussion

The impacts arising from identified pollutants associated with the proposed De Groote Boom Mine operational phase have been appraised using predicted concentration levels and isopleth plots from AERMOD dispersion model.

12.3.1 Findings

Impacts associated with the proposed De Groote Boom Mine have been assessed. The AQIA study shows that the particulate pollution from the proposed mine operation will exert impact on current ambient air quality of the area. With multiple activities conducted at the same time, this results in multiple sources of emission (i.e. drilling and blasting, loading and offloading, hauling of ore and overburden, tipping, and crushing). The main findings of this AQIA study are summarised as follows:

- The predicted highest daily PM_{10} concentration at the mine boundary of 78 µg/m³ without mitigation measures exceeded the current South African standards of 75 µg/m³. Sensitive receptors within the mine study area will be exposed to concentrations below 1 µg/m³. The predicted highest annual maximum was 65 µg/m³, which is higher than the current limit of 40 µg/m³. However, the predicted annual maximum concentration at the mine boundary (20 µg/m³) is below the current standard of 40 µg/m³.

- The highest $PM_{2.5}$ daily (37 µg/m³) predicted is within the current limit of 65 µg/m³. The highest concentration at the boundary of 10 µg/m³, means exposure above the recommend standard is unlikely. The predicted annual levels (13 µg/m³) is within the current standard of 25 µg/m³ and future standard of 20 µg/m³ which will come into effect 1 January 2016.
- The highest dust deposition rates predicted beyond the mine boundary exceeded 2 188 mg/m²/day. This value is higher than the current limits for residential and non-residential areas of 600 mg/m²/day and 1200 mg/m²/day (National Dust Control Regulation, 2013). The dispersion model shows that exceedances will be observed mainly within the study area, and about 400 m from the northwest boundary. Exposure will be higher in the northwestern direction.

The concentrations of the various pollutants have been evaluated at the proposed mine site and sensitive receptors and levels are within the regulatory standards without mitigation measures in place. Once mitigations measures are applied, emissions from De Groote Boom are likely to reduce.

The predicted levels of PM_{10} and $PM_{2.5}$ can be contained with mitigation measures in place. Once dust deposition is contained with adequate mitigation measure factored into the day to day operation of the mine. If emission of pollutants is contained during the operational phase, especially TSP i.e. mitigation measures applied, associated impacts of PM_{10} and $PM_{2.5}$ will be reduced in the surrounding atmosphere including sensitive receptors.

The findings from this study should inform mine management on the monitoring and mitigation measures to ameliorate impact on the ambient air quality of the area. Some of the numerous mitigation measures recommended are listed below:

- The area of disturbance at all times must be kept to a minimum and no unnecessary clearing, digging or scraping must occur, especially on windy days (with wind speed ≥ 5.4 m/s).
- The drop heights when loading onto trucks and at tipping points should be minimised. Coupled with the use of dust suppressants and binders on haul roads to reduce dust generation.
- There is need to minimise travel speed and distances. Dust generating capacity of particles less than 10 µm is contained by 58% when vehicle speed is reduced from 25 mph (40 km/h) to 15 mph (24 km/h).
- Routine maintenance and vegetation of storage facilities i.e. topsoil and waste stockpiles are imperative throughout the lifespan of the mine to avoid exposing surfaces to wind erosion.

- Hazardous waste storage areas should be kept clear of combustible materials and rubbish (oily rags, oil, grease, cartons etc.) to avoid fire outbreak and release of particulate pollutants into the surrounding atmosphere.

12.4 Conclusion

An AQIA was undertaken as a part of an EIA Study for the proposed De Groote Boom Mine, near the town Steelpoort situated in the Limpopo Province, South Africa.

The predominant wind direction is from the east southeast accounting for about 15.5% of the time, and wind speed greater than 5.4 m/s occurring for 11% throughout the period. Secondary wind speeds were also observed from the southeast (14%) and east (~10%). Over the three year period, winds capable of generating dust occurred for some 93 days. Calm conditions (wind speeds < 0.5 m/s) occurred for 0.25% of the time. During the last three years, strong winds greater than 8.8 m/s occurred for approximately 1% of the time. This equates to 11 days throughout the entire three year period.

Pollutants quantified and evaluated in this assessment encompass fine particulates (PM_{10} and $PM_{2.5}$) and (TSP. The modelling results presented in this report confirm that the potential is there to exacerbate the current background concentration above regulatory standards. The dispersion modelling results showed impacts that are mostly confined to the study area. Hauling of ore and waste on dirt road represent the main contributor followed by erosion from stockpiles. Adequate mitigation measures suggested in this report will help reduce emissions from these sources and ensure compliance with regulatory standards. Once dust deposition is contained, emission of PM_{10} and $PM_{2.5}$ load will also decrease considerably in the environment.

Results of the dispersion modelling exercise have shown what the anticipated implications are on surrounding ambient air quality. As a result, mitigation measures should be implemented to bring both the mine study area and surroundings into compliance with the set standards.

In conclusion, fugitive emissions associated with the operation of the De Groote Boom Mine have potential to impact areas beyond the boundary. The most likely areas of impact from these dust sources would be towards the north westwestern section of the boundary. The client provided background information that was used to populate the dispersion modelling suite, and where the gaps existed, default values from the USEPA AP-42 were applied in the dispersion model. It should be noted that the report reflects the operational phase of the De Groote Boom Mine and modelling was conducted for worst-case scenario.

13 Impact Assessment

13.1 Impact Rating and Assessment

The methodology utilised to assess the potential air quality impacts is discussed in detail below. The significance rating formula is as follows:

Significance = Consequence x Probability

Where

Consequence = Type of Impact x (Intensity + Spatial Scale + Duration)

And

Probability = Likelihood of an Impact Occurring

In addition, the formula for calculating consequence:

Type of Impact *=* ***+1*** *(Positive Impact) or* ***-1*** *(Negative Impact)*

The weight assigned to the various parameters for positive and negative air quality impacts is provided for in the formula and is presented in Table 13-1. The probability consequence matrix for air quality impacts is displayed in Table 13-2, with the impact significance rating described in Table 13-3. The list of activities used for the impact assessment of the proposed De Groote Boom mine operation is given in Table 13-4.

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Table 13-1: Air Quality Impact Assessment Parameter Ratings

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts (Type of Impact = -1)	***Positive Impacts (Type of Impact = +1)***			
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or ecosystem. Persistent severe damage. Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order.	Noticeable, on-going social and environmental benefits which have improved the livelihoods and living standards of the local community in general and the environmental features.	International The effect will occur across international borders.	Permanent: No Mitigation The impact will remain long after the life of the Project.	Certain/ Definite. There are sound scientific reasons to expect that the impact will definitely occur.
6	Significant impact on highly valued species, habitat or ecosystem. Irreparable damage to highly valued items of cultural significance or breakdown of social order.	Great improvement to livelihoods and living standards of a large percentage of population, as well as significant increase in the quality of the receiving environment.	National Will affect the entire country.	Beyond Project Life The impact will remain for some time after the life of a Project.	Almost certain/Highly probable It is most likely that the impact will occur.
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to	On-going and widespread positive benefits to local communities which	Province/ Region Will affect the entire province	Project Life The impact will cease after the operational life span of the	Likely The impact may occur.

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts ***(Type of Impact = -1)***	***Positive Impacts*** ***(Type of Impact = +1)***			
	rehabilitate. Very serious widespread social impacts. Irreparable damage to highly valued items.	improves livelihoods, as well as a positive improvement to the receiving environment.	or region.	Project.	
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense social benefits to some people. Average to intense environmental enhancements.	<u>Municipal Area</u> Will affect the whole municipal area.	<u>Long term</u> 6-15 years.	<u>Probable</u> Has occurred here or elsewhere and could therefore occur.
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some.	<u>Local</u> Extending across the site and to nearby settlements.	<u>Medium term</u> 1-5 years.	<u>Unlikely</u> Has not happened yet but could happen once in the lifetime of the Project, therefore there is a possibility that the impact will occur.

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts ***(Type of Impact = -1)***	***Positive Impacts*** ***(Type of Impact = +1)***			
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by very few of population.	Limited Limited to the site and its immediate surroundings.	Short term Less than 1 year.	Rare/ improbable Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the Project but has happened elsewhere. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures.
1	Limited damage to minimal area of low significance that will have no impact on the environment. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level social and environmental benefits felt by very few of the population.	Very limited Limited to specific isolated parts of the site.	Immediate Less than 1 month.	Highly unlikely/None Expected never to happen.

Table 13-2: Probability Consequence Matrix for Air Quality Impacts

Significance

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

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

Consequence

Table 13-3: Significance Threshold Limits

Score	Description	Rating
109 to 147	A very beneficial impact which 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 important positive impact. The impact is insufficient by itself to justify the implementation of the Project. These impacts will usually result in positive medium to long-term effect on the social and/or natural environment.	Minor (positive)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the social and/or natural environment.	Negligible (positive)
-3 to -35	An acceptable negative impact for which mitigation is desirable but not essential. 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 social and/or natural environment.	Negligible (negative)
-36 to -72	An important negative impact which 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 social and/or natural environment.	Minor (negative)
-73 to -108	A serious negative impact which may prevent the implementation of the Project. These impacts would be considered by society as constituting a major and usually a long-term change to the (natural and/or social) environment and result in severe effects.	Moderate (negative)
-109 to -147	A very serious negative impact which 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.	Major (negative)

Table 13-4: Project Activities

Activity	Description
Construction phase	
1	Augmenting existing roads
2	Construction of pollution control dam (PCD)
3	Transport of construction material, mobile plant and equipment to the site; and movement of haul trucks and excavator on haul roads
4	Storage of material / diesel at site in temporary facilities
5	Site clearing and topsoil removal and construction
6	Preparing an area of approximately 2-3 ha for portable plant and infrastructure (crushing, screening, workshops, ablution and offices etc.) and stock piling
7	Use of existing drilled / new boreholes
Operational phase	
8	Storage of fuel and lubricants in temporary facilities
9	Topsoil removal and stockpiling; and extraction and transportation of materials
10	Vehicular activity on haul roads; and operation of mining equipment
11	Crushing and screening of ore in mobile plant
12	Stockpiling material
13	Water management
14	Waste generation and disposal (including sewage)
Decommissioning phase	
15	Demolition / removal of portable and related infrastructure (if applicable)
16	Vehicular activity: removal of mobile plant / equipment and vehicles
17	Rehabilitation of site (As per surface use agreement roads, buildings etc. need not be rehabilitated)

14 Potential Impacts

14.1 Construction Phase

(Should the impact be positive, please re-word to pre-enhancement and post-enhancement in place of mitigation)

Activity No. 1: Augmenting existing roads	
Criteria	**Details / Discussion**
Description of impact	Road construction involves the removal of rock and earth by explosion or digging during augmentation. Vegetation is removed, grading and paving takes place using a range of road construction equipment. This often leads to the generation of fugitive dust comprising TSP, PM_{10} and $PM_{2.5}$ from the dirt roads. This activity will be short-term, localised, and will have low impacts on the atmospheric environment once the construction phase ceases.
Mitigation required	There is need for the application of wetting agents or dust suppressant on the dirt road to avoid incessant suspension and re-suspension or entrainment of dust. Vehicle travel speed and distances should be minimised. Encourage car-pool and bulk delivery of materials in order to reduce the number of trip on dirt roads.

Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	1	2	(-) 2	7	-35
Post-Mitigation	1	2	(-) 1	6	-24

Activity No. 2: Construction of pollution control dam (PCD)					
Criteria	**Details / Discussion**				
Description of impact	The clearing, scrapping, digging and excavation during the construction of the PCD. The associated activities using construction equipment will result in the generation of fugitive dust comprising TSP, PM_{10} and $PM_{2.5}$. This activity will be short-term, localised, and will have low impacts on the atmospheric environment once the construction ceases.				
Mitigation required	There is need for the application of wetting agents or dust suppressant on the dirt road to avoid incessant suspension and re-suspension or entrainment of dust. Vehicle travel speed and distances should be minimised. Encourage car-pool and bulk delivery of materials in order to reduce the number of trip on dirt roads.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	1	2	(-) 2	7	-35
Post-Mitigation	1	2	(-) 1	6	-24

Activity No. 3: Transport of construction material, mobile plant and equipment to site; and movement of haul trucks and excavator on haul roads.					
Criteria	**Details / Discussion**				
Description of impact	Transportation of the workers, mobile plants and materials, haul trucks and excavators on and off site is quite common to operations of this nature. This often leads to the generation of fugitive dust comprising TSP, PM10 and PM2.5, especially from dirt roads as national and provincial roads are tarred. This activity will be short-term, localised, and will have low impacts on the atmospheric environment once the construction phase comes to an end.				
Mitigation required	There is need for the application of wetting agents or dust suppressant on the dirt road to avoid incessant suspension and re-suspension or entrainment of dust. Vehicle travel speed and distances should be minimised. Encourage car-pool and bulk delivery of materials in order to reduce the number of trip on dirt roads.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	3	(-) 4	7	-70
Post-Mitigation	2	3	(-) 2	6	-42

Activity No. 4: Storage of material / diesel at site in temporary facilities					
Criteria	**Details / Discussion**				
Description of impact	Impact is associated with spills and odours. These hazardous products include fuel for the trucks, explosives used in blasting and waste or sewage management. The scale, types and amount of equipment and machinery used on site have bearing on the waste generated. Impacts include evaporation of diesel fuel and heavy fuel from temporary tanks and possible spills during loading of fuel from tanks on site that are used for re-fuelling of heavy machinery and trucks. Some of the waste produced includes waste oils, chemicals and hazardous substances.				
Mitigation required	There is a need to develop a hazardous products and waste management plan. Hazardous substances should be stored and handled in accordance with the local regulations, with such substances stored in clearly labelled containers. Employees should be well trained on the handling and storing hazardous chemicals alongside dealing with emergency procedures.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	2	3	(-) 3	5	-40
Post-Mitigation	1	2	(-) 2	4	-20

Activity No. 5: Site clearing and topsoil removal and construction	
Criteria	**Details / Discussion**
Description of impact	A number of activities, such as land clearing, topsoil removal, loading of material, stockpiling, bulldozing and compaction. Each of the aforementioned activities has its own duration and potential for dust generation. This phase is often associated with the

	generation of fugitive dust i.e. TSP (total suspended particulate), as well as PM_{10} and $PM_{2.5}$ (dust with a size less than 10 µm, and dust with a size less than 2.5 µm giving rise to health impacts). It is anticipated that the extent of dust emissions would vary substantially from day to day depending on the scale and duration of activity, coupled with the prevailing meteorological conditions. The construction phase will be short-term, and presumed localised, and will have low impact that will stop once the construction activities are finalised.				
Mitigation required	Removal of topsoil must be limited to non-windy days and months in order to ameliorate suspension of loose particulate matter and subsequent exposure to airborne dust. The area of disturbance must be kept to a minimum at all times and no unnecessary clearing of vegetation must occur. The drop heights when loading topsoil into trucks should be minimised. Water or a binding agent can also be used for dust suppression on exposed surfaces and roads. When using bulldozers and graders, there is need to minimise travel speed and distance to reduce dust generation.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	2	(-) 2	7	-49
Post-Mitigation	3	2	2	6	-42

Activity No. 6: Preparing an area of approximately 2-3 ha for portable plant and infrastructure (crushing, screening, workshops, ablution and offices etc.) and stock piling					
Criteria	**Details / Discussion**				
Description of impact	During this phase, it is anticipated there will be construction of infrastructure. This will include crushing, screening, workshops, ablution and offices etc. Excavating, grading levelling and compacting of surfaces will have implications on dust generation.				
Mitigation required	To mitigate the impact of construction activities on atmospheric environment, the following measures should be applied: The area of disturbance must be kept to a minimum and no unnecessary digging or scraping must occur on days with high wind speed (>5.4 m/s). Drop heights should be minimised when loading or dumping soil. Water or a binding agent can be used for dust suppression on roads. When using bulldozers and graders, there is need to minimise travel speed and distance. Studies by Watson et al., 1996 showed that the dust generating capacity of particles less than 10 micro meters is reduced by 58% when speed controls are reduced from 25 mph (40 km/h) to 15 mph (24 km/h).				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	2	(-) 2	7	-49
Post-Mitigation	3	2	2	5	-35

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14.2 Operational Phase

Activity No. 8: Storage of fuel and lubricants in temporary facilities					
Criteria	**Details / Discussion**				
Description of impact	These hazardous products include fuel for the trucks, explosives used in blasting and waste or sewage management. The impacts of the hazardous materials and waste management are related to the types and amount of equipment and machinery used on site. Impacts anticipated include evaporation of diesel fuel and heavy fuel from temporary storage tanks and possible spills on site during re-fuelling of heavy machinery and trucks can lead to a reduction in the quality of air in the immediate vicinity. Damage to containers of bags holding powdery chemicals during material handling can lead to release and subsequent erosion with implication on ambient air quality.				
Mitigation required	Hazardous products and waste management plans must be developed and applied. This will encompass the following: identify anticipated waste streams, inspection and waste minimisation procedures, storage locations, and waste-specific management and disposal requirements. Also, a recycling strategy should be entrenched for workers to apply.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	2	3	(-) 3	5	-40
Post-Mitigation	1	2	(-) 2	4	-20

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Activity No. 9: Topsoil removal and stockpiling; and extraction and transportation of materials.	
Criteria	**Details / Discussion**
Description of impact	In the case of De Groote Boom Mine - the topsoil will be removed and stockpiled. ROM will be hauled by road to the crusher using diesel trucks throughout the life of mine. The latter often leads to dust generation. Travel speed on haul roads must be reduced. The reason being that dust generating capacity of particles less than 10 micro meters is reduced by 58% when speed controls are reduced from 25 mph (40 km/h) to 15 mph (24 km/h) (Watson et al., 1996)
Mitigation required	To mitigate the impacts associated with this activity on atmospheric environment, the travel speed haul roads must be reduced. It is

	confirmed that the dust generating capacity of particles less than 10 micro meters is reduced by 58% when speed controls are reduced from 25 mph (40 km/h) to 15 mph (24 km/h) (Watson et al., 1996).				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	(-) 3	6	-72
Post-Mitigation	3	5	2	4	-40

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Activity No. 10: Vehicular activity on haul roads; and operation of mining equipment					
Criteria	**Details / Discussion**				
Description of impact	Vehicular activity on the proposed haul roads. Mining equipment will be utilised on haul roads to access open pit areas, as well as to transport ore and waste for stockpiling.				
Mitigation required	To mitigate the impacts associated with this activity on atmospheric environment, the travel speed haul roads must be reduced. It is confirmed that the dust generating capacity of particles less than 10 micro meters is reduced by 58% when speed controls are reduced from 25 mph (40 km/h) to 15 mph (24 km/h) (Watson et al., 1996).				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	(-) 3	6	-72
Post-Mitigation	3	3	2	4	-40

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Activity No. 11: Crushing and screening of ore in mobile plant					
Criteria	**Details / Discussion**				
Description of impact	Ore will be hauled from the pit to the mobile crusher for sizing. The crushing and screening process often have implications on ambient air quality. This is particularly so if the crusher is not enclosed or covered, hence subject to wind erosion.				
Mitigation required	To mitigate the impacts associated with this activity on atmospheric environment, the following measures should be applied: there is need to have water sprays at the crusher, and crushing should take place in an enclosed space to reduce contact with wind.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	(-) 3	6	-72
Post-Mitigation	3	5	2	4	-40

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Activity No. 12: Stockpiling material - operation and maintenance of the stockpiles, including waste and ROM stockpiles					
Criteria	**Details / Discussion**				
Description of impact	The stockpiling of material i.e. ore and waste will be an ongoing process during the life of mine. This activity is associated with dust generation and will have implications on ambient air quality of the area until such time when the vegetation cover is fully established.				
Mitigation required	In order to reduce emissions from stockpiles, mitigation measures such as reducing the drop heights and spray are imperative throughout the lifespan of the mine, with ongoing re-vegetation of topsoil stockpile to avoid exposed surface to wind erosion.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	4	4	(-) 5	6	-78
Post-Mitigation	3	4	3	4	-40

Activity No. 14: Waste and sewage generation and disposal. All domestic, industrial and hazardous waste is produced during the mining process. Waste includes cans, plastics, used tyres, sewage and oil which must be disposed of in an appropriate manner by a contractor at a licensed waste disposal site.	
Criteria	**Details / Discussion**
Description of impact	Waste generation peaks during the operational phase as consumption of raw material increases and significant amount of wastes are produced. Hazardous products include fuel, waste oil, chemicals, explosives and waste, sewage, amongst others. This activity also includes evaporation of diesel fuel and heavy fuel from temporary tanks and possible spills during loading and re-fuelling of heavy machinery and trucks. Hazardous storage areas should be kept clear of combustible material and rubbish (e.g. oily rags, oil, grease, carton etc.)
Mitigation required	There is a need to develop a waste management plan. This will identify anticipated liquid and solid waste streams and will ensure thorough inspection and waste minimisation procedures are in place. Optimum material handling and recycling strategy should be

	enforced by management and strict adherence on the part of workers during the operation phase. There is need for the provision of secondary containment for fuel storage. Hazardous substances should be stored and handled in accordance with the local regulations and chemicals must be stored in clearly labelled containers. Employees should be trained on the hazards of handling and storing hazardous chemicals. It is essential to ensure regular training and exercise for the staff on the emergency handling of hazardous waste.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	5	(-) 5	5	-65
Post-Mitigation	3	5	3	4	-44

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14.3 Decommissioning Phase

Activity No. 15: Demolition of infrastructure will take place and includes the PCDs, haul roads, pipelines, fuel bay and mine offices and workshop					
Criteria	**Details / Discussion**				
Description of impact	During this activity, dismantling and demolition of existing infrastructure, transporting and handling of topsoil on unpaved roads in order to bring the site to state suitable for alternative land uses. There is cleaning-up and removal of various infrastructures. Potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure as well as features which will remain. The impacts on the atmospheric environment during the decommissioning phase will be similar to the impacts during the construction phase. Demolition and removal of all infrastructures will cause fugitive dust emissions. Any implication this activity will have on ambient air quality will short-term and localised.				
Mitigation required	In order to mitigate the impacts of demolition and removal of rubbles on the ambient atmosphere, demolition should be done judiciously, especially if it occurs during windy periods (August, September and October) with wind speed ≥ 5.4 m/s. The area of disturbance must be kept to the barest minimum, which would limit the area exposed to wind erosion.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	2	(-) 2	6	-42
Post-Mitigation	3	2	2	5	-35

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Activity No. 16: Vehicular activity: removal of mobile plant / equipment and vehicles					
Criteria	**Details / Discussion**				
Description of impact	Transportation of mobile plants / equipment and other materials from site can lead to the generation of fugitive dust comprising TSP, PM10 and PM2.5. This activity will be short-term, localised, and will have low impacts on the atmospheric environment once the demolition ceases.				
Mitigation required	There is need for the application of wetting agents or dust suppressant on the dirt road to avoid incessant suspension and re-suspension or entrainment of dust. Vehicle travel speed and distances should be minimised. Encourage car-pool and bulk removal of materials in order to reduce the number of trip on dirt roads.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	3	3	(-) 4	7	-70
Post-Mitigation	2	3	(-) 2	6	-42

Activity No. 17: Rehabilitation of site (As per surface use agreement roads, buildings etc. need not be rehabilitated)					
Criteria	**Details / Discussion**				
Description of impact	Re-vegetation of the remaining footprint of the mine must be done after the reclamation. The impacts on the atmospheric environment during rehabilitation will be limited to the vehicular activity, spreading of soil and profiling/contouring. The impact will be medium-term, very limited on spatial scale, with limited implication on ambient air quality. Infrastructures with surface use agreement i.e. roads and buildings will be passed on to other users.				
Mitigation required	It is recommended that the rehabilitation process begin during the operational phase. The objective is to minimise the area exposed to wind erosion. These measures should reduce the potential for fugitive dust generation and render the impacts on ambient air quality negligible.				
Parameters	*Spatial*	*Duration*	*Intensity*	*Probability*	*Significant rating*
Pre-Mitigation	2	3	(-) 2	6	-42
Post-Mitigation	1	2	2	6	-30

15 Summary of Significant Impacts

The impact assessment for the proposed De Groote Boom project took into cognisance the influence exerted by mainly the construction and operational phases of the project. Activities such as ranging from clearing, grading, bulldozing and stockpiling of topsoil, extraction of ore, hauling, storage and handling of materials were considered.

16 Mitigation and Management Measures

The mitigation and management measures discussed are recommended in order to maintain the quality of air in the vicinity of the proposed project and beyond. The ambient air quality of the proposed De Groote Boom mining area will be impacted by fugitive emissions – $PM_{2.5}$, PM_{10} and TSP from the mine operations. *The mitigation and management measures are very similar irrespective of the phase,* a summary of the mitigation and management measures are discussed according to the different phases below:

16.1 Construction Phase

- It is advised that removal of topsoil be done judiciously during windy months, to minimise wind erosion of loose particulate matter.
- The disturbed areas must be kept to a minimum and no unnecessary clearing of vegetation must occur.
- Exposed areas should be re-vegetated to reduce wind erosion.
- During the loading of materials onto trucks or stockpiles, the dropping heights should be minimised.
- Water or other binding agents such as dust-a-side, polymers and adhesives can be used for dust suppression on dirt and haul roads.
- When using bulldozers and graders, there is need to minimise travel speed and distances.
- Reducing speed in haul and dirt roads is an effective way to manage fugitive dust. However reducing speed may lower the production capacity 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). Also, it was reported that decreasing the volume of traffic on the haul roads reduces the impacts of dust entrainment.
- The magnitude of mine 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. Hence, it is suggested that trucks loads are covered with tarps.

- The fugitive dust from haul road reduces visibility. Proper road construction is required to manage the fugitive dust from roads. During windy periods, sprinkling of the area until it is moist is ideal for haul roads and traffic routes (Smolen et al., 1988).
- Wind erosion of stockpiles and open areas is reduced when soils are left as clods which are dense thereby resisting erosion. This is done by alternate wetting and drying of the soils, thus firming the crust on dirt roads. This crust becomes stable and resists erosion. Wind barriers can be created using plants, shrubs and trees. Vegetation can be grown on the edges of the stockpile to reduce erosion, and on top once deposition has stopped. Vegetation prevents high winds from getting in contact with surfaces thereby preventing entrainment of loose particulate matter. Mulching of recently disturbed areas can reduce the amount of wind erosion by 80% (Smolen et al., 1988).

16.2 Operational Phase

- Limit drilling and blasting to non-windy days i.e. avoid unfavourable weather conditions.
- Reducing speed in haul roads is an effective way to manage fugitive dust emissions. 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). Also, it was reported that decreasing the volume of traffic on haul roads also results in the amount of dust airborne.
- Minimize the drop height between loading and dumping of materials.
- Use of chemical dust suppressant, wind breaks and rapid vegetation of exposed areas to curtain wind erosion.

16.3 Decommissioning Phase

- Limit grading and bulldozing to non-windy days i.e. avoid unfavourable weather conditions (windy days).
- When using bulldozers, graders, there is need to minimise travel speed.
- It is recommended that the rehabilitated landscape be vegetated and it should begin during the operational phase of the mine. These measures should reduce the potential for fugitive dust generation and render the impacts negligible.
- Use of chemical dust suppressant, wind breaks and rapid vegetation of exposed areas.

NOTE:

Mitigation efficiencies for wind erosion as prescribed by the Australian NPI Emission Estimation Technique Manual for Mining Version 3.1 is reported (Table 16-1) is presented below. The table shows the level of efficiency for the different mitigation methods applied.

Table 16-1: Mitigation efficiencies for wind erosion (After Australian NPI Emission Estimation Technique)

Description	Mitigation efficiency (%)
Wind erosion from stockpiles	50% for water sprays. 30% for wind breaks. 99% for total enclosure. 30% for primary earthworks (reshaping/profiling, drainage structures installed). 30% for rock armour and/or topsoil applied.
Wind erosion	30% for primary rehabilitation 40% for vegetation established, but not demonstrated to be self-sustaining. Weed control and grazing control. 60% for secondary rehabilitation. 90% for re-vegetation. 100% for fully rehabilitated (release) vegetation.

17 Recommendations

Based on the results presented in this report, the following recommendations should be applied during the course of the mining at De Groote Boom project:

- During dry conditions, wind erosion of exposed areas can exacerbated ambient concentrations of particulate matter – TSP, PM_{10} and $PM_{2.5}$. It is recommended that dust monitoring in the area be revived, as records obtained will aid management decision making process in ameliorating potential impacts. Specific management practices, operational controls and mitigation measures should be implemented to minimise dust and air quality impacts anticipated from the proposed De Groote Boom project.
- It is anticipated that the dust impacts during the proposed De Groote Boom project will intensify during the operational phase, but by adopting practical mitigation measures i.e. use of water to dampen dust generating areas such as stockpile, haul roads or exposed soil, housing of crushers, and screens, use of chemical dust suppressant, wind breaks and rapid vegetation and/or re-vegetation of exposed areas, impacts can be contained to within compliance.
- Good housekeeping practice to minimise the accumulation of loose dust piles.
- It is recommended that particulate monitoring of ambient PM_{10} and $PM_{2.5}$ be initiated alongside the dust deposition network.

- Ensure that adopted air quality management practices are sufficient to achieve current and future air quality standards at the closest receptors for the duration of the project.
- Strict control and reporting procedures should be implemented.

17.1 Monitoring

17.1.1 Dust Monitoring Programme

The monitoring of dust deposition rates will commence towards the end of May 2015. It is advised that such monitoring be continued during the project life in order to establish historical repository of data needed to fully understand/address fugitive and airborne dust emissions from the proposed operation of De Groote Boom Mine. If sources of fugitive dust are managed effectively, there will be overall reduction in exposure concentrations, associated ailments, reduced risk of damage to property, improved visibility, and fewer disturbances to existing flora and fauna habitats.

17.1.2 PM_{10} Monitoring Programme

De Groote Boom management should consider setting up PM_{10} monitoring site(s) in the area, to collect data for future assessment of ambient air quality, which will be useful should the mine come under scrutiny from regulatory agencies (proactive approach). Monitoring sites should be selected judiciously, and calibration of monitoring instruments should be conducted once a year to ensure the integrity of the measured data.

17.1.3 Gaseous Monitoring Programme

It is recommended that the management of De Groote Boom conduct monitoring of relevant gases i.e. sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and volatile organic compounds (VOCs) in the vicinity of the proposed operation at least seasonally. Other gases such as CO, CO_2 and O_3 can be included in the suite of pollutants sampled in the area.

18 Conclusion

The findings reported here are mixtures of modelled data and predicted results, provided the background and predicted concentration of identified pollutants likely to be emitted from the operation of the De Groote Boom Mine.

Real-time measurements of PM_{10} and $PM_{2.5}$ are not available. Also, ambient measurement of gaseous pollutants was not available for assessment. If the recommendations are implemented, holistic assessment of particulate and gaseous pollutants in the vicinity of the proposed De Groote Boom will be available for future assessment of the ambient air quality of the area. Implementation of the above recommendation will confirm the commitment of mine management in terms of ameliorate potential impacts and ensure compliance with regulatory requirements.

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Appendix A: CV of Air Quality Specialist

MATTHEW OJELEDE

Unit Manager: Atmospheric Sciences

Division Natural Sciences

Digby Wells Environmental

EDUCATION

BSc (Hons) Geology (University of Benin, Edo State, Nigeria)
MSc Environmental Science (WITS) with course work:

- Environmental Chemistry
- Environmental Management
- Air Quality –Physics and Chemistry of the Urban Atmosphere
- Global Environmental Change: Adaptation and Mitigation
- Geographic Information System
- Mining and the Environment

PhD Environmental Management (UJ)

COURSES

Basic Fire Fighting – Accreditation number: HW591PA0808095

UJ - CALPUFF Advanced techniques in Dispersion Modelling
October 2010

UJ – AERMOD Air Dispersion Modelling
March 2014

Computer Foundation – Advanced GIS Course
May 2011

PROFESSIONAL AFFILIATIONS

National Association for Clean Air (NACA)

South African Society for Atmospheric Sciences (SASAS)

Geo Information Society of South Africa (GISSA)

International Association of Impact Assessment South Africa (IAIAsa)

EMPLOYMENT

June 2012 – September 2012	University of Johannesburg (Researcher)
October 2012 to present	Digby Wells Environmental

EXPERIENCE

- Air dispersion modelling.
- Air quality impact assessments.
- Air quality management plans.

- Preparation of tender proposals, quotes and technical documents.
- Assisting with project management.
- Processing meteorological data.
- Compiling emissions inventories.
- Air quality information unit operational activities: development, implementation, maintenance and support.

Appendix B: Specialist Declaration of Independence

SPECIALIST DECLARATION OF INDEPENDENCE

I,____Matthew Ojelede___________, declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the project;
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2006;
- Do not have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity; and
- Undertake to disclose, to the competent authority, any information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Impact Assessment Regulations, 2006.

___Matthew Ojelede__

Name of the specialist

Signature of the specialist

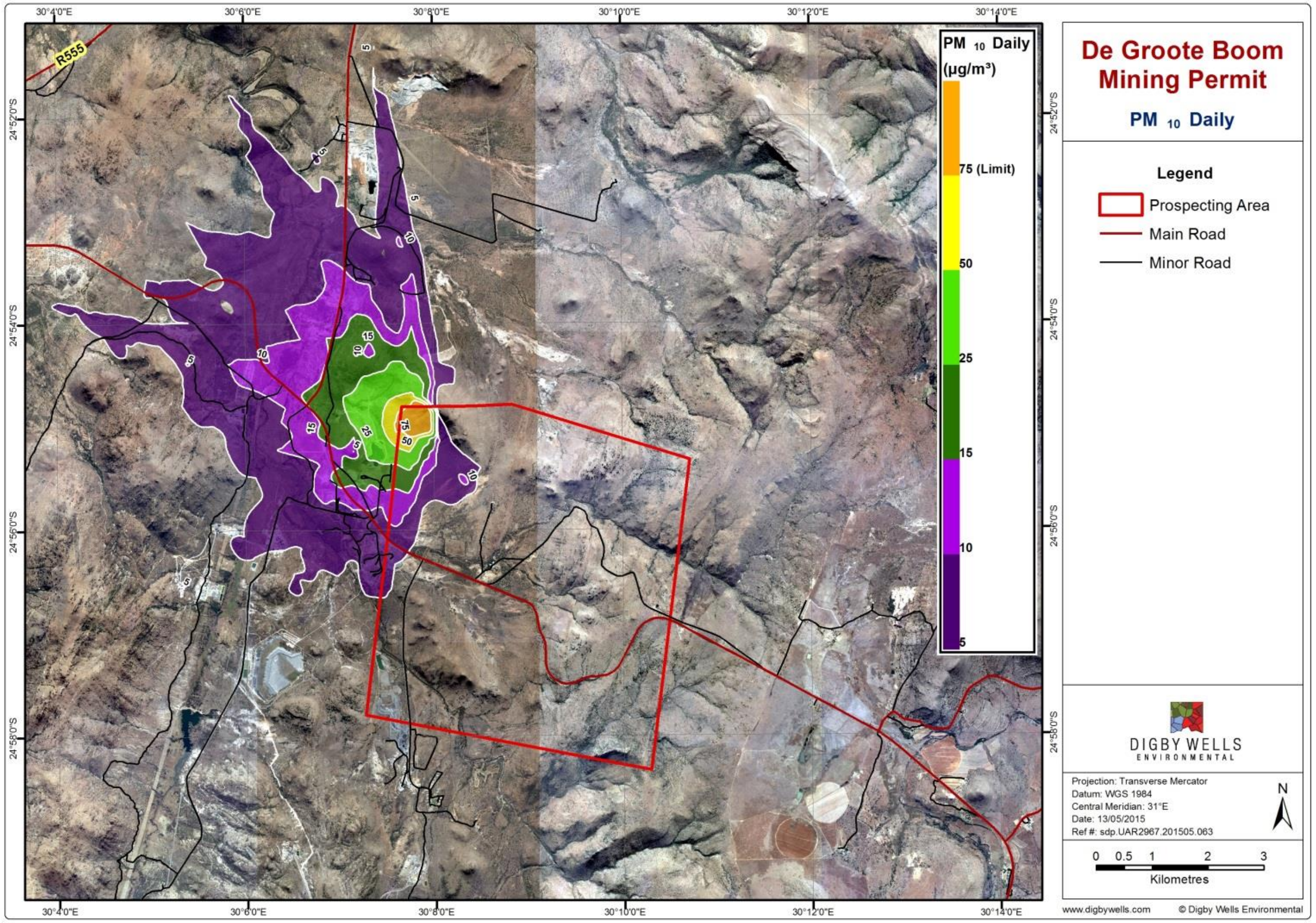
Digby Wells Environmental

Name of company

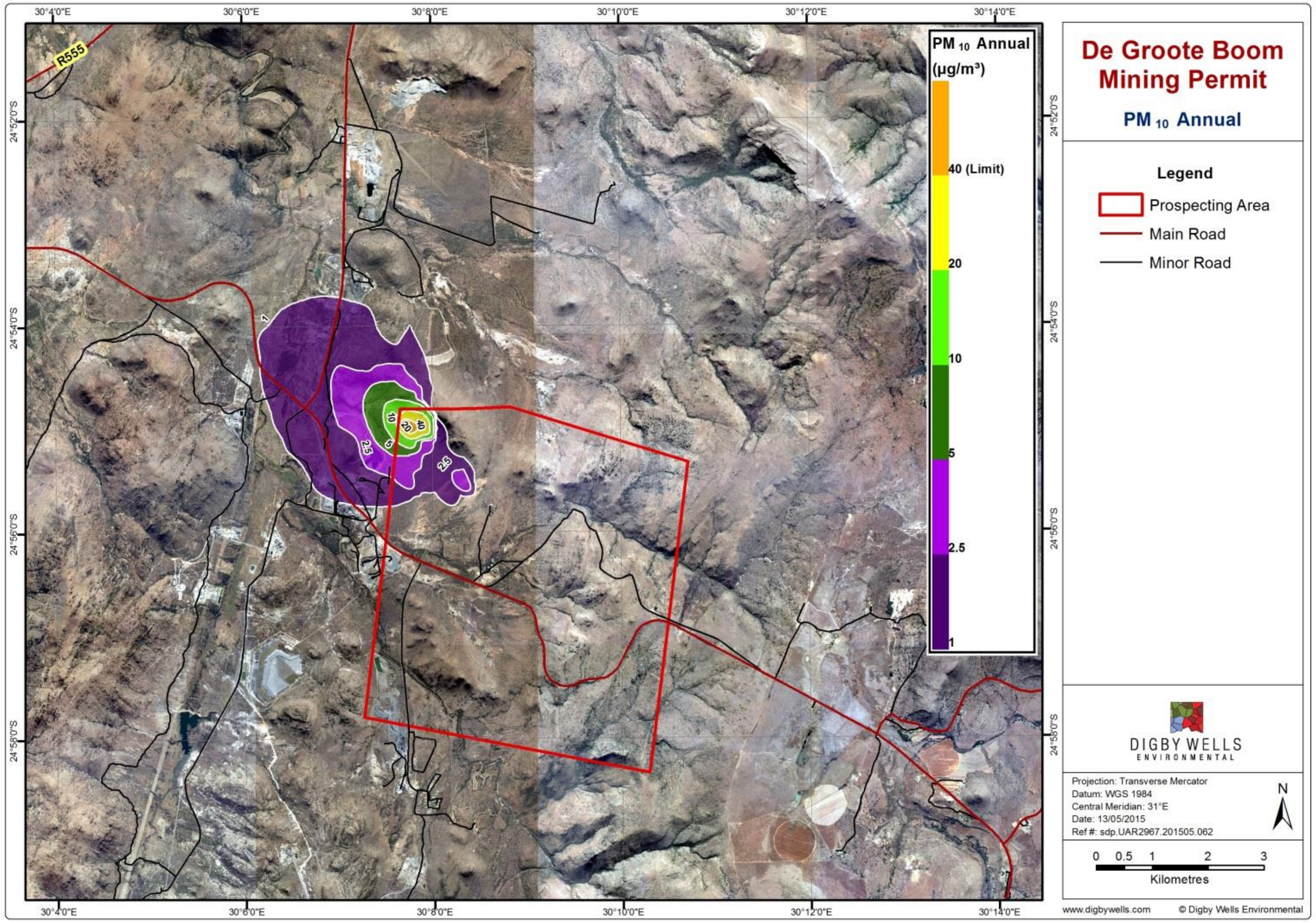
13/05/2015

Date

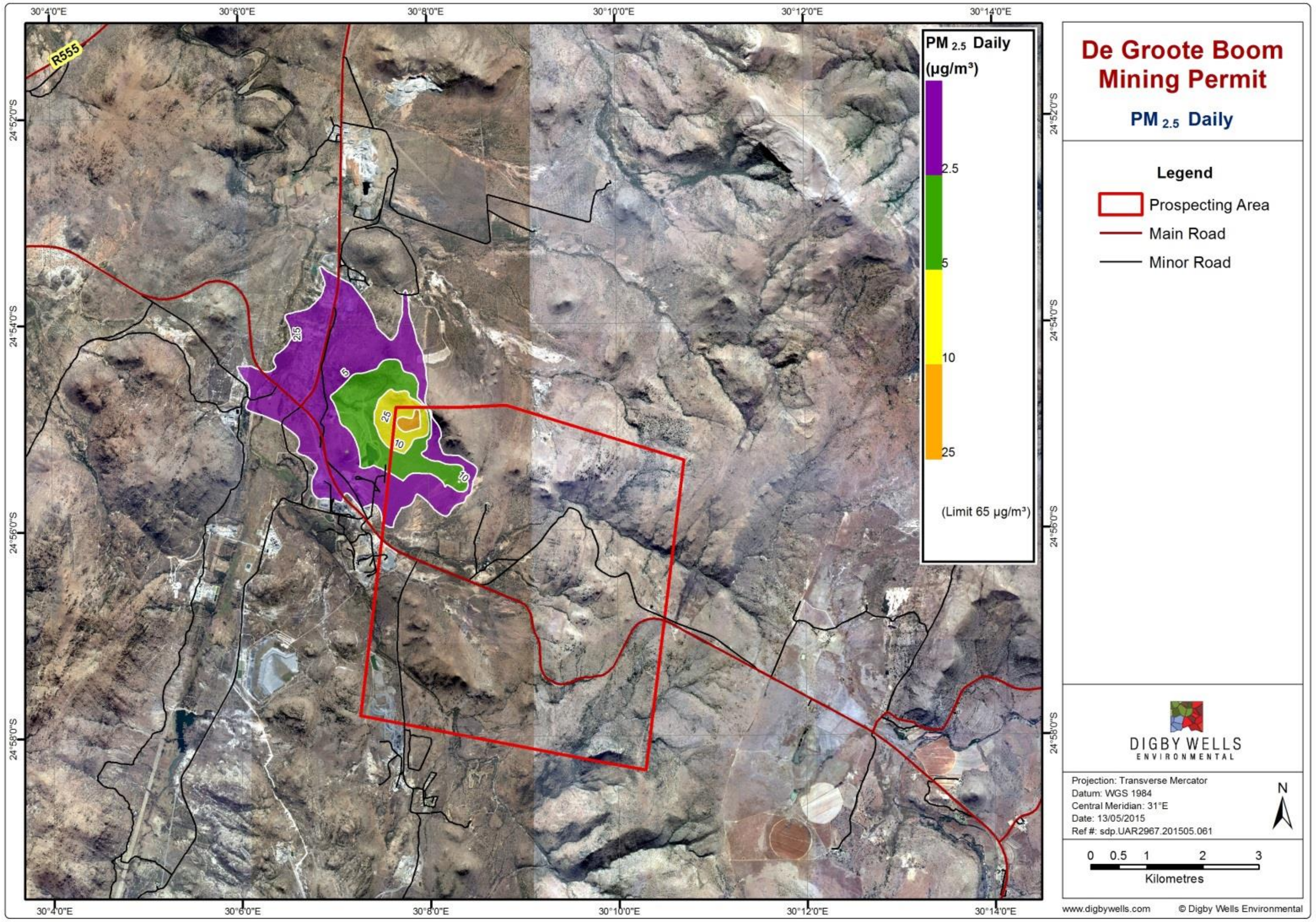
Appendix C: Predicted 4th highest (99th percentile) daily PM_{10} concentrations (µg/m³)



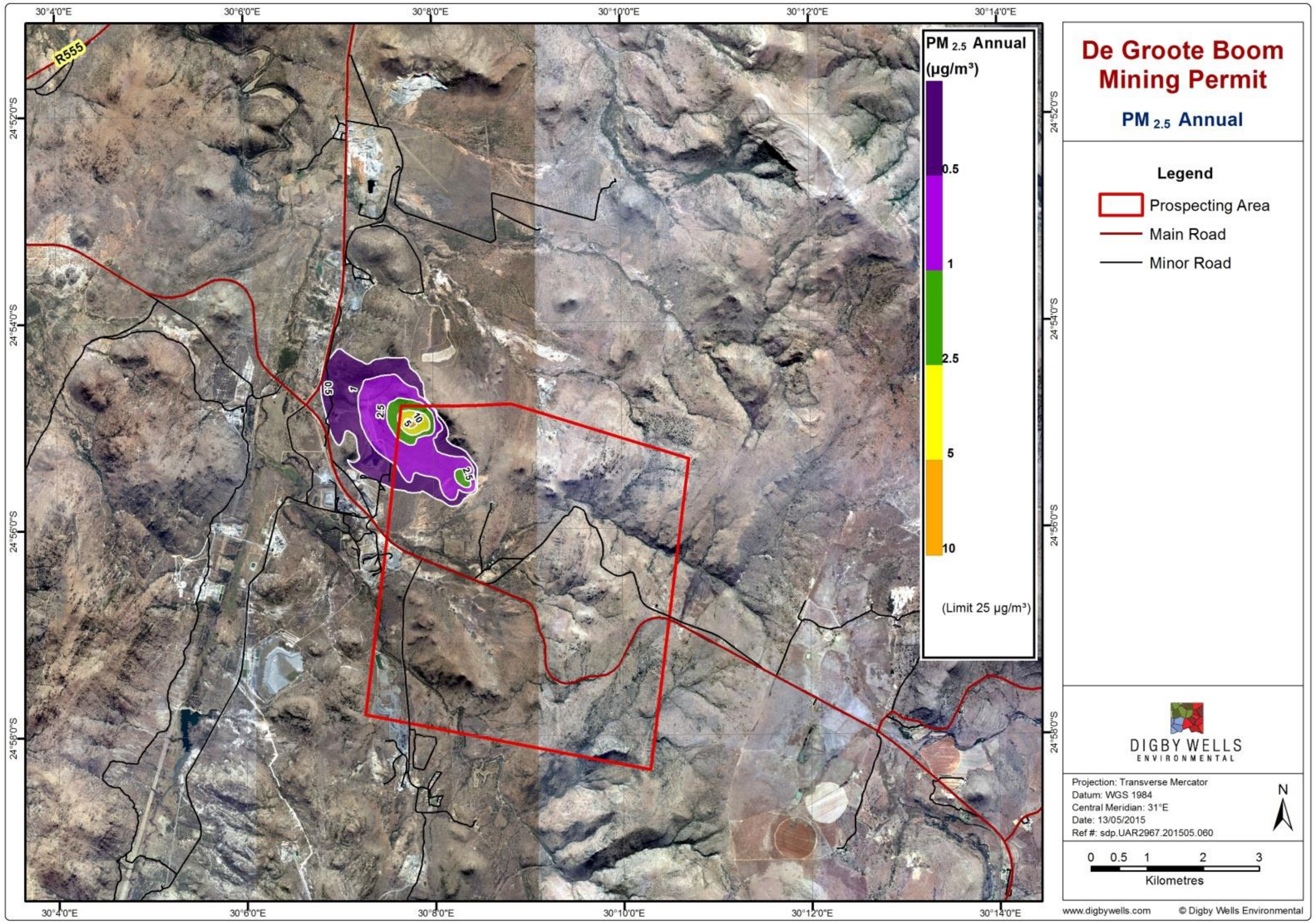
Appendix D: Predicted 1st highest (100th percentile) daily PM_{10} concentrations ($\mu g/m^3$)



Appendix E: Predicted 4th highest (99th percentile) daily $PM_{2.5}$ concentrations ($\mu g/m^3$)



Appendix F: Predicted 1st highest (100th percentile) annual $PM_{2.5}$ concentrations ($\mu g/m^3$)



Appendix G: Predicted maximum (100th percentile) dust deposition (mg/m²/day)