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Tshipi Borwa Manganese Mine Environmental Management Plan Amendment 2: Air Quality Specialist Study

Project done on behalf of **SLR Consulting (Africa)(Pty) Ltd**

Project Compiled by
H Liebenberg-Enslin

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Report Details

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Prepared by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
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Draft Rev 0	29 May 2018	Draft for client review
Final Rev 1	4 June 2018	Final report
Final Rev 2	15 June 2018	Final accounting for additional information

Competency Profiles

Report author: H Liebenberg-Enslin (PhD Geography (University of Johannesburg)

Hanlie Liebenberg-Enslin started her professional career in Air Quality Management in 2000 when she joined Environmental Management Services (EMS) after completing her Master's Degree at the University of Johannesburg (then RAU) in the same field. She is one of the founding members of Airshed Planning Professionals in 2003 where she has worked as a company Director until she took over as Managing Director in May 2013.

She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Hanlie was the project manager on a number of ground breaking air quality management plan (AQMP) projects between 2008 and 2013 and the principal air quality specialist on regional environmental assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality.

Hanlie is also actively involved in the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) and the National Association for Clean Air (NACA) and has lectured in several Air Quality Management Courses. Being an avid student, she received her PhD from the University of Johannesburg in June 2014, specialising in Aeolian dust transport.

The CV of Hanlie Liebenberg-Enslin is provided in Appendix A.

Abbreviations

AEL	Atmospheric Emissions License
Airshed	Airshed Planning Professionals (Pty) Ltd
Australian EPA	Australian Environmental Protection Agency
AQA	Air Quality Act
DPM	Diesel Particulate Matter
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
EMPR	Environmental Management Program Report
GHG	Greenhouse Gas
Ha	hectare
kV	kilovolt
MES	Minimum Emission Standards
M	metre
m^2	Metre squared
m/s	Metre per second
$mg/m^2.day$	Milligram per metre squared per day
NAAQS	National Ambient Air Quality Standards
NAEIS	National Atmospheric Emissions Inventory System
NAERR	National Atmospheric Emission Reporting Regulations
NDCR	National Dust Control Regulations
NPI	National Pollutant Inventory (Australia)
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10µ
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5µ
PPP	Pollution Prevention Plans
SAAQIS	South African Air Quality Information System
SANS	South African National Standards
Tpa	tonnes per annum
Tpd	tonnes per day
TSP	Total Suspended Particles
US-EPA	United States Environmental Protection Agency
WHO	World Health Organisation
WRD	Waste Rock Dump
°C	Degrees Celsius
$\mu g/m^3$	Microgram per cubic metre

Executive Summary

Airshed Planning Professionals (Pty) Ltd was appointed by SLR Consulting (Africa) (Pty) Ltd to qualitatively assess the potential for air quality related impacts on the surrounding environment and human health from the proposed changes in the mine infrastructure. This will be used in the amendment of the approved Environmental Impact Assessment (EIA) and Environmental Management Programme Report (EMPR).

Tshipi Borwa Manganese Mine, located near Hotazel in the Northern Cape, commenced with mine infrastructure in 2012. Mining operations include open pit mining methods (drilling, blasting and excavation of ore and waste rock), with haul roads linking the pit with the surrounding waste rock dumps (WRDs) and processing plant. Ore is hauled from the open pit and tipped at the run-of-mine (ROM) stockpile from where it is send to the primary crusher, and to the secondary crushing and screening plant. Waste rock is hauled from the pit to three existing WRDs – Northern-; Western- and Eastern WRDs. Other infrastructure, amongst others, includes a train load-out facility, a private siding, topsoil stockpiles, product stockpiles, railway line, buildings, etc. Changes to the existing infrastructure layout is needed to address new requirements from the mining operations. Proposed changes to the existing mine layout include:

- Extending the East WRD in a south-easterly direction to join with the Mamatwan WRD and essentially fill the narrow void between these two WRDs;
- Extending the West WRD in a south-westerly direction onto Portion 8 of the farm Mamatwan 331, to provide additional storage capacity for waste rock.
- Accessing the Eskom grid-power by constructing an 11 kV overhead powerline and sub-station along the boundary of Portion 8 onto the existing mining right area and connect this new line into the main distribution centre; and
- Constructing an overland conveyor system from the existing crushing and screening plant to the existing manganese product stockpiles.

The prevailing wind field at the mine is from the south-south-east and south with most of strong winds from the west. Frequent winds also occur from the north. During the day winds are more frequent from the westerly and the northerly sectors, with the strongest winds directly from the west. The wind shifts during the night to south-south-easterly and southerly winds.

Dustfall collected at five locations at and around the mine over a period of 16 months indicate high dust fallout levels, exceeding the National Dust Control Regulation (NDCR) limit for non-residential areas of 1 200 mg/m²/day regularly. Ambient PM_{10} concentrations regularly exceeded the National Ambient Air Quality 24-hour limit of 75 µg/m³, indicating the likelihood of non-compliance with the NAAQS.

The air quality impact assessment conducted in 2009 for the then proposed Ntsimbintle Mine (now Tshipi Borwa) assessed the potential health and nuisance impacts from PM_{10}, manganese (Mn), SO_2, NOx, Diesel Particulate Matter (DPM) and CO due to the mining operations based on the then approved infrastructure layout. Vehicle entrained dust from unpaved roads were the main source of PM_{10} concentrations with crushing and screening contributing most significantly to manganese ground level concentrations. Gaseous emissions were most likely to result from the Sinter Plant, which has not been established yet.

The main findings from the **qualitative assessment** of the proposed changes to the Tshipi Borwa Manganese Mine infrastructure are as follow:

- The draft NAAQSs and MES used in the 2009 air quality study, conducted before these limits and standards were finalised, are the same as the NAAQSs (published December 2009, and July 2012) and the MES (published April 2010, and revised November 2013).
- The mine would have to report annually, before 31 March, on NAEIS on both the Sinter Plant (although this plant has not yet been established) and the mining operation emissions. If stationary equipment at the mine have a combined capacity of more than 10 MW(th), all stationary combustion emissions must be reported annually on NAEIS.
- AQSRs most likely to be impacted on by the changes to the infrastructure are N Fourie (to the south) and D van den Berg (to the west) of the West WRD extension, and to a lesser extent A Pyper to the north-west of the West WRD extension.
- The following changes to the mine infrastructure are likely to result in increased PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates mainly due to the increase of fugitive dust sources. The proposed changes are likely to have an insignificant impact on gaseous emissions and ground level concentrations.

  Construction:

  - Construction of West WRD extension due to land clearing (dozing and scraping activities) of the 142 ha, loading and off-loading of topsoil and trucks on freshly graded access roads, and to a lesser extent the possibility for windblown dust from the cleared areas and topsoil piles. Construction of cells in the WRD extension, and construction activities limited to day-time hours, will reduce the potential for particulate matter impacts significantly.
  - Construction of the East WRD extension will have similar dust generating sources but will result in much lower impacts, likely limited to the mining right area, due to the smaller footprint (5 ha) and the fact that is shielded on both the western and eastern sides by existing WRDs.
  - Construction of the proposed overland conveyor is likely to have an insignificant impact on air quality since the areas to be cleared are small.
  - Similarly, the construction of the Eskom 11 kV overhead powerline and sub-station along the boundary of Portion 8 is likely to have an insignificant impact on air quality since the areas to be cleared are small.

  Operational:

  - During the operational phase, fugitive dust generation from the West WRD would mainly be due to the hauling of waste rock over longer distances than what is currently the case. The way the waste rock may be tipped at the crest of the WRD may result in higher ground level PM_{10} and $PM_{2.5}$ concentrations and dustfall rates at the nearby AQSRs, especially during stable night-time conditions. The potential for windblown dust from the WRDs and topsoil piles are limited due to the infrequent occurrence of high wind speeds. With mitigation measures, such as shorter hauling distances, water sprays or chemical suppressant on the haul roads and not tipping at the crest of the WRD the impacts should reduce significantly.
  - Operations at the East WRD extension are unlikely to have limited off-site impacts due to the smaller footprint, the shielding by existing WRDs on the eastern and western sides, and the shorter duration. Similar mitigation measures as for West WRD would reduce the potential for impacts.
  - Fugitive emission from the overland conveyor system would mainly be from windblown dust from an open conveyor and re-entrainment from spilled material. Impacts would most likely be localised, within the mining right area, and to the east of the overland conveyor. The conveyor transfer points could also be sources of dust generation if not controlled.

Cumulative:

The addition of the new West WRD is likely to result in increased PM_{10} and $PM_{2.5}$ ground level concentrations and dustdall levels at the nearby AQSRs of D van den Berg and N Fourie. This is mainly due to the longer haul distances and the location of the West WRD closer to these receptors. The East WRD is unlikely to result in increased cumulative dust emissions and off-site impacts. It is also expected that the overland conveyor would not result in increased dust generation and that the impacts would be localised and within the surface use area. With no mitigation in place these increases, especially from the West WRD, could be significant but with mitigation measures in place these impacts are likely to have a low significance.

In conclusion, there is a potential for increased PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates off-site and at nearby AQSRs from the construction and operation of the West WRD extension. With mitigation measures in place these impacts should be limited and localised resulting in a low significance. Increased impacts from the East WRD extension and the overland conveyor are likely to be insignificant. No increases in SO_2, NO_2, Mn and CO are foreseen. DPM concentrations might increase due to the increased truck activity but it is unlikely to exceed the guideline.

Recommendations

- A comprehensive dust management plan is required for the mine with specific mitigation measures, the frequency of application and the responsible divisions and persons indicated. This should follow on the dust management measures recommended the 2009 air quality report as well as the mitigation measures recommended in this report.
- The dustfall network as is currently in place should be continued, with three additional dust buckets proposed to be located at N Fourie, D van den Berg and A Pyper before any changes or additions to the mine infrastructure are allowed. It is further recommended that the proposed dust fallout should follow the ASTM D1739 (1970) method as required by the NDCR, on the dustfall unit design, the dust collection and analysis. Dustfall results should be reported annually to the District Municipality Air Quality officer. It is further recommended that these two locations, D van den Berg and A Pyper, be added to the PM_{10} monitoring campaigns.

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1 INTRODUCTION

Tshipi Borwa Manganese Mine, located near Hotazel in the Northern Cape, commenced with mine infrastructure in 2012. Mining operations include open pit mining methods (drilling, blasting and excavation of ore and waste rock), with haul roads linking the pit with the surrounding waste rock dumps (WRDs) and processing plant. Ore is hauled from the open pit and tipped at the run-of-mine (ROM) stockpile from where it is send to the primary crusher, and to the secondary crushing and screening plant. Waste rock is hauled from the pit to three existing WRDs – Northern-; Western- and Eastern WRDs. Other infrastructure, amongst others, includes a train load-out facility, a private siding, topsoil stockpiles, product stockpiles, railway line, buildings, etc. Changes to the existing infrastructure layout is needed to address new requirements from the mining operations. Proposed changes to the existing mine layout include:

- Extending the East WRD in a south-easterly direction to join with the Mamatwan WRD and essentially fill the narrow void between these two WRDs;
- Extending the West WRD in a south-westerly direction onto the remaining extent of Portion 8 of the farm Mamatwan 331, to provide additional storage capacity for waste rock.
- Accessing the Eskom grid-power by constructing an 11 kV overhead powerline and sub-station along the boundary of Portion 8 onto the existing mining right area and connect this new line into the main distribution centre; and
- Constructing an overland conveyor system from the existing crushing and screening plant to the existing manganese product stockpiles.

Airshed Planning Professionals (Pty) Ltd was appointed by SLR Consulting (Africa) (Pty) Ltd to qualitatively assess the potential for air quality related impacts on the surrounding environment and human health from the proposed changes in the mine infrastructure. This will be used to amend the approved Environmental Impact Assessment (EIA) and Environmental Management Programme Report (EMPR).

1.1 Terms of Reference

The scope of work includes:

- Review and collation of available information;
- Review of relevant legal requirements;
- Desktop study of the receiving environment;
- Qualitative discussion of likely sources of emissions, potential changes to the existing emissions inventory and dispersion model results completed for the EMP1, and likely changes in air quality impact area;
- Qualitative human health risk and nuisance impact screening assessment; and
- Compile a specialist opinion report including management and mitigation measures.

1.2 Brief process description

Tshipi Manganese Mine includes opencast mining, a processing plant, a diesel generator plant, as well as various support infrastructure and services. Underground mining is also being considered for future mining development. A sinter plant has been approved in the mine's approved EMP but is yet to be established.

The proposed changes in the mine infrastructure are listed in Table 1 indicating activities likely to give rise to air pollutants. The approved mine layout plan is provided in Figure 1 with the proposed mine layout plan shown in Figure 2.

Table 1: Proposed infrastructure changes with associated air pollution activities and expected pollutants

Proposed changes to Infrastructure	Main activities			Potential air pollutants
	Construction Phase	Operational Phase	Decommissioning and Closure	
Extending the **East WRD** in a south-easterly direction to join with the Mamatwan WRD and essentially fill the narrow void between these two WRDs	Land clearing (5 ha) Dozing and scraping Loading and off-loading of topsoil Windblown dust from topsoil piles	Windblown dust from WRD and topsoil piles Off-loading (tipping) of waste rock Truck activity on access road between open pit and WRD Truck activity on waste rock dump	Windblown dust if not rehabilitated Truck activity during rehabilitation Tipping of topsoil and levelling of side slopes No air pollution related impacts after rehabilitation	Particulates (TSP, PM_{10}, $PM_{2.5}$) Gaseous emissions
Extending the **West WRD** in a south-westerly direction onto the remaining extent of Portion 8 of the farm Mamatwan 331	Land clearing (128 ha) Dozing and scraping Construction of new access points and haul roads Loading and off-loading of topsoil Phased construction of cells in WRD extensions Windblown dust from topsoil piles	Windblown dust from WRD and topsoil piles Off-loading (tipping) of waste rock Phased construction of cells in WRD extensions Truck activity on haul road between open pit and WRD Truck activity on waste rock dumps	Windblown dust if not rehabilitated Truck activity during final rehabilitation Tipping of topsoil and levelling of side slopes Removal of ramps and roads No air pollution related impacts after rehabilitation	Particulates (TSP, PM_{10}, $PM_{2.5}$) Gaseous emissions
Accessing the Eskom grid-power by constructing an 11 kV overhead powerline and sub-station along the boundary of Portion 8	Construction of service gravel roads	Operation and maintenance of service gravel roads	Removal of service roads No air pollution related impacts after rehabilitation	Particulates (TSP, PM_{10}, $PM_{2.5}$) (minor) Gaseous emissions (minor)
Constructing an overland conveyor system from the existing crushing and screening plant to the existing manganese product stockpiles	Land clearing Dozing and scraping Loading and off-loading of topsoil	Windblown dust from conveyor Conveyor transfer points	Removal of conveyor No air pollution related impacts after rehabilitation	Particulates (TSP, PM_{10}, $PM_{2.5}$) Gaseous emissions (minor)

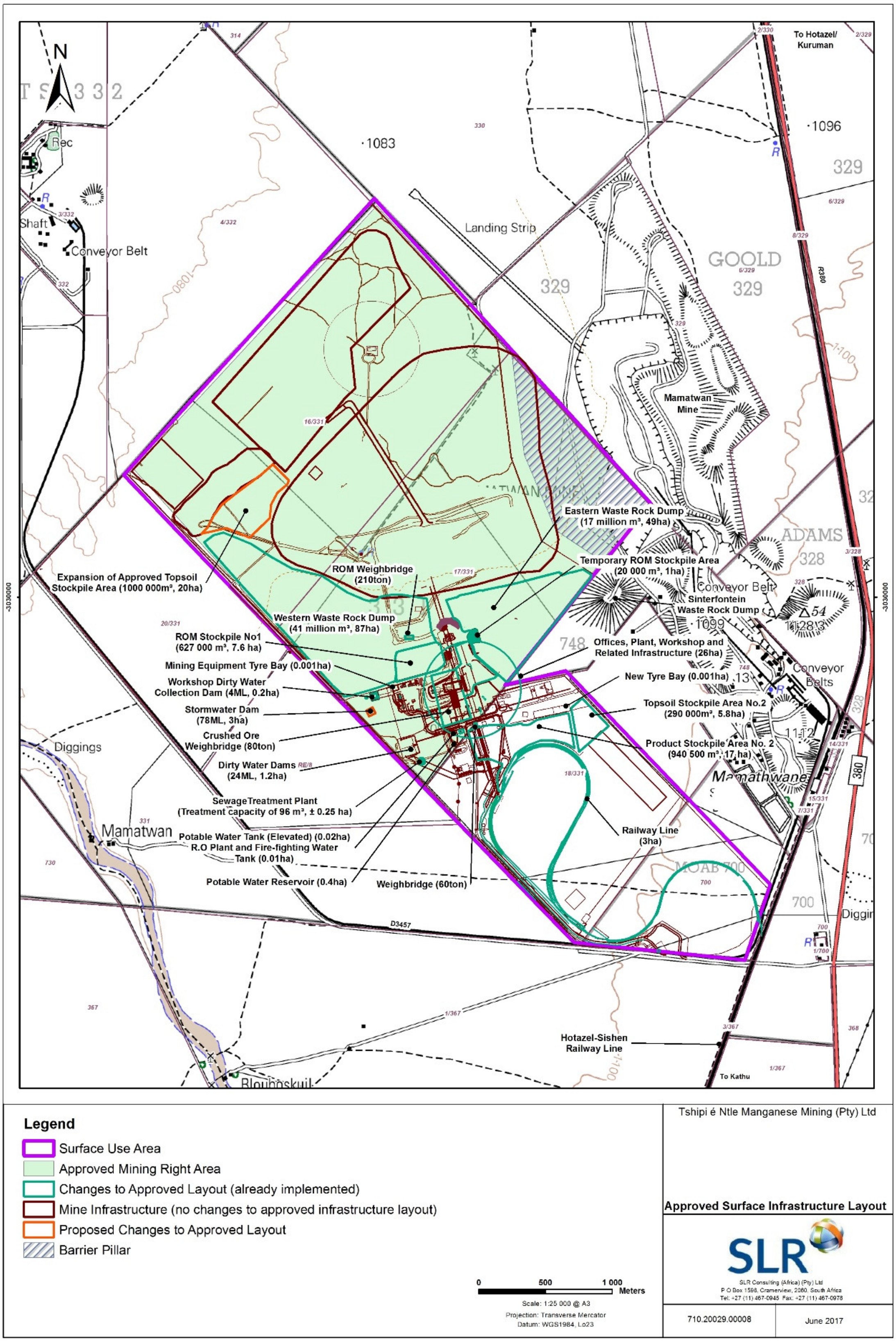

Figure 1: Approved Tshipi Borwa Mine Infrastructure Layout (SLR, 2017)

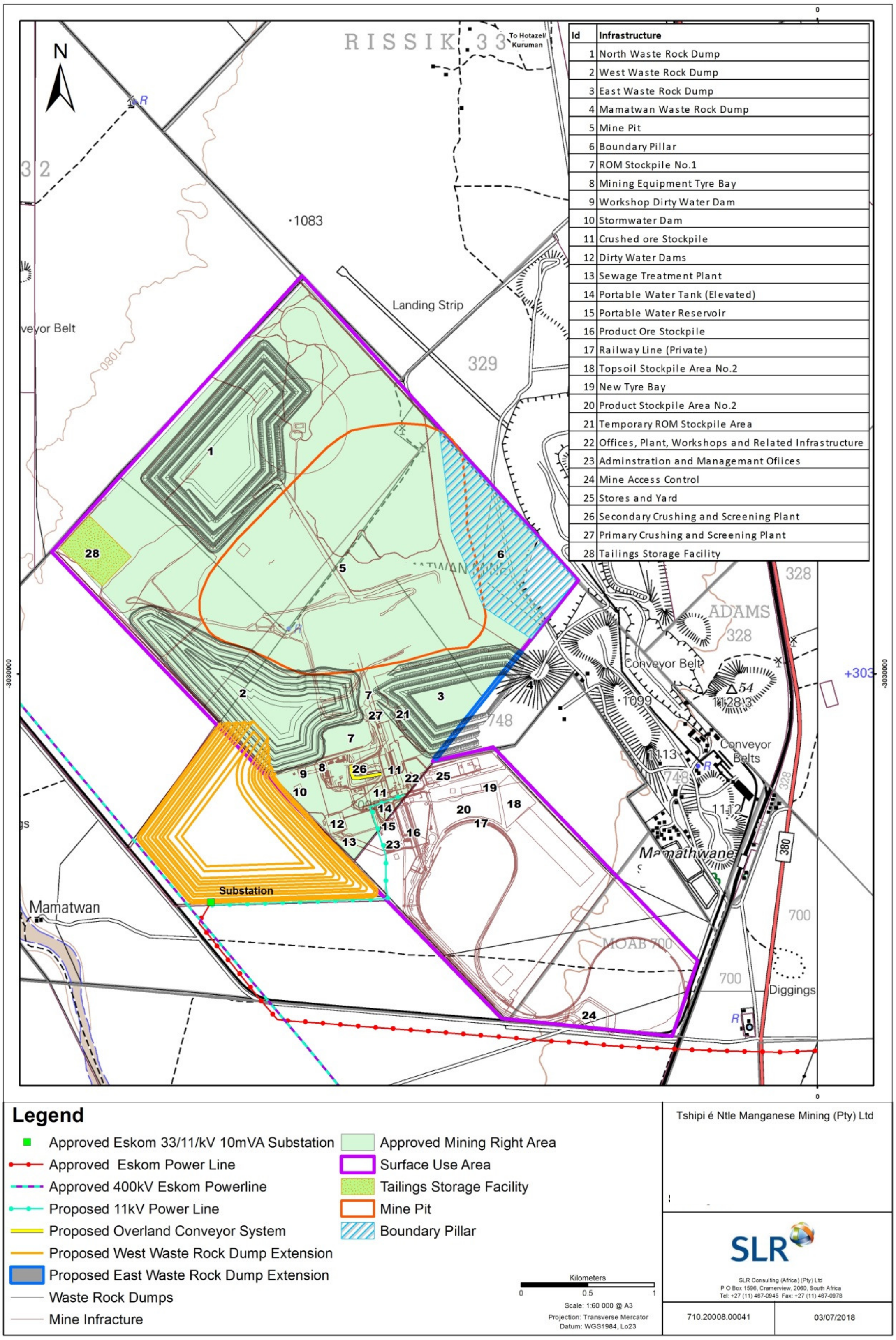

Figure 2: Proposed Tshipi Borwa Mine Infrastructure Layout

1.3 Assumptions and Limitations

The study followed a qualitative approach, with no emissions quantified for the proposed changes or additions to the mine infrastructure layout plan.

The following was assumed:

- The mining rate would remain the same; and
- The modelled impacts from the 2009 study were used to qualitatively assess the potential for any increases in ground level concentrations.

2 LEGAL REVIEW

The Air Quality Impact Assessment as part of the EIA conducted for the Ntsimbintle Manganese Mining Operations (Tshipi Borwa Manganese Mine) was done in April 2009. Subsequently, there have been additions and changes to the National Environmental Management: Air Quality Act (Act no.39 of 2004). The Act commenced with on 11 September 2005 as published in the Government Gazette on 9 September 2005 with sections omitted from the implementation (Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3), 60 and 61). The Act was fully implemented on 1 April 2010, including Section 21 on the Listed Activities and Minimum National Emission Standards (MES) with the revised MES published on 22 November 2013 (Government Gazette 37054, Notice No. 893). Amendments to the Act, primarily pertaining to administrative aspects, were published in 2014 (Government Gazette 37666, Notice No. 390 on 14 May 2014).

Air quality legislation that came into play after April 2009 that is relevant to the project is provided in Table 2.

Table 2: Legislation applicable to the project

Air Quality Legislation	Implementation/ revision dates	Reference	Affected Project Activity
National Framework	updated Dec 2012	Government Gazette 37078, 29 Nov 2013	Industry legal responsibilities
Section 21 – Listed Activities	Implemented: 1 April 2010 Revised: 2013 Amendments: 2015	Government Gazette 37054, 22 Nov 2013 Government Gazette 38863, 12 Jun 2015	Sinter Plant (still to be established)
National Ambient Air Quality Standards (NAAQS)	24 December 2009 29 July 2012	Government Gazette 32816, 24 Dec 2009 Government Gazette 35463, 29 Jun 2012	PM_{10} and $PM_{2.5}$ ground level concentrations as a result from the mining activities
National Dust Control Regulations (NDCR)	1 November 2013	Government Gazette 37054, 22 Nov 2013	Dust fallout rates as a result from the mining activities
National Atmospheric Emission Reporting Regulations (NAERR)	2 April 2015	Government Gazette 3863, 2 Apr 2015	Emissions reporting on mining operations Emissions reporting on Listed Activity (Sinter Plant to be established)
Regulation on Administrative Fines and Air quality offsets guideline	18 March 2016	Government Gazette 39833, 18 Mar 2016	Sinter Plant to be established will require an AEL
Declare Greenhouse Gas (GHG) as priority pollutants	Draft in 2016	Government Gazette 40996, 21 Jul 2017	N.A. [(a)]
National Pollution Prevention Plans (PPP) regulations	Draft in 2016	Government Gazette 40996, 21 July 2017	N.A.[(a)]
National Greenhouse Gas (GHG) Emission Reporting Regulations	3 April 2017	Government Gazette 40762, 3 April 2017	Mining and quarrying to report on all stationary combustion emissions above 10 MW(th)

Notes: (a) only apply to direct emission of GHG in excess of 0.1 Megatonnes (Mt) annually measured as carbon dioxide equivalents (CO_2-eq)

2.1 National Framework

The National Framework (first published in Government Gazette Notice No. 30284 of 11 September 2007) was updated in 2013) and provides national norms and standards for air quality management to ensure compliance. The National Framework states that aside from the various spheres of government responsibility towards good air quality, industry too has a responsibility not to impinge on everyone's right to air that is not harmful to health and well-being. Industries therefore should take reasonable measures to prevent such pollution order degradation from occurring, continuing or recurring.

In terms of AQA, certain industries have further responsibilities, including:

- Compliance with any relevant national standards for emissions from point, non-point or mobile sources in respect of substances or mixtures of substances identified by the Minister, MEC or municipality.
- Compliance with the measurements requirements of identified emissions from point, non-point or mobile sources and the form in which such measurements must be reported and the organs of state to whom such measurements must be reported.
- Compliance with relevant emission standards in respect of controlled emitters if an activity undertaken by the industry and/or an appliance used by the industry is identified as a controlled emitter.
- Compliance with any usage, manufacture or sale and/or emissions standards or prohibitions in respect of controlled fuels if such fuels are manufactured, sold or used by the industry.
- Comply with the Minister's requirement for the implementation of a pollution prevention plan in respect of a substance declared as a priority air pollutant.
- Comply with an Air Quality Officer's legal request to submit an atmospheric impact report in a prescribed form.
- Taking reasonable steps to prevent the emission of any offensive odour caused by any activity on their premises.
- Furthermore, industries identified as Listed Activities have further responsibilities, including:
  - Making application for an AEL and complying with its provisions.
  - Compliance with any minimum emission standards in respect of a substance or mixture of substances identified as resulting from a listed activity.
  - Designate an Emission Control Officer **if** required to do so.
  - Section 51 of the Air Quality Act lists possible offences according to the requirements of the Act with Section 52 providing for penalties in the case of offences.

2.2 Listed activities

At the time of the 2009 EIA, Minimum Emission Standards (MES) were still in the process of being developed and the study evaluated emissions against the then proposed MES for the ferromanganese industry. Sinter Plants fall under Category 4: Metallurgical Industry and requires an Atmospheric Emission License (AEL) to operate. There are two sets of MES applicable to:

- *New Plants* (plant or process where the application in terms of NEMA was made on or after 1 April 2010); and
- *Existing Plants* (plant or process that was legally authorised to operate before 1 April 2010 or where an application in terms of NEMA was made before 1 April 2010).

The sinter plant has not been established yet.

Table 3: Applicable Listed Activity for Sinter Plant Operations

Category 4 - Metallurgical Industry; Subcategory 4.5 – Sinter Plants			
Description:	Sinter plants for the agglomeration of fine ore using heating process, including sinter cooling where applicable		
Application:	All installations		
Substance or Mixture of Substances		**Plant Status**	**mg/Nm³ under normal conditions of 6% O_2, 273 Kelvin and 101.3 kPa**
Common Name	**Chemical Symbol**		
Particulate matter	N/A	New	50
		Existing	100
Sulphur dioxide	SO_2	New	500
		Existing	1000
Oxides of nitrogen	NO_x expressed as NO_2	New	700
		Existing	1200

2.3 National Ambient Air Quality Standards

The South African Bureau of Standards (SABS) assisted the Department of Environmental Affairs (DEA) in the development of ambient air quality standards. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for $PM_{2.5}$ PM_{10}, SO_2, NO_2, ozone (O_3), CO, lead (Pb) and benzene. The NAAQS were published in the Government Gazette (no. 32816) on 24 December 2009, thus after the 2009 EIA was competed. NAAQS for $PM_{2.5}$ was published on 29 July 2012. The NAAQS for are listed in Table 4.

Table 4: South African national ambient air quality standards (Government Gazette 32816, 2009)

Pollutant	Averaging Period	Limit Value (µg/m³)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
Benzene	1 year	10	-	0	Immediate – 31 Dec 2014
	1 year	5(b)	-	0	1 Jan 2015
CO	1 hour	30 000	26 000	88	Immediate
	8 hour(c)	10 000	8 700	11	Immediate
NO_2	1 hour	200	106	88	Immediate
	1 year	40	21	0	Immediate
PM_{10}	24 hour	120	-	4	Immediate – 31 Dec 2014
	24 hour	75(b)	-	4	1 Jan 2015
	1 year	50	-	0	Immediate – 31 Dec 2014
	1 year	40(b)	-	0	1 Jan 2015
$PM_{2.5}$	24 hour	65		4	Immediate – 31 Dec 2015
	24 hour	40(b)	-	4	1 Jan 2016 – 31 Dec 2029
	24 hour	25	-	4	1 Jan 2030
	1 year	25	-	0	Immediate – 31 Dec 2015
	1 year	20(b)	-	0	1 Jan 2016 – 31 Dec 2029
	1 year	15	-	0	1 Jan 2030
SO_2	10 minutes	500	191	526	Immediate
	1 hour	350	134	88	Immediate

Pollutant	Averaging Period	Limit Value (µg/m³)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
	24 hour	125	48	4	Immediate
	1 year	50	19	0	Immediate

Notes:

[1]The number of averaging periods where exceedance of limit is acceptable.

[2]Date after which concentration limits become enforceable.

2.4 National Regulations for Dust Deposition

South Africa's Draft National Dust Control Regulations were published on the 27 May 2011 with the dust fallout standards passed and subsequently published on the 1st of November 2013 (Government Gazette No. 36974). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. SA NDCRs that were published on the 1st of November 2013. Acceptable dustfall rates according to the regulation are summarised in Table 5.

Table 5: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m²-day over a 30 day average	Permitted frequency of exceedance
Residential areas	D < 600	Two within a year, not sequential months.
Non-residential areas	600 < D < 1 200	Two within a year, not sequential months.

The regulation also specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

2.5 National Atmospheric Emission Reporting Regulations (NAERR)

The National Atmospheric Emission Reporting Regulations (NAERR) was published on the 2nd of April 2015 by the Minister of Environmental Affairs. The regulation aims to standardize the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories (DEA , 2015).

Annexure 1 of the NAERR classify **mines** (holders of a mining right or permit in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)) as a data provider under **Group C**. **Listed Activity** as published in terms of Section 21(1) of the AQA falls under **Group A**.

Sections of the regulation that applies to data providers are summarized below.

With regards to registration, the regulation stipulates that:

(a) A person classified as a data provider must register on the NAEIS within 30 days from the date upon which these Regulations came into effect;

(b) A person classified as a data provider and who commences with an activity or activities classified as emission source in terms of the regulation 4(1) after the commencement of these Regulations, must register on the NAEIS within 30 days after commencing with such an activity or activities.

With regards to reporting and record keeping, the regulation stipulates that:

(a) A data provider must submit the required information for the preceding calendar year, as specified in Annexure 1 to these Regulations, to the NAEIS by 31 March of each calendar year.
(b) A data provider must keep a record of the information submitted to the NAEIS for five years and such record must, on request, be made available for inspection by the relevant authority.

With regards to verification of information, the regulation requires data providers to verify requested information within 60 days after receiving the written request from the relevant authority.

2.6 Greenhouse Gas Emissions

Greenhouse gasses – CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 – have been declared priority pollutants under Section 29(1) of the Air Quality Act (Government Gazette 37421 of 14 March 2014). The declaration provides a list of sources and activities including (i) fuel combustion (both stationary and mobile), (ii) fugitive emission from fuels, (iii) industrial processes and other product use, (iv) agriculture; forestry and other land use and (v) waste management. GHGs in excess of 0.1 Megatons or more, measured as CO_2-e, is required to submit a pollution prevention plan to the Minister for approval.

Regulations pertaining to GHG reporting using the NAEIS was published on 3 April 2017 (Government Gazette 40762, Notice 275 of 2017). The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

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

The NAEIS web-based monitoring and reporting system will also be used to collect GHG information in a standard format for comparison and analyses. The system forms part of the National Atmospheric Emission Inventory component of SAAELIP and South African Air Quality Information System (SAAQIS).

The DEA is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the Intergovernmental Panel on Climate Change's (IPCC) default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors. It has been indicated that these factors will only be published towards the end of 2015 (Jongikhaya, 2015). For this assessment, IPCC emission factors have been used.

A draft carbon tax bill was introduced for a further round of public consultation. The Carbon Tax Policy Paper (CTPP) (Department of National Treasury, 2013) stated consideration will be given to sectors where the potential for emissions reduction is limited. Also, in draft is that GHG in excess of 0.1 Mt, measured as $CO_{2\text{-eq}}$, is required to submit a pollution prevention plan to the Minister for approval.

3 DESCRIPTION OF THE RECEIVING ENVIRONMENT

3.1 Site Description

Tshipi Borwa Manganese Mine is situated adjacent to the Mamatwan Mine, approximately 15 km south of Hotazel, 40 km north of Khatu and 43 km west of Kuruman. The site is surrounded by farmland used for grazing. Air quality sensitive receptors (AQSRs) in the immediate vicinity of the mine, as identified in the 2009 study, include a farmhouse (N Fourie) 1.64 km south of the West WRD extension and a farmhouse (D van den Berg) is 800 m to the west. The Farmhouse of A Pyper is about 3.2 km to the north-west of West WRD extension. The old railway housing is 2.32 km south-east of the East WRD extension and 3 km east of the southern part of West WRD extension. There is a solar farm about 3 km to the north-east from the mine, with Mamatwan Mine in-between.

Operating mines located in relatively close proximity to Tshipi Borwa Manganese Mine include Mamatwan opencast mine directly to the east, and United Manganese of Kalahari (UMK) Mine 4 km to the north. Both these mines have on-site sintering (Krause & Liebenberg-Enslin, 2009). Another large opencast mine in the area is Sishen Iron Ore Mine, located 33 km to the south of Tshipi Borwa Manganese Mine. Closed or dormant mines include Middelplaats, Adams, Smartt and Perth.

The area surrounding the site is mostly flat with ridges to the west (about 40 km away) and to the east (about 20 km away). Within a 10 km radius around the mine the terrain is fairly flat with s slight slope from the southeast to the northwest.

The identified AQSRs and other mines are shown in Figure 3.

3.2 Atmospheric Dispersion Potential of the Site

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

Weather data from the on-site weather station were only available for the last six months of 2016 (July – December). In the 2009 study (Krause & Liebenberg-Enslin, 2009)., use was made of the South African Weather Services (SAWS) Kuruman Weather Station (located approximately 43 km to the west of Tshipi Borwa Manganese Mine). More recent data (1 January 2015 – 31 December 2017) from the same station was obtained for inclusion in the report. The data availability varied between the years with poor data availability of 63% (specifically on the wind field) in 2015 but good data availability of 93% and 90% for 2016 and 2017, respectively.

3.2.1 Surface Wind Field

The wind field determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is a function of the wind speed, in combination with the surface roughness. The wind field for the study area is described with the use of wind roses. Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 4 and 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. Calm conditions are periods when the wind speed was below 1 m/s. These low values can be due to "meteorological" calm conditions when there is no air movement; or, when there may be wind, but it is below the anemometer starting threshold.

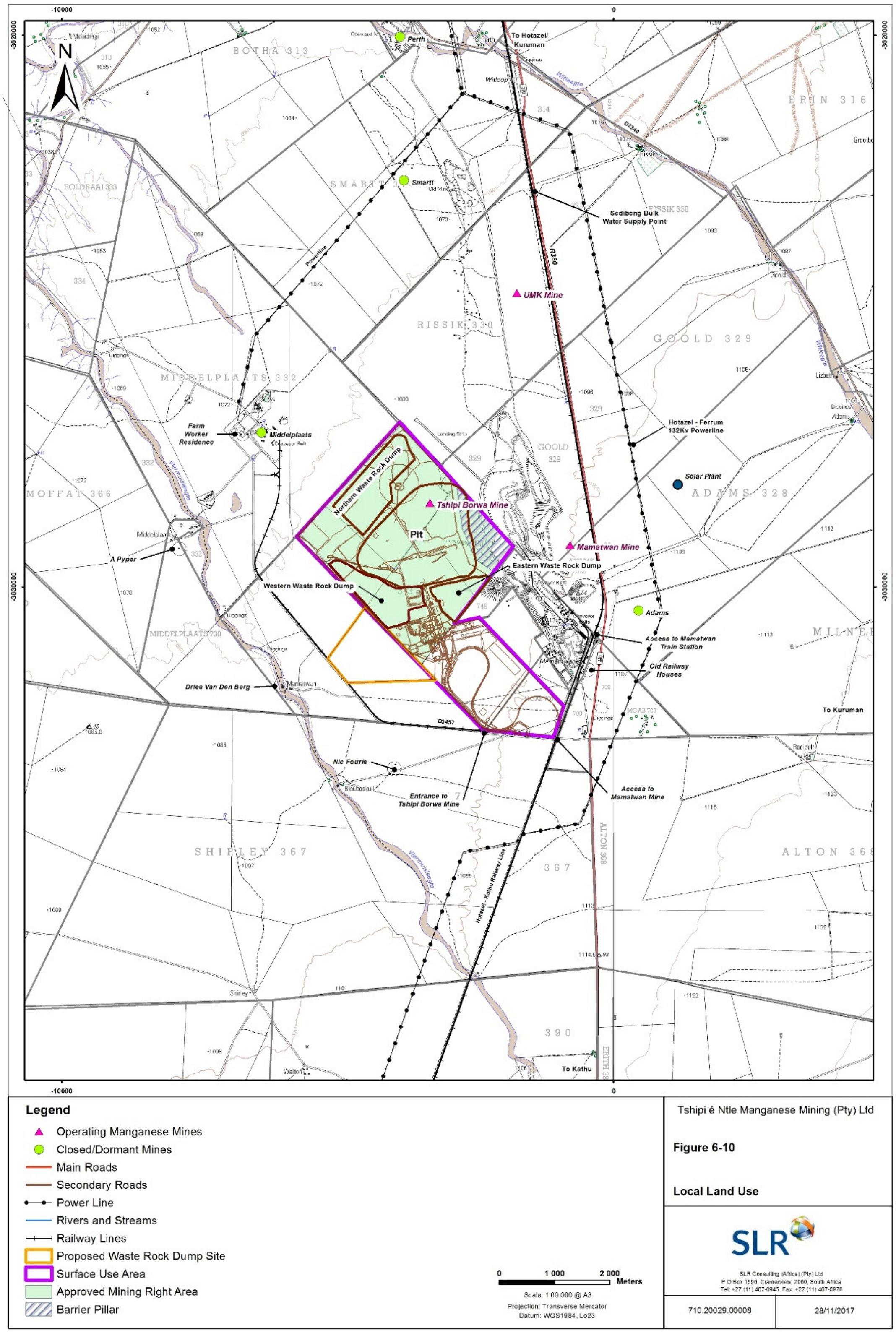

Figure 3: Air quality sensitive receptors near the Tshipi Borwa Manganese Mine

The annual average wind roses for the years 2015, 2016 and 2017 are shown in Figure 4 with the period average wind field (2015-2017) and diurnal variability in the wind field provided in Figure 5. The predominant wind direction is from the south-south-east and south with most of strong winds from the west. Frequent winds also occur from the north. Over the three-year period, the frequency of occurrence of south-south-easterly wind is between 12% and 17%, with winds with a westerly component occurring approximately 15% of the time. Winds occur less frequently from the easterly sector. The year 2015 had low data availability for wind speed and wind direction (63%), which may account for the seemingly less frequent winds from the south-south-east.

As shown in Figure 5, during the day winds are more frequent from the westerly and the northerly sectors, with the strongest winds directly from the west. The wind shifts during the night-time to dominantly south-south-easterly and southerly winds. Day-time calms occurred for 9% of the time, with night-time calms for 24% of the time.

The prevailing wind field is similar to the data used in the 2009 study, with a slight shift in the overall wind field from south-east and south-south-east (2001-2005 data) to the south-south-east and south (2015-2017). Similarly, the 2001-2005 Kuruman data had more prevalent north-westerly winds with a shift to more westerly winds in the later dataset.

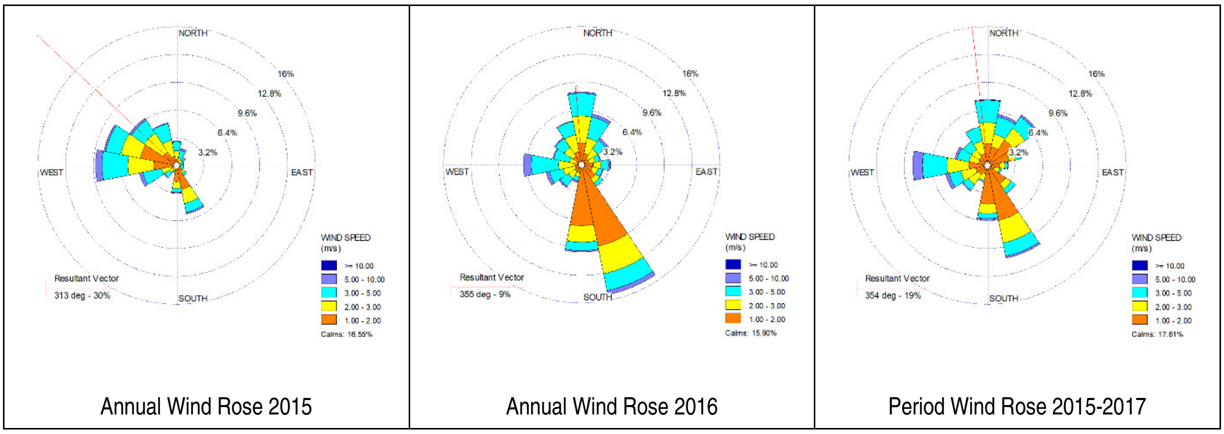

Figure 4: Period and annual wind roses (SAWS Kuruman data; 2015, 2016 and 2017)

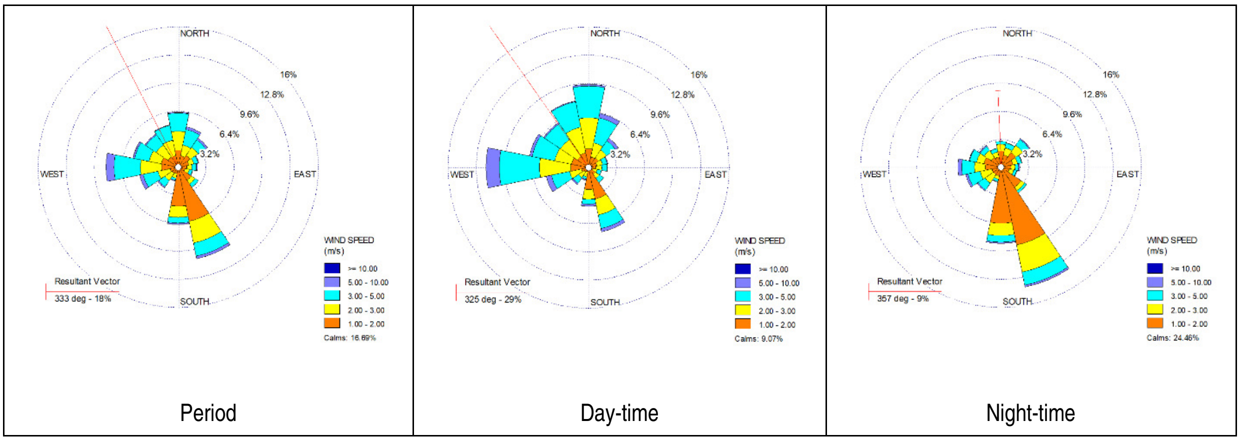

Figure 5: Period, day-time and nigh-time wind roses (SAWS Kuruman data; 2015 to 2017)

According to the Beaufort wind force scale (https://www.metoffice.gov.uk/guide/weather/marine/beaufort-scale), wind speeds between 6-8 m/s equates to a moderate breeze, with wind speeds between 14-17 m/s near gale force winds. Based on the three years of SAWS data, wind speeds exceeding 6 m/s occurred for only 1% of the time, with a maximum wind speed of 10 m/s. The average wind speed over the three years was 2.06 m/s. Calm conditions (wind speeds < 1 m/s) occurred for

17% of the time (Figure 6). The US EPA indicates a friction velocity of 5.4 m/s to initiate erosion from a coal storage piles (US EPA, 2006) and Mian & Yanful (2003). Thus, the likelihood exists for wind erosion to occur from open and exposed surfaces, with loose fine material, when the wind speed exceeds at least 5.4 m/s. Wind speeds exceeding 5.4 m/s occurred only for 2% over the three years (2015 -2017).

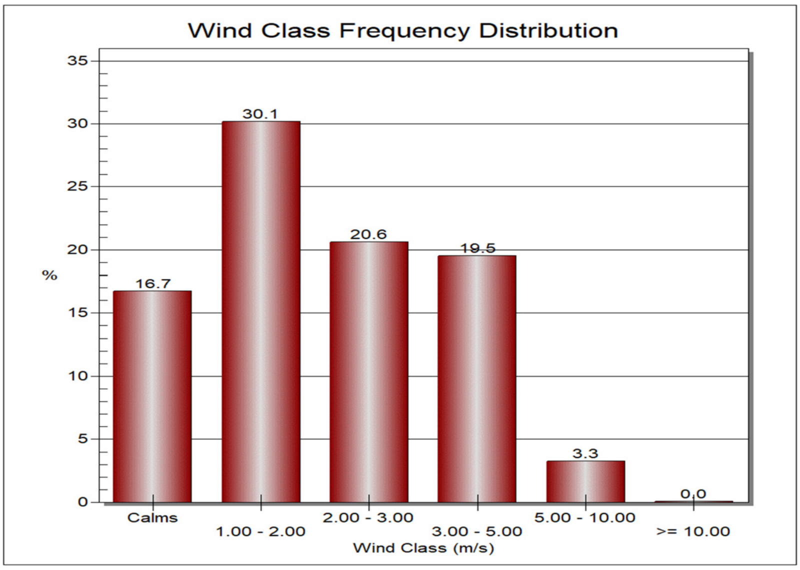

Figure 6: Wind speed categories (SAWS Kuruman data; 2015 to 2017)

3.2.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher a pollution plume is able to rise and determining the development of the mixing and inversion layers. The monthly temperature pattern is provided in Table 6. The area experience hot temperatures above 22°C during summer. Winter temperatures are relatively low especially in the months of June to August. Average daily maximum temperatures range between 43°C in January to 25°C in June, with daily minima between -4.2°C in August to 10°C in January.

Table 6: Minimum, average and maximum temperatures (SAWS Kuruman data; 2015 to 2017)

	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Min	10.1	10	6.4	3.3	2	-3.2	-3.9	-4.2	2.2	2.7	4.3	9.6
Ave	25.1	24.3	22.2	17.9	14.0	10.7	10.8	13.8	18.5	21.7	23.5	26.4
Max	42.6	38.8	35.6	35.3	28.8	25.3	27.1	31.3	34.7	38.5	39.5	39.9

3.2.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Monthly rainfall for Kuruman is shown in Figure 7. Months wherein the most rain occurred ranged between October and May. The most rain was received during the months of January and February in 2017, and April 2016. Total rainfall during 2015 was 397.6 mm, 821.6 mm in 2016 and 498.4 mm in 2017.

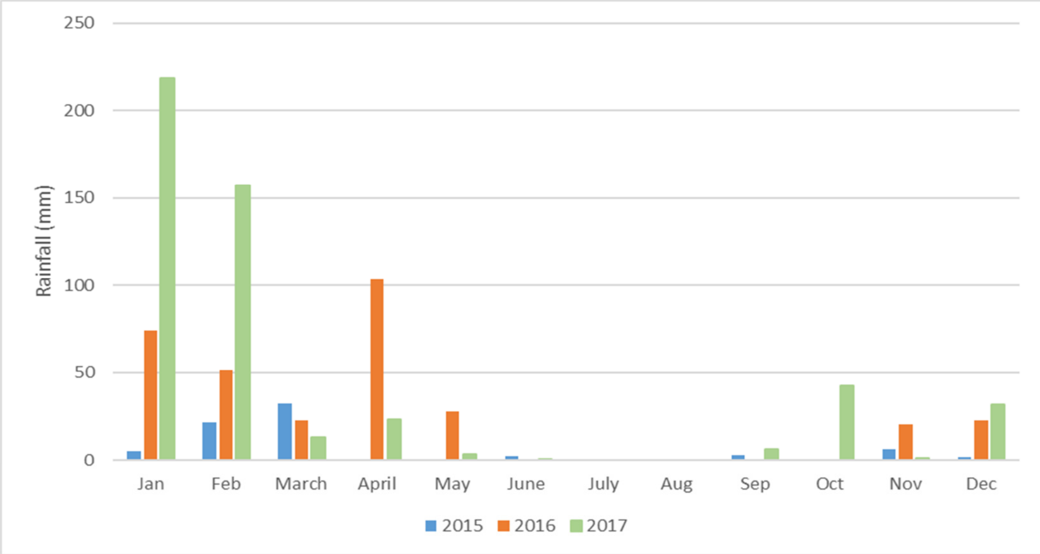

Figure 7: Monthly precipitation (SAWS Kuruman data; 2015 to 2017)

3.2.4 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in several aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class. The Monin-Obukhov length (L_{MO}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004).

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the predominance of an unstable layer. In unstable conditions, ground level pollution is readily dispersed thereby reducing ground level concentrations. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral (which causes sound scattering in the presence of mechanical turbulence).

Atmospheric stability is frequently categorised into one of six stability classes – these are briefly described in Table 7. For low level releases, such as activities associated with mining operations, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions. However, windblown dust is likely to occur under high winds (neutral conditions).

Table 7: Atmospheric stability classes and percentage occurrence (SAWS Kuruman data; 2015 to 2017)

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

3.3 Baseline Air Quality

3.3.1 Dustfall Monitoring network

A dustfall monitoring network is in place at Tshipi Borwa Manganese Mine, comprising of five directional dustfall units (DW-01 to DW-5) as shown in Figure 8. Data is also reported for five single dust fallout units (SW-01 to SW-05), and it is assumed these are located alongside the directional units. Since the NDCRs are based on single dustfalll units following the ASTM D1739 method, the directional units cannot be compared to the NDCR limits. Dustfall results for the period January 2017 to May 2018 for the single units are provided in Table 8. From the data, it is evident that the dustfall is high at and around the mine, exceeding the NDCR for non-residential areas of 1 200 mg/m²/day, often.

Table 8: Dustfall rates from the single duistfall units at Tshipi Borwa Manganese Mine

Start date	End date	Days Exposed	Dustfall rates (mg/m²/day)				
			SB-01	SB-02	SB-03	SB-04	SB-05
11/01/2017	27/02/2017	47	-	1 075	676	1 097	636
27/02/2017	30/03/2017	31	-	1 473	1 343	1 480	1 266
30/03/2017	02/05/2017	33	-	1 375	1 193	1 642	1 119
02/05/2017	30/05/2017	28	-	841	725	771	940
30/05/2017	28/06/2017	29	-	2 003	1 069	1 336	826
28/06/2017	27/07/2017	29	-	1 338	833	1 147	632
27/07/2017	31/08/2017	35	1 680	2 234	1 333	1 539	-
31/08/2017	03/10/2017	33	1 248	2 245	1 618	1 369	-
03/10/2017	30/10/2017	27	831	1 238	726	932	-
30/10/2017	29/11/2017	30	1 325	1 209	866	930	-
29/11/2017	14/12/2017	15	1 495	1 095	1 051	944	1 420
14/12/2017	15/02/2018	63	-	1 933	1 234	1 371	1 162
15/02/2018	19/04/2018	63	-	2 290	930	1 150	594

Notes: Highlighted cells indicate exceedances of the NDCR non-residential limit of 1 200 mg/m²/day

3.3.2 PM_{10} Sampling

PM_{10} sampling campaigns have been on-going since October 2015 at the dustfall locations and next to the Silo. The 24-hour results from the eight campaigns indicate elevated PM_{10} levels around the mine, exceeding the 24-hour limit of 75 µg/m³ for all the campaigns at almost all the locations. It is therefore likely that the ambient air quality around the mine is in non-compliance with the NAAQS (see Section 2.3).

Table 9: PM_{10} daily concentrations at Tshipi Borwa Manganese Mine

Date	SB-01	SB-02	SB-03	SB-04	SB-05	Next to Silo
Oct-15	125	93.7	541.7	187.5	ND	1218.7
May-17	256.9	423.6	0	381.9	809	329.9
Aug-17	73	181	660	160	1316	233
Sep-17	253.5	180.6	211.8	ND	ND	69.4
Oct-17	288.2	430.6	468.7	291.7	83.3	72.9
Dec-17	135.4	93.8	215.3	111.1	784.7	180.6
Feb-18	93.75	0	135.42	208.33	114.58	291.67
May-18	552.08	114.58	187.5	708.33	239.58	625

Notes: ND is No Data. The NAAQS for PM_{10} 24-hour is 75 µg/m³ not to be exceeded for more than 4 days in a year.

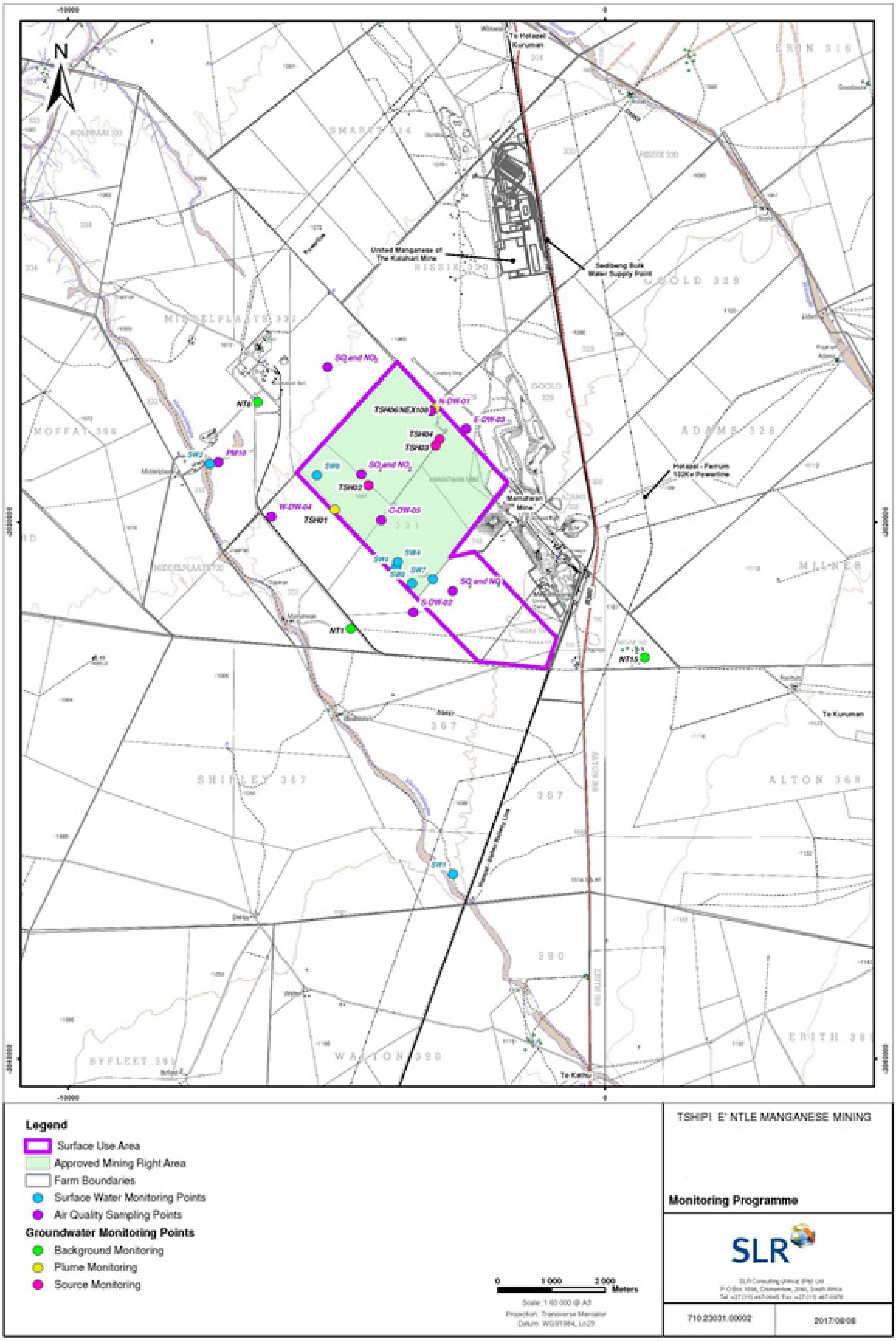

Figure 8: Monitoring Network at Tshipi Borwa Manganese Mine

4 QUALITATIVE AIR QUALITY ASSESSMENT

4.1 2009 Air Quality Impact Assessment

The air quality impact assessment conducted for the then proposed Ntsimbintle Mine (now Tshipi Borwa) assessed the potential health and nuisance impacts from PM_{10}, manganese (Mn), SO_2, NOx, Diesel Particulate Matter (DPM) and CO due to the mining operations per the approved infrastructure layout (Figure 1).

Two scenarios were assessed, namely:

- **Scenario 1**: Included opencast and underground mining, processing and the beneficiation of manganese ore as well as the power generation; and
- **Scenario 2**: Included underground mining, the rehabilitation of the open cast mining area, processing and the beneficiation of manganese ore as well as the power generation plant.

Since Scenario 1 was found to be the worst-case scenario from an air quality perspective. Thus, the comparison to the expected changes in air quality impacts from the proposed 2018 mine infrastructure changes is based on the 2009 Scenario 1 (Krause & Liebenberg-Enslin, 2009).

The main findings from the April 2009 air quality impact assessment for Scenario 1 can be summarised as follows:

- **PM_{10} ground level concentrations**: The modelled annual average and highest daily average incremental and cumulative unmitigated PM_{10} concentrations at the Ntsimbintle boundary were well above the NAAQSs. The annual NAAQS of 40 µg/m³ was exceeded at the Ntsimbintle boundary and the old Middelplaats mine. The daily NAAQS of 75 µg/m³ was exceeded at the Ntsimbintle boundary and a number of identified sensitive receptors (A. Pyper, the old Middelplaats mine and N. Fourie). Mitigation of fugitive dust sources resulted in an average reduction of 87% in predicted PM_{10} concentrations, with only exceedances of the annual and daily PM_{10} NAAQS at the mine boundary and not at any of the sensitive receptors.

  Vehicle entrained dust from unpaved roads were the main source resulting in unmitigated and mitigated PM_{10} concentrations contributing, on average, 88% and 67% respectively to the total PM_{10} ground level concentrations.

- **Manganese ground level concentrations**: The modelled annual average incremental unmitigated Mn concentration at the Ntsimbintle boundary was 20.1 µg/m³ and the cumulative concentration was 20.7 µg/m³ compared to the annual World health Organisation (WHO) guideline of 0.15 µg/m³. Exceedances were also predicted at A. Pyper, the old railway housing, the old Middelplaats mine and N. Fourie. With mitigation in place the impact reduced on average by 69%.

  Manganese dust as a result of crushing and screening operations contributed most significantly, 61%, to the predicted unmitigated Mn concentrations. With mitigation measures in place, emissions from the sinter plant contributed most significantly to predicted manganese concentrations. The sinter plant has not been established.

- **SO_2 ground level concentrations**: The modelled annual, highest daily and highest hourly average incremental and cumulative SO_2 concentrations at the Ntsimbintle boundary were below the NAAQSs for annual and daily averages but exceeded the hourly limit at the Ntsimbintle boundary but not at any of the sensitive receptors.

  Sinter plant emissions were estimated to be the most significant contributor, contributing on average 89%, to predicted incremental SO_2 concentrations. The sinter plant has, however, not been established.

- **NO_2 ground level concentrations**: The modelled annual and highest hourly average incremental and cumulative NO_2 concentrations at the Ntsimbintle boundary was below the NAAQS for annual averages but marginally exceeded the hourly limit at the Ntsimbintle boundary but not at any of the sensitive receptors.

  Sinter plant emissions were estimated to be the most significant contributor, contributing on average 39%, to predicted incremental NO_2 concentrations. The sinter plant has not been established.

- **Diesel Particulate Matter (DPM) ground level concentrations**: The modelled annual average incremental DPM concentration at the Ntsimbintle boundary was above the SANS annual limit of 5 µg/m³, but not at the sensitive receptors.
- **CO ground level concentrations**: Modelled highest hourly average incremental CO concentration at the Ntsimbintle boundary and at any of the discreet receptors was well below the NAAQS.
- **Dustfall impacts**: The modelled maximum daily incremental unmitigated dustfall level at the Ntsimbintle boundary was above the NDCR residential dustfall limit, but within the non-residential limit. With mitigation in place the impacts reduced.

4.2 Qualitative Air Quality Impact Assessment for the proposed changes to the mine infrastructure

The proposed changes in the mine infrastructure are listed in Table 1. The approved mine layout plan is provided in Figure 1 with the proposed mine layout plan shown in Figure 2.

The most significance changes to have an impact on the ambient air quality (as listed in Table 1) are:

1. the extension of the West WRD in a south-westerly direction onto the remaining extent of Portion 8 of the farm Mamatwan 331;
2. the extension of the East WRD in a south-easterly direction to join with the Mamatwan WRD and essentially fill the narrow void between these two WRDs; and
3. the overland conveyor system between the existing crushing and screening plant and the existing manganese product stockpiles.

The construction of an 11 kV overhead powerline and sub-station along the boundary of Portion 8 onto the existing mining right area will not have noticeable impacts on air quality.

4.2.1 Extension of the West WRD

The extension of the West WRD is likely to have the most significant impact on air quality during construction operations due to land clearing (dozing and scraping activities) of the 142 ha, loading and off-loading of topsoil and trucks on freshly graded access roads. Windblown dust from the new topsoil stockpiles and cleared areas is also probable, but only when winds exceed 5.4 m/s as a minimum. The planned phased construction method – construction of cells in the WRD extension – will reduce dust generation from land clearing significantly, result in less topsoil to be handled and fewer trucks on the roads. The areas prone to windblown dust will also be smaller and likely to be continuously vegetated, reducing the potential for wind erosion. Air quality impacts from the construction activities associated with the West WRD extension are likely to be localised except under stronger winds, which only occur for about 2% when the dust plume could be carried to the nearby AQSRs. Gaseous emission from the construction equipment and trucks are unlikely to have significant impacts off-site. Also, construction operations are likely to be limited to daytime hours (06:00 to 18:00) from Monday to Saturday reducing the risk of higher ground level concentrations due to stable night-time conditions.

During the operational phase, the West WRD extension is likely to be the most significant additional source of air pollution to current mining operations. This will mainly be due to haul trucks transporting waste rock – vehicle entrained dust from unpaved roads were the main source of PM_{10} ground level concentrations in the 2009 study. Since it is assumed that the mining rate will not increase, the transport of waste rock will remain the same, but the travel distances will be longer (further from the pit) resulting in more dust generation due to vehicle entrainment. The amount and frequency of waste rock being tipped at the extended West WRD should be the same as at the current WRDs and therefore not result in increased dust generation. Dumping of waste rock on top of a waste rock dump could however be a significant source of dust – tipping of waste rock on the edge causes the material to roll down the slope resulting in significant impact near the WRD. This may cause exceedances of the NAAQCs at the nearby AQSRs of D van den Berg and N Fourie. With the prevailing daily wind field from the west, the impacts at these receptors may be reduced specifically under higher wind speeds when the dust should be blown towards the east. Occasional impacts to the south of the West WRD extension is possible due to the northerly daytime winds. The south-south-easterly winds are most dominant during the night and associated with low wind speeds and stable (night-time) atmospheric conditions, thus likely to result in higher ground level impacts to the north and north-north-west of the West WRD. The potential for windblown dust from the WRDs and topsoil piles are limited due to the infrequent occurrence of high wind speeds. The potential for increases in gaseous pollution impacts are low.

During closure, the WRD would be rehabilitated with the only foreseen source of emissions to be truck activity, and tipping and levelling of topsoil on the WRD side slopes. This could result in significant dust generation, but the duration of these activities would be short with a likely impact significance of medium. With mitigation measures in place such as water sprays at the tip points and reducing the tip heights, the impacts could reduce to a low significance.

4.2.2 Extension of the East WRD

Similar activities to those associated with the extension of the West WRD would apply to the extension of the East WRD, both during construction and operations. The advantage of the East WRD from an air quality perspective is that the footprint is much smaller (only 5 ha), and that it is shielded by the existing Eastern WRD to the west and the Mamatwan WRD to the east. The Eastern WRD should act as a wind barrier from the stronger westerly winds, and to some extent from the northerly winds. The filling of waste rock instead of tipping at the crest of the WRD, would also reduce the impacts. The operational phase of the East WRD will also be of shorter duration, resulting in less dust generation from the access roads and tipping.

Similar to the closure operations of the West WRD, truck activity, tipping of topsoil and levelling out of the exposed side slopes might result in significant dust generation. Due to the significantly smaller area to be rehabilitated and the limited exposed side slopes, the impact significance is regarded to be low.

4.2.3 Overland conveyor system

The construction of the proposed overland conveyor is not likely to have a significant impact on air quality since the areas to be cleared are small. With construction operations are likely to be limited to daytime hours (06:00 to 18:00) from Monday to Saturdays, the impacts are likely to be insignificant for both particulate matter and gaseous emissions.

Dust emissions from conventional conveyors are wind speed dependent with stronger wind speeds causing dust particles to be entrained by the wind. The degree of entrained dust also depends on the level of enclosure, i.e. roof cover and/or sides. This could be a significant local source of dust when stronger westerly winds blow during the day, both due to the entrainment potential of the material on the conveyor as well as the spilled material along the conveyor. The impacts would, however, most likely be localised and to the east of the overland conveyor, thus within the surface use area. The conveyor transfer point could also be significant sources of dust generation if not controlled. No gaseous emissions are expected from the overland conveyor system.

During closure phase the conveyor system would be demolished resulting in likely insignificant air quality impacts.

4.2.4 Cumulative Impacts

Modelled results from the 2009 Air Quality Impact Assessment indicated the potential for off-site exceedances of the PM_{10} daily and annual NAAQS (Krause & Liebenberg-Enslin, 2009). These are confirmed by the high dustfall levels from the dustfall network and the elevated PM_{10} concentrations from the sampling campaigns (Section 3.3). The addition of the new

West WRD is likely to result in increased PM_{10} and $PM_{2.5}$ (although not assessed in the 2009 study) ground level concentrations and dustdall levels at the nearby AQSRs of D van den Berg and N Fourie. This is mainly due to the longer haul distances and the location of the West WRD closer to these receptors. The East WRD is unlikely to result in increased cumulative dust emissions and off-site impacts. It is also expected that the overland conveyor would not result in increased dust generation and that the impacts would be localised and within the surface use area. With no mitigation in place these increases, especially from the West WRD, could be significant but with mitigation measures in place these impacts are likely to have a low significance.

4.3 Management and Mitigation Measures

4.3.1 Construction phase

- Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks transporting waste rock and to apply water sprays regularly on the newly constructed (graded).
- Limit the size of the WRD construction areas as per the proposed design (construction of cells in the WRD extension). This will significantly reduce dust generation from land clearing activities and would result in less topsoil to be handled and fewer trucks on the roads. The areas prone to windblown dust will also be smaller and likely to be continuously vegetated, reducing the potential for wind erosion.
- Mitigation measures, such as water sprays or equivalent controls, to be applied at tipping points resulting in excessive dust emissionsWater sprays at all tipping points.

4.3.2 Operational phases

The control efficiencies provided are from the NPI (2012):

- For the control of vehicle entrained dust it is recommended that water (at an application rate >2 litre/m²/hour), be applied. Literature reports an emissions reduction efficiency of 50%. Applying chemical suppressants on the regular used unpaved haul roads between the pit and the WRD extensions could result in a control efficiency of more than 90%.
- Literature indicates that fitting a roof on the conveyor and covering one side (west side and south side) should have a mitigation efficiency of 65% (NPI, 2012). Alternatively, the material can be sprayed as it enters the conveyer to reduce the potential for windblown dust.
- Mitigation of materials transfer points could be done using water sprays or equivalent controls at the tip points. This should result in a 50% CE. Tipping of waste rock should also be done within the crest of the WRD, if possible, to ensure the material does not migrate down the WRD slope. Should the dumping of waste rock be a significant source of dust deposition and ambient concentrations at the identified AQSRs, additional mitigation measures will have to be applied. A 3-5 m high grassed berm on the western side of the West WRD could be considered to act as a screen from the nearby AQSR.
- In minimizing windblown dust from stockpile areas, water sprays should be used to keep surface material moist and wind breaks installed to reduce wind speeds over the area. Even though high wind speeds are limited, given that this is a dry environment, wind breaks are advised. A mitigation efficiency of 50 % is anticipated. (NPI, 2012).
- Any binding properties would reduce the potential for wind erosion from the WRDs and topsoil piles. One of the most effective measures of minimizing wind erosion emissions is re-vegetation. The control efficiency of vegetation is given as 40% for non-sustaining vegetation and 90% for re-vegetation. Secondary rehabilitation would up the control efficiency to 60% for non-sustaining vegetation (NPI, 2012).

4.3.3 Decommissioning and Closure

- Decommissioning is likely to have similar, but less significant sources of air pollution to that of the construction phase. Thus, basic control measures such as limiting the speed of trucks and vehicles, and to apply water sprays regularly on the unpaved roads used.
- Closure should not result in any significant air quality impacts assuming that the WRDs have been vegetated and that the topsoil piles have been removed or also vegetated.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Main Findings

The main findings from the qualitative assessment of the proposed changes to the Tshipi Borwa Manganese Mine infrastructure are as follow:

- The draft NAAQSs and MES used in the 2009 air quality study, conducted before these limits and standards were finalised, are the same as the NAAQSs (published December 2009, and July 2012) and the MES (published April 2010, and revised November 2013).
- The mine would have to report annually, before 31 March, on NAEIS on both the Sinter Plant (although this plant has not yet been established) and the mining operations emissions. If stationary equipment at the mine have a combined capacity of more than 10 MW(th), all stationary combustion emissions must be reported annually on NAEIS.
- AQSRs most likely to be impacted on by the changes to the infrastructure are N Fourie (to the south) and D van den Berg (to the west) of the West WRD extension, and to a lesser extent A Pyper to the north-west of the West WRD extension.
- The following changes to the mine infrastructure are likely to result in increased PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates mainly due to the increase of fugitive dust sources. The proposed changes are likely to have an insignificant impact on gaseous emissions and ground level concentrations.

  Construction:

  - Construction of West WRD extension due to land clearing (dozing and scraping activities) of the 142 ha, loading and off-loading of topsoil and trucks on freshly graded access roads, and to a lesser extent the possibility for windblown dust from the cleared areas and topsoil piles. Construction of cells in the WRD extension, and construction activities limited to day-time hours, will reduce the potential for particulate matter impacts significantly.
  - Construction of the East WRD extension will have similar dust generating sources but will result in much lower impacts, likely limited to the mining right area, due to the smaller footprint (5 ha) and the fact that is shielded on both the western and eastern sides by existing WRDs.
  - Construction of the proposed overland conveyor is likely to have an insignificant impact on air quality since the areas to be cleared are small.
  - Similarly, the construction of the Eskom 11 kV overhead powerline and sub-station along the boundary of Portion 8 is likely to have an insignificant impact on air quality since the areas to be cleared are small.

  Operational:

  - During the operational phase, fugitive dust generation from the West WRD would mainly be due to the hauling of waste rock over longer distances than what is currently the case. The way the waste rock may be tipped at the crest of the WRD may result in higher ground level PM_{10} and $PM_{2.5}$ concentrations and dustfall rates at the nearby AQSRs, especially during stable night-time conditions. The potential for windblown dust from the WRDs and topsoil piles are limited due to the infrequent occurrence of high wind speeds. With mitigation measures, such as shorter hauling distances, water sprays or chemical suppressant on the haul roads and not tipping at the crest of the WRD the impacts should reduce significantly.
  - Operations at the East WRD extension are unlikely to have limited off-site impacts due to the smaller footprint, the shielding by existing WRDs on the eastern and western sides, and the shorter duration. Similar mitigation measures as for West WRD would reduce the potential for impacts.

- Fugitive emission from the overland conveyor system would mainly be from windblown dust from an open conveyor and re-entrainment from spilled material. Impacts would most likely be localised, within the mining right area, and to the east of the overland conveyor. The conveyor transfer points could also be sources of dust generation if not controlled.

Cumulative:

The addition of the new West WRD is likely to result in increased PM_{10} and $PM_{2.5}$ ground level concentrations and dustdall levels at the nearby AQSRs of D van den Berg and N Fourie. This is mainly due to the longer haul distances and the location of the West WRD closer to these receptors. The East WRD is unlikely to result in increased cumulative dust emissions and off-site impacts. It is also expected that the overland conveyor would not result in increased dust generation and that the impacts would be localised and within the surface use area. With no mitigation in place these increases, especially from the West WRD, could be significant but with mitigation measures in place these impacts are likely to have a low significance.

5.2 Conclusion

There is a potential for increased PM_{10} and $PM_{2.5}$ ground level concentrations and dust fallout rates off-site and at nearby AQSRs from the construction and operation of the West WRD extension. With mitigation measures in place these impacts should be limited and localised resulting in a low significance. Increased impacts from the East WRD extension and the overland conveyor are likely to be insignificant. No increases in SO_2, NO_2, Mn and CO are foreseen. DPM concentrations might increase due to the increased truck activity but it is unlikely to exceed the guideline.

5.3 Recommendations

- A comprehensive dust management plan is required for the mine with specific mitigation measures, the frequency of application and the responsible divisions and persons indicated. This should follow on the dust management measures recommended in Section 7 of the 2009 air quality report (Krause & Liebenberg-Enslin, 2009) as well as the mitigation measures recommended in Section 4.3 of this report.
- The dustfall network as is currently in place should be continued, with three additional dust buckets proposed to be located at the farms of N Fourie, D van den Berg and A Pyper before any changes or additions to the mine infrastructure are allowed. It is further recommended that the proposed dust fallout should follow the ASTM D1739 (1970) method as required by the NDCR, on the dustfall unit design, the dust collection and analysis. Dustfall results should be reported annually to the District Municipality Air Quality officer. It is further recommended that these two locations, D van den Berg and A Pyper, be added to the PM_{10} monitoring campaigns. The following indicators should apply:
    - Dustfall rates should be below 600 $mg/m^2/day$ at the identified receptors (farms of N Fourie, D van den Berg and A Pyper) and if exceeded for two consecutive months, action should be taken by identifying the source of dust and applying additional mitigation measures.
    - Daily (24-hour) PM_{10} concentrations should not exceed 75 $\mu g/m^3$ for more than 4 days per year at these receptors and should these concentrations be above the limit, immediate action should be taken by identifying the source of dust and applying additional mitigation measures.

6 Issues Raised by Interested and Affected Parties (IAPs)

As part of the environmental amendment process to cater for infrastructure layout changes, a public consultation process was undertaken and managed by SLR. In this regard, the table below summarises the issues and concerns raised by IAPs including a response.

Table 10: Comments raised by IAPs

IAP	Date of comment	Issue raised	Response
Andries van den Berg	*14 September 2017 at the public scoping meeting.*	*I am concerned about the changing rainfall patterns. There seems to be a sharp decline of rainfall on my land surrounding the mine, could the change in the local topography by the pit and WRDs and wind patterns have anything to do with this?*	Most of the rain over the three years (2015 – 2017) was received during the months of January and February 2017. In total, 2016 had the highest rainfall at Kuruman over the three years. Rainfall is not likely to be significantly influenced by local topographical changes and is more likely a result of climate change. The Water Research Commission (WRC) is investigating the changes in extreme rainfall in the medium term (2040-2060) and the synoptic drivers of this change in the long term (2070-2099). An initial assessment indicates drier than normal conditions projected over much of southern Africa alongside an increased possibility of extreme rainfall. (http://www.csag.uct.ac.za/projected-changes-in-extreme-rainfall-over-south-africa/)

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Cowherd, C., Muleski, G. E., & Kinsey, J. S. (1988). *Control of Open Fugitive Dust Sources.* United States Environemntal Protection Agency.

Krause, N., & Liebenberg-Enslin, H. (2009). *Air Quality Impact Assessment for the Proposed Ntsimbintle Manganese Mining.*

Liebenberg-Enslin, H. (2017a). *Tshipi Borwa Manganese Mine Environmental Management Plan Amendment: Air Quality Specialist Opinion as part of the Environmental Management Program. SLR Consulting (Africa)(Pty) Ltd*

Liebenberg-Enslin, H. (2017b). *Tshipi Borwa Manganese Mine Environmental Management Plan Amendment: Air Quality Specialist Opinion as part of the Section 24G Requirements. SLR Consulting (Africa)(Pty) Ltd*

NPI. (2012). *Emission Estimation Technique Manual for Mining. Version 3.1.* Australian Government Department of Sustainability, Environment, Water, Population and Communities.

8 APPENDIX A - SPECIALIST CURRICULUM VITAE

CURRICULUM VITAE	HANLIE LIEBENBERG-ENSLIN

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Hanlie Liebenberg-Enslin
Profession	Managing Director / Air Quality Scientist
Date of Birth	09 January 1971
Years with Firm/ entity	18 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) – President 2010–2013, Board member 2013-present
- Member of the National Association for Clean Air (NACA) - President 2008-2010, NACA Council member 2010 –2014

KEY QUALIFICATIONS

Hanlie Liebenberg-Enslin started her professional career in Air Quality Management in 2000 when she joined Environmental Management Services (EMS) after completing her Master's Degree at the University of Johannesburg (then Rand Afrikaans University) in the same field. She is one of the founding members of Airshed Planning Professionals in 2003 where she has worked as a company Director until May 2013 when she was appointed as Managing Director. She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. She has worked all over Africa and has an inclusive knowledge base of international legislation and requirements pertaining to air quality.

She has developed technical and specialist skills in various modelling packages including the industrial source complex models (ISCST3 and SCREEN3), EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff-based model (CALPUFF and CALMET), puff-based HAWK model and line based models such as CALINE. Her experience with emission models includes Tanks 4.0 (for the quantification of tank emissions) and GasSim (for the quantification of landfill emissions).

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

Being an avid student, she received her PhD in 2014, specialising in Aeolian dust transport. Hanlie is also actively involved in the National Association for Clean Air and is their representative at the International Union of Air Pollution Prevention and Environmental Protection Associations.

RELEVANT EXPERIENCE

Air Quality Management Plans and Strategies

Vaal Triangle Airshed Priority Area AQMP Review (August 2017 to July 2019); Strategic Environmental Management Plan Air Quality Management Plan for the Erongo Region Update (May 2016 to February 2019); Provincial Air Quality Management Plan for the Limpopo Province (March 2013); Mauritius Road Development Agency Proposed Road Decongestion Programme (July 2013); Transport Air Quality Management Plan for the Gauteng Province (February 2012); Gauteng Green Strategy (2011); Air Quality and Radiation Assessment for the Erongo Region Namibia as part of a Strategic Environmental Assessment (June, 2010); Vaal Triangle Airshed Priority Area AQMP (March, 2009); Gauteng Provincial AQMP (January 2009); North West Province AQMP (2008); City of Tshwane AQMP (April 2006); North West Environment Outlook 2008 (December 2007); Ambient Monitoring Network for the North West Province (February 2007); Spatial Development Framework Review for the City of uMhlathuze (August 2006); Ambient Particulate Pollution Management System (Anglo Platinum Rustenburg):

Hanlie has also been the Project Director on all the listed Air Quality Management plan developments.

Mining and Ore Handling

Hanlie has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite and mineral sands mines. These include air quality impact assessments for: Trekkopje Uranium Mine near Swakopmund; Bannerman Uranium Project; Langer Heinrich Uranium Mine, Valencia Uranium Mine, Etango (Husab) Project, Rössing South Uranium Mine (Namibia); Sishen Iron Ore Mine (Kathu); Kolomela Iron Ore Mine (Postmasburg); Thabazimbi Iron ore Mine (Thabazimbi); UKM Manganese Mine (Hotazel); Everest Platinum Mine (Steelpoort); Murowa Diamond Mine (Zimbabwe); Jwaneng Diamond Mine (Botswana); Sadiola Gold Mine (Mali); North Mara Gold Mine (Tanzania); Tselentis Coal mine (Breyeton); Lime Quarries (De Hoek, Dwaalboom, Slurry); Beesting Colliery (Ogies); Anglo Coal Opencast Coal Mine (Heidelberg); Klippan Colliery (Belfast); Beesting Colliery (Ogies); Xstrata Coal Tweefontein Mine (Witbank); Xstrata Coal Spitskop Mine (Hendrina); Middelburg Colliery (Middelburg); Klipspruit Project (Ogies); Rustenburg Platinum Mine (Rustenburg); Impala Platinum (Rustenburg); Buffelsfontein Gold Mine (Stilfontein); Kroondal Platinum Mine (Kroondal); Lonmin Platinum Mine (Mooinooi); Rhovan Vanadium (Brits); Macauvlei Colliery (Vereeniging); Voorspoed Gold Mine (Kroonstad); Pilanesberg Platinum Mine (Pilanesberg); Kao Diamond Mine (Lesotho); Modder East Gold Mine (Brakpan); Modderfontein Mines (Brakpan); Bulyanhulu North Mara Gold Mine (Tanzania); Gold Mine (Tanzania); Zimbiwa Crusher Plant (Brakpan); RBM Zulti South Titanium mining (Richards Bay); Premier Diamond Mine (Cullinan).

Metal Recovery

Air quality impact assessments have been carried out for Smelterco Operations (Kitwe, Zimbia); Waterval Smelter (Amplats, Rustenburg); Hernic Ferrochroime Smelter (Brits); Rhovan Ferrovanadium (Brits); Impala Platinum (Rustenburg); Impala Platinum (Springs); Transvaal Ferrochrome (now IFM, Mooinooi), Lonmin Platinum (Mooinooi); Xstrata Ferrochrome Project Lion (Steelpoort); ArcelorMittal South Africa (Vandebijlpark, Vereeniging, Pretoria, Newcastle, Saldanha); Hexavalent Chrome Xstrata (Rustenburg); Portland Cement Plant (DeHoek, Slurry, Dwaalboom, Hercules, Port Eelizabeth); Vantech Plant (Steelpoort); Bulyanhulu Gold Smelter (Tanzania), Sadiola Gold Recovery Plant (Mali); RBM Smelter Complex (Richards Bay); Chibuto Heavy Minerals Smelter (Mozambique); Moma Heavy Minerals Smelter (Mozambique); Boguchansky Aluminium Plant (Russia); Xstrata Chrome CMI Plant (Lydenburg); SCAW Metals (Germiston).

Chemical Industry

Comprehensive air quality impact assessments have been completed for AECI (Pty) Ltd Operations (Modderfontein); Kynoch Fertilizer (Potchefstroom), Foskor (Richards Bay) and Omnia (Rustenburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for SASOL operations (Sasolburg); Sapref Refinery (Durban); Health risk assessment of Island View Tank Farm (Durban Harbour).

Pulp and Paper Industry

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

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the Coal 3 Power Project near Lephalale, Komati Power Station and Lethabo Power Stations. In addition to Eskom's coal fired power stations, projects have been completed for the proposed Mmamabula Energy Project (Botswana); Morupule Power Plant (Botswana); NamPower Van Eck Power Station; NamPower Erongo Power Project (Namibia).

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

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the proposed Coega Waste Disposal Facility (Port Elizabeth); Boitshepi Waste Disposal Site (Vanderbijlpak); Umdloti Waste Water Treatment Plant (Durban).

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the PPC Cement Alternative Fuels Project (which included the assessment of the cement manufacturing plants in the North West Province, Gauteng and Western). Air Impact Reporrs and Pollution Prevention Plans for Lafarge Cement in the North West Province.

Vehicle emissions

Platinum Highway (N1 to Zeerust); Gauteng Development Zone (Johannesburg); Gauteng Department of Roads and Transport (Transport Air Quality Management Plan); Mauritius Road Development Agency (Proposed Road Decongestion Programme); South African Petroleum Industry Association (Impact Urban Air Quality).

Government Strategy Projects

Hanlie was the project Director on the APPA Registration Certificate Review Project for Department of Environmental Affairs (DEA); Green Strategy for Gauteng (2011).

EDUCATION

Ph.D Geography	University of Johannesburg, RSA (2014) Title: *A functional dependence analysis of wind erosion modelling system parameters to determine a practical approach for wind erosion assessments*
M.Sc Geography and Environmental Management	University of Johannesburg, RSA (1999) Title: *Air Pollution Population Exposure Evaluation in the Vaal Triangle using GIS*
B.Sc Hons. Geography	University of Johannesburg, RSA (1995) GIS & Environmental Management
B.Sc Geography and Geology	University of Johannesburg, RSA (1994) Geography and Geology

ADDITIONAL COURSES AND ACADEMIC REVIEWS

External Examiner (January 2018)	MSc Candidate: Ms B Wernecke Ambient and Indoor Particulate Matter Concentrations on the Mpumalanga Highveld Department of Geography and Environmental Management, North-West University
External Examiner (January 2016)	MSc Candidate: Ms M Grobler Evaluating the costs and benefits associated with the reduction in SO_2 emissions from Industrial activities on the Highveld of South Africa Department of Chemical Engineering, University of Pretoria
External Examiner (August 2014)	MSc Candidate: Ms Seneca Naidoo Quantification of emissions generated from domestic fuel burning activities from townships in Johannesburg Faculty of Science, University of the Witwatersrand
Air Quality Law – Lecturer (2012 -2016)	Environmental Law course: Centre of Environmental Management.
Air Quality law for Mining – Lecturer (2014)	Environmental Law course: Centre of Environmental Management.
Air Quality Management – Lecturer (2006 -2012)	Air Quality Management Short Course: NACA and University of Johannesburg, University of Pretoria and University of the North West
ESRI SA (1999)	ARCINFO course at GIMS: Introduction to ARCINFO 7 course
ESRI SA (1998)	ARCVIEW course at GIMS: Advanced ARCVIEW 3.1 course

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Namibia, Malawi, Mauritius, Kenya, Mali, Zimbabwe, Democratic Republic of Congo, Tanzania, Zambia, Madagascar, Guinea, Russia, Mauritania and Saudi Arabia.

EMPLOYMENT RECORD

March 2003 - Present

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

January 2000 – February 2003

Environmental Management Services CC, Senior Air Quality Scientist.

May 1998 – December 1999

Independent Broadcasting Authority (IBA), GIS Analyst and Demographer.

February 1997 – April 1998

GIS Business Solutions (PQ Africa), GIS Analyst

January 1996 – December 1996

Annegarn Environmental Research (AER), Student Researcher

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Excellent	Excellent	Excellent

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Understanding the atmospheric circulations that lead to high particulate matter concentrations on the west coast of Namibia. Liebenberg-Enslin, H., Rautenbach, H., von Gruenewaldt, R. and Burger, L.W. *Clean Air Journal*, Volume 27, No.2, 2017.

- Understanding the Synoptic Systems that Lead to Strong Easterly Wind Conditions and High Particulate Matter Concentrations on the West Coast of Namibia. Liebenberg-Enslin, H., von Gruenewaldt, R., Rauntenbach, H., and Burger, L.W. 2017 Conference of the National Association for Clean Air. 4-6 October 2017. CedarWoods of Sandton, 120 Western Service Road, Woodmead, Gauteng.

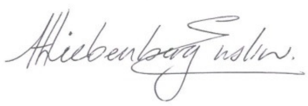
- Cooperation on Air Pollution in Southern Africa: Issues and Opportunities. SLCPs: Regional Actions on Climate and Air Pollution. Liebenberg-Enslin, H. 17th IUAPPA World Clean Air Congress and 9th CAA Better Air Quality Conference.

Clean Air for Cities - Perspectives and Solutions. 29 August - 2 September 2016, Busan Exhibition and Convention Center, Busan, South Korea.

- A Best Practice prescription for quantifying wind-blown dust emissions from Gold Mine Tailings Storage Facilities. Liebenberg-Enslin, H., Annegarn, H.J., and Burger, L.W. VIII International Conference on Aeolian Research, Lanzhou, China. 21-25 July 2014.
- Quantifying and modelling wind-blown dust emissions from gold mine tailings storage facilities. Liebenberg-Enslin, H. and Annegarn, H.J. 9th International Conference on Mine Closure, Sandton Convention Centre, 1-3 October 2014.
- Gauteng Transport Air Quality Management Plan. Liebenberg-Enslin, H., Krause,N., Burger, L.W., Fitton, J. and Modisamongwe, D. National Association for Clean Air Annual Conference, Rustenburg. 31 October to 2 November 2012. Peer reviewed.
- Developing an Air Quality Management Plan: Lessons from Limpopo. Bird, T.; Liebenberg-Enslin, H., von Gruenewaldt, R., Modisamongwe, D. National Association for Clean Air Annual Conference, Rustenburg. 31 October to 2 November 2012. Peer reviewed.
- Modelling of wind eroded dust transport in the Erongo Region, Namibia, H. Liebenberg-Enslin, N Krause and H.J. Annegarn. National Association for Clean Air (NACA) Conference, October 2010. Polokwane.
- The lack of inter-discipline integration into the EIA process-defining environmental specialist synergies. H. Liebenberg-Enslin and LW Burger. IAIA SA Annual Conference, 21-25 August 2010. Workshop Presentation. Not Peer Reviewed.
- A Critical Evaluation of Air Quality Management in South Africa, H Liebenberg-Enslin. National Association for Clean Air (NACA) IUAPPA Conference, 1-3 October 2008. Nelspuit.
- Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007, Vanderbijl Park.
- Air Quality Management plan as a tool to inform spatial development frameworks – City of uMhlathuze, Richards Bay, H Liebenberg-Enslin and T Jordan. National Association for Clean Air (NACA) conference, 29 – 30 September 2005, Cape Town.

CERTIFICATION

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



1/02/2018

Full name of staff member: Hanlie Liebenberg-Enslin