Air Quality Impact Assessment for the additional Waste Rock Dumps at the Tharisa Mine

Project done for **SLR Consulting (South Africa) (Pty) Ltd**

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Version	Date	Comments
Rev 0	July 2022	For client review
Rev 1	August 2022	Addressed client comments

Competency Profiles

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

After earning her master's degree in science from the University of Johannesburg (formerly RAU) in Geography and Environmental Management. Hanlie Liebenberg-Enslin began her professional career in air quality management in 2000 when she joined Environmental Management Services (EMS). The same department at the University of Johannesburg awarded her a PhD in June 2014 with a focus on aeolian dust transport. She is one of the founding members of Airshed Planning Professionals and served as a director of the organization until May 2013, when she assumed the role of managing director.

She has worked across Africa and has considerable experience in the many aspects of air quality management, including impact- and health risk screening assessments, dispersion modelling simulations, and emissions quantification for a variety of source types. Hanlie has been involved in a few United Nations Environmental Programme (UNEP) projects and served as the project manager on numerous innovative air quality management plan (AQMP) developments. She also participates actively in the National Association for Clean Air (NACA) and the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA). She served as an external examiner for various MSc and PhD dissertations and lectured at air quality management courses.

Report author: Rochelle Bornman (M.Phil in GIS and Remote Sensing, University of Cambridge)

Rochelle Bornman started her professional career in Air Quality in 2008 when she joined Airshed after having worked in malaria research at the Medical Research Council in Durban. Rochelle has worked on several air quality specialist studies between 2008 and 2022. She has experience on the various components including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening 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.

Report reviewer: Gillian Petzer

Gillian has been with Airshed since 2003. She holds a bachelor’s degree in chemical engineering from the University of Pretoria. Her experience in air quality started in 2000 with the “Indoor Air Quality” division of Building Research Establishment (BRE) in the UK. Over the last two decades she has been actively involved in the development of atmospheric dispersion modelling and its applications, air pollution compliance assessments, health risk assessments, mitigation measures, development of air quality management plans, as well as meteorological and air quality monitoring programmes. She registered as a professional engineer in 2017. Whilst most of her working experience has been in South Africa, a number of investigations were made in countries throughput Africa as well as recent countries such as Afghanistan and Armenia.

NEMA Regulation (2017), Appendix 6

NEMA Regulations (2017) - Appendix 6		Relevant section in report
1.a)	Details of the specialist who prepared the report.	Report details (page ii)
	The expertise of that person to compile a specialist report including curriculum vitae.	Report details (page ii) Appendix A
1.b)	A declaration that the person is independent in a form as may be specified by the competent authority.	Report details (page i)
1.c)	An indication of the scope of, and the purpose for which, the report was prepared.	Introduction and background (Executive Summary) Section 1.2: Scope of Work Section 1.3: Approach and Methodology
	An indication of the quality and age of base data used for the specialist report.	Section 3.2: Atmospheric Dispersion Potential Section 3.3 Baseline Air Quality
	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change.	Section 5: Impact Significance Rating
1.d)	The duration date and season of the site investigation and the relevance of the season to the outcome of the assessment.	Section 3.2: Atmospheric Dispersion Potential Section 3.4: Baseline Air Quality
1.e)	A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used.	Section 1.3: Approach and Methodology Section 1.4: Management of Uncertainties
1.f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternative.	Section 3.1: Receiving Environment Section 4: Impact Assessment Section 5: Impact Significance Rating
1.g)	An identification of any areas to be avoided, including buffers.	Not applicable
1.h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers.	Section 3.1: Receiving Environment Section 4.3: Atmospheric Dispersion Modelling
1.i)	A description of any assumptions made and any uncertainties or gaps in knowledge.	Section 1.3: Management of Uncertainties
1.j)	A description of the findings and potential implications of such findings on the impact of the proposed activity or activities.	Section 4: Impact Assessment
1.k)	Any mitigation measures for inclusion in the environmental management programme report	Section 6: Air Quality Management Measures
1.l)	Any conditions for inclusion in the environmental authorisation	Section 8: Conclusions and Recommendations
1.m)	Any monitoring requirements for inclusion in the environmental management programme report or environmental authorisation.	Section 6.3: Performance Indicators
1.n)	A reasoned opinion as to whether the proposed activity, activities or portions thereof should be authorised.	Section 8: Conclusions and Recommendations
	A reasoned opinion regarding the acceptability of the proposed activity or activities.	Section 8: Conclusions and Recommendations
	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the environmental management programme report, and where applicable, the closure plan.	Section 8: Conclusions and Recommendations
1.o)	A description of any consultation process that was undertaken during the course of carrying out the study.	Not applicable
1.p)	A summary and copies if any comments that were received during any consultation process.	Not applicable
1.q)	Any other information requested by the competent authority.	Not applicable.

Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
AQSR	Air Quality Sensitive Receptors
ASTM	American Standard Testing Method
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and Environment (previously DEA)
DOE	U.S. Department of Energy
EHS	Environmental, Health, and Safety (IFC)
EIA	Environmental Impact Assessment
FDA	US Food and Drug Administration
GLC	Ground Level Concentration
HQ	Hazard Quotient
I&APs	Interested and Affected Parties
IFC	International Finance Corporation
Ltd	Limited
MEI	Maximally Exposed Individual
NAAQS	National Ambient Air Quality Standards
NDCR	National Dust Control Regulations
NEMAQA	National Environment Management Air Quality Act
NPI	National Pollutant Inventory (Australia)
ORO	Oak Ridge Operations
PGMs	Platinum group metal
PSD	Particle size distribution
RAIS	Risk Assessment Information System
RfC	Reference Concentrations
ROM	Run-of-mine
SABS	South African Bureau of Standards
SANS	South African National Standards
SAWS	South African Weather Services
SoW	Scope of Work
Tharisa	Tharisa Minerals (Pty) Ltd
URFs	Unit risk factors
US EPA	United States Environmental Protection Agency
WHO	World Health Organisation

Symbols and Units

°C	Degrees Celsius
µg	Microgram(s)
µg/m³	Micrograms per cubic meter
L_{MO}	Monin-Obukhov Length
m/s	Meters per second
m^2	Metres squared
masl	Meters above sea level
mg	Milligram(s)
$mg/m^2/day$	Milligram per metre squared per day
mm	Millimeters
mtpa	million tons per annum
PM	Particulate Matter
PM_{10}	Thoracic particulate matter
$PM_{2.5}$	Respirable particulate matter
TSP	Total Suspended Particulate
%	Percentage

Glossary

Air pollution	This means any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances
Ambient Air	This is defined as any area not regulated by Occupational Health and Safety regulations
Atmospheric emission or emission	Any emission or entrainment process emanating from a point, non-point or mobile source that results in air pollution
Averaging period	This implies a period of time over which an average value is determined
Dispersion	The spreading of atmospheric constituents, such as air pollutants
Dust	Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size
Frequency of Exceedance	A frequency (number/time) related to a limit value representing the tolerated exceedance of that limit value, i.e. if exceedances of limit value are within the tolerances, then there is still compliance with the standard
Mechanical mixing	Any mixing process that utilizes the kinetic energy of relative fluid motion
Particulate Matter (PM)	These comprise a mixture of organic and inorganic substances, ranging in size and shape. These can be divided into coarse and fine particulate matter. The former is called Total Suspended Particulates (TSP), whilst PM_{10} and $PM_{2.5}$ fall in the finer fraction.
PM_{10}	Particulate Matter with an aerodynamic diameter less than or equal to 10 µm. it is also referred to as thoracic particulates and is associated with health impacts due to its tendency to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than or equal to 2.5 µm. it is also referred to as respirable particulates. It is associated with health impacts due to its high tendency to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung
Vehicle Entrainment	This is the lifting and dropping of particles by the rolling wheels leaving the road surface exposed to strong air current in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed

Executive Summary

Tharisa Minerals (Pty) Ltd (Tharisa), an opencast mining operation that has been operational since 2008, produces chrome and platinum group metal (PGMs) concentrates. Mining is undertaken in two mining sections, namely the East Mine and West Mine, using conventional open pit truck and shovel methods. Key existing mine infrastructure includes haul roads, run-of-mine stockpiles, a concentrator complex, various product stockpiles, topsoil stockpiles, waste rock dumps (WRDs), Tailings Storage Facilities (TSFs) and supporting infrastructure such as offices, workshops, change houses and access control facilities.

Additional waste rock handling and storage capacity is required to accommodate the waste rock from the open pit operations, and as part of its on-going mine planning, Tharisa has identified the need for additional WRD storage on site:

- The expansion of the existing and approved Far West WRD 1 by a footprint of 109 ha. The expanded area will be referred to as the West Above Ground (OG) WRD. Portions of the West OG WRD will be located on backfilled areas of the West Pit; and
- The establishment of a WRD (referred to as the East OG WRD) on backfilled portions of the East Pit. The proposed East OG WRD will cover an area of approximately 72 ha.

The proposed Project activities will result in air quality impacts in the study area. Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by SLR Consulting (South Africa) (Pty) Ltd to conduct an air quality impact assessment for the Project. The main objective of the air quality specialist study was to determine the potential impact on ambient air quality and air quality sensitive receptors (AQSRs) as a result of the project and to recommend suitable mitigation and management measures.

A quantitative air quality assessment was conducted as part of the Environmental Impact Assessment (EIA) Amendment, including an assessment of the current operations at Tharisa Mine and the future Project operations. Main sources of emissions were identified with the most significant pollutants quantified. Dispersion model simulations were conducted to determine the potential for impacts from the current and proposed future Project operations on the surrounding environment and human health, with the significance rating thereof determined following the methodology provided by SLR.

Main Findings

The findings from the **baseline characterisation** can be summarised as follows:

- Tharisa is an existing opencast chrome and platinum mine using conventional open pit truck and shovel methods, with two mining sections namely the East Mine and West Mine. Tharisa produces chrome and PGMs concentrates.
- The mine is surrounded by communities and settlements, with the Maditlhokwa community directly to the north of West Mine and Lapologang community directly to the southwest. The town of Marikana approximately 1.5 km to the north of the mining rights boundary, with a number of households, farmsteads, and schools in the immediate vicinity of the mine.

- Tharisa Mine does not have a weather station and use was made of simulated Waste Rock Dump (WRF) data for the period 1 January 2019 – 31 December 2021. The general wind field from the south and north, with northerly winds dominating during daytime, shifting to south and south-southwest winds during the night. Calm conditions occur for 7.6% of the time with a period average wind speed of 3.2 m/s. Wind speeds exceeding 5.4 m/s occurred for 8% over the three years. There is a district variation in the wind field between seasons, with winds from most sectors during summer but shifting to southerly winds during autumn and winter with northerly winds dominating during spring.
- The area experiences hot temperatures during summer, with maximum of 36.4°C for the month of October, and low winter temperatures especially in the months of May to July.
- The total annual rainfall for the Project site is given to be between 873 mm and 939 mm, occurring mostly between the months of October and April.
- The main pollutant of concern in the region is particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved and unpaved surfaces), mining and smelter activities, farming activities and windblown dust from exposed surfaces, mine waste dumps and TSFs. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles, mining equipment, smelter and processing emissions.
- A dustfall network is in place comprising of 15 single dust buckets located at and around Tharisa Mine, and passive sampling is conducted at three locations to determine background SO_2 and NO_2 concentrations. Data available for inclusion in this study was limited to the period January to March 2021 and January to March 2022.
    - Results obtained for NO_2 and SO_2 for the months in review were well below the NAAQS.
    - Dustfall only exceeded the NDCR residential limit (600 mg/m²/day) at Sites 2 (toll gate) and 8 (school) during January 2021 and February 2021, respectively. As the NDCR allow for a permitted frequency of exceeding the dustfall rate of two within a year (not sequential months), it could not be determined if the site is compliant or not, as there was not a full year of data available.

The findings from the **impact assessment** can be summarised as follows:

- Construction Phase: Construction activities were not assessed separately since most of the expansion operations will be on disturbed surfaces with little additional land clearing or preparation required. Also, these activities will occur concurrently with the current mining activities. The significance of air quality impacts due to construction are therefore expected to be **Low** without mitigation and **Very Low** with mitigation measures in place.
- Current Operations:
    - Simulated PM_{10} daily ground level concentrations (GLCs), with current mitigation measures in place, are in non-compliance with the NAAQS over a portion of the Maditlhokwa Community and to the north-east of the mining rights boundary, but at no other AQSRs. Annual average GLCs are within compliance with the NAAQS at all AQSRs, except at Maditlhokwa Community.

- $PM_{2.5}$ GLCs are much lower compared to PM_{10} with exceedances of the NAAQS only at Madithlokwa when no mitigation is applied and no exceedances at any of the AQSRs with mitigation measures applied.
- Simulated maximum daily dustfall rates for current mitigated operations are within the NDCR non-residential limit (1 200 mg/m²/day) and the residential limit (600 mg/m²/day) at all the AQSRs.
- The significance of air quality impacts due to the current operational activities are **High** without mitigation in place and **Medium** with mitigation measures.

- Future Project operations:
  - PM_{10} GLCs without mitigation in place exceed the daily NAAQS at 14 of the AQSRs, including the communities of Lapologang and Madithlokwa, and the annual NAAQS at four (4) AQSRs. With mitigation in place the area of exceedance is reduced to fall mostly within the mining rights boundary with non-compliance of the daily and annual NAAQS only at Madithlokwa.
  - Without mitigation measures in place, $PM_{2.5}$ GLCs exceed only the daily NAAQS outside the mining rights boundary and at Madithlokwa. With mitigation in place the impact area reduces to fall within the mining rights boundary with no exceedances at any of the AQSRs.
  - Dustfall rates only exceed the NDCR non-residential limit (1 200 mg/m²/day) and the residential limit (600 mg/m²/day) at the southeast of Madithlokwa without mitigation and reduce to a small area in the southeast of Madithlokwa with mitigation in place.
  - Metals associated with the mine dust include aluminium (Al), barium (Ba), chromium (VI)(particulates), copper (Cu), iron (Fe), manganese (Mn), and nickel (Ni). The hazard quotient (HQ) was below 1 for all the metals evaluated, implying that adverse non-cancer effects are unlikely to occur due to exposure from these elements. The Excess Lifetime Cancer Risk associated with CrVI exposure was Moderate (one in ten thousand to less than one in a thousand) with a low risk (greater than one in a million to less than one in ten thousand) associated to Fe and a very low risk (equal to or less than one in a million) to Ni. It should be noted that the assumption that all Cr is CrVI is regarded as overly conservative.
  - The future Project operations will result in **High** significance without mitigation, reducing to **Medium** significance with mitigation measures in place.
- Closure: The likely activities to result in dust impacts during closure will be similar to construction, resulting in a **Low** significance without mitigation and **Very Low** with mitigation measures in place.

Conclusions

Impacts due to the future Project were assessed with respect to the expansion of the existing and approved Far West WRD 1 (with a portion above ground and a portion located on backfilled areas of the West Pit), and the new East WRD which will be in the East Pit.

Exceedances of the NAAQS were predicted at 14 AQSRs for PM_{10} and at one AQSR for $PM_{2.5}$ under the unmitigated project scenario. With mitigation measures in place, exceedances of the NAAQS are limited to Madithlokwa. For the current mitigated operations exceedances of the NAAQS for PM_{10} are limited to Maditlhokwa. Simulated dustfall levels also only exceeded NDCR for residential areas at Maditlhokwa for mitigated current and future Project operations. No significant differences in air quality impacts from the future Project were found in comparison to the current operations, assuming mitigation measures will be in place. The contribution from vehicle entrainment on the surface roads are likely to be less due to the future Project with a more significant contribution from the in-pit operations due to part of the WRD expansion falling within the East Pit.

The community of Maditlhokwa is currently impacted negatively by the current mining operations with mitigation measures in place and is likely to be similarly impacted on by the future Project operations with mitigation measures in place. From an air quality perspective, the proposed project can be authorised permitted the recommended mitigation and monitoring measures are applied, and PM_{10} monitoring is done in Maditlhokwa to ensure compliance with the NAAQS and NDCRs.

Recommendations

A summary of the recommendations and management measures is given below:

- Construction and closure phases:
  - limiting the speed of haul trucks;
  - limit unnecessary travelling of vehicles on unpaved roads; and
  - apply water sprays on regularly travelled, unpaved sections and freshly graded surfaces.
- Operational phases:
  - In controlling dust due to drilling operations, dust suppression must be fitted on drill rigs to achieve an emission reduction efficiency of 97%.
  - For the control of vehicle entrained dust it is recommended that i) water sprays be applied to in-pit haul roads ensure a control efficiency of 75% (application rate >2 litre/m²/hour should achieve this), and ii) chemical suppressants be applied to all regularly used surface haul roads to achieve a 90% control efficiency.
  - In controlling dust from mobile crushing operations, it is recommended that water sprays be applied to keep the ore wet at the primary crushers to achieve a control efficiency of up to 50%, and enclosure with extraction systems at the secondary crushers and screens to achieve a minimum of 65% control efficiency.
  - Mitigation of materials transfer points should be done by reducing excavator drop heights into haul trucks, using water sprays at the tip points and where dozers operate to ensure a minimum of 50% control efficiency. Also, regular clean-up at loading points is recommended.

- In minimizing windblown dust from stockpile areas, water sprays should be used to keep surface material moist as well as active areas on WRDs (a mitigation efficiency of 50 % is anticipated). Reshaping and covering disturbed areas with topsoil and replanting native species will further reduce the potential for wind erosion.
- To ensure that mitigation is effective, it is recommended that the dustfall monitoring network at the mine be maintained and the monthly dustfall results used as indicators to track the effectiveness of the applied mitigation measures. Due to the potential for non-compliance of both current and future operations at Tharisa Mine, it is recommended that PM_{10} sampling be conducted at Maditlhokwa Community.

Table of Contents

List of Tables

List of Figures

1 Introduction

Tharisa Minerals (Pty) Ltd (Tharisa), an opencast mining operation that has been operational since 2008, produces chrome and platinum group metal (PGMs) concentrates. The opencast mine is located on farms 342 JQ and Elandsdrift 467 JQ, south of the town of Marikana, in the North West Province.

Mining is undertaken in two mining sections, namely the East Mine and West Mine, using conventional open pit truck and shovel methods. The two mining sections are separated by the perennial Sterkstroom River and the D1325 (Marikana Road). Waste rock from the open pit areas is stockpiled on Waste Rock Dumps (WRDs) and some in-pit dumping of waste rock has taken place at the East Mine. Key existing mine infrastructure includes haul roads, run-of-mine stockpiles, a concentrator complex, various product stockpiles, topsoil stockpiles, WRDs, Tailings Storage Facilities (TSFs) and supporting infrastructure such as offices, workshops, change houses and access control facilities.

As part of its on-going mine planning, Tharisa has identified the need for additional waste rock storage on-site (hereafter referred to as the project). In this regard, Tharisa is making an application to the Department of Mineral Resources and Energy (DMRE) for an integrated Environmental Assessment (EA) and update of the mine's current Environmental Management Program (EMPr). The following activities are proposed (Figure 1):

- The expansion of the existing and approved Far West WRD 1 by a footprint of 109 ha. The expanded area will be referred to as the West Above Ground (OG) WRD. Portions of the West OG WRD will be located on backfilled areas of the West Pit; and
- The establishment of a waste rock dump (referred to as the East OG WRD) on backfilled portions of the East Pit. The proposed East OG WRD will cover an area of approximately 72 ha.

As part of the process, specialist studies need to be undertaken. Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by SLR Consulting (Africa) (Pty) Ltd (SLR) to undertake a specialist air quality impact study for the proposed project.

1.1 Study Objective

The main objective of the investigation is to quantify the potential impacts resulting from the proposed activities on the surrounding environment and human health. As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the current and potential future air quality.

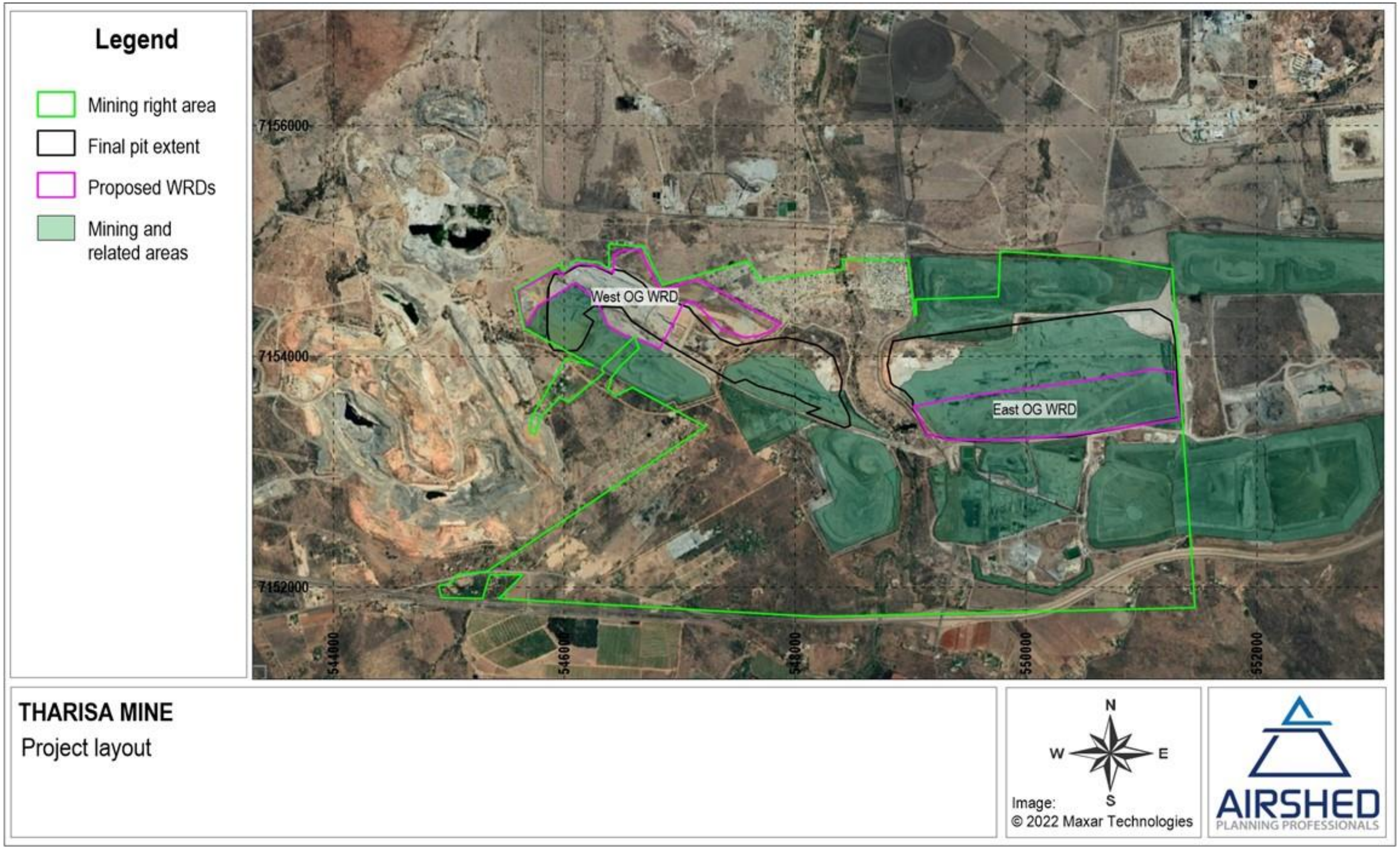

Figure 1: Proposed layout of the Tharisa Mine project

1.2 Scope of Work

To meet the above objective, the following tasks were included in the Scope of Work (SoW):

1. A review of available project information.
2. A review of the legislative framework within which air quality is regulated in South Africa.
3. A study of the affected atmospheric environment, including:
    a. The identification of air quality sensitive receptors (AQSRs);
    b. An analysis of the atmospheric dispersion potential around Tharisa Mine; and
    c. A review of available data to determine the status of current air quality in the study area.
4. An impact assessment, including:
    a. The establishment of a source inventory for current and proposed activities;
    b. Atmospheric dispersion simulations to determine potential air quality impacts as a result of the current and project activities;
    c. Screening of simulated results against relevant environmental standards; and
    d. A qualitative cumulative air quality assessment.
5. Identification and recommendation of suitable mitigation measures and monitoring requirements.
6. Preparation of comprehensive air quality impact assessment report in the prescribed specialist report format.

1.3 Approach and Methodology

The air quality study includes the assessment of both current and proposed project operations. The approach to, and methodology followed in the completion of tasks (or scope of work) are discussed below.

1.3.1 Project Information and Activity Review

An information requirements list was sent to SLR Consulting (South Africa) (Pty) Ltd at the onset of the project. In response to the request, the following information was supplied:

- Layout maps;
- Process descriptions;
- Annual throughputs (current activities); and
- A mining equipment list.

Documentation reviewed included the following:

- Air Quality Impact Assessment for Tharisa Mine (Green Gold Group (Pty) Ltd, 2019).

1.3.2 The Identification of Regulatory Requirements and Health Thresholds

In the evaluation of ambient air quality impacts and dustfall rates reference was made to:

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

1.3.3 Study of the Receiving Environment

The baseline environment was studied by taking into account:

- The local atmospheric dispersion potential;
- The position of AQSRs in relation to the project; and
- Measured ambient air quality in the study area.

As part of the air quality assessment, a good understanding of the regional climate and local dispersion potential of the site is necessary, as well as an understanding of existing sources of air pollution in the region and the current and potential future air quality. Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology.

Modelled WRF meteorological data was obtained for the period 1 January 2019 to 31 December 2021 for dispersion modelling purposes and to describe the local dispersion potential. The dataset included a minimum of hourly average wind speed, wind direction and temperature station. For the purposes of establishing the local climatology, it is necessary to analyse at least one year of on-site data; and at the regulations on Dispersion Modelling (DEA, 2014).

Available measured air quality data included a passive sampling campaign of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) conducted over three months in 2021 (January – March), and dustfall results from 15 locations around Tharisa Mine for the periods January – March 2021, and January – March 2022.

Readily available terrain data was obtained from the United States Geological Survey (USGS) web site (https://earthexplorer.usgs.gov/) in June 2022. A study was made of Shuttle Radar Topography Mission (STRM) 1 arc-sec data.

AQSRs generally include private residences, community buildings such as schools, hospitals, and any publicly accessible areas outside an industrial facility's property. Potential AQSRs were identified from recent maps of the area using Google Earth™ aerial imagery.

1.3.4 Determining the Impact of the Project on the Receiving Environment

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's emissions on the receiving environment. In the quantification of emissions, use was made of emission factors which associate the quantity of release of a pollutant to the activity. Emissions were calculated using emission factors and equations published by the United States Environmental Protection Agency (US EPA) and Environment Australia (EA) in their National Pollutant Inventory (NPI) Emission Estimation Technique Manuals (EETMs).

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. As per the National Code of Practice for Air Dispersion Modelling use was made of the US EPA approved AERMOD atmospheric dispersion modelling suite for the simulation of ambient air pollutant concentrations and dustfall rates.

The dispersion model uses the specific input data to run various algorithms to estimate the dispersion of pollutants between the source and receptor. The model output is in the form of a simulated time-averaged concentration at the receptor. These simulated concentrations are added to suitable background concentrations and compared with the relevant ambient air quality standard or guideline.

Ground level concentration (GLC) isopleths plots presented in this report depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified. Plots reflecting daily averaging periods contain only the 99.73th percentile of simulated ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily average concentration is simulated at certain locations, this may only be true for one day during the period. NAAQS apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the mine property or lease area. The NAAQS are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site.

1.3.5 Compliance Assessment

The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications were used to assess the impact and recommend additional emission controls, mitigation measures and air quality management plans to maintain the impact of air pollution to acceptable limits in the study area. The model results were analysed against the NAAQS and dustfall criteria.

1.3.6 Impact Significance

Potential impacts of the proposed project were identified based on the baseline data, project description, review of other studies for similar projects and professional experience. The significance of the impacts was assessed using the prescribed SLR impact rating methodology provided. The significance of an impact is defined as a combination of the consequence of the impact occurring and the probability that the impact will occur. The impact significance was rated for unmitigated operations and assuming the effective implementation of design mitigation measures.

1.3.7 The Development of an Air Quality Management Plan

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

1.4 Management of Uncertainties

The main assumptions, exclusions and limitations are summarized below:

- Meteorological data: no onsite meteorological data was available and simulated WRF data for the study site was obtained for the period January 2019 – December 2021.
- Tharisa Mine has a dustfall network in place and conduct passive sampling campaigns to determine background SO_2 and NO_2 concentrations. Data available for inclusion in this study was limited to the period January to March 2021 and January to March 2022.
- Operational hours for the mine were assumed to be 24-hours a day, 7-days per week.

- Emissions:
    - The quantification of sources of emission was for project activities only. Background sources were not included.
    - Information required for the calculation of emissions from fugitive dust sources for the current and project operations were provided in the form of volume/ tonnages of topsoil, waste, and reef for a 12-month period covering October 2021– September 2022.
    - Throughputs were provided for current activities only. Since no other information was available, it was assumed that project operations will have the same throughput but at different locations (pit areas and WRDs).
    - Only routine emissions were estimated and modelled. This was done for the provided operational hours.
    - Gaseous emissions from vehicle exhaust and other auxiliary equipment were quantified but not modelled as the impacts from these sources are usually localized and unlikely to exceed health screening limits outside the project area. The main pollutant of concern from the operations at the study site is particulate matter and hence formed the focus of the study.
    - Particle size distribution (PSD) for waste rock, tailings and surface road material was based on analysis of composite samples taken by Airshed personnel during the site visit on 22 April 2022. PSD for ROM and product stockpiles were assumed to be similar to waste.
    - The composite samples (waste rock and tailings) were further analysed for metal composition and used to determine the potential health impacts from the metal content in the inhalable dust. A unit risk factor (URF) applied in the calculation of carcinogenic risk is only available for hexavalent chromium, and since the dust from the mine and process operations are primarily mechanically generated the potential for hexavalent chromium is small, thus resulting in an overly conservative estimation of the cancer risk from chrome as assessed in Section 4.4.4.
- Impact assessment:
    - Impacts due to two operational phases (baseline and project) were assessed quantitatively, whilst the closure and decommissioning phases were assessed qualitatively due to the limited information available. Since it is an operational mine, construction activities will coincide with the current mining operations and were therefore not assessed.
    - The impact assessment was limited to airborne particulate (including TSP[1], PM_{10} and $PM_{2.5}$[2]).
    - There will always be some degree of uncertainty in any geophysical model, but it is desirable to structure the model in such a way to minimize the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere. Nevertheless, dispersion modelling is generally accepted as a necessary and valuable tool in air quality management and typically provides a conservative prediction of emission concentrations.

[1] Total suspended particulates
[2] Particulate Matter with an aerodynamic diameter less than or equal to 2.5 µm.

2 Regulatory Requirements and Impact Assessment Criteria

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

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

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging or exposure periods.

This section summarises legislation for particulate matter (PM) concentrations and dustfall. Discussions on regulations regarding dispersion modelling and emissions reporting are also provided.

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's 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 measurement 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 Emission Standards

The NEMAQA (Act No. 39 of 2004 as amended) (DEA, 2005) mandates the Minister of Environment to publish a list of activities which result in atmospheric emissions and consequently cause significant detrimental effects on the environment, human health and social welfare. All scheduled processes as previously stipulated under the Air Pollution Prevention Act (APPA) (Dept of Labour, 1993) are included as listed activities with additional activities added to the list. The updated Listed Activities and Minimum National Emission Standards (MES) were published on the 22nd November 2013 (Government Gazette No. 37054). An amendment to this Act was published in June 2015.

Tharisa Mine produces PGM concentrate and does not operate a smelter, and none of the Project activities trigger the MES's nor the need for an AEL application.

2.3 Ambient Air Quality Standards for Criteria Pollutants

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. These include carbon monoxide (CO), nitrogen dioxide (NO_2,), sulfur dioxide (SO_2), $PM_{2.5}$ and PM_{10}. The main pollutant of concern for this study is particulate matter.

The South African Bureau of Standards (SABS) assisted the Department of Forestry, Fisheries and the Environment (DFFE) in the development of 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. NAAQS for $PM_{2.5}$ was published on 29 July 2012. The NAAQS are listed in Table 1.

Table 1: South African National Ambient Air Quality Standards (Government Gazette 32816, 2009)

Substance	Molecular formula / notation	Averaging period	Concentration limit (µg m^{-3})	Frequency of exceedance[a]	Compliance date[b]
Particulate matter	PM_{10}	24 hours	75	4	Currently enforceable
		1 year	40	-	Currently enforceable
Fine particulate matter	$PM_{2.5}$	24 hours	40	4	1 Jan 2016 – 31 Dec 2029
			25		1 Jan 2030
		1 year	20	-	1 Jan 2016 – 31 Dec 2029
			15		1 Jan 2030
Sulfur dioxide	SO_2	10 minutes	500	526	Currently enforceable
		1 hour	350	88	Currently enforceable
		24 hours	125	4	Currently enforceable
		1 year	50	-	Currently enforceable
Nitrogen dioxide	NO_2	1 hour	200	88	Currently enforceable
		1 year	40	-	Currently enforceable
Ozone	O_3	8 hours (running)	120	11	Currently enforceable
Benzene	C_6H_6	1 year	5	-	Currently enforceable
Lead	Pb	1 year	0.5	-	Currently enforceable
Carbon monoxide	CO	1 hour	30 000	88	Currently enforceable
		8 hours (based on 1-hourly averages)	10 000	11	Currently enforceable

Notes: [a] The number of averaging periods where exceedance of limit is acceptable.
[b] Date after which concentration limits become enforceable.

2.4 National Dust Control Regulations

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) with changes in regulations published in 2018 (Notice 517 GG 41650 of 25 May 2018). 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 2.

Table 2: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m^2-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 American Standard Testing Method (ASTM, 1970)[3], 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 Inhalation Health Criteria for non-criteria Pollutants

Various non-carcinogenic exposure thresholds for pollutants of interest in the current study are given in Table 3. These Reference Concentrations (RfC) were obtained from the US EPA's Risk Assessment Information System (RAIS). RAIS has been sponsored by the U.S. Department of Energy (DOE), Office of Environmental Management, Oak Ridge Operations (ORO) Office through a contract between URS | CH2M Oak Ridge LLC and the University of Tennessee. The database is subject to quality assurance review before being published. It should be noted that these screening criteria are guidelines only and are not a legal requirement.

To assess non-carcinogen impacts, a hazard quotient (HQ) is calculated for each substance. The HQ is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected (calculated as the exposure divided by the appropriate chronic or acute RfC value). A HQ of 1 or lower means adverse non-cancer effects are unlikely, and thus can be considered to have negligible hazard. For HQs greater than 1, the potential for adverse effects increases, but we do not know by how much. The sum of all HQ's is known as the hazard index (HI). Because different air toxics can cause similar adverse health effects, combining HQ from different toxins is often appropriate. A HI of 1 or lower means air toxins are unlikely to cause adverse noncancer health effects over a lifetime of exposure. However, an HI greater than 1 does not necessarily mean adverse effects are likely.

2.5.1 Cancer Health Risk Factors

Unit risk factors (URFs) are applied in the calculation of carcinogenic risks. These factors are defined as the estimated probability of a person (60-70 kg) contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m³ over a 70-year lifetime. Unit risk factors were obtained from the sources described in the previous section and summarised in Table 3.

The identification of an acceptable cancer risk level has been debated for many years and it possibly will continue as societal norms and values change. Some people would easily accept higher risks than others, even if it were not within their own control; others prefer to take very low risks. An acceptable risk is a question of societal acceptance and will therefore vary from society to society. Despite the difficulty to provide a definitive "acceptable risk level", the estimation of a risk associated with an activity provides the means for a comparison of the activity to other everyday hazards, and therefore allowing risk-management policy decisions.

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[3] ASTM 1739:70 is a previous version of ASTM 1739 which did not prescribe a wind shield around the opening of the bucket; the addition of a wind shield is intended to deflect wind away from the lip of the container, allowing for a more laminar flow across the top of the collecting container (Kornelius *et al*., 2015). SANS 1929-2004 does however refer to ASTM 1739-98 (ASTM, 1998), which has a wind shield.

Table 3: Inhalation RfCs for identified metals

Metal	Chronic Inhalation RfC (mg/m³)	Chronic Inhalation RfC (reference)	Sub-chronic Inhalation RfC (mg/m³)	Sub-chronic Inhalation RfC (reference)	Short-term Inhalation RfC (mg/m³)	Short-term Inhalation RfC (reference)	Acute inhalation RfC (mg/m³)	Acute Inhalation RfC (reference)	Inhalation Unit Risk (µg/m³)$^{-1}$	Inhalation Unit Risk (reference)
Aluminium (Al)	5.00×10^{-3}	PPRTV								
Barium (Ba)	5.00×10^{-4}	HEAST	5.00×10^{-3}	HEAST						
Chromium (CrVI) - particulates	1.00×10^{-4}	IRIS							8.40×10^{-2}	IRIS
Copper (Cu)							1.00×10^{-1}	CALEPA		
Iron (Fe)									1.20×10^{-5}	CALEPA
Manganese (Mn)	1.50×10^{-3}	WHO								
Nickel (Ni) - refinery dust	1.40×10^{-5}	CALEPA					2.00×10^{-4}	CALEPA	2.40×10^{-4}	WHO/ IRIS
Nickel (Ni) - soluble salts	9.00×10^{-5}	ATSDR final	2.00×10^{-4}	ATSDR final	2.00×10^{-4}	ATSDR final	2.00×10^{-4}	CALEPA	2.60×10^{-4}	CALEPA

Notes: IRIS – IRIS U.S. EPA Integrated Risk Information System

CALEPA – California Environmental Protection Agency Office of Environmental Health Hazard Assessment

WHO – World Health Organization (WHO) guideline values

ATSDR – Minimal risk levels issued by the US Federal Agency for Toxic Substances and Disease Registry

HEAST – U.S. EPA Health Effects Assessment Summary Tables

During the middle 1970s, the US EPA and US Food and Drug Administration (FDA) issued guidance for estimating risks associated with small exposures to potentially carcinogenic chemicals. Their guidance made estimated risks of one extra cancer over the lifetime of 100 000 people (US EPA) or 1 million people (FDA) action levels for regulatory attention. Estimated risks below those levels are considered negligible because they add individually so little to the background rate of about 250 000 cancer deaths out of every 1 million people who die every year in the United States, i.e. 25%. Accepting 1 in 100 000 or 1 in a million risk translates to 0.004% or 0.0004% increase in the existing cancer risk level, respectively. Similarly, the European Parliament and the European Council, when considering the proposal for a Directive on Drinking Water, agreed that an excess lifetime risk of 1-in-a-million should be taken as the starting point for developing limit values. Whilst it is perhaps inappropriate to make a judgment about how much risk should be acceptable, through reviewing acceptable risk levels selected by other well-known organizations, the US EPA's application (next page) is the most suitable.

"If the risk to the maximally exposed individual (MEI) is no more than $1x10^{-6}$, then no further action is required. If not, the MEI risk must be reduced to no more than $1x10^{-4}$, regardless of feasibility and cost, while protecting as many individuals as possible in the general population against risks exceeding $1x10^{-6}$"

Some authorities tend to avoid the specification of a single acceptable risk level. Instead, a "risk-ranking system" is preferred. For example, the New York Department of Health produced a qualitative ranking of cancer risk estimates, from very low to very high (Table 4). Therefore, if the qualitative descriptor was "low", then the excess lifetime cancer risk from that exposure is in the range of greater than one per million to less than one per ten thousand.

Table 4: Excess Lifetime Cancer Risk (as applied by New York Department of Health)

Risk Ratio	Qualitative Descriptor
Equal to or less than one in a million	*Very low*
Greater than one in a million to less than one in ten thousand	*Low*
One in ten thousand to less than one in a thousand	*Moderate*
One in a thousand to less than one in ten	*High*
Equal to or greater than one in ten	*Very high*

2.6 Screening Criteria for Animals and Vegetation

Limited information is available on the impact of dust on vegetation and grazing quality. While there is little direct evidence of the impact of dustfall on vegetation in the South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dustfall rates greater than 400 mg/m²/day (Farmer, 1993). In addition, there is anecdotal evidence to indicate that over extended periods, high dustfall levels in grazing lands can soil vegetation and this can impact the teeth of livestock (Farmer, 1993).

2.7 Regulations regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to assess compliance with the relevant ambient air quality standards. Regulations regarding Air Dispersion Modelling were promulgated in Government Gazette No. 37804 vol. 589; 11 July 2014, (DEA, 2014) and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols, and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

a) in the development of an air quality management plan, as contemplated in Chapter 3 of the NEMAQA;
b) in the development of a priority area air quality management plan, as contemplated in section 19 of the NEMAQA;
c) in the development of an atmospheric impact report, as contemplated in section 30 of the NEMAQA; and,
d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the NEMAQA.

The Regulations have been applied to the development of this report. The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Chapter 2 of the Regulations present the typical levels of assessments, technical summaries of the prescribed models (SCREEN3, AERSCREEN, AERMOD, SCIPUFF, and CALPUFF) and good practice steps to be taken for modelling applications. The project falls under a Level 2 assessment – which is described as follows:

- The distribution of pollutant concentrations and deposition are required in time and space.
- Pollutant dispersion can be reasonably treated by a straight-line, steady-state, Gaussian plume model with first order chemical transformation. The model specifically to be used in the air quality impact assessment of the proposed operation is AERMOD.
- Emissions are from sources where the greatest impacts are in the order of a few kilometers (less than 50 km) downwind)

Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Chapter 3 of the Regulation prescribe the source data input to be used in the model. Dispersion models are particularly useful under circumstances where the maximum ambient concentration approaches the ambient air quality limit value and provide a means for establishing the preferred combination of mitigation measures that may be required.

Chapter 4 of the Regulations prescribe meteorological data input from onsite observations to simulated meteorological data. The chapter also gives information on how missing data and calm conditions are to be treated in modelling applications. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the diluting effect of the atmosphere.

Topography is also an important geophysical parameter. The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result.

The modelling domain would normally be decided on the expected zone of influence; the extent being defined by simulated ground level concentrations from initial model runs. The modelling domain must include all areas where the ground level concentration is significant when compared to the air quality limit value (or other guideline). Air dispersion models require a receptor grid at which ground-level concentrations can be calculated. The receptor grid size should include the entire modelling domain to ensure that the maximum ground-level concentration is captured and the grid resolution (distance between grid points) sufficiently small to ensure that areas of maximum impact adequately covered. No receptors should however be located within the property line as health and safety legislation (rather than ambient air quality standards) is applicable within the site.

Chapter 5 provides general guidance on geophysical data, model domain and coordinates system requirements, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air pollutant concentration data. Chapter 6 also provides guidance on the treatment of NO_2 formation from NOx emissions, chemical transformation of SO_2 into sulphates and deposition processes.

Chapter 7 of the Regulation outlines how the plan of study and modelling assessment reports are to be presented to authorities.

3 Description of the Receiving Environment

This chapter provides details of the receiving environment which is described in terms of:

- The identification of Air Quality Sensitive Receptors (AQSRs) from available maps and Google Earth imagery;
- A study of the atmospheric dispersion potential of the area taking into consideration local meteorology, land-use and topography;
- The identification of existing sources of emissions in the study area; and
- The analysis of all available ambient air quality information/data to determine pre-development ambient pollutant levels and dustfall rates.

3.1 Receiving Environment

AQSRs primarily refer to places where people reside; however, it may also refer to other sensitive environments that may adversely be affected by air pollutants. Ambient air quality guidelines and standards, as discussed under Section 2, have been developed to protect human health. Ambient air quality, in contrast to occupation exposure, pertains to areas outside of an industrial site/mine boundary where the public has access to and according to the NEMAQA, excludes areas regulated under the Occupational Health and Safety Act (Act No 85 of 1993) (Dept of Labour, 1993).

The closest residential developments to Tharisa Mine and the proposed Project consist of the Maditlhokwa and Lapologang communities, with the town of Marikana approximately 1.5 km to the north of the mining rights boundary. Individual farmsteads also surround the project area (Figure 2 as identified from Google Earth). The location of selected sensitive receptors (individual homesteads) that have the potential to be impacted by the project have been provided in Table 5.

Table 5: Nearest AQSRs in the vicinity of the mine

Receptor	Easting	Northing
AQSR1	25°43'56.58" S	27°27'31.47" E
AQSR2	25°44'01.67" S	27°27'29.85" E
AQSR3 (Wolvaardt Residence)	25°43'59.08" S	27°27'45.26" E
AQSR4 (van der Hoven Residence)	25°44'01.20" S	27°27'44.10" E
AQSR5 (Retief Primary School)	25°44'20.70" S	27°28'36.02" E
AQSR6 (Pretorius Residence)	25°44'23.72" S	27°28'17.35" E
AQSR7 (du Preez Residence)	25°44'31.14" S	27°28'13.41" E
AQSR8	25°44'37.38" S	27°28'44.96" E
AQSR9	25°44'43.15" S	27°28'26.07" E
AQSR10 (industrial)	25°44'44.48" S	27°28'08.56" E
AQSR11	25°44'55.12" S	27°27'48.04" E
AQSR12	25°44'58.58" S	27°28'31.27" E
AQSR13	25°45'03.48" S	27°28'21.24" E
AQSR14	25°44'55.45" S	27°27'10.91" E

Receptor	Easting	Northing
AQSR15	25°45'00.53" S	27°27'11.63" E
AQSR16	25°44'59.07" S	27°27'03.69" E
AQSR17	25°44'59.51" S	27°26'58.78" E
AQSR18	25°44'55.71" S	27°26'56.19" E
AQSR19	25°45'11.56" S	27°26'58.59" E
AQSR20	25°45'03.36" S	27°26'43.85" E
AQSR21	25°45'02.97" S	27°26'33.10" E
AQSR22	25°44'48.19" S	27°26'22.77" E
AQSR23	25°45'04.49" S	27°26'22.60" E
AQSR24	25°45'00.28" S	27°26'13.00" E
AQSR25	25°45'07.92" S	27°26'07.43" E
AQSR26	25°45'16.99" S	27°26'14.70" E
AQSR27	25°45'23.14" S	27°26'06.55" E
AQSR28	25°45'20.38" S	27°28'27.15" E
AQSR29	25°45'17.14" S	27°28'45.59" E
AQSR30	25°45'13.71" S	27°29'00.99" E
AQSR31	25°44'57.59" S	27°29'13.07" E
AQSR32	25°45'13.65" S	27°29'18.04" E
AQSR33	25°44'57.76" S	27°29'26.85" E
AQSR34 (Potgieter Residence)	25°45'01.54" S	27°29'35.04" E
AQSR35	25°45'19.31" S	27°29'33.01" E
AQSR36	25°45'17.58" S	27°29'43.51" E
AQSR37	25°45'12.25" S	27°29'56.34" E
AQSR38	25°45'23.00" S	27°30'08.07" E
AQSR39	25°45'12.37" S	27°30'23.43" E
AQSR40	25°44'58.18" S	27°30'28.74" E
AQSR41	25°44'51.59" S	27°30'38.53" E
AQSR42	25°44'57.06" S	27°30'47.42" E
AQSR43	25°44'55.34" S	27°30'55.36" E
AQSR44	25°45'21.11" S	27°31'05.52" E
AQSR45	25°43'08.70" S	27°29'01.42" E
AQSR46	25°42'18.33" S	27°29'07.99" E
AQSR47	25°42'38.48" S	27°29'56.16" E
AQSR48 (Lonmin Training Centre)	25°42'31.63" S	27°31'20.42" E

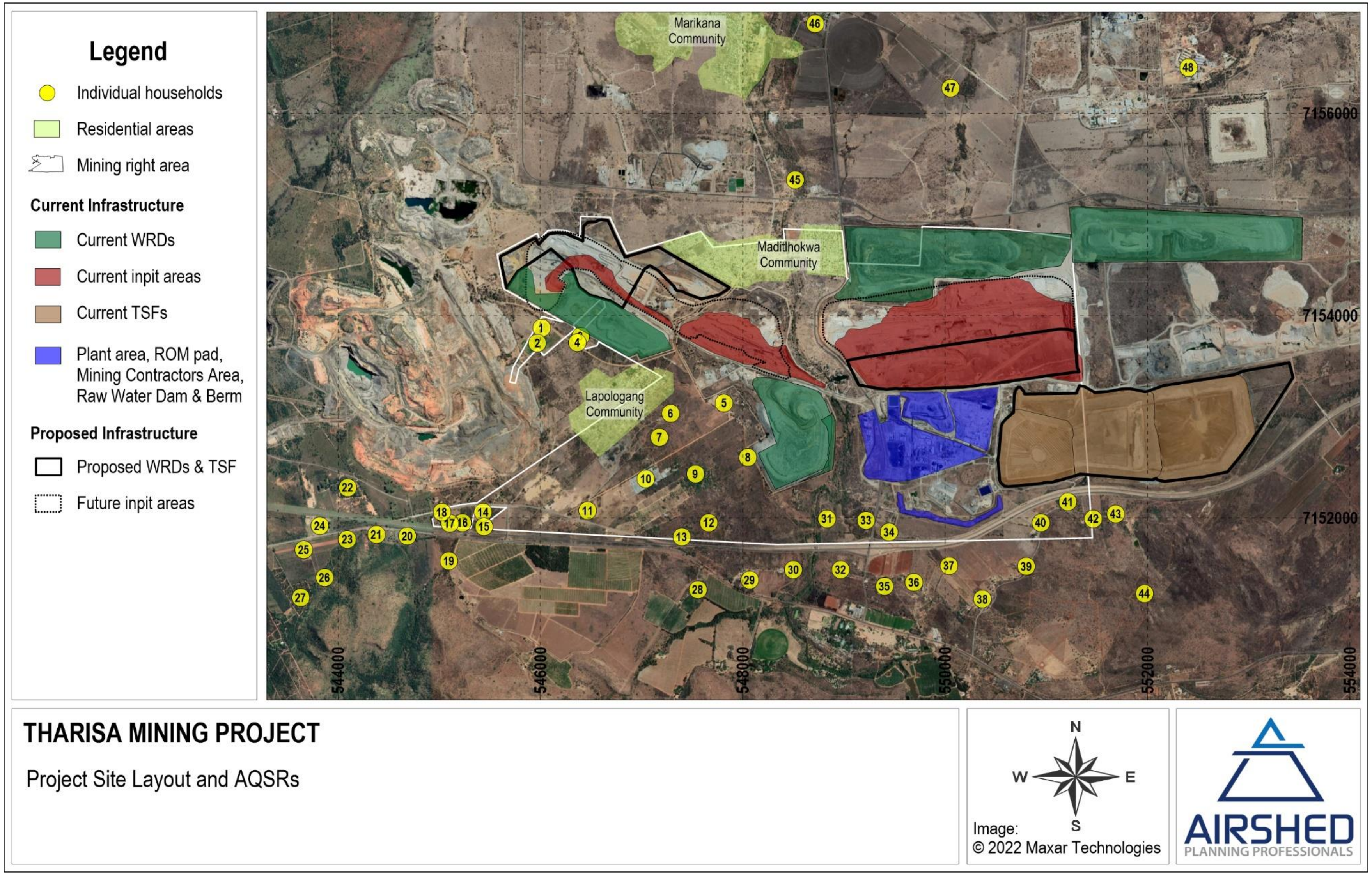


Figure 2: Tharisa Mine layout with AQSRs

3.2 Atmospheric Dispersion Potential

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

Tharisa Mine does not have a weather station and use was made of simulated WRF data for the period 1 January 2019 – 31 December 2021.

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.

The period wind field and diurnal variability in the wind field are shown in Figure 3. The average wind field is predominately from the south and north, with calm conditions 7.6% of the time. The daytime wind field is mainly from the north, ranging between north-west to north-east with 5.1% calm conditions. During the night, the wind field shifts to the south and south-southwest with less frequent winds from the south-easterly sector. The frequency of night-time calm conditions increases to 10.3%.

A distinct seasonal variation in the wind field in visible from Figure 4. During summer, the wind field is varied between most direction with more frequent winds from the north-eastern sector. The wind field shifts to south during autumn, with more frequent southerly winds during winter. During spring, the northerly winds increase with frequent north to north-east winds.

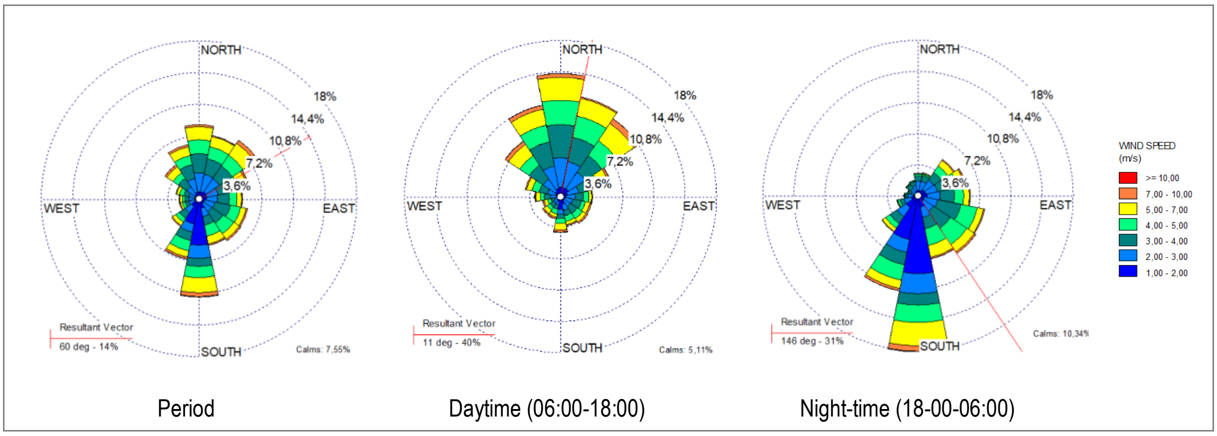


Figure 3: Period, day- and night-time wind roses (WRF data; 2019 to 2021)

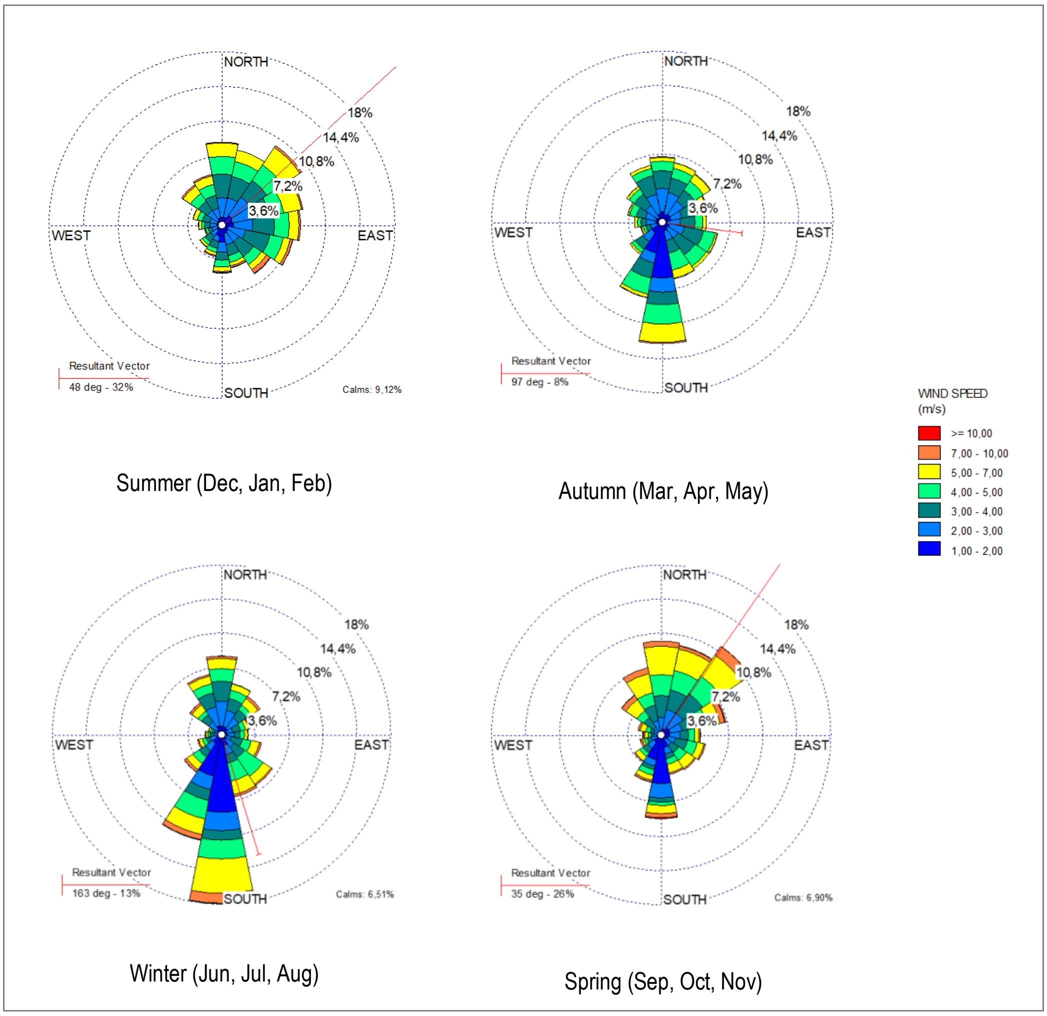


Figure 4: Seasonal wind roses (WRF data; 2019 to 2021)

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 WRF data, wind speeds exceeding 7 m/s occurred for only 3.3% of the time, with a maximum wind speed of 16.1 m/s. The average wind speed over the three years is 3.2 m/s with calm conditions (wind speeds < 1 m/s) occurring for 7.6% of the time (Figure 5). According to the US EPA, 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 (US EPA, 2006). Wind speeds exceeding 5.4 m/s occurred for 8% over the three years (2019 -2021).

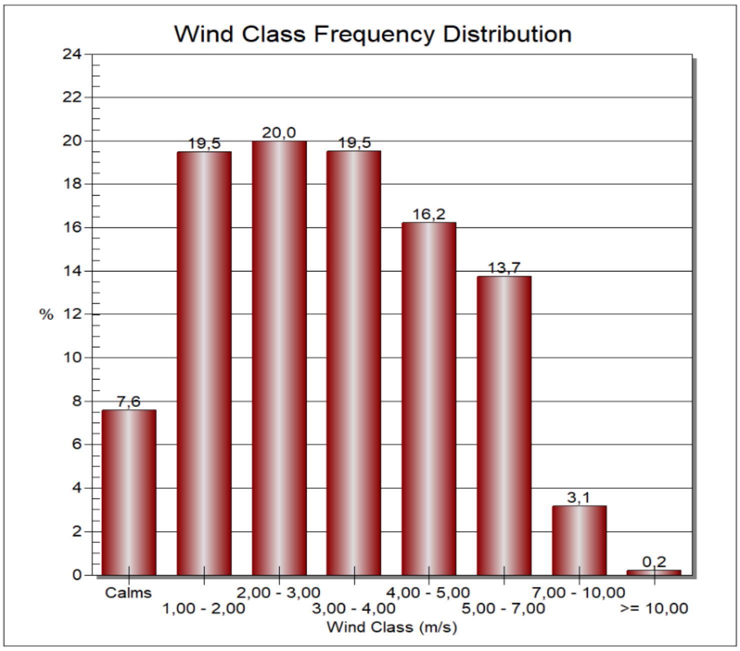


Figure 5: Wind speed categories (WRF data; 2019 to 2021)

3.2.2 Ambient 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 Figure 6. The area experiences hot temperatures during summer, with maximum of 36.4°C for the month of October. Winter temperatures are relatively low especially in the months of May to July.

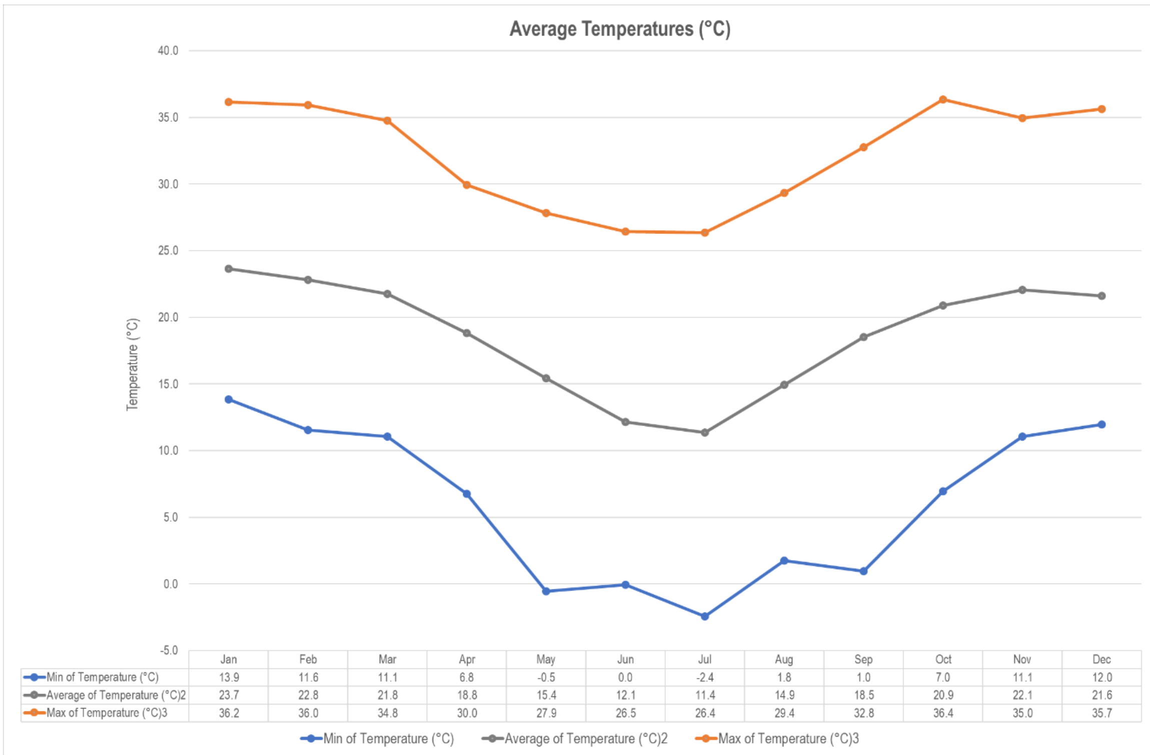


Figure 6: Minimum, average and maximum temperatures (WRF data; 2019 to 2021)

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 the Project site (based on WRF data for 2019 – 2021) is given in Figure 7. Months wherein the most rain occurred stretched from October to April. The total annual rainfall for the Project site is given to range between 873 mm and 939 mm.

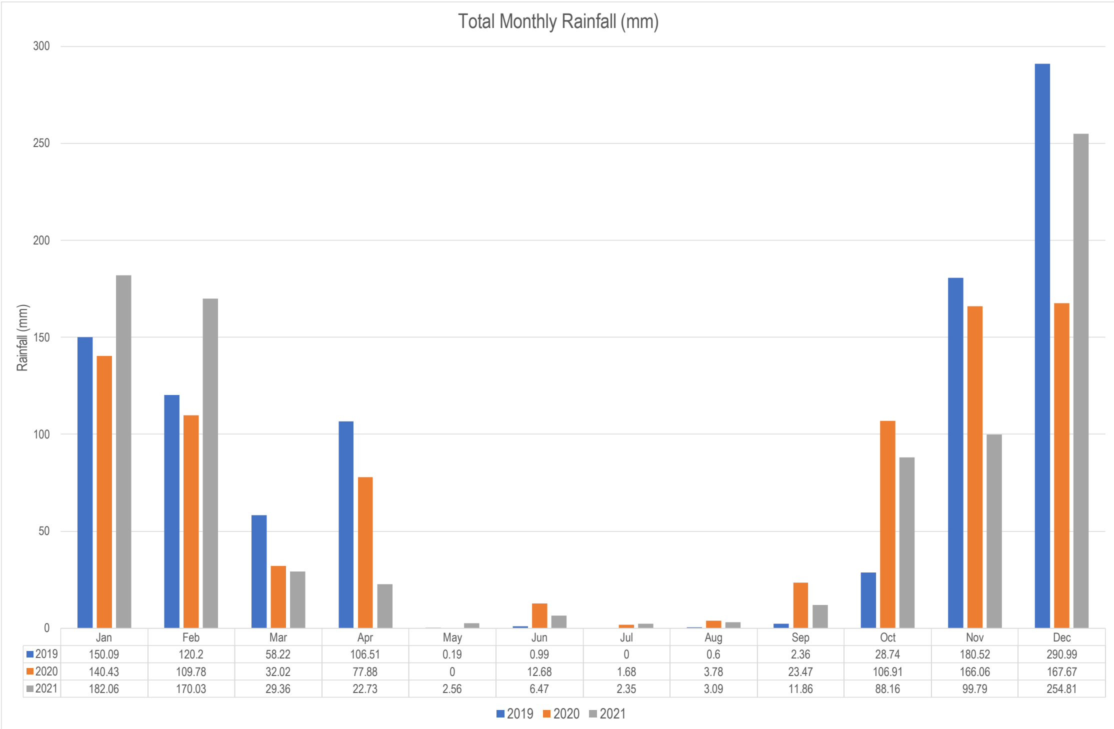


Figure 7: Monthly precipitation (WRF data; 2019 to 2021)

3.2.4 Atmospheric Stability and Mixing Depth

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. The radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. The night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer ranges in depth from a few metres (i.e. stable or neutral layers) during night times, to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons and on some occasions as many as five may occur in the first 1000 m above the surface.

Atmospheric stability is frequently categorised into one of six stability classes – these are briefly described in Table 6. The most commonly occurring stability class calculated the site is Class C and F, representing Unstable and Very Stable conditions respectively. For elevated releases (e.g. from the plant stack), the highest ground level concentrations would occur during unstable, daytime conditions. For low level releases, such as vehicle and materials handling activities, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions. Windblown dust is likely to occur under high winds (neutral conditions).

Table 6: Atmospheric stability classes

Designation	Stability Class	Atmospheric Condition
A	Very unstable	calm wind, clear skies, hot daytime conditions
B	Moderately unstable	clear skies, daytime conditions
C	Unstable	moderate wind, slightly overcast daytime conditions
D	Neutral	high winds or cloudy days and nights
E	Stable	moderate wind, slightly overcast night-time conditions

3.3 Existing Sources of Emissions near the Project Site

Mining and processing activities, farming and residential land-uses occur in the region. These land-uses contribute to baseline pollutant concentrations via vehicle tailpipe emissions, household fuel combustion, biomass burning and various fugitive dust sources. Long-range transport of particulates, emitted from remote tall stacks and from large-scale biomass burning in countries to the north of South Africa, has been found to contribute to background fine particulate concentrations within the South African boundary (Andreae, et al., 1996; Garstang, Tyson, Swap, & Edwards, 1996; Piketh, Annegarn, & Kneen, 1996).

3.3.1 Mining and Industrial Operations

Fugitive emissions from opencast and underground mining operations mainly comprise of land clearing operations (i.e. scraping, dozing and excavating), materials handling operations (i.e. tipping, off-loading and loading, conveyor transfer points), vehicle entrainment from haul roads, wind erosion from open areas, drilling and blasting. These activities mainly result in particulates and dust emissions, with small amounts of oxides of nitrogen (NO_x), carbon monoxide (CO), SO_2, methane and CO_2 being released during blasting operations.

Lonmin Platinum Mine is located approximately 1 km to the northeast of Tharisa and the smelter approximately 3 km to the northwest. Samancor western chrome mine is roughly 3.3 km to the east, and Glencoire WKP UG2 about 3.8 km to the west. Further afield is Bleskop Mines, Kroondal Mine, and Rustenburg Platinum Mine. Anglo Platinum Smelter Operation (Waterval Smelter) and Impala Platinum are all located around Rustenburg, about 20 km to the west-northwest. Rhovan Vanadium is to the north of Brits and Vanchem to the east, both with associated mining operations. Most of the smelters have mining operations associated with it, with tailings storage facilities, unpaved roads and other materials handling activities generating dust.

3.3.2 Agricultural operations

Agriculture is a land-use within the area surrounding the site. Particulate matter is the main pollutant of concern from agricultural activities deriving from windblown dust, biomass burning, and dust entrainment as a result of vehicles travelling along dirt roads. The quantity of windblown dust is a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

Amongst the mining and industrial operations between Brits and Rustenburg, there are a number of citrus farms and other agricultural activities. Crop farming and mixed crop farming include land tilling operations, fertiliser and pesticide applications, and harvesting. By applying fertiliser and pesticides use are typically made of vehicles (tractors) driving on unpaved roads and exposed soil. Land tilling includes dust entrainment on exposed surfaces, windblown dust and scraping and grading type activities resulting in fugitive dust releases. Both particulate matter (PM) and gaseous air emissions (mainly NO, NO_2, NH_3, SO_2 and VOCs) are generated from the application of nutrients as fertilizers or manures (EPA, 1999).

3.3.3 Unpaved Roads

Vehicle entrained dust emissions from paved and unpaved roads represent a potentially significant source of fugitive dust in the area surrounding Tharisa Mine. Unpaved roads include industrial, mine, local farming, and community access roads. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and the silt loading on the roadways. The extent, nature and duration of road-use activity and the moisture and silt content of soils are required to be known in order to quantify fugitive emissions from this source.

3.3.4 Vehicle Tailpipe Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. Notable primary pollutants emitted by vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, DPM and Pb. Secondary pollutants include: NO_2, photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses. Vehicle tailpipe emissions are localised sources and unlikely to impact far-field.

Both small and heavy private and industrial vehicles travelling along the N4 and the R104 as well as the unpaved roads, are notable sources of vehicle tailpipe emissions.

3.3.5 Household Fuel Burning

Domestic households are known to have the potential to be one the most significant sources that contribute to poor air quality within residential areas. Pollutants arising from the combustion of wood include respirable particulates, CO and SO_2 with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

Informal settlements in the region are likely to use coal and wood as energy sources. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, total and respirable particulates including heavy metals and inorganic ash, CO, polycyclic aromatic hydrocarbons (PAHs), NO_2 and various toxins such as benzo(a)pyrene. Pollutants from wood burning include respirable particulates, NO2, CO, PAHs, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

3.3.6 Crop Burning and Wildfires

Crop-residue burning, and general wildfires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. Emissions are greater from sugar cane burning that for savannas wildfires due to sugar cane areas being associated with a greater availability of available material to be burned. The quantity of dry, combustible matter per unit area is on average 4.5 ton per hectare for savannas areas.

The quantification of background particulate concentration, which is of particular importance for the current study, is complicated due to the large number of sources in the region. Sources of particulates also include a significant proportion of fugitive emissions from diffuse sources (e.g. vehicle-entrained dust from roadways, wind-blown dust from stockpiles and open areas, dust generated by materials handling) which are more difficult to quantify than are emissions from point sources. Dust fallout typically impacts in close vicinity of the emission source (up to 3 km) whereas PM_{10} can remain in the atmosphere for days and impact far afield.

3.4 Baseline Air Quality

It is expected that various local and far-a-field sources are expected to contribute to ambient concentrations in the region. Local sources include wind erosion from exposed areas, fugitive dust from agricultural activities and mining activities, vehicles on roadways and veld burning. Long range particulates can result from remote tall stack emissions and from large scale biomass burning in countries to the north of South Africa. These have been found to contribute significantly to background fine particulate concentrations over the interior of South Africa ((Andreae, 1996), (Garstang, 1996), (Piketh, Annegarn, & Kneen, 1996)).

Particulates represent the main pollutant of concern in the assessment of mining operations. The particulates in the atmosphere may contribute to visibility reduction, pose a threat to human health, or simply be a nuisance due to their soiling potential.

3.4.1 Air Quality Monitoring Data

Tharisa Mine has a dustfall monitoring network in place and does passive sampling of NO_2 and SO_2 (Figure 8). Data analysed for the ambient air quality is limited to the period January to March 2021 and January to March 2022. Both NO_2 and SO_2 are screened against NAAQS while dustfall is screened against the NDCR.

It should be noted that the ambient measurements account for all emission contributions in the region, not just the mine.

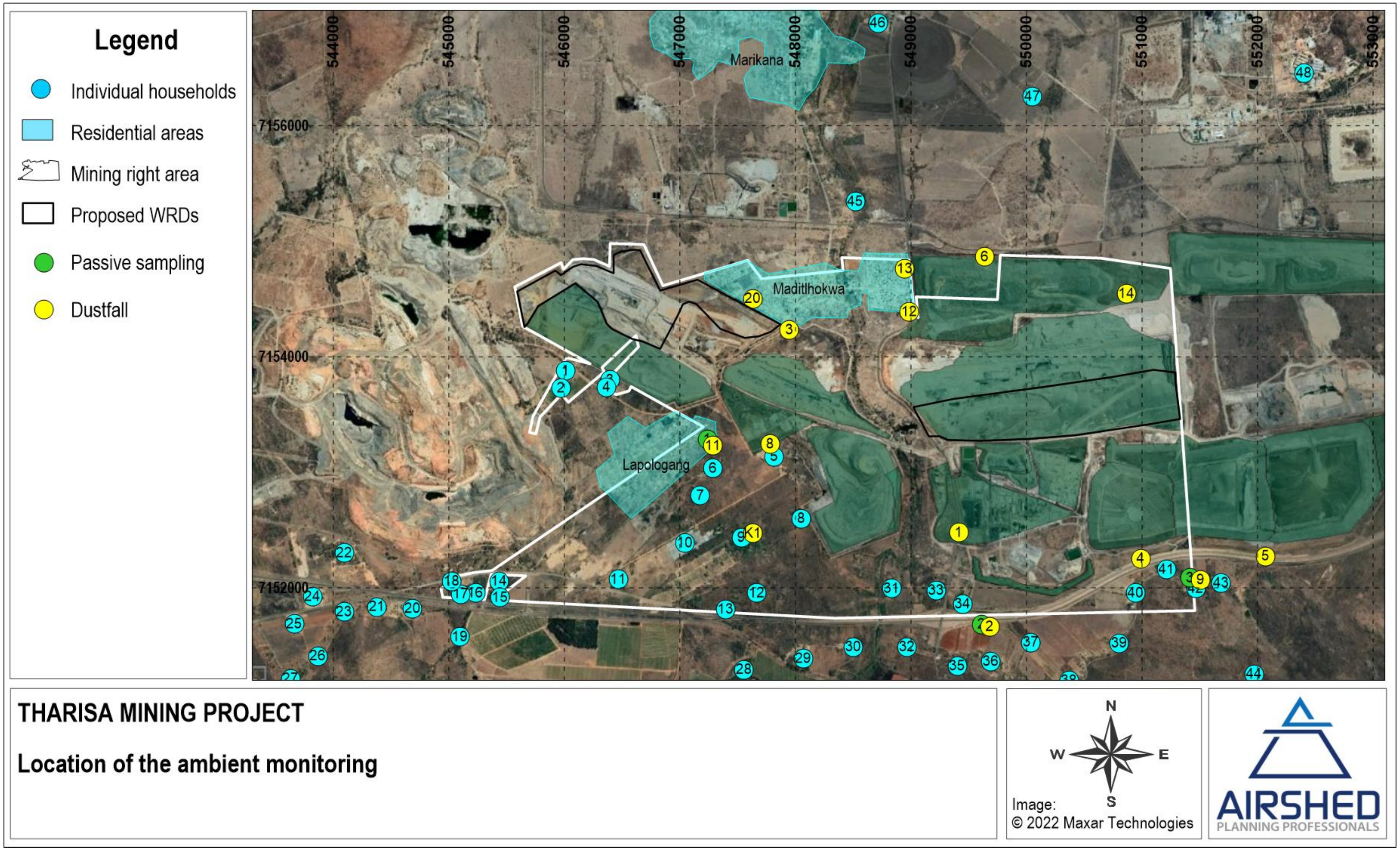


Figure 8: Tharisa Mine ambient monitoring network locations

3.4.1.1 Ambient NO_2 and SO_2 Concentrations

The current monitoring network comprises of three radiello® passive monitors for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). The results of the NO_2 and SO_2 monitoring are represented in Table 7 and Table 8.

While you may not validly compare the NO_2 and SO_2 results obtained to the annual standard unless you continuously sampled for a year and obtained an average, the radiello® passives technique provide an indication of possible high incidences of NO_2 and SO_2 levels at Tharisa Mine. Results obtained for NO_2 and SO_2 for the months in review were well below the NAAQS.

Table 7: Summary of NO_2 concentrations for 2021

Station	Jan 2021 (µg/m³)	Feb 2021 (µg/m³)	Mar 2021 (µg/m³)	NAAQS Annual (µg/m³)
1.Lapologang village	5	3.7	7.1	40
2.Swanepoel	2.3	5.4	10.6	40
3.Glenross farmhouse	4.6	2.2	0.7	40

Table 8: Summary of SO_2 concentrations for 2021

Station	Jan 2021 (µg/m³)	Feb 2021 (µg/m³)	Mar 2021 (µg/m³)	NAAQS Annual (µg/m³)
1.Lapologang village	0.3	1.1	1.1	50
2.Swanepoel	1.4	0.3	3.9	50
3.Glenross farmhouse	0.7	0.9	1.6	50

3.4.1.2 Dustfall Monitoring network

The latest results were taken from the available dustfall monitoring reports which included 15 single dust buckets at and around Tharisa Mine (Figure 8). Aquatico currently performs the dustfall sampling.

From the results of the monitoring campaign, it was found that dustfall at Sites 2 (toll gate) and 8 (school) exceeded the NDCR for residential areas (exceed 600 mg/m²/day) in January 2021 and in February 2021, respectively.

As the NDCR allow for a permitted frequency of exceeding the dustfall rate of two within a year (not sequential months), it cannot be determined if the site is compliant or not, as there is not a full year of data available.

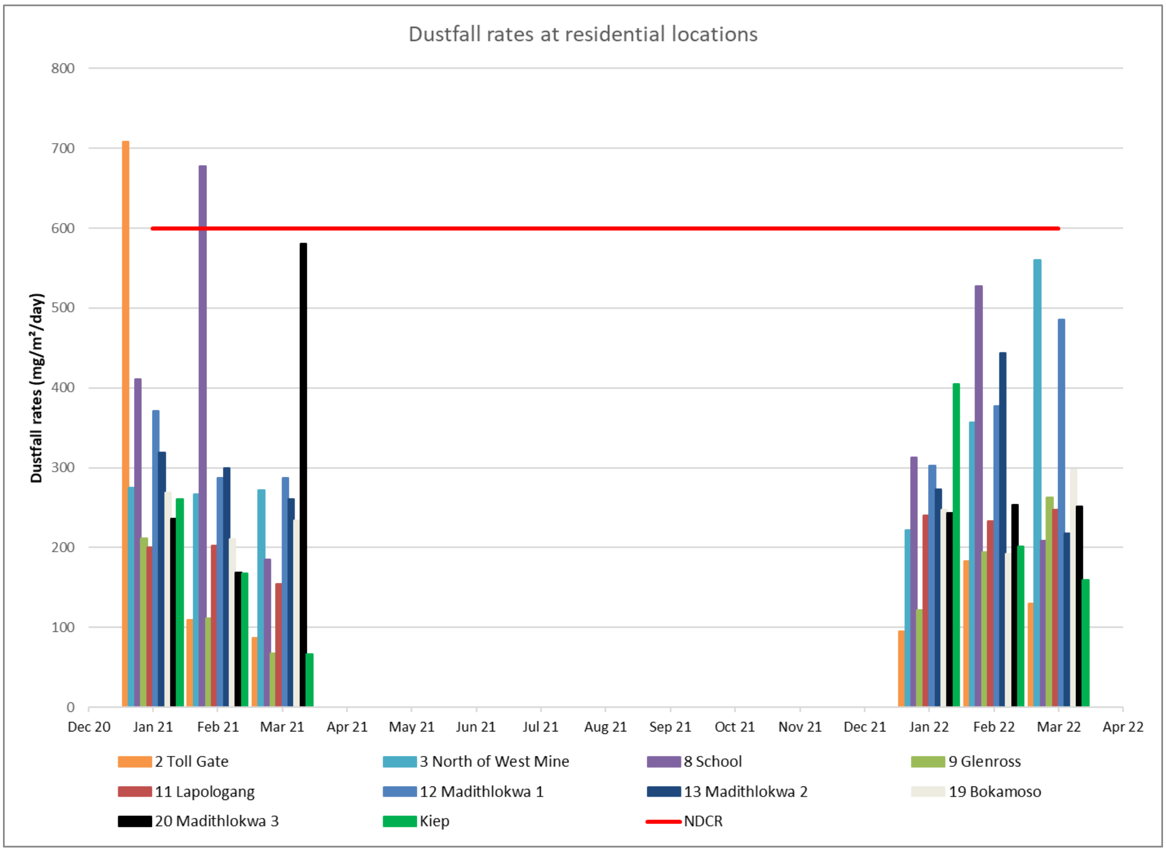


Figure 9: Results of the dustfall monitoring campaign – residential locations

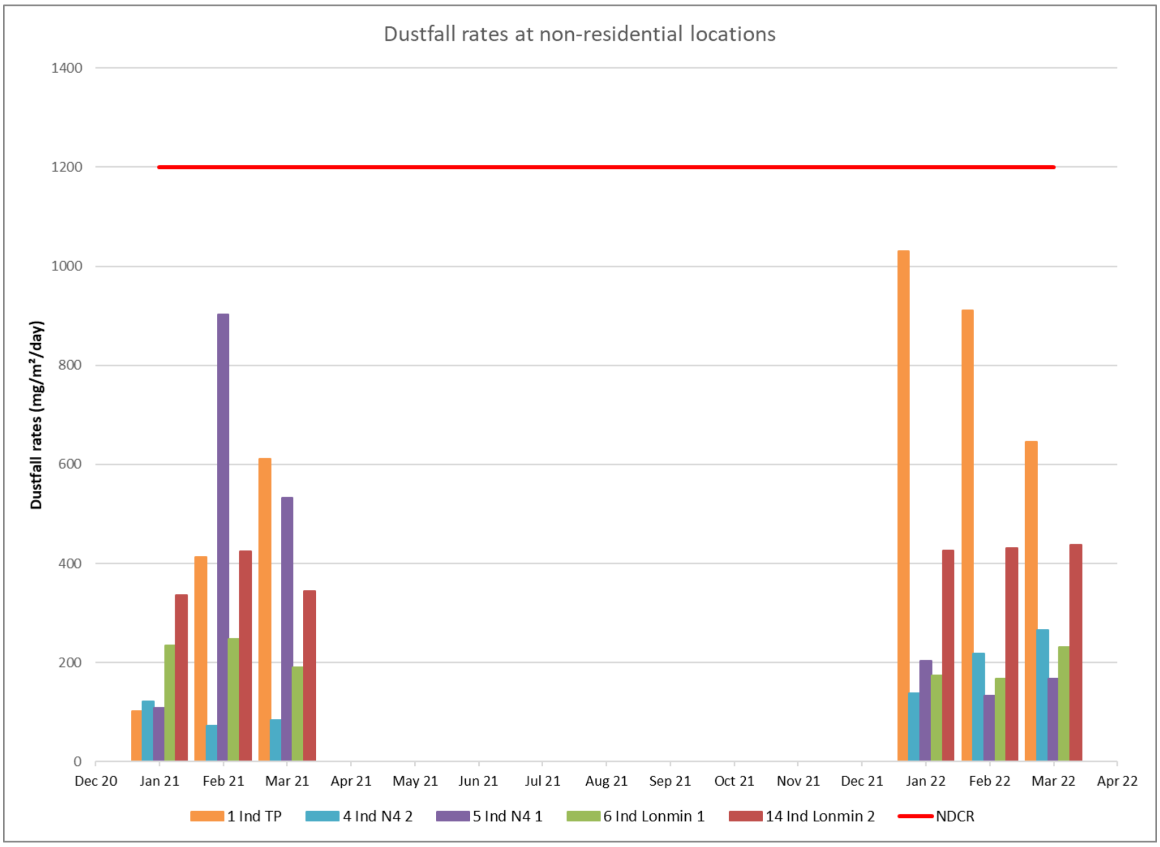


Figure 10: Results of the dustfall monitoring campaign – non-residential locations

4 Impact Assessment

The emissions inventory, dispersion modelling and results are discussed in Section 4.1 and Section 4.2 respectively.

4.1 Project Description

4.1.1 Current Mining and Process Description

The current mining operation locations and layout at Tharisa Mine is shown in Figure 2, with the description provided below as taken from the scoping report (SLR, 2022). The process flow is shown in Figure 11.

Mining:

- The mining method at Tharisa comprises a standard open pit truck and shovel method, with mining at two sections namely the East Mine and West Mine.
- Access to the open pits is by means of haul roads and boxcuts with ramps. The dimensions of the western section are approximately 360m wide, 1km long and 180m deep, and the eastern section is approximately 580m wide, 1km long and 180m deep.
- All topsoil is dozed into stockpiles along the low wall (outcrop) sides of the open pits with separate topsoil stockpiles for use in rehabilitation.
- Waste rock and the ore is drilled and blasted, and waste rock removed by loaded and hauled to the one of four WRDs (Far East WRD; West WRD 1; East WRD; and Far West WRD 1).
- Run of mine ore (ROM) is stockpiled according to ROM type, prior to being sent to the concentrator plant for processing.

Mineral processing:

- Chrome ROM material undergoes primary crushing and secondary crushing (jaw crushers), with oversized material from the secondary circuit returned to the primary crusher feed conveyor for reprocessing. The lumpy and chips from the secondary screening process report to the DMS section, while the undersize report to a mill feed stockpile for milling prior to spiral plant treatment.
- PGM ROM material undergoes primary crushing (gyratory crusher) and secondary crushing (cone crusher). Material from the primary crusher is stockpiled, whereafter it undergoes screening. Oversize material reports to the secondary crusher for further crushing (closed circuit), with undersize from the screen reporting to a silo for storage prior to milling.
- The chrome lumpy material is treated in a Dense Media Separation (DMS) at the chrome plant, while the chip fraction is treated in a cyclone plant. The recovered lump and chip material will be conveyed to separate stockpiles, while the discard (float) material is transported to a discard bin for removal to the waste rock stockpile.
- The Chrome undersize material is fed to a ball mill for grinding, with screened oversize returning to the grinding circuit and undersize reporting to the spirals plant.

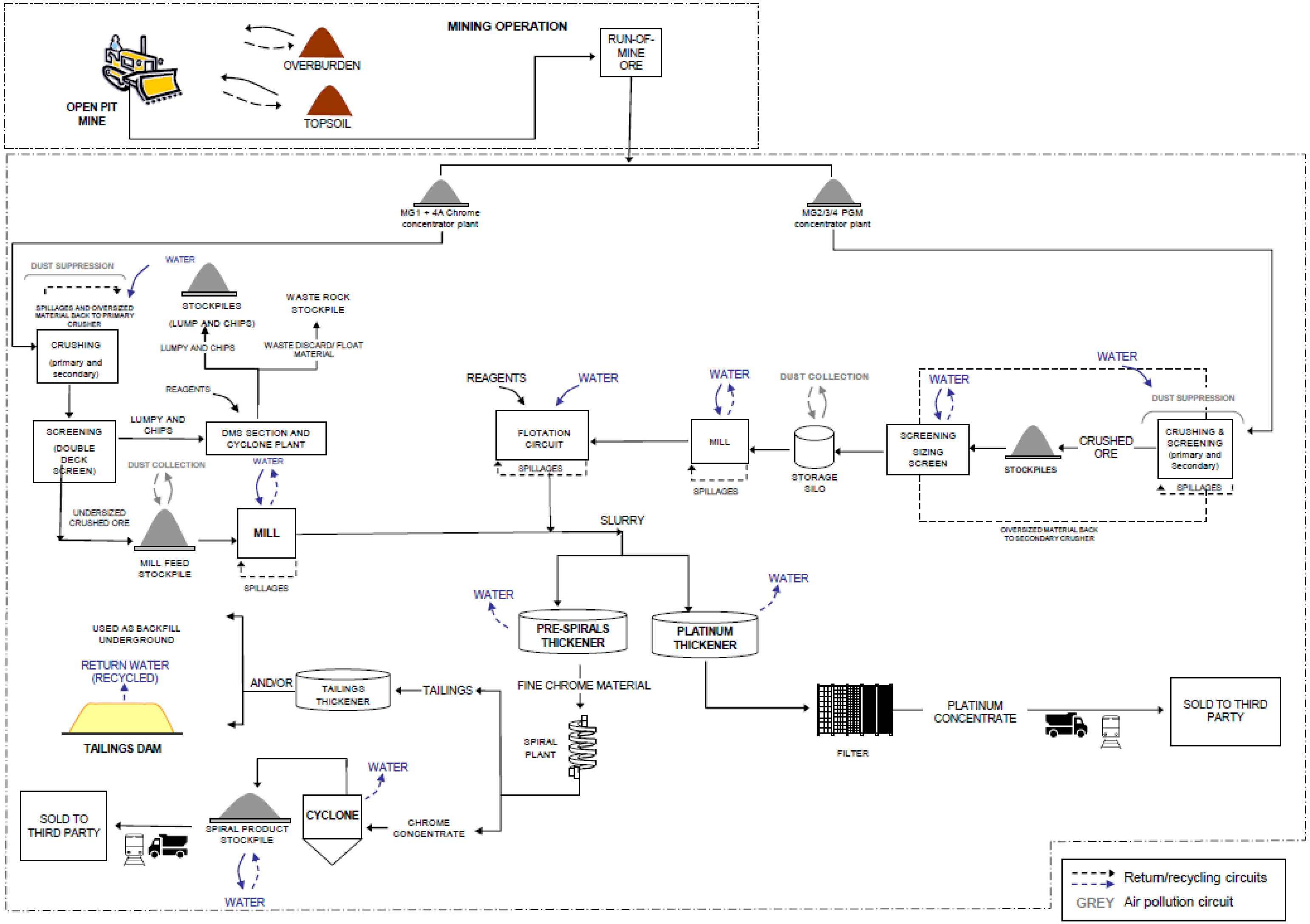


Figure 11: Tharisa Mine conceptual process flow diagram

- The Chrome undersize material from the secondary screening process is fed to a ball mill for grinding, with screened oversize returning to the grinding circuit and undersize reporting to the spirals plant.
- PGM ore from the silo is fed onto the mill feed conveyor, with the milling cycle a wet process.
- Floatation happens only at the PGM plant where PGE's is separated using chemicals to the feed material and PGE concentrate is pumped to a storage tank for loading by truck.
- PGM underflow material from the floatation section is pumped to cyclones with the underflow gravitating into the spirals and the overflow reporting to the tailing's thickener. Two streams leave the spirals plant; a product stream and tailings.
- The chrome material from the grinding section is pumped to cyclones with the underflow gravitating into the spirals and the overflow reporting to the tailing's thickener. Two streams will leave the spirals plant; a product stream (Met and Chem grade chromite) and tailings.
- Slurry from the secondary rougher flotation process will be discarded as tailings.
- Rehabilitation is concurrent with mining with waste rock/overburden used to backfill voids where required. Once the backfill material has settled, topsoil will be placed on top of the overburden and vegetation will be re-established.

Activities during the operational phases of the Project likely to result in pollutants to air are listed in Table 9.

Table 9: Potential sources of air emissions and impacts associated with current Tharisa Mine activities

Activity		**Associated pollutants**
Open pit mining – East Pit; West Pit & Far West Pit	Blasting – intermittent source of emissions	PM; SO_2; NOx; CO; CO_2
	Drilling	PM; SO_2; NOx; CO; CO_2
	Excavation of ore and waste rock	Mostly PM, gaseous emissions from mining equipment (PM; SO_2; NOx; CO; CO_2)
	Loading of ore and waste rock onto trucks	Mostly PM, gaseous emissions from haul truck exhaust (PM, SO_2; NOx; CO; CO_2)
Haulage of ore and waste rock	Ore from pits to ROM stockpiles and from ROM stockpiles to crusher plants (Voyager and Genesis)	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
	Waste rock from pits to WRDs[(a)]	
Off-loading of ore and waste rock	Ore at ROM stockpiles and at crusher plants (Voyager and Genesis)	Mostly PM, gaseous emissions from haul truck exhaust (PM, SO_2; NOx; CO; CO_2)
	Waste rock at WRDs[(a)]	
Wind erosion	From exposed WRD[(b)]- ROM & TSF surfaces	Mostly PM, gaseous emissions from mining equipment (PM; SO_2; NOx; CO; CO_2)
Processing Plants - Voyager and Genesis	Crushing, screening, milling	mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)
	DMS at the chrome plant	PM; SO_2; NOx; CO; CO_2

Notes: [(a)] Far East WRD1; Far West WRD2; West WRD 1; West WRD 2; TSF

[(b)] Far East WRD1; Far West WRD2; West WRD 1; West WRD 2; TSF; East WRD1; Topsoil Berm

4.1.2 Proposed Layout and Activity Changes

The nature of the pits at Tharisa is such that there is continually more waste rock generated than capacity available in the worked-out areas of the pits and the balance must be dumped on surface WRDs. Additional waste rock handling and storage capacity is therefore required to accommodate the waste rock from the open pit operations. As part of its on-going mine planning, Tharisa has identified the need for additional WRD storage on site (SLR, 2022):

- The expansion of the existing and approved Far West WRD 1 by a footprint of 109 ha. The expanded area will be referred to as the West Above Ground (OG) WRD. Portions of the West OG WRD will be located on backfilled areas of the West Pit; and
- The establishment of a WRD (referred to as the East OG WRD) on backfilled portions of the East Pit. The proposed East OG WRD will cover an area of approximately 72 ha.

The potential sources of air emissions due to proposed layout and activity changes are provided in Table 10 and shown in Figure 2.

Table 10: Potential sources of air emissions associated with Tharisa Mine WRD expansion project activities

Activity		**Associated pollutants**
Open pit mining - Future East Pit & Future West Pit	Blasting – intermittent source of emissions	PM; SO_2; NOx; CO; CO_2
	Drilling	PM; SO_2; NOx; CO; CO_2
	Excavation of ore and waste rock	Mostly PM, gaseous emissions from mining equipment (PM; SO_2; NOx; CO; CO_2)
	Loading of ore and waste rock onto trucks	Mostly PM, gaseous emissions from haul truck exhaust (PM, SO_2; NOx; CO; CO_2)
Haulage of ore and waste rock	Ore from pits to ROM stockpiles and from ROM stockpiles to crusher plants (Voyager and Genesis)	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
	Waste rock from pits to WRDs[a]	
Off-loading of ore and waste rock	Ore at ROM stockpiles and at crusher plants (Voyager and Genesis)	Mostly PM, gaseous emissions from haul truck exhaust (PM, SO_2; NOx; CO; CO_2)
	Waste rock at WRDs[a]	
Wind erosion	From exposed WRD[b]- ROM & TSF surfaces	Mostly PM, gaseous emissions from mining equipment (PM; SO_2; NOx; CO; CO_2)
Processing Plants - Voyager and Genesis	Crushing, screening, milling	mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)
	DMS at the chrome plant	PM; SO_2; NOx; CO; CO_2

Notes: [a] West OG WRD; West OG WRD on backfilled areas of West Pit; & East OG WRD on backfilled portions of the East Pit

[b] East WRD1; Far East WRD1; Far West WRD2; West WRD 1; West WRD 2; TSF; Topsoil Berm

4.2 Atmospheric Emissions

4.2.1 Construction Phase

Construction normally comprises a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, etc. Expansion of the WRDs at Tharisa Mine won't require typical construction activities since these expansions will occur on either already disturbed areas or backfilled areas within the pits. For this reason, construction operations were not accessed.

4.2.2 Operational Phase

The emissions inventory was compiled using the throughput of material as supplied by the client for the current operations and based on the latest available 12-months of data (October 2021– September 2022). Two operational phases and three scenarios were assessed, namely:

Scenario 1: Current operations (including currently applied mitigation measures)

Scenario 2: Proposed future operations (unmitigated)

Scenario 3: Proposed future operations (mitigated).

The emission equations used to quantify fugitive emissions from the current and proposed activities are shown in Table 12. For each the current operational scenario existing mitigation measures were applied, whereas for the future scenarios both unmitigated and mitigated activities were assessed and these control efficiencies for the various mining operations are shown in Table 13. The particle size distribution used to calculate emissions for wind erosion from the various stockpile materials are shown in Table 11. The estimated emissions due to current (mitigated) and future (unmitigated and mitigated) activities are provided in Table 14 and

Table 15 respectively.

Table 11: Particle size distributions of materials (given as a fraction)

	WRD	TSF	Roads	ROM		Product	
Size µm	Fraction	Fraction	Fraction	Size µm	Fraction	Size µm	Fraction
1 430	0.032	0.023	0.0088	252	0.107	30	0.15
756	0.150	0.108	0.1121	178	0.152	10	0.23
400	0.188	0.159	0	126	0.123	6	0.04
240	0.193	0.215	0.4014	89	0.057	5	0.10
144	0.115	0.164	0.1459	37	0.561	4	0.12
98.1	0.057	0.088	0.0754	10	0	3	0.06
76	0.079	0.110	0.0986	2.5	0	2.5	0.09
45	0.038	0.038	0.0397	10.10	0.07	2	0.15
31.1	0.031	0.025	0.0288	5.12	0.01	1	0.06
21.2	0.025	0.018	0.0214	2.27	0.00		
14.5	0.020	0.013	0.0161				
10	0.027	0.016	0.0206				
5.21	0.022	0.012	0.0155				
2.5	0.017	0.009	0.0116				
1	0.007	0.003	0.0041				

Table 12: Emission equations used to quantify fugitive dust emissions from the project

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr><td>Drilling & Blasting</td><td>Drilling Emission factors
<table>
<tr><th>TSP</th><th>PM_{10}</th><th>$PM_{2.5}$(</th><th>Unit</th></tr>
<tr><td>0.59</td><td>0.31</td><td>0.31</td><td>kg/hole drilled</td></tr>
</table>
Blasting equation:
$$E = 0.00022 \cdot (A)^{1.5}$$
Where,
E = Emission factor (kg dust / t transferred)
A = Blast area (m²)
The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.</td><td>NPI Section: Mining (NPI, 2012)</td><td>
<table>
<tr><th>Phase</th><th>Area</th><th>Holes per day</th><th>Area(m²)/year</th><th>Blasts per week</th></tr>
<tr><td rowspan="3">Current</td><td>EASTPITC</td><td>379</td><td>1 125</td><td>7</td></tr>
<tr><td>FARWPITC</td><td>45</td><td>387</td><td>7</td></tr>
<tr><td>WESTPITC</td><td>75</td><td>500</td><td>7</td></tr>
<tr><td rowspan="2">Future</td><td>EASTPITF</td><td>274</td><td>956</td><td>7</td></tr>
<tr><td>WESTPITF</td><td>225</td><td>867</td><td>7</td></tr>
</table>
Hours of operation assumed to be 8 760 hours per year.
Number of blasts per week: assumed 1 blast/day</td></tr>
<tr><td>Materials handling</td><td>
$$E = 0.0016 \frac{\left(U/_{2.2}\right)^{1.3}}{\left(M/_{2}\right)^{1.4}}$$
Where,
E = Emission factor (kg dust / t transferred)
U = Mean wind speed (m/s)
M = Material moisture content (%)
The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively.</td><td>US-EPA AP42 Section 13.2.4 (US EPA, 2006)</td><td>The moisture content of materials (assumed): Ore 4%; Waste Rock 3%; Product 4%
The respective throughput of materials during the current and future phases:
<table>
<tr><th>Phase</th><th>Area</th><th>Ore (tpa)</th><th>Waste (tpa)</th><th>Total (tpa)</th></tr>
<tr><td rowspan="3">Current</td><td>EASTPITC</td><td>4 199 704.00</td><td>44 996 268.00</td><td>391 542.80</td></tr>
<tr><td>FARWPITC</td><td>670 190.00</td><td>9 048 529.00</td><td>79 232.35</td></tr>
<tr><td>WESTPITC</td><td>630 139.00</td><td>5 187 876.00</td><td>0.00</td></tr>
<tr><td rowspan="2">Future</td><td>EASTPITF</td><td>4 199 704.00</td><td>44 996 268.00</td><td>391 542.80</td></tr>
<tr><td>WESTPITF</td><td>1 300 329.00</td><td>14 236 405.00</td><td>79 232.35</td></tr>
<tr><td rowspan="2">Current & Future</td><td>Product - Voyager</td><td>4 152 887.22</td><td>-</td><td>-</td></tr>
<tr><td>Product - Genesis</td><td>1 347 145.78</td><td>-</td><td>-</td></tr>
</table>
Hours of operation assumed to be 8 760 hours per year.
Average wind speed of 3.8 m/s, from WRF weather data (period 2019 to 2021).</td></tr>
</table>

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr><td>Dozer</td><td>$$E = k \cdot (s)^{a}/(M)^{b}$$
Where,
E = Emission factor (kg dust / hr / vehicle)
s = Material silt content (%)
M = Material moisture content (%)
The particle size multiplier k is given as 2.6 (TSP), 0.34 (PM_{10})
The empirical constant (a) is given as 1.2 (TSP), and 1.5 (PM_{10})
The empirical constant (b) is given as 1.3 (TSP), and 1.4 (PM_{10})
Fraction of $PM_{2.5}$ assumed to be 10% of PM_{10}</td><td>NPI Section: Mining (NPI, 2012)</td><td>The location of operation and handling rates are:
<table>
<tr><th>Phase</th><th>Description</th><th>Number</th></tr>
<tr><td rowspan="3">Current</td><td>Dozer - Far West WRD</td><td>3</td></tr>
<tr><td>Dozer - West WRD</td><td>1</td></tr>
<tr><td>Dozer - Far East WRD</td><td>13</td></tr>
<tr><td rowspan="3">Future</td><td>Dozer - Future West WRD - Fraction of waste 0.25</td><td>1</td></tr>
<tr><td>Dozer - Future West WRD - Fraction of waste 0.75</td><td>3</td></tr>
<tr><td>Dozer - Future East WRD (include as part of IP EASTWRDF)</td><td>13</td></tr>
</table>
Hours of operation: assumed 8 hours/day, 365 days per year
Silt and moisture assumed?</td></tr>
<tr><td>Vehicle entrainment on unpaved surfaces (mine roads)</td><td>$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} \cdot 281.9$$
Where,
E = particulate emission factor in grams per vehicle km travelled (g/VKT)
k = basic emission factor for particle size range and units of interest
s = road surface silt content (%)
W = average weight (tonnes) of the vehicles travelling the road

The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$ and 1.5 for PM_{10}, and as 4.9 for TSP
The empirical constant (a) is given as 0.9 for $PM_{2.5}$ and PM_{10}, and 4.9 for TSP
The empirical constant (b) is given as 0.45 for $PM_{2.5}$, PM_{10} and TSP</td><td>US-EPA AP42 Section 13.2.2 (U.S. EPA, 2006)</td><td>Truck/ vehicle information:
<table>
<tr><th rowspan="2">Information</th><th rowspan="2">Unit</th><th colspan="3">Current & Future</th></tr>
<tr><th>Ore</th><th>Waste</th><th>Topsoil</th></tr>
<tr><td>No. of Trucks</td><td></td><td>31</td><td>26</td><td>9</td></tr>
<tr><td>Onsite truck Payload</td><td>ton</td><td>96.07</td><td>167.25</td><td>38</td></tr>
<tr><td>Average weight (a)</td><td>ton</td><td>114</td><td>202</td><td>41.5</td></tr>
<tr><td>Average speed (b)</td><td>km/hr</td><td>40</td><td>40</td><td>40</td></tr>
</table>
Notes: (a) assumed average weight to be 1.5 times the payload.
(b) assumed

Vehicle kilometre travelled (VKT) were calculated from road lengths, truck capacities and the number of trips required for transporting materials.

Scenario 1 (Year 7)
<table>
<tr><th>Phase</th><th>Material</th><th>Total road length (m)</th><th>Total trips/hour</th><th>VKT/hour</th></tr>
<tr><td>Current</td><td>ore + waste</td><td>15 995.75</td><td>197.73</td><td>314.71</td></tr>
<tr><td>Future</td><td>ore + waste</td><td>11 760.64</td><td>199.50</td><td>220.19</td></tr>
</table>
Hours of operation: assumed 7 860 hours per year

Silt content (from road composite sample): 25.64% (EPA cut-off 25.2%)</td></tr>
</table>

<table>
<tr><th>Activity</th><th>Emission Equation</th><th>Source</th><th>Information assumed/provided</th></tr>
<tr><td>Crushing and screening</td><td>Emission factors
<table>
<tr><th>Crushing</th><th>TSP</th><th>PM_{10}</th><th>$PM_{2.5}$(a)</th><th>Unit</th></tr>
<tr><td>Primary</td><td>0.01</td><td>0.004</td><td>0.002</td><td>kg/tonne</td></tr>
<tr><td>Secondary</td><td>0.03</td><td>0.012</td><td>0.006</td><td>kg/tonne</td></tr>
<tr><td>Tertiary</td><td>0.03</td><td>0.010</td><td>0.005</td><td>kg/tonne</td></tr>
</table>
Notes: (a) Fraction of $PM_{2.5}$ taken from US-EPA crushed stone emission factor ratio for tertiary crushing.
Where,
E = Default emission factor for high moisture content ore (moisture >4%)</td><td>NPI Section: Mining (NPI, 2012)</td><td>The throughput of the ROM material:
Voyager = 4 152 887 tpa
Genesis = 1 347 146 tpa.
ROM moisture assumed: 4%
Primary, secondary & tertiary crushing at each plant.
Hours of operation assumed to be 8 760 hours per year.</td></tr>
<tr><td>Wind Erosion</td><td>$$E(i) = G(i)10^{(0.134(\%clay)-6)}$$
For
$$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$
And
$$R = \frac{u_*^{\ t}}{u^*}$$
where,
$E_{(i)}$ = emission rate (g/m²/s) for particle size class i
P_a = air density (g/cm³)
G = gravitational acceleration (cm/s³)
u_*^t = threshold friction velocity (m/s) for particle size i
u^* = friction velocity (m/s)</td><td>Marticorena & Bergametti, 1995</td><td>Waste rock and tailings PSD were obtained from on-site composite samples, whereas ROM and product PSD were taken from similar processes (see Table 11).
Areas (m^2) for various sources were taken from GoogleEarth.
<table>
<tr><th>Current</th><th>Area (m²)</th><th>Future</th><th>Area (m²)</th></tr>
<tr><td>Far West WRD (current)</td><td>637 639</td><td>West WRD (Future)</td><td>739 059</td></tr>
<tr><td>West WRD (current)</td><td>624 468</td><td>Tailings (Future)</td><td>2 334 875</td></tr>
<tr><td>Far East WRD (current)</td><td>1 108 533</td><td>ROM Pad</td><td>81 885</td></tr>
<tr><td>Tailings (current)</td><td>2 141 413</td><td>Crushed SP (Plant1)</td><td>3 400</td></tr>
<tr><td>ROM Pad</td><td>81 885</td><td>Crushed SP (Plant2)</td><td>4 173</td></tr>
<tr><td>Crushed SP (Plant1)</td><td>3 400</td><td>Product SP (Vulcan Plant)</td><td>34 305</td></tr>
<tr><td>Crushed SP (Plant2)</td><td>4 173</td><td>Far West WRD (NA)</td><td>415 859</td></tr>
<tr><td>Product SP (Vulcan Plant)</td><td>34 305</td><td>West WRD (NA)</td><td>624 468</td></tr>
<tr><td>East WRD (NA)</td><td>1 098 946</td><td>Far East WRD (NA)</td><td>1 108 533</td></tr>
<tr><td>Berm (for Plant)</td><td>80 309</td><td>East WRD (NA)</td><td>1 098 946</td></tr>
</table>
Notes: NA means not-active dumps.
The moisture contents of materials were assumed as 0.1%.
Typical values for particle density and particle size were assumed:
Layout of WRDs, Stockpiles, TSF was provided.
Hourly emission rate file was calculated and simulated.</td></tr>
</table>

Table 13: Estimated control factors for various proposed operations

Operation/Activity		Control method and emission reduction
Windblown dust from stockpiles		No control
Blasting		No control
Drilling		No control (assumed)
Bulldozing		50% CE for water sprays (assumed)
Haul roads	Surface roads	75% CE for water sprays (assumed)
	In-pit roads	90% CE for chemical suppressants (assumed)
Materials handling		50% CE for water sprays (assumed)
Primary, secondary, and tertiary crushing		50% CE for water sprays (assumed)

Notes: CE is Control Efficiency

Table 14: Calculated particulate emission rates due to current unmitigated and mitigated operations

Description	Current (unmitigated)			Current (mitigated)		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
In-pit operations [(a)]	6 076.39	4 126.87	458.28	3 027.45	2 052.70	223.24
Blasting	2.26	2.23	0.07	2.26	2.23	0.07
Dozing	1 577.79	493.99	74.80	788.89	246.99	37.40
Crushing (primary, secondary, tertiary)	385.00	143.00	71.50	192.50	71.50	35.75
Materials handling	95.97	45.39	6.87	47.98	22.69	3.44
Vehicle entrainment	28 393.52	10 082.27	1 008.23	2 839.35	1 008.23	100.82
Wind erosion	523.38	140.95	51.84	523.38	140.95	51.84
Total	**37 054.31**	**15 034.69**	**1 671.59**	**7 421.82**	**3 545.30**	**452.55**

Notes: [(a)] Including materials handling, drilling and in-pit hauling.

Table 15: Calculated particulate emission rates due future unmitigated and mitigated operations

Description	Future Project (unmitigated)			Future Project (mitigated)		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
In-pit operations [(a)]	8 211.83	5 521.74	624.20	4 095.17	2 750.14	306.20
Blasting	2.21	2.17	0.07	2.21	2.17	0.07
Dozing	371.24	116.23	17.60	185.62	58.12	8.80
Crushing (primary, secondary, tertiary)	385.00	143.00	71.50	192.50	71.50	35.75
Materials handling	30.28	14.32	2.17	15.14	7.16	1.08
Vehicle entrainment	6 114.24	2 424.48	242.45	611.42	242.45	24.24
Wind erosion	451.29	103.10	31.78	451.29	103.10	31.78
Total	**15 566.10**	**8 325.05**	**989.77**	**5 553.36**	**3 234.64**	**407.92**

Notes: [(a)] Including materials handling, drilling, in-pit hauling and backfilling of waste rock at West Pit & East Pit and dozing at backfilling areas.

4.2.3 Closure Phase

All operational activities will have ceased by the closure (decommissioning and post-closure) phase of the project. This will result in a positive impact on the surrounding environment and human health. The potential for impacts during the closure phase will therefore depend on the extent of rehabilitation efforts to be undertaken at the infrastructure area and existing WRD areas and the TSF. Aspects and activities associated with the closure phase of the proposed project are:

- Demolition and stripping away of structures and facilities
- Wind-blown dust from stockpile and exposed areas
- Degradation of roads resulting in exposed surface areas

4.3 Atmospheric Dispersion Modelling

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

- The criteria against which impacts are assessed (Section 2.3);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2);
- The AQSRs in the vicinity of the mine (Section 3.1); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 4.2).

The impact of proposed operations on the atmospheric environment was determined through the simulation of ambient pollutant concentrations. Dispersion models simulate ambient pollutant 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.

4.3.1 Dispersion Model Selection

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. One of the most widely used Gaussian plume model is the US EPA AERMOD model that was used in this study. AERMOD is a model developed with the support of AERMIC, whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

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

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

4.3.2 Meteorological Requirements

For the current study, use was made of simulated WRF data for the study site was obtained for the period January 2019 – December 2021 (Section 3.2).

4.3.3 Source Data Requirements

The AERMOD model can model point, jet, area, line, and volume sources. Sources were modelled as follows:

- Open pit areas – modelled as area sources
- Materials handling – modelled as volume sources
- Crushing and screening – modelled as volume sources
- Unpaved roads – modelled as area sources
- Windblown dust – modelled as area sources.

4.3.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 10 km (east-west) by 10 km (north-south). The area was divided into a grid matrix with a resolution of 100 m by 100 m, with the project located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor points (AQSRs).

4.4 Impact Assessment

Dispersion modelling was undertaken to determine highest daily and annual average ground level concentrations (GLCs). Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations.

Pollutants with the potential to result in human health impacts which are assessed in this study include $PM_{2.5}$ and PM_{10}. Dustfall is assessed for its nuisance potential. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified.

Isopleth plots reflect the incremental GLCs for $PM_{2.5}$ and PM_{10} where exceedances of the relevant NAAQSs were simulated.

It should also be noted that ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, normally outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access.

4.4.1 PM_{10}

The simulated highest daily and annual average PM_{10} concentrations for the current operations and future Project scenarios are provided in Figure 12 and Figure 15 (current – mitigated), Figure 13 and Figure 16 (future Project – unmitigated) and Figure 14 and Figure 17 (future Project – unmitigated), with the GLCs at each of the AQSRs provided in Table 16 for the current operations and Table 17 for future operations.

Current operations: Simulated PM_{10} daily ground level concentrations (GLCs), with current mitigation measures in place, are in non-compliance with the NAAQS over a portion of the Maditlhokwa Community and to the north-east of the mining rights boundary, but at no other AQSRs (Figure 12 and Table 16). The simulated number of exceedances of the daily PM_{10} NAAQS at Maditlhokwa Community are 41 with a single exceedance at AQSR33 and AQSR34 (Potgieter Residence). Over an annual average the GLCs are within the NAAQS at all AQSRs, except at Maditlhokwa Community with an annual average of 40.5 µg/m³ just over the NAAQS (Figure 15 and Table 16).

Future Project operations: PM_{10} daily GLCs, for unmitigated activities, are likely to exceed the NAAQS for a distance of up to 3.5 km from the mining rights boundary on the eastern side and for about 1 km to the west and north (Figure 13). The simulated number of exceedances of the daily PM_{10} NAAQS at 12 of the AQSRs are not in compliance with the NAAQS, including the communities of Lapologang and Madithlokwa (Table 17 Table 16). The annual GLCs are in non-compliance with the NAAQS at four (4) of the AQSRs (AQSR3 – Wolvaardt Residence; AQSR5 – Retief Primary School, Lapologang and Madithlokwa) (Figure 16 and Table 17). With mitigation in place, the area of exceedances of the PM_{10} daily NAAQS is reduced to fall mostly within the mining rights boundary (Figure 14), and non-compliance only at Madithlokwa (140 exceedances) and single exceedances at three (3) AQSRs (AQSR34 – Potgieter Residence; AQSR35 and Lapologang) (Table 17). Over an annual average the mitigated GLCs are within compliance outside the mining rights boundary, except at Madithlokwa with an annual average of 66 µg/m³ (Figure 17 and Table 17).

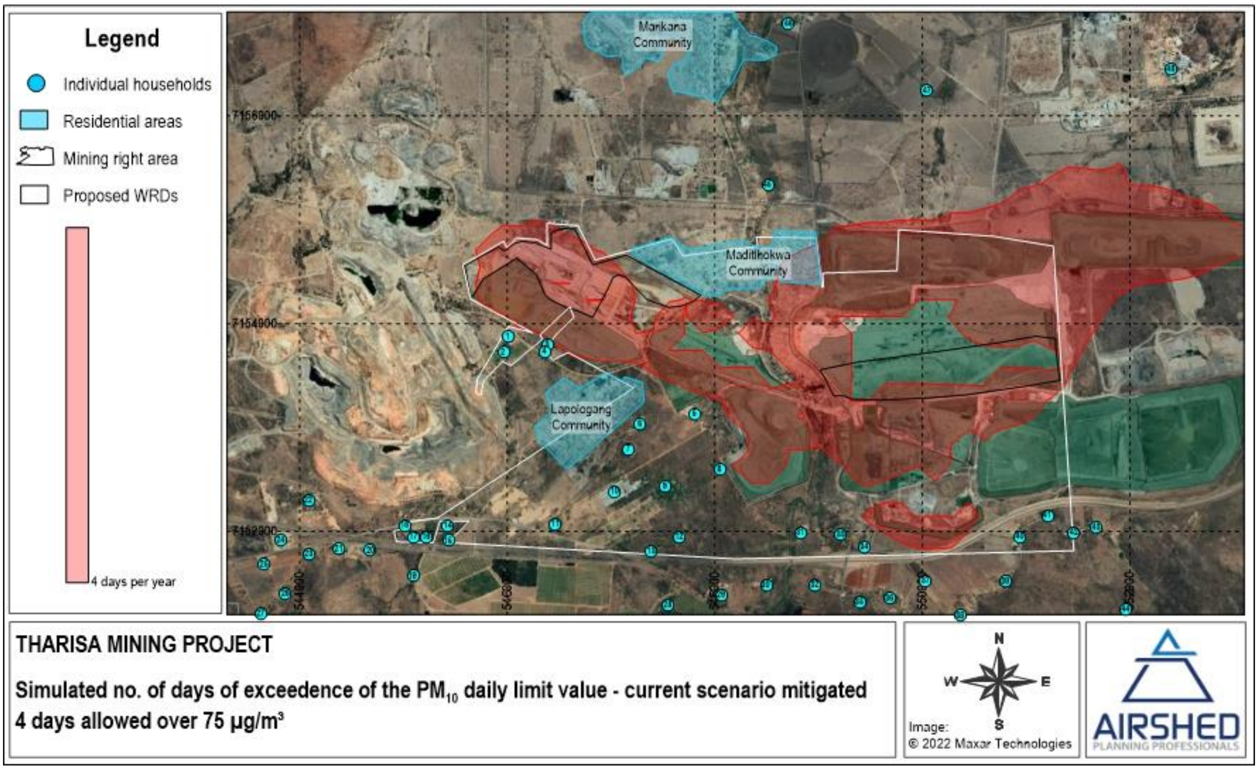


Figure 12: Current scenario – Area of non-compliance of daily PM_{10} NAAQS (mitigated)

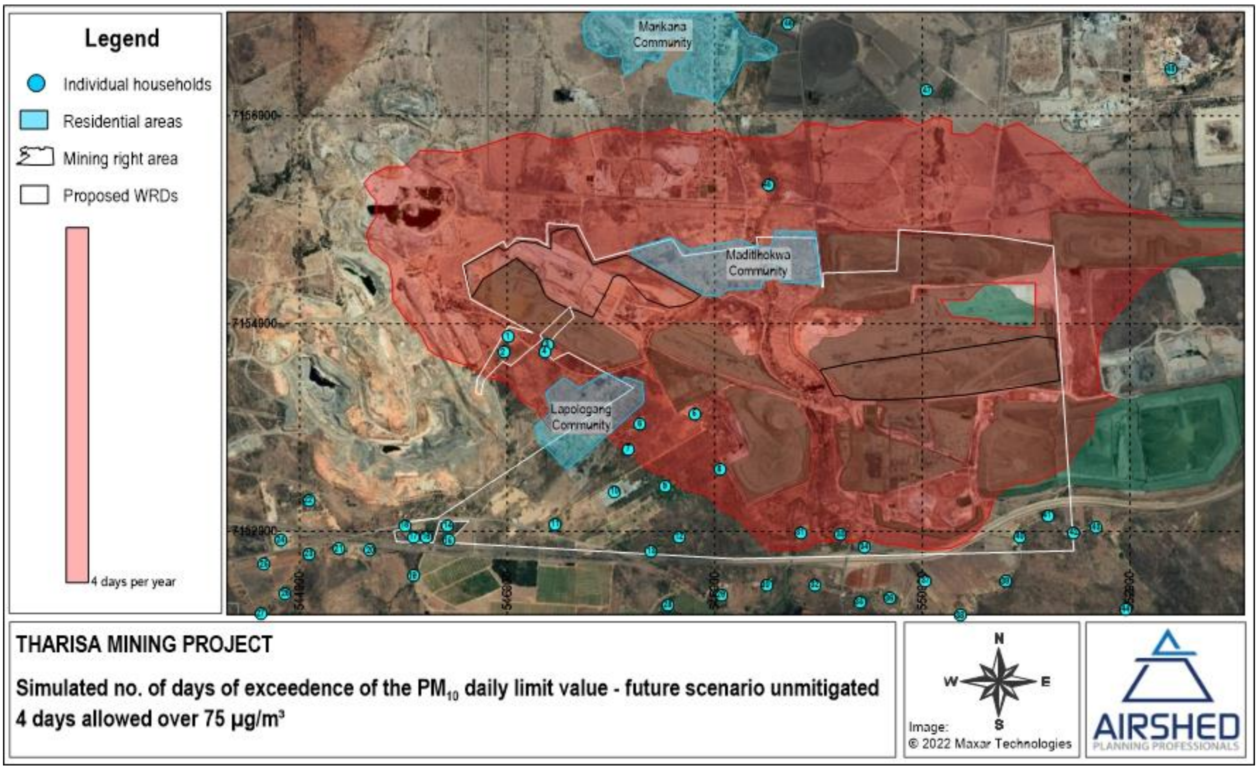


Figure 13: Future Project scenario – Area of non-compliance of daily PM_{10} NAAQS (unmitigated)

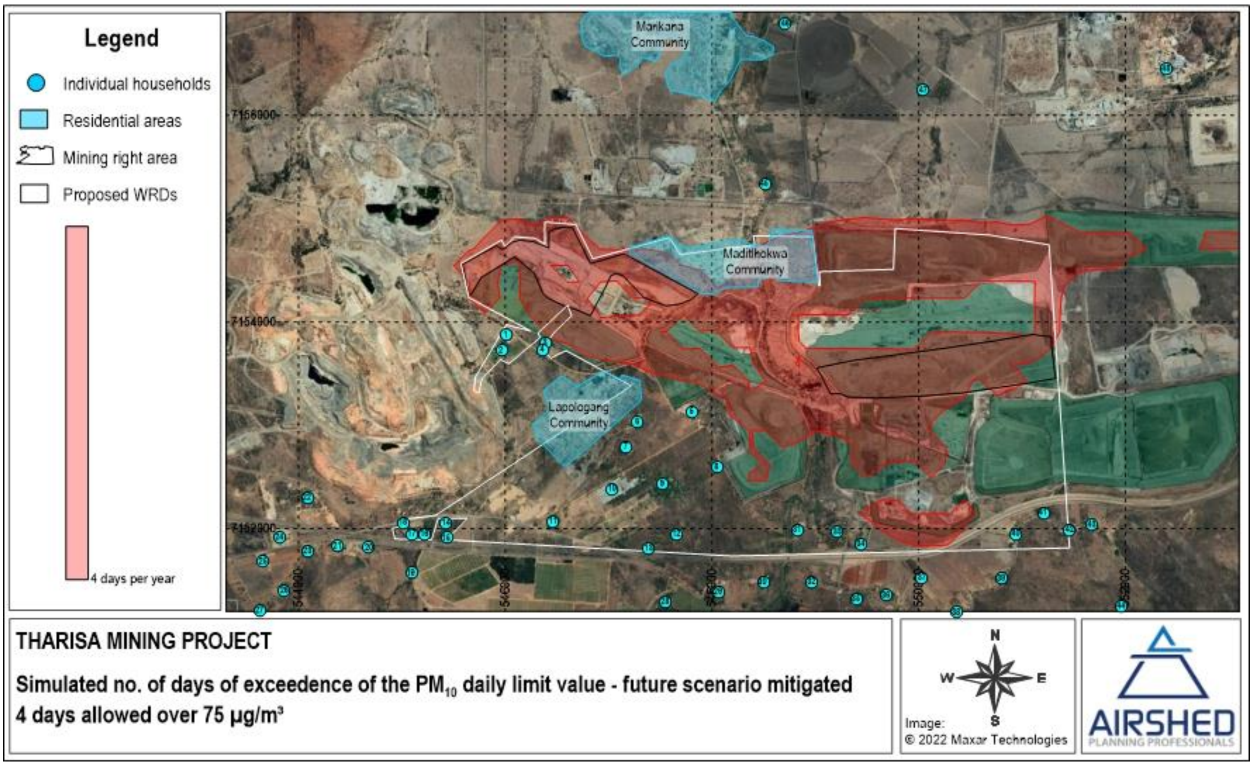


Figure 14: Future Project scenario – Area of non-compliance of daily PM_{10} NAAQS (mitigated)

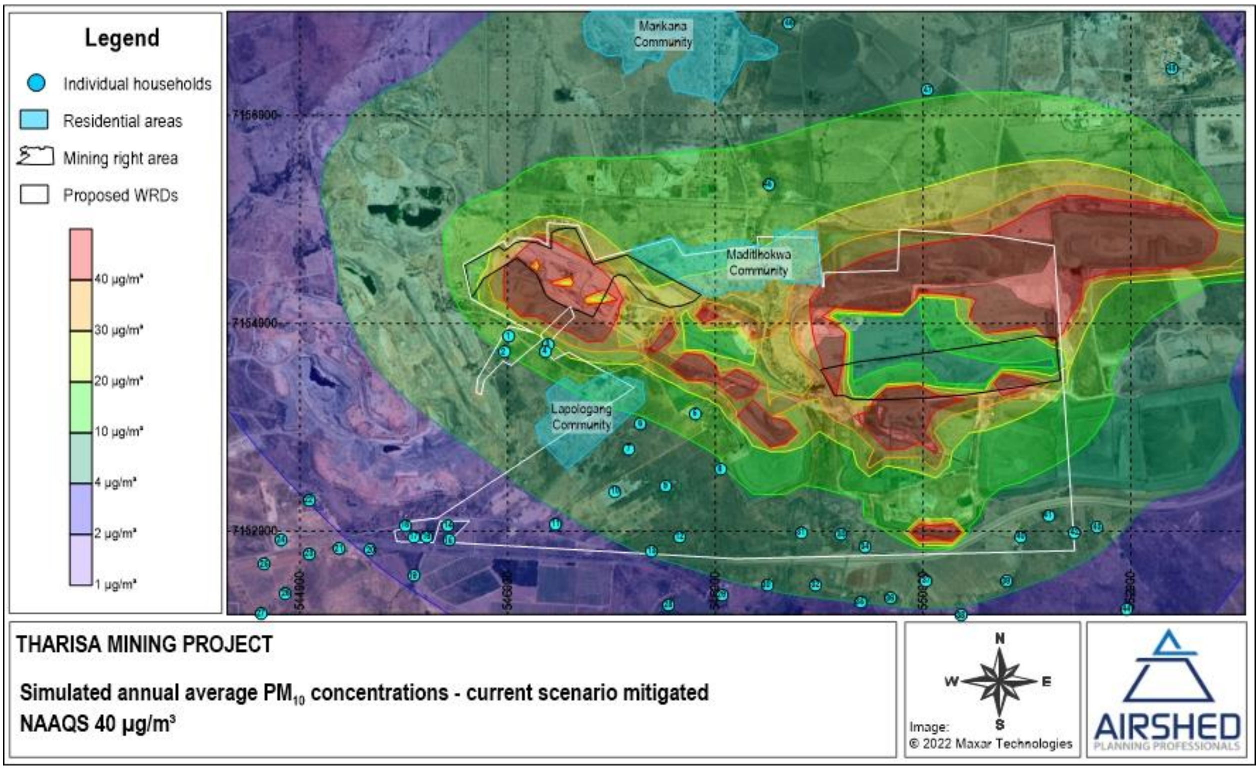


Figure 15: Current scenario – Area of non-compliance of annual PM_{10} NAAQS (mitigated)

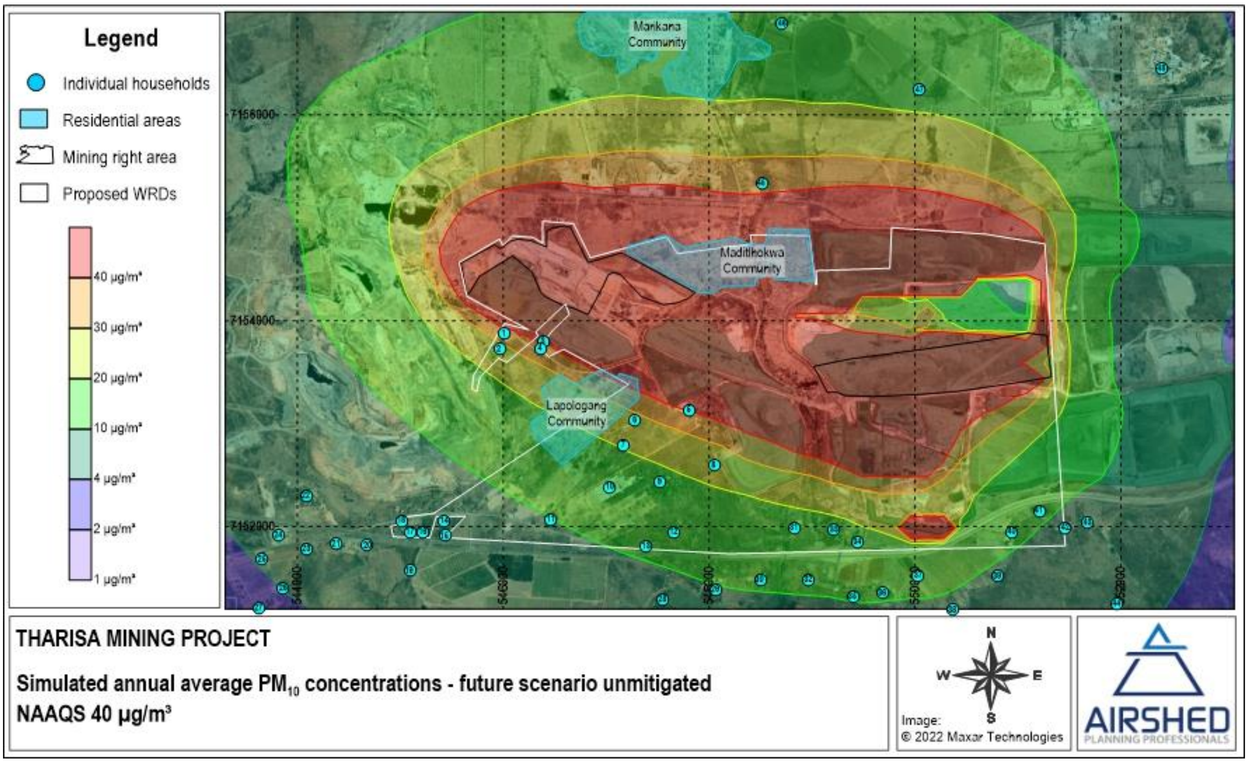


Figure 16: Future Project scenario – Area of non-compliance of ***annual*** *PM_{10} NAAQS (unmitigated)*

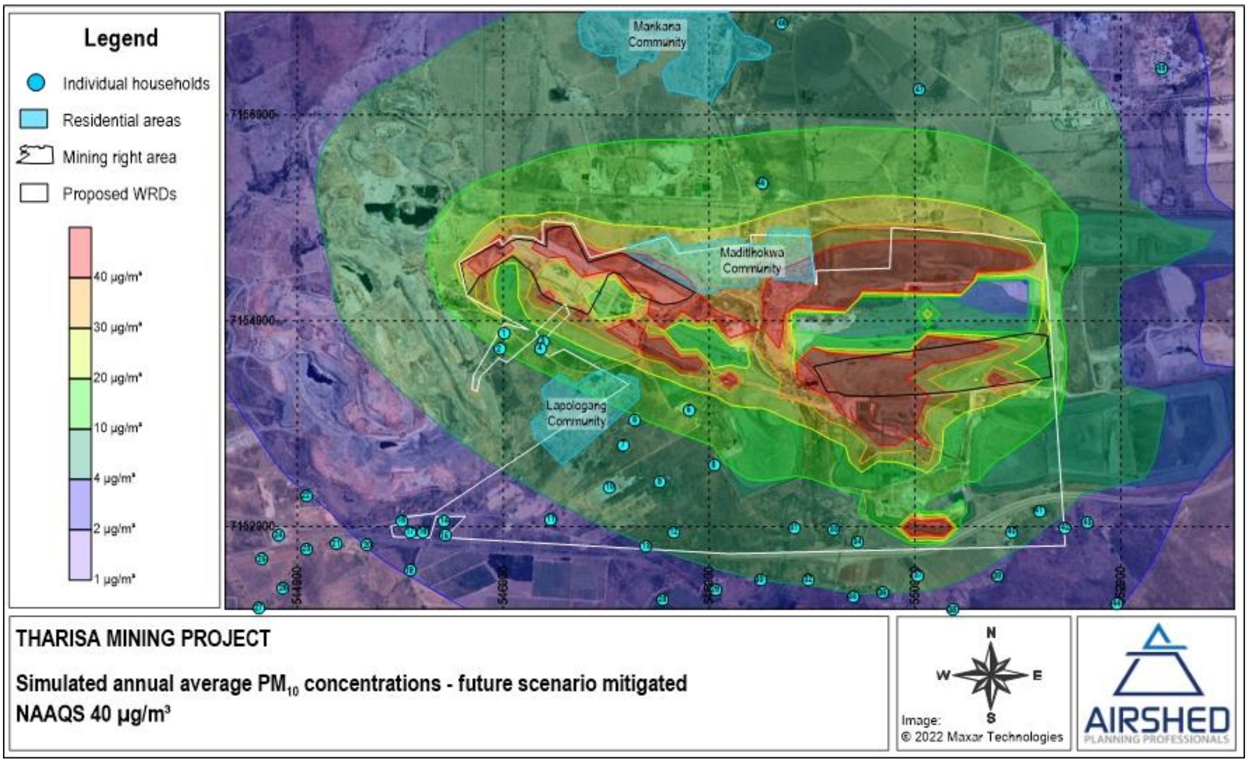


Figure 17: Future Project scenario – Area of non-compliance of ***annual*** *PM_{10} NAAQS (mitigated)*

Table 16: Simulated AQSR PM_{10} concentrations (in µg/m³) due to current operations (mitigated)

	Current Operations (mitigated)			
AQSRs	**Highest Daily**	**Annual**	**No of Exceedances**	**Compliance (Yes/No)**
NAAQS	**75**	**40**	**4**	**-**
AQSR1	61	12.8	0	Yes
AQSR2	48	10.0	0	Yes
AQSR3 (Wolvaardt Residence)	73	17.4	0	Yes
AQSR4 (van der Hoven Residence)	65	14.5	0	Yes
AQSR5 (Retief Primary School)	60	14.1	0	Yes
AQSR6 (Pretorius Residence)	45	9.3	0	Yes
AQSR7 (du Preez Residence)	38	7.4	0	Yes
AQSR8	53	9.0	0	Yes
AQSR9	38	6.3	0	Yes
AQSR10 (industrial)	33	5.3	0	Yes
AQSR11	25	3.7	0	Yes
AQSR12	30	4.8	0	Yes
AQSR13	27	4.1	0	Yes
AQSR14	21	2.7	0	Yes
AQSR15	21	2.6	0	Yes
AQSR16	20	2.5	0	Yes
AQSR17	19	2.4	0	Yes
AQSR18	18	2.4	0	Yes
AQSR19	19	2.1	0	Yes
AQSR20	17	2.1	0	Yes
AQSR21	16	1.9	0	Yes
AQSR22	16	2.0	0	Yes
AQSR23	14	1.8	0	Yes
AQSR24	14	1.7	0	Yes
AQSR25	13	1.6	0	Yes
AQSR26	15	1.5	0	Yes
AQSR27	14	1.4	0	Yes
AQSR28	24	3.2	0	Yes
AQSR29	34	3.6	0	Yes
AQSR30	35	4.1	0	Yes
AQSR31	58	6.4	0	Yes
AQSR32	35	4.4	0	Yes
AQSR33	92	6.8	1	Yes
AQSR34 (Potgieter Residence)	86	6.4	1	Yes
AQSR35	37	4.0	0	Yes
AQSR36	41	4.2	0	Yes
AQSR37	47	4.9	0	Yes
AQSR38	35	3.8	0	Yes
AQSR39	36	4.3	0	Yes
AQSR40	40	5.6	0	Yes
AQSR41	34	6.0	0	Yes

	Current Operations (mitigated)			
AQSR42	32	4.9	0	Yes
AQSR43	32	4.6	0	Yes
AQSR44	21	2.8	0	Yes
AQSR45	45	13.1	0	Yes
AQSR46	25	5.5	0	Yes
AQSR47	35	9.4	0	Yes
AQSR48 (Lonmin Training Centre)	42	5.9	0	Yes
Marikana	31	7.3	0	Yes
Lapologang	75	15.2	0	Yes
Maditlhokwa	127	**40.5**	**41**	**No**

Table 17: Simulated AQSR PM_{10} concentrations (in µg/m³) due to future Project operations (unmitigated and mitigated)

	Future Operations (unmitigated)				Future Operations (mitigated)			
AQSRs	**Highest Daily**	**Annual**	**No of Exceedances**	**Compliance (Yes/No)**	**Highest Daily**	**Annual**	**No of Exceedances**	**Compliance (Yes/No)**
NAAQS	**75**	**40**	**4**	**-**	**75**	**40**	**4**	**-**
AQSR1	165	35.0	**33**	**No**	62	12.9	0	Yes
AQSR2	144	27.5	**13**	**No**	53	10.0	0	Yes
AQSR3 (Wolvaardt Residence)	182	**40.6**	**47**	**No**	68	14.9	0	Yes
AQSR4 (van der Hoven Residence)	168	36.6	**35**	**No**	64	13.3	0	Yes
AQSR5 (Retief Primary School)	190	**40.8**	**51**	**No**	66	13.7	0	Yes
AQSR6 (Pretorius Residence)	144	27.6	**14**	**No**	47	9.5	0	Yes
AQSR7 (du Preez Residence)	107	20.9	4	Yes	42	7.3	0	Yes
AQSR8	111	24.2	**7**	**No**	42	8.4	0	Yes
AQSR9	88	17.4	1	Yes	30	6.2	0	Yes
AQSR10 (industrial)	77	14.4	0	Yes	30	5.1	0	Yes
AQSR11	62	9.9	0	Yes	22	3.6	0	Yes
AQSR12	73	12.8	0	Yes	27	4.6	0	Yes
AQSR13	59	10.9	0	Yes	22	4.0	0	Yes
AQSR14	52	7.4	0	Yes	22	2.7	0	Yes
AQSR15	49	7.0	0	Yes	18	2.5	0	Yes
AQSR16	50	6.7	0	Yes	20	2.4	0	Yes
AQSR17	48	6.5	0	Yes	20	2.3	0	Yes
AQSR18	43	6.5	0	Yes	19	2.4	0	Yes
AQSR19	37	5.6	0	Yes	15	2.0	0	Yes
AQSR20	38	5.5	0	Yes	17	2.0	0	Yes
AQSR21	39	5.1	0	Yes	16	1.9	0	Yes
AQSR22	35	5.4	0	Yes	15	2.0	0	Yes
AQSR23	37	4.7	0	Yes	15	1.7	0	Yes
AQSR24	30	4.5	0	Yes	13	1.7	0	Yes

	Future Operations (unmitigated)				Future Operations (mitigated)			
AQSR25	31	4.1	0	Yes	14	1.5	0	Yes
AQSR26	31	4.1	0	Yes	14	1.5	0	Yes
AQSR27	29	3.7	0	Yes	13	1.4	0	Yes
AQSR28	60	8.3	0	Yes	22	3.1	0	Yes
AQSR29	69	9.7	1	Yes	23	3.5	0	Yes
AQSR30	68	10.8	0	Yes	25	4.0	0	Yes
AQSR31	97	16.6	**7**	**No**	57	6.1	0	Yes
AQSR32	77	11.1	0	Yes	29	4.2	0	Yes
AQSR33	119	17.4	**5**	**No**	92	6.5	1	Yes
AQSR34 (Potgieter Residence)	107	16.3	3	Yes	86	6.3	1	Yes
AQSR35	65	10.4	0	Yes	34	3.9	0	Yes
AQSR36	85	10.6	0	Yes	37	4.0	0	Yes
AQSR37	78	11.9	0	Yes	38	4.5	0	Yes
AQSR38	63	8.9	0	Yes	27	3.4	0	Yes
AQSR39	65	9.1	0	Yes	22	3.6	0	Yes
AQSR40	67	11.3	0	Yes	26	4.6	0	Yes
AQSR41	81	11.0	0	Yes	30	4.6	0	Yes
AQSR42	69	8.8	0	Yes	26	3.7	0	Yes
AQSR43	70	7.8	0	Yes	24	3.3	0	Yes
AQSR44	43	5.0	0	Yes	16	2.1	0	Yes
AQSR45	119	36.4	**29**	**No**	49	14.8	0	Yes
AQSR46	53	12.8	0	Yes	20	5.0	0	Yes
AQSR47	80	17.2	1	Yes	33	7.4	0	Yes
AQSR48 (Lonmin Training Centre)	50	6.0	0	Yes	21	2.6	0	Yes
Marikana	70	19.0	1	Yes	26	7.3	0	Yes
Lapologang	237	**48.2**	**77**	**No**	73	16.0	1	Yes
Maditlhokwa	858	**144.1**	**286**	**No**	184	**66.1**	**140**	**No**

4.4.2 $PM_{2.5}$

The simulated highest daily and annual average $PM_{2.5}$ concentrations for the current operations and future Project scenarios are provided in Figure 18 and Figure 21 (current – mitigated), Figure 19 and Figure 22 (future Project – unmitigated) and Figure 20 and Figure 23 (future Project – unmitigated), with the GLCs at each of the AQSRs provided in Table 18 for the current operations and Table 19 for future operations.

Current operations: Simulated $PM_{2.5}$ daily ground level concentrations (GLCs), with current mitigation measures in place, are in non-compliance with the NAAQS for an area to the north-east of the mining rights boundary (mostly over the WRD), but not at any AQSRs (Figure 18 and Table 18). Over an annual average the GLCs are within the NAAQS at all AQSRs (Figure 21 and Table 18).

Future Project operations: $PM_{2.5}$ daily GLCs, for unmitigated activities, are likely to exceed the NAAQS for a few hundred meters outside mining rights boundary (Figure 19) and at Madithlokwa with 65 predicted exceedances, but at none of the other AQSRs (Table 19Table 16). The annual GLCs are in compliance with the NAAQS at all the AQSRs (Figure 22 and Table 19). With mitigation in place, the area of exceedances of the $PM_{2.5}$ daily NAAQS is reduced to fall mostly within the mining rights boundary (Figure 20), not exceeding the NAAQS at any of the AQSRs (Table 19). Over an annual average the mitigated GLCs are within compliance outside the mining rights boundary (Figure 23 and Table 19).

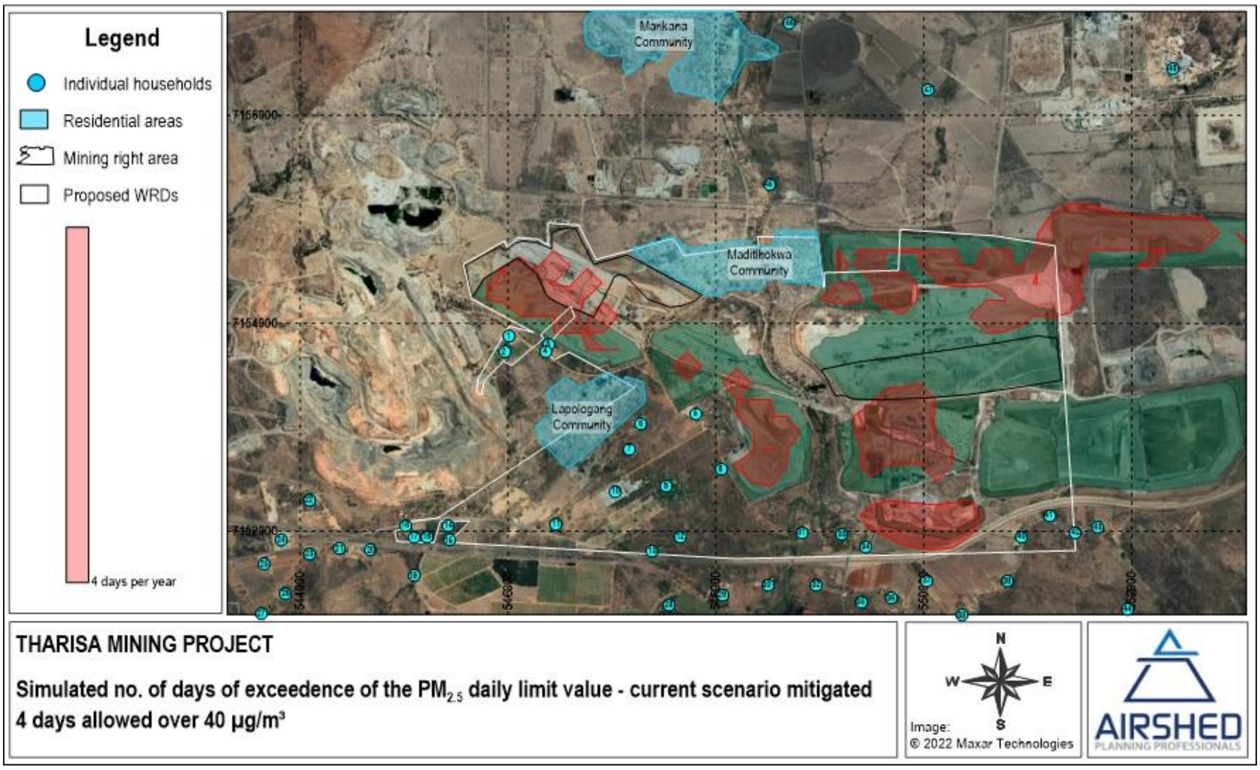


Figure 18: Current scenario – Area of non-compliance of daily $PM_{2.5}$ NAAQS (mitigated)

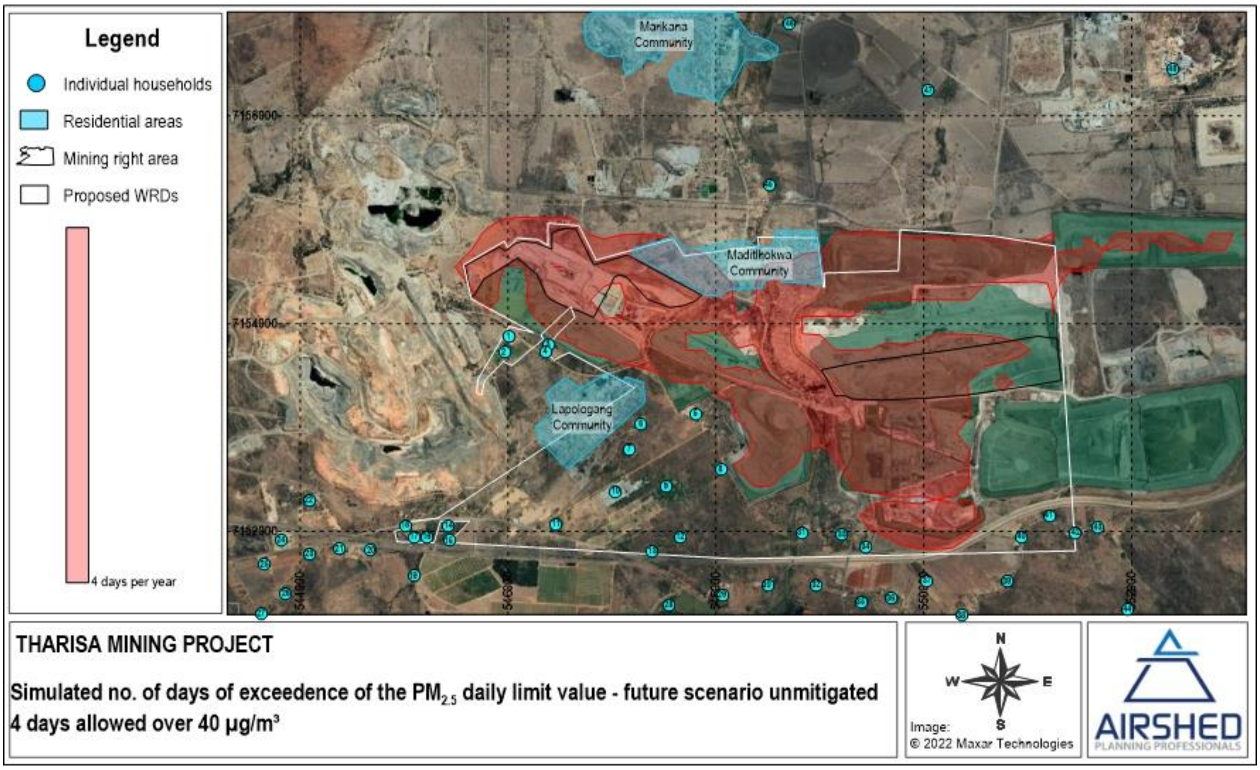


Figure 19: Future Project scenario – Area of non-compliance of daily $PM_{2.5}$ NAAQS (unmitigated)

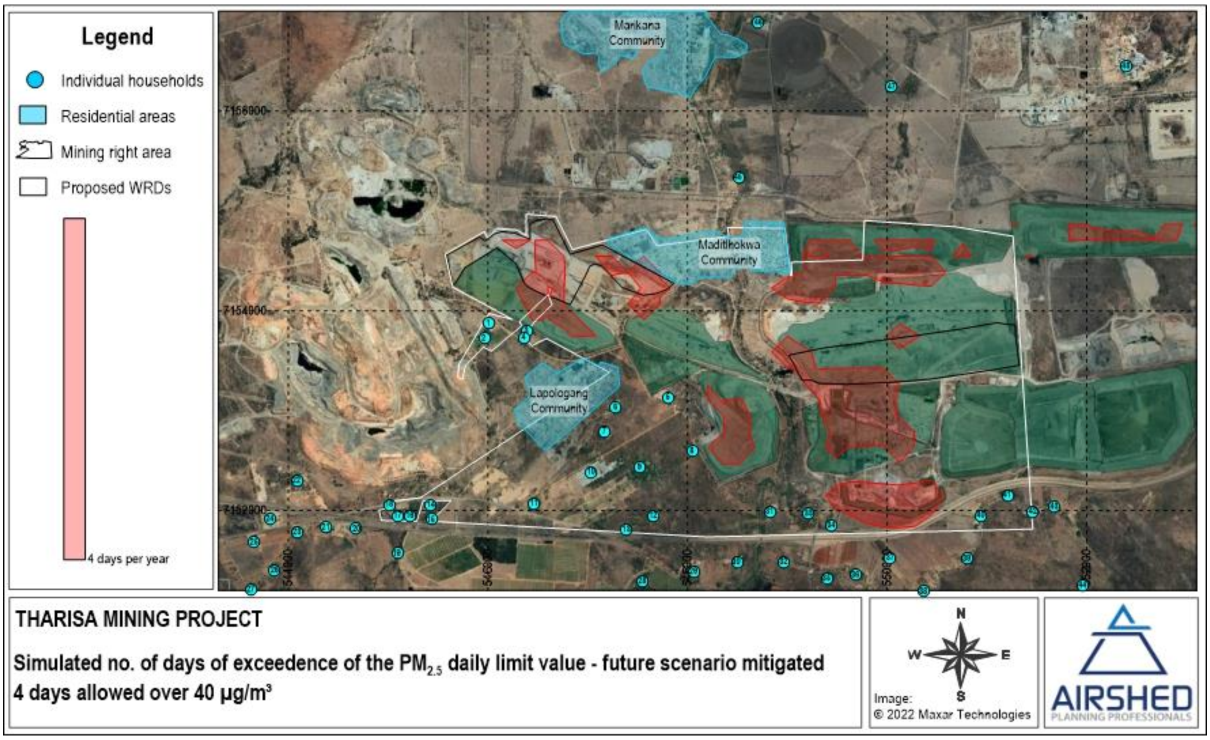


Figure 20: Future Project scenario – Area of non-compliance of daily $PM_{2.5}$ NAAQS (mitigated)

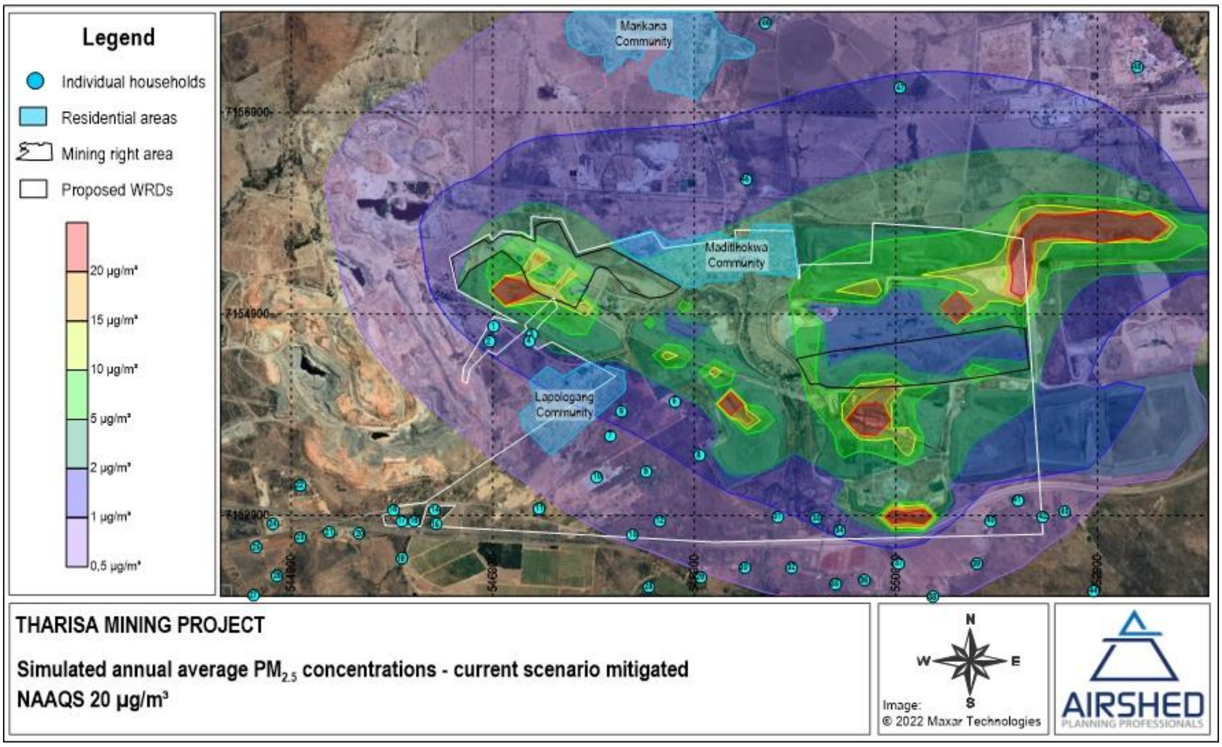


Figure 21: Current scenario – Area of non-compliance of annual $PM_{2.5}$ NAAQS (mitigated)

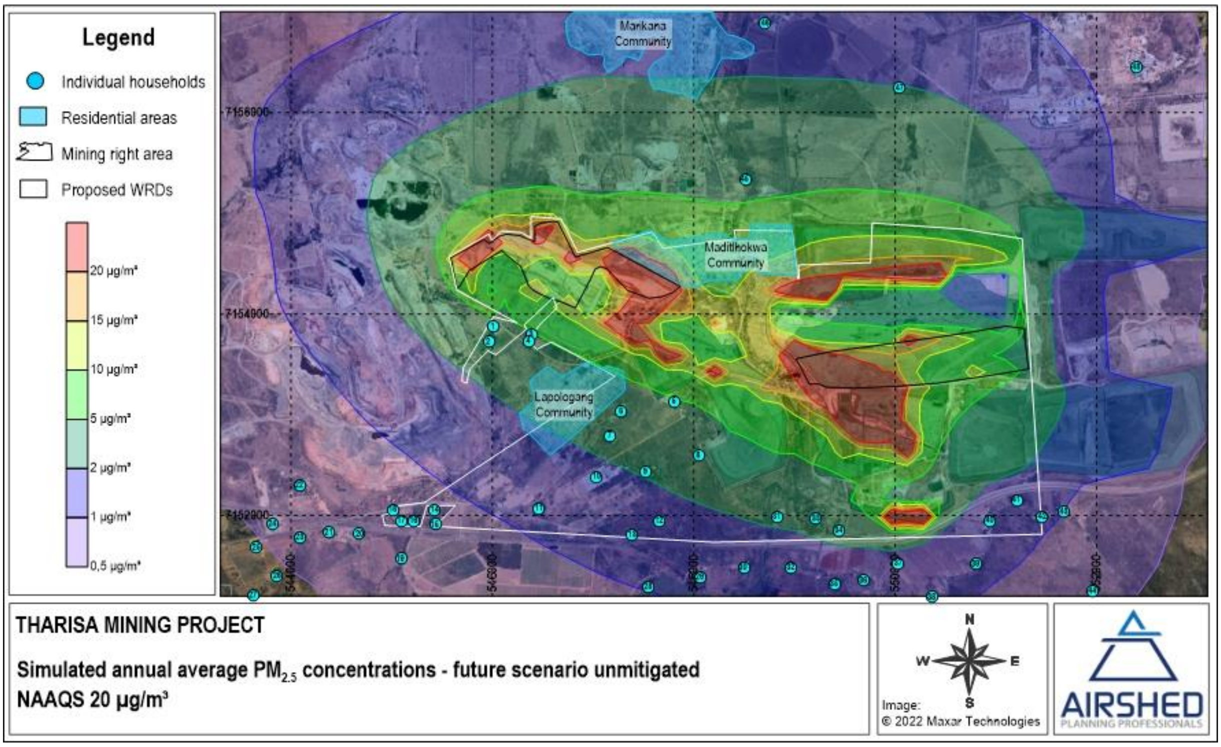


Figure 22: Future Project scenario – Area of non-compliance of annual $PM_{2.5}$ NAAQS (unmitigated)

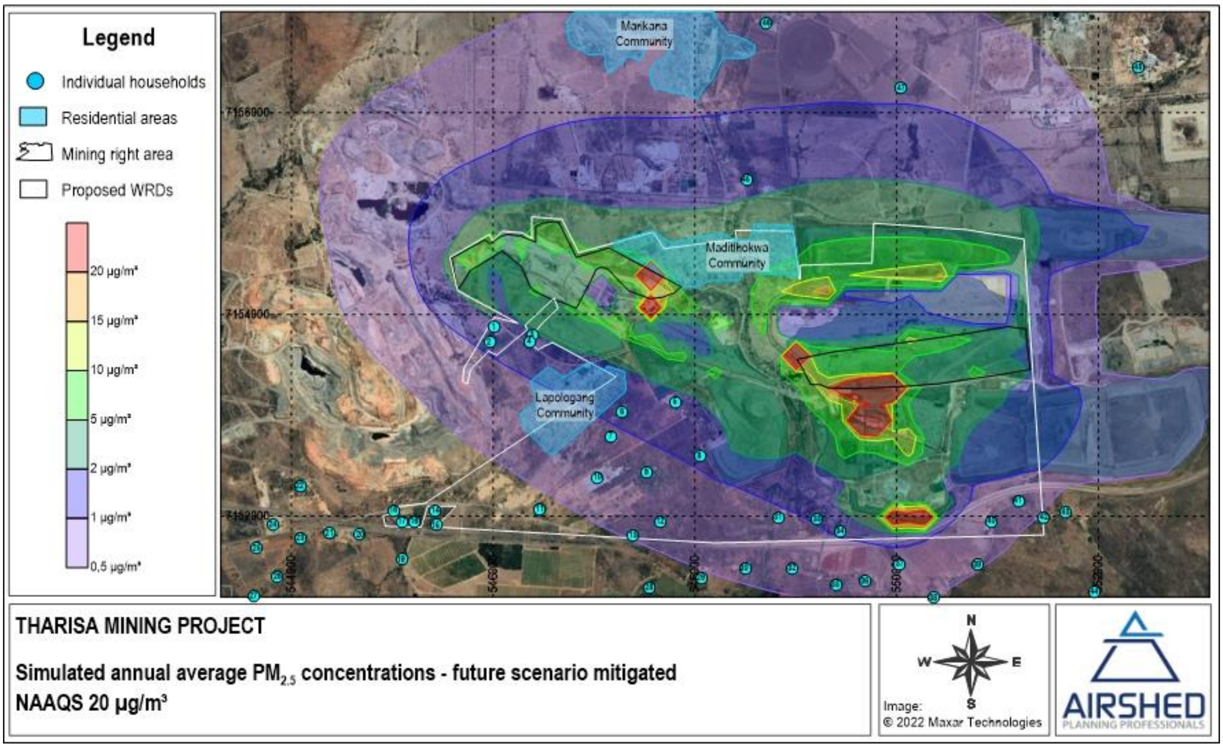


Figure 23: Future Project scenario – Area of non-compliance of annual $PM_{2.5}$ NAAQS (mitigated)

Table 18: Simulated AQSR $PM_{2.5}$ concentrations (in µg/m³) due to current operations (mitigated)

	Current Operations (mitigated)			
AQSRs	**Highest Daily**	**Annual**	**No of Exceedances**	**Compliance (Yes/No)**
NAAQS	**40**	**20**	**4**	**-**
AQSR1	7	1.5	0	Yes
AQSR2	5	1.2	0	Yes
AQSR3 (Wolvaardt Residence)	10	2.0	0	Yes
AQSR4 (van der Hoven Residence)	7	1.7	0	Yes
AQSR5 (Retief Primary School)	7	1.7	0	Yes
AQSR6 (Pretorius Residence)	6	1.1	0	Yes
AQSR7 (du Preez Residence)	5	0.9	0	Yes
AQSR8	10	1.2	0	Yes
AQSR9	5	0.8	0	Yes
AQSR10 (industrial)	4	0.7	0	Yes
AQSR11	5	0.5	0	Yes
AQSR12	10	0.6	0	Yes
AQSR13	7	0.5	0	Yes
AQSR14	3	0.3	0	Yes
AQSR15	4	0.3	0	Yes
AQSR16	3	0.3	0	Yes
AQSR17	3	0.3	0	Yes
AQSR18	3	0.3	0	Yes
AQSR19	2	0.3	0	Yes
AQSR20	3	0.3	0	Yes

	Current Operations (mitigated)			
AQSR21	3	0.2	0	Yes
AQSR22	2	0.2	0	Yes
AQSR23	2	0.2	0	Yes
AQSR24	2	0.2	0	Yes
AQSR25	2	0.2	0	Yes
AQSR26	2	0.2	0	Yes
AQSR27	2	0.2	0	Yes
AQSR28	3	0.4	0	Yes
AQSR29	5	0.5	0	Yes
AQSR30	5	0.6	0	Yes
AQSR31	26	0.9	0	Yes
AQSR32	10	0.6	0	Yes
AQSR33	43	1.1	1	Yes
AQSR34 (Potgieter Residence)	40	1.1	1	Yes
AQSR35	10	0.6	0	Yes
AQSR36	14	0.6	0	Yes
AQSR37	10	0.8	0	Yes
AQSR38	5	0.5	0	Yes
AQSR39	4	0.6	0	Yes
AQSR40	5	0.7	0	Yes
AQSR41	5	0.8	0	Yes
AQSR42	4	0.6	0	Yes
AQSR43	4	0.6	0	Yes
AQSR44	3	0.3	0	Yes
AQSR45	5	1.5	0	Yes
AQSR46	3	0.6	0	Yes
AQSR47	6	1.1	0	Yes
AQSR48 (Lonmin Training Centre)	5	0.7	0	Yes
Marikana	3	0.8	0	Yes
Lapologang	8	1.8	0	Yes
Maditlhokwa	18	4.7	0	Yes

Table 19: Simulated AQSR PM_{10} concentrations (in µg/m³) due to future Project operations (unmitigated and mitigated)

	Future Operations (unmitigated)				Future Operations (mitigated)			
AQSRs	**Highest Daily**	**Annual**	**No of Exceedances**	**Compliance (Yes/No)**	**Highest Daily**	**Annual**	**No of Exceedances**	**Compliance (Yes/No)**
NAAQS	**40**	**20**	**4**	**-**	**40**	**20**	**4**	**-**
AQSR1	18	4.0	0	Yes	7	1.5	0	Yes
AQSR2	16	3.2	0	Yes	6	1.2	0	Yes
AQSR3 (Wolvaardt Residence)	20	4.6	0	Yes	10	1.7	0	Yes
AQSR4 (van der Hoven Residence)	18	4.2	0	Yes	7	1.5	0	Yes
AQSR5 (Retief Primary School)	20	4.7	0	Yes	8	1.7	0	Yes
AQSR6 (Pretorius Residence)	15	3.2	0	Yes	6	1.2	0	Yes
AQSR7 (du Preez Residence)	12	2.5	0	Yes	5	0.9	0	Yes
AQSR8	13	3.0	0	Yes	9	1.1	0	Yes
AQSR9	10	2.1	0	Yes	4	0.8	0	Yes
AQSR10 (industrial)	9	1.7	0	Yes	4	0.6	0	Yes
AQSR11	7	1.2	0	Yes	5	0.5	0	Yes
AQSR12	11	1.6	0	Yes	10	0.6	0	Yes
AQSR13	8	1.3	0	Yes	7	0.5	0	Yes
AQSR14	6	0.9	0	Yes	3	0.3	0	Yes
AQSR15	5	0.8	0	Yes	4	0.3	0	Yes
AQSR16	6	0.8	0	Yes	3	0.3	0	Yes
AQSR17	5	0.8	0	Yes	3	0.3	0	Yes
AQSR18	5	0.8	0	Yes	3	0.3	0	Yes
AQSR19	4	0.7	0	Yes	2	0.3	0	Yes
AQSR20	4	0.7	0	Yes	3	0.3	0	Yes
AQSR21	4	0.6	0	Yes	3	0.2	0	Yes
AQSR22	4	0.6	0	Yes	2	0.2	0	Yes
AQSR23	4	0.6	0	Yes	2	0.2	0	Yes
AQSR24	3	0.5	0	Yes	2	0.2	0	Yes

	Future Operations (unmitigated)				Future Operations (mitigated)			
AQSR25	3	0.5	0	Yes	2	0.2	0	Yes
AQSR26	4	0.5	0	Yes	2	0.2	0	Yes
AQSR27	3	0.4	0	Yes	1	0.2	0	Yes
AQSR28	7	1.0	0	Yes	3	0.4	0	Yes
AQSR29	9	1.2	0	Yes	4	0.5	0	Yes
AQSR30	9	1.4	0	Yes	4	0.6	0	Yes
AQSR31	27	2.2	0	No	26	0.9	0	Yes
AQSR32	12	1.5	0	Yes	10	0.6	0	Yes
AQSR33	44	2.5	1	Yes	43	1.1	1	Yes
AQSR34 (Potgieter Residence)	41	2.4	1	Yes	41	1.1	1	Yes
AQSR35	13	1.4	0	Yes	10	0.6	0	Yes
AQSR36	15	1.4	0	Yes	14	0.6	0	Yes
AQSR37	16	1.7	0	Yes	10	0.7	0	Yes
AQSR38	8	1.2	0	Yes	4	0.5	0	Yes
AQSR39	9	1.2	0	Yes	4	0.5	0	Yes
AQSR40	10	1.5	0	Yes	5	0.6	0	Yes
AQSR41	12	1.4	0	Yes	4	0.6	0	Yes
AQSR42	10	1.1	0	Yes	4	0.5	0	Yes
AQSR43	8	1.0	0	Yes	3	0.4	0	Yes
AQSR44	6	0.6	0	Yes	3	0.3	0	Yes
AQSR45	14	4.1	0	Yes	6	1.7	0	Yes
AQSR46	6	1.5	0	Yes	3	0.6	0	Yes
AQSR47	9	2.0	0	Yes	6	0.9	0	Yes
AQSR48 (Lonmin Training Centre)	6	0.7	0	Yes	3	0.3	0	Yes
Marikana	8	2.1	0	Yes	3	0.8	0	Yes
Lapologang	25	5.4	0	Yes	8	1.9	0	Yes
Maditlhokwa	88	16.2	**65**	**No**	23	7.4	0	Yes

4.4.3 Dust Fallout

The simulated maximum daily dustfall rates for the current operations is provided in Figure 24, and for the future Project operations in Figure 25 (unmitigated) and Figure 26 (mitigated).

Simulated maximum daily dustfall rates for current mitigated operations are within the NDCR non-residential limit (1 200 mg/m²/day) and the residential limit (600 mg/m²/day) at all the AQSRs (Figure 24). For the future Project unmitigated scenario, the dustfall rates exceed the NDCR non-residential limit (1 200 mg/m²/day) and the residential limit (600 mg/m²/day) at the southeast of Madithlokwa, but at no other AQSRs (Figure 25). With mitigation in place, no exceedances of the NDCR non-residential limit are expected, and with the residential limit only exceeded at a small area in the southeast of Madithlokwa (Figure 26).

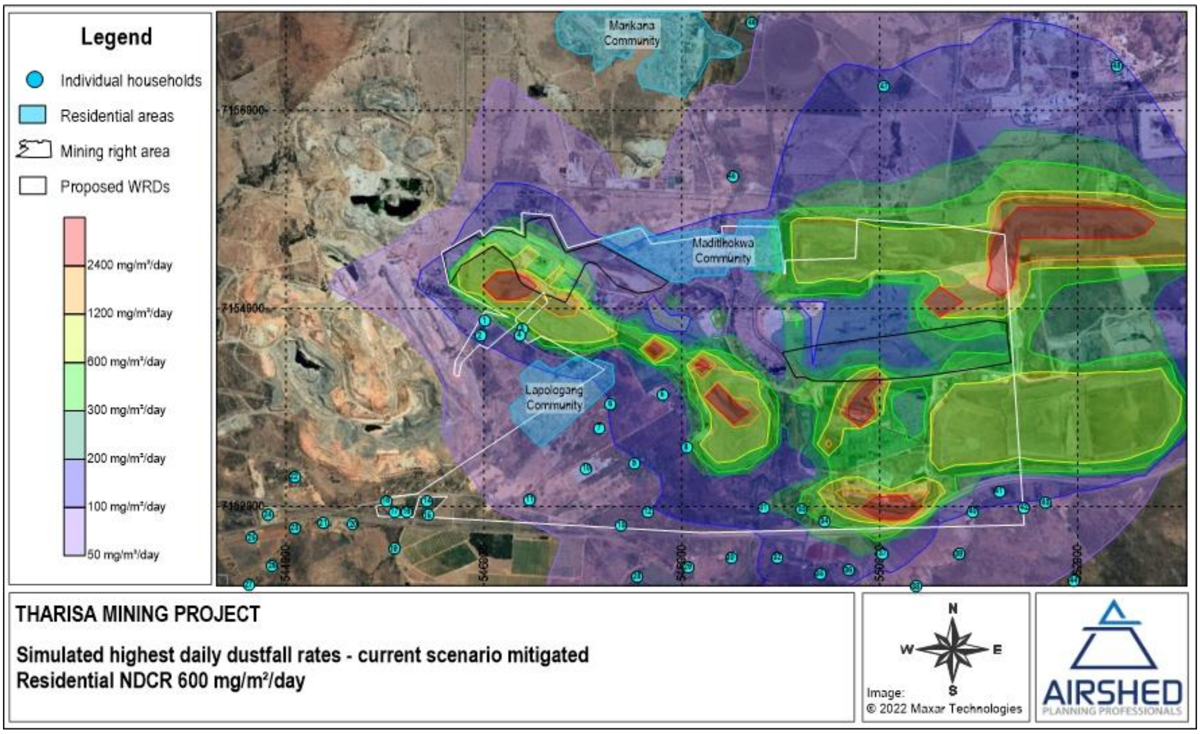


Figure 24: Current scenario – Area of non-compliance with monthly dustfall NDCR (mitigated)

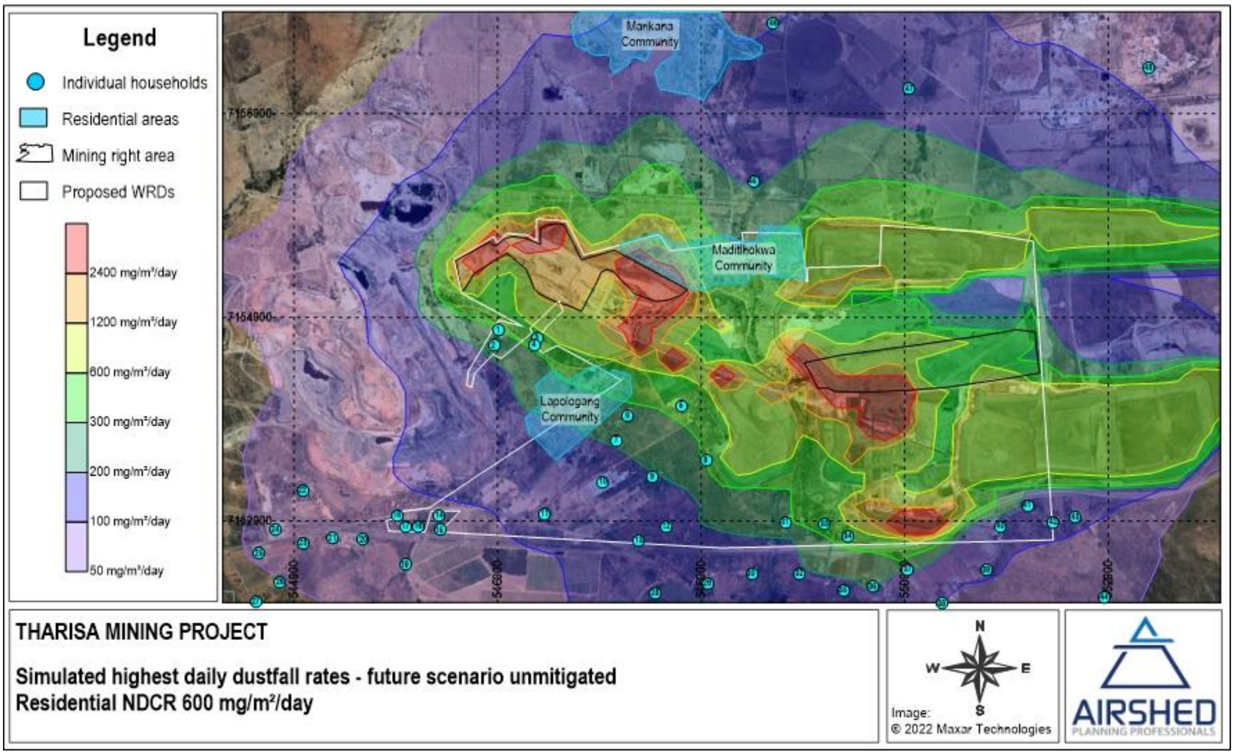


Figure 25: Future Project scenario – Area of non-compliance with monthly dustfall NDCR (unmitigated)

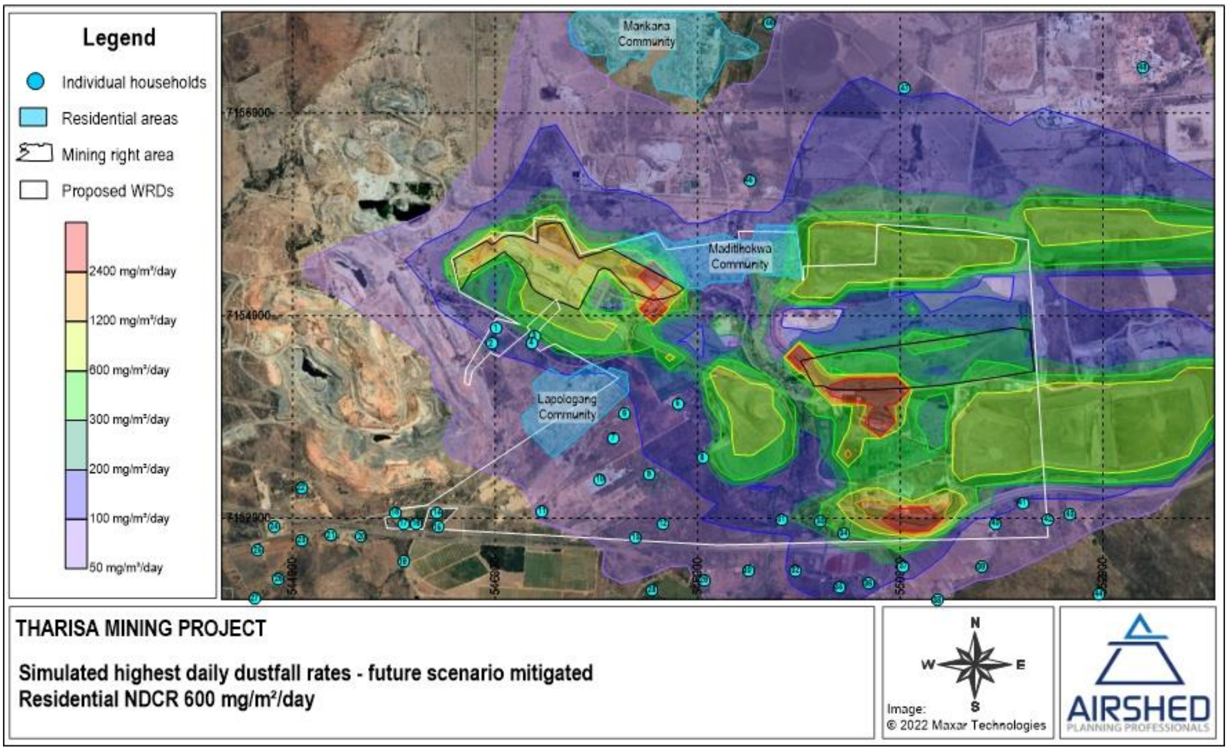


Figure 26: Future Project scenario – Area of non-compliance with monthly dustfall NDCR (mitigated)

4.4.4 Metals

ICP (Inductively Coupled Plasma) Spectroscopy[6] for 42 elements was conducted on the three composite samples from the waste rock, the tailings, and the road surfaces (the IPC results are included in Appendix B). Only toxic metals that had a content above the detection limit were included in the assessment. The highest metal content from the three samples were applied to the PM_{10} simulated dust concentrations and screened against the most stringent RfC to determine the potential for health impacts. The metals with RfCs guideline values include aluminium (Al), barium (Ba), chromium (VI)(particulates), copper (Cu), iron (Fe), manganese (Mn), and nickel (Ni)(Table 4). Only barium (Ba) and nickel (as soluble salts) have sub-chronic RfCs and these were applied to the daily (24-hour) modelled PM_{10} concentrations for all three scenarios. Al, Ba, CrVI, Mn and Ni all have chronic inhalation RfCs which were applied to the annual average PM_{10} concentrations for all three scenarios. The hazard quotient (HQ) was below 1 for all the metals evaluated, implying that adverse non-cancer effects are unlikely to occur due to exposure from these elements.

The Excess Lifetime Cancer Risk (Table 4) are listed in Table 20. The CrVI content in the simulated PM_{10} concentrations have a potential *Moderate* risk, with a *Low* risk associated with iron and a *Very Low* risk to nickel.

Table 20: Excess Lifetime Cancer Risk calculated at all identified AQSR from the simulated PM_{10} annual average concentrations due to current operations (mitigated) and future Project operations (unmitigated and mitigated)

Metal	Current Operations (mitigated)	Future Operations (unmitigated)	Future Operations (mitigated)
Chromium (CrVI)[(a)]	5.1 in 10 000	1.8 in 1 000	8.3 in 10 000
Iron (Fe)	2.9 in 1 000 000	1.0 in 100 000	4.7 in 1 000 000
Nickel (Ni)	3.3 in 10 million	1.2 in 1 000 000	5.3 in 10 million

Risk Ration by colour	*Very Low*	*Low*	*Moderate*	*High*	*Very high*

Notes: (a) Assumed all chromium is hexavalent chrome which is an overly conservative assumption.

[6] ICP Spectroscopy is an analytical technique used to measure and identify elements within a sample matrix based on the ionization of the elements withing the sample.

5 Impact Significance Rating

The significance of air quality impacts was assessed according to an impact significance rating methodology provided by SLR. Refer to Appendix C of this report for the methodology.

5.1 Construction

As indicated in Section 4.2.1, the construction activities were not assessed separately since most of the expansion operations will be on already disturbed surfaces with little additional land clearing or preparation required. Also, these activities will occur concurrently with the current mining activities. The significance of air quality impacts due to construction are therefore expected to be **Low** without mitigation and **Very Low** with mitigation measures in place (Table 21).

Table 21: Significance rating for air quality impacts due to the future Tharisa Mine Project activities (construction)

Issue: Air quality impacts on human health and the environment		
Phases: Construction		
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Minor change (L)	Negligible change (VL)
Duration	Short-term (L)	Short-term (L)
Extent	A part of the site/property (VL)	A part of the site/property (VL)
Consequence	Low (L)	Very low (VL)
Probability	Possible/ frequent (M)	Conceivable (L)
Significance	**Low (L)**	**Very Low (VL)**
Nature of cumulative impacts	Additional dust generating activities during construction.	
Degree to which impact can be reversed	Impact can be partially reversed during the construction if management measures are put in place and strictly adhered to.	
Degree to which impact may cause irreplaceable loss of resources	Very low	
Residual impacts	Residual impacts are anticipated to be very low. Potential residual impacts include: - nuisance dust impacts on nearby communities. - potential new dust generating sources due to land clearing.	

5.2 Operational Phases

The significance of air quality impacts due to the current operational activities are **High** without mitigation in place and **Medium** with mitigation measures (Table 22). Similarly, the future Project operations will result in **High** significance without mitigation, reducing to **Medium** significance with mitigation measures in place (Table 23).

Table 22: Significance rating for air quality impacts due to the current Tharisa Mine Project activities

Issue: Air quality impacts on human health and the environment		
Phases: Operational phase		
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Prominent change (H)	Moderate change (M)
Duration	Long-term (H)	Long-term (H)
Extent	Beyond the site boundary (M)	Beyond the site boundary (M)
Consequence	High (H)	Medium (M)
Probability	Probable (H)	Probable (H)
Significance	**High (H)**	**Medium (M)**
Nature of cumulative impacts	Dust generating activities from current mining and processing activities.	
Degree to which impact can be reversed	Impact can be partially reversed during the operations if management measures are put in place and strictly adhered to.	
Degree to which impact may cause irreplaceable loss of resources	High (impacts on human health)	
Residual impacts	Residual impacts are anticipated to be medium with mitigation measures in place. Potential residual impacts include: - respiratory health effects at nearby AQSRs due to PM_{10} and $PM_{2.5}$ concentrations from the proposed activities. - nuisance dust impacts on the nearby AQSRs.	

Table 23: Significance rating for air quality impacts due to the future Tharisa Mine Project activities (operation)

Issue: Air quality impacts on human health and the environment		
Phases: Operational phase		
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Prominent change (H)	Moderate change (M)
Duration	Long-term (H)	Long-term (H)
Extent	Beyond the site boundary (M)	Beyond the site boundary (M)
Consequence	High (H)	Medium (M)
Probability	Probable (H)	Probable (H)
Significance	**High (H)**	**Medium (M)**

Issue: Air quality impacts on human health and the environment	
Nature of cumulative impacts	Dust generating activities from future mining and processing activities.
Degree to which impact can be reversed	Impact can be partially reversed during the operations if management measures are put in place and strictly adhered to.
Degree to which impact may cause irreplaceable loss of resources	High (impacts on human health)
Residual impacts	Residual impacts are anticipated to be medium with mitigation measures in place. Potential residual impacts include: - respiratory health effects in members of the Maditlhokwa Community due to PM_{10} and $PM_{2.5}$ concentrations from the proposed activities. - nuisance dust impacts on the Maditlhokwa Community.

5.3 Decommissioning & Rehabilitation Phase

The likely activities to result in dust impacts during decommissioning and rehabilitation will be similar to construction, resulting in a **Low** significance without mitigation and **Very Low** with mitigation measures (Table 24).

Table 24: Significance rating for air quality impacts due to the future Tharisa Mine Project activities (Decommissioning & Rehabilitation Phase)

Issue: Air quality impacts on human health and the environment		
Phases: Decommissioning & Rehabilitation Phase		
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Minor change (L)	Negligible change (VL)
Duration	Short-term (L)	Short-term (L)
Extent	A part of the site/property (VL)	A part of the site/property (VL)
Consequence	Low (L)	Very low (VL)
Probability	Possible/ frequent (M)	Conceivable (L)
Significance	**Low (L)**	**Very Low (VL)**
Nature of cumulative impacts	Dust generating activities during decommissioning & rehabilitation.	
Degree to which impact can be reversed	Impact can be partially reversed if management measures are put in place and strictly adhered to.	
Degree to which impact may cause irreplaceable loss of resources	Very low	
Residual impacts	Residual impacts are anticipated to be very low. Potential residual impacts include: - nuisance dust impacts on nearby communities.	

6 Air Quality Management Measures

In the light of the potential exceedances of the air quality limits around the mining operations, it is recommended that the project proponent commit to adequate air quality management planning throughout the life of the project. The air quality management plan provides options on the control of dust particles at the main sources, while the monitoring network is designed to track the effectiveness of the mitigation measures.

Based on the findings of the impact assessment, the following mitigation, management, and monitoring recommendations are proposed.

6.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the project is to ensure that operations result in ambient air concentrations (specifically $PM_{2.5}$ and PM_{10}) and dustfall rates that are within the relevant ambient air quality standards and regulations outside the mining area and at the relevant AQSRs. In order to define site specific management objectives, the main sources of pollution need to be identified. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

6.1.1 Ranking of Sources

The ranking of sources serves to confirm the current understanding of the significance of specific sources, and to evaluate the emission reduction potentials required for each. Sources ranking can be established on:

- Emissions ranking based on the comprehensive emissions inventory established for the operations (Section 4.2); and
- Impacts ranking based on the simulated pollutant GLCs (Section 4.3).

Sources were ranked based on PM_{10} emissions and impacts, since PM_{10} impacts were considered most significant among the three pollutants assessed.

<u>Current operations:</u> For current operations, the source contribution based on emission rate is illustrated in Figure 27, with the impact contribution for a selected number of AQSRs (the ones with the highest PM_{10} GLCs) illustrated in Table 25. The in-pit operations (including drilling, in-pit roads, in-pit dozing and tipping) are the main contributing source group to both emissions and impacts. The second most significant emission and impacting source group is vehicle entrainment on on-paved surface roads. Bulldozing is the third largest emission source and impacting source at some receptors, with crushing (including screening) the third most significant impacting source at other receptors.

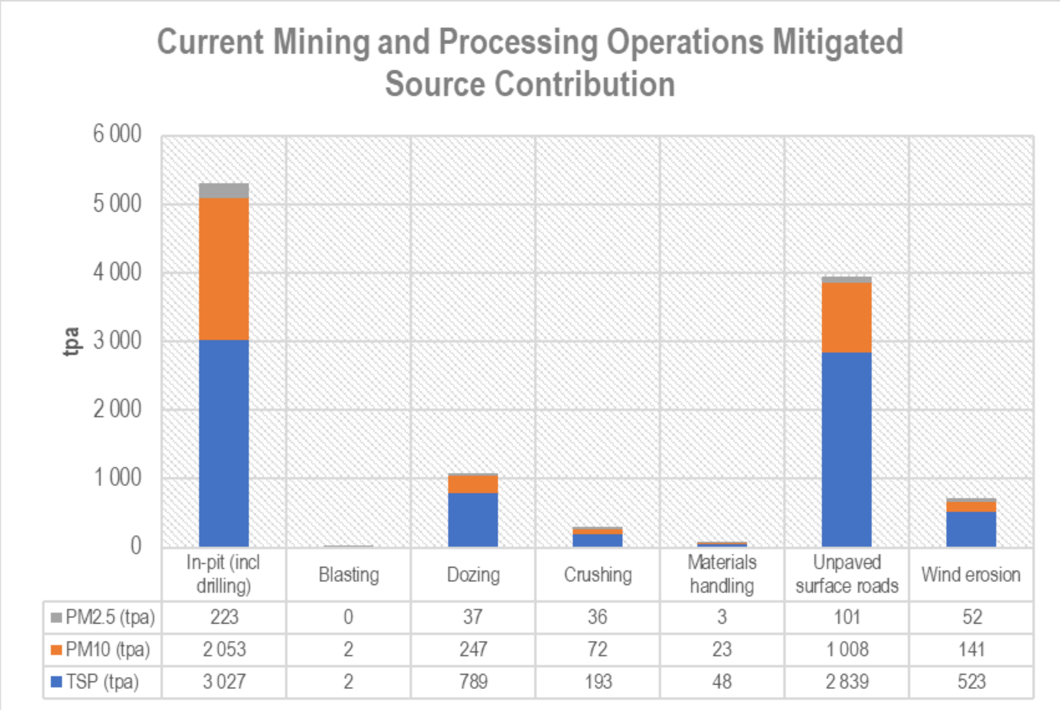


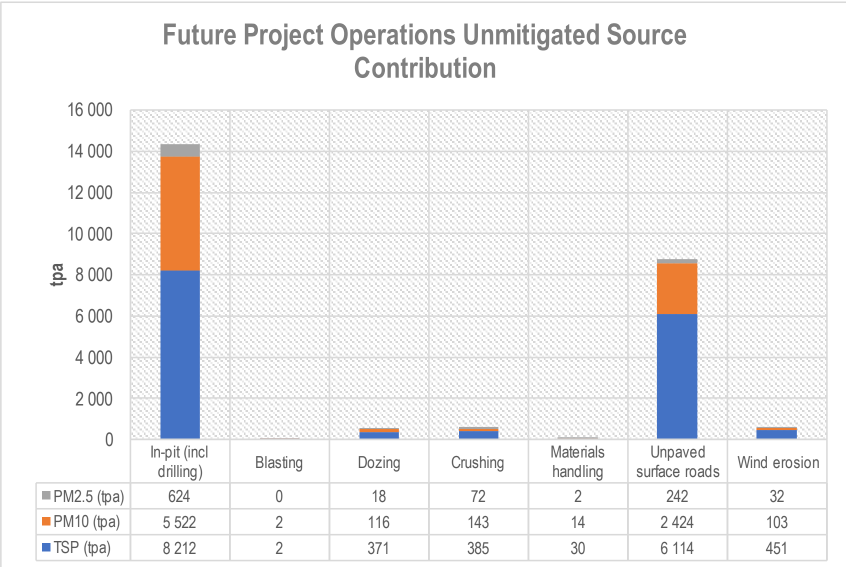
Figure 27: Source ranking for PM_{10}, based on emissions (current mitigated operations)

Table 25: Source ranking for PM_{10}, based on ground level impacts at selected AQSRs (current mitigated operations)

AQSRs	Blast	Crushing	Dozing	In-pit	Unpaved surface roads	Materials handling	Wind erosion
AQSR1	7	4	3	1	2	5	6
AQSR2	7	4	3	1	2	5	6
AQSR3 (Wolvaardt Residence)	7	5	3	1	2	4	6
AQSR4 (van der Hoven Residence)	7	4	3	1	2	5	6
AQSR5 (Retief Primary School)	7	3	4	1	2	5	6
AQSR6 (Pretorius Residence)	7	3	4	1	2	5	6
AQSR7 (du Preez Residence)	7	3	4	1	2	5	6
AQSR8	7	3	4	1	2	6	5
AQSR33	7	3	5	1	2	6	4
AQSR34 (Potgieter Residence)	7	4	5	1	2	6	3
AQSR45	7	3	6	1	2	5	4
AQSR47	7	3	6	1	2	5	4
Lapologang	7	4	3	1	2	5	6
Madithokwa	7	3	6	1	2	5	4
Marikana	7	3	5	1	2	4	6

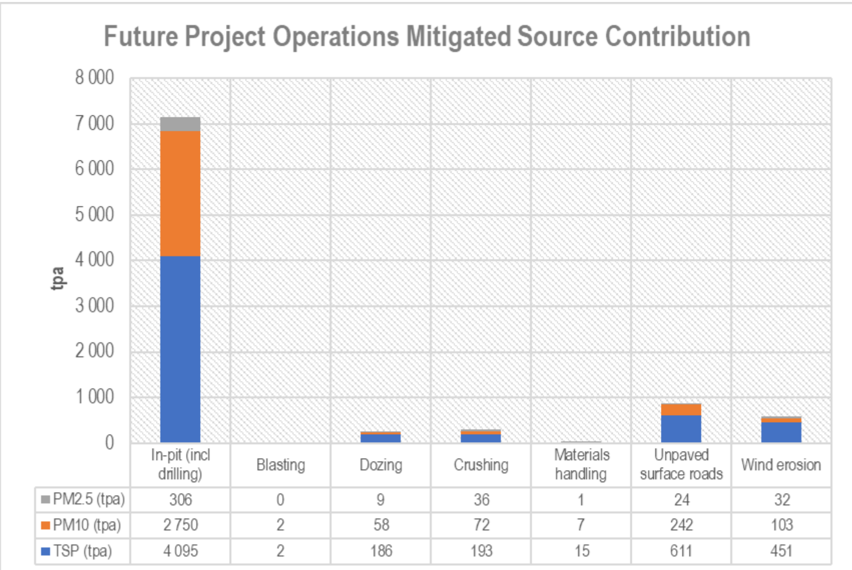
Future Project operations: For the future Project operations, the source contribution based on emission rates is illustrated in Figure 27, with the impact contribution for a selected number of AQSRs (the ones with the highest PM_{10} GLCs) illustrated in Table 26.

For unmitigated operations, the in-pit sources (including drilling, in-pit roads, in-pit dozing and tipping) are the main contributing source group followed by the un-paved surface roads (Figure 27(a)). These are also the main impacting sources followed by crushing and screening and bulldozing (Table 26). With mitigation measures in place, the in-pit sources are the most significant source group with vehicle entrainment on unpaved roads second, but far less significant than when unmitigated (Figure 27(b)). The in-pit sources remain the main impacting source group and unpaved roads second at most of the AQSRs, but with crushing and wind erosion the second most significant sources at some receptors (Table 26).



	In-pit (incl drilling)	Blasting	Dozing	Crushing	Materials handling	Unpaved surface roads	Wind erosion
PM2.5 (tpa)	624	0	18	72	2	242	32
PM10 (tpa)	5 522	2	116	143	14	2 424	103
TSP (tpa)	8 212	2	371	385	30	6 114	451

(a)



	In-pit (incl drilling)	Blasting	Dozing	Crushing	Materials handling	Unpaved surface roads	Wind erosion
PM2.5 (tpa)	306	0	9	36	1	24	32
PM10 (tpa)	2 750	2	58	72	7	242	103
TSP (tpa)	4 095	2	186	193	15	611	451

(b)

Figure 28: Source ranking for PM_{10}, based on emissions for future Project (a) unmitigated and (b) mitigated operations

Table 26: Source ranking for PM_{10}, based on ground level impacts at selected AQSRs (future Project unmitigated and mitigated operations)

	Future Unmitigated							Future Mitigated						
AQSRs	Blast	Crushing	Dozing	In-pit	Unpaved surface roads	Materials handling	Wind erosion	Blast	Crushing	Dozing	In-pit	Unpaved surface roads	Materials handling	Wind erosion
AQSR1	7	4	3	1	2	5	6	7	4	3	1	2	6	5
AQSR2	7	4	3	1	2	5	6	7	4	3	1	2	6	5
AQSR3 (Wolvaardt Residence)	7	4	3	1	2	6	5	7	4	3	1	2	6	5
AQSR4 (van der Hoven Residence)	7	4	3	1	2	6	5	7	4	3	1	2	6	5
AQSR5 (Retief Primary School)	7	3	4	1	2	5	6	7	3	4	1	2	6	5
AQSR6 (Pretorius Residence)	7	3	4	1	2	5	6	7	3	4	1	2	6	5
AQSR7 (du Preez Residence)	7	3	4	1	2	5	6	7	3	4	1	2	6	5
AQSR8	7	3	5	1	2	6	4	7	3	5	1	2	6	4
AQSR33	7	3	6	1	2	5	4	7	2	6	1	3	5	4
AQSR34 (Potgieter Residence)	7	3	6	1	2	5	4	7	3	6	1	4	5	2
AQSR45	7	3	6	1	2	5	4	7	3	6	1	2	5	4
AQSR47	7	3	6	1	2	5	4	7	3	6	1	2	5	4
Lapologang	7	3	4	1	2	6	5	7	3	4	1	2	6	5
Madithokwa	7	3	6	1	2	5	4	7	3	6	1	2	5	4
Marikana	7	3	5	1	2	4	6	7	3	6	1	2	5	4

For construction the most likely sources contributing to impacts are:

- Grading of new roads to the new WRDs;
- Vehicle (trucks) on newly graded unpaved roads; and
- Land clearing for new WRD sections.

For decommissioning & rehabilitation the most likely sources contributing to impacts are:

- infrastructure removal/demolition;
- topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings; and
- vehicle entrainment on unpaved road surfaces during rehabilitation – once that is done, vehicle activity associated with the operations should cease.

6.2 Proposed Mitigation and Management Measures

6.2.1 Proposed Mitigation Measures and/or Target Control Efficiencies

From the above discussion it is recommended that the project include the following measures:

- Construction and closure phases:
  - Air quality impacts during construction would be reduced through basic control measures such as limiting the speed of haul trucks; limit unnecessary travelling of vehicles on unpaved roads; and to apply water sprays on regularly travelled, unpaved sections.
  - When haul trucks need to use public roads, the vehicles need to be cleaned of all mud and the material transported must be covered to minimise windblown dust.
  - The access roads to the processing plants needs to be kept clean to minimise carry-through of mud on to public roads.
- Operational phase – the recommended mitigation measures for the proposed operations are shown in Table 27.

Table 27: Air Quality Management Plan – Operation Phase

Aspect	Impact	Management Actions/Objectives	Responsible Person(s)	Target Date
Vehicle activity on unpaved roads	PM_{10} and $PM_{2.5}$ concentrations and dust fallout	• Regular water sprays on in-pit unpaved roads to ensure at least 75% control efficiency. Literature indicates an application rate >2 litre/m²/hour should achieve this. • Regular apply chemical suppressants on all regularly used surface haul roads to ensure a control efficiency of 90%. • Monthly physical inspection of road surface, daily visual observation of entrained dust emissions from unpaved road surfaces.	Environmental Manager	On-going and during future Project operational phase
Drilling & Blasting	PM_{10} and $PM_{2.5}$ concentrations and dust fallout	• Controlled blasting techniques to be used to ensure minimal dust generation. • Blasting only to be conducted on cloudless days, if possible. • Addition of chemical surfactants to water sprays to lower water surface tension and increase binding properties. • Drill rigs to be fitted with dust suppression to achieve 97% control efficiency.	Mine Production Engineer Drill Rig Operator Environmental Officer	On-going and during future Project operational phase
Materials Handling	PM_{10} and $PM_{2.5}$ concentrations and dust fallout	• Drop height from excavator into haul trucks to be kept at a minimum for ore and waste rock. • Tipping onto ROM storage piles to be controlled through water sprays, should visible amounts of dust be generated. This should result in a 50% control efficiency. • Keep material handled by dozers moist to achieve a control efficiency of 50%, especially during dry periods. • Regular clean-up at loading areas.	Mine Production Engineer Environmental Officer	On-going and during future Project operational phase
Crushing	PM_{10} and $PM_{2.5}$ concentrations and dust fallout	• Water sprays at primary and secondary crushers to achieve at least 50% control efficiency. • Enclosure with extraction systems would ensure better control efficiency. According to literature hooding with cyclones would achieve 65% CE, whereas scrubbers will achieve 75% and fabric filters would result in 83% CE.	Mining Engineer Environmental Officer	On-going and during future Project operational phase
Wind Erosion	PM_{10} and $PM_{2.5}$ concentrations and dust fallout	• Water sprays at ROM stockpiles can achieve 50% control efficiency. Increase in moisture content provides higher threshold friction velocity and ensures that particulates are not as easily entrained due to high surface winds. • Keep active areas on WRDs small and use water sprays to reduce the potential for wind erosion. • Reshape all disturbed areas to their natural contours. • Cover disturbed areas with previously collected topsoil and replant native species. • Rock cladding with larger pieces of waste rock is recommended to reduce wind erosion.	Mining Engineer Environmental Officer	On-going and during future Project operational phase

6.3 Performance Indicators

Key performance indicators against which progress of implemented mitigation and management measures may be assessed, form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly (source monitoring) and the impact on the receiving environment (ambient air quality monitoring). Ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels, at the identified AQSRs, to below 600 mg/m²-day represents an impact- or receptor-based performance indicator.

Except for vehicle/equipment emission testing, source monitoring at operational activities can be challenging due to the fugitive and wind-dependent nature of particulate emissions. The focus is therefore rather on receptor-based performance indicators i.e. compliance with ambient air quality standards and dustfall regulations.

6.3.1 Ambient Air Quality Monitoring

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

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

It is recommended that the current dustfall monitoring network be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Dustfall collection should follow the ASTM method as per the NDCRs. The ASTM method covers the procedure of collection of dustfall and its measurement and employs a simple device consisting of a cylindrical container exposed for one calendar month (30 ±2 days). The method provides for a dry bucket, which is advisable in the dry environment.

It is recommended that PM_{10} sampling be conducted at Maditlokwa since PM_{10} concentrations were predicted to be non-compliant with the NAAQS, even with mitigation measures in place. A suitable location should be around dustfall unit TM D12 - Maditlokwa1 (S25.72764; E27.48858). It is proposed that particulate air concentration monitoring include the thoracic dust fraction which is typically denoted by the fraction with aerodynamic diameters less than 10 µm (or PM_{10}). It is proposed that the sampling be done using one standalone sampler that can sample continuously with a datalogger, modem, solar power system and local WiFi access for viewing data. Data should be downloaded weekly and analysed on a monthly basis.

6.4 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly), with annual environmental audits being conducted. Annual environmental audits should be continued at least until closure. Results from site inspections and monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties (I&APs), including authorities and persons affected by pollution.

The criteria to be taken into account in the inspections and audits must be made transparent by way of minimum requirement checklists included in the management plan. Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

6.5 Liaison Strategy for Communication with Interested and Affected Parties (I&APs)

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans should stipulate specific intervals at which forums will be held and provide information on how people will be notified of such meetings. Given the proximity of the study site to the nearby communities and farmsteads, it is recommended that such meetings be scheduled and held at least on an annual basis. A complaints register must be kept at all times.

6.6 Financial Provision

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

7 Conclusions and Recommendations

A quantitative air quality assessment was conducted as part of the EIA Amendment, including an assessment of the current operations at Tharisa Mine and the proposed future Project operations. The future Project operations include the expansion of the existing and approved Far West WRD 1, of which a portion will be above ground and a portion will be located on backfilled areas of the West Pit, and the new East WRD which will be on backfilled portions of the East Pit. Main sources of emissions were identified with the most significant pollutants quantified. Dispersion model simulations were conducted to determine the potential for impacts from the current and proposed future Project operations on the surrounding environment and human health, with the significance rating thereof determined following the methodology provided by SLR.

7.1 Main Findings

7.1.1 Baseline Characterisation

- Tharisa is an existing opencast chrome and platinum mine using conventional open pit truck and shovel methods, with two mining sections namely the East Mine and West Mine. Tharisa produces chrome and platinum group metal (PGMs) concentrates.
- The mine is surrounded by communities and settlements, with the Maditlhokwa community directly to the north of West Mine and Lapologang community directly to the southwest. The town of Marikana approximately 1.5 km to the north of the mining rights boundary, with a number of households, farmsteads, and schools in the immediate vicinity of the mine.
- Tharisa Mine does not have a weather station and use was made of simulated WRF data for the period 1 January 2019 – 31 December 2021. The general wind field from the south and north, with northerly winds dominating during daytime, shifting to south and south-southwest winds during the night. Calm conditions occur for 7.6% of the time with a period average wind speed of 3.2 m/s. Wind speeds exceeding 5.4 m/s occurred for 8% over the three years. There is a district variation in the wind field between seasons, with winds rom most sectors during summer but shifting to southerly winds during autumn and winter with northerly winds dominating during spring.
- The area experiences hot temperatures during summer, with maximum of 36.4°C for the month of October., and low winter temperatures especially in the months of May to July.
- The total annual rainfall for the Project site is given to be between 873 mm and 939 mm, occurring mostly between the months of October and April.
- The main pollutant of concern in the region is particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved and unpaved surfaces), mining and smelter activities, farming activities and windblown dust from exposed surfaces, mine waste dumps and tailings storage facilities (TSF). Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles, mining equipment, smelter and processing emissions.

- A dustfall network in place comprising of 15 single dust buckets located at and around Tharisa Mine, and passive sampling is conducted at three locations to determine background SO_2 and NO_2 concentrations. Data available for inclusion in this study was limited to the period January to March 2021 and January to March 2022.
    - Results obtained for NO_2 and SO_2 for the months in review were well below the NAAQS.
    - Dustfall only exceeded the NDCR residential limit (600 mg/m²/day) at Sites 2 (toll gate) and 8 (school) during January 2021 and February 2021, respectively. As the NDCR allow for a permitted frequency of exceeding the dustfall rate of two within a year (not sequential months), it could not be determined if the site is compliant or not, as there was not a full year of data available.

7.1.2 Impact Assessment

The findings from the impact assessment can be summarised as follows:

- <u>Construction Phase</u>: Construction activities were not assessed separately since most of the expansion operations will be on disturbed surfaces with little additional land clearing or preparation required. Also, these activities will occur concurrently with the current mining activities. The significance of air quality impacts due to construction are therefore expected to be **Low** without mitigation and **Very Low** with mitigation measures in place.
- <u>Current Operations</u>:
    - Simulated PM_{10} daily ground level concentrations (GLCs), with current mitigation measures in place, are in non-compliance with the NAAQS over a portion of the Maditlhokwa Community and to the north-east of the mining rights boundary, but at no other AQSRs. Annual average GLCs are within compliance with the NAAQS at all AQSRs, except at Maditlhokwa Community.
    - $PM_{2.5}$ GLCs are much lower compared to PM_{10} with exceedances of the NAAQS only at Madithlokwa when no mitigation is applied and no exceedances at any of the AQSRs with mitigation measures applied.
    - Simulated maximum daily dustfall rates for current mitigated operations are within the NDCR non-residential limit (1 200 mg/m²/day) and the residential limit (600 mg/m²/day) at all the AQSRs.
    - The significance of air quality impacts due to the current operational activities are **High** without mitigation in place and **Medium** with mitigation measures.
- <u>Future Project operations</u>:
    - PM_{10} GLCs without mitigation in place exceed the daily NAAQS at 14 of the AQSRs, including the communities of Lapologang and Madithlokwa, and the annual NAAQS at four (4) AQSRs. With mitigation in place the area of exceedance is reduced to fall mostly within the mining rights boundary with non-compliance of the daily and annual NAAQS only at Madithlokwa.

  - Without mitigation measures in place, $PM_{2.5}$ GLCs exceed only the daily NAAQS outside the mining rights boundary and at Madithlokwa. With mitigation in place the impact area reduces to fall within the mining rights boundary with no exceedances at any of the AQSRs.
  - Dustfall rates only exceed the NDCR non-residential limit (1 200 mg/m²/day) and the residential limit (600 mg/m²/day) at the southeast of Madithlokwa without mitigation and reduce to a small area in the southeast of Madithlokwa with mitigation in place.
  - Metals associated with the mine dust include aluminium (Al), barium (Ba), chromium (VI)(particulates), copper (Cu), iron (Fe), manganese (Mn), and nickel (Ni). The hazard quotient (HQ) was below 1 for all the metals evaluated, implying that adverse non-cancer effects are unlikely to occur due to exposure from these elements. The Excess Lifetime Cancer Risk associated with CrVI exposure was Moderate (one in ten thousand to less than one in a thousand) with a low risk (greater than one in a million to less than one in ten thousand) associated to Fe and a very low risk (equal to or less than one in a million) to Ni. It should be noted that the assumption that all Cr is CrVI is regarded as overly conservative.
  - The future Project operations will result in **High** significance without mitigation, reducing to **Medium** significance with mitigation measures in place.
- Closure: The likely activities to result in dust impacts during closure will be similar to construction, resulting in a **Low** significance without mitigation and **Very Low** with mitigation measures in place.

7.2 Conclusions

Impacts due to the future Project were assessed with respect to the expansion of the existing and approved Far West WRD 1 (with a portion above ground and a portion located on backfilled areas of the West Pit), and the new East WRD which will be in the East Pit.

Exceedances of the NAAQS were predicted at 14 AQSRs for PM_{10} and at one AQSR for $PM_{2.5}$ under the unmitigated project scenario. With mitigation measures in place, exceedances of the NAAQS are limited to Madithlokwa. For the current mitigated operations exceedances of the NAAQS for PM_{10} are limited to Maditlhokwa. Simulated dustfall levels also only exceeded NDCR for residential areas at Maditlhokwa for mitigated current and future Project operations. No significant differences in air quality impacts from the future Project were found in comparison to the current operations, assuming mitigation measures will be in place. The contribution from vehicle entrainment on the surface roads are likely to be less due to the future Project with a more significant contribution from the in-pit operations due part of the WRD expansion falling within the East Pit.

The community of Maditlhokwa is currently impacted negatively by the current mining operations with mitigation measures in place and is likely to be similarly impacted on by the future Project operations with mitigation measures in place. From an air quality perspective, the proposed project can be authorised permitted the recommended mitigation and monitoring measures are applied, and PM_{10} monitoring is done in Maditlhokwa to ensure compliance with the NAAQS and NDCRs.

7.3 Recommendations

A summary of the recommendations and management measures is given below:

- Construction and closure phases:
  - limiting the speed of haul trucks;
  - limit unnecessary travelling of vehicles on unpaved roads; and
  - apply water sprays on regularly travelled, unpaved sections and freshly graded surfaces.
- Operational phases:
  - In controlling dust due to drilling operations, dust suppression must be fitted on drill rigs to achieve an emission reduction efficiency of 97%.
  - For the control of vehicle entrained dust it is recommended that i) water sprays be applied to in-pit haul roads ensure a control efficiency of 75% (application rate >2 litre/m²/hour should achieve this), and ii) chemical suppressants be applied to all regularly used surface haul roads to achieve a 90% control efficiency.
  - In controlling dust from mobile crushing operations, it is recommended that water sprays be applied to keep the ore wet at the primary crushers to achieve a control efficiency of up to 50%, and enclosure with extraction systems at the secondary crushers and screens to achieve a minimum of 65% control efficiency.
  - Mitigation of materials transfer points should be done by reducing excavator drop heights into haul trucks, using water sprays at the tip points and where dozers operate to ensure a minimum of 50% control efficiency. Also, regular clean-up at loading points is recommended.
  - In minimizing windblown dust from stockpile areas, water sprays should be used to keep surface material moist as well as active areas on WRDs (a mitigation efficiency of 50 % is anticipated). Reshaping and covering disturbed areas with topsoil and replant native species will further reduce the potential for wind erosion.
  - To ensure that mitigation is effective, it is recommended that the dustfall monitoring network at the mine be maintained and the monthly dustfall results used as indicators to tract the effectiveness of the applied mitigation measures. Due to the potential for non-compliance of both current and future operations at Tharisa Mine, it is recommended that PM_{10} sampling be conducted at Maditlhokwa Community.

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Appendix A – Specialist Curriculum Vitae

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	22 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 Draft Second Generation Air Quality Management Plan (AQMP)(Aug 2017 – Jun 2020); Advanced Air Quality Management for the Strategic Environmental Management Plan for the Uranium and Other Industries in the Erongo Region (May 2016 – Feb 2019); City of Johannesburg AQMP (2016-2019); Air Quality Monitoring and Management for the Al Madinah Al Munawarah Development Authority (MDA) in Saudi Arabia (2016-2017). 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: Namibia – Husab Uranium Mine, Trekkopje Uranium Mine; Bannerman Uranium Project; Langer Heinrich Uranium Mine, Valencia Uranium Mine, Rössing Uranium Mine; and B2Gold Otjikoto Gold Mine. South Africa – Sishen Iron Ore Mine; Tshipi Borwa Manganese Mine; Mamatwan Manganese Mine; Kolomela Iron Ore Mine; Thabazimbi Iron ore Mine; UKM Manganese Mine; Everest Platinum Mine; Impala Platinum Mine; Anglo Platinum Mines; Abglo Gold Ashanti MWS, Vaal River and West Wits complexes, Harmony Gold, Glencore Coal Mines, South32 and Anglo Coal; 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); Zimbiwa Crusher Plant (Brakpan); RBM Zulti South Titanium mining (Richards Bay); Premier Diamond Mine (Cullinan). Botswana – Jwaneng Diamond Mine and Debswana Mining Company. Zimbabwe – Murowa Diamond Mine. Other mining projects include Sadiola Gold Mine (Mali); North Mara Gold Mine (Tanzania); Bulyanhulu North Mara Gold Mine (Tanzania).

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 Erongo Power Project (Namibia), NamPower Van Eck Power Station (Namibia) and NamPower Biomass Power Plant (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).

Green energy projects included several Solar Photovoltaic Projects (Mulilo and Enertrag South Africa (Pty) Ltd) and assessing potential particulate matter impacts from Wind Farms near the South African Large Telescope (SALT)

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).

Vehicle emissions

Transport Air quality Management Plan for the Gauteng Department of Roads and Transport (Feb 2012); 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 and International Strategy Projects

Hanlie in one of the Lead Authors of Section 1.1: Africa's Development: Challenges, Drivers and key objectives, of the United Nations Environment Programme (UNEP), Climate and Clean Air Coalition (CCAC) and Stockholm Environment Institute (SEI) coordinated 'Integrated Assessment of Air Pollution and Climate Change for Africa Report. She was also the Terminal Reviewer of the UNEP/UNDA project "Air quality data for health and environment policies in Africa and the Asia-Pacific region" (May 2020). Hanlie was also 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 2022)	MSc Candidate: P Chidhindi Using dispersion models as a regulatory tool in South Africa Department Geography and Environmental Management, North-West University
External Examiner (February 2021)	PhD Candidate: Ms NM Walton Aerosol source apportionment in southern Africa Faculty of Natural and Agricultural Sciences, North-West University
External Examiner (May 2018)	MSc Candidate: Ms A Quta Characterisation of Particulate Matter and Some Pollutant Gasses in the City of Tshwane Department of Environmental Sciences, University of South Africa
External Examiner (December 2017)	MSc Candidate: Ms B Wernecke Ambient and Indoor Particulate Matter Concentrations on the Mpumalanga Highveld Faculty of Natural and Agricultural Sciences, 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, Morocco, and Saudi Arabia.

EMPLOYMENT RECORD

March 2003 - Present

Airshed Planning Professionals (Pty) Ltd, 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

- Dust and radon levels on the west coast of Namibia – What did we learn? Hanlie Liebenberg-Enslin, Detlof von Oertzen, and Norwel Mwananawa. Atmospheric Pollution Research, 2020. https://doi.org/10.17159/caj/2020/30/1.8467
- Understanding the Atmospheric Circulations that lead to high particulate matter concentrations on the west coast of Namibia. Hanlie Liebenberg-Enslin, Hannes Rauntenbach, Reneé von Gruenewaldt, and Lucian Burger. Clean Air Journal, 27, 2, 2017, 66-74.
- 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.

AIRSHED
PLANNING PROFESSIONALS

1 March 2022

Full name of staff member: Hanlie Liebenberg-Enslin

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

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Appendix B – ICP and Particle Size Analysis Results

CERTIFICATE OF ANALYSIS

R22-23123

BIOGRADE
CC 2006/212609/23

667 Viscount Street
Elarduspark X6
Pretoria
0181
Tel : +27 12 345 5244
Fax : +27 86 637 6838
Email : lab@biograde.co.za

Company	:	Airshed Planning Professionals
Address	:	PO Box 5260, Halfway House, 1685
Contact	:	Hanelie Liebenberg-Enslin
Reference Number	:	20SLR04 HLE
Date Accepted	:	03 May 2022
Date Completed	:	19 May 2022
Condition of sample(s)	:	All samples received at room temperature
Lab Number(s)	:	B185123 - B185125

Analysis of 3 solid sample(s) as received:

Test	:	Metal Elements by ICP
Method	:	Based on NIOSH Method 7303 and OSHA Method ID-125G

Determinant →	TSF2	WRD2	Roads3
Sample ID ↓	Result mg/kg	Result mg/kg	Result mg/kg
Silver, Ag	< 5.9	< 6.0	< 6.1
Aluminium, Al	17032.5	19849.1	17018.1
Arsenic, As	< 5.9	< 6.0	< 6.1
Gold, Au	< 5.9	< 6.0	< 6.1
Boron, B	< 178.4	< 181.1	< 184.2
Barium, Ba	30.5	30.2	33.0
Beryllium, Be	< 5.9	< 6.0	< 6.1
Bismuth, Bi	< 5.9	< 6.0	< 6.1
Calcium, Ca	4271.3	5374.1	4065.5
Cadmium, Cd	< 5.9	< 6.0	< 6.1
Cobalt, Co	< 5.9	< 6.0	< 6.1
Chromium, Cr	149.3	96.3	149.0
Copper, Cu	7.4	8.0	6.8
Iron, Fe	4499.9	5944.3	5775.1
Mercury, Hg	< 5.9	< 6.0	< 6.1
Iridium, Ir	< 5.9	< 6.0	< 6.1
Potassium, K	421.7	263.8	268.3
Lanthanum, La	< 5.9	< 6.0	< 6.1
Lithium, Li	< 5.9	< 6.0	< 6.1
Magnesium, Mg	4982.3	2449.2	3154.0
Manganese, Mn	69.2	105.8	134.3
Molybdenum, Mo	< 5.9	< 6.0	< 6.1
Sodium, Na	1675.4	2120.8	1582.2
Nickel, Ni	32.5	19.2	33.6
Phosphorus, P	< 119.0	< 120.7	< 122.8
Lead, Pb	< 5.9	< 6.0	< 6.1
Palladium, Pd	< 5.9	< 6.0	< 6.1
Platinum, Pt	< 5.9	< 6.0	< 6.1
Rhodium, Rh	< 5.9	< 6.0	< 6.1
Ruthenium, Ru	< 5.9	< 6.0	< 6.1
Sulfur, S	1860.5	< 1509.4	< 1535.0
Antimony, Sb	< 5.9	< 6.0	< 6.1
Selenium, Se	< 5.9	< 6.0	< 6.1
Tin, Sn	< 5.9	< 6.0	< 6.1
Strontium, Sr	48.1	57.6	47.7
Tellurium, Te	< 5.9	< 6.0	< 6.1
Thorium, Th	< 5.9	< 6.0	< 6.1
Titanium, Ti	207.7	335.7	334.0
Thallium, Tl	< 5.9	< 6.0	< 6.1
Uranium, U	< 5.9	< 6.0	< 6.1
Vanadium, V	7.7	9.2	9.4
Tungsten, W	< 23.8	< 24.1	< 24.6
Zinc, Zn	< 5.9	< 6.0	< 6.1
Zirconium, Zr	< 5.9	< 6.0	< 6.1

Results in units specified

Approximate quantitation limit signified by " < " followed by the limit value

Willem Wepener
Head of Laboratory

Particle size distribution

Malvern Instruments

Measurement Details

Sample Name	Average of 'B185123 TSF2 - Screened'
SDS	9613
SOP File Name	Default + 60us LV.msop

Measurement Details

Measurement Date Time	2022/05/10 09:05:56
Analysis Date Time	2022/05/10 09:05:56
Original Record Number	108

Analysis

Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.16 %
Analysis Model	General Purpose

Analysis

Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	6.15 %
Scattering Model	Mie
Analysis Sensitivity	Normal

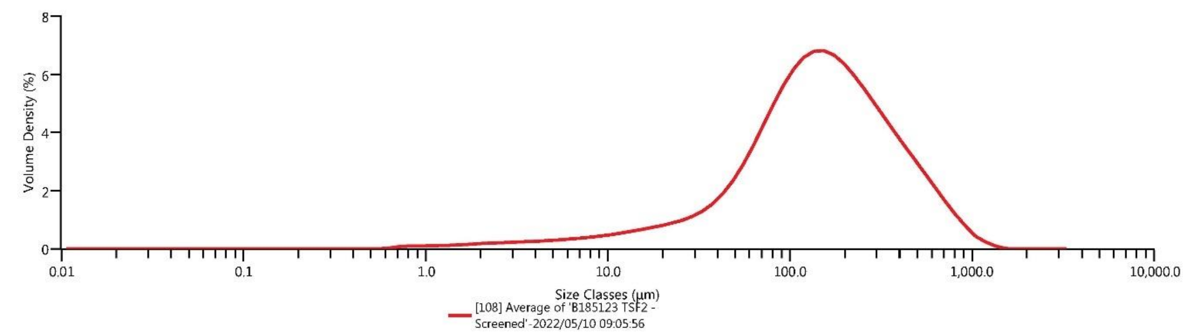
Result

Concentration	0.0317 %
Uniformity	0.889
Specific Surface Area	138.4 m²/kg
D [3,2]	41.3 μm
D [4,3]	204 μm

Result

Span	2.914
Result Units	Volume
Dv (10)	32.9 μm
Dv (50)	146 μm
Dv (90)	457 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.42	12.7	4.71	111	38.13	1110	99.72
0.0114	0.00	0.146	0.00	1.45	0.52	14.5	5.23	127	43.92	1260	99.92
0.0129	0.00	0.166	0.00	1.65	0.64	16.4	5.77	144	49.51	1430	100.00
0.0147	0.00	0.188	0.00	1.88	0.77	18.7	6.39	163	55.04	1630	100.00
0.0189	0.00	0.214	0.00	2.13	0.91	21.2	7.05	186	60.79	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.12	24.1	7.79	211	66.04	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.25	27.4	8.61	240	71.05	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.43	31.1	9.53	272	75.55	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.63	35.3	10.60	310	79.83	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.84	40.1	11.88	352	83.58	3500	100.00
0.0463	0.00	0.460	0.00	4.58	2.06	44.0	13.02	400	86.93		
0.0526	0.00	0.523	0.00	5.21	2.31	45.0	13.30	454	89.86		
0.0597	0.00	0.594	0.00	5.92	2.56	51.8	15.40	516	92.43		
0.0679	0.00	0.675	0.02	6.72	2.84	58.9	17.83	586	94.59		
0.0771	0.00	0.767	0.09	7.64	3.15	66.9	20.77	666	96.36		
0.0876	0.00	0.872	0.16	8.68	3.49	76.0	24.30	756	97.72		
0.0995	0.00	1.00	0.25	10.0	3.90	86.4	28.46	859	98.71		
0.113	0.00	1.13	0.33	11.2	4.26	98.1	33.13	976	99.37		

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Page 1 of 1

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Particle size distribution

Malvern Instruments

Malvern

Measurement Details

Sample Name Average of 'B185124 WRD2 - Screened'
SDS 9614
SOP File Name Default + 60us LV.msop

Measurement Details

Measurement Date Time 2022/05/10 09:11:45
Analysis Date Time 2022/05/10 09:11:45
Original Record Number 117

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.19 %
Analysis Model General Purpose

Analysis

Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 8.05 %
Scattering Model Mie
Analysis Sensitivity Normal

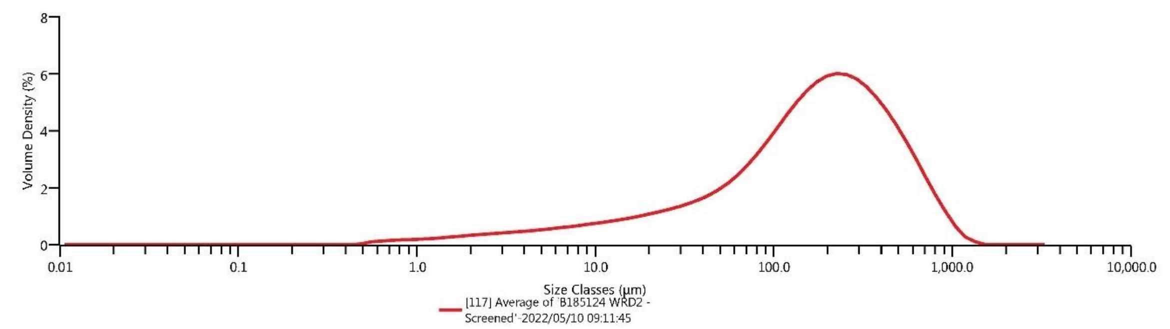
Result

Concentration 0.0254 %
Uniformity 0.919
Specific Surface Area 224.0 m²/kg
D [3,2] 25.5 μm
D [4,3] 232 μm

Result

Span 3.006
Result Units Volume
Dv (10) 16.6 μm
Dv (50) 172 μm
Dv (90) 533 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.97	12.7	8.43	111	35.50	1110	99.70
0.0114	0.00	0.146	0.00	1.45	1.17	14.5	9.18	127	39.53	1260	99.92
0.0129	0.00	0.166	0.00	1.65	1.40	16.4	9.93	144	43.66	1430	100.00
0.0147	0.00	0.188	0.00	1.88	1.66	18.7	10.79	163	48.05	1630	100.00
0.0189	0.00	0.214	0.00	2.13	1.93	21.2	11.67	186	52.98	1850	100.00
0.0215	0.00	0.243	0.00	2.50	2.31	24.1	12.63	211	57.88	2100	100.00
0.0278	0.00	0.276	0.00	2.75	2.55	27.4	13.67	240	62.94	2390	100.00
0.0315	0.00	0.314	0.00	3.12	2.89	31.1	14.77	272	67.84	2710	100.00
0.0358	0.00	0.357	0.00	3.55	3.25	35.3	15.96	310	72.82	3080	100.00
0.0407	0.00	0.405	0.00	4.03	3.63	40.1	17.27	352	77.44	3500	100.00
0.0463	0.00	0.460	0.00	4.58	4.03	44.0	18.31	400	81.77		
0.0526	0.00	0.523	0.02	5.21	4.47	45.0	18.56	454	85.70		
0.0597	0.00	0.594	0.11	5.92	4.93	51.8	20.31	516	89.23		
0.0679	0.00	0.675	0.22	6.72	5.42	58.9	22.12	586	92.27		
0.0771	0.00	0.767	0.35	7.64	5.95	66.9	24.15	666	94.79		
0.0876	0.00	0.872	0.48	8.68	6.52	76.0	26.48	756	96.76		
0.0995	0.00	1.00	0.65	10.0	7.19	86.4	29.16	859	98.21		
0.113	0.00	1.13	0.80	11.2	7.76	98.1	32.18	976	99.18		

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Page 1 of 1

Biograde

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of 'B185125 Roads3 - Screened'
SDS	9615
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/05/10 09:17:48
Analysis Date Time	2022/05/10 09:17:48
Original Record Number	116

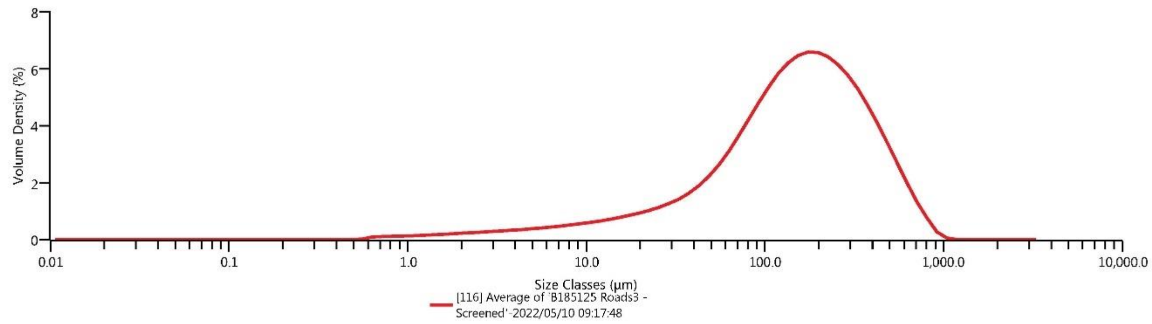
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.18 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	8.43 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0349 %
Uniformity	0.814
Specific Surface Area	172.7 m²/kg
D [3,2]	33.1 μm
D [4,3]	197 μm

Result	
Span	2.686
Result Units	Volume
Dv (10)	24.8 μm
Dv (50)	152 μm
Dv (90)	433 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.65	12.7	6.17	111	37.51	1110	100.00
0.0114	0.00	0.146	0.00	1.45	0.78	14.5	6.79	127	42.65	1260	100.00
0.0129	0.00	0.166	0.00	1.65	0.94	16.4	7.42	144	47.77	1430	100.00
0.0147	0.00	0.188	0.00	1.88	1.12	18.7	8.16	163	53.02	1630	100.00
0.0189	0.00	0.214	0.00	2.13	1.30	21.2	8.93	186	58.71	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.57	24.1	9.79	211	64.14	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.74	27.4	10.75	240	69.55	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.97	31.1	11.81	272	74.60	2710	100.00
0.0358	0.00	0.357	0.00	3.55	2.23	35.3	12.99	310	79.55	3080	100.00
0.0407	0.00	0.405	0.00	4.03	2.50	40.1	14.36	352	83.95	3500	100.00
0.0463	0.00	0.460	0.00	4.58	2.80	44.0	15.51	400	87.91		
0.0526	0.00	0.523	0.00	5.21	3.12	45.0	15.78	454	91.30		
0.0597	0.00	0.594	0.02	5.92	3.46	51.8	17.80	516	94.14		
0.0679	0.00	0.675	0.10	6.72	3.83	58.9	20.01	586	96.38		
0.0771	0.00	0.767	0.19	7.64	4.23	66.9	22.60	666	98.03		
0.0876	0.00	0.872	0.30	8.68	4.66	76.0	25.64	756	99.12		
0.0995	0.00	1.00	0.41	10.0	5.18	86.4	29.19	859	99.75		
0.113	0.00	1.13	0.52	11.2	5.63	98.1	33.18	976	99.96		

Appendix C – Significance Rating Methodology

PART A: DEFINITIONS AND CRITERIA*		
Definition of SIGNIFICANCE		Significance = consequence x probability
Definition of CONSEQUENCE		Consequence is a function of intensity, spatial extent and duration
Criteria for ranking of the INTENSITY of environmental impacts	**VH**	Severe change, disturbance or degradation. Associated with severe consequences. May result in severe illness, injury or death. Targets, limits and thresholds of concern continually exceeded. Substantial intervention will be required. Vigorous/widespread community mobilization against project can be expected. May result in legal action if impact occurs.
	H	Prominent change, disturbance or degradation. Associated with real and substantial consequences. May result in illness or injury. Targets, limits and thresholds of concern regularly exceeded. Will definitely require intervention. Threats of community action. Regular complaints can be expected when the impact takes place.
	M	Moderate change, disturbance or discomfort. Associated with real but not substantial consequences. Targets, limits and thresholds of concern may occasionally be exceeded. Likely to require some intervention. Occasional complaints can be expected.
	L	Minor (Slight) change, disturbance or nuisance. Associated with minor consequences or deterioration. Targets, limits and thresholds of concern rarely exceeded. Require only minor interventions or clean-up actions. Sporadic complaints could be expected.
	VL	Negligible change, disturbance or nuisance. Associated with very minor consequences or deterioration. Targets, limits and thresholds of concern never exceeded. No interventions or clean-up actions required. No complaints anticipated.
	VL+	Negligible change or improvement. Almost no benefits. Change not measurable/will remain in the current range.
	L+	Minor change or improvement. Minor benefits. Change not measurable/will remain in the current range. Few people will experience benefits.
	M+	Moderate change or improvement. Real but not substantial benefits. Will be within or marginally better than the current conditions. Small number of people will experience benefits.
	H+	Prominent change or improvement. Real and substantial benefits. Will be better than current conditions. Many people will experience benefits. General community support.
	VH+	Substantial, large-scale change or improvement. Considerable and widespread benefit. Will be much better than the current conditions. Favourable publicity and/or widespread support expected.
Criteria for ranking the DURATION of impacts	**VL**	Very short, always less than a year. Quickly reversible
	L	Short-term, occurs for more than 1 but less than 5 years. Reversible over time.
	M	Medium-term, 5 to 10 years.
	H	Long term, between 10 and 20 years (likely to cease at the end of the operational life of activity).
	VH	Very long, permanent, +20 years (Irreversible, Beyond closure).
Criteria for ranking the EXTENT of impacts	**VL**	A part of the site/property.
	L	Whole site.
	M	Beyond the site boundary, affecting immediate neighbours.
	H	Local area, extending far beyond site boundary.
	VH	Regional/National

PART B: DETERMINING CONSEQUENCE							
INTENSITY = VL							
DURATION	Very long	**VH**	Low	Low	Medium	Medium	High
	Long term	**H**	Low	Low	Low	Medium	Medium
	Medium term	**M**	Very Low	Low	Low	Low	Medium
	Short term	**L**	Very low	Very Low	Low	Low	Low
	Very short	**VL**	Very low	Very Low	Very Low	Low	Low
INTENSITY = L							
DURATION	Very long	**VH**	Medium	Medium	Medium	High	High
	Long term	**H**	Low	Medium	Medium	Medium	High
	Medium term	**M**	Low	Low	Medium	Medium	Medium
	Short term	**L**	Low	Low	Low	Medium	Medium
	Very short	**VL**	Very low	Low	Low	Low	Medium
INTENSITY = M							
DURATION	Very long	**VH**	Medium	High	High	High	Very High
	Long term	**H**	Medium	Medium	Medium	High	High
	Medium term	**M**	Medium	Medium	Medium	High	High
	Short term	**L**	Low	Medium	Medium	Medium	High
	Very short	**VL**	Low	Low	Low	Medium	Medium
INTENSITY = H							
DURATION	Very long	**VH**	High	High	High	Very High	Very High
	Long term	**H**	Medium	High	High	High	Very High
	Medium term	**M**	Medium	Medium	High	High	High
	Short term	**L**	Medium	Medium	Medium	High	High
	Very short	**VL**	Low	Medium	Medium	Medium	High
INTENSITY = VH							
DURATION	Very long	**VH**	High	High	Very High	Very High	Very High
	Long term	**H**	High	High	High	Very High	Very High
	Medium term	**M**	Medium	High	High	High	Very High
	Short term	**L**	Medium	Medium	High	High	High
	Very short	**VL**	Low	Medium	Medium	High	High
			VL	**L**	**M**	**H**	**VH**
			A part of the site/ property	Whole site	Beyond the site, affecting neighbours	Extending far beyond site but localised	Regional/ National
			EXTENT				

PART C: DETERMINING SIGNIFICANCE							
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**VH**	Medium	Medium	High	Very High	Very High
	Probable	**H**	Low	Medium	Medium	High	Very High
	Possible/ frequent	**M**	Low	Low	Medium	Medium	High
	Conceivable	**L**	Very Low	Low	Low	Medium	Medium
	Unlikely/ improbable	**VL**	Negligible	Very Low	Low	Low	Medium
			VL	**L**	**M**	**H**	**VH**
			CONSEQUENCE				

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
Very High	Potential fatal flaw unless mitigated to lower significance.
High	It must have an influence on the decision. Substantial mitigation will be required.
Medium	It should have an influence on the decision. Mitigation will be required.
Low	Unlikely that it will have a real influence on the decision. Limited mitigation is likely required.
Very Low	It will not have an influence on the decision. Does not require any mitigation
Negligible	Inconsequential, not requiring any consideration.

*VH = very high, H = high, M= medium, L= low and VL= very low and + denotes a positive impact.

Appendix D – Comments Raised by Interested and Affected Parties

Table 28: Comments relating to noise impacts raised by interested and affected parties and responses provided

Interested and affected party	Date comment received	Issues raised	Response provided	Section and paragraph reference in this report where the issues and or responses were incorporated
Elias (Did not sign the register)	15 August 2021	Are you aware of the impacts of the proposed Waste Rock Dumps (WRDs) to the community? The community is currently suffering from the impacts as a result of the existing WRDs and other mining operations. What measures will be in put in place to manage the dust, noise and air quality impacts experienced by the community.	Dispersion modelling was done to determine the impacts from the proposed WRDs on the surrounding environment and human health. The National Ambient Air Quality Standards (NAAQS) and National Dust Control Regulations (NDCR) are likely to be exceeded at Maditlhokwa, and it is recommended that PM_{10} sampling be done to determine the actual concentrations at the community.	Section 4; Section 6 and Section 7
Thabo Maluleka (Lapologang)	8 December 2021	We do not sleep at night because of the noise from the blasting and the vehicles. The dust is also unbearable.		
Tshepo Jonas (Mmaditlhokwa)	15 August 2021	Dust is so visible from the communities? How much dust are communities inhaling daily? The establishment of the additional WRDs will only worsen the situation.		
Zanethemba Badula (Bokamoso)	14 December 2021	Since 2015, Tharisa started with the blasting. The trucks have been making a lot of noise and the dust has been excessive and we have reported all these issues to the councillor, and we do not receive any responses. Tharisa has not even provided us with assistance with these issues since. The proposed WRD will not go ahead in our community if you do not take our issues and concerns seriously.		
Lesiba Mookamedi (Bokamoso)	15 August 2021	Please advise if the area been assessed to determine whether it was safe? What is the distance from the new WRDs to the community? Please advise what is the extent of the buffer in terms of health and safety? What is the buffer that is allowed in terms of the DMRE regulations? SLR should undertake an assessment to identify the environmental issues such as noise from blasting, air quality issues etc. This would inform the discussion with the community leadership. The leadership cannot convince the community to accept the project when people are suffering from the impacts as a result of the existing WRDs and other mining operations. This project will not be supported without answers. The students from communities will be affected by the noise from the Proposed Project.	An air quality impact assessment was conducted for Tharisa Mine, assessing both the current mining operations as well as the proposed Project. Emissions were quantified and dispersion modelling conducted to determine the potential for impacts on the surrounding communities and human health. Samples from the WRDs were analysed for heavy metals and also included to determine the carcinogenic risk from the metals in the dust.	Section 4; Section 5, Section 6 and Section 7

Interested and affected party	Date comment received	Issues raised	Response provided	Section and paragraph reference in this report where the issues and or responses were incorporated
		Please provide the leadership with mitigation measures to address the noise and air quality issues from Tharisa		
Tebogang Makoanjane (Lapologang Community Leadership)	29 April 2022	The waste rock dump (WRD) in the west looks close to Lapologang. How will the impacts of dust and blasting affect our community?	With mitigation measures in place, impacts from the mining activities are within the legal requirements at Lapologang.	Section 4.4
Tseere Mokwala (Mmaditlhokwa Community Leadership)	29 April 2022	Community members close to the mine have had issues with the impacts from mining activities.		
John Salang (Mmaditlhokwa Community Leadership)	29 April 2022	The proposed infrastructure is close to the Lapologang community. There are already existing mining activities that affect the community e.g., noise pollution from the blasting and dust – how do you as a consultant expect that the new infrastructure will affect us?		
Mariette Liefferink	25 April 2022	What consideration will be given to the fact that Tharisa is located in the Bojanala Priority Area? Will the project result in the need to update an Atmospheric Emissions Licence (AEL) for Tharisa?		
Gwendolyn Wellmann	Letter via email on the 17th of June 2022	Comments on Scoping Report for the "Additional Waste Rock Storage Project" application by Tharisa Minerals (SLR Project No: 720.20002.00065)		
Gwendolyn Wellmann	Letter via email on the 17th of June 2022	Relevant information from the 2014 EIA: From the 2014 EIA: "In the case of air pollution, the model predicts that with mitigation that focuses on minimising pollution at the source there may still be exceedances of the NAAQ limits for PM_{10} and $PM_{2.5}$ (particulate matter with a diameter less than 10 micron and less than 2.5 micron) emissions that could result in health-related impacts. If monitoring confirms the model predictions, then relocation of sensitive receptors within the exceedance zone may be required." (Pg. viii) In our opinion, an EIA process undertaken at this time to expand Tharisa Mine's operations, is the most socially unjust process possible. The mitigation measures prescribed in the DMRE-approved 2014 EIA should be implemented with immediate effect and the resettlement process should first be implemented and once there is an approved Resettlement Action Plan in place, then EIA processes for expansion of the mine can be considered. This is	Dispersion modelling was done to determine the impacts from the proposed WRDs on the surrounding environment and human health. The National Ambient Air Quality Standards (NAAQS) and National Dust Control Regulations (NDCR) are likely to be exceeded at Maditlhokwa, and it is recommended that PM_{10} sampling be done to determine the actual concentrations at the community.	Section 4; Section 6 and Section 7

Interested and affected party	Date comment received	Issues raised	Response provided	Section and paragraph reference in this report where the issues and or responses were incorporated
		specifically important because the Scoping Report itself details the following: "Any loss or injury is considered long term and can extend beyond the mine boundary to the communities to which the injured people and/or animals belong. The likelihood of occurrence, in the absence of management measures, is likely given that Maditlhokwa is directly adjacent to the proposed West OG WRD (pg 159)."		