Air Quality Impact Assessment Report for the Proposed Amendments and Expansions at Kolomela Mine

Project done for EXM Environmental Advisory (Pty) Ltd

Report Compiled by:
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Report Details

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Revision Record

Revision Number	Date	Reason for Revision
Draft	September 2021	
Rev 1	September 2021	Updated LOM plan
Rev 2	September 2021	Automated truck scenario
Rev 3	September 2021	EXM comments

Abbreviations

AERMIC	AMS/EPA Regulatory Model Improvement Committee
Airshed	Airshed Planning Professionals (Pty) Ltd
APPA	Air Pollution and Prevention Act
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
AQSR	Air Quality Sensitive Receptor
ASTM	American Society for Testing and Materials
DEA	Department of Environmental Affairs (South Africa)
DFFE	Department of Forestry, Fisheries and the Environment (South Africa)
DMS	Dense Medium Separation
DSO	Direct Shipped Ore
EHS	World Bank Group Environmental, Health and Safety Guidelines
EIA	Environmental Impact Assessment
GLC	Ground Level Concentration
IFC	International Finance Corporation
LoM	Life of Mine
NAAQS	National Ambient Air Quality Standards (South Africa)
NEMAQA	National Environmental Management Air Quality Act
NDCR	National Dust Control Regulation
NMES	National Minimum Emission Standard
NPI	National Pollutant Inventory (Australia)
PM	Particulate matter
PM_{10}	Thoracic particulate matter with an aerodynamic diameter of less than 10 μm
$PM_{2.5}$	Inhalable particulate matter with an aerodynamic diameter of less than 2.5 μm
RoM	Run of Mine
SA	South Africa(n)
TSP	Total Suspended Particulates
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled
WHO	World Health Organization

Executive Summary

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

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

- The study area is dominated by winds from the north. Long term air quality impacts are therefore expected to the most significant to the south of the operations.
- Several farm houses or farmsteads are situated within a few hundred meters from the proposed activities. The nearest residential area is Postmasburg which lies to the north-east of the mine.
- Ambient air quality monitoring for Kolomela mine indicated ambient PM_{10} levels are in exceedance of the National Ambient Air Quality Standards (NAAQSs) at Kapstevel and Kappieskaree. This indicates the ambient air quality is not compliant with NAAQS, however it includes all sources in the area, it is not only due to Kolomela mine.
- Dustfall rates are also elevated and are in non-compliance with National Dust Control Regulations (NDCR). Similarly to PM_{10} levels, even locations upwind of the mine show elevated dustfall levels. This indicates the contribution of other sources to non-compliance with the NDCR.

A comprehensive atmospheric emissions inventory was then compiled for the various operational phases of the proposed amendments and expansions. Pollutants quantified included those most commonly associated with mining i.e. particulate matter (PM) and total suspended particulate matter (TSP).

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

- Operational phase PM emissions ($PM_{2.5}$, PM_{10} and TSP) were quantified and used in simulations.
- Simulated $PM_{2.5}$ and PM_{10} concentrations were compliant with air quality criteria at all of the identified AQSRs, but exceeded the daily NAAQS at the southern boundary.
- Dustfall rates were complaint with NDCR at all of the identified AQSRs, but exceeded the residential rate at the southern mining boundary.

Three distinct emission scenarios were identified:

- Scenario 1: 2027 (year with maximum handled of 91.6 Mtpa, approximately 12.7 Mtpa of ore and 78.9 Mtpa of waste).
- Scenario 2: 2030 (year with maximum ore handled at Kapstevel South, approximately 11.6 Mtpa of ore and 57.4 Mtpa of waste).
- Scenario 2A: 2030 (similar tonnages handled as scenario 2 but using larger automated trucks to move ore).

The scenario with automated trucks (larger haul truck capacity) resulted in lower emissions and impacts slightly lower than the scenario with smaller haul trucks for the ore (especially impacts along the haul roads). However, the impact significance is the same for all the scenarios, as the models show that the NAAQS will potentially be exceeded at the southern boundary, due to the waste rock dumps and the movement of waste in the vicinity of the southern boundary near the Kapstevel pit. No significant change is expected from the current baseline, however impacts are expected to be more localised in the Kapstevel area as mining in that area increases.

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

- The mitigation of sources of emissions. Special attention should be paid to the mitigation of dust from unpaved haul roads and areas with windblown dust potential (such as the waste dumps); and
- Continued ambient air quality monitoring, including:
  - Gravimetric sampling of PM_{10} and $PM_{2.5}$ concentrations.
  - Dustfall sampling at existing locations around operations.

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1 Introduction

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by EXM Environmental Advisory (Pty) Ltd (EXM) to conduct the air quality impact assessment study for the proposed expansions at Kolomela Mine, which includes the Kapstevel South Project, which is in the process of being implemented and also provides for the possible future use of autonomous trucks for the transport of ore. This report provides an update of the Air Quality Impact Assessment (AQIA) completed in 2019 in support of the Environmental Impact Assessment (EIA) completed for the authorisation of the proposed expansions at the mine. The assessment is based on the updated life-of-mine (LoM) plan of 2021.

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

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

1.1 Description of Activities from an Air Quality Perspective

The Kolomela Amendment consists of various projects aimed at satisfying current business requirements, ongoing business improvements (optimization) and possible expansions.

Mining of the Kapstevel South Pit will mean that production levels at the mine can be maintained, and the mining of the larger pit means that the LOM is extended by 3 years.

Some additional infrastructural requirements included are essential requirements to sustain existing mining at Kolomela. The expansion will therefore also include some iron ore reserves within the Kolomela Mine's approved mining rights area. These reserves include Kapstevel South. Only the operational phase was assessed.

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

Airborne emissions may occur during all phases of the mining cycle. The most notable sources of fugitive PM include drilling, blasting, ore and waste rock handling, windblown dust from exposed surfaces such as stockpiles as well as traffic on haul routes. Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007). Gases from the storage and combustion of fuels in stationary and mobile equipment also add to airborne emissions but to a lesser extent.

In the discussion, regulation and estimation of PM emissions and impacts a distinction is made between different particle size fractions, viz. TSP, PM_{10} and $PM_{2.5}$. PM_{10} is defined as particulate matter with an aerodynamic diameter of less than 10 µm and is also referred to as thoracic particulates. Inhalable particulate matter, $PM_{2.5}$, is defined as particulate matter with an aerodynamic diameter of less than 2.5 µm. Whereas PM_{10} and $PM_{2.5}$ fractions are taken into account to determine the potential for human health risks, total suspended particulate matter (TSP) is included to assess nuisance dustfall.

Combustion emissions include PM_{10} and $PM_{2.5}$, carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2), and volatile organic compounds (VOCs). PM emitted from diesel combustion will mostly be in the form of black carbon, commonly referred to as diesel particulate matter or diesel exhaust (DPM or DE). Additional diesel fuel storage may result in volatile organic compounds (VOC) emissions. These are however assumed to be insignificant compared to the fugitive dust and have not been included in this assessment.

1.2 Approach and Methodology

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

1.2.1 The Identification of Regulatory Requirements and Health Thresholds

In the evaluation air emissions and ambient air quality impacts reference was made to the following (as set out in the National Environmental Management Air Quality Act (Act No. 39 of 2004) (NEMAQA)):

- National Minimum Emission Standards (NMES);
- National Ambient Air Quality Standards (NAAQS) and;
- National Dust Control Regulations (NDCR).

1.2.2 Study of the Receiving Environment

Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology. Existing ambient air quality in the study area was also considered.
An understanding of the atmospheric dispersion potential of the area is essential for an air quality impact assessment. Use was made of on-site meteorological data, for the period between January 2019 to December 2020.

1.2.3 Determining the Impact of the Expansion on the Receiving Environment

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

Three distinct emission scenarios were identified (Table 1-1):

- Scenario 1: 2027 (year with maximum handled of 91.6 Mtpa, approximately 12.7 Mtpa of ore and 78.9 Mtpa of waste).
- Scenario 2: 2030 (year with maximum ore handled at Kapstevel South, approximately 11.6 Mtpa of ore and 57.4 Mtpa of waste).
- Scenario 2A: 2030 (similar tonnages handled as scenario 2 but using larger automated trucks to move ore).

Table 1-1: Scenarios selected for the dispersion modelling

Selected Year	LF (a) waste	KF (b) waste	KS (c) waste	Kap S (d) waste	Total waste (Mtpa)	LF ore	KF ore	KS ore	Kap S ore	Total ore (Mtpa)
2027	17.1	16.9	-	44.9	**78.9**	8.06	1.88	-	2.76	**12.7**
2030	-	-	-	57.4	**57.4**	-	-	-	11.6	**11.6**
2030A	-	-	-	58.2	**58.2**	-	-	-	12.1	**12.1**

Notes:

(a) LF – Leeufontein
(b) KF – Klipbankfontein
(c) KS – Kapstevel
(d) Kap S – Kapstevel South

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

1.2.4 Compliance Assessment

Compliance was assessed by comparing simulated ambient criteria pollutant concentrations ($PM_{2.5}$, PM_{10}) and dustfall rates to NAAQS's and NDCR's.

1.2.5 The Development of an Air Quality Management Plan

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

1.3 Assumptions, Exclusions and Limitations

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

- The quantification of sources of emission was restricted to current and proposed operations at Kolomela Mine.
- Project information required to calculate emissions for operations were provided by EXM. Where necessary, assumptions were made based on the specialist's experience and previous studies done for Kolomela.
- Only routine operational phase emissions were estimated and simulated.
- The impact assessment was limited to airborne particulates (including TSP, PM_{10} and $PM_{2.5}$). The impact of CO, NO_x, VOCs and SO_2 was assumed to be negligible.
- Information pertaining to fuel storage was limited. Diesel storage VOC emissions could therefore not be quantified. Even though the storage of diesel on-site is considered a listed activity under NEMAQA if total storage capacity exceeds 1 000 m^3, VOC emissions from such operations are negligible.
- Construction and decommissioning/closure phase impacts were not quantified. Impacts associated with this phase are highly variable and generally less significant than operational phase impacts. Mitigation and management measures recommended for the operational phase are however also applicable to the construction/closure phase.

2 REGULATORY REQUIREMENTS AND ASSESSMENT CRITERIA

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

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

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

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

2.1 National Minimum Emission Standards

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

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

2.2 National Ambient Air Quality Standards for Criteria Pollutants

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

Table 2-1: South African NAAQS for criteria pollutants

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

Notes:

(a) Used in this assessment.

2.3 National Dust Control Regulations

NDCRs were published on the 1st of November 2013 (Government Gazette No. R827). Acceptable dustfall rates according to the Regulation are summarised in Table 2-2.

Table 2-2: Acceptable dustfall rates

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

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

A revised Draft National Dust Control Regulations were published on 25 March 2018 (Government Gazette No. 41650) which references the same acceptable dustfall rates but refers to the latest version of the ASTM D1739 method to be used for sampling.

2.4 Anglo Environmental Performance Standard, Air Quality and Emissions

Anglo American has developed minimum requirements to achieve compliance obligations and enhancement of air quality performance (AngloAmerican, 2017).

The Standard applies to environmental air quality and emissions performance at their operations. It includes all dust and gaseous emissions (excluding noise), released through mining and processing activities, which may pose a risk on the receiving environment (humans, fauna and flora).

The standard is applicable to the entire life cycle of all operations from the project design phase, exploration, commissioning, operational, closure and post-closure phases (decommissioning, remediation and rehabilitation).

The main points of the standard applicable to this assessment are as follows:

1. All operations to develop and maintain an annual emissions inventory of releases to air from its sources.
2. Based on the emissions inventory, the operation must demonstrate compliance to the regulatory requirements applicable to the site i.e. existing and future ambient standards, and site-specific permit/license requirements. Representative air dispersion modelling assessments and air quality monitoring must be undertaken for the compliance assessment, according to internationally accepted methods.
3. Site permits/licenses and host country ambient standards apply, and in their absence, the international best practice standard such as the International Finance Cooperation (IFC) or World Health Organisation (WHO) shall apply. Where host country standards are in compliance, but a residual risk (including community complaints and class action suits; threat of regulatory change; reputational risk; risk of environmental harm) remains, a site must adopt stricter international standards for improved controls of its activities. Where this residual risk still remains after compliance with international standards, the site must design its internal controls to meet even stricter self-imposed standards.
4. The air dispersion modelling study must include the maximum predicted pollutant concentrations on sensitive receptors, the percentage contribution to the applicable standards, and the frequency of exceedances. It must also consider future expansions, emission projections, and the technology solutions required to maintain air quality compliance. A cumulative modelling scenario must be included where ambient concentrations around our sites can be influenced by background sources, such as other mining activities, farming activities and fuel burning by communities for heating and cooking.
5. The air quality monitoring system includes direct source sampling and off-site ambient monitoring; and must be representative of the mines area of influence. The ambient monitoring station locations must be informed by air dispersion modelling results on sensitive receptors and weather conditions, such as prevailing wind directions. The requirements of the site permits/licenses must be reflected in the design of the monitoring system. Daily emissions must be managed via Trigger Action Response Plans (TARP's) using the monitoring results and visual observations of emissions. The monitoring equipment must have a formal maintenance and servicing programme in place, with an annual data capture target of ninety percent (90%) as a minimum for each real-time monitoring station.

2.5 IFC Performance Standard 1

IFC's Sustainability Framework articulates the Corporation's strategic commitment to sustainable development, and is an integral part of IFC's approach to risk management. The Sustainability Framework comprises IFC's Policy and Performance Standards on Environmental and Social Sustainability, and IFC's Access to Information Policy. The Policy on Environmental and Social Sustainability describes IFC's commitments, roles, and responsibilities related to environmental and social sustainability. IFC's Access to Information Policy reflects IFC's commitment to transparency and good governance on its operations, and outlines the Corporation's institutional disclosure obligations regarding its investment and advisory services. The Performance Standards are directed towards clients, providing guidance on how to identify risks and impacts, and are designed to help avoid, mitigate, and manage risks and impacts as a way of doing business in a sustainable way, including stakeholder engagement and disclosure obligations of the client in relation to project-level activities. In the case of its direct investments (including project and corporate finance provided through financial intermediaries), IFC requires its clients to apply the Performance Standards to manage environmental and social risks and impacts so that development opportunities are enhanced. IFC uses the Sustainability Framework along with other strategies, policies, and initiatives to direct the business activities of the Corporation in order to achieve its overall development objectives.

Performance Standard 1 (IFC, 2012) establishes the importance of (i) integrated assessment to identify the environmental and social impacts, risks, and opportunities of projects; (ii) effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and (iii) the client's management of environmental and social performance throughout the life of the project.

In addition to meeting the requirements under the Performance Standards, clients must comply with applicable national law, including those laws implementing host country obligations under international law.

The World Bank Group Environmental, Health and Safety Guidelines (EHS Guidelines) are technical reference documents with general and industry-specific examples of good international industry practice. IFC uses the EHS Guidelines as a technical source of information during project appraisal. The EHS Guidelines contain the performance levels and measures that are normally acceptable to IFC, and that are generally considered to be achievable in new facilities at reasonable costs by existing technology. For IFC-financed projects, application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets with an appropriate timetable for achieving them. The environmental assessment process may recommend alternative (higher or lower) levels or measures, which, if acceptable to IFC, become project- or site-specific requirements. The General EHS Guideline contains information on cross-cutting environmental, health, and safety issues potentially applicable to all industry sectors. It should be used together with the relevant industry sector guideline(s).

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

2.5.1 Requirements

2.5.1.1 Environmental and Social Assessment and Management System

The client, in coordination with other responsible government agencies and third parties as appropriate, will conduct a process of environmental and social assessment, and establish and maintain an ESMS appropriate to the nature and scale of the project and commensurate with the level of its environmental and social risks and impacts. The ESMS will incorporate the following elements: (i) policy; (ii) identification of risks and impacts; (iii) management programs; (iv) organizational capacity and competency; (v) emergency preparedness and response; (vi) stakeholder engagement; and (vii) monitoring and review.

2.5.1.2 Policy

The client will establish an overarching policy defining the environmental and social objectives and principles that guide the project to achieve sound environmental and social performance. The policy provides a framework for the environmental and social assessment and management process, and specifies that the project (or business activities, as appropriate) will comply with the applicable laws and regulations of the jurisdictions in which it is being undertaken, including those laws implementing host country obligations under international law. The policy should be consistent with the principles of the Performance Standards. Under some circumstances, clients may also subscribe to other internationally recognized standards, certification schemes, or codes of practice and these too should be included in the policy. The policy will indicate who, within the client's organization, will ensure conformance with the policy and be responsible for its execution (with reference to an appropriate responsible government agency or third party, as necessary). The client will communicate the policy to all levels of its organization.

2.5.1.3 Identification of Risks and Impacts

The client will establish and maintain a process for identifying the environmental and social risks and impacts of the project. The type, scale, and location of the project guide the scope and level of effort devoted to the risks and impacts identification process. The scope of the risks and impacts identification process will be consistent with good international industry practice, and will determine the appropriate and relevant methods and assessment tools. The process may comprise a full-scale environmental and social impact assessment, a limited or focused environmental and social assessment, or straightforward application of environmental siting, pollution standards, design criteria, or construction standards. When the project involves existing assets, environmental and/or social audits or risk/hazard assessments can be appropriate and sufficient to identify risks and impacts. If assets to be developed, acquired or financed have yet to be defined, the establishment of an environmental and social due diligence process will identify risks and impacts at a point in the future when the physical elements, assets, and facilities are reasonably understood. The risks and impacts identification process will be based on recent environmental and social baseline data at an appropriate level of detail. The process will consider all relevant environmental and social risks and impacts of the project, and those who are likely to be affected by such risks and impacts. The risks and impacts identification process will consider the emissions of greenhouse gases, the relevant risks associated with a changing climate and the adaptation opportunities, and potential transboundary effects, such as pollution of air, or use or pollution of international waterways.

Where the project involves specifically identified physical elements, aspects, and facilities that are likely to generate impacts, environmental and social risks and impacts will be identified in the context of the project's area of influence. This area of influence encompasses, as appropriate:

- The area likely to be affected by: (i) the project and the client's activities and facilities that are directly owned, operated or managed (including by contractors) and that are a component of the project; (ii) impacts from unplanned but predictable developments caused by the project that may occur later or at a different location; or (iii) indirect project impacts on biodiversity or on ecosystem services upon which Affected Communities' livelihoods are dependent.
- Associated facilities, which are facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable.
- Cumulative impacts that result from the incremental impact, on areas or resources used or directly impacted by the project, from other existing, planned or reasonably defined developments at the time the risks and impacts identification process is conducted.

In the event of risks and impacts in the project's area of influence resulting from a third party's actions, the client will address those risks and impacts in a manner commensurate with the client's control and influence over the third parties, and with due regard to conflict of interest.

Where the client can reasonably exercise control, the risks and impacts identification process will also consider those risks and impacts associated with primary supply chains.

Where the project involves specifically identified physical elements, aspects and facilities that are likely to generate environmental and social impacts, the identification of risks and impacts will take into account the findings and conclusions of related and applicable plans, studies, or assessments prepared by relevant government authorities or other parties that are directly related to the project and its area of influence. These include master economic development plans, country or regional plans, feasibility studies, alternatives analyses, and cumulative, regional, sectoral, or strategic environmental assessments where relevant. The risks and impacts identification will take account of the outcome of the engagement process with Affected Communities as appropriate.

Where the project involves specifically identified physical elements, aspects and facilities that are likely to generate impacts, and as part of the process of identifying risks and impacts, the client will identify individuals and groups that may be directly and differentially or disproportionately affected by the project because of their disadvantaged or vulnerable status. Where individuals or groups are identified as disadvantaged or vulnerable, the client will propose and implement differentiated measures so that adverse impacts do not fall disproportionately on them and they are not disadvantaged in sharing development benefits and opportunities.

2.5.1.4 Management Programs

Consistent with the client's policy and the objectives and principles described therein, the client will establish management programs that, in sum, will describe mitigation and performance improvement measures and actions that address the identified environmental and social risks and impacts of the project.

Depending on the nature and scale of the project, these programs may consist of some documented combination of operational procedures, practices, plans, and related supporting documents (including legal agreements) that are managed in a systematic way. The programs may apply broadly across the client's organization, including contractors and primary suppliers over which the organization has control or influence, or to specific sites, facilities, or activities. The mitigation hierarchy to address identified risks and impacts will favor the avoidance of impacts over minimization, and, where residual impacts remain, compensation/offset, wherever technically and financially feasible.

Where the identified risks and impacts cannot be avoided, the client will identify mitigation and performance measures and establish corresponding actions to ensure the project will operate in compliance with applicable laws and regulations, and meet the requirements of Performance Standards 1 through 8. The level of detail and complexity of this collective management program and the priority of the identified measures and actions will be commensurate with the project's risks and impacts, and will take account of the outcome of the engagement process with Affected Communities as appropriate.

The management programs will establish environmental and social Action Plans, which will define desired outcomes and actions to address the issues raised in the risks and impacts identification process, as measurable events to the extent possible, with elements such as performance indicators, targets, or acceptance criteria that can be tracked over defined time periods, and with estimates of the resources and responsibilities for implementation. As appropriate, the management program will recognize and incorporate the role of relevant actions and events controlled by third parties to address identified risks and impacts. Recognizing the dynamic nature of the project, the management program will be responsive to changes in circumstances, unforeseen events, and the results of monitoring and review.

2.5.1.5 Organizational Capacity and Competency

The client, in collaboration with appropriate and relevant third parties, will establish, maintain, and strengthen as necessary an organizational structure that defines roles, responsibilities, and authority to implement the ESMS. Specific personnel, including management representative(s), with clear lines of responsibility and authority should be designated. Key environmental and social responsibilities should be well defined and communicated to the relevant personnel and to the rest of the client's organization. Sufficient management sponsorship and human and financial resources will be provided on an ongoing basis to achieve effective and continuous environmental and social performance.

Personnel within the client's organization with direct responsibility for the project's environmental and social performance will have the knowledge, skills, and experience necessary to perform their work, including current knowledge of the host country's regulatory requirements and the applicable requirements of Performance Standards 1 through 8. Personnel will also possess the knowledge, skills, and experience to implement the specific measures and actions required under the ESMS and the methods required to perform the actions in a competent and efficient manner.

The process of identification of risks and impacts will consist of an adequate, accurate, and objective evaluation and presentation, prepared by competent professionals. For projects posing potentially significant adverse impacts or where technically complex issues are involved, clients may be required to involve external experts to assist in the risks and impacts identification process.

2.5.1.6 Emergency Preparedness and Response

Where the project involves specifically identified physical elements, aspects and facilities that are likely to generate impacts, the ESMS will establish and maintain an emergency preparedness and response system so that the client, in collaboration with appropriate and relevant third parties, will be prepared to respond to accidental and emergency situations associated with the project in a manner appropriate to prevent and mitigate any harm to people and/or the environment. This preparation will include the identification of areas where accidents and emergency situations may occur, communities and individuals that may be impacted, response procedures, provision of equipment and resources, designation of responsibilities, communication, including that with potentially Affected Communities and periodic training to ensure effective response. The emergency preparedness and response activities will be periodically reviewed and revised, as necessary, to reflect changing conditions.

Where applicable, the client will also assist and collaborate with the potentially Affected Communities and the local government agencies in their preparations to respond effectively to emergency situations, especially when their participation and collaboration are necessary to ensure effective response. If local government agencies have little or no capacity to respond effectively, the client will play an active role in preparing for and responding to emergencies associated with the project. The client will document its emergency preparedness and response activities, resources, and responsibilities, and will provide appropriate information to potentially Affected Community and relevant government agencies.

2.5.1.7 Monitoring and Review

The client will establish procedures to monitor and measure the effectiveness of the management program, as well as compliance with any related legal and/or contractual obligations and regulatory requirements. Where the government or other third party has responsibility for managing specific risks and impacts and associated mitigation measures, the client will collaborate in establishing and monitoring such mitigation measures. Where appropriate, clients will consider involving representatives from Affected Communities to participate in monitoring activities. The client's monitoring program should be overseen by the appropriate level in the organization. For projects with significant impacts, the client will retain external experts to verify its monitoring information. The extent of monitoring should be commensurate with the project's environmental and social risks and impacts and with compliance requirements.

In addition to recording information to track performance and establishing relevant operational controls, the client should use dynamic mechanisms, such as internal inspections and audits, where relevant, to verify compliance and progress toward the desired outcomes. Monitoring will normally include recording information to track performance and comparing this against the previously established benchmarks or requirements in the management program. Monitoring should be adjusted according to performance experience and actions requested by relevant regulatory authorities. The client will document monitoring results and identify and reflect the necessary corrective and preventive actions in the amended management program and plans. The client, in collaboration with appropriate and relevant third parties, will implement these corrective and preventive actions, and follow up on these actions in upcoming monitoring cycles to ensure their effectiveness.

Senior management in the client organization will receive periodic performance reviews of the effectiveness of the ESMS, based on systematic data collection and analysis. The scope and frequency of such reporting will depend upon the nature and scope of the activities identified and undertaken in accordance with the client's ESMS and other applicable project requirements. Based on results within these performance reviews, senior management will take the necessary and appropriate steps to ensure the intent of the client's policy is met, that procedures, practices, and plans are being implemented, and are seen to be effective.

2.5.1.8 Stakeholder Engagement

Stakeholder engagement is the basis for building strong, constructive, and responsive relationships that are essential for the successful management of a project's environmental and social impacts. Stakeholder engagement is an ongoing process that may involve, in varying degrees, the following elements: stakeholder analysis and planning, disclosure and dissemination of information, consultation and participation, grievance mechanism, and ongoing reporting to Affected Communities. The nature, frequency, and level of effort of stakeholder engagement may vary considerably and will be commensurate with the project's risks and adverse impacts, and the project's phase of development.

2.5.1.9 External Communications and Grievance Mechanisms

External Communications
Clients will implement and maintain a procedure for external communications that includes methods to (i) receive and register external communications from the public; (ii) screen and assess the issues raised and determine how to address them; (iii) provide, track, and document responses, if any; and (iv) adjust the management program, as appropriate. In addition, clients are encouraged to make publicly available periodic reports on their environmental and social sustainability.

Grievance Mechanism for Affected Communities
Where there are Affected Communities, the client will establish a grievance mechanism to receive and facilitate resolution of Affected Communities' concerns and grievances about the client's environmental and social performance. The grievance mechanism should be scaled to the risks and adverse impacts of the project and have Affected Communities as its primary user. It should seek to resolve concerns promptly, using an understandable and transparent consultative process that is culturally appropriate and readily accessible, and at no cost and without retribution to the party that originated the issue or concern. The mechanism should not impede access to judicial or administrative remedies. The client will inform the Affected Communities about the mechanism in the course of the stakeholder engagement process.

2.5.1.10 Ongoing Reporting to Affected Communities

The client will provide periodic reports to the Affected Communities that describe progress with implementation of the project Action Plans on issues that involve ongoing risk to or impacts on Affected Communities and on issues that the consultation process or grievance mechanism have identified as a concern to those Communities. If the management program results in material changes in or additions to the mitigation measures or actions described in the Action Plans on issues of concern to the Affected Communities, the updated relevant mitigation measures or actions will be communicated to them. The frequency of these reports will be proportionate to the concerns of Affected Communities but not less than annually.

3 DESCRIPTION OF THE RECEIVING ENVIRONMENT

3.1 Air Quality Sensitive Receptors

A study area, determined from the expected impact area, of 20 km east-west by 16 km north-south with the project located centrally was included. The study area is shown in Figure 3-1 with identified scattered AQSR indicated. AQSRs generally include places of residence and areas where members of the public may be affected by atmospheric emissions generated by mining/industrial activities. The nearest residential area is Postmasburg which lies 11 km north-east of the project.

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

3.2 Atmospheric Dispersion Potential

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

3.2.1 Land Use and Topography

The topography is characterised by undulating hills ranging from 1120 to 1340 metres above mean sea level (mamsl). No topography was included in dispersion simulations.

3.2.2 Surface Wind Field

Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; for example, dark green representing winds in between 3 and 4 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind field and diurnal variability in the wind field are shown in Figure 3-2. During the 2019 to 2020 period, the wind field was dominated by winds from the north. The strongest winds (>6 m/s) were also from these directions. Calm conditions occurred 10.5% of the time, with the average wind speed over the period calculated as 2.7 m/s.

Wind speeds decreased during the night-time conditions with an increase in calms from 11.7% during the day to 21.4% during the night.

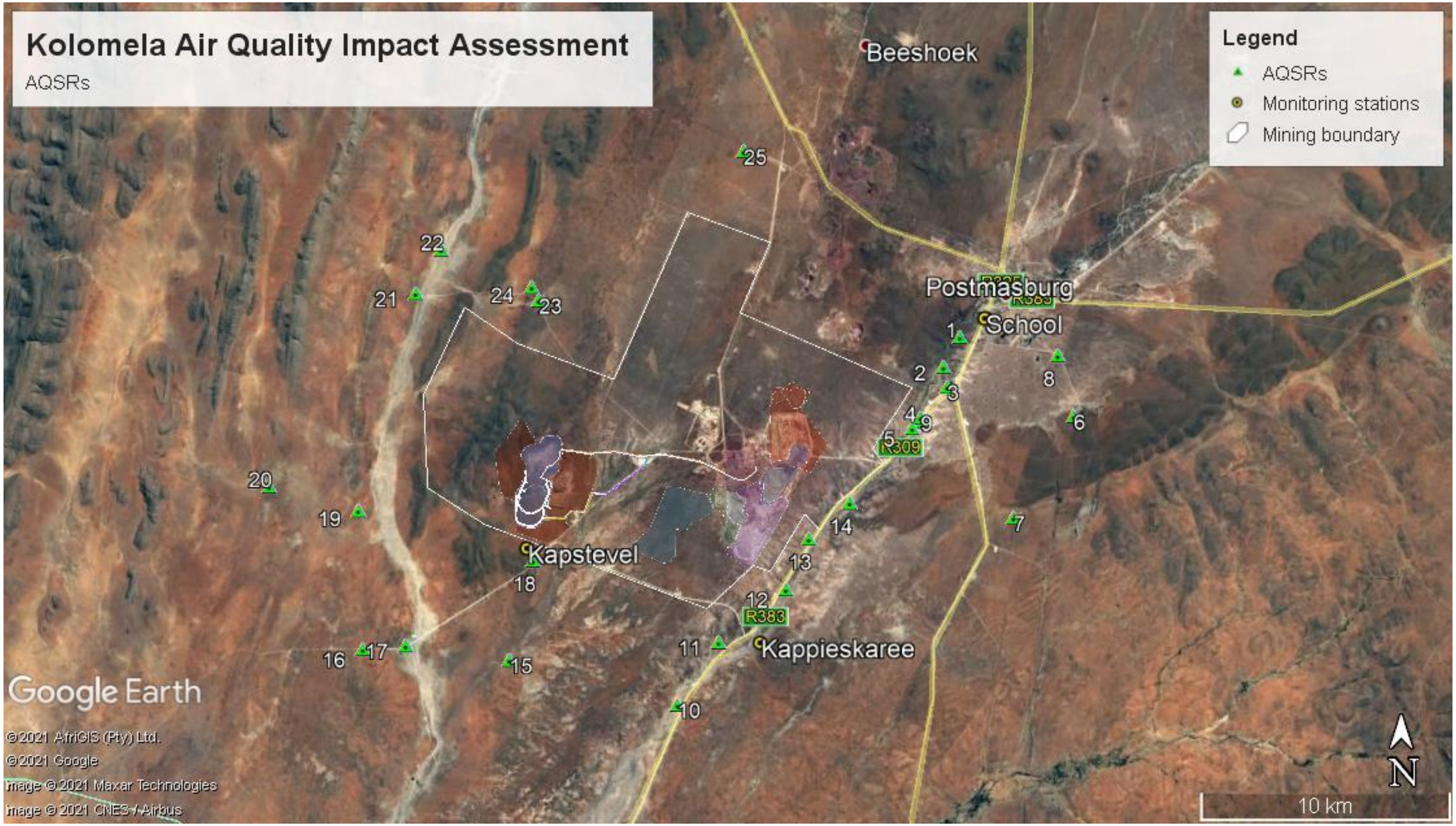


Figure 3-1: Mining boundary and AQSRs

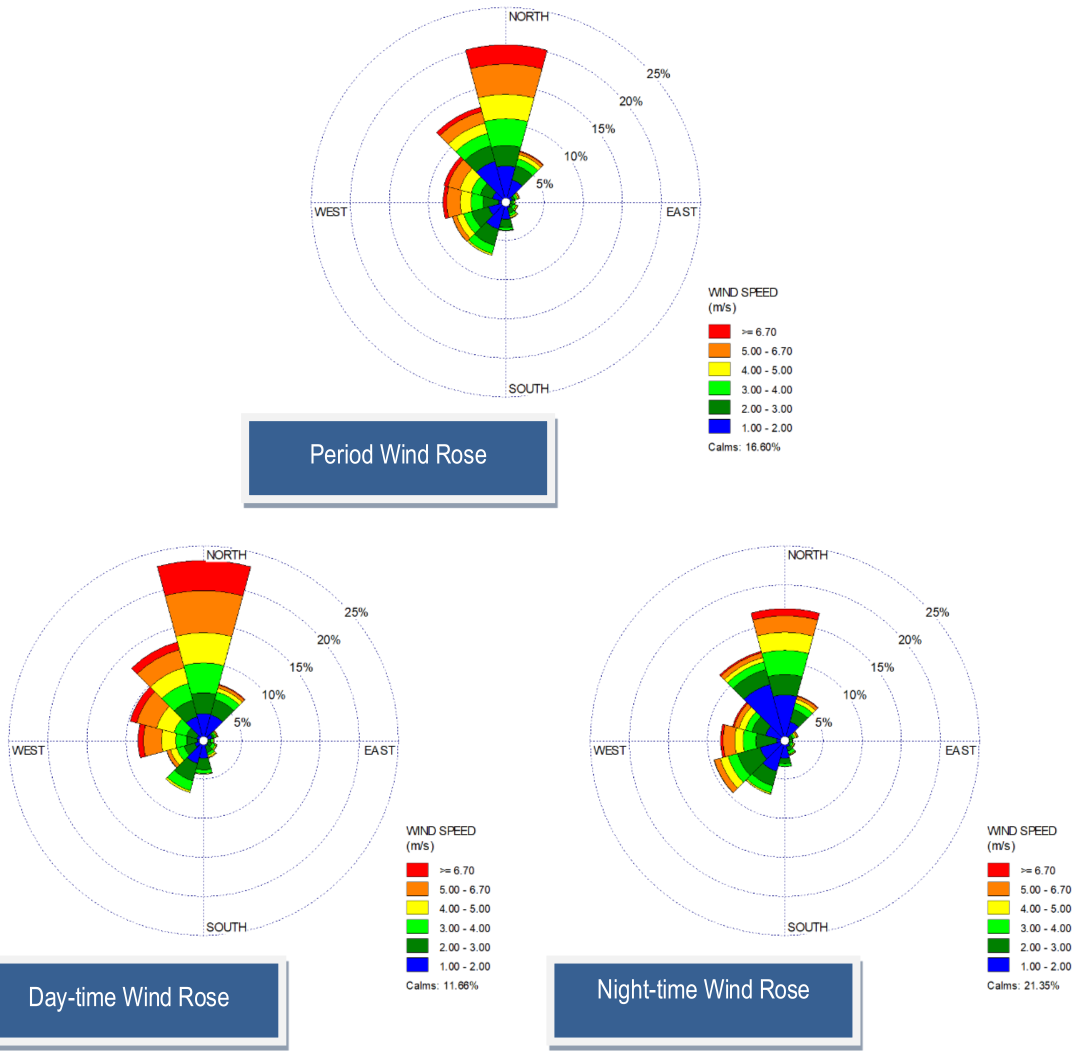


Figure 3-2: Period, day- and night-time wind roses for Kapstevel (on-site data, 2019 to 2020)

3.2.3 Temperature

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

Monthly mean and hourly maximum and minimum temperatures are given in Table 3-1. Temperatures ranged between -7°C and 38°C. The highest temperatures occurred in December and the lowest in July. During the day, temperatures increase to reach maximum at around 14:00 in the afternoon. Ambient air temperatures decrease to reach a minimum at around 06:00 i.e. just before sunrise.

Table 3-1: Monthly temperature summary

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	10.7	12.4	6.5	3.0	-2.3	-7.1	-4.9	-4.5	-0.3	2.2	6.8	8.4
Maximum	37.9	37.1	36.0	32.2	29.4	26.3	25.9	29.0	34.3	36.9	38.1	36.3
Average	27.4	25.2	24.1	19.0	16.2	11.6	11.5	12.7	18.0	21.7	24.0	24.9

3.2.4 Rainfall

Precipitation is important to air pollution studies since it represents an effective mechanism of removing pollutants from the environment. On its way to the surface rain water combines with lots of pollutants in atmosphere; this process may alter the composition of rain by making it acidic but this also means that the pollutants are removed from the atmosphere which may reduce the impacts on human health. There is no reliable ambient rainfall data available for the Kapstevel station, however precipitation here is low and averages 319 mm.

3.3 Ambient Air Pollutant Concentrations and Dustfall Rates

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

Kolomela Mine has a few some monitoring stations; namely: Kappieskaree, Kapstevel, Heuningkranz, and the Postmasburg School (refer to Figure 3-1). The data recorded includes hourly PM_{10}, $PM_{2.5}$, SO_2 and NO_2. SO_2 and NO_2 results were analysed and it was found that neither exceed the relevant evaluation criteria. A dust monitoring network has been installed since November 2011. For this assessment the results are split into on and off-site buckets. Data analysed for the ambient air quality is for the period 2020. Both PM_{10} and $PM_{2.5}$ 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.

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

The results of the PM_{10} and $PM_{2.5}$ monitoring are represented in Table 3-2 and Table 3-3 as well as Figure 3-3 to Figure 3-10.

The PM_{10} annual average recorded at Heuningkranz, Kappieskaree, Kapstevel and Postmasburg School stations was 9 µg/m³, 28 µg/m³, 30 µg/m³ and 29 µg/m³ respectively during 2020 (below the NAAQS of 40 µg/m³). Frequency of exceedence were 0, 12, 16 and 1 days respectively. Therefore, Kappieskaree and Kapstevel were in non-compliance with the daily PM_{10} NAAQS (exceeded 75 µg/m³ for over 4 days of the year). This happens mostly during the spring months (when the area is dry after winter, rainfall is low and the wind speeds increase), and will be a combination of Kolomela sources as well as other sources in the vicinity.

The $PM_{2.5}$ annual average recorded at Heuningkranz, Kappieskaree, Kapstevel and Postmasburg School stations was 4 µg/m³, 6 µg/m³, 6 µg/m³ and 19 µg/m³ respectively during 2020 (below the NAAQS of 20 µg/m³). Frequency of exceedence were 0, 0, 0 and 10 days respectively. The ambient air quality in the vicinity of Kolomela is in compliance with the NAAQS for $PM_{2.5}$, with the exception of the school, but data availability was poor for the year.

Table 3-2: Summary of PM_{10} concentrations for 2020

Station	Data availability (%)	Number of exceedences of 75 µg/m³	Annual average (µg/m³)	Compliance with NAAQS
Heuningkranz	97	-	9	YES
Kappieskaree	78	**12**	28	**NO**
Kapstevel	97	**16**	30	**NO**
School	**47**	1	29	YES

Table 3-3: Summary of $PM_{2.5}$ concentrations for 2020

Station	Data availability (%)	Number of exceedences of 40 µg/m³	Annual average (µg/m³)	Compliance with NAAQS
Heuningkranz	90	-	4	YES
Kappieskaree	93	-	6	YES
Kapstevel	95	-	6	YES
School	**48**	**10**	19	**NO**

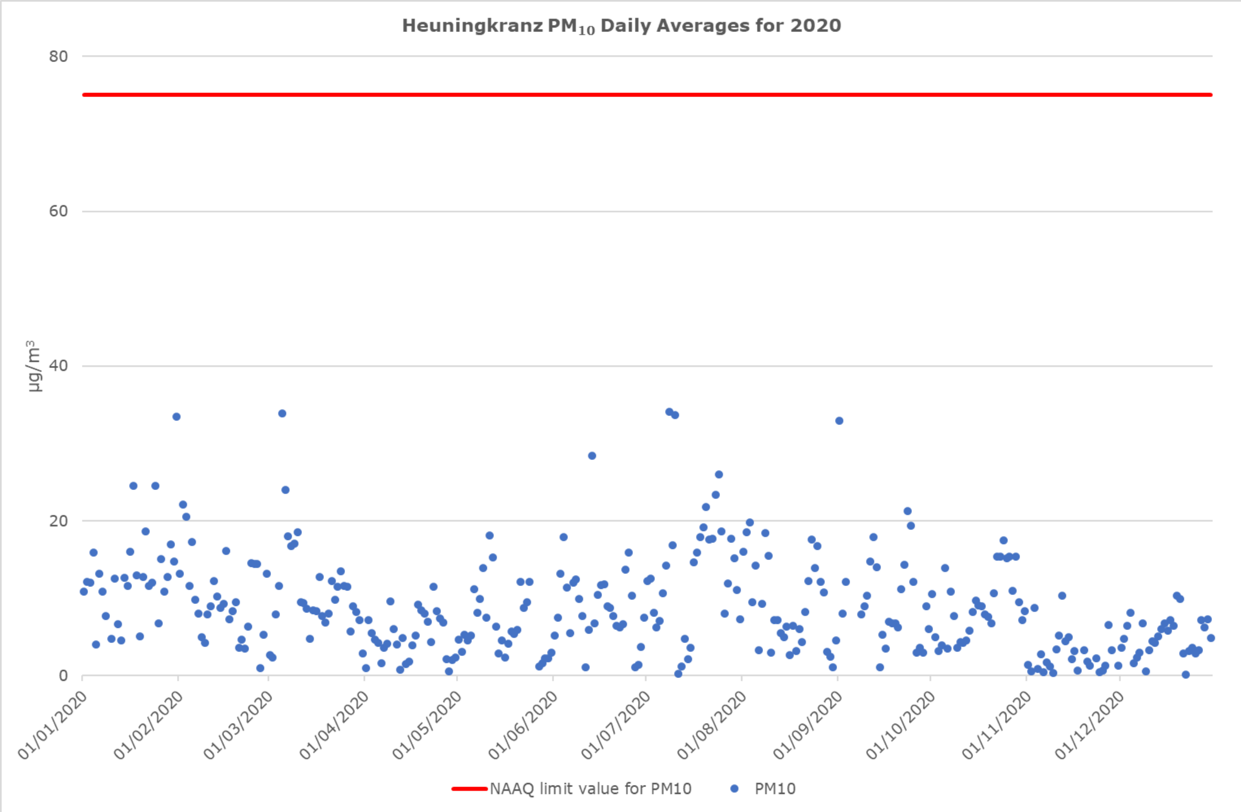


Figure 3-3: Heuningkranz PM_{10} daily concentrations

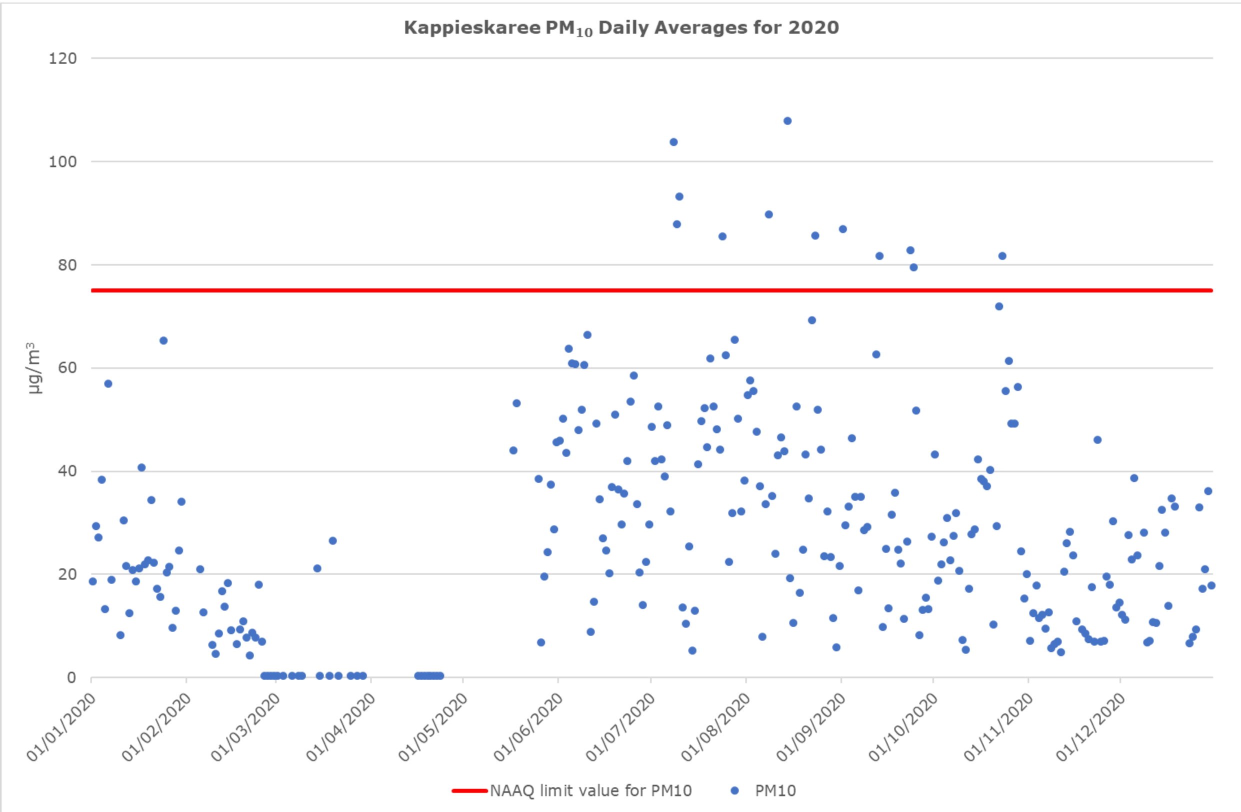


Figure 3-4: Kappieskaree PM_{10} daily concentrations

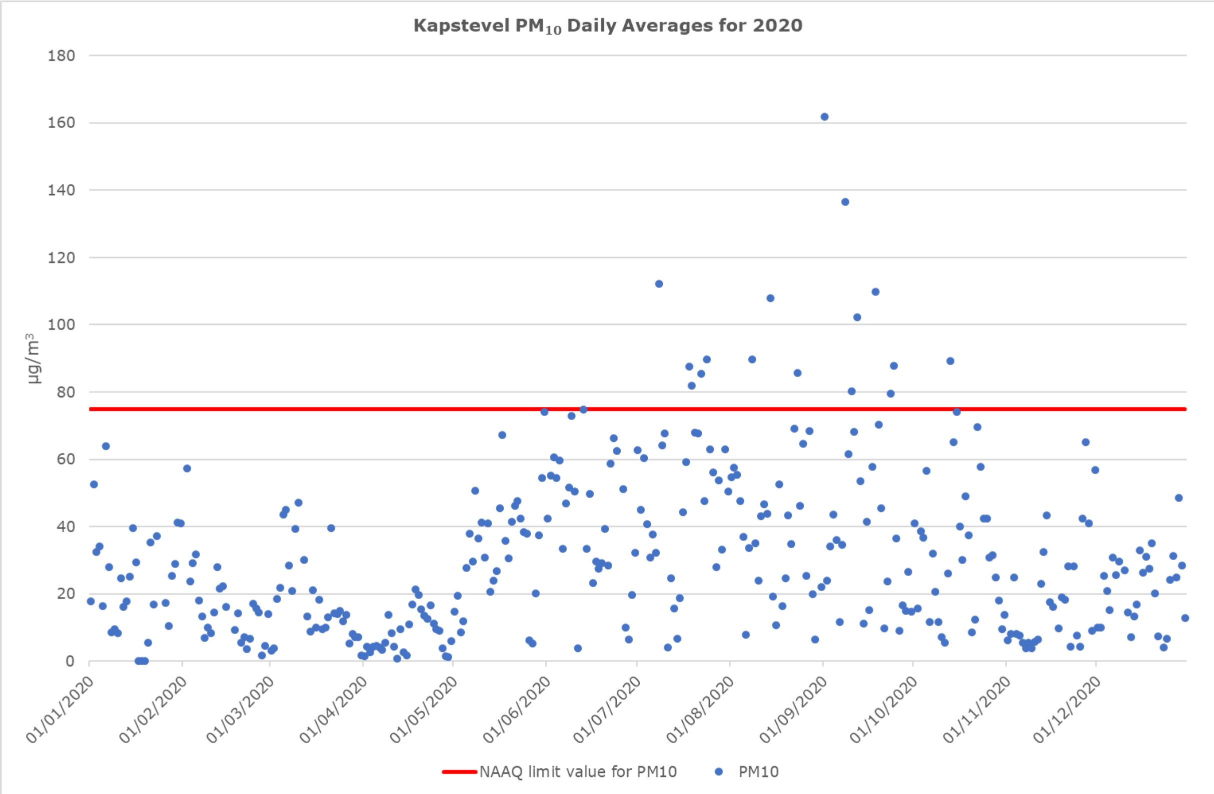


Figure 3-5: Kapstevel PM_{10} daily concentrations

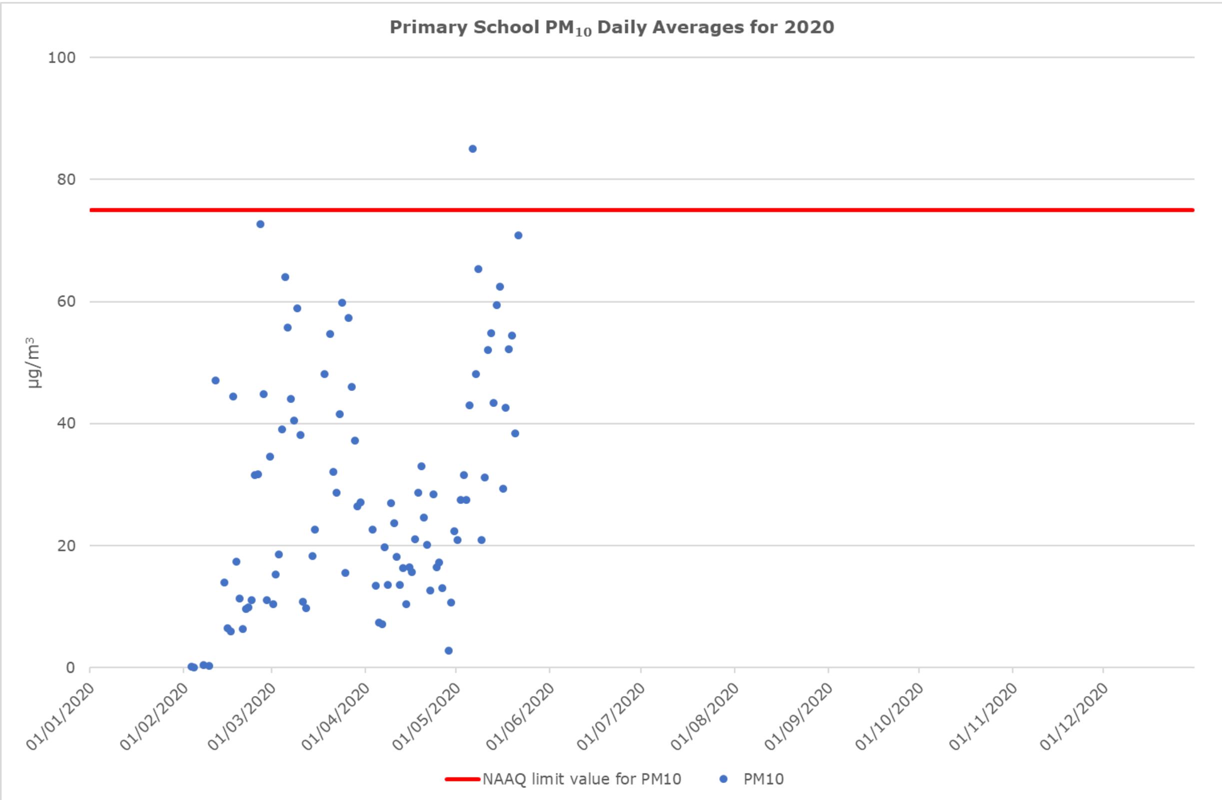


Figure 3-6: School PM_{10} daily concentrations

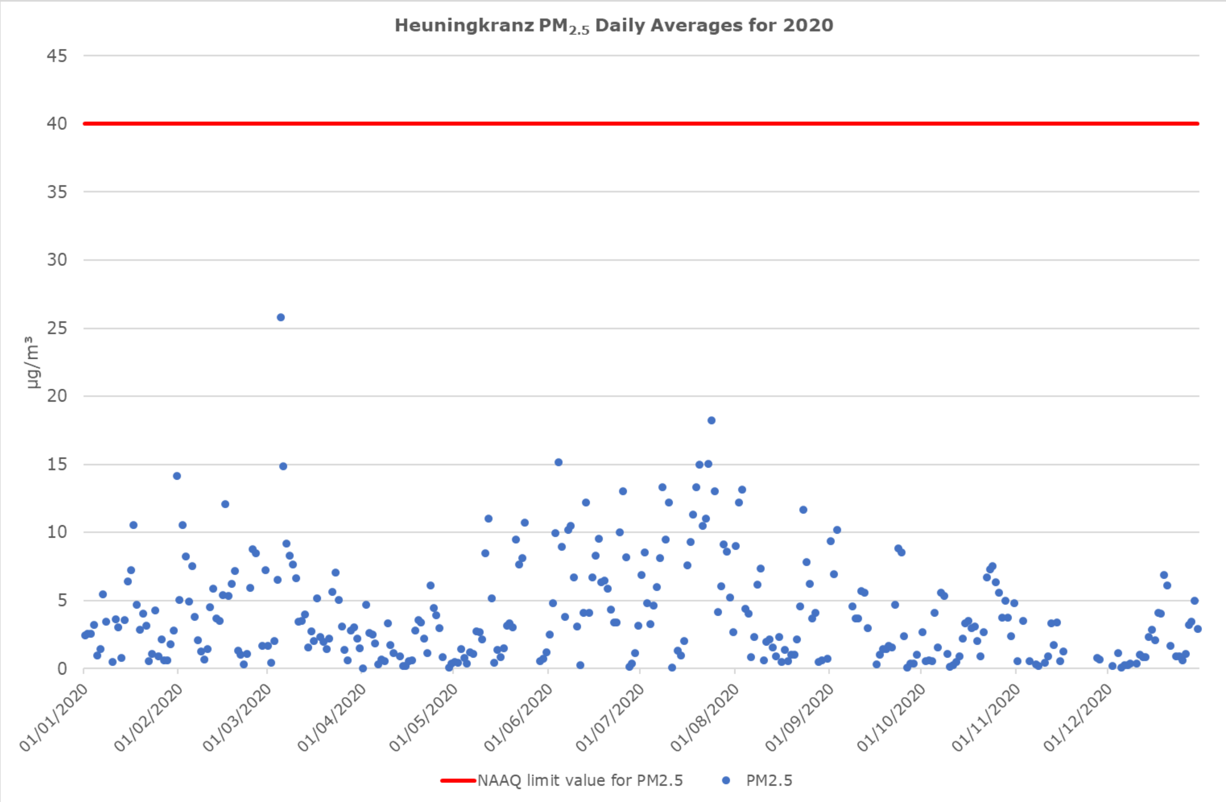


Figure 3-7: Heuningkranz $PM_{2.5}$ daily concentrations

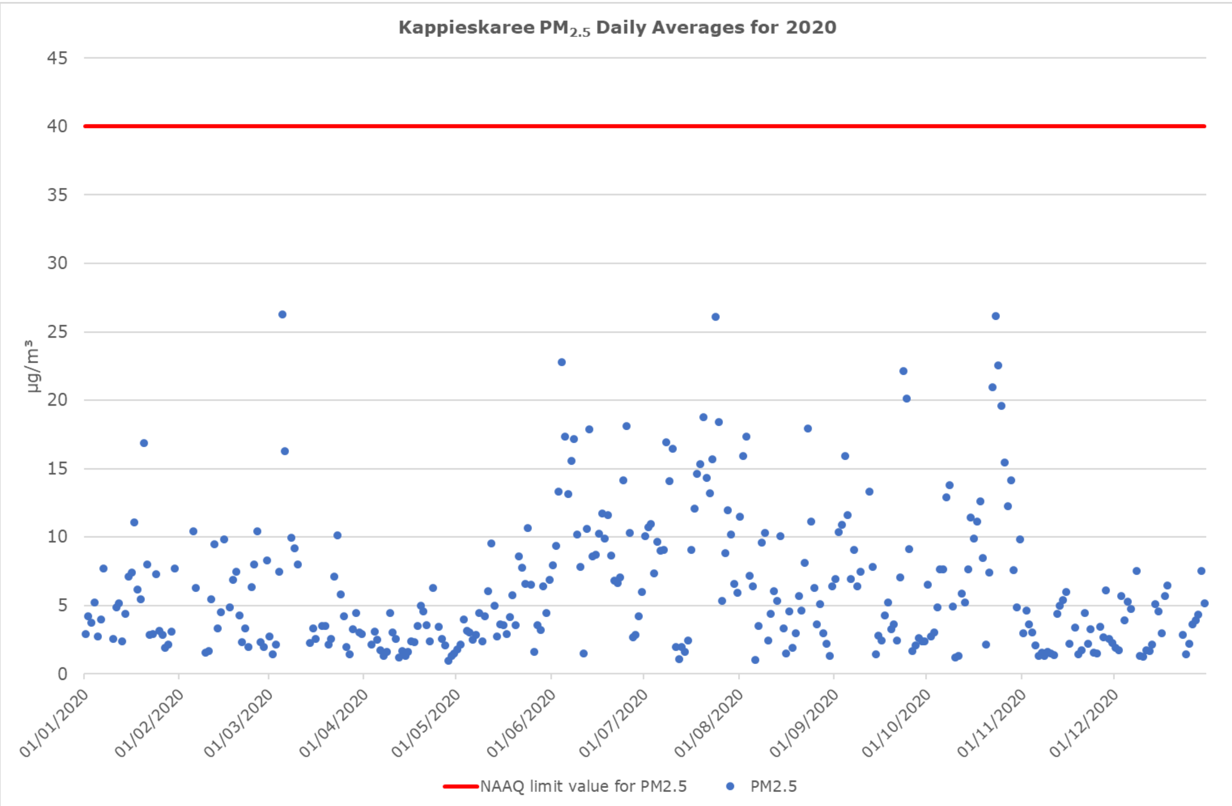


Figure 3-8: Kappieskaree $PM_{2.5}$ daily concentrations

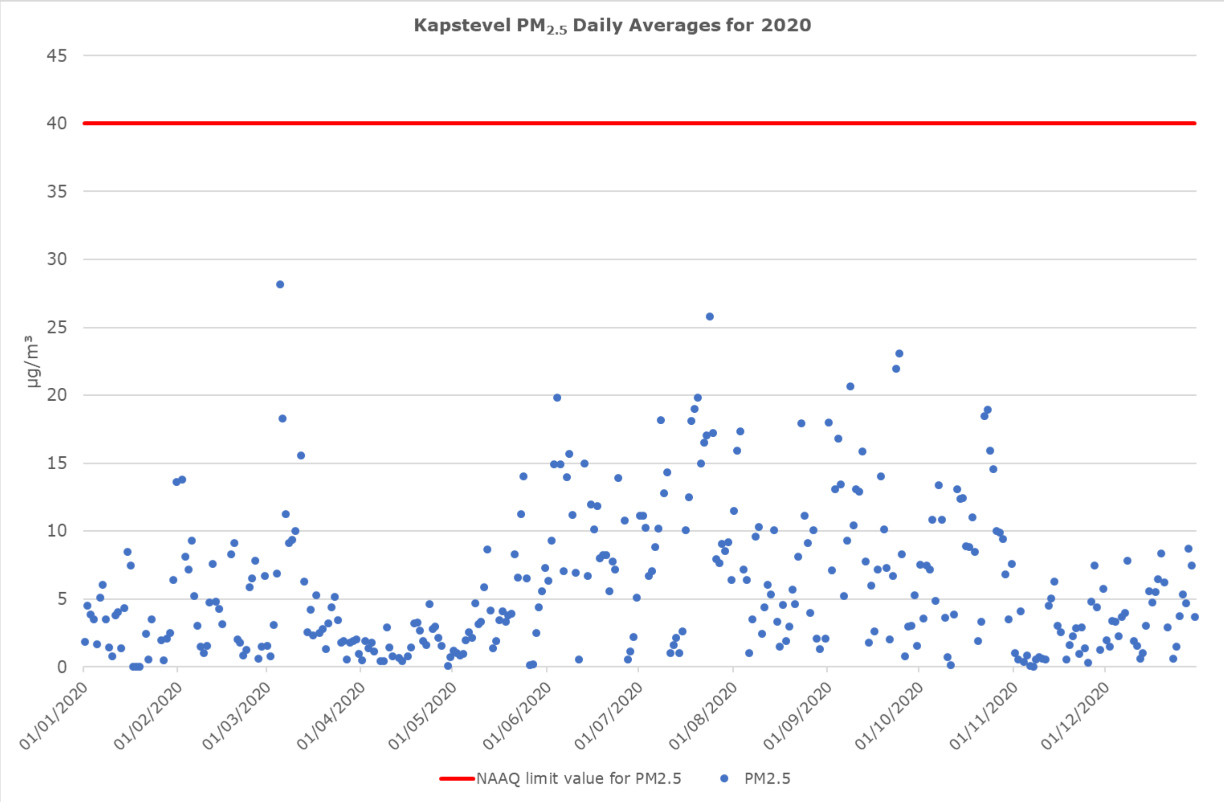


Figure 3-9: Kapstevel $PM_{2.5}$ daily concentrations

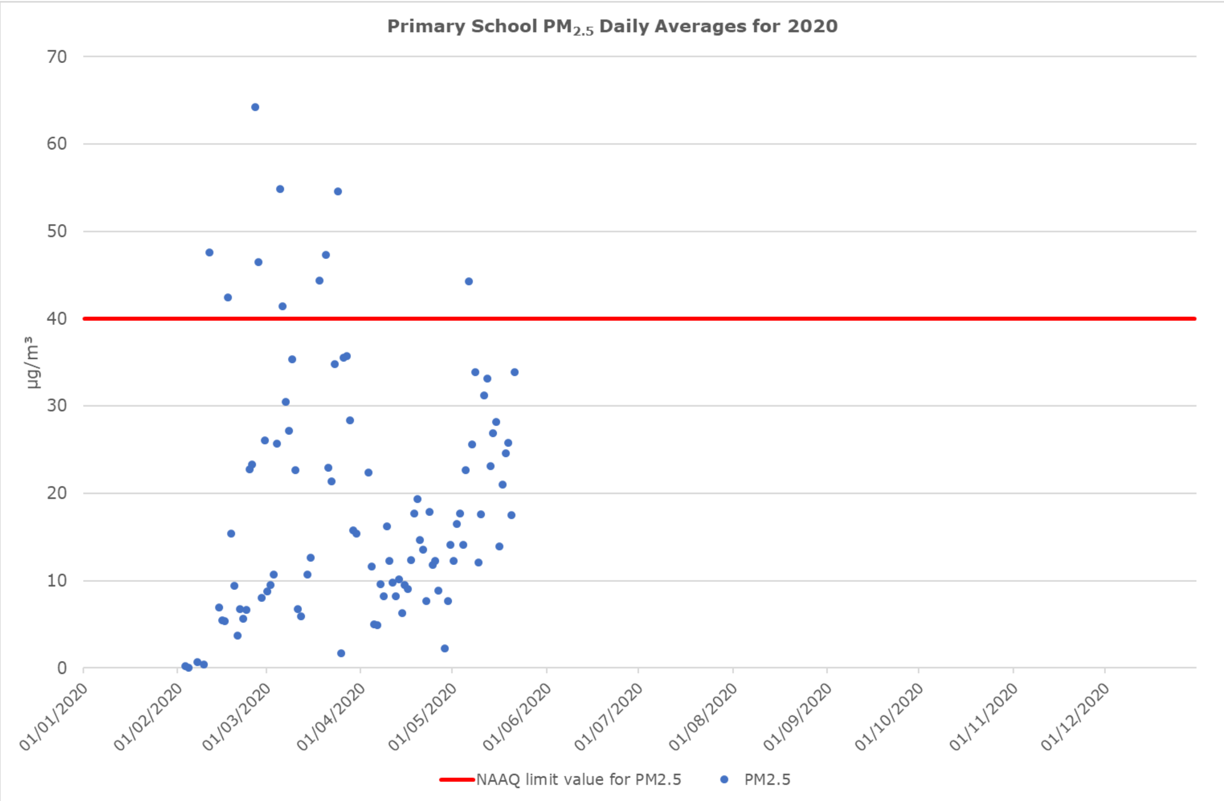


Figure 3-10 School $PM_{2.5}$ daily concentrations

3.3.2 Dustfall Sampling

A sampling campaign for the capture of dustfall has been in operation since 2011. The latest results were taken from the available dustfall monitoring reports and excel spreadsheets (Figure 3-11) which included 19 off-site single dust buckets (Figure 3-12). DustWatch currently performs the dustfall sampling (Dustwatch, 2020).

Figure 3-11: Dustfall monitoring network locations

From the results of the monitoring campaign, it was found that dustfall at the following off-site dust bucket locations are non-compliant with the NDCR for non-residential areas (exceed 1 200 mg/m²/day);

- 2018 – all non-compliant with NDCR
- 2019 – all non-compliant with NDCR (except number 29)
- 2020 – all non-compliant with NDCR (except number 3,11, 12, 13, 14, 20, 27, 28 and 29)

It should be noted that even locations upwind of the mine (for example bucket number 5) show elevated dustfall levels. This indicates the contribution of other sources to the non-compliance with the NDCR.

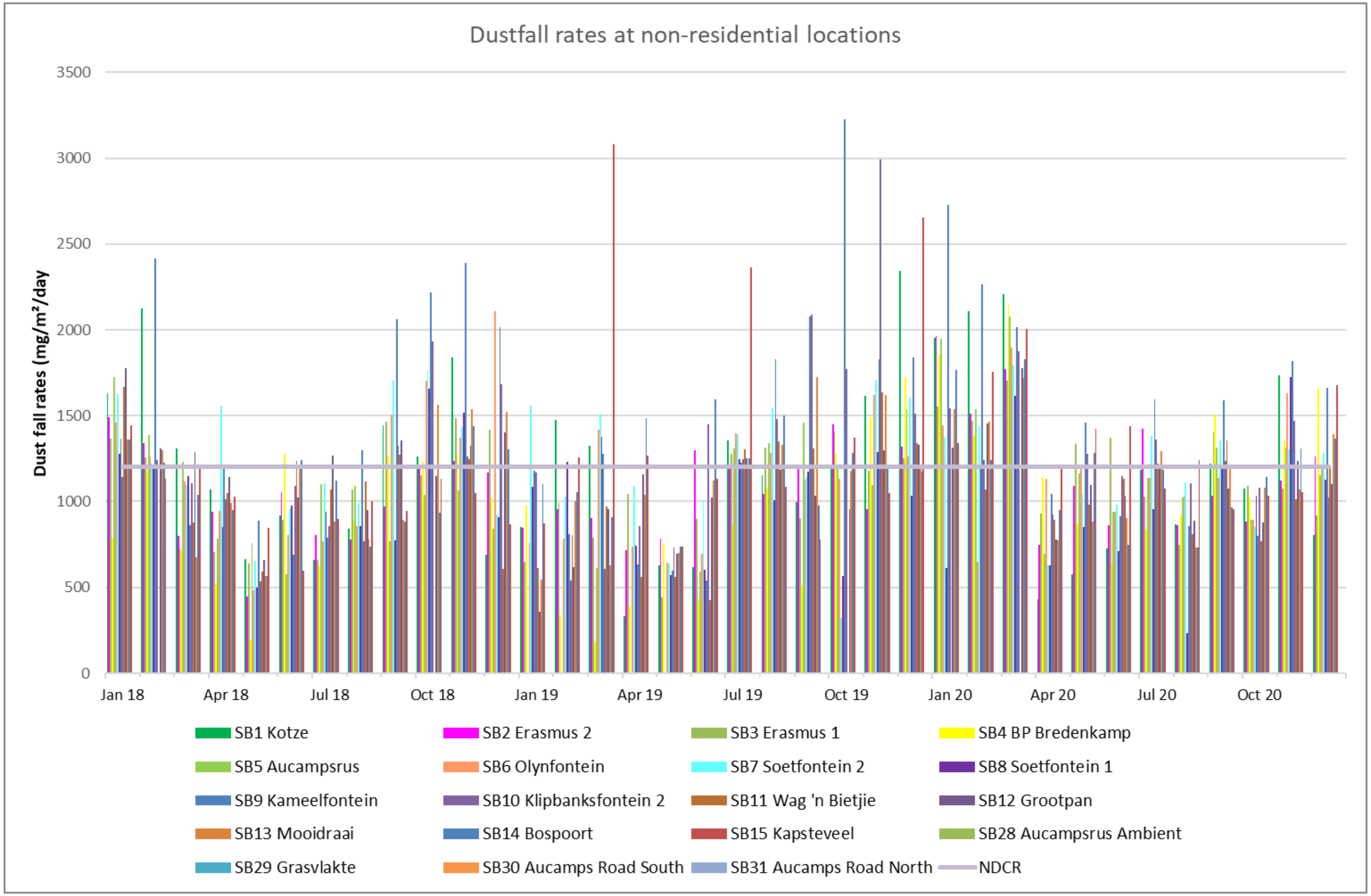


Figure 3-12: Results of the dustfall monitoring campaign – off-site dust buckets

4 IMPACT OF PROPOSED EXPANSION ON THE RECEIVING ENVIRONMENT

4.1 Atmospheric Emissions

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

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

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

All emissions were determined through the application of emission factors published by the US EPA and the Australian NPI. A summary of fugitive dust sources quantified, emissions estimation techniques applied, and source input parameters are summarised in Table 4-1. Estimated annual average emissions, per source group and scenario, are presented in Table 4-2 and Table 4-3.

The following is noted with regards to the emissions inventory:

- Atmospheric emissions of PM are expected to reach a maximum when the mining rate for waste rock and ore is at its maximum (Scenario 1), and when haul distances are at a maximum.
- Maximum operational phase PM emissions amount to 15 200 t/a TSP, 6 426 t/a PM_{10} and 2 610 t/a $PM_{2.5}$ (Scenario 1).
- Maximum TSP emissions result mostly from unpaved roads and wind erosion (Figure 4-1 (a and d)).
- The top contributors to PM_{10} are unpaved roads and wind erosion (Figure 4-1 (b and e)).
- $PM_{2.5}$ emissions result mostly from wind erosion and unpaved roads (Figure 4-1 (c and f)).

Table 4-1: Emission estimation techniques and parameters

Source Group	Emission Estimation Technique	Input Parameters
Primary Crushing	Use was made of NPI single valued emission factors for low moisture (<4%) ore (NPI, 2012): • TSP – 0.2 kg/tonne • PM_{10} – 0.02 kg/tonne • $PM_{2.5}$ – *assumed* to be 0.01 kg/tonne	Primary crushing of RoM at the following rate **3500 t/h** (at the main DSO plant) **Hours of operation:** 7 days per week, 12 hours per day **Mitigation:** 50% due to water sprays (assumption based on the dust management system in place at the DSO plant)
Secondary Crushing	Use was made of NPI single valued emission factors for low moisture (<4%) ore (NPI, 2012): • TSP – 0.6 kg/tonne • PM_{10} – *assumed* to be 0.06 kg/tonne • $PM_{2.5}$ – *assumed* to be 0.03 kg/tonne	Secondary crushing of RoM at the following rate **3500 t/h** (at the main DSO plant) **Hours of operation:** 7 days per week, 12 hours per day **Mitigation:** 98% due to being enclosed (assumption based on the dust management system in place at the DSO plant)
Tertiary Crushing	Use was made of NPI single valued emission factors for low moisture (<4%) ore (NPI, 2012): • TSP – 1.4 kg/tonne • PM_{10} – 0.08 kg/tonne • $PM_{2.5}$ – *assumed* to be 0.04 kg/tonne	Tertiary crushing of RoM at the following rate **2200 t/h** (at the main DSO plant) **Hours of operation:** 7 days per week, 12 hours per day **Mitigation:** 98% due to being enclosed (assumption based on the dust management system in place at the DSO plant)
Drilling	NPI emission factor (NPI, 2012): • TSP – 0.59 kg/hole • PM_{10} – 0.31 kg/hole • $PM_{2.5}$ – *assumed* to be 0.042 kg/hole	**30000 holes drilled per year**: Drilling area in ratio to mine plan. **Hours of operation:** 7 days per week, 24 hours per day **Mitigation:** None
Materials Handling	US EPA emission factor equation (US EPA, 2006) $EF = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$ Where EF is the emission factor in kg/tonne material handled k is the particle size multiplier (k_{TSP} – 0.74, k_{PM10} – 0.35, $k_{PM2.5}$ – 0.053) U is the average wind speed in m/s M is the material moisture content in %	RoM, product ore and waste rock loading and off-loading points were included. The number of transfer points and rates used in the estimation of emissions are: • **Product ore**, rate **1 450 tonnes/hour (2027), 1 324 tonnes/hour (2030)** • **Waste rock**, rate **9 007 tonnes/hour (2027), 6 553 tonnes/hour (2030)** An average **wind speed of 2.7 m/s** was determined from the on-site data set. A **moisture content** of **1.5%** was assumed. **Hours of operation:** 7 days per week, 24 hours per day. **Mitigation:** None
Vehicle Entrained Dust from Unpaved Roads	US EPA emission factor equation (US EPA, 2006) $E = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{0.45} \cdot 281.9$ Where EF is the emission factor in g/vehicle kilometer travelled (VKT) k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) s is the road surface material silt content in % W is the average weight of vehicles in tonnes	Transport activities include the transport of RoM to the beneficiation plant, waste rock to waste rock dumps. VKT were calculated from road lengths, truck capacities and the number of trips required transporting RoM and waste rock. A road **surface silt content of 22.4%** was applied in calculations (based on Sishen mine). Truck capacities of 90 ton for ore and 184 ton for waste were assumed. For the automated truck scenario, a capacity of 220 ton was assumed. **Hours of operation:** 7 days per week, 24 hours per day **Mitigation:** 75% with water sprays on roads within the pit and 90% with DAS on haul roads.
Windblown Dust	Airshed addas program	**Hours of operation:** Continuous

Table 4-2: Estimated annual average emission rates per source group for Scenario 1 (2027)

Source Group	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Drilling and blasting	26	13	2
Vehicle Entrained Dust	10 149	3 520	352
Windblown Dust	2 610	2 503	2 312
Materials Handling	428	202	31
Crushing	1 987	187	94
Total Emissions Scenario 1 (2027)	**15 200**	**6 426**	**2 610**

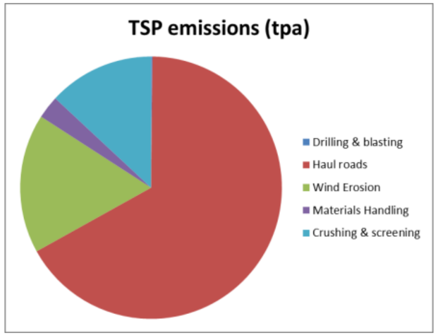
Table 4-3: Estimated annual average emission rates per source group for Scenario 2 (2030)

Source Group	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Drilling and blasting	26	13	2
Vehicle Entrained Dust	9 175	3 182	318
Windblown Dust	2 610	2 503	2 312
Materials Handling	318	150	23
Crushing	1 987	187	94
Total Emissions Scenario 2 (2029)	**14 115**	**6 036**	**2 568**

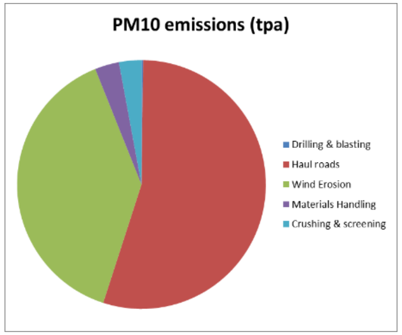
Table 4-4: Estimated annual average emission rates per source group for Scenario 2A (2030)

Source Group	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Drilling and blasting	26	13	2
Vehicle Entrained Dust	7 980	2 768	297
Windblown Dust	2 610	2 503	2 312
Materials Handling	366	173	267
Crushing	1 987	187	94
Total Emissions Scenario 2 (2029)	**12 969**	**5 645**	**2 530**

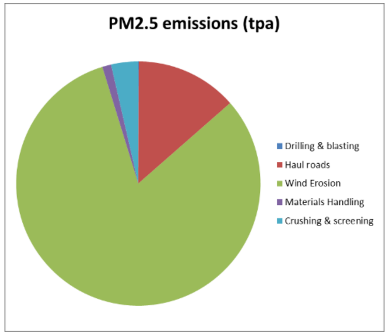
As can be seen in Table 4-4 for the automated truck scenario, although the material handling is slightly higher (due to double handling of ore) the emissions due to vehicle entrained dust are lower (due to less trips required) and overall emissions are lower.



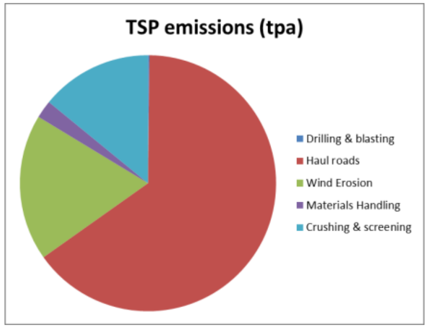
(a) TSP emissions (Scenario 1 – 2027)



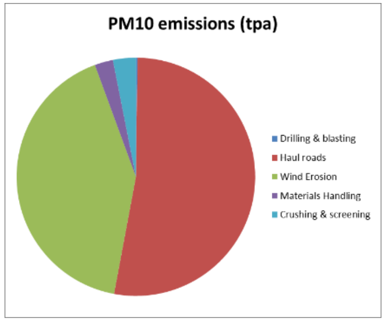
(b) PM_{10} emissions (Scenario 1 – 2027)



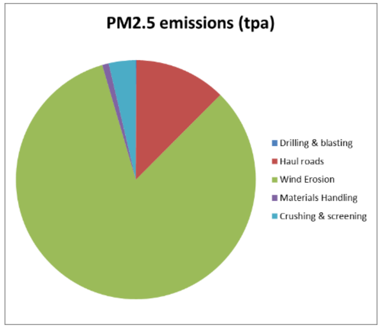
(c) $PM_{2.5}$ emissions (Scenario 1 – 2027)



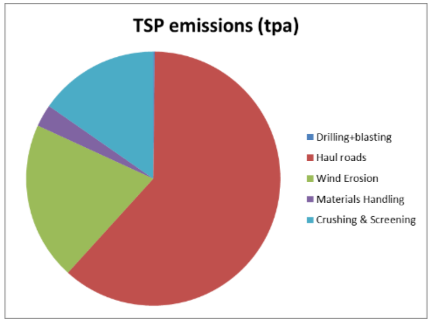
(d) TSP emissions (Scenario 2 – 2030)



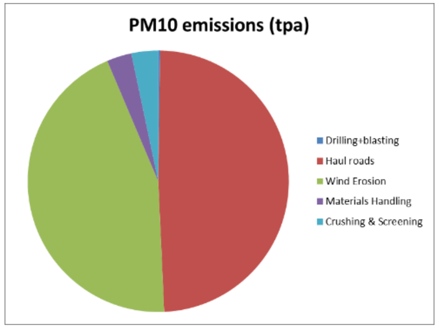
(e) PM_{10} emissions (Scenario 2 – 2030)



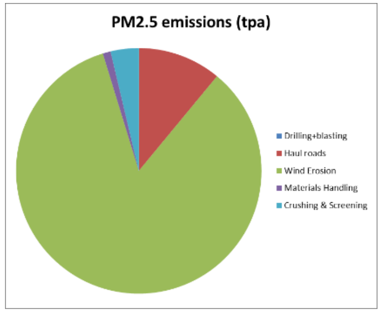
(f) $PM_{2.5}$ emissions (Scenario 2 – 2030)



(g) TSP emissions (Scenario 2A – 2030)



(h) TSP emissions (Scenario 2A – 2030)



(i) TSP emissions (Scenario 2A – 2030)

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

4.2 Atmospheric Dispersion Modelling

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

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

The potential impact on human health as a result of $PM_{2.5}$ and PM_{10} emissions from current and proposed operations are discussed in Section 4.3. The impact of dustfall on the environment, as a result of TSP emissions, is discussed in Section 4.4.

The impact of operations on the atmospheric environment was determined through the simulation of dustfall rates and ambient pollutant concentrations. Simulated air quality impacts represent those associated with the mine's operations only.

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

4.2.1 Dispersion Model Selection

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

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

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

Version 8.1 of AERMOD and its pre-processors were used in the study.

4.2.2 Meteorological Requirements

For the purpose of the study use was made of hourly on-site data from Kapstevel for the period January 2019 to December 2020 (Section 3.2).

4.2.3 Source Data Requirements

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

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

4.2.4 Modelling Domain

The dispersion of pollutants expected to arise from proposed activities was modelled for an area covering 20 km (east-west) by 16 km (north-south). The area was divided into a grid matrix with a resolution of 250 m, with the Kolomela Mine located centrally. The residences were included as AQSR (Figure 3-1). AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor point.

4.2.5 Presentation of Results

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

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

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

4.3 Screening of Simulated Human Health Impacts

4.3.1 Simulated Ambient PM_{10} Concentrations

Simulated ambient PM_{10} concentrations as a result of the operational phase of Kolomela Mine are within annual and daily NAAQS at all AQSRs during all scenarios (Table 4-5). Exceedances of criteria are expected in close proximity to areas of operation (Figure 4-3 to Figure 4-8). For Scenario 2, with movement of waste primarily at the Kapstevel South pit, higher impacts occur at AQSR number 18 (~1 km from the southern boundary). For Scenario 2A, with larger haul truck capacity and lower emissions, the impacts are slightly lower than Scenario 2.

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

Table 4-5: Simulated PM_{10} concentrations

Receptor	Scenario 1		Scenario 2		Scenario 2A	
	Annual Average Conc. (µg/m³)	99th Percentile Daily Conc (µg/m³)	Annual Average Conc. (µg/m³)	99th Percentile Daily Conc (µg/m³)	Annual Average Conc. (µg/m³)	99th Percentile Daily Conc (µg/m³)
1	0.21	1.4	0.10	0.7	0.09	0.6
2	0.26	1.8	0.11	0.8	0.10	0.7
3	0.28	1.9	0.11	0.9	0.10	0.7
4	0.44	2.5	0.16	1.1	0.14	1.0
5	0.45	2.5	0.16	1.1	0.15	1.0
6	0.11	0.7	0.06	0.5	0.06	0.5
7	0.15	0.9	0.08	0.6	0.07	0.6
8	0.12	0.8	0.06	0.5	0.06	0.5
9	0.39	2.4	0.14	0.9	0.13	0.9
10	0.95	3.8	0.91	4.0	0.84	4.0
11	1.39	5.7	0.91	5.0	0.80	5.0
12	2.16	10.2	0.89	9.6	0.82	9.6
13	4.03	11.4	0.71	8.0	0.69	8.0
14	1.63	5.7	0.33	2.4	0.30	2.5
15	0.98	5.0	1.32	6.9	1.26	6.7
16	0.24	1.5	0.30	2.0	0.28	2.0
17	0.39	2.3	0.49	3.2	0.48	3.1
18	7.79	28.8	10.37	37.0	10.22	37.2
19	0.25	1.8	0.32	2.3	0.30	2.2
20	0.10	0.9	0.12	1.1	0.11	1.1
21	0.12	1.2	0.15	1.6	0.15	1.6
22	0.12	1.1	0.15	1.5	0.14	1.5
23	0.35	2.8	0.46	3.9	0.44	3.8
24	0.30	2.3	0.39	3.2	0.37	3.0
25	0.18	1.1	0.18	1.3	0.16	1.2
NAAQS	**40**	**75**	**40**	**75**	**40**	**75**

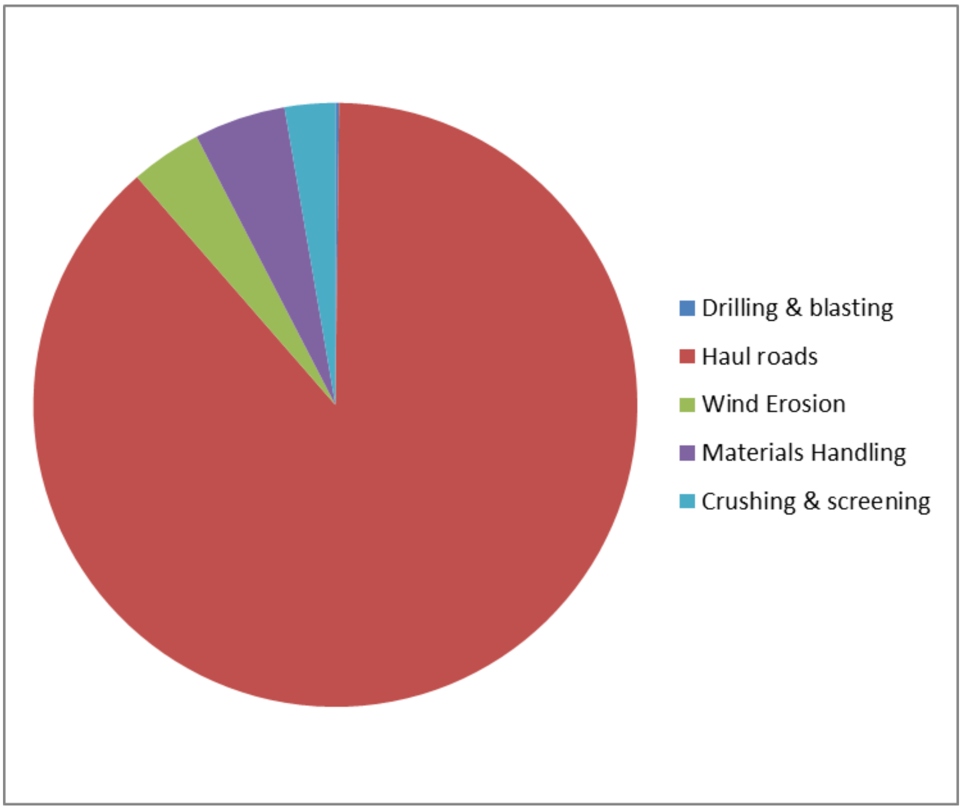


Figure 4-2: Source group contribution to simulated annual average PM_{10} concentrations over all scenarios

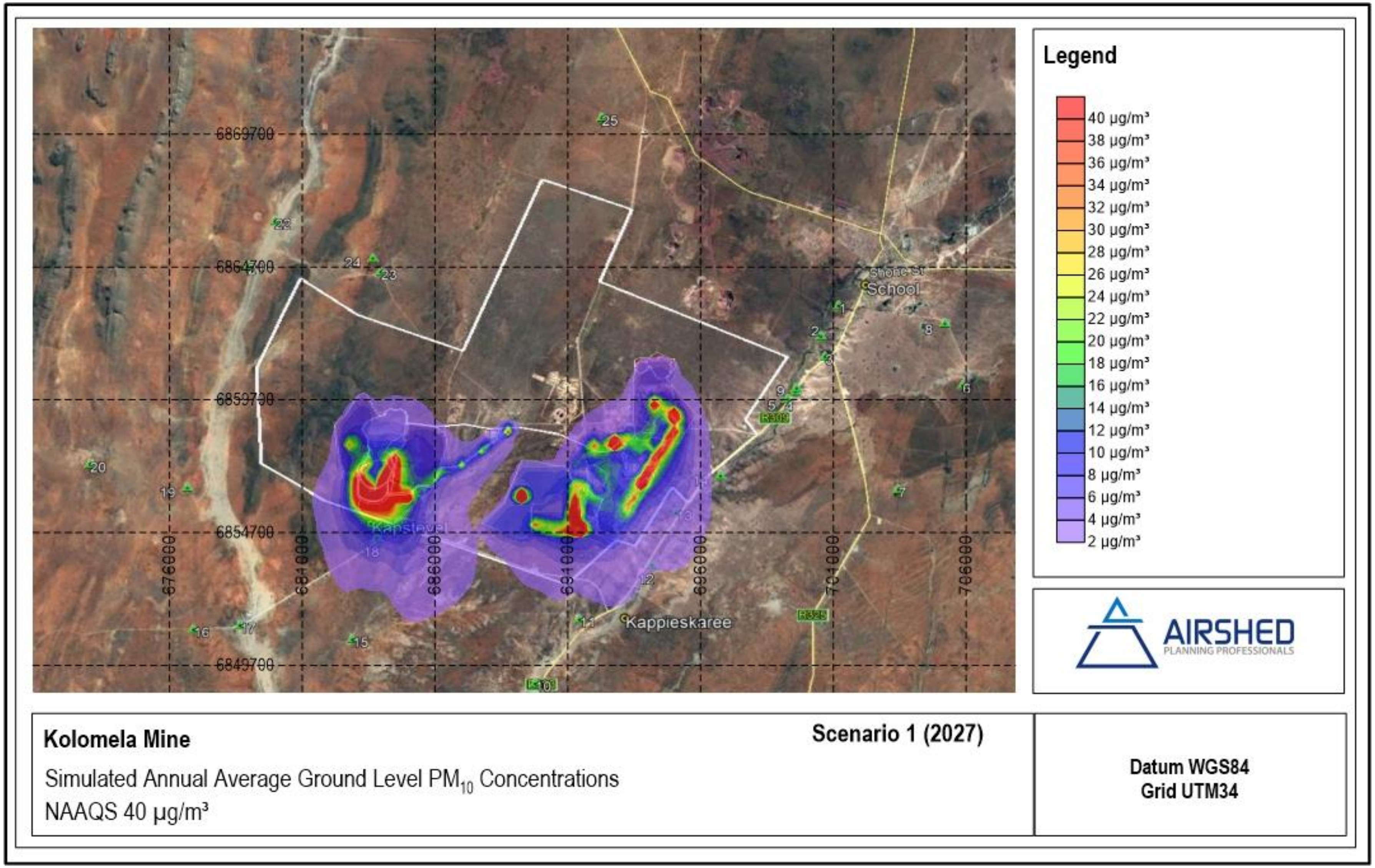


Figure 4-3: Simulated annual average PM_{10} concentrations as a result of Scenario 1 (2027)

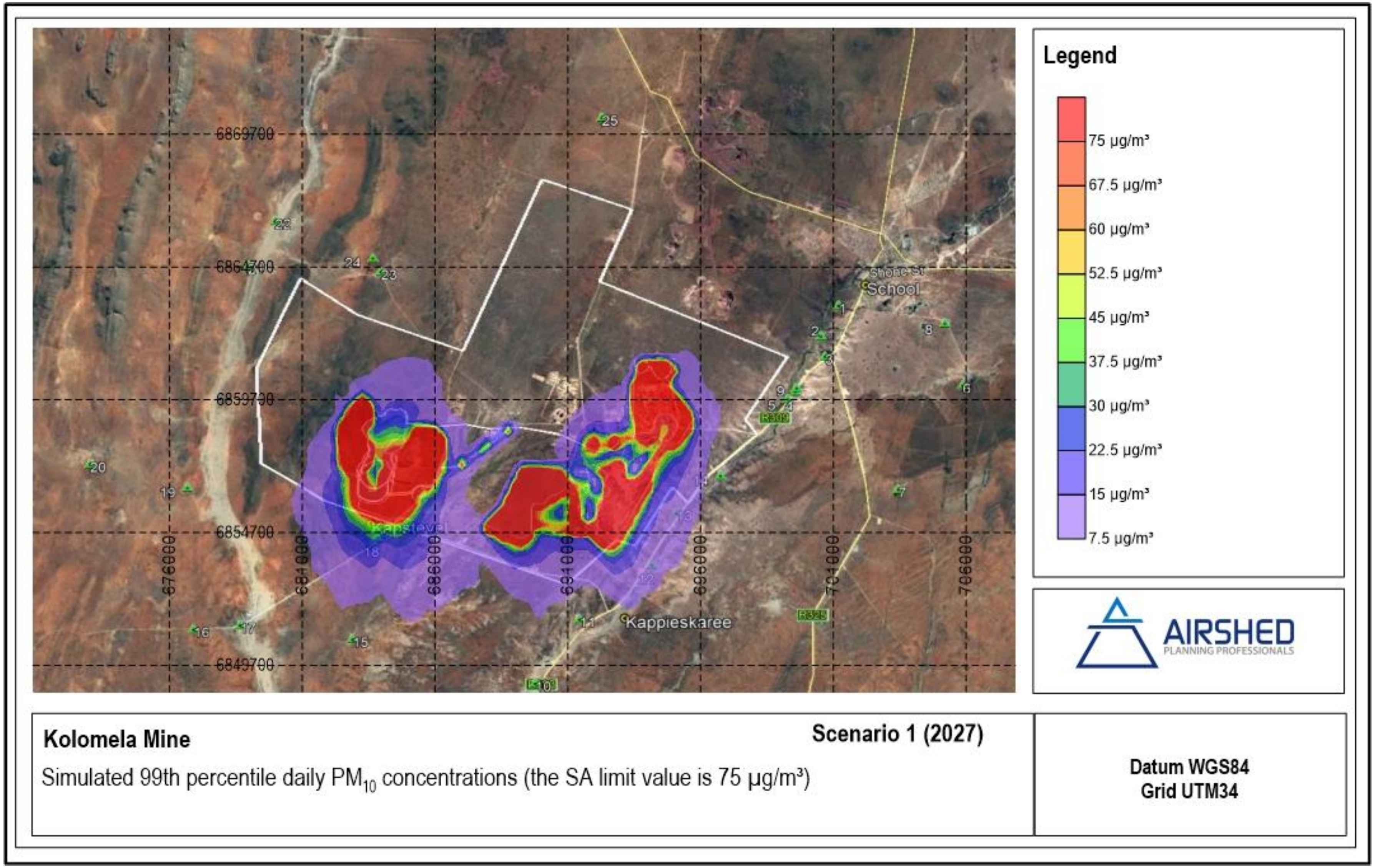


Figure 4-4: Simulated 99th percentile daily PM_{10} concentrations as a result of Scenario 1 (2027)

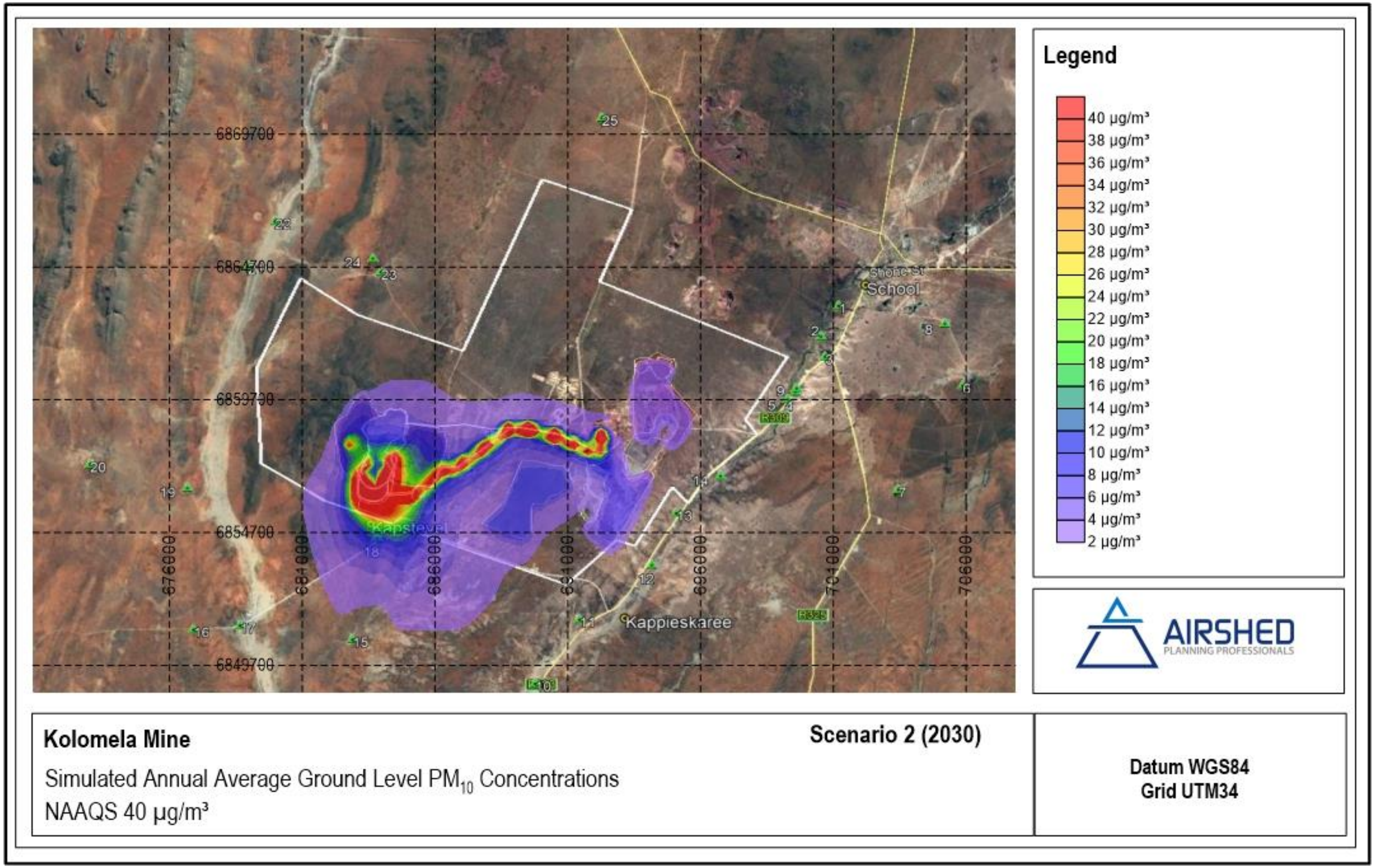


Figure 4-5: Simulated annual average PM_{10} concentrations as a result of Scenario 2 (2030)

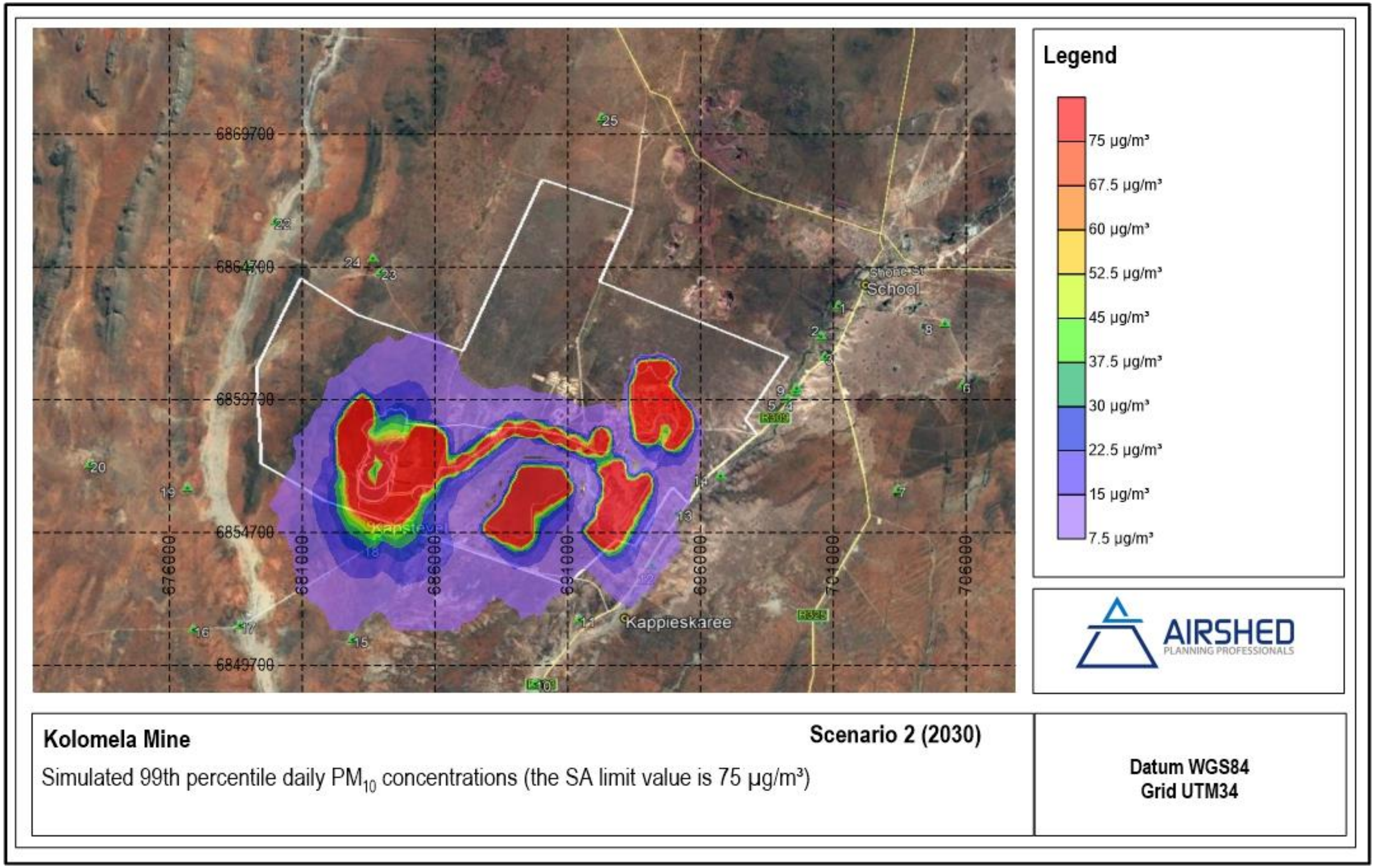


Figure 4-6: Simulated 99th percentile daily PM_{10} concentrations as a result of Scenario 2 (2030)

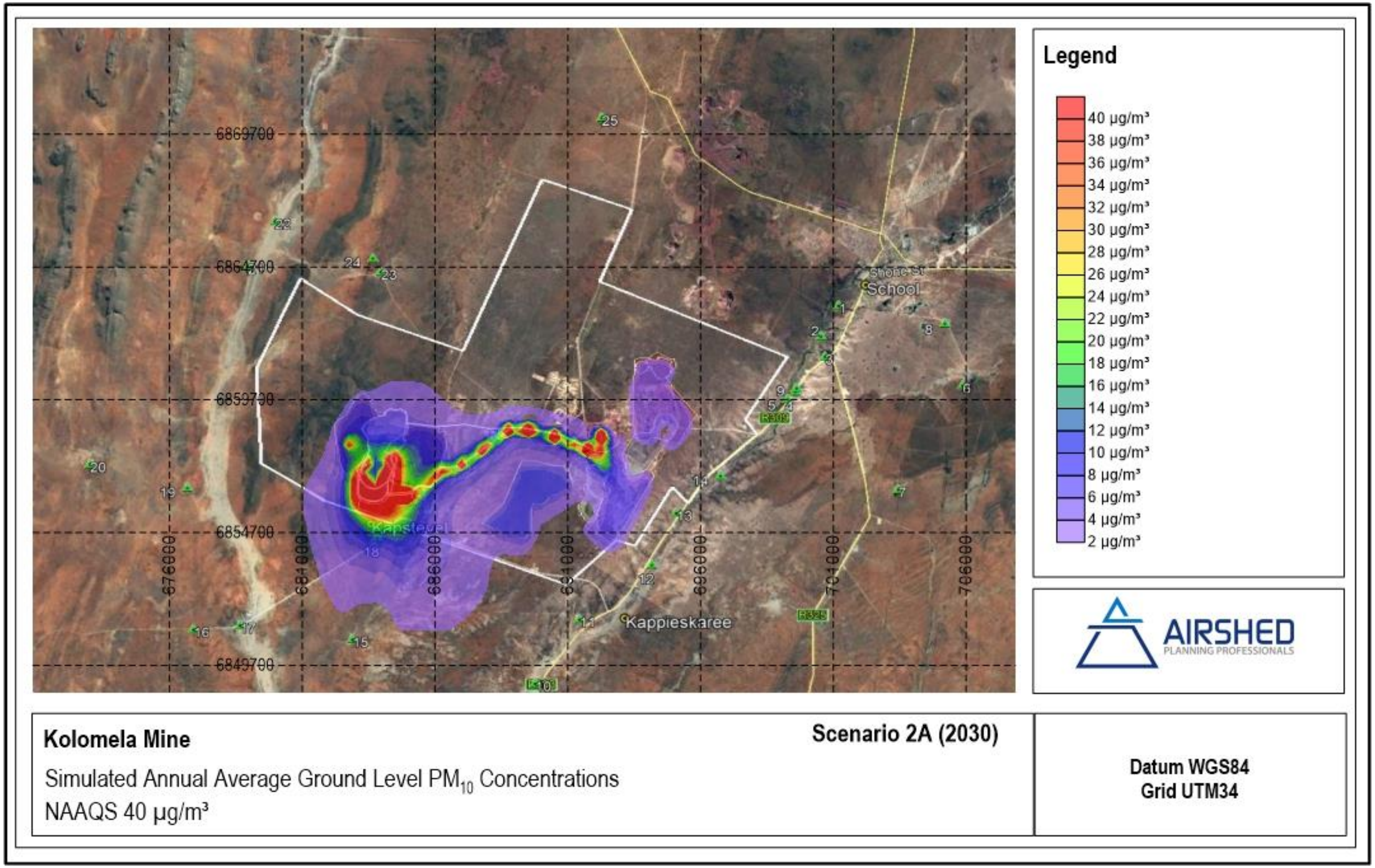


Figure 4-7: Simulated annual average PM_{10} concentrations as a result of Scenario 2A (2030)

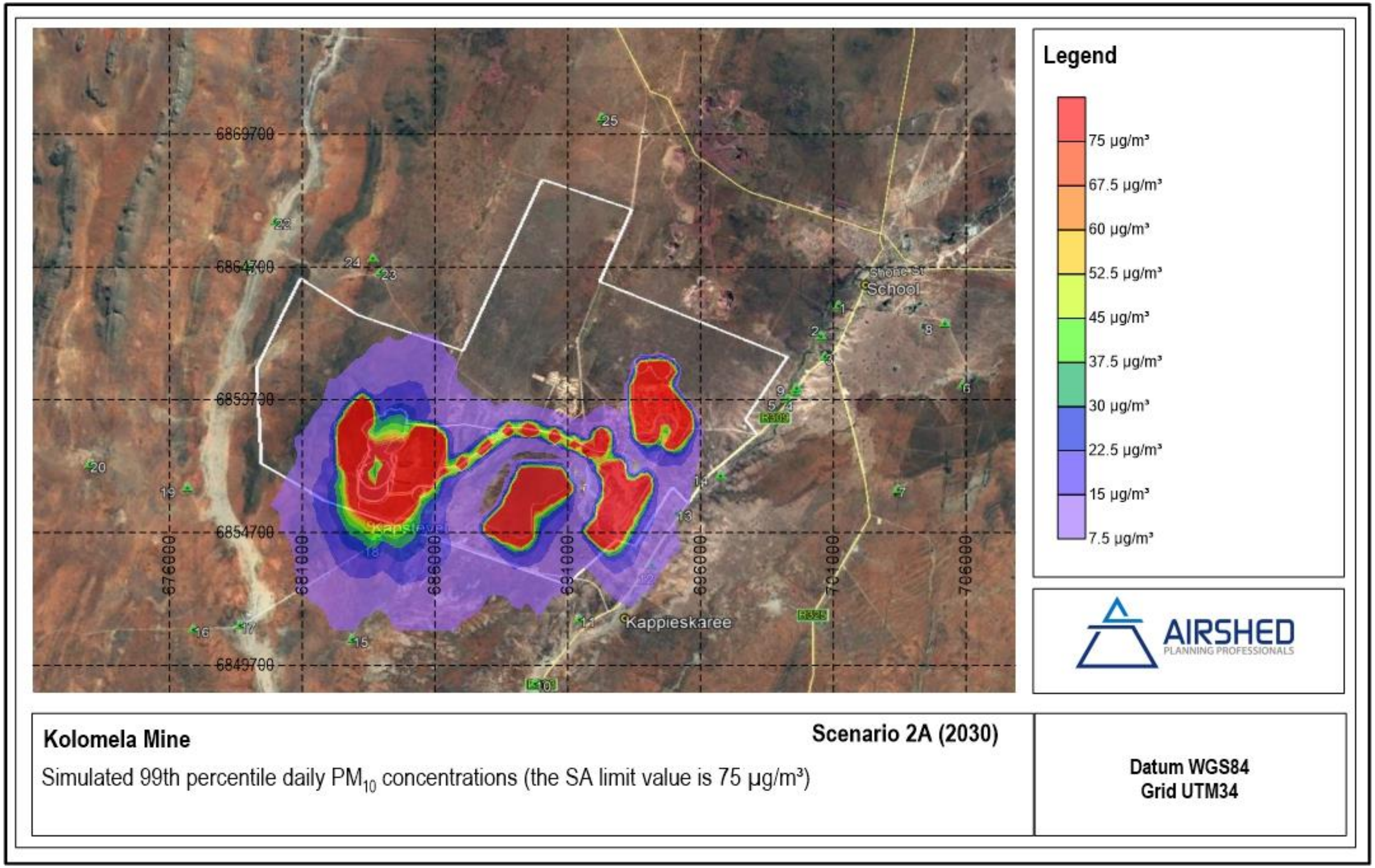


Figure 4-8: Simulated 99th percentile daily PM_{10} concentrations as a result of Scenario 2A (2030)

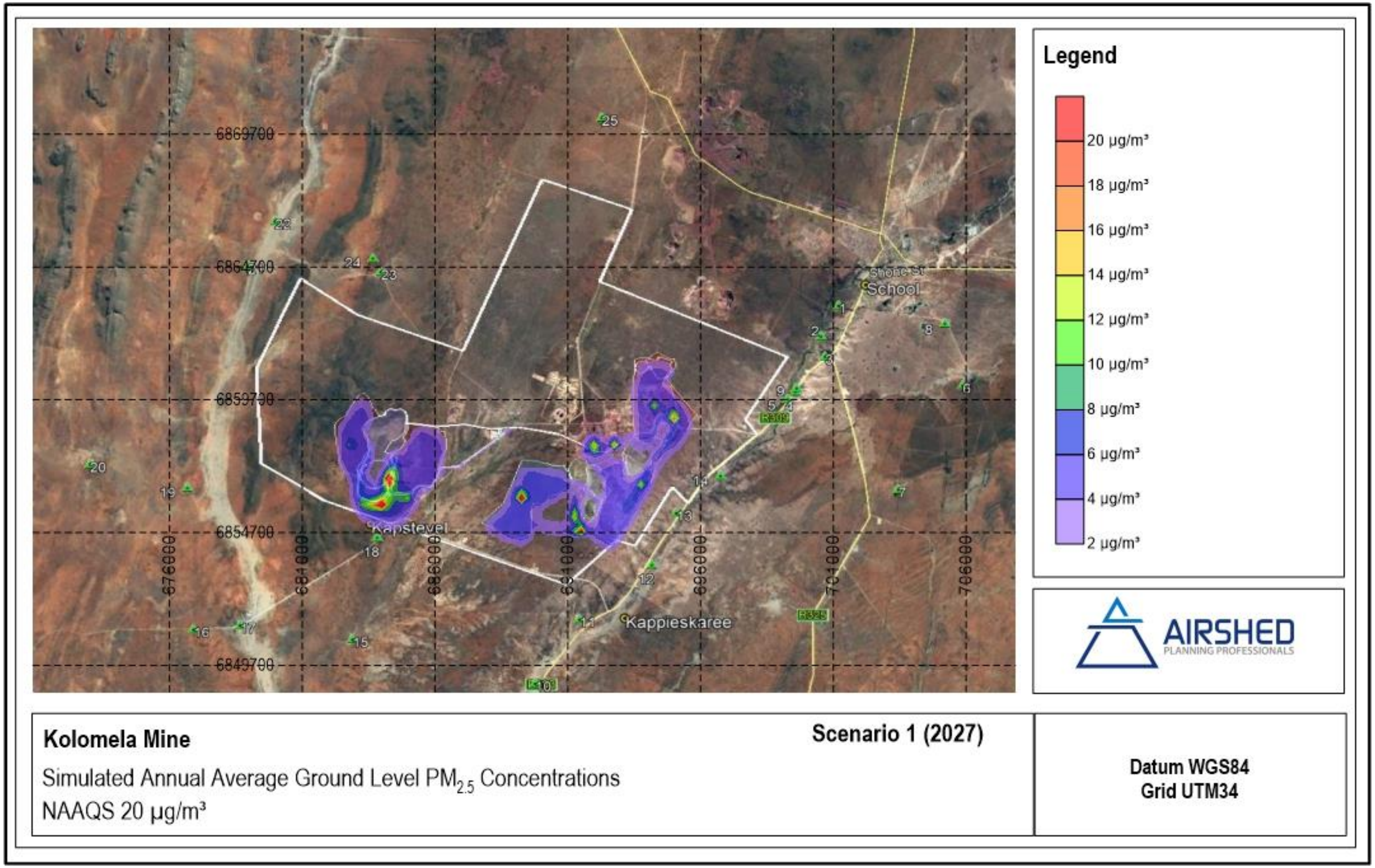


Figure 4-9: Simulated annual average $PM_{2.5}$ concentrations as a result of Scenario 1 (2027)

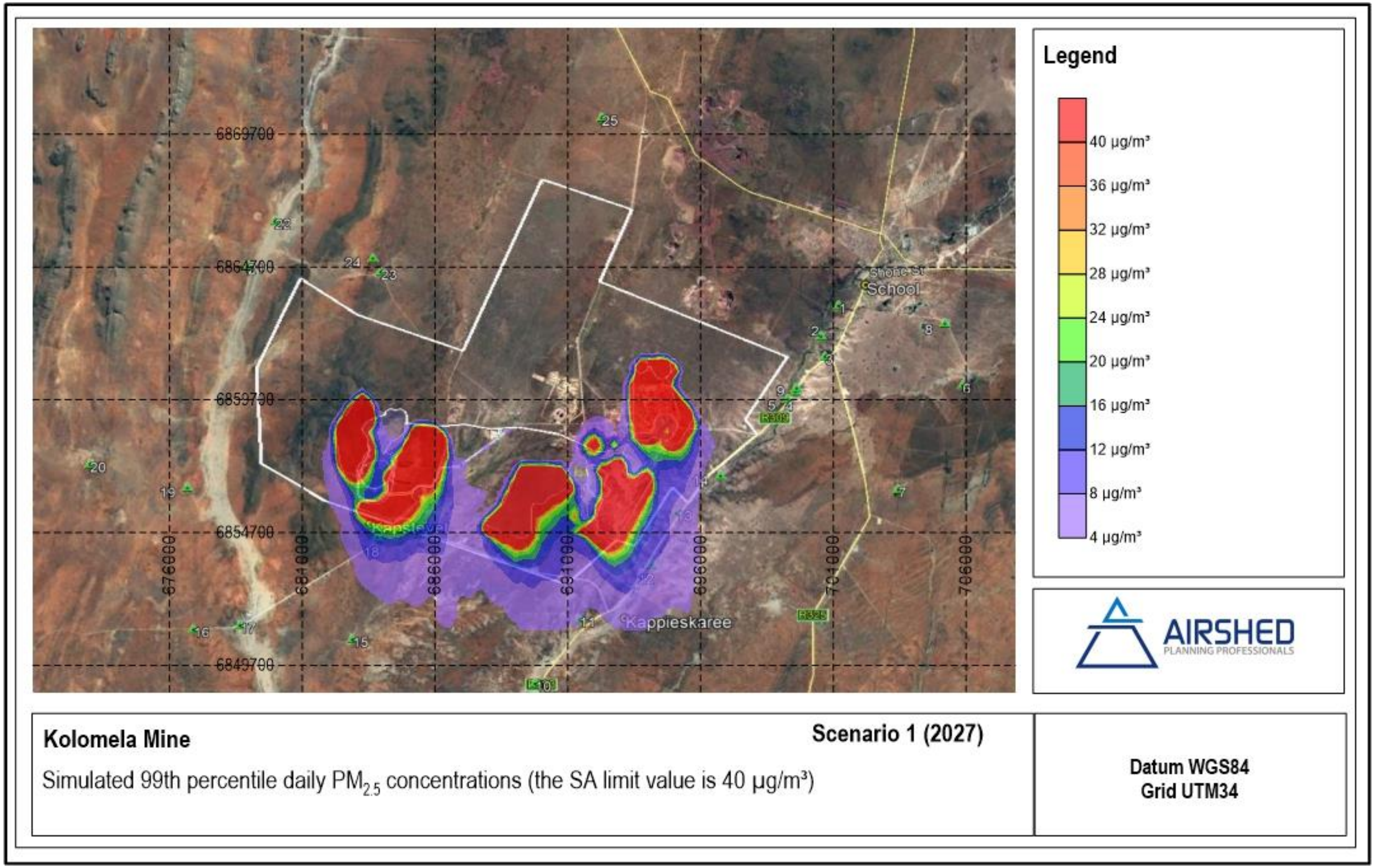


Figure 4-10: Simulated 99th percentile daily $PM_{2.5}$ concentrations as a result of Scenario 1 (2027)

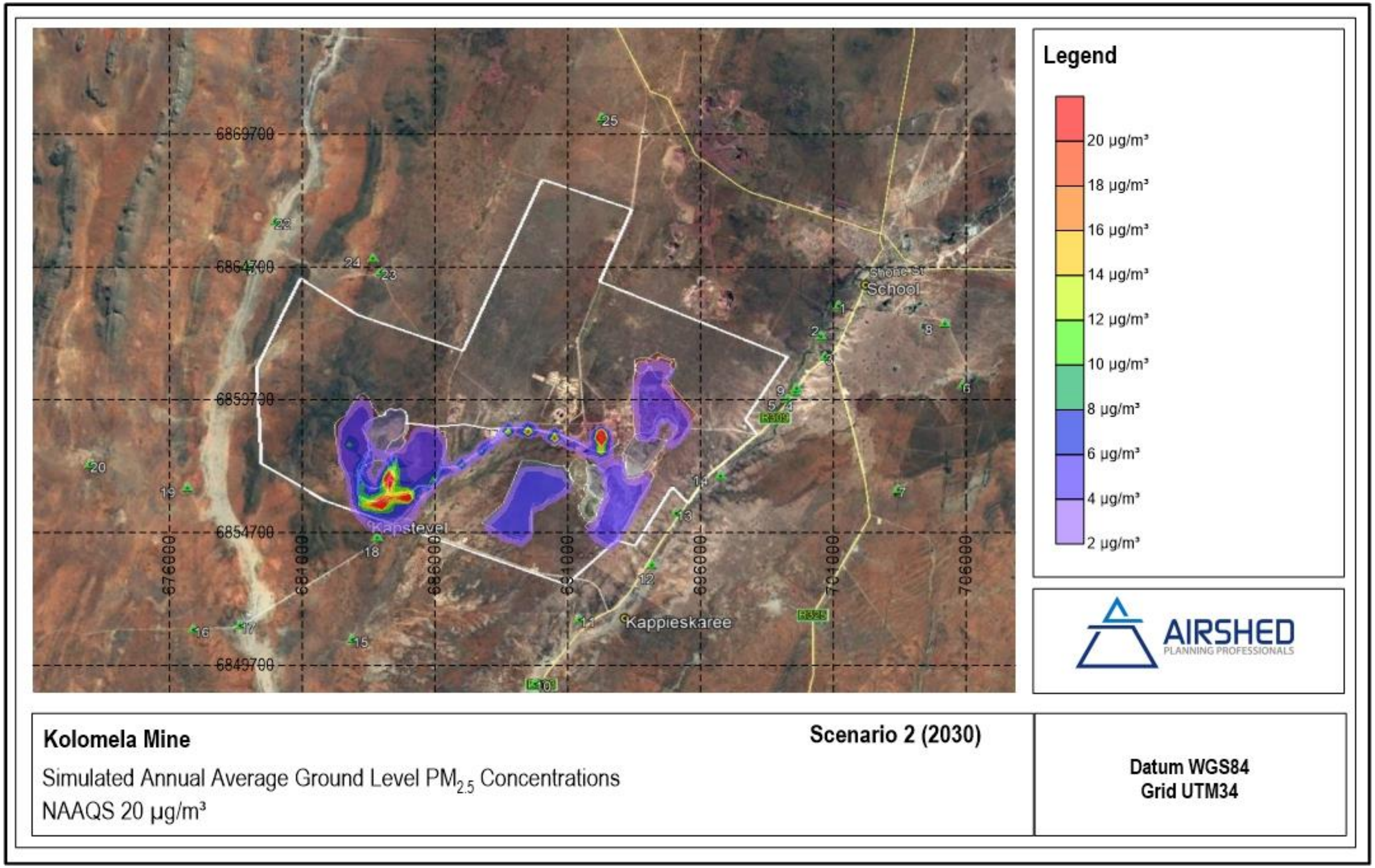


Figure 4-11: Simulated annual average $PM_{2.5}$ concentrations as a result of Scenario 2 (2030)

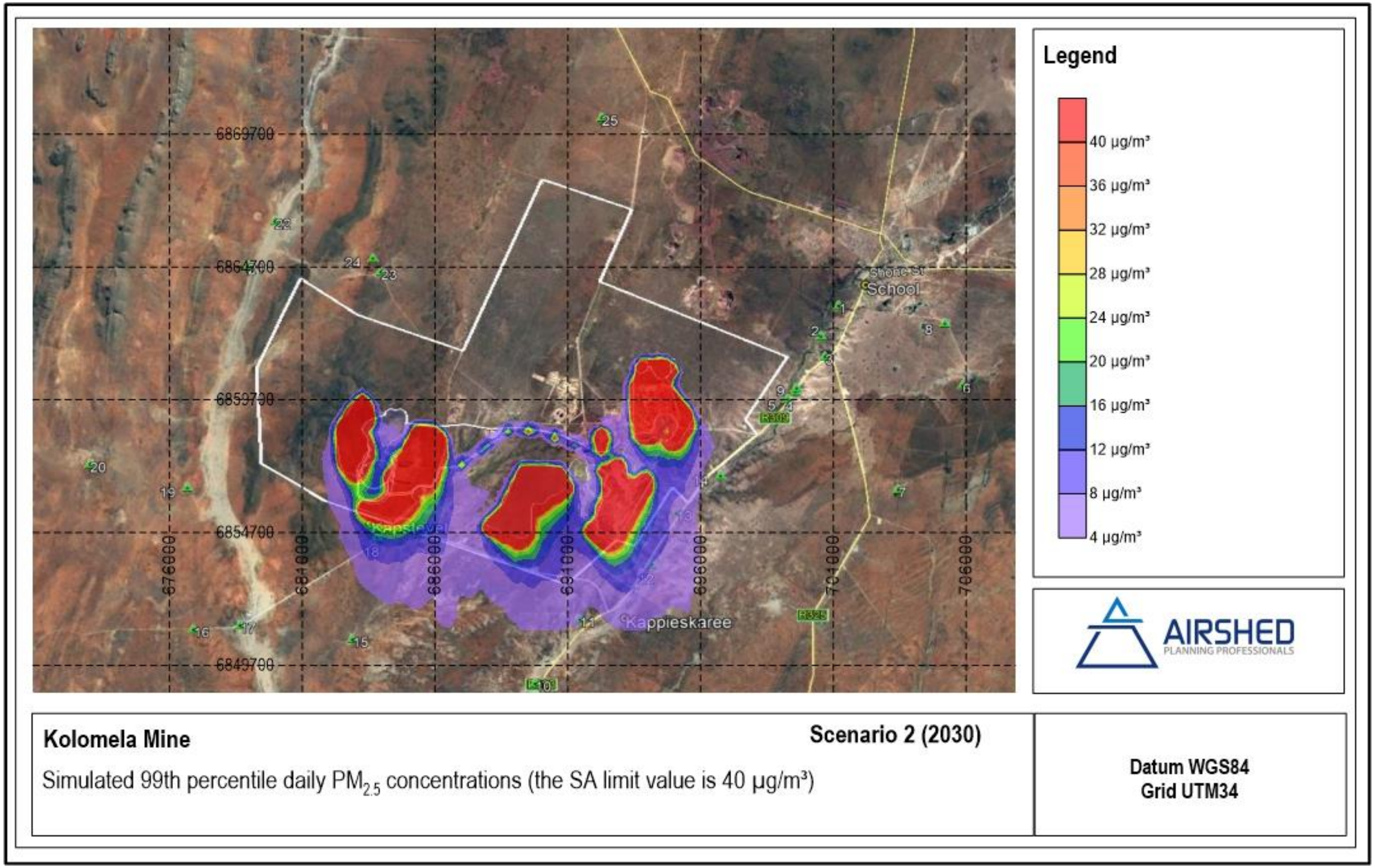


Figure 4-12: Simulated 99th percentile daily $PM_{2.5}$ concentrations as a result of Scenario 2 (2030)

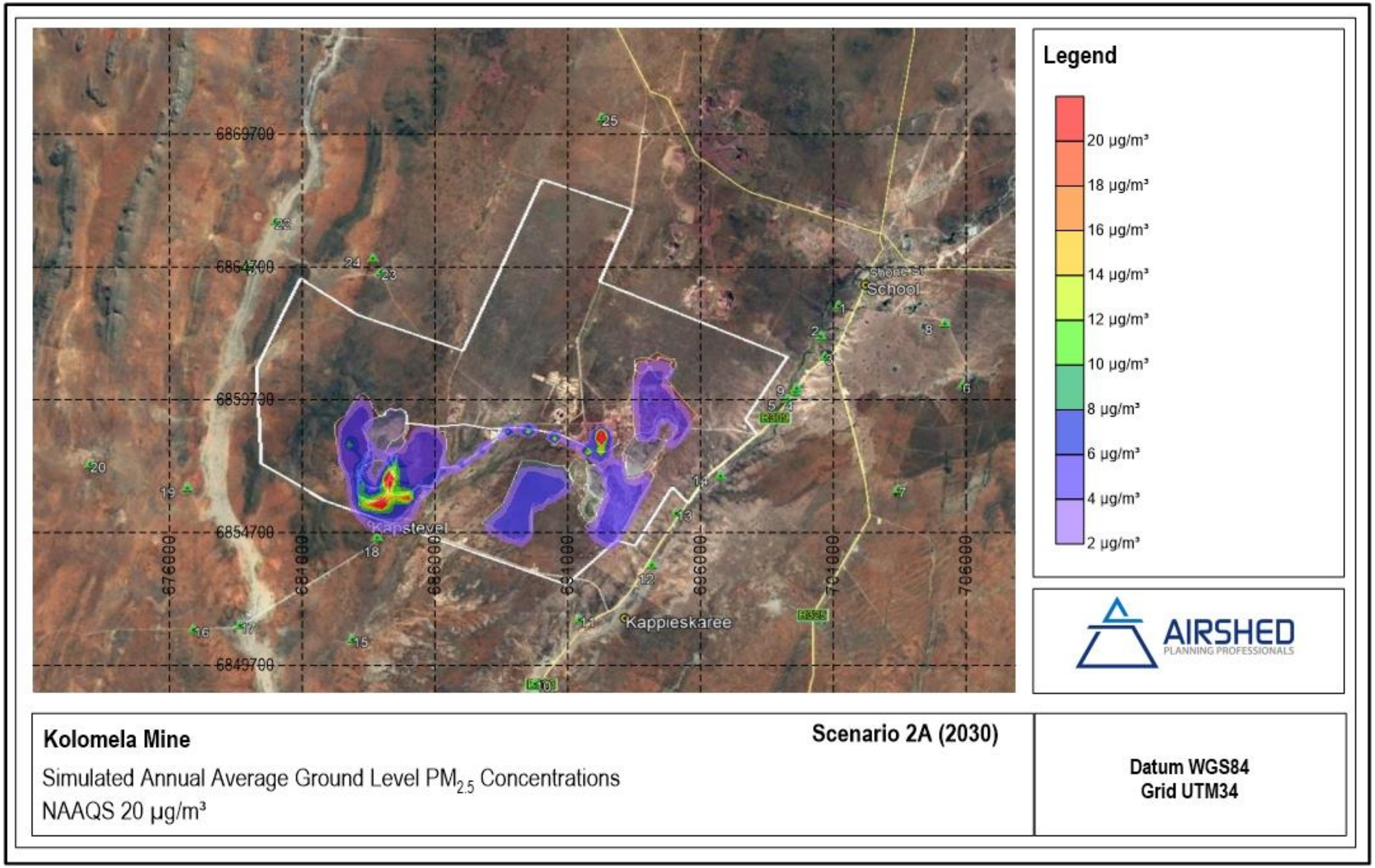


Figure 4-13: Simulated annual average $PM_{2.5}$ concentrations as a result of Scenario 2A (2030)

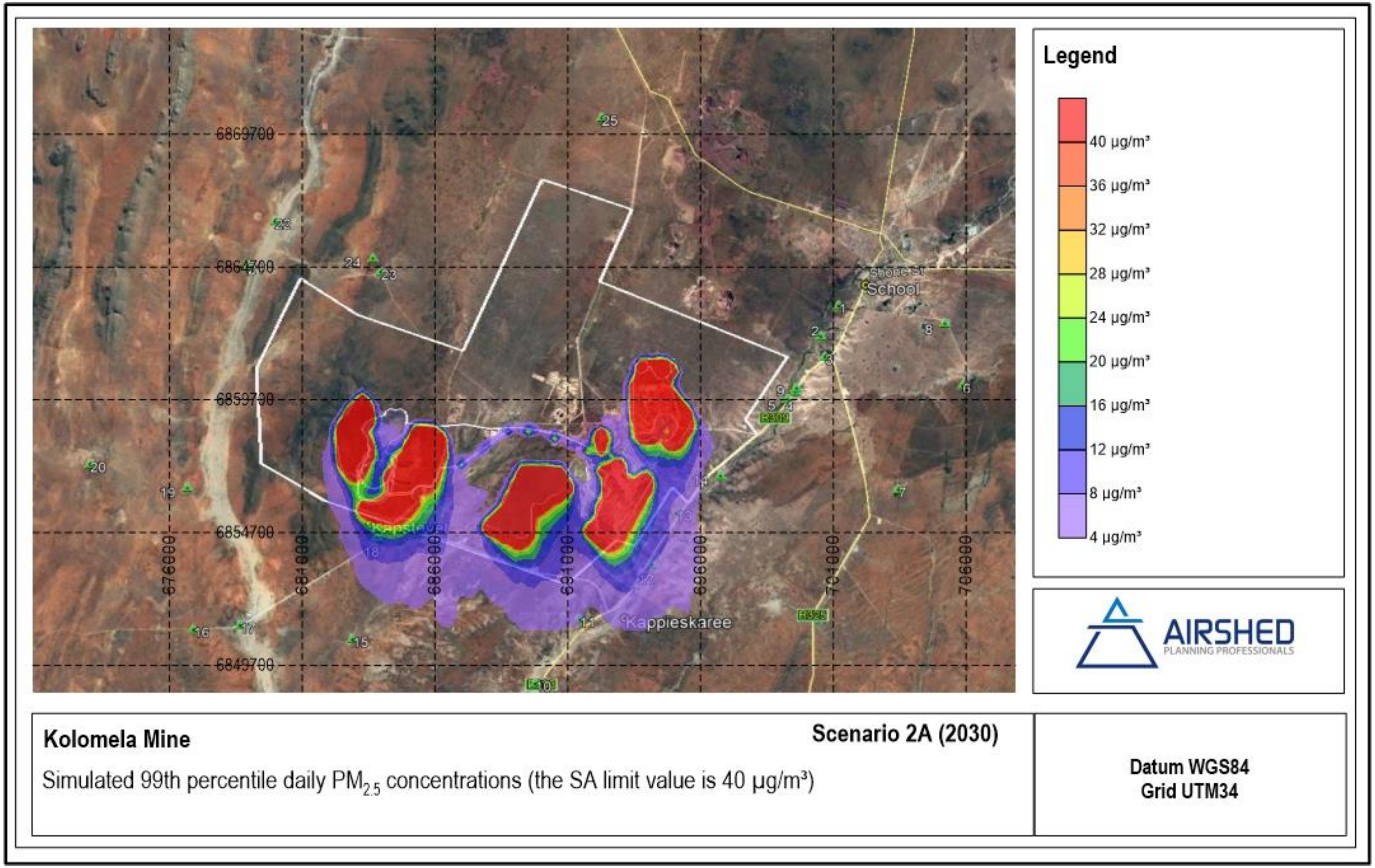


Figure 4-14: Simulated 99th percentile daily $PM_{2.5}$ concentrations as a result of Scenario 2A (2030)

4.3.2 Simulated Ambient $PM_{2.5}$ Concentrations

Simulated ambient $PM_{2.5}$ concentrations as a result of the operational phase of Kolomela Mine are within annual NAAQS at all AQSRs during all scenarios (Table 4-6). Exceedances of criteria are expected in close proximity to areas of operation (Figure 4-9 to Figure 4-14). For Scenario 2, with movement of waste primarily at the Kapstevel South pit, higher impacts occur at AQSR number 18 (~1 km from the southern boundary).

Overall source group contributions to simulated ground level $PM_{2.5}$ concentrations are shown in Figure 4-15. Dust generated by vehicles travelling on unpaved haul roads, wind erosion, and crushing are the most notable contributors to ground level $PM_{2.5}$ concentrations.

Table 4-6: Simulated $PM_{2.5}$ concentrations

Receptor	Scenario 1		Scenario 2		Scenario 2A	
	Annual Average Conc. (µg/m³)	99th Percentile Daily Conc (µg/m³)	Annual Average Conc. (µg/m³)	99th Percentile Daily Conc (µg/m³)	Annual Average Conc. (µg/m³)	99th Percentile Daily Conc (µg/m³)
1	0.02	0.2	0.01	0.1	0.01	0.1
2	0.03	0.2	0.02	0.1	0.01	0.1
3	0.03	0.2	0.02	0.1	0.02	0.1
4	0.06	0.4	0.03	0.3	0.03	0.3
5	0.06	0.4	0.03	0.3	0.03	0.3
6	0.01	0.1	0.01	0.1	0.01	0.1
7	0.03	0.2	0.02	0.2	0.02	0.2
8	0.01	0.1	0.01	0.1	0.01	0.1
9	0.05	0.3	0.03	0.2	0.02	0.2
10	0.17	2.6	0.17	2.6	0.16	2.6
11	0.27	4.3	0.22	4.2	0.21	4.2
12	0.45	8.1	0.33	8.0	0.32	8.0
13	0.63	7.0	0.30	6.8	0.30	6.8
14	0.25	2.1	0.12	1.9	0.12	1.9
15	0.14	1.3	0.18	1.3	0.17	1.3
16	0.04	0.5	0.04	0.5	0.04	0.5
17	0.06	0.5	0.07	0.5	0.07	0.5
18	1.12	12.4	1.38	12.4	1.36	12.4
19	0.03	0.3	0.04	0.4	0.04	0.4
20	0.01	0.1	0.02	0.1	0.01	0.1
21	0.01	0.1	0.02	0.2	0.02	0.2
22	0.02	0.1	0.02	0.2	0.02	0.2
23	0.04	0.3	0.05	0.4	0.05	0.4
24	0.03	0.3	0.04	0.3	0.04	0.3
25	0.02	0.1	0.02	0.1	0.02	0.1
NAAQS	**20**	**40**	**20**	**40**	**20**	**40**

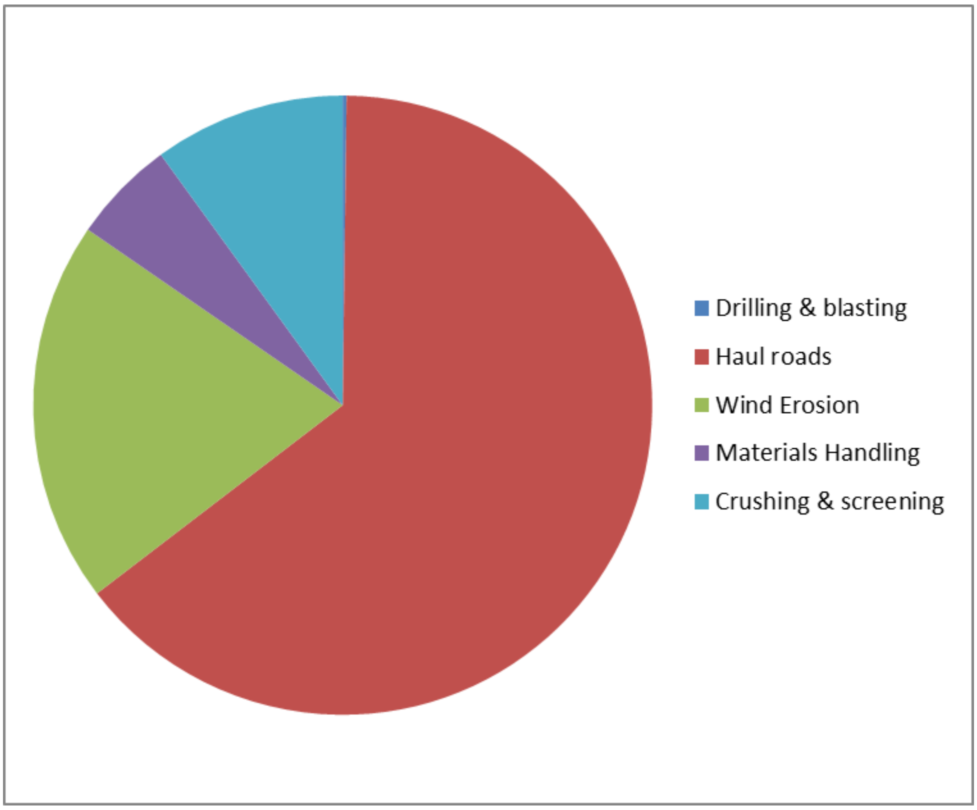


Figure 4-15: Source group contribution to simulated annual average $PM_{2.5}$ concentrations over all scenarios

4.4 Analysis of Emissions' Impact on the Environment

4.4.1 Simulated Dustfall Rates

Simulated dustfall rates as a result of the operational phases at Kolomela Mine are low and within the NDCR for residential areas at all AQSRs during all scenarios. Although incremental dustfall rates are below NDCRs at AQSRs, exceedances of criteria are expected in close proximity to areas of operation (Figure 4-16 to Figure 4-18). The NDCR is exceeded at the southern boundary.

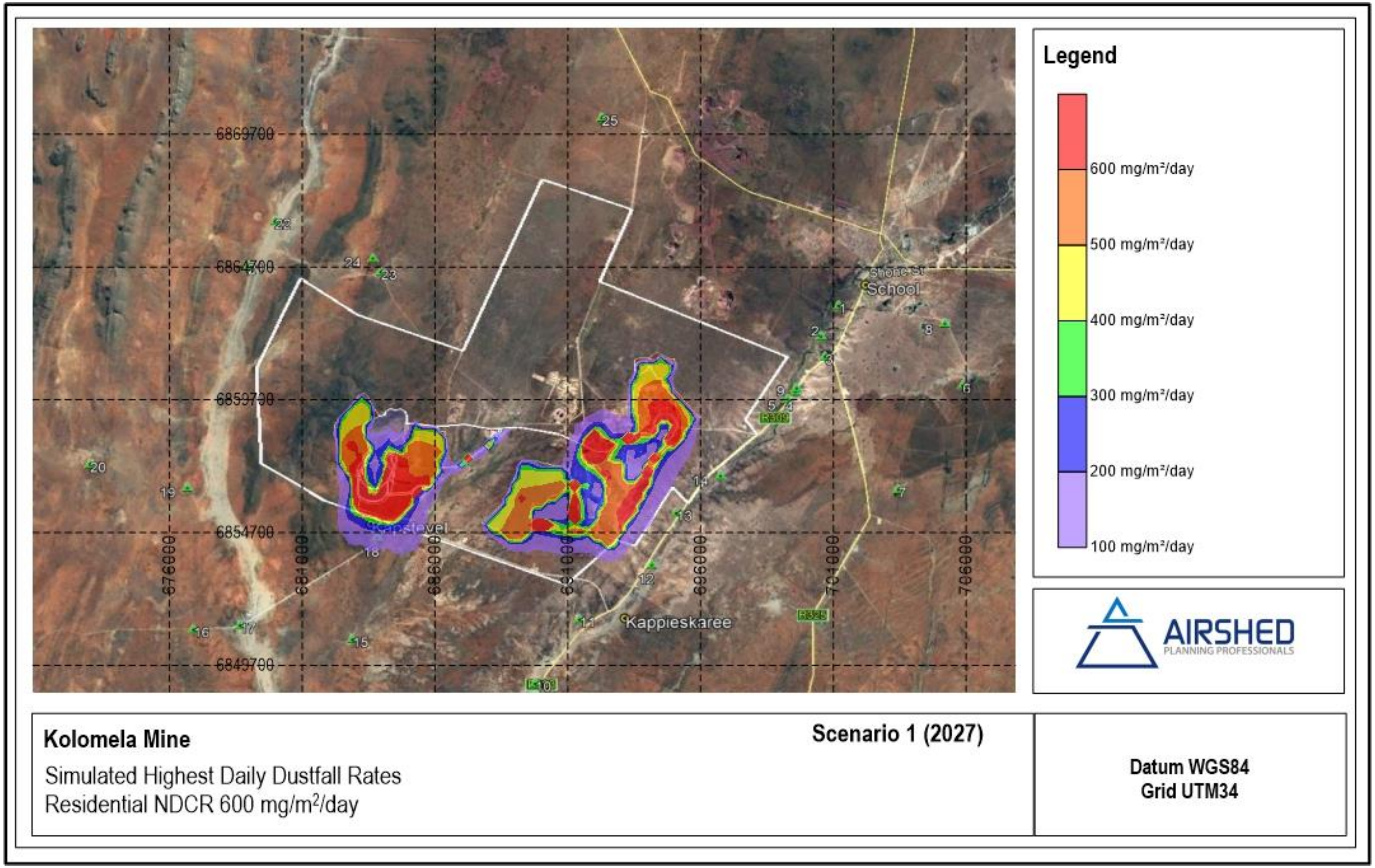


Figure 4-16: Simulated highest daily dustfall rates as a result of Scenario 1 (2027)

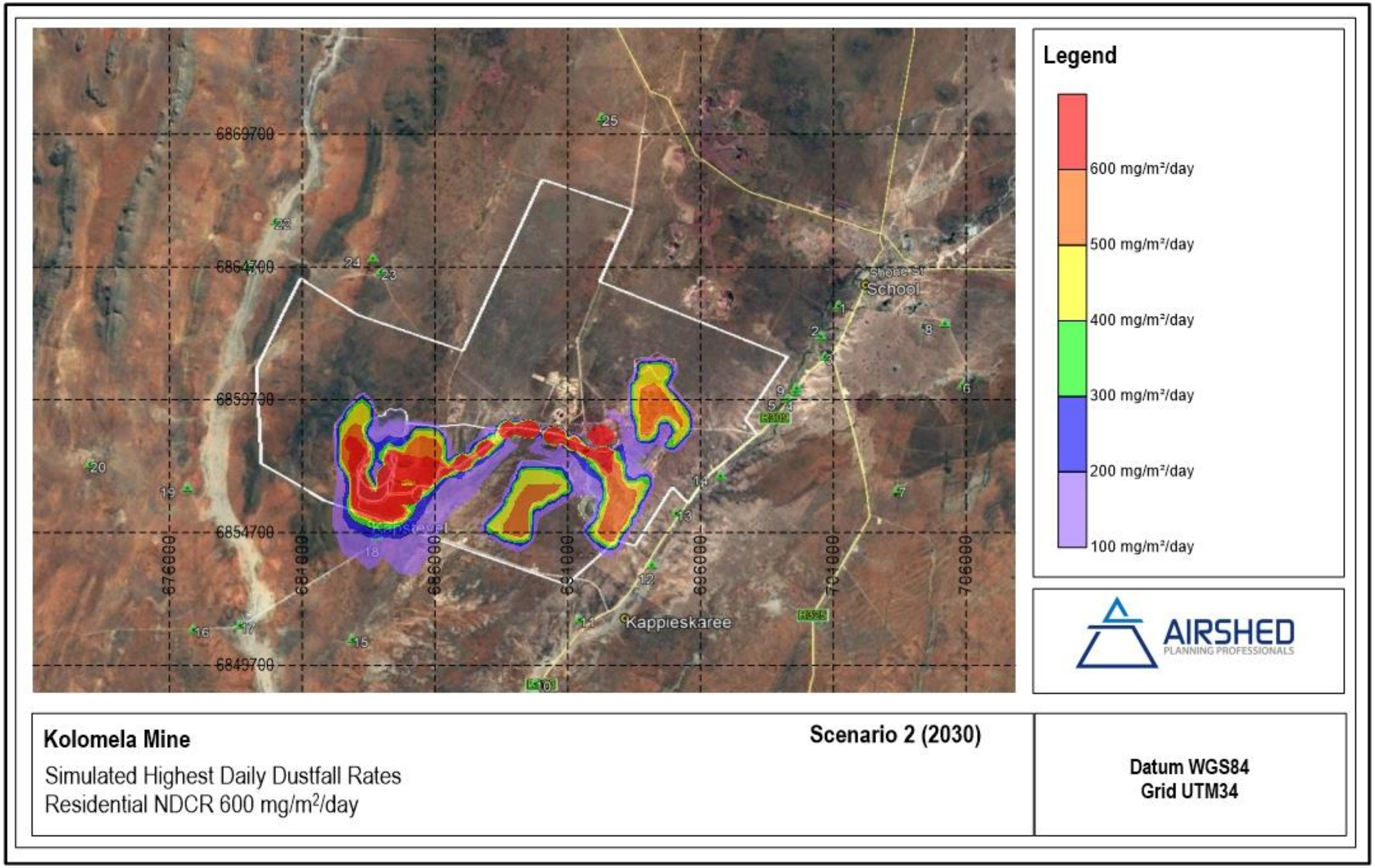


Figure 4-17: Simulated highest daily dustfall rates as a result of Scenario 2 (2030)

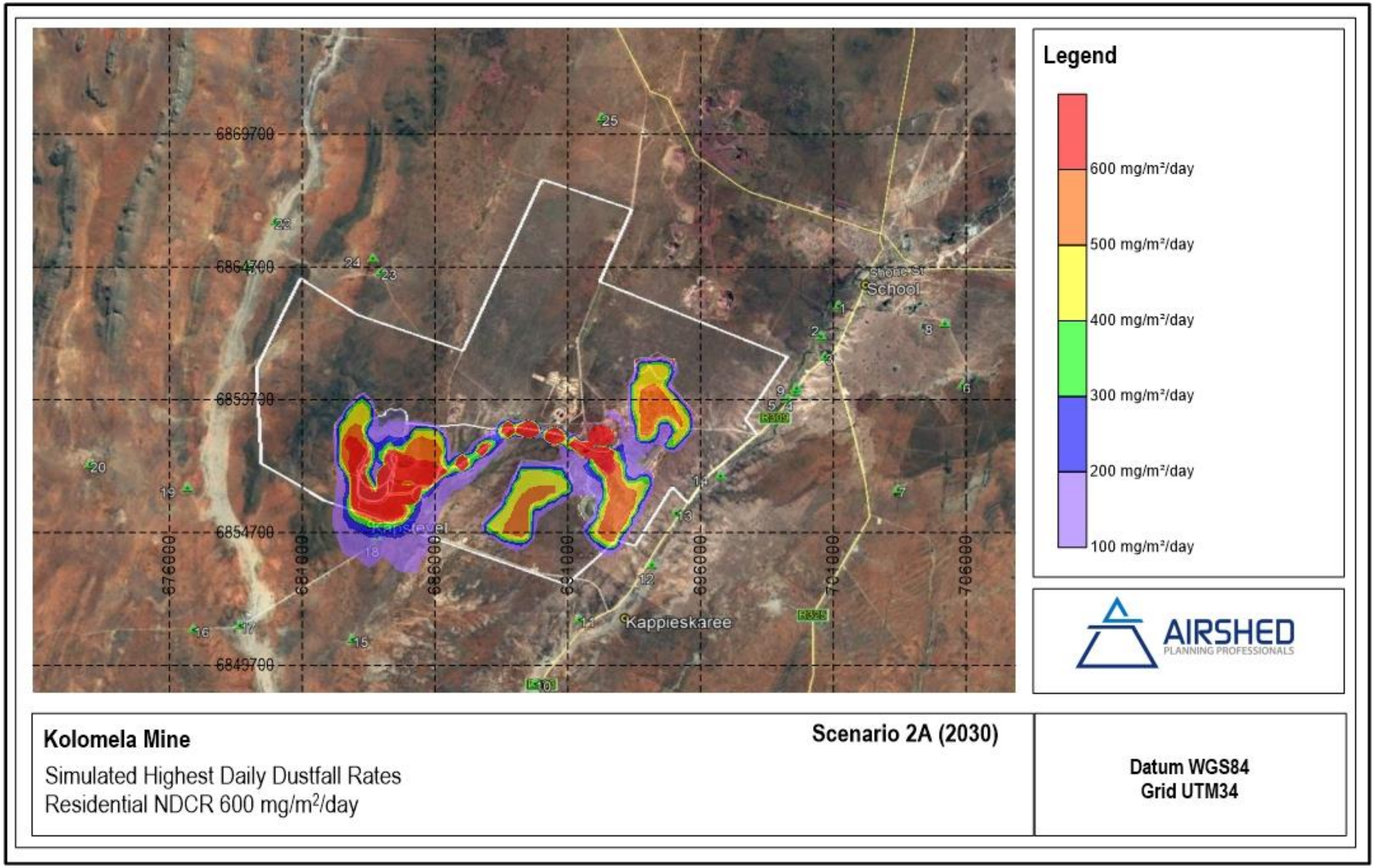


Figure 4-18: Simulated highest daily dustfall rates as a result of Scenario 2A (2030)

4.5 Comparison between measured and simulated

Comparison between simulated and measured ground level concentrations (GLC) at selected AQSRs are shown in Table 4-7 and Table 4-8. Simulated concentrations are lower than measured concentrations. This is likely because of other sources of particulate matter contributing to the baseline ambient concentrations. A similar trend is seen for dustfall. Dustfall rates sampled both upwind and downwind of Kolomela activities show similar high levels. It is clear therefore that the area has high ambient levels.

Although cumulative dispersion modelling was not done, the area surrounding the mine is not heavily populated and no industries are operational in the area. There are however other mining activities in the area.

The measured results give an indication of the cumulative impact.

Table 4-7: Comparison between simulated and measured PM_{10} GLC

Receptor	Measured (2020)		Simulated (2027)	
	Annual Average Conc. ($\mu g/m^3$)	Days of Exceedance of 75 $\mu g/m^3$	Annual Average Conc. ($\mu g/m^3$)	Days of Exceedance of 75 $\mu g/m^3$
1 - Postmasburg school	29	1	0.2	0
11 - Kappieskaree	28	**12**	1.4	0
18 - Kapstevel	30	**16**	7.8	0
NAAQS	**40**	**4**	**40**	**4**

Table 4-8: Comparison between simulated and measured $PM_{2.5}$ GLC

Receptor	Measured (2020)		Simulated (2027)	
	Annual Average Conc. ($\mu g/m^3$)	Days of Exceedance of 75 $\mu g/m^3$	Annual Average Conc. ($\mu g/m^3$)	Days of Exceedance of 75 $\mu g/m^3$
1 - Postmasburg school	19	**10**	0.02	0
11 - Kappieskaree	6	0	0.27	0
18 - Kapstevel	6	0	1.12	0
NAAQS	**20**	**4**	**20**	**4**

5 IMPACT SIGNIFICANCE RATING

The significance of environmental noise impacts was assessed according to the methodology adopted by EXM Refer to Appendix B of this report for the methodology.

The significance of the operational phase of the proposed Kolomela Mine operations were found to be ***moderate*** for all the scenarios identified (Table 5-1). Assuming the adoption of good practice mitigation and management measures as recommended, the significance of impacts may be reduced to ***low*** (Table 5-2).

Table 5-1: Significance rating for operation phase without mitigation

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

Table 5-2: Significance rating for operation phase with mitigation

Significance	RATING
Intensity = Low: impact is of low magnitude	2
Duration = Long-term: impact occurs over the operational life of the proposed extension	4
Extent = Small: impact extends to the whole farm portion	2
Severity = (intensity + duration) / 2	3
Consequence = (severity + extent) / 2	2.5
Probability = Probable: the impact will probably occur	0.8
Impact significance = (consequence x probability) = Low	**2**

6 RECOMMENDED AIR QUALITY MANAGEMENT MEASURES

The management measures given below align with the IFS performance standards (see section 2.5.1). Some of requirements for the performance standard include; monitoring and review, stakeholder engagement, ongoing reporting to communities.

6.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the expansion is to ensure that operations at Kolomela Mine result in ambient air concentrations (specifically PM_{10}) and dustfall rates that are within the relevant ambient air quality standards off-site. In order to define site specific management objectives, the main sources of pollution needed to be identified. Sources area ranked based on source strengths (emissions) and impacts (concentrations). Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

6.2 Source Ranking

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 of emissions at the Kolomela Mine operations are ranked based on:

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

6.2.1 Ranking of Sources by Emissions

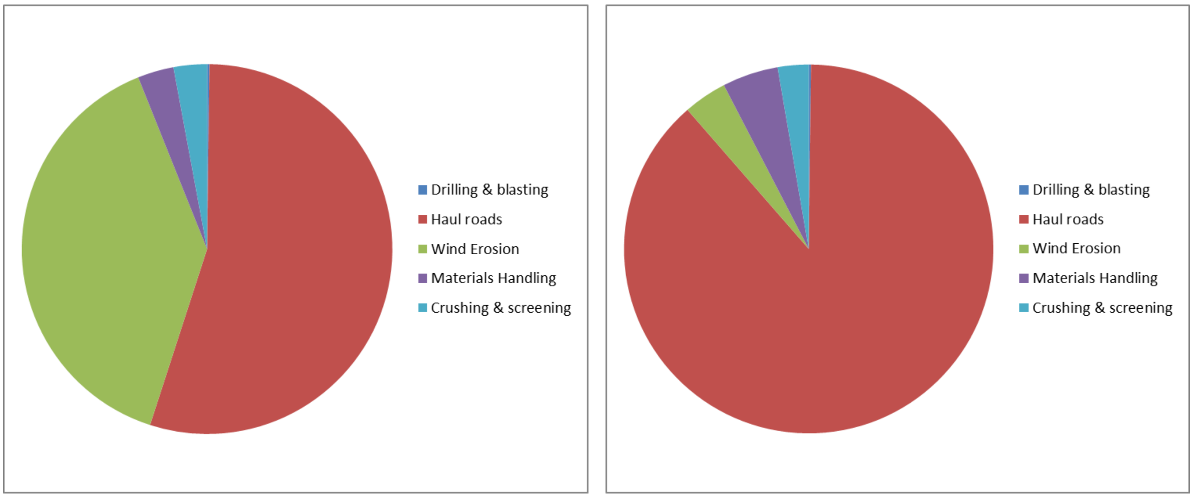
On average, sources of **emission** are ranked as follows from most to least significant (Figure 6-1 (a)):

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

6.2.2 Ranking of Sources by Impact

On average, sources of **impact** are ranked as follows from most to least significant (Figure 6-1 (b)):

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



(a) Emission ranking (b) Impact ranking

Figure 6-1: Average source group contribution to overall PM_{10} emissions and simulated impacts

6.2.3 Conclusion with Regards to Source Ranking

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

Although Kolomela already implements some of these, and the dispersion modelling results incorporate some of these measures (for example wet suppression and chemical suppression on roads), the measures should form part of the management plan and should be regularly assessed to determine their effectiveness.

As the current exceedances are very season specific, these measures should be even more focused at these times of the year.

6.3 Source Specific Recommended Management and Mitigation Measures

6.3.1 Dust Control Options for Unpaved Haul Roads

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

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

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds;
- Number of wheels per vehicle;
- Traffic volumes;
- Particle size distribution of the aggregate;

- Compaction of the surface material ;
- Surface moisture; and
- Climate

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

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

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

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

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

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

6.3.2 Options for Reducing Windblown Dust Emissions

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

- Source extent reduction:
    - Disturbed area reduction.
    - Disturbance frequency reduction.
    - Dust spillage prevention and/or removal.
- Source Improvement:
    - Disturbed area wind exposure reduction, e.g. wind fences and enclosure of source areas.
- Surface Treatment:
    - Wet suppression
    - Chemical stabilisation
    - Covering of surface with less erodible aggregate material
    - Vegetation of open areas

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

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

6.3.3 Materials Handling Dust Control Options

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

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

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

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

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

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

- of the various nozzle types, the use of hollow cone nozzles tend to afford the greatest control for bulk materials handling applications whilst minimising clogging;
- optimal droplet size for surface impaction and fine particle agglomeration is about 500 µm; finer droplets are affected by drift and surface tension and appear to be less effective; and,
- application of water sprays to the underside of conveyor belts has been noted by various studies to improve the efficiency of water suppression systems and belt-to-belt transfer points.

The control efficiency of pure water suppression can be estimated based on the US EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 6-2.

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

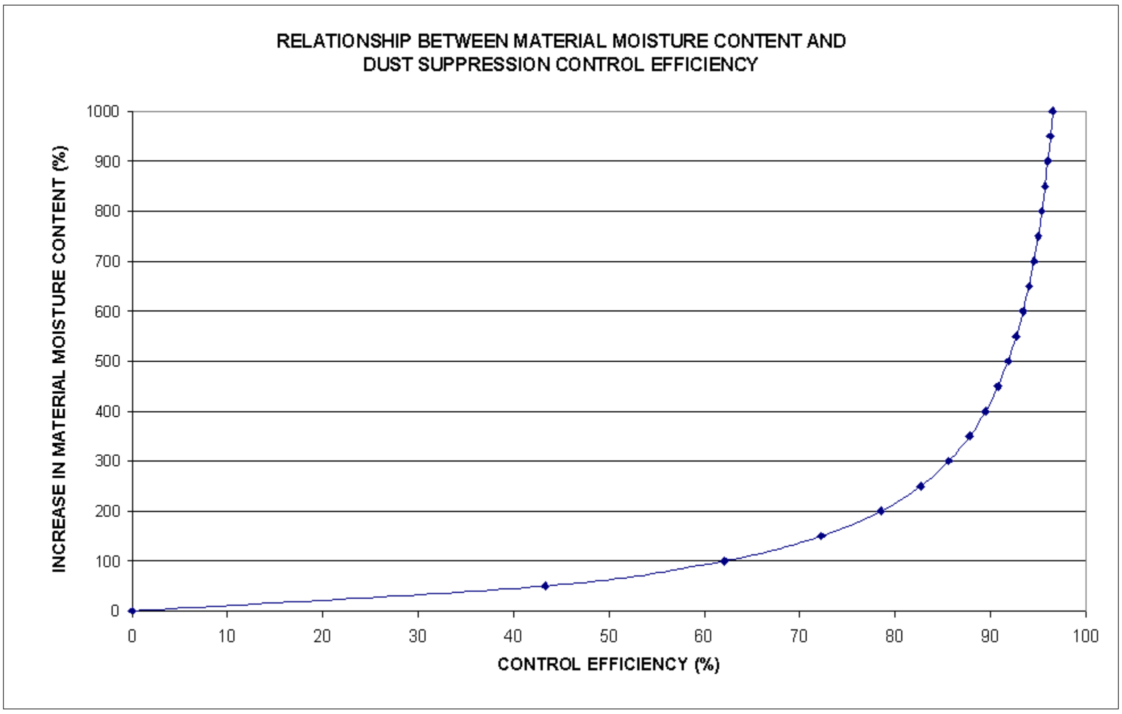


Figure 6-2: Relationship between the moisture content and the dust control efficiency

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

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

As an example, the South African developed Weba Chute is reported by its developer, M & J Engineering (Pty) Ltd, to have been installed in dolomite, iron ore, coal, manganese, kimberlite, phosphate and agricultural product operations. This transfer chute technology is described as being able to be applied in transfer of lumpy, sticky, and slightly wet materials. Spillage avoidance, dust minimization and noise abatement represent the main environmental benefits of the Weba Chute. Examples of Weba chutes are given in Figure 6-3.

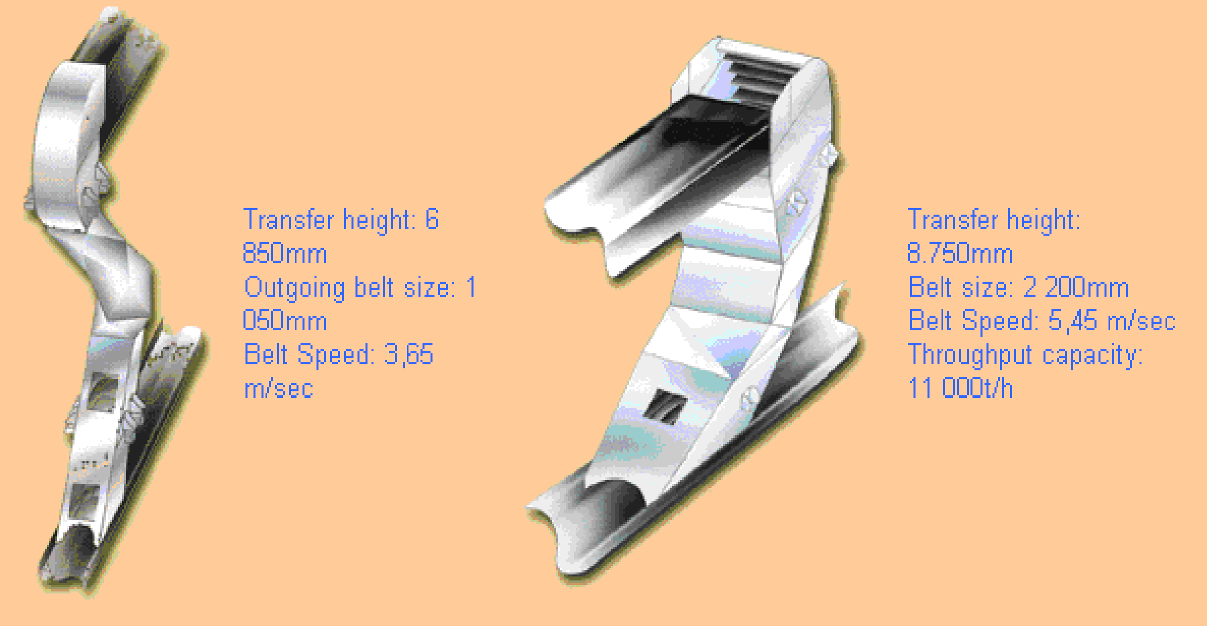


Figure 6-3: Examples of Weba chutes, developed by M & J Engineering (M&J Engineering, 2011)

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

6.4 Performance Indicators

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

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

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

6.4.1 Ambient Air Quality Monitoring

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

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;

- Assist in source apportionment;
- Temporal trend analysis;
- Spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

It is recommended that, as a minimum, Kolomela's continuous dustfall, PM_{10} and $PM_{2.5}$ as well as meteorology, NO_2 and SO_2 sampling be continued as part of the mine's air quality management plan. Careful screening of data and maintenance of monitoring stations is recommended.

The Anglo Environmental Performance Standard (section 2.4) states that the air quality monitoring system should include direct source sampling and off-site ambient monitoring; and must be representative of the mines area of influence. The ambient monitoring station locations must be informed by air dispersion modelling results on sensitive receptors and weather conditions, such as prevailing wind directions. The requirements of the site permits/licenses must be reflected in the design of the monitoring system. Daily emissions must be managed via Trigger Action Response Plans (TARP's) using the monitoring results and visual observations of emissions. The monitoring equipment must have a formal maintenance and servicing programme in place, with an annual data capture target of ninety percent (90%) as a minimum for each real-time monitoring station.

6.5 Record-keeping, Environmental Reporting and Community Liaison

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

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

6.5.1 Liaison Strategy for Communication with I&APs

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Management plans should stipulate specific intervals at which forums will be held, and provide information on how people will be notified of such meetings. For operations for which un-rehabilitated or party rehabilitated impoundments are located in close proximity (within 3 km) from community areas, it is recommended that such meetings be scheduled and held at least on a bi-annual basis.

6.5.2 Financial Provision

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework.

Costs related to inspections, audits, environmental reporting and I&AP liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures. The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

7 REFERENCES

Andreae, M. A.-P. (1996). Trace gas and aerosol emissions from savanna fires. In J. (. Levine, *Biomass Burning and Global Change. Remote sensing, modeling and inventory development, and biomass burning in Africa, Volume 1* (pp. 278-295). Cambridge: MIT Press.

AngloAmerican. (2017). *Environmental Performance Standard, Air Quality and Emissions.*

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

Flocchini, R. G., Cahill, T. A., Matsumura, R. T., Carvacho, O., & Lu, Z. (1994). *Study of fugitive PM10 emissions for selected agricultural practices on selected agricultural soils.* University of California.

Garstang, M. T. (1996). Horizontal and vertical transport of air over southern Africa. *Journal of Geophysical Research, 101 (D19)*, 23721 – 23736.

Hanna, S. R., Egan, B. A., Purdum, J., & Wagler, J. (1999). *Evaluation of ISC3, AERMOD, and ADMS Dispersion Models with Observations from Five Field Sites.*

IFC. (2012). *Performance Standard 1 - Assessment and Management of Enviromental and Social Risks and Impacts.*

M&J Engineering. (2011). *Products: M&J Engineering*. Retrieved December 6, 2012, from M&J Engineering (Pty) Ltd Web Site: http://www.mjeng.co.za/

MFE. (2001). *Good Practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions.* New Zealand Ministry for the Environment.

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

Piketh, S., Annegarn, H., & Kneen, M. (1996). Regional scale impacts of biomass burning emissions over southern Africa. In J. Levine, *Biomass Burning and Global Change.* Cambridge: MIT Press.

Stevenson, T. (2004). *Dust Suppression on Wyoming's Coal Min Haul Roads – Literature Review, Recommended Practices and Best Available Control Measures – A Manual.*

Thompson, R. J., & Visser, A. T. (2000). *Integrated Asset Management Strategies for Unpaved Mine Haul Roads.* University of Pretoria.

US EPA. (2006). *AP 42, 5th Edition, Volume 1, Chapter13: Miscellaneous Sources, 13.2.4 Introduction to Fugitive Dust Sources, Aggragate Handling and Storage Piles.* Retrieved from http://www.epa.gov/ttn/chief/ap42/

US EPA. (2006). *AP 42, 5th Edition, Volume I, Chapter 13: Miscellaneous Sources, 13.2.2 Introduction to Fugitive Dust Sources, Unpaved Roads.* http://www.epa.gov/ttnchief/ap42/.

APPENDIX A – SPECIALIST CURRICULUM VITAE

CURRICULUM VITAE

Name	Gillian Petzer (née Möhle)
Date of Birth	1 December 1975
Nationality	South African
Employer	Airshed Planning Professionals (Pty) Ltd
Position	Principal Consultant and Project Manager
Profession	Chemical Engineer employed as an Air Quality Assessment Consultant
Years with Firm	17 years

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- South African Institute of Chemical Engineers, 2003 to present
- Institution of Chemical Engineers (IChemE) - Membership number 99964317
- National Association for Clean Air (NACA), 2003 to present
- Professional Engineer – Registration number 20170315

EXPERIENCE

Gillian has seventeen years of experience in air quality impact assessment and management. She is an employee of Airshed Planning Professionals (Pty) Ltd and is involved in the compilation of emission inventories, air pollution mitigation and management, and air pollution impact work.

A list of projects competed in various sectors is given below.

Air Quality Management

- Richards Bay Air Quality Management Plan
- Tshwane Air Quality Management Plan
- Dust Management Plan for various mines

Mining Sector

Lusthof Colliery, South Deep Mine, Kangra, MacWest, Sishen Iron Ore Mine, SA Chrome, Esaase Gold Project (Ghana), Mampon Gold Mine (Ghana), Mittal Newcastle, Navachab (Namibia), Skorpion Zinc mine (Namibia), Debswana Diamond Mines (Botswana). Quarries: Afrisam Pietermaritzburg, AMT operations (Rustenburg and Wonderstone)

Industrial Sector

Various Brickworks, Middelburg Ferrochrome, Impala Platinum (Springs), Delta EMD Project, PetroSA, Alfluorco Aluminium Fluoride Project, PPC, Rand Carbide, Vanchem, BCL incinerator, AEL, Namakwa Sands Plant, Liquid Natural Gas Refinery (Equatorial Guinea), Phalaborwa Mining Company, Asphalt plants, Ceramic facilities

Energy Sector

Walvis Bay Power Station Project (Namibia), various small power stations (Eritrea, Nigeria, Mauritania, Kenya), Matimba Power Station, Mossel Bay OCGT Power Station, Sese Power Station (Botswana), Geothermal Power Station (Kenya)

Waste Disposal and Treatment Sector

Rosslyn and Chloorkop Waste Disposal Sites, Organic waste disposal site

Transport and Logistics Sector

Kolomela Iron Ore Railway Line, Guinea Port and Railway Project (Guinea), Grindrod Coal Terminal, VALE Port Project (Mozambique).

Ambient Air Quality and Noise Sampling

- Gravimetric Particulate Matter (PM) and dustfall sampling
- Passive diffusive gaseous pollutant sampling

SOFTWARE PROFICIENCY

- Atmospheric Dispersion Models: AERMOD, ISC, CALPUFF, ADMS (United Kingdom), CALINE, GASSIM, TANKS
- Graphical Processing: Surfer, ArcGIS (basic proficiency)
- Other: MS Word, MS Excel, MS Outlook

EDUCATION

- BEng: (Chemical Engineering), 2002, University of Pretoria

COURSES COMPLETED AND CONFERENCES ATTENDED

- Conference: NACA (October 2003), Attended
- Conference: NACA (October 2005), Attended and presented a paper
- Conference: NACA (October 2007), Attended and presented a paper
- Conference: NACA (October 2008), Attended and presented a poster
- Conference: NACA (October 2009), Attended and presented a paper
- Conference: NACA (October 2012), Attended
- Conference: IUAPPA (October 2013), Attended
- Course: Climate change and carbon management. Presented by Environmental & Sustainability Solutions (July 2014)
- Conference NACA (October 2016), Attended
- Conference NACA (October 2017), Attended
- Process Vessel and Tank Design Course (May 2019), Attended

COURSES PRESENTED

- National Environmental Management: Air Quality Act and its Implementation (course arranged by the North-West University - NWU)

COUNTRIES OF WORK EXPERIENCE

South Africa, Namibia, Botswana, Ghana, Eritrea, Mauritania, Mozambique, Kenya, Guinea, Equatorial Guinea and Nigeria

LANGUAGES

Language	Proficiency
English	Native language
Afrikaans	Full professional proficiency

REFERENCES

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Dr Lucian Burger	Director at Airshed Planning Professionals	+27 (82) 491 0385 lucian@airshed.co.za
Dr. Hanlie Liebenberg Enslin	Managing Director at Airshed Planning Professionals	+27 (83) 416 1955 hanlie@airshed.co.za

CERTIFICATION

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

25/05/2020

Appendix B – Significance Rating Methodology

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

impact significance = (consequence x probability)

Where:

consequence = (severity + extent)/2

and

severity = (intensity + duration)/2

Each criterion is given a score from 1 to 5 based on the definitions given in Table B-1 to Table B-3. Although the criteria used for the assessment of impacts attempts to quantify the significance, it is important to note that the assessment is generally a qualitative process and therefore the application of this criteria is open to interpretation. The process adopted will therefore include the application of scientific measurements and professional judgement to determine the significance of environmental impacts associated with the proposed project. The assessment thus largely relies on experience of the environmental assessment practitioner (EAP) and the information provided by the specialists appointed to undertake studies for the EIA.

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

Table B-1: Criteria for Assessing the Impact Significance (Severity Criteria)

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

Table B-2: Criteria for Assessing the Impact Significance (Probability)

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

Table B-3: Criteria for Assessing the Impact Significance (Impact Significance)

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

≤ 1	Very Low	Impact is negligible.
> 1 ≤ 2	Low	Impact is of a low order.
> 2 ≤ 3	Moderate	Impact is real but not substantial in relation to other impacts.
> 3 ≤ 4	High	Impact is substantial.
> 4 ≤ 5	Very High	Impact is of the highest order possible.