Air Quality Specialist Study Report for the Harmony Kalgold Expansion

Project done for **Environmental Impact Management Services (Pty) Ltd**

Report Compiled by
N Shackleton

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Address: 480 Smuts Drive, Halfway Gardens | **Postal:** P O Box 5260, Halfway House, 1685
Tel: +27 (0)11 805 1940 | **Fax:** +27 (0)11 805 7010
www.airshed.co.za

Report Details

Report Title	Air Quality Specialist Study Report for the Harmony Kalgold Expansion
Applicant	Harmony Gold Mining Company Limited
Environmental Assessment Practitioners	Environmental Impact Management Services (Pty) Ltd
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Prepared by	Natasha Shackleton, Pr. Sci. Nat., BSc Hons: Meteorology (University of Pretoria)
Assisted by	Tinashe Mukota, MEng (University of Pretoria)
Review by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
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Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference. I, Natasha Anne Shackleton as the appointed independent specialist for the "Air Quality Specialist Study Report for the Harmony Kalgold Expansion", hereby declare that I: • acted as the independent specialist in this scoping assessment; • performed the work relating to the study in an objective manner; • regard the information contained in this report as it relates to my specialist input/study to be true and correct, • do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment; • declare that there are no circumstances that may compromise my objectivity in performing such work; • have expertise in conducting the specialist report relevant to this application; • have no, and will not engage in, conflicting interests in the undertaking of the activity; • have no vested interest in the proposed activity proceeding; • undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing the decision of the competent authority; and • all the particulars furnished by me in this specialist input/study are true and correct.
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Revision Record

Revision Number	Date	Section Revised	Reason for Revision
Draft	January 2022	Original	For review by applicant and Environmental Assessment Practitioner (EAP)
Final v1	January 2022		In response to comments received from the Applicant and EAP

Competency Profiles

Report author: N A Shackleton (née Gresse), Pr. Sci. Nat., BSc Hons: Meteorology (University of Pretoria)

Natasha Shackleton is a registered Professional Natural Scientist with the South African Council for Natural Scientific Professions (SACNASP) (registration no. 116335), a member of the National Association for Clean Air (NACA), and a member of the South African Society for Atmospheric Sciences (SASAS). Natasha started her professional career in Air Quality in April 2011 when she joined Airshed Planning Professionals (Pty) Ltd after completing her Undergraduate Degree at the University of Pretoria in Science. In 2011 she completed her Honours Degree at the University of Pretoria in Meteorology. Natasha has worked on several air quality specialist studies since 2011. She has experience in the various components including monitoring and sampling data analysis, emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments as well as the development of air quality management plans. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality. Whilst most of his working experience has been in South Africa, a number of investigations were made in countries elsewhere, including Burkina Faso, Guinea, Ghana, Madagascar, Mozambique, Namibia, Suriname, Tanzania, Zimbabwe and Zambia.

NEMA EIA Regulation (2014, as amended) – Appendix 6

NEMA Regulations (2014, as amended) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report.	Report Details (page i)
The expertise of that person to compile a specialist report including curriculum vitae.	Competency Profiles (page iii) Appendix A: Authors' Curriculum Vitae (page 86)
A declaration that the person is independent in a form as may be specified by the competent authority.	Report Details (page i)
An indication of the scope of, and the purpose for which, the report was prepared.	Section 1.1: Background (page 1) Section 1.2: Study Objective (page 4)
An indication of quality and age of base data used.	Section 1.5: Managing Uncertainties (page 9) Section 3: Description of the Receiving Environment (page 22)
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change.	Section 3: Description of the Receiving Environment (page 22) Section 4: Impact Assessment: Construction Phase (page 38) Section 5: Impact Assessment: Operational Phase (page 43) Section 6: Impact Assessment: Decommissioning and Closure Phases (page 69) Section 7: Impact Assessment: Cumulative Including Other Operations in the Region (page 75)
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment.	Description of the current land use in the region, simulations undertaken for the proposed operations and meteorological data included used in the study are considered representative of all seasons. Section 3: Description of the Receiving Environment (page 22)
A description of the methodology adopted in preparing the report or carrying out the specialised process.	Section 1.4: Air Quality Study Methodology (page 7)
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure.	Section 3.1: Affected Environment (page 22)
An identification of any areas to be avoided, including buffers.	Section 3.1: Affected Environment (page 22) Section 5.2: Assessment of Impact – Proposed Operations (page 48)
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers.	Section 3.1: Affected Environment (page 22) Section 5.2: Assessment of Impact – Proposed Operations (page 48)
A description of any assumptions made and any uncertainties or gaps in knowledge.	Section 1.5: Managing Uncertainties page (9)
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment.	Section 5.2: Assessment of Impact – Proposed Operations (page 48) Section 5.3: Impact Significance Rating of Incremental Operations (page 64) Section 9: Air Quality Management Plan (page 77)

Any mitigation measures for inclusion in the EMPr.	Section 9: Air Quality Management Plan (page 77)
Any conditions for inclusion in the environmental authorisation	Section 9: Air Quality Management Plan (page 77) Section 10: Findings and Recommendations (page 80)
Any monitoring requirements for inclusion in the EMPr or environmental authorisation.	Section 9: Air Quality Management Plan (page 77) Section 10: Findings and Recommendations (page 80)
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised.	Section 10: Findings and Recommendations (page 80)
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan.	Section 10: Findings and Recommendations (page 80)
A description of any consultation process that was undertaken during the course of carrying out the study.	None received
A summary and copies if any comments that were received during any consultation process.	None received
Any other information requested by the competent authority.	None received

List of Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
AQIA	Air quality impact assessment
AQMP	Air Quality Management Plan
AQSRs	Air quality sensitive receptors
ATSDR	US Agency for Toxic Substances and Disease Registry
CALEPA	California Environmental Protection Agency
CH_4	Methane
Cl_2	Chlorine
CLRTAP	Convention on Long Range Trans-boundary Air Pollution Limits
CO	Carbon monoxide
CO_2	Carbon dioxide
CPVs	Cancer Potency Values
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and Environment
DM	District Municipality
DMR	Department of Mineral Resources
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
EMPr	Environmental Management Programme
ESLs	Effect screening levels
g	Gram
g/s	Gram per second
GG	Government Gazette
GHG	Greenhouse Gases
GLC(s)	Ground level concentration(s)
GN	Government Notice
Gt	Gigatonne
GV	Guideline Value
ha	Hectare
Harmony	Harmony Gold Mining Company Limited
HCl	Hydrogen chloride
HF	Hydrogen fluoride
ILCR	Increased lifetime cancer risk
IRIS	Integrated Risk Information System
kg	Kilogram
ktpm	Kilotonnes per month
LM	Local Municipality
m	Metre
m^2	Metre squared
m^3	Metre cubed
mamsl	Metres above mean sea level

MES	Minimum Emission Standards
mm	Millimetres
m/s	Metres per second
MPRDA	Mineral and Petroleum Resources Development Act (No. 28 of 2002)
MR	Mining Right
MRA	Mining Right Application
MRL	Minimal risk levels for hazardous substances
Mt	Megatonnes
NAAQ Limit	National Ambient Air Quality Limit concentration
NAAQS	National Ambient Air Quality Standards (as a combination of the NAAQ Limit and the allowable frequency of exceedance)
NAEIS	National Atmospheric Emissions Inventory System
NEMA	National Environmental Management Act (No. 107 of 1998)
NEM:AQA	National Environmental Management: Air Quality Act (No. 39 of 2004)
NH_3	Ammonia
N_2O	Nitrous oxide
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NSW	New South Wales
NWA	National Water Act
NYSDOH	New York State Department of Health
O_3	Ozone
OEHHA	Californian Office of Environmental Health Hazard Assessment
PAEL	Provisional Atmospheric Emission Licence
PAHs	Polyaromatic hydrocarbons
Pb	Lead
PM	Particulate matter
PM_{10}	Particulate matter with diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with diameter of less than 2.5 µm
PPRTVs	Provisional Peer-Reviewed Toxicity Values
RELs	Reference exposure levels
RfCs	Inhalation reference concentrations
RoM	Run of Mine
S&EIRs	Scoping and environmental impact reports
SAAQIS	South African Air Quality Information System
SAGERS	South African Greenhouse Gas Emission Reporting System
SAWS	South African Weather Service
SO_2	Sulfur dioxide
SRTM	Shuttle radar topography mission
TARA	Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division
TOCs	Threshold odour concentrations
tpa	Tonnes per annum
tpm	Tonnes per month

TSP	Total suspended particulates
UNECE	United Nations Economic Commission for Europe
URFs	Unit Risk Factors
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VKT	Vehicle kilometres travelled
WGS	World Geodetic System
WHO	World Health Organisation
WRF	Weather Research and Forecasting
WULA	Water Use Licence Application
μ	micro
°C	Degrees Celsius

Glossary

Air-shed	An area, bounded by topographical features, within which airborne contaminants can be retained for an extended period
Algorithm	A mathematical process or set of rules used for calculation or problem-solving, which is usually undertaken by a computer
Atmospheric dispersion model	A mathematical representation of the physics governing the dispersion of pollutants in the atmosphere
Atmospheric stability	A measure of the propensity for vertical motion in the atmosphere
Baseline	Information gathered at the beginning of a study which describes the environment prior to development of a project, and against which predicted changes (impacts) are measured.
Calm / stagnation	A period when wind speeds of less than 0.5 m/s persist
Cartesian grid	A co-ordinate system whose axes are straight lines intersecting at right angles
Causality	The relationship between cause and effect
Closure Phase	This stage of the project includes the period of aftercare and maintenance after the decommissioning phase
Configuring a model	Setting the parameters within a model to perform the desired task
Construction Phase	The stage of project development comprising site preparation as well as all construction activities associated with the development.
Cumulative Impacts	Direct and indirect impacts that act together with current or future potential impacts of other activities or proposed activities in the area/region that affect the same resources and/or receptors.
Dispersion	The lowering of the concentration of pollutants by the combined processes of advection and diffusion
Environment	The external circumstances, conditions and objects that affect the existence of an individual, organism or group. These circumstances include biophysical, social, economic, historical and cultural aspects.
Environmental Authorisation	Permission granted by the competent authority for the applicant to undertake listed activities in terms of the NEMA EIA Regulations, 2014.
Environmental Impact Assessment	A process of evaluating the environmental and socio-economic consequences of a proposed course of action or project.
Environmental Impact Assessment Report	The report produced to relay the information gathered and assessments undertaken during the Environmental Impact Assessment.
Environmental Management Programme	A description of the means (the environmental specification) to achieve environmental objectives and targets during all stages of a specific proposed activity.
Impact	A change to the existing environment, either adverse or beneficial, that is directly or indirectly due to the development of the project and its associated activities.
Mitigation measures	Design or management measures that are intended to minimise or enhance an impact, depending on the desired effect. These measures are ideally incorporated into a design at an early stage.

Operational Phase	The stage of the works following the Construction Phase, during which the development will function or be used as anticipated in the Environmental Authorisation.
Specialist study	A study into a particular aspect of the environment, undertaken by an expert in that discipline.
Stakeholders	All parties affected by and/or able to influence a project, often those in a position of authority and/or representing others.

Executive Summary

Harmony Gold Mining Company Limited (hereafter referred to as Harmony), has owned and operated the Kalgold Operations since 1999. The Kalgold operations comprises of open-pit gold mining operations and carbon-in-leach gold plant. The existing Harmony Kalgold operation wishes to increase its production from the current production rate of 130 000 tonnes per month (tpm) to 300 000 tpm. The change in production rate will require expansion of (and modification to) the current operational facilities and layout. Kalgold is located approximately 60 km southwest of Mahikeng in the Ratlou Local Municipality (LM) within the Ngaka Modiri Molema District Municipality (DM) in the North West Province of South Africa.

The proposed expansion operations require Environmental Authorisation (EA) in terms of both the National Environmental Management Act (No. 107 of 1998) (NEMA) (Republic of South Africa, 1998) and Mineral and Petroleum Resources Development Act (No. 28 of 2002) (MPRDA) (Republic of South Africa, 2004), as amended in 2008 (Republic of South Africa, 2009), as well as a Water Use Licence (WUL) issued in terms of the National Water Act (No 36 of 1998) (NWA) (Republic of South Africa, 1998). Due to the Listing Notice activities applicable a full Environmental Impact Assessment/Environmental Management Program (EIA/EMPr) process is requiring scoping and environmental impact reports (S&EIRs) and an EMPr. This process is usually conducted in two phases, the first being the scoping phase which requires the submission of a scoping report. According to NEMA EIA Regulations "a scoping report must contain the information that is necessary for a proper understanding of the process, informing all preferred alternatives, including location alternatives, the scope of the assessment, and the consultation process to be undertaken through the environmental impact assessment process".

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Environmental Impact Management Services (Pty) Ltd (EIMS) to undertake an Air Quality Impact Assessment (AQIA) as part of the EA process to identify key aspects that may have significant air quality impacts during the various project phases. As such the AQIA report will conform to the amended regulated format requirements for specialist reports as per Appendix 6 of the EIA Regulations (Republic of South Africa, 2014) (as amended by Government Notice [GN] 326 of 7 April 2017; GN 706 of 13 July 2018 and GN 320 of 20 March 2020).

Receiving Environment

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

- Modelled Weather Research and Forecasting (WRF) meteorological data for a location on-site for the period January 2018 to December 2020 was used.
- The prevailing wind field in the area consists of north-north-easterly winds.
- The area experiences mild summers and cold winters with monthly average temperatures ranging between 11°C and 26°C. The highest temperature of (38°C) occurred in December and January and the lowest (-5°C) in June and July.
- Nearby residential areas include Old Kraaipan (southeast), Setlagole (southwest) and Mareetsane (15 km east of the permit area). Aside from the residential areas, individual farmsteads near the expansion

operations were identified as Air Quality Sensitive Receptors (AQSRs) and agricultural areas were identified as environmentally sensitive areas.

- Ambient air pollutant levels in the project area are currently affected by the following sources of emission:
    - Current mining and process operations at the Kalgold mine.
    - Agricultural operations – the surrounding land use is predominantly agricultural and hence associated activities may contribute to elevated ground level particulate matter concentrations.
    - Vehicles travelling on public and private roads – fugitive dust emissions would occur because of vehicle entrained dust from local paved and unpaved roads, these are also contributors to mobile combustion emissions.
    - Household fuel burning – particulate matter and gaseous emissions may occur from the burning of fuel within households for cooking and space heating.
    - Biomass burning – burning of agricultural land, fire breaks and unplanned veld fires would result in particulate matter and gaseous emissions.
    - Other sources – windblown dust from open areas.
- PM_{10} (particulate matter with diameter of less than 10 µm) data showed no exceedances of the National Ambient Air Quality Standards (NAAQS) however the station had low data availability (17% in 2019, 29% in 2020 and 52% in 2021).
- There was only one exceedance of the National Dust Control Regulations (NDCR) limit for non-residential areas in 2020 (KG7/HAR07 during April 2020), thus the sampled dustfall rates are in compliance with the NDCR that year; however, four months of data was not provided for 2020. There was one exceedance of the NDCR limit for non-residential areas at two sites in 2021 (KG7/HAR07 during July 2021 and KG4/HAR04 during August 2021), thus the sampled dustfall rates are in compliance with the NDCR that year; however, only 8 of the 12 months data was available.
- Simulated pollutant concentrations from a study conducted by Digby Wells (Digby Wells Environmental, 2014) showed no exceedance to the current daily and annual NAAQS limits for both PM_{10} and $PM_{2.5}$. However, future expansion operations may result in exceedances to the future $PM_{2.5}$ limits effective 31 January 2030. The simulated dustfall rates for the same study indicated compliance with the NDCR.

Simulation Results for the Future Operations

The main findings of the impact assessment are as follows:

- Construction, decommissioning/closure and post-closure phases:
    - The environmental risk rating related inhalation health, nuisance impacts and vegetation impacts are likely to be "low" without and with additional mitigation. The overall environmental risk rating is also expected to be "low negative".
- Operational phase:
    - PM_{10}, $PM_{2.5}$ (particulate matter with diameter of less than 2.5 µm), total suspended partiulates (TSP), sulfur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), diesel particulate

matter (DPM), lead (Pb), hydrogen fluoride (HF), hydrogen chloride (HCl), chlorine (Cl_2), and ammonia (NH_3) emissions and impacts were quantified.
    - PM_{10} concentrations as a result of mitigated operations are not within compliance at one AQSRs over the short-term (24-hour average).
    - PM_{10} and $PM_{2.5}$ concentrations as a result of mitigated operations are not within compliance off-site but are in compliance at all AQSRs over the short-term and long-term (annual average).
    - Dustfall rates are above the NDCR limits for non-residential areas and above 400 mg/m²-day at some agricultural areas; however, the dustfall rates are below the NDCR limits for residential areas at all AQSRs.
    - DPM does not exceed the United States Environmental Protection Agency (US EPA) Integrated Risk Information System (IRIS) Inhalation reference concentrations (RfC) at any AQSRs.
    - NO_x concentrations are in compliance with the nitrogen dioxide (NO_2) NAAQS at all AQSRs over the long-term and short-term.
    - SO_2 and CO concentrations are below the NAAQ limit values.

Impact Significance Ratings

- The environmental risk rating of proposed project operations related to inhalation health impacts is likely to be "medium negative" without mitigation measures applied and becomes "low negative" with mitigation measures applied. The overall environmental risk rating is expected to be "medium negative".
- The environmental risk rating of operations related to nuisance impacts are likely to be "low negative" without and with mitigation measures applied. The overall environmental risk rating is expected to be "low negative".
- The environmental risk rating of proposed project operations related to the impacts on vegetation health is likely to be "medium negative" without mitigation measures applied and becomes "low negative" with mitigation measures applied. The overall environmental risk rating is expected to be "medium negative".

Recommendations

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

- The management of the operations; resulting in the mitigation of associated air quality impacts;
- The dustfall sampling, ambient fine particulate monitoring and operating of the on-site weather station
    - Should the dustfall sampling show higher rates than those estimated in this study it is suggested that Kalgold investigate and consider adopting additional mitigation and management measures. Fallout dust tends to settle relatively close to sources of emissions and thus if the dustfall sampling show significantly higher rates there is likely to be significantly higher finer particulate matter concentrations as well.
- Record keeping and community liaison procedures.

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Air Quality Specialist Study Report for the Harmony Kalgold Expansion

1 INTRODUCTION

Harmony Gold Mining Company Limited (hereafter referred to as Harmony), has owned and operated the Kalgold Operations since 1999. The Kalgold operations comprises of open-pit gold mining operations and carbon-in-leach gold plant. The existing Harmony Kalgold operation wishes to increase its production from the current production rate of 130 000 tonnes per month (tpm) to 300 000 tpm. The change in production rate will require expansion of (and modification to) the current operational facilities and layout.

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1.1 Background

Kalgold is located approximately 60 km southwest of Mahikeng in the Ratlou Local Municipality (LM) within the Ngaka Modiri Molema District Municipality (DM) in the North West Province of South Africa (Figure 1). The mine is owned and operated by Harmony, who acquired the mine in 1999. The mine is in the Kraaipan Greenstone Belt, which is part of the large Amalia-Kraaipan Greenstone terrain. The largest ore body is found in the D-Zone, which was mined out by a single pit operation along a strike length of 1 300 m and to a depth of approximately 290 m below surface. Mining at Kalgold Mine continued at the A-Zone, Windmill and Watertank Open Pits, which are all relatively new opencast operations.

The existing Harmony Kalgold operation wishes to expand its current production. A pre-feasibility study has been undertaken. The findings of the pre-feasibility study have concluded that the following new activities and expansions must be provided for:

- New gold production plant.
- Roads to new plant from the pit and from N18.
- Tailings pipeline from new plant to D zone.
- Return water pipeline from D zone.
- Increased tailings deposition rate at D zone.
- New wastewater treatment plant.
- Discharge of treated water.
- N18 underpass with road diversion.
- Expansion of the existing pits[1].
- Further expansion of Watertank WRD.
- Spanover waste rock dump expansion.
- Expansion of the current Tailings Storage Facility (TSF).
- Tailings pipeline from new plant to TSF.
- TSF return water pipeline.

The proposed changes will likely result in impacts on the surrounding environment and human health during the construction, operational and decommissioning phases. The potential sources and pollutants associated with the proposed changes are presented in section 1.3.

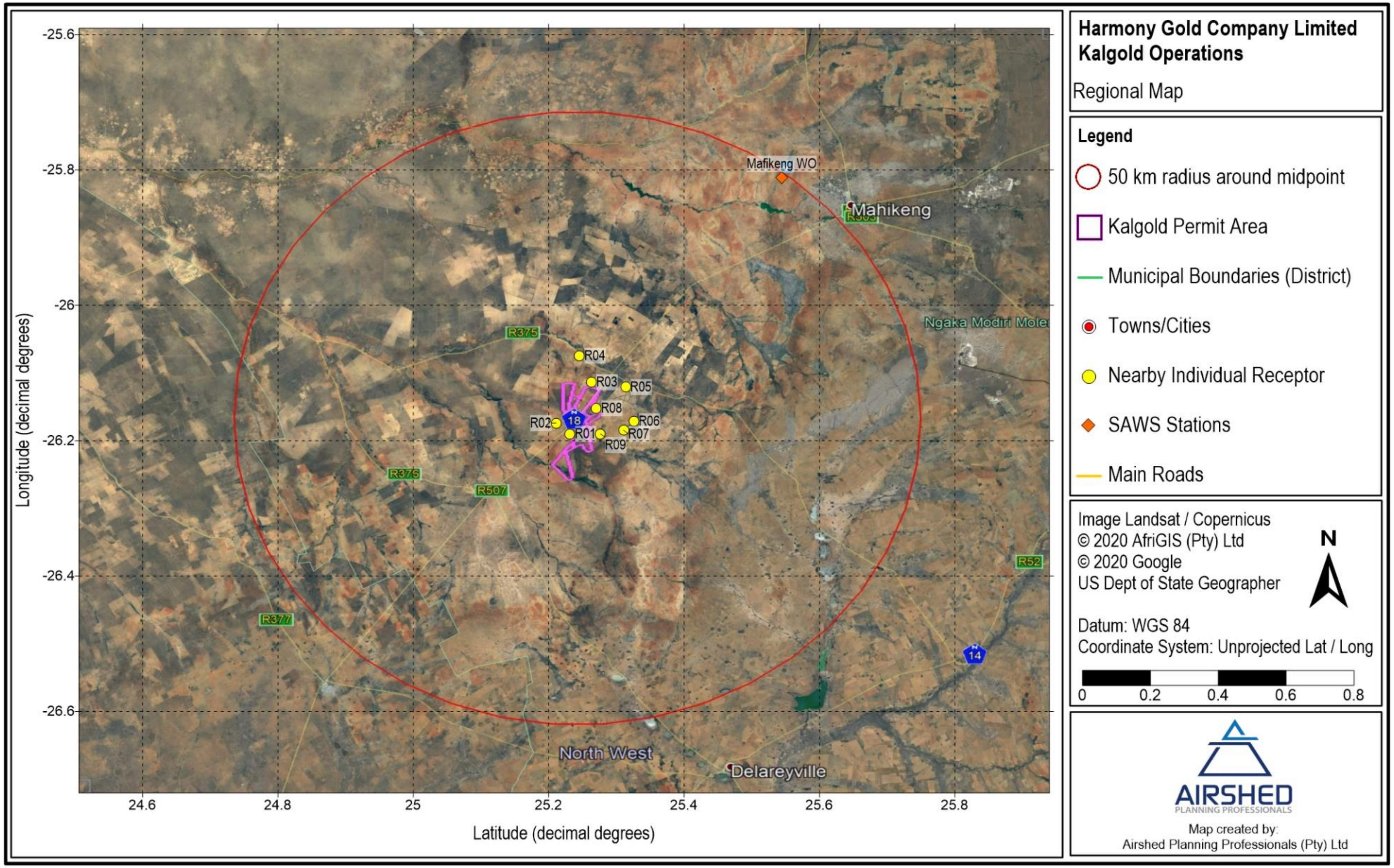


Figure 1: Regional map

1.2 Study Objective

The main objective of the air quality specialist study is to assess the impacts of the current (Kalgold operations without the changes) and future operations (Kalgold operations with the changes) on all aspects of biophysical and socio-economic receptors within the area and recommend mitigation, management, and monitoring measures based on the results of the assessment. The specific terms of reference for the overall study are as follows:

- Identify and describe the existing air quality of the project area, as well as climatic patterns and features (i.e. the baseline);
- Assess (model) the impact on air quality on human health and biota resulting from the existing operations, specifically with reference to
  - total particulate matter (TSP),
  - particulate matter with an aerodynamic dimeter less than 10 µm (PM_{10}),
  - particulate matter with an aerodynamic dimeter less than 2.5 µm ($PM_{2.5}$),
  - sulfur dioxide (SO_2),
  - oxides of nitrogen (NO_x) expressed as nitrogen dioxide (NO_2),
  - carbon monoxide (CO),
  - chlorine (Cl_2),
  - hydrogen chloride (HCl),
  - hydrogen fluoride (HF),
  - ammonia (NH_3), and
  - lead (Pb).
- Assess the impact on human health and biota resulting from the future operations (including impacts associated with the construction, operations, decommissioning and post-closure phases of the project) with specific reference to the same pollutants listed above;
- Identify and describe potential cumulative air quality impacts resulting from the proposed future operations in relation to other existing developments in the surrounding area;
- Recommend mitigation measures to minimise impacts and/or optimise benefits associated with the project; and
- Recommend a monitoring network to ensure the correct implementation and adequacy of recommenced mitigation measures, if applicable.

1.3 Process Description

1.3.1 General Process Description

The current activities at Kalgold that result in emissions include, but are not limited to:

- Drilling
- Blasting
- Excavation of ore and waste within the open pit
- Loading and offloading of trucks
- Vehicles travelling on unpaved roads including trucks, service vehicles and personnel/contractor vehicles
- Crushing and screening of ore

- Other processing activities
- Erosion of stockpiles, TSF and WRD by wind

1.3.2 Project Process Description

Air quality impacts will be associated with four distinct phases namely: the construction phase, the operational phase with opencast mining operations and plant/processing operations, and the closure phase and post-closure phase. During the operational phase all the same sources are expected as what is currently taking place but with a different layout/locality of some of operations. The closure and post-closure phases may only occur upon cessation of all the Kalgold operations. Due to the lack of detailed information and the relatively short duration of most of the activities associated with the construction, closure and post-closure phases the assessment of impacts for these phases will be done qualitatively.

1.3.2.1 Construction Phase

The construction phase will involve the establishment of the new production plant facility and RoM Pad to the south of the Watertank pit and upgrades to existing support infrastructure . The potential construction activities that will take place during the construction phase and the associated pollutants are included in Table 1. It must be kept in mind that during the project construction phase the current Kalgold operations will continue to take place.

Table 1: Potential construction activities resulting in emissions and the associated pollutants

Activity	Associated pollutants
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	Particulate matter (PM)[(a)] and volatile organic compounds (VOCs)
Drilling and blasting	SO_2, NO_x, CO, carbon dioxide (CO_2)[(b)], methane (CH_4)[(b)], nitrous oxide (N_2O)[(b)], and particulate matter (PM)
Clearing, grubbing and other earth moving activities	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Stockpiling topsoil and sub-soil	Mostly PM
Foundation excavations	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Establishment or expansion of access roads (scraping and grading)	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Digging of foundations and trenches	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Delivery of materials, storage and handling of material such as sand, rock, cement, chemical additives, etc.	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)

Activity	Associated pollutants
General building/construction activities including, amongst others: mixing of concrete; operation of construction vehicles and machinery; refuelling of machinery; civil, mechanical and electrical works; painting; grinding; welding; etc	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Handling, storage and disposal of non-hazardous and hazardous waste	PM; gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O), potential for dioxin and furans from blasting cassettes incineration (burning grounds)

Notes: (a) PM comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. TSP represents the coarse fraction >10 µm, with particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$). TSP is associated with dustfall (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.
(b) carbon dioxide, methane and nitrous oxide are greenhouse gases (GHG).

1.3.2.2 Operational phase

According to the mine design, the mining method will be opencast mining with a truck and shovel operation with possible drilling and blasting. The Life of Mine (LoM) is estimated at 13 years. A 2019 production plan by Harmony estimate the current production at the mine to be 135 195 tpm with a 2:3 ore to waste ratio. The mine has a potential optimum performance of 136 000 tpm but the agreed three-year plan was 127 500 tpm at Harmony Kalgold operation. It is proposed to increase the Kalgold operations rate to 300 000 tpm. The proposed future operations and associated pollutants are listed in Table 2.

Table 2: Proposed future operational activities resulting in emissions and the associated pollutants

Activity	Associated pollutants
Mining Operations	
Stripping and stockpiling of topsoil	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Drilling and blasting of ore and waste	PM, SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O
Excavation of ore and waste	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Loading of trucks with ore and waste	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Transportation of ore, waste and topsoil	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)

Activity	Associated pollutants
Storage of materials at stockpiles and WRD (wind erosion)	PM
Stockpile and WRD management using front-end-loaders (FELs) and bulldozers	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Grading of roads	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Processing Operations	
Mobile equipment operating within the plan area	PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
ROM transfer point and reclaim system	PM
Primary ROM crushing and screening	PM
Transfer conveyor to overland conveyor to plant ROM stockpile	PM
ROM feed conveyor	PM
Elution, drying (using kilns) and smelting	PM, SO_2, NO_x, CO, CO_2, Cl_2, HCl, HF, and NH_3
TSF (wind erosion)	PM
Stockpiling of final product and transportation	Mostly PM but also gaseous emissions from equipment exhausts (including but not limited to SO_2, NOx, CO, VOCs, CO_2, CH_4, and N_2O)
Assay laboratory	PM, SO_2, NO_x, CO, CO_2, Cl_2, HCl, HF, NH_3, and Pb

1.3.2.3 Decommissioning/Closure and Post-closure Phases

During decommissioning/closure, bulk earthworks and demolition activities are expected. Very little information regarding the decommissioning phase was available for consideration, from an air quality perspective it is, however, likely to be similar in character and impact to the construction phase. Post-closure phase operations are expected to be periodic site inspections which will have insignificant impacts and no impacts are expected from final landforms provided the rehabilitation is successful.

1.4 Air Quality Study Methodology

The air quality study includes both baseline and predicted impact assessment. The baseline characterisation included the following enabling tasks:

- Identification of existing sources of emission and characterisation of ambient air quality and dustfall levels in the study area;

- A partly quantitative assessment of baseline air quality was possible due to the availability of limited ambient data from the Harmony monitoring station.

- It is important to have a good understanding of the meteorological parameters governing the rate and extent of dilution and transportation of air pollutants that are generated by the proposed operations. The primary meteorological parameters to obtain from measurement include wind speed, wind direction and ambient temperature. Other meteorological parameters that influence the air concentration levels include rainfall (washout) and a measure of atmospheric stability. The latter quantities are normally not measured and are derived from other parameters such as the vertical height temperature difference or the standard deviation of wind direction. The depth of the atmosphere in which the pollutants can mix is similarly derived from other meteorological parameters by means of mathematical parameterisations.
  - The first step was therefore to source any on-site or near-site meteorological observations. As a minimum this data had to include hourly averaged wind speed, wind direction and ambient air temperature.
  - The at least on year of on-site weather station data with the minimum parameters required was available but the data availability is insufficient for dispersion modelling and WRF (Weather Research and Forecasting) modelled data will be acquired for the next phase of the assessment. The on-site data for the period August 2019 to September 2020 was used to construct wind roses, general climatic information such as diurnal temperature variations, atmospheric stability estimates included in this report.
- Potential air pollution sensitive receptors within the study area were identified and georeferenced for detailed analysis of the impact assessment calculations.

The impact assessment included the tasks below:

- The dispersion modelling executed as per *The Regulations Regarding Air Dispersion Modelling* (GN 533 in Gazette No 37804, 11 July 2014). Three *Levels of Assessment* are defined in the Regulations. A Level 2 assessment approach was deemed adequate.
- Preparation of the model control options and input files for the AERMOD dispersion modelling suite. This includes the compilation of:
  - terrain information (topography, land use (albedo, bowen ratio and surface roughness);
  - source layout; and
  - grid and receptor definitions.
- Preparation of hourly average meteorological data for the wind field and atmospheric dispersion model.
- Preparation of an emissions inventory for the existing and proposed operations, including fugitive sources[1] and point sources. The emission rates for the existing stacks will be based on isokinetic sampling measurements and Minimum Emission Standards (MES), and emission factors will be used for the fugitive sources.
- For the study, simulations will be conducted using the AERMOD dispersion modelling suite, which allows for the calculations of the ambient inhalable concentrations ($PM_{2.5}$, PM_{10}, SO_2, NO_x and CO) and dust fallout. The hourly, daily and annual concentrations and total daily dust deposition will be calculated.

[1] 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).

Dispersion modelling was completed for all operations associated with the proposed operations as well as the existing Kalgold operations.

- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications will be used to assess the impact and recommend additional emission controls, mitigation measures and air quality management plans to maintain the impact of air pollution to acceptable limits in the study area. The model results will be analysed against the National Ambient Air Quality Standards (NAAQS) and National Dust Control Regulations (NDCR).
- Determine the air quality impact significance resulting using the EIMS methodology.
- Recommended mitigation, management and monitoring measures to minimise impacts and/or optimise benefits associated with the project were determined based on the simulation results.

1.5 Managing Uncertainties

This portion of the study and the impact assessment portion is and will be based on a few assumptions and is subject to certain limitations, which should be borne in mind when considering information presented in this report and the following report. The validity of the findings of the study is not expected to be affected by these assumptions and limitations:

1. All project information was provided by EIMS; it is assumed that all this information is the most recent data and correct.
2. Meteorology:
    a. Data was available from one on-site weather station. The data availability was insufficient for dispersion modelling and three years (2018 - 2020) of WRF (Weather Research and Forecasting) modelled data was be acquired and used in the dispersion modelling.
    b. The National Code of Practice for Air Dispersion Modelling described in the Regulations regarding air dispersion modelling prescribes the use of a minimum of one year of on-site data or at least three years of appropriate off-site data for use in Level 2 and Level 3 assessments. It also states that the meteorological data must be for a period no older than five years to the year of assessment. The WRF dataset period is within the timeframe recommended by the National Code of Practice for Air Dispersion Modelling, that is three years of data less than five years old.
3. Emissions:
    a. The impact assessment was limited to the pollutants of concern (those included in Section 2). Some of these pollutants are regulated under NAAQS and considered key pollutants released by the operations associated with the future operations.
    b. The quantification of sources of emission will be restricted to the Kalgold operations (current and future). Other existing sources of emission within the area including farming activities, domestic fires, biomass burning, vehicle exhaust emissions and dust entrained by vehicles on public roads will not include as part of the emissions inventory and simulations. Without detailed proposed (for when this project will be operational) operational data for other companies' mining and processing operations as well as estimated future vehicle data for public roads it is difficult to quantify these sources for the period of the proposed project operations. It is difficult to predict the contribution of the domestic and natural fires and farming sources to air quality during the

period of the proposed project operations due to variability of these operations with regards to locality, spatial extent and duration.

4. Greenhouse gases (GHG):
    a. Emissions estimation and modelling is not included in the scope of work.
5. Dispersion Simulations:
    a. For the operations, all significant fugitive sources were simulated with the current mitigation measures applied and the most recent average stack emissions will be included in the dispersion simulation task.
    b. It will be assumed that all NO_x emitted is converted to NO_2.
6. Assessment of impacts:
    a. The health risk assessment was limited to the screening of ambient air concentrations against NAAQS and applicable international legal guidelines and limits and does not include a detailed human health risk assessment. Human health risk can occur due to exposures through inhalation, ingestion and dermal contact. The scope of the study was confined to the quantification of impacts due to exposures via the inhalation pathway only.
    b. A human health risk and nuisance and environmental impact screening assessment for the operational phase was based on dispersion simulation results.
    c. The EA process will be completed by EIMS. For this reason, the expected impact significance of the operations was determined based on the EIMS impact significance methodology.

2 REGULATORY REQUIREMENTS AND IMPACT ASSESSMENT CRITERIA

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

Emission standards are generally provided for point sources, 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 legislation from NEMA and National Environmental Management: Air Quality Act (No. 39 of 2004) (NEM:AQA) (Republic of South Africa, 2005). A portion of the NEMA EIA Regulations, the Listed Activities and MES Regulations, Atmospheric Emissions Licence (AEL) Regulations, Atmospheric Impact Report (AIR) Regulations, National Atmospheric Emission Reporting Regulations, Regulations regarding Air Dispersion Modelling, NAAQS and NDCR are relevant to the Project and are discussed below.

2.1 NEMA EIA Regulations

In terms of the NEMA EIA Regulations (Republic of South Africa, 2014) (as amended by GN 326 of 7 April 2017; GN 706 of 13 July 2018 and GN 320 of 20 March 2020) a specialist report must contain certain information (see table on page iv for full list of information required). A site environmental sensitivity screening must also be conducted for the specialist assessment using the Department screening tool to determine among other information the development incentives, restrictions, exclusions or prohibitions that apply to the proposed development site as well as the most environmental sensitive features on the site based on the site sensitivity screening results for the application classification that was selected. Based on the site sensitivity screening the only requirement is that the next phase report fulfils the Appendix 6 Specialist Report requirements.

2.2 Listed Activities

Atmospheric emissions which have or may cause a significant detrimental effect on the environment, human health and social welfare, economic conditions, ecological conditions or cultural heritage. The list of activities and associated minimum emission standards were established in March 2010 (Republic of South Africa, 2010) and the updated list of activities and associated minimum emission standards were published in 2013 (Republic of South Africa, 2013). The Department of Environmental Affairs (DEA) now the Department of Forestry, Fisheries and Environment (DFFE) published amendments to certain categories in June 2015 (Republic of South Africa, 2015), and further amendments were made in October 2018 (Republic of South Africa, 2018). In March 2020, the minister of DFFE published amendments to Category 1 (Republic of South Africa, 2020). The existing and proposed operations on-site will fall under two listed activities and require an AEL thus national MES, AELs and AIRs are discussed in this section.

2.2.1 Emission Standards

The future operations will be considered a listed activity under Section 21 of the NEM:AQA. The current Kalgold AEL (no. NWPG/ KALGOLD/AEL 4.17 /OCT 2019) states that the facility is licenced for the listed activity category 4, subcategory 4.17. It is however likely that listed activity category 4, subcategory 4.1 will need to be added to the AEL when undertaking the AEL variation or new application. The MES and special arrangements for these activities are included in Table 3 and Table 4. As of 1 April 2020, all plants (whether categorised as existing or new) were required to comply with the new plant standards unless the operator had received approval for an application submitted in terms of postponement or suspension of the compliance timeframes.

Table 3: MES for subcategory 4.1 listed activities, drying and calcining

Description:	Drying and calcining of mineral solids including ore		
Application:	Facilities with capacity more than 100 tonnes/month product		
Substance or mixture of substance:		Plant status[a]	mg/Nm³ under normal conditions of 273 K and 101.3 kPa
Common name	Chemical symbol		
Particulate matter	n/a	New	50
Sulfur dioxide	SO_2	New	1 000
Oxides of nitrogen	NO_x expressed as NO_2	New	500

Table 4: MES for subcategory 4.17 precious and base metal production and refining

Description:	The production or processing of precious and associated base metals through chemical treatment		
Application:	All installations		
Substance or mixture of substance:		Plant status[a]	mg/Nm³ under normal conditions of 273 K and 101.3 kPa
Common name	Chemical symbol		
Particulate matter	n/a	New	50
Chlorine	Cl_2	New	50
Sulfur dioxide	SO_2	New	400
Hydrogen chloride	HCl	New	30
Hydrogen fluoride	HF	New	30
Ammonia	NH_3	New	100
Oxides of nitrogen	NO_x expressed as NO_2	New	300
The following special arrangement shall apply – Thermal treatment standard is not applicable to precious and base metal refining processes.			

2.2.2 Atmospheric Emission Licence

In terms of the NEM:AQA, no person may conduct an activity listed on the national list anywhere in the Republic or listed on a list applicable in a province anywhere in that province without a Provisional Atmospheric Emission Licence (PAEL) or an AEL. The Kalgold operations has an existing full AEL (no. NWPG/ KALGOLD/AEL 4.17 /OCT 2019) in respect of the listed activity category 4, subcategory 4.17; of the Section 21 to NEM:AQA. The AEL was issued based on the information provided in the application dated 04 September 2019 and is valid for a period of five (5) years from 14 October 2019. AEL holders must operate according to the conditions provided within the signed AEL. The proposed changes will require application for a variation AEL. An AEL must include all sources of emission, not only those considered listed activities. In terms of the AEL application, the **applicant** should take into account the following sections of NEM:AQA:

37. Application for atmospheric emission licences:

(1) A person must apply for an AEL by lodging with the licensing authority of the area in which the listed activity is to be carried out, an application in the form required.

(2) An application for an AEL must be accompanied by –

- *(a) The prescribed processing fee; and*
- *(b) Such documentation and information as may be required by the licensing authority.*

38. Procedure for licence applications:

(1) The licensing authority –

- *(a) May, to the extent that is reasonable to do so, require the applicant, at the applicant's expense, to obtain and provide it by a given date with other information contained in or submitted in connection with the application;*
- *(b) May conduct its own investigation on the likely effect of the proposed license on air quality;*
- *(c) May invite written comments from any organ of state which has an interest in the matter; and*
- *(d) Must afford the applicant an opportunity to make representations on any adverse statements or objections to the application.*

(2) Section 24 of the NEMA and section 22 of the Environmental Conservation Act apply to all applications for atmospheric emission licenses, and both an applicant and the licensing authority must comply with those sections and any applicable notice issued or regulations made in relation to those sections.

(3) –

- *(a) An applicant must take appropriate steps to bring the application to the attention of relevant organs of state, interested persons and the public.*
- *(b) Such steps must include the publication of a notice in at least two newspapers circulating the area in which the listed activity is applied for is or is to be carried out and must-*
  - *(i) Describe the nature and purpose of the license applied for;*
  - *(ii) Give particulars of the listed activity, including the place where it is to be carried out;*
  - *(iii) State a reasonable period within which written representations on or objections to the application may be submitted and the address or place where it must be submitted; and*
  - *(iv) Contain such other particulars as the licensing authority may require.*

2.2.3 Atmospheric Impact Report

Under section 30 of NEM:AQA, an air quality officer may require any person to submit an AIR in the format prescribed if a review of provisional AEL or AEL is undertaken. The format of the AIR is stipulated in the Regulations Prescribing the Format of the Atmospheric Impact Report, published by the DEA now the DFFE in 2013 (Republic of South Africa, 2013) and with amendments published in 2015 (Republic of South Africa, 2015).

2.3 National Atmospheric Emission Reporting Regulations (NAERR)

The National Atmospheric Emission Reporting Regulations (NAERR) was published in 2015 by the Minister of Environmental Affairs (Republic of South Africa, 2015). The regulation aims to standardise the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS), towards the compilation of atmospheric emission inventories. The NAEIS is a component of the South African Air Quality Information System (SAAQIS). Its objective is to provide all stakeholders with relevant, up to date and accurate information on South Africa's emissions profile for informed decision making.

Annexure 1 of the NAERR classifies **mines** (holders of a mining right or permit in terms of the MPRDA as a data provider under **Group C**. **Listed Activities** as published in terms of Section 21(1) of the NEM:AQA falls under **Group A**.

As per the regulations, Harmony and/or their data provider should be registered on the NAEIS system as they are currently operating. Data providers must inform the relevant authority of changes if there are any:

- Change in registration details;
- Transfer of ownership; or
- Activities being discontinued.

A data provider must submit the required information for the preceding calendar year to the NAEIS by 31 March of each year. Records of data submitted must be kept for a period of 5 years and must be made available for inspection by the relevant authority. The relevant authority must request a data provider, in writing to verify the information submitted if the information is incomplete or incorrect. The data provider then has 60 days to verify the information. If the verified information is incorrect or incomplete the relevant authority must instruct a data provider, in writing, to submit supporting documentation prepared by an independent person. The relevant authority cannot be held liable for cost of the verification of data. A person guilty of an offence in terms of section 13 of these regulations is liable for penalties.

2.3.1 Greenhouse Gas Emissions

Regulations pertaining to GHG reporting using the NAEIS were published in 2017 (Republic of South Africa, 2017) (as amended by GN R994, 11 September 2020). The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

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

The South African Greenhouse Gas Emission Reporting System (SAGERS) web-based monitoring and reporting system will be used to collect GHG information in a standard format for comparison and analyses. The system forms part of the national atmospheric emission inventory component of South African Atmospheric Emission Licensing and Inventory Portal (SAAELIP). The site operations qualify to report their GHG emissions to SAGERS. The DFFE is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the Intergovernmental Panel on Climate Change's (IPCC) default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors. Technical guidelines for GHG emission estimation have been issued. Also, the Carbon Tax Act (No 15 of 2019) (Republic of South Africa, 2019) includes details on the imposition of a tax on the CO_2-equivalent (CO_2-e) of GHG emissions. Certain production processes indicated in Annexure A of the Declaration of Greenhouse Gases as Priority Pollutants (Republic of South Africa, 2017) with GHG in excess of 0.1 megatonnes (Mt), measured as CO_2-e, are required to submit a pollution prevention plan to the Minister for approval.

2.4 Regulations Regarding Air Dispersion Modelling

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

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

Three *Levels of Assessment* are defined in the Regulations. The three levels are:

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50 km)
- Level 3: require more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situation:
  - where a detailed understanding of air quality impacts, in time and space, is required;
  - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types & chemical transformations;
  - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
  - when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an air-shed; or,

- when assessing contaminants resulting from non-linear processes (e.g. deposition, ground level ozone [O_3], particulate formation, visibility).

The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Accordingly, Level 2 was deemed appropriate for this study:

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

The Regulations have been applied in undertaking this study.

2.5 National Ambient Air Quality Standards (NAAQS)

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. These generally include PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, Pb, and O_3. The state of the air document published by the Department of Environmental Affairs (DEA), now DFFE says: "Air quality limits and thresholds are fundamental to effective air quality management. Ambient air quality limits serve to indicate what levels of exposure to pollution are generally safe for most people, including the very young and the elderly, over their lifetimes."[2]

The initial NAAQS were published for comment in the Government Gazette on 9 June 2007. The revised NAAQS were subsequently published for comment in the Government Gazette on the 13th of March 2009 (Republic of South Africa, 2009). The final revised NAAQS were published in the Government Gazette on the 24th of December 2009 (GN 1210, GG 32816) and additional standards for $PM_{2.5}$ were published on the 29th June 2012 (GN 486, GG 35463) (Republic of South Africa, 2012). NAAQS for the pollutants assessed in this study are listed in Table 5.

Table 5: National Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration (µg/m³)	Permitted Frequency of Exceedance	Compliance Date
PM_{10}	24-hour	75	4	Currently enforceable
	1 year	40	-	Currently enforceable
$PM_{2.5}$	24-hour	40	4	1 January 2016 till 31 December 2029 (currently enforceable)
	24-hour	25	4	1 January 2030
	1 year	20	-	1 January 2016 till 31 December 2029 (currently enforceable)
	1 year	15	-	1 January 2030

[2] https://www.environment.gov.za/sites/default/files/docs/stateofair_executive_iaiquality_standardsonjectives.pdf

Pollutant	Averaging Period	Concentration (µg/m³)	Permitted Frequency of Exceedance	Compliance Date
SO_2	10-minutes	500	526	Currently enforceable
	1-hour	350	88	Currently enforceable
	24-hour	125	4	Currently enforceable
	1 year	50	-	Currently enforceable
NO_2	1-hour	200	88	Currently enforceable
	1 year	40	-	Currently enforceable
CO	1-hour	30 000	88	Currently enforceable
	8-hour	10 000	11	Currently enforceable
Pb	1 year	0.5	-	Currently enforceable

2.6 International Health Criteria and Unit Risk Factors

Air quality screening levels for non-criteria pollutants are published by various sources. These sources include:

- World Health Organization (WHO) guideline values (GVs) for non-carcinogens,
- Inhalation reference concentrations (RfCs) and Unit Risk Factors (URFs) published by the US EPA in its Integrated Risk Information System (IRIS),
- Reference exposure levels (RELs) and Cancer Potency Values (CPVs) published by the Californian Office of Environmental Health Hazard Assessment (OEHHA) department of the California Environmental Protection Agency (CALEPA),
- Minimal risk levels (MRLs) issued by the US Federal Agency for Toxic Substances and Disease Registry (ATSDR),
- Inhalation reference concentrations (RfCs) published by the US EPA Superfund Program as the Provisional Peer-Reviewed Toxicity Values (PPRTVs), and
- Effect screening levels (ESLs) published by the Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division (TARA).

The most stringent non-carcinogenic exposure thresholds for pollutants of interest in the current study will be used; however, other thresholds are also given in Table 6. It should be noted that these screening criteria are guidelines only and are not a legal requirement.

Table 6: Proposed non-carcinogenic exposure thresholds for pollutants of interest for this operation

Pollutant	Averaging Period	Selected Criteria (µg/m³)	Source
Cl_2	Acute	170	ATSDR MRL
	Sub-chronic	5.8	ATSDR MRL
	Chronic	0.145	ATSDR MRL
HCl	Acute	2 100	OEHHA REL
	Sub-chronic	-	-
	Chronic	20	IRIS RfC
HF	Acute	16.4	OEHHA REL
	Sub-chronic	-	-
	Chronic	14	ATSDR MRL

Pollutant	Averaging Period	Selected Criteria (µg/m³)	Source
NH_3	Acute	180	TARA ESL
		1 180	ATSDR MRL
	Sub-chronic	100	PPRTV RfC
	Chronic	70	ATSDR MRL
		500	IRIS RfC
Diesel particulate matter (DPM)	Acute	-	-
	Sub-chronic	-	-
	Chronic	5	IRIS RfC

Notes: 1-hour averaging period results will be compared to acute criteria; 24-hour averaging period results will be compared to sub-chronic criteria; and 1-year (annual) averaging period results will be compared to chronic criteria.

Table 7: Proposed carcinogenic exposure thresholds for pollutants of interest for this operation

Pollutant	Unit Risk Factor/Cancer Potency Value $(\mu g/m^3)^{-1}$	Source
Lead and compounds	0.000012	OEHHA CPV
DPM	0.0003	OEHHA CPV

The identification of an acceptable cancer risk level has been debated for many years and it possibly will continue as societal norms and values change. Some people would easily accept higher risks than others, even if it were not within their own control; others prefer to take very low risks. An acceptable risk is a question of societal acceptance and will therefore vary from society to society. Despite the difficulty to provide a definitive "acceptable risk level", the estimation of a risk associated with an activity provides the means for a comparison of the activity to other everyday hazards, and therefore allowing risk-management policy decisions. Technical risk assessments seldom set the regulatory agenda because of the different ways in which the non-technical public perceives risks. Consequently, science does not directly provide an answer to the question.

Whilst it is perhaps inappropriate to make a judgment about how much risk should be acceptable, through reviewing acceptable risk levels selected by other well-known organizations, the US EPA's application appears the most suitable, i.e. *"If the risk to the maximally exposed individual (MEI) is no more than 1 x 10^{-6}, then no further action is required. If not, the MEI risk must be reduced to no more than 1 x 10^{-4}, regardless of feasibility and cost, while protecting as many individuals as possible in the general population against risks exceeding 1 x 10^{-6}"*. Some authorities tend to avoid the specification of a single acceptable risk level. Instead, a "risk-ranking system" is preferred.

For example, the New York State Department of Health (NYSDOH) produced a qualitative ranking of cancer risk estimates, from very low to very high (Table 8). Therefore, if the qualitative descriptor was "low", then the excess lifetime cancer risk from that exposure is in the range of greater than one per million to less than one per ten thousand.

Table 8: Excess Lifetime Cancer Risk (as applied by NYSDOH)

Risk ratio	Qualitative Descriptor
Equal to or less than one in a million	Very low

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

2.7 National Dust Control Regulations (NDCR)

The NDCR were published on 1 November 2013 (GN R827 in GG 36974) (Republic of South Africa, 2013). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and non-residential areas. The standard for acceptable dustfall rates for residential and non-residential areas is set out in Table 9. According to these regulations the dustfall at the boundary or beyond the boundary of the premises where it originates cannot exceed 600 mg/m²- day in residential and light commercial areas; or 1 200 mg/m²-day in areas other than residential and light commercial areas. In addition to the dustfall limits, the NDCR prescribe monitoring procedures and reporting requirements. This will be based on the measuring reference method ASTM 01739 averaged over 30 days.

Table 9: Acceptable dustfall rates

Restriction Area	Dustfall Rate (D) (mg/m²-day, 30-day average)	Permitted Frequency of Exceeding Dustfall Rate
Residential	D < 600	Two within a year, not sequential months
Non-residential	600 < D < 1 200	Two within a year, not sequential months

Notes: The method to be used for measuring dustfall rate and the guideline for locating sampling points shall be ASTM D1739: 1970, or equivalent method approved by any internationally recognized body

2.8 Screening Criteria for Animals and Vegetation

2.8.1 Assessment Criteria for Vegetation Impacts from Dustfall Rates

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

2.8.2 Assessment Criteria for Vegetation Impacts from SO_2 and NO_2

The impact of emissions on surrounding vegetation was assessed by comparing the simulated annual SO_2 and NO_2 concentrations for each of the emission scenarios against the critical levels for vegetation as defined by the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Trans-boundary Air Pollution Limits (CLRTAP, 2015) (Table 10).

Table 10: Critical levels for SO_2 and NO_2 by vegetation type (CLRTAP, 2015)

Pollutant	Vegetation Type	Critical Level (µg/m³)	Time Period[a]
SO_2	Cyanobacterial lichens	10	Annual average
	Forest ecosystems (including understorey vegetation)	20	Annual average and half-year mean (winter)
	(Semi-) natural vegetation	20	Annual average and half-year mean (winter)
	Agricultural crops	30	Annual average and half-year mean (winter)
NO_2	All	30	Annual average and half-year mean (winter)
		75	Daily average

Notes: (a) For the purposes of mapping of critical levels and exceedances CLRTAP recommend using only the annual average, due to increased reliability of mapped and simulated data for the longer time period. It is also noted that long-term effects of NO_X are considered to be more significant than short-term effects (CLRTAP, 2015).

2.9 Nuisance Odour

2.9.1 Odour Thresholds

In the assessment of potential odour impacts use was made of the 50% recognition threshold odour concentrations (TOCs) published by Verschueren (1996) (Table 11), over a 60-minute period. The 50% recognition threshold is the concentration at which 50% of an odour panel defined the odour as being representative of the odorant being studied.

Table 11: 50% Recognition odour threshold concentrations

Pollutant	Threshold Odour Concentration (µg/m³)	Source
Ammonia (NH_3)	30	Verschueren (1996)

2.9.2 Odour Unit Calculation - Approach for Current Study

The New South Wales' (NSW) EPA draft approach (NSW EPA, 2006a), (NSW EPA, 2006b) was adopted for use in the current study largely given that it is comprehensively documented and more recently published. The approach can be summarised as follows:

- Calculation of the 1-hour average air pollutant concentrations;
- Recognition of the odour detection for a substance (Table 11);
- Calculation of odour units by calculating ratios between the 99.9th percentile 1-hour average air pollutant concentrations and the respective detection limits; and,
- The application of the odour performance criteria set out by the NSW EPA (Table 12).

A summary of the NSW EPA's odour performance criteria for various population densities is shown in Table 12.

Table 12: NSW EPA odour assessment criteria (NSW EPA, 2006a) (NSW EPA, 2006b)

Population of Affected Community	Odour Assessment Criteria (OU)
Rural single residence (≤2)	7

Population of Affected Community	Odour Assessment Criteria (OU)
~ 10	6
~ 30	5
~ 125	4
~ 500	3
Urban area (≥ 2000) and/or schools and hospitals	2

2.10 North West Environmental Implementation Plan

On 15 May 2015 the North West Environmental Implementation Plan 2015 – 2020 (EIP) was published in Extraordinary Provincial Gazette No. 7443 (North West Provincial Government, 2015). This document includes some information of the air quality within the North West Province and the main issues with regards to air quality in the region. Including the statement "Although the ambient air quality is good, regional circulation patterns are likely to impact the situation negatively. The main issue facing North West, however, is the air quality in settlements where domestic fuel is used as an energy source. Elevated levels of pollution in the immediate proximity of main pollution sources are also of concern. Poor air quality, especially as elevated levels of particulate matter, increases morbidity and mortality."

It also states that the North West Air Quality Management Plan (AQMP) is under review and the Bojanala Platinum District Municipality AQMP is in the implementation phase. The Municipal Provincial Air Quality Officers' Forum is an ongoing institution without a limited lifespan. In summary, it notes the following as needs to be undertaken to guarantee Air Quality Management:

- Enforcement of licence conditions and air quality standards;
- The enhancement of air quality management systems including monitoring and Governments' capacity to implement the systems and maintain the monitoring stations;
- Ensuring that monitoring data is fed through onto the SAAQIS;
- Public awareness of air quality in general (and likely the current situation within the area) through educational campaigns;
- Compilation and implementation of AQMPs; and
- In areas of poor air quality, to undertake health risk assessments.

3 DESCRIPTION OF THE RECEIVING ENVIRONMENT

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

- The identification of Air Quality Sensitive Receptors (AQSRs) from available maps;
- A study of the atmospheric dispersion potential of the area;
- The identification of existing sources of emissions in the study area; and
- The analysis of all available ambient air quality information/data.

3.1 Affected Environment

3.1.1.1 Air Quality Sensitive Receptors (AQSRs)

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

Nearby residential areas include Old Kraaipan (southeast), Setlagole (southwest) and Mareetsane (east). Aside from the residential areas, individual farmsteads near the expansion operations were identified as AQSRs and agricultural areas were identified as environmentally sensitive areas. Table 13 is a summary of the nearest farmsteads that may be influenced by air pollution emissions from the proposed Project. The surrounding land uses in the immediate vicinity of the Kalgold operations comprises of crop farming Emissions from vehicles travelling on public and private roads would also have implications on the ambient air quality of the area. Harmony conducts PM_{10} monitoring within the Kalgold permit area.

The nearest residential areas, individual farmsteads, dustfall sampling units and E-sampler locations in relation to the Kalgold permit area are shown in Figure 2.

Table 13: List of the nearest sensitive receptors

Sensitive Receptor ID	Sensitive Receptor Description	World Geodetic System (WGS 84) Unprojected Lat/Long		WGS 84 Universal Transverse Mercator (UTM) Zone 35 S		Distance from Site Boundary(km)	Direction from Site
		Longitude	Latitude	Easting (m)	Northing (m)		
R01	Farmstead	25.23152	-26.18991	323282.88	7102080.35	0.57	South
R02	Farmstead	25.21098	-26.17402	321205.97	7103812.57	1.42	South-west
R03	Farmstead	25.26321	-26.11359	326336.83	7110578.12	1.26	North-north-east
R04	Farmstead	25.24546	-26.07454	324503.95	7114879.70	5.00	North
R05	Farmstead	25.31348	-26.12076	331374.70	7109849.29	4.00	North-east
R06	Farmstead	25.32589	-26.17147	332688.42	7104248.94	4.72	East-south-east
R07	Farmstead	25.31043	-26.18452	331161.41	7102783.10	3.86	East-south-east
R08	Farmstead	25.27014	-26.15222	327086.82	7106307.92	0.51	East-north-east
R09	Farmstead	25.27640	-26.18993	327768.92	7102138.64	2.08	South-south-east

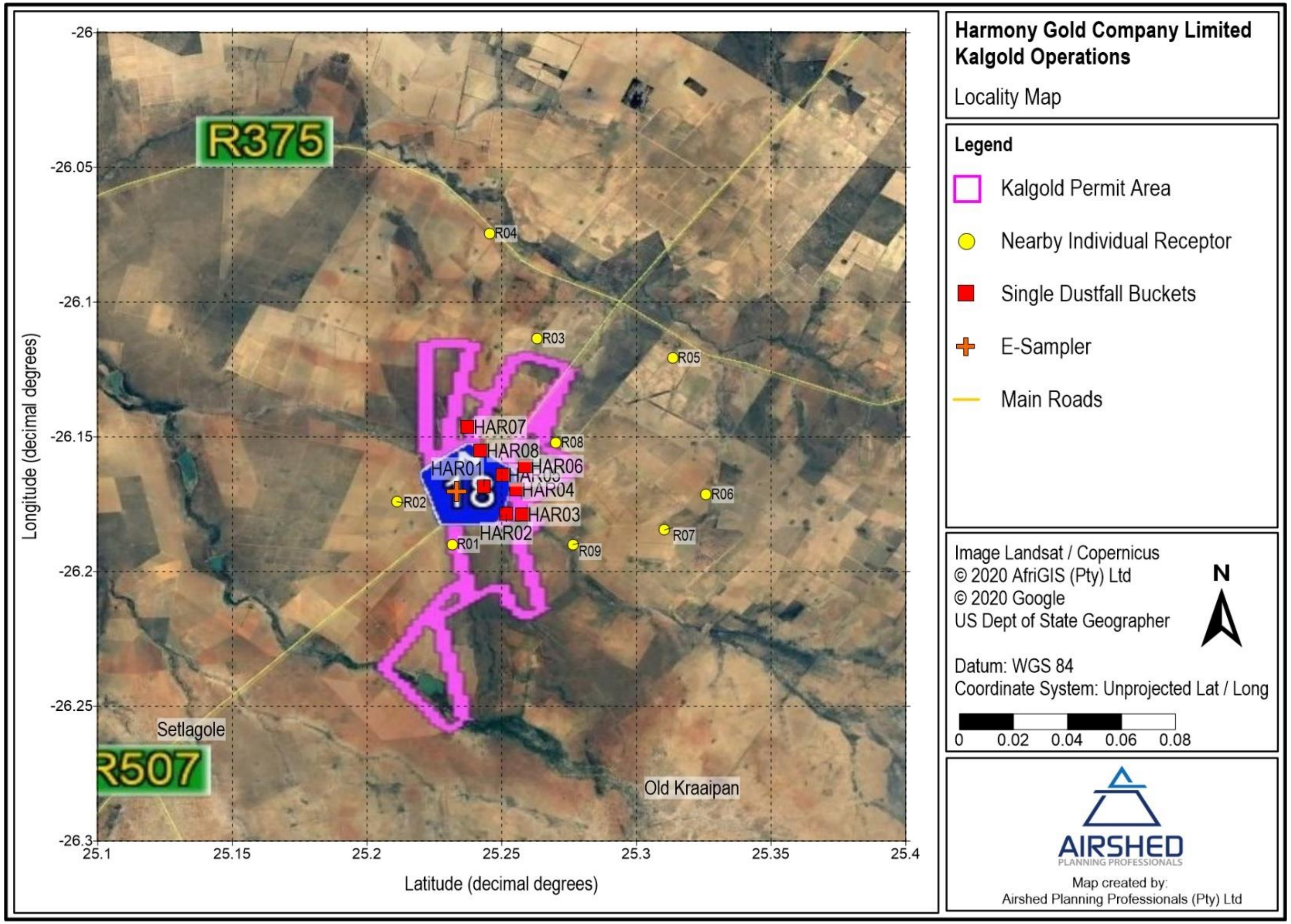


Figure 2: Locality map

3.1.1.2 Sensitivity Map

The EIMS sensitivity mapping categories and specialist knowledge/experience were used to determine sensitive environmental features within the locality map area. All feature/areas identified were assigned one of the following scores (if applicable), 0 (least concern), 1 (low), 2 (medium), 3 (high) or 99 (no-go) (Table 14).

Table 14: Sensitivity information

Preference for Proposed development	Preferable		Restricted		No-go
Sensitivity rating	Least concern	Low	Medium	High	Fatal flaw
Score	0	1	2	3	99
Description	The inherent feature status and sensitivity is already degraded. The proposed development will not affect the current status and/or may result in a positive impact. These features would be the preferred alternative for the project or infrastructure placement.	The proposed development will have not had a significant effect on the inherent feature status and sensitivity.	The proposed development will negatively influence the current status of the feature.	The proposed development will negatively significantly influence the current status of the feature.	The proposed development cannot legally or practically take place.

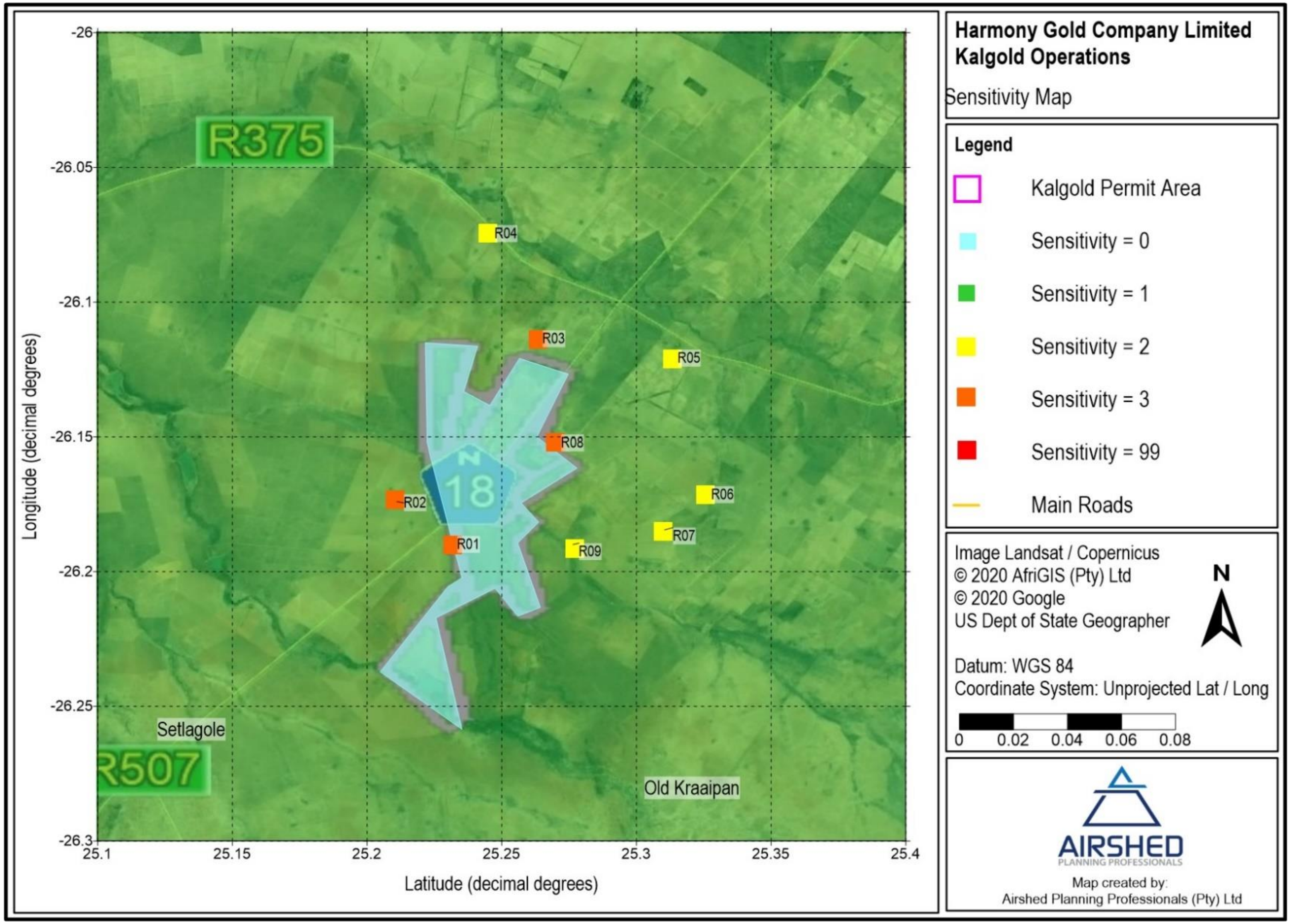


Figure 3: Sensitivity map

3.2 Atmospheric Dispersion Potential

Meteorological mechanisms direct the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. This dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution because of plume 'stretching'. The generation of mechanical turbulence is similarly a function of wind speed, in combination with surface roughness. The wind direction, and variability in wind direction, determines the general path pollutants will follow, and the extent of crosswind spreading. The pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Tiwary & Colls, 2010).

The spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich & Tyson, 1988). The atmospheric processes at macro- and meso-scales need therefore be considered in order to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic systems determining the macro-ventilation potential of the region may be provided based on the review of pertinent literature. These meso-scale systems may be investigated through the analysis of meteorological data observed for the region.

WRF data was used to quantify the atmospheric dispersion potential. A description of the wind field, temperature, precipitation, and atmospheric stability is provided in this section.

3.2.1 Local Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of wind speed, in combination with surface roughness (Tiwary & Colls, 2010).

Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 6 and 7 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. Calm conditions are periods when the wind speed was below 1 m/s.

The period wind field and diurnal variability in the wind field are shown in Figure 4.The wind field is dominated by winds from the north-north-east. These directions were associated with the strongest winds. The period average wind speed is 4.02 m/s with calm winds occurring 2.17% of the time. The day-time wind rose shows predominant northerly and north-north-easterly winds. The average wind speed during the day is 4.34 m/s with calm winds occurring 2.59% of the time. The night-time is characterised by a lower frequency of calm conditions (1.76%) and dominant winds originating from the north-north-east.

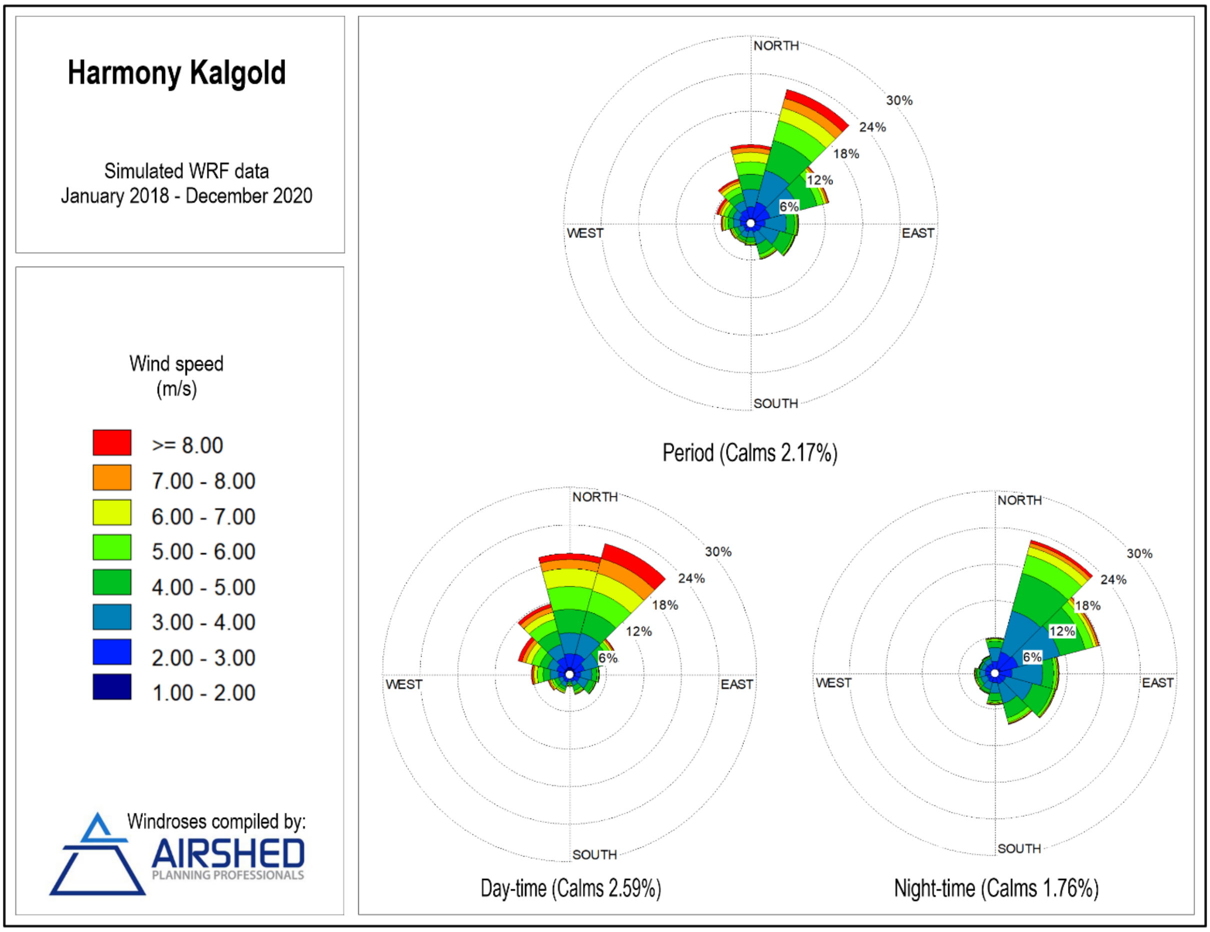


Figure 4: Period, day- and night-time wind roses for AERMET processed WRF data

3.2.2 Ambient Temperature

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

The monthly average and hourly maximum and minimum temperatures are provided in Table 15, and the diurnal temperature profile for the site is shown in Figure 5. Monthly average temperatures ranged between 11°C and 26°C. The highest temperature of (38°C) occurred in December and January and the lowest (-5°C) in June and July. In summer, daytime maximum temperatures are reached between 13:00 and 16:00. Ambient air temperature decreases to reach a minimum at around 06:00 i.e. just before sunrise.

Table 15: Monthly temperature summary for AERMET processed WRF data

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	13	12	9	6	-4	-5	-5	-4	-4	1	9	13

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	38	36	36	31	28	25	26	31	34	36	37	38
Average	26	25	23	20	15	11	11	14	18	22	25	25

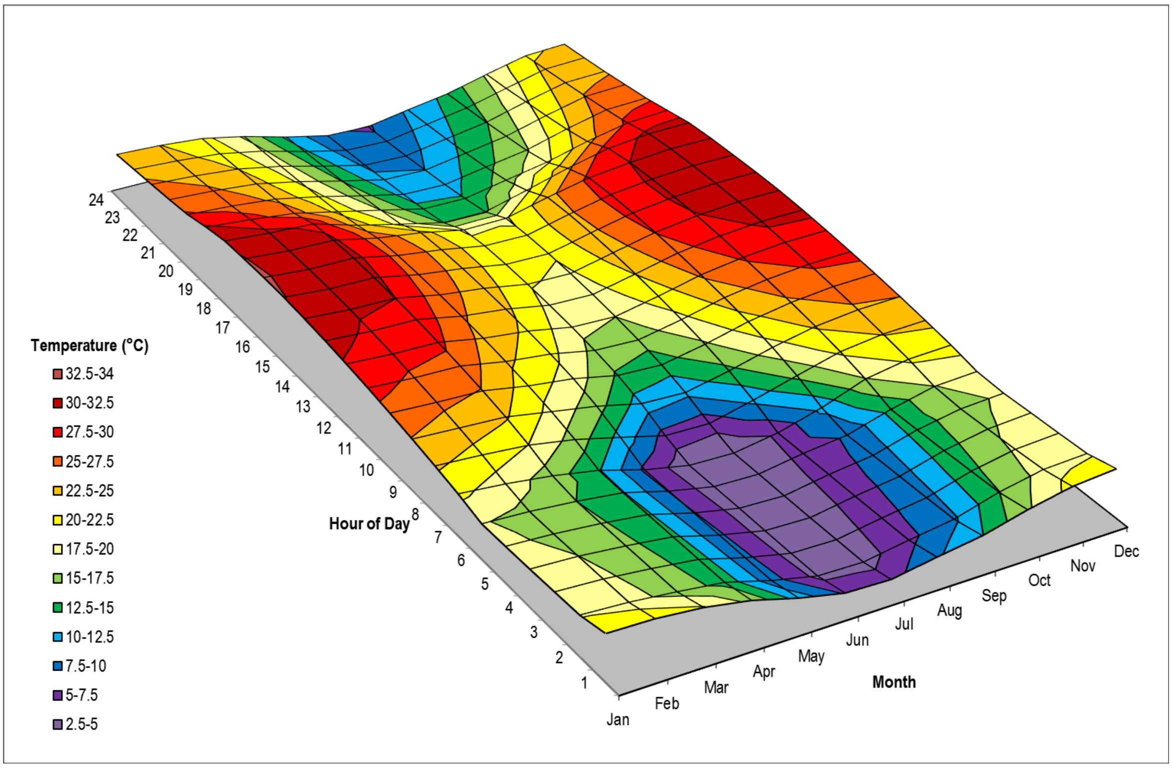


Figure 5: Diurnal temperature profile for the AERMET processed WRF data

3.2.3 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Obukhov length (often referred to as the Monin-Obukhov length).

The Obukhov length (L_{Mo}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.
Diurnal variation in atmospheric stability, as calculated from measured data, and described by the inverse Obukhov length and the boundary layer depth is provided in Figure 6. The highest concentrations for ground level, or near-

ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* (Figure 6(a)) and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning* (Figure 6(b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Figure 6(c)) (Tiwary & Colls, 2010). For ground level releases such as fugitive dust the highest ground level concentrations will occur during stable night-time conditions.

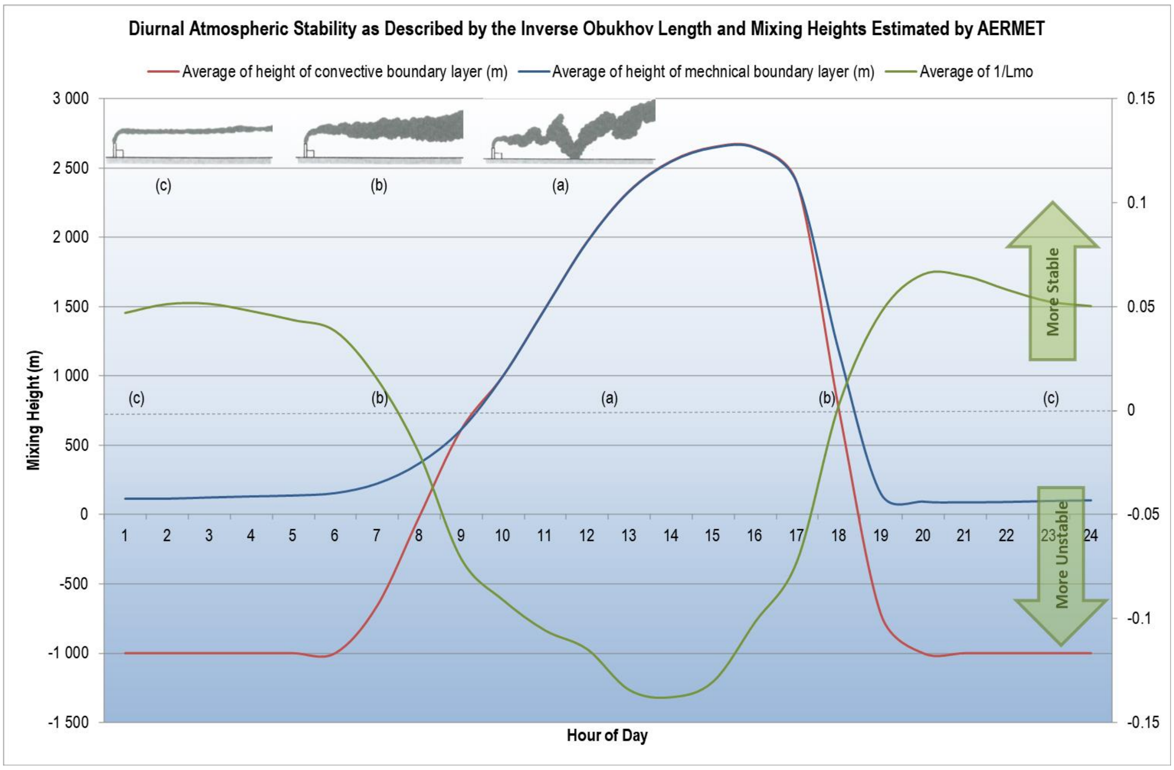
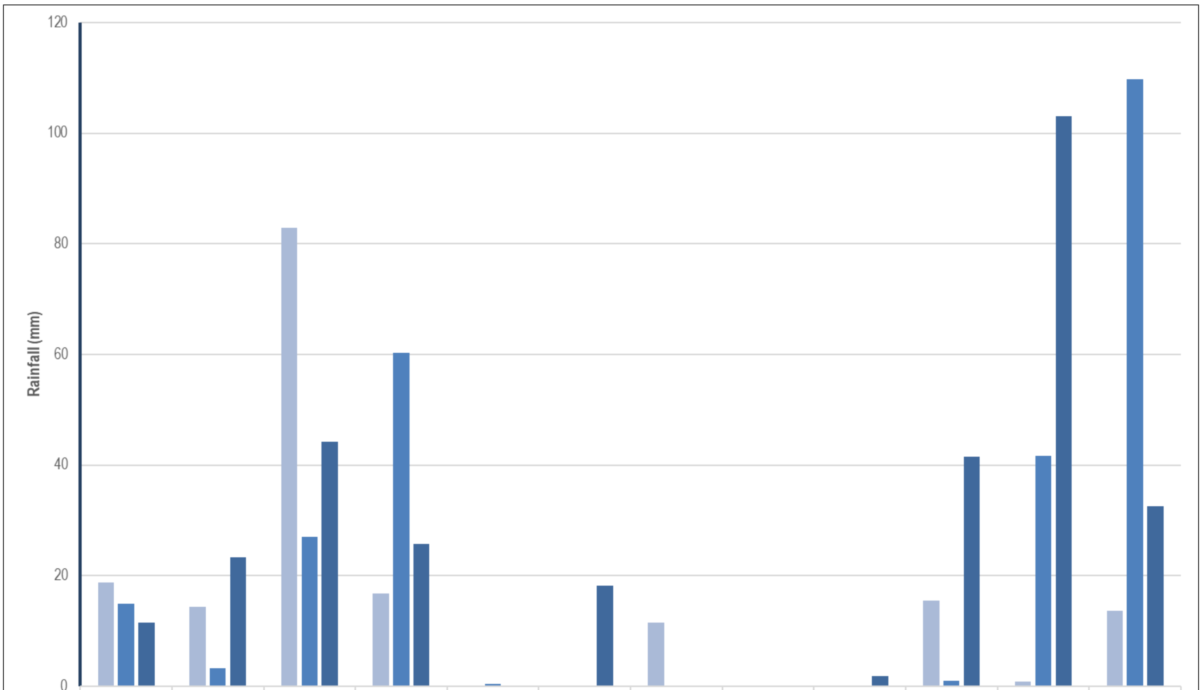


Figure 6: Atmospheric stability calculated from the AERMET processed WRF data

3.2.4 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Rainfall primarily is a result of storms and individual rainfall events can be intense. This creates an uneven rainfall distribution over the study area. Dust can be generated by strong winds that accompany storms. This dust generally occurs in areas with dry soils and sparse vegetation.

The monthly rainfall totals obtained from the hourly sequential WRF data for a location within the mining rights area is presented in Figure 7. The modelled average total annual rainfall from January 2018 to December 2020 is 245 mm. The modelled rainfall for 2018, 2019 and 2020 was 174 mm, 258 mm, and 302 mm, respectively. Rainfall in this area occurs mostly during the summer months although it also rains during late spring and early autumn while the winter months are dry.



	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2018	19	14	83	17	0	0	12	0	0	15	1	14
2019	15	3	27	60	0	0	0	0	0	1	42	110
2020	12	23	44	26	0	18	0	0	2	42	103	33

Figure 7: Rainfall and relative humidity from the AERMET processed WRF data

3.3 Existing Air Quality

3.3.1 Regional Sources

The area surrounding the Kalgold mine is a predominant agricultural zone consisting of beef, maize, sunflower and groundnut production. Kalgold lodged a rezoning application to change the land use on Spanover 552 IO from agricultural to mining. A Record of Decision was received on the 21st of August 2013 from Ratlou Local Municipality granting the rezoning of Spanover farm from agricultural land to mining area (WSP, 2019). Currently the area surrounding Kalgold is being used for crop and livestock farming. Local sources include wind erosion from exposed areas, fugitive dust from agricultural and mining operations, vehicle entrainment from roadways and veld burning.

3.3.1.1 Agricultural Operations

Kalgold mine is predominantly surrounded by agricultural land. Activities associated with agriculture such as land tillage, land clearing by prescribed burning, animal feeding operations, mineral fertilizer application, fuel burning, movement of livestock and manure management often lead to gaseous and particulate pollutants being emitted to the air. Pollutants usually associated with agricultural activities include NH_3, $PM_{2.5}$, PM_{10}, NO_x, VOCs, CH_4, N_2O, and CO_2. However, some of the activities are intermittent and only happen seasonally hence the impacts are usually less.

3.3.1.2 Domestic Fuel Burning

Many households burn fuel to meet all or a portion of their energy requirements. The main fuels with air pollution potentials used by households within the study region are gas, coal, wood and paraffin. Pollutants released from domestic fuels include CO, NO_2, SO_2, inhalable particulates and polycyclic aromatic hydrocarbons. Particulates are the dominant pollutant emitted from the burning of wood. Smoke from wood burning contains respirable particles that are small enough in diameter to enter and deposit in the lungs. These particles comprise a mixture of inorganic and organic substances including aromatic hydrocarbon compounds, trace metals, nitrates, and sulphates. Coal burning emits a large amount of gaseous and particulate pollutants including sulfur dioxide, heavy metals, total and respirable particulates including heavy metals and inorganic ash, carbon monoxide, polycyclic aromatic hydrocarbons, and benzo(a)pyrene. Polyaromatic hydrocarbons (PAHs) are recognised as carcinogens. Pollutants arising due to the combustion of wood include respirable particulates, nitrogen dioxide, carbon monoxide, polycyclic aromatic hydrocarbons, particulate benzo(a)pyrene and formaldehyde. The main pollutants emitted from the combustion of paraffin are NO_2, particulates carbon monoxide and polycyclic aromatic hydrocarbons. A diurnal and seasonal pattern is usually characteristic of domestic fuel burning. Early mornings, evenings and winter are associated with higher emissions due to a demand for cooking and space heating purposes.

3.3.1.3 Biomass Burning

The biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, crop-residue burning and wildfires (locally known as veld fires) may represent significant sources of combustion-related emissions.

The biomass burning is an incomplete combustion process (Cachier, 1992), with CO, CH_4, and NO_2 gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left is the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held et al, 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the proposed mining activity, long-range transported emissions from this source can be expected to impact on the air quality between the months August to October. It is impossible to control this source of atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

3.3.1.4 Vehicles Travelling on Public and Private Roads

Possible contributors to mobile combustion emissions include two main roads, namely, R375 and N18, as well as other access and haul roads surrounding the site. Neighbouring communities are likely to use these routes daily to access the mine and nearby amenities and commercial areas.

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere because of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include CO_2, CO, hydrocarbon compounds (HC), SO_2, NO_x, and PM. Secondary pollutants include NO_2, photochemical oxidants (e.g., O_3), HC, sulfur acid (H_2SO_4), sulfates (SO_4^+), nitric acid (HNO_3) and nitrate (NO_4^+) aerosols.

3.3.1.5 Other Fugitive Dust Sources

Fugitive dust emissions may occur because of vehicle entrained dust from local paved and unpaved roads, wind erosion from open areas and dust generated by agricultural activities (e.g., tilling) and mining. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads, and on the silt loading on the roadways.

3.4 Measured Pollutant Concentrations and Dustfall Rates

3.4.1 Measured Particulate Matter Concentrations

An E-Sampler of the Davis Vantage Pro type is located at the Kalgold premises and was used to collect PM_{10} data. The equipment can bin ambient PM into PM_1, $PM_{2.5}$, and PM_{10} fractions, but can only sample one size fraction at a time (simultaneous sampling of all size categories is not possible). PM_{10} represents the size fraction that would be deposited in and can cause damage to the lower airways and gas-exchange chamber of the lungs. However, only data for the ambient PM_{10} concentrations were available. There are extensive periods and frequent shorter periods of missing data which could indicate a faulty power back-up battery and numerous power failures. Based on the available data at the time of completing this report, the daily PM_{10} concentrations measured on-site are below the 24-hour NAAQS of 75 µg/m³; however, the data availability was low (17% in 2019, 29% in 2020, and 52% in 2021) (Figure 8).

3.4.2 Measured Dustfall Rates

In an assessment conducted by Digby Wells (Digby Wells Environmental, 2020), the dust monitoring was conducted following the American Standard Test Method ASTM 1739-98 (2017) in SANS1137:2019, using a single bucket container to capture dust by gravitational settling. The apparatus comprises a passive dust collector, a vertical pole supporting a 5-liter bucket, a surface area of 227 cm², positioned with the top 2 m above ground. The revised method specifies the use of a single bucket container, with a dry container instead of water-filled and a deeper aspect ratio (minimum H:D=2:1) (ASTM International, 2017).

Buckets were exposed for 30±2 days following the standard operating procedure specified in SANS1137:2019 from July 2019 to March 2020 and November 2020 to May 2021. For April 2020, May 2020, June 2020 and June 2021 the exposure period was 33 days which is not within the 30±2 days recommended. The dust monitoring locations are shown in Figure 2. The dustfall rates for the mentioned period are presented in Table 16 to Table 18. All of the sampling locations can be classified as non-residential areas. There was only one exceedance of the NDCR limit for non-residential areas in 2020 (KG7/HAR07 during April 2020) thus the sampled dustfall rates are in compliance with the NDCR that year; however, four months of data was not provided for 2020. There was only one exceedance of the NDCR limit for non-residential areas at two sites in 2021 (KG7/HAR07 during July 2021 and KG4/HAR04 during August 2021) thus the sampled dustfall rates are in compliance with the NDCR that year; however, only 8 of the 12 months data was available.

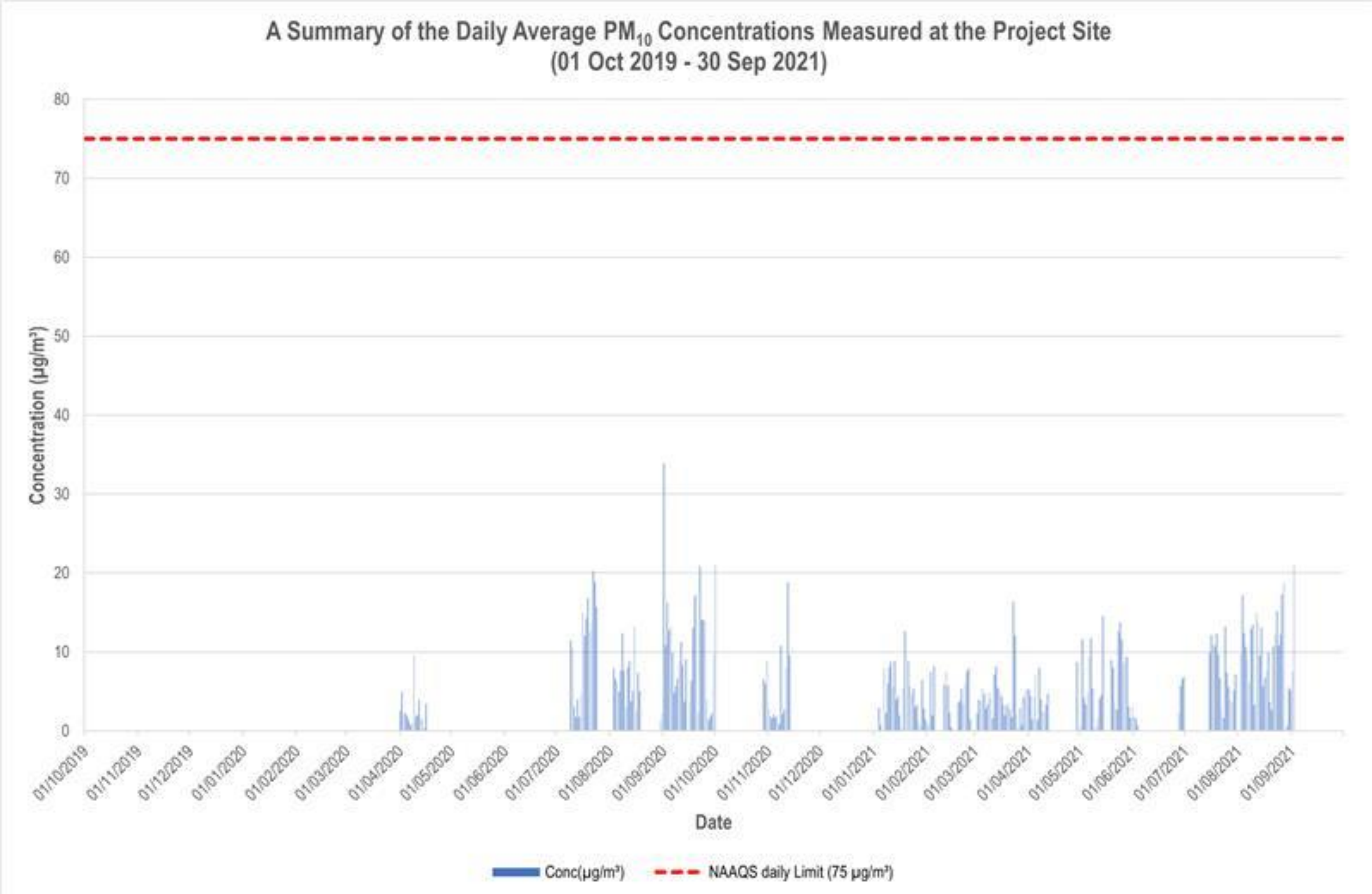


Figure 8: Measured PM_{10} concentrations

Table 16: Monthly dustfall rate per sampling location (July 2019 to December 2019)

ID	Description	Dustfall (mg/m²-day)					
		Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
KG1/HAR01	Core Yard	94	300	51	48	180	301
KG2/HAR02	Farm On Kraaipan Road	83	351	39	86	113	257
KG3/HAR03	Norman Farm	49	677	117	136	183	452
KG4/HAR04	Salvage Yard	189	576	354	380	553	835
KG5/HAR05	N18 Bridge	210	747	207	222	412	431
KG6/HAR06	Slimes Dam	73	322	109	59	148	331
KG7/HAR07	Windmill Area	3	284	297	893	498	271
KG8/HAR08	Major Drilling	328	655	228	1164	841	525

Table 17: Monthly dustfall rate per sampling location (January 2020 to December 2020)

ID	Description	Dustfall (mg/m²-day)											
		Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20
KG1/HAR01	Core Yard	458	66	137	683	84	116					282	171
KG2/HAR02	Farm On Kraaipan Road	221	65	120	283	27	111					169	290
KG3/HAR03	Norman Farm	133	21	155	324	21	30					153	250
KG4/HAR04	Salvage Yard	268	61	172	558	192	170					749	677
KG5/HAR05	N18 Bridge	434	279	191	370	222	194					751	371
KG6/HAR06	Slimes Dam	210	553	83	442	47	119					190	319
KG7/HAR07	Windmill Area	262	178	94	217	1 573	54					337	213

ID	Description	Dustfall (mg/m²-day)											
		Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20
KG8/HAR08	Major Drilling	269	231	121	323	148	459					387	434

Table 18: Monthly dustfall rate per sampling location (January 2021 to August 2021)

ID	Description	Dustfall (mg/m²-day)							
		Jan-21	Feb-21	Mar-20	Apr-21	May-21	Jun-21	Jul-21	Aug-21
KG1/HAR01	Core Yard	210	85	203	178	75	230	248	369
KG2/HAR02	Farm On Kraaipan Road	132	68	157	102	61	111	113	473
KG3/HAR03	Norman Farm	523	192	141	63	40	88	81	294
KG4/HAR04	Salvage Yard	304	232	620	329	319	518	434	1318
KG5/HAR05	N18 Bridge	537	360	480	338	415	471	543	551
KG6/HAR06	Slimes Dam	439	62	381	123	95	207	65	194
KG7/HAR07	Windmill Area	186	66	99	104	101	82	106	213
KG8/HAR08	Major Drilling	590	335	547	574	610	840	1505	1199

3.5 Simulated Pollutant Concentrations and Dustfall Rates for the Kalgold Current Operations Only

3.5.1 2014 Study

3.5.1.1 Simulated Pollutant Concentrations

A 2014 study conducted by Digby Wells (Digby Wells Environmental, 2014), provided simulated $PM_{2.5}$ and PM_{10} results over a 20km by 20km modelling domain using the US EPA recommended AERMOD modelling system. The model was set up to run the worst-case scenario without mitigation. The isopleth plot showed highest daily values for PM_{10} generated by the proposed infrastructures and other activities associated with the Optimisation project on Spanover farm portion to reach a ground level concentration of 139 µg/m³ and minimum of 1.7 µg/m³. The predicted concentrations exceed the current daily limit of 75 µg/m³. The main contributor to these concentrations was the crusher. The levels at the discrete receptors were all within the recommended limit with no exceedances, as emissions were in exceedance only around the proposed crushing area. The least contributor to the ambient air quality was the heap leach with a predicted daily highest ground level concentration of 10 µg/m³. The predicted highest annual values for PM_{10} reached ground level concentration of 20.2 µg/m³ and minimum of 0.2 µg/m³ falling within the annual NAAQS of 40 µg/m³. Evidence suggests that there were no exceedances at the sensitive receptors.

Similarly, simulated $PM_{2.5}$ concentrations were represented as isopleth plots showing highest daily ground level concentrations. The highest calculated value was 37.6 µg/m³ with the lowest value being 0.4 µg/m³. The simulated daily ambient $PM_{2.5}$ concentrations are not in exceedance of the current NAAQS limit value of 40 µg/m³ but are higher than 25 µg/m³ applicable from 1 January 2030. The simulated maximum daily values for $PM_{2.5}$ were assessed for haul roads, crusher, heap leach, low grade stockpiles and waste rock dump without mitigation measures. The main contributor of these concentrations is the crusher, and the least is the heap leach contributing only 2 µg/m³.Simulated ground level concentrations at the discrete receptors were low and below the NAAQS limit values as emissions were only concentrated around the proposed crushing area. The simulated highest and lowest annual values for $PM_{2.5}$ were 5.1 µg/m³ and 0.05 µg/m³ respectively. This is lower than the current annual NAAQS limits of 20 µg/m³ and 15 µg/m³ applicable on 1 January 2030.

3.5.1.2 Simulated Dustfall Rates

Dust fallout levels predicted at Spanover 552 IO Optimisation Project falls within the criteria for residential areas of 600 mg/m²/day. The predicted maximum deposition modelled was 382 mg/m²/day and the minimum was 3.8 mg/m²/day. Of these dustfall rates, the proposed heap leach contributed 72 mg/m²/day. The dust deposition rates at the selected sensitive receptors in the vicinity of the proposed operation were less than or equal to 10 mg/m²/day

4 IMPACT ASSESSMENT: CONSTRUCTION PHASE

4.1 Impact Significance Rating of Construction Activities

Non-compliance of $PM_{2.5}$, PM_{10}, SO_2, NO_x or CO concentrations with the relevant NAAQS could result in human health impacts. The potential significance of the construction impacts based the qualitative assessment of $PM_{2.5}$, PM_{10}, SO_2, NO_x and CO and dustfall rates (TSP) because of the Kalgold Expansion are discussed below. The EIMS rating methodology was used. It must be noted that current operations will continue during the construction phase; thus, cumulative impacts from Kalgold will be greater than for the construction operations only and the regional impacts even greater.

Three potential construction phase impacts on the air quality of the area were identified:

- A1: Potential impact on human health from increased pollutant concentrations due to proposed construction activities (Table 19);
- A2: Increased nuisance dustfall rates associated with the proposed construction activities (Table 20); and
- A3: Potential impact on vegetation from increased dustfall rates and pollutant concentrations due to proposed construction activities (Table 21).).

Table 19: Health risk impact significance summary table for the proposed construction activities

Air Quality	Description	Rating
Project activity or issue	Construction associated with the proposed project	
Potential impact	Increased health risk at AQSRs	
Alternative	All	
Significance Before Mitigation		
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Site (i.e. within the development property boundary).	2
Duration	Short term (1-5 years).	2
Magnitude	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way).	3
Reversibility	Impact is reversible without any time and cost.	1
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-6**
Significance After Additional Mitigation		
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected).	2
Reversibility	Impact is reversible without any time and cost.	1
Probability	Low probability (there is a possibility that the impact will occur; >25% and <50%).	2
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-3**
Potential mitigation measures (construction)	• Reduction of fugitive PM emissions through the watering of roads, stockpiles and inactive open areas and the use of screens. • Reductions of vehicle exhaust emissions through the use of better-quality diesel; and inspection and maintenance programs.	
Priority Factor Criteria		
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change.	3

Air Quality	Description	Rating
Irreplaceable loss	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1.25
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-3.75**

Table 20: Nuisance impact significance summary table for the proposed construction activities

Air Quality	Description	Rating
Project activity or issue	Construction associated with the proposed project	
Potential impact	Nuisance dustfall rates at AQSRs	
Alternative	All	
	Significance Before Mitigation	
Nature	Negative due to increase in dustfall rates at AQSRs	-1
Extent	Site (i.e. within the development property boundary).	2
Duration	Short term (1-5 years).	2
Magnitude	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected).	2
Reversibility	Impact is reversible without any time and cost.	1
Probability	Low probability (there is a possibility that the impact will occur; >25% and <50%).	2
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-3.5**
	Significance After Additional Mitigation	
Nature	Negative due to increase in dustfall rates at AQSRs	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%)	1

Air Quality	Description	Rating
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Potential mitigation measures (construction)	• Reduction of fugitive PM emissions through the watering of roads, stockpiles and inactive open areas and the use of screens. • Reductions of vehicle exhaust emissions through the use of better-quality diesel; and inspection and maintenance programs.	
	Priority Factor Criteria	
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.	2
Irreplaceable loss	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1.13
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-1.40625**

Table 21: Vegetation impact significance summary table for the proposed construction activities

Air Quality	Description	Rating
Project activity or issue	Construction associated with the proposed project	
Potential impact	Degradation of vegetation from increased dustfall rates and pollutant concentrations.	
Alternative	All	
	Significance Before Mitigation	
Nature	Negative due to increase in dustfall rates and pollutant concentrations.	-1
Extent	Site (i.e. within the development property boundary).	2
Duration	Short term (1-5 years).	2
Magnitude	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected).	2
Reversibility	Impact is reversible without any time and cost.	1
Probability	Low probability (there is a possibility that the impact will occur; >25% and <50%).	2
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-3.5**
	Significance After Additional Mitigation	
Nature	Negative due to increase in dustfall rates at AQSRs	-1

Air Quality	Description	Rating
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%)	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Potential mitigation measures (construction)	• Reduction of fugitive PM emissions through the watering of roads, stockpiles and inactive open areas and the use of screens. • Reductions of vehicle exhaust emissions through the use of better-quality diesel; and inspection and maintenance programs.	
Priority Factor Criteria		
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.	2
Irreplaceable loss	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1.13
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-1.40625**

5 IMPACT ASSESSMENT: OPERATIONAL PHASE

5.1 Emissions Inventory

The sources of atmospheric emissions during the operational phase associated with the proposed project include:

- Particulate emissions from
  - drilling
  - blasting
  - excavation
  - material handling
  - crushing and screening
  - bulldozing as part of waste dump management
  - erosion of stockpiles, portions of the waste dumps and the TSF due to the wind lifting and dispersing loose material during high wind incidents (>5.4 m/s)
  - road surface material entrainment along the unpaved in-pit, haul roads and access road
  - grading of unpaved haul roads and access road.
- Particulate and gaseous emissions from
  - vehicles and equipment exhaust
  - smelter, kiln and assay laboratory stacks.

A summary of emission sources quantified, estimation techniques applied, and source input parameters is included in Table 22. A summary of estimated emissions in tonnes per annum (tpa) associated with the proposed operations is provided in Table 23.

Table 22: Emission estimation techniques and parameters

Source group	Emission estimation technique	Input parameters and activities
Drilling	ADE NPI single valued emission factors for drilling (ADE, 2012) TSP – 0.59 kg/hole PM_{10} – 0.31 kg/hole $PM_{2.5}$ – *assumed* to be 0.155 kg/hole (50% of PM_{10})	5 900 holes per month **Simulated hours of operation:** 5 days per week, 24 hours per day **Design Mitigation:** None
Blasting	US EPA emission factor equation (US EPA, 1998) $$EF = k \cdot (A)^{1.5}$$ Where EF is the emission factor in kg/blast k is the particle size multiplier (k_{TSP} – 0.00022) A is the average area in m² PM_{10}/TSP ratio is 0.52 $PM_{2.5}$/TSP ratio is 0.03	8 600 m² per blast day **Simulated hours of operation:** 2 days per week,1 hour per day **Design Mitigation:** None
Excavation	ADE NPI single valued emission factors for excavation of overburden (ADE, 2012). TSP – 0.025 kg/tonne PM_{10} – 0.012 kg/tonne $PM_{2.5}$ – *assumed* to be 0.00179 kg/tonne	It was assumed that all pits will be mined concurrently. **Hours of operation:** 365 days per year, 24 hours per day **Design mitigation:** None
Materials handling	US EPA emission factor equation (US EPA, 2006a) $$EF = k \cdot 0.0016 \cdot \left(\frac{U}{2.3}\right)^{1.3} \cdot \left(\frac{M}{2}\right)^{-1.4}$$ 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 %	An average wind speed of 4.02 m/s was determined from the WRF data set A moisture content of 4% was assumed. **Hours of operation:** 365 days per year, 24 hours per day **Design mitigation:** None
Crushing and screening	ADE NPI single valued emission factors for low moisture ore (ADE, 2012)	**New Plant:** 1 x pre-primary crusher, 1 x primary crusher, 1 x secondary crusher, 1 x tertiary crusher, 1 x screen

Source group	Emission estimation technique	Input parameters and activities
	TSP – 0.2 kg/tonne (primary), 0.08 kg/tonne (screening), 0.6 kg/tonne (secondary) PM_{10} – 0.02 kg/tonne (primary), 0.06 kg/tonne (screening), 0.04 kg/tonne (secondary) $PM_{2.5}$ – *assumed* to be 0.01 kg/tonne (primary), 0.03 kg/tonne (screening), 0.02 kg/tonne (secondary)	**Old Plant:** 1 x pre-primary crusher, 1 x primary crusher, 1 x secondary crusher, 1 x tertiary crusher, 1 x screen **Hours of operation:** 365 days per year, 24-hours per day **Design mitigation:** Water mist systems (pre-primary and primary crushers) and water mist system with scrubber (secondary and tertiary crushers) with a control efficiency of between 65% and 70% according to previous Kalgold studies and the AEL.
Bulldozing	US EPA emission factor equation (US EPA, 1998) and NPI emission factor equation (ADE, 2012) $$EF = 2.6 \cdot (s)^{1.2} \cdot (M)^{1.3}$$ Where EF is the emission factor in kg/hour s is the material silt content as a % M is the material moisture content as a % PM_{10}/TSP ratio = 0.75 (US EPA, 1998) $PM_{2.5}$/TSP ratio = 0.105 (US EPA, 1998)	Bulldozing activities include the bulldozing of waste rock at the waste dump. The waste rock moisture content of 4% was assumed. The silt content of 8.4% was applied in calculations. **Hours of operation:** 365 days per year, 24 hours per day. **Design mitigation:** None
Wind erosion	ADE NPI single valued emission factors (ADE, 2012) TSP – 0.4 kg/ha-h PM_{10} – 0.2 kg/ha-h $PM_{2.5}$ – *assumed* to be 0.1 kg/ha-h	**Hours of emission:** For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. Emissions are only calculated for wind speeds exceeding the threshold of ≥5 m/s for the RoM and product stockpiles as well as a small area of the waste dumps. **Design mitigation:** Partial or full vegetation cover on some existing WRDs.
	The calculation of a windblown dust emission rate for every hour of 2018, 2019 and 2020 was carried out using the ADDAS model, which is based on the dust emission model proposed by Marticorena & Bergametti (1995). A literature review on the model is provided in Appendix C.	The exposed area was included in emission estimations based on project layouts; this was 24 ha for the proposed TSF. **Design mitigation:** None
Vehicle entrained dust from unpaved roads	US EPA emission factor equation (US EPA, 2006b) $$EF = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot 281.9$$ Where EF is the emission factor in g/VKT	Transport activities included were the transport of ore and waste within the pits, transportation of waste rock to the waste dump, transportation of the ore to the RoM pad and then the plant and reagents/gold to/from the plant area. VKT were calculated from road lengths (limited to simulation area), truck capacities and the number of trips required to transport materials.

Source group	Emission estimation technique	Input parameters and activities
	k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) a is a constant (k_{TSP} – 0.7, k_{PM10} – 0.9, $k_{PM2.5}$ – 0.9) b is a constant (k_{TSP} – 0.45, k_{PM10} – 0.45, $k_{PM2.5}$ – 0.45) s is the road surface material silt content in % W is the average weight vehicles in tonnes	The road surface silt content of 11% was applied in calculations for the roads. This silt content was based on road surface samples from (air quality studies conducted for) similar South African Gold Mining and Processing operations located in the region. As it was assumed that both mining areas will be operational simultaneously, all haul roads would also be operational concurrently. **Hours of operation:** 365 days per year, 24 hours per day. **Design mitigation:** Water bowsers applying water to roads with an efficiency of dust mitigation estimated at 50% (previous studies for Kalgold), assumed to have been sources from the ADE NPi Mining EETM (ADE, 2012).
Vehicle exhaust	ADE NPI single valued emission factors (ADE, 2008)	Operational phase diesel use of 1 480 000 litres per month. Note that sulfur content of diesel fuel was assumed to be 50 ppm. **Hours of operation:** 365 days per year, 24 hours per day. **Design mitigation:** None
Grading of unpaved roads	US EPA emission factor equation (US EPA, 1998) and NPI emission factor equation (ADE, 2012) $EF = 0.0034 \cdot (S)^{2.5}$ Where EF is the emission factor in kg/VKT S is the speed as km/h PM_{10}/TSP ratio = 0.60 (US EPA, 1998) $PM_{2.5}$/TSP ratio = 0.031 (US EPA, 1998)	Grading activities include the grading of the haul roads and the access road. **Hours of operation:** 1 day per week, 9 hours per day. **Design mitigation:** None
Stacks	Existing stacks: maximum emission concentrations from 2020 and 2021 iso-kinetic sampling campaigns. Future stacks: MES.	Existing stacks: parameters as per the PAEL. Future stacks: parameters provided by applicant (the same as PAEL sources).

Table 23: Summary of estimated emissions in tonnes per annum for unmitigated expansion operations

Source group	Estimated emissions with no mitigation measures applied (tpa)						
	TSP	PM_{10}	$PM_{2.5}$	DPM	SO_2	NO_x	CO
Drilling	47.9	26.0	13.0	-	-	-	-

Source group	Estimated emissions with no mitigation measures applied (tpa)						
	TSP	PM_{10}	$PM_{2.5}$	DPM	SO_2	NO_x	CO
Blasting	16.3	8.45	4.23	-	-	-	-
Excavation	208	189	29.6	-	-	-	-
Materials Handling	21.6	11.0	1.68	-	-	-	-
Bulldozing	55.8	13.5	6.73	-	-	-	-
Crushing and Screening	6 517	578	289	-	-	-	-
Wind Erosion	72.9	36.3	17.4	-	-	-	-
Unpaved Roads	5 368	2 204	226	-	-	-	-
Vehicle Exhausts	47.1	47.1	43.2	43.2	1.57	589	243
Grading	0.075	0.033	0.017	-	-	-	-
Stacks	unknown	unknown	unknown	-	unknown	unknown	unknown
Total	**12 355**	**3 114**	**631**	**43.2**	**1.57**	**589**	**243**

Table 24: Summary of estimated emissions in tonnes per annum for design mitigated expansion operations

Source group	Estimated emissions with current and design mitigation applied [likely operations] (tpa)											
	TSP	PM_{10}	$PM_{2.5}$	DPM	SO_2	NO_x	CO	Cl_2	HCl	F as HF	NH_3	Pb
Drilling	47.9	26.0	13.0	-	-	-	-	-	-	-	-	-
Blasting	16.3	8.45	4.23	-	-	-	-	-	-	-	-	-
Excavation	208	189	29.6	-	-	-	-	-	-	-	-	-
Materials Handling	21.6	11.0	1.68	-	-	-	-	-	-	-	-	-
Bulldozing	55.8	13.5	6.73	-	-	-	-	-	-	-	-	-
Crushing and Screening	2 155	289	145	-	-	-	-	-	-	-	-	-
Wind Erosion	58.4	29.1	13.8	-	-	-	-	-	-	-	-	-
Unpaved Roads	2 684	1 102	113	-	-	-	-	-	-	-	-	-
Vehicle Exhausts	47.1	47.1	43.2	43.2	1.57	589	243	-	-	-	-	-
Grading	0.075	0.033	0.017	-	-	-	-	-	-	-	-	-
Stacks	11.9	5.34	1.83	-	94.8	71.1	-	11.9	7.11	7.11	23.7	0.427
Total	**5 306**	**1 721**	**372**	**43**	**96.4**	**660**	**243**	**11.9**	**7.11**	**7.11**	**23.7**	**0.427**

5.2 Assessment of Impact – Proposed Operations

Simulation results of the future (proposed) operations are discussed in this section. The simulation results are for the future Kalgold operations only and does not include any other sources' contributions in the area. The simulated concentrations as a result of the Kalgold future operations should only the new plant be used, are presented based on design mitigation measures as reported in Table 24. Results on the option of both plants operational are provided in Appendix E.

5.2.1 *Coarse inhalable particulate matter (PM_{10})*

Simulated annual average PM_{10} concentrations exceed the NAAQS of 40 µg/m^3 beyond the permit area (off-site) but not at any of AQSRs (Figure 9). The 24-hour NAAQS (4 days of exceedance of 75 µg/m^3) is exceeded beyond the permit area (off-site) and at one AQSR (isolated homestead R02) (Figure 10).

5.2.2 *Fine inhalable particulate matter ($PM_{2.5}$)*

Simulated annual average $PM_{2.5}$ concentrations exceed the current and future[3] NAAQS of 20 µg/m^3 and 15 µg/m^3, beyond the permit area (off-site) but not at any of AQSRs (Figure 11). The current 24-hour NAAQS (4 days of exceedance of 40 µg/m^3) is exceeded beyond the permit area (off-site) but not at any AQSRs (Figure 12). The 24-hour future[4] NAAQS (4 days of exceedance of 25 µg/m^3) is exceeded beyond the permit area (off-site) but not at any AQSRs (Figure 12).

5.2.3 *Fallout dust*

Based on the highest monthly simulated dustfall rates, the daily average dustfall rate does not exceeds the NDCR limit for residential areas (600 mg/m²-day) at any AQSRs but are above 400 mg/m²-day at some agricultural areas outside the permit area (off-site) (Figure 13). The daily average dustfall rates exceed the NDCR limit for non-residential areas on-site and beyond the permit area (off-site) (Figure 13).

5.2.4 *Diesel Particulate Matter (DPM)*

Simulated annual average DPM concentrations exceed the US EPA IRIS RfC of 5 µg/m^3 but not beyond the permit area or at any of the AQSRs (Figure 14). The CALEPA CPV of 3×10^{-4} (µg/m^3)$^{-1}$ was applied to simulated annual average concentrations to provide a conservative estimate of increased lifetime cancer risk (ILCR) since it assumes an individual will be exposed to this concentration constantly over a period of 70 years. Increased lifetime cancer risk at AQSRs range between very low (less than 1:1 000 000) and moderate (between 1:10 000 and 1:1 000); the AQSRs where the ILCR was estimated to be moderate are two isolated homesteads (R01 and R02). The sources of DPM are the vehicle exhausts.

[3] Applicable from 1January 2030

[4] Applicable from 1January 2030

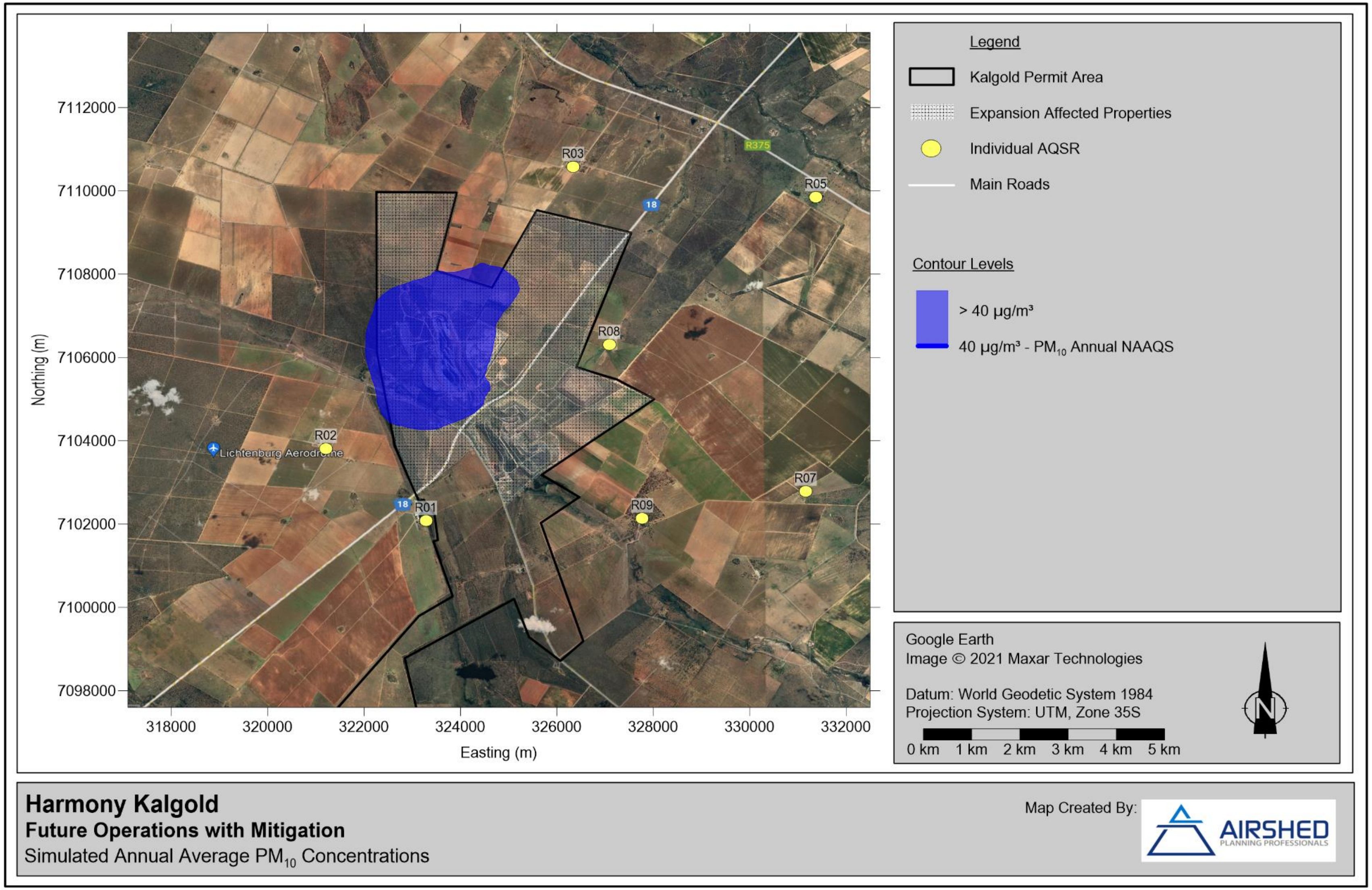


Figure 9: Kalgold expansion operations – simulated area of exceedance of the annual average PM_{10} NAAQS

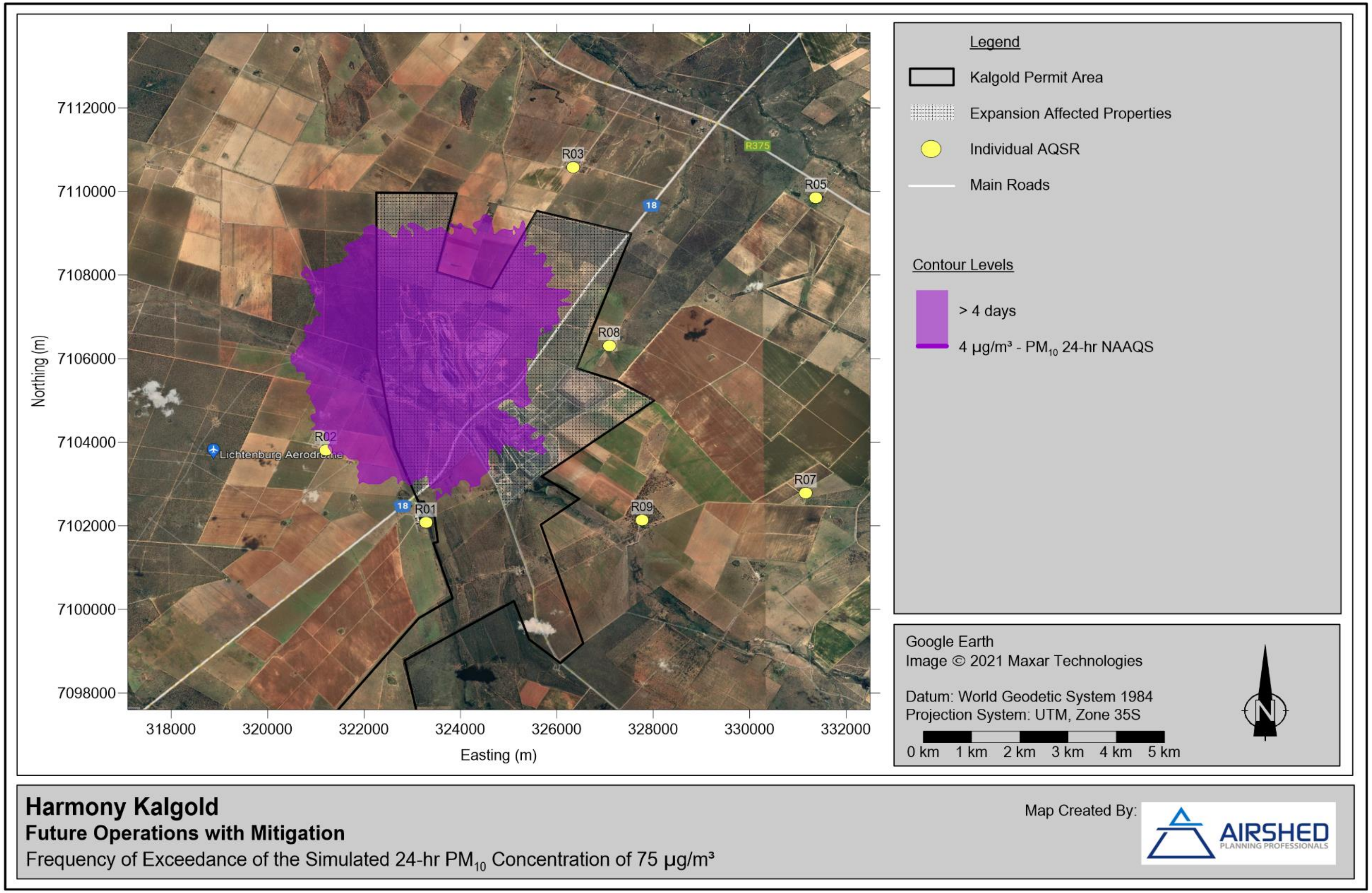


Figure 10: Kalgold expansion operations – simulated area of exceedance of the 24-hour PM_{10} NAAQS

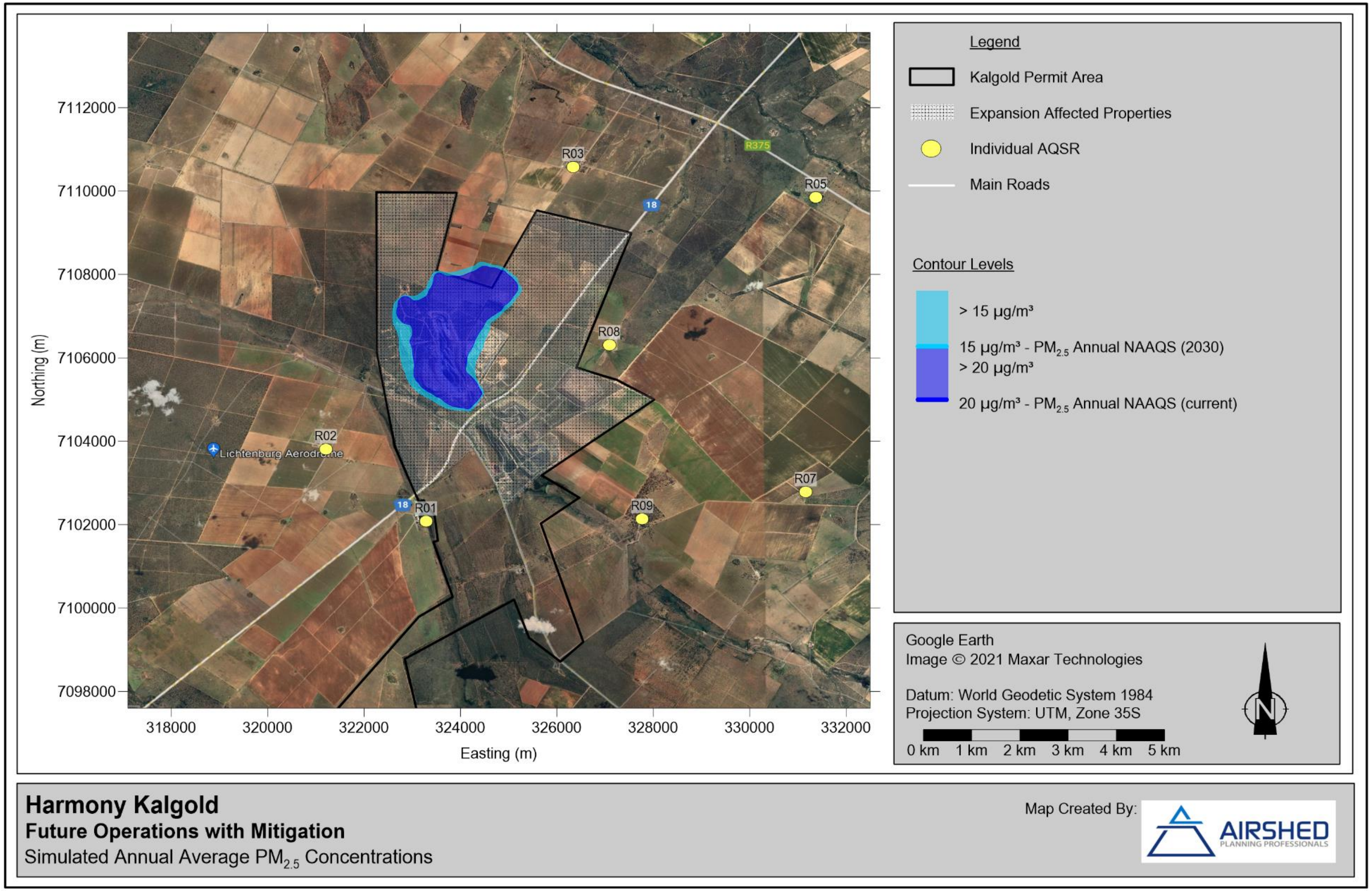


Figure 11: Kalgold expansion operations – simulated area of exceedance of the annual average $PM_{2.5}$ NAAQS

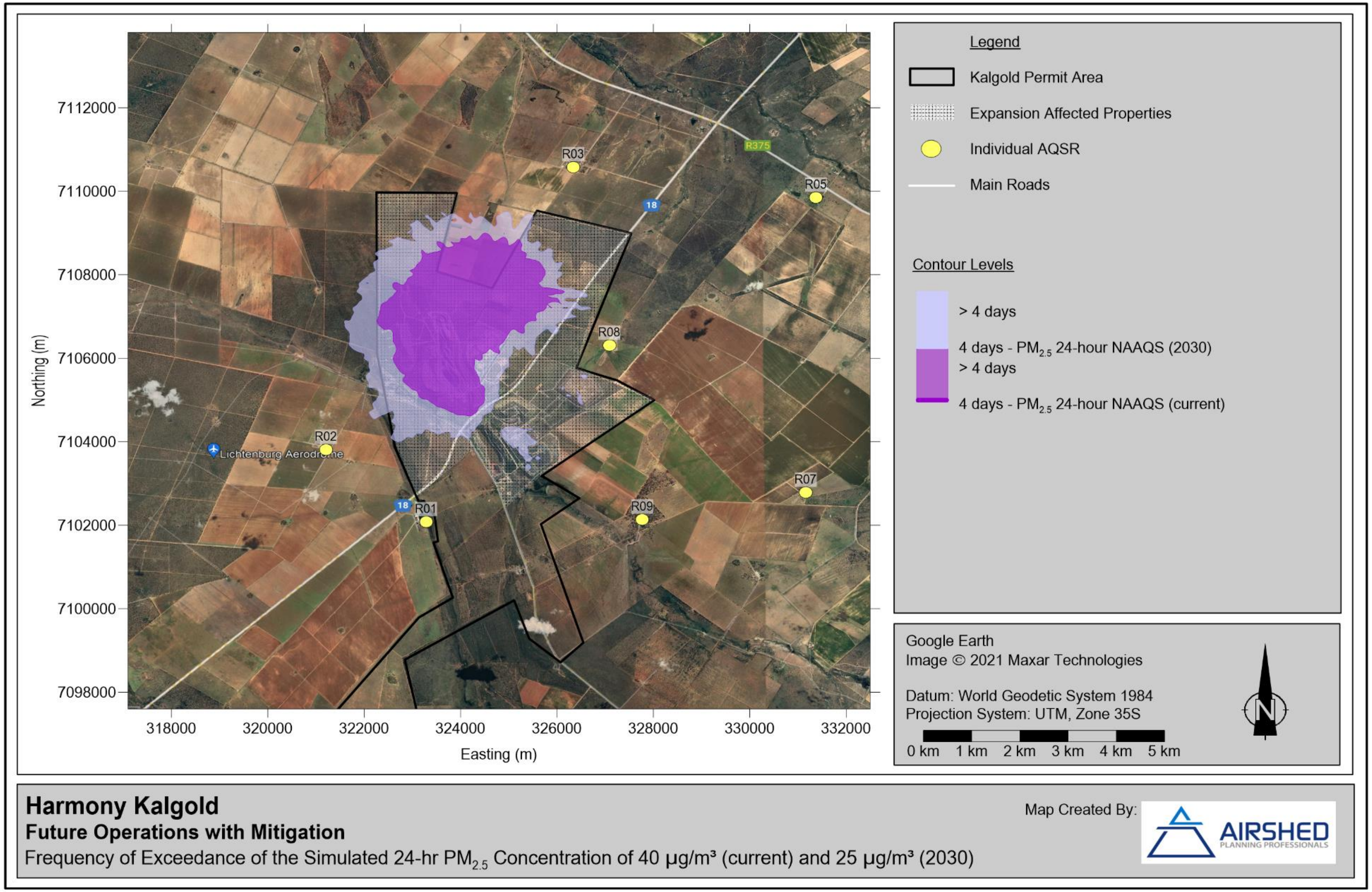


Figure 12: Kalgold expansion operations – simulated area of exceedance of the 24-hour $PM_{2.5}$ NAAQS

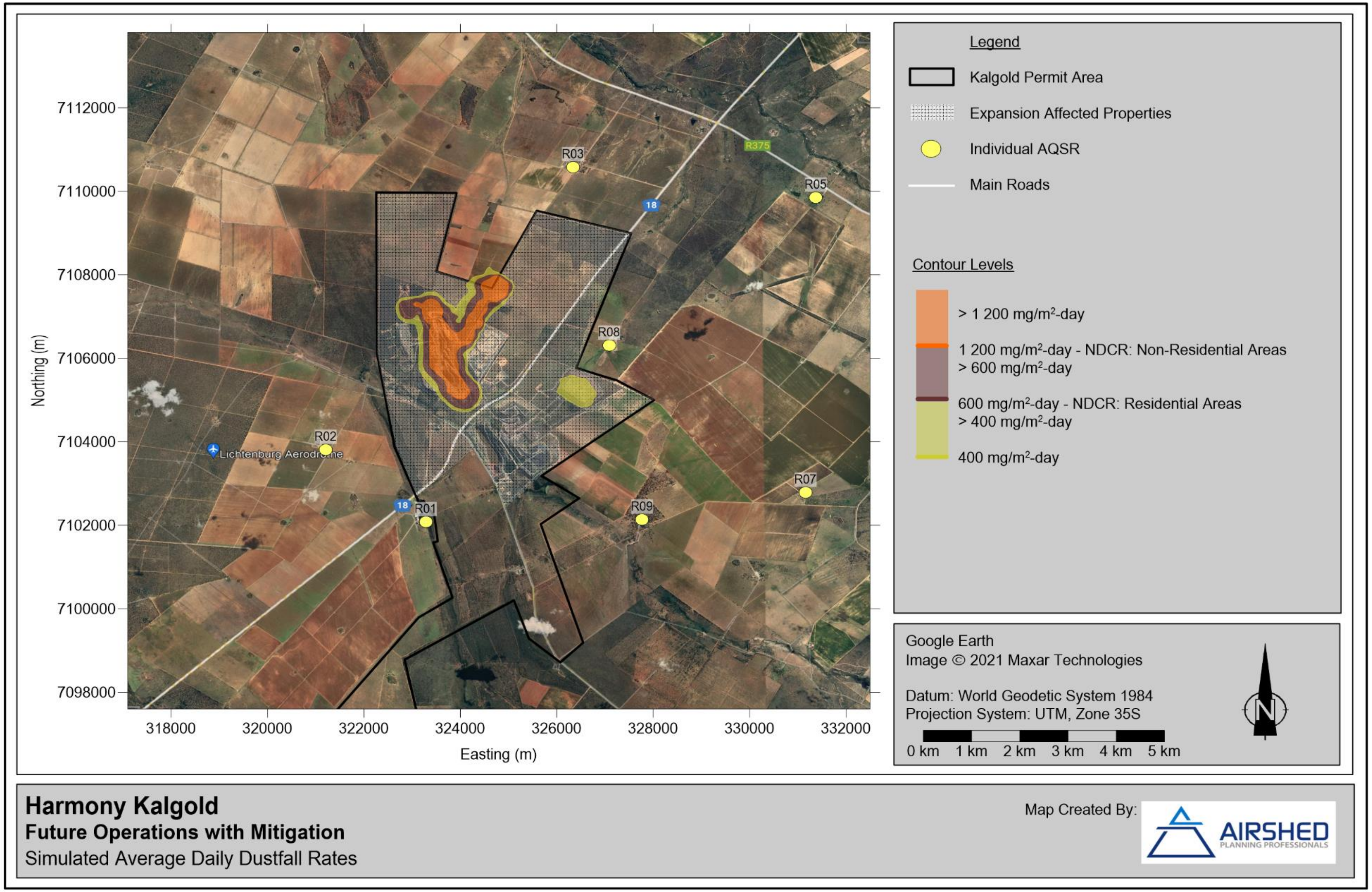


Figure 13: Kalgold expansion operations - average daily dustfall rates based on simulated highest monthly dust fallout

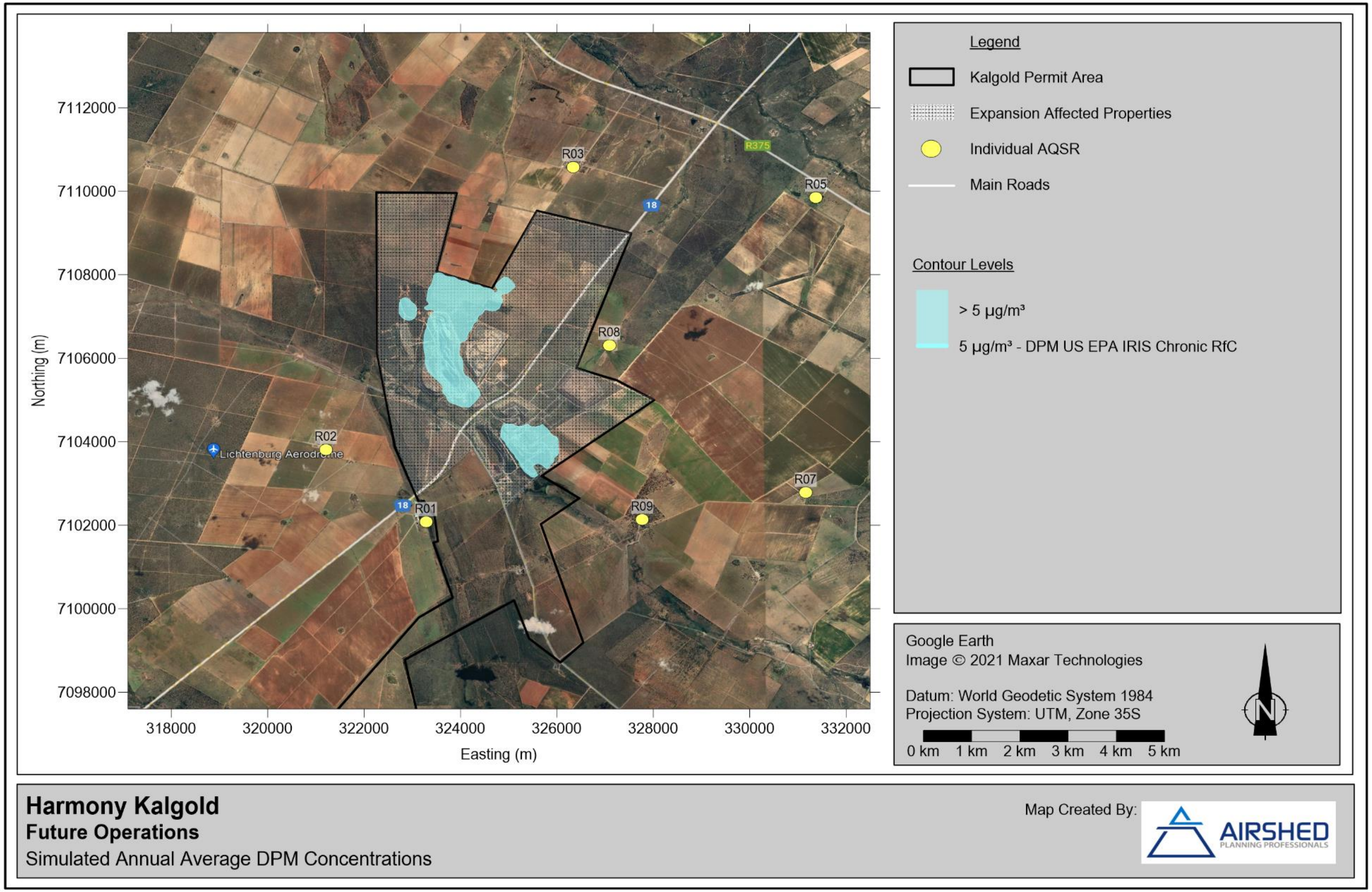


Figure 14: Kalgold expansion operations – simulated area of exceedance of the US EPA IRIS (chronic) RfC for DPM

5.2.5 Sulfur dioxide (SO_2)

Simulated annual average SO_2 concentrations do not exceed the NAAQS of 50 µg/m^3 (Figure 15). The 24-hour NAAQS (4 days of exceedance of 125 µg/m^3) (Figure 16) and 1-hour NAAQS (88 hours of exceedance of 350 µg/m^3) (Figure 17) are also not exceeded; in fact, the concentrations are below the NAAQ limits.

5.2.6 Nitrogen dioxide (NO_2)

Simulated annual average NO_x concentrations exceed the NAAQS of 40 µg/m^3 but not at any of the AQSRs (Figure 18). The 1-hour NAAQS (88 hours of exceedance of 200 µg/m^3) is exceeded but not at any AQSRs (Figure 19). The simulated NO_x concentrations exceed the critical level for all vegetation types (Figure 20). It was conservatively assumed that all NO_x is converted to NO_2.

5.2.7 Carbon monoxide (CO)

The 8-hour NAAQS (11 of exceedance of 8-hour rolling average concentrations of 10 000 µg/m^3) and 1-hour NAAQS (88 hours of exceedance of 30 000 µg/m^3) are not exceeded; in fact, the concentrations are below the NAAQ limits.

5.2.8 Lead (Pb)

The annual NAAQS (concentrations of 0.5 µg/m^3) are not exceeded (Figure 21). The CALEPA CPV of $1.2x10^{-5}$ (µg/m^3)$^{-1}$ was applied to simulated annual average concentrations to provide a conservative estimate of ILCR since it assumes an individual will be exposed to this concentration constantly over a period of 70 years. Increased lifetime cancer risk is very low (less than 1:1 000 000).

5.2.9 Hydrogen Fluoride (HF)

Simulated 1-hour HF concentrations exceeded the CALEPA OEHHA REL of 16.4 µg/m^3 but at any of the AQSRs (Figure 22).

5.2.10 Hydrogen Chloride (HCl)

The simulated concentrations are below the selected criteria for HCl.

5.2.11 Chlorine (Cl_2)

The simulated concentrations are below the selected criteria for Cl_2.

5.2.12 Ammonia (NH_3)

The simulated concentrations are below the selected criteria for NH_3. The simulated 1-hour NH_3 is below the TOC of 30 µg/m^3 at all AQSRs and unlikely to cause odour complaints.

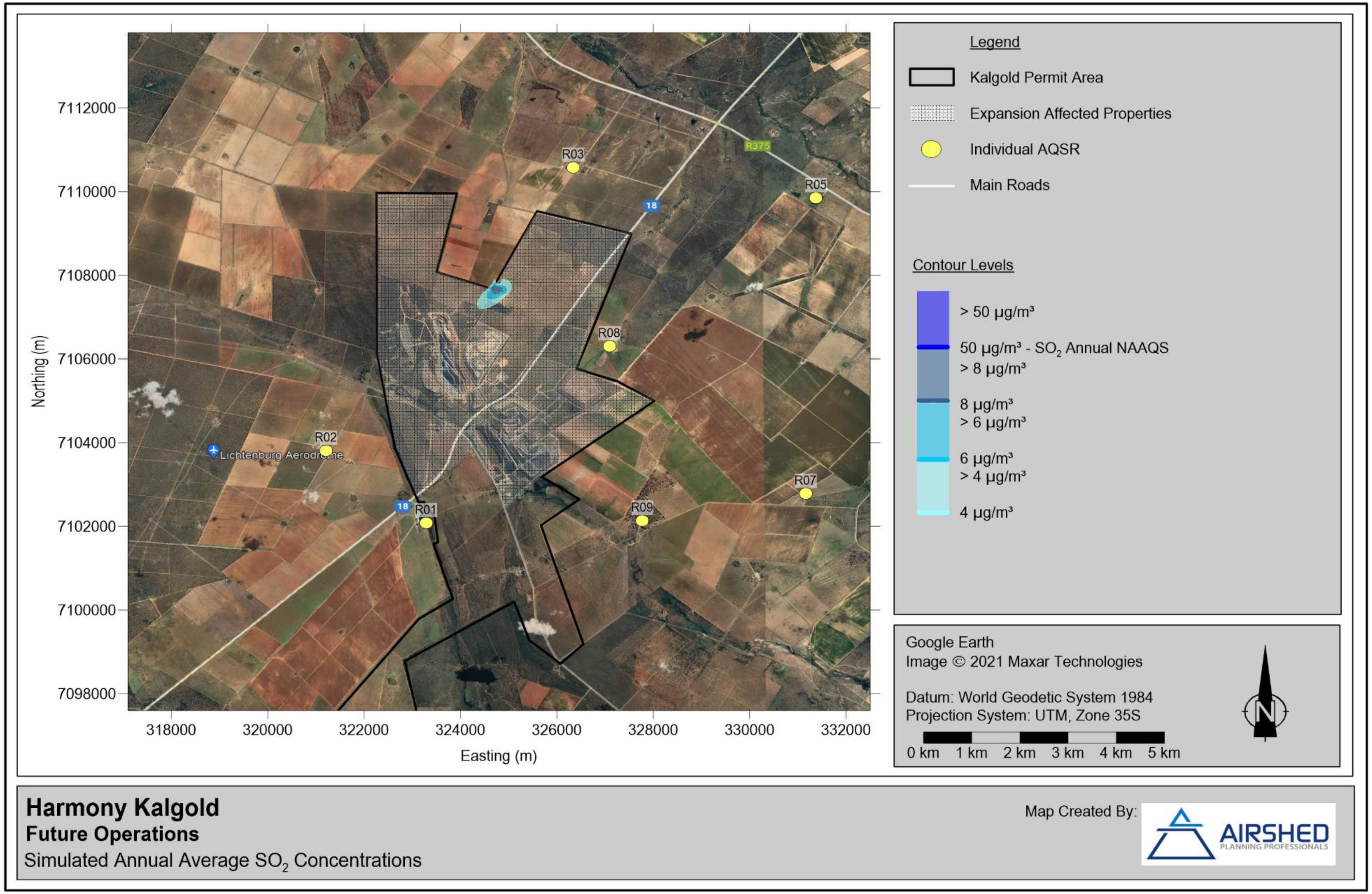


Figure 15: Kalgold expansion operations – simulated annual average SO_2 concentrations

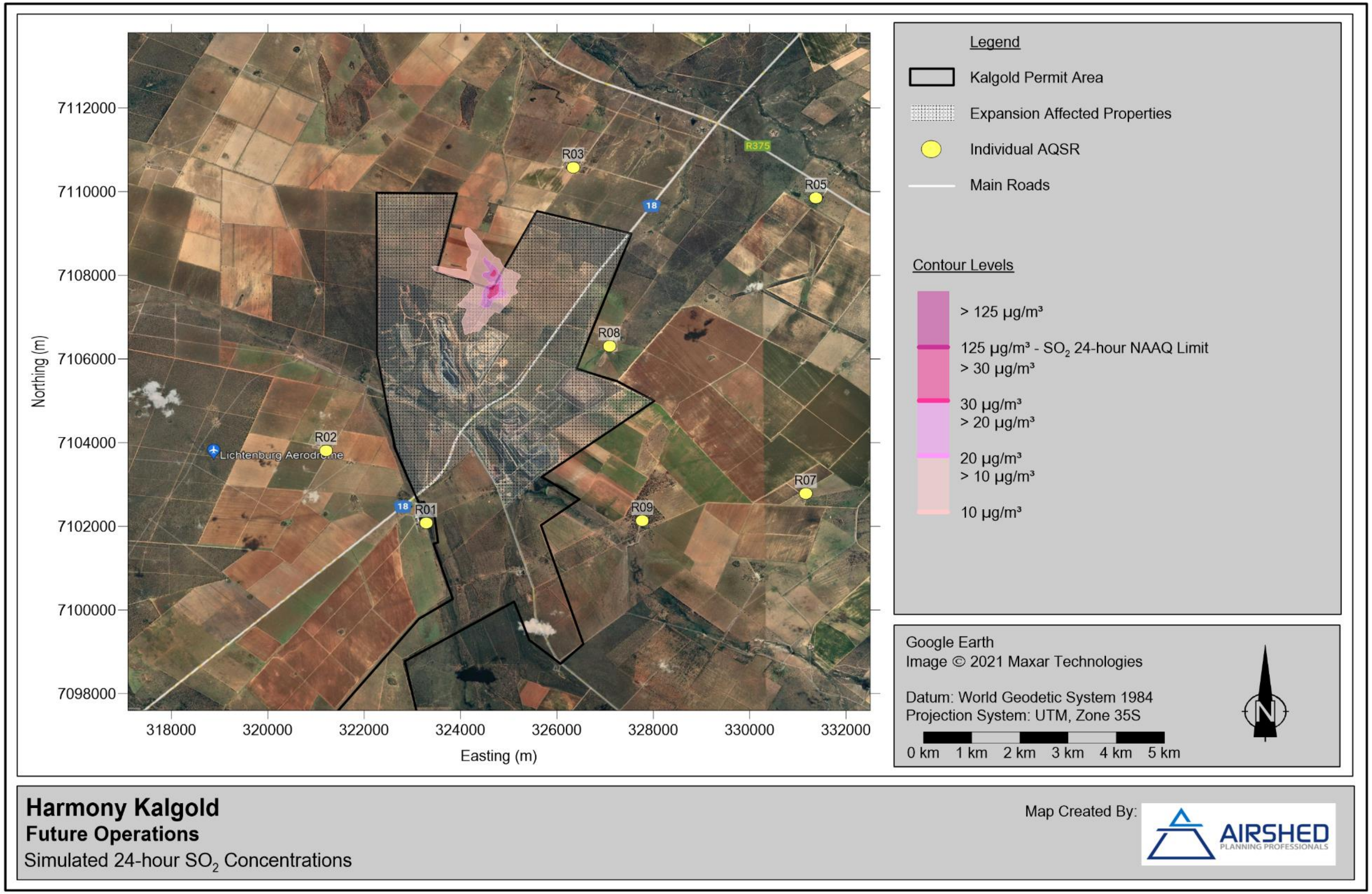


Figure 16: Kalgold expansion operations – simulated 24-hour average SO_2 concentrations

Figure 17: Kalgold expansion operations – simulated 1-hour SO_2 concentrations

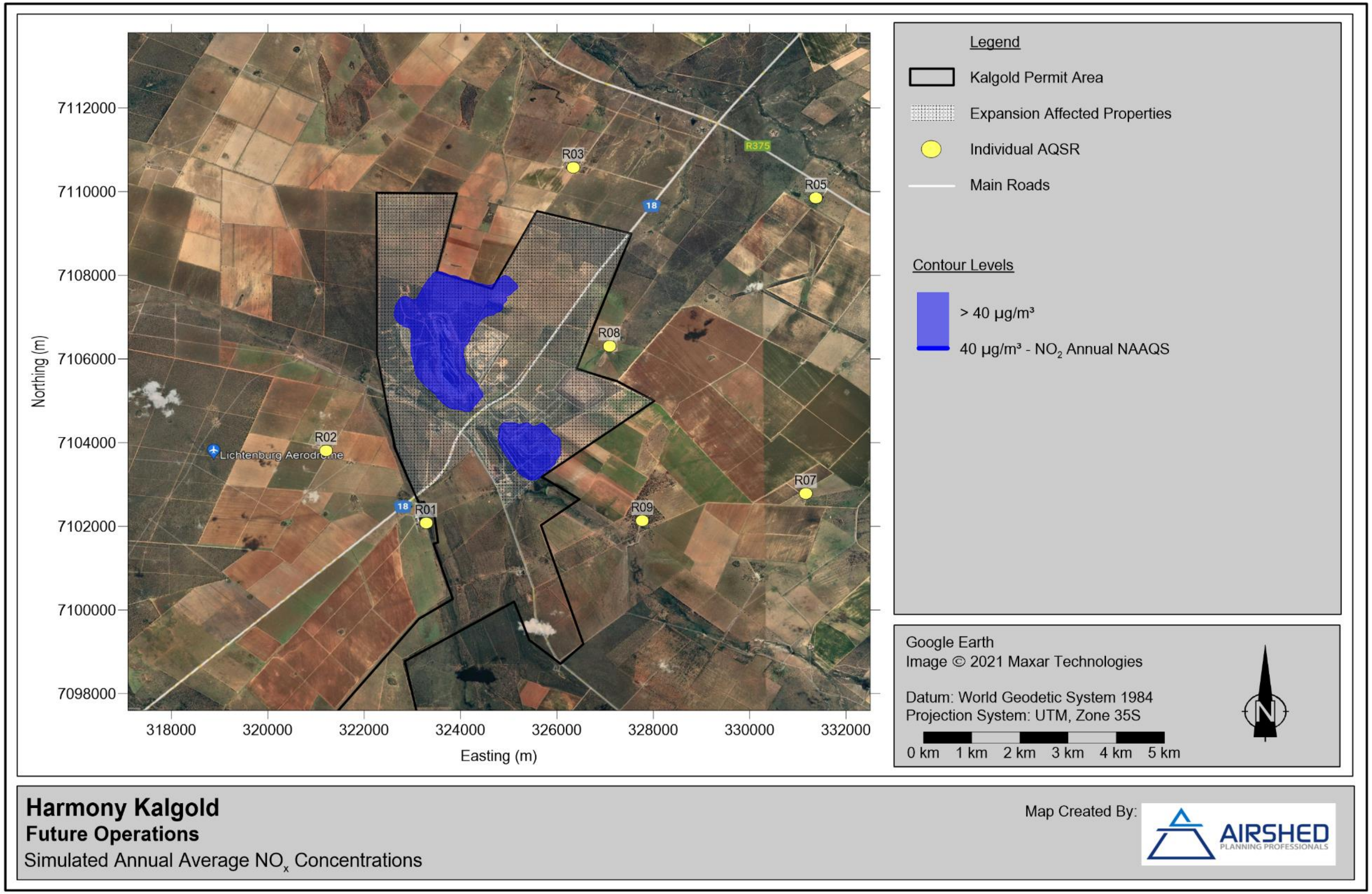


Figure 18: Kalgold expansion operations – simulated area of exceedance of the annual NO_2 NAAQS

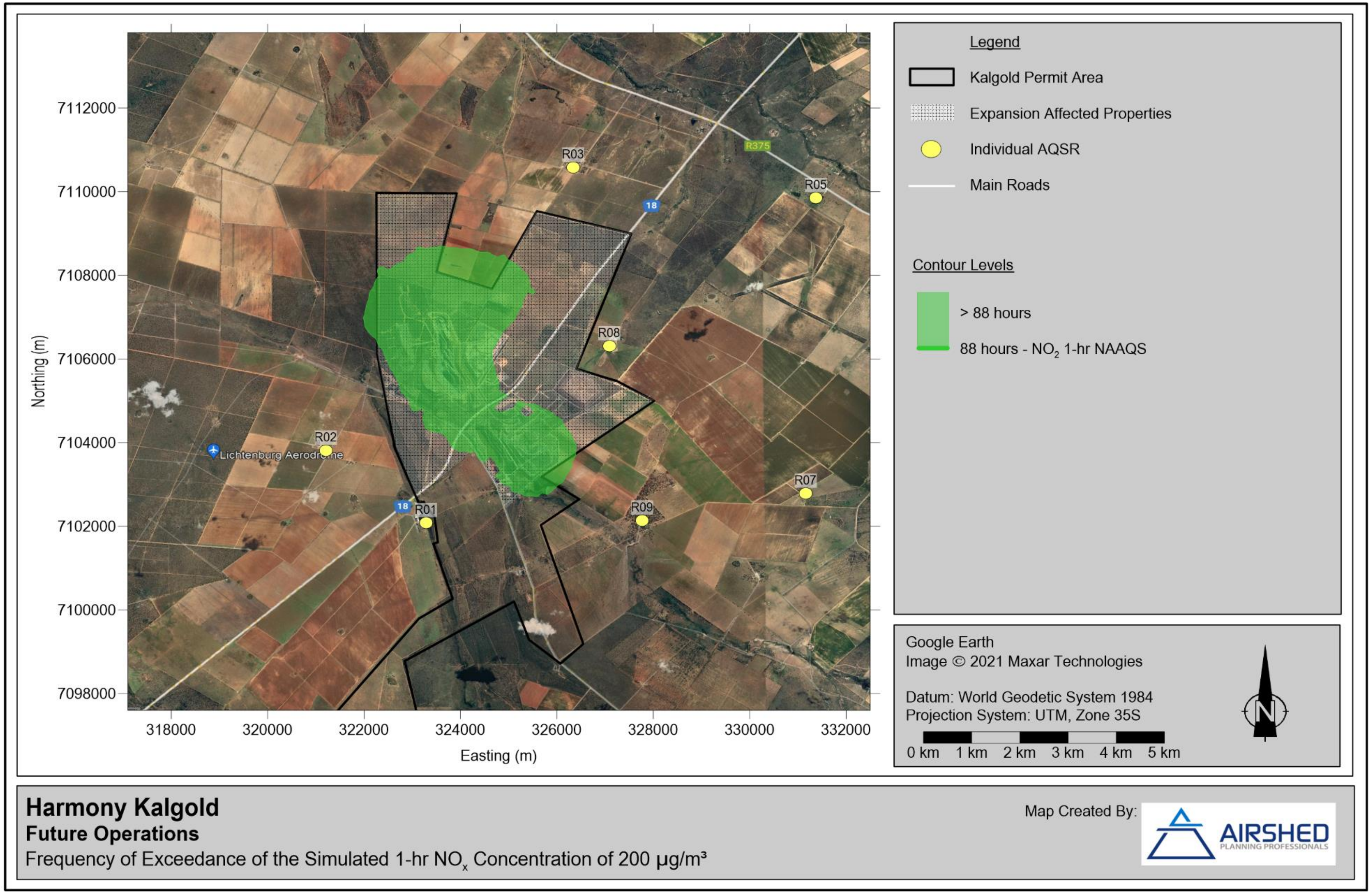


Figure 19: Kalgold expansion operations – simulated area of exceedance of the 1-hour NO_2 NAAQS

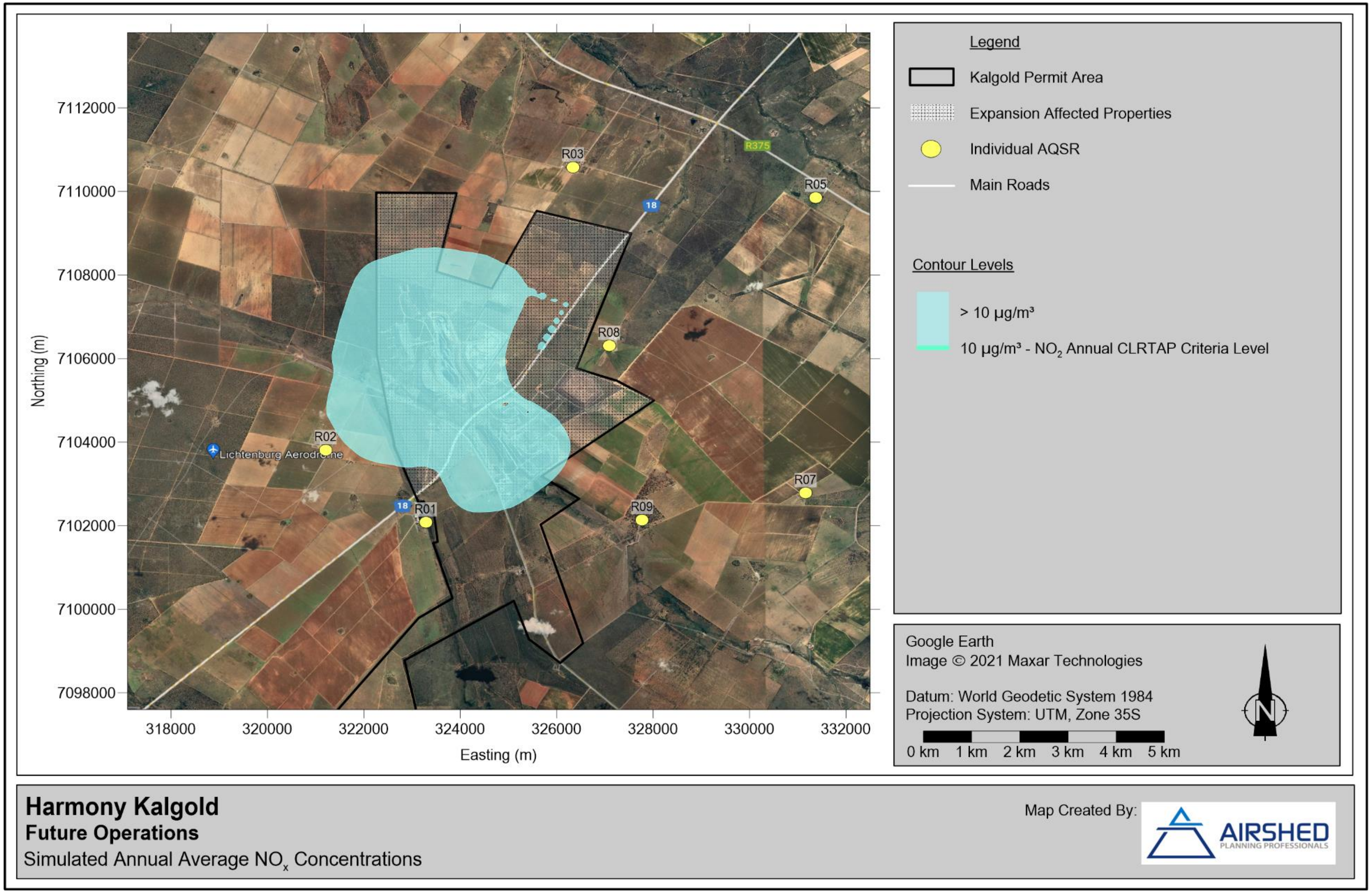


Figure 20: Kalgold expansion operations – simulated area of exceedance of the annual NO_2 CLRTAP limit

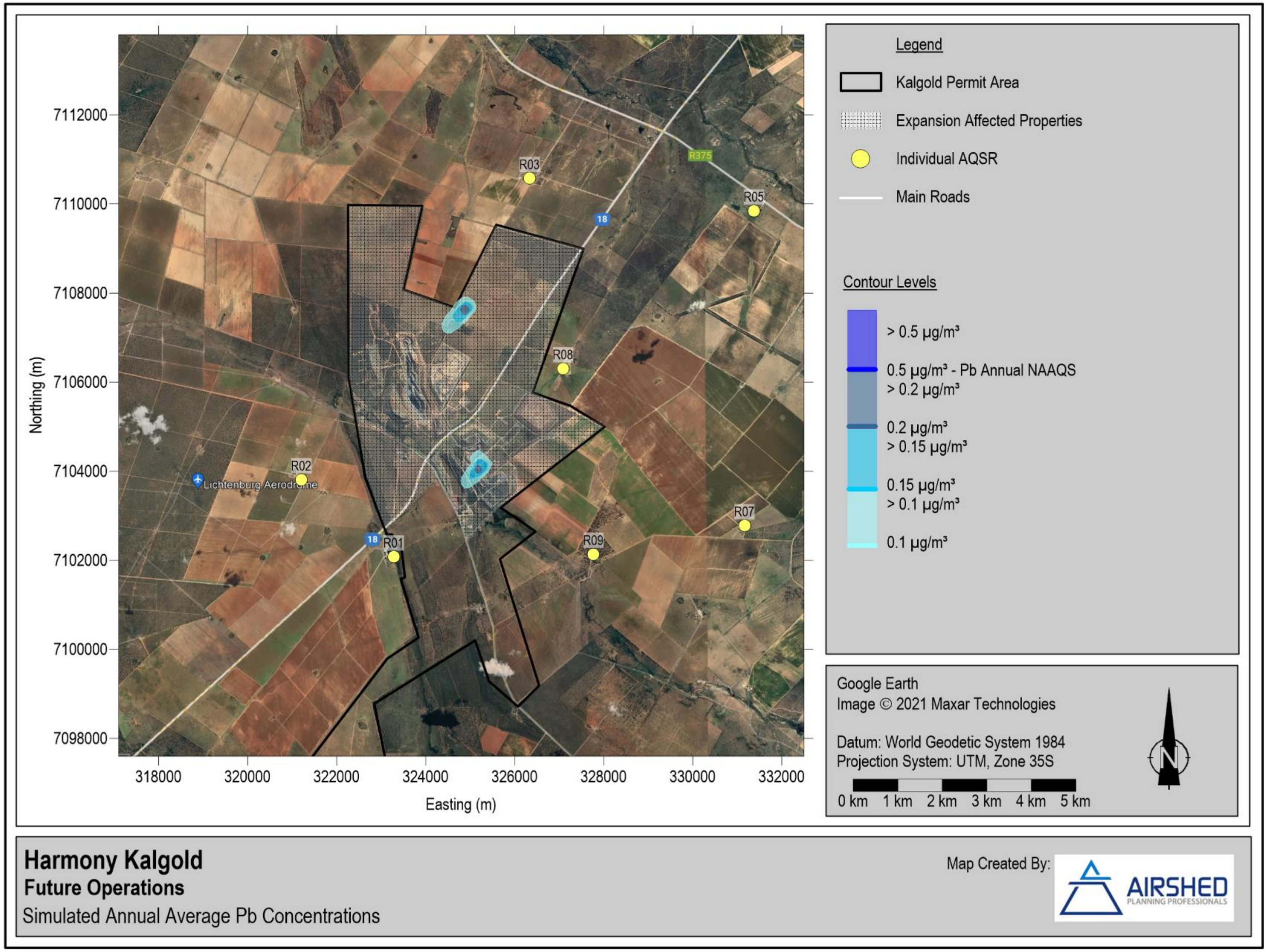


Figure 21: Kalgold expansion operations – simulated annual average Pb concentrations

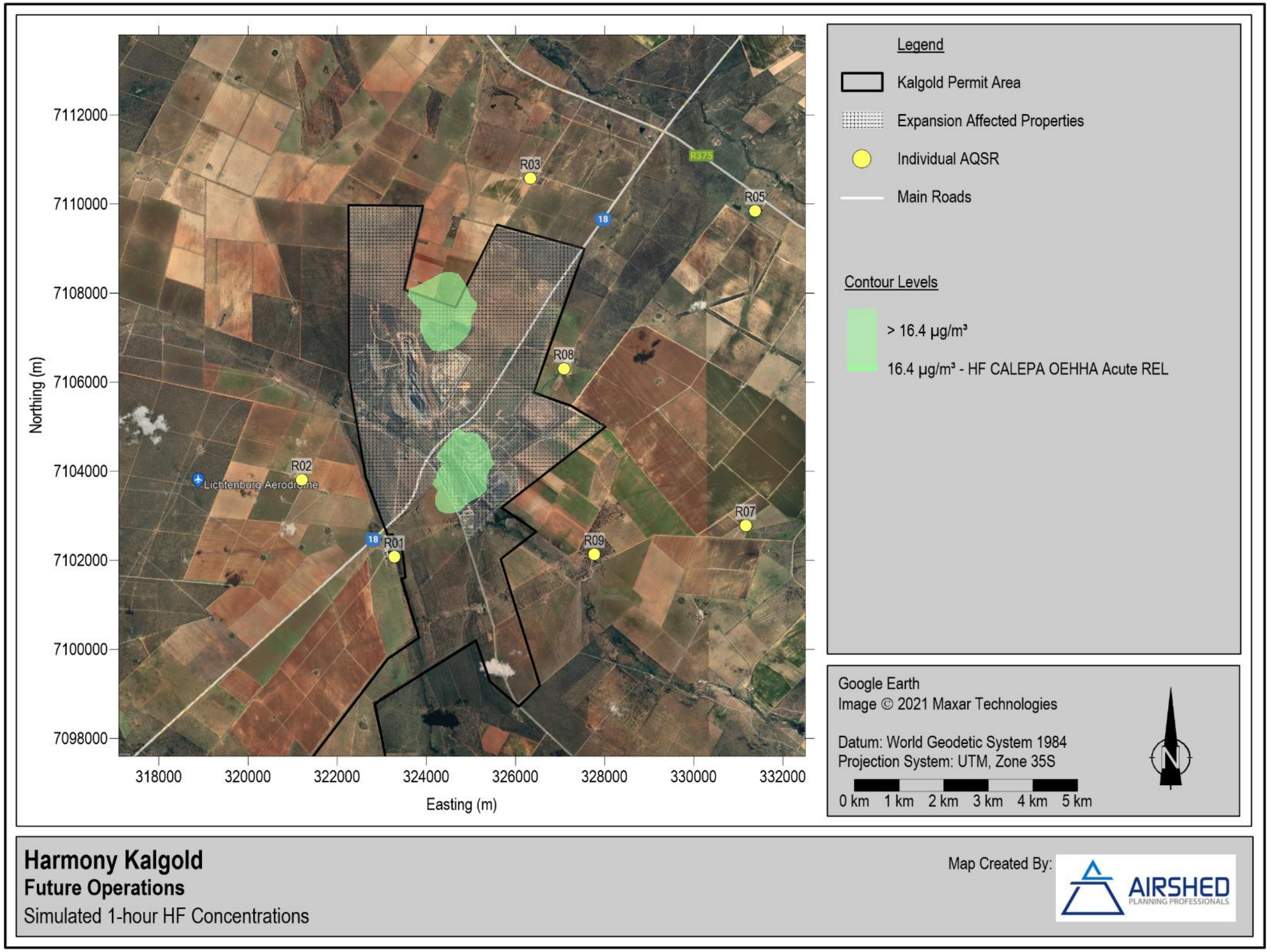


Figure 22: Kalgold expansion operations – simulated area of exceedance of the CALEPA OEHHA Acute REL for HF

5.3 Impact Significance Rating of Incremental Operations

The main pollutants of concern were determined to be PM (including TSP, PM_{10} and $PM_{2.5}$) and NO_x. Non-compliance of NAAQS could result in human health impacts. A quantitative assessment of the potential impacts from PM_{10}, $PM_{2.5}$, NO_x, and dust fallout (TSP) during the operational phase is discussed below. The EIMS rating methodology was used. The NAAQS are intended to indicate safe daily exposure levels for most of the population, including the very young and the elderly, throughout an individual's lifetime. Simulated results show that the NAAQS are not exceeded at any AQSRs, thus the simulated operations are unlikely to be a significant risk to human health at the existing surrounding receptors. Should there be new residential related developments in the exceedance areas, then the simulated operations are likely to be a risk to human health. Dust fallout is associated with nuisance impacts and not human health impacts; however, it could also compromise photosynthetic rates depending on species sensitivity. The simulated NO_x concentrations exceed the critical level for all vegetation types off-site, thus the simulated operations could be a risk to flora health. It was conservatively assumed that all NO_x is converted to NO_2.

Three potential operational phase impacts on the air quality of the area were identified:

- B1: Potential impact on human health from increased pollutant concentrations due to proposed operations (Table 25);
- B2: Increased nuisance dustfall rates associated with the proposed operations (Table 26); and
- B3: Potential impact on vegetation health from increased dustfall rates and pollutant concentrations due to proposed operations (Table 27).

Table 25: Health risk impact significance summary table for the proposed operations

Air Quality	Description	Rating
Project activity or issue	Mining and processing operations associated with the proposed project.	
Potential impact	Increased health risk at AQSRs.	
Alternative	Use of only the New Plant.	
	Significance Before Mitigation	
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Regional (i.e. extends between 5 and 50 km from the site).	3
Duration	Long term (the impact will cease after the operational life span of the project).	4
Magnitude	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease).	4
Reversibility	Impact is reversible without any time and cost.	1
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Medium (i.e. where the impact could have a significant environmental risk).**	**-9.75**
	Significance After Additional Mitigation	
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Local (i.e. the area within 5 km of the site).	3
Duration	Long term (the impact will cease after the operational life span of the project).	4
Magnitude	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way).	3
Reversibility	Impact is reversible without any time and cost.	1
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-8.25**
Potential mitigation measures	Combining chemical suppressants with the use of water sprays on unpaved roads.	
	Priority Factor Criteria	
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change.	3
Irreplaceable loss	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1.25

Air Quality	Description	Rating
Final score	**Medium negative (i.e. where the impact could influence the decision to develop in the area).**	**-10.31**

Table 26: Nuisance impact significance summary table for the proposed operations

Air Quality	Description	Rating
Project activity or issue	Mining and processing operations associated with the proposed project.	
Potential impact	Nuisance dustfall rates at AQSRs.	
Alternative	Use of only the New Plant.	
	Significance Before Mitigation	
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Regional (i.e. extends between 5 and 50 km from the site).	3
Duration	Long term (the impact will cease after the operational life span of the project).	4
Magnitude	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease).	4
Reversibility	Impact is reversible without any time and cost.	1
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-8.25**
	Significance After Additional Mitigation	
Nature	Negative due to increase in dustfall rates at AQSRs	-1
Extent	Local (i.e. the area within 5 km of the site).	3
Duration	Long term (the impact will cease after the operational life span of the project).	4
Magnitude	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected).	2
Reversibility	Impact is reversible without any time and cost.	1
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-7.5**
Potential mitigation measures	Combining chemical suppressants with the use of water sprays on unpaved roads.	
	Priority Factor Criteria	
Confidence	Medium	

Air Quality	Description	Rating
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.	2
Irreplaceable loss	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1.13
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-8.44**

Table 27: Vegetation impact significance summary table for the proposed operations

Air Quality	Description	Rating
Project activity or issue	Mining and processing operations associated with the proposed project.	
Potential impact	Degradation of vegetation from increased dustfall rates and pollutant concentrations.	
Alternative	Use of only the New Plant.	
Significance Before Mitigation		
Nature	Negative due to increase in dustfall rates and pollutant concentrations.	-1
Extent	Site (i.e. within the development property boundary).	2
Duration	Short term (1-5 years).	2
Magnitude	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected).	2
Reversibility	Impact is reversible without incurring significant time and cost.	2
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Medium (i.e. where the impact could have a significant environmental risk).**	**-9**
Significance After Additional Mitigation		
Nature	Negative due to increase in dustfall rates at AQSRs	-1
Nature	Negative due to increase in dustfall rates and pollutant concentrations.	-1
Extent	Local (i.e. the area within 5 km of the site).	3
Duration	Long term (the impact will cease after the operational life span of the project).	4
Magnitude	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected).	
Reversibility	Impact is reversible without incurring significant time and cost.	2

Air Quality	Description	Rating
Probability	Medium probability (the impact may occur; >50% and <75%).	3
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-8.25**
Potential mitigation measures	Combining chemical suppressants with the use of water sprays on unpaved roads to reduce dustfall rates at agricultural areas.	
Priority Factor Criteria		
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.	2
Irreplaceable loss	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.	2
Priority factor		1.25
Final score	**Medium negative (i.e. where the impact could influence the decision to develop in the area).**	**-10.31**

6 IMPACT ASSESSMENT: DECOMMISSIONING AND CLOSURE PHASES

6.1 Increase in Pollutant Concentrations and Dustfall Rates

It is assumed that all operations will have ceased by the decommissioning phase. It is expected that all surface infrastructure will be demolished and removed except for roads which will remain for public use. It is also expected that the stockpile surfaces will be covered with topsoil and vegetated.

The potential for air quality impacts during the decommissioning phase will depend on the extent of demolition and rehabilitation efforts during decommissioning and on features which will remain.
The likely activities associated with the decommissioning phase of the operations are:

- infrastructure removal/demolition;
- topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings;
- vehicle entrainment on unpaved road surfaces during rehabilitation. Once that is done, vehicle activity associated with Kalgold should cease; and
- exhaust emissions from vehicles utilised during the closure phase. Once that is done, vehicle activity associated with Kalgold should cease;

The closure phase includes the period of aftercare and maintenance after the decommissioning phase. During this phase rehabilitated areas are checked and maintained. The activities that may be included are irregular and minimal vehicle entrainment on roads and vehicle exhaust emissions when the property is checked on.

6.2 Assessment of Impact

Insufficient data was available for the decommissioning and closure phases to allow for dispersion modelling of the actual activities that will result in dust emissions to be undertaken. It is anticipated that the various activities would not result in higher $PM_{2.5}$ and PM_{10} GLCs and dustfall rates than the operational phase activities. The temporary nature of the decommissioning activities would likely reduce the significance of the potential impacts. The minimal activities during closure will likely result in insignificant potential impacts. A qualitative assessment of decommissioning and closure operations from the $PM_{2.5}$, PM_{10} and TSP impacts perspective is discussed below.

The environmental risk rating is expected to be the same for decommissioning/closure phase as for the construction phase and the same mitigation measures could be used, thus tables have not been included for this phase. Refer to the construction tables for the environmental risk rating. Three potential decommissioning/closure phase impacts on the air quality of the area were identified:

- C1: Potential impact on human health from increased pollutant concentrations due to proposed decommissioning/closure operations (Table 19);
- C2: Increased nuisance dustfall rates associated with the proposed decommissioning/closure operations (Table 20); and
- C3: Potential impact on vegetation from increased dustfall rates and pollutant concentrations due to proposed decommissioning/closure operations (Table 21).

Three potential post-closure phase impacts on the air quality of the area were identified:

- D1: Potential impact on human health from increased pollutant concentrations due to proposed post-closure operations (Table 28);
- D2: Increased nuisance dustfall rates associated with the proposed post-closure operations (Table 29); and
- D3: Potential impact on vegetation from increased dustfall rates and pollutant concentrations due to proposed post-closure operations (Table 30).

Table 28: Health risk impact significance summary table for the proposed post-closure operations

Air Quality	Description	Rating
Project activity or issue	Post closure activities.	
Potential impact	Increased health risk at AQSRs when doing site inspections.	
Alternative	All	
Significance Before Mitigation		
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%).	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Significance After Additional Mitigation		
Nature	Negative due to increase in pollutant concentrations at AQSRs.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%).	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Potential mitigation measures	Reductions of vehicle exhaust emissions through the use of better-quality diesel; and inspection and maintenance programs.	
Priority Factor Criteria		
Confidence	Medium	

Air Quality	Description	Rating
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	1
Reversibility	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-1.25**

Table 29: Nuisance impact significance summary table for the proposed post-closure operations

Air Quality	Description	Rating
Project activity or issue	Post closure activities.	
Potential impact	Increased nuisance dustfall at AQSRs when doing site inspections.	
Alternative	All	
Significance Before Mitigation		
Nature	Negative due to increase in dustfall rates at AQSRs.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%).	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Significance After Additional Mitigation		
Nature	Negative due to increase in dustfall rates at AQSRs.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1

Air Quality	Description	Rating
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%).	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Potential mitigation measures	Reductions of vehicle exhaust emissions through the use of better-quality diesel; and inspection and maintenance programs.	
	Priority Factor Criteria	
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	1
Reversibility	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-1.25**

Table 30: Vegetation impact significance summary table for the proposed post-closure operations

Air Quality	Description	Rating
Project activity or issue	Post closure activities.	
Potential impact	Increased health risk to vegetation when doing site inspections.	
Alternative	All	
	Significance Before Mitigation	
Nature	Negative due to increase in pollutant concentrations and dustfall rates at vegetated areas.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%).	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
	Significance After Additional Mitigation	

Air Quality	Description	Rating
Nature	Negative due to increase in pollutant concentrations and dustfall rates at vegetated areas.	-1
Extent	Activity (i.e. limited to the area applicable to the specific activity).	1
Duration	Short term (1-5 years).	2
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).	1
Reversibility	Impact is reversible without any time and cost.	1
Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%).	1
Environmental risk	**Low (i.e. where this impact is unlikely to be a significant environmental risk).**	**-1.25**
Potential mitigation measures	Reductions of vehicle exhaust emissions through the use of better-quality diesel; and inspection and maintenance programs.	
Priority Factor Criteria		
Confidence	Medium	
Cumulative	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	1
Reversibility	Where the impact is unlikely to result in irreplaceable loss of resources.	1
Priority factor		1
Final score	**Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).**	**-1.25**

7 IMPACT ASSESSMENT: CUMULATIVE INCLUDING OTHER OPERATIONS IN THE REGION

7.1 Elevated Pollutant Concentrations and Dustfall Rates

Land use in the region includes residences, farming, mining and wilderness. The mining and processing operations (other companies), farming activities, domestic fires, vehicle exhaust emissions and dust entrained by vehicles on public roads without the addition of the proposed operations will likely result in elevated ambient air pollutant concentrations and dustfall rates compared to an area where there are no anthropogenic emission sources. It is difficult to predict the location and contribution of the sources from residences, farming and wilderness to existing air quality. The potential cumulative scenario includes the following atmospheric emissions:

a. Particulate emissions from Kalgold Expansion operations;
b. Miscellaneous fugitive dust sources including vehicle entrainment on roads and wind-blown dust from open areas;
c. Particulate emissions from vehicle exhaust emissions;
d. Particulate emissions from household fuel burning; and
e. Particulate emissions from biomass burning (e.g. wild fires).

Based on the simulated results there is likely to be exceedances of the long-term and short-term NAAQS at AQSRs near Kalgold as a result of the future Kalgold operations.

8 IMPACT ASSESSMENT: NO GO OPTION

8.1 Potential State of the Air Quality

Should the no go option be embarked on, none of the proposed activities will occur in the area. Thus, the potential for an increase in ambient air pollutant concentrations and dustfall rates is small. The current site operations are also likely to cease at some stage and the ambient air quality will improve. There is the possibility of a gradual reduction in ambient air quality in close proximity to the operations should there be any additional mining, industrial and farming operations, vehicle entrainment on roads, wind-blown dust from open areas, vehicle exhaust, household fuel burning and biomass burning.

9 AIR QUALITY MANAGEMENT PLAN

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

9.1 Air Quality Management Objectives

The main objective of the proposed air quality management measures for the project is to ensure that operations at the facility cumulatively result in ambient air concentrations that are within the relevant ambient air quality criteria off-site. To define site specific management objectives, the main sources of pollution needed to be identified. Based on the emissions estimation and dispersion modelling results the two main sources groups associated with the future operations were determined to be crushing and screening operations and vehicles travelling on unpaved roads.

9.1.1 Source Specific Management and Mitigation Measures

Currently Kalgold uses water bowsers applying water to roads (with an efficiency of dust mitigation estimated at 50% (previous studies for Kalgold) and water mist system at the pre-primary and primary crushers and water mist system with scrubber at the secondary and tertiary crushers. Kalgold will continue making use of these mitigation measures for the current and expansion operations. It is recommended that Kalgold combines chemical suppressants with the water sprays. Appendix D includes details on the potential additional mitigation measures that could be implemented.

9.1.2 Source Monitoring

It should be noted that Kalgold should be reporting the annual emissions on the NAEIS system and should continue to do so. Under Section 21 of the NEM:AQA it is compulsory to measure and report annually, PM, NO_x expressed as NO_2, SO_2, HF, HCl, Cl_2 and NH_3 emissions from the smelter stacks; PM, NO_x expressed as NO_2, SO_2.from the carbon-regeneration kiln stacks and requires the holder of an AEL to submit an emission report in the format specified by the National Air Quality Officer (AQO) or Licencing Authority. NEM:AQA does state that the Licencing Authority should establish the final sampling/monitoring and reporting requirements based on knowledge of the sensitivity of the area and the potential significance of the impact of the operations that would have a detrimental effect on the environment (all biophysical and socio-economic aspects). As per the PAEL, the Licensing Authority requires Harmony to conduct quarterly emissions sampling and reporting in the format specified by the AQO. It is therefore recommended that Harmony continue emissions sampling and reporting as currently conducted; and make the necessary changes to the sampling and reporting if there are any associated with the expansion operations PAEL.

9.1.3 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 the Kalgold current dustfall sampling continue to be conducted and that the PM_{10} monitoring is continued, and the weather station remains operational as part of the project's air quality management plan. The equipment must be maintained and kept in good working order to reduce downtime and the quantity of missing data.

The dustfall sampling and reporting must be conducted according to the NDCR. The weather station operators need to check regularly (at least once a week) that the station is operational and ensure that a weather station is recording at least hourly meteorological data and that the units of measurements (metric or imperial/US customary system) remains constant or note changes in the unit of measurements. The inclusion of meteorological data (wind speed, wind direction, and rainfall) in the dustfall reports is a requirement of the NDCR. The on-site personnel should also ensure that there are no nearby structures or trees that could interfere with the wind flow from certain directions as this would produce incorrect readings for the wind field. The cause for the poor data availability from the PM_{10} sampler should be investigated, and the instrument should be calibrated bi-annually to ensure credible data used for management purposes.

9.2 Record-keeping, Environmental Reporting and Community Liaison

9.2.1 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least bi-annually), 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.

Should any environmental emergency incidents occur, the incident will need to be documented in detail and reported to the AQO. The summary of each emergency incident must include:

- Nature and cause of incident

- Actions taken immediately following the incident to minimise impact
- Actions taken after to reduce the likelihood of reoccurrence.

9.2.2 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 in which un-rehabilitated or partly 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. A complaints register must be kept at all times.

9.2.3 Budgeting

The budget should provide a clear indication of the capital and annual maintenance costs associated with 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.

10 Findings and Recommendations

10.1 Main Findings

An air quality impact assessment was conducted for activities proposed as part of the Kalgold Expansion Project. The main objective of this study was to establish baseline air quality in the study area and to quantify the extent to which ambient pollutant levels will change as a result of the proposed operations. The baseline and impact study then informed the air quality management and mitigation measures recommended as part of the Air Quality Management Plan (AQMP). This section summarises the main findings of the baseline- and impact assessments.

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

- Modelled WRF meteorological data for a location on-site for the period January 2018 to December 2020 was used.
- The prevailing wind field in the area consists of north-north-easterly winds.
- The area experiences mild summers and cold winters with monthly average temperatures ranged between 11°C and 26°C. The highest temperature of (38°C) occurred in December and January and the lowest (-5°C) in June and July.
- Nearby residential areas include Old Kraaipan (southeast), Setlagole (southwest) and Mareetsane (20 km to the east). Aside from the residential areas, individual farmsteads near the expansion operations were identified as AQSRs and agricultural areas were identified as environmentally sensitive areas.
- Ambient air pollutant levels in the project area are currently affected by the following sources of emission:
  - Current mining and processing operations at the Kalgold mine.
  - Agricultural operations – the surrounding land use is predominantly agricultural and hence associated activities may contribute to elevated ground level particulate matter concentrations.
  - Vehicles travelling on public and private roads – fugitive dust emissions would occur because of vehicle entrained dust from local paved and unpaved roads, these are also contributors to mobile combustion emissions.
  - Household fuel burning – particulate matter and gaseous emissions may occur from the burning of fuel within households for cooking and space heating.
  - Biomass burning – burning of agricultural land, fire breaks and unplanned veld fires would result in particulate matter and gaseous emissions.
  - Other sources – windblown dust from exposed areas.

- PM_{10} data showed no exceedances of the NAAQS however the station had low data availability (17% in 2019, 29% in 2020, and 52% in 2021).

- There was only one exceedance of the NDCR limit for non-residential areas in 2020 (KG7/HAR07 during April 2020) thus the sampled dustfall rates are in compliance with the NDCR that year; however, four months of data was not provided for 2020. There was only one exceedance of the NDCR limit for non-residential areas at two sites in 2021 (KG7/HAR07 during July 2021 and KG4/HAR04 during August 2021) thus the sampled dustfall rates are in compliance with the NDCR that year; however, only 8 of the 12 months data was available.

- Simulated pollutant concentrations from a study conducted by Digby Wells (Digby Wells Environmental, 2014) showed no exceedance to the current daily and annual NAAQS limits for both PM_{10} and $PM_{2.5}$. However, future expansion operations may result in exceedances to the future $PM_{2.5}$ limits effective 31 January 2030. The simulated dustfall rates for the same study indicated compliance with the NDCR.

The main findings of the impact assessment are as follows:

- Construction, decommissioning/closure and post-closure phases:
  - The environmental risk rating related inhalation health, nuisance impacts and vegetation impacts are likely to be "low" without and with additional mitigation. The overall environmental risk rating is also expected to be "low negative".
- Operational phase:
  - PM_{10}, $PM_{2.5}$, TSP, SO_2, NO_x, CO, DPM, Pb, HF, HCl, Cl_2, and NH_3 emissions and impacts were quantified.
  - PM_{10} concentrations as a result of mitigated operations are not within compliance at one AQSRs over the short-term (24-hour average).
  - PM_{10} and $PM_{2.5}$ concentrations as a result of design mitigated operations are not within compliance off-site but are in compliance at all AQSRs over the short-term and long-term (annual average).
  - Dustfall rates are above the NDCR limits for non-residential areas and above 400 mg/m²-day at some agricultural areas; however, the dustfall rates are below the NDCR limits for residential areas at all AQSRs.
  - DPM does not exceed the US EPA IRIS RfC at any AQSRs.
  - NO_x concentrations are in compliance with the NO_2 NAAQS at all AQSRs over the long-term and short-term.
  - SO_2 and CO concentrations are below the NAAQ limit values.
  - The environmental risk rating of proposed project operations related to inhalation health impacts is likely to be "medium negative" without mitigation measures applied and becomes "low negative" with mitigation measures applied. The overall environmental risk rating is expected to be "medium negative".
  - The environmental risk rating of operations related to nuisance impacts are likely to be "low negative" without and with mitigation measures applied. The overall environmental risk rating is expected to be "low negative".
  - The environmental risk rating of proposed project operations related to the impacts on vegetation health is likely to be "medium negative" without mitigation measures applied and becomes "low negative" with mitigation measures applied. The overall environmental risk rating is expected to be "medium negative".

10.2 Air Quality Recommendations

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

- The management of the operations; resulting in the mitigation of associated air quality impacts;
- The dustfall sampling, ambient fine particulate monitoring and operating of the on-site weather station
    - Should the dustfall sampling show higher rates than those estimated in this study it is suggested that Kalgold investigate and consider adopting additional mitigation and management measures. Fallout dust tends to settle relatively close to sources of emissions and thus if the dustfall sampling show significantly higher rates there is likely to be significantly higher finer particulate matter concentrations as well.
- Record keeping and community liaison procedures.

Based on these findings and provided the measures recommended are in place as well as regular (maximum of 5 years) review of the mitigation, management and monitoring procedures takes place, it is the specialist opinion that the project may be authorised.

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APPENDIX A: AUTHORS' CURRICULUM VITAE AND SACNASP CERTIFICATE

CURRICULUM VITAE

Name	Natasha Anne Shackleton (née Gresse)
Date of Birth	12 September 1988
Nationality	South African
Identification Number	880912 0054 081
Passport Number	A05514095
Employer	Airshed Planning Professionals (Pty) Ltd
Position	Senior Consultant
Profession	Meteorologist employed as an Air Quality and Noise Consultant
Years with Firm	10
E-mail Address	natasha@airshed.co.za
Contact Numbers	+27 11 8051940 (Office Switchboard) +27 10 500 1147 (Office Direct)

MEMBERSHIP OF SOCIETIES

- Registered Professional Natural Scientist (Registration Number 116335) with South African Council for Natural Scientific Professions (SACNASP), 2018 to present.
- National Association for Clean Air (NACA), 2020 to present
- South African Society for Atmospheric Sciences (SASAS), 2016 to present.
- American Meteorological Society (AMS), 2017 and 2018.
- Golden Key International Honour Society, 2011 to present.

EXPERIENCE

Natasha has several years of experience in air quality and noise impact assessments and management. She is an employee of Airshed Planning Professionals (Pty) Ltd and is tasked with completing air, noise, greenhouse gas and climate change studies. These studies usually involve dustfall sampling data analysis, pollutant concentration measurements or sampling data analysis, meteorological data processing and preparation, noise sampling and data analysis; the compilation of emission inventories; undertaking of air dispersion and noise propagation modelling; impact and compliance assessment using her substantial knowledge of South African and international legislation and requirements pertaining to air quality, greenhouse gases emissions and noise; air quality, noise, greenhouse gas and climate change management plan preparation and report writing. Natasha has also assisted with South African Emissions Reporting (National Atmospheric Emission Inventory System [NAEIS] and South African Greenhouse Gas Emissions Reporting System [SAGERS]) for various mines and industries. She has worked on many projects within various countries in Africa which required international financing, providing her with an inclusive knowledge base of IFC guidelines and requirements pertaining to air quality and greenhouse gases emissions.

PROJECTS COMPETED IN VARIOUS SECTORS ARE LISTED BELOW:

Mining Sector

Air Quality Studies

- Coal mining: Argent Colliery; Commissiekraal Coal Mine; Estima Coal Project (Mozambique); Grootegeluk Coal Mine; Matla Coal Mine; Rietvlei Coal Mine; Vierfontein Coal Mine; Goedehoop Coal Mine.
- Metalliferous mines: AngloGold Ashanti Vaal River and West Wits Operations; Harmony Vaal River Operations as part of the Radionuclides Health and Environmental Risks Assessment; Atlantic Sands; Bakubung Platinum Mine; Bakubung Platinum Mine's new Tailings Storage Facility (TSF) Project; Bannerman Uranium Mine (Namibia); Gold Fields' South Deep Gold Mine; Kitumba Copper Project (Zambia); Lehating Manganese Mine; Lesego Platinum Mine; Lofdal Mining Project (Namibia); Marula Platinum Mine; Maseve Platinum Mine; Mkuju River Uranium Project (Tanzania); Namakwa Sands Quartz Rejects Disposal and Mine; Otjikoto Gold Project (Namibia); Otjikoto Gold Mine's Wolfshag Project (Namibia); Pan Palladium Project; Perkoa Zinc Project (Burkina Faso); Storm Mountain Diamonds (Lesotho); Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique); Thabazimbi Iron Ore's Infinity Project; Toliara Sands Project (Madagascar); Tormin Mineral Sands Mine; Trekkopje Uranium Mine (Namibia); Tri-K Project (Guinea); Tschudi Copper Mine (Namibia); Wayland Iron Ore Project; Zulti South Project; West African Resources Sanbrado Project (Burkina Faso); Impala Platinum Rustenburg Mine and Smelter; Mn48 Manganese Mine.
- Quarries: AfriSam Saldanha Cement Project Limestone Quarry; Consol Industrial Minerals; Bundu Mining (air quality and noise), Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique).

Noise Studies

- Metalliferous mines: Bakubung Platinum Mine's new TSF Project; West African Resources Sanbrado Project (Burkina Faso).
- Quarries: Bundu Mining.

Climate Change Studies

- Metalliferous mines: Bakubung Platinum Mine's new TSF Project; Tormin Mineral Sands Mine; West African Resources Sanbrado Project (Burkina Faso); Mn48 Manganese Mine.

Industrial Sector

Air Quality Studies

AfriSam Saldanha Project; CAH Chlorine Caustic Soda and HCl Plant; Consol Industrial Minerals Processing Plant; Corobrik Driefontein new Brick Kiln Project; Metal Concentrators SA Paarden Eiland; Tronox Namakwa Sands Un-Attritioned Magnetic Material (UMM) Plant Environmental Authorisation (EA) application process as well as the Atmospheric Impact Report (AIR) as part of the Atmospheric Emission Licence (AEL) application process and the LNG Project; Otavi Rebar Manufacturing; Phakisa Project; Pan Palladium Project; PPC Riebeeck Cement; Rare Earth Elements (REE) Saldanha Separation Plant; Saldanha Steel; Siyanda Project; Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique); Tri-K Project (Guinea); Tormin Mineral Sands Mineral Separation Plant (MSP); Tronox Namakwa Sands Smelter; Tronox Namakwa Sands MSP including LNG Project; ZMY Steel Recycling Plant; Nyanza TiO_2 Pilot Plant; Musina-Makhado Special Economic Zone (SEZ); West African Resources Sanbrado Project Gold Processing (Burkina Faso), Mortar SA Operations in Darling; Impala Platinum Rustenburg Mine and Smelter including the proposed Second Flash Dryer Project; Mine Waste Solutions (Chemwes) operations including the proposed Kareerand TSF expansion; Sublime Technologies Silicon Carbide Plant; Vanchem Vanadium Products.

Noise Studies

West African Resources Sanbrado Project Gold Processing (Burkina Faso).

Climate Change Studies

Tormin Mineral Sands MSP; West African Resources Sanbrado Project Gold Processing (Burkina Faso); Mine Waste Solutions (Chemwes) operations including the proposed Kareerand TSF expansion.

Power Generation

Air Quality Studies

H2 Energy Power Station; Hwange Thermal Power Station Project (Zimbabwe); Ibhubesi Gas Project; Expansion of Staatsolie Power Company; Suriname Operations (Suriname); Tri-K Project (Guinea); Tete Iron Ore Project / Tete Steel and Vanadium Project (Mozambique); Medupi Power Station; Matimba Power Station; Acacia Peaking Power Station; Port Rex Peaking Power Station; Musina-Makhado SEZ.

Waste Disposal and Treatment Sector

Air Quality Studies

Fishwater Flats Waste Water Treatment Works; Khutala Water Treatment Project; Moz Environmental Industrial Landfill (Mozambique); Koedoeskloof Waste Disposal Site; Interwaste FG Landfill Midrand; Wolverand Crematorium; Green Oil and Lubricants Plant.

Petroleum Sector

Air Quality Studies

Chevron Refinery, Exol Oil Refinery, Puma South Africa's Fuel Storage Facility, Oilkol Depot, Astron Energy Cape Town Refinery; Saldanha Bay Industrial Development Zone Fuel Storage Facilities; Green Oil and Lubricants Plant.

Transport and Logistics Sector

Air Quality Studies

Saldanha Port Project.

Ambient Air Quality and Noise Sampling/Monitoring

Types of Sampling and Monitoring

Gravimetric particulate matter (PM) sampling; Dustfall sampling; Passive diffusive gaseous pollutant sampling; Continuous ambient air quality monitoring; Environmental noise sampling.

Locations of Sampling and Monitoring Projects

South Africa including Limpopo, North West, Mpumalanga, Gauteng and Northern Cape; Burkina Faso; Guinea; Zimbabwe.

SOFTWARE PROFICIENCY

Software utilised in conducting air and noise studies:

- WRPLOT View (wind and pollution rose generation);
- OpenAir (ambient and meteorological data processing);
- Golden Software Surfer (mapping);

- TANKS 4.0.9d (emission estimation model);
- GasSim (emission estimation model);
- SCREEN3 using ScreenView (screening model);
- AERMOD suite (air dispersion model);
- ADMS (air dispersion model);
- CALPUFF suite (air dispersion model);
- CALINE4, CAL3QHC, and CAL3QHCR (traffic air dispersion models);
- GRAL system (air dispersion model);
- DataKustic CadnaA (noise propagation model);
- CONCAWE (noise propagation model); and
- SANS 10201 (calculating and predicting road traffic noise).

EDUCATION

- 2010 to 2011 - BSc Honours (Meteorology) student at the University of Pretoria (Faculty of Natural and Agricultural Sciences), Pretoria. Completed 30 November 2011. Degree issued/conferred 13 April 2012. Research project supervisor: Dr S Venkataraman.
- 2007 to 2010 - BSc student at the University of Pretoria (Faculty of Natural and Agricultural Sciences), Pretoria. Completed 30 June 2010. Degree issued/conferred 2 September 2010.

CONFERENCES ATTENDED, ARTICLES PUBLISHED AND COURSES COMPLETED

- Conference: NACA (November 2020), attended.
- Conference: Innovation Bridge and Science Forum South Africa (December 2019), attended.
- Conference: NACA (October 2018), attended and presented a paper (Correlating Dust Concentration Measurements aloft with Opencast Mining Surface Operations).
- Conference: NACA (October 2017), attended and presented a paper (Correlating Dust Concentration Measurements aloft with Opencast Mining Surface Operations).
- Published Article: Beukes, JP; Van Zyl, PG; Sofiev, M; Soares, J; Liebenberg-Enslin, H; Shackleton, N; Sundstrom, AM (2018). The use of satellite observations of fire radiative power to estimate the availabilities (activity patterns) of pyrometallurgical smelters. Journal of the Southern African Institute of Mining and Metallurgy, 118(6), 619-624., co-author.
- Undergraduate courses passed: computer literacy (word processing, spreadsheet processing, Microsoft power point, Microsoft publisher, use of Internet and Microsoft front page); MATLAB; ArcGIS 9.0.; ERDAS Image; Aan Arbor; IDRISI TAIGA; FORTRAN, GRADS; TITAN; SUMO 3.00; and Danny Rosenfeld 2007-01.

COUNTRIES OF WORK EXPERIENCE

South Africa, Botswana, Burkina Faso, Guinea, Lesotho, Mozambique, Madagascar, Namibia, Suriname, Tanzania, Zambia and Zimbabwe.

LANGUAGES

Language	Proficiency
English	Full professional proficiency
Afrikaans	Limited working proficiency

REFERENCES

Name	Position	Contact Details
Dr Gerrit Kornelius	Associate of Airshed Planning Professionals	+27 82 925 9569 gerrit@airshed.co.za
Dr Lucian Burger	Director at Airshed Planning Professionals	+27 11 805 1940 lucian@airshed.co.za
Dr Hanlie Liebenberg-Enslin	Managing Director at Airshed Planning Professionals	+27 11 805 1940 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.

09/04/2021

SACNASP

South African Council for Natural Scientific Professions

herewith certifies that

Natasha Anne Shackleton

Registration Number: 116335

is a registered scientist

in terms of section 20(3) of the Natural Scientific Professions Act, 2003
(Act 27 of 2003)
in the following fields(s) of practice (Schedule 1 of the Act)

Physical Science (Professional Natural Scientist)

Effective **6 June 2018** Expires **31 March 2022**

Botha

Chairperson

Chief Executive Officer

To verify this certificate scan this code

Appendix B: Methodology for Assessing the Significance of Impacts

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the The impact significance rating methodology, as provided by EIMS, is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/ likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). The impact assessment will be applied to all identified alternatives. Where possible, mitigation measures will be recommended for impacts identified.

Determination of environmental risk

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and Reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$\boldsymbol{C = \frac{(E + D + M + R) * N}{4}}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table D – 1 below.

Table D - 1: Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years)

Aspect	Score	Definition
	3	Medium term (6-15 years)
	4	Long term (15-65 years, the impact will cease after the operational life span of the project)
	5	Permanent (>65 years, no mitigation measure of natural process will reduce the impact after construction)
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected)
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way, moderate improvement for +ve impacts)
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease, high improvement for +ve impacts)
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease, substantial improvement for +ve impacts)
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost
	4	Impact is reversible only by incurring prohibitively high time and cost
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/ scored as per Table D - 2.

Table D - 2: Probability scoring

Probability	**1**	**Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),**
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table D - 3: Determination of environmental risk

Consequence						
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
				Probability		

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table D - 4.

Table D - 4: Significance classes

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk/ reward).
≥9 - <17	Medium (i.e. where the impact could have a significant environmental risk/ reward),
≥17	High (i.e. where the impact will have a significant environmental risk/ reward).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation

Further to the assessment criteria presented in the section above, it is necessary to assess each potentially significant impact in terms of:

1. Cumulative impacts; and
2. The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table D - 5: Criteria for determining prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable Loss of Resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table D - 5. The impact priority is therefore determined as follows:

$$\textbf{Priority = CI + LR}$$

The result is a priority score which ranges from 2 to 6 and a consequent PF ranging from 1 to 1.5 (Refer to Table D - 6).

Table D - 6: Determination of prioritisation factor

Priority	Prioritisation Factor
2	**1**
3	**1.125**
4	**1.25**
5	**1.375**
6	**1.5**

In order to determine the final impact significance, the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is an attempt to increase the post mitigation environmental risk rating by a factor of 0.5, if all the priority attributes are high (i.e. if an impact comes out with a high medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table D - 7: Final environmental significance rating

Environmental Significance Rating	
Value	Description
≤ -17	High negative (i.e. where the impact must have an influence on the decision process to develop in the area).
> -17 ≤ -9	Medium negative (i.e. where the impact could influence the decision to develop in the area).
> -9 < 0	Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).
0	No impact
>0 <9	Low positive (i.e. where this impact would not have a direct influence on the decision to develop in the area).
≥ 9 < 17	Medium positive (i.e. where the impact could influence the decision to develop in the area).
≥ 17	High positive (i.e. where the impact must have an influence on the decision process to develop in the area).

APPENDIX C: DESCRIPTION OF WIND EROSION ESTIMATION TECHNIQUE

Emission quantification was done using the in-house modelled ADDAS (Burger *et al*., 1997; Burger, 2010, Liebenberg-Enslin, 2014). This model is based on the dust emission scheme of Marticorena and Bergametti (1995) referred to as MB95 (from this point forward) and Shao *et al*. (2011) (referred to as SH11). A study conducted by Liebenberg-Enslin (2014) set out to establish a best practice prescription for modelling aeolian dust emissions from mine tailings storage facilities. Site specific particle size distribution data, bulk density and moisture content were used in the dust flux schemes of MB95, and SH11 to test the effects on a local scale. This was done by coupling these schemes with the US EPA regulatory Gaussian plume AERMOD dispersion model for the simulation of ground level concentrations resulting from aeolian dust from mine tailings facilities. Simulated ambient near surface concentrations were validated with ambient monitoring data for the same period as used in the model. Coupling the dust flux schemes with a regulatory Gaussian plume model provided simulated ground level PM_{10} concentrations in good agreement with measured data.

The model inputs include material particle density, moisture content, particle size distribution and site-specific surface characteristics such as whether the source is active or undisturbed. All input parameters that were not measured as part of this work, have been drawn from or calculated using referenced methodologies (Liebenberg-Enslin, 2014).

For the purpose of this study, the MB95 dust flux model as schematically represented in Figure 23 is used.

Meteorological data from the WRF model, run for the years 2014, 2015 and 2016, were extracted for locations close to each of the TSF and used to determine the friction velocity and threshold friction velocity. Parameters of importance include wind speed, wind direction and temperature.

The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by (Marticorena & Bergametti, 1995), is illustrated in Figure 24. The wind speed variation over the storage piles is based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed (us) to approach wind speed (ur), derived from wind tunnel studies for two representative pile shapes, are illustrated in Figure 24 (viz. a conical pile, and an oval pile with a flat top and 37° side slope). The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow (the higher the ratio, the greater the wind exposure potential). These flow patterns are only applicable with piles that have a height to base ratio of more than 0.25.

1 Input parameters

u^* (m s^{-1}): friction velocity

u^*_t (m s^{-1}): threshold friction velocity

η_c (%): clay content

θ (%): total soil moisture

w' (%): adsorbed soil moisture

z_0 (m): surface roughness length

z_{0s} (m): smooth roughness length

D_{ls} (m): mean distance between roughness elements

f : fraction of erodible area

psd (m): particle size distribution

p_b (kg m^{-3}): bulk soil density

pa (kg m^{-3}): air density

g (m s^{-2}): acceleration due to gravity

$p(di)$: dust mass fraction of j^{th} particle-size bin

2 Threshold friction velocity

2a *Threshold friction velocity over smooth surface*

$$u_t^*(d) = \frac{0.129 \times K}{(1.928 \times Re^{0.092} - 1)^{0.5}} \qquad 03 < Re < 10$$

$$Re > 10$$

$$u_t^*(d) = 0.129 \times K[1 - 0.0858\, exp(-0.0617(Re - 10))]$$

$$where:\ K = \left(\frac{P_p g d}{P_a}\right)^{0.5} \times \left(1 + \frac{0.006}{P_p g d^{2.5}}\right)^{0.5}$$

$$Re = 1331\, d^{1.56} + 0.38 \qquad \text{(eq.4)}$$

2b *Drag partition correction* (*R*)

$$R(z_0, z_{0s}) = 1 - \frac{ln\left(\frac{z_0}{z_{0s}}\right)}{ln\left[0.35\left(\frac{D_{ls}/_{30}}{z_{0s}}\right)^{0.8}\right]} \qquad \text{(eq.6)}$$

2c *Moisture correction* (*H*)

$$\frac{u_{tw}^*}{u_{td}^*} = 1 \qquad w < w'$$

$$\frac{u_{tw}^*}{u_{td}^*} = [1 + 1.21(w - w')^{0.68}]^{0.5} \qquad w > w'$$

$$w' = 0.0014(\eta_c)^2 + 0.17(\eta_c) \qquad \text{(eq.11)}$$

$$u_t^*(d; \lambda; w) = \frac{u_{ts}^*(d)}{R(z_0, z_{0s})}(w)$$

3 Horizontal Saltation Flux (WH79)

$$Q(d) = C_0 \frac{P_a}{g} u_*^3 \left(1 - \frac{u_t^*}{u^*}\right)\left(1 + \frac{u_t^*}{u^*}\right)^2 \qquad C_o = 2.6$$

$$Q = \int_{d_0}^{d_n} Q(d)$$

(kg m^{-1} s^{-1})

4 Vertical Dust Flux (MB95)

$$F(d) = 10^{(0.134\, x\, \eta c - 6)} \times Q \times p(dj) \times \frac{1}{K_h}$$

(kg m^{-2} s^{-1})

***4a* Crusting correction (K_h)**

$$F_{crusted} = \frac{F_{uncrusted}}{K_h}$$

$$K_h = -0.03\left(\frac{\tau}{10}\right)^6 + 0.42\left(\frac{\tau}{10}\right)^5 - 2.17\left(\frac{\tau}{10}\right)^4 + 4.88\left(\frac{\tau}{10}\right)^3 - 3.35\left(\frac{\tau}{10}\right)^2 + 0.85\left(\frac{\tau}{10}\right) + 1 \qquad \text{(eq.14)}$$

***4b* Accounting for emissions per particle size group (*p(di)*)**

$$p_m(dj) = \frac{1}{d} \times \sum_{j=1}^{N} \frac{w_j}{\sqrt{2\pi}\sigma_j} exp\left[-\frac{(lnd - lnD)^2}{2\sigma_j^2}\right] \qquad (\text{m}^{-1})$$

(eq.15)

Figure 23: Schematic diagram of parameterisation options and input parameters for the Marticorena and Bergametti (1995) dust flux scheme (Liebenberg-Enslin, 2014)

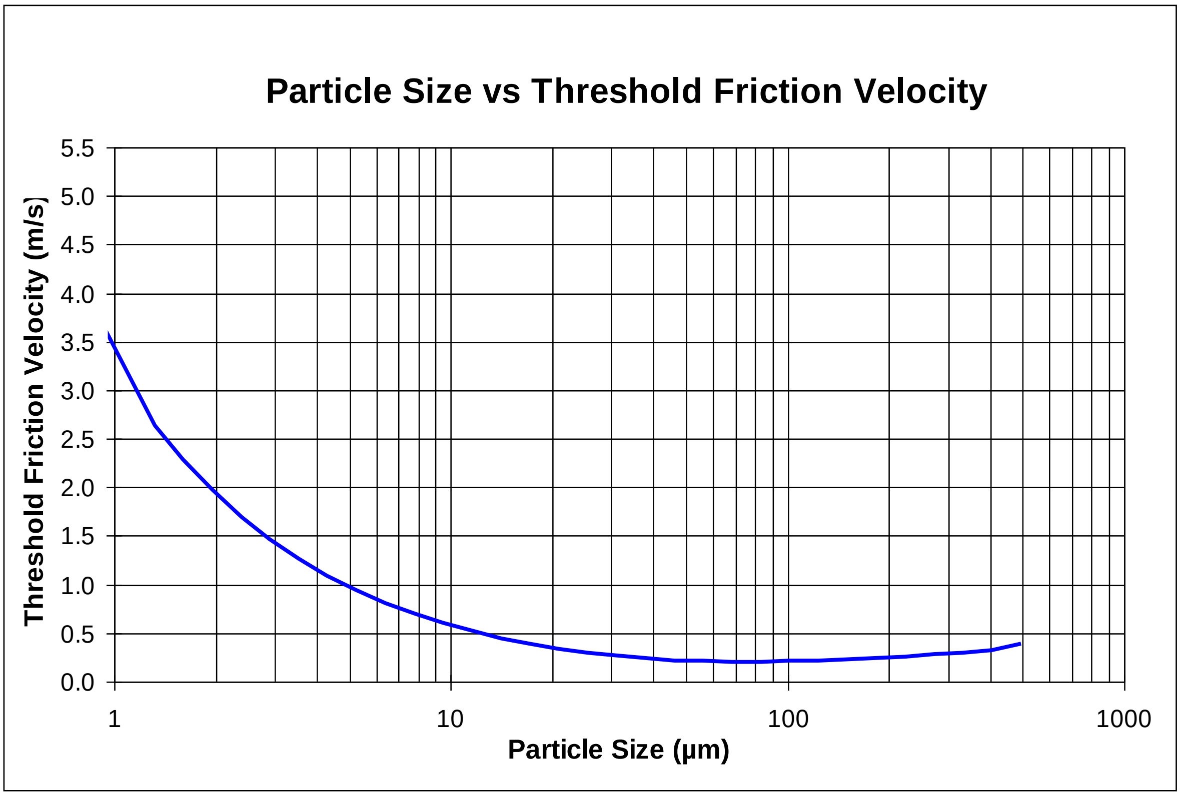

Figure 24: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995)

Appendix D: Additional Details on Dust Control for Unpaved Roads

There are three types of measures that can be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (Cowherd, Muleski, & Kinsey, 1988); (APCD, 1995).

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
- Climate.

When quantifying emissions from unpaved road surfaces, most of these factors are accounted for. Vehicle speed is one of the significant factors influencing the amount of fugitive dust generated from unpaved roads surfaces. 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 effects will be achieved by reducing the truck volumes on the roads. Thus, by increasing the payload of the truck, fewer trips will be required to transport the same amount of material.

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).

Kalgold currently implements the use of water sprays on the unpaved roads.

Appendix E: Simulation Results for Kalgold Future Operations with Both Plants Operational

Estimated Emissions

Table E - 1: Summary of estimated emissions in tonnes per annum for design mitigated expansion operations

Source group	Estimated emissions with current and design mitigation applied [likely operations] (tpa)											
	TSP	PM_{10}	$PM_{2.5}$	DPM	SO_2	NO_x	CO	Cl_2	HCl	F as HF	NH_3	Pb
Drilling	47.9	26.0	13.0	-	-	-	-	-	-	-	-	-
Blasting	16.3	8.5	4.2	-	-	-	-	-	-	-	-	-
Excavation	207.5	189.2	29.6	-	-	-	-	-	-	-	-	-
Materials Handling	21.7	11.0	1.7	-	-	-	-	-	-	-	-	-
Bulldozing	55.8	13.5	6.7	-	-	-	-	-	-	-	-	-
Crushing and Screening	4 310	578	289	-	-	-	-	-	-	-	-	-
Wind Erosion	72.9	36.3	17.4	-	-	-	-	-	-	-	-	-
Unpaved Roads	2 684	1 102	113	-	-	-	-	-	-	-	-	-
Vehicle Exhausts	64.0	64.0	58.6	58.6	2.13	800	331	-	-	-	-	-
Grading	0.075	0.033	0.017	-	-		-	-	-	-	-	-
Stacks	12.7	5.79	1.94	-	95.2	72.4	-	12.4	7.24	7.14	23.8	0.429
Total	**7 493**	**2 034**	**535**	**58.6**	**97.3**	**872**	**331**	**12.4**	**7.24**	**7.14**	**23.8**	**0.429**

Coarse inhalable particulate matter (PM_{10})

Simulated annual average PM_{10} concentrations exceed the NAAQS of 40 µg/m³ beyond the permit area (off-site) but not at any of AQSRs (Figure E – 1). The 24-hour NAAQS (4 days of exceedance of 75 µg/m³) is exceeded beyond the permit area (off-site) and at one AQSR (isolated homestead R02) (Figure E - 2).

Fine inhalable particulate matter ($PM_{2.5}$)

Simulated annual average $PM_{2.5}$ concentrations exceed the current and future[5] NAAQS of 20 µg/m³ and 15 µg/m³, beyond the permit area (off-site) but not at any of AQSRs (Figure E - 3). The current 24-hour NAAQS (4 days of exceedance of 40 µg/m³) is exceeded beyond the permit area (off-site) but not at any AQSRs (Figure E - 4). The 24-hour future[6] NAAQS (4 days of exceedance of 25 µg/m³) is exceeded beyond the permit area (off-site) but not at any AQSRs (Figure E - 4).

Fallout dust

Based on the highest monthly simulated dustfall rates, the daily average dustfall rate does not exceeds the NDCR limit for residential areas (600 mg/m²-day) at any AQSRs but are above 400 mg/m²-day at some agricultural areas outside the permit area (off-site) (Figure E - 5). The daily average dustfall rates exceed the NDCR limit for non-residential areas on-site and beyond the permit area (off-site) (Figure E - 5).

[5] Applicable from 1January 2030
[6] Applicable from 1January 2030

Sulfur dioxide (SO_2)

Simulated annual average SO_2 concentrations do not exceed the NAAQS of 50 µg/m^3. The 24-hour NAAQS (4 days of exceedance of 125 µg/m^3) and 1-hour NAAQS (88 hours of exceedance of 350 µg/m^3) are also not exceeded; in fact, the concentrations are below the NAAQ limits.

Nitrogen dioxide (NO_2)

Simulated annual average NO_x concentrations exceed the NAAQS of 40 µg/m^3 but not at any of the AQSRs (Figure 18). The 1-hour NAAQS (88 hours of exceedance of 200 µg/m^3) is exceeded but not at any AQSRs (Figure 19). The simulated NO_x concentrations exceed the critical level for all vegetation types (Figure 20). It was conservatively assumed that all NO_x is converted to NO_2.

Carbon monoxide (CO)

The 8-hour NAAQS (11 of exceedance of 8-hour rolling average concentrations of 10 000 µg/m^3) and 1-hour NAAQS (88 hours of exceedance of 30 000 µg/m^3) are not exceeded; in fact, the concentrations are below the NAAQ limits.

Lead (Pb)

The annual NAAQS (concentrations of 0.5 µg/m^3) are not exceeded (Figure E - 6). The CALEPA CPV of $1.2x10^{-5}$ (µg/m^3)$^{-1}$ was applied to simulated annual average concentrations to provide a conservative estimate of ILCR since it assumes an individual will be exposed to this concentration constantly over a period of 70 years. Increased lifetime cancer risk is very low (less than 1:1 000 000).

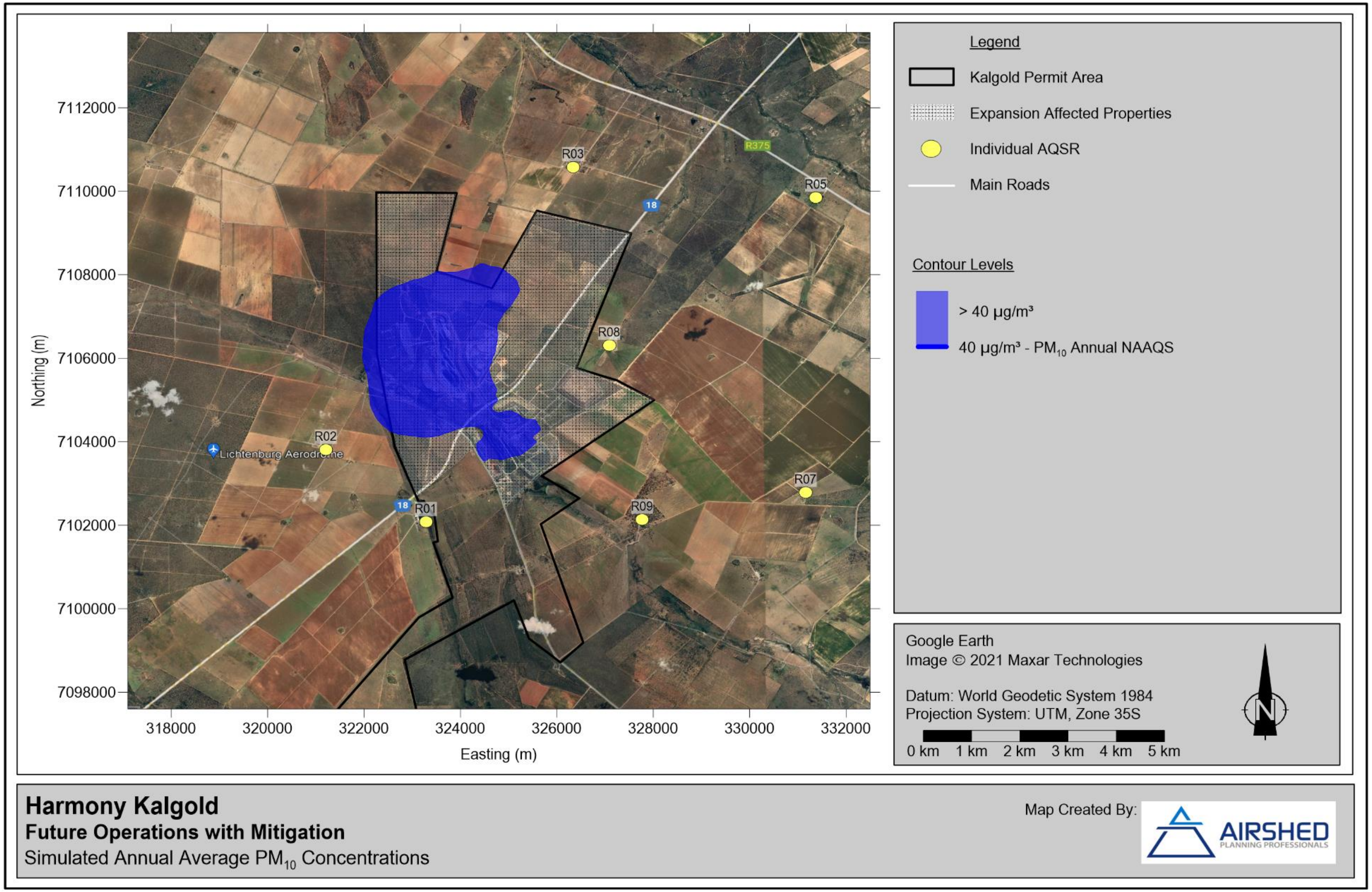

Figure E - 1: Kalgold expansion operations – simulated area of exceedance of the annual average PM_{10} NAAQS

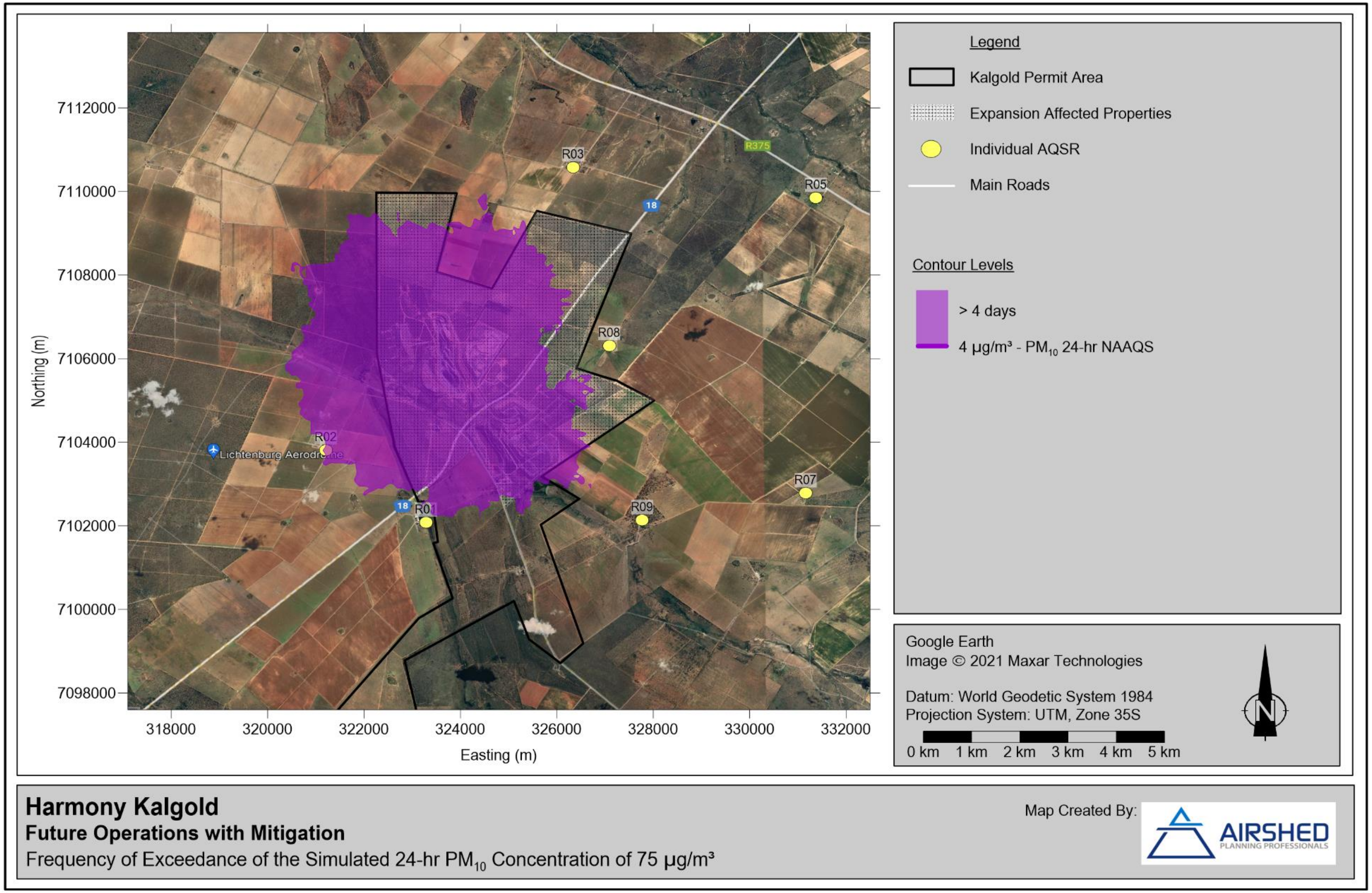

Figure E - 2: Kalgold expansion operations – simulated area of exceedance of the 24-hour PM_{10} NAAQS

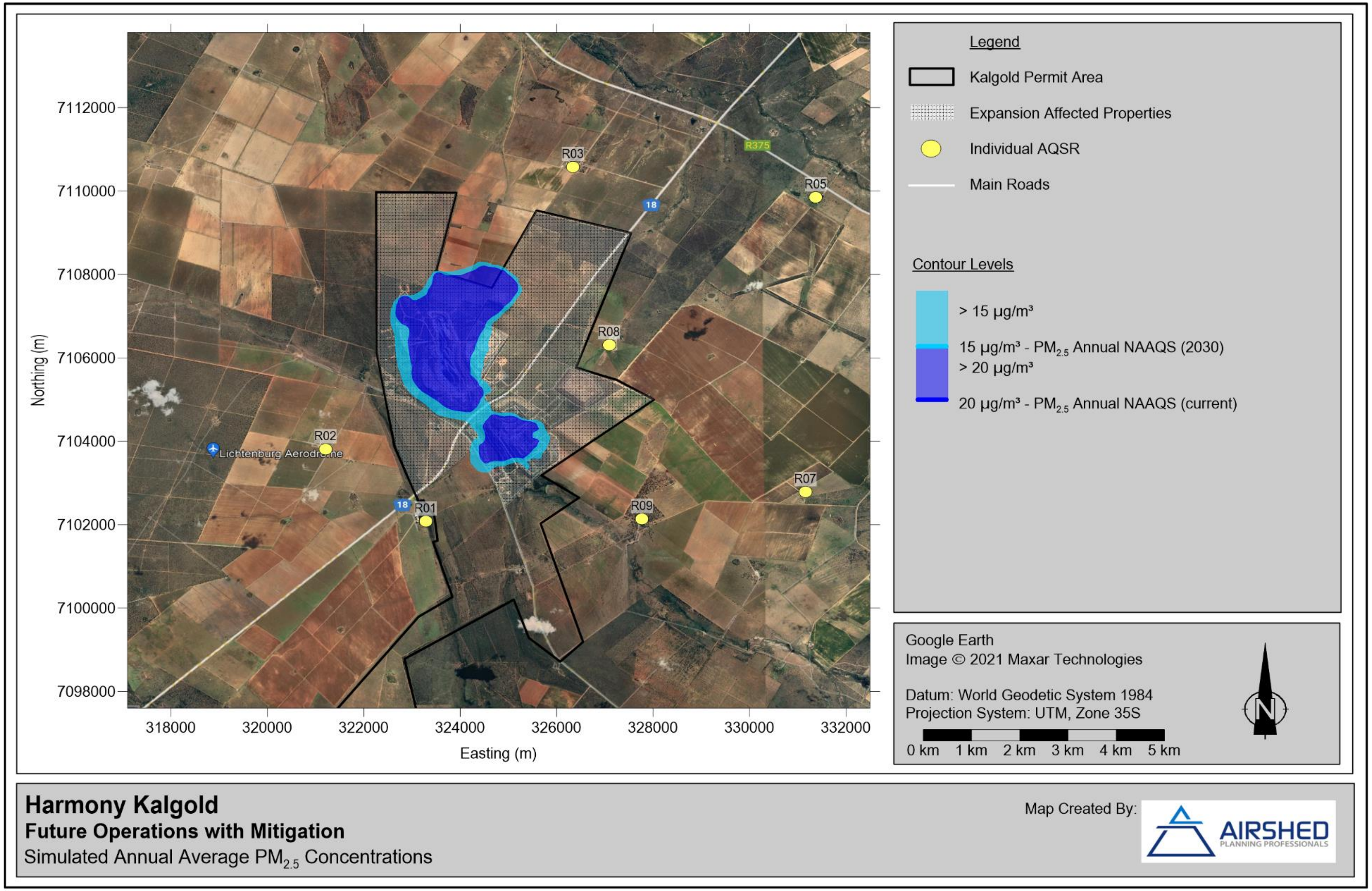

Figure E - 3: Kalgold expansion operations – simulated area of exceedance of the annual average $PM_{2.5}$ NAAQS

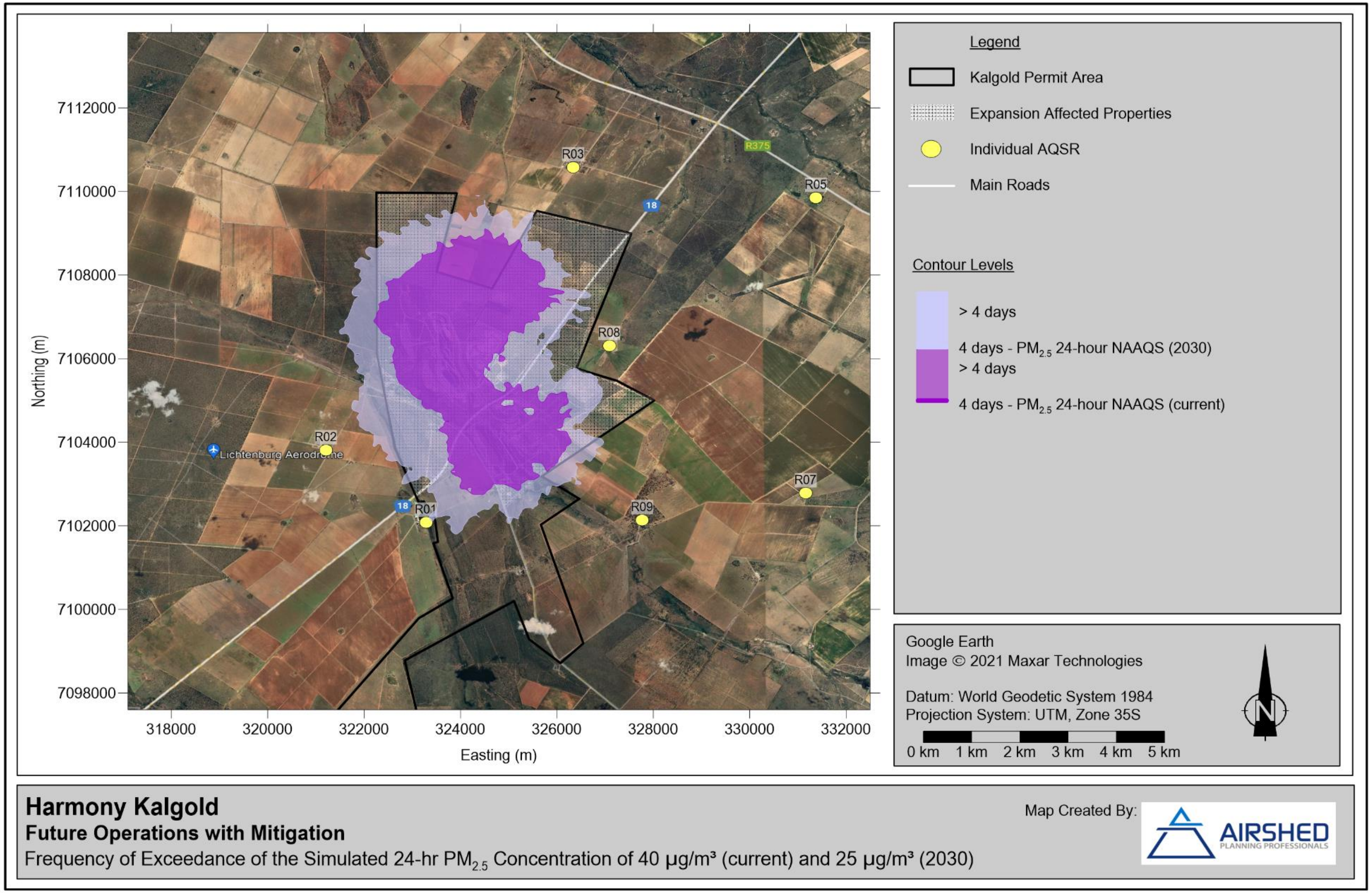

Figure E - 4: Kalgold expansion operations – simulated area of exceedance of the 24-hour $PM_{2.5}$ NAAQS

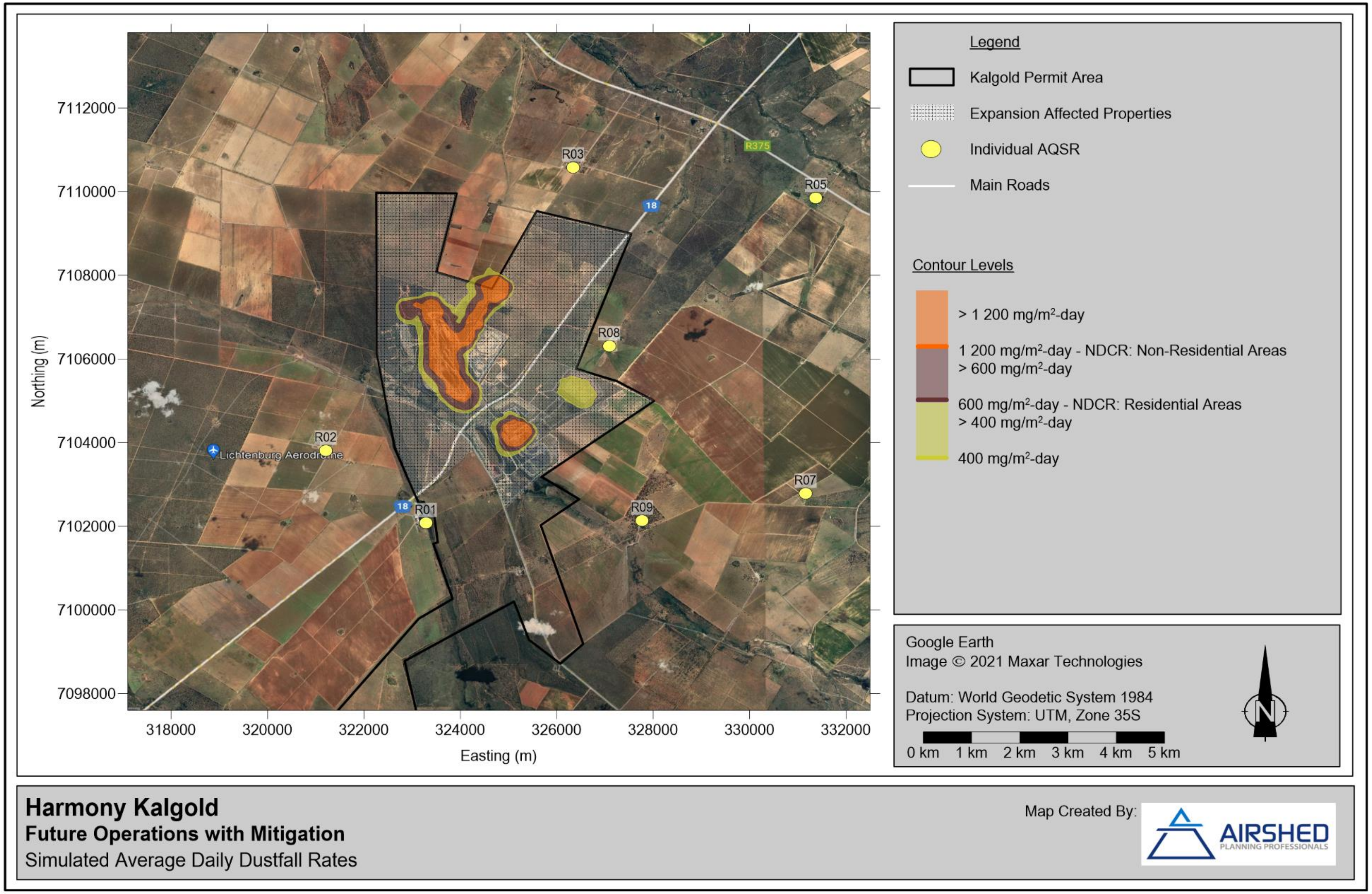

Figure E - 5: Kalgold expansion operations - average daily dustfall rates based on simulated highest monthly dust fallout

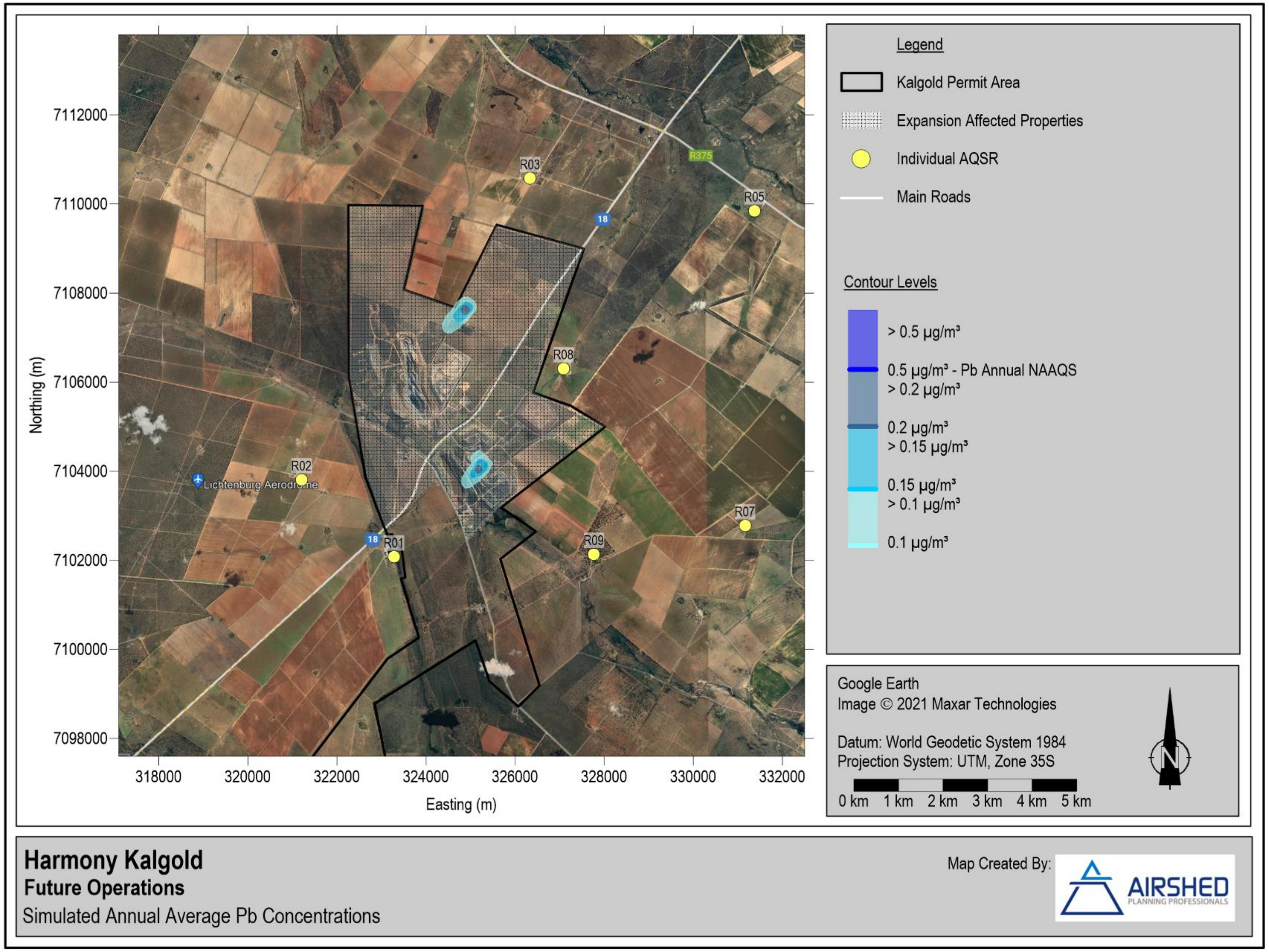

Figure E - 6: Kalgold expansion operations – simulated annual average Pb concentrations