AIRSHED
PLANNING PROFESSIONALS

Air Quality Impact Assessment for the Proposed General Waste Disposal Site at Eskom Majuba Power Station

Project done on behalf of **Savannah Environmental (Pty) Ltd**

Project Compiled by:
Nick Grobler

Report No: 21SAV04 | **Date:** May 2022

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 No.	21SAV01
Status	Revision 1
Report Title	Air Quality Impact Assessment for the Proposed General Waste Disposal Site at Eskom Majuba Power Station
Date	May 2022
Client	Savannah Environmental (Pty) Ltd
Prepared by	Nick Grobler, BEng (Chem), BEng (Hons)(Env) (University of Pretoria)
Reviewed by	Terri Bird, Pr. Sci. Nat, PhD (Wits)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts as well as noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
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.
Copyright Warning	Unless otherwise noted, the copyright in all text and other matter (including the manner of presentation) is the exclusive property of Airshed Planning Professionals (Pty) Ltd. It is a criminal offence to reproduce and/or use, without written consent, any matter, technical procedure and/or technique contained in this document.

Revision Record

Revision Number	Date	Reason for Revision
Draft	May 2022	For client review
Revision 1	June 2022	Addressed client comments, included cumulative impact significance rating

Glossary and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
AQMS	Air Quality Monitoring Station
CALEPA	California Environmental Protection Agency
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
EC	European Commission
EPA	Environmental Protection Agency
EU	European Union
g/hr	Grams per hour
g/s/m²	Grams per second per meter squared
g/m²	Grams per meter squared
g/VKT	Grams per vehicle kilometre travelled
glc	Ground level concentration
hr	Hour
H_2S	Hydrogen sulphide
IFC	International Finance Corporation
IRIS	Integrated Risk Information System
K	Kelvin
kg	kilogram
km	kilometre
kPa	Kilopascals
LFG	Landfill Gas
Majuba Landfill	The proposed General Waste Disposal Site at Eskom Majuba Power Station
m	Metres
m²	Square metres
m³	Cubic metres
mm	Millimetres
mg	Milligram
mg/L	Milligram per litre
m/s	Metres per second
NAAQS	National Ambient Air Quality Standards
ng	Nano gram
NO_x	Nitrogen oxides
NO_2	Nitrogen dioxide
NPI	National Pollutant Inventory (Australia)
NSW	New South Wales
O_2	Oxygen

O_3	Ozone
OEHHA	Office of Environmental Health Hazard Assessment
ou_E	European odour units
ou_E/h	Odour emission rate in odour units per hour
ou_E/m^3	Odour concentration in odour units per cubic meter of air
PM	Particulate matter
PM_{10}	Particulate matter with aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with aerodynamic diameter of less than 2.5 µm
RELs	Reference exposure levels
SA	South Africa
SO_2	Sulfur dioxide
SSG	Sub-surface gas
STP	Standard Temperature and Pressure
TARA	Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division
tpa	Tonnes per annum
tpd	Tonnes per day
TOC	Total organic compounds
TSP	Total suspended particulates
UK	United Kingdom
URFs	Unit risk factors
US	United States
WB	World Bank
VOC	Volatile organic compounds
WBG	World Bank Group
WHO	World Health Organisation
µg	Microgram
µm	Micrometre
%	Percent
°C	Degrees Celsius

Executive Summary

Eskom Majuba Power Station is proposing the development of a new general waste disposal site (Figure 1-1) and associated infrastructure on a site located approximately 13 km southwest of Amersfoort and 40 km north-northwest of Volksrust, within jurisdiction of the Dr Pixley Ka Isaka Seme Local Municipality, which forms part of the Gert Sibande District Municipality in the Mpumalanga Province.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Savanna Environmental (Pty) Ltd to undertake an air quality impact assessment for the proposed General Waste Disposal Facility at Eskom Majuba Power Station (hereafter referred to in this report as the 'Majuba Landfill').

The quantity of general waste generated at the Majuba Power Station is approximately 980 tons per annum. The proposed landfill site will have an expected lifespan of 45 years, similar to the productive life cycle of the power station.

The facility will comprise six cells (C1, C2, C3, C4a, C4b, C4c) with a total capacity of 241 650 m^3. The cells will be linked to a leachate evaporation pond which will be utilised for the storage of leachate. The leachate collection pond will have a capacity of approximately 100 m^3.

The establishment of a comprehensive emissions inventory formed the basis for the air quality impact assessment for the proposed Majuba Landfill on the receiving environment. The emissions inventory included gaseous as well as particulate emissions. Fugitive particulate emissions occur as a result of vehicle-entrained dust from the unpaved road network and dust generation due to material handling as well as wind erosion from exposed areas. Gaseous emissions from the landfill emanate from the work face and covered portions and were modelled in this study.

In the estimation of gaseous emissions from the working faces and covered portions of the landfill, the United Kingdom (UK) Environmental Agency's Gassim model was used. The simulation of ambient air pollutant concentrations was undertaken through the application of the United States Environmental Protection Agency's AERMOD modelling suite. Use was made of meteorological and ambient air quality data from the Eskom Majuba Air Quality Monitoring Station (AQMS), located approximately 2.5 km east-northeast of the proposed Majuba Landfill location for the period January 2016 to December 2019.

The compliance and health risk assessment were done by comparing predicted ambient pollutant concentrations to internationally recognised ambient guidelines, health screening criteria and odour guidelines. The following pollutants and their associated impacts were included in the study:

- Criteria pollutants (i.e. inhalable particulate matter with aerodynamic dimeter of <2.5 µm ($PM_{2.5}$), inhalable particulate matter with aerodynamic dimeter of <10 µm (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and benzene (C_6H_6))
- Non-criteria pollutants:
    - Non-carcinogenic health impacts;
    - Cancer risk impacts;
    - Dust fallout; and
    - Odour impacts.

During the day the wind is predominantly from the west, with a secondary component from the east, with fairly strong wind speeds and little calms. During the night the wind field shifts to be mainly from the east and southeast. The wind is generally stronger during the day with more frequent calms during the night.

Landfill gas (LFG) emissions from the Majuba Landfill gradually increase to reach a maximum during the operation of Cell C4c, when the maximum amount of waste is in place, whereafter it gradually decreases after closure of the landfill. During operation of Cell C4c when emissions are at a maximum, an estimated 6 m^3/hr of LFG will be generated.

In terms of greenhouse gas emissions, over its lifetime, the Majuba Landfill is estimated to result in a lifetime total of 2030 tonnes of CO_2 and 740 tonnes of CH_4 emissions. Annual greenhouse gas emissions are expected to reach a maximum during the operation of Cell C4c. The maximum annual greenhouse gas emissions were estimated at 42.7 tonnes of CO_2/annum and 15.6 tonnes of CH_4 per annum.

The total emission rate of fugitive dust emissions was estimated as 6.92 tonnes per annum of TSP, 1.81 tonnes per annum of PM_{10} and 0.12 tonnes per annum of $PM_{2.5}$.

Simulated PM_{10}, $PM_{2.5}$ and benzene concentrations are in compliance with the SA National Ambient Air Quality Standards (NAAQS) for all areas outside the landfill site, and negligible for all areas outside the property boundary and at all sensitive receptor locations. Simulated dust fallout rates due to the Majuba Landfill operations are below the SA National Dust Control Regulation (NDCR) limits for all areas outside the landfill site, and negligible at all areas outside the property boundary, including at all sensitive receptor locations. The impact of vehicle exhaust from vehicles operating at the Majuba Landfill will have a negligible impact on SO_2, NO_2 and CO concentrations in the study area.

Even though background particulate concentrations in the study area are elevated, the incremental impact of the Majuba Landfill on particulate concentrations is so low throughout the study area that the cumulative impact due to Majuba Landfill operations together with background sources will be indistinguishable from baseline concentrations, with the contribution to the particulate load at sensitive receptor locations deemed to be negligible.

The combined hazard index for all non-carcinogenic pollutant emissions from the Majuba Landfill is below 0.1 for all areas outside the landfill site for all pollutants considered. What this means is that none of the pollutants modelled result in concentrations more than 10% of the relevant international standards and guidelines for any areas outside the landfill site.

The simulated cancer risk for all areas outside the property boundary, including at all sensitive receptor location, is negligible (less than 1:1 000 000 000 or one in a billion increased risk)

Simulated concentrations of all odorous compounds considered were below 10% of the odour detection threshold for all areas, including within the landfill site.

Using the impact significance criteria provided by Savanah Environmental, the proposed Majuba Landfill has a simulated ***low*** impact on air quality, including health impacts, cancer risk and odour impacts at all areas outside the Landfill site, with a ***negligible*** impact at all identified sensitive receptor locations.

Based on the findings above, the following recommendations are made:

- To minimise LFG emissions and the impact thereof on the receiving environment, inactive areas should be capped with the final cap as soon as possible.
- To minimise wind erosion emissions, exposed areas should be revegetated/rehabilitated as soon as possible.
- It is recommended that the dust fallout monitoring network be extended to include a sampling location to the south of the landfill site.

- It is recommended that once-off H_2S sampling, using passive diffusive samplers, be conducted on the western and eastern edges of the landfill site to confirm dispersion modelling results. Since the generation of H_2S is expected to increase with time, it is recommended that this sampling be conducted when the first cell is capped and filling of the second cell starts.
- It is recommended that mitigation measures, such as water sprays, be employed on unpaved road surfaces and to exposed areas when periods of high wind speeds are anticipated.
- A complaints register should be kept on site and complaints should be proactively acted upon to minimise similar future impacts on the nearby communities.

From an air quality perspective, there is no preferred choice between Alternative A and Alternative B, as both options will result in a low impact on ambient air quality outside the landfill site and a negligible impact on ambient air quality at all sensitive receptor locations.

Since no fatal flaws were identified and the simulated impact of the Majuba Landfill on the receiving environment is low for all areas outside the landfill site and negligible at all sensitive receptor locations, this study could find no reason - from an air quality perspective - why the Proposed General Waste Disposal Facility at the Eskom Majuba Power Station should not be authorised.

Table of Contents

List of Tables

List of Figures

Air Quality Impact Assessment for the Proposed General Waste Disposal Facility at Eskom Majuba Power Station

1 INTRODUCTION

1.1 Project Description

Eskom Majuba Power Station is proposing the development of a new general waste disposal site (Figure 1-1) and associated infrastructure on a site located approximately 13 km southwest of Amersfoort and 40 km north-northwest of Volksrust, within jurisdiction of the Dr Pixley Ka Isaka Seme Local Municipality, which forms part of the Gert Sibande District Municipality in the Mpumalanga Province.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Savanna Environmental (Pty) Ltd to undertake an air quality impact assessment for the proposed General Waste Disposal Facility at Eskom Majuba Power Station (hereafter referred to in this report as the 'Majuba Landfill').

A project site, with an extent of ~866 ha has been identified by Eskom Majuba Power Station as a technically feasible site for the development of a new general waste disposal site. A development footprint of ~6 ha has been identified within the project site by the proponent for the development. The 6 ha will accommodate the actual landfill, together with the associated infrastructure that will be required for the operation of the site.

Two alternative sites are being considered for establishment of the landfill site, namely Alternative A, located on Portion 6 of the Farm Witkoppies 81HS and Alternative B, located on Portions 1 and 2 of the Farm Witkoppies 81HS. Both sites are contained within Eskom-owned land.

Infrastructure associated with the new general waste disposal site will include the following:

- Fencing with appropriate signage.
- An adequate access road (gravel or surfaced).
- An access control gate.
- A guard house with an ablution facility.
- A conservancy tank connected to the ablution facility.
- Covered parking facilities.
- A designated area for parking and servicing of plant and machinery.
- Sorting and storage facilities for recyclables.
- Adequate water and electricity connection from the existing rising mains.
- Stormwater drainage network and a stormwater evaporation pond for the stormwater entering the site through the waste body.
- A leachate management system and a leachate evaporation pond.

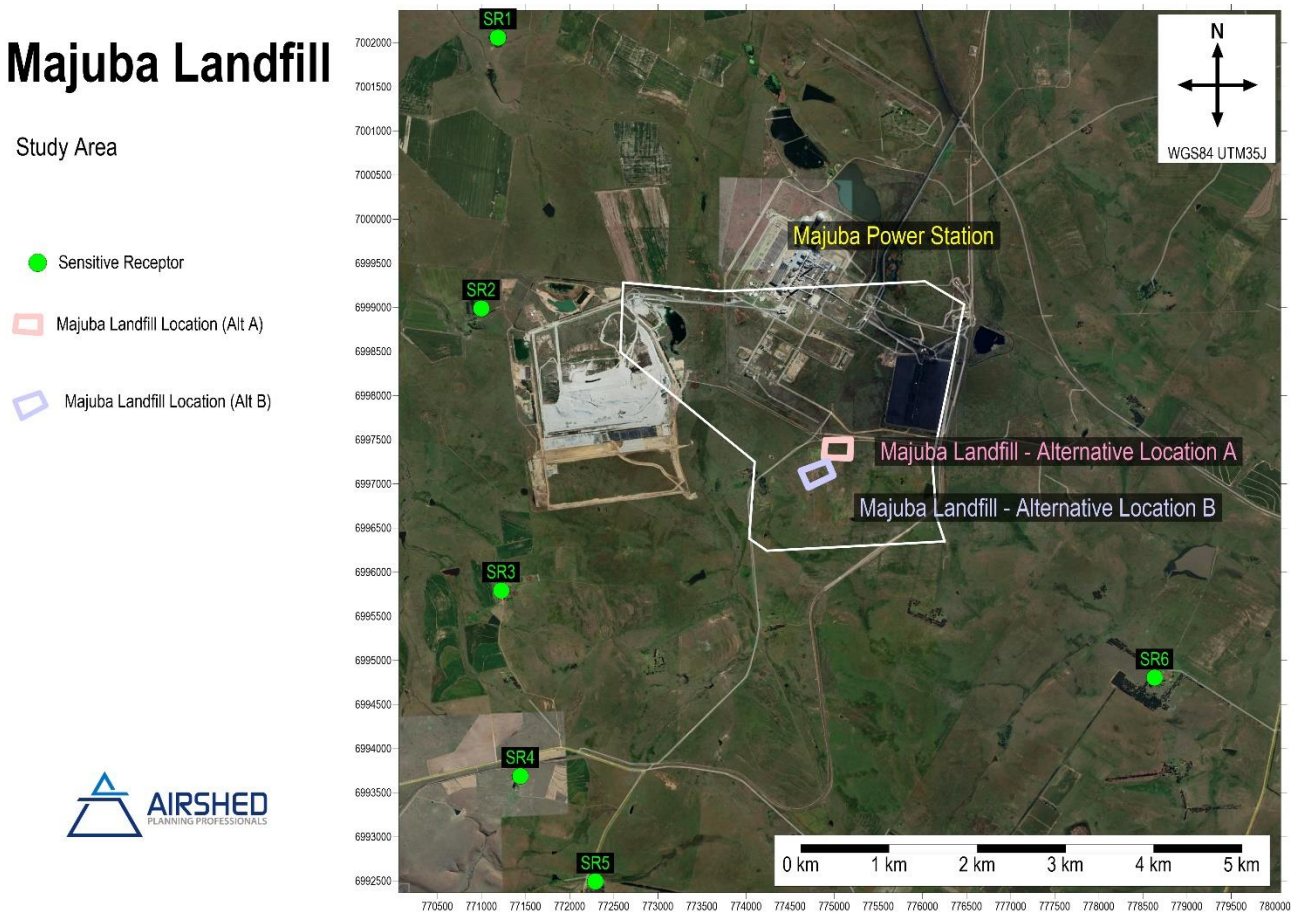

Figure 1-1: Site location, topography and sensitive receptors.

1.2 Terms of reference

The assessment of the proposed operations comprised of a baseline study component and an air quality impact assessment which included the analysis of potential health impacts, and the evaluation of potential odour impacts. The terms of reference of the baseline study component are as follows:

- A study of the site-specific atmospheric dispersion potential;
- Identification of the potential sensitive receptors within the vicinity of the landfill
- Preparation of hourly average meteorological data for the model input;
- Characterisation of ambient air quality in the region;
- A review of the legislative and regulatory context.

The terms of reference for the air quality impact assessment component include the following:

- Compilation of an emissions inventory for the current and proposed operations, comprising the identification and quantification of potential sources of emission;
- Quantifying potential trace gas emissions as well as fugitive particulate emissions;
- Dispersion simulations of ambient concentrations and dust fallout from the proposed operations;
- Analysis of dispersion modelling results;
- Evaluation of the potential for human health, odour and environmental air quality impacts during the construction, operational and decommissioning phases of the project;
- Recommend mitigation measures to avoid and/or minimise and/or optimise benefits associated with the proposed project; and,
- Recommend and draft a monitoring campaign.

1.3 Company Introduction

Airshed Planning Professionals (Pty) Ltd, a South African company, was established in 2003, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003. Airshed comprises a team of professional air quality scientists drawn from a range of disciplines including chemical and mechanical engineering, meteorology, geography and environmental management. Our team holds extensive expertise and experience in all aspects of air pollution impact assessments and air quality management. Airshed is at the forefront of air quality science encouraging and facilitating further study and skills development among our staff and through our association with universities and research organisations. The team is motivated, capable and well equipped to meet the challenge of managing air quality within the sustainable development concept.

1.3.1 *Specialist team introduction*

Report author: NB Grobler, BEng (Chemical Engineering), BEng (Hons) (Environmental Engineering) (Pretoria)

Nick Grobler joined Airshed Planning Professionals after finishing his BEng degree in Chemical Engineering and BEng (Hons) in Environmental Engineering, both from the University of Pretoria. For the past eleven years, Nick has been actively involved in all facets off air quality management, including ambient air quality monitoring, dispersion modelling, air quality impact assessments, and the compilation of air quality management plans. Nick also expanded into conducting environmental noise baseline and impact assessments in 2017. Nick is an associate member of the South African Institution of Chemical Engineers (SAIChE), a member of Golden Key international and a member of Mensa South Africa.

Nick has been actively involved with projects for the opencast and underground mining of: copper, platinum, chrome, gold, iron, coal, limestone, potash, graphite, lead, mineral sands, aggregate stone, clay and zinc. Furthermore, he's also conducted air quality or noise studies for the production of: copper, platinum, PGM metals, gold, base metals, iron, steel, coal, coke, heavy mineral sands, vanadium, solder, lime, urea, chrome, gypsum, asphalt, acetylene, LNG liquefaction, vegetable oil, fertilizer, explosives, wood pulp, cement, grease, oil recycling, tyre and general waste pyrolysis, power generation, fuel storage as well as crematoriums, general waste landfills, meat processing and rendering at abattoirs and animal waste incineration. Nick has experience in working with projects in South Africa, Zimbabwe, Namibia, Mozambique, Republic of Congo, Democratic Republic of Congo, Ghana, Liberia, Guinea, Mali, Suriname and Saudi Arabia.

Report reviewer: Dr Theresa (Terri) Bird, Pr. Sci. Nat., PhD (University of the Witwatersrand)

Dr Terri Bird holds a PhD from the School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg. The focus of her doctoral research was on the impact of sulfur and nitrogen deposition on the soil and waters of the Mpumalanga Highveld. Since March 2012, she has been employed at Airshed Planning Professionals (Pty) Ltd. In this time, she has been involved in air quality impact assessments for various mining operations (including coal, mineral sand, diamond and platinum mines); coal-fired power station and ash disposal facilities; gas-to-power facilities; and various industrial processes. She has been a team member on the development of Air Quality Management Plans, for air quality priority areas, provincial, metropolitan areas, and for specific industries. She has also been involved in various air quality and dustfall monitoring projects.

1.4 Study Approach and Methods

The establishment of a comprehensive emission inventory formed the basis for the air quality impact assessment for the proposed operations on the receiving environment. The emissions inventory included gaseous as well as particulate emissions. Fugitive particulate emissions occur as a result of vehicle-entrained dust from vehicles travelling on the unpaved roads, work faces and covered portions; wind erosion from exposed areas; along with fugitive dust emissions due to material handling activities, both for waste handling and covering operations. Gaseous emissions from the landfill emanate from the work face, covered portions and leachate pond were modelled in this study.

In the estimation of gaseous emissions from the working faces and covered portions of the landfill, the United Kingdom (UK) Environmental Agency's Gassim model was used. This model was developed to provide a standard risk assessment methodology for the Agency, landfill operators and consultants. Gassim is designed to aid landfill gas (LFG) risk assessment, by enabling LFG generation, emissions, migration/dispersion and impact/exposure to be assessed in a reproducible manner by those familiar with the subject, but without the need to build multiple models. In order to quantitatively evaluate the risks of landfill processes and the magnitude of the impacts, Gassim considers the uncertainty in input parameters using a Monte Carlo Simulation. The model allows the calculation of bulk LFG emissions (methane, carbon dioxide and hydrogen) as well as trace LFG such as hydrogen sulphide (H_2S) and benzene.

In the calculation of ambient air pollutant concentrations use was made of the United States Environmental Protection Agency's (US EPA) AERMOD atmospheric dispersion modelling suite. AERMOD is a Gaussian plume model best used for near-field applications where the steady-state meteorology assumption is most likely to apply. AERMOD is a model developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

Meteorological data from the Eskom Majuba Air Quality Monitoring Station (AQMS), located approximately 2.5 km east-northeast of the proposed Majuba Landfill location (Figure 3-4), for the period January 2016 to December 2019 was studied and used in the dispersion modelling simulations,

The dispersion of pollutants was modelled for an area covering 10 km (north-south) by 10 km (east-west) with the Landfill at the centre. This area was divided into a grid with a resolution of 100 m (north-south) by 100 m (east-west). AERMOD simulates ground-level concentrations for each of the receptor grid points.

The compliance and health risk assessment were done by comparing predicted pollutant concentrations to South African National Ambient Air Quality Standards (NAAQS) and international air quality health screening criteria and odour guidelines (Section 2.3). The following were assessed in the study:

- Criteria pollutants (i.e. inhalable particulate matter with aerodynamic diameter of <2.5 µm ($PM_{2.5}$), inhalable particulate matter with aerodynamic diameter of <10 µm (PM_{10}) and benzene.
- Non-criteria pollutants:
    - Cancer risk impacts;
    - Non-carcinogenic health impacts;
    - Dust fallout; and
    - Odour impacts.

1.5 Management of Uncertainty

In interpreting the study findings, it is important to note the limitations and assumptions on which the assessment was based. The most important assumptions and limitations of the air quality impact assessment are summarised as follows:

- Predicted air pollution impacts only include those air emissions associated with the proposed landfill operations. Impacts from other operations in the area, as well as background sources, were not quantified. Cumulative impacts were assessed by superimposing the modelled incremental impacts from the Landfill with baseline pollutant concentrations measured at the Eskom Majuba AQMS over the period 2016 to 2019.
- For the current study it was assumed that information regarding the amount and type of waste disposed, provided by Eskom via Savannah Environmental in the Scoping Report for the facility, is accurate.
- Since it is not possible to compute actual day-to-day operations on the landfill, annual average throughputs were used. Operational locations and periods were selected to reflect the representative worst case scenarios. This is considered to be a conservative approach.
- Where site specific information was not available for use in the estimation of emissions from working surfaces and capped areas, reference was made to default values provided in the Gassim model and data from similar operations in South Africa (SA). In order to quantitatively evaluate the risks of landfill processes and the magnitude of the impacts, Gassim simulates the uncertainty in input parameters using probability density functions and a Monte Carlo Simulation.
- The silt content of unpaved roads was assumed to be the AP42 municipal landfills average silt content of 6.4% for municipal landfills.
- Since no site specific particle size distribution (PSD) information was available for the cover material used at the Landfill, reference was made to surface parameters (PSD, moisture etc) from similar general waste landfills in South Africa.
- Where no emission factors exist for $PM_{2.5}$ from fugitive dust sources, $PM_{2.5}$ fractions were estimated based on PM_{10} emission rates and conservative assumption for the $PM_{2.5}$ based on the source type.
- Gassim uses various statistical distributions to specify sub-surface gas (SSG) concentration variability (e.g. uniform, triangular, normal etc.). Use was made of Gassim's default range for each pollutant since no site-specific sub-surface gas concentration data was available.
- The limitations of the LFG emissions model Gassim are:
    - The model operates at steady state with a minimum time period of one year.
    - Migration of gas is not modelled in the saturation zone.
    - The model does not determine the pressure generated by the landfill and to simplify the model, pressure has been excluded from all modules.
    - Lateral migration is determined using a conservative one dimensional advection and diffusion equation. The diffusivity is determined for the diffusivity of the gas in air, which is corrected for the porosity and moisture content of the medium.
    - The H_2S module assumes that the production of H_2S is controlled by the quantity of degraded organic material and the available calcium sulfate and iron.
    - The biological methane oxidation module assumes that all fissures/discrete features emit the same quantity of gas and that these emissions are not reduced by methane oxidation.
- Ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access, i.e. off-site;
- There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The

total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere. Typically, complex topography with a high incidence of calm wind conditions, produce predictions within a factor of 2 to 10 of the observed concentrations. When applied in flat or gently rolling terrain, the USA-EPA (EPA 1986) considers the range of uncertainty to be -50% to 200%. The accuracy improves with strong wind speeds and during neutral atmospheric conditions.

1.6 Report Outline

Assessment criteria applicable to the proposed project are presented in Section 2. The study area, atmospheric dispersion potential and the existing air quality for the area are discussed in Section 3. The emissions inventory for proposed operations is detailed in Section 4. Dispersion model results are presented in Section 5. An impact assessment and significance rating are provided in Section 6, while management, mitigation and measurement recommendations are provided in Section 7.

2 ASSESSMENT CRITERIA AND REGULATORY CONTEXT

2.1 Regulatory Requirements

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

- Air emission standards are generally provided for point sources and specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment. The Department of Environmental Affairs (DEA), now the Department of Forestry, Fisheries and the Environment (DFFE), published a list of activities (*Listed Activities and Minimum National Emission Standards*), identifying those activities that are regulated by the DFFE and which require the application for an *Atmospheric Emission License* (AEL).
- As a requirement under the Paris Climate Agreement, which South Africa ratified in November 2016, the *National Greenhouse Gas Emission Reporting Regulations* were published in 2017 to allow the DFFE to gather information from businesses to assist South Africa to update and maintain a National Greenhouse Gas Inventory.
- 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 pollution concentration standards included in the *National Ambient Air Quality Standards* (NAAQS) indicate safe daily exposure levels for most of the population, including the very young and the elderly, throughout an individual's lifetime. These air quality standards are normally given for specific averaging or exposure periods.
- Dust controls are regulated under the *National Dust Control Regulations* (NDCR) and provide dustfall rate standards for residential and non-residential areas.

The Minister, in terms of *Section 21* of the National Environmental Management: Air Quality Act of 2004 (NEM:AQA) (Government Gazette No. 27318), published a list of activities which result in atmospheric emissions and which are believed to have significant detrimental effects on the environment, human health and social welfare. All scheduled processes as previously stipulated under Air Pollution Prevention Act 45 of 1965 (APPA) were included as listed activities with additional activities being added to the list. However, the Majuba Landfill operations include landfilling activities waste recycling options (not requiring heat or chemical reactions), and according to Section 21, none of these are considered listed activities (in Section 21) and therefore does not require an AEL to operate.

The *National Atmospheric Emission Reporting Regulations* (*Government Gazette No. 38633*) came into effect on 2 April 2015. The purpose of the regulations is to regulate 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). 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. All activities requiring an Atmospheric Emissions Licence (AEL), controlled emitters and mining operations must report their annual atmospheric emissions on the system by 31 March of each year. Although the Majuba Landfill is excluded from an AEL, by virtue of not falling under any of listed activities in the MES, the requirement to report emissions on the NAEIS may still be required under the NEM:AQA National Greenhouse Gas Emission Reporting Regulations (NGERs). The NGERs came into effect on 3 April 2017 (Government Gazette No. 40762). Each company's greenhouse gas (GHG) Emissions Report will be used as the basis for their carbon tax calculations. Companies, in control of certain GHG emitting activities and which exceed a predetermined threshold, will be required to submit GHG emission data calculated in line with technical guidelines

and in a format prescribed by the NGERs. Listed activities and associated capacity thresholds that require a GHG Emissions Report are provided in *Annexure 1: List of Activities for which GHG Emissions must be Reported to the Competent Authority* of the NGERs. The greenhouse gases covered by the NGERs include, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The reporting threshold for Managed Solid Waste Disposal Facilities is "Receiving 5 tonnes per day or a total capacity of 25 000 tonnes", so the Majuba Landfill will fall below the reporting threshold at the design waste disposal rates.

Since the focus of the study is to illustrate the differences in air quality anticipated with the proposed operations the NAAQS and NDCR will be discussed below. This section, therefore, summarises legislation for criteria pollutants and dustfall, as well as screening criteria for non-regulated pollutants, including carcinogens other than benzene.

2.1.1 *National Ambient Air Quality Standards (NAAQS)*

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. The final NAAQS was published in the Government Gazette on the 24th of December 2009 (Government Gazette 32816) and additional standards for particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$) was published on the 29th June 2012. The standards were developed for those pollutants that are most found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. These generally include CO, NO_2, SO_2, benzene, lead (Pb), PM_{10}, $PM_{2.5}$, and ground level ozone (O_3), as listed in Table 2-1.

Table 2-1: National Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration (µg/m³)	Permitted Frequency of Exceedance	Compliance Date
Sulfur Dioxide (SO_2)	10 minutes	500	526	Currently Enforceable
	1 hour	350	88	Currently Enforceable
	24 hours	125	4	Currently Enforceable
	1 year	50	0	Currently Enforceable
Benzene	1 year	5	0	Currently Enforceable
Carbon Monoxide (CO)	1 hour	30000	88	Currently Enforceable
	8 hour[(a)]	10000	11	Currently Enforceable
Lead (Pb)	1 year	0.5	0	Currently Enforceable
Nitrogen Dioxide (NO_2)	1 hour	200	88	Currently Enforceable
	1 year	40	0	Currently Enforceable
Ozone (O_3)	8 hour[(b)]	120	11	Currently Enforceable
$PM_{2.5}$	24 hours	40	4	Enforceable until 31 December 2029
	24 hours	25	4	1 January 2030
	1 year	20	0	Enforceable until 31 December 2029
	1 year	15	0	1 January 2030
PM_{10}	24 hours	75	4	Currently Enforceable
	1 year	40	0	Currently Enforceable

Notes:
(a) Calculated on 1-hour averages.
(b) Running average.

2.1.2 *National Dust Control Regulations (NDCR)*

The NDCR were published on 1 November 2013, with the purpose of prescribing general measures for the control of dust in all areas including residential and non-residential areas. The standard for acceptable dustfall rates is set out in Table 2-2 for residential and non-residential areas. According to these regulations the dustfall rates 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.

Table 2-2: Acceptable dust fall rates

Restriction Area	Dust-fall rate (D) (mg/m²/day, 30-day average)	Permitted frequency of exceeding dust fall rate
Residential	D < 600	Two within a year, not sequential months.
Non-residential	600 < D < 1 200	Two within a year, not sequential months

Note: 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

In addition to the dust fall limits, the NDCR prescribe monitoring procedures and reporting requirements. This will be based on the measuring reference method ASTM 01739:1970 (or an equivalent method approved by any internationally recognised body) averaged over 30 days.

2.1.3 *Atmospheric Dispersion Modelling Regulations*

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. The *Regulations Regarding Air Dispersion Modelling* 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. These Regulations are applicable in the development of (a) an air quality management plan (as contemplated in *Chapter 3* of the NEM:AQA), (b) a *Priority Area Air Quality Management Plan* (as contemplated in *Section 19* of the NEM:AQA), (c) an *Atmospheric Impact Report* (AIR) (as contemplated in *Section 30* of the NEM:AQA; and, (d) 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 the following situations:
    - 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 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 the most appropriate to assess the impact of the Majuba Landfill on the receiving environment.

2.2 International Ambient Air Quality Guidelines

2.2.1 *Non-carcinogenic Health Risk Factors*

Air quality criteria for non-criteria pollutants are published by various sources. Such criteria include:

- World Health Organization (WHO) guideline values,
- Chronic and sub-chronic inhalation reference concentrations and cancer unit risk factors published by the US EPA in its Integrated Risk Information System (IRIS),
- U.S. EPA Health Effects Assessment Summary Tables (HEAST)
- Reference exposure levels (RELs) published by the Californian Office of Environmental Health Hazard Assessment (OEHHA), and
- Minimal risk levels issued by the US Federal Agency for Toxic Substances and Disease Registry (ATSDR).

Various non-carcinogenic exposure thresholds for pollutants of interest in the current study are given in Table 2-3. These Reference Concentrations (RfC) were obtained from the US EPA's Risk Assessment Information System (RAIS). RAIS has been sponsored by the U.S. Department of Energy (DOE), Office of Environmental Management, Oak Ridge Operations (ORO) Office through a contract between URS | CH2M Oak Ridge LLC (UCOR) and the University of Tennessee. The database is subject to quality assurance review before being published.

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

2.2.2 *Cancer Health Risk Factors*

Unit risk factors (URFs) are applied in the calculation of carcinogenic risks. These factors are defined as the estimated probability of a person (60-70 kg) contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m³ over a 70-year lifetime. Unit risk factors were obtained from the sources described in the previous section and summarised in Table 2-4.

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.

Table 2-3: International health risk criteria for pollutants not included in the NAAQS

Compound	CAS #	Chronic Reference Concentration		Subchronic Reference Concentration		Short-Term Reference Concentration		Acute Reference Concentration	
		Concentration [µg/m³]	Reference	Concentration [µg/m³]	Reference	Concentration [µg/m³]	Reference	Concentration [µg/m³]	Reference
Acetaldehyde	75-07-0	9	IRIS					470	CALEPA
Acetonitrile	75-05-8	60	IRIS	500	HEAST Current				
Acrolein	107-02-8	0.02	IRIS	0.092	ATSDR Final	0.092	ATSDR Final	6.88	ATSDR Final
Acrylonitrile	107-13-1	2	IRIS					217	ATSDR Final
Ammonia	7664-41-7	500	IRIS	100	PPRTV Current			1184.1	ATSDR Final
Arsenic	7440-38-2	0.015	CALEPA	70	PPRTV Current			0.2	CALEPA
Benzaldehyde	100-52-7								
Benzene	71-43-2	30	IRIS	80	PPRTV Current	19.17	ATSDR Final	28.75	ATSDR Final
Butylacetate	123-86-4								
Carbon Tetrachloride	56-23-5	100	IRIS	188.7	ATSDR Final	188.7	ATSDR Final	1900	CALEPA
Chloroform	67-66-3	97.7	ATSDR Final	244.1	ATSDR Final	244.1	ATSDR Final	488.3	ATSDR Final
Cresol, m-	108-39-4	600	CALEPA						
Cresol, o-	95-48-7	600	CALEPA						
Cresol, p-	106-44-5	600	CALEPA						
Dichloroethane, 1,1	75-34-3	500	HEAST	5000	HEAST				
Ethyl Acetate	141-78-6	70	PPRTV Current	700	PPRTV Current				
Ethyl Benzene	100-41-4	1000	IRIS	9000	PPRTV Current	8670	ATSDR Final	21700	ATSDR Final
Ethylene Dichloride	107-06-2	7	PPRTV Current	70	PPRTV Current				
Formaldehyde	50-00-0	9.8	ATSDR Final	36.8	ATSDR Final	36.85	ATSDR Final	49.13	ATSDR Final
Hexane, n-	110-54-3	700	IRIS	2000	PPRTV Current				
Hydrogen Sulphide	7783-06-4	2	IRIS	27.9	ATSDR Final	27.88	ATSDR Final	97.57	ATSDR Final
Methylene Chloride	75-09-2	600	IRIS	1040	ATSDR Final	1040	ATSDR Final	2080	ATSDR Final
Methyl Ethyl Ketone	78-93-3	5000	IRIS	1000	HEAST Current			13000	CALEPA
Methyl Isobutyl Ketone	108-10-1	3000	IRIS	800	HEAST Current				
Pentane, n-	109-66-0	1000	PPRTV Current	10000	PPRTV Current				
Phenol	108-95-2	200	CALEPA					5800	CALEPA
Propionaldehyde	123-38-6	8	IRIS						

Compound	CAS #	Chronic Reference Concentration		Subchronic Reference Concentration		Short-Term Reference Concentration		Acute Reference Concentration	
		Concentration [µg/m³]	Reference	Concentration [µg/m³]	Reference	Concentration [µg/m³]	Reference	Concentration [µg/m³]	Reference
Tetrachloroethane, 1,1,2,2	79-34-5								
Tetrachloroethylene	127-18-4	40	IRIS	40.69	ATSDR Draft	40.69	ATSDR Draft	40.69	ATSDR Draft
Toluene	108-88-3	5000	IRIS	5000	PPRTV Current			7600	ATSDR Final
Trichloroethane, 1,1,2	79-00-5	0.2	Screen Current	2	Screen Current				
Trichloroethylene	79-01-6	2	IRIS	2.15	ATSDR Draft	2.15	ATSDR Draft		
Trimethylbenzene, 1,2,3-	526-73-8	60	IRIS	200	IRIS				
Trimethylbenzene, 1,2,4-	95-63-6	60	IRIS	200	IRIS				
Trimethylbenzene, 1,3,5-	108-67-8	60	IRIS	200	IRIS				
Vinyl Chloride	75-01-4	100	IRIS	76.7	ATSDR Final	76.7	ATSDR Final	1.28	ATSDR Final
White Spirit (as Naphtha)	64742-95-6	100	PPRTV	10000	PPRTV				
Xylenes	1330-20-7	100	IRIS	400	PPRTV Current	2605.4	ATSDR Final	8684.662577	ATSDR Final

Notes: IRIS – IRIS U.S. EPA Integrated Risk Information System
PPRTV – U.S. EPA Provisional Peer Reviewed Toxicity Values
ATSDR – Agency for Toxic Substances and Disease Registry minimal risk levels (MRLs)
CALEPA – California Environmental Protection Agency (CALEPA) Office of Environmental Health Hazard Assessment (OEHHA) Chronic Reference Exposure Levels (RELs)
HEAST – U.S. EPA Health Effects Assessment Summary Tables

Table 2-4: Unit risk factors

Chemical	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Inhalation Unit Risk Source
1,1,2,2-Tetrachloroethane	3.0E-06	WHO
1,1,2-Trichloroehane	1.6E-05	IRIS
1,1-Dichloroethane	1.6E-06	CALEPA
1,2-Dichloroethane (Ethylene dichloride)	2.8E-06	WHO
1,3-Butadiene	3.0E-05	WHO
Acetaldehyde	9.0E-07	WHO
Acrylonitrile	2.0E-05	WHO
Arsenic	1.5E-03	WHO
Benzene	7.5E-06	WHO
Benzo(a)pyrene	8.7E-02	WHO
Bromodichloromethane	3.7E-05	CALEPA
Cadmium	1.8E-03	IRIS
Carbon tetrachloride	6.0E-06	IRIS
Chloroform	4.2E-07	WHO
Chromium (hexavalent)	8.4E-02	IRIS
Ethylbenzene	2.5E-06	CALEPA
Formaldehyde	1.3E-05	IRIS
Lead	1.2E-05	CALEPA
Methylene chloride	4.7E-07	IRIS
Nickel	2.4E-04	WHO
PCDD/PCDF (i-TEQ)	33	IRIS
Tetrachloroethylene	5.9E-06	CALEPA
Trichloroethylene	4.3E-07	WHO
Vinyl chloride	1.0E-06	WHO

Notes: IRIS – IRIS U.S. EPA Integrated Risk Information System
CALEPA – California Environmental Protection Agency Office of Environmental Health Hazard Assessment
WHO – World Health Organization (WHO) guideline values

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

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

Some authorities tend to avoid the specification of a single acceptable risk level. Instead, a "risk-ranking system" is preferred. For example, the New York Department of Health produced a qualitative ranking of cancer risk estimates, from very low to very high (Table 2-5). 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 2-5: Excess Lifetime Cancer Risk (as applied by New York Department of Health)

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

2.2.3 *Odour Impact Evaluation*

Odour thresholds are defined in several ways including *absolute perception thresholds*, *recognition thresholds* and *objectionability thresholds*. At the perception threshold one is barely certain that an odour is detected but it is too faint to identify further. Recognition thresholds are normally given for 50% and 100% recognition by an odour panel. Various odour thresholds published in the literature for odorous compounds are given in Table 2-6. Reported odour threshold data varies considerably, as much as four orders of magnitude for certain chemicals, as is evident from the thresholds included in Table 2-6. Reasons for this variability include differences in experimental methodologies and in human olfactory responses.

Table 2-6: Odour threshold values for common odorants

Pollutant	Detection Thresholds		Odour Recognition Thresholds	
	Concentration µg/m³	Reference	Concentration µg/m³	Reference
1-Pentane	3800	Nagata 2003	350 000	Dravnieks & Laffort 1973
1-Pentene	6.2	Verschueren, 1996		
1,1-Dichloroethane	200000	Rylova 1953	493200	Verschueren, 1996
1,1-Dichloroethene	23000	Verschueren, 1996		
1,2-Dichloropropane	490	Verschueren, 1996		
1,1,2,2-Tetrachloroethane	1600	Dravnieks & Laffort 1972	20000	Lehmann & Schmidt-Kehl 1936
1,3 Butadiene	3540	Verschueren, 1996		
Acetaldehyde	1000	Naus 1982	10000	Naus 1982
Acetone	1000	Naus 1982	20000	Naus 1982
Acrylonitrile			22000	Nagata 2003
Ammonia	1100	Nagata 2003	35000	Naus 1982
a-pinene			64	Verschueren, 1996
Benzene	1500	Naus 1982	16000	Naus 1982
Butane	2880000	Nagata 2003	6160000	Mullins 1955
Butyl mercaptan	0.01	Nagata 2003	3	Wilby 1969

Pollutant	Detection Thresholds		Odour Recognition Thresholds	
	Concentration	Reference	Concentration	Reference
	µg/m³		µg/m³	
Carbon disulphide	100	Naus 1982	1000	Naus 1982
Carbon tetrachloride	29	Nagata 2003	135000	Leonardos *et al* 1969
Chlorobenzene	1000	Don 1986	3000	Smith and Hochstettler 1969
Chloroform	500	Naus 1982	20000	Naus 1982
Cresol (all isomers)	0.24	Nagata 2003	4.4	Leonardos *et al* 1969
Cumene	41	Nagata 2003	230	Hellman and Small 1974
Cyclohexane	8500	Nagata 2003	120000	Schley 1934
Cyclohexanone	480	Hellman and Small 1974	480	Hellman and Small 1974
Dimethyl disulphide	6.6	Nagy 1991	29	Wilby 1969
Dimethyl sulphide	1	Glindemann et al 2006	49	Moschandreas & Jones 1983
Ethyl benzene	730	Nagata 2003	1900	Nagy 1991
Ethyl butyrate			280	Verschueren, 1996
Ethyl chloride			10000	Backman 1917
Ethyl mercaptan	1	Wilby 1969	2.5	Leonardos *et al* 1969
Formaldehyde	600	Nagata 2003	12000	Leonardos *et al* 1969
Hydrogen sulphide	10	Verschueren, 1996	7	WHO
Limonene	10	Apell 1969	58	Fuller et al 1964
Methylene chloride	560000	Nagata 2003	730000	Leonardos *et al* 1969
Methyl ethyl ketone	1300	Nagata 2003	29000	Leonardos *et al* 1969
Methyl mercaptan	0.14	Nagata 2003	2	Wilby 1969
n-Butyl Acetate	77	Nagata 2003	180	Hellman and Small 1974
Phenyl mercaptan	0.14	Stuiver 1958	1.2	Katz & Talbert 1930
Naphthalene	450	Nagy 1991	3370	Morimura 1934
Phenol	21	Nagata 2003	180	Leonardos *et al* 1969
Propionic acid	17	Nagata 2003	100	Hellman and Small 1974
Tetrachloroethylene			8000	WHO 2000
Trichloroethylene	1500	Verschueren, 1996	20000	Naus 1982
Toluene	1300	Nagata 2003	20000	Naus 1982
Vinyl chloride	520000	Hori et al 1972	910000	Hori et al 1972
Xylene (all isomers)	180	Nagata 2003	2000	Leonardos *et al* 1969

Due to the absence of detailed South African guidance, reference was made to the international literature in identifying a suitable method to use in assessing the potential acceptability of odour impacts associated with the Majuba Landfill. Reference was primarily made to approaches adopted in Europe, the USA and in Australia due to the availability of literature on the approaches adopted in these countries. There are two main steps in odour assessment, viz.: (a) calculation of odour units based on predicted or measured ground level air pollution concentrations, and (b) evaluation of odour unit acceptability based on defined odour performance criteria. The manner with which these steps are carried out are discussed in subsequent subsections and a method recommended for adoption in the current study.

The detectability of an odour is a sensory property that refers to the theoretical minimum concentration that produces an olfactory response or sensation. Subsequently, and as used in the USA and Australia, the assessment criteria are based on the number of exceedances of an "odour unit" (OU). An OU is a dimensionless number where a panel (representing the 50% of the population) is presented odours in decreasing dilution (increasing concentration) until it is detected. This point is called the odour detection threshold (DT). Therefore, an odour criterion of less than 1 OU would theoretically result in no odour impact being experienced. In Europe, it is defined slightly differently, i.e. an European Odour Unit, ouE/m³], is the amount of

odourant(s) that, when evaporated into one cubic metre (m^3) of neutral gas at standard conditions, elicits a physiological response from a panel equivalent to that elicited by one European Reference Odour Mass (EROM), evaporated in 1 m^3 of neutral gas at standard conditions. One EROM is equivalent to 123 µg n-butanol, which is equivalent to 1 ouE for the mixture of odorants. Subjects are standardized to n-butanol which is the reference material. When odours are detected at the threshold, it is expressed as a multiple of the reference material. Therefore, whereas an OU is a ratio, a value in ouE is a mass measurement.

Based on the literature available, the level at which an odour is perceived to be of nuisance depends on a combination of several factors, including:

- **Odour quality** – i.e. whether the odour results from a pure compound or from a mixture of compounds. Pure compounds tend to have a higher threshold – lower offensiveness – than a mixture of compounds.
- **Population sensitivity** – any given population contains individuals with a range of sensitivities to odour. The larger the population, generally the greater the number of sensitive individuals contained.
- **Background level** – refers to the likelihood of cumulative odour impacts due to the co-location of sources emitting odours.
- **Public expectation** – whether a given community is tolerant of a specific odour and does not find it offensive. Background agricultural odours may, for example, not be considered offensive until a higher threshold is reached whereas odours from a waste disposal site or chemical facility may be considered offensive at lower thresholds.
- **Source characteristics** – emissions from point sources are more easily controlled that are diffuse sources, e.g. waste disposal sites.
- **Health effects** – whether an odour is likely to be associated with adverse health effects. In general, odour from an agricultural operation is less likely to present a health risk than emissions from a waste disposal or chemical facility.

The perceived concentration can range from 1 ouE/m^3 (point of detection), 5 ouE/m^3 (faint odour) to 10 ouE/m^3 (distinct odour). Based on the *Netherlands Emission Guidelines for Air* ('Dutch Guidelines'), the following maximum permissible air concentrations are specified for densely populated residential areas, agglomerations of buildings situated along roads or other objects sensitive to odour nuisance:

- 0.5 ouE/m^3 as 98th percentile for new situations;
- 1.5 ouE/m^3 as 98th percentile for existing situations

In the case of scattered dwellings and residential clusters on industrial estates the following values should be adhered to for the maximum permissible air concentration:

- 1.0 ouE/m^3 as 98th percentile for new situations;
- 3.5 ouE/m^3 as 98th percentile for existing situations

Whilst the UK and Ireland adopted essentially the same approach as the Dutch, experience gained in NSW (Environmental Protection Agency (EPA)), has indicated that an odour performance criterion of 7 OU is likely to represent the level below which "offensive" odours should not occur for an individual with a "standard sensitivity" to odours (NSW 2006). The OU in this instance, however, is expressed differently and represents the 99th percentile average. The NSW EPA policy recommends that, as a design criterion, no individual should be exposed to ambient odour levels of greater than 7 OU, whereas a stricter criterion of 2 OU applies in densely populated areas, i.e. greater than 2 000 potentially affected people. A summary of the NSW EPA's odour performance criteria for various population densities is shown in Table 2-7.

Table 2-7: NSW EPA odour performance criteria defined based on population density (NSW EPA, 2017)

Population of Affected Community	Odour performance criteria (OU)
Urban area (>2000)	2.0
500 – 2000	3.0
125 – 500	4.0
30 – 125	5.0
10 – 30	6.0
Single residences (≤2)	7.0

The odour performance criteria specified by the NSW EPA is compared to that used in other jurisdictions in Table 2-8. It is evident that the odour performance criteria range specified by the NSW EPA includes the criteria stipulated in various other jurisdictions. The exception being the South Coast Air Quality Management District in the US which permits odour units of up to 10 OU in certain instances.

Table 2-8: Odour performance criteria used in various jurisdictions in the US and Australia (after NSW EPA, 2001)

Jurisdiction	Odour Performance Criteria (given for application to odour units) (OU)
New South Wales EPA (NSW EPA, 2001a, 2001b)	2 to 7
California Air Resources Board (Amoore, 1999)	5
South Coast Air Quality Management District (SCAQMD) (CEQA, 1993)	5 to 10
Massachusetts (Leonardos, 1995)	5
Connecticut (Warren Spring Laboratory, 1990)	7
Queensland (Queensland Department of Environment and Heritage, 1994)	5

It is recommended that the NSW EPA approach (NSW EPA 2017) be adopted for use in the current study.

3 BASELINE CHARACTERISATION

3.1 Study Area

The local study area for the air quality impact assessment was selected based on the expected extent of air quality impacts and possible sensitive receptors, which are limited to scattered farmsteads. A study area of 10 km east-west by 10 km north-south with the landfill located approximately in the centre was chosen (Figure 1-1). The land use in the immediate vicinity of the landfill includes the Eskom Majuba Power Station, located approximately 2 km to the north, and its ancillary infrastructure, including the coal yard located 0.8 km to the northeast and ash dams located approximately 2 km to the west. Land use to the south of the landfill is open grassland, and as far as could be ascertained all buildings within 5 km on the southern section of the landfill are in ruins, with presumably no occupants. Sensitive receptor locations include isolated farmsteads to the west and southeast of the landfill, as shown in Figure 1-1. The closest schools, clinics and residential areas to the landfill are located in the towns of Amersfoort, 15 km to the northeast, and Volksrust, 30 km to the southeast.

The topography of the study area (Figure 1-1) is very flat, gently sloping from approximately 1600 m above sea level in the north of the study area to 1800 m in the south. The AERMOD Implementation Guide recommends that slopes less than 10% incline be excluded from the dispersion model (US-EPA, 2009). On this basis, the flat terrain option was not used in the AERMOD during the model runs.

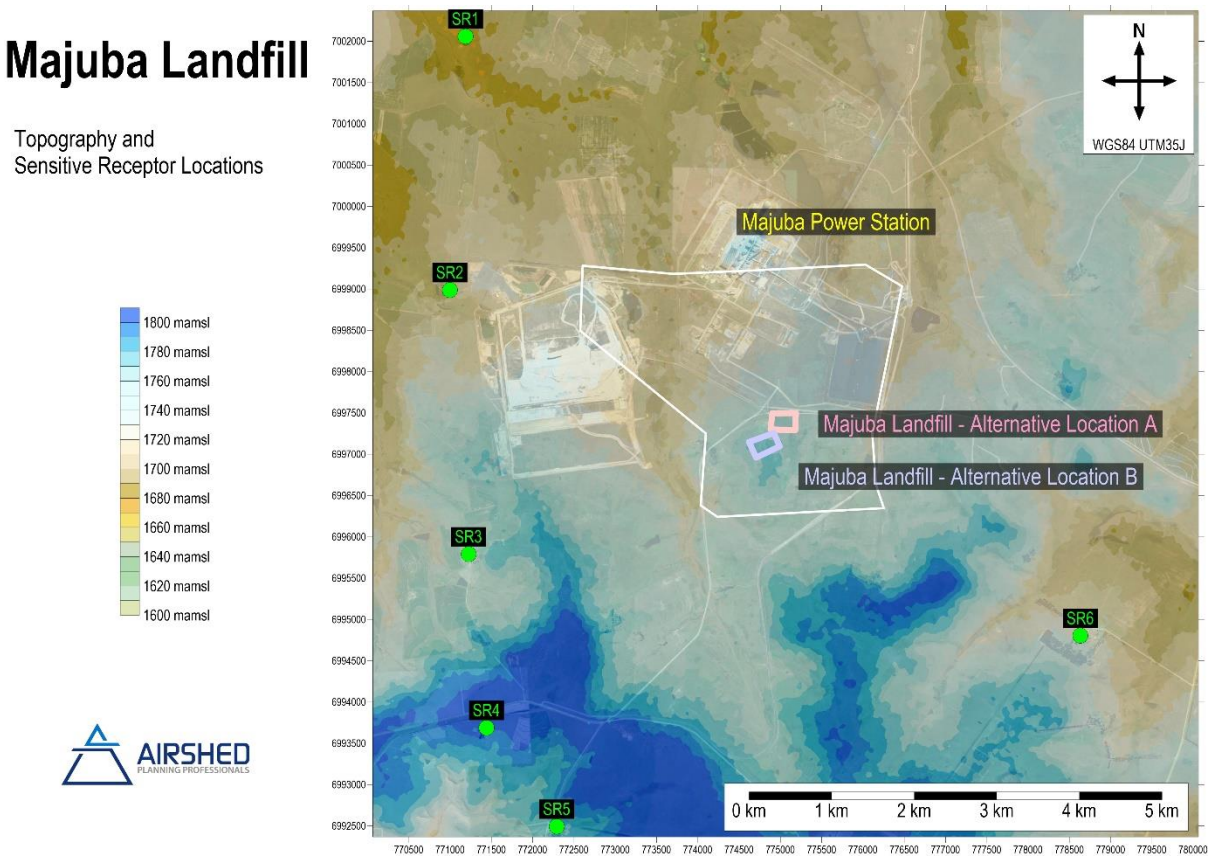

Figure 3-1: Study area, topography and sensitive receptor locations

3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern 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. 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 as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow and the extent of crosswind spreading. 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.

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 and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. Four years of measured meteorological data, from 1 January 2016 to 31 December 2019, was obtained from the Eskom Majuba AQMS, located approximately 2.5 km to the northeast of the proposed landfill location (Figure 3-4).

3.2.1 *Surface Wind Field*

The wind field for the study area is described with the use of wind roses. Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The period and diurnal for the Eskom Majuba AQMS for the period 2016 to 2019 are shown in Figure 3-2. The colours reflect the different categories of wind speeds; the yellow area for example, representing winds of 4 m/s to 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The figure given for calm conditions represents the frequency with which the calms occurred, i.e. periods during which the wind speed was below 0.5 m/s.

During the day the wind is predominantly from the west, with a secondary component from the east, with fairly strong wind speeds and little calms. During the night the wind field shifts to be mainly from the east and southeast. The wind is generally stronger during the day with more frequent calms during the night.

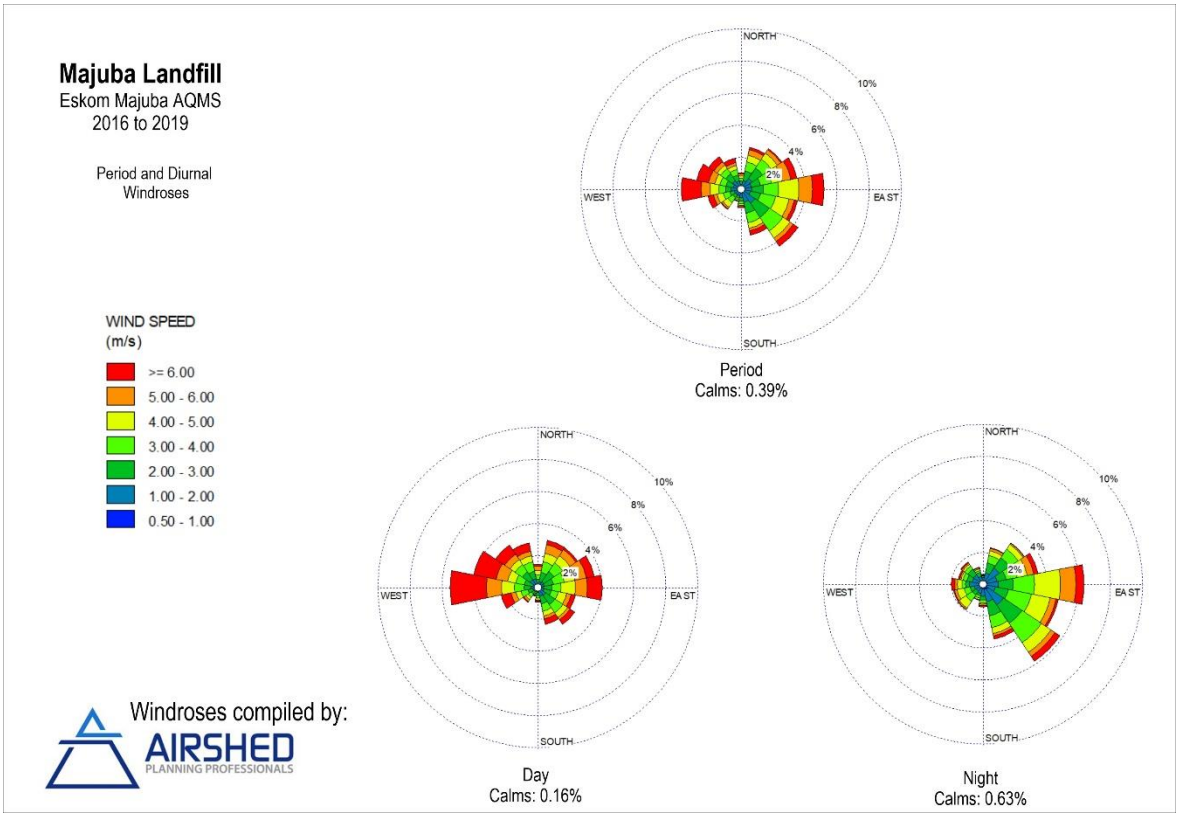

Figure 3-2: Period and diurnal wind roses for the Eskom Majuba AQMS, 2016 to 2019

3.2.2 *Precipitation*

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potential from fugitive dust sources such as entrainment from unpaved roads or wind erosion from exposed areas. Rainfall in the area is mainly in the summer between October to March, with little rainfall in the winter. The greatest rainfall occurs in December and the lowest in June. Average rainfall in the area is approximately 950 mm per year (climate-data.org).

3.2.3 *Temperature*

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers. Whilst not a factor in the plume height from the landfill emissions, it is nevertheless required as an input parameter in the dispersion model.

The average temperature recorded at the Eskom Majuba AQMS over the 2016 to 2019 period was 15.4°C, with the lowest temperature recorded in June (-4.13°C) and the highest temperature recorded in October (33.2°C)

The monthly average diurnal temperature profile for the 2016 to 2019 period is shown in Figure 3-3. Temperatures reach a maximum between 14:00 and 16:00 in the afternoon and a minimum between 6:00 and 8:00 in the morning (i.e. just before sunrise).

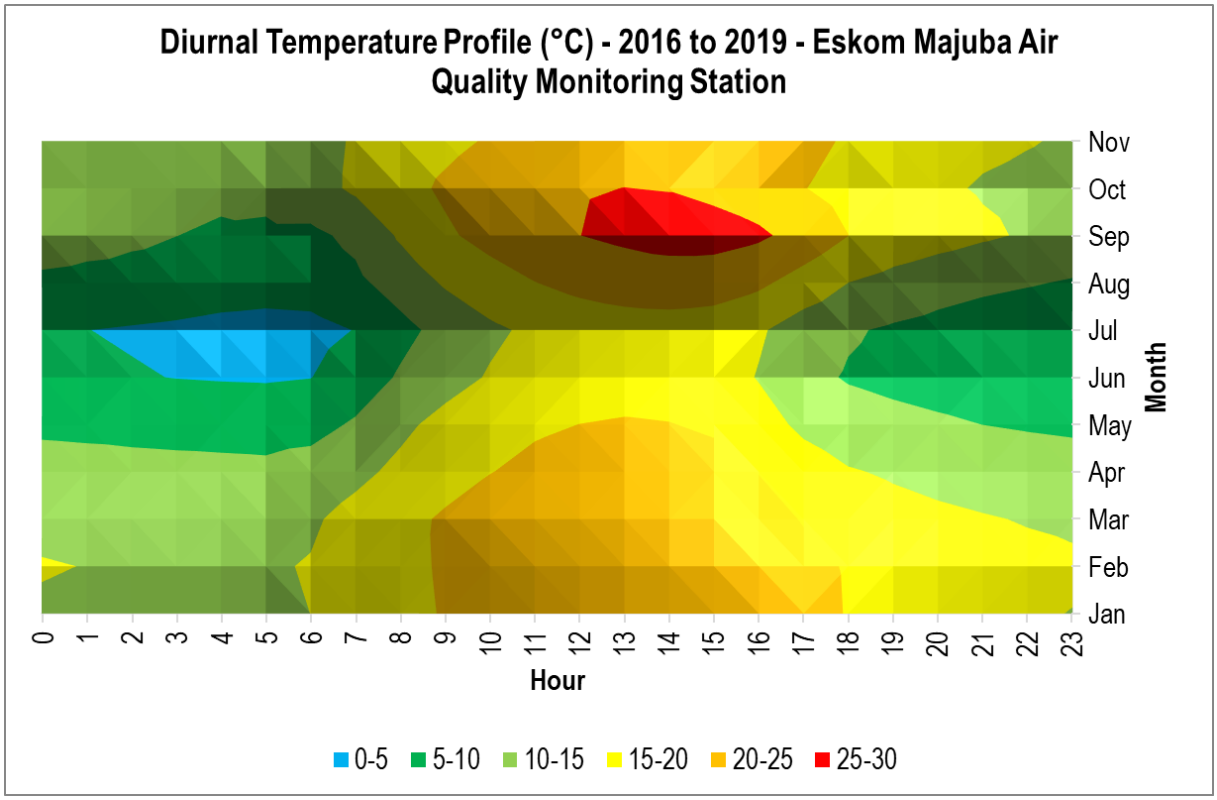

Figure 3-3: Monthly average diurnal temperature profile

3.3 Baseline Air Quality

In the evaluation of baseline air quality and the assessment of cumulative air quality impacts from the proposed landfill, reference was made to air quality monitoring data recorded at the Eskom Majuba AQMS, located approximately 2.5 km to the east-northeast of the proposed landfill location, for the period 2016 to 2019, as well as dust fallout rates recorded at the four closest dust fallout sampling locations to the proposed landfill site during 2021 (Figure 3-4).

While Eskom has an extensive dust fallout monitoring network of 23 sampling locations in place around the Majuba Power station, only dustfall recorded at the four closest locations to the proposed landfill location were referenced for the characterisation of baseline dust fallout rates for this study, as dust fallout at the other 19 locations are likely to be influenced by local sources and not representative of baseline dust fallout rates in the vicinity of the landfill site.

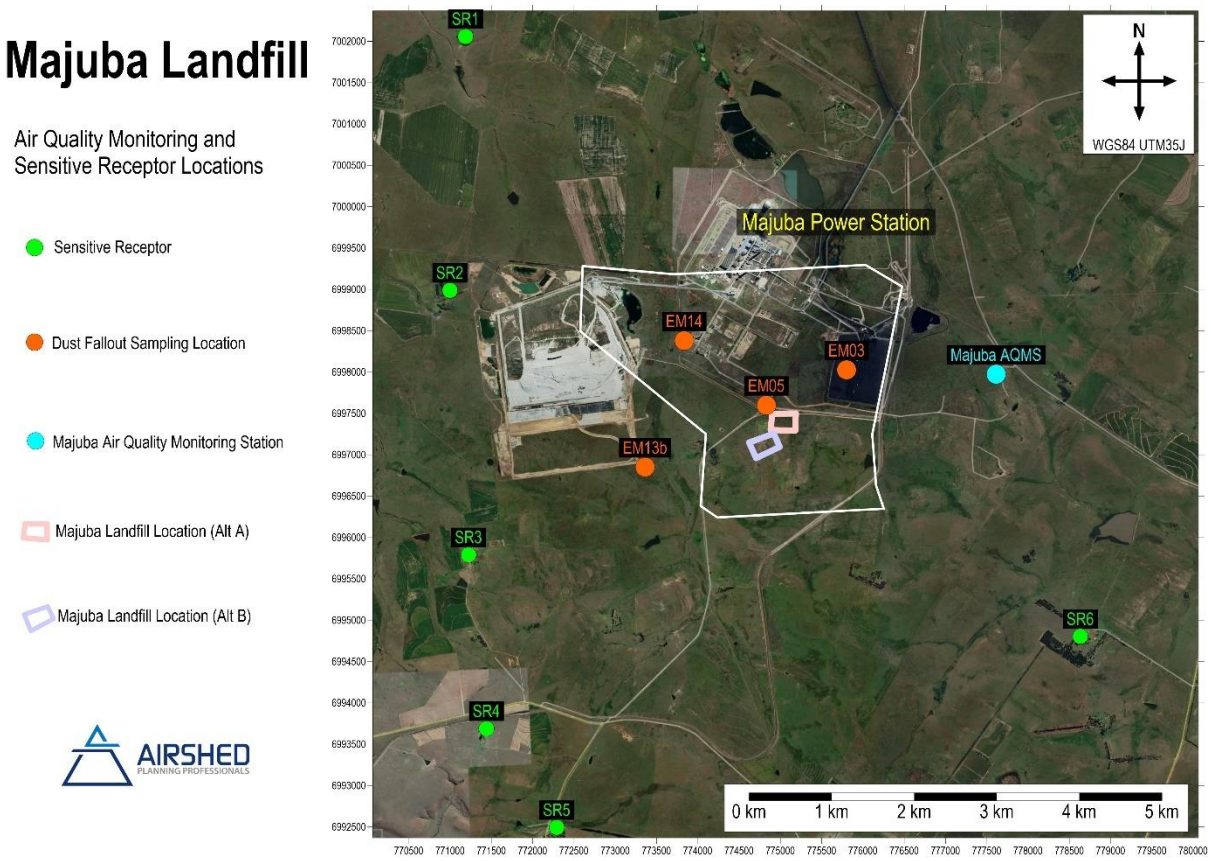

Figure 3-4: Air quality monitoring locations.

Annual average SO_2 and NO_2 concentrations measured at the Eskom Majuba AQMS were in compliance with the SA NAAQS from 2016 to 2019, but annual average PM_{10} concentrations exceeded the annual average limit value of 40 µg/m³ in 2018 and $PM_{2.5}$ concentrations exceeded the annual average limit value of 20 µg/m³ for $PM_{2.5}$ in 2019.

No PM_{10} and $PM_{2.5}$ measurement data was available for 2020 and 2021, but it is likely that particulate concentrations in the study area are elevated and the addition of any particulate emission sources in the area could lead to non-compliance with the NAAQS.

Table 3-1: Annual average pollutant concentrations at the Eskom Majuba AQMS

Year	Annual Average Concentration			
Pollutant	SO_2 (µg/m³)	NO_2 (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)
2016	23.7	17.9	27.3	-
2017	16.5	5.0	11.2	-
2018	26.0	14.5	43.4	15.5
2019	22.1	9.2	-	22.4

Sampled monthly average dust fallout rates were generally low during the wet summer months between December and March, with significantly higher dust fallout rates reported during the dry months between May and September. The highest dust fallout rates were recorded at EM14 during May and July 2021. At the sampling location closest to the proposed landfill site (EM05), only one exceedance of the SA NDCR limit value for non-residential areas was recorded during July 2021.

It is concluded that while particulate concentration in the study area are elevated, dust fallout, and possibly particulate concentrations as well, are dependent on localised particulate sources, with high variability between locations.

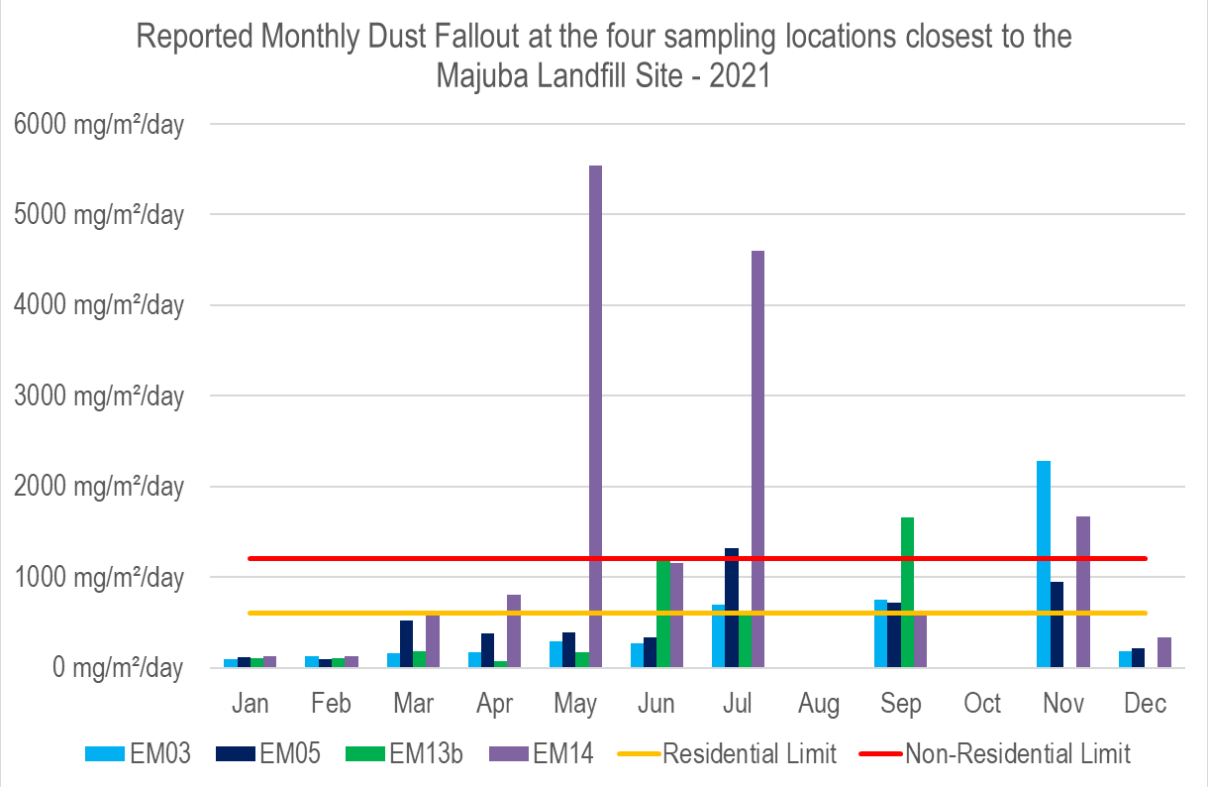

Figure 3-5: Sampled dust fallout rates - 2021

4 EMISSIONS INVENTORY

4.1 Operational Description (as provided by Savannah Environmental)

Eskom Majuba Power Station is proposing the development of a new general waste disposal site on Portions 1, 2 and 6 of the Farm Witkoppies 81HS, located approximately 13 km southwest of Amersfoort and 40 km north-northwest of Volksrust in the Dr Pixley Ka Isaka Seme Local Municipality, which forms part of the Gert Sibande District Municipality, in the Mpumalanga Province. The new general waste disposal site will be constructed adjacent to the existing, closed landfill site at the Eskom Majuba Power Station. Access to the site is possible via the N11, onto existing secondary roads that lead to the site.

A project site, with an extent of ~866 ha has been identified by Eskom Majuba Power Station as a technically feasible site for the development of a new general waste disposal site. A development footprint of ~6 ha has been identified within the project site by the proponent for the development. The 6 ha will accommodate the actual landfill, together with the associated infrastructure that will be required for the operation of the site.

Infrastructure associated with the new general waste disposal site will include the following:

- Fencing with appropriate signage.
- An adequate access road (gravel or surfaced).
- An access control gate.
- A guard house with an ablution facility.
- A conservancy tank connected to the ablution facility.
- Covered parking facilities.
- A designated area for parking and servicing of plant and machinery.
- Sorting and storage facilities for recyclables.
- Adequate water and electricity connection from the existing rising mains.
- Stormwater drainage network and a stormwater evaporation pond for the stormwater entering the site through the waste body.
- A leachate management system and a leachate evaporation pond.

The quantity of general waste generated at the Majuba Power Station is approximately 980 tons per annum. The proposed landfill will have an expected lifespan of 45 years, similar to the productive life cycle of the power station.

Waste types generated at the Majuba Power Station to be disposed of at the Majuba Landfill are listed in Table 4-1.

The facility will comprise six cells with an estimated total capacity of 241 650 m³. The cells will be linked to a leachate evaporation pond which will be utilised for the storage and evaporation of leachate. The leachate collection pond will have a capacity of approximately 100m³.

Table 4-1: Waste types generated at the Majuba Power Station to be disposed of at the new general waste disposal site (provided by Savannah Environmental)

Hazardous waste	Non-hazardous waste	Total waste handled (tons per day)
Most hazardous waste produced at the Majuba Power Station is removed by a registered waste carrier to appropriate landfill sites. No hazardous waste will be disposed of at the new general waste disposal site.	**Organics** • Food waste • Garden waste **Paper** • Newspaper • Cardboard **Plastic** • PET bottles/containers • HDPE bottles/containers • Film and bags • Expanded polystyrene • Other rigid plastic • Packaging **Glass** • Clear and coloured • Plate glass **Metal** • Aluminium beverage cans **Wood waste** • Pallets and other **Construction, Demolition and Land Clearing Waste** • Concrete • Solis, rocks, sand, etc. **Residue** • Dust • Fines and sorting residues **Tyres and other rubber waste** **Other not identified here**	» The initial rate of disposal is estimated at 980 tons/year or 2.68 tons per day, not taking into account future, more progressive, recycling initiatives. » Currently, there are approximately twenty (20) small recycling stations strategically positioned around the Majuba Power station, indicating the applicant's commitment to recycling. » Based on preliminary estimations, it is envisaged that up to 45% of the total waste may be recycled if dedicated resources are available, i.e., paper, plastic, glass, metal, and tyres. » A further 27% of the waste which consists of organic waste may be suitable for composting. As there are no actual records of the various individual waste fractions, the above data is an estimation and can only be confirmed once the site is operational and adequate records are available. As a precaution, the landfill site is planned for the maximum capacity. Provision has been made in the planning for the sorting and collection of recyclable waste.

Table **4-2** below indicates the general waste types generated at the Majuba Power Station to be disposed of at the new general waste disposal site, as well as the quantities expected to be disposed of and salvaged annually. The individual hazardous waste quantities produced at the power station are not included in this table as no hazardous waste will be disposed of at the new general waste disposal site. The total waste generated at the power station as detailed in Table **4-2** does however consider both general and hazardous waste.

Table 4-2: General waste types and quantities expected to be disposed of and salvaged annually at the new general waste disposal site

	Waste quantities	On-site recovery, reuse, recycling, treatment or disposal	Offsite recovery, reuse, recycling treatment or disposal
	TONS/MONTH	Method and location	Method, location and contractor details
1. Organics			
Food waste	16.4	Separation for potential composting	None
Garden waste	6.15	At the Facility	
Percentage	27%		
2. Paper			
Newspaper	8.2	Collection and sorting for recycling	Removal by contactor for recycling
Cardboard	6.15		
Percentage	17.67%		
3. Plastic			
PET bottles/containers	2.05	Collection and sorting for recycling	Removal by contactor for recycling
HDPE bottles/containers	2.05		
Film and bags	0.41		
Expanded polystyrene	2.05		
Other rigid plastic packaging	4.1		
Percentage	13.13%		
4. Glass			
Clear and coloured	1.48	Collection and sorting for recycling	Removal by contactor for recycling
Plate glass	0.16		
Percentage	2%		
5. Metal			
Aluminium beverage cans	1.64	Collection and sorting for recycling	Removal by contractor for recycling
Percentage	2%		
6. Wood waste			
Pallets and other	5.74	Disposal/Landfilling	None
Percentage	7%		
7. Construction, demolition and land clearing waste			
Concrete	4.1	Disposal/Landfilling	None
Solis, rocks & sand, etc.	12.3		
Percentage	20%		
8. Residue			
Dust	0.41	Disposal/Landfilling	None
Fines and Sorting Residues	0.41		
Percentage	1%		
9. Tyres and other rubber			
Tyres and other rubber	0.82	Collection and sorting for recycling	Removal by contractor for recycling
Percentage	1%		
10. Other not identified			
Other not identified here	1.64	Disposal/Landfilling	None
Percentage	2%		
Totals waste generated at the Power Station (general and hazardous waste total)	**81.26 t/month**		
Total percentage recyclable	**15.13%**		
Total Percentage to be taken to Landfill Site	**56%**		

Under standard operating practices, a landfill site is characterised by two main sources of gaseous emissions, namely the working surface and covered portions of the landfill. Although gaseous emissions can also originate from leachate dams or tanks, if these are present, this is often less significant – once the leachate has been collected and removed from the landfill, it must undergo some type of treatment and disposal which also reduces air emissions, particularly volatile organic compounds (VOCs). Leachate at the Majuba Landfill will be evaporated from a planned 100 m³ leachate pond to the north of the cells. It is recommended that best practise mitigation measures be implemented to minimise odorous emissions from the leachate evaporation pond. If the LFG is captured and flared, emissions from the flare would represent a further source of gaseous and particulate emissions. The Majuba landfill will have a small leachate evaporation pond, but will not have a flare. The majority of gaseous emissions are expected from the landfill itself.

Sources of fugitive dust emissions include vehicle-entrained dust from paved and unpaved roads, materials handling operations (e.g. waste movement, compaction and tipping operations), wind erosion of open areas and soil cover, and vehicle activity on the landfill site, including general vehicle traffic (tractors, trucks, etc.) and earthmoving activities.

This chapter describes the methods employed for the quantification of routine landfill gas and fugitive dust emissions, and emission rates estimated for each of the pollutants selected for inclusion in the investigation.

4.2 Landfill Gas (LFG) Generation

Organic waste in a landfill decomposes to form gaseous products and manifests itself as LFG. The waste decomposition process involves several stages during which different groups of bacteria break down complex organic substances such as carbohydrates, proteins and lipids into successively simpler compounds. When the degradation process slowly moves from aerobic condition (presence of free oxygen) to anaerobic condition (absence of free oxygen), carbon dioxide levels continue to be high, gradually falling as the methane concentration builds up. Upon commencement of the degradation process, bacteria consume any oxygen contained within the waste and release mainly carbon dioxide, water and heat. In the presence of atmospheric air, that is near the surface of the landfill, the natural organic compounds are oxidised aerobically, which is a reaction that is like combustion because the products are carbon dioxide and water vapour. Methane production (methanogenesis) only starts after anaerobic conditions have been established in the waste, typically 3-6 months after waste placement (IE EPA 2012). Anaerobic digestion takes place in three stages. In the first stage, fermentative bacteria hydrolyse the complex organic matter into soluble molecules. In the second stage, these molecules are converted by acid forming bacteria to simple organic acids, carbon dioxide and hydrogen; the principal acids produced are acetic acid, propionic acid, butyric acid and ethanol. Finally, in the third stage, methane is formed by methanogenic bacteria, either by breaking down the acids to methane and carbon dioxide, or by reducing carbon dioxide with hydrogen (Themelis and Ulloa 2007). During peak gas production the bulk gas consists typically of 50 to 60% methane and 40 to 50% carbon dioxide (IE EPA 2012). Once all biodegradable substrate in the waste has been consumed, gas production slows and the gas composition in the waste returns to atmospheric conditions.

Apart from methane and carbon dioxide there are more than 500 substances contained in LFG (IE EPA 2012). Many of these trace gases are toxic, odorous, or both. Their combined total concentration is typically in the order of a few percent. Their release to atmosphere occurs mainly because bulk landfill gas, which is produced in much larger volumes, acts as a carrier gas and flushes the trace gases out of the body of waste and into the surrounding environment. Certain compounds of both bulk and trace landfill gas can be defined as VOCs. These include the chemical groups known as alcohols, aldehydes, alkanes, aromatics, halocarbons, ketones and halogenated derivatives of these substances. VOCs are often grouped into methane and other non-methane VOCs (NMVOCs). While many VOCs have no odour (such as methane), several VOCs are highly odorous, for example the sulfur containing mercaptans and dimethyl sulphides.

The quantity of LFG generation would vary with time. An analysis of several anaerobic digestion operations by Verma and Themelis (2004) showed that the reported rate of generation of biogas ranged from 100 to 200 Nm³ of biogas (54 to108 Nm³ methane) per tonne of wastes digested (using an estimated 60% biomass content). For a landfill containing about 70% of biomass materials, Themelis and Ulloa (2007) showed that the theoretical generation rate is 208 Nm³ per one tonne of municipal waste of biogas or 0.149 tonnes of methane per of one tonne of municipal waste, assuming complete reaction.

The Gassim model requires various input parameters based on the characterisation of the waste type and the way the waste is to be stored and managed. Information required by the model include details regarding the waste input, breakdown and composition.

The waste breakdown and composition for input into Gassim was estimated based on the waste types received (first paragraph of Section 4.1) and typical waste compositions at other landfills in South Africa. The waste composition used in Gassim for this study is shown in Table 4-3.

Table 4-3: Waste composition used in the Gassim model

Waste type	Composition
Newspapers	10.1%
Card Packaging	7.6%
Wood	7.1%
Other miscellaneous combustibles	14.1%
Garden Waste	7.6%
Putrescible waste (such as food waste)	20.2%
Fines	1%
Non-degradable waste	32.4%

For practical reasons only key odorous and toxic components and indicator species of the landfill gas was included in the current investigation. The following criteria were adopted during the current investigation for the selection or exclusion of compounds:

(a) Compounds typically recorded at various other landfills were included for consideration, e.g. vinyl chloride, acrylonitrile, and chlorobenzene;
(b) 'Indicator' or 'marker' species were identified for inclusion in the study, including odorous and toxic gases;
(c) Compounds frequently included due to their potential impact on human health: various carcinogens (e.g. benzene, carbon tetrachloride, methylene chloride) and several non-carcinogenic toxins (e.g. chlorobenzene, toluene and tetrachloroethylene). Toluene is considered to be one of the key volatile organic compounds associated with landfills.

Based on all considerations discussed in this section, the compounds listed in Table 4-4 were selected to be included in the current investigation. From the list it is evident that compounds which may be present in the waste accepted at the site as well as compounds anticipated to be generated in the landfill are taken into account.

Table 4-4: Compounds selected for inclusion in the study

Compounds included in this study		
1,1,1,2-tetrafluorochloroethane	chloroform (trichloromethane)	methanethiol
1,1,2-trichloroethane	dichloromethane	nitrogen oxides (reported as NO_2)
1,1-dichloroethane	diethyl disulphide	particulates
acetaldehyde (ethanal)	dimethyl disulphide	propanethiol
acrylonitrile	dimethyl sulphide	sulfur reduced (reported as SO_2)
benzene	ethanethiol	tetrachloroethylene (tetrachloroethene)
butadiene (as 1'3-Butadiene)	ethylbenzene	toluene
carbon disulphide	formaldehyde (methanal)	trichloroethylene
carbon monoxide	hydrogen sulphide	vinyl chloride (chloroethene chloroethylene)
carbon tetrachloride	limonene	xylene (all isomers)

The generation of gas, primarily due to microbial decomposition, climatic conditions, refuse characteristics and land-filling operations, represents an inevitable consequence of the waste disposal in landfills. Numerous factors affect the ultimate rate at which gases may be released from the covered portions of the landfill. Such factors include advection, diffusion, accumulation, generation, adsorption, biodegradation, leaching, capillary action and evaporation. Due to the complexity of predicting emissions from the proposed landfill, use was made of the Gassim model.

It is important to note that the Gassim model makes provision for the input of site-specific gaseous concentrations within the waste (i.e. subsurface gas concentrations) despite containing default values based on information from UK landfill sites. Use was made of Gassim's default subsurface gas concentration ranges as these often include measured values from sampling campaigns as part of its range.

A synopsis of the subsurface gas concentrations selected for inclusion in the estimation of emissions from the landfill is given in Table 4-4.

Table 4-5: Subsurface Gas concentrations selected for use in the emission modelling

Compound	Gassim Default Values (mg/m³)
1,1,1,2-Tetrafluorochloroethane	LOGTRIANGULAR (0.002, 0.2, 2)
1,1,2-Trichloroethane	LOGTRIANGULAR (0.02, 0.28, 3.9)
1,1-Dichloroethane	LOGTRIANGULAR (0.05, 0.25, 6.4)
Acetaldehyde (ethanal)	LOGUNIFORM (0.075,2.546)
Acrylonitrile	LOGTRIANGULAR (0.02, 0.4, 38)
Benzene	LOGTRIANGULAR (3.1, 15, 73)
Butadiene (modelled as 1,3-Butadiene)	LOGUNIFORM(0, 0.02)
Carbon disulphide	LOGUNIFORM (0.9, 170)
Carbon monoxide	LOGTRIANGULAR (0.11, 1.1, 5000)
Carbon tetrachloride (tetrachloromethane)	LOGUNIFORM (0, 0.02)
Chloroform (trichloromethane)	LOGTRIANGULAR (0.001, .2, 70)
Dichlorofluoromethane	LOGTRIANGULAR (0.001, 0.01, 602)
Diethyl disulphide	LOGTRIANGULAR (0.001, 0.02, 2.6)
Dimethyl disulphide	LOGTRIANGULAR (0.001, 0.02, 40)
Dimethyl sulphide	LOGTRIANGILAR(0.001, 0.01, 60)
Ethanethiol (ethyl mercaptan)	LOGUNIFORM (0, 0.08)
Ethylbenzene	LOGTRIANGULAR (0.001, 1e-3, 875)
Formaldehyde (methanal)	LOGTRIANGULAR (0.026, 0.068, 0.188)
Hydrogen sulphide	LOGTRIANGULAR (2.4, 53, 580)
Limonene	LOGTRIANGULAR (0.001, 0.1, 240)
Methanethiol (methyl mercaptan)	LOGTRIANGULAR (0.005, 0.01, 87)
Propanethiol	LOGUNIFORM (0, 0.09)
Sulfur reduced (reported as SO_2)	LOGUNIFORM (30.8, 430.5)
Tetrachloroethylene (Tetrachloroethene)	LOGTRIANGULAR (0.001, 0.01, 7700)
Toluene	LOGTRIANGULAR (0.01, 0.1, 1250)
Trichloroethylene (trichloroethene)	LOGTRIANGULAR (0.25, 1.65, 88)
Vinyl chloride (chloroethene, chloroethylene)	LOGTRIANGULAR (1.1, 31, 730)
Xylene (all isomers)	LOGTRIANGULAR (0.001, 0.001, 61784)

The emission rates calculated by the Gassim model were estimated using the subsurface gas concentrations specified in Table 4-4 and the 95th percentile calculated across 100 iterations simulated.

LFG emissions from the working surfaces of the Majuba Landfill were calculated for approximately 100 years from the start of operations. To illustrate the typical profile of LFG surface emission rates from working surfaces, reference is made to total

LFG emissions as estimated through the application of Gassim (Figure 4-1). The first year of operation was 2023, with each of the modelled for the lifetime of the cell, for a total of 45 years of operation.

LFG emissions from the Majuba Landfill gradually increase to reach a maximum during the operation of Cell C4c, or very shortly thereafter, when the maximum amount of waste is in place. After closure the decomposition of waste and LFG generation gradually decreases, as the amount of decomposable waste gradually becomes less since no more waste is deposited after the landfill is closed and capped. Based on the composition of the waste to be deposited, LFG generation is only expected to decrease to near zero after approximately 100 years.

In terms of GHG emissions, over its lifetime, the Majuba Landfill is estimated to result in the emission of 2030 tonnes of CO_2 and 740 tonnes of CH_4 emissions. Annual GHG emissions are expected to reach a maximum during the operation of Cell C4c. The maximum annual GHG emissions is estimated at 42.7 tonnes of CO_2/annum and 15.6 tonnes of CH_4 per annum.

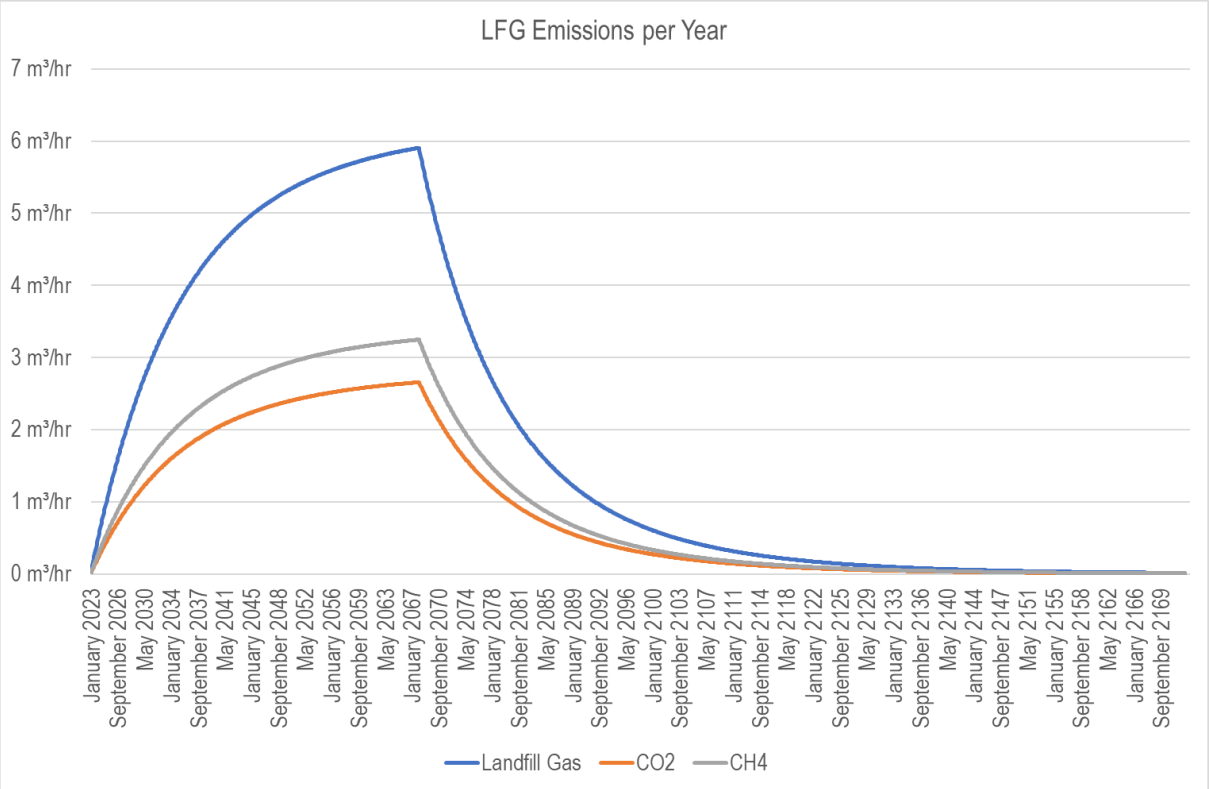

Figure 4-1: Estimated surface bulk landfill gas emission rate

In the non-carcinogenic health, odour and cancer risk impact assessment use was made of the maximum emission rate in the dispersion simulations as a conservative initial screening. The Gassim calculated emission rates of trace pollutants are shown in Figure 4-2.

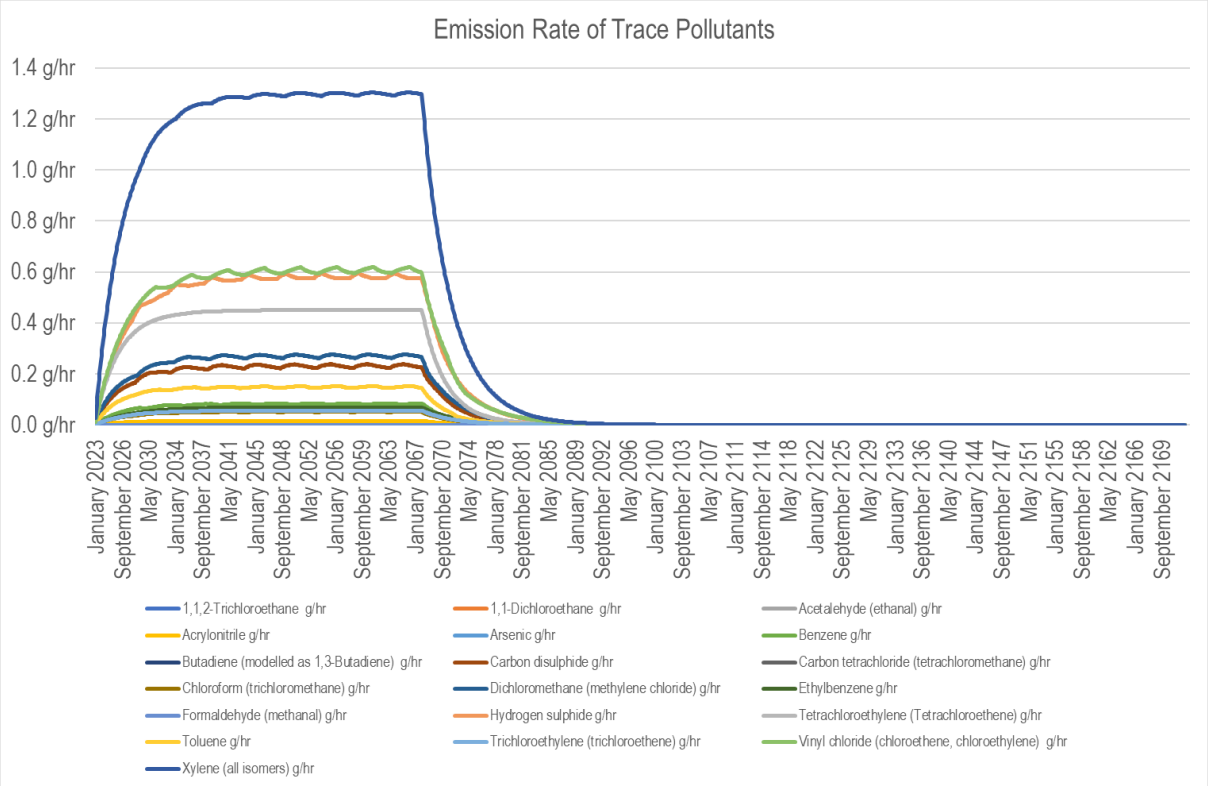

Figure 4-2: Estimated trace pollutant emission rate

4.3 Fugitive Dust Emissions

Fugitive dust emissions at the Majuba Landfill occur as a result of vehicle entrainment, materials handling, bulldozing operations and wind erosion from open areas. Handling and moving of cover material was identified as being the most significant source of fugitive dust at the Majuba Landfill. Information pertinent to all particulate sources was collated and atmospheric emission quantified.

In assessing the impact of fugitive dust emissions, a distinction needs be made between Total Suspended Particulates (TSP) and respirable particulates. Although TSP may be defined as all particulates with an aerodynamic diameter of less than 100 µm, an effective upper limit of 30 µm aerodynamic diameter is frequently assigned. Respirable particulates are generally defined as particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}). PM_{10} and particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) has health implication since it represents particles of a size that would be deposited in, and damaging to, the lungs. In the quantification of PM_{10} and $PM_{2.5}$ emissions, use was made of emission factors published by the US Environmental Protection Agency (US-EPA) in its AP-42 document: Compilation of Air Pollution Emission Factors (Table 4-7).

The emission estimation techniques used in the quantification of fugitive dust emissions are described in more detail in the paragraphs below, with parameters used in the estimation of emissions given in Table 4-6. **The total emission rate of fugitive dust emissions was estimated as 6.92 tonnes per annum of TSP, 1.81 tonnes per annum of PM_{10} and 0.12 tonnes per annum of $PM_{2.5}$.**

Fugitive dust emissions from material handling occur as a result of the loading and unloading of waste and clay used as cover material. The quantity of dust generated from material handling operations will depend on various climatic parameters, such

as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. The US EPA AP42 Section 13.24 equation for materials handling as well as the parameters used to estimate emissions from material handling operations are given in Table 4-6. Cover material requirements were conservatively estimated on 150 mm cover material per 500 mm of waste, with a compacted waste density of 0.9 tonnes/m³ and a cover material density of 2.2 tonnes/m³.

Emissions from bulldozing and compaction conservatively assumed one trash compactor, one bulldozer and one front-end loader to be working simultaneously at the active working face (during the working hours of the site). The equation used to determine the TSP emission factor (in kg/hr) was taken from Table 11.9-2 in the US-EPA AP42 (Western Surface Coal Mining - for bulldozers on material other than coal). The scaling factors for PM_{10} and $PM_{2.5}$ were given as 0.75 and 0.105 respectively. The moisture contents for landfill cover and waste (12% and 20% respectively) were taken from the US-EPA recommended moisture content for municipal landfills.

Entrained dust emissions from vehicles travelling on on-site roads were estimated using the US EPA AP42 Section 13.2.2 emission factor for unpaved roads. The silt content of unpaved roads was assumed to be the AP42 municipal landfills average silt content of 6.4% for municipal landfills. Vehicle weights and the number of vehicle trips per day were based on average daily waste disposal rates.

Wind erosion emissions from the landfill was calculated using the dust emission model proposed by Marticorena and Bergametti (1995). Since no site-specific particle size distribution (PSD) information was available for the cover material used at the Majuba Landfill, reference was made to surface material PSD and moisture content (1.9%) from similarly general waste landfills in SA (Burger & Bornman, 2020). An average hourly wind erosion emission file was created for each hour of the 2016 to 2019 modelling period.

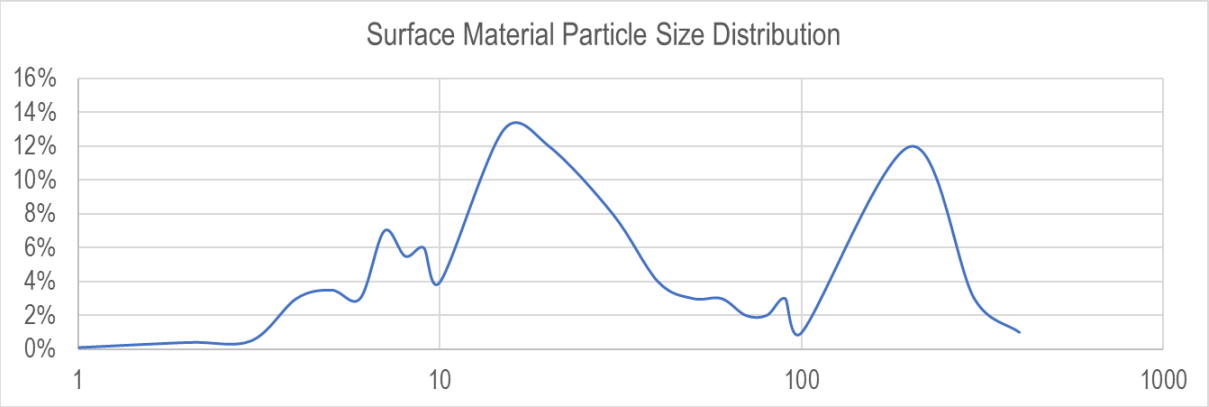

Figure 4-3: Surface material particle size distribution from similar general waste landfills in South Africa

As a conservative approach, all emissions from the landfill working surfaces and covered portions, including LFG emissions, wind erosion, vehicle entrained dust, material handling emissions and emissions from bulldozers and compactors, were modelled at ground level. Wind flow patterns over elevated "hills", such as landfills or mines dumps, follow the contours of hill closely, with emissions from a control volume placed over the hill occurring near ground level on the leeward side of the hill, and not at the height of the crest of the hill.

While previous studies conducted by Airshed (Burger & Bornman, 2020) using computational fluid dynamics models such as the GRAL/GRAMM numerical simulation have shown that increased wind speeds over hills with higher crests could result in higher fugitive particulate emissions from wind dependent sources (approximately 20% higher PM_{10} emissions for a 25 m

height increase), this is highly dependent on the prevailing wind direction and speed, as well as the geometry of the hill. LFG emissions are not dependent on the height of the landfill, but are calculated using total tonnages of disposed waste, which is indirectly dependent on the landfill height, as a lower height would mean less airspace and consequently less waste disposed.

Additionally, due to the inability to simulate actual wind flow patterns in AERMOD, its developers recommend careful application of the model under certain modelling conditions, such as complex terrain, as discussed in AERMOD Implementation Guide (August 2015). For instance, by specifying the release height as the top of the landfill, the model assumes uniform airflow above and below the point of release (Figure 4-4). It would only be appropriate to use an elevated release in situations such as stack emissions. In a situation such as ground level releases from a landfill, the plume would tend to follow the air streamlines defined by the underlying topography. AERMOD may also tend to underestimate concentrations relative to flat terrain results for cases involving low-level, non-buoyant sources with up-sloping terrain since the horizontal plume component will pass below the receptor elevation."

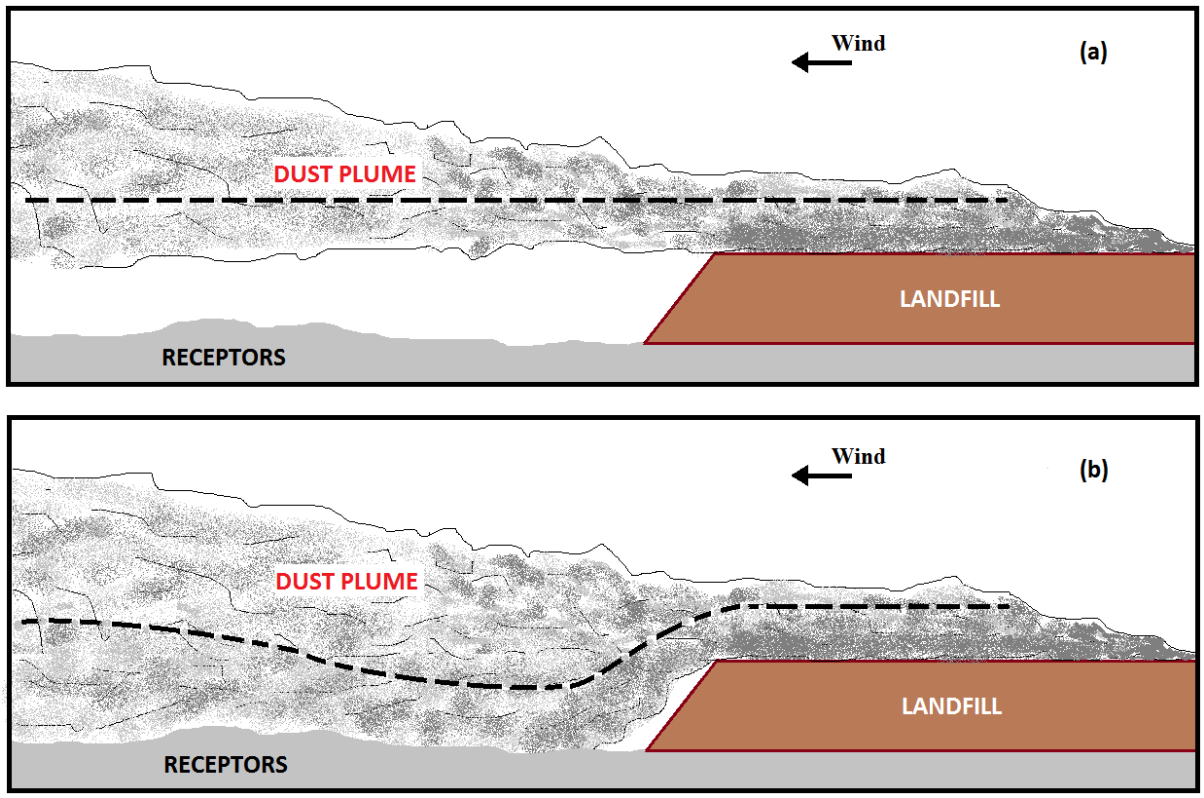

Figure 4-4: Dispersion of pollutants released from a large area source elevated above nearby receptors with (a) a non-terrain-following plume (b) a terrain-following plume

As such the dispersion modelling results (discussed in Section 5) for particulates, and the conclusions drawn therefrom, are deemed to be conservative and applicable for all heights up to 20 m. The impacts from trace gasses in the LFG emissions are also conservative, and the emissions conservatively modelled at ground level.

Therefore, the impacts discussed in Section 5 and conclusions in Section 6 are applicable for all heights up to 20 m.

Table 4-6: Emission rate equations used to quantify fugitive dust emissions

Activity	Emission Equation	Source	Information assumed/provided
Materials handling	$$E = 0.0016\frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}$$ Where, E = Emission factor (kg dust / t transferred) U = Mean wind speed (m/s) M = Material moisture content (%) The $PM_{2.5}$, PM_{10} and TSP fraction of the emission factor is 5.3%, 35% and 74% respectively. An average wind speed of 3.5 m/s was used based on data for the Eskom Majuba AQMS for the period 2016 – 2019.	US-EPA AP42 Section 13.2.4	The moisture content of materials was estimated as follows: Waste: 35% Cover material: 10% The tonnages handled are as follows: 980 tonnes per year waste 808.5 tonnes per year clay as cover material. Hours of operation: 8:00 to 16:00 on weekdays
Vehicle entrainment on unpaved surfaces	$$E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b} \cdot 281.9$$ Where, E = particulate emission factor in grams per vehicle km travelled (g/VKT) k = basic emission factor for particle size range and units of interest s = road surface silt content (%) W = average weight (tonnes) of the vehicles travelling the road. The particle size multiplier (k) is given as 0.15 for $PM_{2.5}$ and 1.5 for PM_{10}, and as 4.9 for TSP The empirical constant (a) is given as 0.9 for $PM_{2.5}$ and PM_{10}, and 4.9 for TSP The empirical constant (b) is given as 0.45 for $PM_{2.5}$, PM_{10} and TSP	US-EPA AP42 Section 13.2.2	In the absence of site specific silt data, silt fractions assumed as US EPA average of 6.4% for municipal landfills, used for access road and all on site haul roads. 2 vehicle trips per day for waste disposal. 2 trips per day for the collection of clay from the clay stockpile. Hours of operation: 8:00 to 16:00 Average distance travelled per trip: 30 days Mitigation: Natural Mitigation: 85 days with measurable precipitation (Volksrust long term climate data).
Bulldozing and compactors	$$E = k \cdot (s)^{a}/(M)^{b}$$ Where, E = Emission factor (kg dust / hr / vehicle) s = Material silt content (%) M = Material moisture content (%) The particle size multiplier (k) is given as 2.6 for TSP, and 0.34 for PM_{10} The empirical constant (a) is given as 1.2 for TSP, and 1.5 for PM_{10} The empirical constant (b) is given as 1.3 for TSP, and 1.4 for PM_{10} Fraction of $PM_{2.5}$ assumed to be 10% of PM_{10}	NPI Section: Mining	Silt contents assumed as 11% Moisture content 35% 1 Compactor, 1 bulldozer and 1 FEL Hours of operation: 8:00 to 16:00 on weekdays
Wind Erosion	Method of Marticorena and Bergametti (1995), calculated using ADDAS Quick software.		Surface material moisture content assumed as 1.9%. PSD as per Figure 4-3.

5 DISPERSION MODELLING RESULTS AND ASSESSMENT

Dispersion modelling was undertaken to determine highest hourly, highest daily and annual average ground level concentrations for each pollutant. These averaging periods were selected to facilitate the comparison of predicted pollutant concentrations with relevant air quality guidelines, odour thresholds, and health effect screening levels. Ground level concentration, risk and odour isopleths presented in this section depict interpolated values from the concentrations predicted by AERMOD for each of the receptor grid points specified. Ambient air quality criteria apply to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site.

Plots reflecting highest hourly and daily averaging periods contain only the highest predicted ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high hourly (or daily) average concentration is predicted to occur at certain locations, that this may only be true for one hour (or day) during the year. Because of the low impacts of the landfill on the receiving environment, only isopleth plots for site Alternative A are shown. Impacts for Alternative B are expected to be similar in scale and magnitude, although shifted slightly to the southwest of those shown for Alternative A.

5.1 Criteria Pollutants and Dust Fallout

Simulated daily average PM_{10} concentrations are shown in Figure 5-1. Simulated PM_{10} concentrations are in compliance with the SA NAAQS for all areas outside the landfill site, including for all areas outside the property boundary and at all sensitive receptor locations. Simulated highest daily $PM_{2.5}$ concentrations and annual average PM_{10}, $PM_{2.5}$ and benzene are lower than 10% of the SA NAAQS, even within the landfill site, for this reason no isopleth plots are shown for these averaging times for these pollutants.

Simulated concentrations of all criteria pollutants are less than 1% of the respective SA NAAQS at all sensitive receptor locations.

Even though background particulate concentrations in the study area are elevated, the incremental impact of the Majuba Landfill on particulate concentrations is so low throughout the study area that the cumulative impact due to Majuba Landfill operations together with background sources will be indistinguishable from baseline concentrations, with the contribution to the particulate load at sensitive receptor locations deemed to be negligible.

Similar to particulate concentrations, simulated dust fallout rates due to the Majuba Landfill operations are below the SA NDCR limits for all areas outside the landfill site, and negligible at all areas outside the property boundary, including at all sensitive receptor locations (Figure 5-2).

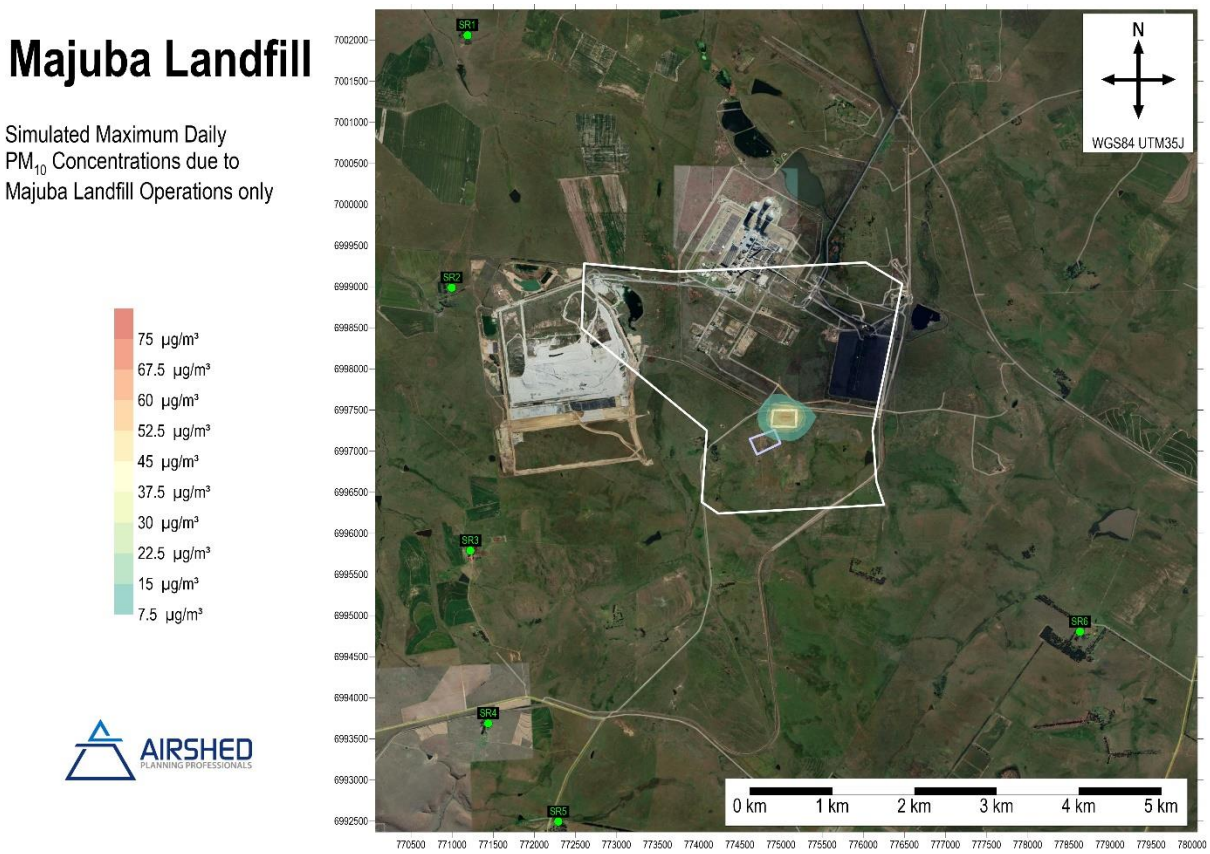

Figure 5-1: Simulated highest daily PM_{10} concentrations

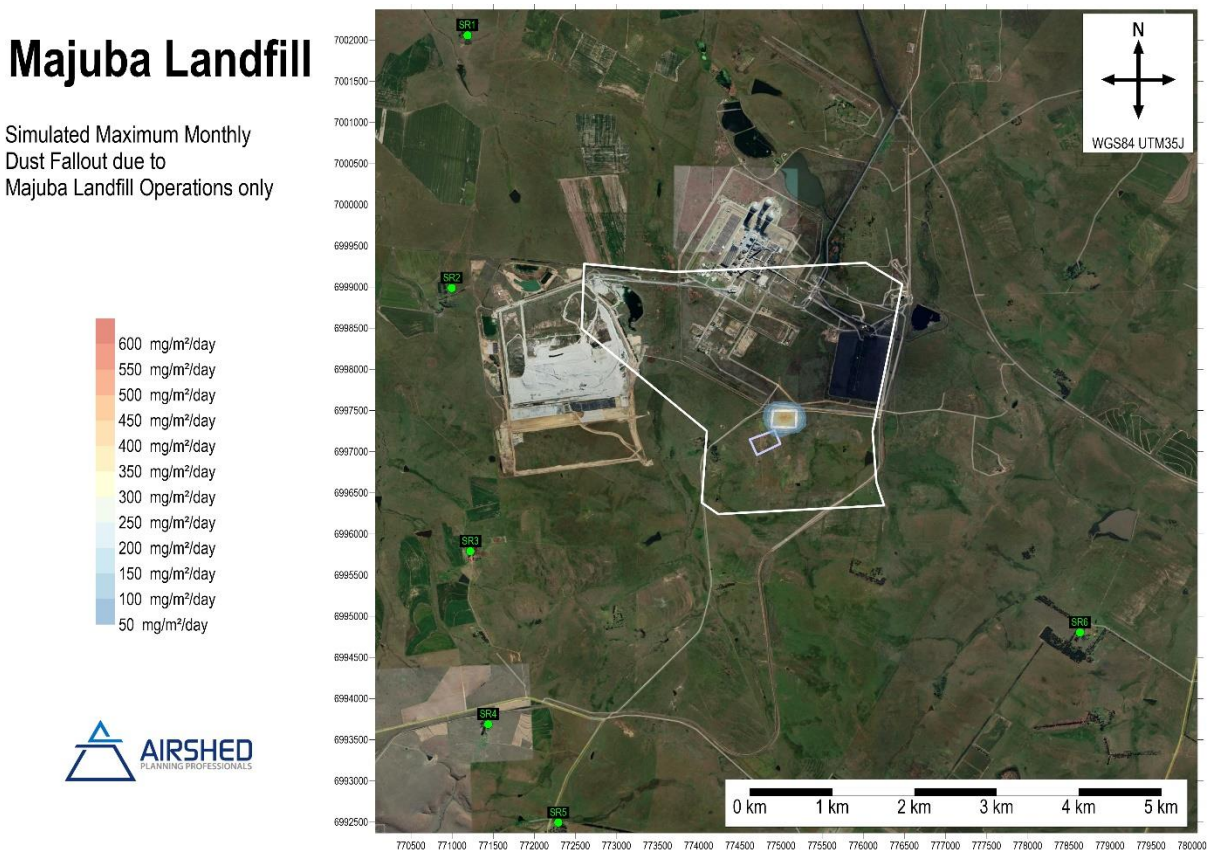

Figure 5-2: Simulated highest monthly dust fallout rates

5.2 Non-carcinogenic health risk

The potential for non-carcinogenic health impacts were assessed based on dispersion modelling results. Highest hourly, highest daily and annual average pollutant concentrations predicted to occur on-site due to landfill operations were determined. Those concentrations were also calculated as a fraction of relevant non-carcinogenic health thresholds in order to highlight the potential that exists for health impacts (refer to Section 2.2.1). The fraction of the concentration for each pollutant divided by the most stringent health threshold is called the Hazard Quotient. The sum of the hazard quotients for all pollutants is called the Hazard Index (HI).

Hazard indices of greater than 1 represent threshold exceedances. Although the health thresholds given are intended for public exposures and are therefore not strictly applicable to on-site pollutant concentrations, the use of such concentrations in the health screening provides an easy way of identifying pollutants that may result in significant off-site impacts.

The combined hazard index simulated for is provided in Figure 5-3. The combined hazard index is well below 1 (shown multiplied by 100 in the isopleth plot) for all areas outside the landfill site, including for all areas outside the property boundary and at all sensitive receptor locations. The contribution of each compound to the final calculated Hazard Index is given in Figure 5-4. It should be noted that the y-axis in Figure 5-4 is logarithmic, thus H_2S contributes significantly more (approximately 64%) to the final calculated hazard index.

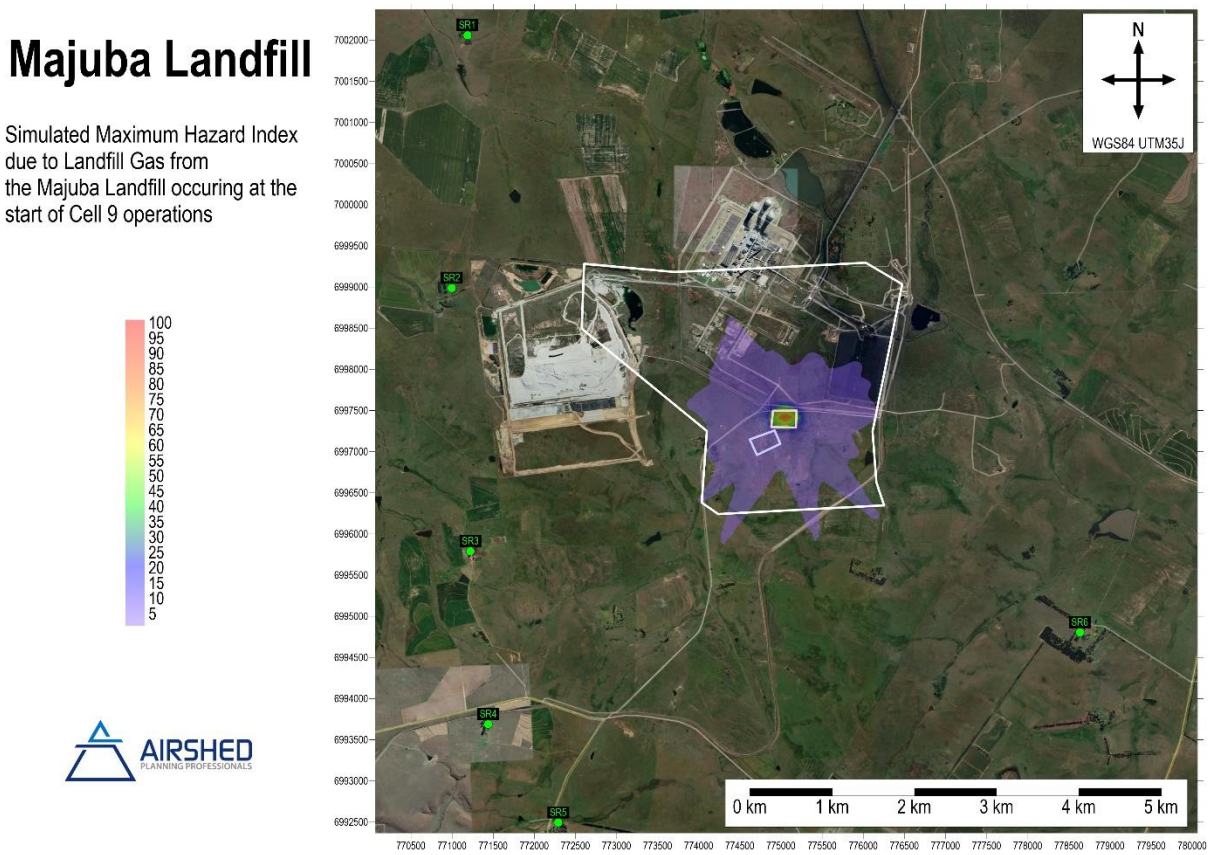

Figure 5-3: Simulated Hazard Index (x100)

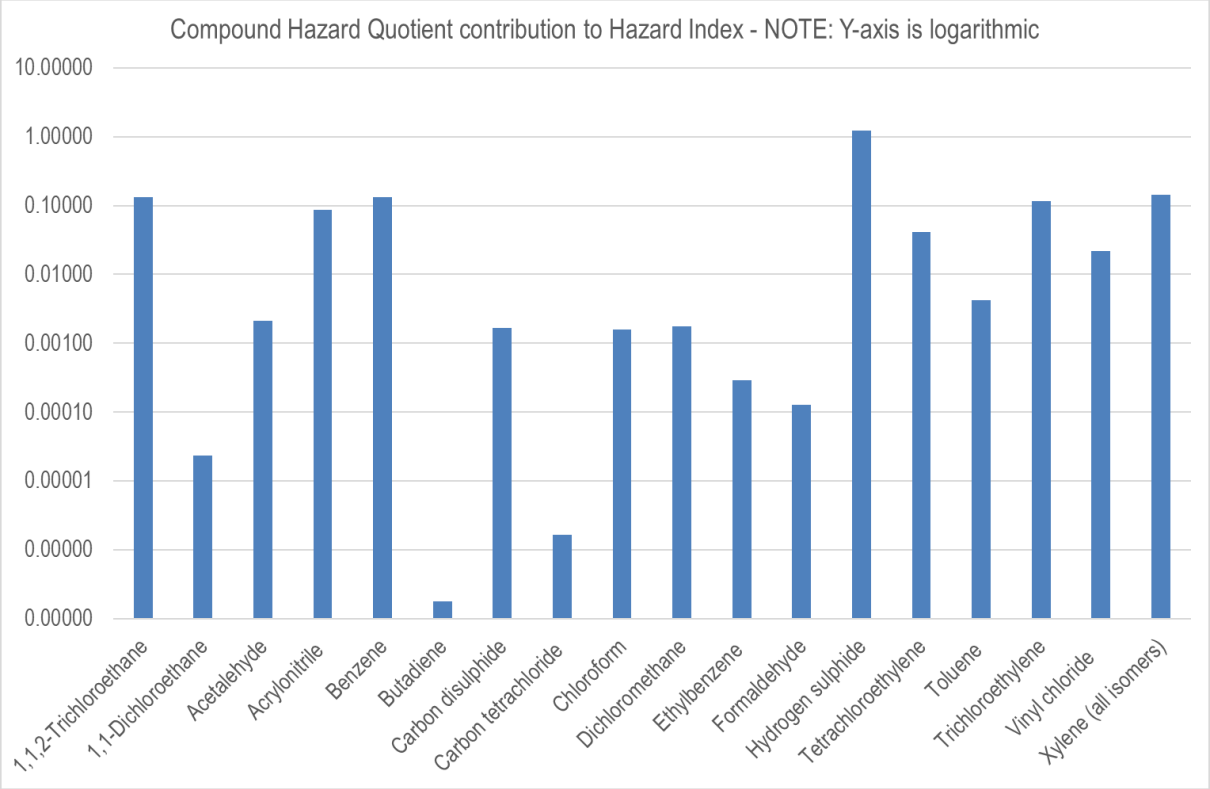

Figure 5-4: Contribution of each compound to the plotted Hazard Index – NOTE: The y-axis is logarithmic

5.3 Cancer Risk

Cancer risks were estimated based on simulated long-term average concentrations. The potential for cancer risks due to individual compounds were determined. For the risk assessment, use was made of the strictest unit risk factors available for each pollutant.

For the pollutants considered in this study, only acrylonitrile, benzene and vinyl chloride (chloroethene) resulted in a ground level cancer risk of more than 1:1 000 000, with the highest risk from vinyl chloride emissions. The increased lifetime cancer risk due to LFG emissions from the Majuba Landfill, calculated from simulated trace pollutant concentrations and unit risk factors for each pollutant (as given in Table 2-4) are shown in Figure 5-5.

The simulated cancer risk for all areas outside the property boundary, including at all sensitive receptor location, is negligible (less than 1:1 000 000 000 or one in a billion increased risk).

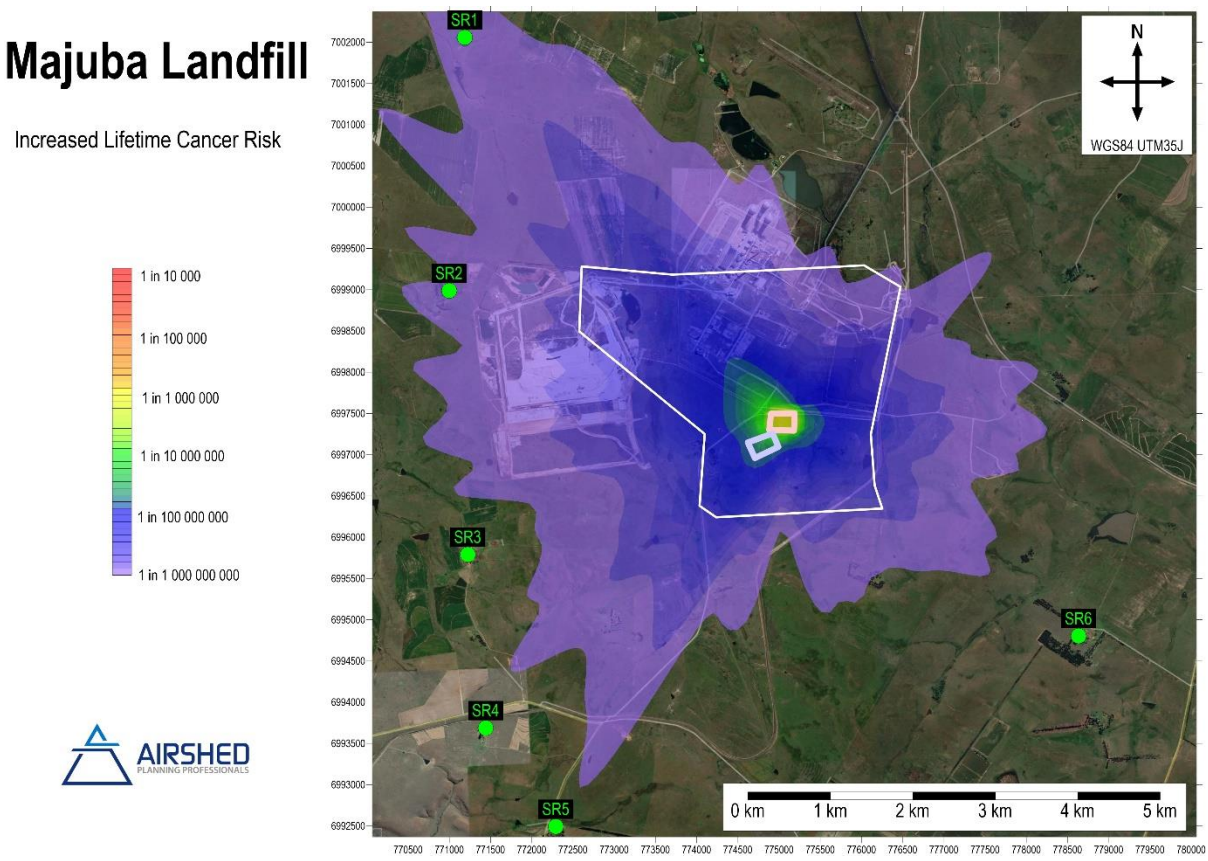

Figure 5-5: Simulated incremental increase in lifetime cancer risk

5.4 Odours Impacts

Simulated highest hourly odour impacts were simulated and are shown in Figure 5-6. Odour impacts due to simulated hydrogen sulphide (H_2S) concentrations, when compared to the odour detection threshold (Table 2-6) of 7 µg/m³, were at least an order of magnitude greater than odour impacts from other compounds - none of which result in an odour impact of more than 0.01 OU/m³ anywhere within the study area, even within the landfill site. H_2S emissions simulated result in an odour impact of 0.1 OU/m³ within the landfill site, and is therefore unlikely to be detected even by the keenest noses. The impact will be negligible for all areas outside the property boundary, including at all sensitive receptor locations.

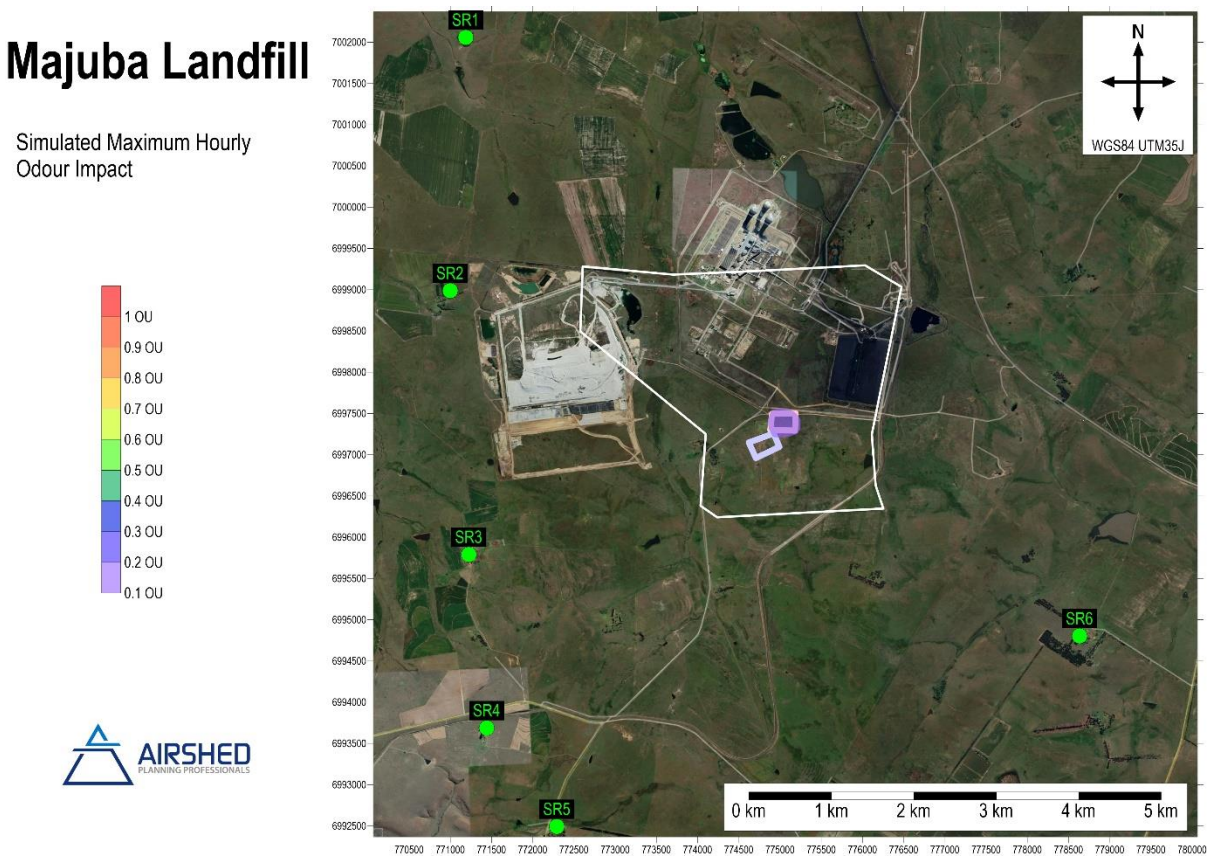

Figure 5-6: Simulated odour impacts

6 IMPACT SIGNIFICANCE RANKING

The impact of the Majuba Landfill on the receiving environment was assessed using the method provided by Savannah Environmental. The proposed landfill has a simulated ***low*** incremental and cumulative impact on air quality, including health impacts, cancer risk and odour impacts at all areas outside the landfill site, with a ***negligible*** impact at all identified sensitive receptor locations.

Table 6-1: Construction Phase impact significance rating of fugitive dust emissions on particulate concentrations and dust fallout

Nature: *Impact of particulate emissions on ambient PM_{10} and $PM_{2.5}$ concentrations and dust fallout rates.*		
Alternative A and Alternative B		
	Without mitigation	**With mitigation**
Extent	Site (1)	Site (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Small (0)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (15)**
Status (positive or negative)	Negative	Negative
Reversibility	High	High
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	Yes
Mitigation: • To minimise wind erosion emissions, exposed areas should be revegetated/rehabilitated as soon as possible. • Mitigation measures such as water sprays be employed on unpaved road surfaces and to exposed areas when periods of high wind speeds are anticipated.		
Residual Risks: Wind erosion from exposed areas could result in dust emissions post closure if areas are not adequately rehabilitated		

Table 6-2: Cumulative impact significance rating of fugitive dust emissions on particulate concentrations and dust fallout during the construction phase

Nature: *Impact of particulate emissions on ambient PM_{10} and $PM_{2.5}$ concentrations and dust fallout rates.*		
Alternative A and Alternative B		
	Overall impact of the proposed project considered in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Site (1)	Site (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (21)**
Status (positive or negative)	Negative	Negative
Reversibility	High	High
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	Yes
Confidence in findings: Medium.		
Mitigation: • To minimise wind erosion emissions, exposed areas should be revegetated/rehabilitated as soon as possible. • Mitigation measures such as water sprays be employed on unpaved road surfaces and to exposed areas when periods of high wind speeds are anticipated.		

Table 6-3: Operational Phase impact significance rating of fugitive dust emissions on particulate concentrations and dust fallout

Nature: *Impact of particulate emissions on ambient PM_{10} and $PM_{2.5}$ concentrations and dust fallout rates.*		
Alternative A and Alternative B		
	Without mitigation	**With mitigation**
Extent	Site (1)	Site (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Small (0)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (15)**
Status (positive or negative)	Negative	Negative
Reversibility	High	High
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	Yes
Mitigation: • To minimise wind erosion emissions, exposed areas should be revegetated/rehabilitated as soon as possible. • Mitigation measures such as water sprays be employed on unpaved road surfaces and to exposed areas when periods of high wind speeds are anticipated.		
Residual Risks: Wind erosion from exposed areas could result in dust emissions post closure if areas are not adequately rehabilitated		

Table 6-4: Operational Phase impact significance rating of generated landfill gas on health, odour and cancer risk

Nature: *Impact of landfill gas generation on health, odour and cancer risk*		
Alternative A and Alternative B		
	Without mitigation	**With mitigation**
Extent	Site (1)	Site (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Small (0)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (15)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	Yes
Mitigation: • To minimise LFG emissions and the impact thereof on the receiving environment, inactive areas should be capped with the final cap as soon as possible. • A complaints register should be kept on site and complaints should be proactively acted upon to minimise similar future impacts on the nearby communities. • It is recommended that once-off H_2S sampling, using passive diffusive samplers, be conducted on the western and eastern edges of the landfill site to confirm dispersion modelling results. Since the generation of H_2S is expected to increase with time, it is recommended that this sampling be conducted when the first cell is capped and filling of the second cell starts. • It is recommended that the existing dust fallout monitoring network at the Majuba Power Station be extended to include a sampling location to the south of the landfill site.		
Residual Risks: The landfill will continue to generate LFG post closure. It is recommended that the landfill be designed with adequate capping to minimise LFG emissions.		

Table 6-5: Cumulative impact significance rating of fugitive dust emissions on particulate concentrations and dust fallout during the operational phase

Nature: *Impact of particulate emissions on ambient PM_{10} and $PM_{2.5}$ concentrations and dust fallout rates.*		
Alternative A and Alternative B		
	Overall impact of the proposed project considered in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Site (1)	Site (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (21)**
Status (positive or negative)	Negative	Negative
Reversibility	High	High
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	Yes
Confidence in findings: High.		
Mitigation: • To minimise wind erosion emissions, exposed areas should be revegetated/rehabilitated as soon as possible. • Mitigation measures such as water sprays be employed on unpaved road surfaces and to exposed areas when periods of high wind speeds are anticipated.		

Table 6-6: Impact significance rating of generated landfill gas on health, odour and cancer risk during the operational phase

Nature: *Impact of landfill gas generation on health, odour and cancer risk.*		
Alternative A and Alternative B		
	Overall impact of the proposed project considered in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Site (1)	Site (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (21)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes	Yes
Confidence in findings: High.		
Mitigation: • To minimise LFG emissions and the impact thereof on the receiving environment, inactive areas should be capped with the final cap as soon as possible. • A complaints register should be kept on site and complaints should be proactively acted upon to minimise similar future impacts on the nearby communities. • It is recommended that once-off H_2S sampling, using passive diffusive samplers, be conducted on the western and eastern edges of the landfill site to confirm dispersion modelling results. Since the generation of H_2S is expected to increase with time, it is recommended that this sampling be conducted when the first cell is capped and filling of the second cell starts. It is recommended that the existing dust fallout monitoring network at the Majuba Power Station be extended to include a sampling location to the south of the landfill site.		

7 RECOMMENDATIONS

Based on the findings above, the following recommendations are made:

- To minimise LFG emissions and the impact thereof on the receiving environment, inactive areas should be capped with the final cap as soon as possible.
- To minimise wind erosion emissions, exposed areas should be revegetated/rehabilitated as soon as possible.
- It is recommended that the existing dust fallout monitoring network at the Majuba Power Station be extended to include a sampling location to the south of the landfill site.
- It is recommended that once-off H_2S sampling, using passive diffusive samplers, be conducted on the western and eastern edges of the landfill site to confirm dispersion modelling results. Since the generation of H_2S is expected to increase with time, it is recommended that this sampling be conducted when the first cell is capped and filling of the second cell starts.
- It is recommended that dust suppression measures, such as water sprays, be employed on unpaved road surfaces and to exposed areas when periods of high wind speeds are anticipated.
- At the time of closure, when LFG emissions are expected to be at a maximum, simulated methane emissions are approximately 3.2 m^3/hr, or approximately 0.28 g/s. Given the low methane emission rate, the relative non-toxicity of methane and the resultant insignificant impact of methane emissions on ambient concentrations, no methane monitoring or management is deemed necessary from an ambient air quality perspective. However, methane monitoring might still be required for other considerations, such as fire risk, but this decision is left up to the landfill's designers.
- A complaints register should be kept on site and complaints should be proactively acted upon to minimise similar future impacts on the nearby communities.

From an air quality perspective, there is no preferred choice between Alternative A and Alternative B, as both options will result in a low impact on ambient air quality outside the landfill site and a negligible impact on ambient air quality at all sensitive receptor locations.

Since no fatal flaws were identified and the simulated impact of the Majuba Landfill on the receiving environment is low for all areas outside the landfill site and negligible at all sensitive receptor locations, this study could find no reason - from an air quality perspective - why the Proposed General Waste Disposal Facility at the Eskom Majuba Power Station should not be authorised.

8 REFERENCES

Backman, E.L. (1917). Experimentella Undersokningar Ofver Luktsinnets Fysiologi. Upsala Laekarefoeren. Foerh. 22:319–470.

Ball J. and Associates. (2001). A Waste Stream Analysis of the General Waste Stream, Prepared for City of Johannesburg.

Burger, LW and Bornman, R (2020) Air Quality Impact Assessment of the Proposed Enviroserv/Averda Vissershok Landfill Height Extension. Airshed Planning Professionals Report No 19LEMC01 Rev0.

CERC. (2004). ADMS Urban Training. Version 2. Unit A.

DEC NSW. (2006). Technical Framework | Assessment and Management of Odour from Stationary Sources. Sydney: Department of Environment and Conservation (New South Wales).

Dravnieks, A. and P. Laffort (1972). Physio-Chemical Basis of Quantitative and Qualitative Odor Discrimination in Humans. In Olfaction and Taste IV. Schneider, D. (ed.). Proc. Fourth Internat. Symp., August 1971, Stuttgart: Wissenschaftliche Verlagsgesellschaft MBH, 1972, pp. 142–48.

EPA. (1999). Compilation of Air Pollution Emission (AP-42). North Carolina: Environmental Protection Agency.

Goldreich, Y., & Tyson, P. (1988). Diurnal and Inter-Diurnal Variations in Large-Scale Atmospheric Turbulence over Southern Africa. South African Geographical Journal, 48-56.

Government Gazette. (2009, Dec 24). National Ambient Air Quality Standards. National Environmental Management: Air Quality Act (39/2004), 32816. Republic of South Africa.

Government Gazette. (2010, March 31). List of activities and associated minimum emission standards. National Environmental Management: Air Quality Act (39/2004), 33064. Republic of South Africa.

Government Gazette. (2012, June 29). National Ambient Air Quality Standard for Particulate Matter with Aerodynamic Diameter less than 2.5 micron metres (PM2.5). National Environmental Management: Air Quality Act (39/2004), 35463. Republic of South Africa.

Glindemann, D., J. Novak, and J. Witherspoon (2006). Dimethyl Sulfoxide (DMSO) Waste Residues and Municipal Waste Odor by Dimethyl Sulfide (DMS): the North-Cast WPCP Plant of Philadelphia. Environ. Sci. Technol. 40:202–07.

Hanna, S. R., Egan, B. A., Purdum, J., & Wagler, J. (1999).) Evaluation of the ADMS, AERMOD, and ISC3 Dispersion Models with the Optex, Duke Forest, Kincaid, Indianapolis, and Lovett Field Data Sets. International Journal of Environment and Pollution, 1-6.

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

Hellman, T.M. and F.H. (1973). Small: Characterization of Petrochemical Odors. Chem. Eng. Progr. 69:75–77.

Hori, M., Y. Kobayashi, and Y. Ota (1972). Vinyl Chloride Monomer Odor Concentration. Plast. Ind. News 18:164–68.

IE EPA (2012). Surface VOC Emissions Monitoring on Landfill Facilities Guidance Note 6 (AG6), Office of Environmental Enforcement (OEE), Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland.

IFC. (2007). General Environmental, Health and Safety Guidelines. World Bank Group.

Katz, S.H. and E.J. Talbert (1930). Intensities of Odors and Irritating Effects of Warning Agents for Inflammable and Poisonous Gases. U.S. Bureau of Mines, Technical Report no. 480, Washington, D.C.: U.S. Dept. of Commerce,

Leonardos G., D. Kendall, and N. Barnard (1969). Odor Threshold Determinations of 53 Odorant Chemicals. J. Air Pollut.Control Assoc. 19:91–95.

Marticorena, B. & Bergametti, G., 1995. Modelling the Atmospheric Dust Cycle. 1. Design of a Soil-Derived Dust Emission Scheme. Journal of Geophysical Research, pp. 100, 16 415 - 16430.

Morimura, S. (1934). Untersuchung uber den Geruchssinn. Tohoku J. Exp. Med. 22:417–48 [German]

Mullins, L.J. (1955). Olfaction. Ann. N.Y. Acad. Sci. 62:247–76.

Nagata, Y. (2003). Measurement of Odor Threshold by Triangle Odor Bag Method. In Odor Measurement Review. Japan: Office of Odor, Noise and Vibration Environmental Management Bureau, Ministry of the Environment, Government of Japan, 2003. pp. 118–127.

Nagy, G.Z. (1991). The Odor Impact Model. J. Air Waste Mange. Assoc. 41:1360–62.

Naus, A. (1975). Olphatoric Properties of Industrial Matters. Prague: Charles University.

NSW EPA (2001). Technical Notes. Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW, New South Wales Environmental Protection Authority, January 2001.

NSW EPA (2006). Draft Policy - Assessment and Management of Odour from Stationary Sources in NSW, New South Wales Environmental Protection Authority, January 2001.

NSW EPA (2017). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, Report No. EPA 2016/0666, Environment Protection Authority, Sydney, Australia.

Preston-Whyte, R. A., & Tyson, P. D. (1988). The Atmosphere and Weather over South Africa. Cape Town: Oxford University Press.

Smith, H.O. and A.D. Hochstettler (1969). Determination of Odor Thresholds in Air Using C14-Labeled Compounds to Monitor Concentrations. Environ. Sci. Technol. 3:169–70

Stuiver, M. (1958). “Biophysics of the Sense of Smell”. Thesis, Groningen.

Themelis N. J. and Ulloa P.A (2007). Methane Generation In Landfills, Renewable Energy 32 (2007) 1243–1257

US EPA, (2009). Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions. North Carolina, U.S. Environmental Protection Agency, 2005. Federal Register / Vol. 70, No. 216 / Rules and Regulations. Appendix W of 40 CRF Part 51.

Verschueren, K. (1996). Environmental Data on Organic Chemicals (3rd ed.). New York: John Wileyu & Sons. Inc.

WHO. (2000). Guidelines for Air Quality. Geneva: World Health Organisation.

WHO. (2000). WHO Air Quality Guidelines for Europe. Retrieved from World Health Organization Regional Office for Europe: http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/who-air-quality-guidelines-for-europe,-2nd-edition,-2000-cd-rom-version

9 ANNEXURE A

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Nick Grobler

Name of Registration Body: South African Institution of Chemical Engineers

Professional Registration No.: 6483

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of section 30 of the Act.

I, **Nick Brian Grobler** , declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at **Johannesburg** on this **17th** day of **May 2022**

SIGNATURE

Senior Air Quality Specialist
CAPACITY OF SIGNATORY

10 ANNEXURE B

CURRICULUM VITAE

Name	Nick Brian Grobler
Date of Birth	14 August 1986
Nationality	South African
Employer	Airshed Planning Professionals (Pty) Ltd
Position	Senior Air Quality and Noise Specialist
Profession	Chemical Engineer employed as an Air Quality Specialist
Years with Firm	11 Years

Membership of Professional Societies

- South African Institution of Chemical Engineers (SAIChE) – Member – 2011 to present.
- Golden Key International Honour Society - 2011 to present.

Experience

- Project management, proposal preparation and project invoicing.
- Emissions inventory compilation. Proficient in quantifying emissions using:
- Engineering calculations, isokinetic and continuous stack sampling results, US EPA AP42 emission factors, Australian NPI emission factors, IPCC emission factors, ADDAS model (wind erosion), US EPA TANKS, Water9, GasSim.
- Meteorological, topographical and land use data processing and preparation.
- Dispersion modeling: experienced in SCREEN, AERMOD, ADMS, CALPUFF, SLAB and HAWK dispersion models.
- Proficient with the following specialist air quality / noise software: R, OpenAir, WRPlot, Surfer, ADDAS, TANKS, GasSim, CadnaA.
- Impact and compliance assessment.
- Air quality and dust management plan preparation.
- Air quality monitoring program design and implementation.
- Air quality monitoring set-up, training, processing and interpretation of:
- SO_2, NO_2, CO, CH_4, O_3, HCl, VOCs, BTEX, H_2S, NH_3, PAHs, PM_{10}, $PM_{2.5}$, dust fallout, salt deposition, chloride deposition and meteorological parameters.
- Environmental noise monitoring campaign design.
- Environmental noise monitoring and data processing.
- Noise source monitoring and sound power level estimation.
- Ground vibration and overblast monitoring and reporting.
- Compilation of noise source inventories.
- Noise impact and compliance assessments.
- Atmospheric Emission License application.
- Greenhouse gas emissions inventories and pollution prevention plan preparation.
- Experienced in the compilation of:
- Monthly, quarterly and annual air quality monitoring reports,
- Noise survey reports,
- Baseline, scoping and air quality impact assessment reports,
- Air quality management plans,
- Emission reduction plans, pollution prevention plans, greenhouse gas and climate change impact assessments
- Health impact assessments, odour assessments and radiation studies.
- Online NAEIS (National Atmospheric Emissions Inventory System) and SAGERS (South African Greenhouse Gas Emissions Reporting System) completion and submission.
- Industry sectors in which experience have been gained with specific reference to air quality include:
- Opencast and underground mining of: copper, platinum, chrome, gold, iron, coal, limestone, potash, graphite, lead, mineral sands, aggregate stone, clay and zinc.
- Production of: copper, platinum, PGM metals, gold, base metals, iron, steel, coal, coke, heavy mineral sands, vanadium, solder, lime, urea, chrome, gypsum, asphalt, acetylene, LNG liquefaction, vegetable oil, fertilizer, explosives, wood pulp, cement, grease, oil recycling, tyre and general waste pyrolysis, power generation, fuel

storage as well as crematoriums, general waste landfills, meat processing and rendering at abattoirs and animal waste incineration.

Software Proficiency

- Atmospheric Dispersion Models: AERMOD, ISC, CALPUFF, ADMS (United Kingdom), HAWK, TANKS
- Other: Golden Software Surfer, Lakes Environmental WRPlot, MS Word, MS Excel, MS PowerPoint, Adobe Dreamweaver

Education

- BEng (Chemical Engineering) University of Pretoria – Completed in 2009
- BEng (Hons) (Environmental Engineering) University of Pretoria – Completed in 2010

Courses Completed

- Spreadsheets as an Engineering Tool, Presented by the University of Pretoria, RSA (September 2012)

Courses Presented

- NWU Centre for Environmental Management Essential Air Quality Management Course
- North-West University Centre for Environmental Management Integrated Waste Law Course – Air Quality Aspects

Countries of Work Experience

South Africa, Zimbabwe, Namibia, Mozambique, Zambia, Democratic Republic of Congo, Republic of Congo, Ghana, Mali, Guinea, Saudi Arabia

Languages

Language	Proficiency
English	Full proficiency
Afrikaans	Full proficiency

11 ANNEXURE C: IMPACT ASSESSMENT METHODOLOGY

Direct, indirect and cumulative impacts of the issues identified through the EIA process, as well as all other issues identified due to the amendment must be assessed in terms of the following criteria:

- The **nature**, which shall include a description of what causes the effect, what will be affected and how it will be affected.
- The **extent**, wherein it will be indicated whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high):
- The **duration**, wherein it will be indicated whether:
  - the lifetime of the impact will be of a very short duration (0–1 years) – assigned a score of 1;
  - the lifetime of the impact will be of a short duration (2-5 years) - assigned a score of 2;
  - medium-term (5–15 years) – assigned a score of 3;
  - long term (> 15 years) - assigned a score of 4; or
  - permanent - assigned a score of 5;
- The **consequences (magnitude)**, quantified on a scale from 0-10, where 0 is small and will have no effect on the environment, 2 is minor and will not result in an impact on processes, 4 is low and will cause a slight impact on processes, 6 is moderate and will result in processes continuing but in a modified way, 8 is high (processes are altered to the extent that they temporarily cease), and 10 is very high and results in complete destruction of patterns and permanent cessation of processes.
- The **probability** *of occurrence*, which shall describe the likelihood of the impact actually occurring. Probability will be estimated on a scale of 1–5, where 1 is very improbable (probably will not happen), 2 is improbable (some possibility, but low likelihood), 3 is probable (distinct possibility), 4 is highly probable (most likely) and 5 is definite (impact will occur regardless of any prevention measures).
- the **significance**, which shall be determined through a synthesis of the characteristics described above and can be assessed as low, medium or high; and
- the **status**, which will be described as either positive, negative or neutral.
- the degree to which the impact can be reversed.
- the degree to which the impact may cause irreplaceable loss of resources.
- the *degree* to which the impact can be *mitigated*.

The **significance** is calculated by combining the criteria in the following formula:

S = (E+D+M)P

S = Significance weighting

E = Extent

D = Duration

M = Magnitude

P = Probability

The **significance weightings** for each potential impact are as follows:

- < 30 points: Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
- 30-60 points: Medium (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- > 60 points: High (i.e. where the impact must have an influence on the decision process to develop in the area).

Assessment of impacts must be summarised in the following table format. The rating values as per the above criteria must also be included. The table must be completed and associated ratings for **each** impact identified during the assessment should also be included.

Example of Impact table summarising the significance of impacts (with and without mitigation):

Nature: **[Outline and describe fully the impact anticipated as per the assessment undertaken]**		
	Without mitigation	**With mitigation**
Extent	High (3)	Low (1)
Duration	Medium-term (3)	Medium-term (3)
Magnitude	Moderate (6)	Low (4)
Probability	Probable (3)	Probable (3)
Significance	**Medium (36)**	**Low (24)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes	Yes
Can impacts be mitigated?	Yes	Yes
Mitigation: "Mitigation", means to anticipate and prevent negative impacts and risks, then to minimise them, rehabilitate or repair impacts to the extent feasible. Provide a description of how these mitigation measures will be undertaken keeping the above definition in mind.		
Cumulative impacts: "Cumulative Impact", in relation to an activity, means the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant, but may become significant when added to existing and reasonably foreseeable impacts eventuating from similar or diverse activities[1].		
Residual Risks: "Residual Risk", means the risk that will remain after all the recommended measures have been undertaken to mitigate the impact associated with the activity (Green Leaves III, 2014).		

[1] Unless otherwise stated, all definitions are from the 2014 EIA Regulations (as amended on 07 April 2017), GNR 326.