AIRSHED
PLANNING PROFESSIONALS

Climate Change Assessment for the Proposed Harmony Nooitgedacht Tailings Storage Facility near Welkom, South Africa

Project done on behalf of **Environmental Impact Management Services**

Project Compiled by:

H Liebenberg-Enslin

Report No: 24EIM08 | **Date:** October 2025

Address: 62 Constantia Avenue, Mnandi AH, Centurion
Postal: PostNet Suite #6 Private Bag x2, Raslouw, 0109

Tel: +27 (0)11 805 1940

www.airshed.co.za

Report Details

Status	Rev 0
Report Title	Climate Change Assessment for the Proposed Nooitgedacht Tailings Storage Facility near Welkom, South Africa
Report Number	24EIM08
Date	October 2025
Client	Environmental Impact Management Services
Prepared by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
Reviewed by	Terri Bird (Pr. Sci. Nat.), PhD (University of Witwatersrand)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in in air quality, climate change and 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**
Rev 0	October 2025	For client review

Executive Summary

Harmony Gold Mining Company Limited (Harmony) own and operate a number of Gold Mines and Plants in the Welkom region in the Free State. Harmony currently deposit tailings onto the Free State South (FSS) 2 Tailings Storage Facility (TSF), St. Helena 4 TSF, St. Helena 123 TSF, Dam 23 TSF, Brand D TSF and Target 1&2 TSF. The current planned Life of Mine (LOM) of the Free State Operations exceed the available deposition capacity of these TSFs, and Harmony is undertaking a feasibility assessment to construct the new 805 hectare (ha) Nooitgedacht TSF. In addition, as part of the Free State Reclamation (FSR) Project where the aim is to increase the reclamation rate of Harmony's Free State Operations tailings from 800 ktpm to 2000 ktpm, where the residue will be deposited onto the proposed Nooitgedacht TSF. Return water from the Nooitgedacht TSF needs to be pumped to a new return water facility / water storage facility in the form of two concrete tanks.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Impact Management Services (EIMS) to undertake a Climate Change Assessment (CCA) for the proposed Nooitgedacht TSF project (hereafter referred to as the project).

Project specific information together with local and internationally published emission factors were used to calculate Scope 1 (direct) and Scope 2 (indirect) greenhouse gases (GHG) emissions for the proposed project. Locally published literature was referenced, to understand the projected changes to climate for the area.

The physical risks of climate change on the study area (based on the Green Book which references the Intergovernmental Panel on Climate Change (IPCC's) fifth assessment report (AR5) data) can be summarised as follows:

- Climate Projections:
  - Temperature:
    - Baseline: 4.6 hot days (90th percentile)
    - High mitigation Representative Concentration Pathways (RCP) 4.5 climate situation: 12 hot days with an increase in temperature of 2.9°C (90th percentile)
    - Low mitigation RCP8.5 climate situation: 27 hot days with an increase in temperature of 3.2°C (90th percentile)
  - Rainfall:
    - Baseline: 13.8 extreme rainfall days (90th percentile)
    - High mitigation RCP4.5 climate situation: an increase of 1 extreme rainfall days with an increase in rainfall of 32.5 mm (90th percentile)
    - Low mitigation RCP8.5 climate situation: an increase of 1.1 extreme rainfall days with an increase in rainfall of 88.6 mm (90th percentile)
- Hazards assuming the low mitigation RCP8.5 climate situation:
  - Wildfires: the settlement of Welkom is at moderate risk of wildfires with the projection of 33 fire danger days over the project area;
  - Drought: the settlement of Welkom has a very low risk of drought with the Standardized Precipitation Index (SPI)[1] of -0.38 for the project area;

1 The Standardized Precipitation Index (SPI) is a widely used index to characterize meteorological drought on a range of timescales. SPI index.

- Exposure to heat extremes: the settlement of Welkom has a high risk of encountering increasing heat stresses; and,
- Flooding: the settlement of Welkom has a low risk of flooding with a slight increase in extreme rainfall days for the project area (1.022).

Based on information provided, the project is likely to result in an estimated total of 67 519 tCO_2e direct emissions, with no indirect emissions due to construction activities. For project operations, the estimated total GHG emissions is 5 003 tCO_2e (direct) and 87 520 tCO_2e (indirect). This was calculated to represent 0.018% (construction) and 0.132% (operation) of the South African annual GHG budget for 2030 (construction) and 2035 (operations), respectively..

The impact of the project's construction phase on climate change was assessed to have a **Very Low** negative risk rating, with the operational phase having a **Low** risk.

The project will be required to report CO_2e emissions annually via the NAEIS and provide a greenhouse gas mitigation plan.

Conclusion

From the perspective of climate change, it is the opinion of the specialist that the project be authorised, on condition that GHG emissions are reported annually according to legal requirements.

Table of Contents

List of Tables

List of Figures

List of Acronyms and Symbols

AFF	Agriculture, Forestry and Fishing
Airshed	Airshed Planning Professionals (Pty) Ltd
AR5	IPCC's fifth assessment report
AR6	IPCC's sixth assessment report
BAU	Business-As-Usual
°C	Degrees Celsius
CCA	Climate Change Assessment
CCS	Carbon Capture and Sequestration (or Carbon Capture and Storage)
CH_4	Methane
CMIP	Coupled Model Intercomparison Project
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DFFE	Department of Forestry, Fisheries and Environment (previously DEA)
DMR	Department of Mineral Resources
EA	Environmental Authorisation
EBRD	European Bank for Reconstruction and Development
ECMWF	European Centre for Medium-Range Weather Forecasts
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services
ER	Exploration Right
FOLU	Forestry and Other Land Use
FSS	Free State South
GCMs	Global Climate Change Models
Gg	Gigagram
GHG	Greenhouse gases
GHGIP	National Greenhouse Gas Improvement Programme
GN	Government notice
GVA	Gross Value Added
GWP	Global warming potential
ha	Hectar
H_2O	Water vapour
HFCs	Hydrofluorocarbons
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
km	Kilometre
KWh	Kilowatt hour
LNG	Liquid Natural Gas
LOM	Life of Mine
l/d	Litres per day
LUCF	Land-Use Change and Forestry LUCF
ML	Million litres
mm/yr	Millimetres per year
MW	Megawatt
N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards
NACA	National Association for Clean Air
NAEIS	National Atmospheric Emission Inventory System
NCEP	National Centres for Environmental Prediction
NEM:AQA	National Environmental Management: Air Quality Act

NDCs	Nationally determined contributions
NOAA	National Oceanic and Atmospheric Administration
O_3	Ozone
PFCs	Perfluorocarbons
PPP	Pollution Prevention Plan
PR	Production Right
PV	Photovoltaic
SAAELIP	South African Atmospheric Emission Licensing and Inventory Portal
SAAQIS	South African Air Quality Information System
SACNASP	South African Council for Natural Scientific Professions
SAGERS	South African Greenhouse Gas Emission Reporting System
SAWS	South African Weather Services
SF_6	Sulfur hexafluoride
SPI	Standardized Precipitation Index
SSP	Shared Socioeconomic Pathway
SST	Sea surface temperatures
SUDS	Sustainable Urban Drainage Systems
t	Tonne
TSF	Tailings Storage Facility
UNFCCC	United Nations Framework Convention on Climate Change
UVR	Ultraviolet radiation
WHO	World Health Organisation

Note:

The spelling of “sulfur” has been standardised to the American spelling throughout the report. "The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled “sulfur”. This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: http://goldbook.iupac.org (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.doi: 10.1351/goldbook)"

1 INTRODUCTION

Harmony Gold Mining Company Limited (Harmony) own and operate a number of Gold Mines and Plants in the Welkom region in the Free State. Harmony currently deposit tailings onto the Free State South (FSS) 2 Tailings Storage Facility (TSF), St. Helena 4 TSF, St. Helena 123 TSF, Dam 23 TSF, Brand D TSF and Target 1&2 TSF. The current planned Life of Mine (LOM) of the Free State Operations exceeds the available deposition capacity of these TSFs, and Harmony is undertaking a feasibility assessment to construct the new 805 hectare (ha) Nooitgedacht TSF. In addition, as part of the Free State Reclamation (FSR) Project where the aim is to increase the reclamation rate of Harmony's Free State Operations tailings from 800 ktpm to 2 000 ktpm, where the residue will be deposited onto the proposed Nooitgedacht TSF. Return water from the Nooitgedacht TSF needs to be pumped to a new return water facility / water storage facility in the form of two concrete tanks.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Impact Management Services (EIMS) to undertake a Climate Change Assessment (CCA) for the proposed Nooitgedacht TSF project (hereafter referred to as the project).

1.1 Scope of Work

The scope of work included a desktop CCA in line with the Consultation on Intention to Publish the National Guideline for Consideration of Climate Change Implications in Applications for Environmental Authorisations, Atmospheric Emission Licenses, and Waste Management Licenses, by:

1. Quantifying the greenhouse gas (GHG) emissions during the construction, operation, and closure and decommissioning phases of the project compared to the global and national emission inventories; and compared to international benchmarks for the project.
2. Discussing the robustness of the project in terms of forecasted climate change impacts to the area over the lifetime of the project.
3. Discussing the vulnerability of communities in the immediate vicinity of the project to climate change.
4. Proposing management and mitigation strategies.
5. Preparation of a climate change statement report.

1.2 Specialist Details

1.2.1 Statement of Independence

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.

1.2.2 Competency Profile – H Liebenberg-Enslin, PhD Geography (University of Johannesburg)

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

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

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

A comprehensive curriculum vitae of H Liebenberg-Enslin, PhD Geography (University of Johannesburg) is provided in Appendix A.

2 REGULATORY CONTEXT AND IMPACT ASSESSMENT CRITERIA

Greenhouse gases (GHGs) are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2007). Human activities since the beginning of the Industrial Revolution (taken as the year 1750) have produced a 40% increase in the atmospheric concentration of carbon dioxide, from 280 ppm in 1750 to 425.83 ppm in June 2025 (Lan, 2025). This increase of CO_2 in the Earth's atmosphere has occurred despite the uptake of a large portion of the emissions by various natural "sinks" involved in the carbon cycle (NOAA, 2021). Anthropogenic CO_2 emissions (i.e., emissions produced by human activities) come from combustion of fossil fuels, principally coal, oil, and natural gas, along with waste processing and decomposition, deforestation, soil erosion and animal agriculture (IPCC, 2007).

The following sections describe the alignment of South African national policies regarding greenhouse gas emissions and reporting with international agreements and targets.

2.1 International Agreements

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change, (UNFCCC) as a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change, and coping with impacts that were, by then, inevitable.

By 1995, countries launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed country parties to emission reduction targets. The Protocol's first commitment period started in 2008 and ended in 2012. As agreed in Doha in 2012, the second commitment period began on 1 January 2013 and will end in 2020 (UNFCCC, 2017) but due to lack of ratification has not come into force.

The Paris Agreement (2016) builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort.

The central aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2.0°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives.

The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts.

In 2018, Parties took stock of the collective efforts in relation to progress towards the goals set in the Paris Agreement to inform the preparation of NDCs. There will also be a global stocktake every five years to assess the collective progress towards achieving the purpose of the Agreement and to inform further individual actions by Parties.

As of September 2024, 195 Parties of the 197 Parties to the UNFCCC Convention, including South Africa, had ratified the Paris Agreement. South Africa submitted its NDC to the UNFCCC on 25 September 2016 and an updated first NDC in September 2021. In July 2025, a draft of the second NDC was gazetted (GG 53092) for public comment.

On January 20, 2025, an executive order was signed by the President to withdraw the United States of America from the Paris Agreement.

2.2 South African National Climate Change Response Policy 2011

South Africa ratified the UNFCCC in August 1997 and acceded to the Kyoto protocol in 2002, with effect from 2005. However, since South Africa is an Annex 1 country it implies no binding commitment to cap or reduce GHG emissions. South Africa later ratified the Paris Agreement (as signed on 22 April 2016) which although not bound to commit to a cap or reduce GHG emissions, pledged to reduce emissions by 34% below Business-As-Usual (BAU) emissions by 2020 and 42% below BAU by 2025. The proposed 2030 target range represents a 28% reduction in GHG emissions commitment from the original 2015 NDC targets. However, these original goals were ambitious, and South Africa subsequently shifted from BAU-based targets for 2020 and 2025 in terms of the Cancun Agreement under the UNFCCC, to absolute GHG emissions targets under the Paris Agreement. This update demonstrates reducing the upper range of South Africa’s targets by a more realistic 17% for 2025 and 28% for 2030, respectively.

The National Climate Change Response White Paper, passed by Cabinet in October 2011, stated that in responding to climate change, South Africa has two objectives: to manage the inevitable climate change impacts and to contribute to the global effort in stabilising GHG emissions at a level that avoids dangerous anthropogenic interference with the climate system. The White Paper proposed mitigation actions, especially a departure from coal-intensive electricity generation, be implemented in the short- and medium-term to match the GHG trajectory range. Peak GHG emissions are expected between 2020 and 2025 before a decade long plateau period and subsequent reductions in GHG emissions.

The White Paper also highlighted the co-benefit of reducing GHG emissions by improving air quality and reducing respiratory diseases by reducing ambient particulate matter, ozone, and sulfur dioxide concentrations to levels in compliance with the National Ambient Air Quality Standards (NAAQS) by 2020. To achieve these objectives, the Department of Forestry, Fisheries and Environment (DFFE) established a national GHG emissions inventory that reports through the South African Atmospheric Quality Information System (SAAQIS).

The Climate Change Act (Act 22 of 2024) was assented to by the President of the Republic of South Africa on 23 July 2024 in Government Notice (GN) 5050 in Government Gazette (GG) 50966 of 23 July 2024. The President proclaimed its commencement under section 38 on 17 March 2025; however not all provisions are in force. The Act is aligned with international policies guidelines and South Africa’s NDC and aim to reduce GHG emissions as primary driver to anthropogenic climate change. The aim of the Act is to achieve an effective climate change response through a long-term just transition to a low carbon economy that is climate resilient and allows for sustainable development of South Africa. When fully in force, the Act will:

- establish provincial and municipal forums on climate change which will be responsible for co-ordinating climate change response actions in each province.

- strengthen the establishment of the Presidential Climate Change Coordinating Commission. Although, the commission has already been established, its establishment only carries legal force after the Act becomes fully enforceable.
- establish a National Adaptation Strategy to guide South Africa's adaptation to the impacts of climate change and develop adaptation scenarios which anticipate the likely impacts over the short, medium, and long term.
- determine a national GHG emissions trajectory, which must be reviewed every five years, and which indicates an emissions reduction objective.
- put in place a 5-yearly sectoral emission targets for identified sectors and sub-sectors that must be aligned with the national GHG emissions trajectory and include quantitative and qualitative GHG emission reduction goals.
- bring into force the carbon budget allocation mechanism, which will be linked to the Carbon Tax Act, which will replace the current National Pollution Prevention Plan mechanism which is enforced under the National Environmental Management: Air Quality Act (NEM:AQA).

2.3 Nationally Determined Contribution

The first South African NDC submission was completed in 2016. This was undertaken to comply with decision 1/CP.19 and 1/CP.20 of the Conference of the Parties to the UNFCC. An update of the first NDC was published submitted to the UNFCCC on 27 September 2021[2] in preparation for the 26th Conference of the Parties (held in Glasgow, Scotland in November 2021). This document describes South Africa's NDC on adaptation, mitigation and finance and investment necessities to undertake the resolutions with updated revisions to the adaptation goals and mitigation targets.

As part of the updated adaption portion the following goals have been assembled:

1. Goal 1: Enhance climate change adaptation governance and legal framework.
2. Goal 2: Develop an understanding of the impacts on South Africa of 1.5 and 2°C global warming and the underlying global emission pathways through geo-spatial mapping of the physical climate hazards, and adaptation needs in the context of strengthening the key sectors of the economy. This will provide the scientific basis for strengthening the national and provincial governments' readiness to respond to climate risk.
3. Goal 3: Implementation of National Climate Change Adaptation Strategy adaptation interventions for the period 2021 to 2030, where priority sectors have been identified as biodiversity and ecosystems; water; health; energy; settlements (coastal, urban, rural); disaster risk reduction, transport infrastructure, mining, fisheries, forestry, and agriculture.
4. Goal 4: Mobilise funding for adaptation implementation through multilateral funding mechanisms.
5. Goal 5: Quantification and acknowledgement of the national adaptation and resilience efforts.

As part of the mitigation portion the following have been, or can be, implemented at National level:

---

2 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/South%20Africa%20First/South%20Africa%20updated%20first%20NDC%20September%202021.pdf

- The approval of 79 (5 243 MW) renewable energy Independent Power Producer projects as part of a Renewable Energy Independent Power Producer Procurement Programme. An additional 6 300 MW is being deliberated.
- A "Green Climate Fund" has been created to back green economy initiatives. This fund will be increased in the future to sustain and improve successful initiatives.
- It is intended that by 2050 electricity will be decarbonised.
- Carbon Capture and Sequestration (or Carbon Capture and Storage) (CCS).
- To support the use of electric and hybrid electric vehicles.
- Reduction of emissions can be achieved through the use of energy efficient lighting; variable speed drives and efficient motors; energy efficient appliances; solar water heaters; electric and hybrid electric vehicles; solar photovoltaic (PV); wind power; CCS; and advanced bioenergy.
- Updated targets based on revised 100-year global warming potential (GWP) factors (published in the Annex to decision 18/CMA.1 of the Intergovernmental Panel on Climate Change's (IPCC) 5th assessment report) (AR5) and based on exclusion of land sector emissions arising from natural disturbance. The first NDC mitigation targets, consistent with South Africa's fair share, are presented in Table 1.

Table 1: South Africa's NDC mitigation targets

Year	Target	Corresponding period
2025	South Africa's annual GHG emissions will be in a range between 398 - 510 Mt CO_2e.	2021-2025
2030	South Africa's annual GHG emissions will be in a range between 350 - 420 Mt CO_2e.	2026-2030

The draft second South African NDC was gazetted in July 2025 (GG 53092) for public comment. This draft sets out to update South Africa's climate change mitigation targets and adaptation goals for 2026-2030 and 2031-2035 period, in line with national development priorities and international obligations.

As part of the updated adaption portion the following goals have been assembled:

1. Goal 1: Adapt South Africa's water and sanitation systems to drying conditions and drought and flood intensification, as water underpins human, plant and animal health and all economic and livelihood activities.
2. Goal 2: Enhance disaster risk management, healthcare and sanitation provision, especially in informal settlements, to reduce impacts of flooding and heat stress on most vulnerable households.
3. Goal 3: Upgrade critical transport infrastructure (roads, rail, ports) to maintain functioning under increased rainfall intensity, heat stress, wind speeds and storm surges.
4. Goal 4: Enhance nutritious food access and affordability through support to agricultural and fisheries producers and distributors in adapting to warmer and windier conditions and changes in rainfall.
5. Goal 5: Enhance climate services, with early warning and impact information made accessible to a wide range of users, tailored to different operational, language, gender, age and disability needs.
6. Goal 6: Enhance ecosystem-based adaptation to heat and water stress, protecting South Africa's natural heritage, biodiversity and improving ecosystem functioning that underpins our cultural identity, food systems, human wellbeing and our tourism economy.
7. Goal 7: Capacitate all spheres of government to implement adaptation through enacting and enforcing all provisions of the Climate Change Act.
8. Goal 8: Enhanced efforts to build climate resilient human settlements and resilient infrastructure.

The updated second NDC mitigation targets are presented in Table 2.

Table 2: South Africa's draft second NDC mitigation targets

Period of implementation	Target
2026 – 2030	South Africa's annual GHG emissions will be in a range from 350 – 420 Mt CO_2e in 2030.
2031 – 2035	South Africa's annual GHG emissions will be in a range from 320 – 380 Mt CO_2e in 2035.

2.4 Greenhouse Gas Emissions Reporting

Regulations pertaining to GHG reporting using the National Atmospheric Emission Inventory System (NAEIS) were published on 3 April 2017 (Government Notice (GN) 257 in Government Gazette 40762 and amendment – GNR 994 in Government Gazette 43712). The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only. The three broad scopes for estimating GHG are:

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

The South African Greenhouse Gas Emission Reporting System (SAGERS) monitoring and reporting system is used to collect GHG information in a standard format for comparison and analyses. The system forms part of the national atmospheric emission inventory component of South African Atmospheric Emission Licensing and Inventory Portal (SAAELIP).

The DFFE is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the IPCC's default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors. Methodological guidelines for GHG emission estimation, which include country specific emission factors for fuels used in stationary and mobile combustion, have been issued (DFFE, 2022b)

Also, the Carbon Tax Act (Act 15 of 2019) includes details on the imposition of a tax on the CO_2e of GHG emissions. Certain production processes indicated in Annexure A of the Declaration of Greenhouse Gases as Priority Pollutants (GN 710 in GG 40966, 21 July 2017) with GHG more than 0.1 Mt/year, measured as carbon dioxide equivalent (CO_2e), are required to submit a pollution prevention plan to the Minister for approval.

2.5 GHG Inventories

2.5.1 National GHG Emissions Inventory

South Africa is a GHG contributor and is undertaking steps to mitigate and adapt to the changing climate. DFFE is categorised as the lead climate change institution and is required to coordinate and manage climate related information such as development of mitigation, monitoring, adaption and evaluation strategies (DFFE, 2022a). This includes the establishment and updating of the National GHG Inventory. The National Greenhouse Gas Improvement Programme (GHGIP) has been initiated; it includes sector specific targets to improve methodology and emission factors used for the different sectors as well as the availability of data.

The 2020 National GHG Inventory was prepared using the 2006 IPCC Guidelines (IPCC, 2006). According to the draft 9th National GHG Inventory Report (DFFE, 2024), the total GHG emissions in 2022 were estimated at approximately 478.888 Mt CO_2e (excluding Land Use, Land Use Change and Forestry (LULUCF)). This was a 2.2% decrease from the 2000 total GHG emissions (excluding LULUCF). LULUCF is estimated to be a net carbon sink which reduces the 2022 GHG emissions to 435.828 Mt CO_2e. The assessment (excluding LULUCF) showed the main sector contributing to GHG emissions in 2022 to be the energy sector, contributing 78% to the total GHG emissions.

2.5.2 GHG Emission Inventory for the Sector

The proposed project would be categorised in the industrial category for both the global GHG inventory and for the national GHG inventory. According to the World Resources Institute – CAIT Climate Data Explorer (http://cait.wri.org/) the 2022 global GHG emissions from the industry category were approximately 3 208.24 Mt CO_2e; 6.4% of the total GHG emissions (including Land-Use Change and Forestry (LUCF)). The South African industry sector contributed 28.32 Mt CO_2e, ~0.88% of the global emissions from the industry sector in 2022.

2.5.3 Draft National Guideline for Consideration of Climate Change in Development Applications, June 2021

The DFFE published (on 25 June 2021) a notice under the National Environmental Management Act (NEMA) requesting public comment on the *Draft National Guideline for the consideration of climate change implications in applications for environmental authorisation, atmospheric emission licences and waste management licences.*

The Draft National Guideline has been developed to support the inclusion of climate change considerations into the Environmental Impact Assessment (EIA) process, and to create a consistent approach for such incorporation, which will help proponents to assess:

- how a proposed development will likely exacerbate climate change;
- the impact of a development on features (natural and built) that are crucial for climate change adaptation and resilience; and,
- the sustainability of a development in the context of climate change projection.

The Guideline puts forward "a consistent approach in providing interested and affected parties (for example, proponents, Environmental Assessment Practitioners (EAPs) and specialists) with the minimum requirements to consider when undertaking a climate change assessment, which forms part of an application for environmental authorisation, an atmospheric emissions licence, and/or waste management licence".

One of the impact requirements for a climate change assessment is an estimation of the GHG emissions, direct and indirect (including upstream GHG emissions) that will be released into the atmosphere annually throughout the impact related to the activity.

The comment period for amendments to the draft guideline has now closed but the final guideline has not yet been published. As far as possible the guideline has been followed in the preparation of this climate change impact assessment in support of environmental authorisation.

3 PHYSICAL RISKS OF CLIMATE CHANGE ON THE REGION

The discussions of physical risks of climate change discussed in this section are likely to be relevant to the project as well as to the communities surrounding the project even if the project is not authorised.

The location of the proposed Nooitgedacht TSF within the Matjhabeng Local Municipality and in relation to the town of Welkom is shown in Figure 1. The closest towns in the immediate region of the project include Welkom and its suburbs (located about 3 kilometres (km) southeast of the project boundary) and Odendaalsrus (located about 5.2 km north of the project boundary).

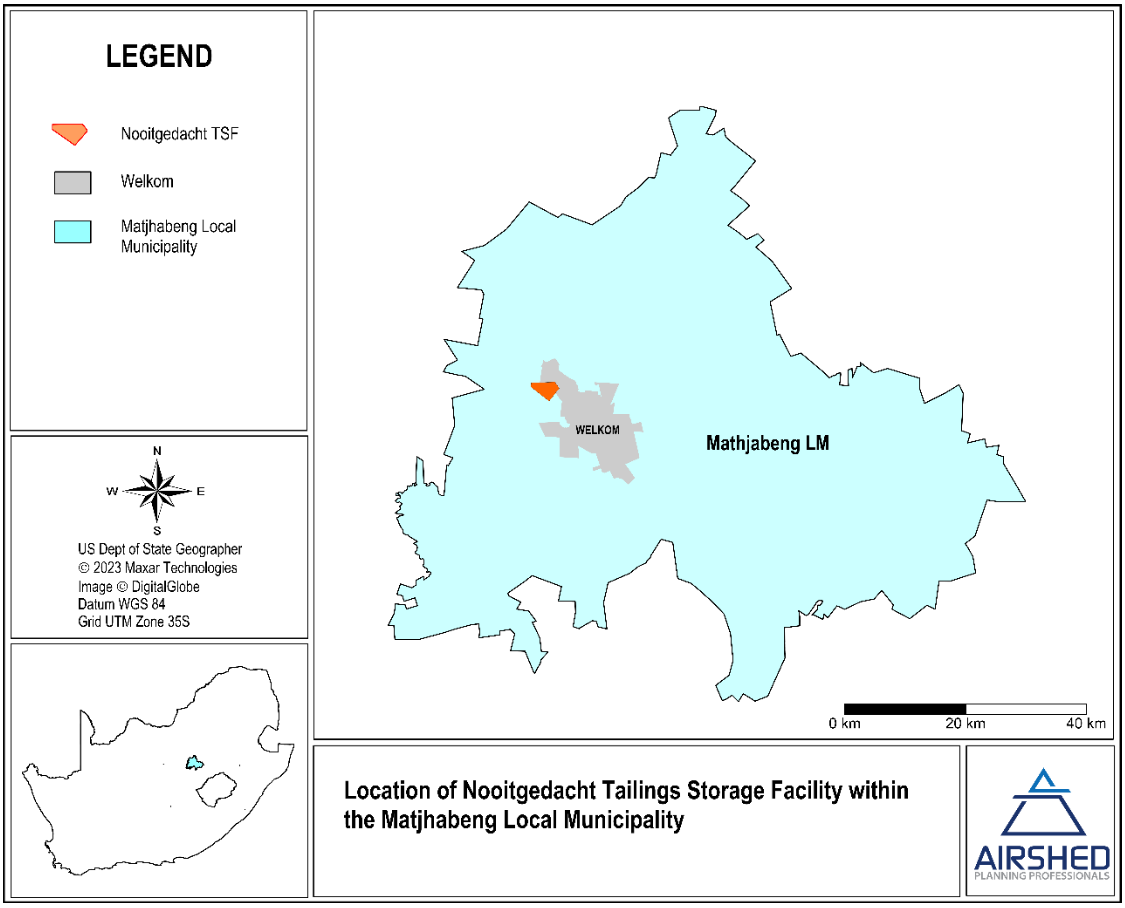


Figure 1: Location of the Nooitgedacht Tailings Storage Facility within the Matjhabeng Local Municipality

3.1 Vulnerability

The Green Book (CSIR, 2024); was developed to be an online platform providing quantitative scientific evidence on the likely impacts that climate change and urbanisation will have on South Africa's cities and towns. A profile for each local municipality, including individual settlements and neighbourhoods, was built in terms the rates of socio-economic, economic, physical and environmental risks associated with urbanisation, population growth and climate change (Le Roux, et al., 2019). The risk profile was accessed for the Matjhabeng Local Municipality[3]. The Matjhabeng Local Municipality socio-economic vulnerability score[4] (out of 10) is 5.3 for 1996, reducing to 4.2 for 2011. The lower score in 2011 compared to 1996 indicates improvement of socio-economic factors. The Matjhabeng Local Municipality for socio-economic vulnerability ranks 4th out of 19 in the province and 81st out of 213 in the country. The Matjhabeng Local Municipality economic vulnerability score[5] (out of 10) is 7.7 for 1996, increasing to 9.9 for 2011. This high score indicates high economic pressure. The economic vulnerability ranks 19th out of 19 in the province and 211th out of 213 in the country. The physical vulnerabilities[6] ranks 4th out of 19 in the province and 50th out of 213 in the country. The environmental vulnerability[7] ranks 13th out of 19 in the province and 102nd out of 213 in the country.

3.2 Baseline Climate

Climate change metrics focus on temperature; the number of very hot days (where temperatures exceed 35°C); rainfall and extreme rainfall events (more than 20 mm in 24 hours). The baseline (1961 to 1990) annual averages for these metrics were accessed for the area near the project site from the South Africa 'Green Book'[8] (CSIR, 2024). The metrics include the minimum, average and maximum values, ranging between the 10th and 90th percentiles[9] as an indication of the variability within the measured data set.

Baseline annual average temperature is 16.76°C, ranging between 10.35°C (minimum) and 23.15°C (maximum) (**Error! Reference source not found.**). The World Bank Group's Climate Change Knowledge Portal (CCKP) gives the mean annual temperature for the area as 18°C for the period 1990 – 2020 (World Bank Group, 2021). The baseline for very hot days (where temperatures exceed 35°C) in the project area is 4.6 days, with 7 heat wave days per annum (where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at the location by 5°C, for a period of at least three consecutive days) (Figure 4). The model-simulated annual average rainfall as shown in Figure 3 is 1 084 mm for the project area (CSIR, 2024) – this is higher than the annual average rainfall provided in the CCKP of 600 - 675 mm for the area (World Bank Group, 2021).

3 https://riskprofiles.greenbook.co.za/

4 Defined as the vulnerability of households based on household composition; education and health; access to basic services; safety and security.

5 Defined as the susceptibility of the municipality to external shocks based on economic diversity; size of economy; labour force; gross domestic product (GDP) growth rate; and inequality.

6 Defined by the physical fabric of connectedness of the settlements within the municipalities and structural robustness.

7 This indicator represents the balance between preserving the natural environmental and the pressures of population growth, urbanisation, and economic development. The indicator is based on air quality, environmental governance and competition between ecology and the urban environment.

8 https://greenbook.co.za/

9 A percentile is a statistical measure to indicate the value below which a given percentage of observations in a group of observations falls. For example, the 90th percentile is the value below which 90% of the observations fall. The 10th percentile is the value below which 10% of the observations fall.

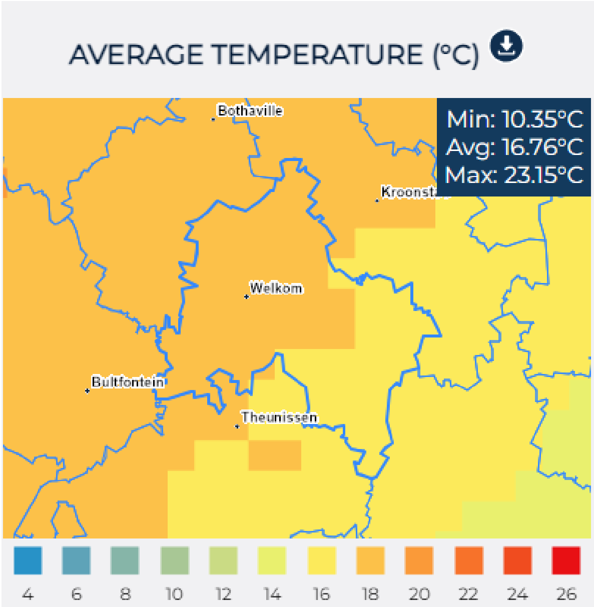


Figure 2: Baseline (1961 to 1990) annual average temperature for the project area (CSIR, 2024)

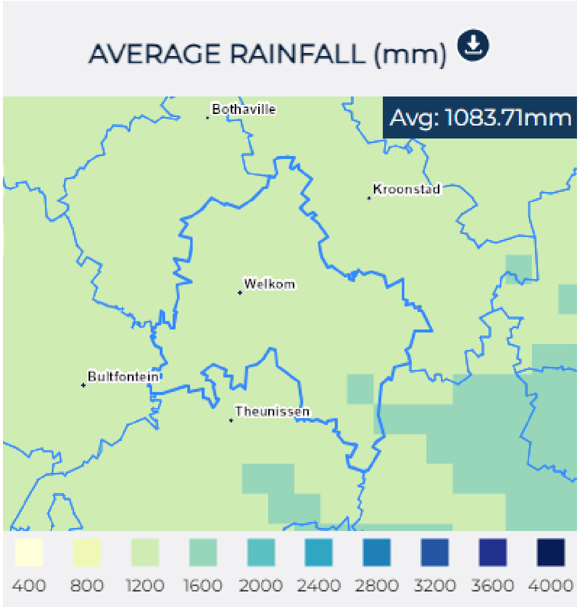


Figure 3: Baseline (1961 to 1990) annual average rainfall for the project area (CSIR, 2024)

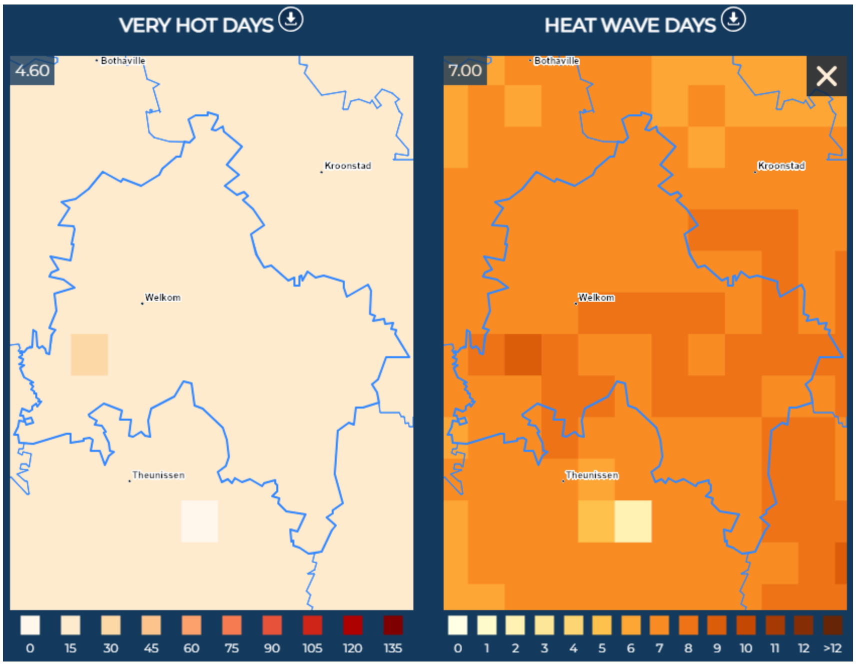


Figure 4: Baseline (1961 to 1990) number of very hot days (>35°C) and heat waves annually for the project area (CSIR, 2024)

Recent changes in climatic conditions near the project site were accessed from MeteoBlue[10] a weather forecasting platform developed at the University of Basel, Switzerland and based on models of National Oceanic and Atmospheric Administration (NOAA) or National Centres for Environmental Prediction (NCEP). The data sets also include historical climate data tracking changes in climate by referencing ERA5, the fifth generation ECMWF (European Centre for Medium-Range Weather Forecasts) atmospheric reanalysis of the global climate, for the period between 1979 to 2023, with a spatial resolution of 30 km. Based on a point selected close to the project site, a slight increase in the annual average temperatures have been observed with temperatures measuring 17.0°C in 1979 to 17.6°C in 2023 (Figure 5 – top panel). The lower part the graph shows the so-called warming stripes. Each coloured stripe represents the average temperature for a year – blue for colder and red for warmer years. The change in rainfall over the same period (1979 – 2023) displays a slight decreasing trend (Figure 6), where the difference from long-term average for each year in the data set is visualised by the stripes in the lower panel of Figure 6 (brown stripes indicate lower than average rainfall and green stripes above average rainfall).

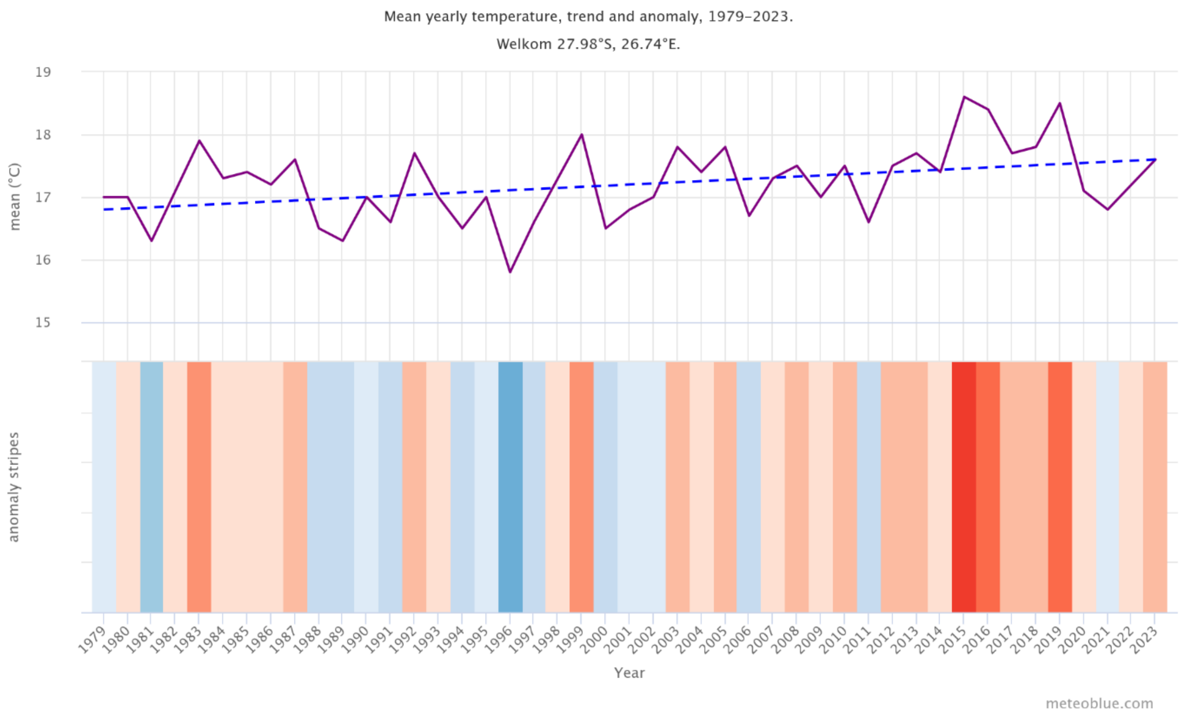


Figure 5: Annual average temperature (top panel) and temperature anomaly (lower panel) between 1979 and 2023 (meteoblue AG, 2024)

[10] https://www.meteoblue.com

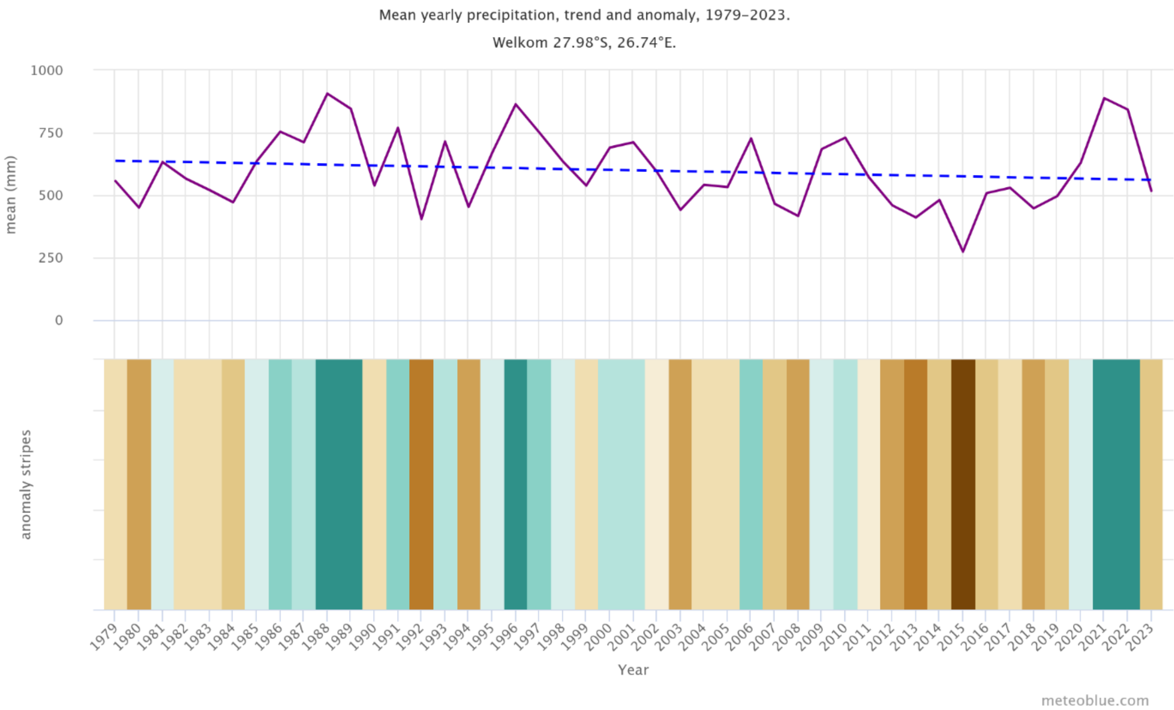


Figure 6: Annual average rainfall (top panel) and rainfall anomaly (lower panel) between 1979 and 2023 (meteoblue AG, 2024)

3.3 Projected Future Climate

Representative Concentration Pathways (RCPs) are defined by their influence on atmospheric radiative forcing in the year 2100. The two typical RCPs selected are RCP4.5 representing the medium-to-low pathway and RCP8.5 representing the high pathway. RCP4.5 is based on a CO_2 concentration of 560 ppm and RCP8.5 on 950 ppm by 2100. In other words, RCP4.5 assumes that current interventions to reduce GHG emissions are sustained (after 2100 the concentration is expected to stabilise or even decrease). RCP8.5 assumes that no interventions to reduce GHG emissions are implemented (after 2100 the concentration is expected to continue to increase). RCP4.5 represents an addition to the radiation budget of 4.5 W/m^2 because of an increase in GHGs. The two RCPs selected were RCP4.5 representing the medium-to-low pathway and RCP8.5 representing the high pathway. RCP4.5 is based on a CO_2 concentration of 560 ppm and RCP8.5 on 950 ppm by 2100. RCP4.5 is based on if current interventions to reduce GHG emissions being sustained (after 2100 the concentration is expected to stabilise or even decrease). RCP8.5 is based on if no interventions to reduce GHG emissions being implemented (after 2100 the concentration is expected to continue to increase).

In 2017 the South African Weather Services (SAWS) published the Climate Change Reference Atlas (CCRA) based on Global Climate Change Models (GCMs) projections (SAWS, 2017), the projections are for 30-year periods described as the *near future* (2036 to 2065) and the *far future* (2066 to 2095). Projected changes are defined relative to a historical 30-year period (1976 to 2005). The Rossby Centre regional model (RCA4) was used in the predictions for the CCRA which included the input of nine GCMs results. The RCA4 model was used to improve the spatial resolution to 0.44° x 0.44°- the finest resolution GCMs in the ensemble were run at resolutions of 1.4° x 1.4° and 1.8° x 1.2°. Findings from downscaled climatic simulations using six global climate models, at an 8 km x 8 km resolution over South Africa, for the time slab 2021 to 2050 were included in the Green Book (Engelbrecht, 2019).

3.3.1 RCP4.5 Trajectory and RCP8.5 Trajectory

Based on the median, for the region in which the proposed facility and communities are situated, the annual average near surface temperatures (2 m above ground) are expected to increase by between 2.0 – 2.9°C for RCP4.5 (average of 2.3°C), and between 2.6 – 3.4°C for RCP8.5 (average of 2.7°C) based on the range between the 10th and 90th percentiles (Figure 7). Very hot days are expected to increase from 4.6 days (baseline) to 12 days (RCP4.5) at the project site (Figure 8), ranging between 2.8 – 28.3 days for RCP4.5 and between 8.9 – 33.8 days for RCP8.5.

Annual average rainfall is expected to increase by 32.5 mm for RCP4.5 (percentile range of 41.9mm – 148.8mm), and by 88.6 mm when considering RCP8.5 (percentile range of 59.4mm – 216.8mm) (Figure 8). Extreme rainfall days is likely to increase on average by 1 day for RCP4.5 and by 1.1 days for RCP8.5 (Figure 10).

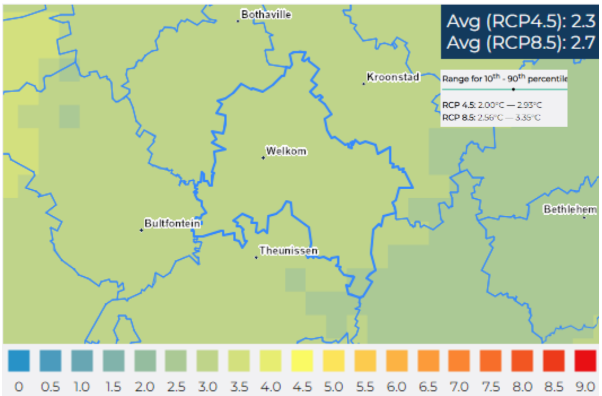


Figure 7: Projected change in annual average temperature for the RCP4.5 trajectory and RCP8.5 trajectory (2030 – 2050)

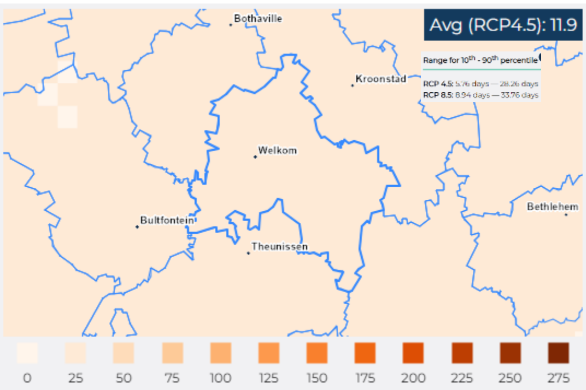


Figure 8: Projected change in very hot days for the RCP4.5 trajectory (2030 – 2050)

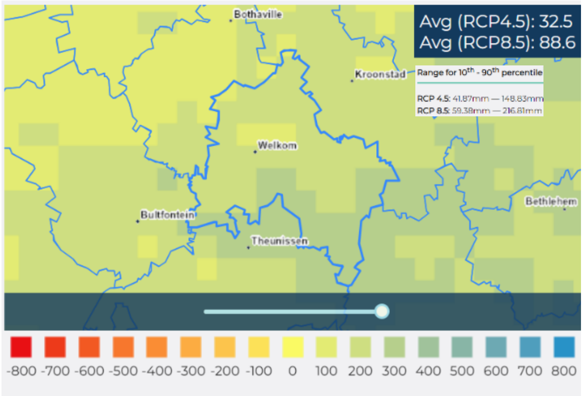


Figure 9: Projected change in annual average rainfall for the RCP4.5 trajectory and RCP8.5 trajectory (2030 – 2050)

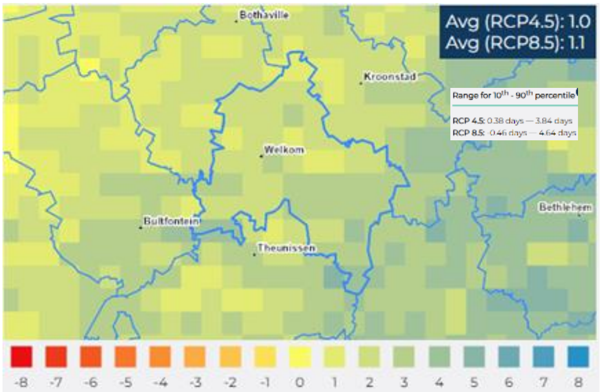


Figure 10: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for the RCP4.5 trajectory andRCP8.5 trajectory (2030 – 2050)

3.3.2 IPCC's Sixth Assessment Report: Temperature and Rainfall Projections

The most recent IPCC data are from the Coupled Model Intercomparison Project (CMIP) which were derived from the sixth phase of the CMIPs (CMIP6) and supports the IPCC's Sixth Assessment Report (AR6) which was released on 9 August 2021 (Working Group I) and 28 February 2022 (Working Group II and 4 April 2022 (Working Group III). Projection data is presented at a 1.0º x 1.0º (100km x 100km) resolution. Different from the previous AR5 RCP scenarios, the report uses five possible scenarios for the future (Table 3). The scenarios are the result of complex calculations that depend on how quickly humans curb greenhouse gas emissions, whilst also capturing socioeconomic changes in areas such as population, urban density, education, land use and wealth. For example, a rise in population is assumed to lead to higher demand for fossil fuels and water. Education can affect the rate of technology developments. Emissions increase when land is converted from forest to agricultural land. Each scenario is labelled to identify both the emissions level and the so-called Shared Socioeconomic Pathway, or SSP, used in those calculations. This first scenario is the only one that meets the Paris Agreement's goal of keeping global warming to around 1.5°C above preindustrial temperatures, with warming hitting 1.5°C but then dipping back down and stabilizing around 1.4°C by the end of the century. Projected changes are defined relative to a historical 20-year period (1995 to 2014).

Table 3: Possible climate change scenarios adopted in AR6

Identifier	Scenario	Description
SSP1-1.9	<u>Most optimistic:</u> 1.5°C by 2050	The IPCC's most optimistic scenario, this describes a world where global CO_2 emissions are cut to net zero around 2050. Societies switch to more sustainable practices, with focus shifting from economic growth to overall well-being. Investments in education and health go up. Inequality falls. Extreme weather is more common, but the world has dodged the worst impacts of climate change.
SSP1-2.6	<u>Next Best:</u> 1.8°C by 2100	In the next-best scenario, global CO_2 emissions are cut severely, but not as fast, reaching net-zero after 2050. It imagines the same socioeconomic shifts towards sustainability as SSP1-1.9. But temperatures stabilize around 1.8°C higher by the end of the century.
SSP2-4.5	<u>Middle of the road:</u> 2.7°C by 2100	This is a "middle of the road" scenario. CO_2 emissions hover around current levels before starting to fall mid-century, but do not reach net-zero by 2100. Socioeconomic factors follow their historic trends, with no notable shifts. Progress toward sustainability is slow, with development and income growing unevenly. In this scenario, temperatures rise 2.7°C by the end of the century.
SSP3-7.0:	<u>Dangerous:</u> 3.6°C by 2100	On this path, emissions and temperatures rise steadily and CO_2 emissions roughly double from current levels by 2100. Countries become more competitive with one another, shifting toward national security and ensuring their own food supplies. By the end of the century, average temperatures have risen by 3.6°C.
SSP5-8.5:	<u>Avoid at all costs:</u> 4.4°C by 2100	This is a future to avoid at all costs. Current CO_2 emissions levels roughly double by 2050. The global economy grows quickly, but this growth is fuelled by exploiting fossil fuels and energy-intensive lifestyles. By 2100, the average global temperature is a scorching 4.4°C higher.

The AR6 projections for the study area for the scenario RCP4.5 indicate an increase in annual average temperatures of 1.9°C for the period 2041 to 2060. The projections for the RCP8.5 indicate an increase in annual average temperatures of 2.4°C for the period 2041 to 2060 (IPPC, 2024). Although the AR5 and AR6 projections are based on different baselines, and the definitions of the scenarios are not the same, the temperature projections are similarly increasing for the two future scenarios with the projections for the AR6 slightly lower than for the AR5.

The AR6 projections for rainfall in the study area for RCP4.5 indicate a decrease in annual rainfall of 0.4% for the period 2041 to 2060. The projections for RCP8.5 indicate increase of rainfall of 0.4% for the period 2041 to 2060 (IPPC, 2024). This projection is different to that of the AR5 that indicates an increase in rainfall for both future scenarios. These differences, however, could be accounted for in the different baselines used, the difference in averaging periods (i.e. mean verses percentiles) and the difference in projected period (i.e. 2021 – 2050 and 2041 – 2060).

3.4 Climatic Hazards

The Green Book risk profile includes an assessment of projected risk to Matjhabeng Local Municipality up to 2050, mostly based on the low mitigation RCP8.5 climate simulations.

The risk of increase in heat stress is a combination of the increasing number of very hot days and heatwave days (baseline reflected in Figure 4). The town of Welkom and surrounding settlements are at high risk of heat stress as shown in Figure 11.

Change in ***extreme rainfall*** days for the year 2050 based on the 95th percentile of daily rainfall is shown in Figure 12, and compared with those under the current rainfall where a value of more than 1 indicates an increase in extreme daily rainfalls. For the project area, it is just over 1 (1.022) thus no increase in extreme daily rainfall is expected with a low flooding potential.

Figure 13 shows the projected change in ***drought*** tendencies (i.e. the number of cases exceeding near normal per decade) for the period 2050 relative to the baseline period, for RCP 8.5. A negative value indicates an increase in drought tendencies per 10 years (more frequent than baseline). The area has a low negative (-0.38) resulting in a Very Low potential increase in exposure to drought.

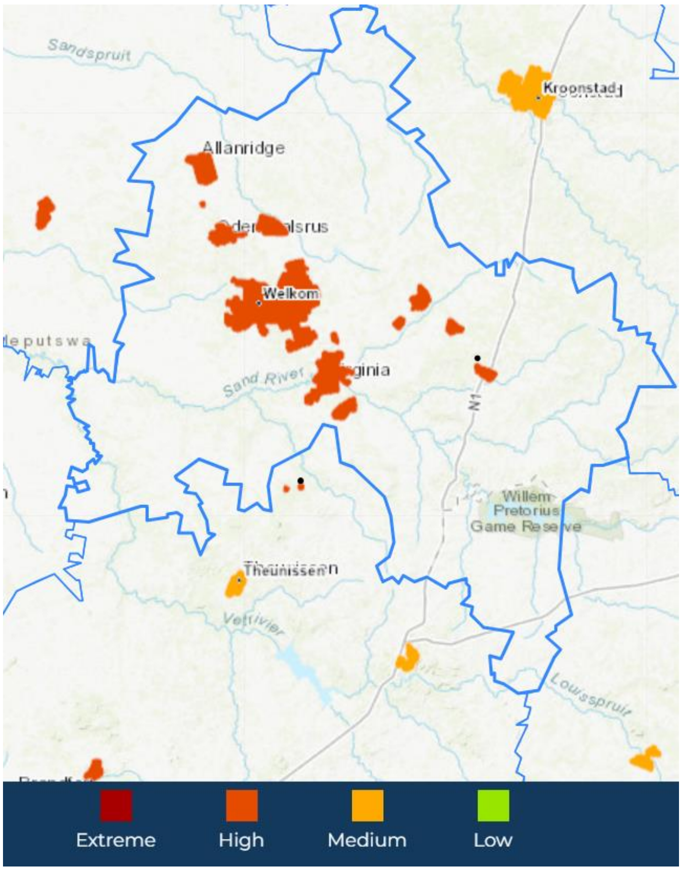


Figure 11: Risk of increase in exposure to heat extremes by 2050 based Risk of increase in exposure to heat extremes by 2050 based on RCP8.5 trajectory

There are isolated pockets of *likely* increased risk of ***wildfires*** within the municipality (Figure 14). For the project area, however, the fire danger increase is 33 days for RCP 8.5, resulting in a moderate potential increase in exposure to wildfires.

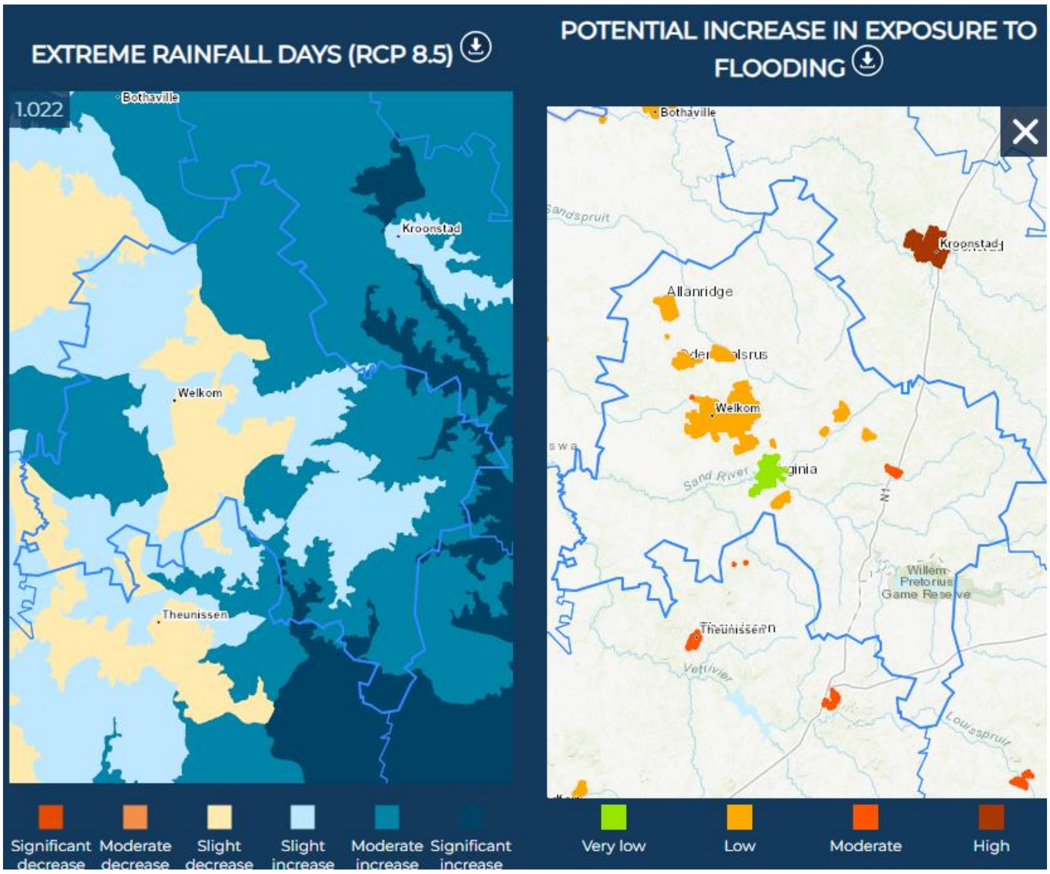


Figure 12: Risk of increase in floods in 2050 based on RCP8.5 trajectory

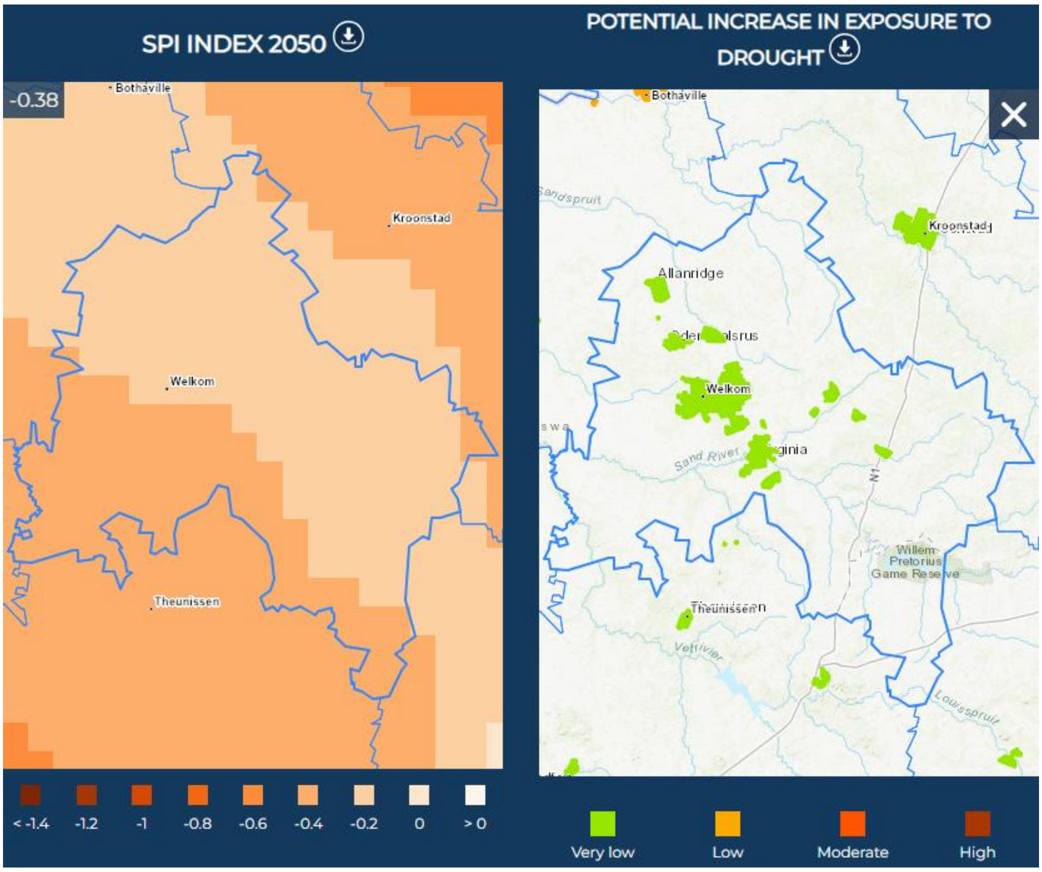


Figure 13: Risk of increase in droughts up to 2050 based on RCP8.5 trajectory

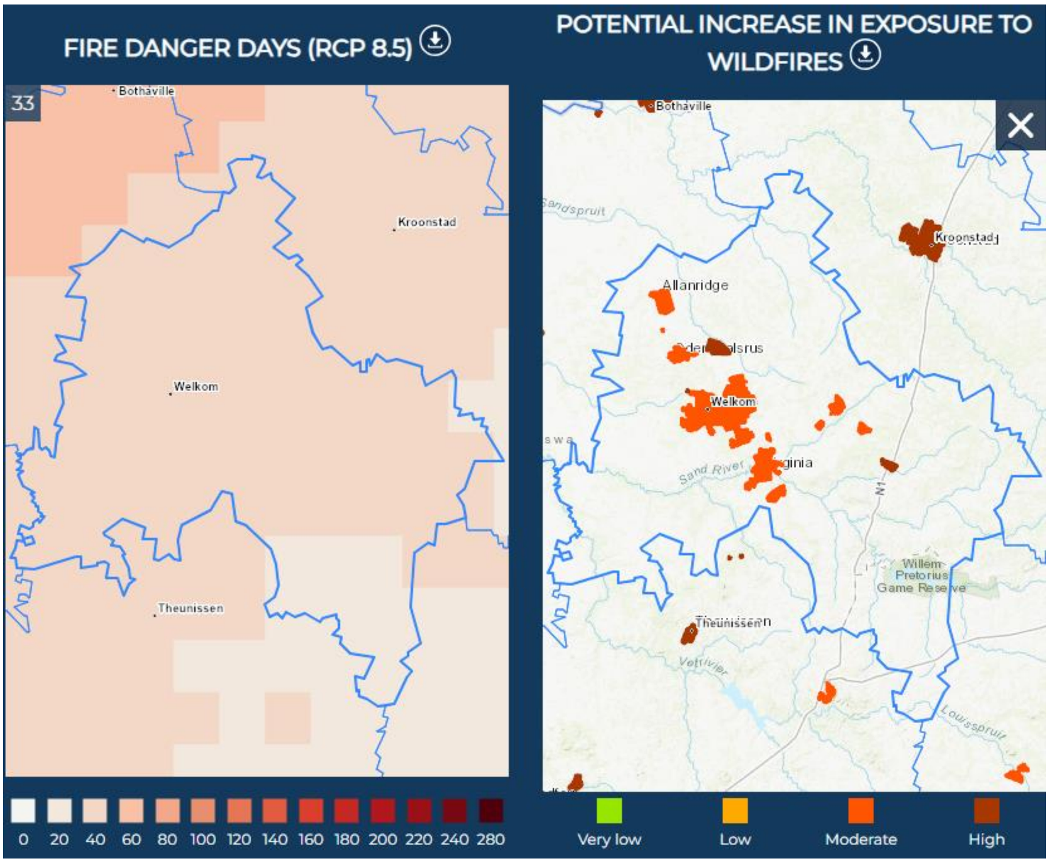


Figure 14: Risk of increase in wildfires up to 2050 based on RCP8.5 trajectory

Extreme weather events affecting southern Africa, including ***heat waves, flooding*** due to intensified rainfall due to large storms and ***drought***, have been shown to increase in number since 1980 (Davis-Reddy & Vincent, 2017). Country wide projections indicate (Davis-Reddy & Vincent, 2017):

- with high confidence, that heat wave and warm spell duration are likely to increase while cold extremes are likely to decrease, where up to 80 days above 35°C are projected by the end of the century under the RCP4.5 scenario;
- with medium confidence, that droughts are likely to intensify due to reduced rainfall and/or an increase in evapotranspiration; and,
- with low confidence, that heavy rainfall events (more than 20 mm per 24 hours) will increase.

In addition to the hazards identified in the Green Book, Hofste, *et al.,* (2019) currently rate the project area as arid with low water use (Figure 15) with near normal water stress projection for the future (2050 based on a conservative low mitigation trajectory) (Figure 16).

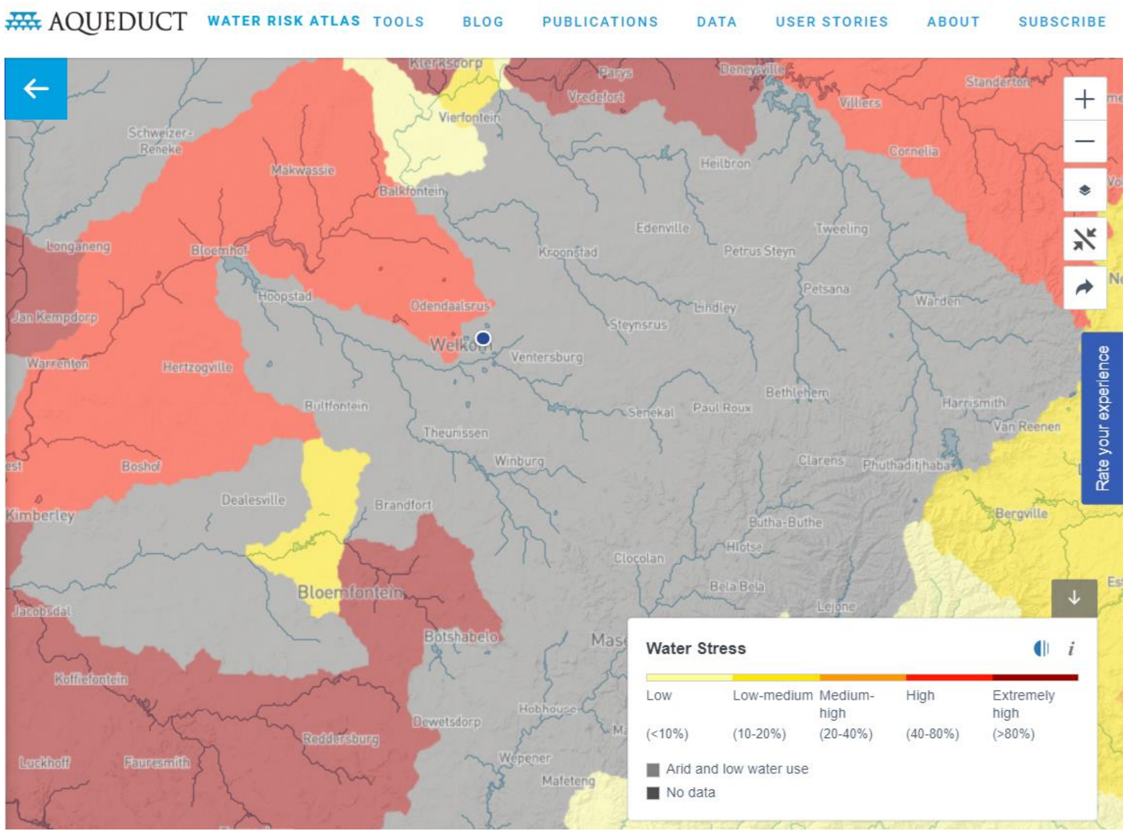


Figure 15: Current water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

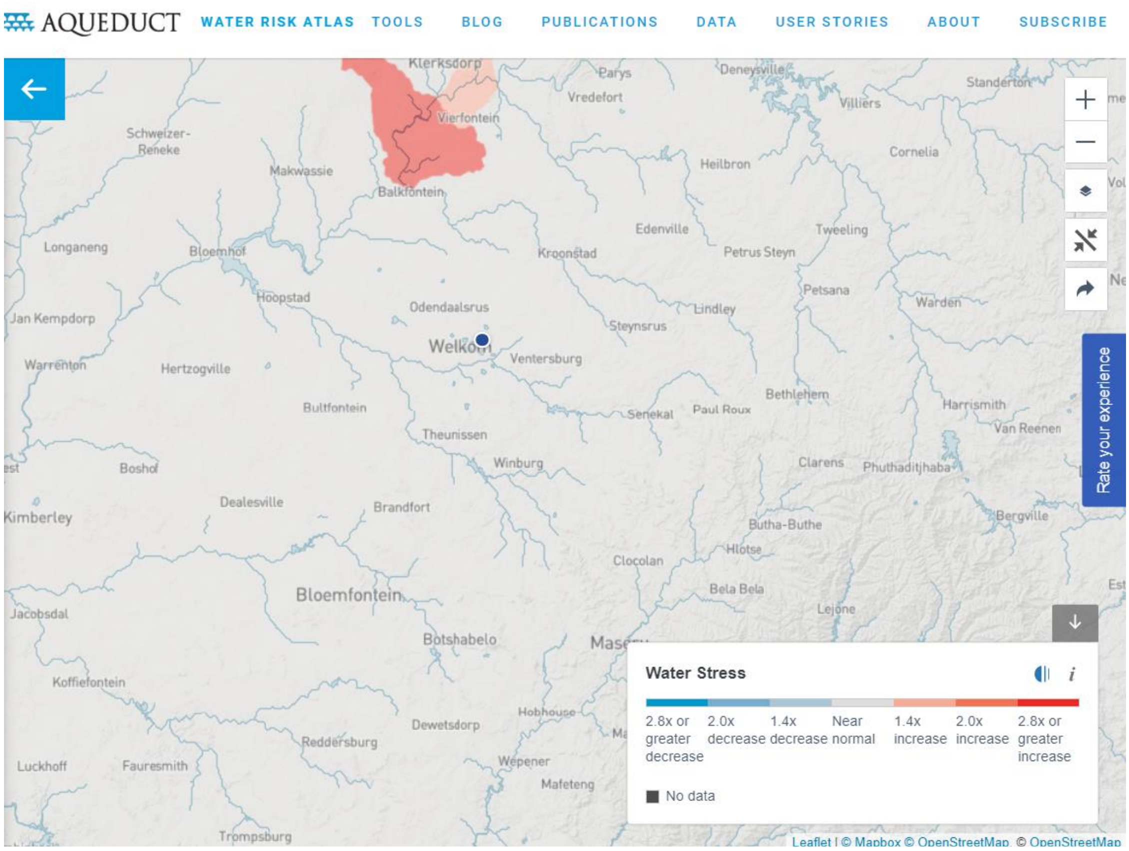


Figure 16: Projected (2050) water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

3.5 Vegetation Disturbance

The vegetation type that will be disturbed over the lifetime of the proposed project – are the Vaal – Vet Sand Grassland (South African National Biodiversity Institute, 2024). This information was used in the quantification of permanent GHG sink losses due to project infrastructure for the CCA.

3.6 Impact of Climate Change

To understand the impact that climate change might have on the major resources of the Matjhabeng Local Municipality it is first necessary to provide an overview of the current situation, which has been provided for water, economy, and agriculture.

3.6.1 Water Supply

3.6.1.1 Current Resources

Figure 17 provides the current water supply vulnerability (i.e., demand versus supply) for the Matjhabeng Municipality (1.43) based on the data compiled for the Department of Water and Sanitation (DWS) All Town's Study (Cole, 2017). The current water demand for the municipality is higher (207 l/d (litres per day)) than the supply (144.5 l/d), with 100% sourced from surface water.

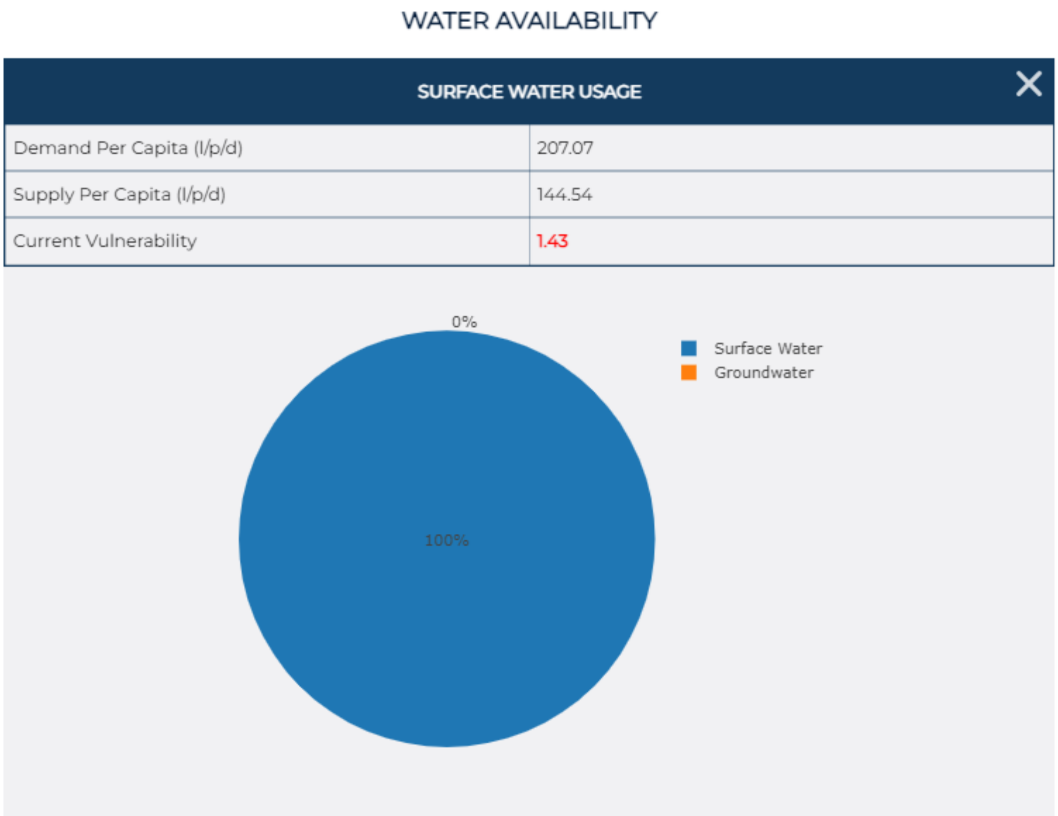
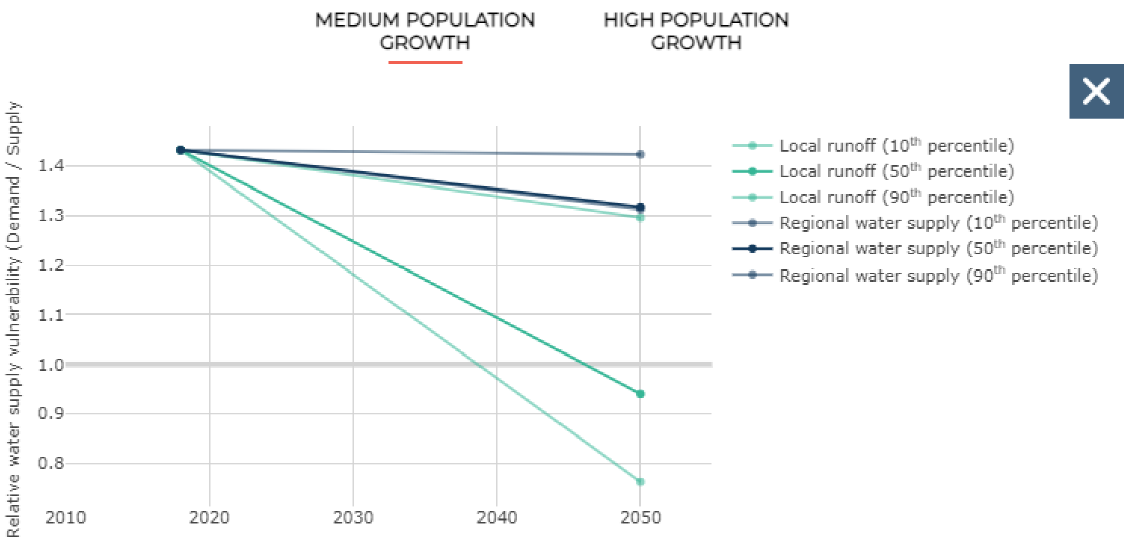


Figure 17: Current water availability for the Matjhabeng Local Municipality

3.6.1.2 *Impact on Resources*

Figure 18 shows the estimated current and future water supply vulnerability (i.e., the ratio of demand to supply) based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk (based on impacts on local runoff), and 2) a regional water supply perspective (based on impacts of regional water supply assuming supply is part of the integrated regional and national bulk water supply network). The mean annual precipitation for the municipality is predicted to increase by 6.5% for 2050 with a regional urban water supply increase of 11.9%.



VULNERABILITY CONTRIBUTION FACTORS		PERCENTAGE CHANGE
Mean annual precipitation	▲	6.5%
Mean annual evaporation	▲	8.02%
Mean annual runoff	▲	56.82%
Regional urban water supply	▲	11.91%
Population growth	▼	-4.72%

Figure 18: Estimated current and future (2050) water supply vulnerability based on medium population growth for the Matjhabeng Municipal

3.6.2 *Surface Water*

The Matjhabeng Municipality is within the Vaal Primary Catchment (Figure 19).

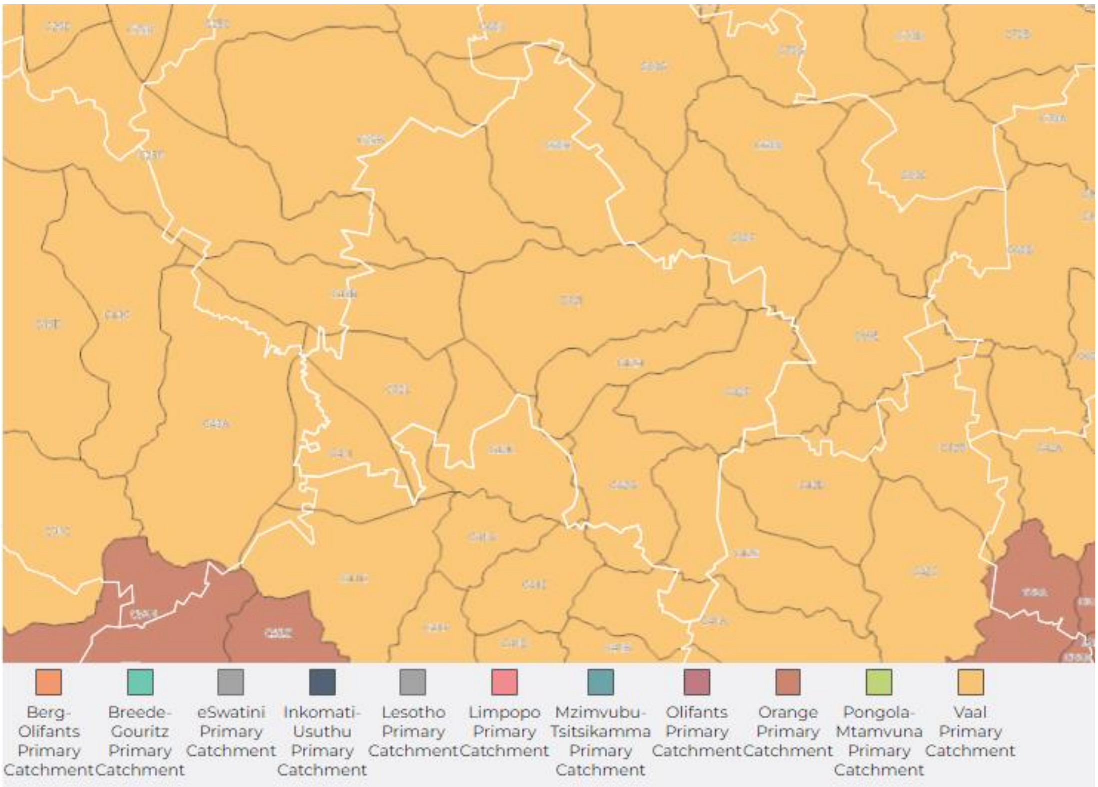


Figure 19: Quaternary catchment areas for the study area

3.6.2.1 Current Situation

Figure 20 depicts the current annual and monthly surface water runoff, precipitation and evaporation for the Vaal Primary Catchment associated with the Matjhabeng Local Municipality. Precipitation and evaporation for the municipality is currently 533.6 mm/yr and 1 615 mm/yr respectively.

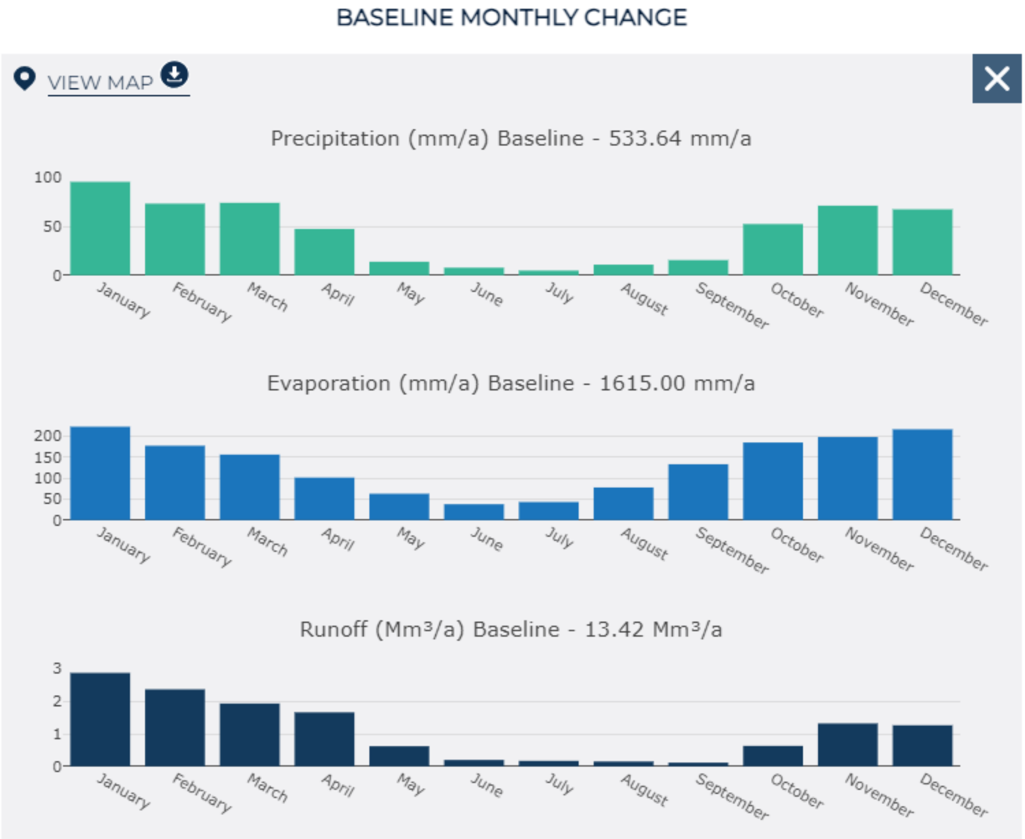


Figure 20: Current annual and monthly surface water runoff, precipitation and evaporation for the Matjhabeng Local Municipality which falls under the Vaal Primary Catchment

3.6.2.2 *Projected Impact*

Figure 21 provides the projected monthly change for future (2050) evaporation, precipitation, and estimated runoff values. The precipitation is projected to decrease during winter months with the evaporation increasing during winter months.

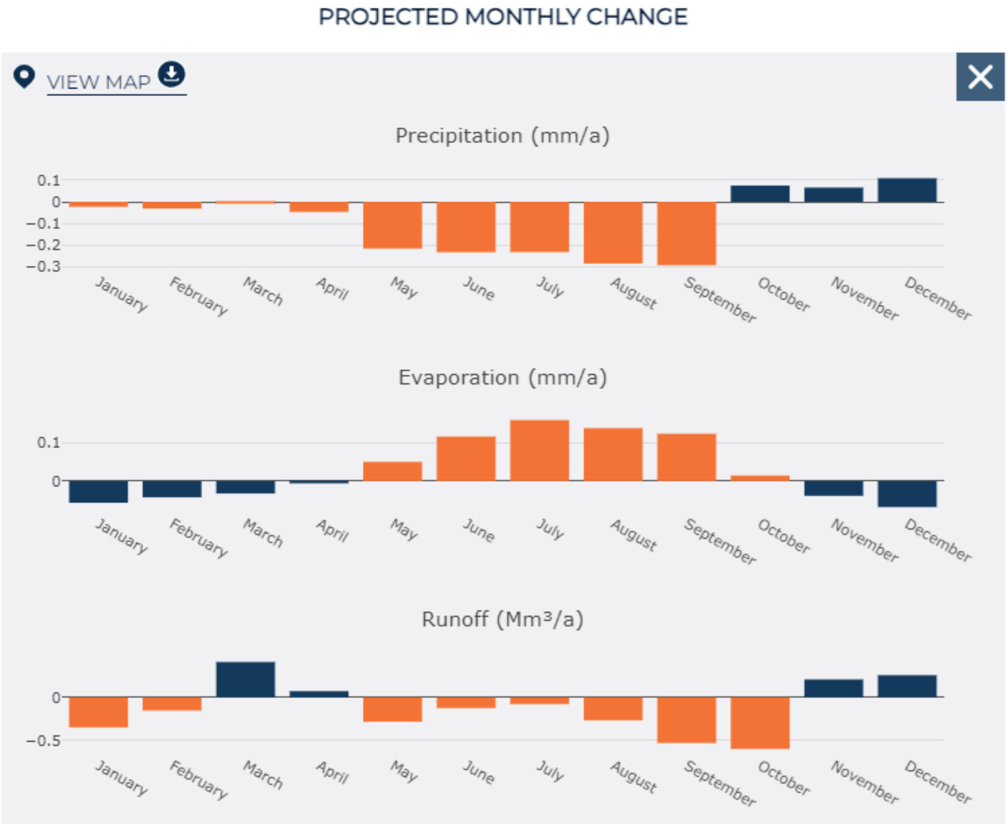


Figure 21: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values

3.6.3 *Ground Water*

3.6.3.1 *Current Situation*

The groundwater recharge potential map indicates the occurrence and distribution of groundwater resources across the country, showing distinctive recharge potential zones. The groundwater dependency map indicates where settlements get their main water supply from, be it groundwater, surface water or a combination of both sources. Settlements that rely on groundwater, either entirely or partially, are deemed groundwater dependent. The settlement of Welkom is not groundwater dependent and get all their water from surface water (Figure 22).

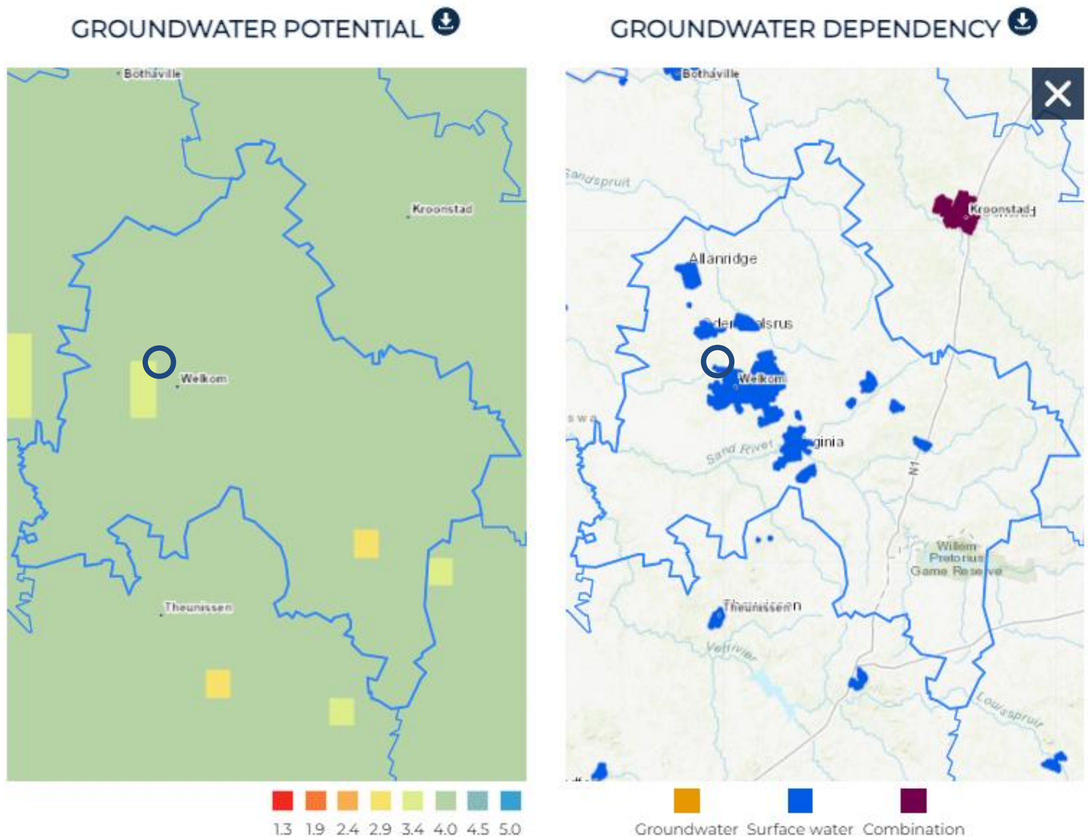


Figure 22: Groundwater potential and dependency for the Matjhabeng Local Municipality (dark blue marker indicates approximate location of the project)

3.6.3.2 Projected Impact

A groundwater depletion risk map was created to determine which of South Africa's groundwater dependent settlements may be most at risk to groundwater depletion based on decreasing groundwater aquifer recharge potential and significant increases in population growth pressure by 2050.The groundwater depletion risk map (Figure 23) is based on the settlement aquifer recharge potential of the 50th percentile RCP8.5 scenario, and the medium population growth scenario. Based on this information, there is no potential change for the project area with the settlement of Welkom not dependant on groundwater.

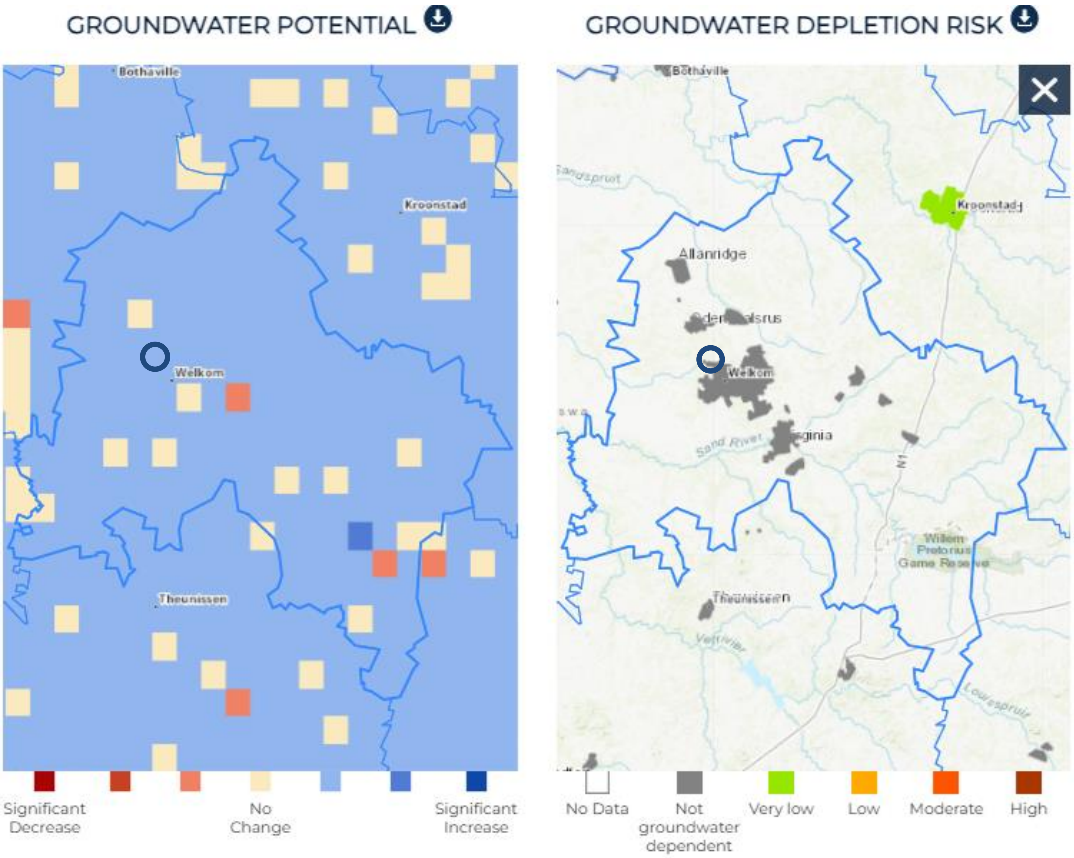


Figure 23: Groundwater potential and depletion for 2050 for the Matjhabeng Local Municipality (dark blue marker indicates approximate location of the project)

3.6.4 Economy

Figure 25 shows the contribution that the different economic sectors make to the total Gross Value Added (GVA)[11] of the Matjhabeng Local Municipality as well as its national GVA rank (total GVA contribution to the national GVA). Mining and quarrying make up the highest economic sector to the total GVA at 41%. The Matjhabeng Local Municipality ranks 15th in the national GVA rank.

[11] Gross value added (GVA) is an economic productivity metric that measures the contribution of a corporate subsidiary, company, or municipality to an economy, producer, sector, or region.

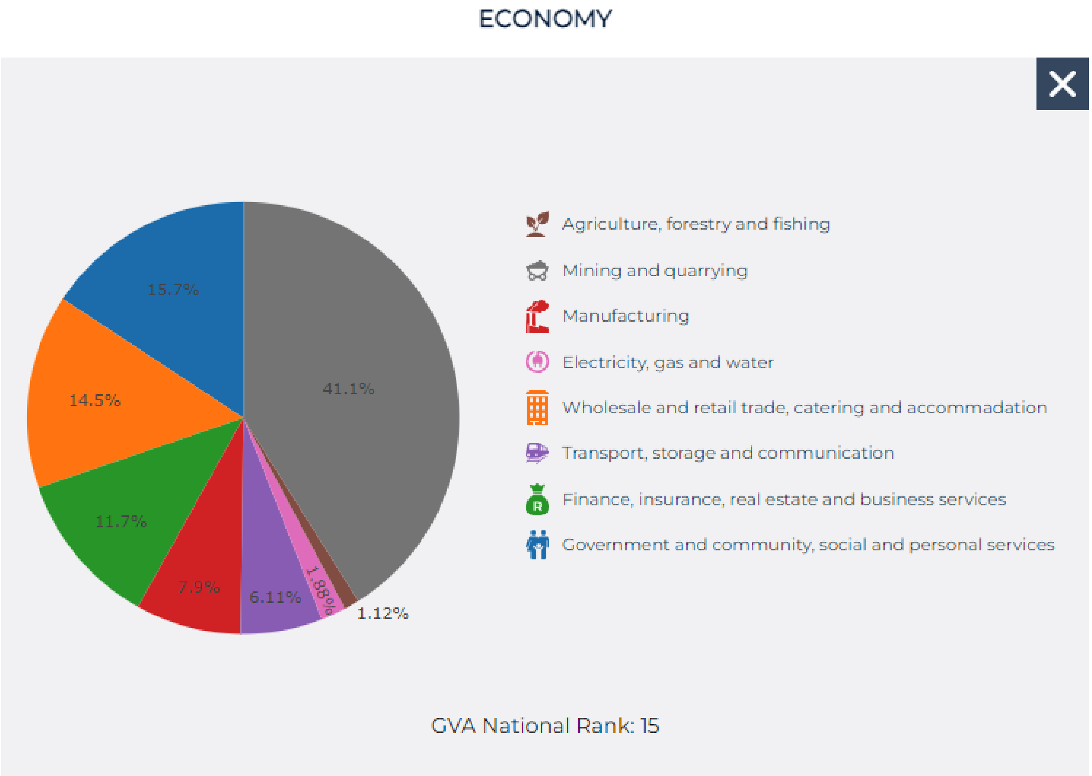


Figure 24: The contribution that the different economic sectors make to the total GVA of the Matjhabeng Local Municipality

Table 4 summarises the forecasted economic gains or losses for the Matjhabeng Local Municipality, under both the RCP4.5 and RCP8.5 scenarios, for each of the contributing economic sectors.

Table 4: Forecasted economic gains or losses for the RCP4.5 and RCP8.5 scenarios

RCP 4.5 Impacts		RCP 8.5 Impacts	
Average	0.92%	Average	-0.05%
Agriculture Sector	1.23%	Agriculture Sector	-0.64%
Forestry Sector	1.73%	Forestry Sector	-0.91%
Fishing Sector	1.24%	Fishing Sector	-0.65%
Mining Sector	-0.1%	Mining Sector	-0.03%
Manufacturing Sector	-0.54%	Manufacturing Sector	0.76%
Electricity & Gas Sector	4.78%	Electricity & Gas Sector	1.29%
Water Sector	-1.54%	Water Sector	-0.42%
Service Sector	0.57%	Service Sector	0.17%

3.6.5 Agriculture, Forestry and Fisheries

The main agricultural commodities for the Matjhabeng Local Municipality are maize, beef cattle and dairy (milk and cream) (Table 5). Agriculture, Forestry and Fishing (AFF) contribute 1.12% to Matjhabeng GVA production and 4.28% to the municipality's total employment. The total AFF GVA production of Matjhabeng Local Municipality contributes 0.5% to the national AFF GVA, ranking them as the 62nd biggest contributor.

Table 5: Economic contribution of main commodities for Matjhabeng Local Municipality

MAIN COMMODITIES		
MAIZE FOR GRAIN	BEEF CATTLE	MILK AND CREAM
AFF contributes 1.12% to Matjhabeng GVA production	AFF contributes 4.28% to Matjhabeng total employment	The total AFF GVA production of Matjhabeng Municipality contributes 0.51% to the national AFF GVA, ranking them as the 62nd biggest contributor

The main agricultural commodities for 2050 for the municipality remain maize, beef cattle and dairy (milk and cream) (under an RCP8.5 low-mitigation scenario) (Table 6). The climate for the municipality is expected to be hotter and wetter with more extreme rainfall events. There is a potential increase in maize yield for near future with the heat stress negatively impacting production towards the end of 2050. The hot, moist conditions will increase the spread of disease and parasites which would negatively impact the beef and dairy production.

Table 6: Projected economic contribution of main commodities for Matjhabeng Local Municipality

MAIN COMMODITIES		
MAIZE FOR GRAIN	BEEF CATTLE	MILK AND CREAM
CLIMATE IMPACT		
Change in climate expected: Hotter and wetter with more extreme rainfall events.		
Potential increase in maize yield for near future. However, towards 2050, heat stress can negatively impact on production.	Increased water availability. Hot and moist conditions cause increased spread of disease and parasites. Reduced growth & reproduction performance due to heat stress.	Hot and moist conditions cause increased spread of disease and parasites. Potential increase in heat stress which could negatively affect conception rates, milk yield and milk quality.

3.6.6 Other Resources

The impacts of climate change on other resources are summarised in Table 7.

Table 7: The impacts of climate change on other resources

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Transport and Mobility	• Increased rate of infrastructure deterioration leading to pavement failure including cracking, rutting, potholes, flushing, and stripping. • Increased stress on bridges, particularly expansion joints, through thermal expansion and increased movement. • Corrosion of steel reinforcing in concrete structures due to increase in surface salt levels in some locations. • Increased infrastructure maintenance cost for road repair and reconstruction work, causing traffic delays and emergency service response delays. • Increased frequency and intensity of wildfires leading to more road closures. • Increased vehicle accidents, due to low pavement adhesion, leading to higher rates of transport-related fatalities.	• Reduced water resources available for construction and maintenance. • Reduced production of some agricultural produce leading to changes in freight flows in the network.	• Increased rate of infrastructure deterioration, especially in areas with poor infrastructure maintenance history. • Temporary and permanent flooding of road, rail, port and airport infrastructure. • Structural integrity of roads, bridges and tunnels could be compromised by higher soil moisture levels. • Potential destruction of bridges and culverts. • Erosion of embankments and road bases leading to undermining of roads or railways. • Increased risk of landslides, slope failures, road washouts and closures. • Undermining of bridge structures (scouring). • Closure of roadways and tunnels leading to traffic delays. • Transportation system disruptions, impacts to traffic signalling and low water crossings. • Increased weather-related accidents.	• Increased drag on vehicles resulting in increased fuel consumption. • Increased safety risk for pedestrians and cyclists due to flying objects or being uncontrollably dragged by winds, additionally leading to reduced trip making by pedestrians and cyclists.	(Mokonyama & Van Wyk, 2018)
Solid Waste	• Increased risk of combustion at open waste disposal sites and illegal dumps and increase in explosion risk associated with methane gas. • Increased rate of decay of putrescible waste resulting in increased odour, breeding of flies, and attracting of vermin. • Increased health and safety concern regarding heat stroke to staff collecting waste. • Increased risk of landfill site instability and failure due to changes in consumption patterns with increased waste creation (i.e., glass, plastic and paper cups).		• Increased risk of flooding due to pressure on stormwater and leachate management systems at landfills. • Increased demand for capacity to cope with large volumes of waste generated by flood events. • Increase in soil saturation causing decreased stability of slopes and landfills linings (if clay or soil based) at waste management facilities. • Inundation of waste releasing contaminants to waterways, pathways and low elevation zones. • Potential loss of value and degradation of paper and cardboard for recycling due to increased moisture content. • Increased flooding causing the risk of localised disruption of waste collection rounds. • Flooding in areas with untreated, dumped waste causing the risk of groundwater contamination. • Increased flooding causing the risk of litter entering the storm water systems.	• Possible increase in nuisance due to waste dispersed by high winds leading to increased health effects associated with particulate matter (air pollution).	(Oelofse, 2018)
Stormwater	• Potential risk of undermining the temperature regime of temperature-sensitive stormwater ponds and receiving waters, resulting in a decrease in water quality. • Increased corrosion in stormwater drains due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids.	• Increased shrinking soils increasing the potential for cracking, increased infiltration and exfiltration of water mains and sewers, which in turn exacerbates treatment and groundwater or storm water contamination.	• Increased risk of flooding due to pressure on stormwater systems. • Increased risk of litter entering the stormwater systems. • Increased risk of damage and failure of stormwater systems due to overloading during floods and intense rainfall events. • Failure of stormwater treatment devices during high flow events leading to by-pass and / or flushing of contaminated water. • High wet-weather hydraulic loads and bottlenecks in stormwater and networks due to inflow and sewer infiltration, leading to local inundation and overflows of untreated wastewater. • Increased rainfall causes soil erosion thus damaging underground stormwater systems. • Increased surface and stream erosion causing deposition of sediments in receiving environments. • Stream morphology for undeveloped, developing and fully developed urban areas, may change, hence affecting existing outfall structures and potential stormwater pond locations.	• Increased wind speed and intensity causing changes in rainfall over complex topography including increasing upwind of hills and ranges.	(Dunker & Van Wyk, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Sanitation	• Increased heat waves, accompanied by dry weather, can exacerbate already stressed water supply systems leading to competition between sectors for water services, affecting sanitation.	• Decrease in water supply for sanitation through decrease in available water to flush sewage systems adequately. • Declining annual rainfall threatening the viability of water-borne sanitation systems, and the capacity of surface water to dilute, attenuate and remove pollution. • Sewers are structurally vulnerable to drying, hence shrinking soils increase the potential for cracking, increased infiltration, and exfiltration, which in turn exacerbates treatment and groundwater or storm water contamination. • Increased corrosion in sewers due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids.	• Increased wet-weather hydraulic loads and bottleneck in stormwater and sanitary sewer networks due to inflow and sewer infiltration, causing local inundation and overflows of untreated wastewater. • Increased rainfall and heavy rainfall events increasing the washing of faecal matter into water sources due to flooding of wastewater treatment works. • Increased risk of flooding resulting in both infrastructure damage and contamination of surface and groundwater supplies. • Increased groundwater levels due to flooding, putting risk on sewage treatment plants (which are often positioned on low-lying ground as sewerage systems rely on gravity). • Increased vulnerability of sewerage pipe systems due to their size and complexity, and their exposure to multiple flood damage threats from source, through treatment, to delivery. • Increased vulnerability of pit toilets (widely used in rural areas) due to flooding, causing serious environmental contamination. • Increase in groundwater recharge and groundwater levels causing flooding of subsurface infrastructure such as pit toilets or septic tanks.		(Duncker, 2018)
Information and Communication Technology	• Increased weathering and deterioration of infrastructure resulting in increased maintenance and repair costs. • Heat stress causing structural damage to infrastructure. • Increased energy demands during heatwaves resulting in power outages which can impact on delivery of telecommunications services. • Increases in temperature and higher frequency, duration, and intensity of heat waves increasing the risk of overheating in data centres, exchanges, and base stations, which can result in increased failure rates of equipment. • Increased mean temperature increasing operating temperature of network equipment which may cause malfunctions if it surpasses design limits.	• Decreased precipitation leading to land subsidence and heave, reducing the stability of telecommunications infrastructure above and below ground (foundations and tower structures).	• Increased risk of flooding of low-lying infrastructure, access holes and underground facilities. • Increases in storm frequency or intensity increasing the risk of damage to aboveground transmission infrastructure and impacting on telecommunications service delivery. • Increases in storm frequency leading to more lightning strikes, consequently damaging transmitters, and overhead cables, causing power outages. • Increased cost of insurance for infrastructure in areas with repeated incidents of flooding, as well as withdrawal of risk coverage in vulnerable areas by private insurers. • Road closures due to flooding thus inhibiting service and/or restoration efforts. • Rising sea levels and corresponding increases in storm surges, increasing the risk of saline corrosion of coastal telecommunications infrastructure, and leading to erosion or inundation of coastal and underground infrastructure.	• Increased risk of storm surges impacting on coastal infrastructure. • Increased storm intensity and frequency impacting on electricity and telecommunications infrastructure.	(Naidoo, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Health	• More exposure to high temperatures causing increased health risks including heat strokes. • Heat waves increase threat of cardiovascular, kidney, and respiratory disorders. • Increase in fire danger days causing increased loss of life and damage to health infrastructure. • Wildfire smoke significantly reducing air quality, both locally and in areas downwind of fires. Smoke exposure increases respiratory and cardiovascular hospitalizations; emergency department visits; medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease, and respiratory infections; and medical visits for lung illnesses. • Increased emissions in biogenic volatile organic compounds from vegetation causing increases in air pollution. • Increase in evaporative emissions from cars contributing to exposure to, and health impacts from, air pollution. • Increase in distribution of vector-borne diseases in warmer areas. • Increased water temperatures leading to an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increased temperatures combined with fewer clouds (e.g., from increased subsidence that is projected for parts of South Africa) causing increased exposure to Information and Communication Technology which will have negative impacts on health. • Increased temperatures increasing the reaction between certain pollutants and sunlight and heat, resulting in more severe hazardous smog events.	• Decreased soil moisture potentially creating more wind-blown dust which has negative impacts on air quality. • Increase in water-borne diseases and diarrhoeal diseases due to inadequate water availability. • Decreased precipitation causing changes in salinity of water, resulting in an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increase in stagnant air, decreasing air quality.	• Wetter climate combined with increased temperatures may have negative health impacts as many diarrhoeal diseases vary seasonally, typically peaking during the rainy season. • Extreme rainfall and higher temperatures increasing the prevalence of fungi and mould indoors, with increased associated health concerns. • Increased flooding increasing the risk of drinking and wastewater treatment facilities being flooded, meaning that diarrhoeal diseases can be transmitted as wastewater systems overflow or drinking water treatment systems are breached. • Increase in natural disasters (e.g., floods) creating a conducive environment for the occurrence of mental health problems.	• Increase in wind-blown dust combined with low humidity causing increased cases of meningitis (Davis, 2014).	(Garland, 2018)
Energy	• Increased heat causing expansion of overhead cables, and cable sag. Sagging below a certain level result in a reduction in the amount of electricity transmitted. • Increased heat stress on electricity transmission networks (overhead cables). • Increase in heat island effect increasing energy demand for cooling, leading to grid stress. • Increased threat of wildfires causing widespread damage to infrastructure and causing disruptions to service provision.		• Increase in flooding causing damage to electricity transmission and distribution infrastructure, poles, lines and sub-stations. • Increase in frequency and cost of maintenance of concrete structures due to frequent and intense rainfall, flooding, or sea level rise. • Increased repair events increasing stress put on service crews and resulting in delays to power restoration.	• Winds causing damage to energy supply infrastructure as winds cause overhead lines to sag, reducing electricity transmission. • Extreme winds causing poles and trees to fall, causing further damage to energy supply infrastructure such as overhead lines.	(Thambiran & van Wyk, 2018)

Parameter	Results of Climate Change				Reference
	Increase in temperature and heat stress	Drought and decrease in rainfall	Increase in rainfall and inland flooding	Increased wind speed	
Ecosystem Services	• Increased risks of water shortages increasing demand for irrigation of gardens and agriculture. • Increased evapotranspiration rates with rising temperatures, reducing the water available in reservoirs and water available for reliant ecosystems. • Increase in temperature leading to water loss via evapotranspiration resulting in decreased water quality and loss of wetlands. • Loss or degradation of indigenous species, including threatened species or ecosystems. • Increased threat from invasive species as competition for water increases. • Dieback or death of susceptible plants (e.g., street trees) and animals (e.g., fish). • Reduced availability of water and increased evapotranspiration resulting in reductions in harvested area (cropping area), yield (ton/ha) and quality. • Warmer winters resulting in reduced period of dormancy (rest period) in deciduous fruit crops, decreasing the production and quality of associated food products. • Warmer climate resulting in shifts in the growing season and life cycles of various plants, including crops, resulting in pests and diseases having a greater destructive impact as well as a shift in climatically suitable areas for specific crops. • Increased humidity levels resulting in higher rates of microbial growth in fresh produce, reducing their expiry time. • Increased heat stress on crops changes the micro-nutrients of crops products, decreasing the nutrient density and quality of food. • Increased water temperature leading to increased growth of aquatic weeds which increases breeding of disease vectors and reduces water oxygen levels. • Milder winters and reduced frost increase the duration of the growing season, increasing the survival rate of insects and diseases. • Increased sea surface temperatures (SST) causing shifts in the spatial distribution of fish species. • Increased SST and ocean acidification decreases marine phytoplankton growth and synthesis of omega-3 polyunsaturated fatty acids (PUFA's), affecting the oceanic food chain and consequent ecosystems. • Increased heat stress and higher humidity levels potentially resulting in the exceedance of the temperature humidity index in livestock, causing reduced immunity, fertility, productivity and even mortality of livestock.	• Decreased amounts of rainfall reaching ecosystems as settlements use rainwater harvesting techniques for increased household use. • Increased reliance on irrigation and greater demand for water to maintain public open space and gardens. • Reduced planting and pollination leading to greater risk of erosion and soil loss. • Increasing temperatures together with increased intensity of drought will potentially increase the occurrence of algal blooms in reservoirs and dams which are damaging to ecosystem functioning and water services. • Drought and decreased rainfall causing wetland habitat loss. • Locally specific changes in humidity levels will have impacts on local vegetation. • Increased threat to watershed and aquifer recharge areas, affecting vegetation. • Reduced soil moisture availability increasing moisture stress leading to dieback and death of plants and the loss or degradation of indigenous communities, including threatened species or ecosystems. • Increased moisture stress leading to decline in crop yield and quality, and reduced fodder quantity and quality for livestock. • Drying up of aquatic systems, perennial systems will become seasonal and seasonal systems will die off and be replaced by terrestrial plants. • Increased spread of drought-adapted alien invasive plant species.	• Rainfall in shorter and more violent spells making recharging groundwater difficult. • Increase in intensity of rainfall and flooding leading to increased surface runoff, resulting in increased soil erosion, soil loss and degradation. • Increased rainfall and floods resulting in waterlogged soils which increase the likelihood of crop failure. • Increasingly saturated soils leading to more standing water (ponding) which can result in more insect (pest) activity and their potential to carry diseases. • Increased wave energy and run-up (sea level rise and more storms) causing degradation of natural coastal defence structures.	• Evapotranspiration rates increase with wind speed, reducing the water available in reservoirs and water available for reliant ecosystems. • Increased rate of fire spread and spotting (the ignition of fires ahead of the main fire front) of fires. • Potential damage to or uprooting of vegetation including trees, which can also damage infrastructure. • Potential wind damage to crops, reducing yield and quality (e.g., sandblasting and fruit fall). • Increased windblown materials (e.g., dust, litter) increasing the need for maintenance and city cleaning. • Degradation of natural coastal defence structures and increased damage to hard coastal infrastructure.	(Pieterse & Crankshaw, 2018)
Culture and Heritage	• Increased temperature having significant impacts on the comfort levels of built heritage resources, resulting in the building no longer being fit-for-purpose. • Increased demand for additional heating and cooling resulting in the installation of heating, ventilation, and air-conditioning systems with potential negative consequences on the heritage value. • Increased heat stress potentially impacting on the materials and structural integrity of heritage resources. • Migration of several plant species due to changing climate patterns, posing a threat to the conservation of biodiversity hotspots, and potentially altering heritage places. • Increase in veld and forest fires raising the threat of fire to all heritage resources, natural and built, as well as posing health risks to heritage resource dwellers from exposure to smoke and ash pollution.	• Decreased rainfall impacting negatively on ground moisture levels and thus the geological conditions of sensitive heritage resources. Drying out clays, for example, will shrink and potentially undermine founding conditions.	• Increased rainfall in areas with clay soils resulting in swelling which poses a threat to the structural integrity of heritage resources. • Increased floods and changes in precipitation resulting in increasing vulnerability of archaeological evidence buried underground due to changing stratigraphic integrity of the soils. • Increased threat to materials and structural integrity of heritage resources exposed to higher humidity/ precipitation levels.		(van Wyk, 2018)

4 GHG INVENTORY

4.1 Approach and Methodology

This assessment has been undertaken in accordance with the principles of:

- ISO 14064-1:2006 Greenhouse gases – Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.
- Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (GHG Protocol) (World Business Council for Sustainable Development and World Resources Institute, 2015).
- IPCC Fifth Assessment Report (2014).

These guidelines are considered representative of good practice GHG accounting internationally and are applicable to the project.

The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (WRI & WBCSD, 2004), provides two approaches. This includes the assessment of GHGs based on: (1) the organisational boundaries and (2) operational boundaries. For the calculation of GHG footprint for the project, the operational boundary approach was selected.

4.1.1 Organisational Boundaries

For corporate reporting, two distinct approaches can be used to consolidate GHG emissions: the equity share and the control approaches. Companies shall account for, and report, their consolidated GHG data according to either the equity share or control approach as presented below.

In setting organizational boundaries, a company selects an approach for consolidating GHG emissions and then consistently applies the selected approach to define those businesses and operations that constitute the company for the purpose of accounting and reporting GHG emissions. If the reporting company wholly owns all its operations, its organizational boundary will be the same whichever approach is used. For companies with joint operations, the organizational boundary and the resulting emissions may differ depending on the approach used. In both wholly owned and joint operations, the choice of approach may change how emissions are categorized when operational boundaries are set.

4.1.2 Operational Boundaries

To help delineate direct and indirect emission sources, improve transparency, and provide utility for different types of organizations and different types of climate policies and business goals, three “scopes” (scope 1, scope 2, and scope 3) are defined for GHG accounting and reporting purposes (Figure 25).

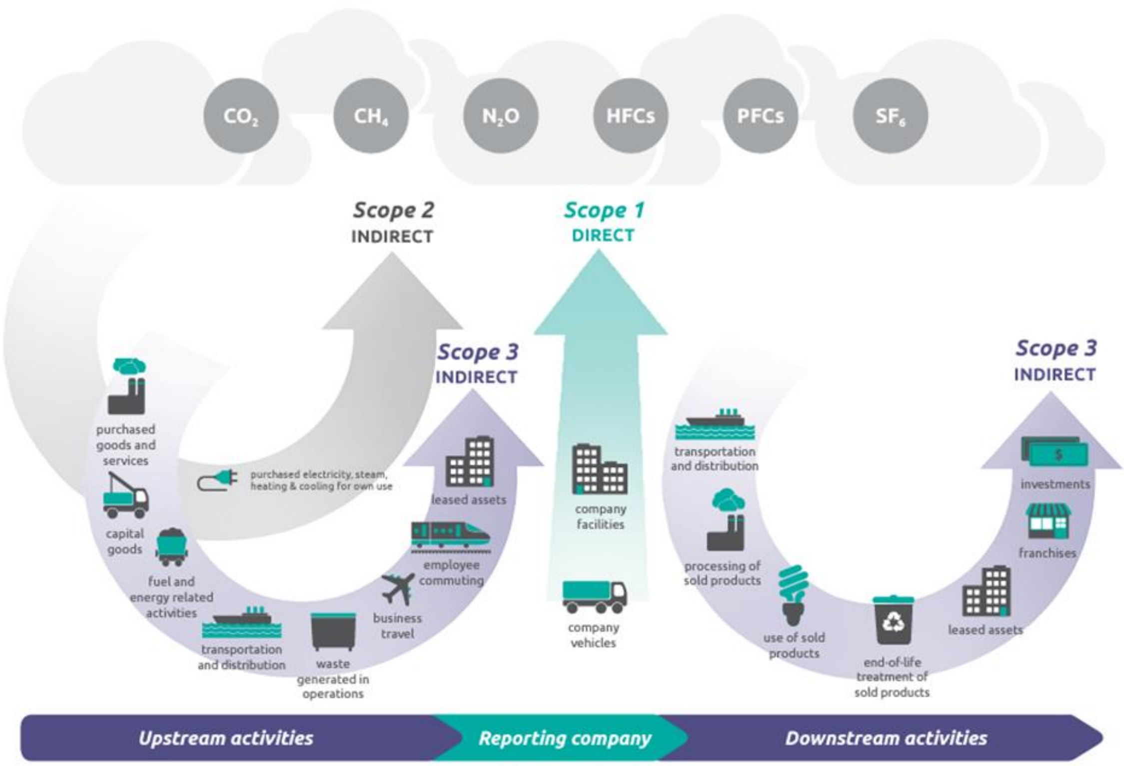


Figure 25: Overview of scopes and emissions (WRI & WBCSD, 2004)

4.1.2.1 Scope 1: Direct GHG Emissions

Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled vehicles, etc.; and/or emissions from chemical production in owned or controlled process equipment.

4.1.2.2 Scope 2: Electricity - Indirect GHG Emissions

Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.

4.1.2.3 Scope 3: Other Indirect GHG Emissions

Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased materials and product; and use of sold products.

4.2 Greenhouse Gases and Global Warming Potential

The GHGs considered in this assessment and the corresponding global warming potential (GWP) for each GHG are listed in Table 8. GWP is a metric used to quantify and communicate the relative contributions of different substances to climate change over a given time horizon. GWP accounts for the radiative efficiencies of various gases and their lifetimes in the atmosphere, allowing for the impacts of individual gases on global climate change to be compared relative to those for the reference gas carbon dioxide. The GWPs from the IPCC Third Assessment report were used in this assessment. These are reflective of radiative forcing over a 100-year time horizon. There are more recent GWP values available (i.e. the IPCC Sixth Assessment report). However, the the recent Methodological Guidelines for Quantification of Greenhouse Gas Emissions (DFFE, 2022) published by the Department of Forestry, Fisheries and Environment stipulate the older GWP values (from the Third Assessment report) to be used.

Table 8: Greenhouse gasses and 100-year global warming potentials

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	23
Nitrous oxide (N_2O)	296

4.3 Assessment Boundary

The following GHG emissions have been considered:

- Clearing of vegetation – construction phase,
- Fuel (diesel) consumption during project activities – construction and operational phases, and
- Electricity consumption during project activities – construction and operational phases.

4.4 Exclusions

The following were excluded from the inventory:

- Insufficient project specific fuel and electricity use data was available and ratios to other facilities were assessed based on the TSF area, which could potentially overestimate emissions.
- Scope 3 emissions due to project operational activities as insufficient detailed information was available for the assessment.

4.5 Source Data and Assumptions

The input data and assumptions used in estimating GHG emissions for the different phases of the project are provided in Table 9 for the Construction phase and Table 10 for the Operational phase. Limited information was provided on the Nooitgedacht TSF and data was extrapolated from the Brand TSF CCA (Von Gruenewaldt, 2024) and information provided for the Kareerand TSF (email correspondence, John von Mayer, EIMS, 2025/09/16).

Table 9: Greenhouse gas assessment source data and assumptions for the construction phase of the project

Construction	Value	Unit	Comments
Construction period	4.6	years	Nooitgedacht information
Scope 1			
Area cleared – Nooitgedacht TSF	805.0	ha	Area already partly disturbed
Area cleared – two concrete tanks	0.43	ha	Dimension ~95m x 45m
Diesel consumed (stationary: i.e. generators, etc.)	381 128.62	litres	Adjusted from Brand A TSF information [a]
Diesel consumed (Mobile/Vehicles)	22 864 531.46	litres	Adjusted from Kareerand TSF information [b]
Scope 2			
Electricity consumed by operations (kWh)	-	kWh	Assumed power will be obtained from generators, with no additional power needed from the grid.

Notes: [a] Adjustment by a factor of 4.2 based on the TSF footprint (ha) of Brand A TSF versus Nooitgedacht TSF.

[b] Adjustment by a factor of 2.01 based on the TSF footprint (ha) of Kareerand TSF versus Nooitgedacht TSF.

Table 10: Greenhouse gas assessment source data and assumptions for the operation phase of the project

Operation	Value	Unit	Comments
Operation period	30.2	years	Adjusted from Kareerand TSF information [b]
Scope 1			
Diesel (stationary combustion) (litres)	0.0	litres	From Brand A & Kareerand - no need for generators
Diesel (mobile combustion - vehicles) (litres)	1 857 188.3	litres	Adjusted from Brand A TSF information [a]
Scope 2			
Electricity consumed by operations (kWh)	96 600 000	kWh	Adjusted from Kareerand TSF - Maximum demand – 7.6MW. Majority is pumping energy for return water and slurry distribution.

Notes: [a] Adjustment by a factor of 4.2 based on the TSF footprint (ha) of Brand A TSF versus Nooitgedacht TSF.

[b] Adjustment by a factor of 2.01 based on the TSF footprint (ha) of Kareerand TSF versus Nooitgedacht TSF.

4.6 Emission Factors

The emission factors used for the assessment is provided in Table 11 and were mainly sourced from the:

- South African Methodological Guidelines for Quantification of Greenhouse Gas Emissions *gazetted by the* Department of Forestry, Fisheries and Environment, No. 47257(2598) (DFFE, 2022b).
- IPCC guidelines (IPCC, 2006)
- South Africa's 2023 Grid Emission Factors Report *gazetted by the* Department of Forestry, Fisheries and Environment, No.53079 (published 25 July 2025).

Table 11: Emission factors used in the assessment

Emission factors	Value	Unit	Source	Comment	Reference document
Scope 1 - Direct Emissions					
Diesel - stationary combustion	74 638	kg CO_2 per TJ	(DFFE, 2022)	Diesel oil	Table A.3 (country specific)
	3	kg CH_4 per TJ			Table A.1
	0.6	kg N_2O per TJ			
Diesel - mobile combustion	74 638	kg CO_2 per TJ	(DFFE, 2022)	Diesel oil	Table A.3 (country specific)
	3.9	kg CH_4 per TJ			Table A.1
	3.9	kg N_2O per TJ			
Decomposition of soil organic matter in drained inland grassland	6.1	tCO_2-C/ha/yr	(1996 & 2006 IPCC)	Default	(1996 & 2006 IPCC)
Scope 2 - Indirect Emissions					
Electricity (national)	0.901	tCO_2e per MWh	(GG 53079, 2025)		Table 1

4.7 Emissions

The estimated GHG emissions over the construction period of 4.6 years are 67 514 tCO_2e per year, and 94 841 tCO_2e per operational year, with a total over the estimated 30.2 year at 2 863 010 tCO_2e (Table 12).

Table 12: Estimated GHG emissions for the lifespan of the project

Source	Input		Annual Emissions (tCO_2e)		
	Value	Units	Scope 1	Scope 2	Total
Construction					
Fuel and Energy related activities					
Area cleared of vegetation – TSF & concrete tanks	805.43	ha	4 913		4 913
Diesel (Stationary Combustion)	381 129	litres	1 013		1 013
Diesel (Mobile Combustion)	22 864 531	litres	61 593		61 593
Electricity usage	-	kWh		-	
Total tCO_2e for construction period			***67 519***	**-**	***67 519***
Operation					
Fuel and Energy related activities					
Diesel (Stationary Combustion)	-	litres	-		-
Diesel (Mobile Combustion)	1 857 188	litres	5 003		5 003
Electricity usage	96 600 000	kWh		87 520	87 520
Total tCO_2e per year			*5 003*	*87 520*	*92 523*
Total tCO_2e for operating period			***151 026***	***2 641 998***	***2 793 024***

The GHG emission contribution for the construction and operation phases of the project is provided in Figure 26. GHG emissions due to construction phase will contribute 2% of the total project GHG emissions, with 98% from the operational phase (assuming 30.2 years of operation).

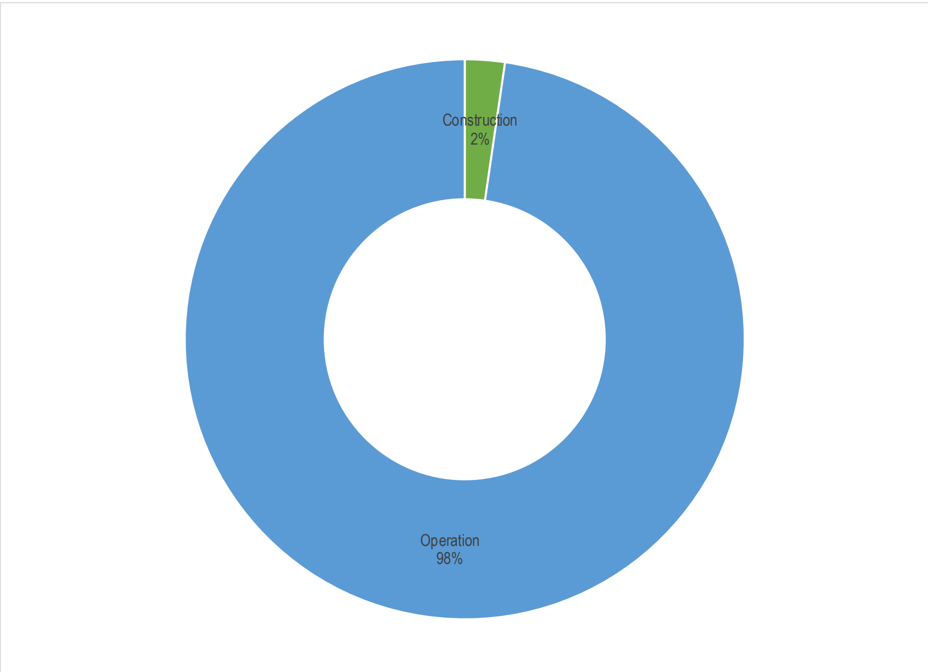


Figure 26: Percentage GHG emissions per project phase

The GHG emissions provided as a percentage per scope for project operations is provided in Figure 27. Scope 2 makes up the majority of the GHG emissions for the operational phase (95%).

Scope 1 emissions for the project construction and operations are 67 519 tCO_2e (~14 678 tCO_2e per annum) and 2 793 024 tCO_2e (~92 523 tCO_2e per annum) respectively. For comparison, international reporting considers a small facility as producing 10 000 tCO_2e per annum, medium at 25 000 tCO_2e per annum and large at 100 000 tCO_2e per annum (for Scope 1 and 2 emissions).

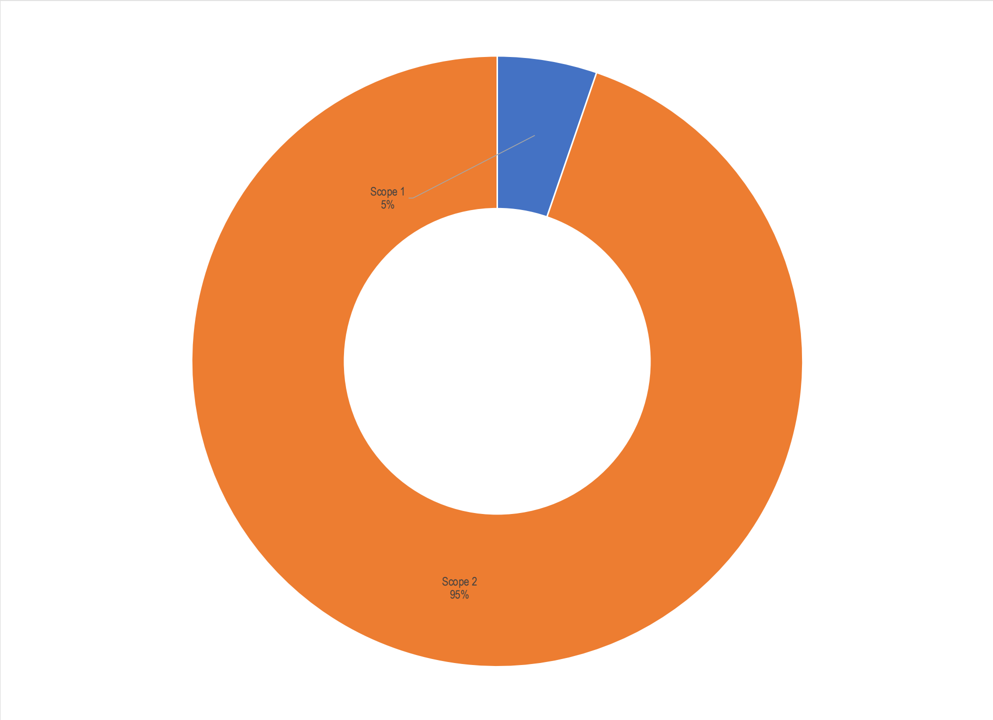


Figure 27: Percentage GHG emissions per scope for project operation activities

4.8 The Project's GHG Impact

4.8.1 Impact on the National Remaining Carbon Budget, the National Inventory and the Sasol Group Inventory

According to the updated first NDC (Section 2.3), the South African remaining carbon budget is in the range of 398 – 510 Mt CO_2e for 2025 and 350 – 420 Mt CO_2e by 2030. The draft second NDC provides a range of 350 – 420 Mt CO_2e by 2030 and 320 – 380 Mt CO_2e by 2035, and the average of the range for 2030 and 2035 for comparison to the project activities (Scope 1 and Scope 2) are used. Assuming the construction activities will be completed by 2030, it will approximately 0.018% to the 2030 National GHG inventory total. Assuming the operational phase would commence in 2030, with five years of operations completed by 2035, the project's operational contribution will be 0.135% to the 2035 National GHG inventory total (474 205 tCO_2e over five years of operations).

4.8.2 Alignment with National Policy

Most of the South African GHG policy is in early phases of implementation where GHG emissions have been reported to DFFE since 31 March 2018 and the Carbon Tax Act came into effect on the 23 May 2019. The project will be required to align GHG reporting with national policy. An annual Carbon Tax environmental levy account will need to be submitted in July of each year after operations commence.

5 PHYSICAL RISKS OF CLIMATE CHANGE ON THE PROJECT AND ADAPTATION MEASURES

5.1 Physical Risks of Climate Change to the Project's Operations

With the increase in temperature, there is the likelihood of an increase in discomfort and possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). Both these have the potential to negatively affect employee performance and productivity along with process efficiency.

From a process point of view, elevated ambient temperatures (up to 45°C) may slightly increase evaporative fuel losses from vehicles and increase temperature related wear on equipment. Similarly, there will be increased water use for drinking water and dust emission abatement on roads.

A moderate risk of increased wildfires is projected for the residential area of Welkom (see Section 3.3). Emergency plans should include the risk of responding to and managing of uncontrolled wildfires potentially crossing the project fence line where cover vegetation could be ignited.

5.2 Project Mitigation and Adaptation Measures

Climate change management includes both mitigation and adaptation. The main aim of mitigation is to stabilise or reduce GHG concentrations as a result of anthropogenic activities. This is achievable by lessening sources (emissions) and/or enhancing sinks through human intervention. Mitigation measures are typically the focus of the energy, transport and industry sectors (Thambiran & Naidoo, 2017). Adaptation measures focus on minimising the impact of climate change, especially on vulnerable communities and sectors. Inclusion of the climate change adaptation in business strategic implementation plans is one of the outcomes defined in the Draft National Climate Change Adaptation Strategy (Government Gazette No.42466:644, May 2019).

To minimise project specific GHG (Scope 1) emissions would require lower fuel use or use alternative lower-carbon fuels., for example conversion to compressed natural gas (CNG), where possible. Effective rehabilitation of above-ground and soil-based carbon stocks could be an effective carbon sink during rehabilitation after mining, and rehabilitation efforts should consider the establishment of artificial or reconstructed wetlands where these have been disturbed by mining operations and permanent infrastructure.

Carbon offset options could include investment in REDD+ (Reducing Emissions from Deforestation and forest Degradation) initiatives (Thambiran & Naidoo, 2017). REDD+ initiatives in developing countries incentivise communities to undertake forestry and related activities that can contribute to reducing land-based GHG emissions associated with deforestation and degradation and through sequestration of CO_2 in forests and agroforestry (Thambiran & Naidoo, 2017). REDD+ programmes are also mechanisms for socio-economic development. However, the expansion of the forestry industry in South Africa, will require quantification of the impact of expanded activities on water resources (as highlighted in the Draft National Climate Change Adaptation Strategy (Government Gazette No.42466:644, May 2019). In the context of this project, community based small scale farming initiatives in the area would be a more feasible investment.

Given the water scarce area and the potential of the facility to be a driver of additional water demand in the area, both for the facility and potential for growing local communities, it is important for the project to consider design systems that could assist in diversifying the water supply. This could include alternate supply of water sourced from less stressed catchments, or interconnections with neighbouring utilities that may have additional supply and/ or capacity (water augmentation). Additional options may also involve exploring alternatives to freshwater resources (e.g. water re-use or desalination) or exploring new technologies (such as desalination, aquifer storage and recovery or using reclaimed water for non-potable purposes) to bolster resilience to climate change.

From an adaption perspective, additional support infrastructure can reduce the climate change impact on the employees. For example, improving the thermal and electrical efficiency of buildings to reduce electricity consumption for air conditioning, ensuring adequate water supply for staff drinking water, amending summer operating hours to avoid the hottest part of the day and potential health and safety impacts for employees, having shaded green rest areas for employees during their shift breaks.

6 IMPACT SIGNIFICANCE RATING

6.1 Potential Impact Description

Gaseous pollutants released from the combustion of fuel is the main source of GHGs from the project. The release of GHG includes mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). GHGs are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), CO_2, N_2O, CH_4 and ozone (O_3) are the primary GHG in the Earth's atmosphere. The effect of climate change is related to changing atmospheric GHG concentrations, increased temperatures, changing weather patterns and sea level rise (indirect negative impact).

6.2 Impact Significance

The calculated CO_2e emissions from the project (Scope 1 and Scope 2) are summarised in Section 4.7, estimating 76 519 t for the project construction (14 678 tpa) and 2 793 998 t for the project operations (92 523 tpa).

The project Scope 1 and 2 emissions due to the project would contribute approximately 0.018% (construction) and 0.132% (operation) of the South African annual GHG budget for 2030 (applicable to construction) and 2035 (applicable to operations), respectively

Local reporting requirements have yet to be developed to describe and assess environmental impacts for GHGs. Guidance is thus taken from international guidelines such as that developed for the Sacramento Metropolitan Air Quality Management District (SMAQMD, 2014). As part of the process to determine if a full GHG analysis and mitigate programme is required, an Initial Study is implemented to determine if a project may have a significant effect on the environment. As such a threshold of 1 100 tCO_2e (project construction phase) and 10 000 tCO_2e (operational phase) for stationary source projects per year is applied to new projects (SMAQMD, 2014). These thresholds were based on capturing 90% of the development projects across the state, ensuring that small projects, which generally have low emission levels, and would generally not be considered significant. As an alternative method of measure, a GHG threshold may be based on the classification of projects by the European Bank for Reconstruction and Development (EBRD), in which projects contributing more than 25 000 tCO_2e per year to have significant GHG emissions (EBRD 2019). This is in line with the International Finance Corporation (IFC 2012). Section 8 of the IFC Performance Standards on Environmental and Social Sustainability: "For projects that are expected to or currently produce more than 25 000 tCO_2e annually the client will quantify direct emissions from the facilities owned or controlled within the physical project boundary, as well as indirect emissions associated with the off-site production of energy used by the project. Quantification of GHG emissions will be conducted by the client annually in accordance with internationally recognised methodologies and good practice". In terms of the Equator Principles, a developer that is seeking funding from a financial institution that subscribes to the Equator Principles is required to publicly report on its combined Scope 1 and Scope 2 GHG emissions if it exceeds 100 000 tCO_2e annually, for the operational phase of the project, during the life of the loan (Equator Principles, 2013). The Equator Principles also encourage clients to report publicly on projects emitting over 25 000 tCO_2e, in line with the IFC Performance Standards (Equator Principles, 2013). As a further example, the South African Declaration of Greenhouse Gases as Priority Pollutants (GG 40966 of 21 July 2017) define production processes in Annexure A of the Declaration with the requirement to submit a Pollution Prevention Plan (PPP) (referred to as greenhouse gas mitigation plans in the Climate Change Act gazetted on 23 July 2024) to the Minister for approval with GHG in excess of 100 000 tCO_2e.Under the Act, this will be replaced by greenhouse gas mitigation plan if the facility is allocated carbon budget.

When evaluating significance, all new GHG emissions contribute to a negative environmental impact; however, some projects could replace existing development or baseline activity that has a higher GHG profile. Therefore, the significance of a project's emissions should be based on its net impact over its lifetime, which may be positive, negative or negligible. To meet the South African (SA) NDC targets and interim budgets, action is required to reduce GHG emissions from all sectors, including projects in the built and natural environment. The proposed project must therefore consider whether and how the project will contribute to or jeopardise the achievement of these targets. Such an assessment would however require a much broader evaluation of the project against all current energy mix and their resources practiced in South Africa. In the absence of such a comprehensive assessment, the current assessment will rely on using thresholds to define the significance of the GHG impact.

The proposed intensity rating for annual emissions is as follows:

<25 000 tCO_2e	:	**Very Low** (i.e., threshold used by EBRD, IFC and Equator Principals)
25 000 – 100 000 tCO_2e	:	**Low** (i.e., DFFE PPP requirement threshold is 100 000 tCO_2e)
100 000 – 500 000 tCO_2e	:	**Medium** (i.e., DFFE PPP to 0.1% of the total gross SA GHG emissions)
500 000 – 5 000 000 tCO_2e	:	**High** (i.e., 0.1% to 1.0% of the total gross SA GHG emissions)
>5 000 000 tCO_2e	:	**Very High** (i.e., more than 1.0% of the total gross SA GHG emissions)

The GHG emissions for project construction (14 678 tCO_2e per annum) are below the “Very Low” threshold used by EBRD (25 000 tCO_2e), with the operational emissions (92 523 tCO_2e per annum) below the “Low” threshold. The impact significance is therefore considered to be **Very Low** during construction and **Low** during operations.

7 FINDINGS AND RECOMMENDATIONS

Project specific information together with local and internationally published emission factors were used to calculate Scope 1 (direct) and Scope 2 (indirect) GHG emissions for the proposed project. Locally published literature was referred to, to understand the projected changes to climate for the area.

Based on information provided, the project is likely to result in an estimated total of 67 519 tCO_2e direct emissions, with no indirect emissions due to construction activities. For project operations, the estimated total GHG emissions is 5 003 tCO_2e (direct) and 87 520 tCO_2e (indirect). This was calculated to represent 0.018% (construction) and 0.132% (operation) of the South African annual GHG budget for 2030 (construction) and 2035 (operations), respectively.

The impact of the project's construction phase on climate change was assessed to have a **Very Low** negative risk rating, with the operational phase having a **Low** risk.

The project will be required to report CO_2e emissions annually via the NAEIS and provide a greenhouse gas mitigation plan.

7.1 Conclusion

From the perspective of climate change, it is the opinion of the specialist that the project be authorised, on condition that GHG emissions are reported annually according to legal requirements.

8 REFERENCES

CSIR. (2024). Retrieved from Green Book: Adapting South African settlements to climate change.: www.greenbook.co.za

CSIR. (2024). Retrieved from Green Book: Adapting South African settlements to climate change.: www.greenbook.co.za

Davis, C. E. (2014). *The International Traveler's Guide to Avoiding Infections. Myers, J., Young, T., Galloway, M., Manyike, P. and Tucker, T. 2011 'References responding to climate change in southern Africa – the role of research',.*

Davis-Reddy, C., & Vincent, K. (2017). *Climate Risk and Vulnerability: A Handbook for Southern Africa (2nd Ed).* Pretoria, South Africa: CSIR.

DFFE. (2022). *Methodological Guidelines for Quantification of Greenhouse Gas Emissions: A companion to the South African National GHG Emission Reporting Regulations. Version No: MG-2022.1.* Pretoria: Government Gazette, 7 October 2022, No. 47257(2598), Department of Forestry, Fisheries and Environment.

DFFE. (2022a). *GHG Inventory Report for South Africa 2000 -2020.* DFFE. Retrieved 09 14, 2022, from https://www.dffe.gov.za/sites/default/files/gazetted_notices/8thnational-greenhouse-gasinventory-reportg47133gon2321.pdf

DFFE. (2022b). *Methodological Guidelines for Quantification of Greenhouse Gas Emissions: A companion to the South African National GHG Emission Reporting Regulations. Version No: MG-2022.1.* Pretoria: Government Gazette, 7 October 2022, No. 47257(2598), Department of Forestry, Fisheries and Environment.

DFFE. (2024). *Draft 9th National Greenhouse Gas Inventory Report for the Republic of South Africa for Public Comment.* Pretoria, South Africa: Department of Forestry, Fisheries and Environment.

Duncker, L. (2018). *Green Book – The impact of climate changeon sanitation services provision within settlements.* Pretoria: CSIR.

Dunker, L., & Van Wyk, L. (2018). *Green Book – The impact of climate change on stormwater management within settlements.* CSIR.

Engelbrecht, F. (2019). *Technical Report: Green Book – Detailed Projections of Future. Report reference number: CSIR/BE/SPS/ER/2019/0005/C.* Pretoria: CSIR (Council for Scientific and Industrial Research).

Garland, R. (2018). *Green Book – The impact of climate changeon human health in settlements.* Pretoria: CSIR.

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Retrieved from Intergovernmental Panel on Climate Change: http://www.ipcc-nggip.iges.or.jp/public/2006gl/

IPCC. (2007). *Intergovernmental Panel on Climate Change 4th Assessment Report.* Retrieved from Intergovernmental Panel on Climate Change: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf

IPCC. (2013). *Intergovernmental Panel on Climate Change 5th Assessment Report.* Retrieved from Intergovernmental Panel on Climate Change: https://www.ipcc.ch/report/ar5/

IPPC. (2024, 04 23). *IPCC WGI Interactive Atlas: Regional information (Advanced)*. Retrieved January 6, 2023, from https://interactive-atlas.ipcc.ch

Le Roux, A., van Niekerk, W., Arnold, K., Pieterse, A., Ludick, C., Forsyth, G., . . . Mans, G. (2019). *Green Book Risk Profile Tool.* (CSIR, Pretoria) Retrieved 09 30, 2022, from riskprofiles.greenbook.co.za

meteoblue AG. (2024, 04 22). *Climate Change Posmasburg*. Retrieved from meteoblue - weather close to you: https://www.meteoblue.com/en/weather/historyclimate/change/waaipoort_south-africa_942262

Mokonyama, M., & Van Wyk, L. (2018). *Green Book - Transport and mobility: the impact of climate change on transport and mobility within settlements.* CSIR.

Naidoo, S. (2018). *Green Book – The impact of climate change on ICT services provision within settlements. .* Pretoria: CSIR.

NOAA. (2021, September). *Earth System Research Laboratory Global Monitoring Division.* Retrieved from National Oceanic and Atmospheric Administration: https://gml.noaa.gov/ccgg/trends/global.html

Oelofse, S. (2018). *The impact of climate change on solid waste management within settlements.* CSIR.

Pieterse, A., & Crankshaw, B. (2018). *Green Book –The impact of climate change on ecosystem services in settlements.* Pretoria: CSIR.

SAWS. (2017). *A Climate Change Reference Atlas 2017 - based on CMIP5 – CORDEX downscaling.* Pretoria, South Africa: South African Weather Service and the Water Research Commission. Retrieved from https://www.weathersa.co.za/home/climatechangeatlas

South African National Biodiversity Institute. (2024, 05 03). 2018 Vegetation Map. Pretoria. Retrieved from Available from the Biodiversity GIS website: http://bgis.sanbi.org/SpatialDataset/Detail/595

Thambiran, T., & van Wyk, L. (2018). *Green Book – The impact of climate change on energy services provision within settlements.* Pretoria: CSIR.

UNFCCC. (2017). *United Nations Framework Convention on Climate Change e-Handbook .* Retrieved from United Nations Framework Convention on Climate Change: http://bigpicture.unfccc.int/

van Wyk, L. (2018). *Green Book – The impact of climate change on culture and heritage in settlements.* Pretoria: CSIR.

Von Gruenewaldt, R. (2024). *Climate Change Assessment for the Proposed Harmony Brand A Tailings Storage Facility near Welkom, South Africa. 23EIM15.* Johannesburg: Airshed Planning Professionals (Pty) Ltd on behalf of Environmental Management Services (Pty) Ltd.

World Bank Group. (2021). *Climate Risk Country Profile, South Africa.* Washington: World Bank Group.

WRI & WBCSD. (2004). *The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard.* Washington & Switzerland: WRI & WBCSD.

APPENDIX A – CURRICULUM VITAE OF ASSESSMENT AUTHOR

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Hanlie Liebenberg-Enslin
Profession	Managing Director / Air Quality Scientist
Date of Birth	09 January 1971
Years with Firm/ entity	25 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) – President 2010–2013, Board member 2013-present

Member of the National Association for Clean Air (NACA) - President 2008-2010, NACA Council member 2010 –2014

KEY QUALIFICATIONS

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

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

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

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

RELEVANT EXPERIENCE

Air Quality Management Plans and Strategies

Vaal Triangle Airshed Priority Area Draft Second Generation Air Quality Management Plan (AQMP)(Aug 2017 – Jun 2020); Advanced Air Quality Management for the Strategic Environmental Management Plan for the Uranium and Other Industries in the Erongo Region (May 2016 – Feb 2019); City of Johannesburg AQMP (2016-2019); Air Quality Monitoring and Management for the Al Madinah Al Munawarah Development Authority (MDA) in Saudi Arabia (2016-2017). Provincial Air Quality Management Plan for the Limpopo Province (March 2013); Mauritius Road Development Agency Proposed Road Decongestion Programme (July 2013); Transport Air Quality Management Plan for the Gauteng Province (February 2012); Gauteng Green Strategy (2011); Air Quality and Radiation Assessment for the Erongo Region Namibia as part of a Strategic Environmental Assessment (June, 2010); Vaal Triangle Airshed Priority Area AQMP (March, 2009); Gauteng Provincial AQMP (January 2009); North West Province AQMP (2008); City of Tshwane AQMP (April 2006); North West Environment Outlook 2008 (December 2007); Ambient Monitoring Network for the North West Province (February 2007); Spatial Development Framework Review for the City of uMhlathuze (August 2006); Ambient Particulate Pollution Management System (Anglo Platinum Rustenburg).

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

Mining and Ore Handling

Hanlie has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite and mineral sands mines. These include air quality impact assessments for: Namibia – Husab Uranium Mine, Trekkopje Uranium Mine; Bannerman Uranium Project; Langer Heinrich Uranium Mine, Valencia Uranium Mine, Rössing Uranium Mine; and B2Gold Otjikoto Gold Mine. South Africa – Sishen Iron Ore Mine; Tshipi Borwa Manganese Mine; Mamatwan Manganese Mine; Kolomela Iron Ore Mine; Thabazimbi Iron ore Mine; UKM Manganese Mine; Everest Platinum Mine; Impala Platinum Mine; Anglo Platinum Mines; Abglo Gold Ashanti MWS, Vaal River and West Wits complexes, Harmony Gold, Glencore Coal Mines, South32 and Anglo Coal; Tselentis Coal mine (Breyeton); Lime Quarries (De Hoek, Dwaalboom, Slurry); Beesting Colliery (Ogies); Anglo Coal Opencast Coal Mine (Heidelberg); Klippan Colliery (Belfast); Beesting Colliery (Ogies); Xstrata Coal Tweefontein Mine (Witbank); Xstrata Coal Spitskop Mine (Hendrina); Middelburg Colliery (Middelburg); Klipspruit Project (Ogies); Rustenburg Platinum Mine (Rustenburg); Impala Platinum (Rustenburg); Buffelsfontein Gold Mine (Stilfontein); Kroondal Platinum Mine (Kroondal); Lonmin Platinum Mine (Mooinooi); Rhovan Vanadium (Brits); Macauvlei Colliery (Vereeniging); Voorspoed Gold Mine (Kroonstad); Pilanesberg Platinum Mine (Pilanesberg); Kao Diamond Mine (Lesotho); Modder East Gold Mine (Brakpan); Modderfontein Mines (Brakpan); Zimbiwa Crusher Plant (Brakpan); RBM Zulti South Titanium mining (Richards Bay); Premier Diamond Mine (Cullinan). Botswana – Jwaneng Diamond Mine and Debswana Mining Company. Zimbabwe – Murowa Diamond Mine. Other mining projects include Sadiola Gold Mine (Mali); North Mara Gold Mine (Tanzania); Bulyanhulu North Mara Gold Mine (Tanzania).

Metal Recovery

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

Chemical Industry

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

Petrochemical Industry

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

Pulp and Paper Industry

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

Power Generation

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

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

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

Waste Disposal

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

Cement Manufacturing

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

Vehicle emissions

Transport Air quality Management Plan for the Gauteng Department of Roads and Transport (Feb 2012); Platinum Highway (N1 to Zeerust); Gauteng Development Zone (Johannesburg); Gauteng Department of Roads and Transport (Transport Air Quality Management Plan); Mauritius Road Development Agency (Proposed Road Decongestion Programme); South African Petroleum Industry Association (Impact Urban Air Quality).

Government and International Strategy Projects

Hanlie in one of the Lead Authors of Section 1.1: Africa's Development: Challenges, Drivers and key objectives, of the United Nations Environment Programme (UNEP), Climate and Clean Air Coalition (CCAC) and Stockholm Environment Institute (SEI) coordinated 'Integrated Assessment of Air Pollution and Climate Change for Africa Report'. She was also the Terminal Reviewer of the UNEP/UNDA project "Air quality data for health and environment policies in Africa and the Asia-Pacific region" (May 2020). Hanlie was the project Director on the APPA Registration Certificate Review Project for Department of Environmental Affairs (DEA); Green Strategy for Gauteng (2011).

EDUCATION

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

ADDITIONAL COURSES AND ACADEMIC REVIEWS

External Examiner (July 2025)	PhD Candidate: TJB van Niekerk Spatial planning solutions to mitigate poor air quality in South African dense, low-income areas Department Geography and Environmental Management, North-West University
External Examiner (January 2022)	MSc Candidate: P Chidhindi Using dispersion models as a regulatory tool in South Africa Department Geography and Environmental Management, North-West University
External Examiner (February 2021)	PhD Candidate: Ms NM Walton Aerosol source apportionment in southern Africa Faculty of Natural and Agricultural Sciences, North-West University
External Examiner (May 2018)	MSc Candidate: Ms A Quta Characterisation of Particulate Matter and Some Pollutant Gasses in the City of Tshwane Department of Environmental Sciences, University of South Africa
External Examiner (December 2017)	MSc Candidate: Ms B Wernecke Ambient and Indoor Particulate Matter Concentrations on the Mpumalanga Highveld Faculty of Natural and Agricultural Sciences, North-West University
External Examiner (January 2016)	MSc Candidate: Ms M Grobler Evaluating the costs and benefits associated with the reduction in SO_2 emissions from Industrial activities on the Highveld of South Africa Department of Chemical Engineering, University of Pretoria

External Examiner (August 2014)	MSc Candidate: Ms Seneca Naidoo Quantification of emissions generated from domestic fuel burning activities from townships in Johannesburg Faculty of Science, University of the Witwatersrand
Air Quality Law– Lecturer (2012 - 2016)	Environmental Law course: Centre of Environmental Management.
Air Quality law for Mining – Lecturer (2014)	Environmental Law course: Centre of Environmental Management.
Air Quality Management – Lecturer (2006 -2012)	Air Quality Management Short Course: NACA and University of Johannesburg, University of Pretoria and University of the North West
ESRI SA (1999)	ARCINFO course at GIMS: Introduction to ARCINFO 7 course
ESRI SA (1998)	ARCVIEW course at GIMS: Advanced ARCVIEW 3.1 course

COUNTRIES OF WORK EXPERIENCE

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

EMPLOYMENT RECORD

March 2003 - Present

Airshed Planning Professionals (Pty) Ltd, Managing Director and Principal Air Quality Scientist, Midrand, South Africa.

January 2000 – February 2003

Environmental Management Services CC, Senior Air Quality Scientist.

May 1998 – December 1999

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

February 1997 – April 1998

GIS Business Solutions (PQ Africa), GIS Analyst

January 1996 – December 1996

Annegarn Environmental Research (AER), Student Researcher

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Excellent	Excellent	Excellent

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

Air Quality Evolution in South Africa over the past 20 years: A Consultants' Journey. Hanlie Liebenberg-Enslin. 55th Annual Conference of the National Association for Clean Air, 4 to 6 September 2024, Johannesburg. Keynote speaker.

Integrated Assessment of Air Pollution and Climate Change for Sustainable Development in Africa – Towards "the Africa we want". Hanlie Liebenberg-Enslin, and Kevin Hicks. Air Protection 2023 & International Conference and 13th Croatian Scientific and Professional Meeting, CAPPA, 20 - 24 September 2023, Dubrovnik, Croatia at Hotel Astarea, Mlini.

Dust and radon levels on the west coast of Namibia – What did we learn? Hanlie Liebenberg-Enslin, Detlof von Oertzen, and Norwel Mwananawa. Atmospheric Pollution Research, 2020. https://doi.org/10.17159/caj/2020/30/1.8467

Understanding the Atmospheric Circulations that lead to high particulate matter concentrations on the west coast of Namibia. Hanlie Liebenberg-Enslin, Hannes Rauntenbach, Reneé von Gruenewaldt, and Lucian Burger. Clean Air Journal, 27, 2, 2017, 66-74.

Cooperation on Air Pollution in Southern Africa: Issues and Opportunities. SLCPs: Regional Actions on Climate and Air Pollution. Liebenberg-Enslin, H. 17th IUAPPA World Clean Air Congress and 9th CAA Better Air Quality Conference. Clean Air for Cities - Perspectives and Solutions. 29 August - 2 September 2016, Busan Exhibition and Convention Center, Busan, South Korea.

A Best Practice prescription for quantifying wind-blown dust emissions from Gold Mine Tailings Storage Facilities. Liebenberg-Enslin, H., Annegarn, H.J., and Burger, L.W. VIII International Conference on Aeolian Research, Lanzhou, China. 21-25 July 2014.

Quantifying and modelling wind-blown dust emissions from gold mine tailings storage facilities. Liebenberg-Enslin, H. and Annegarn, H.J. 9th International Conference on Mine Closure, Sandton Convention Centre, 1-3 October 2014.

Gauteng Transport Air Quality Management Plan. Liebenberg-Enslin, H., Krause,N., Burger, L.W., Fitton, J. and Modisamongwe, D. National Association for Clean Air Annual Conference, Rustenburg. 31 October to 2 November 2012. Peer reviewed.

Developing an Air Quality Management Plan: Lessons from Limpopo. Bird, T.; Liebenberg-Enslin, H., von Gruenewaldt, R., Modisamongwe, D. National Association for Clean Air Annual Conference, Rustenburg. 31 October to 2 November 2012. Peer reviewed.

Modelling of wind eroded dust transport in the Erongo Region, Namibia, H. Liebenberg-Enslin, N Krause and H.J. Annegarn. National Association for Clean Air (NACA) Conference, October 2010. Polokwane.

The lack of inter-discipline integration into the EIA process-defining environmental specialist synergies. H. Liebenberg-Enslin and LW Burger. IAIA SA Annual Conference, 21-25 August 2010. Workshop Presentation. Not Peer Reviewed.

A Critical Evaluation of Air Quality Management in South Africa, H Liebenberg-Enslin. National Association for Clean Air (NACA) IUAPPA Conference, 1-3 October 2008. Nelspuit.

Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007, Vanderbijl Park.

Air Quality Management plan as a tool to inform spatial development frameworks – City of uMhlathuze, Richards Bay, H Liebenberg-Enslin and T Jordan. National Association for Clean Air (NACA) conference, 29 – 30 September 2005, Cape Town.

CERTIFICATION

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

15 August 2025

Full name of staff member: Hanlie Liebenberg-Enslin