Climate Change Assessment for the Motuoane Exploration Right Application (ER386), Free State Province

Project done on behalf of **Environmental Impact Management Services (Pty) Ltd**

Project Compiled by:

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Report Details

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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.
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Revision Record

Revision Number	**Date**	**Reason for Revision**
Rev 0	April 2026	For internal review
Rev 1	April 2026	For client review
Rev 2	April 2026	Editorial changes

EXECUTIVE SUMMARY

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Impact Management Services (Pty) Ltd (EIMS) to undertake a Climate Change Assessment (CCA) for the proposed Motuoane Exploration Right Application (ER386) (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 3 (indirect)[1] greenhouse gas (GHG) emissions for the proposed project. Locally published literature was referred to, 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:
  - Temperature:
    - Baseline: 3.9 hot days (90th percentile)
    - High mitigation climate situation (Representative Concentration Pathway (RCP) 4.5): 18 hot days with an increase in temperature of 2.8°C (90th percentile)
    - Low mitigation climate situation (RCP8.5): 21 hot days with an increase in temperature of 3.2°C (90th percentile)
  - Rainfall:
    - Baseline: 13 extreme rainfall days (90th percentile)
    - High mitigation climate situation (RCP4.5): increase of 0.4 extreme rainfall days with an increase in rainfall of 57 mm (90th percentile)
    - Low mitigation climate situation (RCP8.5): increase of 1.7 extreme rainfall days with an increase in rainfall of 139 mm (90th percentile)
- Hazards assuming the low mitigation climate situation (RCP8.5):
  - Wildfires: the settlements within the study area are at low risk of wildfires with the projection of 30 fire danger days per year over the project area;
  - Drought: the settlements within the study area are at very low risk of drought with the Standardized Precipitation Index (SPI) of -0.38 for the project area;
  - Exposure to heat extremes: the settlements within the study area are at high risk of encountering increasing heat stresses; and,
  - Flooding: the settlements within the study area are at slight to moderate risk of increased extreme rainfall days with low increase in exposure to urban flooding.

Based on information provided, the project is likely to result in an estimated total GHG emissions as follows:

[1] It should be noted that no electricity from the grid will be used during the exploration activities. GHG emissions from Scope 2 will therefore be zero.

- Scope 1 direct emissions:
  - 21 236 tonnes carbon dioxide equivalent (t CO_2e) over a 9-year period
  - 2 360 t CO_2e per annum
- Scope 2 indirect emissions:
  - No electricity from the grid will be used during the exploration activities. GHG emissions from Scope 2 will therefore be zero.
- Scope 3 indirect emissions:
  - 288 t CO_2e over a 9-year period
  - 32 t CO_2e per annum

The GHG emissions from the project was calculated to represent 0.0007% of the remaining South African annual budget for 2030 and 2035 respectively. The contribution to the South African annual budget will also progressively increase throughout the life of the project as the country's Nationally Determined Contributions (NDCs) decrease.

The impact of the project on climate change was assessed to have a **low** negative risk rating for GHG emissions. Subsequently, it is the specialist's opinion that the project may be authorised provide that the mitigation measures recommended in this report are adhered to.

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LIST OF ACRONYMS AND SYMBOLS

AFF	Agriculture, Forestry and Fishing
Airshed	Airshed Planning Professionals (Pty) Ltd
AR3	IPCC's third assessment report
AR5	IPCC's fifth assessment report
AR6	IPCC's sixth assessment report
AWD	Accelerated Weight Drop
BAU	Business-As-Usual
°C	Degrees Celsius
CCA	Climate Change Assessment
CCRA	Climate Change Reference Atlas
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
DEFRA	UK Department for Environment Food & Rural Affairs
DFFE	Department of Forestry, Fisheries and Environment (previously DEA)
DWS	Department of Water and Sanitation
EAPs	Environmental Assessment Practitioners
ECMWF	European Centre for Medium-Range Weather Forecasts
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
ER	Exploration Right
ERA5	Fifth generation ECMWF (European Centre for Medium-Range Weather Forecasts)
GCMs	Global Climate Change Models
GDP	Gross domestic product
GG	Government gazette
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
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
km	Kilometre
kWh	Kilowatt hour
l/p/d	Litres per person per day
LUCF	Land-Use Change and Forestry LUCF
LULUCF	Land Use, Land Use Change and Forestry
m	Metres
mm	Millimetres
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
PEGs	Propelled Energy Generators
PFCs	Perfluorocarbons
ppm	Parts per million
PUFA	Polyunsaturated fatty acids
PV	Photovoltaic
RCA4	Rossby Centre regional model
RCPs	Representative Concentration Pathways
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
t	Tonne
TCFD	Taskforce for Climate-related Financial Disclosures
TJ	Terajoule
ton/ha	Tonne per hectare
UNFCCC	United Nations Framework Convention on Climate Change
%	Percent

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

Motuoane proposes to explore all saleable gases including but not limited to methane, carbon dioxide, helium, and nitrogen in the licensed area. Due to the large area and complex exploration methodology, the Exploration Right (ER) will be required for an initial period of three years with the option to renew three additional periods of two years resulting in a total of nine years. The accepted application for an exploration right (ER386) is located over an area of approximately 58 000 hectares (ha), covering various farm portions near the towns of Virginia, Welkom, Hennenman and Odendaalsrus in the Free State Province.

The main activities are core / percussion exploration drilling and seismic survey activities. The proposed approach is to first determine and map the geographic extent of all boreholes currently emitting gas on and near the ER area. Then measure rates and monitor pressures where possible and perform gas composition analysis. The geophysical wireline logging of existing boreholes (where possible) will include monitoring of water levels. If no existing gas emitting boreholes are identified near a target area, new drilling activities are proposed within that area using percussion or rotary drilling method. Five target areas and nine seismic transects, shown in **Figure 1-1**, are included in the application. Each exploration well will have an overall depth of approximately 650 m and a maximum width of 350 mm, commencing with a 6 m x 323 mm spud hole section, followed by 80 m x 254 mm conductor hole section, then an intermediate hole section of 450 m x 203 mm and finally an open hole section of 650 m x 144 mm. The actual casing sizes and configurations will vary depending on the specific geological characteristics and functional requirements. Each borehole will be steel cased and have cement barriers to prevent leaks as well as plugged at the end of exploration to prevent groundwater seepage.

The seismic survey activities are proposed throughout the exploration right as and when necessary. Motuoane will search records at the Council for Geoscience and the Petroleum Agency for seismic data that was acquired on the Exploration Right in the past. If no data are available, Motuoane will either acquire its own seismic or telluric data on the property, following proper environmental protocols and with the written permission of the landowner. The preliminary proposed transects for seismic / telluric survey are just over 70 km long around known structures and possible drill locations. Seismic and/or telluric locations and lengths are subject to be changed as knowledge increases.

Although the Vibroseis technique is the likely method to be undertaken for the seismic activities, there is also a potential alternative to the Vibroseis known as the Propelled Energy Generators (PEGs), more commonly referred to as the Accelerated Weight Drop Seismic (AWD) which Motuoane may consider over the Vibroseis.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by Environmental Impact Management Services (Pty) Ltd (EIMS) to undertake a Climate Change Assessment (CCA) for the proposed Motuoane Exploration Right Application (ER386) (hereafter referred to as the project). This report details the findings of the CCA undertaken for the project.

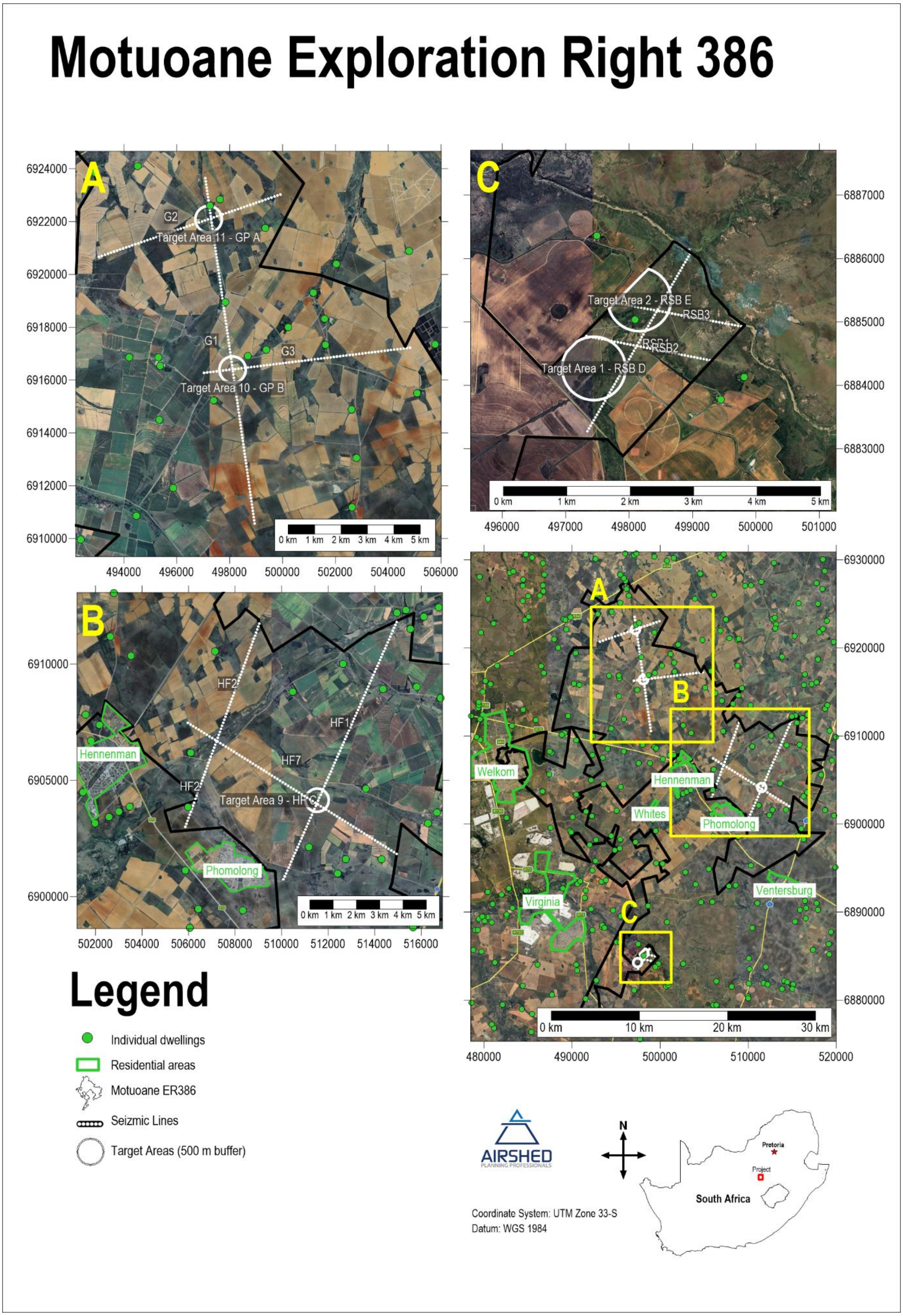

Figure 1-1: Location of the project site

1.1 Scope of Work

The scope of work included a desktop Climate Change Assessment 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 – RG von Gruenewaldt (MSc (Meteorology), BSc, Pr. Sci Nat.)

Reneé von Gruenewaldt is a Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP) and a member of the National Association for Clean Air (NACA).

Following the completion of her bachelor's degree in atmospheric sciences in 2000 and honours degree (with distinction) with specialisation in Environmental Analysis and Management in 2001 at the University of Pretoria, her experience in air pollution started when she joined Environmental Management Services (now Airshed Planning Professionals) in 2002. Reneé von Gruenewaldt later completed her master's degree (with distinction) in Meteorology at the University of Pretoria in 2009.

Reneé von Gruenewaldt became partner of Airshed Planning Professionals in September 2006. Airshed Planning Professionals is a technical and scientific consultancy providing scientific, engineering and strategic air pollution impact assessment and management services and policy support to assist clients in addressing a wide variety of air pollution related risks and air quality management challenges. She has experience on the various components of greenhouse gas emission foot-printing and climate change assessment statements where she has been the principal specialist and manager on these projects.

A comprehensive curriculum vitae of Reneé von Gruenewaldt is provided in Appendix A. The declaration of independence for Reneé von Gruenewaldt is provided in Appendix B.

2 REGULATORY CONTEXT AND IMPACT ASSESSMENT CRITERIA

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 is known as 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 425.8 ppm in June 2025 (Lan, Tans, & Thoning, 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 (Lan, Tans, & Thoning, 2025). 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 GHG 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 United Nations Framework Convention on Climate Change (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 (Government Gazette (GG) 53092) for public comment.

On January 20, 2025, an executive order was signed by the United States President to withdraw the United States from the Paris Agreement. The withdrawal of the United States took effect on 27 January 2026.

2.2 South African National Climate Change Response Policy

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 a Non-Annex 1 country it implies no binding commitment to cap or reduce GHG emissions. South Africa later also 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 proposes 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 the 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 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 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 Bill becomes an Act.
- 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[1] 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.

The following goals were assembled for the first South African NDC:

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

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:

- 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 2-1.

Table 2-1: South Africa's first 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 under plans 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 2-2.

Table 2-2: 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 (GN 257 in GG 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 carbon dioxide equivalent (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 CO_2e, are required to submit a greenhouse gas mitigation plan to the Minister for approval.

The proposed project will be required to report CO_2e emissions.

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 energy category for both the global GHG inventory and for the national GHG inventory. According to the World Resources Institute – CAIT Climate Data Explorer[2] (as accessed

[2] http://cait.wri.org/

in April 2026 and using the Climate Watch data source) the 2023 global GHG emissions from the energy category were approximately 38 990.40 Mt CO_2e; 76.7% of the total GHG emissions (including Land-Use Change and Forestry (LUCF)). The South African energy sector contributed 406.99 Mt CO_2e, ~1.04% of the global emissions from the energy sector in 2023.

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

The DFFE published (on 25 June 2021) a notice under the 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.* On 24 October 2025, the DFFE published a revised draft for a second round of public comment in GN 6759 in GG 53574.

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.

3.1 Vulnerability

The Green Book (CSIR, 2025); 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 and Moqhaka Municipalities[3].

The Matjhabeng 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 Municipality for socio-economic vulnerability ranks 4th out of 19 in the province and 81st out of 213 in the country. The Matjhabeng Municipality economic vulnerability score[5] (out of 10) is 7.7 for 1996, increasing to 9.2 for 2011. 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.

The Moqhaka Municipality socio-economic vulnerability score (out of 10) is 5.5 for 1996, reducing to 4.2 for 2011. The lower score in 2011 compared to 1996 indicates improvement of socio-economic factors. The Moqhaka Municipality for socio-economic vulnerability ranks 3rd out of 19 in the province and 79th out of 213 in the country. The Moqhaka Municipality economic vulnerability score (out of 10) is 5.8 for 1996, increasing to 7.2 for 2011. The economic vulnerability ranks 13th out of 19 in the province and 172nd out of 213 in the country. The physical vulnerabilities ranks 1st out of 19 in the province and 20th out of 213 in the country. The environmental vulnerability ranks 8th out of 19 in the province and 76th out of 213 in the country.

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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.

3.2 Climate

3.2.1 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 African 'Green Book'[8] (CSIR, 2025). The metrics include three percentiles[9] (10th, 50th, and 90th) as an indication of the variability within the measured data set.

Baseline annual average temperature was in the range 16.2°C (10th percentile) and 16.31°C (90th percentile) (**Figure 3-1**) with the number of very hot days varying between 1.68 (10th percentile) and 3.92 (90th percentile) days per year (**Figure 3-2**). High inter-annual rainfall variability is noticed (Figure 3-3) as the range between the 10th and 90th percentiles was 1016.84 mm and 1107.52 mm. Extreme rainfall days varied between 12.36 (10th percentile) and 13.48 (90th percentile) days per year (**Figure 3-4**).

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[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.

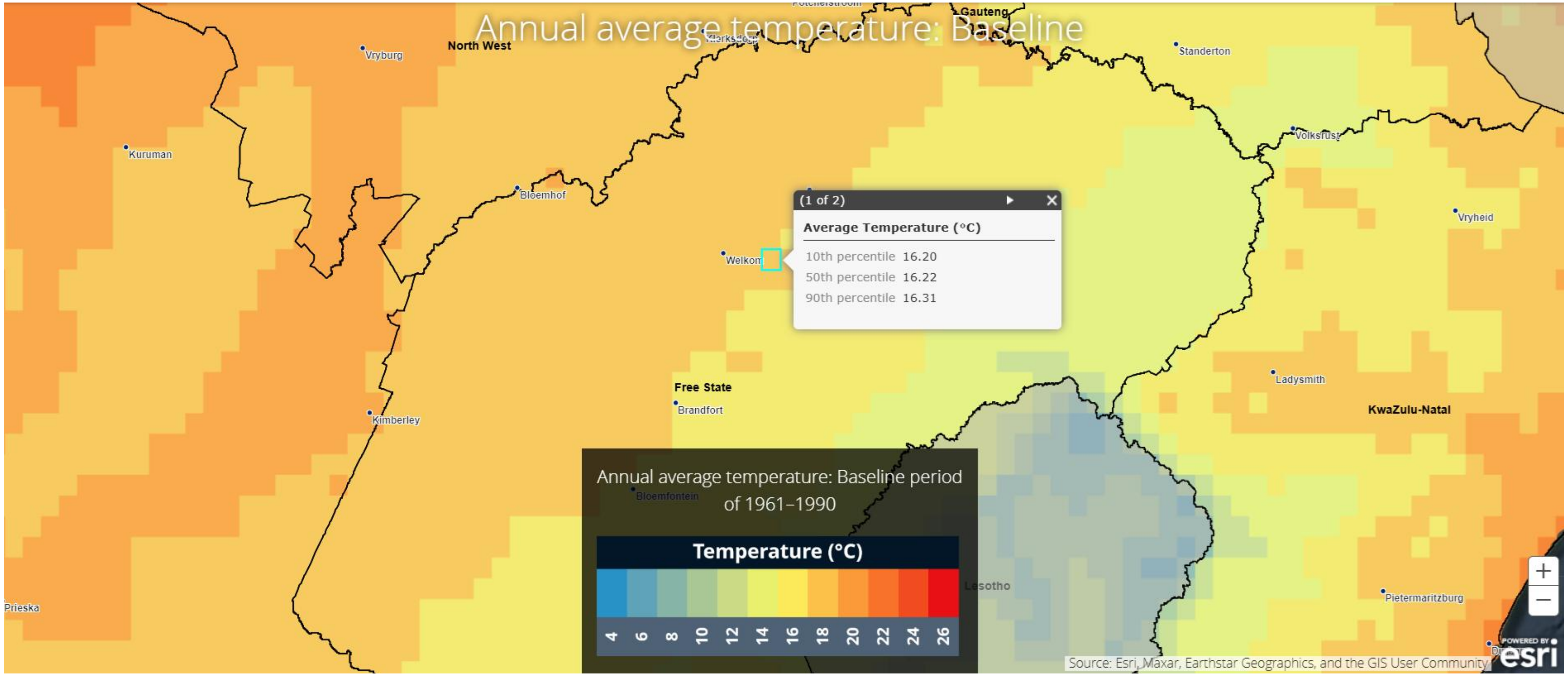


Figure 3-1: Baseline (1961 to 1990) annual average temperature for the project area (CSIR, 2025)

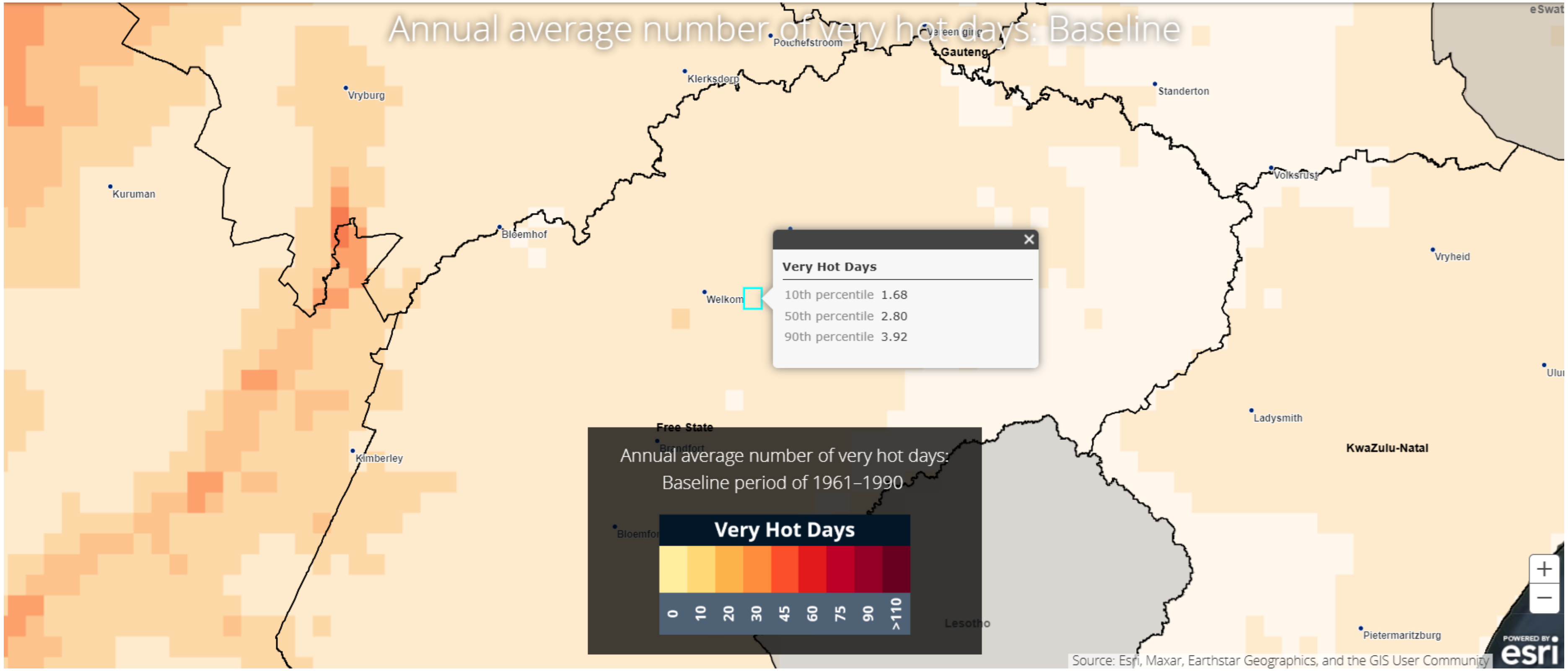


Figure 3-2: Baseline (1961 to 1990) number of very hot days (>35°C) annually for the project area (CSIR, 2025)

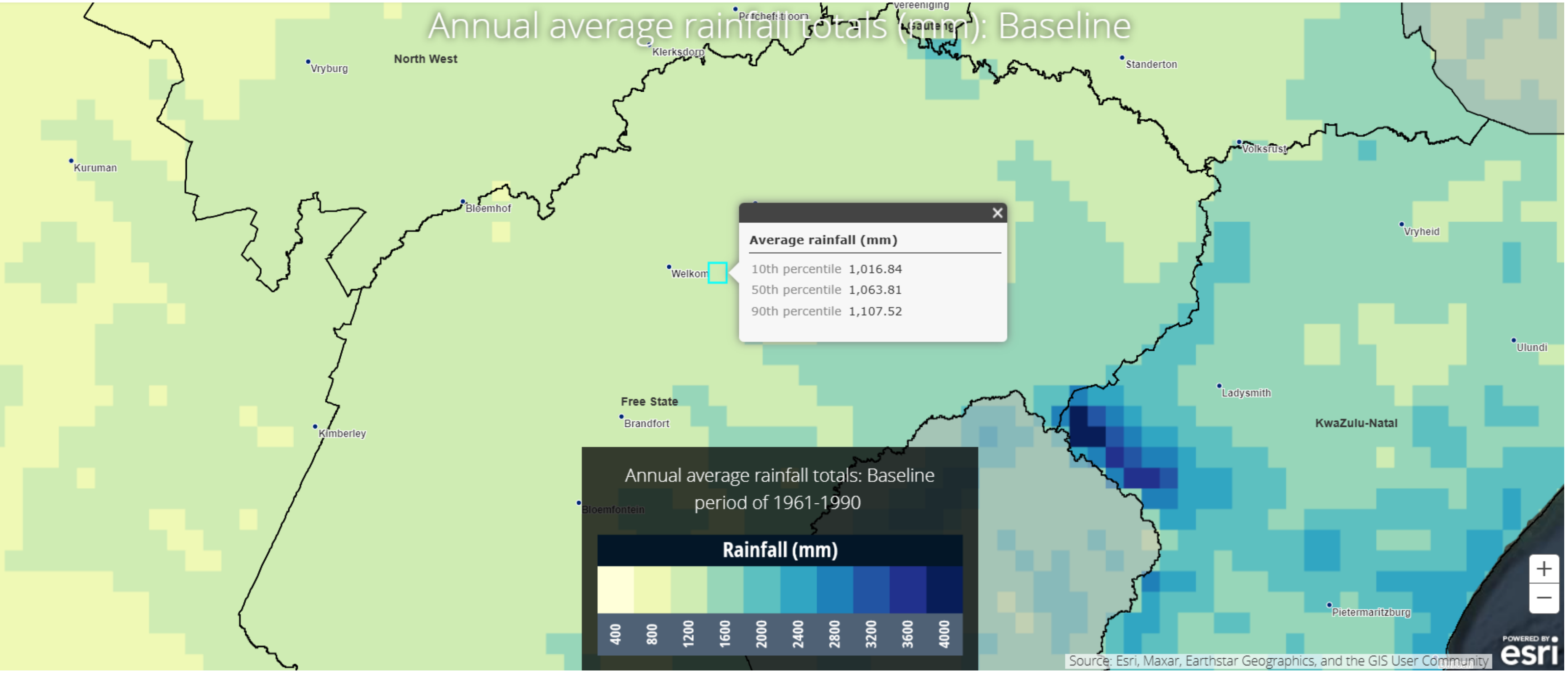


Figure 3-3: Baseline (1961 to 1990) annual average rainfall for the project area (CSIR, 2025)

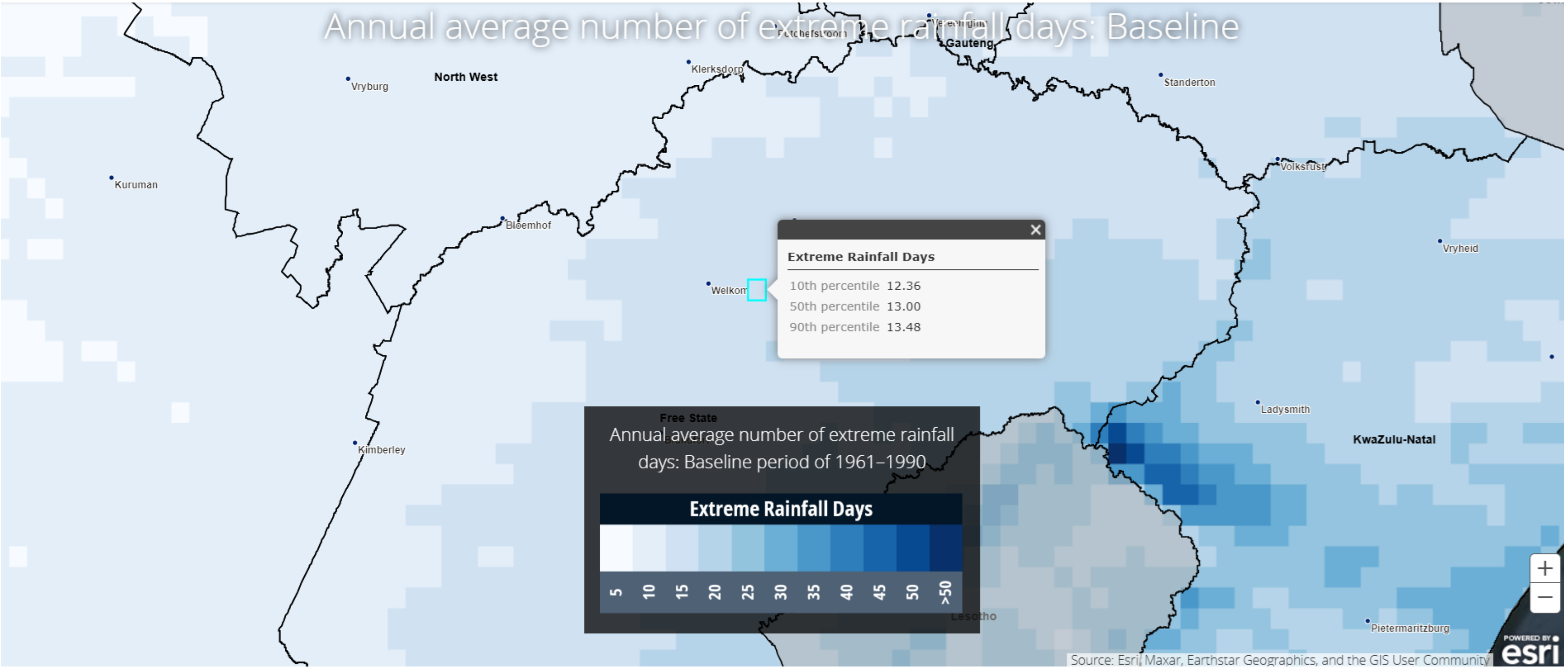


Figure 3-4: Baseline (1961 to 1990) annual average number of extreme rainfall days (>20 mm in <24 hours) for the project area (CSIR, 2025)

Recent change in climatic conditions near the project site were accessed from MeteoBlue[1], 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 2024, with a spatial resolution of 30 km. Based on Hennenman (located within the study area), an increasing trend in the annual average temperatures has been observed with temperatures measuring 16.7°C in 1979 to 18.1°C in 2024 (**Figure 3-5** – 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 – 2024) displays a slight decreasing trend (Figure 3-6), 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 3-6** (brown stripes indicate lower than average rainfall and green stripes above average rainfall).

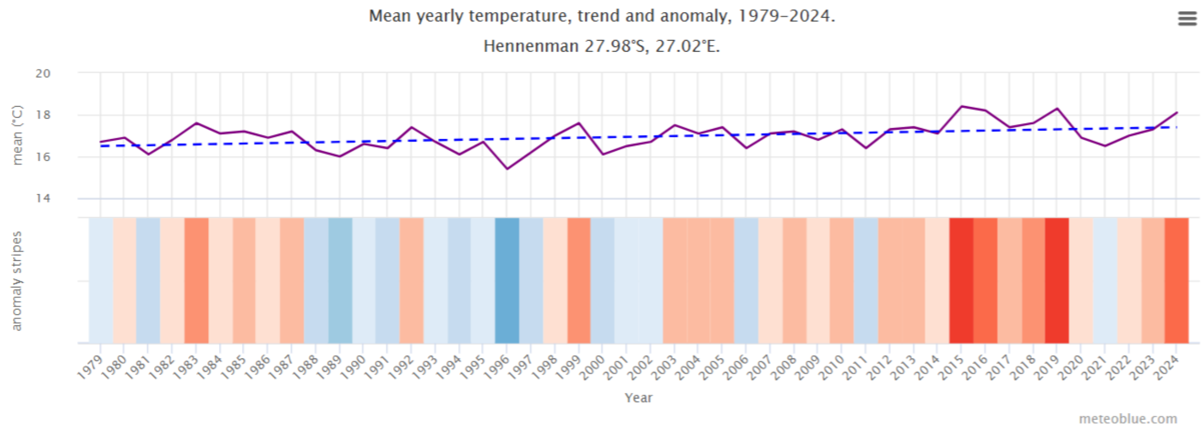


Figure 3-5: Annual average temperature (top panel) and temperature anomaly (lower panel) between 1979 and 2024 (meteoblue AG, 2025)

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

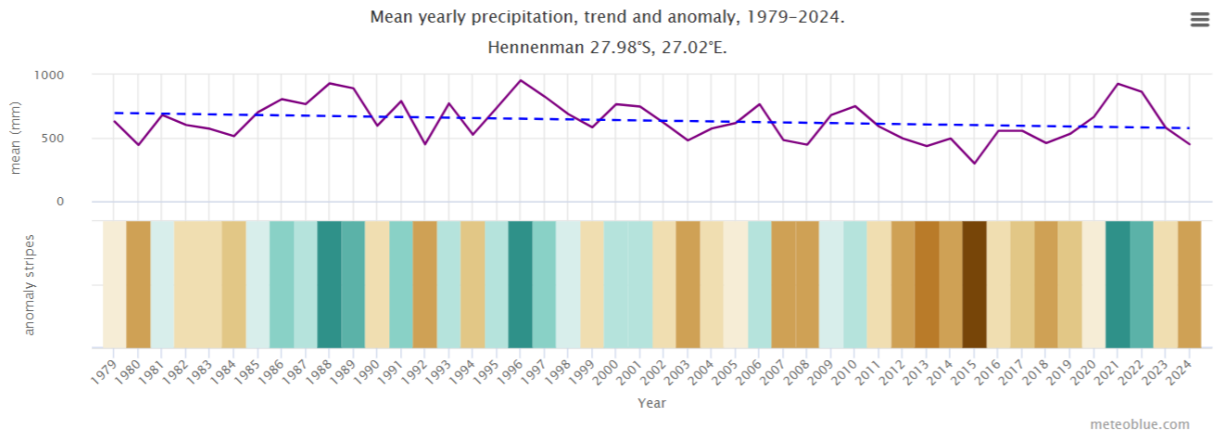


Figure 3-6: Annual average rainfall (top panel) and rainfall anomaly (lower panel) between 1979 and 2024 (meteoblue AG, 2025)

3.2.2 Projected Future Climate

In 2017 the South African Weather Services (SAWS) published an updated Climate Change Reference Atlas (CCRA) based on Global Climate Change Models (GCMs) projections (SAWS, 2017). It must be noted that as with all atmospheric models there is the possibility of inaccuracies in the results because of the model's physics and accuracy of input data. 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 GCMs, 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).

In both the CCRA and the Green Book, two trajectories are included based on the four Representative Concentration Pathways (RCPs) discussed in the IPCC's fifth assessment report (AR5) (IPCC, 2013). RCPs are defined by their influence on atmospheric radiative forcing in the year 2100. RCP4.5 represents an addition to the radiation budget of 4.5 W/m^2 as a result 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).

3.2.2.1 RCP4.5 Trajectory

The Green Book projected temperature changes in the near future (up to 2050) indicate a 50th percentile increase of 2.2°C and a 90th percentile increase of 2.8°C (**Figure 3-7**, Engelbrecht, et al., 2019). The number of very hot days are expected to increase to between 10.8 and 18.2 days per year (**Figure 3-8**). Between 2021 and 2050 the annual rainfall near the project site was projected to increase by 52 mm per year (50th percentile) (**Figure 3-9**, Engelbrecht, et al., 2019), with extreme rainfall days potentially increasing by 0.6 days (50th percentile) in the near future (**Figure 3-10,** Engelbrecht, et al., 2019).

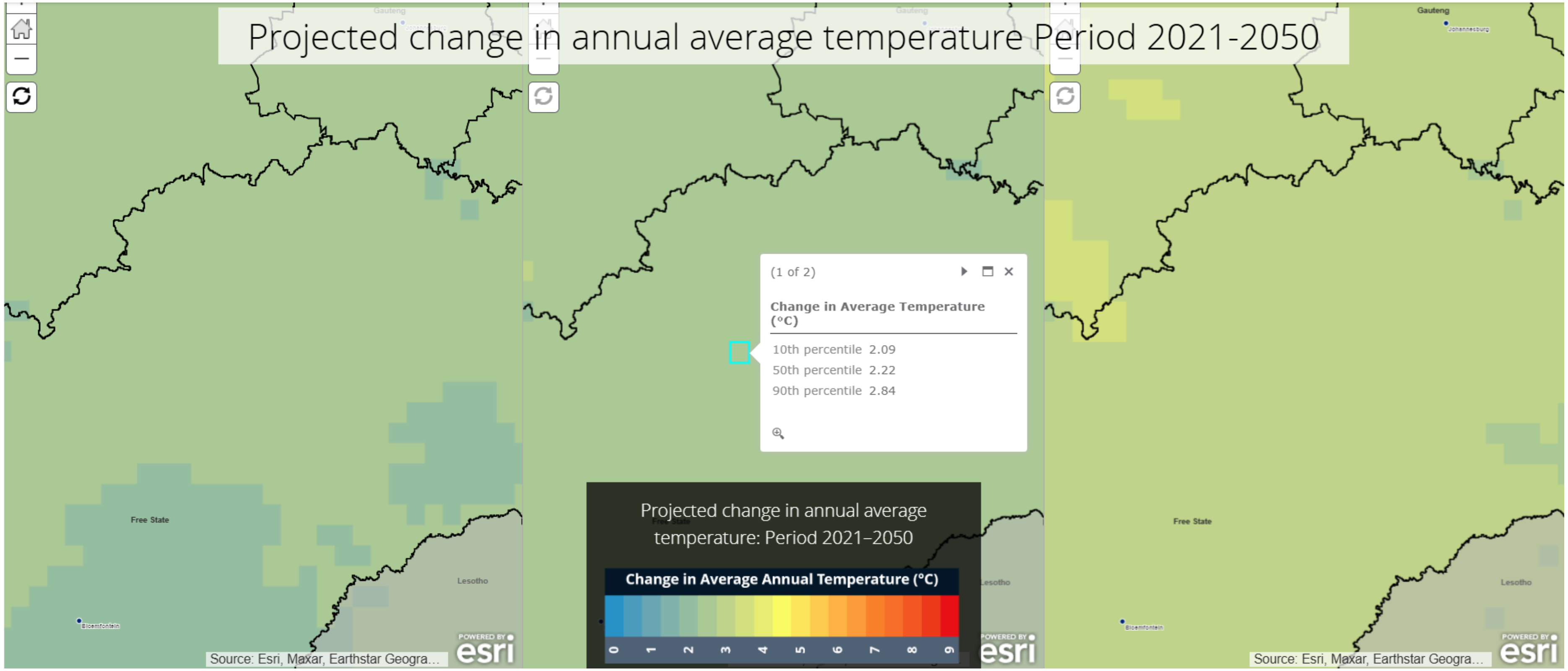


Figure 3-7: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP4.5 trajectory (from left to right, 10th, 50th, 90th percentile)

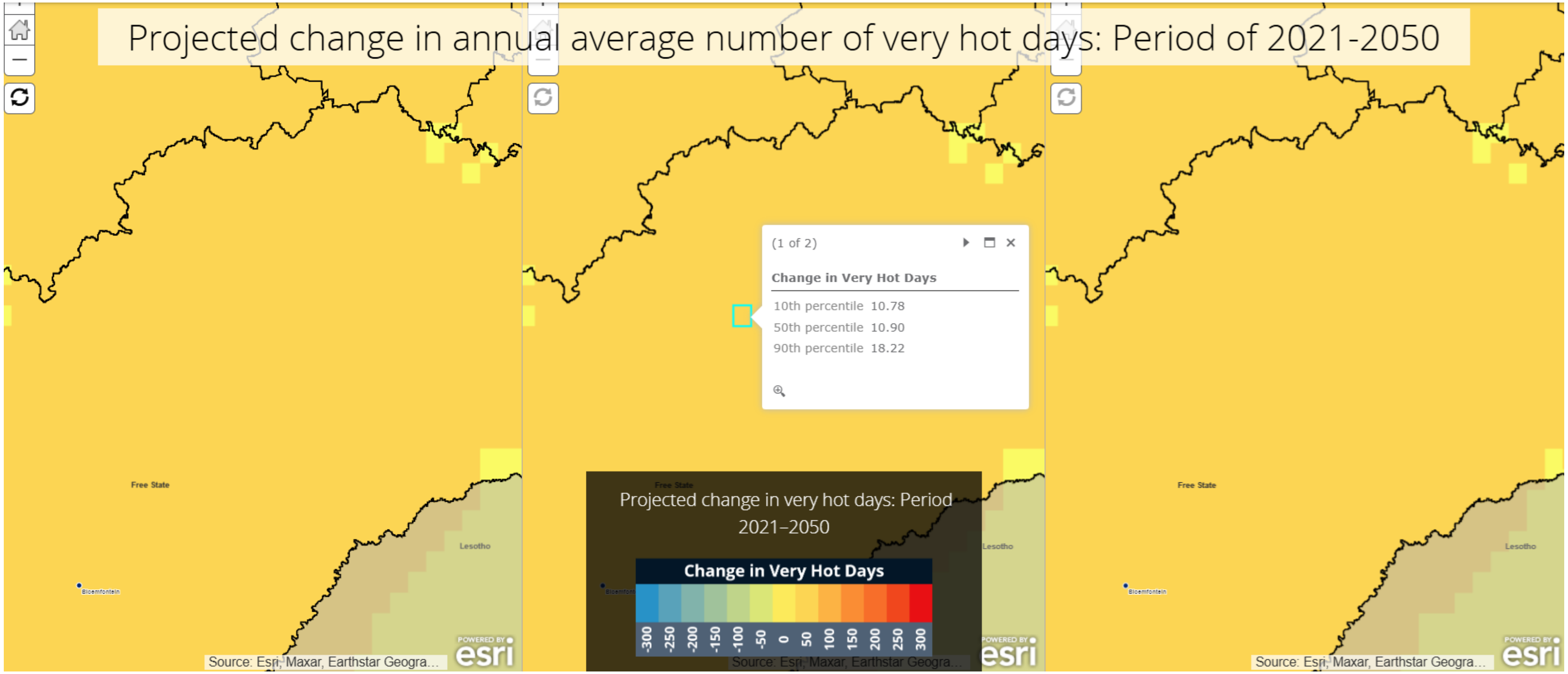


Figure 3-8: Projected change in very hot days for the near future (2021 – 2050) for the RCP4.5 trajectory (from left to right, 10th, 50th, 90th percentile)

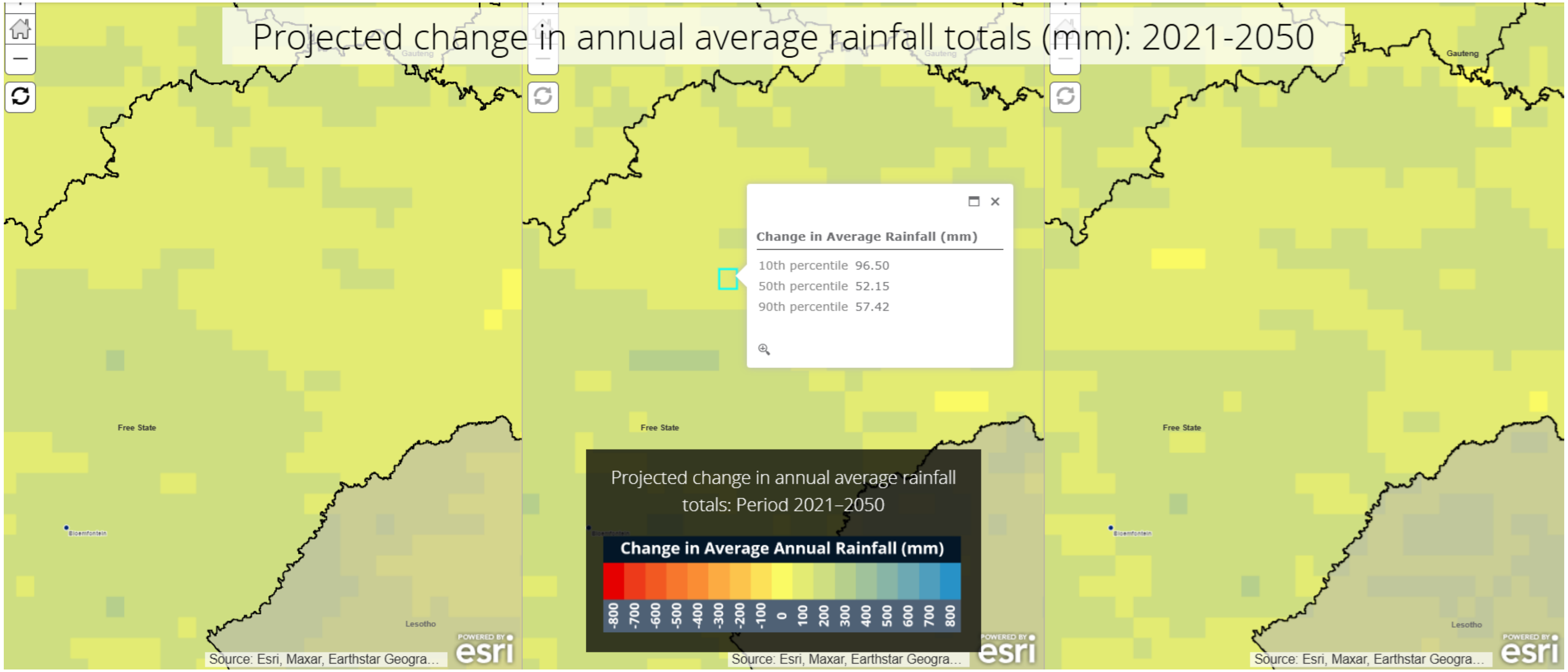


Figure 3-9: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP4.5 trajectory (from left to right, 10th, 50th, 90th percentile)

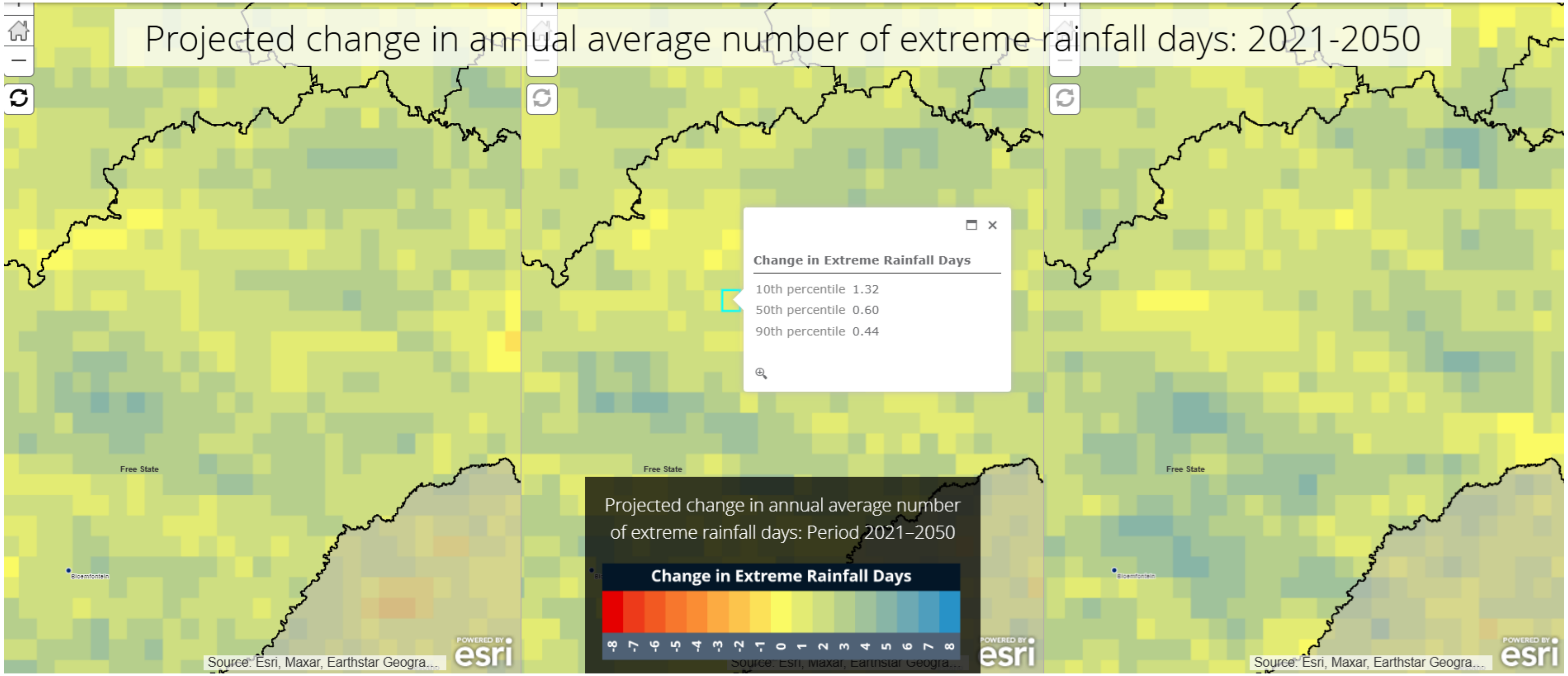


Figure 3-10: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP4.5 trajectory (from left to right, 10th, 50th, 90th percentile)

3.2.2.2 RCP8.5 Trajectory

The Green Book projected temperature changes in the near future (up to 2050) indicate a 50th percentile increase of 2.6°C and a 90th percentile increase of 3.2°C (**Figure 3-11**, Engelbrecht, *et al.*, 2019). The number of very hot days are expected to increase to 14.5 days per year (50th percentile) (**Figure 3-12**). Between 2021 and 2050 the annual rainfall near the project site was projected to increase by 112 mm per year between 2021 and 2050 (50th percentile) (**Figure 3-13**, Engelbrecht, *et al.*, 2019), with extreme rainfall days potentially increasing by 1.5 days (50th percentile) in the near future (**Figure 3-14**, Engelbrecht, *et al.*, 2019).

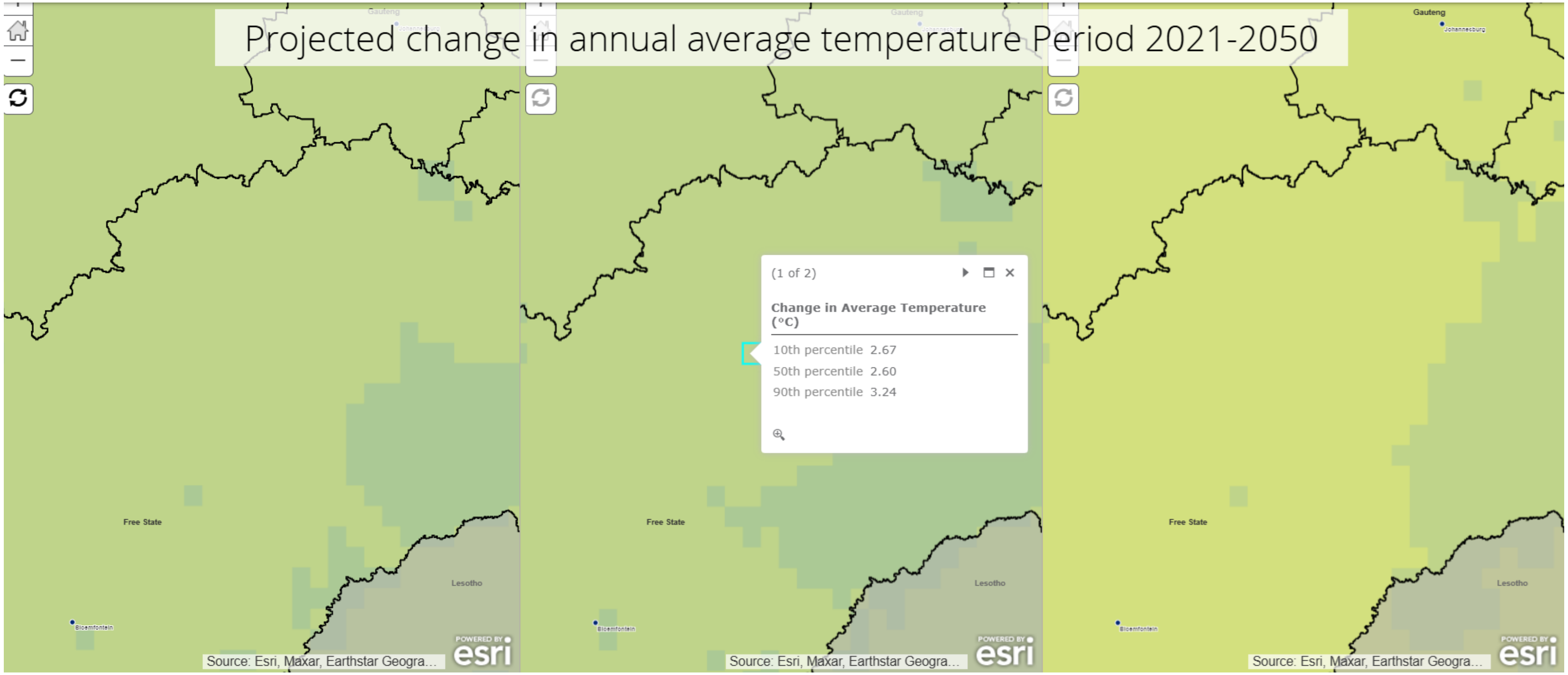


Figure 3-11: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP8.5 trajectory

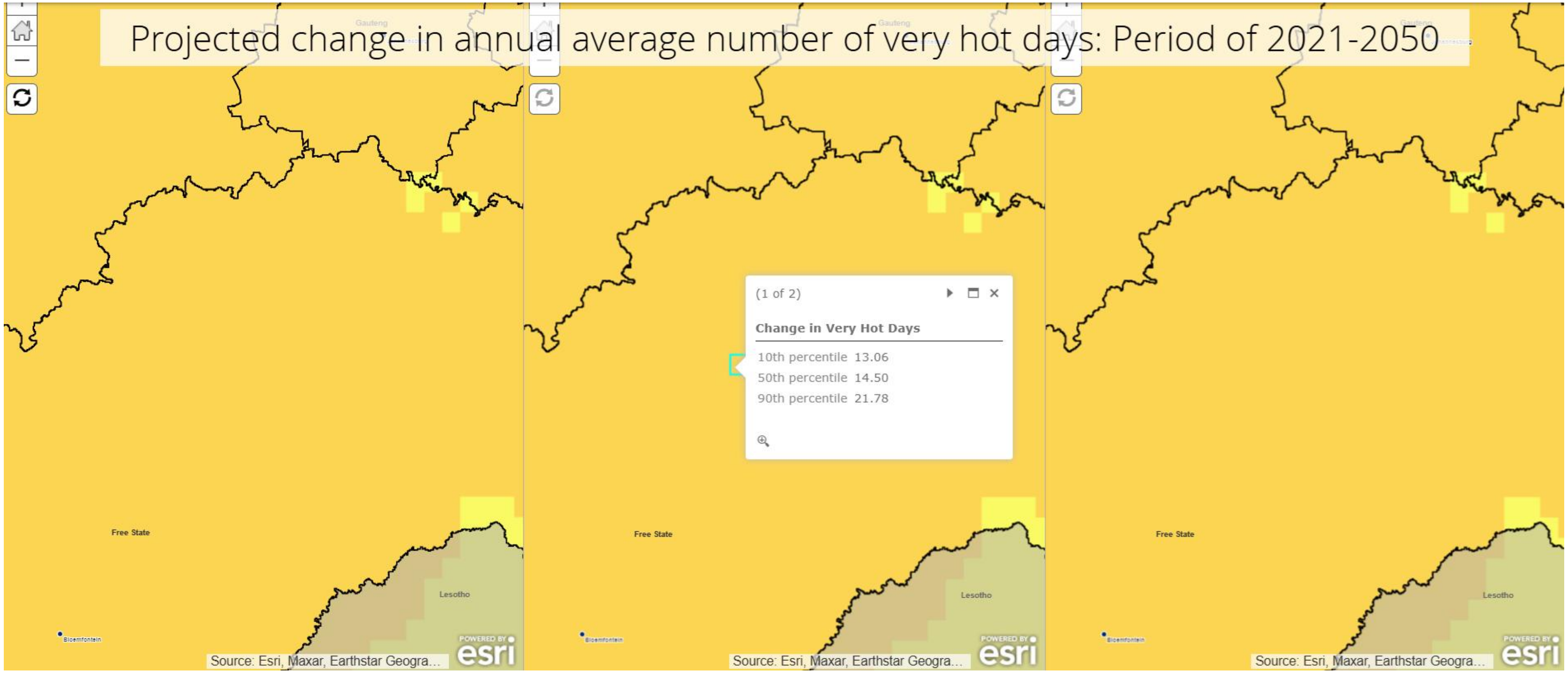


Figure 3-12: Projected change in very hot days for the near future (2021 – 2050) for the RCP8.5 trajectory

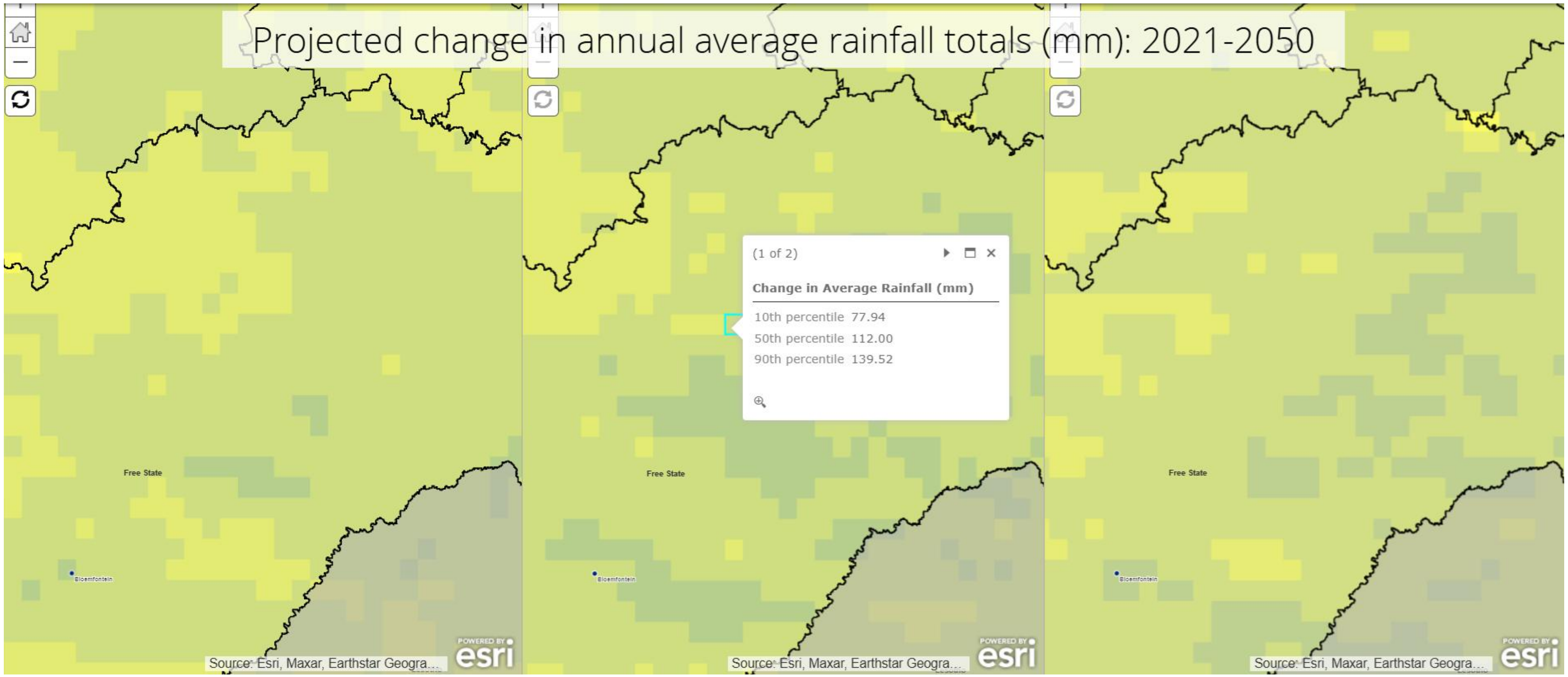


Figure 3-13: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP8.5 trajectory

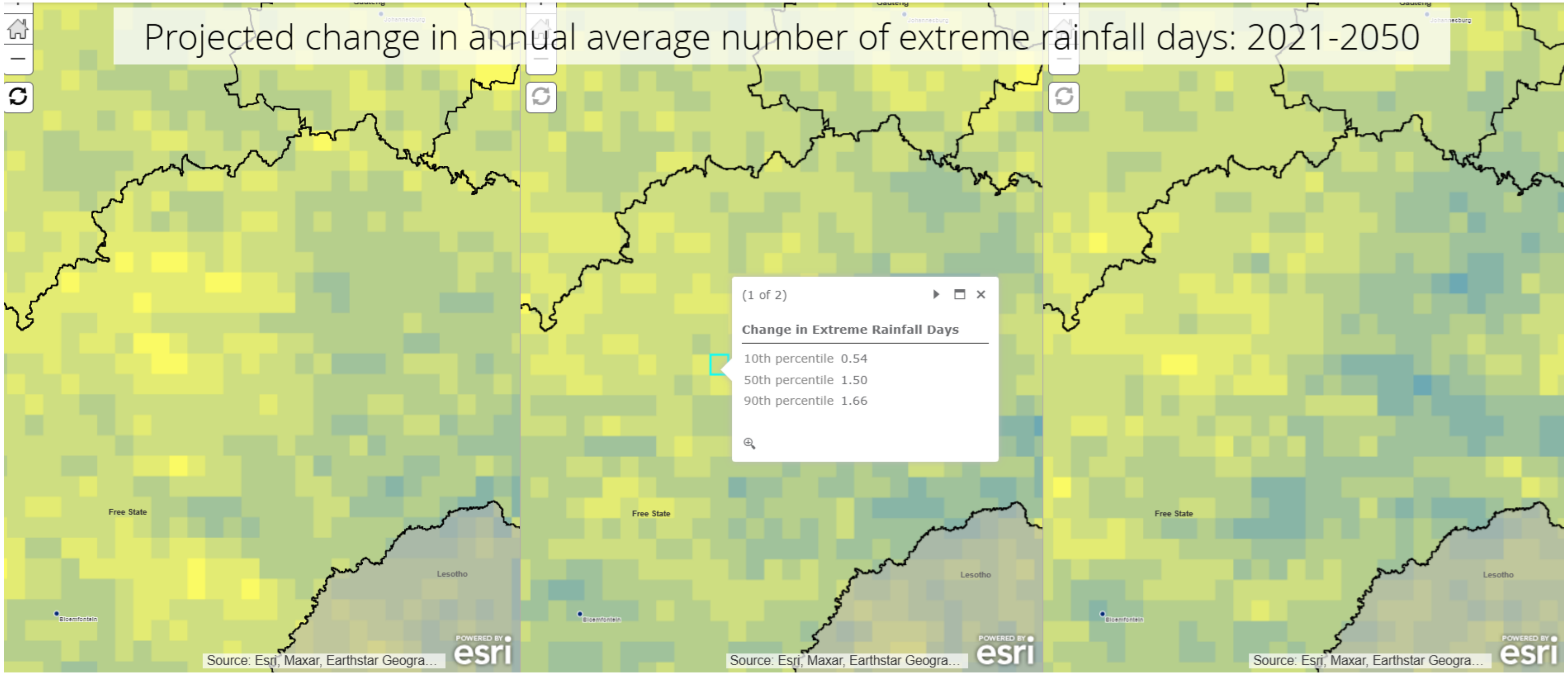


Figure 3-14: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP8.5 trajectory

3.2.2.3 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), 28 February 2022 (Working Group II and 4 April 2022 (Working Group III). Projection data is presented at a 1.0º x 1.0º (100 km x 100 km) resolution. 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).

The AR6 projections for the study area for the scenario RCP4.5 indicate an increase in annual average temperatures of 1.6°C for the period 2041 to 2060 and 2.2°C for the period 2081 to 2100. The projections for the RCP8.5 indicate an increase in annual average temperatures of 2.1°C for the period 2041 to 2060, to 4.9°C for the period 2081 to 2100 (IPPC, 2022). The AR5 projections, for comparison, estimate an increase in annual average temperatures (50^{th} percentile) of 2.2°C for RCP4.5 and 2.6°C for RCP8.5 for the period 2021 to 2050.

The AR6 projections for rainfall in the study area for RCP4.5 indicate a decrease in annual rainfall of 0.9% for the period 2041 to 2060, to 1.2% for the period 2081 to 2100. The projections for RCP8.5 indicate an increase in rainfall of 1.1% for the period 2041 to 2060, to a decrease of 5.8% for the period 2081 to 2100 (IPPC, 2022).

3.3 Hazards

The Green Book risk profile includes an assessment of projected risk to the Matjhabeng and Moqhaka Municipalities in 2050, mostly based on the low mitigation RCP8.5 climate simulations, and highlights the following:

- Isolated pockets of moderate and high increased risk of wildfires within the project area (**Figure 3-15**);
- Isolated pockets of very low risk of increased drought frequency within the project area and the Standardized Precipitation Index (SPI)[1] of -0.38 (**Figure 3-16**);
- Isolated pockets of high increased heat extremes within the project area (**Figure 3-17**); and,
- Areas of slight to moderate risk of increased extreme rainfall days within the project area (**Figure 3-18**).

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

- Isolated pockets of low increase in exposure to urban flooding is expected for the project area (**Figure 3-18**).

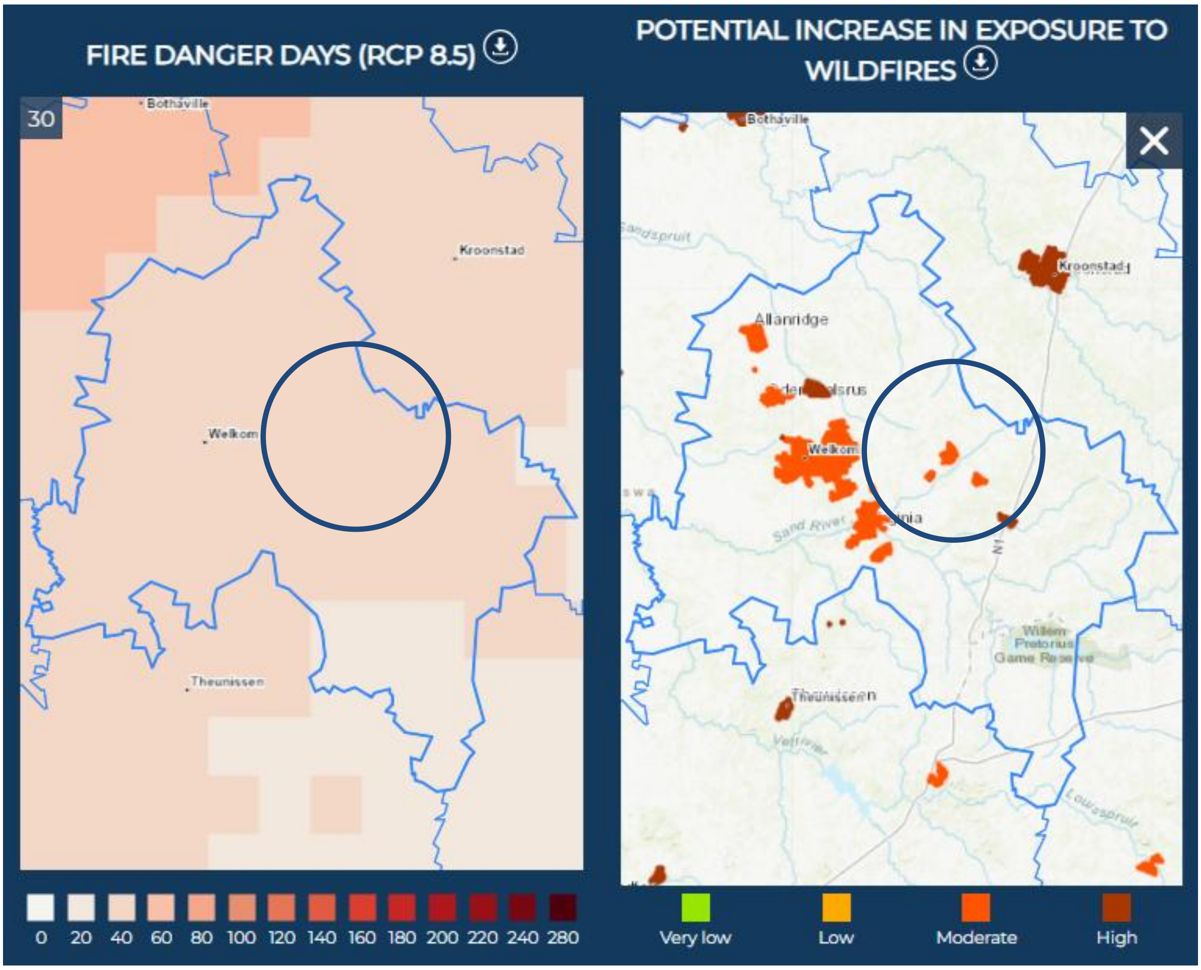


Figure 3-15: Risk of increased wildfires for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

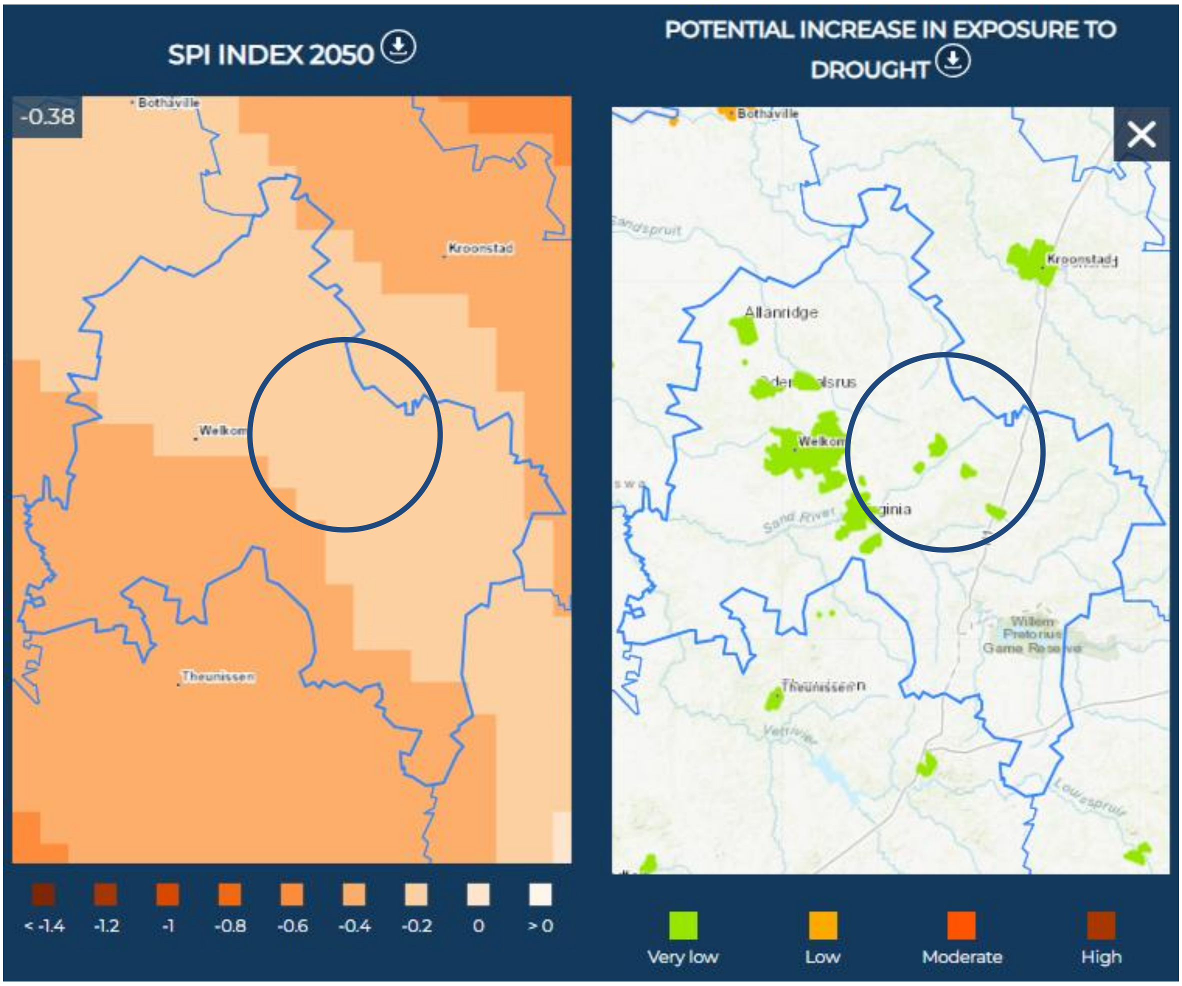


Figure 3-16: Risk of increased drought tendencies for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

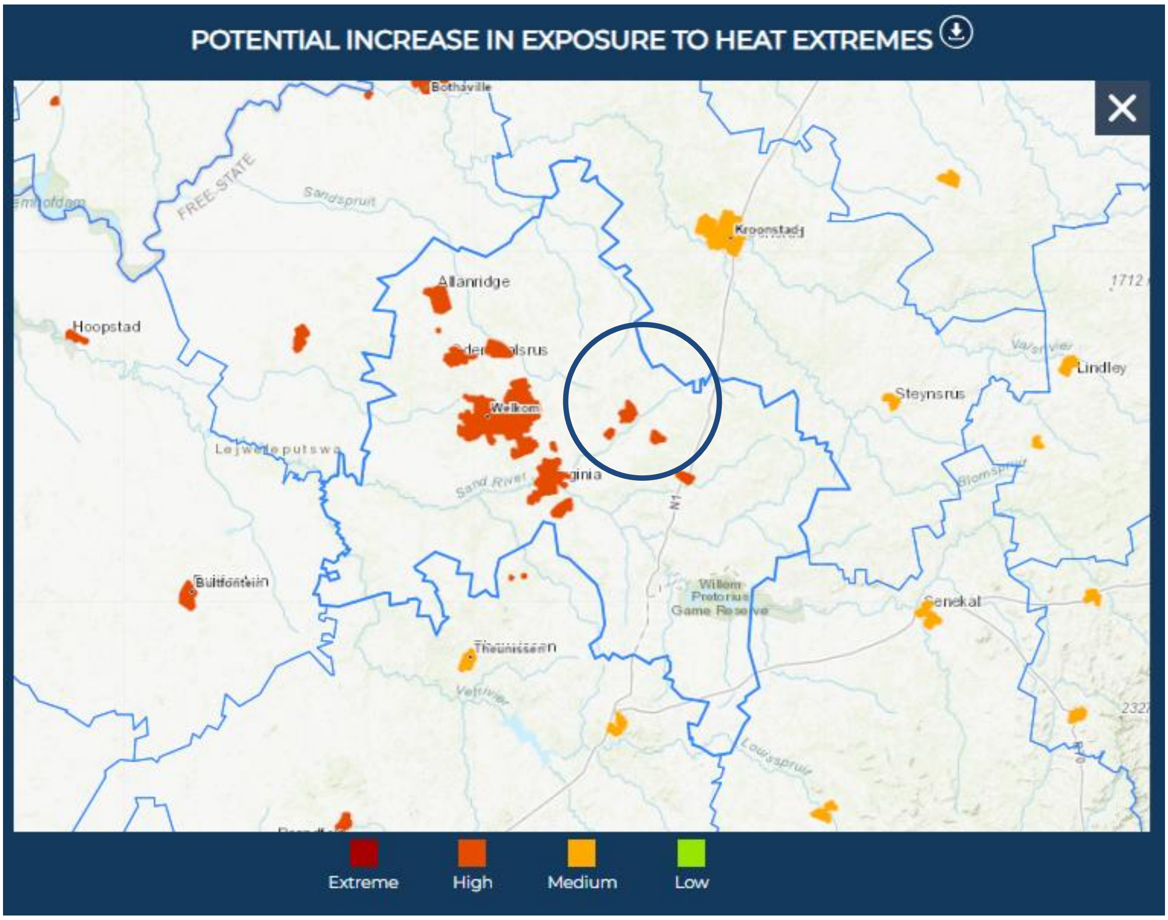


Figure 3-17: Risk of increased heat extremes for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

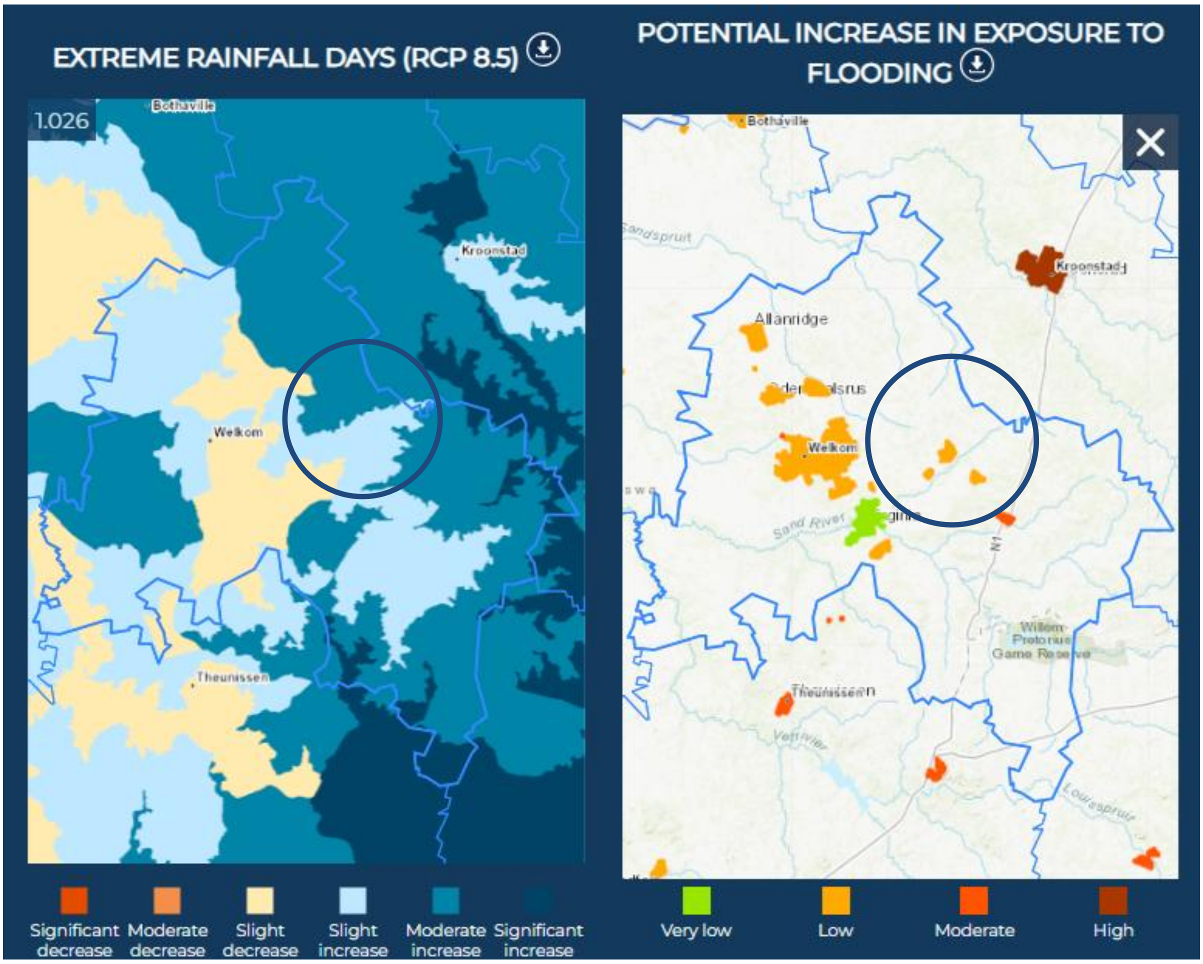


Figure 3-18: Risk of increased flooding for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

In addition to the hazards identified in the Green Book, Hofste, *et al.,* (2019) currently rate the project area as arid and low water use (**Figure 3-19**) with a near normal water stress projection for the future (2050 based on a conservative low mitigation trajectory) (**Figure 3-20**).

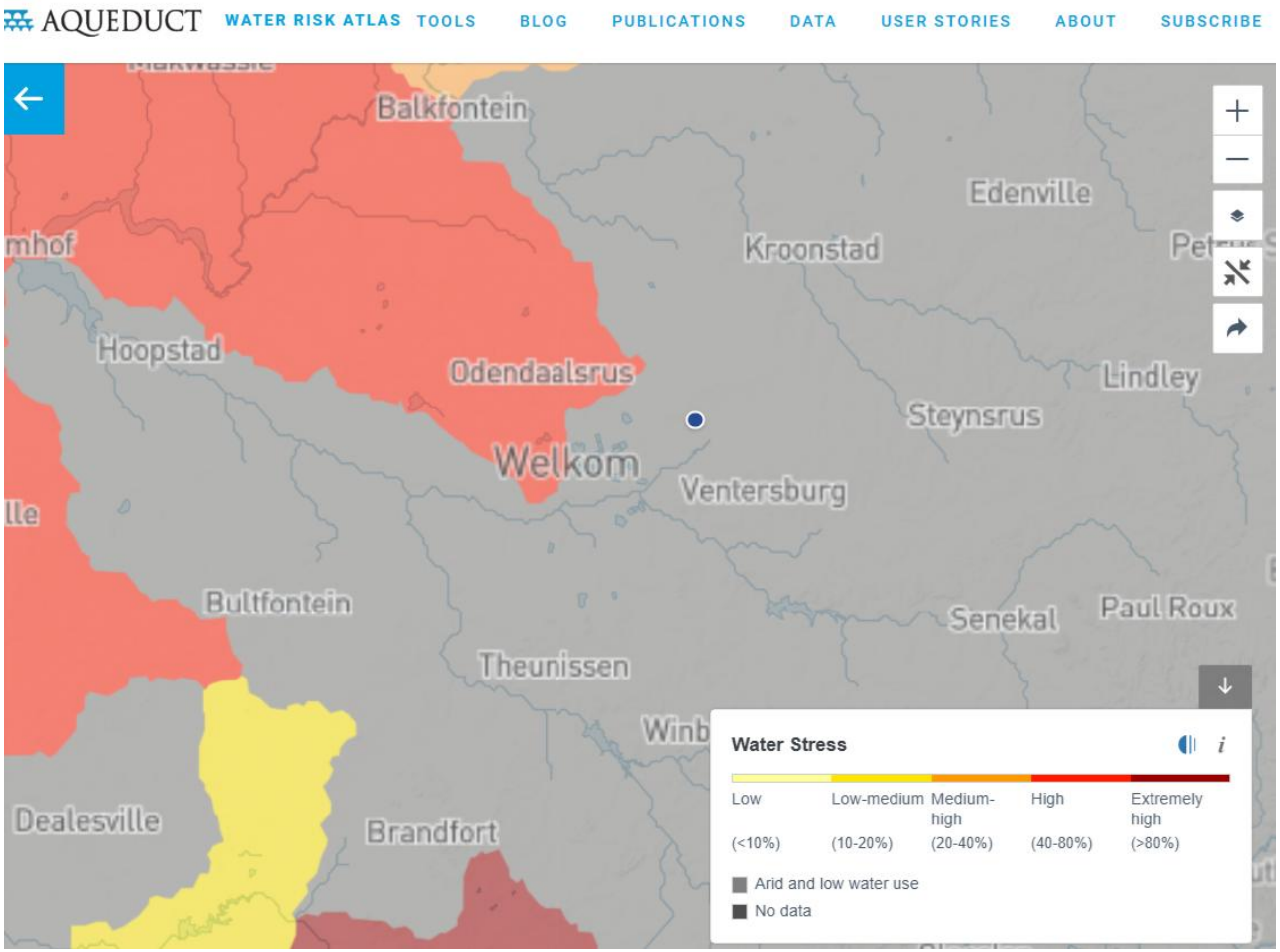


Figure 3-19: Current water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

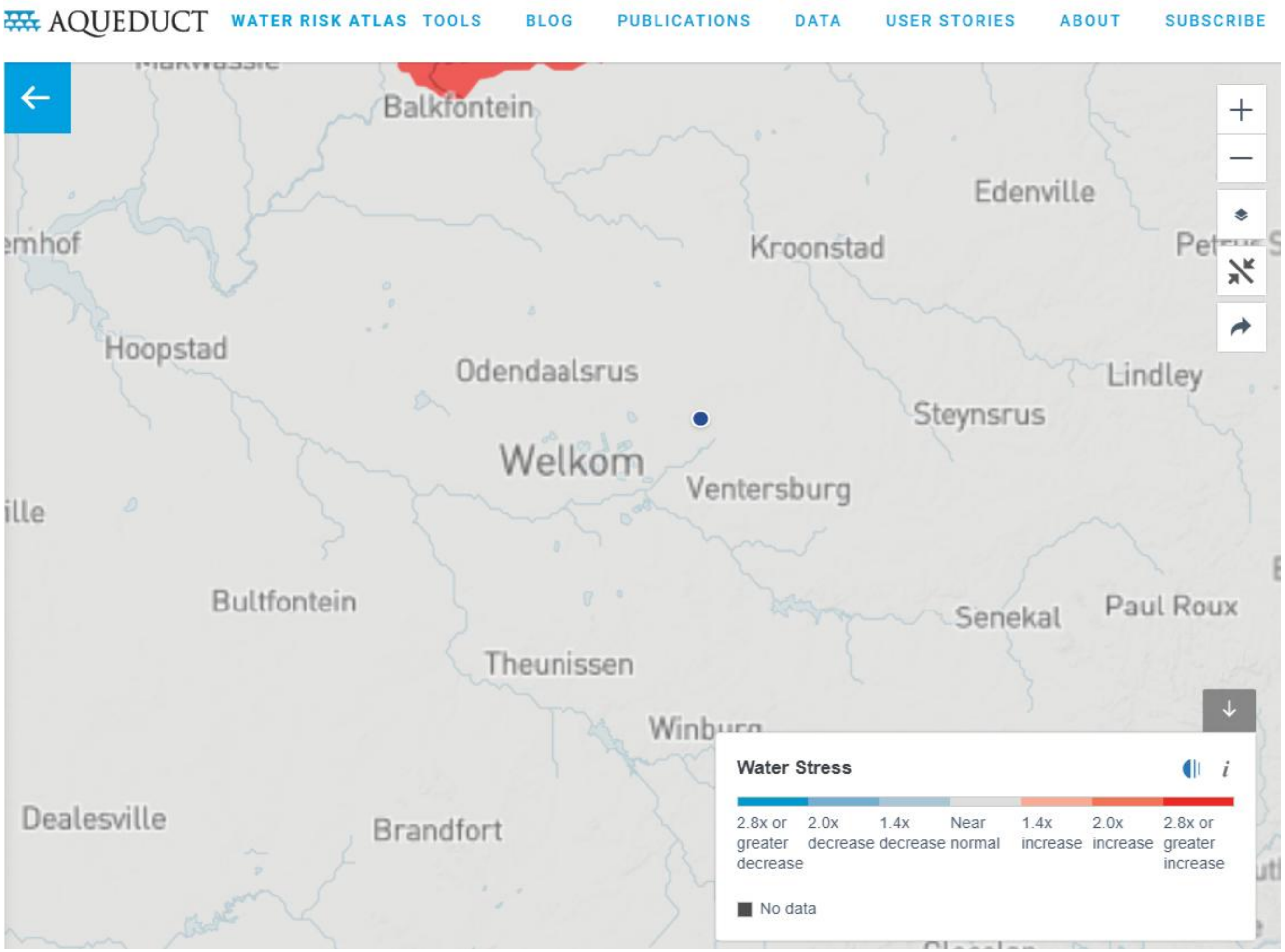


Figure 3-20: Projected (2050) water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

3.4 Impact of Climate Change

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

3.4.1 Water Supply

3.4.1.1 Current Resources

Figure 3-21 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, Bailey, Cullis, & New, 2017). The current water demand for the municipality is 207 l/p/d (litres per person per day) with supply of 144.5 l/p/d, with 100% sourced from surface water.

Figure 3-22 provides the current water supply vulnerability (i.e., demand versus supply) for the Moqhaka Municipality (1.48) based on the data compiled for the Department of Water and Sanitation (DWS) All Town's Study (Cole, Bailey, Cullis, & New, 2017). The current water demand for the municipality is 306 l/p/d (litres per person per day) with supply of 207 l/p/d, with 100% sourced from surface water.

SURFACE WATER USAGE	
Demand Per Capita (l/p/d)	207.07
Supply Per Capita (l/p/d)	144.54
Current Vulnerability	1.43

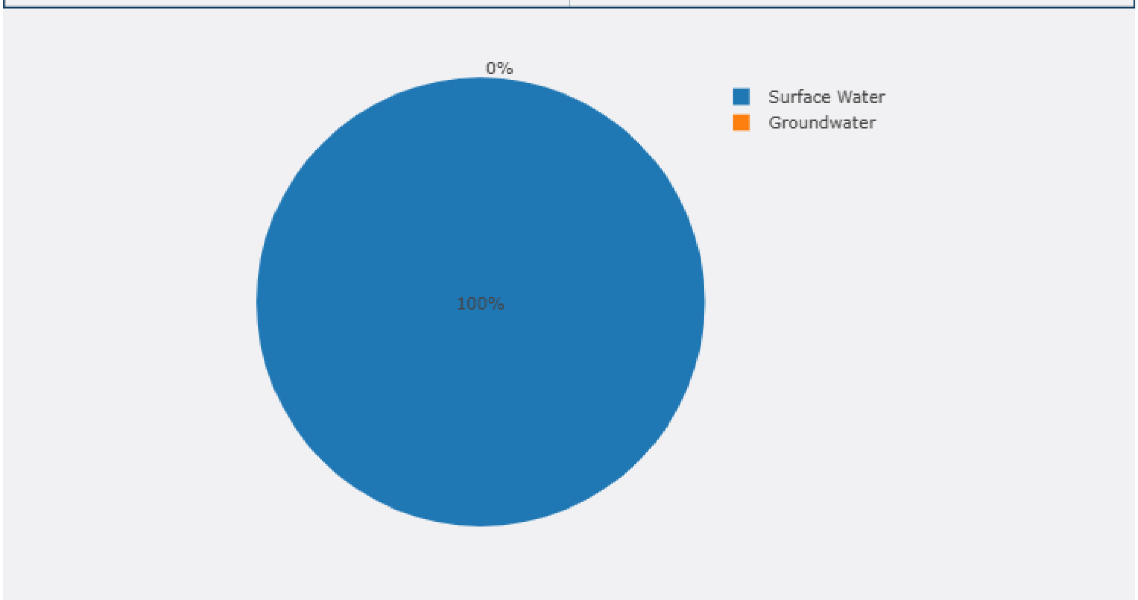


Figure 3-21: Current water availability for the Matjhabeng Municipality

SURFACE WATER USAGE	
Demand Per Capita (l/p/d)	306.06
Supply Per Capita (l/p/d)	207.36
Current Vulnerability	1.48

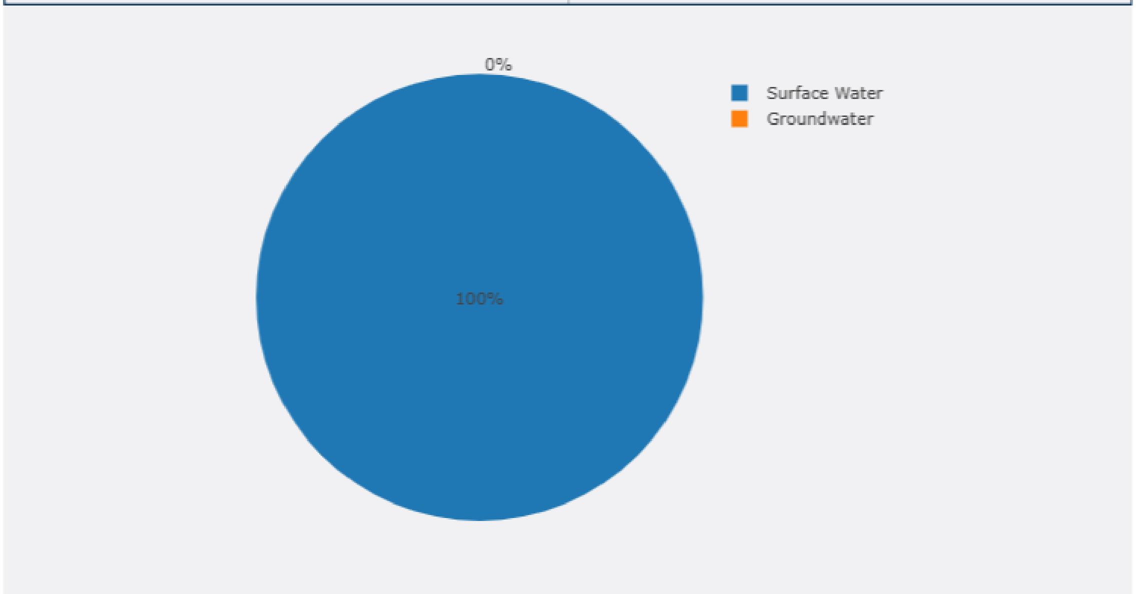
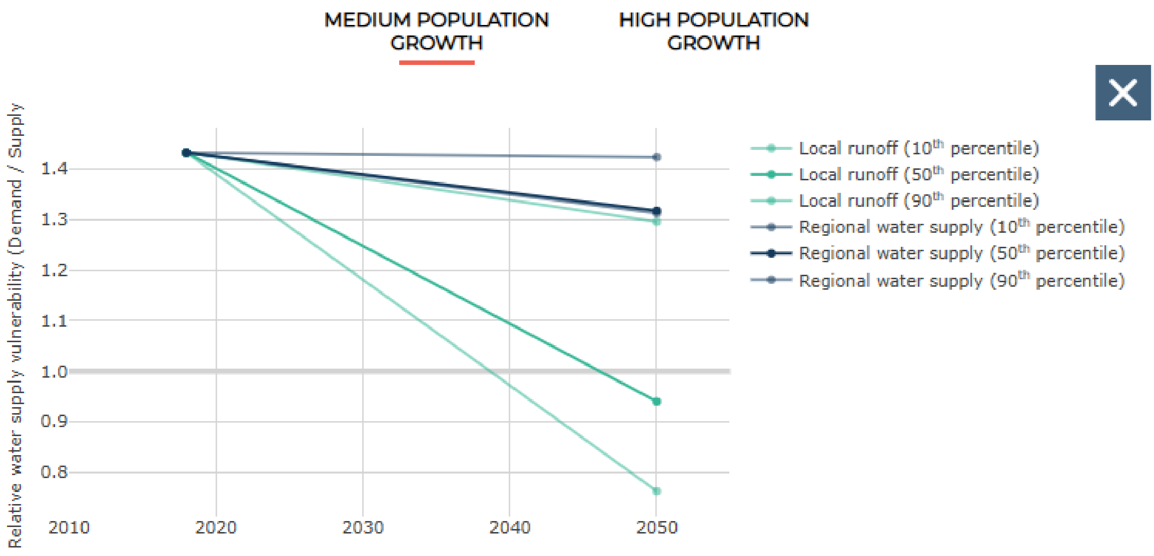


Figure 3-22: Current water availability for the Moqhaka Municipality

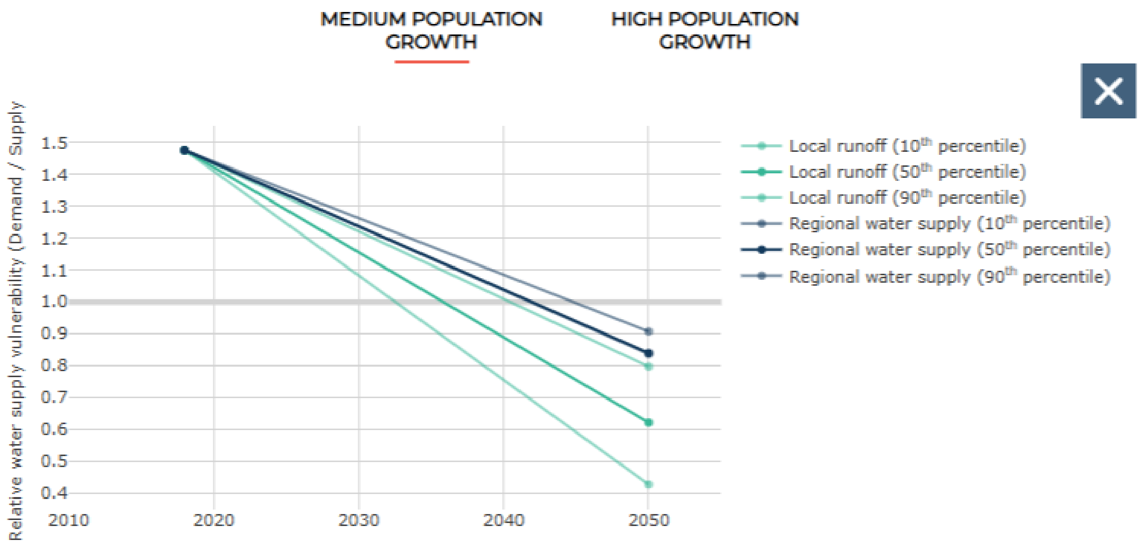
3.4.1.2 Impact on Resources

Figure 3-23 and **Figure 3-24** 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 Matjhabeng and Moqhaka municipalities is predicted to increase by 6.5% and 3.75% respectively for 2050 with a regional urban water supply increase of 11.9% and 3.4% respectively.



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 3-23: Estimated current and future (2050) water supply vulnerability based on medium population growth for the Matjhabeng Municipal



VULNERABILITY CONTRIBUTION FACTORS		PERCENTAGE CHANGE
Mean annual precipitation	▲	3.75%
Mean annual evaporation	▲	9.14%
Mean annual runoff	▲	39.64%
Regional urban water supply	▲	3.43%
Population growth	▼	-46.05%

Figure 3-24: Estimated current and future (2050) water supply vulnerability based on medium population growth for the Moqhaka Municipal

3.4.2 Surface Water

3.4.2.1 Current Situation

The Matjhabeng Municipality is within the Vaal Primary Catchment (**Figure 3-25**).

Figure 3-26 and **Figure 3-27** depicts the current annual and monthly surface water runoff, precipitation and evaporation for the Vaal Primary Catchment associated with the Matjhabeng and Moqhaka municipalities respectively. Precipitation and evaporation for the Matjhabeng Municipality is currently 533 mm/yr and 1 615 mm/yr respectively. Precipitation and evaporation for the Moqhaka Municipality is currently 565 mm/yr and 1 615 mm/yr respectively.

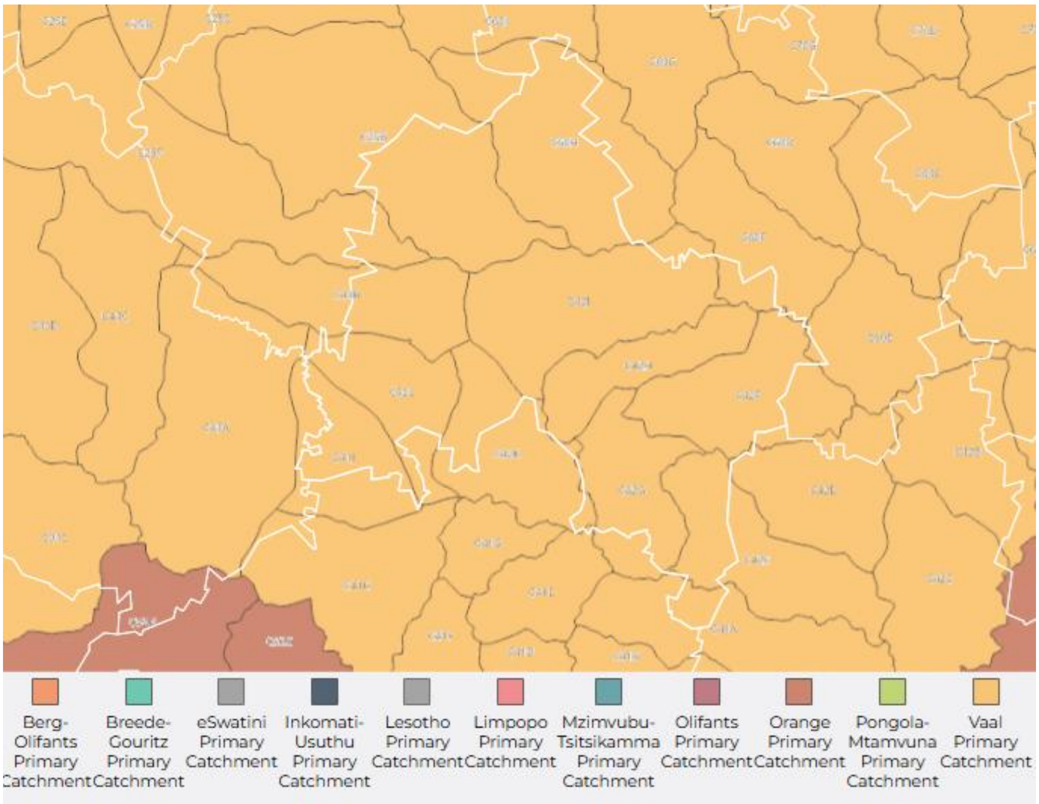


Figure 3-25: Quaternary catchment areas for the study area

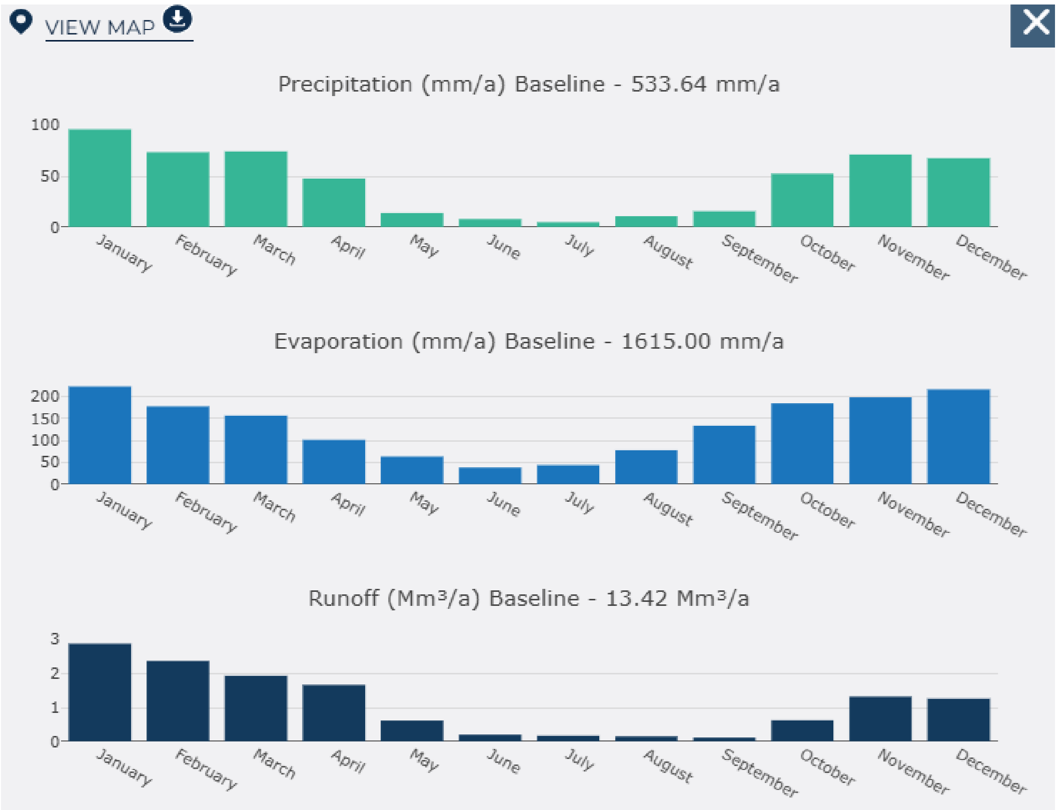


Figure 3-26: Current annual and monthly surface water runoff, precipitation and evaporation for the Matjhabeng Municipality which falls under the Vaal Primary Catchment

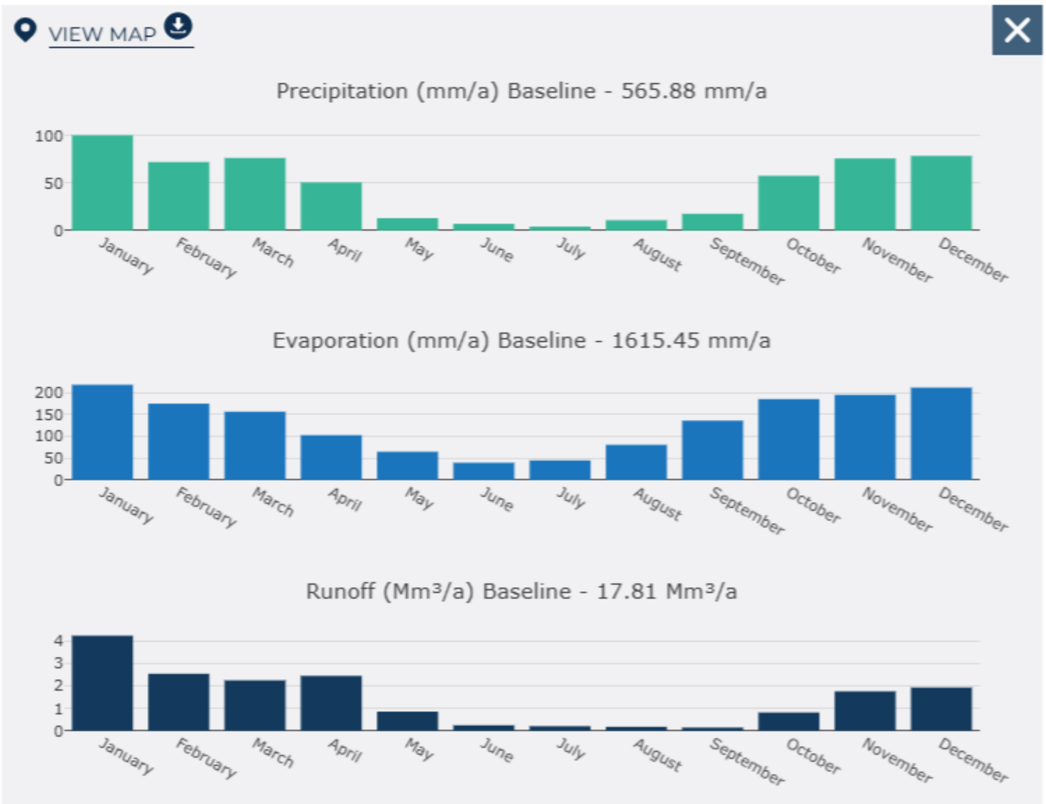


Figure 3-27: Current annual and monthly surface water runoff, precipitation and evaporation for the Moqhaka Municipality which falls under the Vaal Primary Catchment

3.4.2.2 Projected Impact

Figure 3-28 and **Figure 3-29** provides the projected monthly change for future (2050) evaporation, precipitation, and estimated runoff values for the Matjhabeng and Moqhaka municipalities respectively.

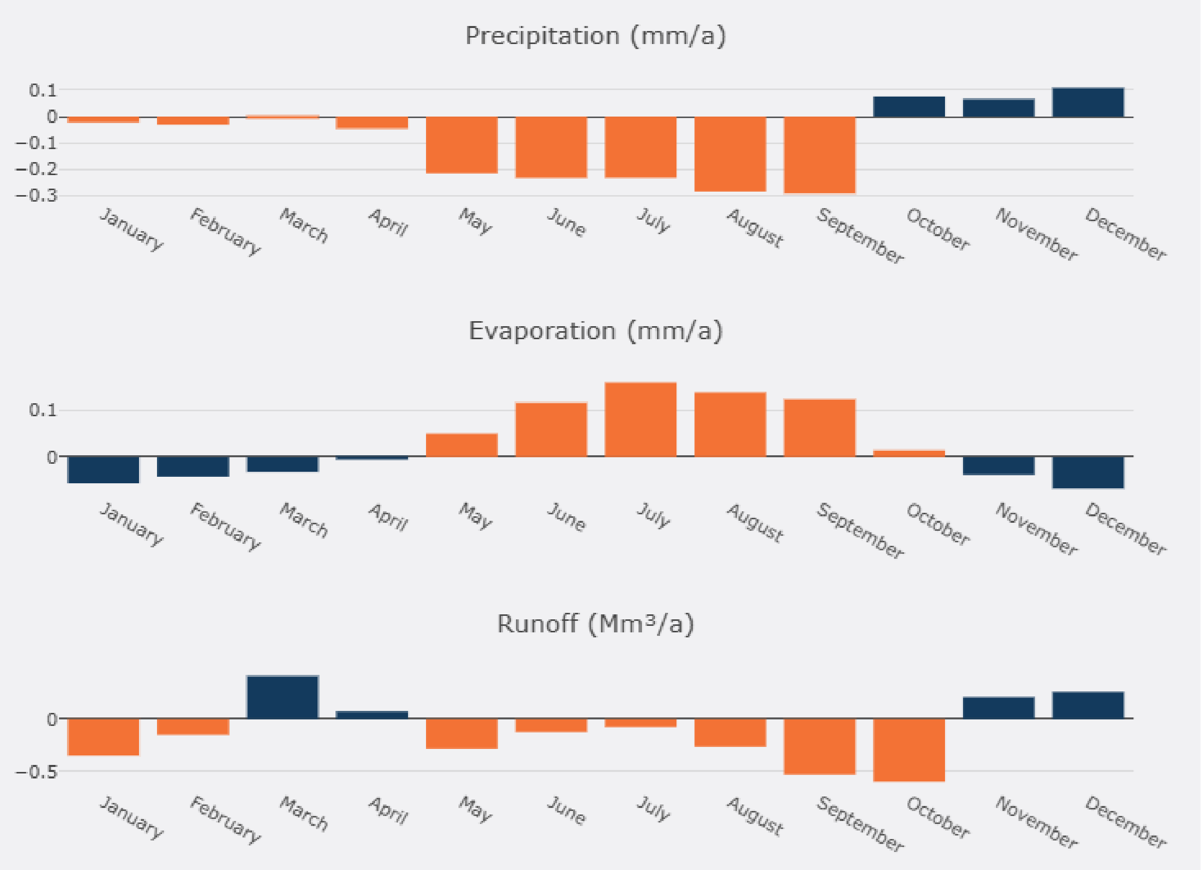


Figure 3-28: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values for the Matjhabeng Municipality

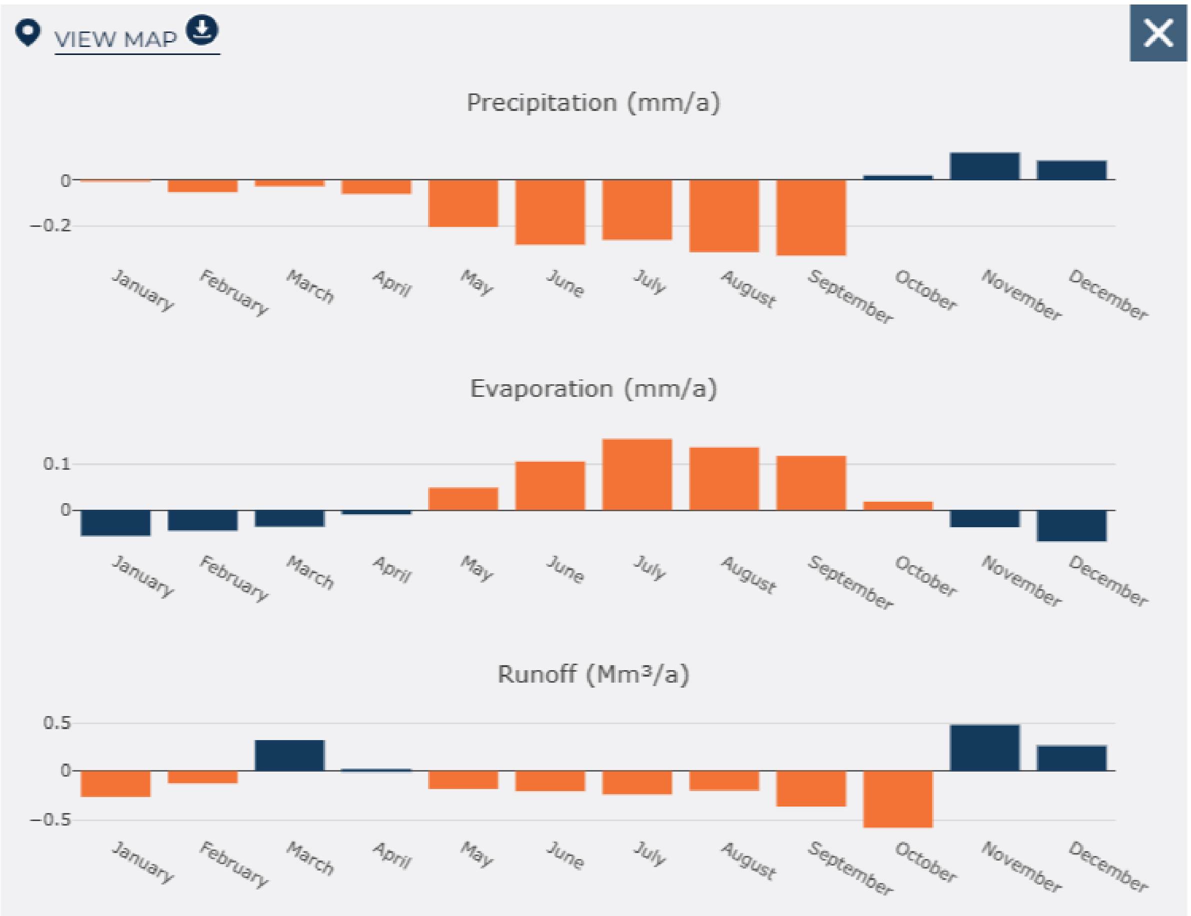


Figure 3-29: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values for the Moqhaka Municipality

3.4.3 Ground Water

3.4.3.1 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 residential settlements within the project area are surface water dependent.

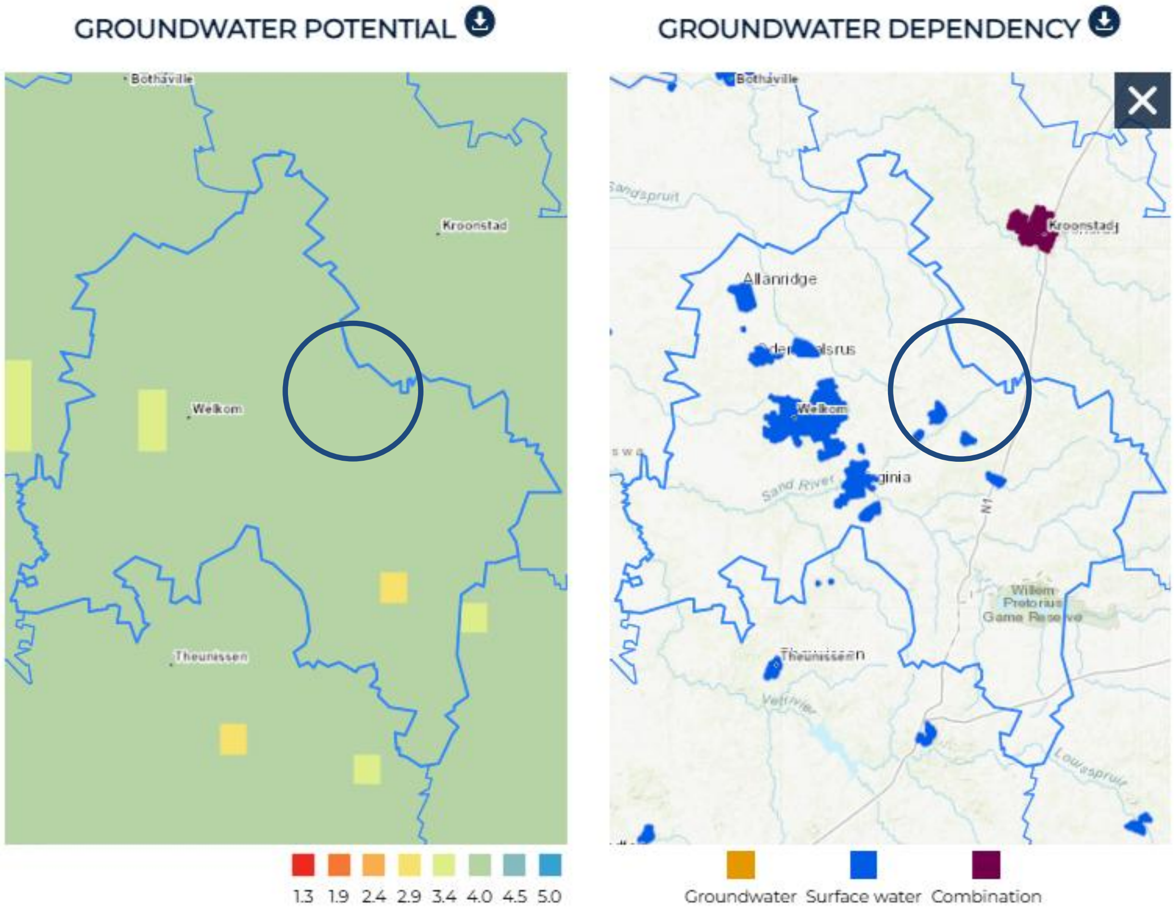


Figure 3-30: Groundwater potential and dependency for the Matjhabeng and Moqhaka Municipality (dark blue marker indicates approximate location of the project)

3.4.3.2 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 3-31**) 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 groundwater depletion risk within the study area.

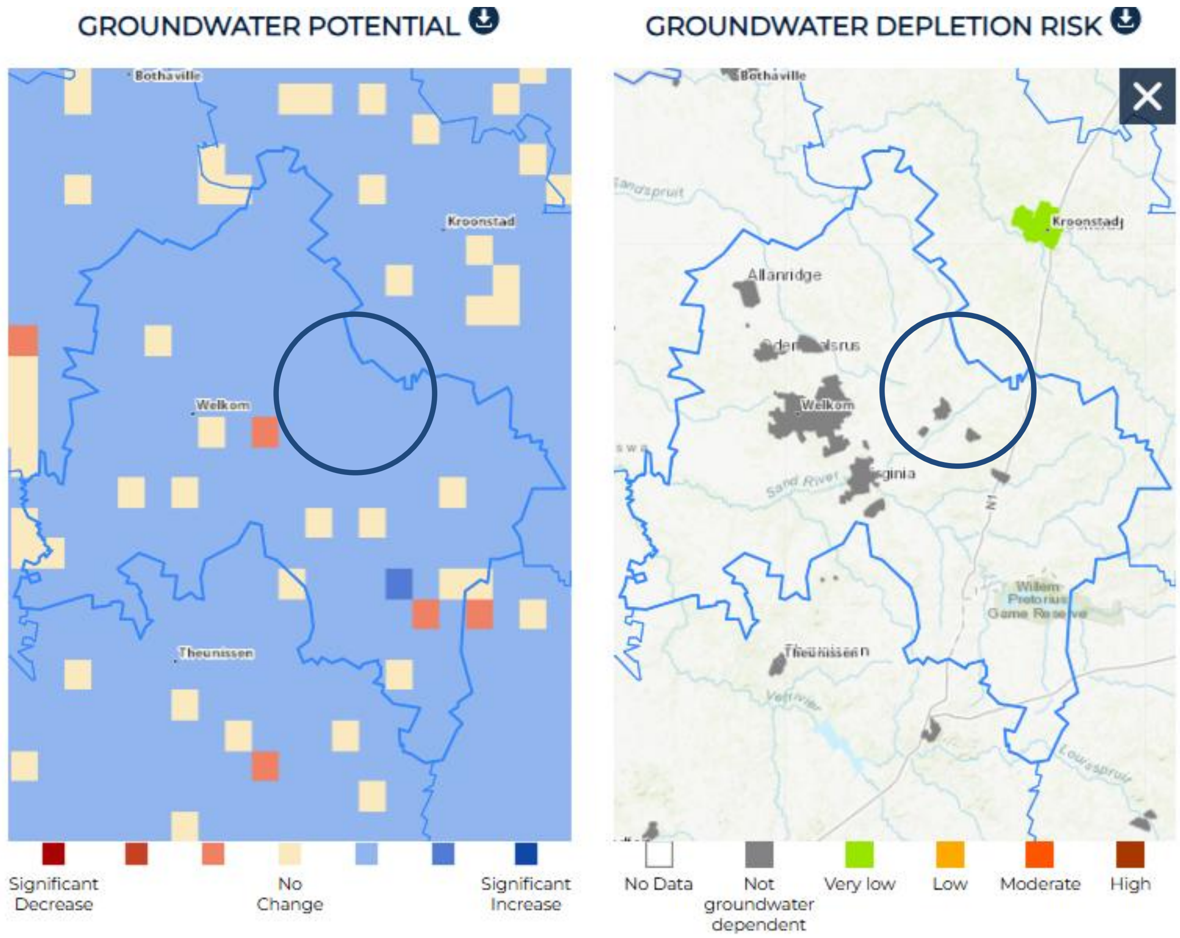


Figure 3-31: Groundwater potential and depletion for 2050 for the Matjhabeng and Moqhaka Municipality (dark blue marker indicates approximate location of the project)

3.4.4 Economy

Figure 3-32 and **Figure 3-33** shows the contribution that the different economic sectors make to the total Gross Value Added (GVA)[13] of the Matjhabeng Municipality and the Moqhaka Municipality respectively as well as its national GVA rank (total GVA contribution to the national GVA). Mining and quarrying activities make up the highest economic sector to the total GVA at 41.1%. The Matjhabeng Municipality ranks 15th in the national GVA rank with mining and quarrying activities making up the highest economic sector to the total GVA at 41.1%. The Moqhaka Municipality ranks 49th in the national GVA rank with government and community, social and personal services making up the highest economic sector to the total GVA at 26.1%. Mining and quarrying activities make up the second highest economic sector to the total GVA at 19.6%.

[13] 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.

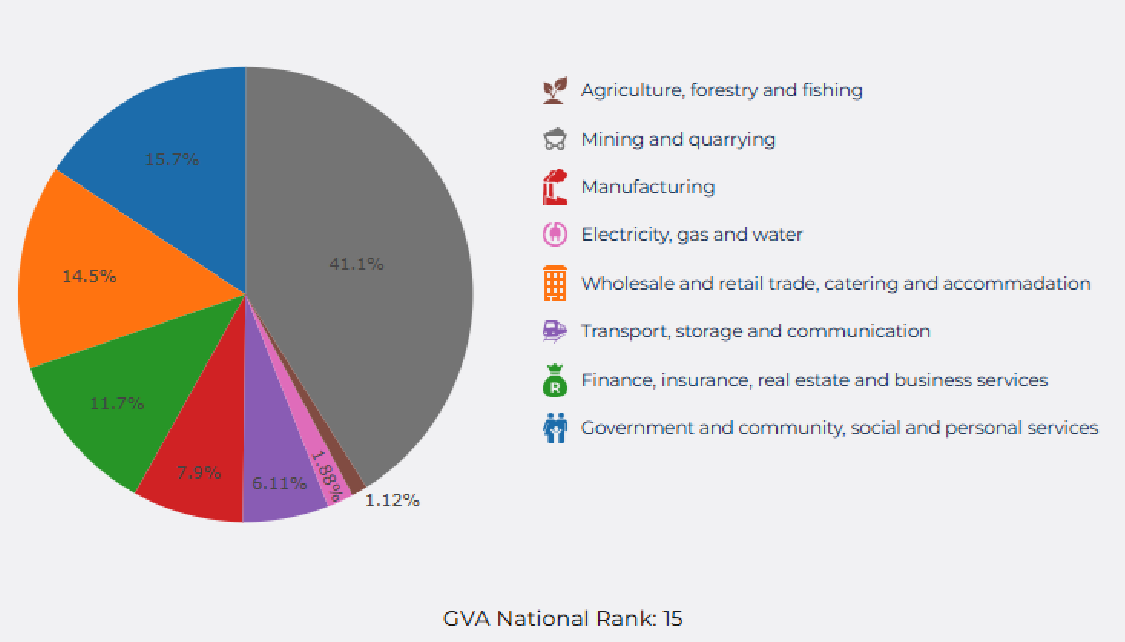


Figure 3-32: The contribution that the different economic sectors make to the total GVA of the Matjhabeng Municipality

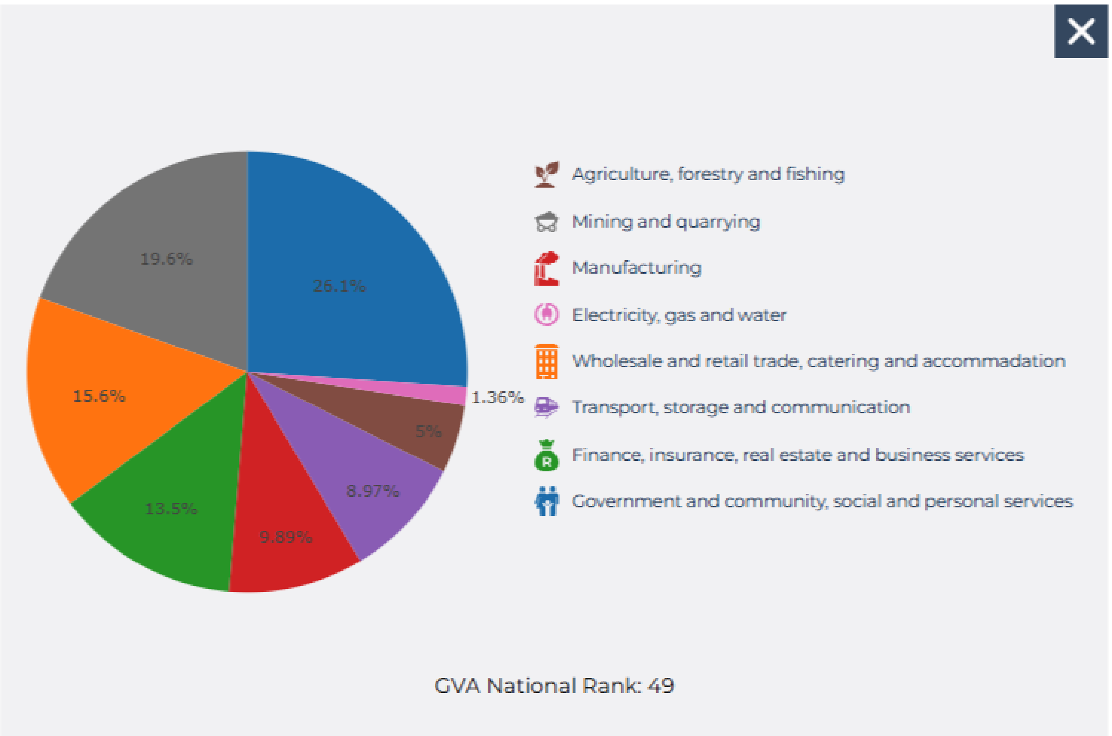


Figure 3-33: The contribution that the different economic sectors make to the total GVA of the Moqhaka Municipality

Table 3-1 and **Table 3-2** summarises the forecasted economic gains or losses for the Matjhabeng Municipality and Moqhaka Municipality respectively, under both the RCP4.5 and RCP8.5 scenarios, for each of the contributing economic sectors.

Table 3-1: Forecasted economic gains or losses for the Matjhabeng Municipality 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%	▲

Table 3-2: Forecasted economic gains or losses for the Moqhaka Municipality for the RCP4.5 and RCP8.5 scenarios

RCP 4.5 Impacts			RCP 8.5 Impacts		
Average	-1.4%	▼	Average	-1.73%	▼
Agriculture Sector	-2.64%	▼	Agriculture Sector	-3.28%	▼
Forestry Sector	-6.52%	▼	Forestry Sector	-8.09%	▼
Fishing Sector	0%	-	Fishing Sector	0%	-
Mining Sector	0.34%	▲	Mining Sector	0.42%	▲
Manufacturing Sector	1.19%	▲	Manufacturing Sector	1.53%	▲
Electricity & Gas Sector	-4.7%	▼	Electricity & Gas Sector	-5.84%	▼
Water Sector	1.73%	▲	Water Sector	2.15%	▲
Service Sector	-0.57%	▼	Service Sector	-0.71%	▼

3.4.5 Agriculture, Forestry and Fisheries

The main agricultural commodities for the Matjhabeng Municipality are maize, beef cattle and milk and cream (**Table 3-3**). Agriculture, Forestry and Fishing (AFF) sector contributes 1.12% to Matjhabeng Municipality GVA production and 4.28% to Matjhabeng total employment. The total AFF GVA production of Matjhabeng Municipality contributes 0.5% of the national AFF GVA (**Table 3-3**).

The main agricultural commodities for the Moqhaka Municipality are maize, wheat and beef cattle (**Table 3-4**). Agriculture, Forestry and Fishing (AFF) sector contributes 5% to Moqhaka Municipality GVA production and 19.9% to Moqhaka total employment. The total AFF GVA production of Moqhaka Municipality contributes 0.6% of the national AFF GVA (**Table 3-4**).

Table 3-3: Economic contribution of main commodities for Matjhabeng 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

Table 3-4: Economic contribution of main commodities for Moqhaka Municipality

MAIN COMMODITIES		
MAIZE FOR GRAIN	WHEAT	BEEF CATTLE
AFF contributes 5% to Moqhaka GVA production	AFF contributes 19.89% to Moqhaka total employment	The total AFF GVA production of Moqhaka Municipality contributes 0.6% to the national AFF GVA, ranking them as the 48th biggest contributor

For the Matjhabeng Municipality, the main agricultural commodities for 2050 are maize, beef cattle and milk and cream (under an RCP8.5 low-mitigation scenario) (**Table 3-5**). The climate for the municipality is expected to be hotter and wetter with slightly more extreme rainfall events. There is the potential increase in maize yield for the near future. However, towards 2050, heat stress can negatively impact on production. The hot moist conditions will result in increased spread of disease and parasites, and the heat stress will result in reduced growth and reproduction performance for beef cattle and milk yield and milk quality.

For the Moqhaka Municipality, the main agricultural commodities for 2050 are maize, wheat and beef cattle (under an RCP8.5 low-mitigation scenario) (**Table 3-6**). The climate for the municipality is expected to be hotter and wetter with more extreme rainfall events. There is the potential increase in maize yield for the near future. However, crop suitability may decline over time as temperatures start to exceed critical crop thresholds. The hot moist conditions will result in increased spread of disease and parasites, and the heat stress will result in reduced growth and reproduction performance for beef cattle.

Table 3-5: Projected economic contribution of main commodities for Matjhabeng 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.

Table 3-6: Projected economic contribution of main commodities for Matjhabeng Municipality

MAIN COMMODITIES		
MAIZE FOR GRAIN	WHEAT	BEEF CATTLE
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.	Potential increase in wheat yield for near future. However,yield and crop suitability decline over time as temperatures start to exceed critical crop thresholds.	Increased water availability. Hot and moist conditions cause increased spread of disease and parasites. Reduced growth & reproduction performance due to heat stress.

3.4.6 Other Resources

The impacts of climate change on other resources are summarised in **Table 3-7**.

Table 3-7: 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)

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	
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)

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	
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)

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	
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.	• 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)

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	
	• 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.				

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	
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)
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	• 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	• 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	• 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	(Pieterse & Crankshaw, 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	
	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	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.	coastal defence structures.	infrastructure.	

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	
	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.				
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	• 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)

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	
	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.				

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 4-1**).

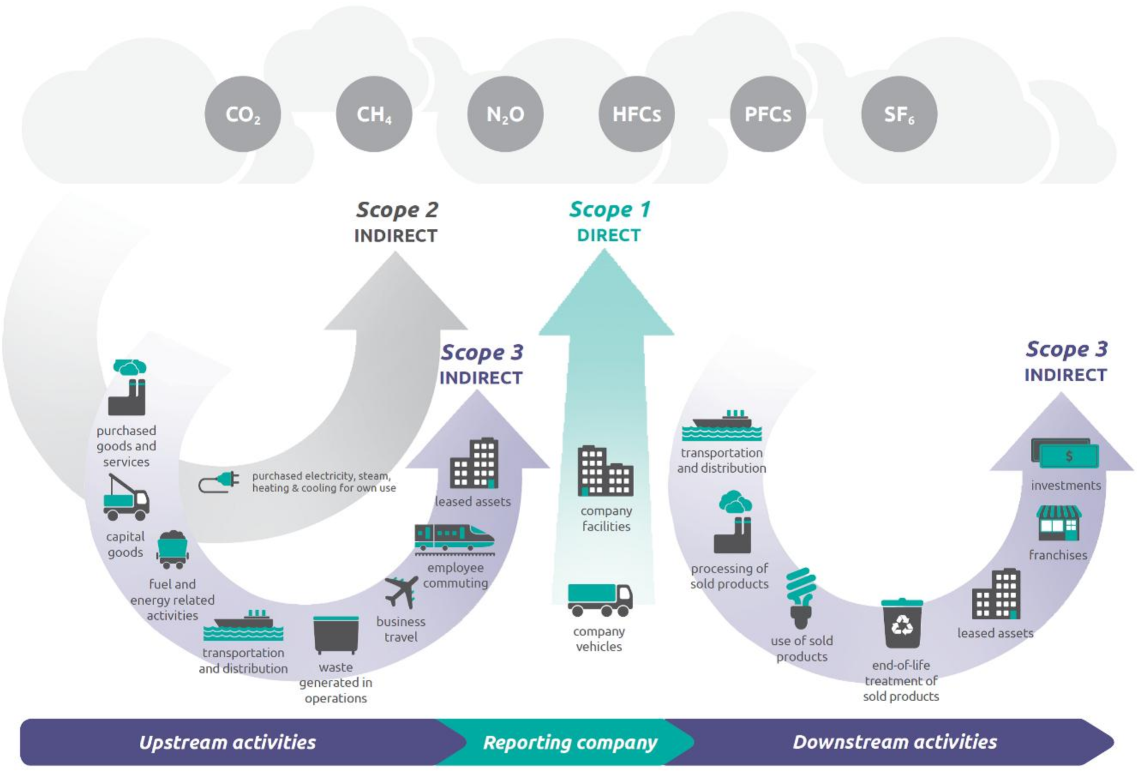


Figure 4-1: Overview of scopes and emissions

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 4-1**. 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 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 4-1: 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

The GWP values from the IPCC Sixth Assessment report and the calculated GHG emissions using these GWPs is given Appendix C.

4.3 Assessment Boundary

The following GHG emissions have been considered:

- Emissions during project exploration activities (Scope 1);
- Fuel consumption during project exploration activities (Scope 1);
- Electricity consumption during project exploration activities (Scope 2); and,
- Upstream project exploration activities (Scope 3).

4.4 Project Activities

The 2019 refinement to the 2006 IPPC guidelines for National GHG Inventories, provides key segments in Natural Gas Systems (**Figure 4-2**). The proposed Motuoane Exploration Right Application (ER386) (the project) entails exploration activities of the Natural Gas System only. The exploration process includes all fugitive emissions associated with activities such as prospecting and/or exploratory drilling, well testing, field development and well development (IPCC, 2019).

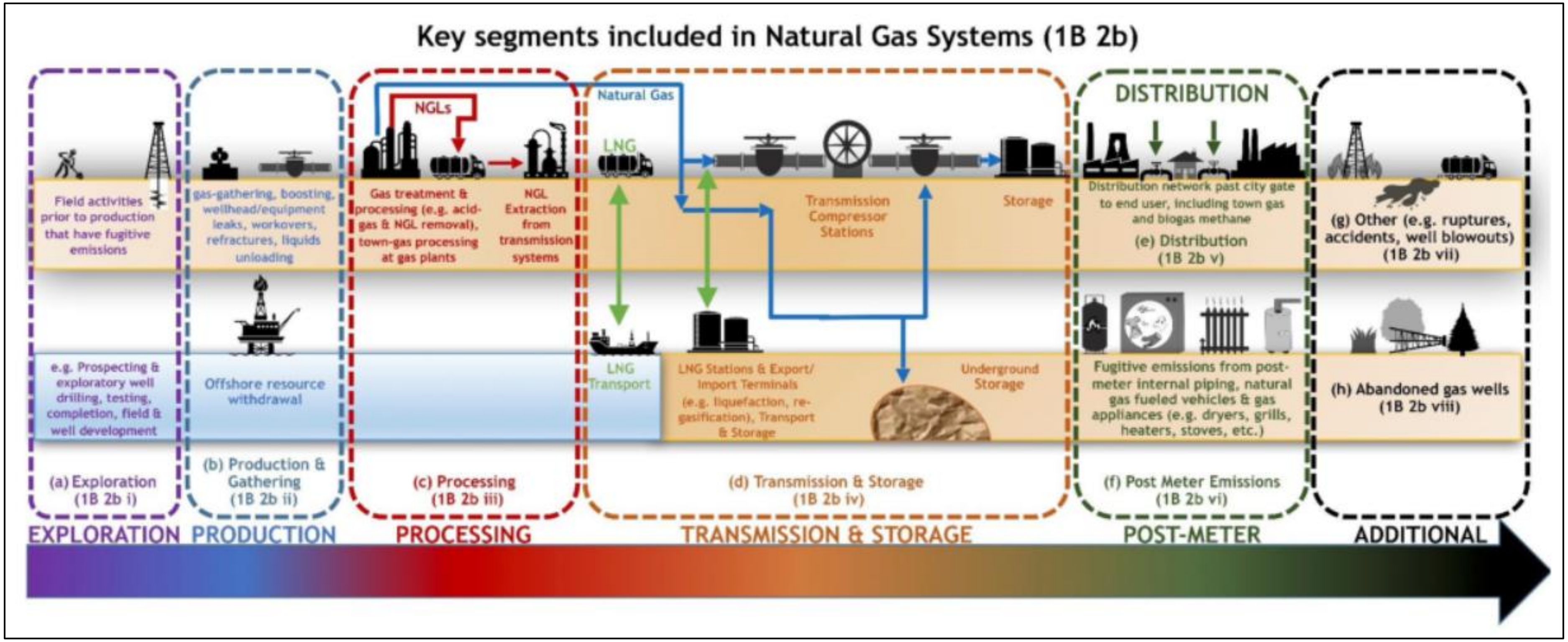


Figure 4-2: The natural gas system (IPCC, 2019)[14]

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[14] The project would only be undertaking **exploration** within the Natural Gas System

4.5 Source Data and Assumptions

The information provided for the assessment is summarised in **Table 4-2**. It should be noted that no electricity from the grid will be used during the exploration activities. GHG emission from Scope 2 will therefore be zero.

Table 4-2: Greenhouse gas assessment source data provided for the project

Project	Value	Unit	Note / Comment
Duration of the project	3 - 9 years	years	Exploration stage
Scope 1			
Methane released due to exploration	151 200	m^3/year	Assumes 3 wells drilled and tested per year at a methane release rate of 150 m^3/hr for 14 days.
Diesel used (stationary combustion)	15 000	litres/year	Drill rig for 3 wells for a duration of 2 weeks per well at 500 litres per day.
Diesel used (mobile combustion - vehicles) (litres)	7 700	litres/year	Two light vehicles, 75 litres per week for normal operations. Additional 2500 litres per year for drilling vehicles and seismic programs.
Scope 2			
Electricity consumed by operations (kWh)	0	MW	This is external grid power used (not power generated by the proponent).
Scope 3			
Distance travelled by materials to site (km)	1 500	km/year	Assumes 2 trucks transporting 3 times per year to Johannesburg.
Raw/grey water requirement	0	m^3/day	
Industrial Waste (tonnes)	45	tonnes/year	Bins for drilling cuttings, assumes 3 wells per year and 4 tonnes per well.
Distance travelled by industrial waste to landfill	300	km/year	Calculated assuming 15 tonne truck capacity and a 100 km round trip.
Municipal Solid Waste (tonnes)	4	tonnes/year	Bins for general rubbish, 4 bins per year at 1 tonne each.
Distance travelled by municipal waste to landfill	27	km/year	Calculated assuming 15 tonne truck capacity and a 100 km round trip.
Employees on site	3	people	Does not include drill staff.
Percent commuters travelling by car	100	%	
Percent commuters travelling by bus	0	%	
Commuter cars per day	2		
Commuter busses per day	0		
Distance travelled per day for commuters	20		

4.6 Emission Factors

The emission factors used for the assessment is provided in **Table 4-3** 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).
- South Africa's 2023 Grid Emission Factors Report gazetted by the Department of Forestry, Fisheries and Environment, No. 53079(6454) (DFFE, 2025) (DFFE, 2024).
- The 2019 refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019).

Table 4-3: Emission factors used in the assessment

Emission factors	Value	Unit	Reference document
Scope 1 - Direct Emissions			
Process related activities			
Gas exploration	33.1	t CH_4 per onshore conventional well drilled in a year	Calculated based on information provided by the proponent
Gas exploration	5.78	t CH_4 per onshore conventional well drilled in a year	IPCC, 2019
Gas exploration	4.72	t CO_2 per onshore conventional well drilled in a year	IPCC, 2019
Gas exploration	0.00003	t N_2O per onshore conventional well drilled in a year	IPCC, 2019
Gas exploration	0.87	t NMVOC per onshore conventional well drilled in a year	IPCC, 2019
Fuel related activities (DFFE, 2024)			
diesel - stationary combustion	74 638	kg CO_2 per TJ	DFFE, 2022
diesel - stationary combustion	3	kg CH_4 per TJ	DFFE, 2022
diesel - stationary combustion	0.6	kg N_2O per TJ	DFFE, 2022
diesel - mobile combustion	74 638	kg CO_2 per TJ	DFFE, 2022
diesel - mobile combustion (off-road)	3.9	kg CH_4 per TJ	DFFE, 2022
diesel - mobile combustion (off-road)	3.9	kg N_2O per TJ	DFFE, 2022
Scope 3 - Indirect Emissions			
Upstream Transportation and Distribution			
Heavy goods vehicle	0.83589	kg CO_2e per km	DEFRA EF (published 10 June 2025)
Waste generated			
Municipal waste	1 164.489	kg CO_2e per tonne	DEFRA EF (published 10 June 2025)
Construction waste	1.008	kg CO_2e per tonne	DEFRA EF (published 10 June 2025)
Commercial and industrial waste	520.533	kg CO_2e per tonne	DEFRA EF (published 10 June 2025)
All Heavy Goods Vehicle (100% laden)	1.01203	kg CO_2e per km	DEFRA EF (published 10 June 2025)
Employee commuting			
Car (average) - Petrol	0.16272	kg CO_2e per km	DEFRA EF (published 10 June 2025)
Car (average) - Diesel	0.17304	kg CO_2e per km	DEFRA EF (published 10 June 2025)
Conversion factors			
Diesel calorific value	0.043	TJ/tonne	
Diesel calorific value	35.5	MJ/l	DFFE, 2022
Diesel - density	0.8255	kg/l	DFFE, 2022
CH_4 - density	0.657	kg/m³	

The quantity of methane released per well was calculated based on the information provided by the proponent. This calculated emission factor was 5.7 times higher than the IPCC emission factor and was used in the CCA.

4.7 Emissions

The GHG emissions estimated due to the project activities is provided in **Table 4-4**. There are no Scope 2 emissions as no electricity from the grid will be used during exploration activities. A duration of 9 years was conservatively assumed for the total GHG emissions.

Scope 1 and Scope 3 direct GHG emissions for the project is 21 236 $tCO_{2}e$ and 288 $tCO_{2}e$ respectively over the 9-year life of the project (~2 360 $tCO_{2}e$ and 32 $tCO_{2}e$ per annum respectively). Scope 1 emissions contribute to 98.7% of the total direct GHG emissions.

For comparison, international reporting considers a small facility as producing 10 000 $tCO_{2}e$ per annum, medium at 25 000 $tCO_{2}e$ per annum and large at 100 000 $tCO_{2}e$ per annum (for Scope 1 and 2 emissions). This project would thus be considered a small facility (2 360 $tCO_{2}e$ per annum for Scope 1 and 2 emissions).

Table 4-4: GHG emissions estimated for the project

Source	Input		t $CO_{2}e$ per year			
	Value	Units	Scope 1	Scope 2	Scope 3	Total
GHG released due to exploration	151 200	m^3 CH_4 per year	2 299			2 299
Diesel used (stationary combustion)	15 000	litres/year	40			40
Diesel used (mobile combustion)	7 700	litres/year	21			21
Transport of materials to site	1 500	km/year			1	1
Industrial waste	45	tonnes/year			24	24
Municipal waste	4	tonnes/year			5	5
Employee travel to site	2	cars/day			2	2
Total t $CO_{2}e$ per year			**2 360**	**-**	**32**	**2 392**
Total t $CO_{2}e$ for exploration period (9 years)			**21 236**	**-**	**288**	**21 525**

The project exploration activities will also result in non-methane volatile organic compounds (NMVOCs) (**Table 4-5**) which are included in the assessment as they can produce increases in tropospheric ozone concentrations, increasing radiative forcing (warming of the atmosphere).

Table 4-5: NMVOC emissions estimated for the project

Pollutant	Source	Value	Units
NMVOC	Emissions released from the well during exploration	2.61	tpa
NMVOC	Emissions released from the well during exploration	23.49	tonnes for exploration period (9 years)

4.8 The Project's GHG Impact

4.8.1 Impact on the National Remaining Carbon Budget

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. Using the lower end of the range for 2030 and 2035, the project (Scope 1) would contribute approximately 0.0007% of the remaining carbon budget per year and represent a contribution of 0.0005% to the 2022 National GHG inventory total.

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 to GHG reporting with national policy.

5 IMPACT SIGNIFICANCE RATING

5.1 Potential Impact Description

Gaseous pollutants released from the exploration of the wells is the main source of GHGs from the project. The release of GHG includes mainly CO_2, CH_4 and 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 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).

5.2 Impact Significance

The calculated CO_2e emissions from the project operations for Scope 1 is summarised in Section 4.7, estimating a total of 21 236 t CO_2e over a 9-year period (2 360 t CO_2e per annum).

The project Scope 1 emissions due to the project would contribute approximately 0.0007% of the remaining carbon budget per year for 2030 and 2035 and represent a contribution of 0.0005% to the 2022 National GHG inventory total.

The draft *National Guidelines for the Consideration of Climate Change Implications in Applications for Environmental Authorisations* (in GN 6759 in GG 53574) provides a Climate Change Significance Rating Framework for assessments (summarised in Appendix D). This framework was used for the evaluation of significance for the project (**Table 5-1**).

The climate change significance rating was as follows:

- Climate change manifestations on the project: **low**;
- Impact of the project on climate change adaptation or resilience: **low**;
- Impact of project on GHG emissions: **low**.

Table 5-1: Climate Change significance rating for the project

Climate Change Impacts or Risks	Impact of Climate Change Manifestations on the Project	Impact of the Project on Climate Change Adaptation or Resilience	Impact of Project on Greenhouse Gas Emissions
Impact or Risk	Increased heat extremes may result in occupational health and operational risks on the project. These risks are driven by higher ambient temperatures which can lead to heat-related illnesses (i.e. heatstroke and exhaustion) in workers and reduced labour productivity.	The impact of the project on the resources is limited to some clearing of land for the exploration areas.	The project would release GHG emissions into the atmosphere during the exploration activities.
IMPACT CRITERIA			
1. Nature	Negative Direct	Negative Direct	Negative Indirect
2. Duration	Short-term	Medium-term	Permanent
3. Extent	Localised	Localised	Global
4. Probability	Unlikely	Probable	Probable
5. Irreplaceability	Limited	Limited	VERY HIGH due to irreversibility of elevated GHG concentrations in the atmosphere.
6 Reversibility and mitigation potential	Easy	Moderate	Reversibility VERY DIFFICULT due to irreversibility of elevated GHG concentrations in the atmosphere.
7. Severity (intensity)	Slight	Slight	LOW - less than 10 000 tCO_2e per year.
8. Significance	Low (-)	Low (-)	Low (-)
9. Residual risk	Low (-)	Low (-)	Low (-)

6 CLIMATE RISK, ADAPTATION AND MITIGATION

6.1 Adaptation Action Plans

6.1.1 Matjhabeng Local Municipality Adaptation Action Plan

As of 2024–2025, the Matjhabeng Local Municipality does not have a formal Climate Change Adaptation Plan in place. The municipality is, however, integrating climate risks into its Integrated Development Plan (IDP) to address infrastructure vulnerabilities, such as drought and flood risks.

Key Climate Adaptation Focus Areas (via IDP and Planning):

- **Infrastructure Resilience:** The municipality aims to enhance service delivery infrastructure against extreme weather.
- **Integrated Planning:** The Draft Review Integrated Development Plan 2025/2026 calls for understanding regional vulnerabilities.
- **Disaster Management:** The 2025/2026 IDP Review, Budget and Performance Management highlights the need for adapting to climate change impacts.

6.1.2 Moqhaka Local Municipality Adaptation Action Plan

Based on available municipal documentation and regional reports, the Moqhaka Local Municipality incorporates climate change adaptation into its planning through the IDP and the Fezile Dabi District climate adaptation strategies.

The Fezile Dabi District Municipality Adaptation Plan was completed in June 2024 (CSIR, 2024) and identified five adaptation goals prioritising risks with the highest potential impact. The goals identified were as follows:

- Goal 1: To ensure water security for human consumption and irrigation under a changing climate.
- Goal 2: To reduce the quantity, improve the quality, and slow the flow of stormwater runoff from developed areas, and to identify suitable areas for managing water runoff.
- Goal 3: To ensure that space is set aside for recreation, ecological support and stormwater management.
- Goal 4: To increase the adaptive capacity of human settlements to climate change and extreme events.
- Goal 5: To increase resilience of the agricultural sector to more extreme events such as heatwaves and storms as well as indirect risks such as pests and diseases.

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

With the increase in heat extremes, 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.

6.3 Transitional Risks and Opportunities of Climate Change on the Project's Operations

The Taskforce for Climate-related Financial Disclosures (TCFD) advocates the disclosure of the financial risks associated with climate change impacts on organisations (TCFD, 2020). These include physical risks resulting in large-scale financial losses caused by storms, droughts, wildfires, and other extreme events (as identified in Section 3). The Taskforce also advocates the quantification of transitional risks associated with the adjustment to low carbon economies, such as the rapid loss in the value of assets due to policy changes or consumer preference; and financial risks to the economy through elevated credit spreads, greater precautionary saving and rapid pricing readjustment (TCFD, 2020). Along with risks, the Taskforce encourages organisations to identify possible opportunities that could build resilience in economies shifting due to climate change.

Although assessment of the full financial risk is out of the scope of the of work, potential transitional risks and opportunities applicable to the project are tabulated below (**Table 6-1** as summarised from TCFD, 2017).

Table 6-1: Examples of climate-related risks and opportunities and the potential financial impacts (TCFD, 2017)

Type	Climate Related Risk / Opportunity	Potential financial impact	Comments
Risks	Policy and Legal		
	- Increased pricing of GHG emissions	- Increased operating costs (for example higher compliance cost, increased insurance premiums)	Carbon tax act proposed 2% increase in baseline carbon tax rate until 2022 and thereafter annual inflation-based increases
	- Enhanced emissions reporting obligations	- Write-offs, asset impairment, and early retirement of existing assets due to policy changes	South African Greenhouse Gas Emission Reporting System (SAGERS)
	- Mandates on and regulation of existing products and services	- Increased costs and / or reduced demand for products and services resulting from fines and judgements.	Country commitment to decarbonise energy supplies by 2050 could influence energy demand. Exceedances of emission standards could result in fines and litigation.
	- Exposure to litigation		
	Technology		
	- Substitution of existing products and services with lower emission options	- Write-offs and early retirement of existing assets - Reduced demand for products and services	Country commitment to decarbonise energy supplies by 2050 could influence product demand.
	- Costs to transition to lower emissions technology	- Capital investments in technology development - Costs to adopt / deploy new practises and processes	
	Market		
	- Changing customer behaviour	- Reduced demand for goods and services due to shift in consumer preferences	
	Reputation		
	- Increased stakeholder concern or negative stakeholder feedback	- Reduction in capital availability	

Type	Climate Related Risk / Opportunity	Potential financial impact	Comments
Opportunities	Resource efficiency		
	- Use of more efficient modes of transport	- Reduced operating costs (through efficient gains and cost reductions)	
	Products and services		
	- Shifts in consumer preferences	- Better competitive position to reflect shifting consumer preferences, resulting in increased revenues	
	Markets		
	- Access to new markets - Use of public-sector incentives	- Increased revenue through access to new and emerging markets (for example partnerships with governments)	

6.4 Project Adaptation and Mitigation 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 the 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).

The project will need to take increased heat extremes into consideration when developing mitigation and adaptation measures for the project.

6.4.1 General Adaptation

The following general adaptations can be considered:

- Continually improving risk management systems and onsite employee training specifically for extreme weather events, such as extreme heat.
- Implementing a health and safety plan for work practices to manage heat stress and temperature extremes for workers. This could consider the following measures:
  - Rotation of staff on hot days,
  - Wearing of protective safety or reflective clothing when exposed to the sun or being outdoors to reflect radiant heat from the ground or infrastructure,
  - Heat-related incidences should also be reported as part of the facilities health and safety reporting, to have such records for future heat related stress,
  - Provision of work-rest procedure – frequent breaks and short work periods.

6.4.2 Technology/Sector-Specific Mitigation

Sector-specific climate change mitigation in gas exploration is focused on mitigating methane emissions due to their high global warming. Key strategies include the following:

1. Robust Leak Detection and Repair (LDAR) Programs:
    - Advanced LDAR programs can include visual checks, utilising infrared cameras (optical gas imaging), drones, satellites, and sensors to detect, locate, and quantify methane leaks from wells.
    - Leading practices recommend frequent (quarterly or even continuous) inspection, particularly for high-emitting components.
    - Upon detection, leaks must be repaired promptly to minimise fugitive emissions.
2. Reducing methane releases during well testing
3. Proper capping and abandonment
    - To prevent leaks from abandoned or inactive wells, wells must be plugged following modern, robust standards, rather than simply sealed with a basic cap.
    - Regular monitoring of capped wells is necessary to identify and remediate leakage from degraded cement or casing, which is a major source of methane seepage.

7 FINDINGS

Project specific information together with local and internationally published emission factors were used to calculate Scope 1 (direct), Scope 2 (indirect) and Scope 3 (indirect) GHG emissions for the project. Locally published literature was referenced, to understand the projected changes to climate for the area.

Based on information provided, the project is likely to result in an estimated total GHG emissions as follows:

- Scope 1 direct emissions:
  - 21 236 t CO_2e over a 9-year period
  - 2 360 t CO_2e per annum
- Scope 2 indirect emissions:
  - None
- Scope 3 indirect emissions:
  - 288 t CO_2e over a 9-year period
  - 32 t CO_2e per annum

The GHG emissions from the project was calculated to represent 0.0007% of the remaining South African annual budget for 2030 and 2035 respectively. The contribution to the South African annual budget will also progressively increase throughout the life of the project as the country's NDCs decrease.

The impact of the project on climate change was assessed to have a **low** negative risk rating for GHG emissions. Subsequently, it is the specialist's opinion that the project may be authorised provide that the mitigation measures recommended in this report are adhered to.

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APPENDIX A – CURRICULUM VITAE OF ASSESSMENT AUTHOR

CURRICULUM VITAE	RENEÉ VON GRUENEWALDT

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Reneé von Gruenewaldt (*nee* Thomas)
Profession	Air Quality and Environmental Noise Scientist
Position	Principal consultant
Date of Birth	13 May 1978
Years with Firm	Since January 2002
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP)
- Member of the National Association for Clean Air (NACA)

KEY QUALIFICATIONS

Reneé von Gruenewaldt (Air Quality Scientist): Reneé joined Airshed Planning Professionals (Pty) Ltd (previously known as Environmental Management Services cc) in 2002. She has, as a Specialist, attained over twenty (20) years of experience in the Earth and Natural Sciences sector in the field of Air Quality and nine (9) years of experience in the field of environmental noise assessments. As an environmental practitioner, she has provided solutions to both large-scale and smaller projects within the mining, minerals, and process industries.

She has developed technical and specialist skills in various air quality modelling packages including the AMS/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, Lagrangian GRAL model. Her experience with air emission models includes Tanks 4.0 (for the quantification of tank emissions), WATER9 (for the quantification of wastewater treatment works) and GasSim (for the quantification of landfill emissions). Noise propagation modelling proficiency includes CONCAWE, South African National Standards (SANS 10210) for calculating and predicting road traffic noise and CadnaA for propagation of industrial, road and rail noise sources.

Having worked on projects throughout Africa (i.e., South Africa, Mozambique, Malawi, Kenya, Angola, Democratic Republic of Congo, Namibia, Madagascar and Egypt for Air Quality Impact Assessments and Mozambique, Namibia, Botswana, Kenya, Ghana, Suriname and Afghanistan for Environmental Noise Impact Assessments) Reneé 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.

RELEVANT EXPERIENCE (AIR QUALITY)

Mining and Ore Handling

Reneé has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite, manganese and mineral sands mines. These include: compilation of emissions databases for Landau and New Vaal coal collieries (SA), impact assessments and management plans for numerous mines over Mpumalanga (viz. Schoonoord, Belfast, Goedgevonden, Mbila, Evander South, Driefontein, Hartogshoop, Belfast, New Largo, Geluk, etc.), Mmamabula Coal Colliery (Botswana), Moatize Coal Colliery (Mozambique), Revuboe Coal Colliery (Mozambique), Toliera Sands Heavy Minerals Mine and Processing (Madagascar), Corridor Sands Heavy Minerals Mine monitoring assessment, El Burullus Heavy Minerals Mine and processing (Egypt), Namakwa Sands Heavy Minerals Mine (SA), Tenke Copper Mine and Processing Plant (DRC), Rössing Uranium (Namibia), Lonmin platinum mines including operations at Marikana, Baobab, Dwaalkop and Doornvlei (SA), Impala Platinum (SA), Pilannesburg Platinum (SA), Aquarius Platinum, Hoogland Platinum Mine (SA), Tamboti PGM Mine (SA), Sari Gunay Gold Mine (Iran), chrome mines in the Steelpoort Valley (SA), Mecklenburg Chrome Mine (SA), Naboom Chrome Mine (SA), Kinsenda Copper Mine (DRC), Kassinga Mine (Angola) and Nokeng Flourspar Mine (SA), etc.

Mining monitoring reviews have also been undertaken for Optimum Colliery's operations near Hendrina Power Station and Impunzi Coal Colliery with a detailed management plan undertaken for Morupule (Botswana) and Glencor (previously known as Xstrata Coal South Africa).

Air quality assessments have also been undertaken for mechanical appliances including the Durban Coal Terminal and Nacala Port (Mozambique) as well as rail transport assessments including BHP-Billiton Bauxite transport (Suriname), Nacala Rail Corridor (Mozambique and Malawi), Kusile Rail (SA) and WCL Rail (Liberia).

Metal Recovery

Air quality impact assessments have been carried out for Highveld Steel, Scaw Metals, Lonmin's Marikana Smelter operations, Saldanha Steel, Tata Steel, Afro Asia Steel and Exxaro's Manganese Pilot Plant Smelter (Pretoria).

Chemical Industry

Comprehensive air quality impact assessments have been completed for NCP (including Chloorkop Expansion Project, Contaminated soils recovery, C3 Project and the 200T Receiver Project), Revertex Chemicals (Durban), Stoppani Chromium Chemicals, Foskor (Richards Bay), Straits Chemicals (Coega), Tenke Acid Plant (DRC), and Omnia (Sasolburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for Sasol (including the postponement/exemption application for Synfuels, Infrachem, Natref, MIBK2 Project, Wax Project, GTL Project, re-commissioning of boilers at Sasol Sasolburg and Ekandustria), Engen Emission Inventory Functional Specification (Durban), Sapref refinery (Durban), Sasol (at Elrode) and Island View (in Durban) tanks quantification, Petro SA and Chevron (including the postponement/exemption application).

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 ash expansion projects at Kusile, Kendal, Hendrina, Kriel and Arnot; Fabric Filter Plants at Komati, Grootvlei, Tutuka, Lethabo and Kriel Power Stations; the proposed Kusile, Medupi (including the impact assessment for the Flue Gas Desulphurization) and Vaal South Power Stations. Reneé was also involved and the cumulative assessment of the existing and return to service Eskom power stations assessment and the optimization of Eskom's ambient air quality monitoring network over the Highveld.

In addition to Eskom's coal fired power stations, various Eskom nuclear power supply projects have been completed including the air quality assessment of Pebble Bed Modular Reactor and nuclear plants at Duynefontein, Bantamsklip and Thyspunt.

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

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the Waste Water Treatment Works in Magaliesburg, proposed Waterval Landfill (near Rustenburg), Tutuka Landfill, Mogale General Waste Landfill (adjacent to the Leipardsvlei Landfill), Cape Winelands District Municipality Landfill, the Tsoeneng Landfill (Lesotho) and the FG Landfill (near the Midstream Estate). Air quality impact assessments have also been completed for the BCL incinerator (Cape Town), the Ergo Rubber Incinerator and the Ecorevert Pyrolysis Plant.

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the Holcim Alternative Fuels Project (which included the assessment of the cement manufacturing plants at Ulco and Dudfield as well as a proposed blending platform in Roodepoort).

Management Plans

Reneé undertook the quantification of the baseline air quality for the first declared Vaal Triangle Airshed Priority Area. This included the establishment of a comprehensive air pollution emissions inventory, atmospheric dispersion modelling, focusing on impact area "hotspots" and quantifying emission reduction strategies. The management plan was published in 2009 (Government Gazette 32263).

Reneé has also been involved in the Provincial Air Quality Management Plan for the Limpopo Province.

RELEVANT EXPERIENCE (GREENHOUSE GAS EMISSION FOOT-PRINTING AND CLIMATE CHANGE IMPACT STATEMENTS)

Mining and Tailings Storage Facilities

Reneé has quantified the direct and indirect (Scope 2 and Scope 3) emissions for numerous mines over the highveld of South Africa and the Democratic Republic of Congo. She has also assessed the climate risks and vulnerabilities of the project and surrounding communities due to increasing ambient temperatures, water scarcity, risk of intense storms.

Gas to Power Plants

Reneé has quantified the direct and indirect (Scope 2 and Scope 3) emissions for gas to power plants proposed for South Africa. She has also assessed the climate risks and vulnerabilities of the project and surrounding communities due to increasing ambient temperatures, water scarcity, risk of intense storms.

RELEVANT EXPERIENCE (NOISE)

Mining

Reneé has undertaken numerous environmental noise assessments for mining operations. These include environmental noise impact assessments including baseline noise surveys for numerous coal, platinum, manganese, tin and zinc mines. Projects include, but are not limited to, Balama (Mozambique), Masama Coal (Botswana), Lodestone (Namibia), Osino (Namibia), Kurmuk (Ethiopia), Gamsberg (SA), Prieska (SA), Kolomela (SA), Heuningkranz (SA), Syferfontein (SA), South 32 (SA), Mamatwan (SA), Alexander (SA) and Marula Platinum Mine (SA), etc.

Power Generation

Environmental noise assessments have been completed for numerous Eskom coal fired power station studies in SA including the Kriel Fabric Filter Plant, Kendal ash facility, Medupi ash facility. Apart from Eskom projects, power plant assessments have also been completed in Botswana (Morupule), Kenya (geothermal power plants), Suriname (EBS power plant) and SA (combined cycle power plants and thermal power plants).

Process Operations

Environmental noise assessments have been undertaken for various process operations including waste disposal facilities (Bon Accord in Gauteng), bottling and drink facilities (Imali and Isanti Project in Gauteng) and Smelter (Gamsberg in Northern Cape).

Transport

An environmental noise assessment was completed for the Obetsebi road expansion and flyover project in Ghana, the Scorpion Zinc Mine transport route in Namibia and the Sisian-Kajaran (North-South Corridor) Road Project in Armenia.

Gas Pipelines

An environmental noise assessment was completed for the Sheberghan gas pipeline in Afghanistan.

Baseline Noise Surveys

Baseline noise surveys have been undertaken for numerous mining and process operation activities (including Raumix quarries, Kolomela and Sibanye Stillwater Platinum Mines (SA)) in support of onsite Environmental Management Programmes.

OTHER EXPERIENCE (2001)

Research for B.Sc. Honours degree was part of the "Highveld Boundary Layer Wind" research group and was based on the identification of faulty data from the Majuba Sodar. The project was THRIP funded and was a joint venture with the University of Pretoria, Eskom and Sasol (2001).

EDUCATION

M.Sc. Earth Sciences	University of Pretoria, RSA, Cum Laude (2009) Title: *An Air Quality Baseline Assessment for the Vaal Airshed in South Africa*
B.Sc. Hons. Earth Sciences	University of Pretoria, RSA, Cum Laude (2001) Environmental Management and Impact Assessments
B.Sc. Earth Sciences	University of Pretoria, RSA, (2000) Atmospheric Sciences: Meteorology

ADDITIONAL COURSES

CALMET/CALPUFF	Presented by the University of Johannesburg, RSA (March 2008)
Air Quality Management	Presented by the University of Johannesburg, RSA (March 2006)

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Ghana, Suriname, Afghanistan, Malawi, Liberia, Kenya, Angola, Democratic Republic of Congo, Ethiopia, Afghanistan, Lesotho, Namibia, Madagascar, Egypt, Suriname and Iran.

EMPLOYMENT RECORD

January 2002 - Present

Airshed Planning Professionals (Pty) Ltd, (previously known as Environmental Management Services cc until March 2003), Principal Air Quality and Environmental Noise Scientist, Midrand, South Africa.

2001

University of Pretoria, Demi for the Geography and Geoinformatics department and a research assistant for the Atmospheric Science department, Pretoria, South Africa.

Department of Environmental Affairs and Tourism, assisted in the editing of the Agenda 21 document for the world summit (July 2001), Pretoria, South Africa.

1999 - 2000

The South African Weather Services, vacation work in the research department, Pretoria, South Africa.

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Understanding the Synoptic Systems that lead to Strong Easterly Wind Conditions and High Particulate Matter Concentrations on The West Coast of Namibia, H Liebenberg-Enslin, R von Gruenewaldt, H Rauntenbach and L Burger. National Association for Clean Air (NACA) conference, October 2017.
- Topographical Effects on Predicted Ground Level Concentrations using AERMOD, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2011.
- Emission Factor Performance Assessment for Blasting Operations, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2009.
- 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.
- A High-Resolution Diagnostic Wind Field Model for Mesoscale Air Pollution Forecasting, R.G. Thomas, L.W. Burger, and H Rautenbach. National Association for Clean Air (NACA) conference, September 2005.
- Emissions Based Management Tool for Mining Operations, R.G. Thomas and L.W. Burger. National Association for Clean Air (NACA) conference, October 2004.
- An Investigation into the Accuracy of the Majuba Sodar Mixing Layer Heights, R.G. Thomas. Highveld Boundary Layer Wind Conference, November 2002.

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Fair	Fair	Fair

CERTIFICATION

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

______________________	11/02/2026
Signature of staff member	Date (Day / Month / Year)

Full name of staff member: Reneé Georgeinna von Gruenewaldt

APPENDIX B – DECLARATION OF INDEPENDENCE

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Reneé von Gruenewaldt
Name of Registration Body: South African Council for Natural Scientific Professions
Professional Registration No.: 400304/07

Declaration of independence and accuracy of information provided:
Climate Change Assessment for the Motuoane Exploration Right Application (ER386), Free State Province

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

Signed at Pretoria on this 9th of April 2026

SIGNATURE
Principal Noise Scientist
CAPACITY OF SIGNATORY

APPENDIX C – CALCULATED GHG EMISSIONS USING THE IPCC SIXTH ASSESSMENT REPORT GLOBAL WARMING POTENTIALS

The IPCC Sixth Assessment report (AR6) 100-year GWP is provided in **Table C-1**. The estimated GHG emissions due to project is provided in **Table C-2**. The quantified GHG emissions using the AR6 100-year GWP is 1.28 times higher than the calculated emissions (2 392 tCO_2e per year and 21 525 tCO_2e for exploration period for Scope 1, Scope 2 and Scope 3) using the AR3 GWP (Section 4.7).

Table C-1: Greenhouse gasses and 100-year AR6 global warming potentials

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4) – fossil	29.8
Nitrous oxide (N_2O)	273

Table C-2: GHG emissions estimated for the project assuming 100-year AR6 global warming potentials

Source	Input		t CO_2e per year			
	Value	Units	Scope 1	Scope 2	Scope 3	Total
GHG released due to exploration	151 200	m³ methane per year	2 974			2 974
Diesel used (stationary combustion)	15 000	litres/year	40			40
Diesel used (mobile combustion)	7 700	litres/year	21			21
Transport of materials to site	1 500	km/year			1	1
Industrial waste	45	tonnes/year			24	24
Municipal waste	4	tonnes/year			5	5
Employee travel to site	2	cars/day			2	2
Total t CO_2e per year			*3 035*	-	*32*	*3 067*
Total t CO_2e for exploration period (9 years)			*27 316*	-	*288*	*27 604*

In the AR6, the GWP for methane from fossil fuels has been estimated as 29.8 (with an uncertainty of ±11) over 100-years. However, methane has an atmospheric lifetime of approximately 12 years, which is much shorter than 100 years. The GWP in this case has been estimated to be 82.5 (with an uncertainty of ±25.8) over 20 years. The CO_2 from the oxidation of methane is formed at the end of a methane molecule's atmospheric lifetime, which, on average, is 12 years. Therefore, to derive the GWP over a 100-year period, the IPCC effectively integrates the radiative forcing effect of this CO_2 over, on average, approximately 88 years of the 100-year time horizon. Furthermore, the IPCC assumes that at the end of its atmospheric lifetime, 25% of the methane is not oxidized to CO_2 but rather is converted to formaldehyde and removed from the atmosphere through deposition on soils and water bodies. Therefore, it is assumed that only 75% of the carbon in methane becomes atmospheric CO_2 through oxidation and 25% as formaldehyde.

Assuming a 20-year global warming potential AR6 GWP is provided in **Table C-3**. The estimated GHG emissions due to project assuming the AR6 20-year GWP is provided in **Table C-4**. The quantified GHG emissions using the AR6 20-year GWP is 3.47 times higher than the calculated emissions (2 392 tCO_2e per year and

21 525 tCO_2e for exploration period for Scope 1, Scope 2 and Scope 3 using the AR3 100-year GWP (Section 4.7).

Table C-3: Greenhouse gasses and 20-year global warming potentials

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4) – fossil	82.5
Nitrous oxide (N_2O)	273

Table C-4: GHG emissions estimated for the project assuming 20-year AR6 global warming potentials

Source	Input		t CO_2e per year			
	Value	Units	Scope 1	Scope 2	Scope 3	Total
GHG released due to exploration	151 200	m³ methane per year	8 210			8 210
Diesel used (stationary combustion)	15 000	litres/year	40			40
Diesel used (mobile combustion)	7 700	litres/year	21			21
Transport of materials to site	1 500	km/year			1	1
Industrial waste	45	tonnes/year			24	24
Municipal waste	4	tonnes/year			5	5
Employee travel to site	2	cars/day			2	2
Total t CO_2e per year			*8 270*	-	*32*	*8 302*
Total t CO_2e for exploration period (9 years)			*74 433*	-	*288*	*74 722*

Referencing the international reporting which considers a small facility as producing 10 000 tCO_2e per annum (Scope 1 and Scope 2), the project, assuming AR3 100-year GWP (2 360 tCO_2e per annum) is considered a small facility. The project, assuming the AR6 100-year GWP (3 035 tCO_2e per annum) and AR6 20-year GWP (8 270 tCO_2e per annum) remains classified as a small facility. A summary of the GHG emissions and the significance of the potential impacts using AR3 and AR6 GWP is provided in **Table C-5**. The various GWP used, therefore, does not change the significance rating of the project. The contribution of project GHG emissions to draft NDC for 2035 and National GHG total emissions is less than 1% assuming AR3 and AR6 GWP.

Table C-5: Summary of GHG emissions estimated for the project assuming AR3 and AR6 global warming potentials and the significance of the impacts

Global warming potentials used in the emission quantification	t CO_2e per year (Scope 1 and Scope 2)	Classification of facility based on international reporting	Significance in terms of severity of GHG emissions (Scope 1 and Scope 2)[(a)]	Contribution to draft NDC for 2035 (assuming lower end of range provided in the NDC)	Contribution to 2022 National GHG total emissions
AR3 100-year GWP	2 360	Small facility	LOW	0.0007%	0.0005%
AR6 100-year GWP	3 035	Small facility	LOW	0.0009%	0.0007%
AR6 20-year GWP	8 270	Small facility	LOW	0.002%	0.003%

(a) Based on the Climate Change Significance Rating Framework that classifies the severity of GHG emissions for facilities of less than 10 000 tCO_2e per year as LOW.

APPENDIX D – CLIMATE CHANGE SIGNIFICANCE RATING FRAMEWORK

The following framework is proposed with respect to climate change risks associated with the following main climate change impact categories:

- Impact of climate change manifestations on the project;
- Impact of the project on climate change adaptation or resilience;
- Impact of the project on GHG emissions.

Table D-1 provides the overall climate change significance rating framework that aligns with the requirements of Appendix 3 of the EIA Regulations for the environmental impact assessment process, particularly paragraph 3(1)(h)(V-VI).

Table D-2 provides a more detailed criteria for the ranking of impact severity.

Table D-3 provides a more detailed criteria for ranking of impact severity (intensity).

Table D-4 provides a more detailed description of significance rating.

Table D-1: Climate change impact significance rating framework

Climate Change Impacts or Risks	Impact of Climate Change Manifestations on the Project	Impact of the Project on Climate Change Adaptation or Resilience	Impact of Project on Greenhouse Gas Emissions
Examples of Impact or Risk	Increased rainfall may expose the project to a higher risk of flooding and damage to infrastructure.	The project may damage coastal dune systems thus compromising the natural coastal defence and increasing vulnerability to tidal surges.	The project may require the consumption of significant quantities of fossil fuels resulting in a significant increase in GHG emissions into the atmosphere.
	Increased sea-level rise and tidal surges may expose infrastructure to damage.	The project could result in the loss of a water resource thus increasing vulnerability to expected drought conditions.	The project may be a renewable energy project that avoids or reduces the burning of fossil fuels thus reducing GHG emissions into the atmosphere.
IMPACT CRITERIA			
1. Nature - the nature of an impact is classified as negative or positive, also whether an impact is Direct or Indirect.	Positive or negative Direct or Indirect	Positive or negative Direct or Indirect	Positive or negative Indirect

Climate Change Impacts or Risks	Impact of Climate Change Manifestations on the Project	Impact of the Project on Climate Change Adaptation or Resilience	Impact of Project on Greenhouse Gas Emissions
2. Duration - the length of time the impact is expected is expected to last, from short-term to long-term or permanent or how often the impact occurs, such as frequency to storm and flooding events.	Table D-2	Table D-2	Probably permanent
3. Extent **Spatial Extent** - the geographical area effected by the impact, ranging from local to global. **Extent of Impact** - the scale of the impact on the receiving environment, such as changes in temperature, rainfall patterns, or sea levels.	Local	Local, study area, municipality or regional	Global
4. Probability - the likelihood of the impact occurring ranging from low to high probability.	Table D-2	Table D-2	PROBABLE based on calculations.
5. Irreplaceability - the extent to which the impact will cause irreplaceable loss of resources.	Table D-2	Table D-2	Probably VERY HIGH due to irreversibility of elevated GHG concentrations in the atmosphere.
6 Reversibility and mitigation potential - the extent to which the impacted environment or system can be mitigated to reduce or avoid the impact through various measures and return to its previous state after the impact occurs. The degree of difficulty of implementing measures to reverse and/or mitigate the various impacts including the practical feasibility, the cost and the potential effectiveness of the measure(s).	Table D-2	Table D-2	Reversibility probably VERY HIGH negative due to irreversibility of elevated GHG concentrations in the atmosphere. Table D-2

Climate Change Impacts or Risks	Impact of Climate Change Manifestations on the Project	Impact of the Project on Climate Change Adaptation or Resilience	Impact of Project on Greenhouse Gas Emissions
7. Severity (intensity) The severity or intensity of the impact on the environment or socio-economic systems. This could include the degree of temperature change, the intensity of storms, or the severity of droughts, or levels of project GHG emissions.	Table D-3	Table D-3	VERY HIGH - > 1 000 000 tCO_2e per year. HIGH - > 100 000 tCO_2e per year. MODERATE - > 10 000 tCO_2e per year. LOW - < 10 000 tCO_2e per year.
8. Significance - The significance of an impact is often determined by combining the rating for above criteria. For example, a high-impact event with a high probability, global extent, long duration, and irreversible effects would be considered highly significant.	Table D-4	Table D-4	Table D-4
9. Residual risk - The residual risk is a measure of the remaining environmental or social risk after mitigation measures or controls have been implemented. Residual risk is the risk "left-over" after mitigation measures or controls have been applied.	Table D-4	Table D-4	Table D-4

Table D-2: Ranking of evaluation criteria

Effect	**Duration**	
	Short term	Less than 2 years
	Medium term	Between 2-10 years
	Long term	Between 10-25 years
	Permanent	Over 25 years or resulting in a permanent and lasting loss
	Extent	
	Localised	Impacts affect a small area of a few hectares in extent. Often only a portion of the project area.
	Study area	The proposed site and its immediate surroundings.
	Municipal	Impacts affect the Local Municipality, or any towns within the municipality.
	Regional	Impacts affect the wider area or the Province as a whole.
	National	Impacts affect the entire country.
	International/Global	Impacts affect other countries or have a global influence.

	Probability	
	Definite	More than 90% sure of a particular fact or impact. Should have substantial supportive data.
	Probable	Over 70% sure of a particular fact, or of the likelihood of the impact occurring.
	Possible	Only over 40% sure of a particular fact, or of the likelihood of the impact occurring.
	Unsure/Unlikely	Less than 40% sure of a particular fact, or of the likelihood of the impact occurring.
Irreplaceable loss of resources	**Irreplaceable loss of resources**	
	Limited	Loss or impact on replaceable or regenerable resources. Restoration is simple and effective.
	Moderate	Resources are degraded or lost, with replacement possible but difficult, costly, or time-consuming.
	High	Major loss of significant resources or ecosystems that are largely irreplaceable. Restoration is technically possible but not guaranteed.
	Very High	Permanent loss of unique and irreplaceable resources with no visible replacement or restoration pathway.
Mitigation potential	**Impact reversibility and mitigation potential**	
	Easy	The impact can be easily, effectively and cost effectively mitigated/ reversed.
	Moderate	The impact can be effectively mitigated/ reversed without much difficulty or cost.
	Difficult	The impact could be mitigated/ reversed but there will be some difficulty in ensuring effectiveness and/ or implementation, and significant costs.
	Very difficult	The impact could be mitigated/ reversed but it would be very difficult to ensure effectiveness, technically very challenging and financially very costly.
Severity (intensity) Table D-3	**Severity (intensity)**	
	Slight	Slight impacts or benefits on the affected system(s) or party(ies)
	Moderate	Moderate impacts or benefits on the affected system(s) or party(ies)
	Severe / beneficial	Severe or intense impacts or benefits on the affected system(s) or party(ies)
	Very severe / very beneficial	Very severe or very intense impacts on or very high benefits to the affected system(s) or party(ies)
Residual Risk	**Residual Risk**	
	Low	There is a low risk that additional environmental and social (E&S) impacts will arise after mitigation measures have been effectively implemented.
	Moderate	There is a moderate risk that additional E&S impacts will arise after mitigation measures have been effectively implemented.
	High	There is a high risk that additional E&S impacts will arise after mitigation measures have been effectively implemented but not sufficient enough to stop the project from proceeding.
	Very High	There is a very high risk that additional E&S impacts will arise after mitigation measures have been effectively implemented and proceeding with the project should be seriously questioned.

Table D-3: Impacts severity (intensity) rating

Impact severity *(The severity of negative impacts, or how beneficial positive impacts would be on an affected system or affected party)*	
Very severe	**Very beneficial**
An irreversible and permanent change to the affected system(s) or party(ies) which cannot be mitigated. For example, the permanent loss of forested land with very high carbon content.	A permanent and very substantial benefit to the affected system(s) or party(ies), with no real alternative to achieving this benefit. For example, the substantial improvement in energy efficiency.
Severe	**Beneficial**
Long term impacts on the affected system(s) or party(ies) that could be mitigated. However, this mitigation would be difficult, expensive or time consuming, or some combination of these. For example, the clearing of forest vegetation with high carbon content.	Long term impact and substantial benefit to the affected system(s) or party(ies). Alternative ways of achieving this benefit would be difficult, expensive or time consuming, or some combination of these. For example, an increase in energy efficiency.
Moderately severe	**Moderately beneficial**
Medium to long term impacts on the affected system(s) or party(ies), which could be mitigated. For example, constructing a road where there was vegetation with a low conservation value or low carbon content.	Medium to long term impact of real benefit to the affected system(s) or party(ies). Other ways of optimising the beneficial effects are equally difficult, expensive and time consuming (or some combination of these), as achieving them in this way. For example, a 'slight' improvement in energy efficiency.
Slight	**Slightly beneficial**
Medium- or short-term impacts on the affected system(s) or party(ies). Mitigation is very easy, cheap, less time consuming or not necessary. For example, a temporary loss of vegetation and carbon content.	A short to medium term impact and negligible benefit to the affected system(s) or party(ies). Other ways of optimising the beneficial effects are easier, cheaper and quicker, or some combination of these.
No effect	**Don't know / Can't know**
The system(s) or party(ies) is not affected by the proposed development.	In certain cases, it may not be possible to determine the severity of an impact.

Table D-4: Description of issues level significance ratings

Significance rate	Description	Colour code
	Negative	
Low	The climate related impacts on this issue are acceptable and mitigation, while desirable, is not essential. The impacts on the issue by themselves are insufficient, even in combination with other low impacts, to prevent the development being approved. Impacts on this particular issue will result in negative medium to short term effects on the social and/ or natural environment.	Low (-)
Moderate	The climate related impacts on this issue are important and require mitigation. The impacts on the issue are, by themselves, insufficient to prevent the implementation of the project, but could in conjunction with other issues with moderate impacts, prevent its implementation. Impacts on this particular issue usually result in a negative medium to long-term effect on the social and / or natural environment.	Moderate (-)
High	The climate change related impacts on this issue are serious, and if not mitigated, they may prevent the implementation of the project. Impacts on this particular issue would be considered by society as constituting a significant and usually a long-term change to the natural and/ or social environment.	High (-)

Significance rate	Description	Colour code
Very high	The climate change related impacts on this issue are very serious, and probably cannot be mitigated, and may represent a "fatal flaw" to the implementation of the project. Impacts on this particular issue would be considered by society as constituting a very severe and usually permanent or very long-term changes to the natural and/ or social environment.	Very high (-)
Positive		
Low	A short to medium term and negligible climate change related benefit to the affected system(s) or party(ies). Other ways of optimising the beneficial effects are easier, cheaper and quicker, or some combination of these.	Low (+)
Moderate	A medium to long term climate change related benefit to the affected system(s) or party(ies). Other ways of optimising the beneficial effects are equally difficult, expensive and time consuming (or some combination of these), as achieving this in this way. For example, a 'slight' improvement in energy efficiency.	Moderate (+)
High	A long-term impact and substantial climate change related benefit to the affected system(s) or party(ies). Alternative ways of achieving this benefit would be difficult, expensive to time consuming, or some combination of these. For example, a material increase in energy efficiency.	High (+)
Very high	Impacts on this particular climate change related issue would be considered by society as constituting highly beneficial and usually a long-term positive change to the natural and/ or social environment. For example, the establishment and formal proclamation of a nature reserve with a high carbon content.	Very high (+)