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

Project done on behalf of **EIMS (Pty) Ltd**

Project Compiled by:

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Revision Record

Revision Number	Date	Reason for Revision
Rev 0	February 2025	For internal review
Rev 1	February 2025	For client review
Rev 2	February 2025	Replacement of Figure 1-1
Rev 3	February 2025	Incorporation of client's comments
Rev 4	April 2025	Changes to site layout

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). This report details the scoping phase of the CCA undertaken for the project which will focus on the physical risks of climate change on the region. The climate change specialist study, which will follow the scoping phase, will assess the significance of impacts of the project greenhouse gas (GHG) emissions generated, along with the potential impact of climate change on the operation of the project.

The physical risks of climate change on the study area (based on the Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC) data) can be summarised as follows:

- Climate:
    - Temperature:
        - Baseline: 3.9 hot days (90th percentile)
        - High mitigation climate situation (RCP4.5): 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.

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LIST OF ACRONYMS AND SYMBOLS

AFF	Agriculture, Forestry and Fishing
Airshed	Airshed Planning Professionals (Pty) Ltd
AR5	IPCC's fifth assessment report
AR6	IPCC's sixth assessment report
AWD	Accelerated Weight Drop Seismic
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
DFFE	Department of Forestry, Fisheries and the 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
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
H_2O	Water vapour
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres per person per day
LUCF	Land-Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
m	Metre
mm	Millimetre
mm/yr	Millimetres per year
Mt	Million ton
MW	Megawatt
N_2O	Nitrous oxide
NAAQS	National Ambient Air Quality Standards
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
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
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
TA	Target drilling areas
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation
W/m^2	Watts per metre squared
%	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)"

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

1 INTRODUCTION

Motuoane Energy (Pty) Ltd (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 60 000 hectares (ha), covering three hundred and eighty-five (385) farm portions near the towns of Virginia, Hennenman and Odendaalsrus in the Free State Province.

The main activities are core 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. Although up to eleven (11) target drilling areas (TA) with 500 m buffer (1 km corridor) within the exploration right may be undertaken over the 9-year period, the current Works Program caters for only three (3) drilling wells. It must be noted that there may be a single, multiple or no drilling activities within some of the target drilling areas. Should more than 3 drilling wells be required within the ER, the current Works Program will be required to be updated accordingly. Majority of the drilling target areas are proposed within the western central area of the exploration right on the agricultural fields between Saaiplaas, Bronville, Thabong and Whites. Two target drilling areas are located in the south of ER386, approximately 7 km southeast of Meloding while TA11 is located approximately 4 km northeast of Phomolong on the eastern boundary of ER386 and TA9 and TA13 are located approximately 20 km northeast of Riebeeckstad on the northern boundary. 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 100 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) (**Figure 1-1**). This report details the scoping phase of the CCA undertaken for the project which will focus on the physical risks of climate change on the region. The climate change specialist study, which will follow the scoping phase, will assess the significance of impacts of the project greenhouse gas (GHG) emissions generated, along with the potential impact of climate change on the operation of the project.

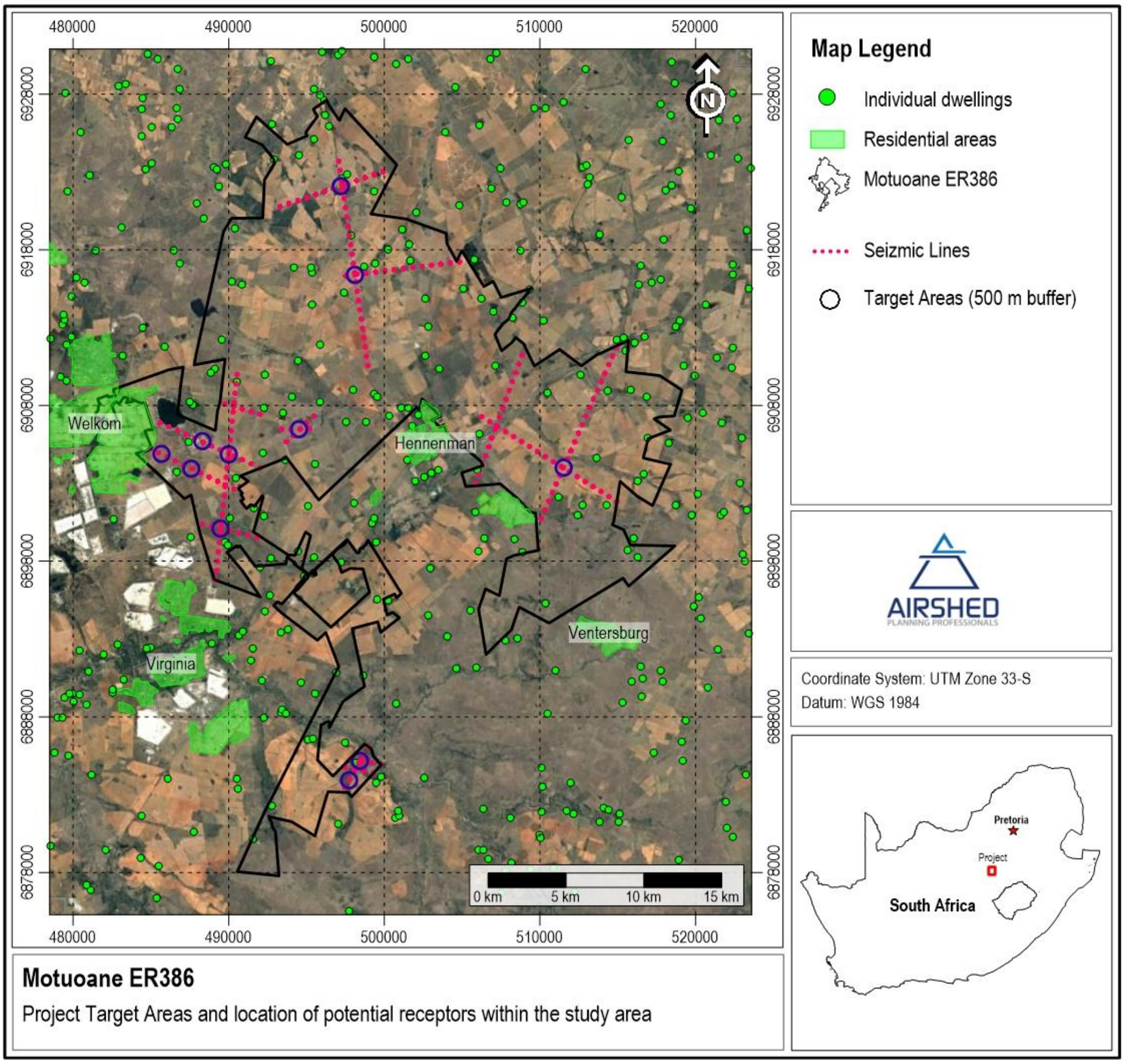

Figure 1-1: Location of the project site

1.1 Scope of Work

The following tasks will be included in the scope of work for the CCA scoping phase:

1. The robustness of the project in terms of forecasted climate change impacts to the area over the lifetime of the project.

2. The vulnerability of communities in the immediate vicinity of the project to climate change.

3. Potential impact of climate change in the region.

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 415 ppm in early September 2021 (NOAA, 2021). This increase of CO_2 in the Earth's atmosphere has occurred despite the uptake of a large portion of the emissions by various natural "sinks" involved in the carbon cycle (NOAA, 2021). Anthropogenic CO_2 emissions (i.e., emissions produced by human activities) come from combustion of fossil fuels, principally coal, oil, and natural gas, along with waste processing and decomposition, deforestation, soil erosion and animal agriculture (IPCC, 2007).

The following sections describe the alignment of South African national policies regarding 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 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 NDC in September 2021.

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

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 an 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 Government Gazette (GG) 50966 of 23 July 2024. Although the Climate Change Act has been promulgated, it is not yet in force as the President must still proclaim its commencement. 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).

It is likely that the Act will commence during the operational lifetime of the proposed project activities, if not before.

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

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

and finance and investment necessities to undertake the resolutions with updated revisions to the adaptation goals and mitigation targets.

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

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

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

- 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 updated NDC mitigation targets, consistent with South Africa's fair share, are presented in **Table 2-1**.

Table 2-1: South Africa's NDC mitigation targets

Year	Target	Corresponding period
2025	South Africa's annual GHG emissions will be in a range between 398 - 510 Mt CO_2e.	2021-2025
2030	South Africa's annual GHG emissions will be in a range between 398 - 440 Mt CO_2e.	2026-2030

2.4 Greenhouse Gas Emissions Reporting

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

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

The South African Greenhouse Gas Emission Reporting System (SAGERS) web-based 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 and to prepare a greenhouse gas mitigation plan.

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] the 2021 global GHG emissions from the energy category were approximately 370 408 Mt CO_2e; 75.5% of the total GHG emissions (including Land-Use Change and Forestry (LUCF)). The South African energy sector contributed 426.12 Mt CO_2e, ~1.115% of the global emissions from the energy sector in 2021.

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

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

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

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

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

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

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

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

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

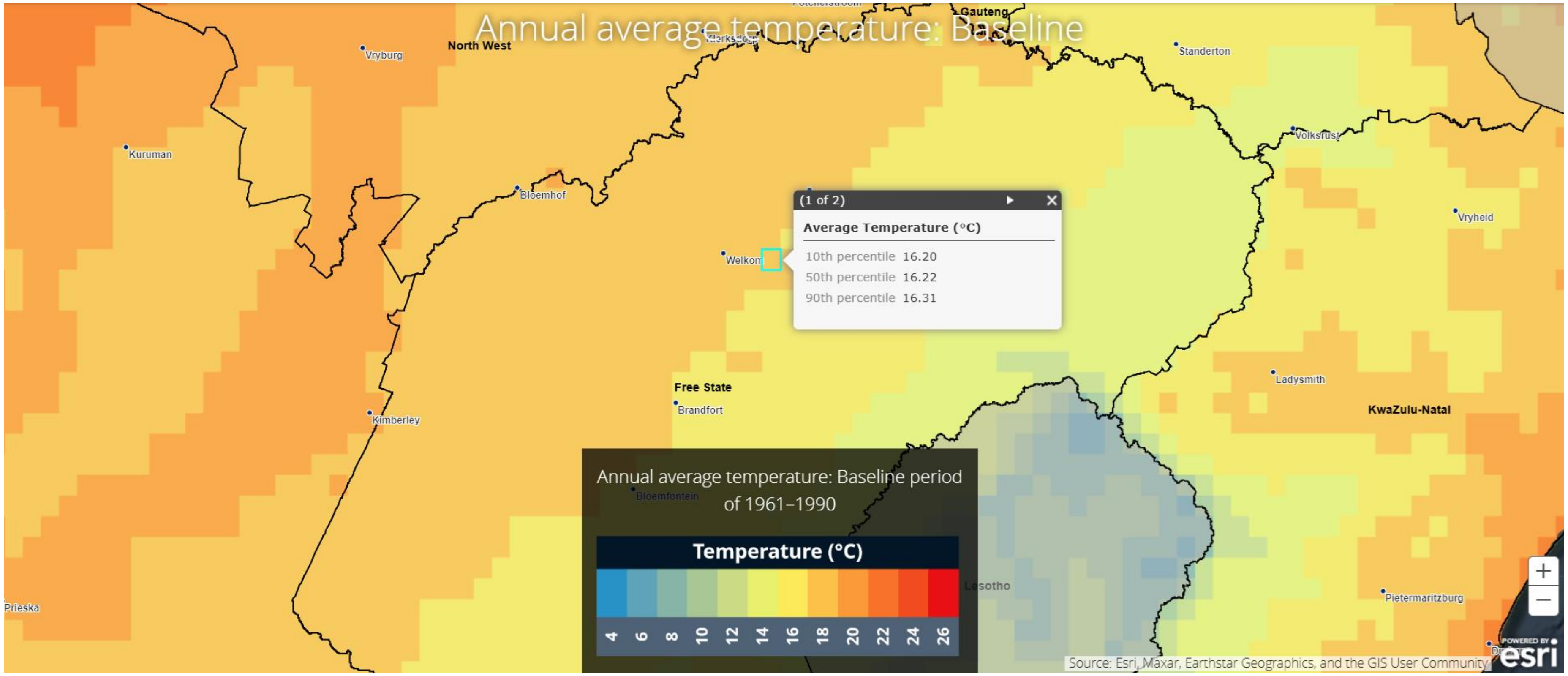


Figure 3-1: Baseline (1961 to 1990) annual average temperature for the project area (CSIR, 2025)

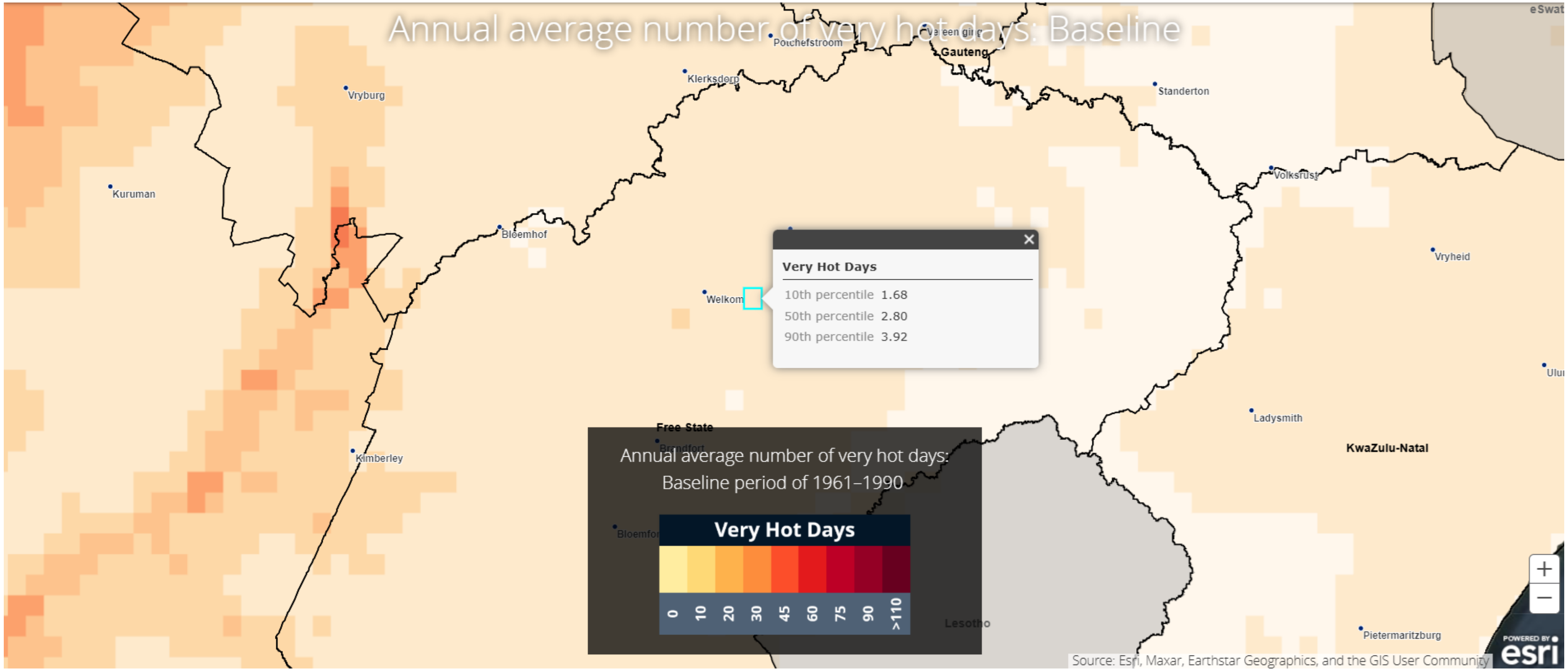


Figure 3-2: Baseline (1961 to 1990) number of very hot days (>35°C) annually for the project area (CSIR, 2025)

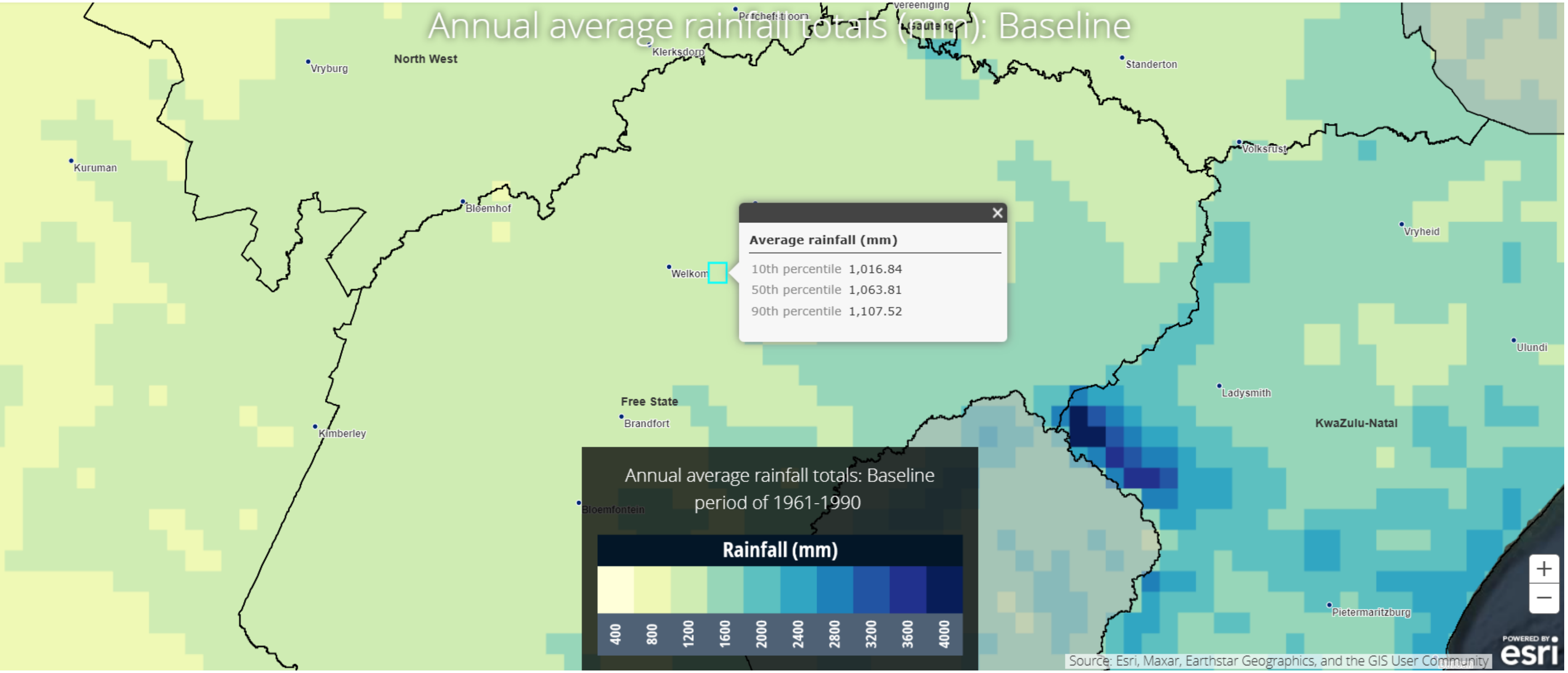


Figure 3-3: Baseline (1961 to 1990) annual average rainfall for the project area (CSIR, 2025)

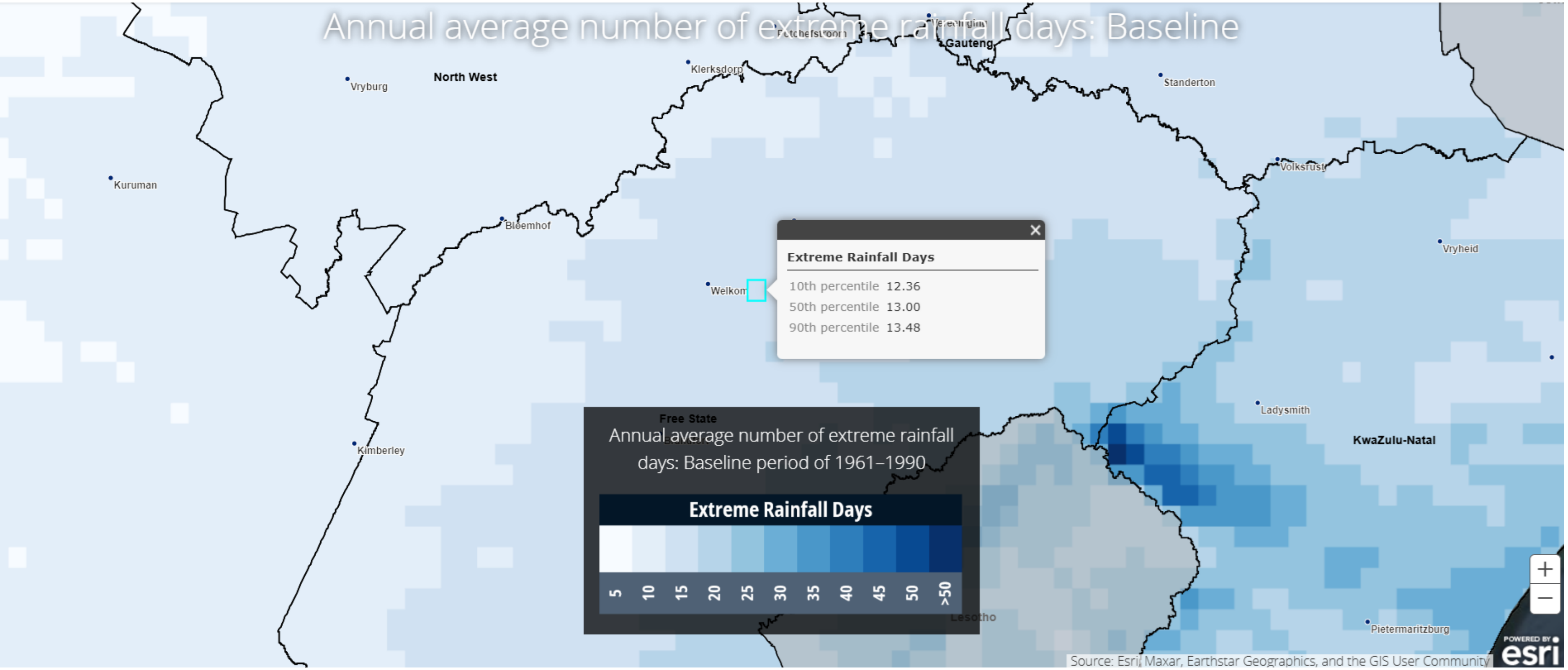


Figure 3-4: Baseline (1961 to 1990) annual average number of extreme rainfall days (>20 mm in <24 hours) for the project area (CSIR, 2025)

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).

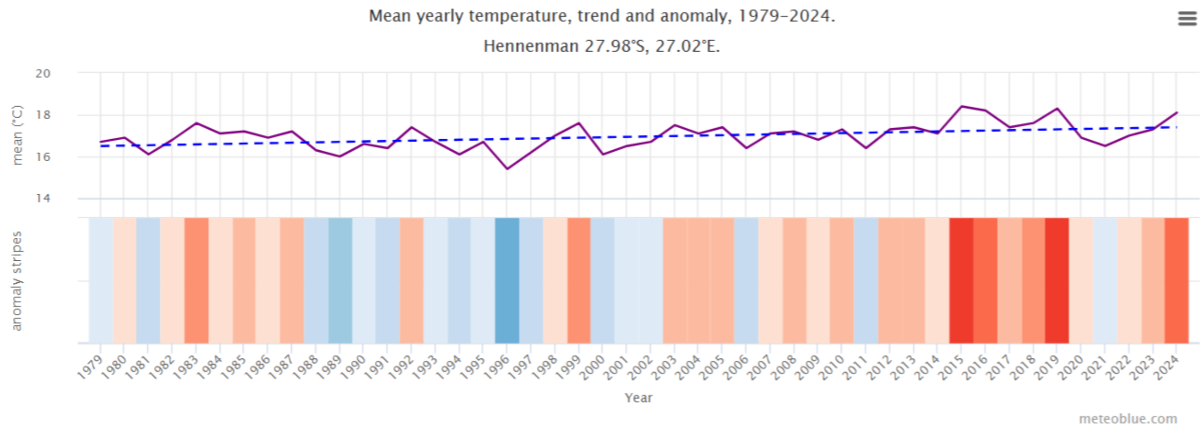


Figure 3-5: Annual average temperature (top panel) and temperature anomaly (lower panel) between 1979 and 2024 (meteoblue AG, 2025)

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

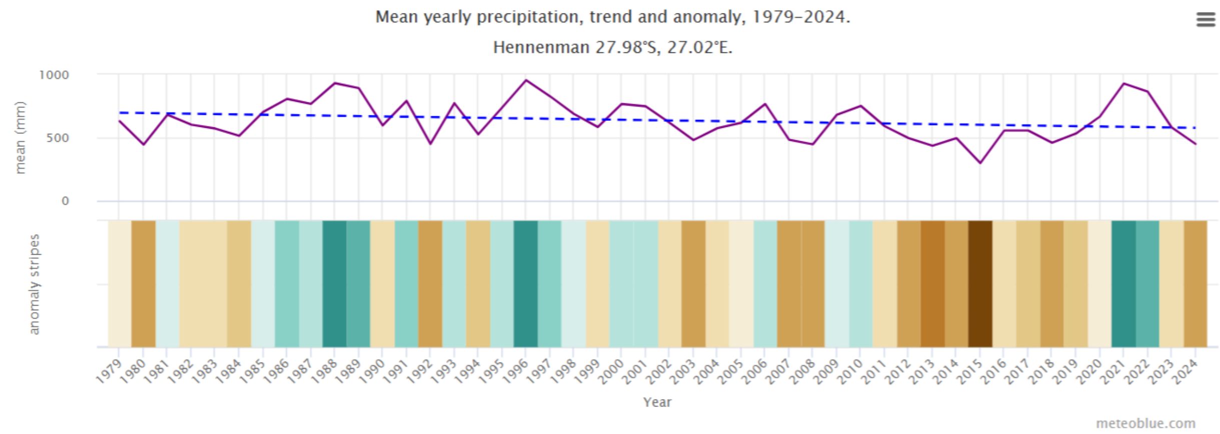


Figure 3-6: Annual average rainfall (top panel) and rainfall anomaly (lower panel) between 1979 and 2024 (meteoblue AG, 2025)

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).

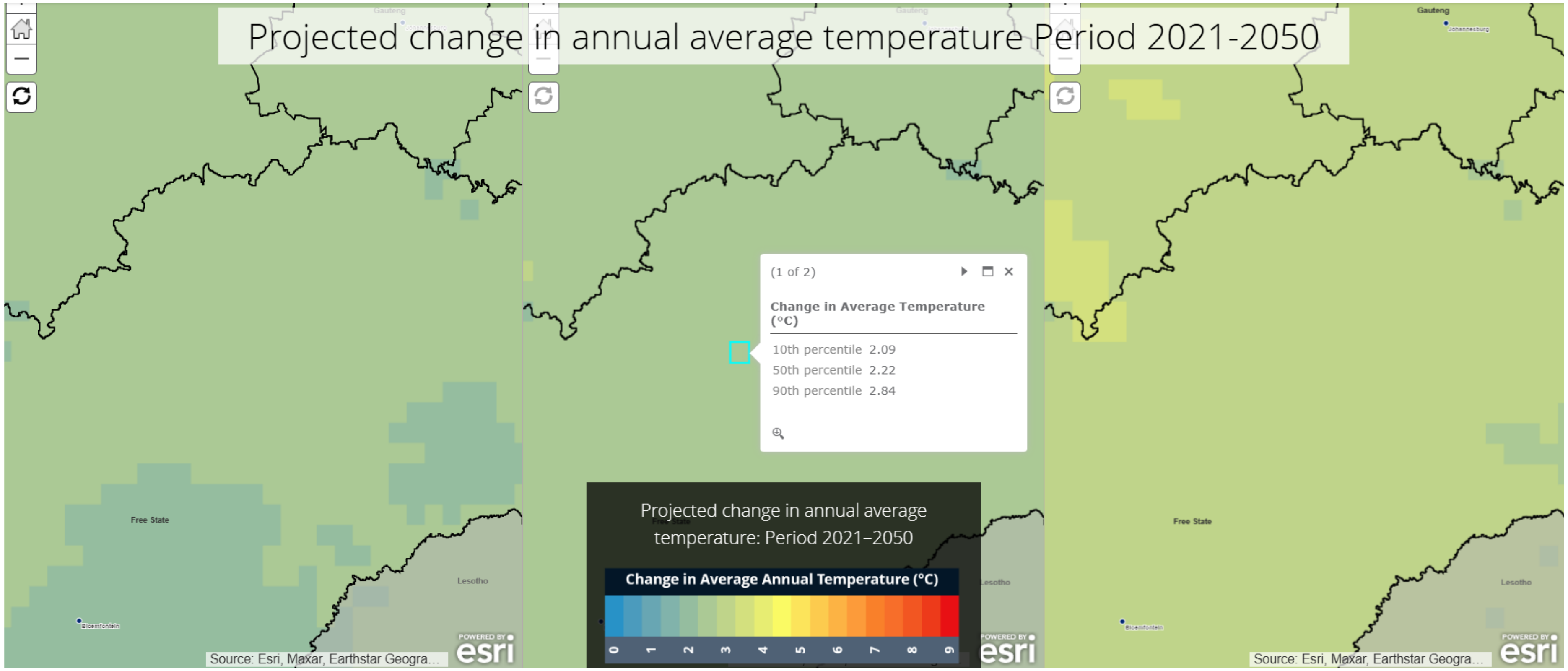


Figure 3-7: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP4.5 trajectory

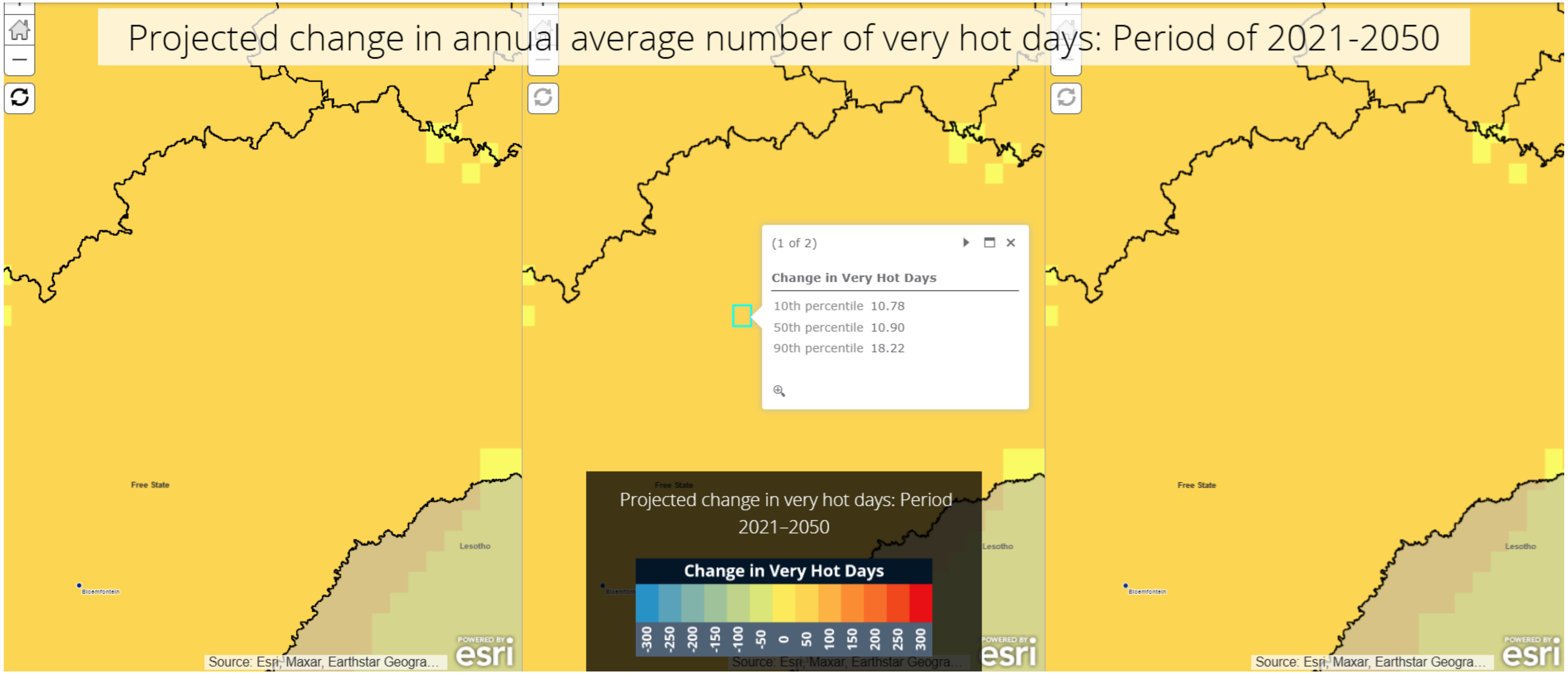


Figure 3-8: Projected change in very hot days for the near future (2021 – 2050) for the RCP4.5 trajectory

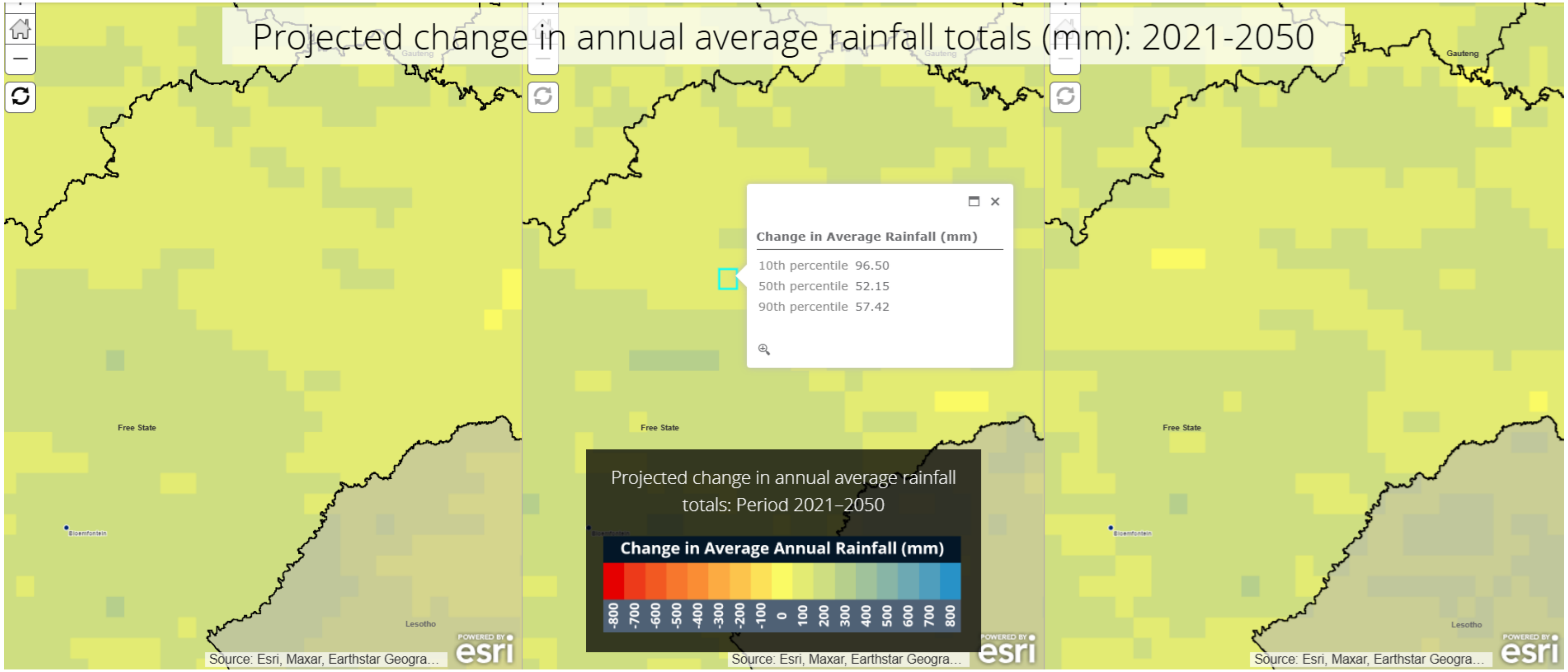


Figure 3-9: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP4.5 trajectory

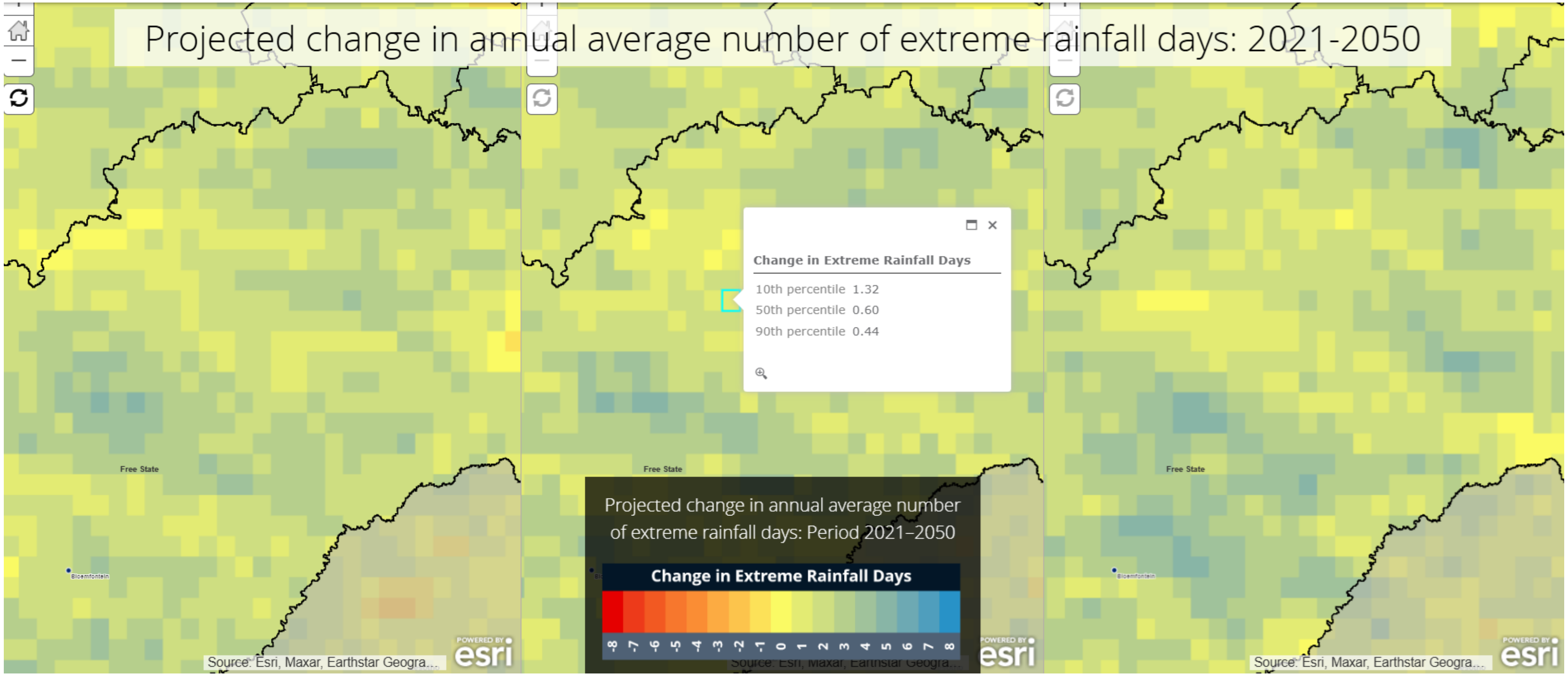


Figure 3-10: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP4.5 trajectory

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).

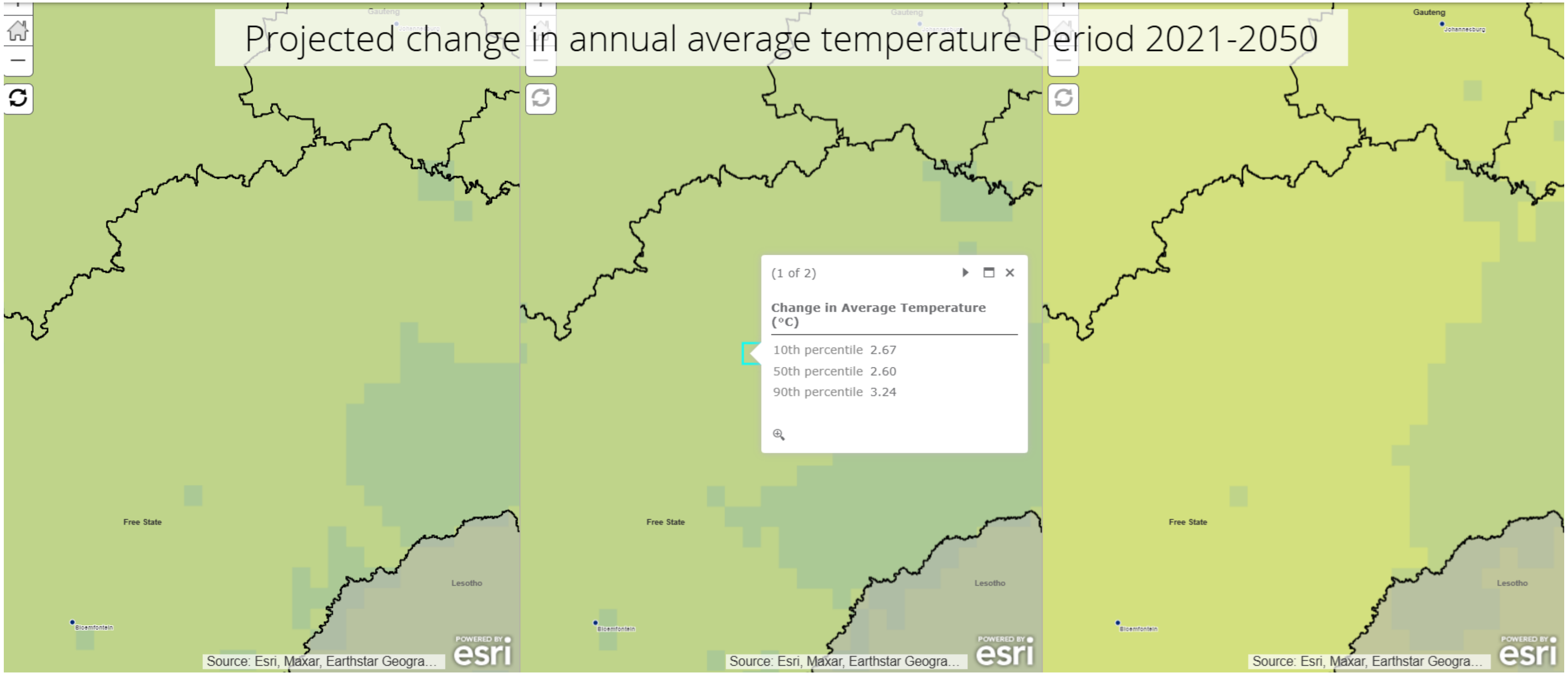


Figure 3-11: Projected change in annual average temperature for the near future (2021 – 2050) for the RCP8.5 trajectory

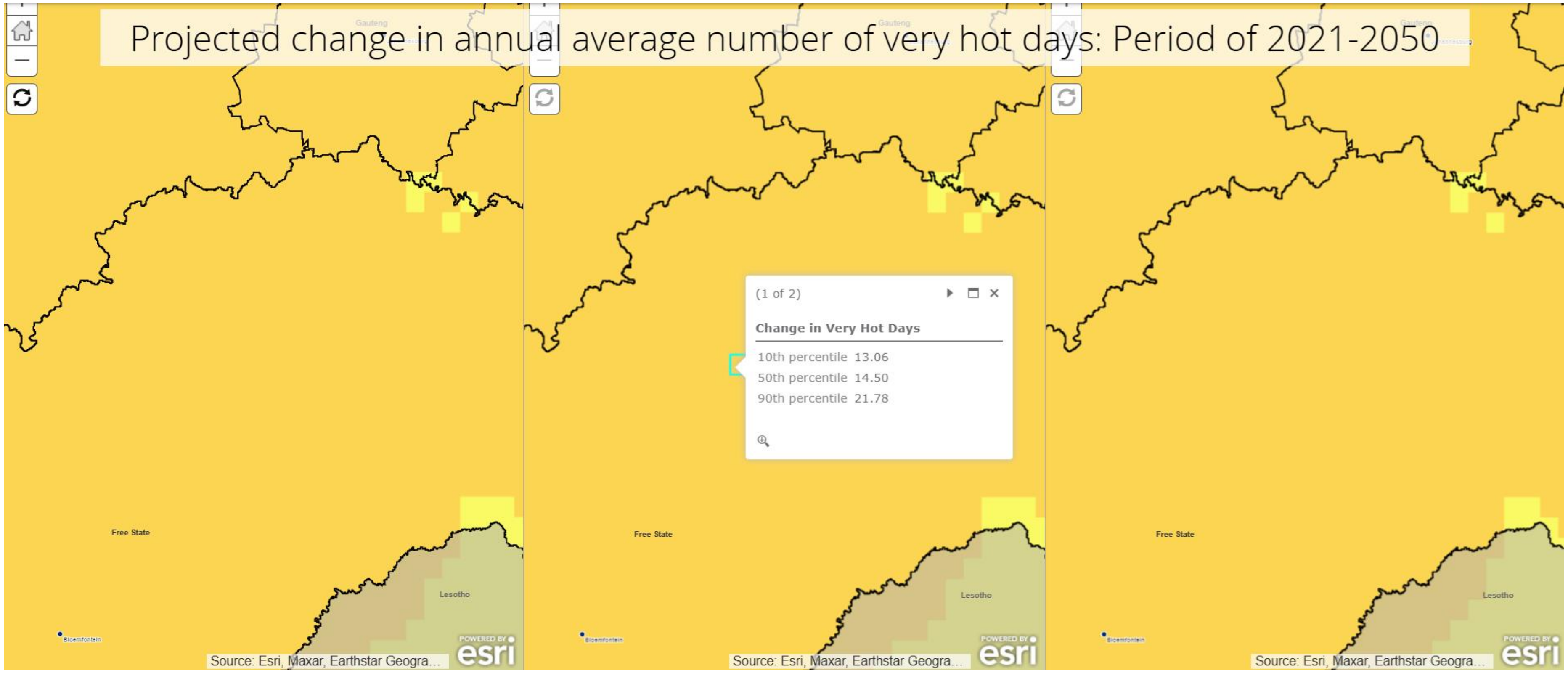


Figure 3-12: Projected change in very hot days for the near future (2021 – 2050) for the RCP8.5 trajectory

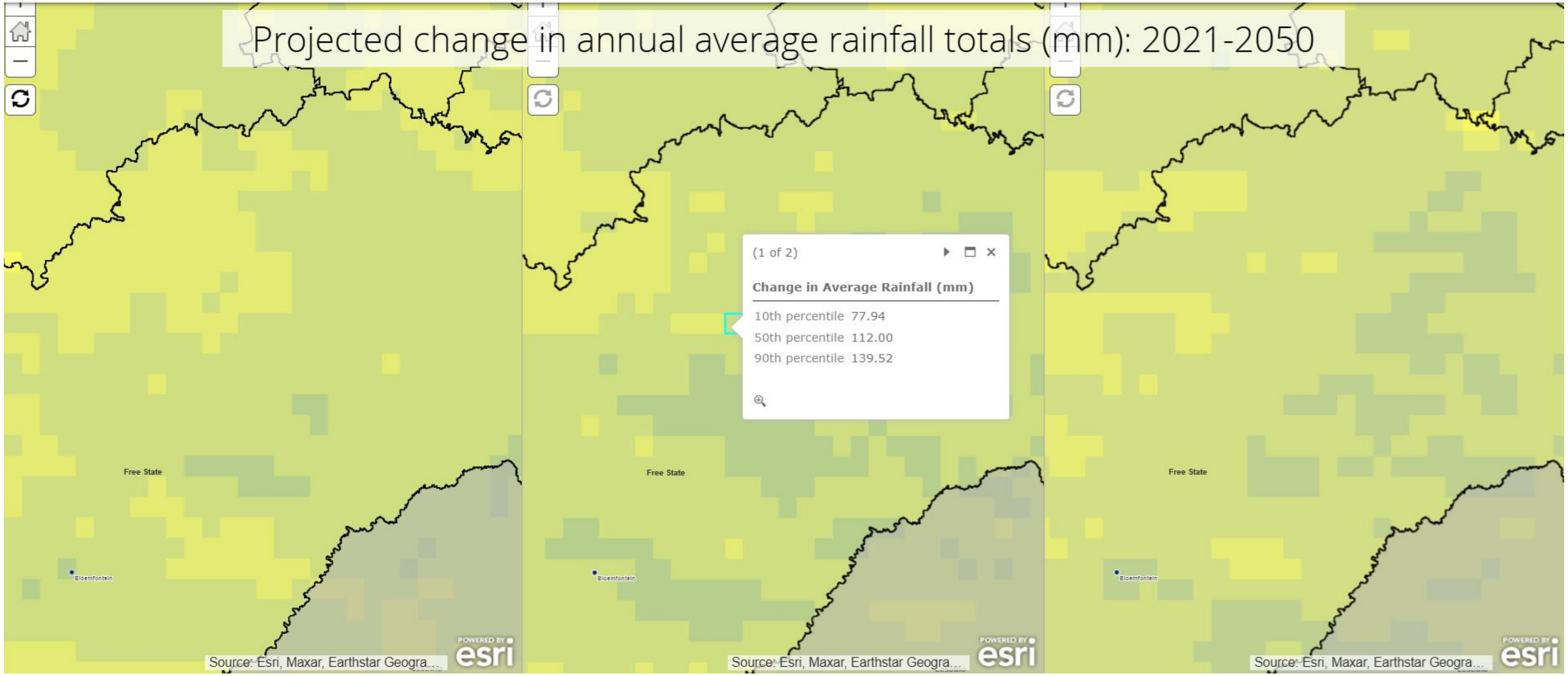


Figure 3-13: Projected change in annual average rainfall for the near future (2021 – 2050) for the RCP8.5 trajectory

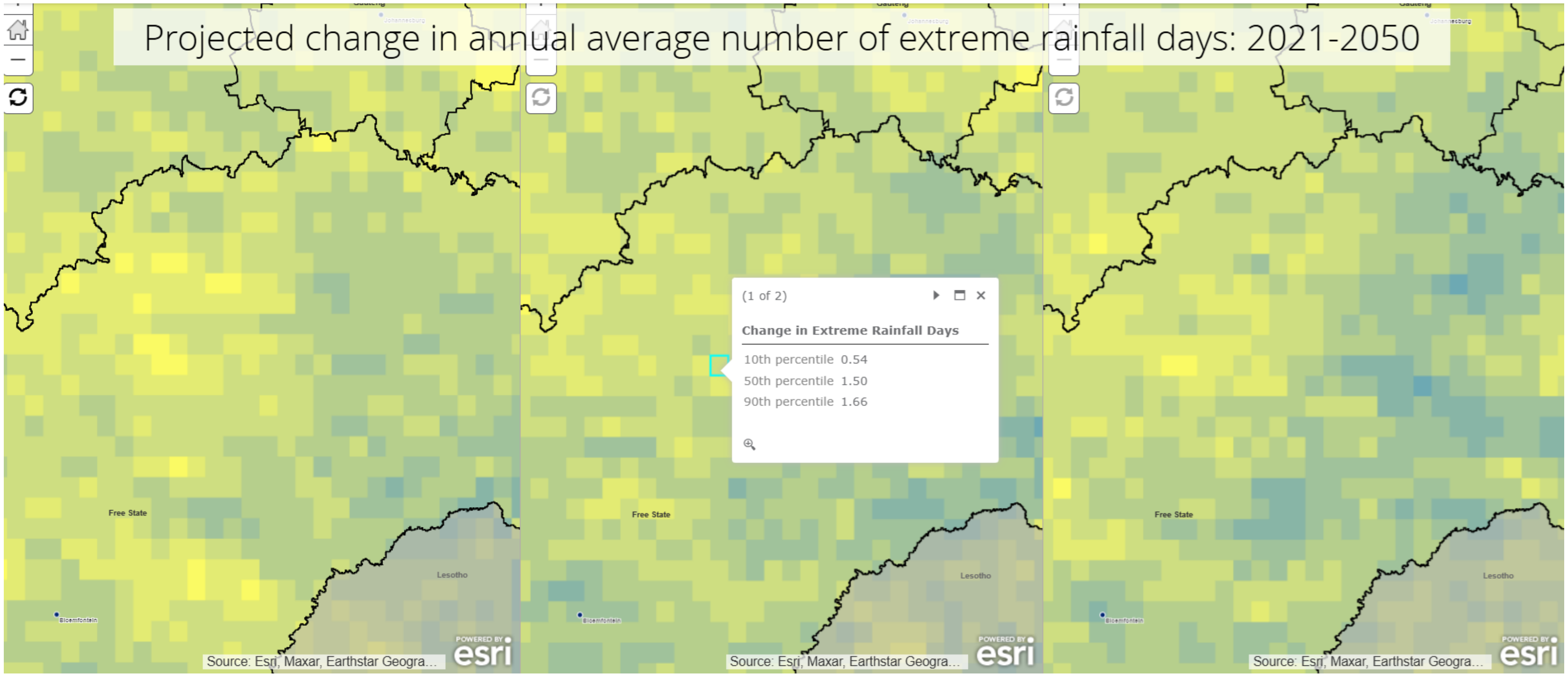


Figure 3-14: Projected change in annual average number of extreme rainfall days (>20 mm in <24 hours) for RCP8.5 trajectory

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**).

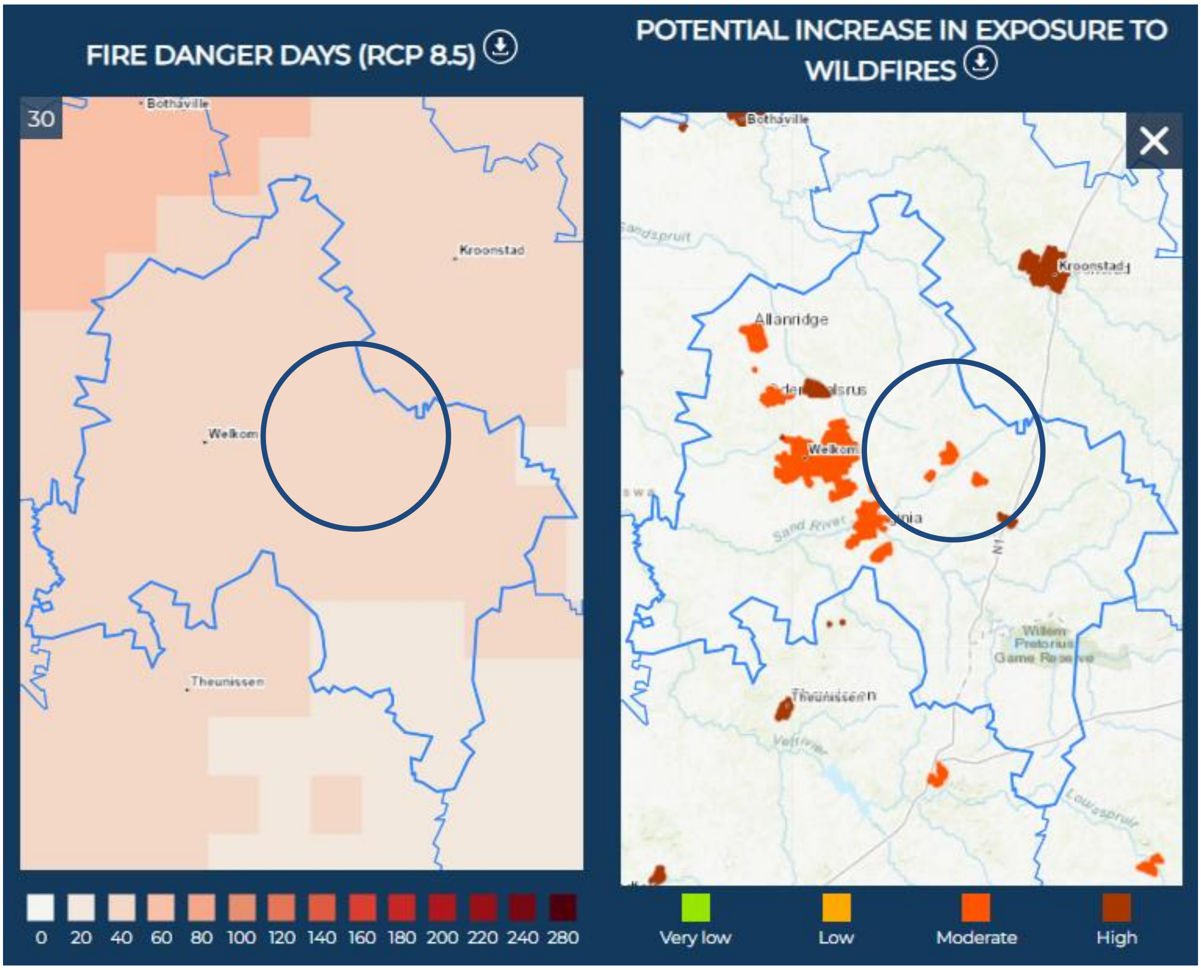


Figure 3-15: Risk of increased wildfires for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

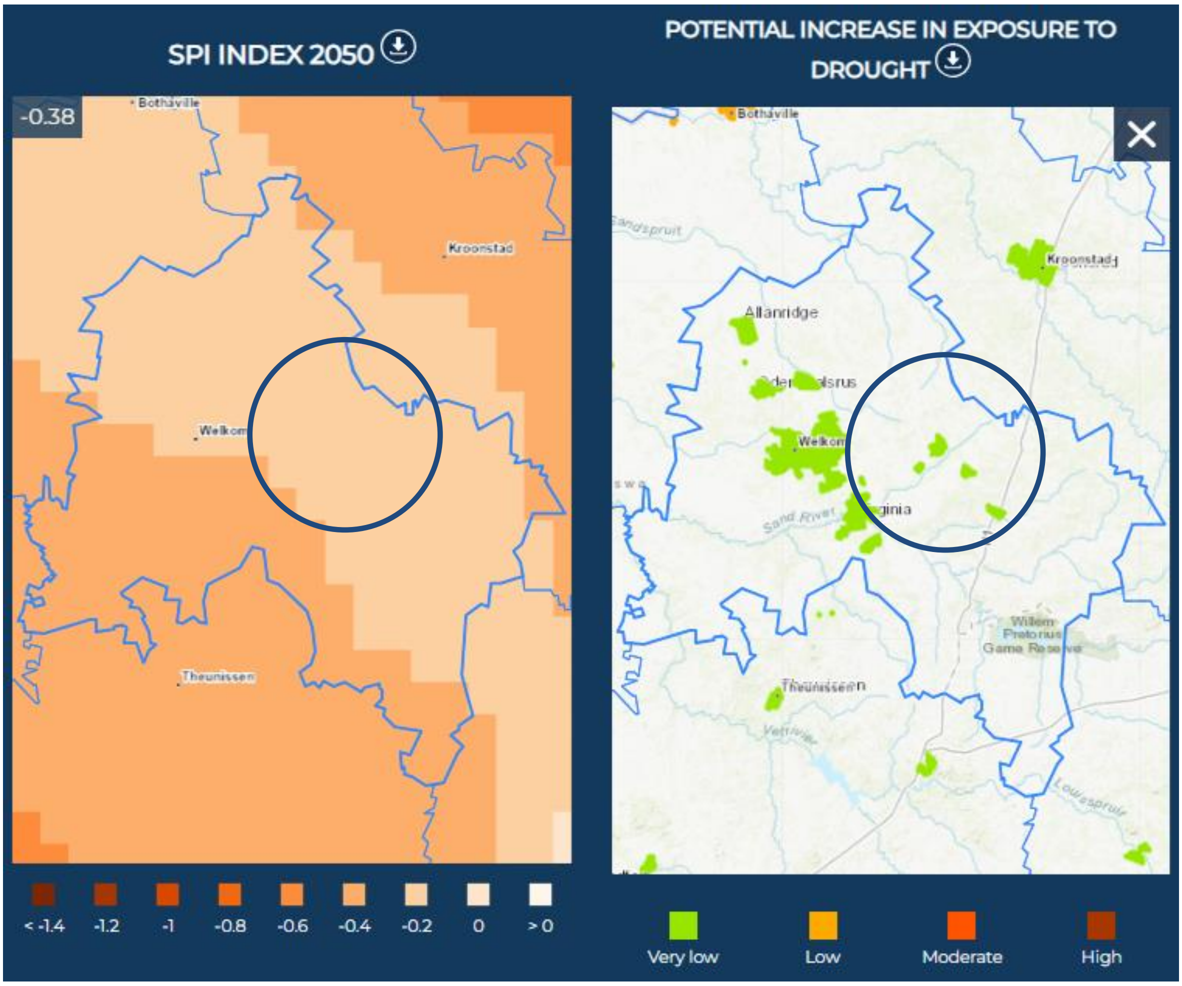


Figure 3-16: Risk of increased drought tendencies for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

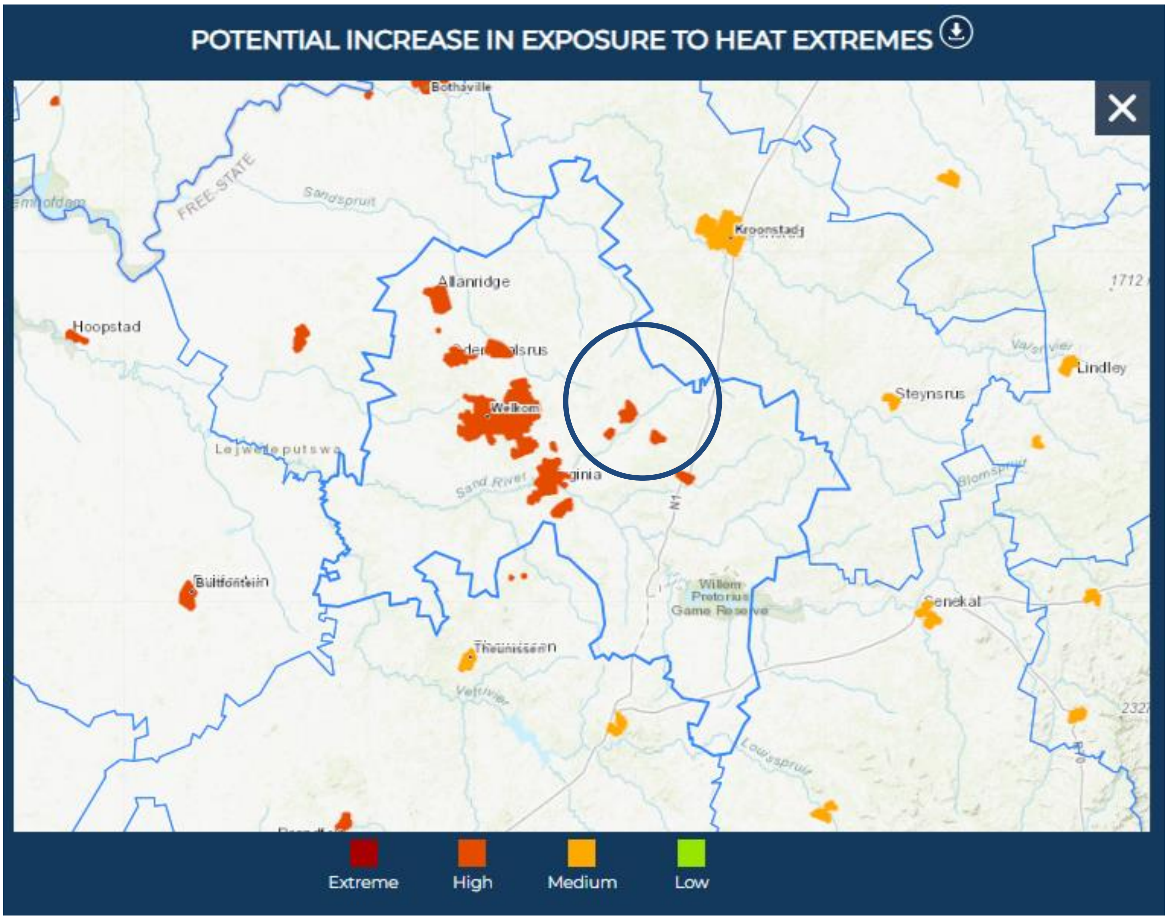


Figure 3-17: Risk of increased heat extremes for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

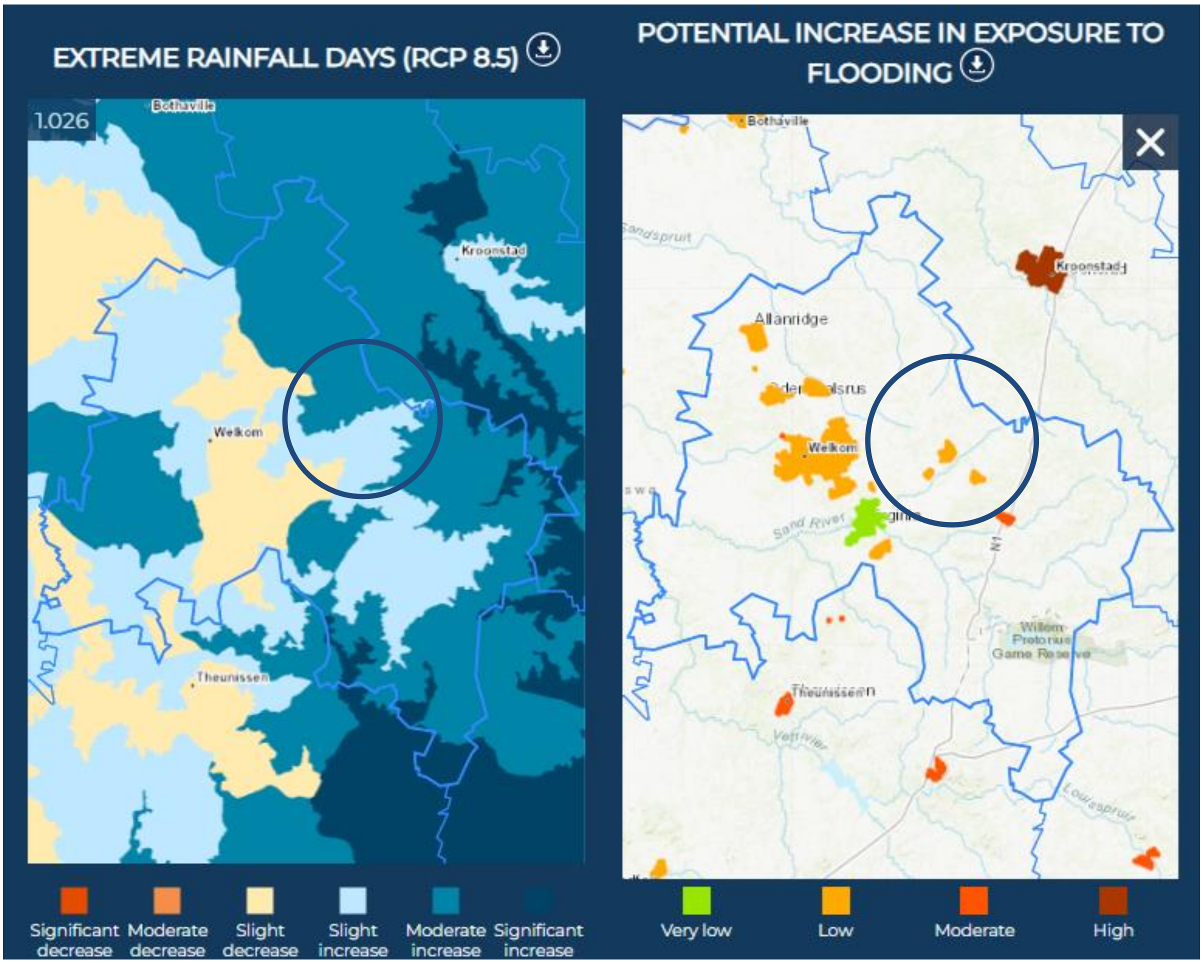


Figure 3-18: Risk of increased flooding for the Matjhabeng and Moqhaka Municipalities in 2050 based on RCP8.5 trajectory (dark blue marker indicates approximate location of the project)

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).

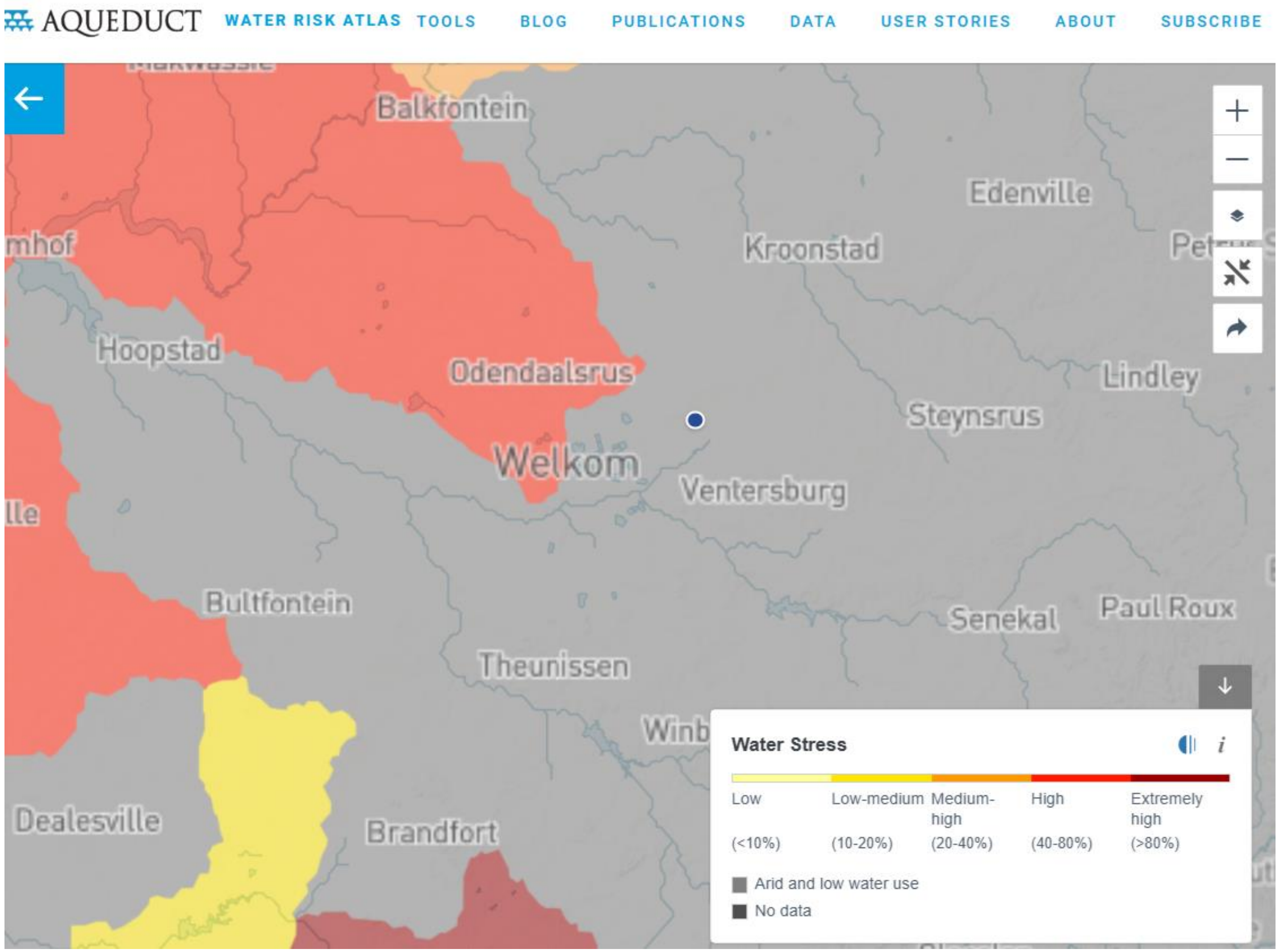


Figure 3-19: Current water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

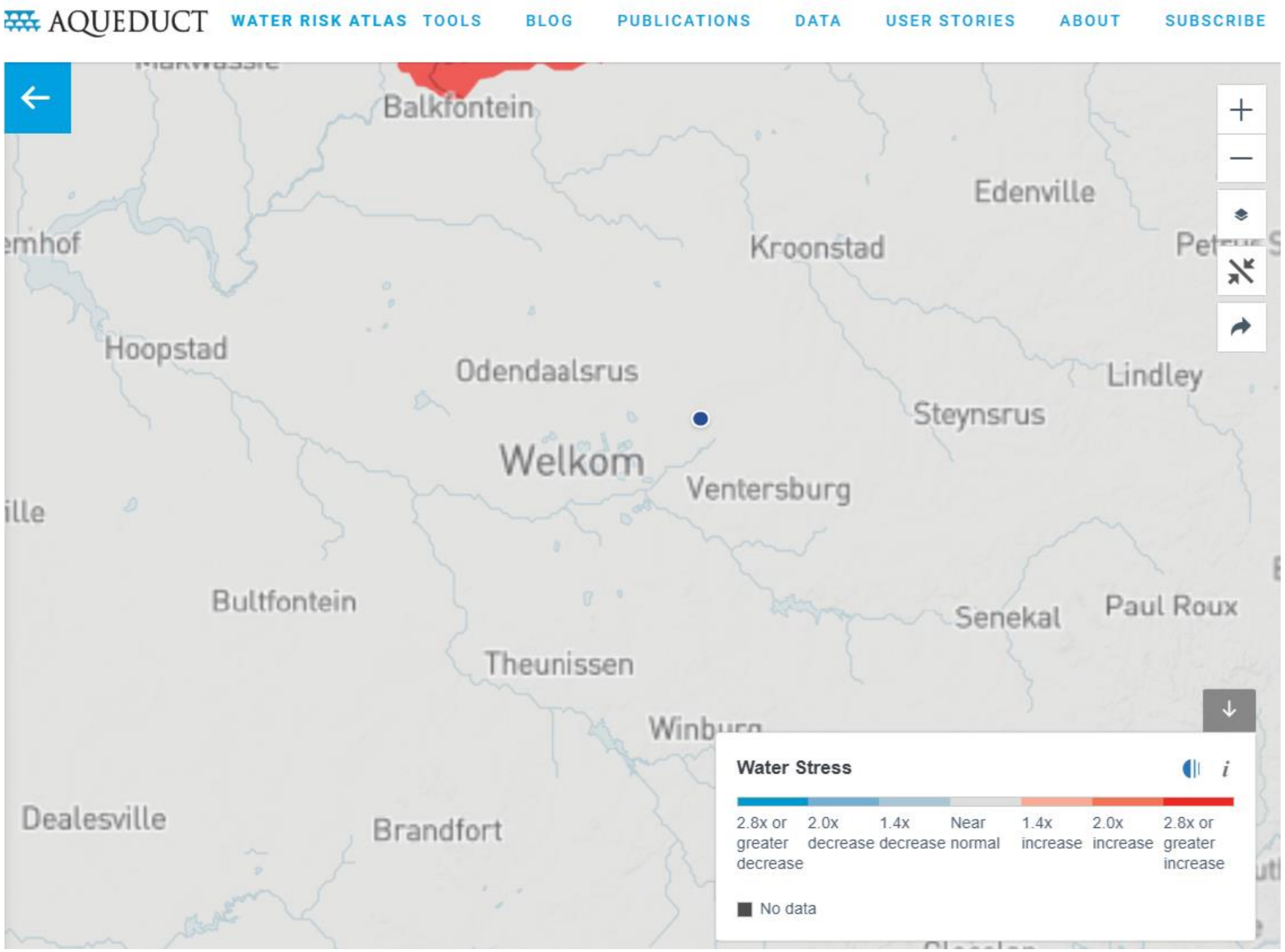


Figure 3-20: Projected (2050) water stress for the project area (Hofste, et al., 2019) (blue dot indicates project location)

3.4 Vegetation Disturbance

The potential vegetation types that will be disturbed over the lifetime of the proposed project include (South African National Biodiversity Institute, 2025):

- Bloemfontein Karroid Shrubland;
- Central Free State Grassland;
- Eastern Free State Clay Grassland;
- Highveld Alluvial Vegetation; and,
- Vaal-Vet Sandy Grassland.

This information will be used in the quantification of permanent GHG sink losses due to project infrastructure for the CCA.

3.5 Impact of Climate Change

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

3.5.1 Water Supply

3.5.1.1 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

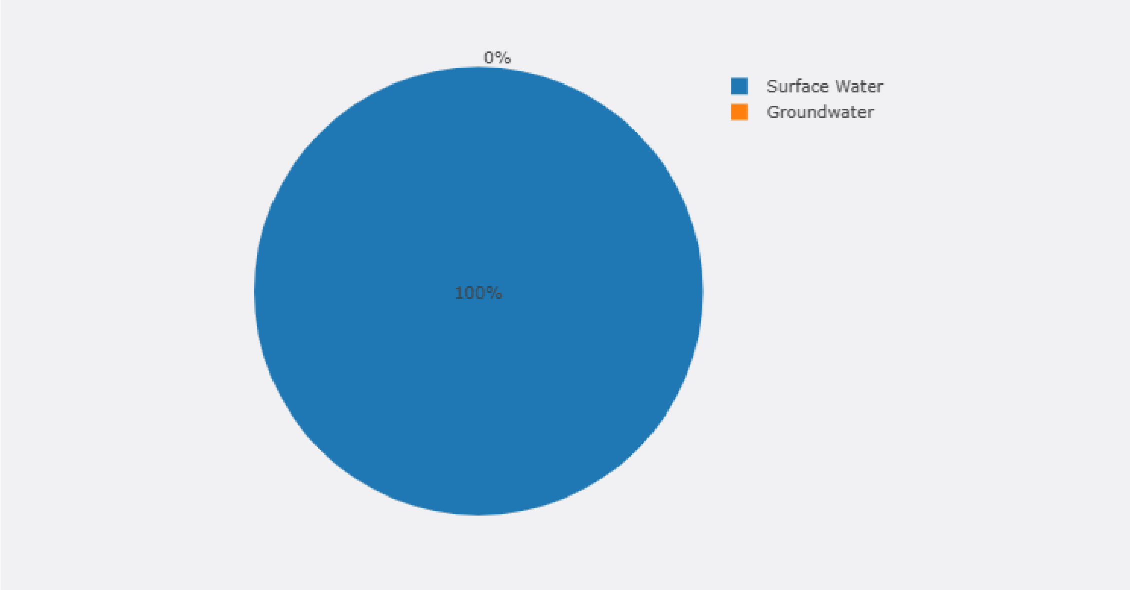


Figure 3-21: Current water availability for the Matjhabeng Municipality

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

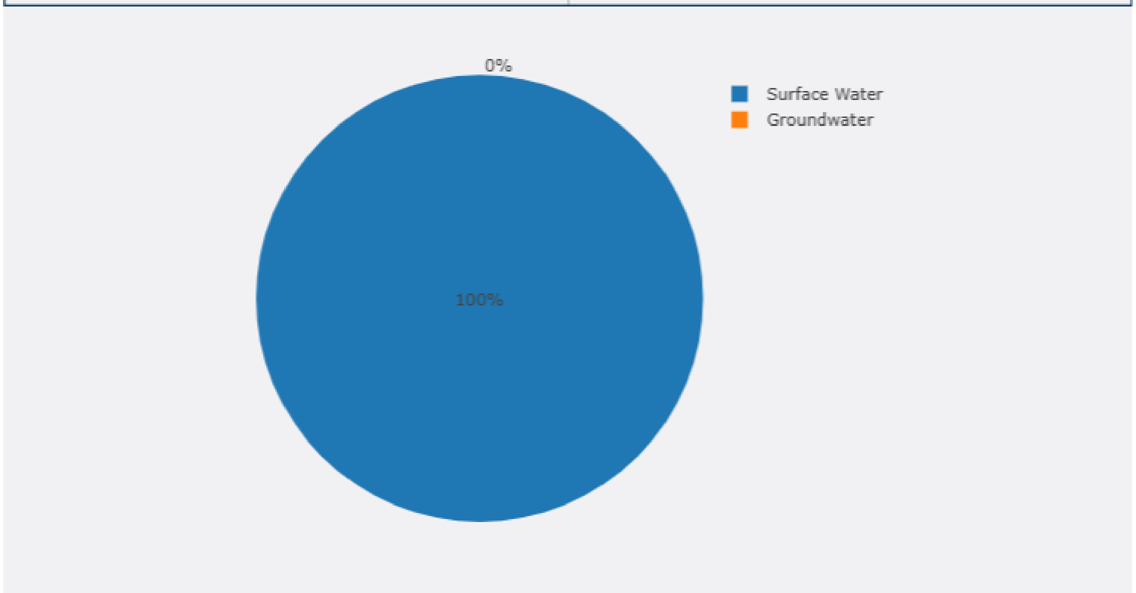
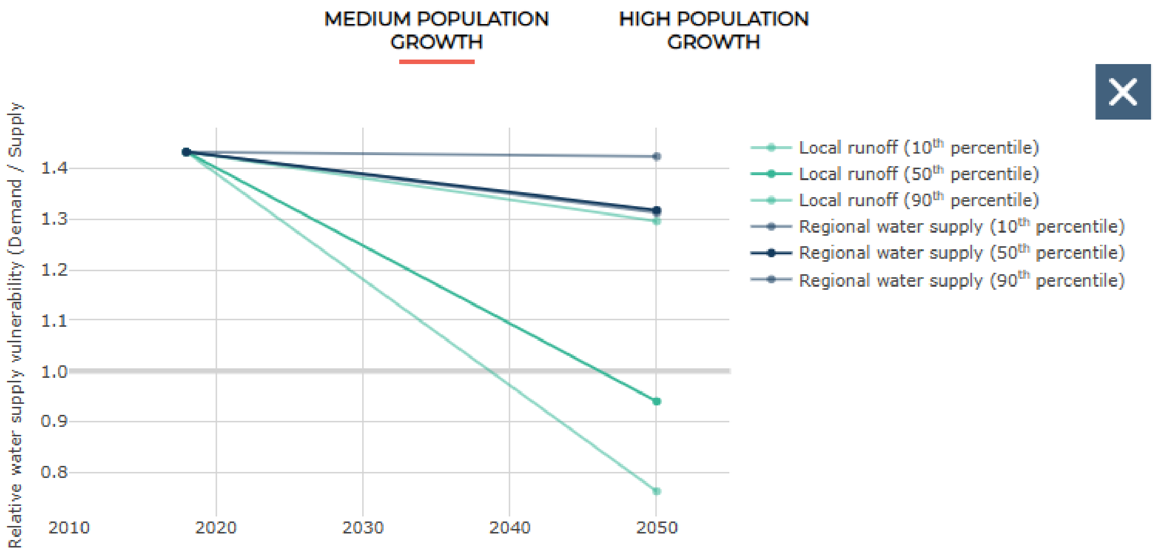


Figure 3-22: Current water availability for the Moqhaka Municipality

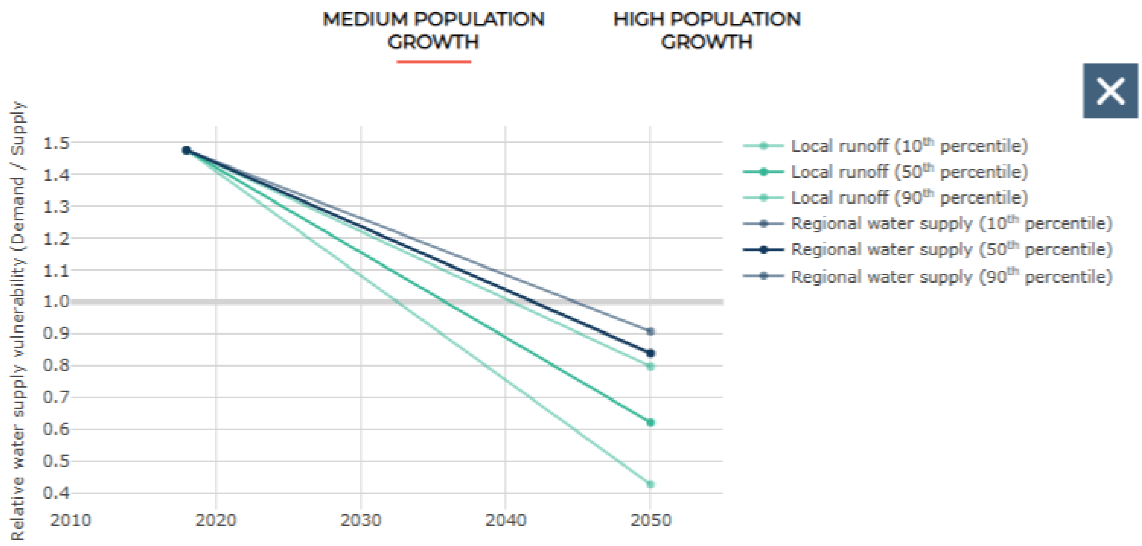
3.5.1.2 Impact on Resources

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

3.5.2 Surface Water

3.5.2.1 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.

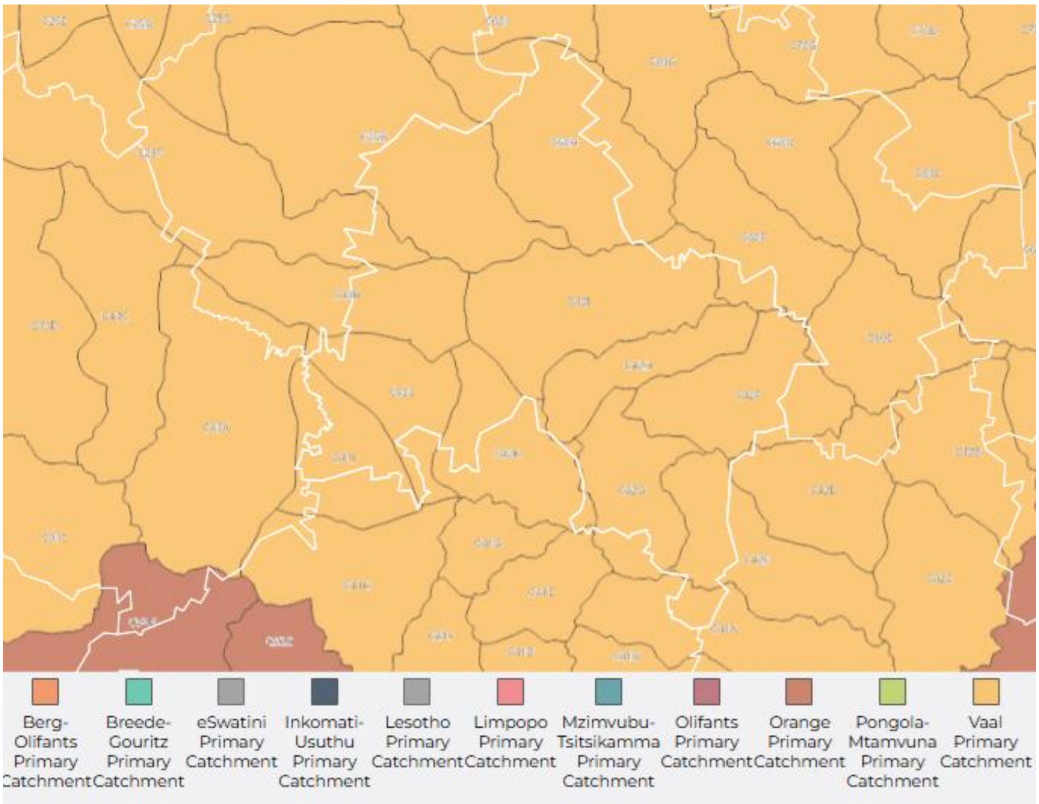


Figure 3-25: Quaternary catchment areas for the study area

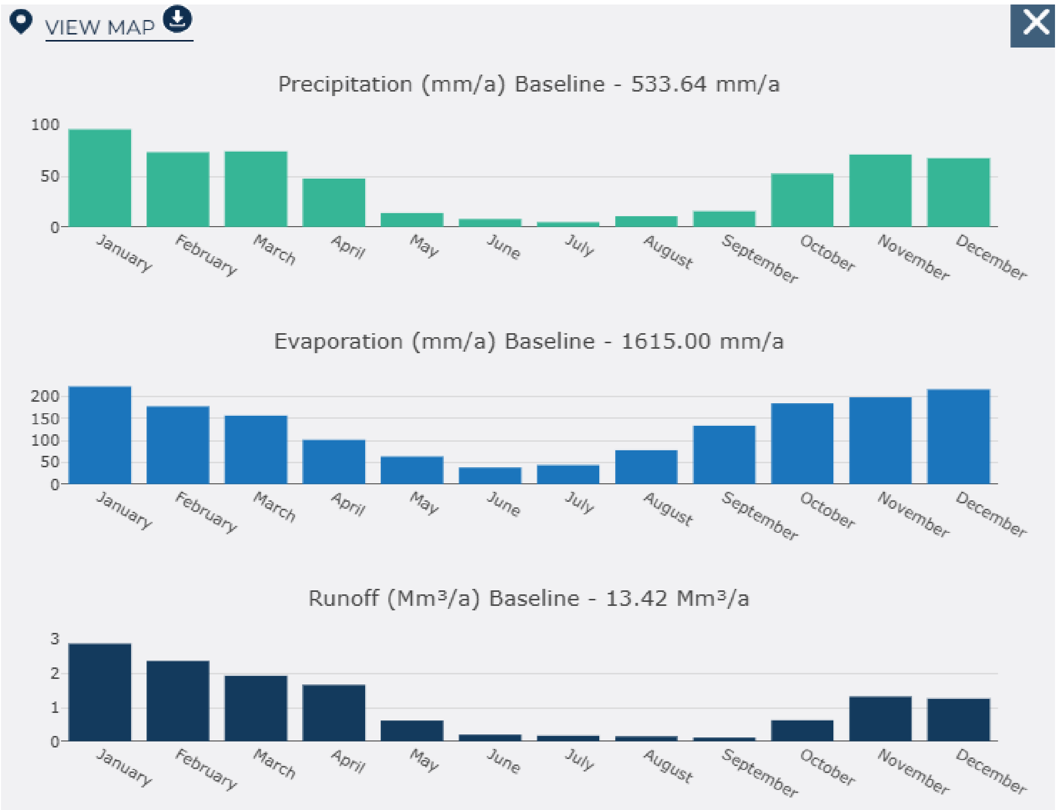


Figure 3-26: Current annual and monthly surface water runoff, precipitation and evaporation for the Matjhabeng Municipality which falls under the Vaal Primary Catchment

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

3.5.2.2 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.

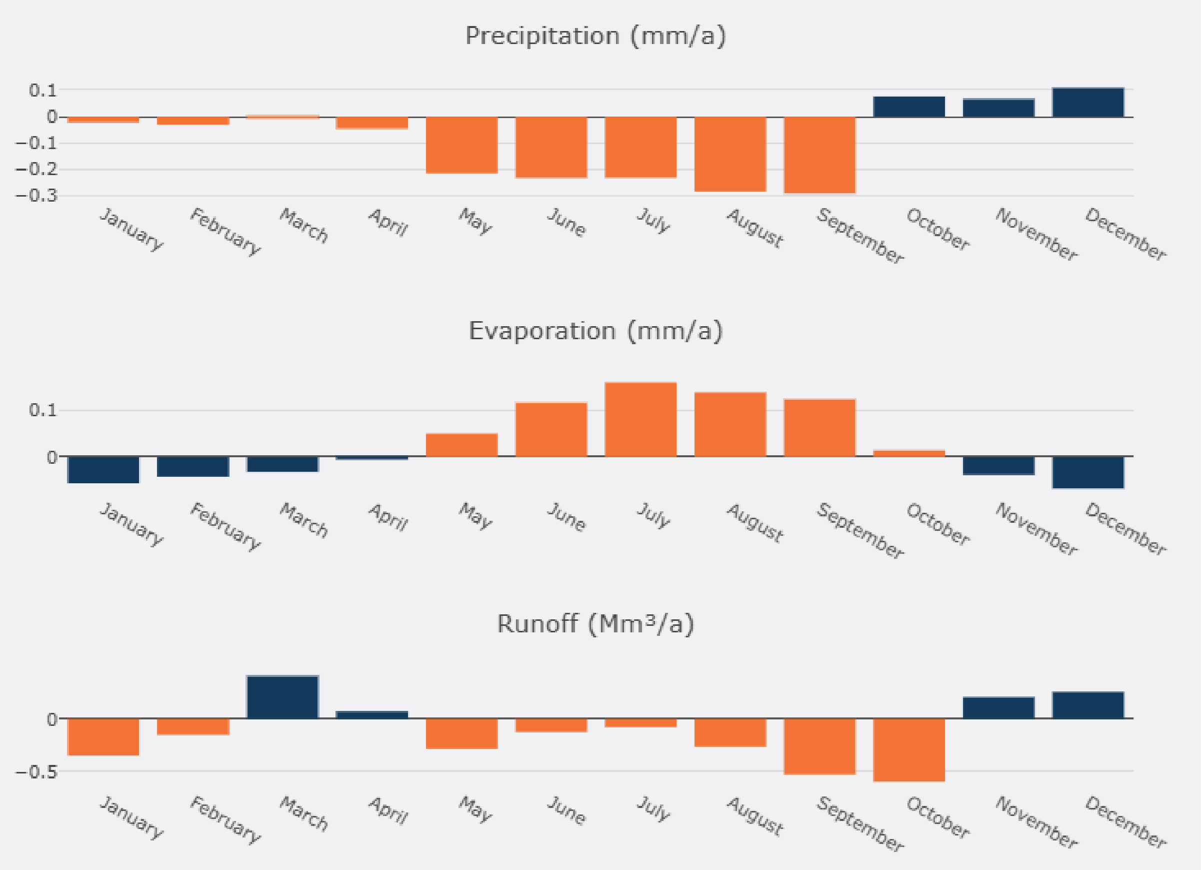


Figure 3-28: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values for the Matjhabeng Municipality

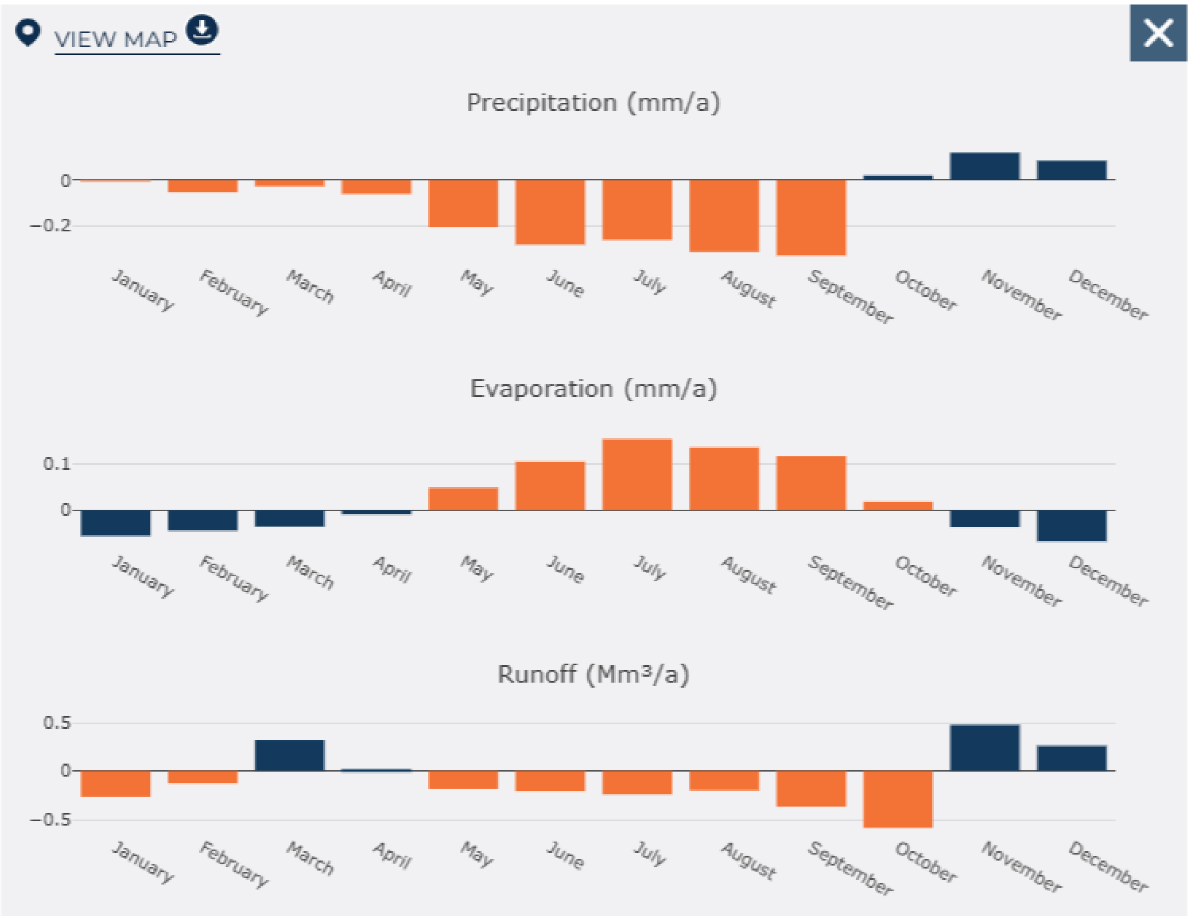


Figure 3-29: Projected monthly change to future (2050) evaporation, precipitation, and estimated runoff values for the Moqhaka Municipality

3.5.3 Ground Water

3.5.3.1 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.

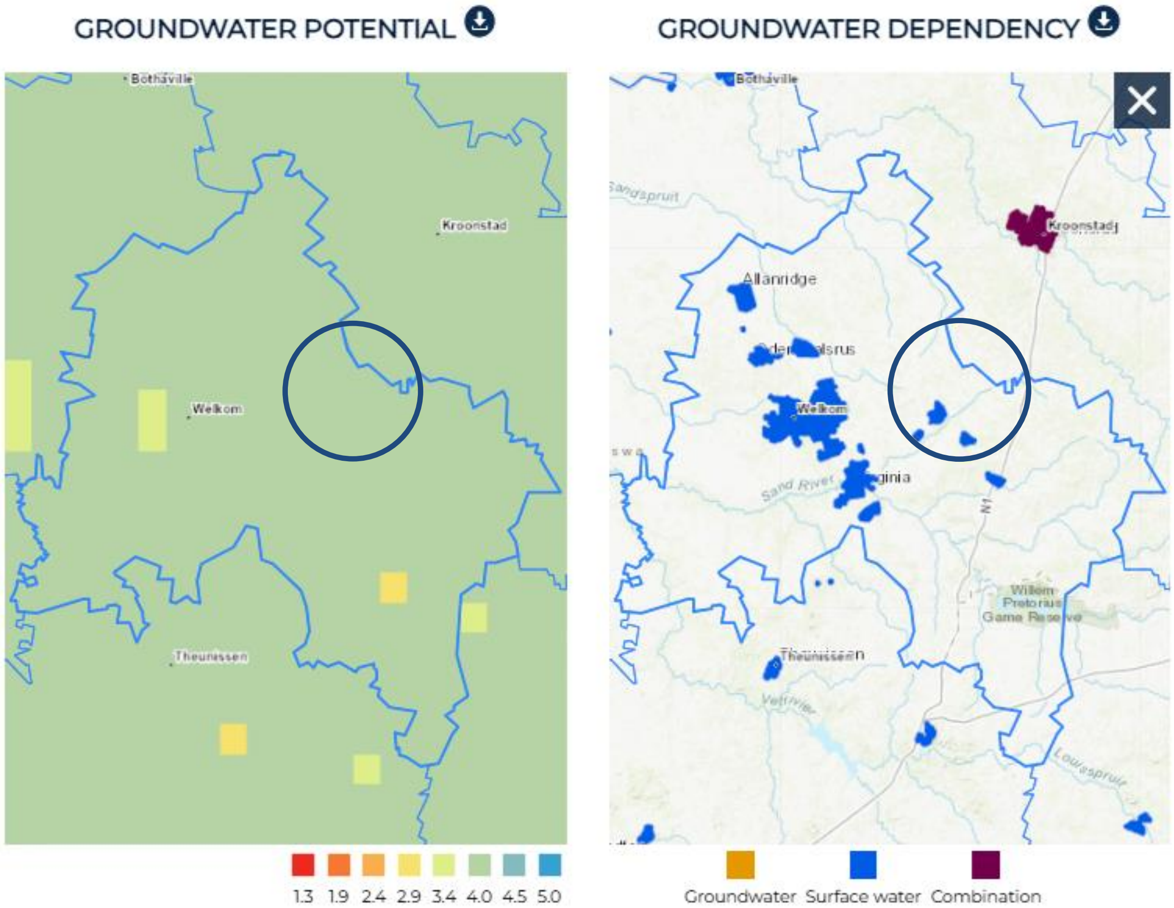


Figure 3-30: Groundwater potential and dependency for the Matjhabeng and Moqhaka Municipality (dark blue marker indicates approximate location of the project)

3.5.3.2 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.

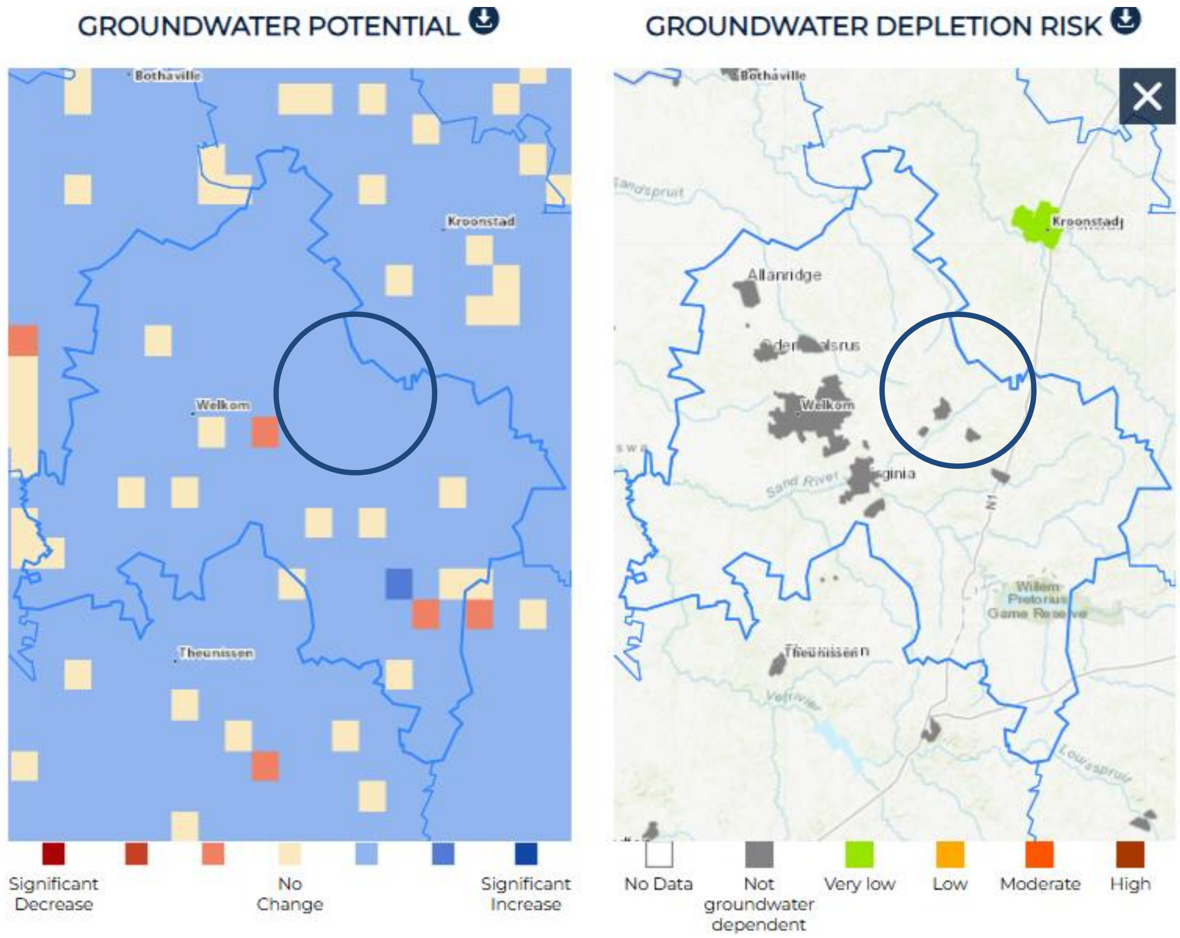


Figure 3-31: Groundwater potential and depletion for 2050 for the Matjhabeng and Moqhaka Municipality (dark blue marker indicates approximate location of the project)

3.5.4 Economy

Figure 3-32 and **Figure 3-33** shows the contribution that the different economic sectors make to the total Gross Value Added (GVA)[12] 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%.

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[12] 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.

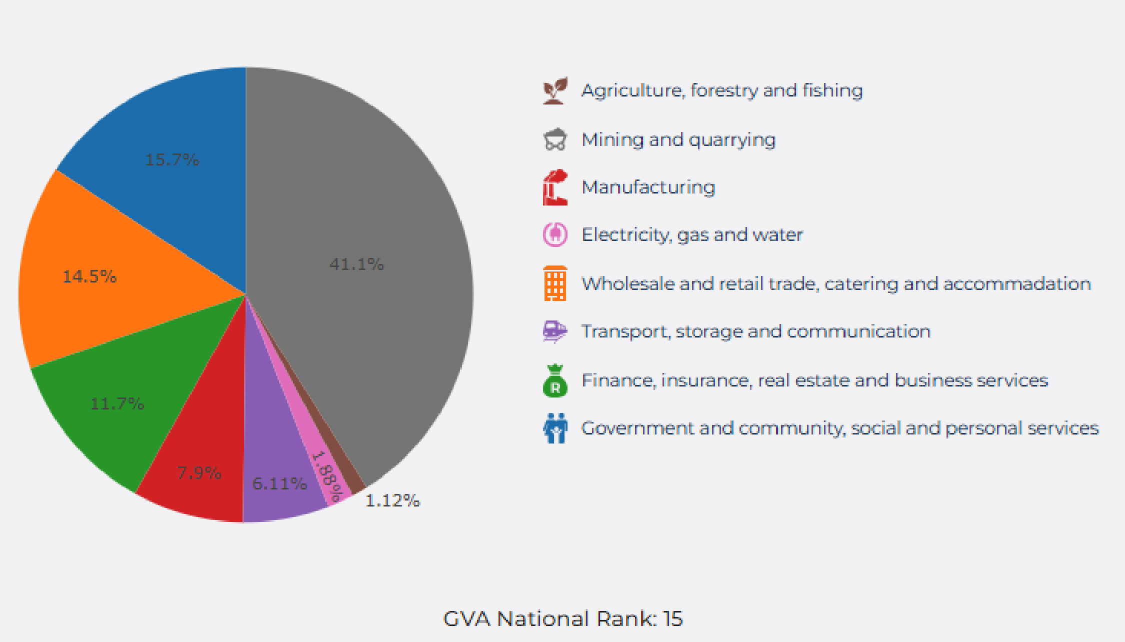

Figure 3-32: The contribution that the different economic sectors make to the total GVA of the Matjhabeng Municipality

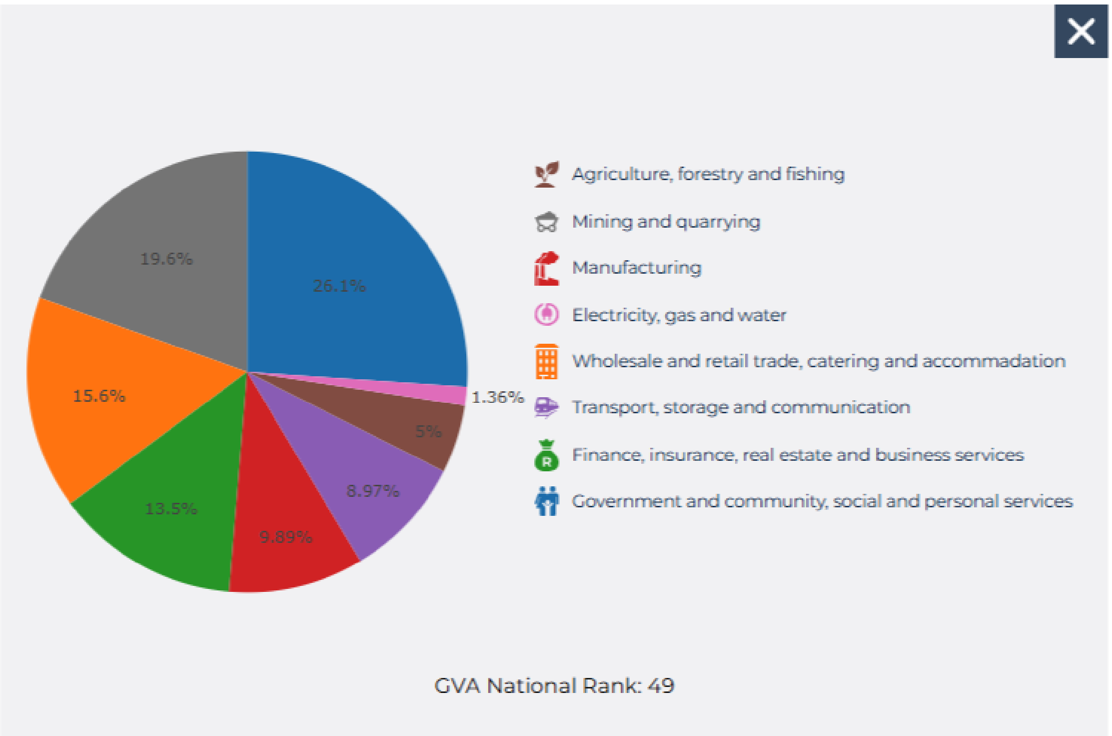

Figure 3-33: The contribution that the different economic sectors make to the total GVA of the Moqhaka Municipality

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%

3.5.5 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.

3.5.6 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)
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)
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)
Health	• More exposure to high temperatures causing increased health risks including heat strokes. • Heat waves increase threat of cardiovascular, kidney, and respiratory disorders. • Increase in fire danger days causing increased loss of life and damage to health infrastructure. • Wildfire smoke significantly reducing air quality, both locally and in areas downwind of fires. Smoke exposure increases respiratory and cardiovascular hospitalizations; emergency department visits; medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease, and respiratory infections; and medical visits for lung illnesses. • Increased emissions in biogenic volatile organic compounds from vegetation causing increases in air pollution. • Increase in evaporative emissions from cars contributing to exposure to, and health impacts from, air pollution. • Increase in distribution of vector-borne diseases in warmer areas. • Increased water temperatures leading to an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increased temperatures combined with fewer clouds (e.g., from increased subsidence that is projected for parts of South Africa) causing increased exposure to Information and Communication Technology which will have negative impacts on health. • Increased temperatures increasing the reaction between certain pollutants and sunlight and heat, resulting in more severe hazardous smog events.	• Decreased soil moisture potentially creating more wind-blown dust which has negative impacts on air quality. • Increase in water-borne diseases and diarrhoeal diseases due to inadequate water availability. • Decreased precipitation causing changes in salinity of water, resulting in an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increase in stagnant air, decreasing air quality.	• Wetter climate combined with increased temperatures may have negative health impacts as many diarrhoeal diseases vary seasonally, typically peaking during the rainy season. • Extreme rainfall and higher temperatures increasing the prevalence of fungi and mould indoors, with increased associated health concerns. • Increased flooding increasing the risk of drinking and wastewater treatment facilities being flooded, meaning that diarrhoeal diseases can be transmitted as wastewater systems overflow or drinking water treatment systems are breached. • Increase in natural disasters (e.g., floods) creating a conducive environment for the occurrence of mental health problems.	• Increase in wind-blown dust combined with low humidity causing increased cases of meningitis (Davis, 2014).	(Garland, 2018)

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 animals (e.g., fish). • Reduced availability of water and increased evapotranspiration resulting in reductions in harvested area (cropping area), yield (ton/ha) and quality. • Warmer winters resulting in reduced period of dormancy (rest period) in deciduous fruit crops, decreasing the production and quality of associated food products. • Warmer climate resulting in shifts in the growing season and life cycles of various plants, including crops, resulting in pests and diseases having a greater destructive impact as well as a shift in climatically suitable areas for specific crops. • Increased humidity levels resulting in higher rates of microbial growth in fresh produce, reducing their expiry time. • Increased heat stress on crops changes the micro-nutrients of crops products, decreasing the nutrient density and quality of food. • Increased water temperature leading to increased growth of aquatic weeds which increases breeding of disease vectors and reduces water oxygen levels. • Milder winters and reduced frost increase the duration of the growing season, increasing the survival rate of insects and diseases. • Increased sea surface temperatures (SST) causing shifts in the spatial distribution of fish species. • Increased SST and ocean acidification decreases marine phytoplankton growth and synthesis of omega-3 polyunsaturated fatty acids (PUFA's), affecting the oceanic food chain and consequent ecosystems. • Increased heat stress and higher humidity levels	• Decreased amounts of rainfall reaching ecosystems as settlements use rainwater harvesting techniques for increased household use. • Increased reliance on irrigation and greater demand for water to maintain public open space and gardens. • Reduced planting and pollination leading to greater risk of erosion and soil loss. • Increasing temperatures together with increased intensity of drought will potentially increase the occurrence of algal blooms in reservoirs and dams which are damaging to ecosystem functioning and water services. • Drought and decreased rainfall causing wetland habitat loss. • Locally specific changes in humidity levels will have impacts on local vegetation. • Increased threat to watershed and aquifer recharge areas, affecting vegetation. • Reduced soil moisture availability increasing moisture stress leading to dieback and death of plants and the loss or degradation of indigenous communities, including threatened species or ecosystems. • Increased moisture stress leading to decline in crop yield and quality, and reduced fodder quantity and quality for livestock. • Drying up of aquatic systems, perennial systems will become seasonal and seasonal systems will die off and be replaced by terrestrial plants. • Increased spread of drought-adapted alien invasive plant species.	• Rainfall in shorter and more violent spells making recharging groundwater difficult. • Increase in intensity of rainfall and flooding leading to increased surface runoff, resulting in increased soil erosion, soil loss and degradation. • Increased rainfall and floods resulting in waterlogged soils which increase the likelihood of crop failure. • Increasingly saturated soils leading to more standing water (ponding) which can result in more insect (pest) activity and their potential to carry diseases. • Increased wave energy and run-up (sea level rise and more storms) causing degradation of natural coastal defence structures.	• Evapotranspiration rates increase with wind speed, reducing the water available in reservoirs and water available for reliant ecosystems. • Increased rate of fire spread and spotting (the ignition of fires ahead of the main fire front) of fires. • Potential damage to or uprooting of vegetation including trees, which can also damage infrastructure. • Potential wind damage to crops, reducing yield and quality (e.g., sandblasting and fruit fall). • Increased windblown materials (e.g., dust, litter) increasing the need for maintenance and city cleaning. • Degradation of natural coastal defence structures and increased damage to hard coastal infrastructure.	(Pieterse & Crankshaw, 2018)

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	
	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 due to changing climate patterns, posing a threat to the conservation of biodiversity hotspots, and potentially altering heritage places. • Increase in veld and forest fires raising the threat of fire to all heritage resources, natural and built, as well as posing health risks to heritage resource dwellers from exposure to smoke and ash pollution.	• Decreased rainfall impacting negatively on ground moisture levels and thus the geological conditions of sensitive heritage resources. Drying out clays, for example, will shrink and potentially undermine founding conditions.	• Increased rainfall in areas with clay soils resulting in swelling which poses a threat to the structural integrity of heritage resources. • Increased floods and changes in precipitation resulting in increasing vulnerability of archaeological evidence buried underground due to changing stratigraphic integrity of the soils. • Increased threat to materials and structural integrity of heritage resources exposed to higher humidity/ precipitation levels.		(van Wyk, 2018)

4 IMPACT SIGNIFICANCE BASED ON SCOPING PHASE ASSESSMENT

The impact significance is based on the quantified GHG emissions from the project. As the quantification of GHG for the project will only be undertaken during the impact assessment phase, the significance rating can only be provided once the impact assessment has been undertaken. No fatal flaws, however, are expected due to the climate impacts.

5 PLAN OF STUDY FOR THE IMPACT ASSESSMENT

During its construction, operation and closure phases the project will emit GHGs, the quantities of which will be estimated during the impact assessment phase of the project.

The impact assessment will include the following information:

- An estimation of the CO_2-equivalent (CO_2e) emissions from the project, associated fuel use, vegetation clearing activities, and electricity use;
- Estimate the impact of the project on national greenhouse gas emissions;
- Evaluation the potential impact of global climate change on the project by identifying potential physical risks to the project, employees, and communities;
- Provide the potential risk of climate change on the project and the risk of the project on climate change;
- Determination of environmental risk according to stipulated Impact Assessment methodology and,
- Recommendation of mitigation and management measures, where applicable.

The climate change impact assessment report will consider Scope 1 emissions, which are the emissions directly attributable to the proposed project, Scope 2 emissions, which are the emissions associated with bought-in electricity over the lifetime of the project, and Scope 3 emissions (as far as is reasonable and practically possible), which consider the “embedded” carbon in bought-in materials and downstream emissions.

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