Rustenburg/Boitekong/Marikana Development Area PHSHDA

Climate Risk Profile Report

SEPTEMBER 2023

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Title:	Rustenburg/Boitekong/Marikana Development Area PHSHDA: Climate Risk Profile Report
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List of Acronyms and Abbreviations

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
CCAM	Conformal-cubic atmospheric model
CDRF	Climate and Disaster Resilience Fund
CMIP5	Coupled Model Intercomparison Project 5
CRVA	Climate Risk and Vulnerability Assessment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHS	Department of Human Settlements
DM	District Municipality
DRR	Disaster risk reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GDP	Gross Domestic Product
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres Per Person Per Day
LM	Local Municipality
LRT	Let's Respond Toolkit
mm	Millimetre
NDMC	National Disaster Management Centre
PHSHDA	Priority Human Settlement and Housing Development Area
PHS	Priority Human Settlement

PHDA	Priority Housing Development Area
PVI	Physical Vulnerability Index
RCP	Representative Concentration Pathways (mitigation scenarios)
RLM	Rustenburg Local Municipality
RBM-PHSHDA	Rustenburg-Boitekong-Marikana PHSHDA
SCIMAP	Sensitive Catchment Integrated Modelling and Prediction
SEVI	Socio-Economic Vulnerability Index
SPI	Standardised Precipitation Index
SPLUMA	Spatial Planning and Land Use Management Act, 2013 (Act No.16 of 2013)
THI	Temperature Humidity Index
WMAs	Water Management Areas
WMO	World Meteorological Organisation
WRYM	Water Resources Yield Model
WUI	Wildland-Urban Interface

Glossary of Terms

Adaptation actions	A range of planning and design actions that can be taken by local government to adapt to the impacts of climate change, reduce exposure to hazards, and exploit opportunities for sustainable development (CSIR, 2023).
Adaptation planning	The process of using the basis of spatial planning to shape built-up and natural areas to be resilient to the impacts of climate change, to realise co-benefits for long-term sustainable development, and to address the root causes of vulnerability and exposure to risk. Adaptation planning assumes climate change as an important factor while addressing developmental concerns, such as the complexity of rapidly growing urban areas, and considers the uncertainty associated with the impacts of climate change in such areas – thereby contributing to the transformational adaptation of urban spaces. Adaptation planning also provides opportunities to climate proof urban infrastructure, reduce vulnerability and exploit opportunities for sustainable development (National Treasury, 2018; Pieterse, 2020).
Adaptive capacity	"The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2022, p. 2899).
Climate change adaptation	"In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2022, p. 2898).
Climate change mitigation	"A human intervention to reduce emissions, or enhance the sinks, of greenhouse gases (GHGs)" (IPCC, 2022, p. 2915). The goal of climate change mitigation is to achieve a reduction of emissions that will limit global warming to between 1.5°C and 2°C above preindustrial levels (Behsudi, A, 2021).

Climate hazards	Climate hazards are a sub-set of natural hazards and a grouping of hydrological, climatological, and meteorological hazards. This includes the spatial extent and frequency of, among others, floods, fires, and extreme weather events such as extreme rainfall and extreme heat. Sometimes referred to as hydrometeorological hazards. The potential occurrence of a climate hazard may cause loss of life, injury, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC, 2022). Climate hazards can increase in intensity and frequency with climate change (Pieterse et al., 2023).
Climate risk	Risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and a hazard. Relevant adverse consequences include those on "lives and livelihoods, health and well-being, economic and sociocultural assets, infrastructure and ecosystems" (IPCC, 2022, p. 144). In the IPCC's 6th Assessment Report, it is confirmed that risks may result from "dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system" (IPCC, 2022, p. 132).
Coping capacity	"The ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage, and overcome adverse conditions in the short to medium term" (IPCC, 2022, p. 2904).
Disaster risk reduction	"Denotes both a policy goal or objective, as well as the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard or vulnerability; and improving resilience" (IPCC, 2022, p. 2906).
Exposure	Exposure implies the physical exposure of elements to a climate hazard. It is defined as the "presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected [by climate hazards]" (IPCC, 2022, p. 2908).
Mainstreaming	The process of integrating climate change adaptation strategies and measures into existing planning instruments and processes as opposed to developing dedicated adaptation policies and plans (Pieterse et al., 2021).

Resilience	"The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation" (IPCC, 2022, pp. 2920–2921).
Sensitivity	"The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)" (IPCC, 2022, p. 2922).
Vulnerability	Vulnerability is defined as the "propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including, sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022, p. 2927). Vulnerability refers to the characteristics or attributes of exposed elements, i.e., elements that are exposed to potential climate-related hazards. Vulnerability is a function of sensitivity and (coping or adaptive) capacity (Pieterse et al., 2023).

1. Introduction

This Climate Risk Profile report, as well as the soon to be developed Adaptation Actions Plan, were developed specifically for the Rustenburg-Boitekong-Marikana Priority Human Settlement and Housing Development Area (also referred to as the RBM-PHSHDA) within the Rustenburg Local Municipality (RLM), to support its strategic climate change response agenda. Both documents are primarily informed by the GreenBook, which is an open-access online planning support system that provides quantitative scientific evidence in support of local government's pursuit in the planning and design of climate-resilient, hazard-resistant settlements. The GreenBook is an information-dense resource and planning support system offered to South African local governments to better understand their risks and vulnerabilities in relation to population growth, climate change, exposure to hazards, and vulnerability of critical resources. In addition to this, the GreenBook also provides appropriate adaptation measures that can be implemented in cities and towns, so that South African settlements are able to minimise the impact of climate hazards on communities and infrastructure, while also contributing to developmental goals (See GreenBook l Adapting settlements for the future).

The purpose and strategic objectives of the Climate Risk Profile and the Adaptation Actions Plan are to:

- Build and further the climate change response agenda,
- Inform strategy and planning in the Priority Human Settlement and Housing Development Area (PHSHDA),
- Identify and prioritise risks and vulnerabilities,
- Identify and prioritise interventions and responses, as well as
- Guide and enable the mainstreaming of climate change response, particularly adaptation.

This report highlights the key climate hazards and risks that the Rustenburg-Boitekong-Marikana PHSHDA faces within the context of the RLM. The most significant climate hazards identified for the local municipality are wildfires and flooding (RLM IDP, 2022). These hazards will impact critical infrastructure, housing, water quality, and human health. Settlement vulnerability is influenced by a number of factors, including socio-economic status, economic development, environmental conditions, population growth pressure, regional economic connectivity, and access to services. Climate risks and vulnerabilities are described in the context of their impacts on key aspects of settlements, such as infrastructure, human health, and services. For example, the increase in heavy rainfall events will increase the risk of flooding, which can damage critical infrastructure such as roads, bridges, and power lines. It can also damage homes and businesses and contaminate water supplies. This can lead to health problems such as waterborne diseases and respiratory infections. The increase in temperature will also have several impacts on human health, water resources, and energy demand. For example, heatwaves can lead to heatstroke and other heat-related illnesses. Increased temperatures can also lead to droughts, which can reduce water availability and increase the risk of wildfires. The expected increase in population growth will add additional pressure on water resources, making it more difficult to provide adequate and good quality water.

Climate risks and settlement vulnerabilities are complex and interconnected. It is important to consider all of these factors when developing climate adaptation plans.

1.1. Approach followed

The approach used in the GreenBook and the Climate Risk Profile report is centred around understanding climate-related risk. Climate-related risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and the occurrence of a climate hazard (see Figure 1). "Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets [as well as] investments, infrastructure, and services (including ecosystem services, ecosystems and species)" (Chen, et al., 2021, p. 64). The components of risk are dynamic. Climate hazards are driven by natural climate variability and anthropogenic climate change. Human activity contributes to Greenhouse Gas emissions that increase temperatures, which in turn affects changes in the occurrence of climate hazards such as drought, flooding, coastal flooding, and heat extremes. Planned as well as unplanned development and growth of our settlements drive the exposure of people, as well as the built- and natural environment to climate hazards. Vulnerability includes the inherent characteristics that make systems sensitive to the effects and impacts of climate hazards. Municipal risk is driven by vulnerability and exposure to certain climate-related hazards.

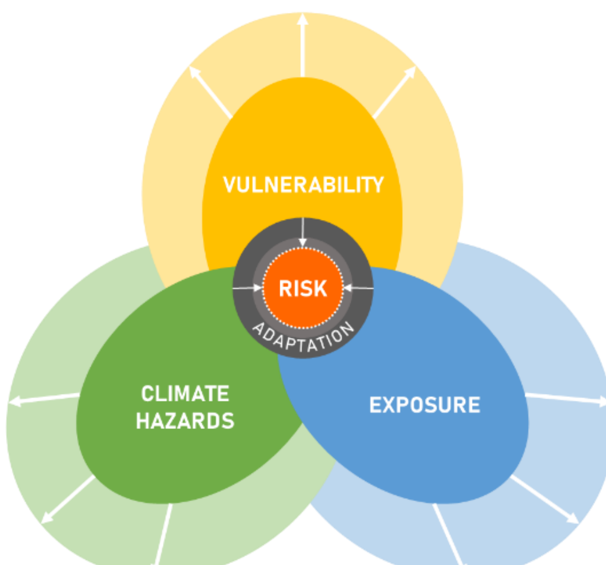


Figure 1: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

To understand climate risk, the exposure of a settlement to certain climate hazards, and its vulnerability to climate change are unpacked. In this Climate Risk Profile report, multiple vulnerability indices are provided, as well as variables for the current and future projected climate. Climate-related hazards such as drought, heat extremes, wildfire, and flooding, and the impact of climate on key resources are also set out for the LM in which the PHSHDA falls.

All information contained in this report is based on the GreenBook, unless otherwise specified. The information in the GreenBook is provided at local municipal level, and at settlement level. In this case, where the PHSHDA falls within a local municipality, the local and settlement level risk profile will be utilised. Information and data were derived using GIS analysis and modelling techniques using secondary data and is not based on local surveys.

1.2. Policy framework

There are various regulatory and legislative requirements for climate change response [planning] in South Africa, at local government level. For instance, the Disaster Management Amendment Act of 2015, which aims to provide measures to reduce disaster risks through climate change adaptation and the development of early warning systems, requires each organ of state, provincial government, and municipality to identify measures for, as well as indicate plans to invest in disaster risk reduction (DRR) and climate change adaptation. The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) outlines five principles intended to guide spatial planning, land development and land use management at all levels of planning, including local government level. Amongst them are the principles of (1) spatial resilience, which encourages "flexibility in spatial plans, policies and land use management systems, to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks" (Republic of South Africa, 2013, p. 20) – some of which may be induced by the impacts of climate change, and (2) spatial sustainability, which sets out requirements for municipal planning functions such as spatial planning and land use management to be carried out in ways that consider protecting vital ecosystem features such as agricultural land, i.e., from both anthropogenic and natural threats, including the impacts of climate change, as well as in ways that consider current and future costs of providing infrastructure and social services in certain areas (e.g., uninformed municipal investments may lead to an increase in the exposure of people and valuable assets to extreme climate hazards).

Furthermore, the National Climate Change Response White Paper – which outlines the country's comprehensive plan to transition to a climate resilient, globally competitive, equitable and low-carbon economy and society through climate change adaptation and mitigation, while simultaneously addressing the country's key priorities, including job creation, poverty reduction, social equality and sustainable development, amongst others – identifies local governments as critical role players that can contribute towards effective climate change adaptation through their various functions, including "[the] planning [of] human settlements and urban development; the provision of municipal infrastructure and services; water and energy demand management; and local disaster response, amongst others." (Republic of South Africa, 2011, p. 38). The Climate Change Bill takes it further by setting out reporting requirements on climate change response needs and interventions for every municipality in the country.

The National Climate Change Adaptation Strategy outlines several actions that are applicable at municipal level, including the development and implementation of adaptation strategies and vulnerability reduction programmes targeting communities and individuals that are most at risk to the impacts of climate change; the development of municipal early warning systems; as well as the integration of climate change adaptation into municipal development plans and relevant sector plans, i.e., mainstreaming. The National Climate Risk and Vulnerability Assessment Framework – which is aimed at all actors, including local governments – guides the development and review of climate risk and vulnerability assessments (CRVAs) to enable alignment, aggregation and comparison across all CRVAs, in an effort to inform an integrated and effective climate change adaptation response across all scales and sectors.

In response to the national call to advance spatial transformation and consolidation in human settlement development, the National Department of Human Settlements (DHS) has identified a total of 136 Priority Human Settlements and Housing Development Areas (PHSHDAs). The PHSHDAs were declared to ensure that housing delivery is used to restructure and revitalise towns and cities, strengthen the livelihood prospects of households, and overcome apartheid spatial patterns by fostering integrated urban forms (DHS, 2020). PHSHDAs were designated using national criteria which includes an area or settlement's potential to support sustainable environmental management (which plays a critical role in mitigating the negative impacts of climate change), as well as its potential to accommodate the integration of land uses and amenities, i.e., in addition to other criteria.

The DHS has identified two key objectives for PHSHDAs, including (1) targeting and prioritising areas for integrated housing and human settlements development to ensure the delivery of housing for a diverse range of income groups within an integrated mixed-use development, as well as (2) transforming spatial patterns which have historically exacerbated social inequality and economic inefficiency (DHS, 2020). As part of the second objective, this initiative aims to develop post-apartheid cities and city patterns that ensure urban access, as well as achieve a balance between spatial equity, economic competitiveness, and environment sustainability (DHS, 2020). As the impacts of climate change become more severe, the latter outcome (i.e., ensuring and maintaining environmental sustainability) will become increasingly important.

Furthermore, as part of the implementation approach for housing and human settlement development in PHSHDAs, the DHS has identified the provision and maintenance of ecological infrastructure to support development in priority areas as a key avenue for integrating climate considerations and mainstreaming climate responses (DHS, 2022).

1.3. Local municipal context

Rustenburg – meaning "Place of rest" – is one of five local municipalities in the Bojanala Platinum District Municipality (DM), located in the Northwest Province, between the Magaliesberg and Witwatersrand. The seat of Rustenburg Local Municipality (RLM) is Rustenburg. The municipality covers an area of approximately 3,423 km^2, which constitutes about 3.6% of the province's total surface area (Rustenburg IDP, 2022). Located in the eastern part of the province, the RLM shares borders with the Kgetlengriver LM to the west, Moses Kotane to the northwest, Madibeng to the northeast, and Ventersdorp/Tlokwe and Merafong LM to the south.

A major national road (the N4 Freeway Platinum Corridor) links Rustenburg to Tshwane in the east and Zeerust to the west. Other regional roads include the R24 which links Rustenburg to Pretoria (east), Johannesburg (south) and Pilanesburg (north). Roads within the RLM include the:

- Rustenburg/Sun City road (R565) (connecting RLM to Rasimone, Luka and Phokeng)
- Rustenburg/Thabazimbi road (R510) (connecting RLM to Tlaseng, Kanana and Boitekong).

In 2011, Rustenburg LM recorded an estimated population of 549,575, growing to 186,064 by 2020 (RBMDA PHSHDA, 2022). This represented about 2,827 dwelling units per annum. The current population is expected to increase by approximately 163,905 people up to 2030, resulting in a population of around 895,044 people. The expected increase the number of households between 2020 and 2030 is 20,536 units (at an average rate of about 2,054 dwelling units per annum).

The RLM's leading economic sector is mining (61.1%), with government and community, social and personal services in second place (11.1%) (Greenbook). Mining contributes 64.2% to the GVA of the district municipality, 57.2% of the province, and almost 14% of the country (Rustenburg IDP, 2020). Out of the economically active population, an unemployment rate of 30.8% was recorded in 2020, translating to about 94 600 people (RLM IDP, 2022).

Although agriculture, forestry and fisheries contribute less than 1% of the municipal economy (GreenBook), the existing Land Use Plan for RLM indicates that agricultural land covers about 150 km^2 (or 86%) of land within the Central Planning Area (Rustenburg IMP, 2015). Most of these are in the north around Bospoort Dam which comprises a number of ridges/koppies, and the central hill areas (PHSHDA, 2022). The ridges to the south form part of the Magaliesberg Mountain Range, which, is the most prominent environmental asset within the municipality.

Several critical biodiversity areas (CBA1 and CBA2) are located near Boitekong around the Hex River (the largest river within the RLM) and the Bospoort Dam, along the Sterkstroom river in the Marikana area, as well as along the Magaliesberg (PHSHDA, 2022). The central and eastern parts of the PHSHDA study area mostly include ecological support areas (ESA1 and ESA2).

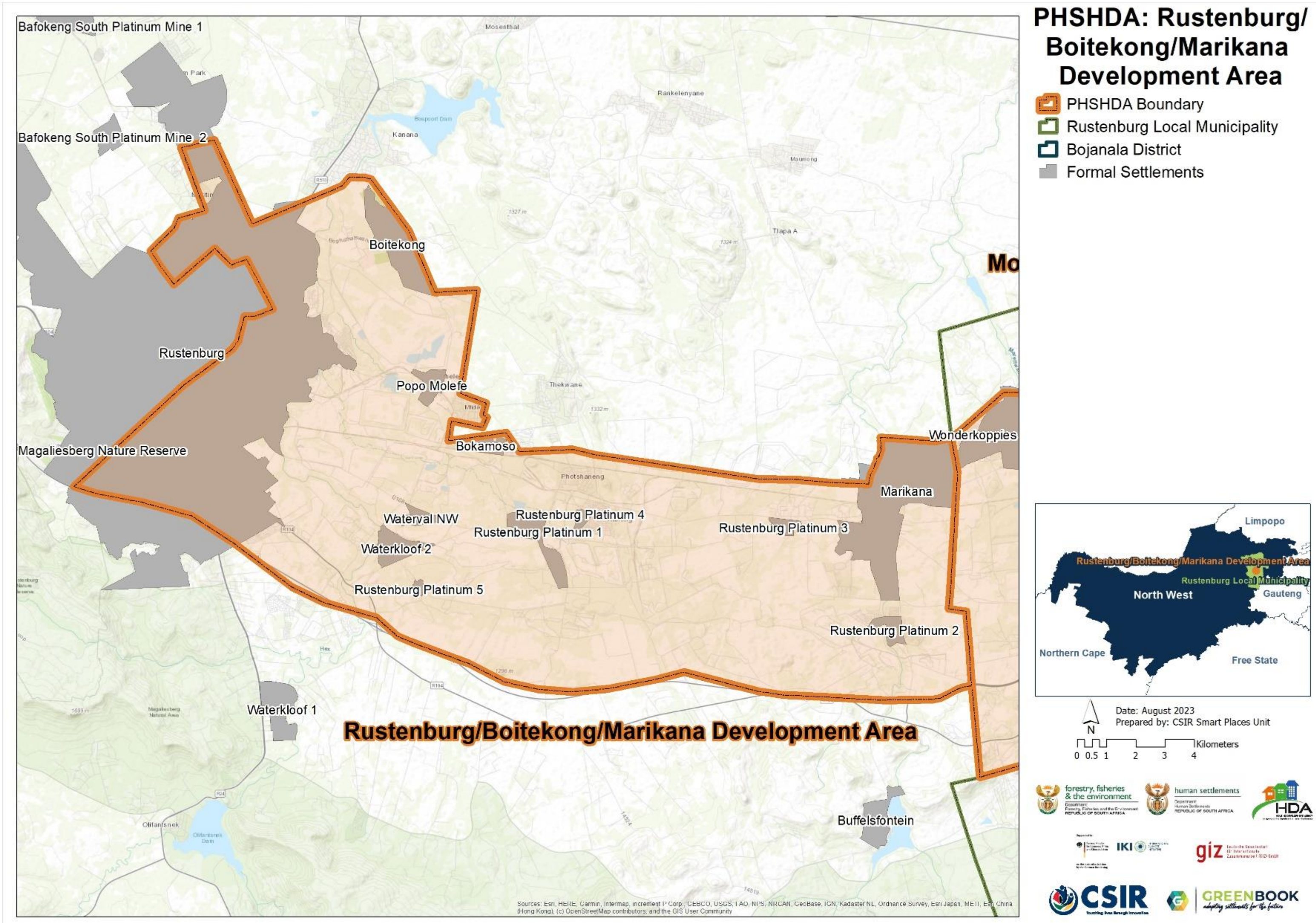


Figure 2: Rustenburg Local Municipality: Rustenburg-Boitekong-Marikana PHSHDA (RBM-PHSHDA) (Municipal Demarcation Board, 2022)

2. Baseline and future climate risk

This section starts with an overview of vulnerability and population change projections, unpacking the components of vulnerability on both the municipal and settlement level as well future population pressures. Thereafter the current and future climate is discussed in terms of temperature and rainfall. Current as well as future exposure to drought, heat, wildfire, flooding, are also set out. Together, this information provides an overview of current and future climate risk for the Rustenburg Municipal Area to inform responsive planning and adaptation.

2.1. Vulnerability and population change

There are many factors that influence the vulnerability of our municipalities and settlements, some of which are unpacked in the following section. The current vulnerabilities for Rustenburg LM and its settlements are profiled using a framework which sets out indicators that can be used to profile the multi-dimensional and context-specific inherent vulnerability of settlements and municipalities in South Africa. The framework describes and quantifies, where possible, the inherent vulnerability of people, infrastructure, services, economic activities, and natural resources by setting out context and location-specific indicators that were specifically designed to support vulnerability risk assessments of South African municipalities. Population changes drives vulnerability into the future, and therefore population growth and decline of settlements across the local municipality are projected to 2050. Spatial population projections are integral in determining the potential exposure and vulnerability of a population to hazards.

2.1.1. Municipal vulnerability

Municipal vulnerability is unpacked in terms of four vulnerability indices, each of which are described below, and in Table 1 the vulnerability scores are provided for Rustenburg LM.

The Socio-Economic Vulnerability Index (SEVI) shows the vulnerability of households living in the municipality with regards to household composition, income composition, education, mobility, health, access to basic services, access to social government services, political instability, and safety and security of households. A high vulnerability score indicates that the municipality houses a high number of vulnerable households with regards to their ability to withstand adverse shocks from the external environment.

The Economic Vulnerability Index (EcVI) speaks toward the economic resilience of the municipality, and considers economic sector diversification, the size of economy, labour force, the GDP growth/decline pressure experienced in the municipality, and the inequality present in the municipality. The higher the economic vulnerability the more susceptible the municipality is to being adversely affected by external shocks.

The Physical Vulnerability Index (PVI) relates to the built environment and the connectedness of the settlements in the local municipality. It is a composite indicator that considers road infrastructure, housing types, the maintenance of the infrastructure, densities, and general accessibility. A high physical vulnerability score highlights areas of remoteness and/or areas with structural vulnerabilities.

The Environmental Vulnerability Index (EnVI) highlights municipalities where there is a high conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation, and economic development. The index considers the human influence on the environment, the amount of ecological infrastructure present that needs protection, the presence of critical water resources, environmental health, and environmental governance. A high vulnerability score highlights municipalities that experience increasing pressure relating to protecting the environment and allowing land use change due to growth pressures.

Rustenburg LM is provided with a score out of 10 for each of the vulnerability indices (Table 1). A score higher than 5 indicates a worse than national average, and a score lower than 5 indicates a better than national average for vulnerability. Scores are provided for both 1996 and 2011, where a lower score in 2011 compared to 1996 indicates an improvement and a higher score indicates worsening vulnerability. Trend data is only available for socio-economic vulnerability and economic vulnerability.

Table 1: Vulnerability indicators across Rustenburg Local Municipality

MUNICIPALITY	SEVI 1996	SEVI 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
Rustenburg	5.1	2.3	↘	6.2	8.5	↗	6.8	N/A	6.2	N/A

As outlined in Table 1, Rustenburg LM's socio-economic vulnerability has decreased (improved) between 1996 and 2011 – thus indicating that the number of vulnerable households has decreased, particularly in terms of their lack of access to basic and social services, and essential resources that influence their ability to withstand adverse shocks from the external environment, including those induced by climate change. However, the LM's economic vulnerability has increased (worsened) within the same period, therefore indicating the municipality's high susceptibility to being adversely affected by external shocks. The physical vulnerability score is the 11th highest in the province; this alludes to the high structural vulnerabilities in the LM, particularly when considering the municipality's buildings and infrastructure. The environmental vulnerability is the highest in the province, indicating that there is conflict between preserving the environment and accommodating growth pressures.

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlement in which the PHSHDA is to be found within the Rustenburg Municipal Area, with regards to six composite indicators. This enables the investigation of the relative vulnerabilities of the settlement (PHSHDA) within the LM compared to other settlements.

A high vulnerability score (closer to 10) indicates a scenario where an undesirable state is present e.g., low access to services, high socio-economic vulnerabilities, poor regional connectivity, environmental pressure or high economic pressures. An indicator of growth pressure, providing a temporal dimension (15-year trend), was added to show which settlements are experiencing growth pressures on top of the other dimensional vulnerabilities.

The Socio-economic Vulnerability Index comprises of three indicators (and eight variables) that show the vulnerability of households occupying a specific settlement with regards to their (1) household composition (household size, age dependency, female/child headed household), (2) income composition (poverty level, unemployment status, and grant dependency of the households), as well as (3) their education (literacy and level of education).

The Economic Vulnerability Index comprises of five variables grouped into three indicators that highlight the economic vulnerability of each settlement with regards to (1) its size (GDP per capita and GDP production rates), (2) the active labour force (taking note of unemployed and discouraged work seekers), and (3) the GDP growth rate for the past 15 years.

The Environmental Vulnerability Index considers the footprint composition of the settlement taking the ration of built-up versus open spaces into account.

The Growth-Pressure Vulnerability Index shows the relative (1996-2011 growth rates) and anticipated pressure on settlements.

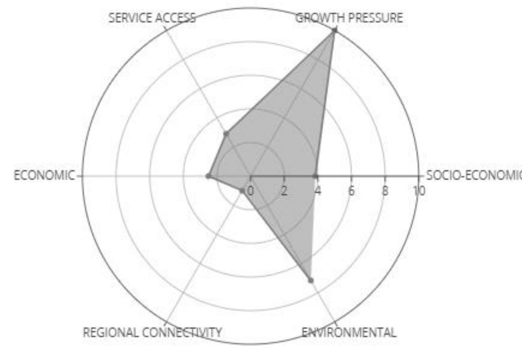
The Regional Economic Connectivity Vulnerability Index looks at the regional infrastructure of each settlement (measured through a remoteness/accessibility index), as well as the role of the town in terms of its regional economy.

The Service Access Vulnerability Index comprises of 10 variables grouped into four indictors, that show the level of services offered and rendered within a settlement and includes the settlement's (1) access to basic services (electricity, water, sanitation, and refuse removal), (2) settlement's access to social and government services (health access, emergency service access, access to schools, and early childhood development), (3) access to higher order education facilities, and (4) access to adequate housing.

The vulnerability of the settlements included into the Rustenburg-Boitekong-Marikana PHSHDA (as determined by the GreenBook settlement footprint typology) are briefly described below.

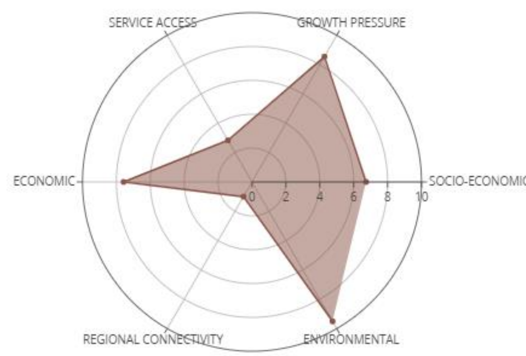
Rustenburg

Rustenburg has the highest growth pressure vulnerability with a relatively high environmental vulnerability.



Boitekong

Boitekong has the highest environmental vulnerability in the PHSHDA with a relatively high growth pressure and economic vulnerability.



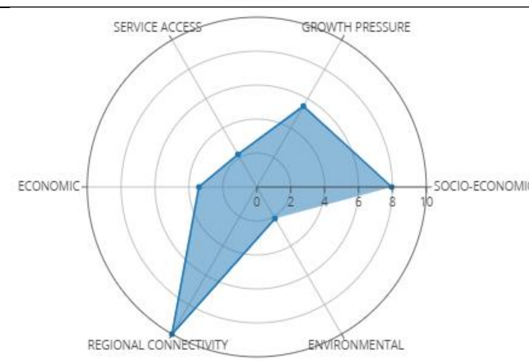
Marikana

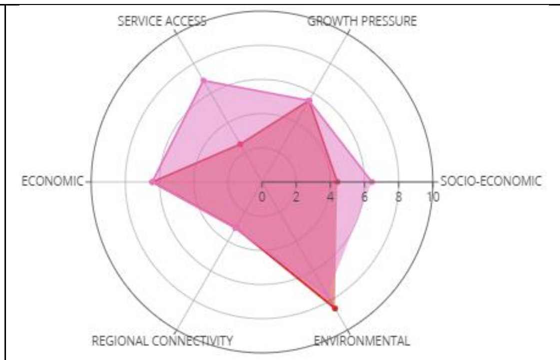
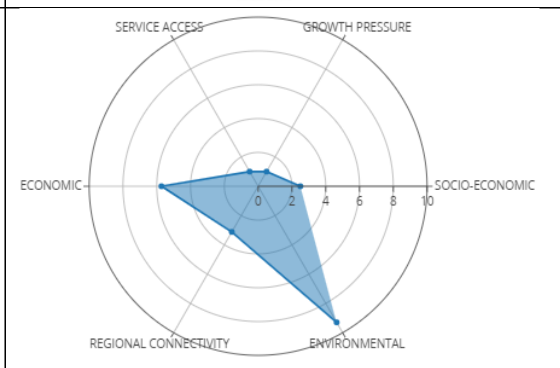
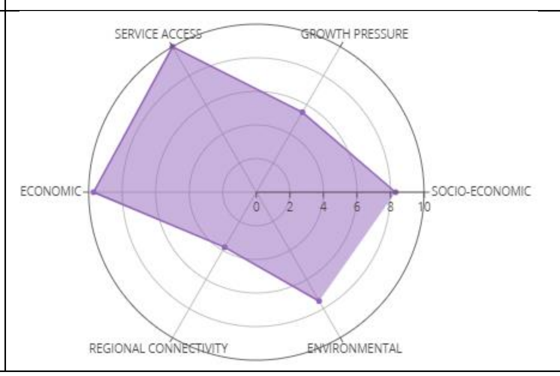
The different types of vulnerabilities in Marikana are generally average in comparison to the other settlements, with economic being the highest in the settlement, followed by regional connectivity and growth pressures.

Molote

Molote has the highest regional connectivity vulnerability in the PHSHDA, and has a relatively high socio-economic vulnerability.

More than 50% of the population was below 20 years or above 60 years, according to the 2011 Census. Females constituted 55% of the population in 2011.



Waterkloof East (showing Waterkloof 1 and 2) Both Waterkloof 1 and 2 have a relatively high environmental vulnerability. The service access and socio-economic vulnerability in Waterkloof 2 is noticeably higher than in Waterkloof 1.	
Bokamoso The economic vulnerability in Bokamoso is the highest in the PHSHDA, while its environmental vulnerability is relatively high.	
Waterval NW The environmental vulnerability in Waterval NW is the second highest in the PHSHDA. Economic vulnerability is average while the other vulnerability indicators are relatively low.	
Popo Molefe Service access and economic vulnerability in Popo Molefe are the highest in the PHSHDA. Socio-economic vulnerability is also relatively high, followed by environmental vulnerability.	

2.1.3. Population growth pressure

The core modelling components of the settlement growth model are the demographic model and the population potential gravity model. The demographic model produces the long-term projected population values at the national, provincial and municipal scale using the Spectrum and Cohort-Component models. The spatially-coarse demographic projections were fed into the population potential gravity model, a gravity model that uses a population potential surface to downscale the national population projections, resulting in 1x1 km resolution projected population grids for 2030 and 2050. The availability of a gridded population dataset for past, current, and future populations enables the assessment of expected changes in the spatial concentration, distribution, and movement of people.

Using the innovative settlement footprint data layer created by the CSIR, which delineates built-up areas, settlement-scale population projections were aggregated up from the 1 x 1 km grids of South African projected population for a 2030 and 2050 medium and high growth scenario. These two population growth scenarios (medium and high) are differentiated based on their in- and out-migration assumptions. The medium growth scenario (see Table 2) assumes that the peak of population influx from more distant and neighbouring African countries into South Africa has already taken place. The high growth scenario assumes that the peak of migrant influx is yet to happen.

Table 2: Population growth pressure across Rustenburg Local Municipality

Municipal Population Growth	2011	Medium Growth Scenario	
		2030	2050
Rustenburg Local Municipality	549 555	852 597	1 120 701
		High growth scenario	
		895 044	1 229 328

Rustenburg Local Municipality is projected to be the fastest growing local municipality in the District Municipality (PHSHDA, 2022). These projections do not account for the stimulus or development effects of the planned PHSHDA activities, but rather the population trajectory trends of the past. Most of the growth is expected to occur between 2011 and 2030. Figure 3 depicts the growth pressures that the settlements across the Rustenburg LM will likely experience. The ap is accompanied by a table that provides, in addition to the expected growth pressure (under a medium population growth scenario), the baseline (2011) and projected (2030 and 2050) population figures for each settlement.

In 2021, Boitekong had approximately 20 500 informal structures (58% of the total), mainly located in eight informal settlements (PHSHDA, 2022, p 45 of 107). Boitekong/Meriting is the fastest growing precinct in the study area having recorded an increment of 15,503 residential units since 2011. Extensive informal, structured settlements have formed east of Boitekong. In 2022, a total of 21 794 informal structures have been recorded within the RBM-PHSHDA (PHSHDA, 2022, p 49).

The Marikana area also showed significant growth since 2011 with an estimated 6040 additional residential units (24% of total) (PHSHDA, 2022 p 45). The number of informal settlements in the area has increased by 1234 over the past 10 years, from about 54 in 2011 (PHSHDA, 2022, p 55 of 107).

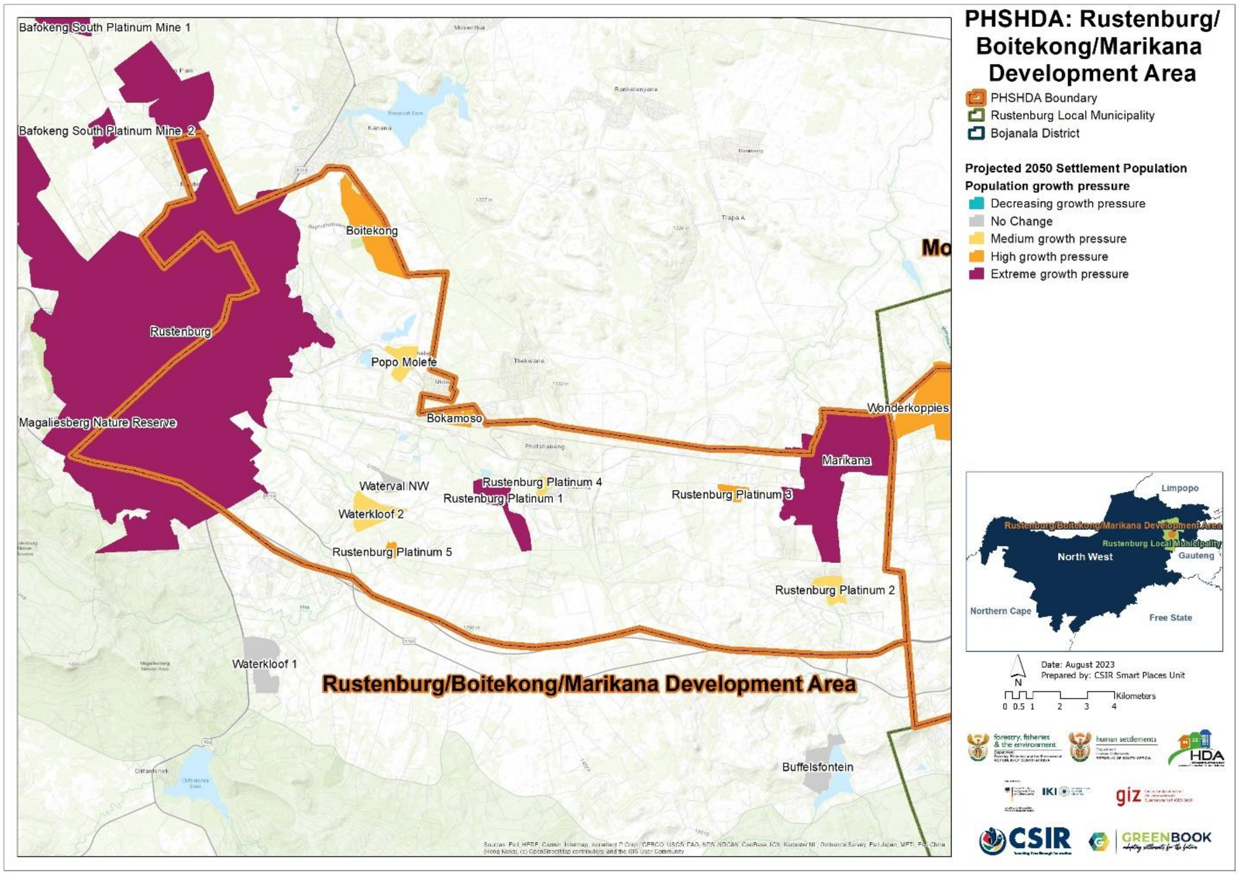


Figure 3: Settlement-level population growth pressure across Rustenburg Local Municipality

As displayed in Figure 3 and outlined Table 3, Rustenburg and Marikana are projected to experience extreme growth pressure, with Boitekong, Bakamoso and Molote projected to experience high growth pressure towards 2050 – thus alluding to the potential increase in the exposure of people and their assets to future climate conditions and their impacts. These projections do not account for the stimulus or development effects of the planned PHSHDA activities, but rather the population trajectory trends of the past.

Table 3: Settlement-level population growth pressure across Rustenburg Local Municipality, showing the main settlements within the RBM-PHSDA study area

Town	Pressure	2011	2030	2050
Molote	High	373	503	618
Waterkloof 1	No Change	2,495	2,523	2,484
Rustenburg Platinum 2	Medium	1,957	2,471	2,925
Rustenburg Platinum 5	High	759	1,226	1,639
Waterkloof 2	Medium	5,664	6,641	7,505
Rustenburg Platinum 3	High	809	1,109	1,375

Town	Pressure	2011	2030	2050
Rustenburg Platinum 1	Extreme	1,316	2,077	2,750
Rustenburg Platinum 4	Medium	5,075	5,815	6,469
Waterval NW	No Change	726	726	726
Marikana	Extreme	20,570	33,457	44,858
Bokamoso	High	5,833	8,227	10,346
Popo Molefe	Medium	4,138	4,987	5,735
Boitekong	High	35,498	46,840	56,874
Rustenburg	Extreme	292,352	506,156	695,098

2.2. Climate

An ensemble of very high-resolution climate model simulations of present-day climate and projections of future climate change over South Africa has been performed as part of the GreenBook. The regional climate model used is the Conformal-Cubic Atmospheric Model (CCAM), a variable-resolution Global Climate Model (GCM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). GCM simulations of the Coupled Model Inter-Comparison Project 5 (CMIP5) and the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) were first downscaled to 50 km resolution globally. The simulations span the period 1960–2100. RCP 4.5 is a high mitigation scenario (assuming a reduction in CO_2 emissions into the future), whilst RCP 8.5 is a low mitigation scenario (assuming "business as usual" emissions).

After completion of the 50 km resolution simulations described above, CCAM was integrated in stretched-grid mode over South Africa, at a resolution of 8 x 8 km (approximately 0.08° degrees in latitude and longitude). The model integrations performed at a resolution of 8 km over South Africa offer several advantages over the 50 km resolution simulations:

a) Convective rainfall is partially resolved in the 8 km simulations, implying that the model is less dependent on statistics to simulate this intricate aspect of the atmospheric dynamics and physics.
b) Important topographic features such the southern and eastern escarpments are much better resolved in the 8 km resolution simulations, implying that the topographic forcing of temperatures, wind patterns and convective rainfall can be simulated more realistically.

For more information on the climate simulations, see the GreenBook [Climate Change Story Map]() and the [full technical report.]()

For each of the climate variables discussed below:

a) The simulated baseline (also termed “current” climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the six downscaled GCMs are shown in this case) (Figure 4).
b) The projected changes in the variable are subsequently shown, for the time-slab 2021–2050 relative to the baseline period 1961-1990 (Figure 5).
c) An RCP 8.5 scenario (low mitigation) is shown (Figure 5).

2.2.1.Temperature

The model was used to simulate annual average temperatures (°C) for the baseline (current) period of 1961–1990, and the projected change for period 2021–2050 under an RCP8.5 mitigation scenario.

https://riskprofiles.greenbook.co.za/assets/icons/filter.svg

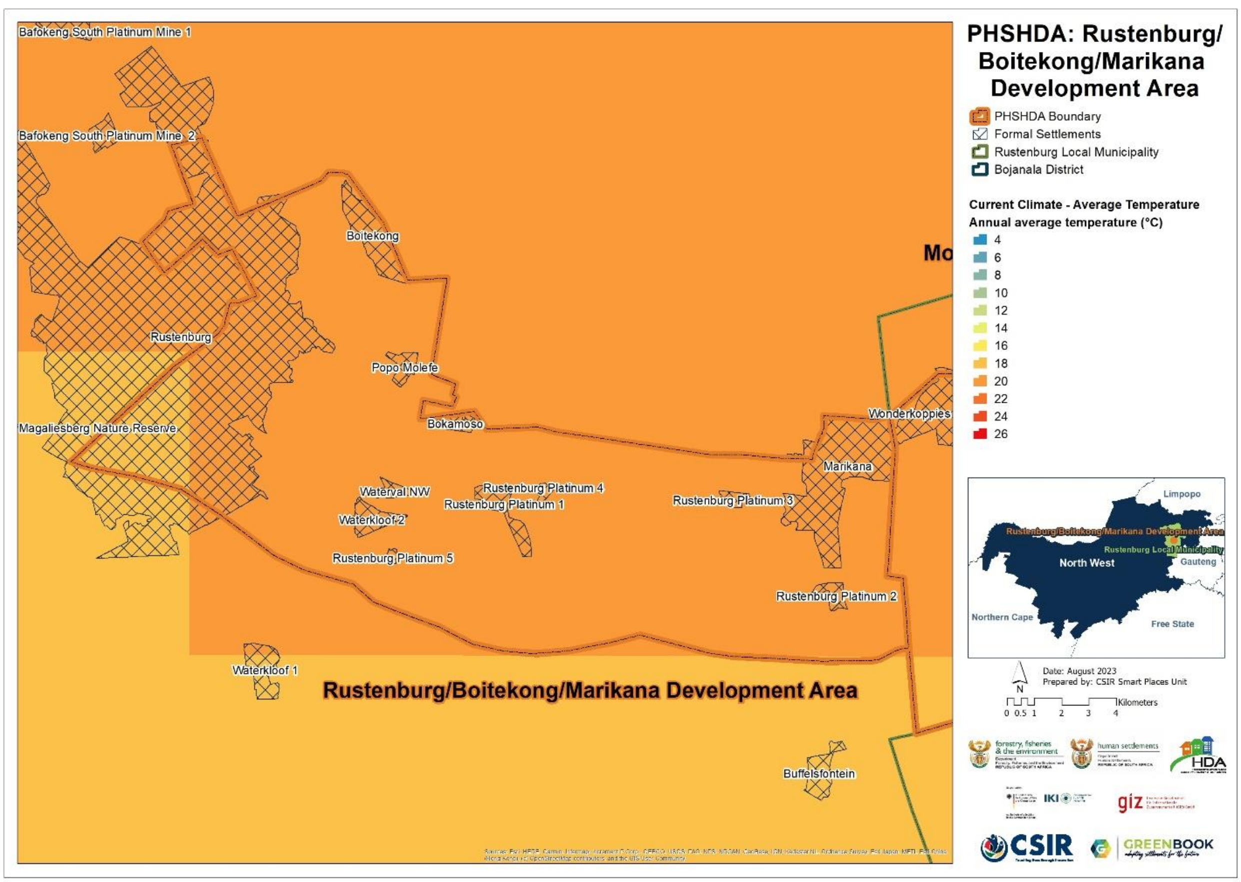


Figure 4: Average annual temperature (°C) for the baseline period 1961 – 1990 for RBM-PHSHDA.

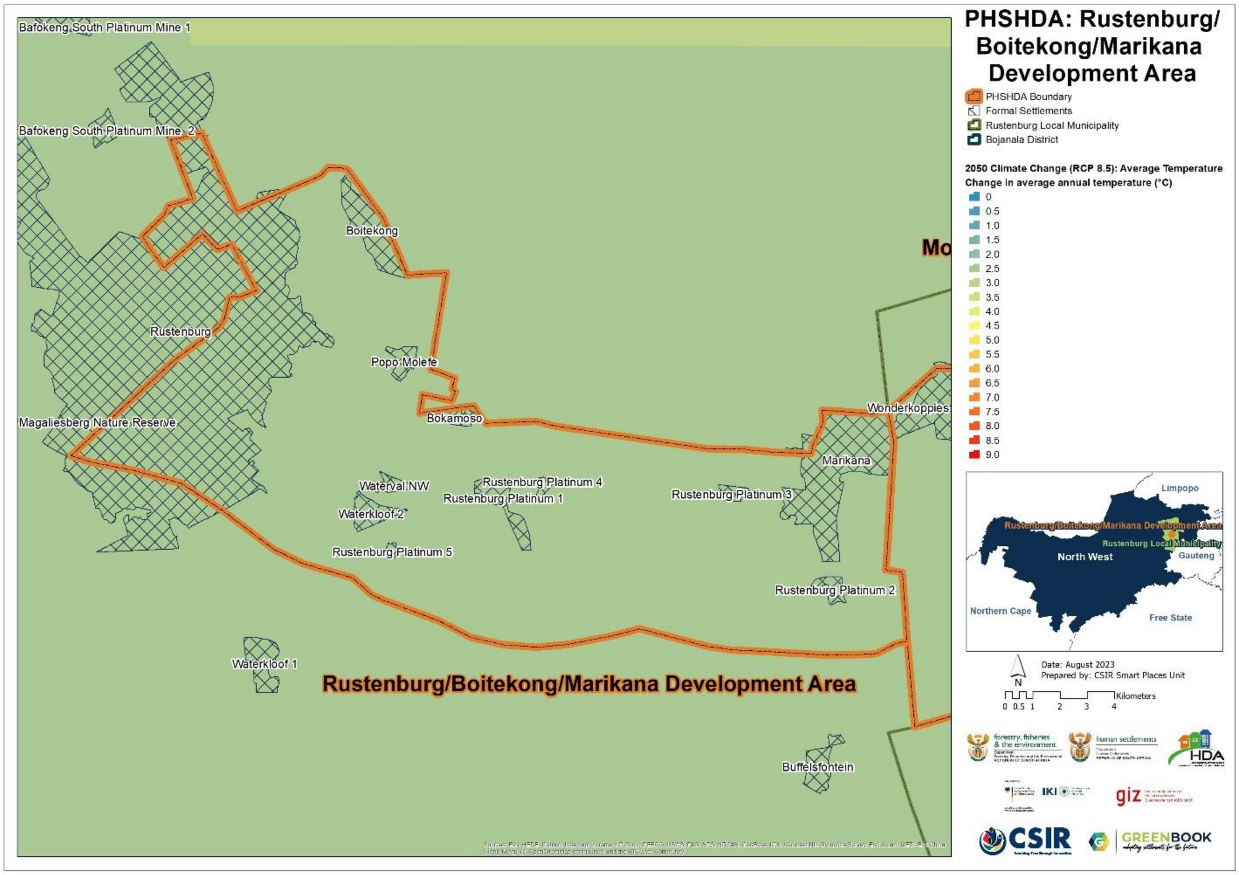


Figure 5: Projected change in average annual temperature (°C) from the baseline period to the period 2021 – 2050 for RBM-PHSHDA, assuming an (RCP 8.5) emissions pathway

The average annual temperature under baseline conditions for the RBM-PHSHDA ranges between 18°C and around 20°C. These temperatures are expected to increase by between 2.5°C to 3° in future.

2.2.2. Rainfall

The multiple GCMs were used to simulate average annual rainfall (depicted in mm) for the baseline (current) period of 1961–1990 (Figure 6), and the projected change from the baseline to the period 2021–2050 under an RCP8.5 emissions scenario (Figure 7).

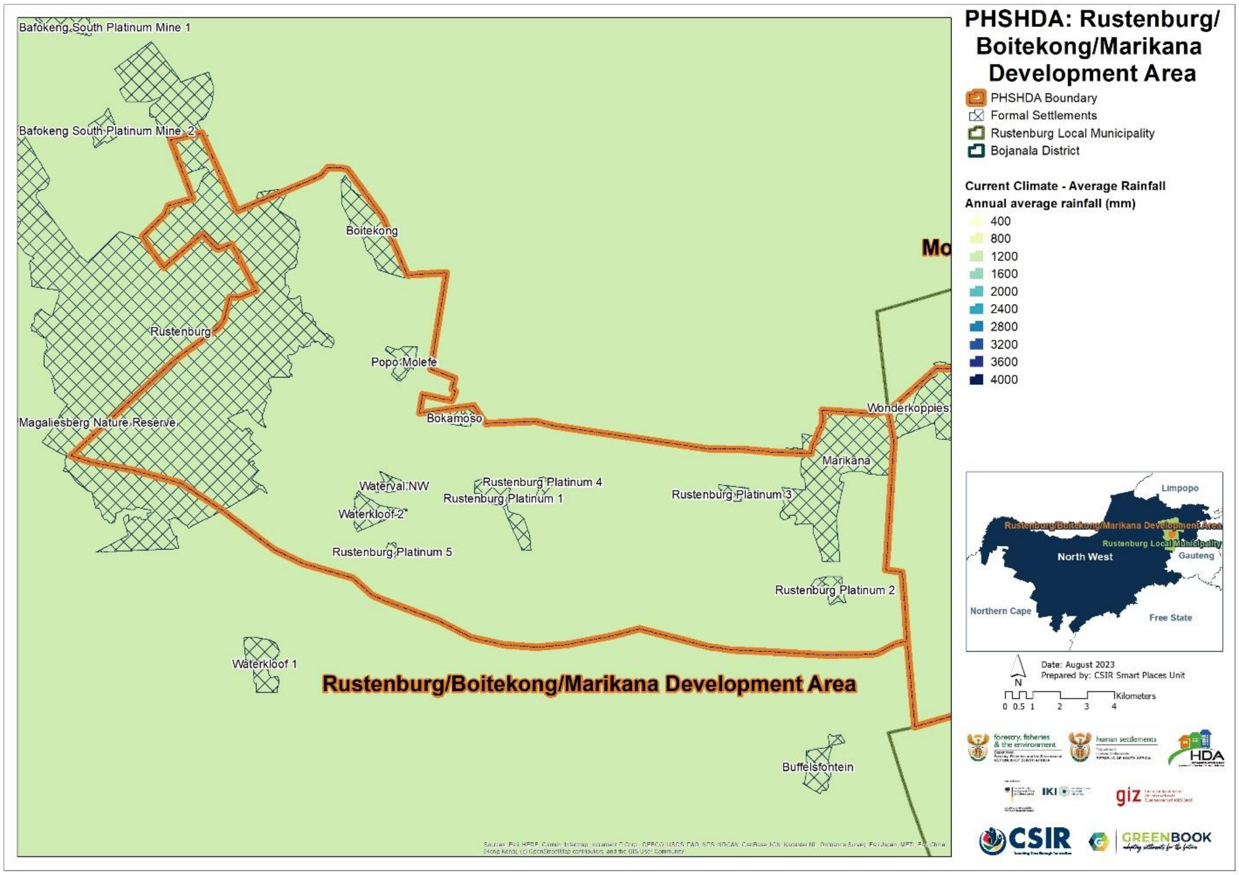


Figure 6: Average annual rainfall (mm) for the baseline period 1961 – 1990 for RBM-PHSHDA

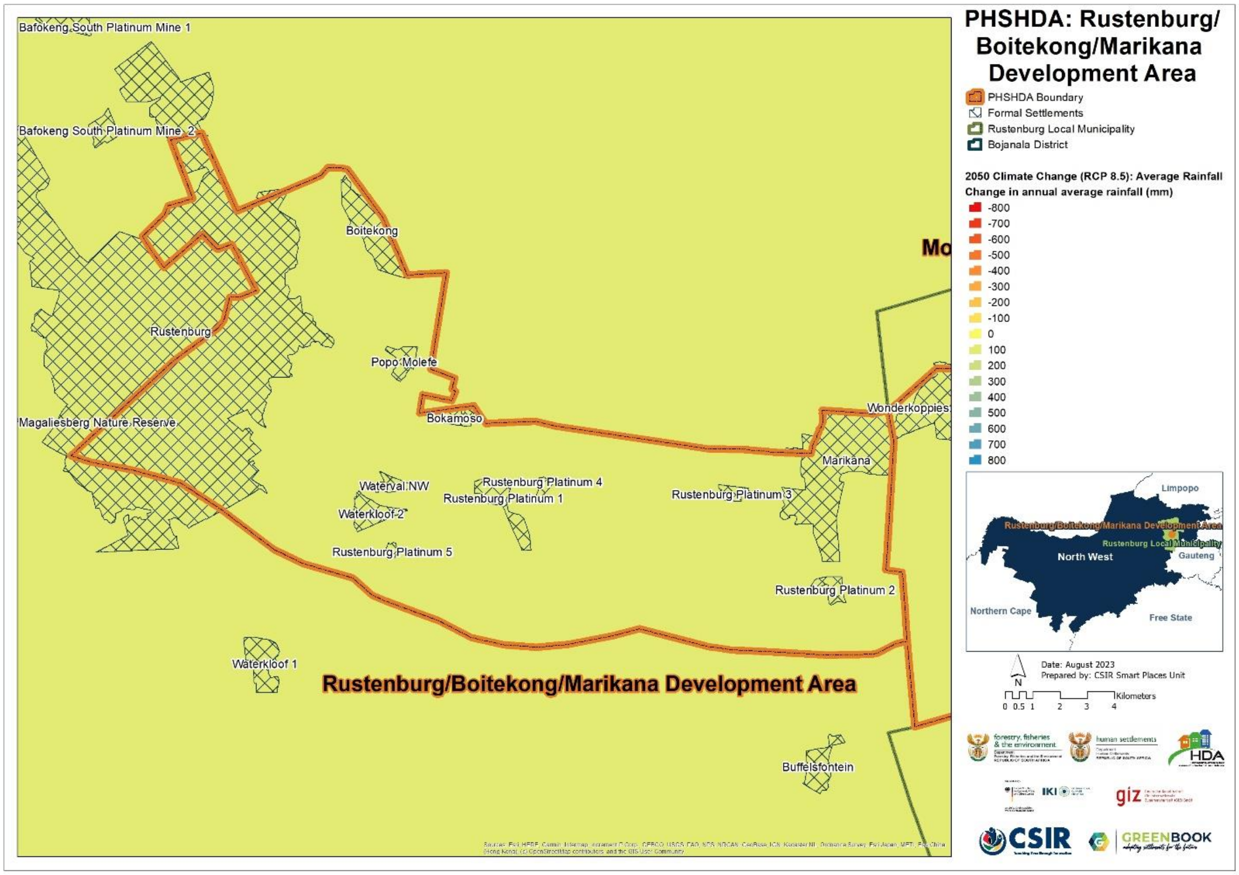


Figure 7: Projected change in average annual rainfall (mm) from the baseline period to the period 2021 – 2050 for RBM-PHSHDA, assuming an (RCP 8.5) emissions pathway

The RBM-PHSHDA currently has a rainfall of 1 200 mm per annum (Figure 6). In future, rainfall is expected to increase by 100 mm or less per annum under the RCP 8.5 scenario (Figure 7).

2.3. Climate Hazards

This section showcases information with regards to RBM-PHSHDA's exposure to climate-related hazards.

2.3.1. Drought

The southern African region (particularly many parts of South Africa) is projected to become generally drier under enhanced anthropogenic forcing, with an associated increase in dry spells and droughts. To characterise the extent, severity, duration, and time evolution of drought over South Africa, the GreenBook uses primarily the Standardised Precipitation Index (SPI), which is recommended by the World Meteorological Organisation (WMO) and is also acknowledged as a universal meteorological drought index by the Lincoln Declaration on Drought. The SPI, with a two-parameter gamma distribution fit with maximum likelihood estimates of the shape and scale parameters, was applied on monthly rainfall accumulations for a 3-, 6-, 12-, 24- and 36-months base period. The SPI severity index is interpreted in the context of negative values indicating droughts and positive values indicating floods. These values range from exceptionally drier (<-2.0) or wetter (>2.0) to near-normal (region bounded within -0.5 and 0.5).

Figure 8 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 1995-2024, relative to the 1986-2005 baseline period, under an RCP 8.5 “business as usual” emissions scenario. A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than the observed baseline), with a positive value indicative of a decrease in drought tendencies.

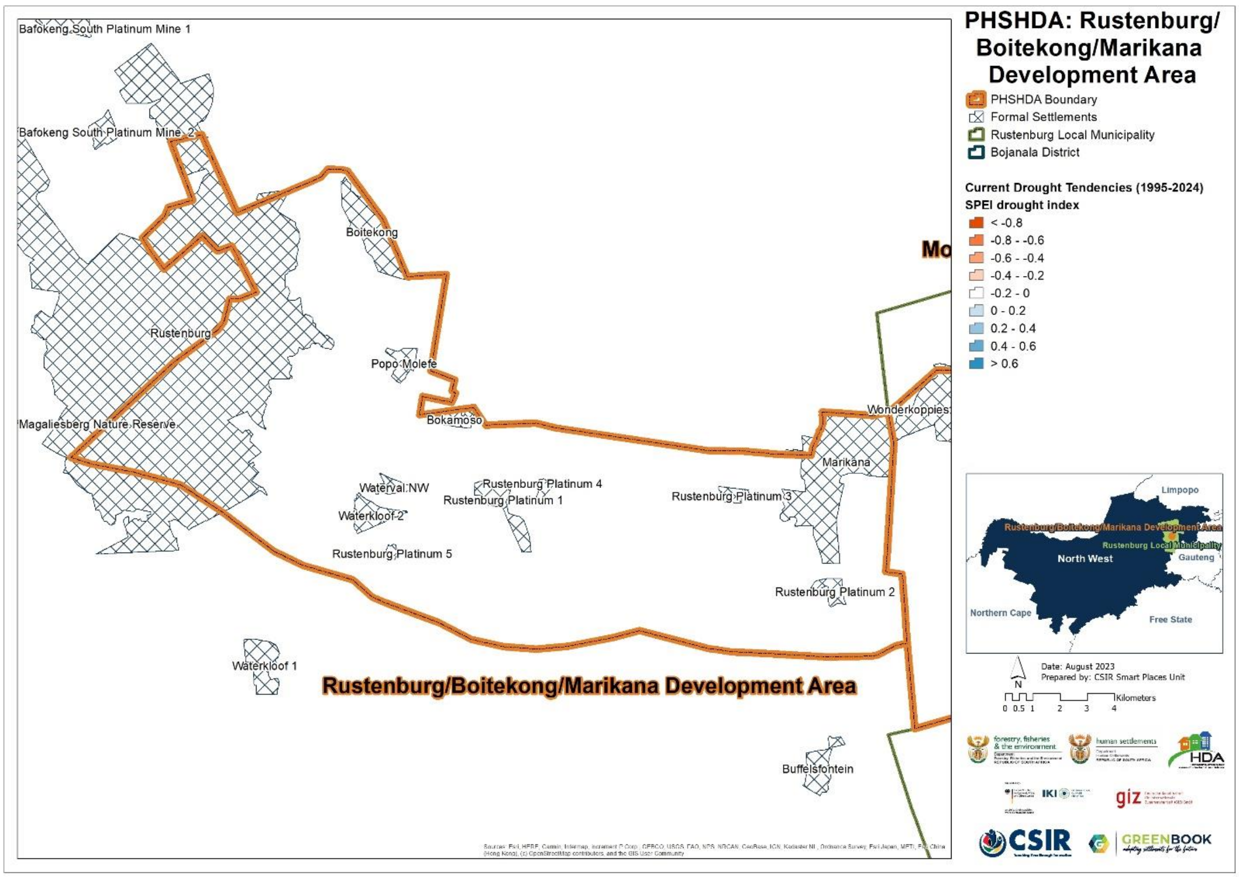


Figure 8: Projected changes in drought tendencies from the baseline period (1986 - 2005) to the current period (1995 - 2024) across RBM-PHSHDA

Figure 9 depicts the projected change in drought tendencies (i.e., the number of cases exceeding near-normal per decade) for the period 2015–2044, relative to the 1986–2005 baseline period, under the low mitigation “business as usual” emissions scenario (RCP 8.5). A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than baseline) into the future period and a positive value indicative of a decrease.

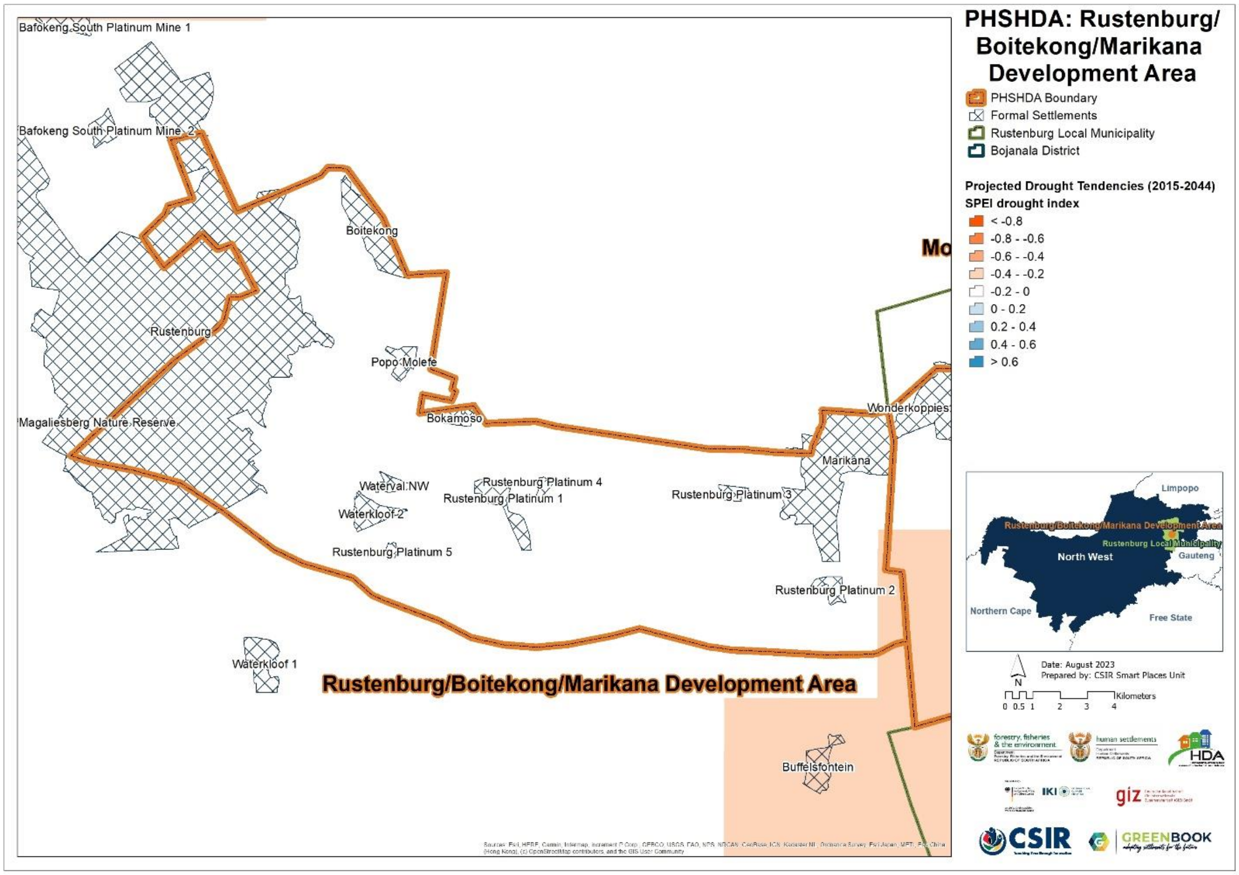


Figure 9: Projected changes in drought tendencies from the baseline period (1986 - 2005) to the future period (2015 - 2044) for RBM-PHSHDA

Figure 10Figure 10 depicts the settlements that are at risk of increases in drought tendencies.

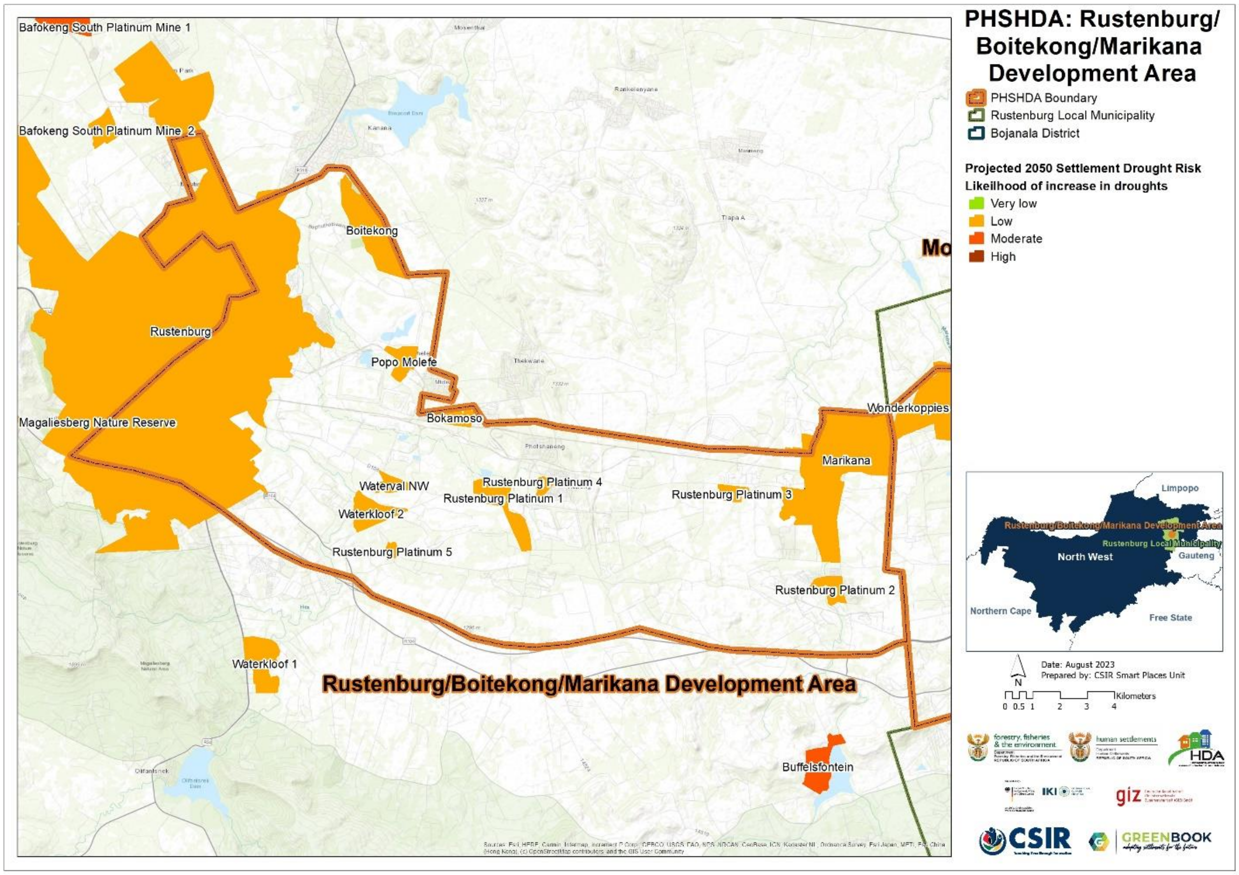


Figure 10: Settlement-level drought risk for the RBM-PHSHDA within the RLM.

Based on the projections for drought tendencies, the RBM-PHSHDA is not projected to have a change in drought tendency up to 2024 (current period) (Figure 8) or for the future period (Figure 9), although a slight increase in drought tendency is expected in the far eastFigure 9. All settlements thus have a low projected 2050 risk for drought (Figure 10Error! Reference source not found.).

2.3.2. Heat

The GCMs were used to simulate bias-corrected, annual average number of very hot days, defined as days when the maximum temperature exceeds 35°C per GCM grid point for the baseline (current) period of 1961–1990 (Figure 11), and for the projected change for period 2021–2050 (Figure 12), assuming a "business as usual" (RCP 8.5) emissions pathway.

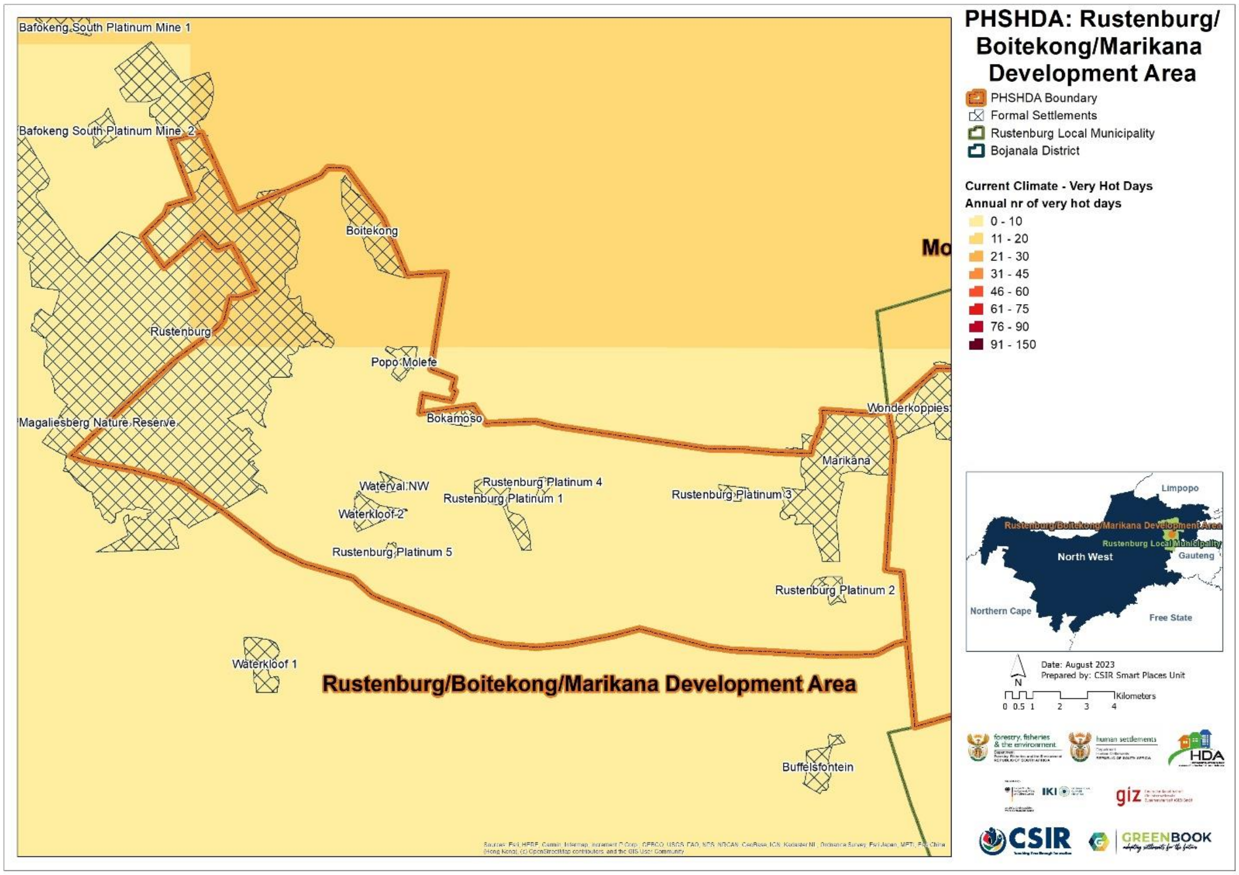


Figure 11: Annual number of very hot days under baseline climatic conditions across RBM-PHSHDA with daily temperature maxima exceeding 35 °C.

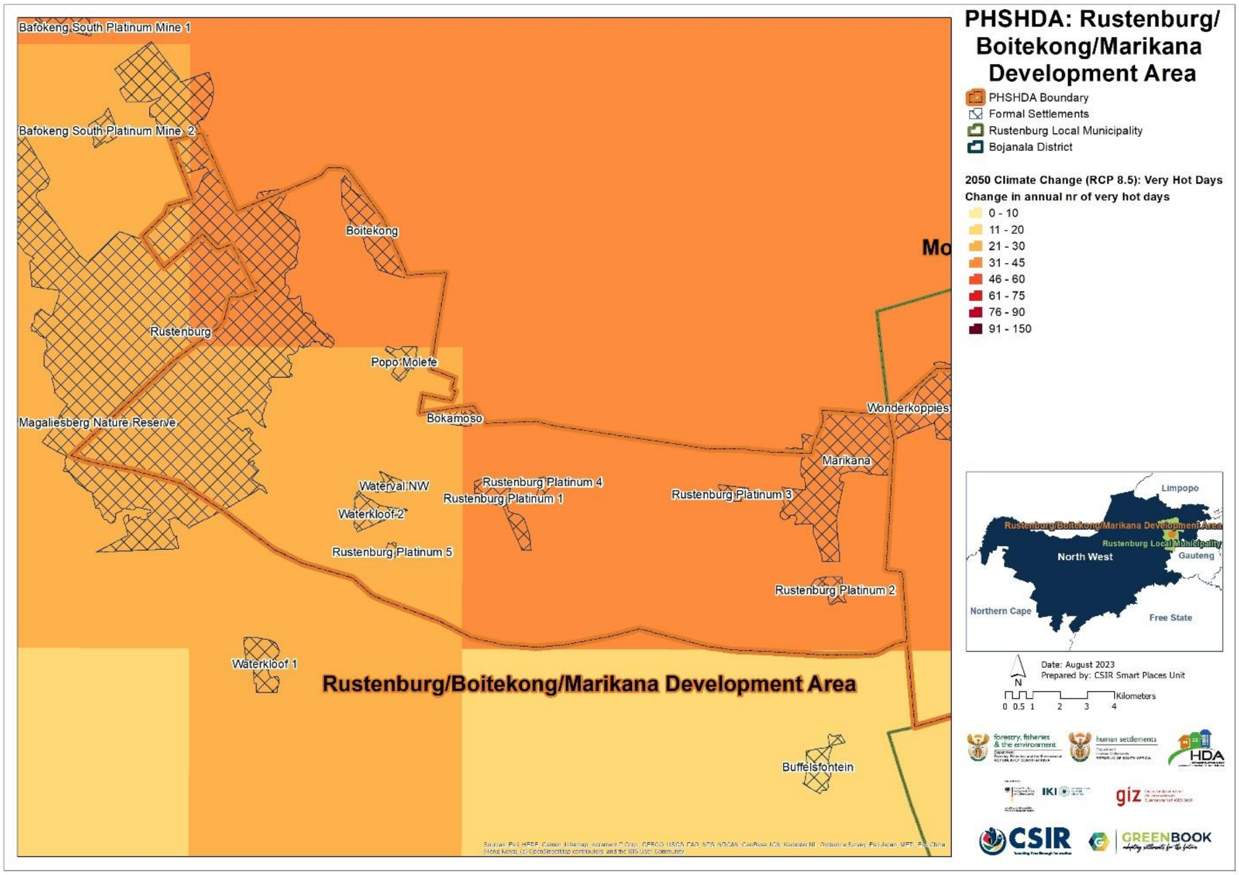


Figure 12: Projected change in annual number of very hot days across RBM-PHSHDA with daily temperature maxima exceeding 35 °C, assuming an (RCP 8.5) emissions pathway.

Under baseline conditions, the RBM-PHSHDA experiences 10 or less very hot days in most areas, and between 11 and 20 very hot days in the north-west of the area (Figure 11). The projected change in average annual number of very hot days by 2050 for the area is an increase of 21-30 in the west and 31-45 days in the north-west and east under the RCP 8.5 scenario (Figure 12).

The annual heatwave days map under baseline conditions (Figure 13) depicts the number of days (per 8x8 km grid point) where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at that location by at least 5°C, i.e., for a period of at least three consecutive days. The projected change in the number of days belonging to a heatwave for the period 2021–2050 (Figure 14), assuming a "business as usual" (RCP 8.5) emissions pathway is also shown.

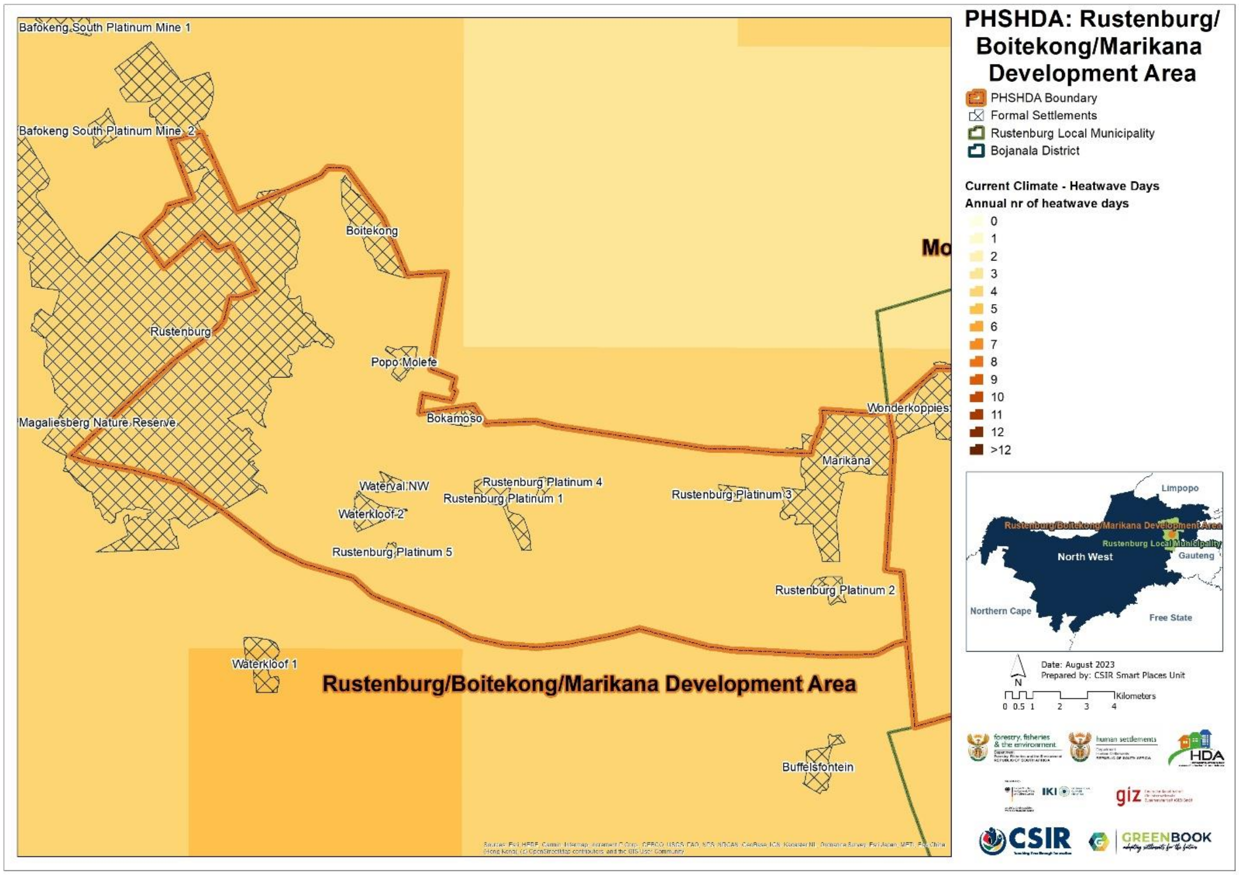


Figure 13: Annual number of heatwave days under baseline climatic conditions across RBM-PHSHDA

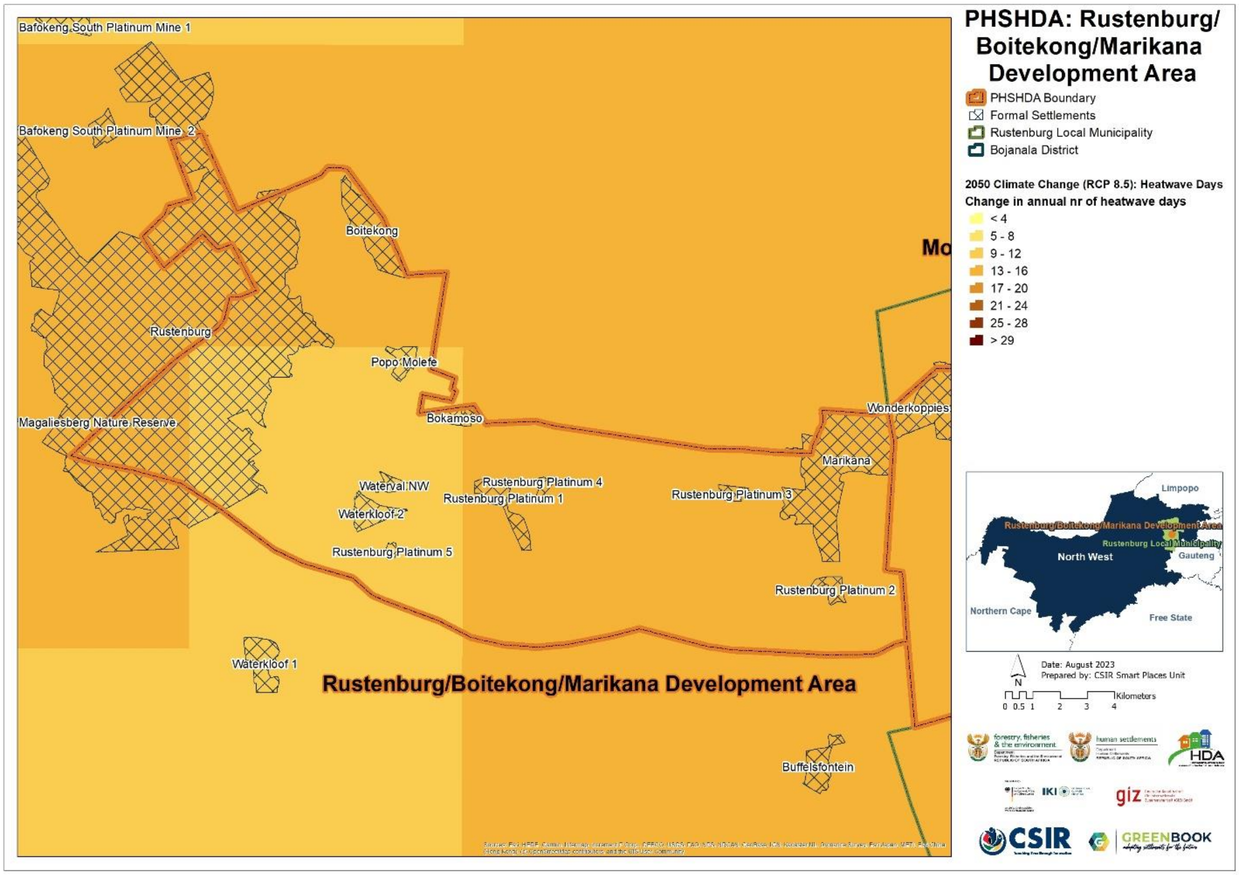


Figure 14: Projected change in annual number of heatwave days across RBM-PHSHDA, assuming an (RCP 8.5) emissions pathway

The current average number of heatwave days for the RBM-PHSHDA less than five days per year (Figure 13). In future, heatwave days will increase by up to four heatwave days in the southwest and 9-12 days in the northwest and east under the RCP 8.5 scenario.

Figure 15 depicts the settlements that are at risk of increases in heat risk.

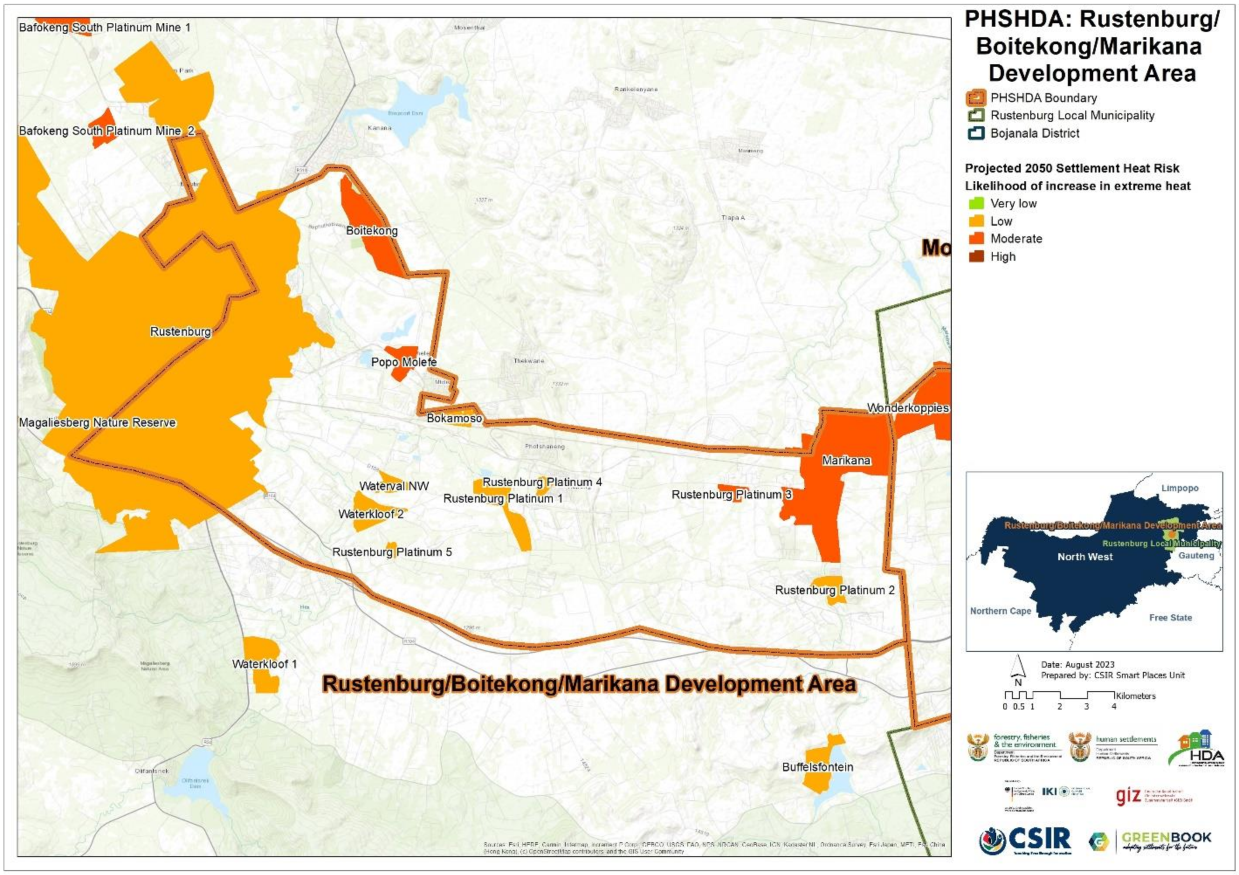


Figure 15: Heat stress risk across RBM-PHSHDA at settlement level in the 2050s

Considering future projections for both very hot days and heatwave days, most settlements in the RBM-PHSHDA have a low likelihood of an increase in extreme heat. Boitekong, Popo Molete and Marikana have a moderate likelihood of an increase in heat risk.

With the changing climate, it is expected that the impacts of heat will only increase in the future. The heat-absorbing qualities of built-up urban areas make them, and the people living inside them, especially vulnerable to increasingly high temperatures. The combination of the increasing number of very hot days and heatwave days over certain parts of South Africa is likely to significantly increase the risk of extreme heat in several settlements.

2.3.3. Wildfire

Wildfires occur regularly in South Africa and often cause significant damage. The main reasons for recurring wildfires are that we have climates with dry seasons, natural vegetation that produces sufficient fuel, and people who light fires when and where they should not. Much of the natural vegetation requires fires to maintain the ecosystems in good condition. At the same time fires are a threat to human lives, livelihoods, and infrastructure. More and more people, assets and infrastructure are placed on the boundary or interface between developed land and fire-prone vegetation – what we call the wildland-urban interface (WUI) – where they are exposed to wildfires. The combination of climate and vegetation characteristics that favour fires, and growing human exposure, results in significant wildfire risk across the country, especially in the southern and eastern parts.

Fire risk is determined by combining the typical fire hazard for a fire-ecotype (i.e., likelihood, fire severity) and the social and economic consequences (i.e., the potential for economic and social losses). The typical fire hazard was used to develop a plausible fire scenario for each fire-ecotype, i.e., what a typical wildfire would be like. The fire scenarios were then combined with the vulnerability to estimate the economic and social consequences. We used a scale where the likelihood was rated from 'rare' to 'almost certain' and the consequences were rated from 'insignificant' to 'catastrophic' to determine a level of fire risk which ranged from 'low' to 'high'. The risks were then summarised for all the settlements within a local authority. Changes in the fire risk in future were accommodated by adjusting either the fire scenarios or the likelihood, or both. Figure 16 depicts the current likelihood and risk of wildfires occurring in the wildland-urban interface (the boundary or interface between developed land and fire-prone vegetation) of the settlement. Figure 17Figure 18 depicts the 2050 settlement likelihood of wildfires.

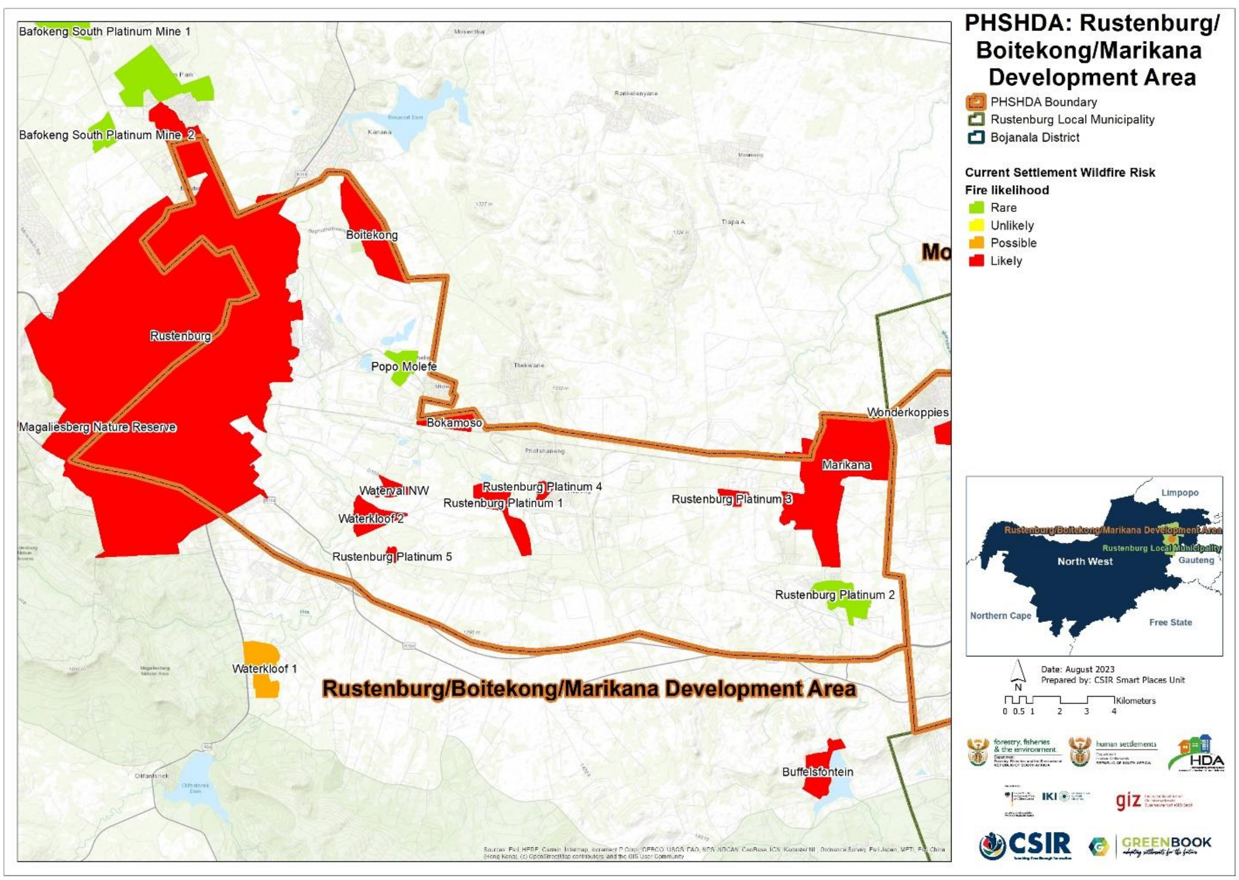


Figure 16: The likelihood of wildfires under current climatic conditions across settlements in RBM-PHSHDA

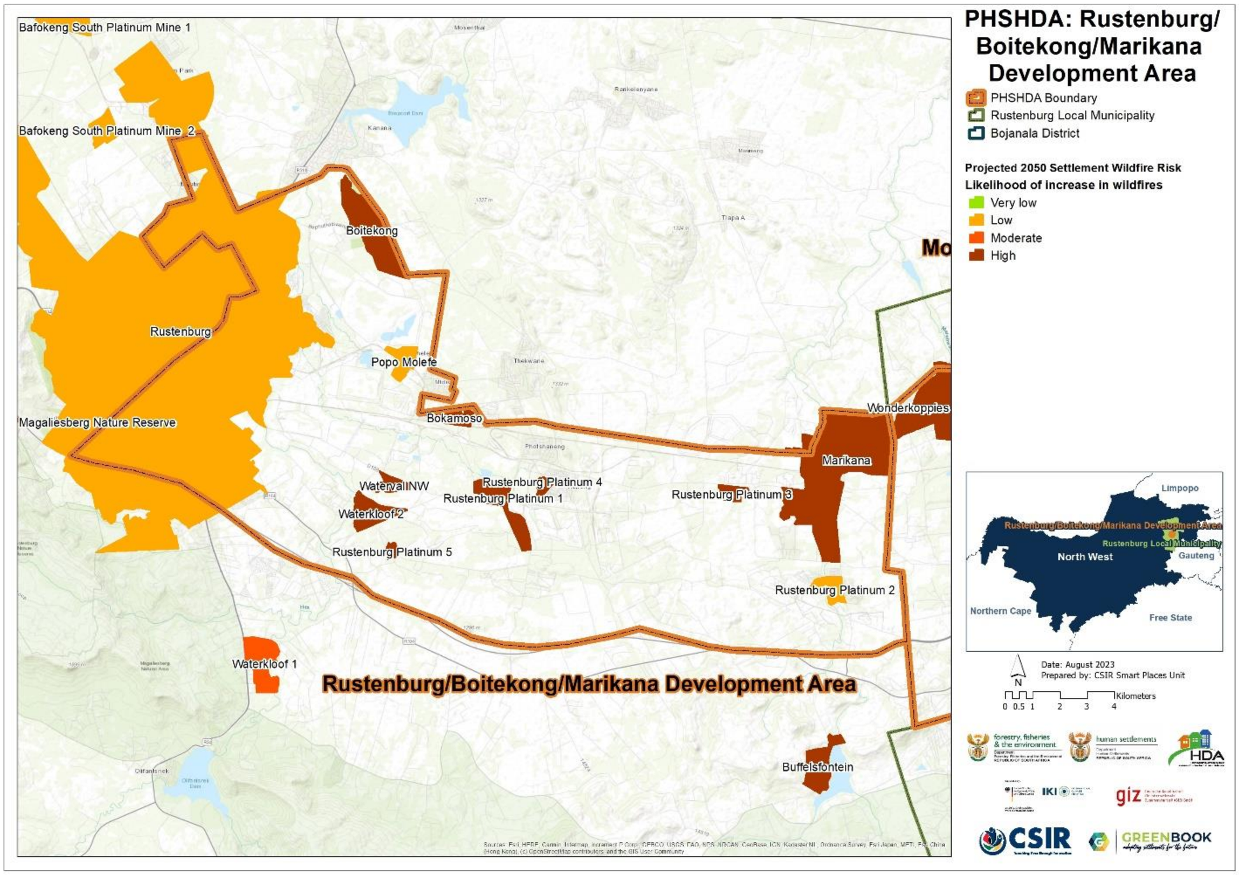


Figure 17: The likelihood of wildfires under projected climatic conditions across settlements in RBM-PHSHDA

The projected number of fire danger days for an 8 x 8 km grid-point under an RCP 8.5 "business as usual" emissions scenario was calculated. A fire danger day is described as a day when the McArthur fire-danger index exceeds a value of 24. The index relates to the chances of a fire starting, its rate of spread, its intensity, and its difficulty of suppression, according to various combinations of air temperature, relative humidity, wind speed and both the long and short-term drought effects. Future settlement risk of wildfires is informed by the projected change in the number of fire danger days. Figure 18Error! Reference source not found. depicts the projected 2050 Fire Danger Days under an RCP 8.5 scenario.

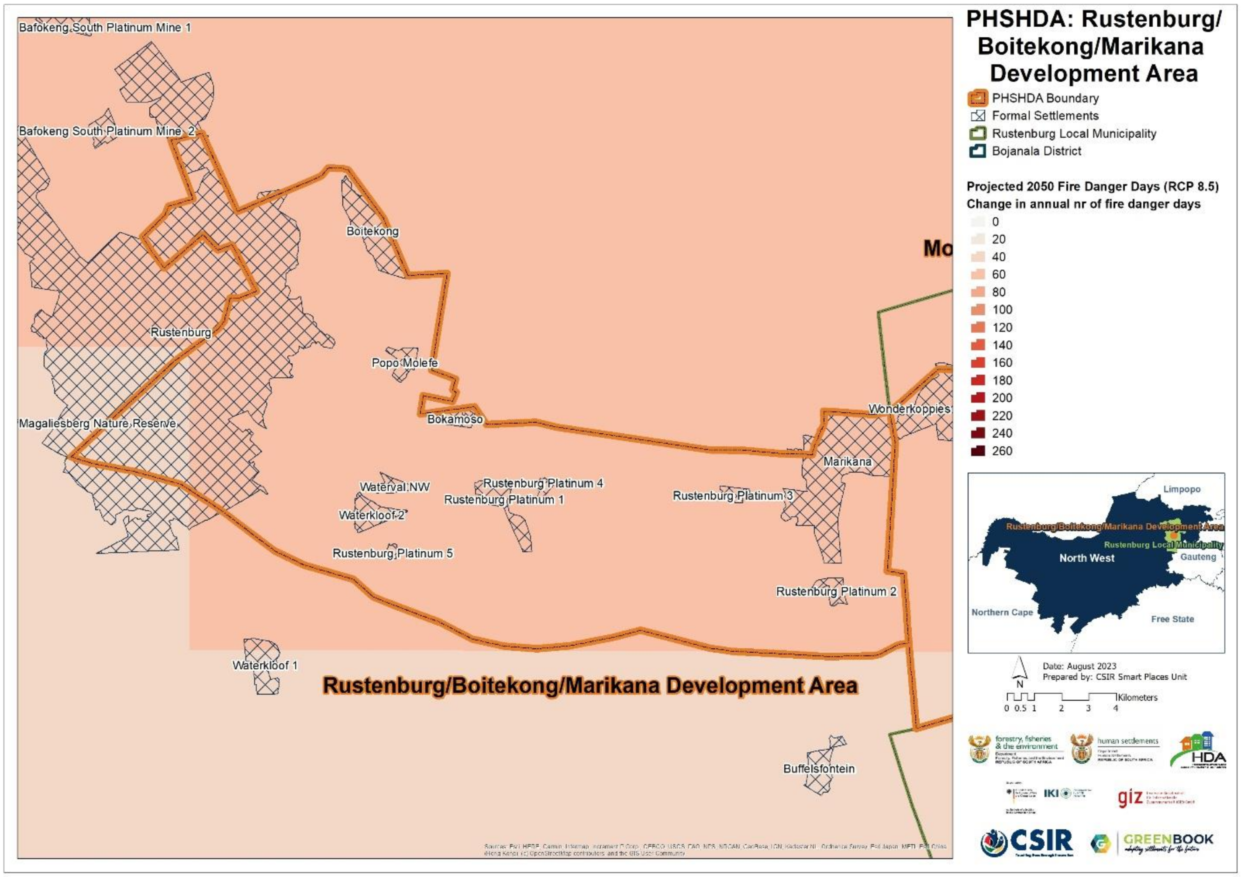


Figure 18: Number of fire danger days projected for the RBM-PHSHDA in 2050 under the RCP 8.5 scenario.

Wildfires under current climatic conditions across the RBM-PHSHDA are likely in most settlements, except in Popo Molete and Rustenburg Platinum, where the likelihood is rare (Figure 16). The likelihood of increases in wildfires under 2050 projected change is high in most settlements, except in the western part (Rustenburg), Popo Molete and at Rustenburg Platinum 2, where there is a low likelihood of wildfires (Figure 17). The number of fire danger days under the RCP8.5 scenario is projected to increase by between 40 and 60 per annum (Figure 18).

The Rustenburg Local Municipality have three fire stations, located in Rustenburg CBD, Marikana (Ward 32) and Phatsima (Ward 1). A 24-hour control room services the community under its jurisdiction. The Greater Rustenburg Fire Protection Association (FPA) has specialised fire equipment and its fire prevention activities have resulted in increased capacity and reduced fire incidents. However, the absence of a two-way radio system, ageing fire service vehicles, bad road conditions and water shortages reduce the ability to respond effectively to fire events.

1.1.1. Flooding

The flood hazard assessment combines information on the climate, observed floods, and the characteristics of water catchments that make them more or less likely to produce a flood. The climate statistics were sourced from the South African Atlas of Climatology and Agrohydrology, and a study of river flows during floods in South Africa (Schulze et al. 2008). The catchment characteristics that are important are those that regulate the volume and rate of the water flowing down and out of the catchment. The SCIMAP model was used to analyse the hydrological responsiveness and connectivity of the catchments and to calculate a Flood Hazard Index. Changes in land cover, such as urbanisation, vegetation and land degradation, or poorly managed cultivation, reduce the catchment's capacity to store or retain water. More dynamic changes in land cover could not be considered in this analysis, such as for example, recent informal settlements that may increase exposure and risk. Additional local and contextual information should be considered to further enrich the information provided here.

Since the magnitude and intensity of rainfall are the main drivers of floods and rainfall intensity is likely to increase into the future, estimates of extreme daily rainfall into the future were obtained from high-resolution regional projections of future climate change over South Africa. The settlements that are at risk of an increase in floods were calculated using a risk matrix, that considered the flood hazard index and the change in extreme rainfall days from the baseline period of 1961-1990, to the 2050s.

Figure 19 depicts the flood hazard index of the individual quinary catchments present or intersecting with the local municipality. The flood hazard index is based on the catchment characteristics and design rainfall, averaged at the quinary catchment level. Green indicates a low flooding hazard, while red indicates a high flood hazard.

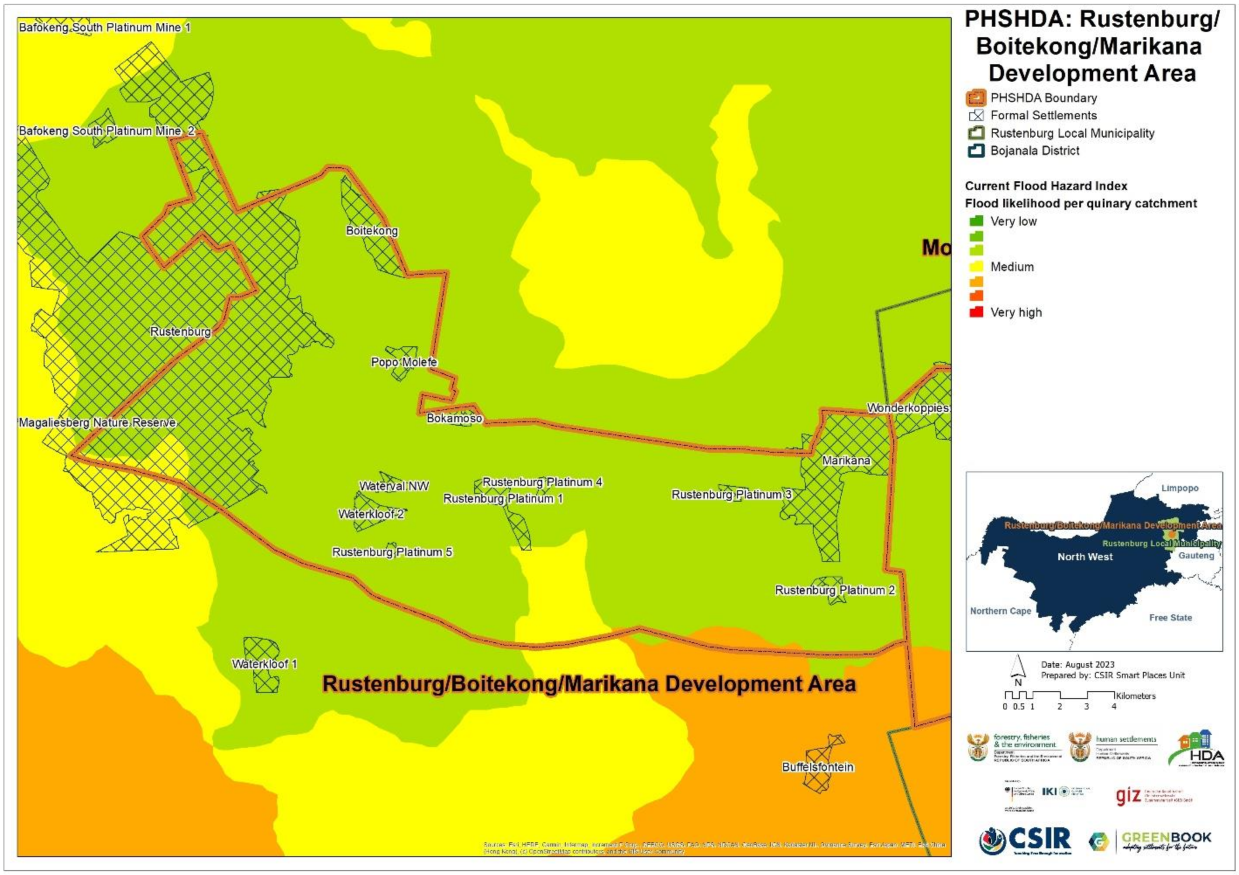


Figure 19: The flood hazard index across RBM-PHSHDA under current (baseline) climatic conditions

The flood hazard index under baseline climatic conditions (Figure 19) indicates that most settlements within the RBM-PHSHDA have a low flood risk, with an area in the lower west and in the middle having a medium (yellow) flood risk.

Figure 21 depicts the projected change for the year 2050 in extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when future rainfall extremes (e.g., 95th percentile of daily rainfall) are compared with those under the current rainfall. A value of more than one indicates an increase in extreme daily rainfalls.

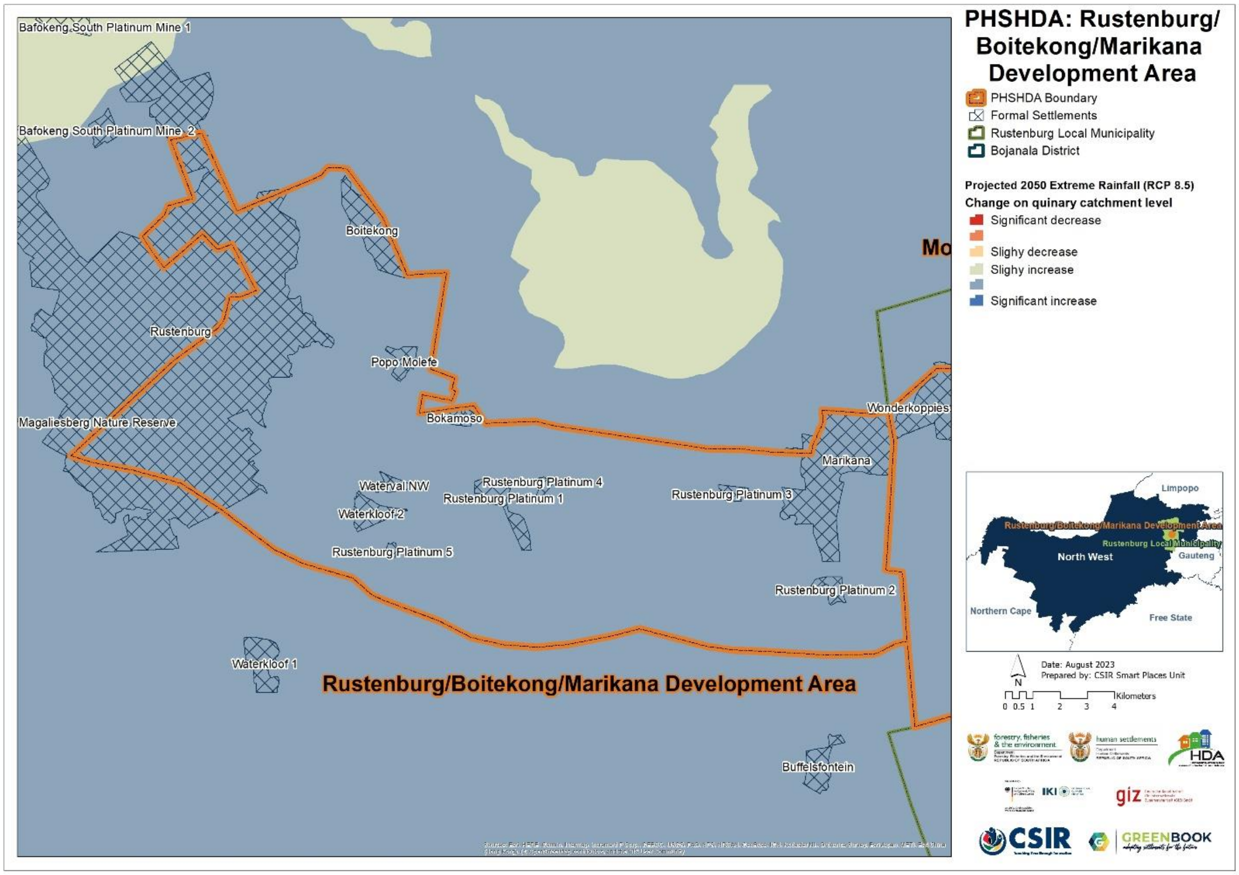


Figure 20: Projected 2050 extreme rainfall on the quinary catchment level across RBM-PHSHDA under an RCP8.5 scenario.

A moderate increase in extreme rainfall is projected for 2050 for the RBM-PHSHDA at quinary catchment level (Figure 20).

Figure 21 shows the change for the year 2050 in extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when future rainfall extremes (e.g., 95th percentile of daily rainfall) are compared with those under the current rainfall. A value of more than one indicates an increase in extreme daily rainfalls.

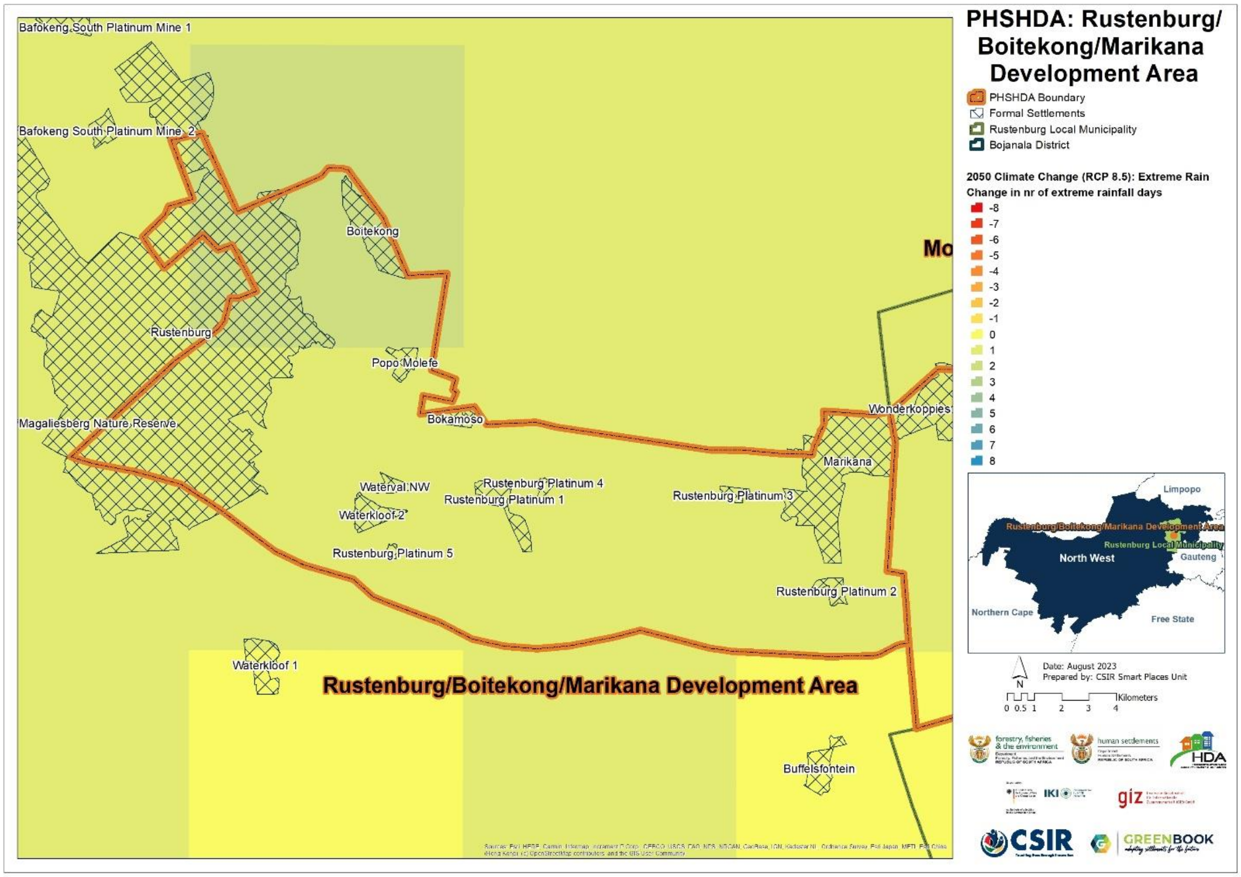


Figure 21: Projected change into the future in extreme rainfall days across RBM-PHSHDA under an RCP 8.5 scenario.

A projected decrease of 0.54 days to an increase of 1.54 extreme rainfall days are expected across the RLM.

Model projections of precipitation manifest uncertain due to several factors, including model sensitivity to spatial resolution at which processes are resolved. At 8 X 8km horizontal resolution, for example, some processes (such as convective systems) that contribute to rainfall are not adequately resolved by the climate models. The precipitation projections therefore could reflect uncertainty in some locations since fine-scale processes that contribute to precipitation and its extremes are not captured. When the modelling ensemble approach used in the online Green Book is considered, and the 10th, 50th and 90th percentiles, per grid point, agree on the directional change relative to the reference period, the signal is considered well developed and conclusive. In the case where the respective model percentiles show conflicting signs, the model ensemble manifest uncertainty and therefore reflect low confidence on which future model realisation/outcome is more likely. It is therefore critical to consider the ensemble distribution uncertainty when devising long-term adaptation strategies.

Figure 22 depicts the settlements that are at increased risk of urban flooding under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario.

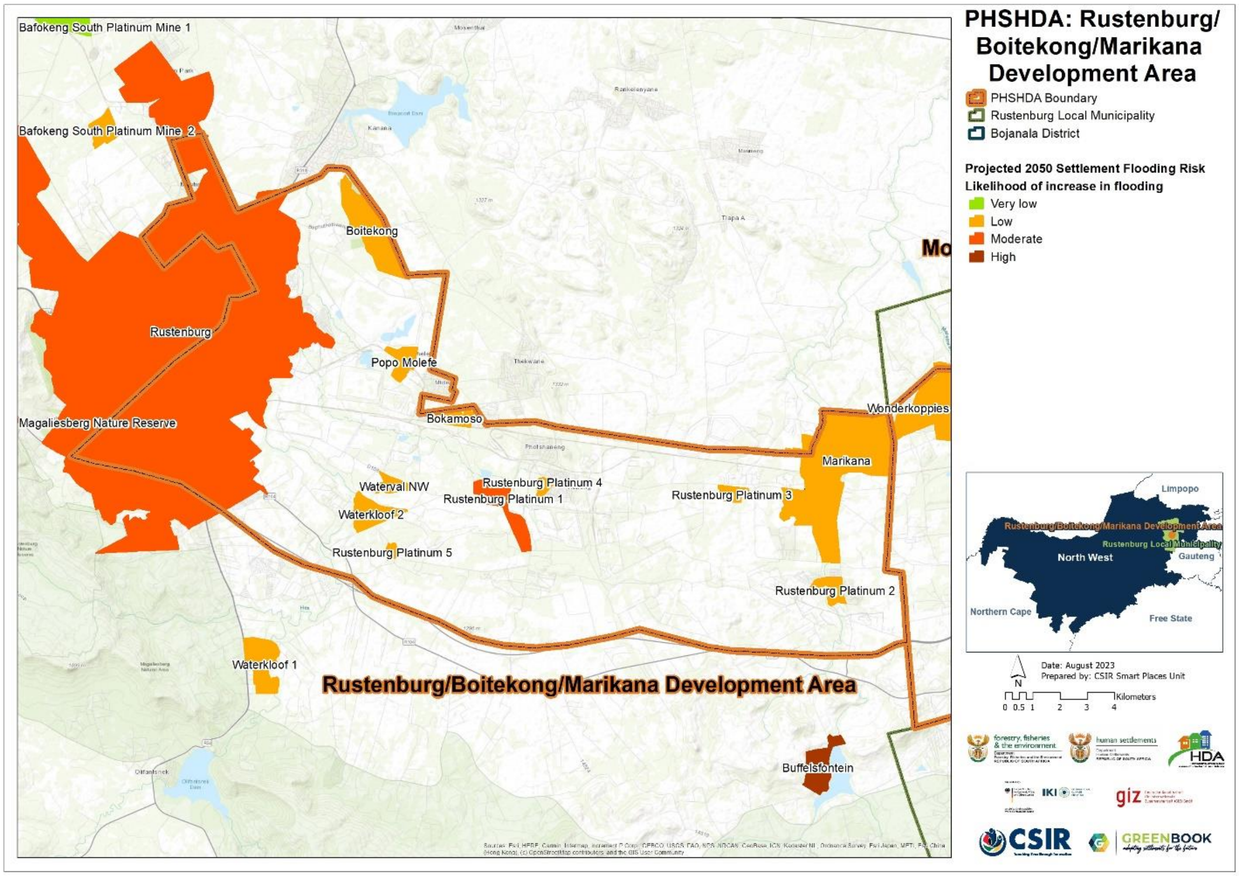


Figure 22: Flood risk into a climate change future at settlement level across RBM-PHSHDA

The western part of the RBM-PHSHDA (Rustenburg) and Rustenburg Platinum 1 are projected to be at moderate risk of an increase in flooding likelihood by 2050 (Figure 22). The rest of the settlements face a low risk of flooding into a climate changed future.

1.2. Climate impacts on key resources and sectors

To understand the impact that climate change might have on major resources, this section explores the impact that climate change is likely to have on the resources and economic sectors of the RLM and the RBM-PHSHDA in particular.

1.2.1. Water resources and supply vulnerability

South Africa is a water-scarce country with an average rainfall of approximately 450 mm per year, with significant annual and seasonal variability, Rainfall also varies from over 1900 mm in the east of the country and in the mountainous areas, to almost zero in the west and northwest of the country. Conversion of rainfall to runoff is also low with an average mean annual runoff (MAR) of only 40 mm, one seventh of the global average of 260 mm per year. Runoff is even more highly variable than precipitation, both in space and time. Furthermore, demand for water is not evenly distributed, with most of the major water demand centres located far from the available water resources. This has resulted in a need to store water and transfer water around the country to meet current and future demands.

Water availability is directly impacted by the climate and climate change. It is not just changes in precipitation that need to be considered, but also increasing temperatures that will lead to increased evaporation which could further reduce runoff and increase water losses from dams. Increasing temperatures will also impact on water demand, particularly for irrigation, but also from urban and industrial users. This could also contribute to reduced water security if existing systems are not able to meet these increasing demands. Increasing air temperatures will also increase water temperatures and hence increase pollution and water quality risks.

To obtain a high-level first order assessment of the relative climate change risks for water supply to different towns and cities across South Africa, a general risk equation was developed to determine the current and future surface water supply vulnerability that combines both climate change and development risks (i.e., due to an increase in population and demand). The current vulnerability of individual towns was calculated based on the estimated current demand and supply as recorded across the country by the Department of Water and Sanitation's (DWS) All Towns study of 2011. The future vulnerability was calculated by adjusting the water demand for each town proportional to the increase in population growth for both a high and medium growth scenario. The level of exposure was determined as a factor of the potential for increasing evaporation to result in increasing demands, and for changes in precipitation to impact directly on the sustainable yield from groundwater, and the potential for impacts on surface water supply. These were then multiplied by the proportion of supply from surface and groundwater for each town. Exposure to climate change risk for surface water supply was calculated in two ways. The first was by assuming surface water supply was directly related to changes in streamflow in the catchment in which the local municipality was located (E1) and alternatively (E2) taking into account the potential benefits offered by being connected to a regional water supply system by using the result from a national study of climate change impacts on regional water supply derived from a high level national configuration of the Water Resources Yield Model (WRYM) that calculated the overall impacts on urban, industrial and agriculture water supply to each of the original 19 (now 9) Water Management Areas (WMAs) in South Africa.

In South Africa, groundwater plays a key strategic role in supporting economic development and sustaining water security in several rural and urban settlements that are either entirely or partially dependent on groundwater supply. Groundwater is, however, a natural resource the availability and distribution of which are highly influenced by climate variability and change. An analysis of the impact of climate change on potential groundwater recharge was conducted for the period 2031 to 2050. The Villholth GRiMMS (Groundwater Drought Risk Mapping and Management System) formulation (Vilholth et al. 2013), which implemented a composite mapping analysis technique to produce an explicit groundwater recharge drought risk map, was adapted to formulate a series of potential groundwater recharge maps for the far-future across South

Africa. Finally, the future period 2031 to 2050 was compared with the historical period 1961 to 1990.

Figure 23 indicates the catchment(s) in which the RBM-PHSHDA is located.

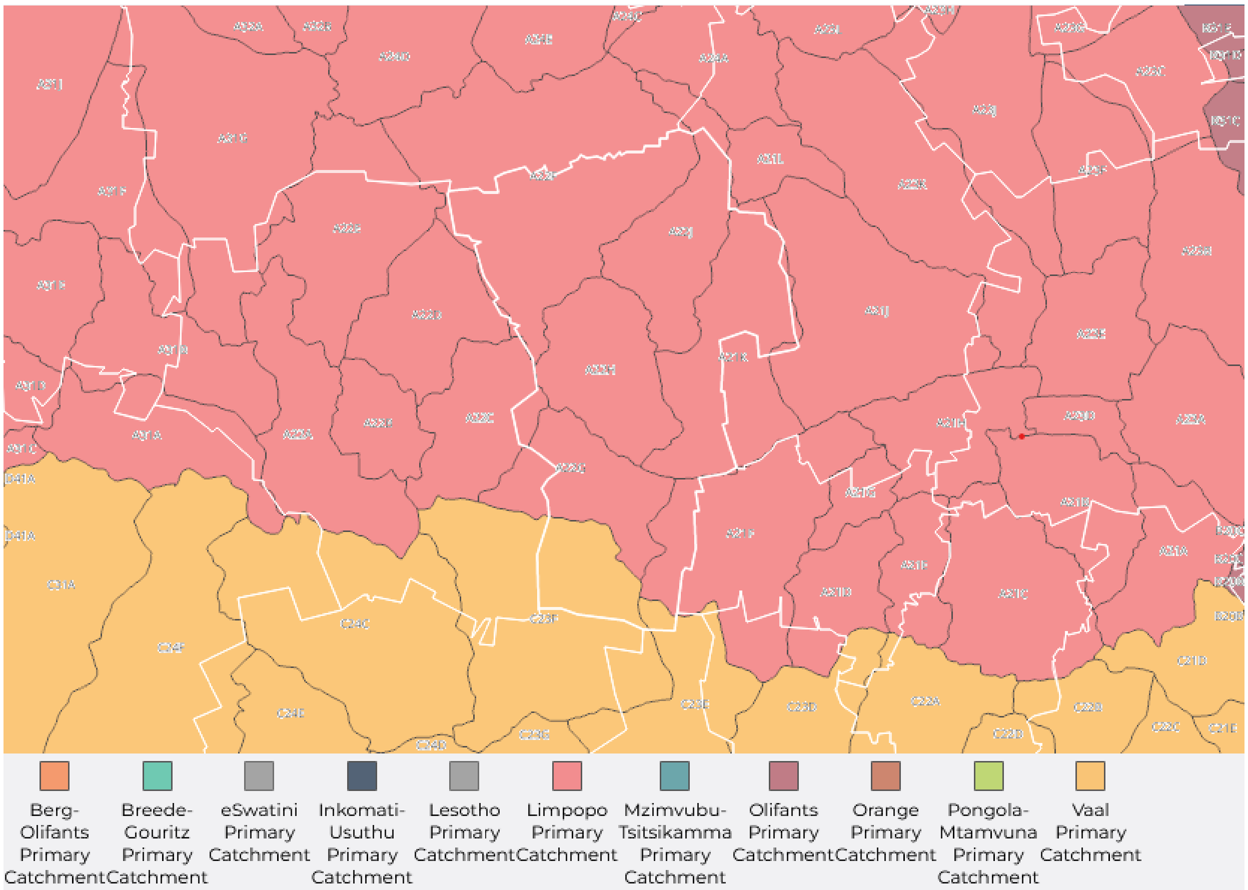


Figure 23: Quaternary catchments found in Rustenburg LM.

The quaternary catchments serving RBM-PHSHDA include the Limpopo and the Vaal Primary catchment (Figure 23).

Figure 24 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.

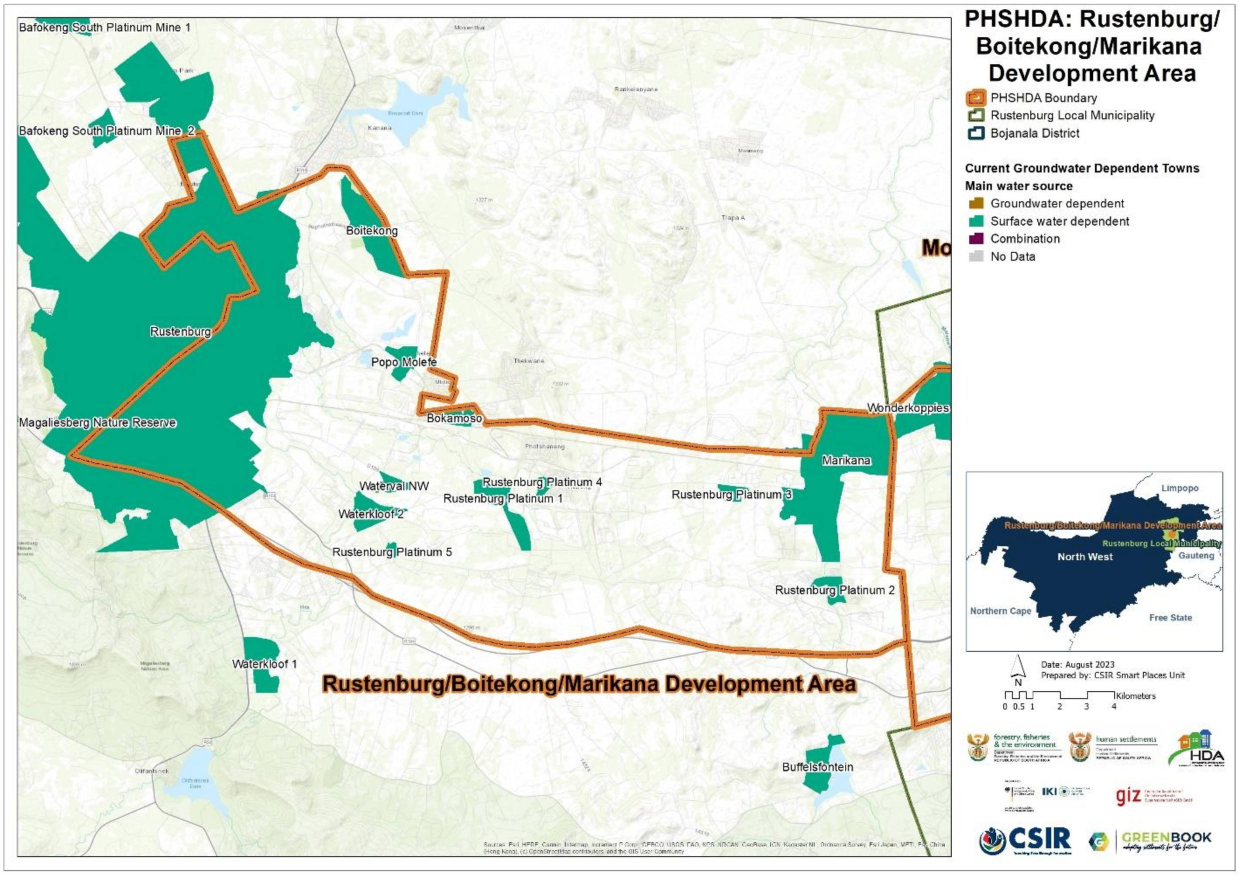


Figure 24: Main water source for settlements in RBM-PHSHDA.

All the towns and settlements in the RBM-PHSHDA are surface water dependent only (Figure 24).

Figure 25Figure 25 indicates the occurrence and distribution of groundwater resources across the Local Municipality, showing distinctive recharge potential zones, while Figure 26 indicates the projected change in groundwater potential. Figure 27 indicates the groundwater dependent settlements that may be most at risk of groundwater depletion based on decreasing groundwater aquifer recharge potential and significant increases in population growth pressure by 2050.

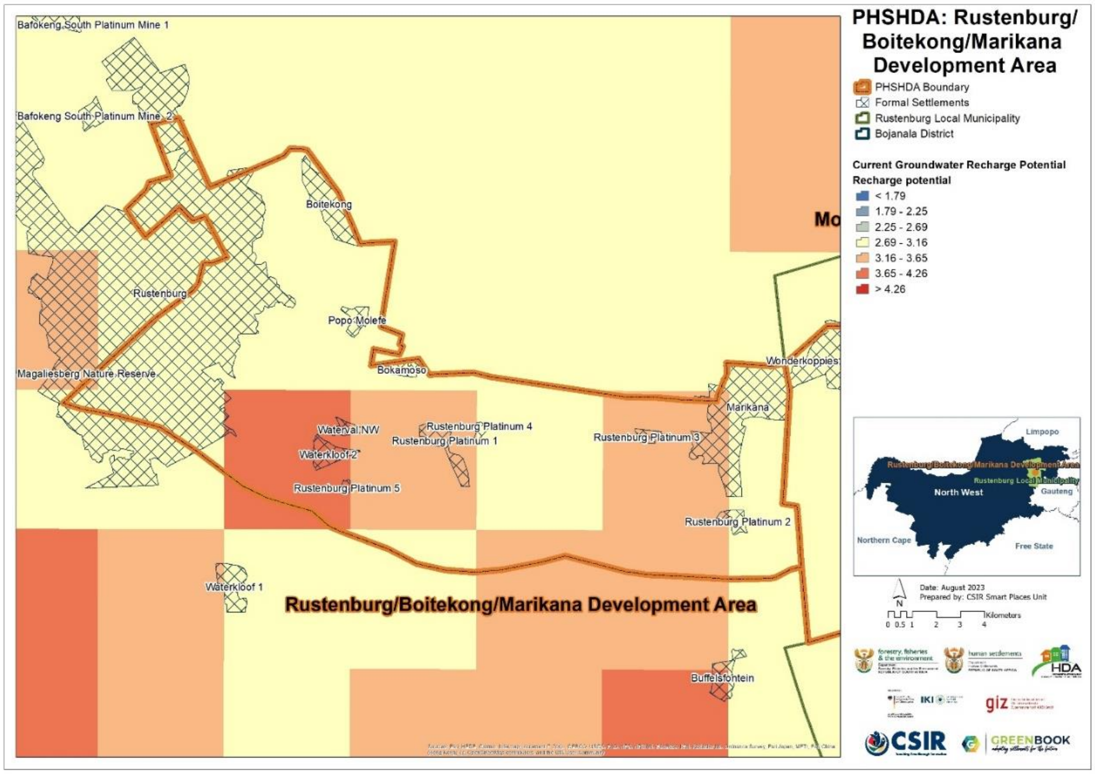


Figure 25: Groundwater recharge potential across RBM-PHSHDA under current (baseline) climatic conditions

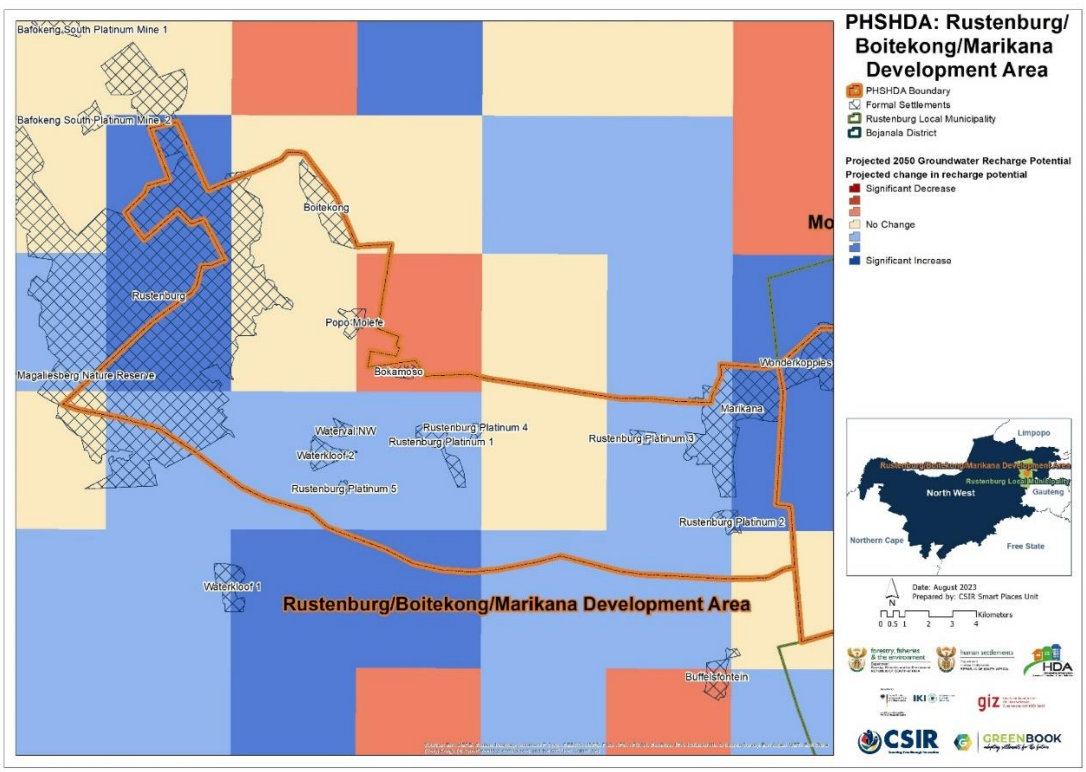


Figure 26: Projected changes in groundwater recharge potential from baseline climatic conditions to the future across RBM-PHSHDA

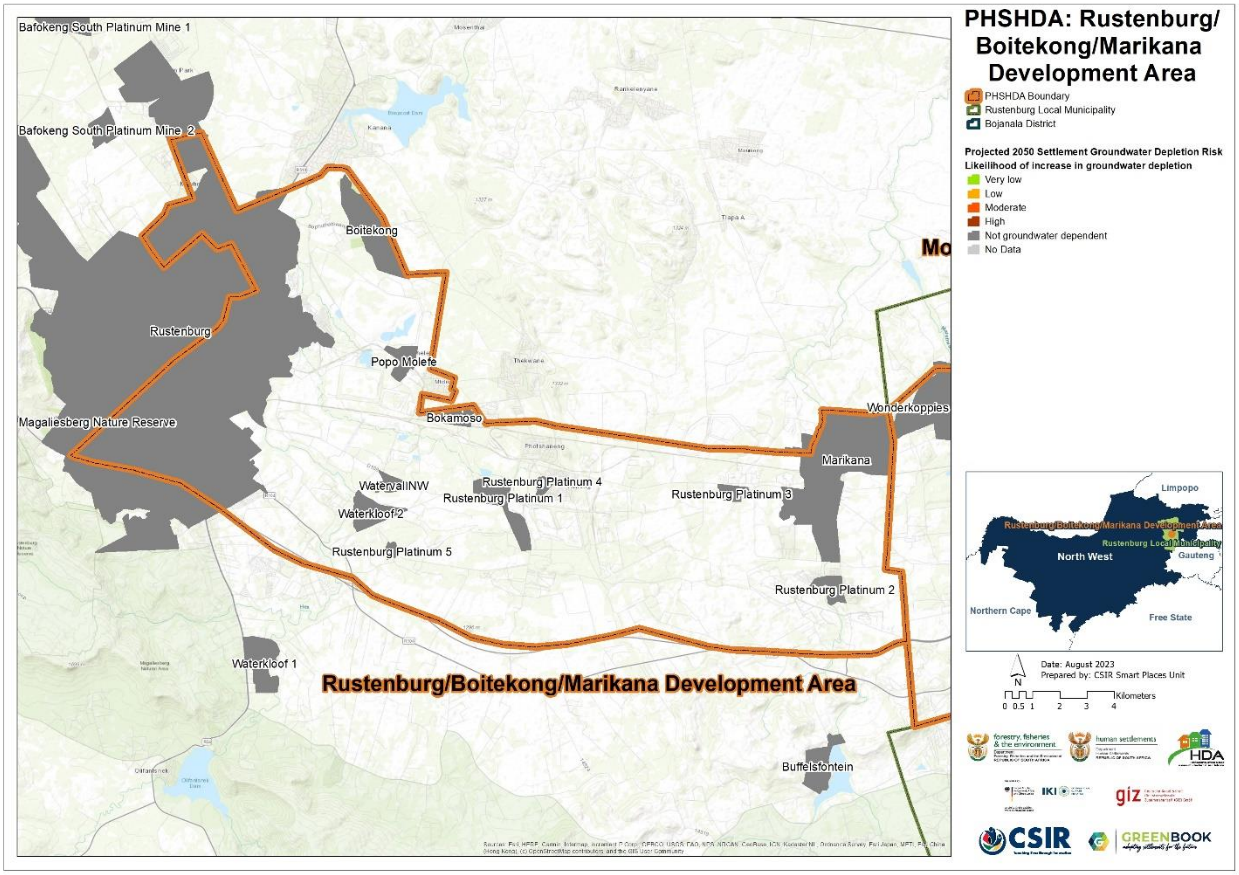


Figure 27: Settlement-level groundwater depletion across RBM-PHSHDA

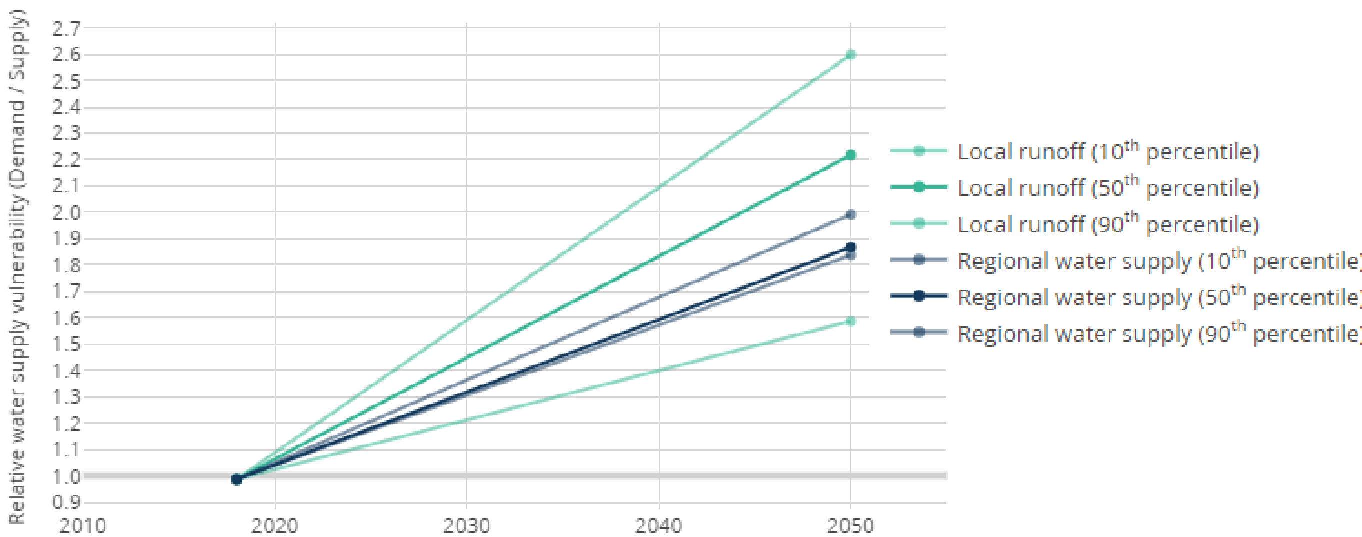
The RBM-PHSHDA has above-average levels of groundwater potential under current (baseline) climatic conditions (Figure 26). The projected changes in groundwater recharge potential from baseline climatic conditions to the future across the PHSHDA indicate a significant increase in recharge potential in the west (Rustenburg) and in the south. A reduction in recharge potential can be seen near Popo Molefe and in Bokamoso (Figure 26). The projected groundwater dependent risk is not applicable, considering that towns and settlements are not dependent on groundwater (Figure 27).

Table 4 provides and overview of current water supply vulnerability (i.e., demand versus supply) in the RBM-PHSHDA based on the data compiled for the Department of Water and Sanitation's (DWS) All Town's Study (Cole, 2017). A water supply vulnerability score above 1 indicates that demand is more than supply, while a score below 1 indicates that supply is meeting demand.

Table 4: Current water supply and vulnerability across Rustenburg District Municipality

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
Rustenburg	132.38	134.19	0.99

Current and future water supply vulnerability estimations are based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk 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 water supply vulnerability estimations do not consider current state of water supply and reticulation infrastructure. The current context and conditions within each of the local municipalities need to be considered when interpreting the information provided in this report. The water supply vulnerability of RLM is discussed below. Figure 28 shows the local municipality's estimated current and future water supply vulnerability, under the two estimation scenarios.



VULNERABILITY CONTRIBUTION FACTORS		PERCENTAGE CHANGE	
	Mean annual precipitation	⌄	-9.35%
	Mean annual evaporation	⌃	11.46%
	Mean annual runoff	⌄	-15.72%
	Regional urban water supply	⌃	0.06%
	Population growth	⌃	69.94%

Figure 28: Current and future water supply vulnerability in RBM-PHSHDA

Rustenburg LM's water demand is currently lower than supply (Table 4). However, the LM's water supply vulnerability is projected to increase (Figure 28) due to the projected decrease in mean annual precipitation, as well as projected increases in mean annual evaporation, and population growth, with regional urban water supply only increasing by 0.06%.

1.2.2. Agriculture, forestry, and fisheries

Agriculture and food production is arguably the sector most vulnerable to climate impacts in South Africa. Many settlements in South Africa owe their existence to the primary sector of the country. Agriculture, forestry, and fisheries (AFF) form the bulk of the primary sector and act as catalysts for the economic development of secondary and tertiary sectors. Where these sectors are the primary economic activity in an area, they contribute to the local economy, employment, food security, and livelihoods. They also indirectly benefit from services such as health care, education, and basic infrastructure. In such regions, social and economic stability are linked with the profitability of the agricultural sector.

Climate change, through increased temperature and changing rainfall patterns, can have fundamental impacts on agriculture if the climatic thresholds of the commodities being farmed are breached. However, the nature and extent of these impacts depends on the type of commodity being farmed and the relative geographic location of the farmer in relation to the industries served, and on the resources available to the farmer. The same climate impact can have different impacts on different commodities and farms. Overall, climate change could make it more difficult to grow crops, raise animals, and catch fish In the same ways and same places as we have done in the past.

The methodological approach to understanding the impact of climate and climate change on AFF consisted of four components. Firstly, the most important areas in terms of Gross Value Added (GVA) and employment for the AFF sector relative to the other sectors of the South African economy were determined. Secondly, an analysis of climate change scenarios was done using historical climate variables, as well as multi-model projections of future climates to help identify specific climate-related risk factors for agriculture within specific regions. Thirdly, crop suitability modelling was done to indicate how the area suitable for crop production under the present climate conditions might shift or expand under the scenarios of future climate change, in addition to using the Temperature Humidity Index (THI) to assess heat stress in livestock. Finally, the climate change analysis was used in conjunction with the crop modelling outputs to assess the potential impacts of climate change over a specific area, or for a specific crop, to give more detail on how predicted climate changes translate into location/crop specific impacts. This was developed at a local municipal level and guided by the outcome of the agricultural industry sector screening and climate scenario analysis.

In the RLM, the AFF sector contributes 0.47% to the local GVA, which is a contribution of 0.39% the national GVA for the AFF sector. Of the total employment, 2.16% is within the AFF sector. The main commodities are beef cattle, maize for grain and tobacco. Climate projections under an RCP 8.5 "business as usual" GHG emissions scenario, show a generally hotter and wetter climate for the LM, with more extreme events projected into the future. Increased water availability will result in hot and moist conditions, causing increased spread of disease and parasites in beef cattle. Growth and reproduction performance may also decline due to heat stress. Maize yield may potentially increase in the near future. However, towards 2050, heat stress can negatively impact on production. The production of tobacco is expected to remain viable as long as heat stress is managed.

2. Conclusion and recommendations

The climate projections indicate the RBM-PHSHDA area will become hotter and wetter towards 2050. The likelihood of an increase in extreme heat is low to moderate. The risk of drought is low. However, a significant increase in extreme rainfall is projected for 2050. Areas in the west and around Rustenburg Platinum 1 are projected to be a moderate risk of flooding. The current water demand is lower than supply. However, despite an increase in rainfall, water supply vulnerability is projected to increase due to a number of factors, including population growth and the fact that urban water supply is only expected to increase by 0.06%.

The greatest likelihood of hazards occurring in the RBM-PHSHDA are floods due to significant projected increases in extreme rainfall, but also wildfires, with a projected high risk of wildfires in several settlements across the PHSHDA. This elevated risk is compounded by the high socio-economic and regional connectivity vulnerabilities faced by some communities in the area, making them more susceptible to adverse outcomes arising from climate change. In addition, the area is projected to have population growth pressure, which may increase the number of people exposed to climate hazards in the future.

The high risk of wildfires has cascading effects of which poses severe health risks to people and animals. Wildfires pose a threat of smoke pollution. It is therefore necessary to ensure that systems are in place to maintain and ensure the public's health, should the need arise.

In response to these climate risks and impacts the following adaptation goals are recommended:

1. To manage the two drainage/catchment areas in the PHSHDA, especially in terms of ensuring that floodlines are adhered to, and that ecological corridors are protected.
2. To improve communication in vulnerable rural settlements such as Molote through implementing a dedicated radio communication channel with a standard ground-to-air-frequency for disaster management purposes (as recommended in the IDP),
3. To improve infrastructure for responding to fire events, such as improving communication and upgrading vehicles and roads, and ensuring water availability, as well as ensuring continuity of fire and disaster awareness campaigns.
4. To establish a multi-disciplinary joint operation centre (JOC) (as recommended in the IDP) to ensure effective coordination between all role players in the event of a disaster.

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Annexure A: Sector specific impacts

Climate hazards and climate events can have far-reaching impacts across a range of sectors. Some of the sectors are discussed and the various climate impacts are summarised in the tables below.

Ecosystem services

Urban areas are dependent on natural ecosystems in and around towns to provide communities with services such as safe and plentiful drinking water, increased food security, better health, decreased exposure to natural disasters and extreme weather, and increased recreational opportunities. For these ecosystems to continue to provide these services they need to be in a healthy condition. Unfortunately, many ecosystems have been degraded because of misuse and overuse of soil, water, plant, and animal species. At the same time global climate change is aggravating the vulnerabilities of these ecosystems and therefore diminishing the benefits that ecological infrastructure can provide. It is therefore critical to rehabilitate and maintain ecological infrastructure in the urban environment to help residents adapt to risks posed by future climate change.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• 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.	• 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	• 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. • 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

• 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). • 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.	dams which are damaging to ecosystem functioning and water services. • Drought and decreased rainfall causing wetland habitat loss. • 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. • 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.	natural coastal defence structures.

Stormwater

A stormwater drainage system collects, conveys and discharges stormwater with the aim to reduce the risk of flooding in settlements and control water quality (traditional pollutants that are commonly associated with municipal and industrial discharges, e.g., nutrients, sediment, and metals). Conventionally rainwater falling onto a hard surface will be collected and drained through surface channels to a collection point or culvert where it will enter a storm water pipe. The pipe will use gravity to discharge the water into a watercourse or a dam. Where a gravity-fed system cannot be used the water will be collected into a storage dam and pumped to the discharge location. Sustainable Urban Drainage Systems (SUDS) seeks to minimize the volume of storm water entering the drainage system. It does this in three ways: first, collect and store as much rainwater at source as possible; second, filtrate as much surface water into the ground as possible as close to the source as possible; third, collect storm water at grade in various storage systems (weirs, wetlands, attenuation ponds, etc.).

Increased temperatures, heat extremes, and drought	Increase in rainfall, inland flooding, and coastal flooding

• 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 bottle-necks 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.

Solid waste

Human settlements generate massive amounts of solid waste that needs to be managed effectively so as not to cause air, water, and soil pollution.

As cities grow and need more land, suitable collection and disposal sites can be difficult to acquire and develop. Most households in South Africa (64% in 2015) receive a waste removal service at least once a week, but there are still households that rely on their own or communal rubbish dump sites. Illegal dumping and littering are problems in most municipalities resulting in solid waste often accumulating in waterways and areas otherwise intended for water run-off and flood control. These conditions make municipalities vulnerable to flooding, contamination of water resources, adverse health effects and rehabilitation costs that may overwhelm the resilience of cities.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• 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 an 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.

Sanitation

Sanitation and wastewater management poses several operational challenges to governments and settlements. Managing water resources involves contributions from various stakeholders at different points in the value chain. The sanitation value chain comprises eight broadly defined stages, as follows: collection/containment; storage; transport; treatment; distribution; wastewater treatment; and discharge. Re-use of wastewater is becoming more acceptable and feasible because of increasing water shortages, improved purification technology and decreasing treatment costs. A water reuse strategy that is forward thinking over ten to twenty years needs to take these possible changes into account. The direct re-use of treated wastewater can pose a risk to public health and safety and thus must be managed carefully and be subject to water quality management and control. Advanced treatment technologies, sufficient operating capacity and proper monitoring of all processes, and quality of potable water produced is essential.

Increased temperatures and heat extremes Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• 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 bottlenecks 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 or sea-level rise, putting as risk 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. • Sea level rise posing a threat to coastal zones in terms of saline intrusion, and damage to/contamination of water

	systems and wastewater treatment works from inundation during coastal storms.

Energy

South Africa's energy mix is primarily dominated by the use of fossil fuels to derive grid supplied electricity and imported crude oil and petroleum products. Regarding access to energy within our human settlements, grid-supplied electricity is transmitted from power stations to sub-stations to settlements typically through overhead powerlines. Electricity supply is not equally distributed within the country with many people within informal settlements still not connected to the electricity grid. Many thus rely on the combustion of fuels within or near their homes to meet their cooking, heating, and lighting needs. Electricity infrastructure is exposed to weather and climate and is vulnerable to the effects of climate change. Variations in temperature (hotter and colder days) will increase the demand for energy for both cooling and heating within homes and buildings, as will urban growth. Thus, both the electricity supply and demand of a settlement are likely to be impacted by climate change.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• Increased heat causing expansion of overhead cables, and cable sag. Sagging below a certain amount 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.

Information and communication technology

Information and communications technology (ICT), or telecommunications, plays a critical role in society and is central to the operations of every industry and sector, and society relies on it for social and leisure purposes as well as work. Climate change impacts on ICT infrastructure in settlements include the impacts of increased warming and precipitation, extreme weather events, strong winds, and sea-level rise and storm surges. The ICT industry experiences weather-related impacts which are expected to worsen due to ongoing climate variability and climate change. Compared to 'heavy' infrastructure sectors like energy, water or transportation, the ICT sector has smaller infrastructure and shorter lifetimes, reliance on a combined network instead of individual structures, redundancy of service and infrastructure and service providers, and fast-paced technological change and innovation. While technologies in the ICT sector in the future may converge towards wireless technologies and reduce dependence on current infrastructure, this will not negate the need for infrastructure altogether, for example, there will still be a requirement for equipment such as mobile or fixed wireless towers to operate this technology.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• 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.

Transport and mobility

Within settlements, transport networks comprise of nodes (e.g., buildings and public transport stops and stations) and various connector links (e.g., walkways, roads, bridges, railways, tunnels, and waterways). Apart from being a large asset base in themselves, these networks are indispensable conduits for the movement of people and goods for social, economic, political, health and recreational purposes. Within the context of climate change, therefore, climate resilient transport networks are necessary to ensure unimpeded functioning of society. Vulnerability of transport networks to climate change depends on infrastructure age, its materials, construction practices, design features, and maintenance history. Societal level of risk to infrastructure failure is dependent on individual functions of different parts of the transport network. Therefore, spatial differentiation should be an integral component of adaptation strategies. Disruption to transport networks due to climatic extreme events may lead to social exclusion, trade interruption, and consequently social disorder. It is imperative, therefore, that the design and in-situ upgrading of transport networks and their operations be responsive to threats posed by climate change, especially in high-risk areas. It is equally important to ensure transport networks do not add to landscape vulnerability – for example increasing erosion of steep slopes, landslides or increasing vulnerability of natural habitats to fragmentation and overharvesting.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• 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.	• 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.

Human health

Settlements are faced with a variety of challenges, which may include rapid unplanned urbanization, climate-related pressures such as floods and heat waves, as well as unequal economic growth between different communities. This affects the health and development status within settlements. Climate-health linkages are complex and multi-faceted, and it can confidently be stated that climate change will amplify some of the existing health threats that are already faced by communities. Certain people and communities are especially vulnerable, including children, the elderly, the sick and the poor. Natural disasters (e.g., floods, drought, fires) can have immediate and long-term impacts on health. Poor emergency service delivery immediately after disaster can impact health, as well as damage to services such as water reticulation can have longer-lasting impacts on public health. Natural disasters can also create a conducive environment for the occurrence of mental health problems.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• 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;	• Decreased soil moisture potentially creating more wind-blown dust which has negative impacts on air quality. • Increase in water-washed 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 diarrheal 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.

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 UVR 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.		• Increase in natural disasters (e.g. floods) creating a conducive environment for the occurrence of mental health problems.

Culture and heritage

Culture refers to the dynamic totality of distinctive spiritual, material, intellectual, emotional and aesthetic features that characterise a society or social group, including its arts, but also intangible aspects such as values, worldviews, ideas and beliefs, and the expression of these in individual and social behaviour, relationships, organisational and societal forms, and in economic, political, educational and judicial systems. The variance between these groups, known as cultural diversity, is illustrated by the many ways in which the cultures of groups and societies find expression. Within an urban context, culture may manifest itself spatially through heritage sites and resources. These areas are vulnerable to the effects of climate change and require particular management and sensitivity within planning. This heritage may include wildlife and scenic parks, sites of scientific or historic importance, national monuments, historic buildings, works of art, literature and music, oral traditions and museum collections together with their documentation. Due to the sensitive nature of culture and heritage, the physical and cultural value associated with these sites and resources is vulnerable to any aesthetic and functional changes caused by climate change. Potential physical impacts may have indirect social consequences.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• 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	• 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 evidences buried underground due to changing stratigraphic integrity of the soils. • Increased threat to properties listed as cultural heritage in coastal lowlands due to increased precipitation, sea level and coastal erosion. • Increased threat to materials and structural

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.		integrity of heritage resources exposed to higher humidity/ precipitation levels.